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CAN ICE LINES CREATE RINGS? THE INFLUENCE OF ICE LINES ON DUST GROWTH IN PROTOPLANETARY DISKS

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Increased fragmentation in regions just outside of ice lines in protoplanetary disks leads to smaller particle sizes which causes pile-ups of material. This increase in surface density can be seen as bright rings in millimeter observations of protoplanetary disks.

Recent high resolution millimeter observations of protoplanetary disks show axisymmetric ring and gap structures (e.g., Andrews et al. 2016). These structures are often attributed to forming planets or to ice lines.

Ice lines are special locations in protoplanetary disks at which a phase transition between the solid and the gaseous phase of volatile species (e.g., H_2O, CO, CO_2) occur. Outside the ice line the temperatures are cold enough for the volatile to freeze out as ice. Therefore, ice lines are of special interest in planetary sciences, since they directly influence the composition of dust and planetesimals in protoplanetary disks. Furthermore, ice lines can have a direct effect on the coagulation physics of colliding dust particles.

Particles that drift inwards through ice lines lose their respective volatile species through evaporation. This newly created vapour can diffuse outwards in the disk, back through the ice line, and can recondenses on the particles there. As Stammler et al. (2017) showed, this vapor will mostly condense onto the smallest dust particles, the monomers, since they contribute most to the total surface area. This leads to larger monomer sizes within dust aggregates in regions just outside of ice lines. Since the fragmentation velocity of dust aggregates is inversely proportional to their monomer sizes (Dominik & Tielens 1997), particles in these regions of increased monomer size are therefore subject to higher fragmentation, which leads, in turn, to on average smaller particles sizes.

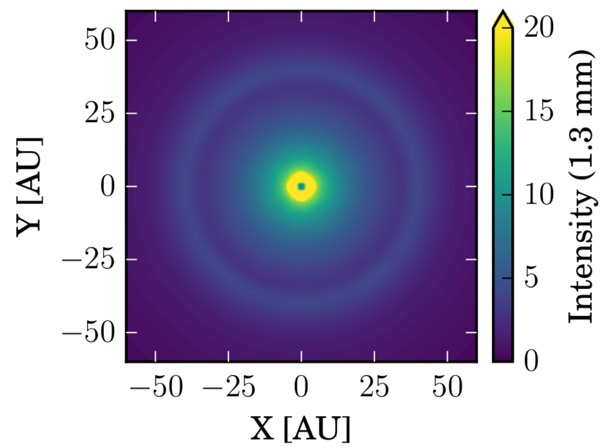

Fig. 1. Radiative transfer simulation of the CO ice line (37 AU) at a wavelength of $\lambda = 1.3$ mm.

Smaller particles, on the other hand, are less affected by radial drift. Particles that enter these recondensation regions and fragment decrease therefore their drift velocity, which leads to a pile-up of material. Our radiative transfer simulations (figure 1) suggest that this increase in surface density just outside of ice lines can be seen as bright rings in millimeter observations. This effect is stronger the more abundant a chemical species is, and might only be observable for the most abundant species in protoplanetary disks.

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