Interpretation of the `Sky Disc of Nebra´ as icon for a bronce age planetarium mechanism with parallels to the moving world-soul in the Timaeus of Plato

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Abstract
The analysis of the geometry and the internal symmetries of the bronce age Sky Disc of Nebra unseals a highly sophisticated mathematical design that could be interpreted as an icon for a planetarium mechanism to simulate the spatial and temporal aspects of the solar year and the visibility of the Pleiades during the seasons as described by Hesiod.
The artistic world construction of the Sky Disc of Nebra is based on mathematical principles similar to the principles for the design of the moving world-soul in the Timaeus of Plato.

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1) Introduction

The recently discovered `Sky Disc of Nebra´ is one of the earliest representation of the night sky with concrete astronomical content. It was illegally excavated by treasure hunters some years ago. The originality of the disc was proved by several analyses using archaeological, metallurgical, chemical and nuclear-physical methods. The preliminary results of these investigations and the astronomical und archaeological interpretations so far are published in [1,2,3,4].
The site of this important finding lies on the mountain `Mittelberg´ near the town Nebra in the state of Saxony-Anhalt in central Germany (51° 17´ N, 11° 32´ E). The hilltop was enclosed by a circular bank and ditch of app. 100 m diameter. The preliminary date is 1600 BC. Astronomical evidence connects the site to some of the symbolic representations on the disc. The sunset on the summer solstice day occurs behind the famous and legendary mountain `Brocken´ and on 1 May the sun sinks behind the mountains of the `Kyffhäuser Forrest´. The angular span of the two golden segments on the edge (one is missing now) can be interpreted as the eastern and western horizon sectors. The angle of 82,7° they cover is the annual solar swing between the two solstitial points for the latitude of Saxony-Anhalt.
The meaning of the other symbols is not clear. The disc shows the night sky but without concrete constellations except the cluster of seven stars, probably the Pleiades. This star cluster is close to the ecliptic and lay in the vicinity of the vernal point in the bronce age. Therefore the Pleiades are of high calendrical relevance. The `central gold disc´ could be the sun or the full moon, the `crescent symbol´ could mean the lunar crescent, but also the partially eclipsed moon or the partially eclipsed sun.

Most enigmatic is the bowlike symbol on the edge, which has so far been interpreted as a \`ship´ crossing the sky from the eastern to the western horizon, the Milky Way or a rainbow. Here a completely different interpretation of this ornament and the whole disc is given.

2) Invention of moving elements – first stage

The mathematical analysis of the disc and the symbols yields to surprising and amazing results. Fitting circles and ellipses with the method of least squares to the circular or curved ornaments unseals a highly sophisticated mathematical design of the disc. The main results are (fig. 1):
The holes on the edge follow an ellipse with the ratio of the major axis to the minor axis of 256/244. An ellipse with nearly the same ratio (within the tolerances of app. 1-2 *mm*) fits to the inner edges of the golden segments. This inner ellipse is rotated 90° against the symmetry axes of the outer ellipse. The symmetry axes of the golden segments are also parallel to the main axes of the ellipses. The \`ship´ is fitted by an outer circle and an inner circle. They touch each other at a point on the symmetry line of the ship. The outer circle surrounding the ship reaches to the centre of the disc (the \`outer ellipse´). This leads naturally to the idea to roll the \`outer ship circle´ on the edge of the disc. Four strong arguments justify this basic and attractive idea of a cyclic movement of the \`ship rotator´:

1) The \`ship rotator´ rolls into four symmetry positions on the minor and major axes of the elliptical disc (fig. 2).
2) Cyclical movement is guaranteed because of the rational proportion of the circumference of the \`outer ellipse´ and the \`outer ship circle´ of 2:1.
3) The sector borders of the ship contact the \`outer ellipse´ at four points. These points are symmetric to the golden segments between the solstitial points and are interpretable as the lunar extremes on the horizon of Saxony-Anhalt during the major lunistices (geocentric lunar declination $e + i$; with e = obliquity of the ecliptic and i = inclination of the lunar orbit to the ecliptic).
4) The impression of a rolling device is mathematically described by the rotation of the centre of the \`inner ship circle´ around the centre of the \`outer ship circle´, which revolves with the same angular velocity around the centre of the \`outer ellipse´. In consequence the centre of the \`inner ship circle´ is a prominent point for the description of the rolling movement. This centre is indicated by the short \`sector borderlines´ of the ship. They point to the centre of the \`inner ship circle´ and not to the centre of the \`outer ship circle´.

During the complete cycle of the \`ship rotator´ the two \`sector borderpoints´ and the two points, where the symmetry axis of the ship reaches the \`outer ship circle´, are sliding on nearly straight lines through the disc. The latter follow the main axes and the former follow the lines pointing to the lunar extremes on the horizon. The rolling movement of a circle within another circle of double diameter is known as Tusi-couple according to the arabian astronomer Al Tusi (1201 – 1274 AD).
Most impressive is the path of the centre of the \`inner ship circle´, which is touching in parts of its turn the edges of the inner ornaments, the central gold disc and the golden crescent symbol. This motion is animated in a digital video file presented at the INSAP IV Conference.

3) Invention of moving elements - second stage

The inner radius of the crescent symbol differs slightly from a circular line but it is possible to fit with least squares a circle to this curve with acceptable accuracy. This \`inner crescent circle´ has the same diameter as the ship rotator. A further circle (\`star circle´), optimized to

enclose the seven clustered stars, is tangent to the `inner crescent circle´ and has the third part of its diameter. These are possible hints for a more complex motion with an epicyclic movement of the star circle within the `inner crescent circle´ in a sense opposite to the rotational sense of the `ship rotator´. The rolling ship trails the `inner crescent circle´ over the disc. These equal sized circles are fixed together and their centre points and intersection points could be interpreted as the four corners of a Bush-Barrow-type lozenge with angles of 105° and 75° (fig. 2). The angle of 105° matches the monthly lunar swing during the major lunistice season on the latitude of 52°.
During a complete cycle of the `ship rotator´ and the trailed `inner crescent circle´ the `star circle´ rolling inside the trailed circle touches the `outer ellipse´ in the western and eastern part of the Sky Disc (fig. 3), but does not leave the disc in any phase of the cycle (this would be the case if the rotational sense of the `star circle´ is changed). The virtual axis connecting the centre of the `star circle´ and the centre of the `inner crescent circle´ is not parallel to the symmetry axis of the `ship rotator´ in the visualized state of rest on the Sky Disc. It is adjusted precisely in the way to produce the described phenomena of touching the outer ellipse. With other initial phase angles between the two rotational axes the `star circle´ would be driven to the outside of the disc or the contact with the border would be prevented.
The complete mechanism is animated in a second video file. Both files are available on demand at the Westphalian Public Observatory and Planetarium of Recklinghausen.

4) Astronomical interpretation

The mechanism simulates the solar year and its division in parts of equal length. The Pleiades vanish completely inside the rolling circle, when the ship is in the two symmetry states on the major axes of the ellipse. They are in opposition to the ship, when it is crossing the two minor axes. If these four symmetry positions are identified as the two spring (ship on the major axes) and the two autumn equinoxes (ship on the minor axes) of two solar years, these states (and dates) match exactly with the heliacal and acronical settings of the Pleiades in the bronce age as describe by Hesiod in `Works and Days´.
This two-year-hypothesis yields to testable consequences since a prominent state in the first year requires a corresponding prominent state in the second year half a turn of the ship later. Especially the four solstices of the two years in the temporal centre between the equinoxes should be indicated distinguished on the disc.
The calculated states for the solstices are indeed of a very special kind: The centre point of the `inner ship circle´ (resp. the centre of the `outer ship circle´ if the ship is in the upper half of the disc) contacts the solstice diagonals (see fig. 4, which shows one of the four solstice states; for a clear and perceptual demonstration of this temporal symmetry the video animation is needed). With the choice of the elliptical form the artist managed to incorporate the spatial aspects of the solstices (the solar swing of 82,7° on the horizon) and the temporal aspects (division of the solar year together with the equinoxes in four nearly equal parts) simultaneously in the design of the disc.
The further division of the solar year leads to the dates in archaeoastronomy usually called Candlemas, Mayday, Lammas and Martinmas. They are indicated by the contact of the `inner ship circle´ with the edges of the two central gold symbols (Lammas, Martinmas) or the contact of the Pleiades with the border of the disc (fig. 3 shows one of the two Candlemas states). The central symbols are arranged in size and position to allow these contact phenomena at the right dates.
The four states of Candlemas and Mayday are brought into prominence by a further interesting contact phenomenon. In these states the ship contacts the vertical symmetry axis of the disc and one of the solstitial diagonals. Then the round stem and stern of the golden ship symbol reaches exactly to the contact point of the diagonal and the ship circle (`inner ship circle´ in the two states with the ship in the upper half and `outer ship circle´ in the two states

with the ship in the lower half of the disc), so that at last also a reason for the dimension of the ship – the sector is spans – is found (fig. 3).

5) The moving world-soul in the Timaeus of Plato

The motion of the two circles of the world-soul in the Timaeus of Plato is explained to the reader in a fashion that may indicate a relationship between the idea of a moving world-soul and the mechanism shown on the Sky Disc of Nebra. The correspondence is not complete, but the two ancient mechanisms are based on the same mathematical principles.
Plato describes the world-soul as made of two connected circles making a coupled movement [5]. Conventionally the two circles are interpreted as the celestial equator and the ecliptic rotating around the polar axis, but the identification with the motion of the coupled circles on the Sky Disc, which is in some parts diagonal–transversal, seems also possible.
Plato´s circles are made of two strings of the same length. The material of the world soul is a mixture of the material of the `Same´ and the `Other´. In the process of mingling these different media the proportions of 3/2, 4/3, 9/8 and 256/243 play essential roles. The ratio of the major to minor axis of the elliptic Sky Disc is identical with the ratio of 256/243 within the tolerances.
The eternally moving world-soul drives more circles. They are conventionally interpreted as the planetary spheres. Plato´s circles have radii in the proportion 54 : 27 : 9 : 8 : 4 : 3 : 2 : 1. The circles on the Sky Disc are in the proportion 24 (circumference of the outer ellipse) : 12 (circumference of the outer ship circle & inner crescent circle) : 11 (inner ship circle) : 10 (outer crescent circle) : 8 (sun circle) : 4 (star circle).
In the Timaeus and on the Sky Disc of Nebra the radii and the motions of the circles follow not exactly the behaviour of the real objects of nature but the idea of a world-construction based on some perfect mathematical idols.

6) References
[1] H. Meller, `Die Himmelsscheibe von Nebra – ein frühbronzezeitlicher Fund von außergewöhnlicher Bedeutung´, *Archäologie in Sachsen-Anhalt*, Vol. (1) 2002, 7-20
[2] W. Schlosser, `Zur astronomischen Deutung der Himmelsscheibe von Nebra´, *Archäologie in Sachsen-Anhalt*, Vol. (1) 2002, 21-23
[3] E. Pernicka, Ch.-H. Wunderlich, `Naturwissenschaftliche Untersuchungen an den Funden von Nebra´, *Archäologie in Sachsen-Anhalt*, Vol. (1) 2002, 24-31
[4] www.archlsa.de/sterne, official website of the Landesmuseum für Vorgeschichte, Halle
[5] *The Timaeus of Plato*; edited with introduction and notes by R. D. Archer-Hind, Macmillan and Co., London New York 1888, reprinted edition by Arno Press Inc. 1973, pp 105 - 119

Appendix 1: The size of the symbols on the Sky Disc

circular symbols	radius	circumf.	proportion (approximate)
outer ship circle	120	754	12
inner crescent circle	122	767	12
inner ship circle	109	666	11
outer crescent circle	97	609	10
sun circle	78	490	8
star circle	40	251	4

elliptical symb., semi axes:	major	minor	circumf.	proportion (approximate)
outer ellipse	244	233	1499	24
inner ellipse	232	215	1358	

Notes:

i) The circumference *u* of the ellipse is calculated approximately according to

$$u \cong p \cdot \left(3 \cdot (a+b)/2 - \sqrt{a \cdot b}\right).$$

ii) The ratio of the semi axes of the outer ellipse of *a/b* = 244/233 is close to 256/243.

iii) Approximate error for all numbers (in arbitrary units): +/- 1…2

iv) The overall size of the disc is 318 mm. To convert arbitrary units (a.u.) to mm multiply each number with 0,626 mm/a.u..

Appendix 2: List of figures

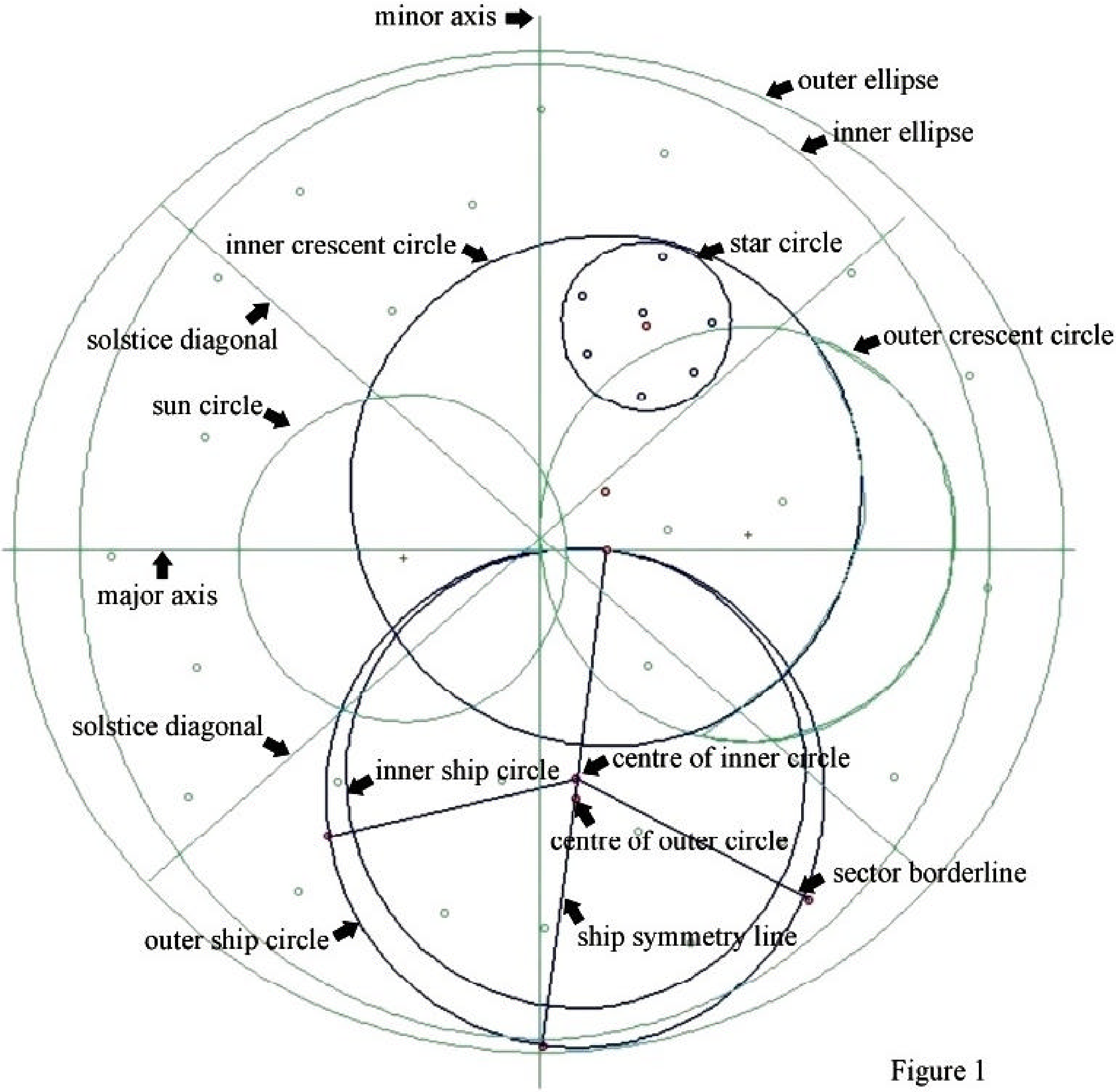
minor axis
outer ellipse
inner ellipse
inner crescent circle
star circle
solstice diagonal
outer crescent circle
sun circle
major axis
solstice diagonal
centre of inner circle
inner ship circle
centre of outer circle
sector borderline
outer ship circle
ship symmetry line

Figure 1

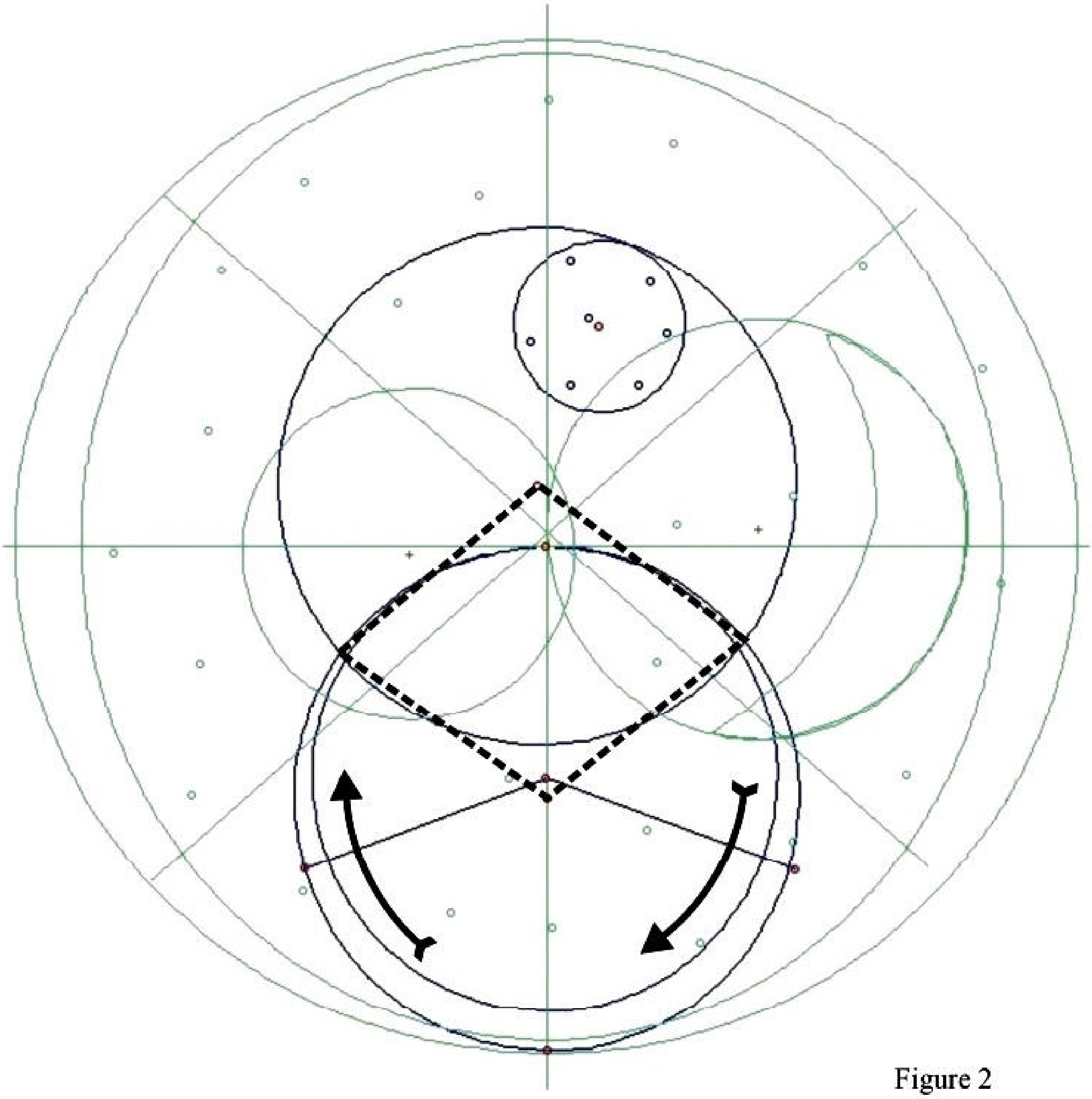

Figure 2

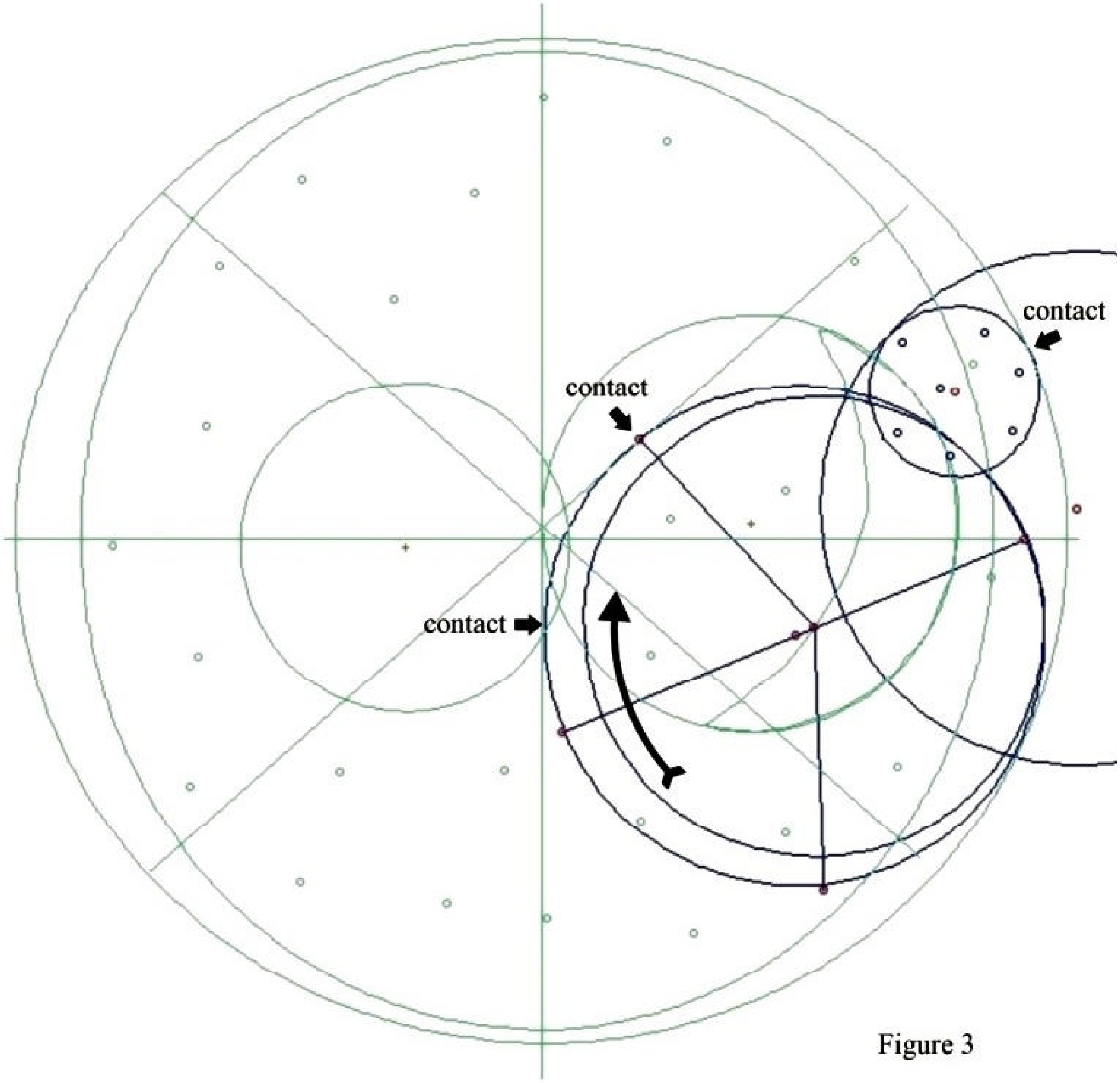

Figure 3

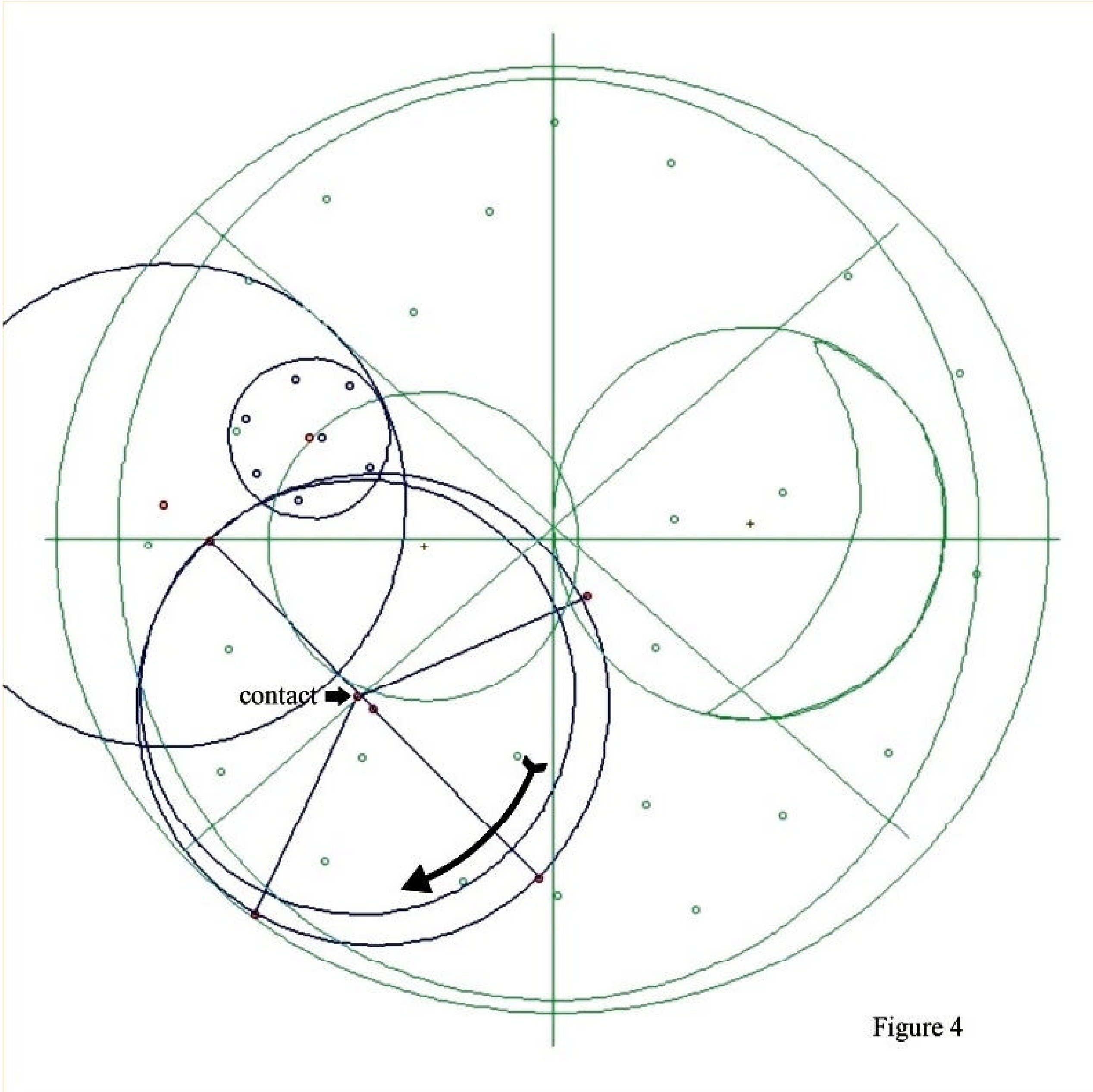

Figure 4