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Collisional Features in Saturn's F Ring

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Abstract

Small (~50km scale), irregular features emanating from Saturn's F ring, termed mini-jets [1], are thought to be the result of collisions with local moonlets. A survey of these features suggested a population of order one hundred objects on nearby orbits [2]. Here we will present the latest work on F ring collisions; updating the survey with new Cassini images to further refine our statistics as well as discussing specific, interesting features that shed light on the collision process. We will also present the results of N-body simulations of the collisions and discuss on-going work to survey the larger "jet" features. These are caused by higher velocity collisions (~30m/s) with more distant objects like S/2004 S 6, which may represent the upper end of the moonlet population in size and in orbit.

1. Introduction

A population of small bodies has long been known to exist in the region, many of which interact with the F ring core, gravitationally and through collisions. Objects like S/2004 S 6 are thought to produce large jets by physical collisions with the core ([3] and refs. therein). Previous work [1] tracked one particular 'mini-jet' (a small jet-like feature) over half an orbital period and suggested a low velocity (~1ms^{-1}) collision with a local moonlet as the origin. A survey of similar features was conducted, cataloguing over 800 [2]. Mini-jets were found randomly around the F ring with little relation to the perturbing moon Prometheus or any other ring features. They were found with a range of orbits (see figure 1), implying multiple Prometheus perturbations for some of their progenitor objects, and ages, suggesting an average lifetime of ~1 day.

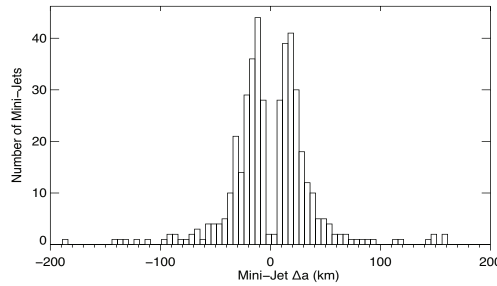

Figure 1: Histogram of calculated mini-jet Δa (semi-major axis of the mini-jet tip relative to its base) in 5 km bins. The maximum Δa perturbation caused by Prometheus is ~20km.

2. Further Observations

We continue to update the mini-jet catalogue with images from 2013, in particular a series of observations with similar geometries and longitude coverage from late August to early October 2013. Tracking features across these sequences to place constraints on their lifetimes and formation rates we find a rate about 5–7 times smaller than previously estimated, along with a correspondingly longer average lifetime, The long lifetimes is explained by repeated collisions forming new, individual mini-jets so that the feature as a whole persists.

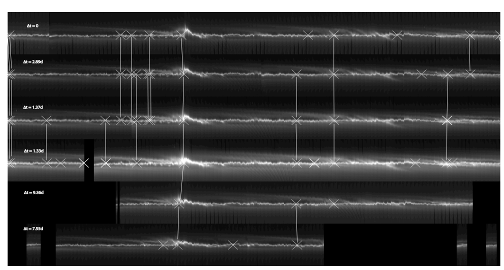

Figure 2: Series of mosaics of the F ring with tracked features highlighted. Each mosaic is around a hundred Cassini images re-projected and placed so

that the y-axis is orbital radius and the x-axis is longitude in a frame co-rotating with the F ring's mean motion. From top the sequences are rev196 FMOVIE 003, 004, 005, 006 and 007, rev197 FMOVIE 002 and rev198 FMOVIE 001.

3. N-Body Modelling

We use the open source N-body code REBOUND [4], a symplectic integrator with built in collisional modelling, to simulate low-velocity collisions between local moonlets and the F ring core. Using a velocity dependent coefficient of restitution [5] and a clump of large particles (radius 500m) impacting smaller ones (1m) we produce structures similar to those observed by Cassini (see figure 3). Having the objects re-collide several times can also reproduce some of the more complicated features seen.

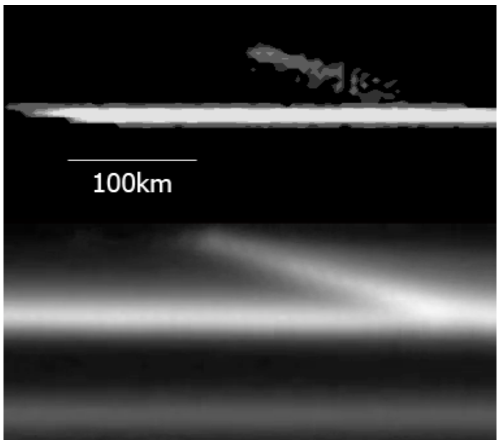

Figure 3: Top: REBOUND simulation of a collision corresponding to bottom: re-projected Cassini image of a mini-jet from the sequence in [1].

4. Surveying Jets

Much larger jet features are also visible, some surviving long enough for Keplerian shear to wrap them around through more than 360° of longitude, forming spiral strands around the core. Some jets are associated with S/2004 S 6 but there are clearly multiple objects involved. Here we will present the results of a survey of jets, tracking their evolution and comparing their orbital distributions and locations to mini-jets in order to compare the different parts of the colliding population.

4. Summary and Conclusions

A range of collisional features is seen in Saturn's F ring. We believe a single population of local moonlets with a range of orbits and sizes can explain all these features and suggest that they are likely formed in the F ring itself, possibly due to the action of Prometheus, before, subsequently, being perturbed onto colliding orbits by further interactions. Those that survive may continue to grow and go on to form the larger visible objects such as S/2004 S 6. Mini-jets, therefore, represent one end of a continuum of collisional features with the other end being the large jets and spiral strands. Image surveying and simulation work is on-going to better characterise this population.

Acknowledgements

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References

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