

The Light of The Moon: Ibn al-Haytham (Alhazen) and Galileo

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Johannes Hevelius (1611-1687)

- He was an astronomer mostly known for his discovery of several new constellations invisible to the naked eye.
- He made his observation by a telescope installed on the roof of his house in Danzig (Gdansk) in the present day Poland.
- The results of his observations of the of the Moon are represented in a book entitled *Selenographia sive Lunae descrtiptio*, published in 1647, five years after the death of Galileo and almost six centuries after the death of Ibn al-Haytham.
- His aim was to complete and to rectify Galileo's description of the Moon as reported in the latter's *The Starry Messenger*.

The frontispiece of Hevelius' *Selenographia*



What we see in this drawing

- The man standing on the left is Ibn al-Haytham, he holds a piece of paper on which there are some geometrical figures.
- The man on the right is Galileo, he holds his sighting tube or telescope
- Beneath the figure of Alhazen we see a schematic drawing of a brain and under it the word “ratione” (reason)
- Beneath the figure of Galileo we see a drawing of an eye and under it the word “sensu” (sense)
- Like many such drawings in the books of that period, this drawing has an allegoric meaning: its aim is to show that astronomy can progress only by a combination of reasoning and observation. Nevertheless, in the book itself there is nothing about Alhazen’s contribution to our knowledge of the Moon. The author mentions Alhazen only for his work on optics.

Alhazen's *Optics* and its destiny in Europe

- Ca 1000, Alhazen writes his *Book of Optics*;
- Ca 1200: Alhazen's *Optics* is translated into Latin;
- Ca 1270: The Polish monk Witelo publishes his *Perspectiva* which is a kind of commentary on Alhazen's *Optics*;
- 14th century: *Optics* is translated into Italian;
- 1572: Risner publishes the Latin translation of Alhazen's *Optics* together with Witelo's *Perspectiva*;
- 1604: Kepler publishes his *Ad Vitellionem paralipomena*, one of the main texts of modern optics;
- 1632: Galileo publishes his *Dialogue Concerning the Two Chief World Systems*;
- 1637: Descartes publishes his *Dioptrique*;
- 1647: Hevelius publishes his *Selenographia sive lunae description*.

Alhacen's new Optics

- **The Main Achievements**

- 1) Doing away with the concepts of visual ray and visual flux
- 2) **The new concept of the secondary light**
- 3) The first explicit formulation of the laws of direct propagation and reflection of light
- 4) Basing the laws on experiment

Alhacen's new Optics

- 5) A full study of the phenomena of reflection and refraction including the formation of images in all kinds of mirrors (plane, concave and convex)
- 6) Putting forward a theory of perception based on the visual perception
- 7) Presenting a more exhaustive theory of visual errors
- 8) **Extending the application of optics to problems which were hitherto thought to be outside the reach of scientific examination (*On the Light of the Moon, On the Face on the Moon, ...*)**

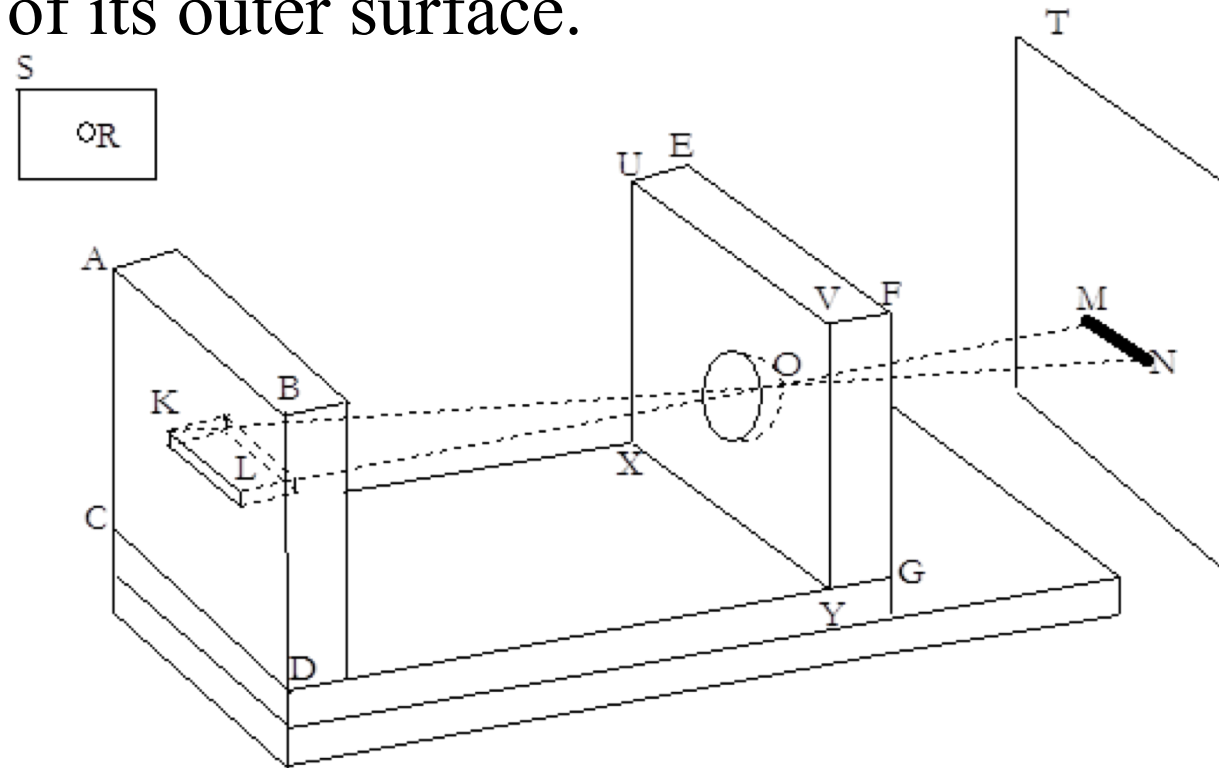
The problem of the light of the Moon

- **The traditional view:**

- The moon receives its light from the sun. This thesis was accepted by everybody at least since the 5th century B. C.
- The moon is a polished body which reflects the light of the sun.
- In his *The Light of the Moon*, Alhazen shows that the Moon emits the light received from the Sun like an opaque earthly body. It does not *reflect* the light.

Experimental verification of the way the Moon emits the light

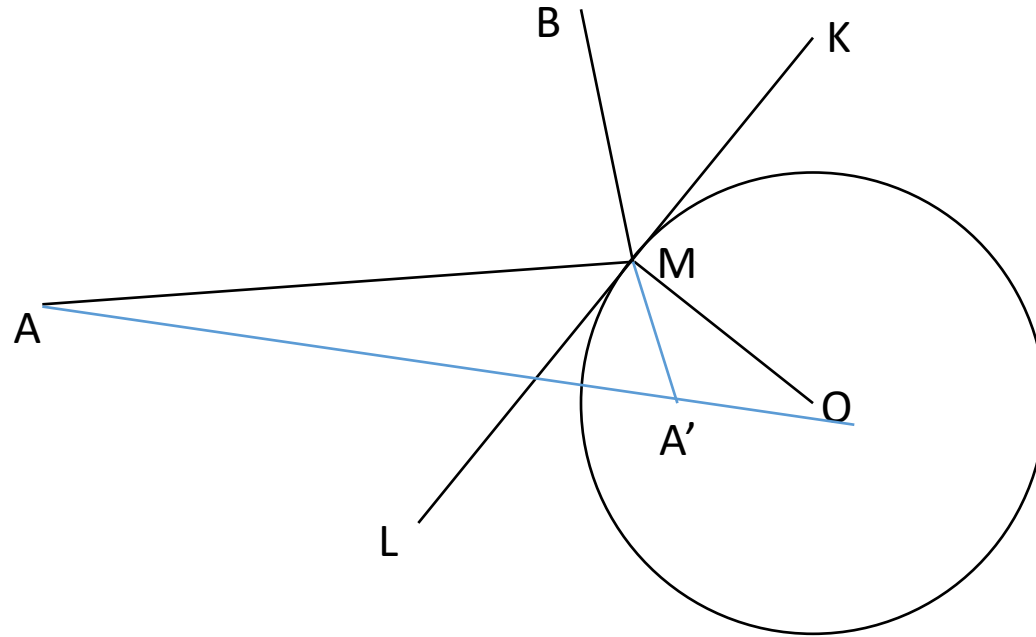
- Alhazen's experimental device to verify that the light of the Moon is emitted from all the points of its outer surface.



Refutation of the theses of reflection

- His demonstration is based on two principles:
- **1** The formation of image in a convex spherical mirror;
- **2** The distances between the Earth, the Sun, and the Moon.

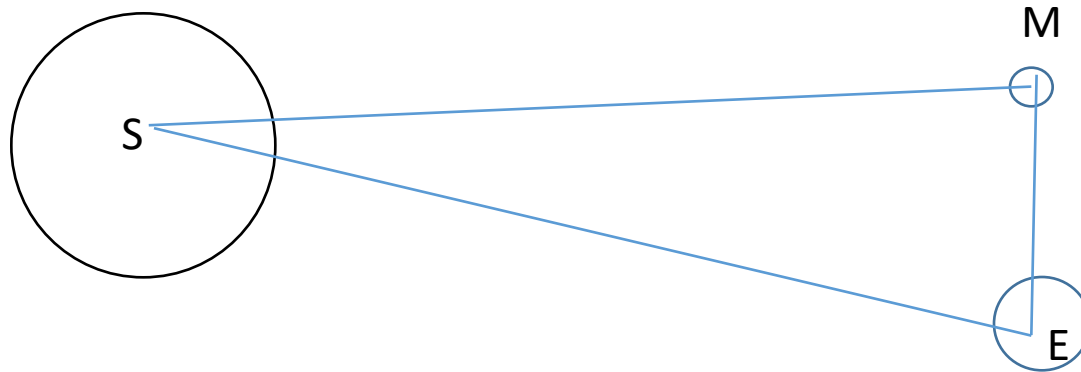
Formation of image in a convex spherical mirror according to Alhazen



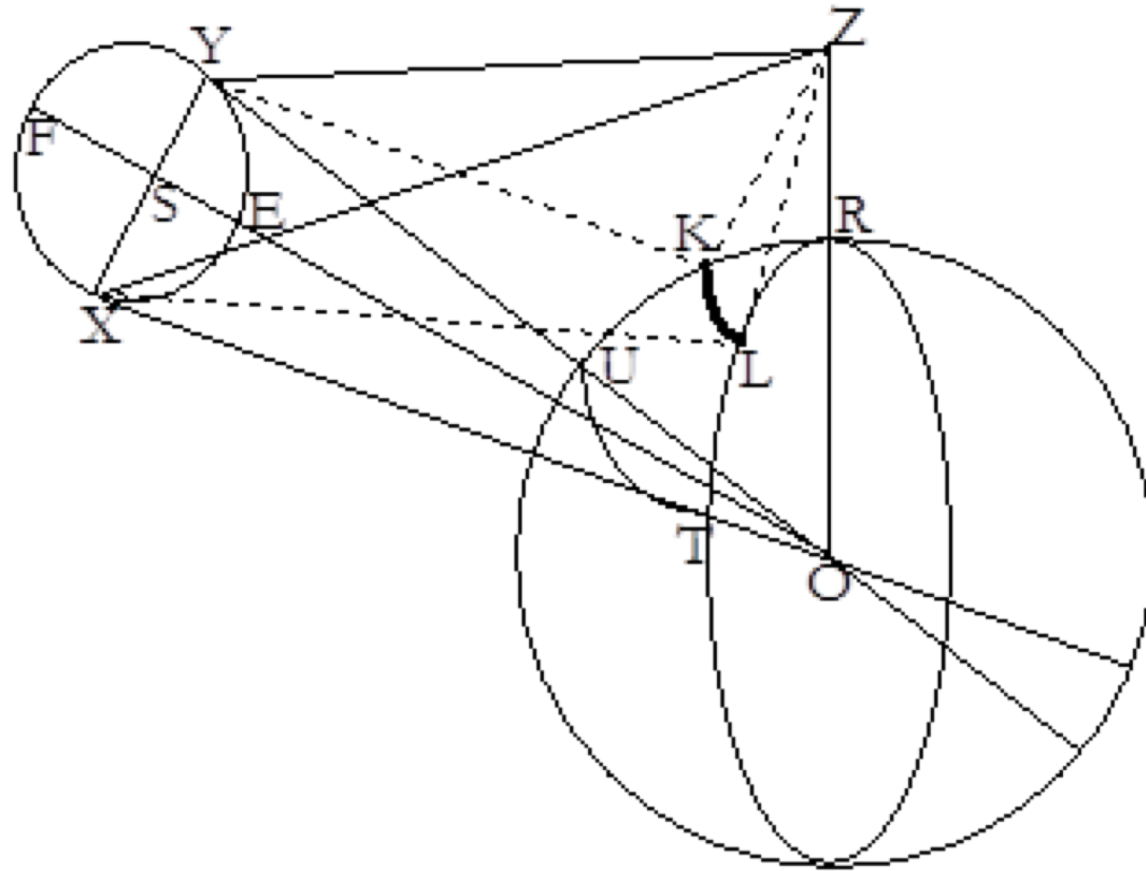
The distances between the Sun, the Moon and the Earth

$ME \cong 50 D$

$ES \cong 1200 D$ (D is the diameter of the Earth). These values were known since the Antiquity. The value of ME is relatively good, but the value of ES is too small. In fact it is only $1/400$ of the real value.



Alhazen's Refutation of the accepted thesis concerning the way the moon reflects the light it receives from the sun



Galileo on the light of the Moon



GALILEO GALILEI

Dialogue Concerning
the Two Chief World
Systems—Ptolemaic &
Copernican *translated*
by Stillman Drake, fore-
word by Albert Einstein

SECOND EDITION

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY AND LOS ANGELES 1967

Galileo: *Dialogue Concerning ...*

- The Dialogues take place in three days between three persons:
- Salviati, a learned man who is in fact the mouthpiece of Galileo;
- Simplicio, an orthodox Aristotelian who defends the Ptolemaic-Aristotelian world-view; and
- Sagredo, an intelligent man willing to accept the new facts and theories put forward by Salviati. His interventions are almost always in favor of Salviati.
- The Moon is the main subject of the first dialogue, because many of Galileo's new discoveries were related to the Moon.

The first problem: the shape of the Moon

- Drawing upon Galileo's telescopic observations of the surface of the Moon, Salviati tries to show that the Moon is an Earth-like body, with mountains and valleys, so it is not the perfect sphere which the philosophers believed.
- But, despite the fact of the existence of its mountains and valleys, the overall shape of the Moon is spherical.
- To demonstrate the sphericity of the Moon, Salviati refutes the rival theses: the Moon is neither a plane surface, nor is it in the shape of hemisphere. Salviati's argument are based upon observable properties of the Moon. They are almost the same as the arguments put forward by Alhazen on his treatise *On the Light of the Moon*.

The second problem: the light of the Moon

- Galileo's argument is based on the difference between reflection on plane and spherical mirrors. In a plane mirror, all reflected solar rays are parallel, while a spherical mirror reflects the incident solar rays in different directions. To show this difference he makes an experiment on a plane and a spherical mirror, both put in a dark room. One sees a good part of the plane mirror illuminated by the Sun, while the spherical mirror seems to be not illuminated at all.

The light of Moon: Galileo, *Dialogue* ...

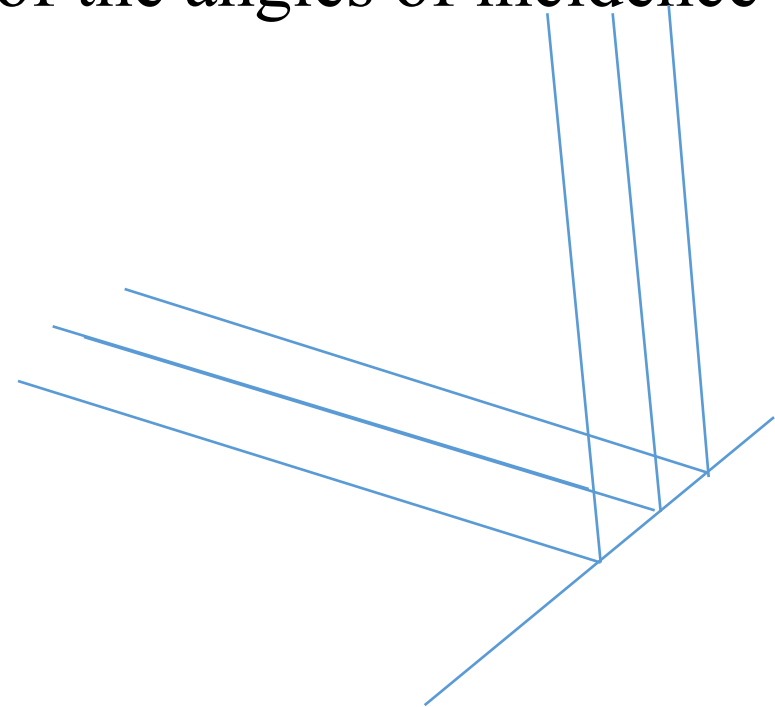
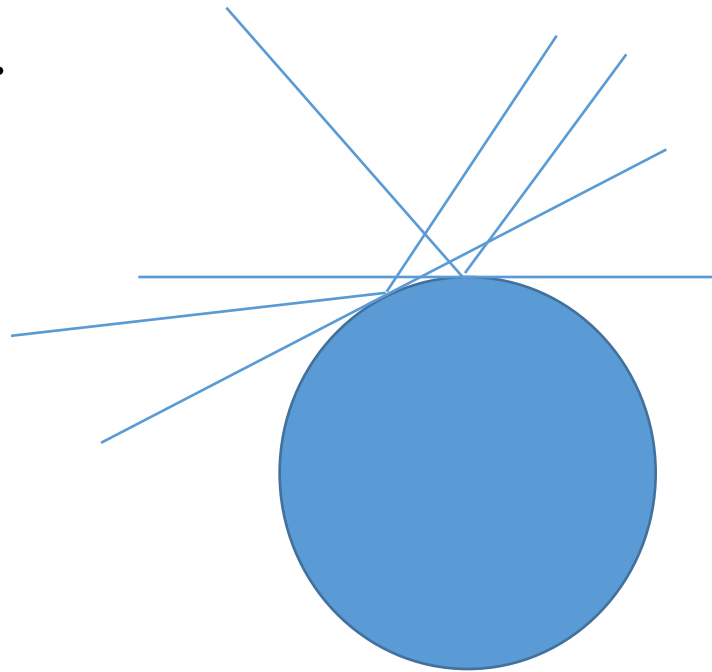
- Let us consider this in regard to what would happen if the mirror had a spherical surface. Unquestionably we should find that of the whole reflection made by the illuminated surface, only a small part would reach the eyes of a particular observer, there being only the very least possible part of the entire surface which would have the correct slope to reflect the rays to the particular location of his eyes.

Galileo, *Dialogue* ..., p. 74

- But the surface of the moon is not flat, it is spherical; and the rays incident upon such a surface are found to be reflected in all directions at angles equal to those of incidence, because of the infinity of slopes which make up a spherical surface. Therefore the moon can send its reflections everywhere and need not send them all to a single place like those of a plane mirror.

Galileo's "experiments" on the reflection of solar rays on a plane and a convex mirror

In a plane mirror all solar rays are reflected in the same direction but in a spherical mirror solar rays are reflected in different directions. The difference is due to the law of the equality of the angles of incidence and reflection.



Alhazen and Galileo: similarities

- Both scientists present the same arguments for the spherical shape of the Moon;
- Both arguments are based on the essential difference between reflection on plane mirror and reflection on a concave mirror;
- Both arrive at the same conclusion: the Moon emits the light in the same way that an opaque earthly body emits the light;
- We can conclude that the optics Galileo knew and used was that of Alhazen.

Alhazen and Galileo: differences

- Galileo had his telescope, he had already seen the surface of the moon with its mountains and valleys and firmly believed that the Moon is a body much like the Earth;
- Alhazen could only draw upon his optical knowledge and on what was known at that time of the sizes and distances of the Sun, the Moon, and the Earth.
- The method of Alhazen is quantitative: he calculates the part of the Moon which can reflect solar rays so that the reflected rays would reach the eye of an terrestrial observer. He shows that this part is so small that is actually invisible.

Alhazen and Galileo: differences

- The argument of Galileo is qualitative, instead of the Moon itself, he uses a spherical mirror.
- For Alhazen, the concept of “secondary light” is an irreducible concept. It is a property of every opaque object to receive light and to emit it in every direction.
- For Galileo, the secondary light is the result of a great multitude of reflections produced on different parts of an opaque body.

Conclusion

- As far as we know, the treatise of Alhazen, *The Light of the Moon*, was not translated into Latin or into any other European Language before the 20th century. So Galileo did not know the result already obtained by Alhazen. He reproduced this result, but in his reproduction he drew upon the optical principles already formulated by Alhazen.
- The main achievement of Galileo in his *Dialogue* is considered to be his idea that the Earth and the heavens are made of the same stuff. It was a great step toward the rejection of the cosmological dualism which was dominant throughout antiquity and the middle ages. I hope to have shown that Alhazen's research on the light of the Moon also put into question this dualism at least in the case of the Moon .