Fluctuation and Equilibration in Artificial Magnetic Quasicrystals

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Frustration is the inability of a physical system to simultaneously satisfy competing constraints. It occurs across physics and beyond, but is a particularly important topic in magnetism, a field in which (relatively) simple systems can be represented by toy statistical mechanical models that can then be extended into other fields model phenomena as diverse as forest fires and financial networks.

The study of frustration in magnetism has recently been given a new lease of life since artificial frustrated systems can now be built and studied using nanotechnology: in the case of magnetism, this is done by constructing arrays of magnetic nanoelements arranged in patterns where their magnetostatic interactions are frustrated. The advantages of this approach is that it is possible to build experimental realisations of models that nature does not provide crystal structures for, with every parameter in the model tunable by adjusting the element size, shape, and spacing. Moreover, the microstates of these artificial statistical mechanical systems can be inspected in detail using advanced magnetic microscopy methods, including time-resolved imaging to study thermal fluctuations in those microstates.

To date, almost all artificial frustrated spin systems have been ‘crystalline’ in that they are periodic arrays. In particular, square and hexagonal arrays have been studied as analogs of spin ice crystals. Thermal excitations in spin ices show appear as emergent quasiparticles with many of the properties of magnetic monopoles, physics that has been reproduced in their artificial counterparts. In this project we will study quasicrystalline systems, where the magnetic nanoelements are arranged on a Penrose tiling. Whilst small parts of this pattern repeat, the whole pattern never does. We have begun to study these Penrose-based systems in an athermal state, where the energy scales are all much larger than kT and so the state of the system is frozen in. In this project we will build systems that are thermally fluctuating by tuning these energy scales towards kT. In this way we will study collective nature of the freezing and melting of the artificial spin system and seek to understand the nature of its emergent excitations.