Macroscopic bodies in Saturn's G ring arc: dynamics and dust generation

Victor Correa Lattari[1]
Rafael Sfair[1,2]

[1]Grupo de Dinâmica Orbital e Planetologia – UNESP/Guaratinguetá
[2] Institut fur Astronomie und Astrophysik, Eberhard Karls Universitat Tubingen, German

[1]victor.lattari@unesp.br [2]rafael.sfair@unesp.br

February 2022

Macroscopic bodies in Saturn's G ring arc: dynamics and dust generation

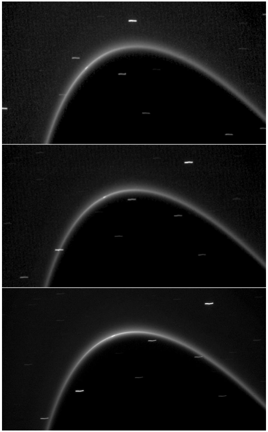

Figure: Sequence of images by Cassini Spacecraft from the G ring arc [PIA11148].

- A bright arc structure in the G ring was discovered by Cassini spacecraft in 2006, and the strong forward scattering indicates the arc population is dominated by dust particles.
- This region located at 168033 km, which covers 250 km in radius and 60o in longitude, is created by a 7:6 corotation resonance with Mimas.
- The source for this structure was credited to Aegeon, a 240 m in radius satellite, which lies embedded in the arc (Hedman et al., 2007).

Macroscopic bodies in Saturn's G ring arc: dynamics and dust generation

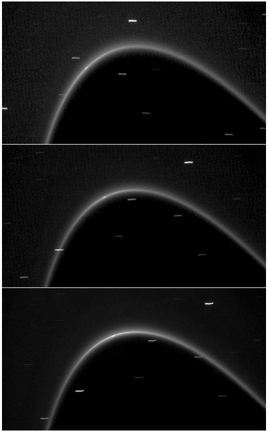

Figure: Sequence of images by Cassini Spacecraft from the G ring arc [PIA11148].

- Madeira et al. (2018) showed the solar radiation pressure is strong enough to remove the dust particles from the region at a rate much faster than the time required to repopulated the arc when considered the ejection of particles from the surface of Aegeon due to the impacts of micrometeoroids.
- LEMMS instrument has detected the existence of macroscopic bodies in the arc.
- An Alternative source.

Objectives

- Cassini data suggest the region contains meter-sized objects, which may collide among themselves and fragment.
- To test this hypothesis we performed a series of numerical simulations to compute the amount of dust that could be generated and verify if it is enough to keep the arc population in a steady state.

Numerical Setup

- We carried out n-body simulations using REBOUND IAS15 integrator (Rein & Spiegel, 2015) and when necessary the orbital elements were computed taking into account the geometric elements.
- Each system was composed of Saturn (with the zonal gravity harmonics up to J_6) and Mimas.
- Massive ring with total mass equivalent to the estimated of macroscopic bodies that may exist in the arc.

Collision geometry

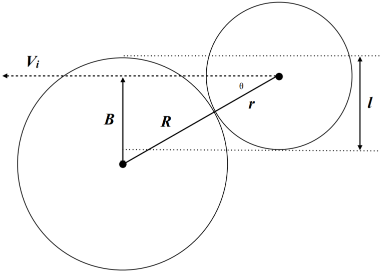

Figure: Collision geometry (Leinhardt & Stewart 2012)

- The collision outcome was computed depending on the relative velocity and the impact angle θ.
- Two regimes where considered: perfect merge or super-catastrophic (when the mass of the largest fragment would be smaller than 10% of the total mass).
- In the later, the two bodies were removed from the simulation and it was assumed that their mass was converted into dust.

Numerical Setup

- Two sets of simulations were carried out with different densities for bodies in the arc.
- As it was done in the previous analysis, we performed simulations with and without Aegaeon. The table summarizes the initial setups.

Simulation	Aegaeon	radius (m)	d (kg/m^3)	N
1	x	20	500	1200
2	-	20	500	1200
3	x	20	900	2000
4	-	20	900	2000

Results and Discussion

- The following graphs ilustrate the outcome of the collisions that happenend in the simulations including the satellite Aegaeon.

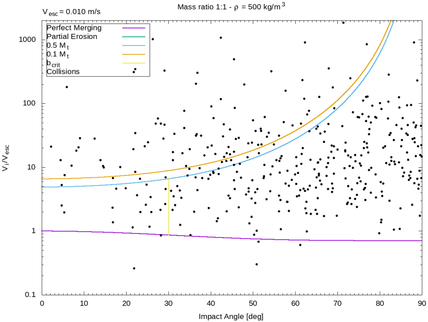

Figure: Collision regimes for interparticle impacts using density equal 0.9 g/cm^3.

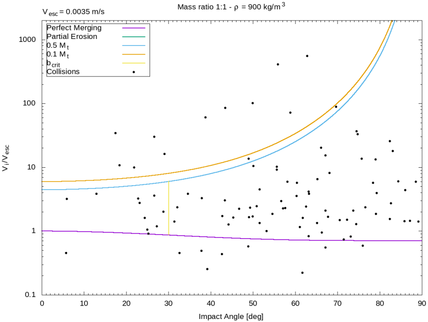

Figure: Collision regimes for interparticle impacts using density equal 0.5 g/cm^3.

Results and Discussion

- The majority of the collisions happen in the hit-and-run regime.
- There is an expressive amount of collisions in the super-catastrophic regime where the remaining major body has only 10% of the total mass of the collision.
- These super-catastrophic collisions may contribute to remain the dust particles in the arc.
- It is hard to generate bigger bodies colliding each other. The mutual escape velocity for the 20 m bodies is too small.

Results and Discussion

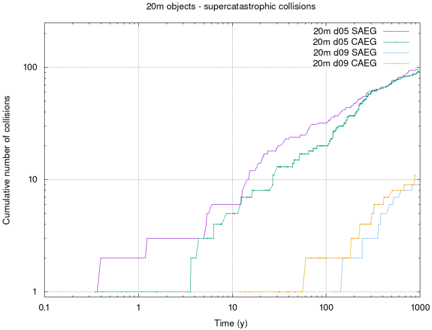

Figure: Cumulative super-catastrophic collision in function of the time)

- The graph illustrates the cumulative number of super-catastrophic collisions for each simulation.
- The purple and green lines represent the simulations using density equals 0.9 g/cm^3 and the others using 0.5 g/cm^3.
- More than 30% of the collision happens in the first 100 years. The time between each collision is consistent with the time for the radiation pressure to remove the dust particles from the arc.
- If we estimate that only 10% of the total mass is transformed into dust, it is possible to remain the dust population in a steady state.

Final Remarks

- In all simulations, the Aegaeon's orbit was not affected by the other small bodies.
- If these macroscopic bodies exist, it is possible to create a steady system in the G ring arc for more than 100 years.
- The majority of the collision is in a hit-and-run regime. However, these collisions can also contribute to the maintenance of the dust particles in the arc.
- In the following steps, we will perform simulations with SPH (Smoothed Particle Hydrodynamics) to better estimate the outcome of these collisions.