Clump Formation In Saturn's F Ring During An Encounter With Prometheus

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One of the most dynamic places in the solar system

Saturn's F ring is one of the most dynamic places in the solar system with interactions between particles and its Sheppard moons taking place over short time periods. The F rings two Sheppard moons are the source of its narrow structure with the inner moon Prometheus regularly entering the ring. Previous numerical modelling [1] [2] showed that Prometheus was responsible for generating some structures observed in the F ring by CASSINI, but here for the first time we map the density as Prometheus encounters the F ring.

Streamer - Channels

Figure 1 | Two Sheppard moons are seen either side of the F ring. The elliptical nature of Prometheus' orbit takes the moon on a journey towards and away from the F ring over the course of one orbit. On its return journey back to the periapsis a string of particles is pulled out into what is known as a streamer. On the second approach the particles in the streamer move in time with Prometheus and create a channel in the ring. Due to the periodic nature of interactions these structures are always spaced at 3.2º, shown as a in the diagram. The red line represents the movement of Prometheus relative to the F ring.

Figure 1

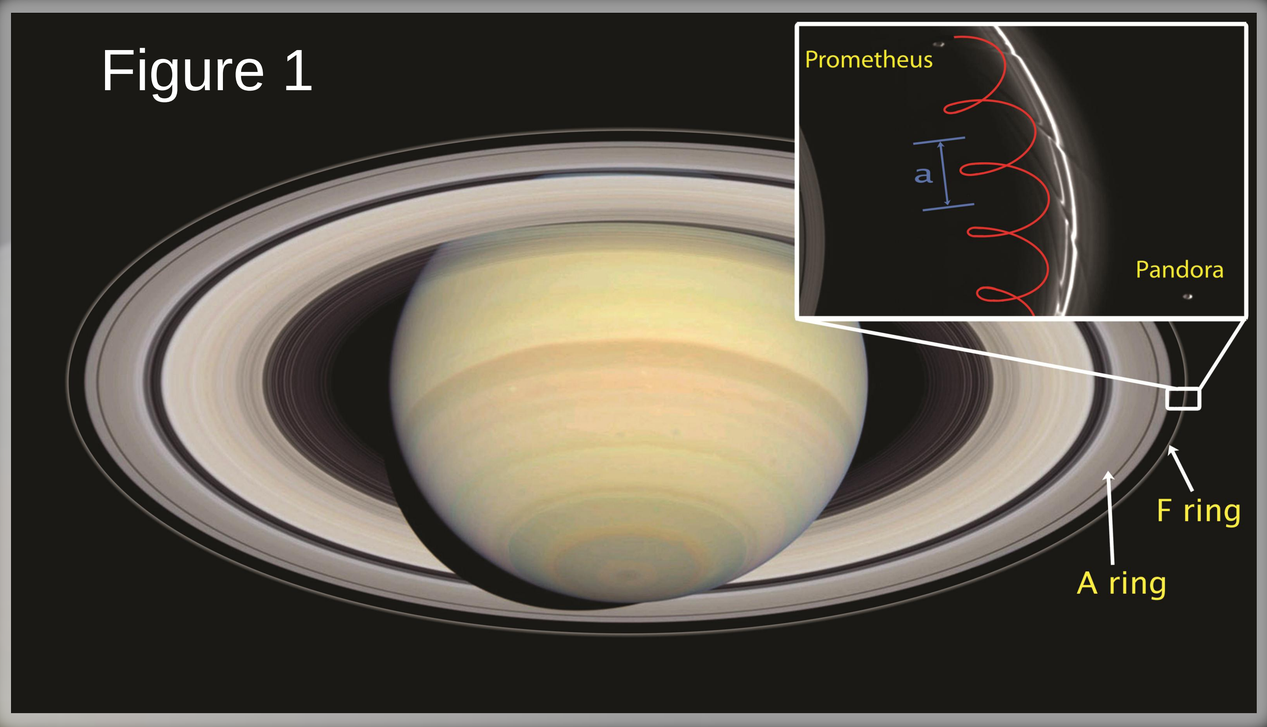
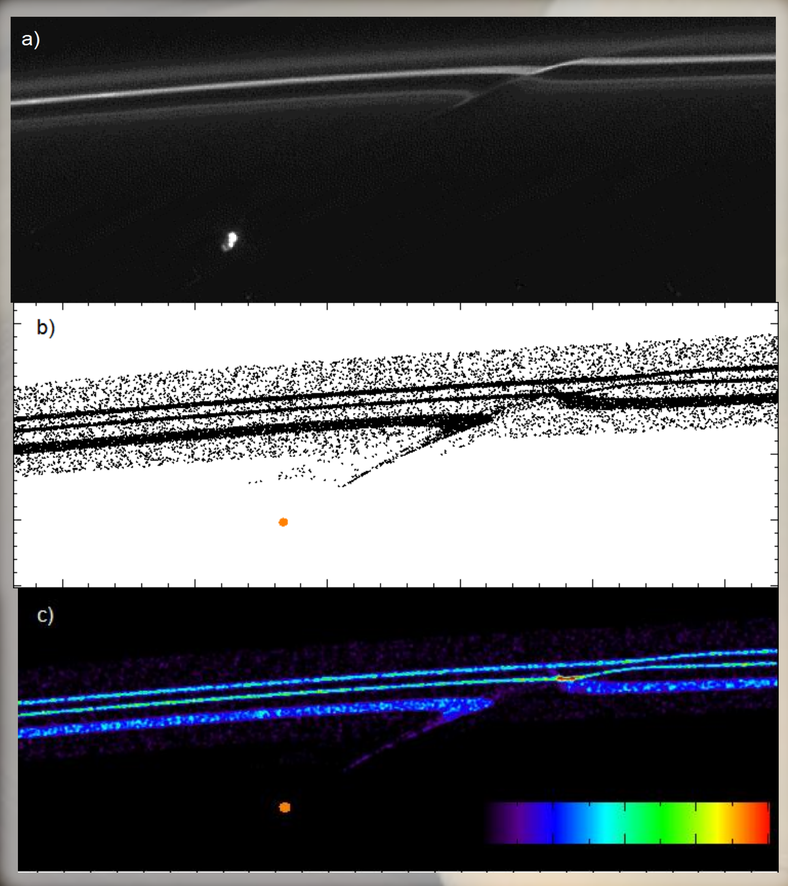


Figure 2



Comparison To CASSINI Observations

Fig 2 represents a zoomed in section of the F ring showing Prometheus forming a streamer. Fig 2 a is an image taken by CASSINI and is compared to our model in fig 2 b. Figure 2 c shows a plot of the density for the same snapshot of our model.

Density During One Orbital Period

Two areas of increased density were observed to form over one orbital period (Fig 4). The first formed at round 30,000 seconds as Prometheus retreated back out of the F ring. Particles bunched up forming an area of enhanced density at the edge closest to Prometheus. This region started to reduce in density as Prometheus pulls out a string of particles from the inner strand, known as a streamer. Relatively low density is seen in the streamer as it is stretched out towards Prometheus. A second region of increased density occurs after the streamer has been created. Particles on the opposite edge of the channel to Prometheus receive a large enough velocity kick from the approach to move into the central strand. As a result an area of high density forms in the middle of the F ring in the central core as particles from the both strands come together.

Moonlets In The F ring

Observations by CASSINI have helped discover structures known as spirals and fans in the F ring, the existence of these suggested that there were small moonlets deep within the F ring. Structures showed the same separation of 3.2° as structures formed by Prometheus, therefore a link between Prometheus and moonlet formation [5] was found. A composite image (fig 3) taken by CASSINI 2008 shows fan structures at the channels edges, and possible locations of moonlets.

Figure 3

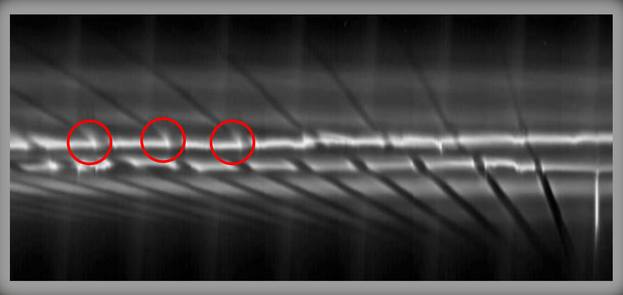


Figure 4

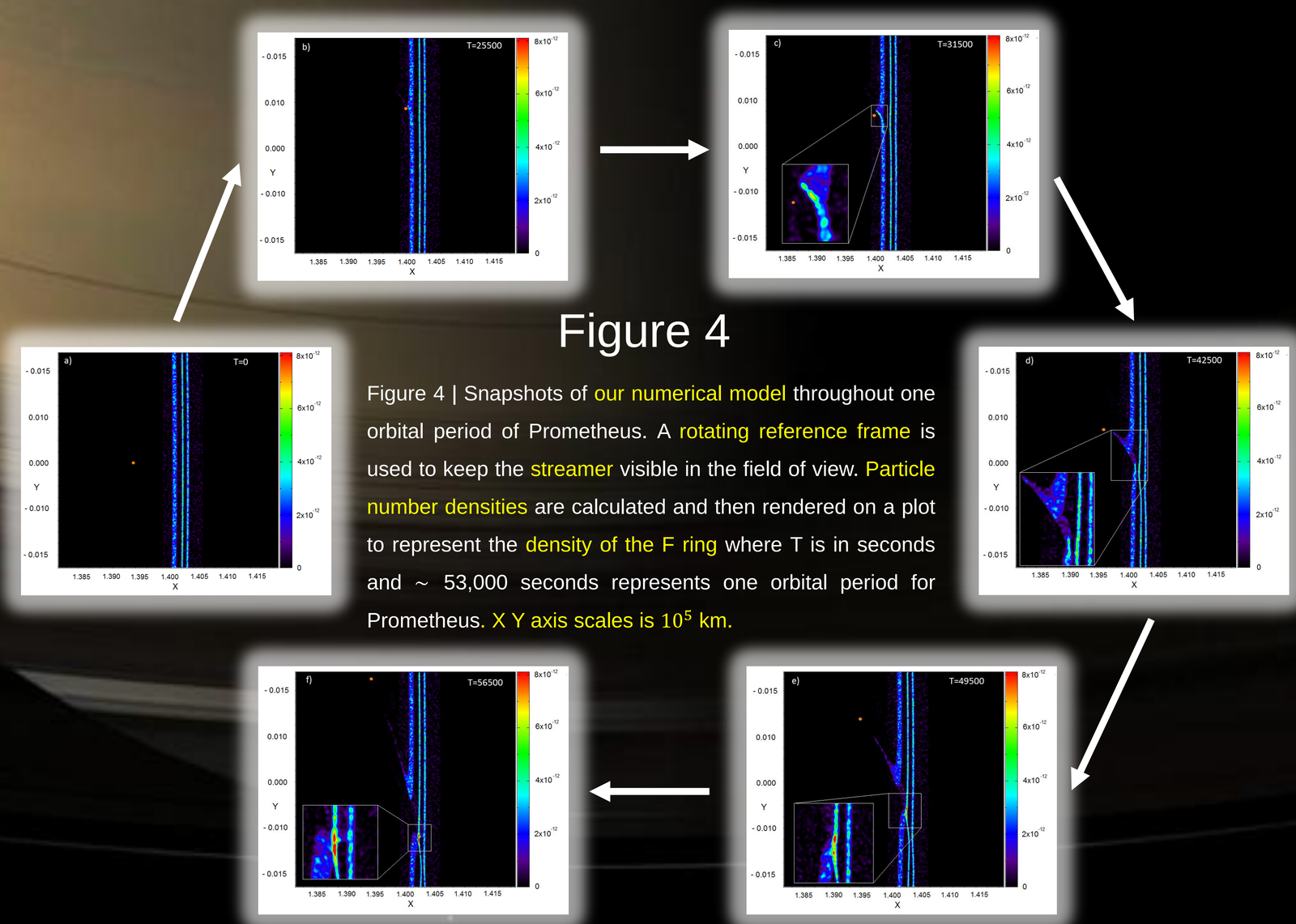


Figure 4 | Snapshots of our numerical model throughout one orbital period of Prometheus. A rotating reference frame is used to keep the streamer visible in the field of view. Particle number densities are calculated and then rendered on a plot to represent the density of the F ring where T is in seconds and ~ 53,000 seconds represents one orbital period for Prometheus. X Y axis scales is 10^5 km.

Conclusion

- If densities in regions that show an increase exceed the local Roche density then collapse through means of gravitational instability is a possibility.
- When Prometheus and the F ring are at minimum separation areas of increased density are formed in the central F ring core. This happens when particles in the inner strand receive a large enough velocity kick to move into the adjacent central strand
- When observed for multiple orbital periods areas of increased density are also found at channel edges but move into the central strand as Keplerian shear elongates the structures.
- Our findings then allow us to predict that moonlets are most likely to be located within the central F ring strand if formed solely by perturbations of Prometheus and when at minimum separation.

References

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Acknowledgements

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