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NASE workshop: Eclipses with models and *camera obscura*

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Abstract. Ibn al-Haytham (known as Alhazen in occident), extensively studied the camera obscura phenomenon in the early 11th century. This instrument was used to obtain the projected image of a landscape on the screen and also was addopte by the scientists and famous painters along the centuries, to experiment with it until their final evolution as the modern photografic camera. The resource in the simple version of the "pinhole camera" can be used at the classroom to experience several phenomena, such us solar eclipses and Moon phases, and to each about optics and geometry. This contribution presents an application of this ingeniuos tool in the framework of solar eclipses, where the scale models are important to understand what really happens with the Sun-Earth-Moon system.

Keywords. education of astronomy, pinhole camera, Sun-Earth-Moon system, eclipses: production, eclipses: models in scale

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1. Solar Eclipse

The eclipse of December 14, 2020 motivated that the IAU-Network for Astronomy School Education program (NASE) considered the possibility to organize a set of activites related to eclipses in order to give teachers and professor more tools to aply in the classroom that help to overcome the misconceptions on this topic.

Considering the gap that often can be find in the knowledge of the general public, it is possible to realize that not all the people accept that the solar eclipses occur when the Moon is in the new Moon phase, since it is necessary that the Moon be between the Earth, the Sun, with a very tight alignment. In that position, the Moon shows the Earth its dark part, while the illuminated part is logically towards the Sun.

To have an eclipse, the distance and sizes are important: the Moon is an small body and the Sun is a big one, but at the actual distance the apparent diameters are the same; but also there is a near perfect alignment when the Moon is new, and this occurs only a few times a year, because there is a angle of 5 degrees betwee the orbit plaes of the Moon and the Earth. On most occasions when there is a new Moon, it passes above or below the Sun, as seen from Earth.

This phenomena can be shown with a model in scale that can be easily built: the Earth will be represented by a small sphere of 4 cm. As the diameter of the Earth is about 12,700 km, at that scale, the Moon would be an sphere of 1 cm and the distance between

Figure 1. a) Simulating a solar eclipse using the model with the real Sun b) Detail of the solar eclipse on the Earth surface.

the Earth and the Moon would be 120 cm (the real one is in average 384,000 km). To contruct the final model, a stick of greater length is used as the base to mount the two spheres on pins, 120 cm apart. This model can be used outside on a sunny day (Fig. 1)to show and explain different concepts, incliding total an parcial eclipse because is possible to identify "umbra" and "penumbra" (Ros, R. M. (2017), Lanciano, N. (2011)).

2. Lunar Eclipse

Eclipses of the Moon can also be simulated by turning the model over. In this case the shadow cone of the Earth covers the Moon.This eclipses are visibles from all over the Earth where it is night, and only occurs when the Moon is in the full Moon phase.

The model is also used to see the ilumination of the Moon at day time, pointig the real Moon with the Moon of the model: the two spheres (the Moon of the model and the real Moon) with the same phase, since both are illuminated by the same Sun, and are seen from the same point of view. If we rotate the model, we can simulate the different phases of the Moon (Fig. 2).

Although it is more didactic to do the experiment with the real Sun, if there are clouds or the experiment is performed inside the classroom, the model can be used by illuminating it with a flashlight. In this case, is possibe to change the scale to 1/5 of the previous model. The Earth will be an sphere of 0.8 cm, the Moon will have a diameter of 0.2 cm, the distance between the Earth and the Moon would be only 24 cm and the flashlight of a mobile will be the Sun (Fig. 3). This model is specially interesting in online courses, but has not the same impact from the didactical point of view.

3. Camera Obscura, Dark Box or Pinhole Camera

The camera oscura can be a room or a box with an small hole through which the ligth enters and project an image in one screen. A simplest version of this tool, is a pinhole camera, a great device to observe the Sun, and also the solar eclipse. To construs a school version of this cara a large cardboard tube is recommended, but also a poster can be roll into a tube of about 10 cm in diameter. To fasten it, elastic bands are used. The length of the tube, determines the diameter of the image of the Sun (Ros, R. M.

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Figure 2. a) Simulating a lunar eclipse with the real Sun b) Comparing the phase of the Moon with the real Moon.

Figure 3. Eclipse simulations: Lunar eclipse and solar eclipse.

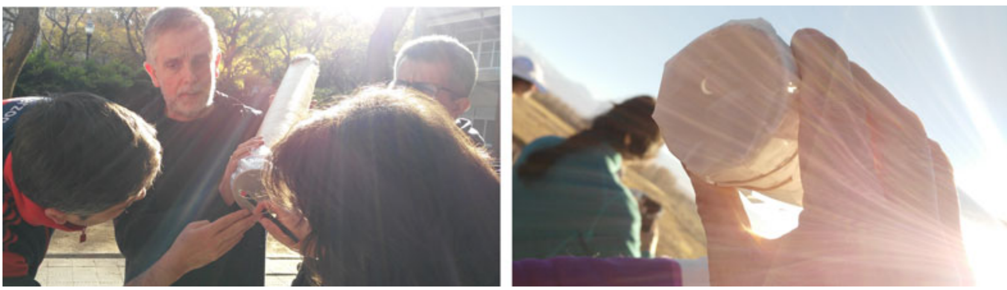

Figure 4. Pinhole camera: a) measuring the diameter of the image; b) observing a parcial solar eclipse.

(2017)). One end of the tube must be cover with aluminum foil (hold it with an elastic band), and a small hole in the center with the wire of a paper clip will be the make. The other end of the tube must be cover with a semitransparent paper, which will serve as a screen. By directing the tube towards the Sun, with the end of the aluminum foil first, the projected image of the Sun will be seeing on the semi-transparent foil. By measuring the diameter of the image of the projected Sun, and the length of the tube, by simple geometry (similar triangles) the distance from the Sun can be calculated, knowing its diameter (or the diameter, knowing the distance).

Expanding this model, the outline of the Sun by projection can be observed in the "shadow" of a simple hole: on cardboard, with the fingers of the hand, kitchen objects (Fig. 5b), and even the holes between the leaves of the trees (Fig. 6a and 6b).

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Figure 5. Eclipse images through the holes: a) fingers; b) kitchen objects.

Figure 6. Eclipse images through the leaves of trees; a) partial eclipse; b) anular eclipse.

It is interesting to note that the size of the hole influences the sharpness and intensity of the image, but not the size of the projected Sun, which depends only on the distance from the hole to the shadow.

As the eclipses are phenomena always impresive, the reccomendation for the teachers if there exits the possibility to observe one of this events, is to perare the activities previously to enjoy the moment with the students and all the communty.

4. Conclusions

Eclipses is a fascinating field in Astronomy. In the classroom it is a topic to teach Geometry, Mathematics, Physics and History, between other subjects. The concepts connected to the eclipses not only ae useful for a moment of the eclipses, but also to observe the environmet with new eyes: the spots of the Sun on the floor (always circular, as the full image of our star), the power of the Mathematics to estimate the diameter of the Sun or the distance between it and the Earth, the uses of the pinhole camera along different days at different times to show that the diameter of the Sun does not change at sunset, are only a few exampes of activities and project to develop as part of the new approach in education to estimulate the students and to present the Astronomy as an opportunity to a better access to science and technology, which are part of every day modern life.

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