Astronomical dating proposals of the ancient Egyptian stellar clocks

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Abstract : On the interior lid of nineteen sarcophagi unearthed in Middle and Upper Egypt necropolis on the one hand, on the ceiling of the cenotaph of *Seti I* at Abydos, Middle Egypt, on the other hand, were painted stellar clocks which worked on the basis of the successive appearances of stars in the east between the end of astronomical twilight and the very beginning of dawn throughout the ancient Egyptian civil year made up of 365 days (Gadré and Roques, 2008b). The present paper aims at dating the twenty stellar clocks by comparing their respective stellar arrangements. The dating proposals are next compared to those deduced from the applying of archaeological, topological and philological criteria.

Résumé : Sur l'intérieur du couvercle de dix-neuf sarcophages découverts dans des nécropoles de la Moyenne et de la Haute Égypte d'une part, au plafond du cénotaphe de Séthi Ier à Abydos en Moyenne Égypte d'autre part, figurent des horloges stellaires qui fonctionnaient sur la base des apparitions successives d'étoiles à l'est du ciel, entre la fin du crépuscule astronomique et le début de l'aube, tout au long de l'année civile égyptienne constituée de 365 jours (Gadré et Roques, 2008b). L'objectif de cet article est de dater ces horloges stellaires en comparant leurs arrangements stellaires respectifs. Les propositions de datation sont ensuite comparées à celles déduites de l'application de critères archéologiques, topologiques et philologiques.

1. The archaeological database

On the interior lid of nineteen sarcophagi unearthed at Asyût (Middle Egypt), Thebes, Gebelein and Aswân (Upper Egypt) and usually dated to the First Intermediate Period and the Middle Kingdom, that is to say, from about 2200 BC to about 1800 BC (Vercoutter, 1992 and Vandersleyen, 1995), were painted diagrams which Alexander Pogo (Pogo, 1932) was the very first to compare to stellar clocks. A similar diagram decorates the ceiling of the *Osireion* or cenotaph of *Seti I* at Abydos (Middle Egypt) whose erection dates as far back as 1300 BC (Vandersleyen, 1995). In total, the archaeological database is therefore made up of twenty stellar clocks usually referenced as follow: S1C, S1Tü, S2Chass, S3C, S6C, T3C, G2T, A1C, S3P, S9C, S5C, S11C, S#T, S1Hil, X2Bas, S16C, S2Hil, EA47605, EA and Osireion (Gadré and Roques, 2008c)[1].

1 In what follows, the stellar clocks are numbered from 1 to 20 (Table 1).

The principle on which the stellar clocks worked was detailed in a previous article (Gadré and Roques, 2008b). The present article more particularly aims at dating them, on the basis of astronomical criteria. To do so, we will first change the twenty stellar clocks which make up the archaeological database into star lists (see §.2), then we will group them according to their archaeological, philological and astronomical features (see §.3), next we will study their respective stellar contents and arrangements (see §.4). Finally, we will compare our astronomical dating proposals with the archaeological dating of the coffins on the interior lid of which nineteen of the twenty stellar clocks were painted (see §.5).

2. Converting the twenty stellar clocks to star lists

The twenty stellar clocks which make up the archaeological database (see §.1) look like the theoretical diagram drawn in Fig. 1 (Gadré and Roques, 2008b)[2]:

- ✔ every twelve lines refers to an hour of the night;
- ✔ every forty columns or so refers to a decade or ten-days period of the ancient Egyptian civil year[3]:
    - ➢ the first thirty-six columns (starting from right) refer to the thirty-six decades or ten-days periods of the ancient Egyptian civil year;
    - ➢ the columns numbered 37 to 39 gather the names of the stars used to tell the night hours during the first thirty-six decades of the ancient Egyptian civil year;
    - ➢ the column numbered 40 mentions the stars used to tell the hours of the night during the last five days of the ancient Egyptian civil year[4].

A previous study (Gadré and Roques, 2008b) showed that the twenty stellar clocks which make up the archaeological database (see §.1) worked on the basis of the successive risings of stars in the east between the end of astronomical twilight and the very beginning of dawn. More specifically, the rising of each star indicated the end of one of the twelve hours of the night; as the decades passed, the rising of a same star marked an always earlier hour of the night. As a consequence, a same star was used to tell the successive night hours – from the twelfth one to the first one – during twelve successive decades of the year (Fig. 1).

2 The content of even the fragmentary stellar clocks (see Table 1) follows the same theoretical scheme.

3 The ancient Egyptian civil year was made up of 365 days divided into 36 decades or ten-days periods plus five days which the ancient Egyptians called *ḥryw rnpt*, litterally « the days upon the year », and which the ancient Greeks later termed as « epagomenal » (Gadré and Roques, 2008b).

4 For convenience, the hieroglyphic name of each star was replaced by a number (1 to 36) or a letter (A to M), depending if it was used to tell the nighthours during the first thirty-six decades of the year or during the last five days of the year. The complete list of these stars is available in Gadré and Roques (2008a).

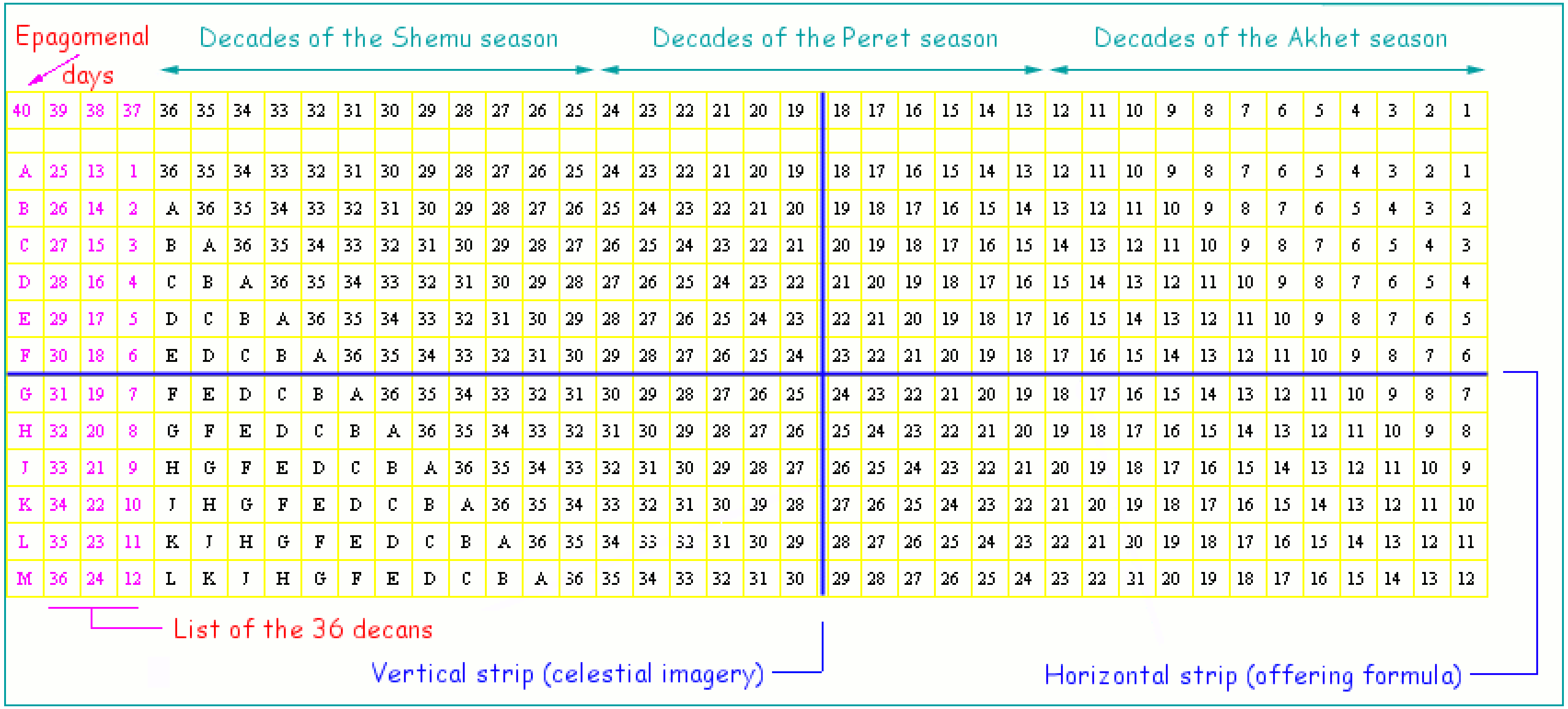

Figure 1: General scheme of a stellar clock

From the theoretical diagram drawn in Fig. 1 can be obtained a star list made up with 48 stars[5] in the order of their successive risings in the east:

- ✔ the first twelve lines of this star list are made up with the stars labelled 1 to 12 which appear in the very first column of the theoretical diagram: these are the stars which marked the successive hours of the night, from the first one to the twelfth one, throughout the very first decade of the year;
- ✔ every following lines of the star list is made up with the number (13 to 36) then the letter (A to L) ascribed to the stars mentioned at the very bottom of the columns numbered 13 to 36: these are the stars used to tell the twelfth and last hour of the night throughout the successive thirty-five decades of the ancient Egyptian civil year starting from the second decade;
- ✔ the last line of this star list is made up with the star labelled M whose rising marked the end of the twelfth night hour during the five epagomenal days.

As we have converted the theoretical diagram shown in Fig. 1 to a star list, we can change every twenty stellar clocks which make up the archaeological database (see §.1) into star lists (Table 1).

No one of the star lists (Table 1) obtained from the twenty stellar clocks which make up the archaeological database looks like another one. Indeed, they differ through:

- ✔ the number of stars: the lists n° 1, 2, 7, 8, 9 and 10 are the only ones to mention every thirty-six stars numbered 1 to 36 and whole or part of the stars labelled A to M, whereas the lists n° 6, 11, 17, 18 and 20 are quite incomplete;
- ✔ the hieroglyphic names of the stars (Gadré and Roques, 2008a): the stars numbered 3, 4, 5, 9, 10, 12, 14 and 20 are absent from the stellar clocks n°13 to 20; a few of them are replaced by stars labelled a or b (Table 2);
- ✔ the position which the stars occupy on the lists: as an example, the star lists n° 1 to 12 mention the stars labelled 1 and 2 which belong to the *ṯmꜣt* constellation (Gadré and Roques, 2008a) in the first and second positions; within the lists n°14 to 19, these stars appear in the fifth and sixth positions or even the sixth and seventh positions, respectively; the stars labelled 31a, 32 and 34 which define the outlines of the *knmt* constellation (Gadré and Roques, 2008a) are mentioned at the top of the lists n°14 to 19[6].

The few differences between the twenty star lists obtained from the stellar clocks which make up the archaeological database let appear the possibility of grouping them according to their respective stellar contents and arrangements (see §.3).

5 Only the star numbered 31 is known to us. It is Sirius or α *Canis Majoris* which the ancient Egyptians called *spd* then *spdt.*

6 In a previous article (Gadré and Roques, 2008b), we have shown that the change in position of the stars numbered 1 and 2 on the clocks n° 14 to 19 resulted from the wandering of the ancient Egyptian civil year: since a sixth epagomenal day was not added every four years to the 365 days which make up the ancient Egyptian civil year, the Egyptian civil year wandered. Every forty years, the content of the stellar clocks had therefore to be updated: practically, each star had to be moved towards the left (Fig. 1). Two hundred years later, the star numbered 1 no more indicated the first hour of the night but the fifth hour of the night during the first decade of the year.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
S1C	S3C	S6C	S1Tü	S2Chass	S16C	S1Hil	T3C	G2T	A1C	S2Hil	S3P	S9C	S5C	X2Bas	S#T	EA47605	EA	S11C	Osireion
1	1	1	[1]	1	[1]	1	1	1	1		1		31a	32		31a	[31a]	[31a]	
2	2	2	2	2	[2]	2	2	2	2		2	[2]	32	34		32	32	[32]	
3	3	3	[3]	3	[3]	3	3	3	3		3a	32	35a	35a	[34]	34	34	34	
4	4	4	4	4	[4]	4	4	4	4		3b	31a	36a	36a	35a	35a		35a	
5	5	5	[5]	5	[5]	5	5	5	5		4		1	1	36a	36a		36a	
6	6	6	6	6	[6]	6	6	6	6		5	[35a]	2	[2]	1	1		1	
7	7	7	7	7	[7]	7	7	7	7		[6]	[36a]	23	3a	2	2		2	
8	8	8	[8]	8	[8]	8	8	8	8		[7]	1	22	3b	3a	3a		3a	
9	9	9	[9]	9	[9]	9	9	9	9	11	8	2	24	4a	3b	3b		3b	
10	10	10	[10]	10	[10]	10	10	10	10	12	[9]	3a	26a	5a	[4a]	4a		[5a]	
11	11	11	[11]	11		11	11	11	11		[10]	3b	27a	6	[5a]	5a		[6]	
12	12	12	[12]	12		12	12	12	12			6	22	7	[6]	6		[7]	
13	13	13	13	13		13	13	13	13	[13]	11	7	27a	8	[7]	7		8	
14	14	14	14	14	14	14	14	14	14	[14]	12	10a	26a	9b	[8]			9b	9a
15	15	15	16	15		15	15	15	15	[15]	13	3a	24	11	[9b]			11	10a
16	16	16	17	16		16	16	16	16	16	14a		22	12a	[11]			12a	11
17	17	17	18	17		17	17	17	17		15	3b	23	13	[12a]			13	12a
18	18	18	20	18	[18]	18	18	18	18		16	6	1	13a	[13]			13a	13
20	20	20	19	20	[20]	20	20	20	20		17	10a	1	14a	[13a]			14a	13a
19	19	19	22	19	[19]	19	19	22	22	18	18	[11]	32	15	[14a]			15	14a
22	22	22	23	22		22	22	23	23	[23]	20	11	21b		[15]			16	15
23	23	23	[24]	23		23	23	24	24	[24]	19	22	21a		[16]			[17]	
24	24	24	25	24		24	24	25	25	25	22	22	31a		[17]			[18]	
25	25	25	26	25		25	20	19	19		23	19	16		[18]			21	
26	26	26	28	26		26	26	26	26		24	19	16		19			21a	
28	28	28	29	28		28	28	28	28		25	17			21a			21b	
29	29	29	30	29		29	29	29	29		26	21a	14a		21b			22	
30	30	30	[31]			30	18	30	30		28	22	13a		22			22a	
31	31	31	32			31	32	31	31		29	22a	13		22a				
32	32	32				32	33	32	32		30		32		23				
33	33	33				33	34	33	33		31		3a						
34	34					34	35	34	34		32		24						
35	35					35	36	35	35		[33]		24						
36	36					36	1	36	36				27b						
1	1					1	2	1	1										
2	2					2	A	2	2										
A	A					A	B	A	A										
B	B					B	C	B	B										
C	C						D	C	C										
D	D						E	26	D										
E	E						F	E	E										
F	F						G	F	F										
G	G						H	G	G										
H							J	H	H										
J							K	J	J										
K							M	K	K										
M								M	M										

Table 1: Star lists obtained from the twenty stellar clocks making up the database.

3. Grouping the twenty stellar clocks

The taking into account of several criteria of archaeological, egyptological and astronomical natures leads to group the star lists issued from the twenty stellar clocks which make up the archaeological database (Table 1). Here are these criteria:

- ✔ ***the geographical origin of the coffins*** on which the twenty stellar clocks were painted (Neugebauer and Parker, 1960, pages 4-21 and 32-35, Locher, 1983, Eggerbrecht, 1990, Locher, 1992, Locher, 1998 and Symons, 2002):
    - sixteen of the twenty stellar clocks (n° 1, 2, 3, 4, 5, 6, 7, 11, 12, 13, 14, 15, 16, 17, 18 and 19) have been discovered in Asyût, Middle Egypt;
    - three other stellar clocks (n° 8, 9 and 10) have been unearthed at Thebes, Gebelein and Aswân, Upper Egypt;
    - finally, the stellar clock n° 20 comes from Abydos, Middle Egypt;

- ✔ ***the ornamentation of the coffins*** on the interior lid of which nineteen of the twenty stellar clocks were painted. As an example, similar texts and a same imagery decorate the inner and outer faces of the coffins n° 8, 9 and 10. This argues in favour of their same origin and leads to group them (Willems, 1988, pages 109-10, 234 and Willems, 1996, pages 22-3);

- ✔ ***the order in which the celestial divinities appear within the vertical strip*** (Fig. 1) (Neugebauer and Parker, 1960, page 28, Locher, 1983, Eggerbrecht, 1990, Locher, 1992 and Locher, 1998):
    - *Nwt*, *Msẖtyw*, *Sꜣḥ* and *Spd* on the clocks n° 1, 2, 3, 4, 5, 7, 12, 15, 16;
    - *Spd*, *Sꜣḥ*, *Msẖtyw* and *Nwt* on the clocks n° 8, 9, 10, 11 and 13;
    - *Spd*, *Msẖtyw*, *Sꜣḥ* and *Nwt* on the clocks n° 14 and 19[7];

- ✔ ***the content of the « offering formulae »*** which separate the sixth and seventh hours of the night (Fig. 1): divinities are mentioned in an order similar to the one in which four of them (i.e., *Nwt*, *Msẖtyw*, *Sꜣḥ* and *Spd*) appear in the vertical strip (Neugebauer and Parker, 1960, page 27, Locher, 1983, Eggerbrecht, 1990 and Locher, 1992);

- ✔ ***the hieroglyphic names of the stars***: stars which are not mentioned within the clocks n° 1 to 11 appear within the clocks n° 12 to 20 (Table 1). These are the stars labelled a or b (Gadré and Roques, 2008a) which can also be found on the ceiling of *Senenmut*'s tomb at Deir el-Bahari (Table 2)[8]. The hieroglyphic names of the stars labelled 3a (*wšꜣti*) and 3b (*bkꜣti)* however recall the name of the star numbered 3 (*wšꜣt bkꜣt*). In addition, the lists n° 13 and 20 mention the stars labelled 9a *(spty)* and 10a *(ẖnwy*) instead of the only star labelled 9b (*spty ẖnwy*) (Gadré and Roques, 2008a);

7 *Nut* was the ancient Egyptian sky-goddess; *Meskhetiu* was the Big Dipper; *Sah* and *Soped* refer to Orion and Sirius, respectively. Their drawings appear on most of the star clocks, in a vertical strip which divides them into two parts (Fig. 1).

8 *Senenmut* was the architect of queen *Hatshepsut*, who reigned over Egypt around 1450 BC.

- ***the stellar arrangements*** which characterize everyone of the twenty star lists (Table 1):
  - the lists n° 1 to 10 and 12 mention the stars 1 (*ṯmꜣt ḥrt*) and 2 (*ṯmꜣt ẖrt*) first – these stars define the outlines of the *ṯmꜣt* constellation;
  - the lists n° 14, 15, 17, 18 and 19 mention the stars labelled 31a (*tpy-ꜥknmt*), 32 (*knmt*) and 34 (*ẖry ẖpd n knmt*) first – these stars belong to the *knmt* constellation (Gadré and Roques, 2008a).

Considering the archaeological, philological and astronomical criteria above, sixteen of the twenty star lists (Table 1) can be gathered into two different groups (Kahl, 1999 and Symons, 2002):

- a first group is made up with the **star lists of *ṯmꜣt* type**: these are the lists n° 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 12 which mention the stars numbered 1 and 2 which belong to the *ṯmꜣt* constellation first. Since they decorate the interior lid of coffins which have been unearthed in Upper Egypt, the lists n°8, 9 and 10 make up a subgroup of this first group;
- a second group is made up with the **star lists of *knmt* type**: these are the lists n° 14, 15, 17, 18 and 19 which begin with the stars labelled 31a, 32 and 34 which define the outlines of the *knmt* constellation (Table 1).

The star lists n° 11, 13, 16 and 20 can also be linked with the one or the other group defined above. Indeed,

- the stellar clock n°11 mentions no one of the stars labelled a or b (Table 2). This argues in favour of its relationship with the clocks n°1 to 10. Although the very beginning of the list n° 11 is devoid of stars, we can obviously rank it among the lists of *ṯmꜣt* type;
- the clocks n° 13 and 20 differ from the clocks n° 14, 15, 16, 19 and from *Senenmut*'s list in the sense that they mention the stars labelled 9a and 10a instead of the only star labelled 9b (Table 2)[9]. Although no star is mentioned at the very beginning of the lists n° 13 and 20 (Table 1), the common figuration of the same stars labelled a or b, moreover in an order similar to the one which characterizes the clocks n° 15, 16 and 19, leads to link the lists n°13 and 20 with those of *knmt* type (Symons, 2002);
- the order of succession of the stars on the list n° 16 is similar to the one which characterizes the list n° 17 (Table 1). We therefore can establish a close relationship between the list n° 16 and those of *knmt* type.

9 This partly explains the reason why Otto Neugebauer and Richard A. Parker dated the stellar clock n° 20 which decorates the ceiling of the *Osireion* at Abydos to 600 years before the monument was built (Neugebauer and Parker, 1960, page 34, Neugebauer and Parker, 1969, page 149 and Parker, 1974, p 56).

Stars *Lists*	3a	3b	4a	5a	9a 10a	9b	12a	13a	14a	21	21a	21b	22a	31a	35a	36a
12	x	x							x							
13	x	x		x	x		x		x	x	x		x	x	x	x
14	x	x	x	x		x	x	x	x	x	x	x		x	x	x
15	x	x	x	x		x	x	x	x						x	x
16	x	x	x	x		x	x	x	x	x	x	x	x		x	x
17	x	x	x	x										x	x	x
18														x		
19	x	x		x		x	x	x	x	x	x	x	x	x	x	x
20					x		x	x	x							
S	x	x		x		x	x	x	x	x	x	x	x	x	x	x

Table 2: Appearance of stars labelled a or b within the lists n° 12 to 20
as well as on the ceiling of *Senenmut*'s tomb (S) at Deir el-Bahari (ca. 1450 BC).

In summary, the twenty star lists which are issued from the stellar clocks (see §.2) which make up the archaeological database (see §.1) can be grouped together as follow:

- ✔ the **A1 group** is made up with the lists of *ṯmꜣt* type n° 1, 2, 3, 4, 5, 6, 7 and 11 obtained from the stellar clocks which decorate the inner lid of coffins unearthed at Asyût, Middle Egypt. No one of these lists mentions any of the stars labelled a or b (Table 1);
- ✔ the **A2 group** is made up with the lists of *ṯmꜣt* type n° 8, 9 and 10 obtained from the stellar clocks which decorate the inner lid of coffins unearthed in Upper Egypt necropolis. No one of these lists mentions any of the stars labelled a or b (Table 1);
- ✔ the **B group** is made up with the only list of *ṯmꜣt* type n° 12 issued from a stellar clock which decorates the inner lid of a coffin found at Asyût, Middle Egypt. This list mentions a few of the stars labelled a or b (Table 2); it therefore can be seen as an « intermediate » list between the lists which make up the A1 and A2 groups on the one hand, the C and D groups on the other hand;
- ✔ the **C group** is made up with the lists n° 13 and 20 issued from stellar clocks which decorate the interior lid of a coffin unearthed at Asyût and the ceiling of the Osireion at Abydos, respectively. These lists mention a few of the stars labelled a or b (Table 2);
- ✔ the **D group** is made up of the lists of *knmt* type n° 14, 15, 16, 17, 18 and 19 obtained from stellar clocks which decorate the interior lid of sarcophagi unearthed at Asyût, Middle Egypt. These lists mention a few, if not all, of the stars labelled a or b (Table 2).

4. Astronomical dating of the twenty stellar clocks

Several criteria of astronomical nature can be used to estimate the conceiving date of the twenty stellar clocks which make up the archaeological database (see §.1). Here are these criteria:

1. ***the wandering of the old Egyptian civil year*** (see note 6): let's suppose that the stellar clock n° 1 is the prototype of the other stellar clocks which make up the database[10]. Any clock conceived (n × 40) years after the stellar clock n°1 and according to a scheme identical to the one of the clock n° 1 should logically mention the star numbered 1 in the (n + 1)-th place and the star numbered 31 in the (n + 18)-th place[11]; n stars numbered 37, 38, 39, 40, 41, etc., should therefore appear before the star 1 (Table 3). Let's now apply this reasoning to the stellar clocks which make up the archaeological database:
   - ✔ on the clocks n° 1, 2, 3, 7, 9 and 10, the star 31 (Sirius) appears at the bottom of the eighteenth column. This implies that they were conceived between (2781–17×40 =) 2101 and (2781–18×40+1 =) 2062 BC[12] and suggests that the lists which form the A2 group[13] date from the same epoch as the lists which make up the A1 group[14];
   - ✔ on the clock n°12, the stars labelled 3a (*wš3ti*) and 3b (*bk3ti)* are quoted instead of the only star 3 (*wš3t bk3t*). This results in the appearance of the star 31 (Sirius) at the bottom of the nineteenth column (Table 1). This information leads us to date the clock n° 12 from 40 years later than the clocks which belong to the A1 and A2 groups, i.e., from one of the years between 2061 and 2022 BC[15];
   - ✔ on the lists n° 14 and 15, the star numbered 1 appears in the fifth place, after the stars labelled 31a and 32 or 32 and 34 then 35a and 36a (Table 1)[16]. This leads us to date these lists from between (2101–4×40 =) 1941 and (2062–4×40 =) 1902 BC;
   - ✔ the lists n° 16, 17 and 19 – and most certainly the list n° 18 as well when it was still complete – let appear the star 1 in the sixth place, after the stars 31a, 32, 34, 35a and 36a (Table 1)[17]. This leads us to date these lists from one of the years between (2101–5×40 =) 1901 and (2062–5×40 =) 1862 BC.

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10 Although they are complete, the clocks n° 8, 9 and 10 can not be considered as prototypes of the other stellar clocks: indeed, the clock n° 8 omits the star numbered 31 and the clocks n° 9 and 10 do not mention the star 19 in the correct place (Table 1). As a consequence, these three clocks can be considered as copies of other clocks – of the clock n°1, in this case.

11 The star numbered 31 (Sirius) appears at the bottom of the eighteenth column of the stellar clock n° 1. In a previous article (Gadré and Roques, 2008b), we have shown that any stellar clock which mentions the star 31 at the bottom of the very first column dates from between 2781 and 2742 BC.

12 In case the stars numbered 21 and 27 would have been unknowingly omitted, the star numbered 31 should appear at the bottom of the twentieth column and the star lists n°1, 2, 3, 7, 9 and 10 should be dated from eighty years later, that is to say, from one of the years between 2021 and 1982 BC, as Jochem Kahl suggested (Kahl, 1993).

13 The list n° 8 was obtained from the first column and the twelfth line of the corresponding stellar clock (see §.2). The content of this twelfth line however differs from the one of the other lines: indeed, the star numbered 20 was inserted between the stars 24 and 26, instead of the star 25; the star 18 appears between the stars 29 and 32, instead of the stars 30 and 31. The omission of one column is responsible for this last mistake. Once emended, the list n° 8 looks like the lists n° 9 and 10. As a consequence, they can all be dated from the same period.

14 Because the star numbered 15 was omitted, the star 31 appears at the bottom of the seventeenth column of the clock n° 4 (Table 1). The clocks n° 5, 6 and 11 are rather incomplete: they do not mention the star 31. Since they look like the other clocks which make up the A1 group, the clocks n° 4, 5, 6 and 11 can all be dated from a same period.

15 In case the omission of the stars numbered 21 and 27 would have been unknowingly (see note 12), the clock n° 12 should rather be dated to one of the years between 1981 and 1942 BC.

16 The stars 31a and 32 or 32 and 34 then 35a and 36a can be compared to the stars 40, 39, 38 et 37.

17 The stars 31a, 32, 34, 35a and 36a can be compared to the stars 41, 40, 39, 38 and 37 (Table 3).

Everyone of the dating proposals above suggests that the lists of *knmt* type which make up the C and D groups are posterior to the lists of *ṯmꜣt* type which form the A1, A2 and B groups (see §.3). The stellar arrangements of the lists of *knmt* type result from the effects of the wandering of the ancient Egyptian civil year upon the lists of *ṯmꜣt* type like the list n° 1 (Table 3) (Neugebauer et Parker, 1960, pages 31-2, 108-9 and Locher, 1998). Thus, the lists of *knmt* type can be considered as later revisions of the lists of *ṯmꜣt* type[18].

2. ***the similarities between the lists which form the D group and Senenmut's list*** – more particularly, the quotation of the stars labelled 3a, 3b, 5a, 9b, 12a, 13a, 14a, 21a, 21b, 22a, 31a, 35a and 36a (Tables 1 and 2). The list n° 19 is almost identical to *Senenmut*'s list[19]. The lists n° 15, 16 and 17 differ from *Senenmut*'s list in that they mention the star labelled 4a between the stars 3b and 5a (Table 1). This information leads us to divide the D group into three subgroups labelled D1, D2 and D3:
   - ✔ the **D1 subgroup** is made up with the list n° 14: only the first six stars, labelled 31a, 32, 35a, 36a, 1 and 2, seem to appear in a correct order. Indeed, the order in which the other stars appear can not result from the wandering of the ancient Egyptian civil year (Table 3);
   - ✔ the **D2 subgroup** is made up with the lists n° 15, 16 and 17 which mention the star labelled 4a between the stars 3b and 5a;
   - ✔ the **D3 subgroup** is made up with the list n° 19 which is almost identical to the star list decorating the ceiling of *Senenmut*'s tomb[20].

   The considerations above let appear that the *Senenmut*'s list lays in direct line with the lists of *knmt* type, more particularly, with the list n° 19.

3. ***the mention of the star labelled 9b on the lists which belong to the C group***:
   - ✔ the lists which make up the A1, A2 and B groups mention the stars 9 (*ḳdty*) and 10 (*ẖnwy*) between the stars 8 and 11 (Table 1);
   - ✔ the list n° 20 (C group) mentions the stars labelled 9a (*spty*) and 10a (*ẖnwy*) before the star 11 (Table 1);
   - ✔ the lists which belong to the D1, D2 and D3 subgroups mention the star labelled 9b (*spty ẖnwy*) between the stars 8 and 11 (Table 1).

   Did the star labelled 9b result from the combination of the stars 9a and 10a or did the star 9b rather give rise to the stars 9a and 10a ? In the first case, the lists which make up the C group would have been conceived between those which belong to the A1, A2 and B groups and those which belong to the D1, D2 and D3 groups. In the second case, the lists which make up the C group would date from a later epoch than those which make up the D1, D2 and D3 groups. The star numbered 10 or 10a appears within the lists which belong to the A1, A2 and B groups. It therefore seems that the star numbered 9 was first replaced by the star labelled 9a, then that the stars 9a and 10a fused to give rise to the star 9b. This leads us to date the lists n°13 and 20 which make up the C group from an intermediate period between the lists which belong to the A1, A2 and B groups on the one hand, to the D1, D2 and D3 groups on the other hand.

18 This result implies that the stars labelled 3a and 3b issued from the star 3 rather than the contrary.
19 The list n° 19 differs from *Senenmut*'s list in the omission of the star 19 between the stars 18 and 21.
20 Since it is quite incomplete, the list n°18 can not be linked with the lists making up the D2 or D3 subgroups.

Star list obtained from the clock n° 1	Star list issued from a clock conceived 40 years after the clock n°1	Star list issued from a clock conceived 2×40 years after the clock n°1	Star list issued from a clock conceived 3×40 years after the clock n°1	Star list issued from a clock conceived 4×40 years after the clock n°1	Star list issued from a clock conceived 5×40 years after the clock n°1
1	**37**	**38**	**39**	**40**	**41**
2	**1**	**37**	**38**	**39**	**40**
3	2	**1**	**37**	**38**	**39**
4	3	2	**1**	**37**	**38**
5	4	3	2	**1**	**37**
6	5	4	3	2	**1**
7	6	5	4	3	2
8	7	6	5	4	3
9	8	7	6	5	4
10	9	8	7	6	5
11	10	9	8	7	6
12	11	10	9	8	7
13	12	11	10	9	8
14	13	12	11	10	9
15	14	13	12	11	10
16	15	14	13	12	11
17	16	15	14	13	12
18	17	16	15	14	13
20	18	17	16	15	14
19	20	18	17	16	15
22	19	20	18	17	16
23	22	19	20	18	17
24	23	22	19	20	18
25	24	23	22	19	20
26	25	24	23	22	19
28	26	25	24	23	22
29	28	26	25	24	23
30	29	28	26	25	24
31	30	29	28	26	25
32	**31**	30	29	28	26
33	32	**31**	30	29	28
34	33	32	**31**	30	29
35	34	33	32	**31**	30
36	35	34	33	32	**31**
1	36	35	34	33	32
2	1	36	35	34	33
A	2	1	36	35	34
B	A	2	1	36	35
C	B	A	2	1	36
D	C	B	A	2	1
E	D	C	B	A	2
F	E	D	C	B	A
G	F	E	D	C	B

Star list obtained from the clock n° 1	Star list issued from a clock conceived 40 years after the clock n°1	Star list issued from a clock conceived 2×40 years after the clock n°1	Star list issued from a clock conceived 3×40 years after the clock n°1	Star list issued from a clock conceived 4×40 years after the clock n°1	Star list issued from a clock conceived 5×40 years after the clock n°1
H J K M	G H J K	F G H J	E F G H	D E F G	C D E F

Table 3: Star lists obtained from the theoretical stellar clocks deduced from the scheme of the stellar clock n°1 but conceived (n × 40) years later.

The following table (Table 4) gathers our astronomical dating proposals of everyone of the twenty stellar clocks which make up the archaeological database (see §.1). It shows that the transition from the lists of *ṯmꜣt* type (A1, A2 and B groups) to the lists of *knmt* type (C, D1, D2 and D3 groups) occurred between the end of the XIth dynasty and the beginning of the XIIth dynasty, that is to say, between the end of the First Intermediate Period and the very beginning of the Middle Kingdom:

<table>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>20</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td></tr>
<tr><td colspan="11">A1 and A2 groups</td><td>B</td><td colspan="2">C</td><td>D1</td><td colspan="3">D2</td><td>D2 or D3</td><td>D3</td></tr>
<tr><td colspan="11">2101 – 2062 BC</td><td>2061 – 2022</td><td colspan="2"></td><td colspan="2">1941 – 1902</td><td colspan="4">1901 – 1862 BC</td></tr>
<tr><td colspan="12">Dynasty XI</td><td colspan="2"></td><td colspan="6">Dynasty XII</td></tr>
</table>

Table 4: Astronomical dating of the twenty star lists in relationship with the old Egyptian chronology[21].

21 Claude Vandersleyen dates dynasty XI from 2137 to 1994 BC and dynasty XII from 1994 to 1797 BC (Vandersleyen, 1995, pages 11-118).

5. Comparison between our astronomical dating proposals and the archaeological dating of the old Egyptian stellar clocks

We are now going to compare our astronomical dating proposals (Table 4) of the twenty stellar clocks which make up the archaeological database with the dating of the corresponding coffins which the Egyptologists deduced from the applying of criteria of archaeological, philological and topological natures:

- ✔ the inner walls of the tomb of *It-ib*, Asyût, are decorated with friezes which are characteristic of the First Intermediate Period and with hieroglyphic texts which recount the military acts of *It-Ib* against the Theban aggressors (El-Khadragy and Kahl, 2004). These informations lead us to date the coffin n° 2 ascribed to *It-ib* from the time Egypt was not yet unified, that is to say, from the beginning of dynasty XI – more accurately, from one of the years between 2137 and 2050 BC or 2137 and 2023 BC (see note 23). This result argues in favour of our dating proposal of the star list n° 2 (Table 4)[22];

- ✔ according to Anne Eggerbrecht (Eggerbrecht, 1990), the coffin n° 7 dates from dynasty XI (2137 – 1994 BC) (Vandersleyen, 1995, pages 11-39). Her suggestion is in quite good accordance with our dating proposal deduced from the place which the star numbered 31 occupies on the corresponding stellar clock (Table 4);

- ✔ the star list n° 8 comes from the stellar clock which decorates the interior lid of the coffin of *Ashyt*, one of the wives of pharaoh *Montuhotep II* who reigned over Upper Egypt next over Upper and Lower Egypt between 2064 and 2013 BC (Vandersleyen, 1995, pages 17-31). According to Harco Willems, the tomb of this queen was closed before Egypt was reunited (Willems, 1988, pages 109-10). The reunification of Egypt took place between 2050 and 2023 BC (Vandersleyen, 1995, pages 17-22)[23]. This archaeological data leads to date the coffin of *Ashyt* from the middle of dynasty XI – more precisely, from one of the years between 2064 and 2050 BC or 2064 and 2023 BC. This dating is somewhat posterior to the one we proposed (Table 7)[24];

- ✔ the examination of the funerary equipment and of the paintings which decorate the inner and outer walls of the coffin n° 10 on the one hand, the similarities between the sarcophagi n° 9 and 10 (Willems, 1996, pages 21-25) on the other hand, lead to date them from the end of dynasty XI or the very beginning of dynasty XII – at the very last, from the reign of Pharaoh *Amenemhat I* – that is to say, from one of the years between 2050 and 1964 BC or 2023 and 1964 BC (Vandersleyen, 1995, pages 43-55). This proposal is several decades posterior to the one we deduced from the place which the star numbered 31 occupies on the corresponding stellar clocks (Table 4). Their stellar arrangements, strictly identical to the one which characterizes the clock n° 8 (Table 1), could not lead us to envisage a so late dating;

22 The rediscovery of this tomb weakens the hypothesis according to which the sarcophagus n°2 would date from the end of dynasty XI, even from the beginning of dynasty XII (Kahl, 1999, page 199).

23 According to Claude Vandersleyen (Vandersleyen, 1995, pages 17-22), it is difficult to accurately date the reunification of Upper and Lower Egypt by *Montuhotep II*: the change in royal titulature which occurred after the fourteenth year of his reign, « the monuments which he commanded to be erected, express at best the idea of reconquest, of triumph, of authority over the « two lands » and of legitimacy ». « The administrative proof » which attests that reunification did occur comes from the forty-first year » of his reign (2064 – 2013 BC). These data lead to date the epoch of reunification of Egypt from between 2050 and 2023 BC.

24 The slight difference between the historical and astronomical dating proposals reinforces the hypothesis that the stars numbered 21 and 27 have not been omitted (see note 12), contrarily to what Jochem Kahl claims (Kahl, 1993).

- ✔ according to Ahmed Kamal, the coffins n° 13 and 19 date from dynasty XII (Kamal, 1916). These datings are in quite good accordance with our dating proposals (Table 4): indeed, the stellar arrangement of the clock n° 13 suggests that it was conceived between the end of dynasty XI and the beginning of dynasty XII; the content of the clock n° 19 suggests a later conceiving date, under the reign of Pharaoh *Amenemhat II* (1919 – 1881 BC) or *Sesostris II* (1881 – 1873 BC) or *Sesostris III* (1872 – 1854 BC) (Vandersleyen, 1995, pages 77-99);

- ✔ according to Günter Lapp, the coffins n° 14 and 16 also date from dynasty XII (Kahl, 1999, page 203). These suggestions are in good agreement with the results we obtained from the astronomical study of the content of the corresponding stellar clocks (Table 4);

- ✔ according to Harco Willems (Willems, 1988, page 103), the coffin n° 15 dates from the time of *Sesostris I* (circa 1964 – 1919 BC) (Vandersleyen, 1995, pages 57-75). This dating, which he deduced from the study of the paintings which decorate the outer surface of the coffin, is in good agreement with our astronomical dating of the corresponding list (Table 4);

- ✔ finally, the coffins n° 1 to 5 are generally dated to the end of dynasty XI or the beginning of dynasty XII and the sarcophagi n° 3, 4 and 15 to dynasty XII (Kahl, 1999, page 199)[25].

In half cases, our astronomical dating proposals (Table 4) of the star lists issued from the stellar clocks are in quite good agreement with the dating of the corresponding coffins (n° 2, 7, 8, 13, 14, 15, 16 et 19). In other cases, our dating of the star lists are anterior to the dating of the corresponding sarcophagi (n° 1, 3, 4, 5, 9, 10 et 12) – the difference amounts to several decades of years, even sometimes hundreds of years.

6. Conclusion

The good agreement between the astronomical dating of the stellar clocks n° 2, 7, 8, 13, 14, 15, 16 et 19 and the archaeological dating of the corresponding coffins suggests that these coffins are contemporaneous to the stellar clocks which decorate their interior lid. The time difference between the astronomical dating of the stellar clocks n° 1, 3, 4, 5, 9, 10 et 12 and the archaeological dating of the corresponding sarcophagi let appear that the interior lid of these coffins was decorated with null and void stellar clocks. These stellar clocks are most certainly late and incomplete copies of earlier stellar clocks: their content recalls a past astronomical reality, indeed.

The astronomical dating proposals of the twenty stellar clocks which make up the archaeological database (Table 4) give the time constraints of a visibility model which will lead us to identify the stars which they mention – the so-called decanal stars (Gadré and Roques, 2008a) – to stars visible with the naked eye of the *Hipparcos* catalogue. The detail of this model and everyone of the identification proposals will be the topic of a next article.[26]

25 The re-examination of the tombs in which the coffins n°1 and 5 were buried could well lead to reconsider their dating, as was the coffin n°2.

26 The detail of this model and the results of the identification work of the decanal stars are available within Gadré, 2008.

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