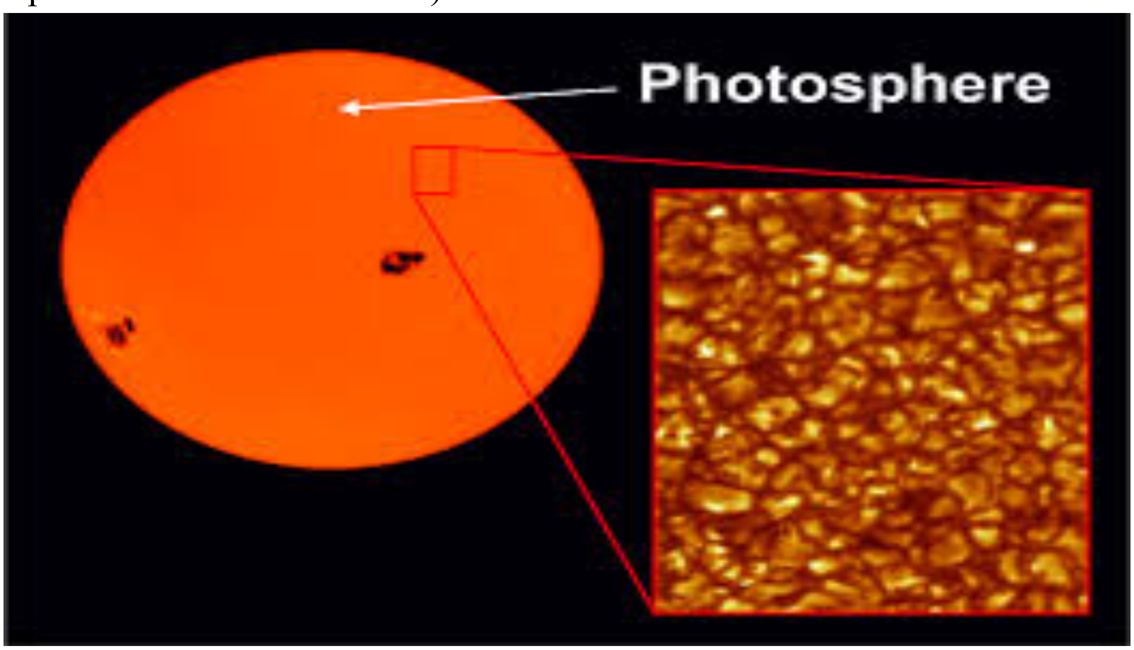
1.2 Solar atmosphere

The photosphere

The photosphere (meaning "sphere of light") is the lowest layer of the Sun visible from Earth. This thin layer is the lowest level in the Sun's atmosphere. Energy finally escapes the Sun from the photosphere, so it is significantly cooler than the solar interior. The temperature at the visible surface is about 5800 K. The solar atmosphere is also dramatically less dense than the interior. The photosphere has a definite texture. It is covered with granules, or luminous grainlike areas separated by dark areas. Granules are continually forming and disappearing. Their grainlike structure results from the convection currents that bring hot gases up to the photosphere. Each granule is a convection cell that measures several hundred miles across. The hot upwelling matter appears bright, while the cooler sinking matter appears dark. Periodically, larger darker blotches called sunspots appear on the photosphere. (Sunspots will be discussed later)



The chromosphere

The layer of the atmosphere above the photosphere is called the chromosphere (meaning "sphere of color"). It is visible as a thin reddish ring around the edge of the Sun during total solar eclipses, the chromosphere is hotter than the photosphere, and its temperature generally rises with altitude. It is marked by countless jets or small spikes of matter called spicules that continually form and disappear, rising up and falling back down within minutes.

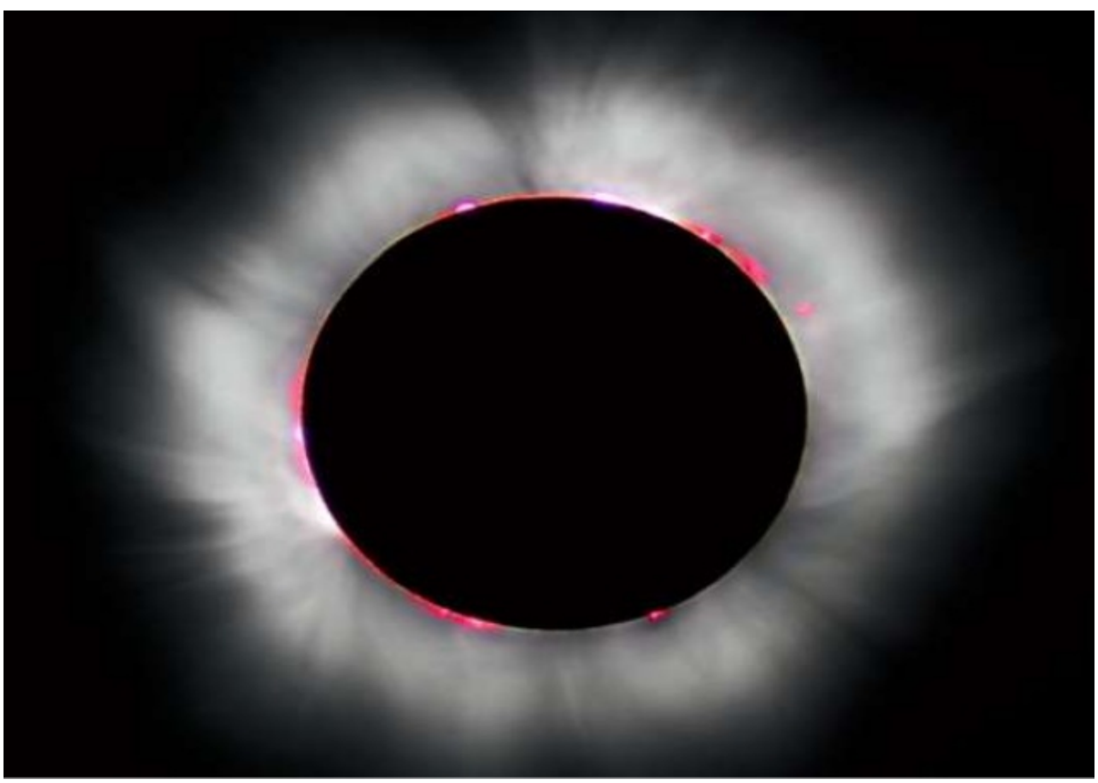
Much of the Sun's "weather" takes place in the chromosphere. This includes the violent eruptions called solar flares, which will be discussed later.

The Corona

The chromosphere is surrounded by a faintly luminous, extremely thin outer atmosphere called the corona (meaning "crown"). As the corona is a million times dimmer than the Sun's disk, it is usually invisible. It can be seen only when the light of the photosphere is blocked, as in a total solar eclipse or with a special type of telescope called a coronagraph

The corona then appears as a silvery halo with long arcs and streamers.

Much or all of the corona's volume consists of loops and arcs of hot plasma. Counterintuitively, the corona is much hotter than the surface of the Sun. Solar scientists thinks that energy from the solar magnetic fields heats the corona.



2.Solar Magnetism: Sunspot, Solar Active Regions, Cycle and Dynamo

The Sun's magnetic activity is quite complex. Rapid, large fluctuations occur in numerous strong local magnetic fields that are threaded through the Sun's atmosphere. Magnetic activity shapes the atmosphere and causes disturbances there called solar activity. This activity includes sunspots and violent eruptions. Overall, solar activity follows about an 11-year cycle, in which the numbers of sunspots and other disturbances increase to a maximum and then decrease again. The Sun seems to have a weak global magnetic field. Once each 11-year cycle, the north and south poles of the field switch polarity.

Sunspots

Periodically, darker cooler blotches called sunspots temporarily appear on the Sun's surface. Sunspots are areas where very strong local magnetic fields interfere with the normal convection activity that brings heat to the surface. The spots usually appear in pairs or groups of pairs. Each spot typically has a dark, circular center, called the umbra, surrounded by a lighter area, the penumbra. The umbras are about 2,000 °K cooler than the photosphere around them (which means that they are still very hot). Sunspots vary greatly in size but are always small compared to the size of the Sun. When they appear in groups, they may extend over tens of thousands of miles. They last from tens of minutes to a few days or even months.

The spots appear and disappear in a cycle and that they are limited to the two zones of the Sun contained between about latitudes 40° and 5° of its northern and southern hemispheres. As mentioned above, the cycle lasts an average of about 11 years. At the beginning of a cycle a few spots appear at around 35° latitudes.

Then they rapidly increase in number, reaching a maximum in the course of around five years. At the same time, the spots get closer and closer to the equator. During the next six years their number decreases while they continue to approach the equator. The cycle then ends, and another cycle starts.

In the early 20th century George E. Hale observed that certain photographs of sunspots showed structures that seemed to follow magnetic lines of force. Often a pair of sunspots appeared to form the north and south poles of a magnetic field. Hale was finally able to establish that sunspots are indeed seats of magnetic fields. In addition, from one 11-year cycle to the next, a total reversal of the sunspots' polarity occurs in the two solar hemispheres. In other words, the north pole of a magnetic field associated with a sunspot pair becomes the south pole, and vice versa.

Solar Active Regions

Many pairs of sunspots are associated with explosive releases of energy from the photosphere. These areas of activity are simply called active regions. Though the exact mechanisms that cause the explosive release of energy from the Sun's surface are not known, we do know that they are related to the rapid conversion of magnetic energy into particle kinetic energy.

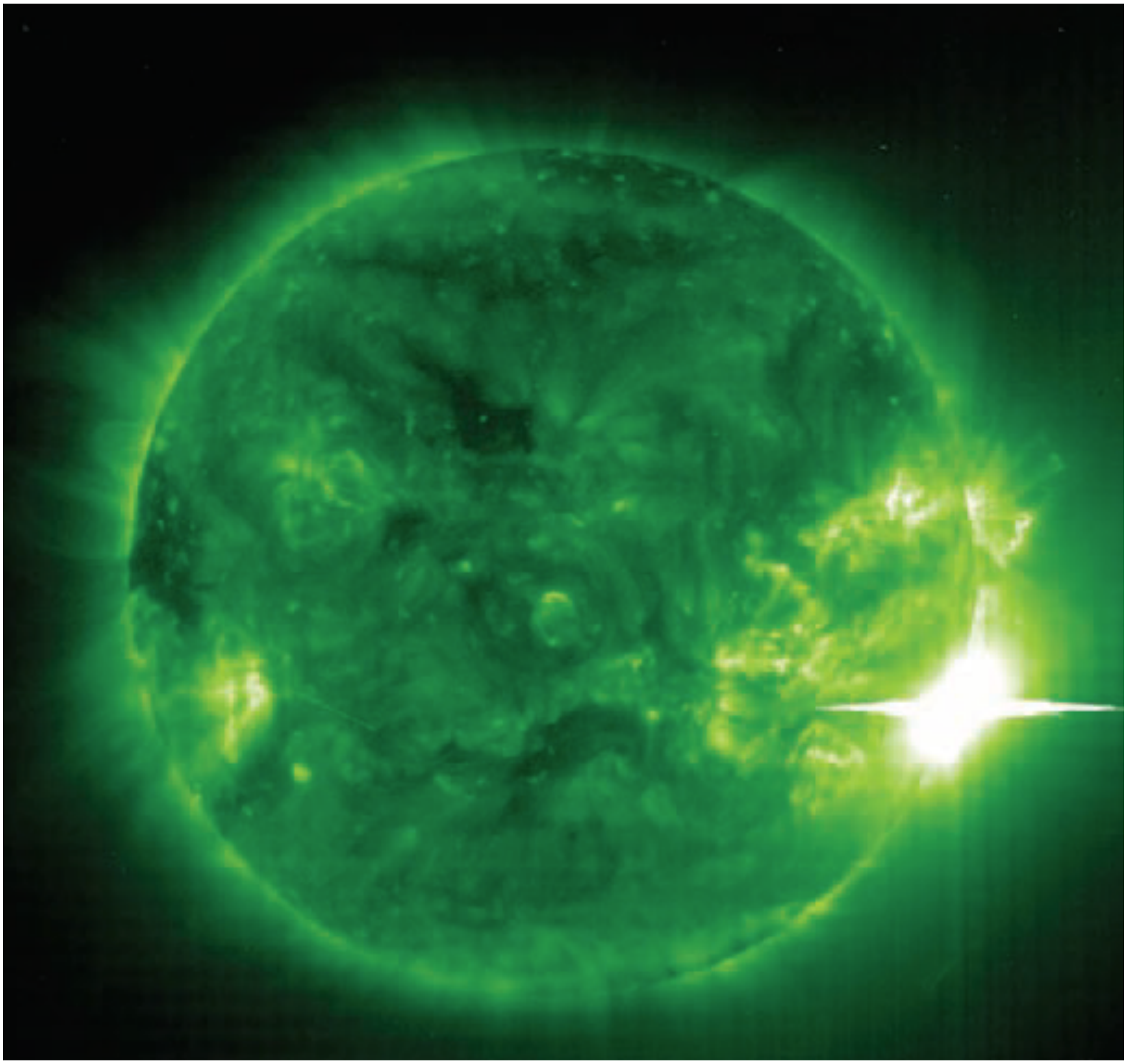
This conversion takes place in regions of strong magnetic fields, and the twisting of the surface magnetic field often leads to rapid energy release.

Prominences are an example of this energy release. Another example, solar flares, are much more energetic than prominences. Flares release tremendous amounts of energy in a few minutes and can reach temperatures of 100 million K (much hotter than even the core of the Sun). This energy is equivalent to hundreds of millions of megaton hydrogen bombs exploding at the same time. The energy of these flares is so intense that the charged particles that make up the solar atmosphere are blasted out into space – some at nearly the speed of light. In addition, the heated gas glows at essentially all wavelengths including X-rays. These energetic particles and electromagnetic radiation are ejected into interplanetary space and often can impact Earth's space environment – one of the causes of space weather.

3.Solar Storms: Flares, Prominences and CMEs

Flares

A more violent phenomenon is the solar flare, a sudden eruption in the chromosphere above or near sunspot regions. Flares release magnetic energy that builds up along the boundaries between negative and positive magnetic fields that become twisted. The flares usually form very rapidly, reaching their maximum brilliance within minutes and then slowly dying out. They emit huge amounts of radiation at many different wavelengths, including X rays and gamma rays, as well as highly energetic charged particles.



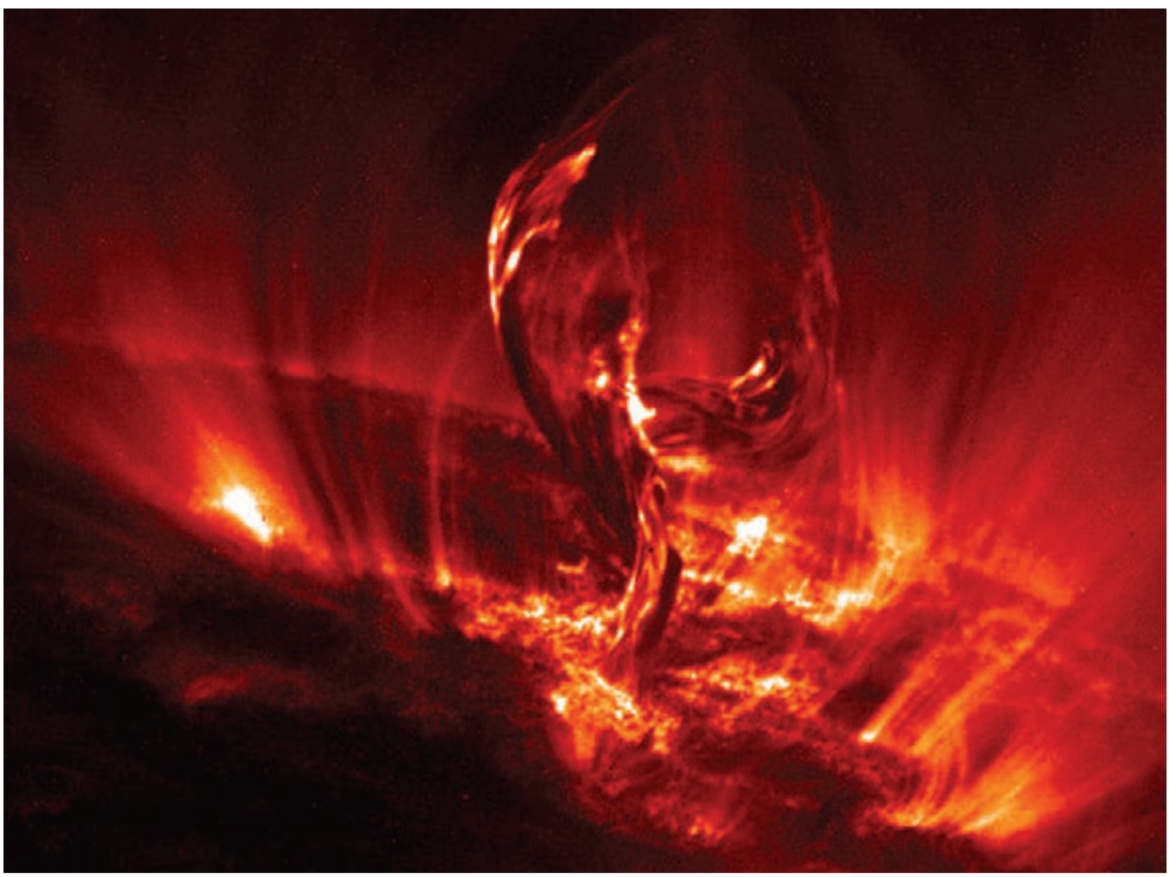
One of the strongest solar flares ever detected appears at right in an extreme ultraviolet (false-color) image of the Sun taken by the Solar and Heliospheric Observatory (SOHO) orbiting spacecraft. Such powerful flares, called X-class flares, release intense radiation that can temporarily cause blackouts in radio communications all over Earth. The flare occurred on Nov. 4, 2003.
SOHO/ESA/NASA

Prominences

Features called prominences also form along sharp transitions between positive and negative magnetic fields. Early astronomers noticed huge red loops and streamers around the black disk of solar eclipses.

These prominences are areas of relatively cooler, denser plasma suspended like clouds through the hot, low-density corona. Magnetic lines of force hold the plasma in place. Prominences appear as bright regions when seen.

Long-lived, or quiescent, prominences may keep their shape for months. They form at the boundaries between large-scale magnetic fields. Prominences in active regions associated with sunspots are short-lived, lasting only several minutes to a few hours. When prominences become unstable, they may erupt upward. These eruptions are significantly cooler and less violent than solar flares.

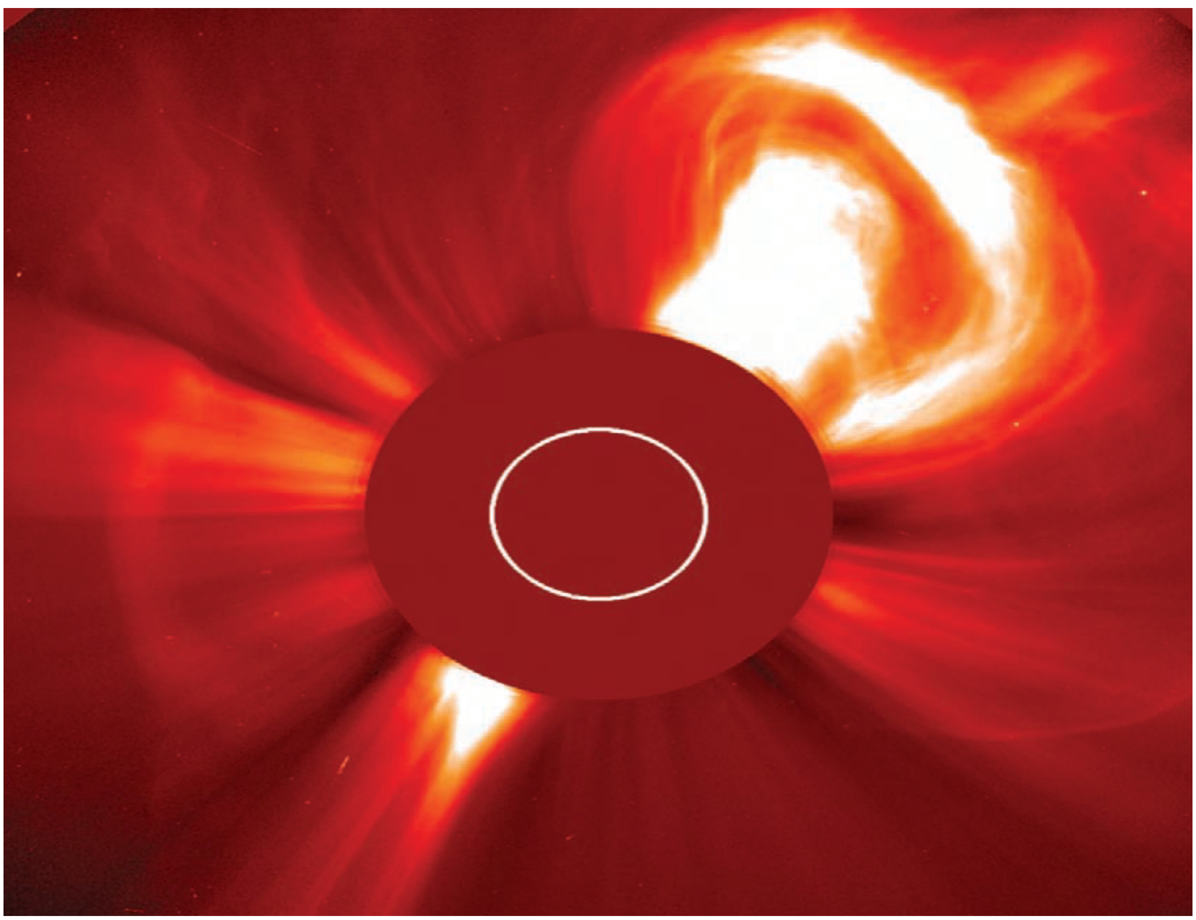


An image taken in extreme ultraviolet light reveals a solar prominence lifting off the Sun. The false-color image was captured by the Transition Region and Coronal Explorer (TRACE) orbiting satellite. TRACE/NASA

Coronal Mass Ejections (CME)

A type of violent eruption called coronal mass ejections also occurs in the corona. The corona sometimes releases enormous clouds of hot plasma into space. Like solar flares, these coronal mass ejections release energy built up in solar magnetic fields. They usually last hours, however, while the rapid eruptions from flares typically last only minutes.

Like other kinds of solar activity, coronal mass ejections are most common during the solar maximum. Scientists believe that flares, prominence eruptions, and coronal mass ejections are related phenomena. Their relationship is complex, however, and not yet fully understood.



A very large coronal mass ejection, at upper right. The red disk in the center is part of the coronagraph used to take the image. The white circle indicates the size and position of the Sun's disk. The false-color image was taken by the Solar and Heliospheric Observatory (SOHO) orbiting space- craft. SOHO/ESA/NASA