Abstract Submitted
for the DFD20 Meeting of
The American Physical Society

Density fluctuations and collective motions of three-dimensional bacterial suspensions ZHENGYANG LIU, WEI ZENG, XIAOLEI MA, XIANG CHENG, University of Minnesota — Active fluids such as bacterial suspensions exhibit unusual large density fluctuations, the so-called giant number fluctuations, defying the conventional wisdom on the density fluctuations of equilibrium systems. While theoretical studies have predicted a non-trivial dependence of density fluctuations on the dimensionality of systems, the fluctuations have only been examined experimentally in two-dimensional (2D) active systems hitherto. Here, we study the density fluctuations of three-dimensional (3D) bacterial suspensions and image the emergence of the giant number fluctuations as the bulk suspensions develop collective motions. Particularly, we observe a gradual increase of density fluctuations with bacterial concentrations, where the rise of giant number fluctuations precedes the formation of the collective motions. At high bacterial concentrations, the density fluctuations observed in our 3D system are significantly stronger than those in 2D systems in existing experiments, contradicting the theoretical predictions. Furthermore, using a genetically engineered light-controlled bacterial strain, we investigate the temporal evolution of density fluctuations through the transition into collective motions and explore the relation between density fluctuations and flow fields. A coupling between the flow divergence and the spatiotemporal variation of density is found, revealing the microscopic origin of the giant number fluctuations. Our experiments provide new insights into the density fluctuations in 3D active fluids and enrich the understanding of the collective dynamics of microbiological systems.

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Date submitted: 02 Aug 2020 Electronic form version 1.4