CASSINI OBSERVATIONS OF THE OPPOSITION EFFECT OF SATURN'S RINGS. 2. INTERPRETATION: PLASTER OF PARIS AS AN ANALOG OF RING PARTICLES.

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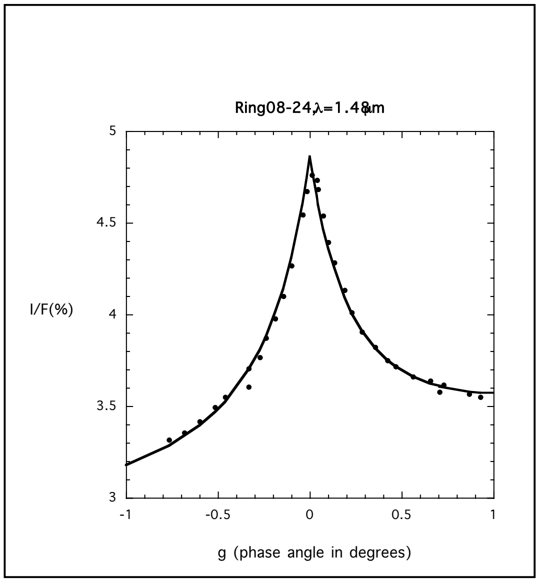
In a companion paper [1] the Cassini VIMS observations of the transit of Saturn's rings by the zero phase point and the method of extracting phase curves of the opposition effect (OE) are described. We fitted a theoretical equation [2] that interprets the phase curves as a coherent backscatter opposition effect to the data. Figure 1 shows a typical fit, in which the dots are the data and the line is the fitted function.



There are two major types of OE: a shadow hiding opposition effect (SHOE), and a coherent backscatter opposition effect (CBOE). In SHOE the particles in a medium cast shadows on others behind them; these shadows are visible at all angles except zero phase when each particle hides its own shadow. In CBOE waves multiply scattered within a medium can traverse the same path but in opposite directions; at zero phase such waves interfere constructively with each other. Historically, the OE of Saturn's rings has been interpreted as a SHOE, in which the shadows are those cast by the ring particles. However, we argue here that it is a CBOE for several reasons: (1) The fit of the theoretical CBOE function to the data is excellent. (2) The OE width is extremely narrow, ~ a degree or less, whereas a typical SHOE is many degrees wide. (3) Earth based observations [3] have shown that the ring OE is accompanied by a narrow region of negative polarization of similar angular width as the OE. This negative polarization is well understood theoretically [4] and is predicted to accompany a CBOE. (4) The angular width of the peak increases with wavelength (figure 2), as predicted by CBOE models but not by SHOE.

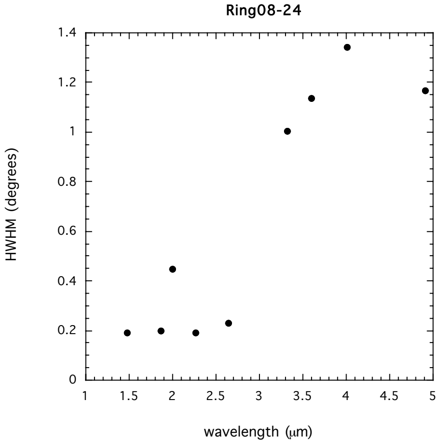
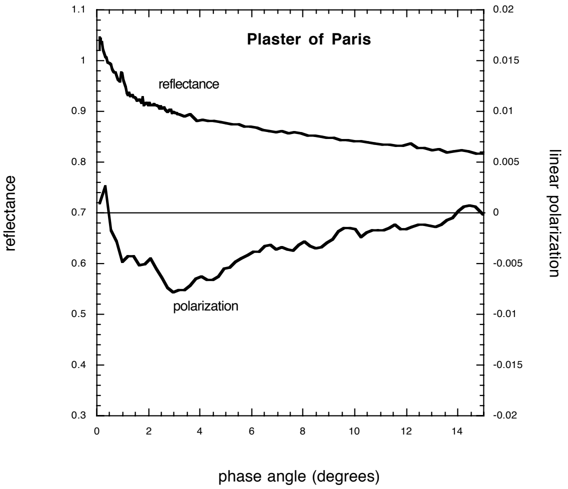


Figure 2.

CBOE theory also predicts that the width depends on the transport mean free path (TMFP), which may be thought of as the distance a typical photon travels in the medium before its direction is changed by a significant angle, and is of the order of the separation of the scatterers in a particulate medium The TMFP obtained from the CBOE fits range from about 40 μm at wavelengths where the reflectance is high to 10 μm where the reflectance is low. Such a dependence is expected because high albedo particles tend to be forward scattering, which lengthens the TMFP, whereas low albedo particles tend to be isotropic or even backscattering, which makes the TMFP approximately equal to the mean particle size. Thus, we infer that the OE is caused by coherent interactions between sub-particles in the outer layers of the ring particles, and that these sub-particles are of the order of 10 μm in size.

We point out that plaster of paris is an interesting analog of the ring particles. In dry powder form plaster of paris consists of $(CaSO_4)_2 \cdot H_2O$. When mixed with water the grains hydrate to gypsum $CaSO_4 \cdot 2H_2O$ and swell to form a porous mass of interlocking micrometer-size particles with considerable strength. Figure 3 (below) shows the phase curve and polarization of a solid piece of plaster of paris. Not only does this material have a well-developed OE, but it also displays a negative branch of polarization of similar width as the brightness peak. Reflectance measurements taken in circularly polarized light (not shown) confirm that the peak is a CBOE. If this model is correct the ring particles are porous aggregates of interlocking grains ~10 μm in size of water frost plus impurities.



References: [1] Nelson, R.M. et al (2006), this conference. [2] Hapke , B. (2002), *Icarus*, **157**, 523. [3] Johnson, P. et al (1980), *Nature* 283, 146 [4] Hapke, B. (1993), *Theory of Reflectance and Emittance Spectroscopy*, Cambridge University Press, Cambridge.