IS THE OPPOSITION SURGE MORPHOLOGY A RELEVANT DIAGNOSIS OF THE KNOWLEDGE OF ATMOSPHERELESS PLANETARY SURFACE ?

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Introduction: Reports of the opposition effect on planetary surfaces of the Solar System have supplied interesting constrains about regoliths and state of the macroscopic surfaces [1-3]. Indeed, the opposition effect is now known to be the combined effect of the coherent backscatter (at small phase angles) and the shadow hiding, at larger phase angles [2]. However such characterization of the morphology of the phase function at the opposition ($\alpha \sim$ 0-20°) is restricted by the angular resolution and the phase angle range of the phase functions. Moreover, some effects, not yet taken seriously into account, can play an important role in a planetary comparative study. This paper describes the results of a full morphological parametrization [4] and comparison of phase functions of main satellites of the Solar System.

Observational data: We use a dozen of optical phase functions available in the photometric community [5-19], and converted in I/F units for practical purposes. The data cover the common range $\alpha \sim$ 0-20° but the zero phase angle is never reached due to the angular size of the Sun which varies from the Moon to Neptune. In order to link the morphological parameters to a physical surface property, we use the single scattering albedo, which represents the normalization factor of the full phase curve, which is already calculated for all the satellites selected for this study [20-28], for a similar range of wavelength.

Discussion: The results of the morphological parametrization lead to the following trends:

Amplitude of the opposition surge. The figure 1 shows a weak dependence of the amplitude of the surge on the albedo. If the full morphological amplitude is due to the coherent backscattering effect [29], and depends on the regolith grain size [30], the weak dependence of A=f(ϖ_0) can be understood as a default of relation between the grain size and the albedo. But the assumption of [29] is not correct because the amplitude of the coherent backscattering effect must saturate at 1.5 whereas the amplitude calculated with the morphological model is sometimes greater than 1.5 in the figure 1. This clearly demonstrates that the morphological amplitude is dominated by the both effects : coherent backscatter and shadow hiding, as underlined by [31]. In addition, the figure 1 shows a colored-layer repartition of the amplitude, indicating that distant objects (as Uranus) are illuminated with a fainter source, which can significantly increase the surge in brightness [32].

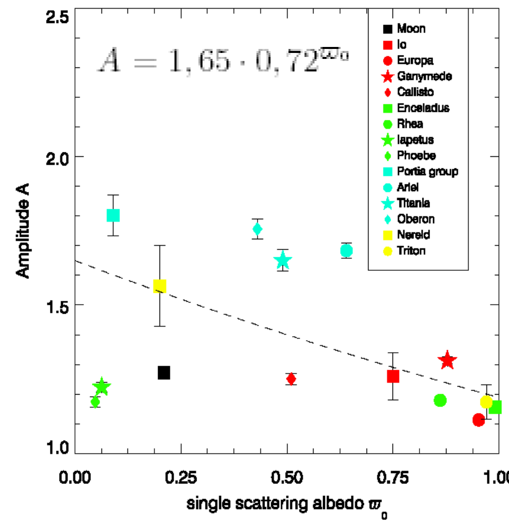

Fig. 1. Amplitude of the opposition surge calculated with the model of [4] as a function of the albedo.

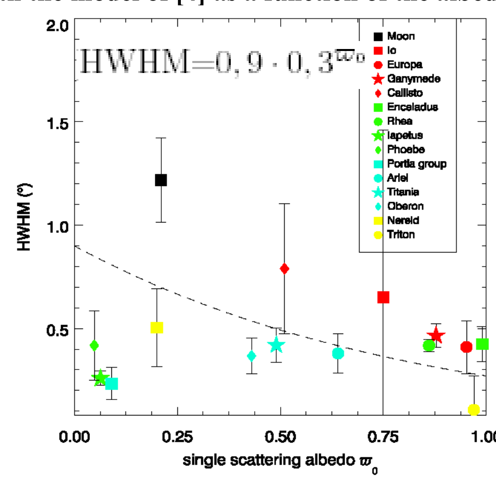

Fig. 2. Half width at half maximum (HWHM) of the opposition surge calculated with the model of [4] as a function of the albedo.

Angular width of the opposition surge. The figure 2 shows, as the amplitude, an important dispersion with the albedo. Current models link differently HWHM with medium physical properties [30,31,33]. But its seems that the morphological HWHM is less than the shadow hiding (SH) width and greater than the coherent backscatter (CB) width, [34], so the morphological width have also a complex relation with SH and CB widths. Consequently, current models can difficultly explain the dependence of the morphological HWHM on the albedo.

Slope of the linear part. In the figure 3, we find a strong correlation of the slope with the single scattering albedo. This correlation seems to mix all the satellites, suggesting that the finite size of the Sun don't have a significant influence on the shadow hiding effect. This new trend demonstrates that the shadow hiding is stronger for high albedo surfaces, which agrees with numerical simulations of the shadow hiding [35].

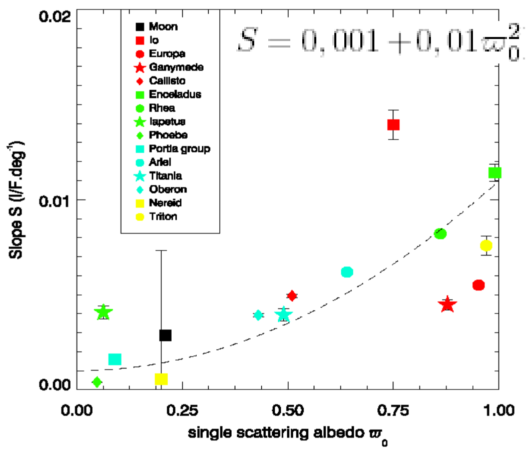

Fig. 3. Slope of the linear part (α ~ 3-20°) calculated with the model of [4] as a function of the albedo.

Summary: In conclusion, two strong trends provide constrains on the morphological parametrization :

The role of the angular size of the Sun. A and HWHM variations are linked to the size of regolithic grains and also to the finite angular size of the source. But our morphological don't clearly show that the Sun size effect dominates the size effect of the coherent backscatter, since the surge of Neptune's satellites have smaller amplitude than the Uranus' ones. It will be interesting to test the importance of these two effects with laboratory measurements.

Albedo dependence on the morphological parameters. We show with this study that the amplitude (for objects illuminated by the same angular source) decreases when albedo increases. A similar anti-correlation is remarked for HWHM, with the same dispersion. By contrast, a strong correlation of the slope S (in I.F.deg^{-1} units) is found with the albedo, implying that the shadow hiding is more efficient in high albedo surfaces, which is also noted for the opposition slope of asteroids (in mag.deg^{-1} units) [3].

Concluding Remarks: For a relevant comparative study of the opposition effect, it is necessary that further analytical models add new effects, as the solar angular size dependence on the opposition surge (via A and HWHM) and the albedo dependence on the shadow hiding (via S). The polarization of the opposition effect need also to be seriously parametrized [1] and integrated to current models [30-31] but polarized data are missing for a majority of the selected satellited in this study. Consequently, accurate data and models (or numerical simulations) could provide in the future a more relevant diagnosis than currently.

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