National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 9-12

Educational Brief

Exploring the Aurora with IMAGE

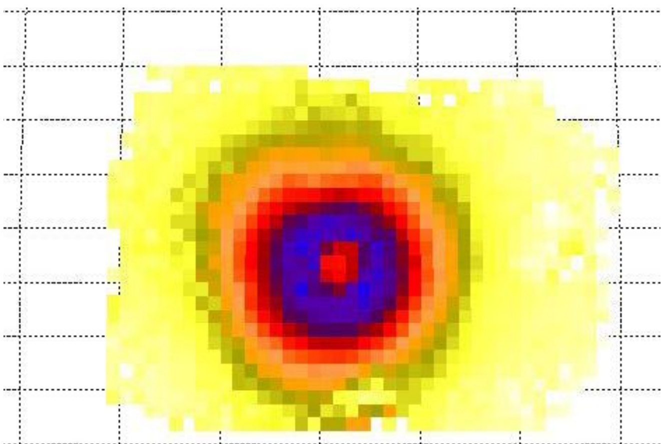


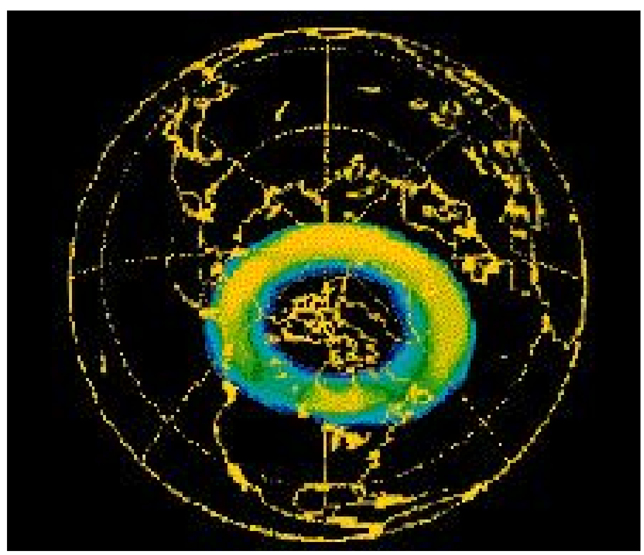
Image of the Geocorona obtained by the SOHO satellite.

The Earth is surrounded by an invisible, and complex, region called the magnetosphere, in which charged particles, called plasmas, are affected by the terrestrial magnetic field. Resembling a comet, the magnetosphere is drawn out into a long tail, called the magnetotail, on the nighttime side of the Earth. The Earth's field changes in complex ways when the sun, or the solar wind are active, causing magnetic storms detectable from the ground. During the most severe magnetic storms, the magnetotail accelerates plasma into the interior of the magnetosphere. There, these currents collide with oxygen and nitrogen atoms to produce the aurora borealis and aurora australis, also called the Northern and Southern Lights.

The Imager for magnetosphere-to-Auroral Global Exploration (IMAGE) will study how aurora are produced using an instrument called the Far Ultraviolet Imager. (http://image.gsfc.nasa.gov/poetry)

Far Ultraviolet Imager (FUV)

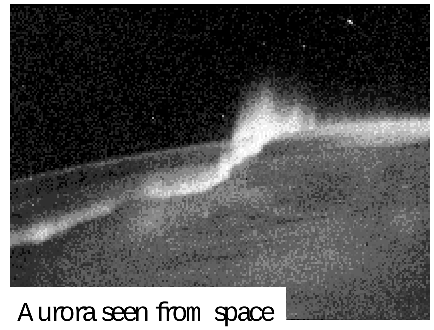
The FUV instrument, onboard the IMAGE satellite, consists of three separate sensors; the Spectroscopic Imager (SI), the Wide-band Imager (WIC) and GEO. These instruments work like a home video camera where focussing lenses concentrate the light, and an imaging sensor array detects the light and builds-up the picture electronically. These instruments also have filters to limit the detected, ultraviolet light to specific wavelengths. This helps space scientists investigate specific issues having to do with the way that aurora are produced and how they change in time. The instruments will be used to study the extended atmosphere of the Earth (called the exosphere), auroras produced by the bombardment of oxygen and nitrogen atoms by



The auroral oval as viewed by the POLAR satellite

The Magnetotail Battery and Aurora

Scientists have proposed that changes in the magnetic field in the magnetotail region, cause releases of energy that eventually supply the battery to 'light-up' the aurora on Earth. Let's explore this idea in more detail to see what they are talking about!



Aurora seen from space

1 How big a battery?

Energy is stored in a magnetic field, and the amount depends on how strong the field is, and how big a volume it occupies. Let's suppose the volume of the magnetotail region is a cylinder with a height of 300,000 kilometers, and a radius of 60,000 kilometers. Use the formula for a cylinder to estimate the magnetotail volume, in cubic meters.

$$V = \pi r^2 h = 3.14 \times (6\times10^{9}\text{ meters})^2 \times (3\times10^{10}\text{ meters}) = 3.4 \times 10^{30}\text{ cubic meters}$$

The formula for the energy of a magnetic field is:

$$E = \frac{10^7}{8\pi} B^2 \times V$$

where B is expressed in Teslas, V in cubic meters, and the energy will then be in units of Joules.

For a magnetic field with a strength of 1×10^{-9} teslas, and the volume of space you just calculated, the total energy of the magnetotail field is:

$$E = 3.9\times10^{5} \times (1 \times 10^{-9}\text{ teslas})^2 \times 3.4 \times 10^{30}\text{ m}^3$$
$$E = 5\times10^{17}\text{ joules}$$

As a comparison, your house uses about 10^8 joules of electricity per day.

2 How much energy do you need to light-up the auroras in the Northern and Southern Hemispheres?

Auroras are powered by currents of electrons that carry about 1,000,000 Amperes. Your home uses about 200 Amperes at 110 Volts. The atmosphere that this auroral current has to flow through has a resistance of about 0.1 Ohms.

Electrical power is calculated using a formula that relates resistance (R) and current (A) to the power (P) that they can produce in a circuit:

$$P = I^2 \times R \quad \text{Joules/second}$$

where R is measured in Ohms, and I is in Amperes.

The total auroral power is then:

$$P = (10^6\text{ Amperes})^2 \times (0.1\text{ Ohms})$$
$$= 10^{11}\text{ Joules/second}$$

3 How many seconds can the magnetotail 'battery' continue to supply energy to the aurora to keep them going?

Suppose that only 1% of the available energy from the magnetotail actually went into producing the aurora. About how long would the aurora last before it has used up the available energy? The answer to the first question tells us how much power is available. The answer to the second question tells us at what rate (energy per second) the aurora are wasting energy as light and heat are generated. To find out how long this can continue, divide the answer from question one, by the answer from question two:

$$\text{Time} = \frac{0.01 \times 5\times10^{17}\text{ Joules}}{10^{11}\text{ Joules/second}} = 5\times10^{4}\text{ seconds, or about 14 hours}$$