NASA Satellites Discover What Powers Northern Lights

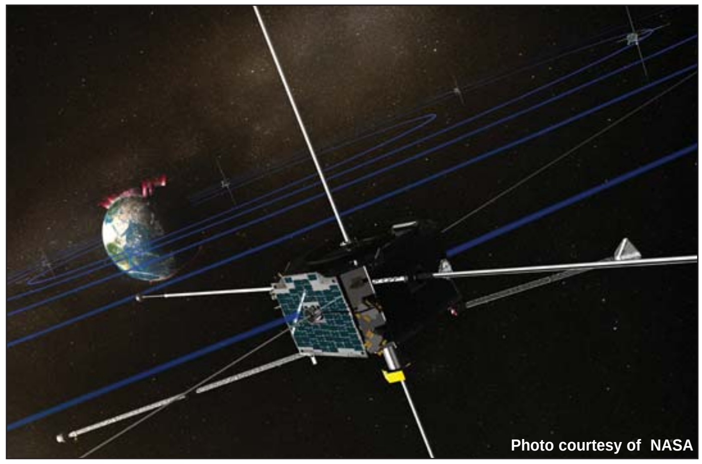
Researchers using a fleet of five NASA satellites have discovered that explosions of magnetic energy a third of the way to the moon power substorms that cause sudden brightenings and rapid movements of the aurora borealis, called the Northern Lights.

The culprit turns out to be magnetic reconnection, a common process that occurs throughout the universe when stressed magnetic field lines suddenly snap to a new shape, like a rubber band that's been stretched too far.

"We discovered what makes the Northern Lights dance," said Dr. Vassilis Angelopoulos of the University of California, Los Angeles. Angelopoulos is the principal investigator for the Time History of Events and Macroscale Interactions during Substorms mission, or THEMIS.

Substorms produce dynamic changes in the auroral displays seen near Earth's northern and southern magnetic poles, causing a burst of light and movement in the Northern and Southern Lights.

A collection of ground-based All-Sky Imagers (ASI) captures the aurora brightening caused by a substorm. Substorms often accompany intense space storms that can disrupt radio communications and global positioning system signals and cause power outages. Solving the mystery of where, when and how substorms occur will allow scientists to construct more realistic substorm models and better predict a magnetic storm's intensity and effects.



Artist's concept of one of the THEMIS satellites in orbit of Earth.

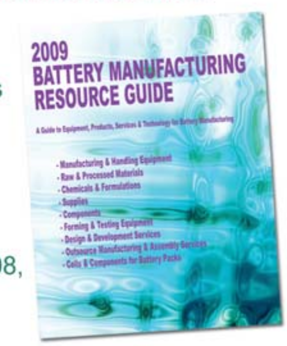
"As they capture and store energy from the solar wind, the Earth's magnetic field lines stretch far out into space. Magnetic reconnection releases the energy stored within these stretched magnetic field lines, flinging charged particles back toward the Earth's atmosphere," said David Sibeck, THEMIS project scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. "They create halos of shimmering aurora circling the northern and southern poles."

Scientists directly observe the beginning of substorms using five THEMIS satellites and a network of 20 ground observatories located throughout Canada and Alaska. Launched in February 2007, the five identical satellites line up once every four days along the equator and take observations synchronized with the ground observatories. Each ground station uses a magnetometer and a camera pointed upward to determine where and when an auroral substorm will begin. Instruments measure the auroral light from particles flowing along Earth's magnetic field and the electrical currents these particles generate.

During each alignment, the satellites capture data that allow scientists to precisely pinpoint where, when, and how substorms measured on the ground develop in space. On Feb. 26, 2008, during one such THEMIS lineup, the satellites observed an isolated substorm begin in space, while the ground-based observatories recorded the intense auroral brightening and space currents over North America.

These observations confirm for the first time that magnetic reconnection triggers the onset of substorms. The discovery supports the reconnection model of substorms, which asserts a substorm starting to occur follows a particular pattern. This pattern consists of a period of reconnection, followed by rapid auroral brightening and rapid expansion of the aurora toward the poles. This culminates in a redistribution of the electrical currents flowing in space around Earth.

THEMIS is the fifth medium-class mission under NASA's Explorer Program. The program, managed by the Explorers Program Office at Goddard provides frequent flight opportunities for world-class space investigations in heliophysics and astrophysics. The University of California, Berkeley's Space Sciences Laboratory in Berkeley, Calif., managed the project development and is currently operating the THEMIS mission. ATK Space (formerly Swales Aerospace) of Beltsville, Md., built the THEMIS satellites.



Princeton Scientists Discover New Electronic States of Matter

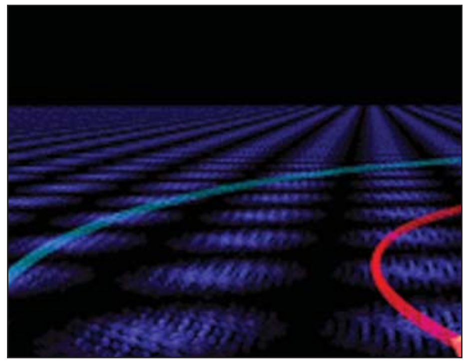
Using very high magnetic fields, a team of scientists has discovered a new way that electrons behave in materials; a discovery that could lead to new kinds of electronic devices.

A team led by Princeton Professor N. Phuan Ong has shown that electrons in the common element bismuth display a highly unusual pattern of behavior, a dance of sorts, when subjected to a powerful magnetic field at ultra-low temperatures. Ong and his collaborators performed the experiment at the National High Magnetic Field Laboratory's DC Field Facility.

Normally, electrons in bismuth come in three different varieties. But in the experiment described by the researchers, the electrons in the magnetized, supercold sample simultaneously assumed the identity of all three classes of electrons, following a strict choreography that could only stem, they say, from the strange rules of quantum physics. Quantum mechanics is the area of physics that governs the behavior of objects in the microscopic world. The experiment documented the first phase transition, a term used to describe an abrupt change in the behavior of a material, ever observed in a Group V element, one of the categories in the periodic table.

"If you can imagine, it's as if we were looking at passengers scrambling through Grand Central Station in New York, watching them run in different directions. All of a sudden, the whistle blows and we see them run to the same train. This is a simple example of a sudden transition to collective behavior," Ong said.

By witnessing what physicists call a collective state, the team saw what Ong described as one of the wonders of nature. "It's a manifestation of quantum mechanics," he said.



This torque cantilever is used to measure magnetic property of bismuth in intense magnetic fields. The bismuth crystal (5.6 mm tall vertical pillar) is glued to the end of a thin cantilever beam made of gold. Deflections of the cantilever in a field are detected by measuring changes in capacitance.
Photo courtesy of N. Phuan Ong

It had been known that, in the complicated environment of a crystalline solid such as bismuth, its electrons move more rapidly than they do in conventional materials. Although the maximum speed of electrons in bismuth is small compared with photons moving at the speed of light, the electrons mimic accurately the behavior of elementary particles accelerated to very high speeds. In bismuth, this relativistic property makes them likely candidates for the quantum behavior the scientists observed.

"This is exciting because this was predicted, but never shown before, and it may eventually lead to new paradigms in computing

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and electronics," said Thomas Rieker, program director for materials research centers at the National Science Foundation.

If scientists are able to document the behavior of the electrons in bismuth and therefore predict their path through a material, they may be able to manipulate those properties for electronic systems powering futuristic "quantum" computing devices.

"In the quest to develop ever smaller and faster transistors, physicists and engineers are attempting to harness the quantum behavior of electrons," Ong said. "Research in bismuth and another material, graphene, may uncover further new results that will expand the tool kit of quantum researchers."

Electrons are the lightest elementary particles with an electric charge. In the past, understanding the rules governing the way electrons move through materials has allowed scientists to make major advances, from the development of medical imaging to the invention of the transistor.

"The modern era of computing and telecommunications rests on advances in solid state physics," Ong said. "We can't yet know what we will learn from this but the past tells us that understanding the behavior of electrons points us in important new directions."

The experiment also involved Mag Lab affiliate and University of Florida Professor Art Hebard; and Robert Cava, the Russell Wellman Moore Professor of Chemistry and department chair, physics graduate students Lu Li and Joseph Checkelsky and postdoctoral fellow Yew San Hor, all of Princeton. Scientists from the University of Michigan also participated.

To obtain the results, the scientists balanced a crystal of high-purity bismuth at the tip of a tiny gold cantilever and measured the minute flexing of the cantilever as the magnetic field changed.

The research was supported by the National Science Foundation through a Materials Science and Engineering Center grant to the Princeton Center for Complex Materials.

Magnetic Nanoparticles Combat Cancer

Scientists at Georgia Tech have developed a potential new treatment against cancer that attaches magnetic nanoparticles to cancer cells, allowing them to be captured and carried out of the body. The treatment, which has been tested in the laboratory and will now be looked at in survival studies, is detailed online in the Journal of the American Chemical Society.

"We've been able to use magnetic nanoparticles to capture free-floating cancer cells and then take them out of the body," said John McDonald, chair of the School of Biology at Georgia Tech and chief research scientist at the Ovarian Cancer Institute. "This technology may be of special importance in the treatment of ovarian cancer where the malignancy is typically spread by free-floating cancer cells released from the primary tumor into the abdominal cavity."

The idea came to the research team from the work of Ken Scarberry, a Ph.D. student in Tech's School of Chemistry and Biochemistry. Scarberry originally conceived of the idea as a means of extracting viruses and virally infected cells when his advisor, Chemistry professor John Zhang, had another idea. He asked if the technology could be applied to cancer. Scarberry suggested it might be an effective means of preventing cancer cells from spreading.

They began by testing the therapy on mice. After giving the cancer cells in the mice a fluorescent green tag and staining the magnetic nanoparticles red, they were able to apply a magnet and move the green cancer cells to the abdominal region.

"If the therapy is able to pass further tests that show it can prevent the cancer from spreading from the original tumor," Scarberry said. "It could be an important tool in cancer treatment."

This technology holds more promise than solely using antibodies to fight cancer because there seems to be less potential for the body to develop an immune response due to the unique peptide-targeting strategy, and the composition of the magnetic nanoparticles.

"If you modify the nanoparticle and target it directly to the tumor cells using a small peptide, you are less likely to generate an undesirable immune response and more accurately target the cells of interest," said Research Scientist Erin Dickerson.

In addition to testing magnetic nanoparticles, the research team is collaborating with other groups at Georgia Tech to determine how peptide-directed gold nanoparticles and nanohydrogels might also be used in fighting cancer.

New Kind of MRI Enables Study of Magnets For Computer Memory

What is there to see inside a magnet that's smaller than the head of a pin? Quite a lot, say physicists who've invented a new kind of MRI technique to do just that. The technique may eventually enable the development of extremely small computers, and even give doctors a new tool for studying the plaques in blood vessels that play a role in diseases such as heart disease.

Scientists report the first-ever magnetic resonance image of the inside of an extremely tiny magnet. Specifically, the magnet is a ferromagnet, a magnet made of ferrous metal such as iron. It's what most people think of when they hear the word magnet.

"The magnets we study are basically the same as a refrigerator magnet, only much smaller," said project leader Chris Hammel, Ohio Eminent Scholar in Experimental Physics at Ohio State University. The disk-shaped magnets in this study measured only two micrometers (millionths of a meter) across.

"Because ferromagnets generate such strong magnetic fields, we can't study them with typical MRI. A related technique, ferromagnetic resonance, or FMR, would work, but it's not sensitive enough to study individual magnets that are this small."

Likewise, medical researchers can't use MRI to image plaques formed in the body, because plaques are too small. That's why this new kind of magnetic resonance could eventually become a tool for biomedical research.

The technique combines three different kinds of technology: MRI, FMR, and atomic force microscopy. They dubbed the technique "scanned probe ferromagnetic resonance force microscopy," or scanned probe FMRFM, and it involves detecting a magnetic signal using a tiny silicon bar with an even tinier magnetic probe on its tip.

As the probe passes over a material, it captures a bowl-shaped image: a curved cross-section of an object. The magnetic signal is more intense in the middle (the bottom of the bowl), and fades away toward the edges. It may sound like an odd configuration, but that's why the new technique works.

Every atom emits radio waves at a particular frequency. But to know where those atoms are, scientists need to be able to localize where the radio waves are coming from.

Large-scale MRI machines, such as those in hospitals, get around this problem by varying the magnetic field by precise amounts as it sweeps over an object. The computer controlling the MRI knows that where the magnetic field equals X, the location equals Y. Sophisticated software combines the data, and doctors get a 3D view inside a patient's body.

Now that they have their imaging technique, Hammel and his team are beginning to record the properties of many different kinds of tiny magnets, a critical first step toward developing them for computer memory.

Experts believe that one day, tiny magnets could be implanted on a computer's central processing unit (CPU) chip. Because system data could be recorded on the magnets, such a computer would never need to boot up. It would also be very small, essentially the entire computer would be contained in the CPU.

Hammel and his team hope to contribute to the development of an instrument that could be sold and used routinely in laboratories. But the technique needs some further development before it could become an everyday tool for the computer industry or for biomedicine. This work was funded by the Department of Energy.