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Abstract—Active particle suspensions, of which a bath of swimming bacteria is a paradigmatic example, are characterized by complex dynamics involving strong fluctuations and large-scale correlated motions [1, 2]. These motions, which result from the many-body interactions between particles, are biologically relevant as they impact mean particle transport, mixing and diffusion, with possible consequences for nutrient uptake and the spreading of bacterial infections. In this work, we use a combination of theory and simulations to analyze these effects. First, a kinetic theory [3] is presented and applied to elucidate the dynamics and pattern formation arising from mean-field hydrodynamic interactions. Based on this model, the stability of both aligned and isotropic suspensions is investigated. In isotropic suspensions, a new instability for the active particle stress is found to exist, in which shear stresses are eigenmodes and grow exponentially at low wavenumbers, resulting in large-scale fluctuations in suspensions of rear-actuated swimmers, or pushers, when the product of the linear system size with the suspension volume fraction exceeds a given threshold; no such instability is predicted for head-actuated swimmers, or pullers. We confirm and extend the predictions from the kinetic model using large-scale direct numerical simulations based on a slender-body model for interacting self-propelled particles [4], accelerated by an efficient smooth particle-mesh Ewald algorithm for the calculation of hydrodynamic interactions. These simulations confirm the existence of a transition to large-scale correlated motions in suspensions of pushers above a critical volume fraction and system size, which is seen most clearly in particle velocity and passive tracer statistics. Extensions of this work to model chemotactic interactions with an external oxygen field [5] as well as steric interactions at high volume concentrations [6] are also discussed.

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