Study reveals an asymmetric dispersion of phason excitations in a skyrmion lattice

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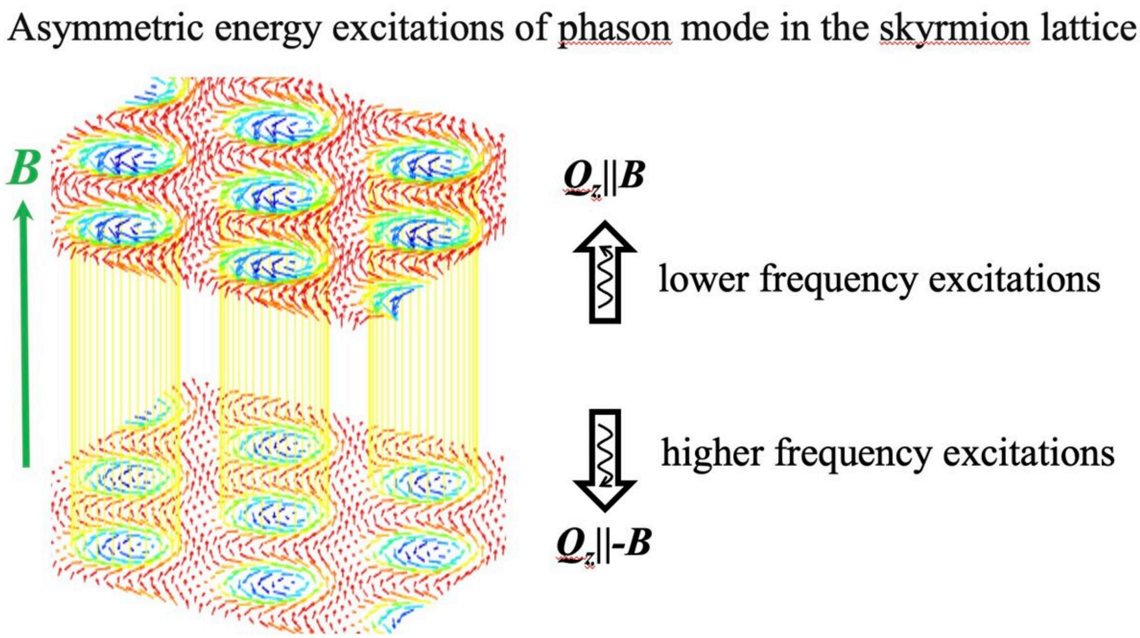

In the magnetic skyrmion phase of MnSi, waves of a given wavelength propagating in parallel and antiparallel directions to the applied magnetic field have different energies - or equivalently, different frequencies. Specifically, the energy of waves propagating in the B-field (+Qz) direction is lower than that of waves propagating in the opposite direction. However, these energies are much smaller than the energy of the incoming neutrons and also of the surrounding lattice. As a result, the neutrons scattered to +Qz can gain this momentum either by absorbing a +Qz wave, or by emitting a -Qz one. This means that on average these scattered neutrons will come out with a slightly lower energy than they came in with. For -Qz they come out with slightly higher energy: it is this difference that can be detected by the sensitive spin-echo technique. Credit:

Minoru Soda @ Ocha. Univ.

Magnetic skyrmions, statically stable magnetic quasiparticles with a topological charge, have been the focus of numerous recent studies, as they could support the development of so-called spintronics. These devices, which leverage the spin of electrons, could perform remarkably well while consuming less power than conventional electronics.

Researchers at the RIKEN Center for Emergent Matter Sciences (CEMS), Ochanomizu University and other institutes worldwide recently examined the low-energy excitations of skyrmions hosted in manganese monosilicide (MnSi), an intermetallic material that has proved promising for spintronics applications. Their paper, published in *Nature Physics*, reports the observation of asymmetric slow dynamics in the material's skyrmion lattice.

"In the rapidly advancing field of spintronics technology, the geometrically nontrivial spin configurations known as magnetic skyrmions have attracted significant attention," Hazuki Kawano-Furukawa, Professor at Ochanomizu University and Team Leader at the RIKEN Center for Emergent Matter Science, told Phys.org.

"Particularly, due to their ability to be controlled with minimal energy expenditure, offering low-power consumption and high-density implementation, they hold promise for applications in non-volatile memory. In fact, their energy scale was reported to be a few orders of magnitude smaller than that required to drive conventional magnetic domains."

For several years, Kawano-Furukawa conducted extensive research using neutron scattering, a technique that uses generated beams of neutrons to attain information about a material's structure and underlying physical dynamics. Recently, she started exploring the possibility of using neutron scattering to study the dynamics of magnetic skyrmions.

"After I started working at RIKEN CEMS, I learned that its theoretical group had predicted that skyrmion crystals could create waves with different energies when subjected to parallel and antiparallel magnetic fields," Kawano-Furukawa explained. "This sparked my strong interest in proving this phenomenon through neutron scattering experiments."

After a series of experimental trials, Kawano-Furukawa and her colleagues successfully observed the dynamics they were hoping to detect, using the state-of-the-art IN15 neutron spin echo spectrometer at the Institute-Laue-Langevin (ILL) in Grenoble, France. As this technology relies on complex experimental processes, such as the labeling of incoming and outgoing neutrons based on their spin direction, and the manipulation of spin directions to enable the detection of tiny energy changes, the researchers then ran further tests to validate their results.

"It is of great significance for research in the field that experimental evidence confirms the predictions made by theorists," Kawano-Furukawa said. "The skyrmions in our crystal have a 'handedness' like a screw, so the +z and -z directions should behave somewhat differently, like the head and tail of a screw. Neutron scattering is the only method capable of observing magnetic fluctuations at micro-electron-volt energies with finite wave vectors, making it the sole approach to demonstrate the predicted asymmetry in the excitations."

Overall, the recent study by this team of researchers unveiled an asymmetric dispersion of phason excitations in the skyrmion lattice of MnSi. In the future, it could pave the way towards further discoveries about the dynamics of magnetic skyrmions, potentially opening new possibilities for the development of spintronic devices.

"The success of this study could be seen as a significant step forward in providing a dynamic interpretation of magnetic skyrmions," Kawano-Furukawa added. "Currently, we are planning to conduct further research on the generation process of magnetic skyrmions. Specifically, our aim is to investigate the coexistence of the conical and skyrmion phases in MnSi."

More information: Minoru Soda et al, Asymmetric slow dynamics of the skyrmion lattice in MnSi, *Nature Physics* (2023). DOI: 10.1038/s41567-023-02120-5.