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Saturn's rings under a microscope: Cassini UVIS results

Miodrag Sremčević
LASP, University of Colorado, 1234 Innovation Drive, Boulder, CO 80303, USA (Miodrag.Sremcevic@lasp.colorado.edu)

Abstract

In this paper we give an overview of small-scale structure directly observed throughout Saturn's main rings. After 6 years of Cassini mission the UVIS instrument recorded more than hundred stellar occultations by Saturn's rings. Most of the observed occultations have excellent resolution on the order of ten meters or even better. We use statistical and spectral methods (Fourier and wavelet transforms, and autocorrelations of the signal) to infer the properties of the microstructure. The multitude of observations allows us to infer the orientation and two-dimensional picture of the underlying structure.

Most of the A ring and outer B ring show 10-50m structures pitched by about 20 degrees from the orbital motion. These observations are consistent with Toomre type self-gravity wakes reported by other researchers, and moreover allow to directly infer their spatial scalings. In a recent, specially crafted high-resolution occultation of the mid A ring we for the first time directly resolved individual self-gravity wakes. The occultation was designed to track the orbital motion of ring particles, achieving the true resolution in the co-rotating ring plane of below a meter. In this unique occultation the self-gravity wakes manifest as opaque or nearly opaque regions (τ>1.5) and constitute about 30% of the total occultation signal. The observed wake lengths can be as large as 200m. Another 30% of the signal is practically transparent (τ<0.05), and somewhat shorter (L<100m). The distribution of wake and gap lenghs L is not of power-law type, but rather remniscent of an exponential function. The opaque and transparent regions are interspersed with material apparently in an intermittent state (0.05<τ<1.5). This picture is consistent with self-gravity wakes and accompanying nearly transparent gaps constantly forming and dispersing, while, somewhat surprisingly, the intermittent dispersed state makes 40% of the observed ring.

The inner A ring and lower optical depth regions in the B ring show 100-200m scale regular waves. These waves have no pitch angle and are consistent with a viscous oscillatory instability, better known as overstability. The most surprising aspect of the wave structure is their patchy appearance throughout the rings. Additionally, occultation geometry dependence of the observed optical depth indicates the presence of self-gravity wakes within the wave structure.

In higher optical depth regions of the B ring the most dominant structure is irregular with spatial scales of about 100m. The structure is axisymmetric and very distinct from the signature of both self-gravity wakes and overstable waves reported up to now. One plausible theoretical candidate for the explanation is viscous or diffusion instability. Such interpretation, however, require either fairly elastic particle properties not observed so far, or alternatively small ring particles. The C ring and Cassini division are void of obvious self-gravity wakes or overstable waves. However, few occultations of double stars indicate the presence of microstructure, but its exact nature remains mysterious.