Absorption and scattering of dust particles in millimeter wavelength

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Recent ALMA observations have provided us a lot of information about protoplanetary disks in (sub-)millimeter wavelength. When we interpret results of ALMA observations, absorption and scattering properties of dust particles play an important role. For example, absorption opacity is often used to derive the disk dust mass. In addition, recent studies have shown that scattering can be important even in the millimeter wavelength, and now millimeter-wave scattering is regarded as a mechanism that is responsible for producing millimeter-wave polarization. In this talk, I will review how dust size, structure, and composition affect absorption and scattering properties of dust particles and discuss their impacts on the interpretation of ALMA observations.

First of all, I will talk about how dust structure and composition affect the absorption opacity in the Rayleigh domain. It is known that coagulated dust aggregates in the Rayleigh domain tend to show large absorption opacity compared to that of the mass-equivalent sphere obtained by the Mie theory. This enhanced absorption effect is due to the aggregate structure. In order to estimate the enhanced absorption of coagulated dust aggregates quantitatively, we perform numerical calculations of absorption opacity of dust aggregates, where we take into account higher order of multipole expansion of the electromagnetic field. As a result, it is found that absorption opacity at millimeter wavelength will be enhanced by a factor of two (four) for silicate (amorphous carbon) compared to the opacity of mass-equivalent sphere obtained by the Mie theory. In addition, it is also found that this enhancement becomes large for fluffy dust aggregates compared to compact dust aggregates. Next, I discuss scattering properties of dust particles. Scattering properties of dust particles have been intensively studied in visible and infrared wavelengths. I will summarize some studies about scattering properties of dust particles in visible and infrared wavelengths including our numerical studies, observations of circumstellar disks (protoplanetary disks and debris disks), and laboratory experiments, and discuss potential candidates of particle models that might explain millimeter-wave scattering polarization of protoplanetary disks.

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