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The Brightening of Saturn's F Ring

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Abstract

Saturn's F ring has brightened markedly in the last 25 years. It is twice as bright in the Cassini data as it was in the Voyager data from 1980 and 1981. This conclusion is based on photometric comparisons of Cassini and Voyager images, and is supported by occultation data. We attribute this change to increasing perturbations by nearby Prometheus, which passes closer to the ring now that it did in the Voyager era, yielding more dust.

Image Analysis

Our analysis procedures follow those originated by Showalter et al. 1992 [1] for the Voyager images. Our primary Cassini data set consists of the narrow-angle, clear-filter images from 19 "FMOVIEs," obtained by staring at a ring tip while the ring rotated underneath. These sample many ring longitudes, enabling us to average out the large intrinsic variations within the ring. This data set is supplemented by ~ 300 wide-angle images, which capture more phase angles but have incomplete longitudinal coverage. We calibrated the images and obtained profiles of ring reflectivity versus radius from each. We measured the area under the curve to yield "normal equivalent width" *NEW*, defined as

$$NEW = \sin(B) \int I/F \, dr \ ,$$

where I/F is the reflectivity (intensity I normalized by solar flux density), r is orbital radius and B is the ring opening angle. *NEW* has the properties that it is independent of image resolution and is also independent of B in the limit where optical depth is small. Figure 1 shows our raw measurements. The color coding (red, yellow, green and blue for increasing $|B|$) shows that *NEW* is systematically smaller for observations taken closer to the ring plane. This suggests that optical depth τ is not small enough for its effects to be ignored. Using standard models for mutual shadowing within the ring (but neglecting multiple scattering), we find that assuming $\tau = 0.1$ eliminates any systematic B-dependence, and thereby reduces the scatter among the points (Fig. 2). We interpret this value as representing the mean optical depth of the ring. The phase curve increases toward high phase angles due to diffraction by the prevalent, micrometer-sized dust grains in the ring. Photometric modeling shows that this curve is consistent with a differential size distribution of the form $n(a) \sim a^{-p}$, where a is the particle radius. The data imply $p = 3.5$–4; such a power-law model is consistent with that found in other dusty rings.

For the Voyager data, we have repeated the analysis of Showalter et al. [1] using the latest calibration and analysis techniques. Voyager measurements show the same B-dependendence, which can be eliminated by assuming $\tau \sim 0.02$–0.04 (Fig. 3). These measurements fall consistently below the Cassini measurements by a factor of 2–3, depending on the exact value of τ assumed. No plausible assumptions about τ can reconcile the two sets of measurements.

If the ring had a strong spectral slope, then the discrepancy might be explained by the different bandpasses of the Voyager and Cassini cameras. However, our measurements indicate that the ring color is neutral. We have also performed a few comparisons of the A ring edge, imaged by both spacecraft under similar lighting and viewing geometries, to confirm that our calibrations are consistent. We therefore conclude that we have detected an actual change in ring properties. However, note that the phase curves from Voyager and Cassini (Figs. 2 and 3) have a nearly constant ra-

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tio, suggesting that the distribution of particle sizes is essentially unchanged.

Occultation Data

We have investigated the optical depth of the ring directly using occultation profiles from Voyager's photopolarimeter (PPS) instrument and from Cassini's Visual and Infrared Mapping Spectrometer (VIMS). We measure the amount of light blocked as a star passes behind the ring, and infer a "normal equivalent depth" *NED*, representing the radial integral of τ after correction for ring opening angle *B*. *NED* from the single PPS occultation is smaller than that from *any* of the 21 VIMS occultations examined, and it is less than half of the the VIMS mean. Because this one measurement could be a statistical outlier, we cannot draw firm conclusions; nevertheless, it provides additional support for the hypothesis that the ring has changed. Measured τ values are generally consistent with our inferences above based on the image analysis.

Discussion

The F ring is almost surely held together by an unseen population of meter- to km-sized bodies. These bodies contain most of the ring's mass, but are masked by the far more numerous fine dust particles. The recent change probably represents an increase in the dust production rate, rather than a change in the number of underlying source bodies. Stirring by Prometheus is probably the dominant driver for dust production. Both the moon and ring are on eccentric orbits, and their minimum separation distance varies as the pericenters go into and out of alignment. The pericenters are approaching anti-alignment, so we hypothesize that closer passages by Prometheus are driving the recent increase in dust.

References

[1] Showalter, M. R., et al. (1992). *Icarus* **100**, 394–411.

Acknowledgments

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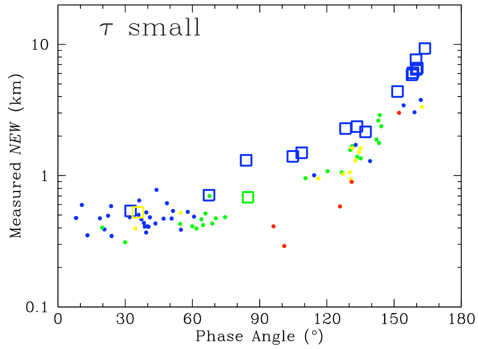

Figure 1: Raw photometry from the Cassini images. Large squares are averages from FMOVIEs; dots are measurements from wide-angle images. Colors red, yellow, green and blue indicate increasing ranges of |*B*| in 5° steps.

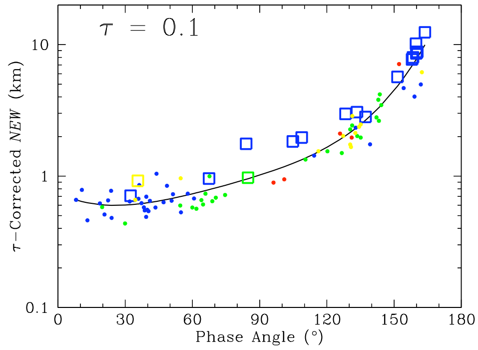

Figure 2. The same photometry as above, but corrected for τ = 0.1. The scatter among the points is smaller and no dependence on |*B*| is evident. A quartic polynomial fit to the data is shown as an approximation to the underlying phase function.

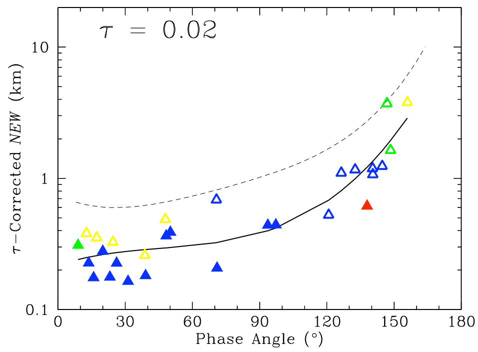

Figure 3. Measurements similar to those above but from the Voyager camera. Open triangles are from Voyager 1; closed triangles are from Voyager 2. A best-fit quartic phase curve is also shown (solid) and the Cassini fit from above is shown for comparison (dashed).