Pitch Angle of Self-Gravity Wakes in Dense Planetary Ring

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In Saturn's ring, gravitational forces between particles tend to form gravitationally bound clumps, while differential rotation tears them apart. Due to these competing processes, spatial structures called self-gravity wakes appear (Salo 1992). The self-gravity wakes are non-axisymmetric structures on sub-kilometer scales. The A and B rings exhibit a remarkable asymmetric brightness variation (Camichel 1958). Salo et al. (2004) found that this asymmetric brightness variation was explained by self-gravity wakes. Thus, the existence of self-gravity wakes was indirectly supported by the observations.

The physical mechanism of the self-gravity wakes has not been understood completely. It was suggested that the swing amplification mechanism may be applicable (Toomre 1981, Salo 1995). The pitch angle of the spiral arms formed by the swing amplification was obtained (Michikoshi and Kokubo 2014). From this estimation, the pitch angle of the self-gravity wakes should be about 10°, which does not depend on the Saturnicentric distance. However, the observational studies indicate that the pitch angle increases with the Saturnicentric distance (Hedman et al. 2007). Therefore, to understood this discrepancy, we investigated the pitch angle of the self-gravity wakes by *N*-body simulations (Michikoshi et al. 2015).

We performed the local shearing box simulations. The inelastic collisions among particles were considered. The self-gravity was calculated by GRAPE-DR in NAOJ. The typical self-gravity wakes are shown in Figure 1. The self-gravity wakes are trailing structures. We calculated the pitch angle from the autocorrelation function. We confirmed that the pitch angle increases with the Saturnicentric distance (Figure 2).

To understand this trend, we considered the simple model of the self-gravity wakes. Comparing the timescales of self-gravity and the shear, we obtained the estimate of the pitch angle

$$\tan\theta \propto a^{3/2}, \quad (1)$$

where a is the Saturnicentric distance. This estimate agrees well with the numerical simulations. Our results suggest that the pitch angle is determined by the strength of the self-gravity relative to the shear.

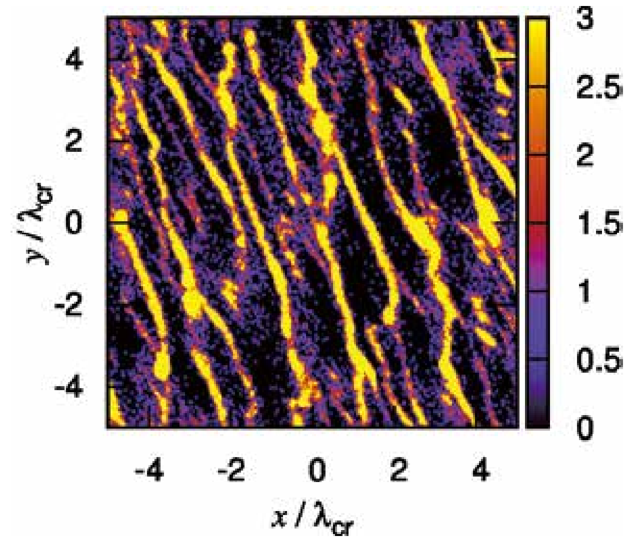

Figure 1: Surface density normalized by the averaged surface density. The clear self-gravity wakes are observed.

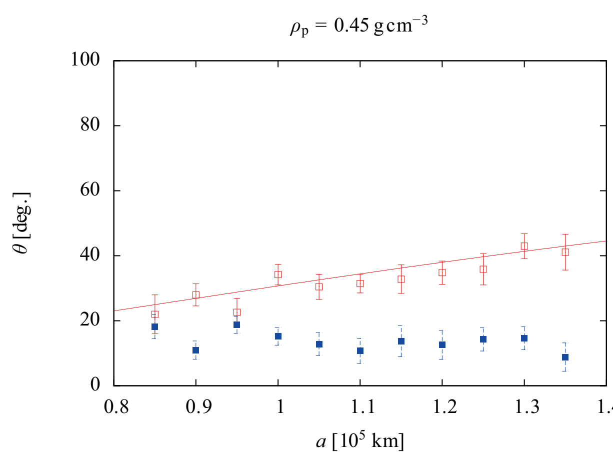

Figure 2: The pitch angle against the Saturnicentric distance. The red open and blue filled squares denote the pitch angle in the high and low density regions, respectively.

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