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Extended Abstract

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High spatial observations of protoplanetary disks review

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Protoplanetary disks are the sites of planet formation but how dust particles evolve into planets in the disks and finally form as a planetary system is a long-standing mystery. In this talk, I will review our understanding of protoplanetary disks in an observational viewpoint and show recent NIR and mm/sub-mm observational results in terms of disk demographics, geometrical structures, dust properties, dust trapping and grain growth and polarization. In particular, the disks with holes or gaps with mass transfer seen as a steamer crossing the disk that many researchers have posited as the signpost of planets will be stressed. I will also introduce chemical composition of the disk including pre-biotic organic materials. I will conclude by showing future directions for our study of planet formation and new observational instruments and operations in the coming years that may provide the answer for the key questions.
The disks that orbit young stars are the essential conduits and reservoirs of material for star and planet formation. Their structures, meaning the spatial variations of the disk physical conditions, reflect the underlying mechanisms that drive those formation processes. Observations of the solids and gas in these disks, particularly at high resolution, provide fundamental insights on their mass distributions, dynamical states, and evolutionary behaviors. Over the past decade, rapid developments in these areas have largely been driven by observations with the Atacama Large Millimeter/submillimeter Array (ALMA). This review highlights the state of observational research on disk structures, emphasizing the following three key conclusions that reflect the main branches of the field.
The formation and early evolution of stars and planetary systems are mediated by interactions with their circumstellar material. That material is organized in a flattened disk of gas and solids that orbits the central host star. Although these interactions between stars, planets, and disks are brief (lasting . 10 Myr), they are literally foundational: such mutual influences set some stellar and planetary properties that persist for billions of years. The hallmarks of the processes that govern these links are imprinted on the disk structures, the spatial distributions and physical conditions of the disk material. Detailed observations enable measurements of those structures, their environmental dependencies, and their evolutionary behavior. Coupled with theoretical simulations and complemented by the collective knowledge of stellar populations, exoplanets, and primitive bodies in the solar system, those measurements help map out how disks shape star and planet formation. Disks are also the material reservoirs and birthplaces of planetary systems. The prevalence, formation modes, masses, orbital architectures, and compositions of planets depend intimately on the physical conditions in the disk at their formation sites, the evolution of that disk structure (locally and globally), and the planetary migration driven by dynamical interactions with the disk material. Measurements of the disk mass, its spatial distribution, and its demographic dependences offer crucial boundary conditions for models of planet formation. Combined with the properties observed in the mature exoplanet population, that information can help develop and refine a predictive formation theory, despite the considerable complexity of the associated physical processes. In these and many other ways, disk structures offer profound insights on how the properties of stars and planetary systems are shaped by their origins. This review is focused on the recent landscape of observational constraints on disk structures: how relevant measurements are made, what they suggest about disk properties, and how those properties are connected to star and planet formation. The most valuable measurements employ data with high angular resolution, as the typical nearby ($d \approx 150$ pc) disk subtends . 1 00 on the sky. Most of any given disk is cool enough (< 100 K) that it emits efficiently at (sub-)mm wavelengths. Coupling these small angular sizes and cool temperatures, this review emphasizes radio interferometry as an essential tool. Indeed, progress over the past decade has largely been driven by the commissioning of the transformational ALMA facility. The specific topic of disk substructures has generated immense interest. The many new opportunities for high resolution observations of disks have triggered a marked pivot in the field toward their interpretation. Despite the deluge in the literature, it is worth keeping in mind that assessments of the broader impacts that substructures have on disk evolution and planet formation are still being actively developed. Nevertheless, it is also clear from their prevalence alone that substructures are fundamental aspects of disks: they likely have profound effects on every practical and physical facet of planet formation research. New quantitative insights on key structure parameters are starting to bear fruit, but the intrinsic uncertainties on physical conditions suggest it is important to consider empirical metrics and translate predictions into the data-space. The origins of these substructures are not yet clear: leading contenders include an assortment of fluid instabilities or dynamical interactions with young planets. In any case, the implications are profound, in that (physical and observational) disk properties could be determined by perturbations at very small scales. An appraisal of how the prevalence, morphologies, locations, and scales of disk substructures depend on host properties, global disk characteristics, environment, and especially age could reveal patterns that help contextualize general demographic trends and clarify the mechanics and variety of the processes that generate them.

Bottom Note: *This work is partly presented at 4th International Conference on Astrophysics and Particle Physics,* December 03-05, 2018, Chicago, USA