The importance of parallel and anti-parallel alignment in the collective motion of self-propelled particles (SPP)

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Abstract:

Collective motion constitutes a challenging example of self-organization. Applications range from robotics to biology.
In particular, emergent large-scale patterns mediated by merely local interactions of individual system components are observed in an amazingly huge number of biological systems of different complexity (e.g. herds, fish schools, bird flocks, swarms of social insects, amoebae and bacteria).
Despite the fact that in each case the interactions between individuals are of a different nature, it is possible to determine common requirements for self-organization. Here, we focus on the implications of alignment and analyze 'ferromagnetic' (1, 2) and 'liquid crystal'-like (3) alignment mechanisms. The latter allows parallel and anti-parallel alignment, while the former only admits parallel alignment.
For the two types of alignment mechanisms, we observe phase-transitions related to the noise introduced into the system. In the case of parallel and anti-parallel alignment, we also observe spontaneous symmetry breaking of the rotation symmetry. We present numerical evidence of this phase transition. In addition, we show that the effect of attractive and repulsive forces lead to different responses depending upon the type of alignment mechanism.

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