IBN AL-HAYTHAM AND SCIENTIFIC METHOD

A Dissertation
submitted to the Faculty of the
Graduate School of Arts and Sciences
of Georgetown University
in partial fulfillment of the requirements for the
degree of
Doctor of Philosophy
in Islamic Studies

By

Sohrab Ghassemi, M.A.

Washington, DC
March 3, 2020
IBN AL-HAYTHAM AND SCIENTIFIC METHOD

Sohrab Ghassemi, M.A.

Thesis Advisor: Jonathan A.C. Brown, Ph.D.

ABSTRACT

This examination into the history of Arabic science explores the methods utilized by Ibn al-Haytham for his scientific investigations. Specifically, this study compares and contrasts his approach towards establishing the equal angles law of reflection for light in chapter three of book four of his Kitāb al-Manāẓir, or The Book of Optics, with the approach taken by him in his maqālat-u fī mā'īyat-i al-athar-i alladhī fī wajh-i al-qamar-i, or "Treatise on the Nature of the Marks on the Surface of the Moon." The analysis focuses upon his technical usage of the word i'tibār, and its variants, in order to arrive at the finding that his most advanced method for inquiry into the natural world did not constitute full experimental testing in the sense of the modern scientific method, but rather can best be understood as a type of controlled observation that yet still goes beyond the ancient Greek idea of empeiría (empiricism). Further, when he was able to utilize instrumentation for his research, he also achieved a science of demonstration (apódeixis) with an emphasis upon the repeatability of his findings. This latter procedure would in fact be a foundational idea for modern science: demonstrable proof. On the other hand, his treatise on the marks on the moon, which was actually written after his work on optics, shows continuity with Greek methods.
for science. In that latter work his methods of proof remain based upon syllogistic logic and deductive argumentation. Ibn al-Haytham then can be seen as occupying a transitional, but not fully transformational, place in the history of the scientific method.

Next, Ibn al-Haytham’s scientific work beyond his justly famous Kitāb al-Manāẓir has often been overshadowed by that magnum opus. Therefore, in addition to analyzing his treatise on the marks on the moon specifically in regard to its methods for scientific inquiry, this dissertation has produced for the first time in scholarship a full and complete English translation of his maqālat-u fī mā‘īyat-i al-athar-i alladhī fī wajh-i al-qamar-i. This translation has been exactly matched in the footnotes of this thesis to a full transliteration of the original Arabic.
I dedicate this study to Barbara Stowasser (1935-2012).
“Truth is one’s reflection on the experiential authenticity of the evidence that you have.”

Patrick Heelan, S.J. (1926-2015)
# Table of Contents

Introduction.................................................................................................................... 1
  Arabic science or Islamic?............................................................................................ 1
  Arabic optics and Ibn al-Haytham................................................................. 7
  Outline of the study.......................................................................................... 17

Chapter 1: Arabic science in history................................................................. 22
  Beginnings............................................................................................................. 23
  Endings.................................................................................................................. 31
  Ibn al-Haytham’s scientific method............................................................ 40
  Concluding remarks......................................................................................... 49

Chapter 2: Ibn al-Haytham’s scientific procedure........................................ 51
  Kitāb al-Manāẓir’s chapter three of book four............................................. 52
  Method of science............................................................................................ 58
  Demonstrable repeatability.......................................................................... 68
  Concluding remarks......................................................................................... 73

Chapter 3: Ibn al-Haytham’s scientific procedure, part two.......................... 74
  Treatise on the marks on the moon............................................................... 75
  Method of science............................................................................................ 88
  Controlled observation (i’tibār).................................................................. 93
  Concluding remarks......................................................................................... 100

Chapter 4: The true nature of the marks upon the moon.................................. 102
  Introduction....................................................................................................... 103
  Refutation of existing theories................................................................. 106
  Ibn al-Haytham’s theory............................................................................ 126

Conclusion............................................................................................................. 144

Bibliography........................................................................................................... 153
Transliteration of the Arabic alphabet

**Consonants**

<table>
<thead>
<tr>
<th>Arabic</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>آ</td>
<td></td>
</tr>
<tr>
<td>ء</td>
<td>Not indicated when initial (all other cases)</td>
</tr>
<tr>
<td>b</td>
<td>t</td>
</tr>
<tr>
<td>t</td>
<td>gh</td>
</tr>
<tr>
<td>th</td>
<td>f</td>
</tr>
<tr>
<td>j</td>
<td>q</td>
</tr>
<tr>
<td>ḥ</td>
<td>k</td>
</tr>
<tr>
<td>kh</td>
<td>l</td>
</tr>
<tr>
<td>d</td>
<td>m</td>
</tr>
<tr>
<td>dh</td>
<td>n</td>
</tr>
<tr>
<td>r</td>
<td>h</td>
</tr>
<tr>
<td>z</td>
<td>w</td>
</tr>
<tr>
<td>s</td>
<td>y</td>
</tr>
<tr>
<td>sh</td>
<td></td>
</tr>
<tr>
<td>s</td>
<td></td>
</tr>
</tbody>
</table>

**Vowels**

<table>
<thead>
<tr>
<th>Arabic</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>ا</td>
<td>ā</td>
</tr>
<tr>
<td>ً</td>
<td>-an</td>
</tr>
<tr>
<td>او</td>
<td>aw</td>
</tr>
<tr>
<td>او</td>
<td>ay</td>
</tr>
<tr>
<td>اٰ</td>
<td>t</td>
</tr>
</tbody>
</table>

**Special constructs**

<table>
<thead>
<tr>
<th>Arabic</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>اٰ</td>
<td>ā</td>
</tr>
<tr>
<td>او</td>
<td>aw</td>
</tr>
<tr>
<td>اٰ</td>
<td>ay</td>
</tr>
<tr>
<td>ء</td>
<td>t</td>
</tr>
</tbody>
</table>
Introduction

This introductory chapter sets out the broad parameters of the study. First, as is typical for most studies of the history of the scientific enterprise in Islamic civilization, I explain why I favor the use of one formulation to describe that historical phenomenon rather than another commonly used phrase to describe the same historical cultural developments. Next, the middle section briefly outlines the key figures in Arabic optics prior to Ibn al-Haytham (d. ca. 431/1040) and then provides a biographical sketch of his own life. Finally, the concluding section to this introduction presents the outline of the subsequent study with a chapter by chapter preview.

Arabic science or Islamic?

The terminology with which to refer to the scientific activities that occurred in classical Islamic civilization is fraught with controversy. For example, those who want to emphasize a connection between Islam as a religion and the science produced by Muslims prefer the phrase Islamic science, especially in contrast to the phrase Arabic science.¹ Issues of ethnicity and language are often cited issues by those who favor utilizing "Islamic science." The point is made that

¹ See, for example, Muzaffar Iqbal's vociferous call for the use of "Islamic science" in reaction against the use of the term "Arabic science," which he claims "is a term contrived by secular historians of science to purge the vast scientific enterprise of the Islamic civilization of its legitimate religious grounding." Page 229, in Muzaffar Iqbal, "Islam and Science: Responding to a False Approach," in Islam and Science, 1:2 (December 2003), Sherwood Park, Alberta, Canada: Center for Islam and Science. Pp. 221-34.
not all scientists in Islamic civilization were Arabs, and that utilizing "Arabic science" makes it seem the contrary. Further, the objection is sometimes raised that science was also conducted in the Persian language contemporaneously with science written in Arabic and that therefore the phrase "Arabic science" is not wholly accurate, or at least not broadly comprehensive enough.

Let us breakdown these difficulties with the goal of precision in our analysis. "Islamic science" is problematic both because of its connotations as well as due to the historical development of science in classical Islamic civilization. When one invokes the Islamic sciences in any conversation about the history of Islam, the first reaction is not to think of mathematics, astronomy, optics, mechanics, medicine, botany, and the like; rather, our attention immediately turns to the religious sciences of Islam: traditions of the Prophet (hadīth), interpretation of the Qur'an (tafsīr), speculative theology (kalām), jurisprudence (fiqh), and the like. These sciences all are rigorous, with their own methods of inquiry and investigation, standards of proof, and understandings of truth. What makes these sciences particularly Islamic is their aim to contribute to the interpretations of how Islam as a religion should be conceived and practiced. At the most fundamental level, the practitioners of these Islamic sciences are attempting to provide responses to questions of theology.

However, the exact and natural sciences that flourished during the course of classical Islamic civilization largely did not seek to participate in theological
discourse. Further, Muslim scientists who undertook investigation of the natural world did not use their scientific findings and science writings to define religion.2 Utilizing the term "Islamic science" to refer to the sciences of astronomy, optics, mechanics, etc. in Islamic history allows for too much confusion and conflation with the truly religious sciences of Islam.3

So, if the term Islamic science carries with it the ability to cause more confusion than clarification regarding the phenomenon of science in Islamic history, then a better terminology is needed, and the obvious alternative is to use the moniker "Arabic science." There is an accepted precedent for referring to a historic tradition of scientific activity with reference to the language in which that tradition operated. There is little controversy regarding classifying the sciences of the ancient and late antique Mediterranean world as Greek science. This tradition of science began in ancient Greece by Greeks, but it continued and spread into a broader geographic area that became Hellenized following the conquests of Alexander of Macedon (d. 323 BCE). Greek science continued under the Latinate rule of Rome and later under the auspices of Constantinople. Many of the most

2 Endress makes an apposite point about Islamic philosophy when he points out that the philosophy of al-Fārābī (d. 339/950) was specifically an "Islamic philosophy" because it was "a philosophy which defined religion and answered the questions of theology in Islam." Page 249, in Gerhard Endress, "The Language of Demonstration: Translating Science and the Formation of Terminology in Arabic Philosophy and Science," in Early Science and Medicine, 7:3 (2002), Leiden: Brill. Pp. 231-54.

3 Of course, other historians of science will disagree with my aversion to utilizing the term Islamic science. For example, Saliba's use of this term is meant to connect the scientific activity to the "more complex civilizational sense" as long as one is clear that the term is not used in "the religious sense." See pp. vii-viii, George Saliba, Islamic Science and the Making of the European Renaissance. Cambridge, Massachusetts: The MIT Press, 2007.
prominent practitioners of Greek science came from outside of Greece, including from the island of Sicily, the shores of North Africa, Lower Egypt, and Asia Minor (Anatolia). These practitioners used the Greek language as their language of learning and wrote their scientific treatises in Greek.

Similarly, Arabic science originated among Arabs who settled in the Near East following their Islamic conquests. This scientific tradition first rose to prominence under the 'Abbāsid caliphate centered in Baghdad, but the science was a widespread phenomenon stretching from the Iberian Peninsula in the west to the edges of China and India in the east. The science continued under myriad and often localized political regimes, and its practitioners were not all Arabs or even all Muslims (though the overwhelming majority were Muslim). Just as non-Greek scientists participated in the Greek scientific tradition by conducting their science in the language of the science of the day (i.e.: Greek), non-Arab and Arab scientists were participating in the Arabic scientific tradition by conducting their science in the language of the science of the day (i.e.: Arabic).4

---

4 The analysis supporting the phrase Arabic science because it is analogous to the commonly accepted phrase Greek science in a historic sense is entirely my own, but the notion that Arabic was the language of learning for a mosaic of people has been made before and often. Saliba, for example, summarizes that "Arabic was for a long time the scientific language of the Islamic civilization, irrespective of the geographic area where those sciences were written or studied. These conditions, which prevailed throughout most of Islamic history, opened various avenues for people of various races and religious backgrounds to participate in the production of this civilization. Those same people may have spoken Persian, Syriac, or even later Turkish and Urdu at home. And yet they mostly expressed their intellectual production, and especially the scientific part of it, in Arabic [my italics]." See p. viii, Ibid.
Some protest will be made, though, that particularly the Persian scientists undertaking Arabic science also wrote scientific treatises in Persian and not always exclusively in Arabic. Therefore, the argument can go that referring to an Arabic science can cause confusion that the science was always a science written in Arabic exclusively, and that this would be an historically inaccurate representation. This is a valid point worth addressing with a mind towards historic precision. When a historian of science examines the phenomenon of a long lasting and well-developed tradition of scientific activity, this analysis must of necessity identify whether there was a well-defined and unique culture that distinguishes one scientific tradition from any other. In the case of the scientific activities conducted within the Muslim world from roughly the second/eighth century and through to the beginnings of the tenth/sixteenth century, the answer is clearly yes.

This scientific tradition was founded upon a systematic effort to translate the near entirety of the intellectual heritage of antiquity into specifically the Arabic language. This science then developed an advanced technical vocabulary for science specifically in the Arabic language. Muslim scientists of later generations who inherited, learned from, and continued to develop this scientific tradition consulted earlier scientific treatises that were only accessible if one had been educated to read the Arabic language in which the science was overwhelmingly written. Importantly, these same scientists, if they wanted their
own science to influence later generations and to be considered as part of the
discourse of scientific learning, were required to write their own works in the
scientific lingua franca of the day, which was Arabic. Even Christendom, which
would develop into the modern West, when it undertook its own efforts to
acquire the intellectual heritage of previous scientific traditions, required
specialists in Arabic who could translate these works into Latin.

The singular unifying factor then of the entire scientific effort of Islamic
civilization was that it was a science based upon the Arabic language. This was the
unrivaled language of learning and scholarship for science over an eight hundred
year period of time. In summary, while Islamic science has been a used
terminology to describe the exact and natural sciences studied in the course of
Islamic history, when this phrase is utilized there is too much possible confusion
with the other Islamic sciences that were primarily religious in nature. On the
other hand, referring to an Arabic scientific tradition not only decreases this
possible conflation but also is more largely accurate from an historical analysis.
This study prefers to identify the over eight hundred year intellectual tradition of
scientific endeavor in the Muslim world as an Arabic science and will mostly
adopt this phraseology.
Arabic optics and Ibn al-Haytham

This study of the Arabic scientific endeavor focuses upon the science of Ibn al-Haytham, whose science was mostly concerned with the nature and properties of light – in other words, with the science of optics. In order to better contextualize this analysis of his science, this introductory section will outline the major figures in the field of Arabic optics as it existed up to the lifetime of Ibn al-Haytham and then provide the latter's biography. When Ibn al-Haytham was born in Basra, in southern Iraq, in the year 354/965 he came of age in a milieu that already had a strong tradition of science. The Arabic scientific tradition in optics traces its origins to the original translation movement that transferred primarily Greek texts into Arabic.

While Ḥunayn ibn Ishāq (d. 259/873) receives the lion's share of attention for his activities translating scientific, and especially medical, works into Arabic, his contemporary translator Qusṭā ibn Lūqā (d. ca. 299/912) can be credited with beginning the Arabic science in optics. As both a translator of these works and also in his commentaries, Qusṭā ibn Lūqā was still very much operating within a Greek science albeit in the new language of learning, Arabic. For example, Qusṭā ibn Lūqā accepts as valid the visual ray theory of vision popularized by

---

Galen (d. ca. 200 CE), and his scientific arguments about the reflection of light upon mirrors are based solely upon geometric studies in the manner of Euclid (d. ca. 265 BCE). Nevertheless his work on optics can be seen as the beginning of the Arabic science in this field because he not only defined the parameters of the science but also set the model for how to investigate its aspects. It is no accident that Qusṭā ibn Lūqā’s major field of research, the reflection of light, would also become a major focus of inquiry for his contemporary al-Kindī (d. ca. 259/873) and then Ibn al-Haytham as well.

Ibn al-Haytham particularly built upon the scientific work on optics conducted by al-Kindī. al-Kindī’s work on optics lies at a middle point. He had doubts about the theories in Euclid’s *Optics* (written ca. 300 BCE), but al-Kindī ultimately accepted Euclid’s theories. He also remained firmly committed to the

---

6 Rashed's analysis has concluded that Ibn Lūqā 's "doctrine about vision is of Euclidean and Galenic origin at the same time ... With Ibn Lūqā we are very much in the area of Hellenistic optics and catoptics." See p. 646 and p. 649, Ibid.

7 Qusṭā ibn Lūqā comments upon the science of optics: "The best demonstrative science is that in which physical science and geometrical science participate communally, because it takes from physical science the sensory perception and takes from geometrical science demonstration with the help of lines. I have found nothing where these two disciplines are united in a more beautiful or perfect way than in the science of rays, above all those which are reflected onto mirrors." For this translation see p. 646, Ibid.

8 The Arabic original of al-Kindī’s work on optics has been lost to history, and we only know of these writings from the medieval Latin translation of the work, which is known by its title *De aspectibus*. The most thorough study of this work has been done by the historian of medieval science David C. Lindberg, who focuses his work upon medieval European optics.

writings of the respected physician Galen, who promoted Ptolemy’s (d. ca. 170 CE) visual theory of extramission.\textsuperscript{10} al-Kindī, more so than Ibn Lūqā, incorporated Galenic theory into Euclid’s theory of vision.\textsuperscript{11}

Following al-Kindī, al-Fārābī (d. ca. 338/950), whose main interest was not the science of optics, includes an important section on the field, ‘ilm al-manāzir, in his ihšāʿ al-ʿulūm (literally, "Enumeration/Counting of the Sciences"), which is a traditional classification of knowledge compendium whose Latin translation by Gerard of Cremona (d. 583/1187), made in Toledo, Spain, became influential in Europe. al-Fārābī’s entry provides the reader an insight into the state of Arabic optics near the time of Ibn al-Haytham’s birth. Echoing Qustā ibn Lūqā, al-Fārābī presents optics, including the key questions regarding vision and the properties of light, as primarily a demonstrative science.\textsuperscript{12}

Finally, we reach the figure of Ibn Sahl (d. ca. 390/1000), who was a contemporary of Ibn al-Haytham. Ibn Sahl, like Ibn al-Haytham, was born in Iraq, but he remained in Baghdad while his contemporary made a permanent move to

\textsuperscript{10} This theory is also known as the emission theory because of its false contention that vision occurs as a result of rays of light emanating from the eye to the object seen. This is the same theory that Qustā ibn Lūqā upheld, followed, and to which he adhered.

\textsuperscript{11} “What is important about this position is that it takes Alkindi outside the Euclidean tradition [and gives] the Euclidean theory a Galenic interpretation at the point where Euclid himself had been entirely silent, namely on the physical nature of visual rays.” See pp. 486-7, David C. Lindberg, “AlKindi’s Critique of Euclid’s Theory of Vision.”

\textsuperscript{12} Kheirandish has concluded that al-Fārābī’s entry on the discipline of optics "reflects aspects of the field that were central to the early optical tradition. Demonstrations were indeed among the key features of the science of optics." See p. 60, Elaheh Kheirandish, “The Many Aspects of ‘Appearances’: Arabic Optics to 950 AD,” in The Enterprise of Science in Islam: New Perspectives, edited by A.I. Sabra and J.P. Hogendijk. Cambridge, Massachusetts: MIT Press, 2003. Pp. 55-83.
Cairo. Ibn Sahl, at least in Europe, did not have a similar magnitude of influence upon science and the study of optics as Ibn al-Haytham, but the scholar of Islamic science Roshdi Rashed has undertaken groundbreaking research to show that Ibn Sahl should be credited with advancing the science of optics from the Euclidean dependence on geometry.\(^\text{13}\) Rashed has convincingly shown that Ibn Sahl discovered the law of refraction.\(^\text{14}\) This particular history in the development of Arabic optics provides an ideal example of the impact when new methods were applied to older scientific problems. Ibn Sahl’s refinements and advancements to the geometric optics of Euclid was a key development that allowed him to explain the law of refraction, a scientific discovery that had not previously been achieved, and that would not be discovered in Europe until the work of Willebrord Snellius (d. 1035/1626) over six hundred years after the lifetime of Ibn Sahl.\(^\text{15}\)

\(^\text{13}\) Rashed maintains that Ibn Sahl took up a new position in the history of optics: "although his work continues the Greco-Arabic tradition of research on buring mirrors, his introduction of refraction and lenses constitutes a break with that tradition as well." See p. 468, Roshdi Rashed, “A Pioneer in Anaclastics: Ibn Sahl on Burning Mirrors and Lenses,” in Isis (a journal of the History of Science Society), 81:3 (September 1990), Chicago: University of Chicago Press. Pp. 464-91.

\(^\text{14}\) “Beginning the study of buring mirrors, Ibn Sahl is the first in history to engage in research on burning lenses: it is the birth of dioptics [the study of how light refracts].” See p. 656, Roshdi Rashed, "Geometrical Optics."

\(^\text{15}\) “Ibn Sahl had conceived and put together an area of research into buring instruments ... (when he was) obliged to think about conical figures ... as anaclastic curves, he was quite naturally led to the discovery of the law of Snellius.” See p. 660, Ibid. Rashed maintains that Ibn Sahl in this manner was the first to develop the new discipline of dioptics. The discipline within the field of optics that his predecessors had mostly concerned themselves with, as we saw above, was catoptrics (the study of how light reflects).
In summation, Arabic optics began with the initial translations of Greek works on the subject, a task that Qusṭā ibn Lūqā played a particularly important role in helping to achieve. al-Kindī then undertook the important task of beginning to critique this Greek scientific heritage while still remaining largely within its parameters and theories. al-Fārābī’s presentation of the state of the field up to his own times further shows a new Arabic intellectual tradition that was already advancing away from the ancient sciences, especially alongside new methodological approaches. With Ibn Sahl we can see a new maturity in Arabic optics whereby new discoveries began to correct errors in the science of Greek optics. His contemporary and immediate successor, Ibn al-Haytham, then, should be seen in the context of the established and continually developing scientific work that preceded him in the Arabic tradition of optics.\footnote{Rashed’s work in particular has pointed to the fact that “it would be equally surprising if earlier important works had not paved the way for a work as revolutionary as that of Ibn al-Haytham.” See p. 491, Roshdi Rashed, “A Pioneer in Anaclastics: Ibn Sahl on Burning Mirrors and Lenses.”}

Before turning to our outline of the current study, let us provide a brief sketch of Ibn al-Haytham’s life and times. Ibn al-Haytham was born in Baṣrah in southern Iraq in 354/965 and died in Cairo, Egypt in ca. 431/1040. He grew-up under the rule of the Būyids, a Shīʿī dynasty that controlled much of Persia and Iraq, including Baghdad, from ca. 333/945 until ca. 447/1055. He moved to Cairo during the reign of al-Ḥākim (ruled 386/996 - 412/1021), and his most productive scientific years occurred here under the rule of another Shīʿī dynasty,
the Fāṭimids. Ibn al-Haytham wrote an autobiography late in his life, but that manuscript has been lost to history, and we can only rely on references made to it by the seventh/thirteenth century sources from which most of what is known about his life and what he produced can be found.

These three sources arise out of the biographical, or ṣabaqāt, literature prevalent in Islamic society. The earliest but least reliable of these sources comes from ‘Alī ibn Zayd al-Bayhaqī (d. 564-65/1169-70). His Taʾrīkh ḥukamāʾ al-Islām contains a short entry on Ibn al-Haytham that establishes very basic facts regarding his place of birth, travels and general activities, but in light of what the two other sources report and agree upon, contains inaccuracies and is not comprehensive.\(^\text{17}\) The next biographical entry regarding Ibn al-Haytham appears in Al-Qifṭī’s (d. 646/1248) Taʾrīkh al-ḥukamā’.\(^\text{18}\) Finally, Ibn Abī Uṣaybi’ah (d. 668/1270) has related the most complete account of Ibn al-Haytham’s life and works in his ‘Uyūn al-anbāʾ fi ṣabaqāt al-ḥubbā’.\(^\text{19}\)

There is actually little known about Ibn al-Haytham apart from his extant writings. It is clear that he received an advanced education in southern Iraq and may have spent some time in Baghdad, but there are no details about what this

---


education entailed and under whom he studied. He most likely served in a high administrative role in the governorate of Baṣrah and Aḥwāz from which he derived his living. What is also discernible prior to his move to Cairo is that he already had an established reputation as an excellent and accomplished mathematician, and al-Qifṭī specifically begins his entry on Ibn al-Haytham by noting his mastery of geometry. The reason for his move to Cairo and the exact year of that move is vague. He may or may not have been personally requested by the ruler of the Fāṭimid dynasty at the time, al-Ḥākim. al-Qifṭī relates the famous story that Ibn al-Haytham assured al-Ḥākim that he could design and construct a hydraulic project on the upper Nile that would help control the annual flooding of the river. After having failed at this attempt, Ibn al-Haytham either fled to Syria or, more likely, remained under the radar in Cairo in order to avoid al-Ḥākim’s infamous wrath. After the death of al-Ḥākim, Ibn al-Haytham took residence near the university of al-Azhar and earned income from copying manuscripts for bookish clients. The works of geometry by Euclid and Ptolemy’s Almagest seem to

---

20 al-Qifṭī implicitly emphasizes the fame and repute of Ibn al-Haytham prior to his move to Cairo by relating the possibly apocryphal story that al-Ḥākim himself led a delegation to receive Ibn al-Haytham and rode out to the entrance of Cairo to welcome him. See p. 166 ; line 7, al-Qifṭī, Taʾrīkh al-ḥukamāʾ
21 See p. 165 ; line 18, Ibid.
22 See p. 166 ; lines 9-13, Ibid.
have been in high demand in Cairo, with Ibn al-Haytham reportedly copying one manuscript of each per year.\textsuperscript{23}

Ibn al-Haytham is reported to have written on all manners of the learning of his time, including logic, music, politics and ethics, and theology, and also worked in the scientific disciplines of mathematics, astronomy, and especially optics.\textsuperscript{24} Interestingly, only his writings on these three scientific fields have survived, which indicates that, unlike his scientific works, his writings on those other fields of knowledge were perhaps not of enough originality or interest to provoke preservation by his intellectual successors. He does not seem to have considered too highly of non-scientific intellectual pursuits. A probably apocryphal story nevertheless captures the spirit of his approach towards knowledge: dissatisfied with the religious sciences, and with ‘ilm al-kalām, scholastic theology, in particular, as an avenue towards perceptible knowledge, he sought ought disciplines where truth could be discerned from the sensible world.\textsuperscript{25} Ibn Abī Uṣaybi‘ah, perhaps working from Ibn al-Haytham’s now lost

\textsuperscript{23} It is very difficult to verify the veracity of stories like this for Ibn al-Haytham. In this case the only source is a report from just under two hundred years after his death. Ibn Abī Uṣaybi‘ah was the first to record this story in his ‘Uyūn al-anbā’ fī ṣabaqāt al-aṭībbā’; see page 375; lines 7-13. A. I. Sabra much more recently has summarized the story: "Yūsuf al-Fāsī (d. 1227), a Jewish physician from North Africa who settled in Aleppo after a short stay in Cairo where he worked with Maimonides ... had "heard" that in the latter part of his life Ibn al-Haytham earned his living from the proceeds (amounting to 150 Egyptian dinars) of copying annually the Elements of Euclid, the Almagest, and the Mutawassāt, and that he continued to do so until he died." See p. 189, A. I. Sabra, “Ibn al-Haytham,” in Dictionary of Scientific Biography (vol. 6). New York: Scribner, 1981. Pp. 189-210.

\textsuperscript{24} P. 190, Ibid.

\textsuperscript{25} Ibid.
autobiography, quotes the scientist directly in his own biographical entry to get across the theme of how Ibn al-Haytham approached truth.26

Ibn Abī Uṣaybi‘ah’s citation of this section of Ibn al-Haytham’s autobiography as a way to explain the latter’s intellectual preferences was most likely the first historical framing of him as an empiricist.27 Ibn Abī Uṣaybi‘ah refers to Ibn al-Haytham as Muḥammad bin al-Ḥasan, and the quoted section more fully is as follows28:

Muḥammad bin al-Ḥasan said: I therefore became absorbed in a variety of views and beliefs and types of religious sciences, and I did not acquire from these anything of use, and I did not perceive from it the truth methodologically, and no path to certain opinion; so, I realized that I would not arrive at the truth except through ideas the origin of which was matters of sensory perception, and the form of which was rational matters.29

And I did not find that except in what Aristotle had established from logic, the natural sciences, and the theological sciences that are philosophy in their own right and whose nature approaches (philosophy).30

26 Ibn Abī Uṣaybi‘ah has him state, “I saw that I can reach the truth only through concepts whose matter are sensible things and whose form is rational.” I have provided Saleh Omar’s translation because his version, which is accurate, has become what is probably the most popularly cited quotation attributed to Ibn al-Haytham. It first appeared in Saleh Beshara Omar, *Ibn al-Haytham’s Optics: A study of the origins of experimental science*. Minneapolis: Bibliotheca Islamica, 1977. See page 13.


28 This is my own translation of the full entry. My translation of the particular sentence rendered also by Omar occurs within my larger translation.


Ibn al-Haytham relates that he tried to study the sciences related to religious belief, but that he was dismayed that there were so many opinions and no way to verify which of the views was correct; so, he did not find this field of endeavor useful for seeking out truth. Instead he wanted to study ideas based upon experience of the natural world and study the rational sciences as Aristotle had described. After establishing these points in his autobiography as related by Ibn Abī Uṣaybi‘ah, Ibn al-Haytham then outlines an Aristotelian approach towards knowledge that is a summation of the method of deduction and proof through the use of syllogism.31

While the biographers can provide this sketch of his life and even characterize the roots of his epistemology, there is a fog as to exactly when and how Ibn al-Haytham died. Almost certainly he finished his life in Cairo in the middle of the fifth/eleventh century. There has been speculation that he, like

31 My translation, continued: "He (Aristotle) began with the arrangement of the general, particular, and special issues, then followed that with the establishment of the logical terms and their division into their primary categories, then followed that with the stating of the meanings that accompany those terms, and the known discourse among them.

Then from that he set aside the information that is the root of analogy and its substance, and he divided them (the terms) into their parts, and reported their components and their characteristics that distinguish some of them from one another; and from among them he enjoins their veracity and their falsehood, and with it (analogy) he demonstrates their agreement and their difference and their contradiction and their incompatibility."


See p. 377 ; lines 6-12, Ibid.
many in that time and place, succumbed to an outbreak of plague. For example, elsewhere in his ‘Uyūn al-anbā’ fī ṭabaqāt al-aṣībbā’, Ibn Abī Uṣaybi’ah relates a description made by the physician Ibn Buṭlān (d. 458/1066), who was practicing medicine in Baghdad during the lifetime of Ibn al-Haytham, about a severe plague that ravaged Cairo in the middle of the fifth/eleventh century. He lists many men of learning who died from this outbreak of disease, including an individual named Abū ‘Alī ibn al-Haytham, who is more than likely the same Abū ‘Alī al-Ḥasan ibn al-Ḥasan ibn al-Haytham appearing in this study.

Outline of the study

The subsequent chapters of this study analyze one particular aspect of the science conducted by Ibn al-Haytham; namely, we look at the method of his scientific inquiry in order to understand where he can be situated on the spectrum of the development of scientific method more broadly. Often he has been singled out from the larger tradition of Arabic science as singularly pioneering and as foreshadowing the modern scientific method. My analysis will show that while he did make methodological breakthroughs while conducting

---

33 Sabra provides this translation of the autograph: “(In that time), when all the burying places had been filled ... fourteen thousand bodies were buried in [St.] Luke's Church in the autumn ... and in al-Fusṭāt and al-Shām most of the [resident] people and all the strangers perished except those whom God saved." See p. 130, Ibid.
34 Ibn Abī Uṣaybi’ah particularly emphasizes the "great plagues affecting knowledge by obliterating the men of science" and lists Ibn al-Haytham as one of those who perished "from among those concerned with the ancient sciences." Ibid.
some of his scientific investigations, those methods already had their roots in the living Arabic scientific tradition of the time. Next, by looking at an aspect of his work outside of his most famous field of study, optics, we can further see that his methods for scientific inquiry were at the same time still quite firmly rooted in scientific methods developed within the Greek scientific tradition.

To further situate Ibn al-Haytham’s scientific methodology within the larger tradition of Arabic science, chapter one begins our study with a three-part literature review. There is a particularly important debate within the scholarship of the history of Arabic science as to the reasons for its rise and the roots of its origins. The question of the beginnings of the scientific tradition have resulted in a standard narrative and a revisionist narrative, and we outline both. Next, a key question in the history of Arabic science concerns its decline. Here again an established scholarly opinion for the reasons of this decline have found their response in another narrative that resists the notion while providing examples to disprove the idea. The third part of the literature review looks specifically at the scholarship regarding Ibn al-Haytham and scientific method. Here, in preparation for this study's own examination of that particular question, we outline the differing conclusions that have been reached regarding how original, or not, Ibn al-Haytham’s methods for scientific investigation were.

Chapter two then begins this study's own examination of the method(s) that Ibn al-Haytham brought to bear upon his science by looking at chapter three
of book four of his *Kitāb al-Manāẓir*, or *The Book of Optics*. This section of the larger work has been selected because if anywhere in his science there would have most clearly been a methodological breakthrough, then it would occur here where he most elaborately sets out his investigation into the reflection of light. My findings, as the reader of this study will see, conclude that Ibn al-Haytham was both an innovator of scientific method but also very much drawing upon an already existing Arabic scientific tradition that especially existed in medicine. Further, I cannot find clear evidence that his approach towards scientific investigation crossed into the experimental testing that has been a hallmark of the modern scientific method.

Chapter three contextualizes and qualifies the findings in chapter two by stepping away from the science on optics for which Ibn al-Haytham is most famous, and instead looks at a late work of his, *maqālat-u fī mā‘īyat-i al-athar-i alladḥī fī wajh-i al-qamar-i*, or "*Treatise on the Nature of the Marks on the Surface of the Moon*." This treatise has been selected for the purposes of a doctoral dissertation primarily because it is unknown, unstudied, and has largely been forgotten. The contrast its method of science provides to what was seen in Ibn al-Haytham's inquiries into the reflection on light further substantiates my claims that we do not in fact see a technical vocabulary for experimental testing emerge from Ibn al-Haytham. Rather, as is also the case in his *Kitāb al-Manāẓir*, we find an understanding of how the act of observation can or cannot result in certainty. The
treatise also provides an important contrast to the methods used in his previous work on optics. Further, his approach in the treatise helps clarify the importance of the use or non-use of instrumentation for scientific investigation, and its impact in determining his methodology alternatively in both works, but especially in optics.

Chapter four is a complete and full English translation of his treatise on the marks upon the moon. While his book on optics is readily available in English, his late treatise has never been translated into English. This is an important contribution for historians of medieval science as it makes available his science on the marks of the moon to those otherwise unversed in the original Arabic. For those historians of Arabic science able to read the original treatise in Arabic, my translation also provides a full grammatical transliteration of the Arabic. I have specified the case of the words in the treatise as part of my transliteration so that an Arabic reader can understand the grammatical choices that I made that then resulted in my English interpretation of the work.

This study then concludes with a summary of my findings about the methods of science deployed by Ibn al-Haytham. This concluding chapter situates my findings in the larger question about the development of the scientific method both within the Arabic tradition and also in the advent of modern science. Accordingly, the conclusion also seeks to qualify a contemporary phenomenon in popular culture that has elevated Ibn al-Haytham as the inventor of the modern
scientific method. Alongside this qualification, the study concludes by assessing how our findings can relate to the debate over the decline of the Arabic scientific tradition.
Chapter 1  

Arabic science in history

A brief overview of the field provides context for the following study. Much of the crucial literature looking at the history of science in the Islamic world consists of studies of the actual science conducted in fields diverse and interconnected: the mathematics of al-Khwārizmī (d. ca. 235/850)\textsuperscript{35}, the mechanical studies of the Banū Mūsā in third/ninth century Baghdad,\textsuperscript{36} the medicine of al-Zahrāwī (d. 403/1013)\textsuperscript{37} and Ibn al-Nafīs (d. 687/1288)\textsuperscript{38}, the astronomy of al-Bīrūnī (d. 442/1050) and Nasīr al-Dīn Tūsī (d. 672/1274) and Quṭb al-Dīn Shīrāzī (d. 711/1311) and Ibn al-Shātar (d. 777/1375)\textsuperscript{39}, etc. Much of this crucial literature looking at the history of science in the Islamic world consists in identifying major categories of research, the Arabic science’s correcting of errors in the previous, especially Greek, science, as well as noting novel discoveries made, oftentimes centuries before similar discoveries would be made in Europe. All this concerns the actual science accomplished in Islamic history, and the scientist focused upon in this study, Ibn al-Haytham, worked at

roughly the half-way point in this centuries long endeavor of science. The historiography concerning the periods before and after his work are of special interest to a historian of science because this literature concerns two of the most debated issues about Arabic science: its beginnings and its decline. This chapter will review the state of the field concerning these two controversies and then provide an historiographical overview of the key scholarship concerning Ibn al-Haytham's work in the field of optics as it relates to his methods for scientific investigation.

Beginnings

In the study of the scientific enterprise and culture of the pre-modern Islamic world, the scholarly accounts for the rise of science in classical Muslim society are especially useful in addressing and revising issues regarding debates over the historiography of the subject matter. The standard accounts for the rise of science in Islamic civilization have as their major theme the denial of agency to Arabic culture in particular. For example, the historian of Islamic science Seyyed Hossein Nasr (b. 1351/1933) has argued that non-Arabs were the major impetus for the rise of non-Islamic, i.e. scientific, learning in Muslim history. The major

---

40 “The scholars belonging to these minority religious communities … were also masters in the sciences in question as well as being well versed in Arabic … When their need for non-Islamic learning was felt by Muslims, the means to acquire it was ready at hand.” See p.639, S. H. Nasr, “Islamic Conception of Intellectual Life,” in Dictionary of the History of Ideas, vol. 2, edited by Philip P. Wiener. New York: Scribner, 1973-4. Pp. 638-52.
thematic is that, in spite of themselves, the Arabs managed to have much of the Greek scientific tradition translated in the course of the third/ninth century, and that this act gave rise to science in Islamic civilization. In support of this contention, the traditional accounts emphasize that an active Syriac/Hellenic science was already thriving in the lands conquered by the Arabo-Islamic armies, and that it was almost exclusively Syriac speaking Christians and other non-Muslims such as self-described Sabeans and Gnostics who managed to translate the bulk of the ancient sciences from Greek into Arabic.41

Further, the standard accounts of the translation movement emphasize that its success was due to the patronage and sponsorship of al-Khilāfah al-ʿAbbāsiyyah, the 'Abbāsid Caliphate, most notably under al-khalīfah al-Maʿmūn (d. 218/833) at the Baghdad located Bayt al-Ḥikmah, or house of wisdom, a scientific institution that came to house the thousands of translated works of Greek science and philosophy.42 The set scholarly narrative also links al-Maʿmūn's support of the Muʿtazili school of theology to the rise of science in Islam. The major theme of this account for the beginnings of science in Islam is that mainstream Islamic

---

41 For example, in an influential article on the Graeco-Arabic translation movement, Max Meyerhof argued that the translators "were all Christians, probably Nestorians ... they were helped by the spirit of scientific tradition which was alive among them." See p. 702, Max Meyerhof, "New Light on Ḥunayn ibn Ishāq and his Period," in Isis (a journal of the History of Science Society), 8:4 (October 1926), Chicago: University of Chicago Press. Pp. 685-724.
culture was not responsible for the rise of science. Further, a now common example given by the standard accounts to further show that science entered Islamic civilization from outside and foreign influences, is the traditional account given for the rise of medicine and the institution of the hospital in Baghdad. S. H. Nasr has argued that prior to Islam a full-fledged medical school, hospital complex, and medical scientific movement was active in Jundishapur, having been established by the Sassanian Persian king Shapur I, near the modern-day city of Dezful in Iran.

The revisionist accounts for the beginnings of the Arabic scientific tradition react to the just outlined standard narrative. Let us present the revised counter-arguments in reverse order, beginning with the story of Jundishapur and its theme of the agency for the rise of science in Islam, in this case the rise of the institution of the hospital, as stemming from non-Arabic culture. The revisionist critique of this presentation is nuanced. The historic fact that after the

---

43 Nasr writes, “The most significant influence of the Mu'tazilites was … in providing an atmosphere in Sunni Islam more conducive to the reception of the philosophical and scientific heritage of the pre-Islamic days. It is not accidental that their period of ascendancy in Baghdad coincides with the height of activity in the translation of works into Arabic.” See p. 641, S. H. Nasr, “Islamic Conception of Intellectual Life.” Sabra generally follows this conception, but he subtly expresses some reservation and doubt as compared to Nasr in crediting Mu’tazili thought with sole credit for the rise of scientific culture in Islam when he writes, "Al-Ma’mūn can truly be said to have given great impetus to the movement which was soon to bring the bulk of Greek science and philosophy within reach of a large number of Arabic-speaking scholars. And his personal interest in the translation activity may well have been connected with his sympathy for the rationalizing Mu'tazilīs." See p. 181, A. I. Sabra, “The Scientific Enterprise.”

44 “This school became important especially in medicine and astronomy and by the seventh century A.D. it was probably the most important medical center in the world.” P. 639, S. H. Nasr, “Islamic Conception of Intellectual Life.”
progression of events within Christianity as a result of the council of Chalcedon in 451 CE, Nestorian Christians were persecuted in the Eastern Roman Empire and fled further east to Sassanid Persia, with many families who were skilled in the craft of medicine settling at Jundishapur, is acknowledged. It is further true that one particular Nestorian family from Jundishapur, the Bakhtīshū', served as the personal court physicians and doctors to the 'Abbāsid caliphs for centuries. However, these historical facts cannot be extrapolated to say that Jundishapur contained the prototype for the important Muslim social institution of the hospital, or that a full-fledged medical science was alive in Jundishapur in late antiquity. To the contrary, the Bakhtīshū' most likely invented the myth of a hospital and medical training school at their old home of Jundishapur in order to increase their own reputations at the 'Abbāsid court. Their own self-

45 “As a result of this council, the Byzantine authorities persecuted (the Nestorians), whom later emerged as the transmitters of Greek medicine to the Persians and the Arabs. The followers of Nestorius fled to the Sasanian [sic] empire to set up the Nestorian church.” See pp. 17-8, Peter E. Pormann and Emilie Savage-Smith, Medieval Islamic Medicine. Washington, D.C.: Georgetown University Press, 2007.
46 “This claim, however, has been challenged and found to be without substance. There seems to be no evidence that there was a hospital in Gondēshāpur nor a formal medical school.” See p. 20, Ibid.
47 “The myth can best be explained in terms of a retrospective historiography. For eight generations, from the mid-eighth century well into the second half of the eleventh century, twelve members of the Bukhtīshū’ family of Nestorian Christian physicians served the caliphs in Baghdad as physicians and advisors. ... It would seem that they or their entourage formed a narrative which would provide them with a mythical and glorious past ... if the Bukhtīshū’ family could claim the hospital as their idea which they had brought with them from Gondēshāpur, then their prestige and medical authority would be greatly enhanced.” See p. 20-1, Ibid.
aggrandizing account emphasized that Nestorian Christians introduced the idea of
the medical school into Islamic civilization.48

Further, and regarding the Graeco-Arabic translation movement that was
centered in Baghdad, the revisionist accounts again acknowledge that there are
elements of historic fact underpinning the arguments of the standard narrative.
For example, under al-khalīfah Hārūn al-Rashīd (d. 193/809) a Bayt al-Ḥikmah
was indeed established, and its activities probably did reach their height under
his son, al-Ma'mūn. However, these facts do not support the generalized
conclusions that the Bayt al-Ḥikmah was an organized center for scientific
endeavor. In fact it was the royal library.49 While that established account for the
inception of the Arabic translation of the scientific heritage of antiquity stresses
the indispensable role of particularly 'Abbāsid state patronage, the revisionist
narratives argue that the translation movement was a widespread social
phenomenon with its roots going back to the al-Khilāfah al-'Umawīyah, the
'Umayyad Caliphate (see next two paragraphs for this explanation).

48 Françoise Micheau, in looking at the origins of the first Arab hospitals in Baghdad, traces the
myth to an account given by the seventh/thirteenth century biographer Al-Qīfī and writes that
"the role played by the physicians from Gundīshāpūr led to the assumption, long held, that the
hospital of this great centre of Persia served as a model for the first Arab establishments.
Current research turns in the other directions: isn't the place of Gundīshāpūr in the history of
the beginnings of Arabic medicine excessive?" See p. 991, Françoise Micheau, “The scientific
49 Micheau notes that "it is difficult to define the exact role of the Bayt al-Ḥikmah in ... [the]
organization of translations ... [and] nothing leads one to think there was such planning. The
principle role that the Bayt al-Ḥikmah played was to provide manuscripts and to put the
translated books at the disposal of scholars. Like every library, the Bayt al-Ḥikmah was a place
where one came to copy works." See Pp. 986-88, Ibid.
The historical corrections made to the conventional account regarding the rise of an Arabic scientific tradition have two major aspects. First, the revisionist account counters that the notion that the act of translating the ancient sciences from Greek into Arabic was itself the cause for the rise of science in Islamic civilization. The historian of Arabic/Islamic science Ahmad Dallal has argued that an existing "knowledge base" had already formed within the cultural milieu of early Islamic civilization.\(^5\) Arabic linguistic activity as a major impetus for laying the foundation for an emergent scientific culture is of noteworthy importance.\(^6\) The rise of philology among Arab speakers in the second/eighth century led to the necessity for systematic thinking, an important prerequisite for scientific thinking. For example, Al-Khalil (d. ca. 174/790),\(^7\) in examining how letter combinations in Arabic correspond to the number of possible words that they could form, in effect engaged in combinatorial analysis.\(^8\)

These historical qualifications and corrections to the traditional scholarly account for the rise of science in Islam undermine the notion that there was no interest in scientific culture within early Islam, and that it took extraordinary top-

---

\(^5\) "For translations to be understood and to have an impact, there must have existed a scientific culture, what I call a knowledge base, on which further knowledge could be grafted." See p. 15, Ahmad Dallal, *Islam, Science, and the Challenge of History*. New Haven: Yale University Press, 2010.

\(^6\) "The specialized lexicons that were produced represent a large-scale attempt at collecting and classifying the knowledge of the Arabs." See p. 16, Ibid.

\(^7\) The philologist al-Khalil ibn Aḥmad al-Farāḥīdī was the author of *Kitāb al-‘Ayn*, the first comprehensive dictionary of the Arabic language.

down forces outside of the mainstream of early Muslim life to bring science into the civilization. Further, this portrayal fails to address what gave rise to the translation movement itself, and this topic is the second major aspect where the revisionist accounts seek to correct the narrative given for the rise of the scientific tradition within Islam. The historian of Arabic astronomy George Saliba has pushed back against an established narrative that is too content to attribute the translation movement exclusively to the state sponsorship of the 'Abbāsid Caliphate. Rather, he has shown that a complex and organic rise of scientific thinking among the Arabs occurred as a result of social and cultural developments within the emerging Islamic civilization, and that it was these factors that helped give rise to the translation movement. At the political level, under the 'Umayyad Caliphate, the decision to translate dīwān records into Arabic already initiated the need for communities of translators prior to the 'Abbāsids. A system of patronage stemmed from this translation activity whereby professional classes competed within society. Further, Arabic started to play an increasingly

---

54 Saliba asks, "What was the connection between the translators of the dīwān and the translators of books on philosophy and science?" He then provides the answer by noting that "the translations of the Persian and Greek dīwāns into Arabic must have included a group of elementary scientific texts, which were in turn very much connected to the philosophical and scientific texts [necessary for collecting revenue and land administration]." See pp. 53-6, George Saliba, *Islamic Science and the Making of the European Renaissance*.  
55 In particular Saliba convincingly argues that the arabization of the dīwāns would have led to an entire class of Greek and Persian bureaucrats losing their jobs and livelihood. See his discussion, p. 58-9, Ibid.
dominant role in non-religious learning, and the translation of the Greek heritage into Arabic was seen as a mark of social prestige by these professional classes.\(^56\)

Finally, we must make note of the importance of the Arabic language itself to the rise of science in classical Muslim societies. Arabic quickly became a universal language of communication across the wide and diverse lands conquered by the Arabo-Muslim armies. It also became the comprehensive language of science and scientific activity in Islamic civilization.\(^57\) This fact allowed previously diverse scientific traditions to be brought together under the single rubric of Arabic science. Therefore, for example, the mathematics, especially the trigonometric sine function, of the Indian scientific tradition could be brought to bear on the Greek sciences of astronomy and geometry in a way that was never possible or imaginable under the Hellenic tradition. In this manner then, repeated countless times across all scientific disciplines, the Arabic language helped give rise to what can rightly be called the first international science in human history.

\(^56\) These now unemployed bureaucrats, Saliba explains, "In order to be able to ... go back and monopolize the high positions of government ... would go back to teach their children and co-religionists and to urge them to acquire the more advanced sciences about which they were well informed by the Greek as well as the Persian classical sources. And since Arabic had by then become the language of competition they were obliged to demonstrate their competence both in the new bureaucratic language as well as in the sciences of the higher order. ... the translation movement that is under discussion was generated by the desire of two communities to re-acquire jobs that their parents and co-religionists had lost in the government offices." See p. 61-2, Ibid.

\(^57\) Dallal connects the elevation of Arabic into "a universal language of science through which several scientific traditions were fused" to the "methods used by [the] ninth-century translators." He notes that "[t]heir efforts led to the creation of a highly precise scientific terminology." See p. 16, Ahmad Dallal, *Islam, Science, and the Challenge of History.*
In summary, the conventional accounts for the rise of science in early Muslim society seem to want, at the broadest thematic level, to take away any and all agency of Arabo-Islamic culture itself for the rise of science in Islamic civilization. Revised accounts based upon more in depth research and analysis, however, have shown that the socio-political milieu of a developing Islamic culture contributed directly towards making Muslims heirs to the scientific legacy of antiquity.

Endings

The intellectual culture of Islamic civilization has been at the center of another key dispute in the historiography regarding the development of science in the Muslim world. The competing narratives here ultimately concern issues that strike at the core of epistemological debates about the history of Arabic science. Here again, as with the question of the beginnings of the scientific tradition, there exists a standard narrative and revisionists accounts that seek to correct the existing scholarship. During the long-lasting period of scientific work during the course of Islamic civilization science across myriad fields of research were vastly transformed, reformed, improved upon, and oftentimes completely refashioned. All good things eventually come to an end, and the key questions in the historiography regarding the disappearance of active science in the Muslim world revolve around an established scholarly narrative of decline.
The decline of science in Islam theory posits the year 504/1111 as the crucial date and turning point, after which no original scientific activity took place in Islamic civilization and a general stagnation and decline set in over the intellectual activities of Muslims. That year marked the death of the towering Muslim thinker al-Ghazâlî, and the attribution of decline to what he represented – the renewed ascendance of religious orthodoxy – has been a powerful narrative in the historiography on Islam. By far the most influential contribution to the standard narrative linking the decline of science in Islam to a rise of religious orthodoxy has been the writings of Ignaz Goldziher (d. 1921 CE). Goldziher portrays an Islamic intellectual culture where religion and science (but particularly philosophy) were at odds with one another.\(^{58}\) This view carried a lot of authority in late 19th-century Europe and its influence was felt immediately as well as in much later scholarship.

Immediatly, the modern epistemology defining the relationship between Islam and science as one rooted in an antagonism between reason and revelation even gained the adherence of the prominent Muslim modernist Jamâl al-Dîn al-Afghânî (d. 1314/1897) when he responded to these critiques by first agreeing

\(^{58}\) "The pious Muslim, however, was expected to avoid these sciences with great care because they were considered dangerous to his faith. ... It was said that disrespect for religious law went hand-in-hand with the cultivation of these sciences." See pp.186-7, Ignaz Goldziher, “The attitude of Orthodox Islam toward the ‘ancient sciences,’” in M.L. Swartz’s *Studies on Islam*. New York: Oxford University Press, 1981. Pages 185-215.
with their basic premise. The view has also persisted in history of science scholarship in the West. For example, in a study tracing the basis for the triumph of modern science in the West, Toby Huff implicitly contrasts its success with a restatement of the standard narrative's proposition that the cultural value systems of Islamic civilization prevented and stifled scientific activity.

The original scholarly narratives of decline conveniently had the rational sciences in Islam peak and complete their golden age just around the time of the birth of al-Ghazālī circa 450/1058. A collection of Muslim scientific giants, all contemporaries of one another, is especially identified to point to the pinnacle of Islamic scientific activity. Foremost among the list are Ibn Sīnā (d. 428/1037), Ibn al-Haytham (d. ca. 431/1040), and al-Bīrūnī (d. 442/1050). With the arrival of al-Ghazālī, though, and his trenchant critique of the discipline of philosophy, along with his upholding of religious orthodoxy and tradition, the conventional narrative in Western scholarship contends that a long-lasting cultural attitude took hold that in effect proved a death blow to rational inquiry within Islamic

---

59 For example, al-Afghānī’s famous reply to Ernest Renan in 1883 accepts and agrees with the conception that religion is intolerant of science. He writes, “In truth, the Muslim religion has tried to stifle science and stop its progress. It has succeeded … in turning minds from the search for scientific truth.” See p. xiv, Muzaffar Iqbal, Studies in the Islam and Science Nexus (Islam and science; vol. 1). Farnham, England: Ashgate Publishing, 2012.

civilization and from which it never recovered.\textsuperscript{61} Therefore, intellectual decline set-in, and scientific activity ceased to exist in Islamic civilization.\textsuperscript{62}

The revisionist riposte to this representation of the decline of scientific culture in Islam involves two main approaches: an epistemological critique and a historic-factual correction. The latter correction demonstrates the significantly advanced science that was achieved in the centuries after the standard account’s periodization of absolute decline following al-Ghazālī. Revisionist presentations often cite al-Jazari (d. 602/1206), who took the work that had been done on mechanical devices well beyond the Banū Mūsā; he composed a comprehensive engineering manual that went beyond mere theoretical descriptions and can be seen as the first practical handbook in a new field of mechanical engineering.\textsuperscript{63} al-Bayṭār (d. 646/1248) produced a similarly comprehensive manual in the field of botany, and his methods of inquiry in the compiling of his data demonstrate that a culture of scientific method continued to exist across disciplines in the conduct of

\textsuperscript{61} “Scientific research was frowned upon and discouraged because of the ignorance and self-sufficiency of Muslim theologians; scientific progress was stopped by their intolerance and their obscurantism.” See p. 36, George Sarton, \textit{The incubation of western culture in the Middle East}. Washington: Library of Congress, 1951.

\textsuperscript{62} George Sarton (d. 1375/1956), seen as the founder of the History of Science field, did not ignore the scientific activities of the east and went out of his way to popularly explain the intellectual indebtedness of the West to the Middle East in particular, but he still followed the narrative of absolute Islamic decline. He wrote that Arabic culture “declined steadily after the twelfth century. That culture was still impressive in the thirteenth and fourteenth centuries, yet was already on the way down.” See p. 34, Ibid.

science in the Islamic world.\textsuperscript{64} Science continued at such an advanced level that figures like 'Omar al-Khayyām (d. 525/1131) and Sharaf al-Dīn al-Tūsī (d. ca. 610/1213) innovated mathematics to a degree that would not be seen in Europe until the seventeenth century.\textsuperscript{65} These are just some representative samples of scientific work conducted during the conventional narrative's period of decline to illustrate one approach that the revised accounts use in order to critique the decline theory.

Briefly, two other markers of the continued scientific culture within Islamic civilization cited by the revisionist studies are its geographic range and functioning institutions. The continuation of science was not an isolated endeavor merely relegated to pockets of activity that were exceptions to a rule of overall general decline; rather, its continued excellence was the rule. Advanced medicine continued unabated in southern Spain with al-Nabātī (d. 636/1239) and in Cairo with Ibn al-Nafīs, who discovered the pulmonary circulation of blood.\textsuperscript{66} Groundbreaking astronomy was conducted at the Marāghā observatory near Lake Urmia in northwestern Iran in the late seventh/thirteenth century and early

\textsuperscript{64} See pp. 211-12, Ibid. The present study will further analyze the scientific method, as it existed in the work of Ibn al-Haytham, by looking at the field of optics.


\textsuperscript{66} "[Ibn al-Nafīs] ended up refuting the doctrines of Galen on the basis of his own observations ... It was in the post-Ghazālī period that such scientists seem to have gained a well-earned confidence in order to challenge their predecessors and through them attack the main Greek legacy that continued to be the site of contention." See p. 239, George Saliba, \textit{Islamic Science and the Making of the European Renaissance}. 
eighth/fourteenth century, and observatories were built on its model as far afield as Samarqand in the ninth/fifteenth century, and further observatories were constructed in Istanbul in the tenth/sixteenth century. Observatories are in effect scientific institutions, and institutions are a prerequisite for any scientific culture to thrive. Indeed, the learning institutes of the Muslim world remained strong and functioning during the scholarly account’s period of decline, and a good example of this is the hospital. The institution of the hospital, with its requisite schools, pharmacies, and training facilities, continued to thrive in places like Constantinople and Edirne in the ninth/fifteenth century, where the hospitals were often part of mosque complexes, and also in Mughal India well into the twelfth/eighteenth century.

In addition to documenting the continued scientific culture of the Muslim world that occurred during the conventional narrative’s assertion of decline as a way of response, the revisionist histories of Arabic science also present a more fundamental argument regarding the impact of al-Ghazālī’s attacks on philosophy and the relationship of science to theology within classical Islamic civilization. First let us review how revisionist scholarship addresses the latter issue.

Revisionist accounts of scientific activity in Islamic civilization argue that

---

67 “All this evidence points to one inescapable conclusion ... the post-Ghazālī period would have to [be] characterize[d] as the most fecund, and in the field of astronomy in particular completely unparalleled.” See p. 242 and the discussion from pp. 240-243 especially, in Ibid.
68 “The hospital is one of the greatest institutional achievements of medieval Islamic societies.” See p. 208, Ahmad Dallal, “Science, Medicine, and Technology: the making of a scientific culture.”
scientists conducted their work as a secular activity independent of religious authority. The revised narrative tries to show that the particular socio-cultural and historical development of Islamic intellectual life in fact allowed scientists to operate in the Islamic world under very different circumstances than the simplistic presentation of a conflict between reason and revelation given by the standard narrative. The revisionist accounts further point to a lack of centralized religious authority within Islam as producing a cultural space in which scientific ideas could coexist alongside other cognitive pursuits. This decentralized approach towards religious hierarchy cut both ways. On the one hand science did not have to constantly justify itself theologically and square its activities to religious meaning and theological authority, but on the other hand

---

69 For example, Sabra argues that science in Islamic civilization was primarily an activity "carried out under the patronage of rulers whose primary interests lay in the practical benefits promised by the practitioners ... In those circumstances science and "philosophy," or falsafa, were secular activities that were practiced, developed, and propagated as rational inquiries completely independent of any religious authority." See p. 662, A.I. Sabra, “Situating Arabic Science: Locality versus Essence,” in Isis (a journal of the History of Science Society), 87:4 (December 1996), Chicago: University of Chicago Press. Pp. 654-670.

70 Dallal has demonstrated that "the traditional Orientalist assertion of a fundamental opposition between science and religion is, to put it mildly, no longer tenable." See p. 111, Ahmad Dallal, Islam, Science, and the Challenge of History. For his summary of how Arabic/Islamic science did not have to answer to theology, see especially pp. 146-8.

71 Gutas has noted that the prevailing cultural orientation of classical Islamic civilization "was an attitude largely of laissez-faire in most ideological matters ... that was largely due to the lack of a centralized authority that would decide – or dictate – the proper views to be held." See p. 286, Dimitri Gutas, "Certainty, Doubt, Error: Comments on the Epistemological Foundation of Medieval Arabic Science," in Early Science and Medicine, 7:3 (2002), Leiden: Brill. Pp. 276-89.
this cultural atmosphere also meant that scientific proof posed no necessary threat to the religious fields of knowledge.  

Second, the alternate narrative of the continued scientific activities of Islamic civilization stretching well past a period of decline further points to another key aspect of why no basic epistemological or cultural reason can be held responsible for an eventual collapse of the Arabic scientific tradition at the hands of the theological attacks on philosophy highlighted by the standard narrative. In effect science operated in an independent sphere from other intellectual pursuits, especially those of philosophy. For example, Dallal has argued that Islamic astronomers were left to explain the heavens through their own methods,

---

72 "In this climate, scientific "truths" would have no more authoritative voice, within society as a whole, than any other view championed by whatever group, scientific or not." See p. 287, Ibid.

73 There is some nuance in the revised accounts regarding the role and non-role of philosophy as it related to the enterprise of Arabic science. As will be outlined immediately below, the historian of science Ahmad Dallal argues that an Islamic achievement key for the success of Arabic science was its secularization. On the other hand, the historian of philosophy Dimitri Gutas argues that science thrived in Islam because it kept a secular approach already established in the ancient Greek philosophical tradition. Specifically, Gutas argues that Islam did not make the mistake of medieval Christendom by integrating philosophy to theology and religious thought. Gutas and Dallal both place the foundation for the success of Arabic science on its secular approach but differ in their conclusions as to why that secularization took hold. Gutas writes, "In the theoretical sciences – and I would like to include among them also philosophy because Arabic philosophy, in contradistinction to medieval Latin philosophy, kept the secular approach it inherited from antiquity – certainty was a function of the method used." See p. 281, Ibid. On the other hand Dallal credits the work of Islamic intellectuals for the secularization of philosophy when he writes, "Philosophy, the overarching discipline in the Greek classifications, was gradually relegated in the Islamic hierarchy of knowledge to one subdivision among many other sciences. Having isolated philosophy, Muslims could then single it out as a potential source of conflict with religion without jeopardizing the other demonstrable sciences." See p. 216, Ahmad Dallal, “Islamic Paradigms for the Relationship between Science and Religion,” in God, Life, and the Cosmos: Christian and Islamic Perspectives, edited by Ted Peters, Muzaffar Iqbal, and Syed Nomanul Haq. Aldershot, England: Ashgate Publishing, 2002. Pp. 197-222.
including “the formulation of principles from within the discipline, or, put
differently, the assertion of the autonomy of the science of astronomy vis-à-vis
natural philosophy.” In effect the revisionist accounts resist the standard
narrative attributing intellectual decline in Islamic civilization to cultural
developments by arguing that al-Ghazālī’s critiques of the Islamic philosophers
were not in fact attacks on science because, in Islam, the two (science and
philosophy) existed in separate epistemological spaces with their own methods of
inquiry and theories of understanding. The revisionists maintain that the
established scholarly narrative does not interpret the relationship between
scientific activity and philosophy within Islam correctly. Therefore, if
contextualized within an historically correct epistemological framework, the
standard scholarship’s attributing of scientific decline in the Islamic world to al-
Ghazālī can be seen as conceptually flawed at its foundations.

In summary, the conventional narrative of the absolute decline of Arabic
science beginning in the sixth/twelfth century attributes this decline to an
internal cultural development that allowed religious orthodox thought to stifle the
continued development of the rational sciences within Islamic civilization. In

---

74 P. 99, Ahmad Dallal, *Islam, Science, and the Challenge of History*. In an essay predating the
aforementioned book, Dallal has convincingly shown that the eastern tradition of
Arabic/Islamic astronomy was able to undertake a reform of the previous Greek/pagan
astronomy specifically because, unlike the western tradition of Arabic/Islamic astronomy, the
epistemological assumptions of its research no longer based itself upon ancient Greek
metaphysics. For this full case study see specifically pp. 207-16, Ahmad Dallal, “Islamic
Paradigms for the Relationship between Science and Religion.”

response to this claim, more recent revisionist histories of the Arabic scientific tradition have posited three major critiques. First, the revisionist scholars have shown the existence of continued and original scientific activity in the Muslim world for at least an additional four hundred years after the death of al-Ghazālī. Second, the revised scholarship has argued that the secularization of scientific activity within Islamic civilization protected it from interference by the standard narrative's hostile religious orthodoxy. Finally, the newer accounts respond to the original scholarly narrative by arguing that the latter's conception of the relationship between science and philosophy in Islamic epistemology was flawed and led to an incorrect analysis of the history of the fate of the Arabic scientific tradition.

*Ibn al-Haytham's scientific method*

The controversies and competing narratives shown in the historiographical review about the beginnings and endings of the Arabic scientific tradition are also sometimes reflected in the scholarship about a particular field of science engaged in the course of Islamic civilization and/or in the scholarship about the work of a particular Islamic scientist. This is indeed the case with the scientist at the focus of this study, Ibn al-Haytham, and it would do us well to briefly review the competing scholarly conclusions regarding his methods for conducting scientific investigation. During the past half century the overwhelming
focus of scholarly studies of Ibn al-Haytham have been upon the science of optics contained in his massive seven volume work Kitāb al-Manāẓir (The Optics), which was completed about twenty years prior to his death. Particularly, three scholars have studied his magnum opus in order to specifically trace his methods of scientific inquiry.

Two of these scholars, A. I. Sabra and Saleh Beshara Omar, are scholars of the Arabic original. The other scholar, A. Mark Smith, is a specialist of the Latin translation of the work, which has been known by the titles De aspectibus and/or Perspectiva. The Arabic version and Latin version are nearly identical in their contents, and the source material for these scholars' analysis cannot be considered to have had an impact upon their conclusions. Further, of specific concern for the present study is the historiography related to the methods of science utilized and deployed by Ibn al-Haytham. All three scholars refer to his The Optics in order to substantiate their claims about Ibn al-Haytham's scientific methodology. In this historiographical debate, the standard narrative about Ibn al-Haytham's use of scientific experimentation lies with Sabra and Omar while the revisionist account has been given more recently by Smith.
The first significant attempt to use Ibn al-Haytham's *Kitāb al-Manāẓir* in order to begin to identify the development of demonstrative science in Islamic civilization was made by A. I. Sabra in a very short article published in 1968. Sabra here does not claim that Ibn al-Haytham invented the theory of experimental science, but he does find that the *Kitāb al-Manāẓir* presents experiment as a methodological tool for the conduct of science. He focuses upon Ibn al-Haytham's use of a technical vocabulary that Sabra argues is consciously meant to indicate experiment rather than merely experience. Sabra argues that Latin translations of Ibn al-Haytham's *Kitāb al-Manāẓir* further indicate a specific idea of experimentation associated with the book because the medieval Latin translators "did not hesitate to render *i’tabara* by *experimentare* (or *experiri*), *i’tibār* by *experimentum* (or: *experimentatio*), and *mu’tabir* by *experimentator." In this early work in his scholarship, however, Sabra does not directly argue that Ibn al-Haytham brought into his science of optics a new standard of proof for science but rather a general mode of testing that was already common in the field

---


77 Sabra posits the following argument: “In Arabic works of peripatetic and Galenic ancestry the most commonly used word to convey the meaning of experience is *tajriba* ... Ibn al-Haytham ignore this word — and quite understandably: a reader of his *Optics* would soon realize the difficulty of trying to subsume its experimental arguments under a theory of [*tajriba*] ... Instead of *tajriba* Ibn al-Haytham employs the nomen verbis *i’tibār*, together with the verb *i’tabara*, and the nomen agentis *mu’tabir.*” See p. 133, Ibid.

78 Ibid.
of astronomy. Specifically, Sabra maintains that Ibn al-Haytham's concept of experiment was an idea that he borrowed from "a previously established procedure in observational astronomy." Further, Sabra traces this conception as having entered Arabic science from ideas contained in Ptolemy's *Almagest*, which was written in the second century of the Common Era.

Saleh Beshara Omar agrees with Sabra that Ibn al-Haytham deploys experiment as a method of his science, but Omar argues that Ibn al-Haytham contributed something new to the methodologies of scientific inquiry and was not just a sophisticated extension of methods already established by Ptolemy.

Indeed, Omar's study links the *Kitāb al-Manāẓir* to the birth of experimental science by arguing that Ibn al-Haytham turned the idea of experiencing nature from a passive activity into a scientific method. Omar argues that Ibn al-Haytham accomplished this by being the "first consistently experimental scientist [his italics]" to use the inductive method as the exclusive approach of his science.

---

79 For the full, but brief, explanation see pp. 134-5, Ibid.
80 Page 134, Ibid.
81 Sabra maintains "that when, in the eleventh century, Ibn al-Haytham wrote the *Optics*, the term *i'tibār* already had an established usage among [Arabic] researchers working in the tradition of Ptolemaic astronomy." See p. 135, Ibid.
82 Omar maintains that Ibn al-Haytham's experiments "must be considered more than technically improved versions of Ptolemy's" because the former was willing to conform his conclusions to the "empirical basis of natural laws" while the latter's approach "served to limit the scope of knowledge, particularly by reinforcing initial, preconceived notions." See p. 150, Saleh Beshara Omar, *Ibn al-Haytham's Optics*.
83 Omar focuses in upon the notion of the direct observation of the natural world and how the way Ibn al-Haytham did this differed from the approaches of previous Greek science. He argues that Ibn al-Haytham made "a distinction between sense-perception as a natural faculty, through which all men derive their knowledge haphazardly, and sense-perception as a conscious tool used to study nature." See p. 147, Ibid.
investigations of the natural world. More specifically, Omar claims that Ibn al-Haytham's inductive method was not the same as ancient Greek, and specifically Aristotelian, understandings of induction. Rather, it was Ibn al-Haytham who first developed the investigative methods of modern science.

Among the scholars who have examined Ibn al-Haytham's Kitāb al-Manāẓir it is Saleh Omar who argues most decisively that Ibn al-Haytham deployed experimental science in a manner and with a method not previously witnessed. A. I. Sabra, as we saw above, early in his scholarship was not willing to credit Ibn al-Haytham with this methodological breakthrough because he maintained that his experimental science was rooted in Ptolemaic astronomy. However, later in his scholarship, Sabra does come around to the conclusion that Ibn al-Haytham's scientific method was indeed an innovative break from the Greek tradition. He argues that the Kitāb al-Manāẓir was even "the first work in which a concept of control experiment, as distinguished from the Aristotelian (and Galenic) empeiría,

\[\text{85 A focus for Omar in his analysis of Ibn al-Haytham's science is to show that a new scientific methodology emerged based upon a new understanding of the inductive approach towards intellectual inquiry that was completely different from ancient Greek syllogistic approaches founded upon deductive methods. Omar maintains that Ibn al-Haytham developed induction, istiqrā' in Arabic, "into the methodology of natural science." See p.71, Ibid. Later, on pages 74-5, Omar provides a succinct explanation of the inductive science that he credits Ibn al-Haytham as having originated. He writes that "the inductive method ... transformed scientific principles from self-evident axioms into probable [his italics] theories, and directed scientific attention to the observation of the particulars on which the theory is based, and to experiment as the controlled form of observation." Ibid.}
first emerges.” Sabra again focuses upon Ibn al-Haytham's use of the Arabic word *i’tibār*, but he now concludes that Ibn al-Haytham's use signifies a move beyond the meaning it had for (Ptolemaic) astronomical observations when he now maintains that, in the *Kitāb al-Manāẓir*, the method of *i’tibār* “is exclusively applied to a procedure of testing that is distinct from mere repetition of observations.”

The slight nuances between Saliba and Omar about what constitutes scientific method and to where its origins should be found point to a larger debate to trace the genealogy of the experimental scientific method in particular and of scientific methods more generally in the discourse of Arabic science writing in particular and in the history of science more generally. The scholar of the medieval Latin translation of the *Kitāb al-Manāẓir*, A. Mark Smith, has provided a revisionist account of the method’s of Ibn al-Haytham's science of optics that has echoes of Sabra’s position and rejects outright Omar’s conclusions. While Omar

---


87Page 11, Ibid. Sabra updates his previous findings from the 1968 article because in that article he interpreted Ibn al-Haytham's method of science, signified by the term *i’tibār*, as basically the same as what was suggested in Ptolemy's *Almagest*: "the idea of performing a test or proof by means of a comparative examination of two sets of observations that are (preferably) separated by a long interval of time." See p. 135, A. I. Sabra, “The Astronomical Origin of Ibn al-Haytham’s Concept of Experiment." His updated conclusion in later scholarship maintains that Ibn al-Haytham actually went beyond forms of testing based upon observation alone. He writes, "Thus, whereas testing in astronomy consisted in comparing sets of observations, it was possible in optics to construct and manipulate apparatuses." See p. 11, A. I. Sabra, “The Physical and the Mathematical in Ibn al-Haytham’s Theory of Light and Vision.”
claimed that Ibn al-Haytham revolutionized scientific methodology by introducing a theory of experiment to his study of optics, Smith maintains that Ibn al-Haytham's theory "reveals very little that is new or original."\(^{88}\) Smith views the real accomplishment of the *Kitāb al-Manāẓir* as a paramount work of synthesis that, rather than being revolutionary, set the groundwork for a future reworking of optical science in 17th-century Europe, when and where the real methodological breakthroughs would occur.\(^{89}\) Smith, like Sabra, finds that Ibn al-Haytham conducted his science within a tradition of empiricism, *empeiría*, already established by Ptolemy, but he does not reach the same conclusion that Sabra reached in his later scholarship: that Ibn al-Haytham moved the Greek concept of *empeiría* into a new methodology of control experimentation.\(^{90}\)

---


\(^{89}\) Smith contends that "without the theoretical groundwork laid by Ibn al-Haytham and his Perspectivist disciples (in medieval Europe), the revolution in optics inaugurated by Kepler and completed by Newton would have been, if not inconceivable, at least difficult to imagine. And herein lies the true significance of Ibn al-Haytham's achievement: not that he overturned past optical tradition but that he brought it to logical perfection and, in doing so, inadvertently laid bare its vulnerability." See p. cxvii, Ibid.

\(^{90}\) Smith's conclusion, rather, is the following: "... the real issue is whether, in following his particular path of induction, Ibn al-Haytham steered the science of optics in a new methodological direction. It is difficult to take this claim seriously in the face of Ptolemy's relatively heavy reliance upon empirical examples and experiemnt in the *Optics* (that is, in Ptolemy's work the *Optics* – not Ibn al-Haytham's *Kitāb al-Manāẓir*). It is even more difficult in the face of Ibn al-Haytham's intimate familiarity with that work. ... This is not to deny that there are differences, sometimes significant ones, between Ibn al-Haytham's and Ptolemy's use of induction. ... At bottom, though, these are differences in degree, not in kind. Ibn al-Haytham may have been more inductive than Ptolemy at the quantitative level, but certainly not at the qualitative level." See pp. cxv-cxvi, Ibid.
Smith, like Sabra and Omar, is ultimately trying to place the science of Ibn al-Haytham’s *Kitāb al-Manāẓir* on a continuum of development regarding the state of (the) scientific method and attitudes towards scientific demonstration. Another prominent scholar of Arabic science, Roshdi Rashed, has also provided studies in the history of Arabic optics that can help qualify the differences and similarities among the three scholars outlined above whose main object of study, unlike Rashed, has been specifically the *Kitāb al-Manāẓir*. Rashed takes a wider angle view of how a particular scientific language of demonstration rooted in Greek antiquity, and that had been developing as part of the Arabic scientific tradition for about two hundred years, was given a strong expression by Ibn al-Haytham in his *Kitāb al-Manāẓir*. Rashed tends to agree with Sabra and Omar in so far as noting that some level of methodological reform did take place with Ibn al-Haytham’s scientific investigations as presented in the *Kitāb al-Manāẓir*.91 However, Rashed does not find that Ibn al-Haytham made a breakthrough into an actual experimental science of testing. In this aspect he would seem to agree with Smith’s conclusions. Smith, as we saw above, traces this experimental breakthrough, at least in the field of optics, to 17th-century Europe. Rashed, however, remains within the Arabic scientific tradition for his further tracing of the development of experimental science after Ibn al-Haytham, and he finds it, for

---

91 Rashed writes, “This reform led to, amongst other things, the emergence of new problems, never previously posed ... and to experimental control as a practice of investigation as well as the norm for proofs in optics and more generally in physics.” See pp. 661-2, Roshdi Rashed, “Geometrical Optics.”
the field of optics at least, at the turn of the eighth/fourteenth century. Kamāl al-Din al-Fārisī (d. 719/1319) produced a commentary on Ibn al-Haytham’s *Kitāb al-Manāẓir* that included updates and corrections to aspects of Ibn al-Haytham’s science of optics, and that also involved the pursuit of new avenues of research. This led al-Fārisī to further advance the field of Arabic optics, and Rashed argues that it was al-Fārisī who deployed methods of scientific inquiry that went beyond what Ibn al-Haytham had done. In fact, Rashed maintains that the methods al-Fārisī utilized to accurately explain how a rainbow forms were closer to experimental testing than anything done by Ibn al-Haytham.92

In summary, the scholarly assessments of the state of the scientific method as seen in Ibn al-Haytham’s *Kitāb al-Manāẓir* lie on a spectrum. Saleh Omar, on one end, finds that this work demonstrates that Ibn al-Haytham invented the scientific method of testing that would become more associated with the innovations of science undertaken in 17th-century Europe. On the other side, A. Mark Smith concludes that Ibn al-Haytham synthesized and organized the already existing empirical approaches of the Greek tradition, but that the methodological breakthroughs in optical science would not occur until Kepler and Newton in the 17th-century. In the middle ground we find A. I. Sabra agreeing with Smith that

92 Rashed maintains that al-Fārisī developed quantitative research methods. He writes, “To introduce experimental norms, where Ibn al-Haytham had failed, al-Fārisī abandons a direct and complete study of the phenomenon in order deliberately to apply the method of models: the glass sphere filled with water will function as the droplet of water in the atmosphere. The mathematically guaranteed analogy allowed al-Fārisī to start (his study of the formation of rainbows).” See p. 668, Ibid.
Ibn al-Haytham's methods for conducting science were largely adopted from Greek science, and he, like Roshdi Rashed, finds some innovation to those methods. Moreover, Rashed points further to the fact that while Ibn al-Haytham cannot be credited with the introduction of experimental testing in the field of optics, one can still find this breakthrough within the Arabic scientific tradition itself with the later work of al-Fārisī. Therefore Rashed, unlike Smith, still places the development of experimental scientific testing within Arabic science — just not directly in the lap of Ibn al-Haytham.

**Concluding remarks**

The differences in understanding the scientific methodology used by Ibn al-Haytham in the production of the science he presents in the *Kitāb al-Manāẓir* reflect the broader debates about the beginnings and endings of the Arabic scientific tradition overall. The core issue centers around assessing how original and groundbreaking that science was, especially in light of the Greek scientific tradition that it inherited. The contextualization and periodization of the era of Arabic science given by the established scholarship presents many issues that have been problematized by revisionist accounts through their further use of the historic record. The conventional narrative portrays the beginnings of the Arabic science leading up to a figure like Ibn al-Haytham as having been a foreign body that entered the new civilization despite and not because of Islamic culture. At the
same time, the practitioners of this story explain the decrease of science in the Islamic world in the period following Ibn al-Haytham’s lifetime as having been the direct result of Islamic culture. In this way the standard scholarly narrative, while acknowledging the richness of Arabic science, most particularly during the fourth and fifth / tenth and eleventh centuries, finds little that was particularly new as compared to antiquity. The revisionist historians of Arabic science maintain that such a conclusion starts to fall apart when appeals are made to the actual historic development of the scientific undertakings of Islamic civilization. Curiously, when it comes to the methods of science deployed by Ibn al-Haytham, the roles in the scholarship are flipped, with the dominant narrative emphasizing his methodological innovation and the more recent revisionist assessment pointing to his continuity with previous Greek scientific methods.
Chapter 2

Ibn al-Haytham’s scientific procedure

Ibn al-Haytham’s Kitāb al-Manāzir, or The Book of Optics, is a monumental work of seven volumes, and it is not the purpose of this study to present an analysis of the entire work, but rather to concentrate upon the one experiment Ibn al-Haytham presents to establish the equal angles law of reflection for the travel of light in volume four. This experiment, presented in chapter three of volume four of his Kitāb al-Manāzir, is his most sophisticated use of an approach towards scientific investigation that has led to the differing conclusions about his methods just outlined in the previous chapter. After outlining the procedure he presents for proving the equal angles law of reflection, my analysis of the finding leads me to a different conclusion about his method of science in comparison to the previous studies outlined above. I focus upon the underpinning of why Ibn al-Haytham presents his science in this way. Further, he frames his findings within a technical formulation that can be isolated to show his effort to transfer a

93 The overall purpose of book four is to understand how reflection affects the eye and what it reveals about certain properties of light. Chapter three in particular established the equal angle principle as a law of reflection. Briefly, this property of light has it that the angle at which light hits a surface (the incident ray) will be equal to the angle at which that same light reflects off that same point of impact upon that surface (the reflected ray). Ibn al-Haytham’s studies of the manner in which light travels anticipated and arguably preceded the work done by Pierre de Fermat (d. 1075/1665) six hundred years later. Today we still refer to the fact that light will travel from one point to another point in the least amount of time possible as Fermat’s principle.
philosophy of demonstration common in the medical science of his time to his own field of optics.

_Kitāb al-Manāẓir’s chapter three of book four_

Ibn al-Haytham begins chapter three of book four of his _Kitāb al-Manāẓir_ by stating the rule that he has discovered for the reflection of light off of a reflective surface: "(when) whatever point on the surface from which reflection occurs is taken, the line of incidence for any form to that point and the line of reflection [extending from that point] will lie in the same plane as the normal dropped to that point; and [that] these lines will maintain an equivalent situation with respect to [that] normal and will form equal angles [with it]."94 The entirety of the rest of the chapter is made-up of a detailed, step-by-step, and tedious description of exactly what Ibn al-Haytham did to arrive at this conclusion. He delivers the report of his experiment and observations to the reader as an instructional guidebook and assembly manual.

He begins as follows: "Take a bronze plaque not less than 12 digits long that is thick [enough] to be quite rigid, and let it be 6 digits wide. Draw a line right along the lengthwise edge [of the plaque] and parallel to it. Place the point of a

94 P. 300; paragraph 2, A. Mark Smith, _Alhacen on the Principles of Reflection_. Volume 2. Philadelphia: American Philosophical Society, 2006. In the subsequent chapter, I provide my own translations of an entire treatise written by Ibn al-Haytham that has never before been translated into English, but since an existing and accomplished English translation of book four of his _Kitāb al-Manāẓir_ has recently been provided by Smith that accurately conveys the contents of his experiments, the translations provided in this section of the current study are taken from that source.
compass on the midpoint of this line and draw a semicircle whose radius is the width of the plaque." For the next four paragraphs he provides additional instructions on how to divide this semicircle marked on the plaque into portions until the very bottom portion of the plaque below the center should be cut out. At this point, from paragraphs nine through fifteen, he provides analogous instructions on how to mark and cut a piece of wood, culminating in the creation of "a circular cavity that is 1 digit deep and of the same thickness as the bronze plaque." Next, he instructs the reader to combine the two pieces just constructed, the cut piece of bronze and the wooden ring: "Now, insert the bronze plaque into this cavity, and it will fit into the cavity all the way to the smaller circle." He further specifies for the reader to check "that the surface of the bronze plaque that is subdivided faces the [upper] face of the ring that is [equivalently] subdivided." With these two pieces now joined, Ibn al-Haytham provides the reader of his text a further six paragraphs worth of instructions on how to mark the created apparatus at certain points and subsequently use an iron drill whose diameter is equivalent to a single grain of barley to make holes in the wood at these points until finally an also constructed iron tube should be inserted

---

95 P. 300-1 ; paragraph 4, Ibid.
96 P. 303 ; paragraph 15, Ibid.
97 P. 303 ; paragraph 16, Ibid.
98 Ibid.
into the holes "so that when it reaches the inside of the ring, it will touch the lines drawn on the bronze plaque."

At this point Ibn al-Haytham instructs the reader to make seven mirrors, made of iron to specific dimensions and polished. For five paragraphs he specifies that the mirrors should be one flat but circular, two spherical but oppositely concave and convex, two cylindrical but oppositely concave and convex, and two conical but oppositely concave and convex. He now proceeds to instruct on the next part of preparing his apparatus for the procedures to come. He states, "Then you should produce seven flat wooden panels whose sides are parallel and orthogonal [at the corners] so that the edges are as parallel as possible, and the panels should be 6 digits long and 4 digits wide." For the next fourteen paragraphs he then instructs how to mark the wooden panels, affix them properly into the bronze piece that has already itself been inserted into the wooden ring, and attach each of the seven mirrors to each of the seven wooden panels. Ibn al-Haytham’s device has by this point been fully constructed by the reader, and he begins paragraph 42 of his chapter on the equal angles reflection of light with the following promise to the reader: "When all of this is carefully done, what we predicted can be empirically verified."
This then is a move into the next phase of the presentation of his findings. Ibn al-Haytham does not seem to find it sufficient to inform the reader as to how to prepare the experiment; rather, with the same detailed exactness that he gave for the construction of his apparatus, he now provides equally specific instructions on how to conduct the observations. Further, he instructs the reader on exactly what they will observe if his instructions are followed exactly. He first wants to prove that his apparatus demonstrates the reflection of light and no other property or phenomenon. Therefore, his apparatus controls the behavior of light and isolates only one feature of its behavior: reflection. He states that the reader should:

Then press [a piece] of parchment up to the holes [in the wall of the cylindrical ring], and make an impression [of each hole] with the finger in order to fill in the holes so that you can make out the impression. Then mark the impression of [each] hole on the parchment with red ink or something else [of that kind]. Leave one of the holes open, however, but not the one directly facing the middle of the tablet, and point the open hole at an [incoming] beam of sunlight. The result of this operation will be clearer if the apparatus is held up to a ray of sunlight entering a room through a window.¹⁰³

And so the stage has been set for Ibn al-Haytham to tell the reader what will be observed. He writes:

Accordingly, when the beam passing into the hole reaches the mirror, you will see it reflected to the corresponding hole [on the wall of the cylindrical ring] along the line on the bronze plaque that forms with the line bisecting the triangle an angle equal to the angle formed by the line from the open hole with the same radius [that bisects the triangle]. On the other hand, if you uncover the hole to which the

¹⁰³ P. 308-9 ; paragraph 42, Ibid.
ray was previously reflected and shine the light through it, you will see the ray reflected to the [previously] open hole.\textsuperscript{104}

In other words, the two holes form a triangle within the apparatus in respect to a third point on one of the mirrors. When one hole is blocked and light enters the other open hole, then the light reflects to the red mark designating the closed hole. When that closed hole receiving the reflected light is then opened while the previously open hole is blocked, then the entering light reflects off the same angle of the triangle and back onto the other red mark designating the hole that first was open but now is closed. Therefore, the light reflects at the same angle regardless which hole is open or closed.

Ibn al-Haytham, though, does not end here as sufficient proof for the reader to have observed definitively that incident light is at an angle equal to its reflected light. He wants to establish that this is the rule for the behavior of light under any condition, situation and at all times, and not just under some circumstances like his first observational example. First, he takes the plane (flat) mirror that he just used and describes how to place it at different angles of exposure to the light entering through the open hole\textsuperscript{105}; therefore, in this manner, he informs that the reader will observe the same equal angle of reflection "whether the panel is [held] upright or at a slant."\textsuperscript{106} Next, he repeats the same procedure in the same manner for each of the other six mirrors in order to

\textsuperscript{104} P. 309 ; paragraph 43, Ibid.
\textsuperscript{105} Pp. 309-10 ; paragraphs 44-50, Ibid.
\textsuperscript{106} P. 310 ; paragraph 51, Ibid.
demonstrate that the shape and contour of a reflective surface does not change the fact that light will reflect off of it at equal angles.\textsuperscript{107}

By this point in his procedural reporting, Ibn al-Haytham has provided the reader detailed instructions on exactly what to do with the instrument and each mirror, step-by step, in order to observe again and again that light reflects at an equal angle. Further, at each precise moment of his procedural manual guiding the reader towards arriving at his scientific finding, he also informs the reader as to exactly what they will observe at every step of the painstaking process. Only after all this does he explicitly declare that there can be no doubt about the equal angles law for the reflection of light:

Hence, it is evident that if any lights shines on any of those mirrors [just discussed], the [lines of] reflection and incidence lie in the same plane ... But the reason reflection follows this rule is not specific to the axis, or to the point on which the light shines, or to the hole through which it shines, or to the mirror ... it holds for any line of incidence as well as for any point on the mirror to which the light may fall ... And the same proof and the same demonstration hold for all cases, so it is certain that this is due not to a particular kind of light nor to the shape of any particular mirror, but it is a characteristic that is common to every polished body and to any kind of light.\textsuperscript{108}

In the rest of book four, Ibn al-Haytham would go on to discuss other aspects of reflective light, but here in chapter three he has established that light reflects at equal angles. Further, with the presentation of one of his most detailed procedures for scientific investigations, he conveys to the reader of his work that

\textsuperscript{107} The other six mirrors, as a reminder, are concave and convex versions of the spherical, cylindrical, and conical shapes. See pp. 310-17 ; paragraphs 52-85, Ibid.
\textsuperscript{108} P. 317 ; paragraphs 86-7, Ibid.
this observation is not mere conjecture but has rather been proven to be an established fact.

Method of science

We saw in the previous chapter the differing assessments about the scientific method as it exists in the Kitāb al-Manāẓir, and the procedure we have just outlined from book four of that work allows this study to assess previous conclusions about Ibn al-Haytham’s method of scientific investigation and contribute a new approach to this historical question. At its core, the question is whether his process for finding that light reflects at equal angles amounts to the establishment of a new theory of experimental testing that is distinct from the pre-existing Greek standard of empirical observation. We will recall that Omar argued that Ibn al-Haytham utilized experimental scientific testing that anticipated Europe's seventeenth century methodological breakthroughs, which latter events are commonly referred to as the Scientific Revolution. While hesitant in his earlier scholarship, Sabra also had eventually concluded that Ibn al-

109 The experimental method that Omar attributes to Ibn al-Haytham traditionally has been cited as a 17th-century breakthrough. For example, a scholar of European science has summarized the modern method of science as follows: "The scientific revolution of the seventeenth century was responsible for a momentous new development in scientific method, the experimental method ... The idea of the controlled experiment implies a more sophisticated probing and questioning of Nature than is possible by passive observation, whether by means of elaborate instruments or through the unaided senses ... The experimental method involves an active interference with, that is direct manipulation of, Nature." See p. 271, George J. Withrow, “An Analysis of the Evolution of Scientific Method,” in L’Age de la science, 3:4 (1970). Pp. 255-80.
Haytham moved fully into experimental testing. On other other hand, Smith had found that Ibn al-Haytham's science in the Kitāb al-Manāzir was very much just a sophisticated and organized expression of the empirical traditions of antiquity. Omar's evaluation bases itself upon how far along towards the modern scientific method Ibn al-Haytham was, while Smith's reference point is how rooted in Greek science he remained. The evaluations of Rashed that we outlined, though, point towards a middle of the spectrum that reduces the risk of isolating Ibn al-Haytham's method of scientific procedure from the very Arabic scientific tradition that he inherited and that he passed along. As we reviewed in the previous chapter, Rashed, like Smith, did not argue like Sabra and Omar that Ibn al-Haytham moved beyond Greek empeiría and into experimental testing.

I would like to suggest that Ibn al-Haytham did consciously move beyond empeiría, but not into testing. My analysis then contrasts with Rashed and Smith (and compares with Saliba and Omar) on the issue of empiricism, but my approach at the same time contrasts with Omar and Saliba (and compares with Smith and Rashed) on the issue of experimental testing. So, if Ibn al-Haytham went beyond an empirical science but not fully into a method of testing, then what method of science do we find in his procedure for establishing the equal angles law of reflection?

My argument here is that, in his science of optics, he developed a method of proof that was demonstrative and not merely observational. In other words his
investigations into the equal angles law of reflection were not merely the observation of the natural word, but also did not amount to an experimental test. Let us use his procedure in chapter three of book four just outlined to show how and why. The proof lies in how Ibn al-Haytham frames the presentation of his procedure in chapter three of book four by utilizing an exact formulation for his scientific approach. Ibn al-Haytham introduces his examination of the equal angles law for the reflection of light with the following prelude: “As for how this theory can be observed with certainty – and by this theory I mean how light is reflected on smooth surfaces – that is described.” He states literally that his goal is to describe for the reader how his theory can be considered in a manner whereby the consideration then carries with it certainty regarding his theory.

Now, following Sabra’s discussion of the method of i’tibār outlined in the previous chapter, he most likely would have translated the first part of this refrain as how the theory can be experimentally tested with certainty. Further, Smith’s placing of Ibn al-Haytham as within Greek empeiría has him interpret the refrain as follows: "We will explain, moreover, how this account of reflection can be empirically demonstrated for all mirrors [my italics]." Given the procedure Ibn al-Haytham details that was just outlined in the previous section of this study, I

---


maintain that the process described by Ibn al-Haytham makes it plausible to interpret his use of the term *i’tibār* as understood to mean “considering (by example),” or “reflecting (upon experience),” or “contemplation (of Nature)” — in other words, a considered observation. Now, pace Smith, observational science is very similar to the classic understanding of the concept of empiricism, or *empeiría*. However, I now want to explain why Ibn al-Haytham’s conception of observational science has actually gone beyond classic *empeiría* and therefore further justify my interpretation of his formulaic statement.

In order to accomplish this it is necessary to place Ibn al-Haytham's scientific language into the context of the scientific culture of Islamic civilization as it had developed by his lifetime. A clue to the internal disciplinary standards for the work of scientists within Islamic culture can be found when their epistemological burdens were acknowledged and noted as distinctive by intellectuals operating in other fields of knowledge. For example, in the southern Iraqi city of Basra, the grammarian al-Zajjājī (d. 336/948) noted that acceptance of a scientific claim required proof and that scientific standards adhere to the principle that "nothing is accepted except after demonstration and presentation of evidence." In the same explanation, and as a point of contrast, al-Zajjājī exempts

---

the religious sciences from the scientific standard for proof and acknowledges that the two spheres of knowledge have different internal criteria of reasoning.\textsuperscript{113} The work of Muslim scientists largely existed separate from theological pursuits primarily because their standard of authority was based upon the ability to provide demonstrative proof, \textit{burhān}, of observable natural phenomena.

In fact, a pattern of discourse for scientific demonstration (\textit{burhān}) can be found across the Arabic sciences at this time. For example, in the field of medicine, Ibn Hindū (d. ca. 420/1029), a direct contemporary of Ibn al-Haytham, utilized a technical vocabulary that remained mostly modeled on ancient Greek philosophy.\textsuperscript{114} Ibn Hindū, in his \textit{Miftāḥ al-tibb}, or \textit{The Key to Medicine}, emphasizes to the reader the importance of observation (\textit{raṣad}) through experience (\textit{tajribah}) in order to understand the signs and symptoms of disease.\textsuperscript{115} Ibn Hindū’s use of the term \textit{tajribah} reflects that his science relied upon the methodological approach of empirical philosophy because \textit{tajribah} was the technical Arabic word for testing/experience.

\begin{flushright}
\textsuperscript{113} Ibid.
\textsuperscript{114} The methods and tools of each discipline (science and philosophy) made them somewhat interrelated and may account for the common grouping of philosophers alongside scientists. Gutas has noted that during the early 'Abbāsid period the methods of philosophy and science "interpenetrated each other, something which made the philosophical and scientific traditions in the Islamic world more interdependent than the modern students of either tradition have been willing to admit or acknowledge." Page 282, Dimitri Gutas, "Certainty, Doubt, Error: Comments on the Epistemological Foundation of Medieval Arabic Science."
\textsuperscript{115} Ibn Hindū writes in his \textit{Miftāḥ al-tibb wa minhāj al-tullāb} the following: "Philosophers undertook to observe (\textit{taraṣṣud}) chance happenings, derive information about specific instances by means of testing/experience (\textit{tajriba}), and draw analogous conclusions (\textit{qiyās 'alā}) on the basis of principles coming about through observation (\textit{raṣad}) and personal inspection (\textit{mushāhada})." For this translation, rendered by Gutas, see p. 280, Ibid.
\end{flushright}
adopted for the Greek idea of *empeiría* (empiricism).\textsuperscript{116} Further, his use of the word *rasad* as the tool of intellectual inquiry and investigation for the medical sciences further shows that his scientific approach remained rooted in the standards of proof connected to Greek empiricism. *Rasad* signifies a particularly passive type of observation sometimes associated with stargazing.

Now, Ibn al-Haytham forgoes the technical vocabulary displayed by Ibn Hindū and does not use *rasad* to indicate observation nor *tajribah* to emphasize experience of nature. Ibn al-Haytham prefers to use *i’tibār* for expressing the same concept and meaning for both observation and experience.\textsuperscript{117} Let us examine what type of science this signifies for his investigations into the reflection of light. Gerhard Endress has suggested that any "discourse analysis of scientific writing" must take into account three levels of analysis: "single words," "pragmatical phraseology," and "genres of exposition and instruction."\textsuperscript{118} In other words, an examination of scientific concepts must identify the technical

\textsuperscript{116} Sabra has also noted the fact that "the term *tajriba* [is] the term corresponding to *empeiría* in the philosophical and medical literature with which he [Ibn al-Haytham] must have been thoroughly familiar, having himself made at one time summaries of many of Aristotle’s and Galen’s writings." See p. 18 of Sabra’s commentary section in Ibn al-Haytham, *al-Ḥasan, The Optics of Ibn al-Haytham*, Books I-III, translated by A.I. Sabra. London: Warburg Institute (University of London), 1989.

\textsuperscript{117} Sabra also, as we have seen, focuses upon *i’tibār*. He, however, categorizes it in terms of experimental science when he says of Ibn al-Haytham’s methods: “And the aim of the proof was still to bring certainty or exactness and precision to an observation by subjecting it to an artificial situation in which conditions can be varied. To operate explicitly with such a distinct concept of experimental proof while regularly attaching it to a definite set of terms (*i’tibār* and its cognates), and thus dissociating it from the idea of accumulated experience or *empeiría*, was a significant conceptual development in the history of experimental science.” See p. 18, Ibid.

\textsuperscript{118} See page 234, Gerhard Endress, "The Language of Demonstration."
vocabulary of the science itself, discern the purpose of specific wording used to
describe the science, and explain how the facts of the scientific findings are
presented and explained to the reader. In the case of Ibn Hindū his technical
vocabulary, raṣad and tajribah, stems from empirical philosophy and Galenic
medicine.119 When this same discourse analysis examines the language utilized by
Ibn al-Haytham in his Kitāb al-Manāẓir to frame and introduce his presentation of
the equal angle laws of reflection, his advancement beyond a merely empirical
science becomes apparent.

First, Ibn al-Haytham breaks from the technical vocabulary (Endress'
"single words") of empeiría and substitutes the word iʿtibār in place of both raṣad
and tajribah.120 Ibn al-Haytham, as we saw in his tedious procedure, very
specifically approaches his scientific investigation of reflection through an
observation that occurs under controlled and constructed conditions; it is an
active observation of a manipulated natural environment whose purpose is to
isolate this particular property of light. This method of observation was
specifically dependent upon utilizing the apparatus constructed to observe the
reflection of light and therefore required a new technical vocabulary – iʿtibār –

---

119 See page 280, Dimitri Gutas, "Certainty, Doubt, Error."
120 In my reading there is a specific reason for the use of this word, especially when Ibn al-
Haytham had a choice of synonyms to choose from. In Ibn al-Haytham’s usage there is a very
particular emphasis on the subject studying rather than the object studied. Experience of nature
(tajribah) is not enough on its own; Ibn al-Haytham stresses with the use of iʿtibār that the
medium through which experience leads to truth is very particularly the act of contemplation
and interpretation by the subject of what has been observed as a natural phenomenon.
that differentiated it from the mere experience of the natural world (*empeiría / tajribah*). Further, Ibn al-Haytham does not use *raṣad* as his technical term for the type of observations that he conducted for his scientific investigations because, by controlling his environment with the apparatus, his subsequent observations were not just passive acts of whatever circumstance nature happened to provide. Instead, his inquiries were a "controlled observation" (*i’tibār*).\(^{121}\)

So, Ibn al-Haytham with his use of the term *i’tibār* indicates that his scientific investigations into the reflection of light are something more than the classical understanding of *tajribah (empeiría)* and its connected term *raṣad*. We will recall, though, that Smith (and implicitly Rashed) maintained that for all his refining of empiricical methods, Ibn al-Haytham did not actually move beyond

\(^{121}\) According to G. J. Withrow the basic method of Greek empirical science is “questioning based on passive observation of natural phenomena, as distinct from experiments that involve active intervention by the scientist in the phenomena he is investigating.” See Page 265, George J. Withrow, “An Analysis of the Evolution of Scientific Method.” In chapter three of book four of his *Kitāb al-Manāẓir*, Ibn al-Haytham’s elaborate procedure clearly goes beyond mere passive observation, but he still established the equal angles law of reflection through observing the controlled environment made possible by his apparatus. I do not find this to be the active experimentation that Sabra (and Omar) have concluded and therefore interpret *i’tibār* as a technical term for "controlled observation" in specific contrast to *raṣad* (passive observation). Rashed does not offer a verdict on the exact nature of the term *i’tibār*, but he makes a passing reference to Ibn al-Haytham’s theories concerning vision as resulting from “ordered observation.” See p. 662, Roshdi Rashed, “Geometrical Optics.” Rashed does not elaborate beyond this brief mention, but we know from our discussion in the previous chapter that he maintained that experimental testing in optics occurred *after* Ibn al-Haytham; so, Rashed may share my view on the *i’tibār* method of Ibn al-Haytham’s science as being a technically particular type of observation. What we both seem to agree upon, in contrast to Omar and Saliba, is that his scientific method did not involve experimental testing. A final note here: Experiment is one specific sub-set of the more general concept of scientific method. In other words, the experimental method evolved out of the broader category of scientific method. The two are not necessarily the same, and you can have scientific methods that do not involve experimentation. Certainly Ibn al-Haytham utilized scientific method(s), but it was not here a controlled experiment in the modern sense.
Greek empiricism. Is there any further indication in the framework he provides for his scientific procedure to offer a new approach to this question? In reference to Endress’ second level of scientific discourse analysis ("pragmatical phraseology"), the clue lies in how Ibn al-Haytham deploys a discursive construction to qualify the controlled observation that he wants to report to the reader of his work: *i’tibāran yaqa’ ma’ahu al-yaqīn.* His emphasis on the importance of the *certainty (al-yaqīn)* of his controlled scientific observations is more than of passing interest. He specifically wants the reader to understand that his theory (of the equal angles law of reflection — *a’nī bihādhā al-ma’ná kayfiyyah ini’kās al-aḍwā’ ‘an al-ajsām al-ṣaqlah*) can be observed with no doubt. Recall his full formulation: *fa’ammā kayfa yu’tabar hādhā al-ma’ná i’tibāran yaqa’ ma’ahu al-yaqīn* — literally, "As for how this theory can be observed with an observation [in which] certainty occurs with it."

What is Ibn al-Haytham indicating to the reader in terms of his type of science here? He specifically links his method of controlled observation to a standard of proof, *certainty (al-yaqīn),* that bases his science on something different than the philosophical tradition of *empeiría (tajribah).* Ibn al-Haytham in effect indicates to the reader that his theory of the equal angles law of reflection will be held to a higher standard of proof than philosophical *empeiría;* he holds his

---

123 Ibid.
124 Ibid.
theory to the standards of demonstrable proof, which the Greeks had called *apódeixis*. For Ibn al-Haytham, demonstrative proof would be the marker as to whether his scientific finding was a valid interpretation of reality.

While Ibn al-Haytham largely conducted his science within the established philosophical standards of empiricism, the legacy of his methods marked a move towards a fully apodictic science, whereby discoveries about the natural world would be capable of demonstration both with certainty and beyond further dispute. This is what his writings accomplished for the specific field of optics, and Ibn al-Haytham moved the Arabic scientific tradition beyond the philosophical standards of proof rooted in concepts of *empeiría*, or experience of the natural world, and towards a specifically scientific criterion of proof related to what the Greeks had called *apódeixis*, which in the optics of Ibn al-Haytham became the ability to move beyond mere experiential observation and towards the actual demonstration of a scientific claim through controlled observation.

Therefore, my analysis of his procedure for establishing the theory of the equal angles reflection of light qualifies the previous approaches taken towards Ibn al-Haytham's scientific method. He does move beyond Greek empiricism but not fully into a modern standard of experimental testing. Rather, he develops a

---

125 Although Ibn al-Haytham does not utilize a single technical word for the Greek concept of *apódeixis*, his formulation "*iʿtibāran yaqaʿ maʾahu al-yaqīn*" amounts to an expression of the definition of the concept. The import of his standard for proof in his optical science is clear: proof must arise out of demonstration, which is the literal meaning of and argumentative procedure for apodictic science. He therefore indicates that his scientific approach is not merely empirical.
path towards and provides a further step into the latter by advancing observational science towards a new standard of demonstrative proof – an apodictic procedure for his optical science that solves for the subjective (and therefore scientifically unreliable) nature of forming theories based upon visual observation of an object.

_Demonstrable repeatability_

Finally, and in reference to the third level of scientific discourse analysis ("genres of exposition and instruction") suggested by Endress, Ibn al-Haytham situates his scientific procedure within an approach that had its roots in Arabic medicine, which itself was indebted to the work of Galen. It is here that we gain a full understanding of why Ibn al-Haytham was so tedious and painstaking in the description of his investigation into the equal angles reflection of light. The very manner in which he presents and explains his science to the reader in chapter three of book four serves the purpose of fulfilling a requirement of his apodictic approach towards science, and it has its roots in the medical science of his time.

Key to this was the creation of a particularly apodictic system of proof for the discipline of optics based upon the introduction of the concept of the ability to reproduce scientific findings in order to demonstrate the certainty of his theory of the equal angles reflection of light. This demonstrable repeatability of a finding had precedents particularly in the discipline of medicine. Ibn Hindū, for example,
specifically makes mention of this concept in his *Miftāḥ al-ṭibb* when he writes that a scientist should offer their findings in such a manner that "other people come after him who receive his knowledge, add to it, and increase it by performing the same observations and drawing the same analogous conclusions."\(^\text{126}\) In effect, Ibn Hindū posits that the standard of proof for a scientific finding begins and ends in the ability of other scientists to reproduce the results discovered through a repetition of the observation used to arrive at the conclusion. Similarly, Ibn al-Haytham presents his scientific findings in a manner that will allow a reader of his work to recreate his scientific procedure and repeat (and therefore confirm) the observation of his scientific finding. His conceptual breakthrough was how apply this standard of proof for a different disciplinary field, which in this case was optics.

The procedure that Ibn al-Haytham presents in chapter three of book four of his *Kitāb al-Manāẓir* is the solution. In effect, this is a science of demonstration by means of visual evidence, and he indeed utilizes a specific Arabic root word (*waṣafa*) that carries with it connotations of description when he reaches the point in the presentation of his scientific findings whereby he wants to provide the proof for his observation. As we referenced in the previous section, he

introduces the demonstration of his controlled observation for establishing the equal angle law of reflection with the following lead-in: *fa’inna dhālik yakūn kamā nasif* 127 — literally, "therefore that [observing the theory with certainty] is as we describe / portray." As we outlined, Ibn al-Haytham then provides detailed instructions for the construction of an apparatus and then further guidance on how to use this apparatus to observe that light reflects at equal angles. We can now understand why he instructed the reader to repeat the observation for every variety of angle and mirror; this is his solution for the field of optics to fulfilling the standard of proof for the repeatability of an observation, and he accomplished this for the reflection of light by having created an instrument that allows for repeated observation under controlled conditions. 128

This demonstrates Ibn al-Haytham’s confidence that his controlled observation (i’tibār), when repeated by other subjects, would yield the same objective result that he recorded. The style of his procedural presentation in chapter three of book four, which as we saw amounts to a guidebook or detailed

---

128 In this manner of constructing and deploying an apparatus to carry out his scientific observations, Ibn al-Haytham also helps get past a doubt that ancient Greek empiricism held about visual science: "In classical antiquity ... it was widely believed that to guard against being deceived by optical illusions no scientific significance could be attached to anything observed by sight alone." See p. 265, George J. Withrow, “An Analysis of the Evolution of Scientific Method.” On the other hand, with his instrument able to test the reflection of light for seven mirrors and at a variety of angles, Ibn al-Haytham instructs the reader to observe the equal angle reflection of light so many repeated times that he guards against any claim that the theory could be based upon an optical illusion. As we noted above, he utilizes a "controlled observation," and now we can further understand that this procedure is in the service of an apodictic science of demonstration.
instruction manual, is such that the text is itself a *burhān*, proof, of his scientific findings. When he so tediously details how to conduct his observation, he was in effect saying that what he will describe to the reader is how they can know to accept his theory as true and therefore have certainty about his concept regarding the equal angles reflection of light. In effect, Ibn al-Haytham instructs the reader to become, like him, the *mu’tabir*,129 or person performing the observation. In this manner, by following his text, Ibn al-Haytham allows the reader to reproduce his scientific findings exactly and therefore confirm the proof of his conclusions, exactly because any subjective individual has the means to observe his theory with certainty.

Here then we have the combination of both his move beyond *empeiría* and into *apódeixis*, as well as his ability to reproduce for the science of optics the standard of proof in medicine for the repeatability of an observation. He can therefore demonstrate that his scientific findings are anything but subjective. The step-by-step and extremely detailed descriptions Ibn al-Haytham provides in chapter three of book four for exactly how he established the equal angles law of reflection in effect provides an instruction manual for another person to repeat

---

129 Sabra translates *mu’tabir*, the active participle of *i’tibār*, as “experimenter,” following the practice of the medieval Latinate translators rendering the word as “experimentator.” Following my interpretation of *i’tibār* given earlier in this chapter, Ibn al-Haytham seems to portray his *mu’tabir* more as a scientist making observations (under artificially constructed controlled conditions) than as one conducting experimental testing. Certainly, though, the observer is expected to consider and intellectually interpret what has been seen in order to confirm the scientific finding reported.
precisely what he did. He knows that this other person, if they follow his written
guide exactly, will still arrive at and observe the same objective outcome that he
did, even if from their own individual subjective experience. This then will prove
that the subjective observation that he witnessed was anything but subjective.
The purpose that Ibn al-Haytham has in mind is the ability of a reader to be able
to repeat the observations carried out by him.\footnote{While my analysis does not go so far as Omar to argue that Ibn al-Haytham deployed the equivalent of modern scientific testing, we do seem to agree that his approach comes closest to capturing the foundational idea of modern science: that a scientific theory can be confirmed because others can repeat the same experiment under the same conditions and arrive at the same result. As Omar states of Ibn al-Haytham, "He is saying, however, that truth or completeness of knowledge about a given object depends on the number of times it is perceived: the more it is perceived, the more the concept is 'established.'" See p. 74, Saleh Omar, "Ibn al-Haytham's theory of knowledge." While Omar implies that Ibn al-Haytham originated this approach, I contend that he at least found precedent for the demonstrable repeatability of a scientific observation in the medical science of his time, which itself was indebted to the medical methods of Galen.}

In sum, Ibn al-Haytham’s expository style of presentation, his goal of
showing procedural certainty, and his deployment of a new technical vocabulary
for his method of observation all amounted to the beginnings of a new scientific
system for optics capable of demonstration (\textit{apódeixis}) and not merely based
upon the standards of empirical science. The operation of this system of science
by a standard of proof requiring the repeatability of an experiment emerged fully
in his work on the equal angles reflection of light, but this was also a concept
rooted in the larger development of the Arabic scientific tradition generally and in
Arabic medicine in particular.
Concluding remarks

In our analysis of how Ibn al-Haytham established the equal angles law of reflection of light in chapter three of book four of his *Kitāb al-Manāẓir*, I have argued that his scientific method should be seen as occupying a transition from a science based upon *empeiría* and into a science of *apódeixis*. His breakthrough was to realize that he could apply this standard of demonstrable proof for the discipline of optics through the construction of tools and apparatuses that would allow for a move beyond mere passive observation of visual evidence. His controlled procedure for observing the reflection of light serves to fulfill a standard of proof required of apodictic science that has its methodological roots in the field of medicine, and I interpret his own method of *i’tibār* as still based upon observational science and not (yet) a science of experimental testing, which would have been a move even beyond *apódeixis* and into modern scientific procedure. This interpretation also helps explain why he qualifies that the presentation of his theory must be done in a manner to establish the certainty of the observational approach. Otherwise, with a science still based upon observation, his theory could have been attacked as merely subjective. Guarding against this possible accusation also ultimately helps explain why he reports his finding in chapter three of book four in the style of a detailed assembly manual and step-by-step instruction guide: his procedure must have the ability to be repeated by others.
Chapter 3

Ibn al-Haytham's scientific procedure, part two

The previous chapter parsed the nuances of what has made Ibn al-Haytham a transitional and transformational figure in the history of science: his work on optics and the methods of science that he brought to bear upon his investigations into that discipline. To fully appreciate and understand his approach towards knowledge, however, and especially his place in the development of methods for scientific inquiry, it is necessary to compare and contrast his optical work with his other scientific investigations. Just as we used a representative sample of his overall body of work on optics in the previous chapter (namely, his investigation into the equal angles law of reflection for light), here we will utilize a treatise he composed later in his life years after his work on the *Kitāb al-Manāẓir*. The treatise concerns his investigations into the nature of the marks seen on the surface of the moon. While I offered a new interpretation of his scientific methodology in the previous chapter in comparison to the existing scholarship regarding his *Kitāb al-Manāẓir*, there exists no significant scholarship examining this treatise. I offer here my examination of the treatise with specific regard to its scientific method and intellectual approach. In the chapter following, I then provide for the first time in our field a full English translation of the complete treatise.
Treatise on the marks on the moon

Ibn al-Haytham's *maqālat-u fī māʾiyat-i al-athar-i alladī fī wajh-i al-qamar-i*, or "Treatise on the Nature of the Marks on the Surface of the Moon," exists in manuscript form (no. 2096 D) in the City Library of Alexandria and has been published in its original Arabic edition.\(^{131}\) As the work directly references and makes mention of the *Kitāb al-Manāẓir* it can be safely assumed that this treatise was composed some time after that major work on optics.\(^{132}\) Ibn al-Haytham’s purpose in this work is to get to the quiddity of the marks on the moon.\(^{133}\) He begins with a factual statement about the marks: "These marks, if they are looked at attentively and considered (my emphasis), are always found to be of a singular property, unchanging in their form, position, size, and the manner of their darkness."\(^{134}\) After establishing this point, Ibn al-Haytham proceeds to outline the differing opinions about the manner of these marks on the moon.

---


\(^{132}\) See, for example, Ibn al-Haytham’s comment: *wa qad sharātnā hādhā al-maʾnā sharh-an musaqṣā fī kitāb-i-nā fī al-manāẓir-i*. ("And we have illustrated this concept thoroughly in our book on optics."). p. 174 (corresponding to Arabic p. 11), Ibid.

\(^{133}\) In his title, Ibn al-Haytham signals this intention by using the word *māʾiyat* in an idaafa construction with *al-athar. māʾiyat* is the same as (and probably an arcane spelling of) *māḥiyat*. He therefore does not set forth to merely present a treatise describing the marks on the moon, but rather wants to systematically clarify and explain their true nature. See p. 180 (Arabic p. 5), Ibid.

\(^{134}\) *wa hādhā al-athar-u idhā tuʾumila wa i’tabara (my emphasis) wujīda dāʾim-an ʾalā ṣifat-in wāhidat-in lā yataghayyar-u lā fī shakt-i-hi wa lā fī wadʾ-i-hi wa lā fī miqdār-i-hi wa lā fī kayfiyat-i sawād-i-hi*. See p. 178 (Arabic p. 7), Ibid.

75
He divides these opinions into three categories. One notion is that the marks are external to the moon and specifically shadows of a permanently dense vapor that has formed between the sun and the moon. Another opinion offered is that the marks are actually images from the earth, such as the oceans or mountains, reflecting off the smooth surface of the moon. Yet another notion cited is that the marks are existing on the body of the moon itself, and that these surface marks are either transparent or rough areas of an otherwise smooth lunar surface – or, a third possibility, that the surface marks are cavities on the body of the moon. Ibn al-Haytham states that he rejects all these theories.

He then proceeds to deconstruct and explain the weakness of each of these explanations for the marks that are seen on the moon. Ibn al-Haytham first debunks the idea that the marks are a result of a shadow cast by a condensed vapor under the moon. He accomplishes this through an appeal to visual evidence that show the idea to be nonsense. He first notes that the positions of the marks on the moon would have to change their perspective depending upon where a viewer on earth was positioned in relation to the vapor. He states that the marks on the moon; however, maintain singular positions and do not change. Furthermore, he writes that if a vapor really was condensed under the moon, then

\[135\] P. 178 and 177 (Arabic p. 7-8), Ibid.  
\[136\] P. 178 (Arabic p. 7), Ibid.  
\[137\] P. 178 and 177 (Arabic p. 7-8), Ibid.  
\[138\] wa jamī’-u ḥādīhi al-ārā’-i tābṭul-u wa taḍamḥalla ūnḏ-a taḥqīq-i al-naẓar-i. (“All of these opinions have been debunked and have dwindled upon investigation of the theory.”), p. 177 (Arabic p. 8), Ibid.
such vapor would not find itself between a viewer’s sight and the moon when the moon dips close to the horizon. In such a case, then, the marks on the moon should not appear in the same manner that they do when the moon is viewed high in the middle of the sky. This difference does not occur, however, and further shows that the vapor cannot exist external to the moon. Therefore, the marks on the moon cannot find their cause from such a vapor.\textsuperscript{139}

The next notion Ibn al-Haytham argues cannot be a cause for the marks on the surface of the moon is that concerning images from earth being reflected off of the moon. Here he invokes his understanding of the equal angles law of reflection demonstrated in his work on optics. He writes the following to make his argument:

and that is that reflection is present along equal angles occurring between ray lines and the smooth surface. And if that were so, then were the moon’s visible position to change, then the angles of reflection that occur between the ray lines external to sight and its surface would also be different.\textsuperscript{140}

His argument continues to state that as the moon’s position changes in the sky, then these changing angles of reflection would terminate back on the surface of the earth at continually differing locations producing marks that change on the

\textsuperscript{139} P. 177 (Arabic p. 8), Ibid. The entire discussion showing the vapor theory to be false occurs over the course of two paragraphs on this page. See the verbatim translation contained as part of my full English translation of the treatise in the next chapter.

moon. He again notes that the marks do not alter their appearance, though, and therefore that this theory cannot hold or make sense.\textsuperscript{141}

Ibn al-Haytham then provides additional examples for why the marks on the moon cannot be reflected images of mountains or oceans on earth. He again makes an appeal to consider the case of when the moon draws near to the horizon. In this case, any reflection of an image from earth would occur at such a sharp angle that it would not fall upon the earth's surface and therefore into the line of sight of a viewer on the earth's surface. In such a scenario, then, the moon should appear with no marks on its surface as a result of a reflected image unable to then be seen from earth. He notes again, though, that the marks on the moon are still ever present even when the moon is at the horizon; therefore, the reflection theory for the marks again cannot be feasible.\textsuperscript{142}

Ibn al-Haytham rounds out his critique of the notion that the marks are in fact reflections of objects on earth with a further example of when the moon is at its zenith in the sky. Again relying upon his knowledge of the reflection of light, he states that when the moon is in such a position the only reflected rays that would return to earth would be from the center portion of the moon, while the rest of the rays would reflect to positions external to the earth. He notes, however, that marks appear on the moon also away from the center of the moon's surface even when it is at the zenith of the sky. He therefore concludes with this thought

\textsuperscript{141} P. 177 and 176 (Arabic pp. 8-9), Ibid.
\textsuperscript{142} Second paragraph on p. 176 (Arabic p. 9), Ibid.
debunking the theory: "And the matter is not so, I mean that the marks do not exist at a given time in the middle of the moon’s surface only, thus the marks on the moon are not an image appearing in reflection."\(^{143}\)

Continuing his critiques of the existing opinions for the marks on the moon, Ibn al-Haytham then turns his attention towards the idea that the marks are on the surface of the moon itself. This critique divides itself into addressing each notion posited for the marks as being on the surface itself: that the marks are transparent on the surface, that they are rough areas of the moon protruding out from the surface, and that there are cavities/depressions on the body of the moon. He first debunks the idea of transparency through an appeal to the phenomenon of the solar eclipse. His appeal to observable data here is straightforward: the sun is luminous, and during its eclipse the moon covers it; however, no light shines through the moon as it would were transparent marks to have been on its surface. Therefore, he states that the marks cannot be transparent.\(^{144}\)

As for the those who believed that the marks on the moon were a result of some manner of roughness on its otherwise smooth surface, Ibn al-Haytham tries over the course of five paragraphs to refute this through appeals to the nature of light as he understood it. First, he notes the possibility that the appearance of the marks is due to a roughness on the surface preventing the reflection of light in

---

\(^{143}\) wa laysa yūjad-u al-amr-u ka-dhālika, a’nī anna-hu laysa yūjad-u al athar-u fī waqt-in min al-awqāt-i fī wasaj-i sāṭh-i al qamar-i faqat, fā laysa al athar-u alladhi fī al qamar-i sūrat-an tazhar-u bi al in’kās. See p. 176 (Arabic p. 9), Ibid.

\(^{144}\) P. 176 and 175 (Arabic pp. 9-10), Ibid.
contrast to other parts of the moon where a smooth surface reflects the light of
the sun more brightly. However, he rejects this scenario based upon his belief that
the moonlight reaching a viewer’s sight is not a result of reflection\textsuperscript{145} [there is an
inconsistency in his position here because he elsewhere notes that light reflects
strongly off of smooth surfaces, as he believes encompasses the moon]. Second, he
considers the same matter but in different terms: the possibility that the brightly
lit parts of the moon result from the reflection of primary light (off a smooth
surface) and that the weaker light indicating the marks result from the reflection
of secondary light (off a rough surface). However, he again rejects this case
because of his perceived rule that the light sight perceives from the moon is not
due to reflection\textsuperscript{146} [I say perceived because some confusion about this point
requires further investigation]. Third, Ibn al-Haytham makes a point to state that
a rough surface would produce weak light but without shadow. Since he claims
that the marks in fact do contain shadows, then the marks cannot be a result of
roughness.\textsuperscript{147} Fourth, he notes that if the marks on the moon were not merely
rough spots but in fact protruding upwards and therefore casting shadows from
the light of the sun, then the shape of these shadow marks should change due to
his contention that the moon is not in a fixed position relative to the sun. He
decides that since the shape of the marks never change even while the position of

\textsuperscript{145} P. 175 (Arabic p. 10), Ibid.
\textsuperscript{146} P. 175 and 174 (Arabic pp. 10-11), Ibid.
\textsuperscript{147} P. 174 (Arabic p. 11), Ibid.
the moon relative to the sunlight changes, then they cannot be protruding from the surface.\textsuperscript{148} Fifth, Ibn al-Haytham extends his argument against protruding marks on the moon by appealing to the notion that such marks would change shape when the moon fully faced the sun as opposed to other times, because in full opposition to the sun, then light would enter the gaps in these features and alter the shadows that they cast. To debunk this theory, he again appeals to the fact that the marks are however always unchanged in form, shape and size.\textsuperscript{149}

A final possibility offered by the opinions that have the marks on the surface of the moon itself is that they are cavities in the body of the moon, and Ibn al-Haytham now turns his attention to explaining why this too is not possible according to his studies. He proceeds with an approach similar to the one he used for the idea of protruding roughness as a cause of the marks. He states that hollows on the surface of the moon would cast shadows, but also that these shadows would disappear when the moon fully faced the sun and light would flood the inner part of the cavities. In this manner then, the form and size of the marks should appear to change when viewed hour to hour; however, Ibn al-

\textsuperscript{148} Ibid.
\textsuperscript{149} \textit{wa al-wujūd-u bi-khalaf-i dhālika, li-anna al-athar-a yūjad-u abad-an fi waqt-i muqābalat-i al-shams-i ‘alā al-ṣifat-i allātī yūjad-u ‘alay-hā qabla waqt-i al-muqābalat-i wa ba’da-hā ‘alā al-shakl-i bi’-ayn-i-hi alladhī huwā la-hu dā’im-an. fa-laysa al-athar-u alladhi fi al-qamar-i azlāl-u khashūnat-in bārizat-in fi saṭh-i al-qamar-i. (“And the finding contradicts that, because the marks exist constantly when the moon is in opposition to the sun, both prior to opposition and afterward, in a singular unchanging form. Thus the marks that are on the surface of the moon are not shadows of protruding roughness on the surface of the moon.”)}, p. 173 (Arabic p. 12), Ibid.
Haytham again states that the reality is contrary to this outcome because the marks on the moon do not change and remain ever fixed. He therefore rejects that the marks could be cavities on the surface of the moon.\textsuperscript{150}

To round out his critiques of the existing theories for the nature of the marks seen on the moon, Ibn al-Haytham returns to the idea of a dense vapor in the sky somewhere external to the moon. In this case, he considers if it were existing directly between the sun and the moon rather than merely condensing as a thick vapor under the moon. To invalidate this theory Ibn al-Haytham makes an appeal to the idea of the epicycle and argues that as the epicycle moves the moon, then the dense mass external to the moon would exit the azimuth that was between the sun and the moon and that therefore it would no longer cast a shadow on the moon. He states that by this logic the marks on the moon would only be present sometimes when the dense part of the sky is in alignment with the azimuth between the sun and moon, and not at all other times. However, Ibn al-Haytham notes that the marks are always present on the moon and that this therefore shows that such marks cannot be a result of this theory either.\textsuperscript{151}

At this point in the treatise Ibn al-Haytham states that the flaws in all the other theories regarding the marks on the moon have now been explained. Further, as the marks have been shown not to result from anything external to the moon and not as an image appearing in reflection, he concludes that the marks

\textsuperscript{150} P. 173 (Arabic p. 12), Ibid.
\textsuperscript{151} P. 173 and 172 (Arabic pp. 12-13), Ibid.
must be a part of the moon itself. However, having just rejected three explanations for the nature of the surface marks (their transparency, their protruding roughness, and their hollowness), he informs the reader that it remains for him to explain the true nature of these marks on the moon.\(^{152}\)

His own theory for the marks on the moon begins by noting that the substance of the moon is different from the stars. He notes that stars are illuminated from within and produce their own light while the light on of the moon occurs from the light of the sun shining upon it. He then turns his attention to stating that an understanding of the nature of this moonlight is necessary for explaining the marks that appear on its surface. He posits that if the surface of the moon were uniform at all its points, then the light emmanating from it would also appear the same at all points of the surface. However, since the moon's light is not uniform and of a singular quality in appearance, parts of the surface of the moon must be different than other parts of the moon's surface.\(^{153}\) He thus reaches this inference: "So the position of the marks, therefore, on the body of the moon, is different from the rest of the moon's body – a manner of difference due to that position [having] different light than the rest of its body."\(^{154}\)

\(^{152}\) P. 172 (Arabic p. 13), Ibid.

\(^{153}\) Ibid.

He then proceeds to state that since the marks are clearly a darkness on the body of the moon, it remains to examine what prevents these affected parts from fully receiving light in the manner of the rest of the moon’s surface. At this point Ibn al-Haytham lays out how a body (like the moon) can receive light. He notes that both transparent and dense bodies can receive light, but that only the former allows light to further transmit through the body. He then comments that light shines differently on bodies that differ in their color, density, smoothness and roughness. The differing abilities of these variations on a body to receive light results in the form of light that appears on a body to also differ.155

Having established that the form in which the moon receives sunlight can vary, he now states his point that the phenomenon causing the marks on the moon results from those parts of the lunar body receiving light in a deficient manner as compared to the rest of the moon’s surface.156 He then turns his examination to explaining why the ability of the position of the marks to receive light is weaker as compared to the rest of the moon’s body. After outlining how light passes through a transparent body, he contrasts this with dense bodies where light remains on their surfaces. He identifies density within an opaque body as the reason light is prevented from reaching the core of the body. He notes that a dense cover over the surface of a body would even prevent light from reaching its surface. Similarly, he states that light can be impeded from

---

155 P. 171 (Arabic p. 14), Ibid.
156 P. 170 (Arabic p. 15), Ibid.
transmitting through and penetrating even a transparent body on account of the density of the body.\(^{157}\) He therefore decides that nothing affects a body's ability to receive light except for density.\(^{158}\)

Next, in order to further advance his argument, he links the phenomenon of color to density. It is here over the course of two paragraphs that Ibn al-Haytham makes clear use of his conception of density to explain color in relation to light. For him, a body with no density at all is completely transparent and lacks color, i.e. is clear. For this reason any other body, or object for that matter, that has color must have some level of density as well. However, he states clearly that color is not density because, for example, a very dense stone could be white while a more transparent stone like an emerald can be darkly colored. He also states that a clearer body receives light more strongly than a darker body. Density dims the light because such density prevents light from arriving at the core of the body and therefore weakens the light of the object. Since sight perceives light as mixed with color, Ibn al-Haytham believes that if this weak light shined upon such a dense body, then the color of that body would appear more prominently than the light. On the other hand, since a body receives light more intensely the clearer (less dense) it is, the strong light acts to weaken the color of the body. In this

\(^{157}\) P. 170 and 169 (Arabic pp. 15-6), Ibid.

\(^{158}\) *wa laysa Shay'un Yamna' u al-ajsam-a min qubul-i al-daw'-i ghayr-a al-kathafat-i, li-anna-hu laysa Shay'un Yamna' u al-duw-a min al-wusul-i ilay-ha ghayr-a al-kathafat-i* ("Nothing prevents bodies from receiving light except density, because nothing prevents light from reaching them except density.'"), p. 169 (Arabic p. 16), Ibid.
manner of reasoning, Ibn al-Haytham has connected sight's ability to see the color of an object with the density of that object. In short, as density constrains the ability of the body to receive light, more of the color of the body reaches sight.\(^{159}\)

With all the above having been reviewed about light, density and color, Ibn al-Haytham proceeds to the final stages of presenting his own theory for the marks seen on the surface of the moon. He notes that the moon's ability to receive light as a non-transparent object being established, and noting that the location of the marks on the moon not receiving light as fully as the rest of the moon's surface shows that there exists a constraint that prevents those locations from fully receiving the strength of the light coming from the sun, and further remembering that density is what prevents light from being received, therefore he puts forward the following:

it has been made clear that density impedes the receiving power for light, and that nothing impedes the receiving ability except density, and the more solid the density the stronger its prevention of the ability to receive light, for the weakness of the receiving ability that is in the position of the marks is in fact a result of the strength of the density that is in that location, so the position of the marks, then, does not fully receive light because in it the density prevents it from complete reception [of the light from the sun].\(^{160}\)

Ibn al-Haytham continues with a qualification explaining the marks. He writes:

\(^{159}\) P. 169 and 168 (Arabic pp. 16-17), Ibid.
And the entire moon is dense. And since that is the case, then the position of the marks on the moon has a greater density than the density of the rest of the surface of the moon, and this increase is what prevents the marks from fully receiving light. So the reason that the receiving power for light that is in the position of the marks is weaker than the receiving ability that is on the rest of the moon’s surface is the greater density of the position of the marks compared to the density that is on of the rest of the surface of the moon. And this is what we set out to explain in this examination.\textsuperscript{161}

Having attributed the marks on the moon to the increased density of those positions in comparison to the lesser density of the rest of the moon’s surface, Ibn al-Haytham finally wants to explain the dark color of the marks. First he establishes, to his mind, that the entirety of the moon’s surface is a dark black color with some shades of red. His proof for this is the observation of lunar eclipses; he states that this is in fact the color of the moon during such eclipse events (when, to his understanding, there is an absense of light and therefore only the color of the body can be seen). He substantiates this claim that the moon’s color is dark by noting its appearance at the beginning of each month when the new moon occurs.\textsuperscript{162} He goes on to state that the moon’s overall ability to receive


\textsuperscript{162} wa ayy-ān fa-inna al-qamar-a fi al-laylat-i al-thānīyat-i wa al-thālithat-i min al-shahr-i tuzhar-u istidārat-u-hu wa yazar-u muḥīt-u-hu muḍī‘-an wa yazar-u jirm-u-hu fi wasaṭ-i al-istidārat-i muẓlim-an, fa-lawn-u al-qamar-i alladhī yakhuss-u-hu huwa lawn-un muẓlim-un. ("Also, on the second and third nights of the month, the moon’s roundness is visible, and its rim appears luminous, and its body in the center of the roundness appears dark – for the moon’s own color is a dark color.")
the light of the sun is so great that the light hides the otherwise dark color of the moon. However, because the light is impeded at the position of the marks compared to the rest of the moon’s surface, the weaker light at those positions allows for the darker color of the moon to come through and mix with the light seen at those positions by a viewer on earth. Therefore, the marks on the moon are the dark color of the moon that otherwise cannot be seen on the rest of the moon’s surface (except during an eclipse), and this phenomenon can be attributed to the weaker reception of light at the positions where the marks are seen.\textsuperscript{163}

\textit{Method of science}

As one can immediately sense from the above outline of Ibn al-Haytham’s treatise to explain the true nature of the marks seen on the surface of the moon, his approach towards his investigation for this subject is markedly different than the one he deployed for his study on the equal angles law of reflection for light. While he helped move the methods of science into a science of demonstration in his work on optics, especially by presenting his findings in a manner whereby his observations could be repeated by others, his later work to understand the marks on the surface of the moon are more in line with the standard approach of empiricism.

\textsuperscript{163} P. 167 (Arabic p. 18), Ibid.
The main method for his study on the moon's marks is Greek syllogism. A representative example of this deductive approach from his treatise is found in his discussion criticizing a previous opinion on the matter. He counters it with the following passage:

And also, when the moon is in opposition to the sun, its illuminated surface is facing the sun. If protruding features were present on its surface, then when in opposition to the sun and while facing it, its light would reach the gaps between those features on which shadows fall when the moon is close to the sun. And the finding contradicts that, because the marks exist constantly when the moon is in opposition to the sun, both prior to opposition and afterward, in a singular unchanging form. Thus the marks that are on the surface of the moon are not shadows of protruding roughness on the surface of the moon.

First, Ibn al-Haytham's approach here is empirical because he makes appeals to the observation of the moon in its natural state as the base of his argument. His method is further deductive in the form of a logical argument. His axiom is that when the moon fully faces the sun, then its surface is fully covered with light. He then states that if there were protusions rising up from the surface of the moon,

---

164 He was clearly aware of and educated in the deductive methods of syllogistic argument, as can be seen in the part of his autobiography cited by Ibn Abi Usaybi‘ah and that was quoted in full in the introductory chapter of this study. There, Ibn al-Haytham summarized his admiration for Aristotle's approach towards logical argument, and he largely follows this path for argumentation in his treatise on the marks on the moon.

then their shadows would disappear at the moment the moon exactly opposes the sunlight. He then notes that observation of the moon, even when fully lit, shows that the marks do not disappear. Therefore, he states that there cannot be protruding features on the surface of the moon.

This method of scientific investigation, as would be obvious to any contemporary reader, resulted in an incorrect findings by Ibn al-Haytham: that the moon has no protruding features on its surface. In comparison to his approach when establishing the equal angles law of reflection for light, it is important here for us to understand why he met limitations in his scientific methods for his investigation into the marks on the moon. At its core, it comes down to a lack of tools and instrumentation to conduct the scientific study presented in his treatise. The field of optics, as we saw above, provided Ibn al-Haytham the ability to construct an apparatus that could reflect light under controlled conditions. His ability to then observe and measure these reflections led to his definite (and correct) conclusion that light reflects at equal angles. It is highly unlikely that he could have arrived at this determination without the aid of his constructed instrument that allowed him to control his observation, a method as we saw that he signified with the term *i’tibār*.

Conversely, for his examination of the marks upon the moon, he could only rely upon his natural observations through his own sight unaided by instrumentation. He then added the method of syllogistic proof based upon these
observations in order to arrive at his conclusions both for countering previous opinions and also for establishing his own theory. We provided the example above whereby he counters the idea of protruding roughness on the surface of the moon, and he also later in his treatise disproves the (correct) idea that there are craters on the moon using the same logic he presented for his debunking of the idea that there are protrusions. He writes the following:

And as for the view of those who say that the marks are a cavity in the body of the moon, and that if the sun rose on the moon, the hollowed area would become shaded within, well that is debunked by saying something like what was put forth concerning protruding roughness. And that is that if the moon opposed the sun, sunlight would strike the inner parts of the cavity, so the shadows from the area surrounding the cavity would be nullified [disappear] when the moon was close to the sun. ... But the finding is contrary to that, and that is that the finding is that the form of the marks do not change, neither during opposition nor at any other time before or after [opposition], thus the marks on the moon are neither a shadow of a cavity nor of protruding roughness.\footnote{wa amma ra'\-y\-u man yaq\-\-ū inna al-athar\-a huwa taq\-\-ār\-un fi ji\-m-i al-qamar\-i wa inna al-shams\-a i\-dhā as\-\-\-y\-a\-qat 'alā al-qamar\-i šārā li-muh\-\-ī\-t-i al-taq\-\-ār\-i zill\-un 'alā bā\-\-ṭin\-i hi fa-inna dhālika yantaq\-\-īd\-u bi-mithla al-qawl\-i alladhī taq\-\-\-\-dama fi al-khushū\-\-nāt\-i al-bā\-\-rizāt\-i. wa dhālika anna al-qamar\-a i\-dhā qā\-\-bālā al-shamsa wa\-\-ṣāla daw\-\-u al-shams\-i ilā bā\-\-ṭīn\-i al-taq\-\-ār\-i, fa-yab\-\-tul\-u al-zill\-u alladhī yakūn\-u min muh\-\-ī\-t-i al-taq\-\-ār\-i 'inda kawn\-i al-qamar\-i qarīb\-an min al-shams\-i. ... wa al-wujūd\-u bi-khīlāf\-i dhālika, wa huwa anna al-wujūd huwa anna shakl\-a al-athar\-i lay\-\-sya yataghayyar\-u lā 'inda al-muqābalat\-i wa lā fi waqt\-in min al-awqāt\-i allatī qabla al-muqābalat\-i wa ba\-\-da-hā fa-laysa al-athar\-u alladhī fi al-qamar\-i zill\-an li-taq\-\-ār\-i in wa lā l-khushūnāt\-in bā\-\-rizat\-in. See p. 173 (Arabic p. 12), Ibid.}

As we outlined in the previous section of this chapter, Ibn al-Haytham counters each notion about the marks before presenting his own theory. For the latter part of his treatise, he further relies upon some aspects of his understanding of the properties of light that he discovered in his previous work on optics in order to present a logical argument supporting his theory that the marks

91
represent areas of the surface of the moon that have more density than the rest of the surface. His theory based upon deductive reasoning stemming from his axioms about the nature of light allowed his findings to adhere to the (then) widespread belief that the surface of the moon is smooth. By having some parts of that uniformly smooth surface to be more dense than other parts, he was able to justify that the dark shades on the surface of the moon are a result of how light behaves in relation to density, which he reiterates in his treatise based upon findings he previously made in his optical works.

In contrasting his methods for scientific investigation in his work on optics with his work in this treatise, we can therefore see the importance of instrumentation for the conducting of science. Tools available (or not available) especially can help determine the methods of science as well as the ability to reach demonstrable proof about natural phenomenon. Unaided by an instrument to explain the marks on the moon, Ibn al-Haytham resorted to established scientific methods of deduction combined with empirical observation. As we saw in the previous chapter of this study, though, his ability to build and utilize an apparatus to observe the equal angle reflection of light allowed him to approach optics in a manner that pushed beyond empirical science and into demonstrative
That transition into apódeixis does not occur in his treatise on the marks on the moon, despite it having been written after his Kitāb al-Manāẓir.

 Controlled observation (iḥtār)

Next, Ibn al-Haytham uses as a verb that key gerund, iṭibār, that formed a linguistic backbone for his method of science in his Kitāb al-Manāẓir, very selectively in his treatise on the marks on the moon. In fact, his use of any word from the root ʿabara in the treatise is limited to three instances of its use as the form VIII verb. These few occurrences help reinforce my conclusion in the

---

167 Interestingly, it would require the use of such instrumentation for a real breakthrough to occur in starting to properly understand the marks that are seen on the face of the moon. Sometimes a scientific breakthrough in a particular field of study cannot occur until a new toolkit (literally) is created for its further exploration. It was the privilege of Ibn al-Haytham to have been able to accomplish this in the field of optics in the fifth/eleventh century. In 1610 CE, it would be the privilege of Galileo Galilei to accomplish this for the marks on the face of the moon. In his famous treatise "The Starry Messenger" he wrote of his construction of a telescope which he then utilized to observe, among other things in the sky, the surface of the moon. It is worth quoting parts of this here to emphasize the role that instruments play in demonstrative science in contrast to a science based upon empeiría alone. Galileo wrote: "About ten months ago a report reached my ears that a Dutchman had constructed a telescope, by the aid of which visible objects, although at a great distance from the eye of the observer, were seen distinctly as if near ... At length, by sparing neither labor nor expense, I succeeded in constructing for myself an instrument so superior that objects seen through it appear magnified nearly a thousand times and more than thirty times nearer than if viewed by the natural powers of sight alone ... I betook myself to observations of the heavenly bodies ... Let me speak first of the surface of the moon, which is turned towards us ... the darker part, like a sort of cloud, discolors the moon's surface and makes it appear covered with spots. Now these spots, as they are somewhat dark and of considerable size, are plain to every one, and every age has seen them ... These spots have never been observed by any one before me, and from my observations of them, often repeated, I have been led to that opinion which I have expressed, namely, that I feel sure that the surface of the moon is not perfectly smooth, free from inequalities and exactly spherical, as a large school of philosophers considers with regard to the moon and the other heavenly bodies, but that, on the contrary, it is full of inequalities, uneven, full of hollows and protuberances, just like the surface of the earth itself, which is varied everywhere by lofty mountains and deep valleys." See pp. 59-63, in Margaret C. Jacob, *The Scientific Revolution: a brief history with documents*. Boston: Bedford/St. Martin's, 2010.
previous chapter about the significance of the term *i’tibār* as a "controlled observation." I would suggest that his use (or more accurately, non-use) of the term *i’tibār* in his treatise on the marks of the moon shows a precision in his scientific language that implies an awareness on his part that his work on the nature of the marks on the moon was not based upon the same standard of proof that he achieved in his work on optics generally and in establishing the equal angles law of reflection for light specifically.

We first encounter the root *’abara* at the the very beginning of the text in Ibn al-Haytham’s treatise in a passage already partially cited in the previous section. He writes:

Theorists have differed on the nature of the marks that appear on the face of the moon. These marks, if they are looked at attentively and considered (my emphasis), are always found to be of a singular property, unchanging in their form, position, size, and the manner of their darkness.  

Here, *i’tabara* has been added as a qualifier to the act of looking at something attentively. Further, *i’tabara* is the connection between the act of looking at the moon and arriving at the conclusion that the marks on the moon never change their form, position, size, or shade of darkness. Since the unchanging nature of the

---


169. Please recall the general point I made about Ibn al-Haytham’s use of the terminology in the previous chapter. I wrote, "I maintain that the process described by Ibn al-Haytham makes it plausible to interpret his use of the term *i’tibār* as understood to mean “considering (by example),” or “reflecting (upon experience),” or “contemplation (of Nature)” — in other words, a considered observation."
marks upon the moon is a fact that is known for certain and cannot be refuted, Ibn al-Haytham returns to this axiom again and again as his standard of proof when countering the various other theories given for the marks upon the moon.

Further, he makes sure that his own theory conforms to this fact. For various other observations about the marks he does not utilize any term that is a variation on the root ‘abara and instead, for those observations based upon sight and visual evidence, utilizes word forms from either the root nāzara or the root zahara.\footnote{For example, when he describes the theory that the marks are a result of reflection, he writes: \textit{wa ra’á qawm-un anna-hu sūrat-un tažhar-u bi-l-in’ikās li-anna sațh-a al-qamar-i ṣaqīl fa-idhā nazara ilay-hi al-nāzir-u in’akasa shu’ā’-u baʃar-i-hi ‘an saṭh-i al-qamar-i līlal al-ard-i kamā yan’akis-u ‘an sufūh-i al-mirāyā fa-yazhar-u la-hu sūrat-a al-ard-i aw ba’d-a-hā.} ("and one group believed that it was an image appearing in reflection because the surface of the moon is smooth—because if one were to look at it, the rays of his vision would reflect off the surface of the moon back to earth, just as they reflect off the surfaces of mirrors, so it appears to him as the image of the earth, or parts of it.")} my italics, p. 178 (Arabic p. 7), Ibn al-Haytham, “Treatise on the Marks Seen on the Surface of the Moon.” See also, for example, the following: \textit{lam yakun budd-un min an yatağhayyar-u mawdi’-u-hu min sațh-i al-qamar-i fi al-ru’yat-i idhā nizira ilay-hi min mawdi’ayn-i mukhtalifatayn-i min al ard-i.} ("then its position on the surface of the moon would have to change in appearance if it were viewed from two different positions on earth.") my italics, p. 177 (Arabic p. 8), Ibid.
"Itibār" as it was used by Ibn al-Haytham in chapter three of book four of his *Kitāb al-Manāẓir*.

The next instance of his technical use of the root ‘abara in his treatise on the moon's marks further confirms our conclusion that *itibār* is specifically an observation that occurs under controlled conditions. When he wants to establish that a solar eclipse is a result of the moon passing in front of the face of the sun, Ibn al-Haytham resorts for the only time in his treatise to relating how this phenomenon can be demonstrated utilizing a controlled observation that involves the use of an apparatus to act as an intermediary for the performance of the viewing by the subject. This time, the apparatus is by no means as sophisticated as the one he constructed to observe the equal angles law of reflection — it is a bucket of clear water. However, conceptually (a vehicle for observation), it is no different than forcing light to reflect off of the mirrors of his apparatus in chapter three of book four of the *Kitāb al-Manāẓir*. He writes the following passage:

And that is that the solar eclipse is in fact the interposition of the moon between the earth and the body of the sun, so that the sun is veiled by the moon, and if all of it is veiled, then it is fully eclipsed, and if part of it is veiled, then that part is eclipsed. And this meaning is evident to the senses on a clear afternoon, because if the sun were eclipsed, and a viewer were to look at it, he would find the body of the moon on the face of the sun.  

---

Ibn al-Haytham then specifies how he can know that the moon blocks the sun during a solar eclipse when he continues with this example:

And if he considered and contemplated (my emphasis) that, he would find it is as we have explained. For if the viewer could not see the sun, then were he to place a bucket in the location of the solar eclipse and filled it with clear water and waited until the water became still, then looked at the water, then he would see the moon reflected, and he would find it on the face of the sun.172

To emphasize the interpretation of this method for scientific inquiry given in the previous chapter, one cannot reasonably state that Ibn al-Haytham's science in this instance involves experimental testing in the sense of the modern scientific method; however, it also is not merely empirical observation of natural phenomenon. Rather, knowing that merely staring at the sun's total eclipse cannot prove that it is indeed the moon blocking its light, Ibn al-Haytham controls for his observation through the device of the bucket of clear water. The image of the moon does appear in the water's reflection and therefore can confirm his finding. Expectedly, he returns to his technical usage of i’tabara for this particular controlled observation because its finding carries with it a certain fact that can be known beyond dispute.

The third usage of the form VIII variation of the root ‘abara by Ibn al-Haytham in his treatise on the moon's marks finally helps confirm that his

---

technical usage as it relates to his methods of science has less to do with experimental testing and more to do with observing natural phenomenon under a control condition that reveals something true about its nature or behavior (as was the purpose of the appartus used to see light reflect at equal angles). Interestingly, Ibn al-Haytham resorts to *i'tabara* when he observes a lunar eclipse in order to draw a conclusion about the color of the moon. The fact that he was wrong about the moon’s color is beside the point because we are interested in the method he used to arrive at his scientific finding, even if the latter was erroneous. Here is his passage regarding the color of the moon:

And the moon has its own color that appears during its eclipse and especially during a total eclipse, and it also appears during a solar eclipse, and especially when fully or mostly eclipsed, and it is a dark color, as if blackness tinged with red. And if the moon is **considered and contemplated** (my emphasis) during its eclipse, its color would be found as we have related it.\(^{173}\)

An observation of the moon in its natural state, to Ibn al-Haytham, would not reveal its true color. This is similar to the fact that, for example, watching light naturally reflect off any natural surface would not immediately show that reflection to be at an equal angle. To demonstrate and observe the latter he had to put light under the control condition made possible by his appartus. In the case of the color of the moon, it is nature itself that provides a control condition when the

---

phenomenon of the eclipse of the moon disrupts its natural state and allows for
the observation of something that would otherwise not have been able to be
detected – the color of the moon. In both cases, he technically described the act
of reaching his conclusion with *i'tabara*. It has been my contention that this term
has been reserved in Ibn al-Haytham’s scientific approach for when the viewing
of a phenomenon occurs specifically under a condition not otherwise typical, thus

---

174 The reason the total darkening of the moon (and therefore the absence of light upon its
surface) would have revealed the color of the moon to Ibn al-Haytham’s mind, is a result of his
understanding of the relation between light and color. His assumption about this relationship
can be seen in his treatise. His belief was that any color signified some absence of a degree of
light while very strong light upon an object would hide that body's color. He mentions this
about the moon in his treatise: *fa-lawn-u al-qamar-i allādhī yakhūṣ-u-hu huwa lawn-un
muzlīm-un, wa al-ḍaw'-u allādhī yazhar-u fī-hi fī sā'ir-i al-aqwāt-i inna-mā huwa al-daw'-u
allādhī yastafīd-u-hu min al-shams-i idhā aṣhraqat 'alay-hi, wa al-ḍaw'-u allādhī yahṣul-u fī-hi
min al-shams-i huwa ḏaw'-un qawwiyy-un, wa al-ḍawwāt-u al-qābilat-u li-l-ḍaw'-i allādhī fī-hi
hiya fī ṣḥāyat-u al-ḍawwāt-i wa aqwā min al-ḍawwāt-i al-qābilat-i allātī fī al-ajsām-i al-ardīyyat-
i, fa-li-fart-i ṣawwāt-i al-ḍaw'-i allādhī fī-hi wa fartaṣ-i al-ṣawwāt-i al-qābilat-i fī-hi ḍaḥīya lawn-u-
uh al-muzlīm-u allādhī yakhūṣ-u-hu.* (*For the moon’s own color is a dark color, and the light
that is visible there the rest of the times is in fact the light that it derives from the sun when it
shines upon it, and the light that it obtains from the sun is a strong light, and its [the moon’s]
receiving power for light is extraordinarily strong – stronger than the receiving ability that is
on the earthly bodies. Therefore its [the moon’s] dark color is concealed by the hyper-power of
light that is on it and its hyper receiving ability [for light].*), P. 167 (Arabic p. 18), Ibid.

For Ibn al-Haytham’s conception of the relationship between color and light, see also this
passage shortly before he discusses how the eclipse of the moon reveals the moon’s dark color:
*wa qād tabayyana anna kull-a jīsam-in mutālāwvin-in idhā aṣhraqa ‘alay-hi ḏaw'-un qawwiyy-un
zahara lawn-u-hu raqiq-an aw fī-hi baḍ'-u al-riqqat-i wa zahara al-ḍaw'-u allādhī fī-hi qawwiyy-
an. wa idhā aṣhraqa ‘alay-hi ḏaw'-un daʿīf-un zahara lawn-u-hu qawwiyy-an, aʿnī aṣḥaba-a wa
azlam-a min lawn-i-hi idhā aṣhraqa ‘alay-hi ḏaw'-un qawwiyy-un wa yazhar-u al-ḍaw'-u allādhī
fī-hi ḍaʿīf-an. wa ‘ilāt-u ḏhālika hiya anna kull-a ḏaw'-in yudrik-u-hu al-baṣār-u fī jīsam-in
mutālāwvin-in fa-huwa yudrik-u-hu muṃtazīj-an bi-l-ḍaw'-i allādhī fī dhālika al-jīsam-i.* (*"It has
been made clear that all colored bodies, if a strong light shines upon them, its color would
dilute or would have some clearness, and the light within would appear strong. And if a weak
light shined upon it, its color would appear strong. I mean more saturated and darker [in
comparison] to its color than when a strong light shined upon it, and the light within it would
appear weak. And for the reason for that is that every light that the eye perceives in a colored body
is perceived as mixed with the light that is in that body.").*, P. 168 (Arabic p. 17), Ibid.
resulting in a specifically controlled observation that can be contemplated for its truth. Especially with this example of his use of the term for his observation of the lunar eclipse in order to understand the moon’s color, it is again my conclusion that his understanding of ḥū’ūd al-muṣna’in cannot be seen as meaning experimental testing but rather as an observation under special control conditions.

Concluding remarks

When analyzed specifically in regard to its method of science, Ibn al-Haytham’s treatise on the marks upon the moon reveal several important points about his scientific approach. First, his approach in this treatise is within the scientific tradition of Greek empeiría (empiricism), with its emphasis upon the passive observation of nature to gain knowledge. He also utilized observation to conduct his science in his work on optics establishing the equal angles law of reflection. However, the method for scientific inquiry that exists in his treatise is markedly different than the one he utilized in his Kitāb al-Manāẓir. In the treatise he takes his empirical observations and formulates them into axioms that can then be utilized in a logical form of argumentation to reach his scientific conclusion. This method of syllogistic proof and the arrival at a finding through deduction was an already established method common to Greek science.

At the same time, though, we see Ibn al-Haytham in the treatise utilize the root word ‘abara with the same technical meaning that it had for him in his
optical work: when a thing can be isolated and known for certain as a result of its observation occurring under a controlled condition not otherwise typical in the natural world. I would argue that he was not able to use this method of controlled observation to explain the marks on the moon because, for that specific inquiry, he lacked the necessary tools and instrumentation to perform such an observation, i.e. Ibn al-Haytham did not have available to him the telescope to use as a scientific instrument. The lack of an instrument with which to investigate the marks on the moon determined that he had to rely upon syllogistic proof as the method to confirm his finding.

On the other hand, in his investigation into the reflection of light, Ibn al-Haytham was able to perform his inquiries with the aid of a constructed instrument, and I would argue that this application of instrumentation to the act of scientific inquiry was the major factor that determined (and allowed him to utilize) his method of controlled observation (i’tibār). Further, the instrumentalization of his optical science in chapter three of book four of his Kitāb al-Manāẓir (as opposed to the science in his treatise on the moon’s marks) allowed him to move beyond the need to rely upon the syllogistic/deductive proof that he uses in his treatise, and instead base his optical science on demonstrative proof. That he was not able to accomplish this feat in explaining the marks on the moon serves to reinforce the conclusions reached in the previous chapter about his expansion and development of the methods for science in the field of optics.
Chapter 4

The true nature of the marks upon the moon

What follows in this chapter is a full English translation, with full grammatical transliteration corresponding to the original Arabic, of Ibn al-Haytham’s treatise regarding the marks that are seen on the surface of the moon. A. I. Sabra has published a full Arabic edition of the treatise from the original manuscript copy no. 2096 D that resides in the City Library of Alexandria. No English translation has previously been made of the treatise prior to my current study, and it is my hope that having such an English version available will be of use to scholars of medieval science. My translation follows the pagination of the published Arabic edition\textsuperscript{175} and not of the original manuscript. Further, my division of the treatise into three parts is my own creation and has neither been suggested by Ibn al-Haytham or Sabra. The division titles are in \textit{italics}. Any part of the translation appearing in [brackets] is my attempt to add words that do not exist in those particular lines of the Arabic text in order to provide clarification of Ibn al-Haytham’s meaning. Further, any part appearing in \textbf{bold} with a parentheses stating (my emphasis) after it, is my own addition of both the parentheses and the bold script to the original Arabic.

Introduction

Treatise of Shaykh Abi Ali al-Hasan bin al-Hasan
bin al-Haytham (may God have mercy on him) on
the Nature of the Marks on the Face of the Moon

In the name of God the Most Merciful, the Most Compassionate

Abu Ali al-Hasan bin al-Hasan bin al-Haytham said:

Theorists have differed on the nature of the marks that appear on the face
of the moon. These marks, if they are looked at attentively and considered (my
emphasis), are always found to be of a singular property, unchanging in their
form, position, size, and the manner of their darkness. People’s opinions on the
matter circulated, and their views spread, for one group believed that they [the
marks] were of the very body of the moon, and one group believed that they were
external to the body of the moon, somewhere between the body of the moon and
the sight of the viewers,\(^\text{176}\)

\(^\text{176}\) maqālat-u al-shaykh abī ʿalī al-ḥasan bin al-ḥasan
bin al-haytham raḥima-hu allah-u
fi māʿiyat-i al-athar-i allādhi fi wajh-i al-qamar-i

bi-sm-i allah-i al-raḥmān-i al-raḥīm-i

qāla abū ʿalī al-ḥasan bin al-ḥasan bin al-haytham:

qad ikhtalafa ahl-u al-nazar-i fi māʿiyat-i al-athar-i allādḥī yazhar-u fi wajh-i al-qamar-i.
wa hādhā al-athar-u idhā tuʿumila wa iʿtabara (my emphasis) wujida dāʿim-an ʿalā ṣifat-in
wāḥidat-in lā yataqhayyur-u lā fi shakl-i-hi wa là fi wadʿ-ī-hi wa là fi miqdār-ī-hi wa là fi kayfiyat-ī
sawād-i-hi. wa qad taṣarrufat zuhnān al-nāṣ fi-hi wa tašhattatāt ārāʿ u-hum, fa-raʿā qawm-un
anna-hu fi nafs-i jirm-i al-qamar-i, wa raʿā qawm-un anna-hu ḵǎrīj-un ʿan jirm-i al-qamar-i wa
mutawassaṭ bayn-a jirm-i al-qamar-i wa bayn-a ābšār-i al-nāzīrīn-a ilāy-hi,
and one group believed that it was an image appearing in reflection because the surface of the moon is smooth—because if one were to look at it, the rays of his vision would reflect off the surface of the moon back to earth, just as they reflect off the surfaces of mirrors, so it appears to him as the image of the earth, or parts of it. And one group said that they [the marks] were an image of the ocean on the earth, seen in reflection, and another group said it was an image of the mountains on the earth, and another said it was an image of a segment of the earth upon which reflected rays have fallen.

As for those who said that the marks are something in-between sight and the body of the moon, they believed that the moon attracted from the earth a vapor with a particular quality: for the vapor rose and thickened, it became permanent under the moon, and of a permanent quality, thus neither its form nor size nor position relative to the moon changed.

As for those who said that they [the marks] were within the body of the moon itself, they differed:177

---

fa-amāmā man qāla inna-hu fi nafs-i jīm-i al-qamar-i fa-inna-hum ikhtalafū:
one faction of them said that they were transparent, emanating within the body of the moon, because if the viewer looked at them, he would see that which is behind them, for the image of light in the transparent area mixed with the image of the sky from behind the moon, so [the marks] appear in contrast with the color of the rest of the moon. Another group said that they [the marks] were rough areas in the location, and that the body of the moon is smooth, so if the light of the sun rose upon them, the rough areas would not receive the light like the smooth [areas]. It might be said that the position of the marks is a protruding roughness, and parts of it are showing, and were the sun to rise on them, the rough parts would come to have shadows on the adjacent areas of the moon’s surface, for the area of shadow would darken, and the marks that are on the moon are the shadows of elements of roughness. And it might be said that within the body of the moon there is hollowness, for if sunlight rose upon it, the hollow area would have a shadow within the interior of the hollowness, and the marks are shadows surrounding the hollowness. And it can be said that in the sky

---

there is a position or positions that have some density, just as the galaxy has some density, except that in the galaxy is light, while light doesn’t appear in those positions, and that one of those positions is between the sun and the moon, so if the sunlight rose upon the moon, that position would shade the surface of the moon, and thus the marks are the shadows of dense areas of the sky.

All of these opinions have been debunked and have dwindled upon investigation of the theory. And we will explain the weakness of all of these opinions, then afterward we will make clear the [true] nature of these marks.

**Refutation of existing theories**

As for the opinion of those who believed the marks were external to the body of the moon, and that they are a vapor that the moon attracted from the earth, and that it is present in-between one’s sight and the body of the moon, it is obviously false. That is because if it were so, then the position of the marks on the surface if the moon would differ relative to different positions on earth

---


wa jamī’-u ḥāḍihī al-ārā’-i tabṭul-u wa taḍamḥalla ‘inda taḥqiq-i al-nazar-i, wa naḥnu nubayyin-u fasād-a jamī’-i ḥāḍihī al-ārā’-i, thumma nubayyin-u ba’d-a dhāliga mā’iyat-a ḥāḍih al-ṭhar-i.

in a single point in time, because every body intervening between sight and the object being seen has a difference in perspective. And the matter is not like that, rather the marks, if examined at night, from the beginning of night to its end, from various positions on earth, they would be seen by the eye to be in a single position on the surface of the moon. For were the intervening body also located in the same body between it and the moon, then its position on the surface of the moon would have to change in appearance if it were viewed from two different positions on earth, especially if the distance between the two points was different.

As for if the intervening body had been in the atmosphere, and it was seen at a single point in time from two positions on earth [and] the distance that is between them different, from the positions the marks would be perceived as being in the middle of the moon's surface, while from the other position  

---

it would appear to be external to the body of the moon and no marks would be seen on the moon because the body intervening between sight and the seen object whenever distant from the seen object, the greater the difference in its perspective.

Also, if the marks were a vapor that the moon had attracted, and it was ever-present under the moon in a fixed position, and if the moon were close to the horizon when the viewer looked at it, then that vapor would not be in-between the viewer's sight and the moon. If it were in-between his sight and the moon, then its position relative to the moon would not be the position that the viewer had seen when the moon was in the middle of the sky or near the middle, because of the difference in perspective. Thus the marks that are on the moon cannot be something between him and the moon.

As for the view of those who believed they [the marks] were an image appearing in reflection, that is debunked with what we relate [as follows]:

\[ \textit{yurā khārij-an 'an jirm-i al-qamar-i wa lā yurā fi al-qamar-i shay'-un min al-athar-i, li-anna al-jism-a al-mutawassīf-a bayna al-bāsar-i wa al-mabsar-i kullmā kāna ab'ad-u 'an al-mabsar kāna ikhtilāf-u manzār-i hi akhtār-a.} \]


\[ \textit{fa-ammā ra'y-u man ra'ā anna-hu šurat-an tażhar-u bi-al-in'ilkās-i fa-inna-hu yabṭal-u bi-mā nadḥkur-u-hu:} \]

and that is that reflection is present along equal angles occurring between ray lines and the smooth surface. And if that were so, then were the moon's visible position to change, then the angles of reflection that occur between the ray lines external to sight and its surface would also be different. And every time the moon moved farther away from the middle of the sky, the angles that occur between the first lines that leave sight to the moon and between the lines reflected from it, would expand, and if these angles expanded, then the positions where the reflected rays terminate would change, and if these rays were to terminate on the surface of the earth, then they would terminate at various locations on earth, and if the rays terminated at different locations on earth, and the marks were the image of the seas or mountains, then the forms of the marks would have to change because the form of the mountains and the form of the seas on the various parts of the earth are different, and the form of the marks are not different at different times, and this difference would have to be apparent on a single night, from a

---

single perspective, because as the moon moved away from the zenith, the position of its external rays would undergo a change to sight and the angles that are between the first rays and between the reflected rays would expand.

And also, if the moon were to draw near the sunset horizon, or if it were close to the sunrise horizon, then the rays that were reflected to the earth would become external to the earth. Because if the moon were close to the horizon then the visible rays external to it would be slanted sharply away from its surface, for the rays reflecting off of it are also sharply slanted away from its surface, and the slant of the reflected rays are toward the opposite side of the earth and thus the rays must not fall on the earth’s surface, and so the moon must, if it were close to the horizon on any side, have no marks appear on it, if the marks were the image of the earth or oceans or mountains or some aspect of the earth appearing in reflection.\textsuperscript{183}

\textsuperscript{183} al-baṣar-i al-waḥīd-i, li-anna-hu kull-a-mā ba’uda al-qamar-u min samt-i al-ra’-i

mun’akisat-u ’an-hā mā’īlat-an ayd-an ’an satth-i-hi shadhīdat-a al-mayl-i, wa yakūn-u mayl-u al-
shu’-ā’āt-i al-mun’akisat-i ilā ḍīdd-i al-jiḥat-i allatī fi-hā al-ard-u fa-yalzam-u min dhālika a-lā 
taqā’-u al-shu’-ā’āt-u ’alā satth-i al-ard-i, fa-yalzam-u min dhālika an yakūnu al-qamar-u idhā 
kānā qarīb-an min al-ufuq-i ayy-ī jiḥat-in kānā min jiḥāt-i al-ufuq-i lā yaẓhar-u fi-hi Shay’-un min 
al-athār-i in kānā al-athār-u huwa šūrat-a al-ard-i aw al-biḥar-i aw al-jibāl-i aw Shay’-un min al-
ard-i yaẓhar-u bi-al-in’ikās-i.
And the matter is not so, rather the marks on the moon are ever-present on the moon, in the exact same position on the surface of the moon, whether the moon is on the horizon or in the middle of the sky or in-between.

And also, if the moon were at the zenith, and often, that is demonstrated in positions where its width is less than the collective of the extent of the sun’s incline to the extent of the moon’s width, then the ray of sight that exits toward the middle of the surface of the moon becomes [as] a perpendicular shaft on the surface of the moon, so it reflects back on itself and returns to the eyesight and the surface of the earth knows nothing of it, and most of the rays that are external to the rest of the moon’s surface are reflected to positions external to the earth, and they are the rays that are reflected from the vicinity of the moon from the positions far from its center. And that which is reflected to earth is reflected from the center of the surface of the moon and from the vicinity of the moon, for the image that appears is appearing only in the center of the moon’s surface.184


And if the marks that are seen on the moon were an image that appears in reflection, then the image would have to be seen only in the middle of the moon’s surface, at a time when the moon was at the zenith. And the matter is not so, I mean that the marks do not exist at a given time in the middle of the moon’s surface only, thus the marks on the moon are not an image appearing in reflection.

And as for the view of those who believed that the marks were of the moon itself, and that [the marks] are simply transparent on the body of the moon, that is invalidated by the solar eclipse. And that is that the solar eclipse is in fact the interposition of the moon between the earth and the body of the sun, so that the sun is veiled by the moon, and if all of it is veiled, then it is fully eclipsed, and if part of it is veiled, then that part is eclipsed. And this meaning is evident to the senses on a clear afternoon, because if the sun were eclipsed, and a viewer were to look at it, he would find the body of the moon on the face of the sun.\textsuperscript{185}


And if he considered and contemplated (my emphasis) that, he would find it is as we have explained. For if the viewer could not see the sun, then were he to place a bucket in the location of the solar eclipse and filled it with clear water and waited until the water became still, then looked at the water, then he would see the moon reflected, and he would find it on the face of the sun. Because insofar as the solar eclipse is a result of the moon, the extent of the eclipse of the sun will vary according to different positions on earth as a result of the difference in perspective of the moon because it is interposed between the moon and the body of the sun. Were the marks that are on the moon transparent on the body of the moon, then they would not cover the sun, and sunlight would appear from behind the light of the moon during the eclipse. And if it didn't appear on a clear afternoon, then the translucence of the moon would have been evident if it had been on the face of the sun and if its translucence were plain. Because every transparent thing would show any luminous thing that is behind it, and if it was transluscent simply,\footnote{wa matá i’tabara (my emphasis) dhālika wajada ‘alá mā dhakarnā. fa-in lam yasta‘ī’ al-nāzir-u al-nazār-a ‘alá al-shams-i, fa-inna-hu idhā waḍa‘a ṭast-an fī mawdī‘-i munkasīf-i al-shams-i wa sakabā fi-hi mā-an ṣāfiy-an wa šabara ilā an yaskuna al-mā‘-u, thumma nażara fī al-mā‘-i, fa-inna-hu yarā al-qamar-a bi-al-in’ikās-i wa yajid-u-hu fī wajh-i al-shams-i. wa li-anna kusūf-a al-shams-i inna-mā huwa bi-l-qamar-i ṣāra al-miqdār-u al-munkasīf-u min al-shams-i yakhtalīf-u ‘ānd-a al-mawāḍī‘-i al-mukhtalīf-at-i min al-ard-i min ajīl-ī ikhtilāf-i manzar-i al-qamar-i li-anna-hu mutawassīf-un bayna al-qamar-i wa bayna jirm-i al-shams-i, fa-law kāna al-ṭahr-u alladhī fī al-qamar-i huwa shafīf-un fī jism-i al-qamar-i la-kāna mā yaṣṣīf-u al-shams-a, wa la-kāna ṣaw‘-i al-shams-i yaḍhar-u min warā‘ā nūr-i al-qamar-i fī waqṭ-i al-kusūf-i. wa idhā lam yaḍhar zuḥūr-an bayyin-an fa-inna-hu qad kāna yaḍhar-u shafīf-u al-qamar-i idhā kāna fī wajh-i al-shams-i wa in kāna shafīf-u-hu yaṣār-an. li-anna kull-a maṣḥaf-in fa-inna-hu yaḍhar-u mā warā‘a-hu muḍ‘-i-an, wa idhā kāna shafīf-u-hu yaṣār-an}
then its translucence would be evident if behind it was a luminous body, and [if] what is behind it does not show and its translucence is not apparent though behind it was a luminous body, then it is not translucent. So the marks that are on the moon are not transparent on the body of the moon.

And as for the view of those who believed that the marks were roughness in the position of the marks on the surface of the body of the moon, while the rest of the surface of the moon was smooth, well the moon attracts light from the sun, and the smooth positions attract light better than the the rough spots, so this theory is invalidated in accordance with what we have explained in our book on the light of the moon. And that is that it has been explained in that book that the moon, if the sun, which itself is luminous, arose upon it and the light that shined from it appeared, then it would shine as light does. For bodies that are lit on their own do not emit light because of their smoothness, or because of their surfaces alone, but rather light shines from every part of them.\footnote{fa-inna-hu yazhar-u shaff-u-hu idhā kāna warā’-a-hu jism-un muḍī’-un, wa mā lā yazhar-u mā warā’-a-hu was lā yazhar-u shaff-u-hu idhā kāna warā’-a-hu jism-un muḍī’-un fa-laysa bi-mashaff-in. fa-laysa al-arthar-u alladhī fi al-qamar-i bi-shaff-in huwa fi jism-i al-qamar-i. wa amma ra’y-u man ra’ā anna al-arthar-a huwa khushūnat-un fi mawdī’-i al-arthar-i min saṭh-i jirm-i al-qamar-i, wa baqiyat-a saṭh-i jirm-i al-qamar-i ṣaqil-un, fa-inna al-qamar-a yaqbal-u al-daw’-a min al-shams-i, fa-l-mawādī’-u al-ṣaqīlat-u tāqbal-u al-daw’-a akthar-a min qabūl-i al-mawādī’-i al-khushūn-un, fa-inna ḥādhā al-ra’y-a yantaqīd-u bi-mā bayyannā-hu fi kitāb-i-nā fi daw’-i al-qamar-i. wa dhālika anna-hu qad tabayyana fi dhālika al-kitāb-i anna al-qamar-a idhā ʿashraqat-ʿalay-hi al-shams-u šaṣrat dhāt-u-hu muḍī’-at-an wa šāra al-daw’-u alladhī yashriq-u min-hu inna-mā yashriq-u ka-mā yashriq-u al-ʿadwā’-a-u. fa-l-ajsām-u al-muḍī’-at-u min dhawat'-i-hā laysa yashriq-u al-daw’-u min-hā min ajī-ṣiqāl-i-hā wa lā min ajī-suṭūn-i-hā faqāt, bal inna-mā yashriq-u al-daw’-u min kull-i juz’-in min-hā.}
and the light is not a result of their smoothness, but rather because of the radiant strength that is within. And something like this meaning is evident in fire and in its components and in parts of bodies containing fire. And also, roughness prevents light from reflecting off it, it doesn't attract light. And despite that, roughness first attracts light [in comparison to] smoothness, because light, if it were to shine on a rough body, it would enter its holes and folds, while smoothness prevents the smooth body from absorbing light. And the reason for that is the reflection of light off of the smooth body. For were the smooth body more sharply absorbent than the rough body, then light wouldn't reflect off of it or return upon impact. Indeed, roughness is not an inhibitor of the absorption of light, but rather an inhibitor of the reflection of light. And if light that appears on the surface of the moon were reflecting, then it would be possible to say that the position of the marks were roughness on the surface of the moon preventing the reflection of light, and the rest of the moon remained smooth.\footnote{wa laysa idā'at-u-hā min ajl-šiqāl-i-hā bal min ajl-i al-quwwat-i al-nūriyyat-i allāti hiya fi-hā. wa hādhā al-ma'āqa yazhar-u mitti'-u-hu fi al-nār-i wa fī ajzā'-i-hā wa fī ajzā'-i al-ajsām-i al-hāmilat-i li-l-nār-i. wa ayd-an fa-inna al-khushūnāt-a tamna'-u in'ikās-ā al-dāw'-i 'an-hā lā qabul-ā al-dāw'-i. wa ma'a dhālika fa-inna al-khushūnāt-a 'ulā bi-qābul-ā al-dāw'-i min al-šiqāl-i, li-āna al-dāw'-i idhā ashraqa 'āla al-jism-i al-khashin-i dhakhala fi masām-i-hi wa ghudūn-i-hi, wa al-šiqāl-u yamnā'-u al-jism-al-ṣaqīl-ā min qabūl-ī al-dāw'-ī. wa al-dalīl-u 'alā dhālika in'ikās-u al-dāw'-ī 'an al-jism-i al-ṣaqīl-i. fa-law kāna al-ṣaqīl-u ashqadd-u qabūl-an min al-jism-i al-khashin-i la-mā kāna yan'akīs-u al-dāw'-i 'an-hu wa yaqrā'-u ṭindi-a muṣādamat-i-hi. fa-laysat al-khushūnāt-u 'ilāt-an māni'id-at-an li-qābul-ī al-dāw'-ī wa inna-mā hiya māni'i-at-un li-l-in'ikās-i al-dāw'-ī. fa-law kāna al-dāw'-ī alladhil yazhar-u fi saṭh-i al-qamar-i inna-mā huwa bi-l-in'ikās-i, la-qad kāna yumkīn-ū an yuqāl-ū inna mawdī'-a al-athar-i inna-mā huwa khushūnāt-un fi saṭh-i al-qamar-i tamnā'-u min in'ikās-i al-dāw'-ī, wa baqiyyat-i saṭh-i al-qamar-i ṣaqīl-un,}
because light reflects off of it, [and] therefore the position of the marks appear bereft of light. Except it has been explained in our book on the light of the moon, its mention of which we set forth beforehand, that light that shines from the moon and the light that sight perceives on the surface of the moon have nothing to do with reflection. For it is not true that there is an absence of light in the position of the marks resulting from roughness in the location of the marks.

If it has been said that the proof of that is that smooth bodies, if light shines upon them, then the light that appeared on their surfaces would be significantly stronger than the light on the surfaces of rough bodies, and therein is the reason that smooth bodies are more illuminable than rough bodies — then we would say in response to this remark that the receiving power for light is not the light that gets to sight but rather the power that establishes light on the body on which light shines. And the light that comes to sight from the bodies on which light shines has two aspects, one of which is reflection, and the other

---

189 fa-l-daw'-u yana'kis-u 'an-hu, fa-li-dhālika šāra mawdī'-u al-athar-i nāqiš-a al-ḍaw'-i. illā anna-hu qad tabayyana fi kitāb-i-nā fi ḍaw'-i al-qamar-i ma'a-mā qaddamnā dhiq-r-a-hu anna al-daw'-a alladhī yashriq-u min al-qamar-i wa al-ḍaw'-a alladhī yudrik-u-hu al-baṣar-u fi saṭḥ-i al-qamar-i laysa shay'-un min-hu bi-l-in'ikās-i. fa-laysa yasīḥ-hu an yakūn-a nuqšān-u al-ḍaw'-i fi mawdī'-i al-athar-i min ajl-i khushūnāt-in fi mawdī'-i al-athar-i.

has to do with the nature of light, and with the property of light such that if it originates within a dense body, it would shine from every point within to every point in opposition to it. And we have illustrated this concept thoroughly in our book on optics. And light which shines from every point of light is that which we have called secondary light. And the light that is reflected onto smooth bodies is really the primary light and secondary light together: as for primary light, smooth bodies resist it and reflect it back to sight, and as for secondary light, the light that comes about on the surface of the smooth body shines from every point of its light to the sight that is in opposition to it, so the two lights combine in the vision, and therefore it is strong. And the light that returns back to sight from the surface of the rough body is only secondary light, and it is the light that shines from every point of light that is on the rough body. For the light that sight perceives from the surface of the smooth body, its strength is not a result of the increase of the receiving power within the smooth body.\textsuperscript{190}

rather its strength is for the reason as we have mentioned. And the weakness of the light that sight perceives on the rough body is also not because of the weakness of the receiving power, but rather the deficiency of the power of the secondary light that returns back to sight. And we have made clear in our book on optics that secondary light is always substantially weaker than primary light. And it has been made clear that the light that sight perceives on the surface of the moon has nothing to do with with reflection. Thus, the strong light that sight perceives on the surface of the moon has nothing to do with its smoothness, and the weak light that is perceived in the location of the marks has nothing to do with its roughness.

And furthermore, the light that sight perceives on the surface of the rough body, if the rough body were monochrome, and was clear of color, then no shadows or difference would be found therein, rather it would resemble light.191

---

And the marks on the moon are constantly illuminated without lighting the rest of
the moon’s surface. And yet, within them are shadows of an unchanging form, as if
it were cloudiness within clearness. For if the marks were roughness of the
position of the marks, then the light there would only be weak, and there would
be no shadow and no color, and the finding is otherwise. If that were so, then the
marks on the moon would not be a result of roughness on the surface of the moon.

As for those who say that the marks are protruding roughness, parts of
which are fixed, then if the sun rose on the surface of the moon the fixed parts
would bear shadows on adjacent areas and in the areas between them on the
surface of the moon, and this view is invalidated as we recount: and that is that
the moon is not fixed in position relative to the sun, because as it moves away
from the sun, its position relative to it [the sun] changes. And were the marks the
fixed shadows of protruding roughness,\textsuperscript{192}


then their position on the surface of the moon would change with the changing position of the moon from the sun, and the form of the group of shadows would also change. But the form of the marks does not change from one moment to another, rather their shape is always uniform.

And also, when the moon is opposite of the sun, its illuminated surface is facing the sun. If protruding features were present on its surface, then when opposite of the sun and while facing it, its light would reach the gaps between those features on which shadows fall when the moon is close to the sun. And the finding contradicts that, because the marks exist constantly when the moon is in opposition to the sun, both prior to opposition and afterward, in a singular unchanging form. Thus the marks that are on the surface of the moon are not shadows of protruding roughness on the surface of the moon.

And as for the view of those who say that the marks are a cavity in the body of the moon, and that if the sun rose on the moon,193

---


wa amma ra’y-u man yaqūl-u inna al-athar-a huwa taqīr-un fi jism-i al-qamar-i wa inna al-shams-a idhā ashraqat ’alā al-qamar-i
the hollowed area would become shaded within, well that is debunked by saying something like what was put forth concerning protruding roughness. And that is that if the moon opposed the sun, sunlight would strike the inner parts of the cavity, so the shadows from the area surrounding the cavity would be nullified [disappear] when the moon was close to the sun. For if it has been said that the moon, when in opposition to the sun, is not truly in opposition— I mean that the two are not on two outermost points of a diameter [of a circle] but rather the moon is tilted away from the end of the diagonal that passes by the center of the sun— then it would be valid that the area around the cavity would be shaded at the time of opposition, and that would likewise be so for protruding roughness, but the response to this notion is that the tilt of the moon away from true opposition, if it had to be the case that the area surrounding the cavity had a shadow, then as circumstances change, a shadow on the area around the cavity during opposition would not be the same as that before opposition.194

Because before opposition, light did not reach the inside of the cavity as it did during opposition. So from that, it must be the case that if the notion put forth is possible— I mean, if there is a cavity on the moon— then the shadow that surrounds it at the time of opposition would be much smaller than its shadow beforehand. Because the position of the moon relative to the sun changes every hour. Thus, the marks must change in form and extent every hour, and this theory must be exactly the same as the shadows of protruding features. But the finding is contrary to that, and that is that the finding is that the form of the marks do not change, neither during opposition nor at any other time before or after [opposition], thus the marks on the moon are neither a shadow of a cavity nor of protruding roughness.

and that if light were to shine on the moon, the place [in the sky that has some density] was therefore a shadow on the surface of the moon — well that is debunked with what we relate [as follows]: and that is that if there were considerable distance between that place and the moon, then there would be visible differences. So this opinion is debunked just as the idea said about vapor was debunked. And if the distance between it [the dense place] and the moon was a small distance, and there were no visible differences because of its proximity to [the moon], then this place would be in the celestial sphere of the moon and close to the moon’s body, so the response is that this [dense] place is either in the epicycle or in the celestial sphere surrounding the epicycle. And if it were in the celestial sphere surrounding the epicycle, and if the epicycle then moved with its own particular movement – I mean its movement around its center – the moon set in motion. And if the moon was set in motion, the moon would exit the azimuth that had resulted from the distance between it\footnote{wa inna al-ḍaw’-a jidhā asharaqa ‘alā al-qamar-i kāna li-dhālika al-mawḍī’-i zill-un ‘alā saṭḥ-i al-qamar-i, fa-inna dhālika yabṭul-u bi-mā nāḏkur-u-hu: wa huwa anna-hu in kāna bayna dhālika al-mawḍī’-i wa bayna al-qamar-i bu’d-un muqtadir-un fa-inna-hu yakūn-u la-hu ikhtilāf-u manzar-in. fa-yabṭul-u hāḏhā al-ra’-u ka-mā batala ra’y-u man yaqūl-u inna-hu bukhār-un. wa in kāna al-bu’d-u alladhī bayna-hu wa bayna al-qamar-i bu’d-an yasīr-an wa laysa la-hu ikhtilaf-u manzar-in min ajl-i qurb-i-hi min-hu, fa-inna hāḏhā al-mawḍī’-a huwa fi falak-i al-qamar-i wa qarīb-an min jirm-i al-qamar-i, fa-I-jawāb-u huwa anna hāḏhā al-mawḍī’-a imma an yakūn-a fi falak-i al-tadwīr-i aw fi al-falak-i al-muḥṭīf-i bi-falak-i al-tadwīr-i. fa-in kāna fi al-falak-i al-muḥṭīf-i bi-falak al-tadwīr-i, fa-inna falak-a al-tadwīr-i idhī taḥarraka bi-ḥarrakat-i-hi allaṭī takhuṣṣ-u-hu, a’nī ḥarrakat-a-hu hawla markaz-i-hi, ḥarraka al-qamar-u. fa-irdhā ḥarraka al-qamar-u kharaja al-qamar-u ‘an al-samt-i alladhī šāra min bu’d-in bayna-hu}
and the sun, and the marks on the moon would be nonexistent. And the finding contradicts that, I mean that the moon is not sometimes devoid of marks because of a dense part in the celestial sphere surrounding the epicycle. For if this dense place upon the epicycle were close to the lunar body, it would be upon one area from the sections of the moon, because its position relative to the epicycle would not change; so, its position relative to that body [the moon] doesn’t change because each part is relative to each body; however, if it [the dense place in the sky] moves, then it would cross that body [the moon], and it is not possible for the body of an epicycle to be pierced [crossed]. So the position of the dense part of the epicycle does not change. And the position of the moon in the epicycle does not change. So this dense area only exists upon one area among the sections of the moon. And the sun is constant, whether to the west of the moon or the east: as for the beginning of the month until the full moon, the sun is to the west197

of the moon, and from the full moon through the end of the month, it is to the east; and, from the beginning of the month through the full moon, the epicycle has moved the moon, transferring it from one side to the other. So if it was the sun, and the moon, and the dense part [of the sky] halfway between the sun and the moon, then it is not fixed at this position except momentarily, then the epicycle would move it with the rotation of this dense part and with the rotation of the moon; so, the dense [part] would exit from the azimuth that is between the sun and the moon, and ends up sometimes north of the azimuth and sometimes south, and sometimes this dense part would be east of the lunar body with the sun to the west of it, and sometimes to the west of it [the lunar body] with the sun to the east of it; for the moon quite often becomes a secant to the azimuth that is between the dense area and the sun, and the dense part [in the sky] does not leave a shadow on the surface of the moon except at particular times and most of the time the moon would be devoid of this shadow.\footnote{198}

So from this notion, it must be that the marks are present on the moon [only] some of the times, while most of the time it is devoid of marks. But the reality is contrary to that, and that is that the marks are ever-present on the surface of the moon, in a defined location, and of a singular form and uniform size. Thus, the marks that are on the surface of the moon are not a result of a dense location in the sky.

And we have made clear from all we have explained the flaw in the theories aforesaid. And it has also been made clear that the marks are part of the moon itself, since it has been made clear that they are neither external from its body nor an image appearing in reflection. Thus it remains for us to explain the true nature of these marks. Therefore we say [the following]:

*Ibn al-Haytham’s theory*

The substance of the moon is different from the rest of the stars, and the indication for that is that all of the stars are illuminated from within, not from

---


the sun shining upon them, and we’ve made this theory very clear in our book on the light of the stars. Since the stars are illuminated internally, without needing the sun to shine on them, and the moon is not lit from within until the sun shines upon it, the substance of the moon is thus different from the substance of the rest of the stars. And if the substance of the moon is different from the substance of the rest of the stars, then it is not impossible for there to be a difference in their parts, be it their substance, or density, or light. And if that is so, then we say decisively that the body of the moon is not uniform in all its parts. And the indication for that is that if the parts were all the same at all times, then its light that appears on its figure would be the same in all its parts, and yet its light is not the same in all its parts due to the marks that appear on it. And it has been made clear that the marks are neither on account of a concept external to its body, nor due to reflection.  

---

And if the marks are not on account of a concept external to its body and not due to reflection, then the marks are on the body of the moon itself. And if the marks are on the body of the moon itself, then its [the moon's] light is not the same in all its parts, rather the light of some of its parts is different from the light of the remainder of its parts. And if the light of its parts differs, then its body is not the same conditions in all of its parts. So the position of the marks, therefore, on the body of the moon, is different from the rest of the moon’s body – in some measure of difference due to that position being of different light than the rest of its body.

And if the moon was receiving light from the sun differently, while not being lit from within, then it receives light from the sun varyingly. Because if it accepted light uniformly, then its light would be the same in all its parts. And if its light was not the same, then the position of the marks would be lesser in illumination and light in comparison to the rest of its body, and its receipt of light would not be the same. And if the reception of light was not uniform,\(^\text{201}\)

\[^{201}\text{wa idhā lam yakun al-athar-u li-ma’ná khārij-in ‘an jirm-i hi wa lā bi-l-in’ikās-i fa-l-athar-u huwa fi nafs-i jirm-i al-qamar-i, wa idhā kāna al-athar-u fi nafs-i jirm-i al-qamar-i fa-laysa daw’-u-hu mutashābih-an fi jami’-i ajzā’-i hi bal daw’-u ba’d-i ajzā’-i hi mukhālif-un li-daw’-i baqiyyat-i ajzā’-i hi. wa idhā kāna daw’-u ajzā’-i hi mukhtalif-an fa-laysa jirm-u-hu mutashābih-a al-ahwāl-i fi jami’-i ajzā’-i hi. fa-mawḍū’-u al-athari idhan min jirm-i al-qamar-i mukhālif-un li-baqiyyat-i jirm-i al-qamar-i naw’-an min al-liḥtīlāf-i min ajl-i hi kāna dhālika al-mawḍū’-u mukhālif-a al-daw’-i li-baqiyyat-i jirm-i hi.}

then the position of the marks would not receive light as does the rest of the lunar body. For the kind of difference that is in the body of the moon, by which the position of the marks differs from the rest of its body, is a phenomenon that inhibits the reception of light with some barrier. Thus sections of the lunar body are different and the position of the marks therein differ from the rest of its parts such that it prevents it from fully receiving light. If that is so, then the true nature of the marks is that they are a darkness on the body of the moon caused by the fact that that part does not fully receive light. So it remains for us to examine the quiddity of import preventing the affected part from fully receiving light. We say:

That every transparent body receives light and conveys light, and every dense body receives light but does not convey light. And as for indicator that a transparent body receives light, it is the penetration of light within, for were it not able to receive light, then light would not be able to penetrate into it, and the penetration of light is evident, thus the reception of it is evident.202

---


And as for the indicator that a dense body receives light, well that is the visibility of light on its surface and its fixedness there, for were it not to receive light, then the light would not hold on its surface and would not be visible, and furthermore, every body has some transparency and some density within, such as glass, water, and clear stones, such that if light shines upon them it would penetrate and be visible to some extent, for they receive light in the two aspects together.

Additionally, if light shined upon different dense bodies, the form of light within would differ in accordance with their colors, smoothness and roughness, and according to the strength and weakness of their density. Similarly, light appears differently in various transparent bodies in which there is some density on account of their color, density, smoothness and roughness, and in all circumstances, when light shines on similar bodies, the form of light is the exact same. And the bodies different in color, density, smoothness and roughness – the form of light upon them appears with varying appearances.²⁰³

---

And what results from all of that is that every body has the receiving power for light – and that the body uniform in its parts at all times has the same receiving ability in all its parts, and the form of light that appears on it is the same on all its parts – and that the body different in its parts, its receiving ability [for light] in its [different] parts varies, and therefore the form of light that appears on it is different [from part to part].

And if that has been made clear, then it has been made clear that the moon has a receiving ability for light. Because it has been made clear that the light that appears on it is light that it receives from the sun. And if it receives light from the sun and the light is fixed and visible on its surface, then it has a receiving ability for light. And it has been made clear that its receiving ability is different across its parts because the form of light that appears on the moon is varied and it is not uniform of parts. And if the body only received light as a result of its receiving ability, then the strength of the light and its weakness

---

204 wa alladhī yataḥṣal-u min jamī‘-i dhālika huwa anā kull-a jism-in fa-fi-hi quwwat-un qābilat-un li-l-ḍaw‘-i, wa anna al-jism-ā al-mutashābih-ā al-ajzā‘-i fi jamī‘-i āḥwāl-i-hi takūn-u al-quwwat-u al-qābilat-u fi jamī‘-i ajzā‘-i-hi mutashābihat-an wa takūn-u ’ṣūrat-u al-ḍaw‘-i allāti tazhar-u fi-hi mutashābihat-an fi jamī‘-i ajzā‘-i-hā, wa anna al-jism-ā al-mukhtalif-ā al-ajzā‘-i takūn-u al-quwwat-u al-qābilat-u fi ajzā‘-i-hi muhtalifat-an fa-takūn-u ’ṣūrat-u al-ḍaw‘-i allāti tazhar-u fi-hi muhtalifat-an.

truly are due to the increase of the receiving power and its decrease, or on account of its strength and its weakness. Then the difference of the light that appears on the moon is truly because of the variation of the receiving ability that is in the parts of the body of the moon. And if all that is so, then the quiddity of the import preventing the affected part that exists on the moon from fully receiving light is the weakness of the receiving power for light that is in the affected part and is its inability for the receiving ability that is in the rest of the moon’s parts. 

And this phenomenon is the cause of the marks, and the difference of this ability [for receiving light] in parts of the body of the moon is truly due to the difference of the condition of the parts of the body of the moon. Thus it remains for us to examine the reason that this receiving ability of the position of the marks is weaker than the receiving ability [for light] that is in the rest of the body of the moon, and this cause is nothing but [on account of] the condition of the part of the body of the moon affected by the marks, so we say:205

That every transparent body receives light and conveys it to what is behind it, and every non-transparent body does not convey light to what's behind it, ergo we say that the receiving ability is not [due to] the transparency. And the indication of that is that when light shines upon the transparent body, it is fixed on it and also passing through it, and the fixedness is not penetration, and the two are opposed, thus the phenomenon by which light remains fixed upon transparent bodies is not the phenomenon by which light penetrates it. And it has been made clear that the phenomenon by which light penetrates is [due to] the transparency, so the phenomenon by which light is established [on a body] is not transparency.

As for the fact that light is fixed upon transparent bodies, we have explained it in our book on optics, where we discussed the attributes of light. And we explained therein that light passes through air and transparent bodies, and with that if light penetrates every point of a transparent body, then a secondary light would shine from it to every point opposing it.²⁰⁶

---

And were light to only penetrate the transparent body and not remain fixed within it, then a secondary light from this light would not shine from each point of the transparent body. And if the transparent body has a fixed light that the transparent body had received along with the penetration of light in it, then the ability in the air and in transparent bodies that holds light steady within them is not the transparency, but rather the receiving ability that is within the transparent body, because the phenomenon by which fixedness exists is receptivity, as every transparent body has a receiving ability and a transmitting ability [for light], and each of these two is not like the other.

And every dense body, if it has no transparency within, then light does not reach its interior. And the indicator of that is that if light shined on the dense body and remained on its surface, when it is cut off from the side opposite to the side of light, there would be no light at all in the location of the disruption. And a transparent body, which has some transparency within, if it were cut off,²⁰⁷

light would be found in the location of the disruption. For the exterior of every
dense body has a receiving power for light. If light reached the interior of the
transparent body, and every position on the transparent body received light, and
when light arrived to every dense body’s surface, it was received and fixed, then
every body that light reached would receive light. And if that were so, then every
body that has a receiving power for light, if light arrived to it, received it. And
there is nothing that inhibits the arrival of light to bodies except density, for the
density that is in the body prevents light from reaching into the interior of the
body. And light does not reach the surface of every body, on the contrary, it does
not reach its surface because a dense cover prevents light from reaching its
surface. For the density in the cover is what prevents light from reaching the
surface of the concealed body. And if light reached every body, then a receiving
power for light is in them, and every light that was reaching the bodies, the bodies
receive it [light], and the locations that light did not reach were due to density.²⁰⁸

hence density is the hindering cause for bodies from the reception of light together with its obstruction of the transparent bodies from the conveying and transmittance of light. Nothing prevents bodies from receiving light except density, because nothing prevents light from reaching them except density.

And also, we find that bodies receive light differently, such that a white body receives light more than does a black body. Similarly, all colored bodies receive light differently in accordance with their colors. The clearer the body in color, the stronger its reception of light with the light appearing stronger within it, while the darker the body in color, the weaker the reception of light and the light [within] weaker – if light that shines on all of the colored bodies remained equal – when a strong light shines on a colored body, its color would appear brilliantly clear, or in it would be some thinness and the light within would appear strong. And if a weak light shined on it, its color would appear strong and the light within would appear weak.


And the reason for that is that sight perceives every light in a colored body and perceives it as mixed with the color that is in that body, so the form of color darkens the light, and the form of light weakens the color. And we have explained this phenomenon clearly in our book on optics. Color is always connected to density, which is a counter to transparency, and color only exists with density because any body that has no density in it, I mean to the utmost degree of transparency, then there is nothing of color in it.

We are not saying that color is density, because a very dense body could be lightly colored, like white stones, and a body could have some transparency and yet be darkly colored, like agate and emeralds and the like, therefore the manner of color is not the mode of density. However, color only appears in a dense body or in a body that has some density, and color is not found in a transparent body that has no density. Thus density is the location of the form of color and the image of color is a decoration unto it, it is like the material of color, density with color.

---


like the material and the form that are always found together, and one does not exist without the other. And if density was a material for the image of color, then the strength of density would increase the shade of the dark color and would decrease the clearness of clear color. The increase in the shade of the dark color and decrease in the clearness of the clear color darken the light that is present in the lit body. Thus the density that is in every lit body darkens the light that is in the lit body. And if density darkens light in every lit body, then density truly impedes the receiving power for light and weakens it. And if that is so, then all density is the hindering of bodies' ability for receiving light from receiving light.

And yet light is fixed upon dense bodies and appears on them as a result of the increase of the ability of reception over obstruction. Obstruction caused by density differs in strength and weakness, so if the receiving power for light on dense bodies is constant while the density varies, then in densest bodies obstruction is strongest and light weakest.211

---

Since all that has been made clear, let us return to the situation of the moon, thus we say: that the moon receives light from the sun, and it is not transparent, so the moon has the receiving power for light but not the ability to transmit light. And the moon’s reception of light despite not being transparent is clear proof that the ability to receive light is not the same as the ability to transmit light. And within this evidence is confirmation of that which we have presented previously, which is that the receiving ability [for the light of the moon] is not the transmitting ability that is in transparent bodies [which allow light to pass through them]. And it has been explained that the moon’s reception of light varies, and that some of its parts receive light fully and some of them, such as the location of the marks, do not receive light fully, and that that is a constraint that prevents the location of the marks from light. And if the entire body of the moon had the receiving power for light and the location of the marks, which does not fully receive light, did not receive light [due to] the constraint preventing it.

it has been made clear that density impedes the receiving power for light, and that nothing impedes the receiving ability except density, and the more solid the density the stronger its prevention of the ability to receive light, for the weakness of the receiving ability that is in the position of the marks is in fact a result of the strength of the density that is in that location, so the position of the marks, then, does not fully receive light because in it the density prevents it from complete reception [of the light from the sun]. And the entire moon is dense. And since that is the case, then the position of the marks on the moon has a greater density than the density of the rest of the surface of the moon, and this increase is what prevents the marks from fully receiving light. So the reason that the receiving power for light that is in the position of the marks is weaker than the receiving ability that is on the rest of the moon’s surface is the greater density of the position of the marks compared to the density that is on of the rest of the surface of the moon. And this is what we set out to explain in this examination.²¹³

It has been made clear that all colored bodies, if a strong light shines upon them, its color would dilute or would have some clearness, and the light within would appear strong. And if a weak light shined upon it, its color would appear strong, I mean more saturated and darker [in comparison] to its color when a strong light shined upon it, and the light within it would appear weak. And the reason for that is that every light that the eye perceives in a colored body is perceived as mixed with the light that is in that body. And the moon has its own color that appears during its eclipse and especially during a total eclipse, and it also appears during a solar eclipse, and especially when fully or mostly eclipsed, and it is a dark color, as if blackness tinged with red. And if the moon is **considered and contemplated** (my emphasis) during its eclipse, its color would be found as we have related it. Also, on the second and third nights of the month, the moon's roundness is visible, and its rim appears luminous.\(^{214}\)

and its body in the center of the roundness appears dark – for the moon's own color is a dark color, and the light that is visible there the rest of the times is in fact the light that it derives from the sun when it shines upon it, and the light that it obtains from the sun is a strong light, and its [the moon's] receiving power for light is extraordinarily strong – stronger than the receiving ability that is on the earthly bodies. Therefore its [the moon's] dark color is concealed by the hyper-power of light that is on it and its hyper receiving ability [for light], and yet its color had darkened the light that reached it, and if it were not for the darkness of its color, then its light would be stronger, the proof of that being what can be seen of the color of earthly bodies when sunlight shines upon them. And because the light that is on the position of the marks is weak and not of the strength of light found on the rest of its surface, its color necessarily becomes tinted – the color that is peculiar to this position is mixed with the light there. And because the light there is not to the utmost degree, the color appears concealed.

\[215\]
So the marks that appear on the face of the moon are the color of the moon mixed with the light that reaches there. And it appears in this location more than the rest of the surface of the moon because the light that is in this location is weaker than the light that is on the rest of the surface of the moon. And the weakness of the light in this location is due to the weakness of the receiving power for light that is in this location, and the weakness of the receiving ability in this location is due to the increase of the density of this position relative to the density of the rest of what appears on the surface of the moon. And that is what we have strived to explain in this treatise.\footnote{fa-l-athar-u alladhī yazhar-u fi wajh-i al-qamar-i huwa lawn-u al-qamar-i alladhī yakhūss-u-hu mumtazīj-an bi-l-daw’-i alladhī yahsul-u fi-hi. wa inna-mā zahara fī hādhā al-mawdī’-i dūna baqiyyat-i saṭh-i al-qamar-i li-anna al-daw’-a alladhī fī hādhā al-mawdī’-i ad’af-u min al-daw’-i alladhī fī baqiyat-i saṭh-i al-qamar-i. wa da’f-u al-daw’-i fī hādhā al-mawdī’-i inna-mā huwa li-da’f-i al-quwwat-i al-qābilat-i lī-l-daw’-i allatī fī hādhā al-mawdī’-i, wa da’f-u al-quwwat-i al-qābilat-i allatī fī hādhā al-mawdī’-i inna-mā huwa lī-ziyādat-i kathāfat-i hādhā al-mawdī’-i ‘alā kathāfat-i baqiyyat-i mā yazhar-u min saṭh-i al-qamar-i. wa dhālika mā qasadnā lī-tabyīn-i-hi fī hādhīhi al-maqālāt-i.}

The Treatise on the Marks Appearing on the Face of the Moon is completed, from the teaching of al-Hasan bin al-Hasan bin al-Haytham.\footnote{tammat al-maqālāt-u fi al-athar-i al-ẓāhir-i fī wajh-i al-qamar-i, min qawl-u al-ḥasan bin al-ḥasan bin al-haytham.}
Conclusion

Two key contributions of this study have been to 1) make available for the first time, as I just did in the previous chapter, a full English translation of Ibn al-Haytham's *maqālat-u fī mā'īyat-i al-athar-i alladhi fī wajh-i al-qamar-i*, or "Treatise on the Nature of the Marks on the Surface of the Moon," and also to utilize this treatise in conjunction with chapter three of book four of his *Kitāb al-Manāzir*, or *The Book of Optics*, to 2) provide a new interpretation for the technical vocabulary that Ibn al-Haytham utilized for his scientific procedure in the latter while also qualifying the place of his science on the spectrum of the methods for the conduct of science. In this concluding chapter, I will review the findings about Ibn al-Haytham's methods for scientific investigation. Next, in light of these findings, we will evaluate the justification for the contemporary celebration of Ibn al-Haytham as the inventor of the modern scientific method. Finally, we will contextualize that discussion within the larger debate about the decline of Arabic science and suggest some possible avenues for further research into that important question.

The main conclusion drawn from our study into the methods Ibn al-Haytham deployed for the conduct of his science is that the methodological breakthroughs that he did achieve in his investigation of the equal angles reflection of light occupy a middle ground on the spectrum of the scientific method. I have disagreed with those scholars who have interpreted his scientific
procedure as amounting to experimental testing. Rather, I have suggested that while he did utilize *i’tibār* and its variants on the root as a technical term, it does not amount to the idea of experiment but rather connotes the meaning of making an observation of natural phenomenon under a controlled condition that otherwise would not have existed in the normal routine of things. Further, and when contrasted to his reliance on an older method of syllogistic logic in his treatise on the moon’s marks, we have also found that access to instruments with which to make this controlled observation possible is a main factor in the ability to isolate and then observe a particular natural phenomenon, such as the equal angles reflection of light, under a controlled condition.

Further, we have seen that Ibn al-Haytham’s approach towards his science in the treatise on the moon’s marks is firmly rooted in the standard notion of Greek *empeiría* (empiricism). On the other hand, he specifically conducts and presents his science on optics in a way that will allow others to repeat his observations and thereby reach the same conclusion that he arrived at. This intention for the repeatability of his science was shown to have its roots in the approach for proof prevalent in the discipline of Arabic medicine as it existed before and during his lifetime, and it marks a move on the spectrum of scientific method away from *empeiría* and into a full science of demonstration (*apódeixis*).

In short, this study has found Ibn al-Haytham as marking a transitional moment in the history of the scientific method. His treatise on the moon’s marks,
which was actually written after his *Kitāb al-Manāẓir*, shows a scientist very much still rooted in and utilizing Aristotelian logic as his scientific proof. On the other hand, his work on the equal angles reflection of light reveals the same scientist basing his findings on demonstrable proof, which would become a major feature of the modern scientific method. Demonstrable proof would eventually form a foundation for experimental testing, and Ibn al-Haytham’s most advanced science among his body of work moved towards that end while not fully arriving at it.

Next, something can be said regarding the contemporary popular revival of Ibn al-Haytham as a towering figure in the history of science in light of our findings about how far along the spectrum of scientific method he reached. A representative sample of this popularization of Ibn al-Haytham can be found in a high profile article about him that occurred in the pages of the *New York Times Magazine*. That publication had a series of issues to reflect upon Christianity’s second millennium as it drew to a close in 1999, and in the first of those issues, the novelist Richard Powers wrote an article claiming that the best idea of the millennium, the advent of the experimental method to conduct scientific inquiry, came from “an obscure Arab scientist.” Powers credited Ibn al-Haytham with having invented the very same modern experimental science used since the

---

Enlightenment. Therefore, to Powers, the very power and importance of Ibn al-Haytham’s scientific methods and discoveries lay in the fact that his emphasis on observation of data from Nature stood in marked contrast to the notion that the world “was an inscrutable riddle invented by God,”219 an Augustinian notion that he leads us to believe was a key reason why scientific enterprise failed to take root in medieval Europe. This very notion lies at the heart of Enlightenment and post-Enlightenment understandings of the relation (or, more accurately, non-relation) between reason and revelation, between science and religion. Powers popularizes Ibn al-Haytham as the most important thinker of the past one thousand years precisely because he views him as the world’s first experimental scientist. Powers enthusiastically wrote, “[Ibn al-Haytham] demolished a whole mountain of systematic theory with a single appeal to data.”220 Powers enjoins the popular culture to see Ibn al-Haytham’s entreaty to glare at the sun as an example of this "single appeal to data."

More recently, Cosmos, a television show on the Fox network in the United States that first aired in 2014, presented a pop-culture history of science programming hosted by the astrophysicist Neil deGrasse Tyson. Tyson further popularized Ibn al-Haytham as a great man of scientific genius who changed the course of history. For example, Tyson narrated the following to conclude his segment on Ibn al-Haytham:

---

219 See p. 82, Ibid.
220 Ibid.
Ibn al-Haytham was the first person ever to set down the rules of science. He created an error correcting mechanism, a systematic and relentless way to sift out misconceptions in our thinking. ... This is the method of science ... (and) it was he who put us on this rough and endless road.221

Ibn al-Haytham is the only Muslim scientist Tyson mentions in his thirteen part series. Tyson widely praises him for his revolutionary scientific discoveries in optics, but he presents Ibn al-Haytham as akin to a lone comet streaking brightly across the otherwise dark scientific night of Islamic history. The impression left for the viewer is one whereby this brilliant Muslim scientist was an aberration of his culture, a lone genius who succeeded apart from his time and despite his socio-cultural milieu. Tyson ends his segment on Ibn al-Haytham in the series _Cosmos_ by crediting him with inventing the rules and methods of modern science, just as Powers had credited Ibn al-Haytham as being the first to employ the modern experimental method.

Our own findings about the middle and transitional position Ibn al-Haytham occupies in the development of the scientific method provides an important critique to this popular revival that goes beyond our own finding disagreeing with the notion that Ibn al-Haytham invented and pioneered the experimental method of modern scientific testing. The critique goes to a deeper issue about the history of Arabic science as a long-lived tradition of intellectual activity. When Ibn al-Haytham becomes elevated and isolated as a singular genius,

---

it risks ignoring the overall and extensive tradition of scientific activity that occurred throughout Islamic culture and history, both before his lifetime as well as well after his lifetime.

In our own presentation, our findings found that Ibn al-Haytham’s science of demonstration arose out of an already prevalent notion for the repeatablity of an observation that existed in the tradition of Arabic medicine both during and prior to his lifetime. Further, we saw especially in his treatise on the moon's marks that, rather than inventing the methods of modern science, Ibn al-Haytham was quite firmly still operating within the empirical approaches of Greek science and the methods of Aristotelian logic. Moreover, just as his demonstrative science was a reflection of an already rich tradition of Arabic science preceding him, we will recall that in our literature review Rashed made the convincing point that even in the field of optics, for which Ibn al-Haytham is so famed, it was actually al-Fārisī, his successor by several centuries, who performed a modelled test (for the explanation of rainbow formation) that moved the method of science much closer to modern experimental testing than any type of observation performed by Ibn al-Haytham.

This is all brought up not to lower Ibn al-Haytham's importance in the history of science but rather to show that celebrating him apart from the larger Arabic scientific endeavor causes us to ignore that his scientific methods drew upon approaches preexisting him in the Islamic cultural milieu and, more
importantly, that the methods for the conduct of science within that Arabic tradition would actually further expand and develop to more sophisticated levels than what Ibn al-Haytham himself deployed.

I note the further development of the scientific method in the Arabic scientific activities occurring after Ibn al-Haytham as the more important critique of the contemporary celebration of Ibn al-Haytham because that point is closely intertwined with the larger debate over the decline of Arabic science. The narrative of decline can sometimes get quite polemical and culturally personal. For example, Neil deGrasse Tyson, the same person who in *Cosmos* celebrated Ibn al-Haytham, has also popularized the notion that science in the Islamic world suffered an absolute and precipitous decline after the fifth/eleventh century. In this manner his narrative further serves to isolate Ibn al-Haytham as a lone man of genius apart from his culture.222

---

222 For example, in a speech from November 05, 2006, where Tyson bizarrely links the terrorist attacks of September 11, 2001 and the lack of science among Muslims as stemming from the same religious impulse, he, after drawing an analogy that if the United States allows religion to dictate its science (as he believes Islam supposedly did after al-Ghazālī), states as a warning that "[we will] lose our civilization as happened to Islam in the 1100s ... and, if you do the math, look at all the Nobel prize winners that ever were ... and ask how many were Muslim, and it's like one maybe two ... and the one we referred to [Abdus Salam, who co-won in 1979 along with Steven Weinberg and Sheldon Glashow] is not Middle Eastern Muslim; he's Pakistani Muslim ... Had Islam not collapsed in its intellectual standing, in the year 1100, and you just do the ratios, they would have every single Nobel prize today. So that fact that it is not just a few, it is near zero, is deeply worrying. I am concerned about what brilliance may have expressed itself and did not in that community over the past thousand years."

Tyson’s slight toward Arabs, his “Middle Eastern Muslim,” is bewildering. I cite his words at such length mostly to illustrate how it is clear that Tyson, and the popular understanding of science that he represents, seems unable to see Ibn al-Haytham, an Arab and Muslim scientist, as having a continuity with the Islamic culture from which he arose.
Tyson’s view about the decline of the Arabic scientific tradition goes hand-in-hand with his also stating that Ibn al-Haytham set down the rules of experimental science, full stop.\textsuperscript{223} It allows for a lacuna to exist in the history of the methods of science as it existed in the history of Arabic science in the centuries after Ibn al-Haytham, because the pinnacle for scientific method is viewed to have already been achieved in that tradition by the fifth/eleventh century. If we are to gain a complete understanding of the development of methods for scientific inquiry prior to the exposition of the modern scientific method in 17th-century Europe, then it will not be enough to credit Ibn al-Haytham with the invention of experimental science and then jump forward by six centuries and continue the story of the scientific method from there.

As I have argued, his methods of science for his optical inquiries pushed the envelope certainly, but did not result in the full development of either experimental testing or a theory of such. Rashed has pointed to glimpses of the...

\textsuperscript{223} Tyson has popularized the notion that science was wiped-out in the Muslim world. In the same speech cited above he further states, “How do you get stars with Arabic names? It happens because there was this particularly fertile period [AD 800 – 1100] and around that three hundred year period, the intellectual center of the world was Baghdad. ... and it is all traceable not to some long thousand year tradition in Islam; it is traceable to this three hundred year period ... and so something happened ... twelfth-century kicks in and then you get the influence of [al-Ghazâlî], and so out of his work you get the philosophy that mathematics is the work of the devil and nothing good can come of that philosophy; that combined with other sort of philosophical codifications of what Islam was and would become, the entire intellectual foundation of that enterprise [Islamic science] collapsed, and it has not recovered since ... and it never recovered because the way of thinking about the natural world, revelation replaced investigation.”
modern scientific method in the work of later scientists operating in the Arabic tradition of science, and it will remain our task to examine across a wide variety of disciplines where and when Ibn al-Haytham's idea of a control observation reappeared and, more importantly, was further developed into control testing and experimentation. A continuity of further development of the scientific method in Islamic civilization, across disciplines, time, and geographic location, would provide more factual evidence against the Islamic decadence narrative that posits the idea of the absolute decline of intellectual activity in the Muslim world starting in the sixth/twelfth century.

With all that said, this particular study has strived to illustrate one aspect of one figure from the rich tradition of Arabic science. Our findings have shown that Ibn al-Haytham's methods for scientific investigation occupy a transitional position, with his approach having one foot in the methods of proof underlying Greek empirical science while also, when instrumentation allowed it, stepping forward into the idea of demonstration. For Ibn al-Haytham, this demonstrative proof was based upon a control observation (i'tibār) that results in the ability to isolate and then identify, with certainty, details of the natural world.
Bibliography


Ibn al-Haytham, “Treatise on the Marks Seen on the Surface of the Moon” 


Iqbal, Muzaffar, "Islam and Science: Responding to a False Approach," in Islam and Science, 1:2 (December 2003), Sherwood Park, Alberta, Canada: Center for Islam and Science. Pp. 221-34.


“Islamic Science Rediscovered: Celebrating a Golden Age of Science and Technology,” exhibited at The Tech Museum, San Jose, CA. 2011-12.


Qustā ibn Lūqā, Kitāb fi 'ilal mā ya'ridu fī al-marāyā min ikhtilāf al-manāzir ["A book on causes for reflections appearing from the variety of aspects"], Mashhad, Iran: Astān-e Quds-e Razavī. MS 392.


