Nonlinear Dynamics of Density Waves in Saturn's Rings

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Saturn's rings exhibit a wealth of substructure on length scales ranging from thousands of kilometers down to hundreds of meters. Many physical mechanisms have been proposed to explain parts of these structures.
In particular, the theory of spiral density waves, originally proposed to explain the spiral structure of disk galaxies, has been applied to explain many features in the rings which were discovered mainly by the Voyager 1 and 2 missions in the early 1980's, and the Cassini-Huygens spacecraft since 2004. Numerous density waves are resonantly excited by moons exterior to the ring system and these waves posses typical wavelengths of 1-10km.
From analysis of density waves one can infer physical parameters of the rings, such as the local surface mass density and viscous properties, by applying kinetic or hydrodynamic models. The Saturnian ring system serves as a laboratory for investigations on various wave phenoma that may bear implications for processes in different astrophysical systems like protoplanetary disks.
The linear hydrodynamic theory for the excitation and damping of density waves in Saturn's rings is well developed. However, it fails to describe many of the observed waves. In order to describe nonlinear density waves, a different approach, based on the description of the ring matter in terms of streamlines, has been developed. It turns out that the damping mechanisms, as well as the role of different nonlinear effects on the wave propagation, are not yet well understood.
First attemps are being made to investigate the excitation and propagation of density waves within a nonlinear hydrodynamical formalism, serving as a simple model to improve our understanding of the properties of these waves.
Furthermore, hydrodynamical simulations of a dense planetary ring are carried out to verify the predictions of the nonlinear model as well as to provide new insights in the dynamics of density wave propagation and structure formation in Saturn's rings. First results of these investigations are presented.

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