Optical properties of fractal dust aggregates

Ryo Tazaki[1,2], Satoshi Okuzumi[2], Akimasa Kataoka[2], Hidekazu Tanaka[3] and Hideko Nomura[2]

[1]*Kyoto University,* [2]*Tokyo Institute of Technology,* [3] *Institute of Low Temperature Science, Hokkaido University*

Recent theoretical studies suggested the presence of highly porous dust aggregates in protoplanetary disks. Since optical properties of the aggregates is not completely understood, it is important to investigate how the fractal dust aggregates absorbs and scatters the lights. We calculated optical properties of fractal dust aggregates by using the rigorous method, T-Matrix Method, and compared the results with that obtained by using Rayleigh-Gans-Debye (RGD) theory and Effective medium theory (EMT). The dust model we used in the calculation is the Ballistic-Cluster-Cluster-Aggregates so that the fractal dimension of the aggregates is $D_f \sim 2$.

Firstly, we show that the angle dependent properties such as phase function and polarization obtained by using T-Matrix method can be well reproduced by using the RGD-theory. Since the aggregates has fractal dimension $D_f \sim 2$, the effect of multiple scattering can be neglected and it certainly satisfies the assumption of the RGD-Theory. We also show that the EMT fails to reproduce the phase function by an order of magnitude even if the wavelength is longer than the monomer radius, or $\lambda > 2\pi r_m$ where r_m is a radius of monomer. The phase function calculated by the EMT deviates from rigorous results when $\lambda < 2\pi r_g$ where r_g is a radius of gyration which gives a typical scale of the aggregates. Since the EMT assumes the sphere with the radius of gyration and the effective refractive index, the phase function is characterized by so-called Porod's law so that it's angular dependence is completely different from that of fractal aggregates. Secondly, we show that the angle integrated properties such as absorption and scattering cross-section can be well reproduced by both the RGD-Theory and the EMT when the wavelength is longer than the monomer radius. However, the EMT results deviates from rigorous results where the monomer's optical properties deviates from Rayleigh limit, such that $\lambda < 2\pi r_m$. However, the RGD-theory gives relatively good agreement with the rigorous results compared to the EMT at such wavelength domain. As a results, we conclude that the RGD-theory is a powerful method for calculating the fractal aggregates with $D_f \sim 2$ and it is quite easy to use than cost numerical methods.