

## Planetary-system formation revealed with ALMA

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I review the current understanding of planetary-system formation that has primarily been obtained from observations of protoplanetary disks, the birthplaces of planets, with the radio astronomical telescope, Atacama Large Millimeter/submillimeter Array (ALMA). High angular resolution is one of the most important observing capabilities to address planetary-system formation, given the spatial scale of the planetary systems including the Solar system (30 au to Neptune), and considering the distance to the nearest star forming regions ( $>100$  pc) where we can observe young planet-forming disks. The resolution of  $\sim 5$  au at least would be necessary to obtain the spatial distribution of disk material (various gas species, dust grains) which are ingredients of planets. ALMA is the interferometer consisting of multiple antennas, providing us the resolution of about 5 au recently. ALMA has provided at least 43 12-m antennas for recent observations, providing also high sensitivity and good image quality.

The ALMA observations have so far shown that (1) rings are common for protoplanetary disk and (2) the diversity in disk structure is still seen including spiral arms and strong non-axisymmetry. Rings and other disk structures often interpreted as the sign of planet-forming activity and these observations have stimulated theoretical study on how planetesimals (km-sized bodies) form and how planet formation proceeds in an entire region of the disk. The detection of various rare molecules including organic ones is another highlight. The emission from such molecules is quite faint and the detections were owing to the ALMA's high sensitivity. Other ALMA results include finding the possible new tool to probe grain growth using polarization, and detections of tenuous gas that may be produced by collisions of cometary or planetary bodies in more evolved debris disks. Those results also give us an insight on the fruitful future in comparative study with the distribution of various material in the Solar system.

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