Nonequilibrium cluster formation in a model of active colloids with chemotaxis

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Recent experiments of active colloids show a coexistence of single particles and clusters [1]. In such a "dynamic cluster state" the clusters are themselves active and their sizes vary in time. Experiments of self propelling bacteria show similar behaviour [2], however, here a collapse to aggregates with large density is observed. We present a model of mobile colloids which exhibits both: a dynamic state and a collapsed state. In the model we seperate selfelectro- and diffusiophoretic effects where the former accounts for activity and the latter for interactions. Each particle produces a gradient of a chemical which generates phoretic motion of nearby colloids; similar to bacteria moving along gradients of chemicals. As the colloids are Janus particles phoretic forces as well as phoretic torques have to be considered.

We present a phase diagram where we investigate the influence of these torques and forces on clustering. For vanishing or negative torques, which orient particles against a chemical's gradient, and sufficiently large attractive phoretic forces we find a dynamic cluster state, as observed in experiments [1]. We show that it is characterized by a power law decay of the cluster distribution. On the other hand, when torques are positive and sufficiently large, similar to chemotaxis in bacteria, the gas-like state collapses into a single aggregate without showing significant clustering. We apply a moment expansion of the one-particle distributions which leads to equations similar to those introduced by Keller and Segel to describe chemotaxis. This analysis sheds light on the transition to the collapsed state.

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2. F. Peruani, J. Starruß, V. Jakovljevic, L. Søgaard-Andersen, A. Deutsch, M. Bär, *Phys. Rev. Lett.* **108**, 098102 (2012).