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THE CROSSOVER OF THE SUN AND THE MOON

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1. INTRODUCTION

The horizon motions of the sun and the moon, and especially their extremes, are well attested as targets for alignments of archaeological sites since prehistoric times, for many cultures across the globe. Monuments such as Newgrange and Stonehenge have their main axis oriented towards the solstices whereas others, e.g. the temples in Malta, also exhibit alignments with the equinoxes.[1] Proponents of lunar alignments tend to focus on the lunar extremes, the so-called lunar standstills. Clive Ruggles's comprehensive survey of British and Irish megalithic monuments shows a preference towards such orientations, and many other cases, within megalithic Europe and outside it, abound.[2]

On the other hand the significance of other, non-extreme, astronomical events involving the sun and/or moon are well attested by the ethnographic and historical records. Examples include zenith and anti-zenith sun and moon.[3] In fact, small-population non-literate contemporary peoples often have a much deeper connection to, and understanding of, the movements of the heavenly bodies than had been previously assumed, even when such is not immediately discernible in their material culture.[4] It is therefore very possible that prehistoric peoples were well versed in the position and movements of the luminaries and would perceive something Westerners have yet to notice. The fact that lunar standstills seem to have eluded astronomers for millennia until Alexander Thom proposed them as targets for certain megalithic sites in Britain potentially indicates that other such cases might abound.

Da Silva[5] proposed the notion of crossover to account for Thom's orientations towards a 'megalithic equinox'. Thom discerned some intentionality in British megalithic monuments to 'miss' the equinoctial marker at 90º of azimuth. Da Silva noted a crossover between the rise positions of the sun and full moon, which occurs around the equinoxes, and used ephemeris simulation to get predicted distributions for this spring full moon. It was found that the predicted peak for the spring full moon was at an azimuth of 97.3º (a declination of –5.7º), which would account for the distribution of orientations of megalithic dolmens in Alentejo, Portugal.

Improved simulations were later developed by Pimenta,[6] who found the main axis of the megalithic enclosures of the same region to be aligned to the autumn full moon. These simulations were commented and expanded upon by Silva,[7] who coined the generalized term 'equinoctial full moons' (hereafter EFMs), and showed that two groups of dolmens in Central Portugal, previously interpreted as having sunrise alignments, actually exhibit the expected EFM peaks in their histograms. The fact that EFMs are 'distribution type events', with highly non-Gaussian distributions,

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was also discussed.

In this paper the notion of crossover is shown in a new light and expanded upon in the hopes that such astronomical targets might in future be considered by archaeo-astronomers and ethnographers. Crossovers are now understood to be observable for all lunar phases but, as ethnography and history tell us, the most significant phases were the full moon and the dark or the crescent moons, and so the focus is on these. Algorithms for ephemeris simulation have been developed and the logic behind them is explained in Section 2. In Section 3, the declination and chronological distributions for all crossover events are shown and analysed. These form the basis for interested cultural astronomers to compare these distributions to their own data. Section 4 presents some preliminary case studies using data available in the literature. The paper concludes with a review of the findings and the impact they potentially have on alignment interpretation. In this last section an alternative interpretation for minor lunar standstill alignments is proposed in light of the findings.

1.1. *Horizon Crossover*

To understand what the crossover is, one has to be aware of the positions of the sun and moon in the sky, relative to each other, throughout the year. Let us start with the equinoctial crossover, the one first introduced by da Silva.[8] If one pictures oneself in the northern hemisphere during winter, one will see the sun rising from the southeast, travelling low in the sky, and setting towards the southwest, whereas a full moon would rise from the northeast, always be very high in the sky, and then set towards northwest. The situation is reversed during summer, in which the sun is high in the sky and the full moon is low. The mere fact that the two luminaries occupy different abodes in different seasons means that they must have swapped places, or crossed-over, at some point. This crossover is empirically observed for the first time at the spring full moon (hereafter SFM). At such a night the full moon and the sun will rise and set very close to each other (the closest they have been since the autumn) but twelve hours apart. They are seen to have crossed over as well, i.e. the full moon rises more southerly than the sun. The same occurs at the autumn full moon (AFM) but the movement is now in the opposite direction. Figure 1 illustrates typical positions of the sun and full moon after the winter solstice (top), during a spring full moon (centre), and after it, i.e. during spring (bottom). The same effect can be observed whether one looks for it at full moon rise or set.

In Western celestial mechanics one can talk of two crossovers. One, the actual, or celestial, crossover, occurs exactly when the sun and moon have the same declination, but this might not be observed at all. The empirical, or horizon, crossover, which always happens at or after the celestial one, is the first time an empirical horizontal confirmation that the celestial crossover as occurred can be made. In this paper only the latter is of interest, since it is the one that is always observable.

This crossover can, in theory, be observed for the moon in any phase of its synodic cycle, not just the full moon. These occur at different times in the year and,

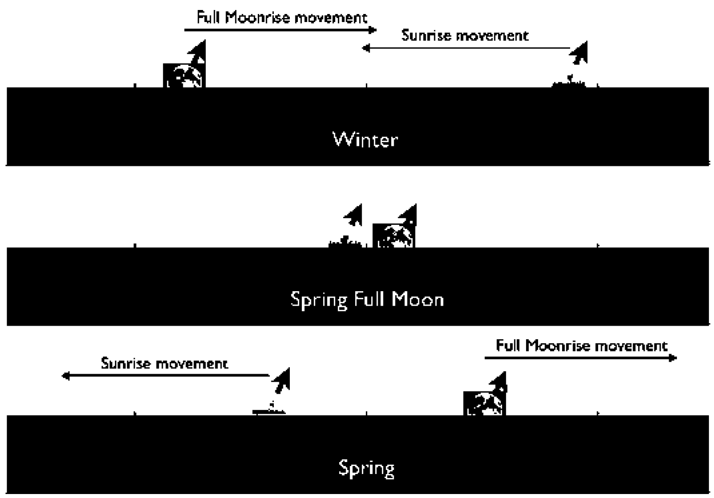


FIG. 1. Positions of the sunrise and full moonrise in the eastern horizon months before (top), during (centre) and after (bottom) a spring full moon. The grey arrows indicate the trajectory of the luminaries in the sky immediately after rising. The black arrows illustrate the direction of change in rising points during the indicated seasons.

most likely, only in one direction (rise or set), as the waxing or waning moon is best observed on the horizon respectively setting or rising. The other 'extreme' is given by the crescent crossovers (since the dark moon is not observable), which involve the lunar crescents, both the first and the last, roughly around the solstices. One now needs to look at the relative positions of the sun and crescent moon, namely whether the moonrise, or set, is seen to be to the right or to the left of the sun. Let us focus on the first crescent moon, seen during sunset and at dusk, and which for many cultures marks the beginning of the month. In the northern hemisphere, during summer and autumn months, the first crescent is seen to set to the left of the sun, i.e. with a more southerly azimuth. The situation is reversed after the winter first crescent, where the first crescent will be seen to set to the right of the sun. The focus here is on the set points, on the horizon. In the northern hemisphere the actual first crescent is always seen to the left of the setting sun, but its declination changes, thus changing the moon-set point. Figure 2 illustrates the position of the sun and first crescent moon months before the winter solstice (top), during (centre) and just after the winter crossover (bottom). The same effect occurs for the last crescent moon, at sunrise and dawn.

An equinoctial crossover is a much more obvious event, because not only are the horizon positions of the luminaries swapped, but also their heavenly abodes, which are effectively divided by the celestial equator. This means that the effect would, perhaps, be more obvious at equatorial latitudes.[9] The crescent ones, on the other hand, truly require horizon observations. This is because the last crescent, in the northern hemisphere, is always seen to the right of the sun at sunrise, and the first

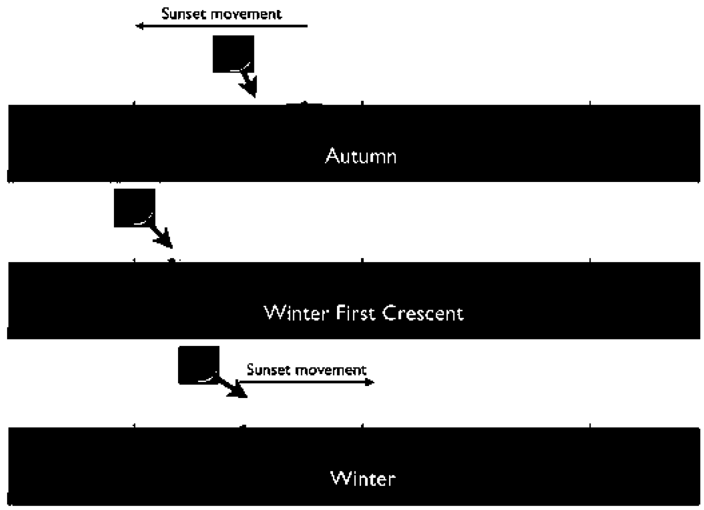


FIG. 2. Northern hemisphere positions of the sunset and first crescent moonset in the western horizon months before (top), during (centre) and after (bottom) a winter first crescent. The grey arrows indicate the trajectory of the luminaries in the sky immediately before sunset, for the sun, and after sunset, for the moon. The black arrows illustrate the direction of change in setting points during the indicated seasons.

crescent to the left at sunset. But precisely because it is subtler it might have been more momentous once it was recognized.

If a crossover event is not observed on a particular day, it can always be tested for the following day. The fact that a particular lunar phase cannot be distinguished by naked-eye alone from one night to the next attests to that. As will be seen in the next section, the algorithm developed for the simulations takes this into account.

The calendrical virtue of these phenomena is that they alone represent events that do not require, in the one hand, multiple conditions to be verified (unlike the solstitial full moons, for instance, which requires both solstice verification and the closest full moon), and on the other hand, the introduction of abstractions, such as geometrical or time interval counting, which, at this stage, cannot be proven and have been criticized in the case of possible equinoctial targets.[10]

As will be shown below, the crescent crossovers are not as chronologically bound to the solstices as the full moon crossovers are to the equinoxes. This is reflected is our nomenclature by the distinction between an equinoctial full moon (or equinoctial crossover) and the crescent crossovers. However, for each solar year there are always two instances of any event, and so when referring to a specific event we will always reference it with respect to the season in which it tends to occur. So equinoctial full moons (EFMs) are divided into spring full moons (SFMs) and autumn full moons (AFMs), whereas crescent crossovers (CCs) are divided into winter crescents (WFCs and WLCs) and summer crescents (SFCs and SLCs, for first and last crescent crossovers respectively).

2. METHODS

2.1. *Simulations*

In order to model the crossover events just described we used the PASCAL language scripting functionalities offered by version 2.8 of Alcyone Ephemeris (©Alcyone Software). In addition to the most common Pascal standard, mathematical and output functions, this software provides functions to calculate astronomical quantities and events in different coordinate centres and planes of reference, as well as epoch conversion, covering the period from 3000 B.C. to A.D. 3000. This software is based upon Steve Moshier's analytical ephemeris using trigonometric expansions for the Earth and planets and the lunar ephemeris ELP2000-85 of Chapront-Touzé and Chapront for the moon, both adjusted to Jet Propulsion Laboratory's DE404,[11] with further adjustments to JPL's more recent DE406, one of the most accurate long-term ephemerides.

The logic behind the crossover scripts is quite straight-forward. For the EFMs, the script starts from the first full moon occurring two synodic months before the equinox date (spring or autumn). It then calculates, for each day, the sunrise/set and moonrise/set azimuths as well as the lunar phase. This process is repeated until the moonrise/set azimuth is bigger than the sunrise/set azimuth (for AFM the condition is the inverse) and the lunar phase is at least 99% full. These values are then outputted into a spreadsheet and the script jumps to the next year and repeats the process. All the lunar values are calculated for the centre of the lunar disc. Scripts were run for latitudes between –60º and +60º and longitudes between –40º and +40º, without major differences (see discussion in next section), but the data will be presented for 40ºN latitude, 0º longitude and 400 metres altitude.

For the crescent crossovers, the script starts from the first dark moon, occurring two synodic months before the solstice date (summer or winter). For the first crescent algorithm days are increased from the dark moon, whereas for the last crescent days are decreased. It carries on calculating, for each day, the sunset (rise, for last crescent) and moonset (rise) azimuths. This is repeated until the moonset (rise) azimuth is bigger than the sunset (rise) azimuth (for winter the condition is the inverse) and the first crescent visibility criterion is met (see below). These values are, again, outputted into a spreadsheet and the script jumps to the next year to repeat the process.

The scripts use topocentric coordinates (azimuths) to test for the crossover condition empirically, after which they are converted to equatorial ones (declination) which is also outputted into the spreadsheets. For each model 428 years were calculated (about 23 cycles of 18.6 years), starting from the year 1620, the date from which most of the sources agree on the value of ΔT, the difference value between ephemeris and universal time.[12]

2.2. *First Visibility Criteria*

As predicting criterion for naked eye first and last crescent visibility, we used an empirical model presented by Caldwell and Laney:[13]

$$\text{altitude of lower limb of moon} + 1/3 \text{ arc of light} \geq 11.3^{\circ}. \qquad [1]$$

This criterion gave similar results when compared with Odeh's criterion,[14] which is a development of Yallop's[15] adaptation of several methods,[16] using topocentric coordinates. Even if these empirical methods do not provide the same degree of accuracy as the modern theoretical model presented by Shaeffer that reduces to half the uncertainty zone of the lunar dateline (the geographical locus of points on which the probability of sighting the crescent is 50%),[17] the authors considered that for the purpose of the present work their accuracy was enough. Even Shaeffer recognized that from the modern empirical criteria, Yallop gave the best results.[18] The reported naked eye visible lunar crescent observations from Schaeffer,[19] SAAO and ICOP lists were used to test the algorithm to good results.

Since the naked eye visibility of the crescents has an uncertainty margin and also depends on atmospheric conditions, we repeated our scripts to test the crossover either on the day of the first crescent visibility or the following day (previous for the last crescent). To simplify reading of the text, the first simulation, which tests for the crossover only on first visibility of the lunar crescents, is denoted by SIM1; whereas the second, which relaxes this criteria to two days, SIM2. In practice these conditions allow the crossover to be empirically tested, in some cases, up to 4 days after the new moon.

3. RESULTS

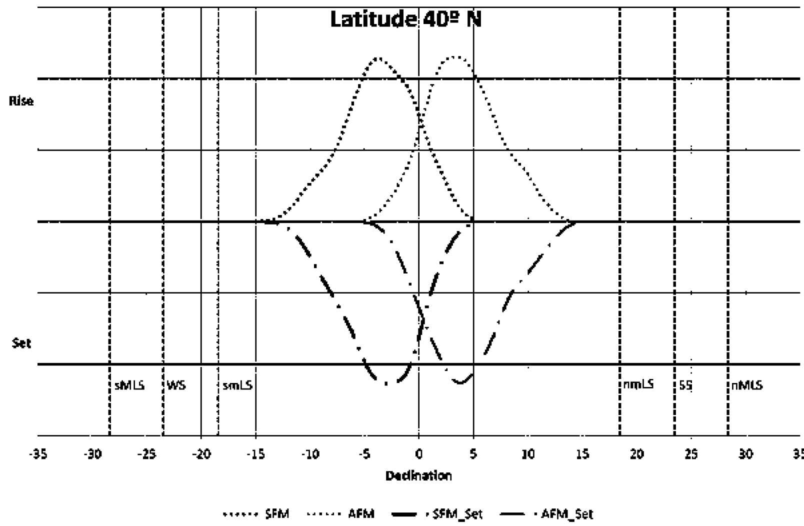
3.1. *Equinoctial Full Moon Distributions*

Figure 3 shows the simulated declination distributions for the full moon crossover events described before, namely: equinoctial full moonrise (dotted), equinoctial full moonset (dash-dotted). The horizontal dotted lines mark the known solar and lunar declination extremes (solstices and lunar standstills). Each of the values of declination obtained from the simulations was used as the average value of a Gaussian distribution with a standard deviation of 1º. These were then all added to obtain the distributions shown in the figure. The top half shows moonrise events whereas in the bottom half are the moonset events.

The equinoctial full moonrise distributions were previously discussed by one of the authors:[20] they are quite broad, non-Gaussian distributions and peak at approximately symmetric values around the celestial equator (±4º declination). The situation for the EFM set is very similar.

Chronologically speaking, the events do not always occur on the same dates on a solar calendar. Figure 3 (below) shows the chronological distributions, where the horizontal axis shows the number of days since the winter solstice. The equinoctial full moons are quite condensed, i.e. they always occur in a period of time which is slightly over a single lunation, and almost always after the equinoxes.

The equinoctial crossovers occur within a time-span of 42 days with the distribution maximum occurring around the 10th day after the equinoxes, which means they



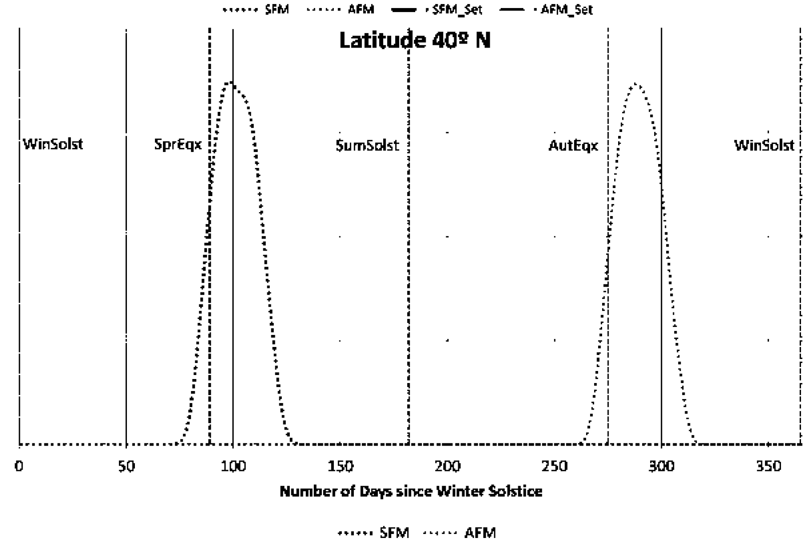


FIG. 3. Declination distributions (above) for equinoctial full moonrise (dotted curves) and moonset (dash dotted curves), and chronological distributions for the equinoctial full moon rise (below), at 40ºN latitude and 0º longitude, 400 metres altitude. Declinations in geocentric coordinates.

happen more often close to that date. However, they are not always the first full moon after the equinoxes. Within the simulated timeframe, about 10% of the spring full moons occur before the spring equinox, i.e. they are not paschal full moons (the first full moon after the equinox). Although the crossover full moon might have been a predecessor to the paschal one (and thus Christian Easter), empirically they are not the same: the former is defined and identified by the crossover event alone, whereas the latter requires identification of the day of the equinox before the full moon is observed. However the declination distributions of the two are not very different (they coincide for nearly 90% of cases), as Gonzalez *et al*.[21] have previously indicated.

3.2. *Crescent Crossover Distributions*

Figure 4 shows the declination distributions of the crescent crossovers, for the simulated period. The first crescent (solid) and last crescent crossovers (dashed) are represented below (moonset) and above (moonrise) respectively.

The last crescent distributions are, again, quite broad, peaking around the declination of the sun at the solstices but exhibiting a 'tail' that encompasses the appropriate minor lunar standstill declinations and beyond. For the first crescents one sees that these distributions are considerably narrower, i.e. the event occurs in a much more confined band of the horizon than the other events, peaking at the declination corresponding to the minor lunar standstill.

SIM2 results (Figure 4, below) show that the summer first crescent distribution essentially becomes equally bi-modal between the declinations of the summer solstice and the minor lunar standstill, and the winter first crescent distribution becomes broader towards the summer solstice.

When we turn to a chronological analysis, the crescent crossovers present very broad chronological distributions, only very roughly situated around the solstices, as can be seen in Figure 5.

The SFCs occur within a time-span of up to 150 days (which decreases with latitude or relaxation of the visibility criteria), centred on the solstices, whereas the SLCs are more likely to occur around up to the 29th day after the solstices and have a time-span of up to 190 days. The proportion of times they occur after solstice / before solstice is roughly 1:1 for the first crescent crossovers and about 3:1 for the last crescents. This shows that the name we have chosen for these events is merely suggestive as they most often occur in the indicated season, i.e. a summer first crescent crossover is most likely to occur in the summer season but can also occur in spring.

It is interesting, at this stage, to note the chronological behaviour of these crescent crossovers over the lunar standstill cycle of 18.6 years, or, in other words, when they occur on minor and major standstill years. It must be remembered that the standstills mark the extremes of the lunistices, and thus the very extreme horizon points at which the moon will rise and set, and so it might seem that some crossovers would not occur on such times. However, one needs to keep in mind the empirical nature and definition of the crossover. In a major standstill year the first crescent crossovers occur 30 to 60 days after the solstice, whereas in a minor standstill year they happen 30 to 60 days before the solstices, thus covering the very extremes of the distributions shown in Figure 5. The chronological extremes do not typically match the standstill years but do occur within 3 years of the standstill peaks, either before (in the case of the major standstill) or after (in the case of the minor standstill).

This analysis undermines the seasonal practicality of the crescent crossovers. Whereas the equinoctial full moons always occur within a month or so of the

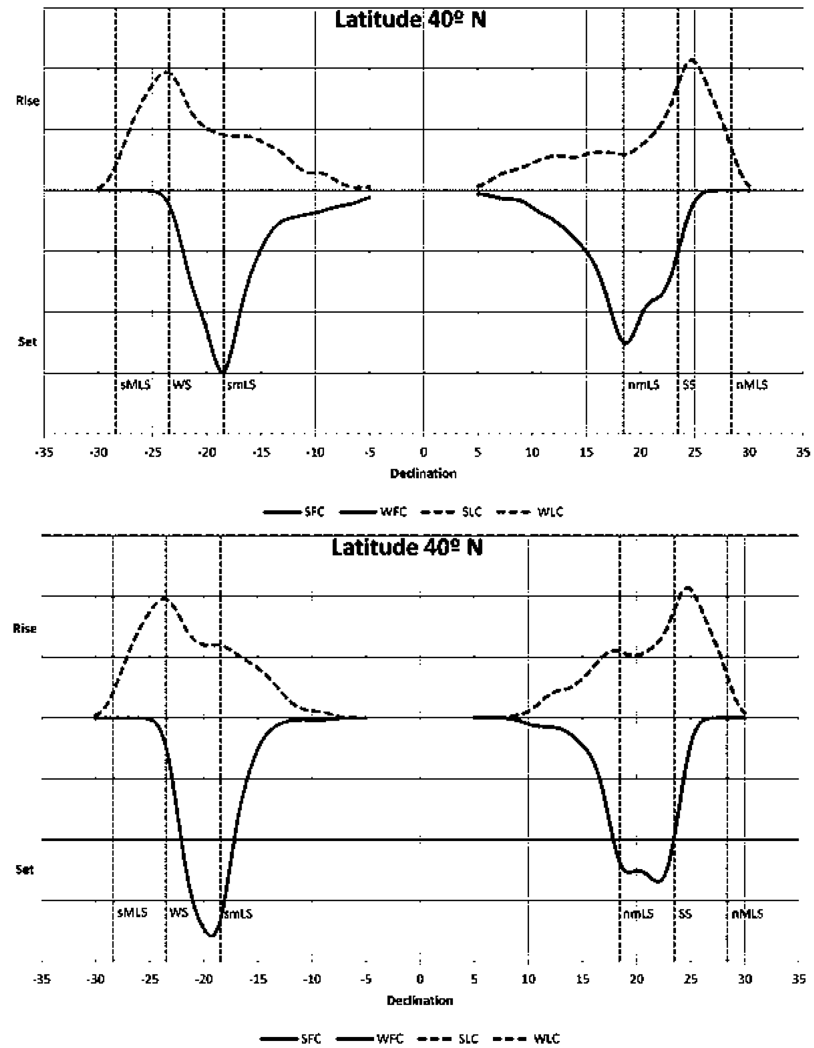
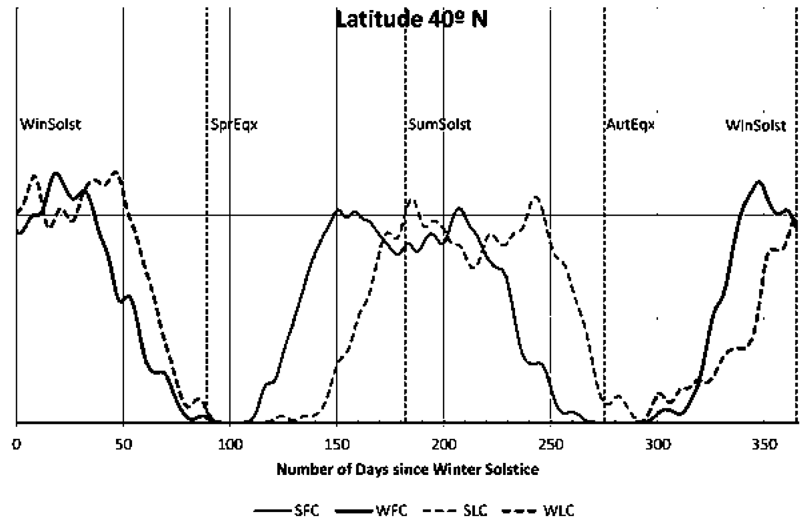


FIG. 4. Declination distributions for first (solid curves) and last crescent (dashed curves) crossover moon at 40ºN latitude and 0º longitude, 400 metres altitude, using SIM1 (above) and SIM2 (below) visibility criteria. Declinations in geocentric coordinates.

equinoxes and could be used as markers of the spring and autumn season in temperate climes,[22] the crescent crossovers, spanning a 150–190 day distribution within a 19-year period, seem too ‘unstable’ to function as seasonal markers. This, however, does not preclude their use in ritual and other symbolic realms where a larger periodicity might be desirable. In fact a crossover, any crossover, is defined empirically by observation, and is not directly related to either equinoctial or solstitial events, despite the chosen nomenclature.



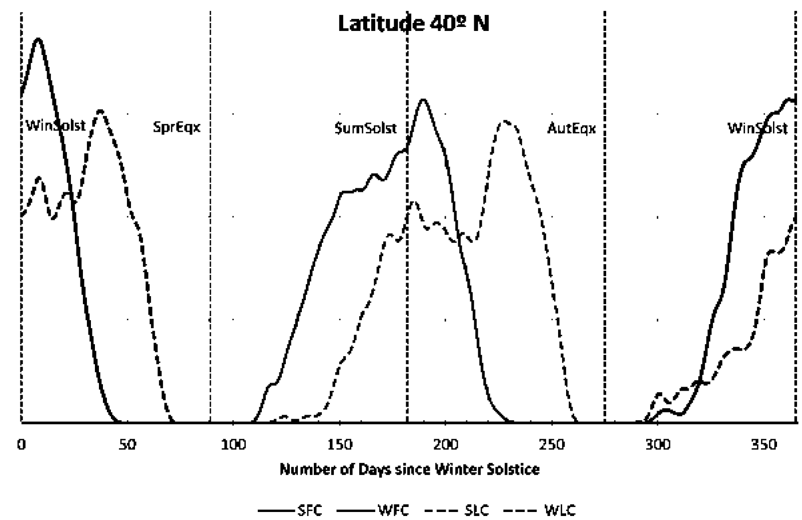


FIG. 5. Chronological distributions for the first (solid line) and last crescent crossovers (dashed) obtained from the results of the simulations SIM1 (above) and SIM2 (below).

3.3. *Effect of Location on the Distributions*

The impact of location on the distributions, i.e. how they change with latitude and longitude, is actually quite interesting. Change in longitude has practically no impact on the distributions; however, a change in latitude is related to a change in the first crescent crossover distributions. This is shown in Figure 6 (above and opposite).

There are some interesting correlations between the crossover distributions and the latitude. The most striking one is that the higher the latitude (whether north or south) the narrower is the winter first crescent distribution, precisely at the declination of the corresponding minor lunar standstill. The frequency of the peak also dramatically increases, thus increasing the likelihood of a WFC occurring at the said declination value. On the other hand the non-Gaussianity of the summer first crescents increases. The equinoctial full moons, both rise and set, are practically unaffected. On the terrestrial equator observers would get symmetrical distributions for both summer and winter crossovers (Figure 6, opposite).

3.4. *Effect of the Variation of the Obliquity*

The variation in the obliquity[23] would move the distribution peaks in declination by an amount no greater than 0.7° away from the equinoxes, for a target date of 4000 B.C.[24] Tests were performed for 3000 B.C., using the JPL Horizons source for ΔT,[25] which gives the best results when compared to those recommended by Fred Espenak and Jean Meeus's polynomial relations,[26] and it was found that, apart from insignificant changes in the shape of the distributions, they follow the variation of the obliquity given by Laskar, so it is simply a case of shifting the distributions accordingly.

4. PRELIMINARY CASE STUDIES

To exemplify crossover alignments in archaeological sites we have selected three cases whose data are easily and freely available on the literature: one set of dolmens in Portugal, one set of megalithic enclosures in Portugal, and the stone rows of Ireland. It is the authors' hope that these cases will stimulate others to try the same on their own data.

As our purpose is merely to present good candidates for crossover alignments, the approach is *ad hoc* but still follows previous similar approaches.[27] When doing such *ad hoc* comparisons between distributions the issue of using appropriate standard deviations arises, because one might be tempted to choose ones that would match the distributions neatly. We have decided, as regards the crossover distributions, to keep to 1º of standard deviation (the one used throughout this paper) which is high enough to accommodate uncertainty due to refraction issues.[28] The minimum standard deviation chosen for the megalithic data was of the order of 2–3º, a number which not only was obtained by comparing different surveys of the same monuments but also seems natural in light of the nature and state of the monuments. But, whenever possible, the individual site estimates were used.

Silva[29] has shown that dolmens in the central Portuguese region between the rivers Douro and Mondego exhibit axial orientations with preference for the equinoctial full moons. The histogram for dolmens of the Mondego basin shows a very broad peak for the southern minor lunar standstill with secondary peaks at –10º declination and another one corresponding to the expected spring full moon one. The other dolmens in the area, once they are all put together, show a very different histogram, with the most prominent peak corresponding exactly to the expected one for the autumn full

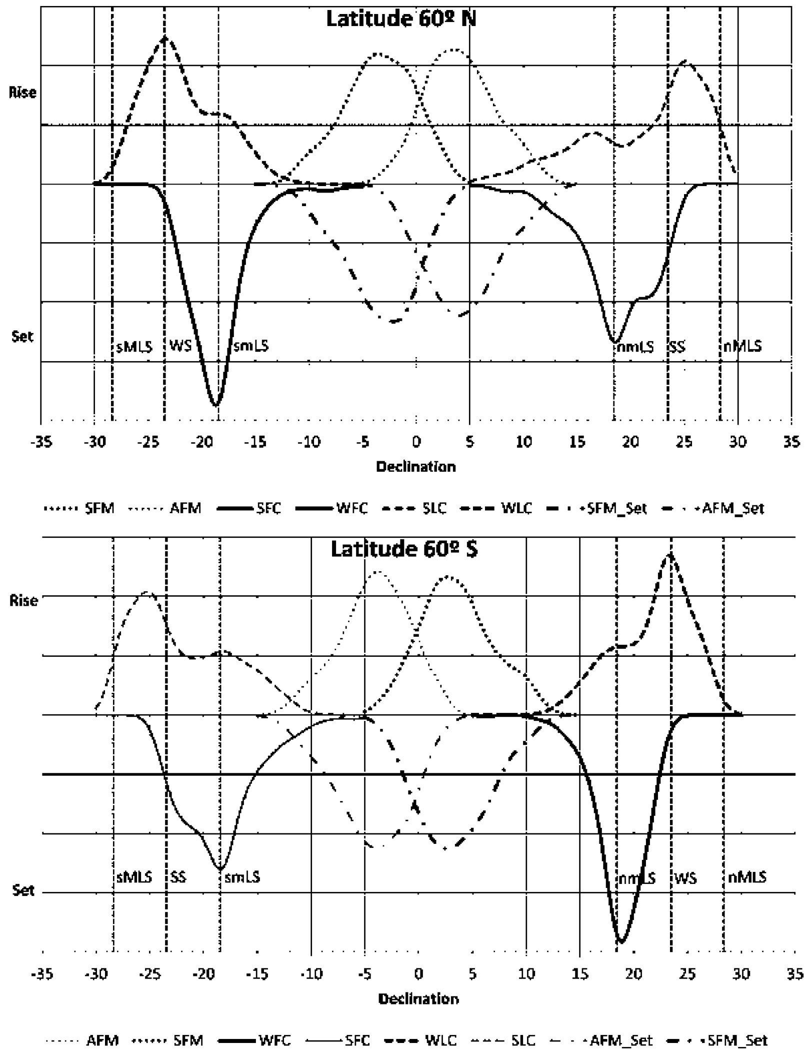
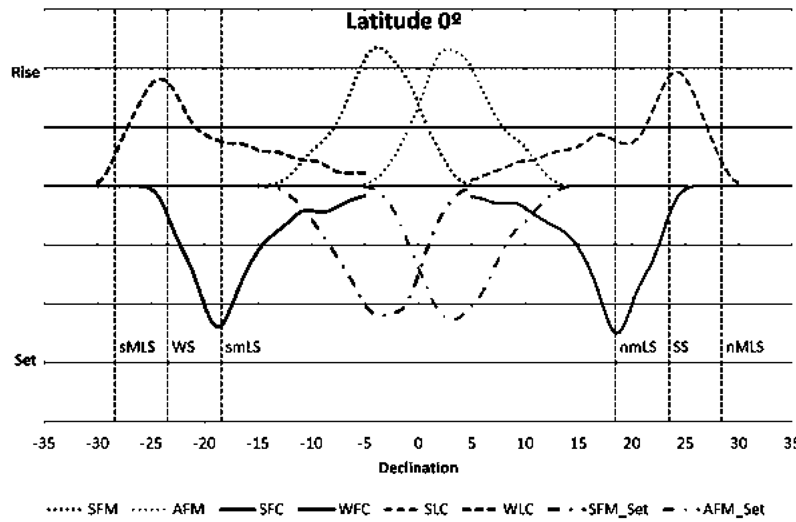


FIG. 6. Declination distributions at 60ºN, 0ºW (above), 60ºS, 0ºW (below), and 0ºN, 0ºW (opposite), using SIM1 visibility criteria.

moon. The distribution for the 39 monuments (standard deviation of 2.5º) is shown as the dashed black curve in Figure 7 (above), whereas the expected distribution for the AFM is the grey dotted curve.

Pimenta *et al.*[30] have shown that the axis of symmetry of megalithic enclosures in the Alentejo province of southern Portugal shows a preference for the autumn full moon. Figure 7 (opposite) top right, shows the data histogram for the 8 monuments surveyed (with the individual standard deviations estimated by Pimenta *et al.*) as a dashed curve, and the expected AFM and SFM distributions in grey and black



dotted lines.

The Irish stone row data show some preference towards the lunar standstill declinations but, according to Ruggles,[31] no clear correlation with actual rising and setting of astronomical bodies. The data from conspicuous hilltops that might have served as the targets for the stone rows, however, suggest otherwise. Figure 7 (opposite) shows these data for the Cork-Kerry stone rows as surveyed by Ruggles (23 orientations towards setting directions, standard deviation of 2º). The histogram is shown in a dashed black curve, and the expected winter first crescent crossover distribution for the location and epoch of the stone rows in solid black. There is a perfect match with the highest peak of the histogram, which also corresponds to the southern minor lunar standstill.

5. DISCUSSION AND CONCLUSIONS

We have presented the empirical notion of crossover of the sun and moon, which can be observed for any of the lunar phases. For the two ‘extreme’ phases, namely full and crescent moons, interest in which is ethnographically and historically verified for many different cultures and periods, the crossovers, occurring respectively around the equinoxes and very roughly around the solstices, have been analysed with archaeoastronomical applications in mind.

Crossover events, especially the equinoctial full moons, might be useful for calendrical purposes too. They are empirical, observable events that do not require abstractions to get the right time. They are, however, mobile in a solar-based calendar like the Western one. Our analysis indicates that crossover events can effectively be used in a conflated lunar-solar calendar, by accurately dividing the tropical year into 12 or 13 lunar periods. They might have been used to define the transitional seasons (spring and autumn) before the equinoxes were used, or as intermediaries in a lunar

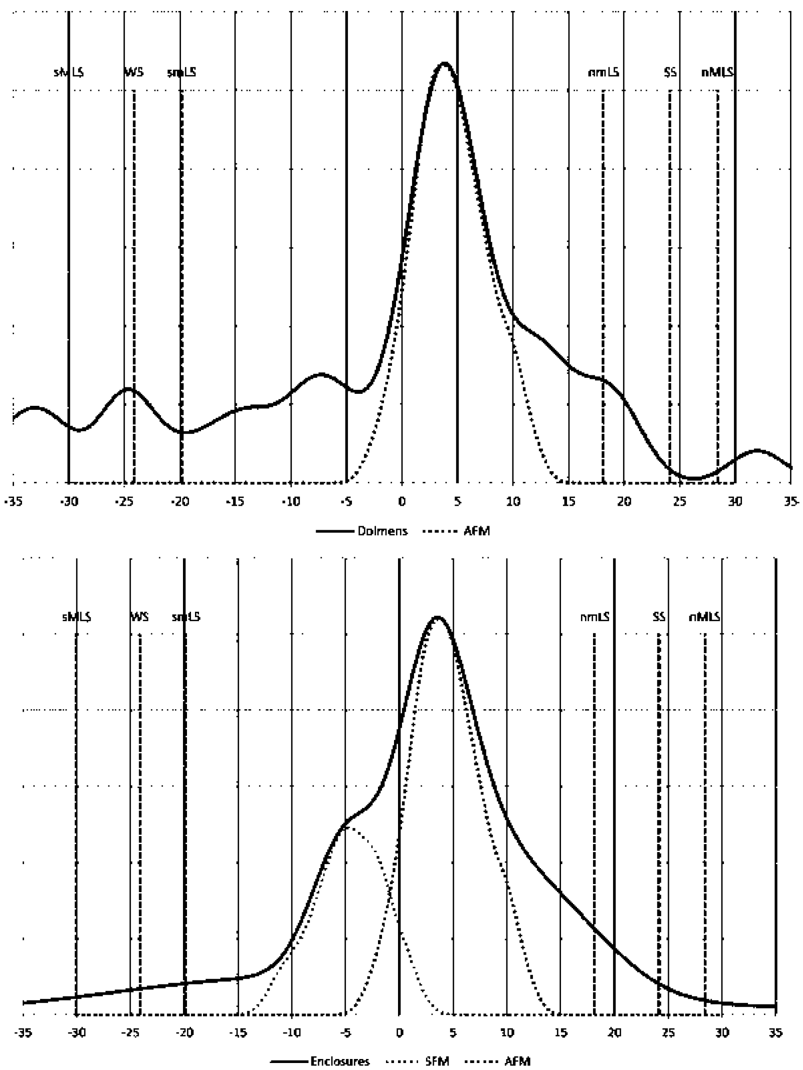
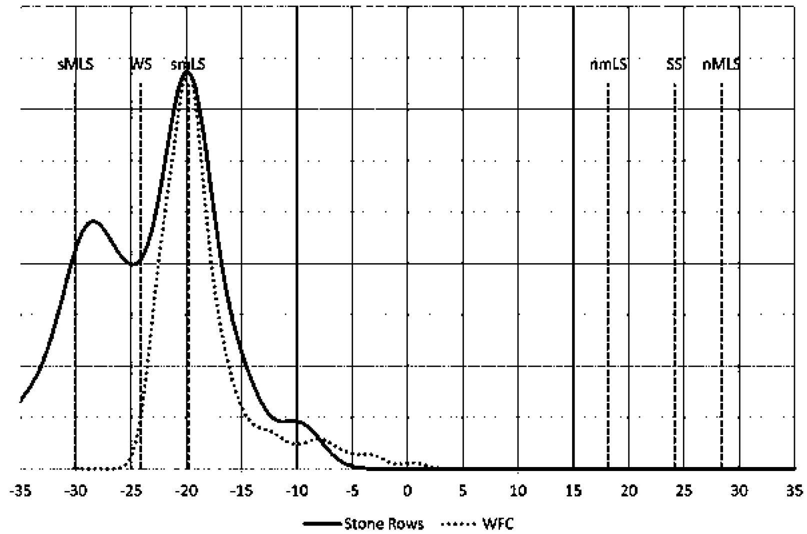


FIG. 7. Histogram of the consolidated survey data for dolmens of the Vouga, Paiva, Torto and Coa river basins of Central Portugal (above), of the enclosures of Alentejo in South Portugal (below), and of Ruggles's data for conspicuous hilltops along the westerly oriented stone rows of Cork-Kerry (opposite). Expected distributions are in topocentric coordinates.

to solar calendar transition by drawing attention to the equinoctial and solstitial directions and times. Further historical as well as ethnographic studies of early and non-literary calendars will need to be conducted to further test this hypothesis.

It seems feasible that the megalith builders of Neolithic, Chalcolithic and Early Bronze Age Europe could also be aware of these crossover events. They might have



attributed a special meaning, timed their rituals, and even aligned their monuments to them. The simulated declination distributions are seen to closely match some datasets of orientations of such sites in Western Europe, sometimes calling for a reevaluation and reinterpretation of the sites and their uses. The case for equinoctial crossovers is easy to make, with several megalithic monuments having been shown to be aligned with them.

Besides providing potential and/or alternative interpretations for ethnographic material, as well as many archaeological sites and monuments, our findings also shed new light on at least two paradigmatic concerns of the field of archaeoastronomy. First of all, the use of 'distribution type' events, previously attempted by only a few scholars,[32] goes beyond the traditional focus of the field on single values of declination to describe events like solstices, equinoxes, zeniths, anti-zeniths and lunar standstills. Surveys of megalithic monuments result in histograms with quite a spread in declination, but also specific peaks. It is common to look at and identify the peaks by comparing them to the expected single values of declination of such events. Most times all other information is left untapped and can lead interpreters astray by clouding the non-Gaussian features of certain distributions. The statistical use of such non-Gaussian, 'distribution type' events is, however, not easy to tackle, and the small sampling of geographically-bound surveys also does not help the issue.

As an example, the fact that the primary peak of the last crescent crossover distributions occurs at the declination of the solstices also indicates an alternative interpretation for such orientations, especially when found in conjunction with other lunar alignments. The issue of distinguishing between lunar or solar intentionality for such cases has been previously discussed.[33] Judging by the distributions we are now presenting, monuments oriented towards the last crescent crossover would exhibit broader peaks in their histogram, encompassing the minor standstill declinations, or presenting a smaller secondary peak at that declination. These would, very likely, be confused with a combination of solstitial and minor lunar standstill alignments. On the other hand, the peak in histograms of monuments oriented to the solstice should be symmetric and concentrated around the solar declination extreme. This is a very simplified and *ad hoc* way of looking at it, as a proper statistical treatment comparing both models with a considerable sample of empirical data would be needed to confidently distinguish between the two hypotheses — unless, that is, qualitative evidence (from the archaeological, ethnographic or the historical records) can be used to shed light on the issue.

The second paradigmatic concern that this paper impacts on is the intentionality of minor lunar standstill alignments. Alignments to major lunar standstills seem not to arouse any suspicion on the part of archaeoastronomers, most likely due to the fact that these mark rise and set points on the horizon that the moon reaches every 18.6 years, but which the sun never reaches. Minor standstills, however, are not special in this sense. Sims[34] has proposed that the significance and intentionality of minor lunar standstills is related to their ties with the winter solstice sunset, which reveals a dark moonset around the said solstice, but also the horizon location where, over a period of 13 sidereal lunations, the synodic cycle of the lunar phases could be seen setting in reverse sequence.

The results of our crescent crossover simulations, especially for the winter first crescent (both for northern or southern hemispheres), exhibit peaks and distributions that are tightly situated around the expected declination value of the minor lunar standstill. Particularly for higher latitudes (> 40º north or south) the distributions for the winter first crescent present a unique striking peak at the minor lunar standstill declination. This is to say that a series of monuments aligned with the winter first crescent would be indistinguishable, as far as statistics is concerned, from monuments oriented towards the setting southern minor lunar standstill. This provides a completely new and alternative interpretation for alignments to such directions, such as the principal peak of the Cork-Kerry stone rows discussed above. Instead of marking an event that occurs only once every 18.6 years, our work suggests that it is possible that such monuments were aligned to the first crescent crossovers, which occur every single year.

We believe megalithic monuments reflect a heavenly dialogue between the moon and the sun, in the form of their relative positions. This paper provides the essence for the use of crossover events as archaeoastronomical targets, and other scholars can now test them with their own data. We hope our *ad hoc* way of matching the expected to the empirical data will stimulate others to develop or apply more advanced techniques from the field of statistics, such as the use of Gaussian Mixture Model techniques, to mention only one example. At the same time the proposed events could also provide a framework from which calendar structures may have evolved. Crossover events will not provide the answer to every question, but they might very well be a step in the right direction for some of them.

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