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A Predator-Prey Model for Moon-Triggered Clumping in Saturn's Rings

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Abstract

UVIS occultation data show clumping in Saturn's F ring and at the B ring outer edge, indicating aggregation and disaggregation at these locations that are perturbed by Mimas and by Prometheus. Timescales range from hours to months. Structure near the B ring edge is seen in power spectral analysis at scales 200m – 2000m. We quantify this sub-km structure using wavelet analysis that estimates the statistical significance of the features. Similar structure is also seen at the strongest density waves, with significance increasing with resonance strength (FIGURE 1).

For the B ring outer edge, the strongest structure is seen at longitudes 90° and 270° relative to Mimas. This indicates a direct relation between the moon and the ring clumping. We propose that the collective behavior of the ring particles resembles a predator-prey system: the mean aggregate size is the prey, which feeds the velocity dispersion; conversely, increasing dispersion breaks up the aggregates. Moons may trigger clumping by streamline crowding, which reduces the relative velocity, leading to more aggregation and more clumping. Disaggregation may follow from disruptive collisions or tidal shedding as the clumps stir the relative velocity. For realistic values of the parameters this yields a limit cycle behavior, as for the ecology of foxes and hares or the "boom-bust" economic cycle. Solving for the long-term behavior of this forced system gives a periodic response at the perturbing frequency, with a phase lag roughly consistent with the UVIS occultation measurements (FIGURE 2).

Figures

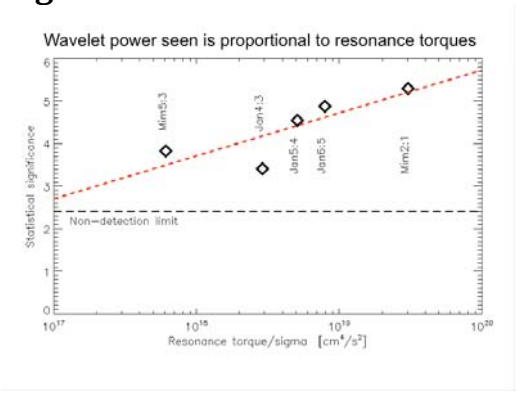

Figure 1: Wavelet Power.

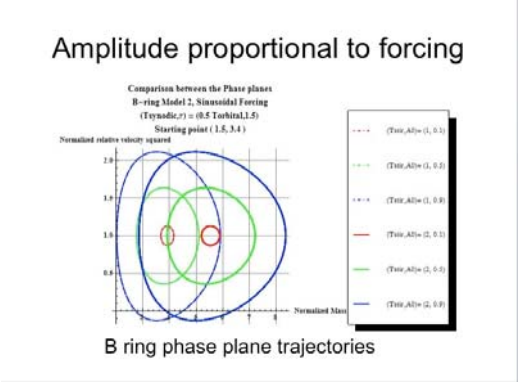

Figure 2. Predator-Prey Model Amplitude.

Conclusions

We conclude that the agitation by the moons at both these locations in the F ring and at the B ring outer edge drives aggregation and disaggregation in the forcing frame. This agitation of the ring material may also allow fortuitous formation of solid objects from the temporary clumps, via stochastic processes like compaction, adhesion, sintering or reorganization that drives the denser parts of the aggregate to the center or ejects the lighter elements. Any of these more persistent objects would then orbit at the Kepler rate. Such processes can create the objects seen at the B ring edge and in the F ring in Cassini equinox images, explain the ragged nature of those ring regions and allow for rare events to aggregate ring particles into solid objects, recycling the ring material and extending the ring lifetime. We would also expect the formation of clumps and some more permanent objects at the other perturbed regions in the rings including satellite resonances, shepherded ring edges, and near embedded objects like Pan and Daphnis (where the aggregation/disaggregation cycles are forced similar to Prometheus forcing of the F ring).

Acknowledgements

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