Beyond skyrmions: Alternative magnetic nano-objects for spintronics

Börge Göbel,[1,2] J. Jena,[2] O. Tretiakov,[3] S. Parkin,[2] and I. Mertig[1]

[1] *Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany*
[2] *Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany*
[3] *The University of New South Wales, Sydney, Australia*

Magnetic skyrmions have attracted enormous research interest since their discovery a decade ago. Especially the non-trivial real-space topology of these nano-whirls leads to fundamentally interesting and technologically relevant effects – the skyrmion Hall effect of the texture and the topological Hall effect of the electrons. Furthermore, it grants skyrmions in a ferromagnetic surrounding great stability even at small sizes, making skyrmions aspirants to become the carriers of information in the future.
Still, the utilization of skyrmions in spintronic devices has not been achieved yet, among other reasons, due to shortcomings in their current-driven motion. In this talk, we present our recent advances in the field of topological spin textures that go beyond skyrmions. The majority of the discussed objects can be considered the combination of multiple skyrmions or the skyrmion analogues in different magnetic surroundings, as well as three-dimensional generalizations. We classify the alternative magnetic quasiparticles – some of them observed experimentally, others theoretical predictions – and present the most relevant and auspicious advantages of this emerging field [1].
A special focus is on magnetic antiskyrmions [2,3,4], bimerons [5], antiferromagnetic skyrmions [6] and hopfions [7]. These objects exhibit advantageous emergent electrodynamic effects compared to conventional skyrmions, either due to their lower symmetry or due to a compensated topological charge. As we will show, all four of these objects can be driven parallel to the current, without a skyrmion Hall effect which makes them the ideal bits in data storage devices. Furthermore, we predict several interesting emergent electrodynamic effects like a pure topological Hall effect for the bimeron [5] or a topological spin Hall effect for the antiferromagnetic skyrmion [6]. Also, we show that some of these objects can even coexist, allowing for an advanced version of the racetrack memory data storage, where a bit sequence could, for example, be encoded by a sequence of skyrmions ('1' bit) and antiskyrmions ('0' bit). This concept would be more reliable than conventional racetracks.

References:

[1] B. Göbel, I. Mertig, O. Tretiakov. Physics Reports 895,1 (2021)
[2] J. Jena*, B. Göbel*, S. Parkin. et al. Nature Communications 11, 1115 (2020)
[3] J. Jena*, B. Göbel*, S. Parkin. et al. Science Advances 6, eabc0723 (2020)
[4] P. Sivakumar, B. Göbel, S. Parkin. et al. ACS Nano 14, 13463 (2020)
[5] B. Göbel, I. Mertig, O. Tretiakov. et al. Phys. Rev. B. 99, 060407(R) (2019)
[6] B. Göbel, A. Mook, J. Henk, I. Mertig. Phys. Rev. B. 96, 060406(R) (2017)
[7] B. Göbel, C. Akosa, G. Tatara, I. Mertig. Phys. Rev. Research 2, 013315 (2020)