# The building blocks for exploring new exotic states of matter

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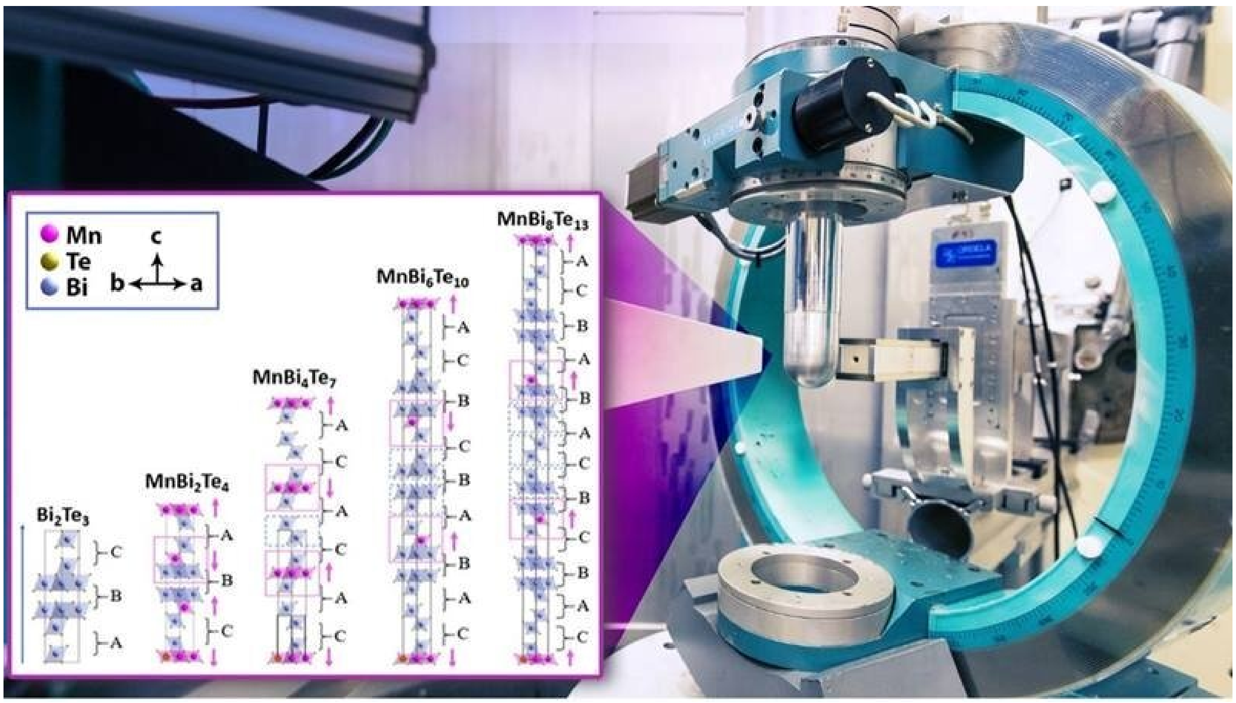


Using the High Flux Isotope Reactor's DEMAND instrument, neutron scattering studies identified the crystal & magnetic structure of an intrinsic ferromagnetic topological insulator MnBi8Te13. The last column of inset shows its crystal & magnetic structures. Credit: Oak Ridge National Laboratory

Topological insulators act as electrical insulators on the inside but conduct electricity along their surfaces. Researchers study some of these insulators' exotic behavior using an external magnetic field to force the ion spins within a topological insulator to be parallel to each other. This process is known as breaking time-reversal symmetry. Now, a research team has created an intrinsic ferromagnetic topological insulator. This means the time-reversal symmetry is broken without applying a magnetic field. The team employed a combination of synthesis, characterization tools, and theory to confirm the structure and properties of new magnetic topological materials. In the process, they discovered an exotic axion insulator in $MnBi_8Te_{13}$.

Researchers can use magnetic topological materials to realize exotic forms of matter that are not seen in other types of material. Scientists believe that the phenomena these materials exhibit could help advance quantum technology and increase the energy efficiency of future electronic devices. Researchers believe that a topological insulator that is inherently ferromagnetic, rather than gaining its properties by adding small numbers of magnetic atoms, is ideal for studying novel topological behaviors. This is because no external magnetic field is needed to study the material's properties. It also means the material's magnetism is more uniformly distributed. However, scientists have previously faced challenges in creating this kind of material. This new material consists of layers of manganese, bismuth, and tellurium atoms. It could provide opportunities for exploring novel phases of matter and developing new technologies. It also helps researchers study basic scientific questions about quantum materials.

The research team, led by scientists from the University of California, Los Angeles, developed the intrinsic ferromagnetic topological insulator by making a compound with alternating layers of $MnBi_2Te_4$ and $Bi_2Te_3$, bonded by weak interlayer forces of attraction between molecules. Scientists recently discovered that $MnBi_2Te_4$ is a naturally magnetic topological material. However, when layers of magnetic $MnBi_2Te_4$ are directly stacked on one another, the magnetic moments within neighboring layers point in opposite directions, making the material antiferromagnetic as a whole—losing the topological aspects of the properties that are important for technologies. The researchers solved this problem by making a new compound with three nonmagnetic layers of $Bi_2Te_3$ between layers of $MnBi_2Te_4$, which, combined, creates $MnBi_8Te_{13}$. This material design increases the distance between the $MnBi_2Te_4$ layers, which successfully eliminates the antiferromagnetic effect, leading to long-range ferromagnetism below 10.5 K with strong coupling between magnetism and charge carriers.

Important aspects of this research were neutron scattering experiments through the DEMAND instrument at the High Flux Isotope Reactor (HFIR) that pinpointed how atoms are arranged within the $MnBi_8Te_{13}$ material and confirmed its ferromagnetic state. Because neutrons have their own magnetic moment, they can be used to determine the magnetic structure inside a material. The scientists additionally used angle resolved photoemission spectroscopy experiments at the Stanford Synchrotron Radiation Lightsource, a Department of Energy user facility, and first-principles, density functional theory calculations to investigate the material's electronic and topological state. Combining the assessments from all of these methods, the researchers were able to validate the ferromagnetic and topological properties consistent with an axion insulator with sizable surface hybridization gaps and a nontrivial Chern number.

**More information:** Chaowei Hu et al, Realization of an intrinsic ferromagnetic topological state in $MnBi_8Te_{13}$, *Science Advances* (2020). DOI: 10.1126/sciadv.aba4275

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