Giant vortex dynamics in confined bacterial turbulence

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We present the results of numerical simulations of the Toner-Tu-Swift-Hohenberg model[1,2] for the dynamics of dense bacterial suspensions confined in two-dimensional circular domains with no-slip boundary conditions. In the absence of confinement, the collective motion of the swimmers develops a turbulent-like regime characterized by the chaotic motion of several large-scale vortices.

Here, we show that the geometrical confinement induces the transition from the turbulent regime to a stable, ordered state in which the angular momentum symmetry is broken[3]. This is achieved by self-organization of the chaotic flow into a single, giant vortex of the size of the domain, surrounded by an annular region of small-scale, radial vorticity streaks (Fig. 1a). We derive a simple analytical prediction for the average radial velocity profile of the giant vortex, which is in agreement with the numerical findings.

The process of formation of the giant vortex has a stochastic nature which manifests in an extreme variability of the transition times τ_t from the initial turbulent regime to the single-vortex state. By comparing numerical simulations with identical parameters and different initial conditions, we find that the probability distribution function of τ_t displays a broad tail which spans over almost two order magnitude (Fig. 1b).

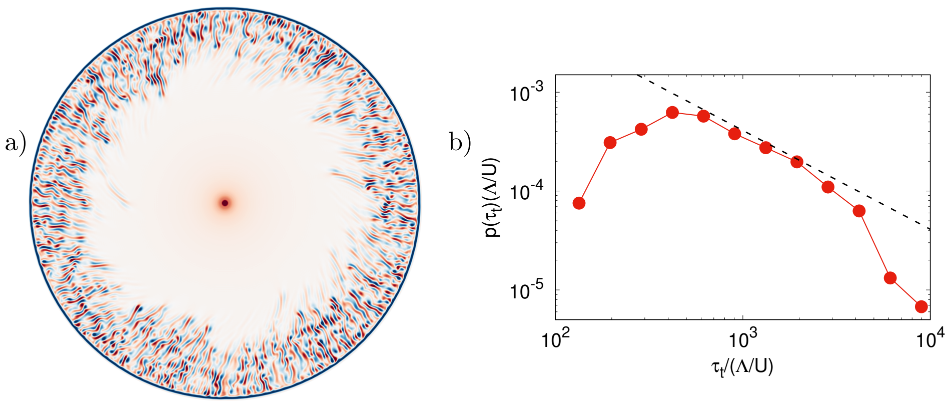

Figure 1: (a) Vorticity field in the giant-vortex regime. (b) Probability density function of the transition times τ_t. The dashed line is the scaling law τ_t^{-1}.

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[2]Dunkel J., et al., *Phys. Rev. Lett.* **110**, 228102 (2013).
[3]Puggioni L., et al., *Phys. Rev. E* **106**, 055103 (2022).