Skyrmions, Merons and Monopoles: Topological Excitations in Chiral Magnets

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Stable topological excitations such as domain walls and vortices are ubiquitous in condensed matter as well as high energy physics and are responsible for many emergent phenomena. In 2009 a new mesoscopic spin texture called skyrmion was discovered experimentally in certain conducting and insulating magnets. It is now believed to exist in Bose-Einstein condensates, 2D electron gases, superconductors, nematic liquid crystals among many other systems. This topological excitation was originally proposed by Tony Skyrme in 1958 in a nonlinear field theory of baryons. In the temperature-magnetic field phase diagram of chiral magnets, skyrmions form a triangular lattice in the low temperature and intermediate magnetic field region (in thin films). In metallic magnets, skyrmions can be driven by a spin polarized current while in insulating magnets by magnons. The threshold current density to depin skyrmions is 4 to 5 orders of magnitudes weaker than that for magnetic domain walls. The low depinning current makes skyrmions extremely promising for applications in spintronics. I will first attempt to summarize the experiments and present an overview on skyrmions. Then I will demonstrate how increasing the easy-plane anisotropy results in a transition from a triangular lattice of skyrmions to a square lattice and eventually to merons. The latter are essentially half-skyrmions, with half the topological charge and have been experimentally observed. Finally, I will show that under current driving skyrmion tubes can split or merge at certain points leading to the formation of magnetic monopoles and anti-monopoles connected by a Dirac string.

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