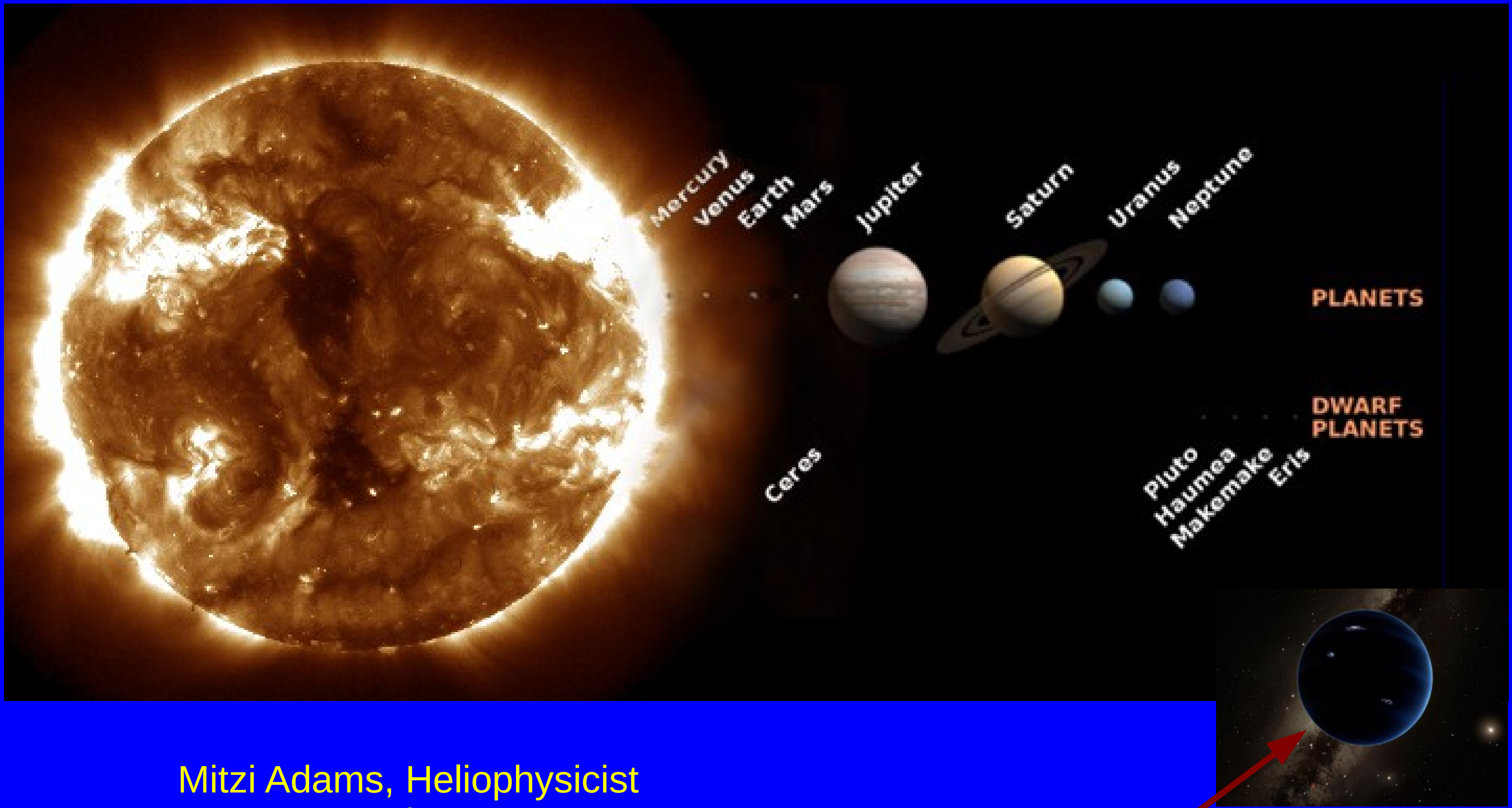
# Our Dynamic Sun: A Star at the Center of the Solar System

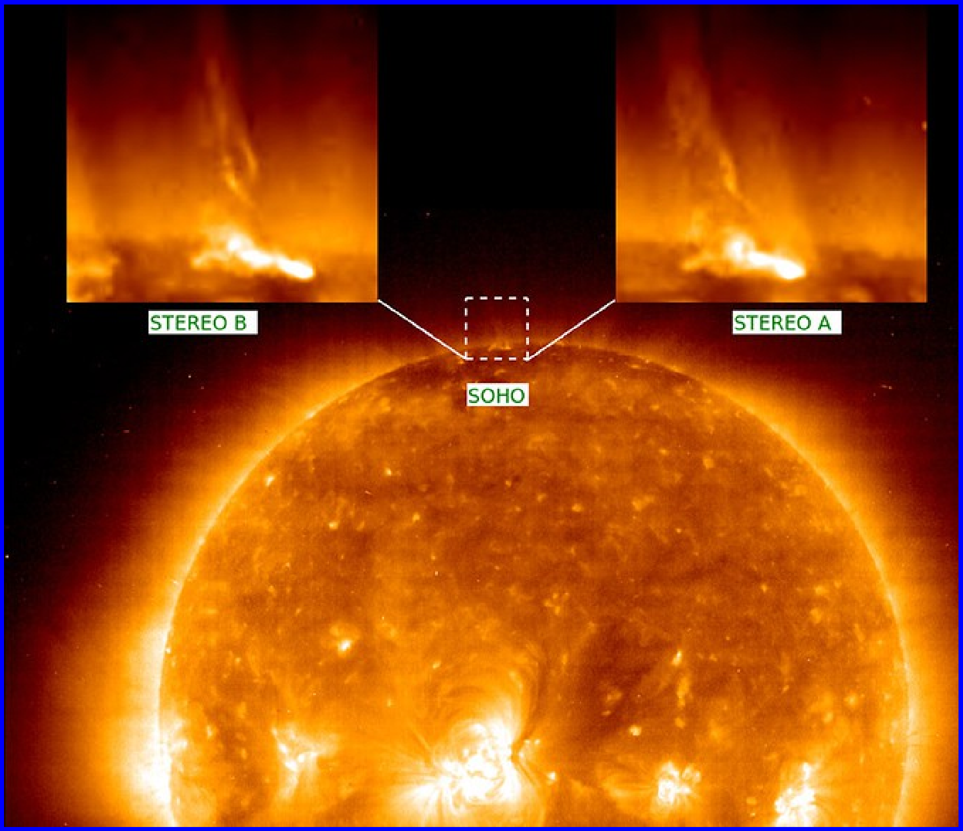



Planet Nine?


Mitzi Adams, Heliophysicist
NASA/MSFC


Presentation for the
University of Alabama in Tuscaloosa's
NASA Days
October 10, 2016

# There is a star at the center of our solar system!



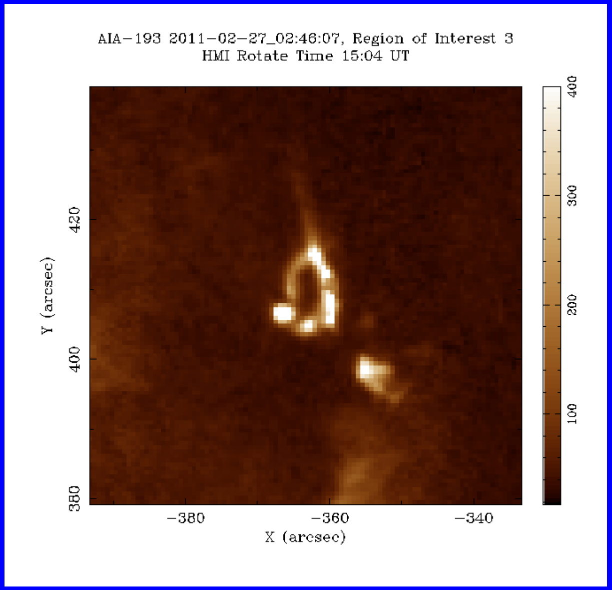


But what is a star?

How do stars work?

What are the characteristics of our Sun?

Are there impacts on Earth?



# Who Am I ?
# Mitzi Lynn Adams

-- From Atlanta, Georgia where I was an observatory/planetarium assistant at Fernbank Science Center while in high school

-- Earned a B.S. in physics with a mathematics minor from Georgia State University

-- Earned a M.S. in physics from University of Alabama in Huntsville while in the co-op program with NASA/MSFC

-- Worked as a solar scientist since 1988 in Huntsville

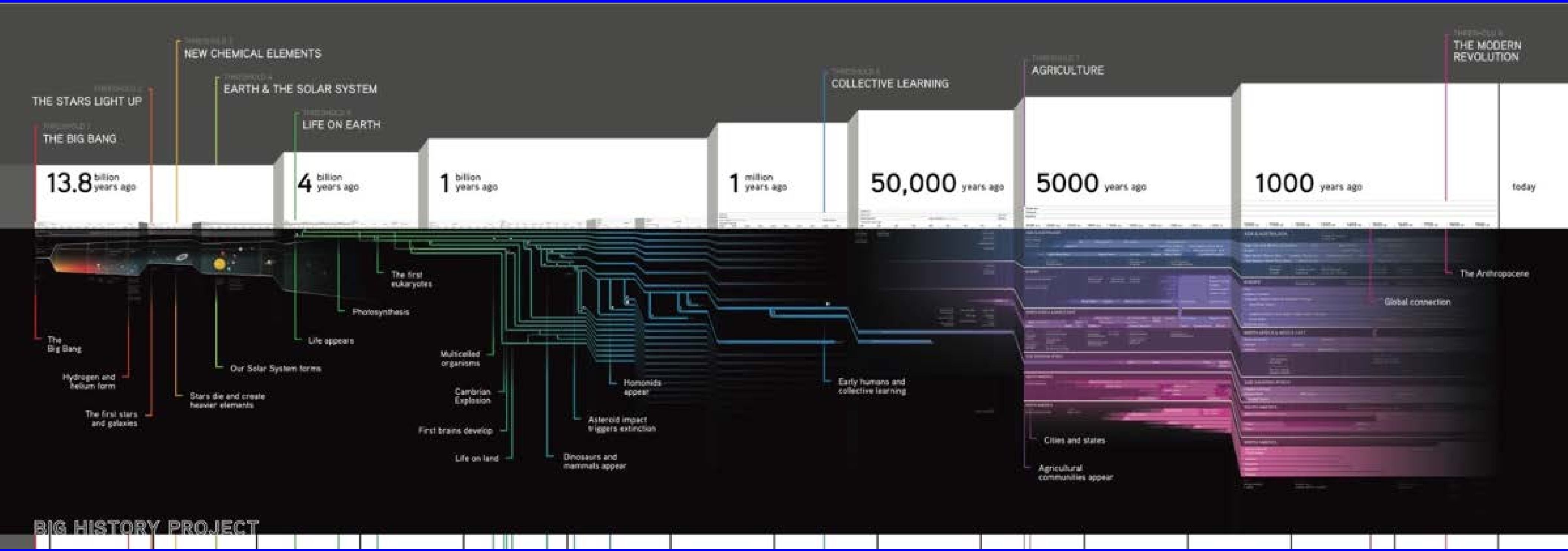
-- As a volunteer, was planetarium director of the Von Braun Astronomical Society's planetarium from 1988-2006

-- Like to run...have completed five marathons

-- Like to visit Peru

-- Like languages, meet with friends every Sunday to read Spanish and Latin and on Monday to read German

# Putting it into Context
# *Astronomical* Scales




## Time, Distance Size

How big is a million, a billion, 13.8 billion ?

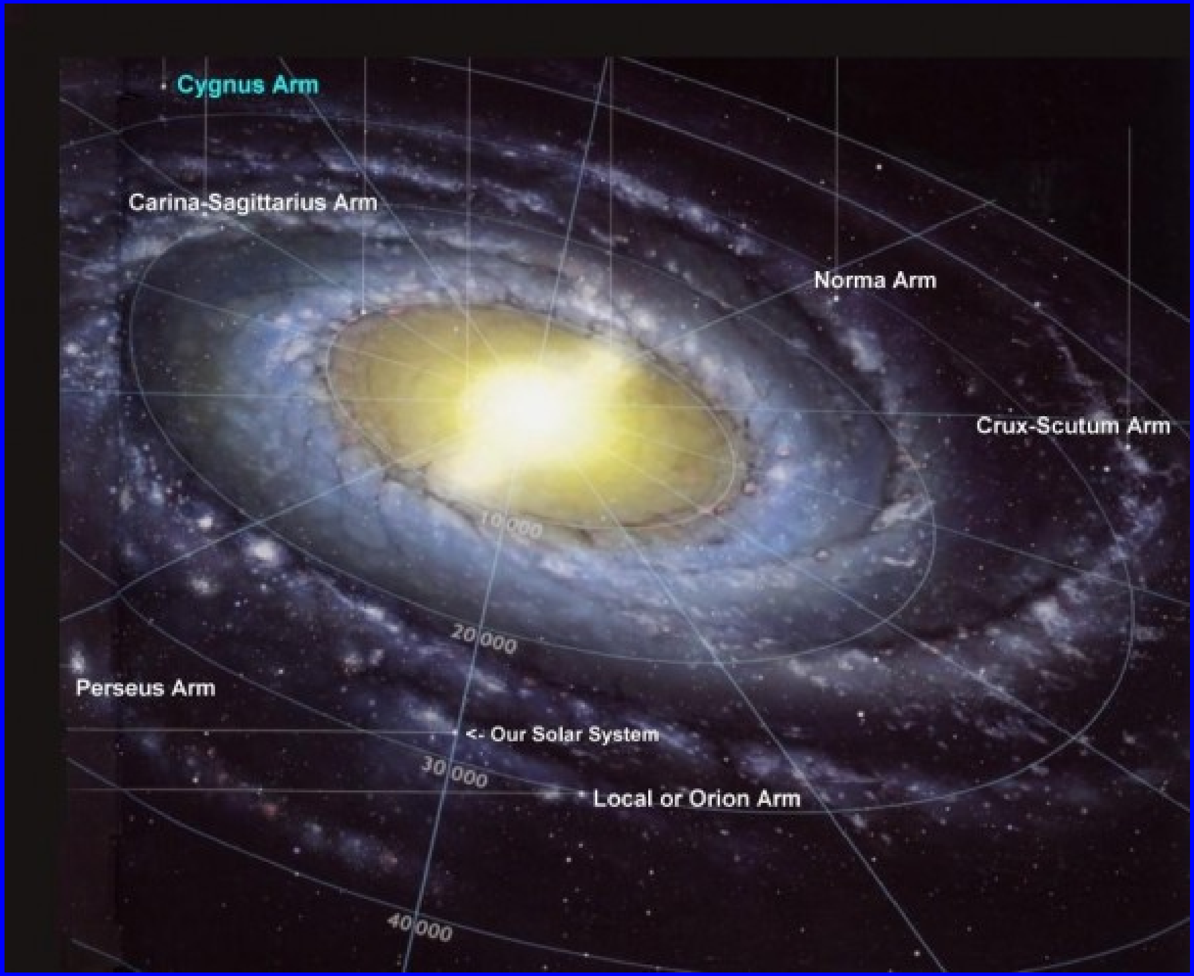
Count numbers, consider each number as one second.

Count to one million -- 11.6 days

Count to one billion -- Multiply 11.6 days by 1000 = 32 years

Count to 13.8 billion --> 439 years

# Perspective, continued...




The Sun is one of more than 100 billion stars in the Milky Way galaxy

There are over 30 galaxies in the local group with a diameter of ~10 million ly

The Sun is 25,000 light years from the galactic core

One galactic "year" takes about 250 million years.

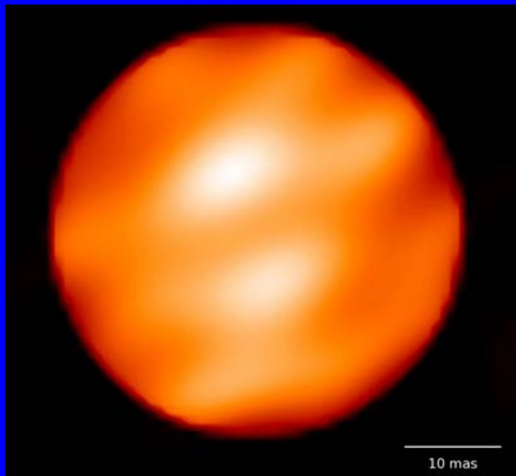
Proxima Centauri: α-Cen-A and α-Cen-B are at about 4.37 ly away,
Proxima is 4.24 ly away
Imagine Sun to be grapefruit sized. With that scale, Alpha Centauri (the system) would be 4,000 kilometers or 2,500 miles away.

α-Cen-A is a G2, α-Cen-B is a K1, Proxima (α-Cen-C) is M6

# What is a Star?

# What is a Star?

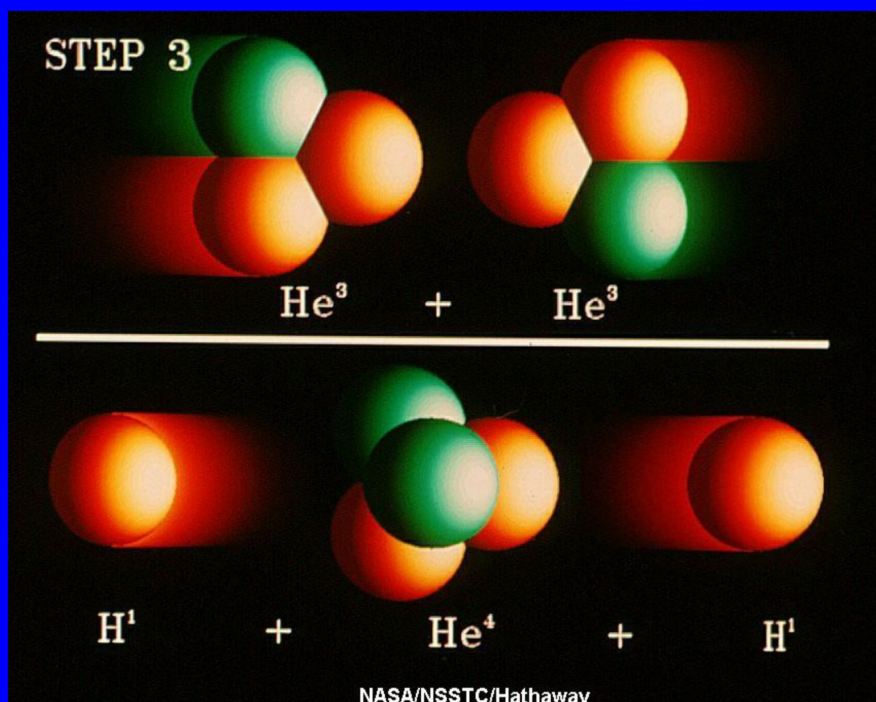
A star is an astrophysical body that produces its own light by thermonuclear reactions in its core.




Betelgeuse: A red giant star, about 600 ly away, 3500 K, 1,180 $R_\odot$, 7.7 $M_\odot$.


Rigel: A blue-white star, about 770 ly away, 11,000 K, 80 $R_\odot$, 20 $M_\odot$.

Basically, hydrogen converts to Helium

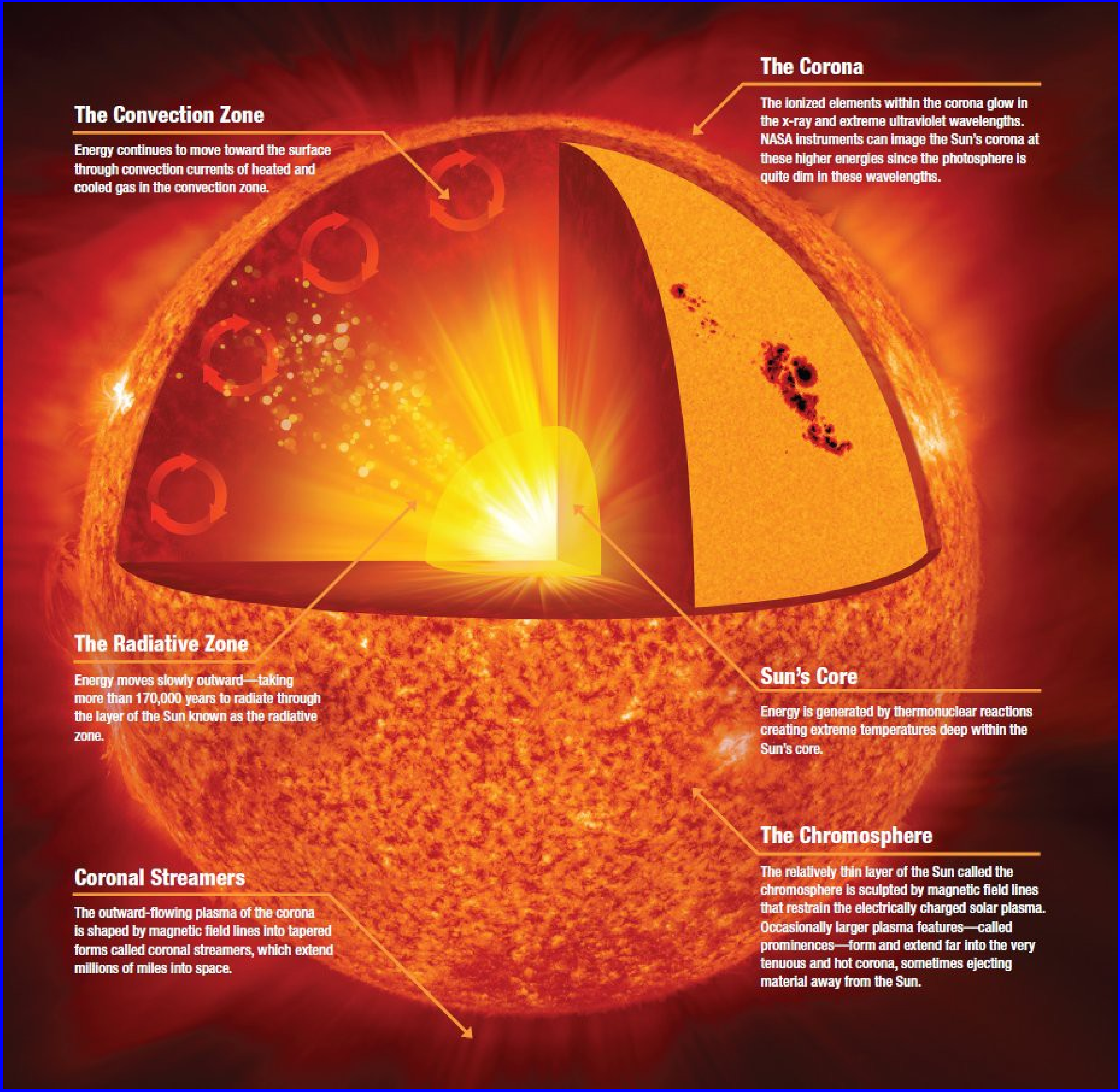



For sun-type stars, there are three steps in the proton-proton chain:

1. Two protons collide, form deuterium, a positron, and neutrino.
2. A proton collides with the deuterium, forming helium-3 and a gamma ray
3. Two He-3s collide to form He-4 plus two protons.

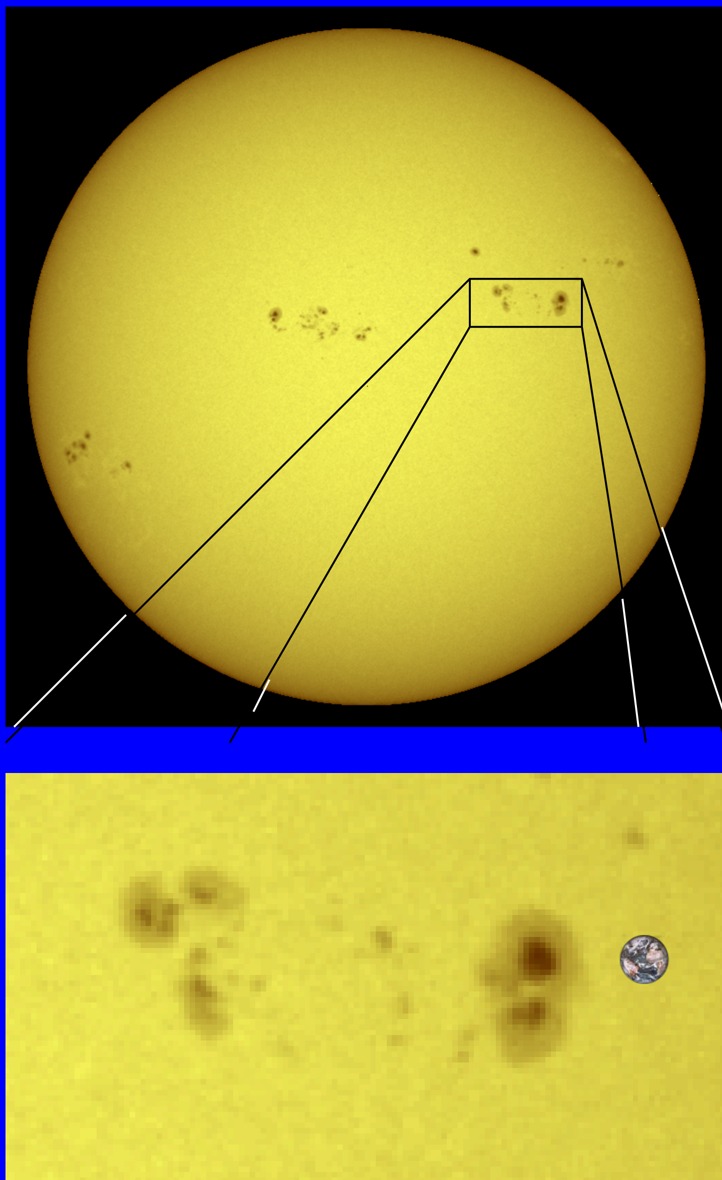
(High-mass stars, greater than about 2 solar masses use a different procedure, called the CNO cycle.)

# Layers of the Sun


The Corona
The ionized elements within the corona glow in the x-ray and extreme ultraviolet wavelengths. NASA instruments can image the Sun's corona at these higher energies since the photosphere is quite dim in these wavelengths.
The Convection Zone
Energy continues to move toward the surface through convection currents of heated and cooled gas in the convection zone.
The Radiative Zone
Energy moves slowly outward—taking more than 170,000 years to radiate through the layer of the Sun known as the radiative zone.
Sun's Core
Energy is generated by thermonuclear reactions creating extreme temperatures deep within the Sun's core.
The Chromosphere
The relatively thin layer of the Sun called the chromosphere is sculpted by magnetic field lines that restrain the electrically charged solar plasma. Occasionally larger plasma features—called prominences—form and extend far into the very tenuous and hot corona, sometimes ejecting material away from the Sun.
Coronal Streamers
The outward-flowing plasma of the corona is shaped by magnetic field lines into tapered forms called coronal streamers, which extend millions of miles into space.

# Surface Features

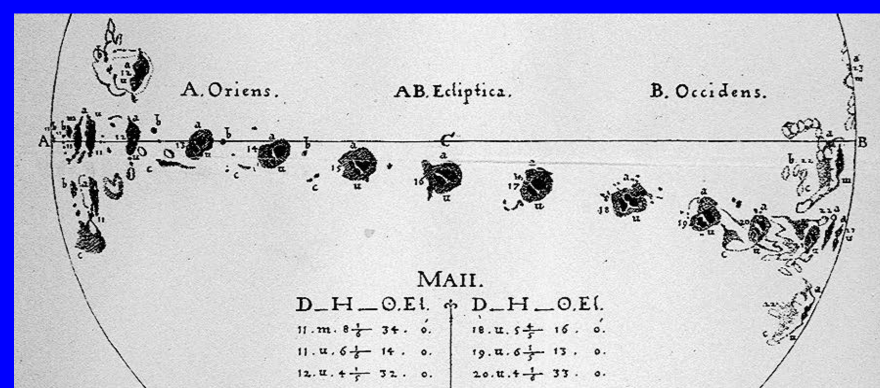
# Sunspots



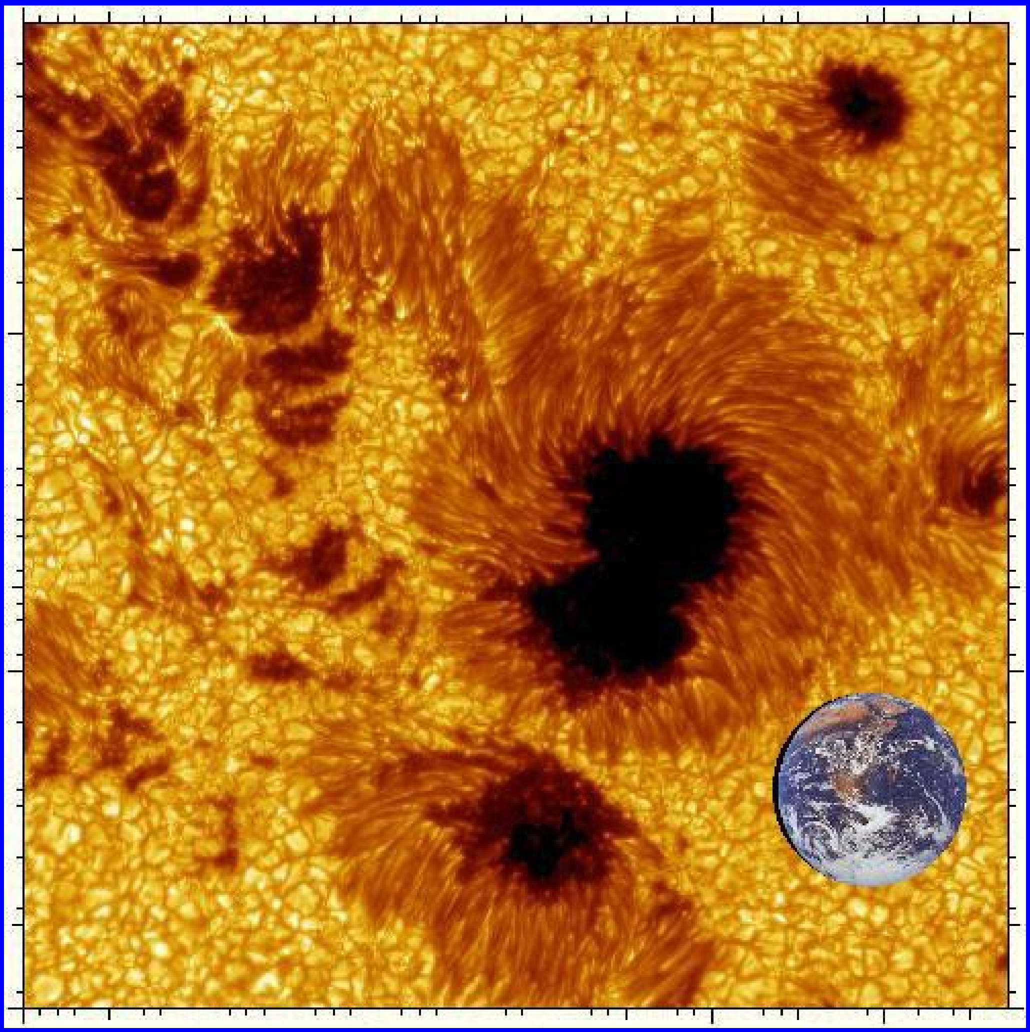
Sunspots are dark (and cooler) regions on the surface of the Sun. They have a darker inner region (the Umbra) surrounded by a lighter ring (the Penumbra).

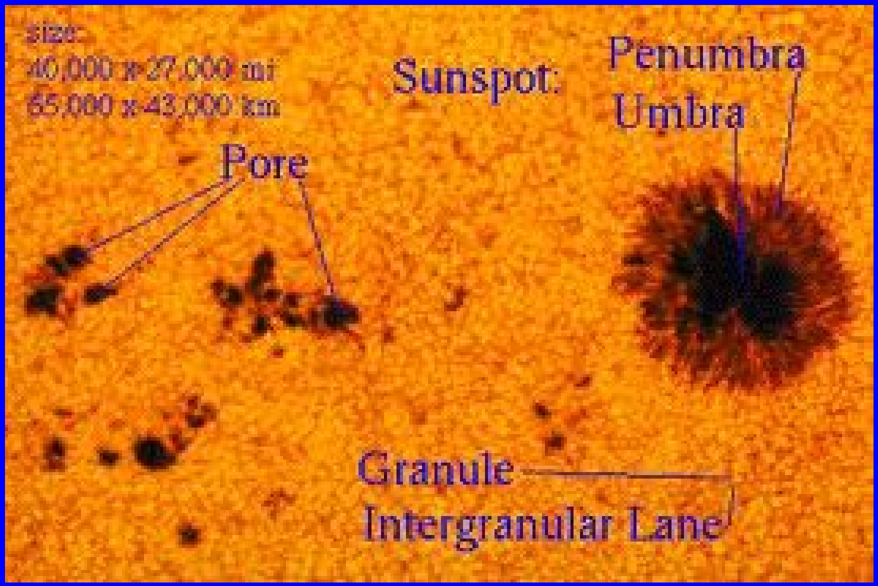
Sunspots usually appear in groups that form over hours or days and last for days or weeks.

The earliest sunspot observations (c. 1609) indicated that the Sun rotates once in about 27 days.



# Sunspots
## Examples



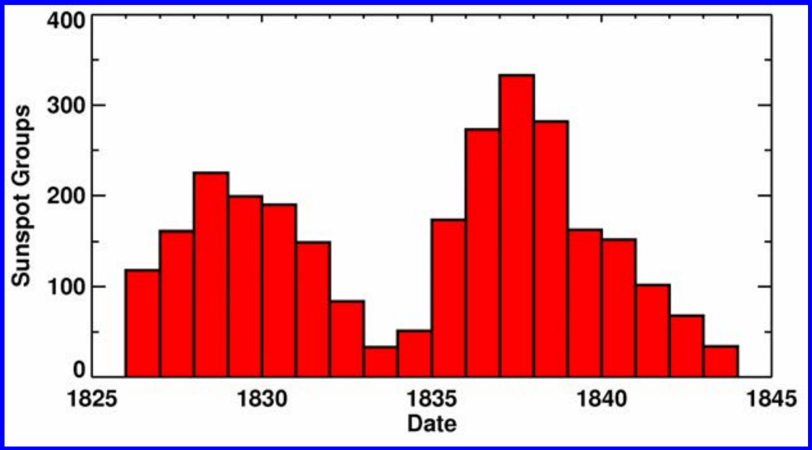


# The Solar Cycle

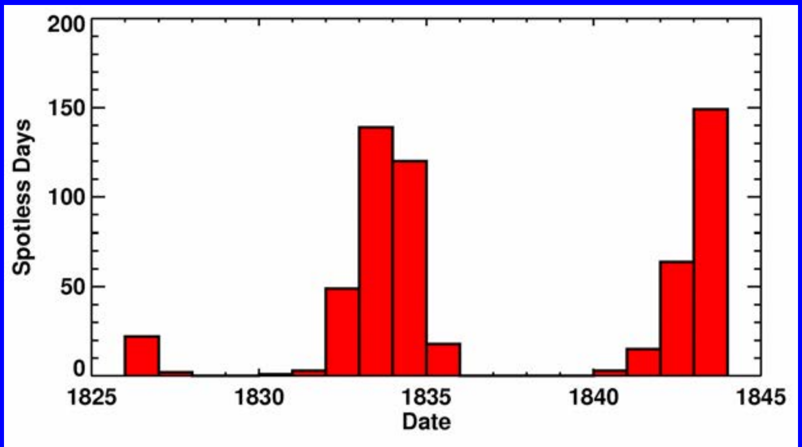
# Sunspot Cycle Discovery

**Astronomers had been observing sunspots for over 230 years before Heinrich Schwabe, an amateur astronomer in Dessau, Germany, discovered in 1844 that the number of sunspot groups and the number of days without sunspots increased and decreased in cycles of about 10-years.**

**Schwabe's data for 1826 to 1843**

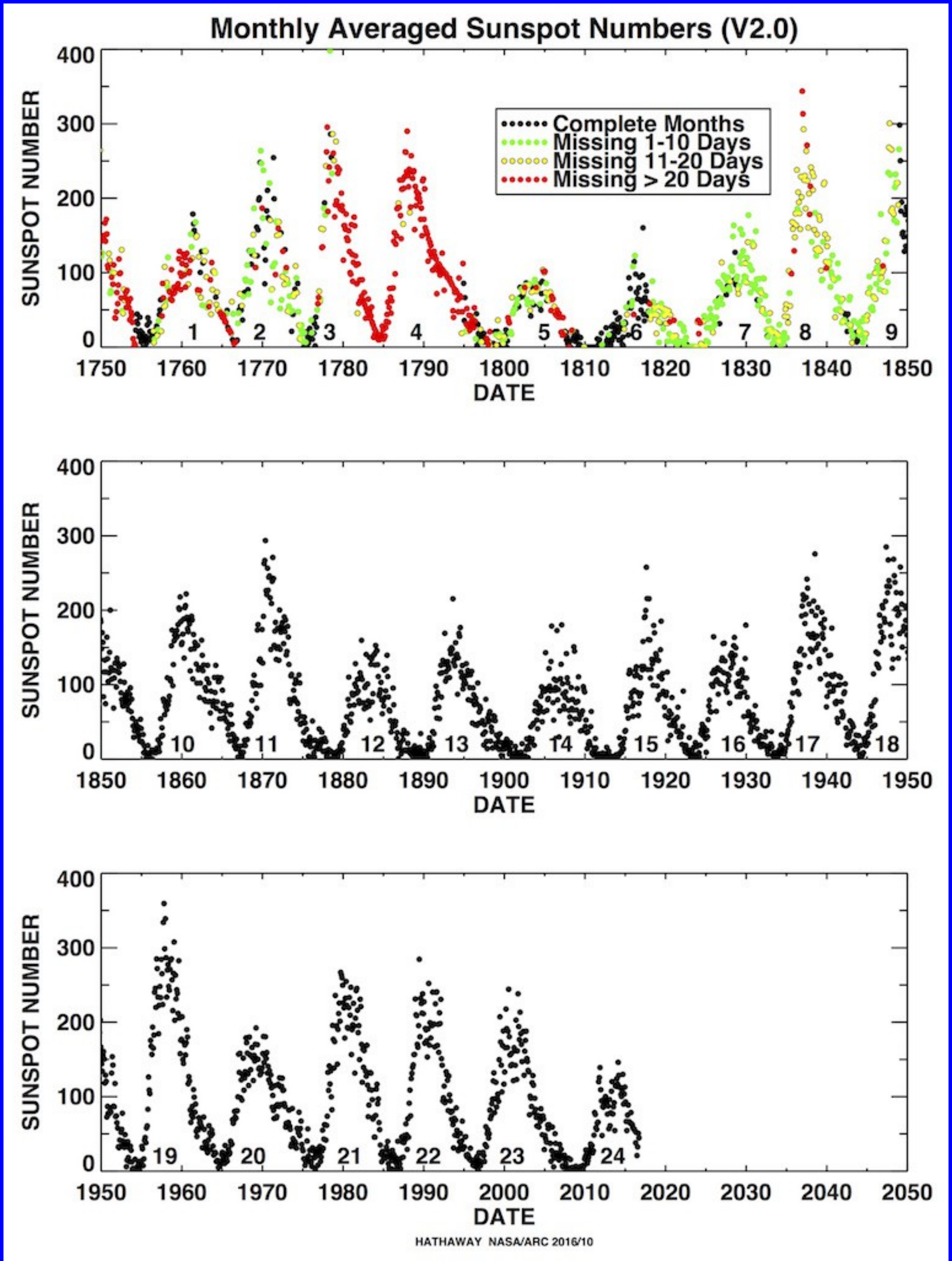



**Number of Sunspot Groups per Year**




**Number of Spotless Days**

# 23 Full Cycles



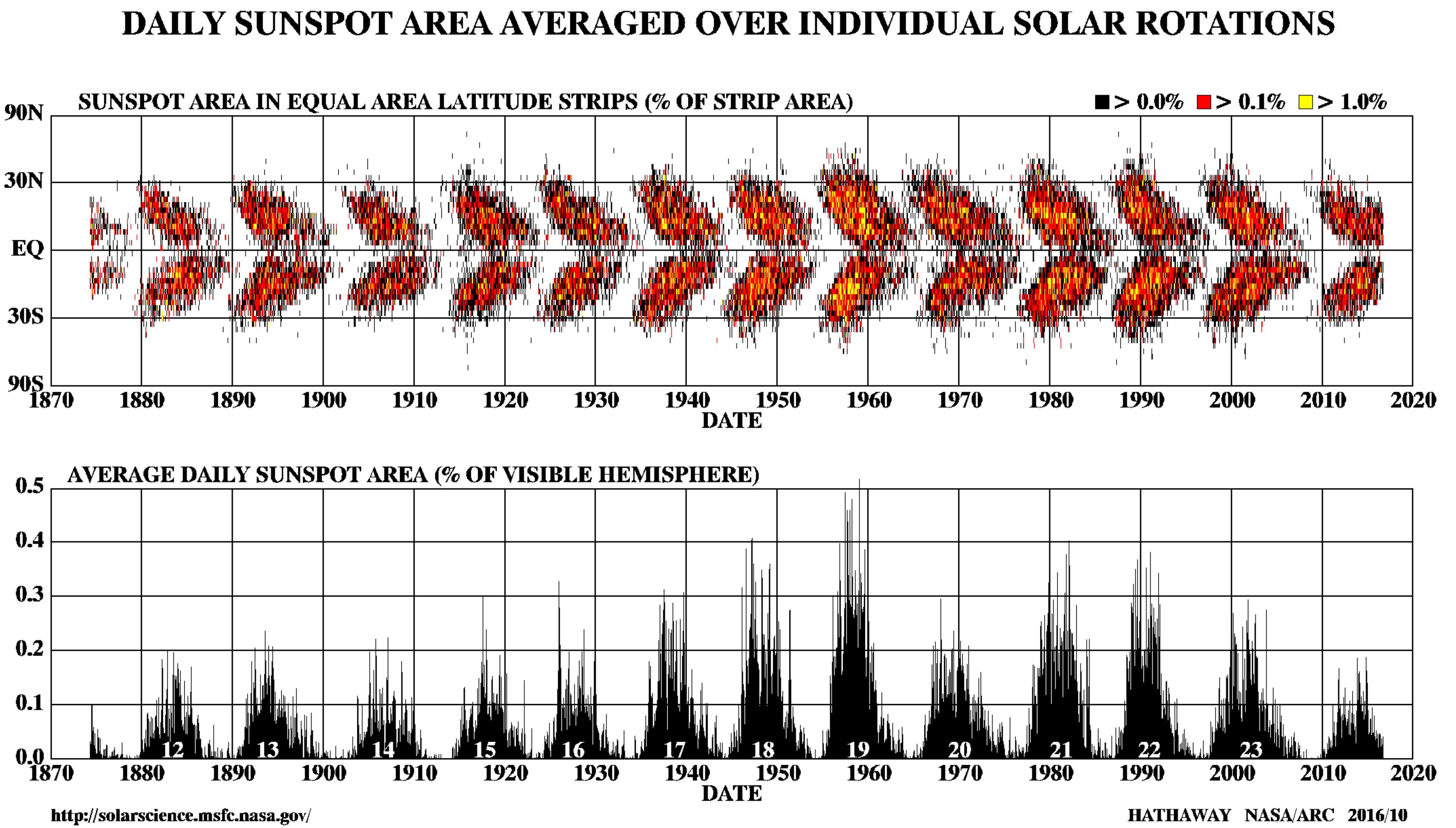

**Shortly after Schawbe discovery Rudolf Wolf proposed using a "Relative" Sunspot Number count. While there were many days without observations prior to 1849, sunspots have been counted on every day since. To this day we continue to use Wolf's Relative Sunspot Number and his cycle numbering.**

**The average cycle lasts about 11 years, but with a range from 9 to 14.**

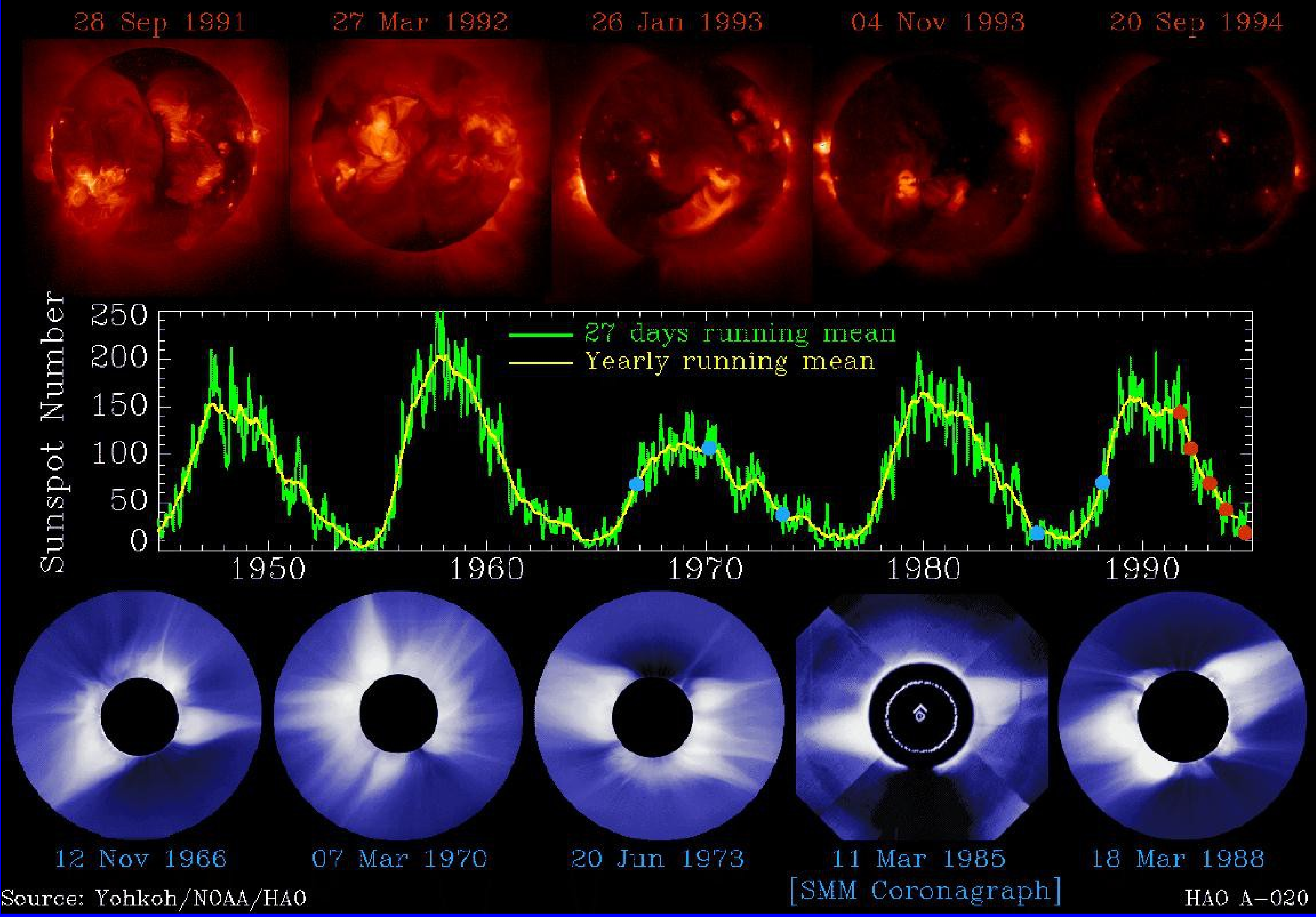
**The average amplitude is about 100, but with a range from 50 to 200.**

# Sunspot Latitudes

**Sunspots appear in two bands on either side of the equator. These bands drift toward the equator as the cycle progresses. Big cycles have wider bands that extend to higher latitudes. Cycles overlap by 2-3 years.**

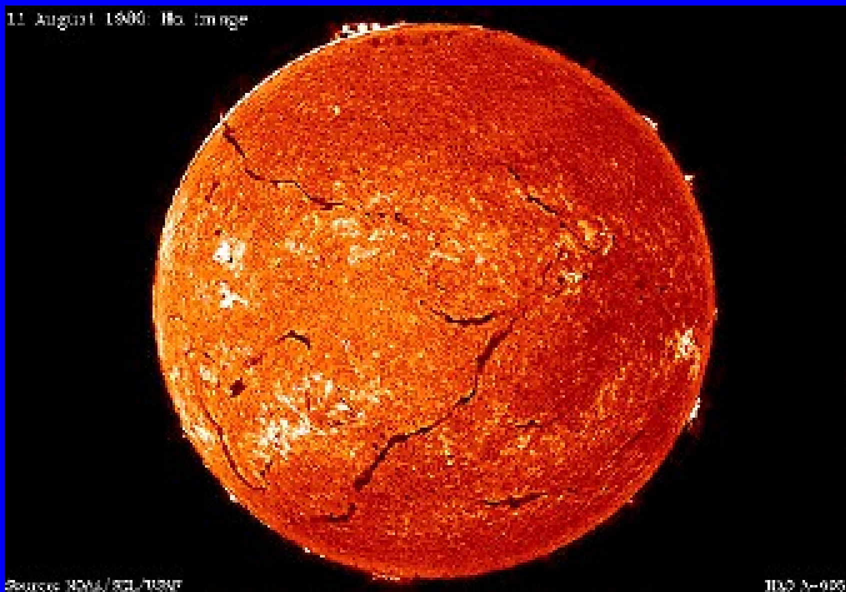


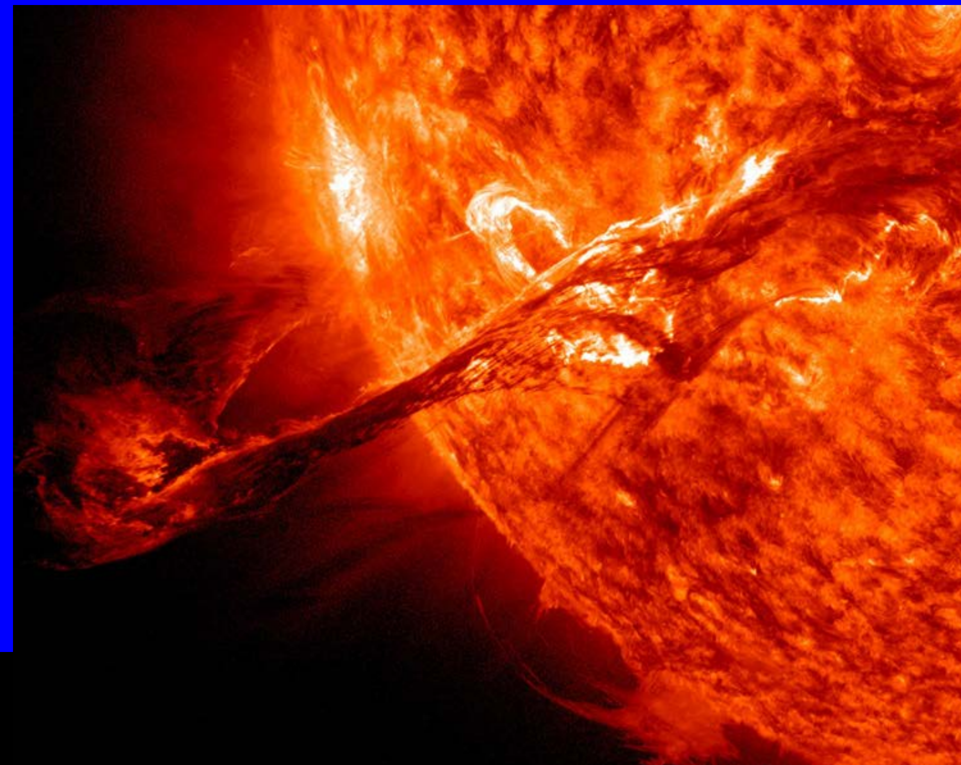
# The Corona and the Solar Cycle

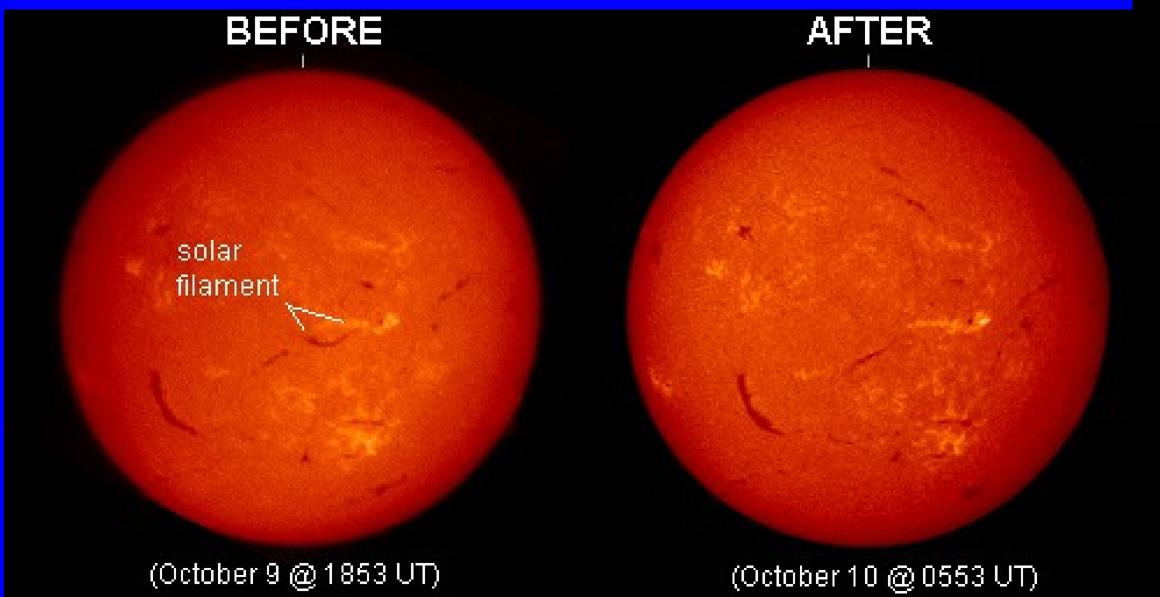


# Solar Eruptions

# Filament eruptions







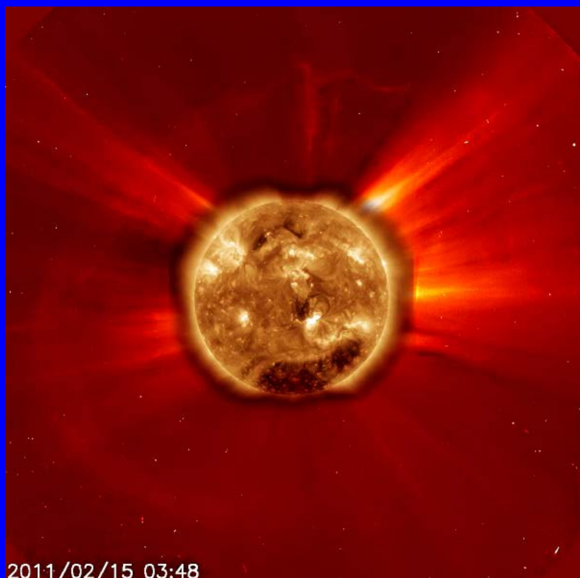

August 31, 2012, a filament erupted, triggering a CME. The plasma had speeds > 900 mi/s. This image is from SDO in 304 Å.

A filament around AR 9182 in October 2000. A C-7 flare was triggered, as well as a halo coronal-mass ejection (CME). Images from NOAA/SEC.

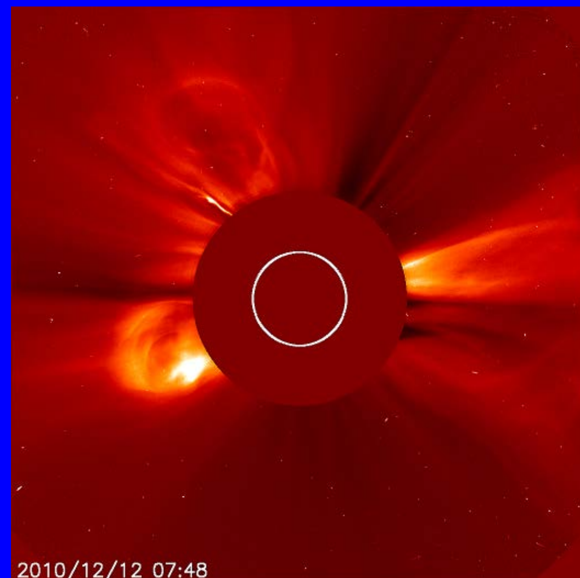
Movie!
Outburst304_big.mp4

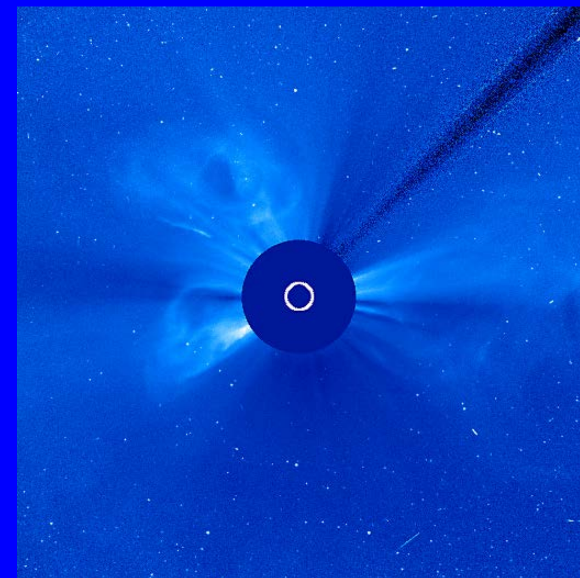
# Other Types of Solar Eruptions

Solar Flares and Coronal Mass Ejections (CMEs)




This combo of SDO and Soho C2 shows X2-flare and a halo CME



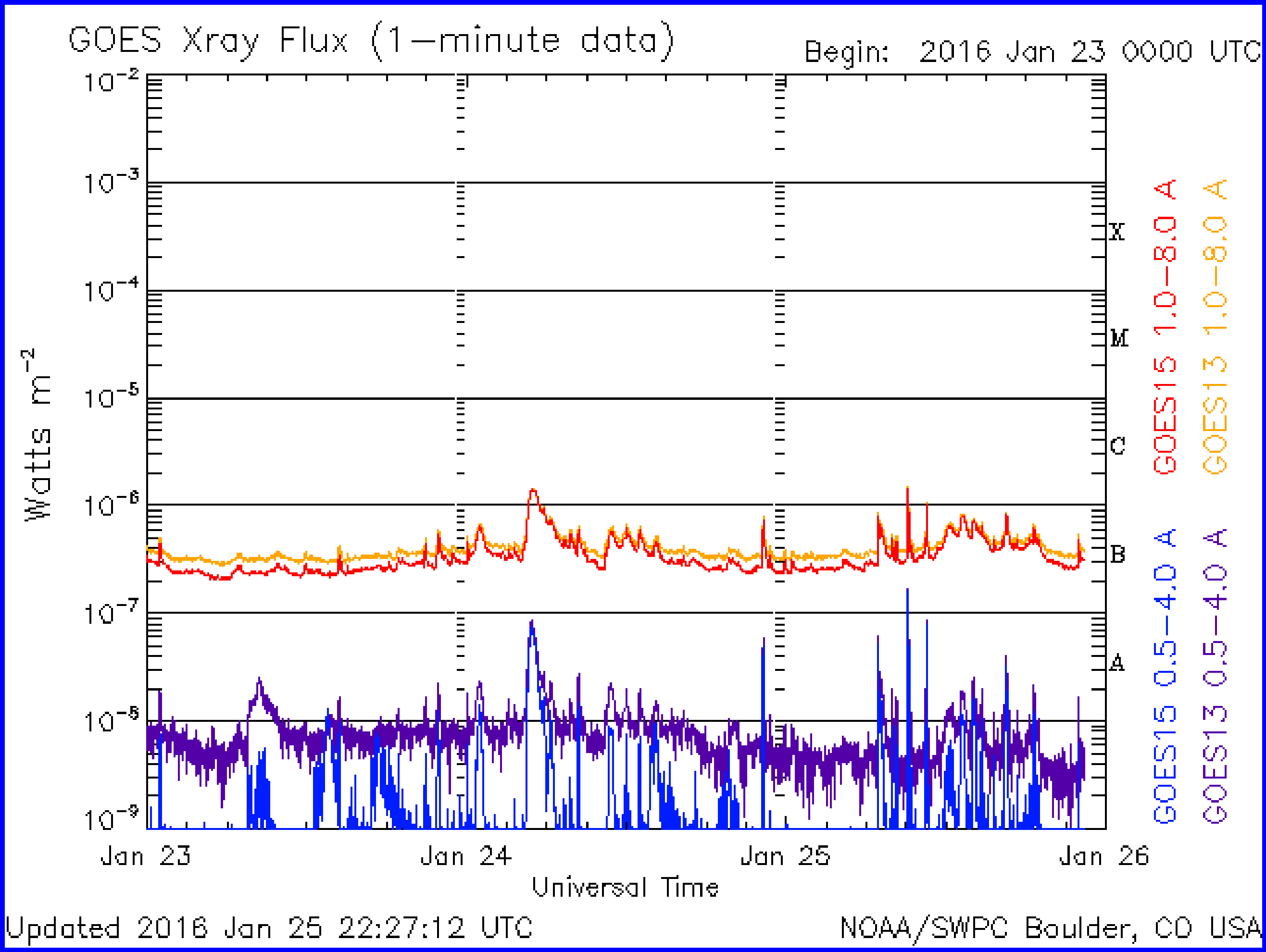



Three distinct CMEs: First (to right) was from a filament eruption, second from north pole, third from far side of Sun. All three eruptions happened within hours of each other.

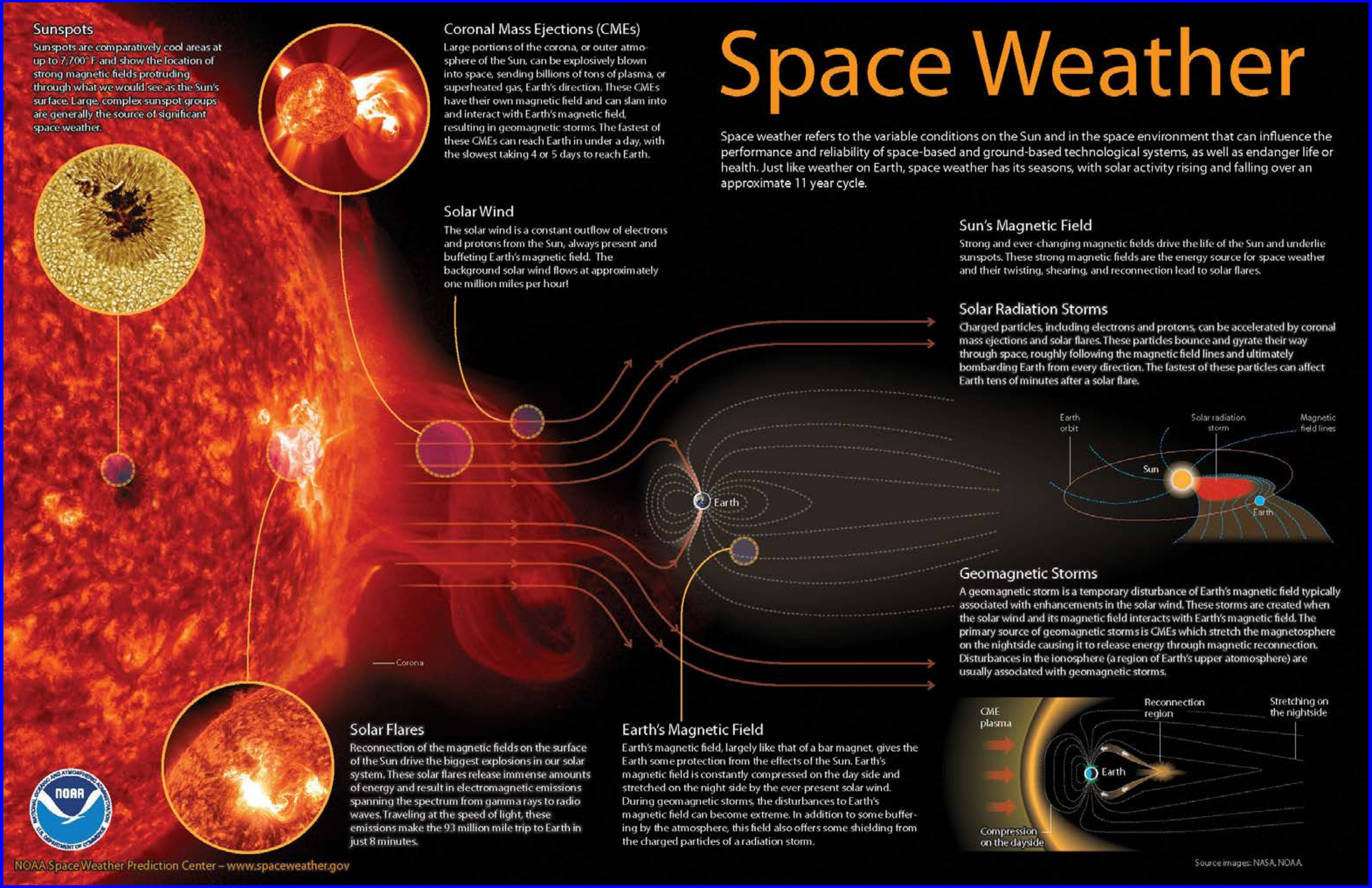
Movies!

c2_halloween_2003.mpg, c3_halloween_2003.mpg, X2_C2_combo_best.mpg

# How to Classify a Solar Flare



# Solar Eruptions and Earth



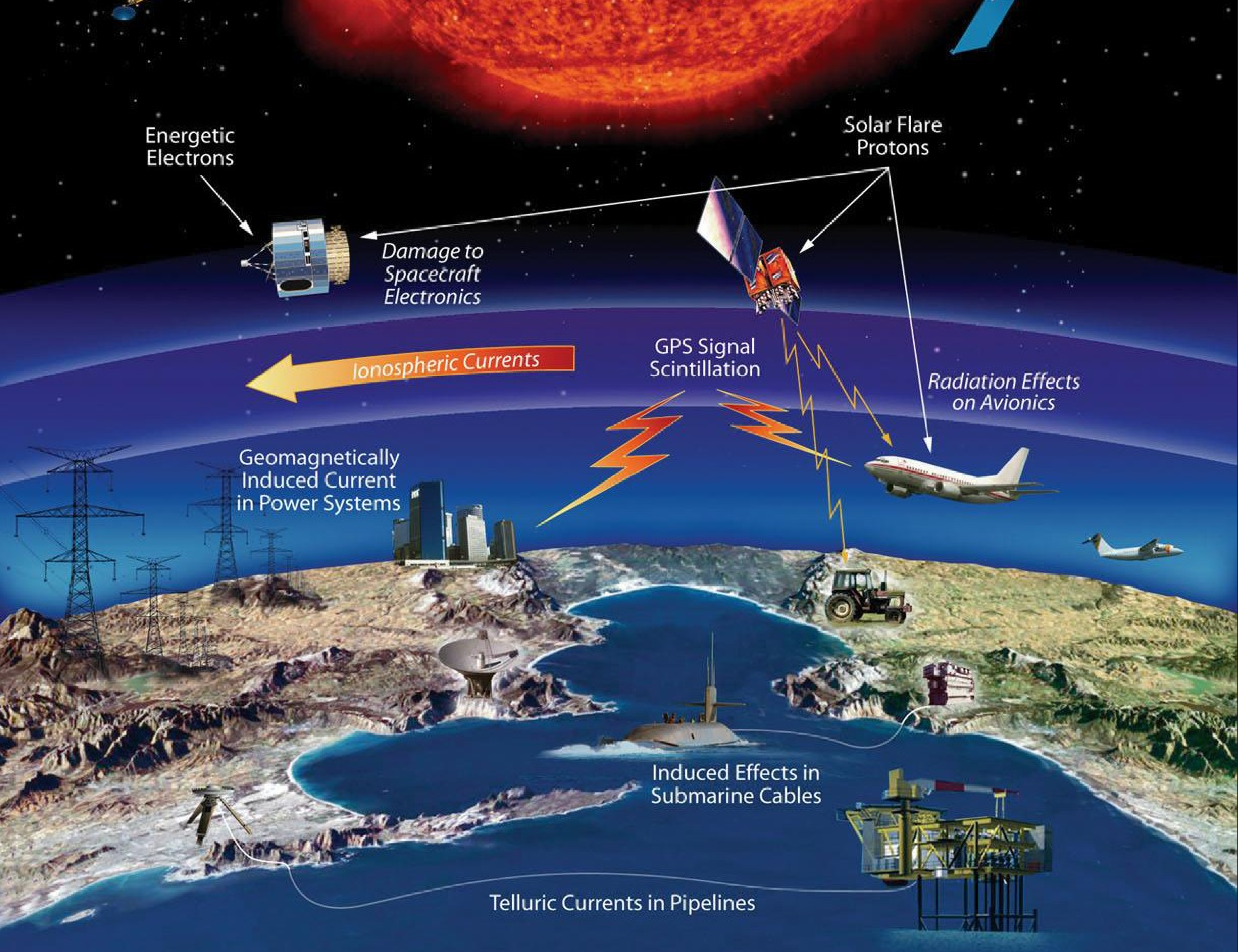

From an Executive Order Signed November 7, 2016 that specifies how the Federal Government will coordinate efforts to prepare the nation for space weather events: “Space weather means variations in the space environment between the Sun and Earth (and throughout the solar system) that can affect technologies in space and on Earth. The primary types of space weather events are solar flares, solar energetic particles, and geomagnetic disturbances.”

# Aurorae

Seen mostly at high latitudes, aurorae are produced when Earth's magnetosphere is disturbed.

Plasma from the magnetosphere precipitates into the upper atmosphere.

Reds are from oxygen (630 nm)
Greens at 557.7 nm are from lower in atmosphere.


Energetic Electrons
Solar Flare Protons
Damage to Spacecraft Electronics
GPS Signal Scintillation
Ionospheric Currents
Radiation Effects on Avionics
Geomagnetically Induced Current in Power Systems
Induced Effects in Submarine Cables
Telluric Currents in Pipelines

# Summary

Our Sun is a single star with a system of planets

The Sun is a stable star, currently happily converting hydrogen to helium

The Sun will remain on the Main Sequence of ~ 4.5 billion years more

The Sun is an active star, which produces spots, flares, and coronal mass ejections

Solar eruptive phenomena can create problems for our technological society such as power outages, computer upsets, orbital decay of satellites, radio blackouts, pipeline degradation

# Eclipse Across America

August 21, 2017

National Aeronautics and Space Administration

## What is a Solar Eclipse?

A **solar eclipse** happens when the Moon, as it orbits Earth, fully or partially blocks the light of the Sun, thus casting its shadow on Earth.

Observers within the path of totality can expect to see something like the image below. bservers outside the path of totality will see the Sun partially eclipsed as a crescent Sun (with safe filters).

## Greatest Eclipse

| Time | Location |
|---|---|
| 10:17 a.m. PDT | Lincoln Beach, OR<br>Depoe Bay, OR |
| 11:26 a.m. MDT | Lime, ID |
| 1:19 p.m. CDT | Valley View, MO<br>Bloomsdale, MO |
| 1:28 p.m. CDT | Calistia, TN |
| 2:47 p.m. EDT | Bethera, SC |

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After the 2017 solar eclipse, the next **total solar eclipse** visible over the continental United States will be on **April 8, 2024**.

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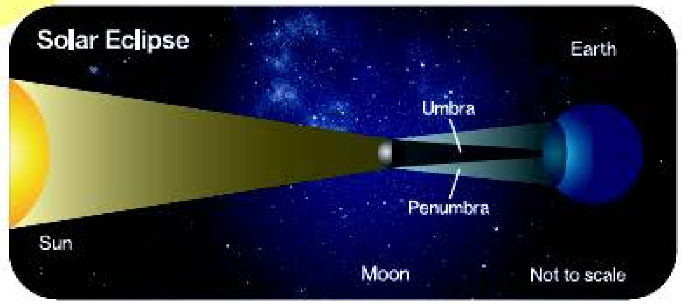



**If the Sun is scaled to about 10 cm (3.9 in), Earth would be about 10 meters away (33 feet).**

## The predicted path of the August 21, 2017 solar eclipse

Duration of Greatest Eclipse:
**2 min 40 sec**
(18:25 UT=13:25 CDT or 1:25 p.m. CDT)

Location Greatest Eclipse:
**36 deg 58 min N; 87 deg 40 min W**
(between Princeton and Hopkinsville, KY)

Path Width: **approximately 115 km**

Eclipse Predictions by Fred Espenak, GSFC, NASA-emeritus


http://mail.colonial.net/~hkaiter/index.html

**The NASA image above shows the Moon's umbral shadow as seen from the International Space Station during the total solar eclipse on 29 March 2006.**

**Never look directly at the Sun unless you have filters that you know are safe.**

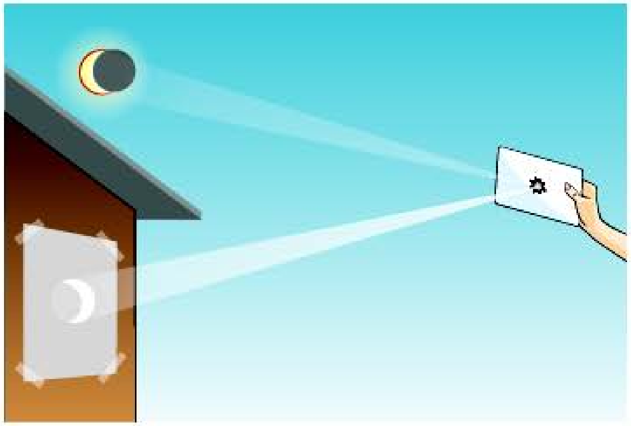
**For more information:** http://eclipse/gsfc.nasa.gov/SEhelp/safety.html

**For more information about solar eclipses:** http://eclipse.gsfc.nasa.gov/solar.html
http://eclipsewise.com/solar
http://eclipsewise.com/solar/SEnews/TSE2017/TSE2017.html
http://eclipse2017.nasa.gov/

**Mitzi Adams • *mitzi.adams@nasa.gov* • 256–961–7626**

# Safely Observing the Sun

**WARNING: Never look directly at the Sun without proper eye protection. You can *seriously* injure your eyes.**



## Mirror in an Envelope

**Slide a mirror into an envelope with a ragged holde cut into the front.** Point the mirror toward the Sun so that an image is reflected onto a screen at least 5 meters (about 15 feet) away. The longer the distance, the larger the image.

**Do not look at the mirror, only at the screen.**

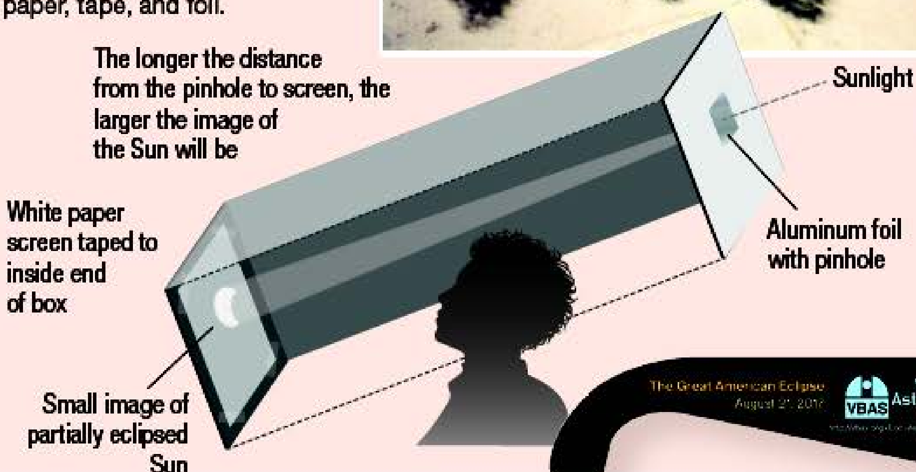
Photograph (below) Copyright © Elisa J. Israel

## Strange Shadows!

Sunlight through trees produces projected crescents during partial phases.

## Go Stick Your Head in a Box

You can make this simple "eclipse telescope" with some cardboard, paper, tape, and foil.




## Local Area Eclipse Details

| Location | % Covered | Start (CDT) | Max (CDT) | End (CDT) |
|---|---|---|---|---|
| Nashville, TN | 100.0% | 11:58AM | 1:28PM | 2:54PM |
| Totality begins 1:27PM • Totality ends 1:29PM | | | | |
| Brentwood, TN | 100.0% | 11:58AM | 1:28PM | 2:54PM |
| Totality begins 1:28PM • Totality ends 1:29PM | | | | |
| Franklin, TN | 99.9 | 11:58AM | 1:28PM | 2:54PM |
| Fayetteville, TN | 98.2 | 11:59 | 1:30 | 2:56 |
| Ardmore, AL/TN | 97.3 | 11:59 | 1:29 | 2:55 |
| Florence, AL | 95.9 | 11:57 | 1:28 | 2:54 |
| Athens, AL | 96.7 | 11:59 | 1:29 | 2:56 |
| Decatur, AL | 96.1 | 11:59 | 1:30 | 2:56 |
| Hartselle, AL | 95.8 | 11:59 | 1:30 | 2:56 |
| Madison, AL | 96.7 | 11:59 | 1:30 | 2:56 |
| USSRC | 96.8 | 11:59 | 1:30 | 2:56 |
| Huntsville, AL | 97.0 | 11:59 | 1:30 | 2:56 |
| VBAS | 97.1 | 12:00NOON | 1:30 | 2:56 |
| Arab, AL | 96.0 | 12:00 | 1:31 | 2:57 |
| Gurley, AL | 97.1 | 12:00 | 1:31 | 2:57 |
| Guntersville, AL | 96.4 | 12:01 | 1:31 | 2:57 |
| Scottsboro, AL | 97.4 | 12:01 | 1:31 | 2:57 |
| Bridgeport, AL | 98.6 | 12:01 | 1:32 | 2:57 |

JAVA Script Solar Eclipse Explorer
http://eclipse.gsfc.nasa.gov/JSEX/JSEX-NA.html

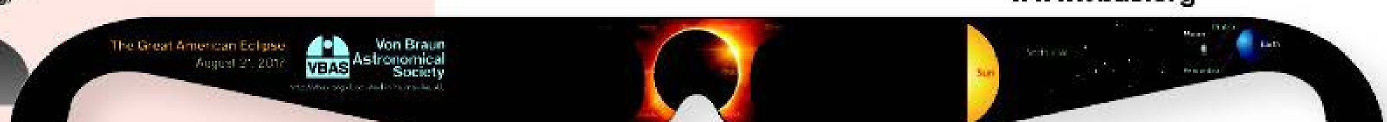
## Sun Funnel

Make this device for your telescope with simple instructions at: www.astrosociety.org/tov/Build_a_Sun_Funnel.pdf

## Cool in the Shades

Visit the Von Braun Astronomical Society (or your local astronomical society) and pick up a pair of these special Eclipse Sunglasses!

**www.vbas.org**

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