Kolmogorovian active turbulence of a sparse assembly of interacting Marangoni surfers

Romain Volk*[1], Mickaël Bourgoin[2], Florence Raynal[3], Cécile Cottin-Bizonee[4], and Christophe Ybert[4]

[1]Laboratoire de Physique de l'ENS Lyon – CNRS : UMR5672, École Normale Supérieure (ENS) - Lyon – France

[2]Laboratoire de Physique de l'ENS Lyon – Laboratoire de Physique de l'ENS de Lyon – France

[3]Laboratoire de Mécanique des Fludies et d'Acoustique (LMFA) – Ecole Centrale de Lyon – France

[4]Institut Lumière-Matière (ILM) – Université Claude Bernard - Lyon I – France

Abstract

Active living organisms, such as bacterial suspension, birds, fishes, etc., tend to self-organize (in swarms, schools, flocks, etc.) and to develop coherent collective motion, with important consequences in terms for instance of nutrient finding strategies or protection against predators. Such systems are intrinsically out of equilibrium as energy is constantly injected at the scale of the particles, and tend to exhibit fluctuations which are hard to model. The emergence of large scale motions with energy injected at small scale underlies the existence of multi-scale coupling mechanisms and correlations driven by inter-entities interactions. Such a scenario, with multi-scale interactions, resonates with the classical picture of the turbulent energy cascade in which energy is injected at large scale and dissipated at small scale, resulting in a kinetic energy spectrum following a power law with exponent -5/3. Here we examine possible connections between an experimental active system and fluid turbulence by investigating the dynamics of abiotic active matter (avoiding biological specificities), made of self-propelled camphor swimmers, in the light of classical statistical indicators (both from the Eulerian and Lagrangian points of view).

The system is composed of an ensemble of agar gel disks loaded with camphor, which are floating on a water surface while confined in a container. When individually deposited at an air-water interface, the disks self-propel by Marangoni effect arising from the camphor spreading at the interface, and have a collective dynamics which depends on the number of swimmers.

Here we track the particles for a very long time using a camera operating at 30 Hz, so that their dynamics is fully resolved and their velocity and acceleration is computed by differentiation along particle trajectories. In agreement with previous observations, we find a transition between a continuous swim configuration for dilute systems and a denser regime with pseudo-periodic burst of high activity. Here we report results obtained in the moderatelly dense regime in which the dynamics of the particles are correlated, with a high level of fluctuations, but without any coherent motion nor large scale organization. In this regime, we observe the particles explore the water surface homogeneously while having a turbulent-like dynamics both in the Lagrangian and in the Eulerian framework. In particular, the second order velocity structure function of the particle pairs, $S_2(r)=\langle((\vec{v}(\vec{X}_j(t)) - -\vec{v}(\vec{X}_j(t))\cdot\vec{r}_{ij}/r_{ij})\rangle$ ($\vec{r}_{ij}=\vec{X}_i-\vec{X}_j$), wefindthatthisquantityincreasesasapowerlaw $S_2(r)\propto r^{2/3}$ whichisreminiscentof3Dturbulence, andcor

*Speaker

Keywords: Active system, Turbulence, Active Turbulence