Thermal stability of metastable magnetic skyrmions

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Isolated skyrmions usually exist as metastable excitations of the ferromagnetic ground state and can be long-lived. Their lifetime under thermal fluctuations can be described in terms of the Arrhenius law,

$$\tau^{-1} = f_0 e^{-\Delta E / k_B T}.$$

In order for skyrmions to be used as information carriers in novel spintronics devices, a high stability at room-temperature is required, and the ability to predict that stability is therefore crucial. In this work, we firstly use Kramers' approach in many dimensions – i.e., Langer's theory [1], to obtain lifetimes of skyrmions [2,3]. While this is a computationally optimal solution, it relies on many assumptions which may not always hold. For this reason, we also employ an alternative method, forward flux sampling (FFS) [4], which enables an exploration of the phase space free from assumptions. We obtain a good agreement between FFS and Langer's method for a skyrmion's collapse rate [5]. Within both methods, we report variations of the Arrhenius prefactor f_0 by several orders of magnitude when varying the applied field, which translates a strong entropic contribution to skyrmions' stability linked with their internal eigenmodes. This highlights the importance of quantifying the prefactor in complex systems with many degrees of freedom.

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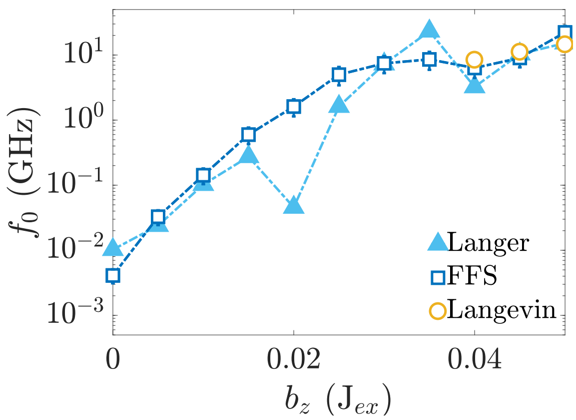

FIG: Attempt frequency for skyrmion collapse rate as a function of destabilizing applied field in units of the isotropic exchange coupling constant J_{ex} calculated via Langer's theory, forward flux sampling, and direct Langevin simulations.

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