PhD: Active matter at the nanoscale

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Active matter is composed of elementary bricks that transduce energy to interact collectively. A prototypical example is given by living systems: nanomotors drive cells, which in turn organize on successive levels of hierarchy. Understanding how such small-scale processes can cooperate to generate a robust action across scales is a central question of biology and physics. Along this line, recent works have demonstrated the potential of synthetic colloidal particles to present emergent behaviors such crowding. However, studies have been focused on the use of micrometric colloids, restraining the range of dynamical behaviors that can be achieved. The effect of a reduction of scale of the elementary bricks in Active Matter systems on their dynamics remains to be explored.

In this context, the aim of this experimental PhD is to study active fluids made of nano-components. More specifically, we will investigate the non-equilibrium dynamics of self-propelled nanoparticles (NPs, 20 – 200 nm), for the bottom-up creation of functional micromachines (5 - 100 µm) [see Figure]. The main advantage of using nanoparticles is the significant increase in complexity per unit volume that can be achieved, with statistical ensembles in micrometric volumes. Due to their small size, nanoparticles also sediment very weakly and have the potential to self-organize in 3D when brought out-of-equilibrium. This suggests nanoparticles as ideal nanomotors to control active stresses at small scale and subsequently drive mesostructures, akin to cellular machineries.

This project investigates the dynamics of nanomotors at the individual and collective scales, with a focus on the non-equilibrium statistical physics of such active fluid. This is a highly interdisciplinary project, lying at the frontiers of active matter, optofluidics, nano-optics, and non-equilibrium statistical physics. In order to analyze the dynamics of nano-objects in

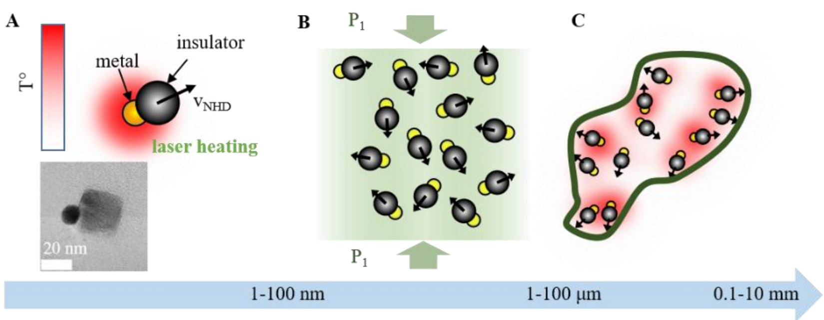

Fig.1: Scheme of the project. **A.** We will use nano-heterodimers as elementary building blocks, actuated by laser heating. TEM image from M.H. Delville. **B.** We will then study their collective dynamics in dense samples. **C**. Finally, we will use their collective behavior to drive a larger structure (here a vesicle), and investigate the effect of active pressure on its deformation dynamics.

spite of their small size and high thermal noise, we will use nano-optical correlation techniques and statistical analysis tools, coupled to fast imaging techniques. *In fine*, the research objectives are the following: i) Develop light-driven and fuel free self-propelled NPs, to build a 3D nanoscale active fluid and study its dynamics. ii) Implement optical tools to control and analyze the dynamics of the nanoparticles on small spatiotemporal scales and in dense samples. iii) Integrate the nanoscale active fluid in a soft structure, in order to explore the effect of internal stresses on its geometry, and reciprocally.

Research profile:

The PhD candidate will be in charge of all the research activity regarding the analysis of the dynamics of an active fluid at the nanoscale (setting and calibrating the setup and instruments, measurements, numerical analysis…). Ideally, the candidate has a training in soft matter and/or optics. A strong taste for multidisciplinary and experimental research is required (active matter, nano-optics, optofluidics, statistical physics, colloidal science…). Previous expertise in one or many of the above-mentioned fields would be a strong value.

Scientific environment :

The PhD student will be a full member of the Optoflow group of the Soft Matter and Biophysics team at the LOMA, University of Bordeaux. The field of expertise of the LOMA combines theory, simulations, experimental soft matter and optics, with non-equilibrium statistical physics, granular and fluid flows, optofluidics and biophysics. An active matter thematic is already implemented at the LOMA at the micro- and macroscale. This PhD research project will bring novel experiments in the field, together with a multiscale expertise in the LOMA. This work will be realized in collaboration with local actors from the University of Bordeaux/CNRS: for the synthesis of nanoparticles (M-H. Delville, DR CNRS, ICMCB, Bordeaux), and for theoretical aspects (J. Lintuvuori, A. Würger, T. Guérin, at the LOMA).

The candidate will have a full optical table at his/her disposal for carrying out the experiments. All components, including the nanoparticles, are already available to start the project.

Application:

Interested candidates should send their application by May 16th, 2022.
Please feel free to contact Antoine Aubret for any complementary information.
The following documents are required for applying:
- a full resume with academic results (max. 2 pages).
- a motivation letter (max. 1 page).
- one or two letters of recommandation for any student who is not part of the University of Bordeaux.
- a copy of the last degree obtained.
- a copy of academic records for 1st and 2nd Master years.