Astronomers make magnetic map of a star

Storing and unleashing vast amounts of energy, guiding the motion of chunks of matter hurled into space, and keeping the lid on cauldrons of roiling gas, magnetic fields profoundly influence the destiny of stars. The sun is close enough to Earth for astronomers to track its magnetic structure by monitoring sunspots, the dark markings that house intense fields. Other stars, however, lie too far away for researchers to have gleaned much about their fields.

Now, scientists have for the first time mapped in detail the magnetic field of a star other than the sun. Relying on the sharp eye of a continentwide array of radio telescopes, astronomers measured the average magnetic field near the surface of the elderly star TX Camelopardalis (TX Cam), which resides 1,000 light-years from Earth.

The field appears to be 5 to 10 times stronger than the sun's, they report in the June 1 ASTROPHYSICAL JOURNAL LETTERS. It also appears to have a remarkably well ordered structure that resembles the bar magnet pattern—exemplified by magnetic lines of force looping from the north pole to the south pole—exhibited by Earth and the sun.

Such a pattern isn't necessarily surprising, notes Athol J. Kemball. He and Philip J. Diamond, both of the National Radio Astronomy Observatory in Socorro, N.M., weren't sure what to expect when they began studying the star with the Very Long Baseline Array (VLBA), a network of telescopes stretching from Hawaii to the Virgin Islands.

Because researchers can't measure the magnetic field of a distant star directly, they use the polarization of radio waves as a tracer. TX Cam proved tailor-made for this approach. Kemball and Diamond had already shown that silicon monoxide gas in the star's cool, bloated atmosphere exhibits maser emission, the radio wavelength equivalent of the bright light of a laser. The polarization of radio waves from this kind of maser is exquisitely sensitive to magnetic fields. In addition, the maser resides low in the atmosphere, providing a probe of magnetic structure close to the star's surface.

The VLBA, which can discern features one-thousandth the size of those recorded by the Hubble Space Telescope in visible light, reveals that most of the maser emission forms a shell around the star. This suggests that the magnetic field resembles that of a bar magnet.

Disruptions in that pattern, says Kemball, may indicate regions of intense magnetic activity, possibly places where mass is expelled. TX Cam is known to shed the equivalent of one-third of Earth's mass each year, far more than the sun expels.

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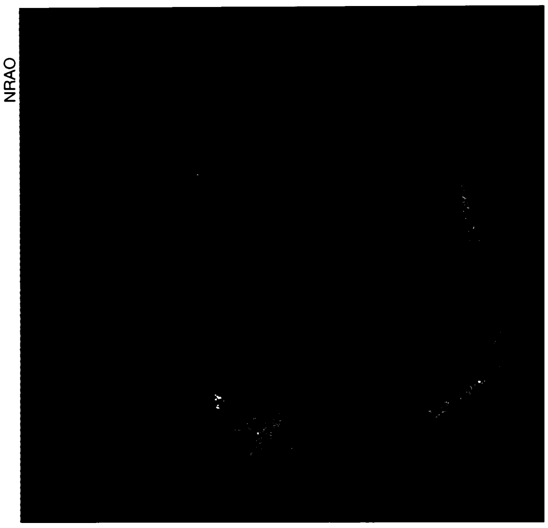


Radio-wave image of the star TX Cam (red disk) shows spots of maser emission (pink-yellow). Light blue lines denote the direction and strength of the polarization of the emission, an indicator of the star's magnetic field.

Calling the radio technique "a tour de force," Moshe Elitzur of the University of Kentucky in Lexington says it provides "the only hope to see what's going on at the surface of a star." —*R. Cowen*

Pinning down a superconductivity theory

How materials known as high-temperature superconductors can carry electric current without resistance has baffled scientists ever since the discovery of these compounds about a decade ago.

Now, researchers have obtained an important clue in the form of experimental evidence strongly favoring an unconventional explanation of superconductivity in thallium barium copper oxide. John R. Kirtley and C.C. Tsuei of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., and their coworkers report their results in the May 29 NATURE.

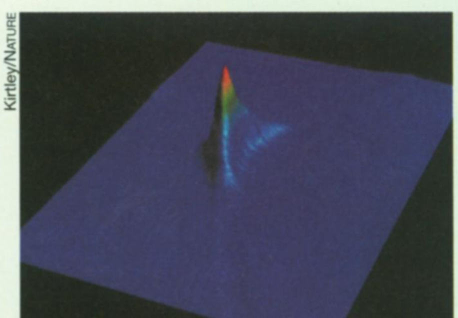
In conventional, low-temperature superconductors like niobium, electrons overcome their mutual repulsion and pair up to pass unhindered through the host material. This pairing is facilitated by vibrations of the material's crystal lattice.

Quantum theory describes the pair by means of a single wave function, which mathematically specifies the probability distribution showing where the two electrons are most likely to be. In a conventional superconductor, the electrons' wave function is spherical, indicating that a pair has an equal chance of moving in any direction. Such a pairing is said to display s-wave symmetry.

In copper oxide superconductors, lattice vibrations alone are not strong enough to maintain the necessary electron pairing at elevated temperatures. Some theorists have proposed that magnetic interactions between the electrons and copper atoms play a key role in forging electron pairs.

In this case, an electron pair would instead have a wave function with d-wave symmetry, resembling a four-leaf clover that has its lobes aligned along the crystal axes.

Kirtley/NATURE



Scanning magnetometer image shows a single magnetic vortex trapped at a point in the superconducting film where two differently oriented crystals meet. The peak's characteristics indicate the presence of d-wave symmetry.

Researchers performed a number of experiments aimed at detecting d-wave pairing. The results pointed to the presence of d-wave symmetry, but they couldn't unambiguously rule out an additional contribution from s-wave pairing (SN: 3/9/96, p. 156).

Kirtley and his coworkers looked for d-wave pairing in a thin film of a thallium barium copper oxide that has a crystal structure known as tetragonal, which is difficult to make but highly symmetrical.

In particular, the crystal geometry requires that the electron pairing be either s-wave or d-wave. "It can't be a combination of the two," Kirtley says.

The results indicate that electron pairs in thallium barium copper oxide display d-wave symmetry. "This is the first time that an experiment has shown that s-wave behavior in electrons is not critical to high-temperature superconductivity," says Jui H. Wang of the State University of New York at Buffalo, a member of the team that fabricated the material.

The identification of a superconductor displaying pure d-wave symmetry serves as a starting point for understanding the more complicated, mixed states that appear to characterize other high-temperature superconductors. —*I. Peterson*