**Solar flare**

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*"star flare" redirects here. For the class of stars that undergo similar phenomena, see flare star.*



Two successive photos of a solar flare phenomenon evolving on the sun. The solar disk was blocked in these photos for better visualization of the flare

A **solar flare** is a large explosion in the Sun's atmosphere that can release as much as 6 × 1025 joules of energy. The term is also used to refer to similar phenomena in other stars, where the term **stellar flare** applies.

Solar flares affect all layers of the solar atmosphere (photosphere, corona, and chromosphere), heating plasma to tens of millions of kelvins and accelerating electrons, protons, and heavier ions to near the speed of light. They produce radiation across the electromagnetic spectrum at all wavelengths, from radio waves to gamma rays. Most flares occur in active regions around sunspots, where intense magnetic fields penetrate the photosphere to link the corona to the solar interior. Flares are powered by the sudden (timescales of minutes to tens of minutes) release of magnetic energy stored in the corona. If a solar flare is exceptionally powerful, it can cause coronal mass ejections.

X-rays and UV radiation emitted by solar flares can affect Earth's ionosphere and disrupt long-range radio communications. Direct radio emission at decametric wavelengths may disturb operation of radars and other devices operating at these frequencies.

Solar flares were first observed on the Sun by Richard Christopher Carrington and independently by Richard Hodgson in 1859 as localized visible brightening of small areas within a sunspot group. Stellar flares have also been observed on a variety of other stars.

The frequency of occurrence of solar flares varies, from several per day when the Sun is particularly "active" to less than one each week when the Sun is "quiet". Large flares are less frequent than smaller ones. Solar activity varies with an 11-year cycle (the solar cycle). At the peak of the cycle there are typically more sunspots on the Sun, and hence more solar flares.

 **Classification**

Solar flares are classified as A, B, C, or X according to the peak flux (in watts per square meter, W/m2) of 100 to 800 picometer X-rays near Earth, as measured on the GOES spacecraft. Each class has a peak flux ten times greater than the preceding one, with X class flares having a peak flux of order 10−4 W/m2. Within a class there is a linear scale from 1 to 9, so an X2 flare is twice as powerful as an X1 flare, and is four times more powerful than an M5 flare. The more powerful M and X class flares are often associated with a variety of effects on the near-Earth space environment. Although the GOES classification is commonly used to indicate the size of a flare, it is only one measure. This extended logarithmic classification is necessary because the total energies of flares range over many orders of magnitude, following a uniform distribution with flare frequency roughly proportional to the inverse of the total energy. Stellar flares (and earthquakes) show similar power-law distributions.

**Hazards**

Solar flares strongly influence the local space weather of the Earth. They produce streams of highly energetic particles in the solar wind and the Earth's magnetosphere that can present radiation hazards to spacecraft and astronauts. The soft X-ray flux of X class flares increases the ionization of the upper atmosphere, which can interfere with short-wave radio communication and can increase the drag on low orbiting satellites, leading to orbital decay. Energetic particles in the magnetosphere contribute to the aurora borealis and aurora Australis.

Solar flares release a cascade of high energy particles known as a proton storm. Protons can pass through the human body, doing biochemical damage. The proton storms are produced in the solar wind, and hence present a hazard to astronauts during interplanetary travel. Most proton storms take two or more hours from the time of visual detection to reach Earth's orbit. A solar flare on January 20, 2005 released the highest concentration of protons ever directly measured, taking only 15 minutes after observation to reach Earth, indicating a velocity of approximately one-half light speed.

The radiation risks posted by solar flares and coronal mass ejections (CMEs) are among the major concerns in discussions of manned missions to Mars, the moon, or any other planets. Some kind of physical or magnetic shielding would be required to protect the astronauts. Originally it was thought that astronauts would have two hours’ time to get into shelter, but based on the January 20, 2005 event, they may have as little as 15 minutes to do so. Energy in the form of hard x-rays are considered dangerous to spacecraft and are generally the result of large plasma ejection in the upper chromosphere.

**Observations**

The following missions have flares as their main observation target.

* Yohkoh - The Yohkoh (originally Solar A) spacecraft observed the Sun with a variety of instruments from its launch in 1991 until its failure in 2001. The observations spanned a period from one solar maximum to the next. Two instruments of particular use for flare observations were the Soft X-ray Telescope (SXT), a glancing incidence low energy X-ray telescope for photon energies of order 1 keV, and the Hard X-ray Telescope (HXT), a collimation counting instrument which produced images in higher energy X-rays (15-92 keV) by image synthesis.
* GOES - The GOES spacecraft are satellites in geostationary orbits around the Earth that have measured the soft X-ray flux from the Sun since the mid-1970s, following the use of similar instruments on the SOLRAD satellites. GOES X-ray observations are commonly used to classify flares, with A, B, C, M, and X representing different powers of ten — an X-class flare has a peak 2-8 Å flux above 0.0001 W/m2.
* RHESSI - RHESSI is designed to image solar flares in energetic photons from soft X rays (~3 keV) to gamma rays (up to ~20 MeV) and to provide high resolution spectroscopy up to gamma-ray energies of ~20 MeV. Furthermore, it has the capability to perform spatially resolved spectroscopy with high spectral resolution.
* Hinode - A new spacecraft, originally called Solar B, was launched by the Japan Aerospace Exploration Agency in September 2006 to observe solar flares in more precise detail. Its instrumentation, supplied by an international collaboration including Norway, the U.K., and the U.S., focuses on the powerful magnetic fields thought to be the source of solar flares. Such studies shed light on the causes of this activity, possibly helping to forecast future flares and thus minimize their dangerous effects on satellites and astronauts.

The most powerful flare of the last 500 years was the first flare to be observed, and occurred in September 1859: it was reported by British astronomer Richard Carrington and left a trace in Greenland ice in the form of nitrates and beryllium-10, which allow its strength to be measured today (New Scientist, 2005).

**Prediction**

Current methods of flare prediction are problematic, and there is no certain indication that an active region on the Sun will produce a flare. However, many properties of sunspots and active regions correlate with flaring. For example, magnetically complex regions (based on line-of-sight magnetic field) called delta spots produce most large flares. A simple scheme of sunspot classification due to McIntosh is commonly used as a starting point for flare prediction. Predictions are usually stated in terms of probabilities for occurrence of flares above M or X GOES class with 24 or 48 hours. The U.S. National Oceanic and Atmospheric Administration (NOAA) issues forecasts of this kind.