

Impacts of ALMA observations of protoplanetary disks on planet formation theory

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Recently, high-resolution observations of protoplanetary disks with ALMA reveal that fine structures are formed in the disks. Many protoplanetary disks with non-axisymmetric, spiral, or ring structures have been observed. Since Planets are expected to form in protoplanetary disks, the structures of the disks affect the formation scenario of planetary systems. However, planet formation scenarios in the disks with complicated fine structures have not been well investigated. Therefore, it is important to clarify the relation between planet formation scenario and the fine structures observed in the disks. The investigation of the structures formed in the disks will provide the important clues to understand the planet formation scenario.

One of the most impressive results of ALMA observations of the disks is multiple ring structure formed in a disk around HL Tau. The observation has revealed that many rings are formed in the disk where the radius is larger than about 30 au and that two deep gaps are formed at the radii of 10 au and 30 au. After the observation of HL Tau, some other disks with ring structures have also been observed. However, the formation mechanism of the ring structures is still unknown. One possible mechanism of the ring structure formation is secular gravitational instability (GI), which is gravitational instability caused by friction between gas and dust in the disk. Since secular GI concentrates the dust, planetesimals could be formed in the rings. Thus, we expect that planet formation might be promoted as a result of secular GI. If the ring structure formation by secular GI is realized in the disk, the outer region corresponds to the earlier growth phase of the most unstable mode of secular GI, and the inner region corresponds to the outcome of the non-linear growth of secular GI. Therefore, this interpretation suggests that we are possibly witnessing both the beginning and end of planet formation in HL Tau.

In this talk, I review ALMA observations of protoplanetary disks, and discuss the relation between the observations and planet formation theory. I also explain our work on rings and planets formation by secular GI.

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