The Sun:
Our nearest star

Galilean Nights

United Nations Educational, Scientific and Cultural Organization

International Astronomical Union

THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

Ancient Sun worship

Observations of the Sun go back as far as humanity itself. People have always known that the Sun gives us heat and light, and because of that is vitally important.

Some ancient civilisations went as far as worshipping the Sun as a deity or God. Sun-worship was prevalent in Egypt, for example.

The ancient Egyptian civilisation is known for Sun-worship.

Image: Ricardo Liberato.

The Egyptian Sun god Ra.

Image: Wikipedia.

A wealth of information about the Sun god Ra is available online. For example: http://en.wikipedia.org/wiki/Ra

Monuments to the Sun

So important was the Sun to people's lives that monuments were constructed to mark its passage in the sky throughout the year. These acted as calendars, signalling the changing seasons and times to plant and harvest crops, among other things.

Image: Frédéric Vincent.

Stonehenge has largely withstood the test of time.

Some of these "ancient observatories", such as Stonehenge in England, exist today.

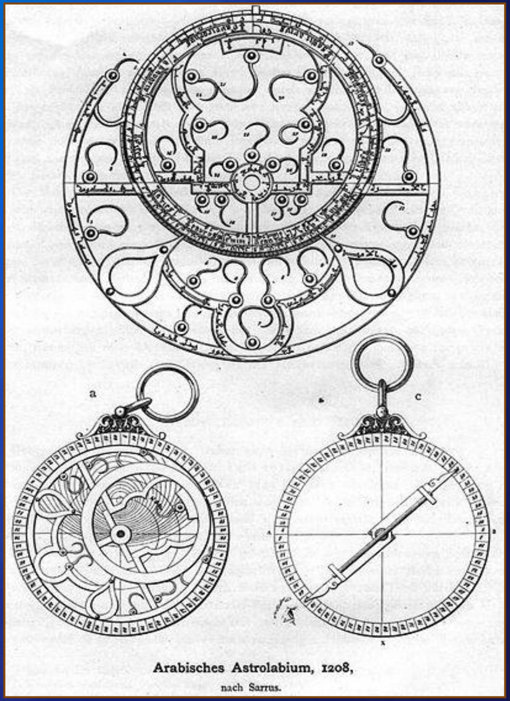
These helped to track the Sun, but knowledge of its nature was out of reach.

The English Heritage Stonehenge website is http://www.english-heritage.org.uk/server/show/nav.16465

Ancient Greeks and Arabs

The ancient Greeks thought long and hard about the true nature of the Sun. Some philosophers reasoned that is was a large flaming ball, very far from the Earth.

Medieval Arabs calculated the Earth-Sun distance, the Sun's circumference, and proved that moonlight is reflected sunlight. The figures they calculated are very close to what we accept to be true today.



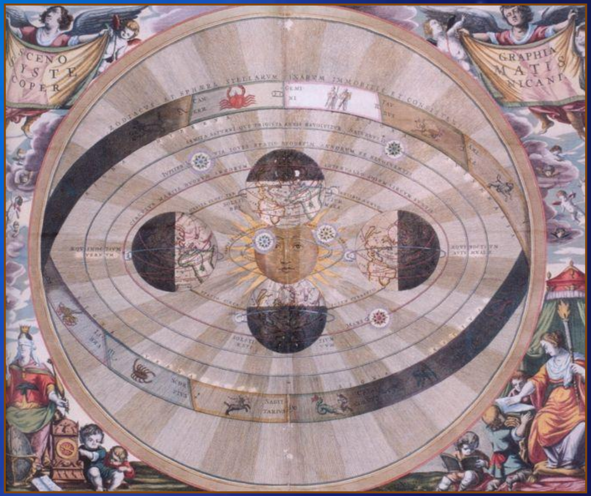
A Persian (Iranian) astrolabe, an instrument used to map the positions of celestial objects.

Ancient Arabic astronomy is a fascinating topic. For an introduction, consider visiting http://en.wikipedia.org/wiki/Islamic_astronomy

Heliocentric system

The theory that the Earth moves around the Sun, and not the other way around, was devised by ancient Greek, Indian, Babylonian, and medieval Arabic astronomers.

This idea was revived and popularised in the West in the 16th Century by Nicolaus Copernicus. This “heliocentric” system would shake the foundations of accepted wisdom.



The idea that the Earth was not at the centre of the Universe was revolutionary.

For a more detailed description of Copernicus’ system, consult http://galileo.rice.edu/sci/theories/copernican_system.html

Enter the telescope

In 1609, the Italian astronomer Galileo purchased in Venice an exemplar of a curious object, which was sold as a toy. It was a very primitive version of what later on would be called a telescope.

He used it to observe dark sunspots on the solar surface. These changed over time, with new ones emerging while old ones disappeared.

This was at odds with the conventional view of the heavens being perfect and unchanging.

Image: IYA2009 Secretariat.

Galileo's drawings of the sunspots (from the Istoria e Dimostrazioni, Florence 1613).

To see current sunspots imaged using modern telescopes and space probes, visit http://sohowww.nascom.nasa.gov/sunspots/

Dissecting the Sun

In the 1670s the great English scientist Sir Isaac Newton turned his attentions to the Sun.

Using a prism, he separated light from the Sun into different colours, which he then recombined using a second prism.

The Sun was a complex object, but it was finally being studied in a scientific manner.

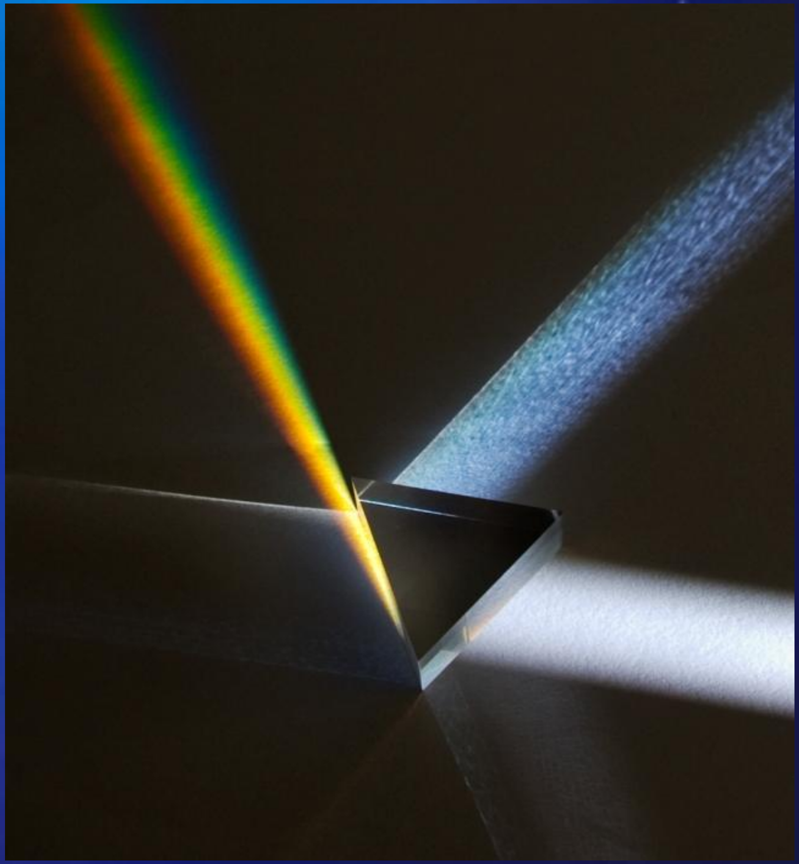


Image: Ricardo Cardoso Reis (CAUP).

A prism "splits" light.

To try Newton's prism experiments for yourself, go to http://micro.magnet.fsu.edu/primer/java/scienceopticsu/newton/

The Sun and infrared radiation

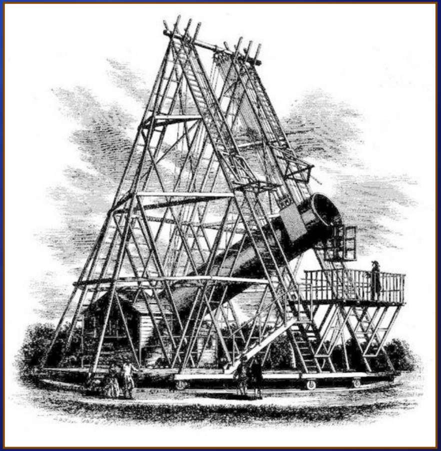
In 1800, William Herschel was observing sunspots using experimental filters. He was surprised to find lots of heat produced when using a red filter.

This was present beyond the red part of the spectrum. It seemed to be coming from some kind of invisible light.

Herschel had discovered infrared radiation, and realised that the Sun was emitting a great deal of it.

Image: IYA2009 Secretariat.

Infrared radiation can be used to see people's heat signature.



Herschel was a keen astronomer, and possessed his own observatory.

An introduction to the wider electromagnetic spectrum is here: http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html

Helioseismology

Helioseismology is the study of the solar oscillations observed at the surface, to probe the structure and the dynamics of the Sun. This works in a similar way as Earth seismology with the study of earthquakes.

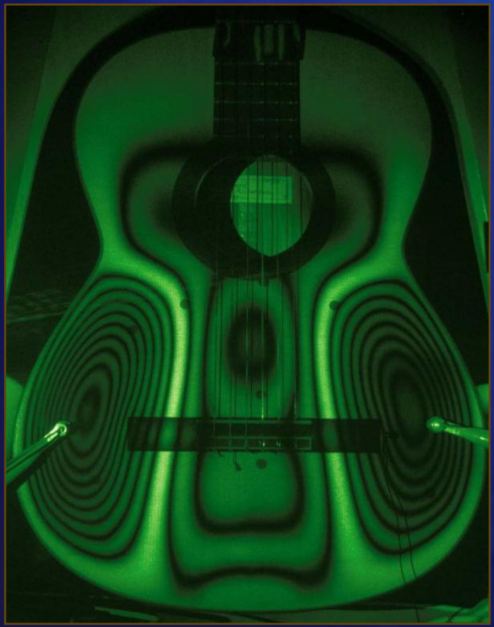


Image: B. Richardson (Cardiff University)

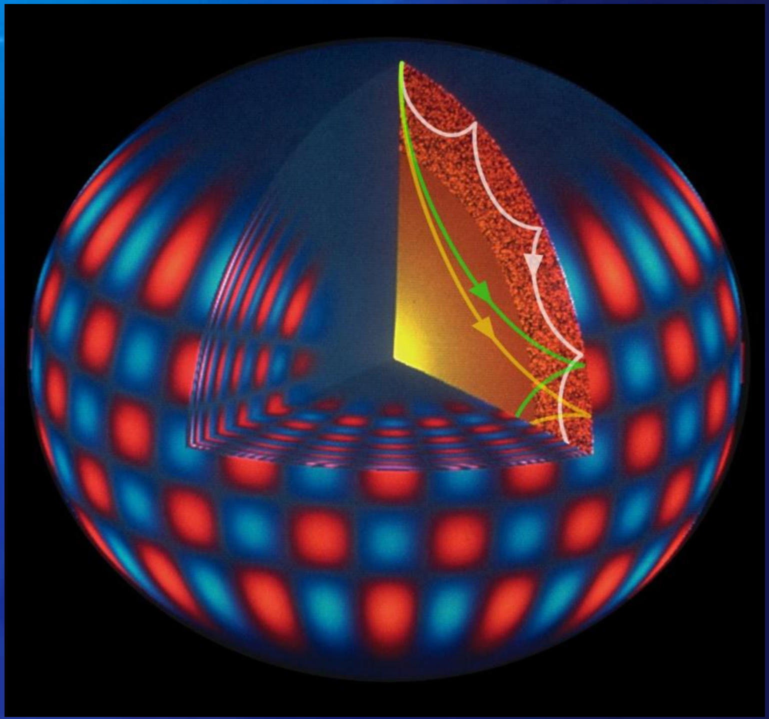


Image: NOAO/AURA/NSF.

The waves of these "Sunquakes" penetrate the Sun to different depths, revealing the interior of the Sun.

The technique is comparable to determining the shape of musical instruments from the sounds they make.

For a more detailed description of Helioseismology, check the HELAS outreach webpage: http://www.helas-eu.org/outreach/

Source of the Sun's power

The Sun's energy was a puzzle that was only solved in the early 20th Century. It was proposed that temperatures in the core were so hot (about 15 million degrees) that nuclear fusion would take place.

Each second, 700 million tons of Hydrogen are transformed in 695 million tons of Helium. The rest is transformed into energy, which sustains the Sun for billions of years.

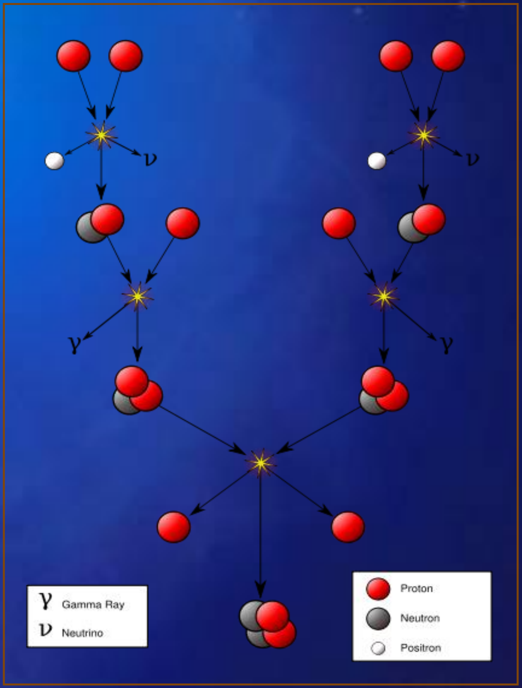


Image: Wikipedia.

Nuclear fusion is very powerful as mass is converted into energy.

For a technical explanation of nuclear fusion, consider visiting http://hyperphysics.phy-astr.gsu.edu/HBASE/NucEne/fusion.html

Solar Structure - Interior

In the layer above the core, energy is transported by radiation. But it takes about a million years for a photon to pass through this zone.

In the next layer, energy is transported by convection, not unlike what happens in a pot of boiling water. Hotter plasma is lighter, so it floats up, cools down in the surface, and then sinks back again.

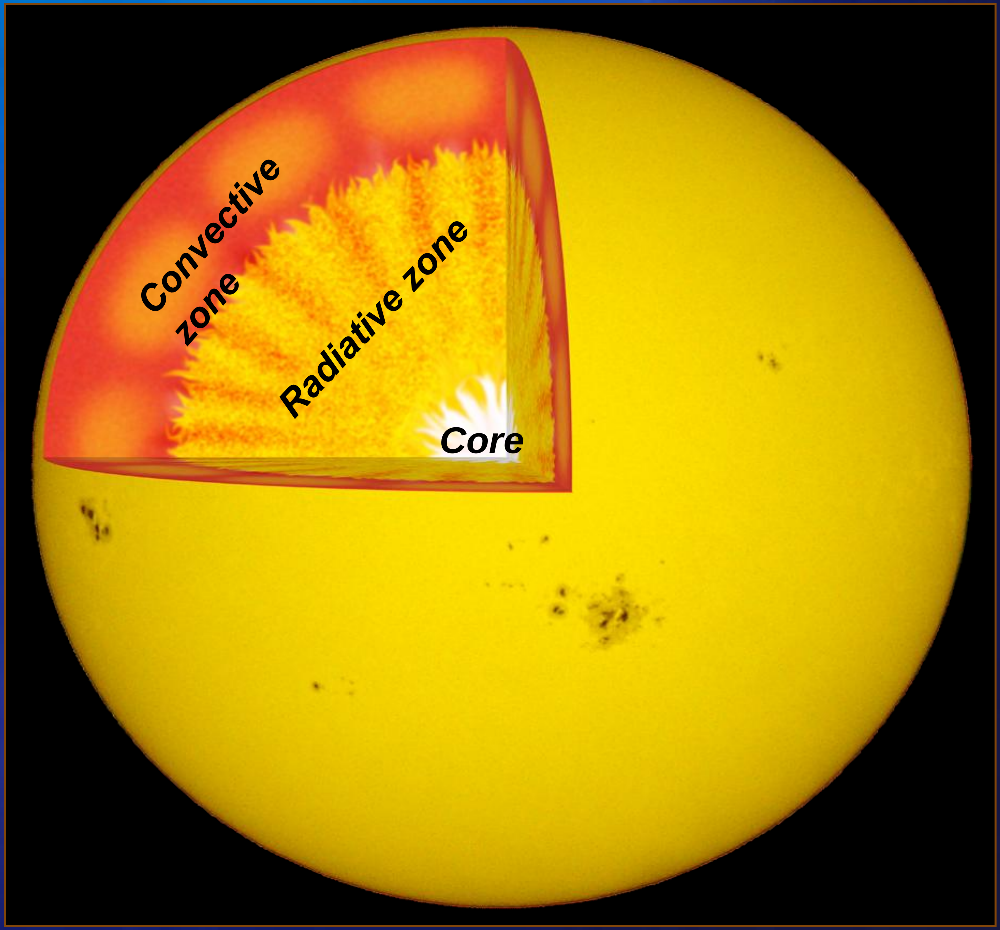


Image: Ricardo Cardoso Reis (CAUP).

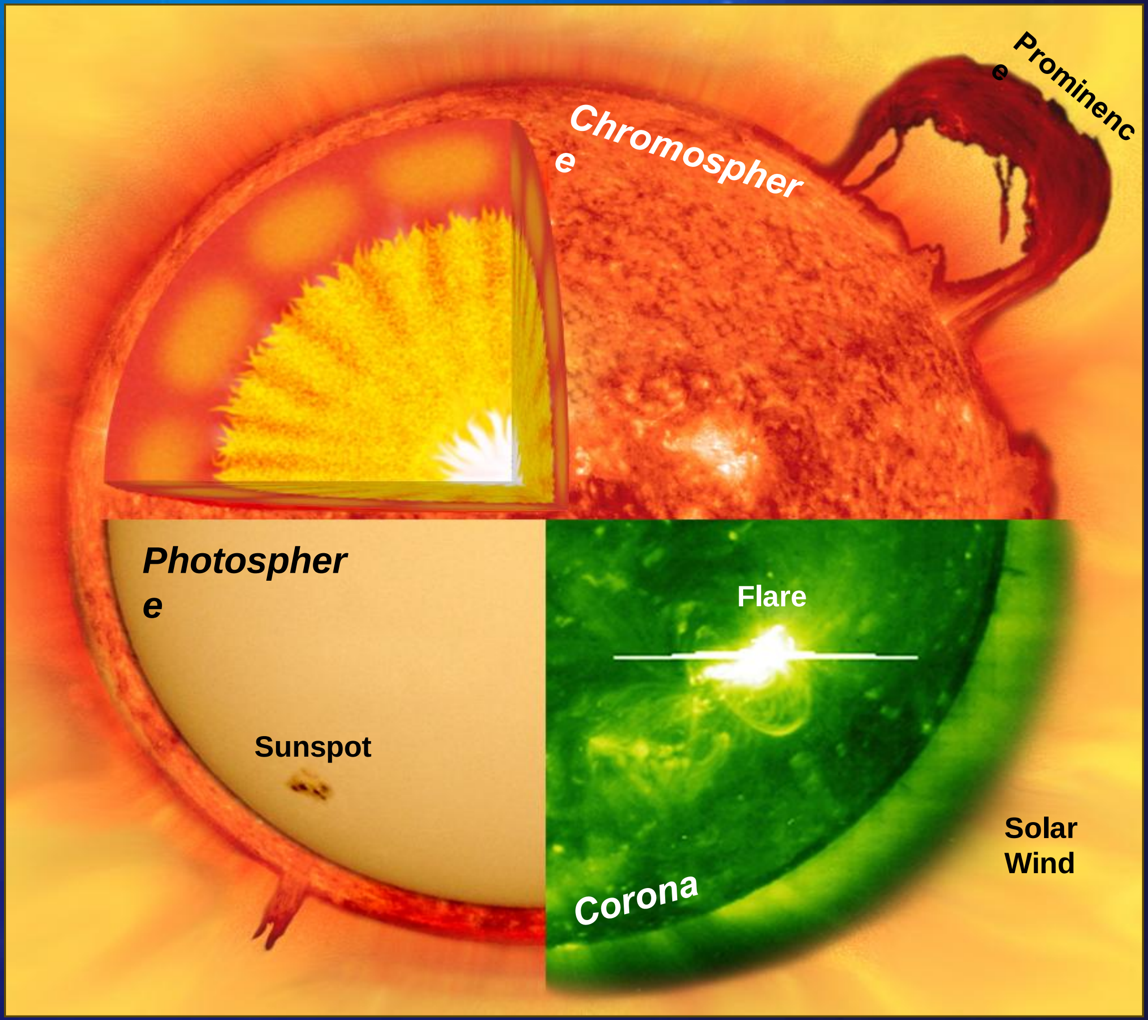
Solar Structure - Exterior

The Sun’s visible layer is called the ***Photosphere***, and has a temperature of about 5500 degrees.

Above it you find the solar atmosphere.

Its first layer is the ***Chromosphere***, visible as a red contour during solar eclipses.

During eclipses you can also see a bright halo around the Sun. This is the outer layer of the atmosphere: the ***Corona***.



Composition: Ricardo Cardoso Reis (CAUP). Sun Images: SOHO (NASA/ESA)

Solar Cycle

The solar cycle is our star's "everyday" life.

Solar activity has a cycle of about 11 years, but it can take up to 13 years.

During this time we see the Sun going from a calm star, to a very turbulent active star, and switching the polarity of the poles.

The easiest activity indicator to detect are sunspots.

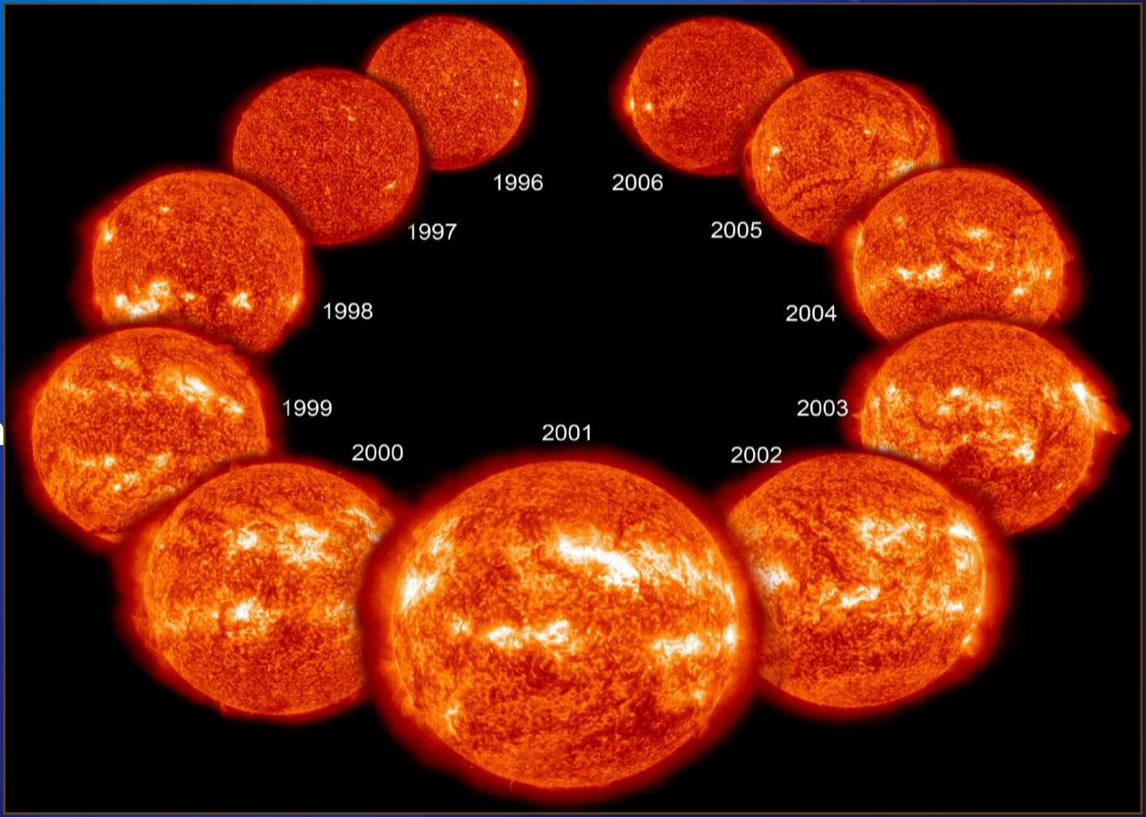


Image: SOHO (NASA & ESA).

Almost a full solar cycle, from minimum in 1996, to maximum in 2001, back to (almost) minimum again in 2006.

Solar Activity – Sunspots

Sunspots are one of the oldest known types of solar activity.

In these active regions of the Sun, magnetic field lines trap the solar plasma, and convection stops. With no means of transporting energy, the plasma cools down to about 4500 degrees, becoming black spots in contrast with the rest of the bright photosphere.

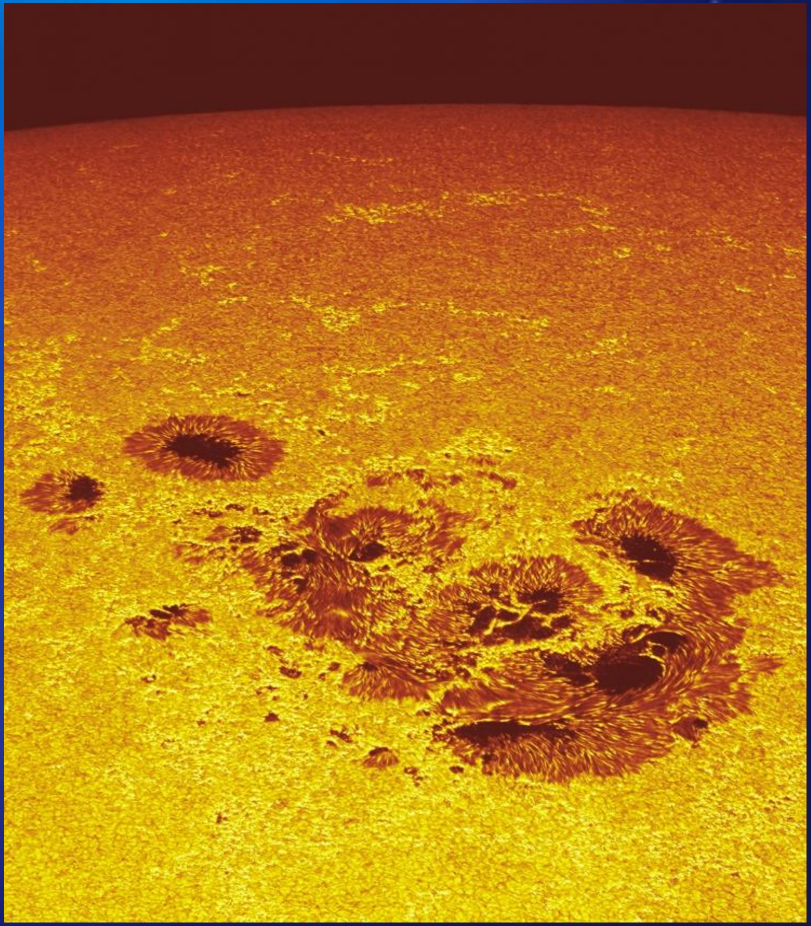


Image: Dutch Open Telescope.

A large group of sunspots, observed in 2003 by the Dutch Open Telescope.

Solar Activity – Flares

Flares are the most violent type of energetic phenomena in the Sun.

In just a few seconds, these solar explosions release the same energy as a billion megatons of TNT, or about 50 billion times more energy than the Hiroshima atom bomb.

This energy release is detected in every wavelength, from radio waves to gamma rays.

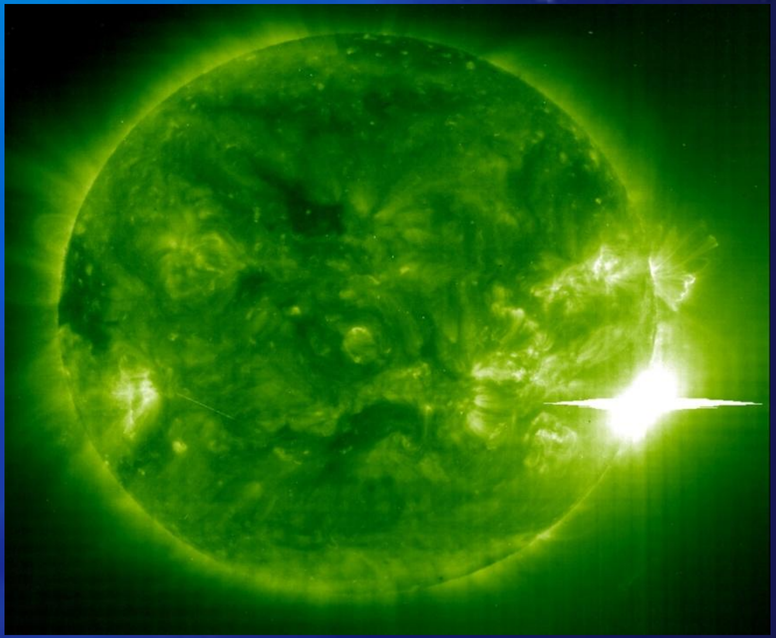


Image: SOHO (NASA & ESA).

In this extreme ultraviolet image of the Sun, the solar flare shines brighter than other areas of the Sun.

Solar Activity – Prominences

When magnetic fields lines ascend above the surface of our star, they drag with them the solar plasma, forming arcs – prominences.

The field lines support the plasma, and while they are stable, so are the prominences. But with time, the base of these magnetic arcs breaks and the plasma no longer has support.

Floating high above the solar surface, this plasma can then be released into space, as an eruptive prominence.

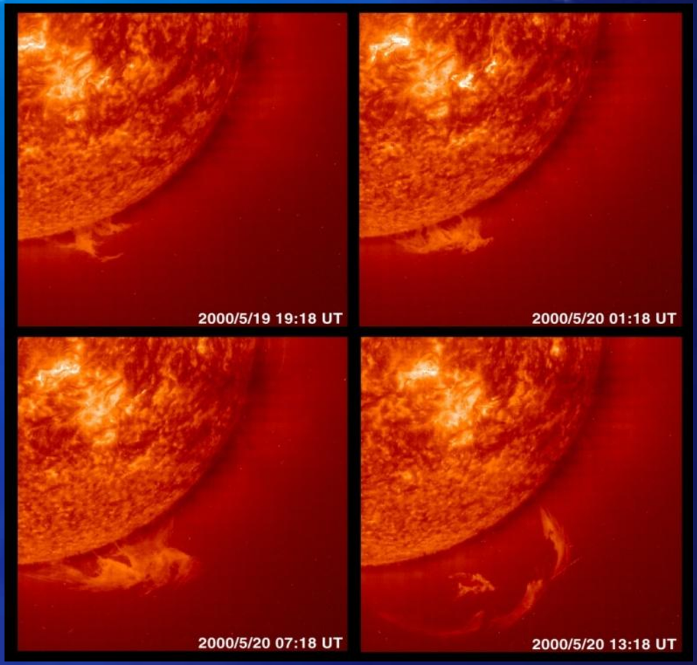


Image: SOHO (NASA & ESA).

An eruptive prominence in the process of being released into space.

Solar Activity – Coronal Mass Ejections

Similar to prominences in its genesis, coronal mass ejections (CMEs) take a different route. They are created when magnetic field lines form a bubble. They cut loose from the Sun, dragging with them the solar plasma.

Travelling at speeds between 200 and 600 km/s, CMEs can reach the Earth in just two days, where they interact with the magnetosphere and the atmosphere.

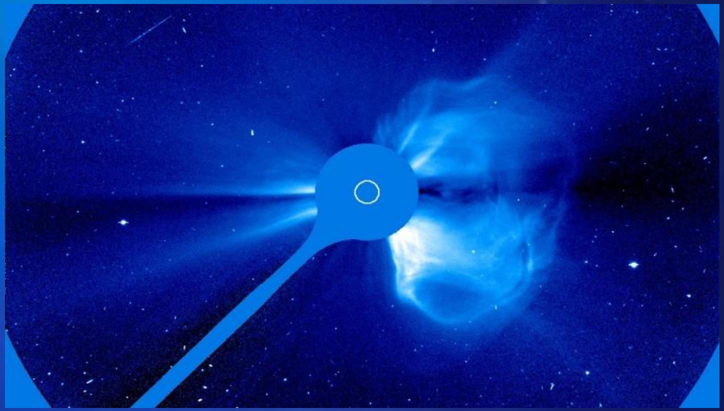


Image: SOHO (NASA & ESA).

CME seen from one of SOHO's coronographs.

Image: Senior Airman Joshua Strang.

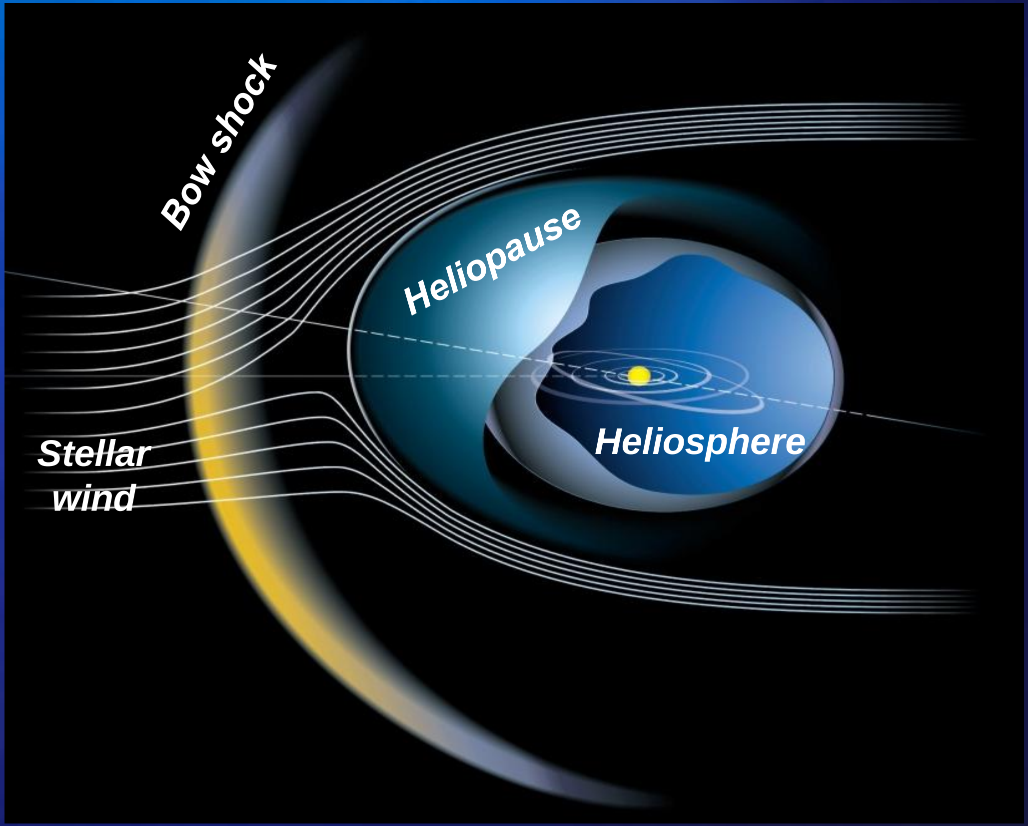
The aurorae are among the most beautiful interactions between solar activity and our atmosphere

Solar Activity – Solar Wind

The solar wind is a constant jet stream of charged particles from the solar corona, with a temperature of a million degrees, and speeds of around 450 km/s.

It travels beyond Pluto's orbit, where it meets the wind from other stars. This is the frontier of our Solar System – the Heliopause.

Some evidences for solar wind comes from observing the tails of comets. Pushed by the solar wind, they always point away from the Sun.



The heliosphere and the heliopause.

Image: ESA, Martin Kornmesser, Lars Lindberg Christensen

Observing from space

Solar observation used to be restricted to instruments on the ground, but in this modern age, space observatories provide us with a wealth of information.

These missions observe the Sun across many wavelengths and in more detail than ever before.

Space weather and other phenomena are being constantly observed by these vigilant spacecraft, like SOHO, Hinode, and STEREO, among others.

Image: NASA.

The NASA/ESA Solar & Heliospheric Observatory (SOHO) craft studies the Sun from its position in space.

The official SOHO mission website is http://www.nasa.gov/mission_pages/soho/

Questions for the future

- Exactly how large is the core?
- How does the solar dynamo work?
- What heats the corona?
- How does solar activity affect our daily lives?

With time these questions will most likely be answered, but new ones will arise!

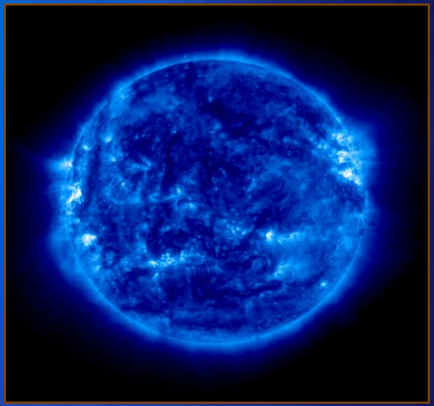


Image: SOHO (NASA/ESA).

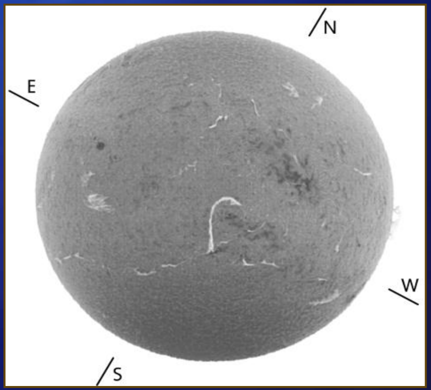


Image: Observatório Astronómico U. Coimbra

Observing the Sun in different wavelengths (such as ultraviolet and H-alpha) reveals yet more information.

Lee Pullen
IYA2009 Secretariat

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Galilean Nights is a Cornerstone Project of IYA2009
http://www.galileannights.org/

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