The analysis of the events of stellar visibility in Pliny's "Natural History"

M.G. Nickiforov[1]
[1]Sternberg Astronomy Institute of the Moscow State University, Universitetskiy pr. 13, 119991, Moscow, Russia
michael.nickiforov@gmail.com

(Submitted on 08.12.2015. Accepted on 08.02.2016.)

Abstract. The Book XVIII of Pliny's "Natural History" contains about a hundred descriptions of the events of stellar visibility, which were used for the needs of agricultural calendar. The comparison between the calculated date of each event and the date given by Pliny shows that actual events of stellar visibility occurred systematically about 10 days later with respect to the specified time. This discrepancy cannot be explained by errors of the calendar.

Key words: agriculture calendar, stellar visibility, Pliny

1. Introduction

In Greek astronomy observations of stars were widely used to synchronize agricultural work with natural phenomena. The first and the simplest agricultural calendar belongs to Hesiod (2001). It contained only five astronomical events, which defined five points of synchronization. In the annex to the Gemin's paper "Introduction to the (celestial) phenomena" the excerpts of parapegms from different later authors are given. The manuscript "Phases of the fixed stars" of Alexandrian astronomer Ptolemy is the most comprehensive of all the Greek works . However, there is reliable evidence that the events of the stellar visibility described by Ptolemy is the results of calculations (Grasshoff, 1993), Nickiforov (2014).

Pliny's "Natural History" contains about a hundred records about risings and settings of stars in different countries and agricultural recommendations associated with these events (Pliny 2009).

In general case we differentiate four events. The first morning visibility is the event when the star comes out from behind the Sun and becomes visible in the rays of dawn. The last evening visibility is the event, when the star comes nearer to the Sun and grows invisible in the glow of the sunset. The first event is called heliacal rising and the second one - heliacal setting. The first evening visibility or acronychal rising is the event when the star has the first visibility during twilight after sunset. The last morning visibility or cosmic set is the case when the star has the last visibility during morning sunrise. The moments of acronychal rising and cosmic setting are determined less accurately than the moments of heliacal rising and setting. We discussed this question in the investigation Nickiforov, 2014 (p.70, p.74-76).

Therefore, for further analysis, we will consider only the phenomena related to the heliacal rising and setting.

2. Chronology of the Roman calendar

It is believed that the first Roman calendar appeared in the VIII century BC. It consisted of 10 months and had the total duration of 304 days. The civil year began in March and ended in December. March, May, Kvintilis and October contained 31 days, and the other months - 30 days. Because of the fact that duration of the calendar year was essentially different from the tropical year such a calendar was inconvenient.

In the VII century BC Numa Pompilius reformed the calendar. Two new months January and February were added to civil year, and its duration increased by 51 days. January and February, respectively, consisted of 29 and 28 days, which gives 57 days in sum. 6 superfluous days were subtracted from six months which had duration of 30 days in the previous version of the calendar. As a result, the duration of April, June, Sekstilis, September, November and December was equal to 29 days, and the duration of the year became 355 days.

Since the duration of the tropical year is equal to $T = 365.24$ days the difference which annually accumulates between the Roman and tropical year is equal to $\Delta T = 365.24 - 355 = 10.24$ days. To eliminate this mismatch the special month of Martsedony with duration of 22 or 23 days was inserted between February 23 and 24 once every 2 years. The intercalation cycle consisted of four years: $1st$ year - 355 days, $2nd$ - 377 days $(355 + 22)$, $3rd$ - 355 days, $4th$ - 378 days $(355 + 23)$. The average duration of the year was 366.25 days, so each year the Roman calendar lagged behind the tropical calendar for a day.

Eventually, the error accumulated and it became evident that the civil calendar started to lag with respect to weather events. To eliminate the shift Romans began to change the duration of the year, but all these changes were not regulated by any rules. The right to change the duration of the year belonged to priests, who were headed by the high priest. For the sake of his political interests, priests often abused their right by shortening or lengthening the year arbitrarily (Seleshnikov 1972). As a result of these manipulations, there appeared a great difference between the civil calendar and the agricultural one. For example, the summer feast of harvest, sometimes was celebrated in winter.

The irregularity of the Roman calendar and its dependence on the will of priests led to the need of reforming the calendar. A new calendar was created by Alexandrian astronomer Sozigen on instructions from Caesar and introduced in 45 BC. It was a solar calendar with the duration of the tropical year equal to $T = 365.25$ days. Sozigen moved the beginning of the New Year to January 1, deleted the inserted month of Martsedony, and changed the number of the days in other months. A month with an odd sequence number (January, March, May, etc.) had 31 days, and an even-numbered month contained 30 days. The exception was February which was used to synchronize the calendars. In a typical year, February consisted of 29 days, and in a leap year it had 30 days. A leap year was inserted once every 4 years, in the years that are divisible by 4 with no remainder. As a result of the reform, an error in one day accumulated in the Julian calendar for $1/(365.25 - 365.2422) = 128$ years.

At the time of the reform, the difference between the civil Roman calendar and natural phenomena was so great that they had to make an additional synchronization intercalation. As a result, in 46 BC the duration of year was equal to 445 days (Seleshnikov, 1972).

Before the implementation of reforms, aiming to achieve the coincidence of events with their respective seasons, the Romans added to the calendar year, besides Martsedony consisting of 23 days, two extra months with the duration of 33 and 34 days.

However, the rule of adding an extra day to the Julian calendar was understood incorrectly. The extra day was added 1 time per 3 years, instead of 1 time per 4 year as it should be. As a result, an error appeared in the new calendar. It was found in 8 BC and to fix this mistake, intercalations were not carried out during the period from 8 BC to 8 AD.

The Roman calendar was put in order again. The month of Sekstilis was renamed to August by the name of Octavian Augustus, who was the ruler of the Roman Empire in those years. One calendar day was removed from February and added to August, so its duration was the same as in July and September. To escape the situation when the calendar contains three months with duration of 31 days, which follow each other, the duration of the last months was changed. The duration of September and November was reduced by a day, while the duration of October and December was increased.

The following facts from the above stated are noteworthy since they will be required in the future.

1. Before Caesar and Sozigen's reform, the Roman calendar did not correspond to natural phenomena. The difference between them was about 2 months.

2. Immediately after the introduction of the Julian calendar the error was made, which was detected in 8 BC and had been corrected by 8 AD. As a result of this error, civic calendar gradually lagged from natural phenomena and it is easy to estimate that by 8 BC, the lag was no more than 3 days. So this is the maximum possible value of difference of calendars. If we consider the entire time interval from 45 BC to 8 BC, the average value of the backlog will be 1.5 days. It is worth noting that this error is much smaller than the error before Caesar and Sozigen's reform of the Roman calendar.

3. Caesar's calendar and August's calendar differ by no more than 1 day, and both calendars have the same numbering up to 28(29) August. The value of error about 1 day is not significant for analyzing the times of the beginning and finishing of stellar visibility.

3. Errors in the descriptions of events

Working with old texts we have to take into account that some information reached us with distortions. In some cases errors in the descriptions of the events of stellar visibility can be found and eliminated. Let's consider a few examples.

(Caesar-14): On the 7th day before the June ides [June 7] Arcturus rises in the morning in Italy.

(Greek-5): On the 6th day [before the calends of May, April 26] in Boeotia and Attica the Dog hides and Lyra rises in the morning.

Verification shows that in the first message the morning (heliacal) rising was confused with the morning (cosmic) setting. The events of the evening (achronical) rising or evening (heliacal) setting are impossible on that date. Therefore, this error may be easily eliminated and in the original text the word "rising" should be replaced by the word "setting". In the second report the morning rising of Lyra was confused with the evening rising. This error also can be unequivocally removed because the events connected with the heliacal/cosmic setting of Lyra are impossible on this date.

A more complicated situation arises when there is a suspicion that date of the event has been transferred erroneously. According to another report, in Greece the setting of Sirius occurred on May 20.

(Greek-6): On the 12th day before the calends of June [May 21] the Dog hides in Attica.

Our calculations show, that the heliacal setting of Sirius takes place on May 6 that is 14 days earlier than it was described by Pliny. In this case, we have to take into account other available reports, which describe the setting of Sirius. The above mentioned message (Greek- 5) describes the visibility of Sirius in Attica. The setting of Sirius comes on April 26 and that is 10 days before the calculated date and 25 days before the date in the message (Greek-6). Thus, for the same region, there are two different dates of the star setting. It's obvious that one of them is incorrect. From a formal point of view, the description of (Greek-5) has a smaller residual in comparison with the description (Greek-6), so the most likely the second message (Greek-6) is wrong. But there is another message that describes the setting of Sirius in Assyria.

(Assyrian-3): On the 4th day before the calends of May [April 28] in Assyria, the Dog hides.

The calendar date in this report fully coincides with the message (Greek-5), so we can conclude that the report (Greek-6) is wrong. The most probable reason for the error lies in the fact that the author confused the calends of May and June. In this case, the setting of Sirius occurred in Attica on April 20.

4. The stellar visibility in Pliny's "Natural History"

The "Natural History" of Pliny contains about a hundred of descriptions of stellar visibility that can be divided on territorial basis into four clusters. Splitting into clusters is necessary for several reasons. The beginning and finishing of visibility of each star depends on the latitude of observation point. If we theoretically calculate the moments of beginning (or finishing) of visibility of the star for different latitudes, the distinction can reach a few days. For this reason, we did not consider the events of the stellar visibility, where the place of observation was not specified. Secondly, the beginning of the stellar visibility depends on the extinction coefficient which characterizes the absorption of light by the atmosphere. It is possible that we will not make a big mistake if we apply the same value of the extinction coefficient for all observations. However, this can be done only after a preliminary analysis of the observations.

As a result, the largest cluster combines observations related to Rome and observations attributed to Caesar. Besides the Roman cluster, we have identified the Assyrian, Greek and Egyptian clusters with prospective observational points placed in Baghdad, Athens and Alexandria. All selected descriptions phenomena of stellar visibility are given in Appendices 1a, 2a, 3a, 4a.

Dates of the Roman calendar were recalculated from calendes, ides, and nones to the dates of Julian calendar, in accordance with the table [Seleshnikov, 1972]. To determine theoretical dates of risings and settings of stars we used a model of stellar visibility during twilight [Belokrylov, 2011] and we made calculations for the year 60 A.D., which corresponds to Pliny's lifetime. It is necessary to note, that when we change the epoch of observation within a period of 100 years the dates of the events do not change for more than a day or two. Therefore, all the calculated dates will be suitable even in case Pliny borrowed some observations. Since the phenomenon of acronychal rising and cosmic setting are defined with less accuracy in comparison with the heliacal rising and setting [Nickiforov 2014], we have not performed the calculations for these events. For all clusters, we used the value of extinction coefficient, which corresponds to an average transparency of the atmosphere k=0.25. The results are presented in appendices 1b, 2b, 3b, 4b.

The comparison of the dates provided by Pliny with our calculations show that on average, the actual event of the stellar visibility comes about 10 days later. The value of delay for the Roman cluster is $\Delta T^R_{avr} = +8.5$ and $\Delta T^R_{Me} = +6.5$ days. (Here and below the first number is averaged value, the second one is the median of number series). The values of delay on average and median are respectively $\Delta T^A_{avr} = +5.0$ and $\Delta T^A_{Me} = +7.5$ days for the Assyrian cluster, $\Delta T^G_{avr} = +10.0$ and $\Delta T^G_{Me} = +12.5$ days for the Greek one, $\Delta T^E_{avr} = +10.7$ and $\Delta T^E_{Me} = +13.0$ days for the Egyptian cluster. Estimates for all four clusters correspond with each other fairly well. If we combine all the results in one set we shall get the following values $\Delta T_{avr} = +8.4$, $\sigma = 13.3$, $\Delta T_{Me} = +10.0$ days and a total number of observations $N = 43$. The median evaluation is more reliable, since it is protected from large errors. To improve the accuracy of the estimates we filtered the data at confidence level 2σ and in the final calculation we used the observation that fall within this interval. As a result, we obtain estimates $\Delta T_{avr} = +8.7$, $\sigma = 11.3$, $\Delta T_{Me} = +10.0$ days which corresponds to the total number of observations $N = 41$.

Thus, the events described by Pliny in reality occurred about 10 days later. For example, when we expect the heliacal rising of a star in fact it hides in the Sun rays and cannot be observed at all. Modeling shows that such a large difference cannot be explained by incorrectly selected value of the extinction coefficient.

The above analysis shows that the phenomenon of stellar visibility described by Pliny cannot be dated back to the period before Caesar's calendar reform. In this case, the error could have amounted to ten calendar days and all stellar markers would not have been suitable for practical use. Therefore, the vast majority of Pliny's data must go back to the post-reform period of the Roman calendar, i.e. to the interval from the middle of the 1*st* century BC, when Julian calendar was introduced, to the 1st century AD, when Pliny lived. However, our estimation showed that the maximum value of difference between the Roman (Julian) calendar and nature events (accurate solar calendar) is less than three days at the worst. Therefore, the obtained value of discrepancy $\Delta T = 10$ days cannot be explained by errors associated with the errors of the calendar.

The detected difference between real moments of phenomena of stellar visibility and Pliny's information is about 10 days. Such a large discrepancy cannot be explained by the errors associated with the using of the calendar or by the inaccuracy of the model of stellar visibility during twilight.

Also the discovered discrepancy cannot be explained by the effects of screening of horizon, which is typical for mountain conditions. In case the observer is surrounded by a ring of mountains we will see the following effect: the real dates of heliacal rising will occur later than the calculated dates of these risings and the dates of heliacal settings will occur earlier than the expected dates. However, we see that heliacal risings and settings occur later.

A possible explanation is the assumption that Pliny's data of stellar visibility are not the result of observation, but the result of calculations, containing a systematic error.

References

Belokrylov R.O., Belokrylov S.V., Nickiforov M.G. 2011, *BlgAJ, 16, 50*

Hesiod 2001, *Polnoe sobranie tekstov. Poehmy. Fragmenty. Antichnoe nasledie.* Moskva, Labirint

Grasshoff G. 1993, *Die Rolle der Astronomie in den Kulturen Mesopotamiens, 96.* Graz

Kurtik G.E. 2001, *Istoriko-astronomicheskie issledovaniya, 21, 45.* Moskva, Nauka

Nickiforov M.G. 2014, *BlgAJ, 20, 68*

Pliniy 2009, *Estestvennaya Istoriya. Knigi XVII, XVIII.* Ryazan, Aleksandriya

Seleshnikov S.I. 1972, *Istoriya kalendarya i hronologiya.* Moskva, Nauka

Appendix 1a. Caesar's cluster observations. (Italy + Caesar.)

C-1. According to Caesar, on the eve of the nones of January [January 4], the Dolphin rises in the morning.

C-2. Before the 6th day of the ides of January [January 8] in Italy, the Dolphin sets in the evening.

C-3. According to Caesar, Arcturus rises on 7 day before the nones of March [March 1] in the evening.

C-4. Caesar marked fatal to him the ides of March [March 15] by rising of Scorpio.

C-5. According to Caesar, the 15th day before the calends of April [March 18] the Raven appears in Italy.

C-6. According to Caesar, on the 12th day before the calends of April [March 21], the Horse sets [rises] in the morning.

C-7. According to Caesar, on the 6th day before the nones of May [May 2] the Piggy's rise in the morning.

C-8. According to Caesar, on the 8th day before the ides of May [May 8] the Goat, that brings rain, rises in the morning.

C-9. According to Caesar, on the next day after the rising of the Pleiades [May 11], Arcturus sets in the morning.

C-10. [According to Caesar] on the 3rd day until the ides of May [May 13] Lyra rises.

C-11. [According to Caesar] on the 12th day before the calends of June [May 21] the Goat sets in the evening.

C-12. According to Caesar, on 11 the day before the calends [of June, May 22], the sword of Orion begins to set.

C-13. In Assyria and according to Caesar, on the 4th day before the nones of June [June 2] the Eagle rises in the evening.

C-14. On the 7th day before the ides of June [June 7], in Italy, Arcturus rises [sets - !] in the morning.

C-15. In Italy] on the 4th day [before the ides of June, June 10] the Dolphin rises in the evening.

C-16. According to Caesar, on the 11th day before the calends [of July, June 21] the sword of Orion begins to set.

C-17. According to Caesar, on the 6th day before the calends of July [June 26] Orion rises.

C-18. According to Caesar, in the morning [on the 3rd day before the calends of August, July 30] the Imperial Star, which is on the breast of the Lion, appears.

C-19. According to Caesar, on the 3rd day before the ides [of August, August 11], Lyre set marks the beginning of autumn, when in reality, it occurs the 6th day before the ides [of August, August 8].

C-20. On the 13th day before the calends of January [December 29] the Eagle rises in Italy.

C-21. On the 16th day before the calends of August [July 16] Sirius rises in Italy.

C-22. In Egypt and according to Caesar, on the eve of the ides of August [August 12] the Dolphin sets.

C-23. According to Caesar and Assyrians, on the 11th day before the calends of September [August 22], the star Vindemiatrix begins to rise in the morning.

C-24. According to Caesar, on the 5th day before the ides of September [September 9] the Goat rises in the evening.

C-25. According to Caesar, on the ides of September [September 13], Arcturus rises to the middle of [??].

C-26. According to Caesar, Spica rises on the 14th day before the calends of October [19 September].

C-27. According to Caesar, on the 11th day before the calends of October [September 22] the sling of Pisces sets.

C-28. In Asia and according to Caesar, on the 5th day [before the nones of October, October 3] the Charioteer rises.

C-29. According to Caesar, on the 4th day [before the nones of October, October 4] the Crown rises.

C-30. According to Caesar, on the 3rd day [before the nones of October, October 5] the Kids rise.

C-31. According to Caesar, on the 8th day before the ides of October [October 8] the brightest star of the Crown rises.

C-32. According to Caesar, on the 6th day [before the ides of October, October 10] the Pleiades rise in the evening.

C-33. According to Caesar, on the ides of October [October 15] the Crown totally rises.

C-34. According to Caesar, on the eve of calends [of November, October 31] Arcturus sets.

C-35. According to Caesar, on the eve of calends [of November, October 31] the Piggy's (Hyades) and the Sun rise together. [In fact, the Piggy's set at sunrise.]

Appendix 1b. Evaluation moments of events of stellar visibility.

Evaluation based on the median: $\Delta T_{Me} = +8.5$ days. Evaluation based on the average: $\Delta_{avr} T = +6.5$ days. $N = 18$ observations

Legend: HR and HS - heliacal rising and setting; AR - acronychal rising; CS - cosmic setting.

№	**Object**	**Event**	**Pliny's date**	**Calcul. date**	**Differ** Δ **T**	**Note**
1	Dolphin	HR	04.01	04.01	0	Delphinus, γDel
2	Dolphin	HS	08.01	08.01	0	Delphinus, γDel
3	Arcturus	AR	01.03	-	-	α Boo
4	Scorpio	CS	15.03	-	-	Scorpion
5	Raven	AR	18.03	-	-	Corvus
6	Horse	HR	21.03	21.03	0	γPeg
7	Piggy's	HR	02.05	09.06	+35	The Hyades, α Tau
8	Goat	HR	08.05	15.04	-23	Capella = α Aur
9	Arcturus	CS	11.05	-	-	-
10	Lyra	AR	13.05	-	-	Vega = α Lyr
11	Goat	HS	21.05	22.05	+1	Capella = α Aur
12	Orion	HS	22.05	20.04	-32	ι Ori, the sword
13	Eagle	AR	02.06	-	-	Altair = α Aql
14	Arcturus	CS	07.06	-	-	setting - !
15	Dolphin	AR	10.06	-	-	Delphinus
16	sword of Orion	HR	21.06	20.07	+29	rising - !
17	Orion	HR	26.06	20.07	+15	κ Ori
18	Regulus	HR	30.07	13.08	+14	The Imperial star, α Leo
19	Lyra	CS	08(11).8	-	-	-
20	Eagle	HR	29.12	16.12	-13	Altair = α Aql
21	Sirius	HR	16.07	30.07	+14	-
22	Dolphin	CS	12.08	-	-	Delphinus
23	Vindemiatrix	HR	22.08	21.09	+29	γVir
24	Goat	AR	09.09	-	-	-
25	Arcturus	HR	13.09	22.09	+9	-
26	Spica	HR	19.09	06.10	+18	α Vir
27	sling of Pisces	CS	22.09	-	-	
28	Charioteer	AR	03.10	-	-	Auriga
29	Crown	HR	04.10	10.10	+6	Begins to rise.
30	Kids	AR	05.10	-	-	ϵ and ηAur
31	Gemma	HR	08.10	10.10	+2	αCrB
32	Pleiades	AR	10.10	-	-	-
33	Crown	HR	15.10	26.10	+11	ϵ CrB
34	Arcturus	HS	31.10	07.11	+8	-
35	Piggy's	CS	31.10	-	-	-

Appendix 2a. Assyrian cluster observations.

A-1. On the 5th day before the calends of May [April 27] in Assyria, Orion completely hides.

A-2. According to Caesar, after 9 days [after the nones of April, April 14] the Pleiades hides in the country of Chaldeans.

A-3. On the 4th day before the calends of May [April 28] in Assyria, the Dog hides.

A-4. According to Caesar and as well as in Assyria the Eagle rises in the evening on the 4th day before the nones of June [June 2].

A-5. On the 4th day before the nones of July [July 4] Orion's belt rises in Assyria.

A-6. According to Chaldean, the Crown sets in the morning on the 4th day before the nones of July [July 3].

A-7. On the 16th day before the calends of August [July 17], Procyon rises in Assyria.

A-8. According to Caesar and Assyrians, the star which is called Vindemiatrix rises in the morning on the 11th day before the calends of September [August 22].

A-9. In Assyria, on the 5th day before the calends [of September, August 28] the Arrow sets.

Appendix 2b. Evaluation moments of events of stellar visibility.

Evaluation based on the median: $\Delta T_{Me} = +5.0$ days. Evaluation based on the average: $\Delta T_{avr} = +7.5$ days. $N = 6$ observations.

№	**Object**	**Event**	**Pliny's date**	**Calcul. date**	**Differ Δ T**	**Note**
1	Orion	HS	27.04	07.05	+10	αOri
2	Pleiades	HS	14.04	06.04	-8	$\eta Taul$
3	Dog	HS	28.04	13.05	+15	Sirius
4	Eagle	AR	02.06	-	-	Altair
5	Orion's belt	HR	04.07	01.07	-3	εOri
6	Crown	CS	03.07	-	-	αCrB
7	Procyon	HR	17.07	17.07	0	α CMi
8	Vindemiatrix	HR	22.08	22.09	+31	ε Vir
9	Arrow	CS	22.08	-	-	Sagitta, γ Sge

Legend: HR and HS - heliacal rising and setting; AR - acronychal rising; CS - cosmic setting.

Appendix 3a. Greek cluster observations.

G-1. On the 3rd day before the calends of January [December 30] the Dog hides in the morning, and on the same day in Attica, and related areas, the Eagle sets in the evening, as they say.

G-2. Next day [from the 8th day before the ides of March, March 9] the Raven appears in Attica.

G-3. On the 3rd day before the nones of April [April 3] the Pleiades hides in Attica.

G-4. And the next day [April 4] in the evening the Pleiades hides in Boeotia.

G-5. On the 6th day [before the calends of May, April 26] in Boeotia and Attica the Dog hides; Lyra rises in the morning [evening - !].

G-6. On the 12th day before the calends of June(-?!) [21 May] in Attica the Dog hides.

G-7. In Attica, on the day [4th day before the nones of July, July 4] Orion rises entirely.

G-8. On the 3rd day before the calends [July 30], in Attica, the Eagle comes in the morning.

G-9. On the eve of the ides of August [August 12] in Attica the Horse appears in the evening.

G-10. In Attica in the nones of September [September 5] Arcturus rises at down and in the morning the Arrow sets.

G-11. At the 6th day before the nones of October [October 2] in Attica the Crown rises in the morning.

Evaluation based on the median: $\Delta T_{Me} = +12.5$ days. Evaluation based on the average: $\Delta T_{avr} = +10.0$ days. $N = 8$ observations.

№	**Object**	**Event**	**Pliny's date**	**Calcul. date**	**Differ Δ T**	**Note**
1a	Dog	CS	30.12	-	-	Sirius
1b	Eagle	HS	30.12	01.01	+2	Altair
2	Raven	AR	09.03	-	-	Corvus, δ Crv
3	Pleiades	HS	03.04	06.04	+3	η Tau
4	Pleiades	HS	04.04	06.04	+2	η Tau
5a	Dog	HS	26.04	07.05	+11	Sirius
5b	Lyra	HR	26.04	-	-	Acronychal rising!
6	Dog	HS	20.04	07.05	+17	Corrected version.
7	Orion	HR	04.07	17.07	+13	κ Ori
8	Eagle	CS	30.07	-	-	Altair
9	Horse	AR	12.08	-	-	α And, γ Peg
10	Arcturus	HR	05.09	25.09	+20	α Boo
11	Crown	HR	02.10	14.10	+12	α CrB

Appendix 4a. Egyptian cluster observations.

E-1. Next day [on the eve of the nones of January, January 5] when in Egypt the Arrow rises, in the evening Lyra rises.

E-2. In Egypt, [in 9 days after the nones of April, April 13] Orion and his sword begin to hide themselves.

E-3. On the 14th day before the calends of May [April 17], in Egypt, Hyades set, in the evening.

E-4. On the 7th day before the calends [of May, April 25] in Egypt Kids rises.

E-5. In Egypt, on the same day [the 8th day before the ides of May, May 8] the Dog hides in the evening.

E-6. In Egypt, the sword of Orion rises 4 days later [on the 17th day before the calends of July, i.e. June 19].

E-7. In Egypt, on the 4th day before the nones of July [July 4] Procyon rises in the morning.

E-8. On the eve of the ides of July [July 14] Orion (ceases to rise) stops rising in Egypt.

E-9. On the 13th day before the calends [of August, July 20] in Egypt, the Eagle rises in the morning.

E-10. On the 4th day before the nones of July [July 4] in Egypt Sirius rises.

E-11. On the eve of the ides of August [12 August] in Egypt and according to Caesar, the Dolphin comes.

E-12. In Egypt, in nones [of September, September 5] Vindemiatrix rises.

E-13. On the 16th day before the calends of October [Sept. 16] in Egypt Spica rises.

Evaluations: $\Delta T_{Me} = +13.0$, $\Delta T_{avr} = +10.7$ days, $N = 11$ observations.

№	**Object**	**Event**	**Pliny's date**	**Calcul. date**	**Differ Δ T**	**Note**
1a	Arrow	HR	05.01	05.01	0	Sagitta, γ Sge
1b	Lyra	AR	05.01	-	-2	Vega, α Lyr
2	Orion	HS	13.04	21.04	+8	β and γ Ori
3	Hyades	HS	17.04	21.04	+4	Aldebaran, α Tau
4	Kids	HR	25.04	18.05	+23	ϵ and η Aur
5	Dog	HS	08.05	13.05	+5	Sirius, α CMa
6	Orion's sword	HR	19.06	08.07	+19	ι Ori
7	Procyon	HR	04.07	17.07	+13	α CMi
8	Orion	HR	14.07	08.07	-6	κ Ori
9	Eagle	CS	20.07	-	-	Altair
10	Sirius	HR	04.07	19.07	+15	α CMa
11	Dolphin	CS	12.08	-	-	Delphinus, γ Del
12	Vindemiatrix	HR	05.09	23.09	+18	ϵ Vir
13	Spica	HR	16.09	05.10	+19	α Vir