Major constructions in the Stonehenge complex are the Cursus and Woodhenge

Pavel Kalenda[1], Eva Kalendová[2]

Abstract

We analysed in the paper the possible purpose of the Great Cursus in the Stonehenge area.

We analysed the ephemeride of Sun and Moon and we found that the border lines of Great Cursus could help to determine the mutual position of all of three bodies – Earth, Moon and Sun, which repeats once per saros (app. 18 years). The moonrise in the beginning of saros, when the angle between Moon´s orbit and equator is the lowest, was in the direction of the Great Cursus during the first and last quarter of the Moon. Therefore, the people, who built the Stonehenge, could predict the solar or lunar eclipse 7 or 21 in advance.

The Stonehenge itself, which was built 500 years after Great Cursus, seems to be (from this point of view) only a „calculator“ of saros cycle, heritage place and superstructure of the Great Cursus.

Keywords

Stonehenge, Great Cursus, solar eclipse, prediction, saros.

1) Introduction

Although the Stonehenge itself was partly decoded as the observation of moonrise and sunrise or sunset during summer or winter solstices, “computer” of long-period cycles and old calendar (Lockyer 1909, Hawkins 1965, Castleden 1993, Johnson 2008), the purpose of other constructions still remains unclear. The recent geophysical and archaeological works on Great Cursus, which was built in late -Neolith age between 3630 and 3375 BC (Pearson et al. 2008), i.e. 500 years before Stonehenge itself, suggest that this area could be procession route during summer soltice (BBC News 2011). On the other hand many archaeologists reasoned that there was an astronomical purpose (Hawkins 1965, Manley 1989, Service & Bradbery 1979), however, the purpose and significance of the Cursus, as a whole, has not been clarified up to now because its rims don't point to any clear significant astronomical object. Burl (1987).

Our aim was to identify the possible astronomical purpose of so huge constructions as Great Cursus, Lesser Cursus and Woodhenge (see Fig.1), which significance can also be testified by the volume of work necessary to build it (ca 1 250 000 working hours), which is comparable to the Stonehenge itself (ca 1 500 000 working hours) (Castleden 1993, Broch et al. 2009).

The hypothesis about the connection between the direction of Great Cursus (the northern and southern rims have azimuths 84.6-84.7° and 83.1°, respectively), of Lesser Cursus (both azimuths are 74.9°) and sunrise, moonrise and other astronomical object rise was tested.

---

[1] IRSM CAS, V Holešovičkách 41, Praha, Czech Republic

[2] Technical University, 17. listopadu 2172/15 Ostrava-Poruba, Czech Republic

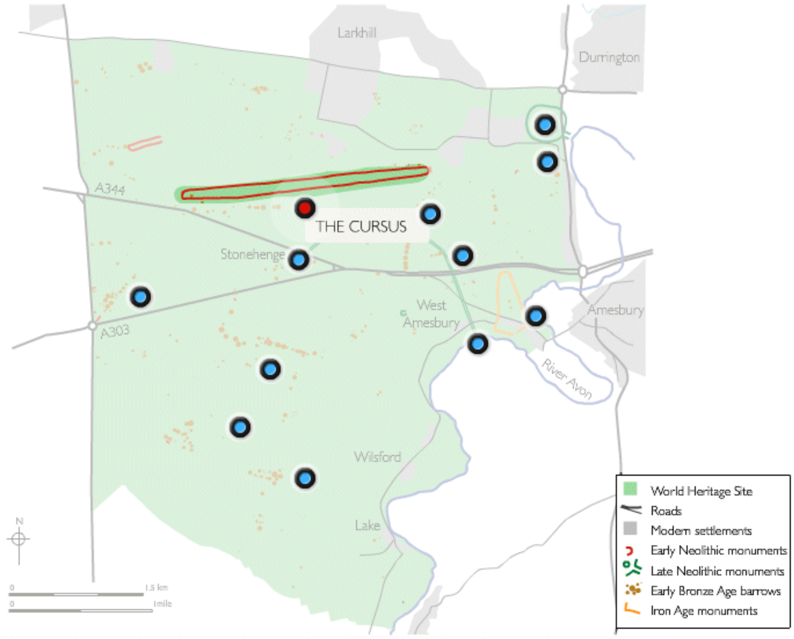


Fig. 1 The situation of the Great Cursus to the north of Stonehenge. In the NE corner is Woodhenge (south of Durrington walls) and Lesser Cursus is to the NW from Great Cursus.

2) Results of analyses

As the most probable purpose of all of construction in the Stonehenge area, which were tested, is the measurement of the mutual positions of three bodies – Earth, Sun and Moon in the space.

The most precise measurement of the positions is during the first and third quarter of the Moon, because in this way it is possible to determine the exact moment of the phase by the naked eye with a precision better than ¼ of a day (5 % of the radius), using only the simplest tools (a straight stick, comparison of terminator's curvature on the left and on the right sides, reading the illuminated and unilluminated part of the equator…) (see Fig.2).

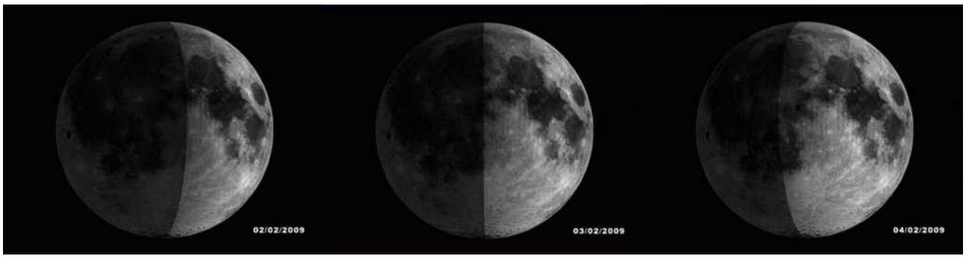
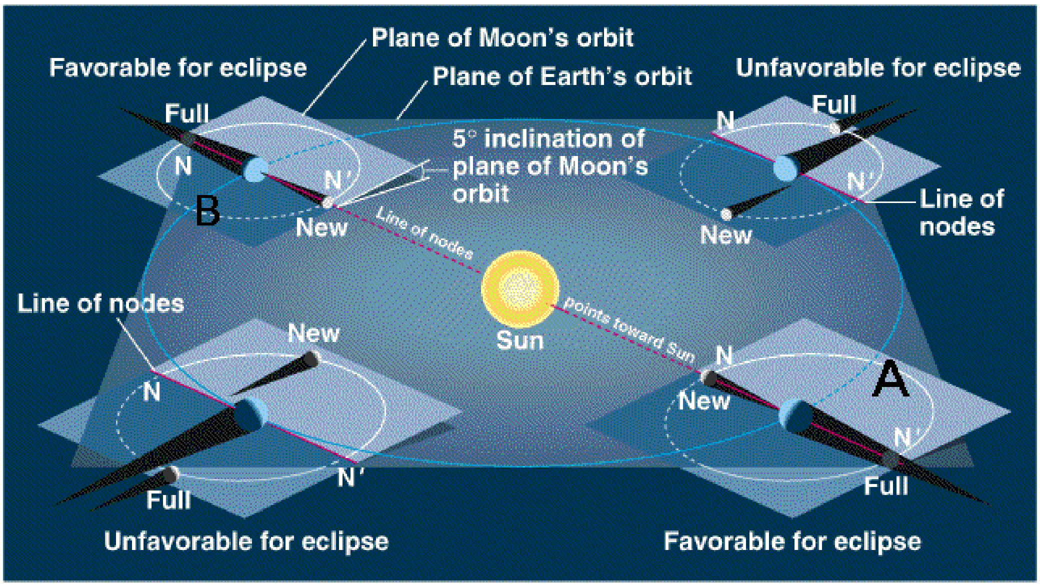


Fig. 2 Change of the terminator's curvature ±1 day of the first quarter

Other phases of the Moon could be measured much worse – the timing of the full Moon is practically impossible due to its bloom and opposite – the timing of new Moon is not visible. However, the moonrise during the firs quarter of the Moon is around noon, therefore only third quarter of the Moon is possible to be measured, because this moonrise is around midnight.

When the measurement will be making during the moonrise during its third quarter, it would be able to evaluate, where the Moon is on its orbit (see Fig.3).



©1997 Wadsworth Publishing Company/ITP

Fig.3 Four major model situations (orientations of the Moon's nodes line to the Sun) in relation to lunar and solar eclipses (O'Connell 2007)

If the position would be in one of the points A or B, than it could be possible to predict the solar or lunar eclipses 7 or 21 days in advance during the transition of the Moon through the ecliptic. Because the Earth rotational axis has the same angle with the respect to the ecliptic, the moonrise will be in the point A (or B) in the same azimuth during the last quarter.

We tested the positions of the Moon during the moonrise before the solar or lunar eclipses in 2010 – 2012 during the first quarter with the help of ephemerid generator JPL NASA Horizon (see Table 1). (the moonrises during the third quarter would give similar results)

Table 1 Solar and lunar eclipses in 2010-2012 (T-total, P-partial, A-annular); "event" means "suspicious" moonrise observable in Stonehenge

date	time (UT)	eclipse	region	event	days before	azimuth err.	phase err.
						degrees	degrees
15.1.2010	7:06	ASE	Indian ocean	24.12.2009	22	0,05	2,47
26.6.2010	11:40	PLE	Europe, Africa	5.6.2010	21	9,66	1,11
11.7.2010	19:35	TSE	Pacific ocean	5.7.2010	6	-3,44	-7,14
21.12.2010	8:18	TLE	Iran	28.11.2010	22	0,99	2,53
4.1.2011	8:52	PSE	Scandinavia	13.12.2010	21	5,73	0,51
1.6.2011	21:17	PSE	N.pole	25.5.2011	7	6,87	13,96
15.6.2011	20:14	TLE	Madagaskar	25.5.2011	21	6,87	13,96
1.7.2011	8:40	PSE	S.pole	8.6.2011	23	2,05	7,04
25.11.2011	6:21	PSE	S.pole	18.11.2011	7	-2,78	5,31
10.12.2011	14:33	TLE	China	18.11.2011	22	-2,78	5,31
20.5.2012	23:54	ASE	Kurily	29.4.2012	21	-15,11	-1,52
4.6.2012	11:04	PLE	Pacific ocean	28.5.2012	7	-1,37	3,53
13.11.2012	23:13	TSE	Pacific ocean	6.11.2012	7	-11,37	0,10

We can see that the "errors" in azimuth or lunar phase are too much in comparison with the lunar diameter (0,5°). One of the most precise moonrise was on May 28, 2012, when the "error" in azimuth was only 1.37° and "error" in phase was 3.53°. We could compare this position with the direction of the Great Cursus (long vertical abscissas on Fig.4) and with Woodhenge position in prolongation of Cursus (long vertical comb-like lines on Fig.4).

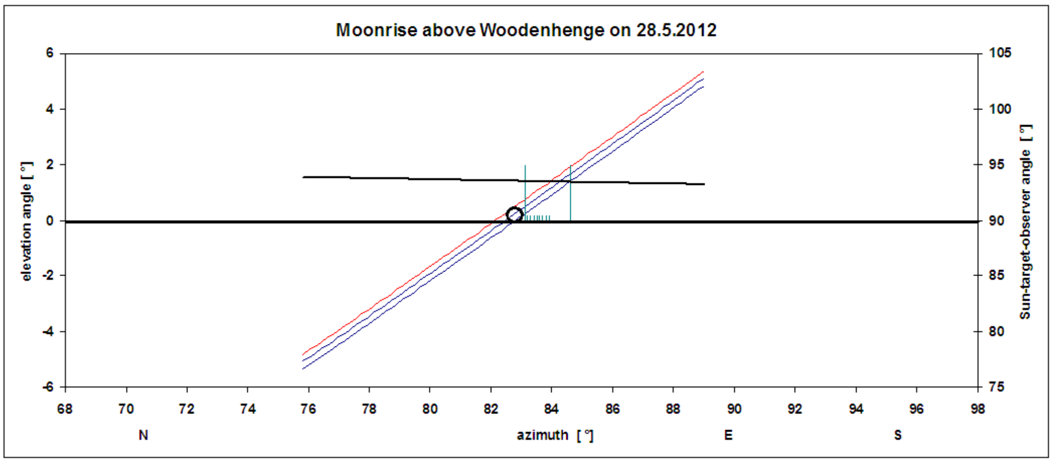


Fig.4 – Moonrise above Woodhenge and Great Cursus on May 28, 2012)

This measurement can be confirmed by measurement at Cuckoo stone, Woodhenge and “Kiwi” saddle (see Fig.5).

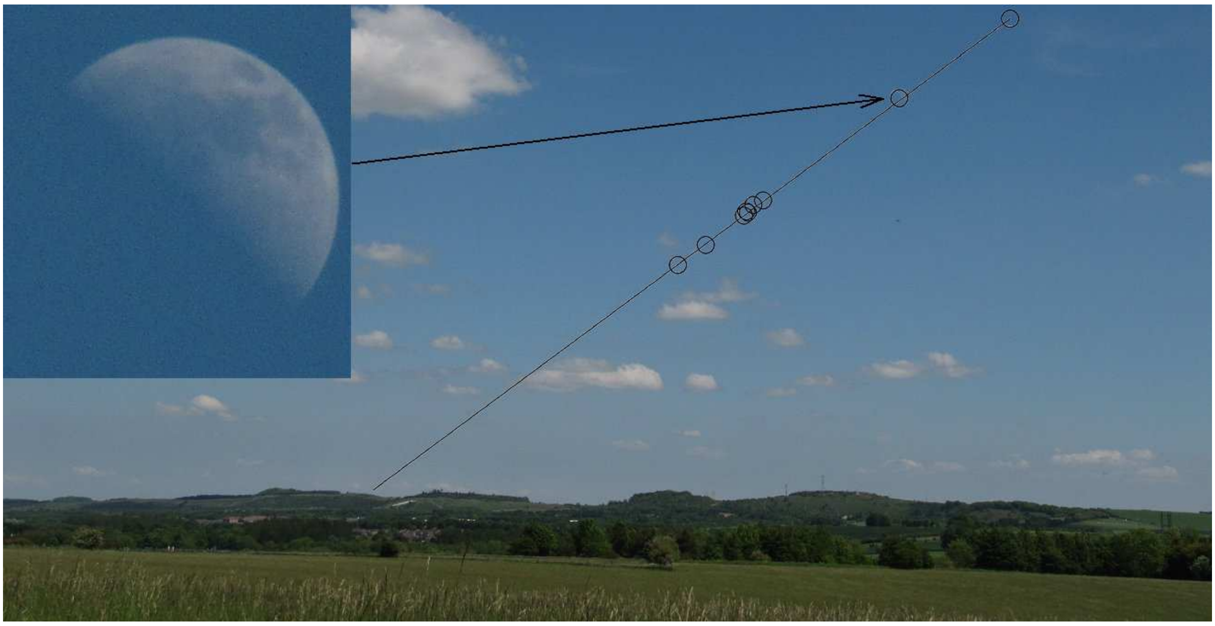


Fig. 5 a) Cuckoo stone – the stick marks the same azimuth of 83.9° as Great Cursus, b) The stick (and the visor in the stone) marks the "Kiwi" saddle on the horizon, c) The moonrise on May 28, 2012 – mosaic of 10 pictures taken by authors.

Which is most important, the moonrise in the same quarter as at Great Cursus is in the direction of Lesser Cursus exactly one month before or after the position at Great Cursus, which means that the measurement at Lesser Cursus could predict or confirm the results on the Great Cursus, but with lesser precision.

Because the moonrises are not exactly in the direction of Great Cursus (or Woodhenge or Kiwi saddle from Cuckoo stone) we analysed the azimuths of moonrise during the first or last quarter during the whole lunar nodal cycle. Data of the moonrise (time and azimuth) and of the angles of the Sun-Moon-observer (corresponding to the Moon's phases) were obtained from the Ephemerid Generator JPL NASA (Horizons 2011). Data of solar and lunar eclipses was obtained from NASA (NASA eclipses 2011) and Wikipedia (Wikipedia – eclipses, 2011). Solar eclipses observable from the British Isles were taken from the work of Beard (2001). Eclipses were plotted with azimuths of moonrise above Woodhenge (see Fig. 6, 7 and 8).

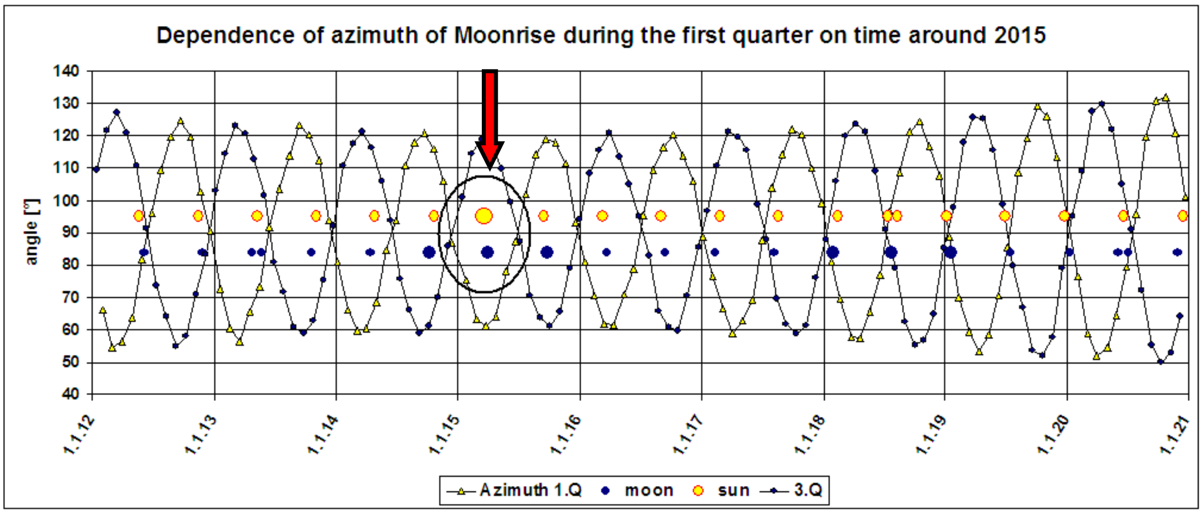


Fig. 6 Solar and lunar eclipses between years of 2012 and 2021 and the azimuths of the moonrise in the first and last quarter. Total eclipses of Sun and Moon are highlighted.

In Fig. 6 the total lunar eclipses and the total solar eclipse on 20.3.2015, which will be visible from the Atlantic Ocean north of British Isles, are highlighted. Three months before and after this total solar eclipse the Moon will be rising above Stonehenge in the first, as well as, the last quarter very close to the ideal azimuth 83.9° (86.9° and 85.9° in the first quarter, and 87.2° and 87.2° in the last quarter). In addition, at this time the Moon's orbit has the lowest inclination to the Earth's equator, and so total eclipses are more probable.

So, if the azimuth of 83.9° determines the moonrise in the significant phase of the Saros cycle, a similar situation will also be before, or just after, the great total solar eclipse 1715, which was visible in the whole southern Britain (Halley 1714, Beard 2001). As seen in Fig. 7, after this eclipse the Moon rose in the first as well as last quarter near an azimuth of 83.9° (85.1° and 85.6°). There was an analogical situation also between the partial solar eclipses in 1710 and 1711 and before the partial eclipse in 1718, which were visible from the British Isles. Both figures 6 and 7 show that the moonrises in an azimuth close to 83.9° during the first as well as last quarter may occur approximately 4x during the Saros. One of these situations comes at the time of the least relative inclination of the Moon's orbit in relation to the Earth's equator. This situation could be marked (by arrow) as the beginning of a new Saros.

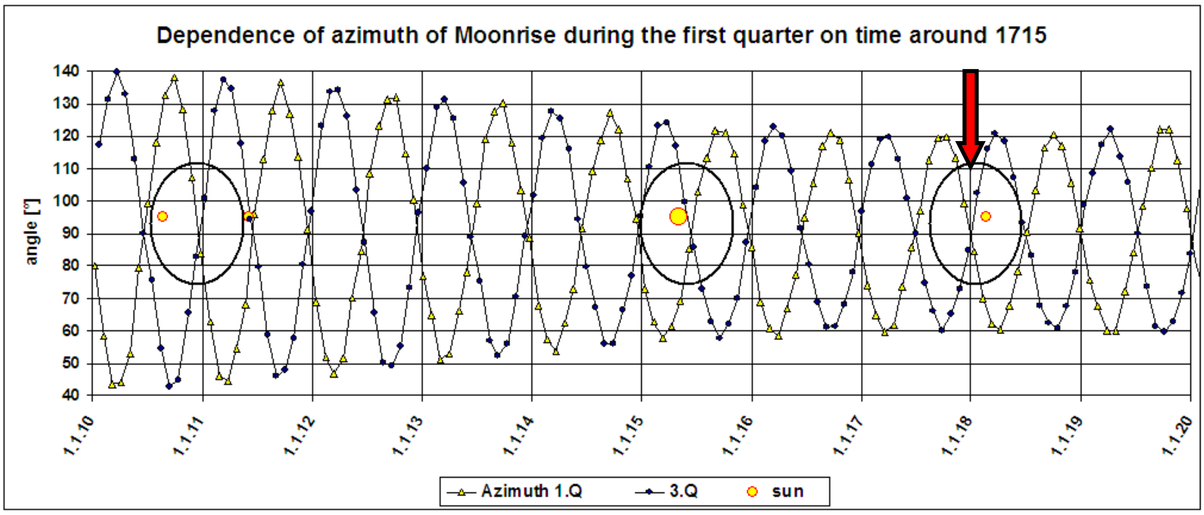


Fig. 7 Solar eclipses between 1710 and 1720 plotted with the azimuth of moonrises in the first and last quarter. The total solar eclipse visible from Stonehenge is highlighted.

The Ephemerid Generator of NASA (Horizons 2011) makes it possible to calculate, precisely, the Moon's ephemerides back to the year 3000 BC, and so the moonrises were calculated for the whole first decade of the 3rd millennium BC (see Fig. 8). Again the assumption was confirmed, that the most „precise" alignments of Moon behind Woodhenge occur just in the period of the lowest inclination of Moon's orbit in relation to the Earth's equator (marked by arrow). In the year 2993 BC, moonrises with an azimuth of 84.0° in the first quarter and 82.2° in the last quarter occurred. One month earlier, the Moon rose to an azimuth of 74.9° in the first quarter, and one month later to an azimuth of 72.0° in the last quarter. These values may be related to the orientation of Lesser Cursus, which could in this way anticipate or confirm the measurements made at Great Cursus.

As the precession of the Earth's axis has a period of ca 25 800 years, we are now approximately in one quarter of a Platonic year since the time when the Cursus was built. Present alignments are not identical to those observed by Stonehenge inhabitants 5500 years ago, though the major ones may again coincide with a similar position of the Solar system to the Galaxy.

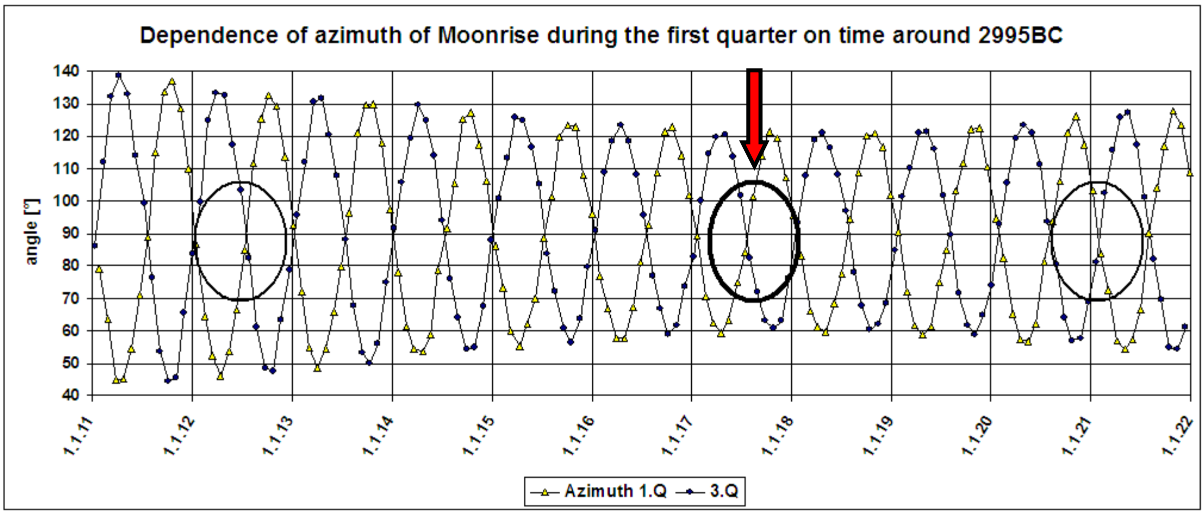


Fig. 8 Azimuths of the moonrise in the first and last quarter between the years 2999 BC and 2988 BC

3) Discussion

As we are gradually finding out, all nations in Neolith (early Stone Age) or Eneolith (late Stone Age) were fascinated by the night sky, which, among other things, was used for orientation in space and time. This was very important because agriculture was at its beginnings and was highly dependent on weather, which largely determined a good or poor harvest. As well as in the ancient Egypt, where the architects always aligned pyramids to cardinal points with help of the stars Kochab and Mizar, which laid on the N-S straight line, the cultures in Britain or today's France used the risings and settings of Sun at significant moments of the year as the basis for orientation. Usually the summer solstice was observed, in the Braiport bay (Gladwin 1985), alternatively a "double" sunset, e.g. in Güímar, Tenerife (Aparicio 2005), the sunrise in times of the first and third quarter of the year (Quarter day sunrise, in the beginning of May and August) (MacKie 2002), or the sunrise in the winter solstice as in Newgrange, Ireland. The same principles of orientation of buildings and determination of the beginning of the year or of significant periods were also taken by Celts in continental Europe (Vosolsobě 2004).

In the first period of the formation of the Stonehenge complex, the Great Cursus was built. Stonehenge itself was built 500 years later. The facts and the cost for building the Cursus testify to the significance of this construction. From that it can be assumed that the importance of the Cursus was primary and Stonehenge secondary.

If we admit, that the Great Cursus was used for the measurements of azimuth of the moonrise (above the horizon), it can be shown that ca. 5000 years ago the Moon in its first and last quarter rose in this direction four times in 18.6 years, when Moon, Sun and Earth came into the same positions (including the inclinations of their orbits and rotation axes) Therefore, it is possible to predict similar situations. If the builders of Stonehenge marked out the northern and southern limits of the Great Cursus according to moonrises before important lunar (perhaps also solar) total eclipses, which occur, most likely, when the Moon's orbit has its lowest inclination to the Earth's equator, they could predict similar total eclipses in the future. In this way they could date the beginning of Saros. In combination with the measurement of the Sun’s position at the time of the summer solstice they could obtain long-term calendar equally as precise as that of Mays, and more precise than that of the ancient Egyptians or Mesopotamians (predicting of lunar eclipses since the 7th century BC).

At the time of the construction of the Stonehenge (phase 1), the knowledge of the long-term calendar was already fixed and past onto future generations. Stonehenge itself, mainly 56 Aubrey holes, functioned rather for records and calculations based on the observation and measurement in the Cursus. Builders divided Saros into 18.61 years and each year into 4 parts involving 3 months of 30 and 29 days. The year began, probably, by the summer solstice, and the day at the moment of sunrise. The determination of the year's beginning was easy, but the detemination of the beginning of Saros was a task for several generations, taking into account the life expectancy around 24 years. Thanks to the geniality of the founders and the transferring of measurement results to new generations it managed to observe the intersection of both cycles (lunar and solar) and in this way obtained the calculation of the repeating of mutual positions of Sun, Moon and Earth in time. So they very likely were able to predict, with high accuracy, the lunar, and probably also solar, eclipses in the region of Stonehenge.

However, ca. 2000 years after building the Cursus the descendants of the founders probably found out, that the solar eclipses were becoming less regular (due to the precession of Earth's axis „their“ beginning of Saros came out of the optimal period, when the planes of Moon's orbit and Earth's equator are least deviated) and the calendar of Saros ceased working. Perhaps from that reason further building of the Stonehenge complex was stopped. At present, ca. 5500 years later than the construction of the Cursus started, the situation is recurring, when the Moon rises (in the first and last quarter) in the prolongation of the Cursus again at the beginning of Saros, which, however, has shifted relatively to the old Saros by ¼ of the Platonic year. Thus, also at present, we could predict the beginning of Saros from the observations in the Cursus, and predict lunar eclipses and, after several generations, also total solar eclipses, visible from Britain.

Conclusion

Both the northern and southern boundaries of the Cursus probably mark the limiting directions of moonrise during the first and last quarters before the lunar or solar eclipse at the beginning of Saros. The limits being to the "left" from northern boundary of Cursus and to the "right" from the southern one. The angular distance of the moonrise from the central line of the Cursus could determine, how deep the eclipse will be. Woodhenge and menhirs in the horizon may have served to scale the distance of the Moon from an absolutely exact position, when all the 3 bodies are in a straight line at the time of the full moon (lunar eclipse) or new moon (solar eclipse).

All the simple tools (grooves and stones in the ground, menhirs in the horizon, vertical stems, reading of the phase by a stick) enabled observes to obtain the Moon's phase with a precision of ¼ of a day (6 hours) and angles with a precision of 0.2° horizontally near Woodhenge, 0.5° in angular distances from Woodhenge larger than 1.5° (3 Moon diameters), and 0.2° vertically. This made it possible to predict total as well as partial eclipse 7 or 21 days before the event.

With the help of the Heel-stone and the hollows in the east and west of the Cursus the builders of Stonehenge could determine the beginning of the calendar year (summer solstice). With hthe lp of the Cursus and Woodhenge they could date the beginning of Saros. So they had at their disposal a calendar, which could predict annual periods as well as long-term cycles of lunar and solar eclipses.

Construction of the Stonehenge complex probably started by marking out the rim lines of the Cursus. In the elevations on the Cursus ends pits were made, which then determined the position of the Heel-stone. In this way the „measuring“ complex was built up. Following the building of the megalithic construction Stonehenge had probably more archive, documentation and religious purpose, and measurement results were saved there via setting pointers of the course of the annual cycle and of the Saros by moving marked stones in the Aubrey holes (Hawkins 1965).

References

Aparicio A.J. (2005): Las Pirámides de Güímar: mito y realidad. http://www.iac.es/galeria/aaj/p_aaj_recension_piramides.htm.

Archelology (2011): http://www.archaeology.ws/stonehenge.html (http://www.youtube.com/embed/YizLYZadoVE)

BBC News (2011): Archaeologists make new Stonehenge 'sun worship' find. http://www.bbc.co.uk/news/uk-england-wiltshire-15917921.

Beard, D. (2001): A millennium of British solar eclipses (1501-2500 AD). Journal of the British Astronomical Association, vol.111, no.2, p.88-98.

Broch, Crannog and Hillfort (2009): The cost of building the Stonehenge complex. Wessex Archeology. http://mitchtempparch.blogspot.com/2009/01/cost-of-building-stonehenge-complex.html.

Burl, A. (1987): The Stonehenge people. J.M.Dent, London.

Castleden, R. (1993): The making of Stonehenge. Routledge, London, 305 pp.

Gladwin, P.F. (1985): *The solar alignment at Brainport Bay, Minard, Argyll.* Ardrishaig: Natural History and Antiquarian Society of Mid Argyll.

Halley, E. (1714): Observations of the Late Total Eclipse of the Sun on the 22d of April Last Past, Made before the Royal Society at Their House in Crane-Court in Fleet-Street, London. by Dr. Edmund Halley, Reg. Soc. Secr. with an Account of What Has Been Communicated from Abroad concerning the Same, Phil Trans R Soc 29: 245-262.

Hawkins, GS (1965). *Stonehenge Decoded*. ISBN 978-0880291477.

Horizons 2011 : Ephemeris generator. JPL NASA. http://ssd.jpl.nasa.gov/horizons.cgi#top.

Johnson, A. (2008): Solving Stonehenge: The New Key to an Ancient Enigma. 288 pp. Thames and Hudson.

J.N.Lockyer (1909): Stonehenge and Other British Stone Monuments Astronomically Considered. 516 pp.

MacKie E.W. (2002): The structure of British Neolithic society a response to Clive Ruggles and Gordon Barclay. Antiquity. http://antiquity.ac.uk/projgall/Pre2003/mackie/mackie.html

Manley, J. (1989): Atlas of Prehistoric Britain. Oxford University Press.

O’Connell (2007): Astronomy 121. http://www.astro.virginia.edu/class/oconnell/astr121/eclipses-stonehenge.html

NASA – solar eclipses (2011): http://eclipse.gsfc.nasa.gov/solar.html

NASA – lunar eclipses (2011): http://eclipse.gsfc.nasa.gov/lunar.html

Pearson, M.P., et al. (2008): Stonehenge Riverside Project. „Excavation V“. http://www.shef.ac.uk/archaeology/research/stonehenge/stonehenge07-05.

Service, A., Bradbery. J. (1979): Megaliths and their Mysteries. Macmillan press.

Vosolsobě S. (2004): Pozorování východu Slunce při letním slunovratu z valu keltského opevnění Semín v Českém ráji. (Observation of the sunrise in the summer solstice from the wall of Celtic fortification Semín in Bohemian paradise)(in Czech) http://hrubaskala.net/pdf/vtrosky.pdf.

Wikipedia – eclipses UK (2011): http://en.wikipedia.org/wiki/List_of_solar_eclipses_visible_from_the_United_Kingdom_1000%E2%80%932090_AD.