Signs on Protoplanetary Disks Created by Planet Fomation Processes

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Planet formation theories predict various observable structures created in protoplanetary disks. It is strongly expected that each high-resolution images of protoplanetary disks obtained by ALMA should give us vital information on building sites of extrasolar planets.
In the early stage of planet formation, dust growth considerably alters temperature and radiation in the disks. It is because dust growth significantly reduces the opacity for radiation. The time scale of dust growth is generally given by several hundreds of the Keplerian period, independently of the disk mass and temperature. In an inner disk region where the Keplerian period is short, dust grains grow quickly whereas their growth is relatively slow in the outer regions. We examined the evolution of disk radiation and temperature due to dust growth, by performing numerical simulations of radiative transfer. The simulations shows that a high-temperature ring-like region is created at the boundary between the inner disk with largely grown dust and the outer disk with primitive small dust. If such a ring region is observed in a protoplanetary disks, we can estimate the age of the disk accurately, using the universal dust growth time.
When a gas giant planet forms in the later stage, on the other side, it create a low-density gap structure along its orbit. We obtained an empirical relation between the planet mass and the gap width from many hydro-dynamical simulations. Hence, from the width of an observed gap, we can estimate the mass of an embedded planet, by using the empirical relation.
Since the degree of progress in planet formation depends on the radial location in disks, both the high-temperature ring region and the gap structure can exist simultaneously in a protoplanetary disk. If such a disk is observed, it enables us to measure the planet mass and age, which gives a crucial constraint on planet formation theories.

Keywords: ALMA, protoplanetary disk, dust, giant planet

