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Peer Review

Review of: "A Complex Topological Phase in C-Spin Active Matter"

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This paper reports the results of numerically solving a 2D model of N swarming particles with spins. The same model was studied by the author in previous papers. There are two types of particles distinguished by the equations of their spin angles. These equations resemble those of the Kuramoto model with a bimodal frequency distribution (the frequencies are $\pm\Delta/2$), except that the coupling constants decay exponentially rapidly with the squared distance between particles. Particle dynamics is overdamped and coupled with spin dynamics (the coupling constant acts as a potential energy, and there is an explicit dependence of the equations of motion on spin). I did not find an explicit reference to boundary conditions, so I assume they are periodic. While the equations of motion are deterministic, the initial conditions of particle positions and spins are random and uniformly distributed in the box and in the $[0,2\pi]$ interval, respectively. The density of the particles is 1, and the difference between the frequencies of the particle spins, Δ, is a control parameter called anisotropy. Depending on its value (and on N), the particles organize in a set of dipoles comprising particles with different spin frequencies but located at the same position (type 1 sync), they form a vortex of moving particles with topological charge 1 or -1 (typically) plus dipoles (type 2 sync), or they form a gas of moving isolated particles (type 3 sync, existing for $\Delta>1$).

With respect to previous papers, the present one has a clearer color code representation and one empirical power law, Eq. (8), giving the dependence of the anisotropy ($0\leq\Delta<1$) on N for the line separating type 1 and type 2 syncs. The accompanying movies are nice, illustrate the results of numerical simulations, and complement the figures. For the different phases/syncs, the analysis of the results involves calculations of the average kinetic energy per particle, the averaged angular frequency, and a Kuramoto-type parameter.

I found the results suggestive of the richness of an interesting model. With respect to type 1 sync, it would be interesting to describe the final stable configuration (stationary?) by calculating the average inter-dipole distance and orientation depending on N. With respect to type 2 sync, the author does not say which features of the initial conditions produce a vortex or an antivortex (topological charges +1 or -1). Given that these patterns are robust, it would pay to figure such features out. Then it would be possible to have initial conditions of two vortices of opposite charges for sufficiently large N and see whether they annihilate each other, and also to inquire how the composite patterns of Figure 7 form.

How about modifying the model? It would be interesting to add sharp cutoffs to the potential and the forces. Then two particles placed at a sufficiently large distance would not see each other (as in the Vicsek model), whereas in the present model they feel a very small but nonzero influence.

Declarations

Potential competing interests: No potential competing interests to declare.

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