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Small Particle Population in Saturn's Rings from Cassini UVIS and VIMS Stellar Occultations

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Abstract

The Cassini Ultraviolet Imaging Spectrograph (UVIS) observes stars with its High Speed Photometer (HSP) at in the FUV bandpass (0.11 – 0.19 μm) as they are occulted by the rings at a sampling rate of 500 or 1000 samples per second [1]. The Cassini Visual and Infrared Mapping Spectrometer (VIMS) observes stellar occultations in the near infrared, with low-noise light curves at 2.9 μm. This factor of ~20 in wavelength would be enough to enable determination of the population of micron-sized particles by differential optical depth measurements: such small particles would not attenuate the relatively long wavelengths observed by VIMS. The population of such particles, with the exception of localized and temporary phenomena such as spokes [2], is negligible in the main rings (A, B, C, and Cassini Division). However, differences in the field of view sizes between UVIS and VIMS lead to an additional separation of the optical depths measured by the two instruments. The small effective field of view for VIMS, coupled with its longer wavelength of observation, means that light diffracted by particles smaller than ~ 1 cm in diameter is not replaced by diffraction from neighboring particles, while all lost diffracted light in UVIS data is replaced by light diffracted from other particles in its larger field of view. The presence of self-gravity wakes in the A and B rings complicates the comparison. We model the wakes including a small particle population. We find a significant population of sub-cm particles in the outer A ring, with the fraction increasing to ~20% of the total optical depth at the outer edge of the ring.

1. Introduction

The UVIS measurements are made at an effective wavelength of 0.15 μm, and the HSP field of view is a 6 mrad square. Thus all diffracted light from particles larger than xxx μm is captured by the relatively large field of view. On the other hand, VIMS reads out only a single 0.25 by 0.5 mrad pixel in which the star is centered during an occultation. This improves the sampling frequency to provide high spatial resolution. However, at that size aperture, particles smaller than ~1 cm will diffract light out of the field of view that is not replaced by neighboring particles. Consequently, if there is a population of sub-cm particles VIMS occultations will see a reduction in stellar signal that is due to diffraction in addition to the attenuation of the direct signal by the intervening ring material. UVIS sees no such reduction due to diffraction, so VIMS optical depths may be higher than UVIS optical depths if there is such a small particle population.

Self-gravity wakes in the A and B rings, in which particles gravitational aggregate into elongated, ephemeral canted structures [3 and references therein] which add an azimuthal dependence to the measured optical depth. Because UVIS and VIMS (almost always) observe different stars, the optical depths measured by the two instruments are dependent on the details of the self-gravity wake structure of the rings. Thus, direct comparisons of optical depths cannot be used to extract particle size information for the A and B rings. We have therefore extended the simple geometric model of the self-gravity wakes of [3] to include a population of sub-cm particles in the inter-wake gaps. We then fit UVIS and VIMS data simultaneously to solve for the self-gravity wake parameters as well as the fractional gap optical depth due to sub-cm particles.

2. Self-Gravity Wake Model

We model the wakes as infinitely long slabs of rectangular cross-section with dimensions H and W and separated by a mean distance of S in the direction perpendicular to the long axis of the wakes [3]. The wakes are assumed to be opaque, and the scales H, W, and S are very large compared to the wavelength of observation (W+S~50 m) so the only difference between UVIS and VIMS optical depths comes from the optical depth due to individual small particles in between the wakes, τ_{gap}. We include in the self-gravity wake model a population of particles that diffract light out of the VIMS field of view. We fit the combined data sets to this model with the additional parameters of the optical depth due to small particles and the size of the smallest particle. If the smallest particle has a diameter below ~1 cm then there is no difference between the UVIS and VIMS measurements.

Figure 1 shows the value of τ_{gap} retrieved from fitting the self-gravity wake model separately to the UVIS and VIMS occultations across the A ring. The VIMS data lead to a higher τ_{gap} than UVIS data, consistent with a population of sub-cm particles between the wakes.

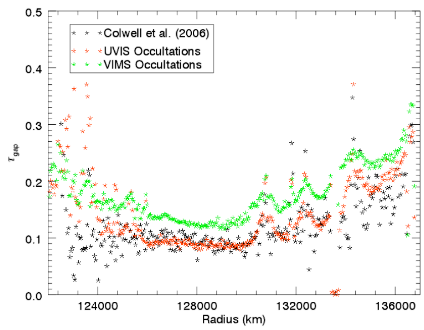

Figure 1: Retrieved values of the gap optical depth fitting only UVIS (red) and only VIMS (green) occultations. The black points are the results from [3] using a smaller set of UVIS data. The larger UVIS data set (red) is consistent with the original analysis, but has less scatter.

3. Results

We find that the optical depth due to sub-cm particles increases towards the outer edge of the A ring (Figure 2). The source of these small particles may be the regolith of larger ring particles. While the Hill spheres of the ring particles are larger in the outer part of the ring system, making it easier for aggregates to grow, collision velocities may be higher on average due to the numerous first order resonances with Pandora and Prometheus.

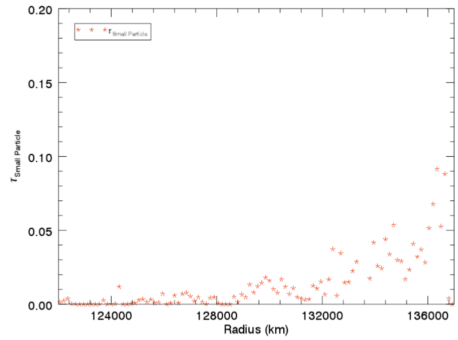

Figure 2: The optical depth due to particles with $d <$ 1.2 cm calculated from the combination of UVIS and VIMS optical depths.

There are a handful of stars that are visible to both UVIS and VIMS making direct comparison of optical depths possible, without modeling the geometric effects of the self-gravity wakes. In addition, the C ring and Cassini Division do not have self-gravity wakes, at least not at the level that results in observable differences in optical depth due to viewing geometry in UVIS data. We can thus make direct comparisons of UVIS and VIMS occultations in these ring regions. Our preliminary results do not show a substantial population of sub-cm particles in those regions.

Acknowledgements

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