Dust growth and settling in protoplanetary disks and radiative transfer calculations

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Circumstellar disks play important roles on mass accretion toward the central star and planet formation in the subsequent evolutionary phases. At the first step of planet formation, dust particles with the interstellar population, ie. submicron sizes, grow to meter sizes by mutual collision in the gas disk. Meanwhile, the dust particles are condensed toward the disk midplane due to the vertical gravity and a dust dominant layer forms. Planetesimals may form in regions where are fragmented by gravitational instability and the density exceeds the Roche density.

In the past 40 years, this problem has been studied in both theory and observation. The dust and gas motions in protoplanetary disks have been solved by hydrodynamic treatments. Various important parameters such as the particle sizes, the thickness of the dust dominant layer, and their time scales are calculated. However, they depend on the strength of the turbulence in the disks. Although theoretical modeling with given parameters allow to predict the behaviour and properties of the disks precisely, observed data are necessary to determine these physical parameters. In observations, flux excesses or shallow spectral flux indices are obtained in (sub)millimetre wavelength ranges, and low optical depth or even gaps are detected in the inner part of the disks in high-resolution mid-infrared imaging. These results evidence the presence of pebble or boulder sized particles in the protoplanetary disks. On the other hand, little evidence for settling has been reported so far. To better understand the dust growth and settling theory, physical models that can be compared with the observations are necessary.

We have modeled stratified disks of low-mass young stars with and without a dust dominant layer in which the dust growth is also taken into account. For these models, the spectral energy distribution and images are produced by means of radiative transfer calculations. We also discuss the interpretation on the observed data from these model results.