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Correlations between the spectra and structure of Saturn's main rings

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Abstract

The Visual and Infrared Mapping Spectrometer (VIMS) onboard the Cassini Spacecraft has performed a number of moderately high-resolution (better than 200 km/pixel) spectral observations of Saturn's main rings. These data show that the rings' spectral properties vary on a broad range of spatial scales. Some of these variations reflect differences in the typical grain size in the ring particles' regolith, while others can be ascribed to different concentrations of impurities mixed with the ring-particles' water ice [1, 2]. VIMS has also observed many stellar occultations of the rings, which provide high-resolution profiles of the ring's opacity. Comparing these two data sets reveals a number of interesting correlations between the rings' spectral and structural properties on spatial scales between 100 and 1000 km. Such correlations provide new insights into how the surface properties of individual ring particles can be influenced by (and thus probe) the local dynamical environment.

1. Observations

The spectral data discussed here were obtained by VIMS in 2005, during the RDHRCOMP observation in Cassini Orbit 008. This observation provides one of the highest-resolution data sets covering all radii in the rings. The spacecraft also viewed the lit side of the rings at low phase angles (13°-41°), so the relevant spectra had very good signal-to-noise. Finally, the observed longitudes in the ring were over 90° from the sub-solar longitude, and thus there was little contamination from Saturn-shine.

The spectral data were calibrated using standard procedures and were geometrically navigated based on selected sharp ring features. The various spectral measurements were then binned onto a regular grid of radii to produce a radial-spectral profile that gave the mean brightness as a function of radius and wavelength. Based on these data, we compute radial profiles of various spectral parameters, including the continuum brightness measurements, infrared band depths and visible colors shown in the top two panels of Figure 1.

The opacity data are derived from an occultation of the star γ Crucis by the rings that was obtained by VIMS in Cassini Orbit 089. This star is very bright and Cassini viewed it through the rings at a very steep angle, so this observation provides one of the highest signal-to-noise measurements of the most opaque rings like the B ring. The recorded measurements of the star's apparent brightness as a function of time are converted to estimates of the ring's opacity as a function of radius, and the resulting optical depth profile is shown in the bottom panel of Figure 1.

2. Discussion

One of the most prominent regions of fine-scale spectral variations can be found in the middle B ring (99,000-105,000 km), where there are sharp variations in both the near-infrared ice-band depths and the so-called "blue-slope" at short visible wavelengths. Since multiple spectral parameters vary together in this region, these variations most likely reflect shifts in the typical grain size in the ring-particles' regoliths. These grain-size variations are strongly correlated with the rings' optical depth, which also shows a series of sharp transitions in this region, each of which can be matched to an abrupt change in spectral properties. This correlation even extends to other parts of the B ring. Between 105,000 and 115,000 km nearly every dip in opacity has a corresponding dip in the ice-band depths. This suggests that the local surface density is affecting the regolith on individual ring particles. Perhaps this reflects differences in the average collision frequencies or impact speeds in these regions.

In contrast to the synchronized spectral variations in the B ring, in the outer C ring different spectral parameters show different trends. In particular, consider the sharp-edged regions of enhanced optical depths known as "plateaux" between 85,000 and 90,000 km from Saturn center. The ice-band depths in the near

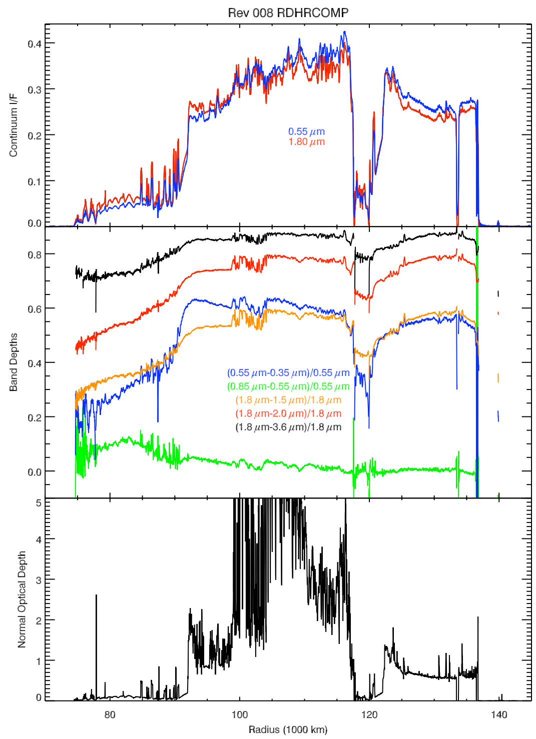

Figure 1: Spectral parameters derived from the Rev 008 RDHRCOMP observations. The top panel shows continuum brightness measurements, while the middle panel gives the band depths and spectral slopes. The bottom panel provides, for comparison, the optical depth profile derived from occultation data.

infrared do not differ much between the plateaux and the background, more transparent C ring. However, the blue slope is noticeably stronger in the plateaux than it is elsewhere in the C ring. This points to a compositional difference between the ring particles in the plateaux and the particles in the rest of the C ring, which could be relevant for understanding the origins of these enigmatic structures.

Finally, in the A ring, we observe features in the spectral profiles at the locations of strong density waves. These features, which were already noted in [2], appear both in the ice-band depths and in the blue slopes, and so again likely reflect changes in the ring-particles' regolith properties. At the core of these features, which correspond to the locations of the waves themselves, the ice bands are enhanced, indicating larger typical grain sizes. Outside of this core, a more diffuse "halo" of reduced band depths can be observed, indicating smaller typical regolith grain sizes. These

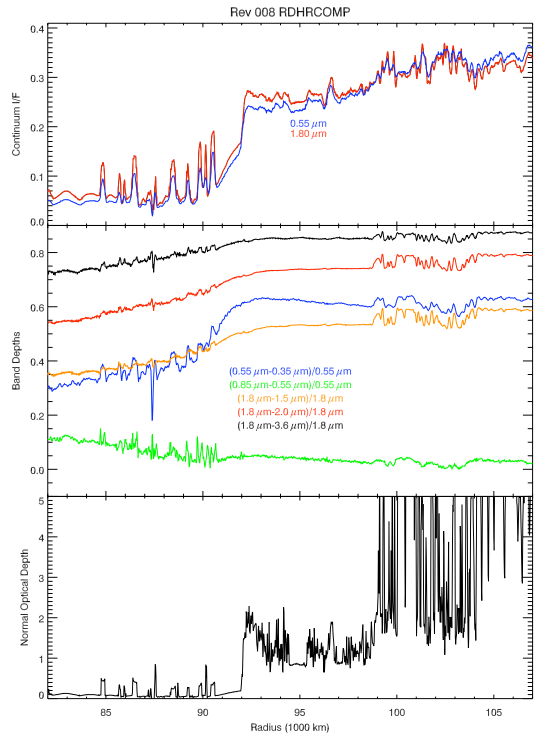

Figure 2: A close-up of figure 1, showing the fine-scale variations in the outer C and inner B rings.

spectral signatures probably result from the enhanced collision frequencies within the density waves themselves. A similar form of dynamical heating may also be responsible for the few features in the B ring's spectral profile that do not appear to be correlated with optical-depth variations, which are also found in association with strong satellite resonances.

Acknowledgements

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References

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