Collective behaviour of a suspension of energy depot repulsive disks

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Active matter systems are made of self-driven units active particles each capable of converting stored or ambient energy into systematic motion. This features leads the system in an out-of-equilibrium state, giving rise to a very interesting phenomenology, such as a unexpected collective behaviour or rich spatio-temporal self-organisation.

In this work [1], we study structural and dynamical features of a two dimensional system of active repulsive disks able to take energy from their environment, store it into an internal energy depot and convert it into kinetic energy [2]. The Langevin equations of the model reads:

$$\dot{\mathbf{v}} = -\gamma(\mathbf{v})\mathbf{v} - \frac{1}{m}\nabla U(\mathbf{r}) + \mathcal{F}(t) \ , \tag{1}$$

$$\gamma(\mathbf{v}) = \gamma_0 - \frac{qd}{c + d\mathbf{v}^2}. \tag{2}$$

Where the parameters q, d and c express the properties of the energy depot. This model uses a velocity dependent friction $\gamma(\mathbf{v})$, in which activity is encoded. Varying the parameters of the model, we study suspensions at different activities.

Unexpectedly, despite the model has no explicit alignment, it displays collective behaviour in the form of a transition between an ordered (flocking) an a disordered state, depending on the system's densities and values of the activity. This transition is studied also from an structural point of view, where we differentiate a band an an homogeneous phase of flocking, similar to what happens it some Active Matter models with orientational alignment.

To unravel the origin of this transition, we suggest a simple argument based on particles' collisions.

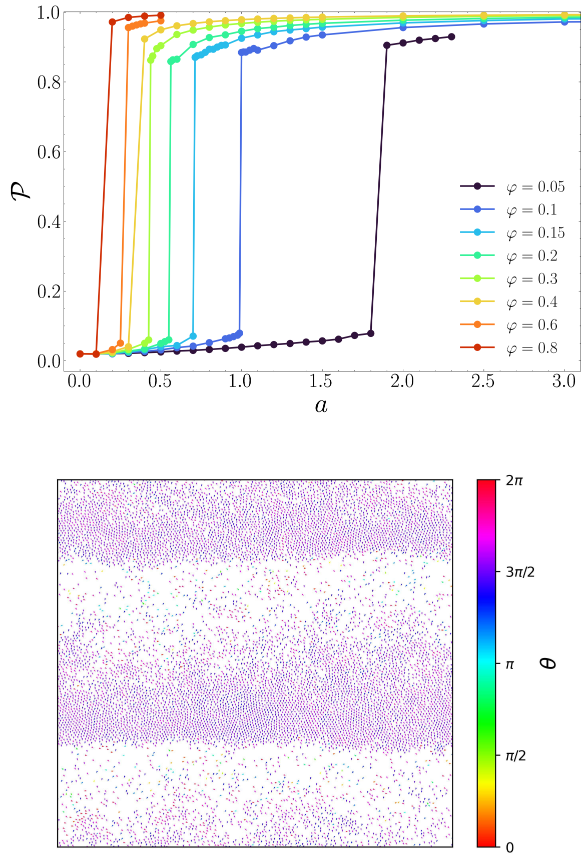

Fig. 1. Top picture: Polar order parameter for diferent activities a and surface fractions φ. Bottom picture: Snapshot of a system with 10000 particles showing orientational order in the form of a band flock.

[1] Miranda-Lopez,J P., Levis, D. & Valeriani,C. (2023). Collective behaviour of energy depot repulsive disks, *In Preparation* (2023),

[2] Schweitzer, F., Ebeling, W., & Tilch, B. (1998). Complex motion of Brownian particles with energy depots. Physical Review Letters, 80(23), 5044.