Active cluster crystals in systems of self-propelled particles

Jean-Baptiste Delfau[1], Emilio Hernández-García[2] and Cristóbal López[1]

[1] IFISC (CSIC-UIB), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain.

The collective behavior of self-propelled particles is a fascinating topic both for its numerous applications, ranging from active colloids to bacterial suspensions, and its intrinsic theoretical interest [1, 2]. Many studies focused on the formation of clusters reporting two main different cases: for "active crystals", self-propulsion leads to a modification of the properties of a pre-existing crystal. On the other hand, for Mobility-Induced Phase Separation (MIPS), the system separates into two phases of different densities. Methodologically, both mechanisms can be studied by considering an effective density-dependent velocity replacing the two-body interacting potential.

We analyze here [3] a different case of cluster formation with active objects. It is the non-equilibrium counterpart of the so-called cluster crystals [4], which appear in equilibrium systems interacting with soft-core repulsive potentials, and are solid-like structures where the unit cell is occupied by a closely packed cluster of particles. Here, clustering appears under a repulsive potential so that it is not a consequence of purely local effects. This is thus very different from the other cases of active crystals and it is unlikely that previous local arguments derived for active crystals or MIPS can describe it. Self-propulsion deforms the clusters by depleting particle density inside, and for large speeds it melts the crystal. Continuous field descriptions at several levels of approximation allow to identify the relevant physical mechanisms.

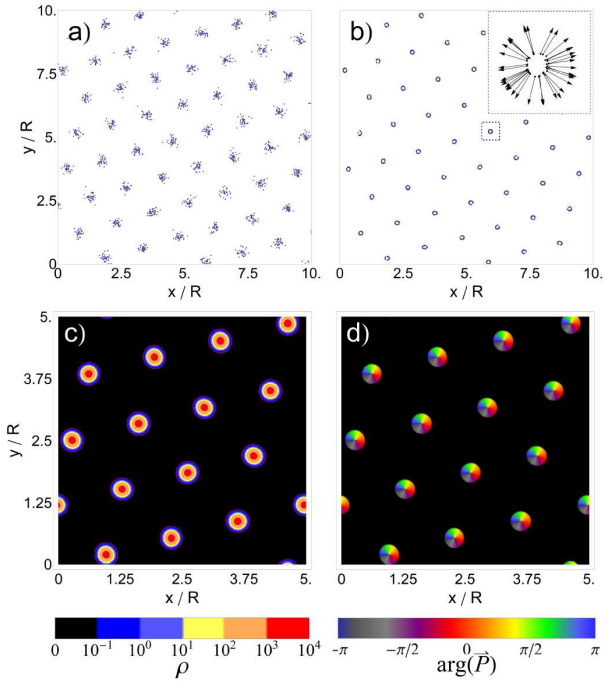

Figure 1: Panels a) and b): Particle simulations. Snapshots of particle positions at different parameter values. Top-right inset is a zoom of the boxed cluster showing the orientation of the particle's velocity vector. Panels c) and d): Steady states obtained by numerical integration of the continuum equations for density and polarization, for the same parameters as panel a). Panel c): density field. Panel d): angle of the polarization field. Black regions denote very small polarization.

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