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Large-scale hydrodynamical and N-body simulations of viscous overstability in Saturn's rings

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Abstract

We aim to understand axisymmetric structure formation in Saturn's A and B-rings on scales of 100 m to several kms through nonlinear hydrodynamical and N-body simulations of the viscous overstability. The viscous overstability is a robust generator of structure on short scales, as witnessed by previous hydrodynamical and N-body simulations (Schmidt and Tscharnuter 1999, Salo et al. 2001), and is hence the most likely candidate responsible for recently observed periodic microstructure (Colwell et al. 2007, Thomson et al. 2007). It is also possible that during its nonlinear saturation the instability gives rise to axisymmetric patterns on slightly longer scales that may correspond to observed irregular structure on 1-10 km (Porco et al. 2005, Latter and Ogilvie 2009, 2010).

Our hydrodynamical and N-body simulations are undertaken in local Cartesian domains that can extend over 10 km in radius and can be evolved forward in time for more than 1000 orbits. These hence provide the scope to fully describe the nonlinear saturation of the overstability and to mainfest the full range of its dynamics. Self-gravity is omitted at this stage, but will be included in future work.

Nonlinear wavetrains dominate all the simulations, and we associate them with the observed periodic microstructure. The preferred lengthscale of these waves (~200 m) is set by secondary modulational instabilities. These wavetrains undergo small chaotic fluctuations in their phases and amplitudes, and may be punctuated by more formidable `wave-defects', that are distributed on longer scales (~ 1-5 km). It is possible that the defects are connected to the irregular larger-scale variations observed. We also speculate on the azimuthal extent of the waves and the influence of self-gravity wakes on their dynamics.

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