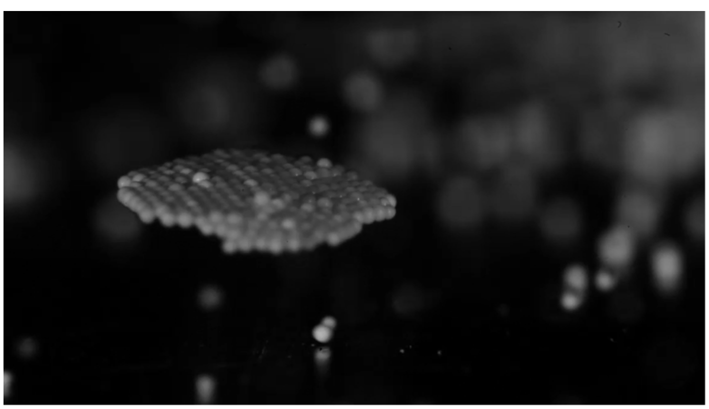
Floating Particle Clump Mimics Asteroids and Nuclei

A disk of plastic particles levitated by sound waves could provide a model for other examples of particle clumps in the physical world.

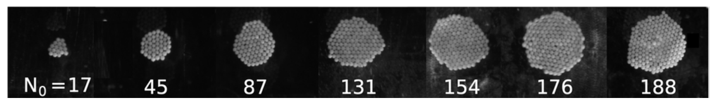
By **Mark Buchanan**

The rapid spinning of an object such as a black hole, asteroid, or atomic nucleus causes its shape to become distorted and can even cause it to be torn apart. Now researchers have devised a way to study this process using a spinning collection of tiny, levitated plastic particles [**1**]. These particle clumps offer a means to probe rotational distortion under a wide range of conditions.

The shape of a spinning object is generally determined by a balance between the cohesive forces that hold it together and the centrifugal forces that tend to pull it apart. To understand the resulting shapes, researchers need model systems able to mimic these effects.



Under the influence of sound waves, plastic particles gradually rise and assemble into a rotating clump. (Particle diameter is about 190 micrometers; video slowed down up by 100 times.)
Credit: M. X. Lim *et al.* [**1**]

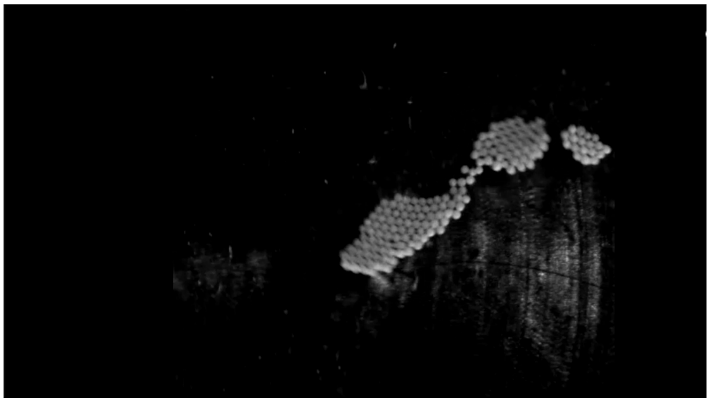


Well-rounded clumps. Acoustically levitated particles arrange themselves into an ordered lattice, and the single-layer clump remains roughly circular as it grows. (N_0 is the number of particles in the clump.)
Credit: M. X. Lim *et al.* [**1**]

Experiments with spinning liquid droplets have provided information on the case where the constituent particles (molecules) are numerous and extremely small compared with the composite object, a regime known as the continuum limit. Such experiments have helped researcher develop models for rotational distortions applicable to these systems. In other collective spinning systems, however, the number of constituent particles may be smaller and the particles relatively larger, such as an atomic nucleus made of a few dozen protons and neutrons. How spinning causes deformation in such "granular" systems is less well understood.

To probe such objects, Heinrich Jaeger of the University of Chicago and colleagues experimented with collections of plastic particles, each less than one millimeter in diameter. Using an audio speaker inside a transparent box, they set up stationary (standing) waves of sound with an amplitude minimum at a fixed height. The spheres levitated stably in a single layer located at the amplitude minimum.

The researchers also exploited two other effects of the sound waves. First, scattering of waves from the particles created a



After reaching sufficient rotation speed, the clump abruptly distorts into an ellipse. Eventually, rotation tears the clump apart, but the pieces later reconnect. (Video slowed down by 60 times.)
Credit: M. X. Lim *et al.* [**1**]

weak attraction between them, causing them to clump together. Second, with a suitable choice of the sound frequency, the field imparted a rotational force on the clump of particles, making it spin at a speed that the experimenters could choose. In this way, the team could create two-dimensional clumps of spheres, spin them up to high speeds, and observe the resulting shape distortions.

“This system lets us study the response of a cohesive particulate material as it spins,” says Chicago team member Melody Lim. “We can look inside the material in close detail and see its shape change.”

The researchers observed changes with increasing spinning speed. As their videos show, at low speeds, the spheres rest in a geometrically ordered structure, much like the atoms in a crystal, with the entire clump being roughly circular. At higher speeds, centrifugal forces distort the circular clump into an ellipse, while introducing some disorder into the “crystalline” structure. At sufficiently high speeds, the single clump breaks apart into smaller fragments, which eventually reunite into a single circular clump.

This final process, says Lim, is akin to surface tension merging a pair of liquid drops. In some respects, however, the clumps behave differently than water, a fact that became clear when the team studied clumps of different sizes. They found that the effective surface tension increases for larger clumps.

“Surprisingly,” says Lim, “this is not like ordinary liquids. A cup of water should have the same surface tension as a bucket of water,” since it reflects the forces of attraction between water molecules. The team doesn’t yet understand the origin of this unusual behavior, but most likely, it comes from details of the interactions between the spheres and the acoustic field.

However, this unusual feature may make the granular clumps similar to other objects of interest, such as asteroids bound together by gravity. For asteroids, the cohesive forces holding the pieces together grow larger with increasing size of the object. As a result, Lim suggests, these granular clumps could model “rubble-pile asteroids”—gravitationally bound aggregates of granular material some hundreds of meters to kilometers in diameter. Solar radiation can spin these asteroids, which distorts their shapes.

“This is a really nice experimental platform,” says materials physicist Karen Daniels, of North Carolina State University in Raleigh. “Many different aspects can be controlled independently, including the particle size, shape, and material.” She says that the experiment offers a new way to explore granular dynamics in a regime closer to astrophysical conditions without having to resort to expensive research on the space station or aboard aircraft in parabolic flights. “This platform really opens new doors,” Daniels says.

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REFERENCES

1. M. X. Lim *et al.*, “Mechanical properties of acoustically levitated granular rafts,” **Phys. Rev. X 12, 021017 (2022).**