Dry or wet? On the efficient formation of planetesimals close to the snow-line inside a dead-zone.
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Abstract: In the today view of planet formation, planetary embryos are seen as an assembling of planetesimals. These planetesimals are thought to form through the so called "streaming instability" by which grains with Stokes number > 0.01 are collected together through aerodynamic drag, then experience a gravitational collapse to finally form bodies > 100km in size. However, the onset for such a process requires that locally, in the disk midplane, the concentration of solid particles becomes comparable to the local gas density, whereas the dust/gas ratio is only about 1% initially. Several processes have been identified to efficiently concentrate dust, and the most efficient of them generally happen close to the water snow-line through re-condensation of water vapor released at the snow-line by inward drifting pebbles. In that case, most of the planetesimals are formed beyond the snow-line, thus must be rich in water ice and volatile material (Drazkowska et al. 2016, 2017). However, meteoritic records show that some families of chondrites (e.g. ordinary or enstatite) have a low oxidation state or low water-alteration, suggesting they formed in a water poor environment. To solve this problem, it was proposed that the effect of gas/dust back-reaction could concentrate dust in a water poor environment, but they rely either on a slow vertical diffusion of dust across of the snow-line (Ida et al., 2016) or on the effect of dust-back reaction on the diffusive transport that is poorly understood for the moment (Hyodo et al., 2019). Whereas they are potentially very promising processes, they are still based on some unconstrained physics.

Here we explore an alternative pathway to concentrate dust efficiently to form dry planetesimals. It is well established that if there is a pressure bump, or a density bump in the disk, then dust should accumulate at pressure maxima (that often correspond to density maxima).

We investigate the conditions under which a gas-pressure maximum could appear close to the snow-line. We show that the most promising mechanism could be, very simply, a local variation of gas effective viscosity at the snow-line. By doing an analytical treatment backed by a numerical analysis, we show, using basic physics that if the average disk viscosity have an abrupt change at the sow-line (which is very possible, through the rapid change of gas composition due to the release of water vapor), then the disk viscous evolution compensates the viscosity change with a surface-density change, in order to maintain the diffusive flux uniform with space. As a consequence, a pressure bump appears and dust is very efficiently concentrated.

We find that this mechanism is further amplified inside a dead-zone (a place of low-ionization and low viscosity) topped by an active layer because the vertically averaged viscosity in a dead-zone is a *decreasing* function of the total surface density (in the alpha-model approximation). Then a positive feed-back process appears by which the higher the surface density, the lower the viscosity, inducing an accumulation of material and so-on. First preliminary results (Figure 1) show that this process can create a dust-trap inward the snow-line, paving the way for the formation of a dry planetesimals population.

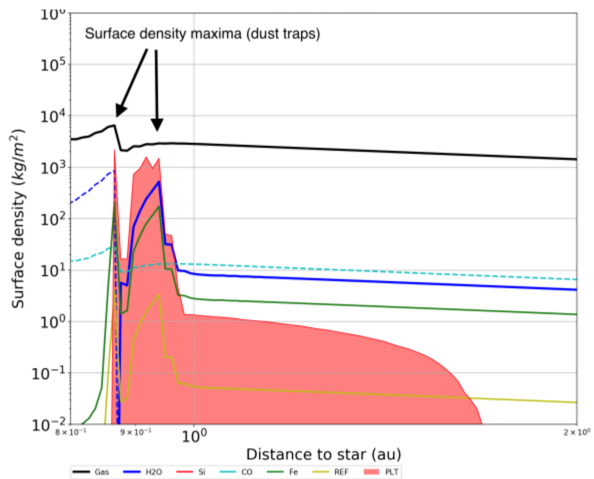

Figure 1: *Numerical simulation of protoplanetary disk using an alpha-disk model, from Charnoz et al. (2018). Black: gas surface density in a protoplanetary disk as a function to the distance to the star. Blue solid: ice, Green-dashed: CO vapor, Dark green solid : Fe solid, Red solid : silicates solid, yellow solid : high temperature refractory minerals. Red shaded region : planetesimals surface density. We see a surface density maximum (= pressure bump) at 0.85 AU whereas the*

snow line is a 0.86 AU. Adapted from Charnoz et al. (2019)

We explore in what conditions this dust-trap appears either inward and outward to the snow-line. We show that it is an efficient process in low-turbulence disks, in agreement with modern views of protoplanetary disks.

The conditions for the timing of formation of planetesimals as well as their refractory/volatiles compositions will be also presented.

References: Charnoz et al., 2019. A&A 627 id.A50; Drazkowska J. et al. 2016. A&A 592, Id.A105 ; Drazkowska J. et al. 2017. A&A 608, Id. A92 ; Hyodo, R. et al., 2019, A&A 629, id.A90; Ida S. et al., 2016, A&A 591, A72