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MAGNETIC SKYRMIONS: FROM THEORY TO APPLICATIONS

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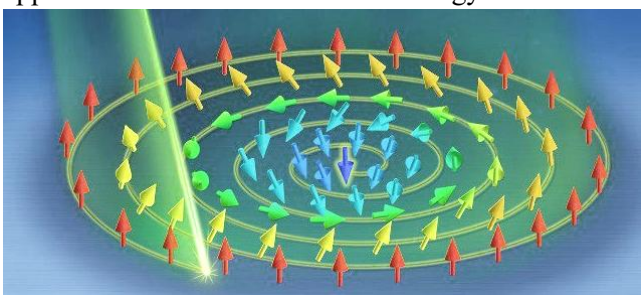
This research master's degree research project could be followed by a PhD	☒ YES ☐ NO

Skyrmions, originally described by Skyrme in 1962, are topological solitons located in space and exhibiting quasiparticle properties: they have a quantized topological charge, interact via attractive or repulsive forces, and can condense into an ordered phase. The mathematical concept of the skyrmion has spread to many branches of physics. In condensed matter, a revival of skyrmion physics was recently motivated by the experimental discovery of magnetic skyrmions [1]. These magnetic skyrmions are local vortices of nanometer-sized magnetization that can be stable at room temperature and controlled by a current or an electric field. These properties are very promising for applications in information technology such as race track memories [2], magnetic logic, and stochastic and neuromorphic computing [3].



Internship Context:
The MEM team specializes in the theoretical modeling and experimental characterization of magnetic nanostructures. The internship focuses on 3D micromagnetic simulations of skyrmions. The intern will be supported to understand the micromagnetic models involved and will contribute to the performance of simulations directly useful for our ongoing publications in collaboration with a laboratory of applied mathematics in Pisa (Italy). These simulations will be based on GPU-accelerated softwares [4,5] which are is based on the theory of micromagnetism. Our recent work on skyrmion and stripes theory [6,7] allowed us to highlight open questions for which micromagnetic simulations are necessary. This particularly concerns the study of how these skyrmions and stripes begin to develop an internal structure as a function of thickness. The answer to this question is fundamental for applications because this structure would modify their dynamics. The internship could continue with a thesis and contain an experimental component.

References:

[1] N. Nagaosa et. al. Nature Nanotechnology 8 899 (2013)
[2] R. Tomasello et. al. Sci. Rep. **4** 6784 (2014)
[3] D. Prychynenko et. al. Phys. Rev. Applied **9** 014034 (2018)
[4] https://mumax.github.io/
[5] https://quantumandclassical.com/excalibur/
[6] A. Bernand-Mantel et. al. PNAS 119 e2122237119 (2022) [here file]
[7] A. Bernand-Mantel et. al. PRB 111 184423 (2025) [here file]

Keywords, areas of expertise	Theory, modeling, simulations, micromagnetism
Required skills for the internship	Taste for applied physics, modeling, programing