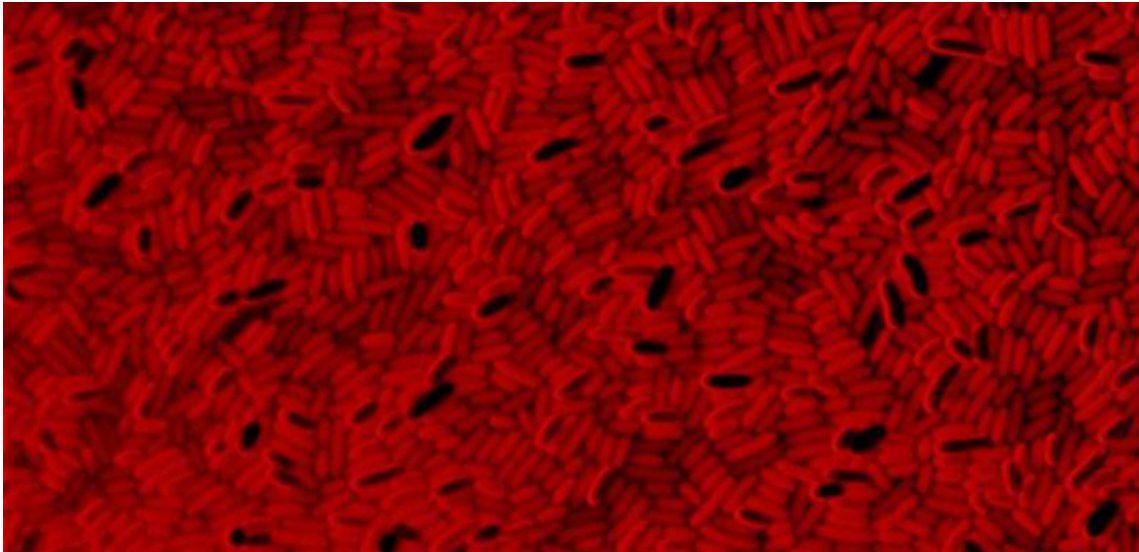


# Turbulence in bacterial cultures

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Collective motion in a bacterial suspension. Credit: Madeleine Opitz

Turbulent flows surround us, from complex cloud formations to rapidly flowing rivers. Populations of motile bacteria in liquid media can also exhibit patterns of collective motion that resemble turbulent flows, provided the cell density is sufficiently high. In a new study carried out by Dr. Vasil Bratanov (MPI for Plasma Physics, Garching), Professor Frank Jenko (University of California, Los Angeles) and Professor Erwin Frey, who holds the Chair of Biological and Statistical Physics at Ludwig Maximilian University, the fluid mechanics of such systems is investigated, and it is demonstrated that they exhibit a novel class of turbulent flows which is characterized by a high degree of self-organization. The results appear in the journal *Proceedings of the*

*National Academy of Sciences.*

Turbulence is a fundamental phenomenon in nature that arises in a wide variety of contexts and on an immense range of spatial scales. Strikingly, a full theoretical description has so far eluded physicists and mathematicians, and the search for a comprehensive understanding remains one of the most challenging tasks in modern physics. One basic parameter that signals the onset of turbulent flow is the Reynolds number, which describes the relationship between inertia and viscosity in the system. "Turbulence normally develops in systems with high Reynolds numbers," Frey explains. "Bacterial suspensions have very low Reynolds numbers, but they nevertheless exhibit swirling patterns that are very similar to typical turbulent flows.

## **Active motion is the key**

It turns out that the key to this conundrum lies in the fact that the bacteria are capable of self-propulsion: The cells actively swim through the medium with the help of helical filaments called flagella which are rotated by molecular motors located within the cell and driven by metabolic energy. "This internal propulsion unit is what makes the difference," says Frey. "It is responsible for inducing a new class of turbulence, in which the injection of energy occurs at the level of the individual particles in the suspension," he explains. Normal turbulence, in contrast, ensues when energy is injected into the system on a large scale and then transferred to ever smaller scales in a cascade-like process. This is the case, for example, when winds blow over a large area of ocean surface and produce a succession of – comparatively small-scale – waves.

Such classical instances of turbulence can be described mathematically by means of the so-called Navier-Stokes equation. But this approach, as it turns out, does not work for the kind of turbulence observed in active

fluids like the suspensions of [motile bacteria](#) studied by Frey and his colleagues. In this case, the biological properties of the bacteria, which modulate the power of the internal propulsion unit, come into play.

"This novel system is much richer than the classical concept, because the instability introduced by the self-propelling nature of the particles must be accounted for in the mathematical description of the dynamics," Frey points out. The three researchers have now demonstrated that a suitably extended version of the Navier-Stokes equation, which provides an adequate description of the streams that form in bacterial suspensions, leads to novel states of [turbulence](#). "The method we have developed is applicable to many kinds of systems that are characterized by the fact that the individual particles are self-propelled," says Frey. "Thus, this breakthrough can make a decisive contribution to our understanding of the physics of active systems."

**More information:** Vasil Bratanov et al. New class of turbulence in active fluids, *Proceedings of the National Academy of Sciences* (2015). DOI: [10.1073/pnas.1509304112](https://doi.org/10.1073/pnas.1509304112)

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