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THE STAR ALIGNMENT HYPOTHESIS FOR THE GREAT PYRAMID SHAFTS

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The small shafts in the Great Pyramid have generated much discussion.[1] The purpose of this article is to examine the contention that "… an increasing number of Egyptologists are now accepting that they [the shafts] may be aligned towards star culminations".[2]

A major objection is raised by Gantenbrink: "All the shafts bend, often several times.... In several parts of the shafts, with the exception of the lower southern one, we even found extreme angle fluctuations.... Given the many angle fluctuations, the shafts could be construed to be pointing at some 100 different stars."[3] Despite this, Gantenbrink did succeed in establishing the shafts' principal angles of slope.

Assuming alignment of the principal angles to culminations, and with construction in the middle of the third millennium B.C., it is possible to calculate[4] an alignment date, remembering that "No building can be planned in such a way as to prevent its axis from pointing to some heavenly body at some date or other; and unless there is some evidence to show that a building was intended to point to some particular body in the sky, nothing can be gained by finding out the date at which it pointed to the body".[5]

Despite the above admonition, we will examine the surviving sources to try and determine the important parts of the sky in the Old Kingdom. We will also investigate shaft geometry.

Cosmology

Allen's analysis of Pyramid Texts leads him to conclude that "Fixed structures in the sky are few, and these may be limited to its rim", suggesting that the horizons were the most important parts of the sky at that time.[6] Earlier, more contemporary, pyramid names such as "Sneferu rises", "Khufu's horizon" and "The power [*ba*] of Sahura rises"[7] support this, as do contemporary royal names; Khafre, "Appearing like Re",[8] contains the hieroglyph of the sun rising over a hill, as does the name of the late third dynasty king Khaba.[9] Areas of the sky away from the horizon became of greater importance in the New Kingdom,[10] more than a thousand years later.

Spence[11] provided support for Old Kingdom observation of culminations, but the data for Abu Rowash, which were published subsequently,[12] did not conform to her predictions.

We therefore lack evidence that culminations were of major interest and/or importance in that era, although this is an argument from silence.

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Slope Geometry

Slopes were defined in terms of the *sqd*, the relation between the horizontal setback and a vertical rise of one cubit, evidence for which is attested as far back as mastaba no. 17 at Meidum as well as at Giza.[13]

Table 1 compares Gantenbrink's measurements[14] with the nearest whole number finger:cubit *sqd* (the cubit was divided into seven palms, each of four fingers), and the table also identifies the percentage differences.

TABLE 1. Shaft slopes.

Shaft (Star[15])	Measured Slope	Nearest *sqd*	% Difference
King's Chamber North (Thuban)	32°36′08″ (32.6°)	11 palms 32°28′16″ (32.47°)	0.40
King's Chamber South (Alnitak)	45°00′00″ (45°)	7 palms 45°00′00″ (45°)	0.00
Queen's Chamber North (Kochab)	39°07′28″ (39.12°)	8 palms, 2 fingers 39°28′21″ (39.47°)	0.88
Queen's Chamber South (Sirius)	39°36′28″ (39.61°)	8 palms, 2 fingers 39°28′21″ (39.47°)	0.34
Mean			0.41

The northern Queen's Chamber shaft, which Gantenbrink was unable completely to explore, reveals the largest difference. Excluding this, the mean difference is less than 0.25%.

There are tolerances in both the construction and measurements.[16] Furthermore there is evidence for settlement. On the subject of the King's Chamber roof Petrie[17] noted: "Round the S.E. corner, for about five feet on each side, the joint is all daubed up with cement laid on by fingers. The crack across the Eastern roof-beam has been also daubed with cement, looking, therefore, as if it had cracked before the chamber was finished."

There is little doubt that the slopes were intended as whole number of finger: cubit *sqd*s.

Shaft Alignment Dates

If we accept that the shafts were aligned to culminations, we can derive dates[18] and these are shown in Table 2.

There is nothing to suggest the Egyptians were able to predict culminations, and so it is necessary to envisage angles being recorded and the nearest finger:cubit *sqd* then used for constructional simplicity.

The minimum period needed would depend on factors such as the observer's visual

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TABLE 2. Shaft alignment dates.

Shaft (Star)	Nearest *sqd*	Date
King's Chamber North (Thuban)	32°28′16″ (32.47°)	2364 B.C.
King's Chamber South (Alnitak)	45°00′00″ (45°)	2492 B.C.
Queen's Chamber North (Kochab)	39°28′21″ (39.47°)	2483 B.C.
Queen's Chamber South (Sirius)	39°28′21″ (39.47°)	2419 B.C.
Mean (range)		2440 B.C. (128 years)

acuity and local sky conditions, which might introduce uncertainties of a few days. Assuming 2400 B.C., civil twilight for Sirius and nautical twilight for the others (which might be difficult for Thuban), the observation periods are (Julian dates):

Thuban: 12 January to 20 June
Kochab: 21 June to 13 November
Alnitak: 3 September to 4 February
Sirius: 16 September to 1 March

All four culminations could be observed between about 20 June and 16 September (88 days) or 13 November and 12 January (60 days), as shown in Figure 1. Both periods involve dawn and dusk culminations, so it would be sensible to extend these

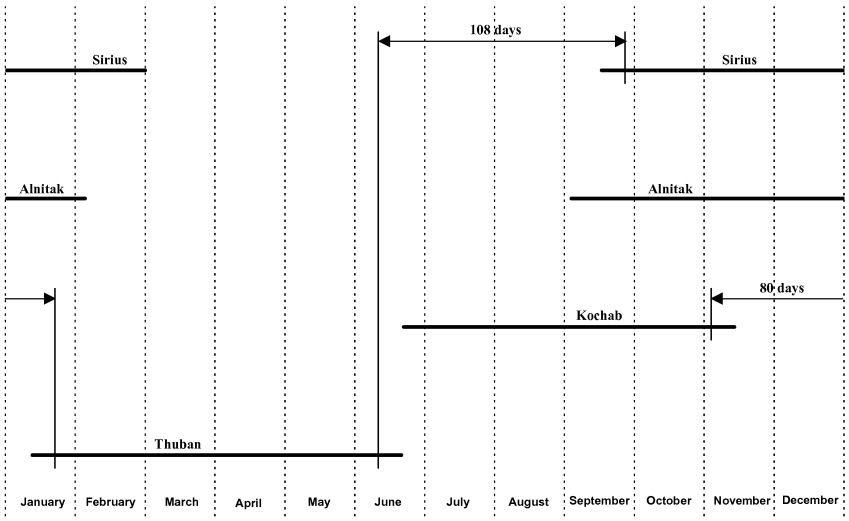

FIG. 1. Star observation periods.

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by 10 days or so (making 98 and 70 days respectively), not least because Thuban is at one of the ends of its visible periods in each case. Other factors include the problems associated with observing a star culminating at the limit of its evening twilight visibility, and the likelihood that multiple observations to refine the readings and reduce the possibility of errors would have been needed. It would therefore be wise to add at least 20 days to each period (10 at each end), giving minimum periods of 108 or 80 days.

The 80-day November to January period is preferable as Thuban would be visible before culmination and hence easier to observe.

Astronomical Observations

Astronomical records (a "record" is a dated event) surviving from Egypt are limited: "… there is nothing in purely Egyptian or even Ptolemaic records remotely resembling Babylonian observations of planets and lunar and solar eclipses ...."[19] There are records of the appearance of the moon, and texts that can be interpreted as recording the heliacal rising of Sirius. A text from the reign of Takelot II (*c*. 850 B.C.[20]) might describe an eclipse: "Afterwards, in year 15, (month) IV of *smw*, day 25 under the majesty of his august father, the God who Rules in Thebes, the sky did not swallow the moon but a storm broke out in this land ...."[21]

Thurston[22] concludes: "The Egyptians' lack of interest in astronomical matters is shown clearly by a 'catalogue of the universe' compiled by Amenhope about 1100 B.C. It lists only five constellations, of which two can be identified as Orion and the Great Bear, and does not even mention Sirius nor list the planets. Astronomy fares a little better in a document of 300 B.C. — very late in Egyptian history ... a eulogy engraved on the base of a statue of a man named Harkhebi. It describes him as observing 'everything observable in heaven and earth' including the culmination of 'every star in the sky', foretelling the heliacal rising of Sirius, and knowing the north–south movement of the sun."

The decanal 'star clocks', and their successors, that appear from the early Middle Kingdom onwards (*c*. 2000 B.C.[23]) must, however, have been the result of systematic observations; initially on the horizon, later of transits.

Observations were certainly undertaken in the Old Kingdom, and Wells,[24] for instance, has proposed that the "... valley temples of the two [5th dynasty] sun temples faced a given star which rose some time before the sun as a warning of sunrise so that the priests would have sufficient time to prepare the daily ritual offering and conduct the associated activity". This is predictive and, thus, testable, should any of the four missing temples be discovered, although it is only a proposal for horizon observations. The subsequent, and comprehensive, work of Shaltout and Belmonte[25] is not, however, supportive of the type of alignments proposed by Wells and must also cast doubt on his "observations".

'Hour watchers' (often translated as 'astronomers'[26]), with a star determinative, are first attested in the Middle Kingdom (after *c*. 2000 B.C.), about the same time as

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the first ‘star clocks’. If they were not known by an earlier title, this suggests that Old Kingdom observations were one of many tasks performed by certain priests. The title “chief [or greatest] of seers”, later held by the high priest of Heliopolis, is attested from the end of the second dynasty (*c*. 2650 B.C.[27]) and has been suggested as “relating to astronomical observations”[28] although it does not contain the star determinative.[29] If it was of sufficient importance for a man to have the skills, and to spend almost three months “observing”, to be able to “align” the shafts, this would have been identified somewhere in the titulary.

Slope Tolerances

If the nearest whole number finger:cubit *sqd* was employed, as proposed above, there was a range of angles, and hence possible observation dates, as shown in Table 3, that would result in a particular choice. Figure 2 shows the information from Table 3 in a graphical form.

The culminations of these stars, at these angles, could have been observed together only *c*. 2400 B.C. (2394 B.C. is the midpoint of the “overlap”).

TABLE 3. Range of observation dates.

Shaft (Star)	Nearest *sqd*	Range	Date
King’s Chamber North (Thuban)	32°28′16″ (32.47°)	32°10′52″ (32.18°)	2403 B.C.
		32°46′15″ (32.77°)	2303 B.C.
King’s Chamber South (Alnitak)	45°00′00″ (45°)	44°29′51″ (44.497°)	2600 B.C.
		45°31′15″ (45.52°)	2385 B.C.
Queen’s Chamber North (Kochab)	39°28′21″ (39.47°)	39°03′58″ (39.066°)	2375 B.C.
		39°53′36″ (39.893°)	2612 B.C.
Queen’s Chamber South (Sirius)	39°28′21″ (39.47°)	39°03′58″ (39.066°)	2554 B.C.
		39°53′36″ (39.893°)	2282 B.C.

Shaft Geometry

Table 4 shows the *sqd*s postulated for each shaft and the ratios that produce them.

The King’s Chamber is offset from the apex, its shafts exiting at the same height.[30] The southern has the simplest slope and this would have presented few difficulties. The northern’s slope was then chosen to give the same exit height whilst accommodating the chamber offset.

The Queen’s Chamber is under the apex, its shafts terminating in the masonry. Each has the same principal angle so that, if extended, like those from the King’s

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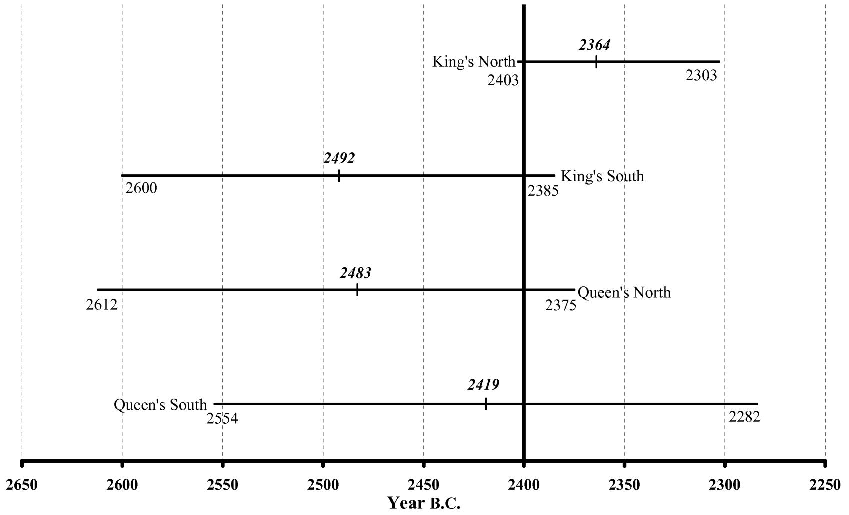

FIG. 2. Range of dates from shafts.

TABLE 4. Shaft ratios.

Shaft (Star)	Nearest *sqd*	Ratio
King's Chamber North (Thuban)	11 palms 32°28′16″ (32.47°)	7:11
King's Chamber South (Alnitak)	7 palms 45°00′00″ (45°)	1:1
Queen's Chamber North (Kochab)	8 palms, 2 fingers 39°28′21″ (39.47°)	14:17
Queen's Chamber South (Sirius)	8 palms, 2 fingers 39°28′21″ (39.47°)	14:17

Chamber, each would have had the same exit height.

The above suggests that it was intended that the shafts from each chamber should exit symmetrically, and that there was no error in the choice of *sqd*. This argument has been made by Legon[31] on the basis of Petrie's data; Gantenbrink's measurements strengthen the hypothesis.

Attempts[32] to justify an additional star alignment function as an example of the use of "sacred mathematics" to achieve a religious function are flawed.[33] Furthermore, the era in which the postulated stars could have been observed together is almost certainly chronologically unacceptable.[34]

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Conclusions

The use of shaft alignments to star culminations to date Khufu's reign should be rejected.

With an incomplete archaeological record, arguments from silence are problematic but, even if an accession date for Khufu of *c*. 2400 B.C. is acceptable, there are too many areas where a culmination–alignment hypothesis lacks support.

If any celestial significance is to be attributed to the shafts it should be of a general orientation towards the northern and southern skies, which is supported by the fact that Khufu's successor's pyramid name contains "*sehdu* 'firmament' or 'starry sky'".[35]

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