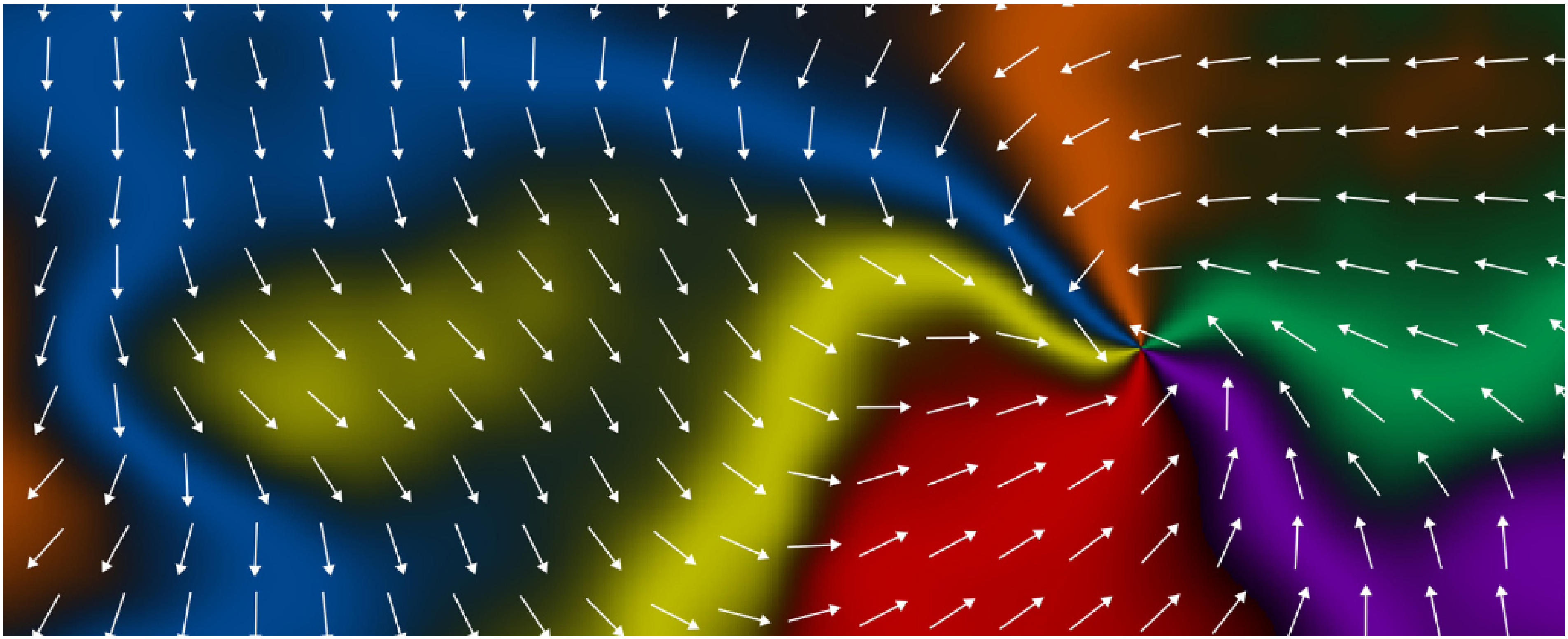
Physicists Confirm The Existence of a Third Form of Magnetism

PHYSICS 03 February 2025 By MIKE MCRAE



X-ray spectrum in colors showing differences in alternamagnetic properties. (Amin et al., *Nature*, 2025)

An experiment in Sweden has demonstrated control over a novel kind of magnetism, giving scientists a new way to explore a phenomenon with huge potential to improve electronics – from memory storage to energy efficiency.

Using a device that accelerates electrons to blinding speeds, a team led by researchers from the University of Nottingham showered an ultra-thin wafer of manganese telluride with X-rays of different polarizations, to reveal changes on a nanometer scale reflecting magnetic activity unlike anything seen before.

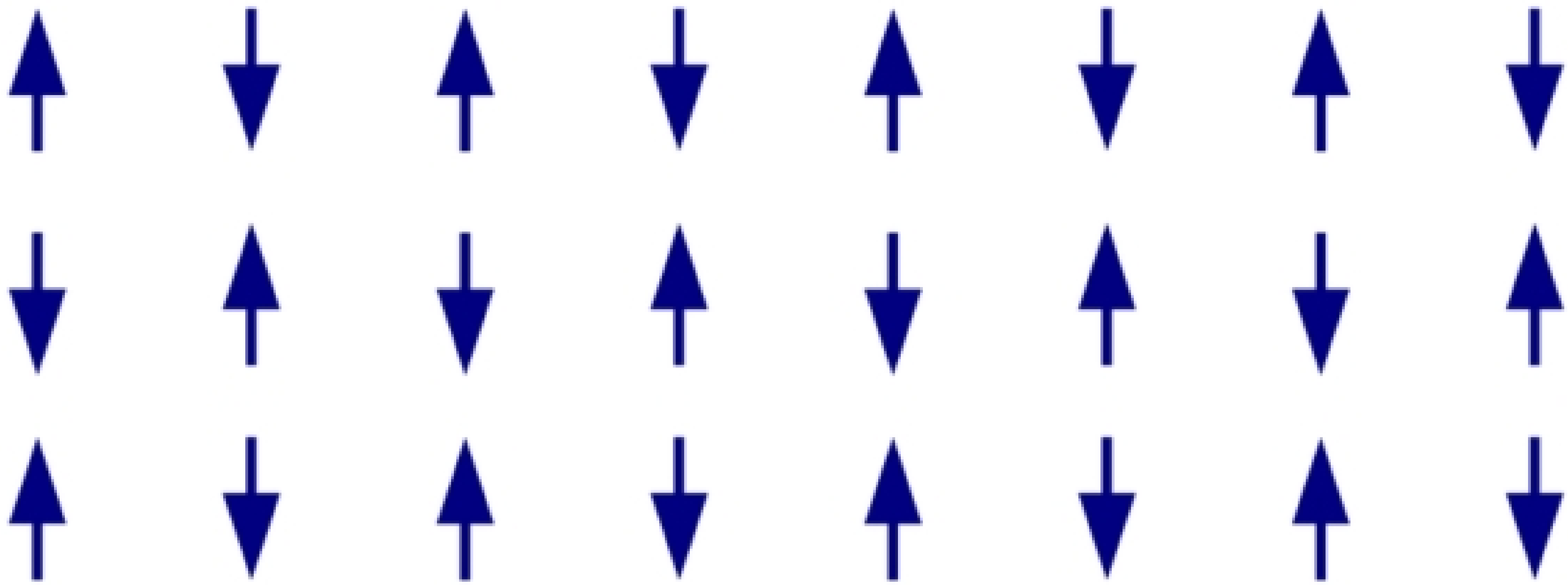
For a rather mundane chunk of iron to transform into something a little more magnetic, its constituent particles need to be arranged so that their unpartnered electrons align according to a property known as spin.

Like the spin of a ball, this quantum feature of particles has an angular push to it. Unlike the rotation of a physical object, this push only comes in one of two directions, conventionally described as up and down.

In non-magnetic materials, these come as a pair of one up and one down, canceling each other out. Not so in materials like iron, nickel, and cobalt. In these, lonely electrons can join forces in a rather extraordinary way.

Arranging the isolated spins can result in an exaggerated north-and-south force we might use to pick up paper clips or stick children's drawings to refrigerator doors.

By the same reasoning, encouraging the unpartnered electrons to arrange themselves in ways that completely cancel out their spin-based orientations can still be considered a form of magnetism – just a rather boring one that looks utterly inactive from a distance.

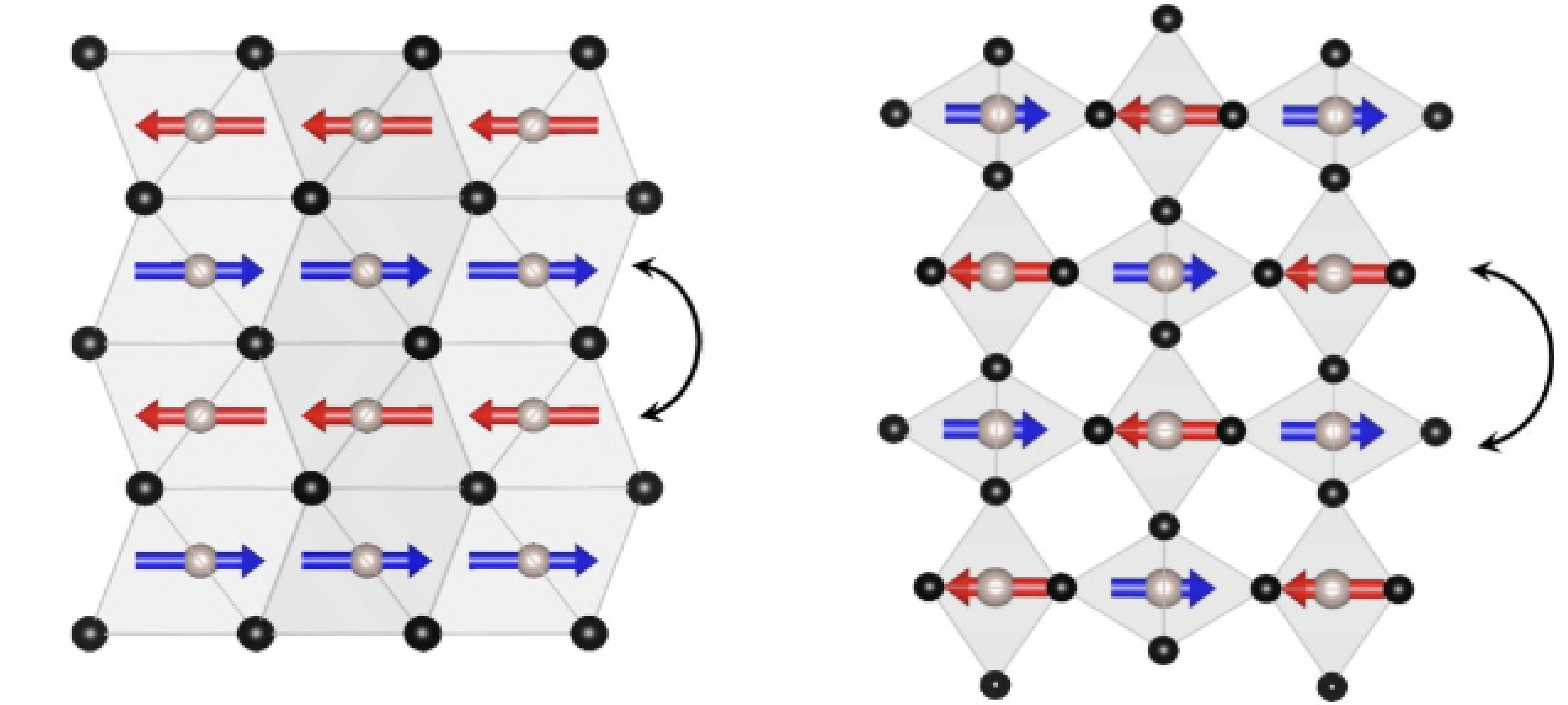


Representation of ordering of electron spins in an antiferromagnetic material. (Michael Schmid/CC BY-SA 3.0/Wikimedia Commons)

Known as antiferromagnetism, it's a phenomenon that has been theorized and tinkered with for the better part of a century.

More recently, a third configuration of particles in ferromagnetic materials was theorized.

In what's referred to as altermagnetism, particles are arranged in a canceling fashion like antiferromagnetism, yet rotated just enough to allow for confined forces on a nanoscale – not enough to pin a grocery list to your freezer, but with discrete properties that engineers are keen to manipulate into storing data or channeling energy.



Altermagnetic manganese telluride (left) and ruthenium dioxide (right) showing spin directions in red and blue. (Libor Šmejkal/Wikimedia Commons/CC-SA-4.0)

"Altermagnets consist of magnetic moments that point antiparallel to their neighbors," explains University of Nottingham physicist Peter Wadley.

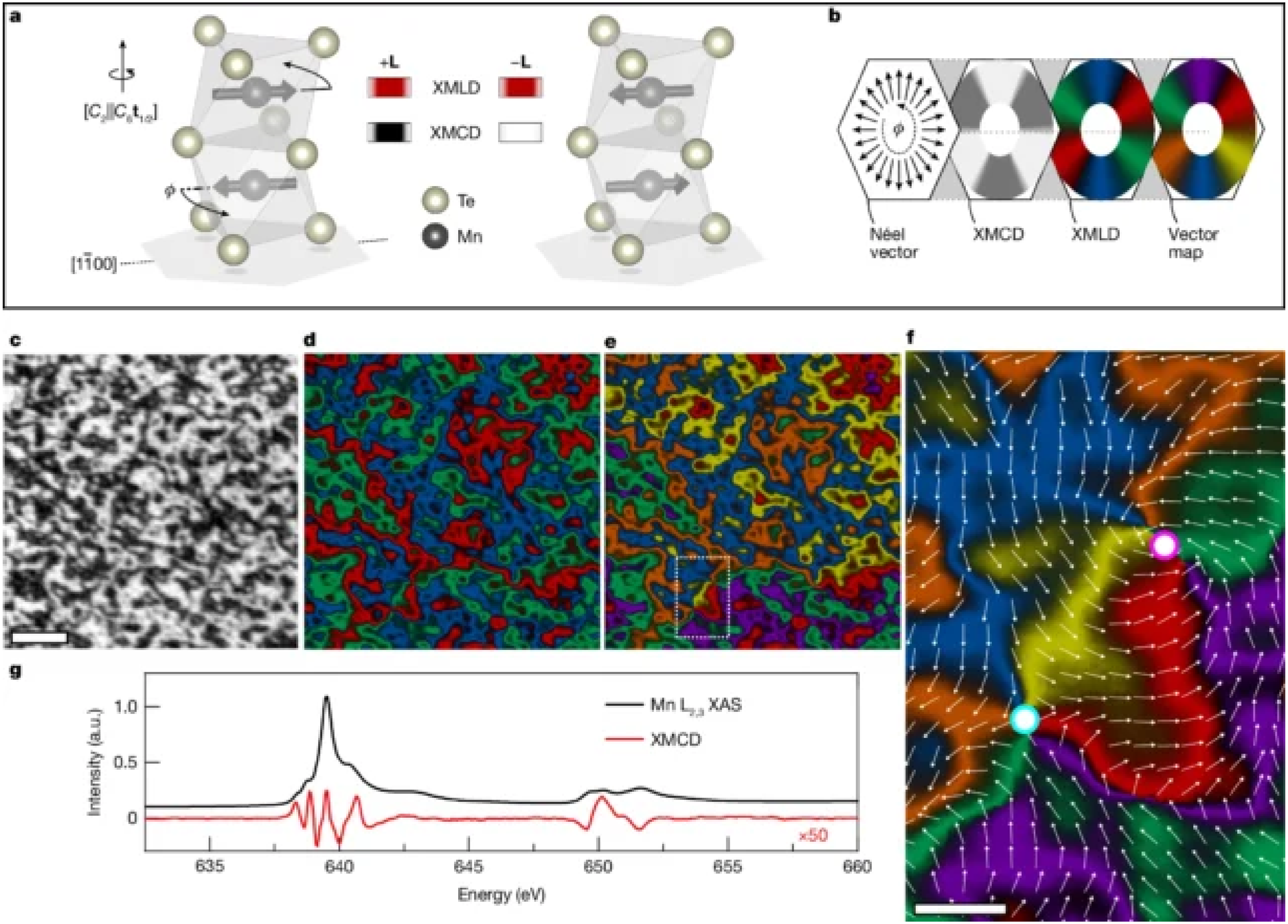
"However, each part of the crystal hosting these tiny moments is rotated with respect to its neighbours. This is like antiferromagnetism with a twist! But this subtle difference has huge ramifications."

Experiments have since confirmed the existence of this in-between 'alter' magnetism. However, none had directly demonstrated it was possible to manipulate its tiny magnetic vortices in ways that might prove useful.

Wadley and his colleagues demonstrated that a sheet of manganese telluride just a few nanometers thick could be distorted in ways that intentionally created distinct magnetic whirlpools on the wafer's surface.

Using the X-ray-producing synchrotron at the MAX IV Laboratory in Sweden to image the material, they not only produced a clear visualization of altermagnetism in action, but showed how it can be manipulated.

"Our experimental work has provided a bridge between theoretical concepts and real-life realization, which hopefully illuminates a path to developing altermagnetic materials for practical applications," says University of Nottingham physicist Oliver Amin, who led the research with PhD student Alfred Dal Din.



Mapping of the altermagnetic order vector in manganese telluride. (Amin et al., *Nature*, 2025)

Those practical applications are all theoretical for now, but have huge potential across fields of electronics and computing as a kind of spin-based memory system, or serving as a stepping stone in learning how currents might move in high temperature superconductors.

"To be amongst the first to see the effect and properties of this promising new class of magnetic materials during my PhD has been an immensely rewarding and challenging privilege," says Dal Din.

This research was published in *Nature*.