Magnetic skyrmions in the presence of free electrons

In the last two decades, a new quasiparticle was found experimentally, called a magnetic skyrmion. A quasiparticle is not a fundamental particle but rather an object which could be described as a particle since it has particle-like properties. Much like one would consider basketball a single entity, but it is really made up of many atoms. Nevertheless, a skyrmion is much smaller, typically on the order of tens of nanometers.

A skyrmion is a stable quasiparticle where the magnetic moments in atoms align in a vortex-like structure, as shown in the figure. The magnetic moment is an intrinsic property that all atoms have, and it can be thought of as an arrow which can point in any direction in three-dimensional space. It is the vortex-like alignment of the magnetic moments which we call a skyrmion.

Consider a coffee mug; if it was made out of play dough, one could deform it into a donut without removing the hole or adding a hole. If we instead consider a ball made out of play dough, then one cannot deform it into a donut without creating a hole. Similarly, in our case, the skyrmion is stabilized by topology, for example, one cannot simply force the skyrmion into a state where everything is just red (see figure) without breaking the topology.

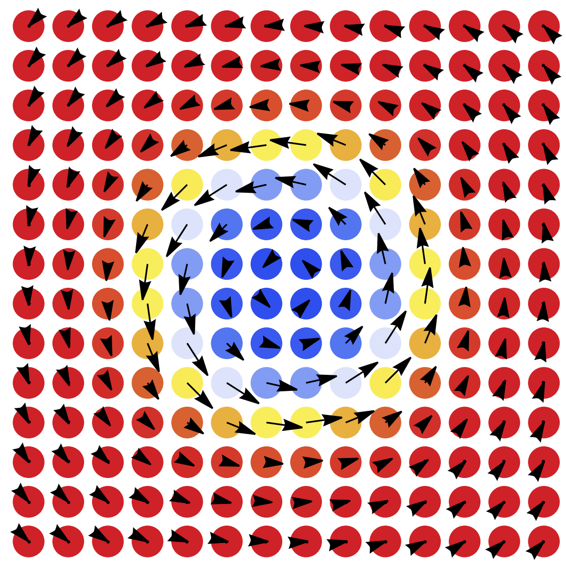

Figure 1: A Magnetic skyrmion in a 2D material. The magnetic moments are shown in the figure. The coloring indicates the z-component where -1 blue, i.e. completely downwards and +1 is red. The arrows then shows the direction in the 2D plane the skyrmion lives in.

Notice that we have a grid in the figure, which we call a lattice, and we will use a lattice model to simulate the skyrmion. A lattice model is a model that lives on a discrete set of points: instead of simulating a continuous space, one can restrict the simulation to discrete lattice sites. This is motivated by the physical scenario that one is faced with in a solid, where atoms are bound together to form a periodic structure. The discrete set of points then corresponds to the orbits of the atoms, where electrons can reside. Lattice models are used extensively in theoretical physics.

We use a much more complicated lattice model than what is common in the community to capture additional physics. The model which we use contains a further important aspect. Namely, it contains free electrons. In the compounds which can facilitate skyrmions, free electrons are typically present. These have previously been shown to have a significant effect, but they should also be addressed in the context of skyrmions.

Using such a model, we study the movement of the skyrmion when an electric current is applied. In previous studies, people have found that the velocity is proportional to the current; this is not always the case in our model. Due to our model also including free electrons, one could argue it is close to reality, and thus, our prediction could be experimentally tested. Additionally, we have found that the included free electrons behave in a topologically out-of-the-ordinary fashion. Furthermore, using our model the behaviour of the free electrons have also been characterized.