Progresses in the Analysis of Density Waves in Saturn's Rings

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In 2009, Rappaport *et al.* designed a procedure to analyze ring optical depth profiles obtained by the Cassini Radio Science Team in 2005, and applied the procedure to the Mimas 5:3 density wave. There are two important concepts at the basis of this procedure. The first one is that it uses the nonlinear representation of density waves, and the second one is that it relies on a combination of optical depth profiles. The procedure yields five smooth functions of the semi-major axes for each resonance: the streamline eccentricities e(a), the streamline lag angle $\Delta(a)$, the non-linearity parameters q(a) and $\gamma(a)$, and the background optical depth $\tau_0(a)$. Application of the nonlinear dispersion relation provides the resonance location a_{res} (in principle), the opacity K, and the velocity dispersion v. Each profile depends of only one parameter, $m\phi$, which depends on the resonance and on the geometry. The procedure is greatly complicated by the fact that the eight Cassini radio science ring profiles that we had at that time did not sample well $m\phi$. There were other difficulties. First, the data (optical depths) are functions of the radius, while the functions we try to determine are functions of the semi-major axis. Second, self-gravity wakes cause the background optical depth to vary. Third, the phase $f(a) = m\Delta(a) + \gamma(a)$ must be very well determined for the procedure to work. Fourth, particle crowding in wave crests may lead to shock features and vertical splashing. A limitation of the procedure is that the five functions cannot be determined in the evanescent part of the wave and in the first peak because the procedure uses the WKBJ approximation, which is not satisfied at the beginning of the wave, so that we cannot compute the torque exerted on the satellite. In spite of these difficulties, we succeeded in analyzing several density waves in the Ring A and in the Cassini Division. We will present several examples.

While the first step of this work was to use only Radio Science data, the second step is to use also UVIS and VIMS ring occultation optical depth profiles. We will be able to use a simpler procedure based on a direct least square method and not requiring the WKBJ approximation. Like for the first procedure, we will start with a simulation to compute the number of profiles needed as a function of the desired accuracy of the torque.

Reference

[1] N.J. Rappaport, P.-Y. Longaretti, R.G. French, E.A. Marouf, and C.A. McGhee, *Icarus* **199**, 154 (2009).