Circumstellar Disks, Planet Formation, and ALMA

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Abstract

The Atacama Large Millimeter Array (ALMA) interferometer project will being science operations in 2011. With its high angular resolution and sensitive continuum and spectroscopic capabilities from 84-850 GHz, it will dramatically advance our observational understanding of the planet formation process by providing unprecedented measurements of the physical conditions in the birth sites of planets, the gas and dust disks around young stars. I will present an overview of a few key ALMA experiments that can be used to address some fundamental issues related to the structure and evolution of these protoplanetary disks, as well as a new technique that may provide unique, new access to characterize extremely young systems of exoplanets.

1. Overview

Astronomers have discovered hundreds of exoplanets orbiting nearyb stars, and a massive effort is underway to find more of them, determine their key properties, and explain demographic trends with models of their formation. But associating the properties of these exoplanets with their formation epoch can be problematic, since the formation process is intimately tied to the physical conditions and evolution of their birthplaces: the disks of gas and dust around young stars. Beginning this fall, the ALMA project will fundamentally advance the field of planet formation by providing unprecedented high angular resolution and sensitive measurements of circumstellar disks, using their thermal dust continuum and spectral line emission from myriad molecular rotational transition in the ~85-950 GHz frequency range. I will review 2 key issues in the field of planet formation as the pertain to protoplanetary disks:

(1) ***Disk Evolution***: Protoplanetary disks are always changing, due to viscous effects related to magnetic turbulence, photoevaporation, and the sedimentation and growth of solid particles. ALMA will play a revolutionary role in helping to characterize these complicated physical process, thanks to its dual capability of large statistical surveys as well as detailed, high-precision measurements for individual test cases. I will present an overview on direct and indirect techniques to constrain viscous evolution with ALMA observations, and comment on the synergy between ALMA and the upgraded EVLA interferometer in the context of dust growth and planetesimal formation.

(2) ***Young Exoplanets***: Ideally, much more information about the planet formation process can be extracted through a comparison of the mature exoplanet systems (now being discovered with radial velocity and transit surveys) and their younger counterparts that are "caught in the act" of formation, still embedded in their natal disks. The direct detection of a planet orbiting a young star is currently a major challenge. However, some properties of young planets can be inferred indirectly, through their disruptive influence on the structure of the remnant disk material. I will discuss a path toward using ALMA-based radio imaging o disk structures to indirectly infer the masses and orbits of extremely young exoplanets.