Transition to universality and Lagrangian anomalies in active turbulence

- Siddhartha Mukherjee

Abstract: Active turbulence, a complex organization of matter driven at the scale of its constituent agents, is confounding. Particularly, analogies with high Reynolds number, inertial (Kolmogorov) turbulence have not survived beyond the qualitative. The lack of scale separation in low-Reynolds active flows breaks away from the familiar notions of the energy cascade and approximate scale-invariance of inertial turbulence. So do experimental studies hinting that active turbulence can manifest anomalous diffusion, while inertial turbulence does not surpass classical diffusion. Now, using a continuum hydrodynamic model for active (bacterial) turbulence we show that, beyond a critical level of activity, the flow transitions to a universal state that is intermittent, maximally chaotic and intriguingly manifests a host of Lagrangian anomalies. This makes the phenomenology of active turbulence rich and riddled with surprising nuances, which at times bridge the analogy with inertial turbulence, and at others break them. Broad-brushed parallels, therefore, obfuscate what may be biologically relevant strategies for survival and growth.

Fig. Tracer trajectories in active turbulence

References:

[1] S. Mukherjee, R.K. Singh, M. James, S.S. Ray, “Intermittency, fluctuations and maximal chaos in an emergent universal state of active turbulence”, *arXiv*:2207.12227 (2022)

[2] R.K. Singh, S. Mukherjee, S.S. Ray, “Lagrangian manifestation of anomalies in active turbulence”, *Physical Review Fluids* 7 (3), 033101 (2022)

[3] S. Mukherjee, R.K. Singh, M. James, S.S. Ray, “Anomalous Diffusion and Lévy Walks Distinguish Active from Inertial Turbulence”, *Physical Review Letters* 127 (11), 118001 (2021)