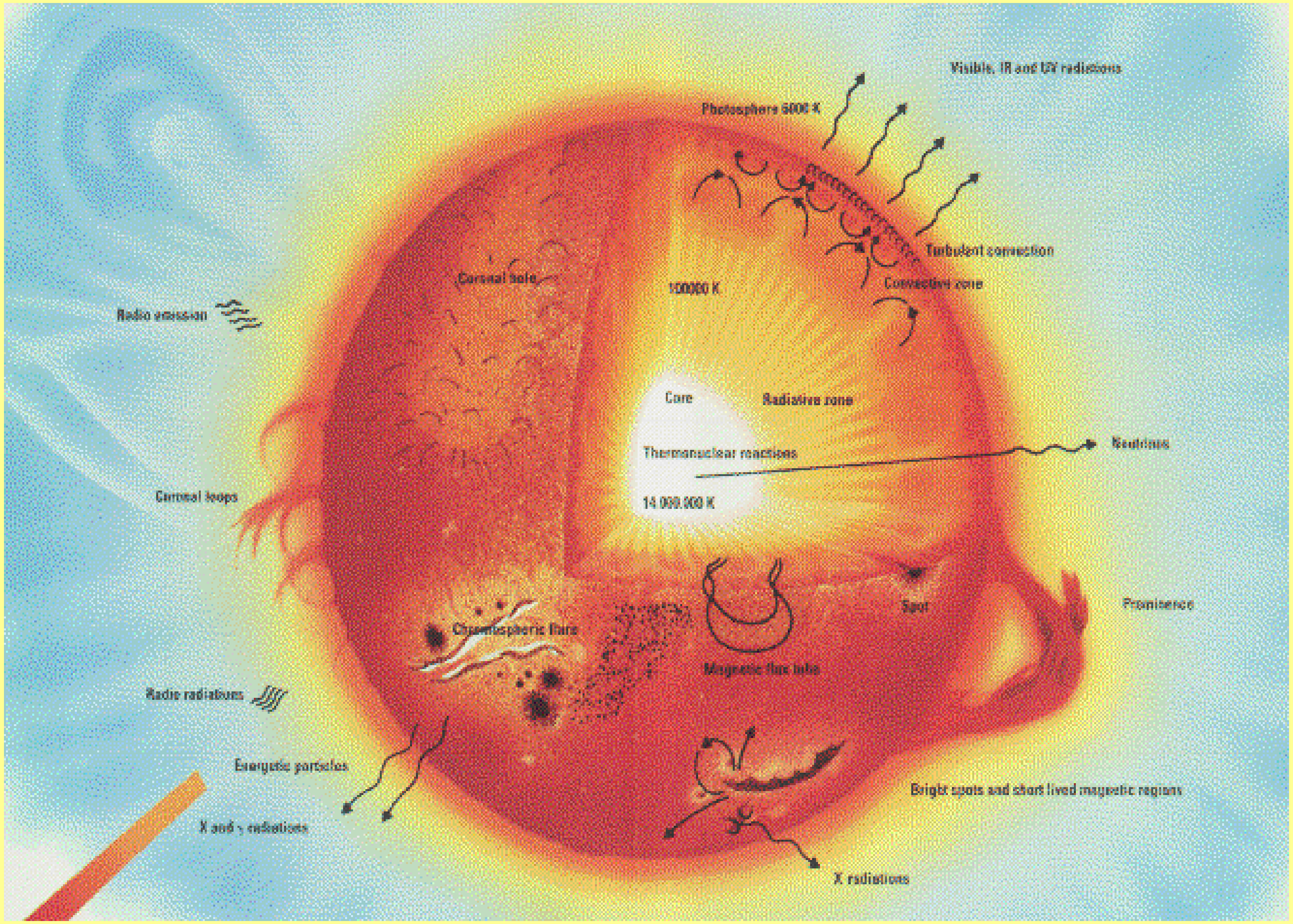
# OUR SUN




By Margaret Yelen*ik

# Purpose

- To understand the physical features of our sun and how they affect our lives on Earth
- To understand how the Sun is a nuclear reactor
- To show how atoms and ions in the sun's atmosphere absorb energy through resonance
- To show how we can understand the Sun's interior by studying it's resonance frequencies
- To gain a better understanding of the concept of solar temperature and how astronomers measure it
- To understand the correct procedure to observe the sun

# SUN

- Is the star closest to Earth & produces the energy that drives our ecosystem, making it the source of all life on Earth.
- The amount of the Sun's energy that falls per second on Earth's outer atmosphere (Solar constant = 1400 watts/$m^2$) is the same amount of **energy** in a week as could be provided from all of our known reserves of oil, coal, and natural gas.
- Is a ball of **plasma** (super heated gases) seething & moving at great temperatures.
- Produces a **solar wind**,a stream of million degree gases which flows out at hundreds of kilometers a second.

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- Contains 99% of **mass** of our Solar System

- Is made of 73%H, 25%He, 2% other <u>elements</u> (68)
- Sun's radius = 696,000km (432,000 miles).
- Whole sun does NOT turn together as Earth does.
- Period of rotation (length for 1 complete turn) =
  - 25 days at the Sun's equator
  - slower at middle latitudes
  - slowest at the poles (about 35 days)

- Strange rotation pattern contributes to the violent activity that takes place on the Sun.

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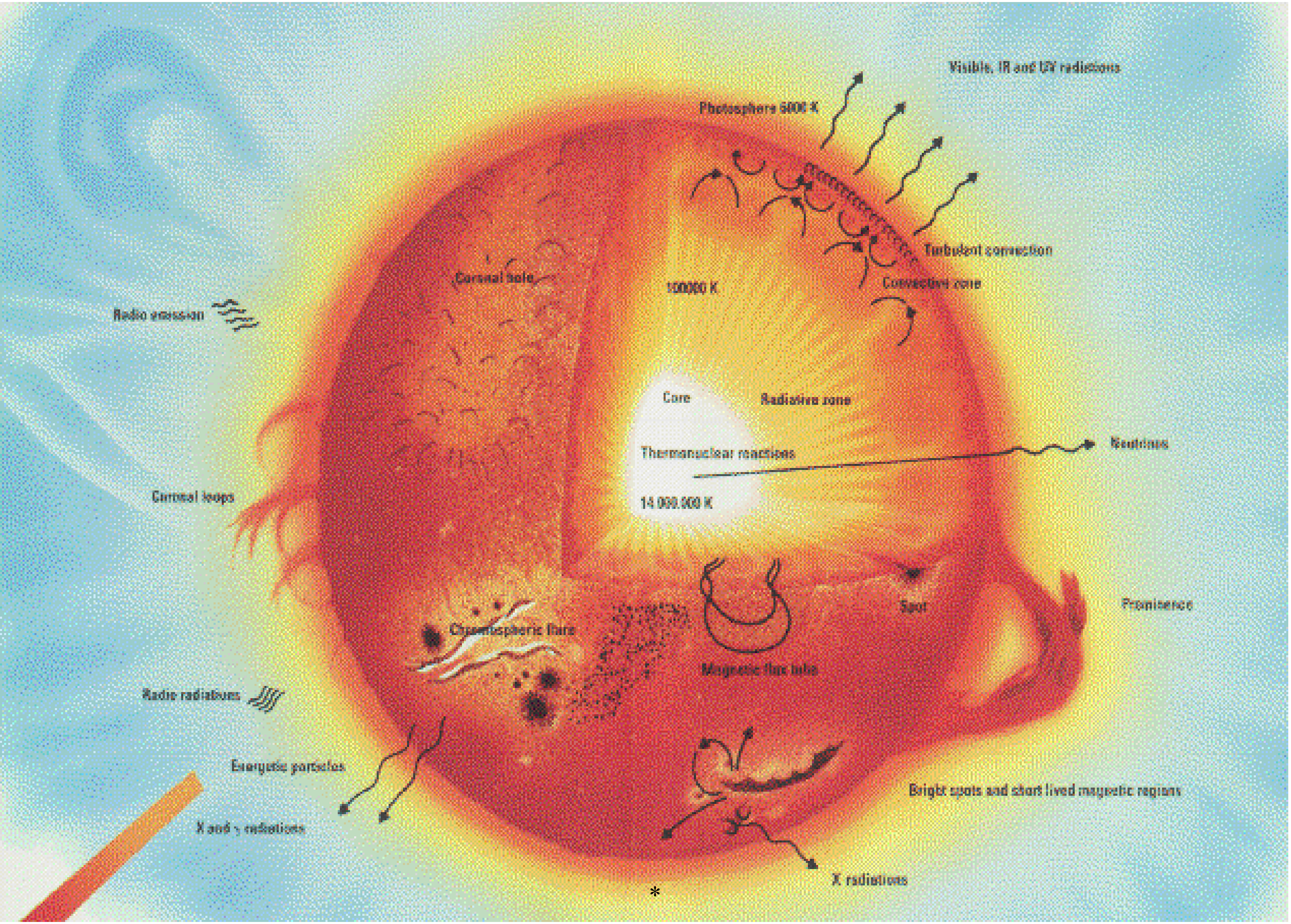
Visible, IR and UV radiations
Photosphere 6000 K
Turbulent convection
Convective zone
Coronal hole
100000 K
Radio emission
Core
Radiative zone
Thermonuclear reactions
Neutrinos
14 000 000 K
Coronal loops
Spot
Prominence
Chromospheric flare
Magnetic flux tube
Radio radiations
Energetic particles
Bright spots and short lived magnetic regions
X and γ radiations
X radiations

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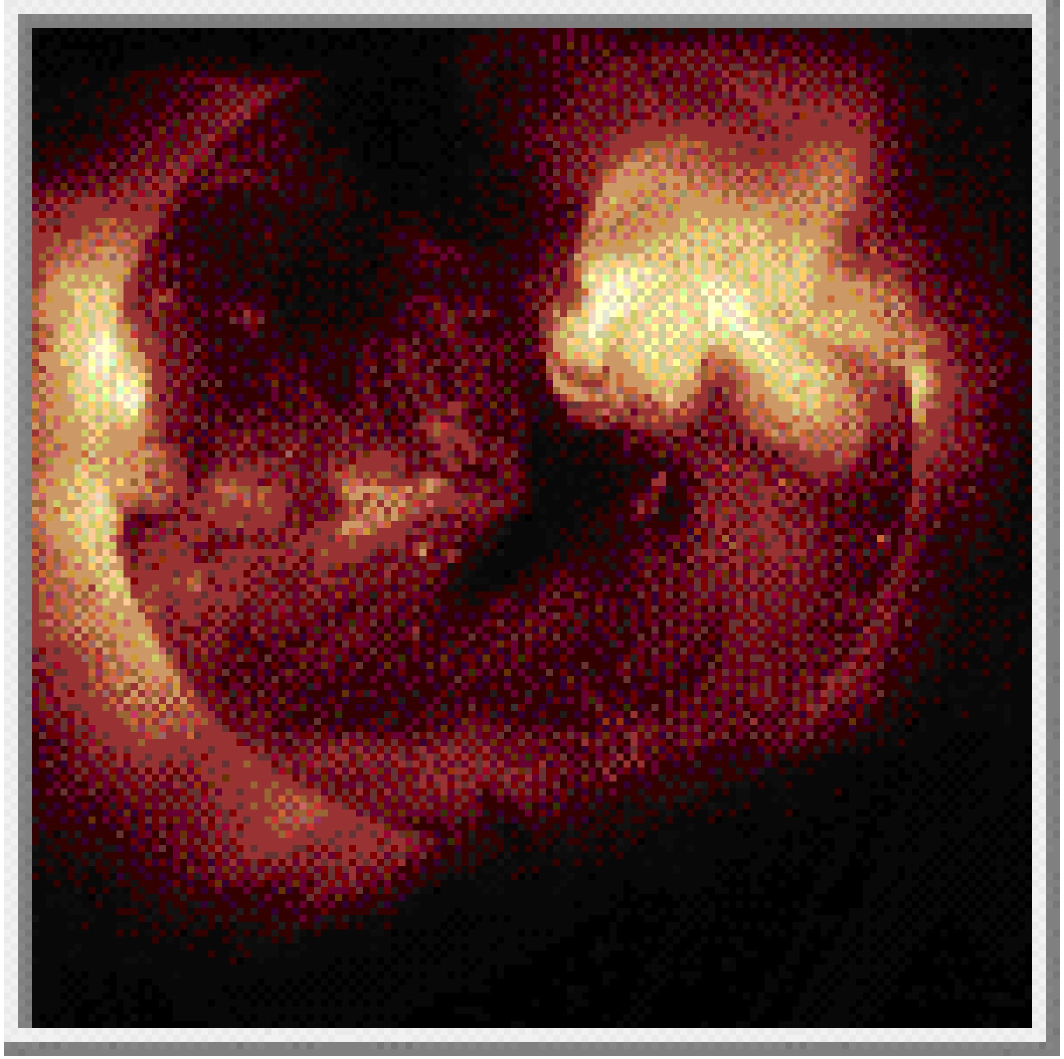
# What is it like inside the Sun?

- **Temperature and density increase inward from the surface..**
- **Core** is a 15 million °C. soup of electrons & protons stripped from the hydrogen atoms - makes up 90% of the Sun. The power plant where nuclear fusion reactions generate the Sun' energy. H is fused into He. The **Pressure** is 340 billion atmospheres. The **density** is over 100 times that of water.
- Closer to the surface, the energy moves out via convection - hot gases rise, cool, & sink back down again.
- It takes about a million years for energy produced in the cor to surface and become sunshine.
- As these masses of gas move, they push off of each other causing "**Sun-quakes**."
- The study of the movement of the Sun's surface is called **helioseismology** which helps us determine the Sun's internal structure.

- The sun's energy is produced by a process called **nuclear fusion**. In fusion, 2 hydrogen atoms come together to form helium. This reaction releases energy and other tiny particles.
- The inward pull of all the hydrogen inside the sun creates high temperatures and violent reaction.
- **Ions** are positively charged nuclei or protons produced in the sun's interior when Hydrogen atoms are broken apart - the electrons are torn from the proton. This gas of ionized particles (has electrical charges) is called **plasma**.
- The pressure and density inside the sun is so great due to the ions (hydrogen nuclei without the electrons) overlying material being so tightly squeezed together. This density is 13 times that of lead and the temperature is 15.6 million °C. This intense heat and pressure causes fusion of four protons into helium (2 protons, 2 neutrons 2 neutrinos, & 6 photons).

**4p $^{4}$He + $2_e$ + 6.**

- http://library.thinkquest.org/C001124/gather/ssun.html?tqskip1=1&tqtime=0803



Nuclear Fusion in the Core

http://library.thinkquest.org/C001124/gather/ssun.html?tqskip1=1&tqtime=0803

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# Why is the Corona so hot?

- Sun's **atmosphere** are outer 3 layers.

1. **Photosphere** ("light ball") visible surface, is a hot, thin, opaque gas layer 10,000°F (5800°K) from which energy is radiated into space as visible wavelengths of light.
2. **Chromosphere** ("color ball') thin, transparent layer 10,000km above photosphere -visible during a total eclipse, red due to H gas. Temp increases outward to 15,000°K.
3. **Corona** ("crown") outermost atmosphere. Rarified, hot gas extending millions of kilometers into space. Temperature = up to 2 million K - shines bright as X-ray wavelengths. During a total eclipse is visible as a jagged white halo around the photosphere.

# What accelerates Solar Wind?

- The **Corona** is constantly expanding into space to form the solar wind.
- The solar wind particles flow out past the farthest planets to form the realm we call the **heliosphere**.
- [Is a plasma, stream of energetic, electrically charged particles -average speed of 450 km/sec (1 million mi/hr)]
- At times the wind blows out steadily, at times the Sun ejects large magnetic field structures called **Coronal Mass Ejections** (CMEs) - brilliant auroras (northern lights).
- Earth's atmosphere & magnetic field protect us from harmful effects.
- SOHO (Solar & Heliospheric Observatory-1995) is a spacecraft that was launched in 1995 to increase our understanding of solar wind.

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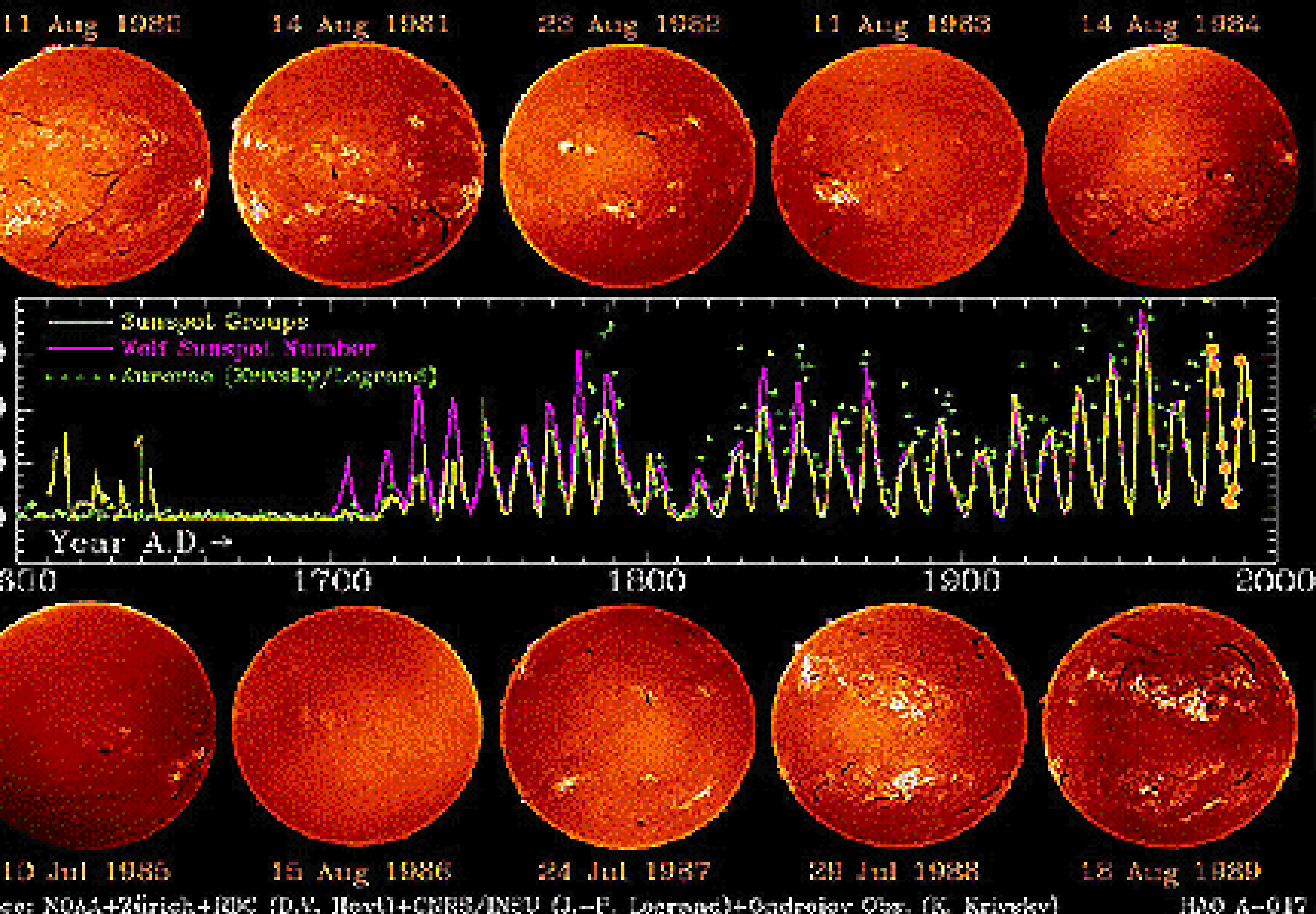
- http://sohowww.nascom.nasa.gov/explore/soho_poster.pdf

# How is the Sun's magnetic field created and Structured?

- The Sun's **magnetic field** is generated by plasma motions below the Sun's surface and extends out to shape and control the solar atmosphere and the entire **heliosphere.**
- Understanding the **Sun's magnetic field** (extends from its northern hemisphere to Pluto) is key to understanding the solar wind, heating of the corona, and solar activity such as CMEs, sunspots, & flares.
- Solar activity increases & decreases in approximately an eleven year cycle. Near the edge of the solar system, the magnetic field bends & returns to the Sun's southern hemisphere.
- Polarity of Sun's magnetic field is reversed every 11 years shortly after the period of sunspot maximum.
- **Solar activity cycle** is 22 years - counting the length of time required for the Sun to return to its original configuration.



14 Aug 1981
23 Aug 1982
11 Aug 1983
14 Aug 1984
Sunspot Groups
Wolf Sunspot Number
Aurorae (Krivsky/Legrand)
Year A.D. →
1700
1800
1900
10 Jul 1985
15 Aug 1986
24 Jul 1987
28 Jul 1988
18 Aug 1989
NOAA+Zürich+RGO (D.V. Hoyt)+CNRS/INSU (J.-P. Legrand)+Ondrejov Obs. (K. Krivsky)
HAO A-017


# Magnetic Fl

# Resonance Rings:

http://sohowww.nascom.nasa.gov/explore/soho_poster.pdf

- All objects have natural frequencies at which they vibrate. The effect of this vibration is called **resonance**.
- When energy from electromagnetic radiation passes through the Sun's corona,it is absorbed at certain wavelengths which match the natural frequencies of atoms and ions in the corona. The frequencies of the absorbed light causes dark lines (absorption lines) in the Sun's spectrum.
- When ions absorb energy through colliding with other ions, they give off excess energy at particular resonance frequencies, resulting in bright lines called emission lines.
- Both absorption & emission lines can be used to study the ions in the Sun's atmosphere, because **each ion has its own unique set of resonance energies**.
- Resonance can also magnify sound waves that travel through the Sun, making it important in the study of the Sun's interior - helioseismology.
- The resonant frequencies are determined by the material, temperature, & density of the plasma through which the waves pass.

## Temperature

•You can measure something's temperature by measuring how much energy (heat and light) it emits, and by checking the color(s) of the light that it emits. To find the temperature of the object from its light, it is important that you look at only the light that the object itself emits, and not at light from some other source that it reflects.

•The colors you see around you during the day are caused by reflected sunlight, so they do not say anything about the temperature of things on Earth, but rather about the temperature of the visible surface (the photosphere)of the Sun.

•Scientists long ago figured out what temperature goes with what color and what brightness, so if they know the brightness or color, then they can easily determine the temperature. If you don't know how far away the thing is that you're looking at, then you can only use the color to figure out what temperature it has. This is the case for many stars.

•In this way, the surface temperature of the Sun has been found to be about 5770 kelvin, or 9900 degrees *F, or 5500 degrees C.

# SPECTRAL CLASSES

- Are the absorption spectra are used to classify stars into seven principal types.
- Hydrogen lines are much stronger in the spectra of some stars than in the sun's spectrum but all visible stars are roughly uniform in composition, made mostly of H & He.
- Stars are classified by the strength of their hydrogen lines in their spectra.
- US astronomer Annie J. Cannon (1863-1941 examined and classified the spectra of 225,300 stars.
- She modified the classification system into a system based on their surface temperatures .

**O B A F G K M** - O = hottest & M = coolest

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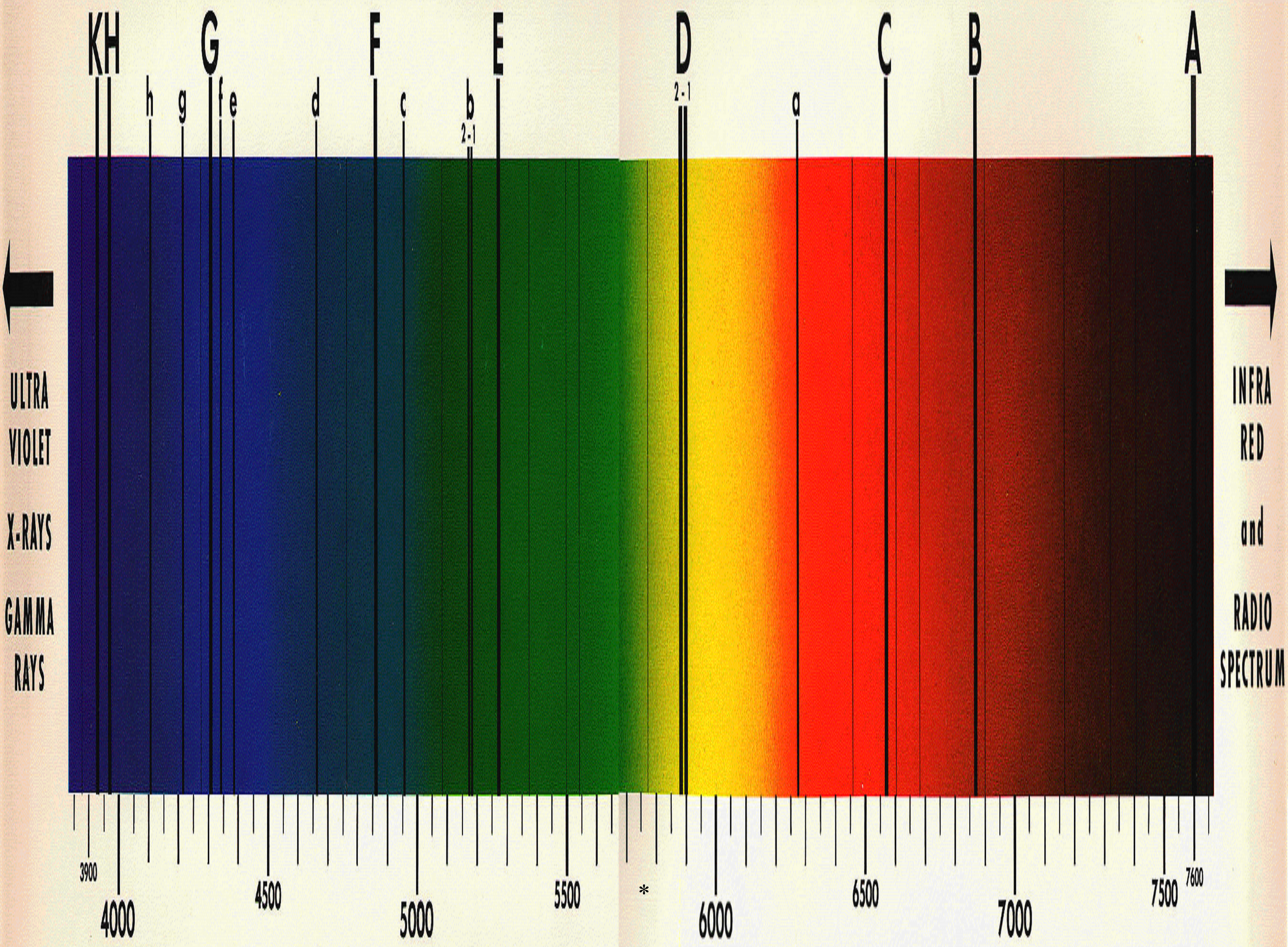
"Oh Be A Fine Girl/Guy Kiss Me"



K H G F E D C B A
h g f e d c b 2-1 2-1 a
ULTRA VIOLET
X-RAYS
GAMMA RAYS
INFRA RED
and
RADIO SPECTRUM
3900
4000
4500
5000
5500
*
6000
6500
7000
7500
7600

# Color vs. Temperature

- Blue = 50,000ºK - - - - - - Rigel 12,000
- Blue-White = 10,000ºK - - Vega & Sirius
- White = 8,200ºK - - - - - - - Altair
- Yellow = 6,000ºK - - - - - Our Sun = 5,800
- Orange = 4,500ºK - - - - - - -Arcturus
- Orange-Red = 4,000ºK - - Aldebaran
- Red = 3,000ºK - - - - - - - Betelgeuse = 3,400

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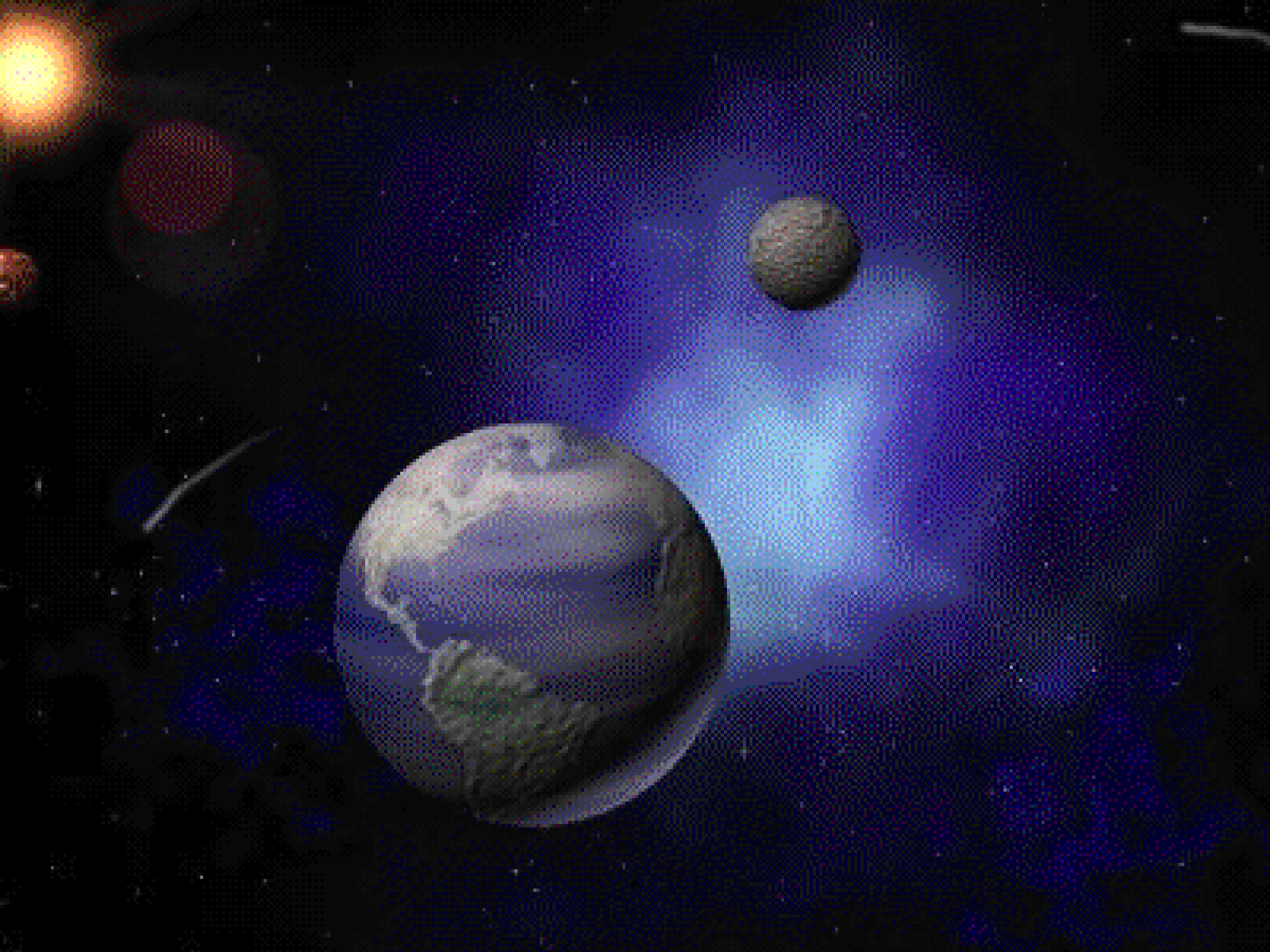

# OBSERVATIONS

- **Optical solar telescopes** photograph Sun's visible surface.
- **Radio telescopes** receive & record radio waves from different parts of the radio sun.
- **Infrared telescopes** observe the solar limb & map sunspots.
- **Spectroheliographs** image the Sun I in light of a single wavelength.
- **Spectroheliograms** are images of the Sun in a single distribution of different gases & local phenomena.
- **Ultraviolet, X-ray, & gamma ray telescopes** record images of processes in the hottest and most active regions (spacecraft & Skylab).
- **Coronagraphs** photograph the corona & is designed to create an artificial eclipse (don't have to wait for a total eclipse) - (Skylab).
- The U.S. robot Solar Maximum Mission (SMM - 1980), first satellite repaired in space by astronauts, completed historic optical, ultraviolet, X-ray, & gamma ray

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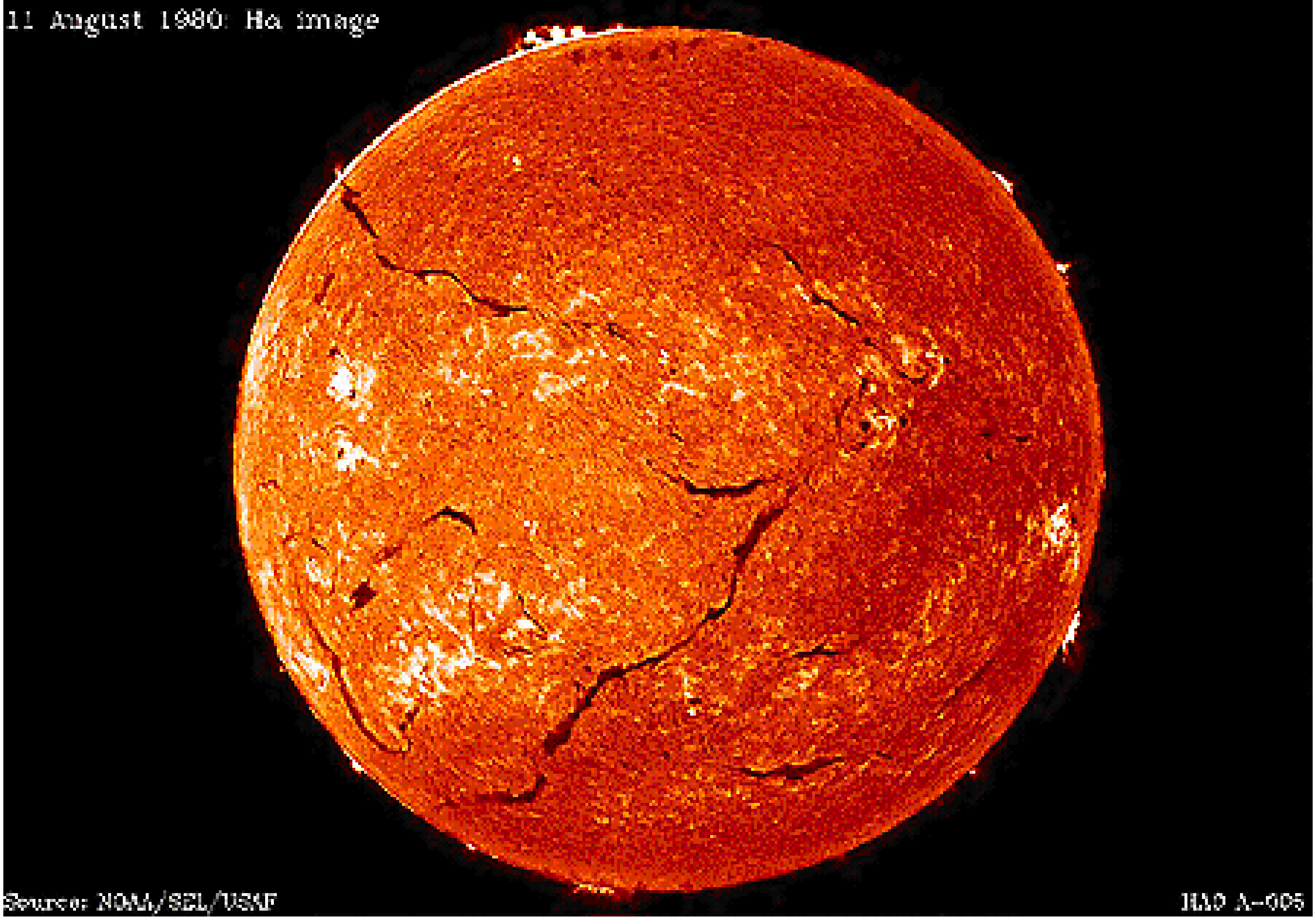


This image is taken through a filter centered on a spectral line of Hydrogen (H, wavelength Å) that forms above the surface of the Sun, although large sunspots are still visible.
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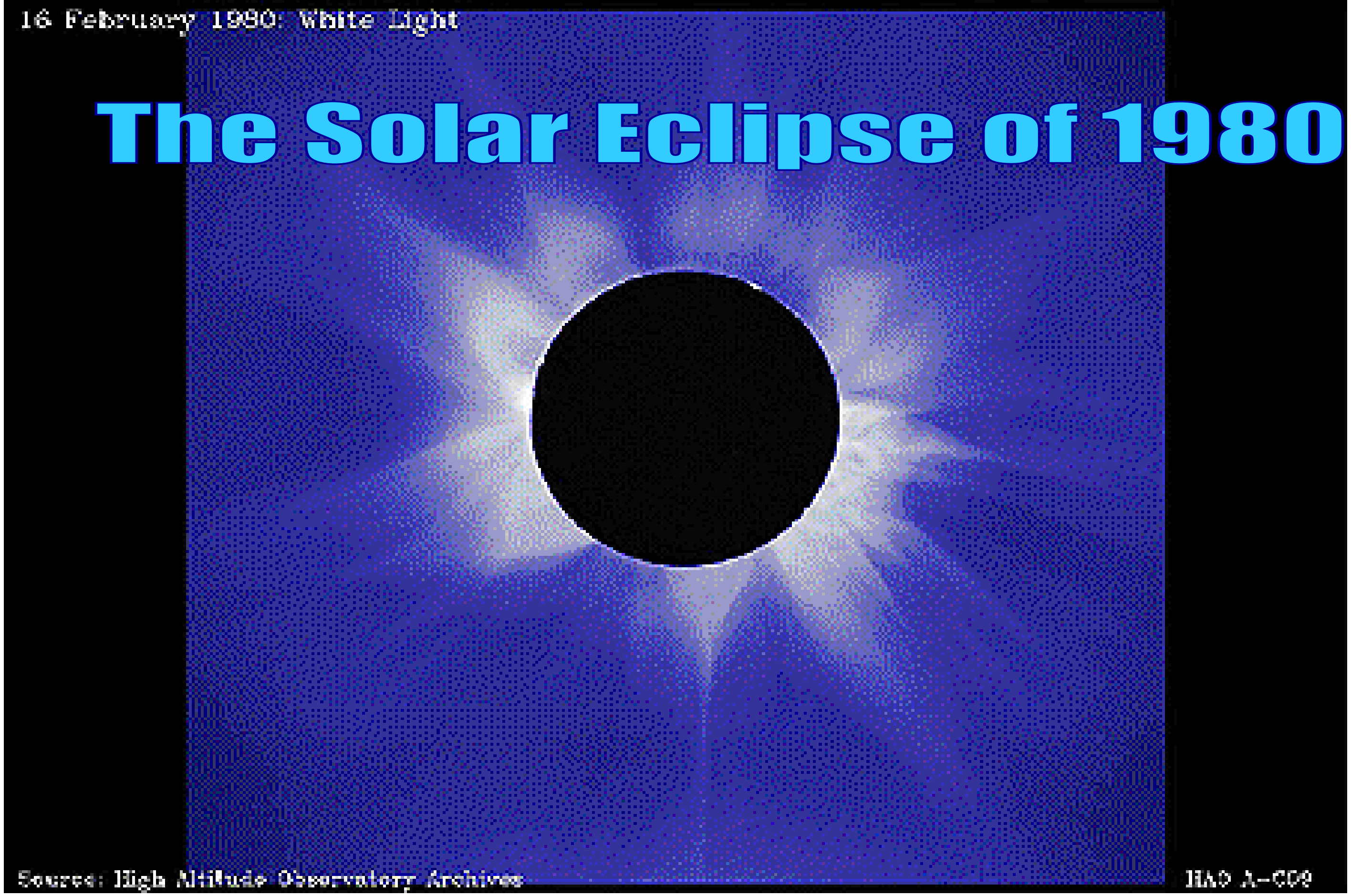
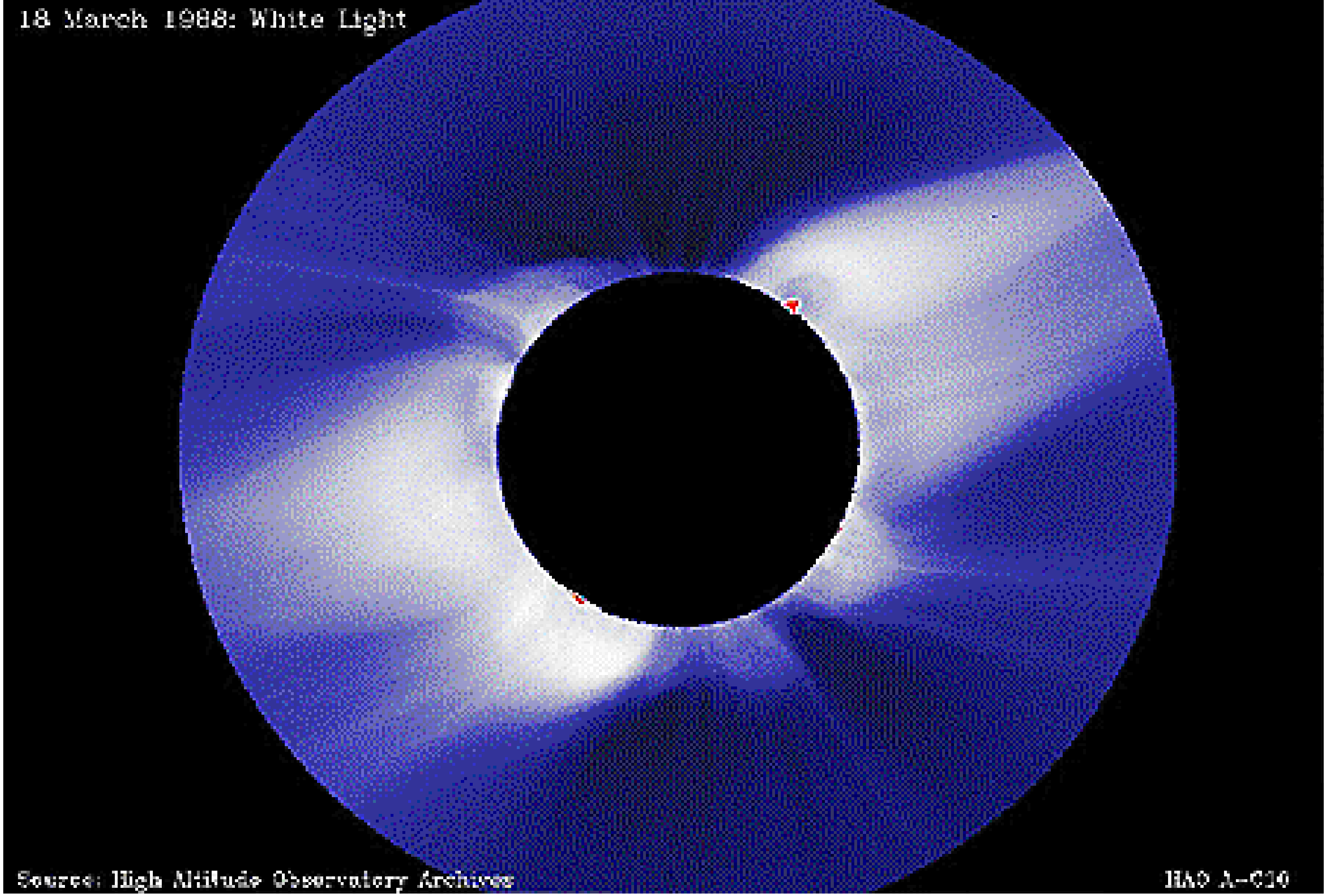
http://www.hao.ucar.edu/public/slides/slide6.html

# The Solar Eclipse of 1980

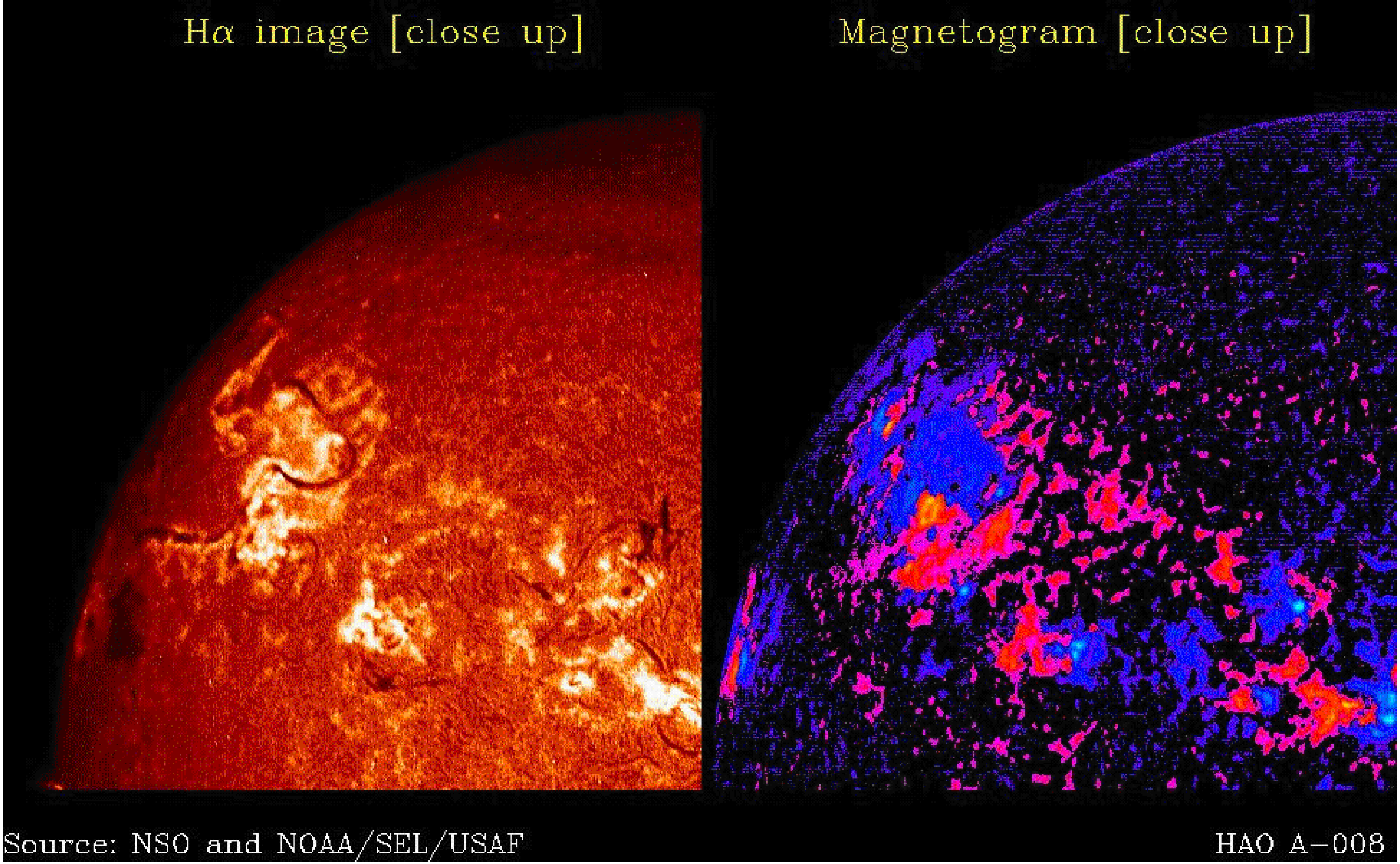



“The corona extends outward many solar radii above the solar surface, and owes its appearance to sunlight scattered by hot (1---2 million degrees Kelvin), tenuous ionized gas streaming away from the Sun. The resulting outflow is known as the **solar wind**. The solar wind flows all the way past the Earth and the outer planets, and terminates in the interstellar medium well outside the confines of the solar system. The process through which K gas streaming upward from the solar photosphere can be heated to temperatures in excess of degrees Kelvin in the corona is believed to involve the solar magnetic field, although its mode of operation is not yet fully understood.” http://www.hao.ucar.edu/public/slides/slide6.html



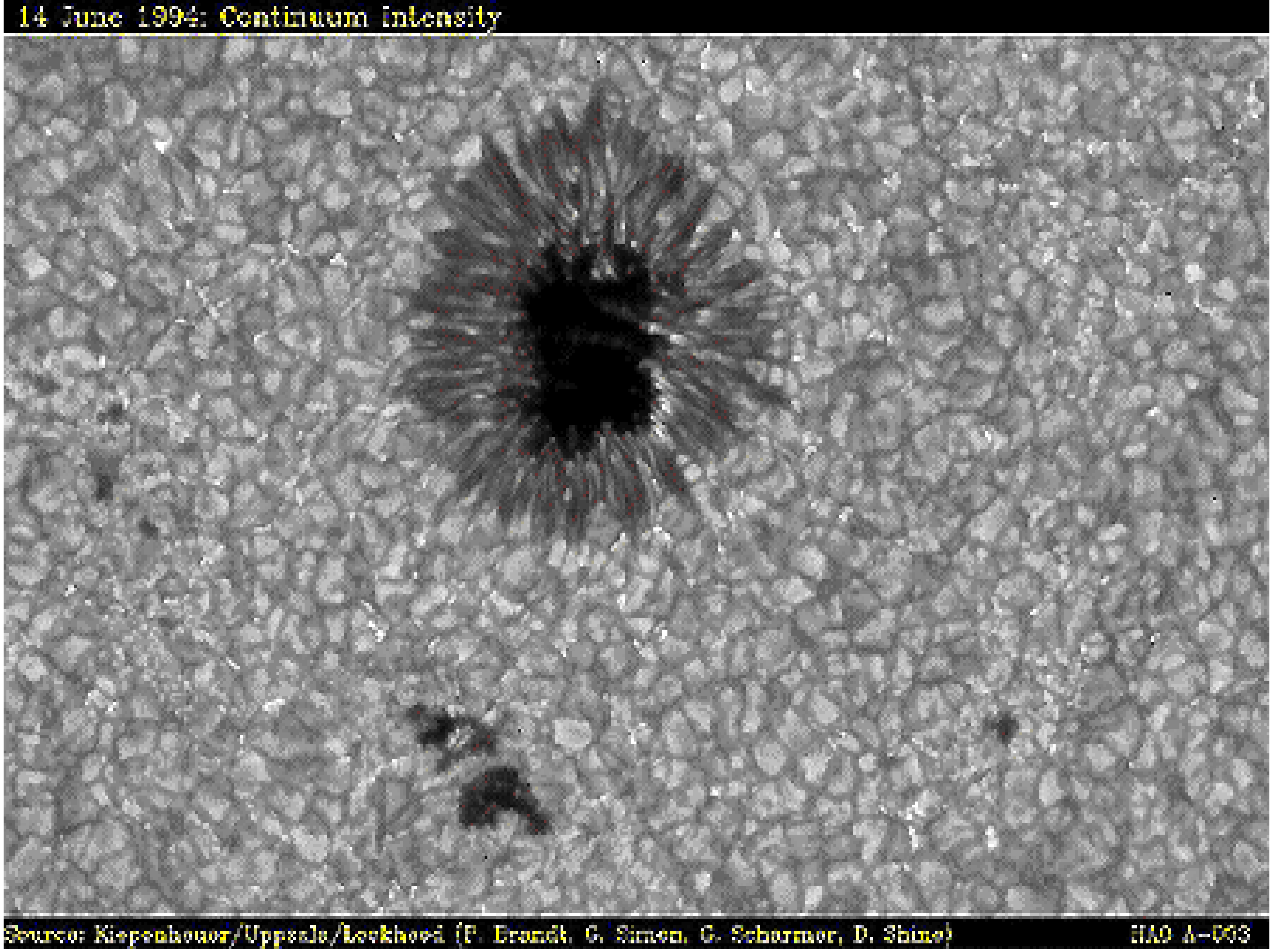

**Total solar eclipse of 1988**

"Unlike the preceding eclipse photograph, streamers big and small no longer extend radially above the solar limb, but instead are bent toward the equatorial plane (running left to right here). The corona never looks the same from one eclipse to the next."
http://www.hao.ucar.edu/public/slides/slide10.html



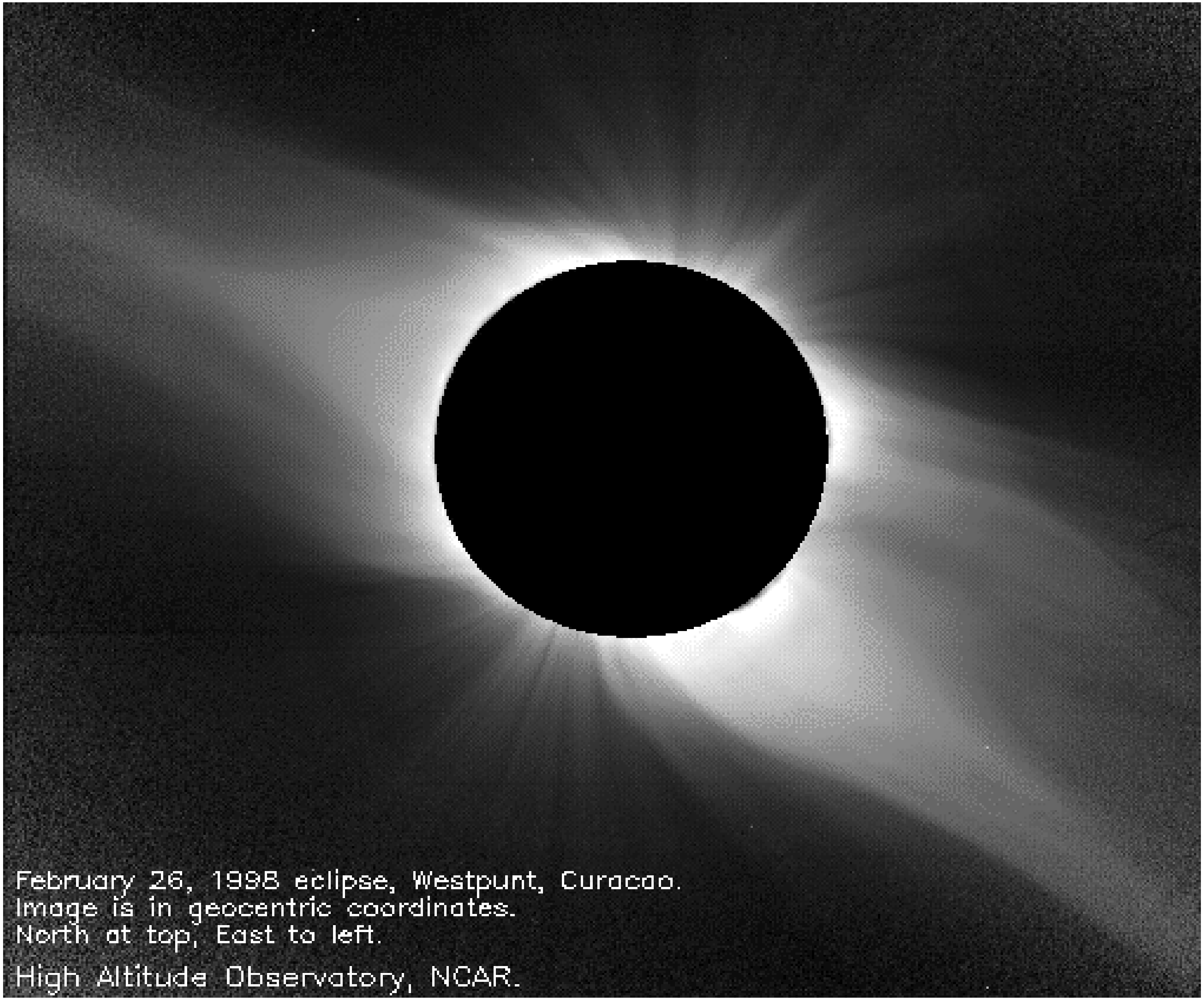

**<u>H alpha filaments and magnetogram</u>**

http://www.hao.ucar.edu/public/slides/slide8.html




**Sunspot and granulation**

"This pattern is called **granulation**, and is associated with large scale fluid motions at and just below the photosphere; the brighter, central regions correspond to rising hotter fluid, and the darker, narrow lanes to sinking, colder fluid. Typical speeds in granular flows are of the order of a few kilometers per second." http://www.hao.ucar.edu/public/slides/slide3.html

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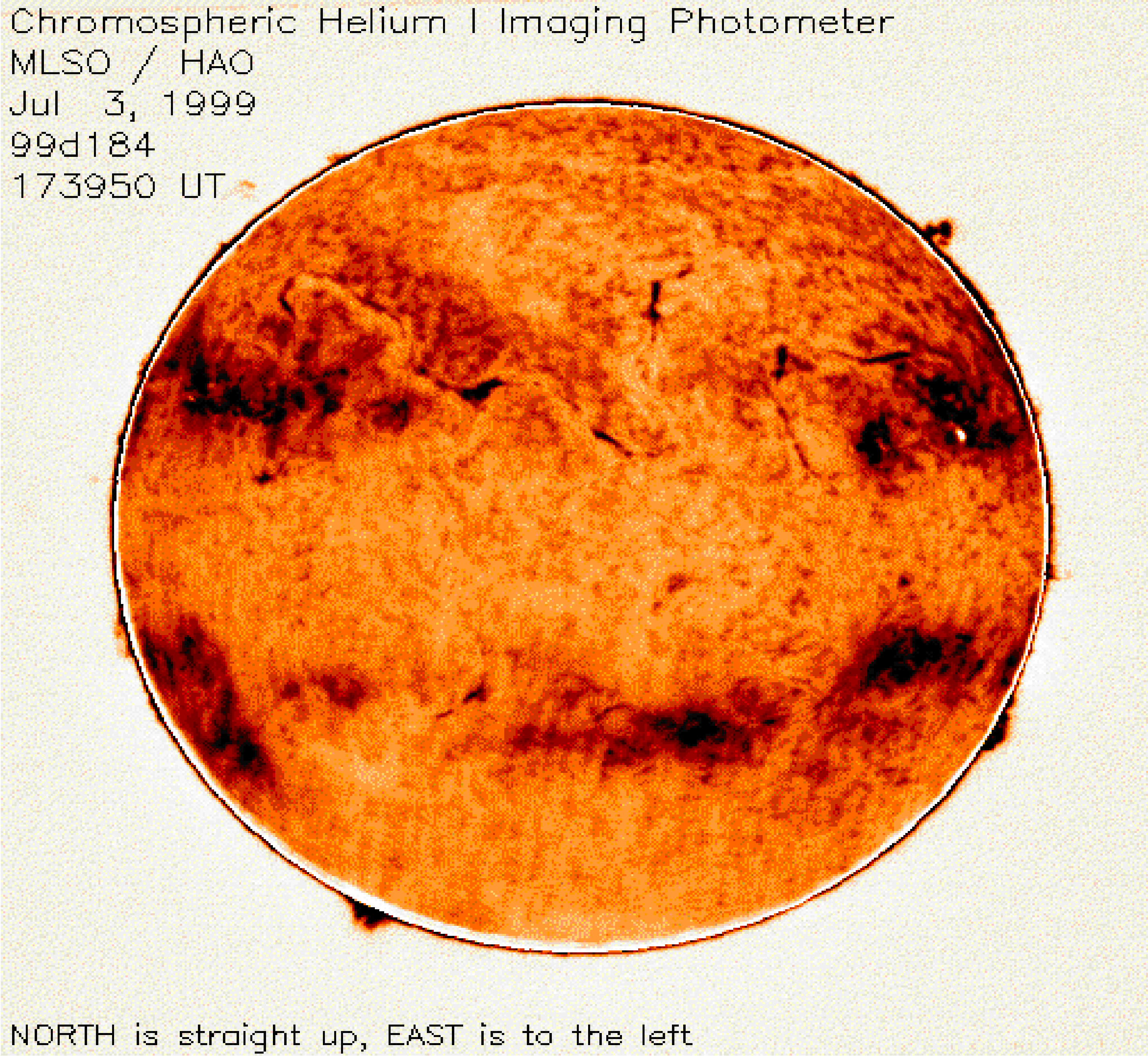


http://umbra.nascom.nasa.gov/sdac.html

# CONCLUSIONS

- The Sun's mass is 99% of our Solar System and its physical features control the Solar System.
- **<u>Helioseismology</u>** (study of resonance waves) is a way to study the Sun's interior. Resonant frequencies are determined by the material, temperature & density of the plasma through which they pass.
- All elements have their own natural frequencies which absorb energy. This is how scientists determine the sun's components.
- Scientists measure temperature in various ways.
- The temperature of stars is determined by matching the star with its spectral classification
- The safe way to view the sun is by looking at it's projected image.

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