Connecting the physics of swarming animals and active matter

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Bird flocks, insect swarms and fish shoals resemble fluids made up of many individuals where the controlling interactions are social rather than physical in character [1]. Some progress has been made reverse-engineering candidates for these interactions that are local in space, either in a metric-based [2] or topological sense [3,4]. A question that has been largely overlooked is whether the interactions should be expected to be local in the first place. We discuss the evidence for them having a non-local character and, furthermore, that there is a natural choice for this that is consistent with the cognitive limitations of a bird's vision. We study the global character of the flocks that emerge from this model and their various phenotypes. Most significantly, an emergent state arises in which the probability that a typical bird can see out (sky) in any direction divided by the probability that its view is blocked by other bird(s) is O(1). We refer to this state as being marginally opaque. We present experimental data on bird flocks that confirm this prediction and discuss how these models may naturally be associated with evolutionary fitness, as well as being physiologically plausible. In the second part of the presentation I draw an analogy with a thermodynamic system of thermophoretic colloids [5]. In our work these are heated by a focussed external light source. We show that these systems can undergo first order transitions from compact to disperse states as the light intensity is varied. Intriguingly, we find that the same state of marginal opacity emerges: no compact state with a density below marginal opacity is stable. This reveals a previously unidentified connection between social and thermodynamic swarms.

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