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Photometric modeling of viscous overstability in Saturn's rings

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Abstract

The viscous overstability of dense planetary rings offers a plausible mechanism for the generation of observed ~ 150 m radial density variations in the B and the inner A ring of Saturn [1, 12]. Viscous overstability, in the form of spontaneous growth of axisymmetric oscillations, arises naturally in N-body simulations, in the limit of high impact frequency and moderately weak selfgravity [4, 8, 9, 10]. For example, a selfgravitating system of identical particles with internal density ~ half of solid ice, becomes overstable for optical depths $\tau > 1$, forming oscillations on about 100 meter scale.

Like self-gravity wakes (with typical ~ 20° trailing pitch angle), overstable oscillations lead to alongitude-dependent brightness of the rings. Due to their axisymmetric nature, the expected longitude of minimum brightness is shifted closer to ring ansae (for small phase angles). Moreover, according to simulations, the axisymmetric oscillations may coexist with the inclined selfgravity wake structures, which can lead to complicated photometric behavior as a function of illumination and viewing geometries, depending on properties of the simulated system. For example, at low viewing elevations, the vertical thickenings associated with the density crests should cast shadows on the nearby ring particles (see Fig. 1 for an example; darker areas are due to shadows, not due to depletion of particles). Though these shadows would be unresolved, they might still affect the integrated brightness at certain geometries. The overstable systems may also exhibit amplitude variations (in km-scales), arising from the mutual beating patterns of the basic sub-km overstable oscillations [3]. Such modulations of oscillation amplitude may lead to associated brightness variations.

New results of photometric modeling of viscously overstable dynamical simulations systems are reported, related to the above mentioned topics. The Monte Carlo method of [5] is used, previously applied to modeling of photometric signatures of selfgravity wakes [6, 2], scattering properties of propeller structures [11], and most recently to the interpretation of elevation-angle dependent opposition effect seen in HST data [7]. In particular, the possible observable signatures of amplitude modulations and vertical splashing are explored.

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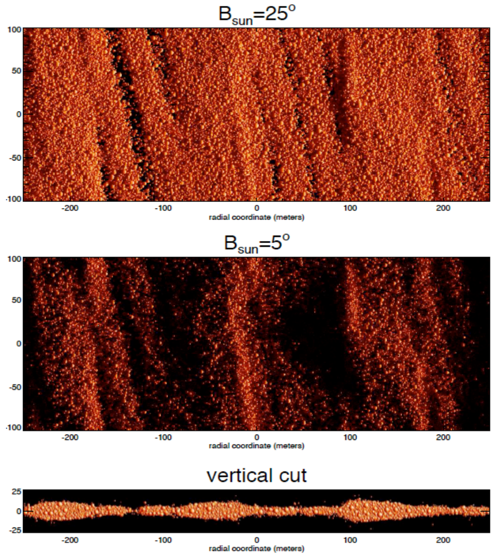

Figure 1: Snapshot from a self-gravitating dynamical simulation of viscous overstability, with geometric optical depth $\tau = 3$, and power-law size distribution with $q = 3$ and $r_{max}/r_{min} = 5$. A constant coefficient of restitution $\varepsilon = 0.5$, internal density 300 kg/m^3 and distance a = 100, 000 km were employed. The upper two frames show a Monte Carlo ray tracing image of the system, illuminated from $B_{sun} = 25°$ and 5° along the radial direction, and viewed perpendicularly. Lambert scattering is assumed, including multiple scattering (see Salo and Karjalainen 2003, [5]). The lower frame shows a cut of the system, illustrating the vertical splashing associated with overstable oscillations.

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