"On the orientation of ancient Egyptian Temples: (4) epilogue in Serabit el Khadem and overview"

J A Belmonte[(1)], M Shaltout[(2)]
M Fekri[(3)], N Miranda[(1)]

(1) Instituto de Astrofísica de Canarias, Spain.
(2) Helwan Observatory, Egypt.
(3) Minufiya University, Egypt.

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ON THE ORIENTATION OF ANCIENT EGYPTIAN TEMPLES: (4) EPILOGUE IN SERABIT EL KHADEM AND OVERVIEW

JUAN ANTONIO BELMONTE, Instituto de Astrofísica de Canarias
MOSALAM SHALTOUT, Helwan Observatory
MAGDI FEKRI, Minufiya University, and
NOEMI MIRANDA, IAC

During the last four years, the Egyptian-Spanish Mission on Egyptian Archaeoastronomy, conducted under the auspices of the Egyptian Supreme Council of Antiquities, has been performed a ambitious scientific project with the aim of studying the cosmovision of the ancient civilization of the pharaohs. Part of the project consists of a re-analysis of the iconographic and historical sources that has allowed, among other, a reassessment of the calendar theory,[1] challenging old fashioned paradigms,[2] or a new proposals for the sky-maps of ancient Egypt.[3]

However, the most expensive part of the project, in time, efforts and resources, has been the five campaigns devoted so far to measure the orientation and study the spatial location of ancient monuments across the Nile Valley and beyond. More than 500 pyramids, hypogea, chapels, sanctuaries or small and big temples have been measured so far. Fieldwork in successive campaigns was organized geographically but also with the intention of testing previous results with new exercises. Accordingly, first campaign was devoted to Upper Egypt, the second to Middle Egypt, the third to the Oases of the Western Desert and the fourth to Lower Egypt, fundamentally. Three successive papers[4] (hereafter Papers 1, 2 and 3) have been published about the temples where, stage by stage, we have analysed the relation of temple orientation and location with the local landscape, understanding landscape in its broadest meaning of both terrestrial (basically the Nile) or celestial (astronomical orientations) aspects. Our works are demonstrating that both components were necessary and indeed intimately correlated.[5] However, in previous campaigns, we did not measure some temples that were located either out-limits of standard circuits (like Aïn Labkha or Deir el Sheluit), at difficult locations (like Mons Claudianus),[6] or even temples that we did not know of their existence 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 such as Heracleopolis or southern Athribis had not been visited yet. A new campaign (our fifth and last campaign so far) was indeed necessary to complete our sample.

Figure 1 shows the location of the places where the data presented in this paper were assembled. As shown in Figure 2, here we will also study monuments that we measured earlier, such as Serabit el Khadim, but that we did not discuss in previous papers because of their special characteristics, or other lesser monuments that we did not pay attention before overshadowed by more distinguished companions, as the temple of Isis Lady of the Pyramids in Giza. Additionally, the 5th campaign was planned with the intention of testing in Upper Egypt the quarter-cardinal family of orientations as argued in Paper 1 and first proposed and defended in Paper 3, of taking relevant pictures to address important solstitial hierophanies (we worked in mid and late December 2006, see Figure 3) and, finally, with the objective of completing our data on the seven minor step pyramids of the early Old Kingdom, an archaeological mystery without a unquestionable solution.[7] The fascinating results yielded by these enigmatic monuments have been presented elsewhere.[8]

The majority of the new monuments that we will discuss in the first part of this paper, with a few exceptions, are in a poor state of preservation. Consequently, as in previous reports, we wish to stress clearly that we are not seeking extreme-precision alignments but rather to obtain a statistically significant sample of monuments where we can perform our archaeoastronomical analysis. Bearing this is mind, we obtained our measurements using a high precision compass (corrected for local magnetic declination[9]), and a clinometer, either as separate instruments or enclosed within a single tandem device. The instruments permit a theoretical ¼° precision for both kinds of measurements. However, an error close to ½º in both azimuth and angular height is probably nearer to reality. This would signify a mean error of order ±¾º in the determination of the corresponding declination. As we have discussed elsewhere,[10] for the latitudes of Egypt, a precision of ½º is perhaps the best we can expect in solar or very bright star observations near the horizon. These are the phenomena we will basically discuss in this paper. However, in the case of fainter stars at greater angular heights, the errors in estimating the azimuth, or the equivalent declination, could range from those values to a few degrees.

1. DISCUSSION

Table 1 presents the results of our June 2006 fieldwork at the isolated sacred complex of Serabit el Khadim, in the Sinai, and of our December 2006 campaign across a dispersed, and in principle unrelated, group of monuments along the country from the Eastern and Western Deserts to the Nile Valley. The new data of some 40 temple are presented. As in previous papers of this series, the table lists azimuth, angular heights and the corresponding declinations. In a few cases, we have also proposed alternative possibilities in the perpendicular direction or larger errors in the determination of the data, due to the still worse state of preservation of some monuments.

Some of the places we visited were not easy to find and were completely out of the standard routes. In Kom Mir we had to suffer the blames and demands of local authorities, since no one person from the Supreme Council 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. Other places, like the fascinating ruins of Mons Claudianus deserved a dedicated programme involving many people, including the director of the antiquities service of the province of Bahr el Ahmar (Red Sea). Some other temples of similar characteristics are still located in the lonely landscapes of the Eastern Desert. Nevertheless, in the last rows of Table 1, we offer, for completeness, the few data that could be obtained from the plans published for some of these places.[11] However, these data will not be used in any of the following analyses since our experience is that these plans often could suffer from certain inaccuracies, confusion between magnetic and geographic north being the most frequent.

The orientation diagram of the data is shown in Figure 3(a). As in similar diagrams of Papers 1 and 3, the data are apparently scattered in all directions of the horizon, although there is a large concentration near NE. This corresponds, among others, to the temples in the area of Athribis and Abydos that will be most relevant in section 1.3. Apart from the intrinsic relevance of the data presented in this paper (we will discuss later some selected cases), a most important aspect of them is that with these 40 monuments, we complete a sample of 330 temples of ancient Egyptian culture in Egypt herself.[12] We have made a revision of most of the relevant archaeological literature and this sample contains data of more than 95% of all the temples to be found nowadays in Egypt. The exceptions are minor temples at faraway sites (as the ones presented in the last rows of Table 1), others than we could not visit in previous campaigns for security reasons (see Paper 2) or at some places that were out of the main routes and could not be studied for the lack of time (for example the temples at Tihna el Gebel, to the north of El-Minya). However, even with those minor exceptions, we consider our sample to be statistically representative beyond any doubt and we are convinced that new data will only serve to reinforce our results.

Figure 5 presents the orientation histogram of all our data as presented in the corresponding Tables 1 of Papers 1, 2 and 3, plus Table 1 of this paper. We present a histogram and not a diagram, such as that of Fig. 3(a), because the huge amount of data would make the figure useless and also irrelevant because it would not illustrate the importance of certain azimuths. On the contrary, Fig. 4 clearly shows two peaks which are statistically significant at 91¼º and 117º. The first is connected to east and we will further discuss it extensively. The second is the azimuth for winter solstice sunrise at the time of the pharaohs for latitudes near ancient Thebes (*c*. 26º). The following peak at 102½º corresponds to a declination of −11¼º for the average latitude of Egypt. Then two peaks at 134¾º and 45º surely correspond to NE and SE directions of the compass. We have shown in previous works and will further demonstrate in this essay that all these azimuths have an intrinsic astronomical meaning.

Hence, the simplest analysis of our data, the rough plotting of azimuth versus relative frequency positively answers the question that was in the origin of this project, if the temples of ancient Egypt were astronomically orientated or not. However, the answer is not always as simple as it looks like and we will go further in our analyses proposing a series of exercises that will permit us to demonstrate: that the Nile also played a critical role in the orientation of the temples (1.1); that certain families of orientations, as already defined in Paper 3, can be confirmed and further developed (1.2); that ancient Egyptians had a certain predilection for establishing an astronomical orientation with a certain procedure and later rotate the axis of the temples by 45º or 135º (1.3); that certain customs remain constant in time and space but others either evolved, or appeared and disappeared along Egyptian history (1.4); and finally, and most important, that ancient Egyptians were probably unaware of the phenomenon of precession, at least until Greco-Roman times, but that a few building orientation might reflect this physical reality (1.5).

1.1. *Testing the Nile hypothesis*

Traditionally, the majority of Egyptologists had considered that the ancient Egyptian temples were orientated according to the Nile. In several occasions, this preconceived idea has precluded any serious or systematic attempt to study the orientations of the temples from the Egyptological community,[13] and most efforts up to a few years ago had come from dedicated archaeoastronomers whose conclusions were not always assimilated.[14] Indeed, during our fieldwork in the last few years we have heard this opinion on several occasions, even being asked by some reputed scholars why we were devoting so much efforts to a question that was crystal-clear. To be fear, we must also mentioned that Egyptologists on site have received us with open arms on several occasion and have been enchanted with our work, arguing that this was indeed a necessary job to be done. So, from the very beginning of our project, one of our primary objectives was to test the Nile hypothesis in order to check if so many scholars could have a wrong opinion. In Paper 1 we demonstrated that they were indeed correct and that in Upper Egypt the Nile was the main source of "inspiration" to orientate sacred buildings, but not the only one. In Paper 2 we tried to falsify the Nile hypothesis by performing fieldwork in a land with no-river, the Oases of the Western Desert, and we found that when the Nile is absent, astronomical orientations certainly dominate the situation. Figures 6 and 4(b) repeat those exercises but with a much larger amount of data.

Fig. 6 shows a histogram where the difference between the orientation of the temple and the course of the Nile versus frequency is presented. The histogram has been produced with the data of 170 temples[15] of Upper, Middle and Lower Egypt, with the particularity that in the Delta the difference is to the closest river branch. The plot clearly demonstrates that temple orientation with the main gate located in front of (axis perpendicular to) the Nile is the most common way of orientating the buildings. Besides, axes nearly parallel to (at ~0º or 180º) or perpendicular to the river, but facing the other way (~270º), were also common. This demonstrates without any reasonable doubt that local topography (the course of the Nile) was very important at the moment of settling the foundations of the temples.

However, there is a peak at the order of 78º that does not fit this rule. It is probably caused, among others, by the group of Million Year temples at Thebes or Abydos and we will find a reasonable answer for it when we will discuss the quarter-cardinal family of orientations in section 1.3.

In contrast, Figure 4(b) shows the orientation diagram of 95 temples of the deserts and oases of Egypt, where there is no river to justify the orientation. The diagram shows a typical form of a Maltese Cross which is likely related to a certain preference for solar and cardinal orientations that could not be obtained without a celestial reference. As a matter of fact, the answer to the controversy is fascinating, both hypotheses should be certainly correct. This is what we have seen along these years and demonstrated in this and previous essays on the topic. Even more, we are almost convinced that certain places along Egypt had an especial sacred character because they presented double (topographic and astronomical) alignments and that some customs, like the selection of cardinal or quarter-cardinal patterns in certain regions, would follow a similar line of reasoning.

1.2. *The families of astronomical orientations*

In Paper 3 (Part I), we proposed for the first time in the studies of ancient Egypt that a number of families or patterns of orientations of ancient temples could be identified. We defined six families, namely: the "equinoctial" or eastern family[16] (I), the solstitial family (II), the seasonal family (III), the *Sopdet* family (IV), the Canopus family (V), the Meridian family (VI) and the quarter-cardinal family (VII). These were the result of an analysis performed to the histogram of the absolute value of the declination of 90 monuments, mostly of Lower Egypt. Indeed, it was worth repeating the exercise with our complete sample of 330 temples.

Figure 7 presents the result of the experiment where seven peaks are easily identified. It is fascinating that these seven peaks correspond exactly to the seven families we preliminary identify with a much smaller sample of monuments (only 28% of the present one). Peak I at ~0º can be associated with due-east. We have the ubiquitous solstitial peak at ~24º (see Fig. 3) afterwards. Then follow the accumulation peak at ~60¼º and another one at ~39½º representing the cardinal and quarter-cardinal families (VI and VII), respectively. We have then a peak at ~11¼. In Paper 3 we had a long discussion about this peak. It mostly corresponds to temples facing an interval of declination between −10½º and −12º. These are the declinations of the sun at dates in the vicinity of February 20th and October 22nd and would mark the beginning of the actual sowing and harvest seasons,[17] hence the name "seasonal". Finally, the peaks at ~17¼º and ~53¾º (for families IV and V) correspond to the absolute value of the declinations of Sirius and Canopus during the New Kingdom (and beyond, if the errors are considered), the two brightest stars of Egyptian skies, respectively.

One important question that may arise from the reality of these families would be if they could actually be identified with any cultural aspect of ancient Egyptian civilization; i.e. we have the facts, the orientations, but how do we explain them? In Papers 1, 2 and 3 we analysed certain study cases where these aspects were taken into account and we also justified the intrinsic importance of certain celestial bodies as for example Sirius, or *Sopdet*, the harbinger of the Flooding. Here we take the opportunity offered by our large sampler of monuments to select two independent groups of them for a new experiment. One is formed by all the temples that were unmistakably dedicated to a goddess (34 in total of which 12 belonged to Isis). Here we will take advantage of Egyptian henotheism[18] which identifies different goddesses (or gods) as diverse hypostases of a single deity. The other group is formed by temples devoted to gods of solar character, or that suffer a process of solarisation (as Sobek-Ra in Qasar Qarum, see Fig. 3).[19] We have 42 of these, of which 20 belonged to Amon-Re.

The results of the experiment are presented in Figure 8, where the corresponding histograms of the absolute value of the declination are presented. Figure 8(a) stands for the goddesses and it is fascinating to notice that the highest peak of the distribution is for a declination of ~18º. The answer could be *Sopdet*! So the most important celestial hypostasis of Isis, at least from the New Kingdom onwards, is the most important reference for the orientation of her (and other deities identified with her) temples. Curiously, other important peaks are found at the solstitial family, the accumulation peak and the family of Canopus. So the temples of the goddesses clearly follow standard patterns, including families II, IV, V and VI. Regarding the "solar" temples, the result is also astonishing (see Fig. 8(b)). The three highest peaks, nearly centred at 24¼º, 0½º and 11¼º have indeed a solar character (families II, I and III, respectively) beyond any doubt. So solar temples are mostly facing the sun at critical moments of the annual cycle! An obvious conclusion of these experiments would be that we might find intimate metaphysical reasons beyond the orientations of a majority of the monuments of our sample.

However, the connections between orientation and temple ascription is not always evident, just the contrary. A good example of this would be one of the monuments presented in this paper, the temple of Set at Naqada. This temple was discovered in the excavations of the site straddling the 19th and the 20th Centuries[20] and has been tentatively assigned to the 3rd Dynasty (possibly reconstructed in the 18th), as the minor step pyramid located nearby, which we have however assigned to the 4th Dynasty and tentatively relate to *Sopdet*.[21] The orientation of the temple corresponds to a declination of −19½º±¾º. This would be the orientation of Sirius at the beginning of the Middle Kingdom. Could the temple be built or re-built at a earlier or later date, respectively, than previously suspected? Is the temple adscription correct? Or were Set and *Sopdet* related in any way? Our archaeoastronomical data can also state quite interesting questions for archaeology. [22]

1.3. *Testing the quarter-cardinal direction*

In Paper 3, when the quarter-cardinal family (VII) of orientation was defined, we announced that the existence of this family would be further challenged in Upper Egypt in the near future. Consequently, we included a test of our previous data in the area of Western Thebes and Abydos in our new campaign in December 2006. However, this campaign has also included new fieldwork in other temples of these areas, the important site of Athribis and one of the most important archaeological excavations handled today in ancient Egypt, the pre-Dynastic site of Kom el Ahmar (see Table 1). All these data will also be useful for our exercise.

The quarter-cardinal family is defined as a group of temples whose orientation is close to 45º, 135º, 225º or 315º, producing in the histogram of the absolute value of declination a peak at ~39º for the latitudes of Egypt. Actually, two symmetric peaks VII+ and VII− can be found if the normal (no absolute value) histogram of declination is considered (see Figure 9 (a)). The idea (Rolf Krauss, private communication[23]) is that this orientation should primarily be achieved by determining a near meridian direction that would be turned afterwards by plus or minus 45º to get the main axis of the new building. In Paper 3, we used the fortress at Zawiyet Umm el-Rakhman (hereafter ZUR) as a prototype of the family. Now, we will test here the possibilities of such an idea with four groups of temples in Upper Egypt (see Table 2).

Figure 10 shows the site of Kom el Ahmar (ancient Hierakonpolis or *Nekhen*) with the four aligned pits for high-poles, now filled with sand, that should have been located at the front of pre-dynastic structure HK29A.[24] This is probably the earliest Egyptian temple we have news from, thus it is very important for our discussion. We believe that this was the first building (if it was not the building associated to a nearby alignment of pits of structure 29B) in Egypt belonging to the quarter-cardinal family. We suggest that a N-S line was first determined by astronomical observations and that the axis of the temple was obtained by rotating this by 45º clock-wise. The question is how the N-S orientation was achieved.

We support the idea that HK29A is the first building ever orientated in Egypt to the simultaneous near meridian transit of Phecda (γUMa) and Megrez (δUMa) as shown in Figure 11(a). This configuration was primarily proposed by the first author to explain the orientation of the gigantic pyramids of the Old

Kingdom.[25] Phecda and Megrez were two distinct stars of *Meskhetyu*, the asterism of the Plough, a most important ancient Egyptian constellation as we have already largely discussed in Papers 1 and 3.[26] We believe that by rotating the astronomically determined axis by 45º, another objective was obtained: that the "temple" entrance would be almost perpendicular to the Nile, in agreement with the Nile hypothesis as we have defended before.

This peculiar configuration of *Meskhetyu* would have been used at Kom el Ahmar perhaps because the constellation was not circumpolar on site at pre-Dynastic times, since Merak (βUMa) would have slightly disappeared below the local horizon. As a rough first approximation, under standard atmospheric conditions, a star is not visible until it reaches an angular height equivalent to its visual magnitude. Table 3 lists the evolution in declination versus time of the seven stars of *Meskhetyu*, and their magnitudes, so that the reader can easily follow the discussions. This is the reason why Merak (m_v=2.36) was invisible at Kom el Ahmar when HK29A was erected.[27] However, *Meskhetyu* was fully circumpolar at other important pre-Dynastic spot a few hundred kilometres to the north, Umm el Qab (see Fig. 11(b)). Umm el Qab, in the desert area of Abydos, was the site of a huge pre-Dynastic cemetery and also contained the tombs of the first kings of Egypt (0 and 1st Dynasties), when the Egyptian state was forming and perhaps some metaphysic aspects related to the king, including the star religion of the Pyramid Texts (hereafter PT),[28] were developing.

We could easily imagine two scenarios. On the one hand, we could imagine that Umm el Qab was selected as the place for the royal cemetery because it was the first place travelling north[29] where *Meskhetyu* would have been circumpolar or, on the other hand, that the relative importance of the stars of *Meskhetyu* as the *ikhemu seku* ("imperishable" stars) per excellence was due to the fact that they were circumpolar at the site of the royal necropolis. Both solutions might be possible (or wrong) but we tend to identify ourselves with the first one, which would be on agreement with the intimate relation between astronomy and landscape that we have encountered throughout our work (see, for example, Papers 1 and 3).

The importance of *Meskhetyu* in the Abydos area would have had continuity in the orientation yielded by other important constructions. For example, the funerary enclosure of king Khasekhemuy at Shunet el-Zebit (the Abydos Fort, see Table 2) would have been orientated to the same configuration of Phecda and Megrez as structure HK29A, but a few centuries later (*c*. 2650 B.C.), as would have been the Osireion of Sethy I (and the associated temple, see Table 2) that would have adjusted to the visibility of Phecda and Megrez, when the vertical transit of these couple of stars actually occurred quite far from the Meridian, as demonstrated in Figure 11(c). The Osireion is in fact an exception to a rule that could be applied to the vast majority of the temples of Abydos, which according to our quarter-cardinal test do not differ in more than 5º from due-north (see Table 1). As shown in Figure 11(d), it is plausible that the "rising" or "setting" of Alkaid (ηUMa)[30] close to due-north was the most common celestial configuration chosen to establish the Meridian line during the New Kingdom in Abydos. A similar explanation could be found for the temples of Athribis but a 1000 years later during the Late and Greco-Roman Periods. Interestingly, as in the case of Kom el Ahmar, we believe that by rotating the astronomically determined axis by 45º, the temple entrances in the areas of Abydos and Athribis would be nearly perpendicular to the Valley of the Nile in the area (not necessarily with the river itself), once more in rough agreement with the Nile hypothesis.

The last case to be analyzed for our quarter-cardinal test is the group from where the idea was originated: the Million Year and nearby temples of Western Thebes (see Table 2). Here, the northern horizon of the temples, except in the case of Sethy I, is hidden by the Theban hills which distend large angular heights from 4º to more than 10º. However, having a look at Tables 2 and 3, we can notice that most of the buildings could have a reasonable explanation with the risings or settings of certain stars of *Meskhetyu* during the New Kingdom and beyond. Among the data, we have three interesting cases and two exceptions. Let us look to the exceptions first. One is the temple of Sethy I and we do not have a reasonable explanation for it. It actually breaks our test. The other is the Million Year temple of Amenhotep III and its beautiful witnesses the Colossi of Memnon, which we strongly believe that was orientated to sunrise at the winter solstice and hence deserves a different analysis.[31] The interesting cases are the couple of temples at Medinet Habu, the temple of Amon at Malqata and the Ramesseum.

Figure 12 shows the northern horizon as seen from the outer court of the Ramses III temple at Medinet Habu. One topographic feature comes out from the rest of the landscape, the plateau aspect of a section of the cliffs of Deir el Bahari which covered a range of azimuths of ~6º. Figure 13 (a) shows how Alkaid would have raised over this feature to get the orientation of the Amon temple on site *c*. 1450 B.C. at the time of Thutmosis III, the constructor of the temple together with Hatshepsut.[32] A quarter of a millennium later, the Million Year temple of Ramses III was built close-by. On this occasion, however, a much better orientation (2½º vs. 8º) was achieved by the observation of the rising of another star of *Meskhetyu* (perhaps Phecda) on the same topographic feature.

The temple of Amon at Malqata is located near Medinet Habu. Curiously, this temple is located at a place where the impressive hill of El-Qorn, crowing the Theban necropolis, marks almost precisely due-north. Fig 13 (c) indicates that for the height of El Qorn (~10¼º), only Alioth (εUMa) was visible tangential to the peak at the mid-New Kingdom, while the rest of the stars of *Meskhetyu* were obscured by the mountain.

Finally, we will devote a few words for a building whose plan and orientation has been a puzzle for most Egyptologists. The Ramesseum (see Figure 14) has a trapezoidal plan that makes it difficult to define an axis of symmetry for the complex. We have defined two primary axes, the first is the one that from the sancta sanctorum permits a clear view all the way long to the entrance of the complex (Main Axis) and the second one is the line perpendicular to the main pylon. They differ by ~2º, meaning that Ramses II perhaps faced two possible alternatives to define the orientation of his Million year temple. We have not found any reasonable hypothesis that could explain this dichotomy if the real directions are taken into account, either in the way looking out (to the river) or looking in (to the mountains), or even considering the perpendicular directions (±90º). Prosaic interpretation like, for example, that arguing that the Ramesseum is orientated to Luxor temple should be abandoned since they are unable to explain the dichotomy or were simply wrong. So, we believe that once more the quarter-cardinal test has the solution. From the Ramesseum, the Theban hills near due-north distend between 4º and 5º, depending where you are located within the complex. At the time of Ramses II (*c*. 1250 B.C., see Table 3), four stars of Meskhetyu were circumpolar in that direction, another one (Alkaid) would offer a bad alignment and a couple, Merak and Phecda offer reasonable alternatives to get an orientation close to the Meridian. Figure 13 (c) and (d) shows how the Main Axis could have been obtained by the observation of the setting of Phecda and the perpendicular to the pylon by the setting of Merak. We could speculate with the idea that the topographers of the king were facing the problem of which of the two stars should be chosen and they decided to select two axes so that the temple would be orientated according to both stars, but we will never know this for sure.

In the temples of Million Years of Thebes, the axes of the monuments were later rotated by 135º from the astronomically determined N-S line. By doing this, the temple façades were almost perpendicular to the Nile but not exactly. As we have discussed in Paper 1, it is the solstitial line which is perpendicular to the Nile at the site of ancient Thebes and the result of the quarter-cardinal exercise does not give an appropriate result. Actually, these temples are the responsible for the peak at ~78º that we found in Fig. 6 when we were discussing the Nile hypothesis.

We believe that in early Egyptian history two concerns about temple orientations were in conflict to accomplish the religious precepts: (i) a temple should be orientated according to the celestial realm, and (ii) a temple should be orientated according to the Nile. The quarter-cardinal family of orientations was the solution found to the problem in many areas of the country, notably Upper Egypt. A preliminary axis (generally a N-S line) would be established through astronomical observations (we believe mostly from stars of *Meskhetyu*) and later by rotating this by 45º or 135º (or even 90º as we will discuss later on) the definitive axis of the temple, perpendicular or nearly perpendicular to the Nile (sometimes parallel), would have been obtained. This intelligent procedure was applied from the very beginning of Egyptian history at Kom el Ahmar to the Roman era (the Serapis temple at Luxor or the temple of Kom Ombo are members of the family, see Paper 1). It should have been so common that even when there were no Nile restrictions, as in ZUR in the Mediterranean coast, the procedure was applied.

As a corollary of this result, and applying the Ockham's Razor, we suggest that proposals for orientations of individual or groups of temples of this family to bright stars like Vega or Arcturus (for positive declinations), or to the stars of the Southern Cross and α and β Centauri (for negative ones, see Paper 1), should be taken with extreme cautions or even directly abandoned.

1.4. *Evolution in time and space*

One advantage of having so many data at our disposal is that it becomes possible to perform comparative analyses with independent series of them. We have imagined two such analyses, one will be done by the data of temples separated by epoch and another one by geographical location. The results of the first are presented in Figure 9, where panel (a) shows the declination histogram of the whole series, panel (b) for the most ancient temples from the early dynastic period to the Old and Middle Kingdoms, panel (c) is for the temples of the New Kingdom and the Late Period up to the Persian conquest and, finally, panel (d) from that moment to the end of the pharaonic era, including the Ptolemaic and Roman periods. The results of the study by geographical location are presented in Figure 15. Panel (a) repeats for completeness and commodity the same plot on Fig. 9(a), panel (b) stands for the temples of Lower Egypt from the province of the "White Wall" (area of Memphis) to the sea, panel (c) is for classical Upper Egypt, including what today we know as Middle Egypt and also Lower Nubia up to the Sudanese border, and panel (d) shows the data of all the temples of the deserts and oases of Egypt from Siwa to the Sinai. We should stress that these plots do not exactly reproduce the results early presented in Papers 1, 2 and 3 because new data have been added to each of these series in successive campaigns. The three series of both analyses have a large enough number of monuments so that the comparison between the different series can be considered realistic and statistically significant.

Fig. 9 -and 15- (a) is complementary to Fig. 7 but offers a little bit more of information. It shows that family I is not as much "equinoctial" as one would expect (peak centred at −1º), that family II is dominated by winter solstice orientations,[33] while family III has a pair of positive and negative declination peaks but still the negative (at −11º) is the dominant. Families IV and V, at −17¾º and −53¾º, are still representative of the declinations of Sirius and Canopus, respectively. The two peaks of accumulation (VI+ and VI−) stand for the cardinal family, dominated by the northern one and, finally, we find the couple of peaks surely associated with the quarter-cardinal directions as discussed in the previous section (VII+ and VII−). However, this plot shows a peculiar feature (underlined in the figure) that we have not found before in our studies at a declination of ~51¾º. We could imagine that this belongs to temples orientated to Canopus but with the gate opened in the opposite direction. Hence we have tentatively numbered it as V+. However, as we will discuss later, the reality of this peak could be much more elaborated. The comparative analysis will be performed by families of orientations and we will try to recognize effects such as possible evolutions, period specialization or geographical peculiarities.

Family I is very interesting. Indeed it is never appropriately working as "equinoctial" as clearly seen in the successive panels of Figs. 9 and 15 so, from now on, we will simply called it the eastern (cardinal) family. It appears in the oldest periods and predominantly in Lower Egypt. Certainly, it is mostly related to the pyramid complexes of the Old and Middle Kingdom. It shows values of the declination of –¾º and –¼º, for 9(b) and 15 (b) respectively. These values do not fit either the astronomical equinox or the mid-day between the solstices (the so-called "megalithic" equinox).[34] However, considering this possibility, we also suggest that we could be facing a situation similar to that of the quarter-cardinal family. Primarily a Meridian axis would have been established for the pyramid complex[35] and then the gate of the temple would have been open to the east afterwards, in order to face sunrise and to achieve the topographic commandments dictated by the Nile. This idea would be reinforced by the fact that, in later periods and, especially, for other geographical areas, eastern orientations were either imprecise (−1º, −2¾º and again −2¾º for Figs. 9(c), 9(d) and 15(d), respectively) or simply absent (see Fig. 15(c)). The solar temples of the 5th Dynasty would be a peculiar exception, as we showed in Paper 3 (Part II), since the original intention of their orientation would have been to face sunrise at *Wepet Renpet* (Egyptian New Years´s Eve) at the moment of their construction.

Family II is associated with the winter solstice and it is ubiquitous in time and space. This demonstrates its importance (see, for example, Fig. 3). It is the dominant during the New Kingdom and in Upper Egypt (see Figs. 9 (c) and 15(c), respectively). Curiously, there is a peak related to summer solstice (II+) both in Fig. 9(b) and Fig. 15(d). We propose that the former could be associated with an interest in this time-mark during the Old Kingdom that might be related, among other aspects, to the foundation of the civil calendar.[36] The later would express the general interest for solar orientations out of the Nile Valley as already discussed in section 1.1. However, there is one peculiar fact of the peaks related to family II in Fig. 9. We have obtained values of −24½º±¾º, −24¼º±¾º and −23½º±¾º for the peaks of the earliest (b), middle (c) and latest (d) periods, respectively. All these values are in agreement, within the errors, with the extreme values of the solar declination in the respective epochs. However, we have detected a certain trend for lower declinations (in absolute value) versus time that perhaps, and this is quite speculative, could be related to the decreasing value of the Ecliptic obliquity along Egyptian history.[37] Indeed, this would not mean that ancient Egyptian were familiarised with this physical phenomenon. The trend would simply be a collateral effect of their continuous interest in the phenomenon and the orientation of temples accordingly. We have already discussed family III and in these new exercises it is demonstrated that seasonal orientations (predominantly associated to peak III−) were present in all epochs and geographical areas.

Family IV has a couple of peculiarities. On the one side, it is not present in the oldest monuments, on the other side, it is absent in the temples of the deserts and oases. We suggest that the explanation for the former could rely on the lesser importance, in certain aspects, of Sirius (*Sopdet*) in the earliest phases of Egyptian history.[38] In the second case, the solution could rely on the fact that *Sopdet* was most important because her connection to the arrival of the waters of the Inundation. In lands where this phenomenon was not present, and thus irrelevant, temples orientated to this prominent star were not so "mandatory". The family of Canopus (V) has a similar behaviour, being absent also in the earliest phases. Perhaps the absence of individual stellar alignments for these period could be related to the over-helming dominance of cardinal (I, VI and VII) and solar (II, III and again I) orientations in those epochs, reflecting different aspects of the star religion and the solarisation process of the kings in these earlier phases of Egyptian history.[39]

It is now the moment to discuss the abnormal feature V+. It is present for almost all geographical areas and almost for all epochs, being especially significant during the Old and Middle Kingdom, when we do not find Canopus orientations (family V), and during the New Kingdom when the corresponding peak is much higher than the one associated to the star. The hypothesis we will defend is that family V+ has nothing to do with Canopus. The idea came during our visit to the excavation of the Ahmose pyramid complex at Abydos, during our last campaign, when we met on site the director of the excavations, Stephen Harvey from the University of Chicago (see Figure 16). Once the discussion had been established and we were telling him what we wanted to do on site, he enthusiastically asked if we could find a solution for the estrange orientations of the structures he was excavating, apart from the prosaic Nile orientation, since they were absolutely abnormal for the area of Abydos, where alignments are predominantly quarter-cardinal as we have already analysed.

The preliminary analysis of our measurements on site revealed one fascinating alternative. The perpendicular clockwise direction to the main axes of three temples (and probably of the pyramid still under excavation)[40] was that of sunrise at the winter solstice (see Table 1). We discussed on site the possibility that Ahmose, being a Theban, would have imported to Abydos a custom that was typical from his homeland (see Paper 1). However, once at home, our results confirmed these ideas, but offer another intriguing alternative since the nearby funerary temple of Senuseret III offered a similar orientation. Whatever the solution could be for the complex of Ahmose (imported custom or imitation, or both), we believe that family V+ (specially significant during the New Kingdom when winter solstice orientation were the dominant) should be predominantly, if not exclusively, ascribed to orientations perpendicular, in the anti-clockwise direction, to winter solstice alignments. We will catalogue this new family as II perpendicular (II⊥). We suggest that even some examples of family V could follow the same rule (rotating clockwise in this sense), although there are cases where we could find perpendicular axes to solstitial alignments that were perhaps deliberately orientated to Canopus, as in the secondary axis of Karnak as defined by pylons VII and VIII.[41]

Within a similar context, another interesting case could be that of the Isis temple complex at Filae that we did not discussed deeply in Paper 1 because we did not have at that moment as much information at our disposal as we have now. The main axis of the temple of Isis was diverted to a declination of −53½º±¾º and could have been orientated to the setting of Canopus, a star presumably related to the myth of Isis and Osiris.[42] However, the perpendicular axis (and that of the temple of Hathor), gave a declination of −16½º±¾º, if a reconstruction of the ancient horizon of Filae is attempted. This perfectly agrees with the declination of *Sopdet*, the celestial hypostasis of Isis (and of Hathor in that period) and, in our opinion, this should be the dominant orientation. What is the correct solution? Either the complex was orientated to Sirius rising and after the main temple axis rotated by 90º clockwise or, and most interesting, Filae is located at a place with a very peculiar phenomenology; a singular place in Egypt where Sirius rising and Canopus setting were perpendicular. As we discussed in Paper 3, it is indeed a pity the lack of information about Canopus, in ancient and classical Egyptian sources, that could clarify the actual relevance of this bright star within ancient Egyptian civilization.

The cardinal family (VI) is present along all periods of Egyptian history and in most areas of the country. Northern orientations (VI+) are dominant to southern counterparts (see Figs. 9 and 15), a fact presumably reflecting that N-S orientations were predominantly, if not exclusively, traced to the north. Curiously, we have only marginal presence of the family in Lower Egypt (Fig. 15(b)) where eastern (cardinal) orientations are predominant. However, this could be related to the already mentioned fact that most eastern cardinal orientations would have been born like northern cardinal orientations.

Finally, our analysis shows a couple of peculiarities for the quarter-cardinal family (VII). On the one hand, its is most typical of the New Kingdom and the early Late Period, when it is only second to the solstitial family and, in certain aspect, substitutes family VI which is scarcely present. On the other hand, it is practically[43] exclusive of Upper Egypt. This could relate to the fact, already discussed in section 1.3, that this procedure of orientation was developed to simultaneously accomplish stellar and river orientation prescriptions, in the Nile Valley.

As a summary of our evolution in time-and-space exercise, we could reach the conclusion that actually only three customs of orientations were present in ancient Egypt across her land and her history: cardinal (i), solar (ii) and stellar (iii).

i. The cardinal custom would be integrated by families I (in most occasions), VI and VII and would be achieved by the observations of certain configurations of stars in the north (predominantly, it not exclusively, stars of *Meskhetyu*). This procedure would initially give a near Meridian axis that would later offer various alternatives: a gate opening north, a gate opening south, a gate opening east (or west) or a new axis by turning the original by 45º or 135º, with the gate opening near NE (or NW) or SE (or SW), respectively.

ii. The solar custom will be formed by families I (in a few occasions), II, II⊥ and III and would basically be related to important points of the annual cycle, or in some cases to especial dates of the civil calendar such as *Wepet Renpet* or the eves of the other two seasons *Peret* and *Shemu*, as suggested in Papers 1, 2 and 3. Paradigmatic examples would be the 5th Dynasty solar temples at Abu Ghurob (I), Karnak (II and II⊥) and Abu Simbel (III).

iii. The stellar custom would be represented by families IV and V. We have no doubts of the pertinence and relevance of the alignments to *Sopdet*. However, we have minor doubts if many of the presumable alignments to Canopus should be interpreted in a different way. In this case, it is difficult that new field data will bring a final answer. Hence, new epigraphic information confirming the importance of this star would be highly desirable.

A final point to discuss is how once an alignment was yielded by astronomical observations in a certain direction, the new axis at 45º, 90º, 135º (in both clock-wise or anti-clockwise directions) or 180º were obtained. The answer to this question could be encountered in a recent hypothesis,[44] which suggests that the sign of Seshat (the divinity mostly involved in temple orientation ceremonies, notably the stretching of the cord), carried by the goddess upon her head in all representations, might perhaps have been a schematic and symbolic representation of an archaic transit instrument, similar to a Roman *groma*, that would have later become the totem of the goddess. This instrument would have had eight radii and a viewpoint, and could have been used at the "stretching of the cord" ceremonies since the dawn of Egyptian history, directly offering the eight directions under discussion from a single astronomical or topographical observation.

1.5. *Epilogue at the temple of Serabit el Khadim*

One of the most fascinating sacred complexes of ancient Egypt is the Temple of Hathor Lady of Turquoise in the rocky plateau of Serabit el Khadim, in the desertic central mountains of the Sinai. The sanctuary and its surrounding landscape have an enigmatic atmosphere, which is plenty of solitude and silence, involving everything with a halo of mystery and fascination. One wonders for what reason the ancient Egyptians could have been interested in this lost and barren land forgotten by the gods. The interest is implicit in the name of the temple. This was one of the best places to obtain the valuable turquoises, a much appreciated semi-precious stone for it sky-blue colour.[45]

The same enigmatic character involves the bizarre plan of the complex (see Figure 17) with a couple of nearly, but not completely, parallel shrines, and a long series of spaces and porticos conforming a different axis, complemented by another minor elements, such as the hypostyle hall (or *hanafiyeh*, **e** in Fig. 17) and the chapel of the Kings (**c**). The temple complex was developed during a very long period of time elapsing from the beginning of the Middle Kingdom to the end of the New Kindom (*c*. 1964 to 1136 B.C. according to the restorers of the site).[46] The oldest structure and main sanctuary of the temple was the hemi-speos of the goddess Hathor (**a** in Fig. 17, see also Fig. 1), first established during the reign of Senuserest I. This was enlarged on several occasions until the times of Ramses IV who built a temple of "Million Years" (**a'**) in front of the façade. To the SW stands the second hemi-speos (**b**). This had been traditionally ascribed to Sopdu, the god of desert regions to the east of the Delta, with an arguable lunar or stellar character.[47] However, the excavators and restorers of the site have recently proposed that this sanctuary was originally devoted to Ptah, Lord of Memphis, in the Middle Kingdom, being enlarged during the New Kingdom and the ascription changed to Hathor, Amon and Sopdu. The situation of this small shrine is still more complicated because of a statue of the lunar god Thoth, in the form of a baboon (see Fig. 1), that has been discovered on the site.

The Middle Kingdom temple was completed by the chapel of the kings, to the NW of the site and with a rectangular enclosure (possible a temple or festival hall, **d**) whose foundations has been found below the New Kingdom structures, straddling the first five room of the main axis from the entrance of the complex. A new monumental gate, including a pylon, was built under Tuthmosis III (**d'**) and several other rooms and porticos were built under successive kings (notably the ubiquitous Ramses II) until a long series of spaces defined a final axis of "symmetry" (**d"**) during the reign of Ramses VI, the last king attested on site. Numerous steles have been found on the temple and others have been found in the surroundings, many of them in the main axis of the complex, inside and outside the temple, as can be see in Figure 18. There are two that we consider especially significant (66 and 82, erected by Senuseret I and Senuseret III, respectively) because they were presumably located on the top of two prominent hills in the western horizon (see Fig. 18) where a small kerb of stone is still visible (the steles have fall down since antiquity).

It was not easy to perform fieldwork in a site with so many axes and interesting features susceptible of a direct measurement. Table 1 summarizes those that we have considered the most logical because they define the main axes of the most relevant structures and the most conspicuous combination of artificial and natural features of the horizon. The data of the declination, reproduced in intervals including the errors, are also presented in Fig. 17. The sanctuary of Hathor does not show any relevant astronomical orientation (A). Surprisingly, the "Million Year" temple built several centuries later does show a possible alignment to summer solstice sunset (A'). However, its smaller companion to the south does show a conspicuous lunar alignment to the northernmost possible moonset (B, major lunastice). We wonder is this could be connected to some of the archaeological findings discovered on site such as the statue of Thoth. These hypotheses could be reinforced by the alignments to steles 66 (F) and 88 (G), as seen from the entrance of the temple. F approximately marks the southernmost moonset and G the sunset at the winter solstice. These four orientations might have served as precious time-markers for the people working on the site, where there were scarcely any other reference (no river, no plants, rare rainfalls), although the lunar alignments are peculiar to Serabit as we have not encountered them anywhere else in Egypt.[48]

Neither the *hanafiyeh* nor the chapel of the kings offered alignments (C and E, respectively) susceptible of an astronomical interpretation. However, the situation is quite different when the alignments associated to the Middle Kingdom temple (**d**) and the successive constructions in its axis are considered. The slight displacements of alignments D, D' and D" offered an interesting possibility. They could reflect the changes of orientation caused by minor differences in the declination of a certain star due to the phenomenon of the precession of the equinoxes. The original building (**d**) could have been orientated to Sirius (*Sopdet*) setting, during the Middle Kingdom. Why *Sopdet*? We have found two possible explanations to this orientation. One is related to Sopdu the other with Hathor.

According to the PTs[49] the god Horus-Sopdu was in some way manifested also in *Sopdet* and we have seen that certain parts of the temple were ascribed to him, although the exact date of this ascription is a matter of controversy. Perhaps, this early structure was devoted to this god, forming a triad with Hathor and Ptah, the owners of the two semi-subterranean shrines. However, the relation with Hathor is still more striking and much more plausible from our point of view. It is well known that *Sopdet* was considered as one of the hypostasis of Hathor at least in the Greco-Roman period, when the assimilation between Isis and Hathor was almost complete, but we do not have enough relevant information to extrapolate this fact to the Middle Kingdom. Or do we have it?

One of the most imposing steles of Serabit el Khadim is that of Horurre (**k** in Fig. 17).[50] Beautifully preserved, this monument contains a long story of the visit of this functionary and his group of workers to the site in a search for turquoises during the late Middle Kingdom (reign of Amenemhat III or Senuseret III). The campaign started in Memphis in the 3rd month of *Peret* (early summer in that epoch) and stayed there to the end of the 1st month of *Shemu*, two months later. Horurre informed us that *this was not indeed the best season* to go to Serabit el Khadim because *the heat was intolerable* and the precious stones were *difficult to find in the glare of the sun* and *dissolved in the hands* of the workers. However, Hathor came to help Horurre; she manifested herself so that our hero could actually envisage her. Where? We believe that in the sky. At the end of the Middle Kingdom the heliacal rising of Sirius occurred in the last decades of the 4th month of *Peret* in the Sinai, after the star had been invisible for more than two months.[51] Hence, if we relate both phenomena, the miraculous vision of Hathor and the heliacal rising of Sirius, we could conclude that Hathor was already seen in Sirius in this early period. This would probably justify the orientation of part of her temple to the star. Indeed, after the "miraculous" apparition of Hathor, the precious stones were recollected in good quantities and the expedition went back home satisfactory and safely.

Later when a new pylon and court were built by Thutmosis III, the axis was changed. Actually, the alignment would not work unless we consider that the star was observed at the astronomical horizon (for example from the top of the pylon itself) but then we need to justify how the orientation was achieved. However, the alignment would have finally worked fine during the last phases of the temple when the setting of *Sopdet* would have been seen close to stele I (see Fig. 18) from the court in front on the temple of Million Years (**a'**) across not less than 15 gates. This is an effect that it is difficult to assign to pure chance. The heliacal setting of Sirius was produced at the end of the spring both in the Middle and the New Kingdoms and would have been a perfect harbinger for the moment to leave the Sinai before the arrival of the intolerable heat of summer.

These diverse possible orientations to *Sopdet*, specially those of the Middle Kingdom and of the late New Kingdom, bring to our memory a problem that we have not deeply discussed so far in our work (except in Paper 1) but that was in our objectives from the beginning of the project, to study whether or not the ancient Egyptians were familiarized with the phenomenon of the precession of the equinoxes. Historiographically, there have been some important sites in Egypt were the possibility of precessional effects had been considered. The most important of these were, on the one side, the couple of temples with close-by but different orientations at Medinet Habu and the turning axis of the temple of Luxor,[52] and, on the other side, the temple of Horus at Thoth Hill in Thebes and the Satet temple at Elephantine whose "Sothic" orientations we already challenged in Paper 1.

We have shown in section 1.3 that the two temples of Medinet Habu were probably orientated to different configurations of the stars of *Meskhetyu* which indeed vary because of precession, although this does not imply an implicit knowledge of the phenomenon. Regarding Luxor, we would suggest that the different successive new axes of the temple (except the original)[53] came forced by the processional way to Karnak and by the early presence in this way of the bark sanctuary constructed by Hatshepsut, which orientation (see Paper 1) of 220º suggests a dependency to the quarter-cardinal family as well (as the temple of Serapis built on site centuries later). Indeed, the case of Serabit el Khadim is also a meagre (although suggestive) proof and it would merely indicate that varying stellar orientations due to precession were indeed achieved but not necessarily that the phenomenon producing these changing orientations was recognized or, even less, understood. So, as in the case of winter solstice orientations and the Ecliptic obliquity variability, we believe at the light of the data we have assembled for the last few years, that varying temple stellar orientations were collateral effects of a physical phenomenon that was indeed in action but that was not recognized by ancient Egyptians.

2. CONCLUSIONS

With the fifth field campaign performed in December 2006, we have accomplished some of the most relevant objectives we had in mind for our archaeoastronomy project of ancient Egyptian culture. The principal dilemma we wanted to solve was whether the temples of this civilization were astronomically orientated or not. Epigraphic sources were clear mentioning 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.[54] We have now measured 330 temples and shrines along the geography of Egypt belonging to all periods of her history. This represents approximately 95% or all the temples in any state of preservation still existing in the country.

We will not go into the details on the fascinating discoveries we have obtained along this research as most of them are summarized in the conclusions of Papers 1, 2 and 3. However, we want to stress a few particular results that are real highlights of the analysis of the complete series of data as presented in this paper. These are:

i. The temples of the Nile Valley and the Delta were orientated according to the Nile as our data have clearly illustrated, but …

ii. The temples were also astronomically orientated beyond 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 places so that they would be compatible (quarter-cardinal directions is a good example of this), or by the 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, kind of targets. One was probably related to different 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 quarter-cardinal direction (families I, VI and VII). 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 calendars (families I, II, II⊥ and III). Finally, the third group of targets was the two brightest stars of ancient Egyptian skies, Sirius and Canopus (families IV and V, respectively). These customs were present during most of Egyptian history[55] and in the different areas of the country, although some minor peculiarities have been discovered.

iv. Surprisingly, or not, the temples of solar deities have predominantly solar orientations while those belonging to goddesses are predominantly orientated to the brightest stars of the sky, notably Sirius.

v. We have detected certain evidences of the precession of the equinoxes and of the variation of the obliquity of the Ecliptic phenomena in our data as collateral effects of the continuous use of stellar and solar orientations along Egyptian history, respectively. However, this marginal detection should never be interpreted under any circumstance as a real recognition of any of these phenomena by the ancient Egyptians.

This is the last paper of our series with data of the temples of ancient Egypt. At the turn of the century we envisaged a project to answer a quite simple question. Now, a few years later, we are really proud by the quantity and variety of the results we have obtained along this period of intensive work. These have been the gate for new demands and questions. Indeed, much more work could be done.[56] However, we consider our sample to be statistically representative beyond any doubt and we are convinced that new data will only serve to reinforce or tinge our results. As a matter of fact, this overview clearly illustrates something that we could only imagined at the very beginning of our project: ancient Egyptians undoubtedly looked at the sky with scrutinized eyes in a permanent search for their correct orientation not only in time but also in space.

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5. For example, we are defending such a case for the temples of Karnak, see Paper 1.
6. For Deir el-Sheluit, Aïn Labkha and Mons Claudianus, see the plans in R. S. Bagnall and D. W. Rathbone (editors), *Egypt, from Alexander to the Copts* (London, 2004), 198, 256 and 286, respectively. Also interesting for Mons Claudianus is S. Aufrère, J. C. Golvin and J. C. Goyon, *L'Égypte restitueé, Volume 2, Sites et temples des deserts* (París, 1994), 221-7. With off-limits we mean temples were the Tourist Police is not happy to see foreign "visitors" due to, on many occasions, unmistakable security reasons. It was not always easy to convince them that the non-Egyptian members of the project were not simple tourists.
7. A good review on these fascinating monuments can be found in A. Ćwiek, "Date and Function of the so-called Minor Step Pyramids", *Göttingen Miszellen* clxii (1998), 39-52.
8. J. A. Belmonte, M. Shaltout and M. Fekri, "Astronomy and landscape in ancient Egypt: challenging the enigma of the minor step pyramids", *Science* (2007), submitted.
9. Once more we should stress that magnetic alterations are not expected in Egypt, where most of the terrain is limestone and sandstone. Nevertheless, the temples were mostly measured along their main axes, from inside the sanctuary to the outermost gate and, on several occasions, in the opposite direction checking for possible alterations of the measurement.
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12. There are still some 30 "Egyptian" temples in Sudan, built either by the Egyptian pharaohs themselves or by the kings of Qush, including those of the 25th Dynasty that governed Egypt. This is less than 10% of our sample. Nevertheless, we are planning a field campaign in Sudan as soon as the circumstances would allow it, once we have obtained the permits and the collaboration from the Antiquities Services of Sudan and the necessary financial resources. The data of these monuments could be very useful as a test to falsify our own results in Egypt.
13. However, there are a few significant exceptions to this rule; see, for example, S. Cauville, E. Aubourg, P. Deleuze and A. Lecler, "Le temple d'Isis à Dendera", *Bulletin de la Société Français d'Egyptologie* no. 123 (1992), 31-48, and L. Gabolde, "La date de fondation du temple de Sésotris Ier et l'orientation de l'axe", in *Le Grand Château d'Amon de Sésostris Ier à Karnak* (Paris, 1998), 123-70, for the temples of Dendera and Karnak, respectively. In Papers 1, 2 and 3 we have discussed and disentangled the vast majority of these works.
14. It is hard to see the early important work of archaeoastronomers, such as E. Krupp, "Light in the temples", in *Records in stone, papers in memory of Alexander Thom*, ed. by C. L. N. Ruggles (Cambridge, 1988), 473-99 (and references therein), mentioned in the literature of Egyptology.

On the contrary, the old fashioned and out-of-date work of J. N. Lockyer, *The Dawn of Astronomy* (New York, 1993), new edition, is frequently mentioned in order to criticize it.

15. The data of the pyramid temples of the Old and Middle Kingdoms have not been considered in the plot to avoid problems of scaling but would also fit that rule within a few degrees.
16. In our writings, we have frequently used the term "equinoctial" for any alignment with declination near 0º and "equinox" for the corresponding time point, associated with orientations close to due-east. However, this does not mean that we are attributing knowledge of the astronomical equinox (i.e. the moment when the sun crosses the celestial equator) to the ancient Egyptians but rather that we believe that such orientation would be a proof of a certain interest in the four cardinal directions. How this interest converted into actual construction planning is discussed later at several points in this paper.
17. Due to the wandering nature of the Egyptian calendar, the seasons of the tropic year (and the associated climatic phenomena and agricultural activities) did not usually follow the seasons of the civil calendar. Hence, economic activities, although completely under the control of the civil calendar, should be done according to the tropic (thus Gregorian) seasons. This is probably the reason why these dates were so important as to be reflected in the orientation of the temples. In Paper 1, we showed how during the reign of Ramses II the calendar and climatic seasons coincided again after fifteen centuries of wandering, perhaps making of Abu Simbel a temple to celebrate the glories of the calendar.
18. For the assimilation of different goddesses into Isis, see Plutarch, *The mysteries of Isis and Osiris* (lxvi). For henotheism, most relevant is E. Hornung, *El uno y los multiples: concepciones egipcias de la divinidad* (Madrid, 1999).
19. Although many of them were indeed advocated to Amon-Re, we are not including the temples of Million Years built in Thebes by the pharaohs of the New Kingdom because their primary use was to serve for the cult of the deified king.
20. For a modern report on the archaeological findings in the area of Naqada, see D. Arnold, *The Encyclopaedia of ancient Egyptian architecture* (Cairo, 2003), 555-7.
21. One of the sides of the pyramid is aligned with the heliacal rising of Sirius at the probable moment of its construction (*c.* 2570 B.C.); see Belmonte et al., *op. cit.* (ref. 8).
22. Curiously, an earlier report of a real observation (not a prediction) of the heliacal rising of Sirius was written in the rocks of Djebel Tjauti, in the mountains to the west of Naqada, in II *Shemu* 11 of the 11th year of an unknown king *c.* 1592 B.C., as reported by J. C. Darnell and D. Darnell, "Gebel Tjauti rock inscription 11", in *Theban desert road survey in the Egyptian Western Desert*, Vol. 1. *Gebel Tjauti and Wadi El-Hol rock inscriptions* 1-45 (Chicago, 2002), 49-52.
23. Rolf Krauss kindly suggested that the second largest peak in our declination histogram of the temples of Upper Egypt (fig. 5 in Paper 1) could be actually caused by monuments with a diagonal originally orientated in a N-S direction. This comment was the origin of the definition of the quarter-cardinal family.
24. R. Friedman, "The ceremonial centre at Hierakonpolis locality HK29A", in *Aspects of early Egypt*, ed. by J. Spencer (London, 1996), 16-35.
25. J. A. Belmonte, "On the orientation of the Old Kingdom pyramids", *Archaeoastronomy* 26 (2001), S1-20. The idea of the simultaneous transit of stars as possible targets for ancient Egyptian pyramid orientations was resurrected by K. Spence in her most controversial: "Ancient Egyptian chronology and the astronomical orientation of pyramids", *Nature* no. 408 (2000), 320-4.
26. In our previous works of this series, we have greatly emphasized the importance of *Meskhetyu* for different aspect of ancient Egyptian culture. However, A. A. Maravelia, *Les Astres dans les Textes Religieux en Égypte Antique et dans les Hymnes Orphiques* (BAR International Series mdxxvii; Oxford, 2006), 437, has questioned this importance on a textual statistical basis. We disagree with her conclusions in this particular case as clearly stressed in J. A. Belmonte, *Essay Review* on "Les Astres dans les Textes Religieux en Égypte Antique et dans les Hymnes Orphiques", *Archaeoastronomy, the Journal for the Astronomy in Culture* xxi (2007), in press. The importance of *Meskhetyu* had also been previously emphasized by E. C. Krupp, *Echoes of the Ancient Skies* (New York, 1983), 211-3; A. M. Roth, "Fingers, stars and the opening of the mouth: the nature and function of the *nṯrwi*-blades", *Journal of Egyptian Archaeology* lxxix (1993), 57-79; R. Krauss, *Astronomische Konzepte und Jenseitsvorstellungen in den Pyramidentexten* (Ägyptologische Abhandlung lix; Wiesbaben, 1997); and P. Wallin, *Celestial cycles. Astronomical concepts of regeneration in the ancient Egyptian coffin texts* (Uppsala, 2002), among many others.

27. The rising and setting of Merak, with a visual magnitude of 2.36, could also have been used during the pre-Dynastic period to align the temples of Hierakonpolis or nearby sites towards north (see Tables 2 and 3).
28. For the Pyramid Texts, see R.O. Faulkner. *The Ancient Egyptian Pyramid Texts* (Oxford, 1969). Interesting readings are also R. O. Faulkner, "The king and the star-religion in the pyramid texts", *Journal of Near Eastern Studies* xxv (1966), 153-61, and Krauss, *op. cit.* (ref. 26).
29. According to most specialists of the pre- and proto-Dynastic periods, see, for example, T. A. H. Wilkinson, *Early dynastic Egypt* (New York, 1999) and A. Pérez-Largacha, *El nacimiento del estado egipcio* (Alcala de Henares, 1993), the kings that unified Egypt (Dynasties 0 and I) were original from Hierakonpolis. However, they established their royal cemetery a couple of hundred kilometres to the north at Umm el Qab, in Abydos. This might support the idea that the place of the royal necropolis was deliberately chosen for religious purposes.
30. Alkaid, with a visual magnitude of 1.85, was almost "tangential" to the horizon at Abydos c. 1250 B.C. Further south, *Meskhetyu* was not circumpolar during the New Kingdom.
31. The temple of Amenhotep III was peculiar in many aspects. B. M. Bryan, "The statue program for the mortuary temple of Amenhotep III", in *The temples in ancient Egypt, new discoveries and recent research*, ed. by S. Quirke (London, 1997), 57-81, proposes that the temple was a sort of huge celestial diagram. Its solar orientation could be associated with the crescent importance of the solar cult during the reign of the king.
32. Interestingly, the small temple of Medinet Habu includes the earliest representations of the stretching of the cord in the New Kingdom (together with the Red Chapel of Hatshepsut) after several centuries of oblivion when the ceremony was probably celebrated but apparently not depicted. However, the damaged associated inscriptions do not contain any explicit reference of an astronomical target as in the texts of later periods. See P. Barguet, "Le ritual archaïque de foundation des temples de Medinet-Habou et de Louxor", *Revue d'Égyptologie* ix (1952), 1-22.
33. In the plot, there is a small peak below the average frequency almost centred at summer solstice declination but we do not consider it as significant for our complete sample. However, we will see how this peak could be associated to certain appropriate periods of Egyptian history and explicit geographical areas afterwards.
34. For a most interesting discussion in the diverse "natures" of equinox, see C. L. N. Ruggles, "Who's equinox?", *Archaeoastronomy* no. 22 (1997), S45-50, and A. C. González García and J. A. Belmonte, "Which equinox?", *Archaeoastronomy, the Journal for Astronomy in Culture* xx (2007), in press.
35. As proposed in Belmonte, *op. cit.* (ref. 25). Other alternatives to get a Meridian orientation are defended by I. E. S. Edwards, *The Pyramids of Egypt*, 3rd ed. (Harmondsworth, 1993), and by M. Isler, "An ancient method of finding and extending direction", *Journal of the Archaeological Research Centre of Egypt* no. 26 (1989), 191-206, who proposes a meridian orientation using the sun instead of the stars.
36. As proposed in Belmonte, *op. cit.* (ref. 1). See also references therein.
37. The obliquity of the Ecliptic (the angle between the Earth rotation axis and the perpendicular to its orbit plane) is diminishing at a rate of ~0.46 seconds of arc per year. It varied from some 24º to 23º 37' from 2900 to 1 B.C. If we are to believe the numbers yielded by our solar alignments (of families I and II, fundamentally), one could suggest that our solar orientations were obtained when the disc was completely above the horizon. Although this is a quite speculative exercise, this situation would agree with the importance and beauty of the illumination effects as shown if Fig. 3 (or in fig. 10 of Paper 1 for Abu Simbel), much more dramatic when the disc is completely above the horizon than when the first rays appear, a phenomenology which is scarcely noticeable unless you are directly looking to sunrise.
38. This was already defended by Belmonte, *op. cit.* (ref. 1). We believe that the relative importance of *Sopdet* was increasing during the Old Kingdom once the wandering calendar and the climatic seasons were clearly diverging. The first references to *Peret Sopdet* date from the Middle Kingdom.
39. The PTs are crystal-clear at this respect. The Sun (or the solar bark) and the Imperishable Stars (the *Ikhemu Seku* of ancient Egyptians of which *Meskhetyu* was a fine example) are frequently mentioned as celestial destinies for the soul of the king after death. See Krauss, *op. cit.* (ref. 26) and Faulkner (1966), *op. cit.* (ref. 28). This is also demonstrated by the textual archaeoastronomical statistical analysis of both PTs and Coffin Texts as performed by Maravelia, *op. cit.* (ref. 26), 122-125. However, according to this analysis, *Sopdet* was the most frequently

mentioned individual star in the PTs, an importance which is not apparently reflected in temple orientation during the Old Kingdom.

40. An excellent actualized report on the excavations can be found in S. P . Harvey, *Abydos* in http://oi.uchicago.edu/OI/AR/02-03/02-03_AR_TOC.html.
41. As postulated by L. Gabolde, "Canope et les orientations nord-sud de Karnak étables par Thoutmosis III", *Revue d'Égyptologie* l (1999), 278-82.
42. The relation between Canopus and Osiris (hence to the mythology of Isis) is mentioned in Plutarch, *op. cit.* (ref. 18), xxii, but it is not clear if the text refers to the star itself or to the pilot of the vessel Argo. However, *Argo Navis*, clearly the constellation now, is related to the boat of Osiris in the same paragraph. The traditional Coptic name of the star, **ⲡⲥⲟⲩ ⲛϩⲱⲣ**, may also relate it to sailing.
43. Curiously, the temple at the fortress of ZUR that we used to define the family in Paper 3 is far away from the Nile Valley. However, it was built during the reign of Ramses II, a king that, if we are right, made a preferential use of quarter-cardinal orientations in Thebes and Abydos.
44. N. Miranda, J. A. Belmonte and M. A. Molinero Polo, "Seshat en las escenas de fundación de los templos y del cómputo de los años reales", in Proceeding of the "III Congreso Ibérico de Egiptología", *Trabajos de Egiptología (Papers in ancient Egypt)* Special Volume (2007), in press.
45. A splendid and actualized description of the temple archaeology and history can be found in D. Valbelle and Ch. Bonnet, *Le sanctuaire d´Hathor maîtresse de la turquoise, Serabit el-Khadim au Moyen Empire* (Aosta, 1996). Also interesting is Aufrere et al., *op. cit.* (ref. 6), 249-61.
46. The Supreme Council of Antiquities, in collaboration with the restorers of the site, has installed at the entrance of the temple of Serabit el Khadim a series of very didactic panels where the structure and evolution of the site are cleverly described. Some of the information discussed in the text comes from these panels.
47. For Sopdu, see E. Castel, *Diccionario de mitología egipcia* (Madrid, 1995), 292-93. For Sopdu in Serabit, see also Valbelle and Bonnet, *op. cit.* (ref. 45) and references therein. For lunar cults in the Sinai, see L. Eckenstein, "Moon cult in Sinai on the Egyptian monuments", *Ancient Egypt* i (1914), 9-13.
48. In our sample of 330 temples, we have found no statistically significant evidence of either lunar or planetary alignments. The moon has a well defined behaviour at the horizon, with an obvious preference for certain positions with characteristics values of the declination (more or less 28½º and –29¼º, or 19º and –18½º, including parallax, for the major or minor, north and south, lunastices, respectively, for 1500 B.C. and the latitudes of Egypt). The major lunastices, by far the more important, are practically absent from the data except for a few isolated cases (e.g. *Hor-em-akhet* temple a Giza, and in this case the temple undoubtedly faces the Sphinx). The minor lunastices have declinations close to the *Sopdet* family of orientations and could be confused with them. However, for historical reasons and, in several cases, for temple adscription, we believe that the Sirius hypothesis is far more probable. Regarding the planets, they normally have declinations close to the solar values because they move close to the ecliptic. Consequently, hypothetical planetary orientations would be almost indistinguishable from solar ones. Hence, Serabit el Khadim is quite unique in presenting two possible lunar alignments to moonset at the north and south major lunastices, respectively.
49. This relation is illustrated in the utterance 632 of the PTs where *Horus-Sopdu goes forth* (for the king) *as Horus who is in Sopdet*. For a discussion on the topic, see for example, Wallin, *op. cit.* (ref. 26), 21-2.
50. For an interesting translation of the stele of Horurre, see Aufrere at al., *op. cit.* (ref. 6), 258, although some of the calendar dates have been wrongly translated.
51. The earliest reference to the phenomenon of the heliacal rising of *Sopdet* dates from the reign of Senuseret III. It is a prediction from the archive of Illahun. See, for example, Belmonte, *op. cit.* (ref. 1). For Illahun archive, see U. Luft, *Die chronologische Fixierung des ägyptischen Mittleren Reiches nach dem Tempelarchiv von Illahun* (Vienna, 1992).
52. As discussed in J.A. Belmonte, "Astronomía y arquitectura: el papel de los astros en la cultura y el arte del antiguo Egipto", in *Arte y Sociedad del Antiguo Egipto*, ed. by M. A. Molinero and D. Sola (Madrid, 2000), 109-36, and references therein. Lockyer, *op. cit.* (ref. 14) also defended, in several occasions, apparent time-dependent stellar alignments as due to precession. The adjustment of Luxor turning axes to Vega was surprisingly accurate for the old 19th Century, now abandoned, chronology of Egypt. Under the new chronological framework, see, for example, Hornung et al., *op. cit.* (ref. 10), this hypothesis should be rejected.

53. Orientated to an azimuth of 33º, it is not easy to justify an astronomical target for it (δ~48¾º). A very prosaic solution would be that the temple was nearly parallel to the Nile (only ~6º difference). However, at the light of the existence of the II⊥ family, we could speculate with the idea of a perpendicular alignment also for Luxor temple. An azimuth of 123º corresponds (for a flat horizon) to a declination of −29¼º. This is the declination of the moon at the major southern lunastice. Provided this hypothesis was correct, we might have two temples at Karnak and Luxor orientated to the southernmost rising position of the sun and the moon, respectively, at the dawn of the Middle Kingdom. We have the handicap that lunar alignments have not stood out in our statistical studies (see ref. 48).
54. For the Nile hypothesis and a preliminary defence of astronomical orientations, see, for example, R. H. Wilkinson, *The complete temples of Ancient Egypt* (London, 2000), 36-9. Edwards, *op. cit.* (ref. 35), 244-6, believed that no direct observations were done during the ritual of the stretching of the cord. Maravelia, *op. cit.* (ref. 26), 250, argues, wrongly from our point of view, against the observation of the Big Bear.
55. Part of this tradition could find its roots in the prehistoric alignments of Nabta Playa, where solar and stellar orientations were perhaps already in operation in the Neolithic period. See J. McKim Malville, F. Wendorf, A. A. Mazar and R. Schild, "Megaliths and Neolithic astronomy in southern Egypt", *Nature* no. 392 (1998), 488-91, and T. G. Brophy and P. A. Rosen, "Satellite imagery measures of the astronomically aligned megaliths of Nabta Playa", *Mediterranean Archaeology and Archaeometry* v (2005), 15-24.
56. We have already mentioned (see ref. 12) our intention to make fieldwork in Sudan. Other interesting possibilities would be to get more accurate theodolite measurements of some exceptionally well-preserved temples, such as the Ramesseum, and to test the alignment to *Meskhetyu* with a higher degree of precision. A same kind of study for the pyramids, trying to reach a precision higher that ¼º for the buildings of the 5th, 6th and 12th Dynasties, would also be highly desirable to finally accept or reject the simultaneous transit versus time theory as defined by Spence, *op. cit.* (ref. 25), reformulated by Belmonte, *op. cit.* (ref. 25) and challenged by many scholars, notably É. Aubourg and Ch. Higy with their data on the pyramid of Djedefre; see B. Mathieu (editor), "Détermination de l'orientation de la pyramide de Redjédef", in *Bulletin de L'Institut Français d'Archéologie Orientale* ci (Cairo, 2001), 457-9. Also, the evolution of temple alignment versus time at a single site could be an interesting exercise. Medamud (see Arnold. *op. cit.* (ref. 20), 142-143) would be a good study case. Even repeating the experiment, including fieldwork, we have performed in our project, preferably by other research team, could be an excellent and healthy exercise.

TABLE 1: Orientation of the scattered group of Egyptian temples and chapels presented in this paper. For each temple is shown the location, the identification of the temple (either the most common name, owner deity or builder), the epoch of construction (i.e. dynasty), the latitude and longitude (L and l), its azimuth (a) from inside looking out, and the angular height of the horizon (h) in that direction (B and b stand for "blocked" view by a modern or ancient building, respectively), and the corresponding declination (δ). The last column contains additional comments or data (capital letters for the case of Serabit el Khadim as in Fig. 17). The data of some additional temples as obtained from plans published in literature are included at the end of the table. See text for further discussions.

Place	**Temple**	**Dynasty**	**L (º/')**	**l (º/')**	**a (º)**	**h (º)**	**δ (º)**	**Comments**
Giza	Isis	21st-26th	29/59	31/08	90¼	0	−0½	
Philadelphia	North Temple	Ptolemaic	29/27	31/51	188¾	1	−58¾	Or the opposite
Heracleopolis	Herishef	19th	29/05	30/56	201	0B	−55¼	
	Monumental Gate	22nd			194	0B	−58½	
Serabit el Khadim	Speos of Hathor	12th	29/02	33/28	306½	0¼	31	A
	Speos of Ptah	12th			303½	0¼	28¾	B
	Hypostile hall	12th			344¼	1	57¾	E (or *hanafiyeh*)
	Kings´chapel	12th			341	1	56¼	C
	Access temple	12th			247½	3¼	−18¾	D
	View of stele 66	12th			242½	2½	−23	F
	View of stele 82	12th			236½	2	−28	G
	Thutmosis III	18th			251	2½	−15½	D' if h~0º → δ~−17º
	Ramses IV	20th			297	0¼	23¼	A'
	Axis of Ramses VI	20th			249½	2¼	−16¾	D''
Mons Claudianus	Serapis	Roman	26/43	33/29	160½	6¼	−52	
	"Isis" chapel	Roman			72¾	7¾	18¾	
	Fort chapel	Roman			269½	4½	1½	
Athribis	Apries	26th	26/30	31/40	46½	0	37¾	
	Phiskon	Ptolemaic			50½	0	34½	
	Auletes	Ptolemaic			135½	0	−40	
	Small chapel	Ptolemaic			314½	0	38½	
	Dromos chapel	Roman			39½	0	43¼	
	Speos	Undated			35½	0½	46½	
Abydos	Sinki	4th ?	26/11	31/54	48¾	0	36	
	Senuseret III	12th			26	0	53¼	Δa~±2º, ⊥ S → −23½º
	Ahmose A	18th			26¾	0	52¾	⊥ S → −23¾º
	Ahmose B	18th			26¾	0	52¾	*Ibid.*
	Nefertary C	18th			26¾	0	52¾	*Ibid.*
	New temple D	18th			31¾	0	49¼	⊥ S → −28½º
	Ramses I	19th			41½	0B	41¾	
	Monkey´s	19th			42½	0B	41	
	Khentamentyu	20th			44½	0B	39½	
Naqada	Set	3rd or 18th ?	25/58	32/44	111½	0	−19½	
Aïn Labkha	Pyris	Roman	25/44	30/34	82¾	0	6¼	
	Pyris (N chapel)	Roman			78	0¼	9	
	Noth temple	Roman			90¼	0¼	−0¼	
Karnak	Achoris chapel	29th	25/42	32/39	286¼	2B	15¼	
Western Thebes	Mentuhotep III	11th	25/41	32/35	121	8	−23½	Δa & Δh ~±1º
Deir el Sheluit	Isis	Roman	25/40	32/36	102½	0	−11½	
Kom Mir	Antoninus	Roman	25/13	32/38	45¼	0B	39¼	
Kom el Ahmar	HK29A	Pre-dynastic	25/05	32/46	48½	0½	36¾	Δa~±1º
	29B (north section)	Pre-dynastic			44½	0½	40½	Δa~±2º
	Fort	2nd			54½	0½	31¾	
El Kanayis	Sethy I	19th	25/00	33/18	7	0½	64	
Extra Temples[11]								
Mons Porfirites	Main temple	Roman	27/15	33/18	342½	?	57½	
Sikait	SKE006	Roman	24/38	34/48	296	1	23¾	
Nugrus	Building 20	Roman	24/37	34/46	154	?	−55¼	
Berenike	Serapeum	Ptolemaic	23/55	35/28	141	0	−45½	

TABLE 2: Testing the quarter-cardinal family in Upper Egypt. The table presents for each location the azimuth of the diagonal of the temple closest to north (i.e. the original azimuth minus either 45º or 135º), and the corresponding angular height of the horizon and declination in that direction. A few relevant comments are added in the last column.

Temple	a_N (º)	h_N (º)	δ_N (º)	Comments
Kom el Ahmar				
29A	3½	0	64	h~2º→ 66¼º
29B	359½	0	64¼	h~2º→ 66½º
Kom Mir	0¼	0B	64¼	
Western Thebes				
Amon at M. Habu	8	5¼	68	
Thutmosis III	352	6¾	69½	
Amenhotep II	0	5½	68¾	
Thutmosis IV	358	6	70	
Amenhotep III	342	8	65¼	
Amenhotep	345	6¾	66¼	
Amon at Malqata	0½	10¼	74½	To el Qorn.
Horemheb	357	6¼	70¼	
Sethy I	349	0	61¾	
Ramses II (Axis)	356½	5	68¾	
Ramses II (Pylon)	358½	4¼	68½	
Merenptah	347½	7½	68¼	
Siptah	357½	6½	70½	
Ramses III	2½	5¼	69¼	
Thot at M. Habu	359	5	69	
Abydos				
Shunet el-Zebit	1	0	63¼	
Sinki	3¾	0	63	
Tuthmosis IV	357	0	63	
Ramses I	356½	0	63	
Sethy I	351	0	61¾	
Ramses II	358½	0	63¼	
Monkey´s	357½	0	63	
Khentamentyu	359½	0	63¼	
Athribis				
Apries	1½	0	62¾	
Phiskon	5½	0	62½	
Auletes	0½	0	63	
Small chapel	359½	0	63	
Dromos chapel	354½	0	59	

TABLE 3: Declination vs. time evolution of the seven stars of *Meskhetyu* along Egyptian history from pre-Dynastic times to the Christian Era. The last two rows show the nearest to the quarter degree maximum and minimum declination of the asterism.

Star	m_v	3500	3000	2500	2000	1500	1250	1000	500	1	500
Dubhe	1.79	66/41	69/01	70/56	72/20	73/09	73/14	73/02	72/24	71/04	69/06
Merak	2.36	64/05	66/06	67/33	68/27	68/42	68/35	68/24	67/15	65/44	63/45
Phecda	2.44	68/51	70/14	70/44	70/37	69/47	69/13	68/28	66/33	64/20	61/47
Megrez	3.30	73/14	74/44	75/19	75/00	74/02	73/21	72/24	70/22	67/57	65/17
Alioth	1.76	77/25	78/03	74/44	76/31	74/33	73/29	72/20	69/48	67/00	64/16
Mizar	2.05	80/02	79/44	78/29	76/24	74/02	72/39	71/23	68/35	65/51	63/04
Alkaid	1.85	77/18	75/40	73/32	71/03	68/19	66/59	65/36	62/48	60/00	57/13
δ_{min}	3.30	64	66	67½	68½	68¼	67	65½	62¾	60	57¼
δ_{max}	1.76	80	79¾	78½	76½	74½	73½	73	72½	71	69

FIGURE CAPTIONS

FIG. 1. Map of Egypt showing the location of places, from the Western and Eastern Deserts to the Nile Valley, where the orientation data presented in this paper have been assembled.

FIG. 2. A couple of peculiar examples of the monuments discussed in this paper. (a) Top; the two speoi of Hathor, completely hidden behind tall steles, and Ptah in the temple of Serabit el Khadim. Notice the small statue of the lunar god Thoth, represented by a baboon with a moon symbol on its head. (b) Below; the temple of Isis "Lady of the Pyramids" constructed in the Late Period over the ruins of the cultic chapel of the pyramid of Henutsen (G1-c). The pyramid of Khufu can be seen in the foreground. Photographs by J. A. Belmonte.

FIG. 3. A splendid light hierophany at sunrise at the winter solstice (December 21st 2006) at the temple of Sobek-Re in Qsar Qarun (Dionysas) in El-Fayum Oasis. Notice the illumination of the inner sanctuary, where the statue of the god should have been located, and of the different successive portals. The winged-disc symbol of Horus Behedety blossoms above the first gate at the pale yellow light of the first rays of his physical counterpart, the solar-disk. Photograph by J. A. Belmonte.

FIG. 4. (a) Orientation diagram of the data assembled for this paper and presented in Table 1. Notice the concentration of monuments near NE corresponding to the area near Abydos. Dot-dashed line stands for the extra temples. (b) All the data of temples measured outside the Nile Valley, as presented in Papers 2, 3 and Table 1, where the river influence should be absent. Notice the Maltese Cross form of the diagram typical of astronomical orientations with a preference for cardinal and solar orientations.

FIG. 5. Orientation (azimuth) histogram of the 330 temples measured during our five campaigns in Egypt between February 2004 and December 2006. Although there are temples orientated to each sector of the horizon, there are obvious clear preferences with statistically significant peaks at near due-East ("equinoctial" sunrise and/or due-north orientations later skewed by 90º) and winter solstice (WS) sunrise. There are also clear peaks at NE and SE. These are undisputable evidences of intentional astronomical orientations. See the text for further discussions.

FIG. 6. Testing the Nile hypothesis. Histogram representing the difference of orientation between the main axes of 170 temples of the Nile Valley and the average course of the river (or river branch in the case of the Delta) at their corresponding locations, for an interval of ±1º, larger than our estimated error of ½º, allowing for probable historical changes in the river flow. Temple orientation with the main gate located in front of (axis perpendicular to) the Nile is the most common way of orientating the buildings. Axes parallel to (at ~0º or 180º) or perpendicular to the river, but facing the other way (~270º) were also common. This demonstrates without any reasonable doubt that local topography (the course of the Nile) was very important at the moment of settling the foundations of the temples but not only. See, for example, the peak at the order of 78º probably caused, among others, by the group of Million Year temples at Thebes or Abydos. See text for further discussion.

FIG. 7. Absolute declination histogram of 330 Egyptian temples and sanctuaries. The figure relates to the possibility that the axis of a particular building under discussion could have been established either in the sense inside looking out, or the opposite. The graph confirms the existence of the six (and only six) families of Egyptian temple orientations as defined in Paper 3: "equinoctial" or eastern cardinal (I), solstitial (II), seasonal (III), Sopdet (IV), Canopus (V), meridian or northern cardinal (VI) and quarter-cardinal (VI), despite of the fact that more than 235 additional temples have been used in the analysis (93 temples for Paper 3). Plot line description as in Fig. 9.

FIG. 8. Absolute declination histograms of a couple of independent series of temples. (a) 34 temples of goddesses of all epochs. (b) 42 temples of divinities with a solar character. Notice the most significant peak corresponding to *Sopdet* family for series (a) and the "equinoctial" and solstitial peaks associated with solar gods. See text for further discussion. Plot lines as in Fig. 9.

FIG. 9. Histogram of declinations of the temples on ancient Egypt versus epoch. (a) Total histogram of our sample of 330 temples showing the 6 families of orientation, including those like III, VI and VII with

positive and negative subfamilies. A new "subfamily", V+, is underlined and will be further discussed in the text. (b) Temples from the pre-Dynastic period to the end of the Middle Kingdom. (c) Temples of the New Kingdom and the Late Period until the Persian conquest. (c) Late temples with a dominance of buildings of the Greco-Roman period. The three series of data plotted in panels (b), (c) and (d) are independent between each other and are statistically significant. Notice the persistence of several families of orientation across time and the fluctuations of some others. In panel (a), the peak of family I rises to more than 12 but has been cut to keep the same scale in the different plots. Long dashed lines stand for equinox and solstice declinations. Short-dashed and dot-dashed lines marked the higher and lower value of the declination of Canopus and Sirius in the pharaonic period, respectively. Dot line stands for a value of one of the normalized relative frequency, i.e. the average value of this magnitude.

FIG. 10. The four aligned holes for standing poles probably located at the façade of the building known as structure HK29A in Kom el Ahmar, the site of Hierakonpolis, one of the most important pre-Dynastic villages of Egypt. This could be the earliest building of Egyptian history simultaneously orientated both topographically and astronomically. The Fort of Nekhen, ascribed to the 2nd Dynasty, can be seen on the foreground. Photograph by J. A. Belmonte.

FIG. 11. Testing the quarter cardinal family (i). Different celestial configurations of the asterism of *Meskhetyu* (the Plough) as observed from different locations and different epochs. (a) Simultaneous meridian transit of Phecda (γUMa) and Megrez (δUMa) in pre-Dynastic times in Kom el Ahmar for the alignment of Structure HK29A. (b) Lower culmination of Merak (βUMa) at early Dynastic times at the royal cemetery of Umm el Qab (Abydos) to help explaining the sacred character of the site. (c) As in the first case, but *c*. 1290 B.C. in order to explain the anomalous orientation of the Osireion and the associated temple of Sethy I in Abydos. Notice the different azimuth and angular height of the stars. (d) Lower meridian transit of Alkaid (ηUMa) in Abydos at an epoch when *Meskhetyu* circumpolar character was ending on site after two millennia due to precession. See the text for further discussions.

FIG. 12. Testing the quarter cardinal family (ii).The cliffs of Deir el Bahari (arrow) seen as a flat topped plateau, with an angular height of some 5¼º, from the temples of Medinet Habu. The buildings of this sacred area, including the 18th Dynasty temple of Amon (right) and the Million Year Temple of Ramses III (left), could have been orientated through the observation of the rising of appropriate stars of *Meskhetyu* at different epoch on this perfect spot of the horizon (see, for example, Fig. 13a). Photograph by J. A. Belmonte.

FIG. 13. Testing the quarter cardinal family (iii). Different celestial configurations of the asterism of *Meskhetyu* (the Plough) as observed from different temples of Western Thebes during the New Kingdom. (a) Rise of Alkaid at a~8º and h~5¼º to align the 18th Dynasty temple of Amon at Medinet Habu. (b). Lower culmination of Alioth (εUMa) on the peak of El Qorn, at h~10º as seen form the temple of Amon at Malqata, while the rest of Meskhetyu was invisible behind the mountain. (c) Setting of Phecda at h~5º on the northern cliffs of Deir el Bahari to align the Main Axis of the Ramesseum. (d) *Ibid*. of Merak at h~4¼º to align an axis that rotated by 135º, in a clock-wise sense, would be perpendicular to the pylon of this temple.

FIG. 14. Testing the quarter cardinal family (iv).The Ramesseum of Thebes as seen from the top of the Theban Hills. This fantastic monument has a bizarre trapezoidal planning with at least two main axes of orientation. This could have been forced by constructive requirements connected, or not, to different axes of orientations established by the observation of near north settings of different stars of *Meskhetyu* (see Fig. 13) in the cliffs above Deir el Bahari. See the text for further discussion. Photograph by J. A. Belmonte.

FIG. 15. Histogram of declination of the temples of ancient Egypt versus geography. (a) Total histogram (as in Fig. 9a) presented for comparison. (b) Temples of Lower Egypt, from Meidum to the sea. (c) Temples of Upper Egypt and Lower Nubia, until Abu Simbel. (d) Temples of the oases and deserts of ancient Egypt, corresponding to the diagram of orientation of Fig. 3b. Once more, the series of data plotted in panels (b), (c) and (d) are independent between each other. However, it is obvious the continuity of different traditions, like the solstitial (II), across all Egyptian geography. In panel (a), the peak of family I rises to more than 12 but has been cut to keep the same scale in the different plots. The lineal features as in Fig. 9.

FIG. 16. The excavations of the Ahmose pyramid complex by the joint University of Pennsylvania-Yale-Institute of Fine Arts New York University Expedition at Abydos, showing the foundations of several temples of the complex. Most of these temples would belong to a new family of orientations, II⊥ (V+ in Figs. 9 and 15) which might have included buildings orientated to winter solstice sunrise, whose axis was later rotated by 90º in a anti-clockwise direction. Photograph by J. A. Belmonte by kind permission of Stephen Harvey, the Director of the excavation.

FIG. 17. Schematic plan of the enigmatic temple of Serabit el Khadim, in the Sinai, showing the most important architectural elements of the temple and the corresponding axes of orientation.[46] The data listed below show the corresponding interval of declinations for each of these axes and some astronomical hypotheses connected with them. SS and WS stand for summer and winter solstice, and SL and NL stand for southernmost and northernmost lunar, respectively. For the relevance of F and G, see Fig. 18. See the text for further discussion.

FIG. 18. The long axis of symmetry of the outer sections of the temple of Serabit el Khadim, showing the associated western horizon. The view was unblocked from the inner court (axis D'', see Fig. 17) to the entrance of the complex and the horizon beyond. Hills F and G were crowned with a kerb of small stones with a high standing stele in the middle (66 and 82, respectively, now fallen) dated from the Middle Kingdom. Other smaller cairns are located near the axis of the temple (I), whose steles are now severely broken or gone, and at H where a couple of damaged steles are still visible. The road of access to the temples passes at the depression between F-G and I. Photograph by J. A. Belmonte.