EPSC Abstracts
Vol. 6, EPSC-DPS2011-732, 2011
EPSC-DPS Joint Meeting 2011

Opposition effect of Saturn's rings. Hints of ring physical properties.

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Abstract

The opposition effect of Saturn's rings as seen by the CASSINI-ISS/WA camera is studied. The shape of opposition surge is shown to be highly dependent on the viewing geometry within the field of view. In Saturn's C ring plateau P8, the peak can be easily reproduced by a photometric model, assuming inter-particle shadow-hiding only (RSHOE) and taking into account the ring finite vertical thickness. Ring properties like particle single scattering albedo, thickness-to-particle-size ratio H/R or ring volume filling factor can be derived.

1. Introduction

The opposition effect manifests itself as a sudden rise of the I/F ring albedo around zero phase angle. Known since Seeliger in 1887 [12], this effect may have several origins. Interparticle shadow hiding (RSHOE) was first proposed ([12]) to explain the surge as particle shadows become invisible as the observer comes closer to the lightning direction. This effect may also take place at the particle scale, between regolith particles (SHOE). The coherent backscattering opposition effect (CBOE) is usually advanced to explain color dependence of the surge and rise at very small phase angle, below 0.4° [6].

Recent analytical study shows that vertical and horizontal phase effects $\Delta\mu$ and $\Delta\phi$ can dramatically impact the brightness surge at very low phase angle when finite thickness and non-zero filling factor is taking into account [Ferrari, A&A submitted]. Unlike [1] and [9], we are willing to test how well RSHOE alone can reproduce the observed opposition effect. Data from Cassini spacecraft [13] are directly fit to models without intermediate morphological study and without global averaging on large datasets to carefully scrutinize the effect of viewing geometry on the shape of the opposition surge.

Ring's macroscopic characteristics such as vertical thickness (H), mean particles radius (R), and ring volume filling factor (D) also interfere in the shape of the opposition surge under our assumptions and can be derived from observations ([2], [3], [4], [7]).

2. Data Reduction

Sixty-four images of the wide-angle camera [10] taken with the visible CLR1+CLR2 filter configuration are used. This data set was taken on the 26 June 2005 from 03:20 pm to 05:04 pm, when the solar elevation $B_0 \approx 21.3°$. The phase angle ranges between 0.023° and 2.28°. After calibration and renavigation to correct from eventual pointing inaccuracy, phase functions (I/F vs phase angle α) are extracted with two different techniques. Either the mean I/F albedo is extracted in different images for a ring along the track of the sunspot or it is extracted on a single image and extracted at a given distance along the ring longitude, apart from the sunspot, where the phase angle is also varying. Both techniques are compatible but the second one allows a more complete illuminating and viewing geometry for our study.

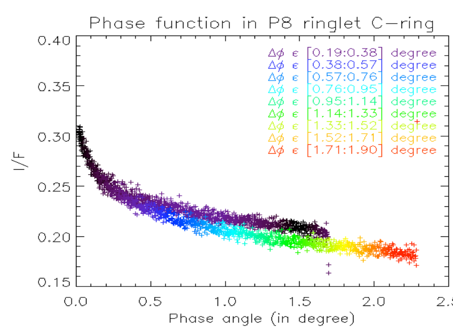

Figure 1: I/F ratio vs of phase angle within a single image. Color code gives $\Delta\phi = \phi - \phi_0$ (respectively ring and solar longitude).

The asymmetry between the two branches observed in Figure 1 can be explained by an horizontal phase effect $\Delta\phi$, which equals zero at two different longitudes within the image: 1) At zero phase angle where both horizontal $\Delta\phi$ and vertical opposition effect $\Delta\mu=\mu-\mu_0=0$ ($\mu_0=\sin B_0$ and $\mu=\sin B_{SC}$ with B_{SC} for spacecraft elevation) take place, and 2) at phase angle equal to 1.5° where only horizontal opposition effect takes place. In addition to this effect, change of $\Delta\mu$ for the upper branch compare to the lower branch causes the difference of the observed I/F albedo value. This reveals that modeling phase function without taking into account the full geometrical conditions ($\Delta\phi$,$\Delta\mu$) is incorrect.

3. Results

The classical layer model including RSHOE takes into account the fact that the probability of an emergent ray to escape from optical depth τ is no more independent of the probability of an incident ray to reach this depth at small phase angle. This dependence translates in a corrective optical depth which increases near opposition. Under these conditions, the ring albedo I/F can be written as (See Ferrari, A&A submitted):

$$\frac{I}{F} = \frac{\omega_0 P(\alpha)}{4} \int_0^{\tau_0} e^{-2(\tau-\tau_c)/\langle\mu\rangle} \frac{d\tau}{\mu} \qquad (1)$$

with $<\mu>=2\mu\mu_0/(\mu+\mu_0)$, ω_0 the single scattering albedo. τ_c is a corrective optical depth, which expression varies with authors ([4], [5], [8]). [5] and [8] unlike [4] assumed a infinite optical depth τ_0 to to provide surface regolith physical properties . Here, optical τ_0 is finite as in [4].

Figure 2 shows the I/F albedo of the C ring P8 plateau (a=88439±40 km) divided by a Callisto-like phase function $P(\alpha)$ [9] fitted with the three models for τ_c, given the photometric optical depth $\tau_{PH} = 0.22$. Fits are consistent and in good agreement with data. as far as dynamical optical depth and single scattering albedo are concerned, and compatible with [9]. They reproduce well the dependence of the phase curve. Ring filling factor D and H/R ratio have reasonable values for the C ring that is optically thin and might be only a few-meters thick with a population of cm-sized particles. This shows that RSHOE alone is able to reproduce the C ring opposition effect without CBOE or SHOE.

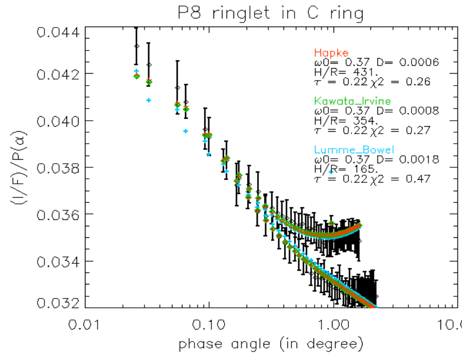

Figure 2: Black dots are ISS observations. Error bars are statistical deviation when binning.

4. Conclusion

It is shown here that varying viewing geometry within single images of the sunspot provide useful constraints on the dependency of the opposition surge with viewing and ring physical properties. Assuming finite optical depth, ring non-zero filling factor and inter-particle RSHOE only, the opposition peak on a C ring plateau could easily be reproduced, giving coherent ring characteristics. Further study will be conducted on other rings.

Acknowledgments

This work was supported by the Centre National d'Etudes Spatiales (CNES).

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