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On the non-monotonic variation of the opposition surge morphology with albedo exhibited by satellites' surface

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Abstract

We used well know phase functions of satellites and rings around the giant planets of our Solar System to study the morphology of the opposition effect (at phase angles alpha < 20 degrees, see Déau et al. 2009, Planetary and Space Science, vol. 57, p.1282–1301). To avoid the effect of the variable finite size of the Sun, we use a deconvolution morphological model to retrieve the morphological parameters of the surge (A and HWHM). These parameters are found to have a non-monotonic variation with the single scattering albedo, similar to that observed in asteroids (Belskaya and Shevchenko, 2000, Icarus, vol. 147, p.94–105), which is unexplained so far. The non-monotonic variation is discussed in the framework of the coherent backscattering and shadow hiding mechanisms.

1. Introduction

When the source of light is directly behind the observer, such that the phase angle approaches 0° a phenomenon called the opposition effect is observed. Coherent backscattering and shadow hiding mechanisms may cause this effect. The opposition effect is characterized by two morphological features on optical phase curves: (i) a surge i.e. a non-linear increase in the scattered brightness of the surface when phase angles approaches 0° (this is described by the amplitude and the angular width of the surge) and (ii) a linear decrease in the scattered brightness of the surface for phase angle values in the range 10° to 50° (this is described by the phase coefficient or the slope of the linear part S). While the slope of the linear part of asteroids shows a monotonic variation with albedo [1], the amplitude A and the angular width HWHM of the asteroids' surge are known to exhibit a non-monotonic variation with albedo. We then investigate the behavior of the surge morphology (A and HWHM) with albedo of other planetary surfaces (satellites and rings of giant planets).

2. From the opposition phase curves to A and HWHM

We used previously published phase functions of satellites and rings around the giant planets of our Solar System to study the morphology of the opposition effect, see Fig. 1 and [1]

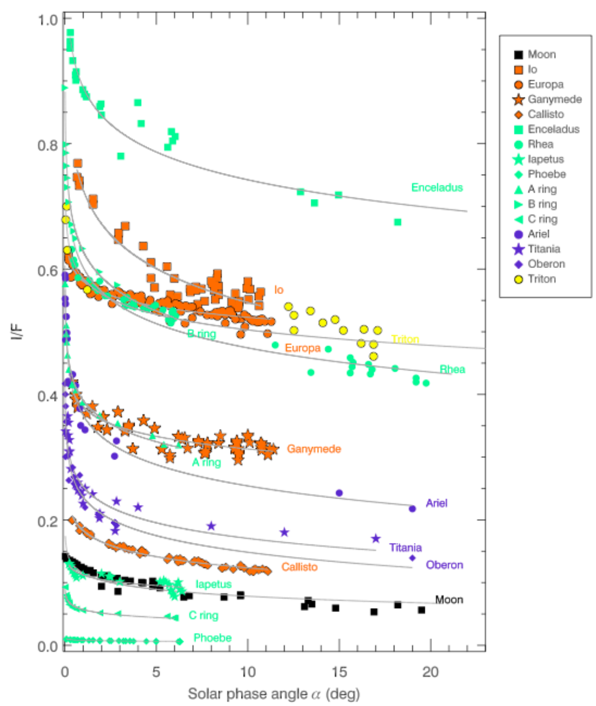

Figure 1: Opposition phase curves of the surface of satellites and rings from [2].

To avoid the effect of the variable finite size of the Sun, we use a deconvolution morphological model to retrieve the morphological parameters of the surge (A and HWHM), see [2].

3. Comparison to asteroids

Regarding the amplitude of the surge, a separate examination of low- and high-albedo objects can lead to conflicting fits: (i) for low and moderate albedo objects, [4] and [5] found a monotonic increase of the amplitude with increasing albedo; (ii) for high albedo objects, the results of [4] suggest a monotonic decrease of the amplitude with increasing albedo.

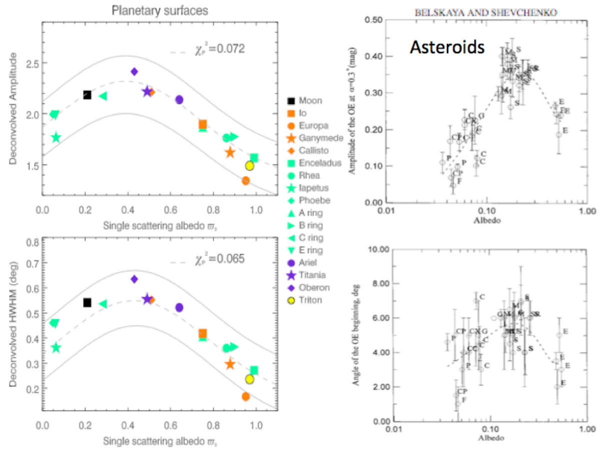

Figure 2: Variations of A and HWHM width albedo for satellites, rings and asteroids.

The present re-analysis of these data demonstrates the presence of a gaussian-like trend for the amplitude and the angular width of the surge (Figure 2). Additional dark planetary surfaces like Phobos and Deimos [1] bring new data in the low albedo range. Thanks to them, Iapetus and Phoebe are not considered anymore as minor outliers disturbing the inappropriate linear fit of [2]. This gaussian-like trend was previously observed in asteroids for both amplitude and angular width (see Figs.3 and 5 in [1]). This trend reconciles the various partial linear analyses cited above. It also harmonizes the marginal behavior of the asteroids with the general behavior of other planetary bodies like satellites and rings.

4. Summary and Conclusions

Since the discovery of the non-monotonic variation of A and HWHM with the albedo, several incomplete and unsatisfactory explanations were proposed:

- [1] proposed that the contribution of the coherent backscattering mechanism for the narrow surge is about 20-60% for low albedo asteroids increasing to 80-90% for high and moderate albedo asteroids. For the larger phase angles, they proposed that shadow-hiding effect has dominating influence on the scattering.
- According to [5], the increase of the amplitude of the surge with the albedo for the dark asteroids is opposite to trend expected for shadow hiding mechanism. For them, it is the evidence that another mechanism is responsible for the increase of A with the albedo for dark asteroids. In particular, they assume that an increase of a portion of light substance in the surface layer of dark asteroids causes increasing contribution of the coherent backscattering mechanism.
- [6] proposed that the shadow hiding accompanying single scattering could influence the coherent backscattering mechanism by blocking its reciprocal components.

For all of these explanations, we distinguish two trends: either the coherent backscattering and the shadow hiding have independent domains of preponderance with respect to the phase angle; either the coherent backscattering and the shadow hiding are coupled, whatever the phase angle range. New multi-wavelength observations (because the shadow hiding is wavelength independant) are necessary to determine the actual origin of the non-monotonic variations of A and HWHM.

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