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The role of collective self-gravity in the nonlinear evolution of viscous overstability in Saturn's rings

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Abstract

We investigate the influence of collective self-gravity forces on the nonlinear, large scale evolution of the viscous overstability in Saturn's rings. We numerically solve the nonlinear hydrodynamic model equations in the isothermal and non-isothermal approximation, including radial self-gravity and employing transport coefficients derived by [3]. We concentrate on optical depths $\tau = 1.5 - 2$, which are appropriate to model Saturn's dense rings. Furthermore, local N-body simulations, incorporating vertical and radial collective self-gravity are performed. Vertical self-gravity is mimicked through an increased frequency of vertical oscillations, while radial self-gravity is approximated by solving the Poisson equation for an axisymmetric thin disk in Fourier space. Direct particle-particle forces are omitted, which prevents small scale gravitational instabilities (self-gravity wakes) from forming, an approximation that allows us to study long radial scales (5 km or more) and to compare directly the hydrodynamic model and the N-body simulations . Our isothermal and non-isothermal hydrodynamic model results, in the limit of vanishing self-gravity, compare very well with the studies of [1] and [2], respectively. In contrast, for rings with non-vanishing radial self-gravity we find that the wavelengths of saturated overstable wave trains tend to settle close to the frequency minimum of the nonlinear dispersion relation. Good agreement is found between non-isothermal hydrodynamics and N-body simulations for disks with strong radial self-gravity, while the largest deviations occur in the limit of weak self-gravity. The resulting saturation wavelengths of the viscous overstability for moderate and strong radial self-gravity ($\lambda \sim 100 - 300$m) agree reasonably well with the length scale of the axisymmetric periodic micro structure in Saturn's inner A ring and the B ring, as found by *Cassini*.

Acknowledgements

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References

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