Supplementary Information for "Spontaneous symmetry breaking induced unidirectional rotation of a chain-grafted colloidal particle in the active bath"

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Experimental methods

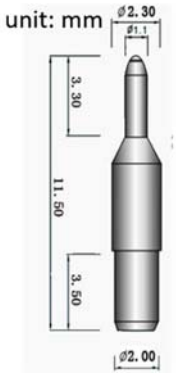
A flower-shaped vessel containing a monolayer of active particles is mounted on an electromagnetic shaker. The petal structure of the vessel may avoid the stagnation and accumulation of active particles along the boundaries. The shaker provides a vertical vibration $Z = A\sin\omega' t$ where ω' is the vibrating angular frequency, and A the vibrating amplitude. The vibrating strength is usually characterized by a dimensionless vibrating acceleration $\Gamma = A\omega'^2 / g$, where g is the gravitational acceleration. In the experiment we set $f = \omega'/2\pi = 50Hz$ and $\Gamma = 5$. A high-resolution camera is used to record the motional details.

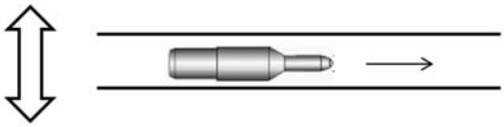
By now, the parameters such as propelling force and rotating rate of the active particles cannot be well controlled and quantified. Therefore, quantitative comparisons between experiment and simulation are left for future.

I. The Vessel

The vessel is made in an acrylic plank with length=width=16*cm* and thickness=3*mm*. The diameter of the vessel is 13*cm*. The radian of each petal is $\pi/4$.

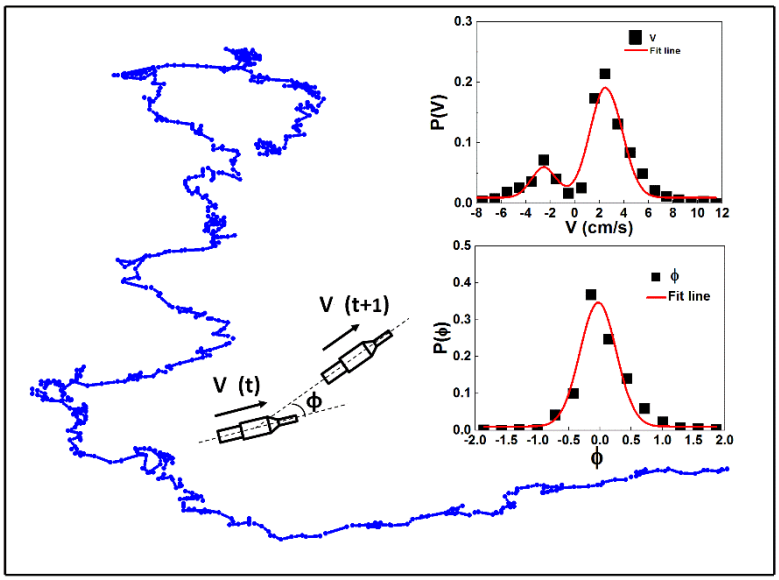
II. The Active Particles





The active granular particle is a tapered, steel rod with the rod length 11.5 *mm*. Due to geometric asymmetry, the rod can be self-propelled towards the thin end along its long axis under the vertical vibration. The typical trajectory of one active particle and the statistical distributions of the amplitude of velocity along the long axis and the deviation angle between two successive steps are shown in the below. (Real time

interval between successive records is 0.04 *sec*.) Totally, 250 active granular particles are put in the vessel.



III. The Granular Chains and the Central Ring

The granular chain is composed of hollow, steel beads and links. The balls (diameter=1.50 *mm* and apparent density=2.488 *g/ml*) are connected to each other by rigid links. The link between two neighboring balls is retractile, and the maximum length can reach 0.50 *mm*. The minimum number of beads that are required to form a

ring is 9, characterizing the stiffness of the granular chain. The number of beads per chain is 25.

A metal ring with an inner diameter of 6 *mm* and an outer diameter of 12 *mm* is anchored to a vertical axis at the center of the vessel, so that it can only rotate around the axis. Sixteen semi-flexible granular chains are attached to the edge of the ring uniformly.

Captions for the movies

Movie1.mpg:

The parameters are *N*=15, $F = 3.6$ and $D_r = 3.6\times10^{-4}$. This movie, corresponding to Fig. 1(a)-(e) and Fig. 5(a), shows that the colloid rotates unidirectionally. The video was made by the rate 1 snapshot per 30τ, where $\tau = \sqrt{m\sigma^2/\varepsilon}$ is the unit time in molecular dynamics simulation.

Movie2.mpg:

The parameters are the same as in movie1. This movie shows the initial process before the start of the unidirectional rotation. To capture such process, we change the rate of the video to 1 snapshot per 2τ.

Movie3.mpg:

The parameters are *N*=15, $F = 3.6$ and $D_r = 0.01$. This movie, corresponding to Fig. 5(b), shows the rapid configurational change or asymmetry of the grafted chains.

Movie4.mpg:

The parameters are N=15, $F = 0.2$ and $D_r = 3.6\times10^{-4}$. This movie, corresponding to Fig. 5(c), shows the slow change of the grafted chains from left curved to right curved.

Movie5.mpg:

The parameters are N=15, $F = 3.6$, $D_r = 3.6\times10^{-4}$ and $\zeta_R = 5000$. This movie shows that the rotation of colloid can't catch up with the motion of chains which leads to the inversion of the asymmetry and the rotating direction.

Movie6.mpg:

The parameters are N=15, $F = 3.6$, $D_r = 3.6\times10^{-4}$ and $\zeta_R = \infty$. This movie, corresponding to Fig. 5(d), shows that the grafted chains vibrate like the beating of cilia.

Movie7.mpg:

Net anticlockwise rotation of the chain-grafted ring. The rate of recording is 25 snapshots per second. The video rate is accelerated by 300 times.