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Propellers in Saturn's Rings

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Saturn's rings - a myriad of icy grains in the size range of centimeters up to even kilometres - are likely the result of a catastrophic impact of a cosmic projectile (comet or asteroid) onto one or few of the icy satellites of Saturn. Depending on the age of this particle disk a certain number of larger bodies ($>$ 50 meters) are expected to exist in the rings. Currently two kilometer-sized moonlets - Pan (10 kilometres) in the Encke division and Daphnis (5 kilometres) in the Keeler gap - are known. However, the (expected) even more numerous 100 metre-sized bodies have not yet been detected because they are simply too small in order to be resolved by the Cassini cameras. The only chance to uncover the existence of such small moonlets is to search for typical structures they grave in the rings. Thus, we investigate the density perturbations in the ring which evolve in the presence of an embedded small moonlet. A Markov-chain model of the gravitational scattering caused by such a boulder has been derived and completed by a collisional induced nonlinear diffusion. The interplay between the moonlets gravity and viscous diffusion causes a typical propeller-shaped structure in the ring for moonlets smaller than $\sim$ 1 km. The spatial scalings of the generated structures enable estimates of the mass of the embedded moonlet and the transport properties of the ring-material (viscosity). We have checked these findings with numerical particle "experiments" and approved the formation a "propeller" interfered with wakes. The scalings in radial and in azimuthal direction, predicted with the analytical Markov-chain model, have been confirmed by these particle-simulations. Recently, four "propellers" have indeed been identified in the A ring of Saturn (Tiscareno et al., Nature, in press) pointing to moonlets in the size range of 40 up to 120 metres. With this detection the number of such boulders in Saturn's rings has been estimated to about 10 million which supports an ongoing erosion/fragmentation and re-accretion processes (recycling of ring matter; L. W. Esposito), and further, the catastrophic origin scenario of planetary rings.