DUST IN PROTOPLANETARY DISKS, update from the Dust-to-Planets ERC Project

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Young Protoplanetary disks are central to the process of planetary formation. Observationally, planets around main sequence stars are ubiquitous and the case for planets detected during their formation, i.e, still within their parent disk, is growing. The formation of a planet requires the growth of solids (dust) by several orders of magnitudes, from (sub-)micron sizes to kilometer sizes. This is a major problem because disks are short-lived, collisions are expected to shatter pebbles / boulders when they reach decimeter-meter sizes, particles are rapidly drifting inward because of gas drag, etc... The ERC Dust-2-Planets 5-year project is focussing on the very first stage of planet assembly, when small dust is assembling into pebbles and pebbles are concentrating in the disk midplane.

Since my first participation to CosmicDust in 2017 in Tokyo, where I presented an observation-based short review of the properties of dust in protoplanetary disks, instruments on large telescopes have provided a wealth of new and spectacular results on the structure and dust content of protoplanetary disks. Interestingly, the signature of dust scattering are now measured not only in the optical and NIR with better resolution than before, but also at mm wavelengths with ALMA, and now with JWST at mid-infrared wavelengths. In this presentation I will highlight several of the new results obtained with these instruments.

During CosmicDust 12 in Chiba (2019) I presented the proof-of-concept that a MicroWave Analogy (MWA) experiment, located in Marseille, France, could be used to characterize the scattering properties of dust analogs of various shapes. This proof-of-concept was instrumental in obtaining the ERC grant. Since then, the experimental set-up has been upgraded and many more results are available. Very Complex disk particle analogs are "routinely" fabricated by 3D printing, with material carefully tailored to match the complex refractive index of astronomical dust across the relevant frequency ranges (NIR & mm) and chemical compositions (silicates and carbonaceous materials).

The presentation is aimed to be a general summary of the results and progress made as part of ERC Dust-to-Planets. I will first briefly introduce the general background and goals of the project. I will then focus on the recent advances telescopes like JWST have allowed. These include a new method to quantitatively estimate the amount of ices in disks, including the important water ice, from JWST images (PhD work of L. Martinien). Contrarily to spectroscopy-based techniques, our method does not saturate when disks are optically thick. I will also very briefly put in context and show selected results from the PhD work of R. Zerna (3D printing and MWA results) and M. Roumesy (scattering phase functions for a sample of disks). They both presented earlier results of their work at CosmicDust in 2025. Should they also participate to CosmicDust in 2026, I would minimise that part of my presentation accordingly. Finally, I will wrap up by opening towards the future by discussing how these new results can be included in Radiative Transfer models (for comparison with data) and in hydrodynamical simulations that include the evolution of dust to improve our understanding of protoplanetary disk evolution and early planet formation.