International Journal of Computational Bioinformatics and In Silico Modeling
Vol. 3, No. 1 (2014): 321-326
Research Article
Open Access

ISSN: 2320-0634

Analogical reasoning roots in Ibn al-Haytham's scientific method of research

Sobhi Rayan*

Education department, Al-Qasemi Academic College, P.O.B. 124, Baka El-Garbiah 30100, Israel

*Corresponding author: Sobhi Rayan; e-mail: sobhi.rayan@gmail.com

Received: 10 January 2014 Accepted: 29 January 2014 Online: 03 February 2014

ABSTRACT

This paper deals with the way that Ibn al-Haytham used *qiyas* (inference and induction by analogy) as an experimental research method in the natural sciences. The paper introduces and analyzes the tools of the analogical method of research, the extent of their application to natural phenomena and discusses an example, taken from the history of the natural sciences that involve analogical qiyas methodology: Ibn al-Haytham's method of research in optics.

Qiyas was known in Islamic culture as a method of research in the religious juristic sciences, but it was used also in the natural sciences. This movement in itself can be considered an important turn in the history of science, as it constituted a change of the method of research in these sciences, from deduction, which had been prevalent for centuries, to qiyas (type of analogical reasoning). The application of this novel method of research in natural sciences at that time contributed a lot to the development of the modern sciences.

Keywords: analogical reasoning, qiyas, Ibn al-Haytham, induction, Research philosophy, Research methodology.

INTRODUCTION

Ibn al-Haytham (d. 1040) is considered one of the greatest scientists that contributed to the development of natural sciences, especially optics. David Lindberg, wrote that "Alhazen was undoubtedly the most significant figure in the history of optics between antiquity and the seventeenth century [1]. He used an experimental scientific method in his researches. “According to the majority of the Historians Ibn al-Haytham was the pioneer of the modern scientific method. With his book he changed the meaning of the term optics and established experiments as the norm of proof in the field. His investigations are not based on abstract theories, but on experimental evidences and his experiments were systematic and repeatable.”[2]

This study aims to answer the following main question, which is: what is the role of qiyas in the Ibn al-Haytham's research? To answer this question, I chose to analyze the qiyas / analogy methods that were used by Ibn al-Haytham in optics.

Ibn al-Haytham describes the method of research that he used in optics saying: "we resume looking through its principles and introductions. We start the research by deducing the visible things and look through the conditions of optics, distinguish the properties of particles, and select by deduction what is related to sight in the case of seeing, and what is repeated without change, and everything that clear and is not doubted by our senses; then we rise in our research and measurements gradually and orderly through selecting the introductions and investigation of the results, and make our aim in everything we deduce, to be based justice and objectivity rather than on our tendencies; we also detect everything that we distinguish, and criticize it in an attempt to achieve justice and objectivity rather than following other tendencies in order to reach in this way the right result that pleases everyone, and gradually, through smoothness, we reach the goal which certainty takes place, and through criticism and reservation we win the truth that solves

any disagreement, and thus the suspected material is determined." [3]

Ibn al-Haytham organizes the stages of research accurately and clearly in the following way:

1) The research starts from principles and introductions of the issue that he wants to discuss, which means that he defines the problem and studies the theoretical background that is related to it rather than starting with a pure experiment or observations that are related to the problem;
2) Then he starts deducing the existing things. Deduction is "limiting the whole into its particles and then making one judgment on the particles that applies on whole…This is an investigation of the particles in order to prove a whole judgment." [4]
3) After looking through the existing things or the particles, the stage of distinguishing the properties of the particles comes. This is an operation of Taqseem (isolation into categories) among the fundamentalists, which means isolation of attributes that are useful for finding the effective cause.
4) Selecting what is relevant to the condition that is under discussion, through selecting introductions and examination of the results, which is called by the fundamentalists as al-Sabr (examination). In other words, this is a definition of the hypotheses and examining them according to the results.
5) Distinguishing and criticism of the hypotheses in order to prove their truth. This examination leads to the correct result or truth that cannot be disproved. This stage is a kind of analysis of the findings.

We notice that these stages that Ibn al-Haytham followed are quite close to the stages of modern scientific research that scientist Bradley Steffens defined: [5]

1. Observation
2. Statement of problem
3. Formulation of hypothesis
4. Testing of hypothesis using experimentation
5. Analysis of experimental results
6. Interpretation of data and formulation of conclusion
7. Publication of findings

This comparison between Ibn al-Haytham's method of research and the modern method applied nowadays confirms the role of Ibn al-Haytham in establishing and developing the modern method of research. This great contribution entitles him to hold the title of the 'First Scientist" [5].

Experimentation (I'tibar) in Ibn al-Haytham's Method

The role of qiyas comes after deduction and testing the causes (I'lal). Ibn al-Haytham's interest in qiyas appears in the following way: when he "proves the primary principles by 'Itibar/ experimentation, he takes these principles as issues through which he deduces by Qiyas the results that lead to them." [6]

Ibn al-Haytham uses the term (I'tibar) instead of "experiment" and it seems that this term is used intentionally in order to distinguish it from the term of 'experiment' that was common in that time. 'Experiment' according to the terminology of scientists in that time, meant the 'issues' that the mind needs in order to determine his judgment regarding repetition of the observation of the things that are seen, "Takrar al-Mushahada."[4] Experiment for Ibn al-Nafis is "testing the effect of medicine before using it on the body."[7] This means exclusiveness of the concept of experiment on the procedural operation including examination and experimentation of a certain issue by repeating it.

Linguistically, the term 'I'tibar' means "referring something to its equivalent and judging it by the same judgment."[4] al-Jurjani defines it as "considering the proved judgment as reference to any meaning that has been confirmed and joining its equivalent to it, and this is the right Qiyas" [8] and "I'tibar means experiment and testing and "referring something to its equivalent and moving from it to its identical and similar things, and judging something with what is applicable to its equivalent." [10]

The term "I'tibar" was used by the Moslem scientists in the sciences of the Prophet's traditions (Hadith) and principles of jurisprudence."For the fundamentalists, 'Itibar is the cause / I'lah' of the judgment."[4] "When something is not based on its source, it is necessary to refer it to another source and judging it by that source" [11]. "The proof by experiment was called proof by 'I'tibar' in parallel with proof by Qiyas." [12] al-Ghazali (1111 AD) says that "the meaning of 'Itibar is the movement / 'ubur/ from one thing to its equivalent if it has the same meaning" [13]. "If there is movement from the tested thing to something else by pointing out the common meaning, the movement is called 'Itibar" [14]. al-Baidhawi says: "what is meant by 'Itibar' is the common amount between qiyas and learning of a lesson (Itti'az), and the common between them is the attribute of 'transcendence'; qiyas transcends the source to the "the Fari'" and Itti'az / learning a lesson is movement from the state of the other to the state on oneself." [15] Ibn Rushd says that "I'tibar is not more than deducing the unknown from the known, and extracting it from it, and this is qiyas/ analogy or by qiyas." [16]

However, the term 'Itibar' for Ibn al-Haytham is not merely a technical term or a kind of proof to prove specific issues in optics, but an experimental research method that deals with issues such as reflection of light by showing the manner of its reflection, and showing the cause of its reflection and showing the mechanical aspect that represents an important component of

'Itibar. “Experimental skill is a feature of Ibn Al-Haitham' researches, even the simplest optical experiment is performed only with the best apparatus accuracy.” [17] Sabra writes, “But what seems to have acquired a new emphasis in the Optics of Ibn al-Haytham is the explicit use of experimentation as paradigmatic type of proof to be distinguished from other types of proof occurring besides it". [18]

“The term 'Itibar' was used by scientists of astronomy and optics before it was used by Ibn al-Haytham. For example, AbiAbdAllah al-Battani, IbnQurra al-Harrani, and Ahmad IbnIssa used the term 'Itibar' in the course of their description of the two sciences that are mentioned by Ptolemy from Alexandria.” [19] Astronomers used this term before Ibn al-Haytham in their translations of the Greek word σύγκρισις which means "comparison".

However, the observers at the two observatories in Baghdad and Damascus during the rule of the Abbasid caliphs, Ma'moun and Mu'tassem, tried to cultivate ancient meteorological observation using the terms "imtihan/ test/ examination', or 'tajribah/ experiment'. Then followed the period of absorption and critical analysis of the inherited science from the previous classical period led by AbiSa'd al-Alaa' bin Sahl and AbiSahl al-Quhi and others. The term ''Itibar' became more frequently used by scientists.”[23]

We notice that the translation of the Greek terms σύγκρισις, πεῖρα did not sufficiently convey the meaning of the term "'Itibar" that was current in Islamic sciences. In addition, they do not express the indication of 'I'tibar' in the studies of Ibn al-haytham. Therefore, it is difficult to attribute the term 'I'tibar' as used by Ibn al-Haytham to the astronomy scientists as Sabra claims: "A result of taking over into optics an idea which had had an established career in astronomy."[22]

'Itibar is not merely a procedural operation that is deduced by terms like "imtihan/ examination,' or 'mihna/ plight,' or 'tajribah/ experiment.' The concept of 'Itibar by Ibn al-Haytham is broader in its indication at the experimental level, and "this concept is close to what is called today 'experimentation', but it is also connected to proof and experimentation that aspire to be sure of the hypotheses in their critical efficiency of science… and the concept of 'Itibar' has historical roots among previous scientists such as Ptolemy and Galinus, and later scientists such as al-Quhi and IbnIssa, but the term gained indicative capacity and rich and fertile methodological systematic use in the context of the structural and critical work conducted by Ibn al-Haytham."[23]

From what has been said above, we can conclude that 'Itibar' is a current and familiar term and concept in Islamic culture. Thus, Ibn al-Haytham's use of the term is in harmony with the linguistic and terminological scientific meanings that were current in those days, and it is closer to the scientific meaning that was used in Islamic sciences than its currency among earlier classical scientists such as Ptolemy and Galinus.

Tools of Research in Ibn al-Haytham's Method

a) Rule of Omission

Ibn al-Haytham used the rule of 'omission,' which is considered one of the bases of verification of hypotheses in an experimental way where the researcher does not leave any hypothesis without making sure that it is correct. Ibn al-Haytham uses the term 'Sabr/ examination" which implies knowledge of the truth and cause of a certain issue in an experimental way; it is a term that indicates decisive experimental verification of the causes that constitute interpretation or correct justification of the phenomenon. al-Sabr in Ibn al-Haytham's view is a decisive experimental way that enables us to count or define the main reasons that lie behind the appearance or non-appearance of this phenomenon or that, and exclusion of all the other reasons that are not considered effective elements in their presence or absence. In this way, we can be certain about our own work” [20]. al-Nasshar adds that "the rule of omission, including Sabr, are among the important rules in the decisive experimental verification of the hypotheses, not for Ibn al-Haytham only, but for other philosophers who adopted it such as Jabir Ibn Hayan."[16]

b) Rule of Moderation

The rule of moderation is considered one of the basic rules in the field of scientific research conducted by Ibn al-Haytham It says that "we should be ready to give up our hypotheses or moderate them if they do not meet our reality, or they mean the correction of the hypotheses, or the hypotheses do not contradict reality."[7] Thus, confirmation of the hypothesis or its refutation depends on experiment.

c) The Way of Refutation

After the research confirms of the correctness of the hypothesis in a certain condition by experiment, he tries to generalize the result on other similar conditions. This method can be considered as a correcting tool of the experimental rule because we reach the stage of coining the rule through testing the hypotheses experimentally. If the hypothesis turns out to be correct, the experimenter will be able to apply his method on other similar conditions and thus it becomes a rule. That happened when Ibn al-Haytham studied the manner of the feeling of sight. He said: “there are two contradicting schools of research. "Every two doctrines are different. Either one of them is right and the other is wrong, or the two are wrong. The truth is different. They can both convey the same meaning, which is the truth, and thus, each of the two schools can be considered insufficient in its research method.”[27]

d) Qiyas al-Tmthil / Analogy of Likeness and Comparison

We notice that Ibn al-Haytham employs qiyas through comparison between two pictures in order to know the degree of similarity and likeness between them.

"Realization does not take place except by a comparison between the picture of the seeing person with a picture that he has seen and realized before. The realization of the likeness between the two pictures happens then. The likeness between the two pictures happens only by qiyas."[6] "Ibn al-Haytham uses the technique of comparison and likeness to prove the rule of reflection."[6] He means by 'Tamthil' moving the judgment from one.

Ibn al-Haytham wanted to show the cause of refraction and explain how it takes place, and why light refracts in the way it does. His theory was the theory of likeness and comparison with a mechanical sample, called 'resistance,' which is a "property that exists in the resisting body that makes the moving body bounce back if it is thrown against it." [21] As we see, Ibn al-Haytham shows the cause of reflection or the manner of its happening by giving a mechanical example where the reflection of light and rate of its speed and movement are calculated according to the polished and smooth surface that bounce back the ball from the surface of the iron mirror. He showed that if the distance from which the ball is thrown increases, the power of its bouncing back will increase. We conclude that Ibn al-Haytham transfers the judgment from one phenomenon to another one that resembles it in one of their common properties. This indicates movement from one part to another part.

e) The Method of Rotation/ Co-extensiveness

The method of rotation/ co-extensiveness is known for the fundamentalists as 'the existence of judgment by the existence of the attribute. Ibn al-Haytham applies this method in his studies of optics to prove the cause/ 'Illah and understand the relation between cause and effect. "If the cause/ 'Illah is cancelled, the effect is cancelled. If it returns, the effect returns. The cause/I'llah that causes that relation in sight is the thing that is seen."[6] Besides, the rotation of I'llah/ cause with the ma'lul/ effect in different conditions proves the existing relation between two variables. Ibn al-Haytham used this maslak/ method in his researches on optics, saying: "and if all optics are deduced in all times and is experimented on and edited, then it will be as we said, co-extensive; it does not differ or change."[3]

The methods which Ibn al-Haytham used in his experimental research are the same methods that were used by the scientists who worked on the sources of jurisprudence, and which were known as masalik al-'Illah/, methods of identification of causes. These methods are based on principles like causality, probability, variables, and concrete seen phenomena. These characteristics make these methods useful for the research of experimental sciences, no matter how much these issues and phenomena differ.

The Role of Mathematics in Natural Sciences

Ibn al-Haytham attributes the disagreements among the researchers on the subject of optics to the difficulty of research. "Certainty is impossible and the desired things are not sure to be reached; facts are ambiguous and the goals are hidden; suspicions are numerous; understanding is unclear; measurements are different; introductions are realized by the senses; the senses are not immune from making mistakes; the road of sight is without traces and the diligent researcher is not immune from making errors."[3] The difficulty of research requires combination of the two methods of natural sciences and educational sciences."Ibn Al-Haitham saw clearly both the physical interpretation of vision in the form of the image and its mathematical interpretation in terms of rays passing from object to eye." [22]

Ibn al-Haytham's attachment to natural sciences is due to the fact that 'sight' is one of the senses, and the senses are natural issues. His attachment to educational sciences is due to the fact that sight conceives of form, position, size, movement and stillness. In spite of that, it has connection with straight azimuths. The search for these meanings can be done by educational sciences. The search for this meaning has rightly become a combination of natural sciences and educational sciences [22]. Ibn al-Haytham emphasizes the specialization of each of the two fields: "Discussion of the entity of light is one of the natural sciences. Discussion of rising of light requires educational sciences for the rays upon which it extends." "He himself viewed his own theory as a synthesis of the "physical" doctrine of forms and the "mathematical" approach of the visual-ray theory."[18]

In another place, Ibn al-Haytham describes his method saying: "dealing with the issues of optics consists of natural and educational methods. The natural method is used to deduce the conditions of the existing things as they exist in the visible reality and the educational method is used to assist in mathematical proofs. However, realization and distinguishing by qiyas require looking through, investigation and exploration of all the meanings or their majority."[6]

He was also the first scientist to adopt a form of positivism in his approach, centuries before a term for positivism was coined. He wrote that "we do not go beyond experience, and we cannot be content to use pure concepts in investigating natural phenomena, and that the understanding of these cannot be acquired without mathematics. After assuming that light is a material substance, he does not discuss its nature any further but confines his investigations to the diffusion and propagation of light. The only properties of light he takes into account are that which can be treated by geometry and verified by experiment, noting that energy is the only quality of light that can be sensed." [24]

al-Marzouqi explains the significance of the combination between mathematics and the experimental method in modern science: "the mathematical organon of concrete realization or the

experimental method that is can be coined from the natural method mathematically due to its treatment by the mathematical organon constitutes the all the sciences, the head of which is the science of optics. This organon depends on a new conception of separation between the purely theoretical mathematical (which is more general than the science of numbers and geometry), and the purely applied mathematical (which is more general than the science of music and astronomy), considering the first as a subject of science of theoretical explanatory pattern of general science or the pure logic; the second is a subject of the science of theoretical explanatory patterns of specific science (of a certain subject), or the applied logic." [25] "Therefore, Ibn al-Haytham adopted the natural method, which is the exploration of the conditions of the existing things as they are in the visible reality: however, the educational significance lies in the geometrical proofs." [26]

In addition to the contribution of Ibn al-Haytham to the establishment of experimental science on scientific criticism and doubt, "he criticized the previous experimental methods that were put forward by Ptolemy." [27] He also criticized Aristotle's inductive method. "Ibn al-Haytham also employed scientific skepticism and criticism, and emphasized the role of empiricism. He also explained the role of induction in syllogism, and criticized Aristotle for his lack of contribution to the method of induction, which Ibn al-Haytham regarded as superior to syllogism, and he considered induction to be the basic requirement for true scientific research" [28].

Ibn al-Haytham explains also the importance of the scientific qualities of the researcher:"the seeker after the truth is not one who studies the writings of the ancients and, following his natural disposition, puts his trust in them, but rather the one who suspects his faith in them and questions what he gathers from them, the one who submits to argument and demonstration, and not to the sayings of a human being whose nature is fraught with all kinds of imperfection and deficiency. Thus the duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and, applying his mind to the core and margins of its content, attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency." [29]

Ibn al-Haytham's use of qiyas as a method of research in physical sciences contributed also to the development of these sciences and to making them experimental sciences in the modern sense of the word. The influence of this development was not exclusive to natural sciences in Islamic culture, but was reflected also in the development of optics in the West. Ibnal-Haytham's most important optical work was his Kitab-al-mandzir (Book of optics), which was translated into Latin as De aspectibus or Perspectiva. This treatise had a profound effect in the Latin west. Influencing the work of Witelo (1225-1275), Roger Becon (1220-1292), John Becham (1250-1292), and many more. Traces of Ibn Al Haytham's theories are even found in the seventeenth century optical writings of Kepler and Newton." [30]

The direct influence of the theories of Ibn al-Haytham on the scientists of natural sciences in the West undoubtedly contributed to the development of modern Western culture. "His theory in which an important analysis of the physical process of sight can be found explains for the first time in middle ages the two principles of light and perspective whose impact upon European culture of the medieval and modern eras has been very relevant."[2]

From what has been said, we conclude that qiyas is an experimental research method that was employed in the field of natural sciences. Qiyas is considered an inductive inferential method according to which judgment or conclusion is taken through movement from the partial to the whole, from the specific to the general. Thus, it is a research into specific particles and the conclusion is generalized and applied on similar cases, or a general rule is made after conducting experiments on specific particles.

CONCLUSION

This paper describes the method of research used by Ibn al-Haytham in his OPTICS experiments. Ibn al-Haytham utilized a method of inference and induction by analogy termed "qiyas" as an experimental research tool in the natural sciences. Qiyas was known in Islamic culture as a method of research in the religious juristic sciences, but it was used Ibn al-Haytham and others in the natural sciences. This movement is considered an important turn in the history of science, as it constituted a change of the method of research in natural sciences, from deduction, which had been prevalent for centuries, to qiyas (type of induction). The application of this novel method of research in natural sciences at that time contributed a lot to the development of the modern sciences.

Acknowledgments

The author would like to thank the reviewers for the valuable comments.

REFERENCES

1. Lindberg, David C. Theories of Vision from Al-Kindi to Kepler.Chicago, University of Chicago Press, 1976, p.58.
2. Rosanna Gorini. "alHaytham the man of experience. First Steps in the Science of Vision". JOURNA OF THEINTERNATIONAL SOCIETYFOR THEHISTORY OF ISLAMIC, Institute of Neurosciences, Laboratoryof Psychobiologyand Psychopharmacology,Rome, Italy, Vol 2.No 4. October 2003, 53-55, p. 55.
3. Ibn al-Haytham (1983).al-Manazir. Ed. by Abd al-Hamid Sabra. Kuwait. The National Council for Education.p. 62.
4. al-Tahanoy (1998). KashafIstilahat al-Funun.Vol. 3.Beirut, Dar al-Kutub al-'Ilmiyyah.P. 576.
5. Bradley Steffens (2006), Ibn al-Haytham: First Scientist, Morgan Reynolds Publishing, (Bradley Steffens, "Who Was the First Scientist?", Ezine Articles.)

6. Nazif, M. (2008). al-HassanIbn al-Haytham: His Researches and Discoveries in Optics. MarkizDirasat al-Wahda al-Arabiyyah, p. 138.
7. Ibn al-Nafis.al-Mujaz fi al-Qanun. LKNO, 1322 h. p. 224. Mursi, p. 210.
8. al-Jurjani (1413). Mu'jam al-Ta'rifat/ Dictionary of Definitions. Ed. By Muhammad al-Minshawi.Dar al-Fasila, p. 29.
9. al-Fayyumi. Al-Misbah al-Munir. P. 202.
10. al-Hanafi. Sadr al-Shari'ah.Al-Tawdhih li Matn al-Tanqih. Vol. 2, p. 54.
11. al-Jassas. Ahkam al-Koran.Vol. 1, P. 440.
12. al-Munshar, A. Sami (1996). Manahij al-BahthindaMufakkiri al-Muslimin.Cairo, Dar al-Ma'arif. P. 370.
13. al-Ghazali. al-Mustasfa. Beirut. Dar al-Kutub al-'Ilmiyyah. P. 293.
14. al-Ghazali (1993). Asas al-Qiyas.Al-Riyadh.Dar al-'Abikan. P. 105.
15. al-Baidhawi (1980). Nihayat al-Soul fi SharhMajhaj al-Wusul. Beirut. Alam al-Kutub. Vol. 4, p. 11.
16. IbnRushd (1994). Fasl al-Maqal ma bayna al-Hikmatiwa al-Shari'ah. Beirut. Dar al-Fikr al-Lubnani, p. 35.
17. Mohaini Mohamed. Great Muslim Mathematicians. Malaysia, Johor DarulTakzim,2000, p.52.
18. A.I. Sabra. Optics, Astronomy and Logic. Collected studies; CS444 Collected studies, Aldershot, Hants : Variorum, 1994, p.134.
19. al-Ba'zati, B. (2010). "Mafhoum al-'ItibarladaIbn al-Haytham."NadwatTarikh al-'Ulum. Markiz al-Banna al-Marakishi li al-Buhuthwa al-Dirasat fi Tarikh al-'Ulum al-'Islamiyyah. Ribat.Maghreb.24th of February.
20. Ibrahim, D. (1995). al-Ittijah al-'Ilmiwa al-FalsafiindIbn al-Haytham. Cairo. al-Haya'ah al-Missriyyah al-Ammah li al-Kitab. P. 201.
21. Mousa, J. (1972). Manhaj al-Bahthal'Ilmiind al-'Arab. Beirut. Dar al-Kitab al-Lubnani, p. 103.
22. H. J. J. Winter. "The Optical Researches of Ibn Al-Haitham.Centaurus, Volume 3, Issue 1, (190-210), 1953, p.196.
23. Ibn al-Haytham.Risala fi al-Dhou', p. 19. In: Mousa, J. Manhaj al-Bahthal'Ilmiind al-'Arab. Beirut. Dar al-Kitab al-Lubnani, 1972, p.94.
24. Rashed, Roshdi (2007), "The Celestial Kinematics of Ibn al-Haytham", Arabic Sciences and Philosophy (Cambridge University Press) 17: 7–55 [19]
25. al-Marzouqi, A. (1994). Islah al-'Aql fi al-Falsafa al-'Arabiyya.Beirut, MarkizDirasat al-Wahda al-'Arabiyyah, p. 194.
26. Mousa, J. (1972). Manhaj al-Bahthal'Ilmiind al-'Arab. Beirut. Dar al-Kitab al-Lubnani, p. 99.
27. al-HassanIbn al-Haytham (1998). al-Shukuk 'alaBatlimus. Ed. Sabra, A. I., Cairo, Dar al-Kutubwa al-Watha'q al-Qawmiyyah.
28. Plott, C. (2000), Global History of Philosophy: The Period of Scholasticism, MotilalBanarsidass, p. 462
29. Ibn al Haytham, Book of Optics (11th century)
30. Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures.Selin, Helaine (Ed.) 2nd ed. James Witter. Physics, 2008, p. 1817.

*****