UV irradiation and organic synthesis on growing dust particles in protoplanetary disks

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Organic-mantled dust particles are commonly found in interplanetary dust particles. Organics have high stickiness in warm environments where they become soft. In warm regions of protoplanetary disks, aggregates of organic-mantled particles may avoid fragmentation at high-speed collisions and grow directly into planetesimals (Kouchi et al. 2002; Homma et al. 2019).

However, it is still unclear how organic mantles can form on dust grains in protoplanetary disks. One possible scenario is that they form by UV irradiation and subsequent heating of volatile ices on the grains. Ciesla & Sandford (2012) show that volatiles in small icy dust particles can be transformed into some radicals by interstellar UV in the outer part of disks. They suggest that the radicals may form organic matter when the icy particles migrate to the inner part of the disks and experience heating. However, Ciesla & Sandford (2012) determine UV-flux ignoring the evolution of distribution, the growth and the fragmentation of dust particles that are dominant components determining UV-flux.

The purpose of this study is to reveal the effects of the evolution of distribution, the growth and the fragmentation of dust aggregates on the UV-absorption of ice dust aggregates. We simulate the growth, vertical transport, and UV absorption of icy aggregates in a protoplanetary disk. We assume interstellar UV radiation near the disk surface and count the number of UV photons absorbed by ice on individual aggregates. We take into account the exchange of UV-absorbed ice between colliding aggregates, a key process that delivers UV-absorbed ice to large aggregates lying near the disk midplane. Based on the results of previous laboratory experiments, we convert the amount of absorbed UV photons into the amount of organics that would form after the aggregates are transported into inner disk regions and experience heating.

We find that UV-absorbed ice is delivered to large aggregates through the cycle of the production, vertical mixing, and reaccretion of small grains. The small grains, which are produced by high-speed collisions of large aggregates, are efficiently transported to the disk surface by turbulent diffusion and receive UV radiation there. These UV-irradiated grains are then incorporated into larger aggregates through collisions. Incorporation of UV-irradiated ice into large aggregates is important because large aggregates generally migrate toward the central star by gas drag (Adachi et al. 1976) and will thereby naturally experience heating that may lead to organic synthesis. We discuss the possibility that aggregates of organic-mantled grains forming this way directly grow into rocky planetesimals in the warm inner region of protoplanetary disks.

Keywords: planet formation, dust , organic synthesis

