The Stellar Horizon of Khufu

On Archaeoastronomy, Egyptology … and some Imaginary Scenaria*

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I. Introduction: Astronomy and Archaeology

During the previous century, several articles concerning the combination of Archaeology and Astronomy appeared. Since the time of Lockyer – father of *megalithic astronomy,* a famous solar astronomer, who presented some interesting ideas, as well as several misconceptions and naïve generalizations, both in the field of study of ancient Egyptian astronomy and of megalithic monuments[1] –, there were some efforts trying to associate the two scientific disciplines.[2] Dinsmoor presented an erroneous theory, concerning the dating of ancient Hellenic temples,[3] but Pritchet answered with an austere critic.[4] The case of Stonehenge has to be highlighted here. The efforts of Hawkins[5] towards an arbitrary theory (or science-fiction), using erroneous assumptions and biased interpretations of the archaeological records, were deservedly and strictly criticized in full scepticism, independently by Atkinson,[6] Hawkes,[7] and Ruggles,[8] who proved that the "monumentologists" – just like the "pyramidologists" – of all eras, project their own misconceptions (gathered through their proper education and psychology), as "genius theories", claiming to explain Antiquity.[9]

In any case, we have to admit that the norm and the right measure, so well evoked by ancient Hellenes and the Latins,[10] is the best basis for this discussion. Archaeoastronomy and its interaction with Archaeology and the Positive Sciences is best attained when both parties do not surpass their proper limits, as well as the common sense.[11] Ruggles, the first appointed Professor of Archaeoastronomy worldwide, has presented the correct interdisciplinary methods in order to work and produce results that have to be scientifically acceptable.[12] There are also scientific journals, where interesting articles on Archaeoastronomy are published, the contribution of which can be considered as very important towards this goal.[13] In the ideal case, Archaeology becomes an inspiration for Astronomy[14] and vice versa, while their convergence could lead towards a unique and fertile synergy. It is to be noted that both disciplines study and examine data and incidents of the past. For Archaeology this is evident. Though one could ask how this comes in Astronomy? Let us remember that the velocity of light is considerably high but not infinite; thus when an astronomical observation is performed, the phenomenon studied appears as it was in the past, when light started to travel from it to reach the earth; hence what we see is a past aspect of this phenomenon, before a period proportional to its distance from our planet. In this

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1 For the megalithic monuments, see Lockyer 1906, and Lockyer/Penrose 1902, 137–147. For the orientation of monuments in ancient Egypt, see Lockyer 1964. For the pyramids in general, see Fakhry 1961; Málek 1986; Edwards 1987; Hawass 1990; Lehner 1998.

2 Lockyer 1909.

3 Dinsmoor 1939, 95–173.

4 Pritchet 1947, 235–243.

5 Hawkins 1964, 1258–1261. See also Hawkins 1965.

6 Atkinson 1966, 212–216. Cf. also Atkinson 1975, 42–52.

7 Hawkes 1967, 91–98, wherefrom comes the proverbial phrase "every age has the Stonehenge it deserves or desires".

8 See for instance Ruggles 1999, 35–41. On Stonehenge, see also the epitomizing article Ruggles 2002, 5–11.

9 Aveni 1997, chap. 3 and notes.

10 Cf. the proverbial statements "Μέτρον ἄριστον" (from the Delphi Oracle), and "Aurea mediocritas" (Horatius: Carmina 2,10,5).

11 Henbest 2001, 81–85. Cf. also Hawkes 1967.

12 Ruggles 1999.

13 The most important is Archaeoastronomy 1–27 [Supplement to Journal for the History of Astronomy (= JHA)], published annually by Prof. Michael Hoskin at Cambridge. Regrettably the publication of AA stopped recently due to technical reasons, but the quarterly issue of JHA is now appearing enlarged with more pages. See also Aveni 1989 and Aveni 1997, 207–209.

14 Henbest 2001, 81–85.

way, the former can offer to the latter unique data and results, which would be impossible to obtain differently, pertaining to: (i) *rare incidents* (supernovae, comets, meteorites, solar and lunar eclipses, planetary conjunctions, and the resulting means for dating); and (ii) *slow incidents* (periodical celestial phenomena like the precession of the terrestrial axis, nutation, the reduction of the timespan of the day, etc.). The study of orientation of ancient monuments, which present an evident astronomical correlation, could be added, so far as the criteria and interdisciplinary methods of analysis are based on common sense and on the scientifically accepted rules, which of course are different than imaginary claims and arbitrary assumptions. Thus, the science of *Archaeoastronomy* (aka *Astroarchaeology*) constitutes a modern and developing interdisciplinary scholarly domain, whose goal is the study of possible astronomical influences on the studied archaeological sites and/or monuments, and vice versa.[15]

The feedback between Egyptology and Archaeoastronomy certainly has to be placed on the same grounds and principles. The present article is first of all a critic of the recent interesting theory presented by Dr Kate Spence,[16] concerning the possible method used by ancient Egyptian priests-astronomers, in order to determine the exact direction North-South, to orientate their pyramids during the OK. Some older relative opinions of Žába (et al.), concerning this thorny issue are also discussed. The important contribution of the former scholar, as well as some of his errors are presented and analyzed. Follows a critic of the PC-generated method of Spence, which examines the preconceived erroneous points of her fictitious scenario, comparing it to those of other scholars. The practicality and applicability of this theory, its criteria for selecting the data, its circular arguments and arbitrary opinions, are examined briefly but in scrutiny and questions as to its validity are asked.[17] We present twelve arguments, in the form of questions, in order to prove the inapplicability of this theory. At the same time, we propose for counter comparison an alternative pair of stars (η-Dra and β-UMa), which give a better chronology for the reign of Khufu (2558 BCE); our date is found in better agreement with the currently accepted chronology. We also review and discuss recent papers that examined or presented Spence's theory.

II. The Contribution of Žába (and Others): Correct and Erroneous Assumptions

The contribution of Žába towards the study of the orientation of pyramids, and his restless efforts to prove that ancient Egyptians were aware of the precession of equinoxes were remarkable.[18] It is to be noted that these opinions are not correct. His interpretation on pl. IV of the lance held by the falcon-headed *Dwn-ʿnwy* as the Meridian seems arbitrary, as well as his erroneous identification of this ancient asterism to *Cygnus* constellation. Žába was the scholar who not only presented critically the previous relevant theories, but in addition he has shown that the theory already proposed by Lexa[19] should be the most competent and plausible.[20] Thus, his work is very important, and it is a pity that Neugebauer and Parker did not comment on it in their famous study.[21] There are though some important errors in Žába's article, which we shall endeavor to present and discuss.

In a critical presentation of Žába's monograph, Peřina had proposed a method that has never been ap-

15 Ibid. We would like to thank Dr Nigel Henbest for sending his article prior to publication, as well as for some useful discussions.

16 Spence 2000, 320–324.

17 Prof. Gingerich, sceptical in the beginning, presented the theory of Dr Spence in the same issue of Nature: see Gingerich 2000, 297f. Mr Kurt Locher informed us that during the congress Under One Sky (25–27 June, 2001 in the British Museum, London) there was a critic against Spence's theory. During the same congress she presented her theory to the public. We are not aware of the content of the articles presented in London. Dr Belmonte offered an interesting and prudent approach on the orientation of the OK pyramids (see Belmonte 2001a). In his article, he discusses Spence's theory, using her principal idea (which, as we point out here, is not a new one), proposing original ideas, which have to be examined seriously; Dr Belmonte discusses only two weak points of Dr Spence's theory. Dr Belmonte, to whom we would like to address sincere thanks for having permitted this quotation from his article, notes in his n. 1: "Spence's work has proved highly controversial, with serious debates between scholars, and her proposals have been severely questioned. See for example H. Thurston: 'Aligning Giza: Astronomical Orientation of the Great Pyramid', Griffith Observer, September 2001, in press; Amanda-Alice Maravelia: 'L'horizon astral de Khéops: Archéoastronomie, Egyptologie … et quelques scénarios de science-fiction', Tôzai 5, 2000 [2002], 11ff.; and C. Lamberti: 'Mizar, Kochab e la piramide di Cheope', L'Astronomia 217, 2001, 32–38". We are discussing the articles by Thurston, Lamberti and others in our paper. Concerning the basic idea of the simultaneous transit theory, as it has been modelled by Dr Belmonte we are not against it in principle, but may we point out that no one can be sure that the Egyptians were using such a method before relevant archaeological finds are uncovered.

18 Žába 1953, 9–74 and pl. 1; 4. See also § II, infra.

19 Lexa 1950, 442–450.

20 Žába 1953, 70–72.

21 Neugebauer/Parker EAT I–III 1960–1969. Isler in his paper points out several errors of Žába different from the ones examined here (see Isler 1989, 192; 194ff.).

plied,[22] in order to examine the validity of some opinions of the former scholar. In this article we applied this method for the first time. It is to be noted that the identification of *Cygnus* to the ancient *Dwn-ʿnwy* arbitrarily accepted by Žába is not correct. Neugebauer and Parker showed that the celestial configuration of the northern sky in the monument of Senmout, as was perceived by the ancient Egyptians, presents a transposition of this ancient asterism, due to reasons of saving space.[23] In addition, Locher[24] has shown that *Dwn-ʿnwy* (aka *ʿnw*) is identical to the modern stars λ-Dra, 38-UMa, 24-UMa, ρ-UMa, ο-UMa, τ-UMa, 23-UMa, υ-UMa and φ-UMa. Hence, this was a misconception of Žába. Following this, we can argue that the considerations of this scholar concerning the precession of the terrestrial axis and its supposed knowledge by the Egyptians of Antiquity were false.[25] His interpretation is arbitrary, because the Egyptians were not preparing celestial maps or scientifically precise diagrams, but only symbolic and mythological representations, which contained rudiments of the truth, but not the whole truth. This issue has to be examined more rigorously in the future, as well as his opinions concerning "le petit cercle autour de l'étoile ζ-UMa", which seem rather exaggerated.[26] His opinions are absolutely arbitrary and his argumentation is not astronomically strict and can not persuade! The knowledge of such a notion – when no explicit texts are known until now – could not be based on absurd, symbolic and primitive images (like astronomical roofs in royal or non royal tombs, quasi astronomical mythological texts, and the like), but only on strict calculations and observations (like those of Hipparchos), that never existed in Egypt! The method proposed by Lockyer could possibly constitute a good solution towards this direction.[27] It would be interesting to examine rigorously the method proposed by the English astronomer, *in situ*, in several similar temples, in order to control its possible validity. If true, this should present us with a precise method of dating. If the Egyptians were in reality aware of the precession and if Lockyer was right, then we could use a simple equation in order to determine the date of neighboring temples annexed to the main construction, as well as prove this supposed knowledge in a rather satisfactory way.[28] Using this formula as starting point, we could apply it easily in order to determine the approximate construction date of the annexed building (if any), with an equation of the type $t(A_{new}) = f[\delta(A_{ancient})]$, where f is a simple trigonometric function of declination; the indexes *ancient* and *new* characterize respectively the azimuths of the earlier and later buildings.

Concerning the Meridian and the stars ζ-Cyg, ι-Cyg, κ-Cyg (and θ-Cyg which is very faint in order to be easily used), the opinions of Žába are not correct.[29] Žába seems having understood that the Meridian is a virtual maximum circle, vertical to the plane of the horizon at any geographical site, whose principal diameter is the direction North-South. We are not sure, though, if he had understood that the Meridian does not move, but remains immobile during the apparent diurnal rotation of the celestial sphere. Hence, two given stars which would constitute pairs in right ascension, could indicate the Meridian only for a single moment: i.e. at the exact time of their upper culmination, or during the former and their lower culmination (should they were circumpolar stars). In addition, it seems very exaggerated that the Egyptians could have ever invented such a sophisticated method in order to determine the Meridian, the meaning of which should have been most probably un-

22 Peřina 1956, 486–488. Lauer, with whom we basically agree, also discussed Žába's article (see Lauer 1960b, 99–124 and pl. 13). We consider his proposal that the stars ε-Cyg and γ-Cyg defined the Meridian (cf. p. 113 and the incomplete fig. 22) as not really significant, since at c. 2723 BCE they had a difference of $\Delta\alpha = 02^{M}20^{S}$ in right ascension. And again, at 2558 BCE this difference should be greater than $\Delta\alpha = 3^{M}$, while the displacement of α-Dra (the former Polaris) from the North Celestial Pole should be almost 1°.5. Hence, even if the use of this pair of stars as approximate pointers to the Pole cannot be excluded for a former era, it could not be used during the actual period of building the Great Pyramids. We think that neither Žába nor Lauer were correct in considering that *Dwn-ʿnwy* was identical to Cygnus.

23 Neugebauer/Parker EAT III 1969, 11; 186 (for comparison of this astral configuration to similar ones found in later Ramesside royal tombs) and 193.

24 Locher 1985, 152f. See also Locher 1991, 216f. and pl. 61–63.

25 Žába 1953, 51–55. At this instance, we have to point out that the book of Sellers (Sellers 1992, 4f.; 9f.; 30f.; 37; 44; 194; 224; passim) is not examining in astronomically acceptable depth the supposed knowledge of the Egyptians concerning the precession of equinoxes. She only presents superficial and arbitrary assumptions, using the myth as a reality, a common contemporary symptom of afrocentric and/or esoteric approaches.

26 Žába 1953, 71f. On this issue, see also the opinion of Isler (Isler 1989, 199), criticized by Wilkinson (Wilkinson 1991, 149–151). Prof. P. Dechain pointed out correctly in a summary of EAT: "Sans doute, tous ceux qui sont persuadés, à la suite de nombreux auteurs Grecs et Romains, que les Egyptiens étaient d'extraordinaires astronomes, seront-ils déçus […]. Example typique de conservatisme religieux, qui nous fournit une nouvelle preuve du *peu de goût des Egyptiens pour les théories*" (see CdE 39 [77/78], 1964, 78–80). Finally, C. Leitz (see Leitz 1993, 116) claims that this same line coincides with the Meridian, but does not discuss the correct argument presented in EAT, for which see n. 23, supra.

27 Lockyer 1964, chap. 7–20; 30, p. 307.

28 It is the equation $\cos A = \sin\delta \cdot \sec\varphi$; where A is the azimuth of the temple axis, δ is the declination of the star towards which the temple was oriented, and φ the geographical latitude of the site. Nowadays, the latitude (and longitude) could be measured by a highly accurate GPS, the theoretical basis of which is presented in Prendergast 2001, 179–181. For this equation, see Smart 1980, 46f.

29 Žába 1953, 44–52. See also nn. 26; 54.

Astronomical Epoch	18-VII-4200 BCE, 23:16': Gizeh (φ = 30°01'N, λ = 31°10'E)			18-VII-2723 BCE, 23:35': Gizeh (φ = 30°01'N, λ = 31°10'E)		
Star	ζ-Cyg = SAO 71070	ι-Cyg = SAO 31702	κ-Cyg = SAO 31537	ζ-Cyg = SAO 71070	ι-Cyg = SAO 31702	κ-Cyg = SAO 31537
Right Ascension, α	$16^{H}53^{M}45^{S}$	$16^{H}53^{M}31^{S}$	$16^{H}54^{M}21^{S}$	$17^{H}54^{M}50^{S}$	$17^{H}29^{M}37^{S}$	$17^{H}26^{M}57^{S}$
Declination, δ	21°27'52"	49°59'23"	52°34'14"	20°07'06"	48°13'55"	50°45'51"
Azimuth, A	180°02'21"	359°52'42"	00°13'28"	179°59'31"	346°56'20"	347°52'21"
Altitude, h	81°28'52"	69°59'37"	67°24'45"	80°08'06"	71°07'26"	68°34'30"
Rising Time, t_r	16:22'	14:18'	13:56'	16:44'	14:25'	14:03'
Setting Time, t_s	06:14'	08:18'	08:41'	06:29'	07:59'	08:15'
Transit Time, t_c	23:16'	23:16'	23:17'	23:35'	23:10'	23:07'
Visual Magnitude	+ 3.4	+ 3.9	+ 4.0	+ 3.4	+ 3.9	+ 4.0

Astronomical Epoch	18-VII-2723 BCE, 23:35': Gizeh (φ = 30°01'N, λ = 31°10'E)	
Star	γ-UMa = SAO 28179	δ-UMa = SAO 28315
Right Ascension, α	$05^{H}14^{M}37^{S}$	$05^{H}11^{M}00^{S}$
Declination, δ	70°27'20"	74°58'02"
Azimuth, A	03°24'25"	02°55'43"
Altitude, h	10°41'53"	15°11'37"
Rising Time, t_r	Circumpolar = Always above Horizon	Circumpolar = Always above Horizon
Setting Time, t_s	Circumpolar = Always above Horizon	Circumpolar = Always above Horizon
Transit Time, t_c	22:57' [lower transit]	22:53' [lower transit]
Visual Magnitude	+ 2.5	+ 3.4

Table 1: Some astronomical data, calculated for Gizeh on 18 July 2723 BCE at 23:35' (see also fig. 1), for the stars ζ-Cyg, ι-Cyg and κ-Cyg, derived by RedShift 2, 1995. It is evident that these stars were not pairs in right ascension during that epoch, as was erroneously proposed by Žába. The same data, calculated for the same geographical site and for the same stars, on 18 July 4200 BCE, at 23:16', show that they were pairs in right ascension. And again, the same data, calculated for Gizeh on 18 July 2723 BCE at 23:35', for the stars γ-UMa and δ-UMa, show that they were almost pairs in right ascension; though, their lower culminations were more than 10–15 min in advance relatively to the upper culminations of the Cygnus' *stars, during that astronomical epoch.*

known to them, at least under its modern scientific conception. Using special software called *REDSHIFT*, a calculating astronomical program[30] described in § III.3, we have found that the previous stars were pairs in right ascension during the astronomical era 4200 BCE (on 18 July, at 23:16'). This date is temporally very distant from the OK period (see table 1). Our results, for Gizeh on 18 July 2723 BCE at 23:35', are presented in figure 1. The stars ζ-Cyg, ι-Cyg and κ-Cyg were not pairs in right ascension during the epoch proposed by Žába (see table 1). In addition, we have calculated that the stars γ-UMa and δ-UMa were nearly pairs in right ascension, but their lower culminations were more than 15 min in advance, relatively to the upper culminations of the stars of *Cygnus*, during the epoch c. 2723 BCE, that was considered by Žába as the beginning of Dynasty IV (see table 1). Consequently, these stars were not laying on the same virtual line of projection on the celestial sphere as the stars ζ-Cyg and ι-Cyg, and could not be useful for the purpose of defining the Meridian. Finally, it seems difficult to understand what exactly Žába was meaning, when referring to "l'œil de *Dwn-ʿnwy*", and furthermore which was this specific star of *Cygnus* constellation (perhaps γ-Cyg? or α-Cyg?), having in mind that this ancient Egyptian asterism does not correspond to the modern constellation of *Cygnus*.[31]

Žába believed that the method proposed by Antoniadi[32] and independently by Lexa, who has also ameliorated it, would be the most appropriate and plausible in order to explain the almost exact orientation of the Great Pyramids.[33] His opinion seems interesting enough and could indeed explain the high precision. The method proposed by Lexa needs an observation on the terrace of a temple.[34] Černý proposed a plausible meaning for the word *sbʾy.w ḫr tp-ḫw.t ʿḥ,* which he translated as *astronomers-observators*,[35] and which might constitute a partial proof for Lexa's opinion. The method proposed by this scholar is applicable only for one star at a time, in order to determine its culmination. Moreover, the

30 RedShift 2/4, 1995–2000.

31 Cf. nn. 23–24, supra. For a short history of *Cygnus* constellation, see Allen 1963, 192–198.

32 Antoniadi 1934, 148–151 and fig. 50.

33 Žába 1953, 70–71, § VII. Cf. although n. 39, infra.

34 Lexa 1950, 442–444 and pl. 15 and figure. We have to point out that Lexa's opinion: "On pourrait utiliser cet apareil n'importe où et n'importe quand." (see p. 444), is not correct. When the sky is cloudy, for instance, it is not possible to use this method.

35 Černý 1963, 173.

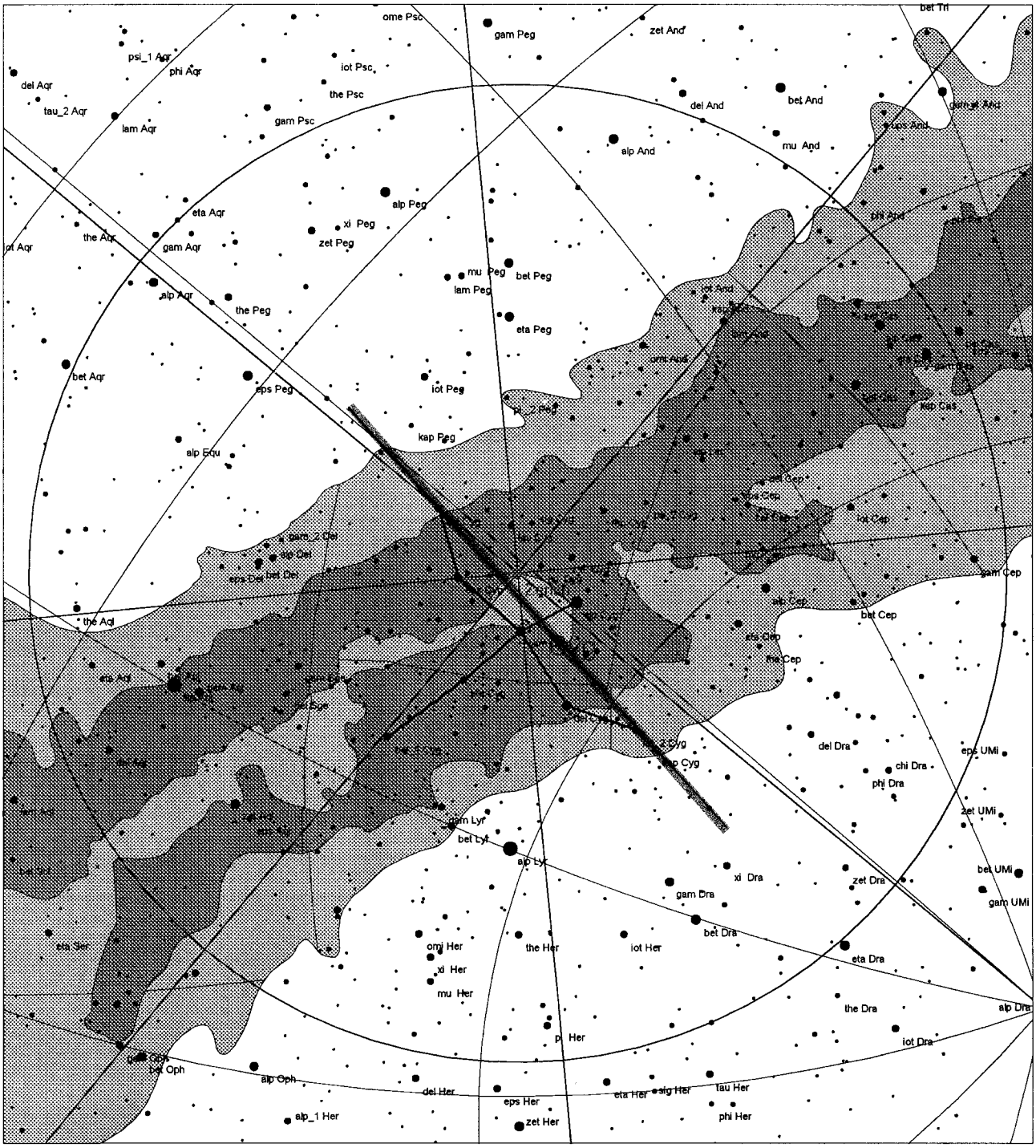


Figure 1: Mapping of the northern sky, around Cygnus *constellation, derived by RedShift 2/4, 1995–2000, calculated for Gizeh on 18 July 2723 BCE at 23:35' (JD = 727046.3993). We have superposed a network of celestial coordinates, as well as the Bayer names of the neighbouring stars down to an apparent visual magnitude of + 6^m.0, which comprises all the stars visible to the naked eye. The lines joining the main stars of this constellation are also superposed, in the way they are conceived today. The thick line uniting the stars ζ-Cyg, ι-Cyg and κ-Cyg is clearly not parallel to the local Meridian (thinner black line). In both this and the next figure 2, the grey-shaded area features the principal characteristics of the Milky Way as they were projected in the corresponding celestial area during that remote astronomical epoch. For the Galaxy and its possible relation to* Cygnus, *cf. Kozloff 1992, 332ff.; 337 fig. XI.8; 342 n. 35; and Kozloff 1994, 169–176; 175 fig. 4–5: though, both her interesting papers have some mistakes and their figures are not accurate).*

same method could be theoretically applicable for the polar star, if there was a bright one during a certain era. Let us note that α-Dra was the polar star at c. 2800 BCE, thus at least 250 years before the time of Khufu

(see § III.3). Therefore, the method proposed by Lexa, viz. *the observation of stellar transits (culminations) in order to determine the local Meridian*, seems more compatible with the archaeological record, and is not based on unreasonable opinions or arbitrary claims. Additionally, it could explain more observed facts with the least number of arbitrary assumptions. A question rising at this point is the following: how would it be possible to explain the increasing deviation from true North of the pyramids, as we move chronologically towards the end of Dynasty IV? In other words, why the precision of orientation was higher for the Great Pyramid of Khufu and less for the other pyramids of the Gizeh plateau, and even less for the subsequent pyramids of the next Dynasties? It seems to us that this could be easily explained on the basis of the errors that were done by the technicians and the priests-astronomers of the following reigns, errors that were either systematic or random (cf. § III.6, infra). But why there were fewer errors done during the reign of Khufu? As Stadelmann[36] pointed out, during the latter's reign the dominant doctrine of the "school" of architects-technicians was responsible of creating "surprising miracles", with a great detail and sophistication, in accordance to the apotheosis of divine monarchy, which was characteristic of that era. Thus, we believe that as time was passing and the financial decline together with the weakening of central authority started to manifest themselves slowly but steadily, this philosophy has been corrupted and drove to less sophisticated techniques and hence more orientation errors and less architectural glow. Lehner notes that the high exactitude of construction of the Great Pyramid[37] might allude to some symbolic and cultic significance which eludes us, or it might have been a response to the architectural disaster of the Bent Pyramid at Dahshur.[38] In any case, these seem more reasonable and plausible assumptions than the arbitrary claims launched by Spence.

It remains to be said that Spence's theory is not so original as it may seem at the very beginning. Basically it is more or less founded on some former methods described in Žába's monograph.[39] Before examining this issue in more detail, let us note that there are other interesting and plausible methods, which endeavored to explain the correct orientation of the Great Pyramids. Those were either stellar,[40] or solar.[41] The solar gnomonic method proposed by Isler, after minor corrections seems to be the best, according to our opinion, in order to explain the precise ancient method of aligning the pyramids to the cardinal directions. We think that this seems even more plausible, if we also take into account the holes that have been found surrounding the Great Pyramid situated at regular intervals.[42] These holes, forming lines that run parallel to the pyramidal sides, are believed to constitute secure standing bases where poles bearing a line thread were put, in order to be used as reference aid by the builders.[43] There are also some relevant articles, which appeared later. Cook has shown how the geometrical elaboration of the Great Pyramid corresponds to the angles of the ventilation shafts, calculated relatively to the position of certain constellations.[44] Bauval and Gilbert proposed a bizarre theory, concerning the position of the Gizeh pyramids,[45] which was criticized by Málek,[46] as well as certain claims for the position of the ventilation shafts.[47] Although this theory may appear extraordinary, we have to point out the absence of scientific proofs, the erroneous catoptric projection of the shape of Orion constellation on the ground, the fact that ancient Egyptians were not conceiving Orion[48] as we do today (hence the modernly conceived as "belt stars" were then related to the "crown" of the asterism of *S3ḥ*), and many more. It is another pseudoscholarly pyramidologic theory that does not use archaeological facts in order to present an acceptable synthesis, but is based on arbitrary claims that try to interpret these facts erroneously. Hellestam proposed two

36 Stadelmann 2000, 66.

37 The mean deviation of the four sides from the cardinal directions is 03'06", and the greatest difference in the length of each side is 4.4 cm. Let it be noted that of the total of 921.44 m of original pyramidial baseline, it is only 54.44 m that remains, much of it badly worn, while only 212.48 m of the foundation platform survive (see Cole 1925; Lauer 1960a, 7–15; and Lehner 1998, 109 and 212–215). It is on the basis of these remnants that the amazing accuracy of the original building is reconstructed by surveyors.

38 See Lehner 1998, 109.

39 See Žába 1953, 26–44. For the orientation problem cf. also Polák 1954, 620–625, and Neugebauer 1980, 1–3. See finally Dorner 1981, where it is shown that the observation of culminating stars can not yield the precise orientation of Dynasty IV pyramids.

40 Edwards 1987, 241–247 and fig. 56. For a critic of Edward's theory, see Isler 1989, 192ff.

41 Isler 1989, 191–206. Isler's theory – taking also into account the corrections by Wilkinson (Wilkinson 1991, 149–154), as well as the former's later paper on the use of *gnōmon* (Isler 1991, 155–185) – seems plausible and very well founded; it could well be the perfect solution to the problem of the orientation of pyramids. On the gnomonic method and its great value, see also Lehner 1998, 214.

42 On this topic, see Goyon 1969, 73, and also Maragioglio/Rinaldi 1965, 66.

43 See for instance Lehner 1985, 136–158, and Lehner 1998, 214.

44 Cook 1994, 29–36.

45 Bauval/Gilbert 1994. Cf. also Bauval 1994, 17–20.

46 Málek 1994, 101–114. Dr Ed Krupp presented also many logical conflicts of Bauval's and Gilbert's claims in his book (see Krupp 1995), as well as in his articles Pyramid Marketing Schemes, in: Sky and Telescope, February 1997, 64f.; and The Sphinx blinks, in: Sky and Telescope, March 2001, 86–88. Recently we had the opportunity of reading his articles.

47 Bauval 1995, 5–13. Cf. also Badawy 1964, 189–206.

48 Locher 1993, 279–284. For a short history of *Orion* constellation, see Allen 1963, 303–320.

"solar" theories, connected to the cult of the sun, in order to:[49] (i) explain the calculations related to the construction of pyramids, as well as their technical and architectural evolution from Djoser to Khufu; and (ii) he accepted that the position of the angles of the Great Pyramid would have been chosen in relation to the apparent solar orbit, in a way that the transitions between the three calendrical seasons *(ꜣḫ.t, pr.t, šmw)* would be marked. Legon[50] has calculated the positions of the constellations related to the ventilation shafts of the pyramid belonging to Khufu; he reexamined the theories on the elaboration of the corridors as related to the stellar system, and concluded that only geometrical factors can explain the observed architectural forms. Haack[51] presented an interesting theory, according to which the orientation of pyramids was based on the use of risings and settings of stars close to the celestial equator; he proposed a chronologically acceptable date, since he considers 2640 BCE as the beginning of Dynasty IV. Haack's theory seems plausible, but it is not at all sure if the Egyptians were aware of the celestial equator as an astronomical meaning, or of various coordinate systems, in order to be capable of tracing equatorial stars. This theory seems more plausible than that of Spence. Finally, an interdisciplinary article, combining fruitfully Physics and Archaeology in studying the pyramids' construction, is that by Kirkland Wier.[52]

III. Spence's Theory of Simultaneous Transit: A Plausible Hypothesis or a Fictitious Scenario?

Spence's theory does not seem correct. It is extremely sophisticated to be true. Furthermore, it contains a plethora of erroneous assumptions and significant errors, which are discussed in this section in the form of questions-arguments. In any case, this theory managed to retrigger the interest of several scholars towards interpreting the precise alignment of the Gizeh pyramids, and towards the study of a possible relation of the orientation to certain stars.

1. Are there any strict and egyptologically acceptable criteria on which Dr Spence bases her theory? The answer is no, not at all! Her theory is rather a well presented imaginary computer-made scenario, which tries to present biased assumptions, as a genius theory, which claims to interpret most of the archaeological facts. But it seems more like a theory, full of important errors and arbitrary assumptions. Furthermore there is no relative semi-religious or astronomical textual and/or epigraphical grounds that could justify Spence's claims,[53] or at least no such source has been found until now, stating explicitly that the supposed observation of two specific stars belonging to *Ursa Major* and *Ursa Minor* was performed in order to align any monument.

2. First of all, why Spence chooses these two specific stars (viz. ζ-UMa and β-UMi) and on what grounds? On what scientific arguments is she based to justify her choice? It seems that she does this absolutely arbitrarily, in order to build her theory. Ancient Egyptians of course were not naïve, but rather cautious – although not systematic – empirical observers, although they have never produced science as the Hellenes. Their adopted methods were used in order to obtain practical results, which would be applicable to their everyday life (calendar, measuring time and land, orientation of monuments), but never did they work out science *per se*.[54] Additionally, they were not using modern computers, in order to be able to "play" and construct PC-generated models or theories, based on highly advanced mathematical software. It is very easy for us that live during the modern era to prepare a theoretically infinite number of plausible models and mappings of the ancient skies, but this does not necessarily mean that all these models were used by ancient persons or were applicable to Antiquity. In other words, the model proposed by Spence could not have been conceived by ancient Egyptians. Why? Simply, because she did not try to put herself in the position of ancient priests-astronomers, asking herself "how these ancient persons would have been thinking, in order to orientate their monuments?", but tried to create fictitious assumptions, using modern computer software. After all, Egyptology does not work like Astrophysics, where one can simulate on the PC galactic mergers, models for stellar atmospheres or even spiral waves in distant galaxies. It is definitely something else in methodology, which of course can make use of correct and unbiased results from the Positive Sciences. Even the most experienced and well-trained ancient Egyptian observers, those who were fully aware of some

49 Hellestam 1994, 21–27.
50 Legon 1994, 29–34.
51 Haack 1984, 119–125. Though for arguments rejecting this theory, see Thurston 2001.
52 Kirkland Wier 1996, 150–163.
53 See Spence 2000, 320–324. Cf. also Gingerich 2000, 298. See also Spence 2001, 700, where the author optimistically refers to the later period temple foundation ceremonies, considering them erroneously as indicative of her ideas, and cf. our n. 76.
54 Pannekoek 1961, 82–85. See also Neugebauer/Parker EAT I–III 1960–1969, where it was demonstrated that the ancient Egyptian decanal system was not precise, because it was not satisfying two fundamental conditions: (i) the choice of constellations close to the celestial equator; and (ii) the observation of their transits from the Meridian. For the ancient Egyptian decans, see also Belmonte 2001b. Finally, cf. Böker 1984.

Astronomical Epoch	19-VII-2558 BCE, 21:48': Gizeh (φ = 30°01'N, λ = 31°10'E)	
Star	η-Dra = SAO 17074	β-UMa = SAO 27876
Right Ascension, α	$16^{H}16^{M}00^{S}$	$04^{H}13^{M}18^{S}$
Declination, δ	73°25'43"	67°14'35"
Azimuth, A	00°04'11"	00°11'53"
Altitude, h	46°33'16"	07°13'37"
Rising Time, t_r	Circumpolar = Always above Horizon	Circumpolar = Always above Horizon
Setting Time, t_s	Circumpolar = Always above Horizon	Circumpolar = Always above Horizon
Transit Time, t_c	21:49' [upper transit]	21:48' [lower transit]
Visual Magnitude	+ 2.9	+ 2.4

Table 2: Some astronomical data, calculated for Gizeh on 19 July 2558 BCE at 21:48' (see also fig. 2), for the stars η-Dra and β-UMa, derived by RedShift 2, 1995. It is evident that there is a difference of 1 min between the simultaneous culminations of the two stars (corresponding to a difference of ΔA = 7'42" in azimuth, or $\Delta\alpha = 12^{H}02^{M}42^{S}$ in right ascension), which would produce a maximum error of 3'51" (West of North or East of North) to the orientation of the northern pyramidal side. Of course, this would be so, if we suppose that the Egyptians were capable of perceiving and using such a method, taking into account the time when the two stars would be separated from the local Meridian by the same angle ΔA/2, a possibility which does not seem reasonable. In any case, 2558 BCE is a date, which agrees better with the currently accepted chronologies for the reign of Khufu.

past accumulated records of celestial phenomena, were incapable of conceiving such a method in order to determine the Meridian at that remote epoch. It is already time for everyone to understand that Archaeology does not function as an arbitrary projection of our modern ideas to the distant past, a period were no one of us lived and hence no one knows exactly and completely![55]

3. In order to prove Spence's arbitrary and unjustified choice of these two stars (ζ-UMa and β-UMi), let us point out that in fact there were several "appropriate" stars that the Egyptians could have chosen. Studying the appearance of the ancient sky at the latitude of Gizeh from 2700 to 2400 BCE, we have determined – between others – the following pairs: χ-Dra and ε-UMa, θ-Dra and α-UMa, η-Dra and β-UMa, ε-UMa and γ-UMi, η-UMa and α-UMi, etc. It is to be noted that with the previous pairs, the precision for the determination of the culmination time would be a little bit less, but how can a reasonable scientist accept that the Egyptians of Antiquity could have ever devised such a method, with a considerable exactitude of which even Brahe and Kepler would have been jealous? And even if we suppose that Spence was partially right, why then the Egyptians were not using this same method earlier (during Djoser's reign) or later (during Dynasty V and onwards), choosing more convenient stars that always could be detected? In order to support our argument, we have produced a relative PC-generated model, using two other stars, namely η-Dra and β-UMa. Let it be explicitly stated that *we did not do this because we agree with Spence! On the contrary, we did this in order to highlight her most weak and arbitrary assumptions.* For this, we have used REDSHIFT 2/4, an extremely precise astronomical software for exact calculations, which follows the DE102 criteria, launched by JPL at NASA, and the VSOP87 analytical theory of planetary motion, developed by the *Bureau des Longitudes* in Paris. This special software takes into account not only the precession of equinoxes, but all the minor corrections due to various astronomical factors (nutation, lunar and planetary tidal forces exercised on the earth, etc.) with a remarkable precision.[56] Figure 2 (see also table 2) shows our results for the ancient date 19 July 2558 BCE at 21:48' in Gizeh, using the pair of stars η-Dra and β-UMa. It is evident that the precision of our model to determine the Meridian is quite satisfactory, although there is a small difference of 1 min of time between the simultaneous culminations (upper and lower, respectively) of the two stars (or an angle difference of ΔA = 7'42" in azimuth). This would produce an error of 3'51" (either West or East of North) to the orientation of the northern side of the pyramid, if we suppose that the Egyptians were capable of using such a method, taking into account the moment when both stars would have been projected simultaneously at an angular distance of ΔA/2 from the local Meridian. Of course this is only a hypothetical point that does not correspond to reality, but is used here in order to justify our argumentation. And of course, 2558 BCE is so far a much better date, in excellent accordance with the currently acceptable chronologies for the reign of Khufu.[57] On the same figure we have superposed the forms of the principal northern circumpolar constellations after Locher,[58] as they were perceived by ancient Egyptians (and

55 See nn. 7 and 46, supra.

56 We would like to acknowledge Dr Chris Lawton, of Maris Multimedia, for his useful information concerning RedShift 2/4 software and its excellent precision. See also n. 30, supra, and RedShift 2, 1995, 64. Let it be noted though that these long standing secular effects do not affect our calculated azimuths by more than 2 arcminutes.

57 von Beckerath 1997.

58 Locher 1985, 152f. See also Locher 1991, 216f. and pl. 61–63.

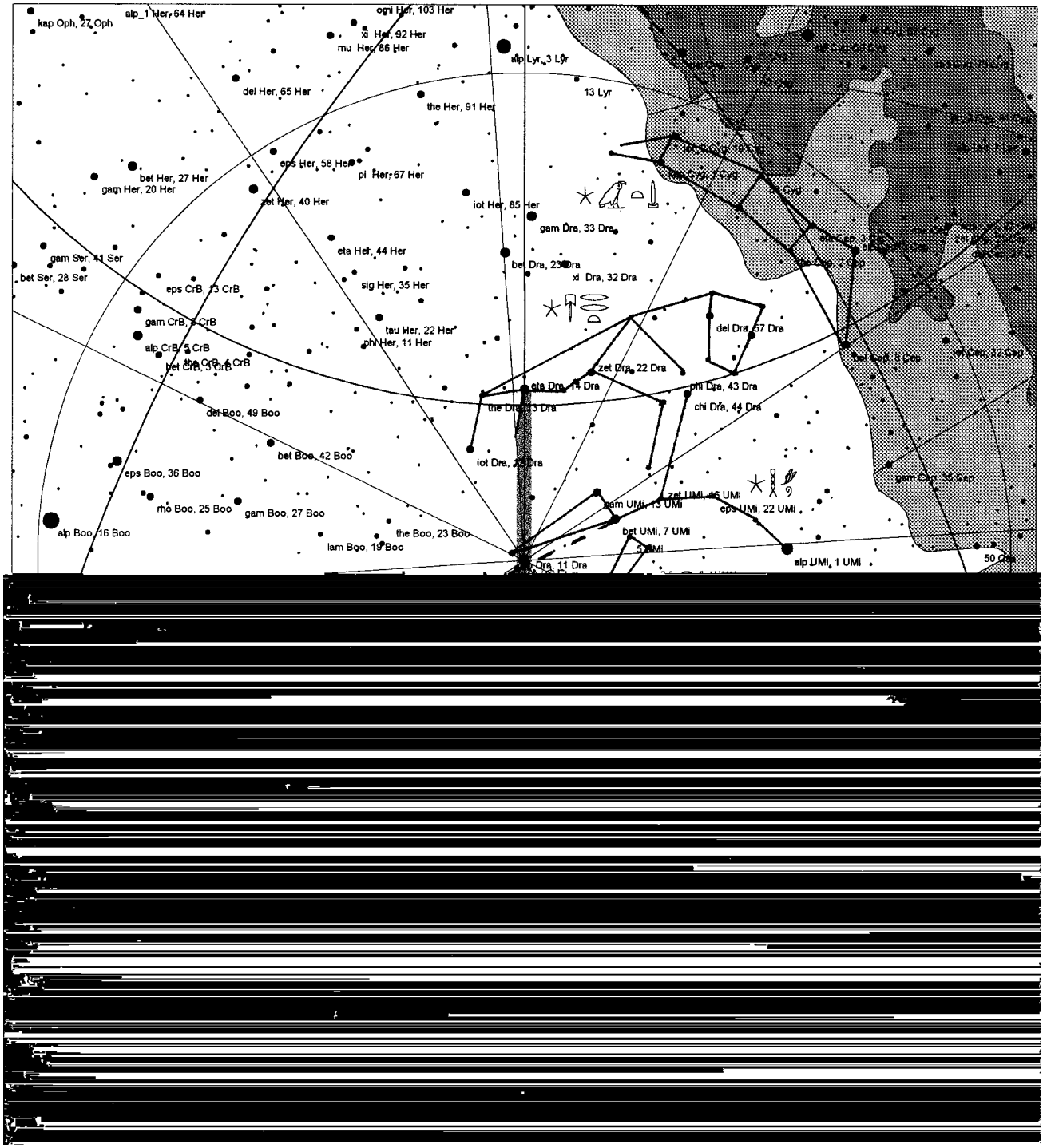


Figure 2: Mapping of the northern circumpolar sky, derived by RedShift 2/4, 1995–2000, calculated for Gizeh on 19 July 2558 BCE at 21:48' (JD = 787313.3250). We have superposed (after Locher) the forms of some principal circumpolar constellations of ancient Egypt. The Imperishable Stars *(Ỉ.ḫm.w-skỉ.w), viz all the stars comprised in a circle of 60° declination (not drawn here) can also be seen. We have also superposed a network of celestial coordinates, as well as the Bayer-Flamsteed names of the northern stars down to an apparent visual magnitude of + 6^m.0, which comprises all the stars visible to the naked eye. On the same figure, we show the imaginary line joining our stars (η-Dra and β-UMa: thick line), as well as that joining Spence's stars β-UMi and ζ-UMa: thin dashed line) for a gros comparison, because the astronomical epoch proposed by Spence is posterior to ours. It is evident that the ancient Egyptian archetypal way of "viewing" the sky was substantially different than the modern way.*

not as they are perceived today), in order to avoid misconceptions or further modern biased assumptions. Spence uses the modern configuration of the sky (see her figures 2 and 3) which biases indirectly the results,

because in the ancient Egyptian mind the forms and archetypal mythological kernel of *Ursa Major* and *Ursa Minor* were different from our modern conceptions of these circumpolar constellations. We have also superposed a grid of celestial coordinates, as well as the Bayer-Flamsteed names of the stars down to a visual magnitude + $6^m.0$, which includes all the stars that are visible to the naked eye. On the same figure we are showing the imaginary line joining our pair of stars and that joining Spence's stars, only for a gros comparison because the astronomical epoch we propose is about a century earlier than Spence's epoch. In this way, we can clearly see that the image of the sky according to ancient Egyptians was fundamentally different from its modern conception of nowadays. Furthermore, it is evident that the priests-astronomers of Antiquity were not conceiving *Ursa Minor* as today, but completely differently (cf. fig. 2). The only important celestial configuration for them partially corresponding *(mutatis mutandis)* to the modern *Ursa Minor* was the small asterism called *The Two Mooring Posts* or *Mnỉty* (β-UMi, γ-UMi, α-Dra, and 4-UMi, 5-UMi, κ-Dra), whose possible significance was discussed by Locher.[59] Completing his arguments, we point out some other ancient parallels from Hellenic mythology. We refer to some *Orphic Hymns,* according to which:[60] (i) the Mother of Gods *(Mater Deorum)* holds the cosmic scepter (= polar axis) of the world: "… | σκηπτοῦχε κλεινοῖο πόλου, πολυώνυμε σεμνή, | ἣ κατέχεις κόσμοιο μέσον θρόνον…"; (ii) the Earth is considered as the center of Cosmos, around which the stars are revolving unceasingly: "…| περὶ ἣν κόσμος πολυδαίδαλος ἄστρων | εἱλεῖται φύσει ἀενάῳ καὶ ῥεύμασι δεινοῖς.| …"; (iii) the all embracing sky is considered to revolve around the earth like a top in precessional motion, and where we could plausibly assume that the notion of the precession is indirectly expressed: "| … σφαιρηδὸν ἑλισσόμενος περὶ γαῖαν, | οἶκε θεῶν μακάρων, ῥόμβου δίναισιν ὁδεύων, | οὐράνιος χθόνιός τε φύλαξ πάντων περιβληθείς, | …"; and (iv) the stars are presented as revolving circularly around cosmic thrones: "| ἐγκυκλίοις δίναισι περιθρόνια κυκλέοντες|". One has to bear well in mind that in ancient Egypt it was *Rrt,* the hippopotamus astral goddess who was depicted holding the mooring posts.[61] The peak of both mooring posts (one of which is represented several times as a tiny crocodile) seems to indicate the north celestial "poles", "near" the stars α-Dra (c. 2800 BCE, angular separation < 7') and κ-Dra (c. 1300 BCE, angular separation < 5°). Let it be noted that the star α-Dra was apparently situated at a considerable distance from the North Celestial Pole during that astronomical epoch, about 1°.5, thus it would not be practical in reality to be used as the polar star. Hence, returning to our previous argumentation, let us point out that there is no good reason to prefer Spence's pair of stars (ζ-UMa and β-UMi), instead of our pair η-Dra and β-UMa, mainly because Spence's pair gives an extremely late date. One of the stars that we propose here (β-UMa) is found at a lower altitude (hence closer to horizon), during its lower culmination, than the corresponding star of Spence ($h_{\beta\text{-UMa}} \approx 7°$, $h_{\zeta\text{-UMa}} \approx 18°$). Nevertheless, this is not a grave issue, because according to Thom's empirical law, the altitude (in minutes of arc) of a star near the horizon, in order to be visible (due to various phenomena of atmospheric absorption), is equal to the magnitude of this very star.[62] Thus, in our case the star ($m = + 2^m.4$) will be visible at about 2°.5 over the horizon (if no distant objects that hide it are present). For a more precise calculation, one has to take into account the phenomenon of atmospheric refraction,[63] (which is maximum 0°.25 at an altitude h = 3°, and minimum 0° at the zenith). Again, the refraction factor can be considered as almost negligible in our case.

4. Let us now suppose that Spence was partially right. Then, the fact that one of the stars she proposes has an altitude of $h \approx 39°.5$ when it is found in upper culmination, implies a high precision, which could not be attained at that remote past. Simple calculations show that for a precision of one minute of arc (let us assume ≈ 1 cm on the ground), the ancient observers would need a rope (let us say a "plumb line") 28 m high, situated at a distance of about 34 m away![64] Let it be noted that the altitude of β-UMi according to Spence is $h_{\beta\text{-UMi}} \approx 39°.5$, thus its tangent is: $\tan 39°.5 \approx 0.82 \approx 28/34$. Or perhaps a rope 10 times less high for a precision of 1 mm on the ground?! And, even if this would be true – which is not

59 Ibid. See also Neugebauer/Parker EAT II 1964, 5.

60 For (i) see the Orphic Hymn to the Mother of Gods (27,4f.); for (ii) see the Orphic Hymn to Gaia (26,8f.); for (iii) see the Orphic Hymn to Ouranos (4,3–5); finally, for (iv) see the Orphic Hymn to the Stars (7,4). For the Orphic Hymns, see Qandt 1973.

61 Hart 1987, 211f.: s.v. Taweret. See also Locher 1991, 216f. and pl. 62f. It is to be noted that in the Books of Day and Night (see Piankoff 1942, 95), which should be more ancient, and hence more original than the mural astronomical representations, both of them are represented as mooring posts, not as crocodiles.

62 Thom 1969, 160–163.

63 Haack 1984, 124.

64 This simple calculation shows that Spence's assumptions are unrealistic, and is given as a proof for this. In any case it does not signify any true knowledge of pure Mathematical Astronomy by the Egyptians, who did not know even the theorem of Pythagoras (see Gillings 1982, 238 and 242)! In their astronomical and mathematical texts, there is no proof that they knew such methods or could profit by them! How, then, could they conceive of such a sophisticated method, as Spence would like to believe? Mathematical Astronomy was only a later product of Hellenic science and reason.

– then: (i) how those ancient observers could see anything at this distance in the darkness of the night, even if they were using torches or oil lamps? (ii) how they could extrapolate the length of 28 m (or 2.8 m, respectively) to the length of the true pyramidal base with such a high precision? This is absolutely impossible! Even if the ancient priests-astronomers were using Lexa's method,[65] it would be impossible to apply it *simultaneously* for two stars that were situated at the northern half of the local Meridian and separated by a difference of $\Delta h \approx 39°.5 - 18°.5 = 21°$ in altitude!

5. And then, why Dr Spence chooses only the alignment of the western side of the Khufu's pyramid? The eastern side shows also properly the direction North-South. She claims that she does this because the graphic plot shows that only the western side was exactly oriented.[66] But, this is a circular argument that forges the results and can not prove her claims. Furthermore, why she shows the points corresponding to the pyramids of Djoser, Wenis, Sesostris I and Amunemhat III on her fig. 1a, without using them to trace the line of least squares? On the contrary, she only uses points 1–8, in order to derive the best fit line. This is another twisting of the results, to make them fit her claims, that does not correspond to reality. Or may we suppose that she was not aware of what the least squares' line is and how it is used in Positive Sciences? In order to justify our arguments, we have analyzed and processed all the data (even those for the pyramids of Djoser, Wenis, Sesostris I and Amunemhat III), using only the chronology proposed by von Beckerath (see also § III.7–8, infra). For Snofru we used the consecutive dates 2575, 2573 and 2570 BCE. Special mathematical software, called *GRAPHER v1.79*^{C}, was used for this purpose, which is a very precise calculating program designed for use in Positive Sciences.[67] In this way, we obtained figure 3a. From this plot we see that the slope of the best fit's line is negative in reality, not positive as Spence presents it by using only 8 points. Furthermore, this line of least squares is not at all satisfactory, because it gives a very poor correlation, with a coefficient $r \approx -0.38$. The linear equation for our best fit is $\Delta\theta \approx -0.094t - 218$, where $\Delta\theta$ is the deviation of alignment (in minutes of arc), and t the corresponding date (in years BCE).

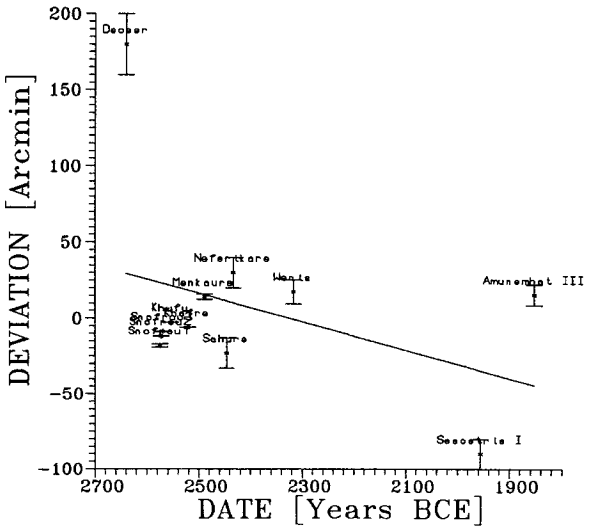
6. Why Dr Spence "reflects" the points, which are not adapted to her line that intersects the horizontal axis? Just to force them to her model (see her fig. 4 and cf. her fig. 1b). In this way, she presents a biased plot, absolutely fictitious, because it also contains the error in chronologies explained in §§ III.7–8, infra. In order to justify our arguments we have analyzed and processed all the data (points 1–8), accepting the chronology proposed by von Beckerath, using again *GRAPHER v1.79*^{C} as the calculating software. In this way, we obtained figure 3b. From this plot it is evident that the best linear fit is again not satisfactory, because the line of least squares gives a poor correlation with a coefficient $r \approx 0.49$. The linear equation for our best fit is $\Delta\theta \approx 0.15t + 372$, where $\Delta\theta$ is the deviation of alignment (in minutes of arc), and t the corresponding date (in years BCE). At this point let us ask another question: why accept Spence's claims as to the explication of the decrease of precision of alignment when we move from Khufu's era towards the end of the Dynasty and then into Dynasty V and not another reason? The observational errors (either systematic or random) made by the ancient priests-astronomers should be important and sometimes quite significant, as already stated in § II, supra. Let us note finally, that the decrease of precision in the orientation of the pyramidal sides for a single pyramid could be partially attributed to the errors done during measuring the arises, starting from the determined axis, as already proposed by Lexa.[68]

7. Why Dr Spence rejects von Beckerath's chronology,[69] when she treats the pyramids of Snofru (see her table 1)? It seems that she does so arbitrarily, just to find an alternative suitable chronology that would be compatible with her claims and arbitrary plots. We have to point out that the chronology for Snofru is very important for her arguments, as is also the "adaptation" or forced adjustment of the three points corresponding to Snofru's pyramids with those of Khufu's. In fact they are critical. Additionally, O'Mara[70] accepts that the builders of the pyramids were using Sirius (= α-CMa) as the principal guiding mark for dating their history, and proposes 2443 BCE as the date for the *ḥb-sd* jubilee of Pepi II, which is admittedly about 150 years earlier than the currently accepted chronology.[71] Who is right after all? Most probably only von Beckerath.

8. If Spence accepted the chronology for Snofru proposed by von Beckerath (ascension at c. 2575 BCE), instead of that proposed by Stadelmann[72] (ascension at c. 2600 BCE), her points on the plot would have been situated below the line that she accepts as the most correct. What does this mean? It means that it is absolutely impossible to make compatible *all* the points corresponding to the pyramids of Snofru, Khufu, Khefren, Men-

65 See Lexa 1950, 443 and figure.
66 See Spence 2000, 321.
67 Grapher v1.79^{c}, 1988.
68 Cf. Lexa 1950, 442f.
69 See n. 57, supra. Cf. also Baines/Málek 1988, 36f.
70 O'Mara 1995, 73–85; O'Mara 1996a, 65–82.
71 O'Mara 1996b, 97–112; O'Mara 1997, 63–82.
72 Stadelmann 1986, 229–240 and Stadelmann 1990. On the reign of Snofrou, cf. also Krauss 1996, 43–50, as well as Krauss 1985.

(a)



(b)

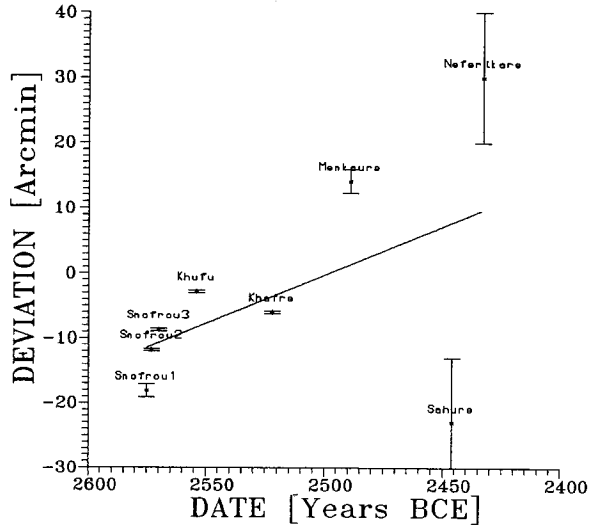


Figure 3: Deviation of alignment of various pyramids (either of their eastern or of their western side), derived by GRAPHER v1.79c, using the chronology proposed by von Beckerath. (a) Analysis of the data for all the pyramids (those of Djoser, Wenis, Sesostris I and Amunemhat III were also included) shows that the slope of the least squares' line is negative, not positive like Spence presents it by erroneously using only 8 points. The best linear fit is not satisfactory, because the correlation is very poor (coefficient $r \approx -0.38$). The linear equation for the line of least squares is $\Delta\theta \approx -0.094t - 218$. For comparison, cf. Spence's fig. 1a. (b) Analysis of the data for the pyramids 1–8 shows that the best linear fit is again not satisfactory, because the correlation is poor ($r \approx 0.49$). The equation for the line of least squares is $\Delta\theta \approx 0.15t + 372$. For comparison, cf. Spence's fig. 4. [$\Delta\theta$ is the deviation of alignment from true North (in minutes of arc), and t the corresponding date (in years BCE)].

kaura and Neferikara on one and the same line (see our fig. 3a). Hence, since we accept the most plausible chronology proposed by von Beckerath (which is the most orthodox methodologically), we shall see that the line Snofru-Khufu becomes more steep, in relation to the astronomical interpretation given by Spence (see her fig. 4: "Line b" and cf. our fig. 3b). The same is also true for the other pair of stars (γ-UMi and ε-UMa) that she uses (see her fig. 4: "Line c").

9. Even if all our previous arguments and questions find answers reasonable and acceptable both egyptologically and astronomically, it seems impossible to accept that the Egyptians would have ever conceived such a sophisticated method, and mainly apply it two times *per annum* separated on purpose by an interval of 6 months, in order to accept the scientific validity of Spence's figures 1b and 4, which are absolutely arbitrary. And if so, why choosing only these specific stars and not another more suitable pair? Why didn't they use this method during earlier and/or later reigns? Finally, why accept the potential order of magnitude error that Spence introduces in the last but one paragraph of her article, and not another one? It is not acceptable neither to choose randomly the error magnitude, nor because it "seems an adequate error allowance (sic!)".[73] These methods are

73 See Spence 2000, 324.

not scientific; they are arbitrary and statistically wrong! This issue of errors needs further discussion and scrutinous statistical analysis that has to be performed in the future.

10. There is no textual or epigraphical evidence, which could possibly show that Spence would be right in her assumptions. Statistically speaking, it is evident that such texts simply do not exist! If they existed, it would be more probable that they would have already been discovered, after about two centuries of scientifically active Egyptology (1822 and onwards), although one can never be absolutely sure. There are several rudiments of astronomical and cosmovisional character in the religious and profane ancient Egyptian literature. We do know of the epigraphically recorded (Late Period and onwards) ceremonies of *stretching the cord*[74] *(wḥ‘ w³w³.t),* as well as of the existence and use of two certain astronomical instruments known as:[75] *mrḫ.t* (ὡρολόγιον) and *b‘y n ỉmy-wnw.t* (φοίνιξ). Nevertheless, until now, no explicit mention of the imaginary ceremonies that Spence introduces arbitrarily (naming them "pyramid alignment ceremonies" and placing them at year 2 of each reign) has been detected, neither on textual nor on epigraphical grounds. And, of course, there is no explicit mention of any "alignment ceremony" found until this moment.[76]

11. We are now in a position to discuss and comment on some papers which refer to Spence's theory, that we were not able to read upon writing the former (French) version of this article.[77] Lamberti wrote a brief but concise critical presentation of Spence's theory, where he discusses some arguments against it.[78] Lamberti found that during the date proposed by Spence (2467 BCE) another relatively prominent star (of an apparent visual magnitude $2^m.9$), namely α-*Canum Venaticorum* (aka *Cor Caroli*), had almost the same right ascension to that of ζ-*Ursae Majoris* (aka *Mizar*).[79] We checked this out using *REDSHIFT 2/4* and absolutely agree, stating that their difference should be only 55", as we calculated. This would mean that the two stars that were proposed by Spence *together with* α-CVn had to be projected almost in the same line on the celestial sphere, hence providing an excellent and natural plumbline for aligning the pyramid. Due to the corresponding value of the declination of the same star (61°04'50") during the same date, and due to the value of Gizeh latitude, it is evident that α-CVn would be close to the horizon during its lower transit through the local Meridian, hence theoretically it would constitute a useful pointer towards the geographic North *together with* the pair of Spence's stars, during its lower transit.[80] Why, then, the ancient priests-astronomers did not observe this, if not when being near the horizon, then during another alignment of the three stars, using them as pointers? Of course a $2^m.9$ star like that would be hardly visible so close to the horizon, but it might be used together with Spence's pair as pointer at another time before or after its lower transit, although it would be not so practical in this context. Lamberti also discusses another pair of prominent circumpolar stars that could have been used by the Egyptians, having right ascensions that were differing by almost 12 hours, in order to align their pyramids during that remote era (cf. also at the beginning of § III.3, supra), namely β-UMa (aka *Merak*) and θ-Dra (aka *Etamin*).[81] He is wondering why not to suppose that the Egyptians could have chosen these stars, instead of Spence's pair? We checked out his values and absolutely agree with him that this pair of pointers could have only being used during the upper culmination of Etamin, because during its lower transit it was under the local horizon. In any case counting "suitable" pairs of stars, which are rather numerous, does not add anything new to the overall problem. Let us now point out to a group of authors, who wrote on Spence's theory. Rawlins and Pickering are the only authors (until now and to the best of our knowledge) who wrote a short scholarly note, presumably agreeing with Spence, although pointing out an important error of her article.[82] They correctly argue that the calculations of

74 Žába 1953, 64f. Cf. although Belmonte 2001a, S7–S9 and fig. 2, for a reference to the oldest known use of this ceremony on the Palermo Stone.

75 Edwards 1987, 244–246 and fig. 54f. See also Borchardt 1899, 10–17.

76 Spence 2000, 320. For the texts dating to the Helleno-Roman Period, describing the symbolic orientation ceremony, see Edwards 1987, 244–246: "[…] a text at Denderah which describes the king as 'looking at the sky, observing the stars and turning his gaze towards the Great Bear' should not be regarded as more than a record of a formal ceremony in which the king *was credited with having himself determined the orientation of the temple,* although in reality *he merely went through the motions,* as is done at the present day in laying a foundation stone." For the original hieroglyphic texts see Žába 1953, pl. 2: Aa; Ab; Ca; Cb; Cc. Moreover, looking towards the Great Bear may not be so significant, because in the textual context this would mean in general staring to the North, which was useful for the subsequent alignment. Hence, because part of this constellation was also prominent and symbolic for the Egyptians, it was probably used as a virtual celestial signpost, and nothing more.

77 See Maravelia 2000, 14 and n. 17.

78 See Lamberti 2001, 32–38.

79 See Lamberti 2001, 36f. For a short history of *Canes Venatici* constellation, see Allen 1963, 114–117.

80 For the projected position of α-CVn relatively to the pair of Spence's stars, see fig. 2 in this article; cf. also fig. 2 in Maravelia 2000, 35. Of course the star would be close to the local horizon and the effects of atmospheric absorption would be significant (see nn. 62f., supra).

81 See Lamberti 2001, 37. For a short history of *Draco* constellation, see Allen 1963, 202–212.

82 See Rawlins/Pickering 2001, 699.

Spence could not be considered as acceptable, because she used the angle between the pole and the vertical line through the pair of stars she proposes, which is less than the deviation from true North at the ground level. In other words, they proved that the actual misorientation rate projected on the ground should imply a drift of 31' per century (after having divided by the cosine of the latitude of Gizeh), instead of Spence's 27' per century, thus expanding the chronology and accepting 2638 BCE as the date of building Khufu's pyramid and 2607 BCE as the date of building Khephren's pyramid. Of course it remains an open issue of debate if these very dates could be considered as acceptable. Rawlins and Pickering proposed another method for aligning the pyramids. They found that *Thuban* and 10-*Draconis* were both equidistant from the North Celestial Pole during 2627 BCE, and very close to each other (less than 1°). They also observed that the midpoint between the virtual linear segment joining them was identical to the North Celestial Pole, hence when they were horizontally aligned they constituted pointers to the geographical North.[83] Of course their proposed method is unrealistic, probably less credible than Spence's scenario. If one is well aware of Astronomy and starts to "play" with computer astronomical software, he/she will find many more celestial coincidences, that seem plausible and exciting, but this does not necessarily mean that each and every one of them has been used in practice by ancient nations, in order to orientate their monuments! Unless one can support such proposals on the basis of textual, ethnographic and statistical grounds, they remain fictitious and purely speculative. Finally, Rawlins and Pickering, although "welcoming Spence's creativity", remarked that her specific suggestions for the supposed practical observation of her pair of stars would be difficult to be performed, unless with "agile quickness", and proposed an easier and more applicable method, in order to base their theory. Spence answered Rawlins and Pickering, admitting her error, but claiming that this did not invalidate her method.[84] She also presented some arguments against Rawlins' and Pickering's theory, as well as some arguments proving that the Egyptians were unaware of the precession of equinoxes, which seem correct and with which we fully agree.[85] Nevertheless, on the basis of our previous arguments we point out that Spence's argumentation in favor of her own theory is unconvincing. Besides, there are no clear Egyptian suggestions – as she claims – supporting her ideas, neither in the tomb of Senmout,[86] nor coming from later textual evidence.[87] Additionally, Spence refers to an older paper by Davis,[88] misinterpreting Davis' opinions in order to base her claims that the Egyptians were considering a line running between two circumpolar constellations, and refers as well to Žába's misconceptions.[89] If Spence is to accept simultaneously both Davis' and Žába's interpretation of the falcon-headed deity (namely *Dwn-ʿnwy*), which is crucial for her argumentation because he is depicted holding the spear (or cord) against the bull's thigh, this would be oxymorous and contradictory, not to say that both are wrong! First of all, Davis' interpretation of the falcon-headed human astral deity as *Ursa Minor*[90] is completely erroneous, and secondly some of her quotations of various religious texts in order to show that the Egyptians were considering two celestial adzes fighting are interpreted rather subjectively. In her quotation from the *Coffin Texts*, the two adzes of Seth are connected with Orion, which was a southern constellation,[91] and apparently not with the two fighting adversaries. Then, Davis' interpretation of her first quotation from the *Pyramid Texts*[92] and her second one[93] are interpreted rather subjectively. The third quotation is not so easy to be clearly interpreted and understood with its original archetypal symbolism.[94] Therefore, the claims of Spence are erroneous and unconvincing. More work and rigorous study is awaiting all of us before being able to claim with certainty about astronomical facts accepted by the ancient Egyptians. Spence's argument for using a thread as a plumbline that could be seen in darkness in order to observe the simultaneous transit has also been discussed above (see § III.4, supra). Furthermore her saying "[…] assuming that the plumbline was hung from a frame, the sighting device could be adjusted to keep the plumbline equidistant between the two stars for several

83 Ibid., 699. See also the review of their results in Thurston 1994. Rawlins also proposed a stellar explanation of the Gizeh pyramids (see Rawlins 1985, 255–268), which we were unable to read until now.

84 See Spence 2001, 699f.

85 See Spence 2001, 700.

86 For this topic, cf. nn. 23 and 26, supra. Cf. also Wilkinson 1991, 149–151.

87 On this topic, cf. n. 76, and § III.10, supra.

88 See Davis 1985, 102–104.

89 On this topic, see § II and n. 23, supra.

90 See Davis 1985, S103, and cf. § II and n. 24, supra. For a short history of *Ursa Minor* constellation, see Allen 1963, 447–460. For *Ursa Major*, see Allen 1963, 419–447.

91 See CT IV, 29. For a translation see Faulkner I 1973, 211. For the publication of the original hieroglyphic text of CT, see de Buck 1935–1961. In this context the two adzes are referred to as weapons of Seth used by the deceased (as Horus the Elder) in order to seize Orion *(S³ḥ)*.

92 See Davis 1985, S103. PT, § 311 is referring to the King "propitiating the two adzes". For a translation see Faulkner 1998, 68. For the publication of the original hieroglyphic text of PT, see Sethe 1908–1922.

93 See PT, § 315, which is referring to the King "getting rid of the two adzes". For a translation see Faulkner 1998, 69. Faulkner in his short commentaries notes that the two adzes were the "two combatants in Unu, who apparently fought with adzes", referring also to PT, § 229b (see op. cit., 68, n. 8).

94 See PT, § 1927. For a translation see Faulkner 1998, 278.

minutes as they came into simultaneous transit"[95] seems meaningless and erroneous, except if we miss something. The two stars in simultaneous transit are projected vertically to the horizon and hence the virtual line joining them must be perpendicular to the ground only during their culmination's moment. On the other hand, we can not understand what is the sighting device (most probably a *b'y*?) and how it could be used additionally in this instance? And how one can see in the darkness a plumbline that is hung far away, according to § III.4, or even from a short distance? If the Egyptians were using the frame with plumbline hung, why use also the *b'y,* if this is what Spence means? And if the plumbline remains still, then it will be always equidistant from both stars some minutes before and some minutes after the transit, two time spans that should be measured. So what is the meaning of her argument? Additionally, according to Dr Krauss (personal communication) because the Egyptians lacked any kind of clock in the Old Kingdom they would have been unable to measure differences in the simultaneous transits of any pair of stars. As for the supposed orientation of the pyramidal airshafts towards specific stars (like β-UMi), this is only speculative and not accepted by all Egyptologists. It might well be that the orientations observed are random and just happened by mere coincidence. This becomes evident if one takes into account that the stellar origins of theological thought, during the OK, were placing the abode of the blessed among the Imperishable Stars in the Fields of Offerings (see fig. 2), which were considered to be among the northern circumpolar stars. This is why they oriented their main pyramidal entrances towards the North. Hence the fact that northern shafts point towards the ancient culmination points of some stars might in reality be insignificant archaeoastronomically.[96] Let us now turn briefly to another relevant review paper, written by Dr Hugh Thurston, author of an interesting book on Archaeoastronomy,[97] whose opinion is rather neutral, although he does not believe that Spence's theory is correct.[98] In his short paper Thurston describes briefly Spence's method, pointing out the error found by Rawlins and Pickering (explaining the precessional displacement with a useful figure), discussing Haack's theory, and expressing general comments about the efforts of scholars to master the alignment technique used by ancient Egyptians.[99] A final review text written by Schilling, an amateur astronomer and writer, also discusses the orientation of pyramids and the progress made during the last decades.[100] This is rather popularly written, addressed to the wider public, and without any bibliographical references. Also in some points it seems that the author has not quite understood important things, like fundamental erroneous points of the simultaneous transit theory, and of course has not tested Spence's theory. Schilling claims that "many Egyptologists agree with Spence", but cites only two names, although these think that the only problem with Spence's theory is "that the pyramids would be some 75 years younger than had previously thought".[101] He also believes that "it is not out of the question that some obscure hieroglyphs could contain indications that would imply that the alignment ceremony was indeed focusing on the two stars". We don't feel that these last speculations deserve any further comments.

12. Finally, it is to be noted that there are also certain geological arguments hinting to the inapplicability of Spence's theory in the case of pyramids at the Gizeh Plateau. It has been correctly argued that the tectonic movement of the Earth's plates[102] is a major factor against theories of orientation like Spence's or in general against theories using precession.[103] According to geologists and specialists in this field there are results published on this topic by NASA,[104] as well as similar tectonic movement effects that have been also proved by recent geophysical

95 See Spence 2001, 700.

96 Dr Rolf Krauss (personal communication) considers the shafts as mere ventilation devices and nothing more. An interesting paper of him on this topic will appear under the title Los canales en la pirámide de Kheops, in Boletín de la Asociación Española de Egiptología 12, Madrid 2003.

97 See Thurston 1994.

98 See Thurston 2001. In his paper Thurston also rejects Haack's method (cf. n. 51, supra).

99 See Thurston 2001. In concluding about Spence's and Rawlins' and Pickering's theories, he points out: "Which of these two methods did the Egyptians use? Perhaps neither. There may be other methods affected by precession of which no one has yet thought. Spence and Rawlins likely have prompted investigations not yet published."

100 See Schilling 2001, 28–31.

101 See Schilling 2001, 29; 31.

102 See for instance Markowitz/Guinot 1968.

103 On this topic see some hints published at the web in Forest 2002 (although some of Forest's claims are erroneous: for instance the sea level is raising, not dropping). There was although a short study, claiming that the slight error in the orientation of the Great Pyramid of Kheops is not due to a defect in the building or a mistake by the ancient architects, but rather it is due to the terrestrial crust motion in Lower Egypt (see Pawley/Abrahamsen 1973, 892f.). In any case, this does not seem plausible, and even the authors of this idea admit it.

104 See Torrence 1998. Egypt on the whole lies in a zone of moderate seismicity, but to the North the Hellenic Arc, runs from the Sarōnikos Gulf to the island of Rhodes and the Anatolian coast. Anatolian fault systems and the collision structure along the Zagros mountains collectively mark the boundary of the Eurasian tectonic plate with the African and Arabian plates (see Wiener/Allen 1998, 21f.). Although earthquakes resulting from volcanic eruptions are local in nature, tectonic shifts present effects, which may be widespread. Indeed, earthquakes in the Hellenic Arc have been known to cause significant damage in the Delta (see op. cit., 22). For the seismicity of Egypt, see Ambraseys, et al., 1994, and references cited in Wiener/Allen 1998, 22: n. 27.

studies, and by recent space studies using lasers and GPSs in artificial satellite observations for geodesy studies.[105] These results would therefore imply an overall movement of about 100 m for the Gizeh Plateau at the Moqqatam Formation, and possibly some significant rotation.[106] Gizeh is moving especially fast, because of its location at the contact point of the African, Arabian and Eurasian tectonic plates, a fact, which also maximizes potential rotation. Another issue is the possible impact of the sea on the Gizeh Plateau.[107] The level of the Mediterranean has raised about 2 m during the last 5,000 years, a fact, which has perhaps affected the tilt of the plateau. In addition, there have been several tidal waves in the broader area of SE Mediterranean. The one that inflicted Cleopatra's VII Alexandria was massive enough,[108] but probably not as big as the one resulting from the volcanic eruption in the island of Thēra at c. 1500 BCE.[109] Hence, with all this subsistent tectonic movement it is difficult to understand – even though we have all the good will to – how Dr Spence can claim to obtain such accuracy in her calculations.[110]

IV. Conclusions

In the present article we presented a brief introduction relative to the interactions and feedback of Archaeology and Astronomy. We have stressed out their fertile interdisciplinary collaboration,[111] based on the solid ground of common sense, appropriate explication of archaeological data with the help of Archaeoastronomy, using as departure point these very data. This means rejection of any attempt trying to manipulate the archaeological record in order to present biased and arbitrary claims as valid and plausible theories.

Such a fictitious theory with many weak points and erroneous assumptions is the theory proposed by Dr Kate Spence, in order to explain the precise orientation of the Great Pyramids. This was examined critically in this article. We have given twelve arguments against this theory (simultaneous transit) in the form of questions, in order to prove that it was neither reasonable nor applicable. At the same time, we presented (only for reasons of comparison, not because we agree with this theory) an alternative pair of stars (η-Dra and β-UMa), that offers a better chronology for the reign of Khufu (2558 BCE), which agrees better with the currently accepted dating system based on von Beckerath's chronology. Spence's theory might seem plausible as a computer-generated astronomical model, because we face it with the eyes of modern science and informatics of the 21st century. Though, if we analyze this model and try to put ourselves in the place of ancient priests-astronomers, who were unaware of sophisticated techniques and did not use Mathematical Astronomy, we are going to be disappointed. We are afraid that Spence's theory (which was presented here critically in full respect for her person, efforts and work, but in full disagreement with her ideas) is tendentious and biased, misinterpreting some results and presenting arbitrary assumptions that can not be based on textual or epigraphical grounds. It has to be pointed out that this is not a personal issue or an aggressive article, but just an effort to clarify things and lead scholarly research towards scientific truth, generating fruitful discussions and correct conclusions. Although, as the most recent theory concerned with the

105 See n. 103. See also McClusky/Balassanian/Barka et al.: 2000, 5696. These researchers studied the GPS constraints on the terrestrial plate kinematics and dynamics in the Eastern Mediterranean and Caucasus, and they refer also to Egypt. They report velocities of 10 mm/year (at 30° N, 31° E) for the motion of the African plate in a northerly direction relative to Eurasia, as well as differential motion between Africa and Arabia about 10–15 mm/year, and also motion of the Arabian Plate in a north-northwest direction relative to Eurasia at a rate of 18–25 mm/year (averaged over 3 Myr). Hence, adopting a mean value of 20 mm/year, we can see that in the course of 4550 years since the approximate construction date of the Great Pyramid, the overall drift is more than 90 m.

106 Dr Krauss (personal communication) correctly points out that if there is any rotation, it would have influenced the Gizeh Plateau and the orientations of the three main pyramids as a whole. At this point let us thank Dr Hesham 'el-Asmar, Professor of Geology at the University of Mansura, for checking and commenting on these geological arguments.

107 See again n. 103. For the Gizeh plateau, see also Lehner 1998, 106.

108 On this topic, see Schuster 1999.

109 See for instance Bond/Sparks 1976, 1–16; and cf. also Marinatos 1939, 425–439. In Avaris, numerous lumps of pumice were retrieved, which originated from the eruption of Thera (NAA analyzed by Austrian atomic scientists), which were transported to Egypt by the tidal wave action (see Bietak/Marinatos 2000, 42). There is also supposed Egyptian evidence for this, describing the devastating effects of a storm, on the Tempest Stele (c. 1530 BCE). On this topic, see Wiener/Allen 1998, 1–28, contra Davis 1990, 232–235, and contra Foster/Ritner 1996, 1–14.

110 Independent of the above geological arguments, Lamberti points out characteristically in his article, referring to Spence's supposed high precision of dating the Great Pyramid: "Utilizzarle per ricavare grafici che poi si pretende siano precisi a meno di 5 anni può essere al limite dell'imprudenza" (see Lamberti 2001, 38).

111 See § I, supra. Cf. also n. 12. See Krauss 1997, as an excellent example for the study of the Pyramid Texts. We would like to thank Dr Krauss for reading our former (Tôzai 5) paper and for some interesting comments.

orientation of pyramids, Spence's model offered something much better. We think that it stimulated again the general interest for this thorny issue, and will create more feedback soon to come. In any case hard work and rigorous study is awaiting all of us before being able to talk with certainty about astronomical facts accepted by the ancient Egyptians.

In this article we have also endeavored to give a brief account of older theories related to the orientation of the Egyptian pyramids. We have shown that there were some major errors in the important work of Žába, concerning the Gizeh local Meridian and some stars of the modern constellations of *Cygnus*, which was not identical to the ancient asterism *Dwn-ʿnwy,* as erroneously proposed by the late scholar. We have pointed out that his opinions about a possible knowledge of the precession of equinoxes by the ancient Egyptians must be erroneous and exaggerated. On the same grounds, we have also determined the astronomical epoch (4200 BCE) during which the stars proposed by him were really pairs in right ascension. Furthermore, we have discussed Antoniadi's theory, ameliorated by Lexa (viz. *the observation of transits and culminations of stars, in order to determine the Meridian*), which although seemingly plausible in order to explain the precise orientation of the Great Pyramids was refuted by Dorner. Lexa's method is applicable only for one star at a time (not necessarily circumpolar), in order to determine its culmination. Additionally, it could be also theoretically applied to the polar star, if there was such a close star to the pole, at any certain astronomical epoch. Another well-founded plausible "gnomonic method" could be that described by Dr M. Isler, of which we think is the best until now explaining the precise orientation. The increasing deviation of orientation from true North with time, as we reach the end of Dynasty IV (and later) could be easily explained on the basis of systematic and/or random errors made by the architects and by priests-astronomers. These errors were lesser during Khufu's and Chephren's reigns, due to the fact that the dominant doctrine of the "school" of architects was capable of creating "technical miracles" in considerable detail and sophistication, in accordance with the apotheosis of pharaonic monarchy and theocracy, which were characteristic of that era. Everything started to fade out and the later pyramidal constructions (Dynasty V and onwards) were less accurately oriented and far less grandiose, as soon as the finances and the power of the central authority deteriorated and the general decline which would lead to the FIP started.[112]

112 For the FIP, see for instance Gardiner 1964, 110ff.

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