Simulating the Dynamics of Magnetic Colloids in Oscillating Magnetic Fields (Simulacije dinamike magnetnih koloida u oscilirajućim magnetnim poljima)

Dr. Deniz Mostarac

University of Rome "La Sapienza"

Description: Magnetic fluids have garnered significant attention in the medical field, particularly in cancer treatment. These fluids have been used extensively as a complementary element to traditional cancer treatment options by inducing magnetic hyperthermia. When an oscillating magnetic field with a frequency below the Brownian relaxation limit is applied, each suspended magnetic colloid rotates along with its magnetization. However, for frequencies above this limit, the particles can switch their internal magnetization, resulting in energy dissipation due to magnetic hysteresis [1]. The application of magnetic hyperthermia in cancer treatment is contingent on manipulating material properties so that oscillating magnetic fields lead to high magnetic losses [2]. To optimize these properties, such as saturation magnetization, anisotropy constant, particle size, and shape, effective use of simulation techniques is required. The complex relaxation processes associated with magnetic colloids have so far warranted a micromagnetic simulations approach. However, this approach has limited scope and is not applicable for the study of collective properties or to even access the relevant timescales.

Goals: This project aims to study the rotation and total magnetization (as a function of time) of spherical, cubic, and disk-shaped, multidomain magnetic colloids in oscillating magnetic fields. To simulate the internal magnetic structure and dynamics of the colloids, we will take a multiscale approach consisting of a single-spin Landau-Lifshitz-Gilbert equation model [3], and a raspberry colloid model where the domains are thermal Stoner-Wohlfarth particles [4]. The knowledge gained in contrasting these approaches to “ground-truth” micromagnetics, using varying levels of complexity, will circumvent current limitations and help expand the potential applications of magnetic fluids in cancer treatment.

Required Skills: coding in Python (must) C++ (desirable), statistical and computational physics (must), theory of magnetism (desirable)

[1]: Yu. L. Raikher, V. I. Stepanov, J. Magn. Magn. Mater., 368 (2014) 421-427

[2]: S. Helbig et al., Phys. Rev. B, 107 (2023) 054416

[3]: T. L. Gilbert, IEEE transactions on magnetics, 40 (2004) 3443–3449

[4]: Chuev, M. A., et al., *Journal of Physics: Condensed Matter* 19.50 (2007): 506201.