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Ibn al-Haitham and the Development of Optical Instruments in Islamic Astronomy: Foundations of Modern Islamic Astronomy

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Abstract: *Ibn al-Haitham, a Muslim scientist from the 10th to 11th century CE, is known as a pioneer in the fields of optics and astronomy. His contributions to the development of modern science often receive insufficient attention, despite their significant impact. This study aims to explore the extent to which Ibn al-Haitham's thoughts influenced the development of Islamic astronomy, particularly in the context of optical instruments, using a literature review method. The results of the research show that Ibn al-Haitham adopted an experimental and mathematical approach to astronomy, which differed from the traditional views of his time. He critiqued Ptolemy's theory and made significant contributions to understanding astronomical phenomena such as eclipses and starlight. One of his significant achievements was the development of a method for determining the direction of the qibla using trigonometry, as well as the combination of empirical observation with mathematical analysis, which became the basis for the modern scientific method in astronomy. Ibn al-Haitham's influence on the development of Islamic astronomy is particularly evident in the evolution of optical instruments. His concept of the camera obscura became the foundation for the evolution of telescopes, theodolites, and instruments for observing the new moon. The optical principles he discovered played a major role in improving the accuracy of astronomical measurements and the development of more advanced observational technologies. His understanding of the behavior of light and image formation became the basis for the development of modern astronomical instruments. Although his thinking had some limitations, such as dependence on Aristotelian cosmological concepts, Ibn al-Haitham's contributions remain a critical foundation for the advancement of Islamic astronomy and astronomy as a whole. His progressive thinking and systematic scientific approach have had a long-lasting influence on the development of science. His intellectual legacy not only demonstrates his individual genius but also affirms the important role of Muslim scientists in advancing global scientific knowledge.*
Keywords: *Ibn al-Haitham, Astronomy, Optical Instruments*

Abstrak: *Ibn al-Haitham, seorang ilmuwan Muslim dari abad ke-10 hingga ke-11 Masehi, dikenal sebagai pionir dalam bidang optik dan astronomi. Kontribusinya dalam perkembangan sains modern sering kurang mendapat perhatian, meskipun pengaruhnya sangat signifikan. Penelitian ini bertujuan untuk mengeksplorasi sejauh mana pemikiran Ibn al-Haitham mempengaruhi perkembangan ilmu falak, terutama dalam konteks instrumen optik dengan menggunakan kajian kepustakaan. Hasil penelitian menunjukkan bahwa Ibn al-Haitham mengadopsi pendekatan eksperimental dan matematis dalam astronomi, yang berbeda dari pandangan tradisional pada masanya. Ia mengkritik teori Ptolemy dan memberikan kontribusi penting dalam memahami fenomena astronomi seperti gerhana dan cahaya bintang. Salah satu pencapaiannya yang signifikan adalah pengembangan metode penentuan arah kiblat menggunakan trigonometri, serta penggabungan observasi empiris dengan analisis matematis yang menjadi dasar metode ilmiah modern dalam astronomi. Pengaruh Ibn al-Haitham terhadap perkembangan ilmu falak sangat terlihat dalam evolusi instrumen optik. Konsep kamera obscura yang dikembangkannya menjadi dasar bagi evolusi teleskop, theodolit, dan instrumen pengamatan hilal. Prinsip-prinsip optik yang ia temukan berperan besar dalam meningkatkan akurasi pengukuran astronomi dan pengembangan teknologi observasi yang lebih canggih. Pemahamannya tentang perilaku cahaya dan pembentukan gambar menjadi landasan bagi perkembangan instrumen astronomi modern. Meskipun pemikirannya memiliki keterbatasan, seperti ketergantungan pada konsep kosmologi Aristotelian, kontribusi Ibn al-Haitham tetap menjadi fondasi penting bagi kemajuan ilmu falak dan astronomi. Pemikiran progresif dan pendekatan ilmiah yang sistematis dari Ibn al-Haitham memberikan pengaruh jangka panjang terhadap perkembangan sains. Warisan intelektualnya tidak hanya menunjukkan kejeniusannya sebagai individu tetapi juga menegaskan peran penting ilmuwan Muslim dalam memajukan pengetahuan ilmiah global.*
Kata Kunci: *Ibn al-Haitham, Astronomi, Instrumen Optik.*

A. Introduction

The contributions of Muslim scientists like Ibn al-Haitham often receive insufficient attention in the history of scientific development, despite their significant influence on the advancement of modern science. Ibn al-Haitham, who lived from the 10th to 11th century CE, is known as a pioneer in the fields of optics and astronomy. His revolutionary thinking not only changed the scientific paradigm of his time but also laid the foundation for the subsequent development of astronomy and celestial science. However, the extent to which Ibn al-Haitham's thoughts influenced the development of astronomy, particularly in the context of optical instruments and observational methods, still needs further exploration. This research aims to fill this gap by conducting an in-depth study of Ibn al-Haitham's thoughts on astronomy and investigating how his ideas have shaped and influenced the development of astronomy to this day. By understanding Ibn al-Haitham's contributions, we not only honor the intellectual heritage of Islamic civilization but also enrich our understanding of the evolution of science and the crucial role of Muslim scientists in global scientific advancement.

Various studies have been conducted to examine Ibn al-Haitham's thoughts and contributions in science and optics, but there has been no specific research on Ibn al-Haitham's contribution to the development of optical instruments in astronomy. In 2009, Nedim Unal and Omur Elcioglu, through their article in the Saudi Medical Journal, specifically discussed Ibn al-Haitham's views on eye anatomy, including his understanding of the structure and function of this visual organ. In terms of scientific methodology, Mohd Syahmir Alias (2015) in his research published in the Journal of Usuluddin University of Malaya analyzed Ibn al-Haitham's thoughts on the concept of truth in scientific inquiry. This research emphasizes the importance of empirical validity and consistent scientific methods as foundations in building knowledge. Meanwhile, Daneshfard, Dalfardi, and Nezhad (2014) through their article in the Journal of Medical Biography explored Ibn al-Haitham's role as a pioneer in developing modern theories of vision. This research shows how Ibn al-Haitham's works became the basis for modern understanding of the visual system. To complete the understanding of Ibn al-Haitham, Ishaq and Daud (2017) in Jurnal Historia conducted a comprehensive study of the biography and bibliography of this Muslim scientist, providing a thorough overview of his influential life and works in scientific development.

This research becomes important as it provides a new perspective on how Ibn al-Haitham's thoughts specifically influenced the development of optical instruments in astronomy. Along with technological advancement, a deeper understanding of Ibn al-Haitham's contributions in developing observational methods and optical instruments will enrich the history of science. Additionally, this research can also demonstrate how the scientific methods developed by this Muslim scientist have influenced various disciplines, including astronomy and optics. By tracing the long-term impact of his thoughts, this research hopes to revive appreciation for the significant role of Islamic civilization in the foundation of modern science.

B. Methods

This research employs a qualitative method[1] with a library research approach[2] that focuses on exploring classical texts, scientific journals, historical literature, and primary sources related to Ibn al-Haitham's thoughts in the fields of optics and astronomy. Analysis is conducted on Ibn al-Haitham's works, particularly *Maqālah fī Sūrat al-Kusūf* (Treatise on the Shape of the Eclipse), and *Maqālah fī al-Kurrah al-Mutaharriqah* (Treatise on the Moving Sphere) as well as other literature documenting his contributions to optics. This research also examines the development of optical instruments in astronomical studies and their impact on understanding the universe. Using a descriptive approach, this research illustrates Ibn al-Haitham's thoughts in astronomy and connects them to the evolution of optical instruments through deductive analysis of the general theories he developed.

C. Results and Discussion

1. Biography of Ibn Al-Haitham

Ibn al-Haitham, or Abu Ali al-Hasan bin al-Hasan bin al-Haitham, is a Muslim scientist who is highly popular among academics but less known to the Muslim community in general. His name is often incorrectly written in various historical records, such as al-Hasan bin al-Husain or al-Husain bin al-Hasan. Some historians even consider that there were two different people with similar names.[3] In the West, he is known as Alhazen and dubbed 'The Second Ptolemy' due to his significant contributions to science, particularly in optics and astronomy, which parallel those of Ptolemy.[4]

Ibn al-Haitham was born in Basra around 965 CE and was known by the title al-Bashry, but was also called al-Mishry because he later moved to Cairo, Egypt.[5] As a polymath, he mastered mathematics, geometry, physics, optics, eye physiology, medicine, philosophy, and astronomy. At the age of 31, at the request of King al-Hakim from the Fatimid dynasty, he moved to Egypt to develop a machine to regulate the Nile River flow. However, the project failed, and Ibn al-Haitham experienced several events that forced him to return to Cairo after al-Hakim's death.[6]

According to some records, Ibn al-Haitham had proposed a plan to build a dam in Aswan to address the Nile River flooding problem, but due to tense political and religious conditions between the Abbasids and Fatimids, the plan was never implemented. He was respected and supported by King al-Hakim, but because he disagreed with the water flow project proposed by the king, he was confined to his own house for several years. During his confinement, Ibn al-Haitham remained productive, producing many important works in optics, astronomy, and

[1]Sugiono, *Metode Penelitian Kualitatif,* (Bandung: CV. Alfabeta, 2012), 57.
[2]Moh. Nazir, *Metode Penelitian,* (Bogor: Ghalia Indonesia, 2009), 76.
[3]Arwin Juli Rakhmadi Butar-butar, *Tradisi Literasi di Peradaban Islam,* (Tangerang: Pustakacompass, 2020), 224.
[4]Ibn al-Haitham, *Maqalah fi al-Kurrah al-Mutharriqah,* diterjemahkan oleh Mada Sanjaya W.S dalam *Refraksi Lensa Optiak Ibn al-Haitham dalam Maqalah fi al-Kurrah al-Mutharriqah,* (Bandung: Cv Bolabot, 2022), 4.
[5]Arwin Juli Rakhmadi Butar-butar, *Tradisi Literasi di Peradaban Islam…,* 225.
[6]Arwin Juli Rakhmadi Butar-butar, *Tradisi Literasi di Peradaban Islam…,* 225.

mathematics, including Kitab *al-Manāzir*.[7] After realizing his plan to regulate the Nile River flow would not succeed and fearing punishment from al-Hakim, Ibn al-Haitham pretended to be insane to avoid the death penalty. He lived under house arrest for about 10 years until al-Hakim's death in 1021 CE. After al-Hakim's death, he resumed a normal life, living in the Al-Azhar complex, and continued his scientific studies. Ibn al-Haitham died in Cairo around 1039 CE or later, leaving behind many important works that had a great impact on the development of science.[8]

2. Ibn al-Haitham's Thoughts in Astronomy

Ibn al-Haitham spent his youth in Basra, a port city that served as a dynamic intellectual and commercial center. There, he received comprehensive education in various disciplines, including mathematics, physics, astronomy, and philosophy. His great curiosity led him to study the works of classical Greek scientists such as Euclid, Ptolemy, and Aristotle. This deep exploration of Greek scientific heritage not only enriched his knowledge but also became the foundation for his revolutionary scientific contributions later on. This formative period shaped Ibn al-Haitham into a brilliant polymath scientist, who later made important breakthroughs in various fields of science, especially optics and mathematics.[9]

In astronomy, Ibn al-Haitham developed an approach that combined theoretical study and experimental practice. He not only studied existing astronomical theories but also conducted direct observations and experiments to test the validity of these theories. His scientific method, which combined theoretical analysis with empirical data collection, allowed him to validate, improve, or refute prevailing astronomical concepts. His work such as Azwā' Al-Kawākīb demonstrates his critical ability in analyzing the nature of starlight and producing conclusions that contradicted common views at the time. Additionally, his treatise on solar and lunar eclipses shows efforts to understand the mechanism of these phenomena scientifically, including providing practical guidance for observing eclipses.[10]

One of Ibn al-Haitham's important contributions was his criticism of Ptolemy's astronomical theory. In his work Al-Syukūk 'alā Batlamius, he identified errors in Ptolemy's model and proposed improvements through mathematical approaches and careful observation. His criticism covered not only technical errors but also the philosophical assumptions underlying these theories, showing deep insight and a modern scientific approach that prioritized empirical evidence. Besides criticizing theory, Ibn al-Haitham also sought to develop more accurate methods and observation instruments, such as the astrolabe for measuring the positions of stars and planets. These improvements were important for obtaining more accurate data and building better astronomical theories.[11]

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[7]D.C. Lindberg, *Theories of Vision from Al-Kindi to Kepler*, (Chicago: University of Chicago Press,1976), 59.

[8]Al-Qifthy, *Tārīkh al-Hukamā'*, Tahkik: Julius Libert (Kairo: Maktabah al-Adab, 2008), 166.

[9]R. Rashed, *Classical Arabic Sciences. Dans Encyclopédie de l'Islam*, (Leyde, Pays-Bas: Brill, 2015), 11-17.

[10]S. Tekeli, *Ibn al-Haytham's Optics, Dalam Proceedings of the Tenth International Congress of History of Science,* (Paris: Vrin, 1971), 101-107.

[11]A.I. Sabra, *Ibn al-Haytham: Brief life of an Arab mathematician,* (Harvard Magazine, 2003), 43.

Ibn al-Haitham also applied mathematical and optical concepts in his work, combining geometry, trigonometry, and algebra to correct astronomical calculations. He explained optical phenomena such as reflection and refraction of light from stars, showing an interdisciplinary approach in studying astronomical phenomena. One of his most significant works was the mathematical calculation for determining the qibla direction. In "Qoul fī Samt al-Qiblah bi al-Hisāb", he developed accurate trigonometric methods for calculating the qibla direction from various locations, affirming the importance of science in Islamic religious practice. This method was highly influential, enabling Muslims worldwide to determine the qibla direction with high precision and facilitating more accurate worship practices.[12]

Ibn al-Haytham's thinking was highly progressive for his time, challenging dogma and baseless authority while encouraging the use of reasoning, observation, and experimentation in the pursuit of scientific truth. However, his thinking also had limitations, such as his adherence to the Ptolemaic geocentric model and Aristotelian cosmological concepts. He remained bound to the idea that the Earth was the center of the universe, although his criticisms of Ptolemy's theory included identifying some flaws in the model. Additionally, his reliance on Aristotelian cosmological concepts limited the scope of his thinking in understanding astronomical phenomena in a more open and comprehensive manner.[13]

Ibn al-Haytham did not question Ptolemy's fundamental assumption about the perfect circular paths of planets, which was later disproven by Johannes Kepler's theory of elliptical orbits. This limitation prevented Ibn al-Haytham from achieving a more holistic understanding of astronomical phenomena. Furthermore, the observational technology available during his time also restricted his understanding of the characteristics of celestial bodies, making his analyses less comprehensive and more focused on observable visual aspects. Nevertheless, Ibn al-Haytham made the most of the resources available to provide rational explanations of astronomical phenomena based on existing observations and reasoning.

Another limitation of his thinking was his lack of understanding of large-scale concepts of space and time. Astronomical phenomena such as stellar evolution and galaxy formation involve processes that occur over vast timescales and distances. Ibn al-Haytham's thinking was limited to phenomena that were more accessible to human observation at that time. He also lacked the opportunity for long-term observations of astronomical phenomena that require extended observation periods, such as the movements of planets and stars. External factors further limiting his thinking included the lack of collaboration and knowledge exchange with scientists from other regions due to the communication constraints of his era.

Despite these limitations, Ibn al-Haytham's contributions provided a strong foundation for the development of astronomy and scientific knowledge. His critical, rational, and experimental approach inspired future scientists to develop more rigorous and objective

[12]Ibn al-Haitham, *Quwl fi Samt al-Qibla bi al-Hisab* translated by Mada Sanjaya W.S. in *Matematika Arah Kiblat Ibn al-Haytham dalam Quwl fi Samt al-Qibla bi al-Hisab,* (Bandung: CV. Bolabot, 2021), 51-82.

[13]R. Rashed, *Ibn al-Haytham and the Origins of Modern Science*, Dans Actas del Primer Congreso de la Unión Europea de Arabistas e Islamólogos, edited by María Jesús Viguera Molins and Concepción Castillo Castillo, 1-21. (Córdoba: Asociación Española de Estudios Árabes e Islámicos, 2015), 75-78. See also Syamsul Hadi, *Ibn al-Haytham: Pemikir Besar Islam*, (Jakarta: Penerbit Hikmah, 2010), 70-72.

scientific methods. His critiques of established astronomical theories and his proposals of more accurate alternative solutions made him one of the most influential Muslim scientists in history. As a tribute to his contributions, a crater on the Moon, located to the west of Mare Crisium, was named after him.

Overall, Ibn al-Haytham's intellectual legacy in astronomy represents an important milestone in the advancement of science. Although his thinking had limitations, his dedication to exploring, criticizing, and refining scientific theories demonstrates a commitment to the pursuit of scientific truth that remains relevant today. His dedication and contributions illustrate how a Muslim scientist can have a profound impact on the progress of global science, proving that knowledge knows no geographical or cultural boundaries but is a collective heritage of humankind.

3. The Influence of Ibn al-Haytham's Thinking on the Development of Optical Instruments in Islamic Astronomy

Before Ibn al-Haytham wrote *Kitab al-Manazir* (The Book of Optics), there were two main theories about how the human eye sees. The most widely accepted was the extramission theory of Ptolemy and Euclid, which suggested that vision occurs because light emanates from the eye toward surrounding objects. When the eyes are closed, this light is not emitted, and thus the eyes cannot see. Ibn al-Haytham opposed this theory and supported Aristotle's intromission theory. According to the intromission theory, vision occurs because light from an external source is reflected by objects and enters the eye. However, at first, Ibn al-Haytham could not experimentally prove how this process occurs or how the eye forms images representing the objects being viewed.[14] It was during his ten years of house arrest under al-Hakim in Cairo that Ibn al-Haytham found evidence to support his theory through his discovery of the dark room, now better known as the camera obscura.

The camera obscura, Latin for dark room, was one of the significant discoveries in the field of optics developed by Ibn al-Haytham. According to various sources, the discovery of the camera obscura happened accidentally while Ibn al-Haytham was conducting experiments on light and vision. In The Optics of Ibn al-Haytham by A.I. Sabra, it is explained that Ibn al-Haytham began experimenting by puncturing a hole in the wall of a dark room to observe the properties of light and the formation of images. He discovered, unintentionally, that light from an object outside the room passing through this small hole would create an inverted image on the opposite wall.[15]

[14]Ibn al-Haitham, *Maqalah fi al-Kurrah al-Mutharriqah,* translated by Mada Sanjaya W.S..., 9-10.
[15]A. I. Sabra, *The Optics of Ibn al-Haytham...,* 115-117.

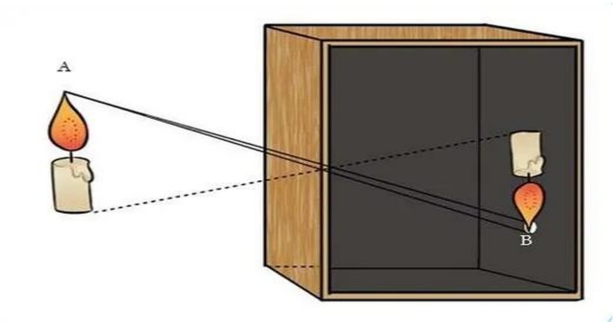

Figure 1: Camera Obscura

The simple concept of the camera obscura involves a dark room with a small hole in one of its walls. Light from an object outside the room passes through this hole and forms an inverted image of the object on the opposite wall. By observing this process, Ibn al-Haytham was able to study the properties of light, such as straight-line propagation, reflection, and refraction. Evidence of Ibn al-Haytham's discovery of the camera obscura can be found in his monumental work, *Kitab al- al-Manāzīr* (The Book of Optics). In this book, he explains in detail how he conducted experiments with the camera obscura and observed the optical phenomena occurring within it. In Encyclopedia of the History of Arabic Science by Roshdi Rashed, it is noted that Ibn al-Haytham's experiments with the camera obscura marked a historical milestone in the fields of optics and photography, as it was the first analysis of the mechanism of image formation within a dark room.

Ibn al-Haytham provided a more in-depth explanation of the camera obscura concept and the phenomenon of image inversion within it, using a geometric approach in his work *Maqālah fi Surat al-Kusūf* (Treatise on the Shape of the Eclipse). This demonstrates the sophistication of the scientific methods he used to study optical phenomena. In addition to observing image inversion in the camera obscura, Ibn al-Haytham also conducted a more thorough study of the characteristics of the formed image.[16] Through his experiments, he explored how the image size is affected by factors such as the size of the aperture and the width of the opening used. As explained in his monumental work *Kitab al-Manāzīr*, Ibn al-Haytham discovered that the aperture width influences the size of the circular image formed on the opposite wall within the camera obscura.[17]

[16]A. I. Sabra, *The Optics of Ibn al-Haytham…,* 145-150.

[17]Ibn al-Haitham, *Maqālah fī Surat al-Kusūf,* translated by Mada Sanjaya W.S dalam *Optika Kamera Obscura Ibn al-Haytham,* Bandung: Bolabot, 2019, 13.

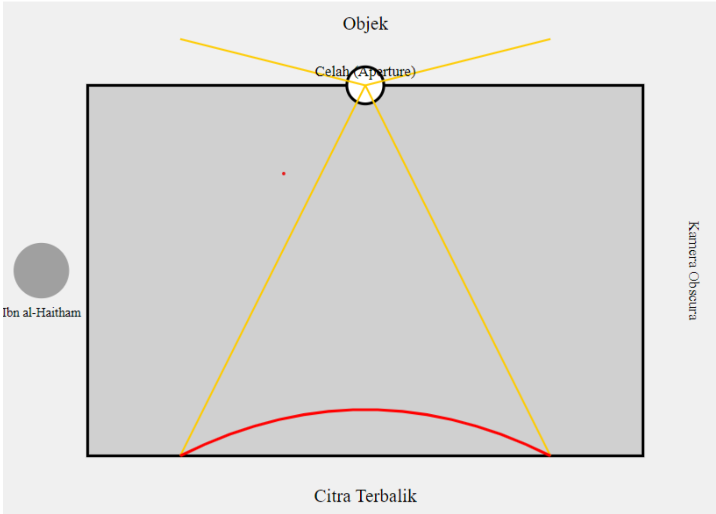

Figure 2: Illustration of Camera Obscura Image

Ibn al-Haytham not only observed the size of the projected image but also noted its shape and characteristics. One of his significant findings was that the concave side of the formed image was not a perfect circle. As described in his work *Maqālah fi Sūrat al-Kusūf* (Treatise on the Shape of the Eclipse), Ibn al-Haytham discovered that the image of the sun projected in the camera obscura was flat, not a perfect circle.[18] By observing the shape of the projected sun and its relation to factors such as eclipse magnitude and the radius of the aperture, Ibn al-Haytham demonstrated sensitivity and precision in observing optical phenomena. This finding enriched the understanding of image formation within the camera obscura.

In his comprehensive research on the camera obscura, Ibn al-Haytham also studied the relationship between the size of the projected image and the focal distance of the camera obscura itself. He found that if the focal distance of the camera obscura was increased, the size of the projected image, such as a crescent shape, would also expand. This discovery became an essential foundation for developing optical instruments like telescopes and cameras in the future, which use focal distance principles to control the size and quality of the produced image.[19]

Furthermore, Ibn al-Haytham researched how the characteristics of the projected image in the camera obscura were influenced by factors such as the shape and size of the aperture. In his work *Kitab al-Manāzīr*, he examined the relationship between aperture shape and the resulting image, discovering that the shape of the aperture only affected the image if the aperture size was widened.[20] However, when using a very narrow aperture (pinhole), the camera obscura produced a sharp image resolution with a one-to-one relationship between the points of the projected image and the object. Additionally, Ibn al-Haytham observed that as the aperture

[18]R. Roshdi, *Ibn al-Haytham's Optics* dalam *Encyclopedia of the History of Arabic Science*, Vol. 2, (London: Routledge, 2007), 364.
[19]R. Roshdi, *Ibn al-Haytham's Optics* dalam *Encyclopedia of...*, 364.
[20]R. Roshdi, *Ibn al-Haytham's Optics* dalam *Encyclopedia of...*, 364.

widened, the image on the screen would decompose or blur.[21] These findings demonstrate Ibn al-Haytham's profound understanding of optical principles and image formation in the camera obscura, as well as the factors that influence the resolution and quality of the resulting image.

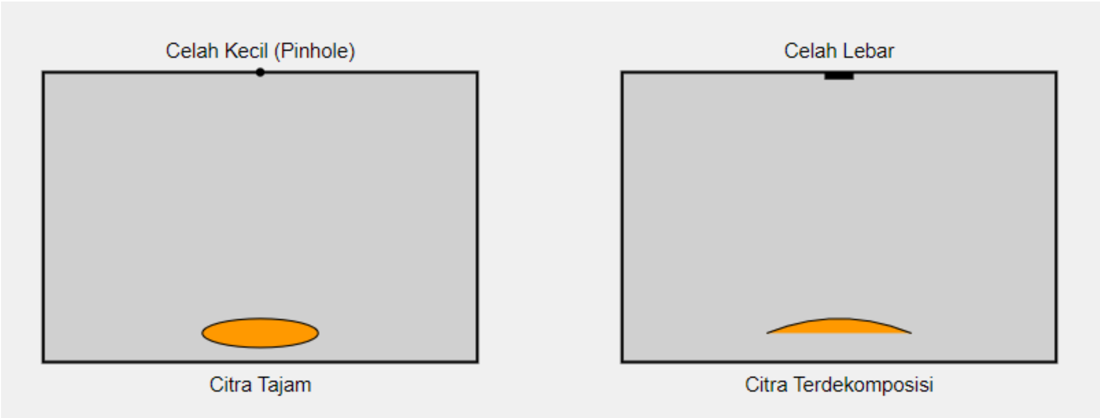

Figure 3: Illustration of Image Differences with Small Aperture (Pinhole) and Large Aperture

In his research on the camera obscura, Ibn al-Haytham also paid special attention to comparing how the images of the sun and the moon formed within this dark room. In his work *Maqālah fi Sūrat al-Kusūf* (Treatise on the Shape of the Eclipse), Ibn al-Haytham proposed two arguments regarding the formation of the sun and moon images, one of which was incorrect and the other correct. First, Ibn al-Haytham was mistaken in claiming that the ratio of light required to display the crescent shape in the moon's image was the same as in the case of the sun's image. However, his second argument proved correct, as he explained that the image of the moon formed in the camera obscura tended to be rounder compared to the sun's image. This is likely due to the loss of the edges and borders of the image, which receive less light than the center. Despite the initial error in his argument, Ibn al-Haytham quickly corrected himself and provided an accurate explanation of the differences in the shapes of the sun and moon images within the camera obscura. This demonstrates his meticulous observation skills and his willingness to revise his theories based on experimental evidence.[22]

[21]Bradley Steffens, *Ibn al-Haytham: First Scientist*, (Philadelphia: Mason Crest Publishers, 2007), 92.

[22]Ibn al-Haitham, *Maqalah fi al-Kurrah al-Mutharriqah,* translated by oleh Mada Sanjaya W.S, *Refraksi Lensa Optiak Ibn al-Haitham…,* 14.

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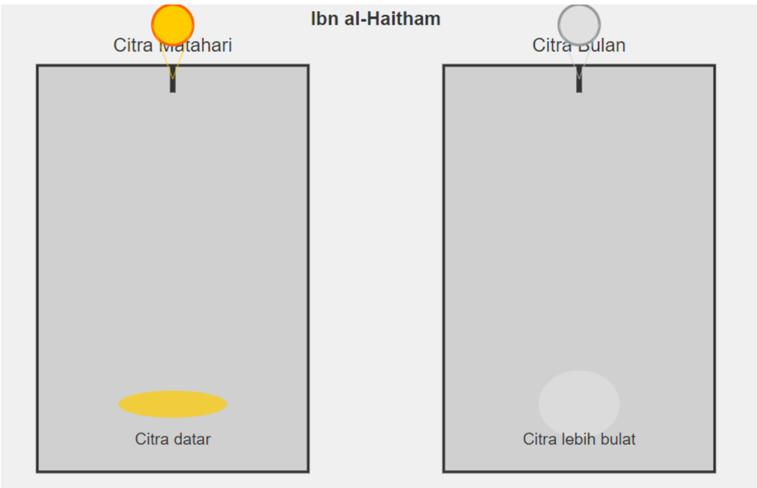

Figure 4: Illustration of the Comparison Between Sun and Moon Images in the Camera Obscura

One limitation of the camera obscura is in the context of large-scale astronomical measurements. Its main drawback lies in the inability to determine an accurate scale representing the distance ratio between the sun and Earth. The difference in scale between the actual Sun-Earth distance (approximately 1010 times longer) and the focal length in the dark room of the camera obscura highlights its limitations. Although effective for smaller-scale observations and measurements, the camera obscura has significant limitations when used for long-distance astronomical measurements. This indicates that while the camera obscura was revolutionary in the history of optics and astronomy, it has practical constraints in certain applications.[23] Despite these limitations, Ibn al-Haytham is regarded as the first scientist to study photometry (a field concerned with measuring light intensity)[24] because, through his research and experiments with the camera obscura, he observed and analyzed the relationship between light intensity and factors such as aperture size, shape, and the distance between the aperture and the projection screen.

Ibn al-Haytham's contributions to optics laid a crucial foundation for developing astronomical instruments. Without his understanding of light traveling in straight lines, later scientists would have struggled to measure celestial positions accurately using tools like the astrolabe and telescope. His explanations of reflection and refraction became key foundations in developing both refracting and reflecting telescopes for astronomical observations. For instance, the reflector telescope developed by Isaac Newton in 1668 would have been impossible without understanding the light reflection principles that Ibn al-Haytham outlined. His mathematical approach to explaining optical phenomena also provided more precise calculation methods for designing optical astronomy instruments. Similarly, the concept of the camera obscura he introduced paved the way for developing various modern astronomical

[23]Ibn al-Haitham, *Maqalah fi al-Kurrah al-Mutharriqah,* translated by Mada Sanjaya W.S, *Refraksi Lensa Optiak Ibn al-Haitham…,* 15.

[24]Ibn al-Haitham, *Maqalah fi al-Kurrah al-Mutharriqah,* translated by Mada Sanjaya W.S, *Refraksi Lensa Optiak Ibn al-Haitham…,* 14.

observation instruments. For example, spectrographs used to analyze starlight spectra evolved from the foundational understanding of light behavior that he explained.

Ibn al-Haytham's thoughts on the camera obscura significantly influenced the development of tools in Islamic astronomy, such as instruments for observing the new crescent moon (*hilāl*), although this influence might not always be direct. Ibn al-Haytham provided detailed explanations of how light behaves when passing through a small opening in a dark space, forming an inverted image. This principle became foundational in further optical understanding, crucial for developing telescopes and other optical instruments used in *hilāl* observations. His insights into light behavior helped design instruments that enhance the accuracy of observing dim celestial bodies like the *hilāl*. Although Ibn al-Haytham did not invent the telescope, his optics concepts contributed to its later development. The telescope became a key instrument in more accurate *hilāl* observations. The camera obscura concept was also applied in projection techniques for observing the *hilāl*. By projecting the crescent moon image onto a screen, observers can view it without looking directly at the sky, reducing observation errors due to glare. Some modern *hilāl* observation instruments, like specialized telescopes with filters and digital imaging systems, use optical principles traceable back to Ibn al-Haytham's ideas. His studies on atmospheric refraction also contributed to a better understanding of how the atmosphere affects *hilāl* visibility. While modern technology has advanced far beyond what was available in Ibn al-Haytham's time, the basic principles he developed continue to underpin the advancement of more sophisticated Islamic astronomy tools for observing the *hilāl*. His contributions to optics have helped improve the accuracy and reliability of *hilāl* observations, which are essential for determining the start of each month in the Islamic calendar.[25]

Ibn al-Haytham's concepts of the camera obscura also had an indirect yet significant impact on developing optical instruments for determining the qibla direction, like the theodolite. The optical principles Ibn al-Haytham developed contributed to the evolution of this precise measuring instrument. Ibn al-Haytham's foundational theories on light behavior, reflection, and refraction were crucial in developing the precise optical systems used in modern theodolites. His camera obscura concept, illustrating how images could be projected through a small aperture, contributed to understanding how distant objects can be projected and measured accurately. This principle is vital in designing the small telescopes within the theodolite. Ibn al-Haytham's studies on lenses and light behavior through different media assisted in the development of advanced lens systems, a key component in modern theodolites. His understanding of geometry and optics contributed to developing more accurate angle measurement methods—a primary function of the theodolite in determining the qibla direction. His optical principles aided in the precise calibration of optical instruments, critical in theodolite design. Ibn al-Haytham's contributions to astronomy and optics helped develop methods that combine terrestrial and celestial measurements (using a theodolite) for more accurate qibla determination. His understanding of projection and measurement from the camera obscura

[25]M. Ilyas, Lunar Crescent Visibility Criterion and Islamic Calendar, *Quarterly Journal of the Royal Astronomical Society*, 1994, 35, 425-461.

concept contributed to developing more accurate scales and gradation systems in the theodolite. The image projection concept in the camera obscura aided in developing improved data visualization methods, important for interpreting theodolite measurement results. Ibn al-Haytham's scientific approach to analyzing optical phenomena has driven ongoing innovation in measurement instrument design, including the evolution of the theodolite over time.[26]

D. Conclusion

1. Ibn al-Haytham made significant contributions to astronomy through an approach that combined theory and experimental practice. His work included studies on starlight, eclipses, and critiques of Ptolemy's theories. Ibn al-Haytham developed more accurate observation methods, refined astronomical instruments, and applied mathematical and optical concepts in his research. Among his major contributions were mathematical calculations for determining the qibla direction. Although his ideas were progressive for his time, he was still bound to the geocentric model and Aristotelian cosmology. Limitations in technology and a lack of collaboration with distant scientists also restricted his intellectual scope. However, his critical and experimental approach inspired future developments in astronomy, making him one of the most influential Muslim scientists in history.
2. Ibn al-Haytham's ideas on the camera obscura and optics provided fundamental contributions to the development of instruments in Islamic astronomy. His theories on the behavior of light, reflection, and refraction laid the groundwork for advancements in optical technology, such as telescopes and theodolites. The principles he developed enhanced the accuracy of crescent moon (*hilāl*) observations and qibla direction determination. Although he did not directly invent modern instruments, Ibn al-Haytham's understanding of image projection, lens systems, and precise angle measurement established a foundation for ongoing innovation. His contributions included improvements in data visualization methods, instrument calibration, and understanding atmospheric effects on observations.

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