Supplementary Information

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1. DESCRIPTION OF THE SUPPLEMENTARY MOVIES

Supplementary Movie 1 and Supplementary Movie 2 report the time evolution of the system from two simulations in the steady-state, for reduced chirality $\omega\tau = 10$ and 2×10^2, respectively. The first shows a typical configuration in the permanent vorticity state, while the second displays a typical one in the self-reverting vorticity state. In both cases, the cluster size square is given by $L_c^2 = 904$, corresponding to a number of particles in the cluster, $N_c = 904$. Each movie consists of two adjacent videos lasting for a total time interval $10^2\tau$. In the left video, particles are plotted as circular points and colored according to their orientational angle θ_i. In the right video, we plot the coarse-grained fields: black arrows are used to denote the velocity field $v(\mathbf{r})$, while the color gradient shows the vorticity field $\Omega(\mathbf{r})$. In both cases, orientations θ_i are random since there are no torques between different particles, and in general, the velocity field $v(\mathbf{r})$ shows global alignment characterized by vortex-like configurations. The main differences between the two movies appear in the global cluster motion and in the time evolution of the vorticity field $\Omega(\mathbf{r})$. In Supplementary Movie 1, the cluster shows a global counterclockwise rotation and $\Omega(\mathbf{r})$ is locally and globally always larger than zero. In Supplementary Movie 2, the cluster is characterized by spinning dynamics while $\Omega(\mathbf{r})$ displays local oscillations between negative and positive values.

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