**Supplementary materials for**

**Programmable active matter across scales**

Hengao Yu1†, Yulei Fu1†, Xinli Zhang1†, Leilei Chen1, Duo Qi1, Jinzhuo Shi1, Wendong Wang1,\*

1 University of Michigan—Shanghai Jiao Tong University Joint Institute, Shanghai Jiao Tong University, Shanghai 200240, China

† These authors contributed equally to this work.

\* Correspondence: wendong.wang@sjtu.edu.cn

This supplementary materials file contains 1 supplementary table.

**Supplementary Table 1** **The force or energy of main interactions in colloidal systems**

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| Interaction type | Force/energy | References |
| Magnetic(Dipole-dipole) | $$W=\left[μ\_{1}⋅μ\_{2}-\frac{3\left(μ\_{1}⋅r\right)\left(μ\_{2}⋅r\right)}{r^{2}}\right]r^{-3}$$where $μ\_{i}$ is the magnetic moment of dipole *i*, ***r*** is the distance vector between dipoles. | (de Gennes & Pincus, 1970) |
| Electric(Dipole-dipole) | $$W=-\frac{μ\_{1}μ\_{2}}{4πε\_{0}εr^{3}}\left(2cosθ\_{1}cosθ\_{2}-sinθ\_{1}sinθ\_{2}cosϕ\right)$$where $μ\_{i}$ is the electric dipole moment, $θ\_{i} and ϕ$ are dipole relative angles | (Yan et al., 2016) |
| Hydrodynamicinteraction | Stokeslet | $V\_{st}(r:p)=a\frac{R\_{0}}{r}[p+\left(p⋅e\_{r}\right)e\_{r}]$where$R\_{0}$ is the charateristic size of the microswimmers, *r* is the distance, $p$ is the unit vector of the microswimmers major axis, $e\_{r}$ is the unit vector of the distance | (Tan et al., 2022) |
| Force-dipole | $$V\_{fd}\left(r:p\right)=b\frac{R\_{0}^{2}}{r^{2}}[3\left(p⋅e\_{r}\right)^{2}-1]e\_{r}$$ |
| Force-quadrupole | $$V\_{fq}\left(r:p\right)=c\frac{R\_{0}^{3}}{r^{3}}[p-3\left(p⋅e\_{r}\right)^{2}p-$$$$9\left(p⋅e\_{r}\right)e\_{r}+15\left(p⋅e\_{r}\right)^{3}e\_{r}]$$ |
| Source-dipole | $$V\_{sd}\left(r:p\right)=d\frac{R\_{0}^{3}}{r^{3}}[3\left(p⋅e\_{r}\right)^{2}-p]$$ |
| Lift force | - | $$F=\frac{ρω^{2}r\_{1}^{4}r\_{2}^{3}}{d^{3}}$$where *ri* is the size of the particle *i*; $ω$ is rotating speed, *d* is distance and $ρ$ is the density of the fluid. | Grzybowski, Nature 2000 |
| Diffusiophoresis | Electrophoresis | $$V\_{E}=(\frac{dln\left(C\right)}{dx})(\frac{D\_{C}-D\_{A}}{D\_{C}+D\_{A}})(\frac{k\_{b}T}{e})\frac{ε(ζ\_{p}-ζ\_{w})}{η}$$where $C$ is concentration, *D* is diffusivity, $ζ$ is zeta potential; $η$ is solution viscosity;$ε$isdielectric permittivity. | (Ibele, Mallouk, & Sen, 2009; Velegol, Garg, Guha, Kar, & Kumar, 2016) |
| Chemophoresis | $$V\_{C}=\left(\frac{dln\left(C\right)}{dx}\right)\left(\frac{2εk\_{b}^{2}T^{2}}{ηe^{2}}\right)ln[1-tanh\left(\frac{eζ\_{w}}{4k\_{b}T}\right)^{2}]$$ |
| Capillary effect | Quadrupole-quadrupole | $$-12πσH\_{A}H\_{B}cos\left[\left(φ\_{A}-φ\_{B}\right)\right]\left(r\_{A}r\_{B}\right)^{2}/L^{4}$$where $σ$ is interfacial tension, $φ\_{i}$ is the angle between quadrupole *i* and the center line, $H$ is the amplitude of the undulation of the contact line, $r$ is the average radius and $L$ is the distance between two particles | (Danov, Kralchevsky, Naydenov, & Brenn, 2005) |
| Hexapole-hexapole | $$-60πσH\_{A}H\_{B}cos\left[3\left(φ\_{A}-φ\_{B}\right)\right]\left(r\_{A}r\_{B}\right)^{3}/L^{6}$$ |
| Multipole (mA)-multipole (mB) | $$-G\_{0}πσH\_{A}H\_{B}cos\left[\left(m\_{A}φ\_{A}-m\_{B}φ\_{B}\right)\right]\frac{r\_{A}^{m\_{A}}r\_{B}^{m\_{B}}}{L^{\left(m\_{A}+m\_{B}\right)}}$$ |
| DLVO theory | Two spheres | **Casimir-Lifshitz force** $F=\frac{-A}{6D^{2}}(\frac{R\_{1}R\_{2}}{R\_{1}+R\_{2}})$A=$π^{2}Cρ\_{1}ρ\_{2}; ρ$ is the number density of atoms, *D* the distance, $R\_{i}$ the radius of colloidal cluster *i*, C the coefficient in the atom-atom pair potential.**Electric double layer** $F=κ\frac{R\_{1}R\_{2}}{R\_{1}+R\_{2}}Ze^{-κ D}$$κ$ is Debye length, $Z$ is interaction constant determined by surface geometry and electrolyte. | (Israelachvili, 2011) |
| Two flat surfaces | **Casimir-Lifshitz force** $F=\frac{-A}{6πD^{3}}$**Electric double layer** $F=(κ^{2}/2π)Ze^{-κ D}$ |
| Sphere-flat surface | **Casimir-Lifshitz force** $F=\frac{-AR}{6D^{2}}$**Electric double layer** $F=κRZe^{-κ D} $ |
| Interfacial tension-driven flow | $$V=MA\frac{r}{r^{3}}$$$M$, mobility of particles; $A$, activity of reaction on particle surface; | (Meredith et al., 2020) |

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