

What is a lunar standstill III¹?

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ABSTRACT – Prehistoric monument alignments on lunar standstills are currently understood for horizon range, perturbation event, crossover event, eclipse prediction, solstice full Moon and the solarisation of the dark Moon. The first five models are found to fail the criteria of archaeoastronomy field methods. The final model of lunar-solar conflation draws upon all the observed components of lunar standstills – solarised reverse phased sidereal Moons culminating in solstice dark Moons in a roughly nine-year alternating cycle between major and minor standstills. This lunar-solar conflation model is a syncretic overlay upon an antecedent Palaeolithic template for lunar scheduled rituals and amenable to transformation.

IZVLEČEK – Poravnava prazgodovinskih spomenikov na Lunine zastoje se trenutno sklepa za razpon horizonta, perturbacijo, prehod Lune, napovedovanje Luninih mrkov, polne lune na solsticij in solarizacije mlaja. Prvih pet modelov ne zadostuje kriterijem arheoastronomskih terenskih metod. Zadnji model lunarno-solarne zamenjave temelji na vseh opazovanih komponentah Luninega zastoja – solarizirane obrnjene Lune, ki kulminirajo v mlaju v solsticiju v devetletnem izmeničnem ciklu med največjim in najmanjšim zastojem. Ta lunarno-solarni model je postavljen na temeljih predhodne paleolitske predloge za načrtovanje lunarnih ritualov in je dojemljiv za preobrazbe.

KEY WORDS – lunar standstill; synodic; sidereal; lunar-solar; syncretic

Introduction

Thom's publications between 1954 and 1975 galvanised a generation – with horror among many archaeologists and inspiration for others, some of whom began reconstructing the discipline of archaeoastronomy (*Ruggles 1999.1–11, 275*). However, since the 1980s, an extended re-evaluation of his work within archaeoastronomy has questioned many of his claims that some monuments of prehistoric North-West Europe were aligned on the Sun's solstices and the Moon's standstills (*Ruggles 1999.49–67*). Nevertheless, some leading archaeologists in Britain have begun to embrace the evidence for prehistoric monuments' 'astronomical' alignments (*Thomas 1999; Parker Pearson 2012*). To unravel what has been lost and gained after half a century of scholarly endeavour, we need to re-examine the

properties of prehistoric monument 'astronomical' alignments to trace their variable engagement by different researchers.

Solar and lunar alignments

A prehistoric monument alignment on the Sun and Moon is an architectural arrangement of materials orientated on a horizon position locating where either luminary rises or sets. At summer solstice, the Sun rises in the north-east and sets in the north-west. Six months later at winter solstice, the Sun rises in the south-east and sets in the south-west. For any given time period, latitude and horizon altitude these horizon positions are fixed. At the latitude of Stonehenge, the azimuths of the solstice Sun are

¹ The first version was my 2007 paper for the 2006 SEAC conference in Rhodes, and the second was an unpublished paper for the 2014 SEAC conference in Malta. This latest, third, paper is an elaborated version of the second paper. It should be read alongside the Forum debate 'What is the minor standstill of the Moon?' in *Skyscape Archaeology 2(1): 67–102*.

about 40° above and below the west-east axis (Fig. 1). From three days before and after the solstice, the unaided human eye cannot detect the 2′ change from its solstice limit, and in seven days it remains within 11′ of its solstice extreme (Ruggles 1999.24–25). Each of the four solstice rise and set events therefore lasts for at least one week in prehistory. Outside of the two weeks of both solstices, for about 5 1/2 months, the Sun’s horizon rise and set positions slowly begin to change towards its greatest rate of daily horizon change during the equinoxes of 24′ per day – three quarters of its 32′ diameter. A monument’s single solstice alignment therefore abstracts out just 1 horizon event repeating for seven days out of a possible 178² solar alignments. While a severe selection of the Sun’s movements, nevertheless these horizon positions do not contradict, and may act as proxies, for the seasonal changes marked by the full suite of the Sun’s movements.

A monumental lunar alignment is a more complex matter and, in important respects, quite different from a solar alignment. For while the Moon also has horizon range limits just as the Sun does, instead of being fixed they vary over an 18.61 year cycle. Thom named this phenomenon the lunar standstills, which every 9.3 years alternate between major and minor standstills (Thom 1971.19, 124, 173). The range of the Moon’s horizon rises and sets complete over the course of the 27.3 day sidereal month – the time it takes to complete its circulation of the earth. During a major standstill of the Moon at the latitude of Stonehenge, the Moon rise and sets about 10° of azimuth further north and south on the horizon than the Sun ever reaches during its solstices. After a period of over a year, the Moon’s orbital plane about the earth begins to reduce from 5° above the earth’s equatorial plane about the Sun to, 9.3 years later, 5° beneath the equatorial plane. This minor standstill’s horizon range limits are now about 10° within the Sun’s solstice positions at the latitude of Stonehenge, and for over a year the Moon returns to these ‘same’ positions (Fig. 1). The Moon therefore has eight horizon limits, unlike the Sun’s four.

Throughout its 18.61 year cycle, the Moon rises and sets on intermedi-

ate horizon positions between these changing horizon extremes of the Moon. Only during the period of a lunar standstill, major or minor, does the Moon return to the same small region of the horizon, when it is at its standstill range limit. It is therefore a selection of just one horizon moment during one day or night out of about 27 days and nights during two periods of the 18.61 year cycle. While, like the Sun, a lunar alignment is therefore a selection from all possible horizon positions, unlike the Sun, it is not an observation repeated over the course of a week, but a one-moment time-lapsed observation separated by periods of about 27 days during either the major or the minor standstill about every nine years. When the Moon returns each sidereal month to its horizon alignment, it does not repeat its earlier lunar phase. While it takes the Moon 27.3 days to circle the earth, during that time the earth is also moving around the sun, and the three bodies re-align at the completion of the synodic month in 29.5 days. Therefore, a lunar alignment presents phase sequences which are about 2.2 days earlier phases than the previous lunar phase alignments. An alignment on a lunar standstill therefore selects lunar phases in reverse sequence to when, contrarily, we view the Moon’s phases over the course of a synodic month. Lastly, as the Moon circulates the Earth, which itself circulates the Sun, the changing gravitational interaction of all three bodies are reflected in small differences in the position of the maximum range limits of either standstill. Modern heliocentric positional astronomy has shown that at different positions in its orbit of Earth, these perturbations exhibit a regular sinusoidal alternation of the order of about 10′ of arc (Thom 1971.15–27; Sims 2006).

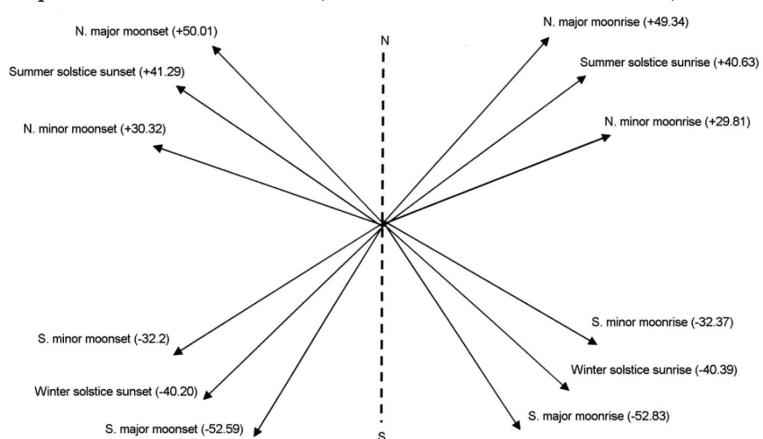


Fig. 1. Plan view of natural horizon alignments on Sun’s solstices and Moon’s standstills at Stonehenge 2500BC (bracketed numbers are degrees of azimuth above or below the west-east axis).

2 Subtracting the 14 days of the two solstice weeks from 365 days (=351), dividing by two for the outgoing and returning Sun overlapping on the same alignment (=175.5), and then adding 2 for the two solstice events, each of one week (=178).

In summary, just like a solstice alignment, a lunar standstill alignment is a selection of a few horizon positions from its total rise or set positions, but unlike the Sun, this alignment is not a simple proxy for other characteristics of the Moon. Instead of four solstice horizon positions, there are eight lunar standstill horizon range limits of the major and minor standstills; its sidereal properties are cryptic, not redundantly obvious as are the solstices; they reverse its lunar phases, and at its horizon limits exhibit small perturbations. It is in the variable interpretation of these similarities and differences between solstices and standstills that scholars in archaeoastronomy have marked out six different approaches to lunar standstills. There is therefore no consensus within archaeoastronomy on how to interpret lunar standstills, and these divisions require resolution (*Sims 2013a*).

To evaluate the strengths and weaknesses of each of these six positions, I will refer to the archaeological details at the Stonehenge monument complex, since this is, arguably, one of the culminating achievements of a wider cosmology extant throughout Neolithic Europe. This late Neolithic and Early Bronze Age site has attracted close scholarly attention, which has amassed enough fine detail to allow us to design discriminating tests between the available interpretive models.

Lunar standstills as horizon range

According to Fabio Silva and Fernando Pimenta (*2012, 206*), the majority view within archaeoastronomy is that lunar standstills were selected by prehistoric monument builders for the Moon's extended horizon range displayed only during the major standstill of the moon. Throughout this period of over a year, every thirteen or so days the Moon reaches its northern and southern limits at azimuths roughly 50° above and below the west-east axis at the latitude of Stonehenge, which is about 10° beyond the Sun at its solstice horizon positions (Fig. 1). Between these periods, the Moon's daily and nightly changes touch intermediate horizon positions and pass through the range limits of the minor standstill, which the Moon reaches 9.3 years later. When the Moon is at its minor standstill, its azimuth is about 30° above and below the west-east line, well within the Sun's azimuth at about 40°. Compared to the major standstill, this approach considers that since the Moon passes through this position for much of the 18.61 year cycle, the minor standstill is both difficult to observe and has little significance because

of the narrower width of its horizon range. Gauging the lunar standstills against the Sun's horizon range is therefore a solarist attribution that the Moon at a major standstill is a 'superior sun' by virtue of wide horizon range alone. Authors who adopt this view emphasise the period of 18.61 years as the time span of lunar standstills.

However, César González-García (*2016*) has shown that it is not difficult to observe the minor standstill of the Moon. During this period, the Moon's horizon range is at its narrowest, while the number of rises and sets remain the same at just over 27 events each sidereal month. This produces a proportionally increased bunching of maximum horizon events which is greater than the maximum horizon range bunching for both the Moon's major standstill and the Sun's solstices. Further, if the solarist understanding of the prehistoric appropriation of lunar standstills is correct, then it would predict that no monuments in prehistory would have alignments on the minor standstill of the Moon beyond those of chance. This is incorrect. Clive Ruggles (*1999, 74–76, 95*) has shown that Scottish recumbent and West Scotland rows have statistically significant alignments on both the southern major and minor standstills, as has Aubrey Burl (*1981*) for the Clava Cairns. Furthermore, along the West Kennet Avenue at Avebury, Lionel Sims (*2015*) has shown that across paired stones 1–37, out of 362 possible alignments, 145 solar and lunar alignments can be found. Using Bernoulli's Law, so accounting for possible overstatement from straight sections along the avenue with a regular horizon, Sims shows that this is a possible chance occurrence for 3.3 in every million times. Within these 145 alignments, 21 are on solstices, 31 on major standstills and 48 are on minor standstills. The rejection of minor standstills as chance alignments therefore does not meet the requirements expected in archaeoastronomy field methods. Emphasising the Moon's extended horizon range during the major standstill is more an extemporary field method device to distinguish a monument's possible orientation on the Sun. But in its rejection of the minor standstill of the Moon, this approach has failed to lay the basis for investigating what properties it may share with the major standstill.

Major and minor standstills as separate phenomenon

The second type of archaeoastronomy theory considers the minor standstill of the Moon as requiring special explanation separate from that of the major

standstill, which is understood to be defined by its wide horizon range. There are currently two versions of this approach – North’s (1996) alternating perturbations and Silva’s and Pimenta’s (2012) crossover model.

North showed that, while in plan view Stonehenge is gaps surrounding an empty space, in elevation view, paradoxically, it is an ‘obscuration’ device of a seemingly near-solid mass of stone when approaching it from the north-east uphill along the Avenue and past the Heel Stone. Viewed from the Heel Stone, two windows can be seen one above the other, framed by the Grand Trilithon and the outer-circle lintels (Fig. 2). From the right-hand side of the Heel Stone, the lower window frames the setting winter solstice sunsets, and from the left-hand side of the Heel Stone at an altitude of about 4–5°, the upper window captures the setting southern minor standstill moonsets. North considered these two alignments separately and suggested that the southern minor standstill moonset perturbations would have been seen in this upper window smoothly zig-zagging left and right four or so times over the course of a minor standstill year. North suggested that since the Sun does not do this when at its solstice horizon range limit, then the people of Stonehenge would have considered this property of the southern minor standstill magical and worthy of a monument (North 1996.441–474; Sims 2006).

It is not clear that the Moon’s perturbations will be observed at Stonehenge, as the architecture of the monument does not assist such high-fidelity observations. The distance from the Heel Stone to the Grand Trilithon is about 88m, which is not enough to provide the resolution to discern the movements of a few minutes of arc of any (obscured) edge of the lunar disc. From the Heel Stone, the height of the upper window would have subtended an angle of about 10′ and a width over one degree. Since the lunar disc is about 31′ in diameter, this upper window would have framed just a descending sliver of the Moon in its 1–2° of oscillating azimuths at its standstill horizon range limits (see

below). That is assuming the perturbations could be seen distinct from other movements of the Moon. As the Moon is constantly changing its declination³, and since the moment of the geocentric declination extreme is generally independent of the moment when the Moon meets the horizon, by the time the Moon is on any horizon, its declination is at a different value from its perturbation limit. Therefore, there will be no regular zigzag horizon movement of the Moon at its minor standstill limit, but irregular movements. This can be seen in Figure 3, which contrasts the smooth sinusoidal perturbations of the Moon when orbiting the Earth with how these become irregular oscillations by the time the Moon sets on the horizon (see also Sims 2007).

Finally, every standstill at its horizon limit, whether major or minor, north or south, rising or setting, exhibits similar (irregular) perturbations to that of the southern minor standstill moonsets, so either all of these are equally ‘magical’ or none of them are. North defines the southern minor standstill by the boundary oscillations of the lunar horizon range limits, and the major standstill by its greater horizon range than that of the Sun, without interrogating the shared properties of both. This model also therefore emphasises the period of 18.61 years between major standstills, and misinterprets minor standstills.

Silva’s and Pimenta’s winter solstice lunar crescent crossover model, the second within this group, offers an alternative explanation to that of alignments on

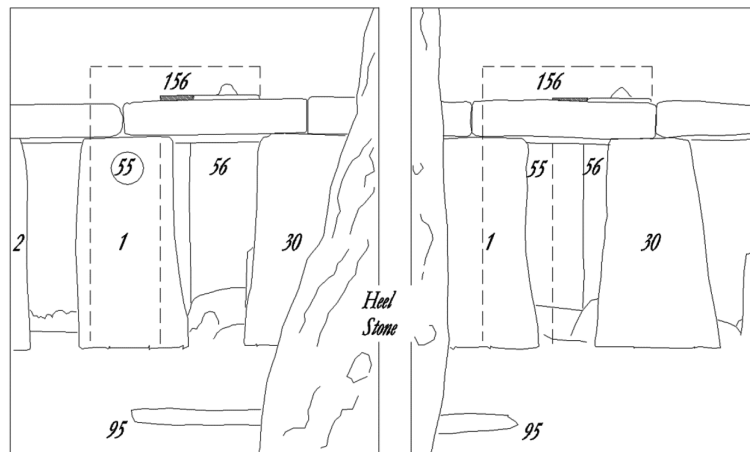


Fig. 2. The lower and upper gaps through the central axial stones at Stonehenge as seen from the left- and right-hand sides of the Heel Stone (North 1996.446). Numbering follows the accepted notation for each stone.

³ This is the measure used in modern heliocentric positional astronomy, and is the number of degrees above or below the celestial equator. In the geocentric flat earth cosmology of prehistory, a concept of declination would have carried no meaning. Instead, some concepts equivalent to our ‘azimuth’ and ‘altitude’ would have been used.

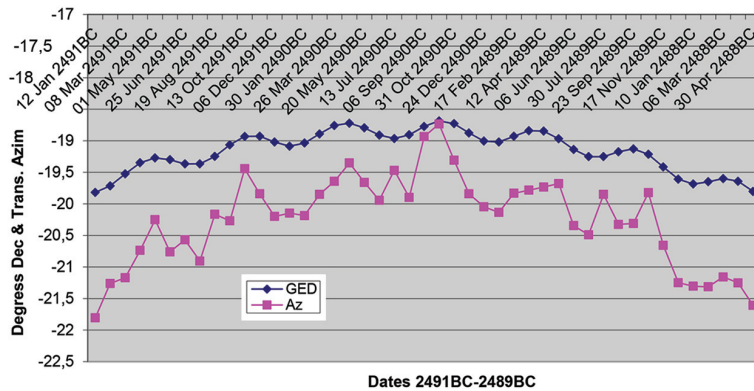


Fig. 3. Contrast between the Geocentric Extreme Declination of the Moon (GED) 2491–2488 BC and Azimuth (Az) of the southern minor standstill Moon setting in the Upper Window at Stonehenge. Note: Azimuth values have been transformed to fit the declination scale, and should be examined for shape, not values, alone.

the minor standstill of the Moon. They demonstrate that during summer and autumn, the first crescent Moon always sets to the left of the Sun’s horizon setting, but within a period of 150 days over winter the Moon switches and sets to the right of the Sun’s setting position. The pattern of alignments for this crossover event is a non-Gaussian distribution with a marked modal frequency which coincides with that of the southern minor standstill of the moon. Any monument with an alignment on the minor standstill would, the authors suggest, be better explained by this annual event. According to the authors, the preferred function for the crossover event would have been to mark annual calendrical calculations, while the major standstill of the Moon is best explained by its wide horizon range (Silva, Pimenta 2012, 202, 206).

While the authors claim that the Sun crosses over the first crescent Moon at the winter solstice, during the 2014/2015 minor standstill of the Moon the actual date of the crossover was the 12th December, not the solstice of 21st December. Not just the time, but the horizon position of the crossover event is also highly variable. While the azimuth band for the range limit of the minor standstill is only about 1–2° (see below), that of the first crescent winter crossover horizon event is spread over an azimuth range of about 26°, a qualitatively higher order of magnitude than that of all lunar standstills. The Stonehenge axial upper window, which captures all the southern minor standstill moonsets, would not be able to capture about 89% of these crossovers.

It remains to be explained why the non-Gaussian distribution of the first lunar crescent crossover with the Sun has a peak which coincides with the south-

ern minor standstill horizon moonsets. A crossover event is an amalgam of the properties of two variables – the movements of the Sun and those of the Moon. To disentangle conjoint influences, we need to elaborate their separate effects. Consider first when the Moon is at the southern minor standstill. For this year and adjacent years, the Moon’s horizon range does not move much further south than when within 10° of azimuth or so of the Sun’s horizon range. Only when the Sun starts to leave its winter solstice declination and begins to set further north on the horizon does it approach close enough to the Moon for a crossover to occur.

Therefore, while the event will coincide or be close to the southern minor standstill declination, it cannot take place at the winter solstice. Since Stonehenge has a lower window aligned on winter solstice sunset, the crossover model cannot explain the monument’s conflation of the Moon and Sun. Now consider when the Moon is at the major standstill. The Moon then sets much further south on the horizon than the Sun ever reaches, but the Moon’s horizon movements from south to north take 13/14 days, while those of the Sun take 6 months. The Moon’s movements will now allow the crossover event to take place when the Sun is still at, or close to, its winter solstice horizon position, but not at the horizon position of the southern minor standstill. Therefore, this event will coincide with a winter solstice declination, but it cannot take place when the Moon is at the southern minor standstill declination.

We now turn to the Moon’s movements when either expanding or contracting its horizon range and can cross over with the Sun. During this inter-standstill period, when the Sun has moved to the horizon position of the southern minor standstill about 6 weeks after the winter solstice, the Moon will cross over the Sun once it has left its southern horizon limit. In both cases, the Sun is not the winter solstice Sun, and neither is the Moon the southern minor moon. In aggregate, these separate effects create the non-Gaussian distribution, with a peak that coincides with the southern minor standstill, yet it will only rarely take place at winter solstice; most frequently, it will take place when the Moon is not at the southern minor standstill, and it will never take place during the southern minor standstill at winter solstice.

Therefore, a monument aligned on the minor standstill of the Moon and the winter solstice Sun cannot be explained by the crossover model.

The shared properties of Major and Minor lunar standstills

The third group of theories for lunar standstills identifies shared properties between the major and minor standstills; three different theories take this approach.

Alexander Thom (1971.15) suggested that monuments aligned on both types of standstill were devices to predict lunar eclipses. In both cases, eclipses occur when the Moon's perturbations coincide and add to the horizon range limits of lunar standstills every 9.3 years. Since the maximum perturbation only very rarely occurs when the Moon is on the horizon, Thom suggested that 'extrapolation devices' were necessary to extrapolate the precise moment of the maximum. There is, however, no evidence for such devices, and it would not be possible to track these tiny horizon movements with low-resolution alignments (Ruggles 1999.63). Nevertheless, as during a lunar standstill, these maximum perturbations always occur close to the equinoxes, and as NW European late Neolithic/EBA prehistoric monuments which conflate the Moon with the Sun choose the solstice Sun, and not its equinoxes (Ruggles 1999.148–151), the monument builders appear to be avoiding not predicting an eclipsed moon. Since an eclipsed Moon is an interrupted full Moon, it seems that the monument builders were selecting for some aspect of an uninterrupted cycle of lunar phases at their ritual centres.

The remaining two models of lunar standstills current within archaeoastronomy engage with the intrinsic properties of the Moon's phases rather than just their horizon location. Ruggles suggests that the monument builders entrained their monuments on lunar standstill full Moons. Ruggles' critique of Thom's work was based on a major field work exercise of five regional groups of monuments in the British Isles. A strong preference emerged from the data for lunar alignments on the southern lunar standstills, both major and minor, and particularly onto settings rather than risings. Ruggles concluded that they would have observed the full Moon setting along these alignments (Ruggles 1999.75, 96–98, 107, 128, 130, 138–9, 149, 154). But for the Moon to be

full when it is at its southern extreme range, whether at the major or the minor standstill, the Sun has to be at its northern extreme, namely at summer solstice. Since all of these monument groups also included alignments on the winter solstice sunsets, not summer solstice, and since they paired the southern standstill moons with the winter solstice, this skyline archaeology provides no justification for conflating the southern standstill Moon as full Moon with the summer solstice. Furthermore, the Sun would not be simultaneously setting in the lower window, but rising on the north-east horizon. Both the astronomy of a single point estimate for a lunar standstill and the skyline archaeology of Stonehenge do not support selecting summer solstice full Moon as the way to interpret the southern minor standstill at Stonehenge (see also Heggie 1981.98).

The final sixth model of lunar standstills addresses the emergent properties from their combination with the Sun's solstices. Sarsen Stonehenge is a binary monument, with two circles and two horseshoes. With the half height, half width and half depth stone 11 it has 29½ stones in the outer sarsen circle and 19 stones in the bluestone horseshoe, both lunar numbers. The building's design principle of obscuration by nested lintelled and ranked wide pillars allows bringing onto one alignment from the Heel Stone a lower window opening onto the setting winter solstice Sun and above it in another window upon the southern minor standstill moonsets (North 1996; Sims 2006; 2016). In short the precise archaeology of sarsen Stonehenge defines what 'astronomy' is being selected for through the cropping of the lunar and solar discs by these two windows.

Both Ruggles (1999) and John North (1996) define a lunar standstill by a single point for its geocentric extreme, and respectively use this value to justify their suggestions that the builders either selected full Moon at summer solstice or alternating perturbations during the minor standstill. To evaluate the details of these positions, consider in Figure 4 the southern minor standstill of the Moon at the latitude of Stonehenge for the thirty months from 9th November⁴ 2510 to 30th April 2507 BC – the minor standstill immediately before the probable date for the building of sarsen Stonehenge around 2500 BC (Parker-Pearson 2012).

The extreme range is reached on 12th April 2508 BC at a declination of -19.25° , when the Moon is a

⁴ All dates are Julian dates.

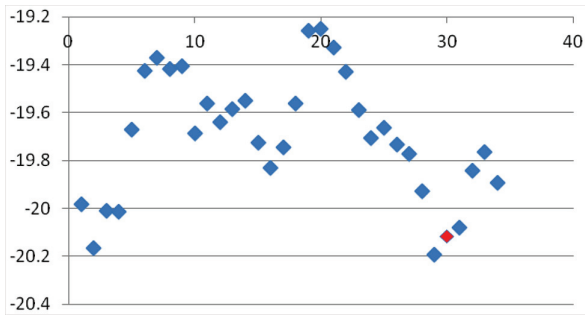


Fig. 4. Southern Minor Standstill 2510–2507 BC at latitude of Stonehenge. Note: 1 Vertical axis in degrees of topocentric declination. 2 Horizontal axis is the number of each southern lunar extreme between 2510 and 2507 BC. The topocentric extreme declination occurred on 12th April 2508 BC at declination -19.25° . 3 Dark Moon during week of winter solstice (in red) on 10th January 2507 BC at declination -20.115° . 4 Declination values for all moonsets at 4 p.m., the approximate time the winter solstice Sun sets in the Stonehenge lower window. 5 Source SkyMap Vers. 8.

waning quarter Moon. Full Moon is met three sidereal months later, during the summer solstice week of the 3rd July⁵ 2508 BC at a declination of -19.59° . Since one degree of declination translates into about two degrees of azimuth at this latitude, ignoring any refraction effects, this summer solstice full Moon is about $41'$ of azimuth less than the extreme point of the standstill. A descending sliver of this Moon would still be seen in the Stonehenge upper window with its declination limits as shown in Figure 4, but to the left by over one lunar diameter and not at the actual extreme value used to define the lunar standstill. This value cannot justify the choice of either full Moon or alternating perturbations as suggested by these two authors. Furthermore, during full Moon, the Sun would not be simultaneously setting in the lower window, but rising on the north-east horizon. Both the astronomy of a single point estimate for a lunar standstill and the skyscape archaeology of Stonehenge do not support selecting summer solstice full Moon as the way to interpret the southern minor standstill at Stonehenge (see also Heggie 1981.98).

Over a period of about 36 months, the southern extreme horizon moonsets of the minor standstill of the Moon irregularly alternate between a declination of about -19° and -20° (Fig. 4). Unlike the sun's solstice horizon position, a lunar standstill extreme limit is not a point, but a small region on the horizon which displays a vacillating reverse sequence of 36

or so lunar phases. These phases of the Moon include all phases that can be witnessed during the transiting synodic Moon, but in reverse. Selecting any one of these phases to define a lunar standstill cannot be justified by a single declination value. The archaeology at Stonehenge, and at the five regional sites reported by Ruggles, is clear – all of these 36 or so reversed lunar phases descend through the upper window at Stonehenge. This includes the dark Moon of -20.115° during the week of winter solstice on 10th January 2507 BC, ten sidereal months after the extreme declination of the Moon (Fig. 4). But the monument builders conflated this sequence in the upper window with the week of winter solstice sunsets in the lower window. By the binary architecture of the monument, this arrangement selects the entire reverse phased sequence of lunations which culminate with the binary astronomy of dark Moon at winter solstice. Since the subsequent Moons on this alignment are reversed waning crescent Moons, and as these are visible only when rising a few hours before sunrise and not at their setting, then for three or so months from the winter solstice no Moon will be seen setting in the Stonehenge upper window. It seems that the monument builders required their rituals to coincide with the start of the longest darkest night.

It may be thought that when a dark Moon coincides with the Sun's solstices outside the periods of lunar standstills, this invalidates selecting this conjunction for standstills alone. For example, dark Moons occurred during this millennium's winter solstice week in 2003, 2011 and will do so in 2017, none of which are standstill years. However, the issue is that none of these occurrences outside of the 2014–2016 period of the lunar standstill could be identified by a stable alignment spread of a few degrees over the course of 36 months. The moon's horizon range limits occupy two very small and stable parts of the horizon only at these periods of the major and minor standstills. This is not possible during inter-standstill years, where the range limits are changing substantially. In Figure 5, it can be seen that over the three years of the inter-standstill years of 2505–2503 BC the southern lunar extremes range from -22.4° to -27.5° declination. This difference of 5.1° declination equals 10.2° of horizon azimuth, and could not be accommodated within the Stonehenge architecture. Only during the period of a lunar standstill could an alignment with a range of two degrees

⁵ Summer and winter solstices were on 3rd July and 9th January, respectively, around 2600 BC, and 2nd July and 8th January, respectively, around 2500 BC.

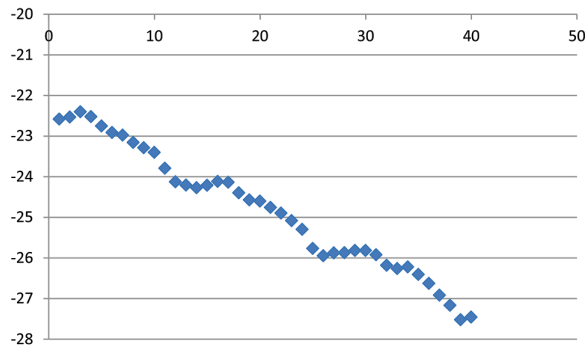


Fig. 5. Southern lunar extremes at the latitude of Stonehenge during the inter-standstill years 2505–2503 BC. (Source SkyMap vers. 8). Note: 1 Vertical axis in degrees of topocentric declination. 2 Horizontal axis is the number of each southern lunar extreme between 2505 and 2503 BC. 3 Declination values for all moonsets at 4 p.m., the approximate time the winter solstice Sun sets in the Stonehenge lower window. 4 Source SkyMap Vers. 8. 5 Another possible challenge concerns the claim for the meshing of lunar phases exactly conflating dark Moon with the solstices between each standstill. Since the standstill cycle recurs every 18.61 years, and as this is an irregular number, repeating standstill dark Moons will not always coincide with the solstices close to the central extreme declination value of the following or preceding standstill.

accommodate a horizon reversed suite of lunar phases culminating in dark Moon at winter solstice and so be enshrined into the axial centre of the monuments. Such was the case for the minor standstill period of 2014–2016, when dark Moons also occurred during winter solstice week on the 22nd December 2014, when the Sun was setting in the Stonehenge lower window.

The peaks and troughs in the Moon's horizon movements will therefore migrate serpent-like through each standstill, and this would seem to invalidate the model's claim that dark moons will always coincide with solstice weeks during lunar standstills.

This misunderstanding of the model is a consequence of defining lunar standstills by the 18.61 year cycle of modern celestial mechanics, whereas prehistoric sky watchers understood it by horizon azimuth. However it should be remembered that the archaeology of Stonehenge, and the five regional groups studied by Ruggles, specify the combined selection of winter solstice sunsets and the southern (major and minor – see below) lunar standstill sunsets. The association of these two alignments migrates through a 36 month period of each standstill, sometimes occurring before the extreme declination and at other standstills after that extreme. Table 1 shows the six minor standstills that occurred during the century before the presently understood building date of Stonehenge. At the latitude of Stonehenge, in these cases over a maximum period of twenty months, the moment of the extreme declination of the Moon varies over the course of the one month of April, while dark Moon coinciding with winter solstice also varies over the course of the third millennium BC, but by either four months before the extreme or ten months after it. In short, within a small alignment horizon band of about $1\frac{1}{2}^{\circ}$ (0.7196×2) over the course of one year in the three years of these minor standstills, 13 reversed phased sidereal Moons culminate in dark Moon at winter solstice for all six minor standstills.

Northern lunar standstills

Our critique through the details of sarsen Stonehenge of the first five archaeoastronomy models of lunar standstills has concentrated on the minor standstill of the Moon at its southern moonsets. An identical structure is revealed in the northern extreme moonsets of the minor standstill and in the southern and northern major lunar standstills. Figure 6 shows the northern and southern minor standstill for 1978 AD and similarly for the major

Year BC	Moon's topocentric extreme date	Moon's topocentric extreme declination°	Winter solstice dark Moon date	Winter solstice dark Moon declination°	Deviation in sidereal months of dark Moon from top. Extreme	Deviation of winter dark Moon from topocentric extreme in degrees declination°
2602	30 April	-19.633	10 January	-20.0101	-4	0.3768
2583	2 April	-19.517	10 January	-19.808	-3	0.3713
2564	28 April	-19.241	9 January	-19.727	-4	0.4853
2546	11 April	-19.367	10 Jan 2545	-19.819	+10	0.4519
2527	11 April	-19.233	10 Jan 2526	-19.953	+10	0.7196
2508	12 April	-19.583	10 Jan 2507	-20.116	+10	0.5325

Tab. 1. Relationship between dark Moon during week of winter solstice and the topocentric extreme of the southern minor standstills at latitude of Stonehenge for 2602–2508 BC. (Source SkyMap vers. 8)

standstill of 1969 AD. It should be remembered that these smooth sinusoidal plots represent the points of the geocentric extremes of the Moon during its orbit around the Earth, but that once reaching the horizon, the Moon's declination will have changed and a more erratic fluctuation will be observed (see Figs. 3 and 4). The remaining pattern and properties shown in Figure 6 are general for all lunar standstills (see *Thom 1971.20; 1978.11-16; North 1996.553-572*).

Just as we found that the extreme declination value for the southern minor standstills occurred at first or third quarter Moons around the time of the equinoxes, this remains the case for northern minor standstills and major standstills at both northern and southern extremes. For the twenty or so sidereal lunations shown here in each lunar standstill, they all occur within a very narrow band of about 30' of declination and all present a reverse sequence of lunar phases every 27 or so days spread over the course of 1 1/2 years. The remaining structural feature of dark Moon synchrony with the Sun's solstice that we have found for the southern minor lunar standstills also belongs to the northern minor standstills and both the southern and northern major lunar standstills. Thus while during the southern major standstill dark Moon happens during the week of winter solstice just as it did for the southern minor standstill, now for the northern lunar standstills, whether minor or major, dark Moon occurs during the week of summer solstice.

For the minor standstill period of 2014-2016 dark Moons occurred not just during winter solstice week on the 22nd December 2014, but also for the sum-

mer solstice week of 17th June 2015. This synchronisation will always occur within a period of about 36 months around the extreme horizon moonsets of each lunar standstill of the Moon. Because of this

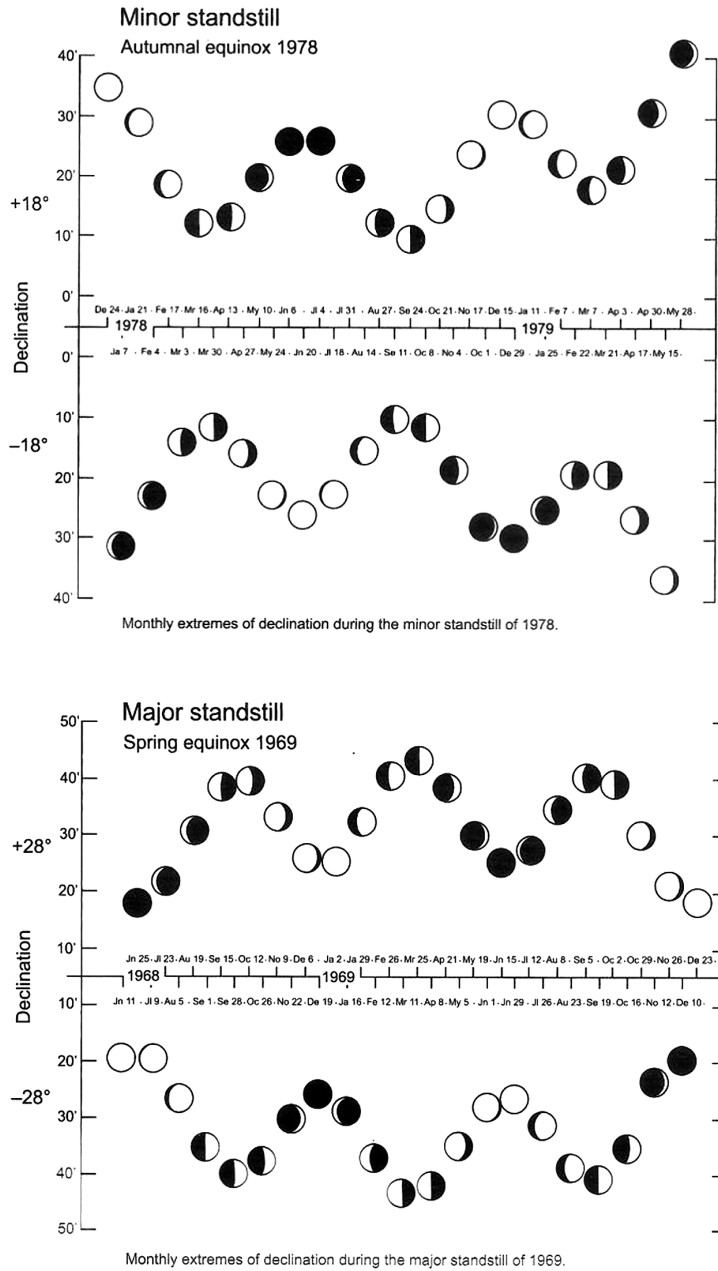


Fig. 6. Monthly geocentric extreme declinations of the 1969 major standstill and the 1978 minor standstill, by date and lunar phase (Morrison 1980)⁶.

⁶ Four considerations need to be kept in mind when interpreting this computer-generated model of lunar standstills: (a) The vertical axis is cropped, so abutting the northern and southern horizon extremes when they are actually widely separated on the western and eastern horizons by about 60° for minor standstills and about 100° for major standstills at the latitude of Stonehenge. (b) The diameter of the lunar orb is not to scale and has been reduced to 5' from its actual 30' to better display its 20' perturbations. (c) The Moon's path is measured by its geocentric declination, which is a modern measure from heliocentric positional astronomy of the distance in degrees from the celestial equator to the centre of the lunar disc. Prehistoric horizon flat-earth 'astronomy' measures by azimuth and horizon altitude to the upper or lower limb of the Sun and the Moon. At the latitude of Stonehenge, 1° of declination translates as about 2° of azimuth for a given horizon. (d) The Moon's geocentric extreme declination occurs at any time in its transit around the earth and only very rarely when it is breaking the horizon. As the Moon is always changing its declination, the regular sinusoidal variation in perturbation displayed in this figure is not observable on the horizon.

fluctuating synchronisation of solstice and dark Moon during each minor and major standstill, the alternation between them is about nine years and the 18.61 year nodal cycle length is an understanding from modern heliocentric positional astronomy and not relevant to a prehistoric flat-earth geocentric cosmology.

Interpreting the model of dark Moon lunar-solar conflation

This understanding of lunar standstills as conflating the Sun's solstices with dark Moon seems counter-intuitive for observational astronomy – "... *this makes no sense...[when] the Moon is new, and hence invisible ...*" (Ruggles 1999.247). It was probably for this reason that Ruggles characterised his own field data, which largely conflate solstice and standstill alignments to the south west, as 'anomalous' (Ruggles 1999.142, 158). But as long as his findings are data, then it is only the interpretation of full Moon that can be anomalous. Instead of making an a priori assumption that the monument builders required a full Moon, we need to ask the question of what properties are revealed by solarising the Moon's alignment? Sims' model of lunar-solar conflation argues that a monument's combined alignment on the Moon and the solstice Sun selects sidereal properties that reverses lunar phases, attenuates a full suite of lunar phases in a time-lapsed observation exercise spread over the course of a year, and culminates at winter and summer solstices with dark Moon at southern and northern lunar standstills, respectively, every nine or so years. In short, this model embraces all of the observed characteristics of lunar standstills as a horizon alignment. We would expect these themes of solarisation, reversal, attenuation and alternating dark Moons over a nine-yearly cycle to inform an interpretive theory of lunar standstills.

The suite of properties which has survived our critique exponentially reduces the number of possible interpretations. Any theoretical model which prioritises full Moon, annual calendars or eclipse prediction is not supported by our findings. This complex portfolio of characteristics suggests symbolic aspects of ritual embedded within signalling the large labour investments required by monumental architecture. If this interpretation is correct, then we would expect similar themes of alternation, reversal and calibration or re-calibration of the lunar and solar cycles to be predicted by an appropriate theoretical model.

Three considerations suggest we should look at this suite of characteristics as the property of a syncretic ritual – an overlay on a previous system of ritual: the formal properties of lunar-solar alignments, the prehistoric archaeology and the anthropology of the prehistoric socio-political systems that built the monuments. Since reversal is built into the properties of a solarised lunar alignment, this is formally consistent with the way in which syncretic systems build reversed structures on those which preceded them, and which they are designed to displace, confiscate and annul. It is also consistent with the continuity paradigm that Neolithic cosmologies derived from their antecedent Mesolithic and Palaeolithic forager ancestors (Silva, Franks 2013). And it is anthropologically sensitive to the monument builder's culture. They were Neolithic cattle herders, who, while continuing to hunt and forage, had split with their Mesolithic/Palaeolithic solely hunter-gatherer origins (Stevens, Fuller 2012). Since hunters earn a wife through a life-time's bride-service, and cattle owners purchase a wife through bride-price payments, this transition is fraught with dislodging matrilineal rights in the interests of an emerging patrilineal culture which prioritises the accumulation of cattle wealth (Sims 2013b). If we pare away the surface overlay that constitutes this solarised lunar syncretism, this formal exercise requires us to reverse the reversed lunar phases of lunar standstills while preserving the themes of alternating dark Moons. The result is to radically simplify the root template out of which lunar-solar conflation can emerge. Instead of reversed-phased Moons, we would then have synodic lunar phases prioritising dark Moon rituals, and instead of lunar-solar attenuated timescales, we have monthly alternation every 29/30 days – in short the transiting Moon as seen in the sky by any observer without the intermediary of a monument alignment. We are left with a ritual system synchronised with lunar phases which culminate with dark Moon. As a formal operation, as Palaeolithic continuity and as gender reversal, we arrive at a lunar transformational template.

Lunar-phased ritual system considered as a transformational template

Our interpretation of solarised lunar standstills as syncretic cosmological systems derives from a prior condition of Palaeolithic gender equality with (synodic) lunar scheduled rituals. This predicts an initial situation, cultural origins model of lunar-scheduled ritual syntax, which entails, consequent upon later socio-economic changes, later Neolithic lunar-solar monument alignments. This lunar template suggests

that those who monopolise ritual power do so through a dark Moon performative achievement. While we have derived this model through the archaeoastronomy of solarised lunar monumental alignments, it converges with the predictions of sex strike theory (*Knight 1991*) that, in conditions of abundant mega-fauna, monthly dark Moon menstrual seclusion rituals of matrilineal siblings were used by Palaeolithic women to motivate prospective ‘husbands’ from other clans for hunting services.

Limiting ourselves in this paper to the archaeoastronomy implications alone, while the model predicts that the ritual syntax of dark Moon is invariant, it also predicts that changing relations of power and economic shifts provide the motivation to transform this lunar template. For example, matrilineal sibling coalitions relying on monthly big game hunt provision will become vulnerable during the mega-fauna extinctions that took place in Palaeolithic Europe between the Aurignacian and the Magdalenian (*Surovell 2008*). Once such resource stress sets in, then according to regional circumstance, the model predicts a number of alternative routes for the ritual appropriation of ‘astronomy’. We have found monumental solarised sidereal lunar alignments at Stonehenge which reverse the synodic Moon while preserving a dark Moon culmination. Ruggles provides the same data for five other regional groups of monuments in the prehistoric British Isles, and North showed it for the Avebury monument complex 20 miles north of Stonehenge. Exactly the same ‘astronomy’ is found in the ancestral Hopi ‘Sun Dagger’ site at Fajuda Butte (*Sofaer 2012; Sims 2016*). It also allows a solar or stellar cosmology to overlay, or replace and annul an earlier lunar cosmology.

Evidence for an earlier version of this transformation can be seen amongst one group of Magdalenian hunter-gatherers in the Praileaitz I cave in the Basque country with a solarised and modularised synodic lunar transformation (*Sims, Otero in press*). For any solar cosmology, we would expect it to carry contrary evidence of an earlier lunar origin exhibiting formal attributes according to lunar laws of motion. For example, it suggests that later versions might include cosmologies appropriating heliacal risings and settings as lunar equivalents of waning and waxing crescent Moons spanning the period of dark

Moon, or using the phases of Venus as lunar equivalents as do the Ona hunter gatherers of Tierra del Fuego (*Bridges 1988*). This critique of lunar standstills reveals the prospect of a lunar transformational template being the source of a ‘periodic table’ of ‘astronomies’ used by the world’s cultures throughout history to buttress ritual systems experiencing varying degrees of stress and emerging social complexity. Rather than archaeoastronomy becoming a field discipline for ‘alignment studies’ eschewing interpretation (*Ruggles 2011*) or as a fringe discipline (*Hutton 2013*), it opens up an alternative robust and scholarly future as cultural astronomy allied to and embedded within archaeology and anthropology.

Conclusion

The ‘Thom paradigm’ (*Aveni 1988*) found solstice and standstill alignments in many prehistoric monuments of NW Europe, and claimed that this was in the service of eclipse prediction. After fifty years of research, eclipse prediction has not been accepted within archaeoastronomy, but the remaining evidence of solar and lunar alignments remain and still require interpretation. In this paper, we have rejected all except one model remaining within archaeoastronomy for this evidence. Horizon range, crossover, perturbation and full Moon fail the tests internal to the discipline to explain the properties of prehistoric monument alignments on the Moon. Our critique instead suggests that a model of lunar-solar conflation points to a ritual syntax centred on dark Moon rituals is amenable to multiple transformations consequent upon shifts in socio-political power. If this model of a lunar transformational template withstands refutation, then these examples open the prospect for archaeoastronomy to find a ‘periodic table’ of alignments that will map onto the world’s cosmologies and religions. It predicts that archaeoastronomy has a central and essential role to play in future research into the cosmologies of the world’s cultures.

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