Sorting of flocking active particles using asymmetric obstacles

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Active matter is a branch of condensed matter physics which studies systems that are intrinsically out of equilibrium, because every component of them is out of equilibrium. Physical examples are entities which propel themselves by taking their energy from the environment, such as living particles.

In this context, we are going to focus on differences existing between trapping particles which show collective motion and run-and-tumble ones.

Run-and-tumble particles mimic the motion of a wide variety of microorganism (as *E. coli*), consisting in straight runs interrupted by tumbles (reorientations of the direction of motion) [1]. We model them by using simple rules of uniformly distributed random tumbles at regular time steps, and constant particle speed during straught runs.

Flocking particles are modeled using the well-known Vicsek model [4, 5, 6, 7], where we consider both the metric and the topological choice of neighbors: in the metric model neighbors are chosen within a fixed cutoff radius R [4, 5, 6], while in the topological one we take the Voronoi neighbors of a particle [7], thus a screening of the interactions is taken into account.

Sorting of run-and-tumble particles by asymmetric obstacles (a wall of funnels) has already been described [2] and experimentally tested using *E.coli* [3]. When the persistence length of particles is large enough, active particles concentrate at the small opening side of the wall.

When using an open geometry, consisting in bands with periodic boundary conditions, formed by parallel funnel walls each having its wide opening side opposed with its neighbor's one, the same trapping effect for run-and-tumble particles is observed (see left panel of Fig. 1). When replacing run-and-tumble particles by flocking particles described by the Vicsek model [4, 5, 6], we observe that, surprisingly, particles are trapped differently: first, they concentrate at the wide opening side of the funnels (contrary to run-and-tumble), and second, the entire flock is trapped (right panel of Fig. 1).The reason for this difference is the trapping mechanism, as presented in bottom row of Fig. 1.

In this particular geometry, the difference between using metric or topological Vicsek model is very small.

We have also designed circular traps for flocking particles, where we observe an important difference between trapping of metric and topologic particles (see Fig. 2). In this case, the lower tendency to cluster of the topologic model becomes evident.

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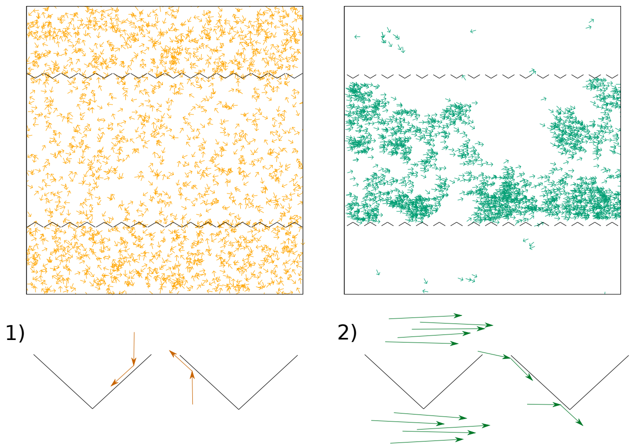

Fig. 1. (Left) Run-and-tumble particles. (Right) Flocking particles in the same geometry. Periodic boundary conditions are used. (Bottom row) Representation of the trapping mechanism: (1) run-and-tumble particles find easier to cross the wall from the wide opening side to the other side, (2) flocking particles, however, first align with the wall and them are pushed to the wide opening side by collisions with walls.

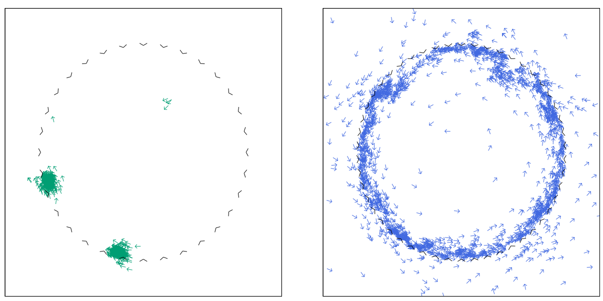

Fig. 2. Circular traps. (Left) Metric Vicsek model. (Right) Topologic one. We see that metric Vicsek model is much more subject to clustering.