The history of Egyptian Astronomy

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1 INTRODUCTION

Egypt is known worldwide for its breathtaking natural and man-made features. The largest river in the world runs south to north along the west side of the country, and has provided fertile land for its inhabitants for millennia. As well as providing ancient Egyptians with ideal farming conditions, the Nile river also inspired one of the first calendars. The evolution of this calendar involved observations of solar, lunar and stellar motions - before ultimately becoming an early prototype of the calendars we use today. The Great Pyramids of Giza, one of the wonders of the world, are some of the most complex structures ever built. These monuments display the astronomical knowledge and mathematical skill of the designers, as well as providing insight into the ancient Egyptian world-view and ideas about the cosmos.

Before the time of pyramids and Pharaohs, nomadic peoples roamed the deserts in search of fertile areas enriched by summer monsoons. The most ancient astronomical site ever discovered, *Nabta Playa*, reveals some of the oldest astronomical practices on Earth. Knowledge of astronomy in this time is evidenced by stone calendars, complex megalithic structures, and navigational expertise.

This essay aims to outline some of the evidence of astronomical practise in ancient Egypt. The first section will focus on pre-dynastic Egypt, referring to the period before the unification of Upper and Lower Egypt around $3,200$ BC. The second section will outline key points of evidence for astronomical use in dynastic Egypt. The focus of this essay is on an independent Egypt, so the western influence of Ptolemy, Eratosthenes, and the Greco-Roman era are only touched upon. The scope of this essay is too narrow to go into great detail for each piece of evidence, so the key points of each subsection are analysed here, with the intention of building a collective account of the Egyptian contribution to astronomy.

2 PRE-DYNASTIC EGYPT

2.1 Prehistoric Egypt

Some time around 9000 BC, the Nubian desert in south-west Egypt became frequented annually by monsoon rains (Van Neer 1993). Consequently, during the “wet” summer period, this hot, dry and arid desert became habitable; if only for a brief period each year (Wendorf & Schild 1998). Rainfall in the area would typically average between $100 - 150$-mm per year.

Despite the harsh conditions, nomadic peoples would travel to the areas where water would collect - perhaps from settlements near to the Nile river. During the early Holocene ($9000 - 3500$ BC), the summer rainfall attracted cattle herders; who then vacated the area as it dried up once more (McK Mahille et al. 2007). Over the subsequent few millennia, groups began to settle permanently in the areas where water would collect, as they became more skilled and adept at living in such testing conditions.

Over time, both settlers and travellers developed rituals, ceremonies and traditions; many inspired in some way by the magnificent sky to which they were exposed each night Pannekoek (1989). Archaeological evidence for the influence of astronomical study in this time is summarised by McK Mahille et al. (2007) as:

1. the orientation of tombs, sacrifices and complex structures towards north
2. the calendar circle
3. the alignments of megaliths towards bright stars.

This evidence is seen at *Nabta Playa*. Located in the western Nubian desert, it is perhaps the site of some of the oldest examples of astronomical use on Earth.

2.2 Nabta Playa

Nabta Playa is a large, internally drained basin (Wendorf et al. 1992). In the summer, rainwater would collect in the area, which was visited by ancient nomadic people. This migration was not always fruitful, as a monsoon cannot be guaranteed every single year, with droughts sometimes spanning multiple years.

In the early Holocene, nomads began to visit Nabta Playa periodically, returning once the rains had enriched the land. Over time, these first visitors started to settle. By 7000 BC, settlements and villages had formed as residents dug greater wells to source water after the autumn dryness (Wendorf 1980). In the following 900 years, the villagers practised pottery, and also herded sheep and goats which were likely imported from southwest Asia (McK Mahille et al. 2007). By the mid-Neolithic period ($6100 - 5600$ BC), separate groups of people would gather together to perform and witness rituals. During this time, Nabta Playa had become a hotspot for ceremonies, which is evidenced by high concentrations of bones of sacrificed cattle. The villagers abandoned the area in the late-Neolithic period due to a long drought. Around 5500 BC, the Ru'at El Baquar (meaning "cattle herders") people settled in the area and held ceremonies of their own. Particularly of astronomical importance are the rituals performed in the *Valley of Sacrifices*, where the Ru'at El Baquar would encourage the arrival of summer rainfall.

2.2.1 The Valley of Sacrifices

The Valley of Sacrifices is a wadi through which rainwater flows and collects in the basin of Nabta Playa. As the name suggests, many bones of cattle, sheep, and goats have been found here in the ten tumuli (burial mounds) identified in the area. The largest tumulus contains the remains of an entire young cow, oriented roughly north-south; perhaps the most valuable sacrifice a cattle herder could make. This may also be the oldest, having been dated at around 5270 ± 270 BC (McK Mahille et al. 2007).

Following the drought that forced their predecessors to abandon Nabta Playa, it is easy to see why the Ru'at El Baquar were keen to ensure the arrival of the monsoon each summer. Ruggles (2014) points out that the reduced rainfall rendered Nabta Playa a rare area of "wetness". Thus, nomadic pastoralists were required to be skilled navigators, implying an intrinsic knowledge of the sky and its uses for navigation. Further to this, they knew when they needed to travel to the wadi, in anticipation of the rains to come. It is a common theme in history for early astronomical study to take place due to its usefulness in both navigation and timekeeping. Take, for example, the ancient Polynesians - whose stellar expertise of the sky made them hugely successful explorers at sea. In Egypt, travellers crossed oceans of sand to reach places of ceremonial importance such as the Cromlech - the calendar circle.

The circle, located on a sandy knoll at the end of the wadi, is made up of sandstone blocks and has a diameter of ~ 4-m. A schematic of it's structure is shown in Figure 1. Two gates are present on its circumference, created by standing pairs of long, thin stones upright. The first gate is oriented such that an observer laying in the sand could peer between the upright stones and be looking northwards. The second faces north-east, and the spectacle it intended to frame is less certain. A likely explanation is that through this second gate, one could observe the rising Sun on the summer solstice - a signal that the monsoon was nearing. Dating back to 4800 ± 60 BC, this is one of the earliest evidenced "calendars" found (Castro Martin 2015). I use the word 'calendar' with caution, as the Cromlech was only capable of marking the beginning of the wet season and does not provide further seasonal information. It is clear that this early use of the Sun and stars was due to observation and practicality, not for the purpose of understanding the sky or the objects it encompasses. This emphasis on the practical use of astronomical study is a theme which will continue throughout this essay.

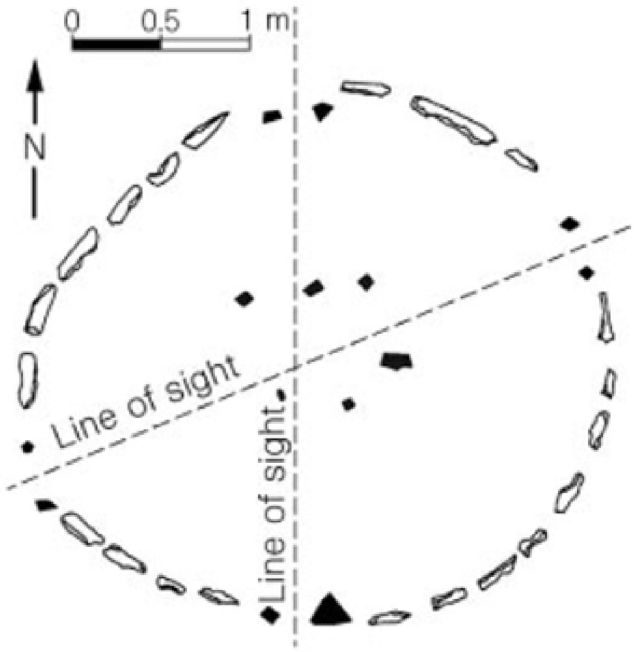

Figure 1: The calendar circle. The two lines of sight (dashed) pointing north and north-east are shown. The reason for the positioning of the six centre-stones remains unknown. Illustration: Malville et al. (1998).

Inside the circle stand six upright stones which do not appear to be gates like those on the edge. The exact astronomical function of these stones is unknown, or at least debated. However, theories exist ranging from sensible to frankly ridiculous (the word 'aliens' comes to mind). In 1930, Bagnold (1931) discovered a similar 8.5-m stone circle in the Liberian desert. Bagnold noted that the stone circle was located in a small basin, and that half of the stones were positioned upright. Its similarity to the Cromlech is further evidence of their ceremonious function, but offers no clue about the inner stones' astronomical functions. Due to their shape, they could have been used as early sundials, by measuring the shadows they cast. However, the absence of an explanation for their numbers and positions renders this a rather unsatisfactory answer. Other explanations have been given such as the two rows of stones corresponding to the shoulders and belt of Orion at different points in the year. However, despite speculation of later projects such as the Great Pyramids achieving this, the link is tenuous and does not demand further investigation.

There are two other possible explanations of orientation of the north-eastern gate, one being to mark the heliacal rising of the bright star Sirius. This was an extremely important event in Egyptian history, signifying the rise of the Nile. However, it is unlikely to have held as much significance to the nomadic people as it did for the those in dynastic Egypt. The other possible function for this gate is to mark the position of the *zenith* Sun, or the "zenith pass". Iwaniszewski (2015) notes that within the gates, an observer could also see the rising point of the zenith sun, which played a significant role in later Egyptian astronomy (Castro Martin 2015). When the Sun is directly overhead, the upright stones of both the gates and centre cast no shadows. This would have allowed the nomads to determine the exact day of the summer solstice, but again fails to explain the layout of the inner stones.

2.2.2 The complex structures

South of the calendar circle lies another significant astronomical site. Following a second drought in the late-Neolithic period ($\sim 4,500$ BC), the Ru'at El Baquar were forced to leave Nabta Playa. Once the rains returned, a new people, the Bunat El Ansalm ("megalith builders") settled there. As the name suggests, their time in Nabta Playa is immortalised by the complex megalithic structures which they built around $6,500$ years ago (McKim Malville 2015).

A set of six of these structures were analysed by McK Mahille et al. (2007) using data from Brophy & Rosen (2005), shown in Figure 2. The largest of the six is shaped like a cow, and is the focal point of the other five megaliths (complex structure **A** in Figure 2). Three of these structures are at azimuths of $25-30^\circ$ from the cow, while two are aligned at azimuths of $115-120^\circ$. In the thousand years between the building of the megaliths and the eventual abandonment of Nabta Playa in $3,600-3,400$ BC, McK Mahille et al. (2007) found that all three northern structures pointed to the bright star Arcturus at some point. This is the first concrete evidence of an affiliation with the stars (not just the Sun) at Nabta Playa. Furthermore, if Arcturus was truly the intended target, it shows a response to precession. The other two structures were found to have aligned with Alnilam in Orion's belt, sunrise on the winter solstice, and Sirius, in this period.

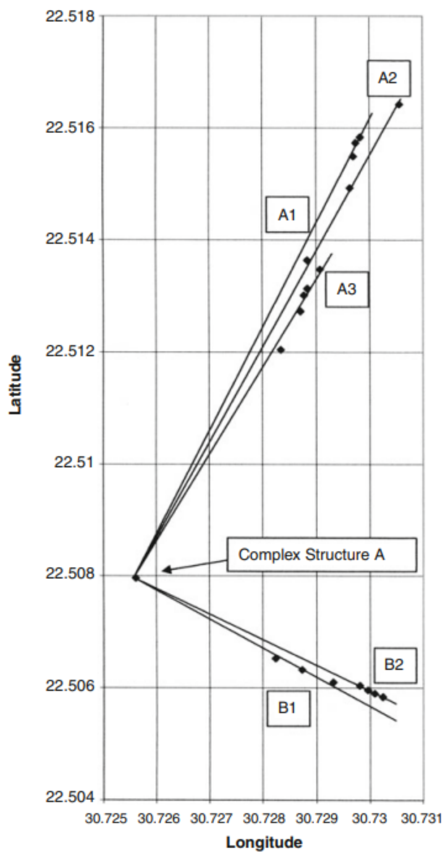

Figure 2: The complex structures. The large cow-shaped structure is labelled **A**. The northern structures are labelled **A1**, **A2** and **A3**, and the south-eastern structures are **B1** and **B2**. Illustration: McKim Malville (2015).

The significance of these alignments is debatable. Malville acknowledges in his paper that there is a strong disagreement with Brophy on the construction dates of the megaliths, as well as some alignments. I find the chronology Malville presents to be more logical. Sensible alignments to the brightest stars of the period are suggested with reasoning behind the timings of certain events. Outlined are two "major periods", $4,600-4,200$ BC and $3,800-3,400$ BC. During the first of these periods, alignments with the bright stars in Sirius, Arcturus, α Centauri and Orion's belt are all implied. The structures also have a navigational implication. The two sets of megaliths are aligned at $\sim 90^{\circ}$, which may have been aesthetically significant to the Bunat El Ansalm people, who had a deep knowledge of the cardinal points from the stars.

2.2.3 The world's oldest astronomical site

The second period coincided with the end of civilisation at Nabta Playa at around $3,400$ BC. The area birthed the first calendar and aided in the development of navigation using the stars. Furthermore, the peoples in Nabta Playa first looked to the stars and constellations and developed a relationship which would influence the next epoch of civilisation in Egypt. As the climate turned the area inhospitable, inhabitants migrated to wetter areas in the south, or towards the Nile river. This spawned the beginning of a new period, where cosmic inspiration spurred ancient humans to build some of the most complex structures in history.

3 DYNASTIC EGYPT

The Egyptian gods, as with many other ancient civilisations, were embodiments of different physical and sociological phenomena. The sky (Nut) was the surface of an incomprehensibly vast, dark and empty ocean (Nu). This ocean fed the seas and the Nile through breaks in the sky. The Sun, Moon and stars were all therefore within the domain of Nut, embodied by deities of their own. Ra (or Re), the Sun god, sailed across the sky every day, passed over to the after-world as he set, before being reborn in the morning (the red sunrise signifying the blood of birth). The idea of rebirth was engrained into life in ancient Egypt, either in the form of an afterlife or with the gods in the sky. As such, great efforts were made to ensure the safe passage of kings - the bridges between mortals and the divine - to their place in the stars (Allen 2015).

The dynastic period began when Upper and Lower Egypt were united under one rule. The King, or Pharaoh, was believed to connect the divine world with the mortal one. When a Pharaoh died, complex ceremonies would take place, ensuring a safe journey with Ra into the afterlife, before joining the god Osiris in his cosmic form - the constellation of Orion. Strong ties between the Egyptian mythos and the sky led to extraordinary feats of maths and engineering, as well as timekeeping systems which influenced those still used today.

3.1 The gift of the Nile and the civil calendar

The Nile is the largest river in the world and is synonymous with Egypt. Once a year in mid-summer, the river floods its banks, providing the land with vital nutrients and allowing civilisation to thrive. The Milky Way was believed to be a reflection of the Nile in the cosmic ocean. The first calendar developed in Egypt was the Nilotic calender, which was based on the Nile's periodic flooding. Neugebauer (1942) strongly opposed the idea that Egyptian calendars originated from the observations of the Sun, Moon and stars, stating that "every theory of the origin of the Egyptian Calendar which assumes an astronomical foundation is doomed to failure". This does appear to be the case for the Nilotic calendar, as evidence suggests the Nile was far more important to the Egyptians than the stars. The seasons, for example, were based on the flooding (Akhet), rising (Peret) and harvest (Shemou) phases of the yearly floods (Castro Martin 2015).

Crescent-shaped hieroglyphs reveal that Egyptian months were derived from the phases of the Moon, resulting in a lunar calendar. This Nilotic calendar with twelve lunar months was very successful until the unification of Upper and Lower Egypt. The flooding of the Nile occurred at different times in these two regions, with almost a month separating the two events in the north and south (Belmonte 2009). The zenith pass provided a new reference point for the beginning of the new year. As with the calendar circle in Nabta Playa, the date of the solstice indicated the impending return of precious water to the land. However, discrepancies in timing still remained between Upper and Lower Egypt, due to differences in local noon (the same reason that Eratosthenes was able to measure the circumference of the Earth). Finally, the true reference point for the civil calendar, from which the Egyptians were first able to measure the length of the year, was a star. The heliacal rising of the bright star Sirius, provided a new reference point for the beginning of the new year. By chance, its rising coincided with the rising of the Nile in mid-summer (as it did of course with the monsoons in Nabta Playa).

The star became associated with the Isis, goddess of fertility and life, and wife of Osiris. With this new calendar, the Egyptians were able to both measure the length of the year, and split it into months, decans, and days. The Greek Herodotus mentions the stellar origins of this calendar: "Egyptians first discovered the length of the year [...] and it's said they did so by observing the stars" (Hornblower & Pelling 2017). Akhet, Peret and Shemou were each split into four months of 30 days each, with each month split into three ten-day decans. There was a final, five-day "short month" at the end of the year devoted to various gods, resulting in a 365-day year.

The days and nights were also split up, each into twelve "hours". These hours were measured using the heliacal rising of 36 celestial objects - also called decans (Magli 2013). Each object would rise ten days after the last, the first being Sirius, which marked the rise of the Nile and beginning of the new year. On the day which the star rises for the first time, it marked the final hour of the night. Over the subsequent ten days, it would continue to mark the final hour, rising higher and higher each night until a new decan emerged - signalling the final hour of the night. The previous star would now indicate the night's penultimate hour. Using this method, there are always twelve hours in the night, and hence as the seasons changed, the hours' duration varied, not their quantity. Decans were eventually replaced with stellar transit clocks, which measured the time using star transits instead of rise-times.

The civil calendar introduced the 365-day year and broke it down into months and decans much like today's months and weeks. However, a correction was not made for the ~ 365.25-day solar year, which resulted in the Nile flood slipping out of phase with the calendar. It is highly likely that this discrepancy was known of, and it would have been easy to simply add an extra day in the short month every four years to account for this. Perhaps the power of the calendar in its reliability in both Upper and Lower Egypt was enough to convince the priests in charge to honour secular traditions above practical reasons. Ironically, Sirius has a high proper motion, resulting in an almost 365.25-day year between heliacal sunrises (Spalinger 2008). Despite the downfalls of this calendar, it was an early and influential achievement birthed from the observation of celestial motions across the sky.

3.2 Orientation and designs of temples and the Great Pyramids

As with the sacrifices of Nabta Playa, early temples and pyramids show evidence of astronomical influence in their orientations and designs. The step-pyramid was the first Egyptian pyramid, built during the reign of the Pharaoh Djoser. Some 300 years later, the "Unas" pyramid was constructed. This pyramid contained an underground passage, leading to a store room and burial chamber. The walls of these rooms are covered in hieroglyphs (see Figure 3), common ones being that of "King" and five-pointed stars. These ancient religious texts outline the resurrection process of Kings, and mention specific constellations to which they should be sent (Faulkner 1969). Also mentioned are so-called "imperishable stars" which refer to the circumpolar stars. Practically, the navigational use of these stars had rendered them important during the nomadic times in Nabta Playa, however, they gained a new spiritual importance as the regions where deceased kings would be sent, never to set again. The significance of the circumpolar stars and constellations such as the bull's leg (Ursa Major) and Orion, is that they served as astronomical targets for complex monuments to send former rulers.

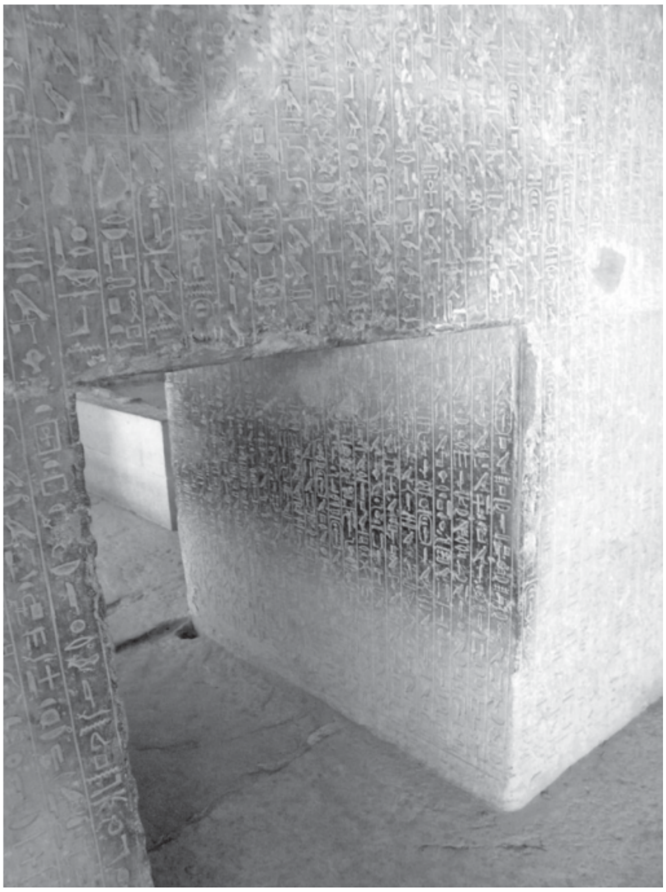

Figure 3: The pyramid texts. Inscribed on the insides of the Unas temple, these are some of the oldest religious texts found - perhaps predating the temple itself. Photograph: Magli (2013).

Many of the early pyramids were aligned according to the cardinal points. The accuracy with which this was done is astonishing. The Bent Pyramid and Red Pyramid represent intermediate steps between the first pyramids and the Great

Pyramids of Giza. The sides of these pyramids were aligned with the cardinal points with an average deviation 12' for the Red, and 5' for the Bent pyramids (' denoting seconds of arc or $1/60$ degrees) (Belmonte 2001, Nell & Ruggles 2014). For such accurate measurements, a precise technique was needed to determine the direction of true north. Edwards (1952) suggested that an observer could mark the rise and set points of a star on an artificial horizon, and find the midpoint of the two to determine true north. While this technique would work, analysis of the accuracies of several pyramid orientations suggest that the Egyptians used a method which was precession-dependent (Haack 1984). A likely method used was *simultaneous transit* (Spence 2000). By observing the rotation of two circumpolar stars such as Kochab and Mizar (shown in Figure 4) around the north celestial pole, true north can be found when the line passing through both stars is perpendicular to the horizon.

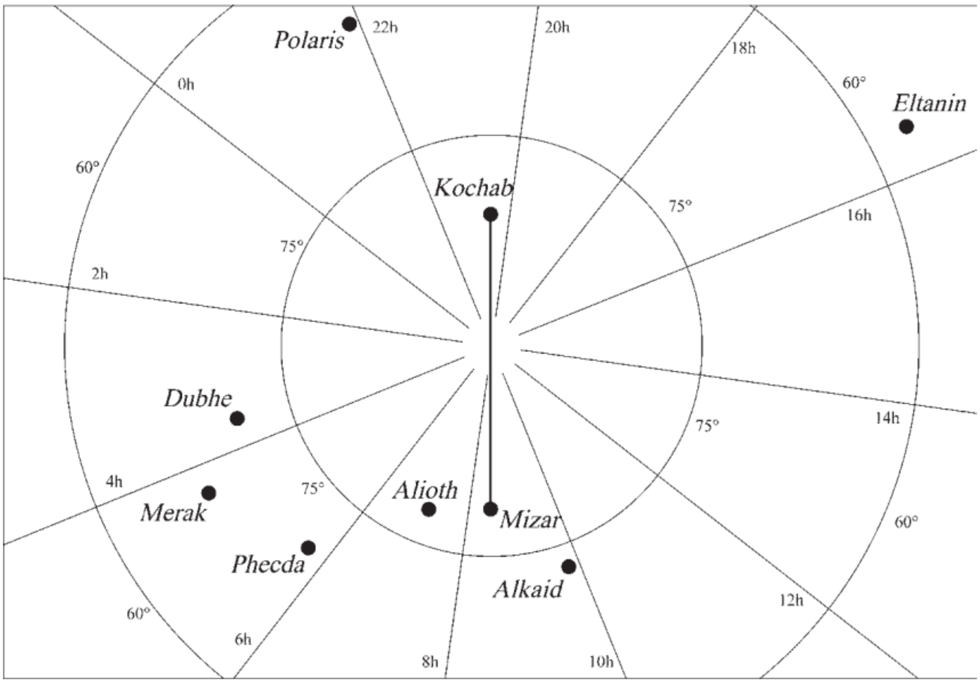

Figure 4: Alignment of Kochab and Mizar. The arrangement of these circumpolar stars perpendicular to the horizon allowed observers to determine the position of true north with high accuracy. Illustration: Emanuela Franzoni Magli (2013).

The Great Pyramids of Giza are even more perfectly aligned, deviating just 3' (Khufu) and 5' (Khafra) from the cardinal points. This resolution is about as precise as could be achieved with the naked eye (Belmonte 2001). As well as their near-perfect cardinal orientation, the Great Pyramids exhibit multiple features which focus on astronomical phenomena. First, it is commonly thought that the Giza pyramids were built in alignment with Orion's belt (BAUVAL & GILBERT 1994). This would be a similar case to the inner stones in the calendar circle in Nabta Playa, which have also been suggested to mimic these stars. However, akin to the case of the Cromlech, there is no hard evidence to suggest an intentional link to the orientation of these stars when they were built (Ruggles 2015).

A second feature, only found in the "first pyramid" Khufu, are four "ventilation shafts" which originate from chambers inside the pyramid. Two extend from the upper King's chamber out to the surface of the pyramid, and two more from the lower Queen's chamber, which simply come to a dead end. Unlikely to be used for ventilation during the construction of the pyramids, the shafts instead appear to be symbolic - pointing at significant celestial objects. This is shown visually in Figure 5. Gantenbrink et al. (1999) found the shafts to be aimed at the following celestial objects within 1°:

North upper: Thuban

South upper: Orion's belt

North lower: Kochab

South lower: Sirius.

These stars were all significant in Egyptian astronomy, Thuban being the pole-star at this time, Kochab a circumpolar star, and Orion and Sirius having significant links to mythology.

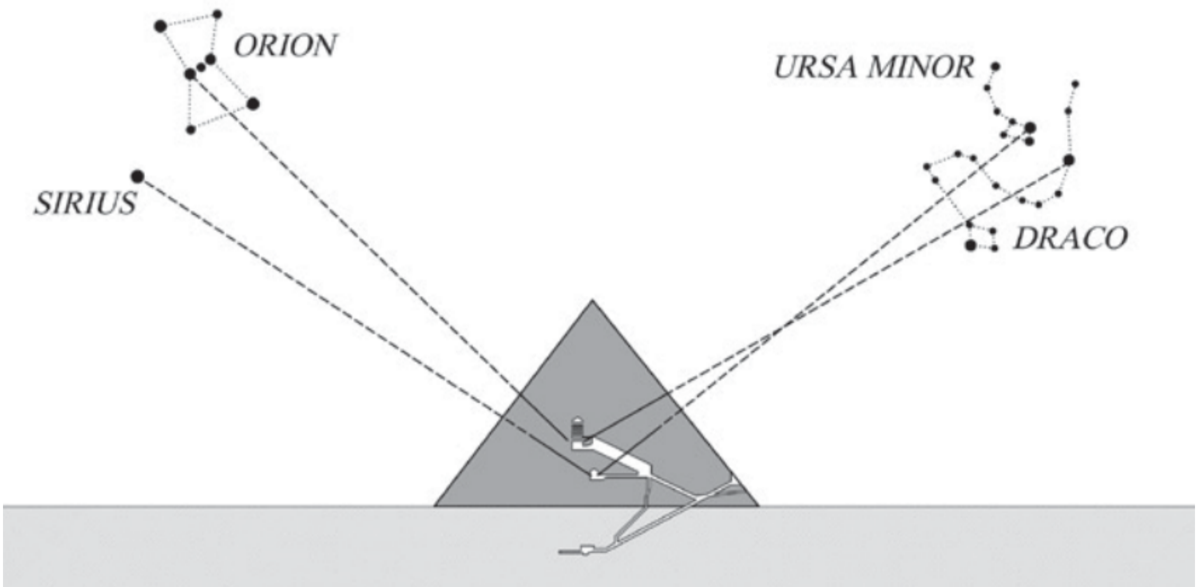

Figure 5: Ventilation shafts of Khufu. Schematic showing the predicted alignments of the so-called "ventilation shafts" in the Khufu pyramid. Illustration: Emanuela Franzoni Magli (2013).

A final astronomical feature of the Great Pyramids occurs as the Sun sets on the summer solstice. At this moment, as viewed from a position south-east of the Sphinx temple, the Sun touches the horizon midway between the Khufu and Khafra pyramids. This alignment was extremely significant, forming a petroglyph of "akhet" (meaning "a place of glorification where the Sun sets") (Magli 2013). As well as being striking (see Figure 6), it is a clear demonstration of both power, and exceptional geometric and astronomical knowledge and planning. The Giza pyramids are perhaps the best representation of the ancient Egyptian approach and application of astronomy, developing strong navigational skills and knowledge of mathematics and geometry while applying less emphasis on the nature of the celestial bodies themselves.

Figure 6: Sunset on the summer solstice. The sun sets between the Khafra and Khufu pyramids, behind the head of the Sphinx on the summer solstice, forming the akhet hieroglyph. Photograph: Juan Belmonte Ruggles (2015).

3.3 Greco-Roman Egypt

Much of the ancient Egyptian astronomy was absorbed by Greek and Roman settlers, following the decline of independent Egypt. The city of Alexandria, famous for its library and being a hub of expansive knowledge including astronomical research. This was also the birthplace of Ptolemy, whose contributions to astronomy are globally famous and recognised still today. It was also in 300 BC that Eratosthenes first calculated the circumference of the Earth, using the zenith pass which the Bunat El Ansalm had used millennia before. The extent of Egyptian influence on successes is hard to quantify, thus it is beyond the scope of this essay.

4 SUMMARY

The most significant astronomical contributions of the ancient Egyptians were their calendars and timekeeping systems. With the civil calendar, the Egyptians introduced the 365-day year, which was divided into twelve months. The ten-day decans also largely resemble today's seven-day weeks, with the final two days of each decan being rest days. The calendrical system was very complex, owing to tradition, power dynamics and geographical factors - the full extent of which could not be covered in this essay (for more on this, see Castro Martin (2015), Belmonte (2009)). Furthermore, the Egyptians introduced the 24-hour day, using the heliacal rising of celestial objects to quantify certain periods of night. Such star clocks were extremely important in the development of timekeeping, the implications of which are outlined in more detail by Symons (2015).

While there was little study of the nature of the stars and planets when compared with other cultures such as the Greeks or Romans, the Egyptians were able to use their motions, periods, and beauty to great effect. Some of the most complex structures in history were constructed using mathematics and geometry that was fundamentally aided by astronomical study. The oldest astronomical site in the world houses early tributes to the stars, many of which contain unsolved mysteries. The extent to which the Egyptians practised astronomy has been a topic of debate (see Neugebauer (1942)), however it is clear that the Greek and Roman inhabitants of Egypt respected it as an area of significant knowledge. Certain parts of this essay were difficult to research, as put by Belmonte (2015), "Archaeoastronomy has never been a favored discipline within Egyptology". However, the interest in ancient Egyptian scripture, architecture and mythos is large enough that data from non-astronomical sources were more widely available.

Ultimately, the ancient Egyptian's triumphs in astronomy are seen in today's calendars, and Egypt's architecture. As archaeological research continues in the country's cities and deserts, there will perhaps be new discoveries evidencing the Egyptian contribution to astronomy. For now, one of the wonders of the world serves as a striking reminder.

References

Allen, J. P. (2015), *Egyptian Cosmology and Cosmogony*.

Bagnold, R. A. (1931), 'Journeys in the Libyan Desert 1929 and 1930', *The Geographical Journal* **78**(1), 13–33.

BAUVAL, R. G. & GILBERT, A. G. (1994), 'The adze of Upuaut: The opening of the mouth ceremony and the Northern shafts in Cheops's pyramid', *The adze of Upuaut: the opening of the mouth ceremony and the Northern shafts in Cheops's pyramid* (28), 5–13.

Belmonte, J. A. (2001), 'On the Orientation of Old Kingdom Egyptian Pyramids', *Journal for the History of Astronomy* **32**(26), S1–S20.

Belmonte, J. A. (2009), *The Egyptian Calendar: Keeping Ma'at on Earth*.
URL: *https://ui.adsabs.harvard.edu/abs/2009iscc.book...75B*

Belmonte, J. A. (2015), *Orientation of Egyptian Temples: An Overview*.

Brophy, T. G. & Rosen, P. A. (2005), 'SATELLITE IMAGERY MEASURES OF THE ASTRONOMICALLY ALIGNED MEGALITHS AT NABTA PLAYA'.

Castro Martin, B. (2015), 'A Historical Review Of The Egyptian Calendars: The Development Of Time Measurement In Ancient Egypt From Nabta Playa To The Ptolemies'.

Edwards, I. E. S. (1952), 'Two Egyptian Statuettes', *The British Museum Quarterly* **17**(4), 71–72.
URL: *https://www.jstor.org/stable/4422393*

Faulkner, R. O. (1969), *The Ancient Egyptian Pyramid Texts*, Aris and Phillips Bolchazy-Carducci, Warminster, GB Oak Park, Ill.

Gantenbrink, R. et al. (1999), 'The upuaut project', *URL: http://www. cheops. org* .

Haack, S. C. (1984), 'The Astronomical Orientation of the Egyptian Pyramids', *Journal for the History of Astronomy* **15**(7), S119–S125.

Hornblower, S. & Pelling, C. (2017), *Herodotus: Histories*, Cambridge University Press.

Iwaniszewski, S. (2015), *Concepts of Space, Time, and the Cosmos*.

Magli, G. (2013), *Architecture, Astronomy and Sacred Landscape in Ancient Egypt / [Electronic Resource]*, University Press, Cambridge.

Malville, J. M., Wendorf, F., Mazar, A. A. & Schild, R. (1998), 'Megaliths and Neolithic astronomy in southern Egypt', *Nature* **392**(6675), 488–491.

McK Mahille, J., Schild, R., Wendorf, F. & Brenmer, R. (2007), 'Astronomy of Nabta Playa', *African Skies* **11**, 2.
URL: *https://ui.adsabs.harvard.edu/abs/2007AfrSk..11....2M*

McKim Malville, J. (2015), Astronomy at Nabta Playa, Southern Egypt, *in* C. L. Ruggles, ed., 'Handbook of Archaeoastronomy and Ethnoastronomy', Springer, New York, NY, pp. 1079–1091.

Nell, E. & Ruggles, C. (2014), 'The Orientations of the Giza Pyramids and Associated Structures', *Journal for the History of Astronomy* **45**(3), 304–360.

Neugebauer, O. (1942), 'Egyptian Planetary Texts', *Transactions of the American Philosophical Society* **32**(2), 209–250.

Pannekoek, A. (1989), *A History of Astronomy*, Courier Corporation.

Ruggles, C. L. N. (2014), *Handbook of Archaeoastronomy and Ethnoastronomy*, Springer Reference, New York.

Ruggles, C. L. N. (2015), *Monuments of the Giza Plateau*.

Spalinger, A. (2008), The Great Dedicatory Inscription of Ramesses II: A Solar-Osirian Tractate at Abydos, *in* 'The Great Dedicatory Inscription of Ramesses II', Brill.
URL: *https://brill.com/display/title/13872*

Spence, K. (2000), 'Ancient Egyptian chronology and the astronomical orientation of pyramids', *Nature* **408**(6810), 320–324.

Symons, S. (2015), 'Egyptian "Star Clocks"', *Handbook of Archaeoastronomy and Ethnoastronomy* pp. 1495–1500.

Van Neer, W. (1993), Fish Remains from the Last Interglacial at Bir Tarfawi (Eastern Sahara, Egypt), *in* F. Wendorf, R. Schild & A. E. Close, eds, 'Egypt During the Last Interglacial: The Middle Paleolithic of Bir Tarfawi and Bir Sahara East', Springer US, Boston, MA, pp. 144–154.

Wendorf, F. (1980), 'Prehistory of the eastern Sahara', *(No Title)* .
URL: *https://cir.nii.ac.jp/crid/1130282270407221888*

Wendorf, F., Close, A. E. & Schild, R. (1992), 'Megaliths in the Egyptian Sahara', *Sahara: Prehistory and History of the Sahara* **5**, 7–16.
URL: *https://www.africabib.org/rec.php?RID=P00059418*

Wendorf, F. & Schild, R. (1998), 'Nabta Playa and Its Role in Northeastern African Prehistory', *Journal of Anthropological Archaeology* **17**(2), 97–123.