Supplementary Information I: Simulation methods

Using the molecular dynamics package LAMMPS[1], we execute Langevin dynamics simulations of point particles in two dimensions with periodic boundary conditions. The damping time of the Langevin equation is set to 0.1 Lennard-Jones time units. This corresponds to a velocity autocorrelation reduction of e^{-1} after $t = 0.1$ time units. To prevent unphysically large overlap between particles in the initial configuration the following scheme is used to prepare the system: First, a random configuration of discs in the x-y-plane is generated, after which we equilibrate with a soft pair potential of the form $V_{ij} = V_0\left(1 + \cos(\pi r_{ij}/r_c)\right)$. V_0 is the maximum of the potential, r_{ij} the distance between particles i and j and r_c is the cutoff distance. During this run the constant V_0 is linearly ramped up from $V_0 = 0$ to $V_{max} = 3000 k_B T$). This ensures that initially overlapping particles are smoothly repelled until they no longer overlap, while any excess kinetic energy incurred by the forces is dissipated due to the viscosity term in the Langevin equation. After this equilibration run, the soft potential is replaced by the repulsive part of a 12-6 Lennard-Jonnes potential, where we have chosen to cut off the potential at one Lennard-Jones length unit. We have verified that the results presented are insensitive to both the exact form of the repulsive potential, and to the cutoff distance of the potential itself (See Fig. 1).

Since the particles here are treated as point masses, there are no torque and rotation effects present in our simulations. While this is a simplification, we expect that the effect of rotations and torques will not alter the conclusions of our work, because (i) the effects of Brownian rotation and translation of spheres in dilute solutions tend to decouple and (ii) rotational motion is expected to be severely damped (the hydrodynamic drag for rotational motion scales with the third power of the radius, as opposed to the linear scaling of the translational Stokes drag).

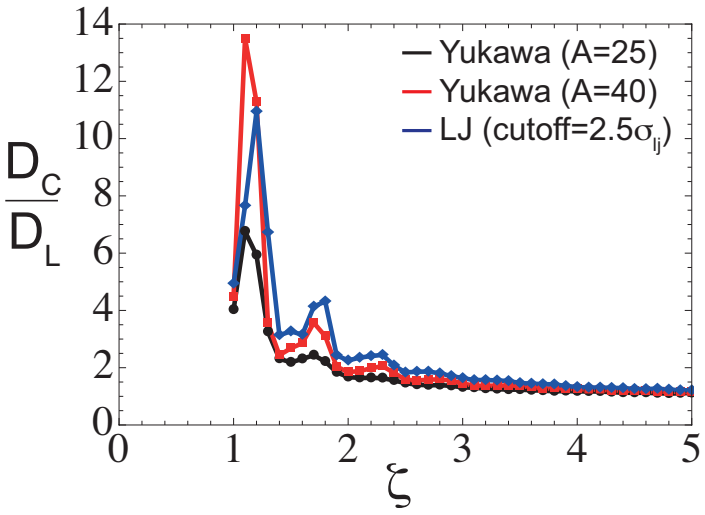

Figure 1: The ratio of the circumferential and lateral diffusivities as function of $\zeta = \pi d/R$ for various interaction potentials. The blue curve represents 2500 LJ particles with a radius $R = 0.5$ where we have set the cutoff at 2.5. The black and the red curve are for 2500 particles with Yukawa potential $V(r) = \frac{A}{r}\exp -\kappa r$, where $\kappa = 0.5$, r the interparticle distance and $A = 25$ for the black curve and $A = 40$ for the red curve. The total system size was kept constant at $2\pi d \times L = 1570.8$ and the temperature equals $T = 1$. This implies that the presented conclusions are independent of the specific interaction potential.

References

[1] S. Plimpton, *Journal of Computational Physics*, 1995, **117**, 1–19.