SUN AND UNIVERSE

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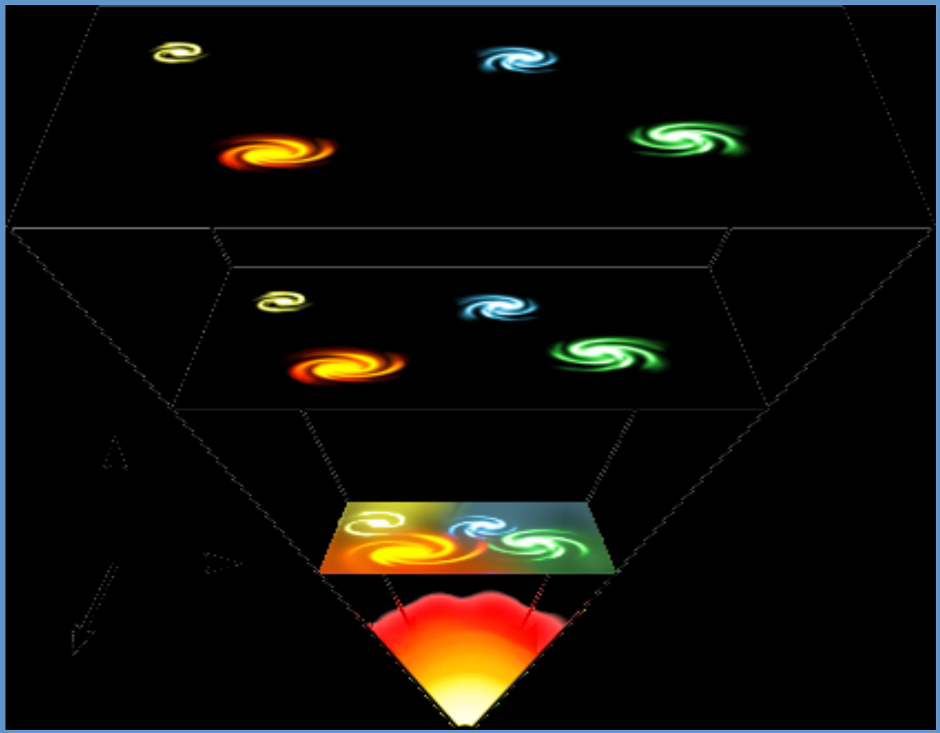
IN THE BEGINING…

BIG BANG THEORY (BBT)

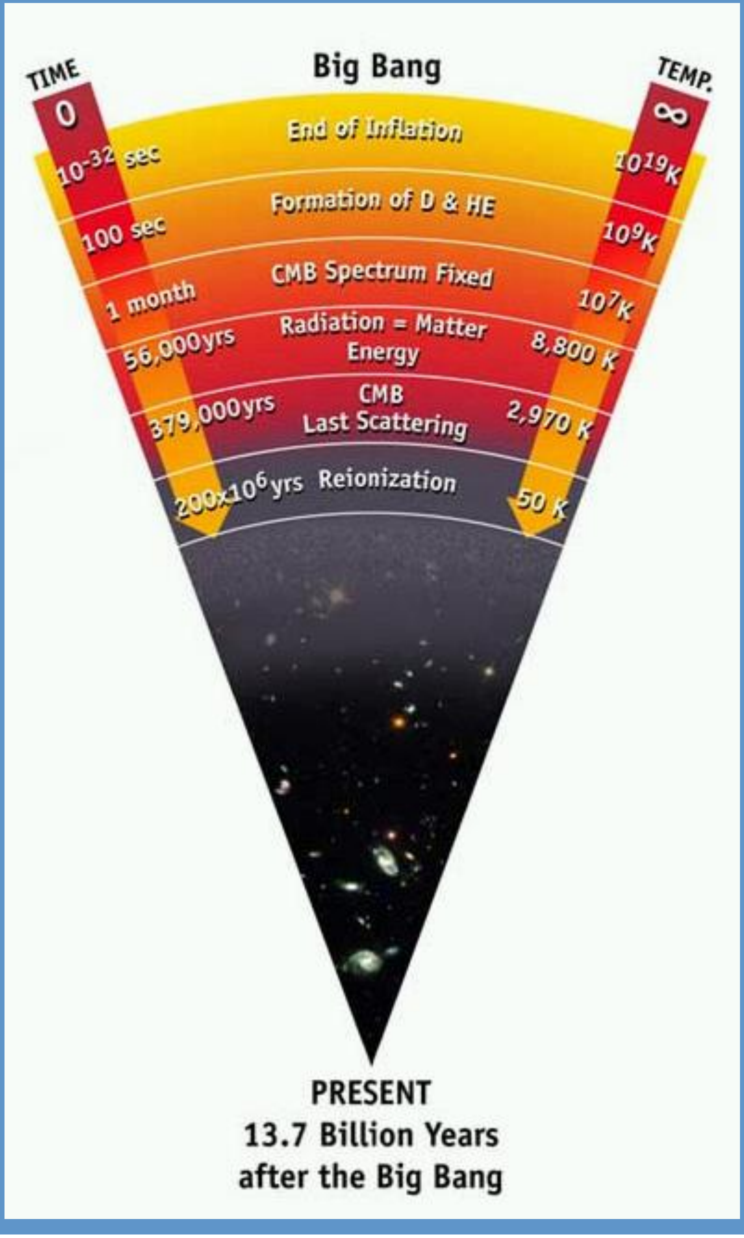


Hubble, 1929: , Doppler shift of light from far away galaxies: Universe is expanding.

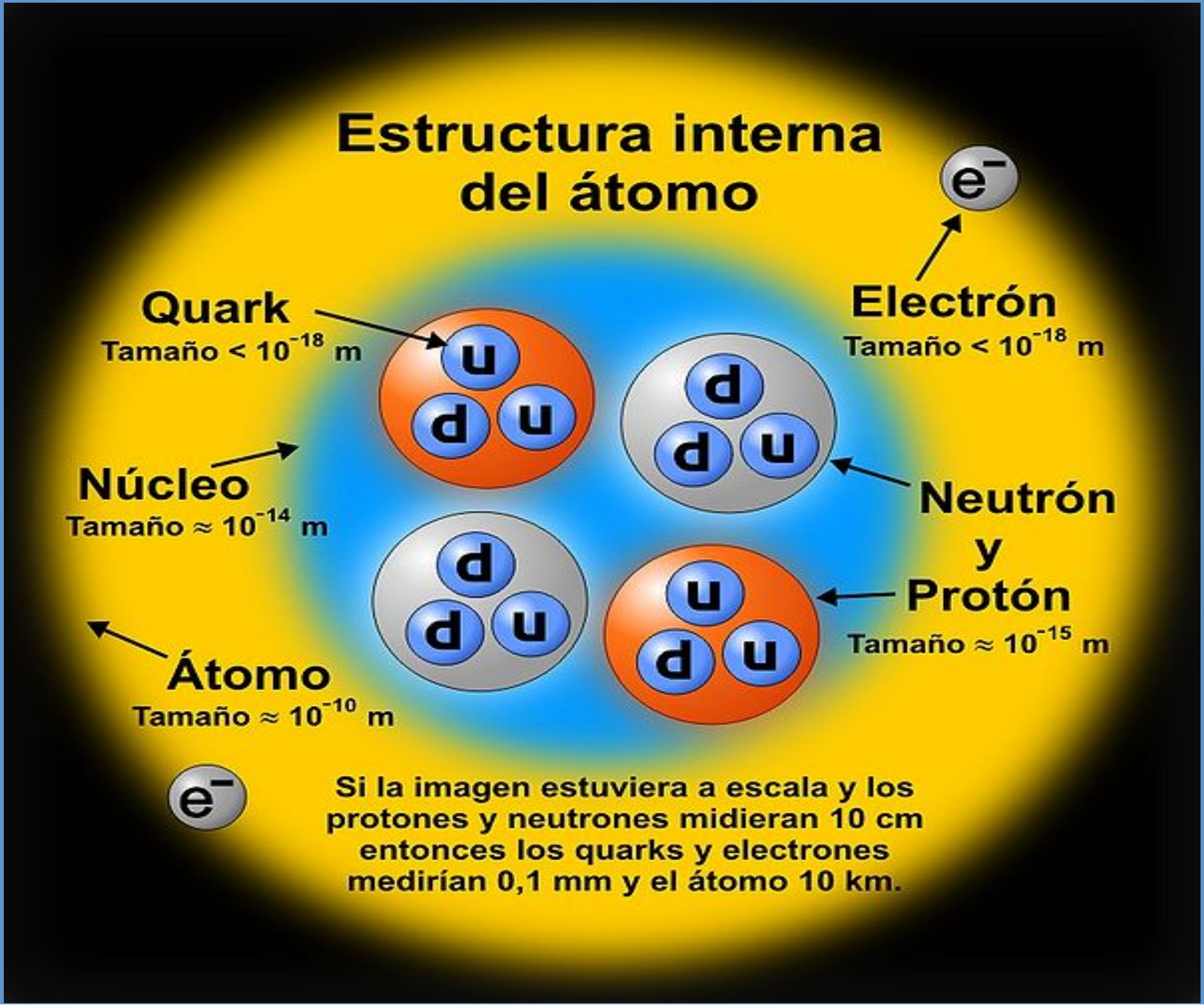
1965 Penzias and Wilson: CMB Predicted 1948, Alpher & Hermann

BBT UNIVERSE AGE AND EVOLUTION

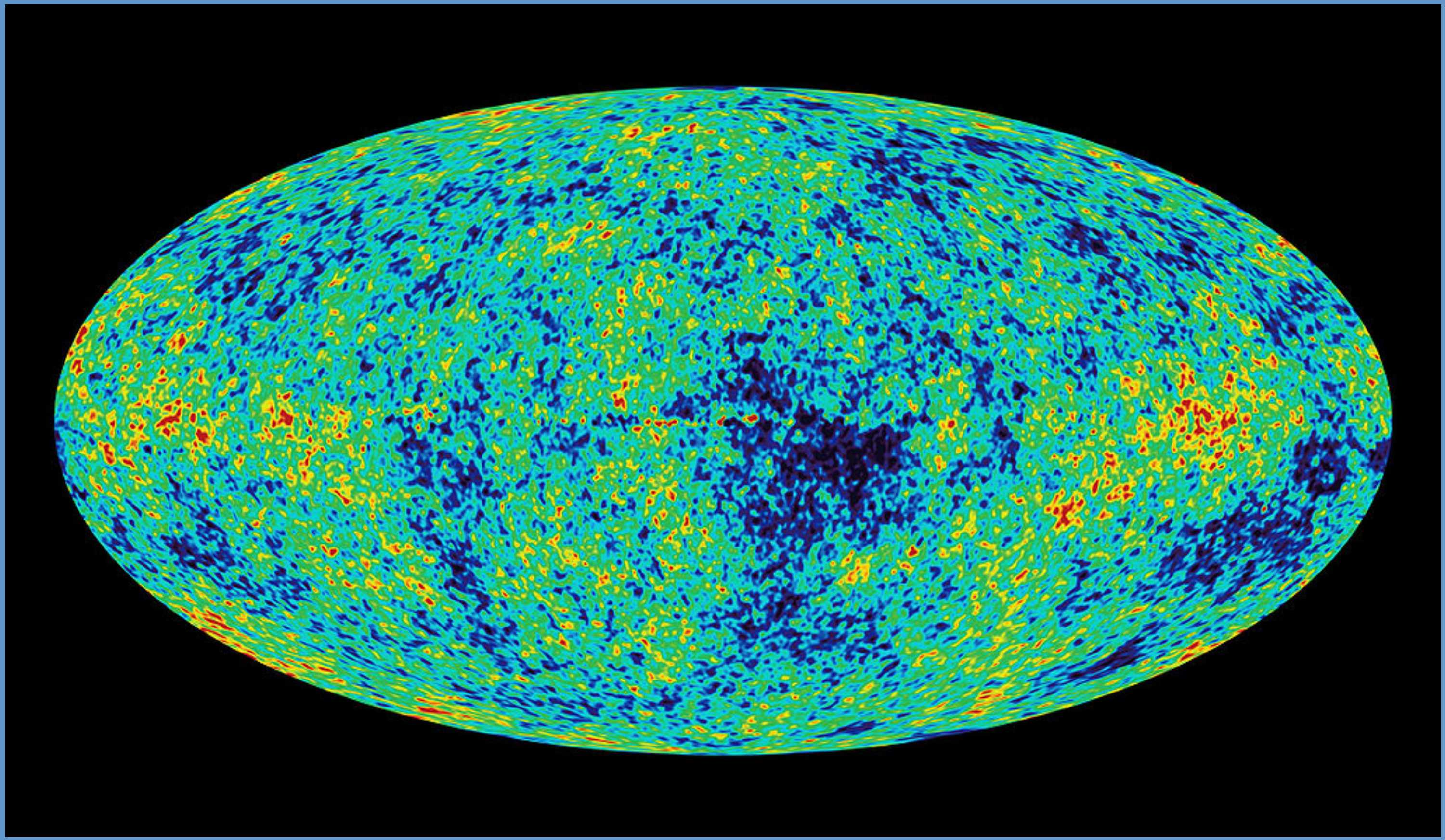
- Big Bang: 1.37 x 10^{10} y ago: Universe infinitely hot, compact and dense.
- $10^{-3\ 0}$ s : inflation(10^{25}), ultra-hot and dense plasma of matter, antimatter, SS, (?)...
- 10^{-6} s: quarks and gluons combine: p´s and n´s
- 100 s: p´s and n´s combine: D, He, Li nuclei
- 3.8x10^5y: p´s and e´s combine: H atoms, CMB



ELEMENTARY PARTICLES IN AN ATOM



CMB anisotropy (WMAP, 2006)

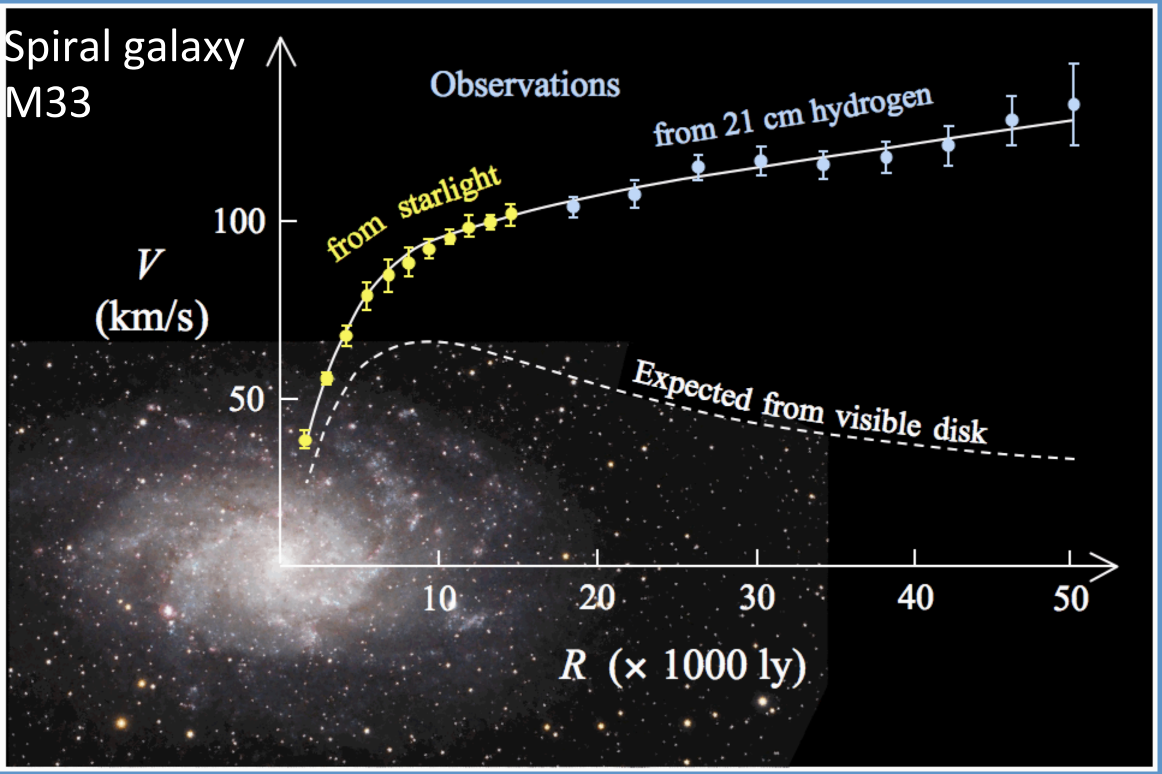


- **10^8-10^9 y: Stars and galaxies form**
- **$9x10^9$ y: Solar System forms**

Dark Matter

Galaxies rotate faster than predicted if they were composed only of ordinary matter (Rubin, 1950).

It surrounds most galaxies in roughly spherical clouds.



Dark Energy

1998-99, *Supernova Cosmology Project & High-Z Supernova Search*:

The Universe expansion is accelerating, a "counter gravity effect".

Two proposed explanations:

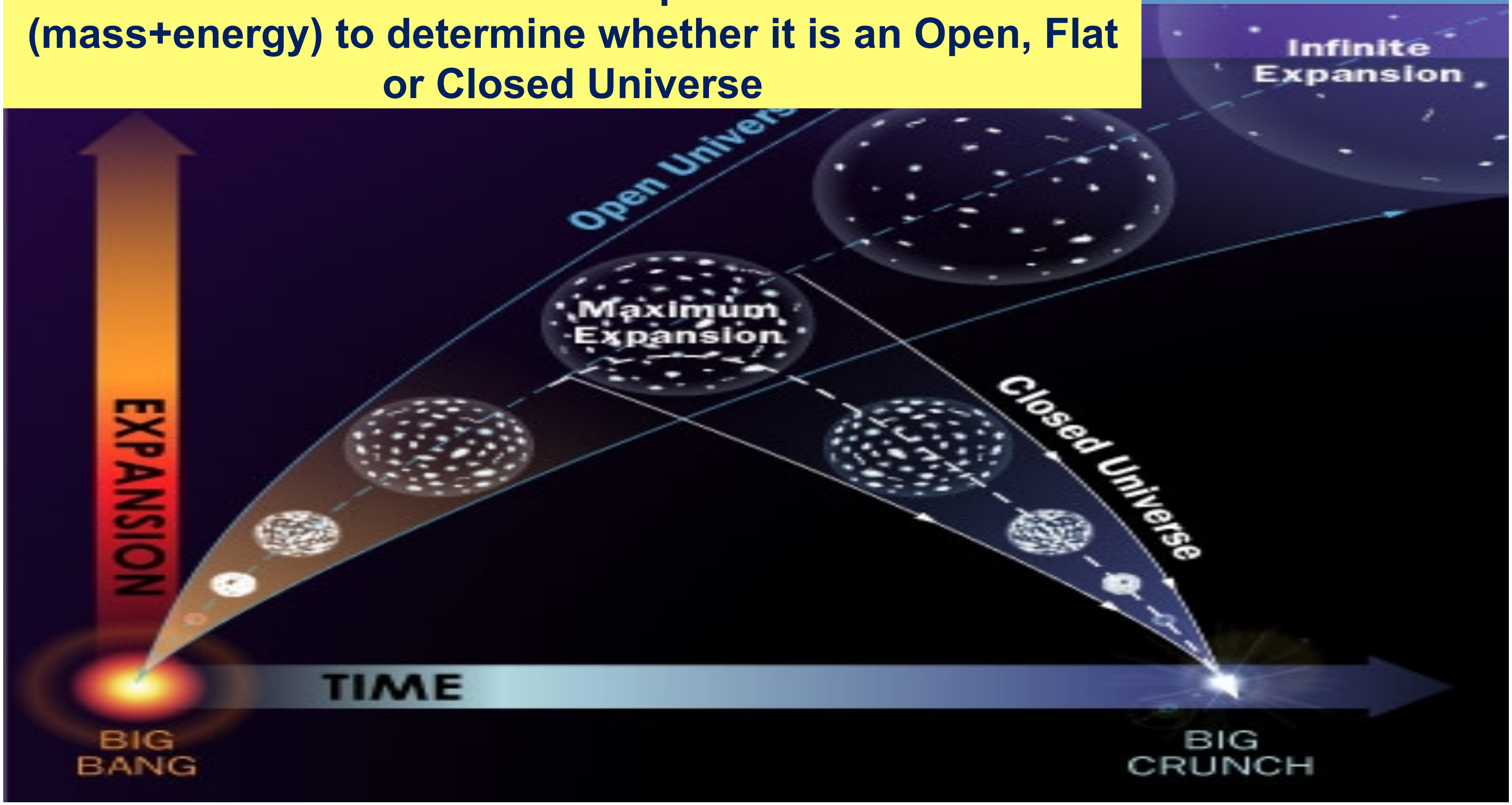
Cosmological constant

Quintessence

COSMOLOGICAL CONSTANT

In the early Universe gravity dominated Dark Energy. 10^4 y after the BB, the Universe expanded, gravity is less strong, Dark Energy becomes more important..

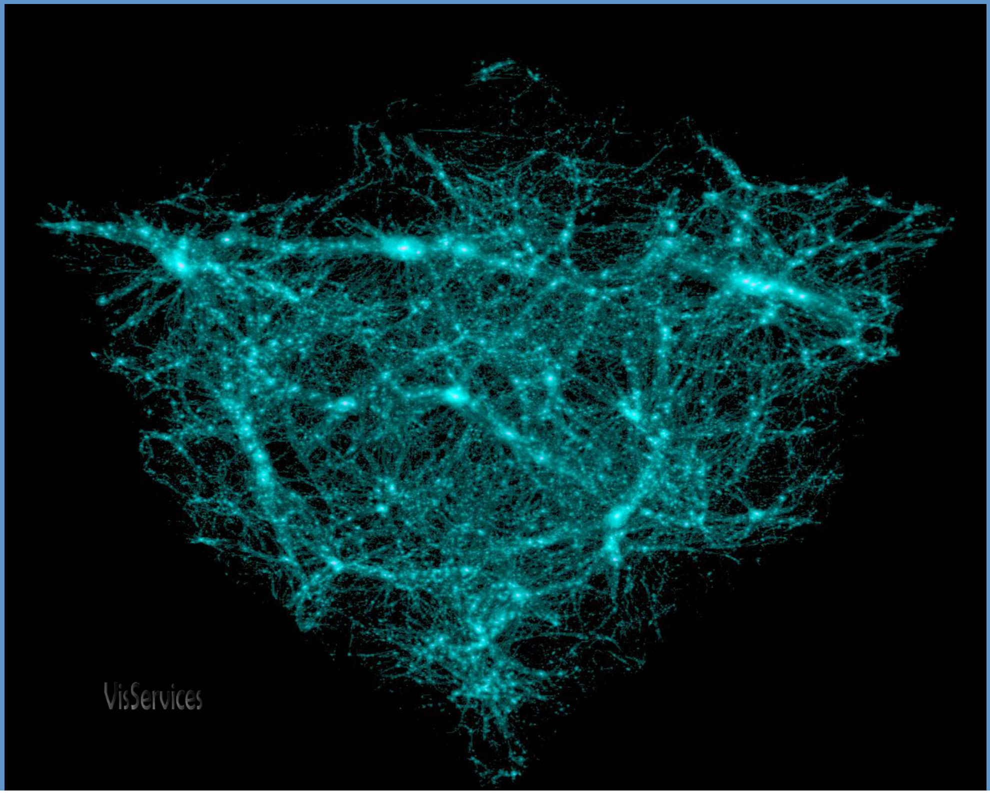
The end of the Universe will depend on its total mass (mass+energy) to determine whether it is an Open, Flat or Closed Universe



QUINTESSENCE

Dynamical Scalar field: Equation of state with Potential and Kinetc terms.

Density closely tracks radiation density until matter-radiation equality which triggers quintessence as dark energy.



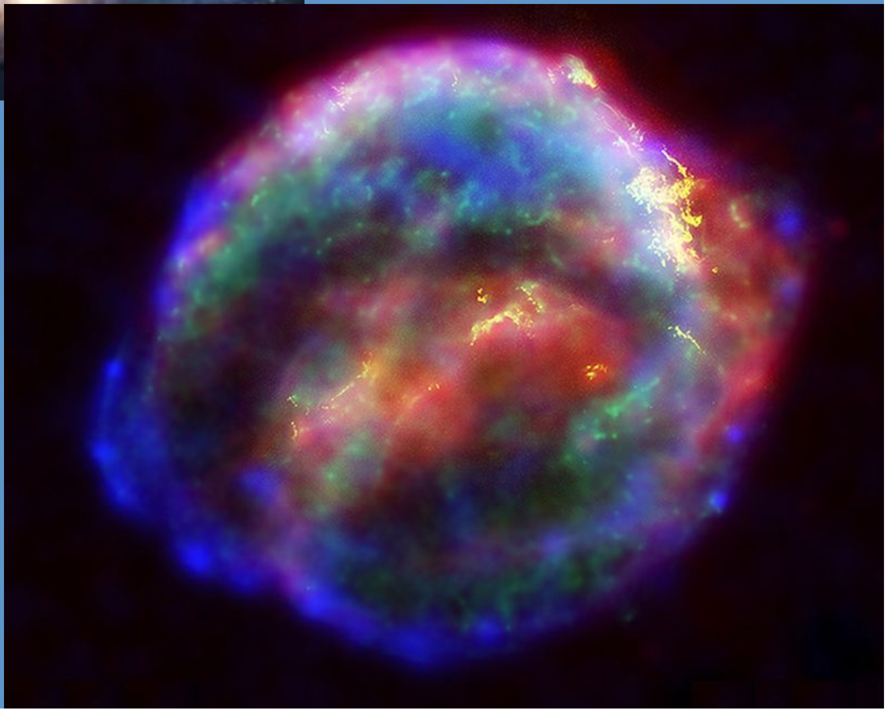
UNIVERSE COMPOSITION

- **70% *DARK ENERGY***

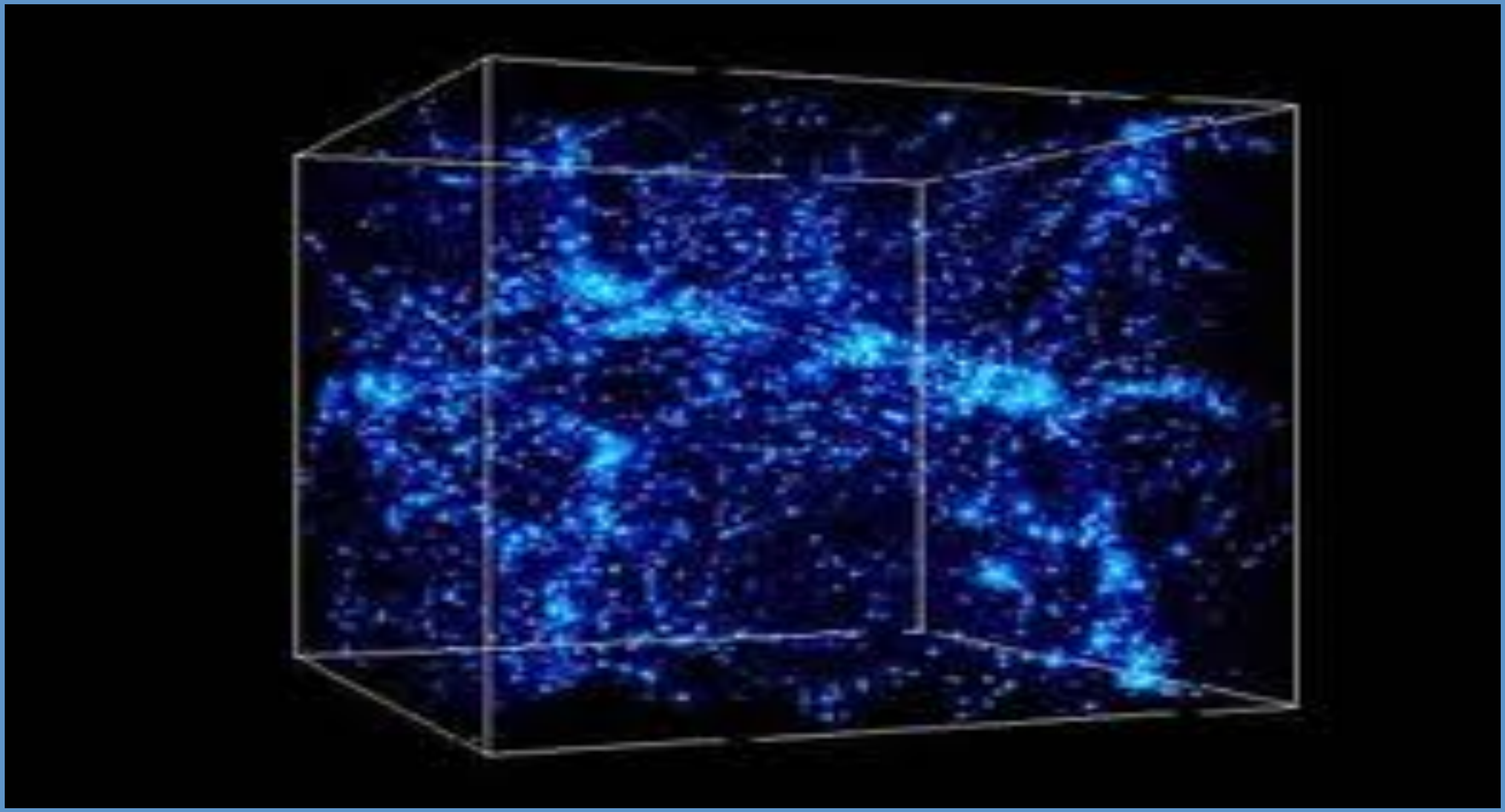
- **30% *MATTER***
  - **-5% common matter (quarks and leptons)**
  - **-25% dark matter (unknown composition).**

With this composition we would have a flat Universe

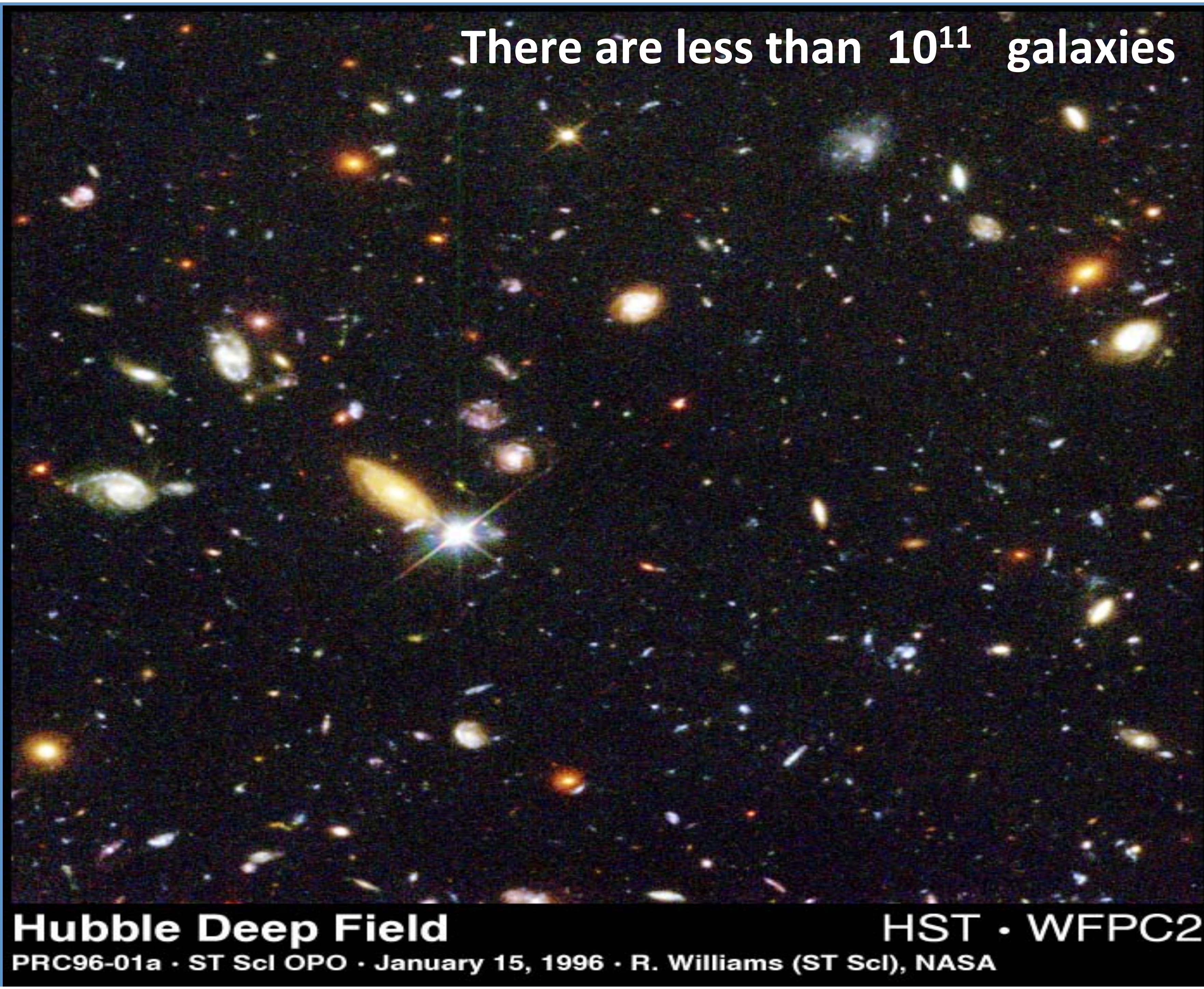

Heavy elements were synthetized in massive star nuclei or Supernovae explosions



UNIVERSE ON A GRAND SCALE

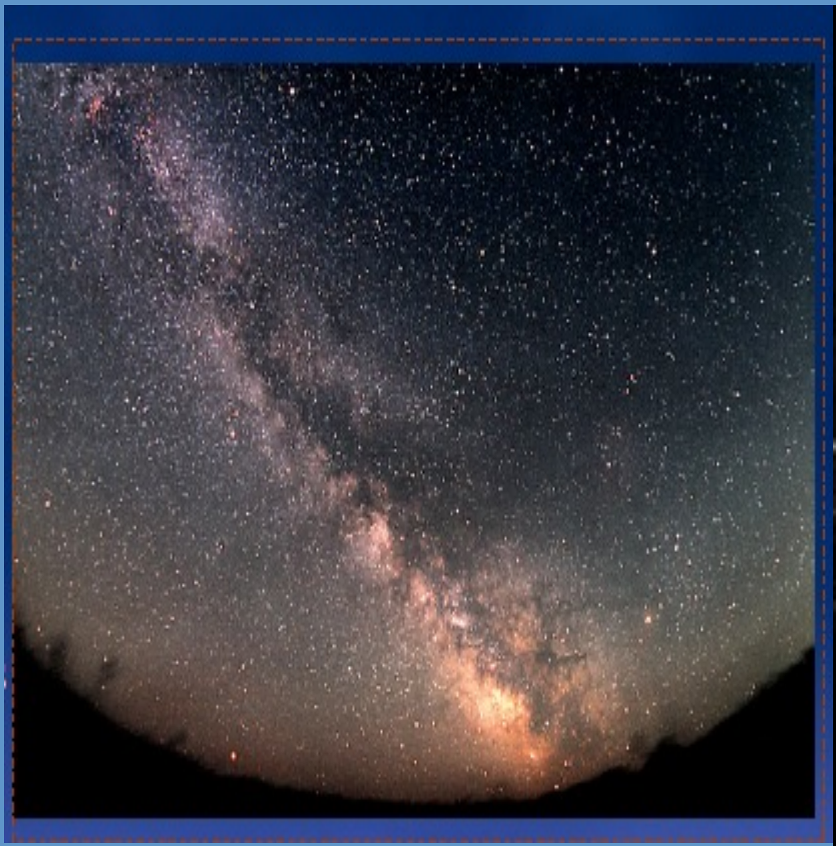


There are less than 10^{11} galaxies



THE MILKY WAY, Our Galaxy

A spiral galaxy surrounded by a few smaller galaxies like the Magellan Clouds and Andromeda (at 2x 10^6 LY) and a couple dozen more form the Local Group. Andrómeda is estimated to be 90% Dark Matter..



RELEVANT DATA OF THE MILKY WAY

- Diameter: 100–120 $\times 10^3$ LY
- Thickness: 1 $\times 10^3$ LY
- Number of stars: 1×10^{11}
- Oldest known star: 13.2 $\times 10^9$ Y
- Mass: 2×10^{11} Solar massses
- Distance of Sun to Galactic Center: 27 $\times 10^3$ LY
- Sun´s rotatonal period around Galactic center: 200×10^6 Y

STAR FORMATION

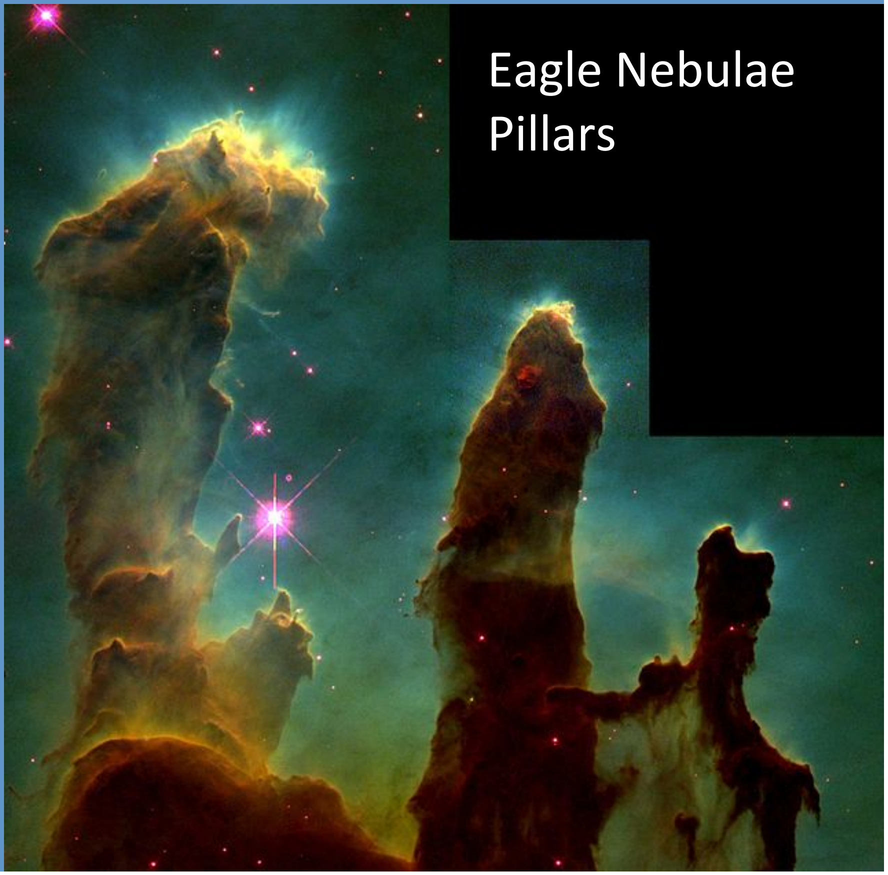
Dense Nebulae (Molecular Clouds) ; H2 regions (90%) with 9% He

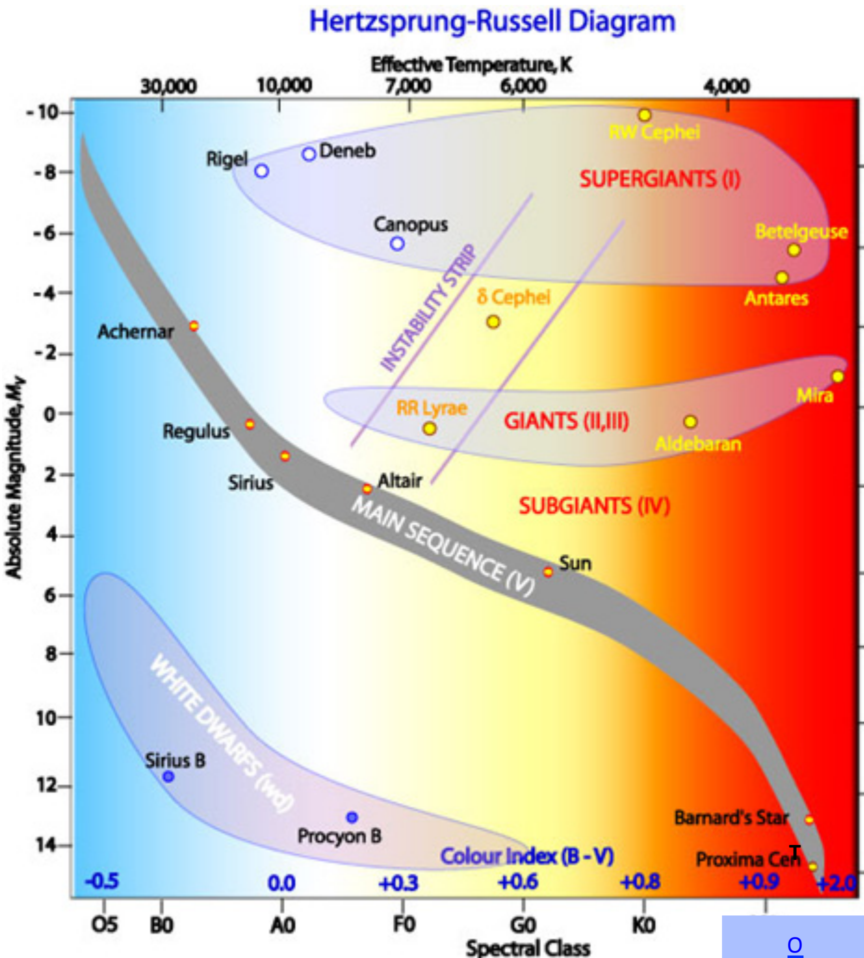
Cold (10-30K) and dense regions (103-104 cm-3)

If Cloud is dense enough, initiates a gravitational collapse (Jeans,1902)

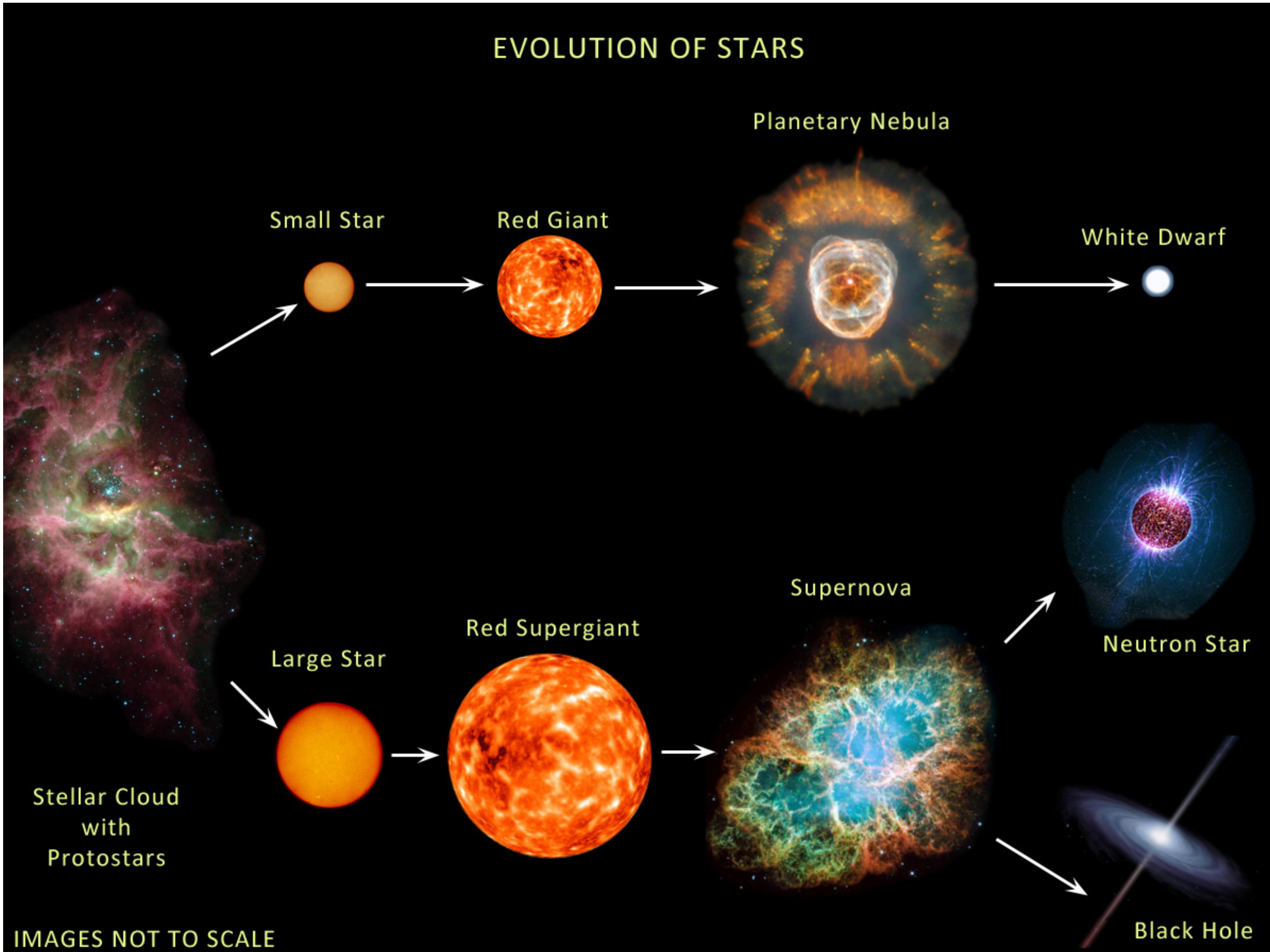
Supernova ⟹ Shock

Galactic collisions ⟹ Tidal forces





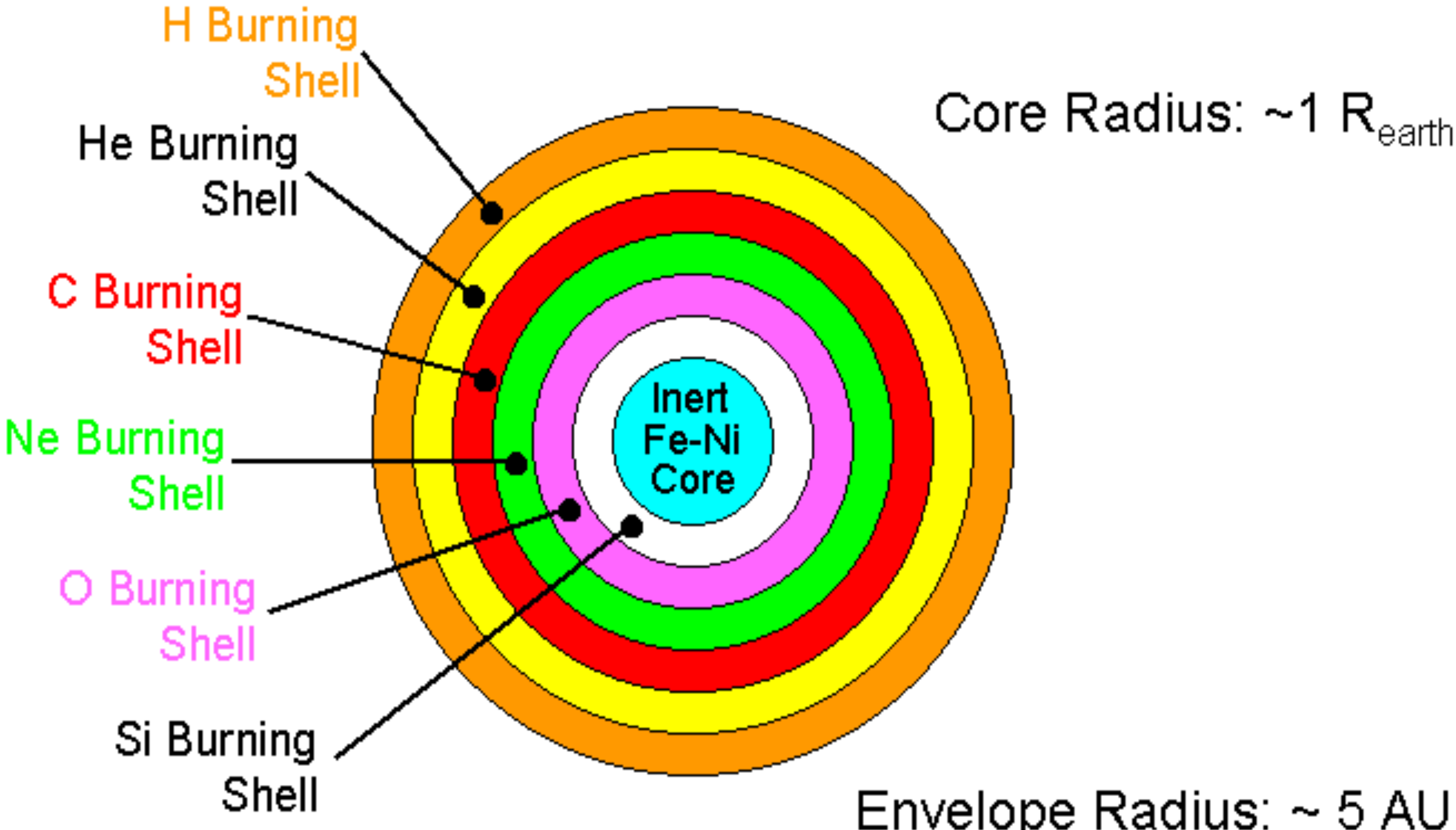
	Temperature (kelvins)	Color convencional	Color aparente[2] [3] [4]	Mass Solar Mass	Radio Solar Radii	Luminosity (bolométric)	Hidrógeno líneas	Fracción de la Secuencia principal[5]
O	≥ 33.000 K	azul	azul	≥ 16 M☉	≥ 6.6 R☉	≥ 30.000 L☉	Débil-Media	~0.00003%
B	10.000–33.000 K	azul a blanco azulado	azul a blanco azulado	2.1–16 M☉	1.8–6.6 R☉	25–30.000 L☉	Medio	0,13%
A	7.500–10.000 K	blanco	blanco a blanco azulado	1.4–2.1 M☉	1.4–1.8 R☉	5–25 L☉	Fuerte	0,6%
F	6,000–7,500 K	blanco amarillento	blanco	1.04–1.4 M☉	1.15–1.4 R☉	1.5–5 L☉	Medio	3%
G	5.200–6,000 K	amarillo	blanco amarillento	0.8–1.04 M☉	0.96–1.15 R☉	0.6–1.5 L☉	Débil	7,6%
K	3.700–5.200 K	naranja	anaranjado	0.45–0.8 M☉	0.7–0.96 R☉	0.08–0.6 L☉	Muy débil	12,1%
M	≤ 3.700 K	rojo	rojo anaranjado	≤ 0.45 M☉	≤ 0.7 R☉	≤ 0.08 L☉	Muy débil	76,45%



Neutron Star: **M>10 SM; radius ~ 20Km, D>1000Ton/cm^3, 10^{-3} Hz..**

Black Hole: 10^6 SM

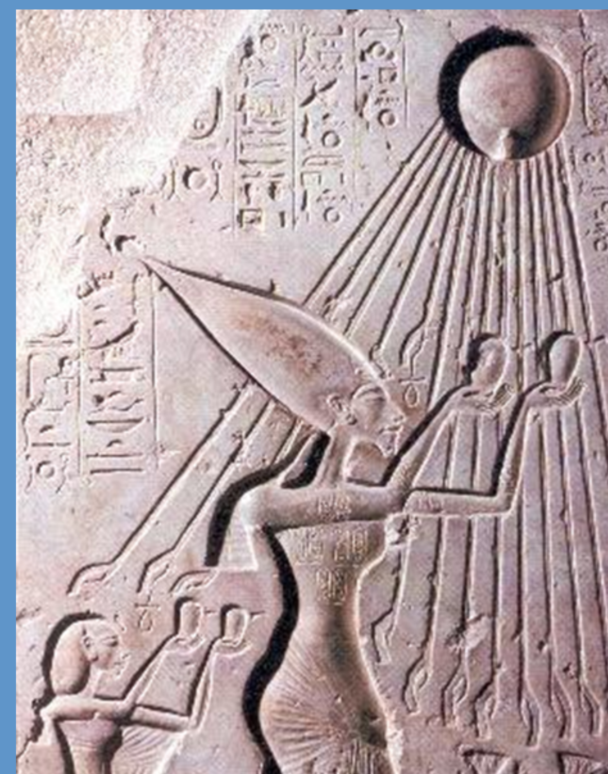
INITIAL MASS (Solar)	FINAL STAGE
M< 0.01	Planet
0.01<M<0.08	Brown Dwarf
0.08<M<9	White Dwarf
9<M< 30	Supernova+NeutronStar
30<M	Black Hole



H Burning Shell
He Burning Shell
C Burning Shell
Ne Burning Shell
O Burning Shell
Si Burning Shell
Inert Fe-Ni Core
Core Radius: ~1 R_{earth}
Envelope Radius: ~ 5 AU

THE SUN, OUR STAR

Ra (Aton),
Egiptian Sun God



Akenaton, 1353-1338, BC

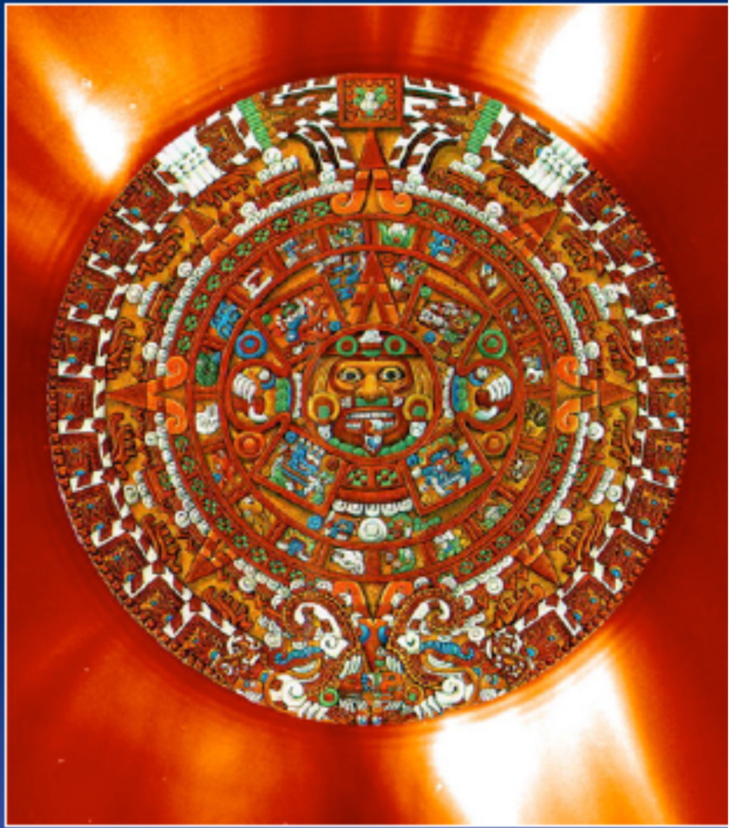
MITRA
Persian Sun God, 2000 BC

Hindu and Roman Cultures
adopted it too

During the IV century AD in Rome the cult was as important
as christianism

Mexican civilizations

- The Aztecs believed they were living in the fifth creation of the world. They called each creation a sun, because its movement maintained human life.
- The central face in the "Calendar Stone" (right) seems to represent Tonatiuh, the Sun god
- The peoples of ancient Meso-America carefully observed the sky and used the calendar to predict solar and lunar eclipses, the cycles of Venus, and other celestial events. The calendar was developed by observing the Sun's motions over a long period of time.

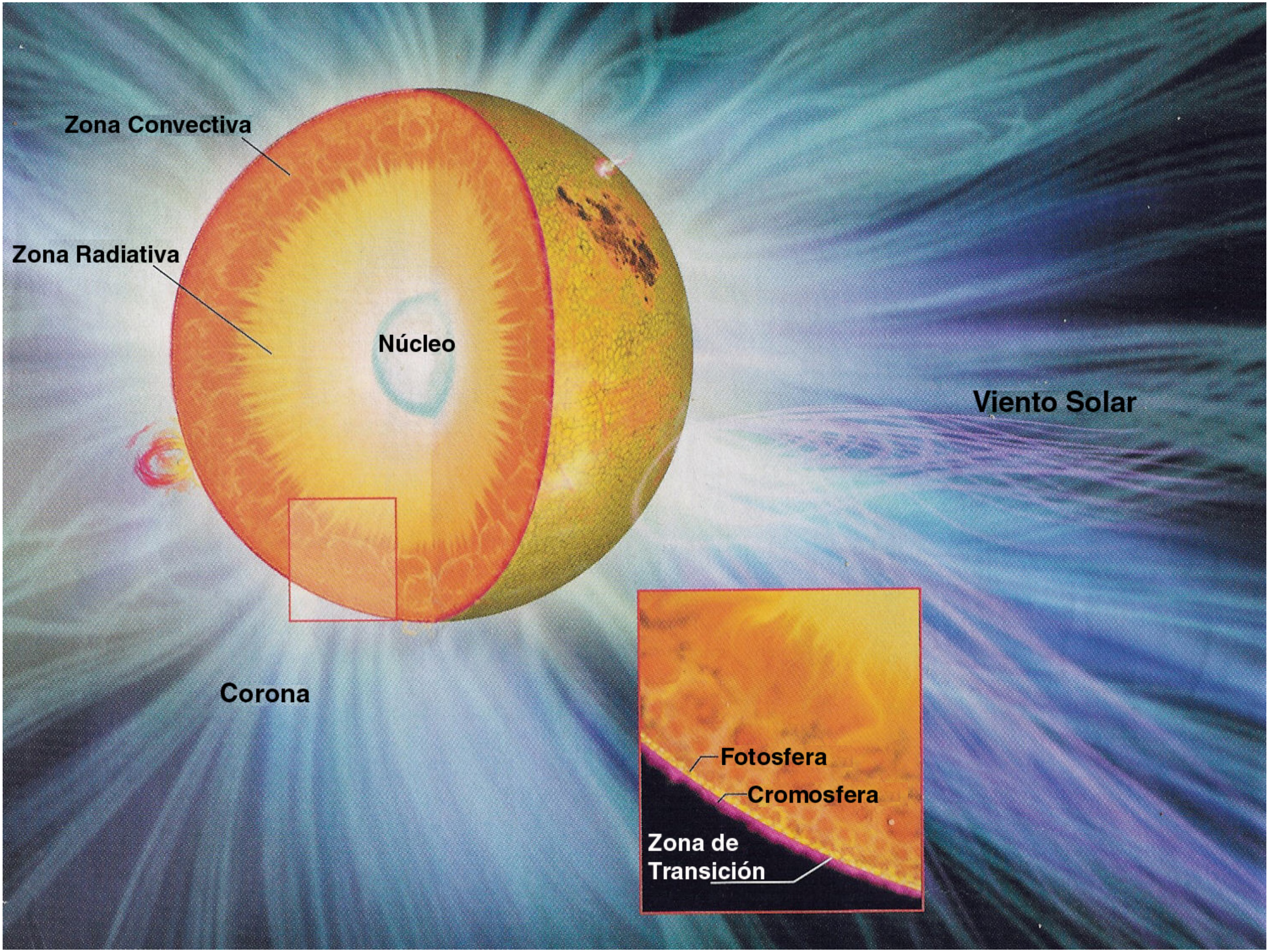


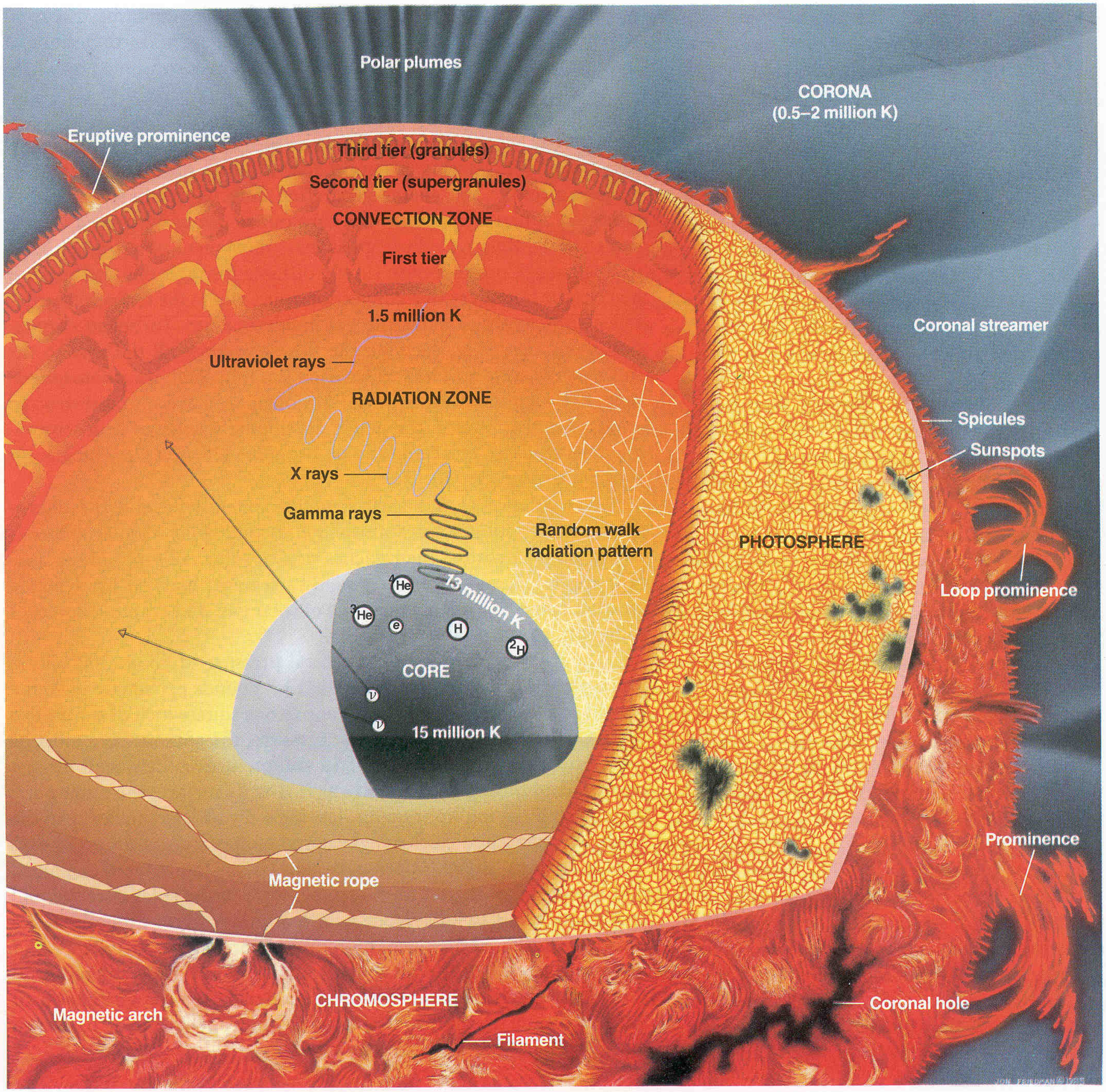
Aztec Sunstone
12 feet wide,
weighs 24 tons

Kinich-Ahau, Mayan Sun God

Peru

At Machu Picchu, high in the Andes Mountains
in Peru, the Incas built an elaborate and remote city. When the Sun rose through one specific window in a building called the Torreon (built around 1500), the Incan Indians knew that the dry season had begun (winter solstice in the southern hemisphere). This is how they began to develop a calendar.

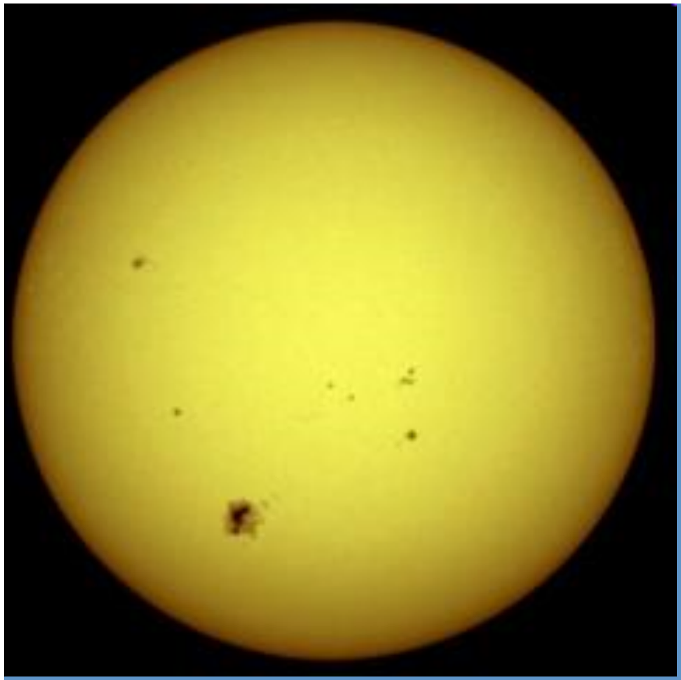
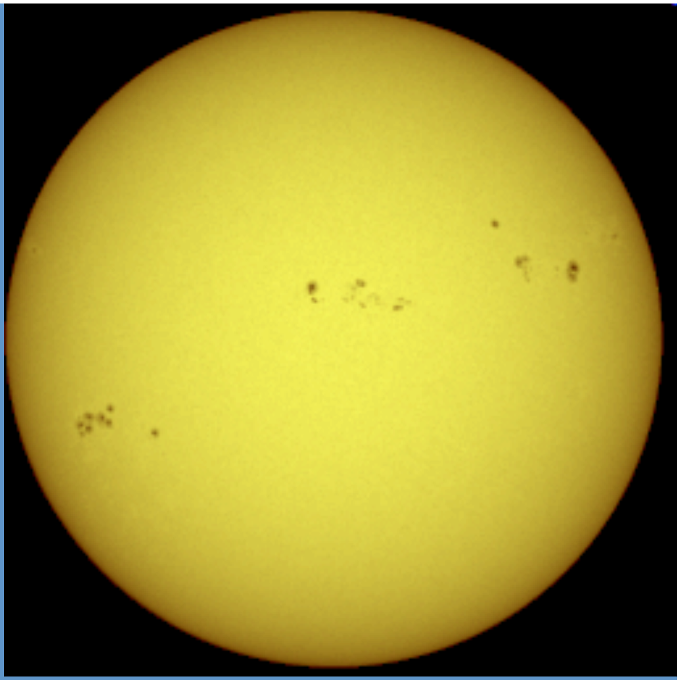
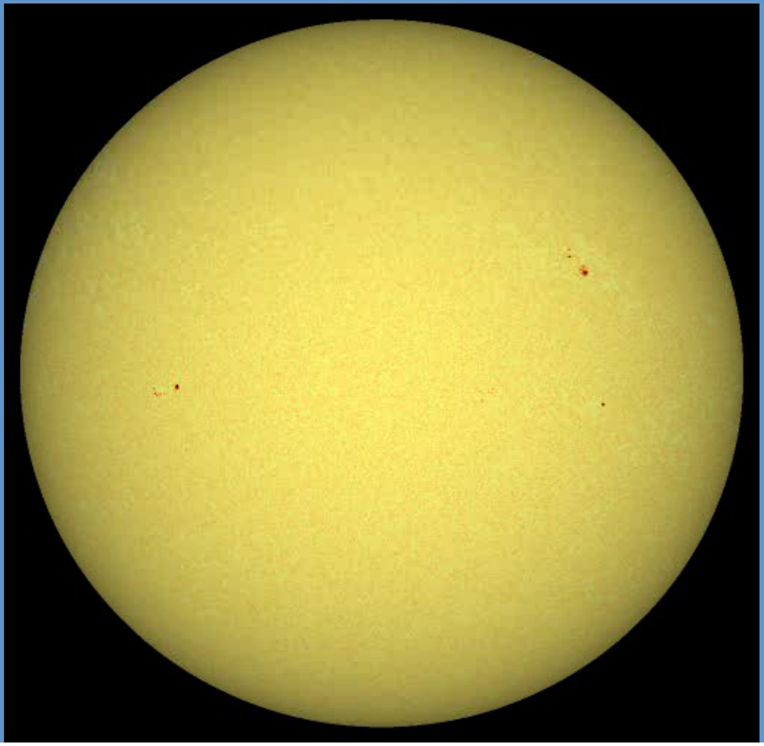

Zona Convectiva
Zona Radiativa
Núcleo
Viento Solar
Corona
Fotosfera
Cromosfera
Zona de
Transición

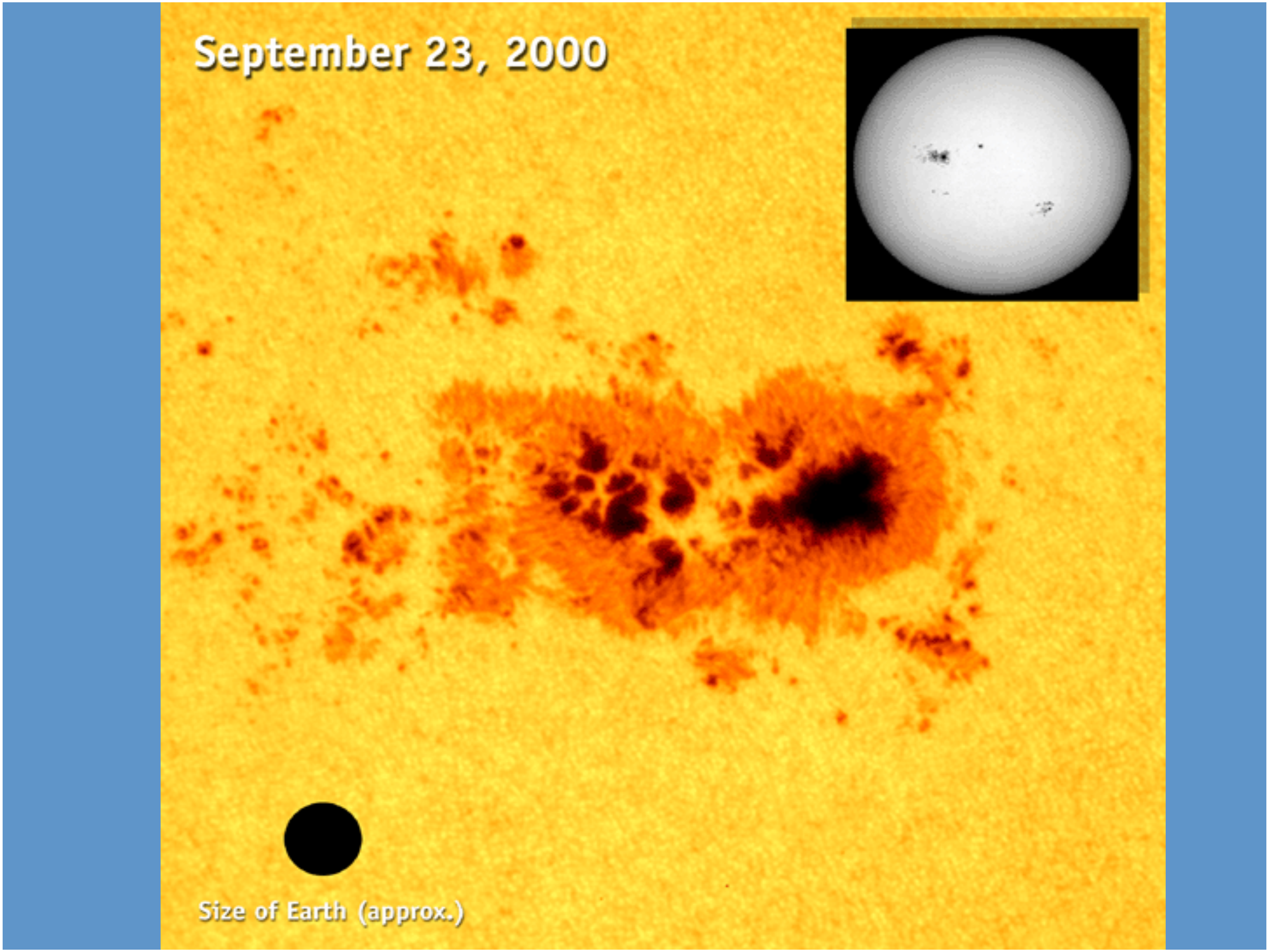


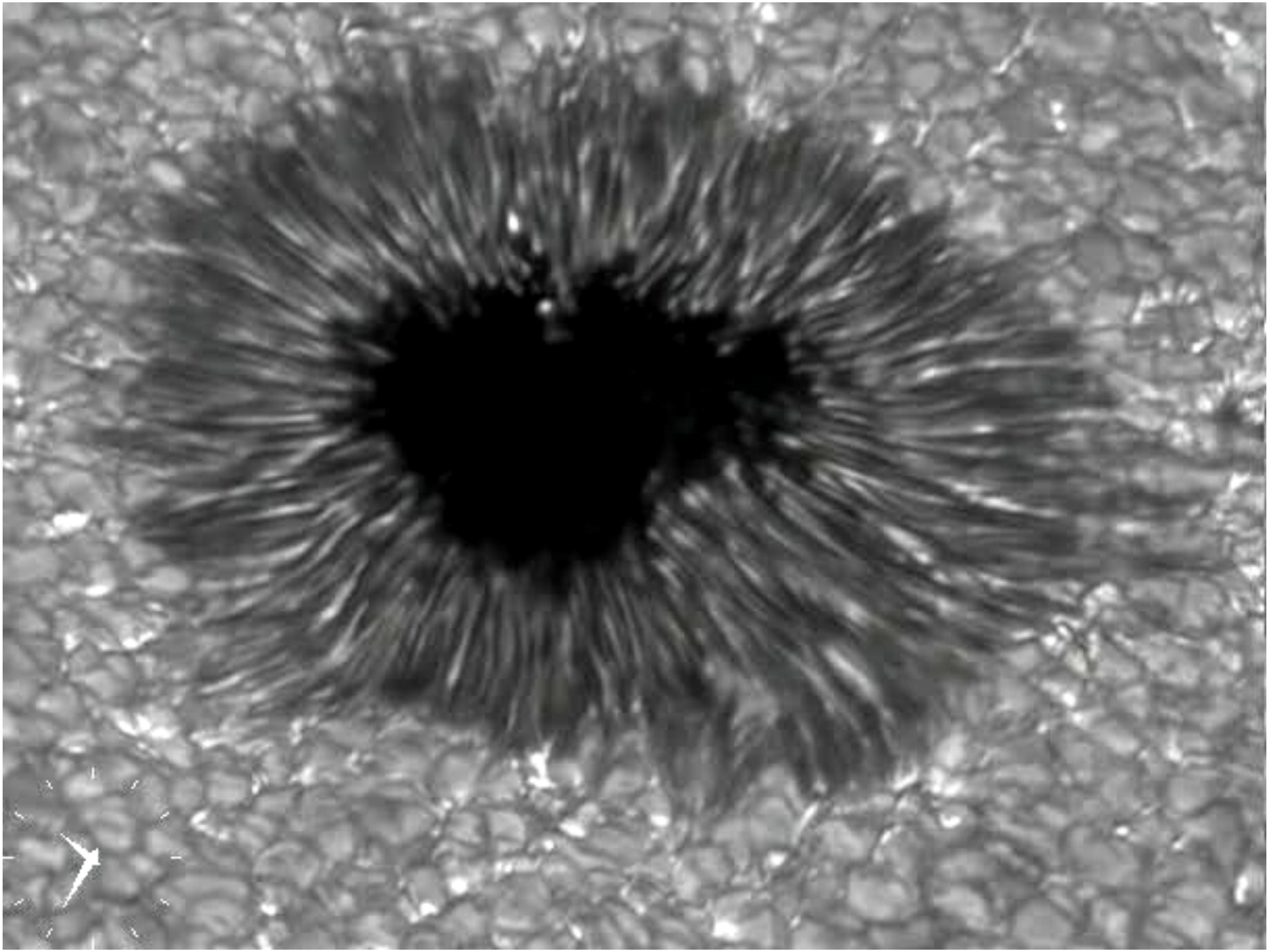
Polar plumes
CORONA
(0.5–2 million K)
Eruptive prominence
Third tier (granules)
Second tier (supergranules)
CONVECTION ZONE
First tier
1.5 million K
Coronal streamer
Ultraviolet rays
RADIATION ZONE
Spicules
Sunspots
X rays
Gamma rays
Random walk
radiation pattern
PHOTOSPHERE
Loop prominence
13 million K
CORE
15 million K
Prominence
Magnetic rope
CHROMOSPHERE
Magnetic arch
Coronal hole
Filament

The Sun, our star

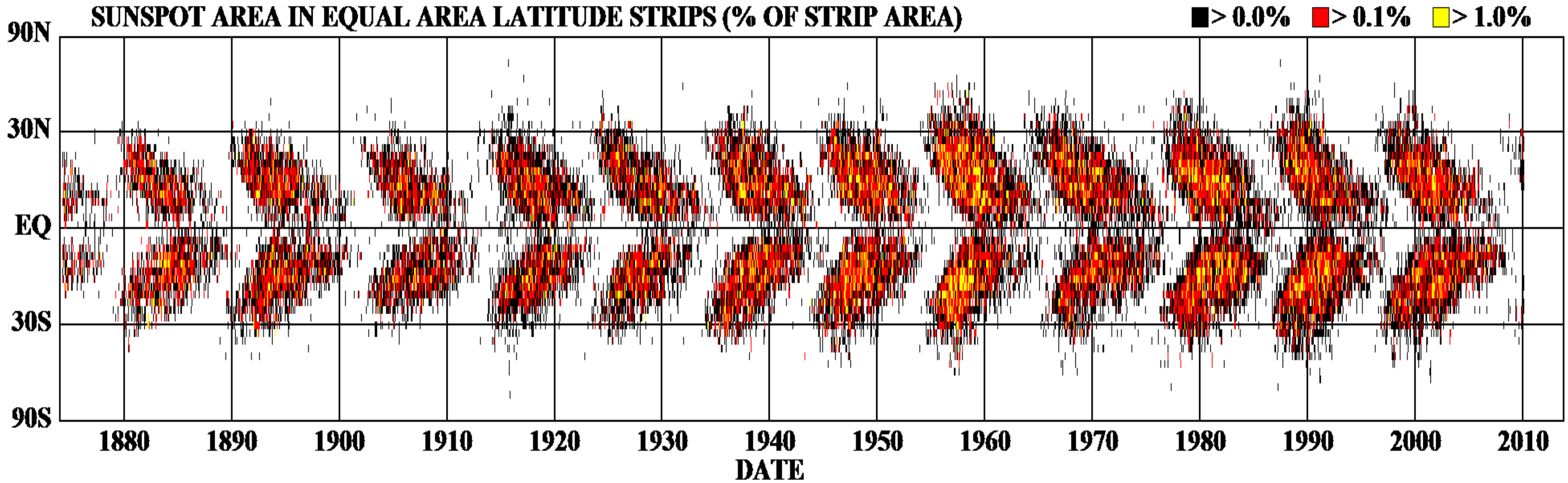
Name	Sun	
Parent galaxy	Milky Way	
Type	fixed star	
Spectral class	G2	
Magnitude	+ 4.8	
Distance to Earth	149,598,000 km	i.e., 1 AU
Radius R_s	696,000 km	i.e., 109 R_E
Total mass M_s	1.989×10^{30} kg	i.e., 333.000 M_E
Density (average)	1.409 g cm^{-3}	
Surface temperature	5800 K	
Rotation duration	27.25 days (synodic), at equator, 25.38 days (sideric), at equator.	
Age	4.60 billion years	
Number of planets	9, plus many tiny ones	
Next neighbor star	Alpha-Centauri, at 4.37 lightyears	
Next neighbor galaxy	Magellan's Clouds, at 165,000 lightyears	
Earth's distance variation	+/- 1.69 % (+ in July, - in January)	
Apparent diameter	31' 59.3" = 1913.3 "	i.e. 0.5 degree
Apparent radius	959.65"	i.e. 1000 arcsec
1 arcsec on sun, from Earth	725 km	
Energy output	3.82×10^{33} Watt	
Energy input into Earth	1,370 Watt/m^{-2}	
total	173 Mio Gigawatt	

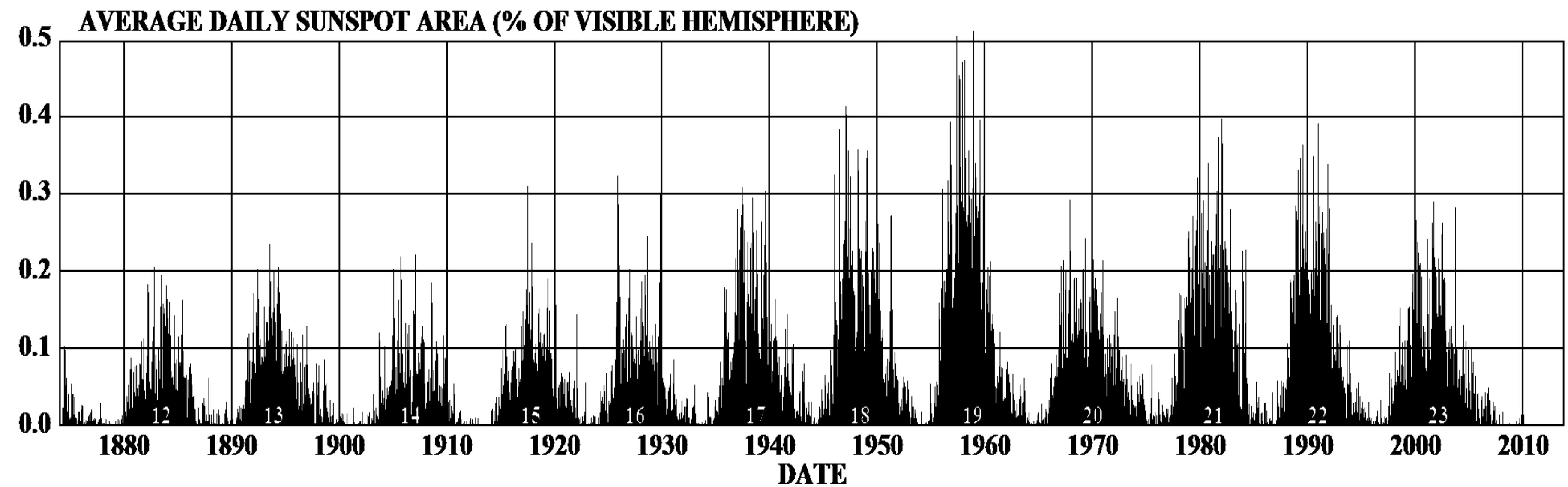





September 23, 2000
Size of Earth (approx.)



DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS

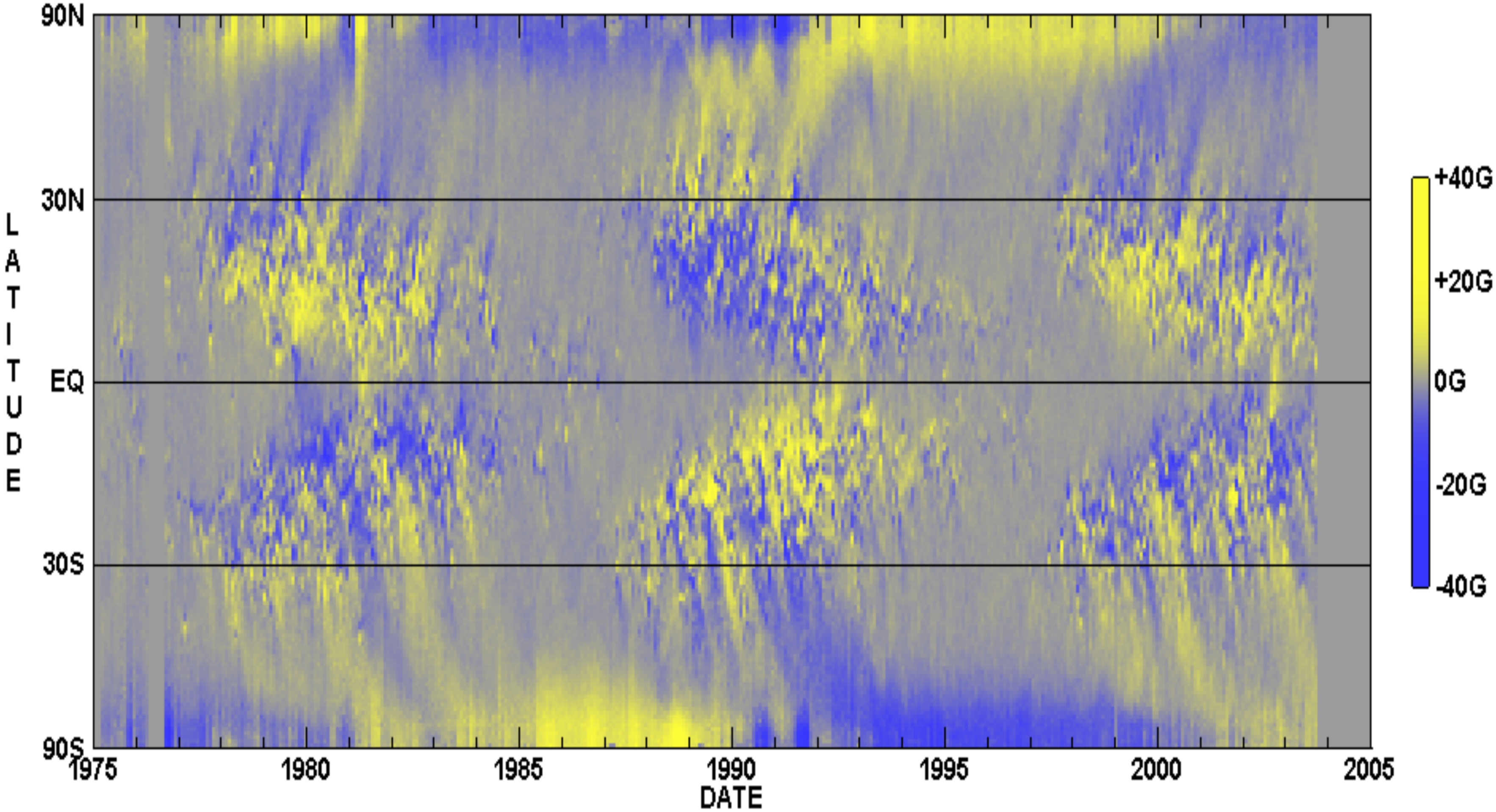




http://solarscience.msfc.nasa.gov/

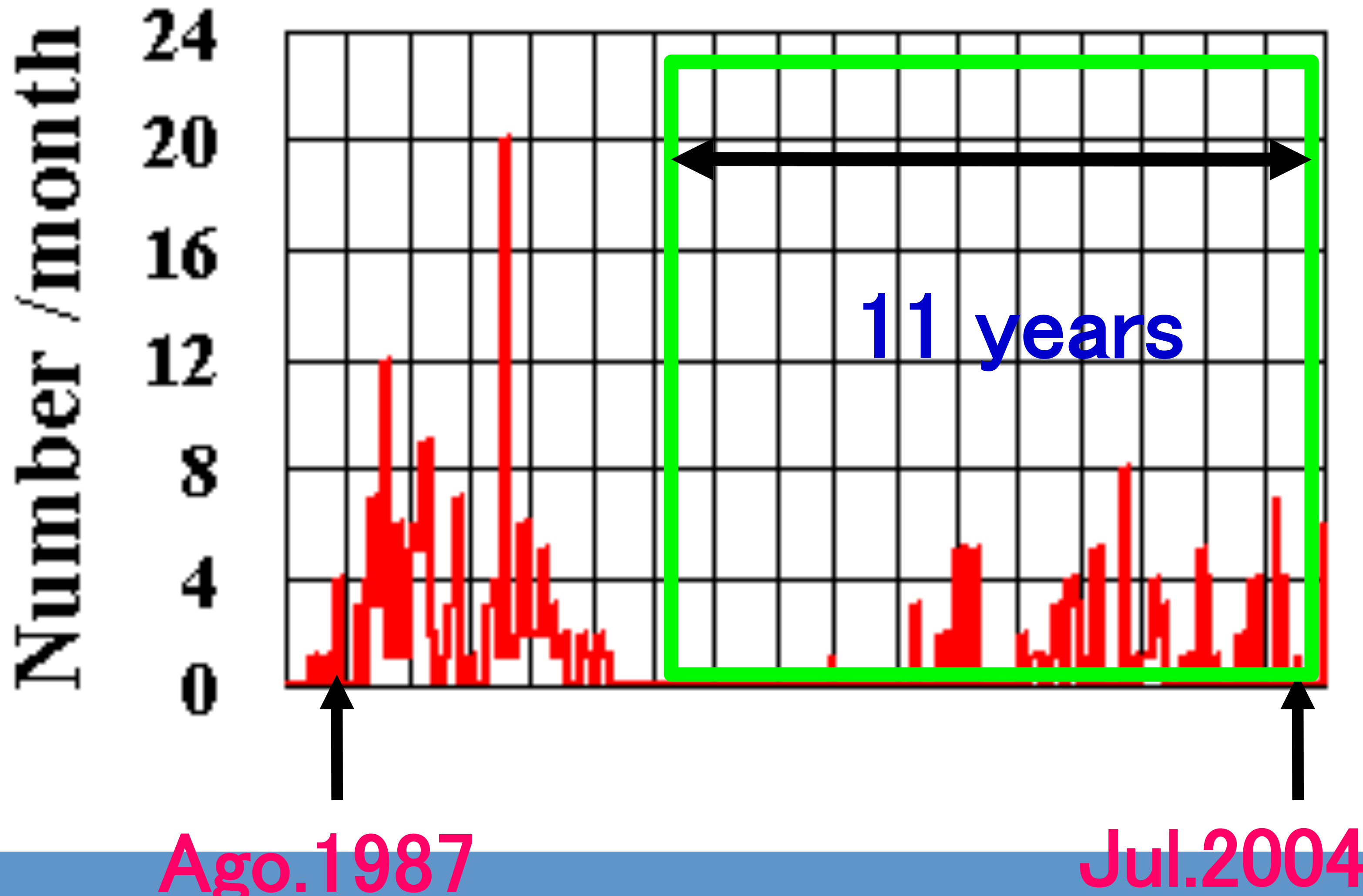
HATHAWAY/NASA/MSFC 2010/04

LONGITUDINALLY AVERAGED MAGNETIC FIELD

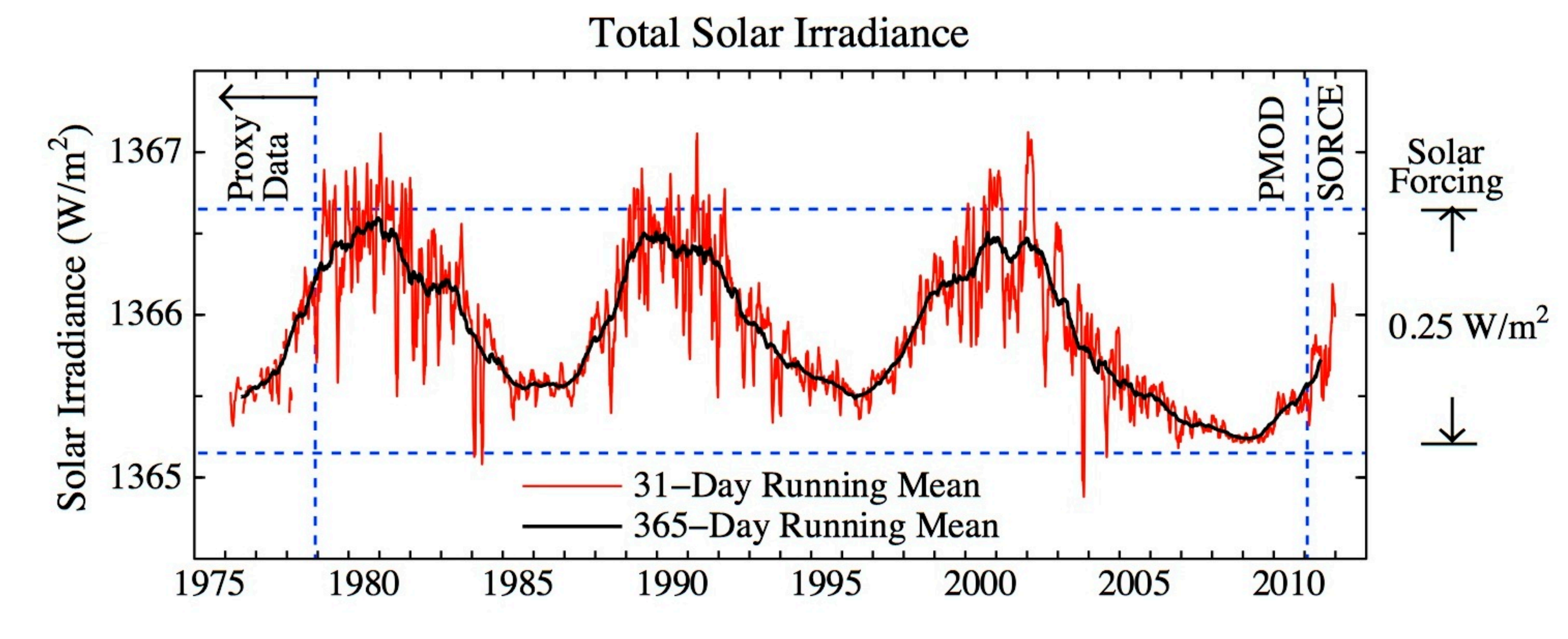


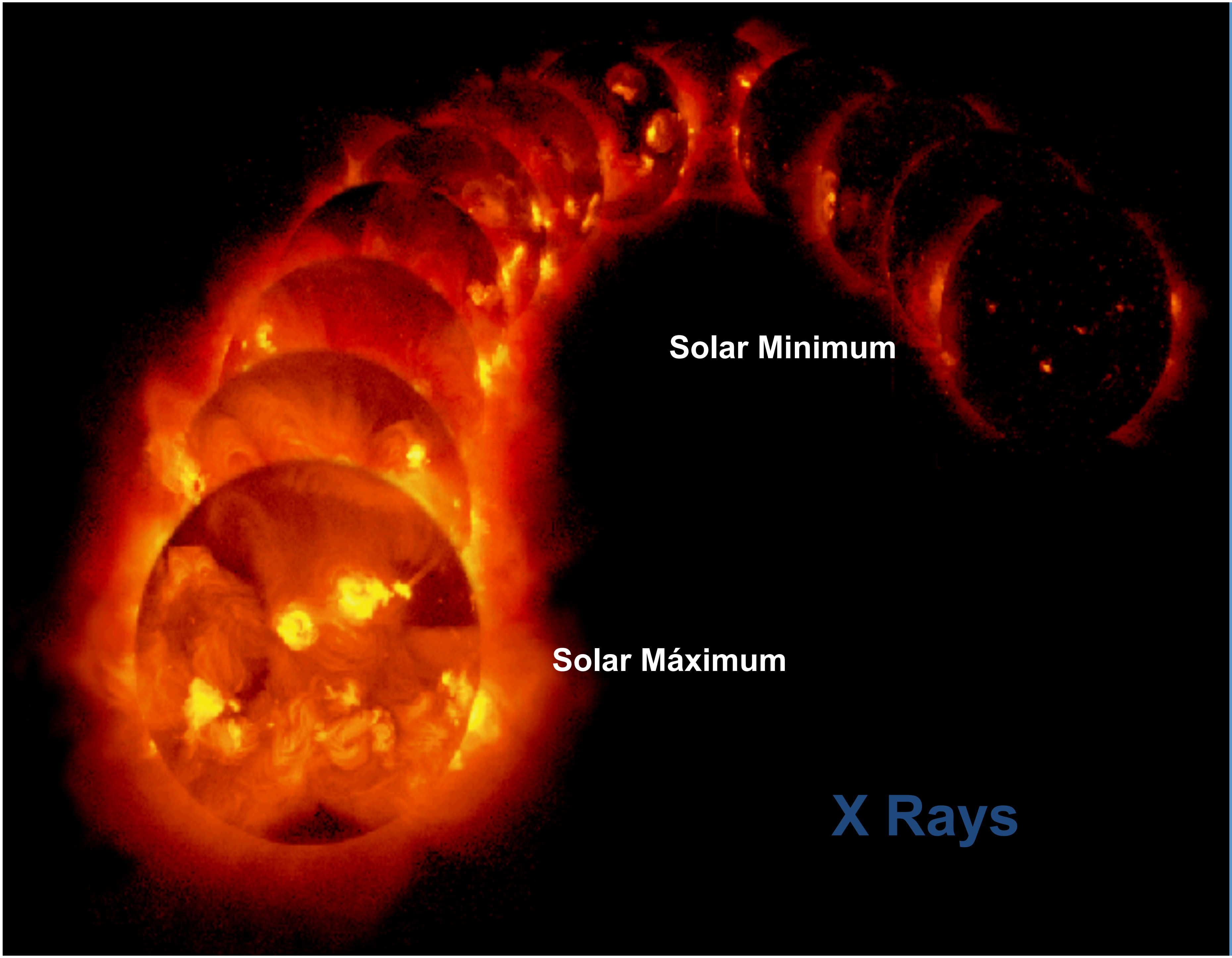
NASA/NSSTC/Hathaway 2003/10

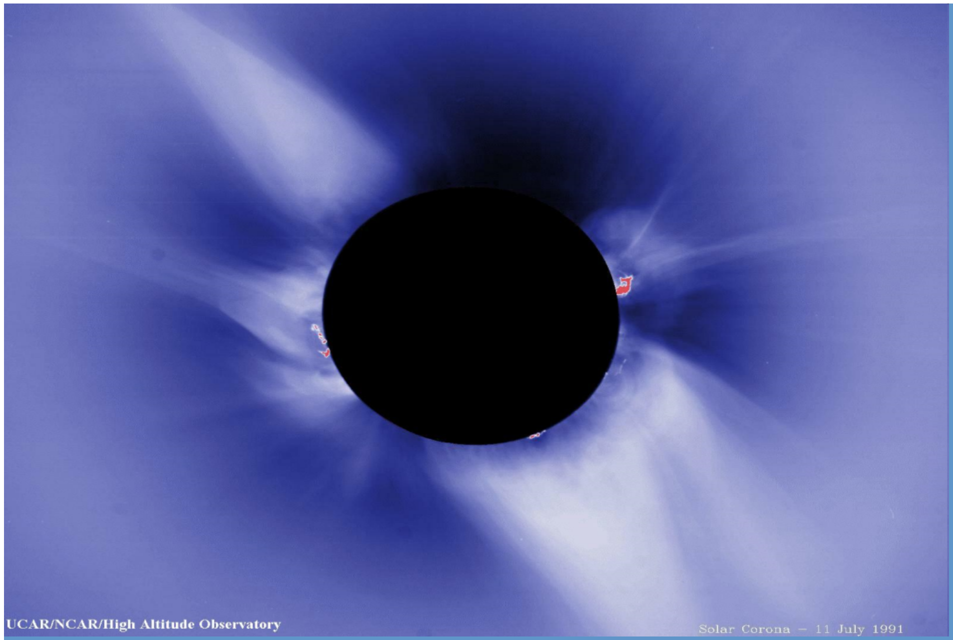
X-Ray Solar Flare Frequency



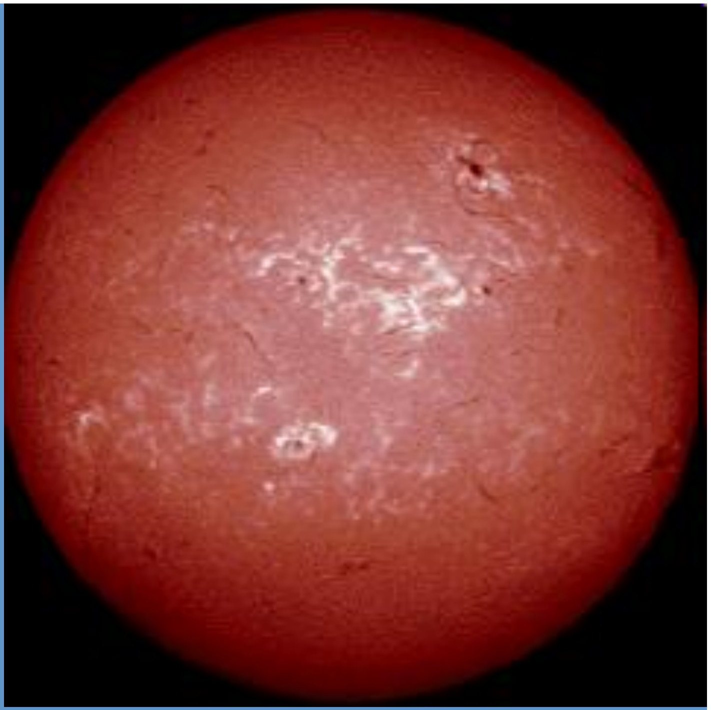
TOTAL SOLAR IRRADIANCE



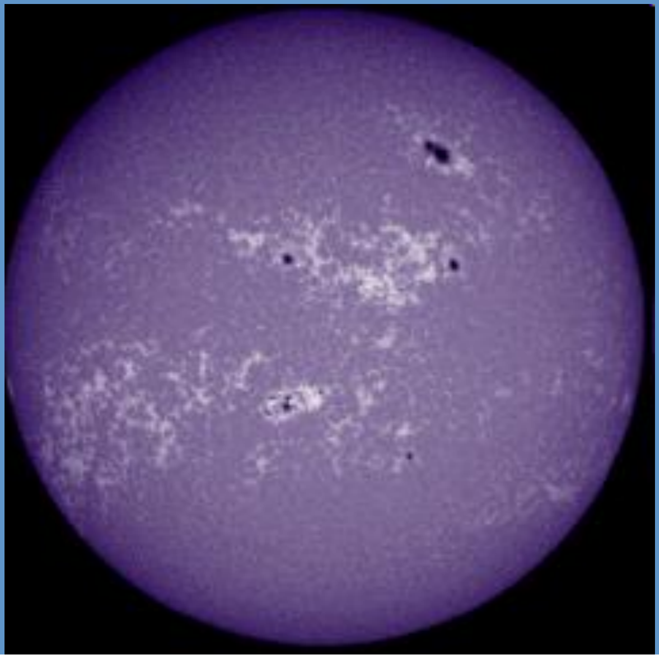

Solar Minimum
Solar Máximum
X Rays



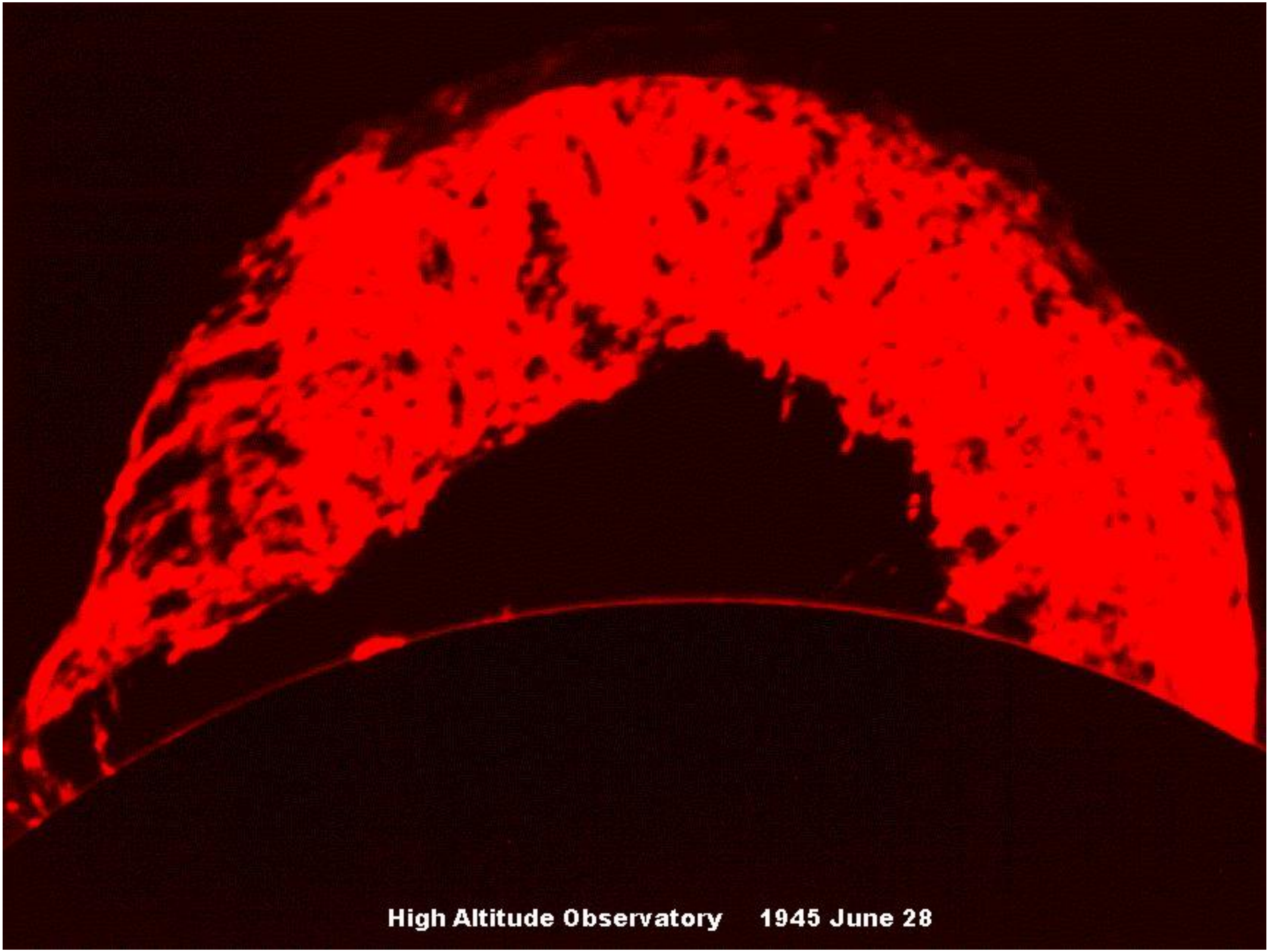
Prominences

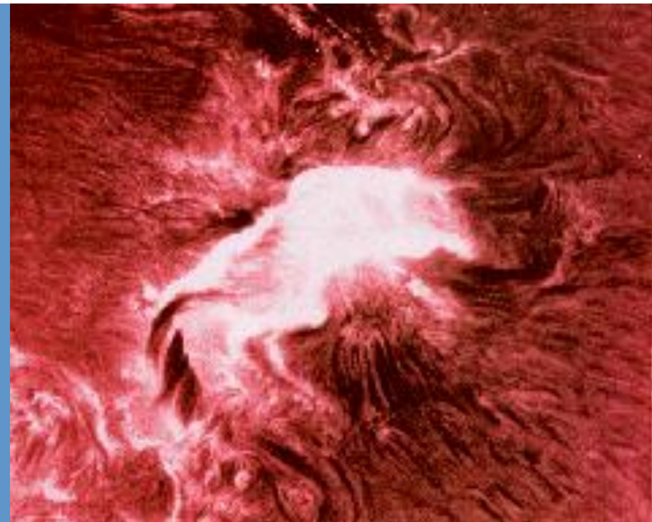


Hα (656.2nm, red)



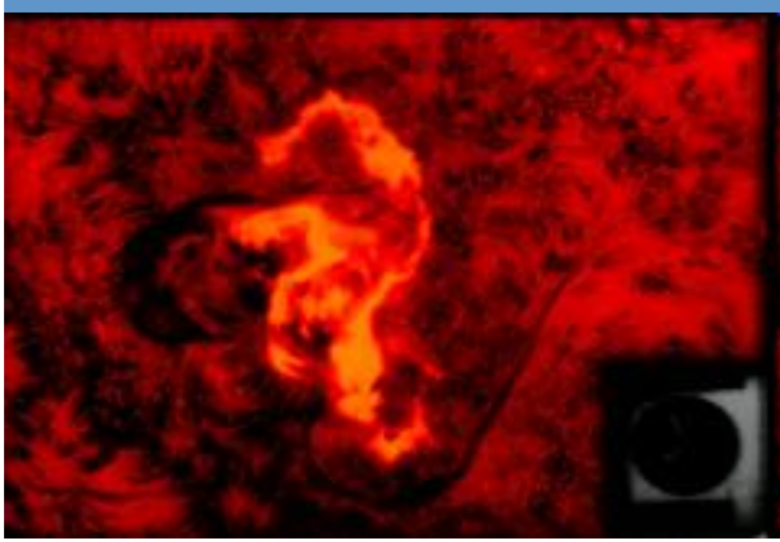
Ca II (393.4nm, violet)


High Altitude Observatory 1945 June 28

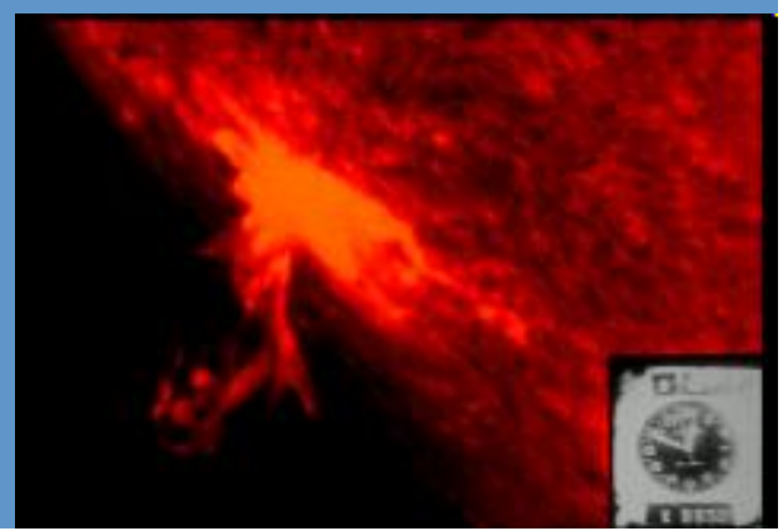


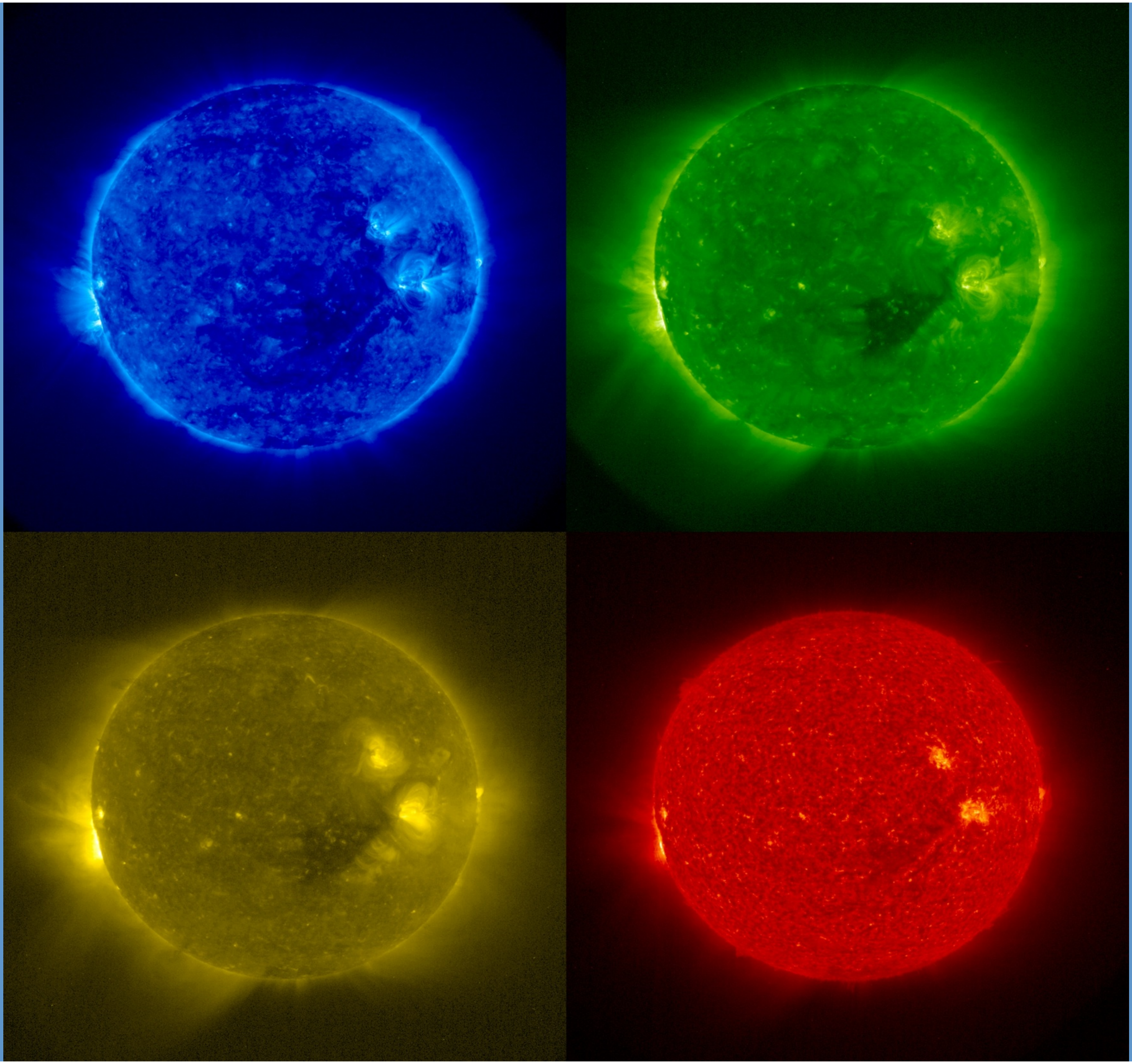
White Light

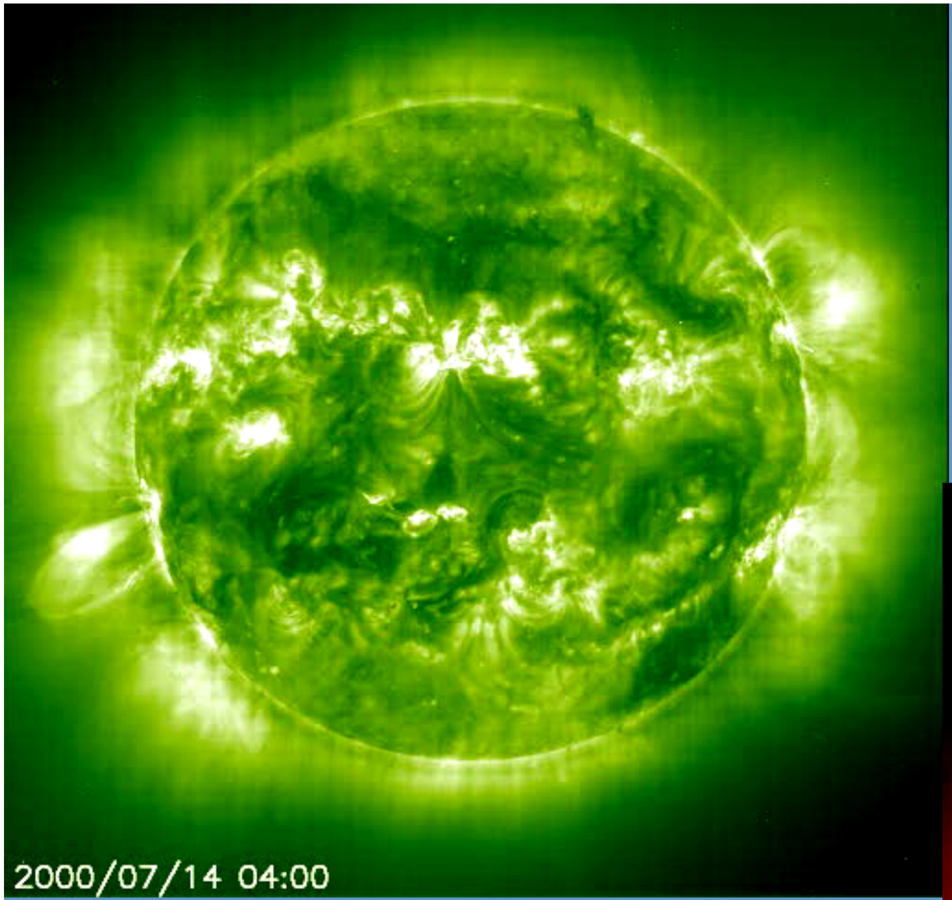
SOLAR FLARES



Hα



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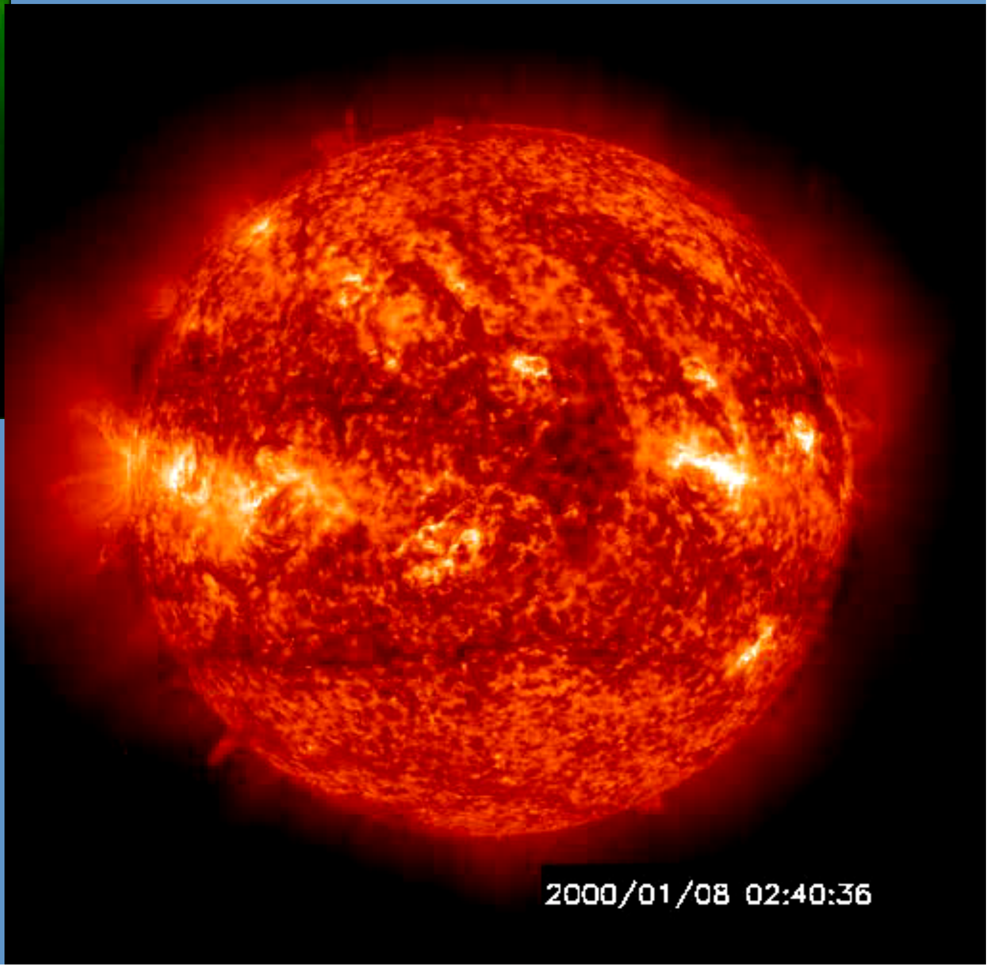
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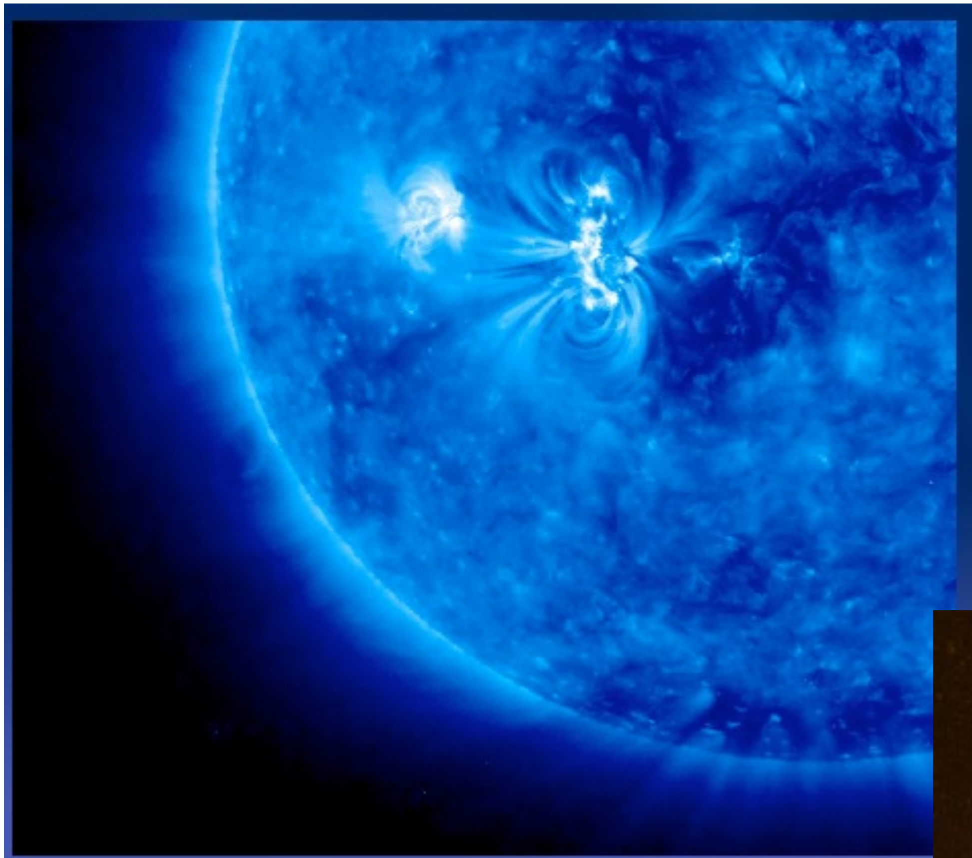
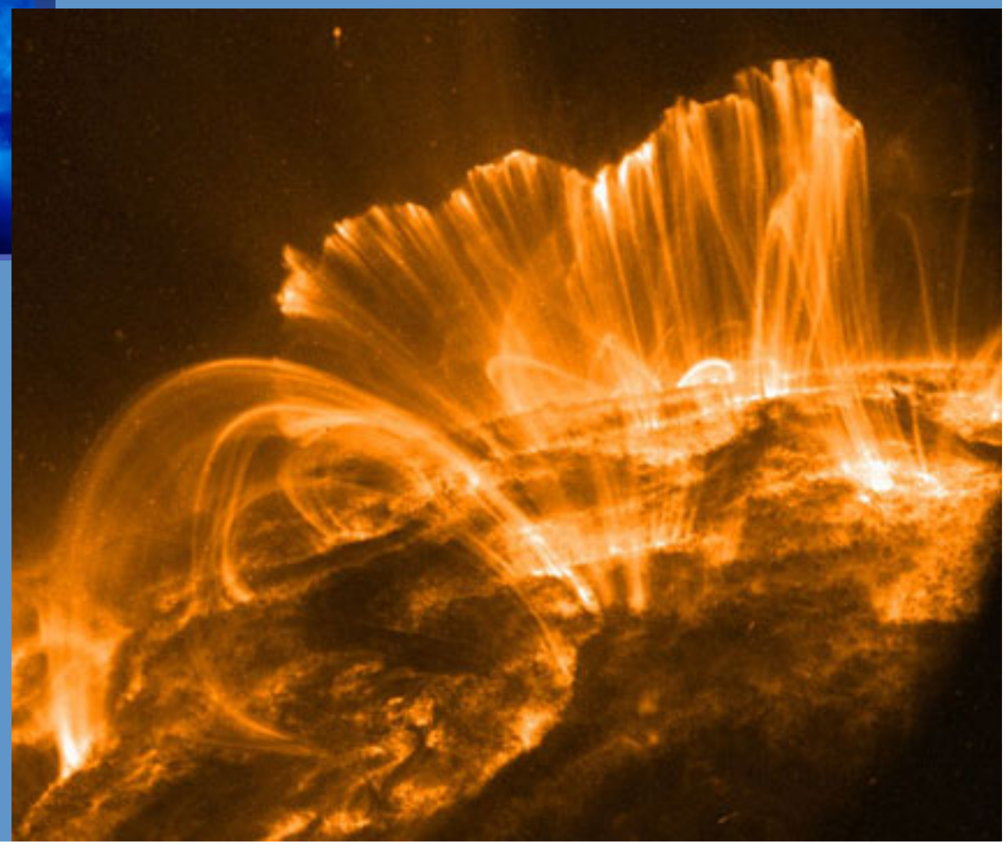
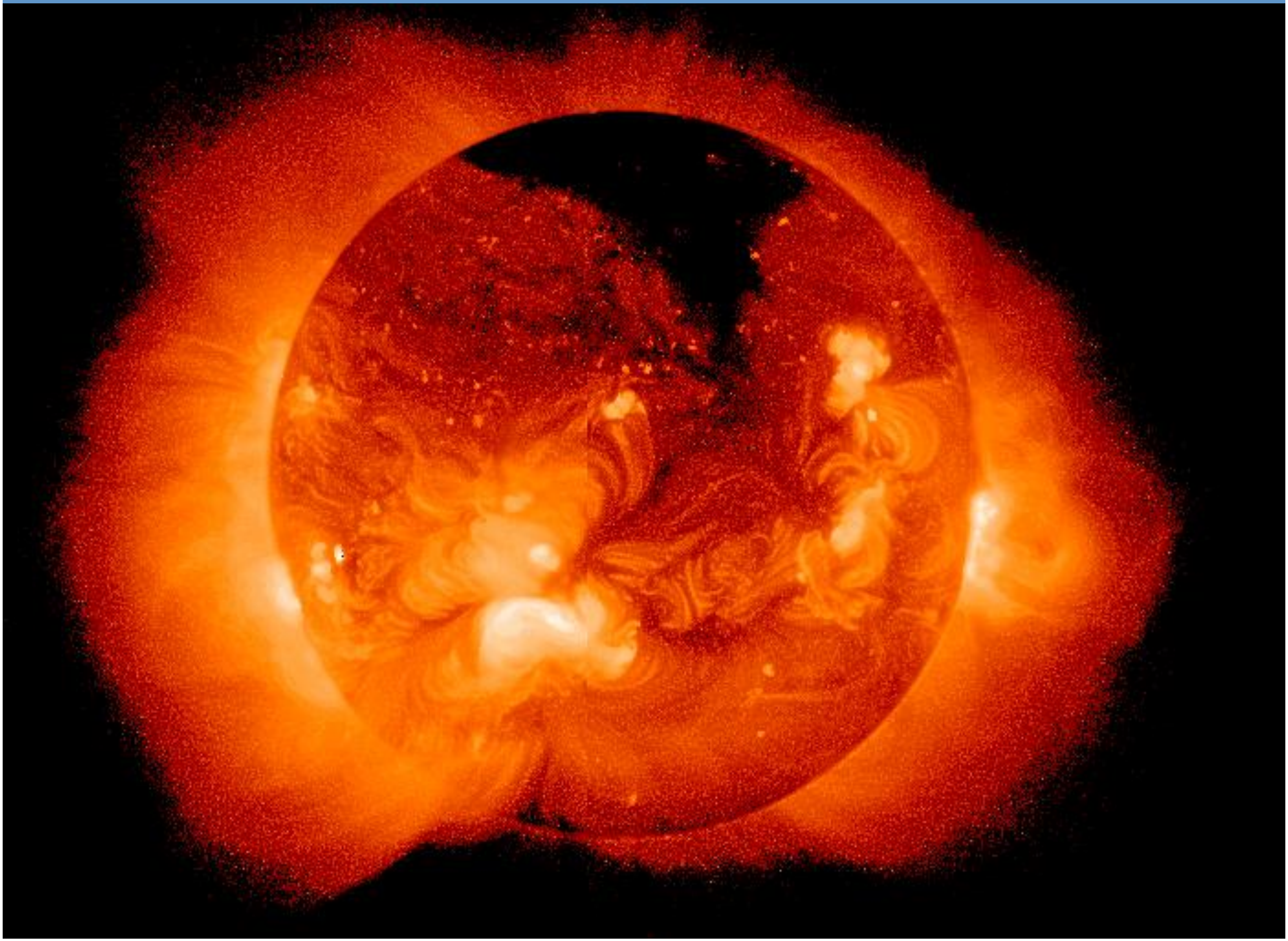
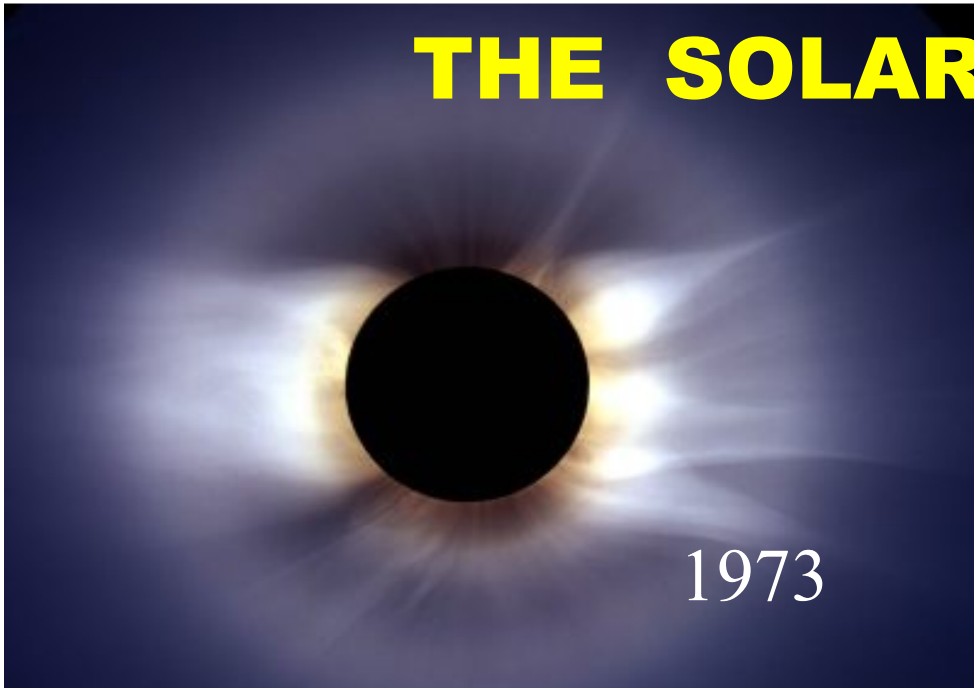
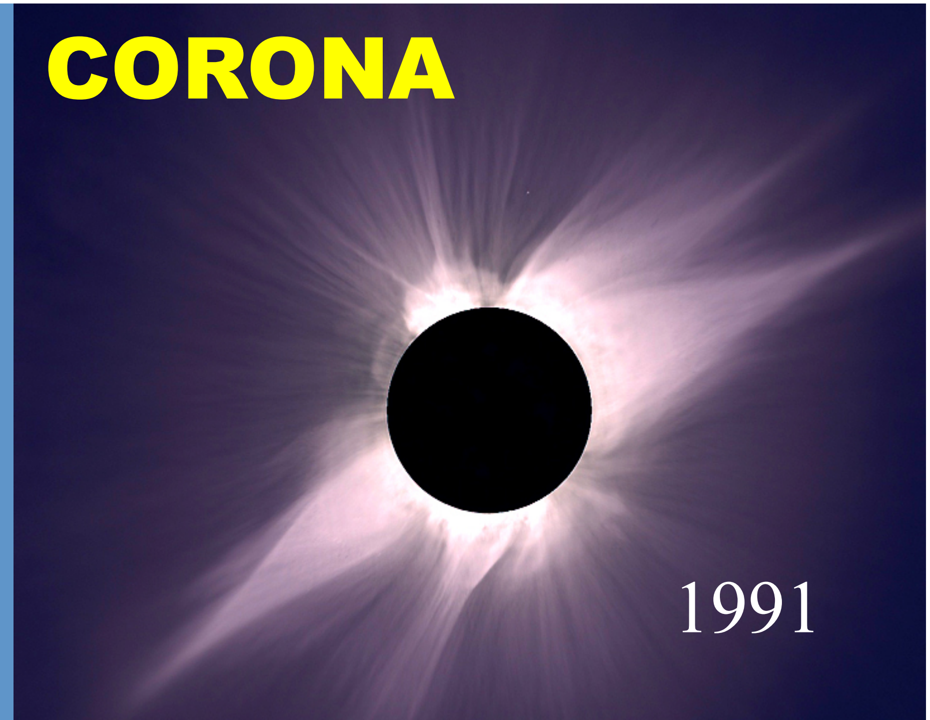






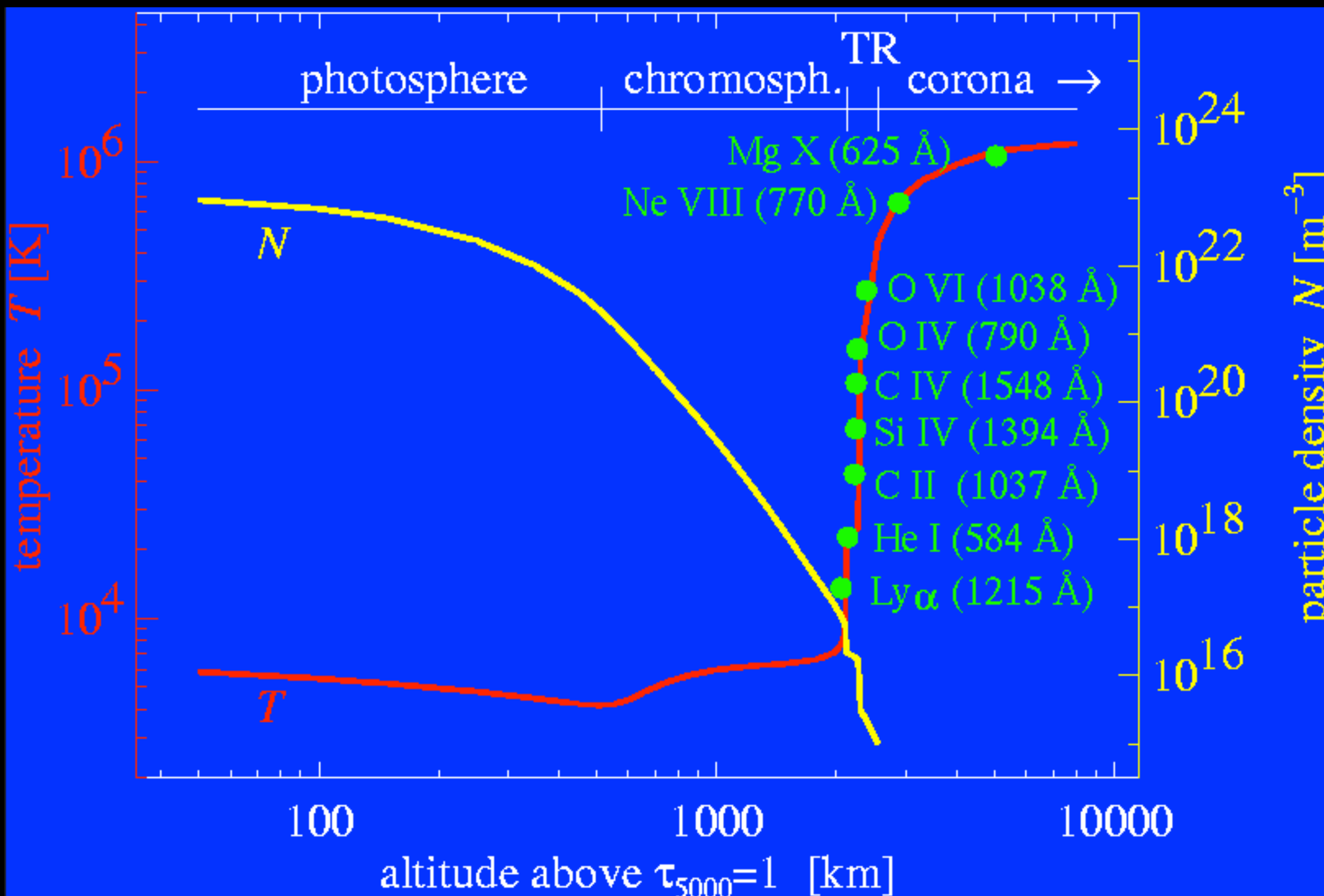
THE SOLAR CORONA





It must be very hot, otherwise it wouldn´t be so extended

TEMPERATURES IN THE SOLAR ATMOSPHERE



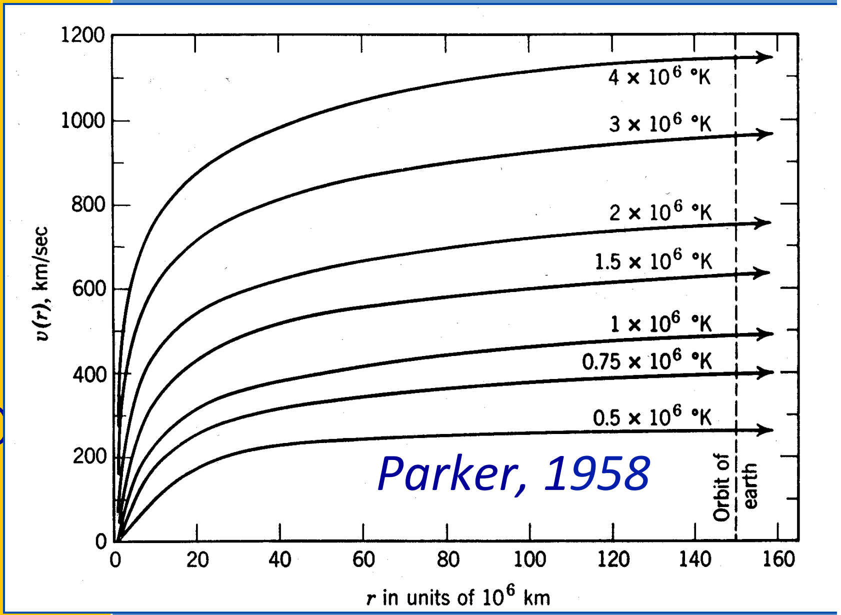
HOW TO HEAT THE SOLAR CORONA?

Types of waves potentially involved

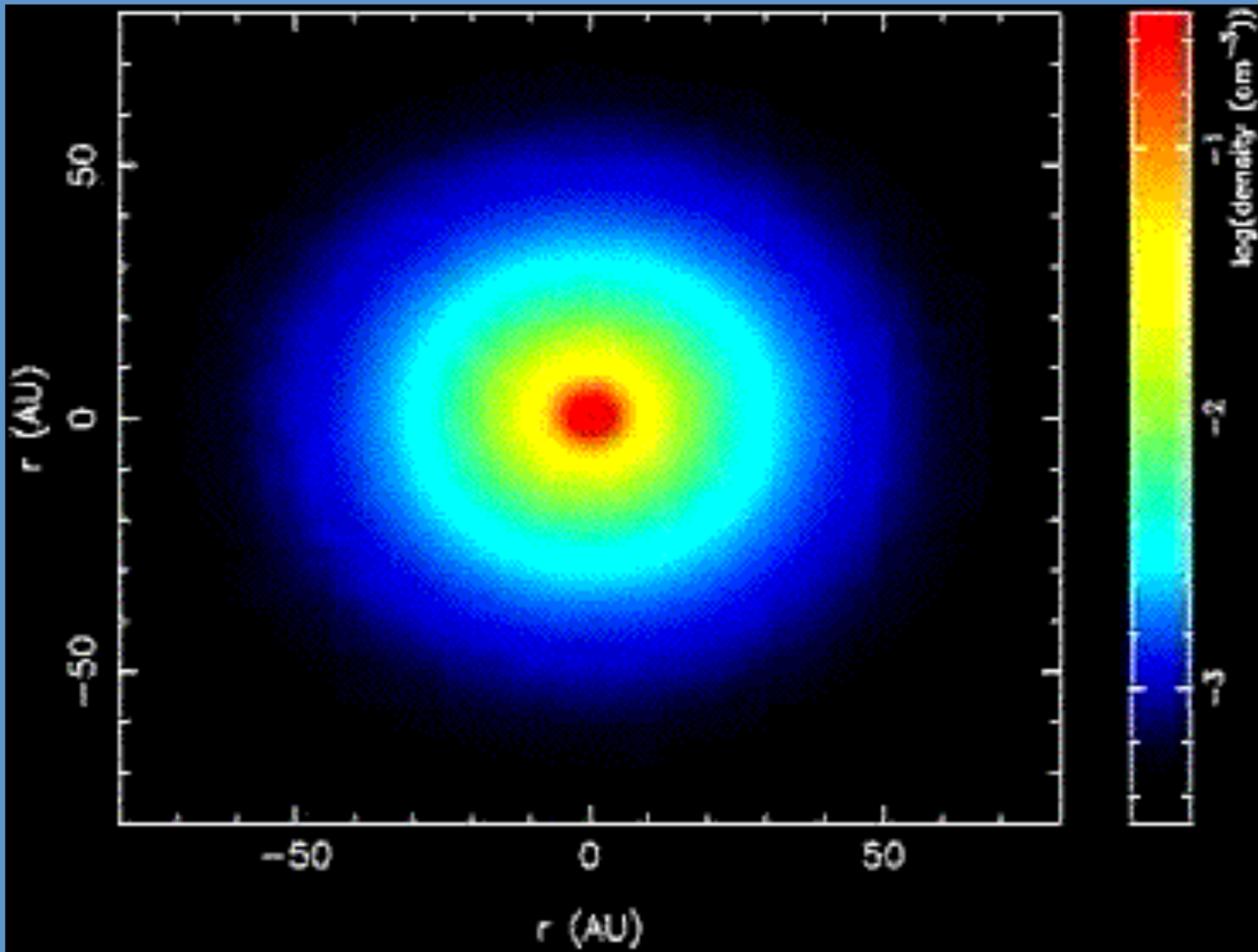
- sound waves, shock waves,
- fast and slow magneto-acoustic (MHD) waves,
- Large Amplitude Alfvén waves,
- surface waves,
- torsional Alfvén waves,
- turbulence,
- plasma waves

Potential mechanisms leading to coronal heating

- wave dissipation,
- resonance absorption of waves (e.g., ion cyclotron resonance)
- current sheets and their dissipation,
- Ohmic heating by field-aligned currents,
- micro- and nanoflares,
- heating by spiculae,
- magnetic reconnection,
- heating by microturbulence (electrostatic waves),
- heating by MHD turbulence (magnetic helicity).

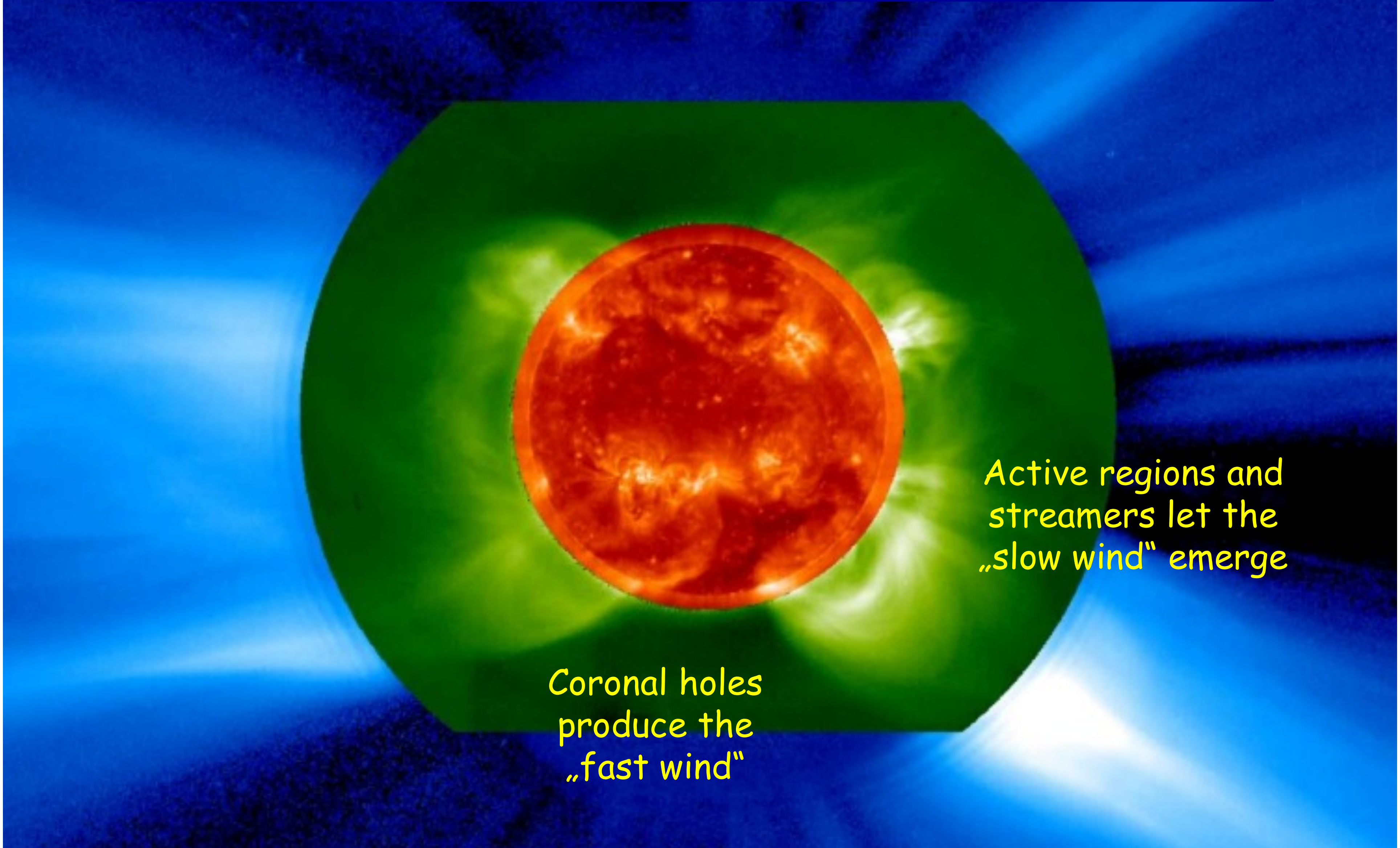


Note: The coronal magnetic field plays the crucial role!



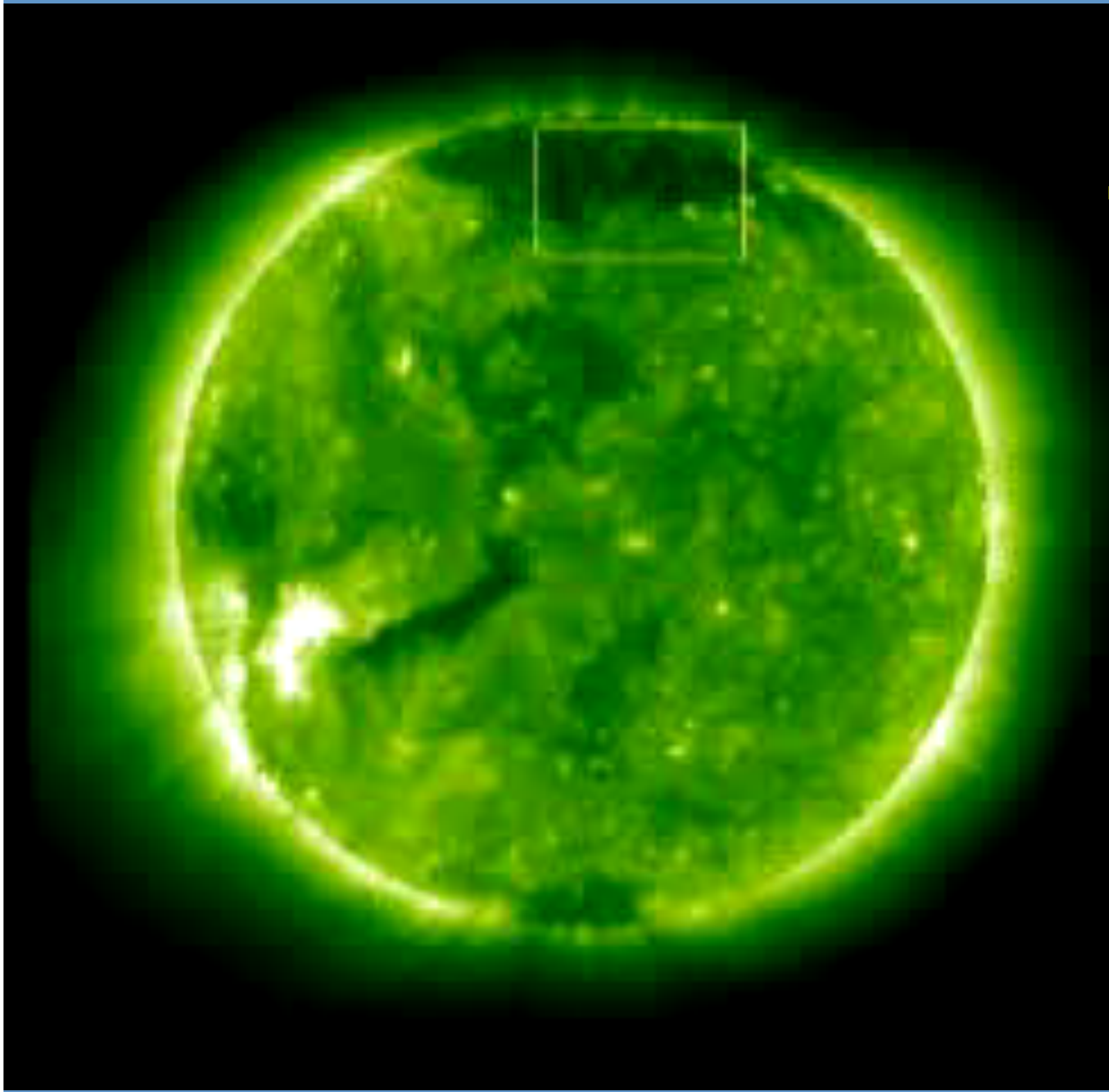
r (AU)
r (AU)
log(density (cm^{-3}))

The two states of corona and solar wind

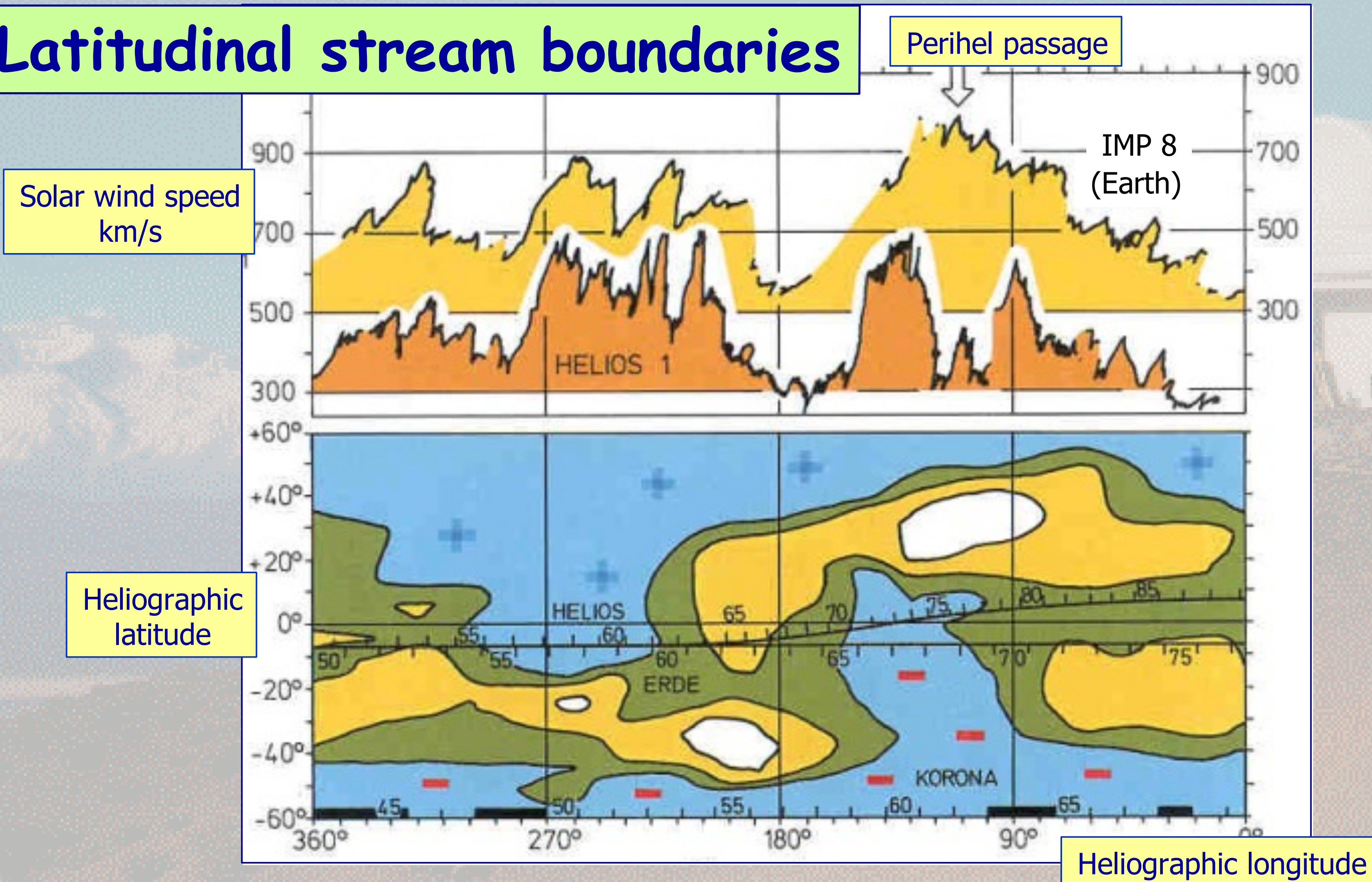


The corona of sun at beginning activity (1998), viewed by **EIT** and **LASCO-C1/C2**

THE ORIGIN OF THE HIGH SPEED SOLAR WIND

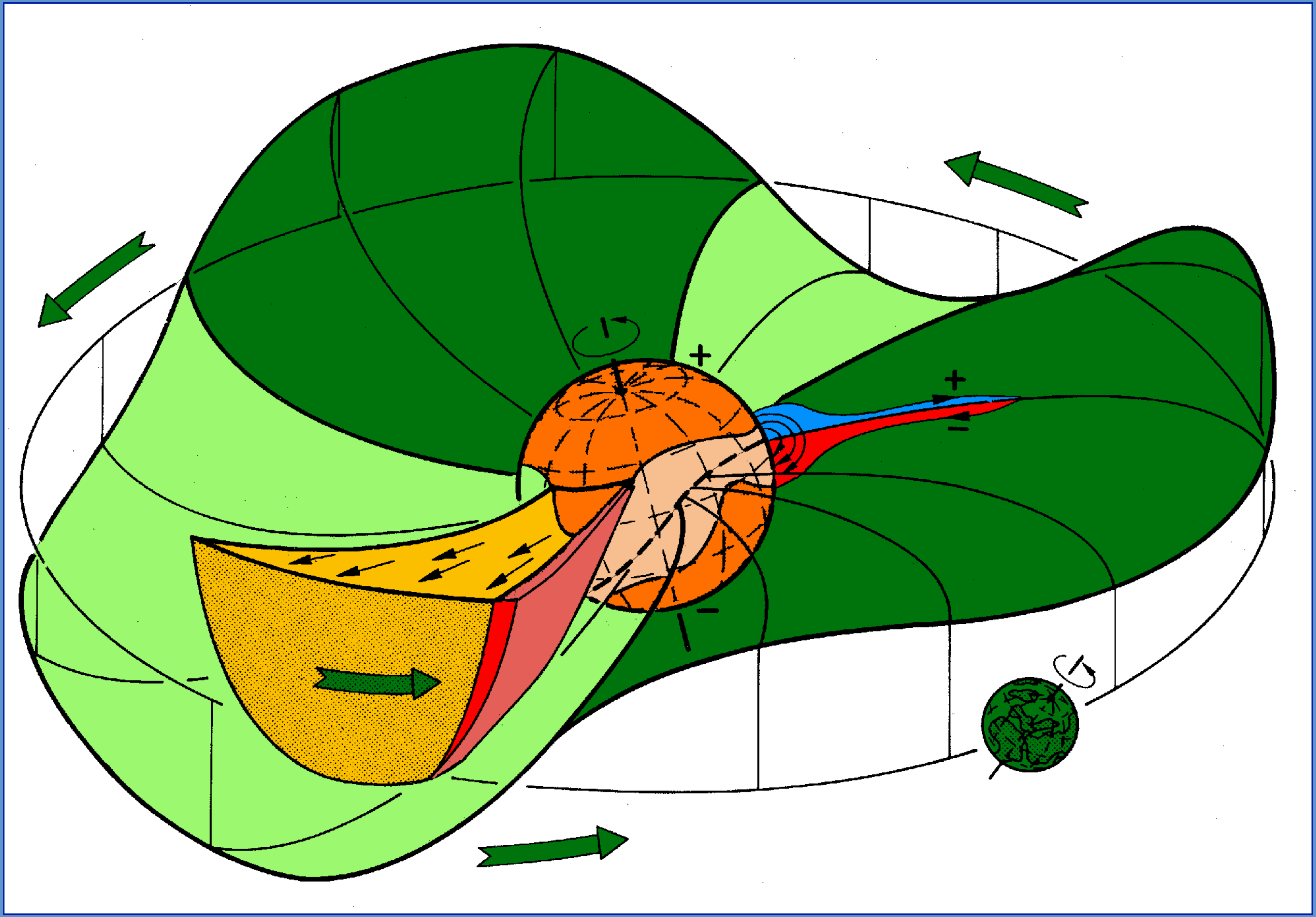


Latitudinal stream boundaries

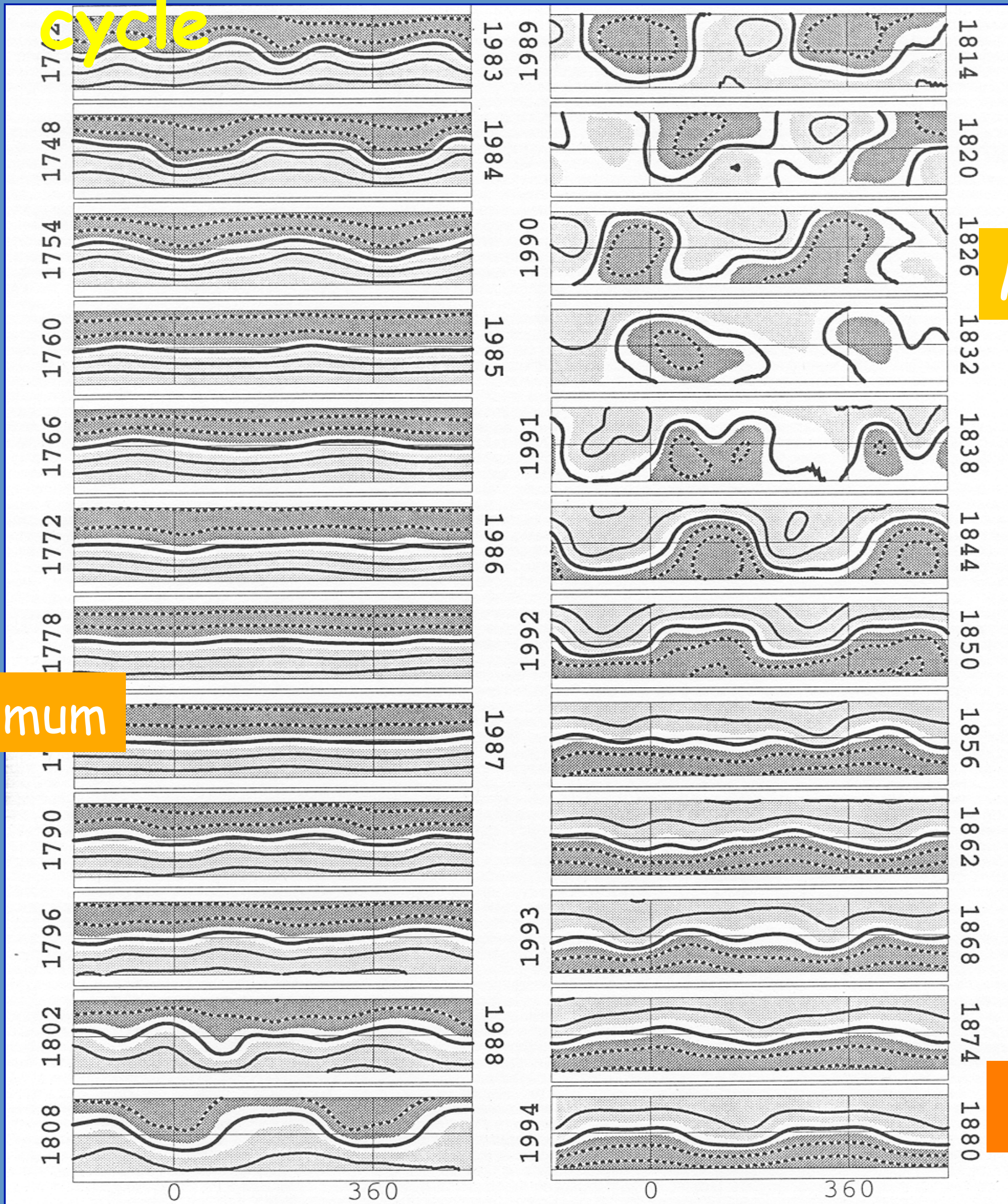


Solar wind stream structure, seen nearly simultaneously from 1 AU and from 0.3 AU (**IMP** and **Helios 1**) in early 1975, associated with coronal hole structure. Note that Helios passed the northern boundary of the fast stream, while IMP at low latitude did not.

THE "BALLERINA SKIRT"



The ballerina dancing through the solar cycle



Maximum

Minimum

Minimum

At activity maximum, the ballerina skirt flips over, and the magnetic polarity is then reversed at next minimum. The magnetic cycle of the sun (the “Hale-cycle”) takes 22 years!

THE HELIOSPRERE IN 3-D

Orbit 1 Orbit 2

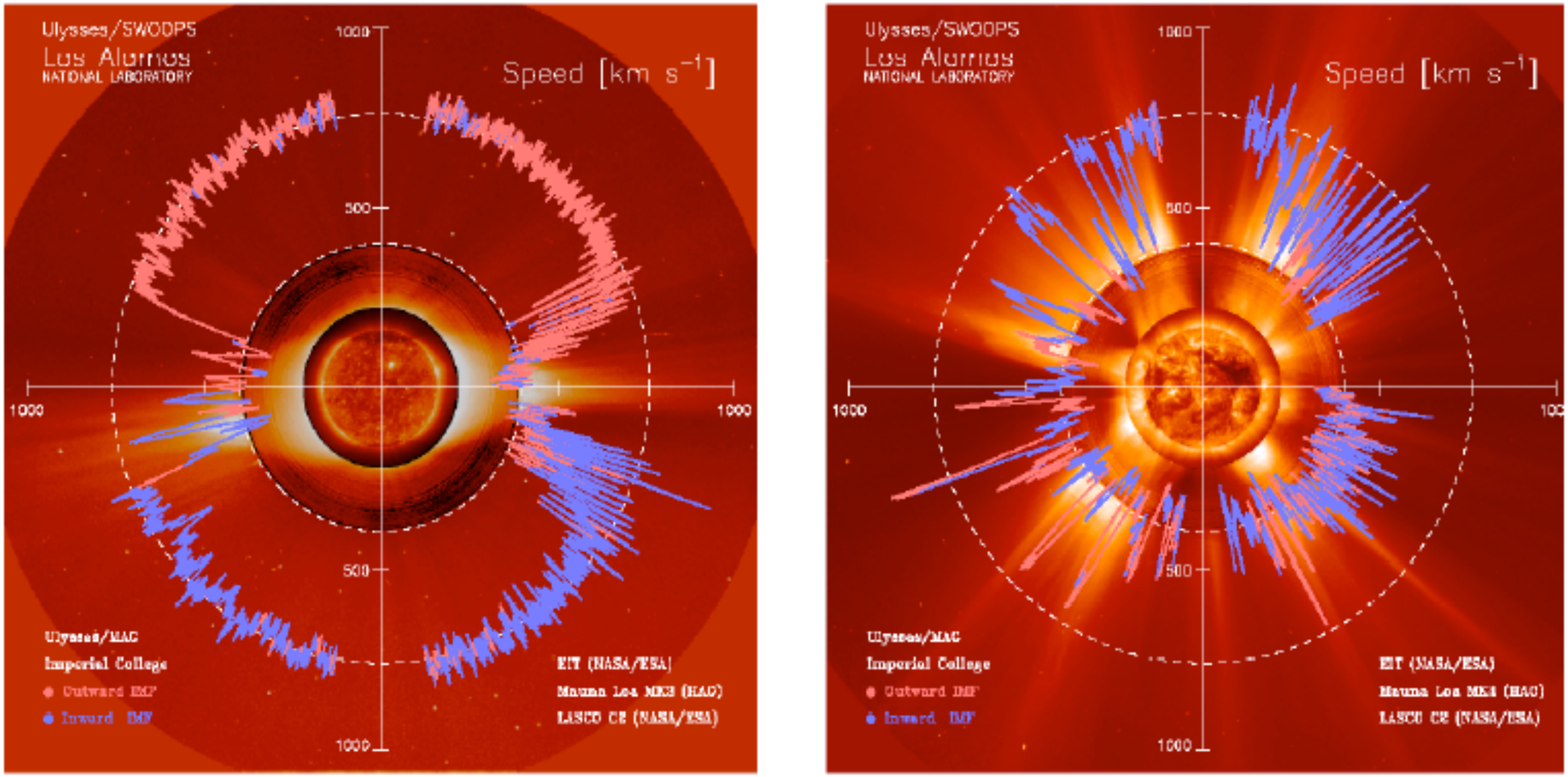
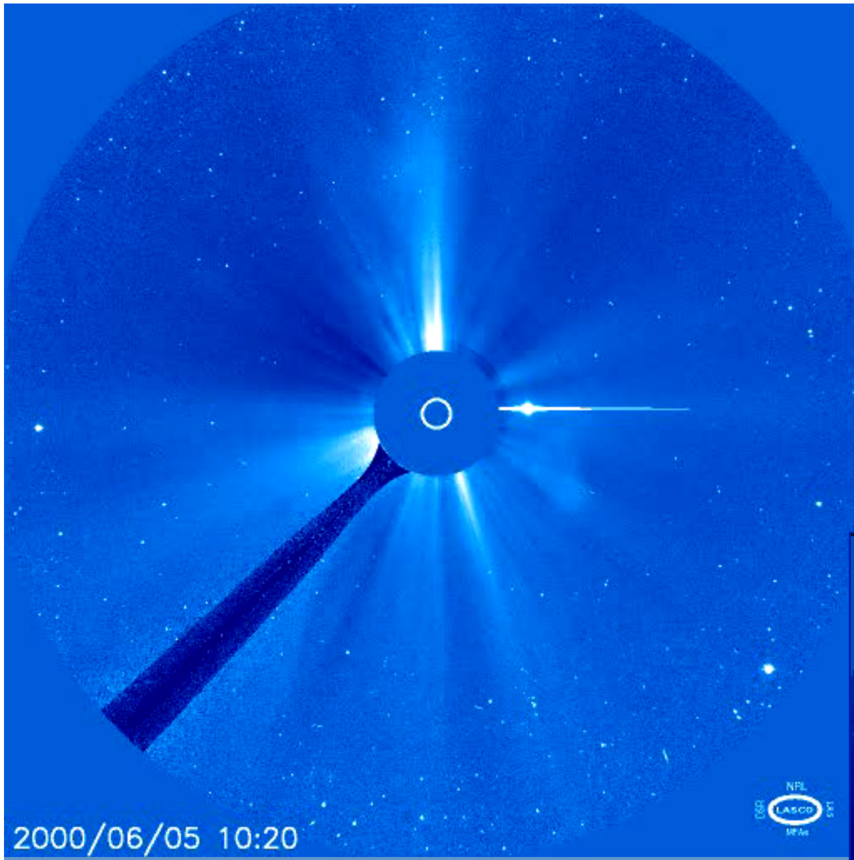
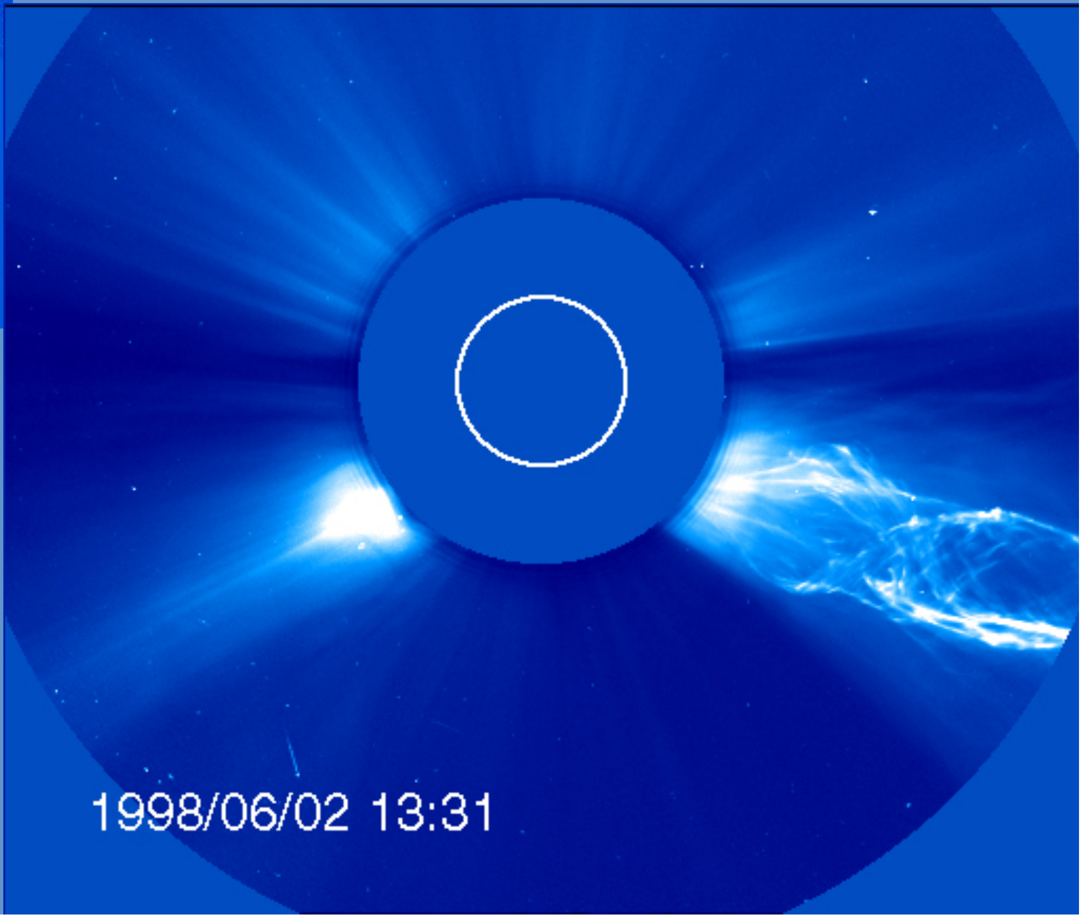


Figure 1.3. Dial plots of solar wind speed with co-temporal coronal images two years prior to solar minimum (Orbit 1) and at solar maximum (Orbit 2). Time runs clockwise from 3 o'clock, along with heliographic latitude. The solar wind speed scales are 500 km/s (1000 km/s) on the inner (outer) dashed circle. The 6.2 year orbits start in 1992 and 1998. The gaps at the north and south poles reflect the maximum Ulysses latitude of 80.2°. The final U-II data point is from December 2002.

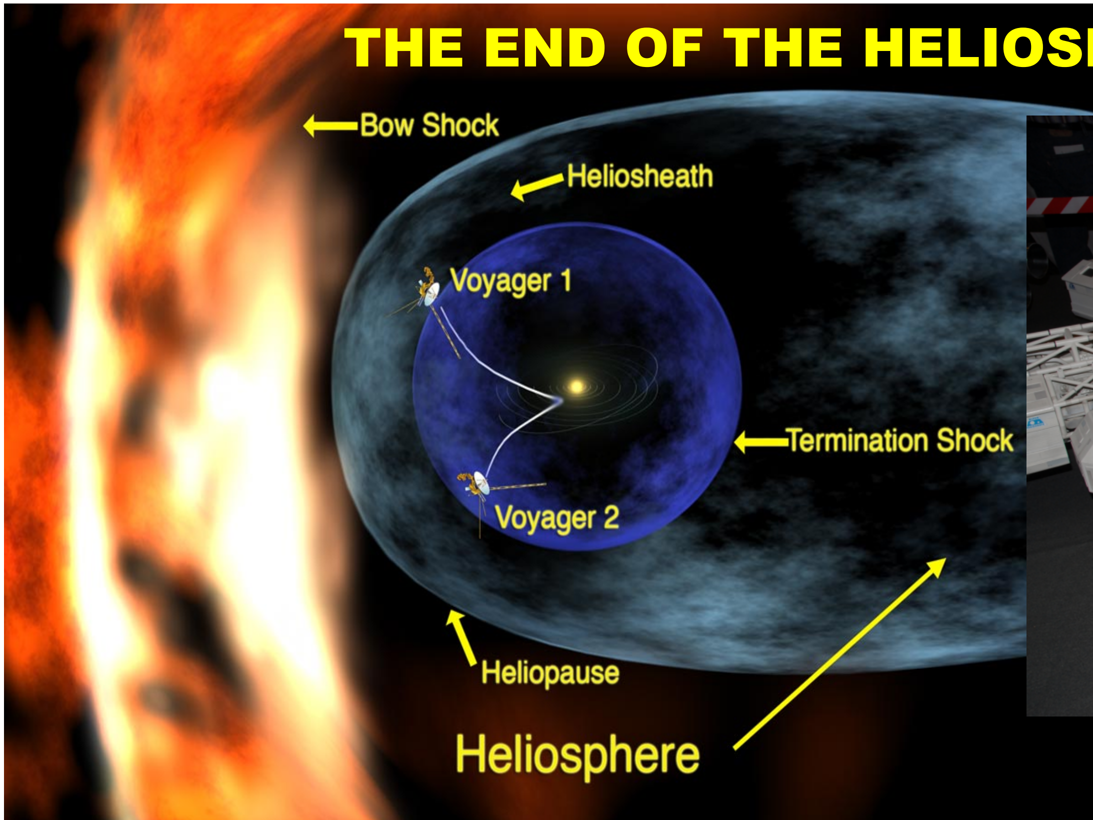
CORONAL MASS EJECTIONS

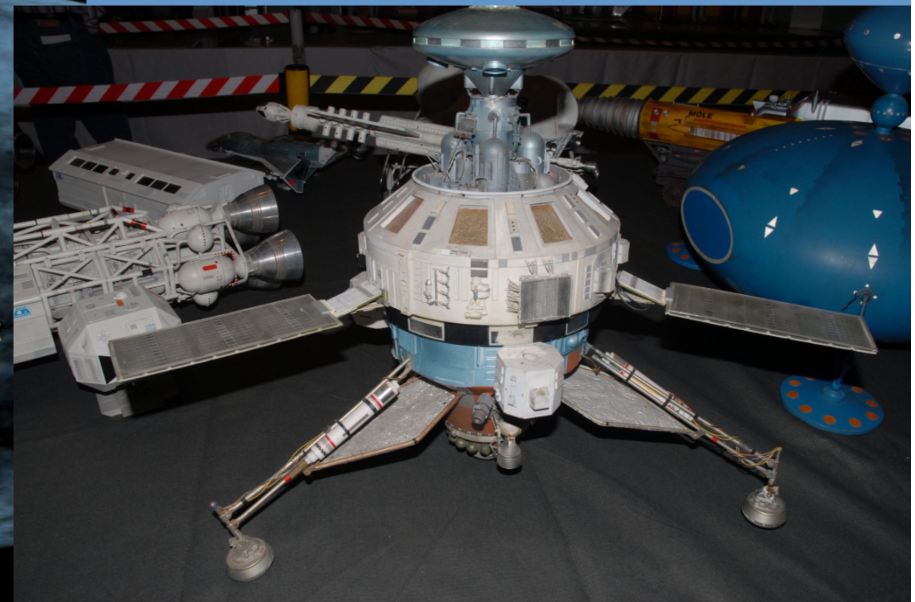
High spped streams in the solar wind,
(Interplanetary shocks)

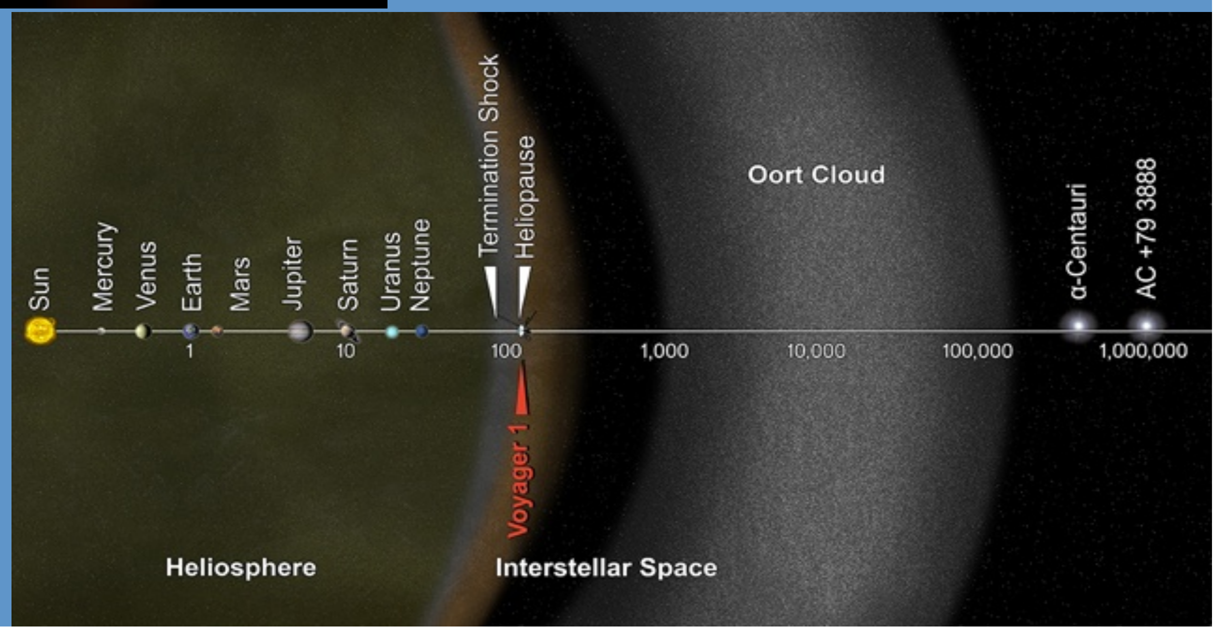


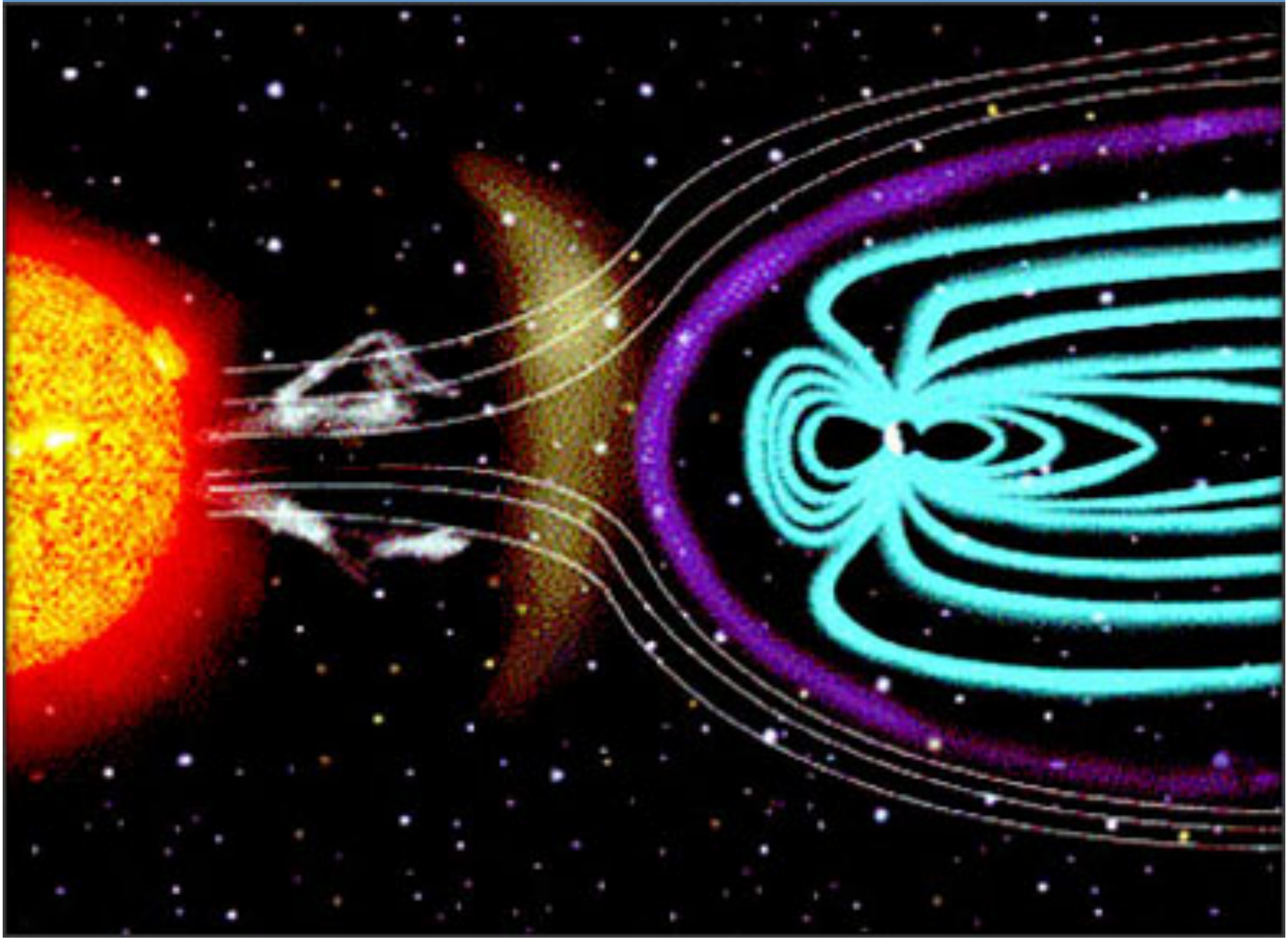


THE END OF THE HELIOSPHERE









Some Major Solar Storms

9/2/1859 - Strongest solar storm recorded, with aurora worldwide and telegraph disruptions

5/13/1921 - Storm shuts down NY City transit system with induced ground currents

3/25/1940 - Easter Sunday storm halts U.S. long distance phone service for hours, radio and wire services disrupted

2/10/1958 - Radio blackout caused by one of the 10 strongest storms

3/13/1989 - Quebec power grid collapses for nine hours

10/29/2003 - “Halloween” storms cause numerous satellite problems and produce the strongest X-ray flare ever recorded

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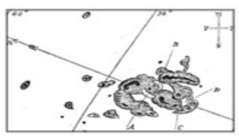
Milestones of Solar Exploration

1610

Galileo Galilei is among the first to study the Sun & sunspots with a telescope

1859

First solar flare observed and sketched by Richard Carrington



1908

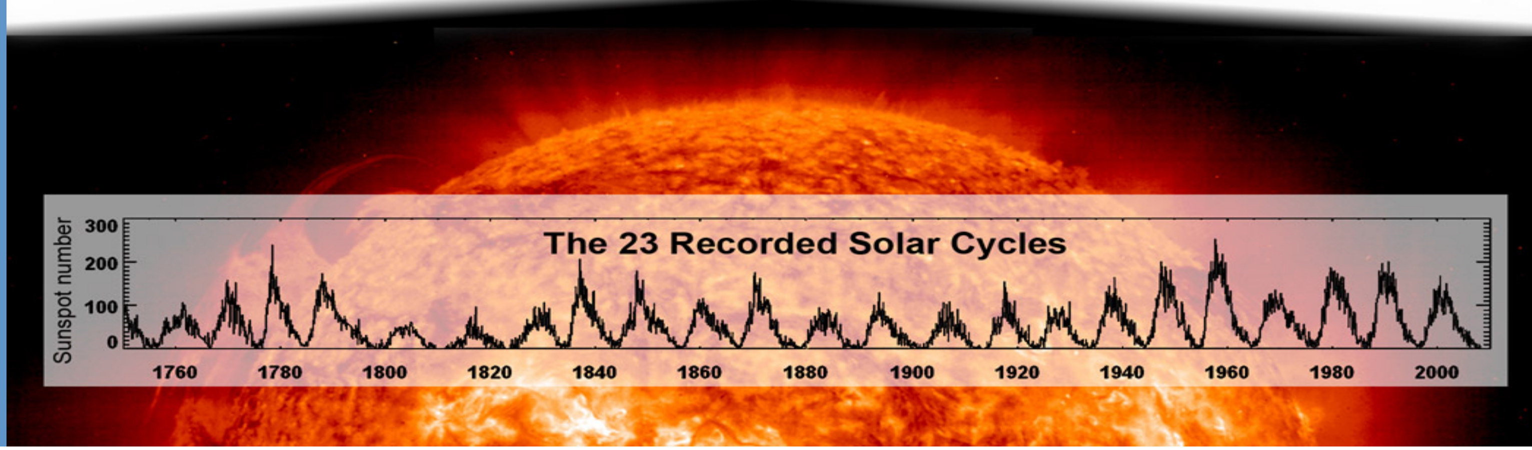
George Ellery Hale discovers magnetic fields in sunspots -- a key to understanding solar activity

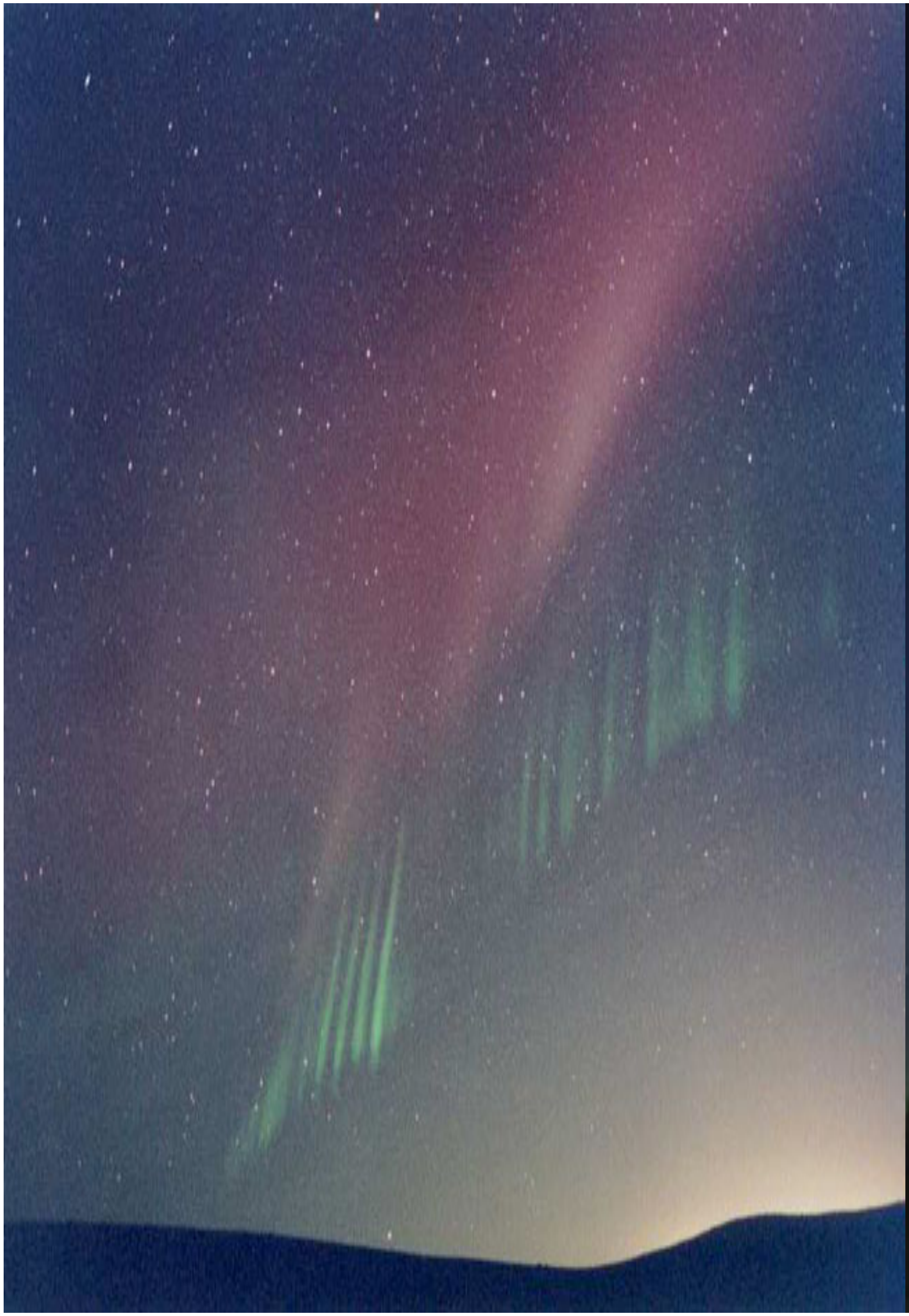
1971-74

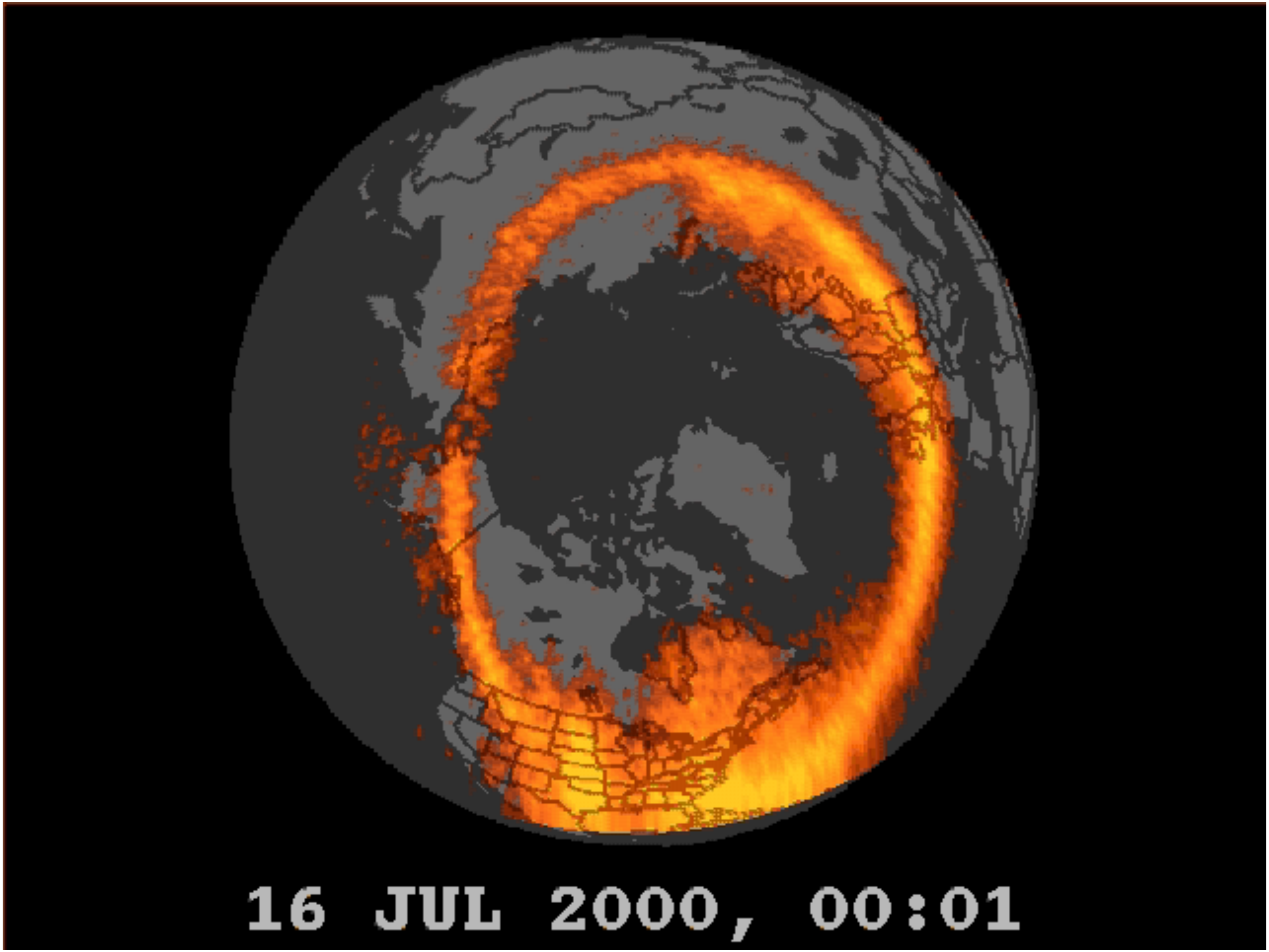
OSO-7, Skylab are first spacecraft to study solar storms

1995

The Solar & Heliospheric Observatory (SOHO) begins sophisticated solar study mission



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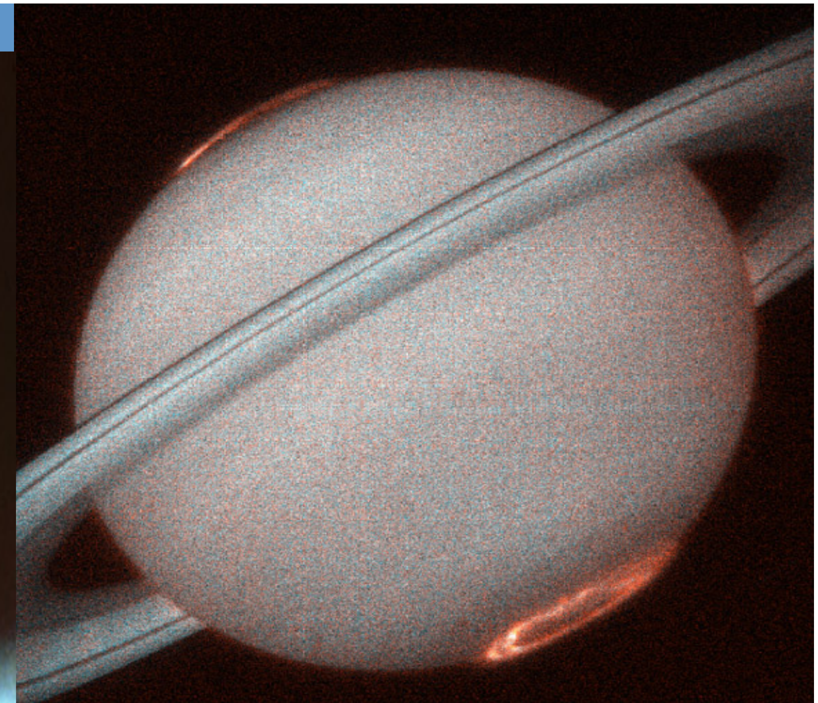
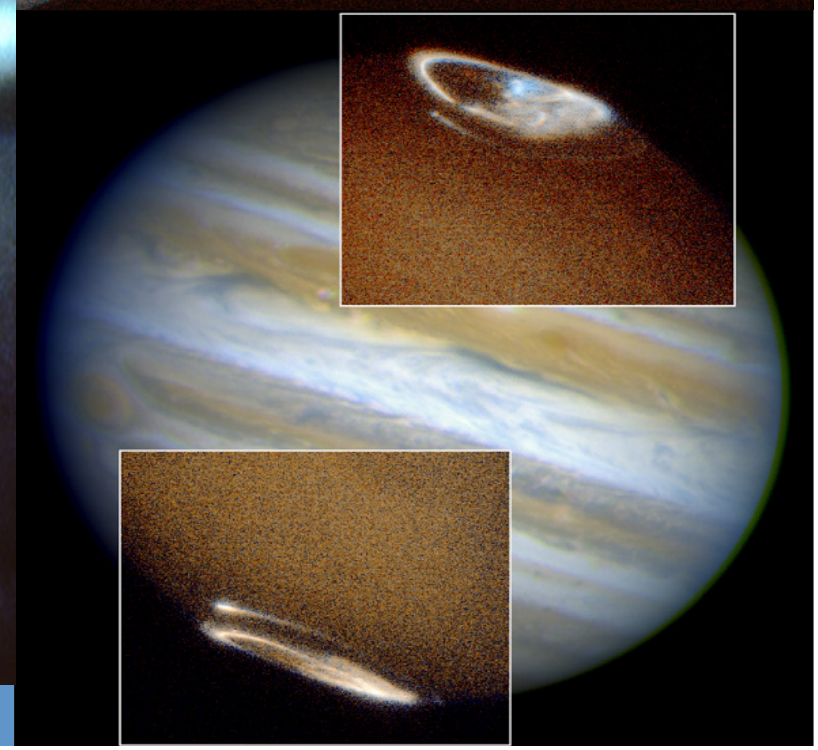
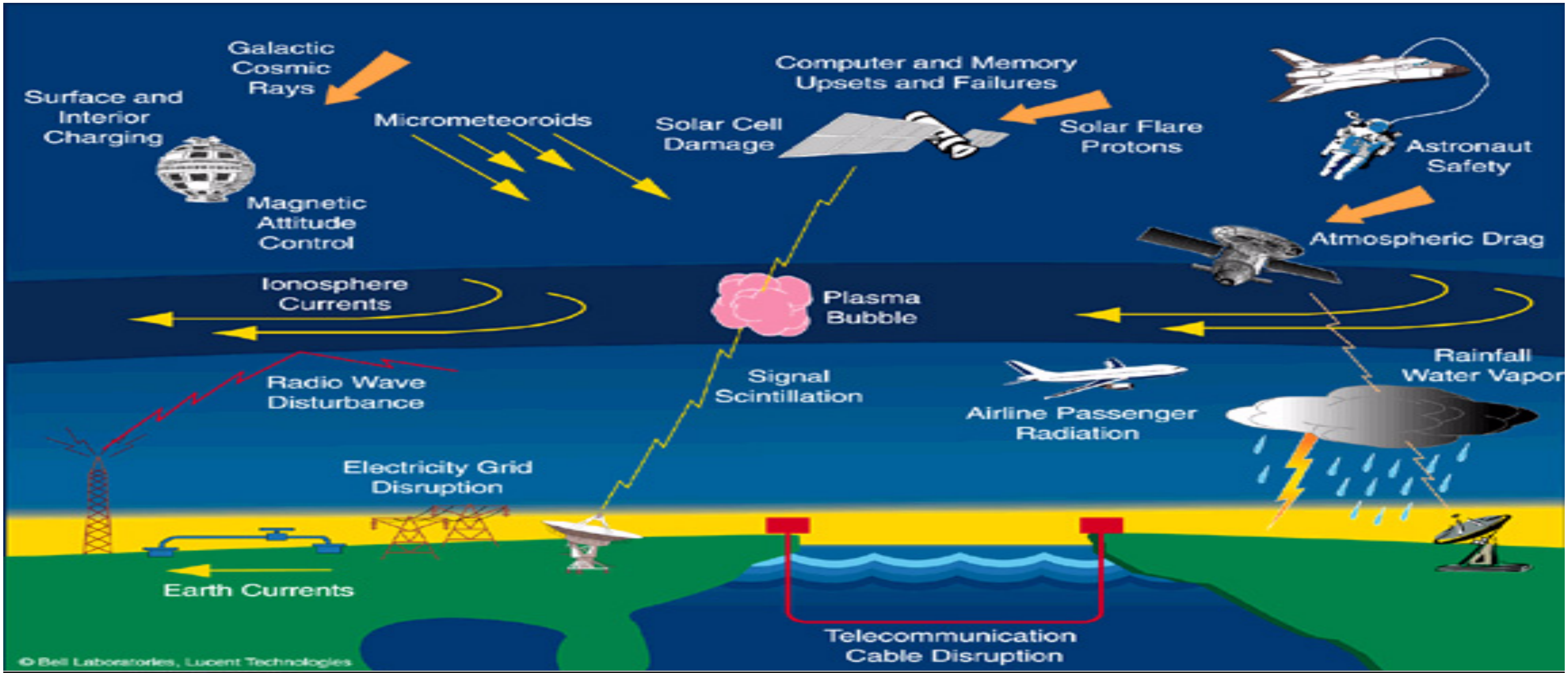


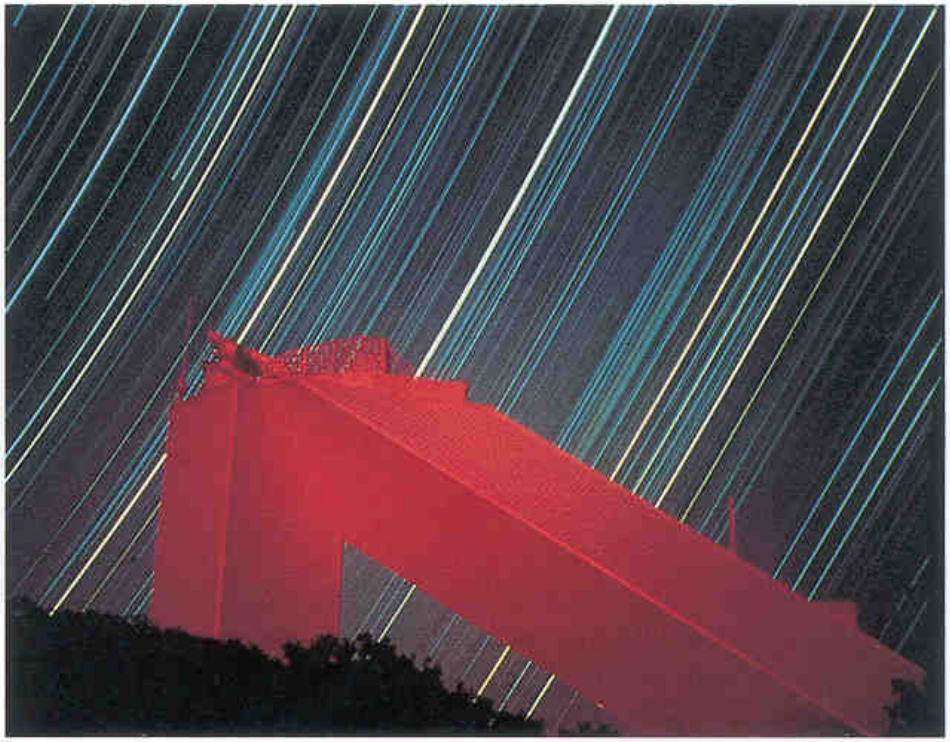


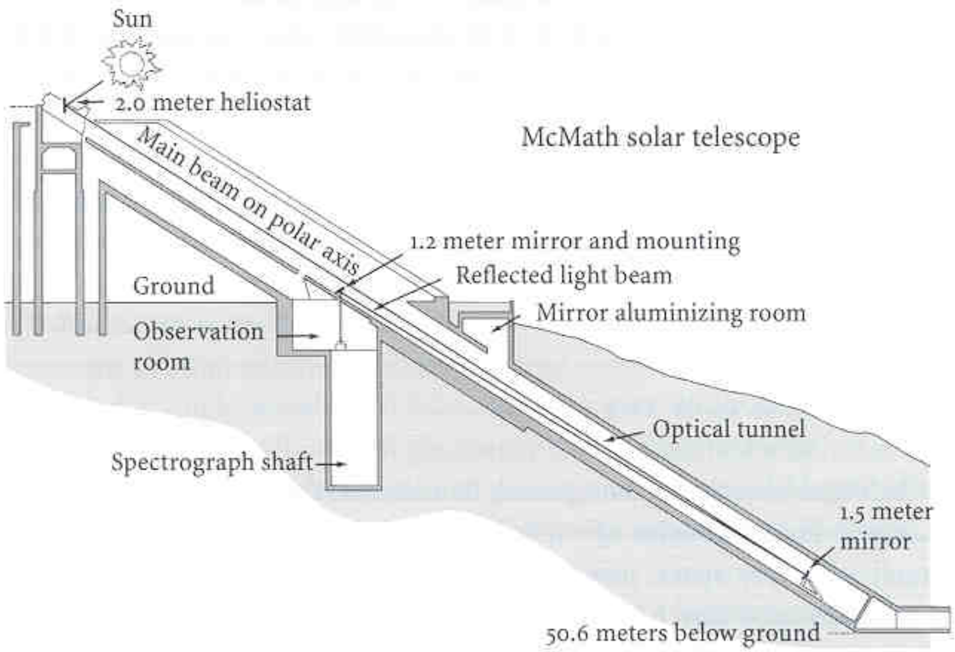

Galactic Cosmic Rays
Surface and Interior Charging
Micrometeoroids
Magnetic Attitude Control
Solar Cell Damage
Computer and Memory Upsets and Failures
Solar Flare Protons
Astronaut Safety
Atmospheric Drag
Ionosphere Currents
Plasma Bubble
Radio Wave Disturbance
Signal Scintillation
Airline Passenger Radiation
Rainfall Water Vapor
Electricity Grid Disruption
Earth Currents
Telecommunication Cable Disruption
© Bell Laboratories, Lucent Technologies


Communications
Intelsat k
Intelsat V
GOES East (75 W Long)
Weather
NOAA-11
DMSP
Navigation
GPS
Polar
Scientific Research
SOHO
Sampex
Remote Sensing
Landsat

Solar observatories around the world

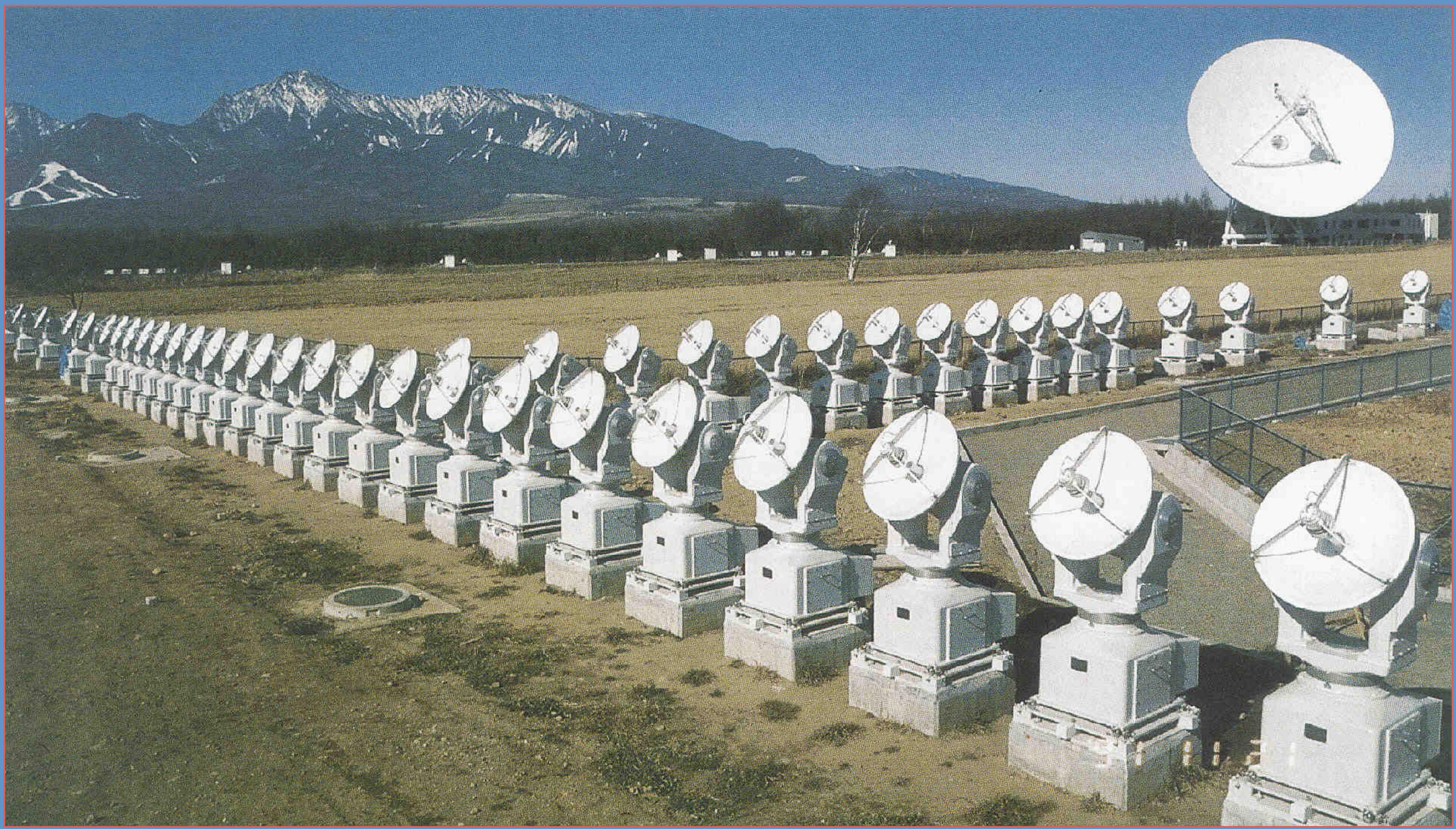
Bernhard Lyot first saw the solar corona here with a coronograph 1930s, without an eclipse



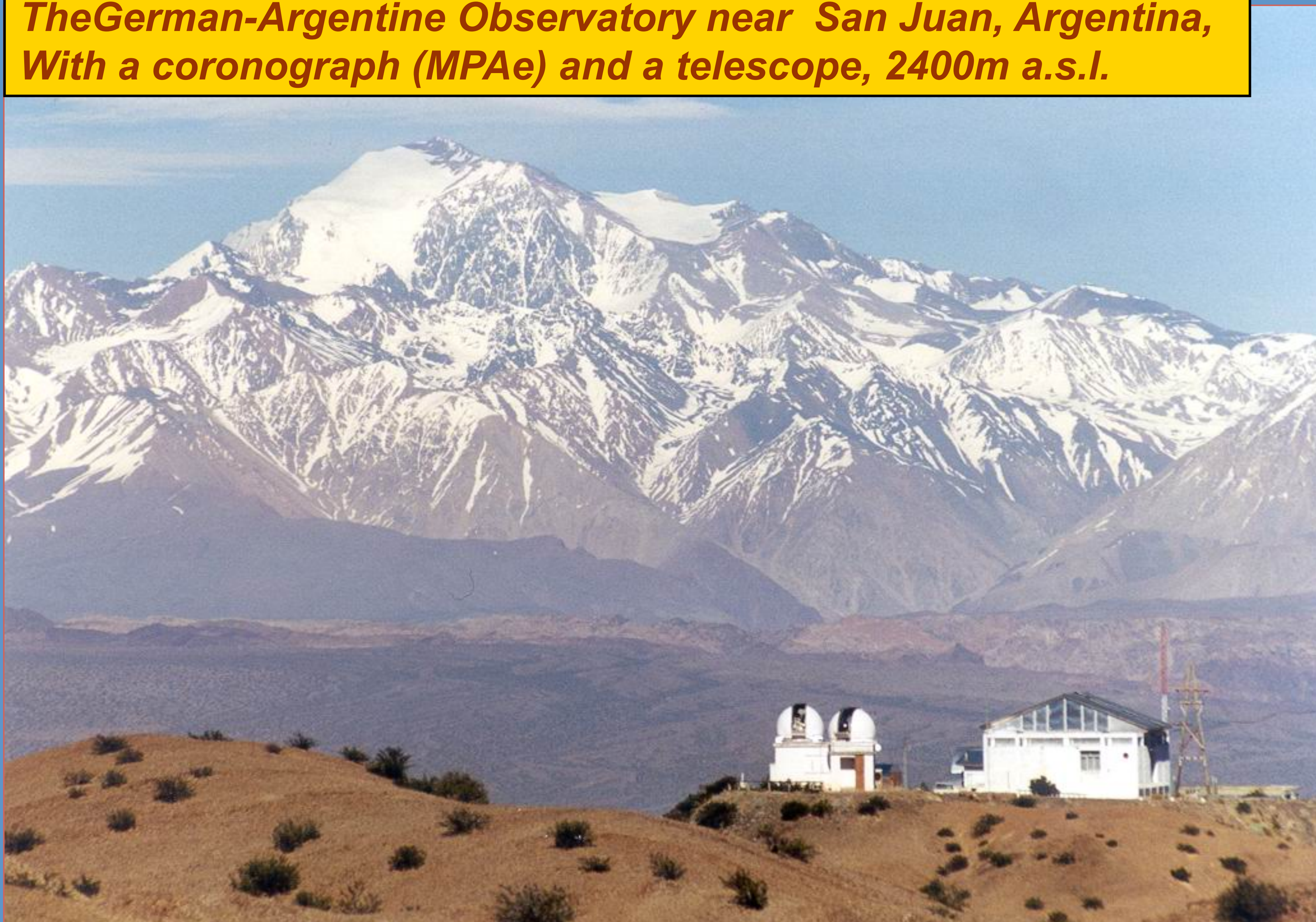


The world greatest Solar telescope Kitt Peak, Tucson, Arizona, 2700m a.s.l.

Radioheliograph at Nobeyama (Japan)
1200m a.s.l.

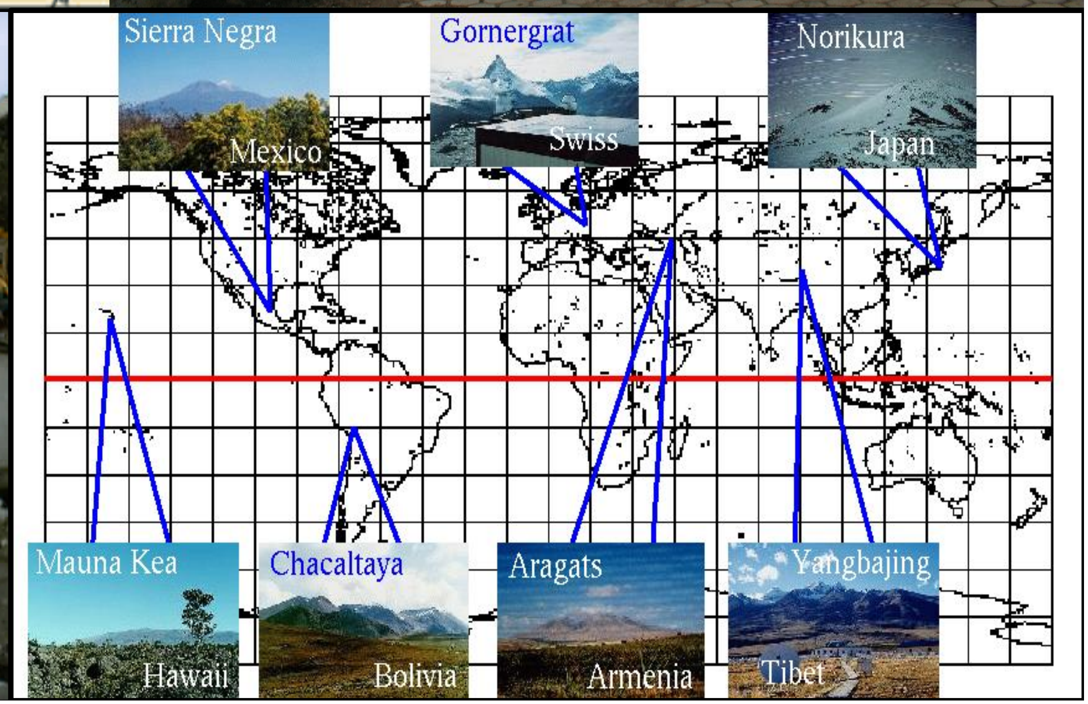


TheGerman-Argentine Observatory near San Juan, Argentina, With a coronograph (MPAe) and a telescope, 2400m a.s.l.



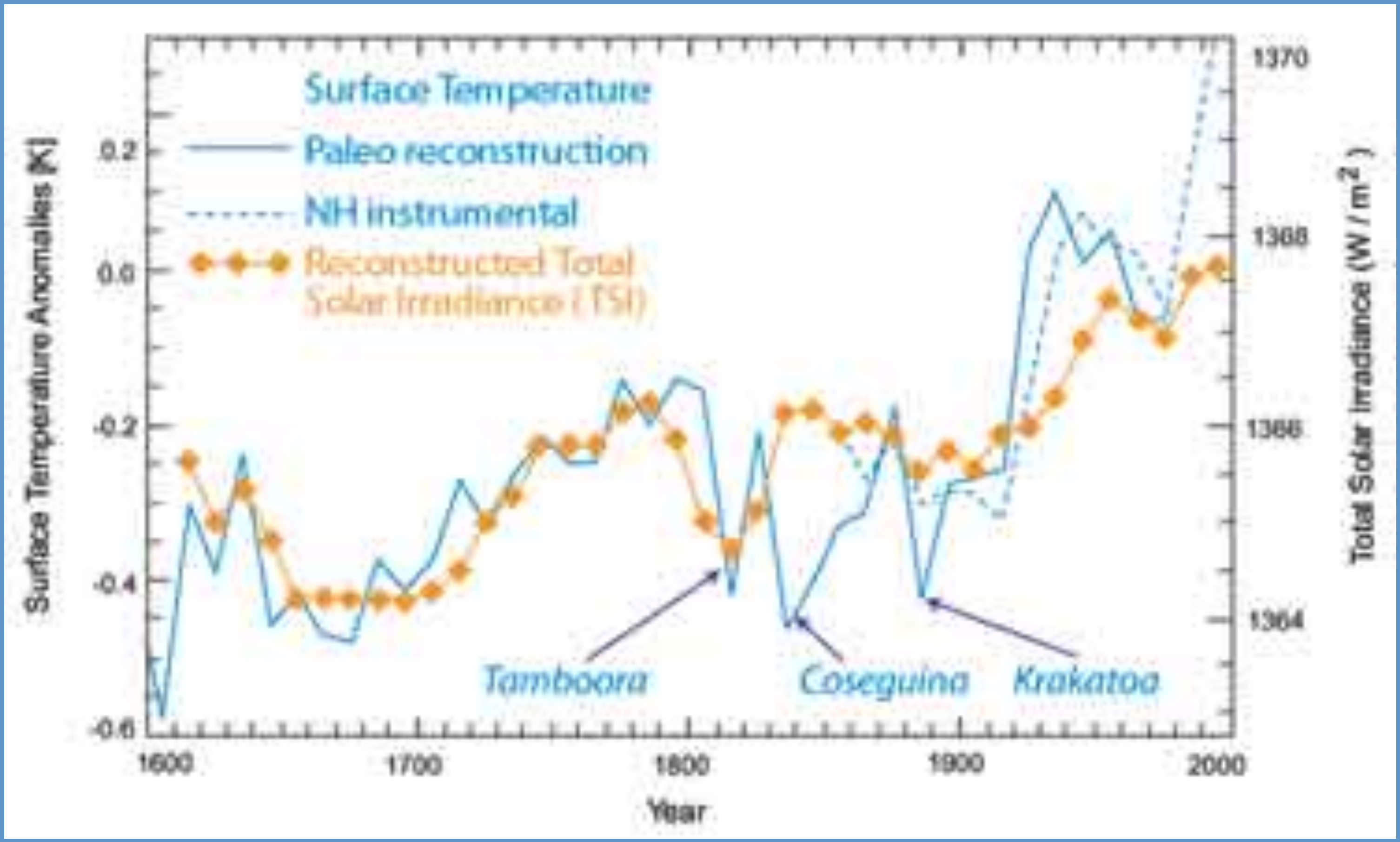

Tijuana
Ensenada
UNITED STATES
Ciudad Juárez
Guaymas
Chihuahua
Topolobampo
Monterrey
Matamoros
Gulf of Mexico
CUBA
La Paz
Durango
North Pacific Ocean
Mazatlán
Tampico
Progreso
Mérida
León
Tuxpan
Guadalajara
LMT
Caribbean Sea
MEXICO
Veracruz
Puebla
Manzanillo
Lázaro Cárdenas
BELIZE
Oaxaca
0 200 400 km
0 200 400 mi
Acapulco
Salina Cruz
GUATEMALA
HONDURAS


TNS
4600 m a.s.l.


Sierra Negra
Mexico
Gornergrat
Swiss
Norikura
Japan
Mauna Kea
Hawaii
Chacaltaya
Bolivia
Aragats
Armenia
Yangbajing
Tibet

Solar activity and C^{14}

EVENT	DURATION	*MAGNITUDE*
Máximo Sumerio	2720-2610 AC	1.3
Máximo Piramidal	2370-2060 AC	1.1
Máximo de Stonehenge	1870-1720 AC	1.3
Mínimo Egipcio	420-1260 AC	-1.4
Mínimo Homérico	820-240 AC	-2
Mínimo Griego	440-360 AC	-2.1
Máximo Romano	20 AC-80 DC	0.7
Mínimo Medieval	640-710 AC	-0.7
Máximo Medieval	1120-1280 DC	0.8
Mínimo de Spoerer	1418-1535 DC	-1.1
Mínimo de Maunder	1645-1710 DC	-1
Mínimo de Dalton	1795-1825 DC	-0.8
Máximo Moderno	1900 en adelante	1



http://lasp.colorado.edu/home/science/solar-influences/

SUMMARY

- The Sun, Our Star is fundamental for life on Earth
- The Sun is an active star with an 11y activity cycle and a 22y magnetic cycle.
- Solar Activity manifestations are manifold
- Solar Activity influenced climate in the past.
- Nowadays the influence of antropogenic activity is much more important

MUCHAS GRACIAS

MUITO OBRIGADO

geoFISICA UNAM