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MYTHOLOGICAL ORIGIN OF CONSTELLATIONS AND THEIR DESCRIPTION: ARATUS, PSEUDO-ERATOSTHENES, HYGINUS

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Abstract. Didactic poem, *Phaenomena* writen by Aratus of Soli, *Catasterismi* (Καταστερισμοί) the only surviving scripture associated before with Eratosthenes of Cyrene and *De Astronomica*, also known as *Poeticon Astronomicon,* attributed earlier to the Roman historian Gaius Julius Hyginus, and their translation to Serbian, have been considered.

1. INTRODUCTION

A long, didactic poem, *Phaenomena* writen by Aratus of Soli (Ἄρατος ὁ Σολεύς; *c.* 315/310 BC – 240 BC) is the oldest preserved astronomical text in Europe, created about 270 BC. The macedonian king, Antigonus II Gonatas (*c.* 319-239 BC) ordered and financed this work. Aratus sought and found the sources of astronomical knowledge in the work with the same name of Eudoxus of Cnidus, which he transformed in a poem, making it easier to read and remember. In the following times his poem became very popular, gladly read throughout ancient Greece and then Rome, often translated into Latin, which greatly increased the number of transcripts so that it has been preserved to these days, unlike the book of Eudoxus.

The similar description of mythical origin of constellations is *Catasterismi* (Καταστερισμοί) the only surviving scripture associated before with Eratosthenes of Cyrene (Ἐρατοσθένης ὁ Κυρηναῖος - *c.* 276 - *c.* 194 BC), the chief librarian at the Library of Alexandria, whose works were burnt down when it is burned and exist only in fragments. This text came to our time as an *epitome*, a short version of a larger work, and, the unknown author is named Pseudo-Eratosthenes. It is also a famous works of antiquity about heaven and, unlike the text of the similar content (*Phaenomena*) of Aratus, from which many mythological topics in this text have been taken, provides data on the number, and brightness of stars in the described constellations, so that represents a kind of the first preserved star catalogue of ancient Greece.

The third book with the similar content is *De Astronomica*, also known as *Poeticon Astronomicon,* attributed earlier to the Roman historian Gaius Iulius Hyginus, though the true authorship is disputed.

We translated in Serbian *Phaenomena, Catasterismi* and *Poeticon Astronomicon.* In this contribution we consider and discuss these three writings.

2. ARATUS OF SOLI AND HIS *PHAENOMENA*

Aratus is born in Cilicia (today in southeast of Turkey), in the Ionian colony of Soli, about 315 BC. He was a student of Menecrates from Ephesus and Philitas from Cos. He was in contact with the stoic philosopher Zeno from Athens, who probably recommended him to the Macedonian king Antigonus II Gonatas (c. 319-239) from Pella. He came to Pela around 276 BC, in the service of the king, as court's doctor. Antigonus most likely ordered and financed the famous work of Aratus, *Phaenomena*., created around 270 BC. Aratus visited also the court of the Antiochian king Antiochus I Soter of Seleucia (324/3 - 261 BC), where he spent some time, as well as Alexandria and other cultural centers of the eastern Mediterranean region. He passed away around 240 BC and has been burried in Soli. Recently, are discovered rests of his monumental grave.

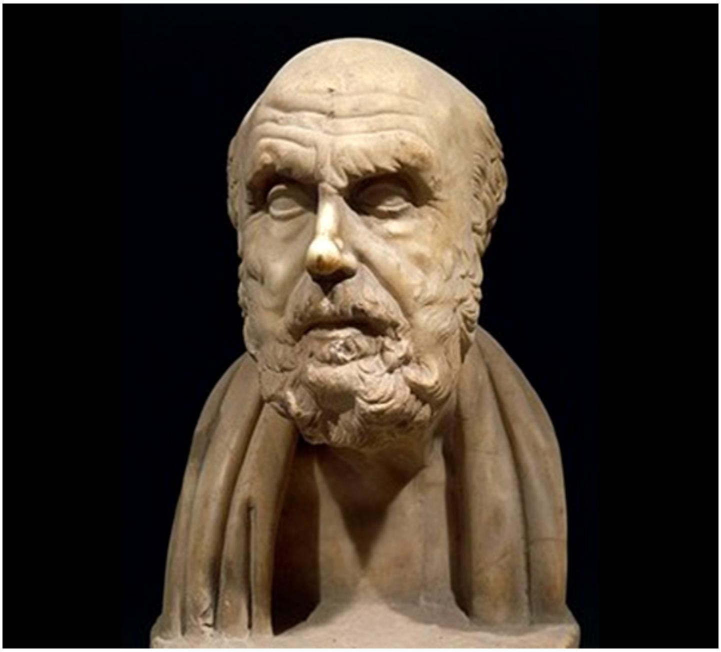

Figure 1: Aratus of Soli, the marble sculpture in the Archaeological museum of Naples.

Aratus's didactic poem *Phaenomena* is based on the astronomical text with the same name of astronomer and mathematician Eudoxus from Cnidus (*c* 390 – *c* 337).

Eudoxus, a student of Plato, left us the first systematic description of the constellations, established the first sophisticated geometric model of the motion of celestial bodies, and significantly improved observational astronomy. He studied mathematics with Architas of Tarentum and after his stay in Asia Minor in Czicus he came to Athens, where he joined Plato's Academy. He later returned to his native Cnidus, where he built an observatory.

He tried to explain all the peculiarities in the motion of celestial bodies on the basis of a combination of uniform circular motions. According to the Eudoxus model, stars are located on a sphere, which once a day rotates around an axis passing through the Earth, and the movement of other celestial bodies is described by a combination of rotating spheres with each axis tilted relative to the previous one at a certain angle.

The Eudoxus system could not predict the movements of celestial bodies accurately enough. Also, he was not able to explain why the planets change their speed, as well as their brightness, since they are always at the same distance from the Earth, if their spheres are concentric. However, he advanced this science so much that the whole period up to Hipparchus is often called the period of Eudoxian astronomy.

Phaenomena is a long, didactic poem, with 1154 verses, divided in several chapters: Stars and constellations, Circles of celestial sphere, About planets, Risings and settings of stars and constellations. The last part refers to atmospheric phenomena and meteorological knowledge and beliefs. This is a book about astro-

Figure 2: The fist translation of “Phaenomena” of Aratus of Soli on Serbian, published 2017.

nomical knowledge of Hellenistic Greece, in the time whe they were only descriptive, when astronomers could only descrie what they saw on the sky.

Aratus's work was very popular and often commented and translated into Latin in the Hellenistic and Roman periods, so that it has been preserved to this day, unlike the original work of Eudoxus, on which the author relied. The most famous of the commentators is Hipparchus, who lived about a hundred years after Aratus, the "father" of mathematical astronomy, whose only preserved work was just the commentary of Aratus' poem *Phaenomena*, to which he added a commentary of the work of Eudoxus from Cnidus. The oldest preserved copy in the Greek language appeared six centuries later by Theon from Alexandria (c. 335 – c. 405). Many translations have been made in Latin, the best known by Cicero, Germanicus and Avenius.

The work of Aratus and Eudoxus still inspires scientists and raises several questions:

1. What are the sources of Eudoxus' astronomical data?
2. How old are the astronomical data that Eudoxus possessed?
3. To what extent did he make observations himself?
4. Did Eudox really make a star globe?
4. From where did he observe the sky?
5. What instruments were available to him?
6. How accurate are his astronomical data?

The answers were sought, among others, by Isaac Newton (17th-18th century), and many scientists after him.

The research to answer some of these questions was conducted by Ovenden (1966), Roy (1984) and Zhytomirsky (1999) and (2003). They came to the conclusion that the latitude of that hypothetical observational place can be approximately determined on the basis of those stars of the southern celestial hemisphere that are not visible from there, that is, those that are not mentioned in the work. Using this premise, they determined that the observation site was located at a latitude of about 36^{o} N (plus or minus 1.5^{o}), which best suits the island of Crete, although it may be in the southernmost parts of Asia Minor. The scientists were also interested in the observation time. Knowing the precession of the Earth's axis, as well as the change in its inclination, they wondered at what point the arrangement of the stars in the sky was exactly as described by Aratus. Using different methods, all three came to very surprising conclusions: Ovenden found that the observation had to be done in 2600 BC (plus or minus 800 years), because some constellations had the positions stated by Aratus just then; Roy determined that it was in the year 2000 BC (plus or minus 200 years), while Zhytomirsky's calculations were very similar to the latter.

Criticizing their works, Schaefer (2002) pointed out several remarks: first, that the authors, when determining the latitude of the place, from which the results would possibly be obtained, did not take into account the refraction of light, so that the position of stars reported by Aratus are different. When this is taken into account, along with a few other astronomical parameters, Schaefer obtained the result that the southern constellations, described in Aratus's work, could be observed from a latitude of 31-33^{o}, which corresponds, for example, to Phoenicia and not Crete. The same author pointed out another remark on the works of Ovenden, Roy and Zhytomirsky: none of these three authors published the calculations on which their conclusions are based.

In 2006, Rousseau and Dimitrakoudis used computer software to analyze Greek myths relating to the stars and constellations, as well as the geographical terms mentioned in them as the scene of the events described in each individual myth. They understood this as potential places of observation of the sky and determined that the data used by Aratus agree somewhere with the time when Eudoxus lived, but sometimes they reach the year 2000 BC. From their work, it follows that Eudoxus, in writing his work, on which Aratus later relied, used sources obtained from different places and at different times. Denis Duke (2008), a mathematician and statistician from the University of Florida, performed a statistical analysis of the Eudox data given by Aratus in his poem. His calculations narrowed the time span of sky observations to between 1150 and 300 BC, but they did little to the problem of determination of the location of the observations.

In the same year Elly Dekker (2008), investigating the conditions necessary to make a star globe, analyzes whether they were fulfilled in Eudoxus' time. The author points out that the descriptive tradition, to which both Eudoxus and Aratus belong, will be replaced by the mathematical one in the following centuries, which will be followed already by Hipparchus. This leads to a certain misunderstanding of Eudoxus's data, so, guided by certain conventions, which already existed at that time, she believes that Eudoxus must not have respected them, when they did not exist yet. Decker underlines a certain degree of standardization of the constellation, which Hipparchus knew and did not exist in the time of Eudoxus.

The same author emphasizes the importance of the fact that, when observing the sunrise on the days of solstices and equinoxes, the observer cannot directly see the constellation in which it is located, because it is shaded by light, but is indirectly oriented towards the constellation from the ecliptic,a briefly seen on the eastern horizon before sunrise (helical sunrise). In order to know exactly where the Sun is at the time of sunrise, the observer needs to have a precise instrument for measuring time and the knowledge that the celestial sphere rotates by 15^{o} every hour. The clepsydra certainly does not allow for such precision. If we add to this the fact that the constellations from the ecliptic were not standardized (to an angular range of 30^{o}), nor was there a convention that the center of the constellation Aries is at a declination of 0^{o}, it becomes clear that Eudoxus could have made a star globe of his own observations, but he could not claim high precision. Eudoxus was not even aware of the precession of the Earth's axis, due to which this zero point moves slowly over time. In the absence of precise tools, it takes too much self-confidence to ignore older data and rely solely on the results of your observations.

Figure 3: The Kugel Globe (perhaps a part of an armillary sphere?) is dated around II century BC. It may be the earliest celestial globe to survive from Classical antiquity. It was acquired 1996 and held for some time in the Gallery J. Kugel Antiquaries in Paris (France). The Kugel Globe, which is now in a private collection, was reportedly found in the area of Lake Van, the largest lake in Turkey, located in the far east of the country.

The conclusion is that Eudoxus could have made a star globe, but it is not at the same time proof that he really did it. This is inferred from indirect data, found on two star maps, one discovered in a manuscript from the 11th century AD, known as Aberistvid NLW 735, the other from Monza, created in the 12th century (MS B 24/163), which show star maps, apparently copied from the globe, whose constellation drawings are quite similar to Eudoxus' data. This indicates that, at the time of writing, there could still be in Europe a specimen of a globe, made according to Eudoxus.

Previous research has shown that Eudoxus most likely observed the sky himself, and that, based on his observations as well as those of his predecessors and teachers, he most likely made the oldest star globe, which unfortunately has not been preserved, but some, a couple of centuries younger, made in his style, fortunately exist, such as the famous "Kugel globe", from the second century BC.

Aratus's work is, now for the first time, translated in the Serbian language (Арат из Сола, 2017).

We used the translation on English of G. R. Mair (Aratus of Soli, 1921) and Greek original.[1]

3. *CATASTERISMI* OF PSEUDO-ERATOSTHENES

Catasterismi are the only surviving scripture associated with Eratosthenes of Cyrene (Ἐρατοσθένης ὁ Κυρηναῖος - c. 276 - c. 194 BC), Greek mathematician, geographer, poet, astronomer and theoretician of music, the chief librarian at the Library of Alexandria, whose works were burnt down when it is burned and exist only in fragments. This text came to our time as an epitome, a short version of a more extensive work, from the end of the first century of our era. In the Middle Ages and during the renaissance, it was believed that it refers to the more comprehensive lost Eratosthenian work. Today, it is generally thought that this is not true, although some scientists defend the opposite view, so often the author is called Pseudo-Eratosthenes.

Catasterismi (Καταστερισμοί) in Greek means placing among the stars and denotes the transformation of a hero or object into a star or constellation. It is one of the most famous works of antiquity about heaven and describes the mythological origin of the constellations, the planets and the Milky Way, but, unlike the text of the similar content (*Phaenomena*) of Aratus of Soli, from which many mythological topics in this text have been taken, provides data on the number, and shine of stars in each of the described constellations, and in a way represents the first preserved star catalogue of ancient Greece. In addition, it also gives indications on the appearance of a person who personifies the constellation so that we can consider them in the way they are conceived in the Hellenistic world. In chapters 1 to 42, 43 constellations were considered, of the 48 (including Pleiades) described by Ptolemy. Chapters 43 and 44 speak of five planets and the Milky Way.

We made the first translation of *Catasterismi* (Димитријевић, Бајић, 2019) to the Serbian language with appropriate comments. We used translation of Kondos (1997) on English, and of Halma (1821) on French where also the text in Ancient Greek is given, as well as the text of Olivieri (Pseudo-Eratosthenes, 1897) in Ancient Greek created on the basis of five complete manuscripts and one partial (*Fragmenta Vaticana*), which used and Kondos. The great contribution of Kondos is his attempt to identify the stars mentioned by Pseudo-Eratosthenes. We included his identifications of stars in our translation.

[1] Aratus, Phaenomena,
http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A2008.01.0483

4. *DE ASTRONOMICA* OF HYGINUS

De Astronomica or *Poeticon Astonomicon* contains information about the knowledge of celestial bodies and their apparent movements, as well as the ways in which that knowledge was incorporated into the understanding of the world and the religion of the ancient Romans and Greeks. It was written by a certain Hyginus, which is quite clear, because the author's signature exists at the very beginning, together with a dedication to a certain M. Fabius. Unfortunately, the author did not use the obligatory Roman trinomial, which defines the identity of a person more precisely. Therefore, it is not entirely clear whether this is the same Caius Iulius Hyginus, the former slave of Octavian August liberated by him and appointed to the post of the Head of the Palatine Library and a friend of the poet, Ovid. There are indications that this is not exactly that Hyginus, because he lived from c 64 BC to 17 AD, while the author of this book lists the constellations in a very similar order, which was used by Ptolemy in his *Almagest*, two hundred years later. Therefore, it is justifiably suspected that the author of this book lived in the second century of the new era, although it must be admitted that he did not quote Ptolemy as the source of his data in any single place. These dilemmas regarding the identity of the author of this book cannot be resolved, because Ptolemy himself could have used the order of describing the constellations of an earlier author, whose work has not been preserved, which would not diminish the significance of his *Almagest.*

Lippincott (2011) noted that Germanicus Iulius Caesar (24 May 15 BC – 10 October AD 19), who in 4 AD wrote a Latin version of Aratus's *Phainomena,* corrected a number of the astronomical mistakes, criticized later by Hipparchus. Lippincott, as an additional argument, underlines the fact that „Eratosthenes was the Keeper of the great Library of Alexandria“ and Hyginus was on the same duty in the Palatine Library in Rome. This facilitated to him to cite in his work 44 Greek authors as counted by Bunte.[2] Lippincott (2011) says that among Greek authors Hyginus cites the work of Eratosthenes 21 times, „with ample evidence of additional, uncredited use elsewhere".

In his preface to Book I of *De Astronomica*, Hyginus says that he wants to give clearer explanations of the celestial sphere than Aratus, as well as to examine these issues more deeply. In the beginning of the Book I is the dedication to a certain 'M. Fabius', and an overview of the topics which the author wants to discuss, followed by detailed description of the celesial sphere and the corresponding circles.

[2] *Hygini Astronomica*, ed Bernh. Bunte, Leipzig, Weigel, 1875, pp. 3-6.

Figure 4: Two pages from the Erhard Ratdolt edition (1492, Venice) of the "De Astronomica" showing woodcuts of the constellations Cassiopeia and Andromeda. http://www.usno.navy.mil/library/rare/rare.html.

Book II gives myths connected with 42 constellations and discuss the mythologies associated with the five planets and the Milky Way. Book III presents desiption of each constellation, with indications of the shape and position of the figure. Additionally, the positions of the stars relative to the figure itself, are provided. Book IV provides the position of the constellations on each celestial circle, the unequal division of the night and day and the risings and settings of the constellations relative to the signs of the zodiac. Hyginus considers also the movements of the Sun and the Moon and the five planets. The end of the manuscript has been lost. Lippincott (2011) assumes that at the end was the consideration of the Metonic cycle, finding an indication for it in the Preface of Book I where Hyginus speaks about Meton and the accuracy of his observations of lunar and solar movements (*Hygini Astronomica,* 17-20, on p. 21) .

De Astronomica was included in the texts used for elementary learning of astronomy so it has preserved in a significant number of copies. It is translated to great world languages and now, we translated t on Serbian. We used one of Latin textes (*Hygini Astronomica*, e1875) and Russian (Гигин, 1997), English (Condos, 1997) and French (Hygin, 1983).

These three manuscripts, Aratus‘s *Phaenomena*, *Catasterismi* of Pseudo-Erathosthenes and *De Astonomica* of Hyginus, first time translated in Serbian, give a view on Eudoxan astronomy and the corresponding developments from Aratus in IV century BC to Hyginus during the reign of Octavian Augustus.

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