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The quantum nature of skyrmions and half-skyrmions in Cu2OSeO3

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The Skyrme-particle, the skyrmion, was introduced over half a century ago in the context of dense nuclear matter. But with skyrmions being mathematical objects–special types of topological solitons–they can emerge in much broader contexts. Recently skyrmions were observed in helimagnets, forming nanoscale spin-textures. Extending over length scales much larger than the interatomic spacing, they behave as large, classical objects, yet deep inside they are of quantum nature. Penetrating into their microscopic roots requires a multi-scale approach, spanning the full quantum to classical domain. We performed such an approach for the first time in the skyrmionic Mott insulator Cu_2OSeO_3. We show that its magnetic building blocks are strongly fluctuating Cu4 tetrahedra, spawning a continuum theory that culminates in 51 nm large skyrmions, in striking agreement with experiment [1]. Another consequence is the presence of two distinct types of modes: a low-energy manifold that includes a gapless Goldstone mode and a set of weakly dispersive high-energy magnons [2]. Using high-field electron spin resonance with a terahertz free-electron laser and pulsed magnetic fields up to 64 T we identified these modes [3], corroborating the presence of fluctuating Cu4 tetrahedra. We also show that the emerging electric polarization **P** is governed by quadrupolar spin contributions from symmetry inequivalent bonds and calculate the induced **P** in different crystallographic directions as a function of the orientation of an applied magnetic field, which are confirmed by experiment [2]. One so far untested prediction that ensues is the temperature-dependent decay of skyrmions into half-skyrmions.

[1] Nature Comm. 5, 5376 (2014)
[2] PRB 90, 140404(R) (2014)
[3] PRL 113, 157205 (2014)