Dominique Raynaud. *A Critical Edition of Ibn al-Haytham's On the Shape of the Eclipse: The First Experimental Study of the Camera Obscura*. Cham: Springer, 2016. 261 pages. ISBN: 9783319479903.

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As the title of Dominique Raynaud's *A Critical Edition of Ibn al-Haytham's On the Shape of the Eclipse: The First Experimental Study of the Camera Obscura* suggests, it involves the first experimental study of the darkroom. According to the author, this book came about as a result of some inconsistencies he had observed a few years earlier regarding the explanations of Eilhard Wiedemann (d. 1914) and Mustafa Nazif (d. 1942) concerning Ibn al-Haytham's (d. ca. 432/1040) *Maqāla fī ṣūrat al-kusūf* [*Epistle On the Shape of the Eclipse*]. The book also presents an edited text and translation of Ibn al-Haytham's work. In addition to filling a gap in the history of physics, Raynaud's work offers many methodological innovations for historians of science. Under the current conditions of increased support from software programs regarding critical edition studies, Raynaud identified five existing copies of *Maqāla fī ṣūrat al-kusūf* and decided to use a software program for his critical edition. After comparing and analyzing the various available programs, he chose PHYLIP 3.69 (Felsenstein, 2009), which provides a complete algorithm package.

Raynaud's first methodological innovation was to cut the digital copies into strips in order to place the entire text on a single line. He then examined the five manuscripts in parallel with the software, which calibrates the baseline by assigning a value of 0.000 at the beginning of the text and 1.000 at the end. This method has become an effective tool for comparing manuscripts, and any

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deviation in a manuscript can be easily identified. The second methodological innovation Raynaud introduced was the application of the same critical edition rules to both the text and figures in manuscripts. Thus, in light of the advances made in diagrammatic studies and digital stemmatology, he utilized a never-before-applied method for the critical edition of geometric figures.

The significance of Raynaud's work lies not only in his application of new technologies as made possible by computer software in his critical edition of the work but also in his analyses of the images produced in Ibn al-Haytham's scientific instrument (i.e., the darkroom) in terms of geometrical and physical optics. Curious about the sharpest image producible by the various parameters in Ibn al-Haytham's darkroom, in particular the focal length, Raynaud tries to find the answer to this question by repeating Ibn al-Haytham's experiments with similar values. In this way, he tests the accuracy of Ibn al-Haytham's results both mathematically and experimentally.

Maqāla fī ṣūrat al-kusūf strictly follows the new experimental method introduced by Ibn al-Haytham. He provided a purely empirical solution to questions dating back to late antiquity, such as why sunlight that penetrates through quadrilaterals produces circular shapes instead of linear ones and why the rays from a solar eclipse appear as a crescent in the direction of the Earth when looked at through a sieve or a leaf.

Raynaud argues *Maqāla fī ṣūrat al-kusūf* to have provided the first successful attempt at unifying the two branches of ancient optics: the science of vision (physio-psychological optics) and the science of light (physical optics). According to Raynaud, the idea that *Maqāla fī ṣūrat al-kusūf* is one of Ibn al-Haytham's earliest works is supported by both the astronomical dating and the first reference to *Conics* by Apollonius (d. ca. 190 BC). According to Raynaud, despite the connotation in its title, Ibn al-Haytham's work is an optical treatise rather than an astronomical study. While the Sun acts as a powerful light source, a partial eclipse disrupts the symmetry of the solar disk. The eclipse of the Sun had thus been made the subject of study as a tool for developing an in-depth analytical approach to the formation of an image.

Raynaud discusses the place *Maqāla fī ṣūrat al-kusūf* has in the history of optics as well as in Ibn al-Haytham's legacy in the introduction and why the need exists for a critical edition in the first chapter. He discusses the copies of the manuscript, how he subjected the figures in the work to an investigation, as well as the editorial procedures, such as the work's transliteration. The author presents the Arabic text and the translation in the second chapter, in addition to relating Ibn al-Haytham's account of how the resulting image of a solar eclipse is affected by the size of the hole in the darkroom through which the light enters and his observations in relation to different light sources such as the moon. Ibn al-Haytham questioned the basis of these observations and discussed the optical/geometric foundations of topics such as the linear propagation of light and the point analysis of the image. He analyzed the relationship between the size of the light hole in the dark room and the distance to the projection surface, as well as the distinction between the concave and convex sides of the resulting crescent; he also analyzed the images of these shaped sides.

Ibn al-Haytham obtained a series of optical results in *Maqāla fī ṣūrat al-kusūf* by considering simple mathematical relationships such as the ratios and proportions in similar triangles and opposite sides of a triangle. Ibn al-Haytham thus turned to the experimental study of the darkroom, first demonstrating how images are reversed in the darkroom. Ibn al-Haytham's difference regarding the phenomenon of image reversal, which had previously been known to al-Kindī (d. around 252/866) and some Chinese scholars, was that he approached the subject geometrically. He studied the shape of the image as a function of the size of the light hole and realized that the wider the hole (aperture), the more rounded the image would become. He then noted that the concave side of the image is not perfectly circular and concluded that the amount of flattening of the solar image depends on the size of the eclipse and the radius of the hole. He also discussed the shape of the image as a function of the focal length of the dark chamber and found that the wider the focal length, the wider the crescent-shaped image. When he analyzed the image as a function of the shape of the hole, he concluded that the image on the projected surface is composed of many overlapping patches of light, each of which is a projection of the Sun's image from a point in the hole, and that rounding of the image will thus also occur regardless of the shape.

Ibn al-Haytham devoted a long chapter to the study of the shape of the image as a function of the light source, comparing how the images of the Sun and the Moon appear in a dark room. He put forward two arguments, one of which Raynaud characterized as false and the other as true. In error, Ibn al-Haytham claimed the ratio that was required for light to appear as a crescent on the Moon to not be met. However, he consistently explained the image of the Moon as being even rounder than that of the Sun to be due to its faintness leading to the disappearance of the edges, as edges receive less light than the center of the image. Raynaud argues

Ibn al-Haytham to have taken the first step toward proto-photometry (light measurement) with these explanations.

Raynaud presents the diagrams from *Maqāla fī ṣūrat al-kusūf* in his book, preserving their original proportions as found in the manuscripts. However, he notes depicting the overall device to scale to be impossible due to the distance between the Sun and Earth being about times greater than the focal distance of the darkroom, and therefore presenting a perfect picture is also impossible. Instead, the book provides a three-dimensional view of the device. In this way, the analysis in the second chapter uncovers the reason why the Sun's light appears crescent-shaped during an eclipse when it passes through one of the holes in the dark chamber and reaches a planar surface parallel to the hole and why the moonlight penetrating through the holes will always appear circular, not crescent-shaped, even when the Moon is crescent-shaped during an eclipse.

The third chapter concerns Ibn al-Haytham's experimental method, introducing Ibn al-Haytham's darkroom in terms of its shape, depth, and width of its light range and describing the process of controlled experimentation that occurs in this scientific instrument. Ibn al-Haytham used new terms in his *Maqāla fī ṣūrat al-kusūf,* such as *iʿtabara*, *muʿtabir* and *iʿtibār,* which refer to the process of comparing different sets of data and are in harmony with the current definition of experiment. Unlike a thought experiment, these experiments require testing under real conditions. According to Raynaud, beyond showing a geometrical analysis of the formation of actual optical images, Ibn al-Haytham's work also shows the place of the experimental method in the production of knowledge. Above all, his use of the experimental method distinguishes him from his predecessors, such as Aristotle (d. 322 BC), al-Kindī, and al-Khujandī (d. 390/1000), who used the darkroom as a simple observation instrument. Ibn al-Haytham would thus succeed in solving problems whose origins dated back to Ancient Greece, and considerable time would be required for Western science to rediscover Ibn al-Haytham's results. While medieval philosophers such as Roger Bacon (d. 1292), John Pecham (d. 1292), and Witelo (d. post-1278) had failed to explain the shape of light in a dark room, only two authors, Egidius de Baisiu (d. around 1300) and Levi ben Gerson (d. 1344), were able to come close to Ibn al-Haytham's results.

In the third chapter, Raynaud also presents an evaluation of Ibn al-Haytham's scientific instrument and examines what is actually seen in the darkroom, a phenomenon that depends on the physical properties of the instrument and is in need of evaluation in terms of modern optics. This chapter is dedicated to determining the optical workings of the darkroom he used and is critical to grasping the scientific scope of Ibn al-Haytham's investigation. Raynaud also discusses the concept of optical stigmatism in this chapter. In modern optics, stigmatism is the ability of an optical system to produce a sharp image of an object. The size of the hole studied in Ibn al-Haytham's darkroom is the main parameter for obtaining a sharp image of the Sun. By asking whether Ibn al-Haytham had been able to observe sharp images, Raynaud based his assessment of Ibn al-Haytham's darkroom on existing scientific knowledge. While the modern concept of stigmatism was unknown to Ibn al-Haytham, Raynaud emphasizes that Ibn al-Haytham appeared to have preferred experimenting with small holes that would have been able to produce images that were practically stigmatisms.

The book's fourth chapter aims to evaluate the findings in *Maqāla fī ṣūrat al-kusūf* by comparing them with the objective data provided by modern optics. According to Raynaud, Ibn al-Haytham's determination that the convex arc observed in the darkroom during the eclipse was the inverse of the convex crescent portion of the Sun shows that Ibn al-Haytham had succeeded in using a pinhole camera to explain the inverted image in the dark room and had found the basis for the conditions of image reversal in both optics and geometry.

Raynaud also tries to understand the relationships that formed the milestones in Ibn al-Haytham's line of reasoning in *Maqāla fī ṣūrat al-kusūf*. Raynaud, in his own laboratory, wants to design Ibn al-Haytham's observational instrument to observe the crescent with a 2-meter helioscope with a 10 mm hole and, in this way, confirms the crescent shape to appear on the projection surface. While trying to understand the geometry of the image in his work, Ibn al-Haytham examined how the image is affected by variables such as hole size, focal distance, hole shape, and light source. While examining light source as a variable, Ibn al-Haytham compared the images of crescents from the Sun and the Moon, which have different distances and light intensities. Thus, he proved that the Moon could never be observed as a crescent in the darkroom. In conclusion, Ibn al-Haytham tested how all the parameters present in an experimental system affect the outcome of the experiment. Raynaud followed his steps one by one while redesigning Ibn al-Haytham's instrument in his own laboratory.

According to Raynaud, what makes Ibn al-Haytham's geometric reasoning successful is how it reflects the physical properties of photometry *avant la lettre* (i.e., before the concept existed). Here Raynaud presents a point analysis of light and a simple way of estimating the amount of light included in an image by taking the sum of the overlapping patches of light in a given region. According to Raynaud, the *Maqāla fī ṣūrat al-kusūf* resembles Ibn al-Haytham's *Maqāla fī kayfiyyat al-aẓlāl* in certain respects. Both texts introduce infinitesimal quantities, explaining the change of light and shadow in a penumbra by dividing the light source into an infinite number of parts, as well as by expressing the change of light in an image through the superposition of an infinite number of light rays. Raynaud identifies both works as distant echoes of the analysis of Archimedes' (d. 212 BC) infinitesimals as revived through works by Banū Mūsā (active 3rd/9th century), Thābit Ibn Qurra (d. 288/901), and Ibn Sinān (d. 335/946-47).

Raynaud also states Ibn al-Haytham's work provides new and reliable data in the historical context; this was possible because Ibn al-Haytham had not repeated the darkroom observations of his predecessors but had instead applied his own new scientific method to the darkroom. In the history of optics, the *Maqāla fī ṣūrat al-kusūf* is both the first mathematical study of the functioning of the darkroom as well as an unprecedented investigation into the conditions of how optical images are formed. Thus, Ibn al-Haytham did not limit himself to treating the darkroom as his predecessors had envisioned but as a scientific instrument for demonstrating the linear propagation of light as well as for setting out to understand its functioning. He did this by putting each mathematized science upon which he based his scientific methodology through the filter of controlled experimentation. As a result, he determined the mathematical rules governing the darkroom and tested the parameters that affect the resulting image. According to Raynaud, Ibn al-Haytham's most striking feature is the highly systematic manner in which he conducted these experiments. In *Maqāla fī ṣūrat al-kusūf*, every factor he was able to identify as a variable or parameter (e.g., hole shape, hole size, dark room's focal length, and shape and distance of the celestial bodies) and repeatedly analyzed various issues such as the shape and distance of the celestial bodies in terms of their effect on the image formed in the dark room.

Raynaud concludes his narrative by stating that complete scientific knowledge can only be achieved in this way. In the Appendix at the end of the book, he focuses on the astronomical dating of *Maqāla fī ṣūrat al-kusūf* by applying an astronomical celestial diary listing the solar eclipses that had occurred in the region where Ibn al-Haytham is thought to have lived. Raynaud lists the eclipses that occurred by calculating the respective projected images. *Maqāla fī ṣūrat al-*kusūf describes the conditions under which the observation had occurred clearly enough to allow an assessment of Ibn al-Haytham's drawings that correspond to reality. Therefore, Raynaud was thus able to date the partial solar eclipse using astronomical methods by analyzing the solar eclipses that had occurred during Ibn al-Haytham's lifetime. As a result, Raynaud concludes Ibn al-Haytham's work to be able to have reported the partial solar eclipse that occurred in Basra on 28 Rajab 380/October 21, 990. Raynaud concludes by stating the need for further research on this issue; however, confirmation by independent sources could also offer a new method for analyzing scientific images, something which scholars have become interested in over the last decade.

Raynaud began his career as an architect but later specialized in the history of science at the Université Grenoble Alpes and publishes extensively in the field of the history of optics; his book is of great importance as it offers a new methodology that historians of physics can follow. Although many unstudied manuscripts are found in the field of physics in Islamic and Ottoman scholarship, no comprehensive inventory of these works has yet occurred in terms of name or artifact. Identifying the copies of a work in the field of the history of physics and following Raynaud's steps in preparing a critical edition, translation, and analysis of that work, we could prepare a critical edition of the text and figures through the use of an appropriate software program. Attempts should also be made to create similar experimental processes to the one Ibn al-Haytham followed in his work but in regard to current conditions, in addition to testing the accuracy of the data presented by the work in the context of modern scientific knowledge. Following Raynaud's methodology will systematize the process of understanding the place that numerous works on the history of physics have on the stage of history.