Supplementary material for "Spontaneous population oscillation of confined active granular particles"

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1. Mean squared displacement (MSD) of active granular particle

To visualize the self-propelling character of the active granular dumbbell, Fig.S1 shows the MSD of an isolated granular dumbbell along its long axis as a function of time, which is equivalent to a one-dimensional motion. The parabolic time dependence of the MSD indicates that the granular dumbbell experiences a self-propulsion along its long axis.

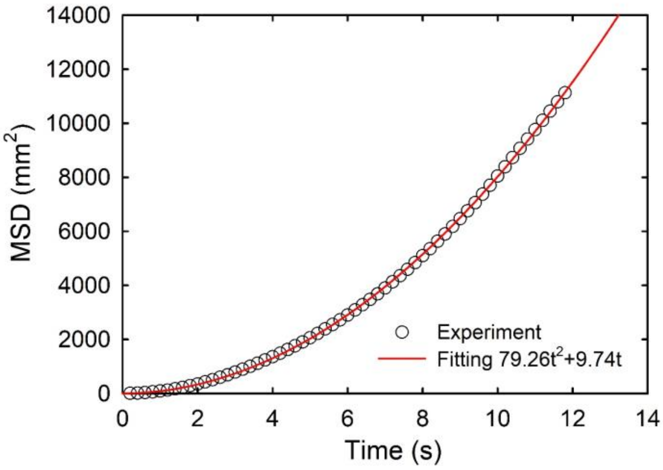

Fig.S1: MSD of an isolated granular dumbbell along its long axis. Here, the vibrating frequency is *f*=80Hz and dimensionless acceleration is $\Gamma = 4.5$. The solid line refers to a fitting with a quadratic function.

2. Theoretical calculations based on experimental fittings

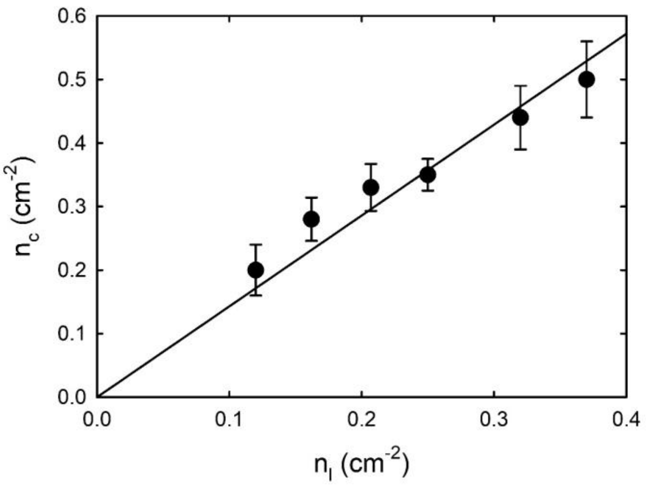

Fig.S2: The number density of particles in the channel *vs* the number density of particles in the source chamber. The slope of the fitting straight line is 1.43, i.e, the n_c=1.43n_l, near the moment when the unidirectional flow reverses.

In the minimal theoretical model, we have assumed that the number density of particles inside the channel is the same as that of the source chamber during the stationary unidirectional flow. To see the rationality of this assumption, Fig.S2 plots the number density of particles in the channel n_c as a function of the number density of the source chamber n_l just before the flow reversal. Although n_c is not equal to n_l, they basically follow a linear relationship, $n_c = kn_l$, in the range of the present parameters. This means that our assumption is approximately reasonable. A linear fitting to the data in Fig.S2 yields the prefactor k=1.43, which is comparable to k=1 as we have assumed in the minimal theoretical model in the main text. With the linear relation $n_c = 1.43n_l$, we can similarly calculate the number densities of particles in two chambers at the reversal moment of the unidirectional flow, and find a better quantitative agreement with experimental data, as shown in Fig.S3.

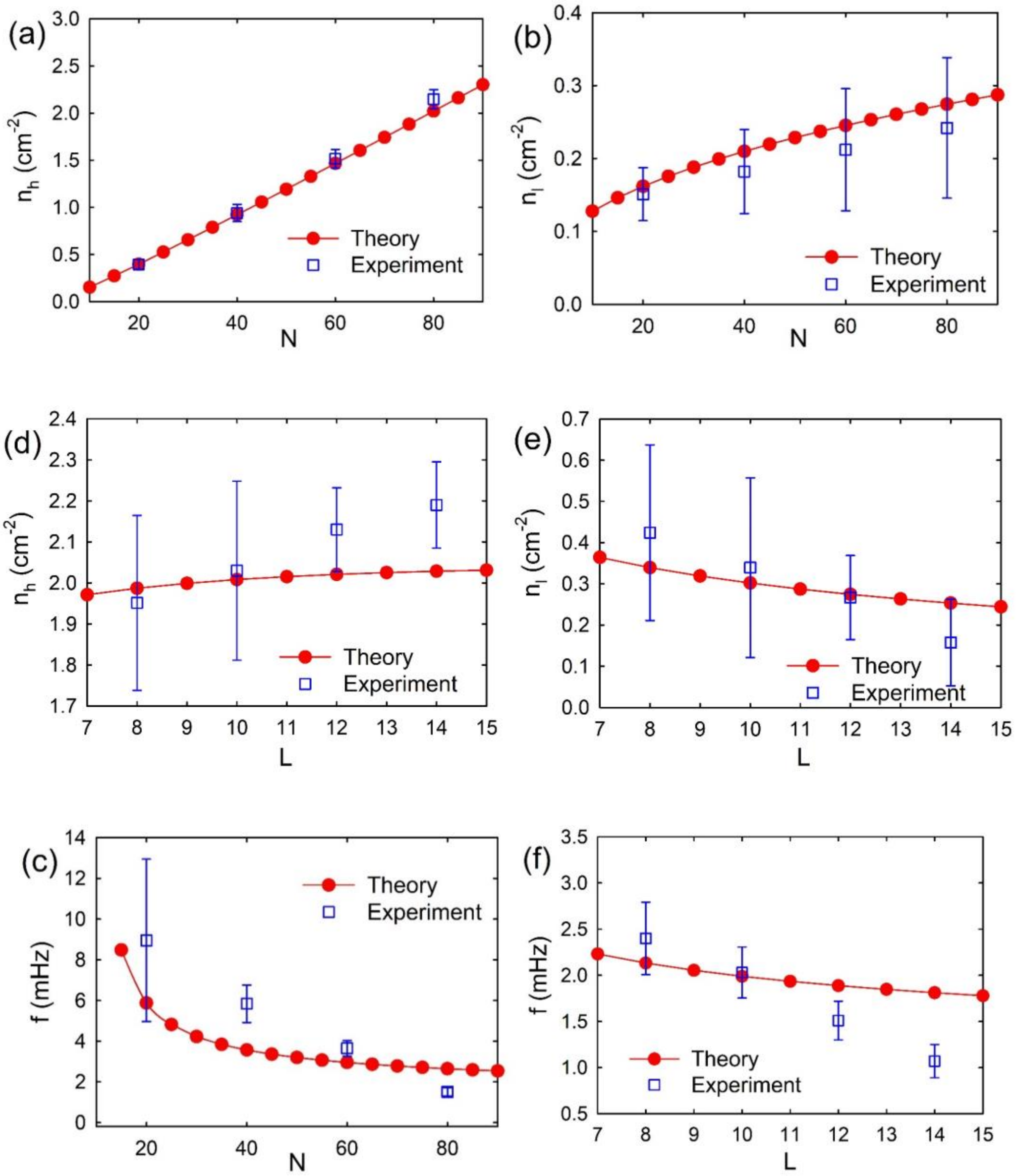

Fig.S3: Comparison of experimental and theoretical results. (a) high number density of particles n_h and (b) low number density of particles n_l at the flow reversal moment as a function of the total particle number. Here, L=12 and $\sigma = 1.25$, and n_c=1.43n_l. (d) n_h and (e) n_l versus the channel length, with N=80 and $\sigma = 1.25$, and n_c=1.43n_l. The oscillation frequency as a function of (c) N with L=12 fixed, and (f) L with N= 80 fixed.

3. Distribution of particle number difference between two chambers

To further compare with the numerical simulation in Ref.[31] of the main text, we measure the distribution of the particle number difference between two chambers in experiments at different total particle numbers, as shown in the Fig.S4. The distribution curves exhibit a bimodal feature, especially for the large particle number. The distribution curves are very similar to those in the Ref. [31] of the main text. For larger particle numbers, such as N=100, the sink chamber is fully filled, while in the channel there remains a long file of particles migrating from the source chamber. The particles in the overcrowding sink chamber fail to reorient (which can also be understood as the vanishing of the corresponding internal motility) and to compete against the unidirectional self-propelling force from the active particles in the channel, so that it is impossible to trigger the flow reversal and a long-lived jammed state survives.

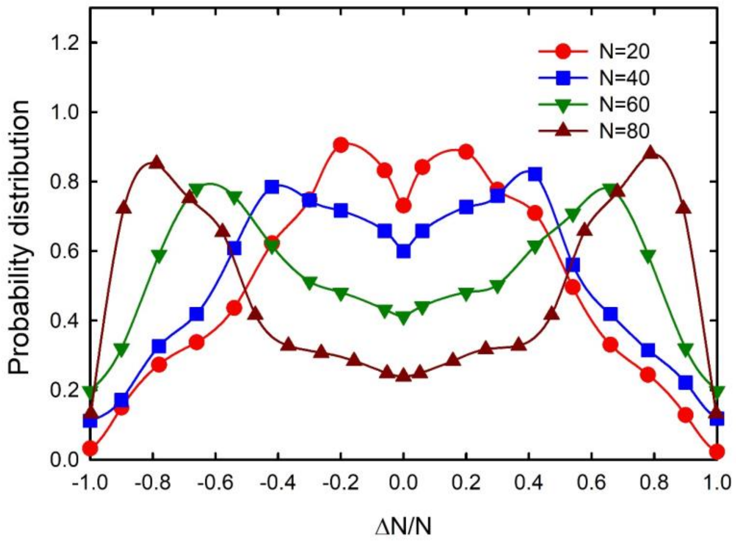

Fig.S4: Probability distribution function of the particle number difference between the two chambers at various total particle numbers N. Here, L=12 and $\sigma = 1.25$.

4. Phase diagram of the collective motion of active granular dumbbells

Figure S5 plots the phase diagram of the collective behavior of active granular system in the parameter space of the channel width versus channel length.

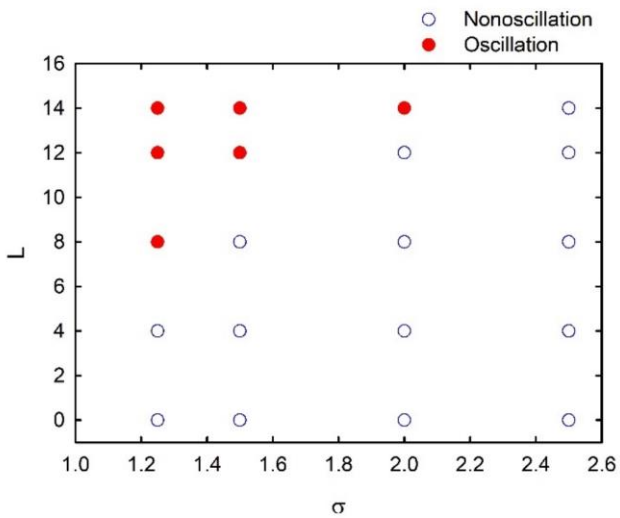

Fig.S5: Phase diagram of the collective behavior of active granular dumbbells in the parameter space of $\sigma - L$. Solid circle indicates the periodic oscillation, and open circle represents the non-oscillation.

5. Videos

Movie S1: Self-propelled particles confined in two chambers connected by a thin channel, alternately filling two chambers, generate spontaneous number oscillation. The parameters in this oscillation: vibrating frequency *f*=80 Hz and vibrating strength $\Gamma = 4.25$, channel length *L*=12 in unit of one self-propelled particle, channel width *D*=1.25, where the channel width *D* is normalized by the diameter d_1 of the large ball on the self-propelled particle, and the total particle number *N*=80.

Movie S2: Copper spheres without any self-propulsion are employed to confirm the crucial roles of the self-propulsion on the oscillation. In the validation experiment, all other conditions maintain the same except for particles. The trials were repeated more than ten times, and no oscillatory behavior can be observed.