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Possible extraterrestrial halo displays – a review

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1. Introduction

Halos are created by light refracting and reflecting on ice crystals in the atmosphere. Usually the crystals are tiny hexagonal prisms, either plate-like or columnar. Comparing the crystals with the halos they produce revealed that these two types of crystals tend to cause different types of halos. Depending on the crystal shapes and the orientation that they have while falling through the air, the halos may vary from rainbow-like coloured circles centered on the Sun, to coloured or white spots and arcs at various places in the sky. The most frequent halos appear at angular distance of about 22 degrees from the Sun, while an infrequent group of halos appears at 46 degrees from the Sun. Occasionally, ice also forms pyramidal crystals that can produce rare halos having unusual radii. Fascinating complex halo displays may be observed if the ice crystals are faultless, well shaped, well oriented and have extremely small tilts [3,14]. On the basis of the above mentioned crystal shape – halo type correlations, we can predict the type and orientation of crystals from the observations of halos in planetary atmospheres. For the examination of the atmospheric crystals of other planets or moons, we can use our experience regarding Earth. If we know the crystal structures and optical properties of the crystals in the given clouds, we can predict their halos [5,6,7,8,9].

2. Halos on other planets or moons

Because different types of ice crystals, they are not equivalent to those of our planet, to predict the possible halos we first have to find the possible shapes and orientations of the crystals.

2.1. Carbon dioxide ice crystals on Mars

Carbon dioxide is the main component of the thin Martian atmosphere**.** Carbon dioxide ice can crystallize as several ways: cube, tetrahedra, octahedra, 12-sided rhombic dodecahedra, or even more complicated forms, as for example pentagonal dodecahedra or 24-sided hexakisoctahedra. They are transparent, aerodynamically almost spherical and more strongly refractive than water ice. If these carbon dioxide crystals are randomly oriented, they can form 26, 30 or 39 degree circular halos. Plate-like octahedral crystals may produce four, cuboctahedra eight, and dodecahedra twelve parhelium-like halos (Figure 1).

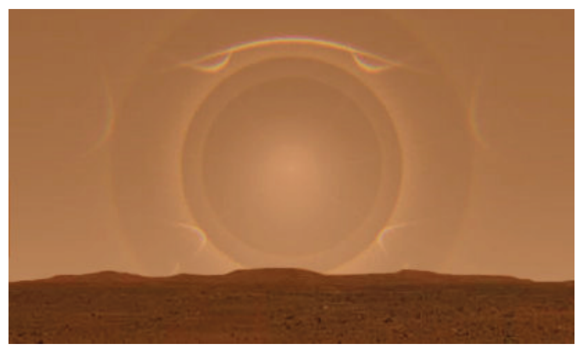

Figure 1: Possible Martian halos caused by different types of carbon dioxide ice crystals (Simulation by Les Cowley, http://atoptics.co.uk)

Clouds of carbon dioxide crystals exist in the Martian sky, especially over the polar regions, consequently these phenomena are likely to appear there [3,4]. Clouds resembling cirrus containing water ice crystals may produce earth-like halos, especially in northern summer hemisphere [12].

2.2. Methane and ethane ice crystals on Titan

Within the current standard models of the Titan atmosphere there may be crystals of methane and ethane. If these crystals are directly lit by the Sun, halos will appear in the Titan sky [1,2,10,11]. Methane belongs to the cubic system too, it can crystallize as cube, square pyramid, octahedron and cuboctahedron. The randomly oriented methane crystals can form 20, 29 or 48 degree circular halos. Ethane, just like water ice, belongs to the hexagonal system, but their refractive index is not the same. Randomly oriented ethane crystals would result – instead of the terrestrial 22 degree halo – a circular 32 degree halo, while plate-oriented ethane crystals could create 32 degree parhelia.

2.3. Several ice crystals on gas giants

The gas giants [3,5,6] have complex clouds with layers of different composition. Ammonia crystals as well as ordinary water ice crystals can produce halo displays there. Ammonia crystals are transparent and have a slightly greater refractive index than carbon dioxide. Halos from the upper Jovian clouds therefore are very similar to those predicted for Mars. Beneath the ammonia cloud layer, we can find superficially earthlike clouds of water molecules because pressures and temperatures are similar to those of Earth in the troposphere. Their ice crystals may form halos resembling those of Earth. The highest clouds of Uranus and Neptune consist of methane ice crystals, therefore we may presume halos similar to the ones in Titan. In the thin freezing atmosphere of Triton, [3,13] halos by nitrogen crystals might occasionally appear (Figure 2).

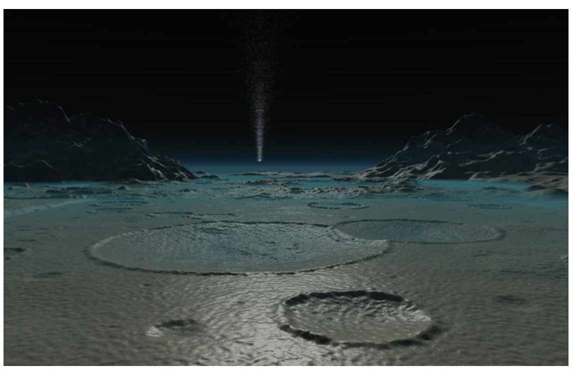

Figure 2: Possible sun pillar caused by nitrogen crystals on Triton (Original graphic by Walter Myers, http://www.arcadiastreet.com.)

2.4. Snow surface halos on ice moons

Under perfect conditions ice crystals can settle onto a snow field and this layer of ice crystals may produce snow surface halos. For such halos, Europa could also be a candidate. In the environment of Enceladus's geyser, carbon dioxide, methane, ammonia and nitrogen crystals were identified, but these crystals seem to be too large and irregular to create snow surface halos [5,6].

3. Conclusions

Successful extraterrestrial halo display observations can help studies of the atmosphere of other planets or moons in the future.

4. References

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