THE EVOLUTION OF PROTOPLANETARY DUST : THE ASTROPHYSICAL PERSPECTIVE

Daniel Apai[1] [1]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore apai@stsci.edu

Introduction: Circumstellar disks around young stars provide potential analogs to the young Solar System. These systems represent snapshots of the diverse evolutionary paths of circumstellar material, from massive accretion disks typical to the first million years, through low-mass protoplanetary disks observed at few Myr-old ages, to tenuous, colliosionally-replenished debris disks typical at ages beyond 10 Myr.

These studies are important to 1) measure the initial and boundary conditions for planet formation; 2) characterize the large-scale disk structure and its evolution; 3) assess the distribution and diversity of these properties as a function of stellar parameters. Astronomical observations reveal an evolution in the disk mass, disk structure, dust properties, and gas content revolutionizing our understanding of dust composition around other young stars.

In this talk I will review the picture emerging from these observations, placing special emphasis on comparative studies of large disk samples and on linking evidence from the early Solar System to astronomical analogs.

Disk Evolution and Lifetime: Micron-sized dust particles in the inner few AU around young stars are warm enough to efficiently emit at infrared wavelenghts. This excess emission over the photospheric emission reveals the presence of dusty disks [e.g. 1,2]. The occurrance rate of the excess emission around young stars as a function of stellar age is a powerful probe of the dust disk lifetimes. Such observations reveal a large diversity in the lifetimes of optically thick dust disks ranging from less than 1 Myr to 8–10 Myr with a typical disk lifetime of 3–5 Myr. Detailed comparisons of the disk lifetime distribution to evidence of fine dust in the young solar nebula suggest that *if* the CAI formation occurred in less than 1 Myr from the protostellar collapse then the lifetime of the Solar System's dust disk was typical [3].

Dust Composition and Properties: High-resolution scattered light imagery with the Hubble Space Telescope and with large ground-based telescopes allow us to constrain the sub–micron-sized grain size distribution in the surface layers of the disks. These measurements demonstrate that the small dust grain population persist for several Myr in some disks, but also often accompanied by micrion–sized or larger grains. Mid-infrared spectroscopy, in particular with the sensitive Spitzer Space Telescope, can probe somewhat deeper in the disk and can measure the precise shape of the 10 micron silicate emission feature. The exact shape of this solid-state band is defined by the combination of the lattice structure, chemical composition, and the size distribution of the silicate grains. Spitzer observations revealed the presence of various amorphous and crystalline silicate species and found a remarkably similarity to the silicate dust observed in the comae of Solar System comets.

Widespread Thermal Processing: One of the most exciting findings of the Spitzer Space Telescope is the widespread presence of crystalline silicates in the 100–200 K regions of protoplanetary disks. The characterisitic crystalline peaks have been identified around stars of various ages [4,5], with very different accretions rates and with very diverse spectral types [6,7]. At some point during their history these fine grains must have been exposed to temperatures in excess of 900 K. The presence of crystals in the warm (100-200 K) disk regions suggests either efficient radial and vertical mixing in the disks [8,9] or powerful in-situ thermal processing, such as shock heating [10]. These high–temperature events may resemble some of the conditions and events that were characteristic to the inner young Solar System. The fact that crystalline silicates are very frequent components of the protoplanetary dust suggests that protoplanetary disks are much more violent and dynamic than current astronomical models predict [11].

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