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Corrugations and Spirals: Recent Disturbances in Saturn's D ring

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Abstract

The D ring is Saturn's innermost ring, extending between 65,000 and 74,950 km from Saturn's center. It is also an extremely dynamic ring, exhibiting a number of structures that vary substantially over time scales of a few years to decades. One particularly interesting class of time-variable features found in this ring are highly periodic variations in the ring's brightness with radial wavelengths that become progressively shorter over time. These patterns are most likely due to some event in the recent past that disturbed the rings and produced organized non-circular motions in the ring-particles' orbits. Indeed, similar features in Jupiter's rings appear to have been generated in 1994 when debris from Shoemaker-Levy 9 passed through the rings [**?**]. These patterns can therefore provide new insights into the rings' recent history. More specifically, one set of patterns may have been generated by a cometary impact in 1983, and detailed examinations of these structures provide constraints on the possible trajectory of the impacting debris. Meanwhile, another pattern appeared in the D ring a few years ago that could have been generated by either another impact or by some disturbance in Saturn's electromagnetic environment.

1. New Information about what happened to Saturn in 1983

Previous investigations of Saturn's outer D ring (73,200-74,000 km from Saturn's center) identified periodic brightness variations whose radial wavenumber increased linearly over time [**?**]. These brightness variations appeared to be due to a vertical corrugation, and later observations revealed that a similar corrugation extended across the entire C ring [**?**]. These patterns could be explained if some event like a cometary impact caused the ring to become tilted relative to the planet's equator plane in 1983. Differential nodal regression then transformed this tilted ring into a corrugated ring with the radial wavelengths we observe today. Additional Cassini observations of these structures now reveal that the outer D ring is not only corrugated, but also contains a time-variable periodic modulation in its optical depth that probably represents organized eccentric motions of the D-ring's particles [**?**]. This second pattern suggests that whatever event tilted the rings also disturbed the radial or azimuthal velocities of the ring particles. Furthermore, the relative amplitudes of the two patterns indicate that the vertical motions induced by the 1983 event were about a factor two times larger than the corresponding in-plane motions. If these structures were indeed produced by an impact, material would need to strike the ring at a steep angle ($> 60^\circ$ from the ring plane) to produce such motions. Also, the corrugation wavelengths in the D ring are about 0.7% shorter than one would predict based on extrapolations from similar structures in the nearby C ring. This could indicate that the D-ring was tilted/disturbed about 60 days before the C ring. Such a timing difference could be explained if the material that struck the rings was derived from debris released when some object broke up near Saturn some months earlier. To reproduce the observed time difference, this debris would need to have a substantial initial velocity dispersion and then have its orbital properties perturbed by some phenomenon like solar tides prior to its collision with the rings.

2. A new pattern in the inner D ring

Images obtained by the Cassini spacecraft between 2012 and 2014 reveal periodic brightness variations in the inner D ring (69,000-71,000 km from Saturn's center), a region that had previously appeared to be rather featureless. The radial wavenumber of this pattern has decreased steadily with time since it was first observed, and it appears to be another pattern created by some event that disturbed the orbital motions of the ring particles. The observed trends in the pattern's radial wavenumber indicate that the ring-

disturbing event occurred in early December, 2011. Similar events in 1979 may have generated the periodic patterns seen in this same region by the Voyager spacecraft. The 2011 event could have been caused by debris striking the rings, or by some sort of disturbance in the planet's electromagnetic environment. The rapid reduction in the intensity of the brightness variations over the course of the last two years indicate that some as-yet unidentified process is quickly dissipating organized epicyclic motions in this region.

References

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