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Mixing in Protoplanetary Disks: The Astronomical Evidence

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The processing and mixing of pre-planetary matter in protoplanetary disks have fundamental impact on the chemical composition and volatile budget of the emerging planetary systems. Studies of primitive materials from the early Solar System, including chondritic components and interplanetary dust particles as well as Stardust samples, revealed a complex interplay of thermal processing and large-scale mixing that took place in the first few million years. With the rapid progress made toward understanding the events that unfolded around the young Sun, the question emerges : how does the early Solar System history compare to the evolution of disks around other stars?

In this talk I will review the key lines of astronomical evidence on the overall evolution and properties of disks around other stars that provide potential analogs to the young Solar System. These systems represent snapshots of the diverse evolutionary stages and 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. I will discuss astronomical observations of the evolution of gas accretion rates and disk masses over the first 10 Myr. I will also show exciting recent results from the Spitzer Space Telescope on the structural evolution of protoplanetary disks and the presence of thermally processed material, including crystalline silicates, that act as a tracer of mixing in the protoplanetary disks. The widespread presence of these presumably thermally annealed grains in disks around both hot and cool stars suggests that violent heating and processing, as well as radial/vertical mixing, may be common around most young stars.
Finally, I will summarize the astro-physical insights on the processing and radial redistribution of material in the protoplanetary disks gained from astrophysical observations and place these in the context of evidence from the early Solar System.

Keywords: Meteorites, Proto-solar nebula, planets, Planet formation, protoplanetary disks, astronomy