Dust polarization observations with ALMA will help us to understand grain growth and magnetic field structure in circumstellar disks for planet formation

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Grain growth of ~ 0.1 micron sized cosmic dust is the first step toward planet formation in circumstellar disks. Constraining dust sizes observationally is therefore essential for understanding how protoplanetary disks evolve into planetary systems. At millimeter wavelengths, polarization provides a unique probe of dust properties, but its interpretation depends strongly on grain size: relatively small grains can remain aligned with magnetic fields in the same way with interstellar dust, whereas larger grains tend to require other polarization mechanisms, such as self-scattering or aerodynamic alignment.

In this talk, I will discuss how recent ALMA observations are beginning to connect dust evolution and magnetic field structure in planet-forming disks. I will first present our multi-band study of the DG Tau disk, which revealed a geometrically thin and smooth dust disk, evidence for dust enrichment, and a radial variation in grain size, with smaller grains in the inner disk and much larger grains in the outer disk. I will then show how multi-wavelength polarization observations can identify regions where small grains still trace magnetic fields. In the lopsided disk around HD 142527, this approach allowed us to derive the three-dimensional magnetic-field structure and field strength observationally. Finally, I will present our new 2.1 mm polarization results for DG Tau, which reveal a predominantly radial polarization pattern on 10 au scales in the inner disk and a transition to a more azimuthal pattern farther out. If the inner-disk polarization is dominated by magnetically aligned grains, the data suggest a predominantly toroidal magnetic field with non-negligible radial and vertical components. These results demonstrate that ALMA polarization can be used not only to diagnose grain growth and dust evolution, but also to constrain the magnetic environment in which planets begin to form.