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Fine-Scale ~ 100 m Density Wave Structure of the Saturnian Ring Disk: A Hydrodynamic Theory

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The linear stability of the Saturnian ring disk of mutually gravitating and physically colliding particles is examined with special emphasis on its fine-scale of the order of 100 m or even less density wave structure (almost regularly spaced, aligned cylindric density enhancements and optically-thin zones with the width and the spacing between them of roughly several tens particle diameters). Jeans instabilities of gravity perturbations (e.g., those produced by a spontaneous disturbance) are analyzed analytically through the use of Navier-Stokes equations of a compressible fluid. An essential feature of this study is that the theory is not restricted by any assumptions regarding the thickness of the system. The simple model of the system is considered: the ring disk is considered to be thin and its structure is considered in a horizontally local Wenzel-Kramer-Brillouin (or short-wavelength) approximation. A plasma physics method is given for the solution of the self-consistent system of the gasdynamical equations and the Poisson equation describing the stability of Saturn's A, B, and C rings when the system is perturbed in an arbitrary manner. That is, when a gravity perturbation does not distort the rings' plane (modes of even symmetry with respect to the equatorial plane, or even Jeans-type perturbations) and when does distort the rings' plane (odd bending-type perturbations). This approach is introduced here for the first time in an astrophysical context. We show that the disk is probably unstable and gravity perturbations grow effectively within a few orbital periods; self-gravitation plays a key role in the formation of the fine-scale structure while particle collisions play a secondary role. It appears very likely that some of the microstructures in Saturn's rings recently revealed by the CASSINI spacecraft high-resolution observations is a manifestation of these **density wave** effects. The predictions of the theory are compared with observations of Saturn's rings by the CASSINI and are found to be in good agreement. Particulary, we show that the quasi-periodic density enhancements are flattened structures, with height/width ratio of about 0.3.

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