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Revisiting the flocking transition using active spins

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Active matter systems are driven out-of-equilibrium by the injection of energy *at the single particle level*. This microscopic breakdown of detailed-balance is responsible for a wide range of phenomena. Among them, the flocking behavior is particularly interesting for physicists since it can be captured by very simple models of aligning self-propelled particles that exhibit genuinely non-equilibrium phase transitions.

Even though these models have been studied extensively in the last decades, the precise nature of the flocking transition and the underlying mechanisms remain elusive. Part of the difficulty comes from the fact that they are very hard to coarse-grain, being defined off-lattice and in discrete time.

We introduce a new flocking model, defined on lattice, that turns out to be simpler both to simulate and study analytically. We consider an active Ising model, in which spins both diffuse and align. The diffusion is biased so that plus or minus spins hop preferably to the left or to the right, which generates a flocking transition at low temperature/high density. We construct a coarse-grained description of the model that predicts this transition to be a first-order liquid-gas transition in the temperature-density ensemble, with a critical density sent to infinity. In this first-order phase transition, the magnetization is proportional to the liquid fraction and thus varies continuously. Using microscopic simulations, we show that this theoretical prediction holds in 2d whereas the fluctuations alter the transition in 1d, preventing for instance any spontaneous symmetry breaking.

[1] A.Solon, J.Tailleur, ArXiv e-prints 1303.4427, 2013