GRANULAR MATTER

Charges dropped

Granular charging can create some spectacular interactions, but gravity obscures our ability to observe and understand them. A neat desktop experiment circumvents this problem, shining a light on granular clustering — and perhaps even planet formation.

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Nearly 2,600 years ago, Thales of Miletus noticed that amber rubbed against wool attracted straw — an effect that must have seemed quite mystical at the time. It is perhaps no coincidence then that the term electricity originates from the Greek word for amber. The electrostatic forces between charged dielectric materials have continued to capture our attention since the time of the ancient Greeks. And now, writing in *Nature Physics*, Victor Lee and colleagues[1] have found a way of better understanding these forces without the confounding effects of gravity.

Lee *et al.*[1] studied the behaviour of a free-falling stream of submillimetre-sized zirconium dioxide–silicate grains using a three-metre-tall 'desktop' drop-tower. A high-speed camera fell with the near-spherical grains, capturing their descent between mutual, partly inelastic collisions. Their paths along fractions of cone sections (ellipses, parabola and hyperbola) pointed to an electrostatic charging due to grain–grain contacts prior to their free fall.

This type of charging among same-material bodies — tribocharging, as it's known — is itself still poorly understood[2,3]. It can cause unpredictable hazards like explosions in grain- or coal-processing facilities and is thought to be responsible for producing natural spectacles like the immense lightning occurring during sandstorms or volcanic eruptions. Even more exciting, it may also play a crucial role in planet formation.

The observation alone would have constituted an experimental feat — an intriguing analogue to celestial gravitational dynamics. But the authors went a step further[1]. They studied the grains' tendency to cluster due to mutual collisions, including electrostatic forces, as well as their dissolution in response to more energetic impacts. They were able to dynamically identify different energetic states of a large aggregate in accordance with theoretical predictions[4].

The work required to separate a constituent from a cluster was also measured, and shown to be orders of magnitude larger than that caused by mere surface cohesive forces, which are usually considered responsible for cluster formation. Lee *et al.*[1] determined that the difference in the binding energies was caused by the mutual electrostatic potential, a finding that might have far-reaching consequences for our understanding of the early phases of planet formation. If tribocharging were important in protoplanetary discs (Fig. 1), these results indicate that a rapid growth of solids in the size range from submicrometres up to metres could be expected, supporting astrophysical observations[5].

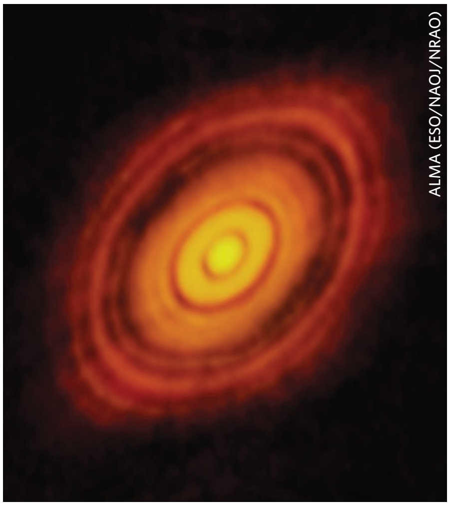

Figure 1 | An image of a protoplanetary disk around the young (about a million-year-old) star HL Tau taken by the Atacama Large Millimeter/submillimeter Array (ALMA). This is the first snapshot of a 'nursery' of planets showing concentric gaps that strongly point to the existence of protoplanets. This observation confirms the quick formation of planetary embryos — putting theoreticians under pressure to explain this rapid evolution.

So far it has been difficult to explain the formation of planetesimals — the kilometre-sized building blocks of planetary embryos. The process is expected to have been completed within a few million years (a relatively short planetogonic period) after the formation of the solar nebula[5]. But this in itself poses a problem: whereas submicrometre particles tend to stick together in collisions, this tendency vanishes following their growth to millimetre- or centimetre-sized aggregates if cohesive contacts are considered glue among the constituents. This slows down the growth processes considerably. Streaming hydrodynamic instability[6] of the gas in a protoplanetary disk has been thought to provide an alternative to concentrate the entrained condensates so that the collective self-gravity can take over in forming planetesimals quickly. Electrostatic interactions among the solid constituents could additionally contribute to a considerable amplification of the growth processes.

Similar experiments were carried out by René Weidling and Jürgen Blum[7] using the drop-tower facility in Bremen almost concurrently with the work of Lee *et al.*[1]. The conditions in the two experiment chambers were quite similar and the size of the solids were also comparable. But Weidling and Blum[7] used aggregates comprising submicrometre-sized particles. And surprisingly, they came to the almost opposite conclusion that electrical charges have a negligible effect.

This seeming contradiction is exciting: two carefully prepared experiments addressing a familiar scientific question — on the growth from dust to planetesimals, a key aspect of the theory of planet formation — have yielded different conclusions. Could a better understanding of the tribocharging process provide a clue to solve this conundrum?

We think that these differing results open a new avenue to address the planetogonic question as to whether tribocharging can play a role for the planetesimal growth in protoplanetary discs. To answer this, one might think of combining the experiences of both teams to carry out experiments with submillimetre aggregates instead of spheres. At the same time, one should combine theoretical scaling analyses along with corresponding experimental studies to find out whether the results obtained by Lee *et al.*[1] can be scaled to different constituent sizes. ❐

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