

Proceedings of the National Academy of Sciences of the United States of America

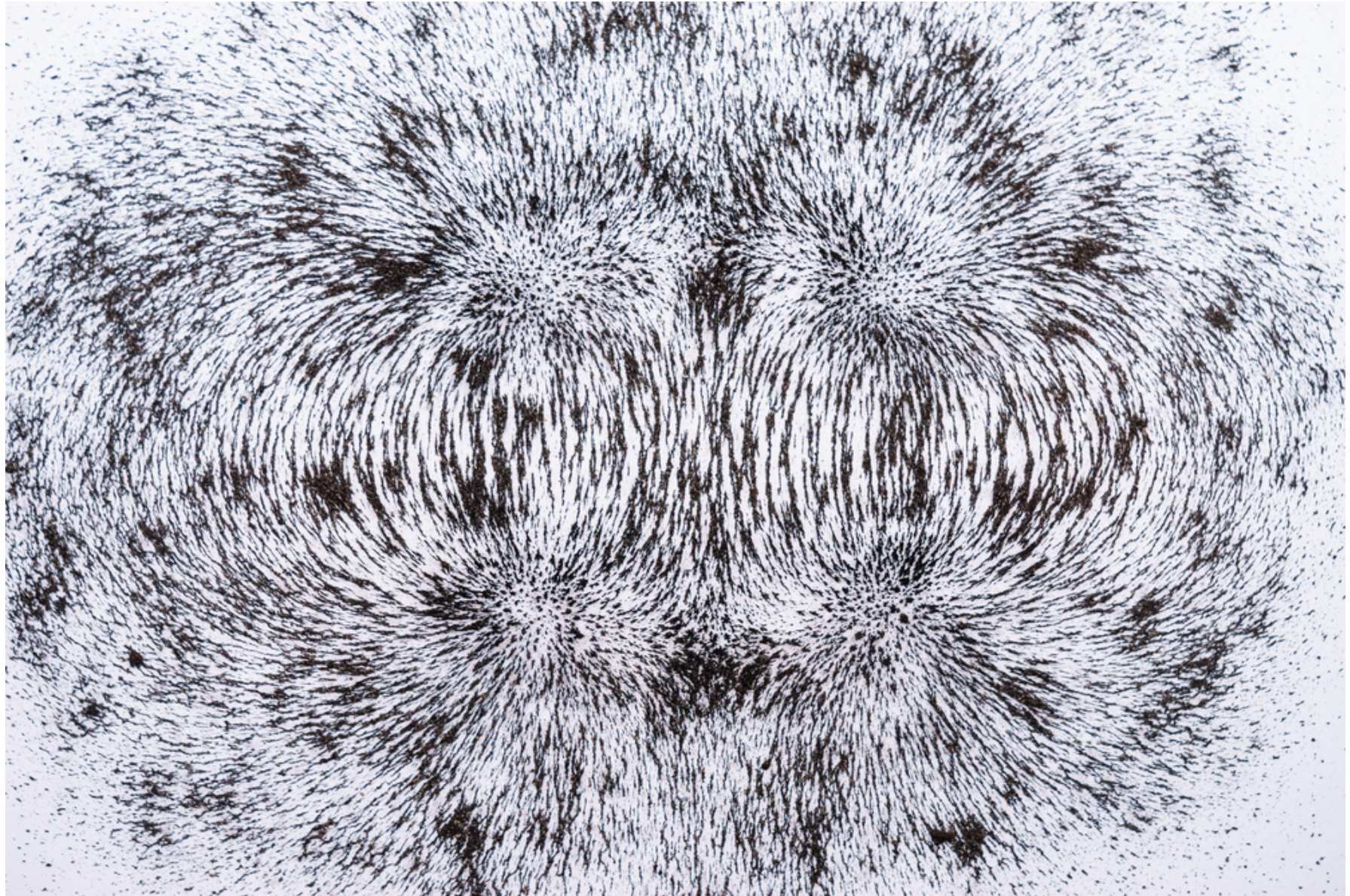
Journal Club

Highlighting recently published papers selected by Academy members

Journal Club: Super-sensitive new microscope uses ultracold atoms to image magnetic fields at high precision

Posted on April 10, 2017 (<http://blog.pnas.org/2017/04/journal-club-super-sensitive-new-microscope-uses-ultracold-atoms-to-image-magnetic-fields-at-high-precision/>) by Stephen Ornes

(<http://blog.pnas.org/author/sornes/>)



(http://blog.pnas.org/wp-content/uploads/2017/04/shutterstock_510595861.jpg)

A new microscope offers the promise of directly imaging the source of a magnetic field with exceptional sensitivity.

Image: Shutterstock/Pichet siritaniwat

In recent years, physicists have developed an arsenal of sensitive, high-resolution tools to probe the smallest magnetic fields, revealing nanoscale subtleties lost in larger-scale measurements. An understanding of these structures can offer insights into exotic quantum materials.

A new microscope uses an ultra-cold cloud of atoms to measure magnetic fields. Called the Scanning Quantum Cryogenic Atom Microscope, or SQCRAMscope, the tool offers the tantalizing possibility of directly imaging the source of a magnetic field with exceptional sensitivity.

Researchers unveiled the device in a recent issue of *Physical Review Applied*

(<https://journals.aps.org/prapplied/abstract/10.1103/PhysRevApplied.7.034026>) , updated from an earlier [paper \(https://arxiv.org/abs/1608.06922v1\)](https://arxiv.org/abs/1608.06922v1) in arxiv.

Scientists have developed other approaches to inspect these tiny fields. Nitrogen vacancy centers, for example, are minuscule defects in diamonds where a nitrogen atom replaces carbon and sits next to an empty spot in the crystal; they're exquisitely sensitive to magnetic fields. SQUIDS (superconducting quantum interference devices), as the name suggests, use superconducting loops.

The recent approach uses a Bose-Einstein Condensate (BEC), a quantum state of matter that forms only in certain particles and at a sliver of a degree above absolute zero. At such temperatures, particles occupy the same quantum state, which means they behave as one big particle. It's like a magnifying glass: BECs lets condensed matter physicists study quantum effects, ordinarily hidden from observation, at larger scales.

Physicist Benjamin Lev at Stanford University in California and his group report that calibration and verification experiments suggest the device performs at a precision two orders of magnitude higher than existing scanned probes of static magnetic fields. In addition, even though the BEC has to be kept near absolute zero, samples of any temperature—even up to room temperature—can be measured. Previous tools of comparable sensitivity have required cold samples.

In a BEC, Lev says, particles are highly sensitive to their surroundings: “It’s easy to push them around and image their positions.” The new device takes advantage of this property. The BEC forms when a diffuse gas of rubidium atoms are chilled to within a fraction of a degree of absolute zero. Then that rubidium sea—now acting as one atom—behaves like a wave of matter, trapped in a tube. The wave is smooth at first. But when a current passes through a sample, next to the BEC, it produces a magnetic field that nudges the atoms in the BEC to the left or right. Imaging the atomic density reveals the field.

Jörg Schmiedmayer, at the Vienna Center for Quantum Science and Technology, at the TU Vienna in Austria, says he’s excited to see what Lev and other scientists discover using the SQCRAMscope. “There are a lot of cool science questions it can address,” he says. It will be useful for understanding bizarre quantum states of matter, such as superconductors, topological insulators, and others. The new tool doesn’t supplant existing ones, he says; it offers new avenues of exploration. The SQCRAMscope, he says, will help reveal the interesting physics going on in bizarre quantum materials.

The idea for the SQCRAMscope originated with experiments in Schmiedmayer’s lab. In 2005, he and his collaborators used BECs to observe that the magnetic fields produced by current flowing in a thin gold film showed irregularities the scientists hadn’t been expecting. “Gold was supposed to be beautifully understood,” he says, “but we saw strange things that in the end we never could clear up.” The work from Schmiedmayer’s group showed that a BEC can be used as a sensitive probe for magnetic fields and current flow. Lev’s team went on to produce usable tool.

Lev, whose research focuses on understanding how quantum systems organize into new states of matter, says his group is already talking about improvements to SQCRAMscope 2.0, and they've begun using it on exotic materials.

"We have a laundry list of materials we'd like to look at with the SQCRAMscope, all sorts of quantum materials that may have technological applications," he says. "We want to understand their behavior." In a forthcoming study, for example, Lev and his group will report on magnetic fields in high-temperature superconductors.

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Online ISSN 1091-6490

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