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Observational study of the formation and evolution of protoplanetary disks

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The mechanisms that lead to planet formation around young stars, and even in our own Solar System, are still not fully understood, in spite of the large laboratory, theoretical and observational efforts. These processes are thought to occur in circumstellar disks around pre-main sequence stars on rather short timescales: surveys in the infrared regime show that the number of low mass stars with disks drop dramatically for objects older than 10^6 years (Mamajek 2009), suggesting that in order to form large solids before the disk dispersal the growth process has to take place within a few million years.

A number of models have been proposed to reproduce the evolution of dust and protoplanetary disks, and an important debate involves the processes of growth from millimeter sizes to planetesimals: the mechanism of direct collision alone is not sufficient, since beyond certain sizes and velocities grains tend to bounce and fragment instead of sticking together (*fragmentation barrier*), moreover large particles should be effectively removed due to aerodynamical friction (*radial drift barrier*). These predictions are at odd with observations of large grains in the outer disks of multiple objects, obtained with millimeter telescopes, and it is now generally accepted that on top of a smooth size distribution controlled by radial drift and fragmentation, other *local* processes are required to trap large grains and promote localized growth. One of the complementary mechanisms that have been invoked is ice condensation near snowlines (i.e. the distance from the central star beyond which a volatile is stable against sublimation): dust grains that are migrating across a condensation front will lose part of their icy mantles, but cycles of sublimation and condensation, due to the concentration gradient that induces vapor to flow outward and recondense just outside the snowline, will lead to an efficient growth (Ros & Johansen 2013).

My PhD project focuses on the investigation of such mechanisms in the evolution of dust, through an observational study of protoplanetary disks with radio interferometric facilities, operating in the submillimeter and millimeter range. Telescopes like ALMA (Atacama Large Millimeter/submillimeter Array) and VLA (Very Large Array), among others, allow to measure the emission coming from the cold inner regions of these disks, which are not heated directly by the central star but receive and reprocess the radiation of the upper layers. These regions, usually referred to as the disks' midplanes, host most of the solid mass and set the physical conditions for the formation of larger bodies and eventually planets. The analysis of the dust continuum emission and the rotational lines of the molecular gas allow us to derive key parameters such as the dust size distribution, surface density and temperature, and thus provide essential constraints on the physical evolution of these objects. The improved capabilities of modern interferometers made now possible to resolve spatially the brightest disks, allowing us to measure the variation of grain properties in function of the distance from the star, and in particular across the condensation fronts (Guidi et al. 2016). Observations at extremely high resolution available in the coming years will represent a huge step ahead in understanding the complex mechanisms involved in dust evolution and planet formation.

References

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