Morphometric findings on the Nebra Sky Disc

Henning Dathe\textsuperscript{a} and Harald Krüger\textsuperscript{b}

\textsuperscript{a}Department of Medical Informatics, University of Göttingen, Göttingen, Germany; \textsuperscript{b}Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany

ABSTRACT

The so-called ‘Nebra Sky Disc’ is arguably the most important archaeological find in central Europe of the last two decades. It is a richly-decorated bronze plate with gold symbols, some of them being interpreted as the Sun, the crescent-shaped Moon and 32 stars. Being dated to the end of the Early Bronze Age around 1600 BC, the Sky Disc is considered the earliest known transportable astronomical representation of the night sky.

Earlier works identified at least four phases in the history of the Disc. In this work we analyse the Disc’s geometric pattern of the earliest phase, considering possible archaeoastronomical relations. Using mathematical techniques, we identify several potential geometric structures: We find that subsets of three or more Disc stars may represent straight alignments, and we argue that symmetries shown by parts of the geometric pattern may be related to an eight- or 16-month calendar – possibly used as a calendrical device prior-ranking to a symbolic or decorative character.

ARTICLE HISTORY

Received 29 August 2017
Accepted 12 January 2018

KEYWORDS

Nebra Sky Disc; Bronze Age; morphometry; geometrical construction

1. Introduction

The Nebra Sky Disc is a spectacular archaeological find from the European Bronze Age. It was illegally excavated by treasure hunters in 1999 on the hilltop of the 252m-high Mittelberg near the village of Nebra in Saxony-Anhalt, central Germany, as part of a hoard of bronze artefacts. The place of discovery was enclosed by a ring-ditch, on the hilltop, about 75m in diameter. Such enclosures are widespread in northern Europe and are thought to have been prehistoric ceremonial or holy places. It is likely that in the Early Bronze Age the hilltop was bare and, with its wide views in every direction, could have served as a natural celestial observation point (Meller 2003), overlooking the about 80km-distant Brocken in the Harz mountain range in the direction of the solstitial summer sunset. With the help of the other datable objects that the treasure hunters had found in the hoard, the Disc has been dated to the end of the Early Bronze Age in central Europe, around 1600 BC (Meller 2002). This time interval is coincident with the last period of construction and usage of the
Stonehenge ceremonial monuments in southern England (Meller 2002; Ruggles 2015).

The Sky Disc measures about 32 cm in diameter and is made of bronze and richly decorated with symbols in gold leaf (Figure 1). The symbols are interpreted as the Sun (or perhaps the full Moon), the crescent-shaped Moon unrealistically facing the Sun, a long crescent-shaped arc with fine dashes along its edges, which is interpreted as an arcuate boat or barge (Meller 2002), two opposed long arcs along the edge of the Disc interpreted as horizontal arcs (one having lost its gold inlay), and 32 small gold spots regarded as stars. Two of the stars were removed and the position of a third one was changed when the two opposite arcs were later attached to the Disc.

A group of seven stars was interpreted as the Pleiades, indicating that the Sky Disc may have been used for calendrical purposes (Schlosser 2003). The Nebra Disc is considered the earliest known astronomical representation of the night sky in

Figure 1. Photograph of the Nebra Sky Disc, which measures about 32 cm in diameter. (Copyright: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Juraj Lipták.)
northern Europe, even though the arrangement of stars on the Disc does not resemble any real constellation in the sky – possibly with the exception of the Pleiades (Schlosser 2003; Pásztor 2015). The Disc’s pattern may have been a pure symbolic expression of the cosmos with some reference to the iconographical system of the Nordic Bronze Age (Pásztor and Roslund 2007).

The degree of manufacture, the aesthetic concept of the design, and metallurgical investigations showed that at least four separate phases can be distinguished in the history of the Disc (Pernicka et al. 2003; Meller 2004; Wunderlich 2004):

- The Disc with gold inlays of 32 stars, the Sun (or full Moon) and the crescent-shaped Moon
- The Disc of phase 1 plus two opposed horizontal arcs, with one star replaced
- The Disc of phase 2 plus an arc representing an arcuate boat or bark
- The Disc of phase 3 plus about 38 to 40 pin holes around its rim

Except for the boat, which is a widespread symbol in Bronze Age Europe, all symbols displayed on the Disc, i.e. the Sun, the Moon and the stars, are unique, and therefore their purpose remains somewhat speculative until good parallels are found (MacKie 2009). Furthermore, the Disc’s purpose may have changed during these four phases. For example, the pin-holes at the outer rim may indicate that the Disc was sewn onto fabric or nailed onto wood in its latest period of usage before it was buried in the ground.

The date of manufacture of the Disc remains unknown due to the lack of a suitable age-dating method for metal objects (Ehser, Borg, and Pernicka 2011). From the sophistication of the craftsmanship, the first phase was likely not much earlier than about 2000 BC, so that the Disc’s usage can be limited to a period of about 400 years at most, i.e. between about 2000 BC and 1600 BC (Meller 2004). This is likely the same time period when many ring-shaped stone monuments were constructed in the British Isles (1800 ± 200 BC: Thom 1967).

By simulating distributions of stars on the Disc, Schlosser (2002) concluded that they are not randomly distributed, instead, the stars seem to be intentionally arranged in patterns. This is supported by Pásztor and Roslund (2007) who found a regular quadratic grid of 51 mm, in which the stars lie more or less regularly distributed in separate squares formed by the grid. The authors concluded that the star pattern was set out freehand to make an aesthetically pleasing picture. These results motivate our more detailed morphometric analysis of the Disc.

2. Morphometric analysis

We assume that the Disc had its full functionality already during its initial phase of usage, i.e. when the Disc pattern consisted only of the 32 stars, the
Sun and the crescent-shaped Moon. Its functionality may have been purely ceremonial, calendrical or astronomical, or, more likely, a mixture of all three of them. For our analysis we did not make any assumption about the Disc’s functionality.

2.1 The precision of the Disc’s manufacture

Before we can derive any conclusions from our morphometric analysis, we have to make some assumptions about the manufacturing accuracy of the Disc. We assumed the Disc has an underlying geometrical construction connected with errors. These errors may have been introduced upon manufacture, or they may be due to a lack of geometrical knowledge at the time of craftsmanship. The reasons for these errors do not affect our analysis.

For a quantitative analysis, we transformed the image of the Disc (Figure 1) into mathematical coordinates by using the program QCAD (http://www.qcad.org). We defined the origin of our coordinate system as the centre of a circle fitted to the circumference of the Disc. Next, we determined the midpoint coordinates and radii of the gold-leaf circles (i.e. the stars), by choosing three points at each star’s circumference. Finally, we determined the average of the radii of all stars. This data-processing was done with the statistical software R (R core team 2016).

The result from examining the radii of all 32 stars is shown in Figure 2. Since we do not know whether any usage of the Disc pattern was based on the centres or the edges of the stars, we assumed a typical error of one star radius.

![Figure 2](image.png)

*Figure 2. A histogram of the star radii measured in image pixels on the Disc. Mean and standard deviation are 20.8 ± 1.4 pixel. Source: Authors.*
as acceptable tolerance. For an easier interpretation of our results, we scaled all coordinates and radii to the average star radius and used this average as our new unit length throughout this work. This means all lengths measures and coordinates are expressed in units of one average star radius in the following.

### 2.2 The letter ‘L’

A simple visual inspection of the Sky Disc immediately reveals two straight lines, both connecting four stars. These two lines are on the left and at the bottom of the Disc (see Figure 3). In the notation introduced in Figure 4, these lines connect stars 3-4-5-6 and 8-12-30-31, respectively.

The accuracy of these four-point lines is remarkable. They are the lines with the highest accuracy found in our analysis (see Section 2.5). These two lines are arranged at an angle very close to 90° with respect to each other, and we call this feature the letter ‘L’ in the following. We will perform a detailed analysis of 3-point and 4-point lines in Sections 2.3 and 2.4.

### 2.3 Symmetry of the Disc

A visual inspection of the left half of the Sky Disc, including the left part of the letter L, indicates that there may be some symmetry in the Disc’s pattern. Another interesting aspect in this context is the fact that when the Disc was
Figure 4. Numbering scheme for easy identification of stars. Note that point #1 is the midpoint of the Sun and point #34 is the centre of the Disc. Source: Authors.
discovered on the Mittelberg, it was standing vertically in the ground, the two horizontal arcs being oriented in East–West direction. The Disc’s decorated side was facing northwards (Schlosser 2003), and the boat was facing downward as shown in Figure 1. This orientation may be related to the ceremonial or astronomical purpose of the Disc and it also indicates that symmetry may have played a role in the Disc’s usage. In the following, our notation ‘top’, ‘bottom’, ‘left’, ‘right’ etc. refers to the Disc orientation shown in Figure 1.

We analysed the Disc symmetry starting with the line formed by stars #2 and #33 as an initial guess for a line of symmetry. Above this line we counted 18 stars, and only 12 below. Therefore, we had to exclude at least six stars from the analysis.

On the upper side there are seven clustered stars, the Pleiades. We excluded five of them because they have no obvious counterpart on the bottom half of the Disc. Together with one more omitted star without an obvious counterpart, see the black dots in Figure 5, we performed our analysis. We sought for a
translation and orientation of the Disc such that the sum of residual distances is minimal.

We mirrored each star along this line of symmetry and calculated the distance between its mirrored position and its counterpart. The sum of squares of these distances is the measure to be minimised. To find the optimum line of symmetry, this procedure was repeated using a rotation and a translation as parameters used for minimisation. The solution is shown in Figure 5.

On the left half of the Disc, the residual distances between a star and its mirrored counterpart, to which a rigid transformation was added, are much smaller than on the right. This, together with the letter L, may be taken as an indication that the two parts of the Disc may have served different purposes when the Disc was in use.

On the left, the centre of the Sun defined as point #1 is remarkably close to the line of symmetry. We take this result as an indication that the Sun centre may have served as an important reference point on the Disc. We will investigate this further in Section 2.4. The right part of the Disc may have another interpretation, for example a relation of the Pleiades to the agricultural

![Figure 6](image-url). The three-point lines through the Sun midpoint (sunrays). The crossing of the lines is slightly above the centre of the Sun. The number of lines is eight. They divide an angle of 180° into eight sections of about 22.5° each. Except for the line 11-1-12, all sunrays may be extended to four-point lines. Source: Authors.
calendar (Schlosser 2003). Note that the Pleiades do not fit well into our symmetry considerations.

### 2.4 The Sun as the midpoint and its rays

The results from Section 2.3 and the letter L formed by two four-point lines indicate that the midpoint of the Sun may have served as an important reference point. We used the stars forming the letter L and the leftmost star on the Disc (#2) as possible starting points for our next analysis step. We extracted eight lines which are shown in Figure 6 (the computational details are described in Section 2.5). We call these lines ‘sunrays’.

They divide a 180° angle into eight equal parts with about 22.5° opening angle. Seven of the eight sunrays are associated with the L, which is formed by the two four-point lines 3-4-5-6 on the left and 8-12-30-31 at the bottom. Only one sunray, i.e. the line connected with the leftmost star #2, is not connected with the L. The sunrays are therefore strongly connected with the letter L.

Note that the crossing point of the sunrays is slightly offset from the Sun centre. It is shifted by x = 0.2 and y = 1.2 in our notation where one unit length is defined as the mean of the stars’ radii. This means the midpoint of the Sun is offset from the crossing point of the rays by slightly more than our assumed tolerance of one unit length. Given that the midpoint of a bigger circle (here the Sun) can be determined with less accuracy by eye than that of a smaller circle (the stars), we believe this tolerance is acceptable.

From Figure 6 we conclude that the Sun centre (point #1) is an important reference point on the Disc, possibly more important than the Disc’s geometric centre at point #34. In particular, there is no dedicated reference point at #34 that would allow for an easy identification of this point. All sunrays except the line formed by the three stars 11-1-12 can also be identified by four instead of three stars, i.e. they may be extended to four-point lines.

### 2.5 Lines with more points on the Disc

In the previous Section we identified straight lines starting from individual preselected stars, in each case connecting three stars. All these lines cross the Sun. In this Section we generalise this approach to identify all possible straight lines by including all stars on the Disc. The investigation of potential four-point lines is the core of our analysis.

If we include the midpoint of the Sun, there are 33 points to potentially form straight lines. In order to identify potential lines connecting four stars, we have to minimise the distance of each star from a potential line. This task is performed by a mathematical algorithm called ‘geometric fit’ (see Chernov 2011) which we implemented in the software R (R core team 2016). It uses the perpendicular distances of the points from the line sought. Note that a
common linear regression would fail to detect vertical lines. The calculation of all possible lines for a pre-defined number of stars on a straight line requires a considerable amount of computing time.

The result is shown in Figure 7. Due to the close proximity of the seven Pleiades stars to each other, many lines include at least one Pleiades star. This leads to a concentration of lines with Pleiades stars involved. Therefore, in a next step, we excluded the Pleiades from our analysis, the result is shown in Figure 8.

We will now discuss the 10 most precise lines in Figure 8. Note that the entity minimised is the mean of the squared perpendicular distances between the points and the line. This entity is denoted by \( l \). Due to the nature of the algorithm, which examines all possible lines, lines which are not interpretable by us may occur by chance.

The line 3-4-5-6 is the most precise one we found (i.e. it has the lowest value of \( l \); see Table 1). We found it already as the vertical line forming the letter L (Section 2.2). The next one, line 9-11-25-29, forms a diagonal and, together with the L completes a triangle. The triangle is nearly equilateral and rectangular with remarkable accuracy. Its edges lie exceptionally close to the circumference of the Sky Disc. The next line, 1-7-8-13, was already identified as a
sunray in Section 2.4. The line 8-12-30-31 is the horizontal bottom line of the L. We cannot interpret the line 6-7-26-27.

The next three lines are quite interesting. We call the line 2-4-10-13 the upper diagonal, line 14-24-25-28 the heavy vertical (because it runs through the Pleiades and can be extended by up to three additional points) and line 2-5-7-12 the lower diagonal. These three lines form a nearly equilateral and rectangular triangle, enclosing the Sun, the edges of the 45° angles are close to the circumference of the Disc, similar to the triangle formed by lines #1, 2 and 4 in Table 1. Note that the heavy vertical is perpendicular to the symmetry line of the Disc with astonishing accuracy. The next line, 1-7-8-10 is a sunray. The last of the 10 lines discussed is 2-5-7-30. It is close to the lower diagonal.

The heavy vertical through the Pleiades can be considered as the border between the left and the right part of the Disc. Together with two diagonals it forms a triangle enclosing the Sun.

This analysis does not reproduce the sunrays connected with points 5, 6 or 12. This is due to the fact that we omitted the Pleiades, and line 12-1-11 is not a four-point line.
3. Discussion

3.1 The falsifiability of this work

This work can easily be falsified by repeating our analysis on an appropriate artefact like, for example, the Inuit artwork of Pásztor and Roslund (2007) or the simulations of Schlosser (2003): If such an analysis leads to a comparable number of three- and four-point lines with the same precision as we find in this work, our conclusions would be disproved. Since our first investigations of this kind lead to different distributions of the parameter minimised (the mean of the squared perpendicular distances of the stars to a line) we encourage the critical reader to repeat such analyses.

Figure 9. Photograph of the Bush Barrow Lozenge, which measures about 18 cm x 15 cm. (Copyright: David Bukach/University of Birmingham and with the permission of the Wiltshire Museum, Devizes.)

Table 1. The 10 best four-point lines highlighted in Figure 8. \( I \) is the mean of the perpendicular distances defined in the text.

| # | Line        | \( I \) | Comment                        |
|---|-------------|--------|--------------------------------|
| 1 | 3-4-5-6     | 0.034  | Vertical line forming the L     |
| 2 | 9-11-25-29  | 0.057  | Diagonal to form triangle with L|
| 3 | 1-7-8-13    | 0.065  | Sunray                         |
| 4 | 8-12-30-31  | 0.067  | Horizontal line forming the L   |
| 5 | 6-7-26-27   | 0.105  | Not interpretable               |
| 6 | 2-4-10-13   | 0.173  | Upper diagonal                  |
| 7 | 14-24-25-28 | 0.173  | Heavy vertical                  |
| 8 | 2-5-7-12    | 0.178  | Lower diagonal                  |
| 9 | 1-7-8-10    | 0.203  | Sunray                         |
| 10| 2-5-7-30    | 0.208  | Close to lower diagonal         |

Table 1. The 10 best four-point lines highlighted in Figure 8. \( I \) is the mean of the perpendicular distances defined in the text.
3.2 Potential calendrical reference of the Sky Disc

In his astronomical interpretation, Schlosser (2002, 2003) assigns the cluster of seven stars on the Sky Disc to the Pleiades. This constellation was widely used for calendrical purposes and the organisation of agricultural activity in ancient Mesopotamia, Egypt and in other societies (Verderame 2016 and references therein): The rising of the Pleiades was used as a reckoning device in calendrical intercalation systems, the so-called Pleiades leap switching rule (German: Plejaden-Schaltregel).

The potential observation of the horizon arc described by the Sun during its annual motion is exemplified by another impressive find from the Early Bronze Age (MacKie 2009 and references therein): A diamond-shaped gold plaque of extraordinary quality was excavated in a burial under Bush Barrow in Wiltshire, southern England, less than a mile away from Stonehenge. At first sight, the diamond-shaped, decorated gold Lozenge bears no resemblance to the Sky Disc at all (Figure 9). The pair of angles of the basic diamond pattern, however, is 82°, in agreement with the angle between midwinter and midsummer sunrises (and sunsets) for the geographic latitude of Stonehenge. This angle was further split into 16, or possibly 32, subdivisions by a fine engraved zig-zag pattern. If interpreted as a calendrical device, the best-fitting date for the angles engraved on the Lozenge is about 1900 BC which agrees with the period of the Disc’s usage within the uncertainties.

Both objects, the Nebra Sky Disc and the Bush Barrow Lozenge, are unique in their appearance, but they may be related in their ritual and possibly astronomical relevance. The Lozenge may be considered as evidence that the prehistoric solar year was divided into 16 or 32 parts. The layout of the Lozenge is such that it could have been used as a device for real observations of the Sun on the horizon on the calendar dates when the Sun was in the corresponding direction. Hints on the Sky Disc for a 16-month calendar were also revealed by our analysis of the three-point lines shown in Figure 6. The fact that the Sky Disc is decorated with 32 stars may point to a 32-month calendar as well. The existence of an eight- or possibly 16-month calendar in the Neolithic was also suggested by Thom (1967), although this is not generally accepted in the archaeological community. However, on the Sky Disc, the pattern does not subdivide the solstice angle but rather the full circle into nearly equal parts. If this is used for a calendar, there must have been a high degree of abstract thinking among the people using the Sky Disc at ancient times.

It should be mentioned that a third artefact that may also have been used for calendrical purposes was found in the Knowth passage grave in Ireland (MacKie 2009 and references therein; Needham, Lawson, and Woodward 2010; Woodward and Hunter 2015): A fan-shaped rock-carving may represent a 16-month calendar in stone.
3.3 The Sky Disc in a European context

There are astronomical aspects of the Disc that may be related to prehistoric sites in Britain, in particular the sightlines to the Sun at the time of the summer solstice, impressively displayed in the Stonehenge megaliths and other monuments nearby (Ruggles 2015). In Saxony-Anhalt, Pömmelte and Goseck are two examples of Neolithic monuments that show similarities with henge structures in southern England, for example Woodhenge and Durrington Walls (Bertemes and Schlosser 2004).

From metallurgical investigations of the Sky Disc and the other artefacts found in the hoard at the Mittelberg, the likely source of the copper used in making the bronze could be traced to the eastern Alps (Mitterberg/Austria: Pernicka 2004). On the other hand, the gold used during the first two phases of the Disc manufacture came from two very different regions in Europe: while that used for the Sun, the crescent-shaped Moon and the 32 stars attached to the Disc in the first phase likely originated from Cornwall/England (Ehser, Borg, and Pernicka 2011), the gold of the two arcs at the rim originated from the Carpathian Basin in Romania (Pernicka et al. 2003). The widespread popularity of metal in the early Bronze Age forms the basis of a European network through which not only manufacturing techniques, raw materials and artefacts were widely distributed, but also ideas, myths and worldviews (Maraszek 2004).

MacKie (2009) pointed out that both metal objects, the Sky Disc and the Bush Barrow Lozenge, were found at almost exactly the same geographic latitude. This means that when observed from any one of the two sites at about the same time, the rising and setting of all celestial objects occur in the same directions on the horizon. In particular, the rising and setting of the Sun at the cardinal points occur in the same directions, which is not the case for observing sites at significantly different latitudes.

Conclusions

We have presented our morphometric findings from a detailed mathematical analysis of the Nebra Sky Disc and its potential relation to a Neolithic calendar. Our analysis referred only to the first phase of the Disc’s usage when its pattern consisted of only 32 stars, the Sun and the crescent-shaped Moon. We conclude that the Sky Disc was a device containing calendrical and geometric knowledge in North-West Europe. We did not reveal the Disc’s practical usage, with the exception of its transportability; we presume it had been a calendrical device prior-ranking to a symbolic or decorative character. The left side of the Disc may have been related to an eight- or 16-month calendar while the right side may be associated with a calendrical intercalation system, the so-called Pleiades leap switching rule.
If both metal objects, the Sky Disc and the Bush Barrow Lozenge, were used in an astronomical context, they were designed to be used near that geographic latitude. Stonehenge, and also likely the region around the Mittelberg in Saxony-Anhalt, were important prehistoric ceremonial sites over many generations. Especially in non-literate societies, the transfer of knowledge plays a key role in social organisation (Pimenta 2015), and in our context devices like the Sky Disc may have been key to the transfer of knowledge, like a kind of blueprint. Astronomical information contained on the Disc is clearly fixed to a given geographic latitude and, thus, any new ceremonial site based on this information had to be erected at about the same latitude as the original one.

We believe that the people who erected monuments like Stonehenge, manufactured the Sky Disc, the Bush Barrow Lozenge, and possibly many other as yet undiscovered similar artefacts were part of a society based on the division of labour. To craft such artefacts, by contrast to a tribal culture, these ancient societies likely embraced travelling merchants and settled people like intellectually skilled priests and farriers, among hunters and farmers, the latter with a demand for a calendar.

Acknowledgements

We are grateful to the Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt and the Wiltshire Heritage Museum, Devizes, for providing us with high-quality photographs of the Nebra Sky Disc and the larger Bush Barrow Lozenge respectively.

The authors would like to emphasise that this work emerged in their spare time.

Disclosure statement

There are no competing financial interests involved in this paper.

Notes on contributors

*Henning Dathe* works at the Department of Medical Informatics in Göttingen. After finishing his Masters degree in theoretical physics, he joined the Biomechanics Working Group, also in Göttingen, where he was trained in morphometrical problems.

*Harald Krüger* is an astrophysicist working in planetary research in Göttingen. He teaches astronomy at the University of Göttingen.

References

Bertemes, F., and W. Schlosser. 2004. “Der Kreisgraben von Goseck und seine astronomenischen Bezüge.” In *Der geschmiedete Himmel*, edited by H. Meller, 48–51. Stuttgart: Theiss.
Chernov, N. 2011. Circular and Linear Regression: Fitting Circles and Lines by Least Squares. Number 117 in Monograph on Statistics and Applied Probability. Boca Raton, FL: CRC Press.

Ehser, A., G. Borg, and E. Pernicka. 2011. “Provenance of the Gold of the Early Bronze Age Nebra Sky Disk, Central Germany: Geochemical Characterization of Natural Gold from Cornwall.” European Journal of Mineralogy 23: 895–910.

MacKie, E. W. 2009. “The Prehistoric Solar Calendar: An Out-Of-Fashion Idea Revisited with New Evidence.” Time and Mind 2 (1): 9–46.

Maraszkew, R. 2004. “Die Einkehr der westlichen Welt: Prunkbeil und Goldkragen.” In Der geschmiedete Himmel, edited by H. Meller, 172–175. Stuttgart: Theiss.

Meller, H. 2002. “Die Himmelsscheibe von Nebra – ein frühbronzezeitlicher Fund von aussergewöhnlicher Bedeutung.” Archäologie in Sachsen-Anhalt 2: 7–20.

Meller, H. 2003. “Die Himmelsscheibe von Nebra. Fundgeschichte und archäologische Bewertung.” Sterne und Weltraum 42 (12): 28–33.

Meller, H. 2004. “Die Himmelsscheibe von Nebra.” In Der geschmiedete Himmel, edited by H. Meller, 22–31. Stuttgart: Theiss.

Needham, S., A. J. Lawson, and A. Woodward. 2010. “A Noble Group of Barrows: Bush Barrow and the Normanton Down Early Bronze Age Cemetery Two Centuries On.” Antiquaries Journal 90: 1–39. https://doi.org/10.1017/S0003581510000077.

Pásztor, E., and C. Roslund. 2007. “An Interpretation of the Nebra Disc.” Antiquity 81: 267–278.

Pásztor, E. 2015. “Nebra Disk.” In Handbook of Archaeoastronomy and Ethnoastronomy, edited by C. L. N. Ruggles, 43–65. New York: Springer Science + Business Media.

Pernicka, E. 2004. “Die naturwissenschaftlichen Untersuchungen der Himmelsscheibe.” In Der geschmiedete Himmel, edited by H. Meller, 34–37. Stuttgart: Theiss.

Pernicka, E., M. Radtke, C.-H. Riesemeier, and C.-H. Wunderlich. 2003. “European Network in Competence at 1600 BC.” Highlights-Bericht des Helmholtz-Zentrums Berlin für Materialien und Energie GmbH 2003, 8–9.

Pimenta, F. 2015. “Astronomy and Navigation.” In Handbook of Archaeoastronomy and Ethnoastronomy, edited by C. L. N. Ruggles, 43–65. New York: Springer Science + Business Media.

R core team. 2016. “R: A Language and Environment for Statistical Computing.” R foundation for statistical computing. Vienna/Austria, https://www.R-project.org/

Ruggles, C. L. N. 2015. “Stonehenge and Its Landscape.” In Handbook of Archaeoastronomy and Ethnoastronomy, edited by C. L. N. Ruggles, 1223–1238. New York: Springer Science + Business Media.

Schlosser, W. 2002. “Zur astronomischen Deutung der Himmelsscheibe von Nebra.” Archäologie in Sachsen-Anhalt 2: 21–30.

Schlosser, W. 2003. “Astronomische Deutung der Himmelsscheibe von Nebra.” Sterne und Weltraum 42 (12): 34–40.

Thom, A. 1967. Megalithic Sites in Britain. Oxford: Oxford University Press.

Verderame, L. 2016. “Pleiades in Ancient Mesopotamia.” Mediterranean Archaeology and Archaeometry 16 (4): 109–117.

Woodward, A., and J. Hunter. 2015. Ritual in Early Bronze Age Grave Goods: An Examination of Ritual and Dress Equipment from Chalcolithic and Early Bronze Age Grave Goods in England. Oxford: Oxbow Books.

Wunderlich, C.-H. 2004. “Vom Bronzebarren zum Exponat – Technische Anmerkungen zu den Funden von Nebra.” In Der geschmiedete Himmel, edited by H. Meller, 38–43. Stuttgart: Theiss.