RECONSTRUCTING THE SKY AND THE CELESTIAL PHENOMENA OF THE PAST

Elio Antonello - INAF, The Brera Astronomical Observatory
SIA, Italian Society for Archaeoastronomy

Observations of the celestial bodies (Sun, Moon, stars, asterisms, constellations, planets) were performed by ancient civilizations for practical and cultual purposes. The Sun was used for calendrical applications, based on solstices (and equinoxes) for defining the year, while the Moon, with its phases, defined months and weeks. The dates of the rising and setting of some bright stars were an essential tool for establishing farming activities throughout the year. Babylonian astronomers set out the zodiacal constellations, interested in the apparent movements of the Sun, the Moon, and planets, and they were able to identify the cycle of eclipses; their astronomical culture was then handed down to the Greeks. As it is possible to simulate reliably the ancient sky, many attempts have been made by scholars to pin down the dates of historical events or the epoch of texts and documents by means of an astronomical analysis. Here I show some examples of the application of astronomy for reconstructing the observations made in the past: the rising and setting of stars (in particular the case of Spica), the observations of the planet Venus, and the use of solar eclipses.

Keywords: farming calendar; Babylonian astronomy; rising and setting of stars; planet Venus; eclipses

1. INTRODUCTION

Anthropological, archaeological, and historical research has shown that ancient civilizations made observations of the celestial bodies, the Sun, the Moon, stars, asterisms, constellations, and planets. The calendrical applications of the Sun were often based on its rising or setting on the horizon at the solstices, which is indeed a practical tool for determining the year; today, our civil year, which begins near the winter solstice, is a sort of heritage from the far past. The Moon, with its continuous changing of phases, has defined the months and the weeks. The dates of the rising and setting of some bright stars or asterisms, with respect to the rising and setting of the Sun, were an essential tool for establishing the farming activities throughout the year.

Babylonian astronomers gave a fundamental contribution to the study of the sky. They introduced the sexagesimal system for arithmetical operations, and then they applied it to the study of the movements of celestial bodies, as we do today. They set out the zodiacal constellations crossed by the apparent movements of the Sun, the Moon, and made accurate studies of planets; they were able to identify the cycle of the eclipses. It is worth recalling that Babylonians had mythical ideas about the cosmos but were not interested in a physical model of it, being apparently interested just in its mathematical description, in relation to the omens. Their astronomical culture was handed down to the Greeks, particularly during the Hellenistic period, and it was the Greeks who began to develop physical models[1].

---

[1] See e.g. Neugebauer 1975, 348, 366, 541.

In this short note, I will discuss briefly how astronomers are reconstructing the observations that were recorded in ancient texts; I will mention the rising and setting of stars, the observations of the planet Venus, and the use of solar eclipse reconstructions.

2. Rising and Setting of Stars

In the Farmer's instructions, a Sumerian short manual, the advice is: *When the constellations in the sky are right, do not be reluctant to take the oxen force to the field many times*; however, the constellations are not mentioned[2]. The rising of Yoke is reported in a tablet of Mari[3]; what is this star or constellation? A similar uncertainty concerns many stars in well-known lists such as MUL.APIN. In a good paper by J.H. Rogers (1998), you can find the reliable identification of some stars and constellations, but there are also question marks for many cases.

H. Hunger and J. Steele published a compendium of MUL.APIN, and discussed the problem of the date of the composition. Several astronomers attempted to give an answer to it, mainly on the basis of the accurate estimates of the rising and setting of stars. The authors, however, note three obstacles. First, the 360-day calendar: Babylonians adopted a practical approach of a year of 360 units, and 12 months of 30 units each, for easier computations; the problem then is the connection with the true date. Second, many of the 'stars' given in these lists are constellations or star groups, so their actual appearance is uncertain. Third, can the ancient star names be confidently identified with modern counterparts? The conclusion of the authors is rather unsatisfactory: we simply do not know when MUL.APIN was composed[4].

The heliacal rising of a star or asterism in the morning is when it can be seen for a while just before the rising of the Sun. The heliacal setting of the star or asterism in the evening is when it can be seen for a while just after the setting of the Sun. The achronic rising of a bright star is when it can be seen for the first time just after the sunset (and there is the corresponding case of its setting just before the sunrise; fig. 1). The sum of the two angles, the stellar altitude above the horizon and the altitude of the Sun below the horizon, is called *arcus visionis* in Latin. The brighter the star, the smaller the *arcus visionis*. R. Hannah (2018) compared the approximate methods adopted in antiquity for estimating the *arcus visionis*.

It is possible to write computer programs to estimate the dates of such phenomena[5]. A program should include several parameters, concerning, for example, the brightness of the background sky near the horizon as a function of the distance of the Sun below it. The input is the stellar coordinates and epoch (for the computation of precession) and the latitude of the site. The output could be the date expressed as the number of days elapsed from the spring equinox, and this can be translated into a calendar date assuming the equinox on March 21; we followed such a procedure for an easier comparison with usual farming.

An example taken from the famous verses of Hesiod: *When the Pleiades born of Atlas rise before the sun begin the reaping; the ploughing when they set. For forty nights and days they are hidden*[6]. The location was Boeotia, with a latitude of about 38°, and the epoch was the 8th century BC. According to the computation, the heliacal rising of Pleiades occurred about 47 days after the spring equinox, that is, between the first and second week of May. One could wonder why so early; apart from the southern latitude, in ancient times, harvesting was done well before the

---

2 Civil 1994.

3 Reculeau 2002.

4 Hunger - Steele 2019, 29-31.

5 See e.g. Schaefer 1985; 1987.

6 Hesiod, *Works and days*, lines 383-385; tr. M.L. West.

complete ripening (a reason was to avoid the loss of grains). During the year, Pleiades could be seen easily in summer, autumn, and winter. Before the end of March, Pleiades could be seen for a while just after sunset (heliacal setting), and then *for forty nights and days* they were no more visible because of the daylight.

Hesiod writes (lines 597-599): *As for the labourers, spur them to thresh Demeter's holy grain as soon as mighty Orion appears*. The heliacal rising of the upper part of Orion occurred a few days before the summer solstice (after mid-June). It is about forty days from the beginning of harvesting. With the modern varieties of cereals, harvesting and threshing today occur altogether. However, in the past, after harvesting, barley and wheat were kept in sheaves for many days before threshing.

The nice tale of Ruth in the Bible offers a good example. Naomi and Ruth came to Bethlehem at the beginning of the barley harvest[7]. The new moon of spring was the first day of the Hebraic new year; fourteen days later it was Pesach (Passover, and Feast of Unleavened Bread), and, according to the law[8], barley harvesting had to begin at that time. It is around April, but the latitude of Bethlehem is only 31°. According to the law, threshing and winnowing of barley and wheat should have been finished before Shavuot (Pentecost, or Whitsunday time), fifty days after Pesach. One may note in passing that the dates of the two main Christian church celebrations are related in some way to cereal farming (i.e., to the bread).

3. Rising and Setting of Spica

Some years ago, I asked myself why the brightest star of the Virgo constellation was named Spica, the ear of wheat, right from ancient times. As a calendar indicator, it has nothing to do with harvesting or threshing, even in Greek and Babylonian times. After having noted that the latitude of Boeotia is also that of Northern Mesopotamia, i.e. the upper part of the Fertile Crescent, and taking into account the indications of Hesiod, I found that the heliacal setting of Spica could have been used for the harvesting in the second half of 9th millennium BC, and its heliacal rising for the threshing right in the second half of 9th millennium BC[9]. Moreover, the rising in the evening (or the setting in the morning) of Spica could have been used as an indicator of the limiting date for ploughing in November (to be compared with Hesiod's indications, lines 614-617, *But when the Pleiades and Hyades and mighty Orion are setting, then be thinking of ploughing in its season*) in the second half of 9th millennium BC. Note that no other bright star allows this combination of dates. Why was this epoch, eleven - ten thousand years ago, so special? It is when, a millennium after the beginnings, the cereals were domesticated and farming began, around 8500 years BC[10], and it is known that farming usually needs a calendar.

This is not proof of the origin of the name Spica, it is just a (nice) suggestion. It is up to pre-historians, historians, and anthropologists to take it into consideration or not.

---

7 *Ruth*, 1, 22; that of wheat began later: *Ruth*, 2, 23.

8 *Leviticus* 23, 5-16; *Deuteronomy* 16, 1-11.

9 Antonello 2013; 2021.

10 See e.g. Willcox 2013.

4. The Planet Venus

The tablet of Ammisaduqa is a copy of VII century BC, and it includes records about the time of the visibility of the planet Venus. G. V. Schiaparelli, at the beginning of the past century, when he retired from the direction of Brera Observatory, gave important contributions to the history of ancient astronomy. He struggled to master the Akkadian language and made a study of the tablet. His preliminary and unpublished conclusion of a large analysis of the East and West appearances of Venus was that the astronomical observations were performed in the time interval between 652 and 637 BC, if the invasion of the Umman-Manda, quoted in the tablet, occurred in that epoch. However, the invasion should have occurred much earlier, and in a letter to his colleague E. Millosevic (January 1907), he wrote: "Surely many people will declare wrong many of my conclusions"[11]. As it is well known, the problem was solved by F. X. Kugler a few years later. The uncertainty of about two hundred years in the possible epoch (about 1702-1550 BC) of Venus has generated different chronologies. Today, the scholars are still fighting with the same methods used by Schiaparelli and Kugler, trying to identify the correct chronology. The task is not easy because the cuneiform tablets should contain errors (as usual in documents copied by humans), and other uncertainties.

The estimate of the East (morning star) and West (evening star) appearance and disappearance of Venus, according to its orbital motion around the Sun, is analogous to that of the heliacal phenomena for the stars. The planet has phases like the Moon, and since the *arcus visionis* depends on the brightness of the objects, it will depend, of course, on the different positions of Venus on its orbit. Today, some scholars have attempted to identify the chronology even by considering the volcanic eruption of Thera-Santorini and its possible huge atmospheric effects that should have changed the visibility condition of Venus for some years[12]. However, there is still significant disagreement between scientists and archaeologists about the possible date of the eruption[13].

5. Solar Eclipses

Babylonians are credited with the discovery of the saros cycle (the name saros derives from the Greeks). It consists of a period of 223 synodic months; eclipses separated by this period belong to the same saros series and share similar geometry and characteristics.

The Five Millennium Canon of past and future solar eclipses, published by NASA, is a reference for this topic[14]. The authors write: "A primary goal of this work is to assist historians and archaeologists in the identification and dating of eclipses found in references and records from antiquity. This is no easy task because there are usually several possible candidates. Accurate maps using the best available values of ΔT coupled with estimates in the standard error of ΔT, are critical in discriminating among potential eclipse candidates". ΔT is the arithmetic difference, in seconds, between Terrestrial Dynamical Time (used in the computations) and Universal Time (the basis of our civil time). The main secular effects to be taken into account in the computations are those related to the Earth-Moon interaction: owing

11 Antonello 2011.

12 de Jong - Foertmeyer 2010.

13 See e.g. Manning *et al.* 2014.

14 Espenak - Meeus 2009; there is also another NASA publication of lunar eclipses.

to the tidal effect, the Earth-Moon distance is increasing, and the day is lengthening very slowly[15].

A famous total eclipse that was visible from northern Mesopotamia occurred, according to the *Five Millennium Catalog*, on 15 June 763 BC (proleptic Julian calendar), just before noon. The Julian calendar is based on the rule of three normal years and then a leap year; note that 1 BC is a leap year. There is a difference of one year between the historical and the astronomical (-762) date. The reason is very simple. Astronomers always looked for practical ways to make easier computations: Babylonians adopted a year of 360 days, today astronomers sometimes use the Dynamical Time instead of the Universal Time, and they have inserted the year 0 between 1 BC and 1 AD.

6. CONCLUSIONS

These were just some illustrations of the way the astronomers attempt to reproduce what ancestors saw in the sky, and of why this can be a useful exercise for a better understanding of history.

Let me address a final remark mainly to people who got an education in the field of natural sciences. In my opinion, astronomical data linked to anthropological problems (those dealt with by historians, archaeologists, anthropologists) should not be considered in the same way as the astronomical data linked to physical problems (those of the *hard science*): unfortunately, this is a quite common confusion (I would say, an ever-present confusion) in archaeoastronomy. But strong scientific rigour is mandatory also in the former case, and this may look like a contradiction; indeed, it is twenty years that I have been fighting with this problem. The task is not simple. However, I found that some humility may help.

[15] Note that dealing with eclipses is not simple, and if you are interested in them, you should interact with an astronomer expert in this field.

BIBLIOGRAPHY

ANTONELLO, E.

2011 "Schiaparelli and the dawn of astronomy", in *Memorie della Società Astronomica Italiana* 82 (2011), pp. 280-289.

2013 "Hesiod's calendar and the star Spica", in arXiv: 1304.2176, https://doi.org/10.48550/arXiv.1304.2176.

2021 "Risings and Settings of Stars: The Case of Hesiod Calendar and the Star Spica", in M. RAPPENGLUCK - M. SHALTOUT (eds.), *From Alexandria to Al-Iskandariya, Astronomy and Culture in the Ancient Mediterranean and Beyond, Proceedings of the SEAC 2009 Conference in Alexandria*, Egypt 2021, pp. 89-91.

CIVIL, M.

1994 *The Farmer's Instructions. A Sumerian Agricultural Manual* (Aula Orientalis Supplementa 5), Barcelona 1994.

DE JONG, T. - FOERTMEYER, V.

2010 "A new look at the Venus observations of Ammisaduqa: traces of the Santorini eruption in the atmosphere of Babylon?", in *Jaarbericht van het Vooraziatisch-Egyptisch Genootschap "Ex Oriente Lux"* 42 (2010), pp. 141-157.

ESPENAK, F. - MEEUS, J.

2009 "Five Millennium Canon of Solar Eclipses: -1999 to +3000", in *NASA Technical Publication TP-2006-214141*, https://eclipse.gsfc.nasa.gov/SEcat5/SEcatalog.html.

HANNAH, R.

2018 "Putting the astronomy back into Greek calendrics: the parapegma of Euctemon", in arXiv:1801.05851, https://doi.org/10.48550/arXiv.1801.05851.

HESIOD

1990 *Hesiodi Theogonia, Opera et Dies, Scutum, edidit Friedrich Solmsen*, Oxford 1990.

2008 *Theogony and Works and days. A new translation by M.L. West*, Oxford 2008.

HUNGER, H. - STEELE, J.

2019 *The Babylonian astronomical compendium MUL.APIN*, London - New York 2019.

MANNING, S.W. - HÖFLMAYER, F. - MOELLER, N. - DEE, M.W. - RAMSEY, C.B. - FLEITMANN, D. - HIGHAM, T. - KUTSCHERA, W. - WILD, E.M.

2014 "Dating the Thera (Santorini) eruption: archaeological and scientific evidence supporting a high chronology", in *Antiquity* 88 (2014), pp. 1164-1179, https://doi.org/10.1017/S0003598X00115388.

NEUGEBAUER, O.

1975 *A history of ancient mathematical astronomy*, Berlin 1975.

RECULEAU, H.

2002 "Lever d'astres et calendrier agricole à Mari", in D. CHARPIN - J.M. DURAND (eds.), *Recueil d'études à la Mémoire d'André Parrot* (Florilegium Marianum VI), Paris 2002, pp. 517-538.

ROGERS, J.H.

1998 "Origins of the ancient constellations: I. The Mesopotamian traditions", in *Journal of the British Astronomical Association* 108 (1998), pp. 9-28, https://adsabs.harvard.edu.

SCHAEFER, B.E.

1985 "Predicting heliacal risings and settings", in *Sky and Telescope* LXX (1985), pp. 261-263.

1987 "Heliacal rise phenomena", in *Archæoastronomy* 11 (1987), S19-S33, https://doi.org/10.1177/002182868701801103.

WILLCOX, G.

2013 "The roots of cultivation in Southwestern Asia", in *Science* 341 (2013), pp. 39-40, doi: 10.1126/science.1240496.

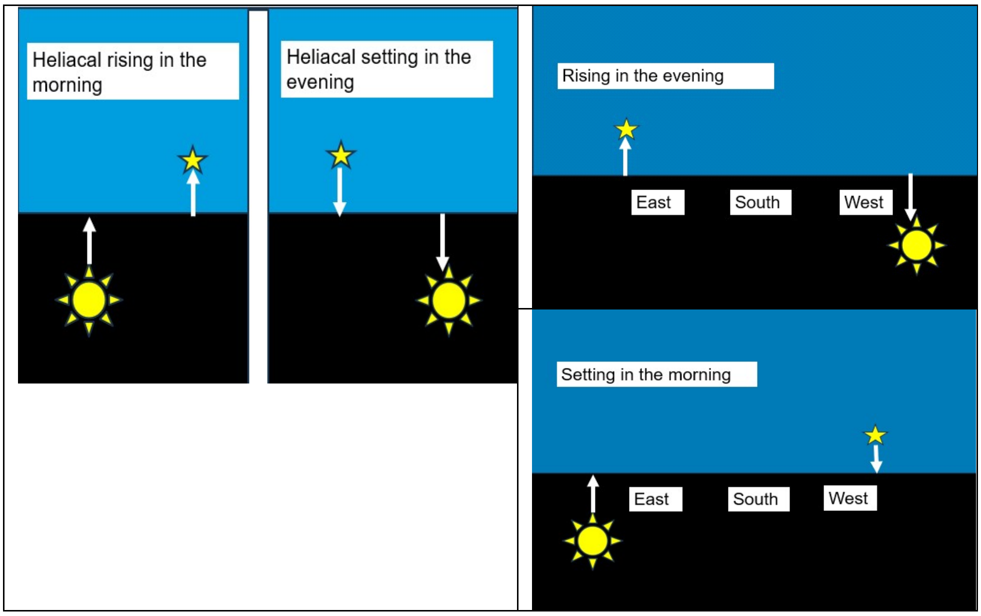

Fig. 1 - Schematic representations of the rising and setting of stars in the morning and in the evening, when the Sun is just below the horizon.