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# $N$-body Simulations of Planetary Rings

Hiroshi Daisaka

*Department of Astronomy, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*

**Abstract.** We present the formation and evolution of a structure in particles obtained from a local $N$-body simulation of a dense planetary ring like Saturn's ring. Our simulations show in a particle system the spontaneous formation of a spatial structure like wakes, clumps, and a structure which could be induced by the viscous overstability. Such a formation depends on parameters characterizing a ring system: the wake is likely to form in Saturn's ring and the existence of the wake is consistent with observations. The viscous overstability would be a good candidate for the explanation of subring structures in the ring.

## 1. Introduction

Detailed structures in planetary rings have been revealed by both earth-based observations and planetary probes: It was found that Saturn's main ring consists of many axisymmetric subrings like a record with scale $\sim$ 10km, and has hyperfine structures in the subrings with a scale of about 100m (e.g., Esposito 1993). Such structures need a mechanism that maintains them, since the viscous diffusion time induced by particle interactions is much shorter than the age of the solar system. So far, several ideas have been proposed to explain these structures and also particle simulations have been done. Here we present results of our local $N$-body simulation for the study of a dense ring system with self-gravitating particles like the Saturn' main ring. A comprehensive version of this paper can be found in Daisaka&Ida (1999) and Daisaka, Tanaka&Ida (2001).

## 2. Formation of spatial structures

Snapshots of spatial structures obtained from our simulations are displayed in Fig. 1. Wake formation could be seen in a simulation with parameters suitable for the B-ring, in which the formation and dissolution of structures continuously occurs due to the self-gravitational instability and tidal disruption. It should be note that the wakes are induced by the combined effects of both self-gravity and inelastic collision of particles. According to detailed analysis of the wakes, the typical scale is approximately given by the critical wavelength of the gravitational instability, $\lambda_{\rm crit} = 4\pi^2 G\Sigma/\kappa^2$, where the symbols have the usual meaning. For the B-ring, the estimated scale is of the order of 100m, which is consistent with the scale of the hyperfine structure. Clump formation arises in a simulation for outside of the A-ring. At the beginning of the simulation, the formation



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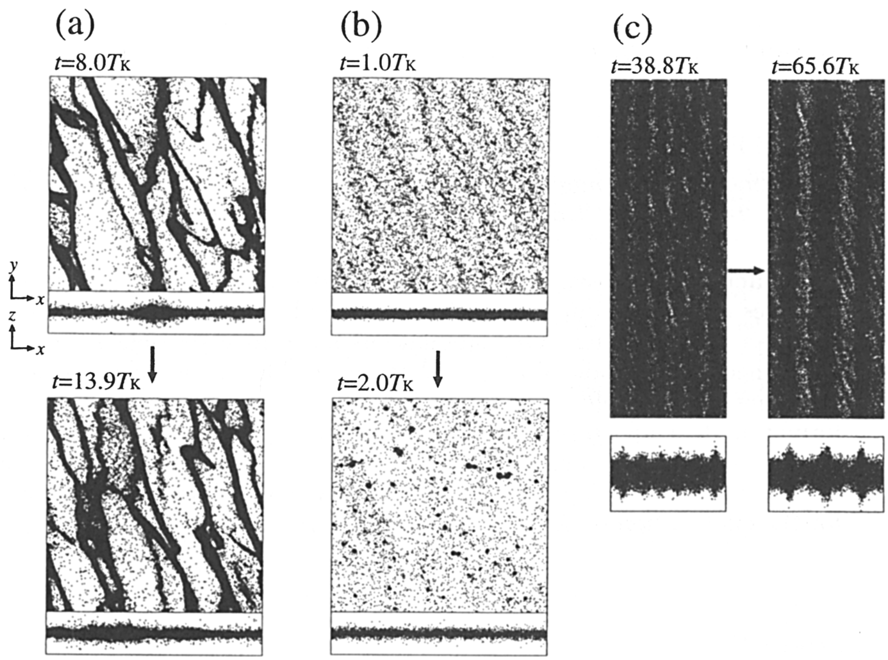


Figure 1. Formation and evolution of spatial structures obtained from local $N$-body simulations, (a) wakes, (b) clumps, (c) structure induced by the viscous overstability.

of the wakes arises and the wakes develop into clumps since the self-gravity is stronger than the tidal effect. The formation of wakes and clumps occurs when Toomre's $Q$ value is less than about unity, and within a few dynamical times. We also found density patterns parallel to the azimuthal direction, which correspond to axisymmetrical structures. This structure is thought to be induced by the viscous overstability (e.g., Schmit&Tscharnuter 1995). The evolution of this structure requires much longer time. Figure 1 shows that intervals between density peaks seems to get wider for several tens of dynamical times. According to Daisaka et al. (2001), a dense ring could satisfy the condition for the overstability. Therefore, this overstability model would be good candidate for the explanation of the ringlet structures in Saturn's ring.

## References

Daisaka,H. Ida,S., 1999, Earth Planets Space, 51, 1195
Daisaka,H., Tanaka,H.,&Ida,S., 2001, Icarus, in press
Esposito,L.W., 1993, Annu. Rev. Earth Planet. Sci., 21, 487
Schmit,U., Tscharnuter,W.M., 1995, Icarus, 115, 304