Thermal Stability of Skyrmions in Transition Metal Dichalcogenide-Based 2D Magnets

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Magnetic skyrmions are topologically nontrivial spin structures at the nanoscale. They can be efficiently manipulated by electric currents or magnetic fields, and offer great potential as information carriers in novel spintronic devices, for high-density, low-power data storage [1] and for novel computing paradigms. The recent discovery of two-dimensional (2D) magnets has significantly enhanced the potential for stabilizing skyrmions in novel 2D materials. Among these, transition metal dichalcogenides (TMDs) are particularly promising due to their unique magnetic properties [2]. TMDs with broken inversion symmetry, such as Janus monolayers (Fig. 1a) and van der Waals heterostructures, combined with robust spin-orbit coupling, provide an ideal platform for stabilizing skyrmion phases, making them promising for spintronic applications with a large control over the magnetic interactions through interface engineering [3]. The thermal stability of metastable isolated skyrmions is a critical factor for their use in applications. Their stability has so far been investigated in transition metal ultrathin films and multilayers, where it was revealed that skyrmions benefit from an important entropic stabilization effect, in addition to stabilization from their energy barrier [4].

In this study, we explore the thermal stability of skyrmions in TMD-based 2D magnets (Fig. 1b) using a combination of density functional theory and atomistic spin simulations. We calculate the magnetic exchange interactions, anisotropy, and Dzyaloshinskii-Moriya interaction from first principles, which are then mapped onto an extended Heisenberg Hamiltonian. The stability of metastable skyrmions is evaluated by means of harmonic transition state theory [5]. The results provide insights into the mechanisms behind skyrmion stability in 2D magnets and emphasize the potential of TMD-based materials for skyrmionics.

References

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Figures

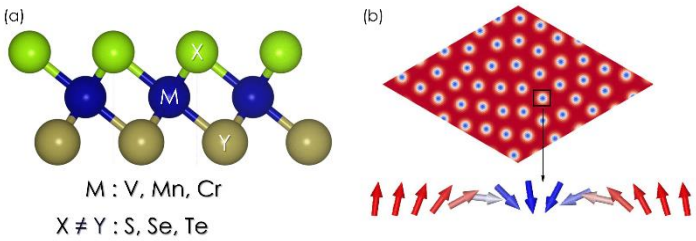

Figure 1: (a) Side view of a 1T phase Janus TMD monolayer, (b) Spin maps of the Néel-type skyrmion lattice phase in CrSeTe (top), and corresponding cross section along the radius of a single skyrmion (bottom).

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