Supplementary Materials for

Entropy of state transitions in macroscopic active matter

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This PDF file includes:

Materials and Methods

Captions for Movies S1 to S2

Other Supplementary Materials for this manuscript:

Movies S1 to S2

Materials and Methods

Active sphere preparation

Upon receiving the motorized spheres (D.Y. Toy), we removed them from their packaging and detached the weasels attached to the shell. Each sphere consists of two screwable half-spheres, which can be opened to insert a single AA battery. Before each experiment, we replaced all AA batteries to ensure consistent torque generation across the entire population. Failing to do so, especially with low or depleted batteries, could introduce artifacts in the rolling behavior of the spheres. The confinements used in the experiments were 3D printed using PLA filaments.

Image analysis

Fiji imaging processing software was used for the processing and analysis of images and video microscopy data (*34*).

Tracking and postprocessing

To extract the trajectories of the spheres and dots from recorded videos, we used the TrackMate plugin within Fiji (*35*). The spheres and dots can be separated by color thresholding, leading to two sets of images. Each set is tracked individually and post-processed using a script in Python 3.7 or Matlab. Both sets of tracks are sufficient to create a reconstruction of the system.

Time symmetry during states and transitions in a system of motorized spheres A Self-organization of motorized spheres. This video shows the emergence of collective rotational motion in a population of motorized spheres confined in a circular domain. Initially, the spheres move chaotically without correlation. Over time, the spheres begin to synchronize their movement, forming coherent structures akin to an active liquid phase. **B-C** The progression of time in both the chaotic and ordered states is time-reversible. Distinguishing whether a movie is being played forward or backward becomes difficult. **D** The progression of time during state transitions. During state transitions time reversibility symmetry is broken and the direction of time becomes evident again.

Entropy of state transitions in macroscopic active matter A Experimental setup and reconstruction. This video shows the motorized spheres labelled with red markers confined in a circular boundary. Tracking both motions independently and reconstruction it subsequently allows the decomposition into translational and rotational components. **B** Entropy and kinetic temperature during state transitions. he video highlights the evolution of entropy and kinetic temperature as the system transitions between different states. Discrete jumps in entropy correspond to these transitions, reflecting the emergence or reduction of degrees of freedom. **C** Number variations reveal different states. As the number of spheres in the system is varied, distinct phases emerge, demonstrating how reducing the number of spheres leads to different phase behaviors