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UNUSUAL HALO DISPLAY RECORDED AT CASPE (SPAIN) IN 1787

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This paper describes an unusual halo observed on the morning of 19 January 1787 from Caspe, Spain. The most striking characteristic of this phenomenon was a vertical tail of light that appears under one of the false suns.

Keywords: atmospheric optics; halo; Parhelion

Atmospheric halos are one of the most spectacular phenomena in nature and human beings have recorded them throughout History. Events of this kind were of great interest to scientists in the 18th century. In this epoch, Spain was characterized by the development of science and the progress of rational knowledge. During this period, appropriate institutions were created, the studies were modified and several science and technology educational centres were founded. In this scientific training, new weapons of artillery and engineers and midshipmen's school established in Cadiz (1717), were prominent and there were significant scientific advances. The creation of the Royal Academies was another of the many achievements of the "Spanish Enlightenment" with great influence in economic, political, and social aspects.

As a result of the progress of science and the rational knowledge, people became more open to examine natural phenomena. We show in this note an unusual halo phenomenon observed from Caspe (Spain) on the morning of 19 January 1787. This observation was made by Fray Bruno de Zaragoza and it was described in great detail in the booklet "Descripción del Fenómeno de los tres Soles" (Description of the Phenomenon of the Three Suns) (Zaragoza 1801). This book was found by chance when we were looking for other documents in a local library.

Fray Bruno de Zaragoza observed a rare halo phenomenon without any astronomical instrument, only with the unaided eye. He made an engraving showing the phenomenon (Fig. 1) that was published in his book (Zaragoza 1801). He defines the observed halo and parhelia as follows: "The tar beams formed an halo or crown, the sun was the centre of the circumference its diameter was about thirty degrees

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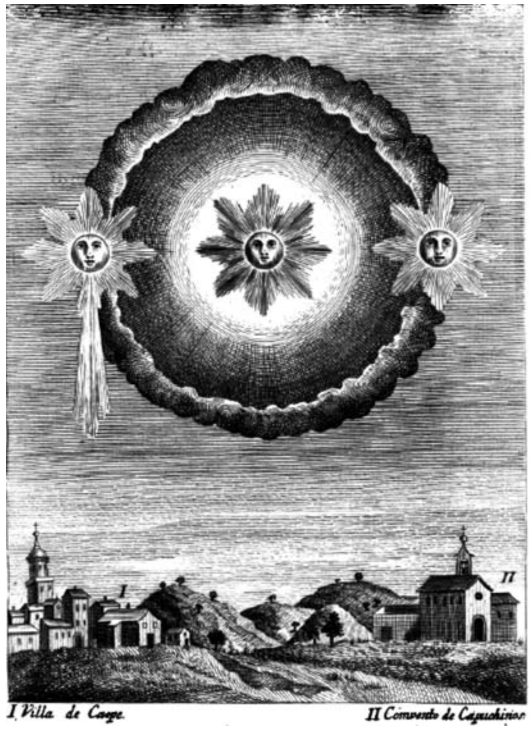

Fig. 1. Drawing that illustrates the phenomenon observed in Villa de Caspe

this situation appeared in the lowest region of the clouds. The colour of the halo or crown was somewhat red. The other two suns appeared at the two ends of the horizontal diameter, although not as bright as that of the center, but very lucid, and of the same size" (Zaragoza 1801, pp. 3–4).

Halos are optical phenomena that can take place from atmospheric refraction of sunlight passing through clouds composed of ice crystals, the reflection of light on the faces of the crystals or a combination of both effects. The light enters these crystals and is reflected several times in their faces, producing different patterns or halos. The most frequent halo is called halo of 22°. This halo is caused by the refraction of light passing through the faces of hexagonal crystals. These light rays are refracted through a layer of a crystal, as they do in a prism of 60° degrees with a minimum deviation angle of 22°, forming a circle around the sun. The inside of this circle is red while the exterior is blue. This distribution is also due to the refraction of light resulting in the separation of light in its different colours: blue is bent more than red. To obtain a complete halo the ice crystals must be distributed in all possible orientations. However, under certain atmospheric conditions, when the flat ice crystals tend to fall on its horizontal bases and the sun is at low altitude, a phenomenon is produced that it can accompany the halos. Under these conditions the crystals refract light on both sides of the Sun, producing two light sources called false suns. The sun appears in the middle the two light sources, and therefore this phenomenon is popularly known as False Suns, Mocks Suns or Sundogs. False Suns take place within the halo of 22° or in the vicinity and the distance among them increases as the sun rises in height over the horizon (Greenler 2000, Tape and Moilanen 2005).

The phenomenon described above is a common optical phenomenon identified totally fine, except for the vertical tail of light that appears under one of the false suns. This document describes this phenomenon as follows: "Bursts of light that in one of the suns represented in our parhelia were directed to the land as a tail or beard shape (and it is delineated in the plate), it seems clear that it caused some sunlight impact, in serving more crass vapours and spheres, who crowded in that part of the halo, and being unable to easily penetrate, they flashed his refraction directly to the Earth under the various sets that makes the light in spherical particles" (Zaragoza 1801, pp. 21–22).

Several hypotheses can be raised about this unusual phenomenon. The first and most intuitive would be a lower pillar phenomenon caused by the reflection of light in drops of water from the atmosphere. It usually appears under the sun or false suns (and even the moon) under appropriate weather conditions. Moreover, the inclination of the crystals must be lower than the elevation of the sun. However, as noted by Zaragoza in this explanation, lower pillar only seems to appear under one false sun as is seen in Fig. 1. For this reason the identification of the phenomenon of halo as a lower pillar is uncertain.

Another hypothesis is that it could be a lower Lowitz arc, a very rare phenomenon to observe over time. This type of halo occurs when the principal axes of the crystals oscillate or rotate on the vertical axis, an unlikely orientation. These arches were documented first by Tobias Lowitz in 1790 in St. Petersburg, Russia.

We have simulated both hypotheses using the software called HaloSim (http://www.atoptics.co.uk). This software creates simulations by accurately tracing up to several million light rays through mathematical models of ice crystals. In the simulation of the first hypothesis, we used the provided file "Hexagonal ice prism.xsh". It describes a crystal with its end faces horizontal and the prism side faces all vertical. Orientation of the plates respect to the axial dispersion were of (5,8,1 and random degrees) with the proportions 40, 20, 15 and 25%, respectively. For the second hypotheses, we take the same crystals with Lowitz orientation (plate or column crystals with tilted about a horizontal axis passing at right angles through to opposed hexagonal prism edges). In both simulations, we use an elevation of the sun of 10 degrees, because the phenomenon occurred in the early hours of the morning, as the author described in the text. Both simulations are shown in Figs 2 and 3.

These simulations were compared with Fig. 1. In our opinion, the original phenomenon observed in the Caspe seems a secondary pillar due to the similarity of the simulation with the drawing. However, the pillar only is observed in the left parhelion in Fig. 1, possibly due to the lack of uniformity in the arrangement of the cloud. An interesting case of asymmetric parhelion probably due to was observed by Vaquero (2002).

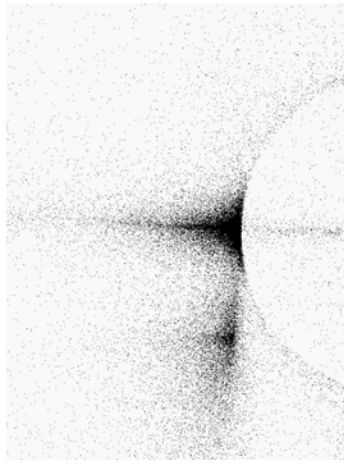

Fig. 2. Simulation of a secondary pillar

Fig. 3. Simulation of a Lowitz arc

In conclusion, it is difficult to know the true origin of this interesting halo display. In fact, establishing the nature of historical phenomena related to weather is not an easy task due to the temporal distance of the events and the kind of descriptions that are available, sometimes very scarce and without details.

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