An Explosion of Light

Using images from the NASA THEMIS mission, a UCLA research team has identified new and dramatic phenomena associated with the aurora borealis.

It seems that the beautiful and seemingly delicate phenomenon known as aurora borealis—the northern lights—has a violent side to its makeup as well.

At northern latitudes in the U.S. and Canada, the shimmering bands of the aurora borealis stretch across the sky from the east to the west. These multicolored light shows are generated when showers of high-speed electrons descend along magnetic field lines to strike the Earth's upper atmosphere.

Discoveries made possible by analyzing images supplied by NASA's THEMIS mission have produced a startling discovery about the aurora borealis: sometimes vast curtains of aurora borealis collide, producing spectacular outbursts of light.

"Our jaws dropped when we saw the movies for the first time," said Larry Lyons, UCLA professor of atmospheric and oceanic sciences and a member of the research team that made the discovery. "These outbursts are telling us something very fundamental about the nature of auroras."

Explosions of light known as substorms occur when the magnetosphere suddenly releases stored solar wind energy. Substorms start from a small region in space but within minutes cover an immense region of the magnetosphere. Different possible triggers have different locations, so the key to solving this mystery is placing spacecraft in various locations in Earth's magnetic field to help find the elusive substorm point of origin.

Larry Lyons with researcher Heejeong Kim.

With a motto of "Understanding Space Weather," NASA's THEMIS mission (Time History of Events and Macroscale Interactions during Substorms) aims to resolve one of the oldest mysteries in space physics: why do auroras occasionally erupt in substorms? THEMIS includes five identical satellite probes, developed in cooperation with the Canadian Space Agency, and 20 all-sky imagers deployed across the Arctic to photograph auroras from below while the spacecraft sampled charged particles and electromagnetic fields from above.

Understanding and predicting space weather is important to describe the environment in which spacecraft and astronauts operate and ensure their safety. Just as hail and tornadoes accompany the most severe thunderstorms, substorms accompany the most intense space storms—those that disrupt communications, cause power line transmission failures, and produce the most penetrating radiation.

Over the last 40 years, substorms have been studied extensively from the ground and in space. However, the sequence of events during a substorm has remained elusive and has been a key subject of debate among scientists who study the physics of the near–Earth space environment.

The breakthrough came earlier this year when UCLA researcher Toshi Nishimura assembled continent-wide movies from the individual ASI cameras.

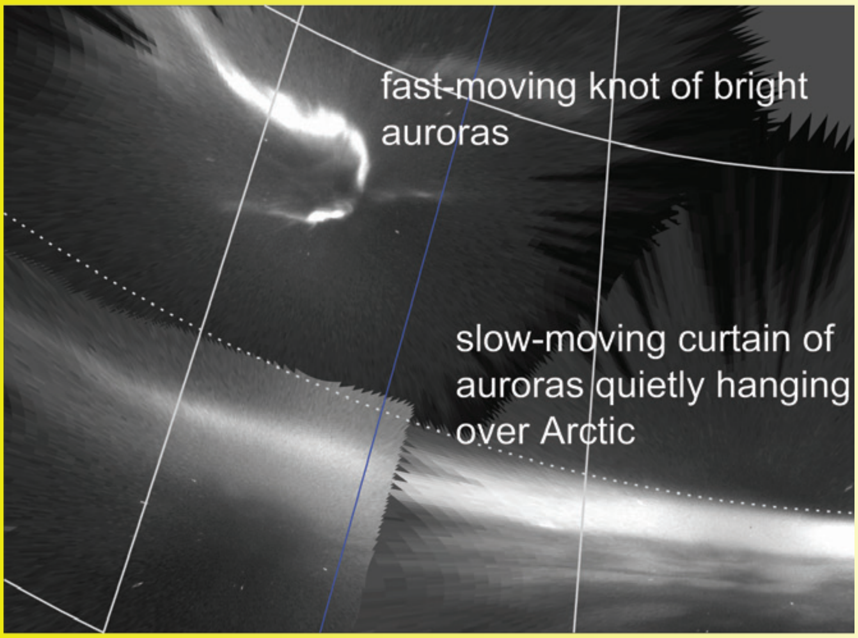
The first movie he showed Lyons was of a pair of auroras crashing together in December 2007.

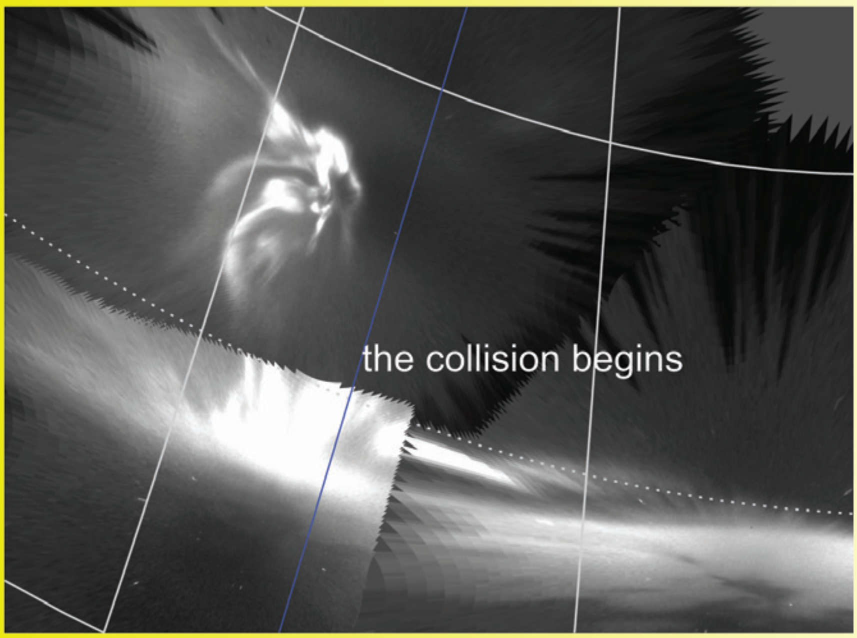
"It was like nothing I had seen before," Lyons recalled. "Over the next several days, we surveyed more events. Our excitement mounted as we became convinced that the collisions were happening over and over."

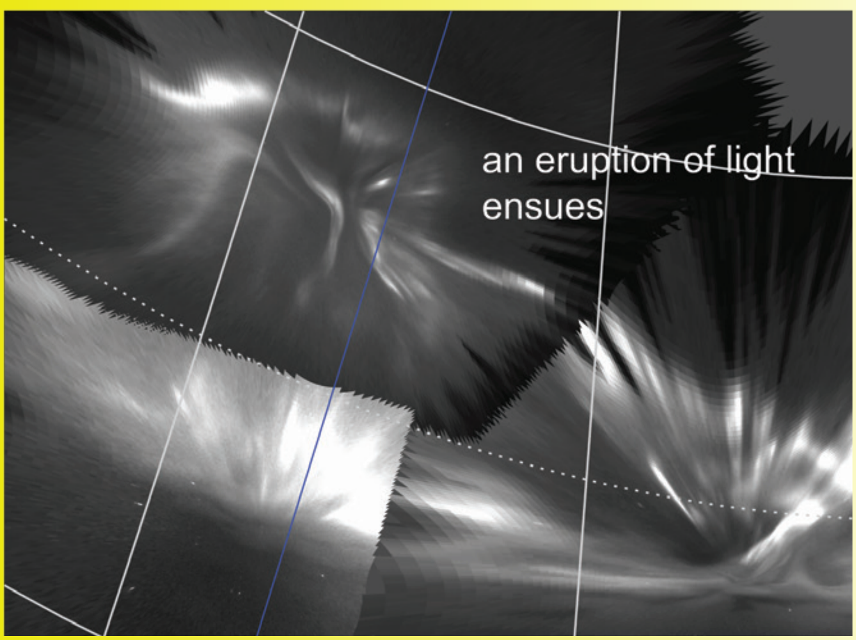
The explosions of light, the researchers believe, are a sign of something dramatic happening in the space around Earth—specifically, in the Earth's "plasma tail." Millions of miles long and pointed away from the sun, the plasma tail is made of charged particles captured mainly from the solar wind. Sometimes called the "plasma sheet," the tail is held together by the Earth's magnetic field.

"Collisions of auroras associated with plasma coming from the deep plasma tail, with the aurora coming from the plasma in the nearest portion of the plasma tail, set up an unstable configuration," Lyons said.

The research team has identified a common sequence of events *(see illustrations)*: it begins with a broad curtain of slowmoving auroras and a smaller knot of fast-moving auroras, initially far apart. The slow curtain quietly hangs in place, almost immobile, while the speedy knot rushes in from the north. The auroras collide, and an eruption of light ensues.







Surprises in the Magnetosphere

Other recent work by Lyons and UCLA colleagues revealed a previously unknown mode of energy transfer from the solar wind to the Earth's magnetosphere—a discovery that could improve the safety and reliability of spacecraft that operate in the upper atmosphere.

"It's like something else is heating the atmosphere besides the sun," said Lyons. "This discovery is like finding it got hotter when the sun went down."

The sun emits a stream of ionized particles called the solar wind that affects the Earth and other planets in the solar system. The solar wind, which carries the particles from the sun's magnetic field, known as the interplanetary magnetic field, takes about three or four days to reach the Earth. When the charged electrical particles approach the Earth, they carve out a highly magnetized region—the magnetosphere—which surrounds and protects the Earth.

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Charged particles carry currents, which cause significant modifications in the Earth's magnetosphere. This region is where communications spacecraft operate and where the energy releases in space known as substorms wreak havoc on satellites, power grids and communications systems.

The rate at which the solar wind transfers energy to the magnetosphere can vary widely, but what determines the rate of energy transfer is unclear.

"We thought it was known, but we came up with a major surprise," said Lyons, who conducted the research with assistant researcher Heejeong Kim and Oceanic Sciences, and other colleagues.

"This is where everything gets started," Lyons said. "Any important variations in the magnetosphere occur because there is a transfer of energy from the solar wind to the particles in the magnetosphere. The first critical step is to understand how the energy gets transferred from the solar wind to the magnetosphere." CR