OBSERVING SUNSET

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Abstract

This workshop can be performed during both sunrises and sunset, but it is more convenient to work with sunsets because the time table.

One of the purposes of this practice consists of observing the shape and colour of the solar disc changes depending on time at which the Sun is close to the horizon. In particular, we study the refraction phenomenon of the sunbeams since because of them the Sun diameter is reduced in vertical with respect to the horizontal size that does not change. We will work on a set of photographs.

Another aim of this practice is to consider the inclination of the solar path with respect to the horizon and its relation with the local latitude by means of a set of photographs taken along a sunset. It is possible to check that this inclination agrees with the stars' tracks and changes with the latitude of the observation place.

Summing up, working on a set of photographs, our goals are:

1. To observe deformation of the solar disc during either the sunrises or sunsets.
2. To check that the Sun diameter along the vertical decreases or increases depending on the Sun altitude over the horizon.
3. To check that the horizontal diameter does not change.
4. To study the existing relation between the solar path respect to the horizon and the local latitude.
5. To check that this inclination agrees with the stars tracks and it changes with the place latitude.
6. To observe that the Sun disappears each day through a different point on the horizon.

1. Introduction

In this workshop we pretend that all participants in this Summer School observe with attention sunrises or sunsets. Purposes that we pursue can be obtained during the sunrises and sunsets indistinctly, but we think that to work with sunsets is easier because the observations' time could be more convenient.

One of the objective of this practice consists of observing the shape and colour changes of the solar disc as a function of the time when the Sun is close the horizon. In particular, the refraction phenomenon of the sunbeams; this phenomenon produces a deformation in the solar disc and therefore, we observe that the Sun's vertical diameter decreases while its size in horizontal does not change.

On the other hand, we consider the inclination of the solar path with respect to the horizon and its relationship with the local latitude by using a set of photographs taken during the sunset. It's very easy to check that this inclination coincides with the star's traces and it changes with the latitude of the observation place. Besides, if we take photographs at the equinoxes and solstices, we could also compute the ecliptic's angle ε.

Even more, we can make a model for visualising Sun's behaviour at places of extreme latitude as the equator and North Pole.

2. Atmospheric refraction

Goals:

-- To observe the deformation of the solar disc during the sunrises or sunsets.
-- To check that the Sun diameter along the vertical decreases or increases depending on the Sun altitude over the horizon.
-- To check that the horizontal diameter does not change.

The phenomenon

Refraction consists in the fact that the light rays deviates when they cross a surface that limits two layers of different densities.

The fact

The air layer close to the Earth surface is thicker than the one that there is just over it. Refraction is bigger in media with larger density.

Light bends much more when it crosses thicker layers, that is to say, in layers closer to the horizon.

Light arrives to us after crossing many layers of different densities.

Consequences

1. The Sun and stars seem us higher in the sky than they are really because the observer sees it in the ray's lengthening with stars' light arrive at our eye (Fig.1).

2. Refraction is closer to the horizon due to the celestial body light's ray has travelled a longer path through the refractory layers (Fig.2).

3. Thus, if a ray comes from the upper part of the Sun will refract less than another one coming from the lower one. As consequence of this fact, we don't see the Sun as a circular disc but lightly elliptic (Fig.3).

It's calculated that sunbeams' entry in the terrestrial atmosphere nearly horizontals but they are lift around 34' by the effect of atmospheric refraction. (We know that the apparent Sun's diameter is 32' approximately).

4. Through the first consequence, refraction is also responsible of the fact that the Sun could be seen even when it is under the horizon, before the sunrise, or after the sunset. This fact advances sunrises and postpones sunsets, i.e. the day's length becomes longer.

5. The colour of the sky also is due to the refraction effect.

   Light colour depends on the wave length. Photons change its direction proportionately to its wave's length by refraction, therefore all colours aren't refracted equal. The blue colour is the most refracted and the red is the less.

   The atmosphere's air disperses solar light, specially the blue; this is what we see sky blue. Sky without atmospheric air should be seen black.

When the Sun is very close to the horizon, only red and yellow rays arrive to us because of the blue ones have been dispersed along its trajectory (Fig.2).

6. The ”blinking” of stars is also due to the refraction effect (tinkle).

Stars' light is refracted at every one of the atmosphere layers with a different angle, from this fact results that light coming from the star is moved swiftly. As a star is very far away, we receive its image as a blinking point.

Theory

As we have said above, the solar disc deformation is only in height but not in width.

1) The no deformation of the solar disc in width is due to the refraction's first law; this law says: **the incident ray, the refracted one and the perpendicular to the incidence plane lay on the same plane**. This event allows us to affirm that **the azimuth of real ray and the apparent one are the same**, it's said, we never observe deformation in width.

2) Instead, height deformation is a consequence of the refraction second law. This law says that **if we name by *Z* the angle between the zenith and the principal ray and by *Z′* the angle from the zenith to the refracted ray then:**

$$\sin Z = \mathrm{n} \sin Z'$$

where n is the refraction index (Fig.4).

If **r** is the refraction angle from the (Fig.4) we deduce:

$$Z = Z' + r\,, \qquad \sin (Z' + r) = \mathrm{n} \sin Z'$$

$$r = (n\text{-}1) \tan Z'$$

because r is as maximum 34', $\sin r \approx r$ and $\cos r \approx 1$.

The refraction's angle is a Z' increasing function. As Z' is complementary of the height, refraction increases as much as Sun's height over the horizon decreases.

Note: At 0°C of temperature and 760 mm of pressure, n-1=60.34".

Computation

For studding how the atmospheric refraction affects the solar disc shape during a sunset we have to observe the Sun when it clears the ground. The west horizon should be plain and without any obstacle in the observation place. In these conditions we will take a set of pictures on which we will be able to make measurements.

Working on pictures (Fig.5) we want to check the two refraction laws. For that, we will go on as follows:

1. On each one of the photographs' set we measure the horizontal diameter **dHi**, the vertical diameter **dVi** and the height **hi** of the superior Sun border over the horizon (where the **i** of dHi, dVi and hi corresponds to the photograph number).

2. We check that first refraction law is satisfied when we do not observe any changes in the horizontal diameter.

3. For each photograph **i**, we calculate the flattening percentage **Ai** by the formula:

$$Ai = \frac{dHi - dVi}{dHi} 100 \ .$$

After computing it for all photographs available, we can observe that while smaller is **hi**, bigger is the flattening percentage **Ai**.

3. Inclination of the solar path

Goals:

-- To study the relation existing between the solar path with respect to the horizon and the local latitude.

-- To check that this inclination agrees with the stars tracks and it changes with the latitude.

-- To observe that the Sun sets each day at a different point on the horizon.

-- If we take pictures the first day of the four seasons, we will be able to compute also the inclination ε of Earth's rotation axis with respect to the ecliptic.

Development of practice and checking

On the photographs taken, we want:

1. To measure the angle between the Sun's path during the sunset and the horizon. Later, to study its relationship with the observation place latitude.

2. To check that solar path's inclination agrees with stars tracks when these are setting on the horizon.

3. Taking pictures from a fixed point (approximately) during a year will allow us to visualise Sun sets each day at a different point on the horizon.

4. We make a model with the end of visualising the Sun behaviour for the above three exercises in the equator and north pole.

These extreme situations produce:

(a) In the equator twilights are shorter because of solar disc appear and disappear perpendicularly to the horizon.

(b) In the Arctic latitudes the midnight phenomenon.

(c) Also with the model, we can observe that the Sun not always rises by the East point and sets by the West point.

(d) We can also measure that the maximum distance between the two more separated sunsets changes with the place latitude.

Figures:

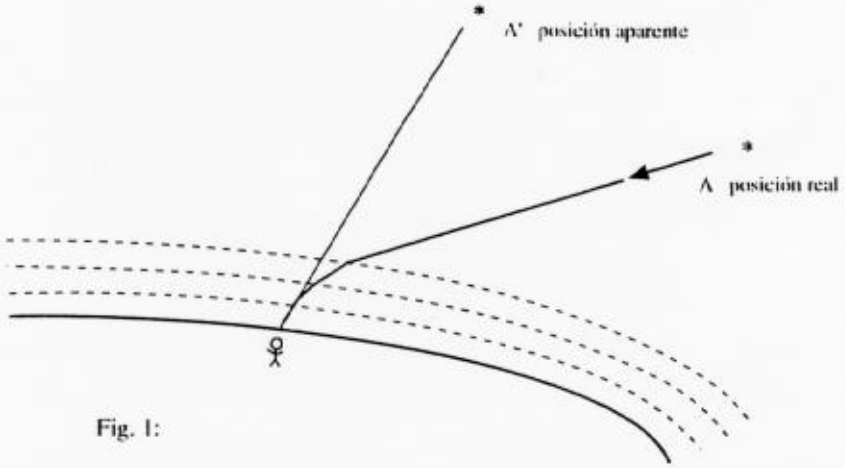

Fig. 1:

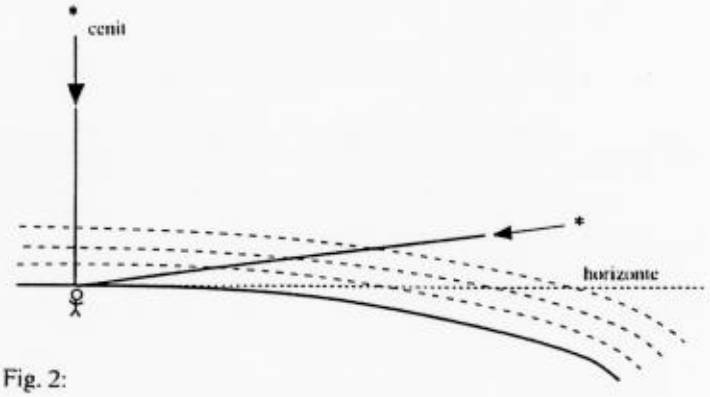

Fig. 2:

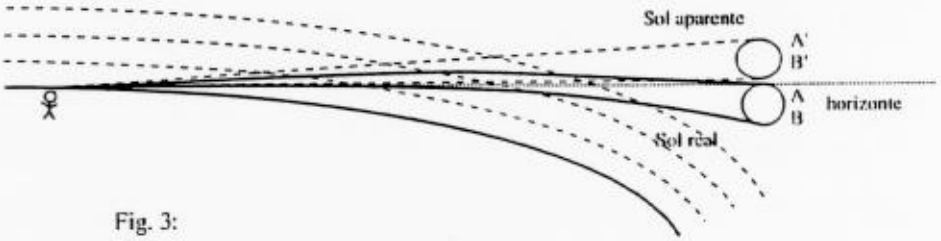

Fig. 3:

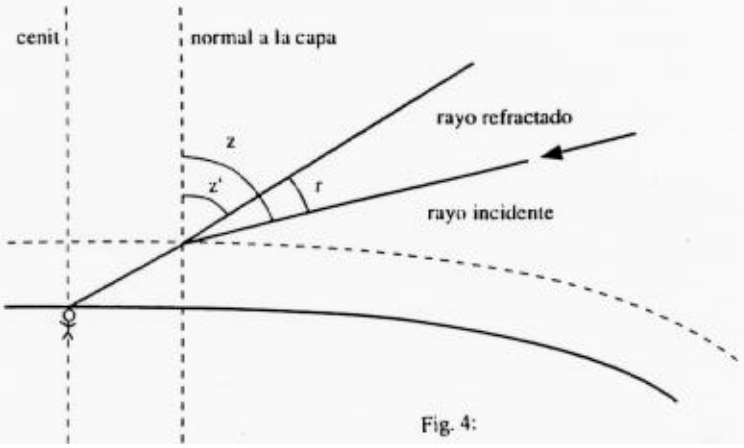

Fig. 4:

Puesta de Sol, 6 de agosto

Puesta de Sol, 7 de agosto

Puesta de Sol, 11 de agosto

Figura 5

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