

Marko Antun de Dominis vs. Galileo Galilei: From Construction to Theory of Binoculars

On the occasion of the 400th anniversary of his death

Marko Antun de Dominis (Rab, 1560 – Rome, 8 September 1624), worked at the transition of the 16th to the 17th century, at a time when epochal changes were taking place in science and the philosophy of science, and in contrast to the traditional Aristotelian approach to the study of nature a new approach is introduced with the application of mathematical methods, of axiomatic deductive system, experiments and observations. Although de Dominis was educated in the Aristotelian tradition, from which he does not deviate completely, he used a new approach in natural sciences research. This is evidenced by his optical work *De radiis visus et lucis in vitris perspectivis et iride* (Discourse on the Rays of Sight and Light in Lenses and the Rainbow), completed at the end of 1609 and published in Venice in 1611. He wrote the work for the most part twenty years before the first public demonstration of binoculars in 1609, and completed it independently of Galileo's work and before the publication of Kepler's works in which the theory of lenses and binoculars is exactly explained. Therefore, this work by de Dominis is not only a valuable original contribution to optics, but also the first work in history that fully interprets the theory of binoculars, an instrument that begins a new era of astronomical and optical research.

Introduction

Marko Antun de Dominis, world-renowned Croatian theologian, physicist, philosopher, dean of Windsor, bishop of Senj, archbishop of Split, primate of Dalmatia and Croatia, was particularly interested in optics. Experimentally and theoretically, he was involved in the research of lenses and their systems. He combined his practical and theoretical research in his physics debut *De radiis visus et lucis in vitris perspectivis et iride* (Discourse on rays of sight and light in lenses and rainbows), published in Venice in 1611 by the printer Tommaso Baglioni. In the final redaction of his work, de Dominis added two chapters on a new instrument - binoculars. The work has a special value for the history of physics because it deals with a very current field at the time and was created at the dawn of a new era of optical and astronomical research. Even Isaac Newton mentions him with great praise in his famous work *Optics* (first edition London,

1704), placing de Dominis alongside the greatest names in science of the 17th century: Descartes, Huygens, Hook, Roemer, Grimaldi, Bartolinus and Boyle.¹ Dedicated to the most topical themes of the period, de Dominis' work had a rich and diverse reception during the 17th, 18th and 19th centuries, and it also experienced different judgments.

With this discussion, which he founded in the period from 1588 to 1595 as a young professor of mathematics at the Jesuit Collegium Patavinum in Padua and Collegio Brixienne in Brescia, and in its final form he supplemented and edited for publication only twenty years later at the end of 1609², de Dominis, independently of Galilei and his contemporaries, got involved in the then-current theoretical controversies surrounding the new binoculars instrument, which sparked interest in the scientific community of Europe at the time and soon enabled major astronomical discoveries. Therefore, the purpose of this paper is to consider from the aspect of history and the development of science the genesis of de Dominis' views on binoculars and the beginning of his optical work, methodological peculiarities, originality and scope, especially in comparison with Galilei's approach and contributions to the understanding of the new instrument as well as other contemporaries, in order to determine and evaluate in more detail the significance of de Dominis's work in that area.

About the discovery of binoculars

Binoculars as an invention were the result of many years of efforts and practical discovery. The construction was realized by chance, with suitably arranged lenses, and it was certainly not created on the basis of theoretical considerations. The first binoculars were the work of practical master opticians and were constructed in the Netherlands in 1608. The merchant and optician Hans Lippershey (1570-1619) from Middelburg was the first to show it publicly in Venice and tried to get a patent.³ In the summer of 1609, just in time when Galilei was staying in Venice, he found out about the visit of Lippershey, who came to offer to the Senate a new optical instrument with amazing possibilities. Galileo was impressed by the new instrument.

Through his influential acquaintance Paolo Sarpi, he planned to slow down the Dutchman's negotiations with the Senate for a while, so that he would have time to construct his own binoculars with even better capabilities and offer them to the Senate.⁴ Galilei tried to present the binoculars as his own invention. Although the

¹ NEWTON 1719: 161–162, 168.

² DOMINIS 2005: 8-10.

³ PAVLOVSKI 2008: 181-187.

⁴ PAVLOVSKI 2008: 181-187.

invention of binoculars is undeniably the result of the practical work of a Dutch optician, Galilei unfoundedly stated that binoculars were the result of his long-term scientific efforts, and thus attributed the credit to himself. In connection with the binoculars, Galilei first presented himself as a person who has great skills in precise constructing (replicating) of the instrument, because in a short time immediately after seeing the Dutch invention, he constructed his own binoculars with even greater magnification. However, without scruples he presented it to the Doge of Venice and the Senate as his own invention, seeing in that great opportunity, since one of his structural improvements from a pre-existing instrument - a calculating scale, called a geometric-military compass, based on the principle of proportional sizes, was already at that time bringing him considerable income.⁵ Thus, Galilei was not the first person to construct a practical invention for viewing distant objects - binoculars, although he presented it as his own invention.⁶ In addition to the fact that binoculars were not Galilei's invention, he was certainly not the first person to point binoculars at the starry sky, because it is known that before Galilei, the distinguished English astronomer Thomas Harriott was the first to observe and draw maps of the Moon with binoculars already in July 1609. and after that he systematically investigated sunspots and other phenomena.⁷ Galilei

⁵ GEYMONAT 1964: 39-41, 50-53. PAVLOVSKI 2008: 181-187. Sarpi made it possible for him to be accepted by Doge Leonardo Diona, and on that occasion Galilei with well chosen words presented and handed over a copy of the binoculars to the Republic, a practical Dutch invention, which he successfully replicated in a short time: With his chosen words, Galilei presented the binoculars, a practical Dutch invention that he successfully replicated in a short time, and said: "This (binoculars) is one of the fruits of science, the science that I have been conducting in Padua for the past seventeen years, in the hope that I will be able to present you with even greater inventions than this one, if God and Your Highness will want that, and if You and God will wish for the rest of your life to your service,..." Published in: Pavlovski, Krešimir. (2008). p. 182. It is interpreted how Galileo believed that skillful use of the instrument could enable him to return to his native Florence. Therefore, not long after discovering the four moons of Jupiter, he sent a request to the Grand Duke of Tuscany Cosimo II. de' Medici with a request to allow him to name the discovered moons the Medici stars and assign them the names of the Grand Duke and his three brothers: Cosimo, Lorenzo, Carlo and Francesco. The plan bore fruit. For his merits and kindness, Galilei was soon appointed court mathematician and, at his personal insistence, court philosopher at the court of the Grand Duke in Tuscany and returned to his native Florence.

⁶ GEYMONAT 1964: 52-52.

⁷ LOHNE 2000: 124-129. Thomas Harriot at the beginning of 1609 bought a "Dutch instrument" (binoculars), and his observations were among the first uses of binoculars in astronomy. Harriot is now considered the first astronomer to draw an astronomical object after observing it through binoculars: he drew a map of the Moon on 26 July 1609, a few months before Galileo. By 1613, Harriot had produced two maps of the entire Moon, with many recognizable features such as lunar craters shown in their correct relative positions that had not been improved for several decades. He also observed sunspots in December 1610. In 1607 Harriot used his notes from observations of Halley's Comet to work out his understanding of its orbit. Shortly thereafter, in 1609 or 1610, Harriot turned his attention to the physical aspects of the Moon and his observations

was among the first to believe in the power of binoculars as an instrument to gather evidence in support of the Copernican theory. As an opponent of peripatetic theories and inclined to the Copernican theory, he hoped to find evidence in support of the Earth's motion and the heliocentric system, and at the same time he sometimes did not choose the way or the means, and the importance of his discoveries, which he hastily published, changed forever the human understanding of the nature of the universe. It should be pointed out that until 1609, when he first encountered the Dutch instrument, Galilei mostly dealt with problems of mechanics and was not particularly interested in optics,⁸ but it was the possibilities of binoculars that encouraged him to intensive astronomical observations that soon yielded significant discoveries. Although the instrument caused a sensation and an avalanche of interested parties, including a large number of skeptics and disputants, Galilei left the theoretical problem of binoculars and the need for its theoretical interpretation aside, focusing on its application in astronomy, so that in that period, despite the fact that he constructed and used it, he did not know how to theoretically and precisely interpret the operation of the new instrument. This is evidenced by his short astronomical treatise *Sidereus nuncius* (Starry Messenger), published in March 1610, dedicated to the Tuscan duke Cosimo II. de' Medici and written with the aim of describing and interpreting his astronomical discoveries made with the help of binoculars, which he only briefly describes in the introductory part of the discussion.⁹

of the first sightings of sunspots. Harriott also studied optics and refraction, and today he is considered to have discovered Snell's law around 1600, 20 years before Snellius, however these manuscripts, like many of his works, remained unpublished.

⁸ GEYMONAT 1964: 39.

⁹ Galileo synthesized all the criticisms of the Peripatetic philosophy and, using observation, looked for evidence of the Earth's motion and in support of the heliocentric system. But observations were not enough, because celestial mechanics also had to be built on mathematical foundations. In order to prove the hypothesis of the heliocentric system, a mathematical proof was needed - and this was made and published in the same year 1609 by Johann Kepler in the epoch-making work *Astronomia Nova*, in which he mathematized celestial mechanics and gave the fundamental laws). Compared to Kepler's work, Galilei's *Star Messenger*, although a short piece in scope, brings his great observational discoveries and contains a large number of drawings and diagrams of the surface of the Moon, Jupiter's moons and stars. Galilei's discoveries of new heavenly bodies threatened the old theory of a perfect and unchanging universe and therefore triggered an avalanche of challengers and also imitators, and only a few voices in his support. At Galileo's express request, Kepler was the first astronomer to support the *Star Messenger* and hastily published his positive judgment in Prague in August 1610 under the title *Dissertatio cum Nuncio Sidereo* (Conversation with the Star Messenger). Surprisingly, at the same time, Galileo did not comment on Kepler's aforementioned masterpiece *Astronomia Nova*, published just before the release of his *Star Messenger*. PAVLOVSKI 2008: 181-187.

Origin of the work De radiis visus et lucis in vitris perspectivis et iride

About twenty years before binoculars were shown to the public in Venice in 1609, de Dominis was interested in optics and researched the properties and theory of lenses even as a young Jesuit at the time when he was a mathematics lecturer at the Jesuit Collegium Patavinum in Padua,¹⁰ and then a professor of mathematics and philosophy at the Collegio Brixiese in Brescia (1587-1595). In that period, he wrote the concept of his two physics works.¹¹ Having joined in 1595 high ecclesiastical and diplomatic positions, he no longer had time to deal with science, which could not be his focus from that period on. However, since the natural sciences were still an area of his permanent interest, over time, as opportunities allowed, he researched and supplemented his knowledge. While he was archbishop in Split and primate of Dalmatia and Croatia, despite the complexity of his obligations and long-term disputes in which he was involved,¹² he followed the events in the scientific community. That he was knowledgeable about current events is evidenced by the fact that immediately after Galilei's public demonstration of binoculars in August 1609, which stimulated the interest of the scientific community, he reacted promptly and in just a few months submitted for publication a redacted old optical discussion into which he added two new chapters on binoculars. Details about the origin of the work can be found in the introduction

¹⁰ KORADE 1983: 101-117., information about de Dominis p. 111. He was educated and developed his intellectual affinities under the auspices of the Jesuit order. Already at the age of 12, he was sent to the Jesuit Croatian College in Loreto (*Collegio Illyrico di Loreto*), where he attended high school and studied grammar, rhetoric and moral theology. In 1579, he joined the Society of Jesus in Novellara, and then went to study in Verona, where he studied philosophy and at the same time taught literature in the lower classes. During his studies, he received an excellent education and formed broad intellectual interests. He begged the superiors to send him on overseas missions, but he was left behind in Italy and from 1587 to 1591 he studied theology in Padua, where he was also a lecturer of mathematics and natural sciences. In that period, in addition to his religious duties, he was completely devoted to scientific work, and that's when he wrote the concept of his two works in physics, which he would publish twenty years later. After completing his studies in 1592, he went to Brescia and taught rhetoric there, then logic and philosophy until the end of 1595, when he left for Rome.

¹¹ He completed and published the second physical work only near the end of his life under the title *Euripus seu de fluxu et refluxu maris sententia*. In it, de Dominis deals with the high tide and ebb of the sea, and refutes the opinion that the shape of the Earth is irregular, advocating for the shape of a sphere. He sees the cause of tides in the influence of the Sun and the Moon on sea waters. The research that de Dominis did as a young man in the period from 1588 to 1595 he was unable to complete and prepare for publication, because then, after the death of his uncle Antun Dominis, bishop of Senj, in the anti-Turkish war under Klis in 1596, the peaceful period of de Dominis' scientific career ends. and religious life. After that, science could no longer be the focus of his work, as he began his rise in the church hierarchy and a stormy period of public, church, political and diplomatic activity that would follow him for the rest of his life.

¹² See: TUDJINA 2006: 41-142.

by the editor Giovanni Bartoli, at whose persuasion de Dominis began to supplement and prepare the manuscript for publication. Giovanni Bartoli was a person of great confidence of the archbishop, husband of de Dominis' niece Franica and attaché at the Florentine mission in Venice.¹³

Bartoli's brief introduction discusses the period of creation of de Dominis' manuscript, his research goals, the circumstances and process of completing and publishing the discussion, creating a starting point for understanding and analyzing de Dominis' optical work.¹⁴ Galilei's public presentation of the telescope in August 1609 prompted them to discussions about a new instrument. De Dominis, recognizing in the displayed properties of the binoculars some of his previous results that he had achieved twenty years ago by performing experiments with lens combinations, showed his old notes to the young Bartoli, about which Bartoli wrote:

“He pulled out of the dust and let me read some very old notes, which he had made about twenty years ago, while first in Padova and then in Brescia, in the then famous schools of the Society of Jesus, he taught mathematics in addition to philosophy, and that only out of love for subject and for pleasure. I found a lot about optics that was incredibly interesting to me, but I paid particular attention to that part of those notes in which this man presented new and previously unknown things about optical glasses or binoculars, as well as the rainbow, accompanying everything with very clever physical and mathematical proofs. I understood that he laid the broadest foundations on which all the theory of this now famous device rests.”¹⁵

Thus, Bartoli believed that in de Dominis' old professorial scripts in optics there were already certain fundamental principles that could interpret the operation of binoculars.¹⁶ Therefore, stimulated by the interest aroused by the instrument publicly displayed in Venice, he succeeded in persuading de Dominis, who at that time was already burdened with heavy worries due to his title and archbishop's position,¹⁷ to revise the manuscript with his editorial help and expand the thematic

¹³ ANTOLJAK 1796: 22–23, 49–61.; LJUBIĆ 1870a: 1–159.; LJUBIĆ.1870b 1–260.

¹⁴ De Dominis' optical work was published here in Latin and translated into Croatian by Stanko Hondl and edited by Darko Novaković in: DOMINIS 2005.

¹⁵ DOMINIS 2005: 8-9.

¹⁶ DOMINIS 2005: 8-9.

¹⁷ De Dominis was already involved in a dispute with the Roman Curia in connection with the conditions related to his appointment as Archbishop of Split. However, his critical attitude towards Rome had deeper roots and stemmed from his dissatisfaction with the autocratic way in which the church was run, with corruption and immorality in the Curia, and above all with what seemed to him to be a gross distortion of basic Christian doctrine and trading in indulgences and superstition. When he stayed in Venice in 1606 due to disagreements with the Split Chapter, the tension between the Roman Curia and Venice reached its peak after Pope Paul V interdict

framework of the discussion by adding chapters in to which he will give the interpretation and theory of the new binocular instrument from his earlier observations on the combinations and properties of lenses.

Content, structure and conception of the work

De Dominis' work, as is evident from the title and announcement in the editorial, interprets the laws of sight, optical glasses and the rainbow. The presented material is systematized in 18 chapters. After Bartoli's introduction, which dedicates the work to the Marquis of Monte a Santa Maria, the commander-in-chief of the entire Venetian infantry, de Dominis presents the content, approach and conception of his research in the first chapter entitled *Propositio dicendorum* (Overview of the exposition). In it, de Dominis emphasizes the experimental and mathematical foundation of his optical research: "So I will explain what my study and thinking led me to after much research and frequent experiments. This work will encroach equally on mathematical and physical considerations, and therefore I will have to clarify a number of accepted opinions in both of these sciences. In part, according to the custom of mathematicians, I will state the propositions on which either everyone can easily agree with me or for which there are multiple proofs in these sciences, but in part it will be necessary not only to state the propositions but to establish and strengthen them, or at least justify them. Let all this enable easier access to the complete realization of the main goal."¹⁸

He states that explanations of vision require many observations, interpretations of light, colors, medium through which light passes, laws of rectilinear propagation of light, reflection and refraction of light within the area he calls *Opticae* or *Perspectivae*. He presents his approach to the research of optical phenomena, emphasizing that all of the above, as well as the numerous effects that result from

against the Republic due to a dispute over some church taxes and jurisdiction over the clergy, in which, among other things, he forbids the clergy from performing church functions on the Venetian territory. De Dominis refused to submit to the interdict and came to the defense of the Republic, opposing the Pope's efforts to impose his authority on the secular government. He secretly began working intensively on his masterpiece *De republica ecclesiastica* (On the Church State) and needed access to the rich Venetian libraries, and he also prepared for publication his physics debut on lenses and binoculars. He thus devoted himself to a detailed study of the church fathers, looking for inspiration for an alternative form of the church, and now, thanks to the Pope's interdict, all this became even more important and urgent for him, because it was about his own position and role as a pastor and church prelate. The Curia did not forgive rebellious clergy and de Dominis was exposed to constant pressure and opposition. Between 1607 and 1616, he stayed in Venice several times and on one occasion stayed for two and a half years. As the main reasons for his long absences from Split, he cited the need to negotiate with the papal nuncio and the Venetian authorities on a solution to his dispute with the bishop of Trogir. See: TUDJINA_GAMULIN 1987.; TUDJINA 2006.:41-132.

¹⁸ DOMINIS 2005: 15.

it, will be explained after a great deal of effort and a large number of experiments. De Dominis emphasizes the experimental basis of his considerations based on a methodically designed experiment, which in that period at the transition from the 16th to the 17th century was a new approach compared to the scholastic Aristotelian method, which was still dominant at that time. It is significant that he emphasizes the role of mathematics, because he uses geometric lessons and items from optics in the theoretical derivations on which he bases his proofs and theoretical derivations. It is already evident from the first chapter of *Propositio dicendorum*, that de Dominis has a clear conception of research and exposition, in which experiment plays an equally important role as theoretical assumptions. Although de Dominis often does not describe his experiments in the work, the analysis of the content indicates that it can be said with certainty how he conducted them, because his interpretations contain, along with the results, detailed data and conditions that he could not have reached without experimental work.

In addition to the introductory parts, according to its content, the discussion can be divided into three parts. The first part presents the geometric and physical foundations of optics (chapters II to IV), the second part contains the theory of vision, the theory of optical lenses and binoculars (chapters V - IX), while the third part presents the interpretation of the rainbow (chapters X - XVIII). De Dominis experimented systematically with the help of devices he made himself, primarily with glass spheres filled with water, and came to an original contribution to the interpretation of the rainbow. He established that light is also reflected on the inner wall of a raindrop and thus interpreted the origin of the inner arc of the rainbow. According to de Dominis, a rainbow is created by the reflection and refraction of a light ray in a raindrop.¹⁹

The first two parts of de Dominis' optical discussion (chapters II to IX) will be analyzed in detail in this paper, while the third part, which contains de Dominis' considerations about the rainbow, goes beyond the thematic framework of this paper and will be the subject of a separate study.

The axiomatic-deductive style of de Dominis' interpretations

In the first part of the discussion (chapters II to IV), de Dominis tries to single out all the necessary claims of geometric and physical optics, which will be useful for him in building and proving his optical interpretations. The second chapter

¹⁹ He explained the first rainbow well, but he did not find the real cause of the second one. During the 18th century, de Dominis's interpretation of the rainbow experienced different judgments from famous scholars: from the great praise of Isaac Newton and Christian Wolff to the critical evaluations of Ruđer Bošković, Christian Hygens and Joseph Priestley. At the beginning of the 19th century, Goethe also praised him in his natural science work *Zur Farbenlehre* (On the Theory of Colors). See: MARTINOVIĆ 2002: 67-145, especially 94.-97.

presents the laws of geometric optics systematized in 11 propositions. They define the basic geometric concepts and facts necessary for the derivation of the theory, which de Dominis will refer to in the discussion. There he deals with the law of rectilinear propagation of light, the law of reflection, the law of refraction and others. Among the collected statements, he distinguishes assumptions (*suppositiones*) and propositions (*propositiones*). It is the intention of the first chapters, from II to IV, to build a formal axiomatic-deductive system modeled after Euclid's *Elements* (4th century BC), an ancient work which, at the threshold of the modern age, was a methodological model in research and conducting evidentiary procedures in science and philosophy.²⁰ The established formal framework was supposed to provide de Dominis with a formal axiomatic-deductive structure for exposition, proof and interpretation of light laws and phenomena. That is why the chapters from II to IV are the fundamental starting point and anchor point for further de Dominis' considerations and his theories of lenses, binoculars and rainbow, because everything presented in the following sections and all proofs are derived by referring to the initial propositions, which he tries to connect with the results of his experimental work.²¹ Certain claims are his original, while others are taken from different sources.

In the third chapter, de Dominis makes seven claims about the eye, sight and colors, relying on the opinions of Aristotle, Alhazen and Witel, and thus takes over the erroneous opinions of his predecessors based on abstract reasoning, and not on the experiment and observation that de Dominis generally accepted as research method. For example, de Dominis says about vision:

“There is, therefore, the most obvious proof that vision occurs in the pupil or in the front surface of the crystalline moisture which is closest to the very opening of the uvea and very little distant from the cornea, with very little aqueous moisture between the opening itself and the pupil: this moisture is uniform and insignificant, and cannot produce any refractions.”²²

In the third chapter, de Dominis also presents fundamental opinions about the origin of colors.²³ In connection with this, he does not refer to observation and experiment, but relies on Aristotle's interpretation that colors are created by the passage of light through denser and darker bodies, i.e. the passage of light becomes colored red, yellow, green... according to whether the substance it passes through is more or less dense or dark. He expresses the opinion that colors are created when light passes through a prism, depending on whether the light passed through the prism in a thinner or thicker place. De Dominis' erroneous interpretation was

²⁰ DADIĆ 1992: 38-45.

²¹ STIPANIĆ 1976: 13-22.; ZENKO 1976: 73-84.

²² DOMINIS 2005: 27.

²³ DOMINIS 2005: 29-31.

challenged by Goethe with an experiment, showing that color depends only on the direction of the light ray.²⁴

The fourth chapter brings basic propositions from geometry with which he will interpret and prove light phenomena and the magnification of the image of the object. He introduces the concept of visual angle, one of the fundamental concepts on which he will base his theory of lenses and binoculars. Although the concept of visual angle is mentioned as early as the 13th century in Witel's *Optics*, nowhere is it formulated as clearly as by de Dominis, who observes the connection between the visual angle and the apparent size of the object and correctly judges that the estimation of the size of the object depends only on the size of the visual angle.²⁵

By analyzing the contents of the first chapters (II - IV), it can be seen that certain statements are de Dominis' original and are the result of his experimental work and thinking, while others are taken from different sources. In his deliberations, de Dominis tried to connect the knowledge he achieved through the experimental-inductive method with the results he obtained through the mathematical-deductive process, and it is precisely this interweaving of methods that is essentially new in relation to the tradition in which he was educated and by what we can, methodologically, place de Dominis and his optical work on the threshold of the modern age. De Dominis is erudite and knows a wide range of optical and mathematical sources from antiquity to the Renaissance, and works of the Western European and Islamic traditions.²⁶ For example, interpreting the rainbow in this way, before presenting his own method and results, de Dominis cites the results of a number of predecessors: Aristotle, Alexander of Aphrodisias, Averoes, Albert the Great and Vitello, Alessandro Piccolomini, Cardano, Scaliger and others. In the field of geometry de Dominis refers to Euclid, and in the field of optics he relies on Pseudo-Euclid's *Catoptrics* and most often on Witel's *Optics*, from which he uses as many as twenty paragraphs from the second, third, fifth and tenth book to prepare the foundation of geometric optics.²⁷ Nevertheless, de Dominis' attempts to unify the mathematical and experimental approach, i.e. theory and experimentally obtained conclusions, did not always give good results. Therefore, in addition to successful interpretations, the discussion also shows failed interpretations of optical phenomena in certain places.²⁸

²⁴ FAJ 1976: 85-92.

²⁵ FAJ 1976: 85-92.

²⁶ The contribution titled Sources of Marko Antun de Dominis in the discussion *De radiis visus et lucis in vitris perspectivis et iride tractatus* was prepared and published as part of the article MARTINOVIĆ 2002: 123-129.

²⁷ MARTINOVIĆ 2002: 67-145, especially p. 86.

²⁸ MARTINOVIĆ 2002: 67-145, especially pp. 86-97.

Although he uses Witel and Euclid as models and sources, de Dominis still fails to perfectly structure a strict axiomatic geometric and physical system, and his optical starting points do not have a uniform structure. Among the starting points that de Dominis chose, we find along correct ones, sometimes vague and incorrect statements. In addition to accurate, he sometimes presents unclear and inaccurate explanations, as well as with consistent ones, we also find inconsistent application of taken positions, mathematical and physical assumptions.²⁹ Therefore, de Dominis' optical work has experienced different judgments throughout history: from exceptional praise to severe evaluations.³⁰

Analyzing the work *De radiis visus*, it can be concluded that de Dominis's mathematical consideration is still mixed with the quantitatively undetermined and approximate considerations of the scholastic method. The interweaving of mathematical with philosophical language and the mixing of original observations with traditional speculations is the source from which some of de Dominis' wrong conclusions arise. De Dominis makes very detailed and good observations, but his optical experiments are sometimes not systematic and his methodical work is not always uniform. Sometimes his very critical and correct analyzes are intertwined with traditional peripatetic assumptions, the legacy of scholasticism and sometimes with superficial conclusions.³¹ In other words, de Dominis' methodologically good mathematical attempts, due to the subjective consideration of the subject and his attempts to stay within the framework of peripatetic philosophy, did not bear fruit in every attempt.

Dominis' Theory of Optical Lenses and Binoculars: From Physiological to Astronomical Optics

From Chapters V to IX de Dominis presents his theory of lenses and optical instruments. It begins with considerations of the eye lens, after which it moves on to interpretations of glass lenses. In the construction of the theory of optical glasses, de Dominis systematically used the term visual angle, which he introduces in the 2nd paragraph of chapter IV. In contrast to the first part of the discussion, now he cites sources sparingly, and he relies heavily on his own experiments in the construction of the theory. De Dominis begins discussions with reflections about the eye and vision in two chapters (V - VI) from the field of physiological optics: *Defectus visionis directae* (Errors of direct vision) and *Adiumentum commune visus ex perspiciliis* (Glasses as a general aid to vision). He shows two deficiencies of eye sight: nearsightedness and farsightedness, and explains how lenses can help

²⁹ MARTINOVIĆ 2002: 67-145, especially pp. 86-97.

³⁰ BOŠKOVIĆ GOTHE Martinović.

³¹ BAJSIĆ 1976: 61-71.

and eliminate these deficiencies. He uses a plankovex lens to correct farsightedness. He first analyzes magnification with a plankovex lens, proving that with it the angle of vision can be increased. Using a drawing, he compares the visual angles with which the eye sees an object without a lens, with the visual angle that results from the refraction of light rays in the lens. He refers to proposition 2 from chapter IV on the angle of vision and concludes that with the use of a lens, the angle is larger, so the object is seen larger.

To eliminate farsightedness, de Dominis correctly suggests a converging lens, which collects the rays scattered on the surface of the eye into a single point in the pupil and thus eliminates different angles of vision. He refers to proposition 11 from chapter II, but his interpretation is partly flawed. It is important to emphasize that from the perspective of the history of science, these interpretations have a special value for the Croatian scientific heritage, because de Dominis was the first Croatian author who investigated the problems of physiological optics at a time when it was just developing in European circles. This work contains the oldest published text by a Croatian author who deals with physiological optics and in it tries to interpret the problem of the formation of an image in the eye, to investigate the defects of refraction and the properties of corrective glasses.³² In this context, it is worth remembering that this optical work by de Dominis was waiting for publication for twenty years, and it was published in the same year as Kepler's famous work *Dioptrics*, in which for the first time an exact interpretation of the image formed on the fundus of the eye and formulating the first scientific definition of myopia.

Then de Dominis shows the effects that lenses have at different positions of the distance from the eye. He first examines a concave and then a convex lens. He explains how a planconcave can help a myopic eye and proves that it reduces the angle of vision, and objects placed in front of such a lens appear smaller.³³ Experiments lead him to new knowledge and concepts, which he describes in the following way:

“So if we now take a lenticular glass in order to find the maximum distance at which the eye operates, the object seen must be moved considerably away from the glass and from the eye. Let that object be a lamp that shines at night. If you put a lenticular glass on your eye, you will see its flame or light as it is. Then move the glass away from the eye in the direction slowly and gradually towards the distant lamp and you will see through the glass that the light gradually increases until it

³² DOMINIS 2005: 43-59; DUGAČKI 1976: 85-92.

³³ De Dominis conducts his research with three assumptions: firstly, that only an upright image of an object can be formed in the eye, secondly, that there cannot be a receiver of images in the eye, and thirdly, that vision must occur in a single point, which is the top of the visual cone. See: MARTINOVIĆ 2002: 97-98.

fills the entire glass. Then you will see nothing, but only the whole illuminated glass: that light in the eye sharpens until it is reduced to a point of great intensity. If you move the glass even further away from your eye, you will only see such distant light as completely inverted. The same happens with everything that is visible. Thus, the maximum length at which the eye can see an object upright and not inverted is the point at which the object begins to twist through the glass so that the upper becomes the lower, and vice versa, while the right becomes left and the left becomes right.” Thus, the experiments he performed by moving the lens along the axis led him to understand the concept of focal length, which he describes in the words: “the greatest distance in which the eye can perceive the object upright and not turned.”³⁴

In his considerations, de Dominis uses lenses correctly and all the derivations and conclusions are logically connected, but since some considerations result from initial assumptions that are not always correct, sometimes the overall outcome of a theoretical consideration, if it was not supported and corrected by a correct experiment, ends up with a wrong conclusion, as could be expected based on incomplete or incorrect initial assumptions.

In the seventh chapter entitled *Vitra perspectiva etiam ab oculo remotiora in visu mira operantur* (Optical glasses have miraculous effects even when they are far from the eye) de Dominis expands the scope of his considerations about lenses with examples when they are very far from the eye. The increase in the visual angle and the field of vision depend on the distance of the lens from the eye and the object of observation. In a certain position, the viewing angle is the largest. De Dominis tries to explain why large objects are dimly seen when viewed through a convex lens.³⁵ Using the initial propositions and the drawing, de Dominis proves that the cause is parallax, that is, that the object is seen under a double visual angle:

“The first is the result of light rays that go directly without refraction, and the second of those that are refracted in the lens towards the axis and enter the eye. For the second vision angle, he correctly proves that it is larger. And he finally concludes that we see the object both smaller and larger at the same time. The consequence is that we see the object indistinctly, regardless of how far we move the lens away from us. Here de Dominis allows the passage of rays without refraction, which is another consequence of his inconsistency in explaining the refraction of light.”³⁶

Finally, de Dominis, in the eighth chapter entitled *Utrunque vitrum tam lenticulare quam excavatum potest simul visui inservire* (Both glasses, both lenticular and hollow, can serve the sight together) moves on to the most important part

³⁴ DOMINIS 2005: 60.

³⁵ DOMINIS 2005: 71-75.

³⁶ FAJ 1976: 85-92.

of his theory of lenses, in which he gives an interpretation of the combination of concave and convex lenses, and proves that an instrument can be constructed using them under certain conditions.³⁷ With these considerations, de Dominis approached the central theme of his discussion. He worked out in detail the two conditions under which the combination of planoconvex and planoconcave lenses provide magnification and a clear image of a distant object. The first condition is that between the lenses there must be an appropriate ratio between the bulging of one and the hollowing of the other lens, and the second is that there must be a valid distance between the lenses.³⁸

The essence of the interpretation lies in the fact that distant objects are clearly seen because this combination removes the mixed direct and refracted rays, so that the direct rays are also refracted, and finally only refracted rays reach the eye.

The same applies to this interpretation as was said about the refraction of light. De Dominis interprets the increase created by this combination of two lenses also by an increase in the visual angle.

With this, de Dominis gave the first interpretation of that combination of lenses on which the construction of binoculars would rest when it becomes discovered. De Dominis' interpretations are deductive, methodologically correct and determine the conditions that must be met in the construction in order to obtain an enlarged image.

Having thus prepared a valid theoretical foundation, de Dominis wrote at the beginning of the ninth chapter *Instrumenti perspectivi ad videnda longe dissita conficiendi ratio et usus* (Principle of construction and application of an optical device for observing distant objects):

“According to what we have said and explained so far about glass devices, it is very easy to build a device that - it seems - was recently invented, or at least published, especially when it comes to Italy. When she caused and still causes the greatest admiration for many, it was not at all strange for me, who practiced the spirit in optics before many others, and for many years, for fun. Immediately when I saw it (and it was very unkempt) I clearly recognized the effect of the two panes. It's a pity that those who first published this device did not present evidence with it.”³⁹

“I was impatiently waiting to see if, together with the evidence required by the effects of this device, the numerous, by no means insignificant difficulties regarding vision and optical issues, which concern optical glasses, would be solved, which - as far as I know - no one has dealt with so far. As much as I could, I was the first to try to interpret and prove them in the previous chapters.”⁴⁰

³⁷ DOMINIS 2005: 81-89.

³⁸ DOMINIS 2005: 85.

³⁹ DOMINIS 2005: 89.

⁴⁰ DOMINIS 2005: 89.

In connection with binoculars, de Dominis tried to solve and interpret several more questions: “Why doesn’t that device perceive what’s near? And why, if the front glass remains the same if you add a second one of lesser indentation to it by shortening the device as explained above, and then if you add a second of larger indentation to it by lengthening the tube, things appear smaller and further away, and the field larger and closer?”⁴¹

“Why is it that if this device is turned closer to the eye and the lenticular glass, everything looks much smaller and further away?”⁴²

“Why doesn’t the visible thing in that device never turn, no matter how much the device itself moves away from both the thing and the eye?”⁴³

At the end of the Chapter IX de Dominis concludes his discussion of binoculars with the words:

“Let what we have said be enough for optical glasses like this. If someone came up with something better, I would be happy to learn from him, because I myself am not completely satisfied with everything I have said and explained so far. s much as I could, I was the first to break the ice and pave the way for others, or at least open it for them, so that they could discuss it more fully and clearly. I now turn to the consideration of another wonderful optical effect, namely the rainbow.”⁴⁴

De Dominis built his optical theory for a long time and methodically on the interweaving of experiments, as a well thoughtful methodical questioning of optical phenomena and mathematical theory. From the experiment, he extracted conclusions and statements that he confirmed twice: with a mathematical derivation and an experiment. The agreement of one and the other result enabled him to make other statements by mathematical deduction that would have to agree with experience. Based on a series of experiments with lenses, he gained a correct, albeit only qualitative, idea of the refraction of light rays, and studied the conditions under which a combination of lenses would act as binoculars. Dominis did not know the exact law of refraction required for a clear quantitative theory, on the basis of which the discovery and construction of binoculars would be achieved purely theoretically, but no one else knew this law in his time either.⁴⁵ Nevertheless, de Dominis shows the refraction in lenses qualitatively quite correctly and consistently applies throughout his work the claim that the ray is refracted towards perpendicular if it enters the lens, and away from perpendicular if it leaves the

⁴¹ DOMINIS 2005: 95-95.

⁴² DOMINIS 2005: 98.

⁴³ DOMINIS 2005: 99.

⁴⁴ DOMINIS 2005: 99.

⁴⁵ DADIĆ 2005: X. The law of refraction and the index of refraction were independently found by Rene Descartes and Willerbrord Snellius.

lens, and so regardless of the fact that he did not know the general law of refraction can provide some qualitative interpretations of lenses.

In determining the exact theoretical explanation, the law of refraction and index of refraction are key concepts, without which it is not possible to quantitatively determine the position and size of the image. De Dominis' interpretation is based on the concept of visual angle,⁴⁶ which he uses as a fundamental concept in the theory of lenses and binoculars. In de Dominis' time, the term visual angle was also used by his contemporaries such as Paolo Sarpi and Giovanni Battista della Porta. However, de Dominis is considered to be the first to put the concept of visual angle as the basis of a whole theory of lenses and to conclude that the essence of magnification is to increase the visual angle.⁴⁷ According to de Dominis, this will be the main principle in the construction of binoculars, which he qualitatively explained exhaustively by examining all the conditions that must be met with regard to the specific refraction properties of concave and convex lenses, as well as the connection between the curvature and the thickness of the lens. It is considered that in the de Dominis' work the most important contribution is his theoretical explanation of the binoculars and the conclusion that the increase in the image of the object depends on the increase in the visual angle, which he previously correctly defined.

Concluding considerations

Based on the data and analysis presented in this paper, it is evident that the works of de Dominis and Galilei in connection with binoculars reflect two completely different approaches. In his work *Sidereus nuncius* approved for printing in March 1610, Galilei gives only a brief reference to the binoculars without interpreting them because he did not know how to interpret them either then or later, since he did not even deal with optics.⁴⁸ His research focused on the fields of mechanics and astronomy. While in the field of mechanics Galilei understood the need to mathematize physics, his work with binoculars is methodologically different. It takes place exclusively in the practical domain of observing and constructing (more precisely, of reconstructing someone else's invention), so in relation to binoculars, his work is based on practical knowledge and skills, without the fruitful interweaving of the empirical aspect with mathematics, as he achieved in his mechanical research. This is partly understandable, since Galilei never dealt with optics so the binoculars was not Galilei's invention, but rather a practical

⁴⁶ The term visual angle was used in the 13th century by the Polish philosopher, theologian and naturalist Witelo, to whom Dominis refers in the work.

⁴⁷ DADIĆ 2005: X-XI.

⁴⁸ GALILEI 1610: 6r, 6v, 7r.

invention of Dutch opticians to which the skeptical scientific community did not even attach particular importance at first, not recognizing at first how much its application in astronomical research would mean for the revolutionary development of cosmology.⁴⁹ Although Galilei did not invent the binoculars, nor was he the first to interpret it scientifically, or even the first to point it towards the sky in order to carry out systematic astronomical observations,⁵⁰ he still advocated it, applied it in astronomical observations at a time when the scientific community did not fully understand its value, he affirmed it in the scientific community because he firmly believed that he had found an instrument in the binoculars that would lead him through astronomical observations to evidence of the movement of the Earth, in support of the heliocentric system and Copernican cosmology. Although he showed himself to be extremely skilled in the reconstruction and improvement of the Dutch invention - the binoculars, it is undeniable that Galilei did not choose the means to present the binoculars to the Venetian authorities and great men as his own invention, while in his letters and texts he tried to bypass and trivialize all those who contributed in different ways to the construction and theory of binoculars, considering and presenting it as "his own" instrument. Kepler himself, who was the first to give Galilei due recognition for the results achieved by astronomical observations, reproached him for this.⁵¹

De Dominis' approach to binoculars is very different from Galilei's. Much before the construction of the first binoculars, De Dominis began systematically researching lenses and their combinations as a young scholar in the period from 1588 to 1595. He recorded the results of experimental work with mathematical proof in a document written in the first version two decades earlier than the binoculars were publicly displayed to Venice in August 1609.

That de Dominis had already developed a comprehensive theory of lenses and their applications and combinations, on which the construction of binoculars is based, is evidenced by the fact that he was able to submit for publication his optical treatise - a complete theory about lenses and binoculars, very quickly in just a few months after the public display of the binoculars, which he based on extensive experimental work and systematized the research results based on Euclid's *Elements* and proved them with optical and mathematical statements and methods, which was not possible to do in such a short time. De Dominis' work is undisputedly the first work to interpret the theory of the new binoculars instrument.

A comparison of the contents of both works, as well as the chronology by which de Dominis' and Galilei's works were approved for publication, testify that

⁴⁹ GREYMONAT 1964: 50-55, 65-66.

⁵⁰ LOHNE 2000: 124-129. The first to do it was the distinguished English astronomer and mathematician Thomas Harriot.

⁵¹ GREYMONAT 1964: 55-56.

Sidereus nuncius was created independently of Galilei's work. After the censors reviewed Dominis' work, he received the imprimatur⁵² authorizing publication in February 1610, and Galilei for his work *Sidereus nuncius* a month later in March 1610.⁵³ Galilei's *Star Messenger* was published immediately in March 1610, and Dominis' *De radiis visus et lucis in vitris perspectivis et iride* only near the end of the following year, 1611. As a reason for delaying the publication, the problems that de Dominis had in searching for an engraver who would make the images necessary for the work in addition to his interpretations are mentioned. The Venetian theologian and natural scientist close to Dominis Paolo Sarpi wrote about this to Giacomo Laschassier in August 1610.⁵⁴ In addition, de Dominis may have hoped to find the strength and time to make another complete revision of the text, in order to correct some shortcomings of the discussion that he was obviously aware of, but this probably did not happen, as he says at the end of chapter IX: "... because I myself am not completely satisfied with everything I have said and explained so far."⁵⁵ If, on the other hand, de Dominis had changed or supplemented something in the manuscript after the imprimatur in that period from February 1609, the text would have had to go through the censorship process once again, and this would be reflected in the date of the issued approval.

De Dominis built his complete optical theory for a long time and methodically on the interweaving of experiments, as a well thought methodical questioning of optical phenomena and mathematical theory. With scientific insight, he abstracted conclusions and assertions from experiments, which he confirmed twice: with a mathematical derivation and an experiment. The agreement of one and the other result enabled him to make other statements by mathematical deduction that would have to agree with experience. Based on numerous experiments with lenses, he gained a correct, albeit only qualitative, idea of the refraction of light rays, and studied the conditions under which a combination of lenses would act as binoculars. It is considered to be the most important contribution of de Dominis, his theoretical explanation of binoculars and the conclusion that the increase in the image of the object depends on the increase in the angle of vision, which he previously correctly defined. De Dominis's research, although with the abundant use of the geometric method and the fact that he was an excellent mathematician who fully understood the importance and role of mathematics in the study of nature, which he himself states in the work, still remain in the domain of qualitative considerations.

⁵² DOMINIS 2005: 10.

⁵³ GALILEI 1610: 4r.

⁵⁴ MARTINOVIĆ 2002: 75-76.

⁵⁵ DOMINIS 2005: 99.

On the basis of the above, it follows that de Dominis' theory of lenses and binoculars is his original and that he built it independently of Galilei, because the Italian scholar never explained the binoculars theoretically. In addition, de Dominis' treatise *De radiis visus et lucis in vitris perspectivis et iride* is the first systematic theoretical interpretation of binoculars. Much remains to be considered in more detail, what exactly de Dominis wrote or changed in relation to the initial version of the manuscript, which is about twenty years old, in the short period of a few months from the fall of 1609 to February 1610, when he was arranging the manuscript for publication. In the introduction to the work, Bartoli vaguely states that he wrote a chapter or two, and this most likely refers to chapters VIII and IX. As according to the decision of the Inquisition on 21 December 1624, de Dominis's manuscripts were burned together with his dead body on the Campo de' Fiori in Rome and thrown into the River Tiber, many of his manuscripts were irretrievably lost and it is not possible to make a more detailed comparison that would answer the question of what exactly was added or perhaps changed in the work in that period.

Due to the fact that the manuscript was largely created almost two decades before its publication, some authors questioned or concluded that de Dominis could have known the binoculars before the instrument was publicly shown in Venice in 1609. In the work, de Dominis himself states that in 1609 he recognized the already known effect of two lenses in the new instrument (and therein lies the essence of the construction of binoculars), but formally he does not attribute the practical discovery to himself, as neither to Galilei after all. Unlike Galilei, De Dominis is very measured in this regard when he says that the device was "recently invented, or at least published, especially when it comes to Italy."⁵⁶ Furthermore, de Dominis does not explicitly mention Galilei anywhere in the work.⁵⁷ It is clear to De Dominis that the binoculars did not arise from theoretical considerations, but were the result of many years of efforts and practical discoveries. The construction was realized by chance, with suitably arranged lenses and was by no means, as Galilei claimed, based on his own optical considerations.⁵⁸ Galilei, describing "his own" invention, will write

⁵⁶ DOMINIS 2005: 89.

⁵⁷ De Dominis clearly distinguished the act of publicly displaying binoculars from its invention and theoretical interpretation. However, the editor Bartoli, under the impression of Galileo's efforts, mentions him in the introduction of the work, when he describes his conversations with de Dominis and says: "...That's why I asked him on several occasions what he thought about that new device that was rumored to have been brought to the light of day and published in Venice by one of ours - Galileo, a famous mathematician, which serves to observe what is very away." However, it seems that Bartoli's wording, using the phrase "it was rumored", left room for judgment as to whether the invention of binoculars really belonged to the respected Italian. DOMINIS 2005: 89.

⁵⁸ GEYMONAT 1964: 53.

that he arrived at it based on optical observations. However, he did not engage in optical observations until 1609, so he could not draw conclusions about the laws of motion and refraction of light. De Dominis vaguely, without mentioning anyone in particular, the Dutch optician Hans Lippershey or Galilei, in the introduction of chapter IX points out the fact that it is a shame that those who first published that device did not present evidence with it.⁵⁹ When he undertook to prepare from old research and manuscripts a work that would give the first theoretical interpretation of binoculars, de Dominis, in accordance with the methodology of his early optical research, decided to combine the practical and theoretical aspects in it. At that time, there were no clear mathematical principles that would explain the exact theory of lenses, and without it, it was not possible to arrive at an exact theory of binoculars.

During the 16th century, many experimented with lenses in an attempt to enlarge the image, but the scientific community did not yet have a completely clear picture of the instrument with such possibilities and its significance for further development. As he himself states, De Dominis already had in the previous version of the manuscript a combination of lenses that would lead to the arrangement of lenses as in binoculars. However, he did not know the exact law of refraction required for a clear quantitative theory, on the basis of which the discovery and construction of binoculars would be achieved through a purely theoretical method. Nevertheless, de Dominis shows the refraction in lenses qualitatively correctly and consistently applies throughout his work the statement that the ray is refracted towards perpendicular if it enters the lens, and away from perpendicular if it leaves the lens, and so on regardless of the fact that he did not know the general law of refraction can provide some qualitative interpretations of lenses. Admittedly, he did not know exactly how that ray is refracted, namely he did not know the mathematical expression for refraction, but no one else knew this law in his time either.⁶⁰

In determining the exact theoretical explanation, the law of refraction and index of refraction are key terms, without which it is not possible to quantitatively determine the position and size of the image. De Dominis' interpretation is based on the concept of visual angle, which he uses as a fundamental concept in the theory of lenses and binoculars. In de Dominis' time, the term visual angle was also used by his contemporaries such as Paolo Sarpi and Giovanni Battista della Porta. However, de Dominis is considered to be the first to put the concept of visual angle as the basis of a whole theory of lenses and to conclude that the essence of magnification is to increase the visual angle.⁶¹ According to de Dominis, this

⁵⁹ DOMINIS 2005: 89.

⁶⁰ DADIĆ 2005: X. The law of refraction and the index of refraction were independently found by Rene Descartes and Willerbrord Snellius.

⁶¹ The term visual angle was used in the 13th century by the Polish philosopher, theologian and naturalist Witelo, to whom de Dominis refers in the work.

will be the main principle in the construction of binoculars, which de Dominis qualitatively and exhaustively explained by examining all the conditions that must be met with regard to the specific properties of refracting the rays in concave and convex lenses, as well as the connection between the curvature and the thickness of the lens.

De Dominis' interpretations are deductive, methodologically correct and determine the conditions that must be met in the construction in order to obtain an enlarged image. Evaluating de Dominis' approach to research, it should be pointed out that it is based on a combination of experimental-inductive and mathematical-deductive methods. Although there are inconsistencies in the text, he wrote the work mainly on the basis of his own experiments and observations, and he systematized and conceptualized the collected material from various sources based on the model of Euclid's *Elements*, which he refers to in the work. Therefore, although de Dominis does not abandon some outdated peripatetic understandings, his work *De radiis visus* has a significant value in the history of optics and bears the key features of the new era because, in addition to traditional starting points, it uses a new methodology based on experimental work and the application of a mathematical axiomatic-deductive style of exposition, which is an early example of a modern approach to research in the natural sciences. In his work *Dioptrice* (1611),⁶² Kepler presented a new axiomatics of optics and interpreted the binoculars with complete exactness, while Galileo complained that Kepler's work *Dioptrice* was so unclear that, in all probability, even the author himself did not understand it.⁶³

⁶² DADIĆ 2005: X-XI.

⁶³ Not long after Galileo's use of binoculars in astronomical observations and the first discoveries, Kepler, using Duke Ernest's binoculars in Cologne, began theoretical and experimental research into the optics of binoculars. He published the results in the work *Dioptrice* (1611). In it, Kepler outlines the theoretical foundations of the double convex converging lens and the double concave diverging lens, as well as the concepts of real and virtual images, upright and inverted images, and the effects of focal length on enlargement and reduction of image.

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Marko Antun de Dominis protiv Galilea Galileja: od konstrukcije do teorije dalekozora

Marko Antun de Dominis (Rab, 1560 – Rim, 8. rujna 1624), djelovao je na prijelazu iz 16. u 17. stoljeće, u vremenu kada se u znanosti i filozofiji znanosti zbivaju epohalne promjene, a nasuprot tradicionalnom aristotelovskom pristupu u istraživanje prirode uvodi se novi pristup uz primjenu matematičkih metoda, aksiomatskog deduktivnog sustava, pokusa i motrenja. Premda se de Dominis školovao na aristotelovskoj tradiciji od koje ne odstupa u potpunosti, koristio se novim pristupom u istraživanju prirodnih znanosti. O tome svjedoči i njegovo optičko djelo *De radiis visus et lucis in vitris perspectivis et iride* (Rasprava o zrakama vida i svjetlosti u lećama i dugi), dovršeno koncem 1609. godine i objavljeno u Veneciji 1611. godine. Djelo je većim dijelom napisao dvadesetak godina prije prve javne demonstracije dalekozora 1609. godine, a dovršio ga je neovisno o Galileovom radu i prije objave Keplerovih djela u kojima se egzaktno tumači teorija leća i dalekozora. Stoga je ovaj Dominisov spis ne samo vrijedan izvorni prinos optici, već i prvo djelo u povijesti koje cjelovito tumači teoriju dalekozora, instrumenta s kojim započinje nova epoha astronomskih i optičkih istraživanja.

Ključne riječi: Marko Antun de Dominis, Galileo Galilei, problem metode, matematika., eksperiment, dalekozor, optika, leće

Key words: Marko Antun de Dominis, Galileo Galilei, method problem, mathematics, experiment, binoculars, optics, lenses

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