M2 internship + PhD – PhD start date any time in 2025

Magnetotactic Bacteria in Porous Media & Active Matter Anderson Localization

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Context Magnetotactic bacteria (MTB) are microorganisms that orient and navigate along the Earth's magnetic field lines, using chains of magnetic nanoparticles embedded in their membranes. These bacteria play an important role in marine ecology and have potential applications in targeted drug delivery. However, their motility and transport in complex porous environments, such as soils or the human vascular network, remain poorly understood.

Under weak confinement, MTB have been shown to move collectively as a soliton, i.e. a density-wave that propagates freely [1]. Yet MTB mostly occupy the seabed, a densely confined porous media. Within such disordered media, we expect the onset of an *Anderson localization* [2], whereby the disorder leads to spatial confinement of these waves; in our context, we aim to understand the critical level of disorder that triggers a localization transition.

Objectives We aim at

1. Generating theoretical models, at the continuum [3] and particle-based [5] levels, that are predictive of the onset of solitons in obstacle-free solutions.

2. Predicting the dispersion of such active soliton within the set of model-disordered systems already implemented in our experimental system (pillar forest, [4])

3. Comparing our theoretical results with experiments performed in the lab of MTB within microfluidic channels.

Methods The work will be mostly theoretical, but depending on the applicant's wish and profile, we can adapt the PhD work from pure theory to a mix of theory and experimental work. The active particle model for MTB will incorporate magnetic torque, hydrodynamic interactions, self-propulsion (active Brownian particles), and steric repulsion from the channel wall.

Relevance and impact Our system is a minimal model to understand the role of soil structure in ecology and network topology in nanobiomedical applications, using active matter concepts.

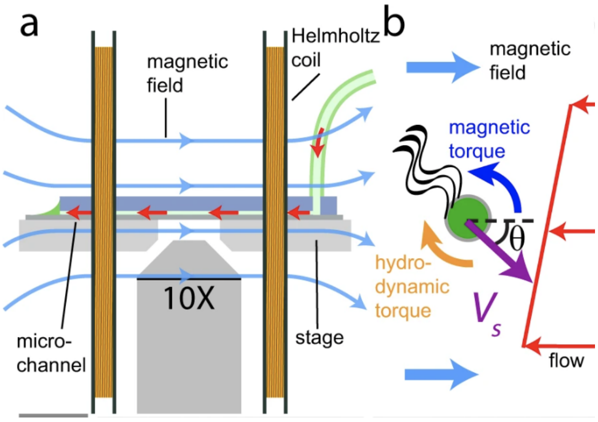

Fig 1: (a) N. Waisbord's team experimental system (b) Sketch of torques on MTB. From Ref. [4].

The team The PhD applicant will be integrated into the AMid*Ex TBTM consortium, with shared supervision with
- **Jean-François Rupprecht,** theoretician building active hydrodynamical models for living materials (Prasad Science 2023).
- **Nicolas Waisbord**, physicist, designing models & experiments of magnetotactic bacteria and porous media [4]. JFR & NW collaboration dates from 2016 [5].

PhD funding is secured through AMid*Ex grant.

Location: Laboratoire de Chimie Bactérienne & Centre de Physique Théorique, Marseille Luminy (within the Calanques National Parc, arguably the most beautiful campus in the world).

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References

[1] Waisbord, N., Lefèvre, C. T., Bocquet, L., Ybert, C., & Cottin-Bizonne, C. *Destabilization of a flow focused suspension of magnetotactic bacteria*. PRF (2016).
[2] Abraham, A. J., Malkov, S., Ljubetic, F. A., Durey, M., & Sáenz, P. J. *Anderson localization of walking droplets*, PRX (2023)
[3] Meng, F., Matsunaga, D., Mahault, B., & Golestanian, R. (2021). Magnetic Microswimmers Exhibit Bose-Einstein-like Condensation, PRL (2021)
[4] Waisbord, N., Dehkharghani, A., & Guasto, J. S.. *Fluidic bacterial diodes rectify magnetotactic cell motility in porous environments*. *Nature Comm.* (2021)
[5] Rupprecht, J. F., Waisbord, N., et al. (2016). *Velocity Condensation for Magnetotactic Bacteria*. *PRL* (2016)