Antiferromagnetic Emergent Electrodynamics

Electric and magnetic fields are one of the fundamental pieces of human knowledge that have invaded our modern life and understanding of the nature. From a practical point of view, these have been the cornerstone of all forms of technologies from the telegraph and computers to Wi-Fi. On the other hand, on the fundamental side, electric and magnetic fields have been important to explore different forms of organization of matter as magnetism and superconductivity as well as exotic phenomena as the quantum Hall effect and topological insulators.

Thanks to Maxwell's formulation, electric and magnetic fields are seen as the manifestation of the same phenomena by promoting them to a unified vision in terms of the *electromagnetic field* concept. However, despite of his very fundamental nature, electromagnetic fields can arise in condensed matter systems as the result of complex microscopic processes that leads to the *emergent electromagnetic fields*. Skyrmions, swirling magnetic structures living in magnets with strong spin orbit interaction, can also be the ground for emergent electrodynamics. Outstanding effects happen when electrons displace along such as structures. If electrons move in some direction these will be affected by a force, which derives from the emergent electrodynamic potential, that deflect its trajectories and thus resulting in a transverse current. This effect is known as *Topological Hall effect* and it turns out to be quantized by the topological charge of the skyrmions.

The central goal of this project concerns the study of the emergent electromagnetic fields generated by magnetic textures in antiferromagnetic materials. As a first step in this endeavor, we will introduce ourselves with basic notions of antiferromagnets and phenomenology of magnetic textures. The next stage embraces the calculation of Maxwell-like equations for the emergent electromagnetic field and its effect on the transport of charge currents in metallic antiferromagnets and magnons in antiferromagnetic insulators. Ultimately, the aim of the last stage is to study the interaction between magnons and a static skyrmion, as a direct application of the above results. Phenomena as topological spin Hall effect and topological magnon Hall effect will be within our scientific radar. This project mainly concerns analytical calculations however numerical simulations are welcome.

Pre-knowledge requirements: Basic courses in solid state physics, electromagnetism and mathematics.

Supervisors:
Arne Brataas
Alireza Qaiumzadeh alireza.qaiumzadeh@ntnu.no
Roberto Troncoso r.troncoso@ntnu.no