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# The Architecture of the Cassini Division.

**P. D. Nicholson** (1), M. M. Hedman (1), R. G. French (2), E.A. Marouf (3) and the Cassini VIMS Team.

(1) Cornell University, Ithaca NY, USA, (2) Wellesley College, Wellesley MA, USA, (3) San Jose State University, San Jose CA, USA

## Introduction

Located between Saturn's A and B rings, the Cassini Division consists of ring material with an optical depth of around 0.10, punctuated by eight nearly empty gaps. Thus far, the only published explanation for the existence of these gaps is a suggestion by Lissauer, Shu & Cuzzi (1981) that each one contains a small moonlet which holds open the gap in a manner analogous to the Encke and Keeler gaps in the outer A ring, which are maintained by Pan and Daphnis. However, no such moons have yet been directly or indirectly detected in any of the Cassini Division gaps.

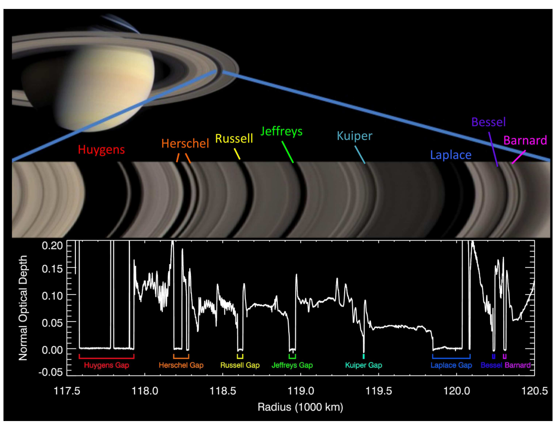


Figure 1: Saturn's Cassini Division, as seen in a mosaic of Cassini images and in an optical depth profile derived from a stellar occultation observed by the VIMS instrument. The locations of the eight named gaps are indicated. Note the eccentric ringlets within the Huygens, Herschel and Laplace gaps. The outer edge of the B ring, which varies in radius by up to 150 km, is visible at the left edge of the profile.

## Observations

Between May 2005 and December 2008, the Visual and Infrared Mapping Spectrometer (VIMS) onboard the Cassini spacecraft obtained 41 high-quality occultation cuts through the Cassini Division in Saturn's rings. The position of the edges of all the gaps (and detached ringlets) were measured for all of these occultations. We find that all five gaps that do not contain dense ringlets have nearly circular outer edges, while all the other edges exhibit significant variations in their radial locations.

As expected based on earlier Voyager and Cassini observations (Porco et al. 1984, Spitale & Porco 2006), we find that the outer edge of the B ring has a large $m = 2$ component due to the nearby 2:1 resonance with Mimas. However, detailed studies of this pattern suggest that the orientation of the B-ring edge slowly drifts or librates relative to Mimas. Fits to VIMS data from 2008 show that the minimum of the $m = 2$ pattern lags behind Mimas by 20 degrees, while data from a set of seven Earth occultations observed by the Cassini Radio Science experiment in 2005 show that the minimum *leads* Mimas by 35 degrees, consistent with imaging observations by Spitale & Porco (2006). All of these data, together with a handful of pre-Cassini measurements from 1980–1995, can be fit tolerably well by an $m = 2$ pattern which either drifts backwards with respect to Mimas by 0.06 deg/day, or librates about Mimas' mean longitude with an angular frequency of 0.06, 0.08 or 0.11 deg/day. As suggested by Spitale & Porco (2006), there is also evidence for other perturbations on this edge, notably a freely-precessing eccentric component (i.e., $m = 1$).

Meanwhile, the inner edge of the outermost gap in the Cassini division exhibits an $m = 5$ component that is probably associated with the nearby 5:4 inner Lindblad resonance with Prometheus. Intriguingly, the inner edges of all the remaining named gaps (i.e., those which do not fall near known first-order resonances with any moon) can be well-fit with simple ellipses that precess around Saturn at approximately the expected rates given their distances from Saturn's center (see Fig. 2). One of these edges was already modeled in this way by Flynn and Cuzzi (1989). The pattern speeds of the observed eccentric edges form a quasi-regular series with a characteristic spacing of 0.05-0.07 degrees/day.

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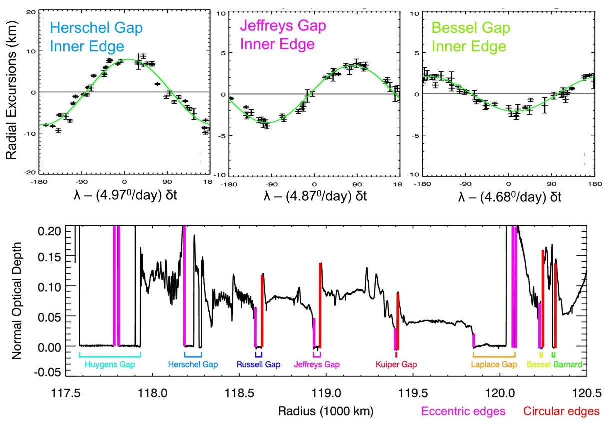


Figure 2: Measurements of the radii of the inner edges of three gaps in the Cassini Division which fit models of keplerian ellipses freely-precessing under the influence of Saturn's oblate figure. Fitted amplitudes are $ae = 8$ km, 3.5 km, and 2 km for the Herschel, Jeffreys and Bessel gaps, respectively, and the fitted precession rates are given in the figure labels. Purple bars in the lower panel indicate eccentric edges, while red bars indicate circular edges.

## Interpretation

Based on these results, we propose an alternative explanation for the basic structure of the Cassini Division, whereby the six gaps not maintained by resonances with external satellites are indirectly established by perturbations from the nearby, resonantly-controlled edge of the massive B ring. Specifically, we argue that the eccentric inner edges of most of the gaps in the Cassini Division may be generated by a type of three-body resonance involving interacting perturbations from Mimas itself and from the B-ring edge. A libration of the $m = 2$ distortion of the B ring edge with a period of approximately 16 years can provide the observed quasi-regular spacing in the pattern speeds of the eccentric gap edges.

The resulting $m = 1$ mass anomaly at the inner edge of each gap may lead in turn to a "shepherding" effect that "repels" the nearly circular outer edge and thus controls the width of the gap.

## References

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## Acknowledgements

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