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WELCOME TO THE UPDATED SOHO PORTFOLIO

This image set (updated in December, 1999) is intended to provide a general audience with easy access to recent and striking images of the Sun in a single, reasonably small, package. It contains images (or groups of images) with explanatory text for each. These may prove useful for teaching about the Sun or for gaining a quick overview of some of the most dramatic images that SOHO (the Solar and Heliospheric Observatory) is producing.

Text and graphics can be copied to the clipboard and pasted into most applications (see Acrobat Help if you need assistance in doing this).

We are in the process of having this new set printed and made available to educators through the NASA Educational Resource Centers. The last page tells you how to order a printed copy from NASA CORE.

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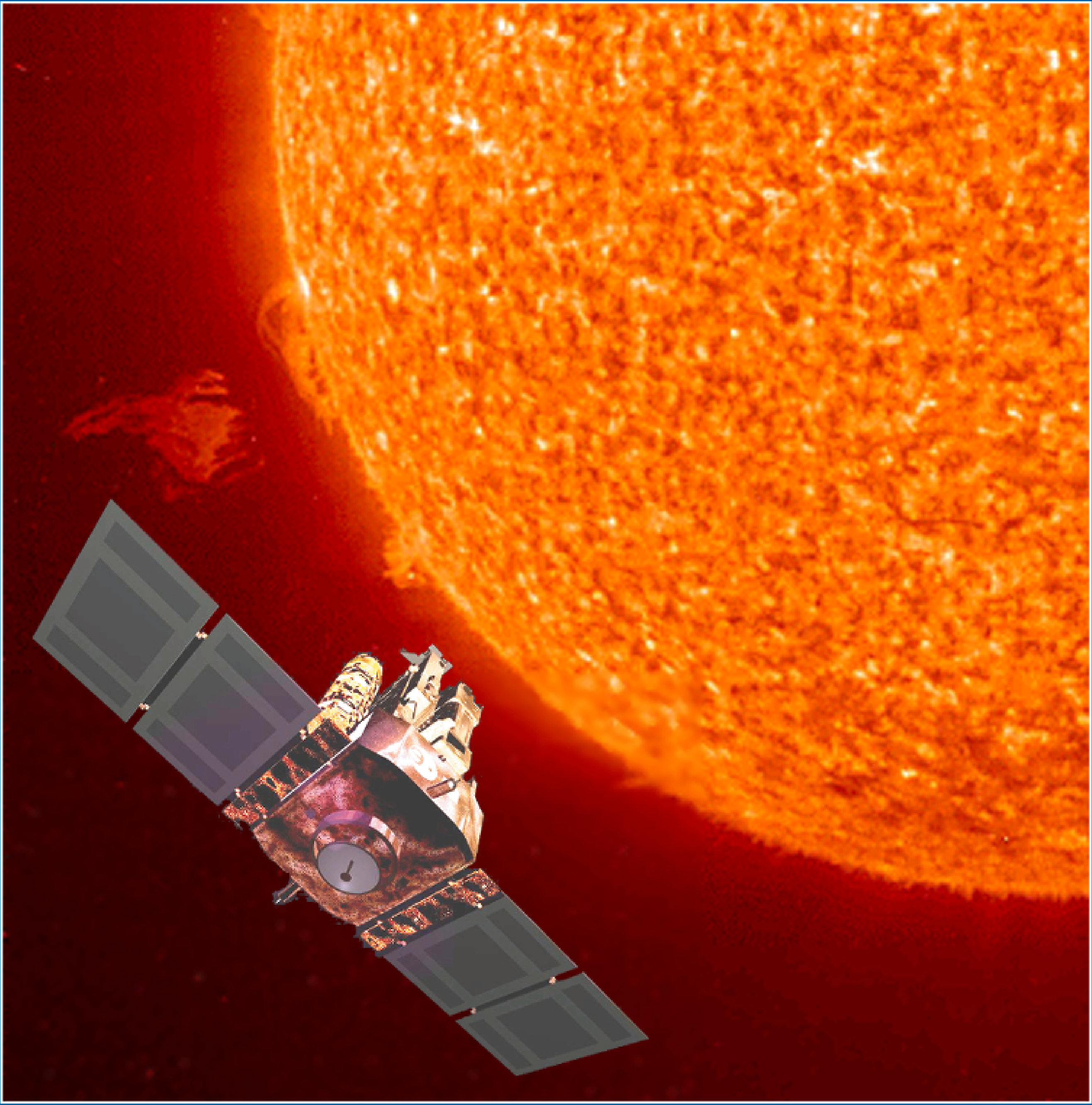

SOHO, the Solar and Heliospheric Observatory, studies the Sun 24 hours a day from space

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The SOHO spacecraft is a very sophisticated instrument package built in Europe. It weighs nearly two tons and stretches about 25 feet across with its solar panels extended. It is pictured here in front of an image produced by one of its instruments, the Extreme ultraviolet Imaging Telescope (EIT). Since it first started sending back data and images in March 1996, SOHO has engendered interest and enthusiasm from the space physics community and other scientists, and has led the way to major discoveries about the Sun.

Because it is far above the Earth's atmosphere, SOHO can capture data and images with unprecedented detail and quality. This also allows it to measure scientifically important kinds of light that are blocked by the Earth's atmosphere, i.e., not available to ground-based telescopes.

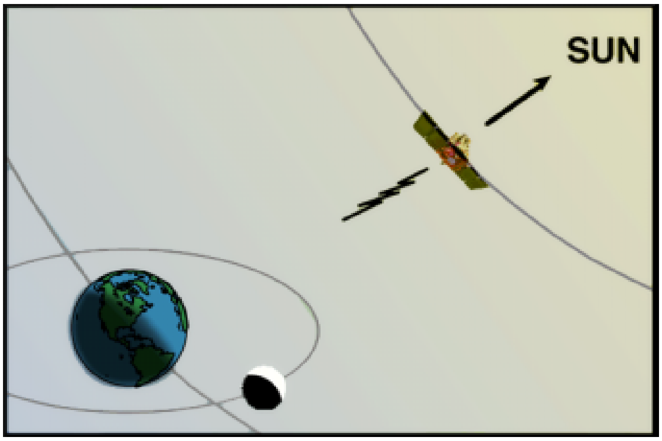

Illustration of the location of SOHO 1.6 million kilometers sunward of Earth

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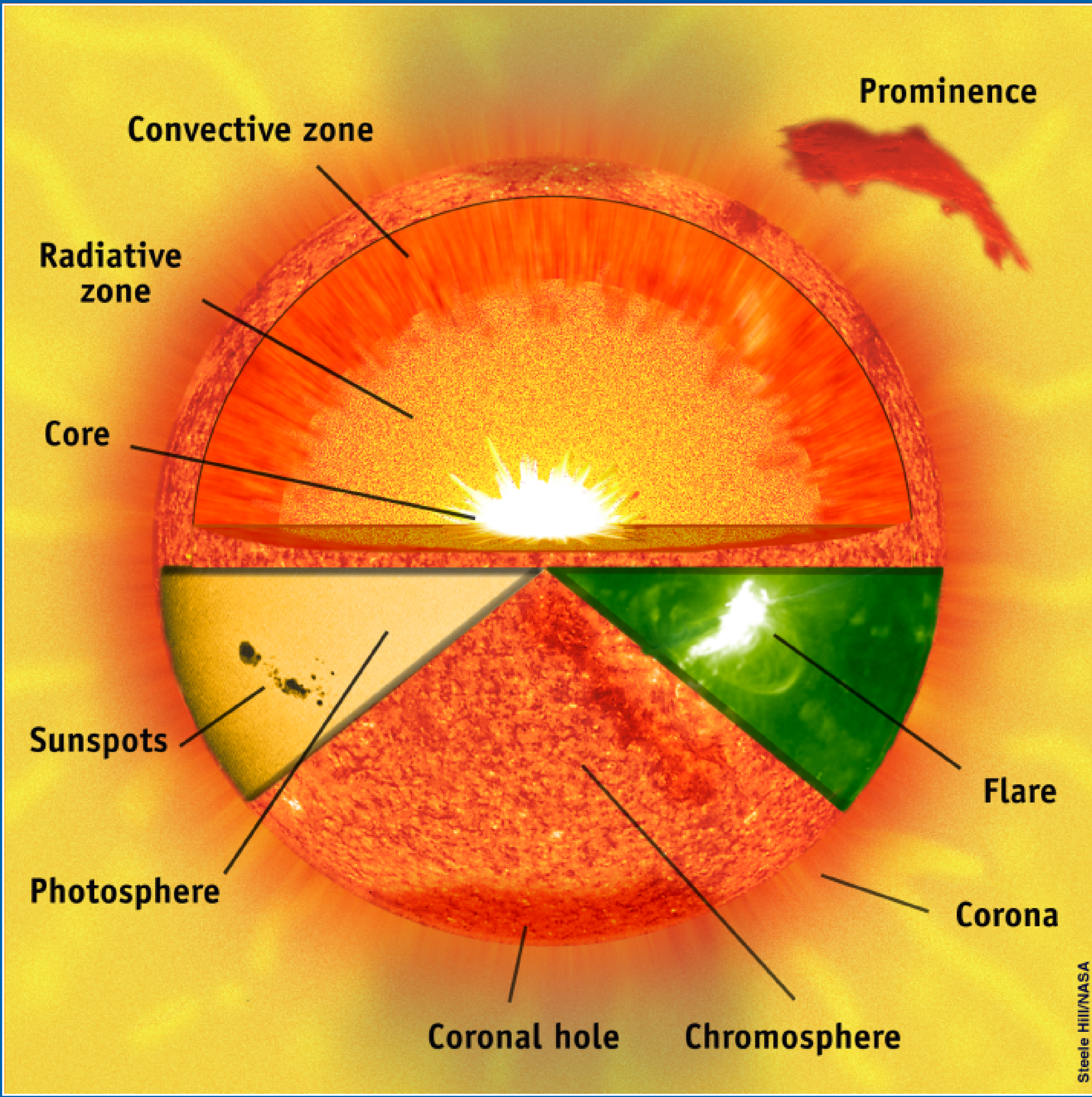

The parts of the Sun

The parts of the Sun

This illustration gives a basic overview of the parts of the Sun. The three major interior zones are the **core** (the innermost part of the Sun where energy is generated by nuclear reactions), the **radiative zone** (where energy travels outward by radiation through about 70% of the Sun), and the **convection zone** (in which convection currents circulate the Sun's energy to the surface).

Some of the other parts identified are:

Sunspot: a temporary disturbed area in the solar photosphere that appears dark because it is cooler than the surrounding areas. Sunspots consist of concentrations of strong magnetic flux.

Photosphere: the visible surface of the Sun. It consists of a zone in which the gaseous layers change from being completely opaque to radiation to being transparent. It is the layer from which the light we actually see (with the human eye) is emitted.

Chromosphere: the layer of the solar atmosphere that is located above the photosphere and beneath the corona. The chromosphere is hotter than the photosphere but not as hot as the corona.

Corona: the outermost layer of the solar atmosphere. The corona consists of highly rarefied gas at a temperature greater than one million degrees Kelvin. It is visible to the naked eye during a solar eclipse.

Coronal hole: An area of the corona which appears dark in X-rays and ultraviolet light and are usually located at the Sun's poles. The magnetic field lines in a coronal hole extend out into the solar wind rather than coming back down to the Sun's surface.

Prominence: a structure in the corona consisting of cool plasma supported by magnetic fields. Prominences are bright structures when seen at the Sun's edge. However, when seen against the bright solar disk, they are dark and are called **filaments.**

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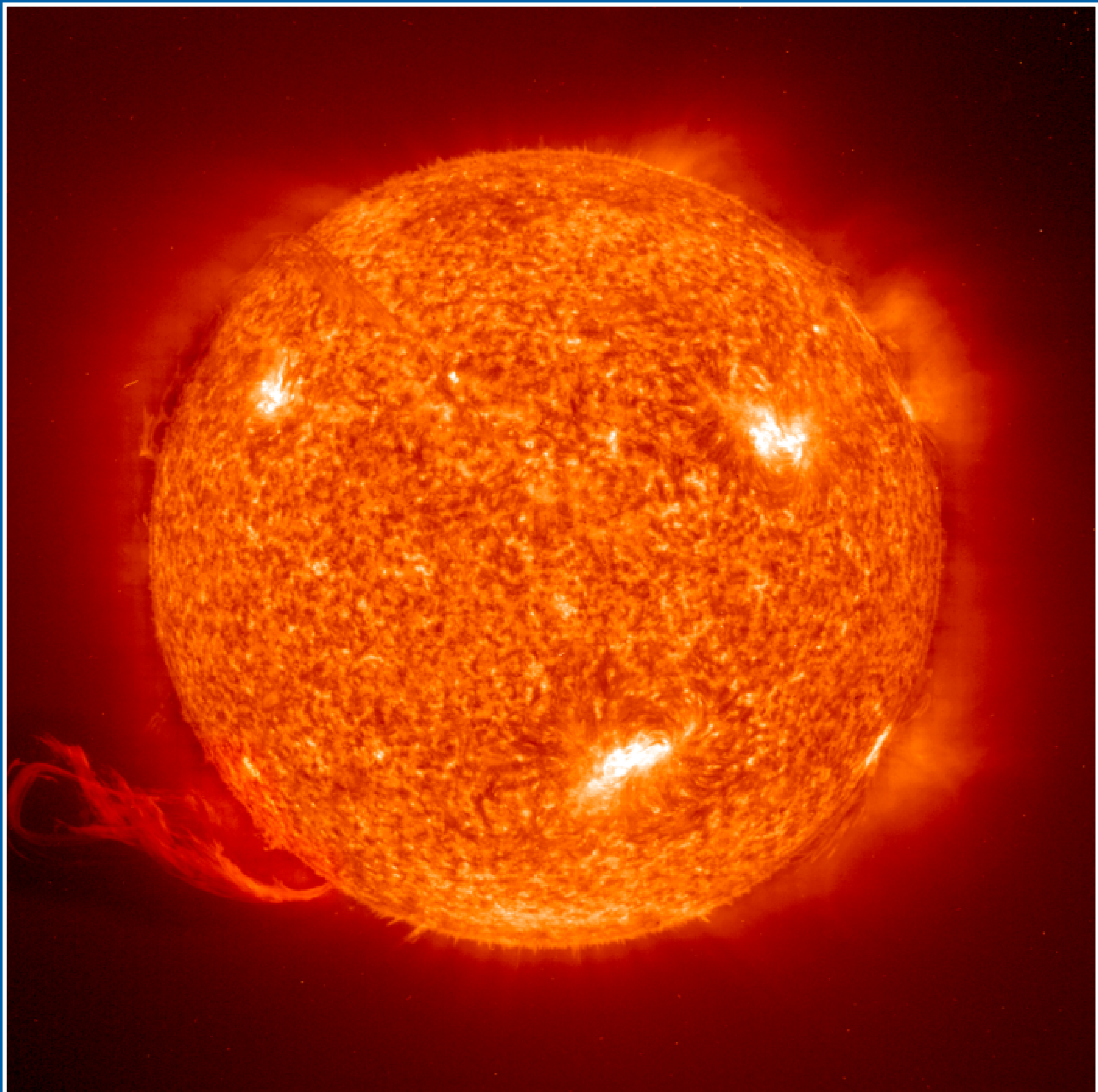

The Sun has eruptions, hotter and cooler areas, and extending prominences

The Sun has eruptions, hotter and cooler areas, and extending prominences

This image, taken by the Extreme ultraviolet Imaging Telescope (EIT), shows the Sun in the He II emission line at 304 Å. It was taken on September 14, 1997. Emission in this spectral line shows the upper chromosphere at a temperature of about 60,000 K. Many features typical of the extreme ultraviolet light corona are visible, including polar coronal holes, polar plumes, active regions, and filament channels. Every feature in the image traces magnetic field structure. The hottest areas appear almost white, while the darker red areas indicate cooler temperatures.

Note the large erupting prominence at the lower left. These eruptions occur when a significant amount of cool dense plasma or ionized gas escapes from the normally closed, confining, low-level magnetic fields of the Sun's atmosphere to streak out into the interplanetary medium, or heliosphere. When aimed in the direction of Earth, powerful eruptions like the one pictured here sometimes produce major disruptions in the near-Earth environment, affecting communications, navigation systems and even power grids. The effect of these storms can be observed as magnificently shimmering auroral displays (called the Northern or Southern lights) in the skies near the North and South poles.

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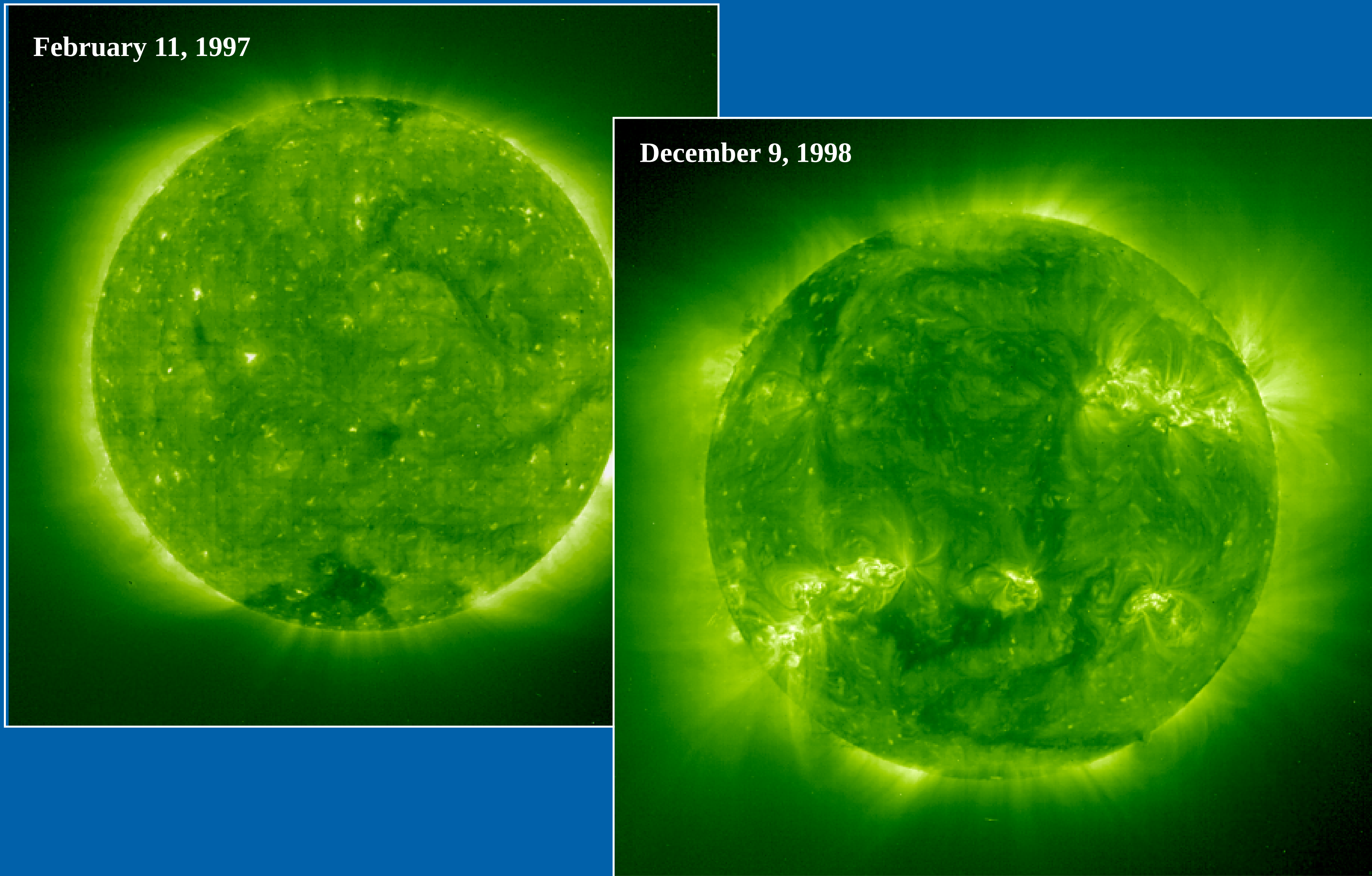
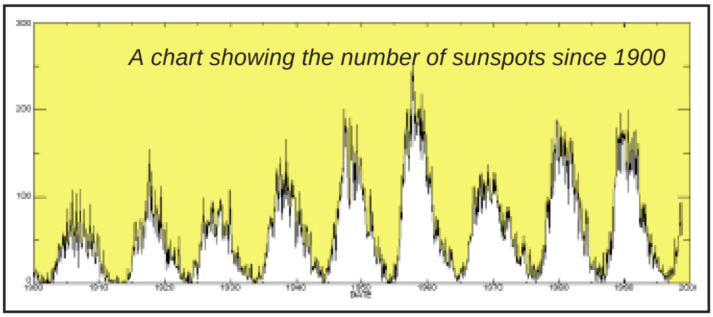


A comparison of two ultraviolet images almost two years apart clearly illustrates how the level of solar activity is increasing significantly as the Sun approaches its next solar maximum in late 2000

A comparison of two ultraviolet images almost two years apart clearly illustrates how the level of solar activity is increasing significantly as the Sun approaches its next solar maximum in late 2000

Every 11 years the Sun undergoes a period of activity called the "solar maximum", followed by a period of quiet called the "solar minimum". During the solar maximum there are many sunspots, solar flares, and coronal mass ejections, all of which can affect communications and weather here on Earth.

In a quick comparison of the pair of extreme ultraviolet images of ionized iron in the corona (at about 1 million degrees K.), the series of active regions (some of which would be seen as sunspots in visible light by other instruments) and the number and size of magnetic loops in the more recent image indicate the expected rise in solar activity.



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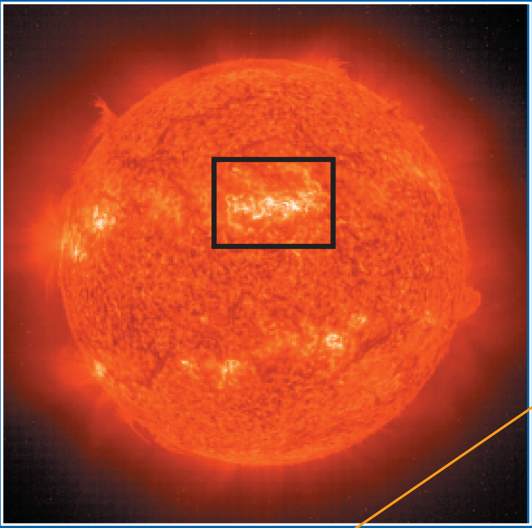
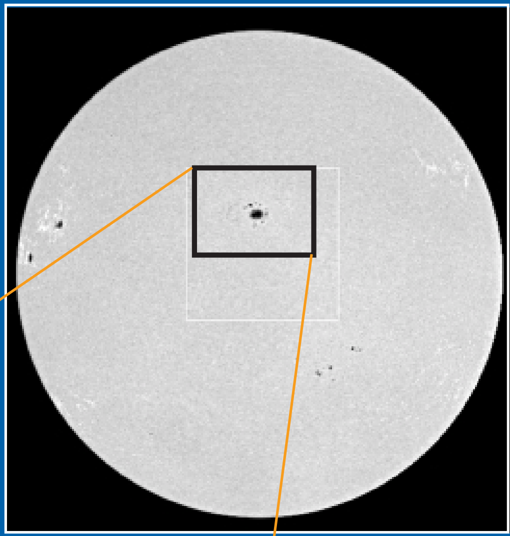
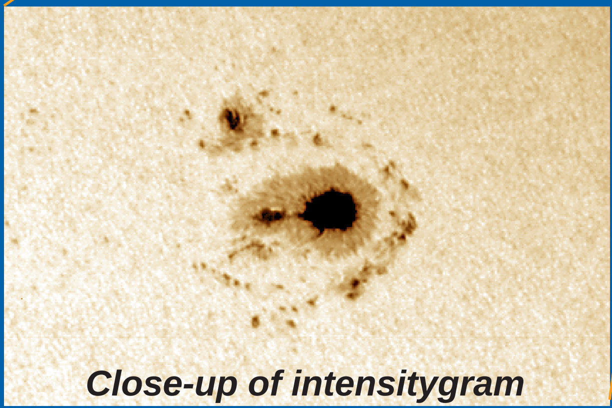


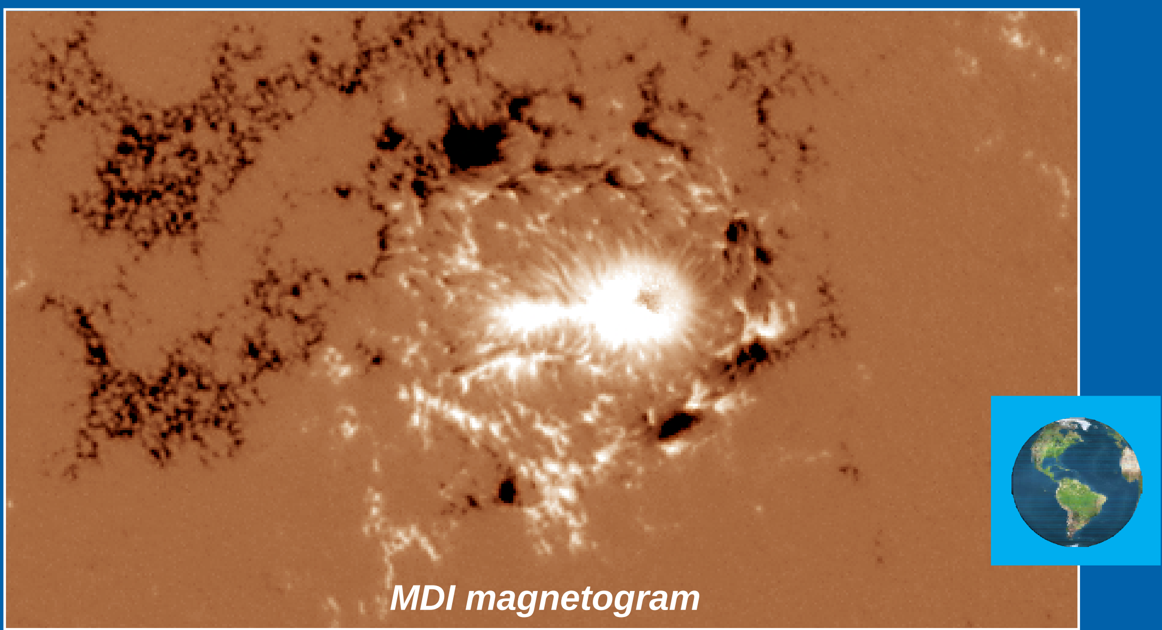
EIT 195Å



MDI intensitygram



Close-up of intensitygram



MDI magnetogram

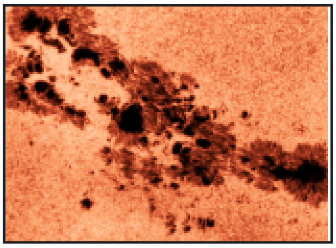
Sunspots, seen as darker spots on the Sun's surface, are cooler regions of plasma

(observed on 5 November 1998)

Sunspots, seen as darker spots on the Sun's surface, are cooler regions of plasma

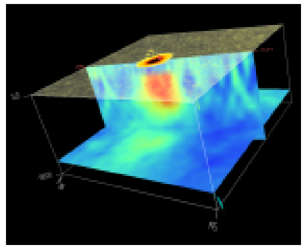
One way we track solar activity is by observing sunspots (relatively cool areas that appear as dark blemishes on the face of the Sun). They are formed when magnetic field lines just below the Sun's surface are twisted and poke though the solar photosphere. The twisted magnetic field above sunspots are sites where solar flares occur, and we are now beginning to understand the connection between solar flares and sunspots.

During solar maximum there are many sunspots, and during solar minimum there are few. The plot below shows the number of sunspots observed during the last nine solar cycles. The last maximum occurred around 1989, and the next is predicted to fall late in the year 2000. You can see a monthly update of this plot at: http://science.msfc.nasa.gov/ssl/pad/solar/sunspots.htm



Close-up of a group of sunspots on the Sun's surface

The subsurface structure (sound speed) below a sunspot as derived from Doppler measurements



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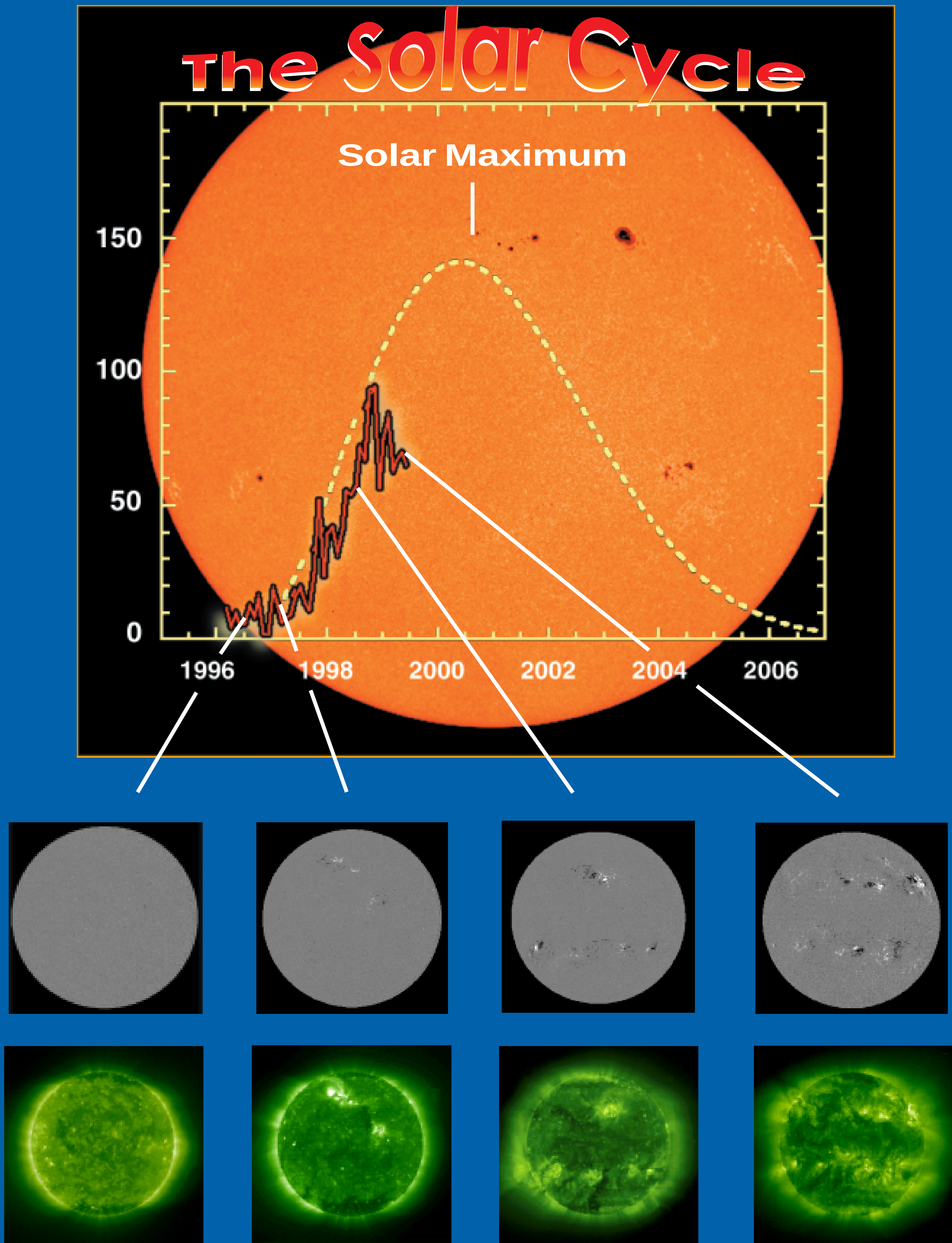

The sun’s 11 year solar cycle as reflected by the number of sunspots recorded to date and as projected (dotted line)

The sun’s 11 year solar cycle as reflected by the number of sunspots recorded to date and as projected

The number of sunspots on the Sun is not constant. In addition to the obvious variation caused by the Sun's rotation (sunspots disappear from view and then re-appear), over time new sunspot groups form and old ones decay and fade away. When viewed over short periods of time (a few weeks or months), this variation in the number of sunspots might appear to be random. However, observations over many years reveal that the number of sunspots varies in a cyclic manner, usually described as the 11 year cycle (in actuality, the period varies, and has been closer to 10.5 years this century). The 11 year sunspot cycle is related to a 22 year cycle for the reversal of the Sun's magnetic field. While the cycle has been relatively uniform this century, there have been large variations in the past. From about 1645 to 1715, a period known as the Maunder minimum, apparently few sunspots were present on the Sun.And the Earth’s temperatures were significantly colder.

Although the number of sunspots is the most easily observed feature, essentially all aspects of the Sun and solar activity are influenced by the solar cycle. Because solar activity (such as coronal mass ejections) is more frequent at solar maximum and less frequent at solar minimum, geomagnetic activity also follows the solar cycle. Why is there a solar cycle? No one knows the answer to this question.

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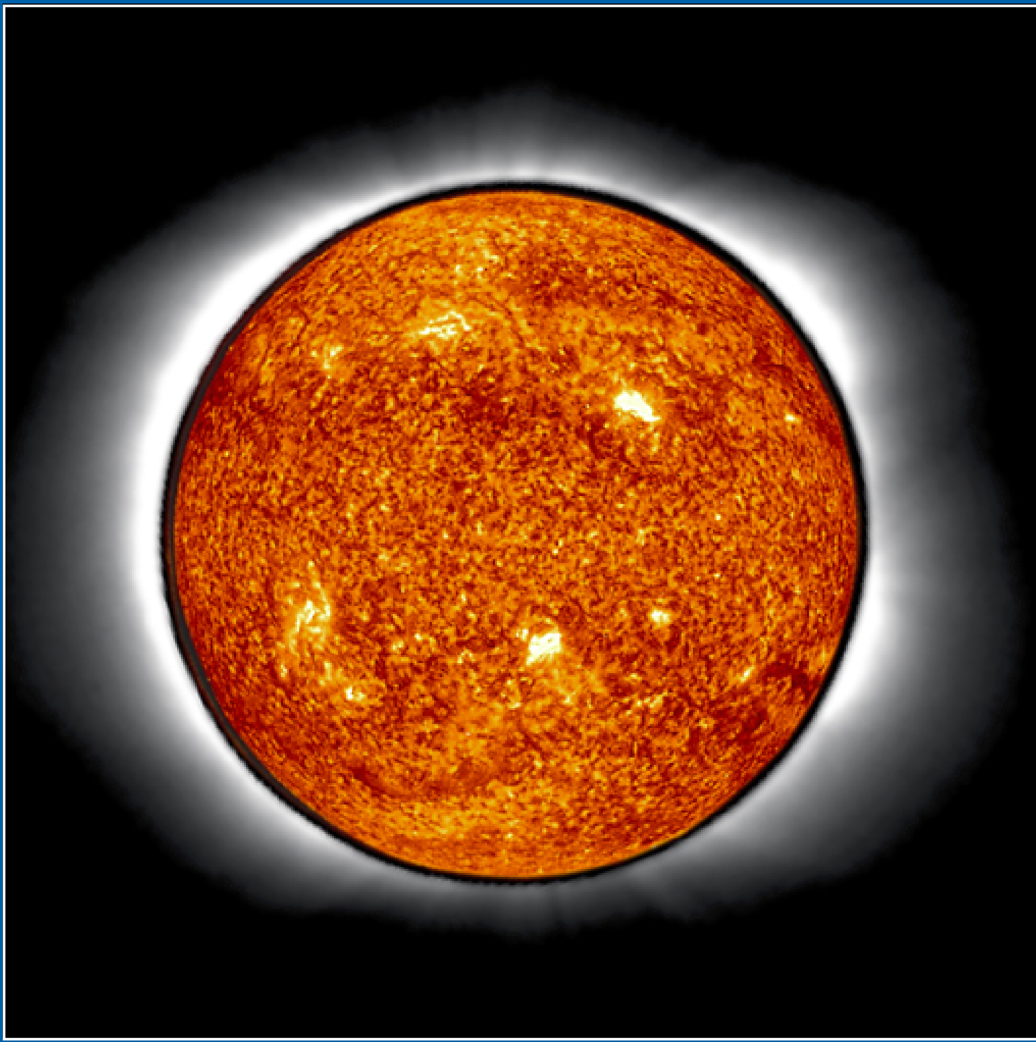
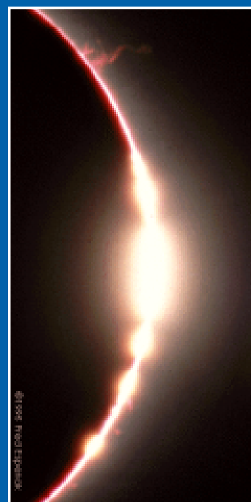
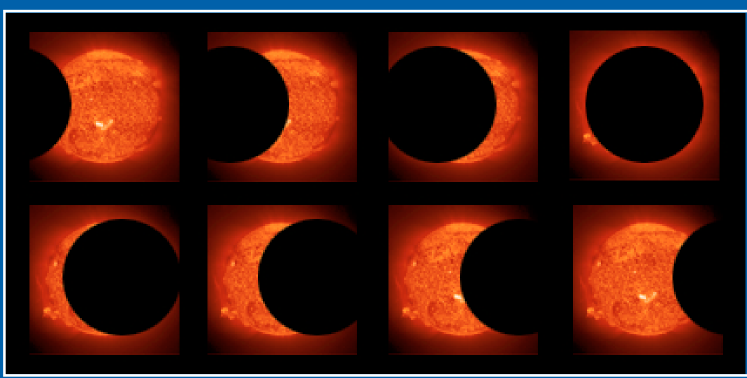




The bright spots that appear as the Sun emerges from an eclipse are called Bailey's beads



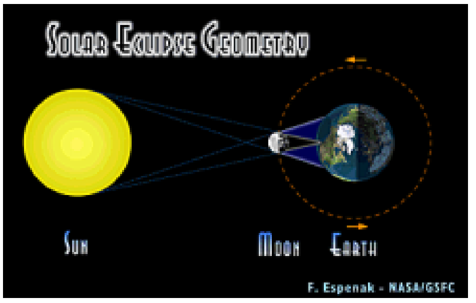
A series of illustrations shows the progress of an eclipse, which lasts less than two hours

Besides capturing the public's interest, eclipses give scientists the chance to study the Sun's corona

Besides capturing the public's interest, eclipses give scientists the chance to study the Sun's corona

The Sun is so bright that it effectively hides anything nearby with brilliant sunlight. When the moon blocks out the Sun's light from an area of the Earth during a total solar eclipse (which happens roughly every 18 months), scientists rush for a chance to gaze for a couple of minutes at the glowing gas and dust that make up the sun's atmosphere, or corona (see below, left).

The Earth and moon shine only by the reflected light of the Sun, and both cast a shadow into space away from the Sun. This shadow consists of a cone-shaped area of complete darkness, the umbra (about 81 miles in diameter), and a larger area of partial darkness that surrounds the umbra, the penumbra. If you are lucky enough to be in the area when the umbra passes over, you will see a total eclipse that lasts for only a few minutes at best. An eclipse, from the beginning to the end, lasts less than two hours.



The basics of a solar eclipse

For about two minutes, the Sun's corona is all that can be seen at the moment of total eclipse

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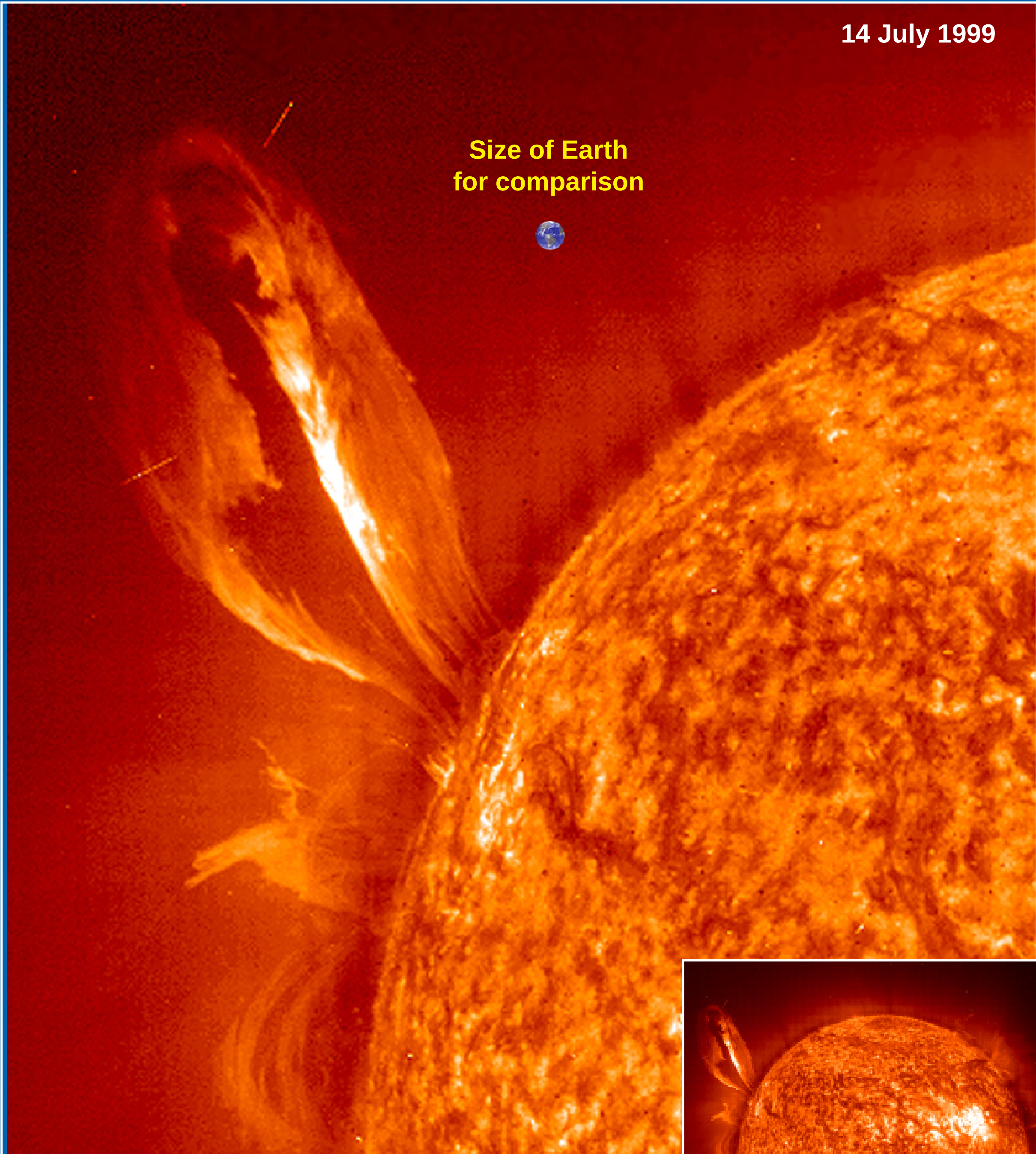

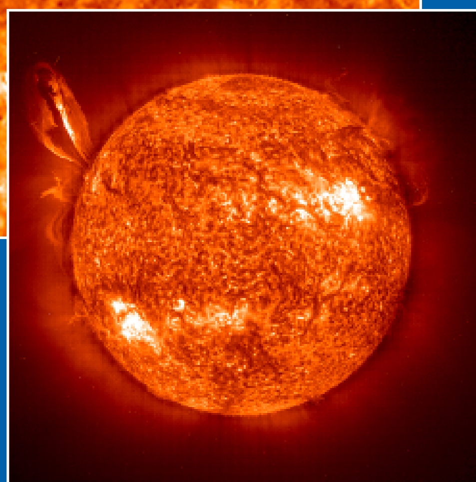

A huge eruption on the Sun’s surface is seen extending out more than 35 times the Earth’s size

A huge eruption on the Sun's surface extends out more than 35 times the Earth's size

This image shows one of the largest solar prominence observed by SOHO to date. The image, from SOHO's Extreme ultraviolet Imaging Telescope (EIT), shows a huge eruptive prominence in the resonance line of singly ionized helium (He II) at 304Å in the extreme ultraviolet wavelength. (A prominence is a structure in the corona consisting of relatively cool plasma supported by magnetic fields.) The eruption expanded at thousands of km an hour. Prominences are frequently observed on the Sun. They are propelled by breaks in the Sun's powerful and complex magnetic field that briefly allow the plasma material to escape before the magnetic field lines connect again.

The material in the eruptive prominence is at temperatures of 60,000 - 80,000 K, much cooler than surrounding corona, which is typically at temperatures above 1 million K. The prominence is over 400,000 km (240,000 miles) across. In the hours after this image was taken, the plasma continued to expand away from the Sun until it broke free and continued on into space.

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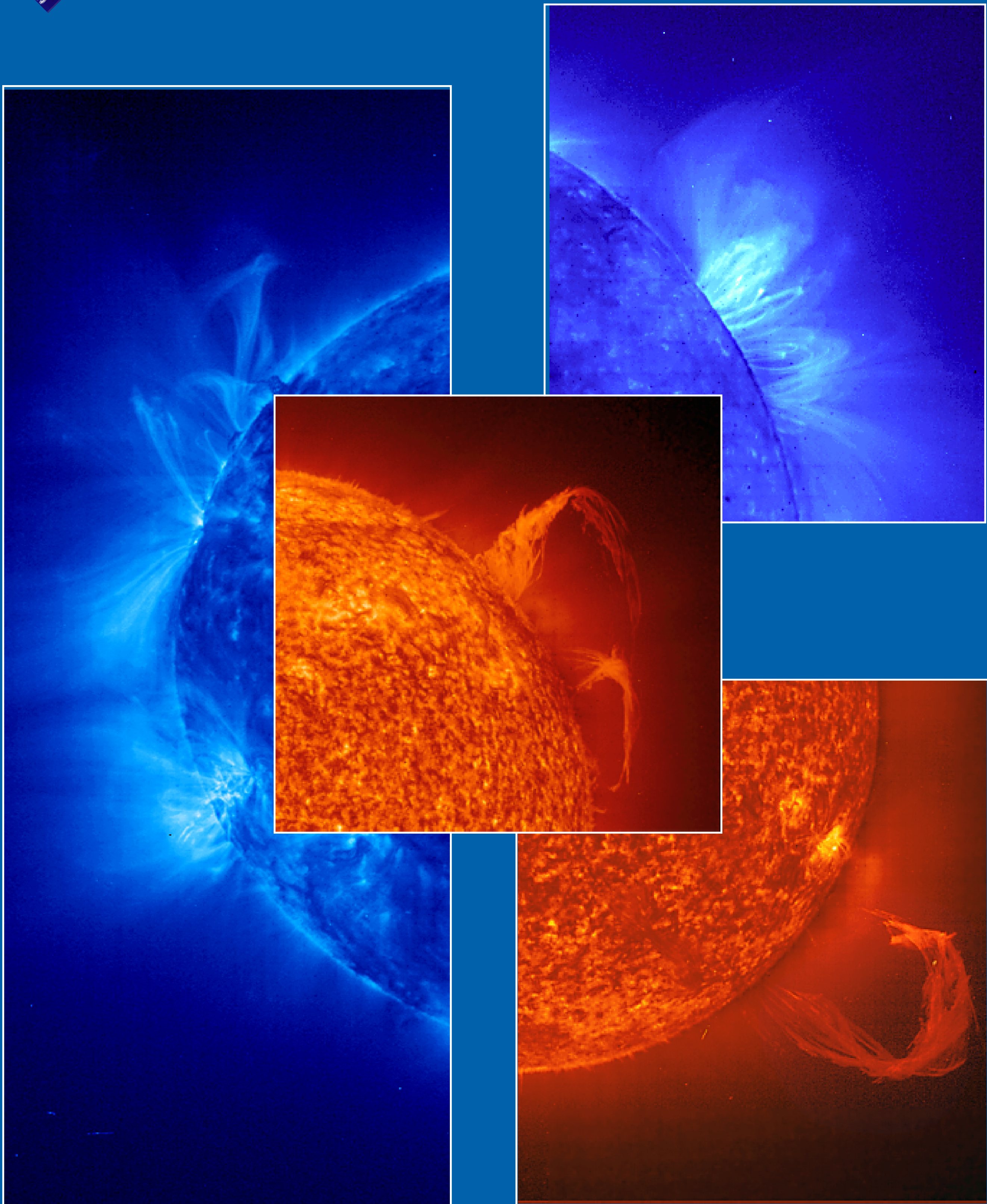
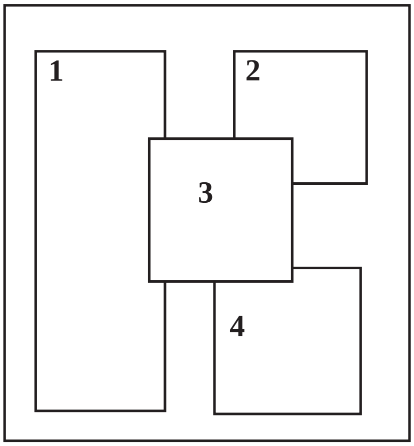


Magnetic loops and prominences are often seen projecting from the Sun

Magnetic loops and prominences are often seen on the Sun

Prominences and loops are observed frequently by SOHO. The highly energized plasma in these features is held in by strong magnetic fields. When the fields finally become unstable and erupt, the plasma breaks away from the Sun's surface at speeds up to millions of kilometers an hour.



1) This 1998 image of about 1-million degrees Kelvin gas in the Sun's thin, outer atmosphere (corona) was taken by the Extreme ultraviolet Imaging Telescope (EIT) which detects ionized iron here at 171Å. The loops of energized particles clearly follow magnetic field lines around an active region.

2) Charged material from the Sun can be seen looping out and back from an active region in this 1998 EIT image of 1-million degrees Kelvin gas at 171Å.

3) Taken by the EIT instrument at 304Å, this image shows the Sun releasing a pair of eruptive prominences (Jan. 11, 1998).

4) Also from the EIT instrument at 304Å, this arcing, eruptive prominence was taken on March 5, 1998.

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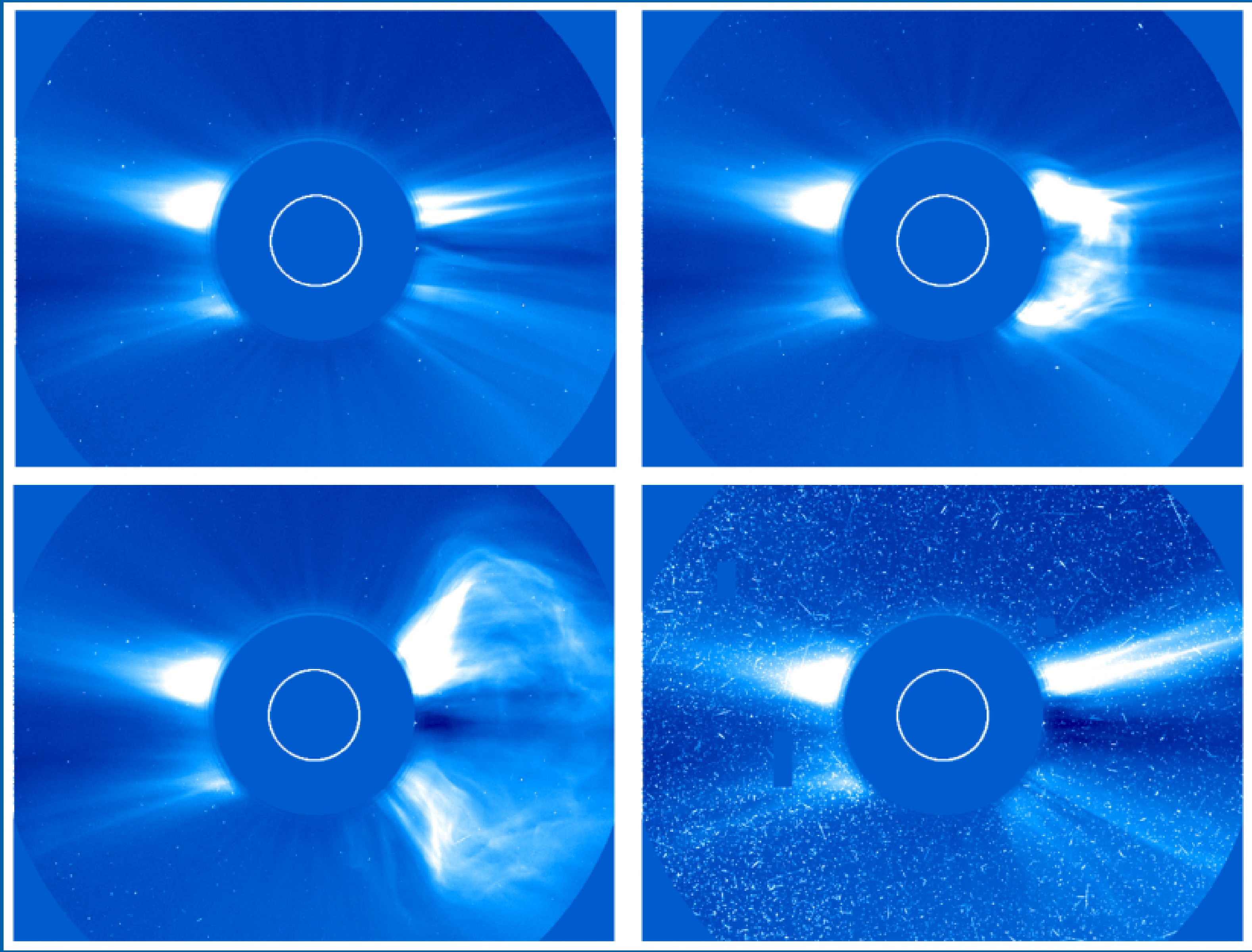

A large solar flare and coronal mass ejection shoot a billion tons of particles into space

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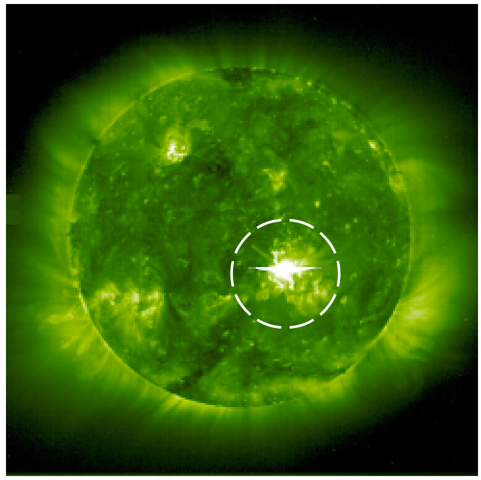
This sequence of composite images taken by SOHO's Large Angle Spectroscopic Coronograph (LASCO) C2 instrument clearly shows a billion tons of particles blasting into space associated with a solar flare on November 6, 1997. The blast was caused by magnetic forces that launched the material outward at millions of km per hour. The sequence shown here lasts only a few hours, yet by the third frame the high-energy protons (seen as white streaks and dots) are already beginning to strike the SOHO instruments, positioned 92 million miles from the Sun. These are also still evident in the fourth image as well. These protons have the potential to harm spacecraft, but the Earth's magnetosphere protects us on Earth from harmful effects.

It is believed that the Sun's magnetic fields tend to restrain each other and force the buildup of tremendous energy, like twisting rubber bands, so much that they eventually break. At some point, the magnetic lines of force merge and cancel in a process known as magnetic reconnection, causing the previously confined plasma to be released and forcefully escape from the Sun.

The white circle on the image on the reverse side indicates the size and position of the Sun. The blue disk blocks the Sun so that the instruments can capture activity in the corona.



The bright flashpoint is an extreme ultraviolet image of the solar flare that preceded the images on the other side of this page

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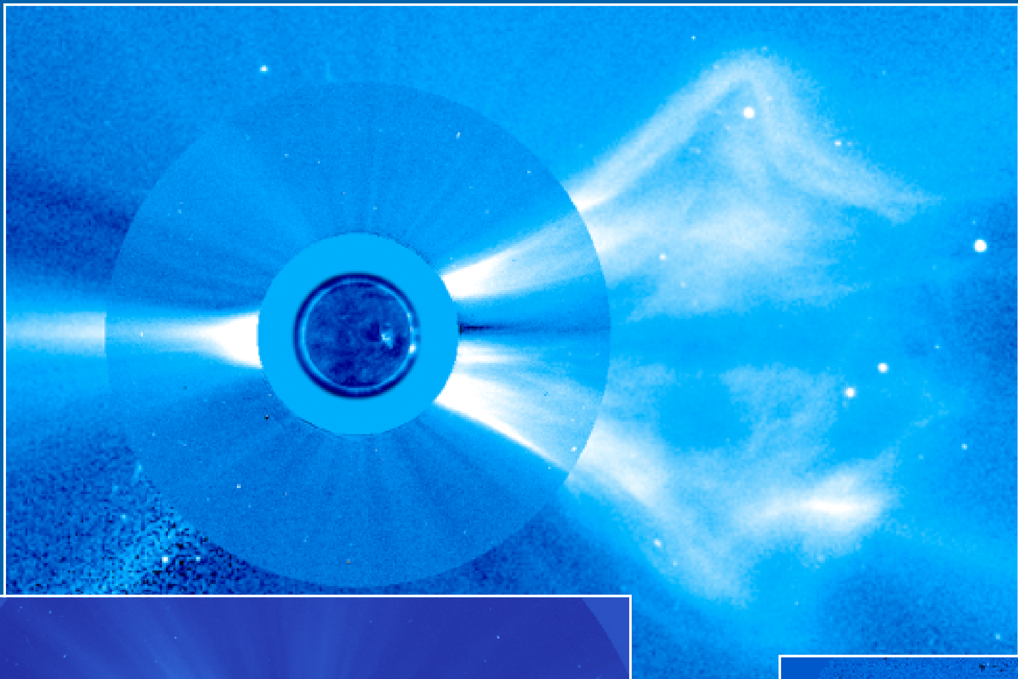

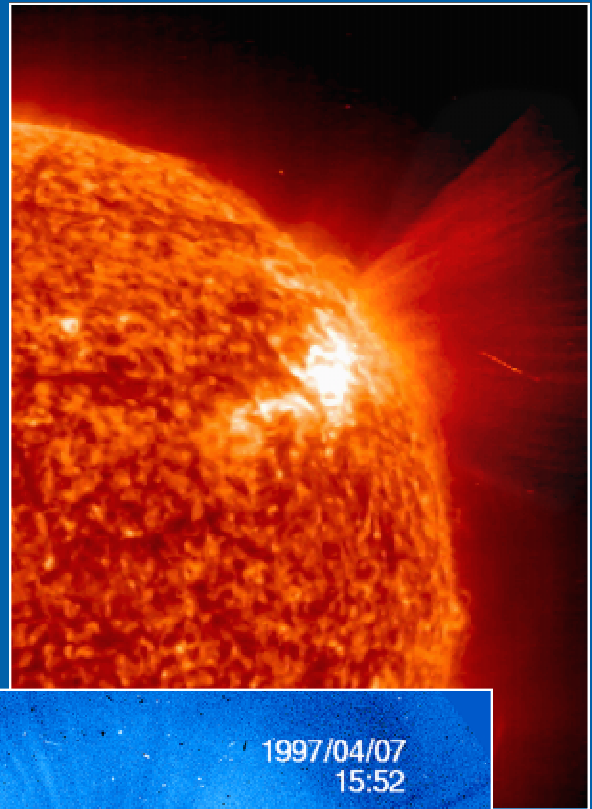

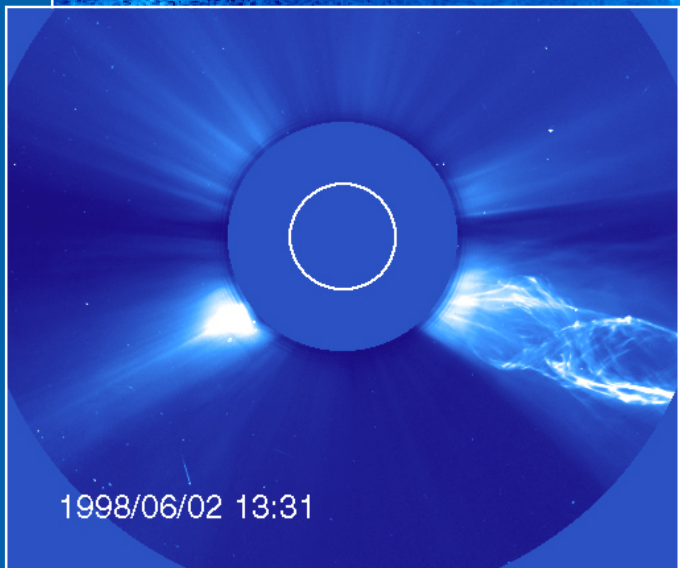

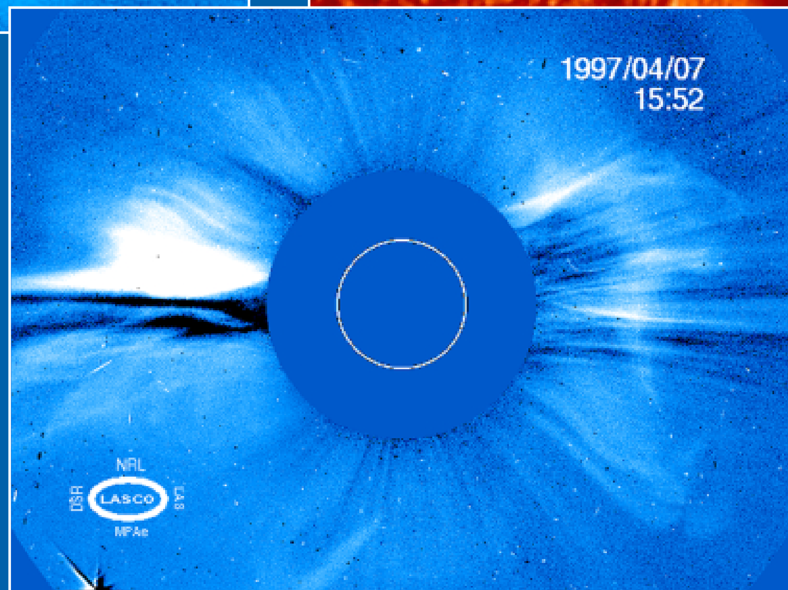

Blasts of particles explode
into space following coronal mass ejections (CMEs) from the Sun’s surface

Blasts of particles explode into space following coronal mass ejections (CMEs) from the Sun's surface

This group of images was generated by several of SOHO's instruments. They all clearly show the Sun hurtling particles into space during a coronal mass ejection or CME.

A CME cloud is composed of a **billion tons** of highly charged particles shooting out at hundreds of km per second. A CME is preceded by a shock wave of matter being pushed ahead of it as if it were a broom sweeping dirt (in this case solar particles) in front of it. By the time it reaches Earth from one to four days later, it has spread out to some 50 million km wide. When it interacts with our magnetosphere, it can causes problems with power plants, navigational instrument and communication systems, satellite functions and position, as well as generate beautiful auroral lights.

CME's occur quite frequently on the Sun, but most are not directed towards the Earth.

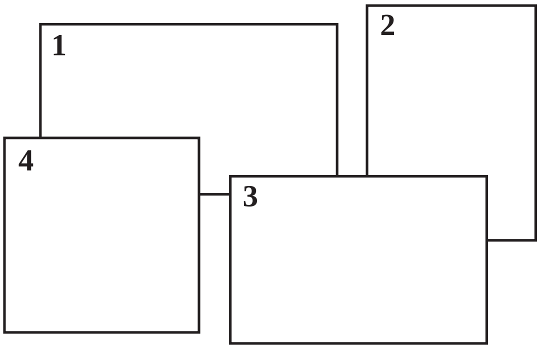

Photo credit: Jan Curtis

Aurora, here captured in the Alaskan sky, are often caused by CME blasts

1) Composite image of two of SOHO's Large Angle Spectroscopic Coronograph (LASCO) instruments showing a "hangar-shaped" blast of particles from a CME. An EIT image of the Sun's surface has been inserted where the Sun would be located.

2) An Extreme ultraviolet Imaging Telescope (EIT) close-up image of a CME blast just as it breaks loose from the Sun's surface.

3) This April 7, 1997 image shows a "halo event" in that the outer edges of the blast seem to extend into a halo around the Sun. This blast was headed toward Earth.

4) In this LASCO C2 image, a helical CME seems to twist off to the right along a narrower path.

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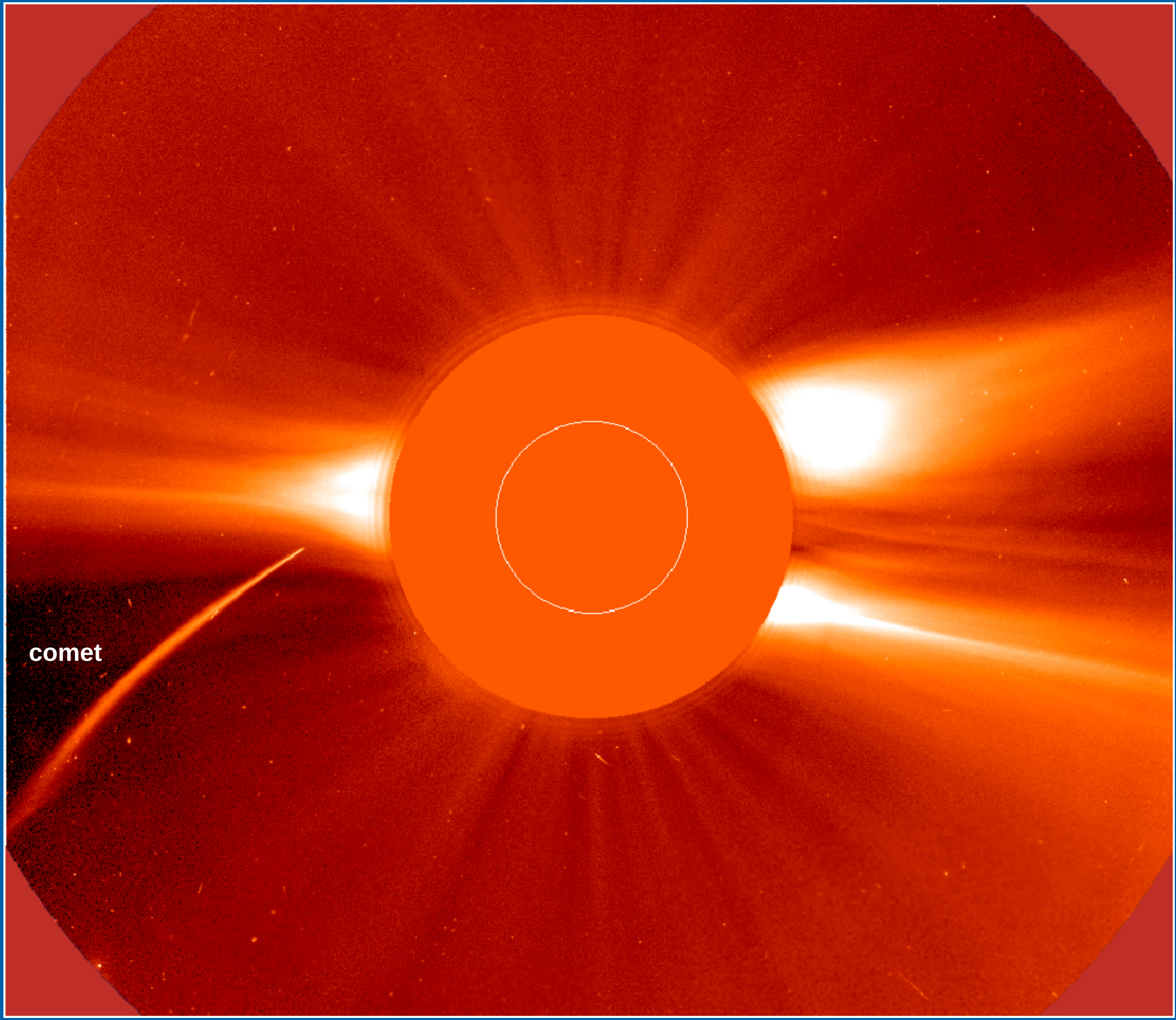


A “sun-grazing” comet about to be burned up by the Sun’s heat

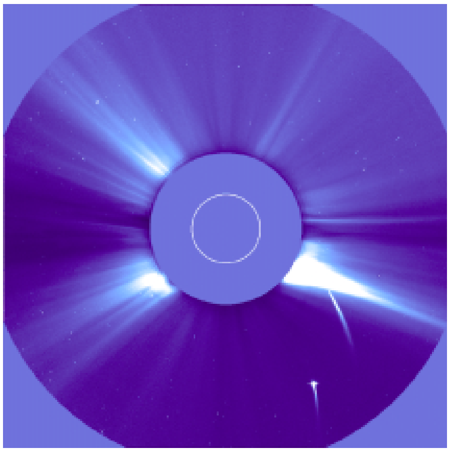
A “sun-grazing” comet about to be burned up by the Sun’s heat

This stunning image taken by one of SOHO’s coronograph instruments on December 23, 1996, shows a streaking comet as it heads towards the Sun. The size of the Sun is indicated by the white circle in the center of the red disk. The red disk in front of the telescope blocks out the Sun and some of the area around it. This reduces its brightness and allows the instrument to better observe the corona extending from the Sun. Comets, composed of ice and dust, characteristically have particles streaming out behind them. Comets can be found zooming around space quite frequently. This one, however, was heated as it neared the Sun until it was totally vaporized. SOHO has identified over 50 “sun-grazing” comets.

The bright areas to the right of the Sun are actually particles being powerfully ejected from the Sun. Within hours after this picture a major blast occurred on the right side. This is called a coronal mass ejection or CME for short.

The image is actually taken in black and white. The red color is consistently added to make this kind of image more attractive and easily identified.

A comet and its long tail



On June 2, 1998 two comets were seen arching towards the Sun in tandem.

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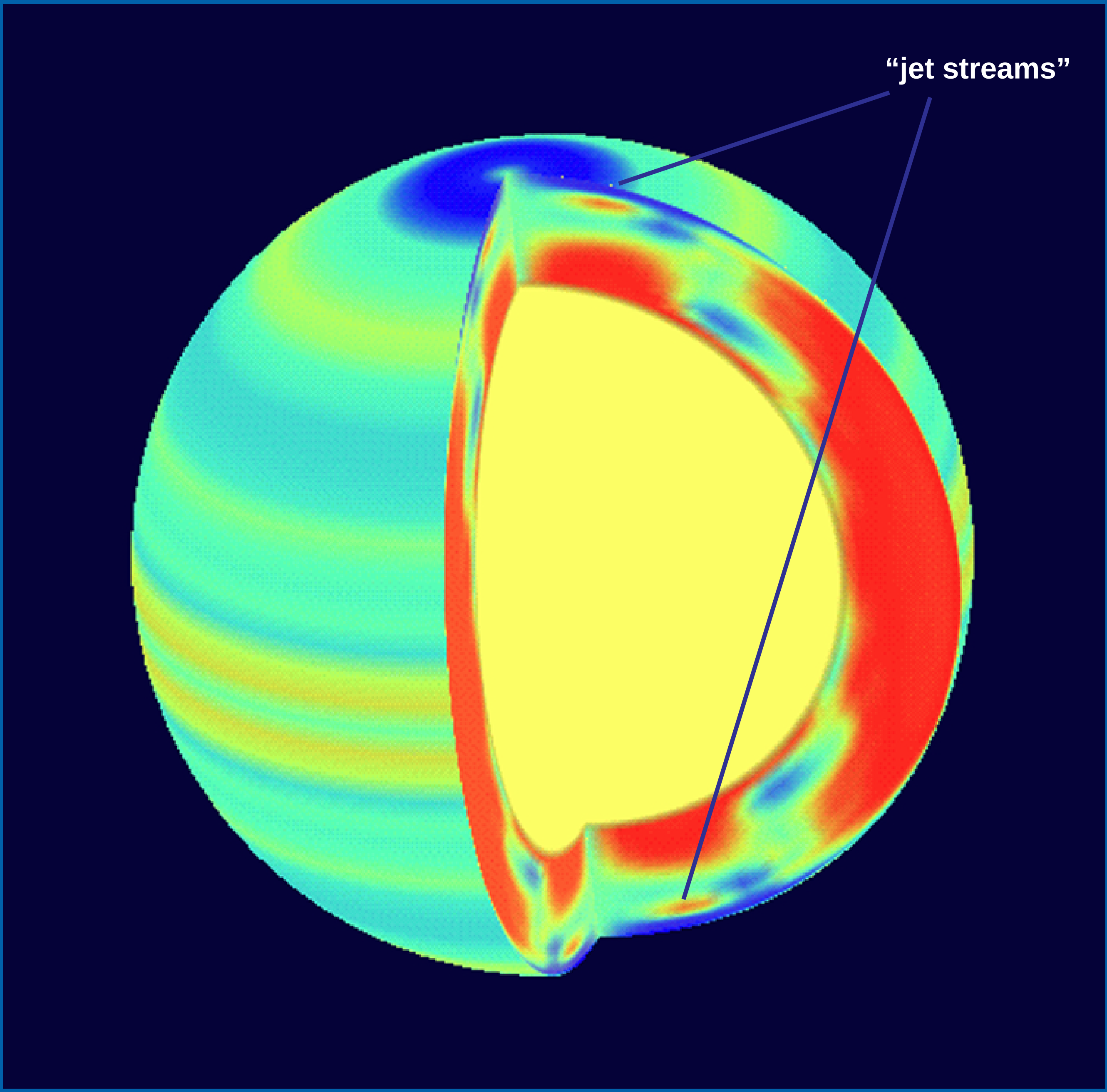

Scientists can now study the inside of the Sun.

Note the newly discovered jet streams of plasma.

Scientists can now study the inside of the Sun.

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This figure was developed using SOHO's Michelson Doppler Imager (MDI) instrument. It is a result of computations using observations taken continuously from May 1996 to May 1997. This false color figure represents the difference in rotation speeds between various areas on the Sun, both at the surface and in the interior. Red - yellow is faster than average and blue is slower than average. On the left side, the light yellow bands are zones that are moving slightly faster than their surroundings. New SOHO observations indicate that these extend down approximately 20,000 km into the sun. Sunspots, caused by disturbances in the solar magnetic field, tend to form at the edge of these bands.

Scientists speculate that this may be due to the differences in speed at the edge of these zones that tend to "twist" the magnetic field generated by the Sun's moving hot, electrically charged gas (called plasma). The cutaway on the right side of the figure reveals speed variations in the interior of the Sun. Only the outer 30 percent of the Sun's interior where the variations are more certain is shown. The recently discovered polar "jet-stream" shows as a red oval, indicating that is it not only faster than the material above around it but also distinctly slower (about 10%) than the surface above it. Each is about 27,000 km across, large enough to engulf two Earths. There is no hint of the jet on the surface. This feature was not expected and could not have been detected without helioseismology techniques. (Photo Credit: Stanford University)

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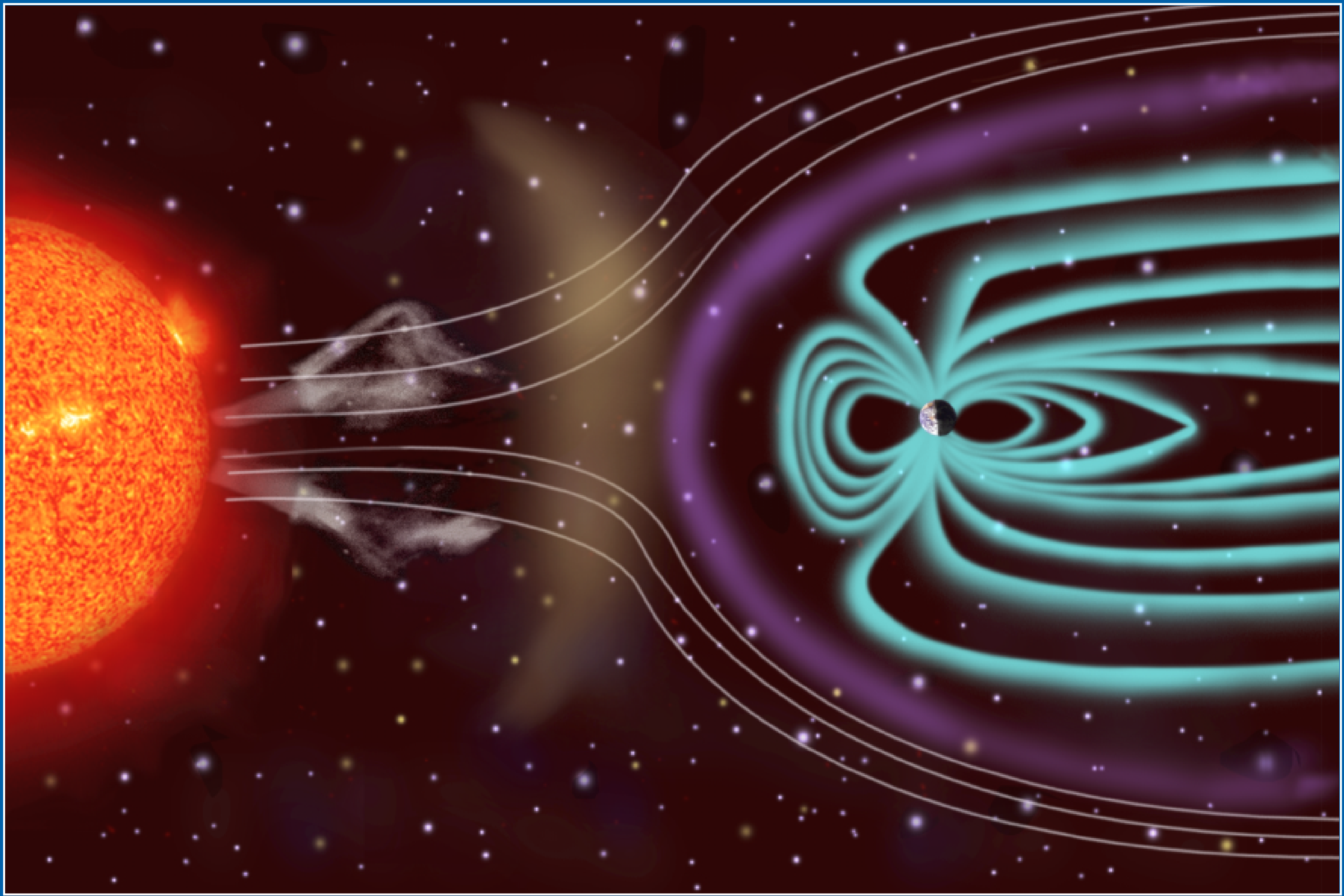


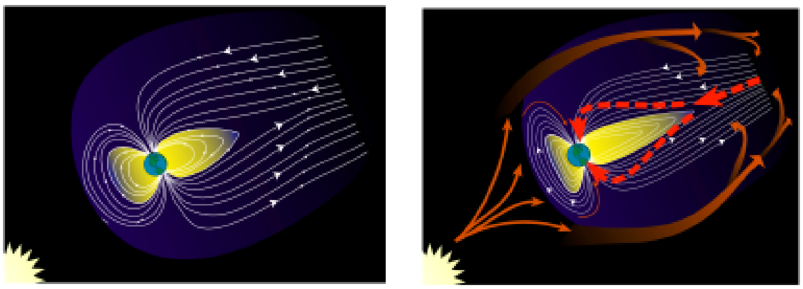
The Sun’s magnetic field and releases of plasma directly affect Earth and the rest of the solar system. Solar wind shapes the Earth’s magnetosphere and magnetic storms (illustrated here as approaching Earth) can disrupt communications and navigational equipment, damage satellites, and even cause blackouts.

The Sun's powerful magnetic forces directly affect the Earth and the rest of the solar system

Events on the Sun can trigger changes in Earth's environment, particularly in the regions of the atmosphere known as the ionosphere and the magnetosphere. For one thing, the solar wind (the stream of gas that blows continuously outward from the Sun through the Solar System) shapes the Earth's magnetosphere so that it is compressed on the side facing the Sun and is much elongated away from the Sun. Like the wind here on Earth, the solar wind blows soft and hard, sometimes leading to magnetic storms in the magnetosphere. The solar wind is essentially the hot solar corona expanding into interplanetary and interstellar space, flowing outward from the Sun at speeds as high as millions of km per hour.

During a geomagnetic storm, portions of the solar wind's energy is transferred to the Earth's magnetosphere, causing Earth's magnetic field to change rapidly in direction and intensity. Magnetic storms, such as the coronal mass ejection illustrated here, can interfere with radio, television, and telephone signals, upset the navigation systems of ships and airplanes, and cause blackouts. Also, Sun-induced storms can damage satellites and spacecraft or force them to re-enter the atmosphere prematurely.

By closely observing the Sun and the energy and material it blows at Earth, scientists may someday be able to anticipate changes in Earth's environment. Aside from disturbing our electronic equipment, the Sun and the solar wind seem to play a role in long-term climate changes on Earth. Finally, since our Solar System is probably typical of other single-star systems in the universe, what scientists learn about the Sun-Earth connection could lead to a better understanding of other Solar Systems.



The illustration at far left shows a normal magnetosphere. When the particles from a CME impact the Earth's magnetosphere (second illustration), the front side flattens and the far side elongates. Some particles enter the magnetosphere along the front field lines to the poles, but most are drawn in on the far side.

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NASA Resources for Educators

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue and an order form by one of the following methods:

- NASA CORE
  Lorain County Joint Vocational School
  15181 Route 58 South
  Oberlin, OH 44074
- Phone (440) 774-1051, Ext. 249 or 293
- Fax (440) 774-2144
- E-mail *nasaco@leeca.esu.k12.oh.us*
- Home Page: *http://spacelink.nasa.gov/CORE*

Educator Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educator Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Educators may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Educator Resource Center
Mail Stop 253-2
NASA Ames Research Center
Moffett Field, CA 94035-1000
Phone: (650) 604-3574

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Educator Resource Laboratory
Mail Code 130.3
NASA Goddard Space Flight Center
Greenbelt, MD 20771-0001
Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
JSC Educator Resource Center
Space Center Houston
NASA Johnson Space Center
1601 NASA Road One
Houston, TX 77058-3696
Phone: (281) 483-8696

FL, GA, PR, VI
NASA Educator Resource Laboratory
Mail Code ERL
NASA Kennedy Space Center
Kennedy Space Center, FL 32899-0001
Phone: (407) 867-4090

KY, NC, SC, VA, WV
Virginia Air and Space Museum
NASA Educator Resource Center for
NASA Langley Research Center
600 Settler's Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 x 757

IL, IN, MI, MN, OH, WI
NASA Educator Resource Center
Mail Stop 8-1
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135-3191
Phone: (216) 433-2017

AL, AR, IA, LA, MO,TN
U.S. Space and Rocket Center
NASA Educator Resource Center for
NASA Marshall Space Flight Center
P.O. Box 070015
Huntsville, AL 35807-7015
Phone: (256) 544-5812

MS
NASA Educator Resource Center
Building 1200
NASA John C. Stennis Space Center
Stennis Space Center, MS 39529-6000
Phone: (228) 688-3338

NASA Educator Resource Center
JPL Educational Outreach
Mail Stop 601-107
NASA Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109-8099
Phone: (818) 354-6916

CA cities near the center
NASA Educator Resource Center for
NASA Dryden Flight Research Center
45108 N. 3rd Street East
Lancaster, CA 93535
Phone: (805) 948-7347

VA and MD's Eastern Shores
NASA Educator Resource Lab
Education Complex - Visitor Center
Building J-1
NASA Wallops Flight Facility
Wallops Island, VA 23337-5099
Phone: (757) 824-2297 / 2298

Regional Educator Resource Centers (RERCs) offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically via NASA Spacelink at *http://spacelink.nasa.gov*

NASA On-line Resources for Educators NASA's Education Home Page serves as a cyber-gateway to information regarding educational programs and services offered by NASA for educators and students across the United States. This high-level directory of information provides specific details and points of contact for all of NASA's educational efforts and Field Center offices.

Educators and students utilizing this site will have access to a comprehensive overview of NASA's educational programs and services, along with a searchable program inventory that has cataloged NASA's educational programs. NASA's on-line resources specifically designed for the educational community are highlighted, as well as home pages offered by NASA's four areas of research and development (including the Aeronautics and Space Transportation, Earth Science, Human Exploration and Development of Space, and Space Science Enterprises).

Access these resources through the NASA Education Home Page: *http://www.hq.nasa.gov/education*

NASA Television (NTV) NASA Television (NTV) features Space Shuttle mission coverage, live special events, interactive educational live shows, electronic field trips, aviation and space news, and historical NASA footage. Programming includes a Video (News) File from noon to 1pm, a NASA Gallery File from 1-2pm, and an Education File from 2-3pm. This sequence is repeated at 3pm, 6pm, and 9pm, Monday through Friday. The Education File features programming for teachers and students on science, mathematics, and technology, including *NASA. . . On the Cutting Edge*, a series of educational live shows.

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NTV Home Page: *http://www.hq.nasa.gov/ntv.html*

How to Access NASA's Education Materials and Services, EP-1998-03-345-HQ This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network, or electronically via NASA Spacelink at *http://spacelink.nasa.gov*