ED 52 - PHAST
Physique & astrophysique de Lyon
Ecole doctorale

UNIVERSITÉ DE LYON

PhD Project : «Magnetic Moment Fragmentation: disorder and topology»

Institute: Ecole Normale Supérieure de Lyon

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Collaborators: Elsa Lhotel (Experiment, Grenoble), Mike Zhitomirsky (Theory, Grenoble)

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Project description:

The quasi particle excitations of the frustrated magnets known as spin ice are topological defects carrying magnetic charge – magnetic monopoles [1,2], solid state analogues of the elusive fundamental particles predicted by Dirac almost a century ago [3]. The magnetic moments of spin ice hence map onto elements of an effective electromagnetic field [4,5] making an experimentally relevant generator of emergent electromagnetism. Remarkably, the field "fragments" [4,5] into distinct divergence full and divergence free parts via a Helmholtz decomposition. This emergent two component system yields an extensive phase diagram, rich in thermodynamic and topological properties [6,7].

In this theoretical and numerical project, we will explore the recently established phase diagram [6,7]. Two particular directions of study will be the stability of the phase diagram in the presence of disorder and the three-dimensional topological phase transitions characteristic of the emergent electromagnetic picture. Both questions are highly relevant for experiment and linked to intensive experimental programs in place in Grenoble and elsewhere.

The project is ideally suited to students motivated by numerical methods but who wish to remain close to the fundamental science. The first axis of study will require high performance methods to deal with long range (Coulomb) interactions and disorder, while the second will require the development of non-local (loop) algorithms adapted to topological questions. Collaborations will initially be with groups in Grenoble, in Argentina and in the United Kingdom.

An attractive three-year Ph. D. scholarship is available for this project, beginning September 2021. The project is also open to students enrolled in the "Diplome d'ENS", with a predoctoral year financed through the "PLR" program. Students will be encouraged to participate in international conferences and schools and funding for these is available throughout the project.

[1] Castelnovo, C., Moessner, R. & Sondhi S. Magnetic monopoles in spin ice. Nature 451, 42-45 (2008).

[2] L. Jaubert and P. C. W. Holdsworth, "Signature of magnetic monopole and Dirac string dynamics in spin ice", Nature Physics 5, 258 - 261 (2009).

[3] P. A. M. Dirac, "Quantised singularities in the electromagnetic field", Proc. R. Soc. A133, 60, (1931).

[4] M. E. Brooks-Bartlett, S. T. Banks, L. D. C. Jaubert, A. Harman-Clarke, and P. C. W. Holdsworth. Magnetic-moment fragmentation and monopole crystallization. Phys. Rev. X, 4:011007, Jan 2014.

[5] Elsa Lhotel, Ludovic D. C. Jaubert and Peter C. W. Holdsworth, "Fragmentation in Frustrated magnets", to appear, J. Low. Temp. Phys., (2020).

[6] V. Raban, C.T. Suen, L. Berthier, P.C.W. Holdsworth, "Multiple symmetry sustaining phase transitions in spin ice", Phys. Rev. B **99**, 224425 (2019).

[7] V. Cathelin et. Al. "Fragmented monopole crystal, dimer entropy and Coulomb interactions in $Dy_2Ir_2O_7$, arXiv:2005.08807, to appear in Phys. Rev. Res. (2020).