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Low-Velocity Collisions in Saturn's F Ring

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Abstract

Small (~50km scale), irregular features seen in Cassini images to be emanating from Saturn's F ring have been termed mini-jets [1]. One particular mini-jet was tracked over half an orbital period, revealing its evolution with time and suggesting a collision with a local moonlet as its origin. Here we present a much more detailed analysis [2] of over 800 F ring mini-jets, examining their distribution, morphology and lifetimes in order to place constraints on the underlying moonlet population. We will also present the latest work in computer modelling of the low velocity collisions that form them.

1. Introduction

The F ring region has long been thought home to a population of small bodies, at least some members 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], [4], [5]). Previous work [1] tracked one particular 'mini-jet' (a small jet-like feature) over half an orbital period. This revealed its evolution with time to be a combination of Keplerian shear and epicyclic motion resulting from its orbit, which differed slightly from that of the core. Low velocity (~1ms^{-1}) collisions with local moonlets were suggested as the origin and a search for similar features was conducted.

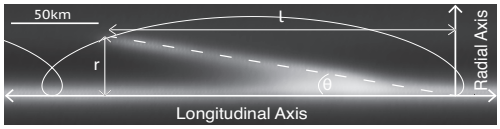

Figure 1: Schematic overlaid on a typical outwards mini-jet. The origin is centred on the point of collision and the white curve is the trajectory of the tip based on the relative orbits. The mini-jet passes through the vertical early in its cycle before looping away down the ring. The colliding object has a similar orbit and will also roughly follow this path.

2. Observations

A search of all Cassini ISS sequences containing resolved images of the F ring has been performed. We identified by eye small features (typically ~10-200km in radial extent and $\ll 1^{\circ}$ in longitude) emanating from the core, excluding bright kinks and clumps within the core itself and the larger jet features. After pointing the images using background stars we re-project a portion of each image containing a feature in an equal aspect radius-longitude plot for direct comparison and measurement and then assigned them to classes according to their morphology.

3. Survey Results

Small, irregular features have been found all around the F ring, throughout the time that Cassini has observed it. Their numbers are highly variable, but average ~15 in the ring at any one time. Based on our analysis of nearly 900 catalogued features they are randomly distributed but with a tendency to clump together in multiple structures suggesting multiple collisions. There may be fewer near the location of Prometheus and more in the years leading up to closest approach with this satellite but these trends seem weak at best. Those with a resolvable linear structure (mini-jets) have angles consistent with a range of ages (see Fig. 2), from a few hours to a few days, and with around a quarter being less than one orbital period (15 hours) old. This is also supported by the repeated detection of several features over the course of a few days, suggesting an average lifetime of ~1 day. Many repeated features also show significant morphological changes between images, including the creation of new mini-jets, emphasising their extremely dynamic nature.

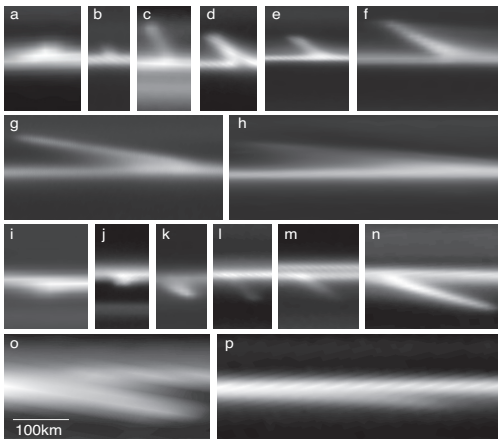

Figure 2: Classic mini-jets re-projected in a radius/longitude frame to the same scale and ordered by age. Outwards mini-jets: (a) N1577813677a, (b) N1604028396, (c) N1733559846, (d) N1613003098, (e) N1597907705, (f) N1612005469, (g) N1623284964, (h) N1623331766c. Inwards mini-jets: (i) N1726901763a, (j) N1607629517, (k) N1605396128a, (l) N1616541581, (m) N1615488367, (n) N1610401148b, (o) N1727800548, (p) N1734593691. Contrast has been adjusted in each case to enhance visibility.

4. Summary and Conclusions

Collisions with a local moonlet population present the most likely explanation and the lifetime and numbers imply that ~ 15 mini-jet forming collisions must happen each day. Depending on assumptions about the structure of the F ring core and the nature of the collisions this implies a population of hundreds of ~1km radius, or smaller, objects. Simulation work to better understand the collisions and thereby refine this estimate is on-going. Some of these moonlets have enough strength to survive multiple collisions but others are disrupted into groups of smaller objects on similar orbits. We suggest that they are likely formed in the F ring itself, possibly due to the action of Prometheus, and are subsequently 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.

Acknowledgements

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