Scientists solve 30-year-old aurora borealis mystery

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THEMIS (Time History of Events and Macroscale Interactions during Substorms) is funded by NASA. (Credit: NASA/JPL/GSFC, UCB)

UCLA space scientists and colleagues have identified the mechanism that triggers substorms in space; wreaks havoc on satellites, power grids and communications systems; and leads to the explosive release of energy that causes the spectacular brightening of the aurora borealis, also known as the northern lights.

For 30 years, there have been two competing theories to explain the onset of these substorms, which are energy releases in the Earth's magnetosphere, said Vassilis Angelopoulos, a UCLA professor of Earth and space sciences and principal investigator of the NASA-funded mission known as THEMIS (Time History of Events and Macroscale Interactions during Substorms).

One theory is that the trigger happens relatively close to Earth, about one-sixth of the distance to the moon. According to this theory, large currents building up in the space environment, which is composed of charged ions and electrons, or "plasma," are suddenly released by an explosive instability. The plasma implodes toward Earth as the space currents are disrupted, which is the start of the substorm.

A second theory says the trigger is farther out, about one-third of the distance to the moon, and involves a different process: When two magnetic field lines come close together due to the storage of energy from the sun, a critical limit is reached and the magnetic field lines reconnect, causing magnetic energy to be transformed into kinetic energy and heat. Energy is released, and the plasma is accelerated, producing accelerated electrons.

Which theory is right?

"Our data show clearly and for the first time that magnetic reconnection is the trigger," said Angelopoulos, who reports the research in the July 24 online issue of the journal *Science*. "Reconnection results in a slingshot acceleration of waves and plasma along magnetic field lines, lighting up the aurora underneath even before the near-Earth space has had a chance to respond. We are providing the evidence that this is happening."

Previous studies of the Earth's magnetosphere and space weather have been unable to pinpoint the origin of substorms, which are large magnetic disturbances. Ionized gas emitted from the sun's surface speeds up as it moves away from the sun, attaining speeds of 1 million mph and interacting with the Earth's upper atmosphere, which is also ionized, Angelopoulos said. Substorms are building blocks of larger storms.

"We need to understand this environment and eventually be able to predict when these large energy releases will happen so astronauts can go inside their spacecraft and we can turn off critical systems on satellites so they will not be damaged," Angelopoulos said. "This has been exceedingly difficult in the past, because previous missions, which measured the plasma at one location, were unable to determine the origin of the large space storms. To resolve this question properly requires correlations and signal-timing at multiple locations. This is precisely what was missing until now."

At high northern latitudes in the northern U.S. and Canada, shimmering bands of light called the aurora borealis, or northern lights, stretch across the sky from the east to the west. During the geomagnetically disturbed periods known as substorms, these bands of light brighten. These multicolored light shows are generated when showers of high-speed electrons descend along magnetic field lines to strike the Earth's upper atmosphere. Scientists want to learn when, where and why solar wind energy stored within the Earth's magnetosphere is explosively released to accelerate these electrons.

THEMIS is establishing for the first time when and where substorms begin, determining how the individual components of substorms interact, and discovering how substorms power the aurora borealis.

"We discovered what sparks the magnificent light show of the aurora," Angelopoulos said.

THEMIS has five satellites — with electric, magnetic, ion and electron detectors — in carefully chosen orbits around the Earth and an array of 20 ground observatories with automated, all-sky cameras located in the northern U.S. and Canada that catch substorms as they happen. The ground observatories take images of the aurora in white light. One satellite is a third of the distance to the moon, one is about a fourth of the distance and three are about a sixth of the distance. The outermost satellite takes four days to orbit the Earth, the next one two days, and the closest ones orbit the Earth in just one day. Every four days, the satellites line up.

As the satellites are measuring the magnetic and electric fields of the plasma above the Earth's atmosphere once every four days, the ground-based observatories are imaging the auroral lights and the electrical currents from space that generate them.

THEMIS was launched on Feb. 17, 2007, from Cape Canaveral, Fla., and is expected to observe approximately 30 substorms in its nominal lifetime.

"Armed with this knowledge, we are not only putting to rest age-old questions about the origin of the spectacular auroral eruptions but will also be able to provide statistics on substorm evolution and model its effects on space weather," Angelopoulos said.

Source: University of California - Los Angeles

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