A REVISION OF ΔT VALUES FOR THE V, VI AND VIITH CENTURIES

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ABSTRACT. Studies of pretelescopic values of ΔT have been arranged by many authors. Ancient observational records of total and annular solar eclipses and in a lesser extend also lunar eclipses and occultation have been used to calculate limits to the value of ΔT (Soma and Tanikawa, 2016; Stephenson et al., 2016; Tanikawa and Soma, 2004) among others. We provide a first approximation for computed values of ΔT from the 5th to the 7th centuries considering all the available ancient astronomical records, paying special attention to those from Western Europe for which new analysis and reductions have been carried out. We present two examples of ancient observations with their associated discussions that lead to new values of some astronomical parameters. Similar studies have been carried out for more than a hundred od ancient registers. The results obtained in the first instance corroborate those obtained by Soma and Tanikawa in the sense that the ΔT for these centuries seems to be significantly lower than that obtained by Morrison and Stephenson (Morrison and Stephenson, 2014; Stephenson, 2010) and Stephenson et al. (2016).

1. EXAMPLE 1: TOTAL SOLAR ECLIPSE. AD 418, July 19

This eclipse was collected in numerous no contemporary European chronicles from Austria, Denmark, Germany, France; in many cases only reference is made to the darkening of the sun in broad daylight with or without mentioning the date. Other more complete records include the time of day the event took place. For these records, we must bear in mid a classical problem that usually appears when we deal with Medieval sources: non-contemporary authors were limited to copying records of other authors prior to them, for mainly prestige reasons. See (Newton, 1972; Soma and Tanikawa, 2016) for a further study. Anyway, some contemporary authors such as Hidatius, from Northern Spain and Philostorgius from somewhere near Istambul, provide valuable and more detailed data (`http://www.tertullian.org/fathers/philostorgius_fn.htm#218`):

> When Theodosius had entered the years of boyhood, on the 19th of July, a little after noon-day, the sun was so completely eclipsed that the stars appeared; and so great a drought followed on this eclipse that a sudden mortality carried off great multitudes both of men and of beasts in all parts. Moreover, at the time that the sun was eclipsed, a bright meteor appeared in the sky, in shape like a cone, which some persons in their ignorance called a comet (. . .) For it arose first in the east, just where the sun rises at the equinox, and then passing across the lowest star in the constellation of the Bear, crossed gradually over to the west (. . .) it at length disappeared, after it had continued its course for more than four months. Its apex, moreover, at one time was carried up to a high and narrow point, so that the meteor exceeded the length and shape of a cone, while at another time it returned to that particular form. (. . .) At the same time with the earthquakes, fire came down from the skies, which seemed to banish all hope of escape; however, it caused no destruction of life, for the mercy of God sent a violent wind which scattered the fire in every direction, and at length drove it into

> the sea. Then a new and strange sight was to be seen; the waves of the sea burning in the day-time, like woods and forests, until at length the flames were extinguished in the waters.

This is a typical fragment containing astronomical material in a narrative source. There is no scientific intent, although scientific data can be extracted and the culture of the epoch can be inferred from the calamities that the author attributes to these phenomena. The mentioned eclipse of the sun apparently must have been total since the author mentions that stars were seen in broad daylight, the day is correctly indicated and the year can be obtained from the context, in addition to the fact also mentioned, of the presence of a comet identified as C/418 M1. The historical discussion of the context, author and how the identifications of the phenomena were carried out exceeds the objectives of this paper. The next problem when we have an observation made from

Figure 1: Path of totality of AD418 , July 19 total solar eclipse using ΔT= 4800 s

several points is that the parameters that are calculated are compatible with all of them. Thus, for example, assuming that the observation of Philostorgius was made from Istanbul, we would obtain a 6800 s $< \Delta T <$ 9000 s, which would have meant that the eclipse had not been total in Braga (Portugal), from where the other contemporary observation (by Hidatius) came. Another possibility was raised by Newton (Newton, 1972), who proposed Borissus ($36^o42'$E $39^o54'$N) as the place of observation and this makes sense, because this was where Philostorgius was born. However, as we have said, it is not our intention to enter into historical context reasoning, but Istambul as the observational place seems to be the most likely.

2. EXAMPLE 2: OCCULTATION OF VENUS BY THE MOON. AD 554,October 9

Occultations of bright planets by the Moon are not usually considered for the calculation of ΔT since they provide a range of this parameter that is too wide to be relevant. However, some special cases (occultations at times near dawn or dusk, occultations observed from several places) the range for ΔT is small enough to be worth considering (Martínez and Marco, 2019). Pingré (Pingré, 1783) collects a variety of reports about the AD 554, October 9 event. Although he points out that different authors assign different dates, between AD 547 and AD 549, to the phenomenon. The primary (and contemporary) source is Gregory of Tours who states:

> In his time, we saw grapes grow on the tree we call saucum [= elder tree] without having any vine on it, and the blossoms of the same trees (. . .) Then a star coming from the opposite direction was seen to enter the disk of the fifth Moon. I suppose these signs announced the death of the king.

The data provided lead us to accept the date of October 9, 554 as the most likely for the occultation, involving Venus and the Moon. Gregory of Tours (538-594) could have witnessed it in his youth, perhaps this explains the error in the appreciation "the fifth Moon" since the Moon would have been, in fact, on his 26th day. The capital of these Merovingian kings was Metz, which we assume as the place of observation. That day sunrise was at 5h50m. The first contact of Venus with the limb of the Moon occurred at 5h15m and the end of the occultation at 6h30m. A $\Delta T < 3000$ s would have meant that the occultation occurred after sunrise, while a ΔT greater than 5500 s would have led to seeing the Venus emersion. Therefore, the values obtained are consistent with those of Espenak and Meeus and with those of Stephenson et al. Soma and Tanikawa (Stephenson, 1997) obtained a ΔT between 2893 and 5246 s. The result that we have obtained is a refinement for the lower limit of this interval.

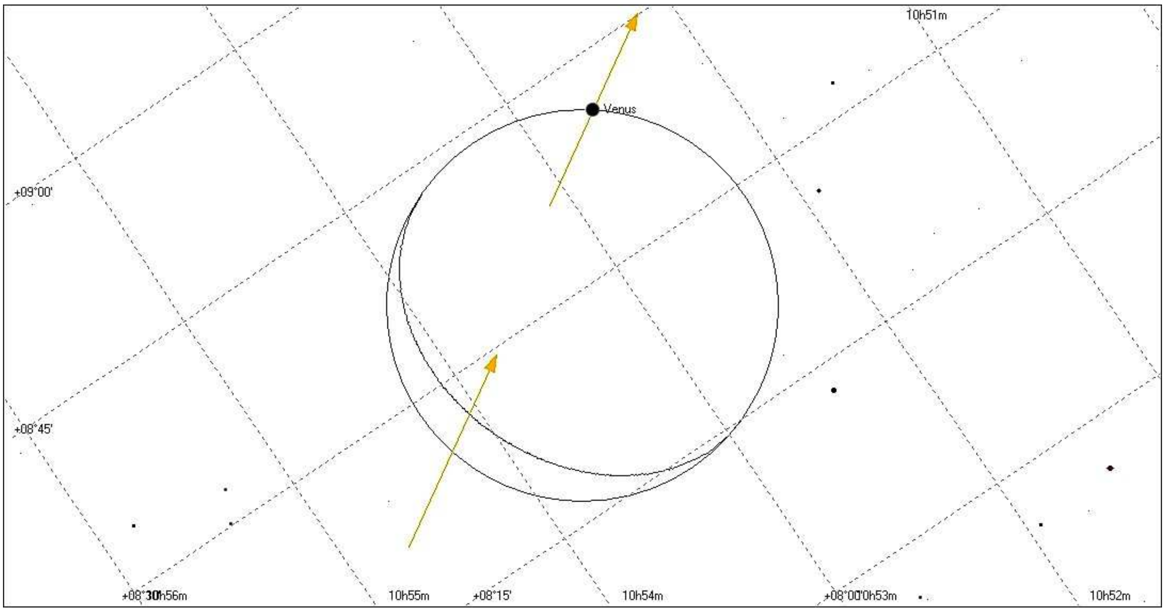

Figure 2: Occultation of Venus by the Moon. AD 554 October 9.

3. CONCLUSION

To obtain preliminary results we have worked with a total of 43 observations included in the AD418-AD693 period and coming from both Asia and Europe and North Africa. Among them are eclipses of the Sun, Moon and occultations of planets by the Moon. Each observation has been examined separately, calculating a new interval of ΔT for which the characteristics of the phenomenon have been taken into account, if it was observed in a single place or in multiple places, the time interval in which it could be observed, in the event that it occurs near sunrise or sunset, etc.

The result obtained can be seen in Figure 3. The solid red and blue lines correspond to the splines obtained Morrison and Stephenson (Morrison and Stephenson, 2014) and Stephenson et al. (2016), respectively. The black line is the spline obtained using our results showing a significantly lower ΔT is than the one provided by other authors for the time considered.

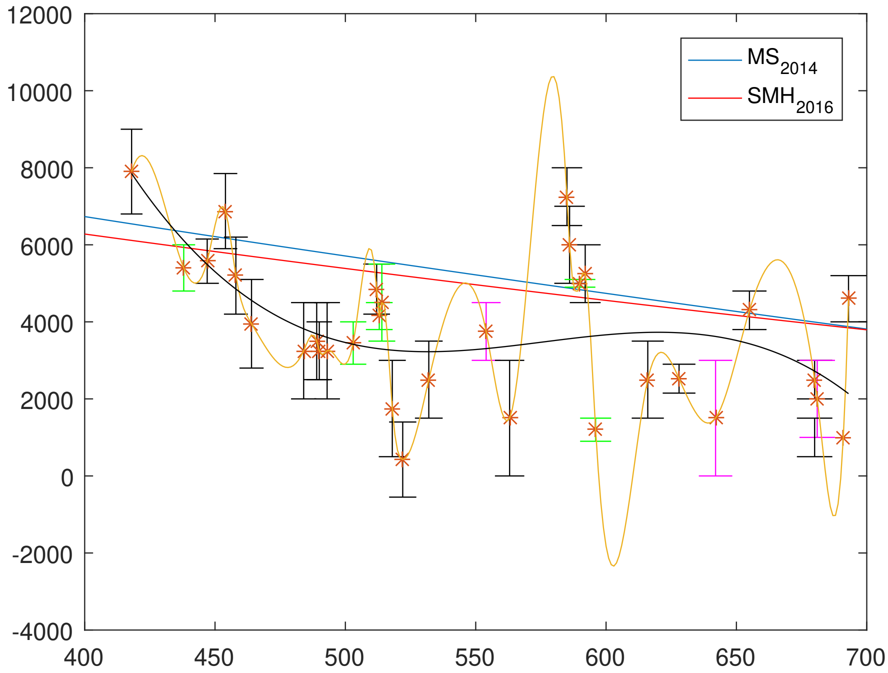

Figure 3: ΔT (s) from AD 418 to AD 693. The asterisks represent the values considered for each observation, for which the error bar is also provided. The black color corresponds to a solar eclipse, the green with a lunar eclipse and the magenta with an occultation of a planet by the Moon.

4. REFERENCES

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