On Artificially Creating Solar Eclipses

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Abstract

In this paper we inform about the partial solar eclipse we created artificially. It aims at inviting those who are interested in the study of solar eclipses to set up their own laboratory to artificially create and study solar eclipses at any time of the day and at any convenient spot on the earth. Anybody interested in the study of solar eclipses can setup his laboratory without much expenditure. What essentially required is a small piece of land exposed to sunlight to arrange the equipment and equipment consists of a telescope, some spherical objects of appropriate size, a mechanical arrangement to hold and move a chosen spherical object at hand, appropriate filters to protect eyes, and a good camera to take photographs of artificially eclipsed sun We report here about our initial efforts done regarding artificially creating solar eclipse of any kind. We provide towards the end of the paper two sample photographs of artificially created partial solar eclipse taken using orange fruit in the role of moon and a photograph of naturally occurred partial solar eclipse for the sake of demonstrating their similarity. We propose here a way to artificially create eclipses of all types, namely, total, partial, or annular in the laboratory at our will. We discuss how to create solar eclipses at any location on earth at any daytime and at any location of the sun on its daytime trajectory. These eclipses formed artificially will be same in every respect to naturally occurring eclipses due to perfect alignment of earth, moon, and sun along a straight line. The only difference in naturally occurring solar eclipses and artificially created solar eclipses lies in replacing the moon by any spherical body of appropriate size to work as artificial moon to obstruct sunrays to form solar eclipses artificially. We may use any spherical body in place of moon, which has diameter matching with the diameter of parallel sun beam entering the telescope, to hide the real image of the sun by this artificial moon.

1. Introduction: Solar eclipse is most spectacular example of the validity of celestial mechanics. It is an eloquent practical demonstration of the clockwork of solar system at work! It occurs when the moon arrives in between sun and earth during its motion. During total solar eclipse for a short period of time the sun is completely blocked out by the moon when viewed from the earth and day briefly turns into night so that some background stars become clearly visible for that short duration.

As explained beautifully in [1], [2], [3] many interesting phenomena occur during this short duration of eclipses which are worth watching and studying: The four contact points (FIG. 1), namely, the first contact point when moon just touches the solar disc; the second contact point when moon just covers the sun almost entirely and only a sharp golden edge, a crescent, of sun disc is only visible; the third contact point when moon moves little further and this sharp golden edge, a crescent ,of sun disc is now visible on the diametrically opposite side; and the fourth contact point when moon touches solar disc at the diametrically opposite point of the first contact point and about to leave the sun are worth recording as they provide useful information to estimate the exact size of the sun.

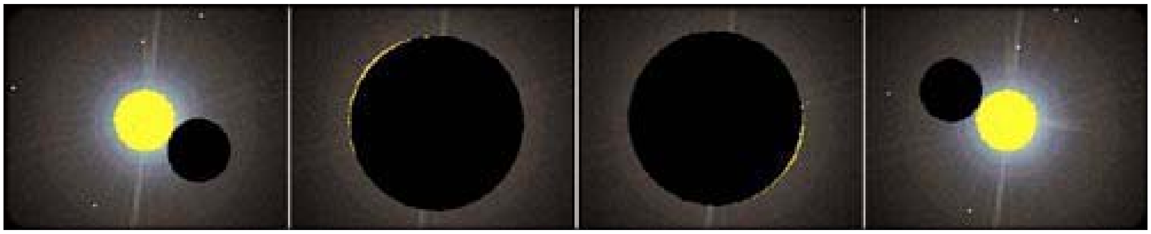

FIG. 1

The other important outcomes like appearance of Bailey's beads (FIG. 2) which are formed when the moon covers the last slice of the sun. The photosphere shining through the valleys creates this effect. The last slivery portion of sun breaks up here into a chain of bright pearls around the edge of the moon.

FIG. 2

Most amazing and awe-inspiring diamond ring is then formed as the last bit of photosphere disappears (FIG. 3).

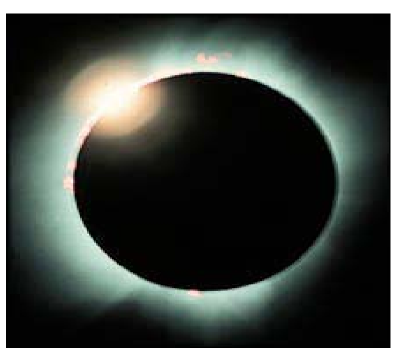

FIG. 3

You see here something that looks like a "diamond ring", the beautiful inner corona forming a ring around the moon with a brilliant white jewel of light.
Then within few moments you witness formation of corona (FIG. 4).

FIG. 4

Annular Solar Eclipses occur when a region on the Earth's surface is in line with the umbra, but the distances are such that the tip of the umbra does not reach the Earth's surface. A beautiful golden bangle forms during annular eclipse (FIG. 5).

FIG. 5

Other effects like, shadow bands, interference bands formed by sunrays unobstructed and sunrays obstructed and reflected by the spherical surface of the moon, are also worth studying. Background stars also become visible for a short duration during totality. For a complete calendar of solar and lunar eclipses one can refer to [4].

More importantly, it can become possible for us to capture stars in our view which are placed near the boundary of sun disc but placed behind and so hidden by the sun disc as was done by Sir Arthur Stanley Eddington [5] during total solar eclipse of 29 May 1919 (FIG. 6), that provides the confirmation of bending of light due to curving of space due to massive star like sun in accordance with Einstein's general theory of relativity!

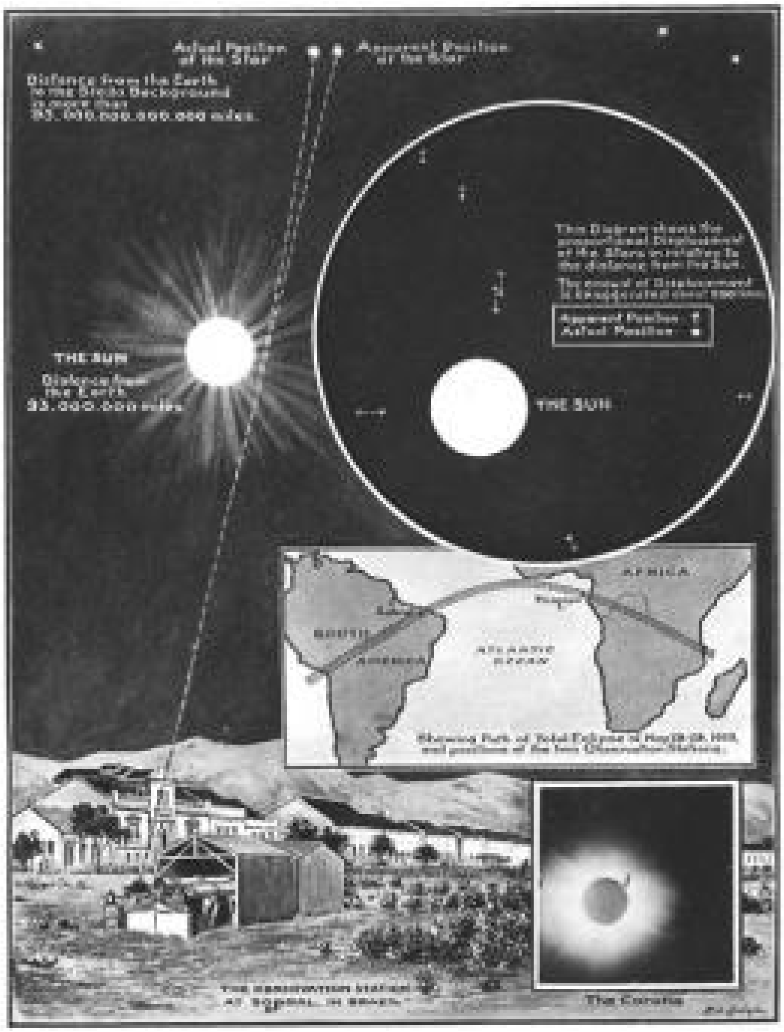

FIG. 6

2. **Solar Eclipses:** Let us discuss now in brief about solar eclipses, their cause and their types, and let us get a geometrical view of the situation leading to their formation. Solar eclipses are the result of periodic motion of the moon about the earth; there are regularities in the timing of eclipses that give cycles of related eclipses. The periodic motion of the trio, namely, sun, earth, and moon are responsible for solar eclipses (FIG. 7).

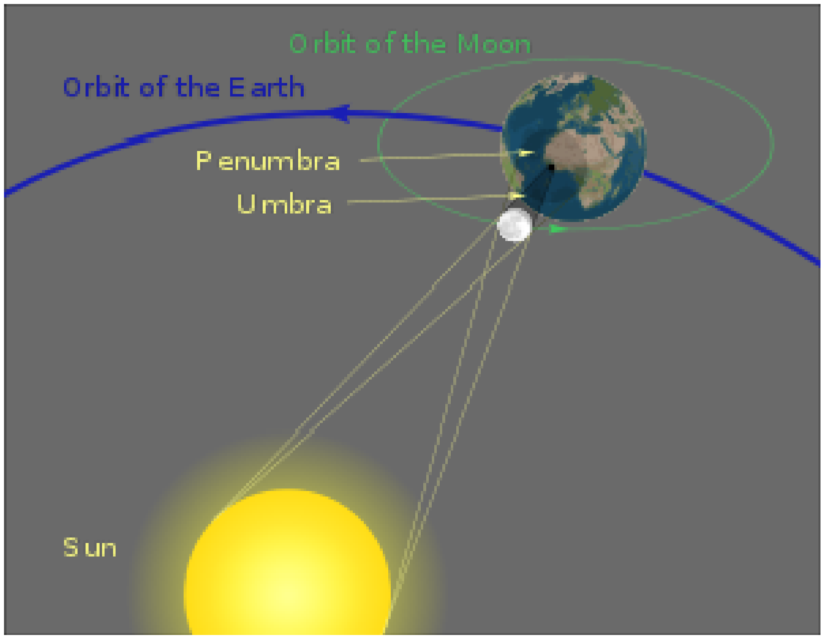

FIG.7

Earth revolves around sun on an elliptical orbit and moon revolves around earth on another elliptical orbit such that the planes in which these orbits lie are inclined to each other. One consequence of the moon's orbit about the earth is that the moon can shadow the sun's light as viewed from the earth, or the moon can pass through the shadow cast by the earth. The former is called a solar eclipse and the later is called a lunar eclipse. The small tilt of the moon's orbit with respect to the plane of the ecliptic and the small eccentricity of the lunar orbit reduces the chance of perfect alignment and thus make such eclipses much less common than they would be otherwise, but partial or total eclipses are actually rather frequent. Among the phases of moon solar eclipse can occur only at new moon when moon passes between earth and sun and may cast a shadow on the surface of earth. When moon’s shadow happens to fall upon earth’s surface we see at that tome some portion of sun’s disc is covered or eclipsed by the moon. Since new moon phase occurs every 29.5 days one might expect eclipse after every 29.5 days. But, as mentioned above moon’s orbit around earth is tilted by approximately 5 degrees to earth’s orbit around sun the moon’s shadow usually misses earth and one can expect alignment roughly twice a year. There are three main types of solar eclipses as observed from any particular point on the Earth (FIG. 8):

1. Total Solar Eclipses occur when the umbra of the moon's shadow touches a region on the surface of the Earth.
2. Partial Solar Eclipses occur when the penumbra of the moon's shadow passes over a region on the Earth's surface.
3. Annular Solar Eclipses occur when a region on the Earth's surface is in line with the umbra, but the distances are such that the tip of the umbra does not reach the Earth's surface.

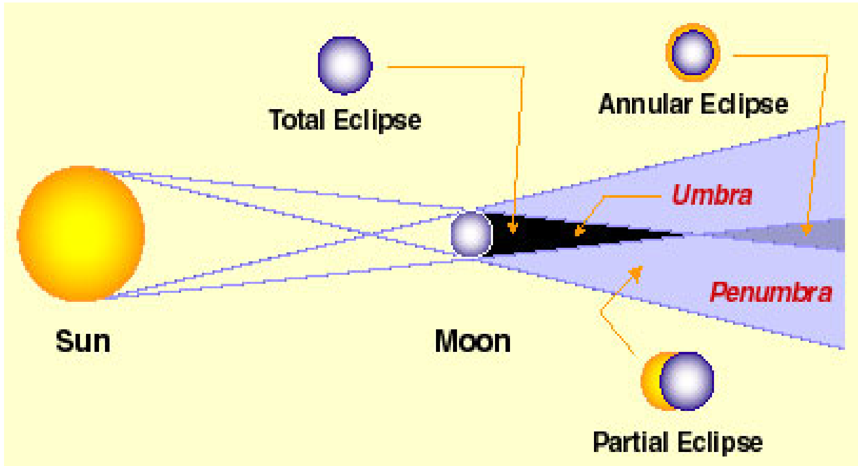

FIG. 8

As illustrated in the figure, FIG. 8, in a total eclipse the surface of the sun is completely blocked by the moon, in a partial eclipse it is only partially blocked, and in an annular eclipse the eclipse is partial, but such that the apparent diameter of the moon can be seen completely against the (larger) apparent diameter of the sun. There is one more type of solar eclipse called hybrid type occurring rarely. This so called hybrid eclipse occurs when the curvature of earth brings different points of path into umbral and antumbral shadows. This can happen in the neighborhood of a point where both umbral and antumbral shadows meet (FIG. 9). The next hybrid eclipse will be in November 3, 2013.

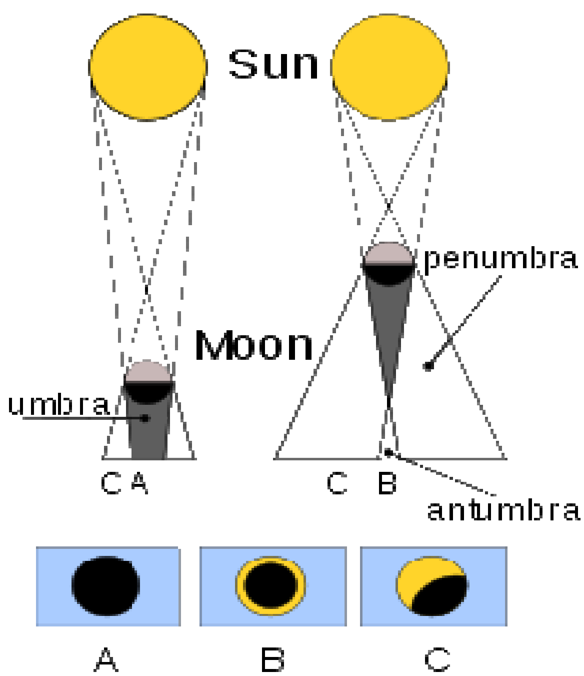

FIG. 9

3. **Artificially Created Solar Eclipse:** We now proceed with the discussion of our main objective: the creation of solar eclipses artificially. What is different in artificially created solar eclipse is choosing of some spherical body of diameter equal to diameter of cylindrical parallel beam of sunrays entering the telescope in the place of moon. In forming the artificial eclipse we use real sun, some real location on earth, and an artificial moon made up of some spherical shaped body. Every type of eclipse we can create artificially, i.e. total, annular, and partial. We can observe every effect that we can observe during usual solar eclipse. Every "effect" that we observe, every "experiment" that we perform is realistic. Solar flux that reaches the earth is low. In order to increase its value we can make use of the arrangement used in a refracting telescope (FIG. 10). We use there a convex lens of larger size and larger focal length. The large size is chosen to ensure capturing of sufficient radiation to converge and larger focal length is chosen to reduce the angle of cone of light converging at the focus of this lens and proceeding further. This light proceeding further is made incident on a lens of smaller size and smaller focal length. The smaller size and smaller focal length of this second lens is chosen to ensure capturing of the sunlight into smaller area to achieve enhancement of solar flux of the parallel beam proceeding ahead from this smaller sized lens. Thus, we can achieve intensified parallel solar beam to enter the telescope (FIG. 10).

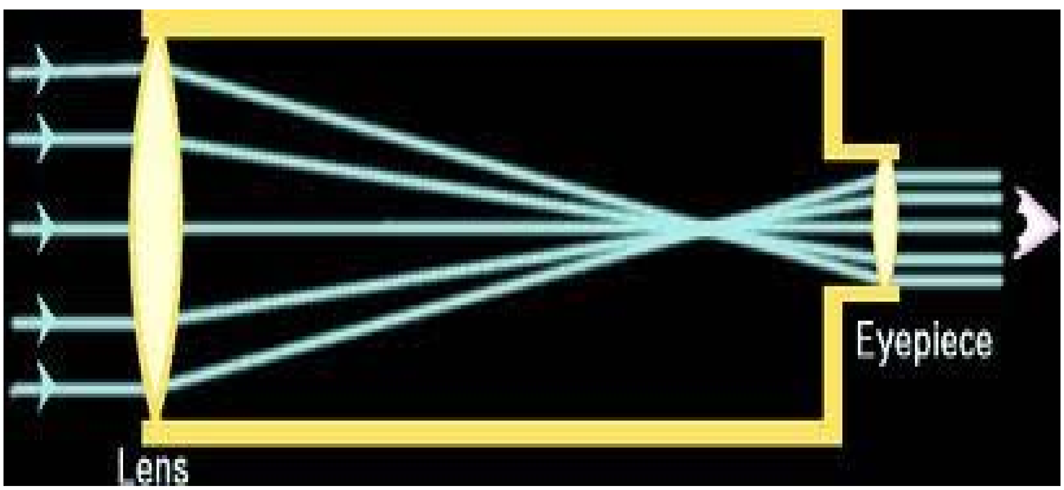

FIG. 10

We can use this intensified beam to enter the telescope to create real image of sun. We may use any convenient telescope of reflecting type Cassegrain telescope (FIG. 11) or Newtonian telescope (FIG. 12) or refracting type telescope (FIG. 13) to create sun's image.

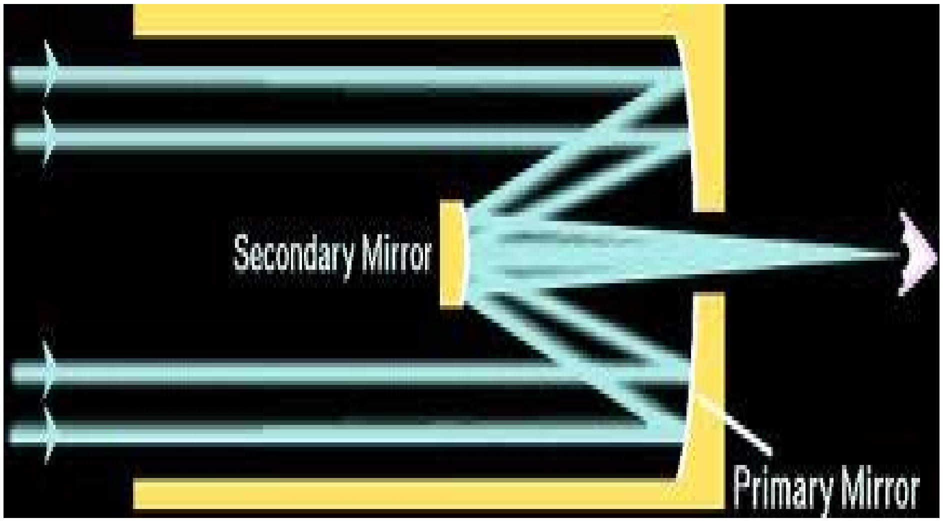

FIG. 11

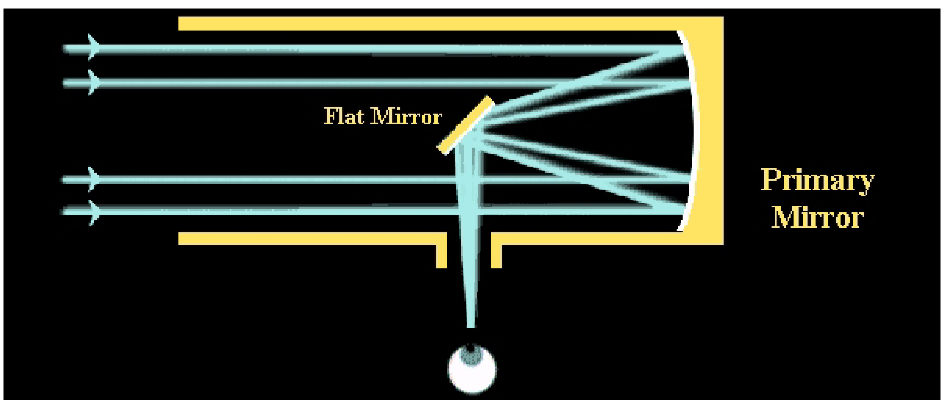

FIG. 12

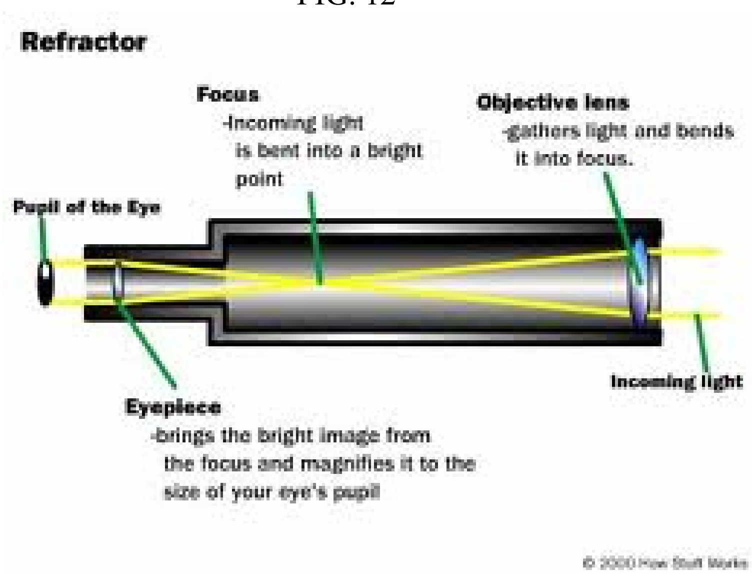

FIG. 13

Let us now consider creation of artificial solar eclipses using Newtonian telescope.

1) In order create total (or partial) solar eclipse artificially we require to keep a body of perfect spherical shape and diameter just equal the diameter of the parallel sunbeam entering from the left side to fall on the primary concave mirror (FIG.12). Alternatively, we can keep the spherical body in the region of converging beam between primary mirror and focus (FIG. 12). The diameter of spherical body smaller than the diameter of cylindrical and parallel sunbeam entering from left side and falling on the on the concave mirror. We position this spherical body with its center lying on the axis of cylinder for achieving total solar eclipse (with center slightly away from axis for partial solar eclipse) forming body of telescope in the beam that converges at focus. Focus is at some point on the axis of cylindrical body of telescope. When the chosen spherical body as artificial moon will slide in the rays reflecting from primary (concave) mirror and converging at the focus, this sliding to be achieved using a mechanical arrangement, towards and away in the converging beam (FIG. 12) we will be capturing all features of the total (partial) solar eclipse and we can have thus exact reproduction of all the interesting phenomena associated with total solar eclipse. Thus, the region between focus and primary mirror in which rays reflected from primary mirror are converging at focus forms the region for placing spherical object of appropriate size to obstruct sunlight to create the total (partial) eclipse artificially.

2) In order create annular solar eclipse artificially we require to keep a body of perfect spherical shape in the region beyond the focus in which the rays diverging from focus and falling on the plane mirror (FIG. 12) to make the sun's image available for viewing. Thus, the region between focus of primary mirror and plane mirror in which the rays are diverging from the focus and are falling on the plane mirror forms the region for placing spherical object of appropriate size to obstruct sunlight to create the annular eclipse artificially.

Since we have perfect freedom in choosing any location (any daytime) of sun in the sky to form artificial solar eclipse we may make use of the sky charts and choose a convenient position of sun in the sky so that we will have distant stars very near the rim of sun and just behind so that we can capture the image of star just behind and close to boundary of sun and verify bending of light while it passes in the vicinity of sun as predicted by general theory of relativity. As an artificial moon we may use any spherical body of appropriate size and made up of any solid material. Its surface can be perfectly reflecting or tar black. It can have topography matching with the topography of moon, or, otherwise.

We now proceed to give below few photographs we have taken that of partial eclipse created using an orange fruit as an artificial moon with the help of Newtonian telescope (FIG. 14) by keeping this orange fruit in the parallel sunbeam entering from left to fall on the primary concave mirror (FIG. 12, FIG. 14).

FIG. 14

FIG. 15 is photograph of un-eclipsed sun taken by us directly by using the telescope shown in FIG. 14.

FIG. 15

FIG. 16, FIG. 17 are photographs taken by us that of partial solar eclipse created artificially by obstructing parallel sun beam entering from left in the telescope (FIG. 14) to fall on the concave mirror by using orange fruit as artificial moon.

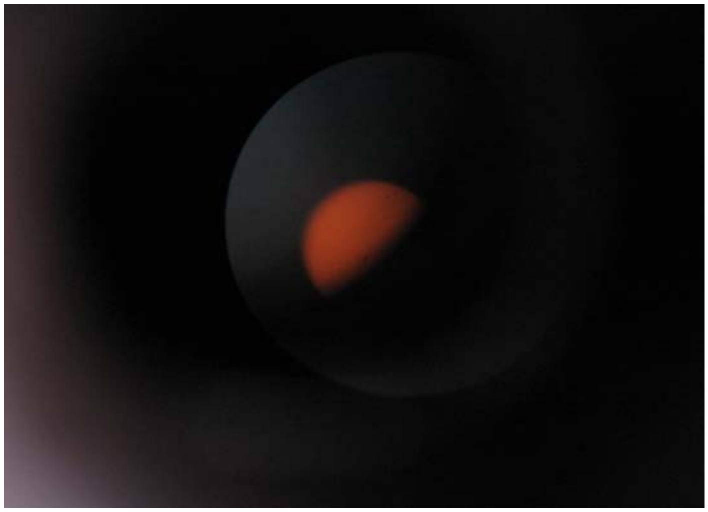

FIG. 16

FIG. 17

In FIG. 18 we have given a photograph of naturally occurred partial solar eclipse caused by real moon to demonstrate the similarity in the photographs of partially eclipsed sun when the eclipse is created artificially and the one which occurred naturally! This image in FIG. 18 was taken by NASA during a partial solar eclipse [6], [7] as seen from Florida in 2001.

FIG. 18

Acknowledgements

I am thankful to Mr. Tushar Purohit for helping me in taking photographs of artificially created partial solar eclipse using orange fruit as moon.

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7. Eclipse image courtesy: NASA JPL-Caltech.

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