



## **The formation and evolution of moonlets in Saturn's F ring**

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Images of Saturn's F ring from the Cassini spacecraft, including several obtained near the time of the 2009 equinox, have revealed bright clumps capable of casting shadows on nearby ring material. In the vicinity of the inner shepherding satellite, Prometheus, the clumps are clearly associated with the edges of the channel structures (Murray et al., *Nature* 437, 1326 (2005)) created by the gravitational perturbations from the satellite. Furthermore, the detection of "fan"-like structures (Murray et al., *Nature* 453, 739 (2008)) in adjacent ring material is consistent with the effect of an embedded object on an orbit with an eccentricity different to that of the F ring; these structures are also associated with the channel edges. Bright clumps have been detected throughout the ring and not just in those regions that have just encountered Prometheus, although the regularity of their spacing is most obvious at these locations. Cassini images of the F ring obtained over several months show that the clumps drift with respect to the core of the F ring implying semi-major axes that differ from that of the core. Numerical simulations of the interaction between Prometheus and test particles in the F ring show that the effect of the satellite's passage is to create regions of enhanced mass density and low relative velocity at the channel edges. These are suitable conditions for instabilities in the ring leading to collapse into gravitationally bound objects or moonlets. The initial perturbation leads to changes of  $\sim 10\%$  in the particles' eccentricities as well as changes in their semi-major axes of up to  $\pm 20$  km. The former could account for the observed "fans" while the latter could account for the observed drift of the bright clumps over time. The same mechanism causes the channels to widen with time and this effect is seen in the Cassini images. Loosely bound objects or moonlets formed in this way could be disrupted by subsequent Prometheus passages or could survive and grow subject to the continual balance between accretion and disruption in the Roche zone around Saturn. The situation in the F ring is analogous to that of perturbations from a gas giant embedded in a marginally stable gas disk leading to disk instability and collapse.