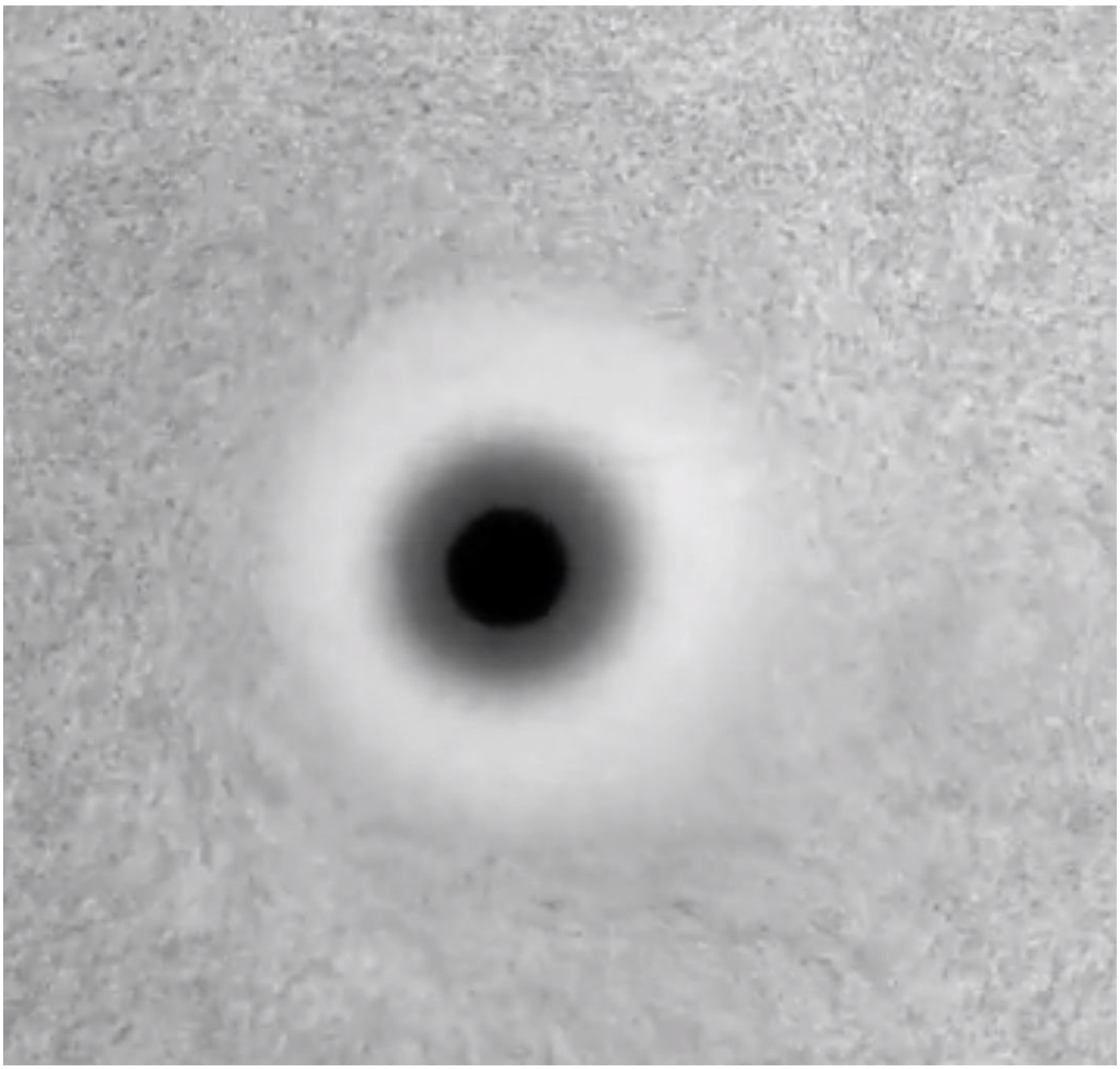
Nova-like explosion of spinning live bacteria explained

April 6 2018, by A'ndrea Elyse Messer



Suspensions of live bacteria in a viscous liquid do not act as expected when spun at certain speeds and now a team of researchers know why the bacterial aggregation appears to explode when the spinning stops.

"We looked at the aggregation and manipulation of active matter—live bacteria or artificial microswimmers—and the depletion area surrounding them when droplets of bacteria are spun," said Igor Aronson, Huck Chair Professor of Biomedical Engineering, Chemistry and Mathematics, Penn State. "We were trying to understand how the depletion ring formed, but instead found that at higher speeds, when the spinning stopped, the aggregated bacteria explode like a nova."

The researchers placed a droplet containing mixtures of a viscous fluid and bacteria on a slide and dropped a tiny particle of nickel onto the droplet. Then the slide was turned over and the particle settled to the bottom of the drop. A spinning magnetic field created by four coils spins the particle. The spinning caused the bacteria to clump together around and under the spinning nickel particle. It also created a depletion ring around the bacteria where few if any bacteria were found. The spinning bacterial cluster and the depletion ring were visible.

Previous research used a liquid with fewer bacteria and spun the magnet at only 2 to 20 Hertz. To investigate the depletion ring, the researchers used 100 times more bacteria and spun the magnet at 100 to 400 Hertz. The system with these new parameters exhibited unusual and unexpected behavior, the researchers reported in a recent issue of *Nature Communications*. This behavior is only seen in active materials—live bacteria or their synthetic analogs.

This behavior, while interesting in itself, might have implications for rotating equipment in environments where biofilms easily form. "We often think that if something spins really fast there will be no bacterial film because the bacteria can't settle," said Aronson. "But this isn't true. This kind of bacterial accretion could be worse on spinning parts."

Another possible implication of this phenomenon might be in new diagnostic techniques to extract a few bacteria from suspensions.

Using both experiments and modeling, the researchers discovered that when the spinning nickel particle causes the bacteria to aggregate to a high enough density, other things are happening as well that cause what appears to be an explosion when the spinning stops.

"We did an analysis and found that if the accretion disk were perfectly round, it would just expand when the spinning stopped," said Aronson. "But because it is not perfect, the imperfect area gets propagated faster and it moves away from the center more rapidly. This makes the bacterial clump unstable and it appears to explode."

When bacteria are spinning they become orderly, arranging themselves in parallel streams. Although when looking down at what appears to be a dense disk of bacteria, the fluid motion itself is more complex. It flows out at the equator and in at the poles. Because the nickel particle that is causing the spinning is resting at the bottom of the liquid droplet that is a barrier, and the bacterial disk is rotating adjacent to the droplet surface, a stagnation zone forms. Once the spinning stops, the stagnation zone disappears and imperfections in the surface of the disk cause the rapid, non-uniform movement of bacteria away from the origin of rotation.

The researchers used mathematical models and a variety of experimental markers to see the behavior of the bacteria, including tomography and florescence. The model agreed with the experimental data.

"The behavior of these bacteria look like the explosion of a star going nova," said Aronson. "Of course, when a supernova explodes, the physics is very different."

Provided by Pennsylvania State University

Citation: Nova-like explosion of spinning live bacteria explained (2018, April 6) retrieved 13 May 2024 from https://phys.org/news/2018-04-nova-like-explosion-bacteria.html

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