Master 2 Internship

Title: Pressure measurement of 2D active and passive colloidal liquids

Type: experimental

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PhD funding (if any): no funding

Active fluids are composed of entities capable of using energy at their own scale to move or exert forces. The most striking examples are living systems, whether at the microscopic scale (bacteria, cells) or the macroscopic scale (fish, birds, mammals). The question then becomes how to describe and predict the behavior of such systems. For instance, can we describe the behavior of a flock of birds, a school of fish, or a suspension of bacteria in the same way we describe a fluid made of water molecules?

For passive fluids (classical fluids made of atoms or molecules), their macroscopic behavior can be described using thermodynamics, through equations of state that relate the relevant quantities of the system (pressure, volume, temperature, number of particles). However, for active fluids, such equations of state do not always exist. In some cases, for example, the mechanical pressure exerted by the system depends on the measuring instrument used, and is therefore not an intrinsic property of the system [1]. In such cases, how can we describe and predict the system's behavior?

In the Turbulence and Instability team, we study the "thermodynamic" properties of synthetic active systems using Janus colloids of micrometer size mimicking bacterial swimming. The goal is to better understand the properties of active systems and to discover new laws describing their behavior. To measure the properties of microscopic active systems, we recently developed in the lab a 2D piston made of magnetic particles that can be controlled by an external magnetic field. This piston will be used to probe and then compare the pressure and the rheology of both active and passive colloidal liquids to see the influence of the activity on the macroscopic properties of such systems.

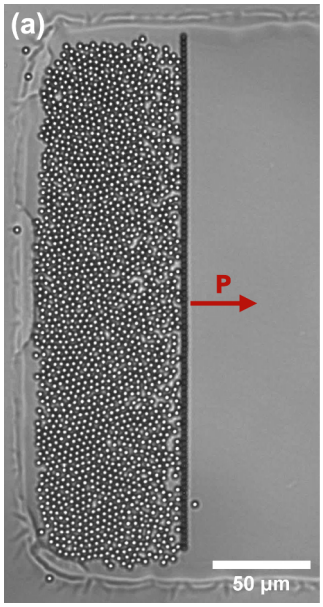

Figure: 2D piston measuring the mechanical pressure of a liquid of passive colloids, scale-bar 50 µm.

During the M2 internship, the student will perform measurements with the piston on a 2D liquid composed of microscopic passive hard spheres (see Figure) and active Janus particles. To do so, she/he will use a magnetic coil systems to manipulate the piston. From videos taken with a microscope, the student will perform image analysis and tracking to extract the position of the particles and the piston and then compute the relevant quantities (density, pressure, etc). She/he will then compare her/his measurements with existing theoretical expressions of pressure in passive and active liquids. This internship will allow to better understand the thermodynamic properties of active fluids and pave the way towards the understanding of living active systems such as bacterial.

[1] Active versus passive hard disks against a membrane: mechanical pressure and instability
G Junot, G Briand, R Ledesma-Alonso, O Dauchot, Physical review letters 119 (2), 028002