Opacity of Fluffy Dust Aggregates

KATAOKA, Akimasa
(SOKENDAI/NAOJ)

OKUZUMI, Satoshi
(Tokyo Institute of Technology)

TANAKA, Hidekazu
(Hokkaido University)

NOMURA, Hideko
(Tokyo Institute of Technology)

Planetesimals are believed to form by coagulation of dust grains in protoplanetary disks [1]. How micron-sized dust grains grow to kilometer-sized planetesimals has been an unsolved problem toward the complete planet formation theory; the intermediate-sized bodies have been believed to be poorly sticky, easily disrupted by collisions, or to quickly fall onto the central star.

On the other hand, observations on protoplanetary disks have put a constraints on planet formation theory. The sub-mm emission of the disk carries information of dust grains in protoplanetary disks because the emission is believed to be optically thin and thus it directly reflects the opacity of dust grains. In addition to SMA or CARMA, the launch of ALMA enables us to investigate even the spatial distribution of dust grains in protoplanetary disks. The proposed planetesimal formation theory should be tested by observations.

The recent study has shown that dust grains coagulate in protoplanetary disks to form fluffy aggregates. Theoretical studies have shown that the internal density of dust aggregates is expected to be as small as $10^{-4}\,\mathrm{g\,cm^{-3}}$ [2]. Disk observations, on the other hand, are interpreted as the emission from compact grains. The emission may come from fluffy aggregates. Therefore, the previous observations should be reinterpreted with highly porous aggregates instead of compact grains. As a first step, in this paper, we investigate the optical properties of such highly porous aggregates.

Figure 1 shows the main result of the paper [3]. If the dust aggregates have a radius a and the filling factor f, the absorption opacity $\kappa_{\rm abs}$ does not change if the product af has a constant value. Figure 1 shows the case of af = 1 mm (see the paper [3] for physical understanding).

This result suggests that the sub-mm emission of protoplanetary disks might not be from millimeter-sized compact grains but from fluffy dust aggregates that have 10 meter in size and 10^{-4} in filling factor. We also proposed a way to distinguish between compact grains and porous dust aggregates with spatial distribution of spectral index of the sub-mm emission of protoplanetary disks. It requires a high spatial resolution and a high sensitivity, which is achievable with ALMA. In near future, therefore, ALMA observations is expected to reveal whether there are fluffy dust aggregates in protoplanetary disks.

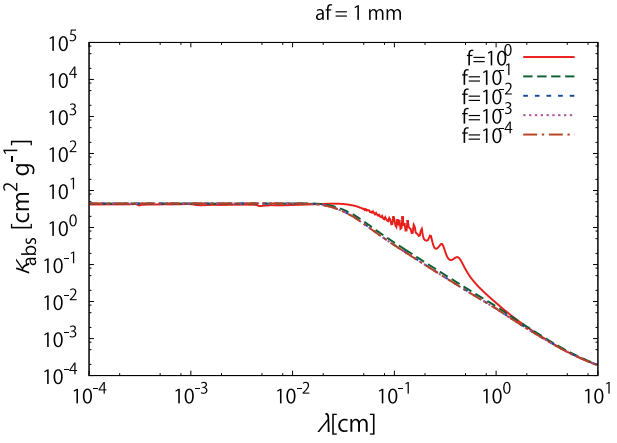

Figure 1: This figure represents $\kappa_{\rm abs}\,[\mathrm{cm^2\,g^{-1}}]$ in the case of af = 1 mm. Each line shows the cases of the filling factor of f = 1, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}.

References

[1] Hayashi, C.: 1981, *Prog. Theoret. Phys. Suppl.*, **70**, 35.
[2] Kataoka, A., Tanaka, H., Okuzumi, S., Wada, K.: 2013, *A&A*, **557**, L4.
[3] Kataoka, A., Okuzumi, S., Tanaka, H., Nomura, H.: 2014, *A&A*, **568**, A42.