

The bows and rings of dawn and dusk

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Research Article

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Abstract

The arcs of dawn and dusk are natural phenomena that define the boundary of the border between day and night. They are associated with the refraction of solar rays at high angles of incidence that converge to project an arc of light onto the back side of the earth's atmosphere. The rings of dawn and dusk, in turn, are associated with rays, also at large angles of incidence, which converge to project the image of the Sun. Arcs and rings become visible by scattering light by clouds or particles suspended in atmospheric air in the region in which they occur. Here we show a model that describes these natural phenomena and report the first-time record image produced in July of this year.

Full Text

Looking at the sky and studying it. This was the most performed activity in antiquity, without any instrumental and or theoretical resource, with the aim of understanding the Universe. Therefore, Atmospheric phenomena were undoubtedly a great source of inspiration, whether for philosophers or for artists, that is, for scientists [1-4]. Certainly, these are among those who produce the most beautiful images you could ever imagine. In times past, witnessing such phenomena was the privilege of few. However, high-resolution digital technology broke this paradigm, as technological advances in image recording have gained high technology and quality in sensors associated with the very high technological evolution of optical and computational imaging systems [5-10]. Today, theories [11-14] and all of this is accessible to a large part of the population that records images of the most diverse types of atmospheric phenomena, in high definition. And the result of that is what you see on the worldwide computer network [15-20].

Despite its beauty, the sunrise and sunset have received little attention from scientists. Thus, a model (Fig. 1) that considers the terrestrial globe as a ball lens of air/water mixture with the rays of the paraxial approach totally blocked by the earth's surface is presented. In this condition, an incident solar beam in the Earth's atmosphere, parallel to the direction of the optical axis, defines a plane that cuts the earth's sphere into two hemispheres. A second sun beam that focuses on point *a*, and is propagating parallel to the optical axis, defines the plane of incidence. In this circumstance, refraction index of the earth's atmosphere is not known, as it should vary with altitude and temperature. However, only rays that cross a trajectory above the tangential line of the earth's surface will reach the unilluminated posterior side of the Earth's atmosphere at point *b* (fig. 1.a).

Figure 1.b shows the ray scheme of the model representation in the incidence plane. In the scheme two possible paths of propagation of the solar rays incident in the earth's atmosphere in the region of *point a*, and which leaves the atmosphere on the posterior side in the region of point *b* were indicated. If an observer on the Earth's surface is in *position O*, and looking directly at its eastern horizon, it will see light from the sun's rays scattered by clouds or constituents suspended in the Earth's atmosphere in the later hemisphere. As the refraction process is convergent, the lateral rays around the secondary optical axis

will converge in the direction of the axis. The observer on the earth's surface will also be able to view the cross-section of the beam of rays projected into the atmosphere through scattered light.

For the visualization of the arc and the early morning rings the atmospheric conditions are quite important. First, it is necessary to remember that the Earth has its own rotation and that at every moment, the horizon line of dawn observation is approaching the illuminated hemisphere of the Earth's atmosphere. The result of fig. 2 was recorded on July 29th, 2021. In image 1, you see the dark sky, and then in image 2, the appearance of a horizon line that begins to be illuminated. This increasing illumination of the horizon line is evidenced in image 3. In image 4, we record the appearance of the dawn arc. This is more evident in images 5 and 6. However, on the upper side of the arch there is a region with higher light intensity (indicated by the red arrow in image 7). It is the presence of the dawn ring that will become more visible in images 8 and 9.

Fig. 3 shows the image of a dawn ring in appearance (image 1- red arrow). Then the ring decreases in diameter (images 2 – red arrow) and closes (image 3 - yellow arrow). In images 4 and 5, the expansion of the ring is observed; and in image 6 the appearance of a point of concentration of light in the center (image 6 – yellow arrow). This center point indicated by the yellow arrow of image 6 becomes more intense and turns into a second ring (image 8 – red arrow). The rings grow and, in the center, a third point of concentration of light appears (image 9 – yellow arrow), which confirms in image 10 (yellow arrow). Both increase in size and in image 11 it is possible to visualize the appearance of a fourth point of concentration of light (yellow arrow), which is confirmed in image 12 (yellow arrow). Given this sequence of visual results, it is concluded that the Earth's atmosphere acts as a ball lens and that clouds, or particles suspended in the air, serve as scattering elements of light from a large projection screen.

In turn, the ring of dusk arises from the effect contrary to that of the ring of dawn. Due to the earth's rotational movement, as the horizon observation line moves away from the line that defines the illuminated hemisphere of Earth's atmosphere, the rings and the arc of dusk are projected into the atmosphere. In fig. 4 a closing dusk ring is displayed. The ring is completely visible in the atmosphere and gradually closes completely (image 4.6). Then, the dusk arc becomes apparent in the atmosphere (image 4.7), and it disappears, indicating that the Earth's atmosphere is no longer visible (image 4.9).

Latitude and atmospheric conditions directly influence the detection of the arcs and rings of dawn and dusk. However, as predicted by the model, they occur every day in regions of the earth's surface where the sunrise and sunset occur. In addition, the results showed that the atmosphere itself, due to its composition, acts as a large projection screen. Therefore, the model explains the appearance of these two atmospheric effects, detected historically for the first time in July of 2021, in the city of Ponta Grossa, PR, Brazil.

Declarations

Competing interests: The author declares no competing interests.

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Figures

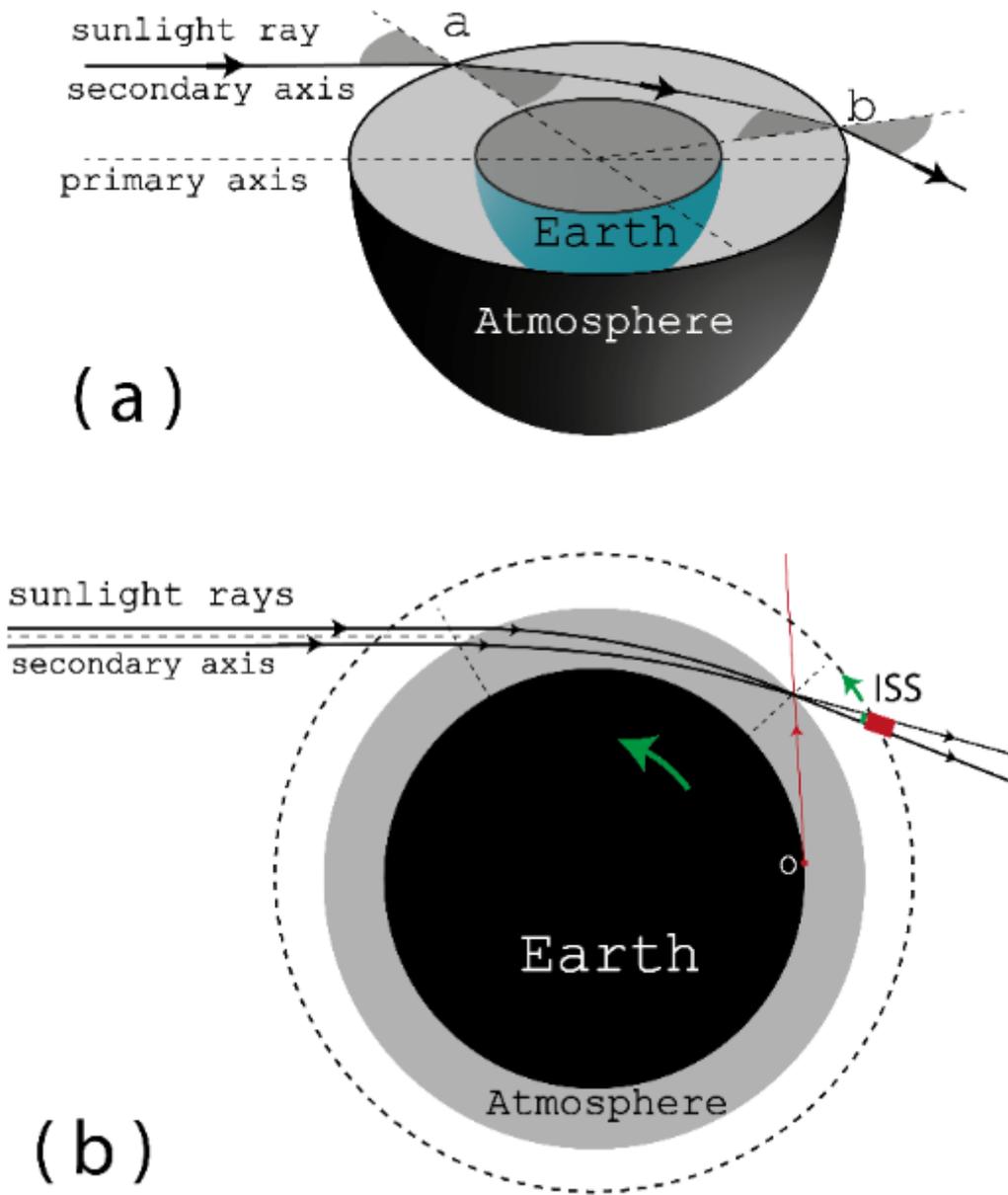


Figure 1

A schematic of the actual situation under study in which one considers a sphere internally composed of the Earth and smothered by its low atmosphere (troposphere, stratosphere, and mesosphere). The schematic is out of size to highlight what happens to the ray of light when crossing the Earth's atmosphere. (a) A ray of sunlight falling in the direction of the primary optical axis defines a plane that cuts the earth's sphere into two hemispheres. A ray of sunlight that focuses on Earth's atmosphere at

point *A*, at a wide angle of incidence, can touch the earth's surface and focus on the back side at point *b*. (b) Rays can tangentially cross the earth's surface and illuminate the atmosphere on the back side. An observer, in *O* on the earth's surface, will be able to see light scattered throughout the atmosphere in the region of point *b*. At the same time an astronaut from the International Space Station will also be able to view the same event.

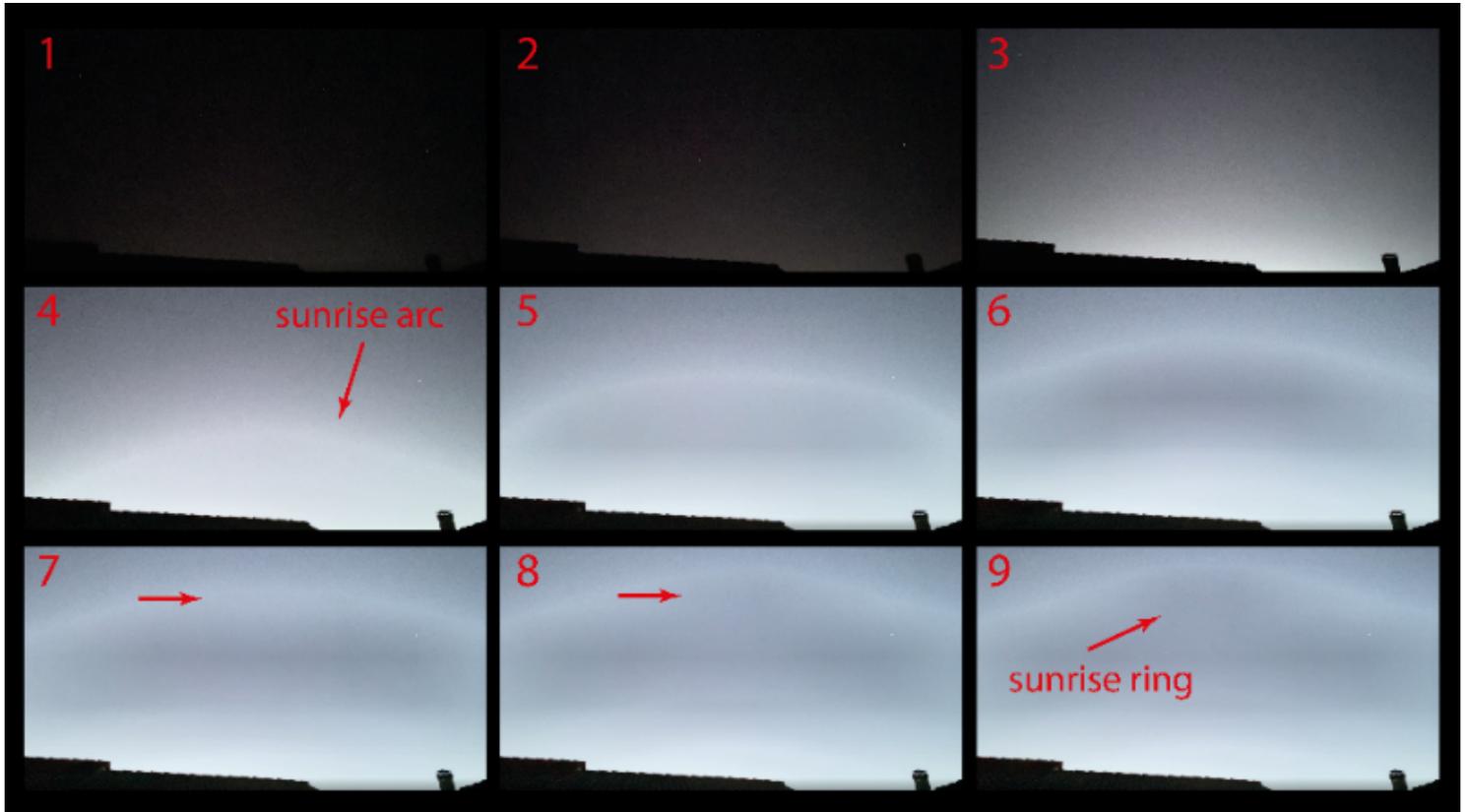


Figure 2

A sequence of images that demonstrate the appearance of the arc and the rings of dawn. The images were recorded on August 29th, 2021, in the city of Ponta Grossa, PR, terrestrial coordinates: 25°4'54.61"S and 50°8'11,90W.

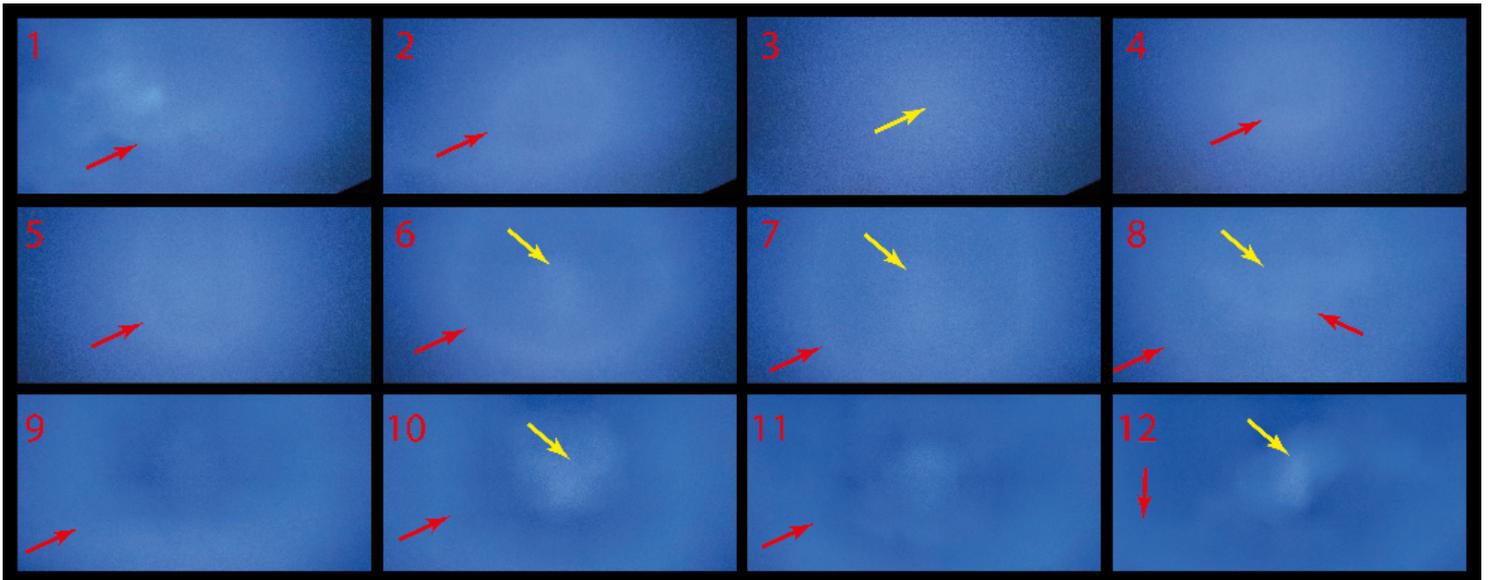


Figure 3

Dawn rings recorded on October 1st, 2021.

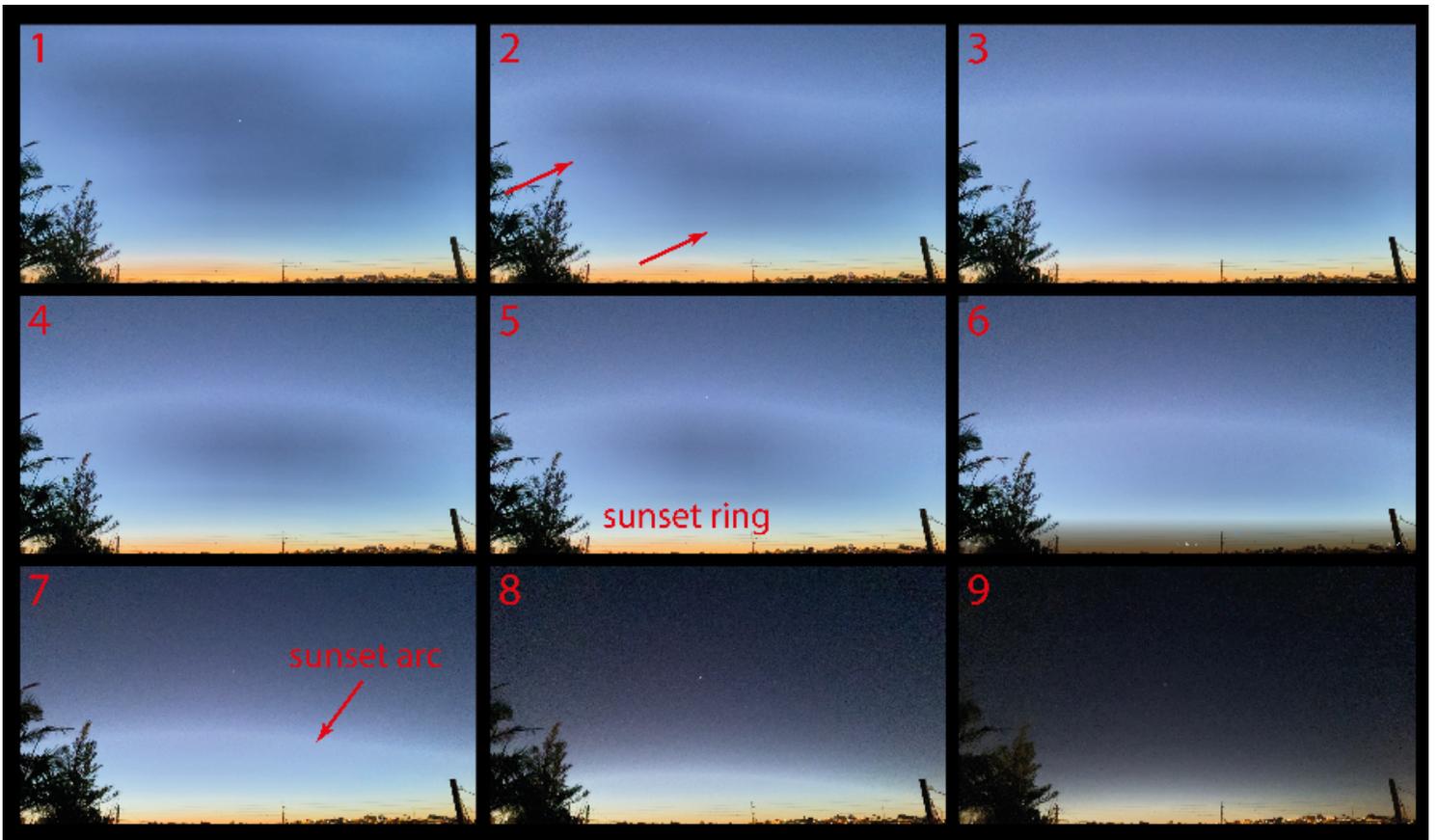


Figure 4

A sequence of images recorded on August 25th, 2021. In image 1, you can see the occurrence of the ring of dusk, indicated by the red arrows. Over time the ring closes and only the arc is visible.