Funky mirror turns electric field into a magnetic field with missing pole

Enlarge / Not the funky mirror used in this study.
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One of the strange truths of the Universe is that magnets always come with two poles. It doesn’t matter how often you cut a magnet in two, both halves will always have a north and a south pole, even down to the level of the smallest particles. The electron, which appears to be indivisible, still has two poles.

But theory tells us otherwise. Theory says that life would be terribly convenient if nature allowed single-poled magnets, otherwise known as monopoles, to exist. The magnetic monopole would, for instance, explain why the electron has a fixed amount of charge. Yet colliders, telescopes, and other instruments have all looked in vain, but no natural monopoles have been found.

That doesn’t stop us from making them, though. What a team of physicists has created is not a true monopole but a kind of analogue of a monopole. As I’m fond of saying, you don’t learn much from analogies, so its existence isn’t necessarily exciting. The technique used to create it, however, was so cool that I couldn’t let that stop me.

Cooking up a monopole

To build a monopole from scratch, you need the following two items: a magnetoelectric material—if you were not aware of the existence of these superhero-esque materials, join the club—and a stationary charge.

A magnetoelectric material is one that generates a magnetic field in response to an applied voltage (an electric field). And, in reverse, an applied magnetic field generates an electric field.

If you place an electric charge just above the surface of a magnetoelectric material, then the electric field from the charge induces a magnetic field in the material. If you could hold the charge still, then the shape of the magnetic field just happens to look like it originates from a point. This point is called a mirror charge, because it looks like a mirror image of the charge sitting above the surface. However, this mirror charge is a bit different.

An ordinary mirror charge is a bit like what you'd expect from the name. When I look into a mirror, I don't expect to see (despite what *you* may expect) a goldfish staring back at me. Likewise, an electric charge generates a mirror charge that looks like itself: the same amount of charge on the other side of the mirror surface. The mirror charge is built up from electrons shifting around in the material underneath the surface.

In a magnetoelectric material, the electrons might shift, but that creates a magnetic field that looks like it comes from the mirror charge. It really is as if I look into the mirror and see a fish.

The magnetic field, however, looks remarkably like it has only a single pole: it's a monopole. Or at least that's what calculations indicate it should look like.

Will you sit still?

So far, so theoretical. However, the researchers were not content with just doing some theory; they also wanted an experiment. The stumbling block to a successful experiment is creating a single stationary charge—charges, like toddlers, are always on the move. Dealing with that is the coolest bit of the paper.

The researchers had access to a source of low-energy muons. Muons are basically heavy electrons. To get the muons to sit still, the researchers deposited a layer of solid nitrogen on top of the magnetoelectric material and then shot the muons into the nitrogen.

The muons were embedded in the nitrogen, which behaves just like dense air and has little to no effect on the magnetic or electric fields. By choosing the thickness of nitrogen and muon energy carefully, the muons end up sitting just above the surface, creating (hopefully) monopoles just below the surface—at least for the fraction of a second it takes for the muon to decay into something lighter.

Set a magnet to catch a magnet

Here, things get even cleverer. The muons are also little magnets. The muon magnet responds to the monopole below the surface by rotating. The speed at which they rotate tells us about the magnetic field they are in.

To summarize this (because it is mind-blowing): the electric charge of a muon creates a mirror image *magnetic* monopole. The monopole then rotates the *same* muon because the muon is also a magnet. The rotation reveals the presence of the monopole.

Remember, this is not a real monopole. It is evidence that we can get the math to work in some circumstances, but it is not evidence that monopoles exist naturally. Nevertheless, it is a

very elegant experiment, and that makes me happy.

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