THEMIS

TIME **H**ISTORY OF **E**VENTS AND **M**ACROSCALE **I**NTERACTIONS DURING **S**UBSTORMS

A Quest to Understand the Onset of Substorms

WHAT IS THEMIS?

If you look up into the sky on a clear, dark night while in Alaska, Canada, or the Northern United States, you may see a bright greenish-white band of light that stretches across the sky from the East to the West. These are the Northern Lights, also known as the Aurora Borealis. These types of lights also occur near the South Pole, where they are known as the Southern Lights or Aurora Australis.

Auroral bands photographed by Jan Curtis in Fairbanks, Alaska

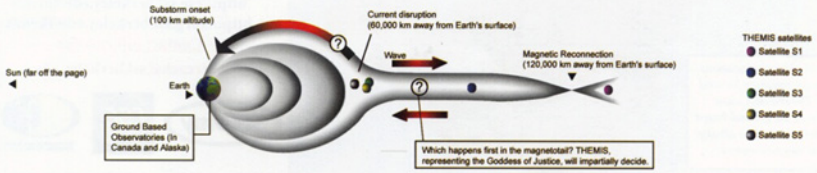
Break-up aurora photographed by Jan Curtis in Fairbanks, Alaska

If you are lucky, you may watch this auroral band continue to brighten as it moves toward the South. Then, within minutes, you may see the band of light break into many bands of light, some of which will move back overhead and to the North, dancing rapidly and turning red, purple, and white. This sequence of events that you have witnessed is the *expansion onset of an auroral substorm* or *substorm onset*.

From observations and experiments in space, scientists have learned that substorm onset is related to the release of energy in Earth's magnetosphere, which is the space where Earth's magnetic field is dominant. Some of the energy in the magnetosphere is always released in the upper atmosphere as a single auroral band. However there are times when the magnetosphere stores more energy than it can release in a slow and steady manner and something inside "breaks." Electric currents and electromagnetic waves propagate from the breaking point and suddenly cause the beautiful and mysterious dancing aurora after substorm onset.

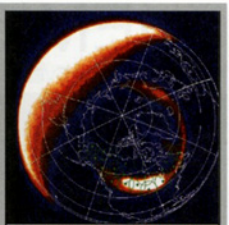
There are two main locations and two different types of processes where this "breaking" can occur: at approximately 60,000 km and 120,000 km away from Earth on the side facing away from the Sun, as shown in the figure below. At 60,000 km, a flow of electrical current suddenly follows the magnetic field lines into the upper atmosphere in a dynamic way, perhaps producing the onset of an auroral substorm. There are many different possible processes that may cause this sudden flow. At 120,000 km, a sudden merging of oppositely pointed magnetic fields may occur, known as *Magnetic Reconnection at the Near Earth Neutral Line*. This causes charged particles in the magnetosphere to flow inward until they are forced to flow along the magnetic field lines as a current into the upper atmosphere, perhaps producing substorm onset. Scientists still do not have the appropriate data to decide which process occurs first and when substorm onset occurs relative to these two processes.

To solve this mystery, ground-based observatories (GBOs) and THEMIS satellites will be appropriately lined up in Earth's magnetosphere to determine the sequence of events. THEMIS will learn which physical process is the initial trigger to release the energy in the magnetosphere, leading to an auroral substorm.



AURORA AND SUBSTORM DISCOVERIES BY SCIENTISTS

1716	Sir Edmund Halley	The aurora is aligned with Earth's magnetic field.
1741	Anders Celsius	The aurora has magnetic disturbances.
1790	Henry Cavendish	Auroral light is produced near Earth at 100-130km,
1859	Richard Carrington	but it is related to distant Solar eruptions.
1866	Anders Angström	Auroral displays are self-luminous and
1896	Kristian Birkeland	due to currents in space,
1907	Carl Störmer	which are carried by field-aligned, energetic electrons.
1932	Chapman & Ferraro	These electrons are accelerated in the magnetosphere
1950	Hannes Alfvén	by the Solar Wind–Magnetosphere dynamo.
1961	James Dungey	Reconnection is important for plasma circulation.
1964	Shun-ichi Akasofu	Auroral substorms have two distinct phases: expansion and recovery, the first of which starts suddenly (onset).
1967	Brice & Rothwell	Substorms are a magnetospheric phenomenon,
1970	Robert McPherron	which begin with a growth phase prior to onset.
1973	Russell, Hones, McPherron et al. Nishida & Nagayama	Onset is proposed to be caused by magnetic reconnection at the Near-Earth Neutral Line around 120,000 km altitude from Earth's midnight equator.
1978	Lui & Burrows	Onset is proposed to be caused by changes in flows of electric current around 60,000 km altitude from Earth's midnight equator.



An image in far ultraviolet (FUV) light of the onset of an auroral substorm over North America (bottom right) and the reflected sunlight off of the upper atmosphere (top left). The FUV instrument on the IMAGE satellite took this image. Continents are drawn in white.

THEMIS TEACHERS AND STUDENTS

Geomagnetic Event Observation Network by Students (GEONS) is a national network of schools, each of which has a THEMIS magnetometer located on its campus. The schools with magnetometers were selected by state-wide competition based on the communities' distance from magnetic field contaminations, commitment of the schools to our program, and local infrastructure with the potential for reaching large communities of students and teachers. The teachers at the GEONS magnetometer schools take part in yearly teacher professional development workshops held by the THEMIS Education and Public Outreach (E/PO) team. Teachers across the country are involved in hands-on activities, which support inquiry and use THEMIS data.

GEONS teachers, engineers, scientists, and E/PO team in front of the Space Sciences Laboratory at a teacher professional development workshop at the University of California in Berkeley, CA in July of 2004.

The GEONS schools are located in rural areas in Alaska, Oregon, Wisconsin, Nevada, Michigan, Pennsylvania, and Maine, as well as in high schools on or near Native American lands in Montana, North Dakota, and South Dakota. Through these rural communities, we reach students and teachers who are typically under-served in science education.

The blue dots show the locations of the 10 magnetometers located in schools. The red dots show the locations of the ground-based observatories which have all-sky cameras and magnetometers.

GLOSSARY

Dynamo: The generation of an electric current by the flow of an electrically conducting fluid through a magnetic field.

Electric current: Moving charged particles such that opposite charges are moving relative to one another, i.e. not at the same speed or in the same direction.

Geospace: The domain of interactions of particles, magnetic fields, electric fields, and radiation from the Sun to Earth's magnetosphere and upper atmosphere.

Plasma: A low-density "gas" of charged particles in which positive and negative charges are equal in number.

Self-luminous: Possessing in itself the property of emitting light.

Solar eruption: A sudden ejection of mass and energy that moves outward from the Sun, such as solar flares or coronal mass ejections.

Solar wind: Charged particles, mostly protons and electrons, that stream outward from the Sun and past the planets in the solar system.

Web pages
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