Dust properties in planet-forming disks: Insights from observation, scattering phase function and disk color

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Dust grains in protoplanetary disks hold the key to the earliest stages of planet formation, but their physical properties remain poorly constrained. Since grain growth depends on coagulation and fragmentation, determining their size, shape, porosity, and composition is essential. Scattered-light imaging, and in particular the scattering phase function, offers one of the most promising ways to probe dust properties. Motivated by the recent increase in high-resolution disk observations, we developed `DRAGyS`, a new GUI-based Python tool that rapidly and robustly estimates disk geometry and efficiently extracts phase functions. Here, we apply `DRAGyS` to a large sample of VLT/SPHERE observations of ring-shaped protoplanetary disks.

We show that scattering phase functions separate into two distinct categories, revealing differences in dust grain properties. The first category is statistically consistent with porous aggregates larger than a micron, while the second is dominated by compact, submicron-sized particles. This suggests that we are directly probing different stages of dust growth within the disk. However, we also confirm that the scattering phase function alone, in a given disk, is not sufficient to fully break the degeneracies between plausible dust models. To go beyond this limitation, we complement the scattering phase function analysis with disk color derived from multiwavelength observations. We perform radiative transfer simulations to show that disk color carries complementary information on dust properties, with strong sensitivity to grain morphology, porosity, and, in particular, monomer size in aggregate particles. Together, these two measurements provide a more robust framework for interpreting scattered-light observations of protoplanetary disks. By combining scattering phase function and disk-color diagnostics, we open a promising path toward a more reliable characterization of dust growth in planet-forming disks.

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