

INTERNSHIP PROPOSAL

Laboratory name: Institut de minéralogie, de physique des matériaux et de cosmochimie (IMPMC), Sorbonne Université – CNRS – MNHN

CNRS identification code: UMR 7590

Internship director's name: Benjamin Lenz

e-mail: benjamin.lenz@upmc.fr

Phone number: 01 44 27 98 19

Co-supervisor: Hebatalla Elnaggar, Helmholtz-Zentrum Berlin (Germany)

Web pages: https://impmc.sorbonne-universite.fr/en/research_teams/quantum-theory-of-matter.html

https://www.helmholtz-berlin.de/forschung/oe/ps/magnons/index_en.html

Internship location: Theory: Sorbonne Université, 4 place Jussieu, 75005 Paris

Experiments: BESSY II synchrotron, Helmholtz-Zentrum Berlin, Germany

Thesis possibility after internship: YES

Funding: NO (PhD scholarship has to be applied for from ED-PIF)

Investigation of Altermagnetism in Perovskite Oxides

Altermagnets are a novel class of magnetic materials that combine properties associated with ferro- and antiferromagnetism: Like antiferromagnets, their magnetic moments compensate each other, resulting in no net magnetisation. At the same time, their particular crystal and magnetic symmetries can produce a spin-dependent electronic structure, a property that is attractive for future technologies based on controlling electron spins rather than only their charge [1,2]. Experimentally demonstrating altermagnetism remains challenging, especially in electrically insulating materials where commonly used transport and photoemission techniques cannot easily be applied.

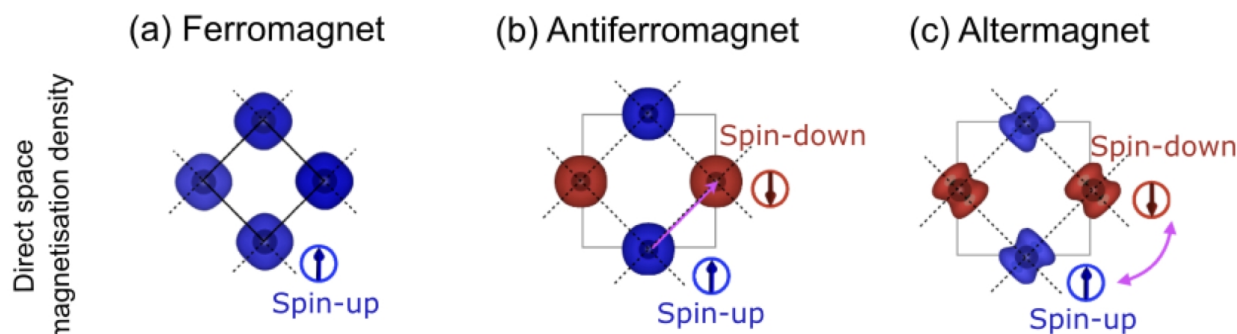


Figure 1: Illustration of the three non-relativistic collinear magnetic phases showing their spin arrangements and magnetization densities: a) Ferromagnet, b) Antiferromagnet, and c) the newly identified Altermagnet.

During this internship, you will investigate a family of magnetic perovskite oxides, ReTmO_3 (Re = rare-earth element and Tm = transition metal), several of which have been predicted to be altermagnetic based on their crystal and magnetic symmetries [3,4]. Perovskite oxides provide a particularly interesting platform because their magnetic properties can be tuned in different ways. Their chemical composition can be modified by substituting different rare-earth or transition-metal elements, while thin films can be grown on different substrates to slightly compress or stretch the crystal lattice.

The project will combine theoretical calculations with state-of-the-art X-ray experiments. You will perform in a first step density functional theory (DFT) calculations at IMPMC, followed by multiplet calculations to understand how the crystal and magnetic structure determines the expected signatures of altermagnetism. You will then have the opportunity to participate in an X-ray magnetic circular dichroism (XMCD) experiment at the BESSY II synchrotron at HZB in Berlin. By comparing theoretical predictions with experimental measurements, the aim will be to determine whether these materials exhibit measurable signatures of altermagnetism and to understand how these signatures depend on their magnetic structure.

References: [1] Šmejkal et al., *Phys. Rev. X*, **12**, 031042 (2022), [2] Krempaský et al., *Nature*, **626**, 517 (2024), [3] S. Bandyopadhyay et al., *Phys. Rev. B* **112**, 064405 (2025), [4] M. Naka et al., *npj Spintronics* **3**, 1 (2025).

Condensed Matter Physics: YES

Soft Matter and Biological Physics:

NO

Quantum Physics:

YES

Theoretical Physics:

MAYBE

Physics of Energy and Climate Dynamics:

NO