MAR17-2016-000561

Abstract for an Invited Paper
for the MAR17 Meeting of
the American Physical Society

A Materials Approach to Collective Behavior

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Aggregations of social animals, such as flocks of birds, schools of fish, or swarms of insects, are beautiful, natural examples of self-organized behavior far from equilibrium. Understanding these systems, however, has proved to be quite challenging. Determining the rules of interaction from empirical measurements of animals is a difficult inverse problem. Thus, researchers tend to focus on the macroscopic behavior of the group instead. Because so many of these systems display large-scale ordered patterns, it has become the norm in modeling animal aggregations to focus on this order. Large-scale patterns alone, however, are not sufficient information to characterize all the dynamics of animal aggregations, and do not provide stringent enough conditions to benchmark models. Instead, I will argue that we should borrow ideas from materials characterization to describe the macroscopic state of an animal group in terms of its response to external stimuli. I will illustrate these ideas with recent experiments on mating swarms of the non-biting midge Chironomus riparius, where we have developed methods to apply controlled perturbations and measure the detailed swarm response. Our results allow us to begin to describe swarms in terms of state variables and response functions, bringing them into the purview of theories of active matter. These results also point towards new, more detailed ways of characterizing and hopefully comparing collective behavior in animal groups.