Skyrmion stability and entropy in presence of thermal fluctuations

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Magnetic skyrmions are attracting a growing attention for both their fundamental properties (non-trivial topology) and possible applications [1]. At room temperature, skyrmions exhibit internal deformations, non-stationary breathing mode and thermal drift [2,3], which give rise to a stochastic behavior of the geometrical parameters, i.e. diameter D, perimeter p and area A of the skyrmion core [2,3]. However, a number of skyrmion configurations having the same energy [3] can be stabilized, so that a conformational entropy can be introduced [4].
Here, we performed micromagnetic simulations of a single skyrmion in a confined circular sample at room temperature T=300 K as a function of the external field H, similarly to Ref. [3]. In order to identify the skyrmion configurations with the same energy, we defined a deformation index d_i computed as $d_i = p^2/4\pi A^2$. In Fig. 1, we show some examples of the skyrmion configurations at H=0 mT with same d_i and, as a result, the same free energy. Similar results are obtained for H=25 mT and 50 mT (not shown). On this basis, we can calculate: (*i*) the average diameter of the skyrmion via an integration over the Boltzmann distribution, and (*ii*) the conformational entropy of the skyrmion by exploiting the analogy of its thermodynamic behavior with the typical one of biological molecules [4].

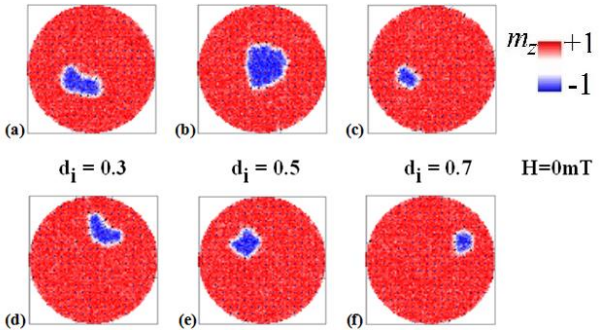

Figure 1: Magnetization spatial distribution of the skyrmion as a function of d_i for H=0mT and *T*=300K. In (a) and (d), d_i =0.3, in (b) and (e), d_i =0.5, and in (c) and (f) d_i =0.5. The color scale is related to the out-of-plane components of the magnetization (blue negative, red positive).

[1] G. Finocchio et al., J. Phys. D. Appl. Phys. **49**, 423001 (2016).
[2] J. Barker et al., Phys. Rev. Lett. **116**, 147203 (2016).
[3] R. Tomasello et al., arXiv:1706.07569 (2017).
[4] K. K. Frederick et al., Nature **448**, 325 (2007).