Fractal aggregates of sub-micron-sized grains in the young planet-forming disk around IM Lup

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Dust aggregation is the first step of planet formation. The detailed properties of dust aggregates, such as aggregate size, monomer radius, and fractal dimension, have been shown to play a fundamental role in planet formation. Despite rapidly growing disk observations, it remains a mystery what primordial dust aggregates look like and what the physical and chemical properties of their constituent grains (monomers) are in young planet-forming disks. Confrontation of models with observations to answer this mystery has been a notorious task because we have to abandon a commonly used assumption, perfectly spherical grains, and take into account particles with complex morphology. In this presentation, we present the first thorough comparison between near-infrared scattered light of the young planet-forming disk around IM Lup and the light-scattering properties of complex-shaped dust particles. We show that the observations are best explained by fractal aggregates with a fractal dimension of 1.5 and a characteristic radius larger than ~ 2 μm. We also determined the radius of the monomer to be ~ 200 nm, and monomers much smaller than this size can be ruled out on the premise that the fractal dimension is less than 2. Furthermore, dust composition comprising amorphous carbon is found to be favorable to simultaneously account for the faint scattered light and the flared disk morphology. Our results support that planet formation begins with fractal coagulation of sub-micron-sized grains.