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Intertwining of Magnetic Skyrmions and Abrikosov Vortices

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Abstract:

We investigate the mutual interaction between Abrikosov superconducting vortices and topological magnetic ordered states such as skyrmions, in a bilayer heterostructure embedded in an external magnetic field. The method that we use to study the system is based on the Fourier expansion of the magnetisation and superconducting order parameter, and the subsequent minimisation of the free energy functional of the combined system. We employ a Lagrange multiplier technique in order to satisfy exactly, at each point in space, the constraint of $M^2 = 1$ required by micromagnetics. By first investigating the non-centrosymmetric magnetic material alone, we identify and compute exactly, up to numerical accuracy, the critical fields corresponding to the helical-skyrmion and skyrmion-ferromagnetic phase transitions induced by the external magnetic field. We also identify new metastable shapes of the skyrmion lattice that have never been observed before, and we argue that such configurations can be stabilised by the presence of superconducting vortices, forming an intertwined lattice with the magnetic skyrmions.