Measurements of the density of dust clusters forming in a granular stream using flash X-ray

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For highly sticky icy dust, planetesimals could form by sticking during collision [1]; however, for silicate dust which has much lower stickiness than icy dust, bouncing was observed during collision and limits growth to millimeter-to-centimeter size in the laboratory [e.g., 2]. Nevertheless, numerical simulations have shown that bouncing never occurs in the situation of a protoplanetary disc and that bouncing can occur only if the coordination number of the dust aggregate is greater than 6 [3].

It has been shown that clusters form in a free-falling stream of particles of hundreds micron in diameter under atmospheric pressure and reduced pressure due to inter-particle force, i.e., stickiness of particles [4, 5, 6]. Such clusters may be useful to understand the collisional process of dust aggregates in proto-planetary discs. However, the bulk density and the coordination number of these clusters were experimentally unknown. In order to obtain an estimation of the average coordination number based on the averaged density of the clusters, we conducted flash X-ray imaging of the clusters.

The measurements were conducted by streaming spherical 45 or 53-μm glass beads, irregularly shaped 45-μm glass powder, or 70-μm quartz sand from a funnel within a vacuum chamber installed at ISAS/JAXA and imaging by flash X-ray at five heights under reduced pressure (0.1 atm). When we obtain the X-ray adsorption amount of a cluster or a stream and the length of absorption path, we can estimate the average filling factor.

As a result of the estimates of the average filling factor of the clusters, we found that the clusters consisting of spherical 45 or 53-μm glass beads had a filling factor of roughly 0.3–0.4 and that the clusters consisting of irregularly shaped 45-μm glass powder or 70-μm quartz sand had a filling factor of roughly 0.15–0.3. Next, we considered the average coordination number of the clusters based on the estimates of the average filling factor. Using the relationship between the average coordination number and the filling factor of the dust aggregates in numerical studies of collisional growth of dust aggregates [3], the average coordination number of the clusters consisting of spherical glass beads whose filling factor was 0.3–0.4 could be roughly 3–6. Similarly, we derived an average coordination number of 2–5 for the irregularly shaped particles with a filling factor of 0.15–0.3. These coordination number values of 2–6 are not greater than the coordination number at which numerical studies found bouncing therefore, when such clusters forming in a granular stream collide, they may grow by collision without bouncing.

References

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