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Planet signatures and Size Segregation in Debris Discs

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1. Context, Objective and Method

The response of a debris disc to a planetary perturber is the result of the complex interplay between gravitational effects, grain collisions and stellar radiation pressure (Stark & Kuchner 2009). We investigate to what extent this response can depart from the pure gravitational case when including grain collisional production and radiation pressure. We use the DyCoSS code (Thébault 2012), designed to study the coupled effect of collisions and dynamics for systems at steady state with one perturbing body. We focus on two outcomes: the 2D surface density profile of the disc+planet system, and the way the Particle Size Distribution (PSD) is spatially segregated within the disc. We consider two set-ups: 1) a narrow ring with an exterior "shepherding" planet, and 2) an extended disc in which a planet is embedded. For each case, the planet mass and orbit are explored as free parameters, and an unperturbed "no-planet" case is also considered. Another parameter is the disc's collisional activity, as parameterized by its optical depth τ.

2. Surface Density Profiles

We find that collisions always significantly damp planet-induced spatial structures. For the extended disc with embedded planet case, the planet's signature remains visible in face-on images if $M_{planet} \gtrsim M_{Saturn}$. If the system is seen edge-on, however, even a Jovian planet only leaves weak asymmetries in a collisionally active disc, even though some planet-induced signatures might be observable with high-resolution observations. For the narrow ring with shepherding planet case, we find that the planet cannot prevent the coupled effect of collisions and radiation pressure from injecting small dust grains in the dynamically "forbidden" region exterior to the ring (see Fig.1). For most cases, the radial density profile beyond the main ring closely mimics that in the absence of any planet, i.e., $\Sigma \propto r^{-1.5}$. Within the main ring itself, an exterior planet on a circular orbit leaves precessing structures that can be used to indirectly infer its presence. For an eccentric planet, the ring becomes elliptic and the pericentre glow effect is visible despite of collisions and radiation pressure, but detecting such features in observed discs is not an unambiguous indicator of the presence of an outer planet (Thébault *et al.*, 2012)

3. Spatial Segregation of the Size Distribution

We find that PSDs are almost always spatially segregated, even in the unperturbed no-planet case. Another surprising result is that, for most cases, the size dominating the disc's geometrical cross section is *not* that of the smallest bound grains. The only case where a standard PSD of $dN \propto s^{-3.5}ds$ is observed is for the unperturbed narrow ring case, but only within the ring itself. Beyond it, the size distribution is peaked around a size $s*$ given by $r_{ring} = (1 - 2\beta(s*)).r$ (β is the ratio of the radiation pressure to stellar

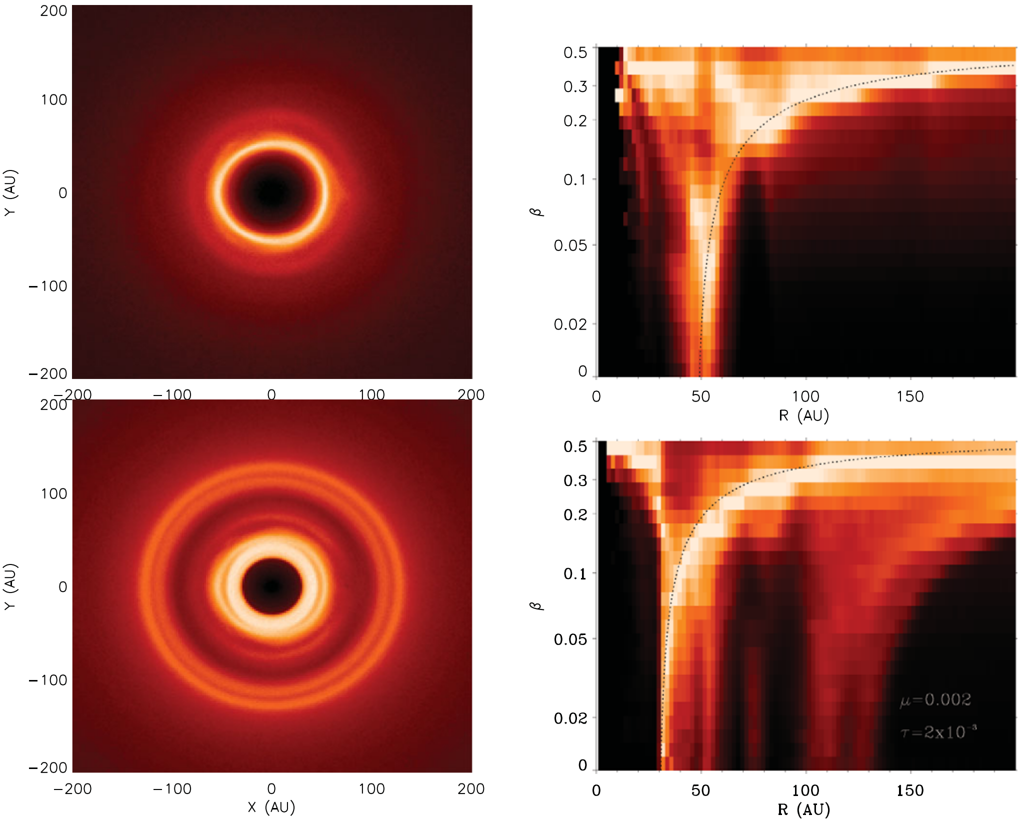

Figure 1. Steady state reached for (*upper panel*) the narrow ring with shepherding planet case and (*lower panel*) the extended disc with embedded planet case. For both cases: $\mu = M_p/M_{star} = 0.002$, $a_{pl} = 75$AU, $e_{pl} = 0$ and τ(optical depth)= 0.002. *Left panel*: normalized surface density profile viewed face-on. *Right panel*: Azimuthally averaged radial distribution of the geometrical cross-section as a function of grain sizes, as parametrized by their β value.

gravity). For an unperturbed wide disc, we find that, at radial location r, the PSD assumes a standard profile in $\sim dN \propto s^{-3.5}ds$ down to a size $s*$ given by $r_{inner-edge} = (1 - 2\beta(s*)).r$. For planet-perturbed discs, PSDs can be very complex. For instance, the L4 and L5 points are mostly populated by large grains, while dynamically unstable regions are populated with small, $\beta > 0.15$ grains (Thébault & Kral, 2013).

References

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