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Computation of many-body hydrodynamic interactions in active colloidal suspensions

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Colloidal particles can be rendered "active" through non-equilibrium processes that produce velocities in a thin boundary layer surrounding the particle surface. Such slip velocities produce fluid flow and particle motion in the absence of external forces and torques. The fluid flow of any one particle entrains other particles resulting in a many-body problem for the particle motion. The solution of such problems are an outstanding issue in the nascent field of active soft matter. Here we descibe a rigorous method that solves the hydrodynamic many-body problem for spherical active colloids. The method encompasses polar, apolar, and chiral active colloids and applies in arbitrary flow geometries. The key theoretical idea underlying the method is to express the solution of the Stokes equation, the three-dimensional elliptic partial differential equation for fluid flow, as a two-dimensional Fredholm integral equation of the first kind over the the particle boundaries. The resulting reduction in dimensionality renders the problem both analytically and numerically tractable, allowing the method to scale to hundreds of thousands of particles in commodity multicore architechtures. With O(N) methods for kernel sums the method can scale to millions of particles. We demonstrate the power of the method by applying it to (a) optically trapped active colloids (b) spontaneous symmetry breaking and orientational ordering in active rods and (c) biomimetic oscillations of active filaments.

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