When do planetary systems become debris disks?

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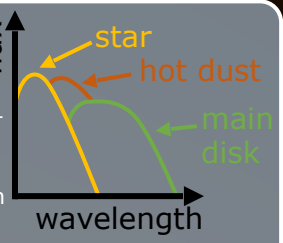
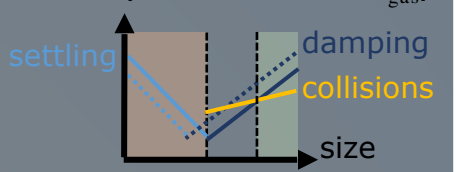
Near-IR excess



Protoplanetary disk spectra show an excess in near-IR, even if the inner disk is otherwise cleared out, presumably by a planetary system where A giant planet stops dust from Moving in toward the star.

This can be explained by the emission of dust close to the star. Where does it come from? Does it sneak through past the giant planet, or could it be locally produced by colliding planetesimals or embryos, in a very early debris disk? The presence of low-density gas can increase dust lifetime, decreasing the required replenishment.

Timescales



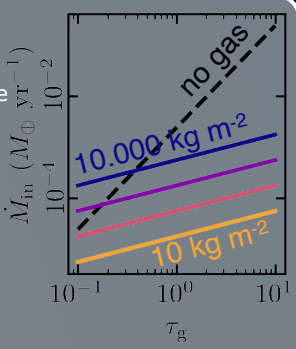
Small particles are bound to the gas, thus do not collide, their lifetime is much longer than in traditional debris disks and they survive until they eventually settle to the midplane.

For large particles collisions occur quicker than damping, forming a cascade which produces smaller particles.
The combined effect is, that the number of small particles is large for extended periods of time.

Required mass flux

How much mass flux do planetesimal collisions have to provide so that the dust If visible to observers? Fragments from a collision are assumed to follow a size distribution

$$\frac{\mathrm{d}N}{\mathrm{d}s} \propto s^{\gamma_\mathrm{f}}.$$



The $\gamma_\mathrm{f} = -3$ case is shown here. In gas-depleted disks (collored curves), the required flux drops to just 10^{-5} Earthmasses per Myr. It may be as low as 10^{-8} for steeper powerlaws.

Conclusions

The presence of low-density gas significantly decreases the mass flux required to sustain an optically thick cloud of dust.

Almost trivial amounts of mass flowing into the collisional cascade can therefore maintain a visible torus of dust.

In transitional disks with warm/hot excess emission, we may already witness the start of a collisional cascade, displaying not primordial, but planetary dust to the observer.

Swinkels & Dominik (2024)
A broken debris cascade as a possible source of hot dust emission in transitioning planet-forming disks.