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Non-classical size-dependent particle diffusion in active fluids¹

ARVIND GOPINATH², Department of Physics and Astronomy, Haverford College, ALISON PATTESON, PAULO ARRATIA, Department of Mechanical Engineering, SEAS, University of Pennsylvania — We experimentally investigate the effect of particle size on the motion of passive polystyrene spheres in suspensions of *Escherichia coli*, a flagellated bacterium that is approximately 2 microns long and swims using a sequence of runs punctuated by tumbles. Using particles covering a range of sizes from 0.6 to 39 microns, we probe particle dynamics at both short and long time scales. In all cases, the particles exhibit super-diffusive ballistic behavior at short times before eventually transitioning to diffusive behavior. Surprisingly, the long-time hydrodynamic effective diffusivity is non-monotonic with particle size; an anomalous response that is fundamentally different from classical thermal diffusion. Consistent with recent theory, we find that for fixed bacterial type, the active contribution to particle diffusion can be predicted by a single dimensionless parameter, the Péclet number. Combining our experimental results, we propose a minimal model that allows us to predict the requirements for a peak in the diffusivity as well as the location and magnitude of the peak as a function of particle size and bacterial concentration. Our results have broad implications on characterizing active fluids using concepts drawn from classical (passive) thermodynamics.

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