

Observational Studies of Protoplanetary Disks: Recent Achievements and Future Prospects

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All sky survey at far-infrared wavelengths conducted by the IRAS in mid 1980's revealed that T Tauri stars commonly show excess emissions at infrared, submillimeter and millimeter wavelengths, leading us to recognize the ubiquitous of protoplanetary disks around young stars. Global physical parameters and the evidence for the decrease in mass accretion rate as they evolve have been obtained by the analyses of the spectral energy distributions (SEDs). Observations at high angular resolution, however, are essential to study the internal structure of these disks, which are less than a few arcseconds in spatial extent. In this talk I introduce recent achievements of high resolution imagings and discuss future prospects of the observational studies of protoplanetary disks with the Atacama Large Millimeter/Submillimeter Array (ALMA).

The first topic of recent achievements is our survey observations of protoplanetary disks with the Nobeyama Millimeter Array (NMA). We made imaging observations of dust continuum emissions at 2 millimeter arising from 13 disks associated with single young stars in Taurus Molecular Clouds: the angular resolution was 1-2 arcseconds, or 140-280 AU. By fitting both the images and SEDs with some disk models, we systematically derived the disk physical parameters including the outer radius and surface density distributions, which cannot be estimated solely by the SED analysis. The most intriguing finding is the evolutionary trend of radial expansion as the mass accretion activity decays. This trend is consistent with the theory of viscous accretion disks. The radial dependence of the surface density distributions, on the other hand, seem shallower than that of the primordial solar nebula assumed in the standard theory (Kyoto model) for the formation of the solar system. The ALMA will achieve 10 milli-arcsecond resolution, allowing us to directly derive the disk physical parameters without employing any disk model.

The second topic is observational studies of gaseous components in the disks. Most observations of gas at millimeter wavelengths before mid 1990's focused on CO, but recent observations have tried to image the emissions from less-abundant species. One of such example is our recent observations of the emission line of H₂CO at 2 millimeter toward the T Tauri star LkCa 15 using the NMA. Using the obtained image we derived its column density distribution, and compared it with some chemical model for disk material. Non-biased line surveys at submillimeter wavelengths have also been made.

The chemical evolution of gas components in a disk should be deeply affected by the UV or X-ray radiations from central stars or neighborhood OB stars, but it is also connected with the physical structure of the disks or the size distribution of dust particles in the disks. Combination of high-sensitivity, high resolution and wide frequency coverage of the ALMA will provide us comprehensive understandings of the chemical evolution of disk materials.

In the rest part of this talk I introduce the recent studies of the Japanese large optical/IR telescope SUBARU, and discuss the importance of comparative studies between the radio and optical/IR observations.