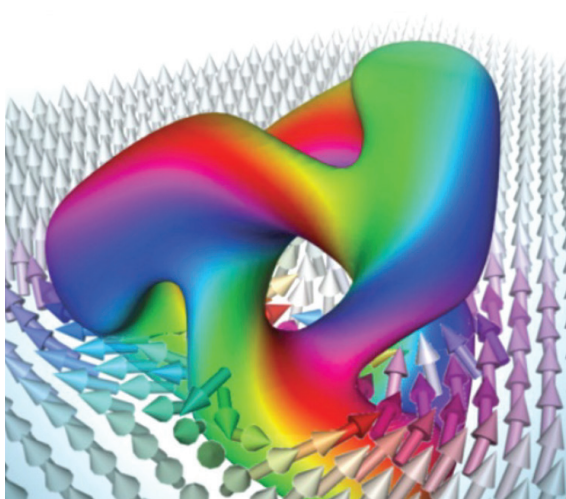


<https://uni-due.zoom-x.de/j/64228670246?pwd=RjVQeFNIUkRKRkpiNVpKYXhJaFNldz09> (gilt für alle Vorträge)

Domain Wall, Skyrmion, Hopfion – The hidden treasures of the Heisenberg Model

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How can comparatively simple microscopic interactions give rise to complex, three-dimensional topological structures in a homogeneous magnet? This question has become experimentally tangible with the observation of magnetic hopfions and related three-dimensional textures, whose internal magnetization structure can now be explored by techniques such as quantitative off-axis electron holography. In particular, our recent observation of hopfion rings on skyrmion strings and of isolated hopfion rings provides a striking example of the topology that can emerge from competing magnetic interactions. In this talk, I will trace these structures back to their microscopic origin. Starting from the Heisenberg model, with exchange parameters determined quantitatively for real materials by density-functional theory (DFT), I will show how competing exchange interactions and the nonlinear constraint of the magnetization generate a remarkably rich landscape of magnetic states. This provides a common framework for understanding one-, two-, and three-dimensional topological magnetization solitons, ranging from phase-slip domain walls and skyrmions to three-dimensional hopfions. By combining DFT, atomistic spin dynamics, harmonic transition-state theory, and micromagnetics in a multiscale approach, we connect microscopic electronic interactions to experimentally observable textures and investigate their stability, lifetimes, and decay mechanisms. Yet the conventional Heisenberg model

captures only the isotropic part of a more general tensorial interaction between spins. In the final part of the talk, I will therefore turn the perspective around and ask how the spin Hamiltonian itself can be systematically generalized and determined from the underlying electronic structure. I will introduce our current efforts to calculate tensorial exchange interactions from first principles, exploiting recent developments in spin-group theory and a vector generalization of the generalized Bloch theorem. This provides a route from electronic structure not only to known topological textures, but toward the unbiased prediction of magnetic order beyond the conventional Heisenberg paradigm.

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