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# Small Particles as Tracers of Dynamical Stirring in Saturn's Rings

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## Abstract

The Cassini Ultraviolet Imaging Spectrograph (UVIS) observes hot stars with its High Speed Photometer (HSP) as they are occulted by the rings at a sampling rate of 500 or 1000 samples per second [1]. Typical stellar occultation tracks across the rings result in a radial ring plane resolution due to the sampling cadence of about 10-30 meters, with a comparable Fresnel zone size on the rings. The total area in the ring particle frame from which a single UVIS HSP measurement is made is typically only several hundred square meters. The largest individual particles in the rings have a projected surface area of several tens to ~100 square meters [4]. As a result, sequential measurements of the intensity of transmitted starlight, $I$, may vary greatly due to the presence or absence of large particles along the line-of-sight for that particular measurement even though over many measurements the average optical depth remains constant or slowly varying. We analyze the magnitude of these fluctuations in the signal to determine variations in the ring particle size distribution. We find evidence for an enhanced population of small particles in perturbed regions of the rings such as density waves, consistent with aggregates being broken apart by more vigorous collisions in these regions.

## 1. Introduction

The UVIS measurements are the sum of two independent Poisson processes: the transmitted stellar signal and the background signal. The background signal $b$ is usually less than 1000 counts/s while the unocculted stellar signal, $I_0$, is usually between several times $10^4$ counts/s and several times $10^5$ counts/s. If the signal transmitted through the rings is itself Poisson-distributed, then the sum of these two processes is also Poisson-distributed [3]. Thus, if the rings act as a gray screen that simply attenuates the the line-of-sight optical depth of the rings, $\mu$=sin($B$), and $B$ is the angle between the line-of-sight and the ring plane, then the observed signal should be Poisson-distributed. For Poisson distributions, the variance is equal to the mean. We calculate the variance of the data in segments corresponding to 1-10 km in ring plane radius and subtract the mean to get an excess variance, $\Delta\sigma^2$. This excess variance can then be used to get an autocorrelation length or effective particle or clump size in that segment of the rings.

Determining an effective particle size or autocorrelation length from the excess variance requires a model for the autocorrelation function and certain assumptions about the effects of diffraction on the size of the integration area, $A$. However, qualitatively the dependence of $\Delta\sigma^2$ on optical depth for a particular particle size or particle size distribution is independent of the details of the model: at low optical depths $\Delta\sigma^2$ goes to zero regardless of particle sizes because the signal and variance are dominated by the unattenuated starlight. Similarly, at high optical depths $\Delta\sigma^2$ again goes to zero because the signal and variance are dominated by the background. The peak excess variance for a given particle size distribution is reached at optical depths of ~0.5. We model the autocorrelation length, $L$, by assuming a particle autocorrelation function that is linear with the offset distance (this is essentially a one-dimensional autocorrelation function, [2]):

$$L = \sqrt{\frac{A\mu\Delta\sigma^2}{\pi I_0^2 \exp(-\tau/\mu)(1-\exp(-\tau/\mu))}}. \quad (1)$$

## 2. Observations

For a given particle size distribution (essentially for a given value of L), $\Delta\sigma^2$ is single-valued with $\tau$, as described above. However, if we look at $\Delta\sigma^2$ as a different distributions and not a single-valued function (Figure 1).

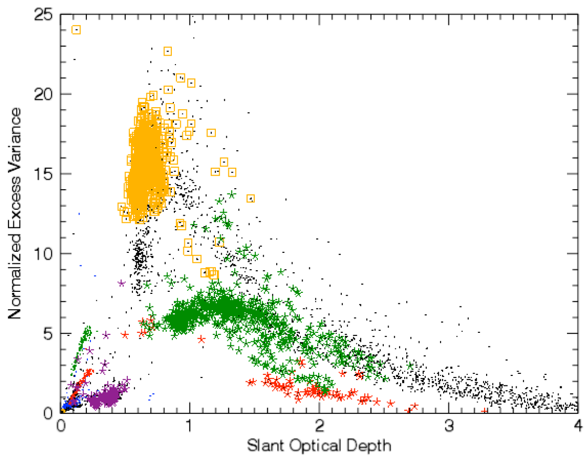


Figure 1: The excess variance (in arbitrary units) as a function of observed (line-of-sight) optical depth for an occultation of β Centauri. The data are not single-valued as would be expected for a single particle size distribution. The lower left corner shows three branches of points (in purple, red and green) indicating three distinct particle populations. Red points: C ring ramp. Blue points: Cassini Division. Green points: Cassini Division ramp. Orange squares: central A ring. Purple asterisks: C ring plateaus. Red asterisks: inner 700 km of B ring. Green asterisks: B1 region.

Figure 2 shows the observed optical depth and the calculated value of L for a region in the A ring containing a strong bending wave and a strong density wave. The effective particle size decreases in the bending wave as well as the peaks of the density wave.

## 3. Summary and Conclusions

The stellar occultation statistics provide a powerful tool to examine particle size variations on small spatial scales in Saturn's rings. Decreases in the effective particle size in some perturbed regions is consistent with a view of particles as loosely bound aggregates that are broken apart by interparticle collisions. Regions where collisions are more frequent or more energetic thus may have a smaller effective particle size.

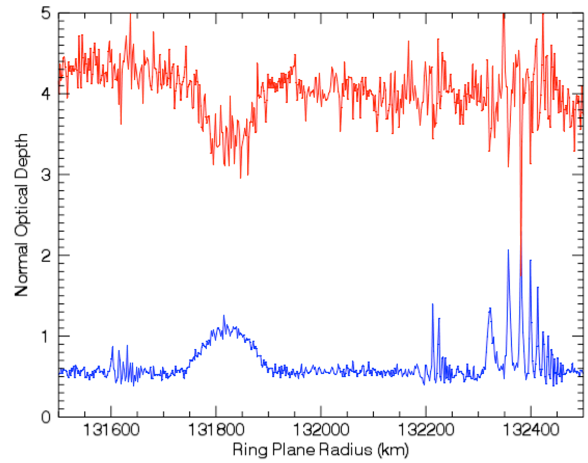


Figure 2: Normal optical depth (blue) and particle autocorrelation length (red, in meters, Eq. (6)) showing the Mimas 5:3 bending wave (131,800 km), the Mimas 5:3 density wave (132,300-132,450 km) and three weaker waves produced by Pandora and Prometheus (two of which overlap). The autocorrelation length drops both in the bending wave and in the peaks of the strong density wave, indicating that the more vigorous collisions at those locations are breaking apart clumps of particles and liberating smaller particles from the regolith of larger particles.

## Acknowledgements

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## References

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