DYNAMIC OF PARTICLES IN SATURN'S RINGS

Mondino-Llermanos, A. (IATE); Giuppone, C. (IATE-OAC)

We have performed numerical simulations using N-body codes to study the dynamics within the Saturn Rings. Several simulations have been carried out in order to better understand the dynamical structures created and the effect of collisions in this environment. These kinds of studies are necessary to understand underlying physical processes and to connect them to the observations. We adapted two different codes in order to simulate some features of particle rings and to try to explain some properties in the Saturn rings.

1. Steady-State of a Dense Particle Disk

We adapted two different numerical codes to study the movement of ring particles around Saturn.

Collisions were calculated using a hard-sphere model with a velocity dependent coefficient of restitution.

We check that in real situations the system may establish an equilibrium state by the combined effects of collisions and shear motion (Salo et al. 1988). Thus helps to understand the height of Saturn's rings (~10 m)

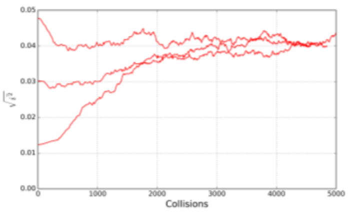
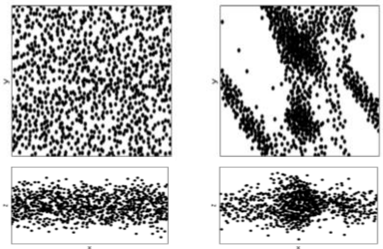


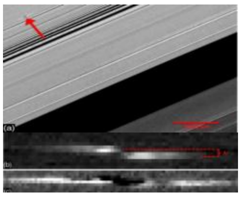
Figure at left describe the evolution of the rms-inclination of ring particles as a function of number of collisions, reaching a steady configuration independent of the initial conditions. The y-axis unit is in correspondence with velocity dispersion in the vertical direction.

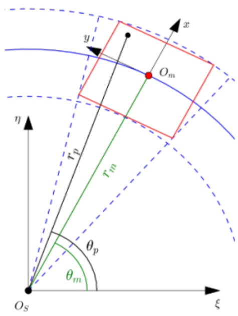
The inclusion of self-gravity forces in a differentially rotating disk modifies the local dynamics in several ways, depending on the mass density of the ring and the distance from the planet. If its radial velocity dispersion falls below a critical value, the disk is local unstable against the growth of axisymmetric disturbances, leading to the formation of shearing tilted wake structures, with individual wakes forming and dissolving in a time scale of about one orbital period (Schmidt et al. 2009). Figure at the bottom shows the formation of this wakes.



2. Propeller structures

Propeller-shaped structures in Saturn's rings are thought to be formed by gravitational scattering of ring particles due to one unseen embedded moonlet. The last displays a non-Keplerian orbital motion (Tiscareno et al. 2010)



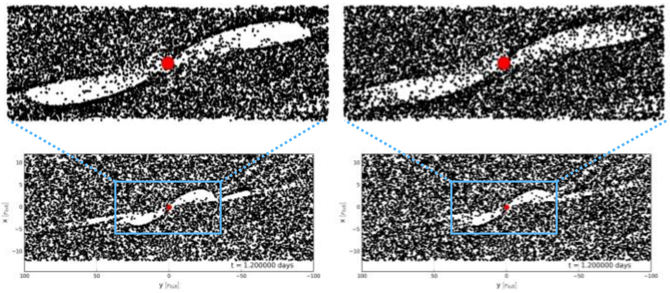


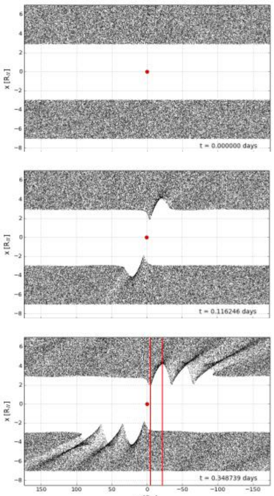
Many authors tried to reproduce propeller-shaped structures making some simplifications of the problem in their simulations, as for example using Hill equations for the particle motion, in order to model the feature structure and also the irregular motion of the moonlet.

We present dynamical studies of the evolution of the system using a full N-body integrator. We study the region around the moonlet in the plane of the ring, including a shearing sheet model for boundary conditions. Figure at left describes the properties of our problem.

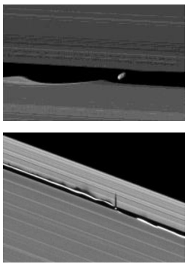
The presence of a moonlet perturbs the particles trajectories, leaving a cleared region. A primary lobe-gap is opened after one orbital period. Beyond it, there are typically secondary, tertiary, etc. structures that repeat the same pattern and are created roughly every orbital period for non particle-particle interaction. The inclusion of collisions and self-gravity in the simulations destroy this repeating pattern (Lewis & Stewart 2005).

The figure at bottom shows the propeller structure, formed after one moonlet orbital period, with and without taking into account overlapping collisions.





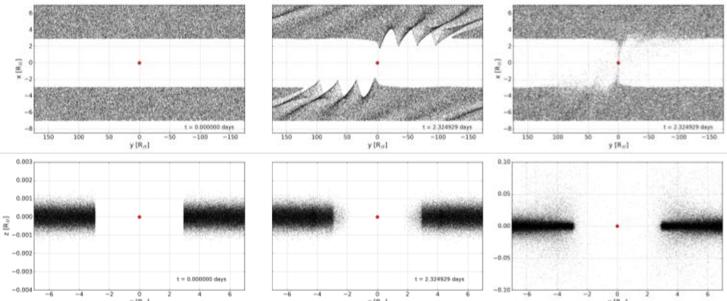
3. Keeler edge-gap structure due to Daphnis



Daphnis was discovered by the Cassini Imaging Science Team on 2005, within the Keeler gap in Saturn's rings. The inclination and eccentricity of Daphnis's orbit are very small, but distinguishable from zero. Both, particularly the inclination, are significantly greater than those of Pan (the larger moonlet which forms the Encke Gap). Daphnis's eccentricity causes its distance from Saturn to vary by ~9 km, and its inclination causes it to move up and down by ~17 km from the ring plane. The Keeler Gap is about 35 km wide (~7 Daphnis Hill radius).

As it orbits, Daphnis creates gravitational ripples on the edges of the gap as ring particles are attracted toward the moon and then fall back down toward the ring. The waves made by the moon in the inner edge of the gap precede it in orbit, while those on the outer edge lag behind it, due to the differences in relative orbital speed.

We simulate a ring of non-collisional particles without self gravity around Daphnis in order to better understand the plane structures observed in Cassini images. Bauer & Thomas (2010) analysis estimates a Daphnis mass of 15.10^{13} kg. We use the last result as our setup value, so that our peak-to-valley distance would be 17 km. We confirm the last value in the left Figure, where red lines shows the distance measured which value is of 2.85 Hill radius (17 km). The eccentricity and inclination of Daphnis where set up null.



Right Figure shows the particles spatial distribution initially (left) and after five orbital periods (middle), also taking into account initial velocity dispersion for the set of ring particles (right). Adding a vertical distribution modified the shape of the ripples in the edge of the gap. Besides, randomization of velocities increase the gain of energy from the systematic velocity field, leading the system to disperse faster.

NEXT STEP: Add the effects of collisions in order to study how the vertical structure of the gap edges change.

REMARK: Previous works without collisions, took into account Daphnis' inclination and eccentricity to reproduce the shape of the gap edge (Weiss et al. 2009)