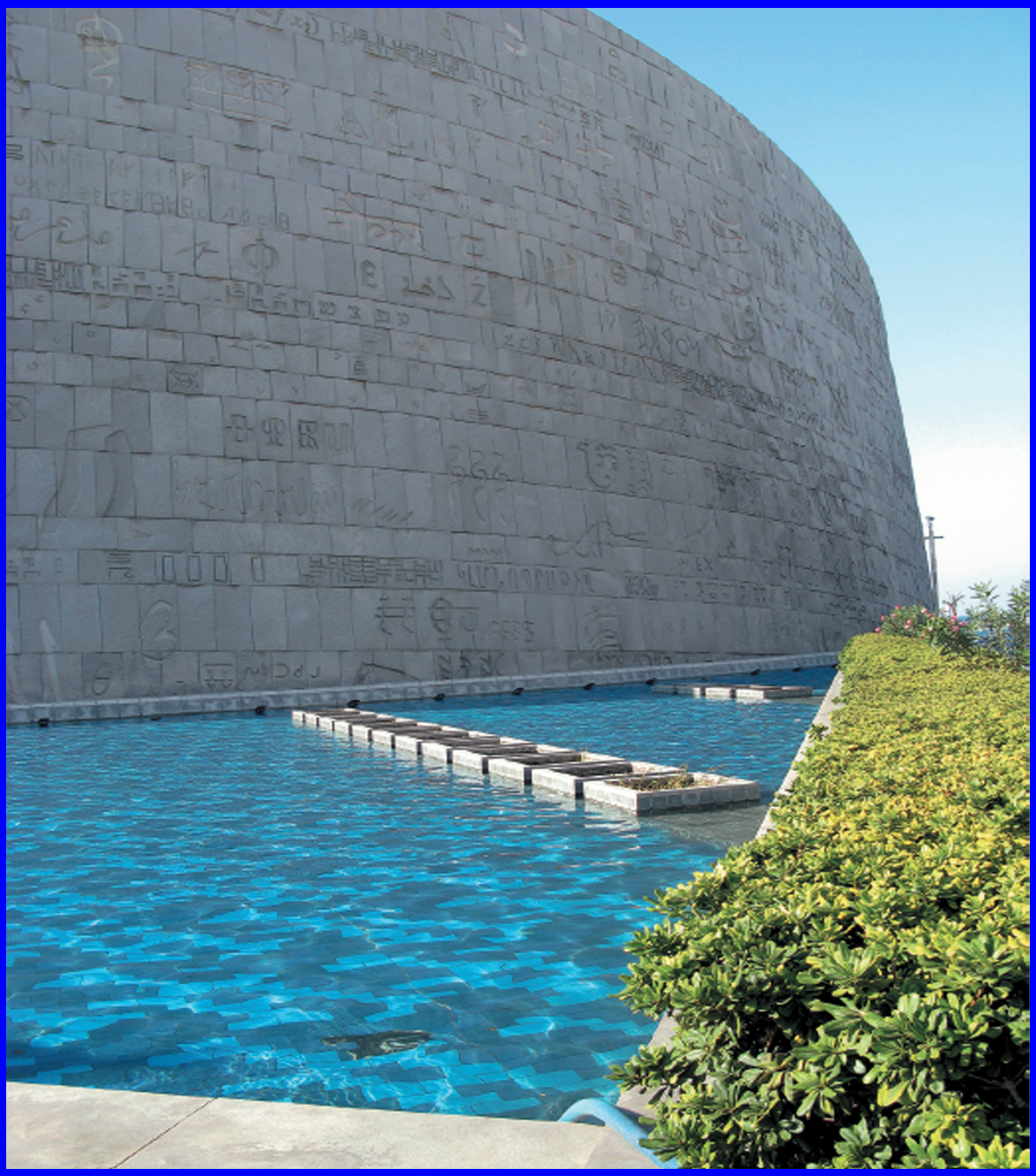
European Society for Astronomy in Culture (SEAC)

From Alexandria to Al-Iskandariya

Edited by

Michael A. Rappenglück & Mossalam Shaltout



Astronomy and Culture in the Ancient Mediterranean and Beyond

Proceedings of the SEAC 2009 Conference in Alexandria, Egypt

Mosalam Shaltout
(Abu-Hamad 1946 – Cairo 2015)

IN MEMORIAM

A very proud of his Andalusian ancestors Prof. Shaltout in front of the Alhambra in Granada
(© Juan A. Belmonte, 2008)

Dr. Mosalam Shaltout was Professor of Solar & Terrestrial physics in the National Research Institute of Astronomy and Geophysics at Helwan (Cairo, Egypt). He had also been the Chairman of Space Weather Research in the Egyptian Space Program, and Vice-President of the Arab Union of Astronomy and Space Science. He published more than 200 papers in the fields of Solar Energy and Environment, Space Science and Technology, History of Astronomy and Archaeoastronomy. He was for a decade the Project Manager of the Egyptian-Spanish Mission on Archaeoastronomy of ancient Egypt and a close collaborator of the *Orientatio ad Sidera* project funding the Mission. This was a real revolution in the field of Cultural Astronomy of the ancient Egyptian civilization. Dr. Shaltout was one of the most famous leading intellectuals in the Arab world, and he was well known to the general public through television, radio and daily newspapers. A good friend, he chaired with me the Conference resulting in the book the reader has now in his hand. This volume is dedicated to his memory.

Juan Antonio Belmonte, November 16 2015

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Frontispice: Prof. Shaltout in front of the Alhambra in Granada (Photo: © Juan A. Belmonte, 2008).

Back Cover: The Planetarium near the New Library of Alexandria (Photo: © Michael A. Rappenglück 2009).

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SEAC 2009: Visit to the necropolis of Saqqara, on the west bank of the Nile, south of Cairo. On the right the step pyramid of Djoser from the 3rd Dynasty of the Old Kingdom, c. 2650 BC Photo: © Michael A. Rappenglück.

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Preface

From 25 to 31 October 2009, the international meeting of the European Society for Astronomy in Culture (SEAC) took place in Alexandria, Egypt.

2009 was a particular year for the science of astronomy: The International Astronomical Union (IAU), in cooperation with UNESCO and numerous associated organisations, had scheduled the International Year of Astronomy (IYA 2009) to celebrate the importance and achievement of astronomy in the history of human cultures. The occasion was also the 400th anniversary of the first use of an astronomical telescope by Galileo Galilei in 1609.

Over the past centuries, instruments expanded human senses, thus leading to an extraordinary change in perception of reality, expanding the earthly world into a vast cosmos on both a small and large scale. An essential goal of the International Year of Astronomy was to inspire people, especially young people, with enthusiasm for astronomy and its neighbouring sciences under the central theme of "the universe to be discovered". The aim was to show that this ancient science contributes significantly to a new understanding of man's position in the cosmos. Since its proto-scientific beginnings during Upper Palaeolithic, astronomy was closely connected with the age-old questions of human beings about the why and therefore of existence. It thus represents a precious common cultural basis for the peoples of planet Earth. In the 21st century, hardly a year goes by without another unusual discovery by telescopes on Earth, Earth orbit, or even space probes. Most recently, there was spectacular direct evidence of the accretion disk around the highly massive black hole at the centre of the supergiant elliptical galaxy M 87, 53 million light-years away, by the Event Horizon Telescope (EHT) in April 2017, presented in April 2019.

The 2009 SEAC Annual Meeting was deliberately planned within the celebrations for the International Year of Astronomy. It should contribute to a deepening of the understanding of human beings as inhabitants of the spaceship Earth in a vast space of countless worlds by looking back at the cultural history of astronomy and with a view to a common starry sky.
The new library in Alexandria, Egypt, was chosen as the knowledge transfer site, as the old library once set it. In libraries, the cultures of all times come together, come alive, and continue to affect the future. It is about the transmission of knowledge and very much about the encounter of people.

The European Society for the Role of Astronomy in Culture (SEAC), founded in 1992, is committed to studying Cultural Astronomy (with its sub-disciplines and in interaction with neighbouring sciences).

The 17th annual conference took place from 25 to 31 October 2009 at the Bibliotheca Alexandrina (BA) host. It was about the following topics: Megalithic Phenomena in the ancient Mediterranean and beyond - Archeoastronomy in the ancient Mediterranean and beyond - Eastern Mediterranean Astronomy (Egypt, Greece, and Rhodes) - Astronomy at the Ancient Bibliotheca of Alexandria - Astronomy in Old Europe - Astronomy in Middle Ages - Islamic Astronomy - Copernicus and Galileo Galilei Revolutions - Babylonian Astronomy - Mesoamerican and Pacific Astronomy - Minoan Civilisation Astronomy - Traditional African Astronomy - Other Topics in Cultural Astronomy. More than lectures, including invited ones, were given. Almost 80 presentations, including some invited, were given. This volume contains contributions (peer-reviewed) from them.

Dr Michael A. Rappenglück M.A.

Vice President-elect (2019) of SEAC
Former President of SEAC (2011-2017) and Secretary of SEAC (2005-2011)

Image left: View into the New Library, Alexandria, Egypt. Photo: Michael A. Rappenglück, 2009. *Image right:* Kitab al-Zij al-Jami' written by Kiyā Abū al-Ḥasan Kūshyār ibn Labbān Bāshahrī al-Jīlī (Gīlānī), ca. 360-420 AH (ca. 971–1029 AD), Iranian geographer, astronomer, and mathematician, on display at the New Library, Alexandria. Photo: Michael A. Rappenglück.

Africa / Ancient Egypt

Climate Change, Nomadic Pastoralism and Astronomy at Nabta Playa, Southern Egypt

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Abstract: The megalithic ceremonial center of Nabta Playa in the Sahara west of Abu Simbel was built sometime after 7500 BP following a short but deep period of aridity. Ritual activity appears first in the Valley of Sacrifices, which contains human and cattle burials and a stone circle with alignments to north-south and June solstice sunrise. These directions reveal two major elements in the life of the nomads: north was necessary for navigation across the desert and June solstice was the time for the arrival of summer monsoon rains. The circle may have been a focus for rainmaking ritual. To the south of the Valley of Sacrifices there are 30 complex megalithic structures built during the Terminal Neolithic starting about 6500 BP. The largest of these is the focal point for five alignments of stele, which may have been aligned to bright stars of the local sky. Nabta Playa demonstrates that a complex ceremonial center can develop from a nomadic culture without the features of sedentism such as agriculture, permanent villages, and a religio–political hierarchy.

Keywords: Nabta Playa (Southern Egypt), Terminal Neolithic, Megalithic structure, bright stars

Introduction

About 10,500 BP summer monsoon rains moved northward from central Africa, converting what had been a hyperarid desert into a savanna–like landscape where nomadic pastoralists with their cattle could survive (Kuper and Kroplin, 2006;Wendorf et al., 1992-3; Wendorf et al., 2001; Wendorf & Schild, 1998; Schild and Wendorf, 2004). Animals of central Africa, such as giraffes, wild cattle, and ostriches, moved into the area (Figure 1). Climate change was extraordinarily rapid: the tropical rainfall belts moved northward by as much as 800 km in a few generations. Some of those living in central Africa who were already adapted to a savanna landscape followed the rains, and perhaps the animals, northward. Others moved out of the Nile valley and moved to the west. For the nomadic pastoralists of the Sahara, cattle were walking larders of milk, blood, and meat, used in a manner similar to those of modern Masai, which allowed people to live in the desert.

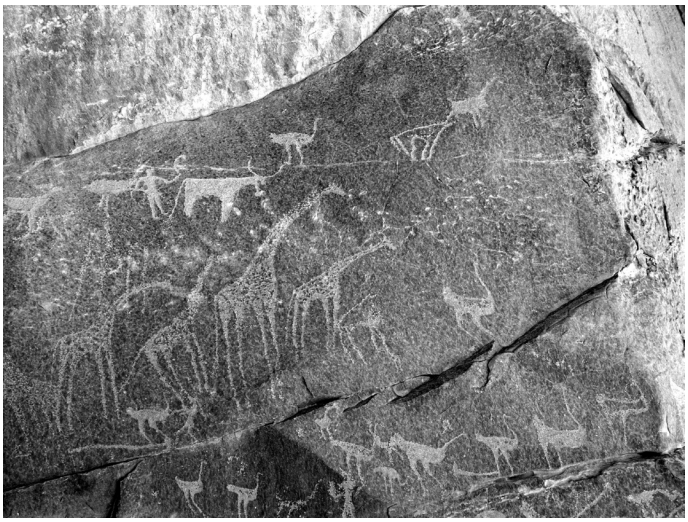


Figure 1. Saharan Rock Art with Giraffes, Cattle, Ostriches, and a Herdsman. Karkur Tahl near Gebel Uweinat (photo courtesy of Andras Zobray).

Nabta Playa ("dry lake") is an internally drained basin, scoured out by winds during the previous hyperarid period between 70,000 and 13,000 years BP. It is located about 100 km due west of Abu Simbel and is the second largest internally drained basin of the southern Western Desert of Egypt. The basin is some 14 km east–west and 10 km north–south The name Nabta was given to a local gebel by the Bedouin workers of the combined Prehistoric Expedition and means "little bushes" and referred to three small clumps of dead tamarisk at the base of Gebel ("mountain) Nabta (Wendorf and Schild, 2001). Nabta Playa once received water from a large drainage area estimated to be 1500 square km, such that at times of rainfall a seasonal lake could form in the basin.

The ceremonial center at Nabta Playa provides a number of fascinating glimpses into cultural evolution in the Sahara during the Neolithic. As proposed by Kuper and Kropelin (206:897), climate change was the motor that drove cultural change. That change was not steady but followed a series of spurts associated with periods of drought. Often a new social group would appear with greater complexity and adaptability following periods of aridity. Cultural change proceeded in a manner not unlike punctuated equilibrium (Gould and Eldridge, 1977; Bak, 1996:161-174) in which stable states are transformed to ones with greater complexity due to stress. Mobility was a key to survival for the nomadic pastoralists and a high value was therefore placed on the ability to navigate across the Sahara by the stars. The constant threat of drought made rainmaking a vitally important ritual similar to modern pastoralist communities, which conduct cattle sacrifices and construct stone circles.

Occupation of Nabta Playa During the Neolithic

The earliest excavated sites at Nabta have calibrated radiocarbon dates of 10,300- 9800 BP. Animal bones from this period include those of a large bovid Bos, gazelle, hare, jackal, turtle, and birds. Wendorf and colleagues (Wendorf et al., 1984; Wendorf and Schild, 1994) have suggested that early groups of cattle pastoralists, who brought their herds into the area, were involved in the earliest steps of domestication of cattle. Occupation of Nabta Playa continued sporadically through the Early Neolithic (10,800-8900 BP) and Middle Neolithic (8300BP-7600BP), interrupted by occasional periods of aridity when the desert may have been abandoned. After these arid periods, reoccupation would occur by new groups sometimes with new traditions and social structures that represented improved adaption to the desert environment (Wendorf and Schild, 1998).

During the Early Neolithic houses, consisted of simple brush or mat covered huts. Nabta Playa may have functioned as one of several regional centers in the desert, to which related groups would return during the summer rains. Some of the nomads could remain throughout the year by digging deep wells in the playa, which they would abandon during the wet season. There is no sign of social authority.

In the Middle Neolithic, houses were slightly more substantial. They were usually semi–subterranean round or oval structures with slab–lined walls, some with wattle and daub walls. There was the same pattern of moving out of the lower part of the basins at the time of the rainy season to the sand dunes above water line. Along the northern beach of Nabta Playa there is a 2 meter deep trash accumulation, numerous stone lined hearths, and the

highest frequency of cattle bones of any locality in the Nubian Desert (Wendorf and Schild, 1998). Among modern African pastoralists cattle sacrifices occur primarily at major ceremonial occasions, and it therefore seems likely that Nabta Playa began to function as a ceremonial center at this time. There was still no evidence of social differentiation or authority.

The Middle Neothlic ended with a short but deep drought, which began around 7600 BP, lasted about 100 years, and apparently emptied the Nubian desert of pastoralists. The Late Neolithic (7500 to 6200 BP) began with a new group that had a complex social system with more organization and control than previously seen. Sites were larger than before, often reoccupied, but always temporary. There are many stone–lined hearths but no evidence of houses. These new people, the Ru'at El Baquar people (the Cattle Herders), were responsible for cattle burials in clay–lined and roofed chambers in the Valley of Sacrifices. The diminished rainfall in the Late Neolithic meant that Nabta Playa was one of only a few watered refuges.

Each fall, when the water in the playas dried up, many of the pastoralists had to move to better watered areas. Mobility was the key to survival. Although there are no permanent settlements at Nabta Playa, the nomads built a large ceremonial complex containing some 30 complex structures, which included both above ground and below ground features, a stone circle, and lines of megaliths crossing the playa. The quarrying and transport of the large slabs and the construction of the shrines involved a substantial investment of energy and resources as well as significant management skill and political control. Wendorf and Królik (2001: 503) suggest that the presence of these structures indicates "an incipient social complexity that is unexpected for Saharan Late Neolithic groups." These nomads skipped sedentism with its associated agriculture, permanent villages, and political hierarchy, and entered the Late Neolithic with their own repertory of concepts involving cosmological symbolism, design of sacred structures, and ritual. Another place where monumental ceremonialism preceded sedentism appears to be Göbekli Tepe (Peters and Schmidt, 2004) in southern Turkey, which dates to 12,500 BP. In both Nabta and Göbekli Tepe symbolic thinking of nomads and hunter–gathers was actualized first in monumental ceremonial structures without needing to be nurtured or amplified in the political and religious structures of a sedentary society.

The climate in the Sahara after 7500 BP may have been the major driving force for development of the ceremonial complex at Nabta Playa. The monsoon rains failed, some two millennia later, and the desert returned to hyperaridity. The ensuing exodus from the desert coincided with the rise of sedentary life along the Nile. Some of the cognitive features of early Dynastic Egypt, such as cattle worship, deification of Hathor —the cow goddess—, symbolic complexity and the role of astronomy in ceremony, can perhaps be traced back to Saharan cattle herders and their heritage.

The Valley of Sacrifices and the Calendar Circle

Along the western rocky bank of a wadi entering Nabta Playa from the north there are at least ten mounds or tumuli. Built of broken sandstone blocks, the tumuli contained offerings of parts of butchered cattle, goats, and sheep. The largest and perhaps the oldest tumulus contained an entire young cow, the most precious offering that a pastoralist can make. A piece of tamarisk from its roof yielded a calibrated radio carbon date of 7270 + 270 years BP. Probably a female just entering adulthood, the animal was lying on its left side, oriented approximately north-south, with its head to the south (Figure 2). One would think that a young heifer would be one of the most precious offerings they could make. One of the few human burials at Nabta Play was that of a healthy young male whose skull was missing and may have been removed before burial as an offering. There are no traces of teeth or crushed skull bones. A little further downstream in the wadi is a sandy mound, which at its base contains the burial of a young human female. This wadi, which is now called the Valley of Sacrifices, brought water to the playa and would have been an appropriate place to ask the gods for rain by performing human and cattle sacrifices and other rituals.

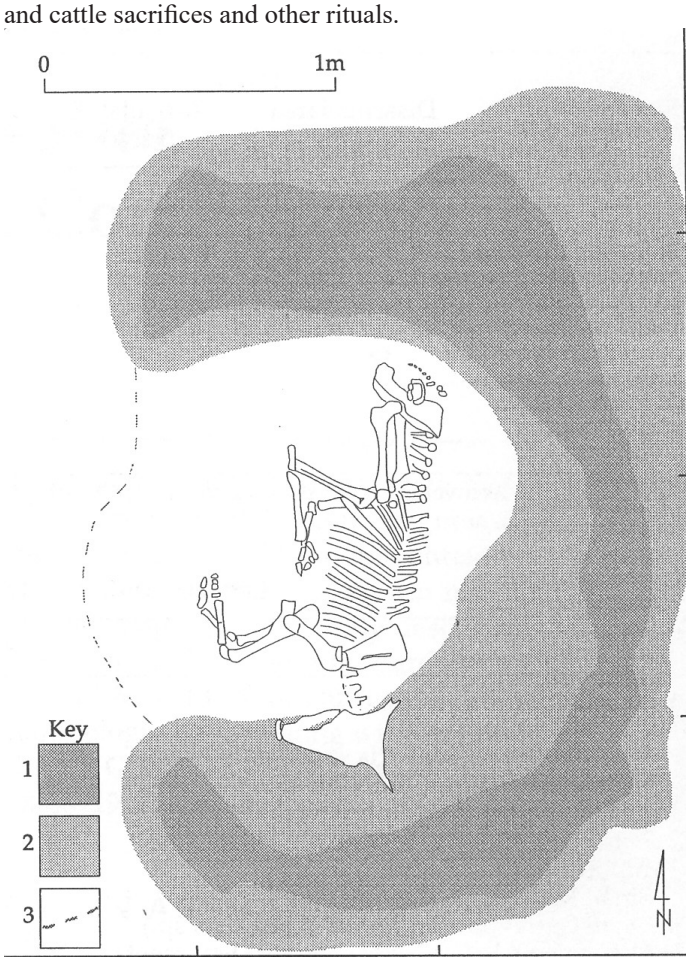
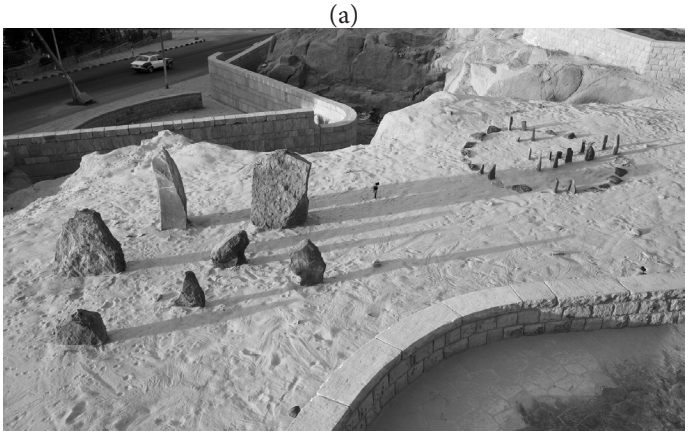


Figure 2. Articulated Cow Burial in the Valley of Sacrifices.

The wadi ends with a small sandy knoll with a circle of stones at its top (Malville et al., 1998; Applegate, 2001; Wendorf and Malville, 2001; Malville et al., 2008). A radiocarbon date from a hearth adjacent to the circle yielded a date of 6800 + 60 years BP. The circle, approximately 4 meters across, contains sets of upright, narrow slabs aiming the eye approximately to the north and to the position of the rising sun at summer solstice. In its stones, the circle holds the two major astronomical elements in the lives of the nomads. North was important when navigating across the oceans of sand of the Sahara. June solstice was significant for the onset of monsoon rains. The north-south alignment may have been symbolic and not intended as a sightline, but the June solstice alignment may have been the focus of rainmaking ritual. My own measurements of the circle were made lying flat on the sand in order to sight through four pairs of standing stones. However, long shadows of the horizon sun at June solstice sunrise and December solstice sunset align with the standing stones (Figure 3b), and these can be viewed from above. The circle could have been a place for group ceremony as people watched the shadows of the rising sun move across the sand into

an alignment near the start of the rainy season. Unfortunately, recent visitors to Nabta have taken it upon themselves to modify the stones of the circle. In order to preserve its integrity the stones of the circle have been moved to the Nubian Museum in Aswan.

(a)



(b)

Among the cattle pastoralists of the Upper Nile, cattle are their primary measure of wealth, the basis for prestige, and are used for bride payments and blood fines. Rainmakers are the usually the most important member of these tribes. They derive their power from spirits of the ancestors and they may serve as the intermediary with their high god for the purpose of bringing rain (Wendorf and Schild, 1998). Herskovits (1926: 28) describes an instance of a Nuer ruler who sacrificed numerous cattle and covered them in an earthen mound to demonstrate his importance and wealth. The rainmakers may be killed if rains fail to arrive. Among the Bari and Lotuko, the shrines of rain makers consist of a circle of upright stones with a mosaic of slat stones in the center (Selligman & Seligman, 1932: 288, 330). The Nuba construct circles of large upright stones with flat stones in the center in which they perform the new fire ceremony (Seligman and Seligman, 1932: 343-344).

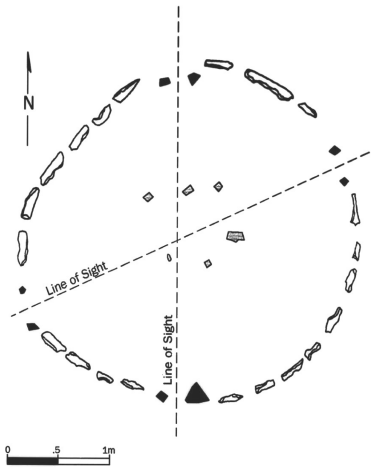
Another well–known stone circle was discovered by Bagnold (1931) in the Libyan Desert. It is larger than the Nabta circle, but it seems to be made up of the same kind of thin stone slabs as at Nabta. No evidence of astronomical orientations has been reported, and none is readily discernable in photographs of the circle. Similar to the Nabta circle, it consisted of thin slabs of sandstone 45-60 cm high. When observed by Badnold, half of the stones were prone and half were still vertical. Recently Andras Zboray (personal communication) has obtained additional measurements of the circle. He reports a north-south diameter of 8.8 meters, a NE-SW diameter of 9 meters, and an east-west diameter of 8.6 meters. There were originally 29 stones with spacing varying from 45 cm to 163 cm. He found no artifact scatter within 400 meters of the circle. Unfortunately the circle has been treated by visitors in a manner similar to that at Nabta. A central cairn had been added although it is clear in the photograph by Bagnold nothing like that was present when he discovered it. Zobray has removed the cairn.

The Complex Structures: Clusters of Stelae

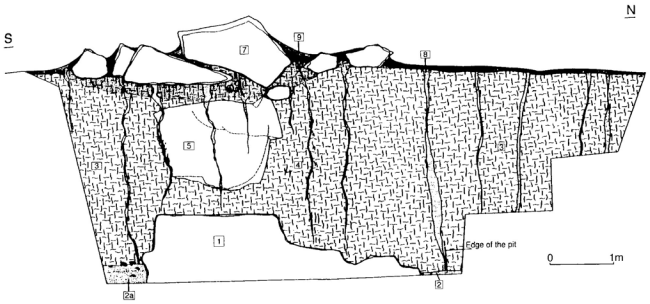
To the south of the Valley of Sacrifices are about 30 complex megalithic structures built during the Terminal Neolithic by the Bunat El Ansalm people or Megalith Builders. The Terminal Neolithic at Nabta Playa extended from 4600 BC to abandonment of the area in approximately 3400 BC. These structures were originally identified by the Combined Expedition as Complex Structures, but Schild (personal communication) recommends that they now be called Clusters of Stele. These clusters were set in silt deposited during the final part of the Middle Neolithic. Some of the stones on the top are standing upright, typically arranged in an oval with larger recumbent stones in the center. The ovals are 5-7 m long and 4-6 m wide, oriented north-south or rotated slightly to the west of north. The recumbent stones have a similar orientation.

The largest of the clusters, A, appears to play a major role in the symbolism that becomes manifest in the ceremonial center during the Final Neolithic (Wendorf and Krolik, 2001). Very significantly, it is the focus of the five radiating megalithic alignments. The builders of cluster A dug a pit through playa sediments to expose a table rock at a depth of 2.6 m (Figure 4). The rock is a thick lens of hard, quartzitic sandstone that remained after the surrounding softer sediments had been removed by erosion. A similar rock was found in the second cluster that was excavated, and in a third cluster another table rock was located by a probe. The table rocks were probably formed during the initial deflation of the Nabta basin by wind, long before the deposition of the playa sediments. In the case of the rock at the base of cluster A, the northern side was flattened to the east-west and the western side was rounded. Its top appears to have been worked and smoothed. After shaping, the oval rock measured 3.3 m by 2.3 m with its long axis aligned north-south.

Figure 3. Stone Circle in the Valley of Sacrifices: (a) In situ at Nabta Playa; (b) After it has been moved to the Nubian Museum at Aswan. Artificial lighting approximates sunset on December solstice. Note the alignments of shadows with the stones. The large monoliths have been moved from Nabta Playa, but were not placed in the same relationship with the circle as at Nabta c) Diagram showing sightlines established by four pairs of standing slabs.



The pit was partially refilled and a large secondary stone, weighing 2-3 tons, was placed over the center of the table rock (Figure 6). This secondary stone was also carefully shaped with a large head-like projection facing north. It was held upright by two large slabs set against the structure at its north end. One side had clearly been smoothed by pecking. The stone may have been a surrogate sacrificial cow.



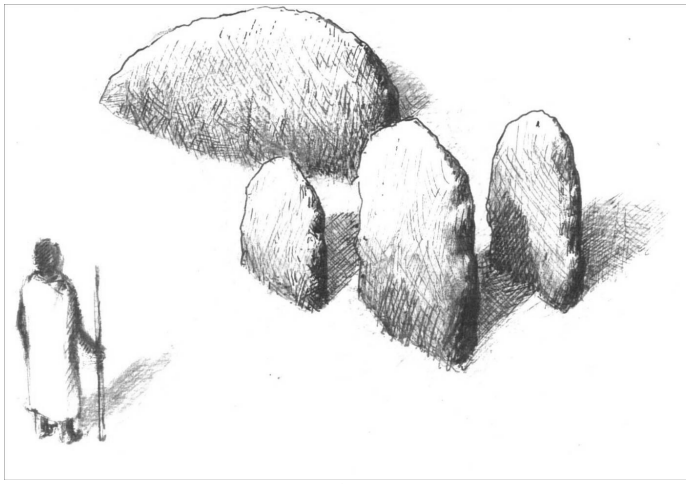
(a)

Figure 4. Cluster of Stele A. (a) North-south profile showing the buried cow sculpture. (b) Cow sculpture with Fred Wendorf.

Alignments

There are five lines of megaliths that radiate outward from the largest cluster A. The number of megaliths in each line ranges from four to six. Many of the megaliths, if not all, are sculptured with anthropomorphic shoulders suggesting that they served as stelae, perhaps representing the dead. A few are upright and others with broken bases embedded in the clays, suggest that originally the stele had been set up vertically, facing north. The dynamics of collapse involved the prevailing northerly winds that carved holes in front of the megaliths and caused their collapse. These depressions can be found underneath the northern faces of the collapsed blocks. The grouping of these stelae may represent departed members of specific clans who perhaps were specialists who used these particular stars for navigation across the desert.

(a)



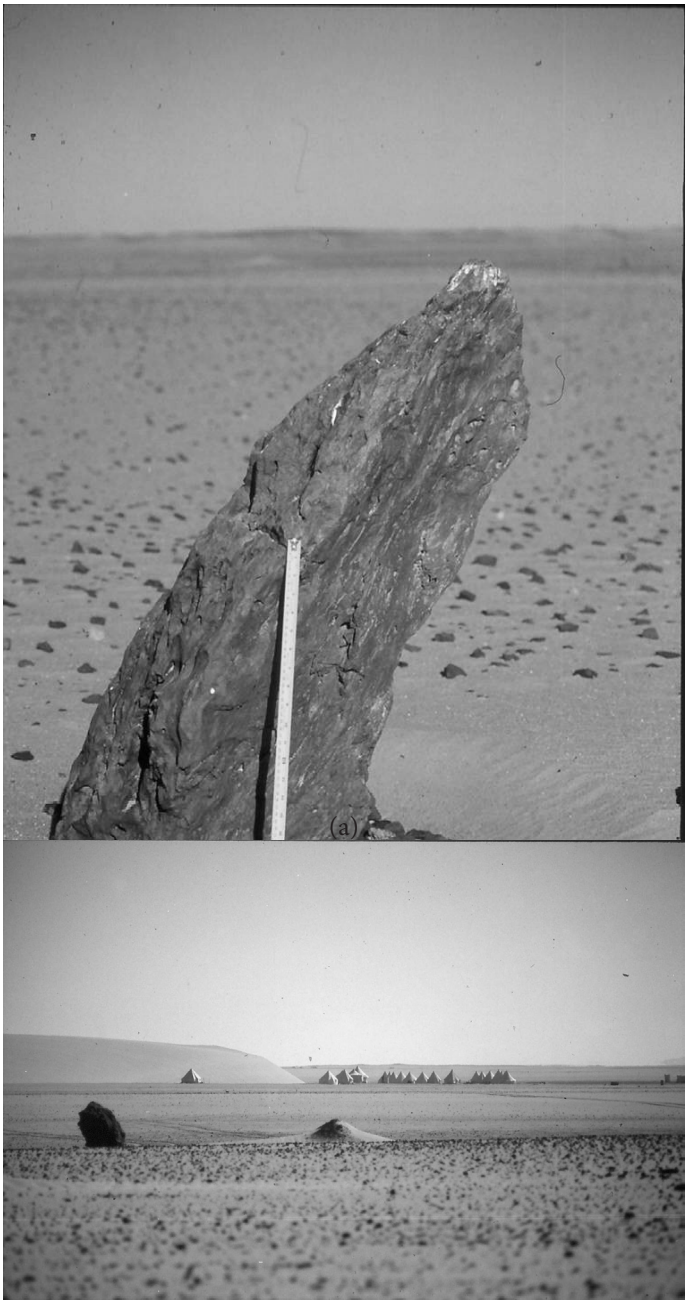
(b)

Figure 5, Stele in Alignment A. (a) Note blow–out of sand on northern side (b) artist's reconstruction.

Dates for the quarrying and placement of these stones in the sediments of the playa are based on radio-carbon dates from the nearby quarry, which range from 6500BC to 6200 BP. Not all the blocks that had been quarried were used, as approximately 100 m east of the quarry is a storage area where dozens of additional sandstone blocks have been stored. Since we also have a carbon date for cluster of stele E of 5600 BP, we estimate that the megalith period lasted for approximately 800-900 years from 6500 BP to 5600 BP.

We consider the possibility that these megaliths were intentionally aligned with the bright stars on the eastern horizon. For our calculations of precession we used the formulae of Bretegon et al. (1997) and have included effects of refraction and extinction. Because of the movement of the dunes over 6-7 millennia, it is impossible to estimate the actual horizon, and we assume a level physical horizon. Many of the stele are fragmented, and in estimating the dates when these alignments may have been oriented to certain stars, we include an uncertainty of + 0.6o.

Alignment	Azimuth (degrees)		Approximate Dates (BCE)
A3	26.3	Arcturus	4530-4320
A2	28.1	Arcturus	4220-4020
A1	30.6	Arcturus	3810-3630
B2	116.6	Sirius Belt of Orion	3700-3430 4300-4100
B1	120.1	Sirius α Centauri	4640-4400 4500-4260



(b)

Figure 6. Northernmost Stele of Alignment A. Note blowout on northern side. (a) Stele with camp in background.

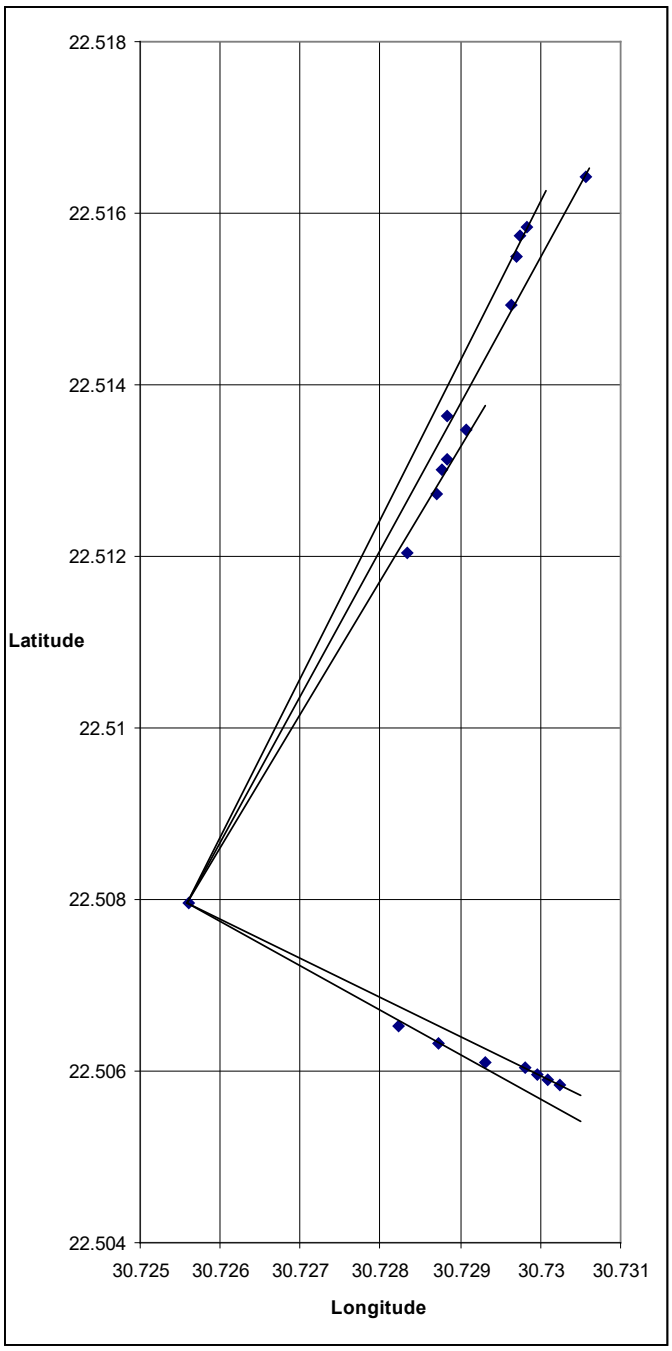


Figure 7. Alignments of Stelae.

The brightest star in the region of the sky north of the celestial equator, Arcturus is a reasonable candidate for the three northern alignments. There were three times when alignments A1, A2, And A3 were oriented to the rising positions of Arcturus in the period of the megaliths. Each of these three alignments may have been built to account for the changing location of that star due to precession.

The alignment, B2, may have been lined up with stars in the belt of Orion between approximately 4300-4100 BCE and later with Sirius, which is the brightest star in the night sky. The set of stele, B1, would have lined up with Sirius and α Centauri, which is the third brightest star in the night sky. A closer inspection of the southernmost alignment, which we had initially designated as C, indicates that it consists of stones resting on the sides and tops of dunes and may not represent an original set of aligned stele.

With the exception of Canopus, these alignments may have been associated with the brightest stars in the night sky of Nabta. In 4500 BCE Canopus would have risen with an azimuth of 159° and would have reached a maximum altitude of approximately 8° above the southern horizon. The two major periods of alignments appear to be 4600-4200 BCE, which would encompass Sirius, two orientations toward Arcturus, α Centauri, and the Belt of Orion. The second window at 3800- 3400 BCE, which would have included Sirius and Arcturus, may reveal a resurgence of interest in the heavens, just as life was getting increasingly difficult in the desert

The People

Judging from the elaborate burials at the nearby cemetery at Gebel Ramlah about 20 km from Nabta Playa, the nomads associated with the ceremonial center were prosperous and healthy, possessing a strong aesthetic sense, and interested in preserving and honoring their dead (Irish et al., 2002; Irish et al., 2003, Kobusiewica & Schild, 2005). The cemetery contained 67 individuals in both primary and secondary inhumations. The most reliable carbon date is from bone collagen giving is 6360 BP ± 60 years.

Inspection of dental features indicates that two different populations, Mediterranean and sub-Saharan, were represented in the cemetery. The lack of differences in burial goods indicates there was little, if any, social stratification in the community.

The exceptional wealth of grave goods is notable. Many were buried with ceramic pots, some of which were elaborately decorated. Vessels known as tulip beakers were apparently produced exclusively as grave goods and usually placed on the chest or near the head. They were also accompanied by sets of cosmetic artifacts consisting of stone pallets, stones for grinding color-bearing minerals, and containers made of ivory, bovine horn, stone, or ceramic. Many of the graves contained large sheets of mica, more than 10 cm across and 1 cm thick. One slab was shaped in the form a tilapia, a fish encountered in the Nile.

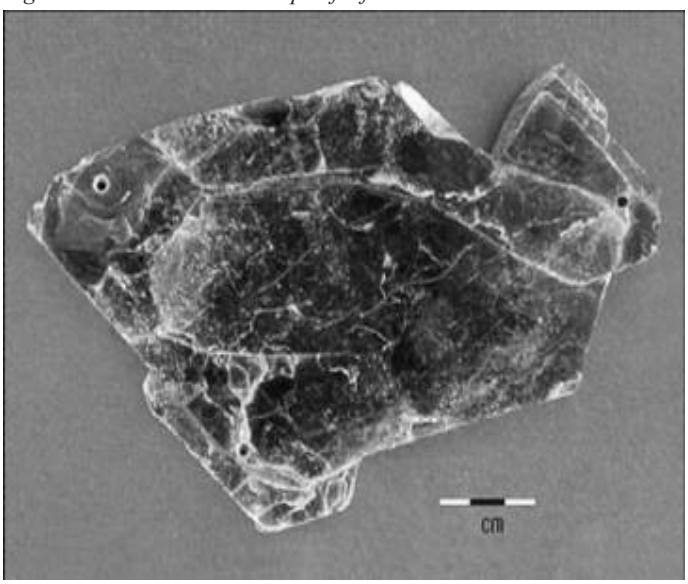
The lack of dental enamel hyperplasia, an indicator of growth disruption during early childhood, also indicates that children must have been healthy and well-fed. The tall stature of the burials suggests good health and nutrition. Secondary inhumations may have been of individuals who died while traveling. All 7 primary inhumations were in flexed position, oriented to west, facing south.

The cemeteries indicate that there was great interest in preserving the remains of the dead. There were two skulls in which some of the upper teeth were replanted in the lower jaw and vice versa. The forearm of one woman was found with four bracelets, which had been fastened to the skeleton after death. Many of the burials were sprinkled with large amounts of red hematite dust, which in numerous cultures is associated with blood, the life force, and high status.

The people living near or visiting the playas of Gebel Ramlah and Nabta participated in a wide trading network, which could bring them into contact with ideas as well as trade goods. Their contacts stretched far as evidenced by turquoise from the Sinai Peninsula, shells from the Nile, mica from mountains along the seacoast, and ivory from elephants.

The individual graves that preserved anatomical order must have been of people who died at the settlement and were interred there. The secondary graves can be interpreted as burials of individuals who died during the distant migrations of the herders. It must have been important to bury them in the clan cemetery at a site that was believed to be the "center place" for the culture.

Figure 8. Mica slab in the shape of a fish.



Summary and Conclusions

The evidence for astronomical observations by these ancient herdsmen comes in three forms. The repetitive orientation of megaliths, stele, human and cattle burials toward the northern regions of the sky reveals a very early symbolic connection to the north. A form of ancestor worship seems indicated by the groups of shaped stele facing north. The second bit of evidence for astronomy is found in the stone circle with its two sightlines toward the north and the rising sun at June solstice, which may reveal sacrifices and ritual associated with rainmaking. Finally, the alignments of monoliths, which are oriented to the brightest stars of Nabta Playa, suggest an even more careful attention to the heavens. There may have been times during the Late Neolithic when shallow waters lay upon the playa. The light from major stars rising in the east would have been reflected in the waters and the monoliths rising from the waters were aligned with some of the stars.

The "empty tombs" beneath the clusters of stele provide some of the greatest enigmas of Nabta Playa. How were the buried table rocks located, and what did they symbolize? Regardless of how they were initially located, the buried table rocks underneath the megalithic slabs apparently became additional manifestations of the sacred for the nomads. There is a strong sense of verticality in Nabta: above and below. Perhaps there were three worlds: heaven, this world, and the underworld. The burial of the surrogate cow beneath the cluster of vertical monoliths suggests an *axis mundi*. The ultimate burial of the monoliths at Göbekli Tepe suggests a similar structuring of an imagined cosmos. The planning of these structures, the time and energy necessary to quarry, move, and place the (possible) cow effigy, as well as the effort needed to dig the pit down to base rock indicates significant commitments to a world of ritual by the transient nomadic visitors over a long period of time.

Nabta Playa started as a regional center, where related but dispersed groups would gather as the edge of the water hole after the start of summer monsoon rains. The regional center was gradually transformed into a ceremonial center, perhaps around 7300 BP. The driving forces for that transformation may have been the stress of the climate change, which gave more value to practitioners of esoteric knowledge, such as navigation and the ability to predict of the onset of the summer monsoon. Navigation across the desert to small playas required the same set of skills as Polynesian voyagers. There was no star at the north celestial pole during this time, but the direction to true north could have been established by locating the area of the sky around which stars circled. Because that area was visible throughout the night and throughout the year, it would have been the most useful navigational tool. In addition, the brightest stars, Arcturus, Sirius, and α Centauri would have been important guides. However, because they change positions throughout the night, specialists would have been needed to measure the position of the stars and convert them at any time of the night and year to the direction of north. The more than 18 megaliths of the alignments, divided among the three bright stars, may indeed represent those specialists who knew how to uses those particular stars to guide parties across the desert. It seems likely that travel primarily occurred at night. We know from our experience with one of our assistants at Nabta that navigation by stars continues to be a skill possessed by Bedouin groups.

Transformation of the landscape from the mundane to the sacred may have been accomplished by a number of hierophanies,

involving stones, water, sun, earth, ancestors, cattle and stars. The presence of water in the playa, no matter how shallow, must have seemed miraculous in the dry landscape of the Sahara. The stars that guided the nomadic pastoralists may have seemed to be gods themselves or to have been provided by the gods. The combination of water in the playa, the reflected stars, and the dark megaliths rising from the waters, aligned with those stars, may well have evoked an overpowering sense of the sacred among the nomads camped on its western shore.

Acknowledgements
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Archaeoastronomical Analysis of Site E-92-9 from Nabta Playa: a Reassesment

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Abstract: The paper reassesses astronomical alignments of Site E-92-9 ("calendar circle") from Nabta Playa, Egypt. In contrast with earlier interpretations, the author concludes that alignments towards the sunrise position on the day of the Sun's zenithal passages could have played much more important role in the sky perception among the Nabta Playa inhabitants.

Keywords: Nabta Playa, Egyptian astronomy, zenithal passages of the sun

The prehistory of the Nabta Basin, located in Egypt's South Western Desert, about 100 km west of the Nile River (see Figure 1), has been intensively researched from the mid-1970s. The Nabta Basin has been the locus of human activities since at least the Late Acheulean (Lower Palaeolithic, Middle Pleistocene, ~ 300,000 BP) and numerous artifacts found in the geological context indicate that palaeoclimatic conditions in the past were wetter than in the Holocene (Wendorf and Schild, 1998: 99). Beside Acheulean artifacts, abundant Middle Palaeolithic (130,000 – 70,000 BP) associated with fossilized spring and lacustrine sediments offer another evidence for dramatic changes in paleoenvironmental conditions. Archaeological investigations indicate that wet intervals during the Pleistocene and early Holocene produced conditions that were favorable for diverse human groups seasonally occupying different locations within the area which today is hyperarid and virtually lifeless.

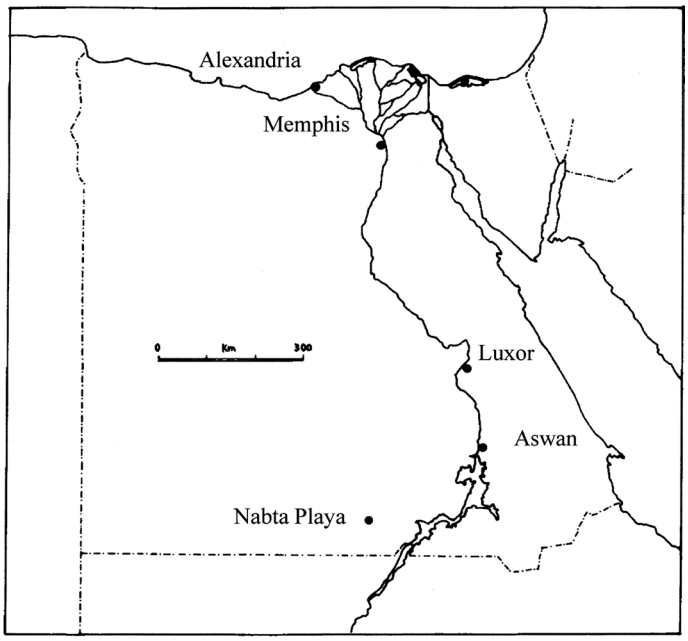

Figure 1. Location of Nabta Playa.

The Nabta Basin is a large drainage area filled with temporary or seasonal lakes (playas) and ponds during wetter intervals, while at drier periods the winds blowing from the desert modeled its landforms (dunes, depressions). Today, in the north and west, the basin is edged by the features of the Western Egyptian Desert – numerous undulating hills and dunes which are often interspaced by valleys and ephemeral springs (wadis). Artifacts scattered around near lakes, ponds and streams show that the basin attracted various human groups during the humid periods that occurred in the past (Wendorf and Schild, ibid.).

During the Neolithic period (around 9250 – 3350/3150 BCE)1 the climatic arid-wet oscillations produced several intervals which were extremely favorable for human habitation of the region (Wendorf and Schild, 1998: 100-111; 2001c: 649-651). Temporary and seasonal lakes and ponds produced by summer monsoon rainfalls attracted many human groups who built seasonal camps and (semi-sedentary) villages, equipped with dwellings, wells, storage facilities, tombs and other stone constructions. Grasses and other plants that matured during the early autumn months attracted pastoralists who brought their animals (cattle, sheep, and goat) for grazing. The Nabta Playa area is believed to have been a regional ceremonial center during the Late and Terminal Neolithic (about 5450 – 3350/3150 BCE); Wendorf and Schild, 1998: 107-111; 2001c: 671-674), when important megalithic structures and alignments were erected suggesting the emergence of a complex society.

Nabta astronomical alignments are associated with two types of monuments: (a) a "calendar circle" located on the top of a hillock (site E-92-9), and (b) a complex of several separate groups of megalithic alignments which produce sightlines aimed at rising points of various bright stars (Sirius, Dubhe and the belt of Orion) and the sun (known as A, B, C Alignments). Archaeoastronomical contributions include Malville et al. (1998), Wendorf and Malville (2001), Brophy and Rosen (2005), and Malville et al. (2007). The abovementioned authors suggest that careful observations of the sky were important for nomadic cattle pastoralists who were moving across the Western Desert to find suitable ecological niches to feed their animals. Moving along the western edge of the Nabta Basin they eventually discovered that the rising sun at summer solstice heralded the onset of the rainy season, the seasonal rise of water reservoirs followed by the growth of grasses suitable for grazing. It is suggested they built a calendrical circle and megalithic alignments to record important astronomical events they associated with those seasonal cycles.

Site E-92-9

1As radiocarbon dating is not precise, I use calendar (mean year) chronology based on calibrated radiocarbon dates (BP). Thus the date of 9500 bp (uncalibrated radiocarbon years) arbitrarily chosen to mark the start of the El Adam Early Neolithic phase (Wendorf and Schild, 2001c: 649) roughly corresponds to 11200 cal (calibrated) BP and to 9250 calendar years (cal) BC (consult Reimer et al. 2004: 1053). A list of uncalibrated radiocarbon dates (bp) from Nabta Playa is available in Wendorf and Schild, 2001b: 52-55. However, even the corrected dates are only approximate and may prove to be in error by tens of years. BC years are equivalent to BCE years. It is important to underline, that in this paper I am converting cal (calibrated) BP years into cal (calendar) BCE years in order to make easier further astronomical calculations which are usually counted astronomically, e.g. the year of 9250 BCE which Wendorf and Schild use to mark the start of the Early Neolithic is the year -9249.

The "calendar circle" is placed on the northern end of an elongated sand-hill, described as "a remnant of an old dune covered with playa silt" (Wendorf and Schild, 2001c: 665), in a relatively flat area. From the north, the hill with its "calendar circle" is adjacent to the Valley of Sacrifices, named after the burials containing diverse offerings (among them, tumuli with cattle burials) located next to the wadi channel that is supposed to bring fresh water to the playa during the summer months; from the south of the hill extends the wide area of playa deposits where archaeologists found two clusters of megalithic structures (Wendorf and Schild, 1998: 107-112; 2001c: 664-665).

The calendar circle consists of about 55 small Nubian sandstone slabs (ranging from the numerous small pieces measuring 20 x 20 x 5 cm, to the few larger ones reaching 70 x 20 x 10 cm). Few of the slabs remained upright while many other were found collapsed; their original locations were carefully followed by Schild and Zedeño (Applegate and Zedeño, 2001: 463, Figs. 14.1 and 14.3). The structure features a circle of at least 29 (28?) smaller slabs measuring less than 4 m in diameter. The main and calendrically meaningful alignments are formed between four pairs of larger slabs, called "windows" (Malville et al. 1998: 490) or "gates" (Applegate and Zedeño, 2001: 466). They appear to be arranged in two pairs composing the following sightlines: a) a rough north-south line (bearing 358˚/178˚), and b) a skewed east-west line (bearing 62˚/242˚), a rough summer solstice sunrise alignment (computed to be at 63.2˚ around 6000 years ago, Malville et al. 1998: 490). The circular structure has been considered as a very imprecise observatory, either because the circle itself was too small (Malville et al. 1998: 490), or because the distances between the stones creating the "gates" were too wide (Applegate and Zedeño, 2001: 466; Wendorf and Schild, 2001c: 669). Since the geographical latitude ($\varphi = 22^{\circ}32'$ N) of the site produces two annual passages of the sun through the zenith falling approximately three weeks before and after the summer solstice (during the beginning of the 5th millennium BC), Malville et al. (1998) further argued that upright slabs casting no shadows under the zenith sun would have signaled the arrival of the rainy season.

Inside the calendar circle are six upright slabs placed in two rough rows of three stones each running approximately along the east-west axis. They have not been commented in an earlier publication (Malville et al. 1998; Wendorf and Malville, 2001; but see Applegate and Zedeño 2001: 463), but in a recent paper Malville et al. (2007:3) confessed they could not find any astronomical functions for them. Despite this, the authors describe the Bedouin use of standing stones who observe their moving shadows to know the passage of time. This fact may be used to identify the moment of a day rather than to mark a seasonal change in the position of the sun.

Dating

The calendar circle was built during the Late or Terminal Neolithic at Nabta, called the Ru'at El Baqar Phase, very likely within the span of few decades after 4890 BC2. The circular structure is indirectly dated by Hearth 9 which is located 2 m to the north of the calendar circle. The dune with a calendar circle is covered by diverse hearth remains and Hearth 9 yielded a date of 6000bp ± 60 years. Archaeologists observed that the slabs forming the calendar circle were placed some time after the abandonment of the nearby hearths, so this date gives terminus post quem for the construction of the circle (Applegate and Zedeño, 2001: 464-465). This dating is in agreement with Late Neolithic artifacts found on the surface of the site (three human burials, pottery remains and lithic artifacts).

Function

Archaeologists accepted the calendar hypothesis as the most plausible explanation for the circular structure rejecting or dismissing the following other possibilities: house remains, above-ground granaries, and circle grave burials (Applegate and Zedeño, 2001: 465-466). They suggested that after a brief arid period, Nabta was re-populated by Late Neolithic Ru'at El Baqar cattle herders who built the calendar circle during the period of intensive construction activities in the nearby Valley of Sacrifices where when diverse ceremonial features were built (Applegate and Zedeño, 2001: 467).

However, given the small size of the calendar circle, its ceremonial-ritual function may be questioned. Small dimensions of the upright slabs (up to 70 cm) combined with a reduced extent of the circle itself (less than 4 m in diameter) do not appear to be big enough to serve for community meetings, rather they imply they were visited by a single individual. Additionally, surface pottery collections from E-92-9 provide samples typical of the Late Neolithic known at other Nabta Playa sites (notably at site E-75-8: Nelson, 2001: 540) and there is no indication of findings of some specialized ritual ceramics (Applegate and Zedeño, 2001: 463). On the other hand, the reduced dimensions of the calendar circle suggest that it could have been easily constructed by a small group or even a single individual, perhaps within a day or even within a few hours. The circle itself forms an irregular design, but it could have been built with some premeditation since the number of stones on western and eastern halves of the circle is equal (14 stones on each side). The site is located close to different cultic features: the hearth area around, at least three human burials found on the same hill to the south and east from the site (about 100 meters from the site), tumuli with cattle burials to the north (within the distance between 250 and 350 meters) and megalithic alignments to the south (about 300 – 900 meters) of this dune-hill. The megaliths adjacent to the dune-hill all belong to Group A and display a rough north-south alignment. When observed from the Complex A Structure, they provide alignments targeted at the rising positions of Dubhe or Arcturus (Melville et al. 2007: 5) during the 5th millennium BCE. The mound with the calendar circle atop is visible across the basin from the Complex A Structure but the reverse direction of the sightline may not be functional: the Complex A Structure may not be visible throughout the surrounding landscape. The sightline that relates the Complex A Structures with the calendar circle passes near to the northernmost row of megaliths (alignment A3).

I conclude that the structure displays *crude alignments* to the summer solstice sunrise position during the 5th millennium BCE and provides an *approximate* North-South axis. Due to its dimensions, the site *is not functional* for large public meetings, or for collective watching of the sun. The site alone is suitable for individual rather than collective sunwatching.

However, bearing in mind that during the wet season various group settlers occupied Site E-75-8 and treated different features around the Valley of Sacrifices as ceremonial locations (Wendorf and Schild, 1998: 108; 2001c: 664-665), I cannot rule out the possibility that Site E-92-9 together with other structures had initially formed an enormous ceremonial area.

2 The site bears the date of 6,000 conv bp (Wendorf & Schild, 2001b: 54). Observe that 6000 conv bp ≈ 6840 cal BP ≈ 4890 cal BCE (two sigma range is between 5038 BCE and 4764 BCE).

Some general questions and minor objections

By proposing that the skewed east-west alignment between two pairs of "windows" was used to watch the summer solstice sunrise, the researchers dismissed all other possibilities (see Figure 2). First, the site offers extended vistas in all directions, and even low sandstone hills which are approximately 2 km to the southwest do not affect significantly the visibility towards the position on the horizon of the winter solstice sunset (see Wendorf and Schild, 2001a: 12 – 13). Though perhaps the decision has been made basing on preconceived opinions derived from later Egyptian astronomy[3], I agree with these arguments because knowledge of the time of the year could have become important when pastoralism became an important factor in the subsistence of Late Neolithic Ru'at El Baqar peoples. It appears that shortly after the summer solstice few showers of rain in the area combined with wadi water discharge covered the basin with ponds and lakes. One of the important wadi channels brought water into the basin just east- and southward from the "calendar" site (Wendorf and Schild, 1998: 107, Fig. 3).

Likewise, it is hard to associate the winter solstice date with equally spectacular seasonal landscape transformation.

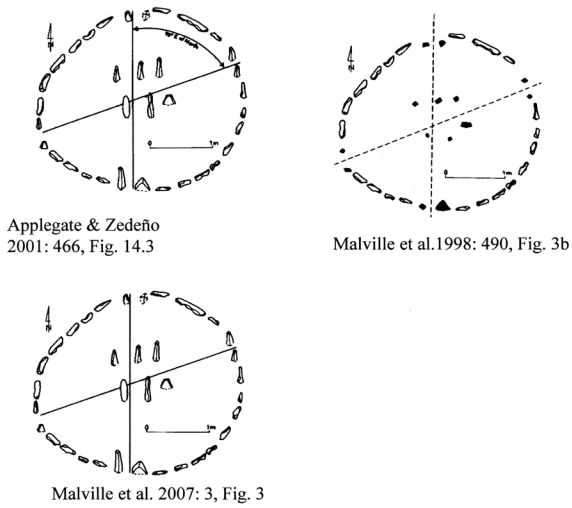

Figure 2. Changing perceptions of the stone circle (site E-92-9). The "windows" are given azimuths of 358° and 62° (Malville et al. 1998), of 65° - 70° (Applegate and Zedeño, 2001), and of a vague reference about the orientation towards the position of the summer solstice sunrise (Malville et al. 2007). Drawings by Anna Potoczny after originals.

Saying the above, I am not assuming that solstitial alignments were intentionally created and encoded in stone at site E-92-9. In my opinion, solstitial alignments might be part of a later tradition introduced into the area from outside - the first solar orientation framework for which we have evidence in Egypt. The geographical latitude places Nabta Playa within the tropical zone and within the research field of Tropical Astronomy rather than that of later Egyptian Astronomy. Assuming that (1) the site was built around 4900 BC, (2) the average Nabta features are located on approximately 215 m above sea level (Wendorf and Schild, 2001a: 12) and (3) the sun is observed at 0˚ horizon altitude, it is easy to determine that the rising sun on the summer solstice was perceived in the direction of 63.27˚ (the value of 63.2˚ given by Malville et al. (1998) is for a different date) and on the day of the solar passage through the zenith – in the direction of 65.23° (see Table 1). As stated above, the "gate" or "window" azimuth provided by Malville et al. (1998: 490) bears approximately 62˚, offering very crude precision of the summer solstice alignment. However, in their description of Site E-92-9 Applegate and Zedeňo (2001: 466 and Fig. 14.3) report on an azimuth of 65˚-70˚ or 245˚-250˚, informing that the gap between the slabs is wide enough to dismiss any precise result. As now the "window" permits a 5°-wide view of the horizon, it opens the way for new interpretations (see Figure 2). This arrangement allows me to propose that the"window" or "gate" might have served as a calendar marking the position of the sun on the days of its zenithal passage rather than on the summer solstice (see Table 1).

Now, the dates of the zenithal passages at Nabta are 22 days before and after the summer solstice. Around 4900 BCE the summer solstice date coincided with the 24th of June (Gregorian), so the dates of the passages of the sun through the zenith coincided with June 2 and July 16, respectively (plus or minus one day). Could these dates be somewhat linked to the dates of the Sirius heliacal rising? As is known, Sirius had a unique celestial distinction in Egypt because its heliacal rise heralded the rise of water influx of the Nile (starting to rise in June, however). The dates provided by Schaefer (2000: 150, Table 1)4 indicate that about 4900 BCE Sirius rose heliacally on July 8, plus or minus one day (in the proleptic Julian calendar, however), This corresponds to May 31 in Gregorian and falls almost on the same day as the first of two annual passages of the sun across the zenith.

Since in north-western Sudan the rainy season is from July through September, it may be true that Nabta sunwatchers were interested in determining the date of the second zenithal passage of the sun (July 16, Gregorian) rather than in marking the sum-

3 As is known, the dates of solstices, especially of the summer one, were extremely important in ancient Egyptian time-keeping system.

4 His Table 1 extends back the optimal dates for observing the heliacal rising of Sirius to 3500 BCE for a latitude of 30° north (appropriate for the old capital of Memphis). He finds that by 3500 BCE the heliacal rising occurred on the date of July 16. The Table 1 displays a general trend of shifting backward 1 day for each 1500 year period, so around 4900 BCE the date of first visibility slips to about July 15th. According to Schaefer (2000: 151) for every degree south of Memphis, Sirius rises one day earlier. As Nabta is located around 7. 5° south of Memphis, so from the date of July 15th should be subtracted 7 days giving a final date of July 8. Given the variable meteorological conditions and the uncertainties in finding extinction coefficients, the date of fist visibility can vary by as much as two days on each side of July 8 (all dates are given in the proleptic Julian Calendar).

Table 1. Sunrise dates for Nabta Playa. The values are rounded to the nearest arc of minute. Declination value for the summer solstice at 4890 BCE is obtained from the modified (computed for J 2000.0 epoch) de Sitter formula. The Sun's first contact is assumed to be visible at 0°02' above the astronomical horizon. The standard refraction correction is corrected for the elevation of 215 m asl. Observe that sunrise azimuths at zenithal passages much better fit the orientations provided by the "window" or "gate" (between 65° and 70°).

Sunrise dates	Sun declinations	Sunrise azimuths in 4890 BCE		
		First gleam	Center of the sun-disk	Last contact
At zenithal passages	22°32'	65°06'	65°13'	65°20'
At summer solstices	24°19'	63°08'	63°15'	63°22'

mer solstice sunrise (June 24, Gregorian). In this case, the second zenithal passage of the sun would have signaled the arrival of the rainy season.

Conclusions

It has to be emphasized that the determination of the exact day of the solstice is a challenging task within the tropics, as the sun appears in almost the same place for several days before and after the date (Aveni, 1981). The perception of the zenithal sun within the tropics is strictly related to shadow observations and requires gnomons or vertical shafts. It is worth noting that some of the stones, both the upright and fallen slabs appear to be finely worked or broken and display multiple sharp edges which seem to be good–enough to produce sharp shadows (R. Schild, personal communication, 2009). It may be hypothesized that utilizing the large variety of different environments nomadic groups created a detailed pattern of mobility in search of water, food and raw materials. Like all other human groups living in the tropics, they could have used the zenithal sun as a guiding principle to orient themselves while moving across the country (Aveni 1981: 161). Examining shadows cast by the sun at midday by the nomadic groups of pastoralists did not require any fixed point of observation and allowed to predict the proper time to arrive at Nabta Playa. Be as it may be, the hypothetical use of shadows may be combined with, or substituted for, the use of the sightlines towards the distant horizon. Around 4900 BCE the positions of the sunrise on days of its zenithal passages could have been singled out from other alignments because they were believed to be somewhat related to other significant seasonal events such as the heliacal rising of Sirius and the start of the rainy season. Thus, I suggest an alternative model for the functioning of the calendar site insisting in its solar zenithal alignments. The structure probably functioned to celebrate either the first zenithal passage of the sun coinciding with the heliacal rising of Sirius or the second zenithal passage of the sun announcing the onset of the rainy season. The Neolithic inhabitants of Nabta brought the knowledge of the zenithal passages of the sun from further south adding it to the ceremonies performed at the site. They eventually associated the moments of the sun's passages through the zenith with Sirius observations (the so-called Alignment C, erected during the Baqar Late Neolithic, Wendorf and Schild, 2001c: 668-669). It is, of course, possible that Nabta alignments follow the directions of the rising/setting sun on still other dates, or are related to the factors unknown to us. Nevertheless, it is probable that high accuracy of astronomical observations was not required and conclusions offered by Malville et al. (1998, 2007) are not definite.

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Sacred and Ceremonial Mountain: Archaeo-Astronomical Observation from Kilimanjaro

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Abstract: Astronomical observation is an ancient science practiced by different early communities. Such communities employed different astronomic symbols depending on their geographical location and physical features such as Oceans, Lakes, and Mountains. This paper present an account of the Chagga society on the slopes of Mount Kilimanjaro and how they relate with the Mountain as an astronomic symbol.

Keywords: Chagga, Kilimanjaro, Mountain, Ceremony

Introduction

This paper is about how the Chagga view and relate with Mt. Kilimanjaro as a sacred and ceremonial mountain. Attention is paid to the relationship between ceremonial and sacred activities with regard to the mountain and the sky. The Chagga, a Bantu-speaking people that live around the mountain, are totally attached to it and are known to accurately interpret every signs that the mountain may exhibits from time to time depending on the weather. The Chagga relate almost every activity from the ancient time to the present with the mountain.

Ethnographical observations have proved to be invaluable in cultural astronomy researches (see Chukwuezi 2008) the ancient Africans have regarded celestial bodies, mainly the sun and moon as god (Chami 2006; 2008). Africans have been unconsciously, using celestial bodies like sun, moon and stars to regulate their daily activities. My personal observation with ethnographic enquiries I conducted in Zanzibar and Kilwa, in July 2005 confirms that people in Tanzania used the sky to determine their activities. The modern study of sub-Saharan African Archaeoastronomy and ancient calendrical reckoning has a varied history. There are several examples: Namoratunga archaeoastronomical site in northwest Kenya; the calendrical system of the Borana of southern Ethiopia; lunar symbols in certain caves of Tanzania; megalithic site of Great Zimbabwe; and, the archaeoastromy of Dogon of Mali, in West Africa with the binary companion star Sirius B that show that archaeoastronomy has been in practice in Sub Saharan Africa since ancient times (see Lynch and Robbins 1978; Doyle and Frank 1997; Ruggles and Turton 2005; Chami 2008).

My work focuses on the Archaeoastronomy of the Chagga people of Kilimanjaro in relation to the sun and the mountain. Like many other places this Archaeoastronomical knowledge is vanishing without being studied properly.

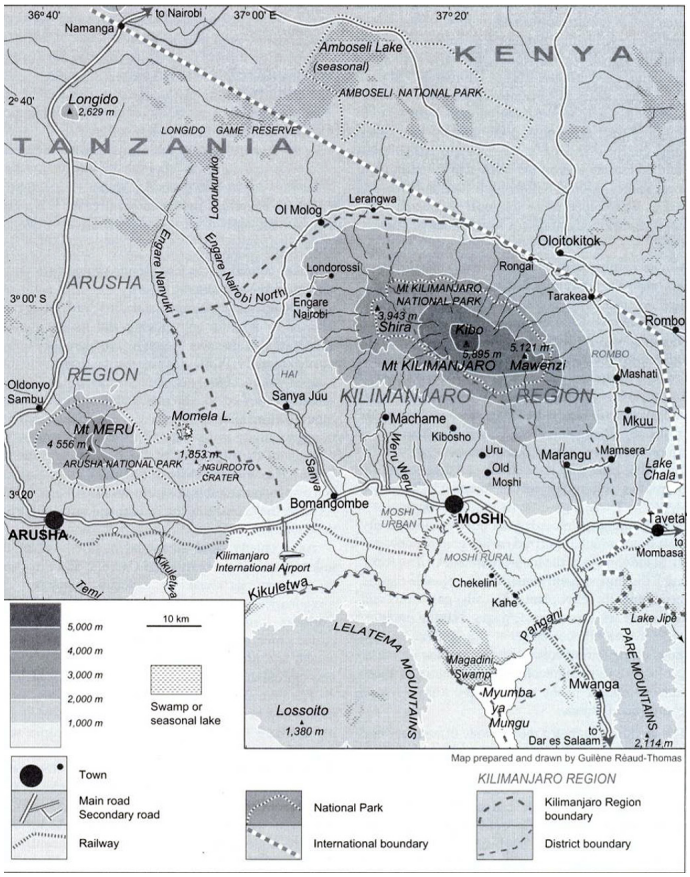
Kilimanjaro

Kilimanjaro region is found in the northeastern Tanzania, East Africa (fig 1). The region is named after Mount Kilimanjaro, the highest mountain in Africa. The settlement in Kilimanjaro dates back to Neolithic epoch (Mturi 1986). Stone bowls found on the lower slopes of the mountain justify that human beings have lived on or around the mountain since at least 1000 BCE (Dundas 1924). It is also documented that over the last 500 years, the mountain has at various times acted as a directional aid for traders travelling between the interior and the coast, (Stahl 1964); as an attraction for Victorian explorers; as a political pawn to be traded between European superpowers who carved East Africa; as a battlefield for these same superpowers; and as a potent symbol of independence for those who wished to rid themselves of these colonial interlopers (ibid).

Unfortunately, little is known about the history of the mountain during the intervening two thousand five hundred years. Yet the mountain can be seen from different directions from a distance of more than 300km as it has served as a point of reference for directions. This must have happened from the ancient time as Ptolemy reported (Huntingford 1980, Chami 2004 and Valerian 2009).

According to Montlahuc and Philipson (2006) the origin of the word Kilimanjaro is uncertain and some say it might not even be a Chagga word. This is not true. The Chagga called the mountain with its three peaks Kibo Mawenzi and Shira as <<Kilima kya ruwa or Kilima kya ro>>. This means 'mountain of god'. The colonialists corrupted the name to 'Kilimanjaro'. The two peaks were also given meaning by the Chagga. The higher one with

Figure 1. Kilimanjaro Region. Source: Bart (2006)



its ice was called Kiboo (top) or Kyamwi (light) in Machame and Kibosho. The other second peak being deeply furrowed was called Mavenge (furrowed) or Kimawenze (stones only) (Chami pers com September 25, 2008) see also Valerian (2009). The earliest record of Mount Kilimanjaro is probably in the Geography of Ptolemy written in the second century CE. Ptolemy reports, a three peaked mountain in the inland from the coast (Huntingford 1980, Chami 2004).

Mt. Kilimanjaro is located 330 km south of the Equator in Tanzania, on the border with Kenya, between 2º45' and 3º25' S and 37º00' and 37º43' E. It is the highest mountain in Africa, composed of three peaks, Kibo, Mawenzi and Shira, which reach altitudes 5,895, 5,149 and 3,962 metres, respectively (Lambrechts et al., 2002; Hemp & Hemp, 2008). The mountain's topography features very deep V-shaped radial valleys, particularly on the western and southern slopes, as well as major barrancos south of Kibo and east of Mawenzi (Tanapa/awf, 1987). In the cultivated areas on the lower slopes, these valleys, together with some secondary vents, create important refuge areas for natural flora and fauna (Hemp & Hemp, 2008). This beautiful landscape fascinated earlier travelers in the region (Le Roy, 1965).

Peopling of Kilimanjaro

These are Bantu speaking agriculturalists living on the slopes of the mountain. The Chagga vocalize a cluster of related dialects (Odner, 1971; Lema, 1973). The Chagga were the subject of different studies dealing mainly with socio-economic (Clemm, 1963; Brewin, 1965; Fernandes et al., 1984; O'Kting'ati and Kessy, 1991; Mdoe and Wiggins, 1997) or ethnobotanical and ethnozoological aspects (O'Kting'ati et al., 1984; Hemp, 1999; 2001). According to Whiteley (1965:68) the Chagga are more related to Kamba and other languages to the east than to the block of languages to the south. However, (Kimambo, 1969:20) says that the Gweno language of the North Pare Mountains resembles the Chagga language. The Chagga language is grouped together with Kikuyu and Kamba and other languages in the interior as having less Bantu 'roots' (Odner, 1971). This led to a controversial argument that Chagga-speaking people arrived fairly late in their present domicile area, around this millennium (Oliver, 1966; McIntosh, 1968). However, archaeological sites of settlements of the first millennium B.C and A.D are known in Kilimanjaro (Mturi, 1986; Odner, 1971).

The Chagga history is well documented for over one hundred years (Jones, 1941:11, Stahl, 1964, 1965; Dundas, 1924; 1932, 1968, Odner, 1971, Lema, 1973, Makule, 2003, Valerian, 2009). Scholars debate about the origin of the Chagga. Mangi Marealle of Marangu in 1890's told Karl Peters that the Wamarangu came from Kamba, the Wa-Old Moshi from Usambara but the Wakibosho had always been on the mountain (Karl Peters, 1895:121). Linguistically, Chagga language includes several dialects including Meru and Gweno spoken on Meru Mountain and Pare respectively (Stahl, 1964, 1965; Kimambo, 1969; Makule, 2003; Blot, 2006). According to Blot (2006:59) these languages can be referred to as 'western Chagga', 'central Chagga', and 'eastern Chagga' or 'Rombo'.

The Archaeoastronomy of Chagga

All the important activities like rituals, ceremonies and sacrifices were done while orienting to the mountain or in the mountain. The Chagga have strong belief in Rua/Ruwa as the most powerful god. Rua/Ruwa in Chagga is sun. The mountain is seen as close to the sun due to its height, hence close to Ruwa. It was thought that in doing so the petition will reach God easily. There are several functions/ activities that are performed by Chagga that have some astronomical association in them. The following are some of them.

Funeral, Initiations and Other Sacrifices

The Chagga people in the ancient time, dealt also with problems like curse and methods of eliminating curses. If the medicine man's efforts to eliminate a curse proved to be in vain, a funeral would be the most likely outcome. As with most Chagga ceremonies, this would vary slightly from place to place and also depended on the status of the deceased. Animal sacrifices would take place on the day of the burial, with the hide of a sacrificed bull used to cover the grave. Interestingly, the corpse on the grave would face the top of the Mount Kilimanjaro. As the Chagga believe that the summit of Kilimanjaro is in some way connected with the afterlife and more close to their mighty God <<Rua/Ruwa>> which is the sun. A lot of beer-drinking is also involved. Sacrifices would continue for the next nine days until, it was believed, the soul had finally crossed the harsh desert separating the earthly world from the spirit world. The afterlife, incidentally, is said to be very like our temporal world, only not as good, with food less tasty and the scenery less majestic. The relationship between the direction of the burial, Mount Kilimanjaro, and the sun symbolizing God is an astronomical exercise which Chagga people practiced unconsciously. However, to the Chagga people north means top of the mountain and south to the valleys. Amazingly, the Chagga travelling abroad will refer to a top of any mountain as north (ndoo). Chagga believe that Ruwa (God) was greater than all other gods they worshipped. They have known Ruwa since ancient times and used to say that all men had their origin in him (Swai 1965). They used four names to glorify Ruwa and his great works. These are (A) Ruwa meaning universality, that which is felt all over the world like the sun from nothing is hidden, (b) Matengera, meaning the one who cares for all his creatures in a peaceful way; (c), fumvu lya mkuu, meaning the mountain of ages and (d), Molunga soka na mndo means that through his great powers there are mysteries for every living creature. The Chagga believes that Ruwa resides in a place up in the blue skies and the peak of Mount Kilimanjaro is close to it (Swai 1965, Makule 2003). Astronomically again, when elderly persons got up early in the morning , they stood outside the house and, facing north towards Kilimanjaro, spat to the sky, saying «tuu, tu,tu, tu, prai» sing Ruwa with the four names and thanking him that they had arisen safely that morning.

Sacrifices to Ruwa were done in the midday when the sun is overhead and was officiated by Mangi or elder of the family. The officiator should recite all the four names of Ruwa while facing the sky. Elsewhere, (Chami 2006; 2008) argues that the Chagga still hold the sun as their highest god-Mungu Iruwa/Iriwa. The Bible has been translated into Kichaga language. The God in the Bible is directly translated as Iruwa / ruwa meaning sun in Kichaga. This god also is seen to belong to water pools (Chami 2006).

Sky Symbols and Mt. Kilimanjaro

The Chagga can also use cloud formations and the colours of the sky as their secret speech (Swai 1965). They can tell when the rain season is going to start and when it is going to end. The dark cloud forming and concentrating on the peak of the mountain symbolize the beginning of the rainy season. The clear and white cloud which diverges from the peak leaving the snow clear symbolize the end of the rain season.

The mountain is above all, for the Chagga, a place of supernatural powers and treasures. The mountain is a sign of misfortune when it glows as if with fire, which often happens in the short rain season after sunset. When this happens then a great famine is predicted (Stahl 1964; Swai 1965; and Marealle 1963).

Mt. Kilimanjaro is the greatest landmark for the Wachagga. They distinguish four directions from the mountain. For example in Machame dialect they have <ndoo< meaning above towards the Mountain, < sinde< down towards the plain, <mwirin< towards the moon. By this they indicate the west because the returning moon first becomes visible to them there as dusk falls, <iremin< in the darkness. This is the expression for the east, which is surprising at first, as hardly anywhere else would one think of so designating the place from which light arises. They are again reckoning by the moon and it is precisely in the east that after the full moon, it disappears from their sight (see also Stahl 1964 and Marealle 1963). There is also a tale among Wachagga that a young man whose father is still alive, may not, while washing or bathing, turn his face towards the plain, but must turn towards Kibo\ Mountain symbolizing the sun. This has an astronomical alignment as well.

Symbolically, Kilimanjaro Mountain is for the Chagga the good and beautiful place, the symbol of their home which disappears from sight only after many days' march. Then, all streams which make their fields green and fertile flow. As argued before, the clouds' colour play a great role here with the so called 'heavy rain clouds'.

Figure 2. Mount Kilimanjaro and the Chagga banana groves (See the snow cap)

Conclusion

This paper has tried to explain the Archaeoastronomy of Chagga, who like any other ancient African community viewed and deified sky objects and used them astronomically. Issues of directions are very important here. The north-south direction seems to have been caused by the mountain top. Is the mountain symbol of sun-god due to its glittering ice? The Chagga have considered Kibo as a symbol of sun hence their god. Also the question that east and west relate to moon rather than sun at the equator is also enigmatic. The sun also ends at the west making the evening dark in the east. The only difference is that the moon first appears in the west and it also disappears in the west. This calls for a further research. Though with few data, the archaeoastronomical information gathered from Kilimanjaro adds somehow significantly to the growing body of knowledge and evidence attesting to the complexity of the prehistoric cultural developments in Tanzania. It suggests that an intensive study of culture should be conducted so that we can get a deeper insight of what the ancient people thought of the sky day and night.

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Lighting the Temples: A Story of Discovery on Egyptian Archaeoastronomy

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Abstract: For a decade, the Egyptian-Spanish Mission for the Archaeoastronomy of ancient Egypt has been performing cultural astronomy research in the country of the Pharaohs. In a series of six campaigns, nearly every corner of the land of the Nile, including the Oases, were visited and more than 500 alignments (350 in temples) in nearly a 100 archaeological sites were measured. The aim of the project was to challlenge the idea of wether ancient Egyptians astronomically orientated their sacred buildings or not.

Keywords: ancient Egypt, temple orientations, Karnak, Giza, Seshat

Introduction

For the last six years, the Egyptian-Spanish Mission for the Archaeoastronomy of ancient Egypt has been hardly working in the country of the pharaohs. In a series of six campaigns, we have visited nearly every corner of the land of the Nile and measured more than 500 alignments (350 in temples) in nearly a 100 archaeological sites. Campaigns were initially planned following a geographical criterion [Upper, Middle, Lower Egypt (respectively), Western and Eastern Desert Oasis, etc.]. However, in subsequent campaigns, we were performing selective experiments, in an attempt to falsify or test earlier hypotheses, often re-visiting sites for new measurements, or in order to get direct observations of predicted astronomical phenomena.

Campaign by campaign, this short report will narrate a brief story of the development of such a project, showing how some preliminary hypotheses had to be abandoned in the process and how new ideas were becoming more and more substantiated as time passed. We will initiate our journey in the splendid temple of Upper Egypt and will finish in the domains of the lunar god, Thoth, demonstrating that Astronomy did play a fundamental role in the search for cosmic order of ancient Egyptians[1].

Figure 1. The pyramids of Giza at high Nile. The relationship between the Nile and ancient architecture is clearly emphasized. Adapted from an original old image by Lehnert and Landrock.

Discussion

Were the temples of the ancient Egyptian civilization astronomically orientated? This is a very important question that is far from being resolved. Recently, Wilkinson clearly stated that most commonly temples built along the Nile were oriented on an east-west axis, according to local cardinal directions as determined by the river, so local topography (Wilkinson, 2000, 36-7) would be the determining reason for temple orientation (see Fig. 1). However, he also pointed out that on occasions, orientation towards the sun or important stars was definitely the priority, and this principle may be more important than is often recognized. Indeed, it has been the main goal of our mission to show that the most commonly is certainly true (see Fig. 2) but that on occasions is far too restrictive and that solar (see e.g. Fig. 3) and stellar orientations were much more common in ancient Egypt than had previously been suspected.

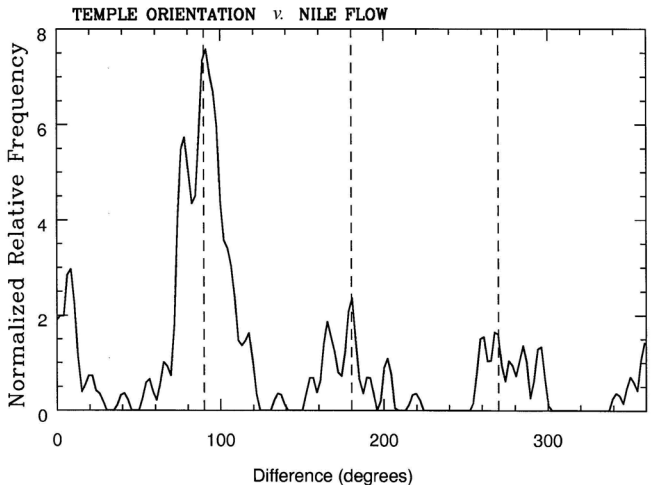


Figure 2. Testing the Nile hypothesis. Histogram representing the difference in orientation between the main axes of 170 temples of the Nile Valley and the average course of the river at their corresponding locations This figure demonstrates beyond any reasonable doubt that local topography (the course of the Nile) was very important at the moment of settling the foundations of the temples, although it was not the only factor to be considered. From Belmonte, Shaltout and Fekri, 2008.

Our first campaign was performed in the late winter of 2004 and we concentrated our efforts in the temples of Upper Egypt and Northern Nubia (Shaltout and Belmonte, 2005). Our main task was to measure all the temples, giving a similar weight to those marvellously preserved and to temples where not more than a few walls are preserved. One of our first intentions was to test the Nile hypothesis. Figure 2 shows an extraordinary outcome of our data since it demonstrated, beyond any reasonable doubt - and for the first time -, that ancient Egyptian temples were orientated in such a way that the main gate of the building could be directly open in a direction perpendicular to the Nile. This had been frequently argued in specialized circles but had never been proven statistically. This figure was obtained when the temple sample was almost complete but it diverges only slightly of the original one yielded by the temples of Upper Egypt.

However, for an archaeoastronomy mission, the most outstanding result was to clearly determine that astronomical orientations were indeed present in our extensive, but still incomplete, cluster of tem-

1 as shown in the different chapters of the recent volume, *In Search of Cosmic Order*, Belmonte and Shaltout, 2009.

Figure 3. Solstitial orientations in western Thebes. Today, as 3350 years ago, the colossi of Mennon still face sunrise at the winter solstice as did the Million year temple of King Amenhotep III behind them. Photograph courtesy of M. A. Molinero and N. Delgado.

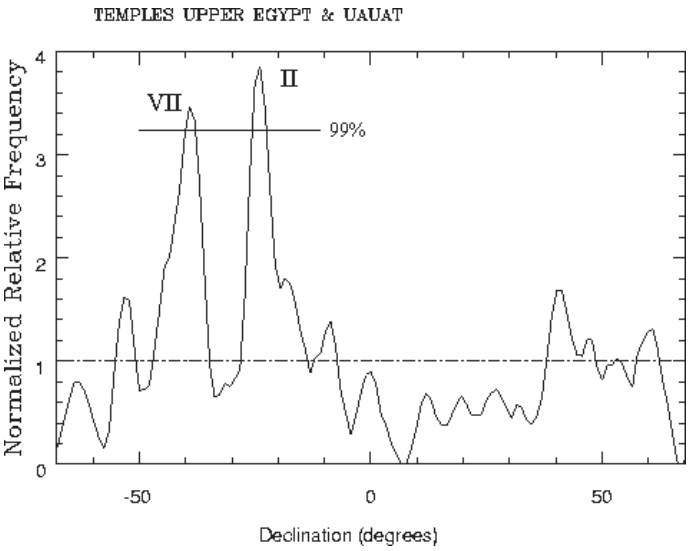


Figure 4. Declination histogram of 108 temples at Upper Egypt and Lower Nubia (Uauat). This figure, already obtained in our first mission, illustrated that the observation of heavenly bodies should have also played a role in temple orientation (see Fig. 10). Adapted from Shaltout and Belmonte, 2005.

Figure 5. The entrance porticos to the tombs of early Middle Kingdom local governors in the necropolis of Beni Hassan. The hypogea are excavated in a commanding cliff running N-S in the eastern shore of the Nile course. All the tomb orientations are concentrated within the range of sunset. Photograph by J.A. Belmonte.

ples. This is well illustrated in Fig. 4 where the histogram of declination of the temples is presented. There was a dominant peak, with a certitude of more than 99% that could be associated with winter solstice orientations that were ubiquitous in the area of Thebes.

However, there was a second significant peak. For this we proposed a tentative orientation to the stars of the Southern Cross and the bright stars α and β Centauri. Our later data showed that we were probably mistaken in our assumption.

The second campaign, in the summer of 2004, was a very brief one straddling a study journey into Egypt of the pupils of the hieroglyph course of La Laguna University, including the first author. This was a very festive event but we took the opportunity to check previous ideas and to measure several temples and tombs in Middle Egypt, including the monuments at Amarna and the suggestive necropolis of Beni Hassan (see Fig. 5). Once more, the presence of the Nile was determinant and we decided that a new, more selective, and clever campaign ought to be organized.

In private conversations, discussing our first results, some Egyptologists have argued that local topography would have been the predominant rule, the heavens playing only a secondary role, the astronomical orientations in some cases even occurring by chance, as in that of the winter solstice alignments in Thebes. Thus, we were dealing with a frustrating dichotomy.

Consequently, we decided that the situation deserved a new campaign in Egypt (the third one); but not a usual one. The idea was to falsify the Nile hypothesis by doing fieldwork in areas where the river could play a null role in the orientation of sacred structures. To achieve these, we went to the Oases of the Western Desert, where the presence of the ancient Egyptian culture, well attested since the Old Kingdom to Roman times, guaranteed the utility and relevance of the data, while the absence of a "Nile" would introduce an interesting new perspective.

The campaign was performed in the early spring of 2005, visiting the oases of Fayum, Bahariya, Farafra, Dakhla and Kharga (Siwa was also visited but in a later campaign). Data were collected at all the oases but Farafra where the scant ancient remains were irrelevant for our purposes. This was the first systematic archaeoastronomical fieldwork ever performed at the oases (Belmonte and Shaltout, 2006).

Our results showed that when the river does not dominate the landscape, ancient Egyptian temples tend to be astronomically orientated according to two dominant customs, one of a presumably solar character and the other following the meridian line (see Fig. 6). We suggested for the first time that this could be the case for the vast majority of Egyptian temples, and that Nile orientations were actually part of a wider general plan where both local topography and sky-watching played a significant role, simultaneously.

As an additional result of the third campaign, a new experiment was designed to account for other solar orientations, within a group of our temples, when these are evidently not dictated by the Nile. This exercise consisted of finding possible alignments to either sunrise or sunset at the wandering New Year Eve (Wepet Renpet) of the Egyptian civil calendar (Belmonte, 2009: 109-14). The results of the experiment showed that, under some special historical and archaeological assumptions, some of these temples might have been orientated according to this quite simple hypothesis. We suggested that, provided the Nile alone does not necessarily govern eastern and western orientations in the valley, this hypothesis could be further tested in other temples across Egypt.

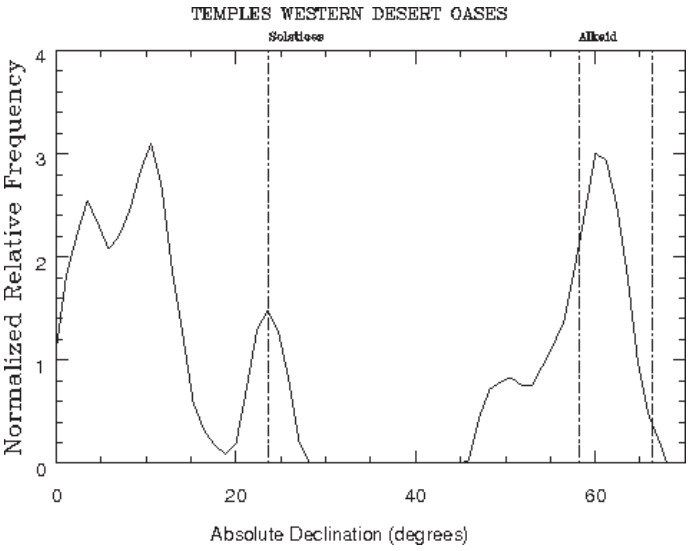
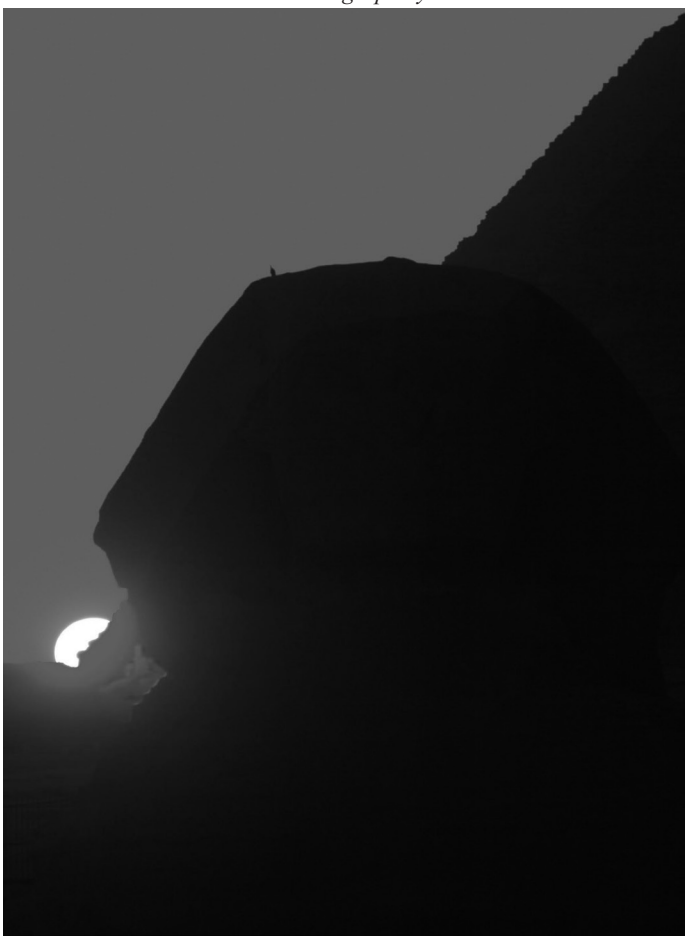


Figure 6. Absolute declination histogram of temples and chapels in the Western Desert Oases. Every single peak can be explained within an astronomical context. Adapted from Belmonte & Shaltout, 2006.

Another suggestive outcome of this campaign was the idea that most of the temples in our sample, aligned nearer to the meridian line, and open to either the north or south, were actually orientated by observations of the northern «imperishable» constellation of *Meskhetyu* (the Plough). These would perhaps respond to certain configurations of the asterism such as meridian transits, extreme polar distances or the rising or setting of certain stars (notably Alkaid). This hypothesis could also be further investigated in several sacred buildings in the Nile Valley, where we were certain, according to the inscriptions, that some of the temples were oriented to this constellation.

Figure 7. The equinoctial sun at 21st March 2005 is setting at the bottom-left corner of the second pyramid as seen from the main axis of the temple of the Sphinx of Giza. This image suggests a relationship between the two monuments. Photograph by J. A. Belmonte.



The timing of this campaign was selected with another special objective in mind. This was the observation, in situ and in due time, of an important astronomical event in suggestive locations where equinoctial alignments had been claimed, notably the Giza Plateau and the solar temples of the 5th Dynasty at Abu Ghurob. Figure 7 shows one of these impressive alignments in Giza, illustrating the celestial relationship between the Sphinx and the pyramids (see also Fig. 8).

The fourth campaign was performed in June 2006 in the north of Egypt, including the Cairo region, the Delta, the Mediterranean coast, the Oasis of Siwa and the Sinai, visiting the vast majority of the relevant archaeological sites in those areas (Shaltout, Belmonte and Fekri, 2007). More than 50% of the data belonged to the important sacred precincts related to the pyramids of the Old and Middle Kingdoms, which provided extremely interesting results. To our knowledge, this was the first systematic archaeo-astronomical campaign ever performed at a complete sample of pyramid complexes. We also took the opportunity to observe relevant astronomical phenomena related to the summer solstice, notably in Giza (Fig. 8).

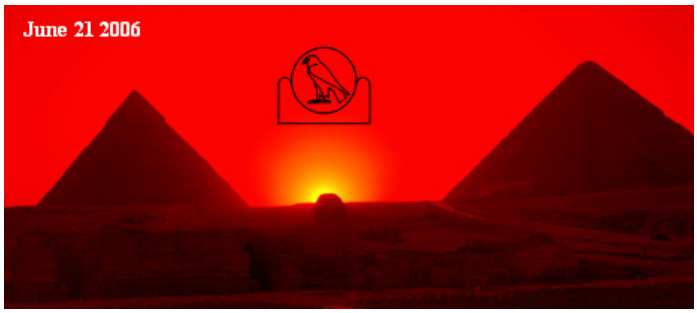


Figure 8. Sunset at the summer solstice at 21st June 2006 behind the Sphinx, in the middle of the two large pyramids. This image might be a reflection of the process of solarisation of the king during the reign of Khufu (c. 2550 BCE), Later on, this image could have inspired the identification of the Sphinx with the god Hor-em-akhet, Horus at the Horizon. Photograph by J. A. Belmonte.

The data for Lower Egypt included the vast majority of, if not all, the measurable monuments in the Delta. We visited temples that are seldom studied or analysed, like the temple of Isis at Behedyt el Haggar or the temple of the Ka of Pepi I at Bubastis (see Fig. 9), with pleasant surprises.

As on previous missions, but certainly with a bit more of emphasis, the analysis of the data obtained in the third campaign proved extremely fruitful and allowed us to achieve excellent results. The most outstanding outcome was the proposal of the existence of seven different families of astronomical orientation for the temples of Lower Egypt and neighbouring regions at the light of the archaeological evidence and the knowledge we had on the ancient Egyptian skies (Lull & Belmonte, 2009). Later on, this hypothesis could be easily extended to the rest of the country.

Two of the families (II and III, see Fig. 10) have a marked solar character with temples orientated to conspicuous landmarks of the annual cycle (the tropic year), such as the solstices and the equinoxes but also to other important time markers related to the real moments of sowing and harvesting in ancient Egypt. Besides, confirming earlier hypotheses, we showed that selected solar orientations, transformed, at certain historical periods, with a view to orientating buildings to the beginning of the seasons of the civil calendar, notably *Wepet Renpet*, the First Day of the first month of the season of the Inundation, I *Akhet* 1 or New Year´s

Figure 9. The temple of the Ka of Pepi I at Bubastis. There are few well preserved temples in the Delta. However, some of them present interesting and suggestive astronomical alignments. Photograph by J.A. Belmonte.

Eve, but also I *Peret* 1 and I *Shemu* 1. The coincidence of these dates with these important points of the tropic year, like summer or winter solstice and spring equinox, could have acted as a mutual reinforcement in the interest of ancient Egyptians for these special days of both the tropic and the civil year.

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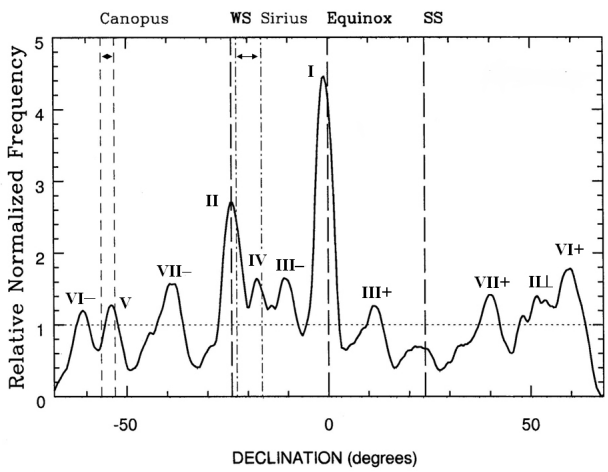

Figure 10. The core of the astronomical hypothesis. Declination histogram of circa 350 temples of ancient Egypt obtained from the data measured in our field campaigns across Egypt. Each peak is identified by a Roman numeral referring to each of the seven families of astronomical orientations as defined in Shaltout, Belmonte and Fekri, 2007.

As a corollary of this, and introducing landscape archaeology studies – understanding landscape in its broadest meaning of both terrestrial (basically the Nile) and celestial (astronomical orientations) aspects –, we proposed as a result of the summing up of high–quality accurate data that a brilliant combination between astronomy and landscape was produced in many areas of ancient Egypt, where a combination of astronomy and local topography drove to an extremely interesting phenomenology in different regions of the country (see Fig. 11).

One of the most fascinating case studies was the one of the pyr-

amid complexes of the Old Kingdom. According to this hypothesis, the location and orientation of several monuments were deliberately chosen in order to fit a general pattern of topographical and astronomical alignments. The apex of this network would have been the city of the sun-god Re, Heliopolis. Especially dramatic, although indeed based on circumstantial evidence, was the hypothesis proposed for the general layout of the majority of the Giza complex, including the Sphinx and the two larger pyramids, as an original design from the reign of Khufu (*Akhet Khufu* conceived as a single gigantic plan *c.* 2550 BCE).

After three years of intensive fieldwork, and four campaigns devoted so far to measuring the orientation and studying the spatial location of ancient monuments across the Nile Valley and beyond we were reaching exceptional results. More than 500 pyramids, hypogea, chapels, sanctuaries or small and large temples had been measured so far, and most of the country had been scanned in detail.

However, in previous campaigns, we did not measure some temples that were located either off–limits of standard circuits (like Aïn Labkha in Kharga Oasis), at difficult locations (like Mons Claudianus), or even temples of whose existence we were unaware in well–known spots when we worked there for the first time (such as various shrines in the area of Luxor). Besides, some important places in Middle Egypt, such as Heracleopolis or southern Athribis had not been visited yet. A new campaign (our fifth one) was indeed necessary to complete our sample.

This campaign was performed in December 2006 with an important aim in mind. This was to carry out solar observations at the precise moment of the winter solstice in several selected locations across the country, notably at Karnak (see Fig. 12), Western Thebes, Qsar Qarun and Dashur.

Some of the places we visited in our fifth mission were not easy to find and were completely off the standard routes, driving to abnormal, sometimes fancy situations. In Kom Mir, south of Esna, we had to put up with the complaints and exigencies of local authorities, since no one from the Supreme Council of Antiquities had gone there for years, and in Naqada, the chief inspector of Qena province was happy to find with us, with the help of satellite images and old plans, the foundations of the temple of Set, whose precise location had been forgotten since its excavation a century ago. Other places, such as the fascinating ruins of Mons Claudianus, in the Eastern Desert, deserved a dedicated programme involving many people, including the director of the antiquities service of the province of Bahr el Ahmar (Red Sea). During the fifth campaign we also took the opportunity to complete our sample of minor step pyramids, a group of fascinating, very ancient monuments (see Fig. 13). Our analysis of these forgotten pyramids has proven extremely fruitful and we were able to demonstrate that landscape, in its broader topographical and astronomical meaning, could help to easily explain their purpose, location and orientation (Belmonte, Shaltout and Fekri, 2005). The December 2006 mission brought with us to Egypt a graduate student of Egyptology, Noemi Miranda, working on the iconography of the Egyptian goddess of computus and time-keeping, Seshat, and the related epigraphy. Figure 14 illustrates some of the outcomes yielded by a most intriguing hypothesis which came out as a parallel exercise of the main results of our mission (Belmonte, Molinero and Miranda, 2009: 193).

With the fifth field campaign performed in December 2006, we had accomplished some of the most relevant objectives we had

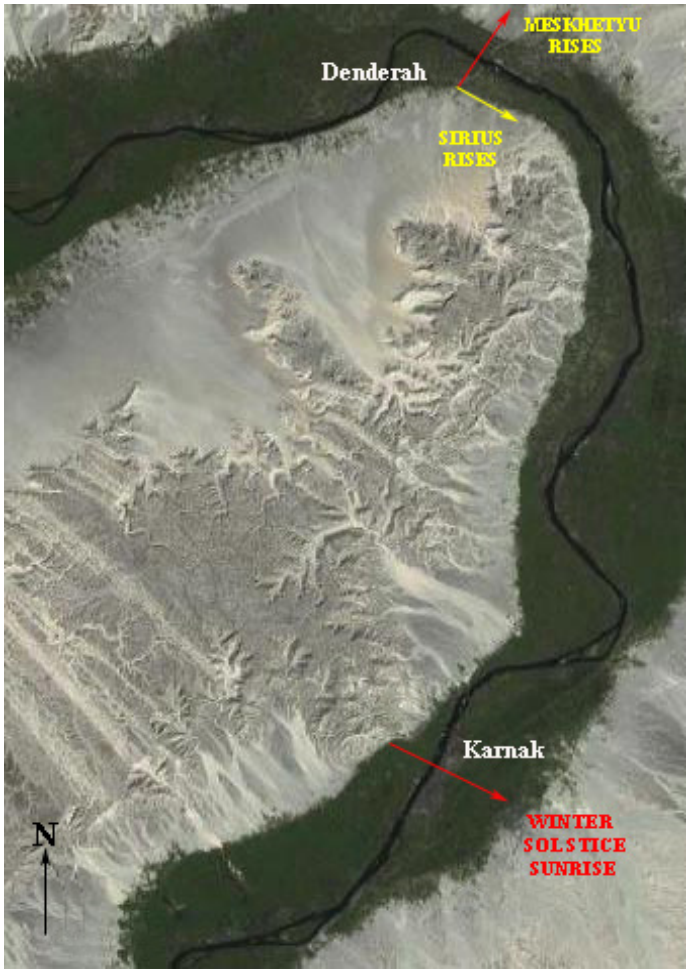

Figure 11. Astronomy and landscape. The location of two important sacred sites in Upper Egypt may have been determined by the presence of a double astronomical-topographical alignment, combining astronomy and landscape. Karnak would have been located at a particular place in the valley where the winter solstice sunrise was perpendicular to the course of the Nile. Dendarah would have been located at a place where the river flow came from the direction where the heliacal rising of Sirius, harbinger of the flooding, was observable. In the Ptolemaic and Roman Periods, the perpendicular to this line signalled the Ax of Meskhetyu. The temples erected at these places had their orientations selected accordingly. Adapted from Belmonte and Shaltout, 2009.

in mind for our archaeoastronomy project of ancient Egyptian culture (Belmonte, Shaltout and Fekri, 2008). The principal dilemma we wanted to solve was whether the temples of this civilization were astronomically orientated or not. Epigraphic sources clear mentioned solar and stellar targets as the references for temple orientations. However, the scientific community only agreed on the planning of orientations according to the Nile and the relevant inscriptions were sometimes considered as mere remembrance of long forgotten practices. At that moment, we had measured 330 temples and shrines throughout the geography of Egypt belonging to all periods of her history, representing approximately 95% or all the temples in any state of preservation still existing in the country.

We will not recall the details on the fascinating discoveries we have obtained in the course of this research. However, we want to stress three particular results that are real highlights of the analysis of the complete series of data. These were:

(i) The temples of the Nile Valley and the Delta were orientated according to the Nile as our data had clearly illustrated, but …
(ii) The temples were also astronomically orientated beyond

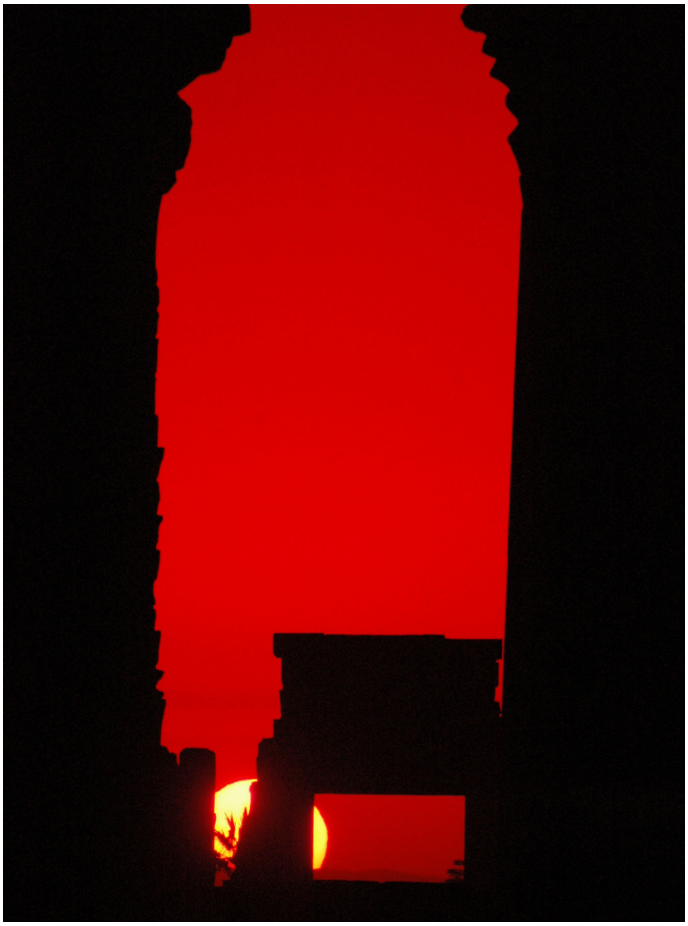

Figure 12. Sunrise at the winter solstice in December 2006 at the main axis of the temple of Karnak as seen from the quay. The phenomenon would have been more accurate 4000 years ago when the temple was first aligned, since at that precise period the disk of the sun would have been a complete solar diameter to its right and would have been visible through the small square window formed by the most distant gate. Photograph by J. A. Belmonte.

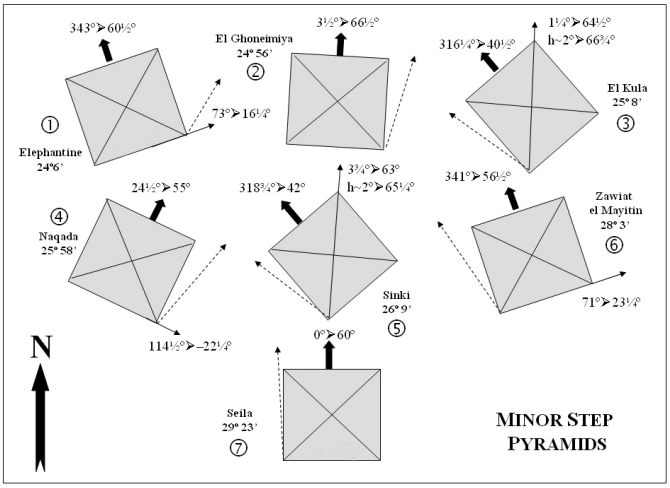

Figure 13. Schematic diagram of the orientation of the seven minor step pyramids, numbered from south to north. Each pyramid shows a characteristic orientation that might be explained within an astronomical and topographical context. Adapted from Belmonte and Shaltout, 2009.

any reasonable doubt as all the successive analyses we have done to our data fully demonstrate. This means that the ancient Egyptians had to deal with special situations to accomplish both necessities. This problem was solved by the selection of appropriate orientations of one or the other class at different sites so that they would be more or less compatible with the Nile course (inter–cardinal directions are a good example of this), or by the deliberate election of selected places in Egypt were the Nile prescription and a conspicuous astronomical orientation were simultaneously achieved.

(iii) Among astronomical orientations, there were three, and only three, kinds of targets. One was probably related to different and conspicuous celestial configurations of the stars of *Meskhetyu* in order to get a near or accurate Meridian orientation. This primary axis could have been rotated later by an eighth, a quarter or half a circumference to obtain any possible cardinal or inter–cardinal direction (families I, VI and VII; see Fig. 10). The second kind of targets had a markedly solar character and was fundamentally related to important time-marks of the annual cycle and/or the civil calendar (families I, II, II⊥ and III). Finally, the third group of targets was formed by the two brightest stars of the ancient Egyptian skies, Sirius and Canopus (families IV and V, respectively). These customs were present during most of Egyptian history and in the different areas of the country.

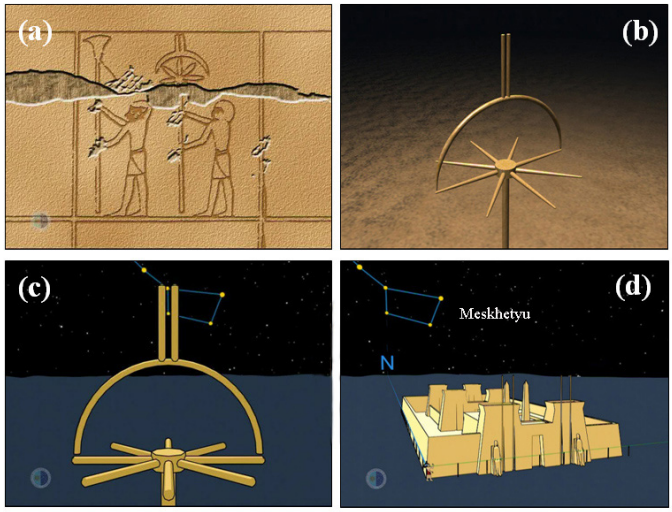

Figure 14. This sequence of images illustrates the hypothesis of the use of the sign of Seshat as a topographical instrument similar to the Roman groma. Panel (a) shows a relief from the solar temple of Niuserre at Abu Ghurob, where the sign appears like a standard or portable object. Panel (b) stands for the nucleus of the idea with the sign transformed into a real object, when changing the two dimensional version of the representation into a three-dimensional image. The uppermost elements of the sign would define a sight device, or eyepiece, in the style of the «merkhet», as shown in Panel (c). Once the alignment had been obtained, the eight radii of the device would directly offer the four cardinal and four (mid) inter-cardinal directions, as illustrated in Panel (d). Diagrams courtesy of SMM/IAC. Adapted from Belmonte, Molinero and Miranda, 2009.

Conclusion

A complete summary of the main results of the Egyptian-Spanish Mission in its first five years of existence can be found in a most recent work by some the authors (Belmonte, Shaltout and Fekri, 2009: 211). This is the largest, and indeed the nuclear chapter of the book «In search of cosmic order, selected essays on Egyptian archaeoastronomy» recently published by the Supreme Council of Antiquities Press and edited by J. A. Belmonte and Mosalam Shaltout. This volume is a quite complete compendium of state of the art essays dealing with different topics on ancient Egyptian astronomy.

At that stage, we considered our sample of 330 temple alignments to be statistically representative beyond any doubt and we were convinced that new data would only serve to reinforce

or slightly tinge our results. Hence, it was the moment to falsify such statement. Two experiments were selected with this purpose. On the one hand, a new campaign, the sixth - and last so far -, was conducted in Egypt in December 2008 at sparse temples of Middle Egypt and the Oasis of Fayum, which could not be measured in previous campaigns for various - mainly security - reasons. The idea was to complete the sample of Egyptian temples nearly to exhaustion. On the other hand, a new complete experiment was designed with temples of Sudan. The results of these experiments have recently been published in by our team (Belmonte et al., 2010).

A most promising Egyptian case discussed in that paper is that of the temple of Thoth at Seikh Abada (see Fig. 15). This New Kingdom temple is the best preserved shrine of Thoth in the area of ancient Hermopolis, the city under his patronage. Actually, it is located at the opposite side of the river where an important *wadi* connecting the Nile valley and the Red Sea open to the father of the rivers and the precise spot where Emperor Hadrian founded the city of Antinoopolis centuries later. The temple axis is not perpendicular to the Nile and is nearly directed, but not precisely, to Hermopolis at the other side of the river so local topography does not seem mandatory.

Figure 15. The New Kingdom temple of Thoth at Sheikh Abada (at the site of classic Antinoopolis). This building is aligned to the direction of moonrise at the epoch of the major northern lunastice. Either by chance or by deliberate selection of the site, the corresponding moon also passed across the local zenith. Photograph by J.A. Belmonte.

However, a very interesting situation is encountered when the opposite direction (from outside looking inside) is considered; then, the northernmost moonrise is produced over the hills of the Eastern Desert. Besides, considering the apparent diameter of the lunar disk, this moon would also pass across the zenith of the temple. It is fascinating to find a temple of the lunar god perhaps orientated to the northernmost rising lunar position (the lunastice) at the precise geographical area within Egypt where the same moon crosses the zenith. In our previous works we were surprised by the lesser importance of lunar alignments in ancient Egypt. This case could be considered as the exception to the rule.

However, the most fascinating results have been obtained in the analysis of Sudanese temples and shrines. A complete test of the astronomical family theory has been carried out, confirming that Kushite sacred buildings followed identical patterns of orientation as the ones we had previously established for ancient Egypt. These are, however, simplified since only four or five of these families are represented, but the dominant ones, solstitial (II), Sothic (IV) and meridian (VI) are highly representative and can be confirmed by local religion and tradition (see Fig. 16).

At the turn of the century, our team envisaged a project to answer a quite simple question. Now, nearly a decade later, we

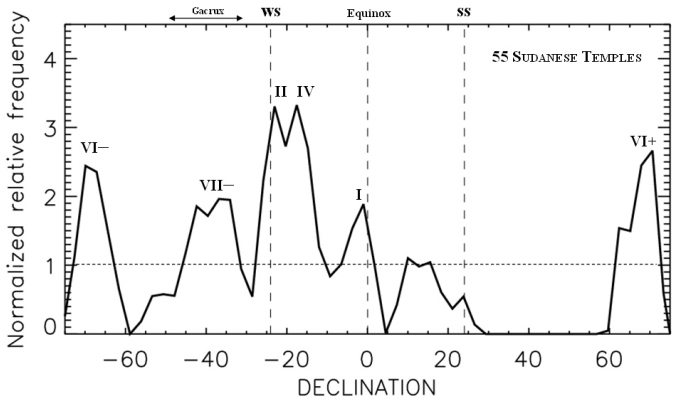

Figure 16. Declination histogram of 55 alignments in Sudanese temples. Six peaks are clearly significant. Interestingly, all these peaks can easily find equivalences in the set of orientation families we had previously discovered for Egyptian temples as shown in Figure 10. From Belmonte et al., 2010.

are really proud of the quantity and variety of the results we have obtained along this period of intensive work. These have been the gateway for new requirements and questions. Perhaps, more work could be and will be done. However, we consider our sample of more than 400 temples (including Sudanese shrines) to be statistically representative beyond any doubt and we are once more convinced that new data will only serve to reinforce or tinge our results.

As a matter of fact, this story of discovery in ancient Egyptian archeoastronomy clearly illustrates something that we could only have imagined at the very beginning of our project: ancient Egyptians undoubtedly scrutinized the sky in a permanent search for their correct orientation not only in time but also in space. Certainly, astronomy did play beyond any reasonable doubt a fundamental role in the culture, the religion, the architectural design and the sacred geography of the Nile Valley civilizations.

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Astronomical Interpretation of the Winding Canal in the Pyramid Texts

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Abstract: A new analytical and comparative interpretation of the Winding Canal mentioned in the pyramid texts is given. Using the simulation astronomical programs, the sky image is studied during the time of building the pyramids of Wenis (Unas), Teti, Pepi I, Merenre and Pepi II (2367 – 2219 BCE), in which these texts were discovered. According to the context and the astronomical information, some of new assumptions will be given in order to understand the ancient Egyptian thoughts during this era.

Keywords: Pyramid texts, Winding Canal, sky image, Milky Way, Imperishable Star, bright stars

Introduction

In the ancient Egyptian civilization, there are many evidences showing their use of many known astronomical observations and facts. Their knowledge in astronomy is supposed to be deep in the history and may be so much deeper than the time of building the pyramids. As many studies discovered that the pyramids were built according to many astronomical facts, observations and calculations, one can say that this knowledge is supposed to be started long time earlier (Predynastic Period). Hellenic traditions assign considerable astronomical knowledge to Egyptian priests who lived some thousands of years BCE, and some of the peculiarities of the pyramids which were built at some such period are at any rate plausibly interpreted as evidence of pretty accurate astronomical observations (Berry, A., 1898) and (Neugebauer, O. 1983).

The Pyramid Texts are inscribed on the walls on ten pyramids which are all situated at the necropolis of Saqqara. These pyramids date to the Fifth, Sixth and Eighth Dynasties of the Old Kingdom (2705 – 2213 BCE). The main part of this enormous collection of texts is inscribed in the pyramids of the kings of the Fifth and Sixth Dynasties: Unas, the last King of the Fifth Dynasty, his successor Teti, who was the first king of the Sixth Dynasty and his successors Pepi I, Merenre and Pepi II. A small selection of these texts is also found in the pyramids belonging to the three queens of Pepi II: Oudjebten, Neit and Apouit.

Pharaoh	Reign Time	Pyramid Position	
		Latitude	Longitude
Wenis	2367 – 2347 BCE	29° 52′ 05.56″	31° 12′ 53.73″
Teti	2347 – 2337 BCE	29° 52′ 30.35″	31° 13′ 19.13″
Pepi I	2335 – 2285 BCE	29° 51′ 14.76″	31° 13′ 10.40″
Merenre	2285 – 2279 BCE	29° 51′ 06.22″	31° 12′ 53.74″
Pepi II	2279 – 2219 BCE	29° 50′ 26.72″	31° 12′ 48.28″

Table 1. Pharaohs of the pyramids in which the texts discovered.

In the pyramid texts, we can read about a journey of the deceased king into heaven which is assumed to be somewhere in the higher sky. The texts describe the journey in some details showing the crossing of what is called a Winding Canal (*ḫ3* Canal) which lies somewhere in the sky until reaching the heaven. The Winding Canal, particularly in those spells, is dealing with the solar journey and the entry of the dead King into Heaven. It would seem to be a body of water surrounding the celestial paradise, seemingly upon all its sides.

Overview on the interpretations of the «Winding Canal»

The oldest interpretation of the word was given by Breasted (Breasted, J. H. 1912). He interpreted *ḫ3* in the Pyramid Texts PT 1228c as «Lily» or «Lily Lake». Breasted interpreted the name of the water way as a construction in the indirect genitive. Perhaps, he thought in «Lily» because the Lotus hieroglyphic word is written as *ḫ3w* «herb flower». Bayoumi (Bayoumi, Abbas, 1940) contradicts this view that the Lotus hieroglyph in the PT was not used for the spelling of the questionable word.

The translation of the term «Winding Lake» for the possible reading of mr nḫ3 as noun and adjective was given by Kees (Kees, Hermann, 1926). But he did not determine its place. Junker (Junker, Hermann, 1917) read it in the same way but he did not determine its meaning.

Sethe interpreted the term *mr nḫ3* as it should be not a lake, but a water course according to the ideogram in PT 595ff, 1228c, 1441a and translated it by the term «Winding Canal» (Sethe K., 1932). He assumed that mr is etymologically related to the hoe which implies the action of digging. In the PT, the two signs and were replaced each other as it is stated in PT 1138d. Sethe defined the topography of the «Winding Canal» as it lies in the east of the sky as it is stated PT 595 and 600. This water course flows from east–west as west–east direction. Its southern side is for climbing to the sky. Sethe left it openly how far this canal should lead to the west.

Speleers translated the water name as an indirect genitive «Lac ou Lotus» (Speleers, Louis, 1934). Weill referred to WB III 218 where the form of ḫ3 was written with the shell. He translated it as «Lac de l' Huitre» (Erman, A., Grapow, H., 1971). Bayoumi derived the Nisba form of *mr nḫ3j* which written in Pyramid Texts 1346a (Pepi I) and 543b (Teti) from the Nisba form of other water name in the Pyramid Texts, such as *šj z3bj*, *šj dw3tj* and *mr mnꜥj*.

Hassan defined the canal as «Meandering Stream» (Hassan, S., 1934). He suggested that it would seem to be a body of water surrounding the celestial paradise, seemingly upon all its sides. Thus, one can read about the deceased crossing the Meandering Stream in the north of the Heaven. Hassan concluded that the northern side of the *ḫ3* canal is the southern side of the sky.

Altenmüller interpreted the canal name as a construction of an indirect genitive and recognized the *ḫ3* canal in the PT as the «Knife Lake» (Altenmüller H., 1986). He suggested that the difference in writing forms refers to the same water way «mr nj *ḫ3*» which appeared in the Old and Middle Kingdom as «Lake of the Destroying», which appeared after that time in the new Kingdom as a «Knife Lake» *mr nḫ3.wj*.

Barta assumed that the *nḫ3* canal is in the north–south direction of the Field of Offerings (Barta, W., 1981). Davis put in 1985

an interpretation of the *mr nḫ3* as a «Shifting Water Way» and assumed that it is the Milky Way itself (Davis, Lee V., 1985). With this respect, the Egyptian northern sky should represent a concave sky area surrounded by the Milky Way with the northern celestial pole, while the southern sky on the other hand is the area lying on the convex outside the Milky Way. Davis stated although it is traditionally translated «Winding Water Way», he would prefer something like «Shifting Water Way».

Krauss assumed that the *ḫ3* canal has to be the ecliptic (Krauss, R., 1997). It is well–known that it is the apparent path that the Sun traces out in the sky during the year. As it appears to move in the sky in relation to the stars, the apparent path aligns with the planets throughout the course of the year. More accurately, it is the intersection of a spherical surface (the celestial sphere) with the ecliptic plane, which is the geometric plane containing the mean orbit of the Earth around the Sun (http://en.wikipedia.org/wiki/Ecliptic). Krauss means that ecliptic strips represent the body of the *ḫ3* canal. He mentioned the features of the *ḫ3* canal which support his assumption. But it is important to mention here that such a celestial figure has to be apparent or visible as it is understood from the texts. Therefore, it is more reasonable to think about a suggestion of a visible figure than to think about a suggestion of an imaginary figure as all of the other mentioned astronomical bodies are visible.

The Winding Canal in the Pyramid Texts

Position of the Winding Canal in the sky

In the *PT* 1440 d – e, it deals with the position and the function of this heavenly water as well as the ascending of the sky. In 1757 – 1759, the king ascends on *hprr* towards the sky on the wings of the *hprr*, and Nut will receive him. So, the *ḫ3* canal lies in the sky, because the context refers to ascending to the sky. In 596a – b, it deals with crossing of the king on Thoth's wings to the eastern side of the sky (Allen, James P., 1910):

«(The King) will cross with you on Thoth's wing to the other side of the Winding Canal, to the eastern side of the sky».

In 1345c, the relation between the *ḫ3* canal and the *wj3* bark of Re was mentioned:

«The king shall go aboard (descend into) the bark like Re on the banks of the xA canal».

The same meaning was mentioned again in *PT* 2172c, so the *ḫ3* canal lies to the east as it mentioned with the bark of Re during his journey in the sky. The descending into *wj3* bark (the bark of Re) takes place on a certain side of the *ḫ3* canal. In *PT* 1250, we found that the descending of Re into the *wj3* bark on the *ḫ3* canal occurs after the day begins, which may imply that it happens on the eastern side of the canal.

Shapes of the canal in the pyramid texts

The different shapes of this canal can be seen in its determinatives of *mr nj ḫ3* that have a special form. The word sometimes appeared with determinative and other times without determinative.

Without determinative:
The shape of writing the word was appeared without determinatives in the texts of the pyramid of Teti 594b, d, f, 595a; 596a; 597b; 599a; 600; the pyramid of Pepi I 162c; 1345c; 1376c; 1382a; 1541a; and the pyramid of Oujebton 2235b.

With determinative:
The shape of writing the word was appeared with some determinatives in many places in the pyramid texts. They can be summarized according to their positions and determinatives in Table 2.

These forms show the precise conception of this *ḫ3* canal in the mythology and reflect the Egyptian imagination about the constellations. The forms depicted in Pepi II and Merenere were the usual forms (or). These forms can be used to determine any body of water and are even employed in line 802b to determine the sea. But the other more carefully written signs, which are mostly written in details in Pepi I, imply that the canal form can be winding, and accordingly the canal seems to be bent. W340d, T343a, P 1084b ;1102d, M 1084b; 1102d; 1138d, N 469a; 594e; 594f; 599d; 802a; 1084b; 1102d; 1162c; 1376c;1377c; 2061c; 2172c, Neit 1759b. T 543b, P. 352a; 802; 1138d; 1441a, M 802; 1704a; 1737a, N. 594b; 594d; 595b; 597b; 599a; 1382a; 1441a. P. 594f; 599b; 1574c. P. 359b. W 469a, P 594b. P 594d. P 594e. P 595b. P 596b P597b, P 599d P 600b, M 1376c, M 1377c, 1441a, M 1441a

Bayoumi joined the shape of *ḫ3* canal in the Pyramid Texts 1205b with the shapes of other canals like mnaj and pAat with the Milky Way and he suggested that the canal is running from north to south (Bayoumi, Abbas, 1940).

The banks of the *ḫ3* canal are mentioned as plural «*jdbw*», and when the text refers to one bank, it mentions «*spt*» or «*pf gs*» (that side) and «*pn gs*» (this side).

In the Pyramid Texts PT 1376a – b, the northern side of the *ḫ3* canal is distinguished from the southern side, where Thoth was there and he took the king on his wings to the northern side of the canal:

«(Tie the lashings; land his ferryboat, for a son of Atum who is hungry and thirsty, thirsty and hungry, on this southern side of the Winding Canal). Thoth in the limit of your bush's shade put Pepi on your wingtip in yonder northern side of the Winding Canal».

Sethe concluded from this text that the southern side of the *ḫ3* canal is for ascending to sky on «this side (*pn gs*)», and its northern «that side (*pf gs*)» is to which he wants to arrive (Sethe K., 1932). The king is hungry and thirsty on the southern side of the *ḫ3* canal. So, he wants to end this case on that northern side of the *ḫ3* canal. Sethe identified the north side of the *ḫ3* canal with the Fields of Offerings. Then, he explained the «wing of Thoth» as a moon sickle. Bayoumi and Barta agreed with Sethe in this interpretation (Bayoumi, Abbas, 1940) and (Barta, W., 1981).

The canal and the Imperishable Star

In PT 818c, the imperishable star was mentioned in the northern side of the sky. In 1000c – d, «I ferry across in order that I may stand on the east side of the sky in its northern region among the Imperishable Stars, who stand at their staffs and sit at their East». One understands here that in the eastern side of the sky in its northern place there is the imperishable star and the king wants to cross to the northern side of the *ḫ3* canal where the imperishable star is.

According to the *PT* 594a, a battle takes place at north side of the *ḫ3* canal and in the same time at the eastern side of the sky. Further, the conflict takes place on the northern side where Thoth is present so that the Eye of Horus is able to jump up on his wing. So, the crossing of the *ḫ3* canal to the eastern side of the sky as mentioned in the *PT* takes place with the help of the wings of Thoth who is on the northern side of the *ḫ3* canal. Then, in 947a – c and *PT* 999 – 1000, the journey continues to the eastern side of the sky (*pt*) and in the same time to the northern region where the imperishable star is there.

The Winding Canal and the southern side of the Field of Rushes

In PT 1083c, 1084a – b, 1086 a – c, 1087a:

«(O thorn – bush, remove yourself from his road,) so that he may take for himself the southern side of the Field of Rushes. The M3ʿ canal is opened, the ḫ3 canal is flooded. The reed floats of the sky are set down for Horus that he may cross to Re at the Horizon».

It is notable that in all texts which mentioned that the reed floats were used to cross the *ḫ3* canal, the crossing was to «*3ḫt*» after crossing the northern side of the *ḫ3* canal, where it is implied that it is only navigable when it is flooded by the inundation. This is quite appropriated in accordance with the nature of the primitive reed floats (See PT 340, 343, 352, 353). One can say that the journey after reaching its aim goes further more and finally stops at the imperishable star. So, the king in his journey with the reed floats to Re in the *3ḫt*, after crossing the northern side of the *ḫ3* canal, would not only arrive to the *3ḫt* in the east but also to the eastern side of the sky in its northern region.

Crossing of the Winding Canal to the Field of Rushes

In *PT* 343a

«*The Nurse canal is opened, the Winding Waterway is flooded, the Fields of Rushes are filled with water, and I am ferried over thereon to yonder eastern side of the sky*».

The same meaning was repeated in 1091a, 1092a, where ḥr.f ḫ3.f ferries the king over to the Field of rushes and put him down on the eastern side of the sky. The interpretation of the texts is that the king on his way to the *3ḫt* (in the east) crosses the *ḫ3* canal from its northern side and then goes further into the southern side of the Field of Rushes and later from there out into the western side of the Field of Offerings as it mentioned in *PT* 1737a. So, one can conclude from the texts that the *ḫ3* canal passes at the edge of the eastern side of the sky. It flows from north to south or from south to north. Accordingly, the Field of Offerings and Field of Rushes could be located at the eastern side of the sky as they were mentioned always after crossing the northern bank of the *ḫ3* canal.

Davis assumed that Nut is a picture of the Milky Way. This explanation cannot be right according to the PT (Davis, Lee V., 1985). The Milky Way and *ḫ3* canal cannot be the same if the Milky Way is assumed to be Nut. The connection between Nut and *ḫ3* canal in the PT 802a was clearly mentioned that Nut and *ḫ3* canal were two different things, because *ḫ3* canal was located northern of Nut.

Treating the Pyramid Texts in the view of the new astronomical knowledge

To interpret the astronomical terms mentioned in the pyramids texts, we used a simulation computer program designed to simulate the sky sheet depending upon the date and the place of viewing. The coordinates of the five main pyramids were determined using geographical computer program. An intermediate point between the whole five mentioned pyramids was taken to be the spatial viewing coordinate. It was of latitude $\varphi = 29^\circ\ 51'$ and longitude $\lambda = 31^\circ\ 13'$. We believe that the pyramid texts represent a hereditary culture that may be existed many generations before. Therefore, we decided to go deeper in the history to the time of Predynastic Period. Accurately, we chose the year 4000 BCE to be the year of our temporal coordinate. Furthermore, we came closer to the time of building these pyramids to see if the features of the sky viewed from the mentioned point have magnificently changed. Therefore, we also checked the sky features in 2400 BCE.

Returning back to what mentioned in the pyramids texts about the Winding Canal *ḫ3*, we can summarize The features of the *ḫ3* canal in the following points:

- It has an eastern and a western bank and it is bent across the sky.
- On the northern side of the canal, there are the Imperishable Star and the Fields of Offering.
- The canal flows from north to south or from south to north.
- In some examples, the canal was crossed from south to north to the eastern side of the «*pt*» sky.
- It lies at the eastern side of the sky «*pt*» (the physical sky) and at the northern side of the sky «Nut» (the mythological sky).
- The canal was crossed by the ferrymen, Thoth on its wings, Horus, anonymous gods and the king.
- The canal was crossed to accomplish a certain reason like nourishment in the fields of offerings at the northern side of the canal, and to speak with Seth because of the eye of Hours.

Results

After applying the graphics aided simulation astronomical program (Redshift 5) and our recent astronomical knowledge, we tried to interpret the term (Winding Canal) and the other associated astronomical terms mentioned in the Pyramid Texts as the following:

A- The Winding Canal

There are many evidences pushing in thinking that the ancient Egyptians considered the Milky Way as the live embodiment of the River Nile on the sky. This thought is based on the interpretation of the term «Winding Stream» (Winding Canal) mentioned in the Pyramid Texts, which means the vibration of the Milky Way around the North Pole during the night and the seasons. There is another interpretation saying that the Giza pyramids and the River Nile were embodied by this band joining the Milky Way by Gemini cluster (Bertola, F., 2003).

The Milky Way has a staggered path crossing the skies of the seasons of the year. In the winter skies, it is a rather narrow band that rises upright from the northern horizon, passes nearly overhead, then, like a river lighted by bright beacons flanking either shore, flows southward until it drops behind the earth just below the great star Sirius. In the evening skies of the spring, the Milky Way can be seen only in the north, though one must have a sparkling night and a clean sweep all along the northern horizon to find it. In summer, and particularly in the month of August, the Milky Way is at its best. It can be clearly seen in all its glory (Peltier, L., 1986).

Figures 1 (a) and (b) show views of the sky in the northern and southern side of the sky on 22nd June 4000 BCE some hours after the sunset respectively, while Fig. 2 shows a view of the sky in the same direction of the sky on 22nd June 2400 BCE at the same time.

According to the features mentioned about the canal, one can notice the following similarity:

a- Dubhe which is assumed to be the imperishable star lies in the northern side of the Milky Way. This star was the polar star at the time of building the pyramids.

b- There are some clusters in the northern side of this galaxy which can interpret the term (Field of Offering).

c- During the night, the Milky Way can be seen as a flowing stream running from north to south or from south to north.

d- When the sun rises, there is no way to see the Milky Way because of the brightness of the sun light. This can interpret the feature saying that the bark of the sun god «Re» does not pass at the *ḫ3* canal.

It is the most probable interpretation for this canal because it matches approximately the features concluded from the texts.

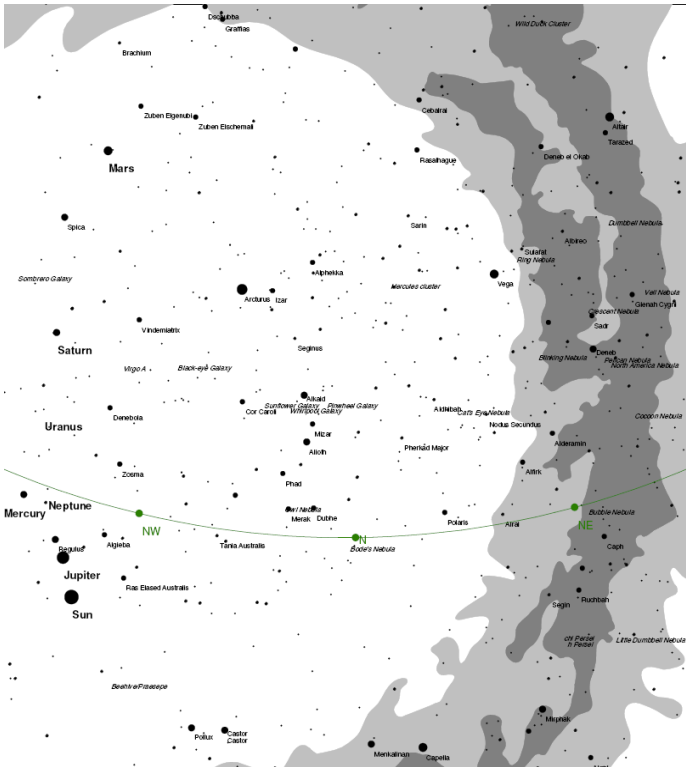
B- Other Associated Astronomical Terms

The Imperishable Star mentioned in the Pyramid Texts can be the polar star at that time (Dubhe), as it does not set below the horizon. Accordingly, the Imperishable Stars are the circumpolar stars which have a maximum angular distance from the polar star less than their minimum altitude. In other words, the Imperishable Stars are those stars whose position from the pole is less than the latitude. These stars never set below the horizon. Accordingly, each star of these circumpolar stars satisfies Relation (1).

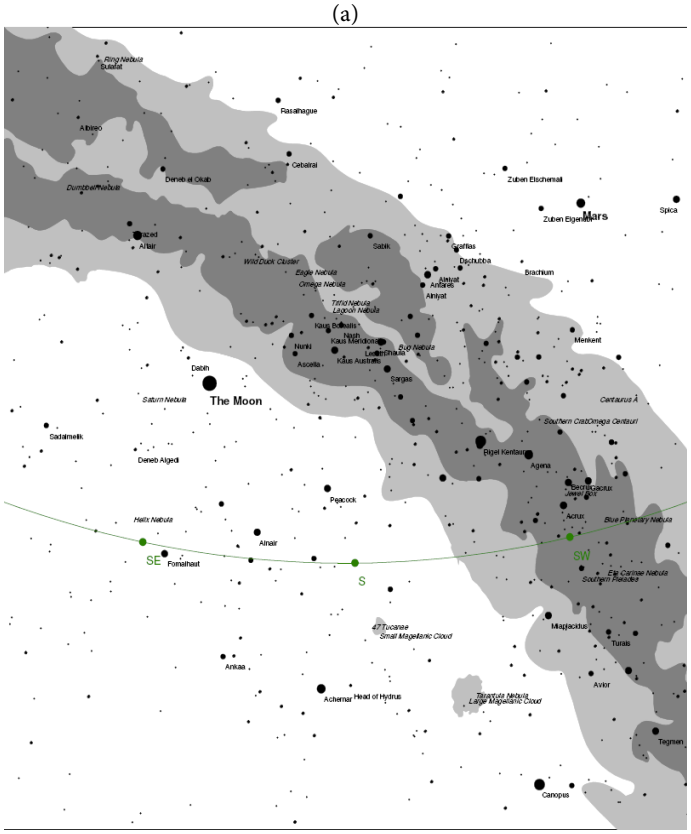
$$90 - \delta < \varphi \quad (1)$$

Where φ is the latitude of the observation point and δ is the declination of the star (Roy A. E. and Clarcke D., 2003).

The Eye of Horus can be interpreted as one of the stars Arcturus or Vega. Both of them satisfy most of the features mentioned in the pyramid texts.



(a)



(b)

Figure 1. A sky view from the position of the pyramids in the northern direction on a summer night of 4000 BCE.

The star Arcturus is found to be visible in the spring and summer nights. It is the brightest star in the constellation Boötes, and the third brightest star in the night sky, with a visual magnitude of −0.05, after Sirius and Canopus, although it is fainter than the combined light of the two main components of Alpha Centauri, which are too close together for the eye to resolve as separate sources of light, making Arcturus appear to be the fourth brightest star in the northern hemisphere. It is the second brightest star visible from northern latitudes and the brightest star in the northern celestial hemisphere. The star is in the Local Interstellar Cloud and has a Right Ascension (*R.A.*) of 14h 15m 39.7s and a Declination (*δ*) of +19° 10' 56" (http://en.wikipedia.org/wiki/Arcturus).

The star Vega is also found to be visible in the summer nights near to the Milky Way. It is the brightest star in the constellation Lyra, the fifth brightest star in the night sky and the second brightest star in the northern celestial hemisphere, after Arcturus with a visual magnitude of zero. It is a relatively nearby star at only 25.3 light–years from Earth, and, together with Arcturus and Sirius, one of

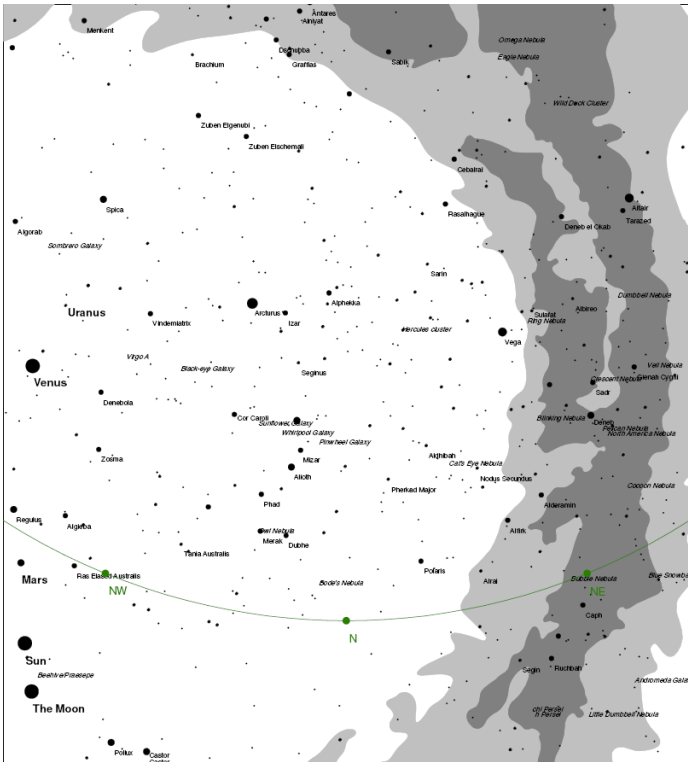


Figure 2. A sky view from the position of the pyramids in the northern direction on a summer night of 2400 BCE.

the most luminous stars in the Sun's neighborhood. This star has a Right Ascension (*R.A.*) of 18h 36m 56.3364s and a Declination (δ) of +38° 47′ 01.291″ (http://en.wikipedia.org/wiki/Vega).

It is also possible that the Eye of Horus can be one of the solar system planets such as Venus, Mars, Jupiter or Saturn, which were often seen and observed in the clear night sky.

The Field of Rushes and the Fields of Offerings can be interpreted as some constellations, galaxies, stars and nebula which can be observed during any clear sky night.

Conclusion

From the previous treatment of the chosen pyramid texts according to our recent astronomical knowledge, one can give the following conclusions:

1. It is clear that the astronomical observations and knowledge was an important part of the old Egyptian civilization so that it constructed an important part of the thought and religion of the people lived at this time.
2. The astronomical knowledge of the ancient Egyptian civilization was so high and developed that they could follow the positions of the stars and their regular movements.
3. The most probable astronomical body which can be given as an explanation of the term Winding Canal (mr nxA) is the Milky Way as its shape and positions match at least 75 % of the features mentioned in the pyramids texts.
4. The Imperishable Star mentioned in the Pyramid Texts can be Dubhe (the polar star at the time of the building of the pyramids). Accordingly, the Imperishable Stars are the circumpolar stars whose positions from the pole are less than the latitude from which they are observed.
5. The Field of Rushes and The Fields of Offerings can be interpreted as some constellations, galaxies, stars and nebula which can be observed during any clear sky night.
6. The Eye of Horus can be interpreted as one of the stars Arcturus or Vega or one of the solar system sighted planets such as Venus, Mars, Jupiter or Saturn.
7. The bark of Re (the sun) does not pass the Winding Canal because this canal is not visible any more when the sun rises. This interprets what is mentioned about the relation between the sun and the so–called Winding Canal.

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Egyptian Decanal Stars in Astronomy, Mythology and Astrology

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Abstract: The objective of this paper is to emphasize the antiquity of the Egyptians' determination of the decanal constellations and to insist on the important function of these particular stars throughout the entire Egyptian civilization in the areas of astronomy, mythology, and astrology. As regards astronomy, we know that the creation of the decanal system which allows determining the night hours for each decade of the year, was already completed around 2100 BC, as attested by the presence of diagonal star clocks on coffin lids of that period. The decans also divided the year into 36 periods of ten days each, called decades. We propose that from its very origin, the Egyptian civil year was built according to a decanal structure, and not a lunar one. In mythology, Sirius, as Sekhmet, and the decanal stars it controls, have mission to eliminate the evildoers and to guarantee cosmic and social order. The astrological function of the decans is detailed on the Naos of the Decades, whose texts illustrate how the Egyptian decanal stars prefigure the zodiac.

Keywords: Archaeoastronomy & Egyptology: Decan; Egyptian Calendar; Gliding Calendar; Sirius; Sothis; Orion; Sekhmet; Maat; Zodiac, Decade.

Introduction

What is called "the Egyptian decans" is, in fact, a number of constellations located on the ecliptic or very close to it. Their definition is foremost astronomical on the basis of the role that these stars played in the division and the counting of time. Shortly after determining these, or very probably from that very moment, the Egyptians attributed mythological functions to these stars which led straight towards their (later) utilization in astrology.

The role of Sirius and the Decanal Stars in the Counting of Time

Sirius–Sopedet, the beginning of the year and the flood

The link between the first rise of Sirius and the beginning of the Egyptian year appears as early as the Pyramid Texts (Pyramid Texts, § 965a–c; Krauss, 1997: 154. Maravelia, 2006: 106, 269). There already, the importance of the star is manifest: Maravelia (Maravelia, 2006: 122) established that its name is mentioned 27 times in these texts. The rise of the constellation of Orion which occurs before the rise of Sirius, was therefore concomitant with the end of the (previous) year and its name is mentioned 26 times in the Pyramid Texts (Maravelia, 2006: 122). Even more revealing is the iconography, showing Sirius in the form of Isis facing Orion as Osiris. This disposition symbolizes the passage from one year to the next. These images, which appear in the First Intermediate Period on the coffins decorated with diagonal star clocks on their inside lids, are then reproduced in the great astronomical paintings from the 18th dynasty on into the Late Period. As regards the texts, there exist hundreds of quotations linking Sirius, the beginning of the year, and the arrival of the flood, especially in the temple of Dendera which is dedicated to the goddess Isis/Hathor with which Sirius can sometimes be identified.

At the very beginning of Egyptian civilization, the first rise of the star occurred at a date close to the summer solstice[1], which explains the contemporaneousness of its reappearance with the rise of the Nile due above all to the rains of the spring monsoon in Ethiopia.

Sirius is part of a constellation which is represented in the form of a cow, as in Dendera[2] (Figure 1), in other temples[3], and in tombs[4]. For the Egyptians, the animal embodied abundance, which is possibly the reason why the star announcing the flood by its heliacal rise is shown in bovine form (von Bomhard, 2008 : 246). The constellation known to us as "The Great Dog", with Sirius representing its head, could thus have been perceived as a cow, or the head of a cow. Showing the constellation in this form does not occur only in temples of the Late Period, it is found already at the very beginning of Egyptian civilization. A pallet of predynastic times found at Gerzeh (Petrie, Wainwright, and MacKay, 1912: pl. 6, 7) is decorated with the head of a cow surrounded by five stars (Figure 2). Wainwright (Petrie, Wainwright, and MacKay, 1912: 22) believes that it represents Hathor: "*It may therefore represent Hathor in an astronomical aspect*". Murray (Murray, 1956: 96) considers this figure as "t*he earliest example of the celestial cow goddess, Hathor or Nout*".

Another object undoubtedly confirms the notion that the bovine head of the Gerzeh pallet must be Hathor: the rim of a magnificent vase from Hieraconpolis (Figure 3), dating from the first dynasty, reproduces the exact same figure as the one on the Gerzeh pallet, and allows identification on both monuments of the goddess in her form of Bat/Hathor.[5]

1 In our time, this rise takes place on August 4 at the latitude of Cairo.
2 In Dendera also on the ceiling of the Osirian chapel East Nr. 2 (the circular zodiac) and in chapel East Nr. 3.
3 As an example, the temple of Deir el Medina (du Bourguet, 2002: 83) at Esna and at Edfu (Neugebauer and Parker, 1969: pl. 29, 30).
4 For example Neugebauer and Parker, 1969: pl. 38A, 51.

5 The word bAt means a ba soul in the feminine gender; Sirius is said to be the ba of Isis. Therefore, the goddess Bat should personify the ba soul of Isis.

Figure 1. Dendera, ceiling of the outer hypostyle hall, Sirius in the form of a cow (Photo Ch. Leitz).

Figure 2. Predynastic pallet, Gerzeh (from Vandier, 1952: 444, figure 297).

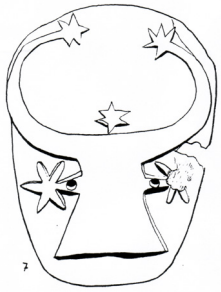


Figure 3. Vase from Hieraconpolis, 1st dynasty (Photo J. Cole).

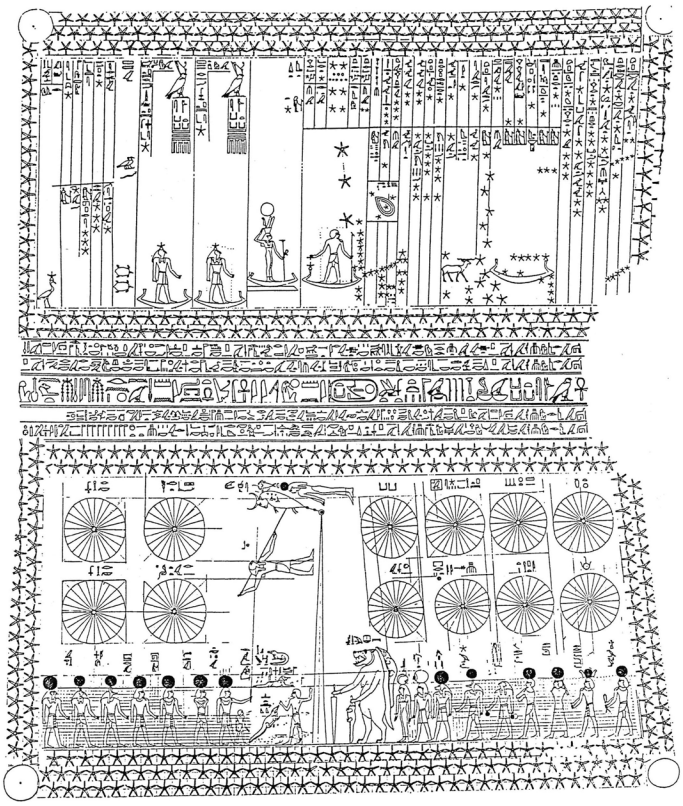


Figure 4. Ceiling of Senmut's tomb. Top: the southern sky, the decans (right) and the planets (left). Below: the northern sky and the months.

The bovine head surrounded by stars on the pallet and the one on the vase are remarkably like the images of Sirius–Sopedet of the Late Period, despite the impressive lapse of time that separates them. Very probably, in predynastic times already, the relationship was established between the terrestrial and seasonal phenomenon of the rise of the Nile on the one hand, and the celestial occurrence of the first rise of Sirius that "brings the flood" and abundance on the other. Sirius-Sopedet is frequently termed "Regent of the decans", because it is followed by the succession of decanal constellations up to the appearance of the great constellation of Orion, which in itself contains several decans (Neugebauer and Parker, 1969: 112-115; Figure 4).

The Decanal Stars

We know that the creation of the decanal system, i.e. the observation of the stars allowing determination of the night hours for each decade of the year, was already entirely achieved around 2100 BC, as the presence of diagonal star clocks on coffin lids of that period attests (Neugebauer and Parker, 1960: 1-35, pl. 1-23. Locher, 1998: 697-702). The decanal stars had two functions:

– First, they divided the year into 36 periods of ten days each, called decades. Each of these ten-day periods is inaugurated by the first rise, after its period of invisibility, of one of the 36 decanal stars. This first function is linked to the trajectory of the earth around the sun in a year.

– Second, the decanal stars, by their successive rise or culmination[6], divide the night into twelve hours. This second function is linked to the rotation of the earth around its axis.

6 According to Neugebauer and Parker, on the diagonal star clocks the decans indicate the hour by their rise (1960, 1) and later, from the 18th dynasty on, by their culmination. However, the culmination is much easier to observe than the rise, and in the Book of Nut, the hours are indicated by culmination. Leitz, 1995: 67-77 believes that they indicate time by their setting. Culmination offers much greater flexibility than either rise or setting, which are much more restricted moments.

The Division of the Year into 36 Decades

The separation of the year into 36 decades is carried out by dividing into 36 segments the great circle that the constellations appear to follow in the sky during one year. Each segment is inaugurated by the heliacal rise of one of the decanal constellations. The distance between two decans, in other words the angle thus defined, amounts for us to some 10°, a space wide enough to be perceived by the naked eye. In addition, it offers, in practice, a certain flexibility to absorb not only the variations in length of the night hours depending on the season[7], but also the additional 5½ days of the year: the 360 degrees were completed in 360 days.

The Decans, the Hours, and the Months

The decans divide the nights into twelve equal segments, which implies that the hours are "seasonal", meaning their length differs according to the season. Only on the two days of the equinox, these hours have the same length as ours, called "equinoctial". Later, the use of water clocks made it possible to count the night hours without having to observe the sky. These clocks were calibrated for each month (Figure 5), and the oldest one known dates from the 18th dynasty.

The close relationship the Egyptians established between the months and the hours appears in a very obvious way on the lower section of the northern part of the ceiling of Senmut's tomb (Figure 4). There, twelve great circles represent the months of the year with their names marked above. These circles are not split into 30 segments to indicate the number of days of each month, as could be expected, but rather into 24 segments like the number of hours of each day, because the relative length of the hours of day and night characterizes the month. Manuel Valdes, an engineer and specialist of solar clocks[8], compared the circular images accompanying the month names on the ceiling of Senmut's tomb and some ancient and very special solar clocks which he photographed himself on the walls of several Romanesque churches in Spain (Figure 6). On "canonical" solar clocks, the engraved lines generally indicate the hours at which certain services are to be celebrated (Valdes, 2003: 5-8). Valdes' comparison appears even more interesting if we bear in mind that in ancient Egypt, the hours of day and night controlled the rituals in the temples.

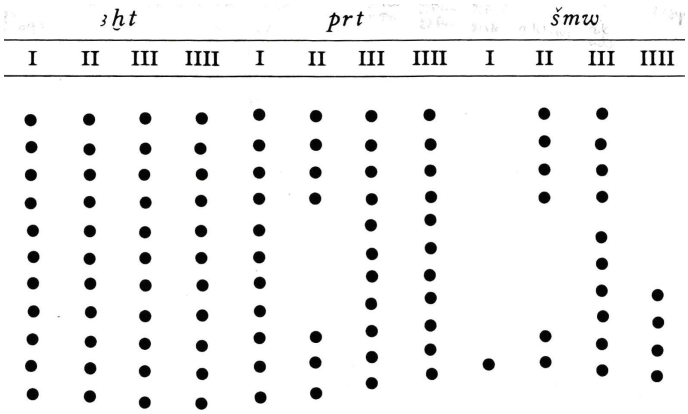


Figure 5. Karnak water clock, inside layout (from Parker, 1950: 40, figure 17)

7 As the appearance of the stars varies very little with the true seasons, the Egyptians were able to slightly and progressively vary the distances between the chosen stars to account for the differences in length of the nights from one season to the next. In addition, the length of the night divided into twelve parts obviously only began when the star indicating the first hour became visible, meaning long after dusk.

8 Valdes, ¿Sólo relojes canónicos? Unpublished MS. I very warmly thank Señor Valdes for lending me his work and photos. He further pointed out that these Spanish solar clocks with 24 divisions are a very small minority among the known total of 450.

The decanal character of the Egyptian month
On the diagonal star clocks each month is split into three decades. This is current already in the Old Kingdom since the papyri of the temple of Abusir show red lines separating each decade on the monthly tables of account (Posener–Krieger, 1968: pl. 3–7, 23–31, 85–86 and 1976: tables Ia, III).

All Egyptian months are composed of 30 days, i.e. three decades, and do not follow the moon: as Belmonte points out, lunar feasts are always related to the civil calendar (Belmonte, 2003: 42).

The decanal structure of the Egyptian year
The Egyptians divided the year into three seasons of four months each, based on the state of the Nile and agricultural life:

Achet, or Inundation;
Peret, or Germination, Winter;
Shemu, or Heat, Summer;

A structure and a systematisation resulting from calculation are superimposed on these agricultural seasons: the twelve months of three decades each add up to 36 decades. To make the year complete, the Egyptians added five days which they called "the five days *in addition* to the year", epagomenoi in Hellenic.

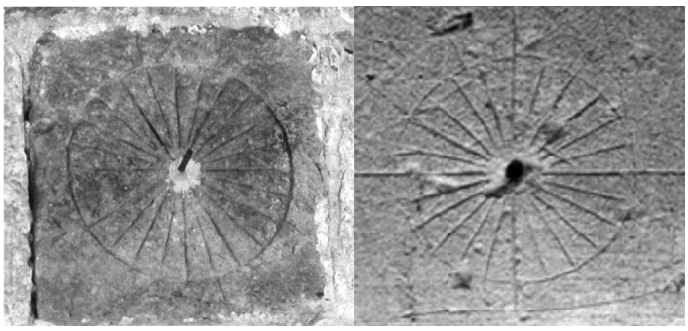


Figure 6. Ancient Spanish solar clocks (Photo M. Valdes).

We already suggested (von Bomhard, 1999: 63) that the Egyptian civil year, which was utilized throughout the entire Egyptian history, was from its very origin built according to a decanal structure, and not a lunar one[9]. Several arguments plead in favour of the Egyptians building the calendar from observation of the decans and not of the moon:

– the five days that the Egyptians explicitly called "*in addition* to the year" underscore the decanal nature of their calendar construction and focuses attention on a year of 360 days: this is the extent of the decanal year determined by the space of ten days between the rise of each of its 36 decanal stars,

– the Egyptian month invariably lasts 30 days grouped in three decades, which implies a purely decanal structure,

– an additional argument in favour of the link between the months and the decans is the relationship the Egyptians established between the month and the hours, as documented by the diagonal star clocks, the water clocks, the ceiling of Senmut's tomb, and certain papyri[10].

The sidereal nature of the Egyptian calendar.
The Egyptian calendar is a sidereal one, i.e. it is built on observation of the stars: Sirius determines the beginning of the true year in phase with the seasons[11]. For the Egyptians, the time of a year was certainly that from one rise of Sirius to the next, because that is what the texts state: at Dendera, we read "the years are counted by his (Sothis') rise" (Mariette, 1870–1: pl. 19g. Brugsch, 1968: 100).

Due to the difference between the length of the civil year (365 days) and the Sothic year (365¼ days), the heliacal rise of the star took place a day later every fourth civil year. For obvious practical reasons, calendars can only count the year in full days. Our own civil year, same as the Egyptian one, counts 365 full days, but every fourth year we use a leap year of 366 days. In the Egyptian calendar, this additional day was never added before the Alexandrian calendar reform. It was absorbed, rather, by letting the date of the rise of Sirius glide in the Egyptian civil year. This system is made possible due to the choice of Sirius, whose year runs for precisely 365¼ days[12].

The utilization of this gliding mechanism between the sidereal year of Sirius (365¼ days) and the Egyptian civil year (365 days) is what we termed "the Gliding Calendar" (von Bomhard, 1999: 29, 37–39, 83). It is a simple and exact way of counting the number of years as well as their true length. In addition, the beginning of the time of one year is linked to an observable astronomical phenomenon, i.e. the heliacal rise of Sirius.

The Ebers calendar illustrates the decanal nature of the civil year and the determination of the months by the rise of decanal stars[13]. In addition, the document clearly provides proof for a gliding between two years, i.e. the fixed Sothic year determined by the rise of Sirius (column A) and therefore in harmony with the true seasons, and the other, civil, mobile or wandering year (column B).

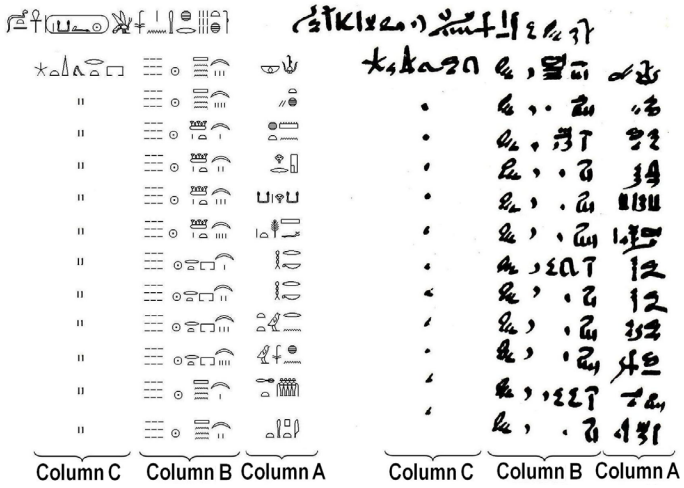


Figure 7. The Ebers calendar, transcription.

There are thirty days between each month name, which is also a feast name. The epagomenes do not appear. In the upper part of Column C, the rise of Sirius opens the year and gives its name to the 12th month (see Fig. 4, ceiling of Senmut's tomb). The

9 Regarding theories in favour of a calendar structure taking the moon into account: Parker, 1950 suggests three successive calendars that are nevertheless connected. More recently, Depuydt, 1997, 2009 associates two successive calendars.
10 Bakir, 1966: pl. 44–45. Leitz, 1994: pl. 44. In this Ramesside document, it is the number of hours that varies according to the month, and not the length of these hours. This illustrates that at least from that time on the Egyptians also knew equinoctial hours.

11 However, there exists also a slow discrepancy between the Sothic year (365.2500 days) and the solar year (365.2422 days), due to the phenomenon of the precession of the equinox, creating a discrepancy of 11 days in one Sothic period of 1460 years
12 The sidereal year of the other stars varies around 365.2560 days. The solar year amounts to 365.2422 days.
13 For the Ebers calendar, see also von Bomhard, 2012: 86-88.

heliacal rise of the star occurs before the beginning of the day: Sirius thus reappears, *stricto sensu,* during the night of the last day of the last month of the preceding *decanal* year. This is the reason for the name "Opening of the Year" given to the 4th month of Shemu. The ditto signs following "Rise of Sirius" in column C probably indicate the rises of the decanal stars that determine the months noted in column A.

The Egyptians system of the gliding calendar has advantages and inconveniences: In order to function correctly, the gliding system requires that the Egyptian civil year of 365 full days be strictly maintained, with its unavoidable consequence of a rapid displacement of the seasons[14] within this civil year, which is for this reason qualified also as "wandering" or "mobile". Despite this major inconvenience, this wandering year has nevertheless been maintained throughout three millennia, a fact which is inconceivable without overwhelmingly strong reasons.

Above all, this gliding system has the very major advantage of requiring no addition of days in the short term, nor any correction or reform in the long run: all astronomical cycles, lunar[15], solar or Sothic are measured within the framework of the civil year of 365 plain days (von Bomhard, 1999: 39, figure 23), and the same astronomical occurrence falls into the same day of the civil year after a lapse of time specific to each of these cycles: the rise of Sirius returns to the same day after 1460 years[16], and the days of each solstice and equinox do so after roughly 1507 years[17].

We must clearly distinguish between the two separate concepts of "the calendar" on the one hand, and "the year" on the other. Following the introduction of the Julian calendar by Julius Caesar, a calendar reform became indispensable despite the exact same length of the Julian as the Sothic year (365¼ days), because in the Julian calendar, the additional day was added every four years. This produced the result, some 1600 years later, of the date of the spring equinox arriving ten days early, which caused the Gregorian calendar reform of 1582.

On the contrary, In the Egyptian Gliding Calendar we proposed, after roughly the same period (1507 years) the spring equinox would return automatically to the same day as 1507 years before, without the slightest need of any reform. In view of the length of Egyptian history, this advantage of the gliding system is particularly remarkable and appreciable.

Nevertheless, it is essential for the correct functioning of our Gliding Calendar to maintain the "wandering" civil year, which explains the fact that it has never been modified until the Alexandrian calendar replaced the ancient Egyptian calendar in 25 BC. Yet even after that reform, the memory of the rise of Sirius and its gliding in the civil year remained alive, as is documented by the Roman grammarian Censorinus, who, in the third century AD still mentioned the coincidence of the rise of Sirius at the beginning of the civil year in 139 AD.

The role of Sirius and the Decanal Stars in Mythology

There is a single Egyptian cosmogony known today which develops the creation of the decanal stars and their mythological functions in a perfectly explicit and extensive manner: it is engraved on one of the outside walls of a monument dating from Nectanebo I, the Naos of the Decades[18]. The chapel is dedicated to the god Shu, and its outside surfaces are covered with frames dedicated to the decades of the year. A small text of an astrological nature accompanies each decade. After the study of this monument by the Habachi brothers (Habachi and Habachi, 1952), Leitz (Leitz, 1995: 3–57) added the translation of the astrological notes.

In 1992, Goddio (Goddio, 1995) announced his project of a topographic survey and archaeological excavation in Alexandria East Harbour and in the Bay of Abuqir, in cooperation with the Egyptian Supreme Council of Antiquities, proposing to use NMR magnetometers developed by the French Atomic Energy Commissariat. The European Institute of Underwater Archaeology which he directs holds the exclusive rights for the use of these instruments in archaeological research. The institute further developed a specific system of underwater positioning (Goddio, Bernand, and Bernand, 1998: 132). The absolute precision of this system allows establishing an exact mapping of the submerged zones and led to the discovery of two submerged townships, Heracleion-Thonis and East Canopus. In 1999, in zone T of East Canopus (Goddio, 2007: 43–44), four big fragments belonging to this naos were discovered, one containing a long engraved text in columns, miraculously preserved after over a thousand years under water. This turned out to be a cosmogony (von Bomhard, 2008: 54–71) of which we have no other version.

According to the first part of this tale, the decanal stars are the souls of the gods that Shu set into the sky together with the discs when he separated the sky and the earth. The god then differentiated life and death for men, gods and all creatures and thereby created strife, combat and sickness. In the second part we see Rē and Thoth intervene: Rē mentions to Thoth that the rise of the sky occurs in a straight line from the hillock of the jujube tree, thus pronouncing the name of Yat-nebes. He indicates that there is a necropolis called "The Headdress House". He ordered Thoth to build in this place a temple dedicated to the decans and decided that these stars should hold the power of life and death: they would spread massacre, sickness and death across the sky, the earth, the duat, the waters and the air. The Sun god then indicates that Shu would command the decans and designates these stars as the children of Rē, of Sekhmet, Nekhbet, Bastet and Wadjit, and as the messengers of Thoth. The end of the text, like its very beginning, is unfortunately destroyed.

It is therefore a divine decree which assigned their role of dispensing life or death to the decanal stars. Rē himself entrusted Shu with the charge of controlling them, and Thoth is to judge the opportunity to send them out. This original cosmogony clearly defines each one's function. In addition, various other texts on this same monument further detail and explain the actions carried out by these stars and by the god Shu who controls them.

The harmful actions of the decans.

The comments that accompany each decade (von Bomhard, 2008: 108–183) describe the massacres and the symptoms of the afflictions that affect the rebels and the enemies of Egypt: the miasma spread by Shu, god of the atmosphere, in the form of morbific airs, also kill cattle and bring pollution to plants. Meteorological catastrophes destroy enemies. The texts separat-

14 The season displace by one month in 120 years.

15 A similar aspect of the moon, e.g. the full moon, falls on the same day in the Egyptian year after 25 years.

16 The rise of the star moved forward by a day every four years, runs through the entire year in 1460 years (365 x 4).

17 The solar year is shorter than the Sothic year.

18 The roof of this monument is in the Louvre since 1817, the base and the rear wall are in the Alexandria Museum since 1940

ing the registers of the decades (von Bomhard, 2008: 194–205) endow the decans with the power of loosening thunderstorms, winds, rain and havoc, but they also carry the Nile flood. The text on the right-side base (von Bomhard, 2008: 213–215) indicates the nefarious actions of the shemayu genies across the universe. The entire monument is dedicated to these stars that are charged with the destruction of the evildoers.

The indications on the naos concerning the decans confirm other known texts, e.g. at Esna (von Lieven, 2000: 43), where it is said that the decans preserve life or kill rebels according to their will, and that they shoot arrows from their mouths at those they see from afar, and also that they pronounce judgement across the entire country and determine all things in the sky and on earth (von Lieven, 2000: 21).

The mythological function of Sirius.

In the astronomical representations found on the ceilings of temples and tombs from the 18th dynasty onward, Sirius is generally shown in an anthropomorphic form. It stands in front of the names of the decans whose cycle it inaugurates. It is called Isis-Sothis and habitually carries a headdress composed of two high feathers to which is added an ostrich feather (Figure 4). The two high feathers have an astral character like the ones borne by the god Shu on the Naos of the Decades. The ostrich feather is the symbol of Justice, because Sirius is assimilated to Sekhmet, as in the Ritual to Appease Sekhmet (Goyon, 2006), but also to Maat, the goddess of justice and cosmic order (Assmann, 1989: 99–102; Maravelia, 2006: 371–372; 2007: 1248–1249; von Bomhard, 2008: 245–246). The star is the Eye of Rē, and is called "Regent of the Decans" because it pulls the decans along in its trajectory across the sky: "the sovereign of the stars, she who directs the decans about what they need to do", as stated in the temple of Opet (De Wit, 1968: 108). Sirius-Sekhmet, and the decanal stars it controls, had the mission of eliminating the evildoers and to ensure that the social order and balanced progress of the world are maintained.

In conclusion, the decanal stars, like Sirius, are uraei charged with defending the Sun. They have the function attributed also to Rē's "headdress" on the naos of Ismaïlia. Under an astronomical light, we proposed (von Bomhard, 2008: 70–71) that this headdress be interpreted as the radiating "solar crown" that appears before the Sun itself, and that the uraeus is the star at its heliacal rise that comes up just above the solar crown and the "head" (disk) of the Sun itself (Figure 8). For the Egyptians, everything depends on the Sun god[19], and the stars that precede him have the charge of his protection.

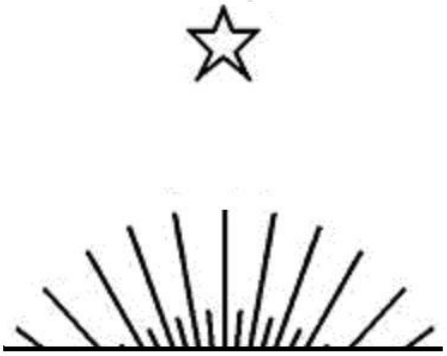


Figure 8. Heliacal rise of Sirius or of a décan and the solar crown.

19 See the orientations of the monuments according to the various interesting studies by Shaltout & al., e.g. 2007, with magnificent photos by Belmonte, ibid.: 418.

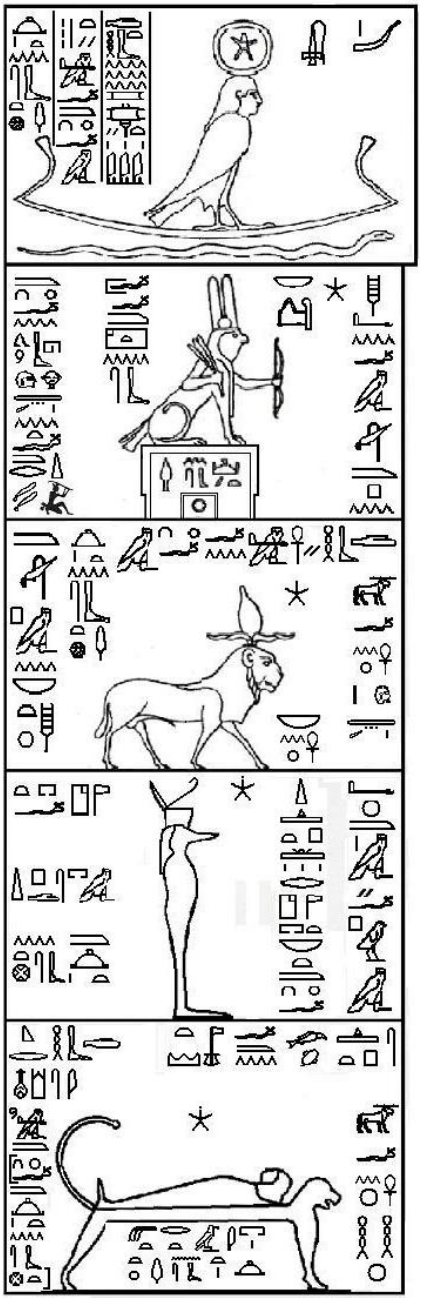
Egyptian Decans and Astrology

The mythological function of the decans becomes "astrological" from the moment where the effects attributed to these stars depend on their movements in the sky as well as on their position in relation to other stars. In this respect, the Naos of the Decades offers an unparalleled example of the passage from mythology to astrology.

If the texts of this monument are much closer to the language of mythology than that of astrology, the action of the stars is nevertheless dependent on their position in the sky because the five figures that appear at each decade (Figure 9) are related to the decanal cycle (Leitz theory, 1995: 8–13; von Bomhard theory, 2008: 91–94):

- the bird represents the rise of the star inaugurating the decade,
- the sphinx the ascending Sun and decans,
- the lion-headed ram the culminating Sun and decans,
- the standing mummy the Sun and decans declining in the west,
- and the reclining mummy the night and the invisible stars of the decade.

Figure 9. The five figures of the decades.



Each astrological text on the naos is thus connected with the daily course of the Sun, within the framework of the decanal stars whose setup moves one step ahead in each decade; we can see on the naos how the Egyptian decanal stars prefigure the zodiac (Figure 10). Before the zodiac appeared, the course of the Sun within the decanal constellations was taken into account, as it is on the naos, and these stars are astrologically active. With time, they simply became way stations in the course of the Sun. When the zodiac appeared in the Hellenistic–Roman period in about 200 BC, the decans at first figured next to and together with the zodiacal signs (e.g. Neugebauer and Parker, 1969: pl. 29, 35, 42, 43), before they progressively disappeared in favour of the sole zodiac. Similarly, their actions, which on the naos concerned entire populations, become increasingly directed towards individuals; texts appear that provide individual prognostications based on observations of the stellar arrangement of the firmament on the day of birth of a person.

The Naos of the Decades precedes this entire astrological documentation by several centuries and appears like a true precursor of Egyptian astrology, based on the decanal system, itself a very ancient properly Egyptian astronomical creation with its own repercussions in mythology and astrology.

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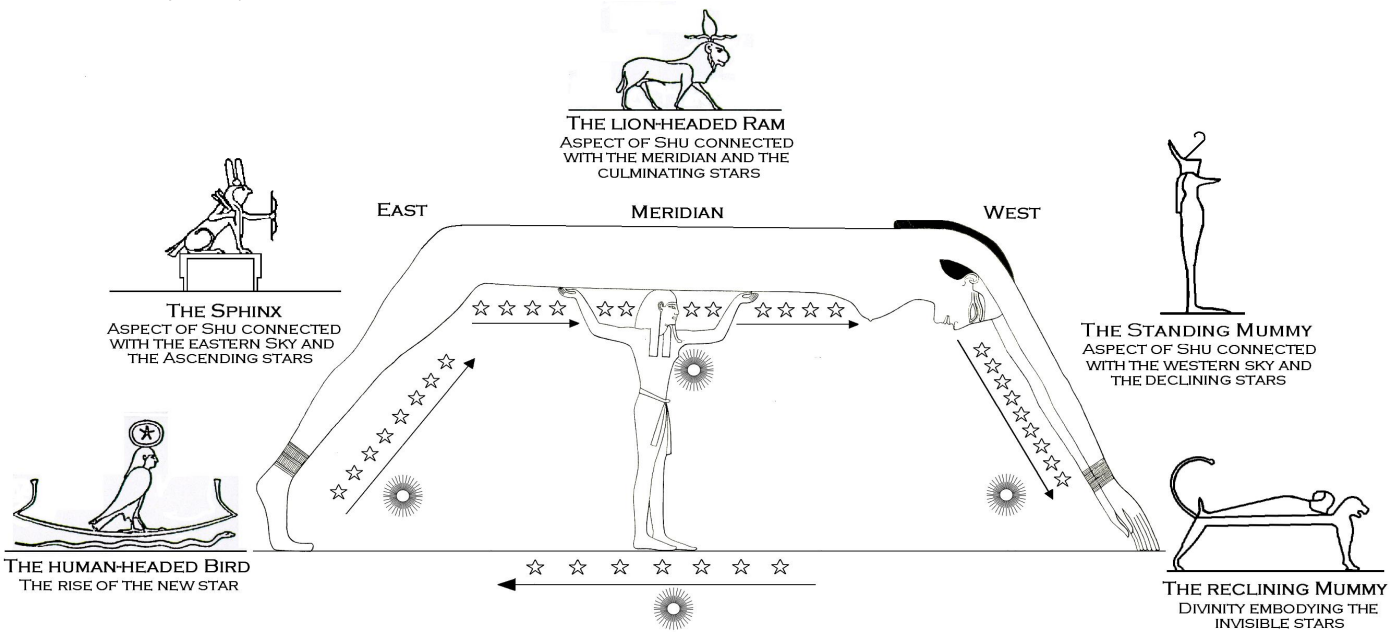
Figure 10. Disposition of the decanal stars as they appear at each decade: the five figures represent the various aspects of Shu according to the various sections of the sky.



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From Giza to Abusir. Astronomy and sacred topography at the passing of a dynasty.

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Abstract: Many unsolved issues exist about the end of the 4th Egyptian dynasty and the beginning of the 5th. From the architectural point of view, these are: the origin and meaning of the strange monument constructed by pharaoh Shepsekaf, the construction of the first Sun temple by Userkaf and, immediately after, the choice of a completely new building site for the king's pyramids at Abusir. In the present paper, which is part of a wider project aimed at a complete analysis of the astronomical and topographical features of the "sacred space" of the pyramid's fields of the Old Kingdom, a general framework for the solution to these problems is proposed and discussed.

Keywords: 4th/5th Egyptian dynasties, Giza, Abu Roash, Abusir, Heliopolis, stars, symbolic choices, sacred topography

Introduction

We will be interested here in the architecture and the topography of the pyramid's fields of the 4th and the 5th Egyptian dynasties. These pyramid fields are located on the edge of the desert, just above the floodplain on the west bank of the Nile. They are distributed along a relatively short line which goes from Abu Roash down to Dashour, less than 30 Kms to the south.

The development of these sites can be skethched as follows. Dashour was the place chosen by the first king of the 4th dynasty, Snefru, who completed there two huge pyramids. His son Khufu moved northward, and choose Giza for the construction of his funerary complex; Khufu's son Djedefre – first king to bring the solar component «re» - moved to the prominent hill of Abu Roash located slighlty to the north of his father's pyramid, and then Khafre and Menkaure choose Giza again. At the end of the 4th dynasty - around 2472 BCE according to Baines and Malek (1984) chronology, which will be used troughout - an abrupt break in the funerary traditions occurs: Shepsekaf indeed preferred to build a sort of giant Mastaba at Saqqara South. With his successor Userkaf however what seems to be a return to the traditions is visible. Indeed, the king choose to build a pyramid in what will become the Saqqara central field, at that time occupied only by the first pyramid ever constructed, Djoser's Step Pyramid. Further, Userkaf also built the first monument of a type usually called *sun temple* further north in the zone of Abu Gorab. With the accession of Sahure (around 2458 BCE), whose name means «Close to Re», we return to «solar» kings. The pyramid of Sahure is located in Abusir, which is a plateau located a few hundred meters south of Abu Gorab. This choice, which will be followed by the successive four kings of the 5th dynasty, remains unexplained (Krejci 2001, Goedicke 2001). Indeed, although a relatively good quarry is avaliable to the southwest, the Abusir geology is not very suitable for the construction of huge monuments. Further, if the king wanted to move north from Saqqara and return close to the "solar" kings, in the whole ridge of the desert from Giza to Abusir there was plenty of space and good areas suitable for pyramids, and indeed an already started pyramid field allotting full of free space was avaliable in Zawiet el Arian, where a 3th dynasty pyramid was standing and an unknown, presumably short-reign 4th dynasty king begun a very huge project which remained unfinished.

A role in the choice of the site of Abusir must have been played by the pre-existance of Userkaf sun temple immediately to the north (Verner 2002), and therefore also the problem of the choice of the position of this temple enters into the game. Another key element must be the existence of a «main axis» at the site. This axis is similar to one existing at Giza; here it connects the north-west corners of the pyramids of three successive kings. As we shall see, all the existing hints sistematically point in the same direction: the solution of the problem of understanding the choice (and also the local topography) of Abusir is connected with the position of the temple of Heliopolis, some 26 Kms afar on the other bank of the Nile.

The aim of the present paper is to show how the methods of archaeoastronomy and archaeo-topography can be used as keys to join all such existing clues – as well as new ones – in what appears to be a coherent, full explanation.

Giza, Abu Roash, and the end of the 4th dynasty

As mentioned above, an interesting feature exists in the layouts of the pyramids of Giza: the presence of a main topographical axis. This axis governed the placement of the subsequent buildings. Indeed, it connects the south-east corners of Khufu, Khafre and Menkaure's pyramids. Actually, the will of obtaining such an alignment is the unique feasible explanation for the placement of Menkaure's project which lies very far into the desert without any practical reason whatsoever. Therefore, the inspiring principles of the general topography at Giza were mainly of sacred, symbolic character. To understand them we observe that the axis points north-east to the temple of the sun of Heliopolis, on the opposite bank of the Nile (Goedicke 2001, Lehner 1985, Magli 2009a). Although the temple is un--excavated, the area where it was standing is easily identified due to a Middle Kingdom obelisk which stands almost in its original position in front of the temple. This area is quite far from the western ridge of the desert and today – due to pollution and buildings - there is no hope to see the pyramids from there. However, a simple calculation shows that, in spite of earth's curvature, a sign-post – say – 20 meters tall placed in Heliopolis would have been perfectly visible from Giza, and of course the reverse was true for the pyramids when viewing from Heliopolis.

The importance of the temple, which existed at least from the 2th dynasty, must have been emphasized with Khufu. According to authoritative scholars indeed (see e.g. Stadelmann 1991, Hawass 1993) Khufu depicted himself as the incarnation of Ra; no relief is known showing Khufu making offerings to Gods, and perhaps this is not due to the lack of documentation but rather is in accordance with the new "cult" which would have equated the king with the god himself. If this is true, then it appears quite natural that the building sites of the 4th dynasty pyramids were chosen in such a way to be visible from Heliopolis. The kings indeed would have had the necessity of showing in explicit, monumental terms their direct lineage from the Sun God in the funerary complexes, by putting them in explicit connection with the temple (Jeffreys 1998).

This explanation however solves only a part of the riddle. Indeed, precisely as a consequence of the alignment, looking from Heliopolis (or from any other point of the axis) the images of the Giza pyramids create a perspective effect: they "contract" on each other and merge into that of the Great Pyramid. Therefore, it can be said that the second and the third Giza pyramids were planned respecting not one but *two* constraints (Magli 2009a): the building sites had to be in view from Heliopolis and the specific positions at the site had to be *the unique available ones* which were *invisible* from Heliopolis. The Giza pyramids consequently stand on a "dynastic" alignment which proceeds into the desert, creating a sort of "mirage" which alludes to the lineage of the Pharaohs from the Sun God. Interestingly enough, a similar effect was planned also at the building site of Djedefre on the Abu Roash hill (Magli 2010). Indeed, if we plot the line which connects Heliopolis with his pyramid's south-west corner, we see that it crosses near the south-west corner of a second Abu Roash pyramid (Lepsius 1, probably a late 3th dynasty pyramid). This monument, today ruined, sits at the easternmost end of the Abu Roash hills (Swelim 1983). The two pyramids thus form a «Abu Roash axis» again pointing to Heliopolis.

It is worth stressing at this point that the existence of topographical, visual connection between subsequent monuments must not be considered as a sort of esoteric message. On the contrary these links were apparent and visible to any pious person approaching the royal Necropolis, the places were the cults of the dead pharaohs were carried out. They were meant to transmit explicit signals of closeness of lineage, religious ideas, or inspirations to different traditions by the kings which were owners of the monuments.

A clamorous, spectacular example of this "explicit message" mechanism can be seen at Menkaure dead and the accession of Shepsekaf. We do not know much about this king; however, I will adopt here the views of many Egyptologists who see hints at a «rebellion» to the solar tradition in his reign (for a complete discussion see Verner 2001).

First of all, the pharaoh's name does not bring the solar component. Second, for his tomb he choose to build a sort of giant Mastaba in an area very far from Giza, not in view from Heliopolis: the area between Saqqara and Dashour. To try to get rid of this enigma, we must first of all observe that the resemblance between Shepsekaf's tomb and a Mastaba is more apparent than real. The monument is, indeed, gigantic in size (around 100x75 meters base and 19 meters tall) and its lower courses were cased in granite, as were those of the pyramid of his father Menkaure; further, the interior apartments are those typical of a pyramid. Also the shape of the "bench" looks more elaborate to that of a Mastaba, with a sort of vault between vertical ends; it has been proposed that it recalls a giant sarcophagus or archaic models such as the so-called Buto shrine (Lehner 1999). Actually, at least in the author's view, the monument also resembles the hieroglyph for "sky"  . All in all, we can be certain that it was conceived, like the giant pyramids, as a monument devoted to occupy the horizon and, consequently, to convey a message. To understand more we must take into account that the south horizon as viewed from Saqqara was already occupied by the Snefru pyramids. As Verner (2001) has already put in evidence, this suggests that Shepsekaf's choices might have been motivated by the will of the king to exploit his dynastic lineage up to Snefru. Actually, who writes is fully convinced (due to a long series of reasons, fully explained in Magli 2009b) that the two magnificent pyramids constructed by Snefru at Dashour form a unique project, conceived, among other things, precisely to form an artificial horizon: the hieroglyph sign of two paired mountains  . Indeed, the ancient pathway leading from the capital to the Saqqara plateau almost certainly raised up a wadi (dried river) located a few hundreds meters to the north of the Step Pyramid and followed a line of archaic mastabas up to the area were the Userkaf and Teti pyramids would later been built. At Snefru times this path was free up to the entrance of the Djoser complex and a person ascending the plateau would have seen the two giant pyramids of Dashour standing alone at the horizon, perhaps representing the two (re-united) parts of the country. Interestingly, immediately thereafter the son of Snefru and first of the solar kings, Khufu, will design his funerary project at Giza following the same pattern, but adding to the paired mountains the sun setting in between, i.e. the hieroglyph akhet  ; the name of the Great Pyramid was indeed akhet Khufu and was replicated every year by a spectacular hierophany occurring at the summer solstice (Lehner 1985, Belmonte, Shaltout and Fekri 2009, Magli 2009a).

When Shepsekaf 's architects begun their work in Saqqara, they conceived their project in order to stress the return of the king to the pre-solar tradition. Thus, they harmonized the monument with the pre-existing landscape, dominated by Snefru's horizon. Indeed, if a line is traced from half the distance between the two Snefru pyramids and the center of Shepsekaf, it is seen that it crosses the Saqqara central field in the same "entrance" area located near the Teti pyramid. As a consequence, anyone reaching the summit of the ridge would have seen (and still can see) the king's tomb forming a sort of regular baseline for the double-mountains symbol created at the horizon by the two giant pyramids of Snefru (the fact that the positioning of the monument was not dictated by the morphology of the territory is easily seen by noting that the huge building is founded on an artificial terrace and is relatively far apart from the ridge of the Plateau).

The 5th dynasty: Abusir

The successor of Shepsekaf , Userkaf, conceived a building program aimed at a return to old traditions of both the 3th and the 4th dynasties. Indeed, to show his closeness to the 3th dynasty he built his pyramid as close as possible to that of Djoser. To exhibit explicitly his connection with Heliopolis and the "solarised kings" tradition of the 4th dynasty, he choose to build a completely new monument, the first sun temple, in Abu Gorab.

This structure was composed, like the standard pyramid's two-temples/causeway complex, by a valley temple, a monumental access ramp sloping upwards and an upper building. Here, a huge stone basement was sustaining a high (non-monolithic) obelisk.

Such a monument was certainly devoted to the Sun God and its plan was probably conceived as a copy of the temple in Heliopolis. As a consequence, it is of fundamental importance to understand the choice of the location of this temple with respect to this sacred center. Interestingly enough, the temple was constructed very near the southernmost available point of the west bank of the Nile from which Heliopolis is still visible (Kaiser 1956). In this way, the king "signalled" to everyone his closeness to the solar tradition in spite of the fact that his pyramid was invisible from Heliopolis.

With Userkaf's successor, Sahure, kingship definitively returns

to the tradition of the «solarised» kings. Thus, it has to be expected that the king wanted a pyramidal complex exhibiting explicitly his connection with Heliopolis. However, Sahure's complex is the first to be built in Abusir, a few hundred meters south of Userkaf Sun Temple and therefore in the first available position which is *not* in view from Heliopolis. Why?

Let us consider the problem which faced Sahure's architects. According to the framework outlined in the present paper, I maintain that *the natural choice for Sahure's pyramid would have been Giza*, with the construction of a fourth monument aligned along the "Giza axis", i.e. in the hypothetical position shown in Fig. 1.

Figure 1. A satellite image of the Giza pyramid field. The main axis of the necropolis and the "would be" position of the Sahure pyramid are highlighted.

However, building a pyramid complex there, even more far away in the desert with respect to Menkaure´s, would have been nearly impossible. Thus, the architect had to find a new idea to allow the king to nest himself firmly into the solar lineage. This idea was precisely to place the pyramid of Sahure in the first available location in the south from which Heliopolis is not visible: Abusir. Approaching Heliopolis from the north and looking west, an observer would have seen the king's pyramid - called «Sahure's soul shines» - disappear merging with the profile of the rock outcrop of the (today's) Cairo citadel, while the shining golden apex of the Userkaf sun temple remained in distant view, to testify the solar character of the king's blood.

I therefore propose that the choice of the Abusir plateau was essentially due to a single, specific reason of *sacred* – as opposed to practical – topography: it was actually the *second available* place which fulfilled the constraint of remaining "just" invisible from Heliopolis, after the architects were obliged to discard the first.

If this model is accepted, then it becomes easy to follow the development of the Abusir pyramid's field. Indeed, after Sahure we have another solar king, Neferirkare. The natural place for his pyramid would obviously have been to the south-west of Sahure, with the *north-west* corner of the base aligned to the corresponding corner of Sahure and all the way up to the (invisible) Heliopolis.

This is exactly the place and the way in which the king's pyramid was planned and constructed.
With Neferirkare, a main axis was thus inaugurated in Abusir (Verner 2001). The successor, the solar king Neferefre, thus had no choices but to align his monument along this axis, very far into the desert, to the south west of Neferirkare pyramid.

This is exactly the place were we can find the (unfinished) monument of Neferefre (Fig. 2). The situation here is very similar to that of the third pyramid of Giza; curiously enough, the two monuments also had a very similar name: "Menkaure is divine" and "The power of Neferefre is divine".

Figure 2. View from the summit of the south wall of the Neferefre monument. The pit of the unfinished pyramid is visible in the foreground. In the background, the huge mole of the Neferirkare pyramid covers Sahure's monument. The main axis of the necropolis passes to the extreme left of the picture and points to the outcrop of the Cairo citadel on the other bank of the Nile.

After Neferefre, his short-reign successor Shepseskare had to confront to the same problem which faced Sahure at Giza, namely, it was impossible to "attach" his pyramid to the pre-existing 3-pyramids "diagonal" without going very far in the desert (for a complete discussion about the possibility that Shepseskare may have preceded Neferefre see Verner 2002). We are unsure of the location of the king's pyramid; however in the small space left between Userkaf's sun temple and Sahure's pyramid the foundation of an unfinished pyramid have been found. If, as it seems likely, this was the building site chosen for Shepseskare's tomb, he remained in this way «just invisible» from Heliopolis.

The problem of finding a place for the pyramid of the next solar king, Niuserre, became dramatic. Indeed, to fulfill the constraints the king should had to move to the next available position along the Abusir axis, which was definitively too far off in the desert (Fig. 3). As a consequence, the planners of his monument had to find another way to exhibit the lineage of the king and his solar ascendance. Although it may seem incredible, the way they did this was to *split* the dynastic and the solar content inaugurating two new, different axes (Fig. 3).

The king's pyramid is in fact located to the east side of that of his father Neferirkare, a quite unique example of "intrusive" design. The dimensions and position are chosen in such a way that a "dynastic" line connects the south-east corner of the pyramid with that of the pre-existing pyramids of Neferefre to the south and of Neferirkare to the north; this line touches also the corner of the Mastaba of Ptahshepses, a very important personage of Niuserre's times (Lehner 1985).
This new Abusir axis solved the «dynastic» problem; however,

the main problem was still standing namely, the fact that the connection of the king with the sun god was not embodied in the topography of his funerary complex. We can therefore speculate that perhaps exactly this was the reason which inspired the construction by Niuserre of his own Sun Temple, located north-west of the Userkaf's one and therefore in plain view of Heliopolis. What remained to be done was to connect the project of the temple with that of the funerary complex: to achieve this Niuserre's architects managed to inaugurate yet another axis. This is a line oriented ~45° south of east which connects the basis of the obelisk of the Niuserre Sun Temple, the south-east corner of Userkaf's temple and the apex of the Niuserre pyramid (Fig. 4). If the line is further prolonged to the north-west, it intersects the south-west corner of the 3th dynasty pyramid in Zawiet el Arian and appears to end at the center of the «Great Pit», that is, the unfinsihed pyramid in the same site (the possible intenionality of such an alignment requires further studies; unfortunately, the site lies inside a military base and it is unreacheable).

The function of this line is thus to exhibit a close link between the funerary complex of the king, his Sun Temple and, consequently, Heliopolis. Actually, the true meaning and origin of the Sun Temples have never been explained satisfactorily. According to existing texts of the epoch, it seems that also Sahure, Neferefre, Neferirkare (and Menkahour later on) constructed one such monuments. However these temples have never been found. As a consequence, some scholars have proposed that the texts actually refer to renewals made by such pharaohs to Userkaf's temple, and thus that the unique other sun temple effectively constructed after Userkaf's was that of Niuserre (Stadelmann 2001; for a complete discussion see Verner 2002. The fact that the temples have never been found is not, of course, a proof of non-existence; however, in view of the analysis of the present paper it is clear that the two known to exist correspond to two pharaohs, Userkaf and Niuserre, who both solved with their construction the same problem, namely that of linking their building activities both to the dynastic lineage and to the Heliopolitan temple.

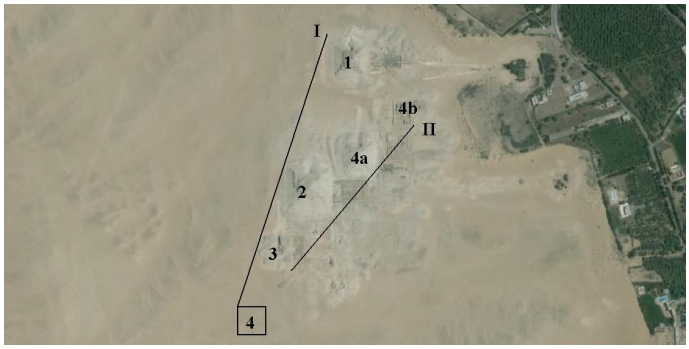

Figure 3. A satellite image of the Abusir pyramid field. 1-2-3 Pyramids of Sahure, Neferirkare, Neferefre; 4a Pyramid of Niuserre; 4b Mastaba of Ptahshepses. The main axis (I) of the necropolis with the "would be" position of the Niuserre pyramid (4) and the "dynastic" (II) Niuserre axis are highlighted.

Figure 4. View from the Niuserre sun temple towards Abusir. A 45° south of east line connects the temple with Userkaf's ruined temple (located between the dunes in the middle) and the apex of the king's pyramid, seen at the center between Sahure's and Neferirkare's. In the foreground is the temple court, with a huge alabaster altar still in situ.

Stars from Heliopolis

Up to now our analysis has been developed taking into account topographical rather than astronomical alignments, in accordance with the view that Archaeoastronomy is a broad science, whose methods apply to all the relationships of the monuments with the landscape, including of course the sky. We will now move to the astronomical analysis.

The idea that also astronomy played a role in the placement of the pyramid fields *with respect to Heliopolis* originates from the following observation. If we list, from north to south, the azimuths of the pyramids of the solarised kings as seen from Heliopolis, we can recognize that *they start with the azimuth of the winter solstice sunset* (~28° south of west) corresponding to the Abu Roash axis, and then decrease. This means that the Abu Roash axis acts as an upper boundary: the sun can never be seen setting on any other pyramid from Heliopolis, and can never be seen rising on Heliopolis from any other pyramid (a thing which is instead sometimes erroneously mentioned in the Egyptological literature). The lower boundary – i.e. the line of minimal azimuth from Heliopolis - is given by the azimuth of the Userkaf Sun temple which, due to the closeness of Abu Gorab to Abusir, essentially coincides with the Abusir axis at ~71° south of west.

If we now study the sector of horizon with azimuths between 28° and 71° south of west at the time of construction of the monuments, the situation becomes intriguing. Indeed the Abu Roash axis also pointed to the setting of Sirius (within one degree if Djedefre accessed in 2528; see discussion in Shaltout et al. 2007). Perhaps this was connected to the name of the pyramid, which was «Djedefre is a star *Sehedu*» (the meaning of the term is uncertain). In any case, as is universally known, Sirius was the most important star of the Egyptian firmament. It was indeed the first of the *Decans.* The Decans were 36 celestial objects whose heliacal rising happened in successive «weeks» of 10 days (Belmonte 2001); the (ritual) use of the Heliacal rising of the Decans to count the hours of the night is documented in Egypt from the 9th Dynasty (2154 BCE) but probably dates before. The second brightest star in the Egyptian sky was Canopus, probably an important Decan as well, and the azimuth of the Abusir axis corresponds to the setting of Canopus (within one degree if Userkaf accessed in 2465 BCE). Clearly, we are at this point led to consider the azimuths of the other pyramid fields of Giza (~45° south of west) and Zawiet el Arian (~56° south of west) and both correspond to important stars of the Egyptian firmament. In the case of Zawiet el Arian we find the decanal star Fomalhaut (within one degree at a fiducial date 2500 BCE), in the case of Giza we have the setting of the brightest part of the Milky Way (Southern Cross-Centaurus group, which contained many Decans). In particular if Khufu is dated 2551 BCE then Rigil sat in optimal alignment with the Giza axis.

Interestingly enough, the above mentioned stars had Heliacal settings in successive periods of the year starting from Sirius

(whose Heliacal *rising* was close to the summer solstice and the beginning of the year) and arriving at Canopus.

Conclusions

The choice of the pyramid building sites had to take into account various practical factors, such as work in progress in the pyramid of the preceding pharaoh, presence of suitable quarries and accessibility of materials (Barta 2005). However, no one of such factors can be considered as decisive for the choice of the Abusir plateau and for the existence there of peculiar topographical features which connect the monuments of dynastically related pharaohs. As a consequence, the very same choice of Abusir represents one of the enigmas related to the passage from the 4th to the 5th dynasty.

I have tried here to tackle this problem in the broader context of the sacred topography of the pyramid fields of the Old Kingdom, as it emerges from a more comprehensive study (Magli 2010). What turns out is that symbolic – as opposed to practical – motivations originated the choices of almost all the sites; the factors which entered in such motivations were both of religious and of dynastic nature. In my view, there is no «hidden», esoteric legacy to be discovered in all this; on the contrary, the will of the pharaohs was to make explicit as much as possible the actualization of their ideas and the origin of their power in the architecture of the funerary complexes. Unfortunately, however, no contemporary textual evidence is available regarding the pyramid's projects and design, and in this respect any analysis is doomed to remain speculative. Let me mention, though, that not only the Pyramid Texts point to the "stellar" afterlife of the deceased pharaoh (a point confirmed by the shafts of the Khufu pyramid, see Magli and Belmonte 2009) but also contain the idea of dynastic lineage from Heliopolis. For instance: «*My father is an Onite, and I myself am an Onite, born in On [=Heliopolis] when Ra was ruler*» (PT 307; Faulkner 1998). Direct ascendance from Heliopolis is also claimed for Userkaf in the famous – although much debated - Middle Kingdom text of the Westcar Papyrus.

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Western Asia

The First Star: an Archaeological and Astronomical Study on the 4th Millennium Ghassulian «Star» and «Notables» Paintings in Jordan

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Abstract: Paintings are the most important evidences of the cultural development of first agricultural human communities. Man has since the prehistory tried to represent the reality of the world around him, but the first artistic expression of cult and religion, as well as the first images of the gods, spread between human communities during Neolithic Period (around the 7th millennium BC) in the Fertile Crescent. In Tuleylat al-Ghassul, on the inner walls of a number of "Area 3" buildings, there are the clearest ancient images of astral world, referred to the stars as divine entities. The aim of this paper is to analyze the famous "Star" and "Notables" paintings of Ghassul from historical, archaeological and astronomical points of view, in order to better understand the role of sky observation in the evolution of cult and human religious thought during the 4th millennium BC. In particular, a comparison between the formal characters of the drawings of the Ghassulian Star and the orientation of the sacred buildings of the site points to recognize in this "Star" a representation the Sun, first important deity of the farmers communities.

Keywords: Tuleilat al–Ghassul, Gassulian paintings, Calendar, Astronomy

Introduction

The site of Tuleilat al–Ghassul is located in Jordan, North East from the Dead Sea, near the modern city of Amman, West from Mount Nebo, on the opposite side of Jordan River with respect the Jericho biblical site. It was first investigated in the 30s by the archeological mission of the Pontifical Biblical Institute (Mallon, Koeppel & Neuville 1934, 1940; North 1961) and this discovery completely changed the vision of the Chalcolithic Period.

At the end of the 5th millennium and the beginning of the 4th millennium BCE, Ghassul appears as a huge settlement of 20–30 ha., with clear attestation of agriculture and permanent domestic architecture. In the Late Chalcolithic, Tuleilat al–Ghassul was the major settlement in the whole Southern Levant, and probably spread its cultural influence over all the sites in this geographical area, so that it is now usual to call that period Ghassulian. The excavation of the Pontifical Biblical Institute and the following archeological mission to the site, operated in the 70s by the University of Sidney (Hennessy, 1977), brought to light an impressive domestic quarter in areas 1 and 3, with houses of different dimensions, all centered on a main court with many rooms around it. Some of these houses have particular features, like paintings along all internal walls, characterized by red, black and yellow colors; most of them presented also many layers of painting, till twenty layers one over another, that, as Cameron (1981a) had noticed in her work, could indicate a periodical re–drawing of the pictures in particular religious occasions such as festivities. The houses in areas 1 and 3 having these paintings present peculiar findings, like many «cornet cups», vessels probably used in rituals. These findings, together with some consideration about the architecture of the houses, showing bigger dimension than those without paintings, suggest that they are elites houses, probably related to the clergy of the community or perhaps connected with cult shrines inside the domestic quarters of the settlement. The discovery in the 70s of an huge sacred temenos in area E clearly indicated the presence, in the site of Tuleilat al–Ghassul, of an important clergy, as dominant elite of a stratified society connected with a centralized economy based on agriculture during the Late Chalcolithic Period, as in the following Early Bronze societies. Stephen J. Burke later investigated this area in 1994–1997 and excavated two buildings, Temple A and building B, clearly related to an important sanctuary (Seaton, 2000). In particular, Temple A presents also an external altar, in an open area or temenos, connected with the temple main door trough a paved road. This important sacred area, with a major temple, a second structure and the temenos was in use for one thousand years at least and indicates the maintenance of a cult, center of the spiritual life of the settlement, connected with agricultural activities, testified also by an adjacent bulk grain storage area. This fact indicates a clergy that dominates an agricultural stratified society accumulating the exceeding food and organizing the public works like in the urbanized bronze societies.

Among the numerous traces of paintings discovered on the wall of the Ghassulian houses, most show scenes that are no more identifiable, like the «Tiger» painting, sometimes identified with a feline or otherwise with a human figure, or the «Bird» painting, of which only an entire partridge–like figure was recovered, together with some «death mask», as Cameron has called them, probably related to priests figures, or also the «Zig–Zag» fragment, related to some geometrical decorations. All these paintings are easily connected with the millenary costume of painting in the ancient Near East; actually, since the Neolithic Period, humanity represented on the walls of domestic units particular scenes related to cult, as it is shown by Anatolic Çatal Huyuk examples, where funerary costumes based on vultures eating corpses were painted (Cameron, 1981b). Also in Syria a number of cases of paintings on house walls are attested in the Neolithic, as in Bouqras (Akkermans and Schwartz, 2003: fig. 4.15), and in the Late Chalcolithic – Bronze Age, as the cult representation of Halawa (Akkermans and Schwartz, 2003: fig. 7.10). All these paintings are clearly connected with the pottery experience, which in all the Near East, from Mesopotamia to the Levant since the Pottery Neolithic Period, was painted in different ways, with geometrical and also human figures.

In this work, we have in particular focused our attention on three Ghassulian paintings, two of them discovered by Mallon and Koeppel in 1929–1934, the «Star» and the «Notables» paintings, unfortunately lost because of a wrong attempt of detachment from the walls, but well documented by photographs and drawings, and third, the «Procession», the only Ghassulian painting preserved and now kept in the Amman Citadel Museum, discovered by Hennessy in 1975–1977. Our hypothesis is that these three paintings reflect a homogeneous religious thinking, related to an important solar cult started in Ghassul by the clergy dominant elite when the main sacred area E was established.

The «Procession» painting

In the «Procession» painting (Fig. 1) three characters are visible, clearly identified as clergymen by the ritual masks; they proceed from right to left, toward a geometrical structure that seems very

similar to the front of the temples as we know them from the contemporary Late Uruk glyptic, also from the 4th millennium BCE (Rova 1994).

In front of the first character, who carries a sort of sickle like the contemporary ones found in Nahal Misnan cave (Cameron 1981a), there is a schematic representation of a throne, probably indicating a divine statue. The different height of human figures reflects probably different ranks of the clergymen represented, or perhaps an attempt to represent the climb toward the temple. The picture could easily be recognized as a sacred scene of inauguration of a sacred building or as a particular festivity connected with the introduction of a divine statue inside a temple. There are many example in the Mesopotamian Late Uruk glyptic of ritual scenes involving priests in front of a temple façade (e.g. the examples in Rova 1994).

The «Notables» painting

In the badly preserved «Notables» painting (Fig.2), it is possible to notice another cult scene. There are two main figures, visible only for the two couple of feet posed on some stone base, perhaps part of two divine statues seated on thrones. Behind them there are other four standing figures again visible only by half of the legs. In front of the first main seated figure there is a smaller black nude figure that probably represents an attendant of the clergy performing some kind of ritual on the divine statue.

This kind of representation is known from Mesopotamian later artistic context, like the Ur–Namma stele, of the end of the third millennium BCE, where on the third register there is the same scene of a nude clergyman operating a purification ritual in front of a statue of a god seated in throne, usually identified as the Sun god Shamash (Matthiae 2000: 45-53). The two divine statues represented on the Ghassulian «Notables» painting look toward a big star, preserved only in the lower part, where a main perpendicular red ray and two couples of smaller yellow rays on the right and on the left of the main one are visible. The big dimension of the star and the characteristic of the rays, of different colors and dimension, identify this object with the representation of an important aster such as the Sun or Venus. The scene of the «Notables» can thus represent an important rite centered on the cult of divine statues, probably posed inside a temple, that look toward a star, that in the ancient Near East religious thinking was always symbol of the divinity itself.

The «Star» painting

The last painting in analysis is the «Star» painting. This particularly well preserved painting shows in the center a big star with eight rays, four in black and four in red; the circular center of the star has two other white stars one inside the other. The smaller stars are inscribed inside two circles, the external one marked by sixteen red and pink triangles, pointing toward the center of the figure. This complicated geometrical representation is easily recognizable as an astral symbol of a god, again related to the Sun or Venus. Some further considerations are necessary on this point: first of all the eight pointed star is known from the northern Mesopotamian tradition since the Halaf–Ubaid cultures, in the 6th Millennium BCE, as a solar symbol (Goff 1963), and only later, in Akkadian culture, at the end of 3rd Millennium BCE, Venus is represented as the Ishtar goddess exclusively by an eight pointed star. When this happened, the Sun, as symbol of the god Shamash, assumes first the representation of a sixteen pointed star, with eight rays characterized by parallel small waves, indicative of the heat transmitted by the Sun, in a similar way of the waves pattern of the star rays of the Tuleilat al–Ghassul Star painting. Later, in the Old Babylonian Period, 2nd Millennium BCE, the symbol of the Sun will be standardized as four points – four rays shape. Last, at the end of the II millennium BCE, with the Cassite Dynasty, the Sun is also represented with an eight rays shape (Pizzimenti, 2014).

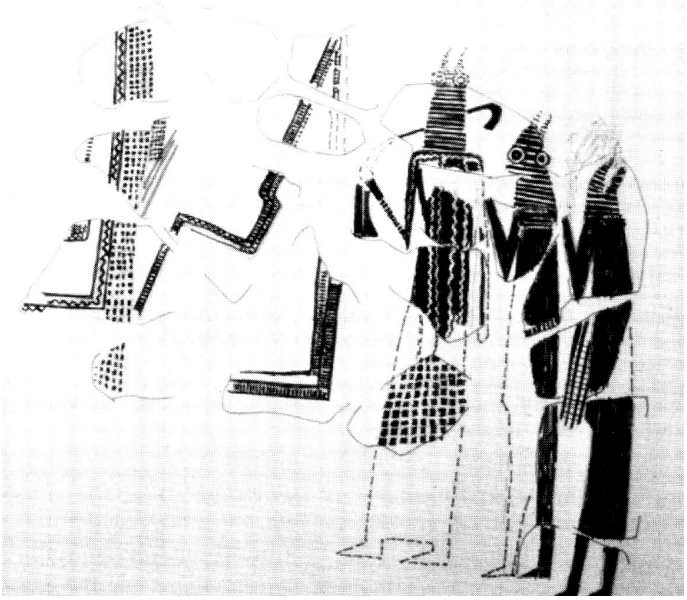

Figure 1. The «Procession» painting (from Bourke 2001: fig. 4.3).

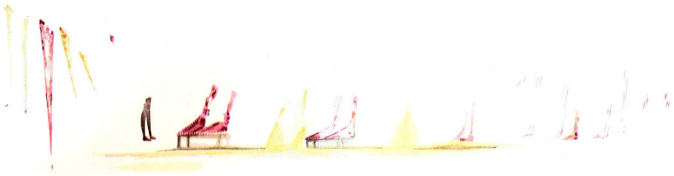

Figure 2 The «Notables» painting (from Mallon, Koeppel & Neuville 1934).

Figure 3 The «Star» painting (from Mallon, Koeppel & Neuville 1934).

The big star of the Tuleilat al–Ghassul Star painting, with a diameter of two meter, was painted over various, more ancient paintings, badly preserved, except one figure painted later and covering part of the ray of the big star on the right. This figure is similar to the one of the Procession painting, representing a temple front wall; moreover in this case there are more similarities with the temple facades on the Mesopotamian Late Uruk seals scenes, with the geometrical design of the «frontone» and the central door (cfr. the examples in Rova 1994). In this scene

a temple was thus painted over the star, clearly connected with the divine symbol.

The sacred area E of Tuleilat al–Ghassul

If we now look at the orientation of the sacred area E of Tuleilat al–Ghassul, we immediately notice that the main Temple A (Fig. 4), the «paved avenue» bringing from it to the altar and the long wall of the temenos are more or less parallel and roughly oriented to the East, as well as the long side of the «Sanctuary B», whose entry door is looking to the South. This orientation is strongly suggesting that the cults celebrated in this area were connected to the rise and to the culmination of the Sun.

Figure 4. The Teleilat Ghassul Sacred Area plan; the alignment discussed in the text are marked in red (Plan from, Seaton 2000: fig.1)

However, a deeper analysis shows that the plan of the area is much less «rough» than it appears at the first sight. First, we have to correct the direction of North in the map for the magnetic declination.

Following the NOAA's National Geophysical Data Center on line computer code (http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp), for the geographical coordinates of Teleilat Ghassul and the years 1977–1997, the correction is of order of 3° (a more precise correction could be given if the exact date of the measurement was known: for instance, for year 1977, it would be 3.5°). The axis of the paved avenue is thus very near to the true East and the entry door of Sanctuary B to the true South. Second, we have to bear in mind that Teleilat Ghassul is located at -298 m with respect to the sea level and that Mount Nebo stands to the East at a level of 813 m over the sea level. This implies that the view in this direction is covered for 5.8° over the astronomical horizon.

It is worth to notice that, at the end of 5th Millennium and the beginning of the 4th Millennium BCE, the Sun reaches a height of 6° at an azimuth of 92° 50' exactly 30 minutes after the astronomical sunrise time at the equinoxes. The paved avenue is thus directed exactly in the direction where, at the equinoxes, the Sun appears over Mount Nebo.

Furthermore, we notice that the wall surrounding the altar is a semicircle. However, its axis does not coincide with the one of the «paved avenue», being instead aligned with the wall of «Sanctuary B» and with a small structure on the temenos wall. This orientation, most probably, is not random.

A solar myth in the «Star» painting?

Looking back to the «Star» painting it is possible to do some considerations concerning the figures on the left: these are mostly badly preserved; moreover it is not recognizable one layer from another so that it is impossible to understand the relationship between them. However, three smaller figures on the upper part of the painting are possibly related each other. These figures are: on the left a horned head of a goat or of a similar animal, at the center a human head similar to the «death masks» of the «Bird» painting and on the right a strange monster, composed by a crescent head with a big open mouth and something behind often identified as a wing. Cameron (1981a; 1981b) interpreted these three figures as a chrysalis on the left, a corpse in the middle and a butterfly on the right representing the birth, the death and the rebirth. In our view, these three figures can be interpreted in a different way. On the left, the goat–like figure is, more probably, the animal connected with the sun god in the Mesopotamian Halaf culture; at the center the so called «death mask» seems more similar to a frontal representation of a face, like the head of the first Sumerian divine statue known, the god Ningirsu of the Eshnunna temple of the third millennium BCE, characterized by the long curls on the shoulders and the big open eyes (Moortgat 1969: fig. 62).

Figure 5. Comparison between the «Death Mask» of the Ghassulian Star painting (left) and the head of the god Ningirsu of Eshnunna temple (right, from Moortgat 1969: fig. 62).

The head represented on the Ghassulian painting has a kind of shining aureole behind, painted in yellow, like the one that appears behind the image of the goddess Ishtar in Syrian glyptic, as it is shown by an example of Mitanni Period (Late Bronze Age, 1500–1200 BCE; Keel and Uehlinger 1996: 151, Abb. 174). Also the representation of Shamash that rises over the mountains in the Akkadian glyptic shows some rays or flames behind the shoulders of the Sun god, representing the heat and the shining of the Sun. This scene seems thus to us similar to the later Mesopotamian glyptic scenes of the Akkadian Period representing myths about gods. In particular, the ones connected to the Sun god Shamash often present the god, followed by sacred animals and fighting against a monster (Collon 1987); this tradition has a long life, as it is shown by an Old Babylonian plaque of the 2nd Millennium BCE, with the Sun god that hits with his sacred knife a cyclopic monster (Matthiae 2000: 109).

Finally, the analyses on the three paintings, the stylistic representation of the solar disk and the orientation of the main Temple A of Tuleilat al–Ghassul point to recognize an important cult inaugurated by the elite clergy of the settlement with the construction of the sa-

cred area E and celebrated with the painting on the elite houses walls, clearly connected with the Sun god. This solar cult is historically well inserted in the economical framework of Ghassulian people, who, in the IV millennium BCE, experimented a fast and strong agricultural implementation in the settlement subsistence economy, as it is attested by the archaeological stratification recognized by the last expedition of the University of Sidney (Seaton 2000; Bourke 2001).

Another question remains: why the Ghassulian clergy demands for the Solar painting such a geometrical representation of the solar disk, so different from the other representation of the Sun in the «Notables» panting? For sure the increase of importance of the solar cult can require the need for a more detailed symbolical sign for the Sun god, now in a main position in the Ghassulian pantheon, in a way similar to the glorious Enuma Elish poem, celebrating the increase of importance of the Babylonian god Marduk in the second millennium BCE (Cfr. Bottero & Kramer 1992: 640-722). So, while in a literate urban society writing is the normal instrument for the diffusion of religious changes, in a non literate proto–urban society like the Ghassulian one, art is the only way for this kind of ideological messages.

A solar calendar?

However, perhaps another tentative explanation for this geometrical Solar disk symbol is its connection with a sort of calendar, linked to Sun cycle that regulates the agricultural life.

Concerning this point, we have first to stress the extreme regularity of the painting, showing that it was made by someone well entrained in geometry.

Second, one of the external points of the rays, the horizontal one to the right, is clearly marked as to identify a «starting point».

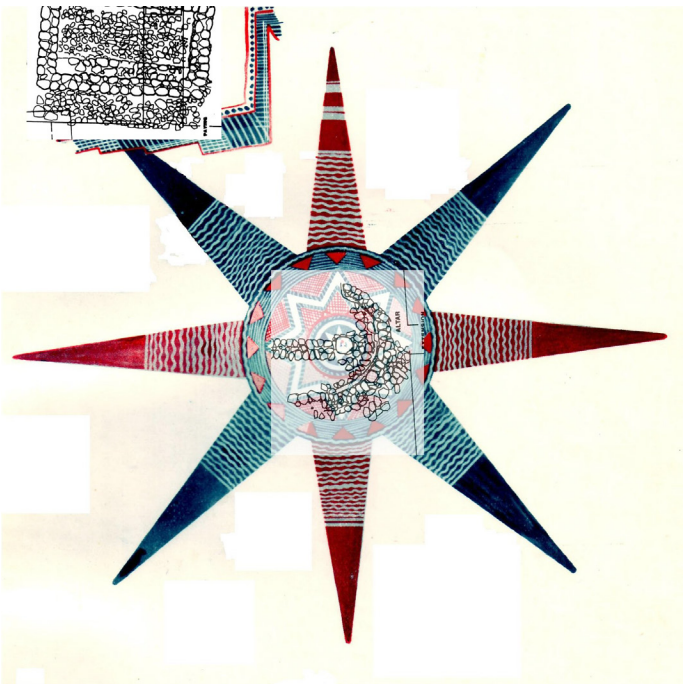

Figure 6 Overlapping of the Ghassulian Star painting to the plan of the Altar of the Teleilat Ghassul Santuary.

Third, 16 isosceles triangles are drawn at regular distance inside the outer circle, of whose 11 are red, 4 are pink and one, dividing the two color series, is half pink and half red.

There is thus a highly asymmetric scheme, inside a very symmetric one: it must thus means something, as well as the asymmetry identified in the sacred area plan

Let thus overlap the plan of the altar of Temple A on the «Star» (Fig. 6): let put the altar in the centre and the beginning of the semicircle in correspondence of the marked ray of the «Star». The end of the larger part of the semicircular wall fits the half red, half pink triangle, the last stone of the semicircle perfectly fits the first pink triangle and the «paved avenue» one of the red rays. Since we know that the paved avenue is directed to East, the marked point thus represents North and the building painted near to the star is Sanctuary B.

Orienting the star following our usual rules (North on top, East on right; see Fig.6), we could suggest that the first pink triangle denote the winter solstice period, corresponding on the altar plan to the last SW stone of the semicircular wall, giving with good approximation the direction of the winter solstice sunset as seen from a point in front of the altar and that the arc denoted by the pink triangles corresponds to the maximum rain period (to date of about 3.5 months, from mid December to beginning of March), covering the same percentage of the painted circle and of the year respectively.

If this hypothesis is correct, we could imagine that the 16 triangles correspond to a subdivision of the year, e.g. a 360 days year divided in 15 «months» of various unknown length, plus a shorter one (may be around the winter solstice) to maintain such a calendar in phase with the rain seasons. The altar of Temple A could have been the device used to perform this task. It is worth to notice that a sort of prehistoric calendar of 16 months, obtained dividing the year first in two parts, corresponding to the solstices, then in four, adding the equinoxes, then splitting this interval in two parts other two times has been suggested by Thom (1967): such a calendar could be recognized in the Ghassulian Star painting and could easily fit the world vision of a society whose life was based on a solar religion.

However, it is commonly accepted that the, at least in Mesopotamia, a lunar calendar of 12 months of 30 days each was used since the earlier times (see, e. g. Brack–Bernsen, 2007): further studies are thus needed to reach a final conclusion.

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Early Bronze Age Geometry in the Dead Sea Region at Tel Arad and Bab Edh-Dhra': Numerical Squaring, Harmonic Compositions and Length–Units

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Abstract: The use of CAD techniques applied to reliable archaeological plans has already proved to be well suited for the deciphering of the interrelations existing among numbers, geometric forms and length units in ancient architectonic structures. In the present work, the geometrical, numerical and metrical contents of the EB structures of Tel Arad and Bab edh-Dhra' are derived. The use of perfect-pythagorean and quasi-perfect triads of integers is attested. The use of square triads is shown to occur in harmonic schemes. One and the same unit of length can be derived for all three structures, which moreover coincides with the known value of the Phoenician cubit of 0.515 m, suggesting a technological continuity from the Early Bronze to the Iron Age. In addition to their archaeological significance, the results also demonstrate the high efficiency of the research methodology used.

Keywords: Early Bronze Age, Daed Sea Region, Tel ARad, Bab Edh-Drha', Geometry

Introduction

In EB (Early Bronze Age) I (end of the IV mill. B.C.E.), Jordan valley is an obligatory passage for the semi nomadic herders seasonally moving from the Transjordanian highlands to the low hills of southern Palestine, before winter and vice versa before summer.

In EB II (III mill. B.C.E.), southern Palestinian and Transjordanian communities are changing from the semi nomadic style of life, to a sedentary one. In the semiarid zones, co–living of agricultural sedentary communities and semi nomadic shepherds allows the creation of villages and towns with mixed economies, controlling lands to be geographically considered as interfaces between the desert and the fertile river valleys.1 It is the forming of the earliest urban structures with an economy based on the development of agricultural techniques (plow, complete seasonal cycles of crops) as is the case of Arad and Bab edh Dhra' (Polcaro 2006: 281-308).

1 Jordan is particularly suitable for interaction and aggregation between the two different communities: its valley is a must for herders moving from the highlands of Transjordan to the hilly landscape of southern Palestine (Levy, 1998 : 243-280).

Arad

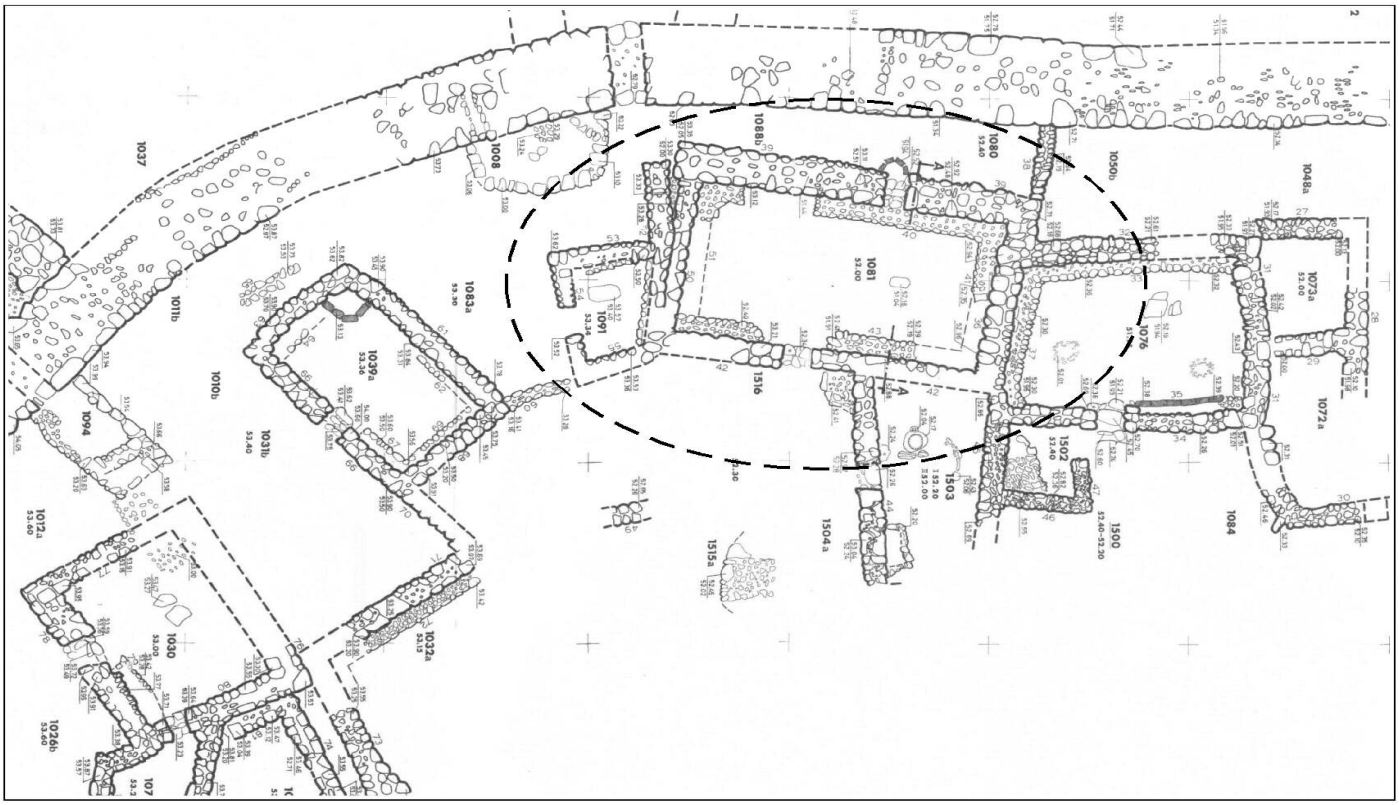
The site of Tel Arad[2] is between the Negev desert and the Judea region at the borders of the fertile valleys of Samaria in South Palestine. The site has right-angled structures and a walled enclosure. Houses have similar building schemes, those of the «Arad House»[3]: a broad-room, benches at the walls, a stone base in the centre to host the pillar for the roof, a door socket at the left side of the entrance. The structures on which the analyses have been done are in the excavation Zones H and M.

Tel Arad Zone H

A partial plan of Zone H, from Amiran 1978, is shown in fig.1. Among the quasi-rectangular structures, one in particular, House 1081 (the largest one), presents a more evident regularity and has been chosen for the analysis.

2 Excavated by Ruth Amiran (Amiran, 1978, Amiran & Ilan, 1996)
3 The «Arad Houses» have also been often found at other EB sites in the region.

Figur 1. EB Arad Zone H III: partial from Amiran 1978, Plate 178. Dashed ellipse encircles House 1081.



In fig.2 the best–fitting rectangle for House 1081 is shown superimposed to the plan of the structure. After calibrating the CAD (Computer Aided Drawing.) measuring tool by means of the 5m distance available on the plan (between two cross marks of the topographic survey), the side lengths of the best fitting rectangle have resulted of 7,700 m and 4,101 m. The sides ratio 7,700/4,101 = 1,877 equals within 0,1 % the proportion ratio of the Perfect (Pythagorean) Triad **M=8–15–17**: 15/8 = 1,875. A grid of 1 unit squares shows clear consistency of the solution with other features of the house (thicknesses of the walls, locations and widths of the apertures, depth of the bench, etc.). The length unit cf associated to the unit squares, results equal to 5/9,729 = 0,514 ± 0,003 m (see fig.2), which equals the known value of the Phoenician cubit (0,515 m). Fig. 3 shows consistency for the rest of Arad Zone H III structures.

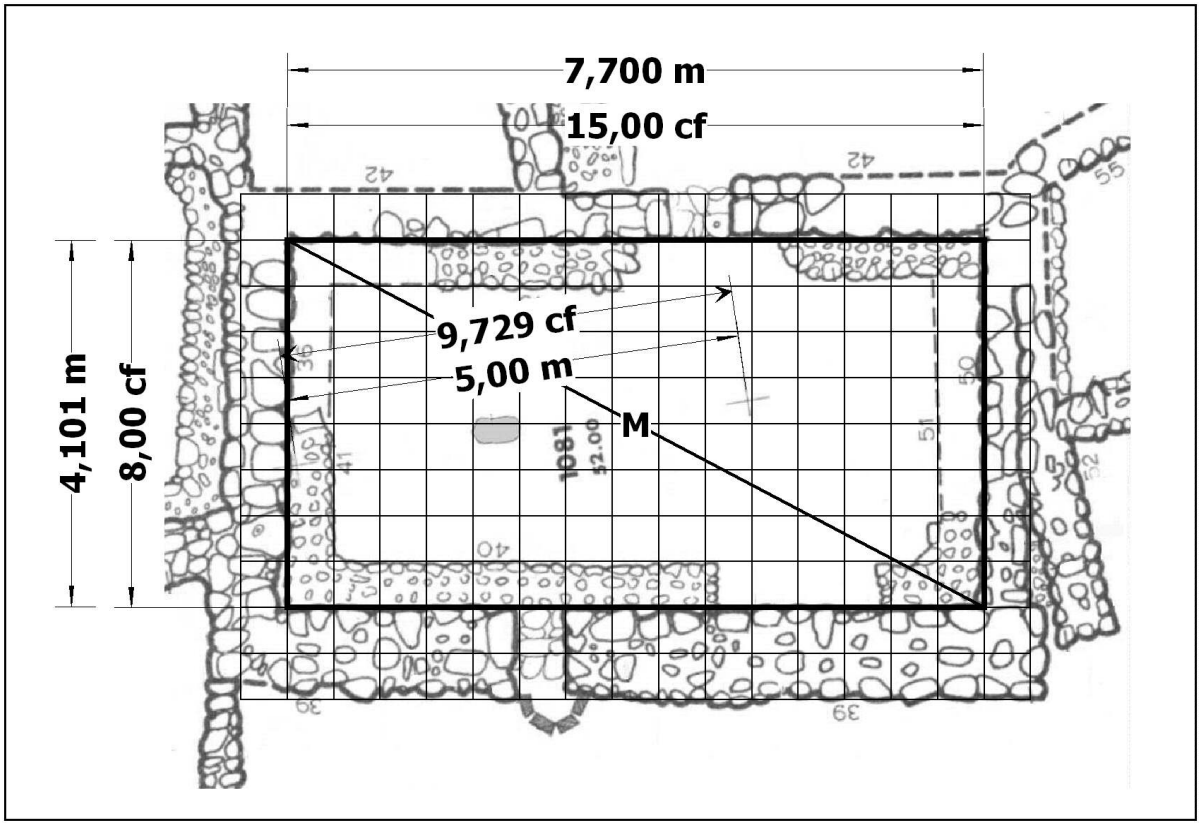


Figure 2. Arad, Zone H III, House 1081. Best–fitting rectangle sides ratio = 7,700/4,101 = 1,877 within 0,1 % = 15/8 = 1,875 , the proportion ratio of the Perfect (Pythagorean) Triad **M=8–15–17**.

Figure 3. Arad Zone H III with superimposed grids of 1 **cf** *unit squares.*

For a comprehensible description of the numerical criterions adopted by the builders we will refer to the harmonic approach proposed by Ranieri (Ranieri, 1997: 223-225). Following this approach, the basic components, the «phonemes», of the architectural language of antiquity are the orthogonal forms achievable with single «squaring» triads A–B–C of (small) integer numbers, a list of which is reported in table 1. Each combination **A–B–C** is labelled with a symbol (first column). Table 1 also shows r = **B / A**, the value of the proportion ratio (column 3). The difference **α** from the perfect right angle is shown in column 4. Perfect (Pythagorean) triples are in bold and have **α = 0° 0'**. All other triples shown are «Quasi-Perfect» with **α** small ≠ **0**.

Considering each single squaring triad **A–B–C** (or equivalently the rectangular shape that it forms with proportion ratio **B/A**) as a «phoneme» (a «letter of the alphabet») of the language, a combination of two or more phonemes will in turn correspond to a «morpheme» (a «word» or part of a word). A complex of words makes a «sentence». etc. To esemplificate, a sigle room can be regarded as a phoneme, a house as a word, a building as a sentence etc. A noticeable class of morphemes, classifiable as «harmonic» exists and are those for which the achieved overall proportion corresponds to a phonemic proportion as well. An example pertinent to our analysis is shown in fig.4. Other examples are reported in Ranieri 1997, p.225.

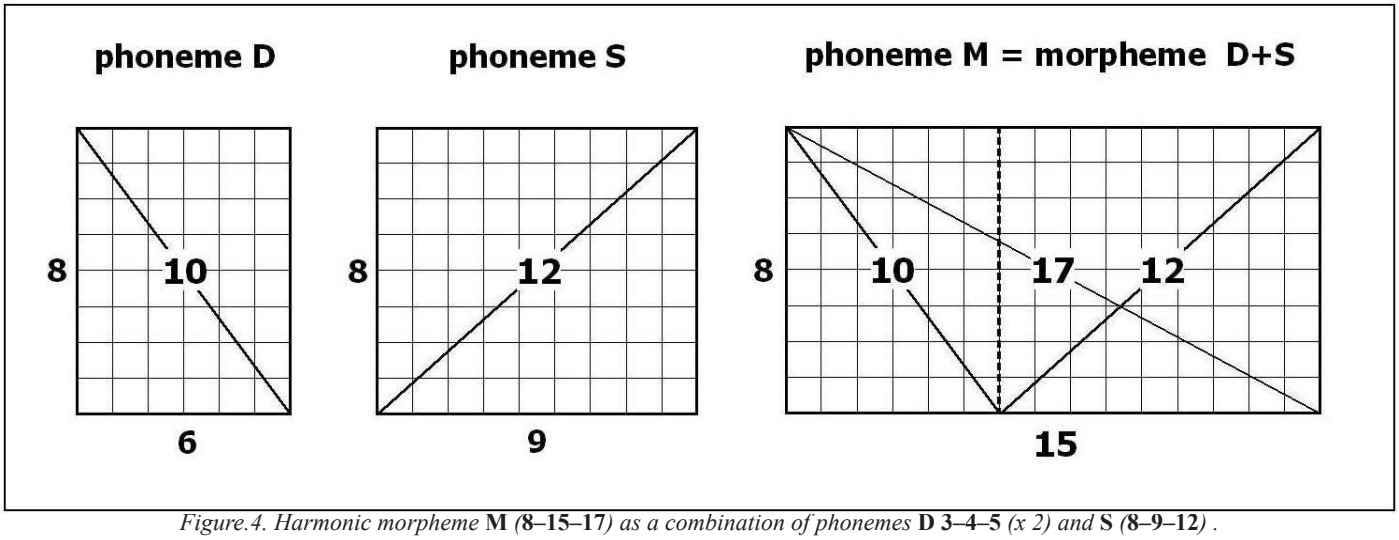


Figure.4. Harmonic morpheme **M** *(***8–15–17***) as a combination of phonemes* **D 3–4–5** *(x 2) and* **S** *(***8–9–12***) .*

Table .1. Squaring triads of small integer numbers: column 1: the triad symbol; column 2: the integers **A**, **B** *and* **C***; column 3: the proportion ratio* **B/A***; column 4: the difference from 90° achieved; Perfect (Pythagorean) are in bold and have* **α** *= 0° 0'. Quasi-Perfect have* **α** *≠ 0.*

Symbol	TRIAD (A-B-C)			r (B/A)	α (° ')	
Q	5	5	7	1.0	1	9
Q	7	7	10	1.0	1	10
Q	12	12	17	1.0	0	12
Q	17	17	24	1.0	0	12
V	**20**	**21**	**29**	**1.05**	**0**	**0**
VA	15	16	22	1.0667	0	21
VB	13	14	19	1.0769	0	38
VC1	10	11	15	1.1	1	2
VC2	18	20	27	1.1111	0	24
S	8	9	12	1.125	0	24
SA	13	15	20	1.1538	0	53
SB	19	22	29	1.1579	0	16
SC	11	13	17	1.1818	0	12
W/2	20	24	31	1.2	0	54
SD1	14	17	22	1.2143	0	7
SD2	17	21	27	1.2353	0	5
3/W	20	25	32	1.25	0	3
D	**3**	**4**	**5**	**1.3333**	**0**	**0**
LDR	19	27	33	1.4205	0	3
LD	16	23	28	1.4375	0	5
G/2	13	19	23	1.4615	0	7
L	10	15	18	1.5	0	11
LA	17	26	31	1.5294	0	16
LT	13	20	24	1.5385	0	46
π/2	7	11	13	1.5714	0	22
W/L=ΦA	10	16	19	1.6	0	54
ΦP	**28**	**25**	**53**	**1.6071**	**0**	**0**
ΦB	11	18	21	1.6364	0	35
LVC	14	23	27	1.6429	0	21

Symbol	TRIAD (A-B-C)			r (B/A)	α (° ')	
4/W	18	30	35	1.6666	0	3
GA/2	7	12	14	1.7143	1	1
2/SB	11	19	22	1.7273	0	16
√3	15	26	30	1.7333	0	4
MA	4	7	8	1.75	1	1
MB	12	22	25	1.8333	0	20
M	**8**	**15**	**17**	**1.875**	**0**	**0**
MC	12	23	26	1.9167	0	19
2Q	4	8	9	2.0	0	54
2Q	9	18	20	2.0	0	53
2Q	13	26	29	2.0	0	20
2QA	13	27	30	2.0769	0	10
2QB	9	19	21	2.1111	0	10
2VC1	5	11	12	2.2	1	2
√5	9	20	22	2.2222	0	29
WA	10	23	25	2.3	0	30
W	**5**	**12**	**13**	**2.4**	**0**	**0**
WB	10	25	27	2.5	0	28
WC	11	28	30	2.5455	0	28
Φ^2	5	13	14	2.6	0	53
√7	11	29	31	2.6364	0	5
2D	6	16	17	2.6667	0	54
√8	6	17	18	2.8333	0	17
G	**12**	**35**	**37**	**2.9166**	**0**	**0**
3Q	6	18	19	3.0	0	16
π	7	22	23	3.1429	0	45
√10	6	19	20	3.1667	0	45
2LVC	7	23	24	3.2857	0	21
GA	**7**	**24**	**25**	**3.4286**	**0**	**0**

As a matter of facts, the entrance axis of House 1081 divides the best fitting M rectangle precisely according to the morphemic arrangement shown in fig. 4, as fig. 5 (left) shows. To be noted is that the base of the pillar is located at the centre of the **S=8–9–12** rectangle: a geometric explanation for its position. A confirmation for units, numbers and use of triads for Arad Zone H comes from the simple structure (Amiran 1978, plate 176) shown in fig.5 (right) in stratum IV where a Precise Triad **D=3–4–5** is employed with a multiplier 3/2=1,5 and with the same length unit of 0,514 m.

Tell Arad Zone M

As for Zone H, among the other structures, one in particular, House 1405 in Zone M III (Amiran 1978, plate 185.), presents more regularity and have been chosen for the analysis. A very similar situation has been found: a best fitting rectangle with a proportion ratio r = 2.412 close within 0.5% to 12/5 = 2.4, that of the Precise Triad **W=5–12–13**. The solution is shown in fig.6 (left). Here the best fitting rectangle is replaced by the precise Triad **W** with sides 5 **cf** and 12 **cf**. The value of **cf** (5 /9,728 = 0,514 m ±0,003) is exactly the same found for House 1081 in Zone H III. The larger rectangle with sides 8 **cf** and 15 **cf** framing the whole structure is in turn referable to the perfect Pythagorean Triad **M=8–15–17** already found at House 1081 in Zone H III. Again is the entrance axis which divides harmonically the M rectangle in two phonemic sections **S=8–9–12** and **D=6–8–10** as shown in fig.6 (right).

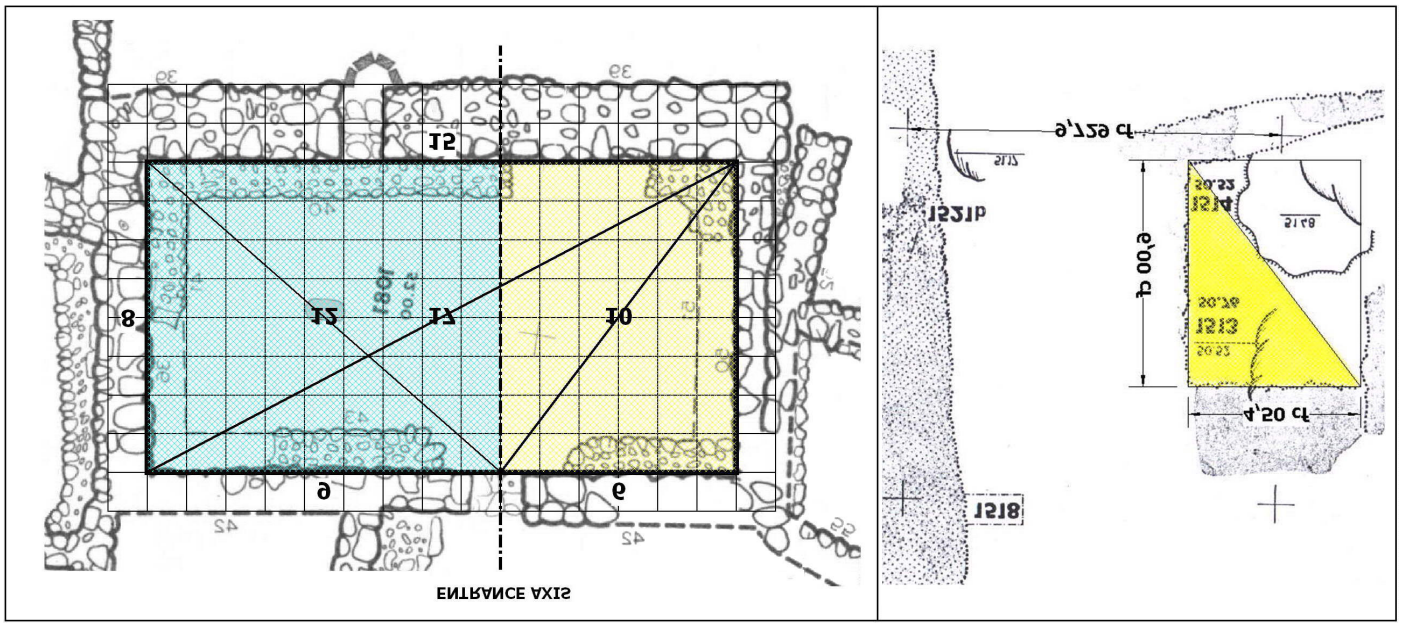
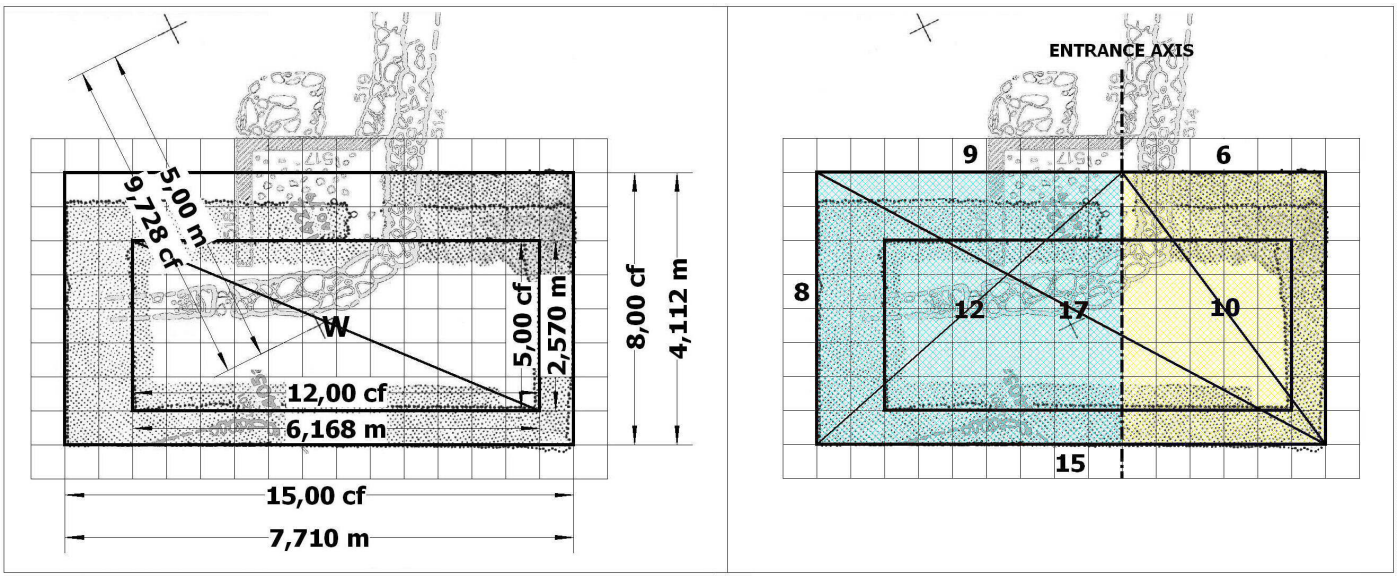


Figure 5. Tel Arad, Zone H Left: Harmonic composition **S+D = M** *for Stratum III House 1081; the base of the pillar for roof support is located at the centre of the S rectangle. Right: a simple structure in Stratum IV showing a perfect squaring with* **D=3–4–5** *(x 1,5) in cf units of 5/9,729 = 0.514 m.*

*Figure 6. Arad, Zone M III, House 1402. Left: grid of 1***cf** *unit squares superimposed to the plan of the house highlights the numerical and Pythagorean nature of the rectangular forms; the value of the* **cf** *unit is derivable from the survey cross marks as 5 /9,728 = 0,514 m. Right: the harmonic morphemic subdivision/composition* **S+D = M** *and related numbers.*



Bab edh-Dhra'

Bab edh-Dhra'[4], was built on the east side of the Dead Sea, in the South Ghor region. The site includes a walled town, an extra-mural occupation and a large Bronze Age IA necropolis.

The EB IA levels of Bab edh-Dhra' necropolis, show the funerary habit typical of semi nomadic populations : the secondary burial (Chesson 2008);[5] the necropolis was used by many clans: only in the following EB IB period it was flanked by a small village, seemingly by people practicing a seasonal agriculture along the Dead Sea shores.

In EB II, because of sedentarization of semi nomadic people, the village grows in size and soon shows public structures typical of town, such as a defensive wall and a temple on the upper part of the settlement (Schaub 2003). In the corresponding EB II levels of the necropolis, funerary habits change radically showing at 90% primary burials; tombs, that were once circular were then made rectangular in imitation of the domestic structures. This type of tomb, the «charnel house», will be the typical burial of the urbanized population of Bab edh-Dhra' for the rest of the life of the settlement. Every charnel house hosted dozens of bodies, representatives of expanded families lived in the same households for several generations (Polcaro 2005). The foundations of the charnel houses had stones set not deep in the ground; walls were made of regular lines of mud bricks. Wooden roofs can be safely hypothesized.[6]

4 The site was excavated first by P. W. Lapp and then by Walter Rast and Thomas Schaub (Schaub, 1989 and Schaub, 2002).

5 An initial burial at a low dept, the exhumation after decomposition followed by a second final burial.

6 The cemetery at Bab edh-Dhra' is one of the largest, most significant, and most extensively excavated EB cemeteries in Palestine (Polcaro, 2006)..

Charnel House A 44

Among the excavated charnel houses, the one that shows the highest regularity is Charnel House A 44 (Schaub 1989: 367-381) the plan of which (Schaub 1989, p.370) is shown in fig. 7 (left). The process of CAD analysis is identical to that described above for Arad. As for the Arad House 1081, and 1402, the main rectangle[7] corresponds to the Pythagorean **M=8–15–17** as fig. 7 (right) shows.

As fig.7 (right) also shows, the length unit that result is 1,5/2,911 = 0,515 ± 0.003 m, the very same unit found for Arad, that is the Phoenician cubit.

As found for Arad Zones H and M an identical harmonic scheme **S+D = M** exists, again considering the position of the entrance axis (fig. 8, left).

A further harmonic morphemic scheme may have been in the minds of the builders: is the one shown in fig. 8 (right) where the addition to the main **M** rectangle of two half-sized **M** rectangles composes a **3/W** morpheme of proportion ratio 5/4.

To be noted is the consistency of the direction of the diagonals of the **M** rectangles with the NS orientation.

7 We have considered as principal rectangle the one that encompasses the lines of bricks sharing the longer sides. The outer line of bricks sharing the shorter sides appears rather as a frame, less structural.

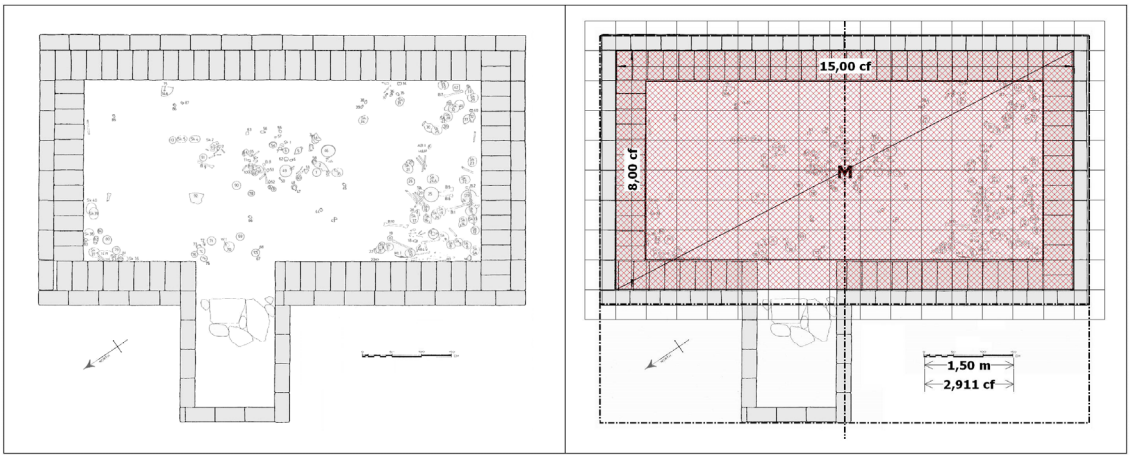
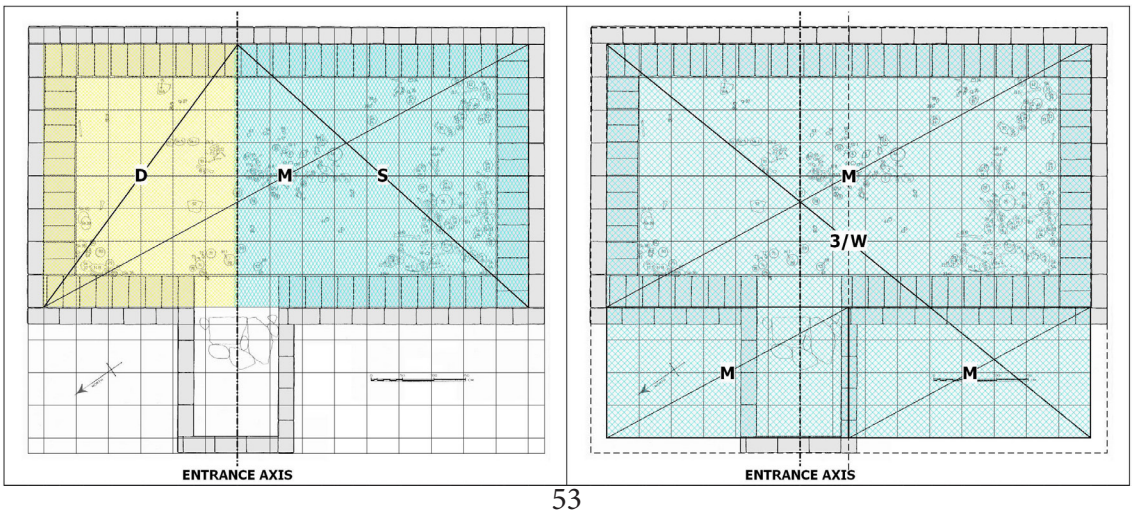


Figure 7. Bab edh-Dhra'. Charnel House A44. Left: plan from Schaub 1989. Right: best–fitting rectangle with sides ratio 7,74/4,12 = 1,878 within 0,1 % = 15/8 = 1,875; 1 **cf** *= 1,5/2,911 = 0,515 ± 0,003 m. Brick size: ≈ 1 x ½* **cf** *. Grid of 1***cf** *unit squares.*

*Figure 8. Bab edh-Dhra'. Harmonic compositions of Charnel House A44. Grid of 1***cf** *unit squares.* The unveiling of the length-unit for Bronze Age Arad and Bab edh-Dhra' has stimulated us to carry out in the future a wider search for length-units on other EB sites of the Dead Sea region.



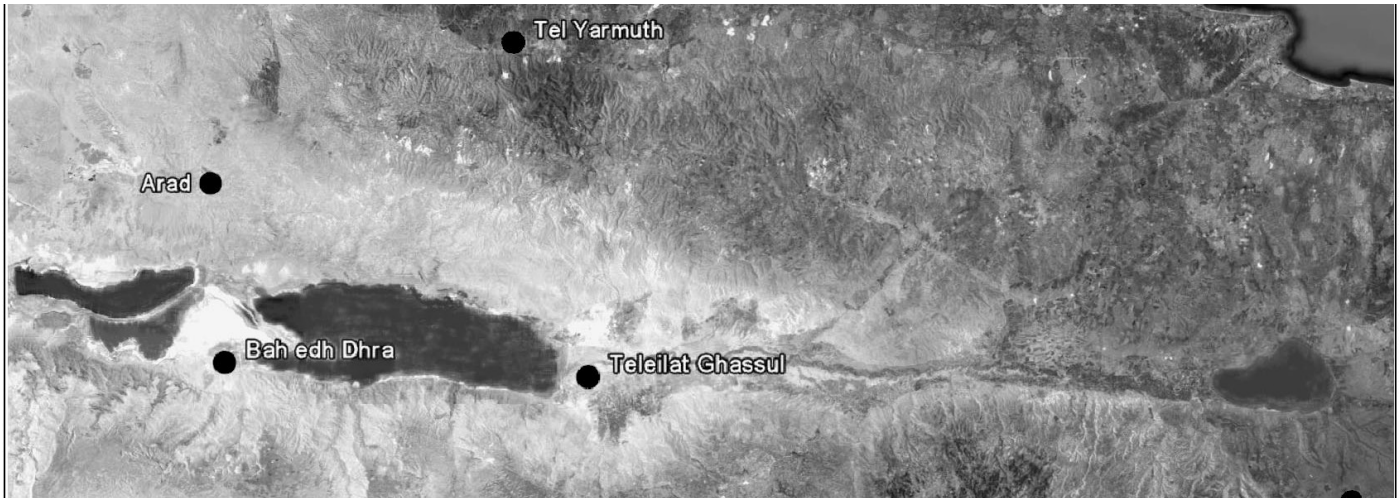
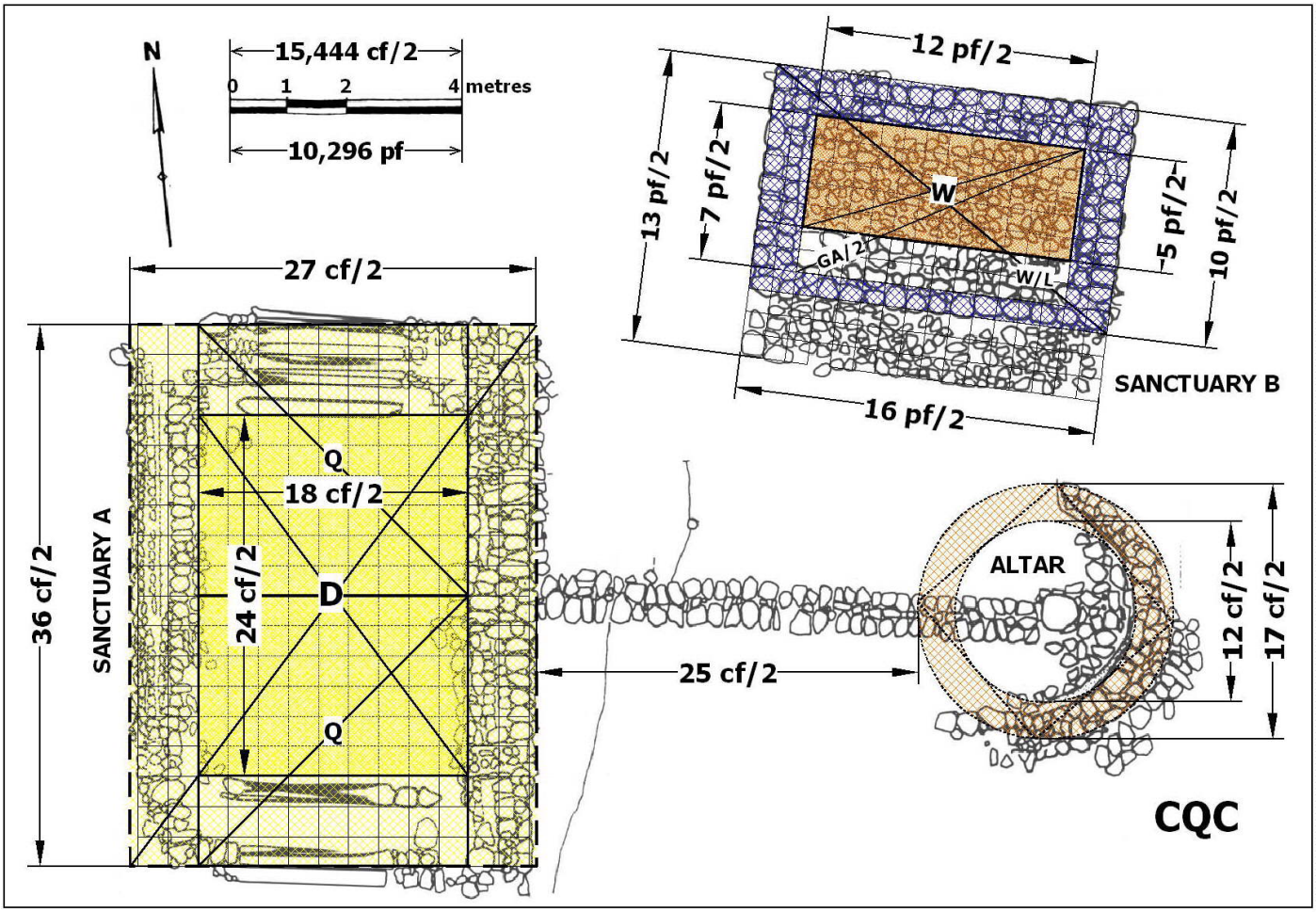


Figure 9. Geographical location of EB. sites: Arad, Bab edh-Dhra', Tel Yarmuth, Teleilat Ghassul and Rujm el Hiri.

ARAD	BAB EDH DHRA'	TELEILAT GHAS-SUL	RUJM EL HIRI	TEL YARMUTH
0,514 ± 0,003 m	0,515 ± 0,003 m	0,515 ± 0,003 m	0,515 ± 0,003 m	0,515 ± 0,003 m
Phoenician cubit	Phoenician cubit	Phoenician cubit	Phoenician cubit	Egyptian cubit

Table 2. Length units as derived from our CAD analyses.

Figure 10. Teleilat Ghassul. Sanctuary A in **cf/2** *units of 4/15,444 = 0,259 m (grid of squares are of 1* **cf***). Sanctuary B in* **pf/2** *units = 4/10,296 m (3/2)* **cf/2** *(grid of squares are of 1* **pf/2***). Altar is interpretable with a* **12-17 CQC** *geometry (internal diameter = side of square = 12 and external diameter = diagonal of the square = 17).*



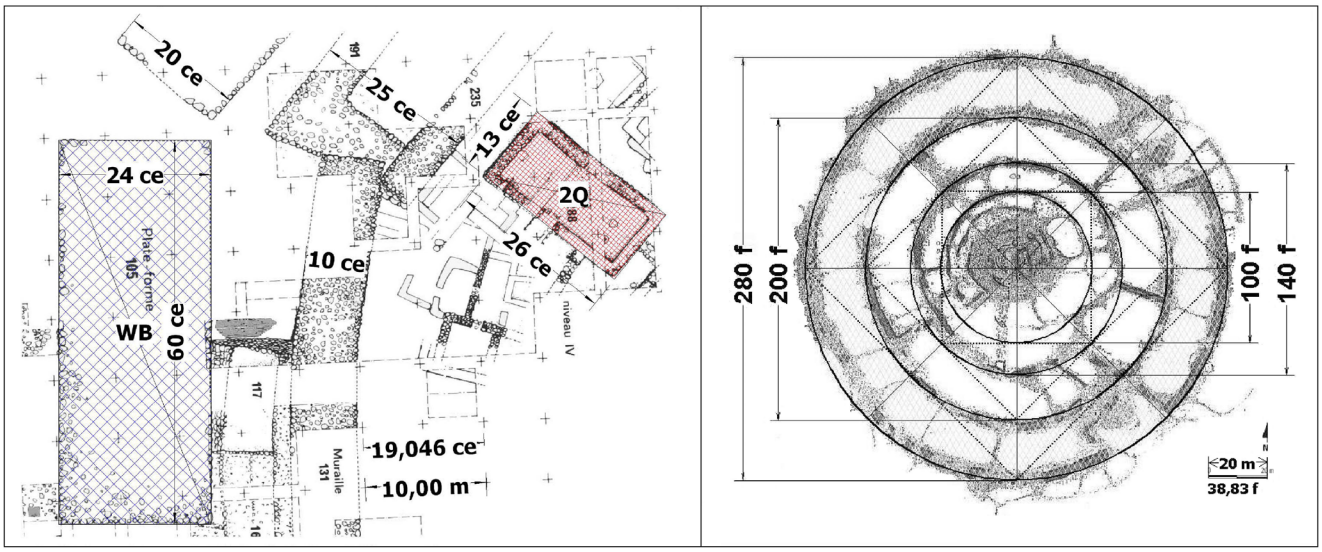


Figure 11. Left: Yarmuth, Platform 105 sized by Quasi-Perfect **WB=6-15-16***(x4) and the nearby building sized by the Quasi-Perfect* **2Q=13-26-29***; the length unit from topographical cross marks is* **ce** *=10/19,046 = 0,525. Right: Rujm el Hiri appears as a combination of concentric circles arranged as* **CQC** *with* **cf** *units of 20/38,83 = 0,515 m (from Ranieri, 2009a).*

Other Calcolithic and Bronze Age sites

We report only few results for Tel Yarmuth, Rujm el Hiri and Teleilat Ghassul. Their geographical location is shown in fig.9 (together with those of Arad and Bab edh-Dhra'). Although preliminary, they show consistency with known length-units (namely, the Phoenician cubit of 0,515 m and the Egyptian cubit of 0,525 m) as summarized in table 2.

Teleilat Ghassul (fig. 10)[8]

Sanctuary A appears rectangular as a frame combination of two **D** rectangles: the inner is a **D=18-24-30 (3-4-5 x6)** and the outer is a **D=27-36-45 (3-4-5 x 9)**; the resulting unit is **cf/2** = 4/15,444 = 0,259 m. The circular structure at the altar is compatible with a **17-12 CQC**[9] combination in **cf/2** units. Sanctuary B, as evidenced by the superimposed grid of 1 **pf/2** unit squares, has a Perfect **W=5-12-13** that suits the smallest rectangle of the interior and a **Ga/2=7-12-14** that suits the form of the whole inner part. The main external rectangle is consistent with Triad **W/L= 10-16-19**. The found **pf/2** unit of 4/10,276 = 0,389 m turns out to be 3/2 of **cf/2** found for Sanctuary A.

Tel Yarmuth (fig.11 left)

The shape of the EB platform 105 has resulted to be consistent with a rectangle of proportion 15/6, that is the proportion of the Quasi-Perfect Triad **WB=6–15–16** (x 4). The nearby rectangular structure has been found consistent with **2Q=13–26–29**. The corresponding length unit derivable from the topography cross marks is 10/19,046 = 0,525 m, the very same well known value of the Egyptian cubit.[10]

Rujm el Hiri (fig.11 right)

It is the most impressive geometrical Bronze Age site in south Levan, located in Golan region. For Rujm el-Hiri, astronomical alignments were also recently identified on the south eastern entrance of the monument (Polcaro and Polcaro, in press).Aveni and Mizrachi have pointed out that Rujm el Hiri «was planned in detail and that a specific measuring unit was employed» (Aveni, 1998, 12). They have arrived to indicate a (large) unit of 4,7 ± 0,25 m. Fig.11 (right) shows a solution proposed by Ranieri in terms of a concentric **CQC** geometry (Ranieri, 2008, 383, figure 5) which leads to a length-unit of 0,515 m.

Concluding remarks

The use of CAD techniques applied to reliable archaeological plans has already proved to be well suited for the deciphering of the interrelations existing among numbers, geometric forms and length units in ancient architectonic structures (Ranieri 1997, 2000, 2003, 2004, 2005, 2006, 2007, 2008a, 2008b, 2009a, 2009b, Malgora 2001, Labianca 2008). In the present work we have derived the geometrical, numerical and metric contents of EB structures of Tel Arad and Bab edh-Dhra'.

For both sites and with a high grade of reliability it has been possible to clearly ascertain the use of Perfect/Pythagorean and Quasi-Perfect triples of integers. The use of the squaring triads has shown to occur within harmonic schemes. In particular one same scheme (S+D = M of fig.4), theoretically predicted (Ranieri, 1997, 225, figure 6.3.), is present identical in all the three analysed structures (Tell Arad Zone H III House 1081 and Zone M III House 1405, Bab edh-Dhra' Charnel House 44) always ruled by the position of the entrance axis. One same length unit has been derived for all the three structures, moreover coinciding with the known value of the Phoenician cubit of 0,515 m, a fact which leads to hypothesize a technological continuity from Early Bronze to Iron ages.

If we refuse to believe that simple shepherds or simple peasants could posses such a sophisticated geometric/numeric knowledge we are lead to conclude that a «educated» class already was differentiated within the clan.

The unveiling of the length-unit for Bronze Age Arad and Bab edh-Dhra' has stimulated us to carry out future work with wider search for length-units of EB sites of the Dead Sea region. Preliminary results for Tel Yarmuth, Rujm el Hiri and Teleilat Ghassul indicates the use of the Egyptian cubit of 0,525 m at Tel Yarmuth and that of the Phoenician cubit of 0,515 m at Rujm el Hiri and Teleilat Ghassul.

The results, aside with their archaeological importance, indicate the high efficaciousness of the employed research methodology.

8 Teleilat al-Ghassul is the most important site of the Late Calcolithic Period (IV mill. B.C.E.), excavated first by Pontifical Biblical Institute in 1929, by the University of Sidney in 1975-1977 and in recent times by Stephen Bourke (Bourke 2000: 107-110). The site presents an impressive sacred area, with a temenos, two temples (A and B), and an open circular altar with a paved road (Bourke 2000: 120-123). Recently it was proposed that the alignments of the temples have astronomical reasons connected with a solar cult (Polcaro and Polcaro, in this volume).

9 CQC (Circle-Square-Circle) are annular combinations of circles and square where one perfect square circumscribes the inner circle and in turn is inscribed in the outer one. For a study of CQC geometries in ancient architectonic structures see Ranieri, 2007 and Ranieri, 2008.

10 This result is confirmed by the historical and archaeological data from Tel Yarmuth, an Early Bronze Age city with a huge royal palace (Palace B), constructed in EB IIIB (2450-2300 BC), that testify a centralized economy, based also on the commercial exchanges with Egypt (De Miroschedji 2000).

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Asia

A new archæo-astronomical research in Arkaim: analysing cultural references

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Abstract: In the South Urals monuments of the Bronze Age were studied, with similar features. Round on the plan, they repeat the outlines of circumpolar constellations, revolving around the ancient celestial pole Alpha Draconis, the relevant Bronze Age. Astronomical characteristics on the plans of monuments identified by conventional astronomers celestial coordinates: Equator, Ecliptic, Galactic.

Keywords: Celestial Pole, the celestial coordinates - Horizontal, Equatorial, Ecliptic, Galactic

In the southern Urals, the first archæo-astronomical research works were carried out in Arkaim reserved area incorporating two archæological monuments with a circular layout. One of the monuments is the site of Arkaim ancient settlement (52.65º N 59.55º E), which is dated to XIX-XVI centuries BCE, according to the official archæological data (Kirillov and Zdanovich, 1996: 69-71), while unofficial archæologists date it to XXVIII century BCE (Bystrushkin, 2003: 3-27). The other monument is Bolshekaragansky sepulchre located 1.2 km to the northeast of Arkaim settlement. It constitutes Arkaim necropolis dated to approximately XX century BCE (Zdanovich, 1995: 43-53; Zdanovich & Kirillov, 2003: 11-24). Both monuments are likely to belong to the same culture; however they differ in the method of interpreting the celestial maps on the earth surface.

As a result of our supplementary archæo-astronomical research carried out in 2006, a new original viewpoint on the conception of Arkaim monuments was put forward. We believe the conception of these monuments to be connected to ancient people's world perception and their dividing the sky into realistic and idealistic mythological structures, which are scientifically interpreted in terms of the basic astronomical coordinate systems (Emchenko and Polyakova, 2009: 475-80).

However these monuments need further research and analysis. Our new archæo-astronomical research in Arkaim aims at revealing and analysing new cultural and conceptual references in context of interpreting Arkaim monuments.

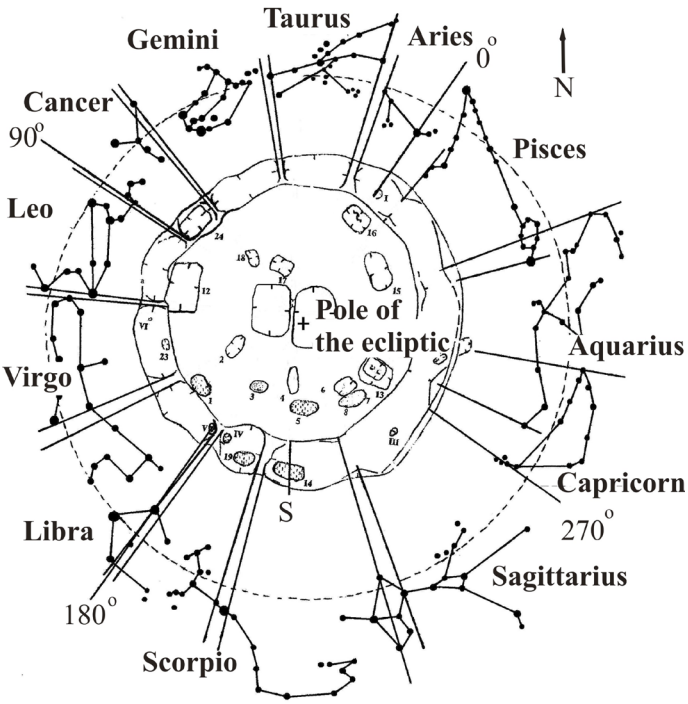
1. Bolshekaragansky sepulchre represents a circle made of twelve pits, which can be interpreted in the ecliptic coordinates. The pits differ in size, and their extension and order correlate to those of the Western ecliptic constellations (Fig. 1).

All the twelve ecliptic constellations cannot be observed simultaneously above the skyline: only a half of them is fixed above the southern sector of the skyline. Therefore the coordinates of these constellations could have been fixed via two stages. One half of the constellations (Cancer-Sagittarius) could have been observed at vernal equinoctial midnight from the biggest central pit. The other half (Pisces-Leo) could have been observed at midnight along the northern arch of the pit through a little pole put in the middle of the central pit.

The stars of Capricorn and Aquarius could not have been observed, thus they could have been fixed by convention, what is proved by the fact that the sepulchre reflects no distinct boundaries of these constellations. Moreover, the near stars of these constellations could have been observed in this location in VI millennium BCE. This age does not correlate to the date of the monument in question. On the other hand, the constellation of Pegasus, which can be easily observed in this area, can be projected on Capricorn and Aquarius. Another observation method was possible during the winter solstice under appropriate weather conditions. In the southern sector of the sky, one could have observed one half of the constellations (Pisces-Leo) after the sunset and the other half (Cancer-Sagittarius) before the sunrise.

The sepulchre might have been used for both burials and other religious ceremonies, such as birth of descendants and defence of ascendants. Archæo-astronomical objects often join their usual functions with the observation of the celestial bodies in the ecliptic coordinates. This arises from the fact that the astronomical phenomena are understandable and can be observed on the ecliptic. For ancient people, such events as the diurnal cycle (day-dark), stellar ascents and descents, including those of the ecliptic constellations, might have reminded of the phenomena characterising the real World. The duality of the real World might have seemed inescapable to them in all aspects of life, particularly in context of crossing the line of life and death. Therefore such ritual monuments usually bear traces of the

Fig. 1. Bolshekaragansky sepulchre map (Arkaim) after Zdanovich, (1995: 44) overlaid with the celestial map of the ecliptic constellations of the Western Zodiac



worship to the Earth gods responsible for fertility of women and soil, prosperity, health, death, etc. If people might have used such monuments as astronomical observatories they could have watched the sets and rises of the Sun, the Moon and, probably, observable planets (Saturn, Jupiter, Mars, Venus) from these observation points.

2. Arkaim settlement is of the same circular layout as Bolshekaragansky sepulchre, but should be differently interpreted. It consists of two circles of constructions, where some of the elements are repeated. This repetition refers to observing the rotation of some astronomical objects round the celestial pole in the equatorial coordinates. For the northern hemisphere, the celestial pole is observed in the viewing direction of the north, meanwhile the stars and planets are observed in the viewing direction of the south, as in the case of the previous monument. The rotation of non-setting circumpolar constellations round the stable celestial pole might have made ancient people think of a non-setting Higher Heaven or some kind of an eternal, impeccable and ideal World. Arkaim settlement might have been built at first for the upper class of solar pagan priests called metallurgists, who worshipped to the Higher Heaven gods. Metallurgical furnaces present in each house and a lack of domestic artefacts confirm this hypothesis. The internal circle of constructions coincides with the rotation of the «dipper» of Ursa Minor round the celestial pole, while the external one coincides with the rotation of Ursa Major's «dipper» (Fig. 2). The figure depicts a restored hypothetical view of Arkaim settlement.

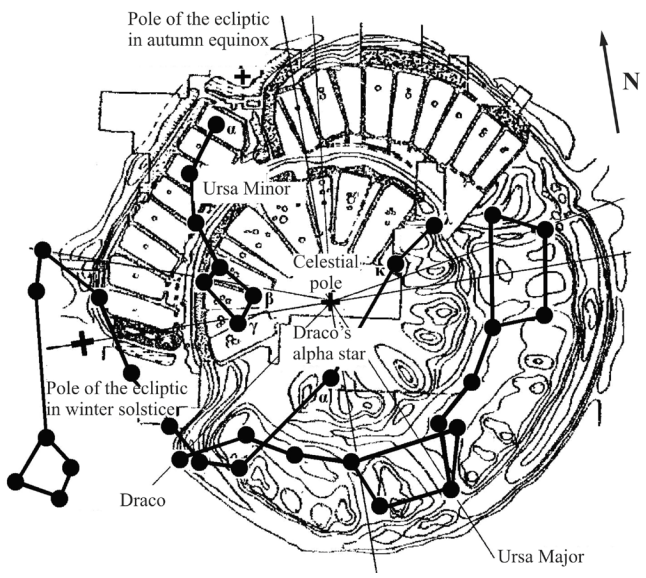


Figure 2. Arkaim settlement map (Zdanovich, 1995: 32) overlaid with the equatorial circumpolar constellation map

On the map of Arkaim settlement, other astronomical coordinates can also be traced. They could have been observed outside the settlement, namely in front of the main western entrance. From that observation point, the skyline was exposed to view without any obstacles such as the settlement walls. Thus, from that observation point exposing the south-western sector of the sky, the sunsets and moonsets could have been observed in the horizontal ecliptic coordinates. A big open space in front of the western entrance might have been used for celebrations and praying to the Earth gods of fertility and prosperity all the year round.

The horizontal galactic coordinates could have been observed from the same observation point, more exactly from three windows in the northern wall of the western entrance, which gave the view of the southern sector of the sky. In this sector, it is possible to observe the winter ascents of extreme southern stars, which cannot be observed in other seasons. In XXI century BCE when Arkaim settlement appeared, three upper stars of Crux rising at the end of autumn could have been observed in Arkaim and in other monuments located at the same latitude (approximately 52º N) (Fig. 3).

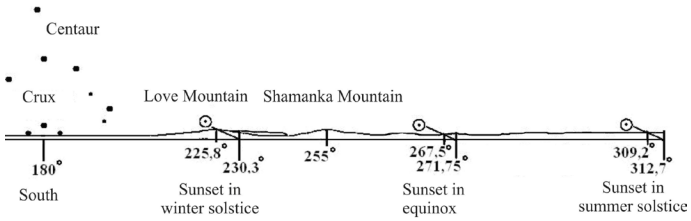


Figure 3. Three upper stars of Crux observed in the southern sector of the sky approximately 52º N in XXII century BCE

At the time of the end of Arkaim settlement (XVI century BCE), only one upper star of Crux was rising there. Later than XV century BCE, the stars of Crux were no more rising at Arkaim latitude.

Situated on the Galactic equator, Crux is projected on the Milky Way. Thus, when Crux rises in the south, the Milky Way lies along the entire skyline and even goes up a little in the south, as if showing the nether World. A well-known autumn holiday celebrated the 30th October may be traditionally connected to the rise of Crux at the ancient times, although the cause of the holiday is likely to be forgotten.
We may come across the mythological descriptions of these astronomical phenomena. For example, in Hellenic myths about Orpheus and Hercules, the entrance to the nether World (Hades) was in the south, guarded by a tricephalous hound called Cerberus. In order to get to the nether World, Orpheus had to cross the Styx River where the centaur Chiron was the ferryman (Kun, 1955: 200-01; Bauer, Dyumots, and Golovin, 1995: 169-70). As the ferryman was a centaur, the constellation rising above Crux is called Centaur. Its lower stars touch the Milky Way stars. The Styx River is likely to have been associated with the Milky Way. These Hellenic cultural references seem more important, taking into account the discovery of an Arkaim artefact referred to the Aegean civilisation of the Mediterranean (Kirillov and Zdanovich, 1996: 71).

3. Searching for other cultural references to the described phenomena, it is important to focus on the rotation of the circumpolar constellations. In Terekty-Auliye settlement (48.66º N 85.87º E) located in Central Kazakhstan, a stone slab (Fig. 4) was discovered where Ursa Major and the celestial pole are depicted as a Horse with a cross over his back (Sagyndyk, 2005: 29-32; Polyakova, 2007: 125-28).

The picture of the Horse represents the style of Seym-Turbino culture, which appeared in XV-XIV centuries BCE in the northern woods of Eastern Europe and Western Siberia. There are few sites representing this culture. Three of them, namely, Seym (51.36º N 37.04º E), Turbino (55.61º N 35º E) and Reshnoye (55.41º N 42.13º E), are located in Eastern Europe; yet another site, Rostovka (55.8º N 74.37º E), is located in Western Siberia. However, some hardware representing this culture happen to be discovered all along Eurasia, from Mongolia to Finland and Moldova. The predecessor of Seym-Turbino culture is believed to be Sintashta culture with its centre in Sintashta settlement, where, as in the case of Arkaim, circular layouts and sepulchres were discovered along the Sintasty River (52.49º N 60.17º E), 30 km away from Arkaim.

If we overlay Ursa Major's stellar map with the picture of the Horse, we can analyse the rotation of this constellation on the map of Arkaim settlement. This analysis makes comprehensive the quo-

tation about Vara taken from the Zoroastrian myth of Yima (strophe 25, Fargard 2 of Vendidad): «Therefore make thee a Vara, long as a riding-ground on every side of the square» (Boyce, 1984: 96). When the myth of Yima and Vara appeared, the mathematical concept of the circle radius had not been invented yet, thus ancient people used a figurative graphic description instead of a mathematical function.

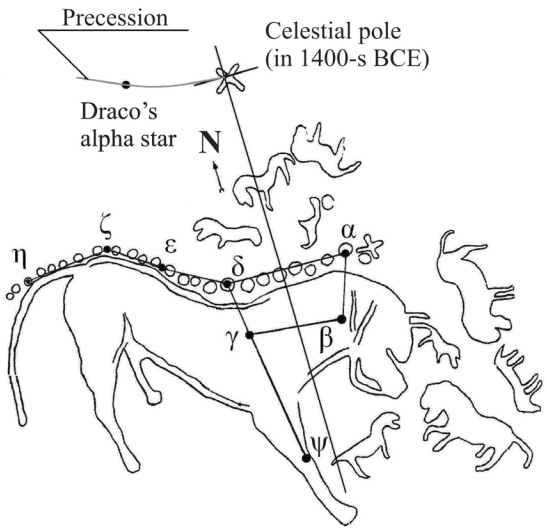


Figure 4. A picture of a Horse with a cross discovered in Terekty-Auliye (Sagyndyk, 2005: 31) overlaid with the stellar map of Ursa Major in 1400-s BCE.

The Avestan scripts can provide a ground for some astronomical suppositions. The researchers of Avesta share the opinion that the image of Yima who was a solar god, ruler of the underground, king of the Golden Age, builder of many cities, etc., arises from the Indo-European tradition and reflects the images of the solar twins Yima and Yimak in the Iranian mythology, Yama and Yami in the Indian mythology, Imir in the Scandinavian mythology, etc. When these myths appeared (III millennium BCE), Draco's alpha star was the pole star. It constituted the rotation centre of the stellar sky and defined the diurnal solar rotation round the Earth, according to the geocentric world model interpretation. Thus, the god of the pole star (Draco's alpha star) might have been considered as a solar god. Next to Draco's alpha star, it is possible to discern another Draco's star, CU Draconis, which might have become a twin symbol of the pole star. However, with time, Draco's alpha star began to move away from the celestial pole. Meanwhile, it stayed close to the celestial pole for about ten centuries and its coordinates allowed to precise the position of the celestial pole. Later, when Draco's alpha star moved far away from the celestial pole, other circumpolar Draco and Ursa Minor's stars were observed to determine the location of the celestial pole. According to the Chinese chronicles, two Draco's stars (κ and λ), both with two Ursa Minor's bright stars (β and γ) were used to detect the location of the celestial pole in II millennium BCE (Kaurov, 1997: 15).

4. Another relevant cultural reference is a petroglyph in Ak-Baur grotto in Western Altai. It is dated to approximately the late II millennium BCE. In the northern part of the petroglyph, which is marked with the squares symbolising the pole of the ecliptic and the celestial pole, there are two people depicted near the projections of Draco's alpha star and its twin CU Draconis. The fact that one of the people depicted has a phallus leads to the interpretation of these two figures as divine symbols of a man and a woman, which were attributed to the abovementioned stars at the time of their location near the celestial pole in III millennium BCE (Fig. 5).

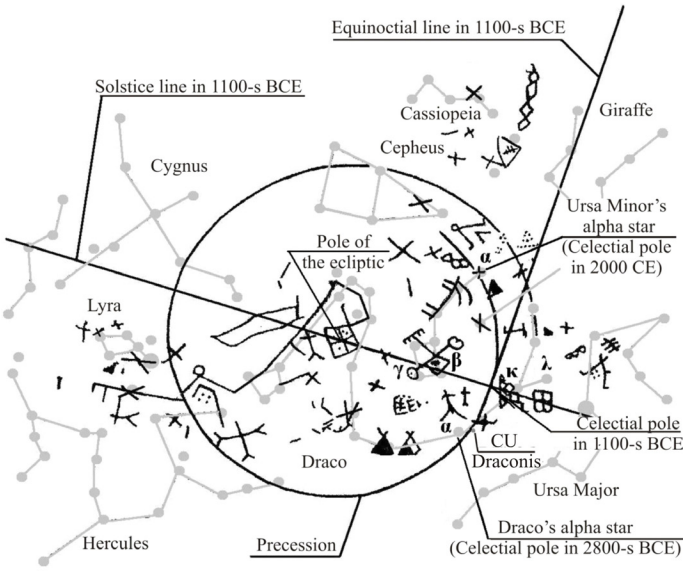
When this petroglyph might have been made in Ak-Baur grotto, Draco's alpha star had already been far from the celestial pole, but the people, who made this petroglyph in the late II millennium BCE, still recalled the names of ancient gods. The petroglyph shows ancient people's ability to detect the location of the celestial pole without observing it directly. For this, they observed the stars of Ursa Major, Draco's «tail» and Ursa Minor's «dipper». Moreover, they depicted the Little Dipper as a chariot. This symbol also occurs in the ancient astronomical scripts written on clay plates found in Mesopotamia, according to which the «celestial chariot» must be located in Ursa Minor (Kurtik, 2007: 301-303).

This can be applied to the case of Arkaim settlement founded in the late III millennium BCE. In the settlement centre, which constitutes the celestial pole, there are no objects, as at that time Draco's alpha star was no more the pole star. However, its rotation is projected near the settlement centre upon the radial wall of the internal circle of constructions. There are some traces of reconstructions, as the rotation radius of the star increased. The invisible celestial pole might have been found by means of Draco's alpha star, the stars of Draco's «tail» (κ and λ) and Ursa Minor's «dipper» (β and γ).

That was the time when Yima did no more fit his divine nature. What was the fault of this symbol of the solar god? Yima's fall is described in strophe 19.34 of «Yasht», one of the hymns of the Avesta. According to strophes 19.33-38 of «Yasht», Yima «brought the lying untrue word into his mind», so he lost «Khvarenah», his divine grace and glory (Boyce, 1984: 30). In strophe 32.8 of the Avestan book «Yasna», Zarathushtra reproaches Yima with giving people flesh of the ox to eat, what symbolised the end of the Golden Age. In strophe 19 of «Yasht» and strophe 3 of Fargard 2 of «Vendidad», Yima refuses to be a preacher or a bearer of Zoroastrianism, but is ready to nourish, rule and watch over the world to make it increase and thrive. Gradually, Zoroastrian religious conception works out and canonises an ambiguous interpretation of Yima's personality. On the one hand, Yima keeps all his positive features; on the other hand, he is blamed with some sins.

In this case, the archæo-astronomical interpretation can be the following: being far from the celestial pole, Draco's alpha star was no more considered as the celestial rotation centre and could

Figure 5. Northern part of the petroglyph in Ak-Baur grotto (Marsadolov and Samashev, 2000: fig. 4) overlaid with the equatorial stellar projections of the circumpolar constellations, the precession, and the equinoctial and solstice lines appropriate to approximately 1100-s BCE



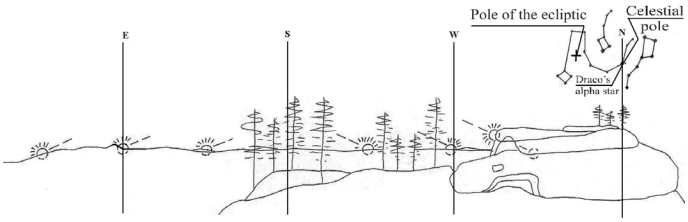
not be perceived as a solar god. Therefore Yima's Golden Age, which lasted for a thousand years while Draco's alpha was the pole star, came to an end. Yima was no more the preacher of the true religion close to the ideal divine grace and glory, which corresponded to the celestial diurnal rotation centre. Thus, Yima lost «Khvarenah» and «brought the lying and untrue word into his mind». Besides, at the beginning and the middle of the Bronze Age (from approximately 4450-s to 2300-s BCE), the vernal equinox was in Taurus, so people's prosperity depended on sacrificing and eating cattle. Soon after 2300-s BCE, when the vernal equinox was in Aries, the symbols of prosperity changed, and eating cattle was considered to be a sin.

The similar shift of existing symbols is described in the Old Testament, when Moses tells the Israelis to reject the golden calf, as it was an alien religious idol, an ancient symbol of the Egyptian Pharaohs. Yet Moses' teaching might have arisen from the fact that the symbol of Taurus as a zodiacal equinoctial sign was old-fashioned at the time the Israelis left Egypt (Bible, 2004: Deuteronomy, 9:16). In the Old Testament, there is also Abraham's appeal to the pole star while he was setting altars in oak woods and on the mountain where the Lord visited him (Bible, 2004: Genesis, 12: 6-8; 13: 18), and his grandson Jacob (Israel) was setting stones to make sacrifices (Bible, 2004: Genesis, 28: 18-22; 31: 45-54; 35: 1-15). However, some time later, new laws were made up, which forbade any worship to ancient idols, cult figures, statues, poles, and stones with images on high mountains and hills, under any branchy tree, «and you shall destroy their name out of that place» (Bible, 2004: Leviticus, 26:1; Deuteronomy, 12:2-3). The Lord (Jehovah) was no more considered in context of ancient celestial symbols, so a possible reason for this paradigm shift might have been the invisible celestial pole, and the Lord's name has been secret ever since.

Ursa Major and Minor are still rotating near the celestial pole and stay the symbols of the celestial solar Horses in the cultural heritage of some ethnic groups. According to the Kazakh fairy-tales, two celestial Horses are tied to the world pole. Bashkir astral myths call these horses Akbuzat and Kharat. These horses soared up to the sky, where they still live as two Ursa Minor's stars.

5. Some similar pole attributes were discovered in Golukha Mountain in September 2009 by a research group of Chelyabinsk Aircraft Institute headed by A.I. Matsyna, O.O. Polyakova and N.I. Chuyev, with students A. Kas'yanov, D. Berdnikov, D. Zverev. Golukha Mountain is one of the splendid peaks in the Chashkovsky Ridge in the southern Urals (54.91º N 60.10º E). These mountains give an entire view of the skyline and the sky (Fig. 6a, 6b).

Figure 6a. The skyline observed from Golukha Mountain peak in the Chashkovsky Ridge, the southern Urals, in 2800 BCE.



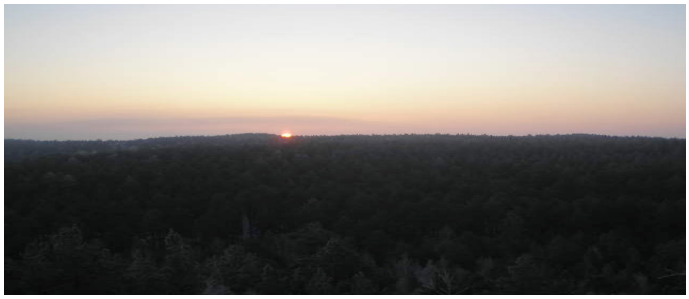


Figure 6b. The sunrise in the vernal equinox, 21st March 2010, from Golukha Mountain peak

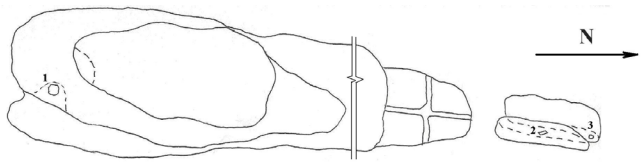


Figure 7. Golukha Mountain plan view 1 - the opening in the horizontal surface of the stone, 2 - horse lower teeth, 3 - a ceramic sliver.

To the east of the peak, a big opening was discovered on the horizontal surface of a stone. This opening is as big as a human head and might have been used for astronomical observations. In the northern part of the steep peak (in the viewing direction of the celestial pole), in a rather low and long fuliginous niche, researchers discovered lower teeth of a horse and a ceramic sliver (Fig. 7).

The two artefacts are directly connected to the pole symbols. Many traditions connect the celestial pole and the pole star to the concept of a pole, in Russian «kol». V. I. Dahl's interpretation of this concept can clear up the astrological context of the artefacts discovered: «Kol (a pole) is a horse laniary tooth, according to Russian horse doctors; a horse lower tooth located between front-teeth… the pole, the pole star… a sliver, a piece… Ursa Major and Minor are two northern constellations; the former is also perceived as a horse tied to a pole… this constellation includes the pole star…» (Dahl, 2009: 455). «Ursa Major and Minor look like a horse walking on a leash round the pole, which is the pole star» (Dahl, 2005: 181). The picture accompanying the last quotation depicts Ursa Major as a horse tied to Ursa Minor's alpha star.

The etymology of the English word «horse» also seems relevant. This word has the same transcription as the ancient Russian name of the Slavic god of the Sun. According to the Slavic myths, the god named Hors has rest in the isle of the Happiness till the morning and later, in his solar chariot, brings the Sun to the sky. Hors was thought to be the ruler of lightning and was usually described as a fair-haired horseman crossing the sky in his chariot or on horseback. The Sun-cult might have arisen in the Eneolithic period, and in the Bronze Age the Sun was associated with the horseman, who glides at the sky since dawn till dark and turns back by the Dark Sea at night. The name «Hors» comes from the ancient Russian root «hor» (in English «chorus»), which means «circle» and refers the god's name to the Sun.

The niche in Golukha Mountain peak may be of an artificial origin. The upper stone might have been moved and put close to the lower stone to make a long and narrow niche providing air draught for the metallurgical works. The first metallurgical furnaces are known to have been built in high places where tem-

perature drops were heavier. At the foot of Golukha Mountain, several artefacts were discovered, which are dated to various ages, beginning from the Stone or Bronze Age (microlites) to the Middle Ages (ceramics).

6. The hypothesis of astronomical observations carried out on Golukha Mountain may be proved by the discovery of identical openings on some mountain peaks in the southern Urals and Kazakhstan. For example, identical opening the author saw on the peak of a mountain situated between two villages, Pavlovka and Kinetkel, in Zerendino area of Kokchetav region, Kazakhstan (53º N 69º E). In 1983, at the foot of this mountain, by a research group of Chelyabinsk State University headed by T.S. Malyutina, archæologists discovered Chaglinka II, a Bronze Age site, with some artefacts dated to Andronovo culture, which is supposed to succeed Sintashta culture.

All mentioned archæological monuments are interconnected by cultural links taking roots in cosmological conceptions of the world perception. These conceptions are characterised by similar features, such as worshipping to the natural elements and realistic gods in the viewing direction of the south and worshipping to the supreme gods in the viewing direction of the north, in the case of the northern hemisphere of the Earth. In the Urals, Kazakhstan and Eastern Europe, a cult of a horse and metallurgical works were attributes of the worship to the supreme gods.

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Mudumal: An Ancient Astronomical Observatory from South India

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Abstract: The astronomical knowledge of the Indians goes in to the hoary past. Mudumal, a megalithic site in south India appears to be an ancient Astronomical observatory. A study of the complex on the days of solar significance like the days of summer and winter solstice revealed that one particular row aligns with the Sun in the morning and another row in the evening. On one of the stone, a depiction of Ursa Mjor constellation was noticed. The site reveals that astronomical knowledge of the ancient megalithic community from south India, going back to some 3000 years.

Keywords: Astronomy, Megalithic, Mudumal, Menhirs, Alignments, Solstice, Cup-marks, Ursa Major, Constellation.

The astronomical knowledge of the Indians goes in to the hoary past. The Vedic literature has special chapters on astronomy. Ancient Indian astronomers like Brahmagupta, Varahamihira, Aryabhata etc. have produced remarkable treatises on astronomy and mathematics. The Vedic and Hindu rituals are based on the observation of the movements of the Sun and Moon. The ancient Indian seers have developed their own system of calendar known as 'panchanga' which is used for calculating auspicious and inauspicious times. The Hindus worship the nine planets as Navagrahas. The Indian Astrology known as jyotisha sastra is completely based on the observations of the constellations. Thus, astronomy is deeply rooted in the Indian culture. The astronomical knowledge of the Indians can be traced back to prehistoric period.

In prehistoric paintings and bruisings we come across depiction of celestial objects. For example on one stone slab with an engraving of a hunting scene found at Burzahom (IAR 1964-65: 13), a depiction, probably, of Supernova was detected. The depiction is found in Neolithic context, dated on carbon-14 technique to about 2300 BCE. (Agarwal and Kusumagar, 1965: 42-43).

Megalithic Monuments in India

India has numerous megalithic sites. The concentration of these sites is more in South India, in comparison to North India, where their presence is very meager. Many types of megalithic monuments like the alignments, avenues, menhirs, dolmens, dolmenoid cists, cists, stone circles, cairn circles, etc. are found in India. Usually, these monuments are associated with either the burials or the funerary rites. Most of the burials contain skeletal remains of several individuals, and thus they are communal burials rather than individual burials. The skeletal remains are always accompanied by funerary assemblage like pottery, iron tools and weapons, ornaments and other miscellaneous material. The megalithic monuments in India are more affiliated to the Iron Age, as it is evident that iron came into wide spread use during this period. The available evidence suggests that the megalithic culture in India can be dated anywhere between 2500 to 300 BC in general. Some of the dates of the megalithic sites based on scientific analysis are listed here: Gachibowli 1995-2505 BCE OSL Dating (Thomas *et. al.* 2008:786), Komaranahalli 1440 BCE Thermoluminiscence (RAO, 1990:319), Naikund 545-505 BCE C-14 (Deo and Jamkhedkar, 1982:7), and Takalghat 555 BCE C-14 (Deo, 1970:13).

Mudumal Monuments

Mudumal (16°22.751N 77°24.691E) is a small village located in the Mahbubnagar district of Andhra Pradesh state in south India. The site is located in an oxbow formation of river Krishna, which is about 1 Km. from the site on the south. The site is located in an undulating terrain, mostly covered my red soil with occasional outcrop of basal granites here and there. The monuments here are spread in an area roughly measuring 1 Km. E-W and 500 Mt. N-S. But, originally, the site must have covered still larger area, as most of the land has now been converted into agricultural land and some of the remnants of the monuments removed. Thus, we can say that, even at the existing state, the monuments cover an area roughly 50 hectares of land, and thus probably, one of the biggest megalithic complexes from India.

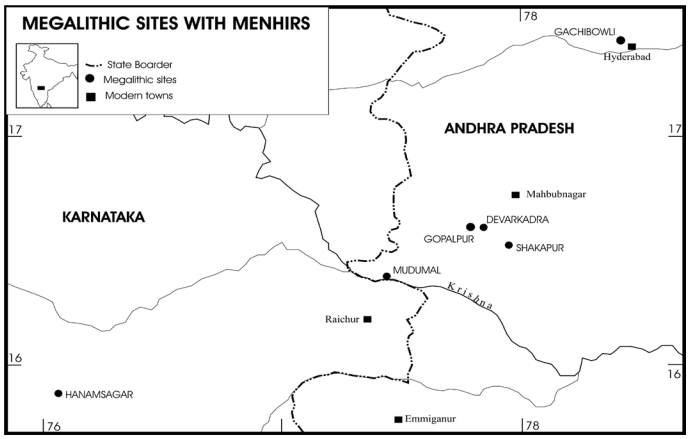

Figure 1. Menhirs at Mudumal.

Typologically, we have menhirs and stone circles in this site. But, the number of stone circles is about 30, as exact estimate is not possible due to the destruction, some of them suffered. Estimation of exact number of menhirs is also difficult, as they

are spread in a very large area, and in a haphazard manner. The menhirs can be divided into two types, the ones which are tall (between 3 - 4 ½ Mt.) and the ones which are smaller ranging from about 50 – 1 Mt. from the ground. The taller menhirs are concentrated in an area about the middle of the site. A total of about 80 menhirs could be noticed in this are, though nearly half of them have either fallen on leaned to sides. All the tall menhirs are of granite, while few of the smaller menhirs are of black dyke rock. The raw material is easily obtainable from the near-by hills. Some of the black stones have a very smooth surface, suggesting water action. A visit to the river suggests that such black dykes are present in its channel and many of the stone are smoothened by water erosion. Most of the stone have a diameter of about 75 cm. to 1.5 mt., but larger dimensions can be seen on some of the flatter stones. No stones bear any cut marks.

Most of the alignments and avenues formed using the taller menhirs are concentrated in an area somewhat in the middle of the site, and they cover about 2 ½ hectares of land. Both the taller menhirs and the smaller menhirs are arranged in various patterns, and deciding any formation of this arrangement is difficult. But it is possible to identify many alignments and avenues among these patterns. Some of the alignments are arranged exclusively with black stones. Observation of these alignments over a period of time revealed that some of these alignments coincide with the direction of the rising and setting Sun, especially on the days of solar significance, like the summer and winter solstice. Thus it is possible that these alignments are arranged in such a manner that the movement of the Sun could be tracked, and the changing seasons could be decided on the basis of the position of the Sun in relation to these alignments. Thus, for example, on the day of summer solstice a particular alignment would be aligned in the line of rising Sun. Similarly, in the evening, another alignment would be in line with the Sun. Thus, when the Sun aligns with a particular row, the local people would know that it signifies the change from southern progression to northern progression of the Sun. These kinds of observations are crucial for the local festivals. For example, the new year festival of the Telugu people known as 'Ugadi' is celebrated close to March 21, i.e. the day of equinox. The *Rathyatra* (procession of the Temple car) of Puri Jagannath temple is celebrated few days after the summer solstice. The Sankranti festival is celebrated by the Andhra people in the second week of January (around 12th January), and on this day of '*makara sankramanam'* the Sun is believed to begin the northern procession.

Figure 2. Sun in line with an alignment, Mudumal.

Observations on the field on various days of solar significance have given the following bearings with reference to north. The readings are of the alignments which are in line with the Sun in the mornings and the evenings.

DATE	TIME	COMPASS BEARING
21st June 2005	Morning	67°
20 December 2005	Evening	242°
21 December 2005	Morning	113°
21st March 2006	Evening	272°
22 March 2006	Morning	88°

However, it may be noted that the above readings are taken with a simple compass, and these have to be rechecked with prismatic compass for exact readings. The planting of the alignments in the direction which coincides with the direction of the Sun on the days of solar significance indicates that these rows of stones are carefully positioned for observations and as indicators of the change of seasons.

In the same area where the taller menhirs are concentrated, there is a remarkable stone circle arranged with menhirs and horizontal blocks alternating and forming into a circle. It appears that three concentric circles were arranged for this monument. This is probably, the only monument of its kind in India, as we do not have any stone circles formed with menhirs. On the northern side inside this circle a stone is worshipped as local deity called as 'Thimmappa'. The local people have great devotion to this deity and they regularly worship here on important occasions like the child birth and after marriage. About 50 Mt. north-west of this place is a small menhir in black stone which is worshipped as 'Ellamma' a female Goddess. There is an interesting story about the existence of these menhirs, which is related to this goddess. According to the story, in the hoary past the local people made an offering to the Goddess in the form of gold coins filled in a basket. Goddess wanted to see what is there in the basket and ploughed her hands into the gold coins. To her astonishment, she found that only the top layer contained gold coins and the rest is filled with rice husk. Upon this she became furious and cursed the people to turn into stones. Hence, the villagers believe that the big standing stones are the humans and the smaller one are cattle and sheep. Due to the currency of this story, usually, the local people are afraid of causing any damage to the monuments. Both standing and fallen menhirs are usually left in their position, though the lands are under cultivation. Thus this aspect has, to some extent, preserved these monuments without much damage. Only in the recent past, the area of 'Thimmappa' temple containing three concentric circles was damaged, as the villagers wanted to construct proper temple in its place. Very unfortunately, the whole circle with all the stones is uprooted using dozers for the purpose.

More significant find from this site is the depiction of 'Ursa Major' on a stone amidst the stone circles. This stone is located about 450 Mt. west of the 'Thimmappa' temple. As per the Google Earth calculation, the area is elevated by about 5 Mts. from the surrounding fields. Thus this stone is visible from most of the locations of this extensive site. The squarish stone measuring about 78 x 76 cm. having a sloping top surface is planted in a diagonal manner with reference to the cardinal directions. The eastern corner is having the maximum elevation with 87 cm. the western corner 68 cm. the northern corner 74 cm. and the southern corner 82 cm. elevations respectively. Thus the top of the stone has a slope from east to west. On the sloping face of this stone 30 cup-marks could be noticed. Careful observation of

these cup-marks reveals that this is a depiction of 'Ursa Major' constellation. The 'Plough' formed by the seven stars and its peripheral stars could be identified. One of the well known features of this constellation is that an imaginary line drawn through two of the stars, i.e., Merak and Dubhe always point towards the pole star. At Mudumal also, the two dots (cup-marks) representing these two stars point to north, which confirms the identification of this depiction as that of 'Ursa Major', apart from the accuracy achieved by the artists who have executed this depiction. The way the stone is planted among the megalithic stone circles on an elevated place suggests that the stone played important role in executing the layout of the entire site. It appears that due to the presence of this stone with these markings, the megalithic people here could determine the directions accurately both in day and night. It may be noted here that the Ursa Major is not visible all the time of the night and also in all seasons. Hence, the stone must have served the purpose of determining the directions in all seasons and time. Though, cup-marks on the megalithic monuments are known from many megalithic sites in India since long, it is for the first time that the pattern of cup-marks could be identified with sky chart for the first time. Usually, we come across only the depiction of either Sun, Moon or few stars in the ancient paintings or rock bruisings. Depiction of a constellation of stars has not so far been noticed any where in India. It may be noted here that this depiction is the earliest sky chart noticed anywhere in south Asia so far. Ursa Major constellation known in India as '*Saptarshi Mandal'*, or constellation of the seven sages, is attached to many traditions and rituals. For example, during a Hindu marriage, the Arundhathi or the faint star known as Alcor which is seen by the side of Mizar in the tail of the Ursa Major or Big Dipper, is shown to the Bride and the Groom to signify the heavenly attachment of husband and wife, which is not supposed to ever separate like the bond of Alcor and Mizar.

The advantage of having a stone indicating the north could be understood easily. This stone must have helped in determining the directions any time and season. The ancient people must have realized that dependence on Sun for determining the directions is fraught with defects due to the apparent change in the direction of the Sun's progression in cyclic way. Further, dependence on the Pole star also has some practical difficulties. The Pole star cannot be sighted in the day time and on cloudy days. Hence, they must have depended on this stone with the constellation marked on it to determine the directions. It is also likely that while erecting the alignments also they must have taken the help of the stone in determining the orientations. The shape and position of the stone on an elevated land also indicates that this stone with the constellation was a key stone which was meant to be seen from long distance.

It is well known that the Indian culture and religion attaches prime importance to the directions. This fact is well summarized by Forthingham thus «orientation was a cardinal factor in every prominent and nearly every ordinary event of daily life in ancient India» (Forthingham, 1917: 433).

From the above, we can understand that this whole megalithic complex must have acted as an observatory to track the movement of the Sun throughout the year, which would help in determining the commencement/end of various seasons. This was, probably, important as the rain-dependent agricultural operations require such predictions. The complex also must have helped the ancient seers in working out the calendar for various events including fairs, festivals and ceremonies. This kind of observatory of such an antiquity has not been found anywhere is India or South Asia. But, unfortunately, the complex is in the process of destruction as evident from the recent uprooting of one of the most important stone circles from this site. Hereby, it is urged that this August body of academicians propose and send an appeal to the Government of India to take-up measures to protect this unique heritage.

Figure 3. Cup-marks depicting Ursa Major, Mudumal

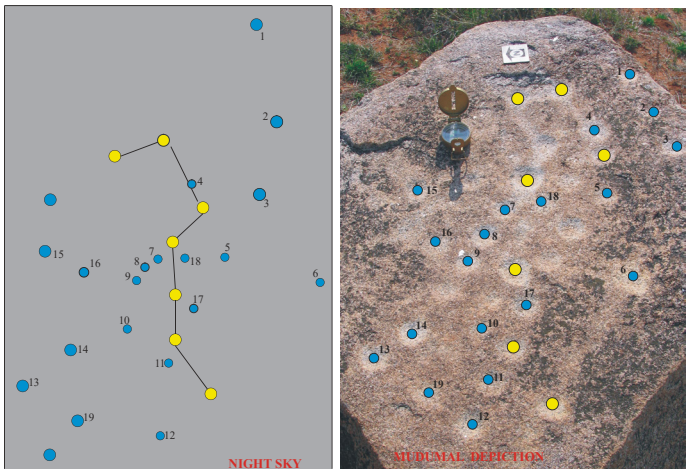

Figure 4. Mudumal depiction compared with modern sky chart.

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Some Ethnographical Aspects in the Study of the Tunguska Phenomenon: Its Reflection in the World View of the Evenks of Siberia

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Abstract: On 30 June 1908, a huge fireball, a bolide, appeared in the daytime sky over the vast area of eastern Siberia between the Lena and Tunguska rivers, apparently emerging from the sun. It was probably moving from the southeast towards the northwest. The apparition moved almost 770 km through the atmosphere in a few minutes before causing enormously destructive consequences over the Tunguska taiga. Witnesses to the explosion were the indigenous people of the Tunguska Taiga - the Evenks. Various expeditions were sent out to investigate the phenomenon and possibly find earthly relics of the celestial body or even craters. The study briefly discusses the multitude of theories about the cause of the phenomenon, including the Evenks' ideas about it. Last but not least, the whole spectrum of human imagination is shown, sometimes combined with a lot of humour.

Keywords: Tunguska phenomenon, Evenks, worldview, theories, ethnography

Introduction

On June, 30th, 1908 the planet Earth collided with a space body weighing more than one million tons. The explosion of a monstrous force which occurred over the territory of Central Siberia (Coordinates of epicenter of explosion 60°53'10" n.w., 101°53'45" e.l.) and caused huge destructive consequences, received the name of the Tunguska phenomenon. Witnesses of the explosion were aboriginals of the Tunguska taiga — Evenks.

Evenki (they call themselves: evenk, tongus. Oorochen — derived from the words «oron» — «deer», and «ile» — «man») — an indigenous people in Central and Eastern Siberia. They speak Evenki language of Tungus-Manchu group which belongs to the Altai family of languages. Evenki ethnic group can be included in the «Guinness Book of Records». Their population is only thirty thousand people but they have explored the incredibly vast territory — from the Yenisei to Kamchatka, from the Arctic Ocean to the border with China. It turns out that on the average the population density there is one Evenki per twenty-five square kilometers (Tugolukov, 1988: 525).

Evenki is one of the oldest nations in the world. It is deduced now that their culture is rooted in the Neolithic period and their history has lasted for at least five thousand years. The data of the population census in 1926 testified that the representatives of this people were proud to say about themselves: «I am Evenk», which meant: «I am a man», thereby confirming their independence and freedom–loving nature.

Evenki are children of nature. They do not separate themselves from nature, knowing its secrets. They are called pathfinders of taiga trails. Many Evenki clans considered wolf as the Totem animal, seeing a strong and very unusual beast in it. Evenki never neglected wolf cubs left without parental care. Evenki are excellent hunters. Bows and arrows in their hands became very accurate weapon. They could hit the target from a distance of three hundred meters, and after that to use the same arrow many times. Evenki had the «Singing Arrows» — special arrows with bone whistles, which fascinated beasts. For centuries, this nation has cultivated a very interesting hunting ethics. After the first fall hunting and killing the first beast, the hunters gave all the meat to their tribesmen and did not leave a single piece for themselves. It was believed that with this kind of behavior their clan would always be fed and their hunting luck would continue.

In XV–XVI centuries Evenki learned reindeer herding, becoming the northernmost herders in the world. For Evenki a deer was not only a breadwinner and vehicle, but even a guard. The life cycle of deers, which was deeply understood by Evenki, not only determined the Evenki existence, but their world outlook, which includes the original mythology — a combination of terrestrial and cosmic principles.

Well–known folklorist and investigator of the North Ivan Suvorov (1914–1972) led the most creative work on the collection of ethnographic material and Evenki folklore. He found a lot of proverbs and sayings, different omens and predictions, fairy tales and fairy tales introductions in their conversational language, as well as an amazing ability to create songs in the process of life, improvising themes close to their lifestyle (Suvorov, 1976: 35-38).

Suvorov studied mode of life, traditions and customs of the Evenki people. Among the myths and sagas he found many legends, stories and tales about how the spirit of the sky — *Agdy* — was offended by people and unleashed on them his fiery arrow — *Pektrume*.

Agdy (Thunder) is the master of thunder and lightning. Evenki represent Agdy in the form of a celestial old man who wakes up in the spring and carves fire with steel. That is why we can hear thunder on the earth, and sparks of lightning strike evil spirits. According to other versions Agdy looks like a little dancing creature with a bear head, human body and wings of an eagle or like a bird with fiery eyes, the flight of which produces thunder, and sparkling of its eyes produces lightning.

In the Tungus–Manchu mythology there are many wonderful characters, symbolizing the cosmological ideas of creation and structure of the world.

Buga (Buva, Boa) is all the surrounding space: the universe, the world, the earth, the sky and weather. Buga also means the supreme being that controls the forces of nature, the life of the taiga, all animals and human species.

On representations of the Evenki Buga is divided into three categories: the top — above the sky (the entrance in this place is a hole in the heaven — the Polar Star), the middle — and the lower land, which includes the crevices in the ground and whirlpools.

On representations of the Evenki the universe mistress — *Bug mushin* — appears either in the form of a female moose or wild deer, or in the form of an old crooked woman who controls the souls of people and animals.

Dyabdar is a giant snake, who participated in the creation of the world. Together with a mammoth Seli he drained the land, paving riverbeds with his body.

Mangi (Mani) is an ancestor, the hero-hunter. Presented as a

huge bear, chasing the celestial elk or male or female bear Heglen, who stole the sun.

This story explains the alternation of day and night and the origin of the constellations: the hunter and the elk or bear, the she–bear is the Ursa Major constellation, and the ski trail of the hunter is the Milky Way.

Seveki (Heveki, Sheveki, Sevki) is the creator of the earth, animals and man. He is the spirit–owner of the upper world, the protector of people and deer.

According to mythology, only water, Seveki and his older brother Khargi existed initially. Seveki took out a little bit of land from the bottom (in other versions it was done under his direction by loon and goldeneye or by the frog Baha), laid it on the surface of the water and fell asleep. Khargi, willing to destroy the earth, began to push it out from under his brother, but only sprained it so much that it took modern sizes. By creating a stone and wood, Seveki ordered them to grow, but they began to dispute who would be higher, and almost prop up the sky, then Seveki knocked off all unnecessary, and since then the rocks crumble, and the parched trees are drying from the top.

Seli (Helir, Holir) is the mammoth, assistant of the creator of the universe Seveki. He took part in the creation of the earth. Together with the serpent Dyabdar (sometimes in the process of their collision) Seli drained the land, pulling out sand, clay and stones, which turned into the plains, mountains and cliffs. Then Seli and Dyabdar fell down into the earth, becoming spirits — guardians of the entrance to the lower world.

Heglen is the personification of the Ursa Major. In most versions Heglen is a giant celestial elk, who stole the sun, or a moose cow with a calf moose chased by the hero-hunter — Mani, Chan chi, Chahintylan or three hunters (for example, Ket, Evenki and Russian).

Hunting, traces of which are visible in the sky as stars of Ursa Major and the Milky Way (a hunter footprint), explains the origin of day and night — a calf moose recoiled after a hunter shot and crashed through a hole in the sky — the Polar Star — on the earth, initiated the beginning of all earthly elks.

Cholbon is the personification or spirit–master of the planet Venus, the celestial deity. Manifesting himself as the morning and evening star. Evenki believe that Cholbon is a mighty and formidable divinity (it is forbidden to tell tales, when he is in heaven).

Agdy was considered as one of the shamanistic spirit–helpers. It was believed that shamans could launch Agdy on alien clan.

The Evenki perceived the cosmic catastrophe that occurred on June 30, 1908 over the Siberian taiga as a manifestation of God Agdy angriness. Stories about the fall of the meteorite Evenki supplemented with fantastic speculations and superstitious additions, but the event itself was represented by them fairly accurately and correctly.

From the memoirs of an Evenki–conductor Nicholas Kochenov:

«When Agdy shot, I was fishing in the southern chunya. My eyes hurt while a watched a fiery arrow in the sky with a round head. And behind her like the tails of feathers sticking out ... then it was not visible. Thunder crashed, then a few more times. A storm began. Water in chunya waved — it flooded one shore, then another. I was frightened. I left the boat and the fishing net, fled to the chum. I looked, and saw that my chum was not there the wind carried it away...»

«And have you seen Pektrume?» — A. Suvorov asked.

«Why, of course I have seen. It was flying low-low in the sky over the woods and shot so often. And when dropped, even louder it shot... Oh, I will not tell more. Aksiri will hear and be offended...»

A. Suvorov recorded Evenki riddles about the Tunguska meteorite:

– *It flew, it fell, and the earth shook. Guess?*
– *Fire fell from the sky; the forest fell on the ground. Guess?*
– *The fire fell on the ground — the fire started. Guess?*
– *People and deer were burnt by the celestial fire. Guess?*
– *The fire roared here, then it roared there, then it flew somewhere. Guess?*
– *Fire was flying in the sky, clucking like grouse, left the white road after itself. Guess?*
– *Glanced at the fire — became blind a little. Guess?*

What really happened on June 30, 1908?

Around 7 a. m. local time, a big fireball — bolide appeared against the sun. Its flight was grandiose. It glided through the sky over the vast territory of Eastern Siberia between the rivers Lena and the Understone Tunguska presumably from the South–East in north–western direction. It was almost hundred meters wide. Leaving a light trail of smoke after itself, it flew almost 770 km during few minutes through the Earth's atmosphere.

People, who watched its flight in the cloudless sky, were horrified by the bright dazzling lights and roaring sounds. The most frightening was the uncertainty. Nearly a thousand miles around the thunder could be heard. The flight of the cosmic stranger over a deserted taiga at an altitude of 5–10 km finished with a grand explosion (Romeiko and Woiciechowski, 2008: 8-19).

Living witnesses to the space disaster were the residents of a small trading post Vanavara and those few Evenki nomads, who were in the taiga at that time. The catastrophic explosion was almost instantaneous. The bright purple glow covered the sky. In seconds the blast knocked down forests, killed animals, and maimed people in a radius of 30–40 km.

80 million trees fell on the earth making a strange figure, vaguely reminiscent of butterfly wings, covering the area of more than 2150 sq. km. According to various estimations the energy of the explosion, ranged from 10 to 40 megatons of TNT (Romeiko, 2006: 65).

At the same time due to light radiance dozens of kilometers of taiga flushed up. The fire which started destroyed what was left after the explosion. Within the radius of about 30 km there was a partial reversal of the soil. And only in the epicenter of a blast wave, running from the top, charred trunks of trees were left standing straight, devoid of their lush crowns. After that this

place was called «telegraph forest». After the explosion a mutation of plants and insects occurred in the taiga, the growth of trees accelerated, the chemical composition and physical properties of soils changed (Romeiko and Woiciechowski, 2008: 144-155).

Earthquakes caused by the explosion, were observed in Irkutsk, Tashkent, Tbilisi, and in the German city of Jena. Seismometers of Irkutsk Meteorological Observatory recorded tremors caused by a meteorite for the first time in the history of science. Earthquake started at 00 hours 17 min 11 sec UT. Arrival of the air wave to the observatory was too late for 2,5 min. Explosive air wave, which rounded the globe, was recorded by many meteorological observatories in the world. Acoustic phenomena spread over more than one million square km in the radius of about 800 km. Such an event is equivalent to a local environmental disaster.

Tunguska fireball also caused significant changes in the magnetic field of the Earth. Strange magnetic storm was observed in Irkutsk, lasted for about 3.5 hours and in many respects resembled the disturbance that occurs after a nuclear explosion. Apparently, it was accompanied by anomalous auroras in the opposite point of the Earth's magnetic field, located at Mount Erebus volcano in the South Pole, where the Anglo–Australian expedition led by E. Shackleton worked at that time.

On the night of June 30/July 1, as well as on the following nights, there was a significant glow of Earth's atmosphere and night-shining clouds (noctilucent clouds) from the western shores of the Atlantic Ocean to Central Siberia from West to East and from Tashkent to Saint Petersburg from South to North in the area of more than 12 million square km (Romeiko, 2008: 65). The light in the sky was so strong that in some places people could not sleep. In several cities in Germany, Britain, Russia at night one was able to read a newspaper. The brightness of the sky, according to experts, exceeded usual in hundreds, in some places thousand times. In Greenwich, at midnight, a picture of the port was made. Danish astronomer T. Kool immediately determined the nature of light anomalies. Already on July 4, 1908, he wrote:

«...it would be desirable to know, if a very large meteorite appeared during recent years in Denmark or somewhere else?».

The glow in the sky did not begin immediately after the explosion, but only after 13–15 hours after the collision of Earth with the space alien. Until now, this fact hasn't got any explanation.

The first reports about the large Siberian bolide were very contradictory. The area between the rivers of Upper and Lower Tunguska River in the early twentieth century was sparsely populated, inaccessible, that is why the information about this event has been leaking out into the center of imperial Russia for years. But, despite of fact that much time had passed, eventually it became clear that the meteorite fell down somewhere in the north of the Angara river.

This news attracted the interest of the Secretary of the Academy Committee on Meteorites L.A. Kulik. In 1927 he undertook an expedition to Central Siberia in search of the site where this unusual meteorite had crashed. In difficult conditions, covering hundreds of miles on horseback and on foot, Kulik finally reached the Vanavara factory. With a small group of colleagues he went deep into taiga and immediately discovered traces of destruction. Moving further with the raft on the taiga river Hushmo, he found the epicenter of the explosion. Broken trees surrounded the swampy hollow in the center of which they found burned–out dead wood. In the large areas of swamps Kulik discovered craters with the diameter of 70 cm to 50 m and depth of up to 4 m. He was convinced that those were the marks made by the fallen fragments of the meteorite. During the next two expeditions their members were conducting tiring work on finding the meteorite substance in the so-called Suslov crater. With the help of a deflector magnetometer the Northern peatery and the basin of the South swamp. Later the aerial survey was carried out, but the meteorite was not found (Romeiko, 2006: 18).

The place, over which the catastrophe happened, is very unusual. The satellite photograph of the area of disaster clearly shows the ring structure of an ancient volcano, which formed over 200 million years ago. Its diameter is about 10 km. Difficult geological conditions significantly complicate the identification of the substance of the Tunguska cosmic body. Rather often abrasion leads to a variety of geochemical and gas anomalies, to the change in the concentration of a number of elements.

Research of the Tunguska meteorite was interrupted by the Great Patriotic War. L. A. Kulik died near Moscow. The search operations were postponed for a long period of time. The Siberian disaster was almost forgotten. But on February 12, 1947 a large iron meteorite weighing about 100 tons fell down in the Far East of Russia, in the Sikhote–Alin mountain range. The research of this meteorite partly initiated new works on Tunguska.

L. Kulik himself tended towards the meteorite hypothesis of the reason of the explosion. Supported by many scientists, this hypothesis has successfully survived until 1958. According to it, the Tunguska cosmic body was a usual very large iron or stony meteorite. However in the process of research it became clear that the meteorite hypothesis could not explain several phenomena observed in the time of the disaster, and after it:

– Why did the meteor explode like the most powerful explosives, and where, in fact, is its substance gone? (so far not a single gram has been found)
– How could the optical anomalies emerge thousands of miles away from the site where the meteorite fell and how are they related to the meteorite?
– Why did the growth of plants accelerate in the epicenter?
– How can the effect of the magnetic storm, which broke out in the ionosphere immediately after the explosion, be explained?

In the 50–ies the Academy of Sciences of the USSR gave an explanation of the Tunguska catastrophe, stating that it was caused by an explosion of the nucleus of a small comet. This hypothesis fully explained the absence of a cosmic explosion, both in the epicenter of the explosion, and beyond. With reservations, the nature of optical anomalies was explained. It was assumed that the comet substance dispersed in the upper atmosphere, causing the glow of the night sky. Modern researchers have found traces of the comet in the peat deposits in the disaster area. They are enriched with elements such as nickel, cobalt, lead and silver. Sodium, zinc, iron, calcium and potassium prevail in the mineral part of the peat, which resembles the chemical composition of the comets spectra (Romeiko and Woiciechowski, 2008: 10).

Russian Academician S.S. Grigorian is the author of a bold theo-

retical hypothesis, which shows that the icy nucleus of the comet, with its vast reserves of energy (in mass and speed), can freely penetrate in the atmosphere and collapse (Grigorian, 2008: 32-34).

But why wasn't the comet, the mass of which amounted about 1 million tons, discovered in advance, before approaching the Earth? Theoretical calculations of the trajectory of a comet's orbit gave the answer to this question: Tunguska cosmic body approached the Earth from the side of the Sun and therefore couldn't be seen from the Earth.

The genetic relationship between the Tunguska body and the orbit of Encke comet was indicated by Soviet astronomer Ivan T. Zotkin and Czechoslovakian astronomer L. Kresak. Basing on the testimony of eyewitnesses and the configuration of the fallen forest, Zotkin calculated the spatial characteristics of the Tunguska bolide. It turned out that it flew to the Earth from the constellation of Taurus, in particular, from the same area in the sky from where each year on June 30th the Beta Taurids meteors, the ancestor of which is the primal comet Encke, fall on Earth. It is assumed that on June 30, 1908 one of the fragments of the nucleus of Encke comet fell down on Earth (Romeiko, 2006: 60-61).

The nuclear hypothesis of the Tunguska explosion is not less popular today, and refers to all technogenic ideas, acknowledging a blast and destruction of any artificial aircrafts, using nuclear fuel. These are usually space missiles, ships, UFOs, etc. The authors of the hypothesis believe that all the spacecrafts carried out some exploratory mission on Earth, but for this is that reason met with an accident that resulted in the death of the ship and crew.

In his scientific fiction story «Explosion» writer A. Kazantsev was the first to propose the hypothesis that, an interplanetary spacecraft, coming to Earth from Mars, met with an accident at the site of the catastrophe. The explosion of the nuclear fuel used in engines, could explain not only the destruction and lack of the meteorite substance, but also the mysterious phenomena, which the locals were the witnesses to (such as «water fight», «face grilling water», «glowing stones», «sickness of local people», etc.). He was also the first to make an assumption that the explosion arose in the air, not on the ground, because no large explosion crater was found at the site of the catastrophe.

A. Kazantsev's idea in the era of rapid development of space technologies had a great impact on society, and immediately attracted many enthusiasts. In 1958 the first Integrated Amateur Expedition (IAE) headed to taiga in search of the remains of a spacecraft. On-ground and aerial inspection of the area could not reveal any material traces of a technogenic disaster. Also no signs of radioactive contamination which could be attributed to the accident of the spacecraft were revealed (Chichmar and Romeiko, 2004: 63-71).

The members of the IAE have been working for already more than half a century. One of its founders is a Ph.D., prof., Director of the Institute of Biology and Biophysics at TSU G.F. Plekhanov. Yearly dozens of people come to taiga to see, learn, and understand what kind of phenomenon the Tunguska meteorite was. The first results of the field works in the late 50–ies were the fused silica and magnetite microbeads of cosmic origin found in the soil. This was the argument in favor of the comet hypothesis, because, in addition to ice cosmic dust is included in the composition of the nucleus of a comet.

Over the years, members of the IAE published several monographs, ten thematic collected books, more than five hundred scientific and popular articles, held dozens of scientific conferences and expeditions.

The nuclear hypothesis has been substantially amended by a geophysicist from Ural A.V. Zolotov. He managed not only to investigate the disaster area, but also to carry out detailed theoretical calculations. Analyzing the conditions of the space alien movements and character of the blast, he concluded that the Tunguska cosmic body could explode only due to its internal energy, i.e. could be artificial.

American researchers, Nobel Laureates, C. Cowen and B. Libby, developing the theory of L. La Paz on anti–substantial nature of the Tunguska meteorite, put forward their own hypothesis about the collision of the Earth with a mass of antimatter, resulting in the annihilation and the release of large quantities of nuclear energy (Romeiko and Woiciechowski, 2008: 192-193). This idea became unexpectedly popular in the world and in our country. Leningrad group of scientists led by the Director of Physical–Technical Institute by the name of Joffe Academician B.P. Konstantinov started working on the idea of anti–substantial nature of the Tunguska meteorite.

Russian and foreign enthusiastic researches of the Tungus problems discover new details of the catastrophe. The only impounded body, which appeared probably in the epicenter of the explosion is the Churgim Waterfalls. According to Italian investigators, the site where the Tunguska meteorite most probably fell is the Lake Cheko.

Over the years there have been dozens of theories giving various reasons for the Tunguska catastrophe. The main are:

- comet theory (30,5%),
- meteorite theory (28.3%)
- nuclear theory (8.5%).

(Source of information: www.tunguska.ru)

A member of the Committee on meteorites, the best expert on the Tunguska problem I. T. Zotkin analyzed all existing hypotheses, which amounted 77:

- meteorite — 28,
- technogenic — 14,
- comet — 11,
- geophysical — 10,
- anti-substantial — 8,
- religious — 3,
- synthetic — 3.

The review of various opinions about the nature of the Tunguska phenomenon, presented below, can be assessed not only by the academic perspective on the events of 1908, but the entire

spectrum of human imagination, and sometimes even the sense of humor:

- The cause of the disaster was the descent of the awesome god Agdy on Earth; he sent the fiery dart Pektrume, which destroyed the taiga and killed many animals (local inhabitants — Evenki).
- On June 30 the Earth came across a cloud of cosmic dust (1908 — Felix de Roy; 1932 — V. I. Vernadsky).
- The explosion occurred due to the detonation of natural gas, fired by a meteorite which entered the atmosphere of (D. Timofeev).
- The explosion is connected with the outcome of powerful electromagnetic ball lightning of «vortex» type (underground storm) from the depths of the Earth (V. Salnikov).
- The explosion is explained by the breakthrough of solar plasma clot, that triggered the formation, and then the explosion of several thousands of ball lightnings with the volume of a quarter of a cubic kilometer (M. Dmitriev, Zhuravlev).
- The destruction in the taiga was caused by the collision of the Earth with the «black hole» (Albert A. Jackson, Michael Ryan (USA)).
- On June 30, 1908 a comet beaten down by an alien spacecraft exploded over the Tunguska taiga (Y. Lavbin).
- The explosion of the Tunguska body was caused by factors similar to those which initiated the destruction of the Phaeton planet. Most probably an UFO exploded on the site of the catastrophe (F. Y. Siegel).
- Tunguska meteorite had earthly origin, and emerged due to the ground impact of small cosmic bodies quite long ago, and in 1908 it «came back». In this case, it may have already been found by D. F. Afinogenov in the early 70–ies on Stojkovic Mountain, located in the epicenter of the explosion (A.D. Belkin, S.M. Kuznetsov).

In1995 the site of the Tunguska catastrophe was declared the State Biosphere Reserve, comprising the area of Kulikovsky inrush of trees, the historic complex of buildings of the first explorers. Scientific research is conducted in the «Tunguska» reserve:

- in the field of soil science,
- botany,
- zoology,
- ecology;

besides an extensive work on development and recovery of the Siberian taiga after natural cosmic and terrestrial catastrophes is performed there. Last years epicentre of Tungus explosion became a popular place of visiting both Russian and foreign scientific expeditions, and as big number of tourists.

Tunguska taiga still has many mysteries and secrets. It will probably continue attracting scientists, adventurers and just curious people...

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Europe

The Sun and the Moon in the Megalithic Period: Symmetry Violation in Megalithic Monuments

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Abstract: A large number of human artefacts and monuments suggest design based on symmetry already in the megalithic period. This seems to have established regular patterns that extend over large numbers of objects or over vast geographical regions. The analysis of some cases of departure from symmetry appears to be archaeologically informative, as they seem to provide insights into human behaviour and mind. Some of these cases seem to hint at the possibility of lunisolar monuments in the Neolithic.

Keywords: Astronomical Orientation, Dolmens, Lunisolar, Megalithic Monuments, Symmetry, Sun, Moon, Equinox.

Introduction

Nature provides us with abundant examples of both randomness and order. However, it is order that we readily associate with life and, in particular, the symmetry of human perceptions, artefacts and monuments with intelligent behaviour. Symmetry might be an abstract concept that comes easily and early. Also, occasional departure from symmetry might indicate intentionality. The main title above, however, appeals to the belief that in the long past of the first sky awareness, the Sun and the Moon might have shown some parity i.e. they may have been equally conspicuous and taken equally in the social rituals. Somehow, these two concepts parity and symmetry, interweave in this paper.

For millennia humans were exposed to the view of other humans of their group or other groups. This constant observation may have impressed in their mind the right–left symmetry of human face, or for that matter of the human body. They may have seen this symmetry in other animals and also in the reflection of their own face in the quiet water where they would drink. When they were capable of some rudimentary form of abstract thinking they would consolidate the concept of right–left symmetry that they would incorporate in their activities.

We seem to recognize this concept in some megalithic artefacts and constructions. The funerary dolmens of western Iberia, particularly in Portugal, have provided thousands of schist plaques (Lillios, 2004) about the size of the human hand (Figure 1). These plaques, which are engraved with a variety of patterns, are thought to be some kind of adornment of the dead taken into afterlife. There is no consensus on their real meaning, ranging from heraldic tags for society groups, to hierarchic status within the group, or even a symbolic representation of death as suggested by the similarity with the shape of an owl. But the design features, i.e. the shape of the plaque and the great variety of patterns, clearly suggest a left–right symmetry.

Early megalithic, indeed proto–megalithic, funerary monuments may initially have been just about human size tombs which in later stages developed into big size structures more than five meters across in any direction. Most probably for this reason the dolmens normally exhibit left–right symmetry in their layout plan, although the dolmen architecture may have evolved into multi–chambered structures and, eventually, into more complex arrangements. The concept of symmetry then appears to have been used in the construction of the funerary dolmens themselves. Regularly the dolmen presents a chamber, an entrance and a corridor. Some dolmens, however, do not display a corridor, and this may occur either because it has been destroyed, or because it is still unearthed one level below ground. Some authors consider that there is a particular class of dolmens with only an entrance opening, i.e. without a corridor.

It is relevant to this analysis that we restrict to the common seven stone chamber dolmens with corridors as they produce a more confined and secluded environment for the dead. The corridor is normally a very narrow and low passage to the chamber, therefore leaving this in sufficient darkness, just enough for chamber management. Also, a typical seven stone chamber (Figure 2) is symmetrical about a vertical plane perpendicular to the back stone that goes across the entrance door and along the corridor general development. This corresponds to the accepted construction procedure where the back stone is first set up followed by the next two stones leaning one on each side of the back stone, and so forth, producing a symmetrical layout.

In some cases we detect slight deviations from this design but not so pronounced as to suggest a real departure from the original plan. We should be able to accommodate some degree of uncertainty due to the heavy weight of the stones (tons each), and to the very primitive methods available that could hardly guarantee accuracy. We must also take into account the movement of the stones, from their original positions, that may have been inflicted by later generations, particularly the present, or by natural causes as, for instance, the growth of a big tree from a seed that may have germinated nearby or in between the stones.

Humans can observe, touch and manipulate objects in their own world, make their own artefacts and constructions. This constant manipulation and observation may have produced a kind of «empirical» symmetry. Once this concept of symmetry is well established, then they may be ready to extend it to objects in the surrounding cosmos that they can neither reach nor manipulate. The awareness of the cosmic regularities thus arising from sedentarisation may have extended the concept of symmetry beyond its initial scope. In fact, one of such natural manifestations is found in the observation of the distribution of the sunrise and moonrise, or setting, in the horizon.

The standard concept of the megalithic monument geographical orientation generally relies on the observation of the regular cyclic movement of the sun across the sky. If the sun is observed against the horizon its rising point is seen to move between two standstill positions that correspond to what we call today the solstice limits. The concept of equinox, since it is not materialised by any observable circumstance, must arise necessarily from an associated second order concept like «the centre between

Figure 1.Schist plaque primitive symmetry (from Leisner and Leisner, 1951).

the solstices» or «the mid point between the solstices». Indeed a centre of symmetry of a more abstract nature. We must then invoke some sort of external circumstance to identify it. At a given stage of cultural development this could well have been a counting procedure, trying to identify a position in the horizon that would separate equal numbers of sunrises on each side in a complete cycle (Thom, 1967: 107), and only later, probably already in literate societies, the division in half of the angle between the two.

It has been pointed out elsewhere that the Full Moon exhibits the same regularity of the Sun although in opposition. The exploration of this circumstance has led to the suggestion of the role of the Spring Full Moon in the megalithic period (Da Silva, 2004; Roslund *et al.*, 2000; Clausen *et al.*, 2008) and indeed to the recognition of the symbolic significance of this, and of the succeeding Full Moons, in ritual practice (Oliveira and Da Silva, 2006; González-Garcia, 2009). M. Hoskin conducted a large survey of Mediterranean megalithic temples and his data show a consistent predominance of orientations to rising azimuths between the solstice standstill sunrises (Hoskin, 2001: 214). Azimuths occur indeed largely between the solstice limits but far from uniformly distributed. Rather, the distribution in a large majority of cases is bell shaped and peaks at about 99º as would be expected from an interpretation associated with the Spring Full Moon and the megalithic equinox.

Some civilizations do really seem not to have given any role to the Moon in their liturgy or ritual practice, which seems odd for an astral body so conspicuous and so inspiring in other societies.

Frequently, symbolic interpretations of the sky, in early pre–historic and historic contexts, in many aspects invoke the sun rather than the moon. However, the full moon is equally impressive in the way it shines at moonrise. If the sunrise announces a daily renewal of life and warmth, a full moon rise may announce an opportunity for an effective hunt and replenishment of food resources equally important for survival, and maybe also an opportunity for a mind dwelling in closer communication with the sky gods, not possible during the day when they are really absent due to the intense sunshine.

It is possible that, whatever the interplay between the sun and the moon may have been in the past, only one of them survived in the official liturgy. In the case of the Mediterranean societies it may have been the moon as can still be observed in the Christian and Jewish Pascal celebrations as well as the Jewish and Arab moon based calendar, along with other features that seem to be recognised in the traditional practices of some populations. In the case of western Iberia also the sun seems to have been incorporated in the ritual calendar of popular festivities on the occasion of both solstices. Here, the winter solstice may have been fully Christianized later but the summer solstice still remains as a prominent popular festivity although this bears the name of Saint John.

Other astral bodies may also have been important for some of these ritual practices as, for instance, the case of stars like Sirius or asterisms like the Pleiades. The «dog» star Sirius survives today in the minds of people (canicula lore) beyond the rise of the Nile, since its heliacal rising (just preceding the sun) continues to be a «Mediterranean» (from Iberia to the Nile) signal for the harvest.

Figure 2. View of the Barrosa tomb facing the (broken) back stone. The corridor clearly departs from the chamber symmetry.

Brief examination of the local archaeological record

It has long been recognized that megalithic tombs (dolmens or antas) have a construction layout that exhibits a design where symmetry plays a role. In fact, it is generally believed that the chamber is built equally to the right and to the left of the first stone erected (the back stone). Usually, the entrance to the chamber lies opposite to the back stone, on the line perpendicular. This line usually coincides with the chamber symmetry axis, and is often continued by a corridor extending in this direction by as much as a chamber diameter or two.

We have scrutinized a number of published plants of dolmens, the majority by the archaeologists Georg and Vera Leisner who, in the 1940's, surveyed the Iberian Peninsula particularly the Alentejo in Portugal (Leisner and Leisner, 1956). From a sample of more than 250 dolmens we selected about 200 in which the corridors are either well developed or are sufficiently recognisable, and concluded that the large majority, 88%, conformed to the above symmetry rule.

We have recognised and documented a few corridors whose construction has apparently departed from the original symmetry rule, and these may be arranged in two categories: the first deals with offset corridors which appear to have been built almost

tangentially to the chamber rather than on the symmetry axis, as in Figure 3 (these are locally designated by «9's» tombs, or «nines», from the similarity of the layout with the writing of the numeral nine); the second category can be designated by «tilted corridor» tombs as the corridors often start at the chamber entrance but do not develop along the symmetry axis (Figure 2), or may show successive segments of different orientations. Only 3% of the total selected could be attributed to the class of «nines» while the «tilted» corridors were more frequent and amounted to the order of 9%. In this case the examination «*in situ*» of the implantations supports the indication that the corridors deliberately depart away from the chamber orientation.

In addition, we have also examined in the field a significant amount of dolmen layouts, in the region of Alentejo, to reinforce the view that the large majority conforms to the usual symmetry plan.

Although this analysis seems straightforward, the case of non–symmetrical layouts warrants a closer inspection considering actual orientation data measured in the scope of this study. All azimuths reported are relative to true north and we review a few typical or representative cases:

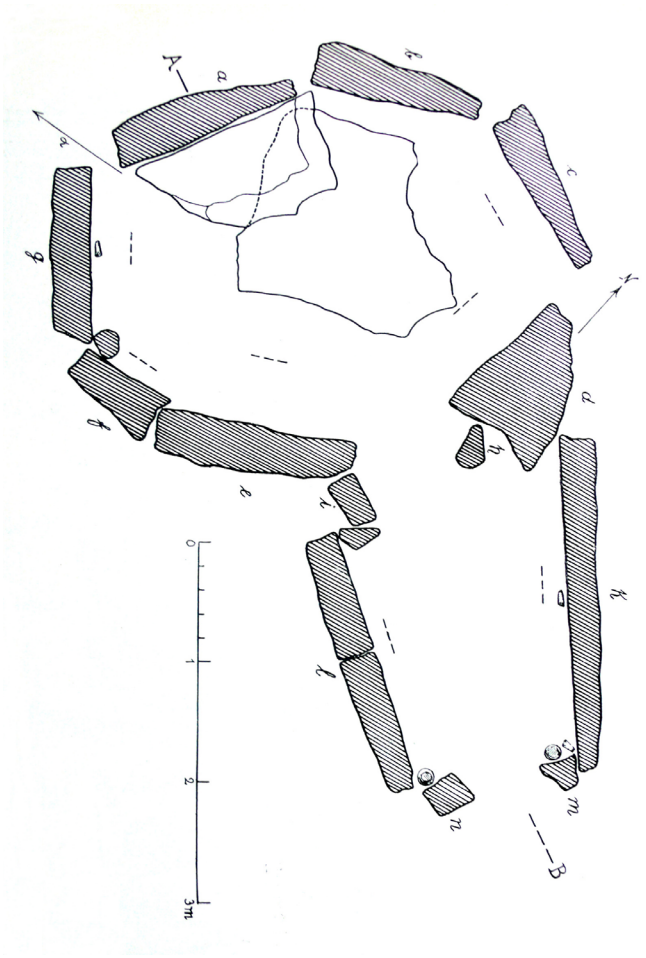

Figure 3.The Vidigueiras tomb displaying the shape of the numeral «9» (from Leisner & Leisner, 1951). The chamber seems to hint at some perturbation of the initial design pushing some stones out.

– The case of tilted and inflected corridors – Although this field survey was not aimed at defining a statistically accurate estimate (as it would certainly require re–visiting a much larger number of monuments) we find that really odd shapes do not represent significantly more than the expected 10 to 12% of the total chamber passageway tombs. The following are two examples of tombs measured during field visits. A well defined corridor south inflection of 8º (096º to 104º) was measured in the Soalheira tomb in Alter (Portalegre, Alentejo). Here the corridor has two sections about the same length (≈3m) the first one in the continuation of the chamber symmetry axis and the second section tilted south. The other example (Figure 2) is a well defined, chamber–corridor tilt of 10º as was observed at the Barrosa tomb (Vila Praia de Âncora, Minho). Here the back stone and chamber symmetry were set at 103º and the corridor starts at the chamber entrance already tilted north at 093º. The cases in which the corridors display significant inflections are relatively frequent. We have equally observed inflections to north and to south although the latter seem more common.

– The case of Stª Rita – Recent excavation of a megalithic tomb at Stª Rita, in the region of Cacela (Algarve, Portugal) close to where other tombs were identified in the past and now disappeared (Veiga, 2005: **1**, 218), has resulted in a beautiful example of a sandstone chamber. This opens through a corridor passage facing the eastern horizon at an azimuth of 099º consistent with the usual spring moon model. However, the striking feature of the construction layout is that this direction is clearly distinct from the construction plan of the chamber, Figure 4, which displays a well defined symmetry axis perpendicular to the back stone and coming out of the chamber entrance at an azimuth of 082º (chamber–corridor tilt of 17º). This situation seems to be further reinforced by a further 13º tilt of the last short section of the corridor in the direction 112º.

According to the excavation coordinator (Inácio *et al.*, 2007; 2009) the rear part of the chamber is thus left in deeper obscurity, and this seems to have been used to provide a preferential niche for burial depositions. Evidence for this niche was found, during the excavation, in the form of a purpose built structure in the dark side of the chamber, an «ossuary», which contained the accumulated bones of various burial deposits.

We tested that direct penetration of light from the sun at sunrise may occur only for just one or two days, twice a year, through a narrow «slit» defined by the chamber doorway and the eastern end of the corridor.

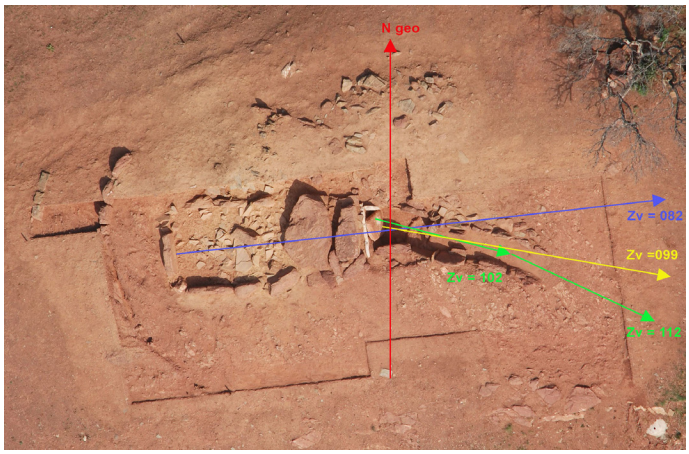

Figure 4.The tilted corridor of the St.ª Rita dolmen. The corridor development at 099º clearly departs from the chamber symmetry axis at 082º. Note a further tilt on the final section of the corridor

Using a laser light shining inside along the corridor, we showed that only a small range (≈1º) of azimuths of the direct light could be admitted to the back corner of the chamber opposite to the

niche, keeping this in obscurity. This could provide an opportunity for chamber management twice a year. One as the sunrise moves south to the winter solstice, and the other in the inverse situation when the sunrise moves north from the winter to the summer solstice. It is a consequence of the regular displacement of the sun in the horizon that these two occasions, in which the sun rises on this azimuth, are distant the same number of days from the intermediate solstice, and always when the sun rises close to a particular point in the horizon.

Thus we seem to be in the presence of a chamber with a kind of sacred area protected against the direct light of the sun (Inácio *et al.*, 2007; 2009).

– The case of the anta 1 of Vidigueiras – Another odd layout is found in the case of the Vidigueiras dolmen (Leisner and Leisner, 1951) in the region of Reguengos de Monsaraz (Central Alentejo, Portugal). This is a typical «9» tomb (Figure 3) in which the corridor seems to originate sideways to the chamber, at an azimuth of 128º, and for this reason it is not coincident neither with the chamber symmetry axis, nor with the perpendicular to the back stone. The same comments may apply to this tomb as in the case of the Stª. Rita monument. However, we note that small modifications of just two stones, one in the corridor and the other in the chamber entrance, seem to be sufficient to reasonably recover the standard seven stone chamber layout. In fact, the direction defined by the centre of the back stone and the corridor exit, 109º, close to the symmetry axis of the modified chamber, is closer to the spring moon average direction than the corridor azimuth. This may suggest that some odd shaped layouts may also occasionally result from improper placement of heavy stones that are not easy to move afterwards into a better position, and therefore are left as they set down.

Discussion

The arguments about the orientation of the megalithic tombs are frequently met with counterarguments that state they are generally oriented facing sunrise, implying the sun as the guiding element in the construction of these dolmens. Also that the layout of the tombs is not always fully symmetrical and therefore no single direction seems to have guided alone the complete construction in these cases.

If in fact the sun was the construction guideline, for instance at the beginning of the construction procedure, then the resulting azimuth distribution would not be uniform but rather «cusped» at the solstice extremes as these are standstill positions involving more days in the same angle interval as compared with the centre of the range. This is exactly the opposite of the observed bell–shaped curve, peaking close to the equinox direction. Some of these counterarguments seem to project in that distant past present day social organization by invoking that some periods in the year would be occupied with other activities and therefore were not available to build dolmens, and thus diminishing the prevalence of the corresponding orientations.

Also, some archaeologists prefer to interpret the referred «nines» odd shapes as evidence against geographical or astronomical orientation of the dolmens. In some cases (e.g. Vidigueiras), slight changes in the position of a few stones may result in more symmetrical layouts. For this reason we may have some reserve about the intentionality of the so–called «nines» class. Some misplacement can occur at the time of construction since a large and heavy stone once misplaced would not be so easy to get back into the intended position. Or even that it was not worthwhile the extra effort given the actual purpose of the construction. There is no reason to believe that the builders were perfectionists.

It is however strange that no similar comments are made regarding a much more common group in which the corridor seems to be tilted relative to the chamber axis, or to the back stone perpendicular, and that some corridors appear to inflect left or right as they develop away from the chamber. The large prevalence of symmetrical tombs seems to offer proper conditions for the analysis of geographical or astronomical orientation.

In the brief examination carried out we can see that a tilted corridor departure from symmetry can be used with a purpose. In the case examined (St.ª Rita) this departure is interpreted as providing an obscure part of the chamber that is not disturbed when the entrance of the tomb is opened, although some light is admitted to the other part of the chamber. Even when the sunrise reaches the chamber the obscure part is not greatly disturbed. The repeated use of the chamber for new interments or for regular maintenance may well have been the beginning of a periodic, and ritual, activity related to the Sun on an alignment originally set for the Moon.

It is not clear, however, that this tilt at Stª Rita was deliberately embedded in the construction to provide the useful secluded area. We can show that about 10% of the cases would display a significant corridor tilt just by following, systematically, the spring full moon when a corridor orientation is needed as the construction progresses in the following years.

In fact, a corridor inflection may also occur during the tomb construction process, particularly if it takes more than one year, as a result from consecutive spring moons not occurring in the same direction. If the construction starts by setting the back stone to the spring moon, then by the time the corridor is going to be constructed in the successive years the spring moon points already to a different direction, and this may continue if extensions of the corridor are built in later years according to the prevailing spring moon. For this reason we have examined the dynamics of the spring full moon rise over a period of more than five lunar node cycles and found that, although shifts of the azimuth of the order of ±5º, or less, are very frequent in succeeding years, larger shifts of the order of ±15º, or greater, are not infrequent and may amount to about 10% of the cases in the first few years following the implantation of the back stone. Only if the corridor is built in the same year of the back stone implantation can we really refer to the intentionality of the tilt. One way or the other both alternatives provide a secluded area in the tomb, protected from external disturbances. In both cases we achieve this protection by a process of light reduction, indeed of light collimation. In the case of the megalithic tombs this process of light collimation seems to be very rudimentary, and trivial, reduced to narrow and low passageways, non–rectilinear corridors or arrangements, and occasionally an extra stone sealing the entrance of the chamber. The same observation in the monuments of more developed societies seems to exhibit construction details, including successive chambers, that remind us the collimation of light in many present day optical devices.

We may conclude that symmetry plays a role in the dolmen construction, and that some departure from symmetry may be informative in the analysis of Neolithic data, emphasizing special

items of archaeological importance and perhaps, also, of ritual practice. The case of Stª Rita examined above seems to be a good example suggesting that the same azimuth line may refer to more than one celestial body (e.g. the Sun and the Moon). In fact, in this tomb the corridor might have been aligned to the range of Spring Moon azimuths that cluster about 100º, as most dolmens do in Southwest Iberia (and in other parts of the Mediterranean). The later use of this direction, as the sunrise shines through, might give the corridor a new function and, eventually, a new ritual practice.

An orientation azimuth close to 100º found in a prehistoric monument strongly suggests that a close examination should be made taking into account the possibility of a lunar role in the alignment. Therefore, this may highlight the possibility of early lunisolar monuments. Orientations close to 100º in single temples do not seem to be infrequent and in this conference three oral presentations referred these orientations in temples so far apart as Finland, Mexico and Egypt.

We believe that the Sun and the Moon were equally prominent in the minds and myths of ancient societies and that it is only the specialization of the ritual events embedded in the particular cultures of each society that selects, as a kind of filter, the processes that become part of the established liturgy. As a consequence of this process people may forget, after several hundred of years, the ancient motivations that were present in the old rituals, and reinforce the new practices which may involve only a particular astral body in its celebration. In some of the above examples we see how the layout of a monument can be set up according to a particular Moon event, and the ritual celebration practiced resorting later to the passage of the Sun in a particular feature of the layout. If this occurred in a man's dominated society, in which the male may usually be associated with the Sun, this tendency may even have been anthropologically reinforced. Eventually, it may have been reflected in the architecture, the tomb being frequently associated with female symbolism and the sun shinning through to the most recessed chamber, in ritual occasions.

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The use of the images in Figures 1 and 3 is a courtesy of the local Science and Technology Foundation–FCT (the most recent successor in a line of similar institutions starting with the Instituto para a Alta Cultura in 1936) and is greatly appreciated. We wish to thank the Centro de Investigação e Informação do Património de Cacela–CIIPC for making available the aerial photo of the Stª Rita dolmen, taken by Lúcio Alves during the first campaign of excavation. This enabled us to better illustrate, in Figure 4, both the chamber and the corridor orientation data measured in the scope of the present work. Also, we would like to thank M. Fernanda da Silva for the critical readings of the manuscript.

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Theoretical sampling of simulated populations at West Kennet Avenue, Wilshire, England

Transcending the individualistic fallacy in Archaeoastronomy by considering monument design and landscape phenomenology as coupled systems.

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Abstract: The dominant methodology in archaeoastronomy is the statistical testing of regional groups of monuments. Such tests for the null hypothesis cannot be used for unique monuments like Stonehenge and Avebury monument complexes in England, nor do they raise inquiry to the level of the meaning of these or even regional groups of monuments. To interpret the collective representations of the ancient monument builders an additional method for archaeoastronomy is to treat monument design and landscape context as a terrain of choices and, together with skyscape, as coupled systems. Competing models of meaning can then be tested by theoretically sampling these domains.

Keywords: Averbury (England), West Kennet Avenue, monument design, landscape, skyscape, archaeoastronomy, coupled systems, terrain of choises

The dominant method in archaeoastronomy is to analyze statistically regional groups of similarly designed prehistoric monuments to see whether the 'astronomical' alignments in any of them are not chance occurrences but 'data' (Heggie 1981; Hoskin 2001; Ruggles 1999). This method cannot demonstrate the intentionality of 'astronomical' alignments for single structures – yet unique structures such as the West Kennet Avenue and Stonehenge in Wiltshire UK and Newgrange in Eire arguably represent culminating achievements of their prehistoric monument building cultures. The statistical method of Monte Carlo simulation does allow testing unique structures by comparing them to alignments that might occur in a virtual population of randomly generated alternative structures (Ruggles1999; Hively and Horn 2006). But while this removes the need for regional groups of actual monuments, the method stays at the level of testing the null hypothesis. If we are to interpret the meaning of alignments in unique structures, we need to devise tests not just on the null hypothesis, but also on those hypotheses generated by alternative methodologies and theories (Sims 2009a). This paper suggests another way to overcome the individualistic fallacy is by theoretically, rather than randomly, sampling a simulated population of unique structures within the available local landscape alternatives. This requires considering skyscape and landscape as coupled systems, and allows testing the null hypothesis for intentionality and to discriminate between competing theories of the cultural meaning behind alignments. As a case study of these claims, this paper will consider the unique West Kennet Avenue, which is one component of the Avebury monument complex in Wiltshire, England.

The West Kennet Avenue was a late Neolithic/Early Bronze Age double row of about 100 pairs of stones between the Avebury circle and the Sanctuary stone and wood circle 2.4km to the south east (Figure 1). Much of the Avenue was either destroyed or toppled as a product of religious intolerance and financial gain in early modern times. The northern section of the Avenue was excavated, surveyed and partially reconstructed before the Second World War by Keiller and Piggot, who showed that the Avenue was a series of straight sections rather than the smoothed 'serpentine' route suggested by Stukeley (Keiller and Piggot 1936; Smith 1965; Mortimer 2003). From field survey of the reconstructed Avenue, opposite pairs or their markers are on average 14.7m apart, adjacent pillars or their markers are 23.2m apart, and the average height of surviving stones is 2.26m (Sims Field Notes). By archaeological convention stone pairs are numbered from 1 to 100 from leaving the southern entrance of the Avebury Circle towards the Sanctuary, and by 'a' and 'b' stones

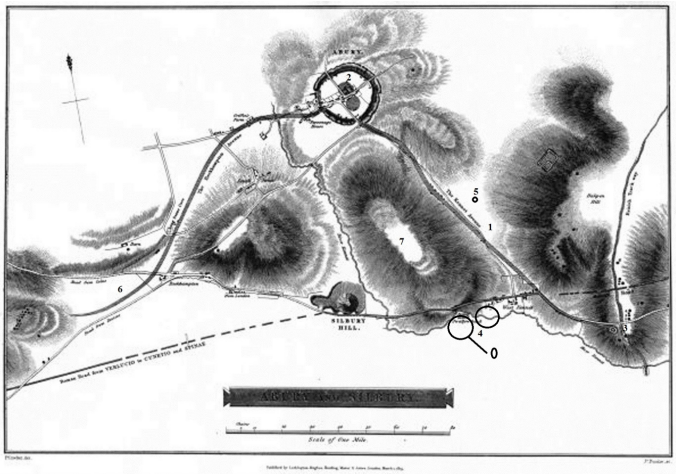

Figure 1 Main Features of the Avebury late Neolithic/Early Bronze Age monument complex, Wiltshire, England, with key to place names mentioned in text. Key: 1 West Kennet Avenue; 2 Avebury Circle and Henge; 3 Sanctuary; 4 West Kennet Palisades; 5 Falkner's Circle; 6 Beckhampton Avenue; 7 Waden Hill. (Adapted from Crocker 1823 – source Glastonbury 2001

whether on the left or right hand side of the Avenue.

In recent papers archaeologists have emphasized power, memory and construction models to interpret the Avenue. Thomas sees the Avenue as a link between structures that enhances their power to manipulate space hierarchically (Thomas 1991); Pollard and Gillings favor avenues as markers of ancestral track ways and midden sites (Gillings and Pollard 2009; Sims 2009b); Richards sees avenues as 'empty' products of building work that commemorate ancient pathways no longer used (Richards 2004).

Each of these models can be tested by sampling the components of the monument complex and alternative sites within the local landscape. The power model interprets avenues as processional routes that link existing buildings to enhance their ability to hierarchically manipulate space. Therefore the West Kennet Avenue's route between the Sanctuary and the larger Avebury Circle is seen to present participants with increasingly larger stones as they are progressively revealed behind nested facades. This model however admits of just two constraints – a start point at the Sanctuary and an end point at the Avebury Circle. It cannot account for why the actual Avenue route passes within 100-200 meters of two other contemporaneous buildings – the small Falkner's Stone Circle in the middle of the valley, and the massive West Kennet Palisades near to the point where the Avenue

turns north to enter the dry valley which leads to the Avebury Circle – but does not link them all up. If power is mobilized by linking monuments, why does the West Kennet Avenue appear to ignore two equally sized monuments also on the same course? There are eight other possible two or three monument combinations that the Avenue might link between these four structures, and none of these are accounted for by the power model. Clearly, the builders saw some categorical distinctions between these structures which required a more complex interaction between them beyond the explanatory abilities of the power model.

The memory model argues that the Avenue commemorates ancestral route-ways into the region, as revealed by ancient midden sites. We can test this model by theoretically sampling the topography of the valley. In transect the dry valley profile is of a roughly symmetrical flattened 'U' shape. The route of the West Kennet Avenue through this valley is decidedly odd, especially if looked at from the point of view of an ancestral Mesolithic hunter. The Avenue 'starts' at the Sanctuary at a height of 167 meters above sea level, then drops quite steeply down to cross the valley floor just below 150 meters, to then climb halfway up the other valley side to take an undulating route along the western side of the valley at about 160 meters. No experienced walker, let alone ancestral Mesolithic hunter, would willingly lose height to then have to so quickly regain it. This is especially so when it is noticed that the Sanctuary is located on the top of a ridge that extends along the eastern side of the dry valley occupied by the Avenue, and which would have afforded a perfect route overlooking the whole valley and still end up in the area where the circle came to be built. This reasoning is not weakened by the archaeology of the area, which provides evidence of Mesolithic remains in the valley that subsequently became the route for the Beckhampton Avenue, but none whatsoever for the valley later occupied by the West Kennet Avenue (Allen 2005).

Keeping with this method of landscape phenomenology generates further insights that weaken these recent archaeological models of West Kennet Avenue. Gillings and Pollard note that the space within the Avenue is littered with a natural spread of sarsen stones close to the surface which would have been hazardous for any procession, and cites this as possible evidence for the 'construction' perspective in which no actual procession ever took place within them (Gillings and Pollard 2009:141-2). Yet elsewhere Gillings and Pollard (2004:91) mention that the chalk that runs along and just outside the Avenue, unlike that within the Avenue, is compressed - indicating paradoxically that the inside of the Avenue was not used as an Avenue in the way the memory and power models suggest. If we consider both pieces of data simultaneously it undermines all three models, since this raises the possibility that processions did in fact take place *outside and along* the Avenue stones, so providing a changing vista of many stone pillar combinations. There are previously unnoticed details of the Avenue's design that suggest it was more than a prehistoric Keynesian exercise in public waste labor projects. It has become clear that the Avenue was not a continuous row of paired stones as assumed by all three models, but included gaps, omissions and changes in form. For example, Keiller placed a marker at position 30b (Figure 2) which by interpolation he calculated a stone ought to be, but noted with some embarrassment that no stone was ever placed in this position (Smith 1965: 212; also Gillings and Pollard 2009). Further, the eight 'burials' along this northern section of the Avenue are all on the northeast side of the Avenue stones (Smith 1965: 209), suggesting some emphasis on placement and orientation. Without commenting upon it, Pollard

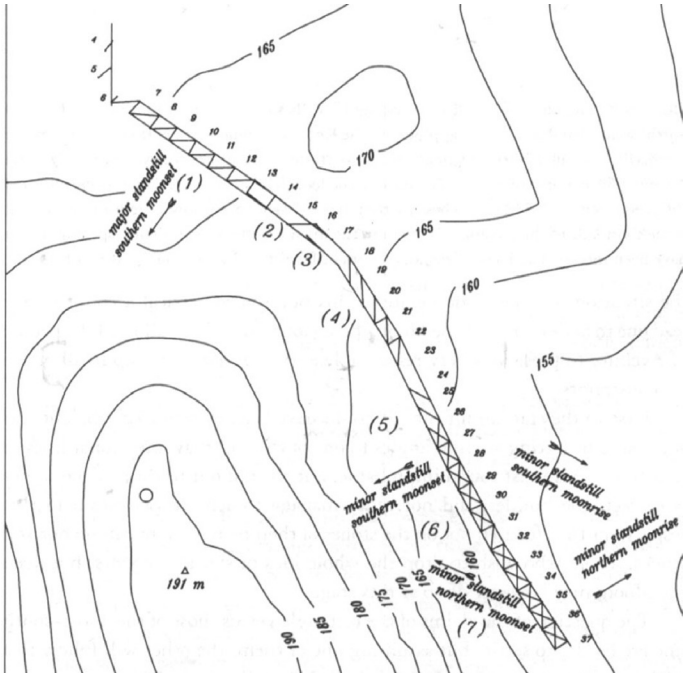

Figure 2 North's lunar alignments for West Kennet Avenue (North 1996: Fig 102). Note: Conventionally stones along the east side of the Avenue are 'a' stones, and those on the west side are 'b' stones. On this Figure, North has drawn construction lines that link the stones, not the stones themselves.

has provided data which shows there is a crisscross pattern of deposition of worked flints between Avenue stone pairs 33 and 28 (Figure 2) and concentrated at position 30b. Each limb of this crisscross regularly alternates in a zig-zag between north-south and west –east (Pollard 2005: Figure 10.3). Between stone pairs 37 and 1, the Avenue is 'partitioned' in two places by three stones placed in line and crossing the Avenue: stones 6b-5a-4b and 15b-16b-17a (Figure 2; Smith 1965: Figure 71; Sims: field notes). For over a kilometer the course of the Avenue along the undulating eastern flanks of Waden Hill (Figure 1) follows approximately parallel to the same 330° orientation as its ridge, so providing a regular, steep and close high horizon varying in altitude between 5-7°. About 1.25 kilometers to the east lay another high and level horizon which offers an altitude from the Avenue of between 1-2°. Many of the stones have been selected and installed so that their tops, when viewed at the 1.65m eye-height of a Neolithic man (North 1996: 58) from adjacent or opposite stones, are arranged to coincide exactly with the background level horizon. The power model calls attention to the average height of the avenue stones being lower than that of the Avebury circle stones, so displaying a growing cadence of power from the Avenue to the Circle (Gillings and Pollard 2004: 18). However, when moving along the Avenue towards the circle between pair 37 to 17 and considering individual rather than average values the stones get shorter, not taller, as the power model would predict. The Avenue section between pairs 37 and 17 is within a gentle gulley on the eastern flank of Waden Hill rising up to a saddle between stone pairs 17-13 and the land then falls again towards the southern entrance to the Henge. Only at position 30b (Figure 2) are the horizons across adjacent or opposite stones of equal altitude whereas elsewhere along the Avenue they are unequal. And lastly, viewing from before pair 37 up to position 30, and standing just outside the Avenue on either side, the heights of *all* the stones of the Avenue are arranged to coincide with the background horizon, thus explaining why the stones get shorter when moving uphill towards pair 17. This property is not apparent when standing within the Avenue.

These ten properties of the Avenue suggest themes not accommodated by the power, memory or construction models and argue strongly for moving to and integrating the method of archaeoastronomy with landscape phenomenology and monument archaeology. The crisscross worked flint cardinal deposition across the Avenue around position 30b, and the northeast position of the eight 'burials' can only have been achieved by prehistoric 'astronomy'. Archaeologists have commonly reported prehistoric cardinal and cross-cardinal alignments of human burials and so wittingly or not have long been archaeoastronomers (Tuckwell 1975). Since the tops of paired and adjacent stones coinciding with the background horizon can only be seen when standing outside the Avenue alongside opposite stones, this reinforces the inference that internal obstacles to procession and external compression marks should be interpreted as evidence of external processions. This raises the possibility that the tops of these stones are designed to merge with some local horizon event. We have shown elsewhere (Sims 2009a) that the Avenue routes are designed to prescribe only those views of Silbury Hill which act as a facsimile of the moon just before, during and after dark moon, all in order to conduct a dark moon ritual at winter solstice within the Avebury Circle. As we will see below this symbolism is repeated *within* the Avenue. As the 29½ 'pair' from the southern entrance to the Avebury henge, position 30b marks the synodic period from one full or dark moon to the next. But 29½ positions from a dark moon Avebury henge entrance bring us to another dark moon. The *absence* of a stone at position 30b, rather than being seen as the anomaly it is for the power, memory or construction models, is *consistent* with dark moon symbolism as predicted by the lunar-solar conflation model (Sims 2006, 2007, 2009a). This inference of lunar numeration is confirmed by the partition of the Avenue with three of the Avenue stones being set in line that cross the Avenue from 15b-16b-17a and 4b-5a-6b. If position 30b indicates dark moon, then positions 15-17 coincide with full moon and positions 4-6 mark last quarter moon and waning crescent. These lines linking three stones across the avenue suggest movement from one side of the avenue to the other, and therefore some symbolic loading to the 'handedness' of the route taken along and outside the Avenue stones. Three further pieces of evidence can be noted to strengthen the lunar sequencing of Avenue stones. The 'burials' along the Avenue are confined to within pairs 29-18 and to stone 5, and are therefore within those lunar Avenue partitions associated with dark moon, waxing or waning crescent moon – all of which are absent for most of the night sky. And since the horizons across opposite and adjacent stones when seen from position 30b are of equal altitude, unlike elsewhere along the Avenue, this signifies a tipping point that the builders have chosen to signify through the absence of a stone. Third, the embodied experience of walking *down* into a gulley along a parallel row of stones from position 50 (The West Kennet Avenue cove – see Ucko et al. 1991; Sims 2009b) to dark moon position 30b, then uphill towards the full moon position 15, and then downhill again to position 6 and on into the henge, suggests a double simulation of walking into and through the dark moon underworld by a *descending* route. If this componential analysis of the Avenue is correct one prediction would be that the West Kennet Avenue should have lunar-solar alignments across paired and adjacent stones that indicated solstice dark moon journeys through a simulated underworld.

In what he emphasized was a first exploratory study of the Avenue, North found lunar and cardinal alignments across paired and diagonal stones, and astral alignments along its length (North 1996: 252-62). Reworking Thom and Thom's data (Thom and Thom 1973), he suggested that there are seven sections between stone pairs 37 and 7 along the northern part of the West Kennet Avenue - all composed of two ideal quadrangular arrangements of stones. The southern sections combined cross alignments in consort with the changing local landscape horizons to provide bearings on the risings and settings of the southern and northern minor lunar standstills, north-south cardinal alignments across one set of diagonals and alignments along the length of the Avenue on stars seen setting on the local north-western horizon. These astral alignments crossed over the positions of human burials alongside Avenue stones. The northern section combined cross alignments on the setting southern major standstill of the moon, west-east cardinal alignments and astral alignments on the local south-eastern horizon (North 1996: 252-62). Unlike the artificial landscape created for the Avebury Circle by the henge bank, North argued that the natural landscape of the Avenue's surrounding horizons had been subtly appropriated within its design to achieve transverse lunar, not lunar-solar, alignments (Figure 2). For John North, this was a continuation with modification of an Early and Middle Neolithic tradition of equal altitude reverse alignments on paired stars across long mounds from their ditches[1].

A number of observations can be made on this treatment. North actually found 10 sections for the Avenue. In Figure 2 he shows three additional short zigzag sections between stones 1-4, 4-6 and 6-7 in the Avenue's final approach to the southern entrance of Avebury henge. Rather than seeing this final connection as 'awkward' (Smith 1965: 208) or a 'mistake' (Gillings and Pollard 2004: 78), North's diagram shows that it includes a repetition in diagonal northings which can be found between positions 37-17. Note also that these sections coincide with lunar numeration for the seven days of waning last quarter and three days of dark moon. And building on his findings, these ten sections can also be considered as just three when diagonals are either northings or westings. What is most interesting is that these cardinal alignments are grouped to coincide with sections we have found where three stones cross the Avenue in a straight line, and which also coincide with the phases of the lunar synodic cycle. Further, at both of these intersections which demarcate these three sections, northings and westings are combined at the jointing pairs of these Avenue turning points. Each of these four properties reinforces the others.

North adopted Thom andThom's method of considering the stones as points, claiming that looking south, North's section one of the Avenue (Figure 2) was aligned on rising Sirius and Rigel, and looking north from section seven on setting Capella. Accepting these alignments requires tolerating dates that span nearly six centuries, from 2320-1750 BC. Since the dates we have suggest the Avenue was built in the last quarter of the third millennium (Gillings and Pollard 2004: 76), these astral alignments are problematical and we will set them aside. For lunar alignments, across the Avenue in sections 6 and 7, he found alignments on the southern and northern minor standstill rises and sets combined with diagonal northings, and in his section 1 on the southern major standstill moonsets with diagonal westings. He argued that the builders had devised an ideal ratio of quadrangular pillar gap length to width of the Avenue which, when located close to the high ridge of Waden Hill, pulled-in the range of the moon's transit to allow combining it with cardinal alignments. He did not provide his data points for all possible combinations of paired and adjacent stones, and presented his results in a schematic way such that it is difficult to know pre-

1 This interesting suggestion still awaits a scholarly re-examination.

cisely which alignments for which stones were being claimed. North was cautious in his claims, noting that problems were posed by the accurate determination of stone positions after millennia of abuse, that the stones were too close together for accurate determination of sightlines, that we cannot be sure how they determined alignments across the different stone shapes, and that few stone tops cut the horizon to provide a precise horizon foresight (North 1996: 257). The caution was in keeping with the assumptions built into 'the Thom paradigm', which claims and expects very accurate astronomical horizon alignments. North was ambiguous in his engagement with 'the Thom paradigm' since, along with Burl and Ruggles, he also argued for a 'religionist' explanation of prehistoric horizon 'astronomy' that does not require extreme precision (Burl 1987; Ruggles 1999). He applied this second view to the West Kennet Avenue, and agreed with Keiller, Piggot, Smith and Burl that the claimed alternation in stone shape between pillar and lozenge fits a fertility theme of male and female, and this is consistent with the solely lunar set of alignments he found. But since no such alternation in stone shapes exists (Sims 2012) it removes or complicates such a proposal. Nor does it fit his main finding that an early Neolithic engagement with winter alignments on paired stars at the long mounds was superseded in the late Neolithic/EBA by monuments which paired lunar and solar alignments, not solely lunar alignments (North 1996).

The route out of these conundrums is through the detailed and correctly specified properties of the Avenue itself, combined with close attention to the assumptions of the models we are using. North showed that around 3,625BC the West Kennet Long mound allowed viewing from its northern ditch and looking south over the mound the star Sirius rising out of the burial chamber, apparently walking along the top of the mound, before sinking back into the mound as it set. In reverse direction and at an equal altitude when looking from the southern ditch, the circumpolar star Arcturus descends and apparently walks along the top of the burial chamber, and then rises up into the heavens (North 1996: 72-85). This is a 'religionist' appropriation of an axial connection between the underworld and the heavens at the point where the illustrious dead are 'buried'. A degree of accuracy is required to construct the illusion, but it is driven by a religious logic - not to meet the standards of some abstract prehistoric science[2]. If North is saying the West Kennet Avenue is a modified continuation of this tradition, then the fact that the closely spaced Avenue stones do not cut the horizon may be a problem for the Thom paradigm's predilection for accurate distant horizon markers, but it is an advantage for religiously investing them with their background horizon alignments on the risings and settings of cosmic bodies in their journeys into and out of the underworld. Further, to suggest each cell of four stones fitted an ideal quadrangle would see deviations from the ideal as 'error', and this would tie the method to one set of, in this case, lunar expectations. It would be a more robust procedure if we just let the data speak for itself and measure the significance if any of the actual Avenue stone's layout as it fails to meet hypothesized 'ideal' dimensions against their individual horizon effects. Instead of using the quadrangle as the unit of selection, we will use the stone pair, since this allows for changes in spacing along the length of the Avenue. To follow this procedure immediately leads to a very different appreciation of the data. The horizon aperture of closely spaced large stones whose tops coincide with the background horizon is large. The observer's eye might be looking from the left or right side of the back-sight stone and to the right or left of the foresight stone, and still the effect would be the illusion of a cosmic body emerging out of or descending into the top of the stone. But then, the religionist hypothesis predicts that this would be one 'astronomic' property the builders sought, so the large range afforded by closely placed stones for viewing such an effect would be *intentional,* albeit contrary to the expectations of the Thom paradigm. Viewing across the different sides of paired stones gives an average deviation of 11°, and for diagonals 5.5°. Since the angle of separation between solstice and standstill alignments is nearly 10° at a latitude of 51° 25′ N, we will use a margin of 5° as a criterion across stones to discriminate between particular alignments. And as the property of stone tops coinciding with the background horizon can be found for any of the ten possible combinations of adjacent stones for any pair of stones (Figure 3), by field survey we can calculate the combined effects of azimuth and horizon altitude for all ten of their possible combinations. The same bearings can be taken across concrete markers[3], and all are shown in Table 1.

Fig. 3 The ten possible orientations from any pair of stones to adjacent pairs

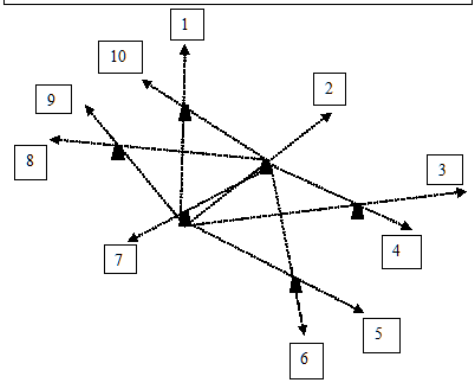

Figure 3. The ten possible orientations from any pair of stones to adjacent pairs

To find 167 alignments across 37 paired stones or their markers in ten differently aligned straight sections is beyond what we would expect by chance alone[4]. We can also apply a test for meaning of the lunar-solar conflation model of the West Kennet Avenue, compared to tests for the null hypothesis, by theoretically sampling the local landscape as a region of alternatives. What is very interesting about the West Kennet Avenue is that by crossing the valley it hugs close to steep local horizons on one side of its route. After descending from the 'start' of its route from the Sanctuary it has a high horizon of about 5° to the northeast and a low horizon of about 1.5° to the southwest, and at its 'end' along the section we have studied it has a high horizon of about 7° to the west and a low horizon of about 2° to the east. If the builders had chosen other routes through the valley, it could have been arranged for either equal altitude horizons of about 2° either side of a middle route through the valley, or it could have reversed the 'gearing' of horizon altitudes either side of stones 37-1 with 7° to the east and 2° to the west for a route along the

2 This is not to say that a religious logic cannot release a dynamic which might later become 'abstract'.

3 If this procedure is accepted, it would also allow a prediction as to the height of the missing stones.

4 If we round the average of each Avenue section to four paired stones, on average they generate nearly 37 possible alignments each, taking into account the two end pairs smaller number of possible alignments. As each alignment span is 5°, the two central pairs could possibly converge with alignments that cover a total range of 80° (12 lunar-solar and 4 cardinal) and the two end pairs a range of 60°. An average total range of 76° gives a 76/360, just over one fifth, chance of hitting an alignment by chance. But since 16.7 average alignments are found for each of the ten sections, rounded to 17, this signifies that we have found 17 actual alignments out of 37 possible – just under one half. This is far more than can be accounted for by accident alone.

Comb:	1	2	3	4	5	6	7	8	9	10
Pair										
1								NMajS		
2			SMinR					NMinS		
3				SMajR		South	SMinS			NMajS
4		NMinR	South				WEST			NMajS
5			SMajR			South		North		
6	North						WSS	NMajS		
7		SSR		WSR	WSR		SMajS	West	NMinS	NMinS
8			East	SMinR	SMinR				SSS	SSS
9			East	SMinR	SMinR		SMajS	West	NMinS	SSS
10				WSR	SMinR		WSS		SSS	SSS
11			East		WSR		WSS		SSS	SSS
12			East	SMinR	SMinR		SMajS	West	SSS	SSS
13				WSR	SMajR		SMajS	West	NMinS	NMinS
14		NMajR		WSR	WSR		SMajS	West	SSS	NMinS
15		NMajR	East				WSS	West	NMinS	NMinS
16		NMajR				South	WSS	West		
17	North	NMinR	SMinR	SMajR	SMajR	South			SSS	
18	North	NMinR	SMinR			South			NMajS	NMajS
19	North	SSR						NMinS		
20	North	SSR	SMinR			South	SMinS	NMinS	NMajS	
21	North	NMinR	WSR	SMajR		South		NMinS	NMajS	
22	North	NMinR	SMinR			South		SSS	NMajS	
23	North	NMinR	SMinR			South		SSS		
24	North	NMinR	SMinR					NMajS		
25		NMinR	SMinR					SSS		
26		NMinR	SMinR					SSS		
27		NMinR	SMinR					NMajS		
28	North	NMinR	SMinR					NMajS		
29	North	NMinR	WSR					SSS		
30	North	NMinR		SMinR				NMinS		
31			WSR					SSS		
32		NMinR						NMajS		
33	North	NMinR	SMinR					NMinS		
34	North	NMinR	SMinR					NMinS		
35					SMajR			NMinS		
36	North	NMinR	SMajR	SMajR				SSS		
37	North	NMinR	SMinR	SMajR	SMajR			SSS		

Table 1 Alignments of West Kennet Avenue stone pairs 1-37 with adjacent and opposite stones. Note: For any pair of stones with adjacent pairs on either side, the ten possible combinations of pairings from the central pair to all six stones are shown in Fig. 2. These combinations are numbered clockwise 1-10 as azimuths from North starting at the northern diagonal and are the column headings in this table. The row headings identify the number of the stone pair positions 1-37. The azimuth bearings for zero horizon altitude at this latitude of 51° 25′ N for lunar standstills, the sun's solstices and cardinal alignments (not to be confused with equinoxes) are: North 0°/360°; Northern Major standstill moonrise (NMajR) 40.5°; Summer Solstice sunrise (SSR) 48°; Northern Minor standstill moonrise (NMinR) 59°; East 90°; Southern Minor standstill moonrise (SMinR) 121°; Winter Solstice sunrise (WSR) 129°; Southern Major standstill moonrise (SMajR) 141.5°; South 180°; Southern Major standstill moonset (SMajS) 218.5°; Winter Solstice sunset (WSS) 231°; Southern Minor standstill moonset (SMinS) 239°; West 270°; Northern Minor standstill moonset (NMinS) 301°; Summer Solstice sunset (SSS) 312°; Northern Major Standstill moonset (NMajS) 320.5°.

eastern side of the valley. The significance of these landscape properties for 'astronomical' alignments is significant, since by choosing one particular route they selected for a particular portfolio of possibilities. For every 1° increase in horizon altitude, the azimuth of any particular rise or set position at this latitude (51° 25′ N) is reduced by 2°. Therefore an eastern horizon of 2° will reduce risings by 4° and a western horizon of 7° will reduce settings by 14°. A gearing in azimuths of 10° between western and eastern horizons either side of the Avenue matches approximately the difference in azimuth between lunar standstill and the sun's solstice alignments. This provides the opportunity to have paired reverse linear alignments with a solstice alignment in one direction and lunar standstill alignment in the other. Columns 2 and 7 in Table 1 show that the builders chose *not* to utilize this given property of the local landscape for all but one case. They selected for alignments on cardinal directions on one set of diagonals (Cols. 1 and 8 in Table 1), lunar and occasionally solar directions on cross pairs and the other set of diagonals (Cols. 2, 3, and 7). The meaning behind these alternatives is that a reverse pairing of lunar standstill and a solstice alignment predictably

generates a full moon to coincide with the solstice sun, whereas a paired alignment of identity in which both sun and moon alignments are along the 'same' alignments predictably generate a dark moon to coincide with the solstice sun. Instead, as we will see below, the builders chose to use the same property of the horizon gearing of alignments to partition combined alignments on moon, sun and cardinality according to handedness, direction of travel and sight of the destination monument.

Whatever the route, the large number of alignments we have found supports our initial hypothesis that processions did take place from outside, not inside, the Avenue. The alignments are not just lunar, but lunar-solar – there are 96 alignments on lunar standstills and 36 on solstices. This is consistent with our prediction that lunar alignments alone are insufficient to specify a dark moon ritual (Sims 2007). The Avenue is partitioned at exactly the sections we predicted by a switch from northings to westings at full moon positions 15-17 and from westings to northings at last quarter moon at positions 5-7 respectively, also confirming our hypothesis that a system of lunar numeration by stone position was being followed by the builders. This is reinforced by the *combination* of northings and westings at the 'focal pairs' of these partitions.

The lunar-solar alignments are settings and risings, but they themselves are partitioned according to the Avenue lunar phase section. Walking north or south and looking forwards or sideways *but not backwards* along either side of the Avenue, each of the ten columns in Table 1 show where the sun or moon can be seen to rise or set in each of the stone tops to the side, diagonally or in front of the viewer from an adjacent stone. Walking north from stone pair 37 the Avenue can be walked from either side viewing rising or settings (Columns 1, 2 and 8), but only up to full moon markers between stone pairs 13-17. Once past this point the Avenue can only be walked northwards on the eastern side viewing settings alone (Columns 7-10 but not Columns 1 and 2). Contrarily walking south from stone pair 7[5] to the full moon markers the Avenue can be walked from either side viewing risings and settings (Columns 3-5 and 7), but once past the stone pairs 13-17 only risings alone can be seen when walking on the west side of the Avenue (Columns 2 and 3 but not Columns 6 and 7). Therefore when walking north from full moon positions 15-17 in the final approach to the dark moon ritual at the henge we see the paired settings of winter solstice sunsets and the southern major standstill moons, and when walking south from the same point towards the Sanctuary circle we see the paired risings of winter solstice sunrises and the northern and southern minor and major standstill moonrises. Both pairing arrangements, alignments of identity, prescribe dark moon rituals at winter solstice sunset and sunrise twice every nineteen years at the circles either end of the Avenue.

The only place where there is a reverse alignment in a single line on a solstice and standstill is in the stone pairs 15 and 16. We already deduced by numeration that this was the area of the Avenue signifying the three or so days of full moon. We now find by alignment that this is the only area where a standstill moonrise is paired in a reverse alignment a solstice sunset (Columns 2 and 7 by Rows 15 and 16). This combination generates full moon in mid winter once every nineteen years. We have now confirmed by numeration, landscape phenomenology and archaeoastronomy that the Avenue is following a lunar partitioning displaced onto a solar timescale.

The dark moon position 30b is also 'astronomically' marked in a special way. It can be seen in Table 1 that either side of position 30b, at stone pairs 31 and 29, there are reverse diagonal alignments on winter solstice sunrise and summer solstice sunset (Columns 3 and 8 by Rows 31 and 29). This arrangement occurs nowhere else along the Avenue. By the use of diagonal reverse alignments to negate the gearing of opposite horizons at these points of the Avenue, the builders have emphasized either side of position 30b that the year turns around the point of dark moon.

We have found that the West Kennet Avenue was a changing vista of stones across which pairs and diagonals were optimally arranged for their tops to be level with their background horizons at points which coincided with the rising and setting solstice sun, standstill moon and cardinal directions. For the sun and moon to be seen setting into a stone top which is also in line with the background horizon suggests another property. For any participant in a ritual along the Avenue to see the sun or moon setting into a stone whose top is in line with the background horizon, then by their agency the only conclusion they can draw is that the stone now endowed with the presence of the sun or moon below the horizon is, as they are, in the underworld. These arrangements allow the stones to be constructed as portals to and from the underworld. It has been shown that exactly the same artifice was used by the monument builders in their arrangement of the both the Beckhampton and West Kennet Avenues views of Silbury Hill (Sims 2009a).

Remains of boys and men, some of whom bear ante-mortem long bone cut-marks and post-mortem violent symbolism (Smith 1965: 209-10), are located along stones which are not associated with full moon or gibbous waning moon – namely the times when moon transits through the night-time sky – but with dark moon, waxing new moon, and waning crescent moon[6]. All of the complete skeletons are on the north-east side of stones between stones18-29, and along that part of the Avenue we have found that when walking south it can only be walked on the west side to view winter solstice risings and southern minor and major standstill moonrises. Handedness is therefore built into the ritual procession, where blood, death and resurrection are on the left side of those processing towards the Sanctuary (Hertz 1960). This suggests a categorical distinction between monuments linked to a processional round, in which winter solstice *sunset* dark moon rituals were conducted at the Avebury Circle and, once completed there, the West Kennet Avenue provided the link to winter solstice *sunrise* dark moon rituals to stage the next part of this cosmology at the Sanctuary. Rather than serving a calendrical function this monumental design emphasizes a ceremonial round alternating between solstice dark moon death and resurrection rituals.

These interpretations of the ethnographic meaning of the West Kennet Avenue have been reached by considering evidence from archaeology, archaeoastronomy and landscape phenomenology. These three disciplines have not been triangulated but integrated by finding what new properties emerge when we test them against alternative structures that could have been made by the builders within the same landscape. By considering landscape, material culture and skyscape as coupled systems, and by theoretically sampling how they might have been combined, it is

5 The section from pair 7 to pair 1 poses particularly difficult field work problems. Half of it was nearly completely destroyed by the modern road, the henge bank horizon was modified in the late eighteenth century, and we only have Keiller's incomplete excavation notes to go on. See Sims 2010 for a treatment.

6 Of course waning crescent moon cannot be observed for the first half or more of the night.

possible to discriminate between the models researchers are presently using to interpret unique prehistoric monuments such as the West Kennet Avenue. This has allowed us to cancel many of the anomalies in present archaeological models for the Avenue by one over-arching model of lunar-solar conflation. By my count 14 design details of the West Kennet Avenue, which are anomalies for the extant models, are cancelled by the model of lunar-solar conflation: processions outside rather than inside the Avenue; stone tops coinciding with background horizons; stones missing by design; burials cross-cardinally aligned; zigzag cardinally aligned flints focused on a gap in the Avenue; avenue partitions marked by three in-line stones that cross the Avenue; an Avenue that clings close to local high horizons; stone heights installed as a section to match local horizons; a route that synchronizes with lunar partitions to descend when approaching dark moon signifiers; points of equal horizons across Avenue stones chosen as partition breaks; the use of 'handedness' to signify ritually marked experience; Avenue direction changes synchronizing with lunar phase; northings and westings combined at the linking pairs between partitions; alterations in Avenue cell dimensions departing from some imposed 'ideal'. These 'anomalous' details can all be explained by a religionist archaeoastronomy of lunar-solar conflation.

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Archaeoastronomical Study of the Iberian Peninsula's Iron Age: Relationship between Urnfield and Celtiberian Necropolis

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Abstract: This work explores the astronomic relevance in Iberian Peninsula's Iron Age. Specifically we study Celtiberian necropolis in relationship with Late Bronze Age's cremation necropolis. We are interested on as much Iron Age necropolis possible orientation as astronomical reflections of cultural change from Bronze to Iron Age. Archaeoastronomy so far have no paid attention on Iron Age, as an example, in Spain only the 3% (Cerdeño et al. 2006) of the total archaeoastronomical studies are about Iron Age period. Undoubtedly it is important to fill this gap in order to get continuity in ancient knowledge. In this paper we will focus on the north-eastern part of the country. n this area, covering Catalonia, Valencia and Ebro Valley nowadays, appears the urnfield civilization in 12th century B.C.E. This represents the substrate for Iberian Preroman peoples. Examples of archaeological sites of this period are Can Bech de Baix (Gerona), Can Piteu-Can Roqueta (Barcelona), Molá (Tarragona), Can Missert (Tarragona), Les Obagues (Tarragona), La Colomina (Lleida) and La Torraza (Navarra). In the Iberian Peninsula's Iron Age we have studied the Celtiberian people. Probably one of the most cited Iberian pre-roman people on classical texts. For the Romans in this period celtiberians were the peoples that lived in Iberian mountainous range, this compiles several native tribes as Arevacos, Pelendones, Lusones, Belos and Titos. Celtiberians were famous in antiquity because of their war abilities against roman army and its high quality swords, made of flexible and resistant blades forged in iron that was managing to be real steel. Examples of archaeological sites of this period are Numancia (Soria), Bílbilis (Zaragoza), Segeda (Zaragoza), Tiermes (Soria), El Ceremeño (Guadalajara) and Los Rodiles (Guadalajara). Celtiberian was one of the most important pre-roman peoples in Iberian Peninsula, inheritors, in any way, of Bronze Age cultural heritage. So, the aim of this study is investigate the Late Bronze Age and Iron Age astronomical connections to funerary world and know if they are linked somehow. To do this we have treated several excavation maps and other types of data for each site, we seek angles to relate them to astronomical events linked to each culture's religious and ideological world. Besides all this we do a reflection about the treatment of geographical data in archaeology in order to avoid past errors can be perpetuated. We think that a standardization of geographical data acquisition will improve these types of studies in future.

Keywords: Iberian Peninsula, Iron Age, Unrnfield culture, Celtiberian necropolis, funerary world, arcaheoastronomy

Introduction

Traditionally archaeological research has been widely focused in material record. Thus is highly common see all kind of studies: typological, scattering, equivalents search and so on. Only in the last very few years appears a true interest to study sites geographically. Obviously the appearance and development of Geographic Information Technologies (GIT) helped to this interest. As reaction of these new techniques, archaeologists started to increase geographical studies in their new projects.

Unfortunately this situation gave us a range of important sites -studied in early years- with poor geographical data in better cases. Focusing in our purposes is very usual having very detailed lists of which material appeared in each tomb but nothing related to its spatial position.

Besides to this problem we have the reality that Iron Age's studies in Archaeoastronomy are very far from being comparable to another cultures and epochs, especially in Spain (Cerdeño et al., 2006).

Culturale Framework

Urnfield culture rises on 13th century B.C.E. in middle-eastern Europe and the north of Italy moving gradually over Europe (Ukraine, Sicily and across France Iberian Peninsula) probably running away from other peoples. They were an agricultural and ranching people, with no shipping knowledge. We can talk already of its presence in Iberian Peninsula since 12th century B.C.E. covering basically the north-eastern quadrant of the peninsula. We can mention as sites of this period Can Bech de Baix (Girona), Can Piteu-Can Roqueta (Barcelona), Molá (Tarragona), Can Missert (Tarragona), Les Obagues (Tarragona), La Colomina (Lleida) and La Torraza (Navarra).

We could fill many pages about this culture but it has no sense here. For our study will be just necessary to highlight one of the most representative features of these peoples, their new burial way. It consists in urn cemeteries –urnfields- with cremated remains. Cultural and ritual changes make the Urnfield culture a key civilization to understand later historical processes; in particular, its high influence on the Iron Age.

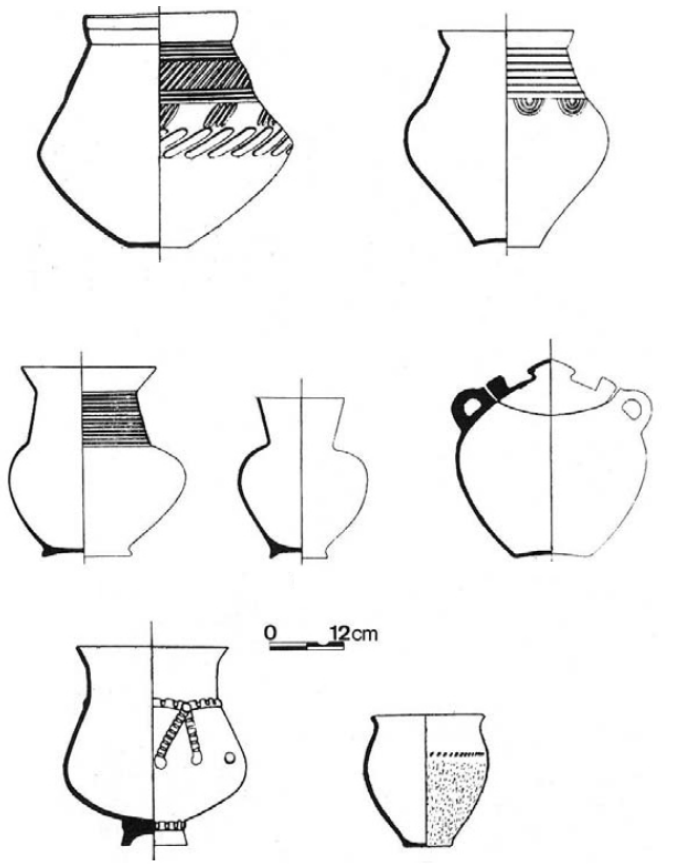


Fig. 1 Main types of urns for southern Catalonia necropolis (Adapted from Almagro 1977).

The first time that we have an explicit reference of Celtiberia is in a Livy text: *«You have spent time enough in hunting cattle on the barren mountains of Lusitania and Celtiberia, and finding no recompense for all your toils and dangers»* (LIVY 21.43.8). In these lines we can see for first time Celtiberia as a different region apart from Lusitania but we have several meanings of Celtiberia in bibliography. But we have other meanings of the word Celtiberian, in 3rd century B.C.E. this term is equivalent to Spanish Celts opposite to other Celtic groups as Gauls for

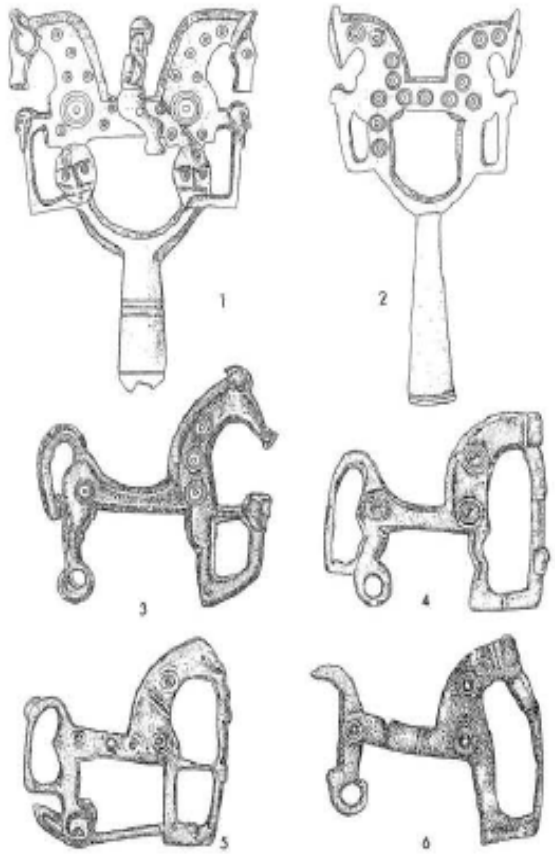


Fig. 2 Signa equitum from Numancia (1, 2) and fibulae from the necropolis of La Osera (4), Arcóbriga (5) and Las Cogotas (6). 3 come from the Barcelona museum. Men's trophy heads can be seen. (Lenerz-De Wilde 2000-2001)

example. But we will use, as usual in current scientific research works, the sense that Roman army gave in 2nd century B.C.E.

Their religion had many common points with Celtic religion; but we can highlight some point for this work. We can read in Strabo the Moon importance between the Celtiberians:

«…Some say the Callaicans have no god, but the Celtiberians and their neighbours on the north offer sacrifice to a nameless god at the seasons of the full moon, by night, in front of the doors of their houses, and whole households dance in chorus and keep it up all night… » (Geography, III, 4, 16)

This nameless god would be The Moon whose name was taboo (Sopeña 2005), but there is another clear reference to celestial bodies, the Sun. We can cite here two pieces found in Celtiberian sites. A sword in iron, silver and bronze found in the necropolis of El Altillo de Cerropozo, Atienza (Guadalajara) decorated with several solar circles (Sopeña 1995, Fig. 37). The second relevant piece is a shield found in Griegos (Teruel) and that can be seen now in Museo Arqueológico de Madrid, decorated with solar symbolism. (Sopeña 2005, Fig. 16).

Celtiberians never formed a state; they only made several war coalitions to defeat another tribe or a common enemy as happens against roman conquest. Between these tribes we know mainly Arevacos, Pelendones, Lusones, Belos and Titos.

Both cultures were no coetaneous but share some of their territory as can be seen in map bellow. Anyway, is doubtless that Celtiberian people, as many other pre-roman peoples in Iberian Peninsula, had cultural bounds to Urnfields culture.

GEOGRAPHICAL FRAMEWORK

Historical territory of Celtiberia covers 61,643 km^2 and spreads nowadays by Autonomous Communities of Aragon, Castilla-La Mancha, Castilla-Leon, Navarra and La Rioja, covering the basin of Ebro, Duero and Tajo Rivers. In present, this area is one of the most economically depressed and uninhabited areas in Spain. Urnfield cultures in our study spreads Catalonia, Valencia and Ebro Valley nowadays (see figure 3).

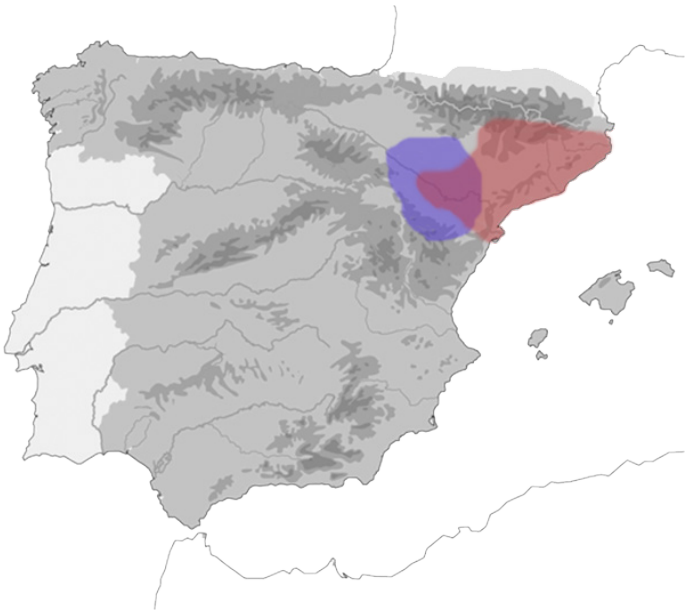


Figure 3. Area of Study. In red Urnfield culture and Celtiberian culture in blue.

This represents one of the natural paths of communication of the Iberian Peninsula that will carry materials and ideologies between inner and coastal peoples.

DATA

Besides Late Bronze Age sites, we took into account the next Iron Age's necropolis:

Protoceltiberian sites: Almaluez, Deza, Escobosa de Calatañazor, Valdenarros, Vinuesa, Clares, Garbajosa, La Hortezuela de Océn.

Protoceltiberian-Celtiberian sites: Alpanseque, Castilfrío de la Sierra, La Mercadera, Montejo de Tiermes, Ucero, Aguilar de Anguita, Alcolea de las Peñas, Alcuneza, Atienza, Carabias, Chera, Hijes, La Olmeda de Jadraque, Ruguilla.

Celtiberian sites: Blacos, Catalañazor, Garray, Gormaz, Izana, Langa de Duero, Layna, Monteagudo de las Vicarías, Montuenga, Ocenilla, Osma (Uxama), Osonilla, Quintanas de Gormaz, La Revilla de Calatañazor, Taniñe, Torlengua, Valdejeña, Ventosa de la Sierra, El Atance, Luzaga, Luzón, Riba de Saelices, Tordelrábano, La Torresabiñán.

In total 57 sites were studied involving several thousands of tombs. We worked over excavations archaeological maps, referencing them –when possible- to known spatial references in order to make a local framework of reference. Next step was adjusting tombs coordinates by linear fit and finally get the azimuth angle of the major direction of the necropolis. In some way we tried to follow the methodology followed by Rodríguez-Caderot et al. (Rodriguez-Caderot et al. 2006), sadly in our case the data were no collected by us in any case and obviously were no collected by Global Positioning Systems or other modern surveying data techniques.

Thus, being the data processed in this way we can obtain a list of values for the azimuth angle for each site.

Related to astronomical data as can be seen in Tables 1 and 2, we calculated the Azimuth and Declination angles for Lunar Major Standstill in rise and set and the Azimuth angle for winter and summer Solstice rise and set. These astronomical events have been chosen for several reasons. Is well known for Celtiberian people a religious pattern related to sun and moon, in particular full moon and lunar major standstill. So, it seems reasonable to stress attention in most interesting events of these celestial bodies all over the year.

LUNAR MAJOR STANDSTILL			
AZIMUTH		DECLINATION	
RISE	SET	RISE	SET
90º 1'	206º 31'	28º 42'	28º 42'

Table 1. Azimuth and Declination angles for Lunar Major Standstill in rise and set.

WINTER SOLSTICE		SUMMER SOLSTICE	
AZIMUTH		AZIMUTH	
RISE	SET	RISE	SET
91º 20'	209º 18'	26º 39'	272º 47'

Table 2. Azimuth angle in winter and summer solstice in rise and set.

Results

Any result show here must be taken in context. As we said before we have a very heterogenic amount of data, in many cases taken from compilations made by other authors. Taking all this into account and looking at the list of azimuth angles we can assume that Iron Age's necropolis seems not to be aligned to astronomical events studied here. The range of azimuth values goes from 200º to 340º with no correlation with solstices or major lunar standstill. No relationship with Late Bronze necropolis is seen neither.

In the other hand we have some peaks near to 320º in azimuth that also appears in Late Bronze necropolis.

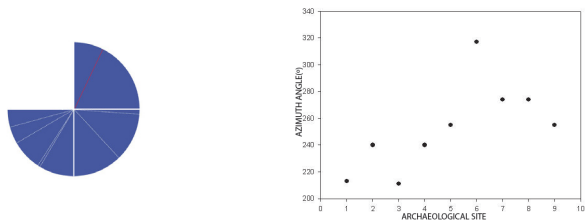


Figure 5. Left, diagram of Azimuth angles scattering. It can be seen in relationship with the azimuth of set in summer solstice (red). Right, correlation between azimuth angles for some archaeological sites.

Conclusions

Maybe, the clearest argument we can give to the situation of geographical studies in archaeological data so far can be seen in diagrams bellow. If we take the whole amount of archaeological sites we have studied in this work, the 82 % of them are useless, i.e. we found no topographical records. From the remaining 18 %, only the 8 % had useful data for our study. Many of them were bad drawn maps or bad referenced maps.

Related to cultural sample we can see, that archaeologically talking, more attention is put in Iron Age's sites than Late Bronze Age ones: 86.79 % opposite to 13.21 %.

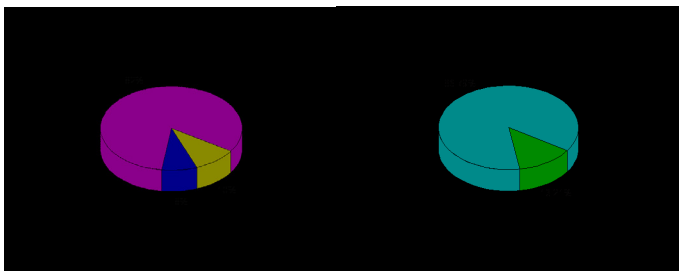
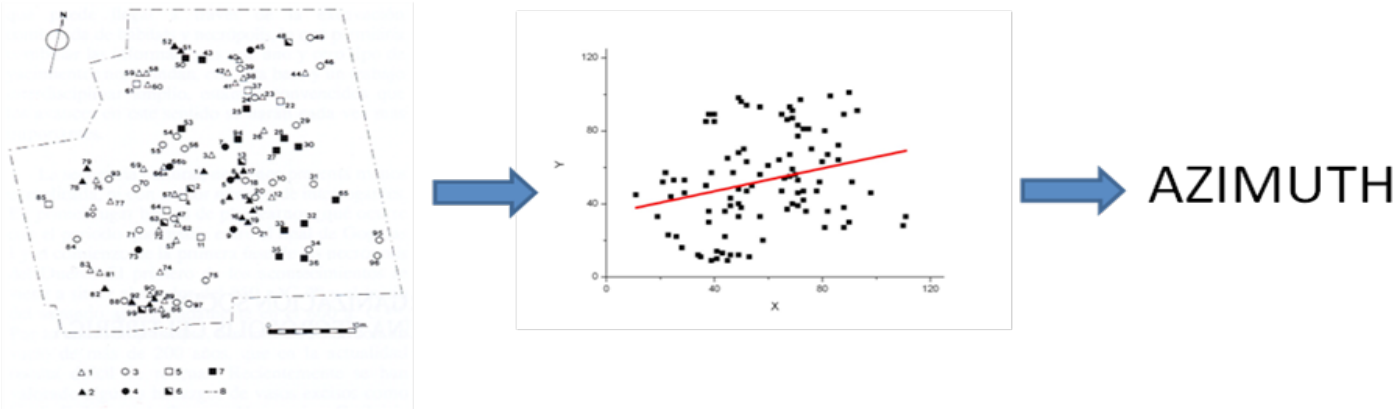


Figure 6. Left, percentages of useful sites. Right, sites percentages attending to their epoch.

Thus, will be necessary in further studies remove this bias produced basically by late publication of site's works. There is no doubt that there is more bibliography related to Iron Age's archaeological sites. Also a methodological standardization for topographical studies in archaeology would be desirable. We could think this is a thing from past studies, with older work methodologies but it is no like this. It is very common seeing in bibliography bad referenced excavations maps or erroneous setting of the north position.

Figure 4. Data processing



Following with our study we have no evidences of lunar or solar orientations in necropolis, we will check for another stellar objects and asterisms in order to find explanations to some picks that appears in Iron and Bronze Ages. Thus, lunar orientations appeared in El Ceremeño (CERDEÑO ET AL. 2006) seems to be an extraordinary case.

Anyway, and unfortunately, there are too many variables and uncertain in this case to make a definitive and direct rebuttal of El Ceremeño results.

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Risings and settings of stars: the case of Hesiod's calendar and the star Spica

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Abstract: A program for estimating the heliacal risings and settings of stars (Schaefer, 1985) has been modified in order to include also the estimate of their acronychal (or cosmic; Kelley & Milone, 2005) risings and settings. The consistency was then verified of the Hesiod's calendar (Ἔργα καὶ ἡμέραι = Works and Days) with the heliacal and acronychal phenomena referred to Bœotia during the 8th century BCE and with the past agricultural techniques. We considered in particular the harvest times of cereals, which, according to Hesiod, were indicated by the Pleiades (harvest) and by Orion (thresh). The large time separation by several tens days between harvest and thresh was a common characteristic of the ancient cultivation of barley and wheat in the Near East (Levant, Mesopotamia). We tried to verify which heliacal or acronychal risings and settings of the brightest stars could be used as indicators of harvest and thresh in the previous millennia in such regions. During the 9th millennium BCE there was essentially one bright star which could be used both for the harvest (heliacal setting of the star) and for the thresh (heliacal rising of the star): Spica, i.e. ear (in Latin) of wheat, barley or other cereals. According to archaeologists, the domestication of barley and wheat occurred in Near East at the end of the 9th millennium BCE. Given the importance of the bright stars and asterisms for ancient farming activities, we propose therefore that the identification of the star α Virginis with an ear should date back to the beginning of Neolithic, possibly well before the identification of the constellation (Virgo) with a maiden.

Keywords: Star phases, software, Hesiod's calendar, Spica, asterism of a maiden, 9th Millennium BCE

Introduction

The change from the life of hunters and gatherers of Palaeolithic to that based on farming activity of Neolithic represents an extraordinary revolution in the human history. It is actually in the Neolithic that we find the roots of the present state of the human race, not only in its domination and exploitation of the environment, but also in the very foundations of our culture and mentality (Cauvin, 2000). During the Neolithic our ancestors understood the close relation between the times of the celestial phenomena (calendar) and the effectiveness of the agricultural techniques. The risings and settings of stars, along with the Sun and Moon, were used to determine the dates of the farming activities. An historic example is given by the ancient poem Ἔργα καὶ ἡμέραι (Works and Days) of Hesiod (8th century BCE), in which stars and asterisms such as Arcturus, Pleiades and Orion were adopted to indicate the dates of the various activities along the year.

The name of the star α Virginis = Spica, i.e. ear in Latin, is suggestive of a possible relation with the farming activities related to harvest in spring/summer, but if we consider the presumable farmer calendars of the past few millennia and the dates of the heliacal rising and setting of Spica, such a name does not seem to be justified. In fact, at mean latitudes, the dates are in the period between november (rising) and september (setting), and the star is not visible during about fifty days between september and november. Here we will try to discuss this curious case, and we will propose a possible solution using as a reference the poem of Hesiod.

Estimate of the dates of risings and settings

There are some possible misunderstandings related to the different meaning of heliacal, acronychal (or achronic, achronal, achronical) and cosmical (or cosmic) risings and settings of stars adopted by different scholars, as discussed by Kelley & Milone (2005). We will adopt the following definitions. Heliacal rising of a star is when it rises just before the sunrise, and heliacal setting when it sets just after the sunset. Acronychal rising of the star is when it rises just after the sunset, and acronychal setting when it sets just before the sunrise.

Schaefer (1985) proposed a computer program for estimating the date of the heliacal phenomena. This was an objective and more scientific approach with respect to previous works. However, the model is not free of some arbitrariness in the choice of the parameters such as visibility conditions, magnitude limits and sky transparency, when it is applied to the sky of some millennia ago in some remote place, for which the true conditions are not known. Therefore the estimated date must be considered in any case as an approximated one. We have rewritten the program in order to include also the acronychal phenomena (for the problems of the acronychal risings, see Schaefer, 1987). We adopted the photometric conditions, stellar visibility conditions and solar longitudes (present solar year) defined by Schaefer. A better sky brightness model based on the data of Koomen et al. (1952) was introduced by using the methods of the statistical regression analysis. The coordinates of the star corrected for the precession were given as input, while the number of days elapsed from the spring equinox was the output. We plan to improve the program in the future by adopting a longitude of the Sun depending on the epoch, and a better model for the precession.

The calendar

Analysis of Hesiod's calendar were performed by several authors, such as Schiaoarelli (1892) and Aveni (1989). However, Aveni did not discriminate between heliacal and acronychal phenomena, so a reader may have some difficulty in understanding his results. Here we discuss the results of our program when applied to that calendar. Hesiod declares: Πληιάδων Ἀτλαγενέων ἐπιτελλομενάων ἄρχεσθ᾽ ἀμέτου (*When the Pleiades, daughters of Atlas, are rising, begin the harvest*). At the mid 8th century BCE in Bœotia, the heliacal rising of the Pleiades (assuming a magnitude 2.0 for the cluster; e.g. Schaefer, 1987) occurred about 47 days after spring equinox (Figure 1), which corresponds approximately to the first week of May in the present day calendar. We adopted a mean latitude of 38 degrees for Bœotia (Figure 2). Hesiod did not specify

Fig. 1. An illustration of heliacal rising: the Pleiades in the 8th century BCE (simulation with the program STELLARIUM; the program was used only for creating nice astronomical images).

the nature of the cereal, whether barley or wheat; this has some importance since barley ripens before wheat. However, one should note that harvest usually begun when the cereal (particularly barley) was still green, in order to avoid the loss of grains, and the ears were collected in sheaves and carefully guarded till complete drying. In Mesopotamia, owing to the poor nature of soils, mainly barley was cultivated; in other regions both barley and wheat were grown, and this could be the case also of Bœotia.

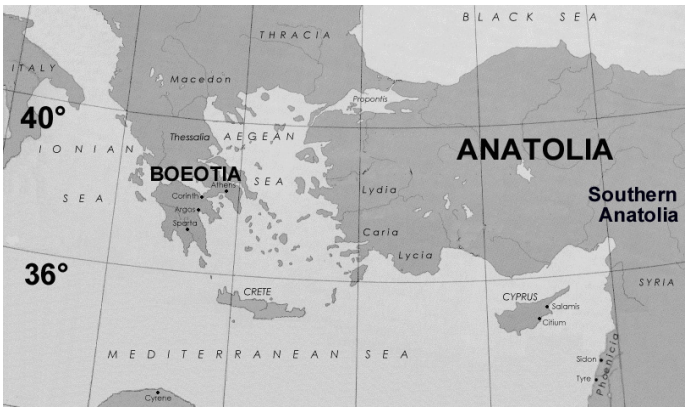


Fig. 2. The latitude of the regions of Bœotia and of Southern Anatolia.

According to Hesiod, threshing and winnowing in Bœotia begun when Orion risen: δμωσὶ δ᾽ ἐποτρύνειν Δημήτερος ἱερὸν ἀκτήν δινέμεν, εὖτ᾽ ἂν πρῶτα φανῇ σθένος Ὠρίωνος (*Set your slaves to winnow Demeter's holy grain, when strong Orion first appears*). The heliacal rising of the first bright stars of Orion, such as Bellatrix, occurred about 85 days after spring equinox, which corresponds approximately to mid June in the present day calendar. That is, the thresh was more than a month (about 40 days) after the harvest. This could be a bit surprising since today we are familiar with farming machines which both harvest and thresh simultaneously, i.e. they cut the dried wheat and separate the grains.

An interesting confirmation of the time separation between harvesting and threshing in the past millennia can be drawn from the biblical book of Ruth and the Hebraic traditions. According to the Bible, Naomi and Ruth arrived in Bethlehem from Moab at the time of barley harvesting. That was around Pesach, usually in April (present day calendar), that is, quite early; the different date from the one for the harvest in Bœotia could be explained by the different latitude. Ruth gleaned after the harvesters with the maiden of Boaz for several days until the end of the harvest of both barley *and* wheat. After some time, Naomi talked to Ruth about the foreseen threshing and winnowing in the threshing floor of Boaz. This was also the occasion for a feast, and all the activity regarding barley and wheat should have been finished before Shavuot, that is fifty days after Pesach.

Spica

Pleiades and Orion could have been probably used as indicators for harvesting and threshing in Bœotia for several centuries during the 1st millennium BCE. Owing to the precession, however, other stars should have been adopted before and after that epoch. The question now is whether and when Spica (Figure 3) could have been one of such stars. We got a very interesting indication from the program. During the second half of the 9th Millennium BCE it would have been possible to use just α Virginis for both harvesting and threshing, since the date of its heliacal setting was about 47 days after spring equinox, and the date of its heliacal rising was about 85 days after spring equinox. Probably this is not a significant result for the prehistory of Bœotia, since the 9th Millennium BCE appears a too early epoch, however it could be of some importance for other regions in the Near East.

The latitude of central Bœotia is about 38 degrees, which is also the latitude of Southern Anatolia (Figures 2 and 4). It is not possible to know exactly the ancient climate in the two regions, and today the climate in Southern Anatolia is presumably more arid than several millennia ago, when this region was part of the Fertile Crescent. We presume a similarity of climate between the two regions in past millennia. According to this hypothesis, the times of the harvest and thresh should have been approximately the same both in Bœotia and Southern Anatolia. On the second half of the 9th Millennium BCE (calibrated radiocarbon dates) there was not yet a developed agriculture, though the process of the domestication of cereals was taking place in the Fertile Crescent (see e.g. Cauvin, 2000). Seeds of domesticated cereals were found for example in Pre-Pottery Neolithic A and Early B villages of Southern Anatolia (Figure 4) such as Çayönü and Nevali Çori (Nesbitt, 2002; about 8th Millennium BCE, uncalibrated dates), and wild cereals were cultivated quite earlier at lower latitudes in the Jordan valley. We could think therefore that people in the Near East found the best dates for harvesting and threshing at the beginning of Neolithic, and associated such dates with the star α Virginis, which was consequently identified with an ear, Spica.

It is interesting to remark the difference of some weeks for the harvest between the Hesiod's calendar and the Hebraic traditions (which were based however on a lunar calendar), that could be explained by the different latitude, i.e. different insolation conditions, and climate. Roughly speaking, we can note a sort of a correlation between the date of the heliacal setting of Spica, the latitude and the epoch. An earlier

Fig. 3. The Virgo constellation and the star Spica (simulation with the program STELLARIUM).

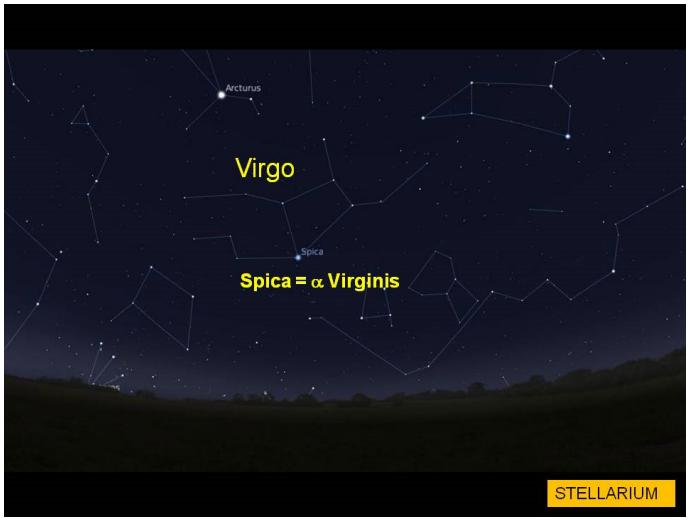
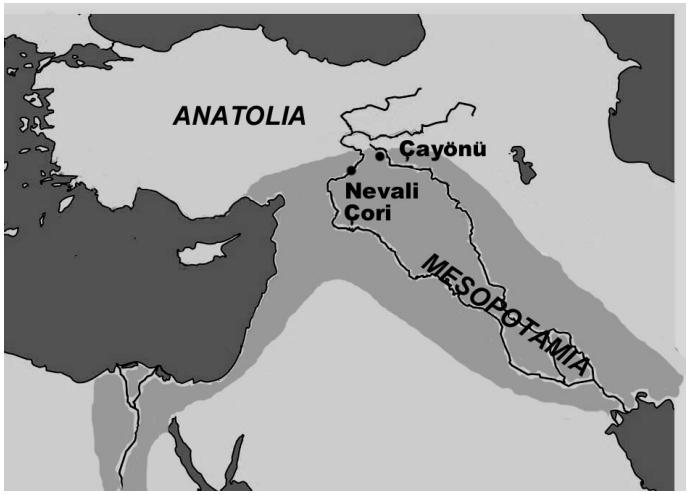


Fig. 4. The light grey area in the map represents the Fertile Crescent. The latitude of the Neolithic sites of Nevali Çori and Çayönü is about 37 and 38 degrees, respectively.



date could have been valid for harvesting at a lower latitude in an earlier epoch, such as mid-April in Palestine on the 11th Millennium, and a later date for harvesting at a higher latitude in a later epoch, such as beginning of May in Southern Anatolia on the 9th Millennium. The progressive change of the date with the epoch is due to the astronomical precession. The setting of Spica could have been used as an indicator for harvesting also at a very late epoch, about the 5th Millennium BCE, in central Europe (latitude of about 50 degrees), right at the beginning of the Neolithic civilization in that European region (Antonello, 2009). This is a reasonable estimate if we take into account the present day farming activity dates at such northern latitudes. Given a possible importance of Spica for the agriculture, one could wonder whether the effect of the precession on this star may have also played some role in the diffusion of the Neolithic civilization (for the problem of diffusion in Neolithic, see e.g. Cauvin, 2000).

As a final check we have verified which stars brighter than the magnitude 2.0 could be used instead of α Virginis during the 9th Millennium BCE at a latitude of about 38 degrees. We considered a period of one week before and after the given dates, that is for example from 40 to 54 days after the spring equinox as a useful time in the case of harvesting. This time interval includes the date of the heliacal rising of just one star, ε Ori, but it should be practically excluded since the declination is less than –40 degrees, that is its zenith distance is larger than 80 degrees, and it was visible just for a very short time. The time interval includes also the heliacal setting of β Centauri besides that of α Virginis, and the star has a declination of –19 degrees. There are no useful acronychal risings of bright stars, while there is the acronychal setting of just one star, α Aquilæ (Altair). The conclusion of this test is that one could choose among only very few bright stars for the indication of the harvesting date during the 9th Millennium BCE. For the threshing date the conclusion is similar.

Conclusion

We think that during the 9th Millennium the people in the Fertile Crescent could have used the star α Virginis as an indicator of the time both of the harvest of cereals (in spring) and of the thresh (about forty days after harvesting). This star could have been of some help for the domestication of wild cereals and the development of farming techniques, and we think this could be the origin of its name, Spica, that is ear. The Babylonians identified α Virginis as the ear of the goddess Shala (ear of barley), while part of the present day Virgo (= maiden; Figure 5) constellation was identified by them not with a maiden but with the furrow made by the plough. Such a name (furrow) could be justified by the use of the constellation as an indicator of the farming activities at the end of summer and beginning of autumn in Mesopotamia some thousand years ago. We remark that it is not clear whether in ancient Mesopotamia this large constellation or part of it was really identified with a maiden, or at least with a goddess (may be Ishtar; Rogers, 1998). The identification of the constellation with a maiden could be actually a Syrian adaptation of Shala (e.g. Lafitte, 2008), and one should conclude therefore that such an identification is not very old. In other words, the association of α Virginis with an ear is probably much older than that of the whole constellation with a maiden (Virgo), and we propose that it dates back to the beginning of Neolithic.

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Fig. 5. The Virgo constellation in the Hevelius Atlas (INAF-Osservatorio Astronomico di Brera). Note the left hand with the ears, where Spica is located. This representation of the maiden is very similar to that on the globe of the Farnese Atlas, the famous roman statue of the 2nd century CE.

Fig. 6. The star α Virginis has been named ear in various languages in the past millennia.

The name of α Virginis	
Akkadian:	Šumbultu
Aramaean:	Šebeltā
Southarabic:	Šubiltān
Arabic:	al-Sunbula
Pahlavi:	Hošāg
Hellenic:	Στάχυς
Latin:	Spica

سنبلة

Ten solar eclipses show that the Antikythera mechanism was constructed for use on Sicily

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Abstract: A highly complex ancient Greek geared bronze mechanism was found in a ship that sunk about 80-65 BCE close to the island of Antikythera. In the present paper five Exeligmos cycles that started in 351, 297, 243, 189 and 134 BCE has been determined by identification of 10 solar eclipses. A computer program compared the predicted pattern of solar eclipses on the mechanism with my tables for Syracuse, Taurmina, Athens and City of Rhodes. The median deviation was 3 minutes for Syracuse, 50 minutes for Athens and 84 minutes for City of Rhodes. The conclusion is that the original calibration was made in Syracuse in 243 BCE by Archimedes. The inscriptions on the Antikythera Mechanism were made in 100-150 BCE and the last Exeligmos started in 134 BCE. The next Exeligmos was expected to start in 80 BCE but it failed. The last year corresponds to the date of the accident when the ship with the Mechanism onboard sunk close to the island of Antikythera.

Keywords: Antikythera Mechanism, Syracuse, Archimedes, Saros cycle, Exeligmos cycle, solar eclipses

Introduction

An ancient ship was found by sponge–divers in 1900, close to the northern shore of the island of Antikythera at a depth of 42 metres. This island is situated between the southern part of Peloponnese and Crete. Some of the finds from the shipwreck were brought to the National Museum in Athens and shown to the Minister of Education, Spyridon Stais, who fortunately was an archaeologist and understood the importance of the new finds from the bottom of the sea. Supported by the Hellenic government, the divers returned to the shipwreck the next year and performed one of the earliest marine archaeological investigations. Among a rich collection of ancient bronze statues, jewellery, amphorae and pottery a mysterious highly eroded object of bronze was found. Its size was about 300 x 190 x 100 mm. The object was not immediately investigated by ordinary archaeological methods, but after some months it fell apart by itself and then it became clear that it consisted of several corroded bronze gearwheels and plates covered by scientific scales and inscriptions in Hellenic. It was a great surprise to find such a complex mechanism together with well–known ancient finds that could be dated to about 80-65 BCE. The earliest known comparable mechanisms did not appear until the astronomical clocks at the medieval cathedrals were constructed more than one thousand years later.

Already in 1905, Albert Rehm, a philologist, understood that the Antikythera mechanism was an astronomical calculator. After decades of careful cleaning of the mechanism the historian of science Derek J. de Solla Price started his investigation of the mechanism in 1951. Price suggested that the mechanism was operated by turning a crank on its outside. All the pointers on the dials from the front and back sides of the mechanism moved simultaneously to their corresponding positions. By turning the crank the user could set the machine to display the information on all dials on a certain date as indicated on a 365–day calendar dial on the front side. It was also possible to include one extra day every fourth year corresponding to the leap year that was introduced in Rome by Julius Caesar in 46 BCE.

There was also a dial on the front marked with a complete 360–degree longitude scale and with the signs representing the 12 zodiacal constellations along the ecliptic, the sun's apparent path among the fixed stars. Price assumed that there was a pointer to mark the sun's position along the ecliptic for a given date. In order to understand how the mechanism worked he tried to estimate the number of teeth of the gears, most of which were damaged and incomplete. In an important study by Price (1974) he cooperated with the radiologist Charalambos Karakalos who used x–rays and gamma–rays to investigate the inner parts of the mechanism without destroying it. Price could now describe 27 gears in the main fragment and improved the counting of the teeth. He discovered that the output of one of these series of gears acting together resulted in a motion that corresponded to the ancient Babylonian cycle of the moon.

Rehm and Price suggested that the mechanism also contained epicyclical gearing, gears connected by intermediate independent systems of gears that resulted in a variable movement of the pointer connected to the axis of the last gear. Such a mechanism is necessary to correctly display the variable velocity of the moon and some of the planets. This technology is not known to have been used until 1500 years later.

The first three–dimensional x–ray investigation was performed by Michael Wright and Allan Bromley. They realised that some of Price's conclusions were wrong while others could be confirmed. Wright found that the dials on the back, which Price had interpreted as concentric rings, are in fact spirals and he discovered an epicyclic mechanism on the front that calculated the phase of the moon (Wright 2003 & 2005a). He also supported the idea by Price that the upper dial on the back might be a lunar calendar, based on the 19–year cycle with 235 lunar months, introduced by Meton in Athens in 432 BC, but earlier used by the Babylonians (Wright 2005b & 2006).

After these investigations it became clear that the Antikythera mechanism was a highly complex ancient geared mechanism with more than 30 gears, the greatest of them with a diameter of 125 mm. The mechanism was constructed to calculate the position of celestial objects and it has therefore been considered as the oldest known complex scientific calculator. It appears to be constructed upon mechanical inventions by Archimedes (287–212 BCE) from Sicily and astronomical theories developed by Hipparchos (ca 190–125 BCE) from Rhodes.

The latest investigations by microfocus x–ray-computed tomography

The mathematician Tony Freeth and the astronomer Mike Edmunds formed an international collaboration including historians of science, astronomers and imaging experts sponsored by Hewlett–Packard in California. In 2005 they could use a microfocus X–ray computed tomograph (CT) similar to the CT scans at hospitals, but with finer details and higher penetration power. It was now possible to isolate different layers inside the frag-

ments and to study all the fine details of the hidden inscriptions and exactly count the number of teeth of the gears and how they worked together in the gear trains. Additional fragments have been found in the basement storage of the National Museum in Athens and there are now all together 82 known fragments of the Antikythera mechanism (Freeth 2009).

The function of all dials was described on the inside of the covering doors. The new x–ray images revealed more than 2,000 new text characters that earlier were hidden deep inside the fragments. A total of 3,000 characters, out of perhaps 15,000 original characters, can now be interpreted and read. Xenophon Moussas and Yanis Bitsakis at the university of Athens and Agamemnon Tselikas of the Center for History and Palaeography in Athens discovered inscriptions that had not been read for more than 2,000 years. One of the inscriptions on the back door is translated as «the spiral divided in 235 sectors», confirming the earlier result that the upper dial on the back was a five–turn spiral describing the distribution of the 235 months in the Metonic 19–year cycle (Freeth et al. 2008).

The earlier investigations had not been able to identify any month names on the Metonic calendar. The computer improvements of the new x–ray images made it possible to identify the names of all the 12 months. Unexpectedly they were of Corinthian origin. The series of month's names was identical with the seven earlier known month names from Taurmina, modern Taormina, a former Corinthian colony on Sicily. This may indicate a cultural heritage going back to Archimedes.

The Metonic calendar on the Antikythera mechanism proved to be much more advanced than scholars had earlier expected. They had dismissed calendars with excluded days to regulate month lengths, described in the first century BCE by Geminos (Evans and Berggren 2006) as implausible. The new investigation could demonstrate their existence in the Antikythera calendar and also explain why the Metonic dial has five turns. Another important result is that the upper subsidiary dial is not a 76–year Callippic dial as previously thought, but follows the four–year cycle of the Olympiad and its associated Panhellenic Games.

The index letters in each glyph on the Saros eclipse prediction dial, at the lower side on the back, were studied in detail. They explained the four turns of the Saros dial in terms of the full moon cycle and the Exeligmos dial as indicating a necessary correction of 8 hours to the predicted eclipse times during the second Saros cycle and 16 hours during the third Saros cycle. However, the investigators did not understand the principle for the generation of the eclipse times and found them to be contradictory.

In the Supplementary Information (Freeth et al. 2008) it is written. «According to Haralambos Kritzas (Director Emeritus of the Epigraphic Museum, Athens) the style of the writing could date the inscriptions to the second half of the 2nd Century BC and the beginning of the 1st Century BC, with an uncertainty of about one generation (50 years). Dates around 150 BC to 100 BC are a plausible range.»

The results from all the earlier studies of the Antikythera mechanism and from the latest investigation are published by Freeth et al. (2008) and Freeth (2009).

The eclipse prediction mechanism

The earlier studies have convincingly demonstrated that the lower back dial on the Antikythera mechanism is a Saros eclipse–

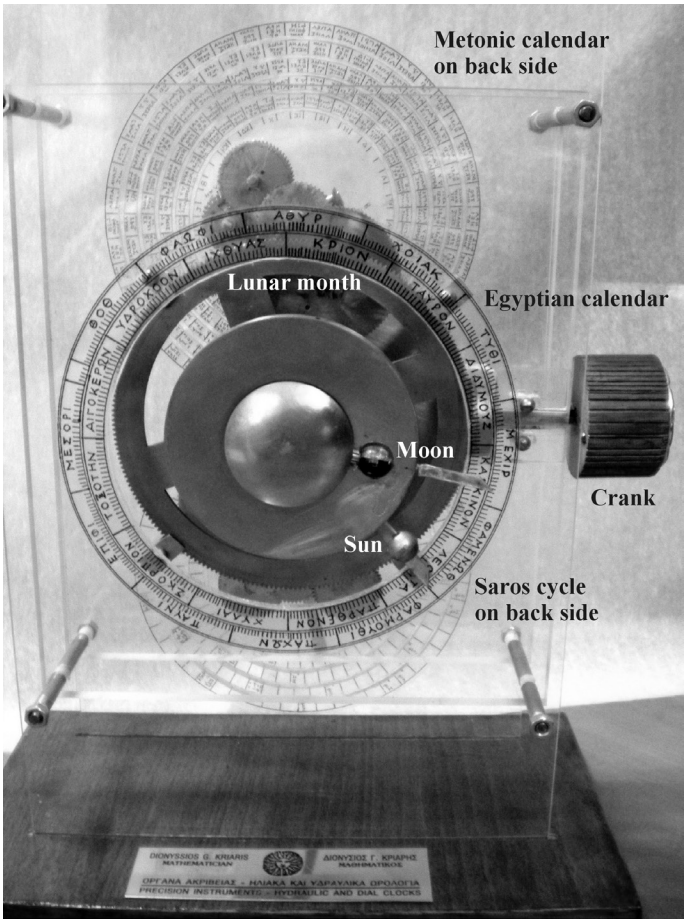


Figure 1. Dionysis G. Kriaris has built this model based on the new findings. (Photo by Göran Henriksson 2009.)

prediction dial, arranged as a four–turn spiral, with glyphs indicating the kind of eclipse, lunar or solar, and the hour of the eclipse. The pointer was adjustable because a pin at the pointer's tip followed a groove along the four turns of the spiral and changed the length of the pointer so that the tip always pointed at the actual month.

From the CT data of the large fragments A, B, and F it was possible to identify 48 scale divisions and to establish the existence of 223 divisions in the four-turn spiral starting at the bottom of the dial (Freeth et al. 2006). The 223 subdivisions were easily identified as the lunar months in a Saros cycle corresponding to 18 years, 11 days and about 8 hours. In the fragmentary instruction on how to use the dials, on the inside of the door on the back, the number 223 is mentioned on line 46 «… 223 coming together …» and a gear with 223 teeth has also been found. Between the divisions they found 16 blocks of characters, which they call «glyphs». They appeared at intervals of one, five and six months. These are predictions concerning lunar or solar eclipses, or both kinds of eclipses. There is information about the kind of eclipse, the hour of the eclipse and the number of the eclipse in the series. On the first line there are the letters Σ (*sigma*) or H (*eta*) or both letters. Freeth (2009) realised that Σ stands for *selene*, Hellenic for «moon», indicating a lunar eclipse and H stands for *helios*, Hellenic for «sun» indicating a solar eclipse. On the second row the first letter shows if it is hours of the day or hours of the night, followed by a letter that corresponded to the hour of the eclipse. The bottom line gave the number of the eclipse in the Saros series.

A correlation analysis that was performed with historical data (Espenak 2005) indicated that during 400 BCE – 1 CE the sequence of eclipses marked by the identified glyphs would be ex-

actly matched by 121 possible start dates. An important result was that the matching only occurred if the lunar month starts at first crescent. The sequence of eclipses was later used to predict the expected position of missing glyphs on the whole dial. It was concluded that the Babylonian Saros canon is the only known source of sufficient data to construct the dial (Freeth et al. 2006).

A small dial showed the actual Saros cycles within the so–called Exeligmos, a series of three Saros cycles, corresponding to about 54 years and 33 days. During the first Saros cycle in the Exeligmos series the hour of the eclipse could be read directly in the text for a certain eclipse, but during the second Saros cycle the pointer showed that eight hours must be added to that time, and during the third Saros cycle the pointer showed that 16 hours must be added to the given time.

The motivation for the investigation by present author

I have with great interest followed the progress in the studies of the unique Antikythera mechanism during the last 40 years and have mentioned it sometimes in my lectures. The most important paper to me at that time was written by Gunnar Pipping (1993) curator at the Technical Museum in Stockholm. However, it was not until the SEAC conference on Rhodes in 2006 that I had the possibility to listen to lectures about the latest CT–investigations by Mike Edwards of Cardiff University in Wales and Xenophon Moussas from the University of Athens (Freeth *et al*. 2006).

When I met Xenophon Moussas during the SEAC conference in Granada in 2008, he offered me the possibility to arrange an exhibition on the Antikythera mechanism and a bronze model of it in Uppsala, Figure 1. After contact with Ing–Marie Munktell, Director of *Museum Gustavianum*, the University Museum in Uppsala, a very successful exhibition was set up as the start of the International Astronomical Year 2009 in Uppsala. Museum Gustavianum was that year the most visited museum in Uppsala.

During my opening lecture of the exhibition, I mentioned that it in principle might be possible to determine when and where this mechanism was constructed by identification of solar eclipses predicted by the Saros cycles on the mechanism. (At the end of my lecture I gave a half promise to the audience, in the overfull lecture hall, that I could do it). When Xenophon Moussas come to Uppsala to bring the exhibition back to Athens, I asked him if he could help me to read the hour of the predicted eclipses. He looked at magnified CT images of the glyphs (Freeth et al. 2008) on my computer screen, and at 2 o'clock in the morning he was finished after three hours of intense work. Xenophon was able to read 9 of the hours for the predicted solar eclipses, one of them he considered as somewhat uncertain. (Other authors have identified only 8 of the hours for the predicted solar eclipses).

I have a long experience in calculations of solar eclipses and to me it is completely clear that the circumstances of every solar eclipse is in principle unique for a certain time and place on the earth. Of course, if we take into account the uncertainties and errors in the original records and our misunderstandings and errors in the calculations of the circumstances of eclipses, the situation is only unique within certain margins of errors. My hope was that the combination of all errors was small enough to give a unique solution in this case.

The «historical data» used by Freeth et al. (2006) was good enough to show that the distribution of subdivisions with glyphs on the Saros dial matched with the calculated interval between the eclipses. In this paper they believed that glyph times were constructed from the Babylonian Saros canon, the only known source with sufficiently good data. However, in Freeth et al. (2008) after an unsuccessful attempt to correlate the glyph hours on the Saros cycle with the calculated times (Espenak 2008), they assumed that this series of eclipse months and hours was based on purely theoretical speculations by the people who constructed the mechanism. They write: «We conclude that the process of generation of glyph times was not sound and may remain obscure.» In my opinion they blamed the constructors of the mechanism for their own failure. When we look at all the other details on the mechanism, we can understand how they work, we are astonished by the advanced technical ability and intellectual level of the constructors. These modern investigators have overestimated the accuracy of their own calculations.

When I read the sentence quoted above, it became clear to me that this was not the best possible investigation and that I had some work to do on the Antikythera mechanism. I have presented a series of successful identifications of ancient solar eclipses, mostly total, from different cultures and epochs back to at least 2500 BCE (Figure 5). The expected error in my calculations back to 3000 BCE is at most ± 3 minutes depending on the non–tidal effects caused by variations in the earth's global temperature. Other computer programs are based on different principles and a calibration during only 300 years, while my program is calibrated on a 2200–year–old observation by Timocharis from Alexandria, Figure 3, and ancient total solar eclipses. The typical systematical error in other computer programs is about 15 minutes for eclipses around 100 BCE, and the main authority Richard Stephenson admits that he can not calculate solar eclipses before 700 BCE. In my opinion he has severe problems already at about 500 CE. This is obvious from his failures when he tries to calculate eclipses close to the horizon. I will discuss the different ways to calculate solar eclipses below.

The investigation by the present author

When the user of the mechanism knew the hour of a certain eclipse, it was possible to calculate if the eclipse should be visible from the user's location. If the result was that a solar eclipse took place during night hours, the sun was below the horizon and could not be observed at the place in question. However, even if the sun is above the horizon there is no guarantee that there will be an observable solar eclipse because the magnitude of a solar eclipse is strongly dependent on the location of the observer. Total solar eclipses are only total within a narrow zone on the surface of the earth, and the magnitude decreases for observers outside the zone of totality; at a certain distance there is no eclipse at all, Figure 2. On the other hand, all lunar eclipses with the moon above the horizon could be observed with almost the same magnitude. It is therefore much easier to predict lunar eclipses than solar eclipses.

My computer program has an uncertainty in the calculated time of solar eclipses that is less than 2 minutes around 100 BCE. The uncertainty in the calculated time of sunrise or sunset is less than a minute and depends more on the altitude of the unknown local horizon. It is unlikely that errors in my calculations will cause any problem for this investigation.

In antiquity the 12 hours of the day were reckoned from sunrise to sunset and the 12 hours of the night were reckoned from sunset to sunrise. The question is if they used seasonal hours with unequal length or equinoctial hours with equal length, independ-

ent of the season. My calculations showed that the hours on the mechanism corresponds to equinoctial hours and the mechanism must either have been driven by some kind of water clock or it must have been used together with a water clock or some other kind of clepsydra that was calibrated to give equinoctial hours.

I developed a special computer program that compared the pattern of months with solar eclipses marked on the mechanism with solar eclipse tables computed by my own computer program. As pointed out above the appearance of solar eclipses is strongly dependent on the locality of the observer. This means that if the hour for the solar eclipses marked on the mechanism are based on correct local observations, or generated by correct transformations of good observations made at another place, it should in principle be possible to determine the location by looking for the place where the eclipse predictions with the Antikythera mechanism works best. The best solution is also time dependent, which gives the dates for the basic eclipse observations.

The computer program was constructed in such a way that all tests and identifications were performed automatically and without any manual interventions as I expected that it should be necessary to make the calculations for many places. It was also necessary to run the program many times to be able to set acceptable limits for the deviations of important parameters. I had no time to include a calendar subroutine in my program and therefore I did not know in advance the exact time of sunrise for the date of the solar eclipses and I must assume that sunrise always took place at 06.00 in the morning, which is true only during the equinoxes. This was of course a serious problem for solar eclipses during the first or last hour of the day far from the equinoxes. It was initially necessary to accept deviations between the hour marked on the mechanism and my corresponding calculated hour of three hours. However, this was a very simple and successful strategy, and for the only acceptable solution the deviations proved to be only a few minutes when the actual time of sunrise in the morning of the eclipses finally was calculated.

I decided to start my calculations with Taurmina on Sicily, as it seemed to me to be the most likely origin of the mechanism since the series of month names engraved on it agreed with the month names used in that city. The result from this first test was astonishingly good. I continued with Athens to get data from a somewhat more northerly latitude and finally I tested how the solar eclipse predictions on the mechanism worked for the city of Rhodes, earlier considered as the most likely place of origin. When it was clear that the result for Taurmina was the only acceptable one and that an even better result could be expected for a place to the west or south of this city, there was an obvious candidate – Syracuse, the city on Sicily that was the home of the famous ancient scientist and inventor Archimedes. The result for Syracuse was even better and in fact one could not expect to get a better result. The tables included all visible eclipses with a magnitude greater than 0.05 of the sun's diameter during the time interval 600 BCE–2 CE at these four places.

The result of calculations for the four different places

A solution that includes 10 calculated solar eclipses determines the dates for the beginning of four complete Exeligmos cycles, with 54 years and 33 days, by a successful matching of three time glyphs in the well–preserved beginning of the Saros cycle dial. My calculations work only if the counting of the months starts at the inner end of the four–turn spiral series of months. Only less than 25 % of the circumference is preserved and the hour of the eclipse can only be read for 9 of the solar eclipse predictions. Xenophon Moussas made an independent interpretation of these time glyphs for me.

The predicted times for the eclipses is rounded off to the nearest hour on the Saros dial. If the clock was started in the moment of true sunrise and the time was read at the true moment of maximum eclipse we must expect deviations of up to 30 minutes for an individual observation. If it was cloudy in the morning it may have been difficult to start the clock at true sunrise and it may also be difficult to define the moment of maximum eclipse with a precision better than 5 minutes even with some technical device.

They must have used reflection in a water surface to avoid damage to the eyes during observations of a partial solar eclipse. Individual deviations by as much as 40–45 minutes in the observed time can easily be explained during the calibration. There is also reason to believe that the calibration of the time for the eclipses is better for the first Saros cycle in the Exeligmos because the date for the eclipse in the second Saros is delayed by 11 days and for the third Saros by 22 days. This means that the time is not reckoned from the same sunrise, as during the first Saros, and at the equinoxes an extra timing error of ± 11 minutes is introduced during the second and ± 20 minutes during the third Saros cycle. This error is reduced to a few minutes close to the solstices. For this reason I decided to try to get matches only from the first Saros in the Exeligmos in this preliminary investigation.
The number of identified solar eclipses and the completeness of the Exeligmos cycles are very good for Taurmina and Syracuse but incomplete for Athens and the city of Rhodes, Table. The match is very good for Taormina, with a median difference of only 4 ½ minutes, and the mean error of the mean corresponds to about 15 minutes. The median difference is 50 minutes for Athens and 84 minutes for the city of Rhodes with the mean error of the mean of about 25 minutes. The two most deviating points have been excluded in all the solutions because errors of the order of three hours cannot be real observational errors, see Table. Such great deviations are probably caused by intrinsic limitations in this method, as the Saros cycle is in fact only a simple rule to predict eclipses. All my dates are given according to the Gregorian Calendar.

Table

Result for Syracuse

Year	Date	LT	SR	LT-SR	AT	(LT-SR)-AT	Magnitude
-349	30/9	7.43	05.57	1.77	1	0.77	0.943
-348	19/9	13.15	05.46	7.48	6	1.48	0.092
-295	2/11	8.47	06.31	2.27	1	1.27	0.585
-294	22/10	12.21	06.19	6.03	6	0.03	0.387
-241	5/12	10.54	07.06	3.80	1	2.80	0.134
-240	24/11	12.50	06.55	5.92	6	-0.08	0.589
-186	27/12	13.23	07.19	6.07	6	+0.07	0.528
-182	15/10	11.05	06.11	4.90	8?	-3.10	0.638
-131	29/1	12.45	07.10	5.58	6	-0.42	0.475
-128	17/11	14.36	06.47	7.82	8?	-0.18	1.001

Result for the city of Rhodes

Year	Date	LT	SR	LT-SR	AT	(LT-SR)-AT	Magnitude
-349	30/9	8.50	05.56	2.90	1	1.90	0.954
-348	19/9	14.31	05.46	8.75	6	2.75	0.207
-295	2/11	9.59	06.29	3.50	1	2.50	0.458
-294	22/10	13.43	06.17	7.43	6	1.43	0.461
-240	24/11	14.10	06.53	7.28	6	1.28	0.543
-236	12/9	10.17	05.39	4.63	8?	-3.37	0.080
-186	27/12	14.40	07.16	7.40	6	1.40	0.363
-182	15/10	12.24	06.10	6.23	8?	-1.77	0.768
-178	2/8	19.02	05.03	13.98	10	3.98	0.696
-131	29/1	13.58	07.08	6.83	6	0.83	0.274
-128	17/11	15.47	06.45	9.03	8?	1.03	0.906

LT = Local time (hour), SR= Sunrise (hour), AT = Antikythera time (hour)
(?) = somewhat uncertain reading

The best fit is obtained for Syracuse. The median deviation is only three minutes and the mean error of the mean corresponds to 15 minutes, which is a very good result for the eight identified predictions on the Antikythera mechanism calculated for Syracuse. The mean value for the deviations, +22.1 minutes, is acceptable as deviations from the predicted time of the maximum phase because the time on the mechanism is only given in hours, see above.

The oldest Exeligmos started with the powerful partial solar eclipse, magnitude 0.967, on 30 September, in 350 BCE. This eclipse took place in the 13th month of the Saros cycle. The latest solar eclipse in this preliminary investigation corresponds to the 72nd month of the Saros cycle and took place on 17 November, in 129 BCE. It was total in Syracuse and had the magnitude 0.999 in Taurmina. Hipparchos who lived on Rhodes described this eclipse as total in the countries of the Hellespont, Figure 2. It had magnitude 0.954 on Rhodes and 0.939 in Athens.

The most exact documentation of an ancient solar eclipse can be found on two separate cuneiform tablets (Sachs 1974), in the British Museum, which tell us about a total solar eclipse in Babylon, 15 April (Julian Calendar) in 136 BCE, with the time given for three different phases of the eclipse. The difference between the time recorded in the cuneiform texts and the author's computed time is 0 ± 2 minutes.

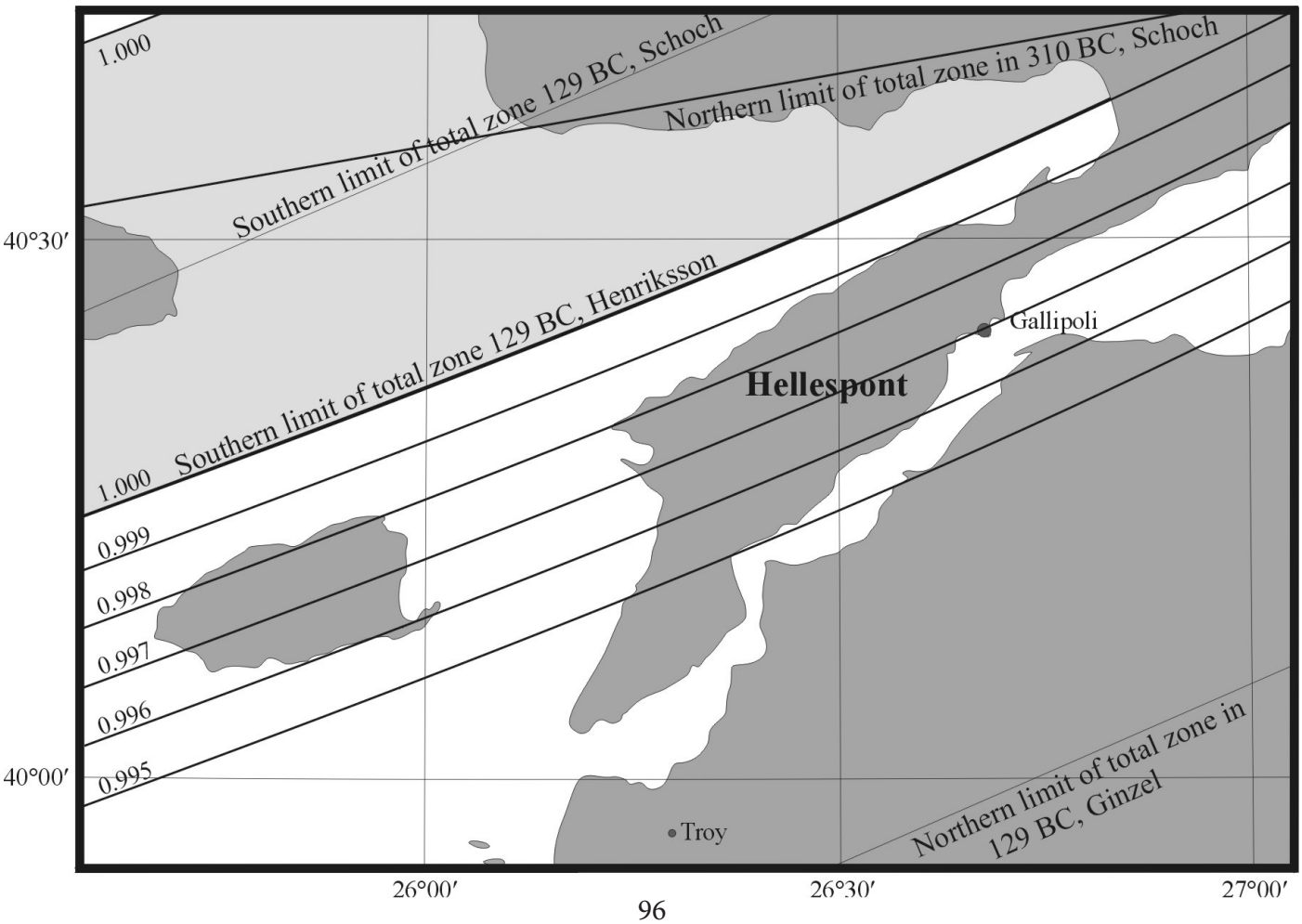
The accuracy of the author's solar eclipse calculations

In my computer program for calculation of eclipses I always use Carl Schoch's values for the sidereal lunar secular acceleration, $\dot{n}$ = –29.68 arcseconds/century^2, and for the braking of the rotation of the earth, 36.28 seconds/century^2 (Schoch 1931). The high precision of this computer program is demonstrated in Figure 4.

In 1985 I started a test of my computer program by a comparison with the total solar eclipse in Babylon in 136 BCE, see above, and a Chinese solar eclipse record, the so–called «double dawn» eclipse in Zheng, during the Zhou Dynasty, which could be dated to 899 BCE. These results and identifications of several solar eclipses depicted on Swedish rock–carvings from the Bronze Age were presented in 1996 at the Oxford V Symposium in Santa Fe, Henriksson (2005). After successful identification of the two important total solar eclipse records in Babylon, separated by 301/300 years with the total solar eclipses in 1859 BCE and 1558 BCE, it was possible to date the Old Babylonian Kingdom, the Old Assyrian Kingdom, the Old Hittite Kingdom and the 13th–20th dynasties in Egypt, presented in papers at the SEAC 2002 Conference in Tartu, Henriksson (2006) and at the SEAC 2004 Conference in Kecskemet, Henriksson (2007). At the Oxford 8 and SEAC 2007 Conference in Klaipeda I presented my identification of the oldest Chinese solar eclipses that can date the Xia, Shang and Western Zhou dynasties, Henriksson (2008). At the SEAC 2008 Conference in Granada, I demonstrated that my method to calculate ancient eclipses is so exact that it is possible to test Einstein's general theory of relativity, Henriksson (2009).

John Steele (2000), one of the co-authors in Freeth (2008), tries to identify ancient eclipses by a computer program designed by F. R. Stephenson. Steele writes on page 15–16: «These programs

Figure 2. The solar eclipse on 17 November, in 129 BCE, mentioned by Hipparchos, who lived on Rhodes, as total in the countries of the Hellespont. The magnitude of the eclipse in Gallipoli was according to this calculation 0.997 of the sun's diameter. The longitude difference between Gallipoli and the limit for totality is 28 minutes of arc, which corresponds to 112 seconds of time. The observed magnitude in Alexandria was 0.79±0.04, which corresponds well to my calculated magnitude 0.78. No other modern computer program can reproduce this solar eclipse.



are based upon the solar ephemeris of Newcomb (1895) and a corrected version of the lunar ephemeris designated *j*=2 (IAU 1968), incorporating a lunar acceleration of –26”/cy^2 as determined by Morrison and Ward (1975) from analysis of the transits of Mercury.» His values for *ΔT* are taken from Stephenson and Morrison (1995). These values are obtained from a spline fit of both timed and untimed eclipse observations made in various cultures. However, a simple parabola is expected from the tidal braking, but this does not satisfy all the constraints of the data, as is discussed in Stephenson and Morrison (1995). The introduction of a spline curve is an attempt to correct for systematic errors caused by *wrong values of ΔT and* $\dot{n}$. This method has been used in all later computer programs, but the result is mostly not useful because different programs give different results.

The value of $\dot{n}$ = –26”/cy^2 is fixed in modern computer programs but the user has an option to change ΔT! This violates the principle of conservation of angular momentum in a closed system. It is written on page K8 in the *Astronomical Almanac*: «To calculate the value of ΔT for a different value of the tidal term ($\dot{n}$’), add –0.000 091($\dot{n}$’+26)(year–1955)^2 seconds to the tabulated values of ΔT.»

Steele (2000) avoid a discussion of several famous early total solar eclipses such as that predicted by Thales from Miletos, in 585 BCE, and reported by Herodotus to have taken place during a battle. That eclipse had earlier been used as a fundamental test of the formulae and methods for calculations of ancient eclipses. Frustrated modern eclipse calculators who cannot calculate this total solar eclipse have convinced themselves that it was a total lunar eclipse!

Conclusion

I assumed that the series of months with eclipses and the calibration of the predicted hour of the eclipse were made from real observations. This assumption was successful and I was able to identify ten solar eclipses. They defined five Exeligmos cycles that started in 351, 297, 243, 189 and 134 BCE.

The most probable year for calibration of the Exeligmos on the Antikythera mechanism is the middle one because the deviations from the expected values should start with the smallest deviation. The first and the last of the five Exeligmos may have errors that are just within the acceptable limits or error.

The hours for the solar eclipses on the Antikythera mechanism can have been calibrated during the lifetime of Archimedes (287–212 BCE) because a new Exeligmos starts on 16 November in 243 BCE. The solar eclipse in the 25th month of the Saros, took place on 24 November, in 241 BCE had a time error of only 5 minutes. This calibration may have been used when the Antikythera mechanism was constructed in 100–150 BCE.

The last Exeligmos cycles with this calibration started on 23 January in 134 BCE, but it did not function in 80 BCE when the next Exeligmos cycle was expected to start. This corresponds to the date, about 80–65 BCE, when the Antikythera mechanism was on board the ship that sunk north of Antikythera. At that time the mechanism may have been useless for eclipse predictions and was only considered as a valuable antiquity.

The cargo in the sunken ship, north of Antikythera, came mostly from Pergamon in Asia Minor and it is most likely that the destination was Rome. The mechanism must have been taken on board the ship earlier and may have been useful as a navigational instrument by the captain of the sunken ship!

This extraordinary astronomical mechanism from about 150–100 BCE employed bronze gears to make simultaneous calculations based on cycles of the Solar System. The new interpre-

Figure 3. Conjunction between Spica and the Moon observed by Timocharis in Alexandria, on 4 November, in 283 BCE, at 03.08.45 local mean solar time, mentioned by Ptolemy in Almagest. Spica appeared at the northern limb of the Moon in the middle of the 10th hour of the night or 9 ½ hour after sunset. If sunset was reckoned from 06.00 the conjunction took place ca 03.30. Sidereal lunar secular acceleration –29.68 "/cy², according to Carl Schoch 1931. (Gregorian calendar.)

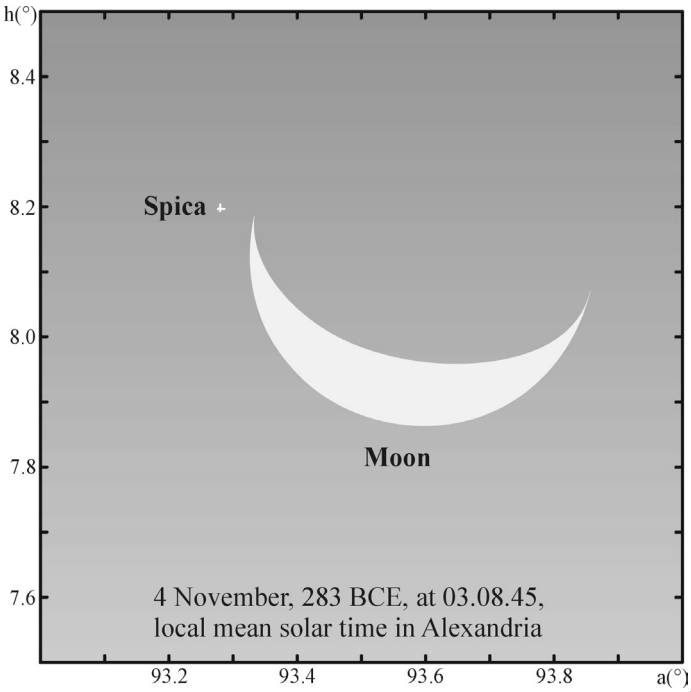
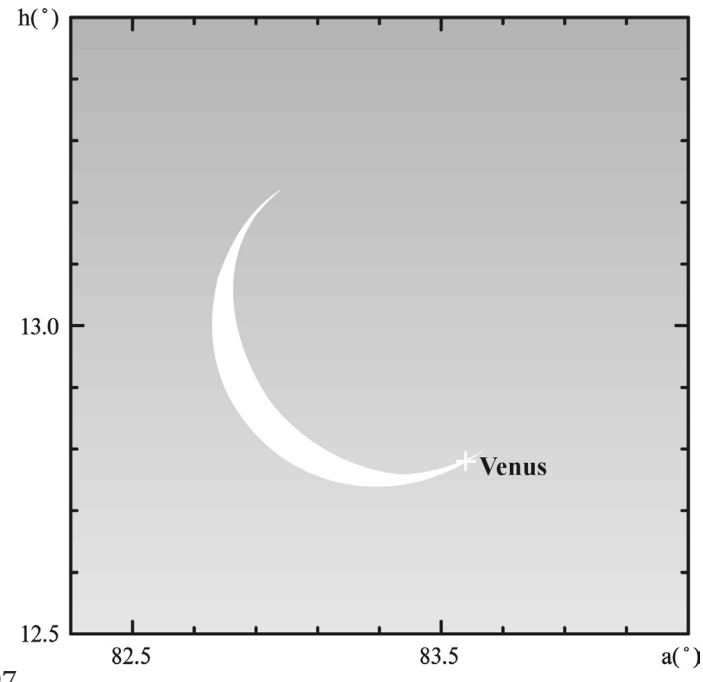


Figure 4. Venus enters the southern horn of the moon, on 13 June, 419 BCE, at 04.00 local mean solar time in Babylon. The sun was 8.65° below the horizon and the magnitude of Venus was -4.3. (After the cuneiform text VAT 4924 from Babylon, now in Berlin.)



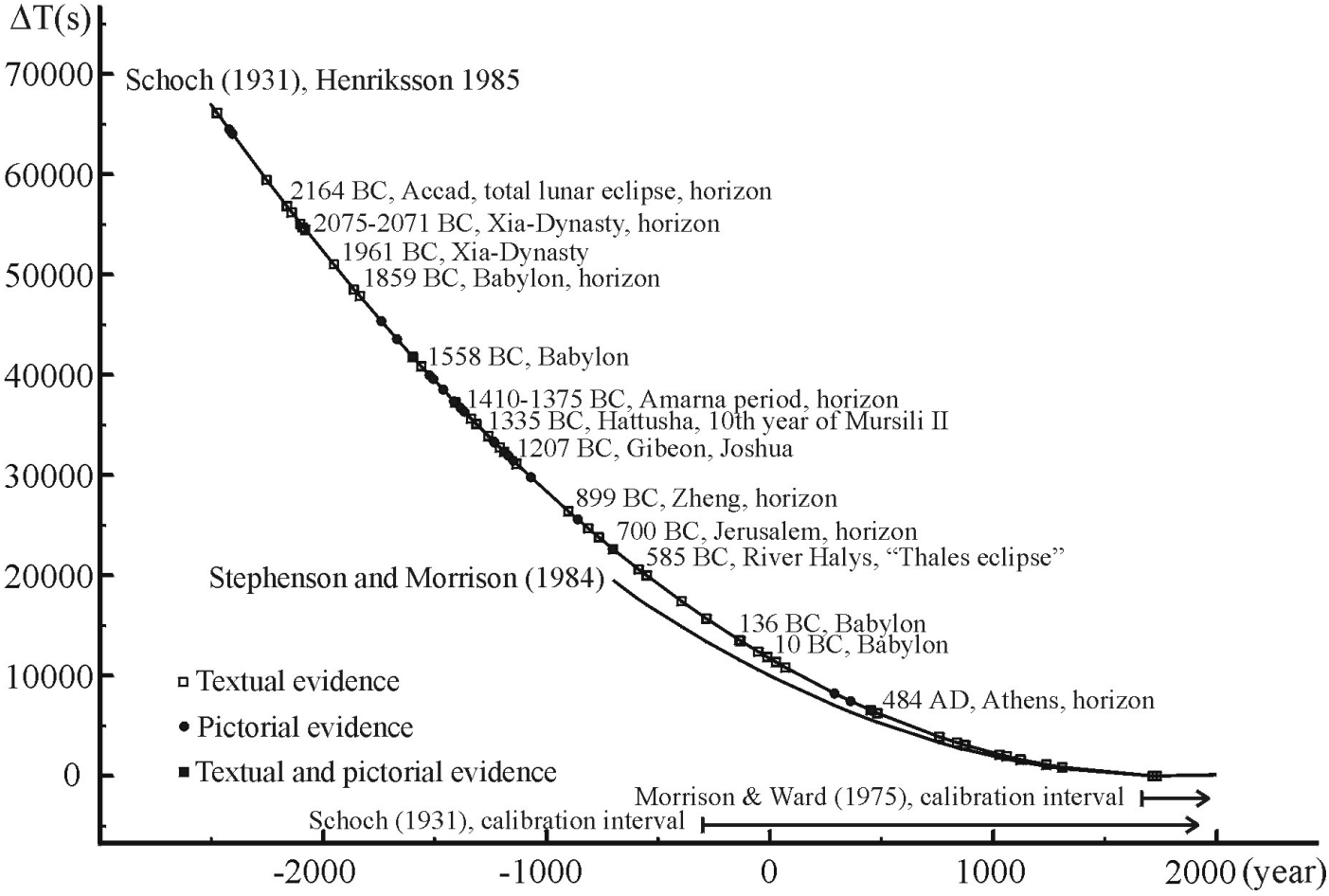


Figure 5. The parabolic time–shift, ΔT, due to the tidal deceleration of the rotation of the Earth as a function of time with the coefficient 36.28 from SCHOCH (1931) and 31.0 from STEPHENSON & MORRISON (1984). The unit for the coefficients is seconds/(century)² and the time is reckoned from 1800.0. The symbols correspond to identified solar eclipses, mostly total or annular. Most of the identified eclipses can be found in HENRIKSSON (2005, 2006, 2007 and 2008).

tations of the mechanism is important for our understanding of how ancient people were able to integrate their astronomical knowledge in the mechanism's gear work and how they used the Metonic calendar with a special Olympiad dial and performed eclipse predictions.

Acknowledgement
I am very thankful to all earlier investigators of the Antikythera mechanism. Without their careful work I would not have been able to write this paper. I am especially grateful to Xenophon Moussas, University of Athens, for his reading of the text on the Saros eclipse prediction dial and Mary Blomberg, University of Uppsala, for the reading of my manuscript and improvements of my English.

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ORIENTATIONS OF THE GIANT'S CHURCHES IN OSTROBOTHNIA, FINLAND

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Abstract: Giant's churches are Neolithic stone enclosures, unique to the coastal area in Ostrobothnia, Finland. They date from 3000–2000 BCE, and are concentrated on the ancient seashore. They are 15–60 meters long and most often rectangular in shape. The function of the structures is not known and has been a matter of debate for over a hundred years. The orientations of the long axes and gates of these structures have been measured. The results support an interpretation of the function of the structures related to an early solar or lunisolar calendar for the largest giant's churches, while some of the smaller ones may be large dwellings. The building of these megalithic structures was probably related to the cultural changes of the Middle Neolithic in the region.

Keywords: Giant' churches, Neolithic, Finnland, orientation, calendar

INTRODUCTION

The so-called 'giant's churches' are Middle Neolithic stone structures, unique to the coastal area between Yli–Ii and Närpiö in Ostrobothnia in the western Finland (Europaeus, 1913: 90-1). They have been dated to the period 3000–2000 BCE, and are concentrated on the Neolithic seashore (Okkonen, 2003). Most of them were built on islands or drumlins on the coast, but are now situated as far as 30 kilometres inland due to the effects of the post–glacial rebound. There are 40 to 50 of them, depending on the definition, which is not unambiguous, as their function is not yet known.

The giant's churches are large, the length of their long axes varying from over 60 meters to about 15 meters, and most often rectangular (see Figures 1 and 2). On the other hand, the height of their walls is rather low, from about half a meter to about two meters. Most of them have gates, which are openings in the walls, suitable for entering the structure. Some of them also have so-called 'sacristies', which are large stone cairns either constructed as parts of the walls or situated immediately outside of them.

The function of the giant's churches has been a matter of debate for over a hundred years. They have been seen as dwellings, burial sites, temples, fortresses, natural formations, giant cold stores for seal meat, and hunting enclosures (see Okkonen 2003, and references therein). Some of the smallest constructions may have been dwellings, but the largest ones would have been impractical for that purpose. No signs of permanent inhabitation have been found inside the structures.

In this paper, the results of an archaeoastronomical study are presented, where the possible deliberate orientations of the giant's churches to celestial events have been examined. With its sample of 39 structures, the present paper completes the statistical study on the orientations of the majority of the currently known giant's churches.

MEASUREMENTS

The orientations of the structures were measured as follows. (1) In rectangular structures (denoted with Q in Table 1), the directions of the walls were measured to determine the orientation of the long axis of each structure. (2) In the rectangular and round structures, the directions of the gates and the sacristies were measured as seen from the centre of the structure. The centre of the structure was determined from the measurements of the surrounding walls. In the structures with double walls (Q2), the

Fig. 1. Stone walls of the giant's church of Kastelli in Raahe. The greatest length of the structure is 62 m.

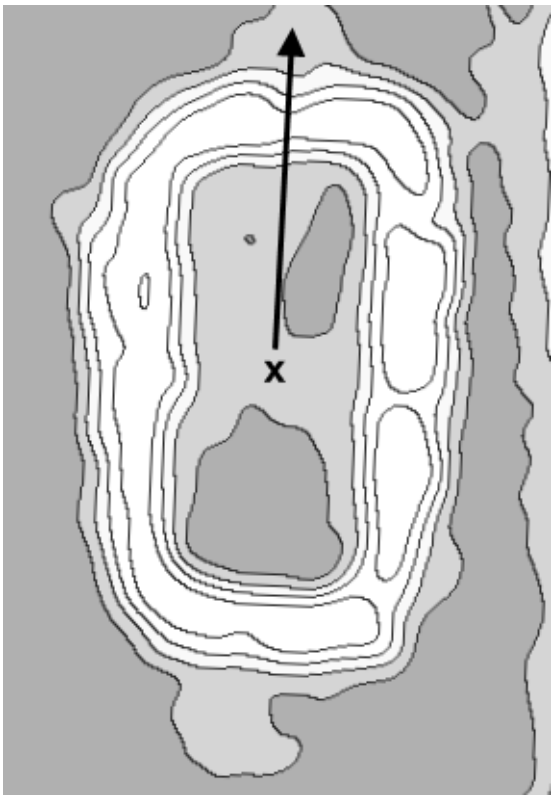

Fig. 2. Elevation model of the giant's church of Kastelli in Raahe. The arrow illustrates how the orientations of the gates were measured from the center of the structure, marked with 'x'.

centre of the structure was determined using the inner walls, if those were clearly detectable. (3) In two cases, Hangaskangas and Kiviojankangas, where the structures are so–called 'open rectangular' (Open R), i.e., lacking one or two walls to create a full rectangle, the directions of the walls and the directions towards the ends of the open walls were measured. In Hangaskangas, the directions towards the ends of the walls were measured as seen from the sacristy in the middle of the 'bottom' wall of the open structure, whereas in Kiviojankangas, the directions towards the ends of the open walls were measured from the single gate in the long wall.

As the giant's churches were originally built on the seashore or on islands, the original horizon height towards the west was zero in almost all cases. Because they were most often built on the highest points of the natural formations protruding out of the former sea floor, they were situated higher than the surrounding terrain, and also the eastern the horizon height was, in most cases, close to zero. Only in few cases the orientations were observed to be towards a nearby elevated point, another rocky island or drumlin. In these cases, the height of the horizon is given in Table 1. The existence of trees on the islands would, of course, have affected the horizon height, but, at this point of research, this effect is impossible to estimate, as it is not yet known whether most of the structures were built when the locations were still bare outer islands, or already parts of the forest–covered coastal region.

The results of the measurements for the long axes, gates and sacristies of 39 giant's churches are given with the precision of one degree in Table 1. The greatest source of error in the study comes from the level of preservation of the structures, which affects the estimated exact locations of the centres and gates of the structures. Some of the giant's churches, like Kastelli, are rather well preserved and have been cleared from the surrounding forest. In three cases (marked with an asterisk in Table 1), the digging of a sand pit or forest ploughing has destroyed parts of the structures. In two cases (Storbacken and Kåtabacken), the structures were so thickly covered with ground cover that no gates could be reliably observed. In two cases (marked with a question mark in Table 1), the existence or original direction of a gate towards which the orientation was measured, is unclear due to level of preservation. Due to the method of measurement and the level of preservation of the structures affecting the original widths of the gates and the exact locations of the central points of the structures, even an orientation with an error of +/- 5 degrees compared to the nearest solar date was considered a possible one.[1]

The northernmost of the sites is Metelinkirkko in Yli–Ii (65.4 deg N, 25.7 deg E), and the southernmost is Höjsaltträsk in Vöyri–Maksamaa (63.1 deg N, 22.4 deg E). Between these latitudes, the change in the azimuth of the rising point of the upper limb of the sun at the winter solstice is about nine degrees. Because of this variation in the rising and setting points, also the distance in full degrees to the exact orientation of the nearest solar date is given in Table 1.

The study concentrated on solar events, as the extreme lunar rising and setting points at the times of the maximum lunar standstill are ill-defined at the latitudes of Ostrobothnia. The solar events considered in this study were the solstices, the equinoxes and the so-called Mid-Quarter Days (see, e.g., Ruggles, 2005: 265). As the two Mid-Quarter Days surrounding each solstice have the same solar positions, only two of them need to be considered. In Finland, the most important festivals coinciding with these four parts of the year have traditionally been Vappu (St. Valborg's Day) in May, and Kekri, which was the ancient festival of the dead predating historical times, celebrated in November. For the sake of brevity, the names of these ancient local festivals are used below.

The eight main solar dates of the year correspond to ten different rising and setting points of the sun on the sky. At the latitude of Raahe, the rising and setting points of the sun at these dates correspond to about one tenth of the width of the full horizon. With the error limits of +/-5 degrees, the rising and setting points correspond to about one third of the horizon. At the lower latitudes of Central and Southern Ostrobothnia, these numbers decrease slightly.

As Table 1 shows, within the error limits of +/-5 degrees, about half of the 39 giant's churches have their long axes oriented to solar events. Also about half of the 90 orientations towards gates and sacristies are oriented to solar events. Within error limits of +/-1degrees, one quarter of the gates and sacristies are oriented to solar events. If cardinal points, i.e., the north and the south, are taken into account, the amount of axes orientations to defined events rises slightly to 62 percent, and the amount of gate and sacristy orientations to 60 percent.

Two thirds of all of the giant's churches have either an axis, or a prominent gate or sacristy orientation towards a solar event. If cardinal orientations are included, the amount of possible deliberate celestially motivated orientations rises to 79 percent. For all structures that are 25 m or longer, the respective percentages are 70 (23 out of 33) and 85 (28 out of 33). It is perhaps interesting to note that 7 out of 11 of the largest, over 40-m giant's churches have their axis oriented to solar events, and four of those are towards either winter or summer solstice.

In addition to the orientations to the positions of the rising and setting sun on the eight main solar dates of the year, there are possible orientations to the solar positions on these dates determined using a lunisolar calendar. For example, the middle eastern gate of Kastelli, which is the largest of all known giant's churches, is oriented towards the sunrise 11 days before the spring equinox, or 11 days after the autumn equinox. The error of eleven days is, of course, the error in calculation when the length of one tropical year, 365 days, is calculated using 12 lunar synodic months, which equals 12x29.5=354 days.

Kåtabacken, which is one of the largest giant's churches, has its axis oriented to 11 days before Kekri, while, e.g., Hiidenlinna and Metelinkirkko have axis orientations to sunrise about 20 days after the vernal and autumnal equinox, respectively. The latter orientations point towards calculating the length of one solar year using 13 synodic months. Together, these kinds of orientations may indicate that the builders of the giant's churches were familiar with the use of a lunisolar calendar.

Discussion

The Giant's Churches are large, enclosure–type constructions, reminiscent of the early Neolithic rondels or henges and Mega-

1The measurements were made with a compass. The error due to the magnetic declination at each geographical location was corrected. The position of the sun was also measured with the compass to detect and eliminate possible local magnetic effects resulting, e.g., from rock type. The total error of the compass measurement was estimated to be +/- 1.5 degrees maximally. The error resulting from the uncertainty in the location of the centre of a structure was estimated to be +/- 1.9 degrees max. for a giant's church of an average size (about 30 m long).

	Name	Location	Shape	Size (m)	Ori. of axis (deg)	Horizon	Solar event	Name of event	Other ori. (deg)	Horizon	Solar event	Name of event
1	**Metelinkirkko**	Yli-Ii	Q2	38x29	109	0	x+18	Eqx srise				
2	**Rajakangas**	Haukipudas	Q2	32x26	55	0	x+5	Vappu srise	55	0	x+5	Vappu srise
									270	0	x	Eqx sset
3	**Laivakangas NE**	Kiiminki	Q	25x15	95	0	x+4	Eqx srise	95	0	x+4	Eqx srise
									275	0	x+3	Eqx sset
4	**Keskimmäisenkangas**	Oulu	Q2	25x15	72	0	x-17	Eqx srise				
5	**Jättiläissaari**	Muhos	Q	20x16	117	0	x-14	Kekri srise	137	0	x+3	Kekri srise
									156	0	x-2	WS srise
									305	0	x-8	Vappu sset
6	**Metelinkangas**	Tyrnävä	Q2	40x22	69	0	x+18	Vappu srise	244	0	x+15	Kekri sset
7	**Mustosenkangas**	Liminka	Q2	37x23	148	0	x-11	WS srise	58	0	x+7	Vappu srise
									234	0	x+5	Kekri sset
									148	0	x-11	WS srise
									328	0	x-12	SS sset
8	**Linnakangas**	Tyrnävä	Q	25x15	138	0	x+4	Kekri srise	39	0	x-9	Vappu srise
									143	0	x+9	Kekri srise
									293	0	x-20	Vappu sset
									s67	0	x+16	Vappu srise
9	**Kotakangas**	Tyrnävä	Q	29x15	146	0	x+12	Kekri srise	146	0	x+12	Kekri srise
									326	0	x+13	Vappu sset
									s48	0	x	Vappu srise
10	**Linnamaa***	Liminka	Q2	40x28	130	0	x-1	Kekri srise	310	0	x	Vappu sset
11	**Linnakangas**	Siikajoki	Oval	27x18	5	0	N+5	Cardinal	80	0	x-9	Eqx srise
12	**Kastelli**	Raahe	Q	62x36	13	0	x	SS srise	10	0	x-2	SS srise
									46	1	x-6	Vappu srise
									103	1	x+11	Eqx srise
									169	1	x	WS srise
									197	0	x	WS sset
13	**Kiviojankangas**	Raahe	Open R	40x21	168	1	x	WS srise	258	0	x-12	Eqx sset
									o40	0	x-8	Vappu srise
									w78	0	x-11	Eqx srise
									o149	0	x+15	Kekri srise
									w168	1	x	WS srise
14	**Pesuankangas**	Siikajoki	Q	33x24	138	0	x+4	Kekri srise	138	0	x+4	Kekri srise
									318	0	x+5	Vappu sset
15	**Kehämaa**	Raahe	Round	10x10					s68	1	x+14	Vappu srise
									s104	1	x+11	Eqx srise
16	**Pikku Jakenaro**	Raahe	Q	33x16	178	0	S-2	Cardinal	178	0	S-2	Cardinal
									358	0	N-2	Cardinal
									260	0	x-10	Eqx sset
17	**Kettukangas***	Raahe	Q	30x20	48	1	x-4	Vappu srise	193	0	x-4	WS sset
									s204	0	x	WS sset
18	**Pirttivaara**	Raahe	Q2	38x26	175	0	S-5	Cardinal	175	0	S-5	Cardinal
									355	0	N-5	Cardinal
19	**Pirttihaudankangas**	Raahe	Q2	54x31	87	0	x-2	Eqx srise	80	0	x-9	Eqx srise
20	**Hangaskangas**	Kannus	Open R	40x30	133	0	x+1	Kekri srise	so115	0	x-15	Kekri srise
									so193	0	x-8	WS sset
									w32	0	x+8	SS srise
									w123	0	x-7	Kekri srise
									w147	0	x-7	WS srise
21	**Hiidenlinna**	Himanka	Q	46x29	73	0	x-16	Eqx srise	90	0	x	Eqx srise
									247	0	x+17	Kekri sset
									164?	0	x+5	WS srise
									181	0	S+1	Cardinal
									342	0	x	SS sset
									s52	0	x	Vappu srise
									s115	0	x-14	Kekri srise
22	**Hautakangas**	Kokkola	Q	30x20	5	0	N+5	Cardinal	229	1	x+3	Kekri sset
23	**Kämppäkangas**	Kokkola	Q	14x8	111	0	x-18	Kekri srise	102	0	x+11	Eqx srise
									293	0	x-15	Vappu sset
24	**Pikku Hautakangas**	Kokkola	Q	25x13	145	0	x-8	WS srise	s102	0	x+11	Eqx srise
									s125	0	x-4	Kekri srise
25	**Honkobackaharju N**	Kruunupyy	Q	25x20	178	0	S-2	Cardinal	178	0	S-2	Cardinal
									358	0	N-2	Cardinal
26	**Brantbacken 1**	Kruunupyy	Q	13x10	173	0	S-7	Cardinal	171	0	S-9	Cardinal
									357	1	N-3	Cardinal
27	**Brantbacken 2**	Kruunupyy	Q	12x10	56	0	x+4	Vappu srise	56	0	x+4	Vappu srise
28	**Ollisbacken 1**	Kruunupyy	Q	25x15	52	0	x	Vappu srise	52	0	x	Vappu srise
									232	0	x+1	Kekri sset
29	**Ollisbacken 2**	Kruunupyy	Q	25x15	57	0	x+5	Vappu srise	55	0	x+3	Vappu srise
									240	0	x+9	Kekri sset
30	**Ollisbacken 3***	Kruunupyy	Q	25x15	55	0	x+3	Vappu srise	53	0	x+1	Vappu srise
31	**Kåtabacken**	Kruunupyy	Q3	70x30	120	0	x-9	Kekri srise				
32	**Högryggen**	Kruunupyy	Q2	36x20	175	0	S-5	Cardinal	175	0	S-5	Cardinal
									355	0	N-5	Cardinal
33	**Snårbacken**	Kruunupyy	Q	17x10	120	0	x-8	Kekri srise	282	0	x+10	Eqx sset
34	**Hembacken**	Pedersöre	Q	50x20	149	0	x-3	WS srise	39	0	x-11	Vappu srise
									270	0	x	Eqx sset
									330	0	x-5	SS sset
									s155	0	x	WS srise
									s180	0	S	Cardinal
35	**Tallbackharju**	Pedersöre	Q2	25x20	1	0	N+1	Cardinal	181	0	S+1	Cardinal
									s270	0	x	Eqx sset
									s243	0	x+12	Kekri sset
36	**Svedjebacken**	Pedersöre	Q2	58x34	113	0	x-15	Kekri srise	113	0	x-15	Kekri srise
									293	0	x-15	Vappu sset
									207?	0	x	WS sset
									s27	0	x+1	SS srise
37	**Storbacken 1**	Evijärvi	Q	35x20	63	0	x+10	Vappu srise				
38	**Jäknabacken**	Pedersöre	Q	65x35	148	0	x-4	WS srise	148	0	x-4	WS srise
									s327	0	x-5	SS sset
39	**Höjsaltträsk**	Vöyri	Q2	38x20	27	0	x	SS srise	27	0	x	SS srise
									207	0	x	WS sset
									s32	0	x+5	SS srise

Table 1. Orientations of the giant's churches. The azimuths of the orientations and the horizon hights are given in full degrees. The solar dates have been calculated for the year 2500 BCE. Abbreviations: WS = winter solstice; SS = summer solstice; Eqx = equinox; srise = sunrise; sset = sunset. The azimuth of the closest solar event is given as x+n = m, where x is the event given in 'Name of Event', and n is the difference between this event and the measured orientation m. 'w' denotes the orientation of a wall, 'o' is an orientation towards the end of an open wall, and 's' denotes an orientation towards a sacristy; all unmarked orientations are towards gates. A question mark denotes an uncertain or partly destroyed gate; a partly destroyed giant's church is marked with an asterisk.

lithic stone enclosures (Okkonen, 2009: 184). The observed solar orientations from the centres of GCs towards the gates are in accordance with the archaeoastronomical studies of the nearest analogs of these types of large ritual enclosures in other contemporary and previous cultures in Northern and Western Europe.[2]

The latitudes, where the giant's churches are located, are unique in the Northern Hemisphere, because, between them, the daily path of the sun is very close to the horizon at the winter solstice, and at the summer solstice, the sun barely sets. Increasingly towards the northernmost latitudes, the azimuthal positions of the sunrise are so close to the true north or south at the summer and winter solstices, respectively, that it is difficult to distinguish deliberate cardinal orientations from solar ones. In some cases they are, in effect, the same within the precision with which the orientations can be measured due to the preservation of the structures. This is especially true for the winter solstice orientations, if the horizon is elevated.

An interesting point can be raised based on this movement of the sun close to the horizon line. It is known from the historian Diodorus Siculus that the movement of the moon close to the horizon was considered significant by the builders of at least one Megalithic temple, identified by A. Burl as the ring of Callanish on Lewis, Outer Hebrides (Burl, 1995: 150). Ostrobothnia is too far north for the extreme maximum standstill points of the moon to be used for orientating buildings (since at its maximum and minimum declinations, the moon neither rises nor sets in most of Finland), but a similar effect to the one described by Diodorus Siculus is produced by the movements of the sun on the winter solstice. This effect could have been used for orientation purposes. One reason for building these monuments in Ostrobothnia could thus be related to this special kind of movement of the sun at these latitudes.

In many giant's churches, the gates are at the ends of the long axes of the structures. The observed correlation between the axis orientations and the orientations of gates partly reflects this fact. However, the gates are not always in the middle of the end wall, which gives them an orientation different from the axis orientation.

The orientations of the sacristies must be, at this point, considered secondary in importance to the gate orientations. However, their importance is emphasized by the fact that at some giant's churches, there are no gates, but only prominent sacristies near the walls.

Most of the sacristies have pits in the middle of them. There are also pits in the walls of many giant's churches, which have lead to speculations on wooden posts having once stood in them. During the measurements of the project, observations were made on standing stones situated in some sacristies, as well as in some walls, either still erect in their pits or fallen next to those. Therefore, it is possible that there may have been both stones and wooden posts in the pits in the walls, as well as in the pits of the sacristies. The orientations measured for the sacristies show that some of those wooden posts or stones may have marked solar positions. Thus, the orientations of the sacristies may be significant and should be further studied in the future.

The study did not reveal a specific reason why most of the giant's churches were built rectangular instead of circular, as henges or rondels. The reason is probably that the beach ridges were made use of, thus keeping the amount of work needed as small as possible. This is also why the Finnish monuments were built using smaller stones than the Megalithic stone circles: the stone material already at or near the building site was used as efficiently as possible. At those sites where large boulders were readily available, they were used as parts of the walls (e.g., in Jäknabacken and Pesuankangas).

The long axes of the open–walled giant's churches turned out to have solar orientations. The study could reveal no reason why these structures were not completed into a full rectangle. However, one possible function of the open walls is revealed by the orientations towards the ends of the walls in Kiviojankangas. The open structure of Kiviojankangas belongs to the largest concentration of giant's churches in Raahe, near Kastelli, where there are four giant's churches in the area of three square kilometres. The open walls of Kiviojankangas were constructed so that both Kastelli and the small round giant's church of Kehämaa could have been visible for an observer standing in the middle of the structure and looking towards the ends of the open walls.

The statistics for the giant's churches larger than 25 meters suggest that especially the largest giant's churches may have had some ritual functions, while many of the smaller ones may be remains of dwellings. This suggestion can be compared to the results of the studies of the immediate surroundings of Kastelli, where bases of rectangular dwellings, as well as other signs of permanent inhabitation and various economical activities have been found (Okkonen, 2003: 187).

The society that built the giant's churches was essentially a Mesolithic-type maritime culture, living by the sea and off it, largely by seal hunting and fishing. However, agriculture had already arrived in the region. The first signs of grain cultivation in the Northern Finland are from Puolanka in 2200 BCE (Vuorela, 2002). Puolanka is located about 70 km from the giant's churches in Tyrnävä and Muhos.

The Northern Mesolithic society probably cooperated with the first Neolithic farmers by trade. Regular trading relations were established not only with the farmers living nearby, but also via longer routes, the inland water routes and the Baltic Sea. Long-term contacts lead to the adaptation of new ideas, which eventually altered the social structure and cultural practices, including the concept of time (Okkonen, 2003: 184, 219–226; 2009; Ollila, 1999).

At the time, social complexity increased. The building of monumental structures may reflect this change (Okkonen, 2003: 184). The cultural transformation of the hunter-gatherer society by obtaining, amongst other influences, calendrical information from the Neolithic farming societies could explain the building of large structures with solar orientations. The orientations of some of the largest giant's churches related to the lunisolar calendar suggest the arrival of a new, more precise calendar to the area in the Early or Middle Neolithic.

Thus, the giant's churches of Ostrobothnia can ultimately be seen as part of the Neolithic enclosure-building, which first manifested itself in the rondels of Northern Germany in 5000–4500, and continued in the later enclosures in the region and in the

2 For the orientations measured for rondels and henges, see, e.g., Bertemes et al., 2004; Bertemes and Spatzier, 2008; Burl, 1995; Pásztor and Barna, 2008; Ruggles, 2005; Schlosser, 2004.

Fig. 3. Sun setting behind the western gate (az 268 deg) of the giant's church of Rajakangas in Haukipudas on the spring equinox in 2009. The arrow points to a rod placed in the snow to mark the position of the gate.

constructions of the Megalithic culture in Western Europe (see, e.g., Baldia, 1995; Bertemes et al., 2004; Bertemes and Spatzier, 2008; Burl, 1995; Hoskin, 2001, 2008; Pásztor and Barna 2008; Ruggles, 2005; Schlosser, 2004).

However, it is too early to say whether the giant's churches were used primarily as cult places. They may have had other functions, too. Orientating the structures towards important solar dates may also have been a 'mode of fashion' rather than the manifestation of new religious beliefs. Further research on the sites is required to understand the meaning of the solar orientations of the giant's churches observed in this study.

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Fig. 4. Sun rising behind the eastern gate of Kastelli in Raahe on the spring equinox. The orientation of the gate (az 103 deg), marked with an arrow in the figure, is towards the sunrise 11 days before the spring equinox as measured from the centre of the structure. The orientation may be related to the calculation of the solar year using lunar months.

Medieval Time in Orient and Occident

The contribution of al-Ṣūfī to the study of the astrolabe

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Abstract: The astrolabe was the most widespread astronomical instrument from the Greek-Roman period to the end of the Middle Ages and the beginning of the Renaissance. Among the most important treatises on the use of the astrolabe was those written by the astronomer cAbd al-Raḥman al-Ṣūfī (903-986AD). In this paper, the outline of the 3 treatises of al-Ṣūfī on the astrolabe is presented, with a focus on the description of the construction of the almucantars on a disk of the astrolabe, and the calculation of the distance between two cities using the astrolabe. There is also a comparison between the 3 versions. The work of al-Ṣūfī on the astrolabe inaugurated a new era in the study of the instrument. The preserved treatises on the use of the astrolabe before al-Ṣūfī are short and elementary. Al-Ṣūfī tried to compile complete and detailed treatises, not only including and systematizing the previous knowledge, but also correcting the errors of the former authors and expanding the use of the astrolabe to thousands problems included in his treatises.

Keywords: astrolabe, al-Ṣūfī, stereographic projection, almucantars, distance between cities, destour

Introduction

The astrolabe was the most widespread astronomical instrument from the Greek-Roman period to the end of the Middle Ages and the beginning of the Renaissance. A lot of treatises on the theoretical background, the construction and the use of the astrolabe have been written in various languages as Greek, Syriac, Arabic, Latin etc.

The astronomer cAbd al-Raḥman ibn cUmar ibn Muḥammad ibn Sahl Abū al-Ḥusayn al-Ṣūfī (b. 291H/903AD, d. 376H/986AD) from Rayy of Persia, famous for his book on the fixed stars (بك‌اوك‌ال روص باتك) -perhaps the most important treatise on the fixed stars in the Middle Ages- had also written treatises on the construction and use of the astrolabe.

There exist at least 9 manuscripts of these treatises that can be classified in 3 versions; we shall call them T, G and S versions. The existent publications of those treatises are the following: The text of the manuscript Paris 2493 (Arabic) belonging to T-version, which is the poorest version, has been published in Hyderabad[1]; the English introduction by Kennedy and Destombes to the Arabic text was published later[2]. A facsimile edition[3] of two manuscripts, Topkapi, Ahmet III, 3509/1 (T-version) and Aya Sofya 2642/2 (S-version) by F. Sezgin, was the basis of a bad edition of both manuscripts in Rabat[4]. There is nothing published from G-version[5], which originally comprised 1760 chapters, but the first half of the treatise has been lost. The G-version was the main work of al-Ṣūfī on the astrolabe.

In the following, I will present the main features of my thesis "Les traités d'al-Ṣūfī sur l'astrolabe". I am thankful to Prof. R. Rashed who proposed to me this subject and to Prof. R. Morelon who supervised my research.

1 Al-Ṣūfī, *Kitāb al-ᶜamal bi-l-asṭurlāb,* ed. M. ᶜAbdul Muᶜid Khān (Hyderabad-Deccan, 1962)

2 Kennedy, E. –Destombes, M., *Introduction to "Kitab al-'amal bil-asturlab"* (Hyderabad-Deccan, 1966)

3 Al-Ṣūfī, *Two books on the Use of the Astrolabe*, Institute for the History of Arabic-Islamic Science (Frankfurt am Main, 1986)

4 Al-Ṣūfī, *Two books on the Use of the Astrolabe*, ed.Ali Amraoui (Rabat, 1995). The text of the treatises has been changed in many cases, without any reference. The notes of a reader have been incorporated to the main text of MS Topkapi (e.g. in chapters T9, T10, T11 p.98; T20, T23 p.102). In pp. 93 and 95, in the drawings of the front side and of a dismounted astrolabe respectively, the "murī" (مرى)namely the index of the spider- is represented as an ostensor, although al-Ṣūfī explains the meaning of "murī" giving its description in the first chapter of each treatise. In many cases the person who edited the manuscript, was not able to read it correctly. For example the table of the astrolabe stars in chapter T40 has been terribly distorted (p.122), while a "corrected" table is presented (p.123), where the positions of the stars and the value of the obliquity of the ecliptic are those of our era! The above are indicative of the quality of the edition of Rabat; it is not worth listing further details.

5 Coming from the manuscript Paris Arabe 5098.

Early history of the astrolabe

The Greek origin

In order to evaluate the contribution of al-Ṣūfī in the theoretical study and the use of the astrolabe, we have first to study the history of the astrolabe, examining the Greek origin of the astrolabe and the contribution of the Arabs up to the time of al-Ṣūfī and a short period after him.

The oldest existing treatise relative to the astrolabe is the *Planisphaerium* of **Claudius Ptolemy** (~150 AD). The original Greek text under the title «Ἄπλωσις ἐπιφανείας σφαίρας»[6] (Unfolding the Surface of a Sphere) is lost but the treatise is preserved through Arabic and Latin translations[7]. In the *Planisphaerium*, Ptolemy gives the theoretical background for the construction of the astrolabe, although the word "astrolabe" does not appear in text. He describes the construction of the elements of the astrolabe (the horizon, the equator, the tropics and the ecliptic are represented as circles, while the horary circles as straight lines). He presents proofs for the bisection of the great circles of the sphere in their projection on the plane, he calculates the radii of the tropics, the ecliptic and some circles parallel to the equator that are useful for the division of the zodiac, and he determines the position of the center of the ecliptic. He calculates the rising times of the zodiacal signs in the right and oblique sphere; those in the right sphere are useful for the division of the zodiac. He also studies the construction of the circles parallel to the ecliptic, mentioning that the circle parallel to the ecliptic through the south celestial pole is represented by a straight line.

All the above are consistent with what we call today stereographic projection from the south celestial pole on a plane parallel to the equator.

Since the "Memoir on the little astrolabe" (Εἰς τον μικρόν ἀστρολάβον ὑπόμνημα)[8] of Theon of Alexandria (4th cent. AD) is apparently lost, the oldest preserved treatise on the description and use of the astrolabe is that of **Joannes Philoponus** (6th cent. AD), comprising 15 sections and written in Greek[9]. In this trea-

6 Suda Lexicon, letter pi, entry 3303: «Πτολεμαῖος ὁ Κλαύδιος».

7 The Latin version of *Planisphaerium* is translated into German by Drecker, J., 'Das Planisphaerium des Claudius Ptolemaeus', *ISIS*, IX (1927): 255-78 and the Arabic version of it is translated into English by Anagnostakis, C., *The Arabic version of Ptolemy's Planisphaerium*, Ph.D. Thesis (Michigan, 1984)

8 Suda Lexicon, letter theta, «Θέων, ὁ ἐκ τοῦ Μουσείου» entry 205

9 Joannes Philoponus, 'Joannis Alexandrini, cognomine Philoponi, de usu astrolabii eiusque constructione libellus', ed. H. Hase, *Rheinisches Museum*, 6 (1839): 129-56. The subjects of the sections in Philoponus' treatise are the following: 1. Introduction, 2. Description of the back of the astrolabe, 3. Description of the disks, value of ε, 4. Description of the spider, 5. Measuring the altitude of the sun

tise, he gives a detailed description of the astrolabe (sections 2-4) and he resolves a series of problems using the astrolabe (sections 5-15).

Severus Sebokht (7th cent. AD) follows the Greek tradition and writes a treatise on the astrolabe in the Syriac language[10]. Similarly to Joannes Philoponus he describes the astrolabe and its use for solving a series of problems. In the description of the astrolabe he had used at least two different sources for his treatise, without realizing that they were incompatible. In one of them the disk of the astrolabe is limited by the tropic of Capricorn (figure 1), while in the other (figure 2) the disk is limited by the antarctic circle, namely the greatest of the circles of perpetual occultation. The combination of the descriptions of the two disks as one makes a confusion. There are also several errors in the description of the use of the astrolabe[11].

Although Sebokht's treatise deals with some subjects not discussed in the treatise of Philoponus, it ranks at a lower scientific level because of the numerous errors that appear in it.

The contribution of the Arabs before al-Ṣūfī

Thereafter the Arabs handed over the evolution and the study of the astrolabe. The translation and study of the works on the Greek science, which flourished in particular in the House of Wisdom in Baghdad, prompted the Arab scholars to write numerous treatises on the astrolabe. These works are cited by authors contemporary or subsequent to that period, as Ibn al-Nadīm[12] and Ibn al-Qifṭī[13]. Unfortunately most of the treatises before the 10th century are lost and the existing evidence is not enough to compile a complete account of the works of the Arabs related to the astrolabe. Only a few treatises on the astrolabe from the 9th century AD still survive; among them the treatises of ᶜAlī b. ᶜIsā al-Ḥarrānī or al-Asṭurlābī[14], Muḥammad b. Mūsā al-Khwārizmī[15] and Aḥmad b. Muḥammad b. Kathīr al-Farghānī [16]. The Latin treatise[17] that circulated under Māshā'allāh's name (~730-815 AD) is not taken in consideration because according to Kunitzsch[18] it is a western compilation.

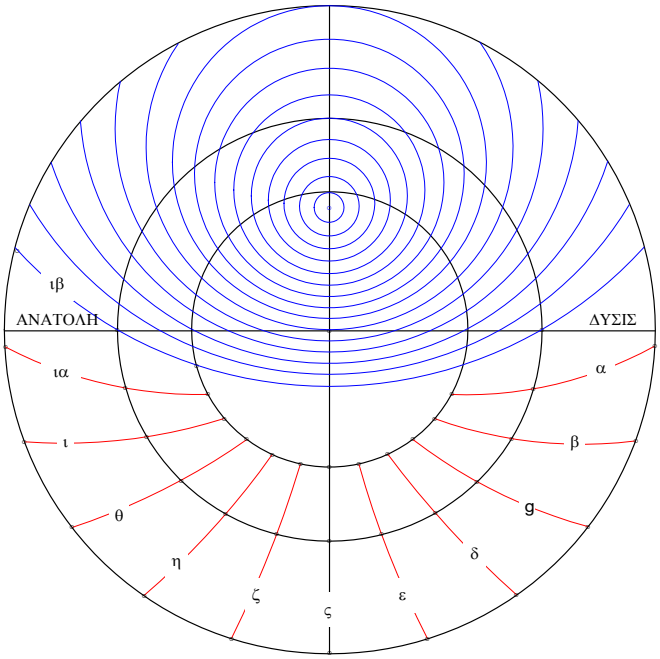


Figure 1. The disk of the astrolabe, limited by the tropic of Capricorn, according to the description of Joannes Philoponus.

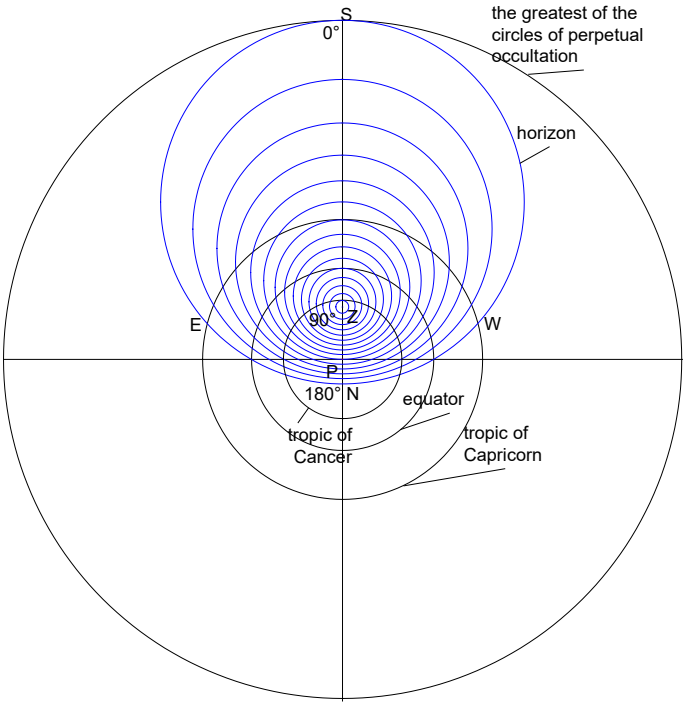


Figure 2. A disk whose rim coincides with the greatest of the circles of perpetual occultation.

The treatises of **ᶜAlī b. ᶜIsā** and **al-Khwārizmī** deal with problems that can be resolved using the astrolabe; that of ᶜAlī b. ᶜIsā contains also a description of the astrolabe. The subjects of those treatises are related to elementary calculations on the diurnal movement of the celestial sphere and time calculations, determining the positions of the sun, the fixed stars and the planets, determining the time of the Muslim prayers and they also have to do with Astrology. In total there are less than 60 different subjects.

The treatise of **al-Farghānī** deals with a completely different subject: the theory of the stereographic projection and the construction of the astrolabe. The 1st chapter of the treatise, which is devoted to the theory of the stereographic projection, contains three theorems, among them the fundamental theorem of the stereographic projection: "The circles of the sphere are projected

and determining the time in unequal daytime hours, 6. Determining the fraction of an unequal hour. Position of the lines of unequal hours, 7. The 4 centers, 8. Measuring the altitude of a star and determining the time in unequal nighttime hours, 9. Determining whether the sun or the star is before or after the meridian. Maximum altitude of a degree of the ecliptic, 10. Rising times of the zodiacal signs, 11. Degrees corresponding to an unequal day- or night-time hour, 12. Determining the longitude of the sun, 13. The same near the solstices. Degrees of the ecliptic reaching the same maximum altitude, 14. Determining the longitude of the planets, 15. Declination of the degrees of the ecliptic, the sun, the moon, the planets and the fixed stars.

10 The text has been translated into French by Nau, accompanied by an introduction and comments: Nau, M.F, 'Sévère Sabokt: Traité sur l'astrolabe plan', *Journal Asiatique*, série 9e, tome XIII, (1899) 56-101, 238-303. Gunther has also included an English translation of the French text in Gunther, R. T., *The astrolabes of the world* (Oxford, 1932): 82-103, but this translation is not reliable.

11 See Vafea, F. *Les Traités d'Al- Ṣūfī sur l'astrolabe,* Ph.D. Thesis (Paris, 2006): 13-22

12 Al-Nadīm, *Kitāb al-Fihrist*, ed. Flügel, G. (Leipzig, 1871-72) and Al-Nadīm, *Kitāb al-Fihrist*, ed. Reza Tajaddod (Tehran, 1971)

13 Ibn al-Qifṭī, *Tārikh al-Ḥukamā*, ed. Lippert, J. (Leipzig, 1903)

14 Edited in Arabic: ᶜAlī ibn ᶜIsā, 'L'astrolabe et la manière de s'en servir' "بالرطصألاب لمعلا باتك", ed. Cheikho, L., *al-Mashriq*, 16 (1913): 29-46, and translated into German by C. Schoy 1927, 'ᶜAlī Ibn ᶜIsā: Das Astrolab und sein Gebrauch', *ISIS*, IX (1927): 239-254

15 Frank, J., 'Die Verwendung des Astrolabs nach al-Chwārizmī', *Abhandlungen zur Geschichte der Naturwissenschaften und der Medizin*, Heft III, (1922): 1-32

16 Edited in Arabic with English translation and commentary by Lorch, R., *Al-Farghānī On the Astrolabe* (Stuttgart, 2005)

17 It contains two parts: "*De compositione astrolabii*" and "*De operatione uel utilitate astrolabii*", edited by Gunther (Gunther, *Chaucer and Messahalla on the astrolabe*, Early Science in Oxford, vol.5, (Oxford, 1929), 195-231.

18 Kunitzsch, P., 'On the Authenticity of the Treatise on the Composition and Use of the Astrolabe ascribed to Messahalla', *Archives Internationales d'Histoire des Sciences*, 31 (1981): 42-62

as circles onto the plane"; the proof of al-Farghānī is the oldest one preserved of this theorem. The 2nd chapter describes the stereographic projection of the circles of the celestial sphere as circles or straight lines on the plane. In the 3rd chapter, methods for the calculation of the radii of the circles on the surface of the astrolabe and the position of their centers, while in the 4th chapter these methods are used for the compilation of various tables for the construction of the astrolabe. In the 5th and 6th chapters the construction of a northern and a southern astrolabe is described respectively, while in the 7th chapter al-Farghānī claims that the methods that he had presented are the unique correct methods.

The treatises of al-Ṣūfī on the astrolabe

The work of al-Ṣūfī on the astrolabe inaugurated a new era in the study of the instrument. Al-Ṣūfī was not satisfied with the short treatises written on the astrolabe before him and tried to compile a complete and detailed treatise, not only including and systematizing the previous knowledge, but also correcting the errors of the former authors and expanding the use of the astrolabe to thousands problems included in his treatises. The results of his long-lasting study on the astrolabe were written down in 3 treatises that we shall call T, G and S versions. The research on the treatises of al-Ṣūfī on the astrolabe was based on the following manuscripts (table 1):

T-version

The manuscripts of T-version

The first 7 manuscripts of table 1 consist the T version. The best of the above manuscripts is that of Topkapi. There is a complete list of contents at the beginning of this manuscript and the chapters are enumerated in words or in Arabic letters (abjad). We have applied the enumeration of the Topkapi manuscript to the manuscripts of Istanbul University and St. Petersburg, since there is no enumeration in the latter two. The letter **T** is attached in front of the number of a chapter, to indicate that the enumeration corresponds to that of Topkapi manuscript.

The manuscript Paris 2498 includes also a list of contents for 400 chapters, but the main text stops in chapter 355. Moreover 15 chapters have been omitted during the copying. The enumeration of MS Paris 2498 is in accordance with that of MS Topkapi. The manuscript of Istanbul University has no list of contents, tables, figures and enumeration, but the text of 400 chapters is almost complete.

The manuscript of St. Petersburg is made up of 2 fragments, copied from the same source. The first fragment contains the chapters T1 to T154 and the second one the chapters T119 to T157.

The manuscripts Paris 2493 (National Library of France), Teheran 703 and 704 (Library Sīpahsālār of Teheran) are almost identical copies of the same manuscript, transcribed between 1859 and 1880. We shall call these manuscripts the group P. The manuscripts of the group P appear to have 386 chapters, while the Topkapi manuscript has 402 chapters; this led to the conclusion that the group P is not complete and it contains the first 386 chapters of the Topkapi manuscript[19]. A closer examination of the contents of the above manuscripts shows that only five chapters of MS Topkapi have been completely omitted from the group P (T40[20], T47, T86, T245 and T400). The division of the treatise in chapters is different in the group P, although the content of the treatise is almost the same with that of Topkapi[21]. In the following, the letter **P** attached in front of the number of a chapter indicates enumeration corresponding to the group P.

The character of T-version

T-version was the first treatise on the astrolabe compiled by al-Ṣūfī. As he mentions in the introduction of the treatise, a noble man, whose name is not mentioned, asked him to make a presentation of the knowledge concerning "the instrument containing the disks" -namely the astrolabe- and its use, because he found that the books already existing in that field, which he had read, were not complete nor perfect. So, al-Ṣūfī hurried to write this book in order to please and satisfy him.

Al-Ṣūfī collected all the existent knowledge on the use of the astrolabe and added new subjects. T-version contains about 400 chapters, while the survived treatises of the previous authors on the use of the astrolabe contain less than 50 chapters. In T-ver-

19 Sezgin, F., *Geschichte des arabischen Schrifttums*, Band VI: *Astronomie* (Leiden, 1978): 215

20 Chapter T40 contains a table of positions of fixed stars taken from the book of al-Farghānī on the astrolabe, already out of date at the time of al-Ṣūfī.

21 For example chapter P299 contains T302-303, P383 contains T389-394, P384 contains T395-T397, P385 contains T398-399 and T401. Chapter P63 (on the determination of the ascendant using the five planets) is included only in the manuscripts of group P. The chapter P63's position should be between T64 and T65. For a detailed comparison between the P group and the rest of the manuscripts of T-version see the table 1.3.21 and the Appendix Vb in Vafea, *Les Traités d'Al-Ṣūfī*.

Table 1. The manuscripts of the treatises of al-Ṣūfī on the astrolabe.

Manuscript	Date	Nr. Of folios	Number of chapters	Tables & Figures	Remarks	Version
Topkapi 3509/1	676 H 1277AD	261	402	5 tables 7 figures		T
Paris 2498	10th c.H	114	340 developed	-	incomplete	T
Istanbul Univ. 1325/2	10th c.H	59	400	-		T
St. Petersburg B 1029	1053 H 1643AD	a.35 b.10	a.153 b. 39	2 tables	2 fragments a and b	T
Paris 2493	1283 H 1866AD	185	386	10 figures	the 3 MSS are almost identical	T
Teheran 703	1275 H 1859AD	203	386	8 figures		
Teheran 704	1290-97H 1873-80 AD	212	386	1 figure		
Paris 5098	4th c. H	308	816 surviving out of 1760	2 tables 24 figures	unique of this version	G
Aya Sofya 2642/2	871H 1467AD	65	170	-	unique of this version	S

sion, al-Ṣūfī expands the use of the astrolabe for solving astronomical problems such as

– the visibility and the daily displacement of the moon, the visibility of the planets and the lunar and solar eclipses (T145-157)

– the angular distances of the sun, the moon, the planets and the fixed stars from the tropics, the equator or the celestial poles (T253-266)

– the rising and setting of the poles of the ecliptic and the maximum and minimum altitude and maximum depression of them (T238-247)

He also introduces

– measurements on the surface of the earth, using the back of the astrolabe (T344-353),

– the study of the sine, the inverted sine and the arc sine (T109-115),

– the examining of the correctness of an astrolabe (T363-401)

– a study on the astrolabe stars following the Arabic tradition (T402).

Al-Ṣūfī also presents various methods for solving the same problem.

Although T-version was an important step in the evolution of the study of the astrolabe, we cannot ignore some significant defects:

– The term "longitude" (طول، مطلع) or "degree" of a star (درجة الكوكب) is used for the "mediation" of the star, namely the degree of the ecliptic that culminates simultaneously with the star, while the term "latitude" (عرض) is used for the difference of declination between the star and its "degree". This is an influence of the Sindhind tradition. These terms appear also in previous authors who wrote treatises on the astrolabe in Arabic.

– The order of presentation in T-version is not the appropriate one

– There are some incomplete or not accurate methods; there are also some roundabout methods beside simple ones.

– The use of the maximum altitude of a star or the sun, instead of the declination or the polar distance, complicates the solution of problems.

– The study of the astrolabe stars is in a low level, including errors and ambiguities.

In the epilogue of T-version, as presented in manuscripts of group P and Istanbul University, al-Ṣūfī writes that he does not claim that he had included all the knowledge concerning the astrolabe in this treatise, and that he, or somebody else, might increase this knowledge. This was the motive for composing G-version, which includes an exhaustive study on the use, the construction and the check of the astrolabe.

G-version

The unique representative of G-version is the manuscript "Paris 5098" from the Arabic collection of manuscripts in the National Library of France. It is the remnant of the main work of al-Ṣūfī on the astrolabe, which contained 1760 chapters arranged in 16 books, from which only 816 chapters from the last 8 books have survived. It was written for the library of the prince ᶜAḍud al-Dawla (reigned 949-983), as al-Ṣūfī mentions in the introduction of S-version. It is the oldest manuscript of the treatises of al-Ṣūfī on the astrolabe, since it was copied in the 4th century H[22]. It consists of 308 folios (307 enumerated but there are two folios under the number 210). Some folios are bound in disorder[23].

In the surviving part of this treatise, the use and the construction of the astrolabe are studied, also the construction and use of devices for measuring the time as a bowl (طاس) in chapters XV.73-80 and a sundial (مزاخر) in chapters XV.81-101. The whole book XVI was devoted to a detailed check of the astrolabe, except for the last chapter (XVI.110), which dealt with the astrolabe stars. Unfortunately chapters XVI.53-110 are apparently lost. Since we have no evidence for the contents of the first half of the treatise[24], we cannot say if the theory of the stereographic projection was included in G-version.

The character of G-version

G-version was the mature and detailed work of al-Ṣūfī on the astrolabe. After he realized the problems of T-version, he tried to solve them and to cover all possible cases in the use of the astrolabe. In the problems studied, he examined the cases where there is a disk for the desired latitude or not, where the desired star is drawn or not on the astrolabe, where the sine is constructed or not on the astrolabe etc. He studied the problems not only for the place of the observation, but also for a different place. Many of the problems of T-version, mentioned above, where solved in G-version, but the details of the study and the immensity of the treatise made it hard to use.

The stereographic projection in G-version

We present below the methods for the construction of the horizon and the almucantars, as an example of the work of al-Ṣūfī in G-version. Although the basic theorems of the stereographic projection are not present in the surviving part of the manuscript, the methods are applications of the theory of the stereographic projection.

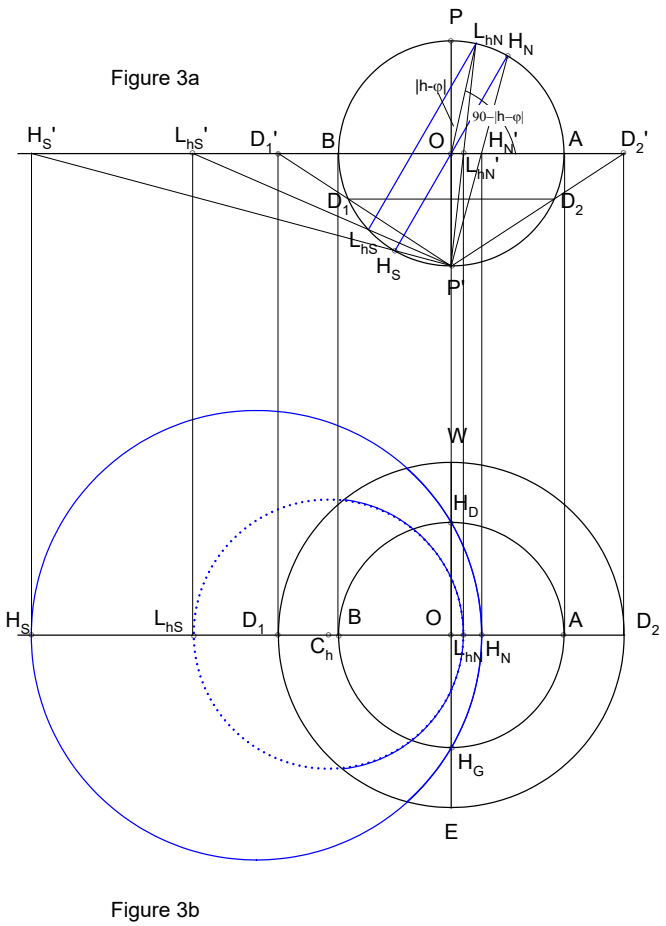
In the stereographic projection for the construction of a northern planispheric astrolabe, the south celestial pole plays the role of the pole of the projection, while the plane of the celestial equator, or any plane parallel to it, plays the role of the plane of projection. For the construction of a southern planispheric astrolabe, the north celestial pole is used as the pole of the projection. Before examining the methods of al-Ṣūfī, let us study how the horizon and the circles parallel to it can be projected onto the plane of the equator.

Let the circle (O, OA) be a meridian section of the celestial sphere, AB be the diameter of the circle representing the equator, D_1D_2 a chord parallel to BA, such that $A\hat{O}D_2=\varepsilon$, representing the tropic of Capricorn and H_NH_S be a diameter of this circle forming an angle $H_N\hat{O}P=\varphi$ with the axis PP′ of the celestial poles and representing the horizon. Let $L_{hN}L_{hS}$ be a chord of the circle, parallel to H_NH_S having a distance of h degrees from H_NH_S; this chord corresponds to the almucantar of altitude h (figure 3a). The stereographic projection of the horizon, or the circles parallel to it, will be the intersection of the plane of the projection with the

22 Sezgin, *Geschichte des arabischen Schrifttums*, VI, 215, also Kennedy – Destombes, *Introduction* , pp. 4-5.

23 The correct sequence is given in Vafea, *Les Traités d'Al-Ṣūfī*, section 1.3.2.1.

24 Except for the mention of al-Ṣūfī, in chapter S127 (S-version), that he had described the construction of a disk of latitude $\varphi=90°-\varepsilon$ in chapter VII.37 (G-version).



Figures 3a-3b. The stereographic projection of the horizon and the circles parallel to it.

cone having as vertex the pole of the projection and as base the circle to be projected, as it is proved in the second chapter of the treatise on the astrolabe by al-Farghānī[25]. For the determination the projection of the one of the above circles, we determine the projection of its diameter on the line AB that represents the plane of the projection. For the horizon, we draw the lines $P'H_S$, $P'H_N$ that intersect line AB at the points H_S' and H_N' respectively (figure 3a); the circle of diameter $H_S'H_N'$ will be the projection of the horizon on the plane (it is the circle of diameter H_SH_N in figure 3b). Similarly for the circle of altitude h parallel to the horizon, we draw the lines $P'L_{hS}$, $P'L_{hN}$ that intersect line AB at the points L_{hS}' and L_{hN}' respectively (figure 3a); the circle of diameter $L_{hS}'L_{hN}'$ will be the projection of that circle on the plane (it is the circle of diameter $L_{hS}L_{hN}$ in figure 3b).

Construction of the almucantars (first method)

In G-version al-Ṣūfī presents two methods for the construction of the northern astrolabe. In the first method the various lines of the astrolabe are constructed directly on it, by projecting the necessary circles and points on each one of the astrolabe disks. This method is presented in chapter **XV.102**. Here al-Ṣūfī presents a geometric construction of the horizon and the almucantars, without calculating their radii, or their distances from the center of the astrolabe.

The construction of the almucantars is described for a sexpartite astrolabe and for a disk of latitude φ=30°. The method can also be applied to a n-partite astrolabe[26] (n=1, 2, 3, 6) for any latitude φ.

25 See Lorch, *Al-Farghānī* : 50-57.

26 In a n-partite astrolabe, the almucantars whose altitude is multiple of n degrees are drawn, e.g. a sexpartite astrolabe contains the almucantars of altitude 6°, 12°, 18°, 24°, …, 84°, 90°.

For the construction of the almucantars (Figure 4), we draw the radii of the disk that terminate between φ and 90+φ degrees of the limb, leaving an interval of n degrees of the limb between two successive radii. In the example of the manuscript, we draw the radii between 30 and 120 degrees of the limb, leaving an interval of 6 degrees of the limb between two successive radii. We put a red mark at the intersection of each radius with the circle (P, PG)[27]. The red mark corresponds to the northern point of the almucantar[28] of altitude of h degrees and is determined by the radius terminating at 90+φ-h degrees of the limb[29].

We also draw the radii of the disk, which terminate between 270+φ and φ degrees of the limb, leaving an interval of n degrees of the limb between two successive radii. In the example of the manuscript, we draw the radii between 300 and 30 degrees of the limb, leaving an interval of 6 degrees of the limb between two successive radii. We put a black mark at the intersection of each radius with the circle (P, PG). The black mark corresponds to the southern point of the almucantar of altitude of h degrees[30] and is

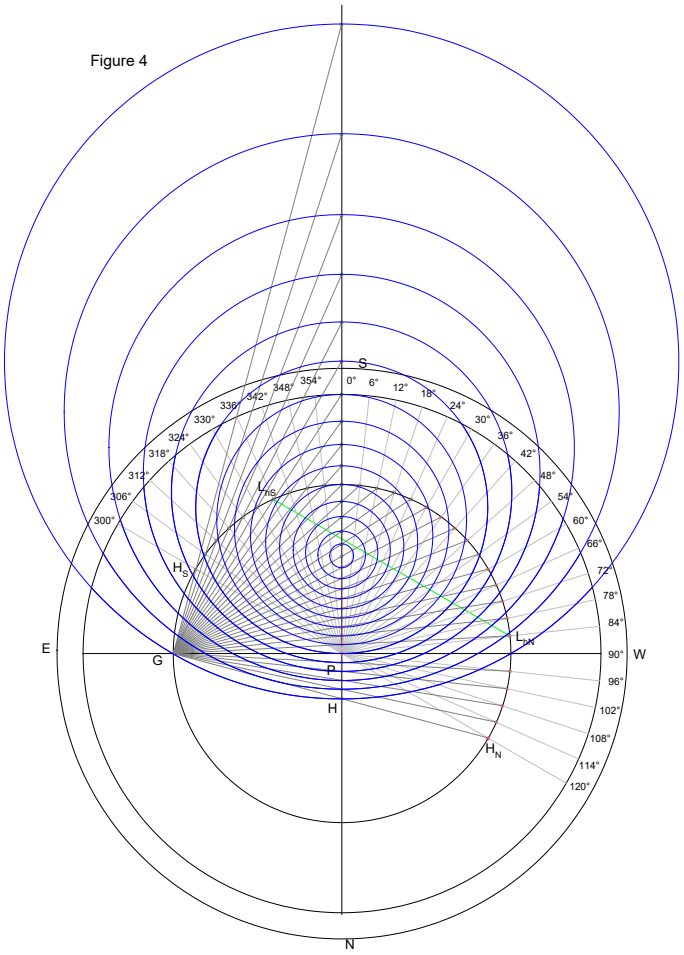
27 The circle (P, PG), which is the projection of the equator on the disk, here represents the meridian section of the celestial sphere. The point G represents the south pole of the sphere, namely the pole of the stereographic projection, while the straight line NS, which is the projection of the meridian on the disk, represents here the plane of the projection.

28 By the term "northern point of the almucantar" we mean the point of intersection of the almucantar with the meridian to the north of the zenith, while by "southern point of the almucantar" we mean the point of intersection of the almucantar with the meridian to the south of the zenith.

29 The red marks on the equator correspond to the positions of the points H_N and L_{hN} ($h=k\cdot n$, $k \in \mathbb{N}$, $0<k<90/n$) on the meridian section of the celestial sphere in figure 3a

30 The black marks on the equator correspond to the positions of the points H_S and L_{hS} ($h=k\cdot n$, $k \in \mathbb{N}$, $0<k<90/n$) on the meridian section of the celestial sphere in figure 3a.

Figure 4. Construction of the almucantars according to the 1st method presented by al-Ṣūfī.



determined by the radius terminating at 270+φ+h degrees of the limb, if φ+h<90°, or at φ+h-90 degrees of the limb, if φ+h≥90°.

The red and the black marks on the radii terminating at 90+φ and 270+φ degrees of the limb are respectively the northern and the southern extremities of the horizon, represented as the segment H_NH_S that forms an angle of φ degrees with the axis of the poles, here represented by the east-west line EW. The red and the black marks on the radii terminating at 90+φ-h and 270+φ+h (or φ+h-90) degrees of the limb, are respectively the northern and the southern extremities of the almucantar of altitude h, represented as the segment $L_{hN}L_{hS}$ parallel to the horizon H_NH_S. The red and the black marks on the radius terminating at φ degrees of the limb are identical and correspond to the zenith.

We fix the disk on a board and we extend the meridian NS towards the south. We connect the point of rising of the first point of Aries G with each one of the red and black marks on the equator by a straight line, and we put a red or a black mark respectively at the point of intersection of each line with the meridian NS [31]. There are 90/n red marks between the zenith and the line of the center of the earth HN[32], and 90/n black marks above the zenith, within or outside the disk. Each pair of a red and a black mark on the meridian, corresponding to the almucantar of the same altitude h, defines the diameter of the almucantar of altitude h. We draw the circles of the almucantars; the almucantars of altitude h, where 90°>h≥h♑=90°-φ-ε[33], are drawn as complete circles on the disk; the almucantars of altitude h, where h♑=90°-φ-ε>h≥0°, are drawn partially on the disk and partially on the board (the part on the board is drawn in a dotted line in figure 4). The almucantar of the horizon intersects the tropic of Capricorn at d/2 and 360-d/2 degrees of the limb, where d/2 is the half daytime arc of the first point of Capricorn for the latitude φ.

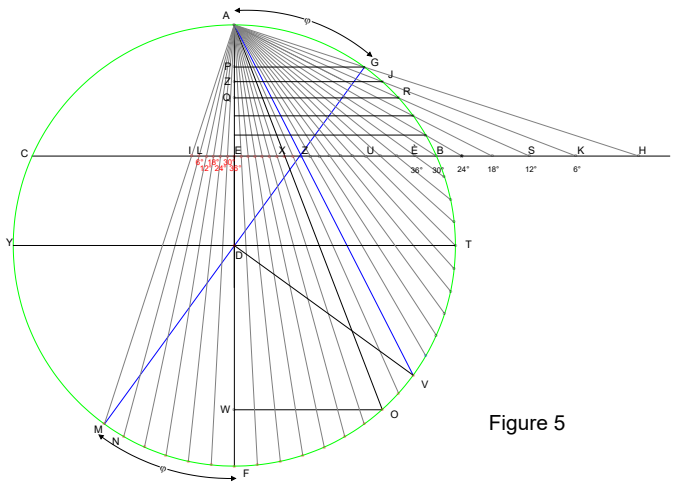


Figure 5

Figure 5. Construction of the almucantars according to the 2nd method, using the destour.

Construction of the almucantars by the use of the ***destour*** *(second method)*

The second method is presented in chapters **XV.103-105**. Here we work on a circle drawn on a board or a piece of paper, called the *destour* (دستور). We make the stereographic projection on this *destour*, determining the radii and the positions of the centers of the three circles, the ecliptic, the horizon and the almucantars and we transfer the results to the astrolabe we construct. The second method is equivalent with the first one. We shall present only the work with the almucantars.

We draw the circle (D, R), where R=60, and two perpendicular diameters of it AF and TY (figure 5). We take a point C on the arc YA, such that the arc YC is equal to the obliquity of the ecliptic ε, and we draw the chord CB//YT. The chord CB intersects the diameter AF at the point E. The segment CEB will be the diameter of the disk corresponding to the meridian, E will be the center of the disk and the radius R_d=EB of the disk will be equal to Rsinε=55.

We take the points M, G respectively on the arcs FC, ABF, such that the arcs FM, AG are equal to the latitude φ of the disk. We divide the arc ABF into 180/n parts, where n=1,2,3 or 6, for a n-partite astrolabe, each part is an arc of n degrees. We also divide the arc FM into φ/n parts, each part is also an arc of n degrees. We take on the arc FB a point V, such that the arc FV is equal to the complement of the latitude of the disk, 90°-φ.

For the stereographic projection on the *destour* (Figure 5), the circle (D, R) represents the sphere that we project, the point A represents the pole of the projection (south celestial pole), while the line CB represents the plane of the projection parallel to the equator YT. The point F is the north pole on the sphere, while the point E is its projection, the center of the disk. The diameter MG represents the horizon and forms an angle φ=GDA=MDF with the axis AF of the poles, while the almucantars are chords parallel to the horizon having a distance of n degrees between them, where n=1, 2, 3, 6, according to the type of the astrolabe[34]. Zenith corresponds to the point V of the circle (D, R); VD⊥MG since MDV=MDF+FDV=φ+90°-φ=90°. We mark the divisions on the arc MV with red marks (northern extremities of the almucantars) and those on the arc GV with black ones (southern extremities of the almucantars). The red and black marks of each almucantar are equidistant from V.

We connect the pole A with the extremities M, G of the horizon; the lines AM and AG intersect the line CB at the points I, H respectively. The projection of the diameter of the horizon will be the segment IH and that of its radius the segment ΘI (ΘI=ΘH), while the distance of the arc of the horizon from the center will be EI. We transfer this distance EI as PH on the meridian of the disk, starting from the pole P towards the point N (figure 6). Then we draw the arc of the horizon having a center on the line of the middle of the sky HS[35], radius equal to IΘ and passing through the point H. This arc must pass through the points of rising and setting of the first point of Aries G, G′.

We work similarly with each almucantar: we connect the red and the black marks corresponding to the extremities of each almucantar with the pole A and we take the projection of its diameter on the line CB, marking red or black the projection of the corresponding extremity. We also determine the center of each almucantar as the midpoint of its diameter. The projection of the almucantar of altitude h=φ, if it is drawn on the disk (this hap-

31 The red marks on it correspond to the positions of the points H_N' and L_{hN}', while the black marks on the meridian correspond to the positions of the points H_S' and L_{hS}' (h=k·n, k ∈ ℕ, 0<k<90/n) on the meridian section of the celestial sphere in figure 3a.

32 The segment HN is the part of the meridian below the horizon and it is called the line of the center of the earth.

33 h♑=90°-φ-ε is the maximum altitude of the tropic of Capricorn, which coincides with the rim of the disk.

34 In the examples of the manuscript n=6; in chapter XV.103 φ=30° and in chapters XV.104-105 φ=36°. Figure 6 corresponds to φ=30°, while figure 5 corresponds to φ=36°.

35 The half line HS is the part of the meridian above the horizon and it is called the line of the middle of the sky

pens when the latitude φ is integer multiple of n), passes through the point E (the center of the disk), since the red mark of its extremity is on the point F (north pole). The projection of the zenith V will be the point Z, which is the intersection of the line VA with the line CB.

We take the distance of the red mark[36] of the projection of each almucantar from the center E, and we transfer it as a red mark onto the meridian of the disk (Figure 6) starting from the center P towards N for an altitude h<φ or towards S for h>φ; for h=φ the almucantar passes through the center P. We draw the circle (or the arc) of each almucantar; its center is on the line of the middle of the sky HS, the radius has been already determined and it passes through the corresponding red mark on the meridian. The almucantars of altitude h<90°-φ-ε will be drawn as arcs; the corresponding black mark of the extremity is outside the circle (D, R) on the segment BH in figure 5. The almucantars of altitude h≥90°-φ-ε will be drawn as circles; the black mark of the extremity is inside the circle (D, R) on the segment ZB. We also place the zenith Z on the line of the middle of the sky of the disk, having a distance PZ from the center of the disk (Figure 6) equal to the distance EZ on the *destour* (Figure 5).

Calculation of the distances of the almucantars from the center of the disk and the radii of the almucantars (Figure 5)

We continue with the calculation of the radii of the almucantars and the distances of the almucantars from the center of the disk, as described in chapter XV.104. For this calculation the *destour*, as previously described, is used. The method presented can be applied for any latitude φ, although the example presented is for φ=36°, and for any size of the astrolabe we want, although the presented example is for the sizes of the astrolabe corresponding to the radii R_d=55 and R'_d=30 of the disk. In the following the medieval sine function will be symbolized by "Sin", denoting Sinx=R·sinx, while the sine of the complement by "Cos", denoting Cosx=R·sin(90-x) =R·cosx. The inverted sine (سوكنم بيج) means here R-Cosx.

We shall calculate the distances d_h, b_h of the northern and southern points of each almucantar (red and black marks respectively on the line CB) from the center E of the disk, for any latitude φ. For our convenience, we shall call "northern distance" the distance d_h of the intersection to the north of the zenith, and "southern distance" the distance b_h of the intersection to the south of the zenith.

Calculation of the northern distance

We take the point F as the zero point on the circle (D,R), assuming for our convenience that the arcs from the point F towards the point V have positive sense, while the arcs from the point F towards the point M have negative sense. Similarly we take the point E as the zero point on the line CB and we define a positive sense from the point E towards the point B (south direction) and a negative sense from the point E towards the point C (north direction).

The northern point of the almucantar of altitude h=k·n (k ∈ ℕ, 0≤k≤90/n) corresponds to the point O on the arc MV, such that the arc FO=h-φ=k·n-φ. We draw the line AO that intersects the line CB at the point X; EX will be the northern distance of the almucantar of h degrees from the center. We also draw the line OW//BC, where W is on the diameter AF. Since EX//WO, the triangles AEX, AWO are similar, then

$$\frac{AE}{EX}=\frac{AW}{WO}\cdot$$

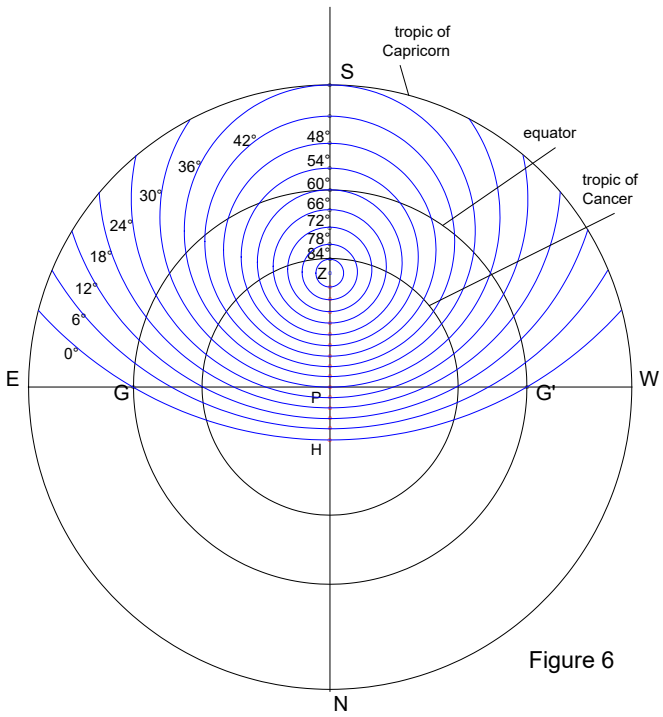


Figure 6. An Astrolabe disk.

We know that AE=AD-DE=R-Sinε=60-24=36, WO=Sin(h-φ) and AW=AD+DW=R+Cos(h-φ). Thus the distance d_h of the northern point of the almucantar of altitude h from the center will be:

$$d_h=EX=\frac{AE\cdot WO}{AW}=\frac{(R-Sin\varepsilon)\cdot Sin(h-\varphi)}{R+Cos(h-\varphi)}=\frac{36\cdot Sin(h-\varphi)}{60+Cos(h-\varphi)}$$

The equivalent of this formula is used by al-Ṣūfī in his calculations. We can rewrite the formula as:

$$d_h=\frac{(R-Sin\varepsilon)\cdot Sin(h-\varphi)}{R+Cos(h-\varphi)}=\frac{R\cdot(1-\sin\varepsilon)\cdot R\cdot\sin(h-\varphi)}{R\cdot[1+\cos(h-\varphi)]}=\frac{R\cdot(1-\sin\varepsilon)\cdot\sin(h-\varphi)}{1+\cos(h-\varphi)}$$

For an altitude h, such that h>φ, the point O is between F and V and we have sin(h-φ)>0 consequently d_h=EX>0 that means the point X will be between E and B. For an altitude h, such that h<φ, the point O is between F and M and we have sin(h-φ)<0, consequently d_h=EX<0 that means the point X will be between E and C. For an altitude h, such that h=φ, the point O coincides with F and we have sin(h-φ)=sin0=0 and 1+cos(h-φ)>0, consequently d_h=EX=0, that means the almucantar passes through the center E of the disk.

Calculation of the southern distance

The southern point of the almucantar of altitude h=k·n (k ∈ ℕ, 0≤k≤90/n) corresponds to the point R on the arc GV, such that the arc RA=φ+h=φ+k·n. We draw the line AR that intersects the straight line CB at the point S; ES will be the southern distance of the almucantar of h degrees from the center. We also draw the line RQ//BC, where Q is on the diameter AF. Since RQ//SE, the triangles AQR, AES are similar, then

$$\frac{AQ}{QR}=\frac{AE}{ES}$$

We already know that AE=R-Sinε=60-24=36. We have QR=Sin(φ+h) and AQ=AD-DQ=R-Cos(φ+h).

Thus the southern distance b_h of the almucantar of altitude h will be:

$$b_h=ES=\frac{AE\cdot QR}{AQ}=\frac{(R-Sin\varepsilon)\cdot Sin(\varphi+h)}{R-Cos(\varphi+h)}=\frac{36\cdot Sin(\varphi+h)}{60-Cos(\varphi+h)}$$

36 The red marks are on the segment IZ (Figure 5).

The equivalent of this formula is used by al-Ṣūfī in his calculations. We can rewrite the formula as:

$$b_h = \frac{(R - Sin\varepsilon)\cdot Sin(\varphi + h)}{R - Cos(\varphi + h)} = \frac{R\cdot(1-\sin\varepsilon)\cdot R\cdot\sin(\varphi+h)}{R\cdot[1-\cos(\varphi+h)]} = \frac{R\cdot(1-\sin\varepsilon)\cdot\sin(\varphi+h)}{1-\cos(\varphi+h)}$$

The result of the above formula is always positive.

The radius of the *destour* is taken as R=60, which corresponds to a radius R_d=55 for the disk. The distances d_h, b_h obtained by the above formulas correspond to such a disk. In the case that the disk has a different radius R'_d, the distances must be multiplied by the ratio $R'_d/R_d=R'_d/55$; the *destour* is standard and its radius R cannot be changed.

Calculation of the radii of the almucantars (Figure 5)

Al-Ṣūfī calculates the diameter of each almucantar, using the distances of the intersections of each almucantar with the meridian from the center. For the almucantar of altitude h, where $0\leq h<\varphi$, the diameter will be $2R_h=b_h+|d_h|$ ($d_h<0$); for $h=\varphi$, the diameter will be $2R_h=b_h$ ($d_h=0$); for $\varphi<h\leq 90°$, the diameter will be $2R_h=b_h-d_h$ ($d_h>0$). Thus, in all of the cases, we can use the formula

$$R_h = \frac{b_h - d_h}{2}$$

for the radius of the almucantar of altitude h.

The radii obtained by the above formula correspond to a disk of radius R_d=55. In the case that the disk has a different radius R'_d, the radii must be multiplied by the ratio $R'_d/R_d= R'_d/55$.

The above general method, but avoiding the distinction between positive and negative sense, is applied in chapter XV.104, for a latitude φ=36° and n=6. The method is explained in detail in the calculation of the southern and northern distances of the almucantars of 0°, 6°, 12° from the center of the disk and that of the distance of the zenith from the center, as well. In the text the distances are calculated for two sizes of the disk (R_d=55 and R'_d=30), but the diameters and the radii of the almucantars are calculated only for R'_d=30. For the rest of the almucantars the results are presented without detailed calculation, for both sizes.

S-version

The unique representative of S-version is the manuscript Aya Sofya 2642/2 from Istanbul [37], transcribed in 871 H/ 1467 AD [38]. Since G-version is half preserved and T-version is the less elaborated among the 3 versions of al-Ṣūfī's treatise on the astrolabe, we have chosen S-version as the base for the study of the work of al-Ṣūfī on the astrolabe. S-version contains 170 chapters on the description, use and check of the astrolabe; the last chapter deals with the astrolabe stars [39]. We shall use the letter **S** attached in front of the number of a chapter to indicate enumeration corresponding to the chapters of S-version.

The character of S-version

S-version was the last treatise written by al-Ṣūfī on the astrolabe. In the introduction of this treatise, he mentions that this is a short but comprehensive version of his great book on the astrolabe, which contained 1760 chapters, and that he wrote the short version for the prince Abū al-Fawāris Shīrzīl -or Sharaf al-Dawla- son of his patron ᶜAḍud al-Dawla (d. 372H / 983AD). The purpose of this short version was to facilitate the study of the astrolabe; the treatise was intended for both beginners and scholars. The whole treatise follows a new order, which is the best possible; new simple methods replace the complicated ones; the wording is compact and reveals an experienced writer.

S-version was the quintessence of the knowledge on the astrolabe; including only the essentials, free of errors and tiring details.

Determination of the distance between two cities

Among the new subjects that appear in G and S-versions there is a calculation of the distance between two cities using the astrolabe (in chapters XV.68-72 and S145-149 respectively), knowing their geographical coordinates. This problem is interesting because it combines Astronomy and Mathematical Geography. Heron of Alexandria, in his work *Dioptra*, describes how to find the distance between Alexandria and Rome using the *analemma* [40]. Al-Ṣūfī uses the astrolabe to determine the distance between two cities. We will have a close look at this problem.

The distance between two cities A, B is the length of the arc AB of the great circle of the Earth that passes through the points A and B (Figure 7). In order to find the length of the arc, al-Ṣūfī first determines in degrees the central angle AÔB, which is subtended by the arc AB, and then multiplies it by the length of one degree, assuming that the Earth is a perfect sphere.

The length of one degree is taken as d=56 (Arab) miles by al-Ṣūfī. The length of one degree along a terrestrial meridian was estimated as 56 or 56 2/3 miles during the expedition organized by caliph al-Ma'mūn (reigned 813-33 A.D.)[41]. An Arab mile is equal to 4000 black cubits or 1973.2 meters[42], thus the length of one degree along a terrestrial meridian for d=56 (Arab) miles is 110.4992 km and the length of the same degree for d=56 2/3 (Arab) miles is 111.8146 km; the accurate value is 111.3 km[43].

37 According to Sezgin, *Geschichte des arabischen Schrifttums*, VI, 215, MS Paris 2498 and MS Istanbul University 1325 are of the same version as MS Aya Sofya 2642/2, but this is erroneous.

38 Reported by Sezgin in Editor's Introduction in Al-Ṣūfī, *Two books on the Use of the Astrolabe* (1986), and by Kennedy-Destombes, *Introduction*, p. 5

39 The contents of S-version can be summarized as follows: 1. Description of the astrolabe: S1, 2. Diurnal movement: S2-18, 3. The ascendant: its use for astrology and for determining the altitude: S19-24, 4. Measuring the shadow with the astrolabe. Midday altitude of the sun: S25-28, 5. Determining the season of the year and the position of the sun on the ecliptic: S29-31, 6. Determining the time of prayers: S32-35, 7. Rising, culmination, setting of a star. Day- and night-time arc of a star: S36-50, 8. Right and oblique ascension and declination. Latitude of a place: S51-70, 9. The year of the world: S71-74, 10. Culmination at the zenith: S75-79, 11. Determining whether the latitude of a star is north or south: S80-81, 12. Determining whether a northern star sets or not in a given latitude: S82-84, 13. Determination of the elevation of the pole. Study of the trajectory of the poles of the ecliptic: S85-92, 14. Culmination, rising and setting of a star, before, after or simultaneously with its degree: S93-105, 15. Determination of the parts of the ecliptic where the stars rise and set before or after their degree (φ<ε): S106-109, 16. The notion of *tasyīr*: S110-125, 17. Determination of the ecliptic coordinates of a star drawn on the astrolabe: S126-130, 18. Time intervals between the emergence of the dawn or the end of the twilight and the rising or the setting of the sun: S131-137, 19. Degrees of the ecliptic and stars revolving on the same circle: S138-140, 20. Mensuration using the back of the astrolabe: S141-144, 21. Determination of the distance between two cities: S145-149, 22. Check of the astrolabe: S150-169, 23. The stars drawn on the astrolabes: S170

40 Neugebauer, O., 'Über eine Methode zur Distanzbestimmung Alexandria-Rom bei Heron', *Det Kongelige Danske Videnskabernes Selskab, Historisk-filologiske Meddelelser*, 26.2 & 26.7, (Copenhagen, 1938-39), also Kipouros, Ch., *Ήρωνος Αλεξανδρέως, Μετρικά – Διόπτρα*, (Athens, 2000)

41 Al-Bīrūnī [in *The determination of the coordinates of positions for the correction of distances between cities*, ed. Jamil Ali (Beirut, 1967): 178-179] reports this expedition, which took place in the plain of Sinjār, near Mosul, and in which learned astronomers such as Khālid al-Marwarūdhī, ᶜAlī bin ᶜIsa and Aḥmad bin al-Buḥtarī participated. The value for one degree of a terrestrial meridian that resulted from this project, as al-Bīrūnī mentions, is ambiguous between 56 and 56 2/3 miles.

42 Nallino, C., *Arabian Astronomy: Its history during the medieval times* (Cairo, 1911): 288 (in Arabic).

43 According to Kennedy E., 'Mathematical Geography', in *Encyclopedia of the History of Arabic Science*, 3 vols., (London-New York, 1996), vol.I: 188.

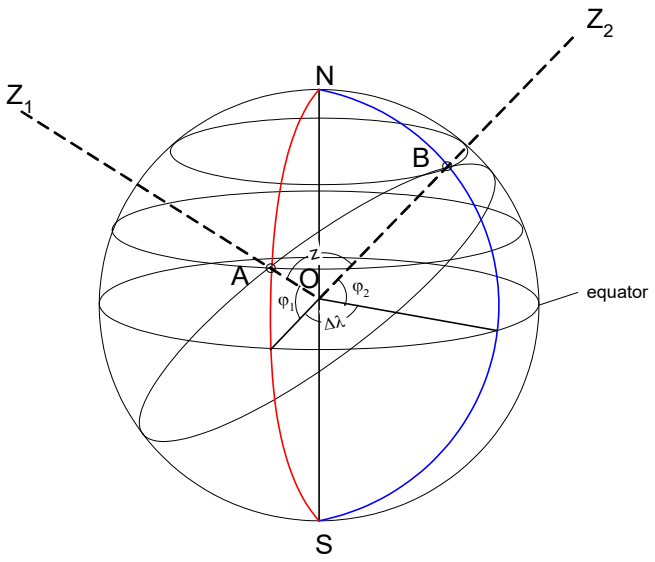


Figure 7

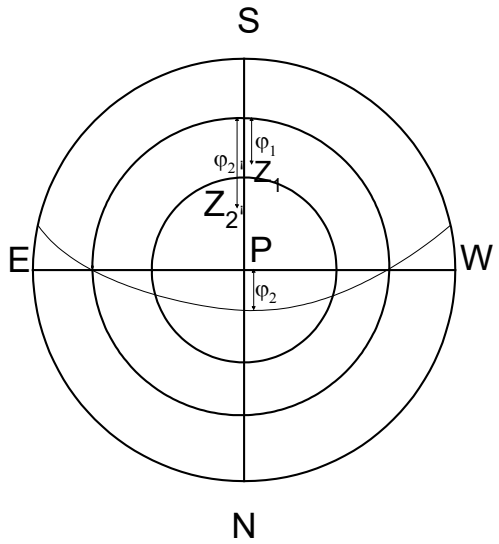


Figure 8

Figure 7. Calculation of the distance between two cities, view on the terrestrial sphere.

Figure 8. Calculation of the distance between two cities: Determination of the zenith Z1 of the locality A on the disk of latitude φ2 of the locality B.

The angle AÔB (figure 7) coincides with the angle $z=Z_1\hat{O}Z_2$, where Z_1 and Z_2 are the zeniths of the localities A and B respectively. We consider a point M of the celestial sphere, which culminates at the zenith Z_1 at time t_1. At that moment the point M will have a zenithal distance z from the zenith Z_2.

We use the disk of latitude φ_2 on the astrolabe and we locate on it the position of the zenith Z_1, counting on the meridian φ_1 degrees from the equator towards the pole (figures 8, 9). Rotating the spider we locate a point M of it that touches the point Z_1. We keep the point M on the meridian touching the point Z_1 and we mark the position of the index. We rotate the spider as many degrees as the difference $\Delta\lambda$ of longitude between the two cities (figure 10). Since the difference of longitude $\Delta\lambda$ is equal to the difference of local time Δt, the new position of M on the astrolabe will be the one observed from the city B, at the moment t_1 when M culminates at the zenith Z_1 of the city A. We find the altitude h of the point M on the almucantars; its zenithal distance z=90°-h from Z_2 multiplied by the length d of one degree will give the distance between the two cities.[44]

44 We could also find directly the distance between the two cities with spherical trigonometry: in the spherical triangle NAB (figure 7) $\cos AB=\cos(90°-\varphi_1)\cdot\cos(90°-\varphi_2)+\sin(90°-\varphi_1)\cdot\sin(90°-\varphi_2)\cdot\cos\Delta\lambda$ or $\cos AB=\sin\varphi_1\cdot\sin\varphi_2+\cos\varphi_1\cdot\cos\varphi_2\cdot\cos\Delta\lambda$, but this method is not used by Al-Ṣūfī.

Figure 9. Calculation of the distance between two cities: Determining a point M culminating at the zenith Z_1 of the locality A.

Figure 10. Calculation of the distance between two cities: Determining the position of the point M as seen from the city B at the instant of culmination at the zenith of the city A.

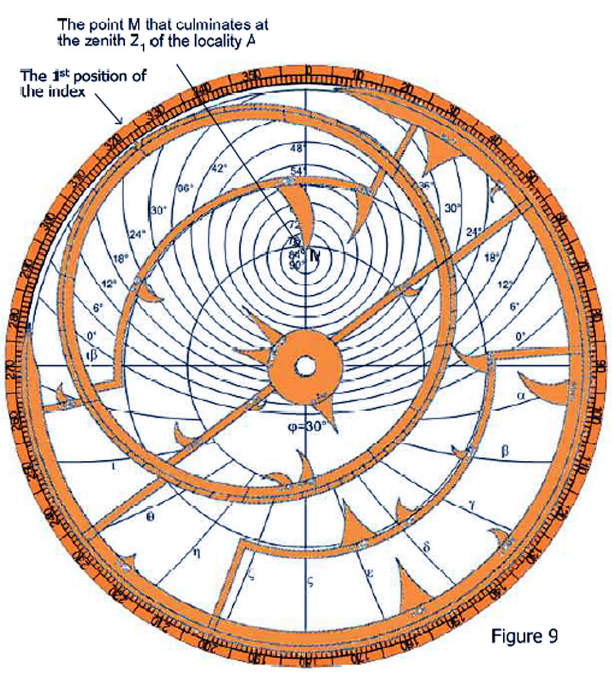


Figure 9

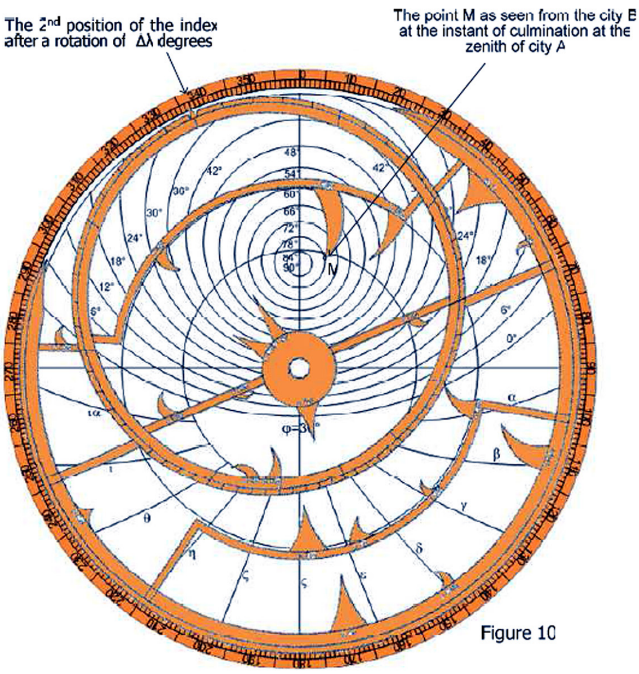


Figure 10

A comparison between the three versions

When al-Ṣūfī undertook to write his first treatise on the astrolabe (T-version), he tried to collect all the existing knowledge on the astrolabe, this knowledge was not free of errors and inaccuracies. He added many new subjects and he intended to systematize all this knowledge on the use and the construction of the astrolabe in a book. Soon he realized that the treatise he wrote was not complete[45]. Thus he compiled a great treatise on the astrolabe (G-version) in 16 books. Each one of the 8 surviving books contains 110-120 chapters. It was an ambitious work, attempting to cover all cases on the use of the astrolabe, including a meticulous check of the astrolabe and detailed instructions for the construction of a northern or a southern astrolabe. The enormous size of the treatise and the detailed study of special cases made G-version hard to use. Next step was the compilation of a concise version of 170 chapters, which included the basic uses of the astrolabe, the check of its construction and a short description of the astrolabe stars.

The comparison of the three versions gives some interesting results:

1. An obvious evolution of ideas is developed from T to G and S versions. For example:

i. There is a transition from the Sindhind tradition followed in T-version to the Ptolemaic tradition followed in G and S versions. In T version the terms "longitude" (لوط، عضوم) and "latitude" (ضرع) are used respectively for the degree of mediation and the difference of declination between the star and its degree of mediation, while in G and S versions the same terms are used to express the ecliptic coordinates.

ii. The study of the astrolabe stars in T-version follows mainly the Arabic tradition and shows that at that time, al-Ṣūfī was not acquainted with the Ptolemaic tradition. He also presents a regional conception of the sky, giving the maximum altitude of some stars[46]. Later he studied the Almagest and compiled the Book of Stars, combining both Ptolemaic and Arabic traditions. S-version was written after the Book of Stars (there are references to this book) and the description of the astrolabe stars is elegant and follows both Ptolemaic and Arabic traditions.

There is an enhancement of the accuracy in G and S-versions, where al-Ṣūfī is more precise about the choice of some astronomical values, than in T-version. The value ε=23° 30′ for the maximum declination, namely for the obliquity ε of the ecliptic, used repeatedly in T-version, has been replaced by the value ε =23° 35′ in G and S-versions. In these two versions, al-Ṣūfī avoids repeating the value and he prefers to call it "maximum declination". This value is presented only twice in S-version (chapters S60, S70), where he mentions that he had measured it using the "ᶜAḍudī" ring[47]. The avoidance of repeating the value (in contrast to T-version) shows that al-Ṣūfī knew that the obliquity of the ecliptic changes by time and that he preferred to give the chance to the prospective readers to put the value of the obliquity that corresponds to their era. He also adapted the resulting magnitudes, such as the rising times of the zodiacal signs and the radii of the equator and the tropic of Cancer, to the new value.

2. The order of presentation in T version is not the appropriate one. The situation is better in G, while it is corrected in S-version. For example:

In the study of the diurnal movement in T-version, the arc of revolution from sunrise or sunset, the arc corresponding to an unequal hour, the ascendant, the shadow and the duration of the day- and night-time in equal hours are used in the solution of problems, before explaining how these quantities can be determined. In S-version the order of study has been rearranged and some bothersome chapters have been omitted[48].

i. The study of the right and oblique ascension, the declination, the polar distance and the terrestrial latitude is scattered in T-version (chapters T116-137, 257, 263-264, 82-86 / P113-133, 250, 256-257, 80-83), while in S-version the whole study has been collected in one place (chapters S51-70). The scattering in T-version causes superfluous repetitions, which are avoided in S-version[49]. The above studies are not included in the surviving part of G-version.

ii. In T-version there is also a disorder in the sequence of the chapters in the determination of the degrees of the ecliptic that revolve on the same circle with a given star: first the degrees of the ecliptic revolving on the same circle with the star are determined (T226-228 / P222-224) and then the existence of such degrees is examined (T229-231 / P225-227). The situation is slightly better in G-version and completely corrected in S-version.

3. There is an obvious evolution of methods between the 3 versions of the treatise on the astrolabe. New simple methods replace more complicated ones, for example:

i. The use of the polar distance of a star in S and G versions[50], instead of its maximum altitude in T and sometimes in G version[51], simplifies the examination of whether a star sets in a given latitude and the determination of the minimum altitude of a star that does not set.

ii. In the determination of the degrees of the ecliptic that revolve on the same circle with a given star not drawn on the astrolabe or a planet, the declination instead of the maximum altitude of the star is used in S-version (S140), giving an elegant solution of the problem, while the use of the maximum altitude of the star generates a lot of cases and complicates the study in T and G versions (T230 / P226 and XIII.113)[52]. S140 is an improved version, which replaces the chapters XIII.109, 113 and 114 of G-version and T227, 228, 230 and 231 of T-version.

iii. In the check of the astrolabe in G-version, the position of a star is examined by the ecliptic coordinates of the

45 Even in the epilogue of T-version, as presented in the manuscripts of group P and Istanbul University, he mentions that "I do not claim that I had included all the knowledge concerning the astrolabe in this treatise, I or somebody else might increase this knowledge"

46 The altitude corresponds to the latitude φ=35° which is the latitude of Rayy. See Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.23.3.

47 Al-Ṣūfī measured the obliquity of the ecliptic in Shiraz using the "ᶜAḍudī Ring" and found it 23 1/3 1/4 degrees, as he mentions in his treatise on the use of the celestial globe (MS Topkapi, Ahmet III, 3505/1, f.7a). According to al-Bīrūnī (*The determination of the Coordinates*, pp. 68-69) al-Ṣūfī measured the obliquity of the ecliptic in winter and summer solstices in the years 338-339 Yazdegerd of the Persian calendar (corresponding to 969-970 AD). This measurement must have taken place between the writing of G and S-version.

48 See Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.2.3 (1).

49 See Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.8.3 (1, 2).

50 in chapters S83-84 and XI.3,5,15

51 in T-version chapters T209-210,214-215 / P205-206,211-212 and in G-version XI.4,14.

52 See Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.19.1.3.

star (XVI.48-52) using a disk of latitude φ=90°-ε, instead of its distances from the equator, the tropics and the north pole in T-version (T401 / P385c)[53].

iv. In the determination of the terrestrial latitude in S-version, the declination of the degree of the sun is used in S65, while in the corresponding chapter T83 / P81 the difference between the altitude of the degree of the sun and that of the first point of Aries is used. The method of T-version is more complicated[54].

v. In T-version there are some wrong or incomplete methods; there are also some roundabout methods beside simple ones. In S-version those problematic methods have been omitted or completed.[55]

Conclusions: The contribution of al-Ṣūfī to the study of the astrolabe

Although the evidence about the astrolabe literature before al-Ṣūfī is not enough to reach a verdict, comparing the work of al-Ṣūfī with the surviving treatises on the use of the astrolabe prior to his, we notice the enormous difference in the quantity and quality. The problems studied in his treatises cover a wide range of uses of the astrolabe. Even if a great portion of this knowledge existed before al-Ṣūfī, it is due to him that all this knowledge was written down, systematized and preserved for the following generations.

We also notice enhancements on the instrument of the astrolabe that facilitate the solution of various problems. In the description and construction of the astrolabe, al-Ṣūfī quotes the following elements of the astrolabe, not mentioned in the surviving treatises of the previous authors:

i. the sine[56], the lines of the unequal hours and those of the Muslim prayers on the back of the astrolabe[57],
ii. the two crepuscular arcs[58] on the disks of the climates
iii. the unequal hours on the alidade[59],
iv. the disk of latitude φ=90°-ε, that can provide directly ecliptic coordinates[60].

In the introduction of S-version, al-Ṣūfī refers to G-version, saying that "*It is mentioned in it, the most that can be understood of the gentle device. I made easier the way to build up on it for the one who wants it.*" In fact, the existence of the treatises of al-Ṣūfī encouraged the rapid evolution of the study of the astrolabe by the end of the 10th and the beginning of the 11th century AD. The numerous treatises of al-Bīrūnī on the astrolabe, the construction of peculiar types of astrolabe by al-Sijzī, the treatise of al-Qūhī on the Geometry of the astrolabe examining various methods of projection might have not be written, if the previous knowledge was not collected and systematized by al-Ṣūfī. The bloom of the study of the astrolabe continued in the following centuries with the construction of the universal astrolabe by al-Zarqallī and the linear astrolabe by Sharaf al-Dīn al-Ṭūsī and the numerous treatises compiled on the astrolabe. Traces of the work of al-Ṣūfī can be also found in the treatises that appeared much later in the Western Europe.

53 See Vafea, *Les Traités d'Al-Ṣūfī*, sections 3.3.22.1.13 and 3.3.22.4 (1vii)

54 See Vafea, *Les Traités d'Al-Ṣūfī*, sections 3.3.8.1.4 and 3.3.8.3 (3iii)

55 For example in chapters T35 / P35, T60 / P58, T215 / P212, T377 / P372a etc.

56 See chapter T1 / P1: the sine and G-version chapter XV.111 (Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.1.1.1 and appendix VII).

57 See chapter T1 / P1: the quarters of the circles and G-version chapter XV.107 (Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.1.1.1 and appendix VII).

58 See chapters T1 / P1 and S1: the two crepuscular lines (Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.1.1.4), also S34, 131, 133, 135, 169.

59 See chapter T1 / P1: the alidade and G-version chapter XV.108 (Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.1.1.1 and appendix VII).

60 In chapters S127, 129 and in G-version chapters XI.9, 16, 24, 30, 33, XII.2, XVI.48, 51 (see Vafea, *Les Traités d'Al-Ṣūfī*, section 3.3.17).

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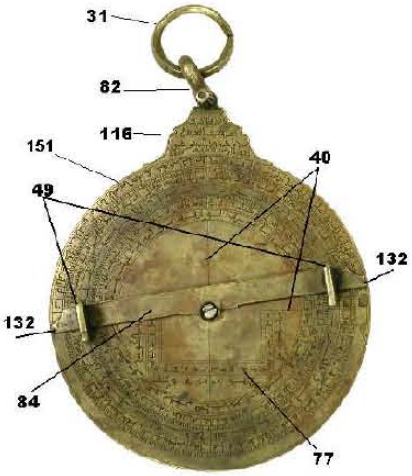
APPENDIX

The astrolabe
(as described by al-Ṣūfī)



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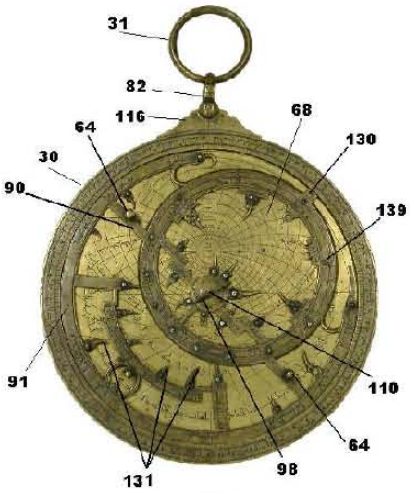

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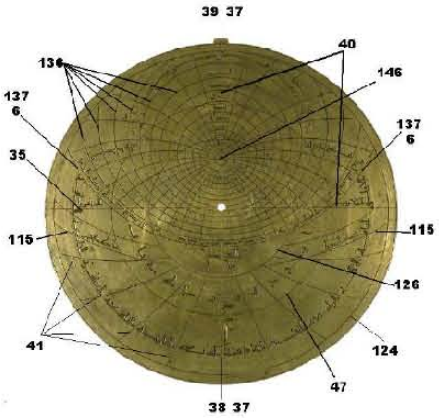

68 - 69

The planispheric astrolabe has on its backside an altitude scale, which can measure the altitude of the celestial objects and a shadow scale. The altitude and the corresponding shadow can be measured by the use of the diopter (Gr. διόπτρα) or the alidade (Ar. العضادة). This is an oblong, thin piece of metal with 2 sighting vanes. The alidade is pivotable round the central axis (the pole).

On the face of the astrolabe, the spider (Gr. αράχνη, Ar. العنكبوت), which is an openwork disk representing the celestial sphere, can rotate on the plates or disks (Gr. τύμπανα, Ar. الصفائح) of the various latitudes, giving the image of the sky at any desired moment. For the construction of the spider and the plates the stereographic projection of the celestial sphere on the plane is used. The circle of the ecliptic and a number of astrolabe stars are represented on the spider. The limb, namely the rim of the front of the astrolabe, is divided into 360 degrees.

On the disks of the various latitudes, there are 3 concentric circles: the tropic of Cancer, the equator and the tropic of Capricorn, which is almost always the outer circle. There also the horizon and the circles parallel to it (almucantars) and very often the circles of equal azimuth. Below the horizon the lines of the unequal or seasonal hours are designed and often the 2 crepuscular arcs.

6 horizon
30 limb
31 ring
35 east-west line
37 meridian
38 line of the center of the earth
39 line of the middle of the sky
40 the lines of quadrature
41 the lines of the hours
47 equator, cycle of the first points of Aries and Libra
49 sighting vane
64 handle, the protruding splinter on the face of spider
68 disk, plate
69 disk having azimuths
77 shadow
78 back of the astrolabe
82 shackle, handle
84 diopter, alidade
90 column of Aries and Libra
91 spider
98 mare, horse
110 pole
115 the two arcs of the emergence of the dawn and the disappearance of the twilight
116 throne
124 tropic of Capricorn
126 tropic of Cancer
130 index of the degrees
131 image, pointer of a fixed star
132 pointer, tip of the alidade
136 circles parallel to the horizon, almucantars
137 eastern almucantar/ western almucantar (= east-west horizon)
139 circle of the ecliptic
146 zenith
150 front of the astrolabe
151 altitude scale

Naked Eye Estimates of Morning Prayer at Tubruq of Libya

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Abstract: Naked eye estimates at Tubruq sky (φ = 32° 05´, λ = 23° 59´) in Libya at the Mediterranean coast during the two years (2008 – 2009) of morning twilight led us to get some estimates about morning twilight, as it is necessary to determine the time of Al-Fajr prayer. The beginning of the morning twilight is estimated to be around 13.5° depression of the sun below the horizon. This value can reach a minimum depression around 11.5° at low visibility and a maximum around 13.5° at very good visibility. The azimuthally range of observation about the solar vertical extends from 0° up to ±20°, while the phenomenon was followed from 0° up to 20° along the altitudinal range.

Keywords: Prayer times, Fajr, Morning Prayer, Twilight begin, Naked eye observations.

Introduction

The human eye is a device which can receive focus and sort out the incident light, and then convert it into chemical, thermal and electrical energy which are necessary to trigger nerve propagation. About 96 % of the light falling on the cornea passes on through the lens and about 4 % is reflected. The eye behaves as an instrument, as though it had an arbitrary variable gain control capable of adjusting itself automatically to a condition under which the output signal is of comfortable strength. Its remarkable ability to adopt itself to the very range of brightness from the day to the night sky levels makes the eye a convenient device for ordinary needs of light, color and form perceptions. The focal length of the human eye is about 20 mm, and the maximum aperture under dark adaptation is about 8 mm. The fovea centralism, which is the region of highest acuity, covers a filed of 0.7° and the resolving power is about one minute of arc. At high brightness levels, where fovea vision comes into use, the threshold is determined by the minimum recognizable contrast in surface brightness. At the boundary between extended areas, this contrast is about 2 %. The time constant of the eye is a function of the brightness level. It is 0.1 sec for very low brightness and 25 m. sec., at higher brightness of 0.01 lumen/cm^2 (Rosenberg (1966) and Allen (1973)).

It has been determined experimentally that for a point source of light to be detectable, the minimum energy rate for light striking the eye must be 10^{-16} Watts. If we consider a light of wavelength, say 500 nm, the number of photons arriving at the eye each second is 250 photons. The eye's response to intensity is logarithmic. This means that the eye's response to brightness is equal to a constant multiplied by the natural logarithm of the actual change in intensity. The logarithmic response of the eye may be demonstrated by experiments in which the intensity of an observed light source is varied in relation to a background light of fixed intensity.

The optical phenomenon of twilight takes place near the time of sunset and sunrise. It occupies the time interval separating the illumination conditions of daytime from night. The appearance of the sky under both twilight and daytime conditions is wholly governed by the optical structure of the atmosphere, particularly its interaction with sunlight. As the sun sinks towards the horizon, an increase in the optical path of its rays through the atmosphere is associated with a decrease in its brightness. This leads to a weakening in the illumination of the earth's surface by both direct and scattered light in the atmosphere. The combined luminance of the daytime conditions shows a slight dependence on the sun's altitudes. A progressive drop in the luminance begins to accelerate sharply when the sun's altitude is 5 - 10°, and the twilight is considered to have set in. Sky twilight observations and measurements entail considerable troubles (Roach and Gordan (1973) and Donald Mc Gillivray (1987)).

There are six general factors contributing in the night sky brightness: (1) integrated light from distant galaxies; (2) integrated starlight within our galaxy; (3) zodiacal light; (4) night airglow; (5) aurora; and (6) twilight emission lines. Night airglow, aurora and twilight emission lines are the results of a planting within the atmosphere and magnetic field. Zodiacal light is a result of being within a solar system. The remaining two contributors would be present anywhere within our galaxy. Night airglow is the fluorescence of the atoms and molecules in the air from photochemical excitation. It occurs primarily in a layer about 100 km above the earth and is variable depending on sky conditions, local time, latitude, season and solar activity. There is a component that is present at most wavelengths, called the continuum, primarily caused by nitrous oxide and other molecules, but the major component is caused by distinct emission lines.Both components are always present, tend to increase in brightness near the horizon and are not strongly affected by geomagnetic activity (Arne A. Henden and Ronald H. Kaitchuck (1982)).

The latest photoelectric observations of twilight in North Africa was done by Issa and Hassan (2008) in 3 papers I, II and III for Bahria/Egypt, in which they found that Al-Eshaa and Al-Fajr are in due time if the depression D_o of the sun are ≈ 18° and ≈ 14.5° respectively if A = 10°, a = 5°.

The aim of the present work is to determine at which instant the first light of Al-Fajr appears depending on the naked eye and an adjusted hand-watch.

At this stage, we find it necessary to call attention to the naked eye studies of some astronomical phenomena. We believe that all the bases of the today astronomy and astrophysics owe its presence to the naked eye observations and studies. Early civilizations like the Egyptians, the Babylonians and the Chaldeans have observed the skies to develop agricultural and religious calendars. This goes back to antiquity times where no telescopes were present. We can assume that all astronomical observations before Galileo (1564 – 1642) were recorded just by naked eye. Tycho Brahe (1546 – 1601) continued observing a supernova star just by naked eye for 16 months until disappeared. Star-counting techniques in its very early times depended only on the naked eye. For more readings see (Exploration of the Universe) chapters 2 and 3. Recently, Lynds (1962) presented a catalogue of opacities of 1802 dark clouds depending only on naked eye estimations. Some studies later on gave evidence to one-to-one

correspondence of Lynds-opacity classes and absorption values estimated by star counting techniques. The praying times of Al-Fajr and Al-Eshaa which are in action nowadays by the National Authority of Survey in Egypt have no observational grounds. Two foreign astronomers visited Aswan of Egypt in 1908. They were asked to give an opinion about the problem of Al-Fajr and Al-Eshaa times. They were aware of the twilight phenomena. After some discussions with some Moslems, they gave a 19.5° for Al-Fajr and 17.5° for Al-Eshaa. Our opinion is that these two foreign astronomers knew that the astronomical twilight ends at 18° of the sun's depression below the horizon. So, they assigned 19.5° depression for Al-Fajr because it is related to the fasting month (Ramadan) and assigned 17.5° depression for Al-Eshaa.

From a scientific perspective, twilight is defined according to the position of the Sun (its centre) relative to the horizon. There are three established and widely accepted subcategories of twilight: civil twilight (brightest), nautical twilight and astronomical twilight (darkest), which correspond to 6°, 12° and 18° of the sun's depression below the horizon respectively.

Civil twilight is roughly equivalent to lighting up time. The brightest stars are visible and at sea the horizon is clearly visible. **Nautical twilight** happens when the horizon at sea ceases to be clearly visible and it is impossible to determine altitudes with reference to the horizon. **Astronomical twilight** happens when it is truly dark and no perceptible twilight remains (http://aa.usno.navy. mil/faq/ docs/ RST _defs.php & Robin 1985).

Al-Fajr starts with the morning twilight (dawn) whilst Al-Eshaa starts at the end of the evening twilight (dusk). There is some debate as to which twilight angle should be used in the calculation of Al-Fajr and Al-Eshaa. For a discussion on the subject, we refer you to Dr. Ilyas' book: (Astronomy of Islamic Times for the Twenty - first Century). Here is a brief extract from chapter five of Dr. Ilyas' book.

In modern times, astronomical twilight (18°) has come to be widely used for the determination of Al-Eshaa and Al-Fajr times. As the average intensity curve of evening twilight indicates, the flux decreases to a minimum level, and thus it would seem appropriate that even for Islamic purposes, this should indicate a reasonable starting value for the end of Astro-Islamic Twilight (AIT). Indeed, 18° depression was a commonly used value for Al-Fajr and Al-Eshaa in the medieval period, when it must have been based on careful naked eye observations. Nevertheless, slight variations from this value - between 16° and 20° - were also used during the medieval period.

According to King, D. (1986, 1993 & 2005), 20° and 16° were the parameters used by Ibn Yunus for morning and evening AIT respectively, whereas 19° and 17° were the parameters used by various Egyptian astronomers. King David has confirmed that although Muslim astronomers widely used 18° /18° symmetrical values or a slight variation to 19°/17° (morning/evening)-and in a few (earlier) cases even 20°/16° values were adopted-no record has been found of the use of a value as small as 15°. This is of specific interest to us because a few years ago, values of 15°/15° for both AITs were proposed by Bagvi on the authority of Maulana Rashid Ahmad Ludianvi of Karachi, who is reported to have made some observations personally. Indeed, Ilyas himself followed Bagvi in preparing the first South Australian Islamic Time Table, although he did consider the need to examine the matter very carefully and introduced a distinct term for it. Subsequently, this 15° degrees proposition has come under criticism and is apparently not proved by others' observations made in recent years in that particular area (Karachi). Concern on this matter is obviously understandable because an erroneous delay in the beginning of Al-Fajr would have serious implications for the beginning of the Fasting. One of the useful studies arguing against this 15° depression for AIT is that of Abdul Aziz (1986), who claims to have conducted some observational work. Unfortunately, Lateef has argued for a fixed 18°/18° case for all over the globe-no less and no more. This may not be the true situation either as there seems to be some room for geographical variability and perhaps 18° serves as a good upper limit only. The value for morning AIT has widely been used as 18°, although a practice of using 20° prevails in Egypt and Indonesia / Malaysia (under Egyptian influence, apparently owing to the concerned persons having been trained there). Possibly, 20° is taken as a safeguard because of the sanctification of the Fasting. On the other hand, the use of smaller values than 18° for India and Yemen has been reported to Ilyas in personal communications by Abdul Hafiz Maniar of Surat, India, and Qurashi of Islamabad, Pakistan, respectively. However, as we have noted elsewhere, in general, at 18° depression, no detectable trace of twilight flux will be found, meaning that 18° represents an upper limit (Ilyas 1984, 1986, Abdul Lateef 1986 & Moulana 1989).

Al-Fajr in the Islamic sources

The prayer is the second pillar in the Islamic religion, since the pillars of Islam are five:

1- The two testimonies
2- Prayer
3- Giving Zakat (Support of the Needy)
4- Fasting the Month of Ramadan
5- The Pilgrimage to Makkah

There are five prayers which have to be done during the day and night. Al-Fajr is one of these five prayers which are called and described as follows: The Morning Prayer (Al-Fajr), the Noon prayer (Al-Zuhr), the Afternoon Prayer (Al-Asr), the Dusk Prayer (Al-Maghreb) and the Evening Prayer (Al-Eshaa). As we see, all prayers depend on scientific (astronomical) bases.

The twilight in the Holy Quran

For more than a billion Moslems in the world, it is necessary to determine the prayer times according the religious texts. One of the most confidential problems nowadays is to determine the accurate time of Al-Fajr prayer as it depends upon the beginning of the morning twilight which is a very fine astronomical phenomenon.

The Noon

The time of Noon is considered to be the first step to calculate any prayer time. The Noon Prayer time (Al-Zuhr) begins after midday when the trailing limb of the sun crosses the meridian of the observer.

Twilight

«So I do call to witness the ruddy glow of Sunset; The Night and its Homing; and the Moon in her Fullness: Ye shall surely Travel from stage to stage» Quran (Surat Al-Ensheqaq) (84: 16 – 19).

Night sky

«So (give) glory to ALLAH when ye Reach eventide, and when ye rise in the morning» & «Yea, To Him be praise, in the Heavens and on earth; and in the Lat afternoon, and when the day begins to decline» Quran (Surat Al-Room) (30: 17 – 18).

Al-Eshaa (Night Prayer):
«That is because ALLAH merges night into day, and He merges day into night, and verily it is ALLAH who Hears and Sees (all things) » Quran (Surat Al-Hajj) (22: 61).

Most of Islamic scholars agree to adopt the beginning time of Salat Al-Eshaa at the disappearance of the red – glow sky of the evening twilight in the western horizon (D_o = 17.5°, 18° or 15°, see Table (2). This differs, however, from our finding that Al-Eshaa begins at the threshold of the eye in the red.

Al-Fajr
Al-Fajr (the twilight begins), which depends mainly on normal (typical eye verification, has been mentioned in Holy Quran six times in five Surahs namely:

(1) Surat Al Bakara (The Cow) in (2:187)
(2) Surat Al-Israa (The Night Journey) in (17:78) (twice)
(3) Surat Al Nour (The Light) in (24:58)
(4) Surat Al-Fajr (The Dawn) in (89:1)
(5) Surah Al-Qadr (The Fate) in (97:5)

The beginning of Salat Al-Fajr is strictly determined in the Holy Quran:

«…And eat and drink, until the white thread of dawn appears to you distinct from the black thread» Quran (Surah Al Bakara) (2:187).

Those who are in touch with nature know the beautiful appearance of dawn lights. First, a weak thin thread of a fluorescent light appears along the eastern horizon extending on both sides of the solar vertical direction. Only experts can distinguish this light. This light is followed directly by a black thread and then the dawn. We believe that the black thread is the horizon of the observer, since before dawn the sky and the horizon are black. When the dawn announces itself as a white light, the horizon stays black making this contrast. This will be followed by a pinkish white light zone clearly distinguishable in the dark. Some areas define this dark when the sun is of a depression angle 19.5° below the horizon, while some others take it at 18° and others believe that it is at 15° below the horizon. Our value in the present work is inherited with some bias, since the first co-author of the present work is affected by the results of the project of photoelectric observational verification of the Al-Fajr and Al-Eshaa prayers executed by the National Research Institute of Astronomy and Geophysics (NRIAG) in the period 1983 – 1985. This is the true dawn as defined in Holy Quran, when fasting begins directly.

The site of Observations
Watching the morning sky twilight was carried out at Tubruq city in Libya on the two years, (Dec. 2007- Sep. 2009, except August in each). The observers (Hassan and Rahoma) carried out the observations on cloudless selected days directly by naked eyes.

Table (1) shows the geographical latitude (φ) and longitude (λ) of the site which were determined astronomically, besides the elevation (h) above sea level in meters and the topographic nature of the site (N. L.).

Latitude (φ)	Longitude (λ)	h	N. L.
32° 5'	23° 59'	10 m	Sea – desert area

Table (1) The geographical data of the Tubruq site.

Al-Fajr and Al-Eshaa in some countries
Table (2) summaries the times of Al-Fajr and El-Eshaa in some Arabic and Islamic countries for some areas which are found to be populated by some Muslims like in the U.S.A. and Europe. Some areas like Pakistan and surrounding areas like Bangladesh, Afghanistan, India and some parts of Europe fixed both twilights (of Al-Fajr and Al-Eshaa) at 18° depression of the sun below the horizon. This value corresponds to the astronomical twilight. It should be mentioned that, when the suns depression is 18° below the horizon, the eye receives the least possible non-perceptible light in all wavelengths from the twilight. This does not enable the normal eye to distinguish any horizon. So, people in the sea depend totally on stars of the sky to find their directions. No religious signs for Al-Fajr and Al-Eshaa are considered. North America, Canada, parts of U.S.A. and U.K. took a value of 15° which lies somewhere in between the nautical and the astronomical twilights. Um Al-Qura calendar is adopting a value between 18.5° and 19 for Al-Fajr and 22.5° for Al-Eshaa nowadays for the sun depression below the horizon except in Ramadan in which the value is increased to be 30°. All the Gulf countries follow Saudi Arabia in this regard. It should be mentioned also that Um Al-Qura calendar does not follow the religious signs (e.g. the twilight thread for Al-Fajr or the minimum red light for Al-Eshaa). Egypt, some African countries, Syria, Iraq and Lebanon follow the published values of the Egyptian General Authority of Survey (19.5° for Al-Fajr and 17.5° for Al-Eshaa).

Organization	Angle of the sun below the Horizon (Beginning)	Angle of the sun below the Horizon (Evening)	Region
University Of Islamic Sciences, Karachi	18 Degrees	18 Degrees	Pakistan, Bangladesh, India, Afghanistan, Parts of Europe
North America	15 Degrees	15 Degrees	Parts of the USA, Canada, Parts of the UK
Muslim World League	18 Degrees	17 Degrees	Europe, The Far East, Parts of the USA
Umm Al-Qura Committee	18.5 Degrees (19 degrees before 1430 Hijry)	90 minutes after the Sunset Prayer 120 minutes (in Ramadan only)	The Arabian Peninsula
Egyptian General Authority of Survey	19.5 Degrees	17.5 Degrees	Africa, Syria, Iraq, Lebanon, Malaysia, Parts of the USA

Table (2) The basis of calculated of the beginning (Al-Fajr) and evening (Al-Eshaa) twilight for the Islamic regions in the world as the sun vertical depression (Do).

Observations and Method
From a corrected hand-watch adjusted daily by time signals from a radio, we recorded the local time corresponding to what we believe to be the first light signal due to early twilight. This time is taken from the hand watch has been denoted by the hour angle H_o. Using H_o in the following equation, we get D_o:

$$D_o = \sin^{-1}(\sin\varphi \sin\delta + \cos\varphi \cos\delta \cos H_o) \quad (1)$$

We then calculated the hour angle of the sun corresponding to the z = 104° for an observer at Tubruq from the relation:

$$H_o = \cos^{-1}\left[\frac{(\sin z - \sin\varphi \sin\delta)}{\cos\varphi \cos\delta}\right] \quad (2)$$

Al-Fajr, then, is deduced from:

$$Fajr = Noon - H_o \quad (3)$$

where $Ho=H/15$ and Noon is defined by:

$$Noon = 12 + \frac{T}{60} - \frac{\Delta\lambda}{15} \quad (4)$$

where φ is the latitude of Tubruq, δ is the declination of the sun,

H is the hour angle of the sun, z is the zenith distance of the sun (z = 104°), T is the equation of time and $\Delta\lambda$ is the longitude difference between the standard and the local meridians.

The computer program (Moon calculator) version 6 delivered to us by Monzur Ahmed was used to calculate the depression below the horizon at Al-Fajr time D_o. Getting Al-Fajr time in this manner enables comparison with D_o as deduced from Eq. (1) and as given in wall calendars. The zenith distance z was taken to be 104° which means that the sun's depression angle was taken to be 14° below the horizon which is nearly the same value we got in Issa and Hassan (2008) from the observations.

Results

From December 2007 to December 2009, about 429 observations were recorded. These include exact at which the first light of the morning twilight was noticed by one of us (Hassan, A. H.). It should be mentioned that the hand-watch was adjusted daily to the radio time signal. Watching the sky was carried out by the observer from the balcony of his apartment directly on the shore of the Mediterranean Sea in Tubruq. The horizon is directly open everywhere one looks (except backwards). City lights have a little effect. Table (3) shows the average depression of the sun below the horizon as determined from Eq. (1) corresponding to the recorded time t_o. This average is 12.38° ± 0.402° in a range between maximum depressions of 13.5° to minimum at 11.5°. This average is so small compared to the adopted value of 18.25° below the horizon. It should be mentioned that a value of 12.38 is very near to a value about 15° deduced observationally for some 5 sites in Egypt using a well-calibrated photoelectric photometer and taking into account the religious conditions for Al-Fajr (white thread, threshold of the eye, suitable light filter, etc.) (Issa and Hassan, (2008)). We can say that an average value of the sun depression angle D_o = 12.38° ± 0.402° suffers a bias and some errors due to the fact that the eyes of the observer are not typical and the hand-watch, although adjusted every day to the radio signals, still must suffer from some error. The two authors of the 2008 paper (Issa and Hassan) must be affected by their long term observations done photoelectrically on 5 sites in Egypt following the religious statements regarding Al-Fajr and Al-Eshaa. This could be the main cause of the bias. Column 3 in Table (3) shows the differences in degrees between the adopted depression (19.5°) and the calculated depressions, while column 4 gives this difference in time measure.

Table (4) represents the beginning of twilight (Al-Fajr) in Tubruq in hours and minutes depending on the zonal time of Libya (2 hour + UT), according to the applied Al-Fajr (at sun depression of 18.25°, the suggests mode Fajr of 14°, the nearest of true (15° at North America organization) and the sun rise at four seasons (the equinox and the inverse seasons) in the zonal time (Z.T.). From this table, we notice that, the difference between the mode of Al-Fajr of 14° sun depression and the now applied Al-Fajr is about 4.25° (22 to 34 minutes), while the difference between it and the 15° mode of sun depression which is applied in the north American is relatively small (about 1°).

Table (5) represents the monthly mean variation of the sun vertical depression (*Do*), the standard deviation and the dispersion of the values for the some recorded days.

Table (6) represents the statistical classification of the sun vertical depression D_o according to the varies of the visibility from visibility 5 to visibility 8, where the range of the visibility (from 5 to 8 Okta) corresponds with the rang of D_o, as Visibility 5 means (11.5° $\leq D_o \leq$ 12°), visibility 6 means (12° $\leq D_o \leq$ 12.5°), visibility 7 means (12.5° $\leq D_o \leq$ 13°) and visibility 8 means (13° $\leq D_o \leq$ 13.5°). From this table, the majority of the relative number of days lays in the visibility 6 (35%), while 62 days lay in the visibility 8 representing about 15% (very good visibility) from the total days. This mean that the percents of the high visibility (8) with respect to the total year is simple. This leads to the values of D_o = 13.5° which represents the ideal values and is considered to be the authoritative values. The relation between the visibility and the sun vertical depression (D_o) over the total days (429 days) is very good (Correlation Coefficient = 0.948 and Standard error = 0.312).

Figure 1 shows the monthly average of the sun depression below the horizon (Do). The squares stand for the year 2007, the circles stand for the year 2008, while the triangles-up stand for the year 2009. Accordingly, the triangles down stand for the average of the monthly averages of the sun depression. As it is shown, a distorted wave–like structure appears with a minimum at May and a maximum at June followed by another minimum at October. The highest peak lies between November and December. The distortion can be due to the uncertainty, the error of the hand–watch of the observer and the turbulence of the atmosphere.

Figure 2 displays the monthly average of the white thread (Al-Fajr) begins along the time interval from December 2007 to December 2009. The squares represent the hand–watch observations, the circles represent times according the wall–calendar (D_o = 18.25°), while the triangles stand for a constant depression of 14°. A sinusoidal wave–like structure assumes itself. A maximum time at January followed by a minimum at June and repeated afterwards to the end of the period can be easily shown.

Figure 3 shows the correlation between the true Fajr and Fajr 14° over 429 days. The fitting curve gives the relation of Eq. (6):

$$\text{Fajr } 14 = 1.021925508\ (\text{Fajr true}) - 0.2696218835 \qquad (6)$$

The correlation coefficient of this curve is 0.998, while the standard error is 0.0436. As we see, the results indicate high correlation values and accordingly we can consider that the mode of D_o = 14° (Fajr 14°) as the basis of calculating Al-Fajr at this region is more suitable.

Figure 4 represents the relative abundance of the days for the sun vertical depression. We can note that sun depression values which lay in the interval 11.5° $\leq D_o \leq$ 13.5° take place in the visibility range of 5 ≤ visibility ≤8, as visibility 5 represents (11.5° $\leq D_o \leq$ 12°), visibility 6 represents (12° $\leq D_o \leq$ 12.5°), visibility 7 represents (12.5° $\leq D_o \leq$ 13°) and visibility 8 represents (13° $\leq D_o \leq$ 13.5°).

According to the Tables (3, 4, 5 and 6) and Figs. (1, 2, 3, 4, 5, and 6), we can suggest that the beginning of twilight (Al-Fajr) is at D_o = 14°.

The problem

The problem is that all Arabic regions and many Islamic countries are adopting the sun vertical depression ≥18° (the Egyptian General Authority of Survey 19.5°) for calculated Al-Fajr. The observations assure that it is a wrong value. The observations showed that the correct sun depression angle of Al-Fajr is around 14.5° in Bahria (Issa and Hassan 2008, I, II, III) and around 13.5° in this study. As we see, the applied mode now at Libya (D_o = 18.25°) is far away from the true value D_o = 13.5°. Therefore, we can say that the value D_o = 18.25° is impractical.

Invitation

We would like to invite all astrophysicists, amateur and unprofessional (and we shall help you, amir_hassan30@hotmail.com and ahhas-

Results	D_o (Degrees)	Gape (Hours)	Gape (Minutes)
Maximum	13.5	0.7	42
Minimum	11.5	0.4	25
Mean	12.38	0.526	32
Median	12.41	0.516	31
Rang	2	0.3	18
Variance	0.234	0.0041	0.246
Dispersion	0.402	0.052	3.12
SD	0.483	0.064	3.84
Standard error	0.0233	0.00316	0.2

Table (3) The statistical results of Al-Fajr true and the gap between true and non true (hour and minute) for D_o over 429 days, the dispersion represent the average deviation.

Date	Fajr 18.25° H:mm	Fajr 14° H:mm	Fajr 15° H:mm	Sunrise H:mm
21 March	5:03	5:25	5:19	6:26
21 June	3:36	4:02	3:58	5:18
21 September	4:48	5:08	5:06	6:11
21 December	5:51	6:13	6:09	7:20

Table (4) The beginning of twilight (Al-Fajr) for applying now (Fajr 18.25°), Fajr 14°, Fajr 15° and sunrise at different seasons for Tubruq.

Number of days	Month	Mean of D_o (Degrees)	S.D. (Degrees)	Dispersion (Degrees)
29	Jan.	12.562	0.409	0.409
31	Feb.	12.33	0.363	0.294
38	Mar,	12.407	0.611	0.466
32	Apr	12.359	0.466	0.389
40	May	11.892	0.331	0.287
41	June	12.572	0.277	0.228
44	July	12.388	0.459	0.413
-------	Aug.	--------	-----	----
39	Sep.	12.406	0.406	0.295
54	Oct.	12.029	0.41	0.346
46	Nov	12.626	0.468	0.514
35	Dec.	12.69	0.403	0.322
Mean		12.39	0.418	0.360

Table (5) The monthly mean variation of the sun vertical depression (D_o), the standard deviation and the dispersion of the values for the some recorded days.

Statistical Parameters	Visibility 5 D_o (11.5-12°)	Visibility 6 D_o (12-12.5°)	Visibility 7 D_o (12.5-13°)	Visibility 8 D_o (13-13.5°)
Number of days	96 (22%)	153 (35%)	116 (27%)	62 (15%)
Number of missing values	13	20	8	6
Minimum	11.5	11.95	12.5	12.9
Maximum	11.94	12.52	12.94	12.5
Range	0.44	0.57	0.44	0.6
Mean	11.725	12.26	12.703	13.123
Median	11.71	12.3	12.69	13.035
Standard error	0.0132	0.0134	0.0113	0.0222
Variance	0.0166	0.027	0.0147	0.0306
Dispersion	0.1119	0.145	0.1049	0.1544
Standard deviation	0.129	0.166	0.1214	0.175

Table (6) Statistical classification of the sun vertical depression D_o (from 11.5° to 13.5°) according to the visibility range (from 5 to 8 oktas).

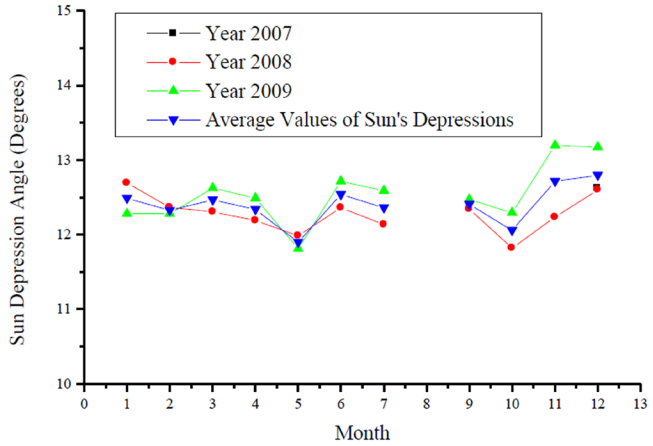

Fig. 1. The monthly average of the sun depression below the horizon (D_o).

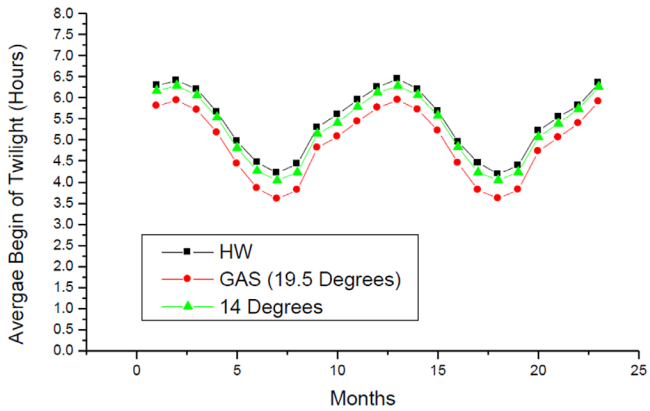

Fig. 2 The monthly average of the twilight thread (Al-Fajr) begins along the time interval from December 2007 to December 2009.

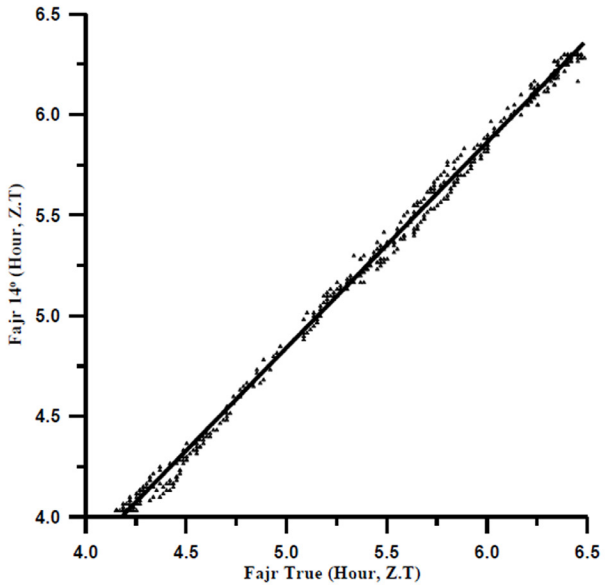

Fig. 3 The correlation between the true Fajr and Fajr 14o over 429 days.

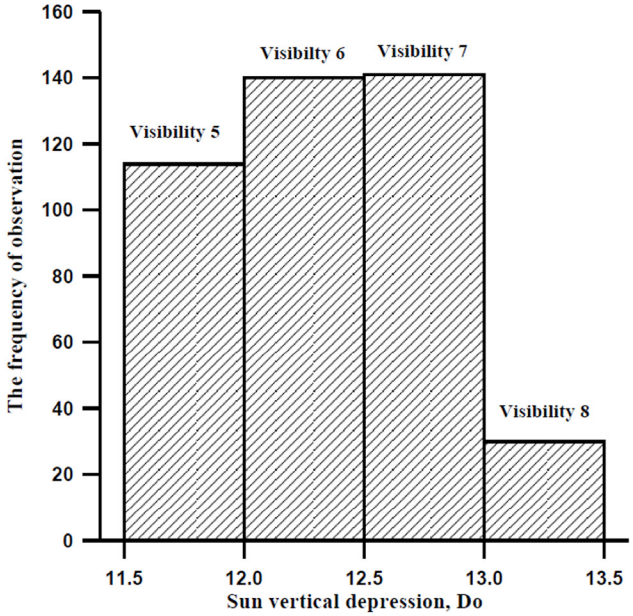

Fig. 4 The distribution of the sun vertical depression values.

san210@yahoo.com) in the world and especially in the Arabic and Islamic world to observe Al-Fajr (the beginning of twilight according the eye criteria in the visual light) by the eyes over a long period (one year or more), where this method doesn't need any instruments. But only some astrophysical knowledge such as, the direction of the sunrise, the different between the false of Al-Fajr and the true of Al-Fajr, the back ground of the night sky, the degree of the visibility (Oktas 0 - 8 km). The observer has to observe the twilight apart from the cities and the human activities to avoid the parallax in the observations.

Conclusion

According to our observations of twilight by the eyes for two years, it can be concluded that,

1. The beginning of twilight (Al-Fajr) at this region (Tubruq - Libya) takes place when the sun vertical depression angle reaches the value of 13.5°.

2. The error in the beginning of twilight (Al-Fajr) in the sun vertical depression is 4.25° ± 0.5° between the true depression angle (D_o = 13.5°) and the false depression angle (D_o = 18..25°).

3. The minimum error between the true and false twilight is 25 minutes and takes place in the equinoxes (March and September months) while the maximum error is 42 minutes and takes place in June and July months.

4. The error in the naked eye observation is found to be around 0.5° ≈ 2 minutes.

5. The sun depression angle adopted by the North American Organization (D_o = 15°) is the nearest value adopted for calculating Al-Fajr.

6. We suggest the sun depression angle value D_o = 14° as the basis for calculating Al-Fajr at this region (Tubruq).

7. The results for the twilight observation of eye in Tubruq (D_o = 13.5°) is nearby and agree with the photoelectric observation in Bahria Oasis, D_o = 14.5° (Egypt).

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Verification of Al-Eshaa and Al-Fajr Prayer Times at Matrouh of Egypt VI

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Abstract: Through a project supported by Al-Azhar, Dar El-Iftaa and the Academy of Scientific Research and Technology in Egypt, twilight observations were carried on in the period between «1983 - 1985» in different seasons at different sites mainly to deduce Al-Eshaa and Al-Fajr Prayers. One of these was the Matrouh site. Twilight observations were taken using a refractor of 10 cm diameter associated with a photoelectric tube of the type (φ → Y – 51) using 3 filters namely, the blue, red and visual filters. The photoelectric system was calibrated with international photoelectric color system. The phenomenon were followed with an alt–azimuth scanner in steps each 10o in both altitude and azimuth. The depression of the sun below the horizon where the normal eye can just characterize the phenomena was recorded. The results indicate for the latitude of Matrouh, that Al-Eshaa Prayer (the end time of the red color of twilight) occurs when the depression of the sun is between 16° and 19°, while Al-Fajr Prayer (the begin time of the yellow color of twilight) occurs between 14° and 15°. The brightness of the twilight phenomena was followed, however, to different altitudes and azimuths [0° ≤ a ≤ 50° and 0° ≤ A ≤ 60°].

Keywords: Fajr, Eshaa, Prayer times, Photoelectric Observations.

Introduction

Along with papers of Issa, I. A. and Hassan, A. H. I, II, III and what was mentioned therein regarding the main aim of this project, which was supported by Al-Azhar, Dar El-Iftaa and the Academy of Scientific Research and Technology in Egypt and carried out at the National Research Institute of Astronomy and Geophysics (NRIAG), we proceed further to give and discuss the prayer times (Al-Fajr and Al-Eshaa) at the third site (Matrouh in Egypt). For more details and literature, see papers I, II and III.

Weather Parameters at Matrouh

Weather parameters (wind speed, water vapor, pressure, density, etc.) affect twilight brightness. The climate status at Matrouh is summarized in Table (1) in spring for the period May 1984, 4 – 7. In the evening twilight, dispersed white clouds were noticed at altitude 5° to 10°. On May 5, heavy black clouds were observed at 30° altitude. On May 7, heavy white clouds were noticed, while in summer (June 1 to June 6), clear sky with no clouds was dominating. Table (1) is self explained.

Weather Parameters		Summer
Pressure reduced to M.S.L.		1012.6 mb
Relative Humidity		68 %
Surface Temperature, (mean)		23.3°C
Total Rain Fall, Tr		2 mm
Evaporation per day at 06 U.T.		8.4 Liter/day
Mean no. of days of occurrence of	Haze (vis. < 1000 meter)	0.80
	Fog., (vis. > 1000 meter)	2.4
	Mist (vis. >1000 meter)	0.3
	Dust or Sand rising > 1000 meter	2.7
	Dust or Sand rising < 1000 meter	0.3
Mean surface wind speed in Knots (1 knot = 1.75 km/h)		10 Knots
Cloudy (Total Sky Coverage at U.T. 0600, 1800)		2, 1.6 Oktas

Table 1. The meteorological conditions in summer at Matrouh.

Method

With a small refractor of 10 cm diameter associated with a photomultiplier of type (φ→ Y – 51), the twilight brightness was followed each 10° altitude up to 60° and from 0 to 60° in azimuth, measured from the solar vertical (see paper I and II Issa and Hassan 2008) of this series for further details). This was done as a function of the sun depression D_o below the horizon for both evening and morning twilight. However, for prayer times verification of Al-Eshaa and Al-Fajr, we limited ourselves in the ranges ($0° \leq a \leq 5°$) and ($0° \leq A \leq 10°$). D_o was calculated from the local time recorded for every observational scan. The brightness of the twilight is expressed in S_{10} units, which is the number of 10th magnitude stars of the solar type. Averages were always considered. The air mass *X(z)* was determined from Young empirical formula (Van der Hulst, 1957 and Chamberlain, 1961):

$$X(z) = \sec\left(a\left(1 - 0.0012 tan^2 a\right)\right) \quad (1)$$

where *a* is the altitude of the object, while the transparency *P* of the atmosphere is given by:

$$P = e^{-\tau} \quad (2)$$

where *τ* is the optical thickness of the atmosphere and the brightness of evening and morning twilights were determined from the equations:

$$I_1 = I_o e^{-x(z)} \quad (3)$$

and

$$m = m_o - 2.5X(z) Log\, P \quad (4)$$

where *m* is the magnitude of the star inside the earth's atmosphere, while m_o is its magnitude outside, I_1 and I_o are the corresponding intensities (Hardie, 1962).

Standard stars were followed directly after the end of evening twilight till the beginning of morning twilight to determine the *X(z)* and the optical depth *τ* then *P*.

It should be mentioned that the sun's depression below the horizon was determined according to the following relation (Roach and Gordon, 1973):

$$D_o = \sin^{-1}(\sin\varphi \sin\delta + \cos\varphi \cos\delta \cos H) \quad (5)$$

where *φ* is the latitude of the place, *δ* is the declination of the sun and *H* is the hour angle in degrees measured since solar noon.

Results

Transparency and Extinction

The one-to-one correspondence between the color system of our scanner and international UBV and RGU is shown in paper I (Issa (1966) and Hassan (2008)). The correlation coefficient approaches ($r > 0.98$) which indicates nearly perfect correspondence.

Figures 1, 2 and 3 show the relation between Log I_1 and air mass $X(z)$ for standard stars observed at Matrouh (summer) along 4 nights dated from June 1 to 5, 1984) using blue, yellow and red filters. Where the number of stars observed was 20 in the blue, 20 in the yellow and 13 in the red. The three figures show the results obtained for the site of observation, where least square solutions are used to determine the best fit. The slopes of the lines give the values of (K), the optical thickness (τ) and the intersection with the (Log I_1 – axis) gives the values of Log I_o as it would be outside the earth's atmosphere, where Z = 0. Table 2 gives the deduced values of S_{10} in the B, V and R colors for Matrouh.

The values of Table 2 are multiplied by the relative measurements of sky night brightness deduced from Equations (1 – 4) to get the brightness in S_{10} units in the blue, yellow and red colors. The scatter shown in Figures 1, 2 and 3 is mainly due to instability of the atmospheric conditions. The effect of these instabilities can be noticed even during a single night. The extinction varies with direction in the sky. The variation was of particular interest during strong storms that occurred sometimes. The extinction is bigger in the blue than in the yellow and the red.

Applying Equations (2-4), the optical thickness (τ), extinction coefficient (K) and the mean values of the atmospheric transparency (P_λ) have been calculated in the blue, yellow and red filters. The results are given in Table 3 and represented in Figure 4.

Table 3 indicates that Matrouh area is very turbid (the mean transparency is 0.64). The atmospheric transparency P_λ is fair for the red color (0.76) and accordingly the extinction coefficient is low (0.119). The extinction coefficient in the blue is bigger (0.208). The coefficient of the atmospheric attenuation decreases with increasing wavelength, showing a general reddening. These results can be explained by the meteorological conditions of Table 1, where the relative humidity was 68% and the average temperature was 23 C°. The increase in the temperature can cause an increase in the relative humidity which causes an increase in the optical thickness and, therefore, increasing the extinction coefficient. The mean value of the transparency in the three colors is 0.64, indicating very turbid atmosphere in summer in Matrouh.

Date	Blue	Yellow	Red
Summer (June)	1899	1632	1603

Table 2. The values of S_{10} (B, V, R) at Matrouh – 1984.

Blue			Yellow			Red		
τ	K	P	τ	K	P	τ	K	P
0.645	0.208	0.524	0.467	0.203	0.627	0.275	0.119	0.759

Table 3. The mean transparency P_λ (B, V, R), the extinction coefficient (K) and optical thickness (τ) at Matrouh for summer.

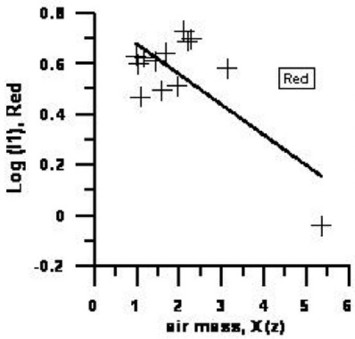


Figure 3. The relation between Log (I_1) and X(z) for red color.

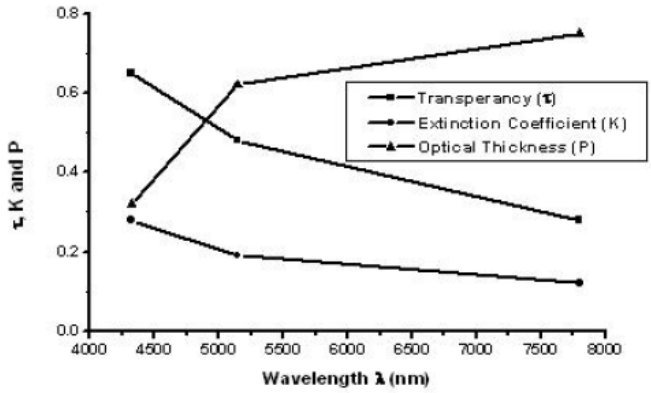


Figure 4. The values of the Tao (τ), K and P for three colors.

Brightness and depression

For $A = 0°$ and $a = 0, 5, 10, 20, 30, 40, 50°$, the logarithm of the twilight brightness (log B) in S_{10} units studied as a function of a depression of the sun below the horizon (D_o), in the V and R colors for both evening (E) and morning (M) twilights is shown in Figure 5. The general trend of the change of twilight brightness with time after sunset and before sun rise, agree well with the corresponding figures published by other authors (Rosenberg (1966)). At $a = 5°$ for morning twilight, we expect that the brightness of the twilight becomes noticeable to the typical eye. Saturation of the curves starts to be noticed at $D_o = 14.0°$ and continues to 15.0° in the visual color (according to the religious statement). It varies between ($13° \leq D_o \leq 16°$) at different altitudes. If the minimum threshold of the eye is taken into account (3 in S_{10} units for both B, V colors), D_o for Al-Fajr was found to be 14.5°.

Shown also in Figure 6 are the differences in brightness between evening and morning twilights as a function of the depression D_o. No significant differences are shown except of slight differences

Figure 1. The relation between Log (I_1) and X(z) in the blue color

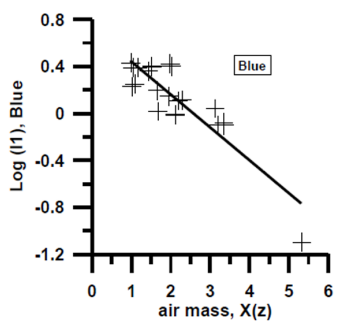


Figure 2 The relation between Log (I_1) and X(z) in the yellow color.

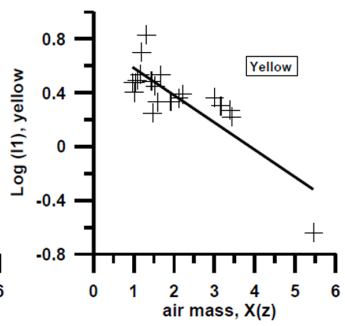
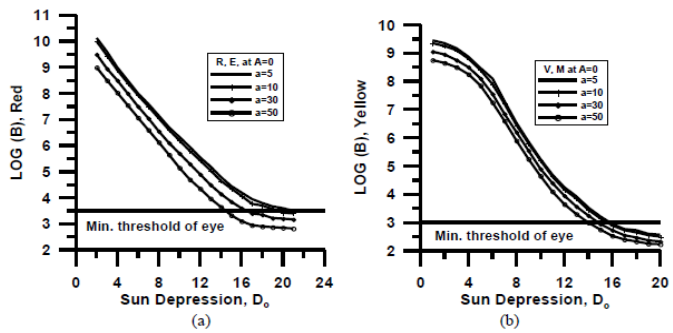


Figure 5. The relation between Log. B expressed in S_{10} units in the (R and V) colors and the sun's depression (D_o) at Matrouh, for: (a) evening (E) and (b) morning (M) twilight, (A = 0° and a = 5, 10, 30, 50°).



at high depressions due to sudden atmospheric changes as we go from day lights to night lights for Al-Eshaa and vice versa for Al-Fajr. Saturation is also seen in the different curves at different azimuths. The depression values for both prayers are nearly the same as in Bahria site (Issa, I. A. and Hassan, A. H. II (2008)). The difference becomes bigger at high depressions around the minimum threshold of the normal eye. The very negligible differences indicate that we are in front of a completely identical but reversible phenomenon (Rosenberg (1966)).

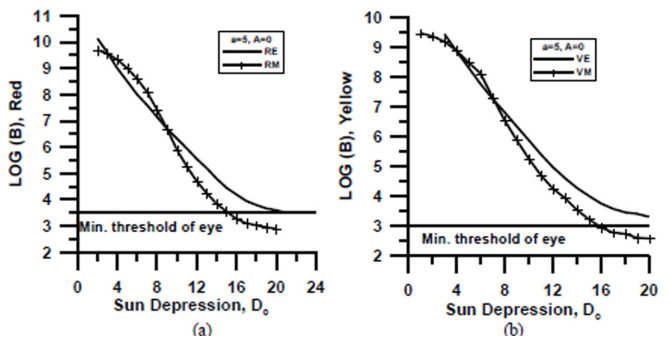
Color index and prayer times

Before approaching the horizon, the brightness of the sun decreases gradually with dramatic changes in its color. The shortwave length, the blue light, is dramatically refracted that the whole sky becomes blue, while the long wavelength passes through. Near the horizon and near the sun, the sky acquires yellow-orange colors, while the sky becomes pale on the horizon on the opposite side. Approaching more to the horizon, the disk of the sun becomes dark red. After sunset, the sky becomes orange-yellow which changes to green-azure in the upward direction. On the opposite horizon, a blue grey color prevails due to earth's shadow. More sinking of the sun below the horizon, the sky becomes deep-red, while a rose color assumes itself at $a = 20° – 25°$. At the beginning of astronomical twilight, a pale-greenish white band appears.

With the above discussion in mind and religious statements regarding Al-Eshaa and Al-Fajr, we can understand the following dependence of the color indices:

Figs. 7 and 8 show the variations of the color indices ($B – V$), ($B – R$) and ($V – R$) as a function of the sun's depression *Do*, below the horizon for both evening and morning twilight. The first figure in set 1 shows ($B – V$) against D_o. The values of ($B – V$) can be (-ve, 0.0, +ve). If they are zero, then the B magnitudes is as big as the V magnitudes. This indicates that the amount of energy emitted in the B is as big as in the V range. If $B > V$, then the amount of energy radiated in the visual range is bigger than in the blue. If $V > B$, then the amount energy illuminating the sky in the blue is dominating and the sky tends to be blue. Accordingly, we can read the above mentioned variation in the figures. The positive values in ($B – V$) indicates $B > V$ so the visual illumination of the sky is dominating. As the difference becomes small, the blue illumination becomes bigger on account of the V brightness. It continues so till becoming equal at ($B – V$) = 0 at small depressions. The scenery becomes reverse; the blue brightness becomes bigger on account of V until reaching maximum blue illumination at ($10^o \leq D_o \leq 14^o$). Then, it changes again in the opposite sense until becoming of equal effect on the sky around ($B – V$) = 0. Then, again, visual illumination prevails all over the sky.

Figure 6. The difference between the brightness of evening (E) and morning (M) twilights in S10 units at a = 5o with A = 0o in summer in the (a) red and (b) visible colors.



Saturation starts to show itself nearly at $D_o \geq 18^o$ with a dominating visual illumination. We are looking for red sky according to the religious statement for Al-Eshaa. In the second subfigure in set 3 of Fig. 8 taken from the top, the ($V – R$) curves are all positive indicating $V > R$, so R illumination of the sky is dominating. The curves can show saturation starting nearly at $D_o \geq 18^o$. To summarize, we expect Al-Eshaa to be somewhere between ($18^o \leq D_o \leq 20^o$). The change in color from set 1 to set 2 and set 3 curves indicates a continual increase towards a reddened sky for Al-Eshaa. As the sun's depression increases, the reddening starts to increase. The limit at which the normal eye can just characterize the reddening is our aim. It is Al-Eshaa praying time. It is between $16^\circ \leq D_o \leq 19^\circ$.

The study has been continued to different altitudes till $a = 60^o$ and azimuths to $A = 60^o$. If we are dealing with prayer times in a certain area, we have to confine ourselves to the range ($0^o \leq a \leq 5^o$) and ($0^o \leq A \leq 10^o$).

For Al-Fajr, Fig. 8 comes in focus, with the same sense of discussion about Al-Eshaa, we can read the color index curves of Fig. 8. Since in Al-Fajr we are looking for a white thread of light that can just be intercepted by the normal typical eye, the very early start of saturation is our aim. This occurs at ($14^o \leq D_o \leq 16^o$), which indicates dominating visual color.

For Al-Eshaa prayer, we must rely on the religious statement translated nearly as: «*Twilight is reddening, if twilight sets, Al-Eshaa is in due time*» or «*Al-Eshaa is in due time if the twilight (the reddening) had just set*». The curves show a general saturation starting nearly at $D_o = 14°$ and continues till $D_o \geq 20°$. This indicates a general reddening as will be seen in the red color index curves in Figs. 7 and 8. The red threshold of the eye (3.5 S_{10}) and the religious fact of delaying Al-Eshaa as possible as we can lead us to assume Al-Eshaa whenever saturation starts to be leveled and parallel to the D_o–axis. This happens nearly at $D_o \approx 18°$- 19°. For the scientific studies, we extended our observations to the range ($0° \leq a \leq 60°$) and ($0° \leq A \leq 60°$).

In Table (4) at certain depressions $D_o = 2^o$ to 19°, the brightness values for the three colors (B, V, R) for the morning and evening twilights and the differences between the both cases are given against D_o. These differences in brightness between evening and morning twilights as shown in Fig. 6 are very slight which is in agreement with that mentioned by Rosenberg (1966) as differences mentioned therein. These small differences can be attributed as due to some sudden changes in the atmospheric conditions happening between day and night and along the same night from evening to morning. Saturation at high depression shows itself. It starts at $D_o \approx 14^o$ (Al-Fajr) and continues until $D_o \geq 18^o$ (Al-Eshaa).

Comparison

If we compare our color index variation with the sun depression to that given in Rosenberg's text (1966) about twilight Figs. 26 and 27 page 37, we find a fairly good coincidence. Rosenberg citing with the observation of Megrelishvili stated that «when the sun has dropped to 9 – 11° below the horizon, the blue coloration of the sky gives way to reddening. In our figures the same can be deduced from set II as in Fig. 2, where we can read that at small depression ($4^o \leq D_o \leq 8^o$), the sky tends to be red, the reddening gets smaller as we go

to bigger depression and then the sky gets blue again between ($8^o \leq D_o \leq 12^o$), where it starts to get reddened. Another comparison can be made with our study at Bahria oasis, (Issa and Hassan III (2008)), which shows a strong agreement. It should be mentioned that the explanation given by Rosenberg was done at the zenith as in his Fig. 26, while in Fig. 27 it was at $z = 70^o$ and $A = 0^o$. The general trend in Rosenberg (1966) curves tends to agree completely with ours.

Conclusions

For Matrouh in the summer we can conclude the following results:

1. Evening twilight ends in summer when sun depression lies between ($16° \leq D_o \leq 19^o$) if the minimum threshold of the eye in the red is 3.5 in S_{10} units. This happens at a = from 5° to 50° and A = from 0° to 60°.

2. Morning twilight announces its begin at ($14^o \leq D_o \leq 15^o$) and at $a = 5^o$ and $A = 10^o$, if we take the eye threshold to be 3 in S_{10} units observed at yellow.

3. The time interval from sunset to the end of evening twilight is bigger than for morning twilight if the threshold of the normal eye is considered.

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Table 4. Variation of twilight brightness at constant D_o values as read from all brightness curves as a function of D_o. $\Delta B = (E - M)$ B, $\Delta V = (E - M)$ V, $\Delta R = (E - M)$ R.

	Evening (*E*)			Morning (*M*)			Color Difference		
D_o	*B*	*V*	*R*	*B*	*V*	*R*	*ΔB*	*ΔV*	*ΔR*
2	9.64		10.1	8.9	8.84	9.12	0.74		0.98
3	9.24	9.34	9.56	8.73	8.55	8.9	0.51	0.78	0.66
4	8.65	8.77	8.92	8.44	8.23	8.67	0.21	0.53	0.25
5	8.18	8.25	8.5	8.14	7.88	8.39	0.04	0.37	0.11
6	7.63	7.69	8.02	7.71	7.47	8.01	-.08	0.22	0.01
7	7.18	7.15	7.57	7.24	6.96	7.51	-.06	0.19	0.06
8	6.72	6.64	7.08	6.7	6.39	6.98	0.02	0.25	0.1
9	6.25	6.12	6.61	6.1	5.8	6.4	0.15	0.32	0.21
10	5.8	5.66	6.15	5.5	5.19	5.81	0.3	0.47	0.34
11	5.35	5.2	5.68	4.9	4.67	5.28	0.45	0.53	0.4
12	4.88	4.78	5.21	4.34	4.2	4.72	0.54	0.58	0.49
13	4.47	4.37	4.78	3.87	3.77	4.26	0.6	0.6	0.52
14	4.08	4.01	4.37	3.42	3.38	3.81	0.66	0.63	0.56
15	3.68	3.7	4.01	3.04	3.02	3.44	0.64	0.68	0.57
16	3.39	3.47	4.73	2.75	2.8	3.15	0.64	0.67	0.58
17	3.18	3.3	3.53	2.57	2.7	2.95	0.61	0.6	0.58
18	3.03	3.2	3.42	2.43	2.6	2.85	0.6	0.6	0.57
19	2.96	3.17	3.34	2.39	2.53	2.8	0.57	0.64	0.54

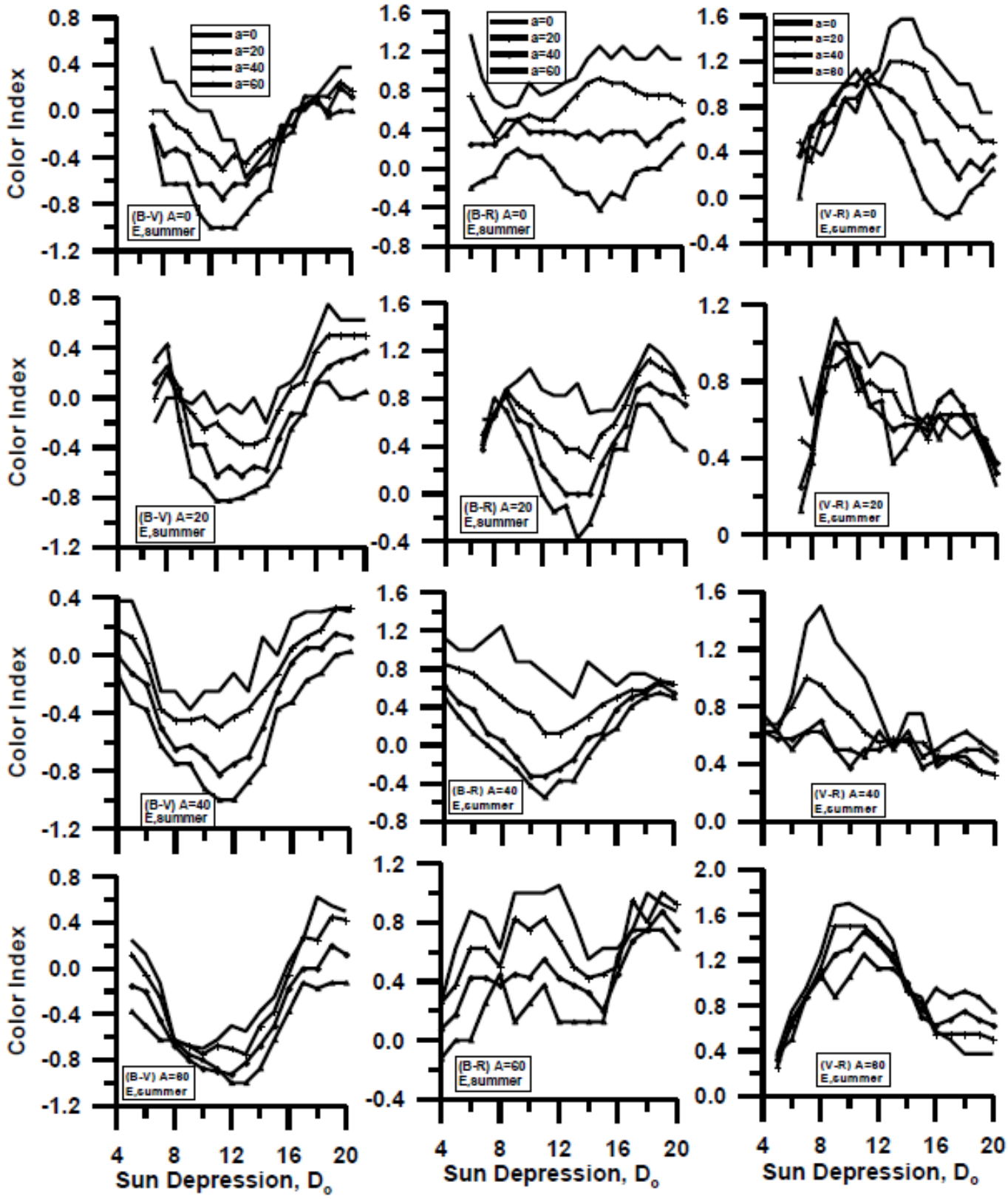

Figure 7. The relation of the color index with D_o of evening twilight (E) at different altitudes (a) and azimuths (A) in summer.

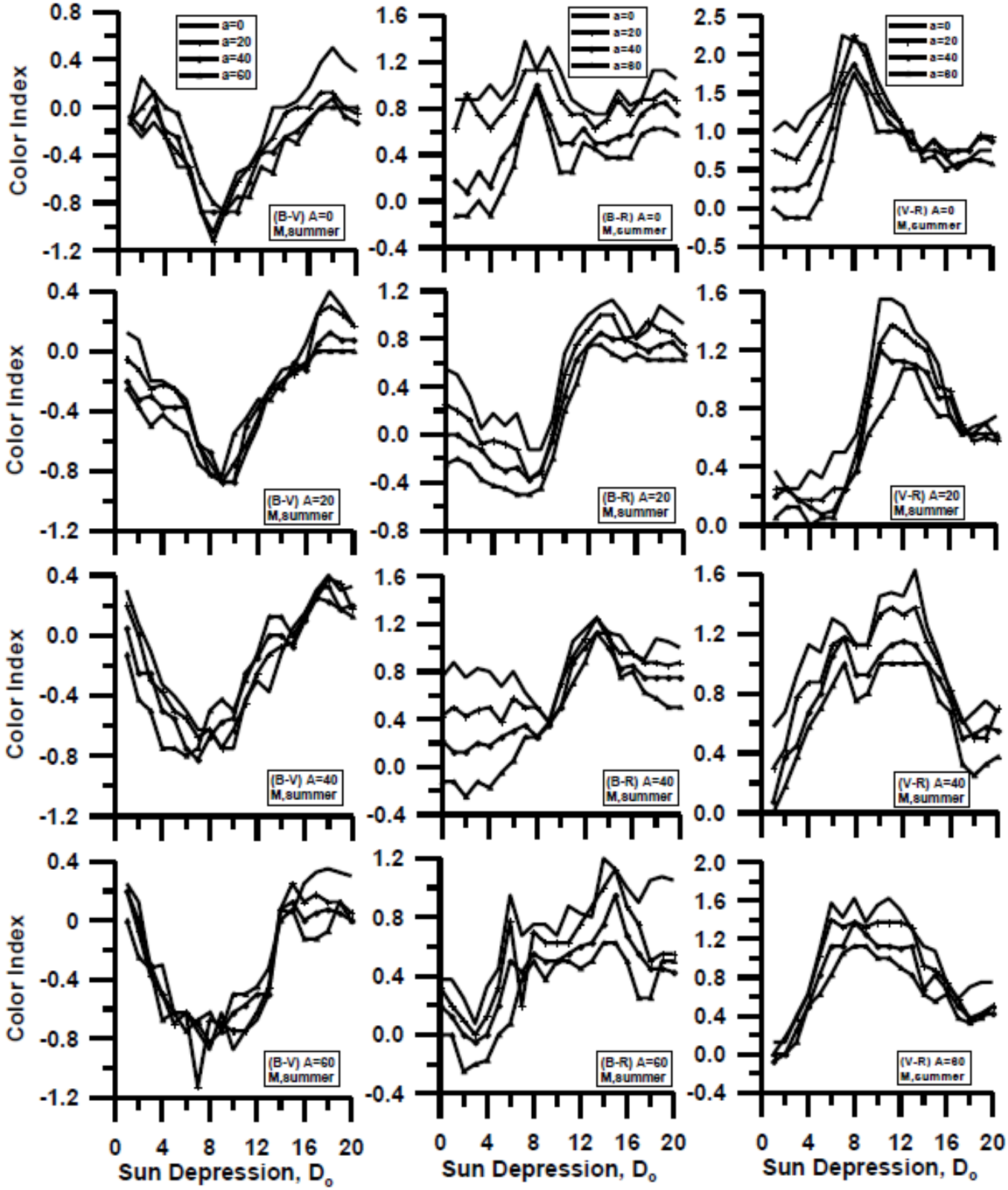

Figure 8. The relation between the color index (B – V), (B – R) and (V – R) respectively and the sun depression angle D_o at different altitudes (a) and azimuths (A) of the morning twilight (M) in summer.

Early medieval planetary astronomy

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Abstract: Up to the 12th century only a few ancient works on planetary astronomy were available in Europe. From the 8th CE onwards the knowledge contained in these few works was frequently illustrated by diagrams. They range from purely schematic representations of the ordering of the planetary spheres over quantitative representations of data from the ancient texts to elaborate representations of planetary positions. Interpretation of these diagrams is complicated. For the purpose of unraveling the diagrams it is useful to study available texts on planetary positions. A careful analysis of such diagrams in favorable cases makes even possible the determination of the date of the displayed planetary constellation. A planetary diagram from a 12th century manuscript in the university library of Graz provides a good example for medieval planetary diagrams. Possible interpretations of the diagram as well as of the surrounding text and dating of the diagram will be discussed.

Keywords: Planetary diagrams, MS 38 in University Library Graz (Austria), Christian Middle Ages, planetary positions, dating

Introduction

For a long time it was commonly accepted opinion that early medieval astronomy in Europe was little more than *computus*, the calculation of the Easter date and the calendar. Recently, however, investigations have revealed a more complex picture, showing that planetary astronomy was a topic well represented in scientific thinking and teaching of the time.

This was not an easy task, however, since up to the 12th century the main astronomical works of antiquity were not available in Western Europe. These included the works of Ptolemy, most notably his *Almagest*, and also the texts of Aristotle, especially his doctrine on the celestial spheres that was to become so dominant in late medieval astronomy. And the books that were known did not represent original scientific work but were of encyclopedic or didactic character.

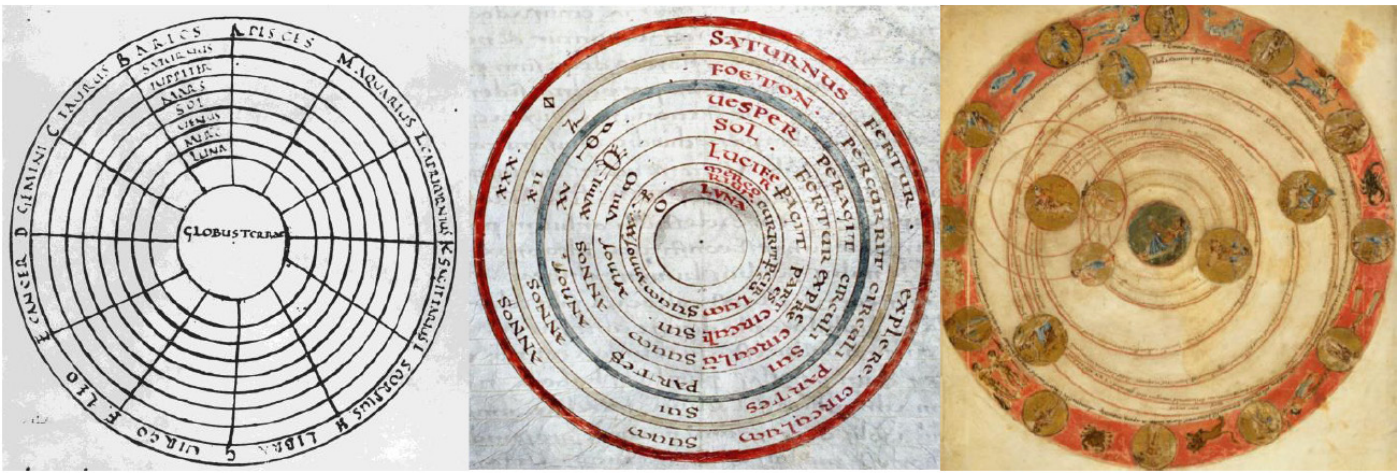
Among those was Pliny's *Historia naturalis*, an encyclopedic work covering the entire field of ancient knowledge. In the second book he deals at length with the planets including, of course, sun and moon. Another one was the 4th century commentary of Chalcidius on Plato's *Timaeus*, the main source for medieval knowledge on Hellenic philosophical thinking. Then there was the encyclopedic work of Martianus Capella, called *De Nuptiis Philologiae et Mercurii*, or *On the Marriage of Philology and Mercury*. One of its chapters is dedicated to astronomy, where Capella describes a mixture of geo- and heliocentric models: the earth is at rest in the center of the universe, circled by the stars and most planets. Mercury and Venus, however, circle the sun. Last but not least there was Macrobius commentary on *Scipio's Dream*, the sixth book of *De re publica* by Cicero. In this work the late Scipio Africanus appears to his grandson and describes the constitution of the universe. This is used by Macrobius to discuss the nature of the cosmos.

From the 8th century onwards the knowledge contained in these few works was frequently discussed in manuscripts and illustrated by diagrams. They range from purely schematic presentations showing only the ordering of the planetary spheres, over quantitative representations of data from the ancient texts to colorful illustrations of planetary positions. They always consist of a certain number of circles representing the planetary spheres, sometimes accompanied by planetary symbols, signs of respective deities or of the zodiac. Sometimes astronomical texts or geometrical information are included into the diagram (Fig 1).

Planetary diagram MS 38

A quite interesting planetary diagram exists in the library of the University of Graz in Austria. It is a planetary diagram from the 12th century, only a one-sided end paper on the first page of a bible manuscript with the number MS 38 (Fig. 2). Binding of the volume was done in the 15th century in the Cistercian monastery Neuberg an der Mürz in Austria. Due to the fact that the monastery in Neuberg was founded in 1327, and the manuscript is dated to the 12th century, it must have been written in another location, but probably in the same region.

Figure 1. Medieval planetary diagrams: (a) Macrobian diagram of planets, after Macrobius, Somnium Scipionis, 9th century; Burgerbibliothek Bern, ms 347, fol. 9r; (b) Isidor de Seville, De natura rerum, Dombibliothek Köln, Cod. 83ii 136v ca. 800; (c) Aratus, Phaenomena; interprete Claudio Germanico Caesare, Universiteitsbibliotheek Leiden, VLQ 79, 93v



The *tabula astronomica* summarizes the astronomical knowledge of that time, but in a very special way. The accompanying text explains the movement of the planets. The author of the diagram took the text from Beda Venerabilis, an English monk in the early 8th century, who wrote it in his work *De natura rerum*. The text says *«Inter terram celumque septem sidera pendent certis discreta spatiis, quae vocantur errantia, contrarium mundo agentia cursum, id est, laevum illo semper in dextra praecipiti. Et quamvis assidua conversione immensae celeritatis attollantur ab eo, rapianturque in occasus, adverso tamen ire motu per suos quaeque, passus, advertuntur, nunc inferius nunc superius, propter obliquitatem signiferi vagantia. Radiis autem solis praepedita, anomala, vel retrograda, vel stationaria, fiunt.»*. «Between heaven and earth there are seven stars in discrete distances. They are circulating against the world etc. ». The only difference is that Beda wrote *Inter coelum terramque* …. (Beda, De natura rerum liber Cap. XII), and the Graz manuscript says Inter terram celumque … Maybe this very small difference once could help us to identify the original source of this work.

A completely different text is found below the diagram: In two lines the various forms of the Latin word *vesper* and its explanations are given: *vesper – sidus* a star (that means the evening star Venus), *vesperus – significans tempus* denoting the eventide, *vesperum – ipsum tempus* denoting the same time, *vespera – temporis officium* religious worship in the (evening) time, and *vespere – adverbium* an adverb. It seems that this text was written for students, since they had to be familiar with those forms and should have been able to distinguish between the name for the evening star and the notation of time. At the end of the page there is an explanation of the numerical values of the Hellenic alphabet, because Hellenic numerals are a system of representing numbers by letters. Including this into the manuscript is an indication that at that time Hellenic texts with astronomical content were known even in an Alpine monastery.

Figure 2. Planetary diagram from MS 38 in the University Library Graz, Austria. 12th century.

The main part of the page is the planetary diagram. It consists of ten concentric circles. In Pythagorean numerology the number ten is the perfect and sacred number. However, it is peculiar to this diagram that the circles are divided by a cross of two orthogonal lines, dividing the diagram into four parts. At the endpoints of the lines in the outmost circle the cardinal points, *meridies, occidens, septemtrio*, and *oriens,* meaning south, west, north, and east, are given. In addition, the outmost circle contains the notation «*Hic est signifer qui Grece zodiacus appellatur*» that means «this is the sign-bearer, in Hellenic language called zodiacus». In the following circle the signs of the zodiac are listed, starting on the left with Aries, the sign of the vernal equinox. This sign correlates with the east side as well, where Aries arises at the beginning of spring. This also fits the cardinal points with the four seasons: spring in the east, summer in the south, autumn in the west and winter in the north. All the other signs of the zodiac follow in clockwise direction. In contrast to most other planetary diagrams there are no pictures of the signs, only their respective names.

The inner circles show the planetary spheres, including those of sun and moon. Along with the planetary sign in every circle there is a comment on the respective planet. The texts always consist of two parts, written in different colors. The first part, written in black, gives the name of the planet, its astrological character, and its orbital period. The second part, written in red, gives some additional information on the visibility. Every planet is indicated by a symbol (Fig. 3); however, those symbols are not the common ones we know today: Sun and moon are shown as faces; all other planets are rhombs with two rectangular-crossing lines or three crossing lines. The symbols of Mercury and Venus are identical.

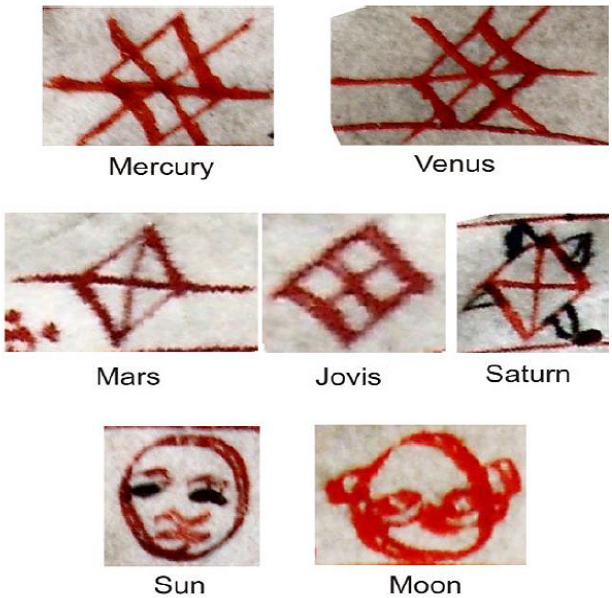


Figure 3: Planetary symbols in the manuscript MS 38

The spheres of the planets start with Saturn, the outmost planet, its circle follows the one with the signs of the zodiac. The symbol of Saturn can be found close to the axis directing towards south. The text says «*The supreme of the planets is Saturn, cold by nature. In 30 days he traverses the zodiac. As the Mars he shines 170 days*». The last sentence is written in red, the first one in black. Similar texts can be found for the other planets. It

is interesting that for Venus the text does not fit to the drawing. The text says «*Below that (the sun) there is Venus, the morning and evening star. From the sun she is no more away than 46 degrees*». However, shown in the picture, Venus is much further away, about 135°. A possible explanation for this discrepancy will be given below.

In the center of the inner circle rests "terre moles", the mass of the earth. The picture follows the scheme of a T and O map, first described by Isidore of Seville in his *Etymologiae* (Fig. 4a). In this map Asia takes up one half of the diagram, the part which is directed towards the orient, Europe and Africa share the other half. The diagram shows this very clearly, oriented according to the cardinal points at the axis. However, it is remarkable for this map, that meridies, the south, can be found at the top. Usually at that time the east was at the top of the map. A T and O map in combination with a planetary diagram is rare, but can, for example be found in the *Liber floridus* (Lambert of Saint-Omer, ca. 1120) (Fig. 4b), a medieval encyclopedia that was compiled in the 11th century by Lambert of Saint-Omer. The perpendicular lines and the geographical directions so far have not been found in any of the medieval planetary diagrams. Both features in first sight do not make much sense in connection with planetary positions, but as will be shown later in this special case they have their astronomical justification. In addition in the center there is a triangle with the following inscription on its sides: «*Pyramidis figura. Ad circulum lune.*», which means «Figure of a pyramid. To the cycle of the moon». This figure in an astronomical diagram is not common for that time; nevertheless again in one of Beda's works, *De temporum ratione* (Beda, De temporum ratione Cap. VII), we can find an explanation for such a pyramid. He writes «that the night is the same as the shadow of the earth, which with a darkness pointed like a pyramid sometimes touches the moon», a very original formulation to explain a lunar eclipse.

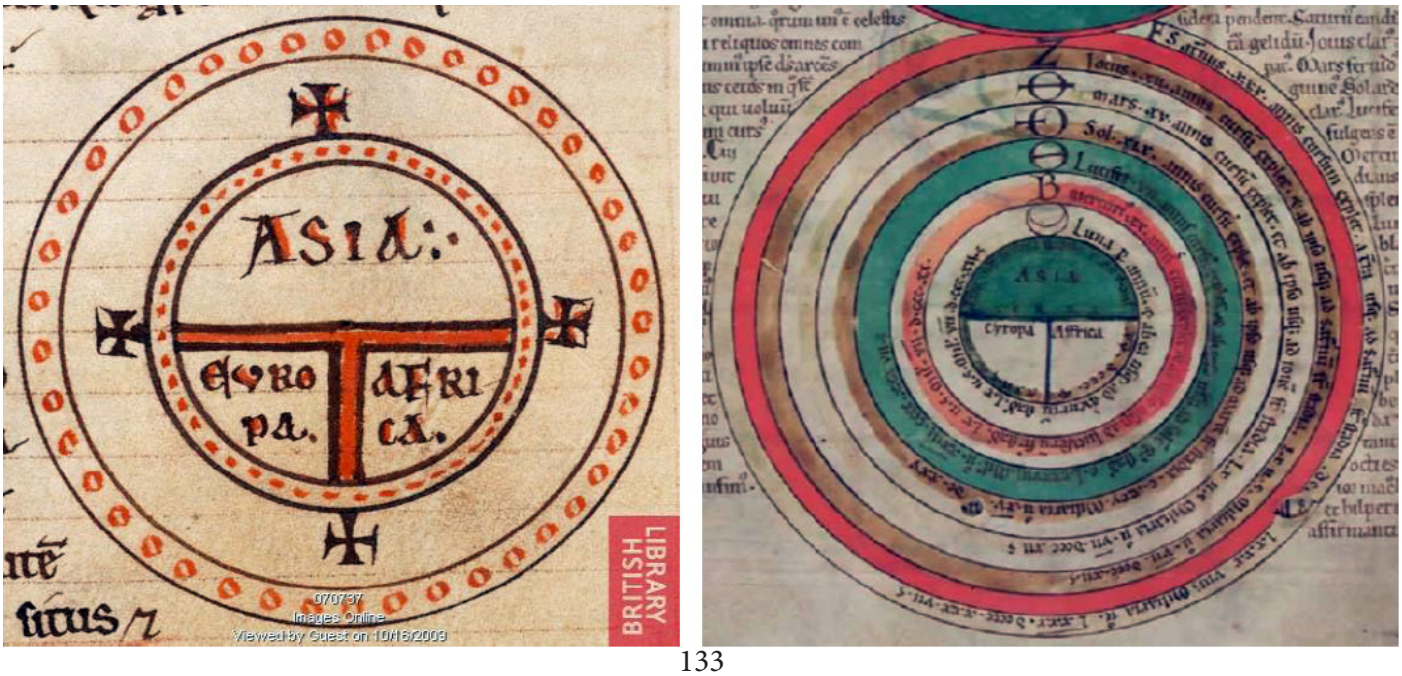
Dating diagrams

When studying planetary diagrams it is interesting to find out whether the positions of the planetary signs do have a really meaning, especially, if the positions of the planets correspond to a real date. Interpretation of such diagrams is complicated by a number of facts: It is often difficult to find out what the diagram is aiming at. The different planetary theories and their interpretations lying behind a diagram are not always easy to find out. Medieval astronomers often displayed different sets of data in a single diagram that in later time would have been kept separate. And in addition, the coordinate system used to determine the data is often dubious. For interpreting diagrams following alternative possibilities have to be taken into account: First of all, it is possible that the position in the diagram does not have any astronomical significance. In this case further interpretations are obviously not reasonable. The position of the planets could be oriented with respect to the cardinal directions. In this case the illustration would refer to a special time of the night, which would be rather curious. Furthermore, the position of the planets as well as sun and moon could be oriented with respect to the signs of the zodiac, or only the sun might be oriented in such a way while the planets are oriented relative to the sun. In both cases dating of the diagram is possible.

However, another fact has to be taken into account: Very often it is not clear whether zodiacal signs were meant as the real constellations seen on the sky or as fixed angular sections along the ecliptic. The assignment of zodiacal signs to certain dates was done in antiquity. At this time the real position of the sun was in the corresponding zodiacal sign. Especially the vernal equinox was in the sign of Aries. Due to the precession of the Earth's axis, the position of the vernal point changes over time by 360° in about 25.700 years. This means that the coordinate origin, being in the constellation of Aries in early antiquity, moved onwards into Pisces around the beginning of the Christian era and continues moving on by about 0.012 degrees per year. For astrological purposes, Aries is still maintained fixed at the vernal point and every sign is attributed an angle of 30 degrees. In reality, however, the vernal point varies with time. Furthermore, the real angular extension is rather different for the various signs of the zodiac. So before interpreting a diagram it has to be verified whether the position of the planets are related to the real constellation on the sky or related to the astrological signs.

Fortunately there exists a text that helps us to solve such problems: Hrabanus Maurus, Archbishop of Mainz in the 8th century, wrote a treatise named Liber de computo, where problems of

Figure 4: (a) Isidore de Seville, Etymologiae, British Library 070737, Royal 12F. IV, f. 135v; (b) Lambert of Saint-Omer, Liber floridus Herzog August Bibliothek Wolfenbüttel Cod. Guelf 1 Gud lat f. 61r.



astronomy and calendar making are discussed in the form of a dialog between student and teacher. In one chapter the student asks for the current position of the planets, and the teacher states (Maurus, Cap. XLVIII) for the date July 9th, 820 that the sun is in the 23rd degree of Cancer, the moon in the 9th degree of Taurus, Saturn in Aries, Jupiter in Libra, and Mars in Pisces. Venus and Mercury are so close to the sun that they cannot be observed. Modern computer programs easily can calculate the astronomical positions for the respective date. The best agreement with the given positions is found for July 10th, 820, with a discrepancy of only one day. In addition it can be concluded that Maurus had the vernal point at 5° in Aries and counted 30° for each zodiacal sign, which means, he followed the astrological computation and did not rely on observations for the sun and the moon. The reason is quite obvious: A direct observation of the sun's position in the zodiac is impossible, and the position of the moon is important only in relationship to that of the sun, since the movable feasts and the eclipses are governed by the relative position of these two. The positions given for the other planets obviously are based on direct observations. Hence we see that the coordinates are counted from the vernal point fixed at 5° Aries. For the other readings the names do not mean the fictive signs but denote the real constellations. In the times of Maurus the difference was about 10°, because the vernal point had moved to about 25° Pisces. This small difference was no real difficulty to early medieval astronomers. In interpreting diagrams, however it is necessary not to overlook this difference and consider the unequal treatment of calculated and observed data. Maurus' treatise also shows that early medieval scholars had the ability both to calculate and to observe planetary motions, though probably not to the same degree of accuracy for every planet.

A marvellous example for an astronomical work that satisfies even highest aesthetic demands is the so-called *Leiden Aratea* written and drawn in the beginning of the 9th century. It contains the *Phaenomena* of the Hellenistic poet Aratus (c.310-245 BCE) in a Latin translation by Germanicus Iulius Caesar. The text is accompanied by a superb collection of artwork illustrating the constellations as well as a planetary system. This diagram differs very much from others (see Fig. 1c). First of all, it is much richer in decoration. The outer ring shows beautiful pictures of the zodiacal signs. The interspaces between every two signs are filled with medallions on gold leaf characterizing the respective month. The iconography of these medallions dates back to antiquity. Also the seven planets are shown as their appropriate deities on gold leaf. From the astronomical point of view, the representation of the planetary spheres is remarkable: They are strongly eccentric, and Mercury and Venus are shown orbiting the sun. The direction of eccentricities obviously follows Pliny, while Martinanus Capella seems to be the source for the heliocentric orbits of the inner planets. The text along the orbits is a compilation from various authors. An interesting peculiarity in this diagram is the fact that the position of the planets does not follow any obvious system. This led Bruce Eastwood to suggest (Eastwood, 1983: 2) that «it places planets in zodiacal signs according to a configuration representing a real date» with a first suggestion of the date March 28, 579 and a later correction by Mostert & Mostert (Moster & Mostert, 1990: 248), who suggested March 18, 816.

In the planetary diagram MS 38 the position of sun, moon, and the other planets is denoted by symbols. As noted already, the arrangement of the planets on first sight seems to be in conflict with astronomical facts, since Venus and sun are apart by about 135°, while the inscription for this planet correctly states the maximum angular distance to be at most 46°. It seems unlikely that a person will make a drawing incompatible with its text. So probably another interpretation has to be found for the position of Venus. To do so, the geographical directions given in the diagram will get their justification. The sun is shown in Leo, and Saturn, Mars, and Mercury are so close by that they cannot be observed. Venus, on the other hand, is shown in the north-east, that could mean that the planet appears as morning-star. The moon is in opposition to the sun and has a full face. Also Jupiter is close to opposition. It seems that the author of the diagram follows the procedure of Maurus: Only the sun's position is given exactly, the other planets' positions are given according to their visibility in the sky. Taking these specifications seriously, there is only one date fitting the given positions. It is the night of July 26th/27th, 1154. For paleographic reasons the diagram has been dated to the 12th century. It is, therefore, probable that the author depicted the planetary positions for a date of his own life-time, maybe the date of the composition of the diagram. Because of this date of production, in the diagram and its text no traces of influence from Ptolemy can be found, because his opus became available only in 1175 through the translation by Gerard of Cremona. It is quite notable, however, that at that time astronomical knowledge and ability in a remote monastery was developed enough to reproduce the planetary positions sufficiently exact that 850 years later the diagram could be readily dated.

Acknowledgement

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Astronomical knowledge in sacred medieval Italian architecture

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Abstract. This text describes the results of archaeoastronomical examinations of sacred buildings in Italy dating from the medieval period. The buildings are complex and well-constructed, and were mainly built in the period after the year 1000 by workmen who were both expert and cultured. The training of the architects and of the possible archaeological knowledge which would have been widespread at the time, will also be briefly dealt with. The buildings can be subdivided according to type: abbeys, cathedrals, basilicas, and baptisteries. An in-depth historical analysis has been carried out for each site: these are buildings which have undergone numerous changes though the centuries due to war, damage or because of changes in architectonic language or in the building's functions. The various surveying methods used will be described (direct, instrumental analysis, scanner laser 3D), as well as the orientations (instrumental survey). The issues considered include: the importance of the astronomical orientation of the buildings, the design relationships between the floor plans of the buildings and their elevations (the arrangement of the windows), the lighting effects created to illuminate liturgical areas and decorative displays, and the presence of astronomical and astrological iconography.

Keywords: Archaeoastronomy, sacred architecture, Christian Middle Ages, Italy, lighting effects, astronomical and astrological iconography, surveying methods

Architects and Astronomical knowledge before 1000 AD[1]

From some sporadic accounts, during the Byzantine period, we know that architectural students studies included *quadrivium*: arithmetic, astronomy, geometry, and music (Frothingham, 1909; Meek, 1952; M. Briggs, 1927; Vagnetti, 1980; Kostof, 1977; Venditti, 1967).

Pappo Alessandrino (4th Century AD), following the writings of Vitruvius (Downey, 1948), wrote that it was necessary to study architectural theory alongside practical skills (such as carpentry and construction etc.). With Pappo, the architect took the name of *mechanicus* (which was often combined with *magister* and *ingenator*), while the term *architectus* was reserved only for the Master Builder. It is important to remember that in the Western Empire, the role *mechanicus* was of great importance and social status. This can be seen in the figures Antemio di Tralle (474 ca. - 534 AD) and Isidoro of Mileto (442 – 537 AD).

Liber artis architectonicae by M. Cezio Faventino (4th centruy AD) was another important cultural reference which had gnomonic themes (Toneatto, 1995; Cam, 2001 and 2002; Plommer, 1973).

Among the figures that Vagnetti (1980, n. 23 cap. II) identified as foremen or coordinators of construction were:

– The Builder Monks

– The Lay Master Guilds. This group includes the *Magister* of Comancini, who were cited in the Rotary Edict (643 AD). They were probably simple itinerant stonemasons who were originally working in the Diocese of Como, then later their work area expanded up to Burgundy, in Switzerland, to the Reno Valley, as well as in many other parts of Italy, down to Puglia.

The Lay Worker School took place in the so-called *officina* (workshop) under the guide of a *magister*. The ideas and *operative rules* were passed on orally, without written text, and eventually became characteristic of each work group. From these developed the trade secrets that were adopted in the building activity of the *guilds* between 1100 and 1400 AD.

The only schools (in the modern sense of the word) were the Episcopal schools, run by the Curia or the Court, or the monastic schools.

Charlemagne was the first who helped to open the first architectural schools (Vagnetti,, 1980). We do not have detailed accounts of these, however. We do know that at Charlemage's court, architecture was linked to the liberal arts of *quadrivium* (Hägermann, 2004; Leonardi, 1981; Cisam, 1975). The in depth analysis of all the studies of direct and indirect witness accounts showed that the following people had access to Vitruvius' manuscripts (Krinsky, 1967):

– Einhard and Vussin (a student of the Carolingian School who was in correspondence with Einhard);

– Alcuin of York (735-804);

– Hrabanus Maurus (780 ca – 856 AD).

Copies of *De architectura* were also in the medieval libraries at Reichenau, Murbach, Gorze (South Tirol), Bamberg, Regensburg, Fulda, St. Gall and Melk.

Architects and Astronomical knowledge after 1000

At the turn of the 11th Century: only a few buildings and written witness accounts survive, (and often those which survive are difficult to date).
11th Century: there were manuscripts of Vitruvius in Toul in the Low Countries.
12th Century: the text was known in Rouen, Cluny, and Montecassino.
15th Century: by the middle of the 15th Century, the treatise was not only available in Italy, but also in Spain, England and Poland.
Krinsky lists the following scholars who must have known of Vetruvius' 10 books, or at least fragments of them:

- Hermann the Paralytic of Reichenau (Reichenau 1013-1054),
- Hugo of St. Victor (1096-1141), *Didascalicon de studio legendi* (III,2)
- Gervase of Melkley (start XIII sec.),
- Vincent of Beauvais (1190 ca.-1264),
- William of Malmesbury (1180 ca-1243 ca.),
- Theoderich of St. Trond,
- Petrus Diaconus (1107 ca.-1159),
- Albertus Magnus (1206-1280)
- Perhaps Filippo Villani (1280-1348),
- Jean de Montreuil, canon in Rouen and secretary of Charles VI
- Petrarch (1304-1374),
- Boccaccio (1313-1375),
- Giovanni Dondi (1330-1388),
- Domenico di Bandino,
- Nicola Acciaioli (1359).

1 This is discussed in greater depth in Incerti (2010).

Among the medieval scholars who may have heard of Vitruvius or his teachings are:

- Those in Florence who had access to *Mappae clavicola.*
- Bernwald of Hildesheim (960-1020 CE)
- Thomas Aquinas
- The circle of Intellectuals at the court of Frederick II
- The 15th Century architects of the Cathedral of Milan.

In Italy, 39 manuscripts concerning the *De architectura* survive (Krinsky, 1967: 36-70). Their distribution over the centuries is:

- before the 10th Century: None
- 12th Century: 3 manuscripts
- 13th Century: 4 manuscripts
- 14th Century: 4 manuscripts

In the 13th Century, Guido Bonatti (12-301296) referred to the relationships between astronomical knowledge and the art of building. He was a famous astronomer from Forli who dedicated the third chapter of his book to urban buildings and *castrum* (Bonattus, 1506). He cites the following buildings as being influenced by astronomical theory:

- *Vivanorum* Tower near the Church of St Gugliemo in Forli.

Examples of religious buildings that remind him of the

- *Archipiscopatus Pisanorum*
- St Marco in Venice,
- St Vitale in Ravenna,
- "*plures alie ecclesie fratum minorum Bononie"*,
- the bell tower of Forlì,
- Baptistery of Florence.

Bonatti stresses that the day of construction must be different for cathedrals inside towns to sacred buildings (churches and monasteries) outside the walls.

The survey archaeoastronomical

It's possible to identify three different design issues in the relationship between Architecture and the heavens.

1. The first concerns the alignment of buildings with visible points on the horizon on certain days of the astronomical calendar or of the liturgical year, if referred to sacred spaces, with the rising or setting of celestial bodies such as the sun, the planets, the stars or the moon.

The orientation: an accurate survey is not necessary to establish a building's position. All that's needed is a good eidotype (hand-drawn sketch) showing the longitudinal axis of the interior space established through direct measurement. Afterwards, with the help of a theodolite or a total station, the direction is placed outside the building, establishing a new station point directly lit by the sun. The value of the azimuth compared to the north is calculated by comparing it to the azimuth of the Sun. The examples show the results of the analysis of several azimuthal values that were surveyed.

- Abbey of Chiaravalle della Colomba (Parma, 1135): sunrise Assumption of Mary (15 August);
- Abbey of Fontevivo (Parma, 1142): direction equinoctial;
- Abbey of St Martino dé Bocci in Valserena (Parma, 1198): St Martin (11 November);
- Abbey of St Maria in Strada (Bologna, 1250): direction equinoctial;
- Abbey of Pomposa (Ferrara, 1026): direction equinoctial;
- Baptisery of Parma (Parma, 1196), (Figure 1): Purification of Mary (2 February);
- Chapelle of the Scrovegni di Padova (Padova, 1303): festivity of the Perdon d'Assisi (2 August);
- Chapel of St Salvatore (Terni): direction solstitial, sunrise winter solstice, sunset summer solstice;
- Cathedral of Pienza (Siena, 1459): summit of the mountain Amiata.
- Chartreuse of Ferrara (Ferrara, 1452-61): direction equinoctial;

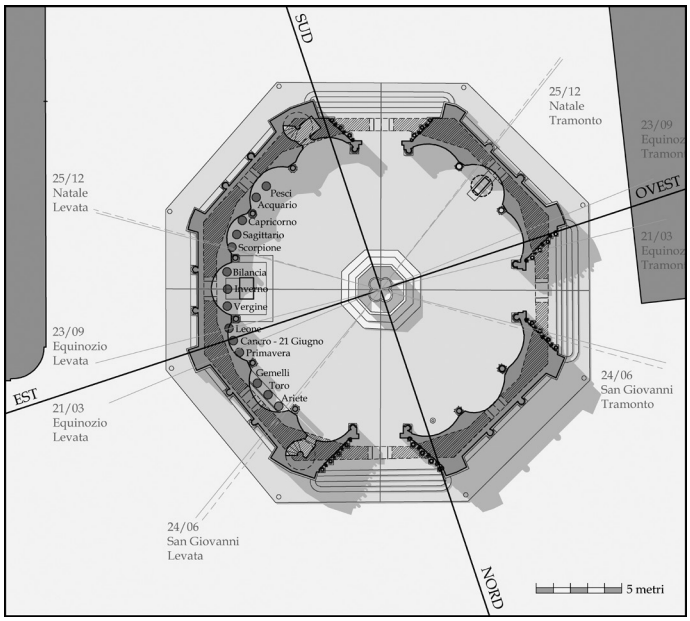


Fig. 1. Baptistery of Parma (1196, under the direction of Benedetto Antelami).

The main axis from the (altar to the baptismal font points to the rising sun on the feast of the Purification of the Blessed Virgin Mary (2nd February). The patron saints of the Baptistery are the Virgin Mary and the St. John Baptist and the episode of the Purification is also displayed in of the inner lunettes. The solstitial direction (very near the feast of St. John Baptist, 24 June) is indicated by numerous elements found in the fifteenth sector: the bas-relief of St. John Baptist, the beginning of the Cycle of the months, the unexpected appearance of St. John Evangelist in the sector reserved at the Prophets, the singular cross with leafs in the last starred sky. As highlighted by the lines that indicate the sunrise and sunset on the equinoxes and solstices, it is likely that the placement of the statues of the months and of Antelami's zodiac were influenced by astronomical considerations. The cycle starts with the summer solstice sunrise. The statue of spring is aligned with the equinoctial axis, but is not positioned between the appropriate statues of the month. The strange position of spring (between Gemini and Cancer) can be explained on archeoastronomical principles.

2. The second is the *relationship between planimetric design and the design of the elevations***.** We are all now familiar with several "light effects" that sometimes have almost hierophanic characteristics which, on certain days of the year, were used to engross, captivate and amaze the spectator.

Several buildings dating from very different ages testify to the accurate alignments created between a precise point in space and a gap in a wall where an observer was obliged to stand in order to observe the transit of heavenly bodies (the moon, the planets or the stars.). Confirmation of these events has often lent support to the theory that the form and position of these openings, from

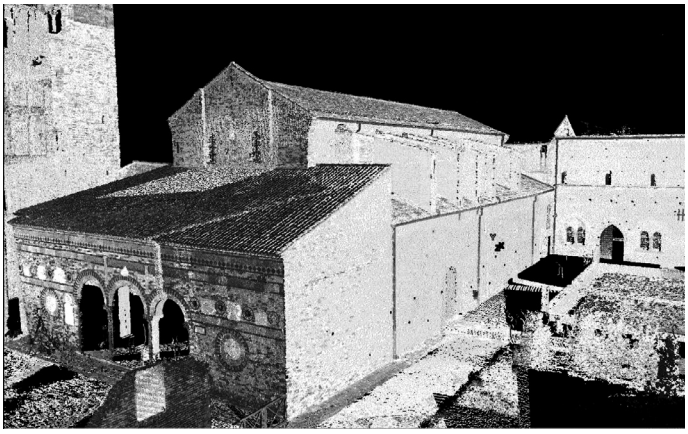


Fig. 2. The Abbey of Pomposa: the points cloud taken from 25 station points with 42 scans. The church (1026) is facing in a equinoctial direction.

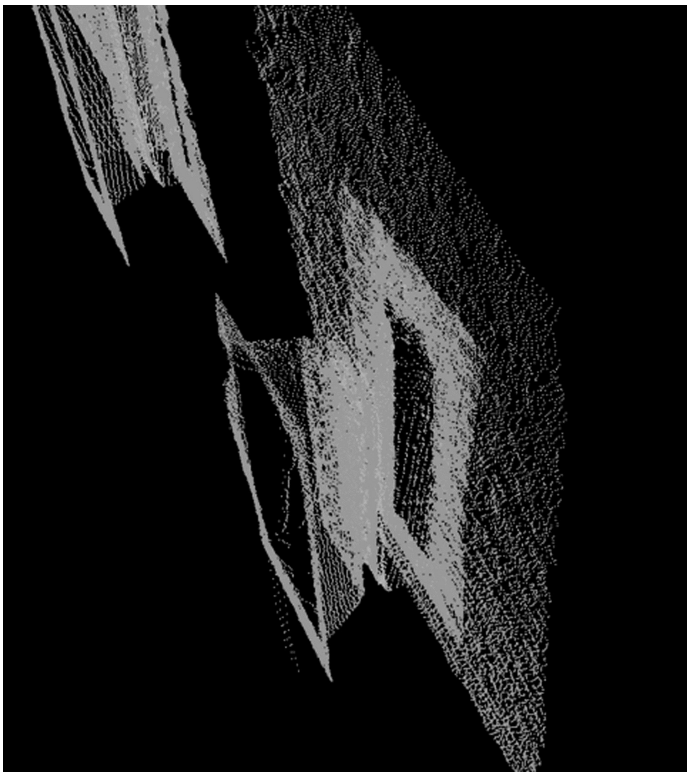


Fig. 3. The Abbey of Pomposa: scan of window with one opening.

the smallest to the biggest and most impressive, were in some cases based on precise astronomical goals.

Light and Openings: when carrying out a survey to study the relationship between designs in which the plan and the elevations have astronomical implications, care should be taken to focus on the identification of the morphological and dimensional data of windows and rosettes (open or plugged), as well as on horizontal and vertical surfaces.

3D laser scanners integrated with topographic data have started to be used together with traditional survey methods (widely used by the author in several studies.) For example, the interior and exterior of the Abbey of Pomposa (Figures 2 and 3) were surveyed with a series of 25 station points and a total of 42 scans.[2]

One of the most amazing episodes confirming this type of in-

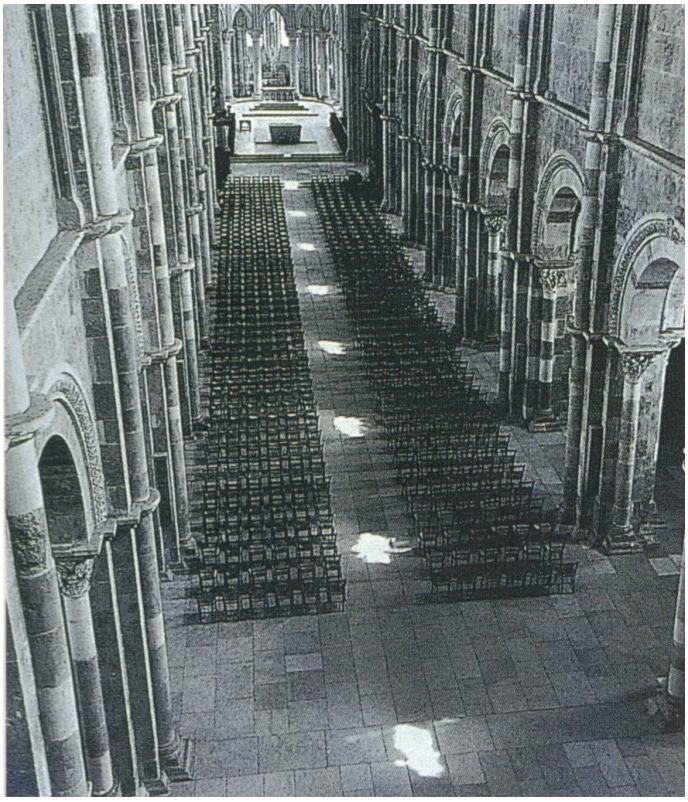


Fig. 4. Oursel R. (1993). The reconstruction of the central aisle of Vézelay is dated to around 1106 by some writers, and only after 1120 by others. On the day of Saint John the Baptist, the rays of light fall between the pillars onto the centre aisle. The pattern of light on the floor doesn't clash, however: it reinforces the rhythm of architectural distribution.

tentional design are the unique light effects that occur at a certain time of the year in the central nave in Vézelay. The day the Church celebrates the ancient feast of St. John the Baptist (June 24), very close to the summer solstice, the light falling through the south windows creates a series of solar 'notches' on the floor of the central nave. These notches are perfectly aligned with the axis of the church (Figure 4).

They clearly have both symbolic and spiritual implications; at midnight, the near-round patches link two paradigmatic areas of the sacred space: the atrium and the apse, irresistibly inducing the believer to look towards the Gothic choir. We should also emphasise the designer's remarkable competence and the elegant way in which he aligns the 'patches of light' (from the windows in axis to the keystone) and the main pillars of the central nave: not only is the sun-induced pattern on the floor pleasant to look at, it reinforces the rhythm of the architectural score.

Many similar episodes also take place in the Cistercian Abbey of Chiaravalle della Colomba (Alseno, Parma, 1135; see Incerti,1999: 146-160). Again on the feast of St. John the Baptist, the light from the two small oculi on the vertical wall between the transept and the apse manages to reach the entrance door (Figures 5 and 6).[3] The two north-east windows are located at an ortive amplitude very close to the limit established by the summer solstice. The azimuth at sunrise on June 21 (Julian calendar) is in fact 56.1 degrees, while the axis of the church is 69.25 degrees; this kind of opening can capture the sun's rays for only a few days a year and, plainly, only in the very early morning when the

2 Each scan was carried out with a 5 cm grid to organize and recognize targets, a 2 cm grid for the survey itself, becoming 1 cm frequent on all the openings, for a total of approx. 37 million points. For a description of the study and the credits, see Incerti, 2006: 73-76.

3 It is a well-known fact that St. John the Baptist is traditionally associated with the symbol of the "door," i.e. the opening through which the catechumens become members of the family of the sons of God after Baptism. The Benedictine rule, faithfully adopted by the Cistercians, document the presence of monks in church at this time of the day to celebrate the First hour.

Fig. 5. The ray of light that strikes the door of the Abbey of Chiaravalle della Colomba on the feast day of St. John the Baptist (Prime).

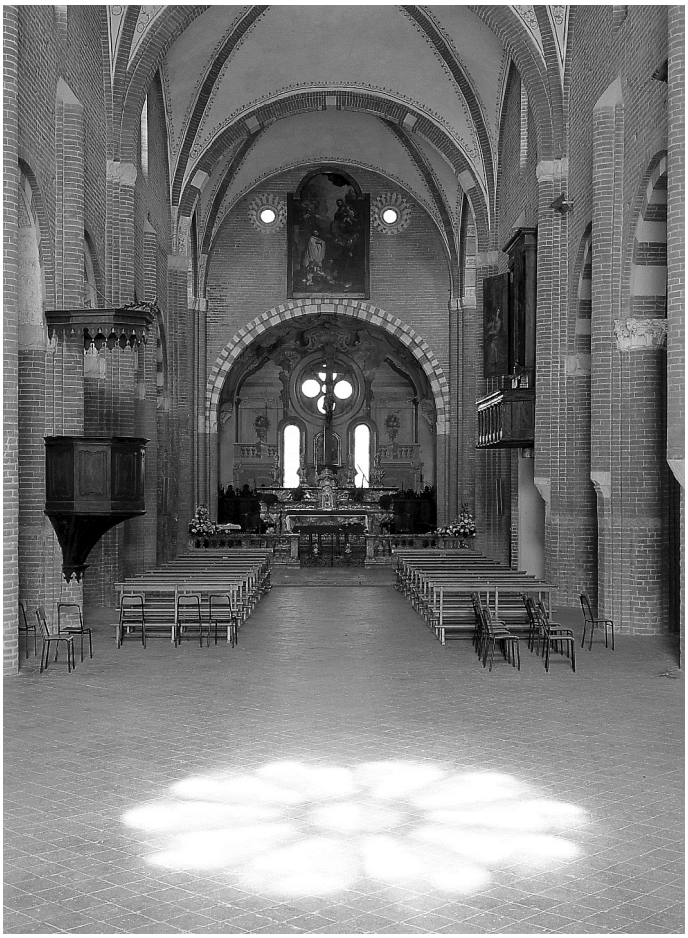


Fig. 6. Abbey of Chiaravalle della Colomba (1135).

sun is very low on the horizon.

Given the size and angular values of the triangle that is created,[4] if the *oculi* had been moved by a mere 20 centimetres, this would have horizontally shifted the patch of light by approximately 80 centimetres. Therefore, it's clear that the unknown architect of the Chiaravalle Abbey carefully calculated the position of the small windows on the vertical wall to create this unique light effect.The figures 7-9- investigate many similar episodes that can be found in several sacred medieval architectures.

3. Contrary to the first two issues, the third comes after the design and building stages and concerns the question of decorative elements. It is reasonable to believe that, many years after the works were terminated, certain wall finishing were chosen rather than others to paint frescoes or place statues. Whoever did this

4 The base of the right-angled triangle is 52 m ca.

Fig. 7. Abbey of Pomposa (Ferrara, 1026): survey of axis.Ividessi in se ca retilius ad consuludam su molia? Oc, cre ad sentionit; huium niaed cris, viverem are endena, cum derte omporimortes hocrudent. Etriore ssenesteste aucteri te corem escerox nostuitus, dendum adem re tanditurox nia inihil horis, cae et vis. Patium sil vertium horsusquemum orum tatis. Catis consus, quod culiber firitilint. At virio mentenam iamque ina, qui confescero ve, publintiam facie aut vivit, Catquer orsuludet; enihilicio perfes noctor auc iaedo, quit? Osta ve, nem inim consus, pat et L. Catam ut quam me que perid iptem host enicae aridiis Multis con Etratu quit vitis ipicend acciesitam ade te conscienat, es conlocr itasdac.

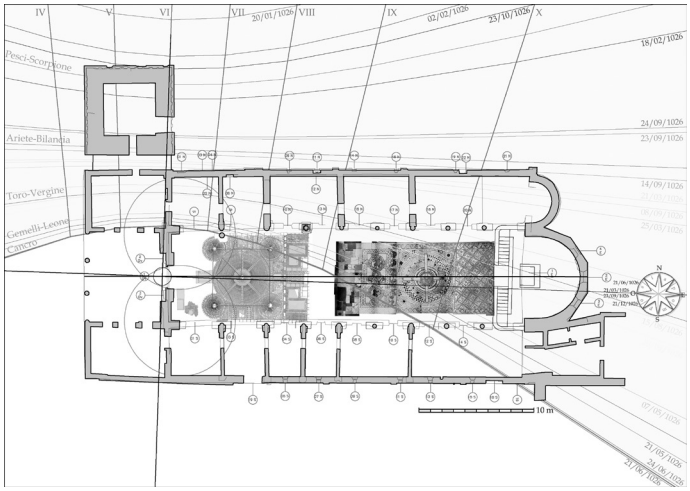
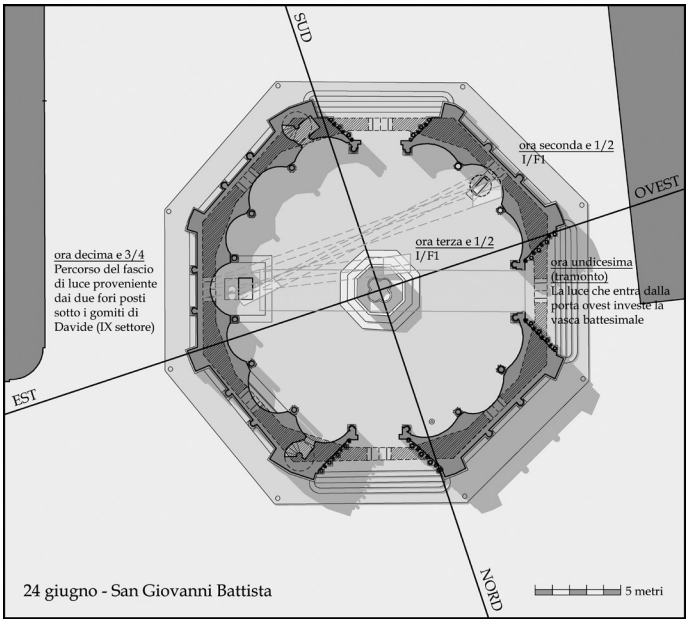


Fig. 8. Abbey of Pomposa: planimetry.

Figs. 8-9. The Baptistery of Parma (1196): feast day of St. John the Baptist. The main baptismal font is struck by a ray of sunlight. Other events involve the smaller baptismal font and the altar.



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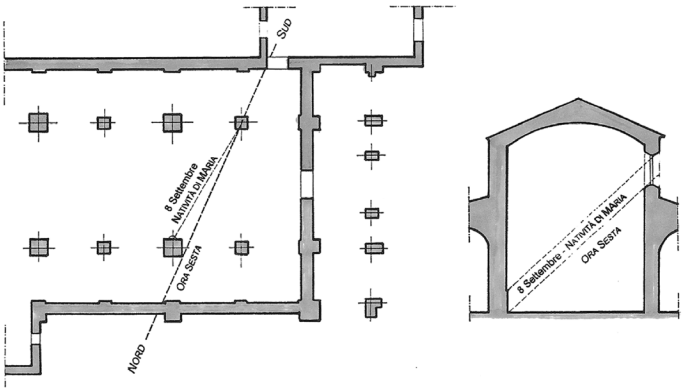

Figs. 10 and 11. The Abbay of Chiaravalle della Colomba (1136): the ray of light that strikes the fresco of Mary on the feast day of the birth around the Sixth Hour (Sext). Unlike the first two aspects, the third comes after the design and building stages and concerns the question of decorative elements. It is reasonable to believe that, long after the construction was finished, artists installed certain wall furnishings, e.g., frescoes or statues, in particular places which, they had observed, would be struck by a single ray of light on a specific day.

was fully aware – thanks to direct observation – that these finishing would be struck by a single ray of light on a specific day. Light, images and sculptures: there are many examples of attempts to find symbolic implications in the design and position of these images and sculptural elements (Figures 10 and 11). In the Abbey in Chiaravalle della Colomba, the fresco of the Virgin Mary on one of the Abbey's main pillars is illuminated at the *sexta hora* on September 8 (Mary's birthday); the fourteenth-century fresco of the Crucifixion, perhaps from the Grotesque school, appears to be struck by a ray of light during the days that fall around the winter solstice (Christmas).

Several episodes that occur in the Baptistery in Parma involve the main protagonists of the decorative elements. The most important, due to its accuracy and incredible scenic effect, is the fresco of the Baptism of Jesus, an excerpt from the cycle of St. John the Baptist (the fifth register of the cupola); a ray of light from the window of the third order, in the ninth sector, squarely hits the figure of the Messiah. This phenomenon used to begin on March 25 and ended around April 10; it lasted approximately two weeks and took place

Figs. 10 and 11. The Abbay of Chiaravalle della Colomba (1136): the ray of light that strikes the fresco of Mary on the feast day of the birth around the Sixth Hour (Sext).

right in the middle of the Easter period (Figure 12). The cited studies have also been published in: Incerti, 2001.

It is impossible to speak about archaeoastronomical analyses without covering the subject of astronomical and astrological iconography which was very common in the Medieval These representations were mostly symbolic and provide evidence that at this time people were aware of cosmology and themes related to the calendar.

Conclusion

There are three different design aspects of the relationship between medieval architecture and the heavens which, with its elements and reciprocal movement, has influenced the history of humanity.

The first concerns the alignment of buildings to visible points on the horizon on certain days of the astronomical calendar or of the liturgical year, governed by the rising or setting of the Sun, the Moon, the planets, or the stars.

The second is the three-dimensional relationship between ground plan and building elevations. These can produce the familiar "light effects" that sometimes have almost hierophanic characteristics which, on certain days of the year, can engross, captivate and amaze the spectator. Several buildings dating from even very different ages testify to the accurate alignments created between a precise point in space and a gap in a wall where an observer was obliged to stand in order to observe the transit of heavenly bodies (the moon, the planets or the stars.). Confirmation of these events

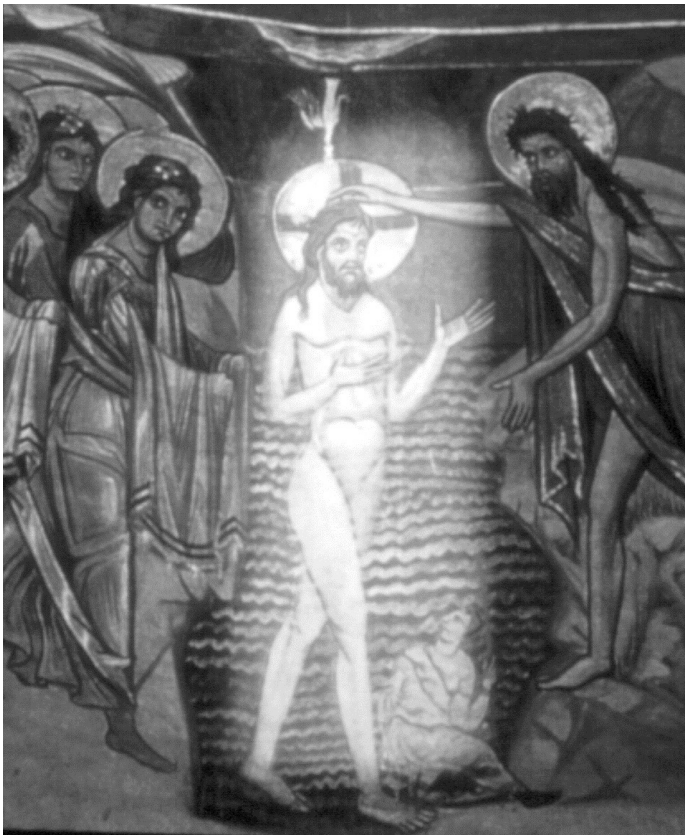

Fig. 12. Baptistery of Parma (1196). On the feast of St. John Baptist (24 June) many light effects occur. The main baptismal font is struck by a ray of sunlight. Other events involve the smaller baptismal font and the altar. On the fifth level of the cupola a ray of light strikes the painting of the Baptism of Jesus in the Jordan during the Easter period, beginning on 25 March and ending around 10 April. This corresponds to the practice of the early church of only celebrating baptismal rites on a few days: Easter and Pentecost (movable fests), and the nearly solstitial feasts of St. John the Baptist, Epiphany, and Christmas.

Fig. 13. Baptistery of Parma. The sky with golden/dark stars.

has often lent support to the theory that the form and position of these openings, from the smallest to the biggest and most impressive, were in some cases based on precise astronomical goals.

Unlike the first two aspects, the third comes after the design and building stages and concerns the question of decorative elements. It is reasonable to believe that, long after the construction was finished, artists installed certain wall furnishings, e.g., frescoes or statues, in particular places which, they had observed, would be struck by a single ray of light on a specific day.

Due to the singular and symbolic nature of each case, the application of statistical analysis at this point is not thought to be meaningful.

Fig. 14 Baptistery of Parma, Southern Portal. The sun, moon, day, and night are depicted in a scene from the legend of Ballam and Josaphat.

Fig. 15. Chiaravalle della Colomba (1136), zodiac?

Fig. 16. Baptistery of Parma. The statues of the months and of Antelami's zodiac were influenced by astronomical considerations.

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A Survey of the Astronomical Manuscripts Collection in the Ghazi Husrev-bey Library in Sarajevo

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Abstract: The Ghazi Husrev-bey Library in Sarajevo was established in 1537 as a cultural and research institution focused on Islamic cultural heritage, Islamic sciences and education. Around hundred thousands of books, manuscripts and other documents in Arabic, Persian, Turkish, Bosnian and other European languages represent its rich resources. A collection of astronomical manuscripts was strongly influenced by Ottoman administration during their several centuries long presence in Bosnia, which brought Islam as a new religion that required some applied astronomical knowledge for everyday usage. This paper shows results of a survey about authors, works, transcribers, Bosnian cultural centres and other relevant parameters related to Astronomical manuscripts collection of the Ghazi Husrev-bey Library in Sarajevo. Presentation of this collection of manuscripts contributes to historic and philosophic research on astronomy in Bosnia and Herzegovina, where eastern and western civilization in different ways influenced development of practical astronomy.

Keywords: Bosnia and Herzegovina, Islamic astronomy, manuscripts, Sarajevo, The Ghazi Husrev-bey Library

Introduction

Advances in astronomy were globally influenced by different civilizations and scientists, particularly Hipparchus, Eratosthenes, Ptolemy, al-Bīrūnī, Copernicus, Galilei and Kepler. Those giants shaped new views of understanding the world around us and in particular the sky phenomena. Astronomy did not have that kind of importance on the territory of Bosnia and Herzegovina. Astronomy in Bosnia and Herzegovina was never systematically studied in proportions that could yield important scientific or practice accomplishments like the ones made by developed civilizations. Available literature showed no original or authentic contributions by astronomers from the territory of Bosnia and Herzegovina, where astronomy had primarily a practical value in satisfying religious needs such as timekeeping with astronomical instruments or orientation regarding current position of known planets and stars (Hadzibegovic, 2004).

Medieval Bosnia remains a puzzle regarding the level of astronomical knowledge of its inhabitants. Currently, there are no data on the relationship between social life and astronomy in medieval Bosnia. Comprehensive research of astral elements found on the medieval Bosnian tombstones ("stećci") might bring new insight in the meaning of astronomy for medieval Bosnia social and cultural life, and the reflections of its inhabitants towards the Sun, Moon and the stars. First documented astronomical knowledge on the territory of Bosnia and Herzegovina dates in the end of the 15th century, and coincides with the coming of the Ottoman Empire.

Astronomical knowledge that was easily applied to everyday religious needs become useful for inhabitants of Bosnia and Herzegovina in the 15th century, especially ones from the Bosnian Church that converted to Islam. By accepting Islam as their new religion, Bosnians accepted also the duty of five daily prayers, with exact timing based on astronomic calculations. Timekeeping by astronomic methods, and other activities such as construction of calendars or determination of the sacred direction to Mecca during prayer, required for professionals skilled in mathematics and astronomy. In the beginning, these educated professionals came along with the Turks from the Empire. They were teachers to native students and scientists and introduced them not only to astronomical instruments and timekeeping techniques, but also to basic principles and postulates in astronomy and mathematics as well.

Ottoman Empire brought intensive development of cultural and teaching institutions, and the schooling system. At first, they were primarily institutions of mainly religious character like mosques or elementary religious schools. The most important person involved in cultural life of that time was the Turkish regent Ghazi Husrev-bey. During his regency Sarajevo experienced swift expansion and became cultural and social centre of the most-western part of the Ottoman Empire. He donated large share of his riches to Sarajevo and built cultural, educational and humanitarian institutions like mosques, schools, libraries, hospitals, aqueducts, fountains with personal resources. Many of them are still preserved in its full function.

Several scientific and cultural centres in Bosnia and Herzegovina keep numerous oriental manuscripts that represent inestimable cultural heritage and resources for scientific research. Most of them are situated in Sarajevo: the Ghazi Husrev-bey Library, National Museum of Bosnia and Herzegovina, Oriental Institute, National and University Library of Bosnia and Herzegovina, Bosniak Institute by Adil Zulfikarpašić Foundation, and Historical Archive of Sarajevo. Some of these institutions held precious collections of manuscripts and other documented material, but most of it was lost during brutal terror campaign by the Bosnian Serb army in the period between 1992 and 1995. Invaluable cultural treasures of Oriental Institute in Sarajevo, together with its numerous scientific manuscripts burnt in just one day after atrocious bombing of Sarajevo and its cultural wealth. Those brutal actions abruptly stopped ongoing research on science and culture of this particular geopolitical region where eastern and western culture interweaved. In addition to cultural and educational institutions in Sarajevo there are other important institutions like the Archive of Herzegovina in Mostar, Archive of Tuzla Canton, Behrambey Library in Tuzla, together with several private libraries of eminent Bosnian intellectuals, that are waiting for new researchers of Bosnia and Herzegovina's rich heritage.

The aim of this review is to present manuscripts related to astronomy kept in the Ghazi Husrev-bey Library, and to highlight its scientific, cultural and social importance.

The Ghazi Husrev-bey Library importance for culture and science

The Ghazi Husrev-bey Library (GHL) in Sarajevo holds more than 80000 books, manuscripts, journals, historic letters, newspapers and other library materials. It is the biggest resource of oriental written treasure in Bosnia and Herzegovina and the most important cultural institution in Sarajevo (Dobraća, 1963: xiii). It was built in 1537 by Ghazi Husrev-bey, great statesman and cultural professional from the time of Ottoman rule in Bosnia. The library holds an important role among students, educators and heritage investigators of all times. It was founded with

a purpose to grow into a central cultural institution for Islamic sciences, based on its rich legacy. Rich collection of a variety of written materials has been a useful resource in the research for paths of knowledge transfer between East and West, and also original contribution of Bosnia scholars in culture, science and art. GHL was founded with initial intention to develop scientific education within Islamic culture. It was testified by a reference from Ghazi Husrev-bey's foundation (waqf):

«*The unexpended balance of building costs shall be spent on good books to be used in the school referred to, so that every reader may derive benefit from them and transcribe them for the purpose of study*» (Dobraća, 1963: xiv).

Consequently, GHL has always been opened to public and has represented the largest conserved bibliographic collection, not only in Bosnia and Herzegovina, but in Southeast Europe as well. In the period between 1867 and 1950 numerous library collections from different Islamic schools (madrasas) were transferred to GHL, together with many private collections. The process of donating written materials to GHL has never stopped thus continuously increasing the collection of the library. In addition to various manuscripts, books, journals and calendars GHL holds many court records of the judicial district of Sarajevo (kadiluk) and ancient ledgers of Ghazi Husrev-bey Waqf.

GHL collection of manuscripts contains also astronomical manuscripts that had survived through five turbulent centuries, and had witnessed the development of astronomical science and its implementation in the culture of Bosnia and Herzegovina.

Manuscript collection in the Ghazi Husrev-bey Library

In the GHL there are about 10000 manuscripts in four languages: Arabic, Turkish, Persian, and Bosnian, all written in Arabic alphabet. To date, 9381 manuscripts have been listed in 16 volumes of GHL Catalogue prepared between 1963 and 2008. Complete contents of the Catalogue were prepared in printed and digital form, and fully available to public.

Manuscripts held in the GHL were made as written or rewritten works in important cultural centres like Cairo, Baghdad, Mecca, Medina, Istanbul etc. Manuscripts were brought by the Turks who pursued various tasks in this part of the Empire, merchants, Bosnian students in Islamic centres and Bosnian hajj pilgrims who visited Mecca and Medina. Many manuscripts emerged from transcribing tradition of scientists and intellectuals in cultural centres of Bosnia and Herzegovina, chiefly in Islamic schools and libraries between 17th and 19th century. Together with Sarajevo libraries, one of the largest libraries in Bosnia was a madras's library in Travnik, an old town in Central Bosnia. Today, most of Travnik library collection is held in GHL in Sarajevo.

Astronomic manuscripts, that are the main object of this survey, can be divided into 2 basic groups. One group of manuscripts is works listed in the 12th volume of the GHL Catalogue, together with mathematics, pharmacy, astrology, medicine and veterinary medicine writings. Other group includes items enclosed into collections of texts from Islamic sciences and listed in various volumes of the Catalogue. Some of the manuscripts were transcriptions made by scholars from cultural and educational centres in Bosnia and Herzegovina. Manuscripts that previously were a part of library collections of other old Bosnian cultural centres like Mostar, Prusac, Travnik, Foca, Gradacac are held today in the GHL. These small cultural centres were places of vivid activity of scholars, practitioners and intellectuals interested in astronomy.

A brief analysis after survey of the Ghazi Husrev-bey Library astronomical manuscript collection

Astronomical manuscripts held in the GHL are mainly transcribed astronomical works of prominent astronomers from golden era of Islamic civilizations between 11th and 15th century, or commentaries and supercommentaries and glosses to respected works. In addition, astronomic tables, calendars, descriptions of astronomic instruments and instruction manuals for astronomic instruments are also a part of this astronomical manuscript collection. According to types of astronomic disciplines these manuscripts can be classified into five categories: theoretic astronomy, practical astronomy, mathematic methods in astronomy, astronomic instruments and calendars. Original authors of these works are mainly less recognized in the world's literature, although there are some works by world famous scientist like 'Abdullah Ibn Sīnā (Avicenna), Sibṭ al-Māridīnī, al-Jaghmīnī and Ulūgh Bey (Hadzibegovic, 2007a).

Total number of astronomic manuscripts of GHL is 145. There are 75 manuscripts in Arabic, whereas 59, 7, and 4 manuscripts are written in Turkish, Persian, and Bosnian language, respectfully. All manuscripts refer to works of Islamic astronomy, some of them made in 11th and 12th century (2 items), 15th century (5 items), and 18th and 19th century (totally 11 items). Among all astronomic manuscripts, authors of only 58 items are known. Comparably, there are only 19 manuscripts with known transcribers (Hadzibegovic, 2004).

Analysis of manuscript contents showed that most of the work was done in the field of practical astronomy. Most frequent texts were about quadrants (around 50 items), whereas calendars and astrolabes featured in 18 and 8 manuscripts, respectfully. An important finding is a representation of work from a world known scientist Ulūgh Beg from the 15th century. In particular, it is a transcription of his astronomic tables «Zīj Ulūgh Beg»[1], and a commentary to this work written in Persian language. It is reasonable to assume that his tables were used by Bosnian practical astronomers.

The greatest number of items by one author is 26 manuscripts by Mustafā b. 'Ali al-Muwwaqqit, written mainly in Turkish language. Total number of 18 manuscripts was written by Badruddīn abū 'Abdullah Muḥammad b. Muḥammad Sibṭ al-Māridīnī (Jahić, 2003: 185-187). Most cited and transcribed work is a textbook of theoretical astronomy «Al-mulakhkhas fī al-hay'a» (Compendium of the Science of Astronomy) by medieval author Mahmūd b. 'Umar al-Jaghmīnī al-Khwārizmī (died in 1221). This work was frequently used by scholars in whole Ottoman Empire. Copies of this work can be found in thousands existing copies of the original in many world libraries: Berlin, Oxford, Paris, Istanbul, Cairo, Bombay, London etc (Hadzibegovic, 2004). This textbook is based on geocentric Ptolemy's model and Aristotle's natural philosophy. It is noteworthy that practical astronomers and students from Bosnia and Herzegovina used this textbook even in early 20th century, when these ideas and postulates were long abandoned in Western civilizations. Among native authors, it is important to point out a 690 pages manuscript in form of a calendar from 19th century by a practical astronomer Sālīh Sidqī Hājjī Husayn-zāde al-Muwaqqit[2].

1 Jahić, 2003: 296-297. The GHL manuscript 7371 in Persian language has no any detail (name of copyist, place or date of its transcription).

2 Jahić, 2003: 290-291. A calendar for Sarajevo city prepared by Sālīh Sidqī

The al-Jaghmīnī's textbook as most used astronomical manuscript

The basic text of the al-Jaghmīnī's astronomical treatise «Al-mulakhkhas fī al-hay'a» appears as the most used manuscript by Bosnian practical astronomers. It is a manuscript that could be considered as textbook following its usage in many places in Bosnian territory where some special institutions for timekeeping or religious schools had been established.

In the GHL there are six commentaries on this text given by Qādī-zāde ar-Rumī (Jahić, 2003: 169-170, 173-174) who lived in fifteenth century and worked at the Ulūgh Beg's astronomical observatory in Samarkand (Uzbekistan today). There are also two samples of a supercommentary by al-Birjandī (Jahić, 2003: 174) (died after 1528), and one supercommentary by Ahmad al-'Imadī (Jahić, 2003: 175), seventeenth century.

The structure of the al-Jaghmīnī's compendium on the astronomy is the same as one of the manuscript which is kept in Leipzig and translated to German by Rudloff and Hochheim3. Differences between treatises from Sarajevo and Leipzig are mainly in amount and kind of drawings. The al-Jaghmīnī's compendium from GHL consists of a short introduction and two sections. Introduction includes the system of spheres, information about simple and complex objects in the Universe and structure of matter (FIG. 1). Throughout its five subsections, Section I relates to the spheres' nature and motions, the explanations about planetary motions of Mercury, Sun and Moon, coordinate systems used, and astronomical parameters relevant for objects' position in the Universe. Section II is the arrangement of three subsections and gives details about Earth and its geographical zones, geographical parameters, time units, timekeeping, instruments, and sacred direction methods. In the Herzegovina Archive in Mostar there is also one sample of the al-Jaghmīnī's treatise, containing almost the same basic text, but different number of drawings compared to the manuscripts from Sarajevo and Leipzig (Hadzibegovic, 2007b). This survey also analyzed a manuscript from the GHL collection transcribed in Edirne (Turkey), and brought to Sarajevo in 17th century.

It is reasonable to conclude that Bosnian practical astronomers were using these manuscripts primarily for prayer timekeeping, finding of the sacred direction Kiblah, and for studying planetary motions (Hadzibegovic, 2004, 2007b).

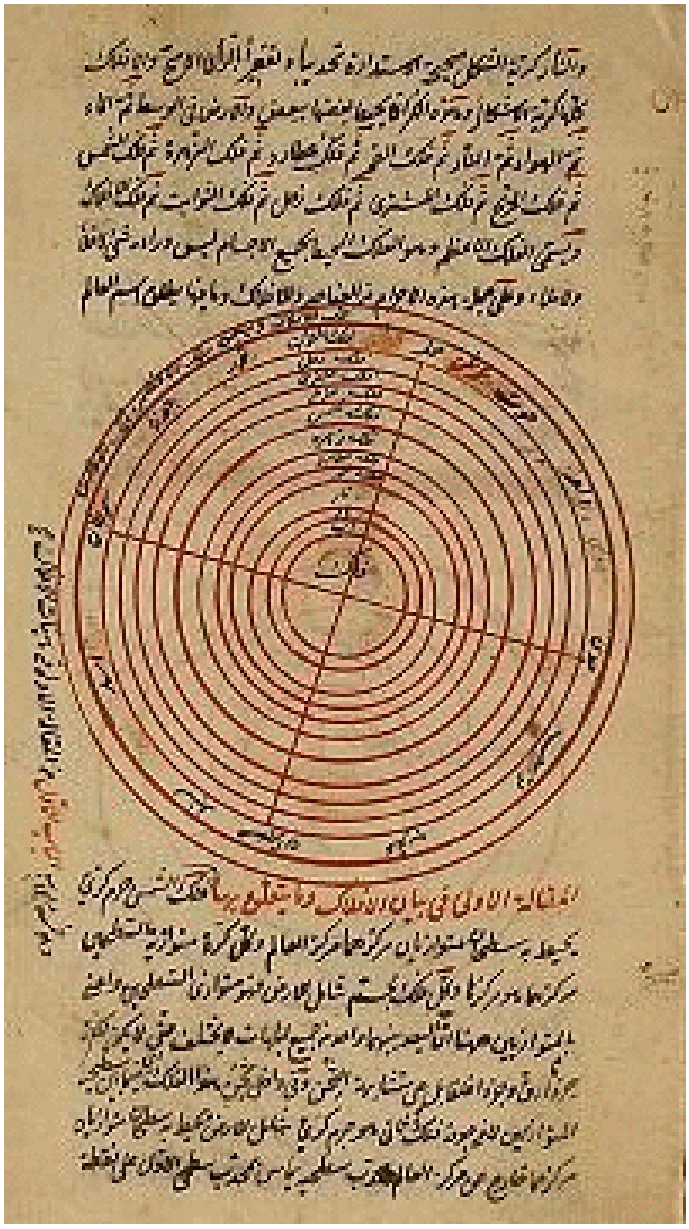

Figure 1. An extract from the treatise «Al-mulakhkha ϖ fī al-hay'a» on geocentric astronomical theory about system of spheres, 13th century, by al-Jaghmīnī, transcribed in Edirne, Turkey, 17th century. (Reproduced from the manuscript 7292, 1 with kind permission of the Ghazi Husrev-bey Library in Sarajevo.)

Conclusion

The Ghazi Husrev-bey Library is the most important institution of culture, science and history of education in Bosnia and Herzegovina, and essential for understanding its cultural heritage. It is also a place where many researchers could meet their strong interests in many fields of research. Its library materials have not been examined enough because there are no institutions or research groups that would investigate the history of astronomy in Bosnia and Herzegovina. GHL could be a meeting point for many world scientists in the quest for paths of knowledge transfer in the field of astronomy from East to West and «vice versa».

According to the analyzed manuscripts, ideas in Bosnian science were mainly influenced by Arabic-Islamic countries, whereas European influence was less important. Even in the time of Copernican heliocentric ideas, the old Islamic astronomy was still current in Bosnia and Herzegovina, primarily for satisfying religious needs of Muslims, such as prayer timekeeping and sacred direction location by scientific methods. This presentation of the GHL astronomical manuscripts and other collections contributes to awareness on value of historic and philosophic research on astronomy in Bosnia and Herzegovina, where Eastern and Western civilization in different ways influenced application of global knowledge in astronomy.

Hājjī Husayn-zāde al-Muwaqqit for years:1868-69, 1874 and 1887-89.

3 Rudloff and Hochheim, 1893: 213–275. (German translation of the «Al-mulakhkhas fī al-hay'a».)

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Early Modern Period

Cultural Heritage and Architecture of Baroque Observatories

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Abstract: In this paper the development of architecture of observatories since the invention of the telescope (1608) will be presented. The emphasis of the discussion are not the famous observatories of baroque era like Paris or Greenwich but some less known university or monastery observatories (e. g. Bologna or Eger, Hungary) and their connection to the cultural heritage. But also the typical instruments of that time will be presented and what the observatories contributed to astronomical science, to our modern view of the world. In the baroque era astronomy was linked very often to other sciences, not only celestial, but also terrestrial and meteorological observations were made. Especially the mathematical tower of Kremsmünster, Austria, offers a lot of cultural implications like baroque paintings and sculptures but also a baroque museum of science; this collection intends to present the large variety of the world, a microscopic image of the macrocosm. In summary one can see very well the relevance of baroque observatories to the cultural heritage of mankind.

Keywords: Cultural Heritage, Architecture, Observatories, Baroque era, Meridian lines, Scientific Instruments, solar observation, Jesuits

1 Introduction – Baroque Time, 17th and 18th Century

On the UNESCO World Heritage List buildings of science are currently under-represented. The discussion about «Astronomy and World Heritage» had started in 2008 in order to establish a link between science and culture and to raise awareness of the cultural importance of astronomical sites. «Outstanding Universal Value» in respect to architecture, instruments, scientific, cultural and historic value has to be demonstrated. The cultural implications of astronomy are remarkable; I would like to mention Baroque paintings, sun dials, astronomical clocks with many details of the christian calendar, meridian lines in churches, and in addition time keeping and navigation – important for the society.

«Between 1650 and 1750, four Catholic churches were the best solar observatories in the world. Built to fix an unquestionable date for Easter, they also housed instruments that threw light on the disputed geometry of the solar system, and so, within sight of the altar, subverted Church doctrine about the order of the universe.»[1]

After the famous four meridian lines in the Cathedral of Santa Maria del Fiore in Florence (Toscanelli and Alberti, 1468/75), San Petronio in Bologna, Santa Maria degli Angeli in Rome (Francesco Bianchini, 1702) and St. Sulpice in Paris (Henry Sully, 1743), more churches were turned to solar observatories in the 18th century like Milan (1786), Bergamo, Palermo, Catania, but also some Baroque observatories like Prague and Padua. Meridian lines combine many fields of science and cultural history like astronomy, mathematics, architecture, ecclesiastical and civil history.

But here I would like to put my emphasis on observatories. One cannot find early observatories from the medieval time in Europe like Beijing (1127, 1442) or in the Islamic countries like Maragheh (al-'Urḍī, 1259), Samarkand (Uluġ Beg, 1420) and Istanbul Observatory (1575). In Europe, in the Renaissance and Baroque time, there are not yet observatories in the modern sense, with fixed instruments in special buildings. City fortifications, church towers or balconies of castles were used as observatories.

Early Baroque Observatories, 17th Century

After the invention of the telescope and inspired by the impressive series of astronomical discoveries, the activity concerning the formation of observatories increased. Apart from the general scientific interest to explain the world and to satisfy the representational needs, practical tasks, the benefit to the state and society played an important role, including economic interests. In many observatories time keeping and the creation of calendars played a leading role, but also the calculation of planetary tables, the preparation of star catalogues and the prediction of astronomical events (eclipses, Venus transit). Paris Observatory (1667), which was established in connection with the Academy of Sciences, was also important for geodetic tasks (measuring the shape of the earth), Royal Greenwich Observatory (1675) played a significant rôle in connection with the Navy (creating astronomical tables for navigation, development of methods for determining longitude at sea).

Johann Gabriel Doppelmayr (1677–1750) presented in his *Novus Atlas coelestis* (Nuremberg 1742) the following most important eight observatories in Europe, they are sketched in the corners of the plates «Hemisphaerium Coeli boreale» and «Hemisphaerium Coeli australe»:

1. Under the sponsorship of King Frederic II of Denmark (1534–1588) Tycho Brahe (1546–1601) built his observatory, called «Uraniborg» (Wolfschmidt 2002a) on the Danish Island Hven (today Ven, Swedish). The brick building with sandstone and limestone frames was erected in 1576–1580 in the style of Flemish Renaissance by the architects of the royal Danish court in close cooperation with Tycho; in the cellar was Tycho's alchemical laboratory. The observatory measured 16 m × 16 m, with a 19 m tower and two small round towers to the north and south of 6 m diameter, with galleries around for the instruments. It was the first time in Europe that a building was erected especially for the purpose of astronomical observations. In 1584 Tycho founded a second observatory, Stellaeburgum (Stjerneborg), 80 m to the south of Uraniborg. In its five round towers with cone shaped domes, called 'crypts' by Tycho, his instruments were well protected against the wind – in the underground. Very striking is the similarity of Tycho's instruments, the triquetrum, armillary sphere, sextant and quadrant, described in his Astronomiae instauratae mechanica (Wandsbek, 1598), with those used in Islamic observatories.

2. The Round Tower (Rundetårn) in Copenhagen, erected in 1642 by the architect Hans Steenwinkel the Younger (1587–1639) in Flemish Renaissance style during the reign of King Christian IV (1588–1648). The 209 m long spiral ramp is unique in European architecture. The building was used for scientific purposes, as an astronomical observatory, a student church and a university library, until 1861. The platform, 34.8 m above the street, offered excellent observation possibilities. The Round Tower is the oldest functioning observatory in Europe; today, it is a public observatory and an astronomical museum.

3. In 1649 the beer brewer Johannes Hevelius (1611–1687) [Hewelcke or Polish Jan Heweliusz] built his private observatory on a platform above the roofs of three burger houses in Danzig (today Gdańsk, Poland, 1649); it was the largest observatory of that time (destroyed in WW II).

4. Paris Observatory (1667): The architect Claude Perrault

1 Quoted after Heilbron 2001.

(1613–1688) and Giovanni Domenico Cassini (1625–1712) each in his own way, wanted to make this building an outstanding instrument of astronomy (Petzet 2009; Débarbat et al. 1984, 1990; Petzet 2000). It had a large central hall as meeting room for the Academy of Sciences. On the roof of the palace like building the long telescopes were used.

5. The Royal Greenwich Observatory was created in 1675 and erected by the leading architect Sir Christopher Wren (1632–1723) for the first Royal Astronomer John Flamsteed (1646–1719) (Clifton 2009). The building is smaller than Paris Observatory. In the center was the octagonal observing room.

6. Nuremberg, Eimmart's Observatory (1677 to 1757): On the Vestnertor bastion of the fortification of Nuremberg castle Georg Christoph Eimmart (1638–1705) built a private observatory in 1677. It was one of the major observatories of Europe's Baroque period. However, it existed only until 1757, because the instruments did not survive outside; there was only a shelter for the clock and valuable smaller instruments. The Eimmart observatory was not just a private observatory, but also a scientific institution for research and especially for the training of astronomers, as Hans Gaab (2010) has shown it even served as a first public observatory; today a monument for Eimmart markes the place.

7. The Berlin Academy Observatory was inaugurated in 1700 in connection with the founding of the Brandenburg Society under the direction of the famous mathematician Leibniz; the important early directors were Kirch, Bode and Encke. But the first observatory building (1711) in present-day Dorotheenstraße is no longer existing.

8. The Palais Bellevue in Kassel was built in 1714 by the Frenchman Paul du Ry (1640–1714) as an observatory for the Hessian Landgrave Karl (1654–1780), changed in 1790.

Figure 1: The Round Tower (Rundetårn) in Copenhagen, erected in 1642

Architecture of Baroque Observatories: Octagonal Shape – Inspired by the Tower of the Winds

Many early Baroque observatories were tower observatories like Padua, using the fortification, the city wall. Sometimes a small tower or a look-out was built on the roof of a house like in Kassel (1714), University Observatory in Altdorf near Nuremberg (1711–1803) and St. Petersburg Observatory on the roof of the Royal Academy (1725). The first modern observatories after the invention of the telescope were erected in the 17th century in Paris (1667) and Greenwich (1675).[2] In the case of Greenwich we find an interesting feature, the octagonal room, which can be found relatively often in observatories – but already in Antiquity.

The great Pharos of Alexandria, built by Sostratos of Knidos in 299–282 BCE dedicated to Ptolemaios I. Soter (367/366–283/282), was one of the Seven Wonders of the Ancient World, described by the poet Antipater of Sidon around 130 BCE.[3] This most important lighthouse marked the port entrance and lasted for over 1500 years in Alexandria. According to a description of an Arab traveler (1166), the Pharos consisted of a three-stage tower (about 117 m high): On a square platform with a side length of 190 m, made of granite stone, the lowest square tower (56–65 m high) with a side length of 30 m was placed, the middle level was an octagonal building with a height of about 30 m. At the top level was the round lantern with 7–9 m high columns with the beacon. The Pharos served as a model for the small lighthouse with the same three levels (square, octagonal and round) in Abusir, 20 km from Alexandria, from the time of Ptolemy II (285–246 BCE), and for the Roman lighthouse La Coruña (2nd century CE) in Galicia, Northwestspain.

The Tower of the Winds, an octagonal marble structure with a conical roof (Noble & de Solla Price 1968), on the Roman Agora in Athens was designed by Andronikos of Kyrrhos around 50 BCE (according to Vitruvius), archaeologists now date the tower already in the Hellenistic period, in the 2nd century BCE; the clocktower (horologion, today called Aerides) shows outside the eight wind gods and sundials, on the top a wind vane (in the shape of Triton), inside a water clock (clepsydra) and with anaphoric disk.

The Pharos and the Tower of the Winds in Athens inspired the Radcliffe Observatory of Oxford University. In 1772 the octagonal Tower of the Winds (decorated with 8 wind gods and with zodiac signs), placed above a semi-circular central building in neoclassical style, was erected with funds from the trustees of John Radcliffe (1652–1714), a royal physician and parliament member. After having observed the Venus transit in 1769 from a room in the Radcliffe Infirmary, Thomas Hornsby, Savilian Chair of Astronomy, suggested to erect this observatory; it was started by Henry Keene (1772–1776) and completed by James Wyatt (1794). Telescopes could be used in the octagonal observing room with large windows or on the balcony around the tower. The old Radcliffe Observatory building is used by Green Templeton College since 1979. The building is in good condition and the original instruments can be found in the Museum of the History of Science in Oxford.

The Collegio Romano was founded by Ignatius of Loyola in 1551, authorized as university by Pope Paul IV in 1556. The new building was erected by Bartolomeo Ammannati (1584); the Jesuit mathematician Christoph Clavius (1537/38–1612) and Athanasius Kircher (1601–1680) were professors here. The Tower of the Winds (73 m) in the Vatican with a meridian line built by Danti, served as a first Vatican Observatory (1576) under the sponsorship of Pope Gregory XIII in connection with the calendar reform. The name Specola Vaticana was placed in 1784 on the door of the library. The (second) Specola Pontificia Vaticana (1789–1821) was established on the top of the Gregorian Tower under the directorship of Filippo Luigi Gilii (1756–1821). In 1821 this observatory was already closed and the astronomical, meteorological and seismological instruments were transferred to the Roman College. After the suppression of the Society of Jesus (1773), the Pontifical Observatory of the Roman College was founded in 1774 and the tower of Guiseppe Calandrelli was built (1787). In 1814 the College and Church St. Ignatius were

2 The development of observatories was studied by Müller 1992. The instruments can be found in Howse 1986.

3 The great Pharos was conquered by the Arabs 642 CE, but an earthquake damaged it about 50 years later.

given back to the Jesuits. They were expelled again in 1848, but quickly reopened with an observatory on the top of church St. Ignatius (1849/52). The Vatican Observatory (Maffeo 1991) was re-established a third time in 1888/91 by Pope Leo XIII in the Gregorian Tower and in addition a Tower of the Leonine Fortress at the top of the Vatican Hill. In 1904 in the forth period four domes were used. The Vatican Observatory as one of the oldest astronomical research institutions in the world needed better observation conditions in the growing city and moved its headquarters to the papal summer residence in Castel Gandolfo, 25 km south-east of Rome, in 1935 (fifth period). Other examples for octagonal observatory buildings were the original buildings of Rapenburg Observatory Leiden (1633), remarkable was the octogonal rotating turret, and Sonnenborgh Observatory Utrecht (1642), on the top was a platform with a building in octagonal shape. In addition one should mention the old university observatory in the botanic garden in Halle / Saale (1788), also an octogonal building in neo-classical style by Carl Gotthard Langhans (1732-1808), who is famous for the Brandenburg Gate in Berlin.

Figure 2 a: Radcliffe Observatory of Oxford University, 1772

Baroque University and Academy Observatories, 18th Century

In the 18th century, during the Baroque time and Enlightenment, the number of foundations of observatories in universities, Jesuit colleges and monasteries increased. In Cambridge University, the second oldest university (1209) in the English-speaking world after Oxford and the fourth oldest in Europe, a first observatory was founded in 1704, based at Trinity College on top of the gatehouse. The Radcliffe observatory was already mentioned. The observatories of the 18th century in Italy were built upon towers or palaces in the middle of the cities, many have their original building preserved (cf. Milan-Brera 1764, Palermo Palazzo Reale o dei Normanni 1790), the best examples are Bologna (1721–1725) and Padova (1761).

La «Specola» in Bologna is the first university observatory in Italy. In 1669 Giovanni Domenico Cassini I (1625-1712) was hired as director of the new Paris Observatory. Astronomy in Bologna lost its importance until the patron Count Luigi Ferdinando Marsili (1658–1730) erected an tower observatory on the top of his palace, the «Specola marsiliana», and offered this building and his instruments to the astronomers, active until 1709. In 1712 the Academy of Science, *Istituto delle Scienze di Bologna*, was established at the Palazzo Poggi with the participation of Pope Clement XI. The tower of the observatory was started by the architect Giuseppe Torri in 1713 and completed in 1725. Eustachio Manfredi (1674–1739), observer at the Specola Marsiliana, became director. The main instrument was as usual a large wall quadrant.

The Astronomical Museum in Bologna was created in 1979. The instruments, used by the Bolognese astronomers in the «Specola marsiliana» and later in the «Specola», restored with regard to both original appearence and function, have been brought back to these rooms, with their original placing in mind (Bònoli 1990). The ancient tower has three rooms, globe room (sala dei globi), the meridian room (sala meridiana) and the turret room (sala della torretta). The iron attachment, used for managing long telescopes, was built into the parapets. The observation room did not suffer remarkable changes. Nowadays the early 18th century wooden telescope tubes are exhibited there, for example the 10.5-foot and the 22-foot lenses made in the late 17th century by Giuseppe Campani (1636–1715), famous maker of lenses and telescopes in Rome.

Stockholm Observatory (1748/53) was built in Rococo style by the architect Carl Hårleman (Elmqvist Söderlund 2009c). It is situated on top of a hill and is a squarish building with three floors, and small turret on the roof. For observing the central octagonal room on the ground floor and the meridian room to the east were used. But in difference to many 18th century observatories, Stockholm is not a tower observatory or an observatory where the observing took place like in Paris on the roof of the building. The building is well preserved and restaurated and used as an observatory museum; it is part of the Center for the History of Science at the Royal Swedish Academy of Sciences, whose main objectives include preservation of an astronomical heritage. All Swedish observatories were put under monument protection; this concerns the observatories in Stockholm (the old observatory and Saltsjöbaden), Lund[4] and Observatorieparken Uppsala.[5]

The University of Vilnius, Lithuania, one of the oldest and most famous establishments of higher education in Eastern and Central Europe,[6] was founded in 1579; until 1773 it belonged to the Jesuit order. In 1752 an experienced architect, mathematician and astronomer Thomas Zebrowski (1714–1758) designed a plan of an astronomical observatory and the building was started in 1753, erected on the top of the three-storey university building. It is a beautiful building with two three-storey rectangular towers and decorations, in perfect condition still nowadays. For the large meridian quadrant (diameter of 8 feet) an extension to the south was designed by the famous architect Marcin Knack-

4 Lund university was inaugurated in the 1668; in 1865 to 1867 the first free standing purpose-built observatory was erected (compare also Tartu, Estonia).
5 Uppsala university was founded in 1477, the Uppsala Observatory in 1730, a new observatory was erected in 1844–1853. It was designed in collaboration between the professor of astronomy Gustaf Svanberg and John Way.
6 Cracow University Observatory besides Vilnius and Warsaw to the oldest observatories in Poland. Under Jan Sniadecki (1756–1830) Cracow Observatory was erected in 1792 and is still existing today.

Figure 2b: Vilnius Observatory, Lithuania, 1753 (copyright Gudrun Wolfschmidt, 2015)

fuss in 1782–1788. The classical structure had two towers for observations and a firm sandstone wall in the plane of the meridian. The front wall of the observatory was decorated with the signs of Zodiac and Latin quotations.[7] The old building is in use by the university, in perfect condition still nowadays.

Observatories in Jesuit Colleges

Almost since the establishment of the *Society of Jesus* in 1534 by St. Ignatius of Loyola, confirmed by the Pope in 1540, Jesuits have been engaged in the work of education; they founded colleges, often combined with observatories in the 17th and 18th century and with a chair of mathematics. Jesuits prefered the middle of the 18th century in their teaching the Aristotelian physics and – inspite of Copernicus publication of the new world view (1543) – they favoured the Tychonic system; Newtonian physics was introduced not before 1757.

Early important examples for Jesuit Observatories are Ingolstadt (1549), Prague Clementinum (1556/1722/1751), Avignon (1676), Marseille (1702), Lyon (1745), Graz (1745), Trnava (1753, Nagyszombat, Hungary), Florence (1755), Parma (1757), and Milan (1760). Other observatories were founded by civil governments, then later entrusted to the Jesuits: Lisbon (1722), Vilnius (1753), Vienna (1733/55), Würzburg (1757), Schwetzingen (1764), and Mannheim (1772). The whole number was about 30 during the years 1540 to 1773 (10 observatories in the German empire, 8 in Italy, 6 in France, one in Spain, 2 in Portugal, 2 in Poland and 1 in Latvia), that means one quarter of all existing observatories (Udías Vallina 2003), in addition in the mission countries like the Imperial Observatory Beijing (1644–1773/1803) or India. This active time of the Society of Jesus ended with the beginning suppression of the Jesuits (1750 to 1773) and finally with the prohibition of the Jesuit Order by Pope Clemens XIV in 1773 and the following dissolution; the expulsion happened earlier in Portugal (1759), France (1764) and Spain (1767).[8]

Scheiner's Sunspot Observing Posts in the Jesuit College in Ingolstadt

Around 1608 the most important new instrument was invented – the telescope, but there were not yet special observatories; most observations were carried out on towers, from balconies or roofs. Astronomical observations of the Sun started in 1609 by different astronomers like Galilei, Thomas Harriot (1560-1621), Johannes Fabricius (1587-1617) and Simon Marius (1573–1624). Christoph Scheiner (1575–1650) joined the Jesuit order in 1595, and started his studies in 1601 at Ingolstadt, southern Germany, where he later taught mathematics from 1610 to 1616; the college was built in 1611. He moved to Innsbruck in 1616, was in Rome from 1624 to 1633.[9] There are two places for observing the Sun in Ingolstadt: a platform of the Jesuit College and the tower of Kreuzkirche. Scheiner began to observe sunspots in 1611, together with his assistant Johann Baptist Cysat (1587–1657). Scheiner used an astronomical telescope (Kepler type) with a special parallactic mounting for observing the Sun and projected the Sun through the window on a screen. Through this improved technique he increased the accuracy of his observations of sunspots; Scheiner was involved in a controversy with Galilei. By careful observing the apparent paths of sunspots across the solar disk for 15 years, Scheiner correctly concluded that the Sun's rotation time is 27 days and the inclination of the rotation axis is 7°. Finally in 1630 Scheiner published his results in *Rosa Ursina sive Sol* (1630).

The Orbansaal of the former Jesuit College in Ingolstadt was established in 1725 as a museum to accommodate the extensive collection of Father Ferdinand Orban. The stucco and the ceiling frescoes with the images of Sun, Moon and stars, cartouches and angels, should document together with Orban's exhibits in the museum a synthesis of the arts. Four wall paintings of famous Jesuit astronomers in the shape of a contrabass (so-called «Bassgeigenbilder») are shown in the corners: Chr. Scheiner and J. B. Cysat of Ingolstadt, Athanasius Kircher and Christoph Clavius of Rome, painted in 1725 by Christoph Thomas Scheffler (1699–1756). More examples of Baroque wall paintings or frescos can be found, e. g. Michelangelo's Creation of the Sun in the Sistine Chapel or in Prague in the mathematical hall of the Clementinum or in the Academy of Sciences in Vienna.

Prague Clementinum (Jesuit College), Astronomical Tower, 1722 to 1725, Observations 1751

Astronomy in Prague has a long tradition (Wolfschmidt & Šolc 2005), I would like to mention for example the activities of Tycho and Kepler or the astronomical frescos in the Wallenstein Palais. Here the Jesuit observatory should be presented. The Jesuit Order came to Prague in 1556; they were first active in the Dominican monastery already in Tycho's time. The Dominican Studium generale, the Latin school, was established in 1347 at the same time like the Charles University, founded by Charles IV

7 Vilnius kept up close contacts with many well-known observatories such as Berlin, Greenwich, Königsberg, Paris, Pulkovo and others. In 1921 it was decided to build a new observatory in the outskirts of the city. Matulaityté 2004.

8 Since 1814 with the restauration of the Jesuit Order new observatories were founded, especially the leading research centers like Collegio Romano (1824), Stonyhurst College in England (1838) and Georgetown University in Washington D. C. (1841), in addition around 1900 Calcutta, Manila or Kalocsa in Hungary.

9 Kurt Scheuerer: Materialsammlung zur Geschichte von Ingolstadt, Ausstellung: Die Jesuiten in Ingolstadt, cf. http://www.ingolstadt.de/stadtmuseum/scheuerer/ausstell/schein05.htm

in 1348. In 1622 both universities merged, the Utraquist (Protestant) Charles University came under control of the Jesuits. The Baroque Library Hall of the Clementinum was erected together with the Mirror Chapel and the observatory, Astronomical Tower (Šima 2001), all of this undertaken under the direction of the university's chancellor Francisco (František) Retz, General of the Jesuit Order. Architects were František Maximilián Kaňka, Kilian Ignaz Dientzenhofer (1689–1751), a famous Bohemian architect of German origin in the late Baroque time, and finally Anselmo Lurago. The building was finished in 1722 to 1725; the appearance and arrangement of the Baroque Library Hall – even the labels on the library bookcases – survived intact. Thus it provides us with an example of the setting of an authentic Baroque library. The books show a large variety of theological and philosophical literature written in all languages except Czech. The ceiling decoration in the mathematical hall shows the fresco «allegory of the sciences» (1760).

The Clementinum Astronomical Tower (originally: Mathematical Tower) is crowned with a statue of an Atlas (2.4 m high), carrying the celestial sphere on his shoulders with a golden Sun in the middle (1723). Some historians attribute this sculpture to the atelier of Matyas Braun. There are several sundials at the tower and in the court; a great rarity is a northern sundial! Observations started in 1751 with the first director Josef Stepling (1716–1778). After suppression of Jesuit Order in 1773 the observatory belonged to the state and its director became «Astronomer Royal». The instruments, the large southern and northern mural quadrant (r=7ft, 1751, and r=6ft, around 1765) in the second floor, made by Johann Klein, are built firmly into the wall. In this meridian room is also a meridian line for the determination of the apparent solar noon. In addition there were refractors with focal length up to 8ft (1751–1768) and a refractor with equatorial mounting. In addition the Clementinum tower is the oldest weather observation station, considered unique in whole Central Europe. Very important is the variety of meteorological instruments, now in the first floor, in use since 1752 (measurement of temperature, atmospheric pressure, preserved since 1771, and rain fall since 1804). The first regular meteorological measurements were initiated there in 1775 and this series has been continued until now. The tower was used for astronomical observations until the 1930s.

Figure 3 The Astronomical Tower of the Clementinum in Prague, 1722 to 1725, with the sundial and the statue of Atlas carrying the celestial sphere

The Clementinum, the second largest complex of buildings in Prague after the Hradschin (Prague castle), is a college with library and observatory of outstanding importance, the buildings nearly not changed up to the present. It is used as National Library and Museum of Astronomy. The so-called *Museum Mathematicum Collegii Clementini* was already established in 1722 as a cabinet of curiosities typical at that time. It was the first museum in the Czech Lands and even in Europe, comparable to famous Jesuit collections in Rome or Cologne. Besides scientific instruments (optical, magnetic, electric, astronomical, chronometric, gnomonic instruments, models for geometry, minerals and ores, botanic, zoologic and ethnographic specimens, mechanical toys and automats) it contained exotic objects brought by Jesuit missionaries. The museum was dissolved in 1785 and the objects ended up in different collections; several valuable globes and clocks survived in the Library, the famous sextants of Tycho and Habermel are in the Technical Museum in Prague.

The old Jesuit Observatory in Mannheim was constructed in Baroque style in 1772 to 1774, near to the castle and the Jesuit college (1733–1760), for Christian Mayer (1719–1783) who was appointed as court astronomer of Prince elector (Kurfürst) Carl Theodor (1724–1799). In 1779 the «Societas Meteorologica Palatina» was founded, an international network with 39 stations from Eastern America to the Ural mountains, using standard instruments, standard procedures and observations at fixed local times, the so-called Mannheim hours.

Beijing Jesuit Observatory, 1669

China already had a long tradition in astronomy: In the 11th century Shen Kuo (1031–1095) had developed astronomical instruments. In the 13th century China came under Mongol-Islamic influence (Kublai Khan, a grandson of Genghis Khan, 1260 to 1294, started the Yuan dynasty 1279 to 1368). In 1279 Kuo Shou-Ching built a great armillary sphere and an equatorial torquetum for the 'ancient' Beijing Observatory. These two instruments were copied in 1439 during the Ming dynasty (1368 to 1644) by Huangfu Chung-Ho.[10] But for over two hundred years there was no further interest in new instruments.

In 1669 the Jesuit astronomer Ferdinand Verbiest (1623–1688) succeeded in convincing the Chinese Emperor that a new observatory in Beijing with western-type instruments was necessary. In the years 1670 to 1673 Verbiest built the new Beijing Observatory with following instruments: ecliptic armillary sphere, equatorial armillary sphere, azimuth circle, quadrant, sextant and a celestial globe – everything in the style Tycho Brahe. This series of six large instruments, made during the Qing dynasty (1644 to 1912), are on a 14 m high platform. The last two instruments, the azimuth quadrant is introduced by Kilian Stumpf (1655-1720) in 1715, the armillary sphere by Ignaz Kögler [Tai Chin-hsien] (1680-1746) in 1744. Two valuable early 17th cen-

10 They are since 1931 in the Purple Mountain Observatory in Nanjing.

Figure 4: Jesuit Astronomical Observatory in Mannheim, 1772/74, Meteorological Observatory «Societas Meteorologica Palatina», 1779

tury large Chinese maps can be found in Bologna, in the Globe room.[11] The Beijing Observatory is restored and well preserved how it was in Baroque time.

6 Observatories in Monasteries

Monchs in monasteries were besides the Jesuits very much interested in astronomy. By the secularization in 1803 (Reichsdeputationshauptschluss) a major redistribution of buildings and territories held by an ecclesiastical ruler to secular states was decided. Therefore the workshop of Utzschneider, Reichenbach & Liebherr could move into the former monastery Benediktbeuren. There are examples for monastery observatories in Italy, in France (Abbaye de Sainte Geneviève), but the best example which is today still in original shape is Kremsmünster (and also quite good Eger).

Eger, Specula Observatory, Hungary (1785)

Ferenc Barkóczy, bishop of Eger, wanted to establish a university ('Universitas') in Eger; the construction in late Baroque style (1765–1785) was supported by Károly Eszterházy, who originates from a famous Hungarian aristocratic family. A number of renowned architects were involved in its design, among them were especially Mátyás Gerl and Jakob Fellner. The frescos were painted by artists of high reputation throughout Europe, such as Franz Anton Maulbertsch and Franz Sigrist. One of the interesting features of the building is the decorated assembly hall on the first floor, which displays Baroque paintings that represent the four faculties of the 'universitas':

1. Faculty of Sciences with land surveying, astronomy, military and political geography;
2. Faculty of Medicine with anatomy and curing;
3. Faculty of Theology with the church fathers, angels, the firmament and allegorical images, and
4. the Faculty of Law with the sculpture of Justice and the Table of Seven (of the contemporary Hungarian Court of Justice).

Due to a law by Maria Theresa in 1777 only one university was allowed in Hungary (this was already in Buda), the building was turned into a Lyceum (Gimnázium) of the Esterházy Károly College. From the beginning an observatory was included in the «universitas-idea». In the tower on the library building the Specula Observatory (Magic Tower of the Natural Sciences) was founded in 1776, completed by 1785. Eszterházy acquired the best instruments of his time. Renowned Hungarian astronomers like János Madarassy (1741-1814), Pál Tittel (1784-1831) or the last director, Ferenc Albert (1811-1883), worked in the observatory.

In addition in Eger a camera obscura was already used in 1552 for observing the attacking Turks, but later also for observing sunspots. Since the end of the 13th century the camera obscura was used by astronomers for observing the sunspots or solar eclipses in order to avoid to look directly into the bright Sun. Christoph Scheiner used a walkable camera obscura. The camera obscura was prepared by optical experts from Vienna, especially according to ideas from Maximilian Hell (1720–1792), who undertook a Venus transit expedition to Lapland. The now existing instrument dates back to 1779. This very interesting construction has a periscope (1779), which projects the panorama of the city onto a white table located in a darkened room.[12] The first astronomy museum in the country can be found in the tower of the library, the specula. The Lyceum functions nowadays as a teacher training college. The Specula Observatory is used today as a museum of astronomy and science in general. Several attempts were made to renovate the ancient astronomical instruments. During the past decade, the association created for the protection of the Astronomical Tower has made major efforts for the preservation. The Diocesan Library in the Lyceum, containing 30,000 volumes and including codices and the first book printed in Hungary in 1473, can be visited. The Eger Observatory with the Baroque library and the decorative carvings and the beautiful ceiling frescos is an outstanding building of science.

Specula Cremifanensis Mathematical Tower, Kremsmünster (1758)

In the Benediktine monastery Kremsmünster,[13] today Austria, in the 18th century the idea came up to start with astronomical observations; according to the first plans the observatory should be installed above the bridge gate; even the wooden architectural model has been preserved. In 1748 the very ambitious decision was made to erect a fully free-standing nine-storey tower in the garden, finished in 1758. In art history it is described as one of the historical beginnings of modern highrise building architecture, the highest building of that time. Already the name *mathematical tower* points out the strong link between astronomy and mathematics, which is valid until the middle of the 19th century when astrophysics started. An interesting architectural feature is the pendulum shaft (1764, height 54 m, diameter 135 cm) for experiments with falling bodies; it could also be used as an astronomical well for seeing stars at daylight, an idea already existing in the ancient world. Already in 1851 a Foucault pendulum was installed there. In addition a meridian line was built (1765); near the southern mural quadrant the sun hole can be found.

The institution is not only an observatory but an important step in the history of museums and one of the first preserved museum buildings which originates really from Baroque time. The museum's collection was intended to present the large variety of the world, a microscopic image of the macrocosm. These early cabinets of rarities are structured into the main categories naturalia and artificialia (Wolfschmidt 2002). The idea for this «universal» comprehensive museum in Kremsmünster was to guide the visitor from inanimate nature (minerals and fossils on the second floor) to lower living nature – botany and zoology (plants and animals), then to the human sciences and arts (art chamber and picture gallery on the third and fourth floor), further to the cosmos (the large observatory hall on the sixth floor).

11 Both come from Beijing Observatory; the first one, a geographic one, was made by Father Matteo Ricci (1552-1610) and is one of the few remaining in the world; the second one, a celestial one, was made by the Mathematician Adam Schall von Bell (1592-1666).

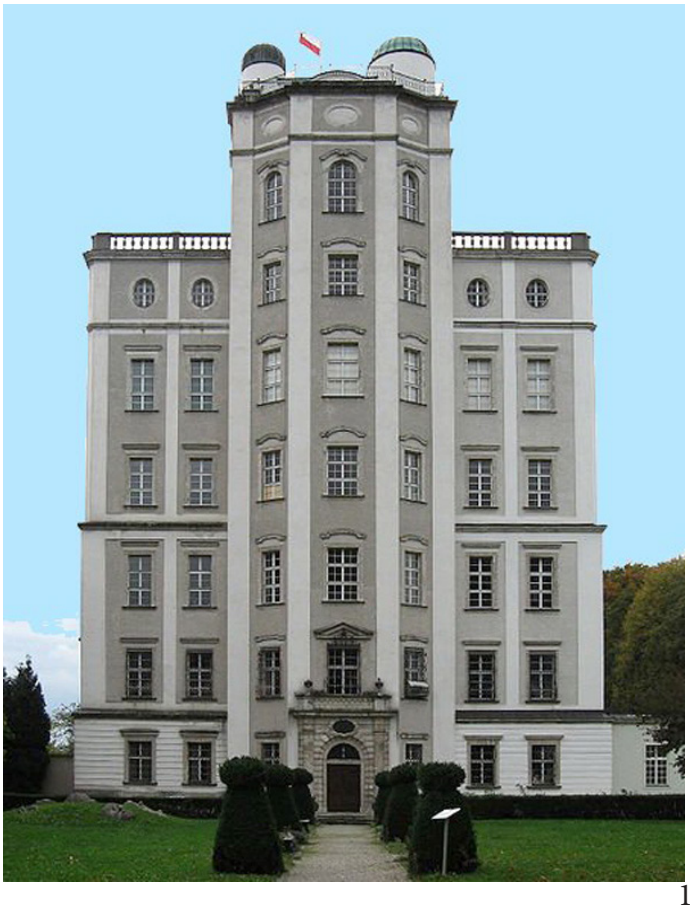
12 Other camera obscuras exist in Budapest University, as well as in Edinburgh (1853), Dumfries, Bristol und Greenwich (London) in UK.

13 The following paragraph is written after the comprehensive study of Klamt 1999.

The astronomy collection includes an astronomical table (1590), several terrestrial and celestial globes, sundials, the observatory pendulum clock made by Kessels of Altona (Nr. 1448), many astronomical instruments, including an iron sextant which was probably used by Kepler in Prague. This collection of all kinds of scientific instruments of 18th century is very remarkable. The large azimuthal quadrant made by J. B. Illinger after Brander's famous azimuthal quadrant (Augsburg 1754) was used in the observatory in the sixth floor, – and finally to the reflection of God (the chapel on the seventh floor). In the academic chapel on the seventh floor there are three portraits of Abbot Alexander Fixlmillner (1731–1759), architect of the observatory, of Pater Nonnos Stadler (1696–1783), founder of the knights academy (Ritterakademie, 1743 to 1789) and the observatory, and of Johannes Illinger (1733–1800), mechanician and instrument maker of the observatory, in addition two wooden architectural models of the observatory made by Father Anselm Desing (1699–1772). Three sculptures in the staircase, Ptolemy, Tycho Brahe, and Kepler, represent the progress in our world view. Another important feature is the «weather room» (Wetterkammerl) which offers meteorological observations since 1762 up to the present day – the only one with 230 years of observation without a change in location.[14] This long observation series can be compared with Prague (1752), Stockholm (1756) or Mannheim (1779). Besides the observatory on the sixth floor there was also a station for magnetic research, a geophysical observatory (1836), founded in the context of the international «Magnet Association», founded in 1833 by Gauß and Weber in Göttingen. In 1897 seismological measurements were started in addition (recording of earthquakes). This observatory is an outstanding example of Baroque science, including all kinds of natural science, astronomy as well as geo science, seismology and meteorology. The integrity of the building and the completeness of instruments is astonishing and remarable. The observatory with the museum shows an integral picture of scientific practice of Baroque time, practically not changed until today, as well as the close connection of science and religion.

14 Temperature, barometric pressure, wind direction, weather characteristics were recorded in the NNE-window in the first floor of the observatory; since 1784 in addition atmospheric humidity.

Figure 5: Benediktine Monastery Kremsmünster, Austria, mathematical tower, 1758



Conclusion

In this lecture I have presented the development of architecture and instruments of university, Jesuit and monastery observatories since the invention of the telescope (1608) and other typical instruments and their connection to the cultural heritage. My emphasis was not to discuss the most famous observatories of the 17th century, Paris and Greenwich, which are already described in detail in many publications. In the Baroque time it is not only interesting what the observatories contributed to astronomical science, to our modern view of the world, because in that time astronomy was linked very often to other sciences, not only celestial, but also terrestrial and meteorological observations were made. This is typical for the rising time of Enlightenment in the 18th century, science enormously gained in importance in contrast to humanities or classical theology. Monasteries began to cultivate the new sciences and started with astronomy, physics and mathematics. Only until Baroque time one could find a unity of science, arts, architecture and religion, which was lost in the time afterwards. In the 19th century observatories were purely scientific institutions. The emphasis was on astrometry, meridian circle astronomy and celestial mechanics. Then around 1860 a complete new topic came up, astrophysics, a new research method, started and many new instruments and a new design and structure of observatories were introduced.[15] Especially the mathematical tower of Kremsmünster, Austria, offers a lot of cultural implications like Baroque paintings and sculptures but also a Baroque museum of science; this collection intends to present the large variety of the world, a microscopic image of the macrocosm. In summary one can see very well the relevance of Baroque observatories to the cultural heritage of mankind.

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15 This further development is discussed in detail, cf.. Wolfschmidt 2009.

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Mesoamerica

Lunar Cycles among the Classic Maya – from lunar symbolism to the Lunar Series

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Abstract: It will be shown how popular and common concepts of the sky were derived from lifeworld categories in the past and later manipulated and reshaped by elites to show that their ability to predict celestial events and cycles enabled them to act successfully on earth. The conflation of the figures of the maize god and the moon goddess influenced the visual imagination of ordinary people, while the standardisation of the moon count indicated the degree of political dependence/independence on the ruling centres in Calakmul and Tikal. The issues raised in this paper clearly show that non-Western knowledge systems should be studied as products of specific cultures and not as equivalents of modern scientific disciplines. The study makes clear that the meaning of the celestial environment cannot be understood by simply removing it from its social and cultural context. Cultural astronomy really needs to go beyond the simple study of astronomical practices.

Keywords.Classic Maya, Lunar cycles, lunar symbolism, lunar series, cultural astronomy

Introduction

In recent years there has been growing emphasis on separating the research field of archaeoastronomy from that of cultural astronomy. Current archaeoastronomy often deals with the ancient and/or non-Western (=indigenous) *technical* knowledge of the sky and tends to conceive it as a type of pre-modern astronomy in the sense of the physical sciences, conceptually separated from its social-cultural meaning and analyzed in terms of western logic (Iwaniszewski, 2009a: 253). In my opinion, archaeoastronomy's view of indigenous celestial knowledge is seriously incomplete.

In the perspective that will be advocated in the present paper, celestial lore, like every type of indigenous knowledge, is treated as acquired, produced, altered, represented, etc. in the process of dwelling in the world (Ingold, 2000: 5, 185-187; Iwaniszewski, 2009a: 253). Knowledge about the Universe is therefore linked to the cultural framework of its makers and constrained by multiple local (temporal, spatial, social, functional, symbolic, communicative, physical, etc.) components that should not be separated from each other. That' s why it should be elicited inside the context in which it functions. Instead, modern astronomical knowledge rests on the principle of universality that transcends ethnic, national or cultural frameworks. By isolating technical astronomical knowledge from an indigenous celestial lore and a broader system of understanding the world, we may discover that facts about past and non-western societies are 'value-free' or 'value-neutral' and therefore suitable to be explained with the aid of the epistemological rules and formulae derived from our western scientific knowledge. However, it well may be that our scientific knowledge is not always capable of explaining or interpreting non-western systems of knowledge simply because the values and concepts developed by past and non-western societies as well as the meanings of the objects they made and used cannot be validated by the logical criteria of western epistemologies alone (Iwaniszewski, 2009a, 2009b). Whether or not there exists a natural world independent of people dwelling in it, knowledge about its existence is made manifest by concrete societies and thinkers. In the present paper I will show that in order to properly understand the role of astronomical observations in ancient societies we should to look for celestial lore both in practical actions and functional uses, as well as in mythological narratives and symbolic representations. Moreover, I will propose that celestial lore is often produced in the negotiation of both actions and representations in the course of their performance.

Theoretical framework

Like all human populations, the Maya groups which populated southern Mesoamerica during the Preclassic (600 BCE – 250 CE) and Classic (250 – 890 CE) periods dwelled in meaningful lifeworlds, or "familiar worlds of everyday life" (Schutz and Luckmann, 2003: 25-29). The adoption of the dwelling perspective means that ancient Maya groups cannot be treated as isolated or self-contained entities that started to occupy particular physical environments but as active agents in their environments (Ingold, 2000: 185-187). Ingold (2000: 349-361) has suggested that acting in the environment is the practitioners way of knowing it. Saying this I mean that the Maya lived within specific conceptual frameworks based on common-sense categories inherited from previous generations or borrowed from their neighbors to which they eventually added the current knowledge of the (natural, social, and personal) world. Though their conceptual worlds were perceived as bounded and ordered entities, they nevertheless attempted to transcend its limits endlessly exploring the celestial, earthly and subterranean realms, always moving beyond static conceptions of space and time, successfully exposing the different meanings of the objects, images and icons used in ritual activities and mythological narratives. In sum, lifeworld patterns enabled various Maya groups to interact more effectively with their world and to shape their worldviews, or "culturally organized systems of knowledge" (Kearney, 1975: 247-248). This implicit rather than consciously created knowledge about the world allowed them in turn to conceive and represent all fundamental ideas of the world within which they lived[1]. In contrast to modern cosmologies, Maya worldviews were not fixed, abstract and formalized bodies of specialized knowledge having been separated from everyday activities. Instead, their worldview concepts were embodied in practical actions, functional uses, as well as in symbolic representations, mythological narratives, pre-conceived paradigms and conventional and collective acting in-the-world. Having evolved over millennia, Maya worldviews were deeply embodied both in daily activities and ritual practices, in the negotiation of actions and in symbolic representations and classifications of the natural, social or personal perceptions of events, processes, and phenomena.

To avoid misunderstanding, I may emphasize that worldview systems base on collective representations of self, other, time, space, causality, relationship and on shared classificatory systems (Kearney, 1975, 1995) originate from common sense or ready-made concepts, beliefs and categories that receive their form and shape from particular lifeworlds. It is perhaps trivial to assume that in order to be able to communicate with each other; the members of particular societies should rely on shared common values, developed by social processes. The categories they use are loosely defined concepts which remain embedded in a context of a specific practice which constitutes the source

1 I am referring here to the concepts of themselves and others, of time and space, of immediate physical surroundings and cultural classifications, of causality and relationship, etc., cf. Kearney, 1995: 41-47 and Iwaniszewski, 2009: 101).

that validates this knowledge of the world. In consequence, there is reason to believe that like all other objects that occur in the surrounding world, astronomical phenomena cannot be perceived as physical and material entities alone which display entirely mechanistic relationships, but in the first place as functional signs and meaningful symbols which represent a complex cultural symbolic system (magical, religious, mythical, ritual, ideological, etc. see Bourdieu, 1979: 77).

We may therefore expect to find that the ancient Maya populated the celestial firmament with various mythological entities or supernaturals attributing to them qualities stemming from their collective lifeworld representations. Maya skies resembled a social field rather than a relatively uniform space of astronomers. The celestial vault was organized by relationships between structured areas symbolically represented by the four divisions aligned with the solstitial directions, and by relationships made with powerful entities embodied in celestial bodies and believed to act like human agents. The points where the sun rose and set at solstices defined the corners of the Maya quadripartite world, and the colors associated with the quarters of the world were related to the sun's daily and seasonal movement (the red East, the black West, the yellow South and the white North were all related to the sun's movement and the maize agriculture, Bassie-Sweet, 2008: 58-61). Celestial bodies were perceived as animate and thus invested with the ability to act. The supernaturals, ancestors and other entities that inhabited the sky maintained varied relationships between them and with the humans; this is described by the Maya in terms of kinship ties, obligations, alliances, etc. For example, "star-war" events were announced on the days of specific Venus positions, varied categories of human victims were speared by Venus at its heliacal rising dates, farming was dependant on the lunar phases, etc. These examples reflect the manner in which the Maya interacted with the heavens. Maya Universe was structured according to a set of principles which were both ancestral with regard to current practices and mythological (Freidel *et al.* 1993). This is to say their worldview was ontologically explained through mythological narratives, ritual practices and "ready-made interpretative models" (Sommer, 2001: 247) rather than through elaborated technical terms abstracted and presented as context-free entities, or epistemologies (Iwaniszewski, 2009b: 103-105; 2009d). Maya celestial lore was not context-free, nor universally applicable; on the contrary it was embedded within the Mesoamerican cultural tradition.

Saying this, I will now offer two working definitions of the terms used in this paper: worldview and cosmology. As stated above worldview systems are suppositions about the Universe informed/structured by commonsense categories, shared by wider communities. On the other hand, cosmologies are suppositions/speculations about the Universe made by specialized agents who in addition invent and use technical concepts and terms which constitute a differential use (break) of common worldview categories. Thus in worldviews the knowledge of the world is based on the things alone, in accordance to their ontological structures (mythological narratives, ritual content, esthetic values, *doxic*, or stable unquestioned interpretations of reality, etc.) while, on the other hand, cosmologies rely on epistemological frameworks created in ways that are context-free and universally applicable. My conceptualizations of what the categories of worldview and cosmology may be rely upon the proposals delineated by Sommer (2001) and Lash (2005: 31-32, 111-116).

If lifeworld systems are defined as the patterned ways in which human beings (and societies) perceive their natural and/or social environments (either natural or social or both) as (functionally, symbolically, conceptually) meaningful, then peoples structural relationships to their lifeworlds may be defined in terms of "embedding". They attempt to understand things in the context of everyday life events and processes, so they describe them referring to common-sense categories rather than in abstracted way which tends to present them as context-free entities. For that reason, their model of understanding of a surrounding world is deeply embedded in all structures of their social life and knowledge of the world may only be acquired through unmediated experience and taken-for-granted categories rather than through *apriori* defined concepts and principles. To say that the knowledge of the world is culturally (socially) embedded, means that it should not be separated from the world of social and physical actions and that it is produced in the process of dwelling in the world (Ingold, 2000). The terms in which the world is apprehended, grasped, explained or understood are inseparable from the practical, and/or common-sense meanings. Arriving at this point we may say that the knowledge of the world is embedded in complex social structure, everyday practices, relationships between a society and its environment, ritual engagements, mythological narratives, etc. Within such a worldview all individual events and objects are related to one another by ethno—categories and ethno—classificatory systems that often use the concepts of analogy, resemblance, and logic of pairing based on binary oppositions.

Maize Symbolism in the Mesoamerican Cultural Tradition and the Maya Maize God

Numerous generations of stargazers who lived within the area we today call Mesoamerica carefully tracked the positions of important celestial bodies in order to understand how to conduct their life on earth. From the celestial vault, and from naked eye observations, they gained the practical knowledge of their environment. Just as they conceived their lifeworld as an extension of their own bodies, the patterns perceived in the surrounding environment became explained in terms of metaphors based on the universal human sensory-motor experience and/or derived from the categories of the human life itself.

Though maize is only one of many plants cultivated by the Mesoamericans, it became one of their most important domesticates. Due to its high protein contents, a significant increase in the reliance on maize was desirable so it became a basic staple cereal crop in Mesoamerica. The ways in which Mesoamerican agriculturalists understood their world were therefore structured or patterned around the planting cycle of maize, their main staple food. Not only was the maize god considered as the mythical father who participated in world creation, each agricultural activity starting with field preparation and planting and ending with harvesting and storing of maize in specialized areas became associated with appropriate rituals to honor the maize gods. Hence, it is not surprising that their worldview was shaped by metaphors and symbols stemming from these activities. Homologies found between the cycles of the human life and the growth of the maize plant provided the Maya with the conceptual means (symbols, metaphors, allegories, etc.) necessary to understand the structure of the universe. Both cycles provided the Maya with the required terminology ranging from the description of the basic phases of the maize growth to the narrative of the mythical creation of the world (see Bassie-Sweet, 2000). However, while the Maya most probably they utilized metaphors and symbols "apprehended and appropriated in an unconscious manner" (Griffioen, 1989: 84), at occasions, which might range from collective rituals marking

the onset of the rain season to celebrations of the accession of a new ruler or the inauguration of a new building, they deliberately refined, or altered their meanings to suit new demands arising in the course of time. Thus on a long-term basis, in Mesoamerica the phases of the human life were often seen as paralleling the cycles of growth and decline observed elsewhere in the physical environment, positioning the maize plant in structural relation to other entities, but on a short–term basis these homologies were appropriated by ruling elites to specify their particularly socially privileged position within particular Maya polities.

Although Maya social and political structure changed over time, its society remained divided into two basic classes: the rulers and the ruled. The Maya sociopolitical organization was determined by kinship relationships, the access to certain offices was controlled by particular lineages, and paternal descent was a common rule. Images of the rulers displayed both on stone monuments and polychrome vessels clearly define the nature of the ancient Maya kingship. Like their African, Asiatic or European counterparts, the Maya rulers often claimed divine descent and their power and wealth were often believed to be sanctioned by their supernatural patrons and ancestors. They represented the ordering features of the universe and acted through the manipulation of different classes of objects; they aimed at controlling the movements of the sky. They also used their knowledge of the 260- and 365-day calendars to design architectural monuments, and to select proper instants suitable for military assaults. Much of their ritual and ideological imagery revolved around the growth cycle of maize (Bassie-Sweet, 2000).

In his numerous publications Taube (1985, 1992: 27-31, 41-50; 1995, 1996) has explored maize symbolism in Mesoamerica and found that the growth cycle of maize, represented by the mythological narrative of the Maize God, became the metaphor for the concept of the life cycle itself. It is probable that maize imagery first appeared during the Middle Formative period (ca. 900 – 300 BCE) in the Olmec hinterland and was adapted by their neighbors, including the Maya rulers (Taube, 1996: 54). The plant was believed to grow from infancy to adulthood and themes of fertility and resurrection became basic metaphors applied to many other aspects of Maya culture. The Maize Gods were born, sacrified, dead, buried and again reborn, corresponding to the agricultural activities of planting, sprouting, ripening, and harvesting.

The episodes of the Maize God's life known from the mythological narrative were also rendered in art and represented by the rulers during their ritual performances (Hansen and Guenter, 2005; Fields and Reents-Budet, 2005: 138). As the Maize God played important role during the creation of the Universe, so in ceremonies replicating those primeval acts Maya rulers were often dressed in the guise of the Maize God. It is no coincidence that the Maya lords who participated in agricultural and propitiatory rituals to ensure the wealth of maize surplus, were also dressed in the Young Maize God costumes acting as god's impersonators (Miller and Martin, 2004: 53). Paralleling a sprouting young maize plant reborn from the seeds previously planted in the *milpa,* the maize-field, the Young Maize God, known as Hun Nal Ye, "One Maize Revealed" (Quenon and Le Forte 1997: 884) emerged from the Underworld also providing metaphorical explanation needed to ensure and legitimate the transition in the royal succession from the dead lord-father to his young son (Stuart and Stuart, 2008: 174-179; 198-215). While the rulers portrayed themselves as impersonators of the Maize Gods, all human beings were thought to be created from the maize dough. Therefore, the "interests of the humble farmer and high king were entwined and basic sustenance set at the heart of Maya religion" (Martin and Grube, 2008: 14).

In Mesoamerican imagery a maize plant represented also the idea of the world tree; therefore the image of a maize plant emerging from the turtle carapace was believed to bridge all the three realms of the universe. In the similar vein the ruler's ceremonial costume worn during public rituals was believed to make explicit the concept the universe, his body being perceived as the image of the world, or Weltbild. His costume and headdress symbolism clearly indicated the close correspondence between the microcosm represented by the ruler's body and the macrocosm represented by the divinities he embodied during the ceremonies (Baudez, 2000).

According to Maya mythology, the Maize God was decapitated by the Lords of the Underworld, but from the Underworld he was also reborn. A critical moment in maize mythology was the rebirth of the Maize God, the event coinciding with the arrival of the rains and the sprouting of maize plants. The youthful Maize God was often portrayed as a supernatural rising out of the earth, emerging from the turtle carapace because the surface of the earth was perceived as the back of a turtle (Taube, 1985: 181; Miller and Martin, 2004: 56-57). This variant of the Maize God often rendered him as a young male wearing a characteristic skirt ornamented with a diamond-like (Bassie-Sweet, 2002: 107) or a net design (Quenon and Le Fort, 1997: 885, 895) (see Figures 1 and 2). Quenon and Le Fort (*ibid*. 895) first observed that this motif resembled the pattern displayed on the turtle carapace. The connection between the netted skirt and the turtle carapace probably alludes to the moment of the Maize God resurrection (Quenon and Le Fort, *ibid*. 889, 895-898). However, it is also probable that the rebirth of the Maize God also concern the origin of humankind- the above mentioned creation of people from maize dough. By wearing this costume, human impersonators represented the place from which emerged both their ancestors and their sustenance.

Figure 1. The Maize God, Hun Nal Ye, is emerging from the turtle carapace, aided by the Twin Brothers. K1892.

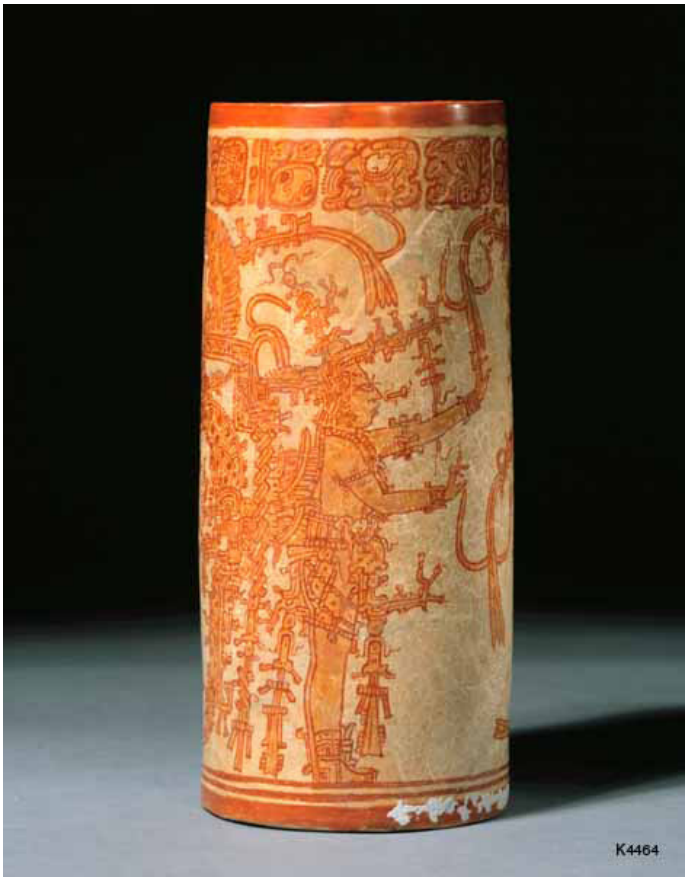

Figure 2 The Young Maize God. K. 4464.

Figure 3. The Maize God with a lunar sign.

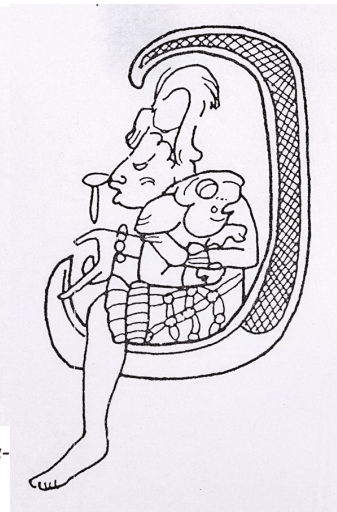

Figure 4. The Young Moon Goddess wearing a netted skirt.

Maize God and the Moon Goddess

Several scholars observed that impersonators of the Moon Goddess displayed the regalia similar to those of the Maize God costume. The diamond-like or jade net pattern is often shared in the costumes worn by both deities or their impersonators. The overlapping or conflation of both divinities is attributed either to their ancestral-mythical character that considers them as the First Father and First Mother of the gods (Freidel *et al*. 1993: 279, 464; Looper, 2002: 177-181; Schele and Miller, 1986: 309; Tate, 2000: 1060), or to the widespread use of the moon phases for planting and harvesting in pre-Hispanic Mesoamerica (Milbrath, 1999: 133-135; Taube, 1992: 68-69). Be as it may be, the overlapping costume elements reveal certain associations existing between this plant and the Moon. By extension, the costumes worn by Maya rulers and other individuals displayed Maize God forms sometimes merged with Moon Goddess representations causing a certain ambiguity among diverse female and male impersonators (Looper, 2002: 177-184; Quenon and Le Fort, 1997: 894-895).

Maya rulers and other individuals dressed in the Maize God regalia and the Lunar Series

Sometimes Classic Maya sculptures displayed the images of human impersonators dressed in the Maize God costume (i.e. wearing the jade netted skirt). The Maize God male impersonators appear to wear a short skirt while the Moon Goddess female impersonators are dressed in the skirt that descends below the knee (Looper, 2002: 178-181). However, in many instances the iconographies of both types of impersonators remained merged. Perhaps, this was related to the complementary rather than opposite relationship of masculine and feminine principles (Looper, *ibid*. 184).

In their paper, Quenon and Le Fort (1997) examined several monuments that displayed various individuals (rulers and non-rulers) wearing the Maize God (netted skirt) costume. Their study included El Peru Stela 24, El Zapote Stela 5, Copán Stela H and Yomop Panel (unprovenanced). Their list of monuments with the individuals displaying the Maize God/Moon Goddess regalia was augmented by Looper (2002). Having noticed that several of the mentioned monuments were covered with the inscriptions containing a Lunar Series record, I started to examine possible relationships between the information concerning the cycle of the Moon and the figures portrayed (see Figure 5). To better understand the political statements of Maya rulers, I offer a short description of both the monuments and inscriptions.

On the back side of El Zapote Stela 5 is depicted afigure traditionally interpreted as female because of a netted skirt costume. However, this can be questioned and as the above mentioned discussion indicates in this case the Maize God regalia are worn by a male impersonator (Schele *et al*., 1992a). The text begins with the Initial Series Date of 9.0.0.0.0, followed by the Lunar Series, however the rest of the inscription is heavily eroded so we do not know the context. The text continues on the other lateral side of the monument, indicating another date also followed by the Lunar Series. Schele *et al.* (1992) reconstructed this date as being 4.0.0, or 1440 days later and this date seems to refer to the dedication of the stela. On the other lateral side of the monument already noticed, in this case the male impersonator may be dressed in the Maize God costume it may be she is wearing a netted skirt. The squared object held by the impersonator resembles the Mexican year sign with the number twelve attached to it; this type of sign was utilized in Teotihuacan (Clancy, 1999: 95). The only royal title mentioned in the text is that of *k'inich*.

The FRONT side of Copán Stela H portrays Waxaklajuun Ubaah K'awiil (695-738), dressed in the guise of the Maize God (long netted skirt). Displayed on the stela Waxaklajuun Ubaah K'awiil reenacts the dance of the god emerging from the Underworld. The text is very short, only 16 glyphs survived indicating the reconstructed date of 9.14.19.5.0 (730 CE) which commemorates the setting up of the monument by Waxaklajun Ubaah K'awiil, the thirteenth ruler of Copán (695-738 CE). Together with Stela A both monuments were set up to commemorate the k'atun ending of 9.15.0.0.0 (731 CE). It is easy to observe that Stela H was dedicated 260 days before the k'atun ending. Fortunately Altar H' records the dedication of Stela H although its Initial Series Date goes back to CE 680 (9.12.8.3.9) followed by the Lunar Series. This ruler was responsible for the installation of K'ahk' Tiliw Chan Yopaat on the throne at Quiriguá. This ruler was capable to raise the rank of Copán among the four most power-

ful states in the Maya region, together with Tikal, Calakmul and Palenque, as he recorded on Stela A.

Stela H at Quiriguá was commissioned by K'ahk' Tiliw Chan Yopaat (724-785), the fourteenth ruler of Quiriguá to commemorate the k'atun ending date on 9.16.0.0.0 (751 CE). It's front side of represents a ruler standing on a zoomorphic base, possibly a representation of a mountain, with portions of his figure displayed on lateral sides. The north lateral side displays the Maize God image among the foliage motives attached to the mountain-like base (Looper, 2003: 90-91). According to Looper (*ibid*. 92-93) the frontal side of Stela H portrays K'ahk' Tiliw Chan Yopaat embodying the lightning deity that splits the carapace of the cosmic turtle to bring sustenance to the people. The Initial Series Date is followed by the Lunar Series and refers to the erection of the monument on the K'atun Ending (Looper, 2003: 215-216). As is known in 738 K'ahk'Tiliw Yopaat seized and decapitated Waxaklajuun Ubaah K'awiil of Copán.

On the front side of Naranjo Stela 24 is displayed Lady Six Sky impersonating the Moon Goddess. She is a captor of K'inich Cab, of Ucanal in 693, who is rendered below her feet. Lady Six Sky was the daughter of B'alaj Chan K'awiil, ruler of Dos Pilas and arrived to Naranjo to reestablish its dynasty. The text begins with the Initial Series Date is followed by the Lunar Series and refers to Lady's Six Sky arrival at Naranjo. Glyph D of the Lunar Series states that it was 18 days after the Moon *juliy*, "arrived" (at C5) and uses the same glyph (*juliy*) to tell that she arrived at Naranjo (at C8). Furthermore on 699 Lady Six Sky made some action impersonating the Moon Goddess (at E4) (Houston *et al*. 2006: 261), so it may be said that she arrived at Naranjo like the Lunar Goddess/the Moon arrives on the sky. She was the mother of K'ak' Tiliw Chan Chaak, a vassal of the Calakmul ruler Yuknoom Yich'aak K'ak'.

Another feminine figure, that of Ix Kanil Ajaw, is rendered on El Perú Stela 34 in the guise of the Maize God costume. The monument was erected to celebrate the k'atun ending of 9.13.0.0.0 (692 CE), together with Stela 33. Unfortunately, it bears no Lunar Series glyphs. Lady Kanil Ajaw came to El Perú from Calakmul bearing the *kaloomte*' title.

It has been generally assumed that the observations of the moon led the Maya skywatchers to the development of the complex system of moon reckoning known as the Lunar Series. Within this system three types of the information about the lunar cycle were considered: the age of the current moon, the number of moons completed in a series 6 (or 18) differentiated lunations, and the alternating of 29 and 30-day formal lunations.

Thanks to John Linden (1996), Linda Schele (Schele *et al.* 1992b: 4),Nikolai Grube (Schele *et al.* 1992b: 4), Jens Rohark (1996) and Gerardo Aldana (2006) we today know that Glyph C was composed of two variable elements: the numerical coefficients varying from 1 to 6 and three variable head variants (see Figure 6). Furthermore, these authors argued that during the Uniformity Period (Teeple's estimations falling between 9.12.15.0.0 and 9.16.5.0.0, or AD 687-756, or recent Aldana's estimations between 9.13.0.0.0 and 9.15.0.0.0, or AD 692-731) the sequence of Glyph C head variants followed a fixed order: either as a sequence of 1-6C female, 1-6C young lord and 1-6C skull (Schele *et al.,* 1992b: 4; Aldana, 2006: 241) or as 1-6C skull followed by 1-6C female and 1-6C young lord (Linden, 1996: 345-346, 351-352; Rohark, 1996: 66-69).

Moreover, in his 2006 paper Aldana proposed that changes in the Uniformity Period seem to be associated with political changes. Observing that *kalomte'* title was the highest or most prominent title recognized by the Maya rulers, this scholar concluded that in a similar way as the calendar was standardized, the determination of lunar periods was controlled by the *kalomte'* rulers, forcing the lesser and dependent rulers to share the same vision of the cosmos (Aldana, 2006: 255). Through the imposition of the same and standardized lunar count onto their vassals, *kalomte'* showed they were able to control the knowledge of the sky. Since it was important for many Mesoamerican rulers to act according to the celestial events that might have been interpreted as auspicious for performing certain rituals, and their power was derived from their knowledge of celestial events and cycles, it was important for the highest ranked rulers to be able to control this knowledge, too. Several years ago Johnston (2001) commented that capturing of calendar-and-sky-watching specialists was part of political strategies aimed at the weakening of enemy rulers, because the loss of the capacity of producing public monuments reaffirming political aspirations of rulers diminished their authority and the possibility to receive any support from other noble families to govern over the commoners and to conduct the affairs at the city-state level.

Figure 5. The Lunar Series glyphs incorporated to the texts accompanying the figures of rulers dressed in Maize God/Moon Goddess costumes.

Monument	Protagonist, Royal title	Costume convention	IS Date DD Dates marked with asterisk	Lunar Series, Glyph C Head variants: s - skull, f – female, m – mythological	Lunar Series Convention
El Zapote, Stela 5 back side	Male *K'inich*	Long skirt	9.0.0.0.0 (435 CE)	3D 4Cs 29 (4.36D 4s)	Uniformity
El Zapote Stela 5			*9.0.4.0.0 (439 CE)	?D 4Cm 29 (26.87D 4m)	Uniformity
Copán, Stela H Altar H'	Waxaklajuun Ubaah K'awiil (695-738), k'uhul xukpi ajaw	Long skirt	9.12.8.3.9	22D 5Cs 29 (23.27D 5Cs)	Uniformity
Quiriguá, Stela H	K'ahk' Tiliw Chan Yopaat, *ajaw* and south *kaloomte*'	The figure of the Maize God below the ruler	9.16.0.0.0 (751 CE)	5D 5Cm 30 (5.47D 5Cm)	Uniformity
El Peru, Stela 34	Na Kan Ajaw	Long skirt	9.13.0.0.0 (693 CE)		
Naranjo, Stela 24	Lady Six Sky	Long skirt	9.12.10.5.12 (702 CE) *9.13.10.0.0	18D 1Cm 30 (18.48D 1Cm)	Uniformity

Author	Head Variant 1	Head Variant 2	Head Variant 3
Schele et al. (1992)	Skull	Female	Young lord
Linden (1996)	Skull	Human	Mythical
Rohark (1996)	Hunhunahpu	Ixquic	Ixbalanque and Hunahpu
Aldana (2006)	Death	Moon Goddess	Jaguar God of the Underworld

Figure 6. Head variant identifications according to different authors.

Examples given above indicate that all rulers portrayed in the Maize God/Moon Goddess regalia were bearing high-ranking political titles and their Lunar Series reflected a uniform calculation. This also shows that Maize God imagery was extremely important for the Maya and not all of the rulers were capable of presenting themselves wearing his regalia.

Conclusions

With all probability the impersonators, or individual rulers who wore the regalia of the Maize God, were considered as embodying the sacred power, represented by this god, that guaranteed the arrival of rains and abundant crops. As rulers or agents, they performed ceremonies loosing much of their individual identities and as impersonators they acquired much of identities of the gods active in the creation stories. As both the rulers and deities acted in accordance with (or were constrained by) the same cultural code and meaningful matrix, so the rulers who embodied deities acted as embedded individuals. However, since the celestial lore was important to produce a list of powerful statements allowing the rulers to assert (and maintain) their power, its development was controlled.

The present paper illustrates the ways in which popular and shared concepts of the sky were drawn in the past from lifeworld categories and later manipulated and transformed by the elites to show that their ability to predict celestial events and cycles allowed them to successfully act on the earth. The merging figures of the Maize God/Moon Goddess affected the visual imagery of the commoners, while the standardization of the lunar count denoted the degree of political dependency/independence from the ruling centers at Calakmul and Tikal. Cultural astronomy has really to go beyond the simple study of astronomical practices.

The questions raised in the present paper clearly show that we should examine non−Western systems of knowledge as products of specific cultures rather than as equivalents of modern scientific disciplines. It also shows that it is meaningless to consider the different ways in which scientific categories can interact with cultural categories. After all, social relations and all possible kinds of interactions are performed by human beings and take place between them. Therefore, any theoretization of the relationships between social life and the celestial environment can only be done indirectly, through the mediation of the social-cultural matrix of the acting individuals, members of the society we are studying. We cannot understand the meaning of the celestial environment simply by lifting it up out of its social and cultural context.

Meanings attached to the sky are neither homogenous, universal, nor static. They are based on the activities performed by agents and their knowledge indicating how and when to act. Interpretations based on the notions derived from the categories of lifeworld and worldview, such as social spatiality, social temporality, situatedness, relatedness, embeddedness, embodiment, are needed to overcome existing epistemological divisions generated by the prevailing nature—culture paradigmatic dichotomy.

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South America

The «Petre de la Mola» megalithic complex on the Monte Croccia (Basilicata)

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Abstract: The "Petre de la Mola" ("Grindstone Rocks") (40° 33' 02" N, 16° 11' 39" E) is a natural outcrop of the Monte Croccia (1.049 m), in the Basilicata area of the Apennines mountain range, showing clear intervention by the men hands. A laser scanner measurement of the complex was performed on June 2008: artificial solar alignments were found, directed to the meridian and to the winter solstice sunset. These alignments where confirmed by direct observations performed at winter solstice of 2008. Other peculiarities, connected to a possible calendar use of the megalith, were discovered during observations performed at summer solstice 2009. Furthermore, artificial basins, extremely similar to the ones on the top of other astronomically aligned megalithic complexes of the same area, were found on the top of "Petra de la Mola". No dating is available for the megalith: a survey, performed in the 1950s by the Basilicata Archaeological Superintendence, revealed that the site was inhabited form the Neolithic epoch up to the 4th Century BCE. The whole archaeological area, including the megalith, cover a surface of about 60000 m2. The area, inhabited by Lucani population between 6th and 4th Century BCE, was then fortified at the end of the 4th Century BCE. The final settlement is surrounded by walls, made by perfectly cut rock blocks, the better preserved being the one around the acropolis, more than 2000 m long: its main entrance door is facing the megalith exactly to West, suggesting the sacred value of this rock.

Keywords: Archaeostronomy, Megaliths, Basilicata, Bronze Age

Introduction

Apart for the Apulia area (Tunzi et al., 2008) the presence of astronomically oriented megalithic structures is scarcely documented in southern Italy. However, the case of an oriented megalith, the «Preta 'ru Mulacchio» («Bastard Child Rock» in local dialect) on Monte della Stella in Cilento (see Fig.1), that satisfies the three Schaefer (2006) tests of intentionality, has been recently published (Polcaro & Ienna, 2009). The «Preta» is basically composed by three rocks that were originated along of natural reasons from a single block of sandstone in its upper part and of a rough conglomerate in the lower one: between the three rocks, two galleries were thus formed. However, it is easy to see that the «Preta» was deeply modified by human intervention: large stones were wedged in exact position between the three original blocks or positioned as a cover. One gallery has an astronomical azimuth of 359° and the other of 240°: inside the measurement precision (±1 °), the galleries are thus respectively oriented to the meridian and to the sunset of the winter solstice. Furthermore, modern folklore associated to the rock seems to remind very ancient fertility rites. From a statistical analysis of the alignments and an archaeological study of the complex, it was thus concluded that «Preta 'ru Mulacchio» is most probably a monument, dated to an epoch presently unknown but possibly preceding the Hellenic colonization of Cilento, built in order to determine with a high precision the winter solstice because of ceremonial reasons, probably connected with fertility rites.

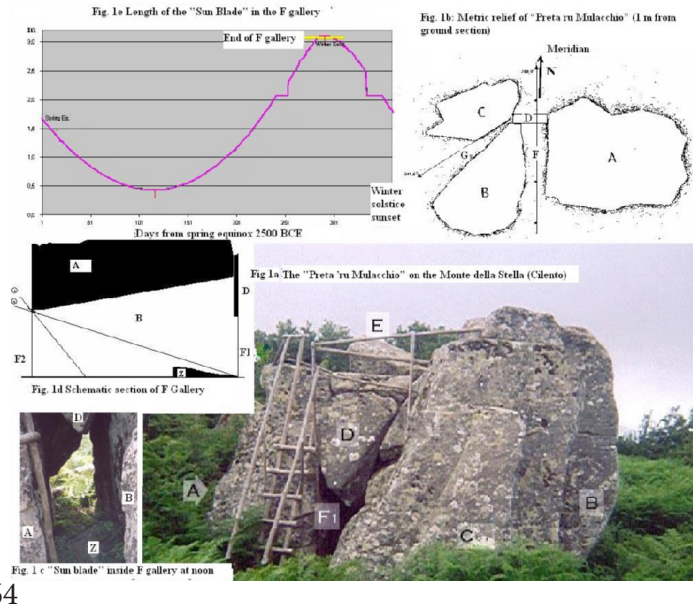
After the publication of this results, a very similar megalithic complex was noticed near the Croccia Cognato archaeological site, only 97 km from the «Preta 'ru Mulacchio» one.

The Croccia Cognato Archaeological Site.

The Croccia Cognato archaeological site (40° 33' 02" N, 16° 11' 39" E) is sited at 1150 m over the sea level on a mountain belonging to the Lucanian Dolomites range, dominating the Basento Valley and the upper flow of the Cavone river. Traces of human frequentation go back to Neolithic Age (12,000 – 8,000 BCE) and also during the Bronze Age the area was surely frequented. The first archaeological investigations of the area were performed by Michele Lacava (1887) at the end of the 19th Century; later, Vittorio Di Cicco performed five excavation campaigns, uncovering an osco–samnite settlement, dated between the 6th and the 4th Century BCE, with a double surrounding wall and various structures sited on the acropolis, whose building technique was similar to the Hellenic one (Di Cicco,1896). Last excavations in the site were performed in 1998 by the Basilicata Superintendence: the southern side of the fortification was explored for a length of about 60 m and the southern and the eastern part of external wall, joining the acropolis one, was reconstructed (Russo, 1999). The external wall, dated between the end of the 8th and the end of 6th Century BCE1, is made part in squared and part in polygonal huge sandstone blocks, alternated to natural outcrops of the bedrock. The acropolis is sited on the top of the mountain; it is surrounded by a second wall in squared opus with emplecton, of quadrangular shape, 700 m long and dated, on the base of the related archaeological findings, to the beginning of the 4th Century BCE. The southern side of the two walls is common. Five posterns are sited on the northern, east-

1 Due to the presence of "curtain ceramics" and fragments of B2 type Ionic cups.

Fig. 1: The «Preta 'ru Mulacchio» on Monte della Stella



ern and southern side of the internal wall, whose well preserved main entryway is made by two doors closing a small courtyard.

Fig. 2 The external wall of the Croccia Cognato settlement

The lack of systematic excavations does not allow a precise dating of the settlement. However, it seems sure that it had two phases, the first one in Archaic Epoch, at the time of the building of the first wall, the second around the 4th Century BCE, when the settlement is localized on the top of the mountain. Actually, during the excavation performed at the end of the 19th Century by Di Cicco, the remains of a relatively large squared building, divided in a number of rooms, located inside the internal wall were discovered: inside, a Republican Age bronze coin, an iron spear head and a little bronze fibula, were found, together with remains of tiles and of rough pottery, strongly suggesting the housing use of the building. The same archaeologist reported the presence of the remains a possible small temple in the acropolis, though the present state of this building does not allow a precise determination of its use.

The data collected to date suggest that the settlement was abandoned in the 3rd Century BCE, when, due to the Roman pressure, most of the small Lucano fortified settlements were left (Osanna, 2001).

On the eastern slope of the mountain, not far from the previously described settlement and on the opposite side respect to the megalithic complex described in next section, a number of elite graves, contemporary to the fortification walls, was found inside an area employed as a quarry and for rock blocks working. One of these graves restituted a funerary equipment, made by a Corinthian beaver, iron weapons and a red figures proto – Lucano crater, restored with lead hooks and bitumen. The necropolis was built over a previous settlement and the stratigraphic sequence goes from the end of the 8th to the end of the 4th Century BCE, though some traces seem to testify a frequentation starting in the proto – Villanovian B (Di Cicco, 1919).

The «Petre de la Mola» on Monte Croccia

At a distance of about 200 m East of the main gate of the settlement an imposing group of rocks is sited on a small, rather flat area of the mountain slope, at 1049 m height. This rocks, named in local dialect «Petre de la Mola» («Grindstone Rocks»), are natural outcrops of the limestone bedrock, cracked in various boulders because of the rain and wind erosion (Fig. 3).

Fig.3 The «Petre de la Mola» megalithic complex

The fortuitous discovery by one of the authors (M.M.) of a singular light effect due to the sunlight at noon let us suppose that these rocks too, as in the case of the «Preta 'ru Mulacchio» were modified by human intervention, in order to be transformed in an instrument for calendrical measurements.

Because of this reason, a laser scan of the megalith was performed in July 2008. Two clear astronomical alignments where found from a single observation point, a break on the natural platform on the North side of the megalith, as it is illustrated by the horizontal section of this scan, shown in fig. 4.

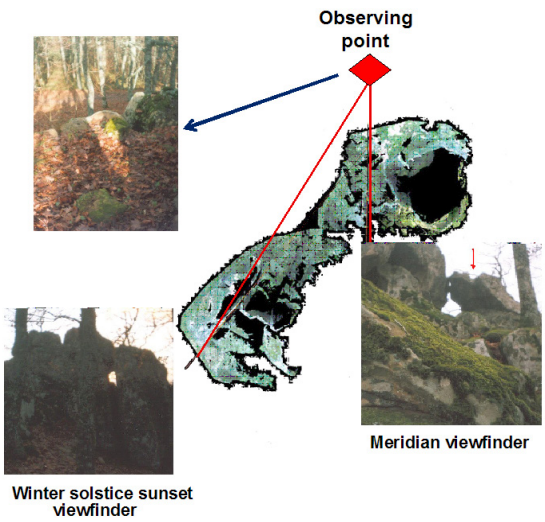


Fig. 4: Horizontal section of the «Petre de la Mola» laser scan. The two detected astronomical alignments are shown as red lines; pictures of the related viewfinders are shown at the end of the lines

In order to finally verify these alignments, we visited the site on the winter solstice of 2008. As it was foreseen by our measurements, the Sun appeared at the meridian viewfinder at noon and in the SW one at the sunset, as it is shown in Fig. 5.

It is worth to notice that the effect shown in Fig.5b does not happens at the time of the astronomical sunset, but a few minutes before,

Fig. 5: Light effects at the «Petre de la Mola» at winter solstice: A) Noon B) Sunset. Both pictures have been taken from the same observing point: the break on the natural platform on the North side of the megalith shown in Fig.4.

when the Sun height is of about 5 deg. Actually, the field of view seen through the viewfinder shown in the upper panel of the figure is a due to the intersection of a narrow gallery in the rocks with the local horizon given by the mountain chain West of the complex.

A further visit was made at the summer solstice 2009, in order to identify other eventual calendrical marks. In was actually found that, at noon, sunlight falls into an hole carved in the rock, repeating the shape of the projected light beam (see Fig. 6), though it is difficult to prove that this hole is artificially carved. Furthermore, it seems that the summer solstice sunset from the same observing point points to the mountain top (not yet completely proven because of the heavy forest trees coverage to date).

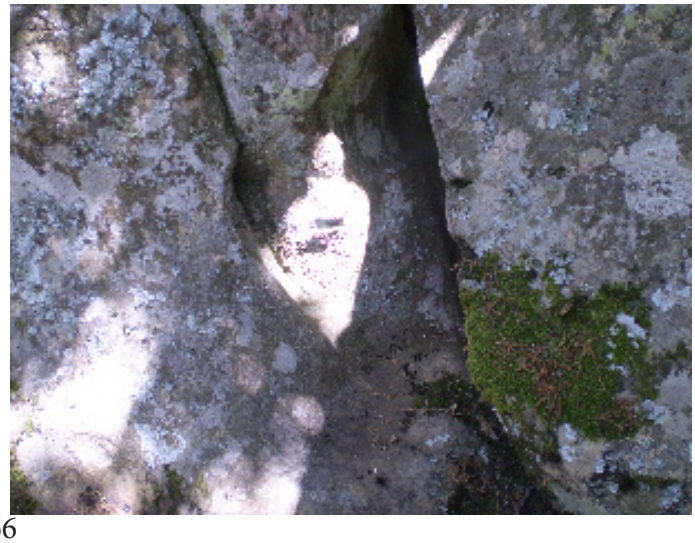
We have now to evaluate if this situation is intentional, following the Schaefer's (2006) standards. In this case, archaeological proofs of the intentionality of the alignments is more difficult to find respect to the «Preta 'ru Mulacchio», where clear evidences of human intervention were visible. Actually, in the case of the «Petre de la Mola», only minor modifications of the natural rock were necessary in order to obtain the detected alignments and they traces on the sandstone are very difficult to identify after a surely very long exposure to atmospheric agents, though it is possible that some traces on the blocks where the viewfinders are found should be attributed to human actions.
To date, the only unequivocal proof of human intervention on the complex are a dry-stone wall on the right of the observing point, probably made in order to obtain a relatively flat area around it by means of landfill and two basins, very similar to the ones carved on the top of the «Petra 'ru Mulacchio» complex.

From the ethnological point of view, the Proto-Lucani élite graves demonstrate that the megalith was considered, at least at that epoch, a sacred place. Furthermore, the megalith is seen exactly at East form the main entryway of the Lucani settlement. These facts could indicate that the sacred value of the megalith lasted long time. Another proof of the cult use of the megalith is given by the two basins carved in its top, collecting the rain water. However, none of this elements give us a sure evidence that the megalithic complex was used for calendric purpose too and only dedicated excavations can solve this point.

On the other hand, a statistical analysis shows that the detected alignments have a very low probability to be due to chance. Actually, respect to the null hypothesis (random orientation), the probability that the length of the sunlight beam at the winter solstice is equal to the distance between the meridian viewfinder and the break in the rock platform is $\leq 1/365$, being the solstice equivalent, from the statistical point of view, to any other day of the year and taking into account the fact that the sunbeam projection could also never reach the break in the rock. This probability, in a Gaussian statistics, corresponds to 3.25 σ. Furthermore, being the probability of a single solar alignment equal to $1/22 \approx 2.08\ \sigma$ (Schaefer 2006), the probability of 2 coexisting solar alignments (as in our case the meridian and the azimuth of the sunset at the winter solstice) from the same observing point corresponds to 2.94 σ. Last, we have to evaluate the probability that the local sunset happens, inside a ± 1 deg[2], at a Sun height equal to the one defined to the angle under which the viewfinder is seen by a defined observing point. Respect to the null hypothesis of chance orientation this probability is equal to 2/90, corresponding, in Gaussian statistics, to ~2.5 σ. The total probability of the simultaneous chance occurrence of the detected independent events can thus be evaluated to be $\geq 5.05\ \sigma$ corresponding to about 1 over 8,000,000. The intentionality probability is further increased by the presence of the «mark» hole corresponding to the summer solstice.
Despite of this statistical evidence, the final proof of the intentionality of the detected astronomical alignments will be given only by a dedicated archaeological campaign, confirming the human intervention on the complex and proving the calendrical and cult use.

2 Being the Sun an extended object with diameter of ±0.5 deg

Fig. 6: The sunlight passing through the meridian viewfinder is projected inside a hole with a shape similar to the sunbeam at noon of the summer solstice



On the other hand, we have now two similarly oriented megaliths at a distance of less than 100 km. A third one on the same area, sited at Cannilicchio di Calstelgrande, presenting similar alignments and geographical position (at ~ 1000 m on a mountain with a wide view), is presently under study. Though this study is at the beginning, it seems that astronomical aligned megaliths are relatively common in Basilicata and in the surrounding area. In absence of dedicated archaeological excavations it is not yet possible to attribute these artefacts to a definite epoch or culture. However, it is reasonable to hypothesize their association with the Proto – Apenninean culture, whose nearby Trinitapoli Sacred Area clearly shown the interest for celestial phenomena, with its extraordinary astronomically oriented rows of holes, covering an area of more than 60000 m^2 (Tunzi et al., 2009).

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The aspects of the Brazilian Archaeoastronomical Culture.

RONALDO ROGÉRIO DE FREITAS MOURÃO
in Memoriam (*Rio de Janeiro, 25.5.1935, †Rio de Janeiro, 25.7.2014)

The article is a translation from Brazilian Portuguese (De Freitas Mourão, 2010).

Abstract: A brief description of what is known about indigenous Brazilian astronomy. At a time when serious, objective research concerning American aboriginal astronomy is beginning, nothing could be more logical than also to conduct a brief study of Brazilian natives' astronomy, mainly in view of the innumerable petroglyphs which exist in Brazil, and which have not yet been analysed from the astronomical point of view.

Keywords: Ethonastronomy, Carajá, Asterisms, Milky Way, Tupi, Moon, Sun, Astro-Idolatry

Tupi Astronomy

Apart from being a military engineer and a member of the Rondon Commission, Coronel Themistocles Pais de Souza Brasil, headed, for a long period, The Commission for the Demarcation of the Western Sector Border, and wrote a valuable account on his activities in 1935, in which he relates important observations on the customs and habits of his country's aborigines. One of the most curious and interesting chapters of this short work (Coronel Themistocles Pais de Souza Brasil, 1937) refers to indigenous astronomy, in particular to the ideas and astronomical knowledge of the natives who still live on the banks of the Rio Negro.

From the observations of Coronel Themistocles Brasil, it is possible to identify the name and location of some constellations, as well as understand the meanings of some indigenous phenomena and astronomers.

In the region of the Rio Negro, the Ursa Major constellation is easily visible near the northern horizon, in the months of April, May and June. The natives usually name it **Jauareté**, meaning "the leopard".

Another fundamental Brazilian asterism in uranography (the study of the sky) is the open cluster of the Pleiades, visible from November through March. Situated in the constellation of Taurus (the bull), this cluster is known by the natives as **Siuci** or **Ceucy**, an originally Tupi term meaning mother of water. The legend has it that when the Pleiades rise in the East, at four in the morning, before the Sun rises, in November, the natives, with their wives and children, proceed to the riverbank in order to bathe; as soon as the daylight starts to appear, they pronounce the words: *"Siuci, Siuci ita ce anga ce ceté santa"*, which is the equivalent of saying: "*O Pleiades, O Pleiades, may my body and my soul remain strong and hard as stone for a long time."* According to local tradition, those who do not offer up this prayer annually, become weak and do not live for very long. The legend tells that Siuci is responsible for the **Muquentaúa**, a cane griddle for roasting or drying meat or fish. The **Muquentaúa** exists in the sky, represented by the open cluster of Hiades. This cluster is also located in the constellation of Taurus (the Bull) and appears in the shape of an acute angle, or better still, with an appearance similar to the letter A. According to indigenous mythology, **Siuci** roasts those individuals who do not bathe at the time of the morning appearance of the Pleiades. According to Barbosa Rodrigues, **Munquetaúa** would be Canopus, the brightest star in the constellation of Carina.

In the lovely constellation of Orion, which dominates the sky during the summer months, **Ararapari** is to be found, the name of the fencing around fish farms, which is familiarly known as the "Three Marys" asterism**,** and which, according to Greco-Roman mythology, represents Orion's belt.

The constellation of Scorpio (the Scorpion) is designated by the native term **Boiunaçu**, the big black snake, which is said to have swallowed the egg of a macaw, **Ararasopiá**, supposedly getting it stuck in its throat. In effect, observing the constellation of Scorpio, one can find in its curvilinear interior, a very bright, reddish-coloured star, traditionally named Antares. This star, the brightest star in the Scorpio constellation, is precisely the indigenous star **Ararasopiá**, meaning macaw's egg.

The natives linked the disappearance, in the West, in November, immediately after Sunset, of the head of the snake, **Boiunaçu**, with the swelling of the rivers. Such floods were known as boiunaçu floods, or, in the local language: **boiunaçu iuquicé.**

The constellation of Corvus (the crow) which is made up of a small quadrilateral of stars which disappears in the West, in September, forms, in the native mind, the **Tatu** (or armadillo), a celestial animal which was also associated with the swelling of the rivers.

It can be seen form these accounts that the natives marked or foretold the periods of the river floods by the approximate positions that the stars occupied in the sky. Thus, the Boiunaçu flood occurred up until the Siuci constellation disappeared in the West, immediately after Sunset in April. On the other hand, the Tatu floods were in the period when the fish swan upstream, when the waters once again took over the *igarapés* (roughly equivalent to bayous). This was the great moment for fishing with the **timbó**: a vine containing a poison which facilitates fishing; or with the **cacuri**, a trap made of canes or sticks which the natives set up in rivers, as soon as the Pleiades announced the arrival of the first rains.

Thus it may be seen what great importance the natives attached to the appearance of the Pleiades, when the tribes therefore spread out over the **igarapés** with their **timbós**, for the purpose of fishing in still waters so as to stun the fish in the **muqueantaúas** until they became completely dry. By doing so, they could preserve their food for the periods when there was no fishing.

The Constellation of the Southern Cross formed, in native mythology, the **juaraúa**, or manatee, which, in the sky, flees its two eternal persecutors, the **Piracaçaras**, which form the Alpha and Beta stars of the Centaur, situated to the East of the Cross, seen by an observer looking South. **Piracaçaras** means, in the native tongue, fishermen. In this same region of the southern sky, there is another constellation, the **camarão** (or prawn), formed by Lupus (the wolf) and part of the Southern Cross. The most brilliant stars of the Cross form the body of the **Camarão** and those of **Lupus**, the claws. Very near the **Camarão**, is situated the **Jacundá**, a sort of fish, represented in the sky by a small number of stars.

In the concept of the natives along the banks of the Rio Negro, the Moon is Jaci, a very beautiful girl who lived in a hut, along with her married sister. Her brother-in-law was very disrespectful; during the night he took advantage of the dark to nudge up against Jaci. Unable to discover who was responsible, the young girl prepared a bowl with genipap fruit, which she put beside her hammock to mark the cheeky fellow who used to touch her at night. It so happened that, feeling his way in the dark, the brother-in-law put his hand into the bowl of genipap and afterwards, when he passed his hand across Jacy's face, he stained her with blacking. This is the reason why the Moon has stains on its face. This legend is very similar (De Freitas Mourão, 2000) to the one told in the Brazilian classic, **Macunaíma (1928)**, by Mário de Andrade (1893-1945).

Apart from this, they knew the phases of the Moon, which was called **Jacicua-çu**, the full moon, where **suaçu** means very big; **Jaci-pirera**, the waning moon, where pirera means the remainder, and **Jaci-peçaçu,** new moon.

It is possible to evaluate how much is still missing before we can understand the importance which astronomy represented to pre-Columbian peoples by reading the book **"Native American Astronomy**" (Aveni, 1977), recently published by the University of Texas, which gathers together work presented at the Arqueo-astronomical Congress held in 1975, in New York.

At a time when serious, objective research is beginning concerning American aboriginal astronomy, nothing could be more logical than also to conduct a brief study of Brazilian natives' astronomy, mainly in view of the innumerable petroglyphs which exist in Brazil, and which have not yet been analysed from the astronomical pint of view.

In these cave inscriptions, known to Brazil's natives as *itacuatiaras*, a word of Tupi origin which means painted stone, it is possible to identify, in one of the photographs which exist at the *Pedra Lavrada farm* (Da Silva Cézar 2013), in *Ingá* (Itacoatiaras of Ingá River: S 07°19' 30,2", W 35°35'6,8"; 10,000 BC to 1,400 AD; Pavia 1986, 2005, 2006; Lull, 2006), the Emperor's former villa, in *Paraíba* state, drawings of the stellar cluster of the Pleiades, also commonly known as Setestrelo (or Seven Stars).

The Pleiades were known to all Brazilian natives, who joyfully hailed their annual return. In effect, as soon as night fell, when the stars became visible and the Pleiades were born on the eastern horizon, a new year began for the natives, which also coincided with the start of the dry season. Their disappearance, which occurred around April/May, was accompanied by an increase in the rains, which made navigation almost impractical. They recognized, according to André Thevet (1516-1590), that the Pleiades were responsible for the growth of manioc, the root from which they made flour, one of their main foods (Thevet, 1558; Lestringant, 1997) Despite the importance of the Pleiades, evidence provided by foreign travellers, who came to Brazil after its discovery (1500), among them Jean de Léry (c. 1536-c. 1613), Willem Piso (1611-1678), and d'Abbeville (before 1590-1632), is, however contradictory (De Lery, 1611; Lestringant, 1994; d'Abbeville, 1614; Piso, 1658). Thus, whilst for some authors the appearance of the Pleiades was linked to the start of the dry season (in the North and Northeast of Brazil), for others it was associated with the indicative signs, or even with the arrival, of the rainy season (on Brazilian soil). However, these differences of opinion result from the fact that only rarely did the texts relate the exact moment of the night on which the observation was made. So, it is not known if they were related to the cosmic birth (the moment of the birth of a star, which happens simultaneously with the rising of the Sun) or to the heliacal dawn (the first appearance of a star on the western horizon, when the first rays of the Sun appear. In this way, the visibility, or non-visibility, of the Pleiades could be related with the western horizon after the Sun sets or with the eastern horizon before the Sun rises.

The Tupi natives called the Pleiades **seixu**, the bees, as Claude d'Abbeville so well recognizes in his book **"History of the Capuchin Monks' Mission on the Island of Maranhão and Surrounding Counryside",** published for the first time, in French, in 1614. According to *Rodolfo Garcia* and B*atista Caetano*, in the term seixu may be seen an interaction of ideas between the Tupis of the North and their brothers in the South, who also called them **eichu**, meaning a type of bee. In time, the word **seixu** came to mean the 12-month period which makes up our calendar year. So they behaved having in mind that the start of the new year was determined by the observation of the appearance of the Pleiades.

The Pleiades make up a stellar cluster, that is, a group of stars which, apart from being associated with one another by gravitational pull, also possess a joint movement in cosmic space. Typical examples of stellar clusters, visible to the naked eye, in the southern hemisphere, are the **Pleiades** and the **Hiades** in the constellation of Taurus, and, in the northern hemisphere, in **Presépio**, in the constellation of Cancer.

Brazilian natives also knew the Hiades, which they designated by the Tupi term **Sembiara rajyguara**, that is, *the tapir's jaw*, since, apart from having the shape of tapir jaws, it was also used by the aborigines to announce the arrival of the rainy season, when it appeared on the eastern horizon, immediately after sunset. The constellation which announced the end of the rainy season in March was the **Guanham-y**, the *lagostim*, a kind of crab, which would definitely seem to correspond to our zodiacal constellation, Leo.

In making all these analyses of the names and meanings of Tupi origin, we have been helped by an excellent work, published recently, under the title "*Dicionário Histórico das palavras portuguesas de origem tupi*" (or "Historical dictionary of Portuguese words of Tupi origin"), by the philologist *Antônio Geraldo da Cunha* (Da Cunha, 1978). Here we can find the names of the main animals of American origin used by the natives to designate their constellations. In fact, many tribes grouped stars together in constellations. The distribution and association of stars in constellations set out by the natives do not coincide with our way of doing so. Ancient Tupi natives distributed the stars in groups, which they named **Nhandu**, **Panacu**, **Poti**, **Tapiti**, **Cacucri** etc. Some of these names are easily correlated with those presently in use. Thus, **Nhandu**, a type of emu, should correspond to Gemini; **Panacu**, or long basket, corresponds to the complex formed by the star Rigel, Betelguese and the Three Marys, which, linked together, really do form an elongated basket; **Poti**, the prawn, seems to be the constellation of Cancer; Tapiti, the rabbit, is perhaps our Libra; the **Urubu** (Vulture), seems to correspond to the present constellation of Corvus, and the **Cacuri**, a type of fishing net/trap used by the natives, to our Southern Cross.

The natives had the concept of winter as well as of summer, which they called, respectively, **cuarassy**, which also means

Sun, and **roy**, cold or cool. They had notions of sunrise and sunset, called **cuarassy reiqueaba**, the West or setting Sun, and **cuarassy sembaba**, the East or rising Sun. Since they accompanied the annual movement of the solar year, they could know when the Sun was nearest to its zenith when it was summertime, which is how they thus named this period of the year.

As a consequence, they knew that the Sun in its movement apparently never passed beyond the two tropics, observing that, when the Sun moved from North to South, winds and breezes occurred and, when the Sun moved in the opposite direction, it brought the rains.

They divided the year into twelve months, which they called moons. They called eclipses **jaci-pituna**, which means night of the Moon.

They attributed to the Moon the flux and reflux of the sea; thus they knew very well that the two major tides always occurred a few days before the full moon and the new moon, as d'Abbeville tells us, in 1614 (d'Abeville, 1614). It is, moreover, worth remembering that only in 1687 did the English physicist, Isaac Newton, demonstrate that the phenomenon of tides was the result of a joint action of the Sun and the Moon.

The Milky Way, that beautiful milky strip across the sky, named Tapiirapé, that is, the path of the tapir. This denomination is very curious, since all primitive peoples always had the same idea of designating the Milky Way as a type of highway. The Egyptians did so, seeing in the Milky Way the path of the Sun's conveyance, which crossed the sky every day. And, for others, it was merely the road which led to the dwelling of the gods or to Jupiter's Palace. Everything would seem to confirm that there really does exist a great similarity in the structure of the mind of all primitive peoples, who, straight off, used notions of astronomy, mixed with others of a mythical nature, with an aim to correlate them to climactic phenomena with which they sought to plan their agricultural activities, their main source of survival.

Lacking a perfect solar calendar, since lunar months did not coincide with the 365 days of the solar year, they sought to use a stellar calendar, in which the seasons, and, therefore, the resulting climate changes, were marked by the appearance of certain stars or asterisms, such as the Pleiades or the Hiades.

Carajá Astronomy

Reading the fine reports of the indigenist, João Américo Peret, in his book Carajá Myths and Legends (Peret, 1979), I began to understand that it was already time to return to my old project of a Brazilian Uranography in which all the descriptive aspects of indigenous Brazilian astronomy might be brought together. In fact, Brazil's autochthonous astronomical culture is very little known compared with that of other countries. A few years ago, we began a collection of sources which might permit, as a start, an individual analysis of the astronomical concepts and ideas of each tribe, which would, later, be studied together, with a view to seeking to understand them as a whole, and, in this way, try and discover if there really did exist points in common between the constellations thus defined and others described by tribes in regions that sometimes were very far apart.

Since they did not possess writing which might have perpetuated their ideas, almost everything we know was transmitted on starry nights besides beaches or in clearings, near their huts, by the old natives who, placed in the middle, ended up surrounded by the younger ones who listened to them. In this process of transmission, many ideas were lost in time, causing their authenticity to suffer the effects of the greater or less fidelity of the tribe's storytellers. So, many of the accounts ended up showing more of a poetic/mythological character than astronomy. Indeed, such influence is in no way inferior to that as developed by so-called civilized peoples, who, despite using more sophisticated technology did not, fortunately, lose their imagination and poetry, as may easily be verified by reading the book Astronomia e Poesia (or Astronomy and Poetry) by one of the authors published by Difel in São Paulo (De Freitas Mourão, 1977).

The Carajás imagined that the earth was flat and very extensive; infinite, perhaps, since they did not know where it began nor where it ended. They held the same ideas in relation to the dominions of their tribe, which they imagined extended for many miles in the neighbourhood of the banks of the Berô-Rekan, or Big River, as they called the River Araguaia.

They knew the apparent daytime movement of the Sun (**Tí-ú**) which rotates, like the Moon (**Rrá-dô**) over the region where they lived. They associated these apparent dislocations with the phases of the Moon which they named **Rrá-dô-tiuri-miára** (full Moon), and **Rrá-dô-uratirarairére** (waning quarter Moon). They did not know the new Moon, perhaps because they did not possess the capacity for abstraction which would permit them to designate what they did not observe.

Some called the Milky Way **Tainá titire** (path of stars) whilst for others the Milky Way (**Rroria-ciú-rô-rô** or **Rro-vi** (vrô) was compared to a huge pathway, where the evil Carajá (**Xandirioré**) roamed, cooking up evil spells and willing them upon the natives who inhabited the Earth. One of these evils, according to native accounts, were falling stars, or, as they put it, stellar lances (**Tainá-ré-áre**), real incendiary arrows shot by **Xandirioré.** According to accounts of the inhabitants of the Lower Araguaia, another celestial shooter of these arrows was the Carajá Hunter (**Doró botó**) who had supposedly transformed himself into the Pleides cluster, when he tried to catch the Tapir (**A-onidurarú**), which is the equivalent of our Taurus. The most brilliant star in this constellations is Aldebarã, which, for some natives, would be the eye, and, for others, the tip of one of the Tapir's teeth. It is worth noting that this stellar cluster also received another designation. Thus, for the Aruanãs, that is, for the natives of the Upper Araguaia, the Pleiades were seven parakeets (**Birri**).

The other stars (**Tai-ná**) which are spread out over the heavenly dome formed a replica of what happens in the woods, where the trees appear to envelop the rivers or pathways inside immense earthly forests. Thus **Biú** or **Biú-ti**, the sky, represented to the imagination of the Carajás, an enormous cosmic forest. In the mental make-up of the natives we find a tendency to try transferring to the sky, the flora and fauna which made up their knowledge or cultural heritage. From the Constellation of Orion, they only knew the giant's belt, that is, the Three Marys, as they are known in Brazil, and the upper part of the constellation which consists of the stars Betelguese and Bellatrix. With these five stars, they imagined the figure of **Xian**, a tanager bird, better known in various places in Brazil by *Acorda, Maria*! (or Wake up, Mary!), by virtue of its morning song, immediately after the Sun's first rays. For this reason, they served as an excellent "alarm clock" for the natives. Indeed, the Carajás used this constellation to begin their long hikes. The time for the Carajás to

begin a journey was precisely when Xian was at its zenith, since, in this way, they could enjoy the good, healthy, fresh morning air during a good part of the journey.

The nebulous darkness of the Coal Sack constituted the image of an enormous rayfish (**Boró**) which, along with the Alpha and Beta Stars of the Cross, formed the eyes of the ray (**Boró-rruéne**). Near these stars, are found the Alpha and Beta stars of the Centaur, which formed the frightened eyes of the emu (**Biurá-et-kú**) which lived, in the sky, pursued by the leopard Aloé. This Aloé, sometimes termed **Aloé-lubú**, that is, the black leopard, since, in fact, this region of the sky, where the Cameleon, Carina, Flying Fish and Popa constellations are located, has very few stars. This association with an Emu pursued by a leopard, reminds one of the Scorpius constellation, which, according to western mythology, was supposed to have been sent by Diana, the huntress, to kill Orion who was meddling in her affairs.

A dark, elongated stain, which, according to the indigenist *Brito Machado* (pers. communication) may be observed when we face North, to the left of the Milky Way, constitutes **Inuni-kan**, the Big Snake, in honour of an enormous snake (**Inui**) which existed in the Lower Araguaia. This Carajá constellation appears to form one of the faults existing in the Milky Way, near the constellations of the snake and of Ofiúco. Such an association partly allows the explanation of how the structure of the analysis of heavenly aspects by primitive minds was, in fact, always the same.

As far as the planets were concerned, it would appear that they only knew Venus, which was considered two different stars. Thus, when it appeared as a morning star, before sunrise, it took on the name of **Tainá-Kan**, Big Star; however, when it rose as an evening star, immediately after sunset, it was called **Beorá-rrá-tainá**, the Star of the wet season.

For the Carajás, the year began in August, when the flowers started appearing, for this reason called **Berá-ri-aré**, which was also used to designate the time interval of a year in which the seasons followed on from one another.

They distinguished the four seasons of the year, calling the summer **Béorará**, which means the time of the waters or rains, whilst winter was termed **Knará-rakan**, which literally means big beach, since at this time of the year, due to the river's low-water mark, the Araguaia's beaches grew wider. The first, they called **Biu-iche**.

Dominated by the idea, so well expressed by the famous phrase of the French writer and philosopher, *Blaise Pascal* (1632-1662): "Le silence eternel des ces espaces infinis m'effraie / I fear the eternal silence of these infinite spaces…" (Pensées, XV. Transition, 201-206; Pascal 1977), man has been trying to understand the universe around him. In fact, since the beginnings of his existence, man has been trying to fight against the anguish of infinite spaces, building organizational schemes whose objective is to establish a familiar image of the world surrounding him.

Some hundreds of thousands of years ago, pre-Neanderthal man lived in a world where everything was divinities: the Sun during the day; the Moon and the stars by night, the divinity of the tree which bore fruit, all this created a magical and familiar world whose easy explanations made it respected and admired by man.

Ten thousand years ago, a mystical universe arose, the kingdom of the gods. All natural phenomena, including the creation of the universe, were the consequences of divine action, of the loves and passions of the gods, their hatred and their violence.

The reproductive function of the woman inspired innumerable myths about creation. For the Babylonians, five thousand years ago, *Anu* – god of Heaven – was supposed to have been born of the coupling between the female, *Tiamat*, with *Apsu* – the god of the abyss of the oceans. *Anu* and *Tiamat* engendered, in their turn, *Ea* – god of the Earth.

In the mystical universe of the Egyptians, the ocean was the primordial source of life. In it lived the first being, *Atum*, from whom originated all existence and who later became *Rá*, the god of the Sun. On this primordial ocean floated *Geb* – the earth -, a flat disc surrounded by mountains. The body of the beautiful goddess *Nut*, with the support of *Shu* – god of the air -, made up the heavenly dome. The jewels which shone like fire over *Nut'* s body made up the planets and the stars. *Rá* – the Sun – in its daily movement across the sky, moved by boat along the coasts of Nut by day, diving by night into subterranean waters from which he emerged the next day.

In the Chinese universe, there were no personified gods. The world was a consequence of the reciprocal effect and dynamics of two opposing polar forces; *yin* and *yang*. The sky was *yang*, the male force, creative and strong. The earth was *yin*, the feminine, maternal force. *Yin* and *Yang* followed one another in a perfect circle: *yang*, hot, dry light from the Sun, ceded its place to the dark, humid and cold light of the Moon, *yin*.

The concepts of Brazilian natives were no different. Perhaps they were richer in their imagination.

The Brazilian people maintain clear astro-idolatrous vestiges inherited from the Europeans, Negroes and Amerindians. Such vestiges may be observed in the dazzling impression of the Sun, the Moon, the luminous multitude of the stars and in the mystery of meteorological phenomena; they are evident in customs, respectful gestures of veneration, rote obedience to ritual, forbidden in former times. The biggest contingents of these vestiges originate in the Portuguese, a compendium of peoples and bearers of traditions from the Orient via Moorish Iberia. Next came the Negro slave and, closing the circle, the native. The Sun, the Moon, the stars, are invoked in the prayers and psalms, which are superstitious, but enjoy incredible popular prestige, with allusions to catholic hagiology. There is the prayer to the Sun and the prayer to the stars; powerful psalms to attract and fixate love. The day, due to the Sun's presence, is revered, providing special times for supplication and witchcraft, closed hours, open hours, the first and last sunlight. There is also a prayer at midday. As a result, the Sun takes part in this instinctive religion, but already becoming articulate in hearthside prayers , exactly as in Rome. It is therefore the inviolability of the flame, embers, trivet, oven stone, the ceremonial requesting fire etc….. The Moon is invoked abundantly in nursery rhymes and there are requests and appeals to the star, faithful to the tradition that it multiplies and augments things submitted to its influence. Stars cure infirmity, buboes.

An Initiation to Astro-idolatry

The stars are present in the initiation rite for young girls of the Uanana nation. When they attain puberty, the Moon serves initially to mark the time when menstruation comes. In the initiation rite, the chief shaman, with a large cigarette in his hand, says: Moon, here is a woman whom Mahsenkeró (Jurupari, in

the Uanana language) has deflowered by your hand; help me to make her perfect so that she might be given to the Sun! Make her as beautiful as you! For the male sex, there is the *Kamuanú Nindé*, the boys' initiation in Mehsenkeró customs. Both initiations use the Moon to measure time. For the male sex, the first initiation takes place at age eight, when the boys learn about the ritual instruments forbidden to children and women. The second initiation, which complements the *Kamuaná Nindé*, is only performed when the initiated boys become apt for fecundation. The time of preparation for the initiation obeys the phases of the Moon. The beginning of the ceremony is an invocation to the Sun (Sen), to the Moon (also Sen) and to the Pleiades (Itapitiontara):

Behold the Sun
Behold the Moon
Behold the Pleiades
They will take up our customs
Which Mahsenkeró teaches us
O Sun, warm their hearts
O Moon, heat their anger
O Pleiades, make their speech sweet
And may they know how to keep
Al that Mahsenkeró teaches.
O Sun, make their hearts brave
O Moon, sweeten their talk
O Pleiades, teach them to flee from
From one day telling all.

In Rondônia, Roquete Pinto (Roquette-Pinto, 1919) describes a curious festive dance which he is supposed to have watched during his stay, in 1912, among the Nambikuara natives, in Northern Mato Grosso. Let us take a look at the account:

Men, women and girls took part in the festive dance. To the sound of an interminable chant, a large circle was formed. The women on the men's left made up succeeding pairs, closing the circle; each man put his hand on the shoulder on his respective "lady". Within the circle, three girls of the same age, more or less, accompanied them in file, very close together, with their eyes lowered, their hands crossed over their breasts. The one in the middle served as the axis for this whole choreographic system…

It started going round at seven in he evening, the chanting did not stop. The girls, without protest, left regular dusty marks on the ground, which the light lit up perfectly. One might say that they placed their feet in the same tracks made the first time around. At midnight, beside the bonfires, which each family lit, the old people were asleep; some were mumbling, lighting rope wicks, which looked like small rubies. And in the circle, sweating, covered in dust, looking more dead than alive, we all joined the chorus:

Tagnani-i Tagnani-i
Tangré!

And so it continued for the rest of the night. When one of us escaped, looking for his hammock, two or three strapping big fellows, followed, talking a lot; and pushed the deserter back to his position…

In his considerations about this Tagnani tribal dance, Roquete Pinto believes, by virtue of the evocation of the name Tangrê, which, in the native language means star, that it is possible to interpret this dance as a very primitive manifestation of astro-idolatry. On the other hand, as there existed three figures which made up the dance's centre, Roquete Pinto's thoughts upon seeing it, went back to the famous asterism of the Three Marys, which is located within the constellation of Orion.

In his contacts, Roquete Pinto discovered that the Nambikuaras, apart from distinguishing between the directions of the sunrise and the sunset, that is, the daily points where the Sun is born and disappears, determined the times by day from the position of the Sun in relation to the horizon. They thus were able to point out with a gesture, where the Sun would be at a predetermined hour.

They did not seem to distinguish between the constellations, since they always gave the same name to whatever star they pointed out. Tangrê meant Orion's belt and the Three Marys, as well as the biggest stars in this constellation: Rigel and Belatrix.

During the total eclipse of the Sun on October 10th, 1912, very easily visible from the northern mountain range, in Mato Grosso do Norte, Roquete Pinto, there at the time, saw that the eclipse did not impress the Nambikuaras in the very least.

According to Roquete Pinto's conclusions, their religion was pantheistic fetishism, characteristic of the more backward native groups, although among the most advanced, such as the Tagnanis, who lived on the banks of the Amazon River, North of the city of Vilhema, he did find innumerable signs of nascent astro-idolatry, such as the dance described above.

It appears that there exists a correlation between the cultural development of prehistoric peoples and astro-idolatry. To check such a conclusion, we could not only limit ourselves to Brazil's natives, but also extend it to all the other peoples, among them, those of pre-Columbian America, such as the Maias, Incas etc.

The explanation for this relationship is associated with the agricultural needs of primitive peoples, who, in time, ended up discovering the existence of a relationship between periods rains or floods with the appearance of certain stellar groups, such as the Pleiades and the Hiades. Moreover, the very name of this latter cluster, the Hiades, means rain, by virtue of its appearance announcing the period of the arrival of the rains among the inhabitants of Mesopotamia. It is believed that, as these correlations began to be discovered by the natives, they, who did not know the fundamental cause of the rains, were led to discover, by their worship of the stars, a way of intervening with the forces of nature which they did not yet know about. In this case, the Nambikuaras resorted to dancing.

In fact, man, even the most primitive one, feels the need to discover, and, especially, to organize his observations into systems of ideas, which, apart from furnishing the illusory satisfaction of understanding the phenomenon, offers them the possibility of foretelling their occurrence and transformations, as also their periodic returns, such as rainy seasons etc.

For the ethnologist, C. Lévi-Strauss, such intellectual systems for explaining and foretelling are equivalent to primitive myths. In a wider generalization, we might say that science is also a vast mythology and astronomy a particular branch of this mythological structure. Indeed, for thousands of years, astronomy was truly mythology, in the traditional sense of the word, where the gods personified forces of nature and substituted, poetically,

various scientific principles, such as we show in our book Astronomy and Poetry, edited in 1977 (De Freitas Mourão, 1977), in which we describe the origins of some of these ideas. Thus astro-idolotry, as Roquete Pinto concluded, would represent a stage of the mental development of primitive peoples.

However, present day science differs fundamentally from other mythologies seeing that it possesses the capacity to enrich itself by changing itself, or better still, suffering additions within well established rules. It tests its predictions by way of observation and experience.

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Inkas Constellation

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Abstract: This article will present some principal constellations of the Inkas, these constellations were collected reading of some manuscripts, chronic and the oral tradition of different peoples Quechua speakers of the Andeas, principally of Cusco, Apurimaq, Ayacucho, Puno, the Altiplano in general and specific location like Cusco downtown, Sacred Valley of the Inkas, Qurawasi, Paucartambo, Marqapata, Quillabamba and many more, they are places where my grandparents and parents were born and where I live. There are many constellation that I knew them by tradition before they are read in manuscript, also there are constellations in the manuscripts, will say they are in some places in the sky, but that by tradition and logic are in other coordinates in the sky, so also there are constellations that do not talk in which they are located or indicated briefly, but by having lived here, by know the traditions, by understand and live the worlview Inka, I was relatively easy locate, clear that there are constellation that are spoken in manuscripts, but has lost its location and its mythology thanks to idolatry extirpators; constellations that are also found in various places, and are of different form and type, but have the same name as in the case of Ch`akana.

Keywords: Archaeoastronomy, Constellations, Inkas, Cusco, Tawantinsuyo.

Introduction

All human beings in different cultures has been questioned itself by the innate curiosity that does these bright point in the sky mean? The ancient Inkas had knowledge that these points are stars, and similar to the other Occidental and Oriental cultures tried to put them in order. Nevertheless, unlike the Occident Cultures, the inka's classification included not only constellations but also individual stars and the dark regions of the sky. Each figure in the sky had a definite meaning: each animal and living being had a representative in the sky that took care about them and was responsible for procreation. For example the Llama constellation had been responsible about all family of auquenides (llama, vicuña, alpaca). There was no star of first magnitude without forming part of a constellation. In this work will be presented a list of constellations well identified in the sky like Machaqway, Llama, Laja manta, Collqa, Chaska punchu, etc. The importance of some constellation for Inka's culture will be explained, telling the legends related to them. This data was collected by our grandparents and great-grandparents and form part of the oral tradition, which is about to lose. Written sources including the Chronics of Polo Ondegardo, Bernave Cobo, Miguel hair Balboa, Monzón, Warochiri anonymous manuscript have also been used. Reviews of the Incas written by Garcilaso de la Vega, Pachaquti Yanqui Salqamayhua, Guaman Poma de Ayala Avendaño, Arriaga, Calancha, and several chronic has been analyzed. Several additional lexicons, today called linguists such as Fray Domingo de Santo Tomas, Ricardo Antonio, Gonzales and Ludovico Olguin, and the Aymara lexicon of Bertoni, has been included into analysis as well as dictionaries of Urton. It is necessary to mention, that only very few data can be rescued from other written sources, because these texts have been written at different times, and include fragments of anterior texts. Since Manqo Qapaq until Atawallpa through the biggest Pachaquteq Inka, the Incas felt a great respect for nature and the universe. So they thought they came hertan and children of the stars. That is why they put names to the individual stars, these groups and regions in the dark sky, and studied them throughout the years and several years to make a calendar based on the cycles of the stars, constellations and the Sun, they called Inti. This calendar allowed them to determine exact dates to plant and harvest different products such as corn, potatoes, cassava, Oqa, coca, peanuts, sweet potatoes, quiwicha, quinoa, etc. This is a contribution to the diet of the people in the whole planet Earth. By observing different constellations during the year, Inkas were able to predict whether the next year will be a good year for agriculture or otherwise. They also followed him to celebrate various ceremonies which had been made in solstices and equinoxes. They gave the names of the following constellations: Qollqa also called onqoy, Urquchillay and catachillay, chuquichinchay, choquechinchay, Chaska Waraqa Machaqway also called the dark constellation the flame with their eyes that called llamaqñawin are the alpha and Beth centaur, Mayu, Yaqana and yutu, quntur, suyuntu and Huaman, orqorara and ranch, foot, chasqa punchu, chaqana, Chaska, Aquayoq and Catuilla, Chuchuqoyllor, Mallki Kotu Sankha, puma yoke, flagstone hayquna, kapuwara wara. Several of these constellations are in a plate of gold Usno the Qorqancha, from which only the drawing made by Pachaquti salqamaywa is conserved.

Types of Inkas Constellations.

As we have studiado and collected, the constellation Inkas are threefold. 1) Constellations of individual star or clusters of star individual, for example Chuchuqoyllor Constellation that are two stars who have been together for Qollqa. 2) Constellations that bind diferent stars such as for example Ch'aska Waraqa thas is the tail of the Scorpion. 3) Constellation formet of bright and dark areas, such as the constellation of Laja Haykuna. And the constellation mixtures between them as for example the llama or Yaqana Constellation that is composed by the dark zone and two bright stars that are called llamaqñawin and are winged Southern Cross.

Principals Inkas constellations

In the Andean worldview there are two philosophies that are deeply rooted in the way of life of people and are the concepts of Paqarina and Waqa that until today we can see; Paqarina is a place (Orqo = hill, mountain, Riti = Snow, Pampa, Qocha = Lagoon, Inti = sun.) were the andean people think that their ancestors came from there, were generally near their homes or which could see them from where they lived or walked. Waqa is a place or thing to which they had great respect and had them as Apus (Gods), generally coincided with the Paqarina, but could also be objects, animals, plants and/or intangible or phenomenological entities, in general anything that caused them admiration, respect, joy, whether or not logically explainable. Have as Waqas also their constellations, many terrestrial waqas had their representation in the sky, too other animals or plants that were not considered waqas had their constellation associated ; these constellations were responsible of care the Waqas that representing, and also to care the animal, plants and things that representing. In the case of animals and plants, they were responsible for procreation to have food in abundance as well as not to harm them for example the Mach`aqway constellation was asked for the Yaqumama not hurt them when they were interned at Amazon.

Among all the variety of Inkas Constellation are:

Qollqa. Is the most important constellation of the Inkas, is the open cluster called the Pleiades, in inguish means barn, were plac-

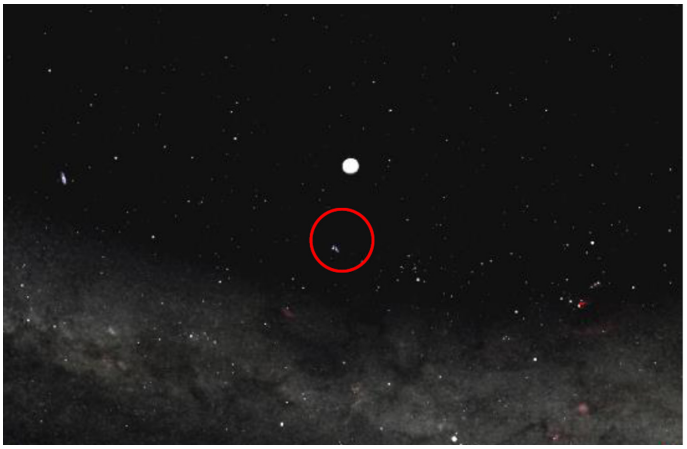


Fig. 1. Qollqa Constellation (Pleyades)

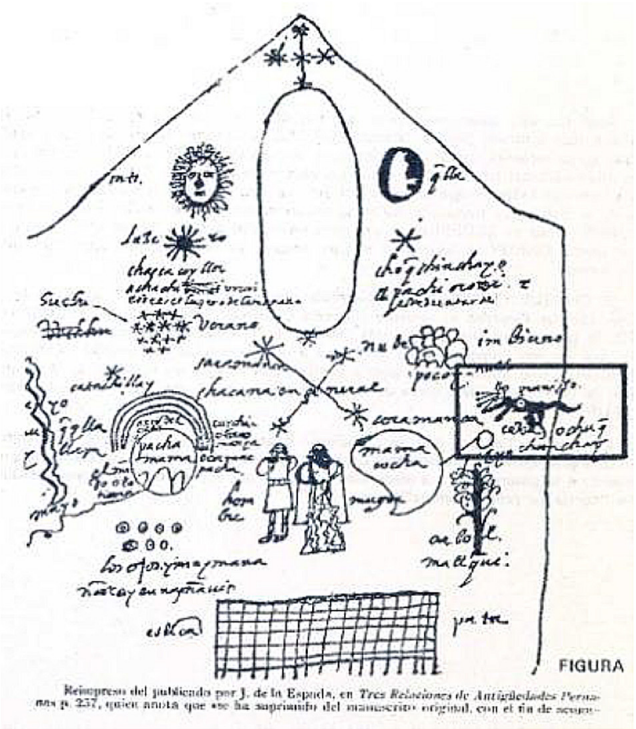


Fig. 2. Qollqa Constellation is on the left side.

es where different dry products were stored as corn or sara in quechua, beans, quinoa, quiwicha and more, mitas product, the mitas were jobs being made to the nobility and to have reserves for times of drought; these places were important because the people knew that if somewhere in the Tawantinsuyu had production problems, then resorted to these reserves so as not to starve, for this reason the constellation representing these sites was therefore Qollqa that was closely linked to food and life and therefore was considered the Paqarina of all the other constellations.

These constellation was regarded as a granary, that at first glance seems like a whole grain seen in the sky (see fig. 1) and was linked to agriculture that this constellation has just heliacal rising winter solistice in june,beginning of freezing time and for this reason it is also called Onqoy which means disease.

In the Inka empire was a person engaged in the temple of Qoriqancha every morning to see that this star appeared on the projection of the hill of Cusco which has an angle of 20º approximately to the horizontal plane. When it was first seen for the Inkas began the year, this period coincided approximately with the June solstice and was made a festival called IntipRaimi.

Fig.3. Special room for monitoring the heliacal rising of Qollca.

This constellation is very important, could not be absent from the picture he drew Pachaquti Salqamaywa (see fig.2).

This Constellation had a special room in the Qoriqancha (see fig. 3), this figure may be noted that there are holes, there were plated gold and silver plates with precious stones inlaid and the spanish with his hunger to steal gold and his desire to extirpate idolatry hat to destroy the stone wall to get the Gold and Silver.

Urquchillay and Qatachillay. These constellations are located in the Constellation Lyra, in that region are three important stars who are Bega Altair and Deneb. Urquchillay means in the Quechua of Cusco an Qurawasi my machito (mean) and Qatachillay means lead to the foothills (Information obtained from Professor Emilio huaman Huillca), If these constellation were from star to star, then in this region should be animals like the llama or lamb, so Urquchillay represented the lambs and therefore is responsible for their care and their procreation, There are also versions that say that these constellation were represented by these only stars Urquchillay to Vega and Qatachillay to Deneb. Appear named in the drawing of Salqamaywa (see fig. 4).

In Cusco and Qurawasi crossover stars were called, I think tha`s because it gives the impression that they are stones that you put into the river to cross and this river in the sky is nothing that Ch `askamayu that is the Milky Way as we can see in fig. 4. and there also must be included the stars Gienach and Sadr.

It also gives the feeling of crossing the Celestial Ecuator with a certain error. We can also interpret Qatachillay from translation, to bring the foothills, and is that just this star is near a region of many stars that look like a hill on whose summit is a nebula NGC7000 and even gives the image of a Volcano.

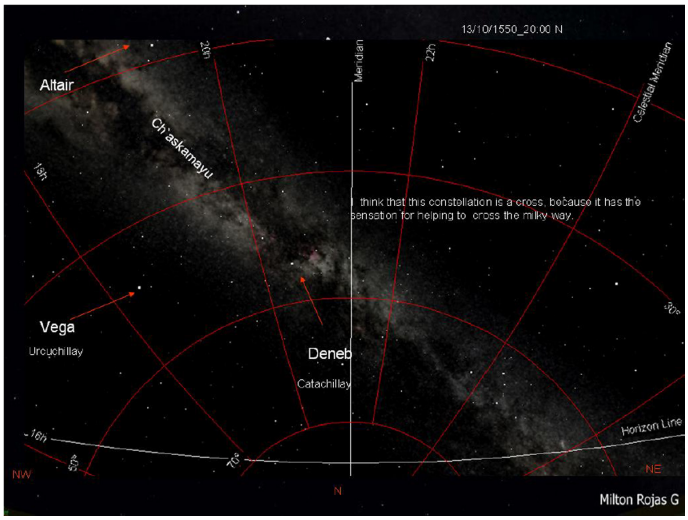
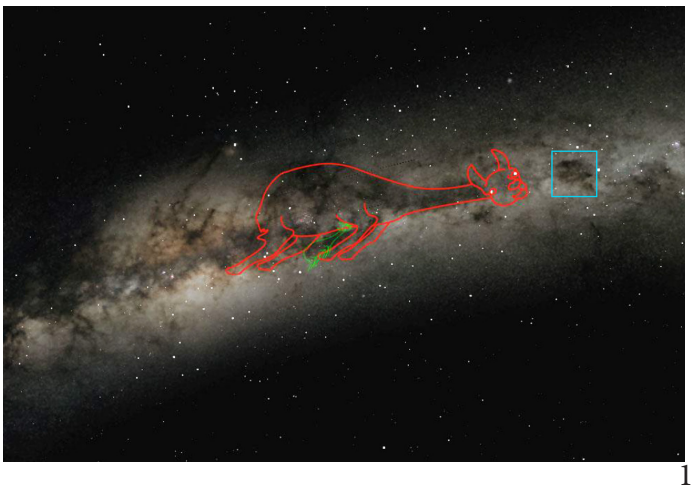


Fig. 4 Urquchillay and Qatachillay Constellation.

Mach`aqway. This Constellation is the tail of the Scorpion (see fig. 5), was known throughout the Tawantinsuyu, since this represented the Snake in general and more in Antisuyu since there live Yaqumama or Anaconda. The Antisuyu is the region of jungle were the Amazon begins and part of this. To this Constellation is begging for the runas to keep them front biting snakes when to be interned to the jungle. Moreover was the representative of Apu terrestrial Mach`aqway that was the Apu of Uju Pacha, Apu of Wisdom, of knowledge.

Fig. 5 Mach`aqway Constellation, Is the tail of Scorpion.

Fig. 6 Llama or Yacana Constellation and Yuthu Constellation.



Llama or Yaqana and Yuthu. These constellation are examples of dark constellations, acording to the oral tradition in the Cusco area, had his eyes (llamaqñawin) to Alpha and Beta of Centaurus Constellation, and this Yaqana swimming in a river of star with a long neck, so it's easy to look the sky and see the constellation even see the baby Llama that breastfeeding (see fig. 6). We can also observe to Yuthu or Perdiz or Partridge, is a bird, that is a dark Constellation and yu can see berween Llamaqñawin an Southern Cross.

Ch`aska Punchu, Chacra, Orqorara, Chakana, Quntur, Suyuntuy, y Huaman. In the Andean, the stars of the Orion Costellation formed by the belt i. e. the three Marías (Mintaka, Alnilam y Alnitak), Betelgeuse, Bellatrix, Rigel y Saiph; have various interpretation and mithologies, for example all these form the constellation of Ch `aska punchu in inglish means Poncho of stars (see fig. 7), the Poncho is a article of clothing that is widely used in the andean due to cold weather in height, has a rectangular shape with an opening in the middle, similar to unku of the Inkas, only that this latter was closed by the sides and had orifice for arms, (see Fig.8)

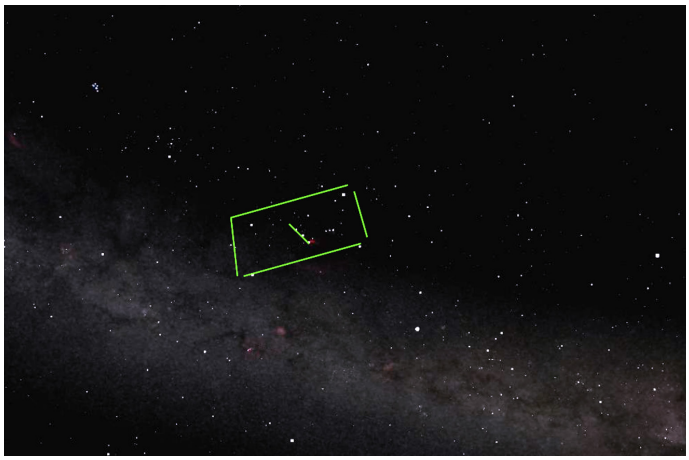


Fig. 7 Ch´aska Punchu, Chacra, Orqorara, Chakana, Quntur, Suyuntuy, d Huaman Constellation.

Fig. 8 In the tirst two photos, you can see to children and gentleman using Punchu and third looks a Unku.

Another interpretation they gave to this rectangle was Chacra (see fig. 9) which is similar to the cultivation area, was very important these areas because how the babies were born, he had a topo (mole) of area to grow and when they married they gave a topo more for the barons and a half over topo for women. When they married was made the Minga in which the people gathered to make theirnew home to the new united cuple and also to help preparate their land for planting by using Chaquitaqllas. The Three Marias is also called Orqorara, translate is a three stars all the same; as shown at the top stop of Salqamaywa figure but Orqo means hill. The two perpendicular stars to these three must be Betelgeuse and Rigel. On the same page of manuscript of Salqamaywa where this the fig. 2, is also drawn to the Three Marias, Be-

telgeuse and Rigel, there is even an oval in the same place where it should be the nebulae M42 and M43 which we believe is the same extended oval located on the large graphic, so it would be a nebula. It could also be that these nebulae has to do with the hill.

The stars of Orion's Belt have their names individually, to Quntur called Mintaka, Alnilam called Suyuntuy and Alnitak called Huaman.
Also the three Marys is called Ch`aka Tinkucheq including Betelgeuse and Rigel, in Inglish means bridge that links, in our opinion this is because across the Celestial Ecuator with a slight error (see fig.10), is like a bridge linking the two hemispheres where they are Betelgeuse in the North and Rigel in the South, it follows that the Inkas knew the Celestial Ecuator. Tested this because they were building as windows that pointed to celestial south pole (see fig. 11).

Also at the Southern Cross was called Ch`akana (see fig. 12) and this appears in the graph of Salkamaywa in which is written Chacana in

Fig. 9 To the left part of Sacred Valley of the Inkas in Cusco were we see several Chacras and to the right a Inka bridge that serves to this day

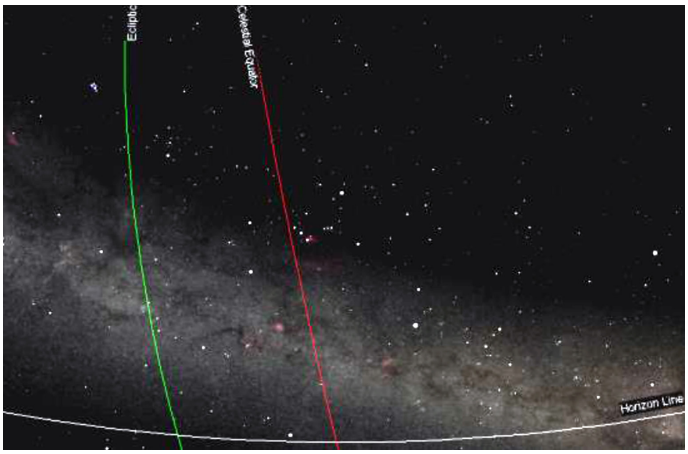


Fig. 10 Ch`aka Tinkucheq Constellation formed for the Orion's Belt, Betelgeuse and Rigel

Fig. 11 Window pointing to the celestial south pole, this construccion is near to salineras of Cusco (It is not the Salineras of Maras)

general. Also can see that the Maiz (corn) and Qoqa (Coca), important in the diet Inka, had his representative stars, the two are the main pale of the Southern Cross, one is called Saramanqa (Pot of maiz) and the other is called Qoqamanqa (Pot of Qoqa).

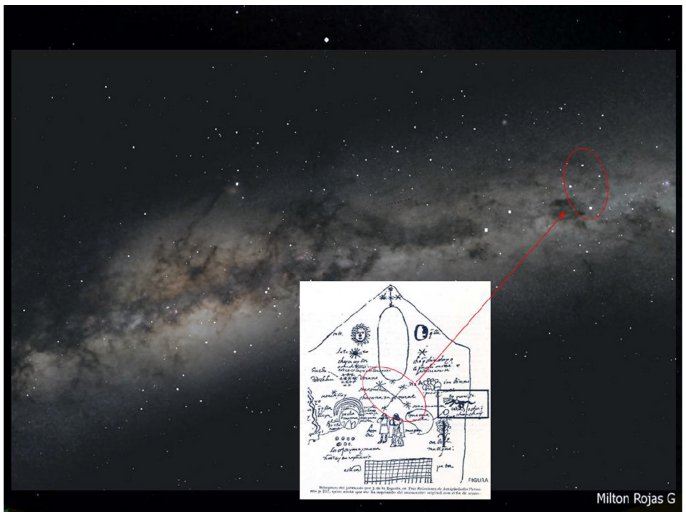


Fig. 12 Ch`akana Constellation, is the Southern Cross. Appears in the salqamaywa picture, we see the two star of main pale of the Southern Cross, one is called Saramanqa (Pot of maiz) and the other is called Qoqamanqa (Pot of Qoqa).

Chuchuqoyllor. This constellation representing the twins, and those born of feet because that means Chuchu; Chuchu also means very dry or Hard, are the two stars that are near to the Pleiades, are the feet of Perseus (see fig . 13).

Fig. 13 Chuchuqoyllor Constellation, near to Qollqa Constellation.

This Constellation was the waqa of the peoples and animals that born different to normal.

Mallki. Is the constellation of the tree, is located in the Aries Constellation, in this form we can see in the horizon; is also drawn and written in the Salqamaywa picture (see fig. 2)
Kotu Sankha. Means in Inglish, coals of fire, is located in the constellation of the Hyades, Aldebaran there is Fire and the stars that are very nears are the coals (see fig 14)

Puma Yunta. It means in Inglish, pair of pumas friends, is located in the Gemini constellation, the eyes of these Pumas are the stars Castor and Pollux (see fig. 15). It is recalled that in the mythology Inka the Puma, the Quntur (Condor) and the Mach`aqway were considered sacred. The Quntur (Condor) is the Apu of Peace and represented the Hanan Pacha (The space and time of the overworld, World above), the Puma is the Apu of

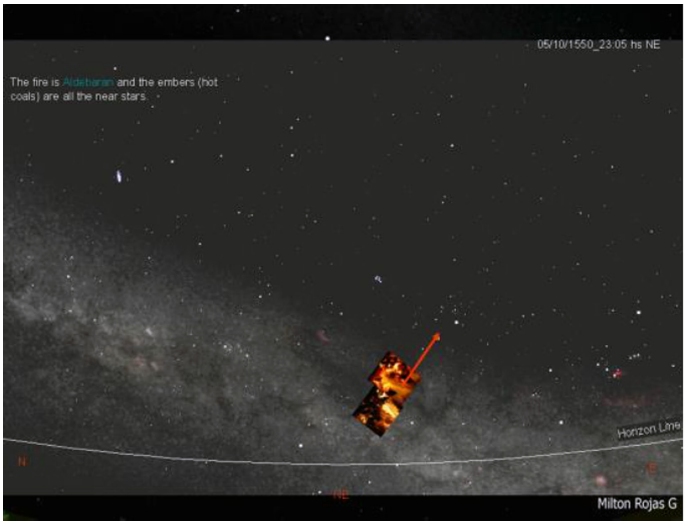


Fig. 15 Chinqana grande, large túnel, behind Saqsaywaman; is said to be connected to Qoriqancha, where was the room dedicated to Qollqa.

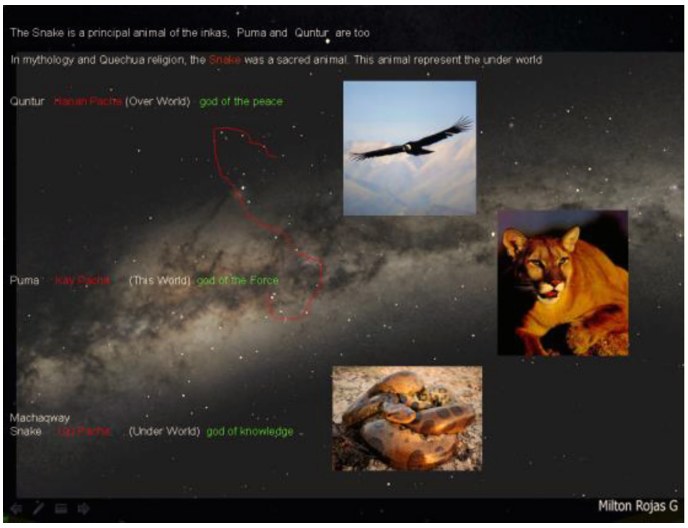


Fig. 16 Are observed at Quntur, Puma and Mach`aqway, in the Inkas mythology were considered Apus.

the Force and represented the Kay Pacha (Space and time of this World, we perceive with our senses) and the Mach`aqway is Apu of Wisdom and knowledge, and represents the Uju Pacha (The space and time of the Underworld) (see fig.16).

Laja Haykuna. It means entry into the darkness, this constellation is located in the constellation of Argo Navis, above of the May Cross (see fig. 17), was like a door to the Chinqana (tunnel) (see fig18)

Conclusion

We have given a summary of the most important constellations of the Inkas, however there are many more that could not be presented, we will present in new works.

Some of these constellations are still present in the minds of rural people in Cusco, in general andean peruvian people, but thanks to idolatry extirpator have been long forgotten by the people. The presented here were obtained mainly by asking to locals peoples, grandparents of provinces of Cusco and its surroundings, principally to Amauta Emilio Huaman Huillca, with which we are heirs of the Inka blood. Also were some taken of the chronicles as Pachaquti Yanqui Salkamaywa, Guaman Poma de Ayala, Blas Valera, manuscript Warochirí, Ondegardo Polo, and more.

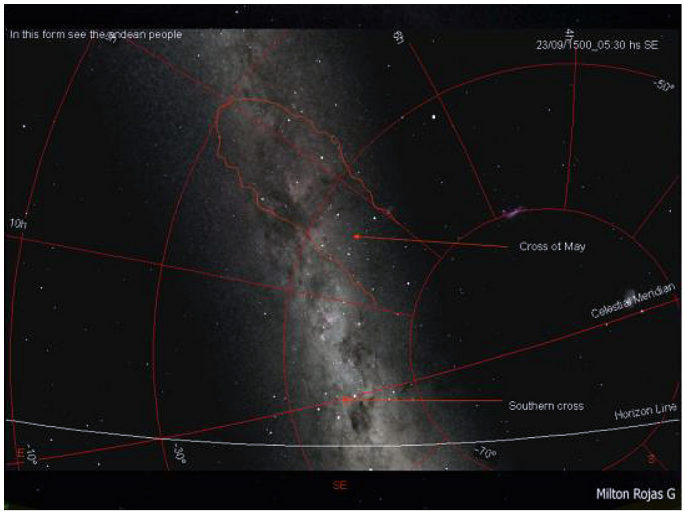


Fig. 17 Laja Haykuna Constellation, jeans entry into the darkness, near to May Cross Constellation.

The fundamental principle of the Inca's world-view was the AYNI ("reciprocity"). Another two basic principles - Mita and Minka - are based on AYNI. Mita and Minka are two ways of work organization based on reciprocity. This world-view is also reflected in the constellations. The inkas believed that the constellations were taking care and protecting the animals or plants which represented following the same principle of reciprocity. It is one of main reasons why the Incas were building the temples and performing the ceremonies to worship these constellations.

It is important to disseminate this knowledge is already being lost, because with them we will recover the worldview, philosophy and lifestyle of the Inkas. The Inkas had great progress especially in relation to the Pachamama (Mother Earth), time and space in general, so we can at least do not explode much to our planet.

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General Topics

IYA2009USA: Cultural Astronomy and Storytelling

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Abstract: In August 2008, I was appointed chair of the Cultural Astronomy and Storytelling Group for the International Year of Astronomy 2009 in the United States of America. The goals of the group were to plan and execute a series of events and projects that highlighted cultural astronomy, storytelling, and the ethnic diversity of the United States. I present an overview of our projects highlighting our achievements (the Cultural Astronomy Summer School, the Barnes & Noble Book events, StarryTelling, Cultural Astronomy Films), mentioning our failures, and assessing the impact of our activities on the American public. An achievement was the completion of the film Hubble's Diverse Universe (HDU), a 45 minute documentary that focuses on African American and Hispanic American astrophysicist.

Keywords: IYA2009, Cultural Astronomy, Diversity, Outreach, Astronomy

Defining Cultural Astronomy

Cultural Astronomy is a broad discipline that is the scientific study of the many ways that humans interact with the sky. It includes folkloric studies of the myths, legends, and religions associated with the night sky and celestial bodies on one hand; and the history of astronomers on the other hand with everything in between. Cultural astronomy as a discipline does not serve the purpose of promoting astronomy and advancing scientific or modern astronomy, however, cultural astronomy is a synergistic partner in such activities; because oftentimes, the results of cultural astronomy research are used by astronomers in their classes and outreach activities. For IYA2009, it was necessary to provide definitions for visitors to the internet site: See http://astronomy2009.us/storytelling/ where Cultural Astronomy and the sub-disciplines of Ethnoastronomy, Archaeoastronomy, History of Astronomy, and Historical Astronomy are defined.

USA Team Members

The late Dennis Lamenti, a graduate student at the University of Indiana and a member of the Navajo Native American group, had made the case and fought for the existence of the Cultural Astronomy and Storytelling working group (CAST) in the USA IYA2009 efforts. The final working group members were invited in August 2008 to participate. Cultural Astronomy by definition is interdisciplinary and thus the team members were drawn from a variety of disciplines. The most active members had already done some work in cultural astronomy or regularly did astronomy related outreach before joining the team. Most teammembers were drawn from the cultural astronomy community, two were astronomers known for their outreach activities, and two were professional storytellers that specialized on stories about the sky. See Table 1 for details on individual team members. Not all of the members of the group completed IYA2009 activities, some did not contribute to the working group in any way, yet the choice was made to keep everyone's names on the official website regardless of their contribution.

Group Members:

Susana Deustua	IYA2009USA Co-Chair Astronomer at the Space Telescope Institute
Thomas Hockey	Professor in Earth Sciences at University of Northern Iowa
Jarita Holbrook (Chair)	Research Scientist in the Bureau of Applied Research in Anthropology at the University of Arizona
Timothy Livengood	Researcher at the National Center for Earth and Space Science Education (NCESSE) (URL = http://ncesse.org/), NASA/GSFC, and Voices in the Glen (http://voicesintheglen.org/)
J. Kim Malvile	Professor of Astrophysical & Planetary Sciences at University of Colorado
Hakeem Oluseyi	Assistant Professor of Physics & Space Sciences at the Florida Institute of Technology
Derek Pitts	Chief Astronomer at the Franklin Institute
Barbara Tedlock	Professor of Anthropology at SUNY Buffalo
Elizabeth Wallace	Founder of Starrytelling

Diversity

Perhaps the biggest contribution that the Cultural Astronomy and Storytelling group brought to IYA2009USA was diversity. The United States consists of Indigenous Native Americans and immigrants from all parts of the world. The population of professional astronomers in the United States in no way reflects this diversity, and the leaders of IYA2009USA were aware of this disparity along with the gender disparity. Beginning with the composition of the working group four of the nine team members were women and three were African American; thus, for the USA the CAST working group was the most diverse. CAST activities that included a storytelling component presented different meanings attributed to the sky and celestial bodies from around the world especially representing indigenous cultures that are normally not associated with astronomy. Finally CAST targeted diverse communities for their activities such as African American, Native American, and religious communities.

Projects and Activities

The cornerstone project for the Cultural Astronomy and Storytelling group was to create films that reflected the diversity of astronomy. Other CAST activities included hosting star parties, K14 school visits, and cultural astronomy lectures.

The Films and Film Festival

Four films were proposed for the Cultural Astronomy and Storytelling group: Hubble's Diverse Universe, Hagoromo: A Japanese Celestial Story, 5 Minutes at 7 Degrees North, and Skies Alive!

Of these four proposed films, only one was funded and completed: Hubble's Diverse Universe. Briefly, Hagaromo proposed by Tom Hockey was to be a dramatization of the Japanese legend of the stars Vega and Altair and with the Milky Way as the celestial river that divides them. 5 Minutes at 7 Degrees North proposed by Jarita Holbrook was to be a documentary film about the 2009 total solar eclipse in the US Marshall Island and the American astronomers doing science during the eclipse. Skies Alive! proposed by Elizabeth Wallace was to be a film festival for American children of films created by American children with the best entries being compiled together into the final film. Hubble's Diverse Universe proposed by Jarita Holbrook focused on African-American and Hispanic American astronomers and astrophysicists and their connections to the Hubble Space Telescope. The documentary shows the diversity found within the astronomy community. It premiered in July 2009 and continues to have showings throughout the USA. Hubble's Diverse Universe was supported by a NASA grant that was submitted in 2008 and the film was originally not proposed to be part of IYA2009, however, it became one of the biggest successes of CAST.

Star Parties

Star Parties are group events that include viewing through telescopes. Though star parties usually take place at night, the team conducted both daytime and nighttime star parties during 2009. During the daytime events Venus, the Sun, and the Moon were viewed. What made CAST team star parties unique is that they always had storytelling activities in conjunction with telescope viewing. CAST members often partnered with professional storytellers who donated their time for IYA2009USA. Noteworthy are the star party with storytelling events that occurred in December 2008 and January 2009 at the Tucson Barnes & Nobles stores. These were fundraising events that were nationwide, but less than $100 was raised overall.

School Visits and Lectures

Team members visited schools to talk about astronomy, cultural astronomy, and IYA2009. Visits included a powerpoint presentation and question and answers. Cultural Astronomy lectures were included in IYA2009 activities nationwide. As mentioned in the Diversity section, these lectures were events were hosted by diverse communities. IYA2009USA Cultural Astronomy and Storytelling activities were also reported at Cultural Astronomy conferences such as those of the AAS Historical Astronomy Division and the European Cultural Astronomy Society.

Sponsorship

The group also lent their name to conferences and activities throughout the USA that were initiated by non-team members such at the Conference on Archaeoastronomy of the American Southwest in June.

The Cultural Astronomy Summer School

The first Cultural Astronomy Summer School took place in conjunction with the AAS summer meeting (2009) in Pasadena. The goal was to teach astronomy graduate students, postdocs, and educators cultural astronomy that could enhance their teaching. Organized by Tom Hockey and subsidized by AAS Historical Astronomy Division, the Summer School brought together prominent scholars Stephen McCluskey, Ed Krupp, and Joann Eisberg. Associate Professor of Astronomy (Chaffey College) Joann Eisberg taught history of astronomy, Professor Emeritus (University of West Virginia) Stephen McCluskey taught indigenous astronomy, and Griffith Observatory Director Ed Krupp focused on time keeping, navigation, and calendars. Sixteen people participated in the Summer School.

IYA2009 and Beyond

The Cultural Astronomy and Storytelling group has planned many activities that will continue beyond IYA2009:

Hubble's Diverse Universe

The documentary film Hubble's Diverse Universe continues to screen throughout the USA. In 2012 the film had a successful festival run being accepted into four film festivals. There are plans to put the entire film online in 2013.

Skies Alive! Film Competition and Festival

The film festival invites amateur and professional filmmakers to submit original works that tell a story about the sky, astronomers, or otherwise link to cultural astronomy. There are six film categories for the competition. The Skies Alive! Film Competition's website is also under development and team members are helping to raise funds for the competition. Until funding is secured the festival cannot move forward.

Cultural Astronomy Walking Maps

The Cultural Astronomy Walking Map project is an effort to get communities to create maps of those things that can be found that are related to astronomy including celestial street names, observatories, and sundials. The project consists of a website which has instructions, suggestions, and a place to download maps that have already been created. This project is a way to get people to recognize the history and culture of astronomy within their own communities.

Special Issue of Communicating Astronomy to the Public (CAP)

Jarita Holbrook guest edited an issue of CAP focused on Cultural Astronomy and IYA2009 worldwide. IYA2009 single point of contacts were solicited to write a small report on their activities that included storytelling and other cultural astronomy content. The result is CAP volume 9 published in 2010.

Conclusions

IYA2009USA was an opportunity for cultural astronomy scholars to engage in outreach and education. The Cultural Astronomy and Storytelling group undertook several projects that were successful, however there were many more fantastic projects proposed by the group that were unable to move forward due to lack of funds: three films, a film festival, a Cultural Astronomy study abroad, and podcasts. IYA2009 offered an opportunity to introduce the USA and the world to cultural astronomy and it was an opportunity that was not missed.

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Cosmic Players: Simulating, Understanding and Communicating Astronomical Phenomena and Processes by Games

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Abstract: Through "games", not only basic structures and interrelationships of personal and social life, but also some astronomical phenomena can be modelled and understood. Games help to practise factual knowledge in a practical way, using psychological as well as pedagogical methods. Quite often, games are associated with myth, ritual, dance and fortune-telling. Among the many different games that have been known in cultures around the world since ancient times, there are some that have astronomical significance, sometimes not apparent at first glance. These "astral games" illustrate the rhythm of time, the movement of celestial bodies around the world axis or on the ecliptic, the particular shape of constellations, the basic features of calendar calculation, the structure of the world (according to ancient views) or even the functionality of astronomical instruments (example sundial). Sometimes even the structure of architectural monuments follows the conception of specific cosmic games. The study provides an overview of the topic.

Keywords: Cosmic games. astronomical phenomena, cosmology, cosmic dance, fortune telling, spiritual voyage, astro–edutainment

Introduction

Playing, a vital activity, already well known from advanced animals, is an a priori of human personal and social development (Fink, 1960; van Binsbergen, 1996; Huizinga, 1999; Handelman, 2005; Hiltebeitel, 2005; MacAloon, 2005; Hillborn, 2008.). It is quite a particular way humans become familiar with the natural world around them, social structures, and themselves. Playing can be defined as a voluntary activity, using peculiar, goal-oriented tools, following specific rules, and being aware of coincidences. In most cases, interaction is an essential element of games. By playing, dynamic phenomena of nature and crucial personal and social life structures can be imitated, modelled, and mastered. Games can help to exercise practical skills and serve psychological and educational purposes. They require specific strategies or are devoted to chance. They are related to myths, rituals, dance, divination, and foretelling. Among the many different games known by cultures across the world and throughout time, there exist such, which are loaded with an astronomical meaning (Dong, 2001; Handelman & Shulman, 1997; Handelman, 2005; Masayoshi, 2005; Dunn-Venturi & Schädler, 2006; E-Wha, L. & Park, J.-H., 2006: 21-23; Shotwell, 2007; Shotwell, 2008). There are numerous variants of ancient games, partially with modern successors (Murray, 1952; Bell, 1979; Schädler, 2008; Glonnegger, 2009). Thus this study concentrates on some fundamental astronomical characteristics of a couple of selected games. Finally, the idea of a new approach to Astro–Edutainment by Games is presented.

The Age of Games

There are reliable evidences that the history of games can be traced back several Millennia, at least to the 4th Millennium BCE (Culin, 1895, 1898; Erasmus, 1952: 381-382; Murray, 1952; Brown, 1964; Finkel, 1991; Klejn, 1999; Glonnegger, 1999; Parlett, 1999; Röllicke, 1999; Berger, 2004; Hiltebeitel, 2005: 3260; Masayoshi, 2005 ; Shotwell, 2007; Shotwell, 2008; Finkel, 2007; Mark, 2007; Schädler, 2008). But, probably, the cultural history of games goes back to the Neolithic epoch, 6th to 7th Millennium BCE (Kirkbride, 1966; Rollefson, 1992; Rollefson, 1996; Shishido, 1997). It is still discussed whether games' roots are in the Upper Palaeolithic epoch (Pletser & Huylebrouck, 1999). Some of the games share common concepts of design. They build certain game families, which gives evidence that they have a common genealogy.

The World as a Game

According to specific concepts of ancient cultures, the world is a tremendous play of belligerent powers. That creates and destructs spatiotemporal entities for an observer's perception, triggered by regularity and chance. People tried to model, imitate, and master this principal nature of existence by fabricating astral or cosmic plays (Aberle, 1942; Heesterman, 1957; Luchterhand, 1994; Handelman & Shulman, 1997; Daryaee, 2002; Shotwell, 2006). The general idea of these is as follows: A spatial framework exists, which acts as a stage for the spectacle and a set of celestial actors. The reference system is given by the earth's horizontal plane or is established by the zodiacal belt like a heavenly ground. Both are copied in playing surfaces, game and divination boards or dance floors. The acting community consists of the sun, the moon, and the classical five planets. Of course, there exist some perturbators like meteors, comets, new stars (novae, supernovae), the aurora borealis, meteorological phenomena, and others. These add a hazard chaotic component to the cosmic regularities just like the throw of knucklebones (astragaloi), sticks, cowries, nuts, dices or other objects to the laws of a game (Lüders, 1907: 16-20; Handelman & Shulman, 1997: 61-68). The cyclical moving sun, moon, and five planets, related to the fixed stars, are thought to be special tokens, rhythmically set in the cosmic play (Kurke, 1999: 258). In particular, Saturn, Jupiter, and Mars, which periodically are moving along epicycles back and forth, made people think that the celestial bodies play tag with each other, like young animals or children. While being in conjunction with the sun and obscured by daylight, stars, moon, and planets seem concealed from the observer. Short before or after passing by (heliacally rising / setting) the daystar or positioned at the opposite (apparent cosmic setting / apparent acronychal rising), skywatchers spot them again. Archaic humans compared this celestial hustle and bustle with the children's play of hiding and sought, with a wild chase, or with dancing. Thus games are very suitable to model the spatiotemporal structure of the cosmos tangibly.

The Cosmic Hazard Chaotic Component and Fortune–Telling

In a letter dating from the 4th of December 1926, Albert Einstein wrote to Max Born: «Quantum mechanics is very worthy of regard. But an inner voice tells me that this is not yet the right track. The theory yields much, but it hardly brings us closer to the Old One's secrets. I, in any case, am convinced the He [the lord] is not playing dice.» (Einstein & Born, 1971: 91) However, archaic people and modern quantum physicists are thinking different: The hazard essentially participates in the process of the world. Ancient people globally used tossing by Mikado like games for divination (Culin, 1898a, 1898b, 1902). According to the ancient Indians, time and chance are deeply related: They thought that the seasons (ṛtū) are personalised as six men, who play with golden and silver dice (Mahābhārata: Book XIII, 2368, 2381; Huizinga 2002: 57). The Egyptian god Thoth (ḏḥw-

ty) gambled with Khonsu, the moon, to win 1/72 of its light (five days). He then added these to the initially 360 days of the year and got 365 days. The Old German myths tell that after the primordial chaos was ordered into a cosmos, the gods (Æsir) came together to throw dice on golden game boards (De Vries, 1957: 154). During doom, they will be lost. Afterwards, the gods will be reborn, and they will rediscover their originally game boards. The ancient Indians handed down the story of Siva playing dice with his wife, affecting the whole world whereby. Another alternative was that the gods were like dice, giving wealth and poverty (White, 1989: 288-289; Hiltebeitel, 2005: 3263-3264). In this latter case, it would not be a god or the gods who played dice with the universe but, instead, the universe that played dice with the gods and, by extension, with all living creatures (Handelman & Shulman, 1997: 61-68). Similar ideas are delivered by people in other ancient cultures, e.g. by the ancient Hellenic (Kurke, 1999: 257). It can be attested that there is a close relationship between certain mantic practises and cosmic games.

The World as Competition of Powers – Antagonistic Matches

Ancient people were aware of competing for cosmic powers, which antagonistically create, influence, and destruct all world phenomena. California Native Americans, for example, the Chumash and Yokuts, consider the world an awesome cosmic battle game. Two teams compete. The result determines the wealth or penury of people in the coming year (Werness, 2000: 112). The observation of fundamental polarities in nature and culture, for example, light and darkness, day and night, summer and winter, sun and moon, male and female, right and left, good and evil, life and death, and many others, led on to modelling them in matches (Culin, 1898: 245-252; Gaster, 1938; Cammann, 1946; Hiltebeitel, 2005: 3260; MacAloon, 2005: 3266.). The antagonistic playing powers are made «tangible» as certain actors and symbolised by particular objects, which both follow a classification in multiple binaries (Ivanov, 1983). Concerning team and board games, specific colours, often black and white, are chosen to signify the competitors. The matches occur within a bound area, initially given by a particular locality, landscape or the more abstract natural horizon, denoting the entire world and later by a game board or table. To it, a kind of dividing structure is added, which manifests the dichotomy. That can be a river like in archaic Chinese chess, particular fields that prevent passing, as known from many games, a let or something else. However, the dividing object is not an entire boundary but is semi-permeable according to specified rules. In astral games, the polarities of day and night, the seasons, sun and moon, the star phases, the diametrical positions of stars and asterism contribute to the conceptions of a celestial competition or even a battle.

Cross and Circle Games – Models of the Centred Cosmos

All over the world and throughout several millennia up to now, there exists a family of board games, which initially consisted of a circle divided by a cross into four equal sectors: Liu Po (Liu Bo), Ashte Kashte, Pachisi, Chopat (Chaupat), Chaupar, Patolli, Yut (Nyout, Yoot, Yunnori), Tafl, Ludo, Mensch–ärgere–dich–nicht, and others (Tylor, 1879). The Mesoamerican Pecked Cross Circle probably belongs to the same category if it is considered a game (Aveni, Hartung & Buckingham, 1978). Frequently, mostly in later times, the circle was omitted. This type of game board refers to ancient concepts about the centre of the world, the cosmic axis, cardinality, the layered cosmos, and the orbit of celestial bodies. The cosmographical design, however, appears closely amalgamated with hierarchical graded power. That shows up in socio-political systems. It also illustrates ideas concerning personal psychosomatic transformation and the passage to other realms of the cosmos, which are processes of creation, destruction, and recreation during life and beyond.

The four sections of the game board correspond with the spatial quarters of the world and the temporal ones, which are the four seasons (Schuster, 1936; Hiltebeitel, 2005: 3260). North American Natives have a game of tossing with arrows, which are, by specific colouring, designated to each quarter of the world (Culin, 1898: 247-252). They regard the opposite faces of the rods, which are signified with white and black colours, indicating light and darkness, day and night, and the male (active) and female (passive) cosmic power (Culin, 1894: 355-358). A further bisection of the four quarters creates eight equal parts. Continuing the process leads to 16, 32, 64. These numbers are all well–known from different game boards, geomantic instruments, and wind roses. It is also interesting that a combination of the number of the main cardinal directions with the points of summer and winter solstices on the horizon gives the number 8, too. Some of the numbers resulting from a successive halving, starting with a bisected circle, were essential for ancient spatial astronomical and terrestrial division and calendric calculations (Menon, 1932: 41).

Moreover, the hub or the central area is very significant for the cross and circle games. Odd numbers, e.g., 5, 9, 17, arise by adding the middle to the even number of cardinal points. The centre is emphasised by a hollow, a particular bounds area, a geometrical figure, an asterism, depictions of divine beings, or something else. Often it coincides with the essential goal of the play. The high relevance of the centre is understandable by archaic perceptions: According to ancient cultures, only at the hub of the world, it is possible to get in contact with creative power and knowledge (Rappenglück, 2002: 161). In a 2D view, the centre was seen as the point of origin. Out of it, a potential cosmos unfolded itself as reality in different areas and into which it contracted again. A 3D perspective recognised the polar cosmic axis, holding up, connecting, and piercing the hierarchically arranged cosmic spheres. According to an old way of speaking, these are other worlds (worlds, skies), often equated with different energetic and psychical levels. Mostly ancient people believed in three layers – the sky, the earth, and the underworld. Representations of specific landscapes, and the plants, animals, humans or gods living there, signify the layers above, in the middle and below. This conception was derived from the orbits of the sun at the summer solstice, equinoxes, and winter solstice. But there existed concepts of seven, nine or other counts of levels, too. In this context, the Babylonian Astrolabe has to be considered, showing a plane image of the three orbits and the constellations, related to divination (Berger, 2000). It may be one of the precursors of cosmic game boards.

The centre and the world–axis were thought to offer a possibility to reach and travel through the hierarchical layered but coexisting realms of the universe (Rappenglück, 2002: 16). It was the place of origin and return. At the centre, sensitive persons tried to get in meditation or ecstasy, rulers were crowned, jurisdiction took place, sacral areas, buildings or cities were founded, and sacrifices were carried out. Entering the centre offered the dead a pivotal transformation into the otherworld. Thus sensitive persons, for example, shamans, and rulers tried to reside in the middle of the world, to access cosmic power and knowledge for their purposes (Berger, 2004: 12-13, Figure 5). The ordinary people also hoped to participate in the forces of the centre and therefore settled closely nearby.

The world–axis often directed a kind of a cosmic circumambulation, a dance or a game. The celestial pole acted as a personal master or mistress of the phenomena in the world, in particular the living beings. Moreover, he was seen as a musician who conducted the music for the cosmic dance. The Hellenic myth of Orpheus gives a famous example. Ancient Indian myths show the polestar as the «master of the dance». His professional female dancing partner is the circumpolar area (Rappenglück, 2002: 159). For millennia people worldwide tried to imitate the rotation of the world–axis, the strata and the stars. A rock engraving from Bohuslän, Sweden, shows an ancient custom (Rappenglück, 2002: 159). There are many examples of ritual circumambulations around a mountain, a rock, a pole, a tree, a temple or through a labyrinth (Hallmann, 1994; Rappenglück, 1999: 257-258; Greene, 2001; Rappenglück, 2002: 159). Some of them are still alive today: the walking around the Kaaba or the Mount Kailash, the whirling dervishes of Sufism, the dancing around the maypole or the tradition of the Los Voladores de Papantla (Dance of the Flyers) in Central America. There is a close relation between cosmic games, dances, and 3D– or 2D labyrinths dedicated to a later study.

The sun circling an upright or inclined pole, set on a horizontal or oblique base, which is a model of the world–axis and establishes a sundial, cause a particular case of a cosmic dance. The shadow plays cast by the sun, which contains a simple but rather appropriate spatiotemporal model of the cosmos, inspired ancient people to transform them into geometric patterns, which provided a basis for certain cross and circle games.

Adding quadruple cardinality to each stratum and putting the three main layers of the sun's yearly course one on top of the other, sized according to the length of the nocturnal arc, a kind of abstract pyramidal «world–mountain» is shaped. Access to the different levels is possible by climbing up the pyramid diagonals, designed as ladders or stairways in the mythic image and the architectural model (Hiltebeitel, 2005: 3260). There is evidence that European folk tales' mythic «Glass Mountain» (Riemschneider, 1968: 137-149) represents this imagination. In principle, the architecture of step pyramids, stupas, and other similar sacral buildings follows the same ideas, but frequently the show more cosmic layers, taking into account the orbits of the moon and planets, too (Lehner, 2006).

Going back to ancient China, the deep connections of divination techniques, the geomantic, and later magnetic compass, astrolabe, and cosmic games are evident (Needham, 1962: 315; Berger, 2000; Berger, 2004: 17). The diviner's board Shih, known as early as the Warren Empires (475–221 BCE), is a cosmic diagram composed of a square plate representing the earth and a discoid plate symbolising the sky rotatably mounted over it. On both important astronomical items are cyclical depicted: the compass–points, the lunar mansions, and the sidereal reference points. Moreover, the Book of Changes (I Ching) symbols are represented as technical terms of divination. Sets of different tokens symbolising cosmic entities and powers are thrown onto and moved around on the playfield. The board was astronomically set into the cardinal directions. Later, perhaps in the 2nd c. BCE, the rotating pointer, originally made from non–magnetic matter, was replaced by a lodestone, which was modelled as a spoon, representing today's Big Dipper asterism. The pointer and some of the tokens magnetic attraction caused the tokens to remain after being thrown. The Shi Lian Guang Ji (13th c. CE) describes a similar instrument. It was equipped with a wooden turtle, containing a metallic inlay and needle, set atop of a conical pivot made of bamboo and revolving in a bearing, made in a wooden plate. The board has 24 lines engraved, indicating the directions. The shape of a turtle is not casually chosen. That animal symbolised the cosmos, the rotational polar world axis, and the primaeval partition of the universe into nine sectors. Remarkably, the Chinese didn't distinguish between the practice of divination aided by such an instrument and the war game of chess. From the Greco–Roman period, comparable divination tools are known, which follow the Cross–and–Circle concept, except the use of a magnetic pointer: the Sphere of Democritus and the Sphere of Petosiris had been used for prognostication, partially referring to astronomical time–reckoning (Bertholet & Ruelle, 1888:I, 86-88). There exist some other examples of astrological divination boards coming from antiquity. One of them is the so-called «Table Daressy» (Egypt), dated to the High Roman Empire (44 BCE–305 CE). It shows in the centre bas–reliefs of sun and moon, surrounded by 12 animals of the Dodekaoros, followed by the 12 constellations of the Hellenic zodiac in the outer circle, starting with Aries (Evans, 2004: 9). The table was used for mantic purposes. As it is known from the Ps.–Callisthenes romance of Alexander (the Great), horoscopes had been cast aided by a pinax and special dices, made of gemstone, each dedicated to a certain planet (Kroll, 1926: I.1-14, 34). The 12 segments symbolised spatiotemporal sections of the cosmos with corresponding stars, which had to be consulted to know the future and fate. The Tabula Bianchini (Evans, 2004: 7-9), which comes from the Aventine in Rome, present a very similar design, except the fact that the zodiac appears twice and that the respective three Decans, associated with each constellation, are displayed at the outermost circle. Moreover, the bas–reliefs of the gods of the planets, related to a specific Decan, are depicted (Vermaseren, 1997: 18-19). From Grand (Vosges, Alsace–Lorraine, France) comes a comparable ivory astrological divination board, dated to the 2nd c. CE (Gundel, 1992: 232; Evans, 2004: 5-7).

Spatiotemporal positioning within the framework of the cosmic board game was made possible by dividing it according to the cardinal points, the seasons, and the cycles of stars, the moon, and planets. People initially developed a 3D model of the world centred and built around the world's polar axis. That was first mapped into a circular and later into a square plan, using the methods of partitioning and borders (Menon, 1932, 36-51). Combining some or all of the presented ideas and making a plane model of the cosmic spatiotemporal layout, one arrives at the shape of different game board families.

The Innermost Centre of the Cosmos: Starting with Merel

Merel (Berger, 2004) boards belong to the oldest game boards known worldwide. Several variations exist, e.g., Three Men's Morris, Six Men's Morris, Nine Men's Morris, and Twelve Men's Morris. They show the most crucial characteristic of a cosmic game. Three Men's Morris is based on the number 9, meaningful in cosmographical, gnomonic, geomantic, and calendric concepts of specific ancient cultures related to the magical square of 3 x 3 (Cammann, 1961).

Often Nine Men's Morris has a unique hollow in the centre. The players put the captured stones there. That symbolised the passage of the defeated dead humans into the other world through the hole at the world's navel, where the cosmic axis runs through the cosmic strata.

The innermost field of the 9 x 9 game board of Tablut (a Tafl variant) is named the «thrown of the king» (Pennick, 1984: 43).

The centre of the Madagascan Fanorona game (Alquerque in Malaysia) is called «the navel». The player, who occupies this field, has power over the world (Pennick, 1984: 44). The ancient Irish game board of Ballinderry embodies the anthropoid corpus of the world with the navel field in the centre and the four quarters in the corners. The game piece of the «king» was set just at the navel point (Pennick, 1984: 54-55, 90-91). Laplanders knew a similar play. In German mythology, the tree Yggdrasil, Odin's throne, extends into the nine worlds (Metzner, 1994; 188-200; Nakhapetjan, 1994). Though younger than merel, the play of skittles continues some of the archaic ideas: The «king» sitting at the throne, centred in the cosmos, was considered the ninepin in the middle of the play (Hirsch, 1965: 210). Interestingly, in the Korean game Yut the king is placed in the centre of the board (I-Hwa et al. 2006: 22; Park 2008). Many other similar examples are known from different cultures all over the world. The geometric figure of the merel could be illustrated by certain animals, too, which mattered in particular games. For example, such a cosmic play is known by the Maori and called «torero» (Levinson & Sherwood, 1984: 129-130). The game board shows the depiction of an octopus, extending his eight tentacles (kawai) like radials. Eight tokens, divided into two sets distinguished by shape or colour, can be moved from the centre to one radial or an adjoined vacant radial. The goal is to prevent any moving of opponent tokens. A Maori myth tells of the octopus body embodying the sky hemisphere with centre and cardinal directions (1 + 8 = 9). The spider is another animal illustrating such a model of the cosmos, which is merel–like. Ancient cultures related the weaving of a cobweb to the construction of the world's structure. There exist depictions of Merels, which emphasise this idea (Berger, 2004: 13, Figure 10). Finally, there is a relationship of the merel to the cosmic turtle, which was well–known by ancient people in Africa, Asia, and South America (Rappenglück, 2006; Eberhard, 1985: 207, 232; Lewis, 2006: 30, 32, 40-41, 44, 46, 50, 54, 57, 60, 62, 66-70, 72, 105, 111, 113, 140, 142, 165 n. 38, 169, n. 81, 171, n. 91). Following ancient Chinese ideas, for example, the division of the world into a grid-like structure consisted of nine fields, creating a magical square, with the centre as the celestial pole or the middle of the earth (Cammann, 1961). A primal cosmic sea surrounds the structure. The magic square refers to the nine cauldrons brought by a female turtle of the north, creating order and balance in the cosmos. The nine fields were mountains, rivers, provinces, tripods, and other things.

A special kind of hopscotch in Germany is the «Enclosure of Nine» (Neunerbox). It relates to the polar world–axis and the solstices cardinal points on the horizon. The Italian people call it Gioco di Bussola, the compass game (Hirsch, 1965: 195-96). That has an analogy in the ancient Chinese game of the «Castle of Nine», which is astral divination by lot, and related to the magical squares Ho Tu and Lo Shu (Berny, 1913: 208-209; Cammann, 1961; Granet, 2000: 128-130, 134, 136-137, 142, 146, 149, 154 188, 199, 218-219, 223, 239, 242, 261, 266, 271; Karpenko, 2004). The hopscotch tradition in Germany (Hirsch, 1966; Hirsch, 1965) makes clear that the initially imitation and representation of the cosmic sectors together with prominent asterisms, rotating around the world axis, was completed by displaying the annual course of the sun and the moon in the «Heaven and Hell» games. The geometrical, as well as the dynamic aspect, unfold thereby in a play or dancing field.

Indian and African stories are about the nine cosmic treasures. According to Celtic people, a holy mill or a cauldron exists at the centre of the Merel. It symbolises creation and regeneration. The four cardinal directions, elements, and winds emanate from this kind of primordial crater (Mohr, 1997: 30–32). The nine muses of Hellenic myths belong to the same topics. The abode of the nine Muses, the cosmic centre in the 3 x 3 square, is to be found on the world mountain and is related to the Great Bear constellation, rotating around the polar world axis helically. That again leads on to the designation of the game as a «mill», more precise a «cosmic mill» (Hirsch, 1965: 96-97; De Santillana & Von Dechend, 1969: 88-89, 98-102, 104-108, 111, 116, 137-138, 140, 146, 388; Pennick, 1986: 67-69): The construction of a horizontal mill with one grinder, one millstone, and one blade whee acts as a model. The centre of the mill is called «bushel»: That is also the name of the Dipper, the Big Dipper, and Polestar in ancient China, which symbolises an exact measure for offerings, a closed space, an excellent standard, and the control of destiny (Schipper, 1993: 72-73). The Sampo myth of the Finnish Kalevala (De Santillana & Von Dechend, 1969: 98-102, 111, 121, 128, 133, 205, 221, 232) gives a similar concept. All this calls in mind again the Chinese divinatory compass tool. It is no time to go further. But finally, the relation of cross and circle games to the shadow stick or sundial (gnomon) has to be briefly stated.

In ancient India, the number nine is associated with the god Agni, responsible for creating fire. The Celts hand down a similar relationship: 81 men take care of the fire rituals at Beltane (Cooper, 1986: 224-225). There is a reason for the relation of the cross and circle games and fire rituals: Some N–S orientated Merels are seen as shadow sticks (König, 1980: 196−198; Berger, 2004: 17-18). Also, Liu Po board pattern, dating from the Han dynasty (206 BCE – 220 CE), were depicted at sundials. Some Liu Po game boards, turtle divination diagrams, and prognostications refer to each other. The Liu Po (Cammann, 1948; Röllicke, 1999; Yang 1952: 124-139; Sen 1999: 29.54.) connected with Weiqi (GO) and the TLV–pattern on cosmic mirrors of the Han Dynasty, can be dated to the 4th c. BCE, but maybe also to the 7th or 6th c. BCE. It served as a mantic instrument and a tool for time–reckoning, based on a specific cosmological concept (Yang, 1947, 1952; Cammann, 1948; Seidel & Kalinowski, 1982: 95-98, 101; Röllicke, 1999; Zeng, 1999). The central square was commonly called «the water». It symbolises the primaeval cosmic power. Around the central field, the 28 lunar mansions were distributed. Liu Po and Weiqi may be precursors of Chinese Star Chess.

Thus nine, the magical square of nine, the Merel etc., symbolised the nucleus of the complete spatiotemporal cosmos, especially its dynamic aspect. This basic idea was transformed and further extended again and again in the initially sacral architecture of altars, simple settlements and cities. The checkerboard initially imitated the parcelling of an acre, of a settlement or a woven textile. According to ancient Indian tradition, people originally carved the game fields into the ground (Lüders, 1907: 13, fn. 3). Thus, the checkerboard design probably comes from a graticule. That was applied to the earth and figuratively to the sky, the heavenly fields, too. Therefore it isn't surprising that the squares on game boards in different languages are called «fields» or «houses» (Menon, 1932: 70-75). Astrology still knows the term «Houses».

The construction of the Hindu temple follows a checkerboard-like grid to implement the cosmic spatiotemporal structure and power (Snodgrass, 1985: 107). It illustrates a tangible representation of the physical and psychical cosmos, according

to the Vastu Purusha Mandala and numerological ideas: The cosmic centre of creation – the gnomonic axis –, the different strata of the empirical and metaphysical world, the unfolding of the universe into cardinality and seasonality, the cycles of sun, moon, planets with the main stations, and some other are manifest in the building. Concerning the ritual construction, the 8 x 8 = 64 and 9 x 9 = 81 squares symbolised the mandala of the universe and thus were very prominent (Cooper, 1986: 224-225). That calls in mind that the Banqueting Hall of Tara (Ireland), related to the layout of the Tafl game, consisted of 9 sections (Botheroyd & Botheroyd, 1992: 253).

Cities in ancient India were designed according to geomantic rituals, cosmological concepts and game boards (Pennick, 1986: 36-39; Menon, 1932) like Sadurangam (5 x 5), Ashte–Kashte (7 x 7) or Ashtāpada (8 x 8). Probably in the 6th or 7th c. AD the Ashtāpada, from which the rules are unknown and seem to be related to the Liu Po, offered a basic board to play Nard (a Persian precursor of Backgammon) and Chaturanga (an Indian precursor of chess). The Chinese variant of Chess Xiangqi (Representational Chess), which perhaps can be traced back to 4th c. BCE (Warring Empire) was called the «Astronomical Game» (Murray, 2002: 121-124).

Celestial Combats and Earthly Battles

Chess represents a specific model of the antagonistic powers of the world, which people considered in celestial combats of seasons, stars, and planets, and in earthly battles of humans (Cammann, 1946; Daryaee, 2002; Mark, 2007). Initially, four persons played chess. That reminds of the original cardinality and seasonality involved in the cosmic cross and circle games (Schuster, 1936). Once, the so–called «Chess of the Four Seasons» also existed, which was a Backgammon variant (Schädler, 1998: 30-31). The Knight's move might remind the retrograde motion of the outer planets (Menon, 1932: 151). However, applying a fleshly military aspect and reducing the number of players to two enhanced the antagonistic topic of the cosmic battle element. Moreover, most of the Chess variants lost the original centre field. That opened the way to a much more dualistic concept of the world, in particular human life.

But there once existed circular variants of the game, which had been designed especially as Celestial Chess. King Alfonso X. (1221–1284 CE), in the Libro de acedrex, dados e tablas (finished 1283; Wollesen, 1990: 277-308), describes this kind of astronomical chess, which earlier was already presented (Schädler, 1998: 48-50) by the Arabic scientist Al–Mas'udi (896-956 CE): The game board shows 12 (= 7 + 4 + 1) concentric circles, each divided in light and dark fields. The innermost four circles signify the four elements fire, air, water, and earth. The orbits of the seven planets follow Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn. The zodiacal signs occupy the outermost circle. Thus the complete circle on the board is divided into 12 sectors, giving the Moon 12 fields and Saturn 24 squares. At the start of the play, one sets the planets in the corresponding houses. The draw happens according to the throw of a seven–sided dice. Following the aspects of the planets, profit and loss are calculated. The game illustrates the changing good and bad influences of the planets on the course of the world and on human life in particular.

In the Persian version Al–Falakiya (Al–Falahia or Kawakib [stars]), the planets were moved by their celestial ranking one to seven squares corresponding to Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn. Sometimes colours played a particular role in the movement of the tokens (Dabīrsīāqī, 1992: 397). The regression of planets within a certain field was imitated by moving back the corresponding numbers of squares. The pieces moved back and forth between the outer and inner circle. If the tokens of paired Sun and Jupiter came together at one side and were in opposition to a couple of Mars and Saturn, the game ended.

Imitating Movements of Celestial Bodies by Ball Games

Ball games offered another possibility to imitate the movement and the antagonistic powers of the celestial bodies (Mendner, 1956; Krickeberg, 1948; HWA 1: 860-863; HWA 8: 258-259; Schroeder, 1955; Cohodas, 1975; Hiltebeitel, 2005: 3260-3261). Sometimes instead of a ball, a disk was used. Frequently, these plays took place at the change of the seasons and were very dedicated to the main point in the sun's annual course. In Christian tradition (England, Germany), the Easter ball games should strengthen the solar force starting with the spring equinox (Berny, 1913: 212). A gilded leather ball was played from East to West. Ball games were also conducted at Carnival, May Day, Ascension Day, Midsummer's Day, and Christmas.

There exists a close connection of such ball games to certain fire rituals. Fire ceremonies (New Fire) and fire drilling were also essential features associated with Mesoamerica ball games (Rice 1999: 44; Uriarte, 2006: 24-26). People constructed special ball courts, shaped like the letter "H ", to imitate the movement of the Sun, Moon, and Venus across the sky and particular their ascend and descend from and into the underworld (Scarborough & Wilcox, 1991; Cohodas, 1975; Linden, 1993; Van Bussel, 2002; Uriarte, 2006: 23-24). The round markers at the ball court indicated access to the underworld, embodied by the narrow alley in the playing field. The Mesoamerican ball games bear upon the Popol Vuh: There once the Hero Twins participated in a ball game against the gods of the underworld to resurrect the Maize God, their father (Schele & Freidel, 1990: 66-67; Miller & Taube, 1993: 43). Thus the ball game expressed deep views about life, death, and regeneration (Cohodas, 1975; Uriarte, 2006).

Finally, an ancient ball game, dated to ca. 2400 BCE, comes from ancient Egypt, played by the pharaohs and their priests (Piccione, 2003a: 36; Crowther, 2007: 28-29): Batting the Ball (seker–hemat). The play was associated with rituals of fertilisation and renewing life in spring. The ball signified the eye of Apep (Apophis), the dangerous snake, which represented the chaotic world. By batting the ball, the pharaoh was able to ward off evil and restore and maintain the balance of cosmic powers. This was closely connected with the ritual of «Overthrowing Apep».

The transformation from this life to the afterlife: Senet / Game of Karma (Snakes and Ladders)

There exist particular games, focusing primarily on the transformation from this life to afterlife, referring to cosmographical ideas (Piccione, 1980; Piccione, 2003b): The Egyptian Senet (ca. 3050 BCE) and the Indo–Tibetan Game of Karma (before 14th c. CE), for example.

The Senet game board shows three parallel lines of 10 squares each. Guided by throwing sticks or bones, two players moved their draughtsmen across the board. By the end of the Eighteenth Dynasty (1293 BCE) the game was intended to illustrate the passage of the departed soul (Ba) through the netherworld. The Senet gaming ritual helped both the living and the dead prepare for their safe journey to Ra. They waited for being united with the sun god

and to achieve resurrection. In the New Kingdom, the game board was associated with the death and new life of Osiris (Orion), who conjoined Ra, correlated to New and Full Moon (Lieven, 2007). During the Greco–Roman period (since the 4th c. BCE), the 30 squares had been equated with the synodical lunar month and later served as an astronomical device to denote the Moon phases.

The Indo–Tibetan Game of Karma (Nagapasa) was played on a board having 72 squares and showing 15 black and red snakes (nagas) (Shimkhada, 1983: 308-322; Topsfield, 1985). The game is dedicated to the liberation from karma by moving through different strata of the universe. The player struggles with the nasty black snakes, which force him back on lower levels of existence. The benevolent red snakes lift him higher towards his liberation. The number of 72 (8 x 9) squares is deeply rooted in Buddhist cosmology. While eight is the number of the world of phenomena, nine symbolises the absolute behind them. Together they set up the nexus of karma, which moves all players on the world scene.

Other Games Illustrating Astronomical Contents

There exist some other games, which illustrate astronomical contents, for example, astronomical card decks (Hargrave, 2003: 108-109, 211) or string figures (Cunnington, 1906; Stolz, 1911; Compton, 1919; Franciscan fathers, 1919: 488-489; Stanley, 1926; Dawkins, 1931; Grimble, 1931; Maude, 1971; Culin 1975: 764; Emory &. Maude, 1979; Shishido, 1983; Shishido &. Noguchi, 1987; Mindt-Paturi, 1988a; Eguchi & Sato, 1996; Rappenglück, B., 2003; Sherman & D'Antoni, 1996-2007). Mostly they served as mnemonic support for memorising essential astronomical facts and procedures. Their purpose is to become familiar with various terms used in astronomy (and astrology) concerning the state of knowledge available at that time. Sometimes a deeper astronomical meaning is suggested, but it is not really clear, as is the case considering the Tarot card deck.

Astro–Edutainment by Games – A New Approach

The strength of indigenous and modern astronomical games in comparison to the standard way of teaching is based on the following points: They stimulate interaction, appeal much more to the senses, thereby improving learning, inseminate knowledge apropos of nothing, enhance team working, they simplify abstract concepts, break down barriers set up by scientific administrations, and last but not least, they bring fun and entertainment (Manxoyi, 2008). There are some reinvented astronomical games: string figures (Mindt-Paturi, 1988b; Paturi, 1996; Shishido, 1997; Sato, 2001), special game boards (e.g. the astronomical version of Monopoly (Made by USAopoly), Constellation (Made by Green Board Games), Stellar Journey (Made by Other Worlds Educational Enterprises), Solar System (Made by Iziko Planetarium, Cape Town), card decks and bingos (Stellar Bingo, Moon Phase Bingo, Sun Bingo (Made by Lake Afton Public Observatory, Wichita, Kansas, USA), Prof. Noggins Outer Space Game), and others. Though some of the traditional games are still played, computer games continuously replace them. Astro–Edutainment can include all kinds of games, from hopscotch to computer games. As it was in ancient times, it is necessary to use one's imagination. We should do our best!

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Astronomy and the Ultimate Culture: Elucidating the Origin of the Universe will spell the Integration of Science, Philosophy and Religion.

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Abstract: The world of astronomy could be at a new and pivotal crossroad. In recent decades the controversial debate on the origin of the universe in relation to the conflict among science, philosophy and religion has reached a crescendo to the extent that humanity is quite confused on how to interpret the nature of the realities of the universe. Is science an atheistic endeavor and are philosophers and prophets of religion just scientific illiterates. Astronomy, the oldest and biggest branch of Science, has been intimately linked to human culture including philosophy and religion for millennia or even longer. Advances in cosmology and astrophysics on the one hand and the natural sciences on the other hand are now producing insights which could, in the coming decade, elucidate in quite concrete scientific details how most probably our universe originated and what could be the nature of the intriguing realities of the universe such as the nature of matter, life, energy, gravity, the mind and consciousness amongst many other riddles. This paper will show a bit of the trends in relation to mindsets on the universe and its origin and will predict that in due course we will have a new way of profoundly looking at the universe, its realities and of the place of humanity in it. This new view of our ultimate realities, when it materializes and mature, would progressively bring science, philosophy and religion under a common umbrella, spearheaded by a new Scientific Cosmological Argument.

Keywords: origin of universe, singularity, inflation, relativity, quantum theory, philosophy/religion/science interconnection, astronomy/culture

"*I want to know how God created this world. I am not interested in this or that phenomenon, in the spectrum of this or that element. I want to know his thoughts. The rest are details." Albert Einstein.*

"God does not care about our mathematical difficulties. He integrates empirically." Albert Einstein.

"The positivists have a simple solution: the world must be divided into that which we can say clearly and the rest, which we had better pass over in silence. But can anyone conceive of a more pointless philosophy, seeing that what we can say clearly amounts to next to nothing? If we omitted all that is unclear, we would probably be left with completely uninteresting and trivial tautologies".Werner Heisenberg,

"I take a positivist viewpoint that a physical theory is just a mathematical model and that it is meaningless to ask whether it corresponds to reality". Stephen Hawking,

"The most difficult aspect of this problem is not the existence of the singularity itself, but the question of what was before the singularity . . . . This problem lies somewhere at the boundary between physics and metaphysics." Linde

"The big bang, the most cataclysmic event we can imagine, on closer inspection appears finely orchestrated." George Smoot and Keay Davidson

Introduction

The five quotes, from Einstein, Heisenberg, Hawking, Linde, Smoot and Davidson following the title of this article, aptly convey the magnitude of the problems in relation to the ultimate realities of our world and which the author intends to gradually address in his work. The focus of the present paper is about the scientific understanding of the origin of the universe and about its possible impact on astronomy and human culture and it is implied that we need to develop a significantly more fundamental astronomical and cosmological concept. The colossal challenge posed in attempting to explain scientifically the origin of the universe has created, in contemporary cosmology, a melting pot of ideas and theories. A study of the history of man's interpretation of the universe shows that, throughout the ages, this interpretation has greatly influenced his views about himself, his belief or disbelief in a supernatural all powerful mind, his literary and political evolution, and has created around him various senses of purpose for his existence. However the debate between atheists and theists, firmly rooted in one's appreciation of the realities of the universe and of its manner of origin, continues unabated.

Generally speaking if we compare the views about the origin of the universe in modern times with those of ancient philosophers we find that today's concepts of experts, although firmly grounded in generally accepted but mostly speculative scientific and mathematical concepts, are basically as philosophical as those of ancient philosophers. The gist of the argument is that we are still far from being quite clear whether the universe 'just is' accidentally or has intrinsic scientific realities which would indicate a strong blend of scientific and metaphysical origin. Various contemporary concepts, sometimes mind boggling, offer little understanding for a useful and widely accepted mechanism of the origin of the universe. They range from Lemaitre's theory which paved the way to the Bing Bang concept, negative and positive energies in general terms, vacuum fluctuations, multiverses, a universe in your backyard, or universes in hidden dimensions centimeters away from your face, amongst others. These constitute simply modern philosophical approaches, couched in scientific mantle, which weakly attempt to unravel hopefully how our universe could have originated whether by design or by accident. Philosophy is a manner of reflective intellectual activity having as main aim a better appreciation of what constitutes the realities of existence and of the universe. Philosophy and religion interpret the realities of the universe while science explains them. Scientists are well versed on what constitutes solid scientific evidence. So far we have to make do with little that science can offer due to, we must admit, formidable challenges to unravel events at the earliest fraction of time during that first very beginning of creation of the universe and to the moment, if any, before that incredibly fateful instant of origin.

We may not be far from an initial tangible solution of how the universe originated and of how the universe is related to our existence in their various facets, including some of the unsolved puzzles of science such as for instance the evolution of matter and of life and the relationship if any between the quantum microscale and the macrostructure of the universe. Astronomy as the oldest intellectual cosmic culture of mankind is intimately linked to man's speculation about the mysteries of the cosmos, a deeper appreciation of which would have an enormous beneficial impact on the how we view the universe, ourselves and planet Earth.

The origin of the universe has been basically related to some act of creation or to an eternal existence. Starting from the Greek period down to modern times man's views evolved from a generally blind acceptance of a supernatural act of creation according to mythological or religious beliefs to a modern scientific notion of infinite universes leaving our own universe as a mere statistical and accidental event popping out from practically nothing, a view propagated by various authors in contemporary modern times.

Earlier the era of scientific reflection, starting as from the 17th century, brought about a decisive turning point in man's spiritual perception for we saw the development of a materialism which became a serious challenge to traditional religious observance. Subsequently the early parts of the 20th century were confronted with a dramatic new way of seeing reality based on quantum theory. Gradually the nature of the universe in terms of quantum and relativity concepts became significantly enlightened through the work of some of several key scientists (Young, 1802, 1804;Planck,1900, 1901; Einstein, 1905, 1916a, 1916b, 1917; Bohr 1913, 1935; Heisenberg,1927, 1958); de Sitter, 1917; Friedman, 1922; Dirac, 1928; Einstein, Podolsky and Rosen, 1935; Schrodinger, 1926, 1935;Hubble, 1929; Bell, 1964; Hawking and Ellis,1975: Peerally, 2008) and many others. That space and time are not absolute separate entities were done away with Einstein's relativity theories. Henceforth relative space/time replaced the old notion of absolute space and time. Peerally(2008) added a new concept of the universality of relativistic effects for massive objects in Keplerian orbits with a proportionality of 1:2 between special and general relativity. Quantum theory, strongly supported by Bohr, Heisenberg and Planck, introduced the notions of mystery, unpredictability and indeterminism in science, an approach which clashed with Einstein's vision of an eventually explainable, predictable and deterministic universe. These two views, deterministic or indeterministic, have remained a dispute up to now, but the indeterminism concept appears to win the debate. Strangely enough Einstein was one of the pioneers of quantum theory which heralds that an unpredictable nature characterizes our microscale structure of the universe but he quite adamantly hesitated to accept it.

Our limited comprehension of the nature of the infinitely minute singularity which led to the cosmic inflation and expansion in the Big Bang Theory, has resulted in a fertile speculative ground for modern writers to propose a wide range of theories on the origin of the universe, some arguing in favour of a singularity and others strongly opposing it in disbelief proposing instead equally incredulous alternatives. The more modern hypotheses, as alternatives to the Big Bang theory, are for instance those of, Alan Ruth (creating a universe in your laboratory or in your backyard, 1981, 1982, 1995,1998), Linde (chaotic inflation, 1982, 1983,1984), Martin Rees (multiverses, 2007, 2009), Bojowald (cosmic bounces, 2007, 2008) and others. The whole situation is far from scientifically and philosophically clear so that it is opportune to wrap up the gist of the debate. The lacuna created by this state of affairs encourages hectic debates between the atheists and the theists.

There are, in the scientific literature, some reliable notions in broad terms, of the origin of the universe, particularly arising from Einstein's general relativity such as time frame, the possibility of inflation and subsequent continuing expansion. However the quantum basis of gravitational attraction and of the Big Bang singularity, a very critical consideration in this scientific riddle, cannot be resolved using current theories. This paper will hopefully arouse additional interest towards a more scientific approach to unraveling how the universe came up some 13.7 billion years ago in a manner which should encompass the nature of the various realities of the universe.

Since the beginning of the scientific era in the 17th century we have seen how an intellectual conflict has been, by and large, the most prevalent phenomena characterizing the relationship between religion and science. Dialogue and integration have up to now been looked upon as two beneficial interactive processes of how the human intellect is potentially capable of bridging science and religion. From a look at the available literature it appears that such an ambition is yet to become healthy reality. This is largely due to the notion that religion and science are duplicating the same fundamental goals of understanding the world and that only one is the necessary eternal reality, and clearly the most common claim is that religion would eventually disappear as humanity evolves more and more intellectually and scientifically. In a gist it strongly implies that only an extreme kind if materialism and positivism would eventually prevail. Nothing can be a more unfortunate fate for humanity. The reason being that currently, but not necessarily forever, science is meant to provide the material explanation of things while religion gives the spiritual explanation. There are many who, understandably, believe that these apparently incompatible features, spirituality and scientific materialism, are inextricably and mutually exclusive concepts and could never integrate. However it is well documented that quantum physical realities are mysterious and indicate realities beyond the current comprehension of science and may actually remain so forever, albeit in a better understood way. Science and religion could ultimately deal with both material and spiritual matters and these two disparate disciplines would become mutually intelligible and in some ways would merge into a new way of thinking. Consequently Philosophy would thrive anew in a grand modern fashion.

There is hope for a new interpretation of cosmological phenomena based on scientifically coherent arguments, especially with respect to the integration of quantum mechanics with the large scale appreciation of the universe. If successful, which is not unlikely, such a development will be the springboard of a new era of culture for astronomy and cosmology by disentangling humanity from the current science/religion conflict. Hopefully a new acceptable cosmological interpretation would, in retrospect, materialize Einstein's dream of reading the ultimate mind on how the universe came into existence to better understand the role of humanity and of consciousness, of energy and matter in the universe.

Astronomy sparks the imagination of people. The sheer mysterious marvel of the complexity and magnitude of the universe, if its origin can be attributed to some universal scientific notions, could catalyze a new astronomy culture. In spite of the scientific deadlock in terms of understanding the initial moments of the origin of the universe, there is hope of new dramatic findings. While it was strongly believed that Einstein's theories were an end to themselves the author was able to show the occurrence of a new universal law of proportionality of relativistic effects (Peerally, 2008). We will in due course produce concepts of cosmology based on a quantum integration of special relativity and general relativity to show the road ahead for new vision of the universe. That fits in with the declaration of the International Astronomical Union Strategic Plan 2010-2020 as follows: "*Astronomy (IYA) 2009, which commemorates 400 years since Galileo first turned a telescope to the sky to make fundamental discoveries that changed people's perceptions of the Universe, has motivated the IAU to commit even more ambitious programs of educating the world to the beauty of the Universe and the sense of common humanity that derives from it*".

A profound scientifically based philosophy of astronomical knowledge which gathers public support could sprout a less materialistic scientific culture, rather than perpetuating a perma-

nently speculative affair as much of astrophysics and cosmology is presently(Markus. The STOQ project created by Pope John Paul II established in 2003 and the Templeton Foundation aim at promoting constructive dialogue between theology, philosophy and the sciences. In due course one could realize that Einstein's desire to understand God's mind was not a vain hope.

Science, theology and philosophy

The manner philosophers, theologians and scientists have viewed the origin of the universe has shown a dramatic evolution since Plato and Aristotle popularized their observation on the nature of the universe.

Plato (429-347 BCE), based on a discovery of Parmenides(born 515 BCE) that all only five shapes(triangles, squares, hexagon, octahedron and dodecahedron) exist whose sides are regular polygons, believed that the atoms of matter were produced by these five shapes. Thus the composition of air, water, fire and earth could thus be explained. The fifth of Plato's five elements of matter, was subsequently identified by Aristotle(384-322 BCE) as the ether, composed of dodecahedronal atoms. Plato's dodecahedron recently inspired a dodecahedronal universe (Luminet et al., 2003). In the view of Plato and other Greek philosophers of that early first millennium, the universe must have an infinite existence for that was compatible with their philosophy of absolute perfection. Later natural theologians preached that the universe was caused to exist through an act of creation by a cause. The most documented and authoritative references are those of Al-Ghazali(A.D. 1058-1111) and Thomas Aquinas(AD 1225-1274).

However consistent and progressive development of modern science in relation to the realities of the universe occurred since the 17th century after Isaac Newton published his *Philosophiae Naturalis Principia Mathematica* in 1687. Several other scientists, often well versed in philosophy, of the period made significant advances: Robert Hooke (1635-1703), Johannes Kepler(1571-1630), Galileo Galilei (1564-1642), Pascal and others. Francis Bacon (1561-1626), Rene Descartes (1596-1650), Wilhelm Leibniz (1646-1716) and Samuel Clarke(1675-1729). Their philosophical and scientific contributions inevitably affected religious thoughts especially in the appearance of positive atheism and of the latter's impact on science/religion interconnection.

From the 17th to the present time science/religion debate has been characterized by conflicts and independence. Religion has always been a matter of pure faith where believers have to follow suit or run the risk of being branded as indifferent or sinful. On the other hand a scientific notion of reality is what emanates from theories and experiments. Professor J. Polkinghorne(2003, 2007a, 2007b), (Templeton Prize, 2002), renowned British particle physicist and theologian, described the relation between science and religion as having the following interactions:

- Conflict when a take-over bid is attempted by either over the legitimate concerns of the other
- Independence, each is entitled to be regarded as an independent form of enquiry.
- Dialogue, in which both can benefit through constructive interaction.
- Integration, where matters of common interests can be unified into a single common concept of enquiry.

Dialogue and integration could apparently be beneficial interactive processes of the human intellect potentially capable of bridging science and religion. From a look at the available literature it appears that such an ambition is yet to become reality in relation to both the micro and large scale structure of our universe.

The philosophical literature on the natural and supernatural origin of the universe (Craig, 1979, 1997; Mackie, 1982; Koons, 1997; Davies 1984, 1988, 2000; Ellis, 1993), is voluminous and intellectually significant. The belief based on a supernatural origin, is supported by an impressive list of eminent cosmologists, astronomers, astronauts and Nobel Laureates who have often instinctively, attributed a superior intellect to the unbelievable orderliness and perfect mathematics inherent in the nature of the universe. On the other hand there are various scientists who have argued in favour of a natural origin. The concepts of Carl Sagan described in 'Cosmos' (1980), S. Hawking (1988), and of Paul Davies (1988), believe in a universe which is 'just is', without any previous temporal or atemporal history of any kind.

The Cosmological Argument

For three millennia there has existed and there continues to exist a powerful debate on the moment of creation of the universe if any. The reasoning behind this philosophy reached a climax when two natural theologians, Al-Ghazali (A.D. 1058-1111) and Thomas Aquinas (A.D. 1225-1274) fully developed what is called the Cosmological Argument. Al-Ghazali's cosmological argument relies on the fact that every being which begins has a cause for its coming into existence. Therefore the universe must have had a beginning at a finite moment in time. The reasoning was that an infinite series of events into the past was not possible for the present would not have come. This concept has been revisited and popularized by the American philosopher William Lane Craig(1979, 1997)as "The Kalam Cosmological Argument". As Craig pointed out, if there was an infinite series of events in the universe how could we have 'today'. Since such an infinite scenario was impossible, for an event to begin there must have been a cause, one can conclude the universe, an event, had a time in the past when it was created through a cause.

Thomas Aquinas' Cosmological Argument is based on the absolute existence of an "unmoved mover" of motion. Since the universe started in a state of motion, there must have been a mover from an outside dimension to set it in motion. That was the "unmoved mover", a supernatural force. These early thoughts in retrospect were very profound and valid ideas which thinkers and philosophers are capable of but such interpretation requires scientific support, a typical example of how science and religion could be catalyzed into a common debate.

Clearly the power to create a universe must be out of proportion with what the human imagination can possibly visualize. As George Ellis (1993), Templeton Laureate, said: "To *make sense of this view (design as opposed to accident), one must accept the idea of transcendence: that the Designer exists in a totally different order of reality or being, not restrained within the bounds of the Universe itself."* The notion of transcendence implies the possibility of having, as Aquinas proposed, an unmoved mover, if the universe started through an unknown mover, that was equivalent to having creation with a cause by an uncaused cause. Here obviously the uncaused cause means a supernatural force which the author of the present article would call the "mind" behind the universe. The Cosmological Argument was also sup-

ported and enlightened by such great thinkers like Wilhelm Leibniz (1646-1716) and Samuel Clarke(1675-1729).

In the foregoing discussion we have seen that the cosmological arguments of Al-Ghazali and Thomas Aquinas, during the period of the 11 to the 13th century, and as subsequently argued by Craig, in the 20th century, strongly support the thesis of a finite universe similar to what is indicated from modern scientific work influenced by Einstein's general relativity theory mainly. This suggests that our present knowledge of the nature and origin of the universe historically started from a substantial combination of theological, philosophical and scientific concepts.

The evolution of our scientific knowledge of the origin of the universe

The historical scientific evolution of ideas relating to the origin of the universe can be seen to consist of two broad periods: the first from the 10th century starting with Al-Haytham up to the second half of the 20th century with the establishment of the Big Bang theory as a credible idea of the origin of the universe; the second starting late 20th century up to the present time which has seen the development of various alternatives to the big bang.

The earlier scientific period

Our present state of modern science, unfortunately, has had a relatively brief historical period of development, spanning just over eleven centuries if we regard Ibn al-Haytham as the initiator of the scientific method of investigation. Richard Powers (1999) has praised al-Haytham extraordinary scientific methods and influential ideas. Al-Haytham is credited with evolving the first notion of inertia which was later further developed by Descartes and Newton. In addition to Al-Haytham, Galilei Galileo (1564-1652) is recognized as being the father of modern observational astronomy, father of physics and father of modern science. Descartes (1596-1650), another great mind of that early period, is particularly recognized for his laws of motion, which must have influenced Newton. A profound appreciation about the deep nature of the universe was Descartes' intriguing belief of the universal conservation of the quantity of motion as one of the fundamental governing principles of the entire cosmos since its origin. Of much philosophical and possibly cosmological interest is Descartes famous statement: *Cogito, ergo sum*: I think, therefore I exist.

In addition to Descartes, Galileo and others, another great scientist of the period was Borelli (1608-1679), who made several important researches in astronomy. Not only did he observe that comets follow a parabolic path he also observed Jupiter's satellites during which he reflected on their orbits. As a result Borelli postulated that a centripetal tendendy of orbiting attracted them towards the body around which they orbit and that this centripetal force was balanced by a centrifugal force. The balance of these forces was realized by Borelli as the reason which kept the satellites in a regular path in their orbits. These ideas could have influenced Newton who actually acknowledged Borelli's work in his Principia.

Newton (1642-1726) is recognized as one of the most influential scientists who ever lived. His accomplishments in theoretical astronomy, physics and mathematics have left a permanent imprint in scientific books and encyclopedia all over the world. Newton's monumental work on motion and gravitation has led to his being regarded as one of the greatest scientific giants. His laws of motion, along with the work of his contemporary scientists and philosophers constitute the basis of the coining of the term Classical Mechanics from its precursor, Newtonian Mechanics. A lot of the mathematical concepts and methods were invented by Newton and his predecessors and contemporaries. A particularly deep reflection of Newton was made in a letter he wrote to Bentley in 1682 as follows:

That on body may act upon another at a distance through a vacuum without the mediation of anything else, by and through which their action and force may be conveyed from one another, is to me so great an absurdity that, I believe, no man who has in philosophic matters a competent faculty of thinking could ever fall into it".

The so called force of gravity has to this day remained a scientific puzzle in terms of its physical quantum reality. The quantitative approach of Newton based on his force of gravity, he believed, could also govern the motions of stars and planets, which was rejected by Descartes who believed in a non-mathematical model consisting of vortices of cosmic matter. To Descartes the invisible force of gravity was an occult phenomenon, hidden from human senses. Though Descartes was generally accepted within the 17th century conception, his vortex notion fell in disrepute in the 18th century and Newton's mathematical models moved from success to success. However Descartes' view of gravity illustrates the mystical nature of a phenomenon yet to be elucidated. While to Newton there was in the manifestations of heavenly orderliness a sign of divine perfection and will, there were those who criticized his work as a destabilizing philosophy for religion and philosophy.

In terms of hypotheses put forward in the 18th century relating to the universe are those also of Kant, which made such an impact, that for over a century astronomers were either Kantians or Laplacians. Kant's hypotheses were related to nebulae. The first Nebular Hypothesis reasoned that diffuse nebulae, made up of gas and dust, would in the course of time collapse under the force of gravity. They consequently start to spin and flatten into a disk that would then produce planets and stars. It was Laplace who turned the hypothesis into a mathematical theory. Interestingly both Kant and Laplace were proved correct. It was Kant's second hypothesis that created a huge debate for nearly a century. After Thomas Wright in 1750 proposed that the Milky Way was itself a spinning disk, Kant imagined that the spiral nebulae were in fact external galaxies themselves, outside the Milky Way. In fact this astronomical imagination of Kant eventually proved to have been a correct guess. The difficulty of verifying these hypotheses was mainly then due to technological know-how, for without spectroscopy it was not possible to see the three dimensional large scale distribution of celestial bodies.

It was gradually realized, contrary to Newton's philosophy that cosmic orderliness was a manifestation of divine will, that the stability of planets in the solar system could also be contemplated as being due to gravity in a purely mechanistic explanation so that a divine power was not required to explain the orderliness of the heavenly bodies. As a result it started to dawn on the mind of people that science started to pose as a rival to religion, in the sense that now people could turn to a new source of knowledge, scientific knowledge, for understanding the truth about the universe and cosmological phenomena. The theological rhetoric that various manifestations were the work of a supernatural power was becoming less and less acceptable to some groups of people, philosophers, writers and scientists.

The nature of the universe as an infinite static one was beginning to attract some questioning especially from Loys de Cheseaux(1718-1751), a Swiss astronomer. He studied nebulae

and discovered several and was among the first to remark that if the universe is infinite, then the night sky would be bright, a notion later to be called Olbers' paradox.

The 18th century scientific and cosmological revolution catalyzed a literary, theological and political reassessment that would express itself in the following century accentuated by further and sometimes dramatic new scientific knowledge.

The period of the 19th century

On the other hand a significant revolution took place in the 19th century, where the applications of mathematics, chemistry and physics to astronomy led to a better understanding of the composition and origin of the universe. Fundamental discoveries were made, including all the planets and satellites of our solar system. The application of instrumentation like photography and spectroscopy and improved telescopes made possible the study of the chemical composition of the sun and stars. Astrophysics began to develop into a new scientific field, for astronomers were now able to map and know the nature of stars and other cosmological bodies and photographed them as well. It became possible also to start to realize that there could be different kinds of nebulae. The century also saw dramatic new perceptions of the origin of species, including the natural evolution of man from primates, and the manner characters are transmitted from generation to generation. The realization that man could have originated from apes together with the general belief in an infinite static universe provided the 19th century with the basic ingredients for fostering atheism and the unquestionable natural origin of man and of the universe.

Maxwell's theory and studies of electromagnetic radiation, together with the work of Faraday, were crucial in giving a new interpretation to energy and magnetism. It was then widely believed that there was an 'ether' in the universe which was a propagating medium for light. In 1878 Michelson conducted an experiment to investigate the influence of the ether and of the earth's rotation on the speed of light. The result was reported in 1881 with the conclusion that the hypothesis of stationary ether was incorrect. With significantly improved experimental procedures Michelson and Morley did the measurement again in 1887 with the same negative result for an 'ether', which led to the discovery of the constancy of the speed of light, one of the pillars of Einstein's theories of relativity.

Another genius of the period was Boltzmann who was a protagonist of the atomic theory of the matter while the period was dominated by energetics, a concept which held energy as the fundamental physical unity. Boltzmann came up with the concept of a kinetic energy theory strongly linked with an atomic theory while opponents to the atomic theory included powerful intellectuals like Ernst Mach (1838-1916). Boltzmann (1844-1906) proposed one of the first rudimentary representations of the atomic orbital overlap diagrams. Referring to the then known dissociation of molecular iodine vapour into atoms, he speculated the presence of 'sensitive regions' on or inside atoms which allow them to associate into molecules. Boltzmann in his kinetic energy theory also developed ideas of entropy law or disorder law. He argued that the second law of thermodynamics was one of increasing disorder basing himself on colliding particles in a gas for he concluded that in a world of colliding particles, the disordered states are the most probable.

The second law of thermodynamics thus introduced strong barriers in the concept of a static universe. However the notion of an infinite static universe which was conceived by the early Greek philosophers continued to be generally accepted.

Of all the sciences undoubtedly cosmology and astronomy, in view of their ethereal nature and mental proximity with the divine consciousness and heavenly phenomena and beliefs of the unknown, would have lasting impressions on scientists, writers, philosophers, poets and theologians, and eventually on social systems and politics. Thus during the Romantic Period (1800-1840) writers and poets reacted against the domination of new scientific findings particularly astronomical and cosmological hypotheses of the 18th century, which, like a tidal wave, had an inexorable impact on what was previously a blind belief in the central position occupied by humanity in the universe and in an all-powerful Deity. The new reality, resulting from science, was considered as a tangible materialism and rationalism which was dragging people away from a more fundamental religious allegiance. That period of materialism and rationalism was the period of positivism where only strictly provable science was useful.

The period of the 20th Century

Strange as it may seem, considering where cosmology and astronomy are today, at the beginning of the 20th century, science was still in a state of infancy. By 1905 cosmology and physics had two conflicting and problematic concepts, one at the macro dimension of the universe where we have stars, planets and nebulae, amongst others and the other, where the realities are waves and particles at the micro dimension. These were problematic because at that early beginning of the 20th century many areas of physics and cosmology were just beginning to be understood and they were nearly all at the frontiers of knowledge. The evolution of the atomic theory aptly illustrates this surprising fact. The atomic theory, which states that matter is composed of indivisible discrete ultimate units called atoms, had been a concept, in natural philosophy for thousands of years, in ancient India and Greece. It remained practically the same conceptual idea until the beginning of the 20th century when it started to be unraveled within mainstream scientific thoughts, in spite of the fact that Dalton stated the first truly scientific atomic theory in the first decade of the 19th century. He formulated the concept that each chemical element is composed of atoms of a unique type which can combine to form complex substances. The atomic theory was not then accepted by the whole scientific community. By the end of the 19th century Boltzmann, one of the most ardent advocate of the atomic theory, postulated a kinetic theory of gases which strongly postulated the reality of atoms and molecules, but many of his colleagues like Ernst Mach, and Wilhelm Oswald, were against their existence. Actually there was then another school of thought which believed that all physical phenomena and behavior was ultimately the effect of a continuous electromagnetic state. This movement continued around 1900 with the strong opposition of the supporters of the concept of pure thermodynamics. That was how the 20th century started the beginning of modern scientific evolution. In 1909 Planck wrote a paper defending the atomic theory and pointed out the importance of physical constants like the gravitational constant and the existence of other such constants which were independent of the human mind. In 1910 Mach responded and again showed his opposition to atomic theory. Actually it was Einstein who, in 1905 published a paper on Brownian motion which was an experimental verification of the kinetic theory. The scientific importance of the theory was two-fold. First it provided experimental support of the occurrence of molecules in the liquid causing the motion of the pollen grains, but more

importantly it confirmed the Boltzmann's kinetic theory account of the 2nd law of thermodynamics as an essentially statistical law. The idea of matter being made of particles went even further when Einstein's 1905 photoelectric effect paper described light as bundles or quanta of energy later to be called photons, a term coined by Gilbert Lewis(1926), so that even light behaves as a particle in addition to its wave nature.

Maxwell and Morley failed attempt to obtain experimental evidence of a permeating ether in the universe was dealt a death blow by Einstein in his 1905 paper on special relativity where he argued for the occurrence of a speed of light constituting a universal constant and of a space-time where the two together was a combined reality, and not separate parameters. This is a just one clear example of the frontiers of science moving forward at the beginning of the 20th century. By 1915 Einstein extended his special relativity to the general relativity to include Newtonian gravitation and a space-time involving gravitation. When Einstein realized that his theory of general relativity produced a universe that could either expand or contract, he was disturbed as the fashion of the period was a static infinite universe and to make his theory more plausible he introduced a cosmological factor that would counteract the attractive force of gravity by an anti-gravitation phenomenon. This modified version of his general theory was actually to eliminate totally the existence of any remnant of Newtonian absolute distance and time and also because it was compatible with Einstein adherence to the Mach's Principle, i.e. space time was the resultant of the effect of matter. The factor he inserted in his theory was basically equivalent to a vacuum energy density and could be put either on the right or left side of his equation. He thus missed the golden opportunity to predict an expanding universe, but in retrospect it is true that it was not then possible to make such a prediction, in view of the muddled state of knowledge about the universe. Einstein's cosmological constant led to a static universe and his 1917 paper emphasized that the cosmological constant was important to produce a closed static universe.

For example round about that time, strangely enough, cosmologists were still arguing on the macro scale structure of the universe in two opposing schools of thought: the Kantians and the Laplacians. The former believed in a universe with many galaxies while the Laplacians conceived of a universe of a single galaxy with the earth playing a role of some predominance with our sun at the centre of that galaxy. What had been seen as a multitude of galaxies by the Kantians were interpreted by the Laplacians as just dusty clouds except the single galaxy of our cosmic system. This dilemma was eternalized by the debate on the two schools of thought between H. Shapley and H. D. Curtis, at the National Academy of Sciences, in the USA, and which became known as 'The Great Debate' on 26th April 1920. Shapley believed in a single large galaxy universe with the sun far from the centre, while Curtis defended a many galaxy universe with the sun at the centre of our small galaxy.

The big bang theory

Before the Big Bang model of the universe became an established theory, the universe was thought to be infinite and eternal. In1916 when Einstein put forward his Theory of General Relativity, the belief in an eternal infinite universe was so prevalent that when he found his theory would produce a universe that could expand, he inserted a cosmological constant in his equation in order to stabilize it to produce a static universe. This episode in Einstein's work has been well documented by W. Jansen (1998). He described correspondences between De Sitter and Einstein starting from 1916. They agreed that that the model of the universe in Einstein's general relativity had a remnant of Newtonian absolute space and time due to the occurrence of boundary conditions in an infinite universe. Einstein subsequently came up with the notion that there could be distant masses near the boundary which could influence space time there to which De Sitter objected sharply. Subsequently in 1917 Einstein came back to Sitter with a new idea, that of abandoning a static infinite universe by introducing his Cosmological Constant simply by removing the infinity element to produce a closed universe. The cosmological constant was introduced (Einstein, 1917) into Einstein's field equations in order to make the universe static and finite. The factor was meant to be a vacuum energy density, in other words one where nothing would happen, such as contraction or expansion of the universe, thereby giving a static universe. However, the cosmological constant was in 1931 modified by Einstein to give the universe a finite expanding nature.

When Hubble's research and the Lemaitre-Friedman model revealed that the universe was expanding as time moved forward then questions were put as to the past history of the universe. Therefore extrapolating the expanding universe backwards through time would produce in the very distant past a progressively smaller universe until we reach a point structure of infinite mass and infinite energy. The expansion of this point mass would eventually produce the universe as we know it now. The interpretation of this model was that the universe has existed for a finite time and was created out of nothing just before the big bang, or more of less along these lines.

To many scientists and non-scientists it is hard to believe, as indicated by Lemaitre's Cosmic Egg concept, how the Planck's density of at least 5.1 x 10 power 96 Kg/m cube, which represents our whole universe could be compacted into a space with the size of an atomic nucleus. This represents 10 power 23 solar masses packed into the volume of one atomic nucleus. The cosmic egg singularity in the modern concept of singularity has also been represented as an infinitely dense singularity with zero volume, zero curvature and with infinite energy, and some authors have argued it would be very hard if not impossible to explain how the universe could be produced from such an incredibly infinitesimal initial condition. This has been used as strong arguments for claiming that science cannot explain creation ex nihilo and therefore there could not have been a supernatural power to cause the beginning of the universe. Accordingly the universe just popped out into existence from nothing.

Scientific theories, on the basis of which various researchers have been developing their origin of universe concept, invoking cosmic egg, singularities, positive and negative energies, vacuum fluctuation (Tryon, 1973), negative gravity energy and positive matter energy, and from nothing (Vilenkin, 1982), have in the final analysis ignored important scientific facts such as the law of conservation of energy, and elusive issues relating to quantum theory and matters like consciousness. All of these concepts could be very good mathematical models, Extrapolating from them the origin of the realities of the universe could be very misleading. How can we know for certain that a singularity with or without a crucial boundary of space time should be what was definitely present to initiate the big bang scenario? Could there not have been another scenario with real time to initiate the big bang? How do we know for sure that general relativity, which correctly applies to the macro structure of the universe, cannot explain the moment of earliest origin of the universe and cannot be transformed with additional reasoning into a quantum gravitation theory? There are reasons to speculate that it is possible to integrate within general relativity a theory of quantum gravity and such a theory could then be used to describe in some details

how the universe was possibly created. There would then ensue various approaches to explain the mysteries of quantum theory and those of the realities of existence.

The difficulties created by our inability so far to resolve the conceptual problems associated with a singularity of infinite density, infinite energy, infinite heat and infinite size and zero volume, arising ex nihilo have opened the doors to disbelief. This in turn has motivated several authors to speculate on other theories of the origin of the universe, many of which seem to suggest that a universe, or universes or an infinite number of universes arise ex nihilo easily. Several eminent scientists have taken a statistical or probabilistic attitude to the origin of the universe because of the anthropic belief ingrained into their theories. Thus they imply that a universe like ours with its living creatures and particularly man is such an improbable possibility that this could only have happened if we have an infinite number of universes. Strangely and paradoxically enough the author takes the view that even an infinite number of random universes would not be able to produce a universe like ours, if that depends only on chance phenomena.

One would expect that the emergence of our universe through the mediation of a mystical singularity, although taken seriously, was over the years sort of set aside. The main explanation was the difficulty of understanding by the scientific community how a singularity with the mass of our universe compressed into an infinite size could have originated according to some, ex nihilo, and according to others, from an unknown source of some unknown kind of energy. This is quite understandable and the inability of cosmologists and physicist to find an adequate theory became intolerable. However the possibility of our universe having had another origin than the one suggested by the big bang theory became irresistible to several scientists who started to speculate of other scenarios of the origin of matter and life was brought in to make the accounts of origin somehow more anthropic. However that produced, in some of the new theories, a scientifically major departure from the line of thought which led to the big bang notion, an observation worth noting, for the context of the emergence of the big bang theory is a scientifically extraordinary story. On the other hand most of the big bang theories, like multiverse, infinite universes, metaverse, bouncing universes, inflationary universe with infinite budding off of new universes, a universe in your backyard for example, are non-falsifiable theories, and are not strictly speaking scientific, for you they are not theories which can be modified by using scientific arguments. The two scientific theories are the big bang and the steady state theories, and as of date the big bang remains the most acceptable version of how the universe originated.

However the Big Bang has, over the decades, due to its inherent implication of a finite creation of the universe, been rated as philosophically acceptable. Big Bang according to Hubert Reeves rests on a metaphysical connotation which may be either appealing or revolting. Thus John Maddox, a former Editor of the science journal Nature, wrote an editorial in 1989, describing the theory as philosophically unacceptable, for theological creationists find sufficient justification for their theist creed in it. On the other hand Emeritus Professor Christopher Isham of Imperial College, believes that theories which challenge the Big Bang finite universe model have been tenaciously advanced in a manner which far exceeded their intrinsic worth.

Steady state theory

The Lemaitre's cosmic egg and the Big Bang singularity had a strong tinge of a supernatural origin and found its way well into the 20th century as an acceptable theory of the origin of the universe. The Steady State Model of Gold and Bondi (1948) and Hoyle (1948) proclaimed an infinite universe in time and space which otherwise would possess the same physical parameters of our universe in terms of homogeneity and isotropy. New matter in the universe would arise and would balance the continuous availability of negative energy thus explaining the existence of an expanding universe which maintains its density and the steady state of an infinite universe.

The state of scientific and cosmological knowledge was such in the 50s and 60s that the predictions of the Steady State theory had to be verified. Two such predictions were the unchanging nature of the universe over time and the second the requirement for new hydrogen and deuterium being continuously produced to form the new matter. When put to the test, the postulate that our universe is static as against the non-static universe of the big bang model the Steady State model failed quite miserably. No evidence could be obtained to prove that new hydrogen and deuterium as required by the quantitative prediction of the theory is actually being formed. The non-static nature of our universe predicted by the big bang model was further supported by the fact that new heavy elements were continuously being added from the activities of supernovae. Further non-static evidence was provided by the evolution of galaxies during cosmological history such as the occurrence of unusually shaped galaxies in earlier times of history than in more recent times. Due to lack of cosmological evidence the Steady State Theory lost most of its adherents as from the late 60s, particularly with the demonstration of the occurrence of the cosmic microwave background radiation which dealt a death blow to the theory. The CMBR was a prediction of the big bang concept to the effect that the universe had been actively evolving rather than being unchanging and static over time. The CMBR has been a product of the very early phase of inflation of the big bang and not a continuous cosmic activity originating from ancient stars and subsequently progressively dispersed by cosmic dusts. Finally another observation discrediting the notion of a universe being invariant with time was that quasars and radio galaxies which have not been seen in near galaxies had been detected only in very far away regions of the distant past. The declining fate of the Steady State theory was met with attempts to modernize its concepts to prevent it from disappearing into oblivion. Thus in 1993 Hoyle, Burbidge and Narlikar resuscitated the theory by inserting the notion of minibangs or little bangs but the new Quasi-steady state version of the theory has not incited any significant positive impression and is not likely to do so. In spite of the negative outcome of the Steady State model, its progressive loss of support is actually a great plus for it. Only a theory which had had a good support in the past would take decades to lose its glamour for it must have made sense to a range of good scientists. It was instrumental, because of its clear cut predictions, in catalyzing cosmologists to undertake research on matters like the homogeneity and isotropism of the cosmos. It was in the light of research and scientific reasoning that the Steady State model gradually lost its appeal. One can therefore regard Fred Hoyle's theory as being a worthwhile attempt to understand the origin of the universe.

Carl Sagan: The Universe "just is"

Carl Sagan(1934-1996), famous science writer is clear about the nature of the universe and his famous quote on this puzzle as follows: "The Cosmos is all that is or ever was or ever will be", (Sagan, Cosmos, 1980) reflects a lot of his notion of the universe,

which he felt was beyond human comprehension as can be seen in the following quote again from his book Cosmos:

"The size and age of the Cosmos are beyond ordinary human understanding……..In a few millennia we have made the most astonishing and unexpected discoveries about the Cosmos and our place within it, explorations that are exhilarating to consider. They remind us that humans have evolved to wonder, that understanding is a joy, that knowledge is prerequisite to survival."

However he did say also that while some scientists when confronted with new scientific evidence contrary to those held by them do admit they were wrong and would never again repeat the same mistake, a similar attitude is not usual in religion and philosophy. He has also been reported to say that the existence of a creator of the universe would be impossible to substantiate if the universe is proved to be eternal.

Parallel Universes, Multiverses Theory

Martin Rees(2009), a powerful proponent of the theory of Infinite universes or multiverse, remarked,

"Our big bang may not be the only one. An option to consider is brane worlds- many universes embedded in a higher dimensional space. Bugs crawling on a large piece of paper, in their two dimensional universe, would be unaware of other bugs on a separate sheet of paper. Likewise, we would be unaware of our counterparts in another unverse only a millimeter away- if that millimeter were measured in a fourth spatial dimension- we are imprisoned in just three."

He is perplexed by the incredible fine-tuning of the physical properties of the universe due to the impossibility of understanding what happened just before the big bang or at the earliest moment of the origin of the universe, he came to the realization that the universe of ours was a statistical event arising from an infinite number of similar but less successful events.

Martin Rees (2001) in his book "Our Cosmic Habitat" asks a number of pertinent questions. To start with the Prologue's title "Could God have made the world any differently" shows that Rees thinks that God did make different universes differently for he believes that our universe would be a special possible unique one where the laws of physics we have are unique and allowed life to emerge.

It would be appropriate now to comment on Einstein's famous question about whether God had any other option for the model of universe which He created. In addition to asking that question as the title of his prologue to his book, Martin Rees also in the prologue quoted another observation of Einstein*: The most incomprehensible about the universe is that it is comprehensible.* This is actually a fabulously interesting question coming from Einstein but we have to note that Einstein did not accept the uncertainties of quantum mechanics and he had a materialistic view of the secrets of nature. We know that he was well aware that time would elucidate the secrets of nature but the truth of the matter up to now is that the biggest riddle of science is that we find the universe is very incomprehensible as Rees himself implies. Actually, in a manner of speaking, if these deep secrets behind the deep realities of the universe had been comprehensible we would have already understood quantum mechanics, quantum gravity and the nature of charges and the ultimate building blocks of matter at the most elementary levels, thereby linking the microworld with the cosmos as Rees emphasized. However reality is an entirely different kettle of fish. The inability to view the deep reality has a lot to do with the current deadlock of cosmogony and of a lot of physics and of biology, not to speak of theology. To attempt to probe into the meaning and implications of Einstein's statement about whether God had any alternatives in creating our universe, and if we believe He did create it, then looking at the micro and macro structure of the universe there appears to be the possibility of having different kinds of universes, but our universe seems to tell us that the mind behind it would be able to create different universes which would imperatively be also able to sustain intelligent beings of some kind or another, in other words orderly systems of matter and space time in a universe sustainable over time. If we fail to understand this possibility and substantiate it, then the only consequence would be a game of loto with infinite universes where hopefully one or two would sustain life as ours do. In the author's opinion no matter how many sets of infinite universes we reasonably speculate could exist without a cause, it is not possible to produce the scientific biophilic universe like ours by a process of chance and probability alone. Far too many variables and challenges have to be brought together, but other conceptual issues like what is reality, matter, and uncertainty have also to be taken on board before trying out all sorts of speculations, which nevertheless produce good reading and reflections.

Inflationary concepts

Lemaitre's expanding universe from a cosmic egg had actually implied a rapid phase of expansion in the initial early moment of creation of the universe. Later de Sitter realized that Einstein's static universe could not be correct for there was a real possibility of having an expanding universe. Decades later various authors (Guth, 1981, 1982; Linde, 1982. 1983, Vilenkin, 1983) turned these early ideas into dynamic new ways of viewing the realities of the early universe. Now generally speaking the inflation which took place during the first earliest fraction was an exponential one, which became an important topic of deep research and various explanations have been proposed in attempts to understand how and why that event occurred. The cosmologist Alan Guth was the first to use the term Inflation to refer to that inflationary epoch of creation. Why the inflationary epoch gave way to a slowly expanding universe is also considered to be a mystery to the extent that a hypothetical particle, inflation, has been coined to try to give a quantum basis to the phenomenon. There is room according to other workers to include the phenomenon of inflation into the concept of supersymmetry or of a supersymmetric grand unified concept. The Large Hadron Collider project plans to find experimental support for both inflation and supersymmetry.

The Inflationary concept has been criticized by various authors including John Earman and Jesus Mosterin (1999) and by Roger Penrose (1988). In a future publication the author will show that the inflationary epoch during the earliest fraction of a second of the origin of the universe could be scientifically and soundly linked to an exponential entropic event due the rapid formation of particles from pure energy. It is thus believed that the law of entropy produced the inflationary epoch and the current expansion to eventually lead to a slowly expanding universe that in due course dies completely. The current superluminal expansion rate of the universe, although apparently a mind boggling velocity, is just a very minute fraction of the incredible hectic inflation which occurred at the time of creation.

Stephen Hawking on the origin of the universe

Stephen Hawking in his 'Brief History of Time' prominently based his philosophy of the origin of the universe around such

a measureless singularity in the following manner. Under the classical general theory of relativity the origin of the big bang could have been a singularity of infinite density and infinite curvature where no laws of physics would exist. Actually no physical laws applicable at that stage can be imagined. Classical theories would not be applicable and one necessarily must resort to theories based on quantum gravity but so far the combination of quantum mechanics and quantum gravity has not been successful on a scale which would be desirable apart from the speculation which such an approach may engender. One may have to speculate on the passage of waves through imaginary time. Even more mind boggling is the need to speculate that imaginary time might actually be more real than real time! The choice might be to decide to resort to imaginary time without a singularity or resort to a singularity without the possibility of understanding how you would fit real time into it. To conclude Hawking says that as we have no scientific laws that can explain how the universe started with a singularity, then it is possible to speculate that God blew over the singularity to breathe action into it for evolving into the universe that we know. On the other hand if imaginary time is an acceptable possibility then we could have had a beginning of the universe that had no boundary, as opposed to a singularity which imperatively must have, and such a universe without edge would not require creation so that it would just be, without the need to invoke a creator. What he means is that if there was no time preceding the big bang stage then there was no need for any creation by a God, for the universe would have been an accidental occurrence.

Hawking's account of the possible act of creation of our universe from a singularity illustrates a bit of the problematic in attempting to unravel the realities of the universe. Originally Lemaitre's notion (1927) was a straightforward theory of the universe having possibly arisen from a cosmic egg but he foresaw the possibility of an expanding universe. Friedman's interpretation of General Relativity without Einstein's stabilizing cosmological factor produced an expanding universe which Lemaitre also independently concluded. However this was not taken as adequate presupposition by Hawking who introduced the occurrence or not of real time or imaginary time in his theory. As irrespective of whether it is real time or imaginary time Hawking was unable to reconcile creation by a supreme mind with either scenario and therefore there is no possibility of the universe having had a supernatural origin.

Conclusion

Scientific theories, on the basis of which various researchers have been developing their origin of universe concept, invoking cosmic egg, singularities, positive and negative energies, vacuum fluctuation, negative gravity energy and positive matter energy, extra dimensions etc. have in the final analysis not been quite convincing enough to create a consensus on how the universe could have credibly originated and have decidedly not been able to explain things like the various physical realities of the universe like gravity, mass and others like consciousness and biological evolution. All of these concepts could be good mathematical or physical models but extrapolating from them the origin of the realities of the universe would be very misleading and difficult. How can we know for certain that a singularity with or without a crucial boundary of time should be what was definitely present to initiate the big bang scenario? Could there not have been another scenario with real time to initiate the big bang? How do we know for sure that General Relativity Theory, which applies impressively to the macro structure of the universe cannot explain the origin of the universe in greater details and cannot be transformed with additional reasoning into a quantum gravitation theory? There are reasons to speculate that it is possible to integrate within general relativity a theory of quantum gravity without invoking additional dimension and such a theory might then be used to describe in some details how the universe was created. There would then ensue various approaches to perhaps explain the mysteries of quantum theory and those of the realities of existence.

The difficulties created by our inability so far to resolve the conceptual problems associated with a singularity of infinite density, infinite energy, infinite heat and infinite size and zero volume, arising ex nihilo have opened the doors to disbelief by some on the merit of the Big Bang as a theory of creation. This in turn has motivated several authors to speculate on other theories of the origin of the universe, many of which seem to suggest that a universe, or universes or an infinite number of universes arise ex nihilo easily. Several eminent scientists have taken a statistical or probabilistic attitude to the origin of the universe because of the anthropic belief ingrained into their theories. Thus they imply that a universe like ours with its living creatures and particularly man is such an improbable possibility that this could only have happened if we have an infinite number of universes. Strangely and paradoxically enough the author takes the view that even an infinite number of random universes would not be able to produce a universe like ours, if that depends only on chance phenomena. That would not imperatively produce the physical constants, space-time, all the appropriate matter particles, the energy carrying particles, the atoms and molecules, the DNA and subsequently the proteins and organic molecules leading to life and humans, through just a probabilistic process arising from a kind of an infinite game of chances. The parameters needed to produce a universe like our, including the parameters imperatively required to produce the initial stuff from which the universe/universes would arise all that makes it hard to imagine that it is a matter of statistics and chances to produce our universe. Mathematics can indicate such a statistical possibility but we would always suspect that the methodology used could be faultless.

One would expect that the emergence of our universe through the mediation of an elusive to explain singularity, although taken seriously for decades, is being gradually over the years sort of side lined. The main explanation was the difficulty of understanding by the scientific community how a singularity with the mass of our universe compressed into an infinitely small size could have originated ex nihilo, and according to others, from an unknown source of some unknown kind of energy. This is quite understandable and the inability of cosmologists and physicists to find an adequately credible theory of creation appears increasingly as an impossible hurdle. On the other hand most of the alternative theories to the classical Big Bang , like multiverse, infinite universes, metaverse, bouncing universes, chaotic inflation universes with infinite budding off of new universes, a universe in your backyard for example, are non-falsifiable theories, and are not strictly speaking scientific, for they are not theories which can be verified by using scientific arguments or by circumstantial evidence at least. As of date the big bang still remains the most acceptable version of how the universe originated and with it the notion of creation.

The Big Bang concept, over the decades, due to its inherent implication of a finite creation of the universe, has been rated as philosophically acceptable. Big Bang according to Hu-

bert Reeves rests on a metaphysical connotation which may be either appealing or revolting. Thus John Maddox (1989), a former Editor of the science journal Nature, wrote an editorial describing the theory as philosophically unacceptable, for theological creationists find sufficient justification for their theist creed in it. On the other hand Emeritus Professor Christopher Isham of Imperial College, believes that theories which challenge the Big Bang finite universe model have been tenaciously advanced in a manner which far exceeded their intrinsic worth.

On the other hand the quotations at the beginning of this article by Einstein, Heisenberg, Hawking, Linde, Smooth and Davidson hide a deep cavern of meaning which the world will have to elucidate as our comprehension of the mysteries of ourselves and the universe unfold. The theories we have globally all say there was a mass of energy at the very beginning from which one or zillions of universes originated. Clearly such approaches leave us with a lot to wonder about due to the obvious inadequacy engrained in what they are able to explain. The quotes from their reputed authors referred to above tell us in no uncertain terms that we have to delve much deeper into the mysteries surrounding our realities and hopefully we may not be too far from such a possibility.

The search for a theory of everything to explain the realities of the universe including its origin has always been regarded with suspicion. Such an idea was strongly supported by Hawking in his popular book on Time and he even predicted that it would materialize by the end of last century. That not only proved incorrect but we do not seem to be getting nearer to anything like a universal theory capable of unifying a large number of physical and perhaps even biological phenomena. The future will tell. To start with ongoing experiments like the LHC will in due course substantiate or repudiate many claims and concepts on the ultimate physical realities of the universe including issues like mass, supersymmetry, the Higgs Boson on which important theories of the origin of the universe rest as well as the quantum nature of gravity. If all that fails to reveal any breakthrough it will be the duty of science to continue to generate new concepts which would hopefully enlighten humanity about our ultimate origin and nature. There are reasons to be hopeful that the coming decade would bring new ways of thinking towards the fulfillment of such a dream. We have Cosmological Arguments in theology and philosophy which are quite clear and which may be accepted or discarded depending on one's way of thinking, but in science the critical issue is that we do not have a universally acceptable Scientific Cosmological Argument for the origin of the universe. Such a modern scientific cosmological argument should make sense not only scientifically and philosophically but also to various disparate creeds.

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DEVELOPING AN EASY GRAPHICS SOFTWARE FOR ARCHAEOLOGICAL STUDIES

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Abstract: Two of the aims of this project are: to use diverse GPS technologies, e.g. EGNOS corrections or Real Time Kinematic (RTK), to make topographic levelling of the archaeological deposit and calculate non casual orientations and the employment of graphical software of general use to plot concrete structures.

Keywords: Archaeology, topographical studies, GPS technologies, CAD software, Archaeoastronomy

Topographic Measures

When we study the possible relation between the construction (tomb, house, sanctuary….) and the celestial or terrestrial landscape, we need measure an important parameter, the azimuth (Rodríguez-Caderot, 2006). Then we will try to found a relation between the azimuth of the building and several astronomical events or marker points of the topographical horizon (Cerdeño et al., 2009). We can use the wide ability of the GPS (Rodríguez-Caderot et al., 2007, Amado Reino, 1999) to measure and calculate, precise and quickly azimuths angles. Putting both GPS receivers onto the baseline extremes we want measure, it is possible to obtain the geodesic coordinates and then, applying the well known geodetic formulae (Wolf, 2002), to calculate the desired azimuth.

DEVELOPING A GRAPHIC TOOL

Normally, we manage a lot of data in archaeological studies. Therefore, it is necessary to answer an important question; can we manage a lot of data in an easy mode? To answer this, we are developing a graphic tool that can be used by non-professional users as graphic user interface (GUI) between them and the sophisticated software.

The second objective of the project consists in the graphical plot and interpretation of the data surveying records acquired in the first steps of the archaeological works by appropriated software for the archaeologist.

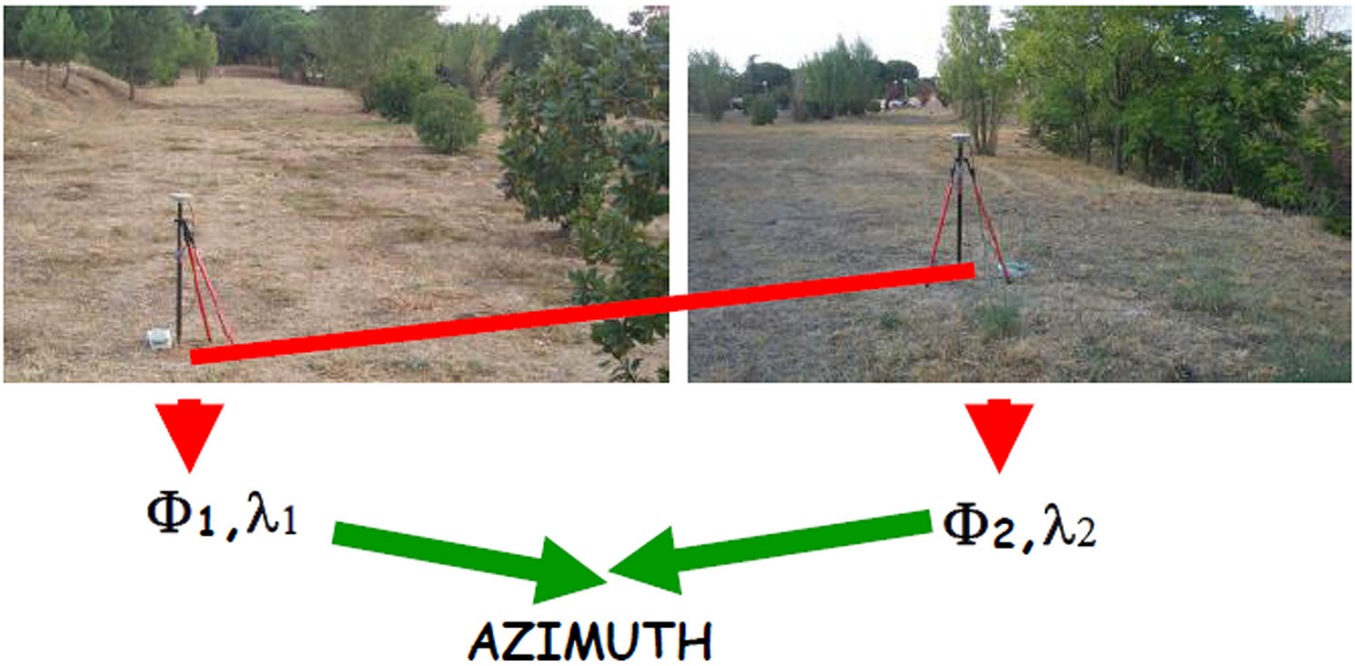
This part of the study is been developed in three steps:

1. Worksheets design for the capture of information in order to obtain a homogeneous capture of data.

2. ASCII file generation in order to store the worksheets information and which will be completely independent from CAD program that will be used a posteriori.

3. Develop a CAD software macro that takes the stored information as input and, as output, it generates a representative graphics of the deposit on the topography layout.

Figure 1. Practical method to calculate the azimuth using GPS techniques.



The design tool used in order to carry out these steps is ARQUEOPLOT. Their main characteristics are:

- generate the ASCII file containing data
- include a representative figure of the deposit in the topography CAD file.

In the next figure we presented a short example of the utilities of this tool, applied to an archaeological site, the Iberian culture "Los Rodiles" hillfort and necropolis.

ARQUEOPLOT can also manage the data for azimuth calculation of selected lines. In the Figure 3, the information capture flow diagram worksheet in order to calculate azimuth of a line can be seen.

Conclussions

1. We created a software able to give archaeologists the possibility to use on-site information in a CAD software almost instantaneously.

2. That information will give archaeoastronomers a better input information for further topographical studies.

3. ARQUEOPLOT does not make the archaeoastronomical work. We need the cultural component to discern between hypothetical and real astronomical orientations.

4. It is a fantastic tool to make archaeologist and archaeoastronomers talk in the same language.

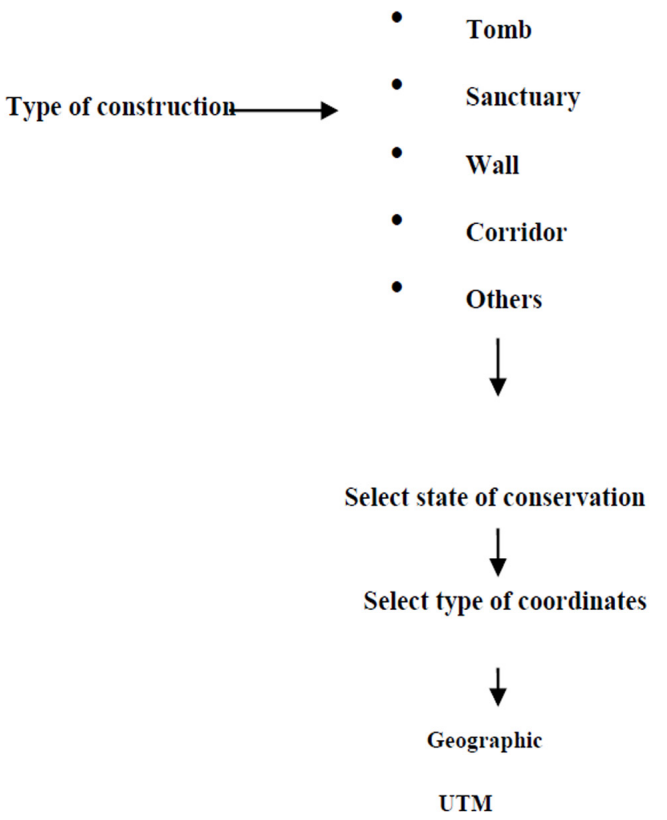
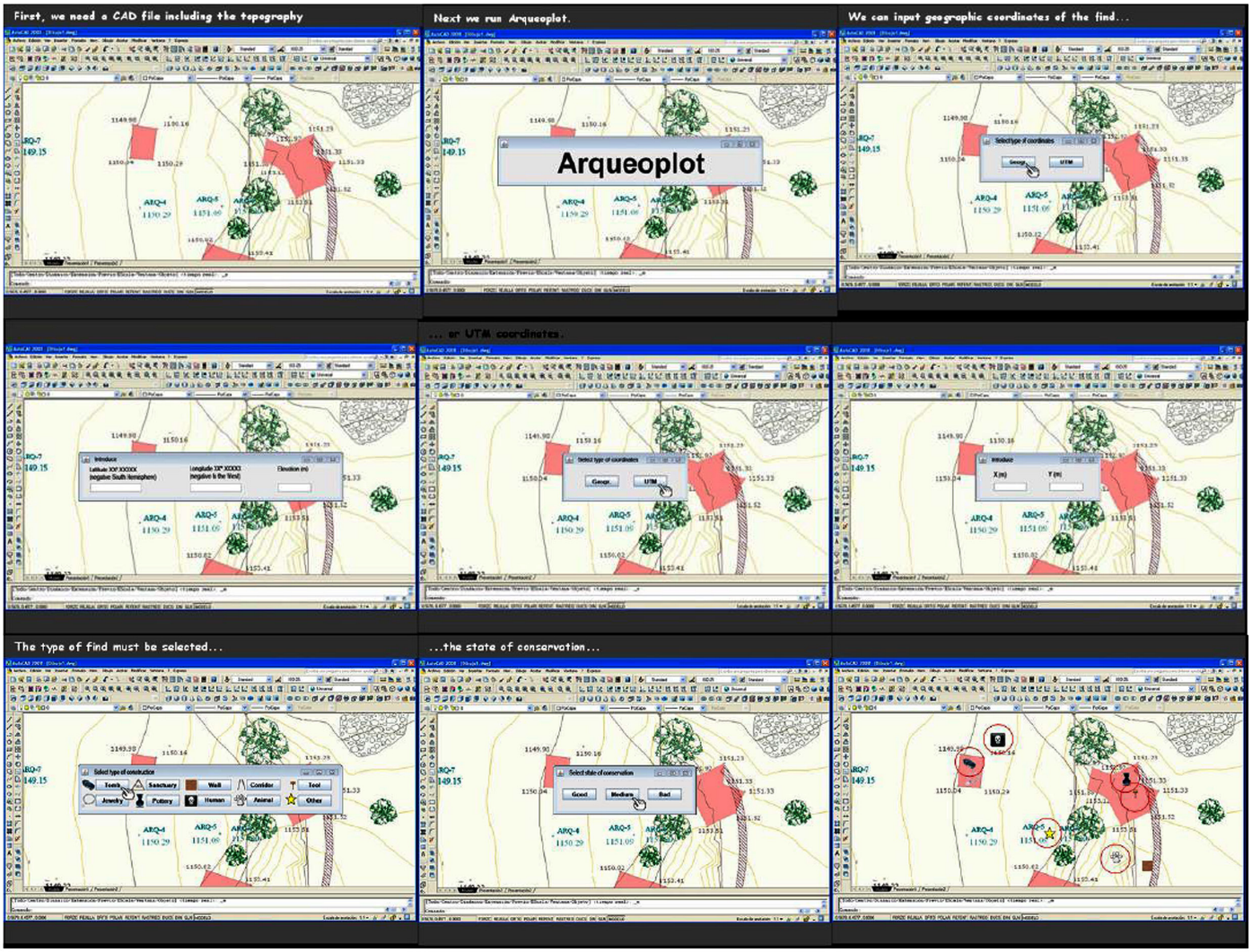


Figure 2. Diagram of the worksheets for the capture of information in order to homogenize the acquisition of the data.

Figure 3. Some pictures of the complete process of capture and graphic representation of the archaeological deposit found in a hillfort.



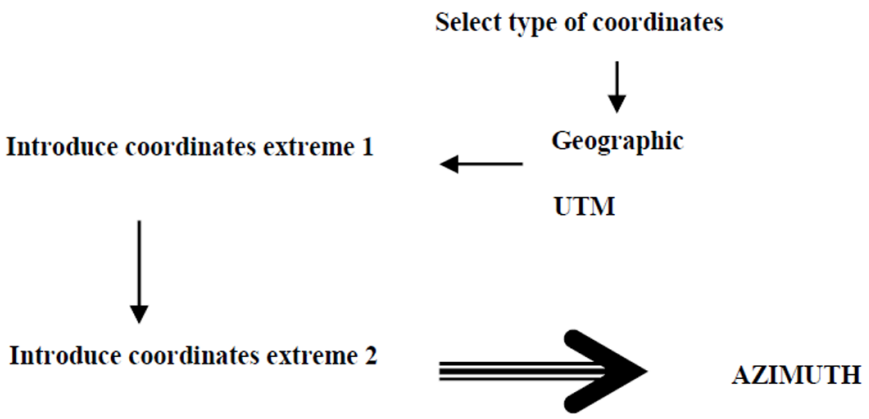


Figure 4. Information capture flow diagram worksheet in order to calculate azimuth of a line.

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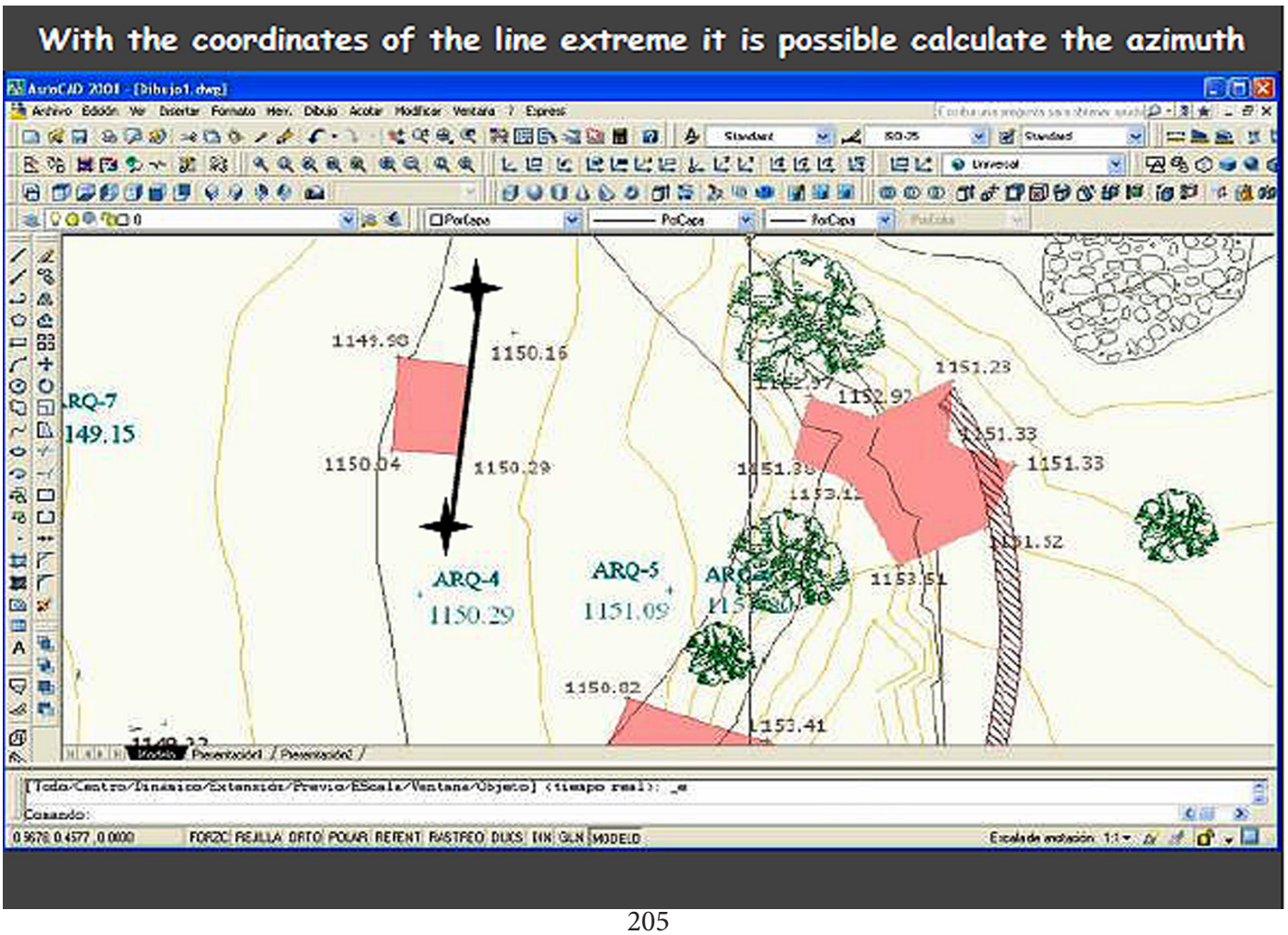
Figure 5. Flow diagram for the azimuth determination and final product.



Thinking „Out of the Box“

Climate Change in the Nile Delta from Prehistoric to the Modern Era and their Impact on soil and Vegetation in some Archaeological Sites

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Abstract: Since the time of the rainy Holocene So far, there have been periods of consecutive rain and drought on Egypt. It is the study of carbon 14 in the long-lived coniferous tree rings could see activity in the sun (spots and solar flares) and during its twelve years. As well as knowledge of possible flooding of the Nile and the periods of increase and decrease of the extent necessary to meet the Soil around Lake Qarun Fayoum From historical records in ancient Egypt and Muslim countries. Well as the possible link between periods of the disappearance of sunspots on the solar disc for several years and is known to inch lower level and role of the minimum level of Mandour creeping ice on Southern Europe to the Mediterranean Sea and the offset of the drought in North Africa and the And the Sahel region of Africa during the last thousand years. Were also analyzed pollen fossils of the overlapped layers of soil in two areas of the Delta are Avaris Sharkiya Province and Mendes Dakahliya Province. The study pointed out that there are differences due to environmental conditions, as demonstrated by the analysis of soil pH increased Connectivity and electrical evidence of sulfates and chlorides in the salinity of Mendes in Avaris. Also from the analysis of pollen fossils of successive layers of soil for both regions resulted in findings of the existence of the sovereignty of pollen fossils of the species Chenopodiaceae by 51.2% % in Mendes, while 7% in the Avaris. This is strong evidence of the existence of conditions of salt in Mendes than Avaris archaeological sites.

Keywords: Climate change; Wet habitat; palaeoecology; palynology; Prehistory; Predynasty; Avaris and Mendes.

Introduction

Climate change is often invoked as a trigger for the collapse of civilisations. The fall of the Akkadian Empire and the end of the Egyptian Old Kingdom around 4200 years before present (BP) have both been attributed to climatic change resulting in regional desiccation (Cullen et al., 2000; Hassan, 1997; Weiss, 1997). However, there is widespread evidence that climatic and environmental stress played a major role in the emergence of early civilisations, and that aridification in particular acted as a trigger for increased social complexity associated with urbanisation and state formation. Evidence that the desert belt of the northern hemisphere experienced wetter conditions in the past is widespread, but is particularly rich in the Sahara (Jolly, 1998; Kutzback and Liu, 1997; Lezine, 1989; Lioubimsteva, 1995; Maley, 1977). Dating of archaeological sites, lake sediments and faunal remains indicates that wet conditions were established in the Sahara by around 10,000 BP after a long period of aridity associated with the last glacial period (Goudie, 1992, Ritchie, 1994; Roberts, 1998). This humid phase was associated with an intensification of the African Monsoon caused by increased northern hemisphere summer insolation, resulting in its penetration far north of its current northernmost position (Claussen et al., 1999, 2003; Ganopolski et al., 1998; Tuenter et al., 2003).

The early Holocene humid phase was, however, punctuated by episodes of aridity that appear to have coincided with North Atlantic cooling events evident from ice-rafted debris and Greenland ice-core records (Alley et al. 1997; Bond et al., 1997; Cremaschi et al., 2001; Di Lernia and Palombini, 2002; Goodfriend, 1991; Smith, 1998; Guo et al., 2000). While summer insolation remained strong, the Saharan region recovered from these arid interruptions, and humid conditions were re-established. However, there is evidence that recovery was at best partial in the eastern Sahara after an arid event around 6000 BP (Di Lernia and Palombini, 2002; Goodfriend, 1991; Smith, 1998), and the entire Sahara had entered a period of desiccation by around 5000 BP (Cremaschi, 1998; Grandi et al. 1999; Jolly et al. 1998; Lioubimsteva 1995). The process of environmental desiccation that followed the southward retreat of the monsoon was mediated by geography; while water persisted at or near the surface in some locations long after the cessation of significant rainfall, hyper-arid surface conditions were established rapidly in other Saharan regions (Cremaschi and Di Lernia, 1998). It has been noted that the rise of Dynastic civilisation in Egypt coincided with the onset of widespread Saharan desiccation, and a number of authors have suggested that increased social complexity in the Nile Valley may have been precipitated by desertification in the eastern Sahara. Adams and Cialowicz (1997) state that the formation of the pharaonic state was the result of the expansion of the Naqada culture of Upper Egypt and was "encouraged by the pressure of a greater population in the south, where climatic change in the late Predynastic had reduced winter rainfall and husbandry in the deserts and brought about a reliance of agriculture in natural basins." This view is supported by Wilkinson (2003), who argues that populations that had previously practiced seasonal migration between the Nile Valley and the summer savannah in what is now Egypt's Eastern Desert were forced to settle permanently in the Nile Valley as a result of the cessation of summer rainfall. Malville et al. (1998, p 448) suggest that "an exodus from the Nubian Desert at 4,800 (uncalibrated radiocarbon) years BP may have stimulated social differentiation and cultural complexity in pre-dynastic Upper Egypt." It is plausible that the necessity to settle permanently in the Nile Valley, coupled with a likely Increase in population due to immigration resulting from the desiccation of the surrounding Saharan**.**

Aim of Study

The aim of this study is to provide information on the evolution of vegetation ecosystems and to document their response to climate change during the Prehistory, Predynasty and recent. Finally, we examine the response of dry and wet ecosystems to changes in regional climate and, based on the fossil pollen data of the Nile Delta region.

About The Study Areas

Avaris (Egyptian: Hatwaret, Greek: Auaris), thought to be located at Tell el-Dab'a (some still argue for different locations), was the ancient capital of the Hyksos dynasties in Egypt. Located in the northeastern region of the Nile Delta, Avaris was the base of the Hyksos kings of Egypt's Second Intermediate Period. The city was built atop the ruins of a Middle Kingdom town that had been captured by the Hyksos. After their takeover, the Hyksos heavily fortified the city and ruled the country using new technology, specifically the chariot which had never been witnessed before by the Ancient Egyptians.Tell El-Daba'a (Avaris), located in the northeastern Nile Delta (fig1), has been known since 1885. This part of the Nile Delta is generally characterized by a low alluvial plain with southwest-northeast trending belts of higher ground known as geziras (Arabic:sand-islands)

and archaeological sites known as tells which are accumulations of ancient settlement debris. Excavations at the site have been conducted since 1966 (Bietak 1996).

Mendes is a city just north-west of Avaris in the Egyptian delta and the sacred goat (often called Khem, Chem or Ham) was the zodiacal goat of Capricorn. In accordance with the Dragon Court tradition, Mendes, the Greek name of Ancient Egyptian city of Djedet, also known in Ancient Egypt as Per-Banebdjedet ("The Domain of the Ram Lord of Djedet") and Anpet, is known today as Tell El-Ruba. The city is located in the eastern Nile Delta (fig1) and was the capital of the 16th Lower Egyptian nome of Kha, until it was replaced by Thmuis in Greco-Roman Egypt. The two cities are only several hundred meters apart. During the 29th dynasty, Mendes was also the capital of Ancient Egypt, which lies on the Mendesian branch of the Nile (now silted up), about 35 km east of al-Mansurah. Mendes was mentioned in the sarcophagi texts as the meeting place of Osiris and Ra. They unified and became the "united Ba", the same texts estate that Osir's ba was manifested through the ram's body consecutively Osir was represented as a ram and the worship of Osir went on to the Ptolemaic era. Mendes became the capital of Egypt during the 29th Dynasty. Civilization in the area goes back to the Old Kingdom as the most ancient discovered tombs there are mastabas referred to the first and second dynasties but scholars proved their use during pre dynasties and archaic periods Redford, (2001).

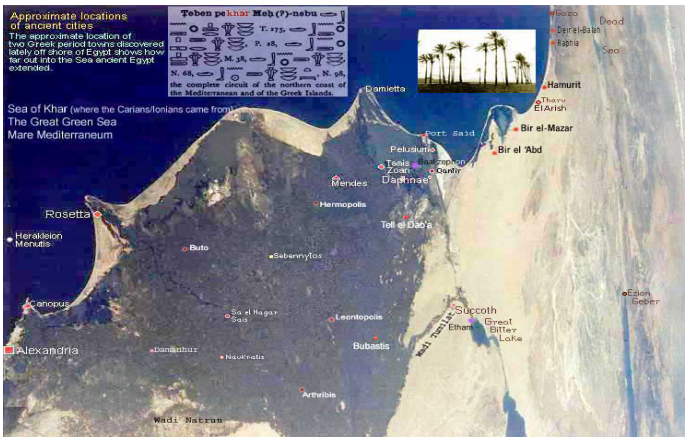


Figure 1. Satellite map of the of Ancient Nile Delta.

Materials and Methods

Two profile sectors were dug to 120 cm depth, at two locations both Avaris and Mendes archaeological sites. , Soil samples were taken every 10 cm for pollen analysis, and every 25 cm for physical and chemical analysis. Chronology of soil strata was obtained by Austrian Mission for archaeological excavations at Tell el Dabaa Sharkiya Province Canadian Mission for archaeological excavations at Tell el Robaa Dakahlia Province during March and April 2003. Radiocarbon dating of bulk samples of 1 cm3 obtained from Canadian Mission for archaeological excavations. The soil samples were extracted for their pollen content, sieved according to Faegri and Iversen (1989) .Ten gm of soil were taken from the required sector level. Five gm (subsample) were placed in boiling thermoplastic tube, mixed with 10ml KOH (10%), placed in boiling water bath for 15 minutes. The samples were sieved through a 100um aperture. The pollen grains were settled in monofilament sieve (7um), then washed with dist water .The washings were made up with dist water and centrifuged at 3000r.p.m for 3 minutes .The liquid was decanted and 10ml of Hydrofluoric HF (40%) were added, boiling water bath overnight, centrifuged and decant .The pellet resuspended in 10% HCL,to dissolve residual silicoflorides, centrifuged and decant. The pellet resuspended in Glacial Acetic Acid to dehydrate prior to acetolysis. Asetolysed according to Moore et al, (1991). The purified samples mounted on glass slides and counted for their pollen grains up to 300 grains. Pollen identification routinely used x400 magnification with x1000 magnification for small and difficult types with reference standard keys Andrew, (1984)., and reference herbarium collection specimens of Environmental Studies and Research Institute (ESRI) Sadat City, Minufiya University. While, pollen and spores nomenclature follows Bennet et al. (1994). Pollen percentage, concentration, calculations were based on the sum of total land pollen, which included terrestrial Pteridophyte spores, Cyperaceae pollen, and unidentified pollen types. Concentrations of pollen-slide >12 µm were determined. Since particle fragmentation occurs during pollen processing, a sieving-based methodology, modified from Rhodes (1998).

Figure 2. Showing soil profile at Mendes (Tell el Robaa Archaeological site) / Photo (2): Showing soil profile at Avaris (Tell el Dabaa Archaeological site).

Results Soil Analysis:

Avaris (Tell el Dabaa Archaeological Site), Table (1): The data obtained showed, the main bulk of the soil is mainly of medium and fine particles with values range between 38.8-32.5% at depths 0-25cm-125-150cm.The soil pH, ranged between 8.6-7.2 at depths 0-25-125-150cm. Ca-carbonates content ranged between 7.6-2%,total nitrogen 40-6 ppm, while electro-conductivity ranged between 0.4-0.35ml.Mohs/cm at depths 0-25and125-150cm, the amount of Na ranged between 1.24-0.78 M.meq/L, chlorides (CL) ranged between1.05-1.75 M.meq/L at depths 50-75 and 125-150cm, the amount of sulphates (SO4), ranged between 1.48-0.14 M.meq/L at depths 0-25 and 50-75cm.

Mendes (Tell el Robaa Archaeological Site), Table (2): The data obtained showed, the main bulk of the soil is sand with values range between 32.5-26.2% at depths 125-150 and 0-25cm.The soil pH ranged between 8.9-7.5 at depths 0-25 and 125-150cm. Ca-carbonates content ranged between 44.6-29%, total nitrogen 98-20ppm,while electro-conductivity ranged between 12.7-2.6 ml.Mohs/cm at depths 0-25and125-150cm, the amount of Na ranged between 20.3-3.0 M.meq/L, chlorides (CL) ranged between150-27.3 M.meq/L at depths 0-25 and 125-150cm, the amount of sulphates (SO4), ranged between 36.93-0.12 M.meq/L at depths 0-25 and 125-150cm.

Pollen record at Avaris

Period 1: Modern
In total 12 samples were analysed, in which 9 pollen types were recognized (Table 3). Records of the most important individual taxa are presented in Fig. 2. The identified pollen, pteridophyte spores from Avaris profile Open Vegetation,*Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances17.5,17, 21.7 and 19% respectively. Swamp Vegetation, *Typha*ceae 3.6%.

Period 2: New Kingdom about (1550-1070BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances7.9,4.6, 36.1 and 4.7% respectively. Nile water plants, Nymphaeaceae and Onagraceae with abundances 0.5 and 0.7%. Swamp Vegetation, *Typha*ceae 0.9%.

Period 3: Middle Kingdom about (2040-1700BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances16,12, 50.4 and 14.5% respectively. Nile water plants, Nymphaeaceae and Onagraceae with abundances 0.7 and 0.8%. Swamp Vegetation, *Typha*ceae 0.7%*Pinus* type 0.9%.

Period 4: Early Dynasty about (2920-2575BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 6.2, 34.5, 61.4 and 26.1% respectively.Nile water plants, Nymphaeaceae and Onagraceae with abundances 10.3 and 12%. Swamp Vegetation, *Typha*ceae 3.5%., *Pinus* type 3.6%.

Period 5: Predynasty about (3500-3100 BC)
Open Vegetation. *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances2.4, 9.3 33.8 and 17% respectively. Lycopodium spores 3.5%, *Pinus type* 8.5%. Swamp Vegetation,- *Typha type* 11.8%.

Period 6: Prehistory about (8500BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 5, 2, 18.6, 47.3 and 10.5% respectively. Nile water plants, Nymphaeaceae and Onagraceae with abundances 4.1 and 5.3%. Swamp Vegetation, *Typha*ceae 8.9%, *Pinus* type 9.3%.

Pollen record at Mendes

Period 1: Modern
In total 12 samples were analysed, in which 9 pollen types were recognized (Table 4). Records of the most important individual taxa are presented in Fig. 3. The identified pollen, pteridophyte spores from Mendes profile. Open Vegetation,*Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 51.2,0.6, 24.6 and 1% respectively.

Period 2: New Kingdom about (1550-1070BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 40.5,2.3, 16.3 and 4.9% respectively.

Period 3: Middle Kingdom about (2040-1700BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 28.8, 10, 9.6 and 5% respectively. Nile water plants, Nymphaeaceae and Onagraceae with abundances 10 and 6.5%. Swamp Vegetation, *Typha*ceae 1.5%, *Pinus* type 0.9%.

Period 4: Early Dynasty about (2920-2575BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 5, 7.4, 74 and 8.2% respectively. Nile water plants, Nymphaeaceae and Onagraceae with abundances 6 and 11.1%. Swamp Vegetation, *Typha*ceae 3.5%, *Pinus* type 3.6%.

Period 5: Predynasty about (3500-3100 BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 2.4, 3, 48.2 and 15% respectively. Lycopodium spores 5.5%, *Pinus type* 8.5%. Swamp Vegetation,- *Typha type* 10.5%.

Period 6: Prehistory about (8500BC)
Open Vegetation, *Chenopodiaceae, Asteraceae, Poaceae* and *Cyperaceae* with abundances 5.2, 3, 48.5 and 11.6% respectively. Nile water plants, Nymphaeaceae and Onagraceae with abundances 3 and 6.2%. Swamp Vegetation, *Typha*ceae 9.8%, *Pinus* type 9.5%.

Table 1. Physical and chemical properties of soil samples profile at Avaris Archaeological site. M= Moisture content – G= Gravels – C= Coarse sand – M = medium – F= fine sand – SC= finer sediments – T.N = Total nitrogen

Chronology	Depth/Cm	Physical					Chemical											
		Particle size %					PH	CaCo3 %	N ppm	E.C Ms/Cm	Anions / M.meq/L				Cations / M.meq/L			
		G	Sand			SC					CL	S_{O4}	C_{O3}	HCo_3	Na	K	Ca	Mg
			C	M	F													
Recent	0-25	10.3	3.9	38.8	36	12.3	8.6	7.6	40.0	0.4	1.2	1.48	-	1.0	1.24	0.44	1.4	0.8
Early, Middle and New Kingdoms about(2920-1070BC)	25-50	22.4	5.35	37.5	29.5	10.6	8.4	5.9	22	0.2	1.6	0.5	-	1.2	1.21	0.29	0.8	0.65
	50-75	26.3	4.99	37.1	28.1	9.3	8.2	3.0	20	0.18	1.05	0.14	-	0.98	0.78	0.26	0.65	0.6
Predynasty 3500-3100 BC	75-100	16.0	3.7	36.2	36	9.8	8.1	2.5	17	0.58	1.5	0.4	-	0.8	0.78	0.11	0.61	1.6
Prehistory About 8500BC	100-125	10.8	4.2	32.7	27.2	15.3	7.9	2.2	9	0.36	1.0	1.02	-	1.0	1.06	0.43	0.8	1.0
	125-150	8.3	2.8	32.5	30.1	15.6	7.2	2.0	6	0.35	1.75	0.82	-	1.5	1.14	0.53	0.63	0.24

Chronology	Depth/Cm	Physical					Chemical											
		Particle size %					PH	CaCo3 %	N ppm	E.C Ms/Cm	Anions / M.meq/L				Cations / M.meq/L			
		G	Sand			SC					CL	S_{O4}	C_{O3}	HCo_3	Na	K	Ca	Mg
			C	M	F													
Recent	0-25	3.5	16.0	26.2	22.3	32.0	8.9	44.6	98.3	12.7	150.0	36.93	-	1.6	20.3	6.15	66.2	94.8
Early, Middle and New Kingdoms about(2920-1070BC)	25-50	4.0	18.1	26.9	20.5	30.1	8.4	35.9	92.4	10.5	115.0	22.8	-	1.2	14.6	4.92	37.8	62.3
Predynasty 3500-3100 BC	50-75	5.1	19.8	26.3	19.2	29.0	8.2	37.2	80.0	7.6	89.0	21.6	-	1.3	10.4	3.2	17.5	48.1
	75-100	2.8	17.0	29.0	21.0	25.1	8.1	35.6	75.6	5.1	65.0	21.9	-	0.8	7.2	4.67	13.3	42.6
Prehistory About 8500BC	100-125	4.9	19.0	32.7	18.6	26.3	7.9	28.1	60.5	3.8	42.50	0.82	-	1.7	8.0	2.0	14.0	16.5
	125-150	5.0	20.0	32.5	19.2	26.6	7.5	29.0	20.3	2.6	27.3	0.12	-	2.0	3.0	1.5	5.8	10.7

Table 2. Physical and chemical properties of soil samples profile at Mendes Archaeological site. M= Moisture content – G= Gravels – C= Coarse sand – M = medium – F= fine sand – SC= finer sediments – T.N = Total nitrogen

Table 3. The relative abundance% of different pollen types in of Avaris Archaeological site. Pteridophy = Pteridophyta – Lycopod= Lycopodium-Gymn = Gymnospermae- Pin = Pinus Monocot = Monocotyledonae -TY= Typhaceae- PO = Poaceae (Graminae) - CY= Cyperaceae-Dicot = Dicotolydonae – CH = Chenopodiaceae – NY = Nymphaeaceae –AST = Asteraceae (Compositae) - ON = Onagraceae.

Chronology	Depth/ cm	Pteridophyta	Gymn	Monocot			Dicot			
		Lycopod	Pin	TY	PO	CY	CH	NY	AST	ON
Recent	0-10 Surface	-	-	3.6	21.7	19.0	17.5	-	17.0	-
	10-20	-	-	1.9	24.5	15.7	12.6	-	15.3	-
	20-30	-	-	1.6	29.2	15.6	10.0	0.5	10.7	-
New Kingdom about(1550-1070BC)	30-40	-	-	0.9	36.1	4.7	7.9	0.5	6.4	0.7
Middle Kingdom about(2040-1700BC)	40-50	-	0.3	0.7	50.4	14.5	16.0	0.7	12.0	0.8
	50-60	0.2	0.9	1.5	55.0	16.2	9.0	1.0	35.0	1.4
Early Dynasty about(2920-2575BC)	60-70	0.9	1.3	2.6	43.9	20.3	6.2	5.5	42.1	6.2
	70-80	2.0	3.6	3.5	61.4	26.1	5.0	10.3	34.5	12.0
Predynasty about (3500-3100 BC)	80-90	2.9	5.1	5.0	57.1	22.6	3.3	8.2	20.6	4.1
	90-100	3.5	8.5	10.5	33.8	17.0	2.4	6.4	9.3	5.2
Prehistory About (8500BC)	100-110	5.6	6.4	7.0	37.4	12.1	3.4	3.9	11.2	6.0
	110-120	10.4	9.3	8.9	47.3	10.5	5.2	4.1	18.6	5.3

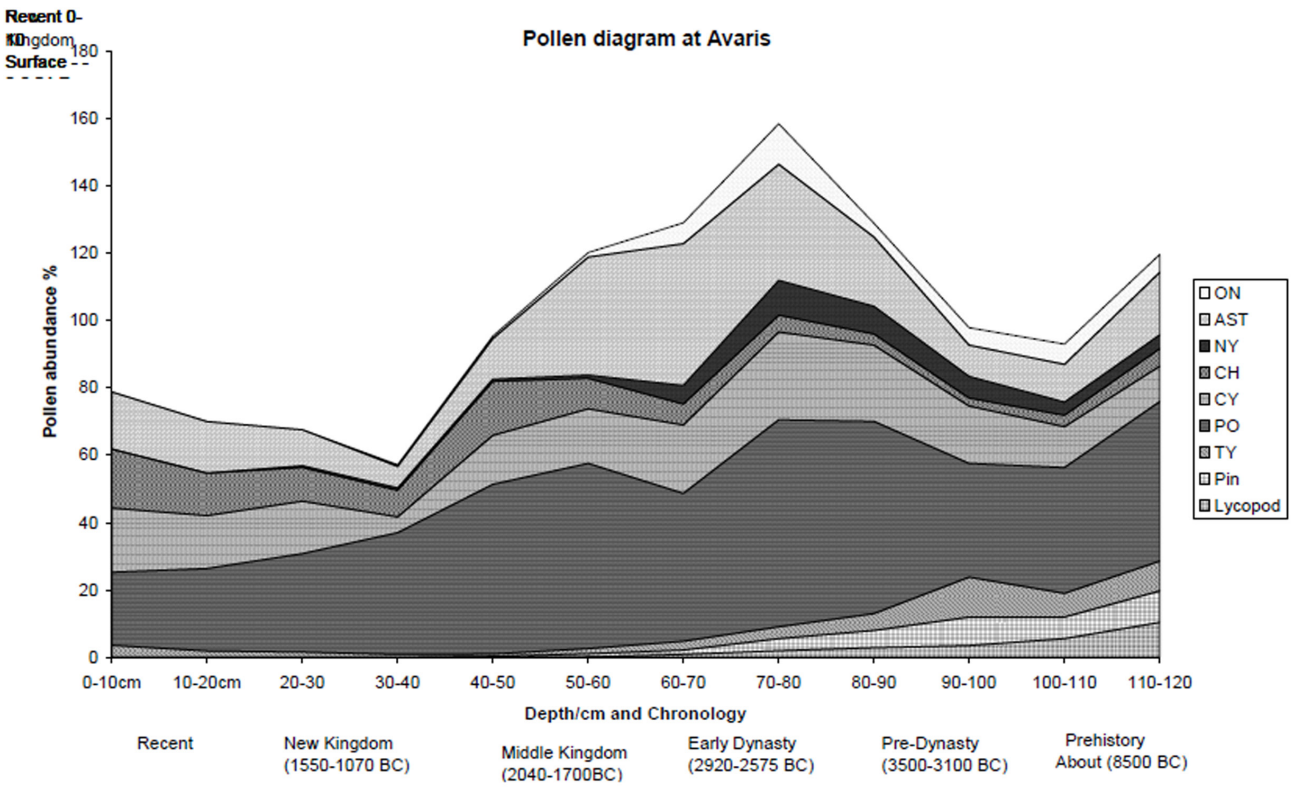


Figure 2. Pollen diagram showing the relative abundance of pollen at Avaris.

Table 4. The relative abundance% of different pollen types of Mendes Archaeological site. Pteridophy = Pteridophyta – Lycopod= Lycopodium-Gymn = Gymnospermae- Pin = Pinus Monocot = Monocotyledonae -TY= Typhaceae- PO = Poaceae (Graminae) - CY= Cyperaceae-Dicot = Dicotolydonae – CH = Chenopodiaceae – NY = Nymphaeaceae –AST = Asteraceae (Compositae) - ON = Onagraceae.

Chronology	Depth/ cm	Pterid	Gymn	Monocot			Dicot			
		Lycop	Pin	TY	PO	CY	CH	NY	AST	ON
Recent	0-10 Surface	-	-	-	24.6	1.0	51.2	1.8	0.6	0.9
	10-20	-	-	-	25.0	2.0	49.8	2.0	2.7	0.6
	20-30	-	-	-	16.8	4.0	36.9	3.0	13.4	0.8
New Kingdom about(1550-1070BC)	30-40	0.3	-	-	16.3	4.9	40.5	4.7	2.3	19.5
Middle Kingdom about(2040-1700BC)	40-50	0.7	0.3	-	7.3	-	31.8	10.7	2.7	31.8
	50-60	1.8	0.9	1.5	9.6	5.0	28.8	10.0	10.0	6.5
Early Dynasty about(2920-2575BC)	60-70	2.6	1.3	2.6	53.6	7.1	20.0	6.5	8.5	5.2
	70-80	3.1	3.6	3.5	74.0	8.2	5.0	6.0	7.4	11.1
Predynasty about(3500-3100 BC)	80-90	3.4	5.1	5.0	83.3	10.5	3.3	4.2	3.3	3.3
	90-100	5.5	8.5	11.8	48.2	15.0	2.4	4.6	3.0	4.5
Prehistory about (8500BC)	100-110	10.6	6.4	7.0	45.5	14.8	3.4	5.3	5.0	4.1
	110-120	15.5	9.8	9.8	48.5	11.6	5.2	3.0	3.0	6.2

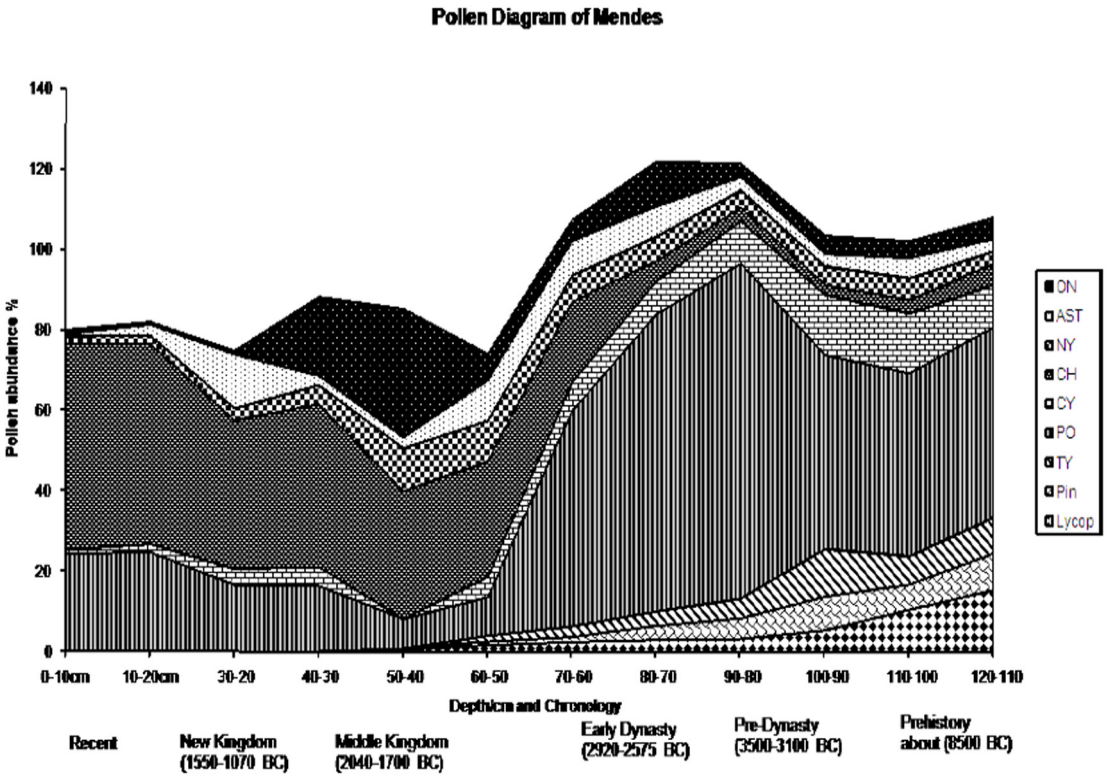
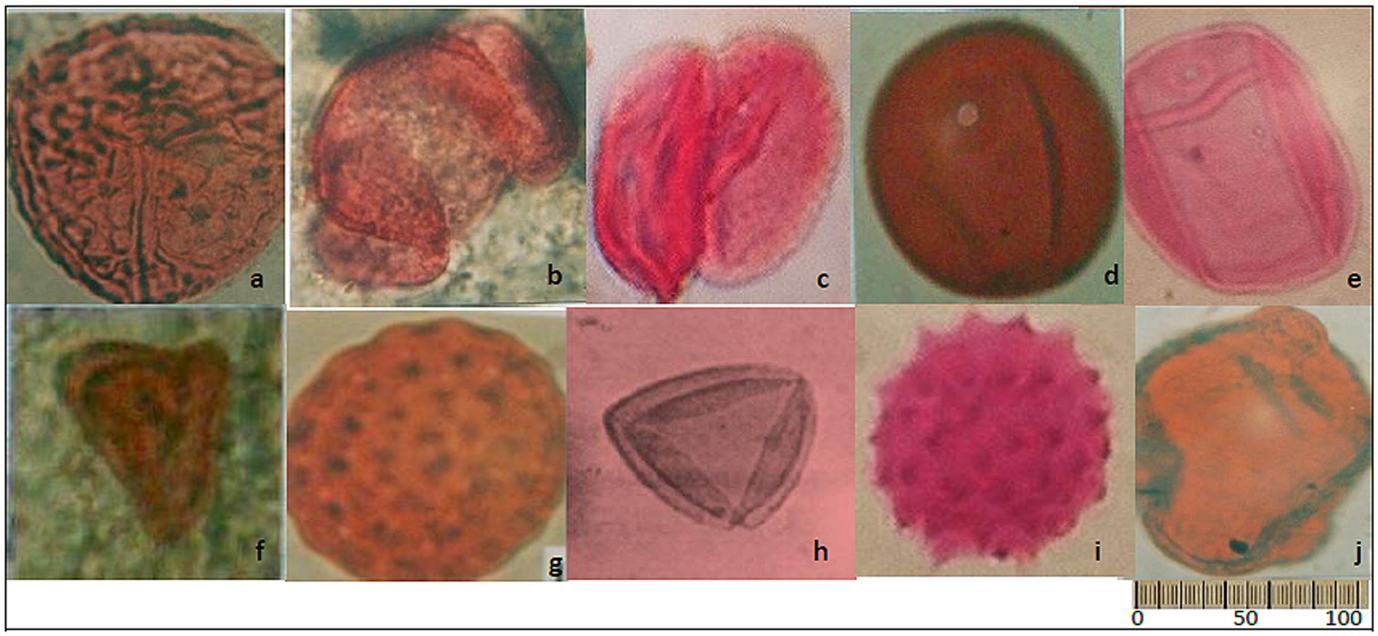


Figure 3. Pollen diagram showing the relative abundance of pollen at Mendes Profile.

Plate 1. (a) Lycopodium spore 50um, (b) Pinus type 48um, (c) Typha pollen type 39um, (d) Cereals type 74um, (e) wild grasses 43um, (f) Cyperus type 43um, (g) Chenopodium type 30um, (h) Nymphaea type 48um, (i) Eclipta type 30um (j) Jussiaea pollen type 80um.



Discussion

Climate change is often invoked as a trigger for the collapse of civilizations. The fall of the Akkadian Empire and the end of the Egyptian Old Kingdom around 4200 years before present (BP) have both been attributed to climatic change resulting in regional desiccation (Cullen et al., 2000; Hassan, 1997; Weiss, 1997). However, climatic and environmental stress played a major role in the emergence of early civilizations. Dating of archaeological sites, lake sediments and faunal remains indicates that wet conditions were established in the Sahara by around 10,000 BP after a long period of aridity associated with the last glacial period (Goudie, 1992, Ritchie, 1994; Roberts, 1998). This humid phase was associated with an intensification of the African Monsoon caused by increased northern hemisphere summer insolation, (Claussen et al., 1999, 2003; Ganopolski et al., 1998; Tuenter et al., 2003). It has been noted that the rise of Dynastic civilisation in Egypt coincided with the onset of widespread Saharan desiccation, and a number of authors have suggested that increased social complexity in the Nile Valley may have been precipitated by desertification in the eastern Sahara. Adams and Cialowicz (1997) state that the formation of the pharaonic state was the result of the expansion of the Naqada culture of Upper Egypt and was "encouraged by the pressure of a greater population in the south, where climatic change in the late Predynastic had reduced winter rainfall and husbandry in the deserts and brought about a reliance of agriculture in natural basins. This view is supported by Wilkinson (2003), who argues that populations that had previously practiced seasonal migration between the Nile Valley and the summer savannah in what is now Egypt's Eastern Desert were forced to settle permanently in the Nile Valley as a result of the cessation of summer rainfall.

Soil analysis: of the present study reflects decrease salinity with depth; this can be explained with continuous leaching of salts at two studied sites according to Abd El Fattah et al., (1993).

Palynological studies: One of the aims of pollen studies is the reconstruction of palaeoenvironmental change, Birks (1973). The relative abundance of certain pollen and spores reflects the conditions in which they survive also habitats conditions. During **Period 1** (recent) local swamp vegetation dwindled and, at the end of the period, dry forest decreased to reach a minimum representation. This marked decrease in forest species, together with abundant open vegetation reflects a progressive decrease in humidity, strongly suggesting decrease in precipitation. *Chenopodiaceae* recorded highest abundances 51.2% Period 1 recent layer at Mendes.While, **Period 2** New Kingdom about (1550-1070BC), characterized with increase of open vegetation, also the Nile flooding is good. During **Period 3** (Middle Kingdom, about 2040-1700 BC), the data of pollen abundances revealed that dominance of Nile water plants e.g *Nymphea* and *Jussiaea* pollen types 10.7 and 31.8% at Mendes, the presence of these plants suggest Nile water and tributaries, also reflects Nile flooding at this period, Patel et al, (1984) and El Ghazali, (1989). *Asteraceae and Poaceae* reached maximum representation during **Period 4** Early Dynasty about (2920-2575 BC) Avaris, 74% for *Poaceae* same period at Mendes and 26.1% for *Cyperaceae* at Avaris Same Period, *Cyperaceae* pollen reflects to a significant degree herbaceous vegetation on the valley floor, and therefore should be included in the pollen sum is best supported, in this connection Ayyad, (1988) stated that *Cyperaceae* species were growing in wet or dry places, it is salty or unsalty. While, during Predynastic **Period 5** about (3100 BC), *Typha* pollen type was high 10.5 and 11.8, this high abundance may indicates reed swamps conditions at the two sites during this period, Ritchie (1985), the palynological assemblage indicates humid climatic conditions for this period, and an increase of precipitation. During Prehistoric **Period 6**, *Lycopodium* spores (plate1), recorded 10.4% and 15.5% at Avaris and Mendes`, this may indicates ahumid climate and habitats according to Rossignol (1969). On the other hand Pinus type recorded abundance 9.3 and 9.8% at the same depth and Period of Avaris and Mendes, This high representation reflects higher precipitation, also suggest the downslope migration of the lower forest and we conclude that climatic conditions became moist to relatively wet according to Schulz (1974).

Conclusion

We can conclude that, there is a succession climatic changes leads to vegetation successions during the six studied periods, the ecosystems respond sensitively to changes in plant available moisture (precipitation) where the wet habitats forest vegetation were dominant during period 6 (Prehistory), followed reed swamps during Predynastic, period 5 (about 3100 BC). The habitats changed to herbaceous vegetation during period 4(Early Dynasty about (2920-2575 BC), then Nile water flooding and dominance of Nile water plants during period 3(Middle Kingdom, about 2040-1700 BC), while dominance of open vegetation cover during period 2 New Kingdom about (1550-1070BC), then decrease in humidity, strongly suggesting decrease in precipitation. Chenopodiaceae recorded highest abundances 51.2% Period 1 recent layer at Mendes indication to habitate changing to halophytic vegetation, while changed to mesophytic habitats at Avaris recent time. So, Palynology serves in reconstruction of the past vegetation and climate changes.

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PALAEOBOTANICAL STUDY ON SOIL STRATA OF LAKE QARUN SHORE SINCE HELLENO-ROMAN PERIOD

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Abstract: The present study, provides a great palaeoenvironmental information's about habitat changing of Lake Qarun from a humid and wet during the Hellenic Period to reed swampy early Roman, to Nile Flooding middle Roman, to mesophytic Late Roman, then halophytic and salt marshes Chenopodiaceae recent time. Using indicator plants and their remains i.e. pollen grains and spores , palynological studies of different soil strata revealed presence of 13 pollen and spores types e.g. Lycopodium spores, Typhaceae type, Juncaceae, Poaceae, Cyperaceae, Caryophyllaceae, Chenopodiaceae, Nymphaeaceae, Fabaceae, Asteraceae, Tamaricaceae,Onagraceae and Lamiaceae.

Key words:Lake Qarun-Palynology-Soil Strata-Graeco Roman-fossil pollen.

Introduction

Pollen as a part of the reproductive system of plants are tiny grains discharged like dust from the male plant and rely on wind and insects to be transported to female plants. Pollen grains are distinctive to each plant species and sub-species, and their tiny and dense structure mean that they may survive in many soil types for thousands of years (Dinacauze, 2000) .The pollen analysis, vegetation history study using microfossils provide useful information about the environmental conditions in the present and past. The outside of the pollen grain wall is made of highly resistant material, so, the pollen from 400 million years ago can be found today. Each pollen and spore is different in shape and structure, thus the morphology is a key to understanding the types of vegetation. Pollen analysis was first produced by the Swedish geologist Von Post in about 1916. From the pollen diagram , information can be obtained about vegetation , floristic composition, climatic changes , lake sedimentation ,wind direction , turn over rate of the lake ecosystem and sea levels too (West , 1971) .Palynological investigations were introduced to the Egyptian archaeological sites e.g. Mehringer et .al (1979) ,who studied the sediments and fossil pollen of two short cores at Birket Qarun in Fayum ,Egypt. The data obtained reflect the Nile floods, lake levels, and agricultural developments of the last 325 years, demonstrate the potential of detailed record from the Fayum Depression. The chronology of these cores is inferred by correlation of historic events with changes in the fossil and sedimentary records. The analysis revealed abundant pollen of shallow –water, rooted aquatic plants e.g. (Typhoo pollen type) provides evidence for continued low lake levels through 1700s. A high lake level, resulting from the extreme Nile flood of 1817- 1818, is recorded by hystrichospheres, reworked by wave action, from Eocene marine sediments exposed on the north shore of Birket Qarun. Also, Mehringer et al. (1979) added that, the political administrations, as reflected in agricultural policy, is also recorded in lake history. Changing lake levels are, in part, correlated with canal neglect during Malmo and Ottoman control, and renewed canal maintenance under the agricultural policy of Mohamed Ally. Few studies were carried out on palynological ,archaeobotanical e.g. Mehringer et al., (1979),who study the introduced plants during Mohammed Aly Policy of agriculture at Lake Qarun.

This study objective includes:

- Clarify the plant habitat changes since Greco-Roman period, using pollen analysis.
- To reveal the Nile flooding, using indicator plants and their pollen.
- Reconstruct vegetation history of Lake Qarun.
- The present study is an attempt to apply the concept of plant and pollen indicators to habitat conditions in different soil strata at archaeological site (Lake Qarun)

History of Lake Qarun

Lake Qarun (Birket Qarun) in Fayoum - Egypt, located about 80 kilometers southwest of Cairo in the Egyptian Fayoum not far from the Nile Valley, is one of Egypt's most treasured natural landmarks and a resource that has helped support human culture for some 8,000 years. It is the only natural contemporary lake of any size in Middle Egypt. It is therefore rich in both natural and archaeological resources. In reality, Lake Qarun is a huge salty body of water that makes it unfit for drinking. And while its southern and eastern shores are populated, where fresh water can be brought from irrigation systems, the northern shore is bare desert, uninhibited, and difficult to reach. The lake has an interesting history and there are some fascinating theories about how it came to be known as Lake Qarun. The lake and the nearby Qaser Qarun are said to take their names from the Greco-Roman city of Karanis to the east. However, the lake was known in the thirteenth century, some eight hundred years after the abandonment of Karanis, as Birka El Seid, or "the lake of fishing" in Arabic. Therefore, many believe that it is unlikely that Karanis would today. Late Roman period. Many Ptolemaic (Greek) and Roman towns were situated here. Furthermore, much of the area was cultivated until the decay of the Roman Empire, when local governmental mismanagement led to the loss of fertile land to the desert and the abandonment of the towns. Even recent reclamation work, which has made the southwestern shore of the lake green again, has failed to make good the huge losses of agricultural land incurred during the late Roman times. Qarun may thus have been a particularly unpopular Roman governor under whose careless rule this land was deserted, or else a fictional character epitomizing the Roman administration in general. The biblical and Quranic connections were probably added later when the similarity between the two stories was noticed. The Lake Qarun today, 45 meters below sea level, has a surface area of 214 square kilometers. It has a maximum depth of just over 8 meters (west of Golden Horn Island) and a volume of 800 million cubic meters. It is 42 kilometers long and 9 kilometers wide at its broadest point. About 370 million cubic meters of drainage water reach the lake annually, and as the lake level now stays fairly constant and there are no known outlets, this figure is also taken as the annual rate of evaporation. If follows that, if the water supply to the lake were cut off, it would dry up in two years. The high rate of evaporation has led to a concentration of salts, the lake is now as saline as the seawater, with a ratio of

around 34.5 parts per thousand, said to be growing at the rate of 0.4 parts per year. For comparison, sea water ranges between 34 and 37 per thousand, while Jordan's Dead Sea has between 300 and 330 per thousand. The water is less salty in the East and the South of the lake, where the two main canals bring in fresh and drainage water.

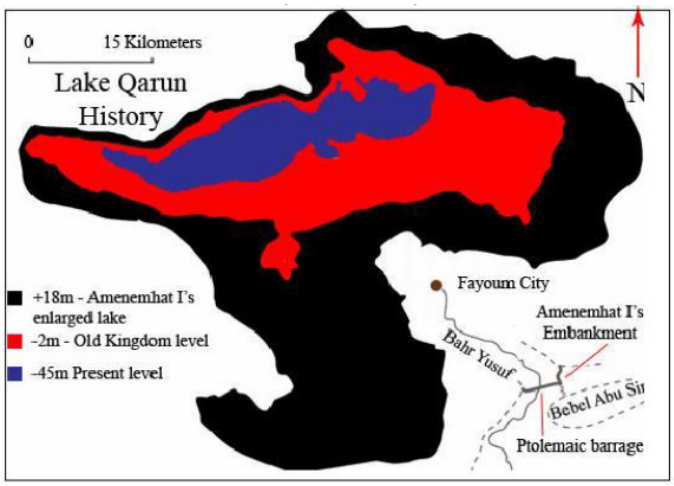

Figure 1: Historical map of Lake Qarun.

Figure 2: Lake Qarun view from the eastern side (arrows indicate sampling locations).

Figure 3: Marshes along the Eastern edge of the lake.

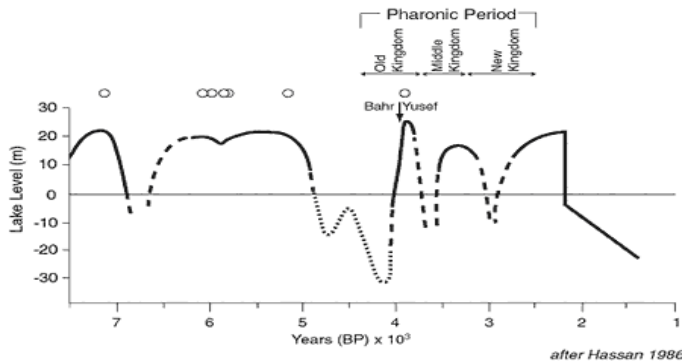

Figure 4: Lake Level during (Pharaonic Period).Hassan et al (2006).

Materials and Methods

Three profile sectors were dug to 120 cm depth, at three locations of Lake Qarun shore. , Soil samples were taken every 10 cm. Chronology of soil strata was obtained by Austrian Mission for archaeological excavations at Sharkiya Province. The soil samples were extracted for their pollen content, sieved according to Faegri *et al*. (1989) .Ten gm of soil were taken from the required sector level. Five gm (sub- sample) were placed in boiling thermoplastic tube, mixed with 10ml KOH (10%), placed in boiling water bath for 15 minutes. The samples were sieved through a 100um aperture. The pollen grains were settled in monofilament sieve (7um) , then washed with dist water .The washings were made up with dist water and centrifuged at 3000r.p.m for 3 minutes .The liquid was decanted and 10ml of Hydrofluoric HF(40%) were added, boiling water bath overnight ,centrifuged and decant .The pellet was resuspended in 10% HCL,to dissolve residual silicoflorides ,centrifuged and decant. The pellet resuspended in Glacial Acetic Acid to dehydrate prior to acetolysis. Acetolysed according to Moore *et al. (*1991). The purified samples mounted on glass slides and counted for their pollen grains up to 300 grains. Pollen identification routinely used x400 magnification with x1000 magnification for small and difficult types with reference standard keys Andrew, (1984)., and reference herbarium collection specimens of Environmental Studies and Research Institute (ESRI) Sadat City, Minufiya University. While, pollen and spores nomenclature follows Bennet *et a*l. (1994).

Results

Lycopodium spores:

Table (1), Fig (5 and 5cont plate1-A)

The highest value 10.4%was recorded at bottom stratum (110-120cm) depth during Greek Period (300-200 B.C),while the lowest 0.9% recorded at(40-50and 80-90cm) Roman Period see table (1),fig (5-a).

Typhaceae Pollen:

Table (1) and Fig (5-b plate1-B) showed the highest value 11.8% at depth (90-100cm) during Roman Period, the lowest 0.4% at depth (10-20cm) recent layer.

Juncaceae:

Table (1) and Fig (5-c plate1-C), the highest value 12.6% was recorded at depth (0-10cm) recent layer while, the lowest 2% at depth (20-30cm) recent.

***Poaceae (Gramineae)*:**

Table (1) and Fig (5-d plate1-D), the highest value 83.3% was recorded at depth (80-90cm) Roman while, the lowest 7.3% at depth (40-50cm) Roman Period.

***Cyperaceae*:**

Table (1) and Fig (5-e plate1-E),

The highest value 15% was recorded at depth (90-100cm) Roman while, the lowest 1% at depth (0-10cm) recent layer.

***Caryophyllaceae*:**

Table (1) and Fig (5-f plate1-F), the highest value 10% was recorded at depth (10-20cm) recent, the lowest 3.3% at depth (30-40cm) Roman.

***Chenopodiaceae*:**

Table (1) and Fig (5-g plate1-G), the highest value 51.2% was recorded at depth (0-10-20cm) recent, the lowest 2.4% at depth (90-100cm) Roman.

Nymphaeaceae:
Table (1) and Fig (5-h plate1-H), the highest value 10.7% was recorded at depth (40-50cm) Roman, while the lowest 2% at depth (10-20cm) recent

Fabaceae (Leguminosae):
Table(1)and Fig(5cont-I plate1-K),the highest value 8.8% was recorded at depth(20-30cm) recent while, the lowest 1.9% at depth (50-60cm) Roman Period.

***Asteraceae(Compositae)*:**
Table(1)and Fig(5cont-j plate1-I&J),The highest value 13.4% was recorded at depth(20-30cm) recent while, the lowest 0.6% at depth (0-10cm) recent layer.

***Tamaricaceae*:**
Table (1) and Fig (5cont-k plate1-L), the highest value 8.3% was recorded at depth (10-20cm) recent while, the lowest 0.9% at depth (30-40cm) Roman.

***Onagraceae*:**
Table (1) and Fig (5cont-l plate1M), the highest value 31.8% was recorded at depth (40-50cm) Roman while, the lowest 0.8% at depth (20-30cm) recent layer.

***Lamiaceae(Labiatae)*:**able(1)and Fig(5cont-m plate1-N), the highest value 12% was recorded at depth(40-50cm) Roman while, the lowest 0.3% at depth (30-40cm) Roman Period.

Discussion

One of the aims of palynological studies is the recognition of vegetation and plant communities on the bases of associated pollen grains.In the present study soil samples have been analysed for their pollen content.The data obtained revealed that, *Lycopodium* spores has been dominant during Greek Period with relative abundance 10.4% (at 110-120cm) (see table1-fig5),these spores indicate a humid conditions at this period Rossignol, (1962 and 1969), also recorded in Holocecne Nile Slits from the Nile Delta, Saad and Sami (1967). The above stratum was dominated with Cat tail (*Typha* pollen type) *Typhaceae* 11.8% at depth 90-100cm, Roman Period (30 B.C-600 A.D).These plants are well known reed swamps which indication a swampy habitat, according to Ritche(1985) and Ayyad (1988).At the middle stratum , dating to middle Roman period dominated with Primerose willow(*Jussiaea* pollen type) *Onagraceae*31.8%,at (40-50cm) depth, Sacred lotus (*Nymphaea* pollen type) *Nymphaeaceae*10.7%,(40-50cm) depth and Budding grass(*Mentha* pollen type) *Lamiaceae* 12% (40-50cm) depth, these plants are known as Nile water , so indicating Nile flooding to the Lake Qarun during Middle Roman Period. In this connection, Patel *et al* (1984) and El Ghazali (1989), reported that *Jussiaea* and *Nymphaea* indication to khor,tributaries and aquatic habitats.While, at the following stratum (20-30cm) depth, dating Late Roman Period , the following plants recorded highest values ,Goose foot(*Chenopodium* pollen type) *Chenopodiaceae* 36.9%, Common groundsel (*Senecio* pollen type*) Asteraceae* 13.4% Ray grass (*Lolium* pollen type*) Poaceae* 16.8%,and Common Vetch (Vicia pollen type) Fabaceae 8.8%, these plants were classified mesophytic, which indicating mesophytic habitats at Late Roman Period, El Hadidi (1985).At surface stratum (0-10 and 10-20cm), dating recent time, recorded the highest abundance of the following ; Salt wort (*Salsola* pollen type) *Chenopodiaceae* 51.2%,Sharp rush(*Juncus* pollen type) *Juncaceae* 12.6%, Sand spurrey (*Spergulria* pollen type) *Caryophyllaceae* 10%,and Tamarisk salt tree (*Tamarix* pollen type) *Tamaricaceae* 8.3%, these plants are known as salt loving or halophytic so, it supporting halophytic and salt marsh habitats.In this connection, Abd El Fattah (1990) reported that, *Salsola* and *Spergularia* were from wet halophytic plants, also,El Shenbary (19985) mentioned that *Juncaceae* and *Chenopodiaceae* were a salt marsh plants, while *Tamarix* and *Casuarina* were flourish under arid and hot climate. Some pollen types recorded few representations; this may due to wind dispersion from another sites. For lakes and marine sites where water borne pollen are the major influx, the assemblage must be varied in all values, Brown *et al* (2007). This is directly comparable to some high resolution pollen and spores diagrams from laminated lake sediments which typically show these high-frequency fluctuations in values (Kerig and Lechterbeck, 2004). The dramatic changes in land cover, this accords with the general dampened response of many lake diagrams to human impact Brown *et al*,.(2005).

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Table 1. The frequencies of different pollen types in five grams soil at different depths of Qarun Lake profile. Pteridophy = Pteridophyta – Lycopod= Lycopodium- Monocot = Monocotyledonae -TY= Typhaceae-JU= Juncaceae- PO = Poaceae (Graminae) - CY= Cyperaceae-Dicot = Dicotolydonae – CAR = Caryophyllaceae – CH = Chenopodiaceae – NY = Nymphaeaceae – FAB = Fabaceae (Leguminosae) – AST = Asteraceae (Compositae) - TA= Tamaricaceae – ON = Onagraceae – LA = Lamiaceae (Labiatae)

Chronology	Depth/ cm	Pteridophy	Monocot				Dicot							
		Lycopod	TY	JU	PO	CY	CAR	CH	NY	FAB	AST	TA	ON	LA
Recent	0-10 Surface	-	0.9	12.6	24.6	1.0	6.6	51.2	-	-	0.6	2.5	-	-
	10-20	-	0.4	-	25.0	2.0	10.0	49.8	2.0	-	2.7	8.3	-	-
	20-30	-	3.4	2.0	16.8	4.0	8.0	36.9	-	8.8	13.4	2.7	0.8	3.2
Roman	30-40	-	-	-	16.3	4.7	3.3	40.5	4.7	4.7	2.3	0.9	19.5	0.3
	40-50	0.9	-	-	7.3	-	-	31.8	10.7	2.7	2.7	-	31.8	12.0
	50-60	-	-	-	9.6	5.0	-	28.8	10.0	1.9	10.0	-	6.5	7.1
	60-70	-	-	-	53.6	7.1	-	20.0	-	7.1	8.5	-	-	3.7
	70-80	-	-	-	74.0	-	-	5.0	-	2.0	7.4	-	11.1	-
	80-90	0.9	-	-	83.3	-	-	3.3	-	-	3.3	3.3	3.3	2.3
	90-100	3.5	11.8	8.1	48.2	15.0	-	2.4	-	-	3.0	5.0	-	2.0
Greek	100-110	5.6	7.0	10.2	45.5	14.8	-	3.4	-	-	5.0	2.2	1.1	5.0
	110-120	10.4	8.9	7.6	47.3	10.5	-	5.2	-	-	3.0	1.0	-	6.0

Figure 5. Variations in the frequency of pollen grains and spores in differnt soil samples from Qarun lake profile.

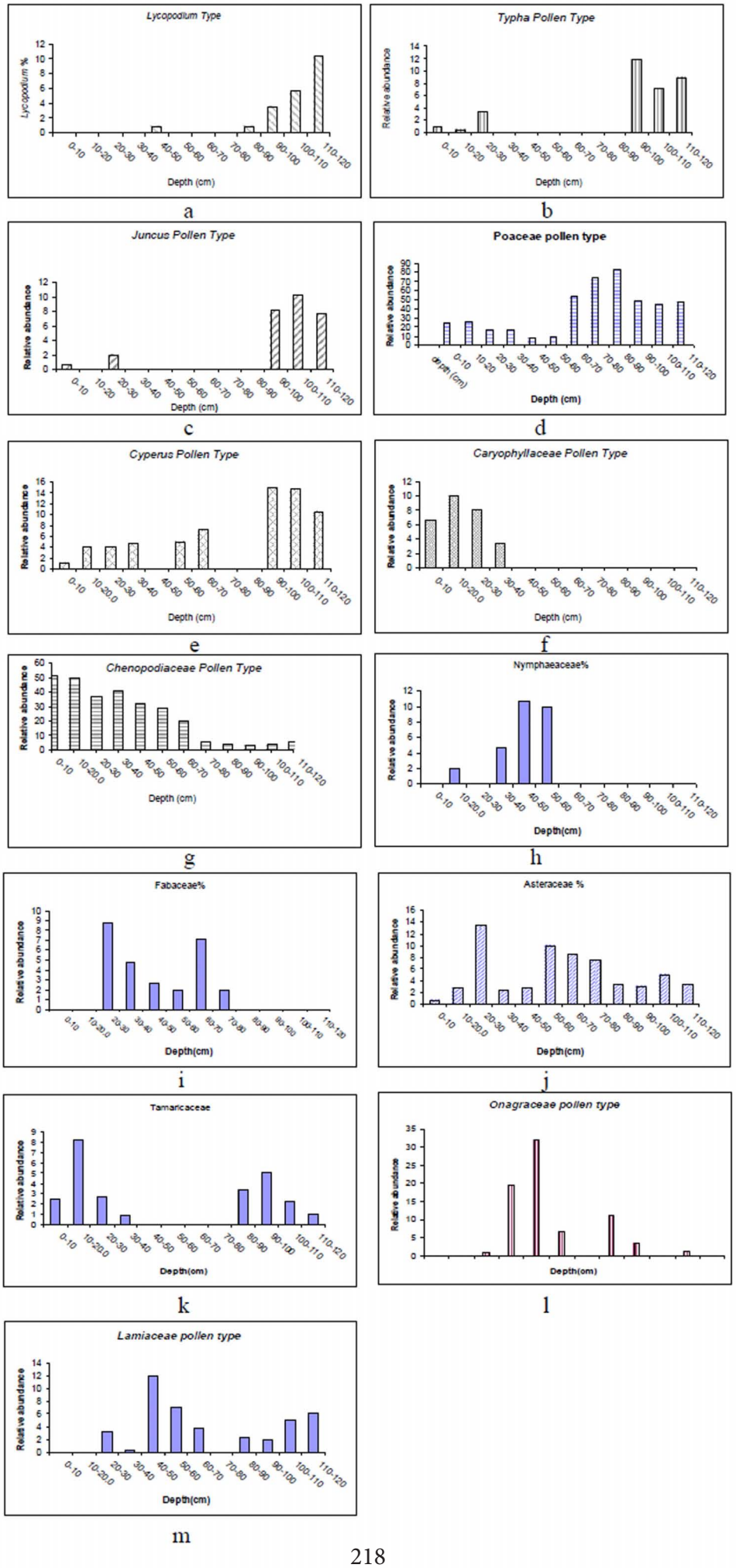
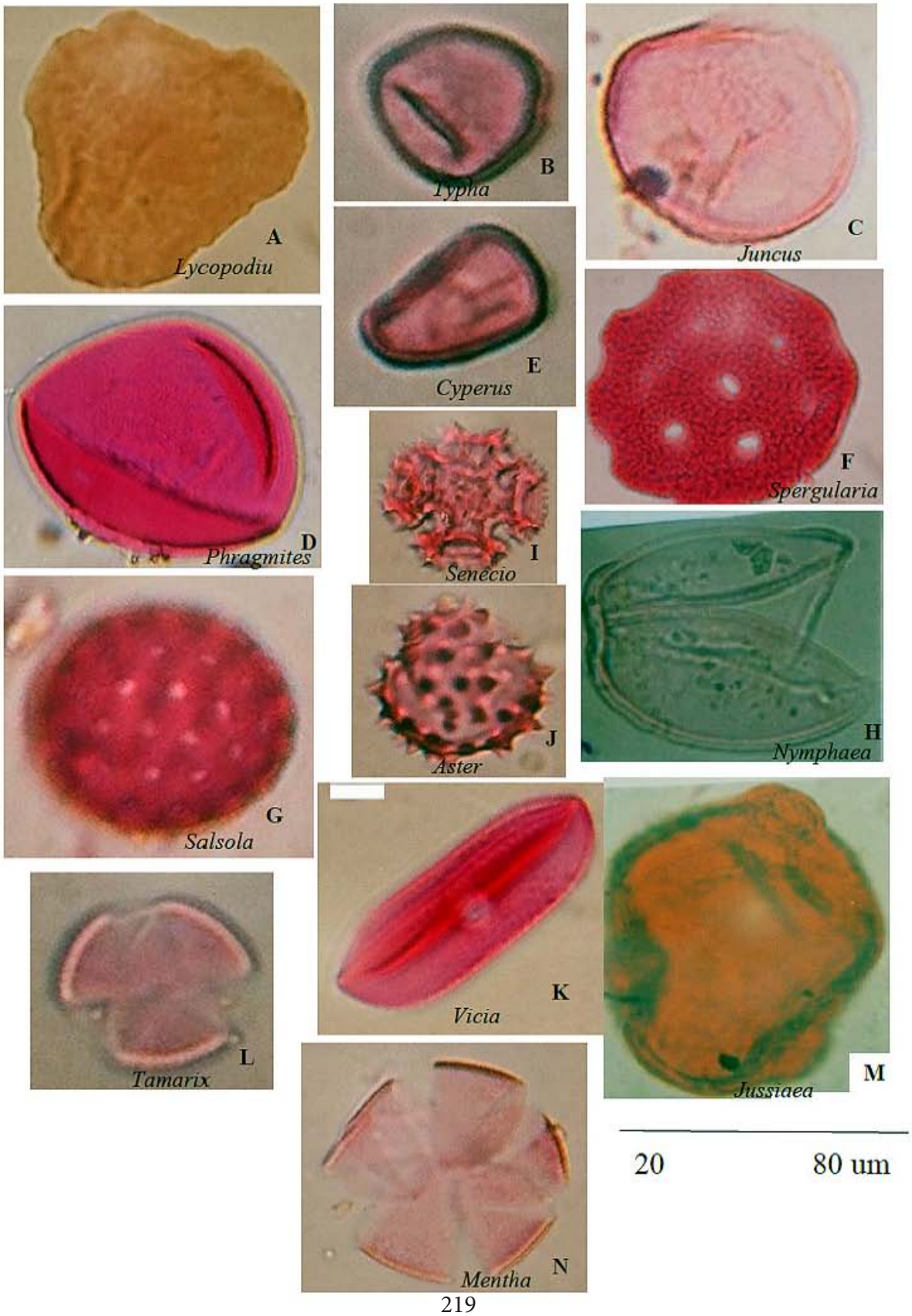


Plate 1. Showing Pollen and Spores. Legends to Plate: A- Lycopodium spore: Sexine, reticulate sculpture,trilete spore, size(49um). B-Typha pollen type: Spheroidal shape, monoporate, porus indistinct, exine semitectate, sexine thicker than nexine, micro-reticulate-heterobrochate sculpture, grain size (38um). C-Juncus pollen type: Spheroidal shape, radially symmetrical, inaperturate, size (46um). D-Phragmites pollen type: Monoporate, spheroid ovoid shape, porus circular, psilate granulate sculpture, grain size (36um). E-Cyperus pollen type: Pear like shape, inaperturate, exine, tectate-perforate and psilate sculpture, grain size (29um). F-Spergularia pollen type: Radially symmetrical, rounded, pore number 12-16, pantoporate, grain size (45um). G-Salsola pollen type: Spheroidal shape, radially symmetrical, polypantoporate, perforate sculpture, 40-45 pores, with grain size (38um). H-Nymphaea pollen type: Aperture almost equals the diameter of the whole pollen grain, syncolpate, psilate to psilate scabrate sculpture, grain size (48um). I-Senecio pollen type: Fenestrate type, grain with coarse network of high echinate ridges separated by large lacunae, tri-or tetra-zonocoporate, grain size (42um). J-Aster pollen tape: Tri-lobed shape in polar view, aperture, tri-zonocolporate, echinate surface, no columellae visible, spiny wall, grain size about (35um). K-Vicia pollen type: The grain shape longer than broad, colpi long, suprareticulate, and endoporus well defined, aperture tri-zonocolporate, L-Tamarix pollen type: Isopolar, radially symmetrical shape, tri-zonocolporate, reticulate sculpture, clip long, grain size (20um). M-Jussiaea pollen type: Simple aperture, pore situated at the corners, vestibulate, sculpture psilate at the inter pori and psilate scabrate near the vestibuli,grain size(80um). N-Mentha pollen type: Elliptic shape, sex simple aperture, colpi slit shaped, mrgo present, reticulate sculpture, reticulum containuous all over the surface, grain size (49um). (All magnifications 1000X)



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