Active matter: emerging behavior and statistical description of intrinsically out of equilibrium systems.

Ignacio Pagonabarraga[1,2,3]
[1]CECAM, Ecóle Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
[2]Departament de Física de la Matèria Condensada, Universitat de Barcelona, Barcelona, Spain
[3] Universitat de Barcelona Institute of Complex Systems (UBICS), Universitat de Barcelona, Barcelona, Spain

Flocks of birds, schools of fishes, or bacterial colonies constitute examples of living systems that coordinate their motion. In all these systems their constituent elements generate motion due to energy consumption and can exchange information or react sensitively to chemical cues in order to move together or to react collectively to external signals [1]. Artificial systems, such as nanorobots, exploit the heterogeneous compositions of their surface to displace as a result of the heterogeneous chemical processes that take place in the presence of appropriate chemical substances.

All these systems are intrinsically out of equilibrium in the absence of any external driving. Therefore, their collective properties result as a balance between their direct interactions and the indirect coupling to the medium in which they displace, and a self-consistent dynamical approach is required to analyze their evolution. The mechanical balance that determines the states they develop spontaneously make these systems very versatile and have a natural tendency to for large scale aggregates. However, an understanding on the basic principles underlying the emergence and self-assembly on active systems poses fundamental challenges [2]. How do the relevant entities interact with each other? Can we identify universal, generic principles associated to the main features in the self assembly and emergent behavior of intrinsically out of equilibrium systems? [3] Are there mechanisms that can be shared by living systems and synthetic, active materials?

I will consider simple statistical models to address fundamental questions associated to these systems and will analyze the implications the generic self-propulsion has in the emergence of structures in suspensions of model self-propelled particles. I will discuss the potential of schematic models to address fundamental questions that still remain open, such as the connection of the effective phase diagram and pressure with effective equilibrium concepts [4]. In general, the steady state that characterizes these systems requires a consistent dynamic treatment. I will analyze the role that the medium in which active colloids displace has in generating correlations among active particles them. I will consider different mechanisms, such as swimming [5] or heterogeneous catalysis [6], that lead to spontaneous self-organization in the absence of external driving for a variety of active suspensions. Such a comparison will help to discern between specific ingredients and general features determining the emergent properties of active matter.

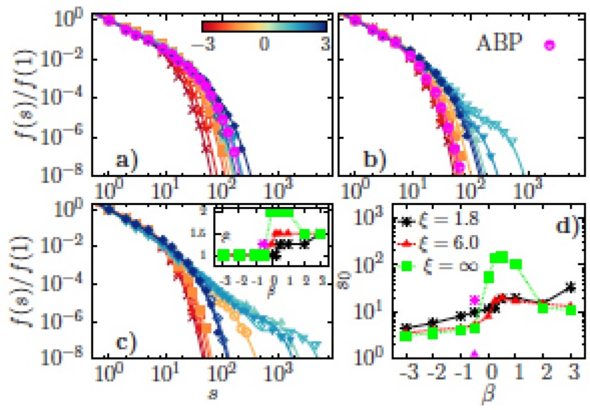

Figure 1: Cluster size distributions, $f(s)$, of suspensions of model swimmers at an intermediate volume fraction, $\phi = 0.1$. The swimming particles are spherical and interact through a Lennard-Jones potential. They displace in a Newtonian fluid at low Reynolds number. These model swimmers are characterized by their self-propelling velocity and the stress they generate in the surrounding fluid, quantified by β. Depending on the strength of the Lennard-Jones attraction, quantified by ξ, and the stress induced in the fluid $f(s)$ can vary significantly and develop, in some cases, an algebraic tail. In general, the suspension is characterized by the coexistence of dynamic clusters of rather different sizes (Figs.1 a-c). Fig.1.d shows the change of the characteristic cluster size as a function of the stre(extracted from Ref. [5])

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