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ON THE ORIENTATION OF ANCIENT EGYPTIAN TEMPLES: (1) UPPER EGYPT AND LOWER NUBIA

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Les architects tenaient compte avant tout du terrain et des commodités d'accès. Nos textes suggèrent au contraire qu'ils se déterminaient par l'état du ciel, sans entrer dans le détail des opérations.

P. Montet, "Le rituel de fondation des temples Égyptiens", *Kemi*, 1960, 84.

Were the temples of the ancient Egyptian civilization astronomically orientated? This is a very important question and one that, as the above quotation stresses, is far from being solved. Recently, Richard Wilkinson, in his useful *The complete temples of Ancient Egypt*, clearly stated that "most commonly temples built along the Nile were oriented on an east–west axis, according to local cardinal directions as determined by the river",[1] and if so local topography would be the commanding reason for temple orientation. However, he also pointed out that "on occasions, orientation towards the Sun or important stars was definitely the priority, and this principle may be more important than is often recognized".[2]

As we have explained elsewhere,[3] the ground plan of a temple (or at least its four corners), including the orientation of its main axes, was normally established in a ceremony known as the "stretching of the cord", records of which exist as early as the 1st Dynasty. The first depiction of the ritual dates from the reign of Khasekhemuy, last king of the 2nd Dynasty (*c*. 2750 B.C.).[4] The ceremony is represented on several occasions throughout Egyptian history but only in the Graeco-Roman period do the associated inscriptions refer to the way in which the axis was placed. As shown in Figure 1, the earliest inscriptions are written on the walls of Horus's temple in Edfu, whose foundations were settled in 237 B.C.[5] The texts are unanimous: the King was looking at Meskhet(yu), the Bull's Thigh or Foreleg, the asterism of the Plough. So, for the Egyptians, at least of later epochs, the orientation was astronomical, in apparent contradiction with the opinion of most specialists.[6]

This fact has been well known since the nineteenth century when the inscriptions at Edfu were first translated, and one would have expected that a close collaboration between (archaeo)astronomers and Egyptologists would have been resulted. However, this potentially productive synergy never occurred. We could raise the question of why and the answer, or the blame, could probably be attributed to a book, *The dawn of astronomy*,[7] published at the end of that century by an otherwise reputable astronomer. This volume was written by Sir Norman Lockyer, the first editor of the

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FIG. 1. The stretching of the cord ceremony as represented in the second hypostyle hall of the Horus temple at Edfu. The king together with the writing and timekeeping goddess, Seshat, defines the axis ("the four corners") of the temple while the former is "looking at the stars of Meskhet(yu)", i.e. the Plough. Photograph by M. Sanz de Lara.

journal *Nature*, and it is considered today by archaeoastronomers worldwide as the founding work of their discipline.[8] Throughout the text, the author made abundant use of precession in dating temples in Egypt and basically supported the accepted long chronology of his time, which placed the 1st Dynasty around 5000 B.C. The book also included a high degree of religious speculation that earned it the opprobrium of most Egyptologists of the time. When the long chronology was abandoned at the beginning of the twentieth century, any possibility that archaeoastronomy would become an auxiliary science of Egyptology died with it. It was not until the last quarter of the century that the works of Gerald Hawkins,[9] widely promulgated by the reputable archaeoastronomer and outreach specialist Edwin Krupp,[10] re-opened the question; but there was still a failure to rouse any sort of enthusiasm about ancient astronomical practices among the Egyptological community.[11]

Much more recently, Marshall Clagett's pivotal volume might well have proved a turning point.[12] However, yet again, archaeoastronomy and its scholarly possibilities have mostly been ignored. As an example of this, we can mention that in the 27 issues of the former *Archaeoastronomy* supplement of this journal, published between 1979 and 2002, only two papers dealt with astronomical alignments of Egyptian monuments and both related to the pyramids, one appearing in 1984 and the other in 2001.[13]

This was how things stood at the beginning of the present century, when we decided that this situation ought to be rectified. To achieve this, the authors collaborated to plan a project with the main objective of putting the study of ancient Egyptian astronomy on the footing it deserves in the context of present-day Egyptology.[14] An Egyptian-Spanish Mission has been created under the auspices of the Egyptian Supreme Council of Antiquities, with the aim of measuring the orientation of the vast majority of the ancient temples across Egypt, within a reasonable period of time (four years). Our purpose is to obtain fieldwork data in a quantity sufficient to prove (or disprove), through statistical studies, all the speculations concerning temple orientation from both the topographical and the astronomical point of view.

This paper presents the results of a first campaign conducted in February 2004 and covering almost all the remaining temples of Upper Egypt, from Abydos to Aswan, including Philae. The campaign ended on 22 February with an observation of the sunrise illumination at the main temple of Abu Simbel. As shown in Figure 2, most Egyptian temples do possess a clear axis of symmetry that can easily be

FIG. 2. Main axis of the funerary temple of King Siptah and Queen Tewosre in Western Thebes. The vast majority of Egyptian temples, with only a few exceptions (e.g. Luxor, see Table 1), had a well-defined symmetry axis from the innermost sanctuary (close-up in the image), across different courts and pylons (in the foreground), to the entrance. This is the axis we normally measured. Photograph by J. A. Belmonte.

TABLE 1. Orientation of Egyptian temples of Upper Egypt (from Abydos to Aswan) and Lower Nubia (Uauat). 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 (Φ and λ), its azimuth, from inside looking out, (a) and the angular height of the horizon (h) in that direction (B and b stand for "blocked" view by a modern or ancient buildings, respectively), and the corresponding declination (δ). We list the difference in degrees between the main axis of the temple and the average direction of the flow of the Nile at the temple location (Δ). Finally, some related comments are included. It is important to notice that the azimuth and angular height of Lower Nubia temples is for their current location, after having been rescued from the waters of Lake Nasser. See text for further discussions

Place	Temple	Dynasty	Φ (º)	λ (º)	a (º)	h (º)	δ (º)	Δ (º)	Comments
Abydos	Shunet el-Zebit	2nd	26.19	31.91	46	0	38.2	96	Khaseskhemwy
	Tuthmosis IV	18th			42	0	41.5	92	
	Ramesses II	19th			$43\frac{1}{2}$	0 ?	40.3	$93\frac{1}{2}$	
	Sethy I	19th	26.18	31.92	36	0	46.2	86	Main axis
					306	4	33.7		Osireion Gate
Dendera	Hathor	Ptolemaic	26.14	32.68	18	1	59.1	74	Main axis
	Mammisi II	Roman			$108\frac{1}{2}$	3+	−15.3	$201\frac{1}{2}$	
	Mammisi I	30th			$107\frac{1}{2}$	$4\frac{1}{2}$	−13.6	$202\frac{1}{2}$	
	Isis	Ptolemaic			108	0	−16.4	202	Temenos Gate
	"	30th			112	3+	−18.3		Old Axis
	"	Roman			18	B	58.1		High room
Qift	Min	18th	26.0	32.82	262	0+(B)	−7.4	88	Main axis
Al-Qala'a	Claudius	Roman	26.0	32.82	$88\frac{1}{2}$	0+(B)	1.1	$261\frac{1}{2}$	Main axis
	"				178	0+(B)	−64.5	172	2nd axis
Shenhur	Augustus	Roman	25.86	32.78	$189\frac{1}{2}$	0+(B)	−63.1	$135\frac{1}{2}$	
Medamud	Montu	Ptolemaic	25.75	32.70	283	$2\frac{1}{2}$	12.7	105	To Djebel Thoth
Karnak	Amon (Main)	12th−19th	25.72	32.66	$296\frac{3}{4}$	$3\frac{1}{2}$	25.4	$88\frac{3}{4}$	Amon precinct
	Sun High Place	18th			$116\frac{3}{4}$	0	−24.2	269	"
	Hatshepsut	18th			$116\frac{3}{4}$	0	−24.2	269	"
	Re-Horakhty	19th			$116\frac{3}{4}$	0	−24.2	269	"
	Sethy II	19th			206	0+(b)	−54.5	182	"
	Ramesses III	20th			$26\frac{1}{2}$	0+(b)	53.3	$-1\frac{1}{2}$	"
	Khonsu	20th−21st			$208\frac{1}{2}$	0	−52.7	$180\frac{1}{2}$	"
	Opet	Ptolemaic			$298\frac{1}{2}$	$3\frac{1}{2}$	27.0	$89\frac{1}{2}$	"
	Amenhotep II	18th			$291\frac{1}{2}$	$3\frac{1}{2}$	20.8	$96\frac{1}{2}$	"
	Ptah	18th			$304\frac{1}{2}$	3	32.0	$83\frac{1}{2}$	"
	Osiris	30th			32	0+(b)	53.6	4	"
	Osirian Chapel	25th			$132\frac{1}{2}$	0+(b)	−37.8	$284\frac{1}{2}$	"
	Amasis Chapel	26th			142	$1\frac{1}{2}$	−44.5	294	"
	Montu	18th			27	0	53.0	−1	Montu precint
	Raet-tawy	18th			28	0	52.3	0	"
	Maat	18th			$205\frac{1}{2}$	4	−51.5	$182\frac{1}{2}$	"
	Nectanebus II	30th			$114\frac{1}{2}$	0	−22.2	$266\frac{1}{2}$	"
	Mut	18th	25.71	32.66	18	2(b)	60.4	−10	Mut precinct
	Khonsupakherd	18th−21st			289	$3\frac{1}{2}$	18.5	99	v
	Ramesses III	20th			$19\frac{1}{2}$	2(B)	59.5	$-8\frac{1}{2}$	"
	Kamutef	20th			$287\frac{1}{2}$	$3\frac{1}{2}$	17.2	$100\frac{1}{2}$	"
	Boat station	18th			$107\frac{1}{2}$	0	−16.0	$259\frac{1}{2}$	"
Luxor	Ipet Resyt	12th−18th	25.70	32.64	33	0+(b)	48.7	5	Sanctuary
	Amenhotep III	18th			34	0+(b)	47.9	6	Column hall
	Tutankhamon	18th			$35\frac{1}{2}$	$3\frac{1}{2}$(b)	49.4	$7\frac{1}{2}$	Columnade
	Hatshepsut	18th			220	0+(b)	−44.0	168	Boat chapel
	Ramesses II	19th			$42\frac{1}{2}$	0	41.3		Court main axis
	"				311	4	38.2	77	West Proc. way
	"				$39\frac{1}{2}$	0	43.7	$11\frac{1}{2}$	⊥ Pylon

TABLE 1 (*cont'd*).

Place	Temple	Dynasty	Φ (°)	λ (°)	a (°)	h (°)	δ (°)	Δ (°)	Comments
Luxor	Serapis	Ptolemaic			135	0	−39.9	287	
Thoth Hill	?	Archaic	25.76	32.62	119½	−½	−26.9	91½	"Ancient" axis
	Horus	11th			117	−½	−24.7	89	Main axis
Deir Bahari	Mentuhotep II	11th	25.73	32.60	118¼	0	−25.5	90¼	
	Hatshepsut	18th			115½	0	−23.1	87½	
	Sun altar	18th			115½	b	−16.6		12°–13° (at base)
	Hathor chapel	18th			116	0	−23.5	88	
	Thutmosis III	18th			118½	0	−25.7	90½	
El Assasif	Mentuemhat	25th	25.73	32.60	92½	3½	−0.8	64½	Axis Sun hall
	"				21	25	71.1		Gate
Qurna	Sethy I	19th	25.73	32.63	124	0B	−30.5	96	
	Roman temple	Roman			35½	0B	46.8	7½	Sethy I enclosure
	Thutmosis III	18th			127	0	−33.1	99	
	Amenhotep II	18th			135	0	−39.9	107	
	Ramesses II	19th			131½	0	−36.9	103½	Ramesseum
	"				133½		−38.7		⊥ Pylon
	Thutmosis IV	18th			133	0	−38.2	105	
	Siptah-Tawosre	19th			132½	0	−37.8	104½	
	Merenptah	19th	25.72	32.61	122½	0	−29.2	96½	
	Amenhotep III	18th			117	0	−24.4	90	Memnon colossi
	Amenhotep	18th			120	0	−27.0	92	
M. Habu	Ay-Horemheb	18th	25.72	32.60	132	0	−37.4	104	
	Thoth	Ptolemaic			134	0	−39.1	106	
	Amon	18th			143	0	−46.4	115	Small temple
	Ramesses III	20th			137½	0	−41.9	109½	–
	Amenardis I	25th			47½	4½b	39.8	19½	Funerary chapel
	Shapenupet	26th			47½	4½b	39.8	19½	Funerary chapel
Malqata	Amon	18th	25.72	32.60	135½	0	−40.3	107½	
D. Medina	Hathor	Ptolemaic	25.73	32.61	147	10	−42.0	119	
	Sethy I	19th			139	6½	−38.9	111	
	Amenhotep I	18th			115½	0	−23.1	87½	
	North temple	19th			111	0	−19.1	83	
	Amon	19th			323	22	56.1	295	
	Votive chapel	19th			120½	6½	−23.9	91½	
	Meretseger	18th			331½	17½	62.3		Rock sanctuary
Armant	Montu	18th	25.62	32.54	151½	0(B)	−52.8	74½	
	Mammisi	Ptolemaic			152	0(B)	−53.1		
Tod	Montu	12th	25.58	32.53	145½	2	−46.9	248½	Old court
	Montu	Ptolemaic			323	0(B)	45.7	66	Main axis
	Boat chapel	18th–19th			240	7+	−23.3	163	
Esna	Khnum	Ptolemaic	25.31	32.57	56	0+(B)	30.1	67	
El Qab	Nekhbet	29th	25.12	32.80	140	½	−43.9	190	Within city wall
	Thoth	18th			140½	½	−44.3	190½	"
	Mammisi	Ptolemaic			230½	0	−35.5	79½	"
	Roman	Roman			229	0	−36.7	81	"
	Thoth	18th	25.14	32.82	49½	3	37.4	80½	El Hamman
	Nekhbet	Ptolemaic			155	1½	−54.3	155	Speos
	Amenhotep III	18th	25.14	32.83	227	0	−38.4	83	
Edfu	Horus	19th	24.98	32.87	92	1½B	−1.3	75	Old pylon
	Horus	Ptolemaic			181¾	B	−65.5	164¾	
	Mammisi	Ptolemaic			102½	1½B	−10.8	85½	
Dj. Silsila	Horemheb	18th	24.67	32.93	92½	2	−1.6	86½	Speos
Kom Ombo	Sobek/Haroeris	Ptolemaic	24.45	32.93	223	0	−42.7	73	

TABLE 1 (*cont'd*).

Place	Temple	Dynasty	Φ (º)	λ (º)	a (º)	h (º)	δ (º)	Δ (º)	Comments
Kom Ombo	Hathor	Ptolemaic			223½	0	−41.6	72½	
	Mammisi	Ptolemaic			134	0	−39.5	156	Auletes Pylon
Elephantine	Khnum	18th	24.1	32.89	138½	2+(B)	−42.2	101½	
	Satet	18th			118¼	2+(B)	−24.8	81¼	Over 6th–11th–12th
	Satet	Ptolemaic			114½	2+(B)	−21.5	77½	
	Hekaib	11th–18th			318	0+(b)	42.4	111	
Aswan	Isis	Ptolemaic	24.1	32.89	261	2½(B)	−7.3	118	
	Khnum	Roman			281	2½(B)	10.9	116	
Lower Nubia									
Filae	Nectanebus	30th	24.02	32.88	11½	(b)	63.0	18½	Pavillion
	Arensnuphis	Ptolemaic			284	½+	12.8	68	
	Imhotep	Ptolemaic			186½	5½(b)	−59.9	165½	
	Isis	Ptolemaic			201½	6b	−53.5	151	Main temple
	Mammisi	30th			189	3	−61.8	168	
	Harendotes	Ptolemaic			122	16(b)	−20.7	130	
	Augustus	Roman			66	1+	22.1	74	
	Hadrian Gate	Roman			300	0+	26.9	52	
	Hathor	Ptolemaic			111½	2+	−18.8	119½	h~7º (−16.5º)
	Trajan Pavillion	Roman			272½	2(b)	3.0	79½	
	Idem Terrace				93½	2+	−2.5		h~7º (−0.4º)
	Tiberius Gate	Roman			119	2+	−25.5	127	h~7º (−23.0º)
Qertasi	Kiosk	Roman	23.65	32.87	12½	0+	62.9	2½	
Beit el Wali	Ramesses II	19th	23.58	32.86	42½	0+	42.2	64½	
Kalabsha	Mandulis	Roman	23.56	32.86	104½	0+	−13.5	116½	
	"				110½		−18.9		⊥ Pylon
	Dedun	Roman			100½		−9.9	112½	
G. Hussein	Ramesses II	19th	23.27	32.89	97½	0+	−7.1	65½	
Dakka	Thoth	Ptolemaic	23.18	32.75	20½	1+	59.9	−8½	
Maharraqa	Isis	Roman	23.05	32.68	111	0+	−19.5	82	
Es Sebua	Ramesses II	19th	22.76	32.55	147	1+	−50.3	69	
Amada	Amon	18th	22.72	32.24	228	½+	−38.1	85	
Abu Simbel	Ramesses II	19th	22.34	31.62	100½	¾+	−9.6	52½	Main temple
	Re-Horakhty	19th			116½	¾+	−24.2	68½	
	Thoth Chapel	19th			101	¾+	−10.1		Chapel axis
	"				117	¾+	−24.6	68½	Gate axis
	Nefertari	19th			142½	¾+	−47.0	94½	

measured, provided that the general plan of the building can be discerned. Although there are many temples standing to this day, there are many others of which only the base of some of the walls remains *in situ*, showing merely the ground plan or even only the foundations. Consequently, our main task was to measure all the temples, giving a similar weight to those marvellously preserved (e.g. the Horus temple at Edfu) and to those where only a few walls survive, such as the one shown in Figure 2. Consequently, we wish to stress clearly that we were not searching for extreme-precision alignments of the sort most previous works have been concerned with. Bearing this is mind, and considering the huge number of monuments to be studied, we obtained our measurements using a high precision compass and correcting for local magnetic declination, and a clinometer (and also with compass and clinometer in tandem). Each permits data with a theoretical $\frac{1}{4}°$ precision. However, owing to various considerations, an error close to $\frac{1}{2}°$ in both azimuth and angular height is probably nearer to reality.

As we have discussed elsewhere,[15] we can be confident that, for the latitudes of Egypt, a precision of $\frac{1}{2}°$ is perhaps the best we can expect in solar or very bright star observations near the horizon and, in the case of fainter stars, such as those of the constellations of the Thigh (*msẖtyw*) or *sꜣḥ*, or important asterisms, such as the famous Pleiades (*ẖꜣw*),[16] the errors in estimating the azimuth can be as high as several degrees. This is why Haack's theory of the orientation of the pyramids, published in the *Archaeoastronomy* supplement in 1984, was never seriously considered (and his discovery of the error versus time trend forgotten) and Isler's and Edwards's theories[17] concerning Egyptian astronomical alignments involved abandoning horizontal astronomy for a cast shadow system or a high level artificial horizon, respectively. Consequently, we consider our altazimuth data of good enough quality to pursue our main quest. If a particular temple were thought to deserve further study, involving the search for greater precision in the corresponding alignments, theodolite measurements could always be planned for the future.[18]

1. DISCUSSION

Table 1 presents the results of our 2004 campaign in Upper Egypt and Lower Nubia (called Uauat by the Egyptians). Additional data for some of the temples on the shore of Lake Nasser had been obtained in September 2002.[19] The data presented in this paper are very compact from both the geographical and historical points of view. On the one hand, the entire area is completely dominated by the flow of the river and the local topography can be easily established relative to the direction of the Nile. On the other hand, there were continuous political links between Abydos and Aswan from early dynastic times; in periods of internal division, on each occasion when the country was divided and a serious political formation was established in the south, the frontier of this state was normally located at, or somewhat to the north of, Abydos.[20] To this compact area, we can add Lower Nubia which was frequently connected both politically or economically to the rest of the country, but especially to Upper Egypt.[21]

Figure 3 presents the orientation diagram of the data contained in Table 1. This diagram shows the first, apparently discouraging, result of our work. As the figure illustrates, Egyptian temples were orientated towards every possible direction of the horizon. Thus, at a first glance, astronomical or even topographical (layout perpendicular to the Nile) orientations could not be easily justified. However, and fortunately, a closer inspection clearly shows that the sector of the horizon between due east and a little further south of southeast was somehow preferred to the rest of the horizon. This deserves further investigation.

In fact, the Nile flows mostly from south to north throughout the majority of Lower Nubia and Upper Egypt. However, there are places where the river changes course

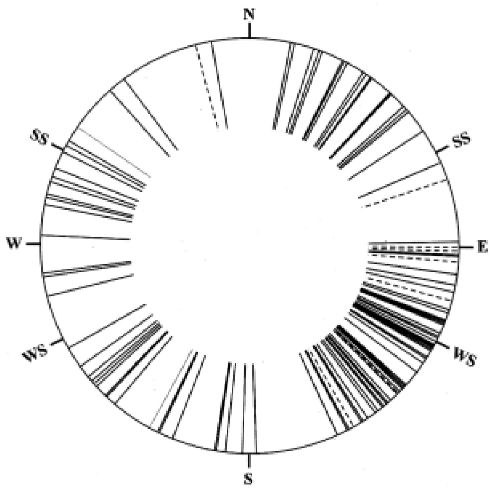


FIG. 3. Orientation diagram of the main axes of 115 ancient Egyptian temples of Upper Egypt and Lower Nubia. Although we find temples orientated in most directions, notice the concentration in the ESE octant of the horizon. Dashed lines stand for those temples between Kalabsha and Amada where we do not know how well the older axes were preserved in the new locations.

abruptly (as in the bend of Qena), even flowing east to west or west to east. Bearing this in mind, we have produced average values for the direction of flow of the river for all the places where we have carried out fieldwork, in order to further test the Nile hypothesis. The difference between the azimuth of the main axis of each temple and the average direction of flow has been estimated, presented in Table 1, and illustrated in Figure 4. In the plot, two different bandpasses are presented, a smaller 1° pass, associated with an instrumental error of just $\frac{1}{2}$° (continuous line), and a bigger one (2°) associated with larger uncertainties in the direction of flow (dotted line). In our opinion, this figure shows a remarkable implication of our data since it demonstrates, for the first time, that ancient Egyptian temples were orientated in such a way that the main gate of the building could open in a direction perpendicular to the Nile. This had been frequently argued in specialized circles but had never been proved statistically. Such a layout could have had twin objectives, the temple being orientated according to the Egyptian way of organizing the world,[22] and the sacred structure being approachable directly from the river or by a channel derived perpendicularly from its course. Figure 4 shows that this orientation to the Nile (90°) was six times more frequent than any other direction. However, the plot also illustrates the relative importance of the average directions parallel to the Nile (i.e. 0° and 180°) and those cases where the temple axis was perpendicular to the river but was facing outwards, in the direction of the desert (270°). Accordingly, our data show that ancient Egyptian temples in Upper Egypt and Lower Nubia were topographically orientated.

Where does this result leave astronomical orientations? Does it mean that the sky

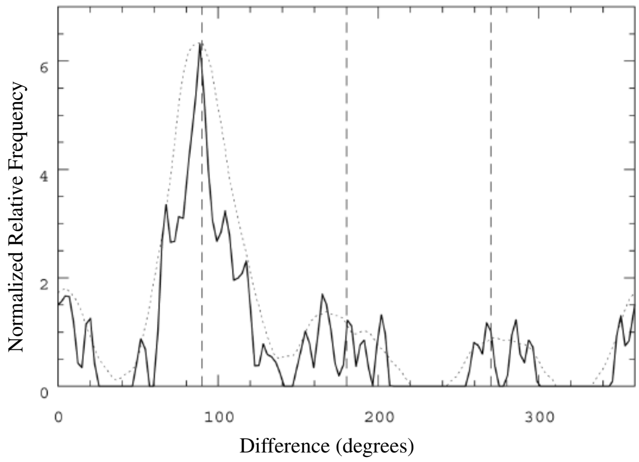


FIG. 4. Histogram representing the difference (Δ, see Table 1) of orientation between the main axes of the temples of Upper Egypt and Lower Nubia (Uauat), and the average course of the Nile at their corresponding location. The continuous line is for our instrumental estimated error of $\frac{1}{2}$°. The dotted line allows an interval of 2°, taking into account that it is difficult to establish the direction of flow of the Nile with a precision that is much better, along with presumed historical changes. Notice that temple orientation with the main gate located in front of (axis perpendicular to) the Nile is by far the most common way of orientating the buildings. Axes parallel to (at 0° or 180°) or perpendicular to the Nile, but facing the desert (at 270°) were also common. This clearly demonstrates that local topography (the course of the Nile) was most important at the moment of settling the foundations of the temples. See text for further discussion.

was not important? Is, then, the problem resolved? We do not think so. Egyptian civilization was highly elaborate and most aspects of its culture could have more than one reading or deserve more than one interpretation. We believe the same happened in this particular case. Figure 5 presents the declination histogram of our sample of temples. This has been calculated with a bandpass of $1\frac{1}{2}$°, corresponding to an average error of ~$\frac{3}{4}$° in the estimation of the declination. As in the previous case, the data have been normalized to the average. If Figure 3 demonstrated the importance of sacred topography, Figure 5 undoubtedly illustrates that astronomy too played a very important role in the orientation of Egyptian temples.

The histogram shows two statistically significant peaks. The highest is located at a declination of –24°. This was the declination of the sun at the winter solstice around 2900 B.C. and, considering our estimated error (i.e. ±$\frac{3}{4}$°), it is representative of any winter solstice solar phenomena throughout Egyptian history. As a matter of fact, the sun at its lower limits was an important point of reference (although not as much as Nile flow). In Section 2, we shall further discuss different aspects and implications of this singular result. Curiously enough, the other solstice, the summer one at +24°, is largely absent from our data.[23]

The second peak, at a declination of –39¼°, is much more difficult to interpret. At such a low declination, all solar, lunar or planetary alignments must be dismissed. Only stars are present in this declination range. As has been argued,[24] the Egyptians had a complete map of the firmament; they recognized important stars and asterisms and frequently organized them within constellations. Is there any important Egyptian star or asterism at such declinations during the time interval of Egyptian civilization? The answer is both Yes and No. On the one hand, the answer is Yes because the bright α and β Centauri, or the stars of the conspicuous Southern Cross asterism, had declinations within the appropriate interval. All of them have been identified as stars of the decanal belt.[25] However, on the other hand, the answer is No because we do not have any written evidence (such as that concerning the Thigh) that any of these stars was ever used to align temples or even that they played any important religious role in the otherwise extremely rich Egyptian stellar mythology.[26] But "the absence of evidence is not evidence of absence", and we should leave the door open to further textual studies and new archaeoastronomical data before drawing a final conclusion.

One important feature of our results, as presented in Figure 5, is that every single peak in the declination histogram is real, i.e. it represents real data and not noise. Consequently, we might feel obliged to find a reasonable explanation for every single peak above the average in the histogram. However, considering the many possibilities

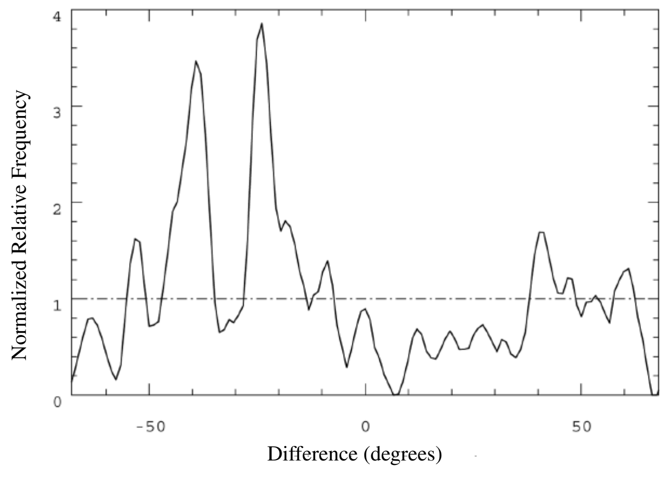


FIG. 5. Declination histogram of 108 temples in Upper Egypt and Lower Nubia (Uauat). This figure illustrates that the observation of heavenly bodies also played a role in temple orientation. Two significant peaks are found at declinations of –24° (the highest) and –39¼°. The former is easily explained by the declination of the sun at the winter solstice (around 24° at 2900 B.C.). However, we do not yet have a reason for the latter. The dot-dashed line stands at the average. See the text for further discussion.

as a result of the number of stars that can be observed and the long duration of Egyptian civilization (at least 3000 years), we do not feel this is a reasonable, or even a viable, exercise. Nevertheless, it is at least striking that the following three peaks at $-18\frac{1}{2}°$, $40\frac{1}{3}°$ and $-53\frac{1}{3}°$, correspond, within the errors ($\pm\frac{3}{4}°$), to the declination of the three brightest stars (apart from α Cen, already discussed) of ancient Egyptian skies: Sirius, Vega and Canopus, respectively.[27] There is no doubt concerning the importance of Sirius (Egyptian Sepdet, Sothis in Hellenistic Egypt) in ancient Egyptian religion and timekeeping.[28] Unfortunately, the relative cultural importance, or even the identifications, of Canopus and Vega is not yet established.[29]

Once more, we feel confident in asserting that sky-watching played a role in the orientation of Upper Egyptian temples. Our data show that there were some preferred astronomical phenomena, notably the winter solstice, and perhaps some stellar alignments. Indeed, this is not the first discussion of Egyptian archaeoastronomy that can be found in the literature. Solstitial alignments have been widely discussed[30] and Sothic ones have been proposed for several temples.[31] However, this is the first time that the argumentation does not reside in single, peculiar examples, but rather is based on a large, statistically significant number of temples. In any case, some of these particular cases are worth discussing in the light of the new evidence presented in this paper.

2. FOUR STUDY CASES

In the recent debate over astronomical alignments in ancient Egypt,[32] there are four particular cases involving temples of Upper Egypt and Lower Nubia that, from our point of view, deserve a wider discussion in the light of our results. Two of the temples show "solar" alignments, the Ipet Sut complex of the god Amon at Karnak and the jubilee temple of Ramesses II at Abu Simbel. The other two, the Horus temple on the summit of Djebel Thoth in Western Thebes and the Isis temple at Dendera, have been proposed as temples orientated to the (heliacal) rising of Sepdet. We will show how our results partially support some previous ideas but also contradict (or refute) others.

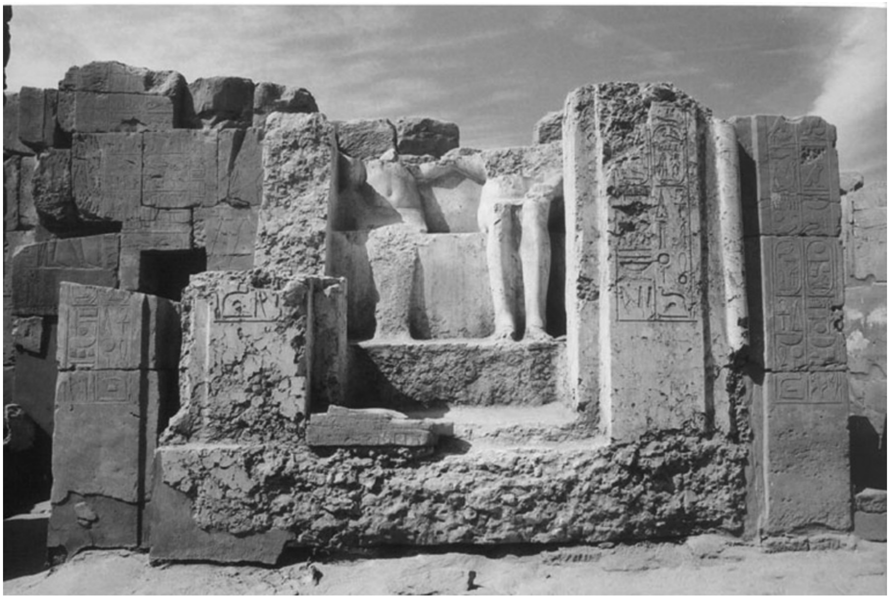
2.1. *Ipet Sut: The Amon complex at Karnak*

This magnificent religious complex ought to have formed part of a relevant chapter in any history of archaeoastronomy. Lockyer[33] argued that the main structure of the complex, the temple of Amon, would have been orientated towards sunset at the summer solstice, as the alignment of the main axis suggested. However, when he asked for this hypothesis to be checked on site, he learnt that the hills of Western Thebes precluded such an alignment, and that the light of the setting sun actually never reached the interior chambers of the temple, and never had done unless the temple was constructed 56 centuries before, i.e. around 3600 B.C. When Lockyer was writing, this date did sound problematic but nevertheless reasonable for the

FIG. 6. Two significant structures of the Amon complex at Karnak related to sunrise at the winter solstice. *Above* (a), the so-called "high room of the sun", accessible from the Festival Hall of Thutmosis III. From this holy place, it was possible to observe the rising of the sun at the winter solstice through a window (in the centre of the image) located in the appropriate direction. *Opposite* (b), an image of the innermost chapel of the temple of Amon-Re-who-hears-the-prayers, erected by Hatshepsut, and orientated originally towards the open horizon to the place where "her father" rises. It is highly probable that this huge temple complex was built at a place where this significant direction (the same direction as that of the main axis) was actually perpendicular to the Nile. This would be a splendid example of combined astronomy and topography. See the text for further discussion. Photographs by J. A. Belmonte.

working chronology. However, when the old chronology failed, at the beginning of the twentieth century, his hypothesis collapsed. As a consequence, the potential solstitial alignment of Ipet Sut was forgotten for three-quarters of a century.

In the early 1960s, Barguet argued that the inscriptions on the walls of the complex supported the idea that, although the main temple entrance opened to the west and to the river, the temple was somehow associated with the east and especially with sunrise.[34] These ideas were later exploited by Hawkins, who first reported on the winter solstice alignment of the 19th Dynasty temple of Re-Horakhty, but particularly called attention to the so-called "high-room" of the sun, presented in Figure 6(a). This had probably been built by Thutmosis III as an "observing" site connected to his "Hall of Festivals" (the Akh-menu), although the inscriptions on the walls, which honoured sunrise, date from the reign of Ramesses III. We shall not go into the details of the astronomical significance of this structure since it has been extensively discussed elsewhere.[35] We prefer to study other interesting possibilities,



one reinforcing the astronomical importance of the complex axis, the other relating this to local topography.

On the one hand, in the first half of the fifteenth century B.C. something extraordinary happened in Egypt. A woman, the royal wife Hatshepsut, proclaimed herself "King" of Egypt (*nsw-bity*). To do so, she had to proclaim that her father had been none other than the god Amon-Re himself, who had chosen her for royal status.[36] At this time, the great temple of Ipet Sut had been standing for at least half a millennium, since the time of the early Middle Kingdom, when, according to some specialists, it had been originally orientated towards sunrise at the winter solstice.[37] However, the Middle Kingdom temple, and later enlargements by Amenhotep I and the two first Thutmoses, had faced west, towards the hill of Thebes.

"King" Hatshepsut built a new temple to Amon-Re-who-hears-the-prayers exactly on the same axis but open to the east, this therefore being the first structure at Karnak actually to be orientated towards sunrise at the winter solstice (see Table 1). Apart from the mere cult requirements, why was this temple erected? The objective was probably both religious and political. A passage of the Petrie stela concerning two obelisks erected before one of the temples of the Karnak complex reports on the erection of these obelisks "one on each way between which my father rises", indicating that Amon is clearly identified with Re, and that we are dealing with some sort of solar alignment.[38] We suggest that the temple mentioned in the stela is that of Amon-Re-who-hears-the-prayers, in front of which it is known that a pair of gigantic rose granite obelisks were erected.[39] At the dawn of the winter solstice, a beautiful hierophany must have been produced. The morning sun would have risen between the two obelisks and illuminated the embraced statues of Amon-Re and Hatshepsut, as we show in Figure 6(b). Since this temple was in a court open to the public, we can only imagine the political revenues that such a divine manifestation of support would have accrued for Hatshepsut. Besides, while this was occurring on the east bank of the Nile, on the west bank the "temple of million years" of the Queen, the Djeser-djeseru, better known as Deir el Bahari, was also perpendicularly illuminated by the rays of the rising sun (see Table 1). It is important to notice that at this time sunrise at the winter solstice may have had important mythological and/or calendrical implications, the discussion of which is, however, beyond the scope of the present paper.[40]

On the death of Hatshepsut, the true legitimate sovereign, her nephew Thutmosis III, began his reign alone. Although it is not yet clear when the *dannatio memoriae* of Hatshepsut was performed, it is obvious that many monuments of the female "King" were either usurped by the new King or somehow lost prominence. This was the case with the temple of Amon-Re-who-hears-the-prayers. Thutmosis erected a new structure in front of it, thus preventing the illumination of the statue of the Queen by the sun's rays. The main focus of this new structure was a single huge obelisk, the highest ever to be erected in Egypt and which today adorns the square of St John Lateran in Rome. This granite monolith was located exactly on the main axis of Ipet Sut. We speculate that, at the same time, Thutmosis gained credit through this new work because, thanks to its height, the top of the obelisk could be seen from the opposite extreme of the complex, so that anybody located at the main entrance (e.g. on the quay) could have seen the rising sun of the winter solstice appearing behind it. Afterwards, during the reign of Ramesses II, the obelisk was surrounded by the structures of the new temple of Re-Horakhty, and the temple of Amon-Re-who-hear-the-prayers became sandwiched between two larger structures, the very situation in which we can see it today (without obelisks), which makes it difficult to imagine how it would have been when it was the first temple in the Ipet Sut complex facing the winter rising of "her father Amon".

On the other hand, Ipet Sut, and most of Thebes, is located at the only site in the Nile Valley, above the first cataract, where the river flows in such a way that the average perpendicular direction to the water course is the solstitial line connecting winter solstice sunrise and summer solstice sunset. We support the idea, previously stressed by other researchers,[41] that this natural accident might have been discovered by the Egyptians and helped to establish the sanctity of Thebes, the area of Karnak above all. Actually, as a working hypothesis, it might explain the importance of the winter solstice alignment family that we have established (see Figure 5). We would then be facing an extraordinary case of combination of topography and astronomy, a singular case of what has been called the archaeology of landscape, understanding by "landscape" not only the earthly one but also that of the sky.

2.2. *The Nest of Horus over Thebes*

Perched on the summit of the highest peak in the Hills of Thebes, the Djebel Thoth, there is a fascinating temple dedicated to the falcon god Horus by the 11th-dynasty king Mentuhotep III (*c*. 2000 B.C.). This is presented in Figure 7. Djebel Thoth must have been an important landmark in the sacred landscape of Luxor area: the Montu temple at Medamud, for example, was evidently facing it (see Table 1). Off the beaten track, the temple was not studied in detail until the 1990s when it was excavated by a Hungarian mission conducted by Győző Vörös.[42]

One of the most suggestive results of the excavations was the discovery that below the Middle Kingdom structure lay the foundations of an older temple that was attributed to the archaic (*c*. 3000 B.C.) period by the excavators and, most fascinatingly, that the axes of the two temples differed by ~$2\frac{1}{2}$° in azimuth (see Table 1).[43] The Hungarian team, in collaboration with astronomers from Konkoly Observatory, cleverly associated this change of axis with the possibility of stellar alignments and a change in a star's rising position due to precession between 3000 and 2000 B.C. Their calculations suggested that the target could be Sirius (more exactly, the star at the moment of its heliacal rising) and they related the star to Horus, the divinity to whom the temple was dedicated.[44] It is true that the summit of Djebel Thoth would

FIG. 7. The Middle Kingdom Horus temple at the summit of Djebel Thoth, the highest peak of the Theban Hills. It is built above the foundations of an archaic period temple with a slightly different orientation. Was it oriented towards Sirius and corrected for precessional changes, or simply another example of the winter solstice rising orientation family established in this paper? See the text for further discussion. Photograph by J. A. Belmonte.

have been a marvellous spot from which to observe the heliacal rising of the star, well above the haze of the river banks, and we would tend to agree with this idea since, nearby, in the scarps of Djebel Tjauti, a report of the observation of the heliacal rising of Sepdet (Sirius) was inscribed on the rocks during the 17th Dynasty.[45]

In an attempt to confirm all these hypotheses, we climbed the difficult path to the top of Djebel Thoth. The temple was restored by the Hungarian mission and most of the archaic structures have been covered again and were thus impossible to measure.[46] The preserved walls of the Middle Kingdom structure offered a plan that actually gave us several possible azimuths with an average value of 117°. If the temple had not been excavated, our suggestion would have been that we were simply confronting another case of the winter solstice family of orientations. Actually, there are a couple of aspects that do not accord with the Sirius hypothesis. On the one hand, Horus, the temple dedicatee, was mostly associated with the planet Venus in the Old and Middle Kingdoms (and Sirius is always related to the goddess Sepdet)[47] and, to our knowledge, the connection with Sirius is much more recent and associated with the merging of Horus with the god Sopdu; the mythological aspect is therefore unconvincing. On the other hand, our data would imply that on this hypothesis the heliacal rising of Sirius would have been observed at a angular height of nearly 9°, both in 3000 and 2000 B.C.; our experience, however, and that of others suggests that Sirius is easily visible at a height of 4° to 5° at the moment of its heliacal rising.

So, in our opinion, and in spite of our original wishes as astronomers, the precession hypothesis is far from being proven, and, taking Ockam's razor into account, we feel obliged to choose the possibility of the winter solstice alignment, perpendicular to the course of the Nile, as being the most persuasive explanation. This alignment would be almost parallel to that of the nearby temple of Mentuhotep II, father of Mentuhotep III, at Deir el Bahari (see Table 1).[48]

Bearing in mind this situation, we must also argue against the Sothic alignment claimed for the Satet temple at Elephantine,[49] erected by "King" Hatshepsut; this we believe was also aligned to the winter solstice rise of "her father Amon" (see Table 1), following the same political project that motivated the construction of her other temples in Thebes. It is in fact difficult to know the precise orientation of earlier Satet temples at the same location (particularly those of Mentuhotep II and Senuseret I, dated in the Middle Kingdom) or of the original archaic shrine enclosed by three large granite boulders, as shown in Figure 8. However, when the first sanctuary was erected (*c*. 3200 B.C.),[50] Sirius was rising in almost the same position as the winter solstice sun and thus it is possible and even probable that, for earlier epochs, a double alignment was in operation at this particular place on Elephantine.[51]

This left us with the open question of whether the Egyptians were aware of the phenomenon of precession. We hope to be able to answer this question definitively at the end of our project, in a few years from now, when much more information becomes available. However, we can mention two arguments supposedly related to the phenomenon. The first concerns the change of axis with time of the temple of Amon at Luxor (Ipet Resyt). The axes of the successive enlargements of the temple

FIG. 8. The archaic sacred precinct of Satet at Elephantine. This area was enclosed on three sides by three large boulders of granite and opened roughly towards the southeastern area of the horizon, where the sun rises at the winter solstice and where Sirius rose heliacally in 3200 B.C. The shrine is preserved in a cellar below the concrete terrace where the temple of Satet, erected by Hatshepsut, has been reconstructed. Photograph by J. A. Belmonte.

towards north suffered subsequent changes of orientation to higher azimuths (see Table 1). Lockyer[52] claimed that this was due to the different rising azimuths of Vega, and his hypothesis worked reasonably well for the chronology accepted in the late nineteenth century; but it is untenable today. We suggest on the contrary that at least some of the axis changes (e.g. that made by Ramesses II) were compelled by the presence of earlier monuments (such as the boat chapel of Hatshepsut), and that precession has little if anything to do with this particular problem. The second argument deserves a section in itself.

2.3. *The temples of Hathor and Isis in Dendera*

In the early 1990s, the team led by the French scholar Sylvie Cauville made a detailed study of the temple complex of the goddess Hathor at Dendera. From textual evidence, Cauville proposed that the axes of the main temple, the one devoted to Hathor, was laid down on 16 July 54 B.C., during the reign of Ptolemy Auletes, the father of Cleopatra VII.[53] However, for the temple of Isis, located at the back of the main temple, the situation was different. This temple shows no fewer than three main axes: an older one, formed by earlier foundations from the reign of Nectanebus (30th Dynasty) and later constructions of Ptolemy VI and Ptolemy X; a processional axis leading to a monumental gate at the temenos wall of the complex; and the axis of a high room devoted to the birth of Isis and erected at the time of Augustus. The first two (see

Table 1) differed by 4° from one another, whilst the third represented a turn of 90° to make the axis of the high room parallel to the axis of the temple of Hathor.

According to Cauville and her colleagues,[54] the change of axis can be interpreted as a change in orientation towards the rising of Sirius caused by precession. According to their interpretation, the older one (at 111°11′ according to their precise measurements), that of Nectanebus's original building, retains the original orientation of a previous building (of which some fragments are preserved) erected in the same location during the reign of Ramesses II (*c.* 1270 B.C.). The new one, at ~108°, was that of the rising of Sirius in 54 B.C., when the axis of the new complex was established. This implies that the axis of the complex was not determined according to the orientation of the main axis of the Hathor temple, as one might have expected, but rather to the perpendicular direction, the one of the processional way to the temple of Isis. From the mythological and social point of view this solution looks reasonable, provided that Isis had been largely identified with Sepdet, and thus with Sirius, since early times.[55]

However, as Figure 9 demonstrates, the inscriptions in the Hathor temple are perfectly clear and, according to them, the astronomical target observed for the laying down of its main axis, and thus presumably the plan of the whole complex including

FIG. 9. Hieroglyphic text accompanying one of the scenes of the stretching of the cord ceremony at the outer walls of the temple of Hathor at Dendera. According to the text, the temple should be orientated towards the *ꜣḫ msḫt(yw)*, in the constellations of the Plough. However, there are indications that Sirius may also have played a role in the laying down of parts of the temple complex. See text for further discussion. Photograph by J. A. Belmonte.

the Isis processional way and the birth of Isis high room, was the constellation of the Bull's Foreleg, Meskhet(yu), today the Plough. In the text accompanying one of the stretching of the cord ceremony scenes, we can read:[56] "The king stretches the rope in joy. With his glance toward the *ꜣḫ* of *msḫt*, he establishes the temple of the Lady of Dendera, as took place there before."

Here the text cites the *ꜣḫ* of the Plough. The term *ꜣḫ*, plural *ʿkhu* [*ꜣḫw*], we find mentioned ever since the Pyramid Texts, and it has been translated as "spirit", "brilliant" or "blessed". Hence, we might translate it as "the brilliant (star) of the Plough". However, bearing in mind that the seven stars of the Plough are of almost equal brightness (only Megrez, δ UMa, is slightly fainter), Krupp had suggested that *ꜣḫ* "most likely refers to a particular position and orientation of the Plough in its circular course around the Pole".[57] However, our current hypothesis is a different version of the same idea. In 54 B.C., at an azimuth of 18°, Alkaid (η UMa), the conspicuous star at the end of the handle of the Plough, was first visible when rising at an angular height of ~2°.[58] This star was perhaps already pinpointed between its constellation counterparts in the ceiling of the tomb of Senenmut.[59]

Consequently, we must agree with the Egyptians that the temple of Dendera was orientated towards a conspicuous star of Meskhetiu and not towards Sepdet.[60] Could we be facing another fortuitous circumstance, as in the case of Karnak, the site having been selected because of the possibility of a double alignment, astronomical in this case? That might be the case, but it would work only for the period around 54 B.C. when the new building plan was laid down, and not for earlier epochs. Unless new textual evidence comes from the Dendera inscriptions, confirming the chances of a Sirius alignment, once more we cannot be completely sure that the Egyptians were aware of the precession phenomenon, and that they erected new buildings accordingly in order to cope with the more than probable concomitant ritual problem that this would have posed.

2.4. *Abu Simbel and the calendar*

We cannot conclude a paper on the archaeoastronomy of the temples of Upper Egypt and Lower Nubia without mentioning the world-famous phenomenon of the illumination of the innermost sanctuary of the main temple of Ramesses II at Abu Simbel. At dawn on 22 February 2004 we were among the few privileged to observe the complete phenomenon from the interior of the sanctuary while numerous Japanese tourists passed behind us, completely astonished,[61] as were we, by the spectacular hierophany that was being enacted before our eyes, as shown in Figure 10.[62]

Much has been written about the phenomenon, and we have little to add to the recent papers published by the first author.[63] We do agree that it is likely to be associated somehow with the calendar and with its social, political and religious consequences. The presence within the temple complex of a chapel devoted to Thoth, the god of wisdom and "inventor" of the calendar, supports this view. The time of Ramesses II was very important for the history of the calendar of ancient Egypt because during

FIG. 10. At dawn on 22 February 2004, the light of the rising sun enters the *sancta sanctorum* of the main temple of Abu Simbel. The rays illuminate the figures of Amon-Re, the divinized king and Re-Horakhty, all of them gods of solar character, while the figure of Ptah, god of the netherworld, stays in darkness. This marvellous hierophany may have occurred at the beginning of the *prt* and *šmw* seasons of the ancient Egyptian calendar, during the first decades of the reign of Ramesses II, the temple builder. See text for further discussion. Photograph by J. A. Belmonte.

most of his reign the seasons were in rough agreement with nature.[64] This concordance between calendar and nature was especially dramatic for Abu Simbel. At the latitude of the temple, the helical rising of Sepdet took place in I *3ḫt* 1, the feast of *wp rnpt*, the Opening of the (Civil) Year, in the quatriennium around 1270 B.C., around the tenth regnal year of Ramesses II.[65] This happened for the first time after the beginning of the Age of the Pyramids, 1460 years earlier, when perhaps the heliacal rising of Sepdet had not yet been observed.[66]

Furthermore, in Ramesses's time the illumination phenomena happened twice, in I *prt* 1 and I *šmw* 1, the beginning of the other two seasons of the Egyptian year, throughout an interval of nearly 48 years centred on 1269 B.C. for the late October illumination (I *prt* 1) and on 1253 B.C. for that of late February (I *šmw* 1), i.e. during most of the reign of the king (1279–1216 B.C.). To complete the calendrical aspect of the temple, we must refer to the sun chapel located just to the north of the colossi. According to earlier studies,[67] this was orientated towards the sunrise at the winter solstice, and our data confirm that suspicion within the errors. We again are confronted with a shrine contributing to the well-established winter solstice family. However, a calendrical note can be added. In 1260 B.C., the winter solstice fell in III *prt* 1, the date of a very important festival dedicated to Amon-Re.[68] Because of the slow movement of the position of sunrise at the solstice, which is virtually unchanged for nearly an Egyptian decade (of ten days), the solstitial alignment could have been observed at III *prt* 1 over a period of some 40 years, again during most of the reign of Ramesses II. This might have had a series of religious and/or political implications that, associated with the spectacular hierophany inside the sanctuary, we can hardly imagine today.

3. CONCLUSIONS

As a result of the archaeoastronomical field campaign by the Egyptian-Spanish Mission in February 2004 we were able to obtain data for more than a hundred temples of Upper Egypt and Lower Nubia. Analysis of our data has proven extremely fruitful.

We have been able to demonstrate statistically for the first time (see Figure 4) that the temples in the upper Egyptian Nile Valley were topographically orientated in such a way that most of the axes of the buildings were perpendicular to the course of the river, normally with their gates facing it and seldom in the opposite direction. Axes parallel to the river course were also common. This pattern of orientation presumably agreed with the Egyptian way of understanding the cosmos.

However, ancient Egyptian temples had also to be in harmony with the cosmos above (the sky), and so astronomical orientations were also frequent, as inscriptions from the Ptolemaic period confirm. Our data show that a family of orientations towards the winter solstice sun can be established. Several of the temples of this family are located in the area of ancient Thebes, where astronomy and topography combined to organize the universe, provided that those temples orientated to the winter solstice sunrise were, at the same time, perpendicular to the course of the Nile.

Some stellar orientations have been suggested by our data, notably towards one or various celestial bodies of the conspicuous group formed by α and β Centauri and the stars of the Southern Cross. However, we do not feel able fully to confirm these results until new data and/or different approaches to the problem[69] confirm or refute these hypotheses. New textual evidence supporting stellar alignments would be also highly welcomed.

In addition, our data (and personal impressions) suggest that some temples that had been previously supposed to have Sothic orientations could be reinterpreted as belonging to the winter solstice family. These are the temple of Horus at Djebel Thoth, erected by Mentuhotep III, and the temple of Satet at Elephantine, erected by Hatshepsut. This does not necessarily imply that earlier constructions in the same places could not hide Sothic orientations within their walls. The same could be argued for the temple of Hathor at Dendera, erected by the late Ptolemaic rulers, where, however, our data fully confirm the inscriptions found on the walls of the main building, supporting an orientation towards *ꜣḫ msḫt*, which we have interpreted as the star η UMa, Alkaid.

More campaigns in other parts of Egypt are planned for the near future. We hope that these will finally offer a clear picture of the way in which the ancient Egyptians located and orientated their sacred buildings in order to be in complete harmony with the order of the universe, the Maat.

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7. J. N. Lockyer, *The dawn of astronomy* (new edn, New York, 1993).
8. This opinion is today highly controversial.
9. G. S. Hawkins, "Astroarchaeology: The unwritten evidence", in *Archaeo-astronomy in pre-Columbian America*, edited by A. Aveni (Austin, 1975), 131–62. See also G. S. Hawkins, *Beyond Stonehenge* (New York, 1973).
10. See e.g. E. C. 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. See also E. C. Krupp, *In search of the ancient astronomers* (New York, 1977), 208–19; and *idem*, "Egyptian astronomy: Temples, traditions, tombs", in *Archaeoastronomy and the roots of science* (American Association for the Advancement of Science Symposium 71; Westview, 1984), 289–320. In Krupp's books, *Echoes of the ancient skies* (New York, 1983), *Beyond the blue horizon* (Oxford, 1991), and *Skywatchers, shamans and kings: Astronomy and the archaeology of power* (New York, 1997), various points of the relation between archaeoastronomy and ancient Egyptian culture are emphasized.
11. There was not even a single reference to astronomical alignments in ancient Egypt in the otherwise magnificent: O. Neugebauer and R. A. Parker, *Ancient Egyptian astronomical texts* (3 vols, Providence, 1960–69).
12. M. Clagett, *Ancient Egyptian science*, ii: *Calendars, clocks and astronomy* (Philadelphia, 1995).
13. These are S. C. Haack, "The astronomical orientation of the Egyptian pyramids", *Archaeoastronomy*, no. 7 (1984), S119–25; and Belmonte, *op. cit.* (ref. 3). However, during the same period, *Archaeoastronomy* published dozens of papers on megalithic astronomy.
14. Other members of the team are the Egyptologists Dr Magdi Fakry, from Minufiya University, and Dr Zahi Hawass, Director of the Supreme Council of Antiquities of the Arab Republic of Egypt.
15. J. A. Belmonte, "Astronomy on the horizon and dating, a tool for ancient Egyptian chronology?", in *Handbook of Egyptian chronology*, ed. by R. Krauss (Berlin, 2005), in press.
16. For the identification of these constellations, see J. A. Belmonte, "The Ramesside star clocks and the ancient Egyptian constellations", in *Calendars, symbols and orientations: Legacies of astronomy in culture*, ed. by M. Blomberg, P. Blomberg and G. Henrikson (Stockholm, 2003); or J. A. Belmonte, "A map of the ancient Egyptian firmament", in *Ad astra per aspera et per ludum: European archeoastronomy and the orientation of monuments in the Mediterranean basin*, ed. by A.-A. Maravelia (BAR International Series, 1154; Oxford, 2003), 31–38.
17. M. Isler, "An ancient method of finding and extending direction", *Journal of the American Research Center in Egypt*, xxvi (1989), 191–206; and I. E. S. Edwards, *The pyramids of Egypt*, 3rd edn (Harmondsworth, 1993). For Haacks, see *op. cit.* (ref. 13).
18. Magnetic complications alterations are not expected in Egypt, where most of the terrain is limestone and sandstone. In any case, the temples were mostly measured along their main axis, from inside the sanctuary to the outermost gate and, on several occasions, in the opposite direction, to check for possible differences in the measurement. In a few cases, as at Djebel Thoth, the data were obtained from various walls and averaged. However, theodolite measurements will surely be needed in future campaigns for the study of the problem of pyramid orientation.
19. All the temples of Lower Nubia that we are presenting were removed to other sites during the Nubia Rescue Mission in the 1960s. In the case of some of them, such as the temples of Philae and Abu Simbel, it is widely accepted that the re-erections preserved the previous orientations to the nearest degree. This situation is not as evident for the temples between Kalabsha and Amada. Certainly, the corresponding horizons have been completely altered. However, in Table 1, we have made an effort to reconstruct the eastern horizon of Philae (~7°). These data are those plotted in Figure 5. The small temples of Debod and Dendour, now reconstructed in Madrid and New York respectively, were not taken into account.
20. This can be checked in any manual or atlas of ancient Egyptian history. See, for example, J. Baines and J. Málek, *Atlas of ancient Egypt* (Oxford, 1981).
21. This is certain for the New Kingdom and the Ptolemaic and Roman periods, when most of the temples

we have measured were erected.

22. For the Egyptians, the main orientation was dictated by the course of the Nile from Lower Egypt (north) to Upper Egypt (south), i.e. going south was going up. Consequently, east and west were identified as the left and right banks, respectively. Theoretically, every sacred structure had to follow this pattern. See M. A. Molinero Polo, "Templo y cosmos", in *Arte y sociedad del antiguo Egipto*, ed. by M. A. Molinero and D. Sola (Madrid, 2000), 69–94. For a very preliminary discussion on temple orientations, see A. Badawy, *A history of Egyptian architecture*, iii (Berkeley, 1968), Fig. 111.
23. Exactly the opposite to that recently pointed out by Wilkinson, *op. cit.* (ref. 1), 37. Rolf Krauss, private communication, emphasizes that the summer solstice was probably not as important a time-mark, and consequently a feature of the horizon, as the winter one.
24. In Belmonte, "A map" (ref. 16).
25. See J. A. Belmonte, "The decans and the ancient Egyptian skylore: An astronomer's approach", *Memorie della Societa Astronomica Italiana*, lxiii (2001), special vol. i, 43–57.
26. See, for example, R. Krauss, *Astronomische Konzepte und Jenseitsvorstellungen in den Pyramidentexten* (Ägyptologische Abhandlung, lix; Wiesbaben, 1997), and R. O. Faulkner, "The king and the star-religion in the pyramid texts", *Journal of Near Eastern studies*, xxv (1966), 153–61. For the Pyramid Text, see R. O. Faulkner, *The ancient Egyptian pyramid texts* (Oxford, 1969). Actually, in a very recent discussion with the authors, Krauss suggested, with some reservation, that the orientation of this particular group of temples might have started out with an astronomically oriented north–south axis line where two corners of the temple were established; i.e., this line would be one of the diagonals of the building. Then, a squared or rectangular plan would have been worked out which, in most cases, would have shown a main axis azimuth close to SE (135°). This is almost exactly the azimuth corresponding to a declination of $-39\frac{1}{4}°$ for the latitude of Thebes. We plan to test this interesting hypothesis in coming campaigns.
27. We had already advanced this possibility with worse data. See J. A. Belmonte, "Some open questions on the Egyptian calendar: An astronomer's view", *Trabajos de Egiptologia*, no. 2 (2003), 7–56, Fig. 7.
28. See R. Krauss, "Egyptian calendars and astronomy", in *Cambridge history of science*, i (Cambridge, in press); and U. Luft, *Die chronologische Fixierung des ägyptischen Mittleren Reiches nach dem Tempelarchiv von Illahun* (Vienna, 1992). For a still more recent approach, see Belmonte, *op. cit.* (ref. 27).
29. This is not the case for the constellations of *sꜣḥ* (part of Orion and Lepus) and *msḫtyw* (the Plough), for which numerous references can be encountered. Curiously, in Fig. 5, there are still two peaks above the average value level (dot-dashed line) at $8\frac{3}{4}°$ and 61°. These would correspond to the declination of ε Ori (Alnilam) *c.* 1150 B.C. and η UMa (Alkaid) *c.* 270 B.C., respectively, and might be representative of alignments with these important constellations.
30. See, for example, Lockyer, *op. cit.* (ref. 7), Hawkins, *op. cit.* (ref. 9, 1975) and Krupp, *op. cit.* (ref. 10, 1988).
31. See, for example, R. A. Wells. "Sothis and the Satet temple on Elephantine: A direct connection", *Studien zur Altägyptischen Kultur*, xii (1985), 255–302.
32. The debate is especially inflamed with respect to pyramid orientation. See K. Spence, "Ancient Egyptian chronology and the astronomical orientation of pyramids", *Nature*, cdviii (2000), 320–4; and Belmonte, *op. cit.* (ref. 3). See also C. Leitz, *Studien zur Ägyptischen Astronomie* (Agyptologische Abhandlungen, xlix; Wiesbaden, 1991).
33. Lockyer, *op. cit.* (ref. 7), 118.
34. P. Barguet, *Le temple d'Amon-Re à Karnak* (Cairo, 1962).
35. As for example in Hawkins, *op. cit.* (ref. 9, 1975) or Krupp, *op. cit.* (ref. 10, 1988). However, it is important to notice that, according to some reconstructions, the opening on the eastern wall of the "high room" would be a niche and not a window: see C. Traunecker, "Observations sur les cultes à ciel ouvert en Égipte ancienne: La sale solaire de l'Akmmenou à Karnak", in *L'space*

sacrificiel dans les civilizations Méditerranéens de l'Antiquité (Paris, 1991), 252–4. Indeed, our personal impression is that it was a window.

36. See the recent Ch. Desroches Noblecourt, *Hatshepsut, la reina misteriosa* (Barcelona, 2004).
37. See L. Gaebolde, "La date de fondation du temple de Sésotris Ier et l'orientation e l'axe", in *Le Grand Château d'Amon de Sésostris Ier à Karnak* (Paris, 1998). In Belmonte, *op. cit.* (ref. 15), the ideas stressed by Gaebolde are put in quarantine.
38. See A. Varille, *Karnak I* (Cairo, 1943), 15. The paragraph is mentioned by R. A. Parker, *The calendars of ancient Egypt* (Chicago, 1950), 77.
39. Noblecourt, *op. cit.* (ref. 36), 209–15.
40. A long discussion about this particular issue can be found in Belmonte, *op. cit.* (ref. 27), 34–38.
41. See, for example, Krupp, *op. cit.* (ref. 10, 1977), 225.
42. G. Vörös, "The ancient nest of Horus above Thebes: Hungarian excavations on Thoth Hill at the temple of King Sankhkare Montuhotep III (1995–1998)", in *Egyptology at the dawn of the twenty-first century*, i: *Archaeology*, ed. by Z. Hawass (Cairo, 2002), 547–56.
43. Vörös, *op. cit.* (ref. 42).
44. Vörös, *op. cit.* (ref. 42). Curiously, unlike the other examples, this very recent result has already been widely admitted by Egyptologists. See Wilkinson, *op. cit.* (ref. 1), 37.
45. As reported by J. C. Darnell and D. Darnell, "Gebel Tjauti rock inscription 11", in *Theban desert road survey in the Egyptian Western Desert*, i: *Gebel Tjauti and Wadi El-Hol rock inscriptions 1–45* (Chicago, 2002), 49–52.
46. As a consequence, our datum of the azimuth for the archaic temple relies on the measurements of the Hungarian mission.
47. This is widely demonstrated in Krauss, *op. cit.* (ref. 26, 1997).
48. This would leave us without an explanation for the orientation of the archaic temple. From the published plans it is quite difficult to judge how precise would be the orientation leading to a declination of ~–27°. However, considering the errors (i.e., at least $\pm\frac{3}{4}$°), this is close to the minimum value of the declination that Venus (i.e. Horus) could reach 5000 years ago.
49. Wells, *op. cit.* (ref. 31).
50. For the early archaeology of Elephantine, see K. A. Bard, *Encyclopedia of the archaeology of ancient Egypt* (London, 1998), 283.
51. Elephantine was probably very important in establishing the fundamentals of the Egyptian calendar. See for example R. Krauss, *Sothis und Monddaten: Studien zur astronomischen und tesnichen Chronologie Altägyptens* (Hildesheimer Ägyptologische Beiträge, Hildesheim, 1985). See also Belmonte, *op. cit.* (ref. 27), 25.
52. Lockyer, *op. cit.* (ref. 7), 328.
53. 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.
54. Cauville *et al.*, *op. cit.* (ref. 53).
55. As suggested in the Pyramid texts, see Faulkner, *op. cit.* (ref. 26, 1969). The assimilation is complete in the New Kingdom as can be read in the astronomical ceiling of the Ramesseum or of the tomb of Sethy I in the Valley of the Kings.
56. The translation of many temple inscriptions associated with the stretching of the cord ritual can be found in Zaba, *op. cit.* (ref. 3), and in M. Isler, "The Merkhet", *Visual arts*, vii (1991), 53–67.
57. Krupp, *op. cit.* (ref. 10, 1983), 211–13.
58. The magnitude of Alkaid is 1.9. This means that, according to some basic extinction parameters, it cannot be seen until it is at an angular height of the same order, around 2°. At this moment, a "particular" configuration of the Plough would happen since the complete constellation would be visible again above the horizon after having been partially hidden below.
59. In the astronomical ceiling of the tomb of Senenmut at Deir el Bahari, the constellation of Meskhetyu is represented in such a way that the last star of what might be the handle of the Plough is signalled

with a red symbol. This perhaps indicated that Alkaid played a differential role within the stars of this important circumpolar constellation.

60. This result clearly contradicts the arguments stressed earlier by Dorner, *op. cit.* (ref. 6).
61. We were impressed not only by the hierophany but also by the large numbers of tourists (several hundred) who concentrated at Abu Simbel to observe the phenomenon, another example of mass culture. More than 80% were Japanese whose attraction for the rising sun (their goddess Amaterasu, ancestor of the imperial family) is well known.
62. The phenomenon must have been slightly different when the temple was on its original location at the banks of the river, 60 metres below its present position. Then, the eastern horizon, instead of being almost flat as it is today, would have consisted of a ~2° high mountain range penetrated by different valleys. Apparently, the temple was orientated to one of these valleys and thus the illumination phenomenon would have not produced a square of light as today. Unfortunately, we could not find anybody at Abu Simbel who was able to remember how the phenomenon was before the saving of the temple.
63. M. Shaltout, "Sun perpendicularity on Abu Simbel great temple phenomenon", *Al Alem*, no. 213 (1994), 18–21; and, in collaboration with Dr Maravelia, A.-A. Maravelia and M. Shaltout, "Illumination of the sacrarium in the great temple of Abu Simbel, its astronomical explanation and some hints on the possible stellar orientation of the small temple", in Maravelia (ed.), *op. cit.* (ref. 16), 7–30.
64. Belmonte, *op. cit.* (ref. 27).
65. For the chronology of Ramesses II, R. Krauss, private communication, as reported in Belmonte, *op. cit.* (ref. 27), 49. See also, Krauss, *op. cit.* (ref. 28).
66. There are no references to *prt spdt* (the heliacal rising of Sirius) before the Middle Kingdom. Consequently, we have proposed that perhaps this celestial event was not widely taken into account in earlier epochs. See Belmonte, *op. cit.* (ref. 27).
67. Hawkins, *op. cit.* (ref. 8, 1975) and Krupp, *op. cit.* (ref. 10, 1988).
68. This was the moment when the god (Amon) "enters the sky". Belmonte, *op. cit.* (ref. 26), 37.
69. As the one suggested by Krauss (ref. 26).