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Predator-Prey Model for Haloes in Saturn's Rings

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Abstract

ISS, VIMS, UVIS spectroscopy and occultations show haloes around the strongest density waves. Based on a predator-prey model for ring dynamics, we offer the following explanation:

•Cyclic velocity changes cause the perturbed regions to reach higher collision speeds at some orbital phases, which preferentially removes small regolith particles;

•This forms a bright halo around the ILR, if the forcing is strong enough;

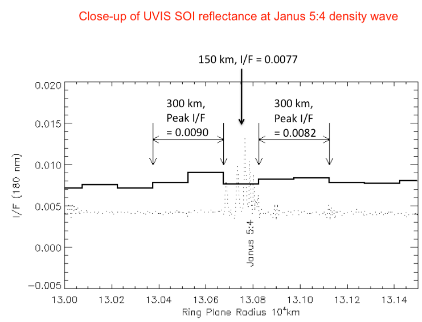
•Surrounding particles diffuse back too slowly to erase the effect; they diffuse away to form the halo.

1. Introduction

Particles in Saturn's rings have a tripartite nature: (1) a broad distribution of fragments from the disruption of a previous moon that accrete into (2) transient aggregates, resembling piles of rubble, covered by a (3) regolith of smaller grains that result from collisions and meteoritic grinding. Evidence for this triple architecture of ring particles comes from a multitude of Cassini observations. In a number of ring locations (including Saturn's F ring, the shepherded outer edges of rings A and B and at the locations of the strongest density waves) aggregation and dis-aggregation are operating now.

2. Haloes

UVIS SOI reflectance spectra showed bright 'haloes' around the locations of some of the strongest resonances in Saturn's A ring (Esposito etal 2005). UV spectra constrain the size and composition of the icy ring particles (Bradley etal 2013). The correspondence of IR and UV spectroscopy, HSP wavelet analysis and correlation lengths indicate that we all detect the same phenomenon, characterized by larger particles and higher collision velocities. In this talk, we investigate the Janus 4:3, 5:3, 6:5 and Mimas 5:3 inner Lindblad resonances as well as at the Mimas 5:3 vertical resonance (bending wave location).

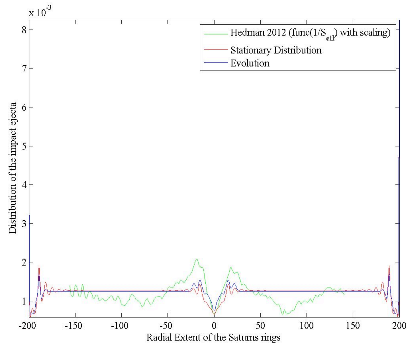


3. Dynamical Models.

Models of ring particle regolith evolution (Elliott and Esposito 2011) indicate the deeper regolith is made of older and purer ice. The strong resonances can cause streamline crowding (Lewis and Stewart 2005) which damps the interparticle velocity where the streamlines merge, allowing temporary clumps to grow, which in turn increase the velocity, eroding the clumps and releasing smaller particles and regolith (see the predator-prey model of Esposito etal 2012). This cyclic behavior, driven by the resonant perturbation from the moon, can yield collision velocities at particular azimuths greater than 1m/sec, sufficient to erode the aggregates (Blum 2006), exposing older, purer materials; breaking the aggregates and releasing smaller particles. The perturbations may drive some aggregates into the gravity-dominated regime, where they are longer-lived and stir the higher dispersion velocities among the surrounding ring particles. The released regolith material will settle in the less perturbed neighboring regions surrounding the stirred locations, along with newly produced ejecta from meteoroid bombardment of the exposed surfaces.

4. Diffusion Models

Diffusion would spread these ring particles with smaller regolith into a ‘halo’. Thus, the radial location of the strongest resonances can be where we simultaneously find both large aggregates and also the disrupted fragments, in a balance maintained by the periodic moon forcing. If this stirring exposes older and purer ice, the velocity threshold for eroding the aggregates can explain why only the strongest Lindblad resonances show haloes. Diffusion can explain the morphology of these haloes, although they are not well-resolved spatially by UVIS. Diffusion can roughly match the morphology of VIMS haloes found by Hedman etal (2013).



5. Summary and Conclusions

ISS, VIMS, UVIS spectroscopy and occultations show haloes around the strongest density waves. Based on a predator-prey model for ring dynamics, we offer the following explanation:

•Cyclic velocity changes cause the perturbed regions to reach higher collision speeds at some orbital phases, which preferentially remove small regolith particles;

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Implications. ‘Straw’ features in Cassini images, UVIS power spectral analysis, F ring ‘kittens’ and the equinox objects show the prey (mass aggregates); while the haloes show the predators (velocity dispersion) at regions stirred in the rings. Stirring can create longer-lived aggregates that protect their interiors from meteoritic darkening and recycle the ring material to maintain the current purity of the rings. It also provides a mechanism for creation of new moons at resonance locations in the Roche zone, as proposed by Charnoz etal (2010) and Canup (2010).

Acknowledgements

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