Scaling in Magnetic Neutron Scattering

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We report the discovery of scaling in the mesoscale magnetic microstructure of bulk ferromagnets. Supported by analytical micromagnetic theory, we introduce the field-dependent scaling length $l_{\mathrm{C}}(H)$, which describes the characteristic long-wavelength magnetization fluctuations that are caused by microstructural defects by means of magnetoelastic and magnetocrystalline anisotropy. The scaling length l_{C} is identified to consist of the micromagnetic exchange length of the field l_{H}, which depends on the magnetic interactions, and a field-independent contribution that reflects the properties of the magnetic anisotropy field and the magnetostatic fluctuations. The latter finding is rooted in the convolution relationship between the grain microstructure and micromagnetic response functions. We validated the scaling property by analyzing experimental data for the magnetic neutron scattering cross section. When plotted as a function of the dimensionless scaled scattering vector $\mathfrak{q}(H) = q\, l_{\mathrm{C}}(H)$, the field-dependent amplitude-scaled neutron data of nanocrystalline Co and a Nd-Fe-B-based nanocomposite collapse onto a single master curve, demonstrating universal behavior. The scaling length l_{C} provides a framework for analyzing the field-dependent neutron scattering cross section, highlighting the existence of critical length scales that govern the mesoscale microstructure of magnetic materials.

References:

[1] V. Rai and A. Michels, Phys. Rev. B **112**, 144403 (2025)