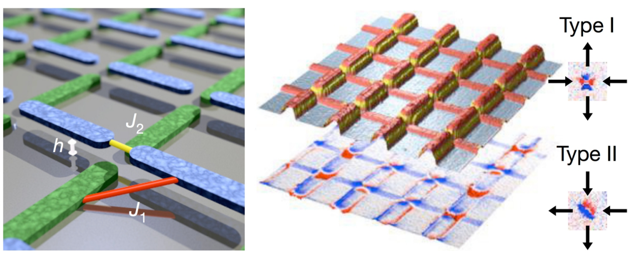
Artificial frustrated spin systems

In physics as in chemistry, it is generally accepted that matter orders, like in a crystalline solid, when cooled at sufficiently low temperature. There also exist systems that remain disordered in the manner of a gas or a liquid, even at the lowest temperatures accessible experimentally. What is much more rare is a state of matter that would be both ordered and disordered everywhere in the system, i.e. that would be both solid and liquid for example. Such a phase, “liquid” and “solid” at the same time, has been observed recently in our group, in an artificial magnetic system made of elongated nanomagnets arranged as a lattice of equilateral triangles connected by their corners (kagome lattice) [1]. This unusual state of matter is distinctly different than the magnetic equivalent of a glass of water containing ice cubes, which would be, simply, a system presenting the coexistence of two physically separated phases, out of thermodynamic equilibrium. Here instead, we have demonstrated, in an artificial system, the magnetic equivalent of both liquid and crystalline phases at any time, without being phase separated [1].

More generally, artificial magnetic systems offer the opportunity to explore intriguing and fascinating phenomena in condensed matter physics and constitute a formidable playground to test experimentally many different theoretical predictions. For example, we also fabricated for the first time a peculiar disordered magnetic state on a square lattice that was predicted back in the sixties, but never observed experimentally [2]. This system is interesting as it is characterized by a finite entropy, even at zero temperature, thus (apparently) violating the third law of thermodynamics. Besides, excitations in this square system behave as classical analogues of magnetic monopoles, thus (apparently) contradicting what we learn from magnetostatics. We now would like to go a step further and investigate some of the exotic properties predicted in these two systems.

The main objective of this PhD work is to explore possible new states of matter in kagome and square arrays of nanomagnets. Some properties have been predicted but never observed experimentally. The goal of this PhD is to image these states and their associated properties in real space, using magnetic imaging techniques available in the lab. The PhD student will be involved in the design of the artificial magnetic systems based on nanofabrication techniques also available in the lab.



(left) Schematics of the artificial square system we studied. (right) Topographic (top) and magnetic (bottom) images of an experimental realization of an artificial square system characterized by a finite entropy at low temperature and monopole-like excitations. From Ref. 2.

[1] B. Canals et al., Nature Communications **7**, 11446 (2016).
[2] Y. Perrin, B. Canals and N. Rougemaille, Nature **540**, 410 (2016).

Required skills: nanosciences, nanophysics, condensed matter physics.
Host laboratory: Institut NEEL – Grenoble, France Starting date: October 1st, 2018
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