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THE SKY DISK OF NEBRA REVEALS ITS SECRETS

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Abstract

The paper presents the method and results of decoding the content on the Sky Disk of Nebra. It has been shown that the symbols found on it, suggesting the Sun, the Moon and the solar barge are only geometric figures facilitating the recording of astronomical knowledge. The paper first defines a polar system on the horizon plane. This system describes the range of the directions of sunrise and sunset in the annual period and the Moon in the 18.61-year cycle. It turned out that astronomical knowledge was recorded on the surface of the disk on two planes: horizontal and perpendicular one (the meridian plane). With the help of geometric constructions located on the meridian plane, it was possible to decode the range of changes in the altitude (zenith distance) of the Sun in the annual period, at the time of its upper culmination. Also, using two different geometric structures, the range of changes in altitude (zenith distance) of the Moon at the time of its upper culmination in the 18.61-year cycle was decoded.

DYSK Z NEBRY ODSŁANIA SWOJE TAJEMNICE

Słowa kluczowe: Dysk z Nebry, Słońce, Księżyc, archeoastronomia

Abstrakt

W pracy zaprezentowano metodę i wyniki rozkodowania treści zawartej na powierzchni dysku z Nebry. Wykazano, że znajdujące się na nim symbole sugerujące Słońce, Księżyc i barkę słoneczną są tylko figurami geometrycznymi ułatwiającymi zapis wiedzy o charakterze astronomicznym. W pracy w pierwszej kolejności zdefiniowano układ biegunowy na płaszczyźnie horyzontu. W układzie tym opisano zakres kierunków wschodu i zachodu Słońca w okresie rocznym i Księżycy w cyklu 18,61-letnim. Okazało się, że na powierzchni dysku zapisano wiedzę astronomiczną na dwu płaszczyznach: horyzontalnej i na płaszczyźnie do niej prostopadłej (płaszczyźnie południka). Za pomocą konstrukcji geometrycznych znajdujących się na płaszczyźnie południka udało się rozkodować zakres zmian wysokości horyzontalnej (odległości zenitalnej) Słońca w okresie rocznym, w momencie jego kulminacji górnej. Również za pomocą dwu różnych konstrukcji geometrycznych rozkodowano zakres zmian wysokości horyzontalnych (odległości zenitalnych) Księżycy w momencie jego kulminacji górnej w cyklu 18,61-letnim.

INTRODUCTION

The Sky Disk of Nebra was found in 1999 at the archaeological site on the Mittelberg hill, located about 4 km from the city of Nebra. The sky disk was discovered illegally by treasure hunters using a metal detector. The author [4], Dr. H. Meller, director of the Prehistoric Museum in Halle, Saxony-Anhalt, for the first time de-

scribed how the Sky Disk of Nebra was recovered only in 2002. The 32 cm disk is made of bronze. A number of astronomical signs were marked on its surface with the use of thin gold plates, probably representing the Sun in the form of a circle, a crescent Moon, stars, two symmetrical bows around the circumference of the circle, and a bow in the shape of a solar barge. In addition, there is a grouping of seven stars on the Sky Disk of



Fig. 1. The Sky Disk of Nebra [5]

Rys. 1. Dysk słoneczny z Nebra [5]

Nebra. This group is associated with the Pleiades, located in the zodiac belt in the constellation of Taurus. Initially, the disk was carefully examined to confirm its authenticity and the age of its construction. The Sky Disk of Nebra was found to be authentic, made in the Bronze Age about 3,600 years ago. The discovery became a great sensation among archaeologists and astronomers. It turned out that the disk was created in several stages. In the initial phase, the symbols of the stars, the Moon and the Sun were marked on the sky disk. A little later, two golden bows were added around its perimeter. The disk became an instrument for tracking

the movement of the Sun. Then a golden barge silhouette was added. In the final stage, 39 holes were marked around the entire circumference of the disk, approximately equidistant (Fig. 1).

The Sky Disk of Nebra was entered into the UNESCO Memory of the World Register in 2013 as one of the greatest archaeological discoveries of the 20th century. The astronomical aspects of the discovered sky disk have been extensively described by the astronomer, Prof. Wolfard Schlosser from the University of Ruhr [5]. First, the professor noted two golden bows on either side of the sky disk, documenting the annual

range of sunrise and sunset azimuths in Central Europe at a latitude of approximately $\varphi = 51^\circ$. Along this latitude there is the place where the disk was found and the ancient observatory from the Neolithic age in Goseck. The Sky Disk of Nebra continues to inspire astronomers and archaeologists. In articles on astronomy, the authors focus on astronomical phenomena in the past epochs near the Pleiades. However, it is still believed that the disk is a mysterious object difficult to decode. The author's approach presented in this article differs significantly from the publications that have been prepared so far. All objects on the disk found a logical use. Several layers were marked on the horizontal surface of the disk, describing the full range of changes in altitude (zenith distance) of the Sun during the year during the upper culmination on the meridian plane. The changes in altitudes in the Moon's upper culmination over its 18.61-year cycle have been described very thoroughly.

SUNRISES, SUNSETS AND THE MOON ON THE SKY DISK OF NEBRA

We begin the study of the Sky Disk by introducing a polar horizontal system using two symmetrical gold bows located on its edge. These bands, according to the observation of Prof. Schlosser [5], cover a range of azimuths of 82° sunrise and sunset times a year. We use the symmetry of the east and west points with respect to the north-south axis. We mark the beginning of the system by means of the extreme directions of sunrise and sunset during the year. We connect the point of sunrise on the day of the summer solstice – S_1 with the point of sunset on the day of the winter solstice – S_4 (Fig. 2). The second line is created by connecting the point of sunset on the day of the summer solstice, S_2 with the point of sunrise on the day of the winter solstice, S_3 . The origin of the O (Observer) system determines the intersection

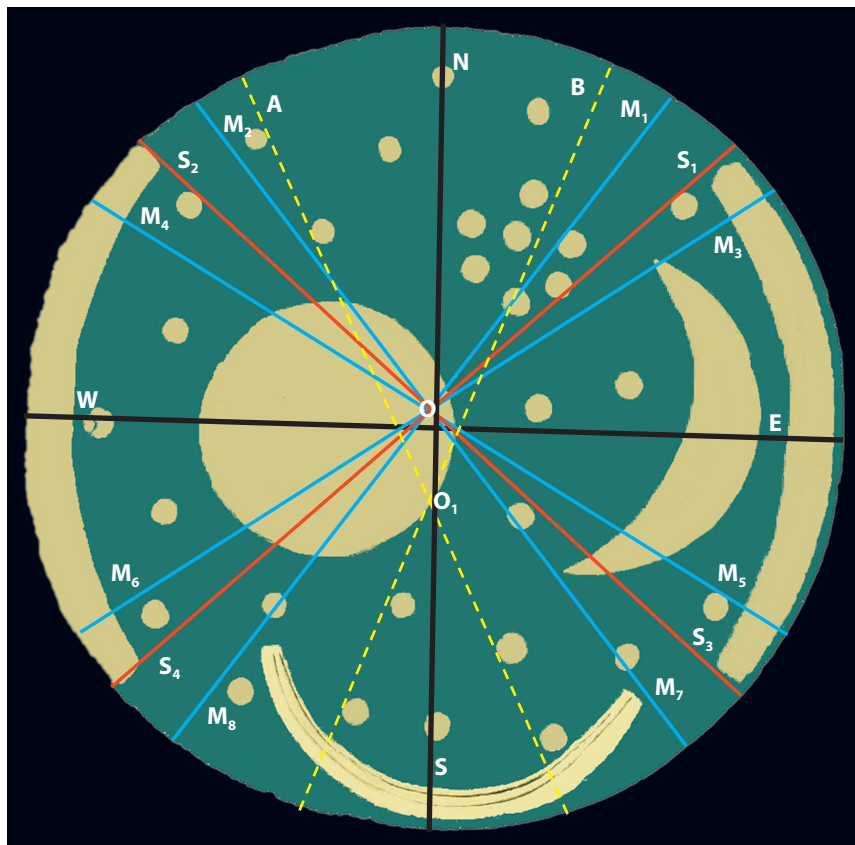


Fig. 2. The range of sunrise and sunset (S) directions during the year and the Moon (M) in the 18.61-year cycle. By W. Góral (background: disk copy, Wikimedia, [6])

Rys. 2. Zakres kierunków wschodu i zachodu Słońca (S) w ciągu roku oraz Księżyca (M) w cyklu 18.61 lat. Oprac. W. Góral (tło: kopia dysku, Wikimedia, [6])

point of the two lines. The bisector of the angle S_1OS_2 sets the north-south axis. It turns out that this line coincides with the line defined by two points, which we denote as north – N and south – S. A line perpendicular to the S–N axis, drawn through the beginning of the system O, indicates the direction east–west, E–W (Fig. 2). As a result of measuring the angles S_1OS_3 and S_4OS_2 we get as a result of 82° . Hence, it follows that the azimuths of individual directions are as follows: OS_1 (49°), OS_2 (311°), OS_3 (131°), and OS_4 (229°).

On the day of the summer solstice, the declination of the Sun (δ) reaches its maximum value in a given year, which is equal to the angle of the ecliptic plane to the equatorial plane (ε). This angle, and therefore the declination of the Sun on the day of the summer solstice, is currently slowly decreasing. At the time of the disk creation, this value was approximately 24° . When calculating the east (west) azimuth of the celestial body, the atmospheric refraction is taken into account. Its standard value on the horizon is $35'$. When the centre of the sun's disk is in the horizon plane, the value of the zenith distance is $z = 90^\circ 35'$. When introducing it to the calculations, we use the cosine formula of spherical trigonometry for a parallactic triangle [3].

$$\cos A = (\sin \delta - \sin \varphi \cos z) / \cos \varphi \sin z \quad (1)$$

For the zenith distance $z = 90^\circ$, this formula is simplified to the following form

$$\cos A = \sin \delta / \cos \varphi \quad (2)$$

Using the above formulas, we check for which latitude range the condition $S_3 - S_1 = 82^\circ$ is satisfied.

From the analysis of the data contained in Table 1, we can see that the values of the sunrise azimuths calculated by formula 1 (columns 2–4) differ in the results calculated by formula 2 (columns 5–7) by about one

arc degree. In turn, the differences between the azimuth of sunrise on the winter and summer solstices are the same. The condition $S_3 - S_1 = 82^\circ$ is best met for a width of more or less 52° . Fig. 2 also introduces 4 directions of the Moon's east: OM_1 , OM_3 , OM_5 , OM_7 and the directions of its west symmetrical to the N–S axis. The moon rises and sets are characterized by two cycles: a monthly cycle and an 18.61-year cycle.

In the monthly cycle, the declination of the Moon varies from $-29^\circ 09'$ to $29^\circ 09'$ (High Moon) within one revolution. Then, in the winter full moon at the time of its upper culmination, the Moon rises in the direction of $OM_1(38^\circ 31')$ and culminates at maximum altitude of 67.15° . And during the full moon near the summer solstice, the Moon will be extremely low above the horizon, rising in the direction of $OM_7(141^\circ 29')$ and culminating at $h = 8.85^\circ$. After 9.3 years, the declination of the Moon varies from $18^\circ 09'$ to $-18^\circ 09'$ during one monthly cycle. In this case, at latitude 52° , the azimuth of the direction of the moon rising is in the range: $OM_3(58^\circ 44')$ to $OM_5(121^\circ 16')$.

CULMINATION OF THE SUN AND THE MOON RECORDED ON THE SKY DISK OF NEBRA

The phenomenon of celestial body culmination, observed in the meridian plane, is described in the horizontal system using the altitude h or the zenith distance ($z = 90^\circ - h$). The altitude of a celestial body at the moment of culmination depends on its declination δ , and the latitude φ of the observation site and is expressed by the formula: $h = 90^\circ - \varphi + \delta$. The declination of the Sun during the year, about three thousand years ago, varied in the range from -24° to 24° . This knowledge is recorded on the Sky Disk of Nebra by the lines O_1A and O_1B defined uniquely by three points on the disk (Fig. 2). The angle AO_1B is $2\varepsilon = 48^\circ$. This is the extent

Table 1. Azimuth values of the directions of sunrises at the solstices

Tabela 1. Azymuty kierunku linii wschodu Słońca w dniu przesilenia letniego i zimowego

φ	$A, \delta = 24^\circ$	$A, \delta = -24^\circ$	$S_3 - S_1$	$A, \delta = 24^\circ$	$A, \delta = -24^\circ$	$S_3 - S_1$
50°	$49^\circ 50'$	$128^\circ 22'$	$78^\circ 32'$	$50^\circ 45'$	$129^\circ 15'$	$78^\circ 31'$
51°	$48^\circ 47'$	$129^\circ 20'$	$80^\circ 33'$	$49^\circ 44'$	$130^\circ 16'$	$80^\circ 32'$
52°	$47^\circ 39'$	$130^\circ 22'$	$82^\circ 43'$	$48^\circ 39'$	$131^\circ 21'$	$82^\circ 32'$

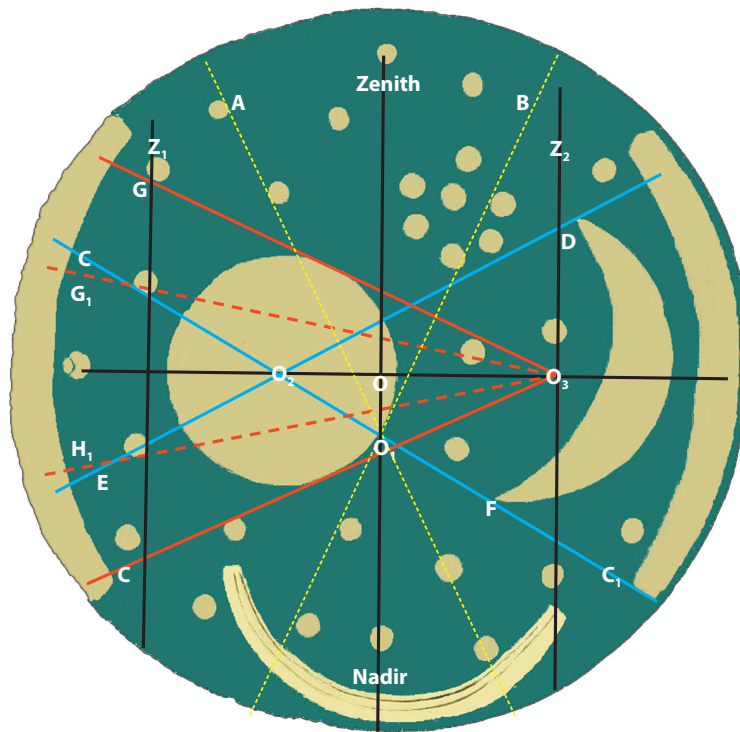


Fig. 3. The range of declination (altitude) of the Sun at the culmination of the year, and the range of the Moon over 18.61 years. By W. Góral (background: disk copy, Wikimedia, [6])

Rys. 3. Zakres deklinacji (wysokości horyzontalnej) Słońca w kulminacji w ciągu roku oraz Księżyca w okresie 18.61 lat. Oprac. W. Góral (tło: kopia dysku, Wikimedia, [6])

to which the declination of the Sun and its altitude change at the peak during the year.

The bisector of this angle AO_1B in Fig. 2 coincides with the S–N axis, and in the meridian plane its counterpart is the Zenith–Nadir (Z–N) axis (Fig. 3). The angle marked with the letter ε determines the deviation of the ecliptic pole from the celestial pole, which is equivalent to the deviation of the ecliptic plane from the celestial equator plane. At the time of the culmination of the upper Sun, on the day of the summer solstice, it is on the plane of the ecliptic, with the maximum deviation north of the equator (24°).

The angle AO_1B from Fig. 2 fits perfectly on the disk as the angle CO_3G , which covers the disk of the symbol of the Sun (Fig. 3). The apex of this angle O_3 is on the line Z_2 , parallel to the line Z–N. The bisector of the angle CO_3G is perpendicular to the line Z–N, and passes through the centre of the solar disk along the line $O-O_2$. The intersection of lines A and B marks an additional point O_1 on the disk on the Z–N axis. It turns out that it

lies on the straight line touching the lower Moon symbol – F and the lower part of the bow – C_1 . The extension of the line C_1-F-O_1 in the opposite direction marks the point O_2 at the intersection with line $O-O_3$. This point coincides with the centre of the sun's disk. Then we connect point O_2 with the upper symbol of the Moon at point D. It turns out that the value of the measured angle FO_2D , including the figure of the Moon, is about 58° . This value is in line with the difference between the Moon's maximum declination value of 29° and its minimum value of -29° . The Moon's altitude changes to the same extent over its 18.61-year cycle.

The angle of CO_3G has been divided by the lines: O_3G_1 , O_3O_2 , O_3H_1 into four approximately equal sectors (Fig. 3). In the direction of $O_3G_1(12^\circ)$, the Sun is at its declination of 12° , which takes place around February 16 and August 20. In the direction of $O_3O_2(0^\circ)$, the Sun is on the Spring and Fall Equinoxes, and similarly in the direction of $O_3H_1(-12^\circ)$, the Sun is around February 16 and October 25. Thus, as it was written on the disk, it

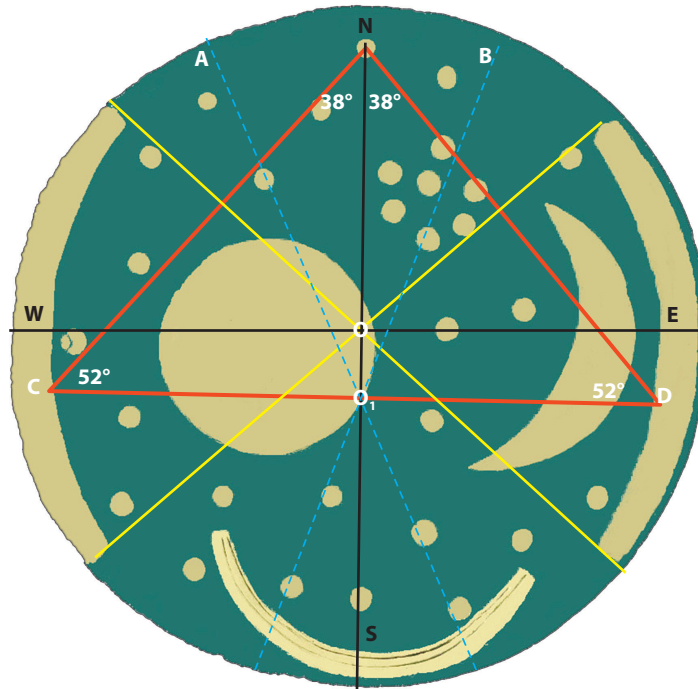


Fig. 4. Angles 52° and 38° written in two right triangles CNO_1 and DNO_1 . By W. Góral (background: disk copy, Wikimedia, [6])
Rys. 4. Kąty 52° i 38° zapisane w dwu trójkątach prostokątnych CNO_1 i DNO_1 . Oprac. W. Góral (tło: kopia dysku, Wikimedia, [6])

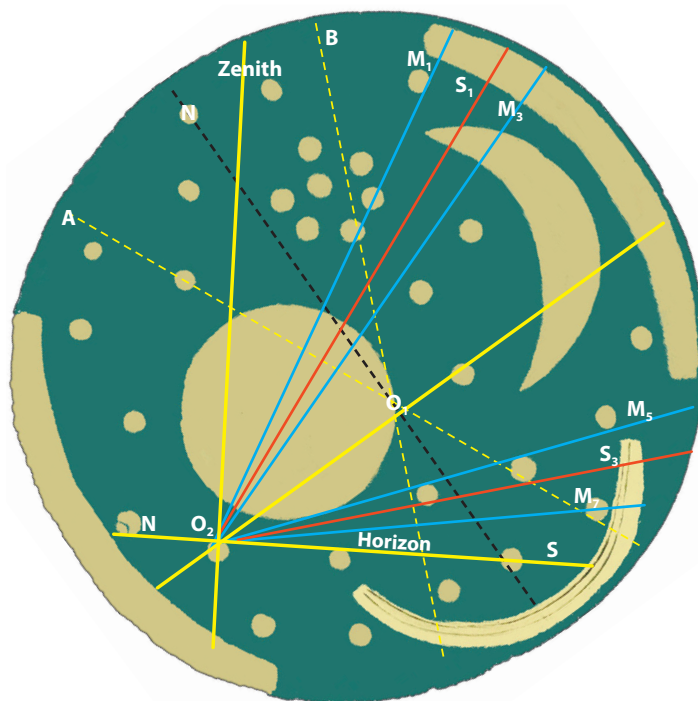


Fig. 5. The altitude (zenith distance) of the Moon and the Sun at its culmination. By W. Góral (background: disk copy, Wikimedia, [6])
Rys. 5. Wysokość horyzontalna (odległość zenitalna) Księżycy oraz Słońca w momencie kulminacji. Oprac. W. Góral (tło: kopia dysku, Wikimedia, [6])

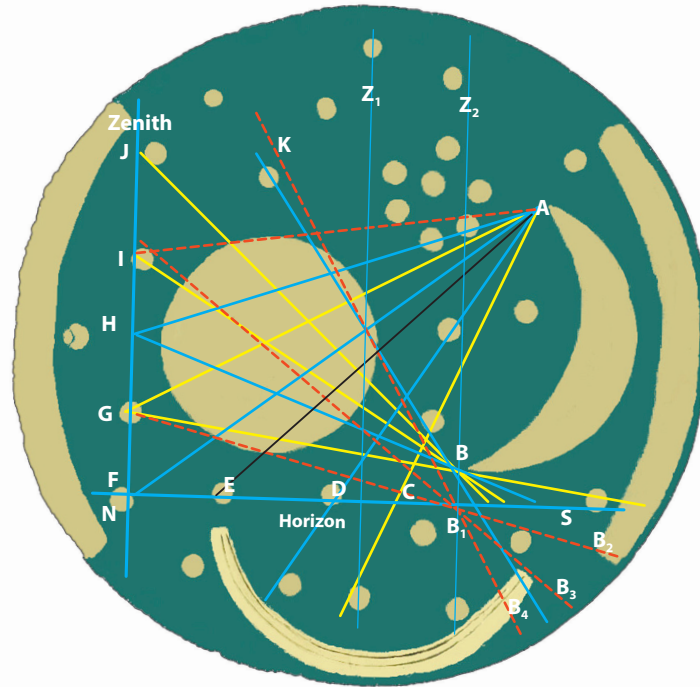


Fig. 6. The altitude of the Moon culminating in the 18.61-year cycle, and of the Sun in the annual period. By W. Góral (background: disk copy, Wikimedia, [6])

Rys. 6. Wysokość horyzontalna Księżyca w kulminacji w cyklu 18.61-letnim, oraz Słońca w okresie rocznym. Oprac. W. Góral (tło: kopia dysku, Wikimedia, [6])

could also be used as a calendar. Particularly noteworthy about the Sky Disk of Nebra are two right-angled triangles: CNO_1 and DCO_1 , symmetrical in relation to the N–S axis (Fig. 4). The red-marked CND triangle is an isosceles triangle, which consists of two right triangles. The measured value of the CND angle is 76° , so the other two angles are 52° . The angle of CNO_1 of approximately 38° defines the horizontal height of the celestial equator in the plane of the local meridian. The value of the measured NCO_1 angle is related to the parallel of latitude approximately 52° .

On the Sky Disk of Nebra, two methods were successfully deciphered describing the range of changes in the Moon's altitude at its culmination in the 18.61-year cycle, and the Sun's annual cycle. In the first method, presented graphically in Fig. 5, the origin of the system is located at point O_2 . This drawing enables measurement of the horizontal height from the O_2S axis. The angle $SO_2O_1(38^\circ)$ describes the altitude of the celestial equator above the horizon in the plane of the local meridian. The four directions shown in Fig. 5 have been assigned the following altitudes as a function of the

Moon's declination: $O_2M_1(67^\circ, 29^\circ)$, $O_2M_3(57^\circ, 18^\circ)$, $O_2M_5(19^\circ, -18^\circ)$, $O_2M_7(9^\circ, -29^\circ)$.

The range of knowledge describing the moon's culmination in the second method has been increased and graphically significantly improved. Two systems were introduced with the beginning attached at both ends of the Moon symbol: A, B (Fig. 6). The range of changes in the Moon's altitude in the upper culmination in the 18.61-year cycle includes 7 lines hooked at point A: $A(IA) = 38^\circ - \varepsilon - i = 9^\circ$, $A(HA) = 38^\circ - \varepsilon + i = 19^\circ$, $A(GA) = 38^\circ - 2i = 28^\circ$, $A(EA) = 38^\circ + i = 43^\circ$, $A(DA) = 38^\circ + \varepsilon - i = 57^\circ$, $A(CA) = 38^\circ + \varepsilon + i = 67^\circ$, $A(FA) = 38^\circ$. The lines: $BG(9^\circ)$, $BH(23^\circ)$, $BI(33^\circ)$, $BJ(43^\circ)$, $BK(57^\circ)$ are hooked at point B, at the bottom of the Moon. Three lines marked in red have been hooked at B_1 , on the horizon line: lines B_2, B_3, B_4 determine successively the altitude of the Sun at its culmination, at the winter solstice 14° , the spring (autumn) equinox 38° and at the summer solstice 62° .

Fig. 7 shows the basic geometrical figures on the Sky Disk of Nebra, which were used to determine the values of the desired angular quantities.

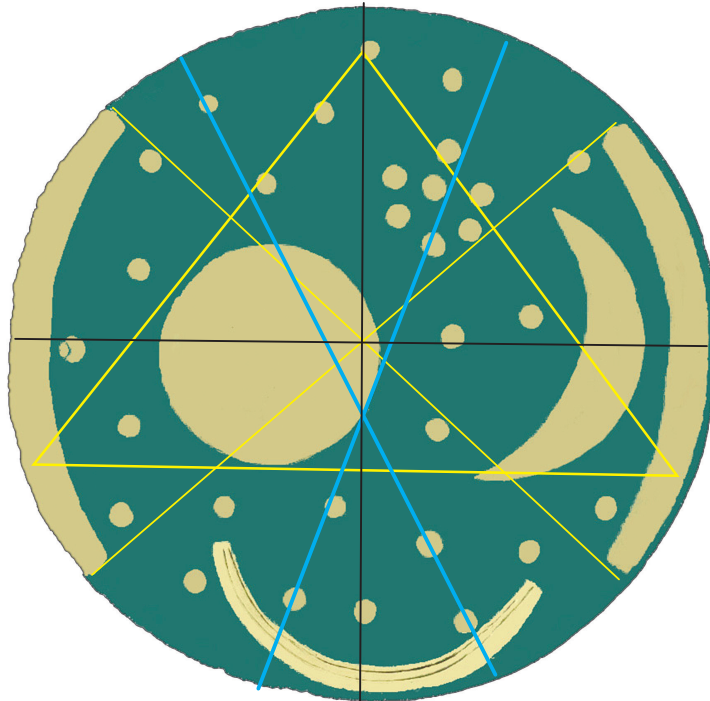


Fig. 7. Basic geometrical figures on the Sky Disk of Nebr. By W. Góral (background: disk copy, Wikimedia, [6])
Rys. 7. Podstawowe figury geometryczne na dysku z Nebr. Oprac. W. Góral (tło: kopia dysku, Wikimedia, [6])

FINAL REMARKS

A collection of small gold circles plotted on a disk is considered to be symbols of stars in astronomical terms. Many publications have been written on this premise. Despite numerous attempts, it has not been possible to assign them to specific stars or constellations with high probability. In the geodetic aspect, these objects are reference points on the surface of the Earth with which the most important phenomena observed in the sky were recorded and then documented on the disk using the language of geometry. The paper shows that the Sky Disk of Nebr covers a significant range of astronomical knowledge encoded on several layers in the polar horizontal system and on the meridian plane. This knowledge is written using angles in right triangles. The use of the symbols of the Sun, Moon and the sun barge, the shape and location of which fits perfectly with the content of the message, is admirable. In the geodetic aspect, all point features unambiguously define a series of lines with three or more of them. The Sky Disk of Nebr turned out to be a description of an extensive Neolithic observatory. Many astronomical aspects of Stonehenge are mirrored on the surface of the

Sky Disk of Nebr. The author had previously encountered similar problems while studying the astronomical aspects of Krakow's prehistoric mounds [1], [2].

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