Supplementary Material:

Dynamics of Marangoni-Driven Elliptical Janus particles

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I. EFFECT OF DIFFUSION COEFFICIENT, D

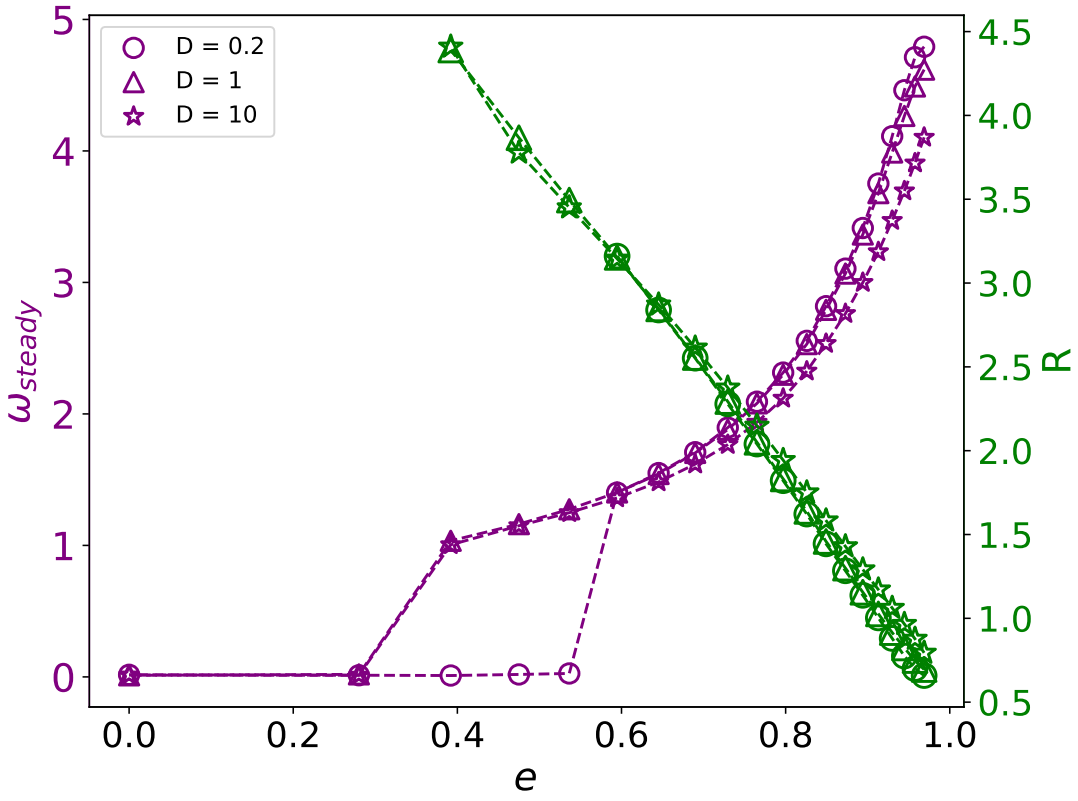

FIG. S1: Comparison of particle dynamics for different D values $(0.2, 1.0,$ and $10)$ for $a = 1.25a_0$. The overlapping curves demonstrate that for a single, non-interacting particle, the dynamics remain invariant to changes in D(in a large range of $(0.2, 10)$). It only affects the placement of the bistable region, supporting the selection of $D = 2.5a_0^2\alpha_0$ as a representative constant.

II. EFFECT OF PARTICLE SIZE

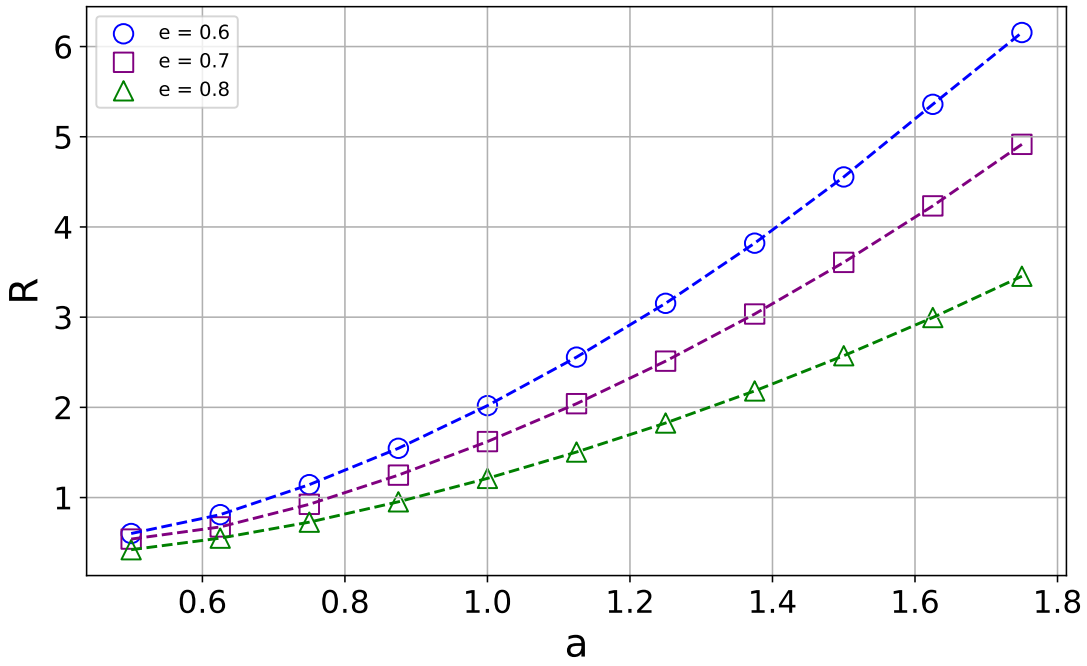

FIG. S2: The Radius of the particle's trajectory is plotted against its size (which is increased by increasing the semi-major axis of the particle and keeping the eccentricity constant).

III. EFFECT OF NOISE

We have studied the particle dynamics by introducing Gaussian white noise in equations 6 and 7 via $\xi_{\parallel}$, $\xi_{\perp}$ and ξ_{θ}, which are independent noise strengths corresponding to parallel, perpendicular, and rotational components, such that,

$\langle \xi_i(t) \rangle = 0, \qquad \langle \xi_i(t)\xi_j(t') \rangle = \delta_{ij}\delta(t-t'),$

where i,j $\in \{\parallel,\perp,\theta\}$. The strengths of the translational and rotational fluctuations follow the fluctuation-dissipation relation. The Marangoni force arises from surface tension variations, with the characteristic scale given by $\delta\gamma \sim \kappa c$. For the results shown below, we take $\kappa \sim 0.5\,\gamma_0\alpha_0/f_0$. Since the typical concentration scale is $c \sim f_0/\alpha_0$, this yields $\delta\gamma \sim 0.5\,\gamma_0$. Consequently, the thermal energy can be expressed in units of $\gamma_0 a^2$, and we explore the range $K_bT \sim 10^{-2}-10^{1}$. Within this range, the system remains largely robust to fluctuations, with

the observed dynamics remaining unchanged over most of the explored range. Noticeable deviations from the deterministic behaviour appear only at the largest noise strength, $K_bT = 10$.

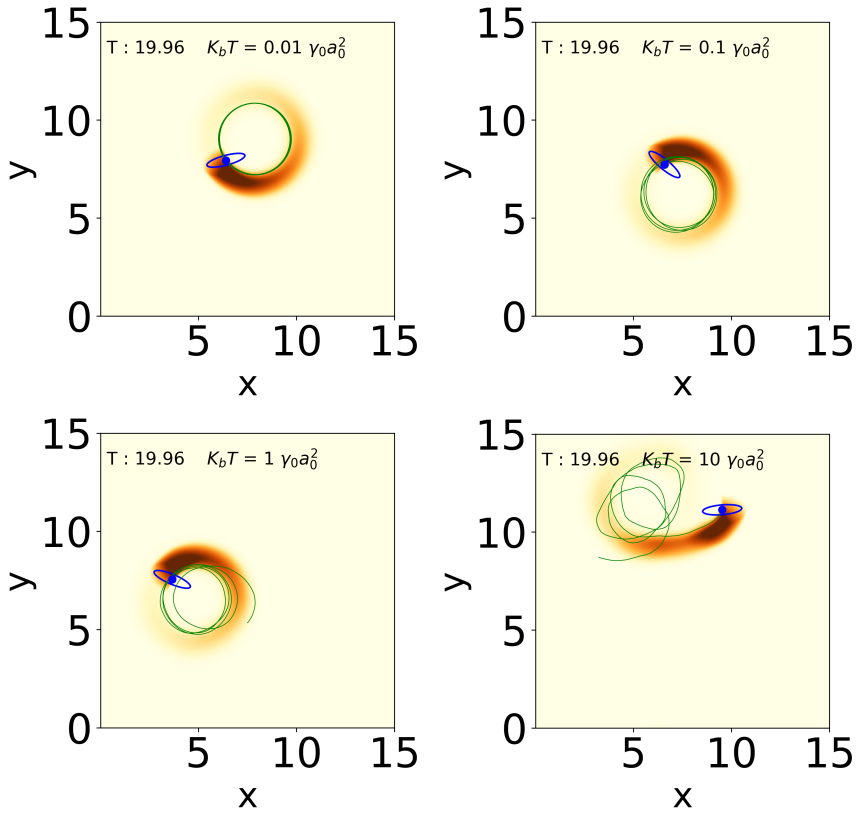

FIG. S3: The trajectory is unaffected for $K_bT = 0.01\gamma_0 a_0^2$ to $K_bT = 10\gamma_0 a_0^2$ showing that the particle dynamics is robust to $k_bT/\gamma_0 a_0^2 \sim 1$.

IV. EFFECT OF CHAMBER GEOMETRY: SQUARE CHAMBER

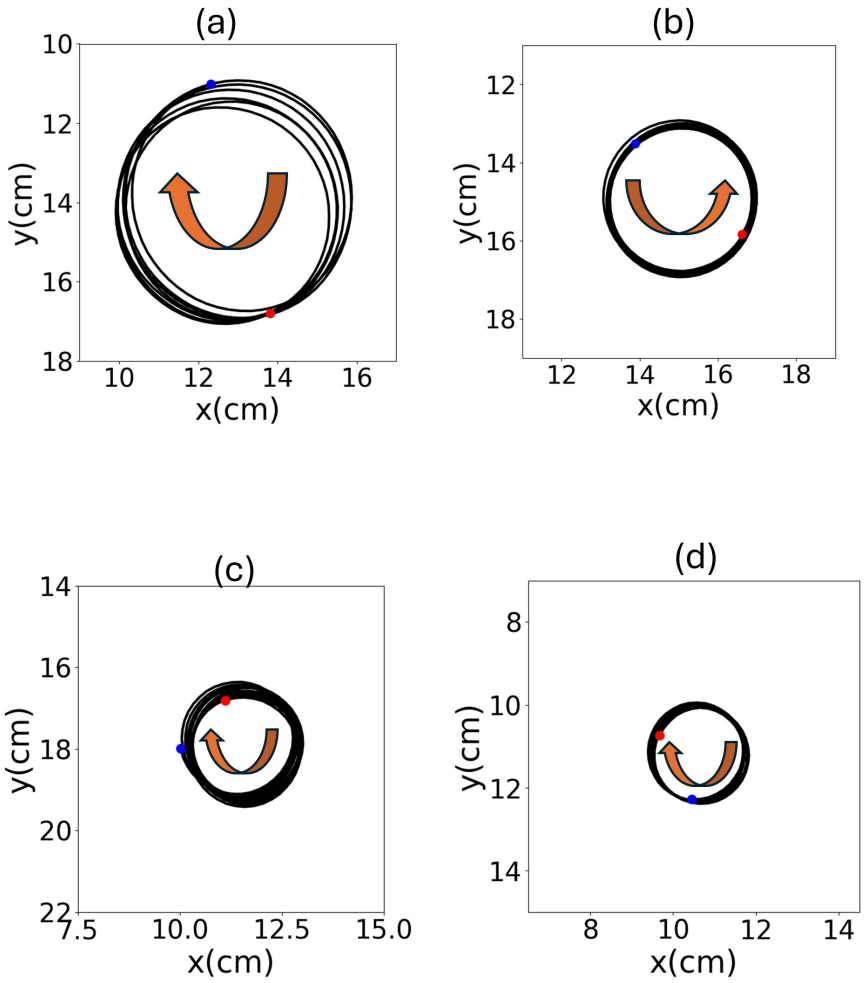

FIG. S4: (a) - (d) Trajectories of elliptical Janus particles of major axis 2a and minor axis 2b in a square prtri dish of arm length 21 cm. In all cases, the particles exhibit almost circular motion. (a) 2a = 1.9 cm, 2b = 1.6 cm (b) 2a = 1.9 cm, 2b = 1.4 cm (c) 2a = 1.9 cm, 2b = 0.8 cm (d) 2a = 1.9 cm, 2b = 0.6 cm