Physics 777

Lecture 0

Introduction of the Sun


Disk Photometer
65 cm Vacuum Reflector
25 cm Vacuum Refractor
15 cm Singer Full Disk Telescope
Seeing Sensor
TON
7.5 cm Photometric Full Disk Telescope
15 cm Earthshine Telescope
GONG
http://www.bbso.njit.edu/

2 27 Meter Dishes in the Owens Valley Solar Array (OVSA)

Unique in the World

- Array Includes

3 (soon to be 5) 2 meter dishes

- Frequency Agile
- Multiple Baselines

Structure of the Sun

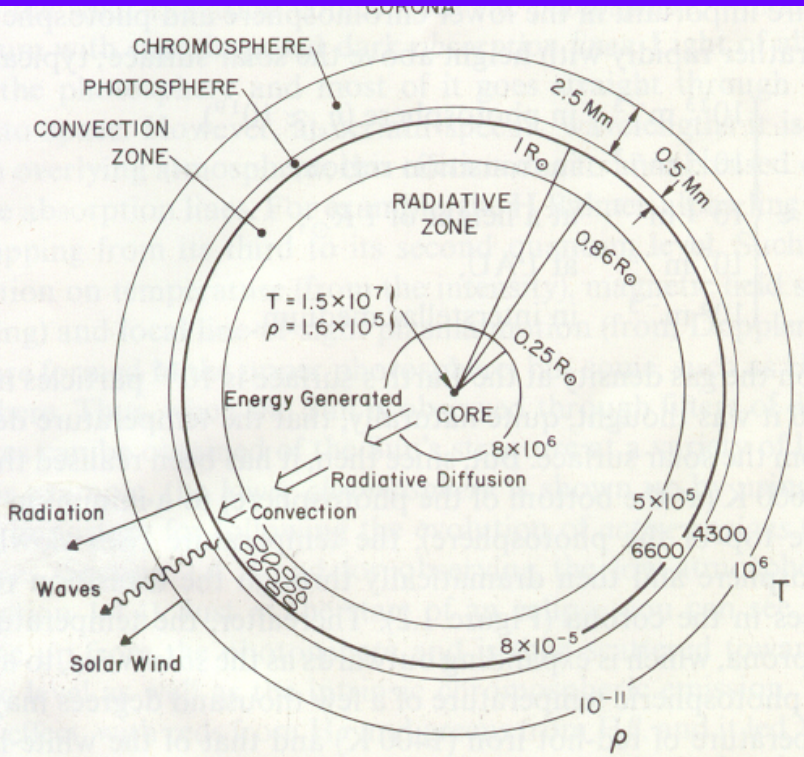


Fig. 1.1. The overall structure of the Sun, indicating the sizes of the various regions and their temperatures (in degrees K) and densities (in kg m^{-3}). The thicknesses of the photosphere and chromosphere are not to scale, and recent models place the base of the convection zone at about 0.7 $R_\odot$ rather than 0.86 $R_\odot$

Temperature of Solar Atmosphere

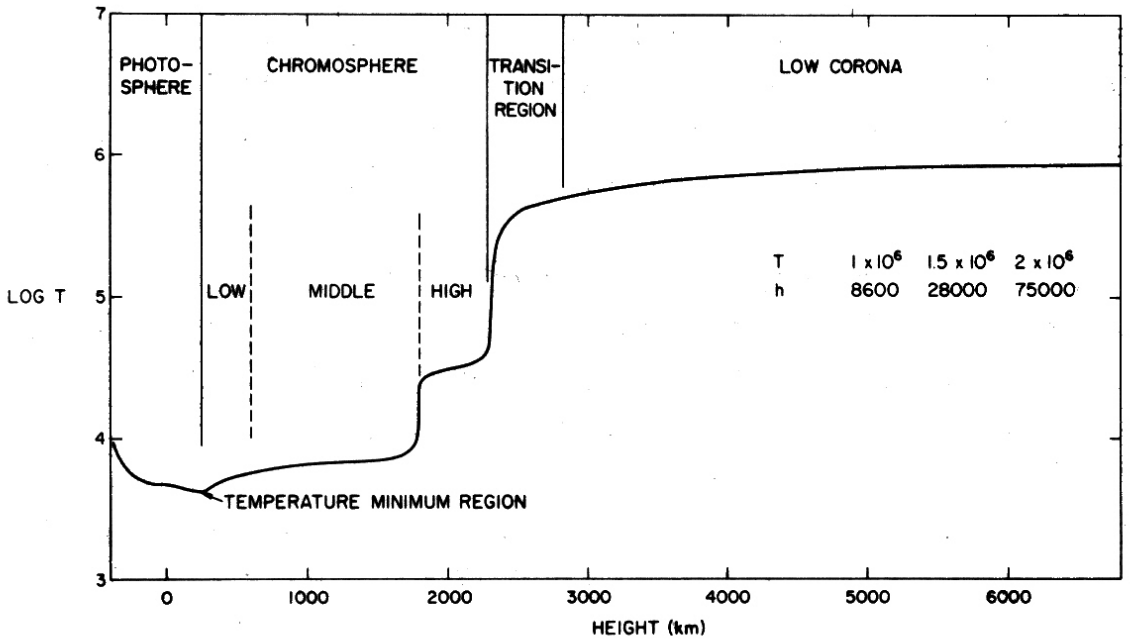


Fig. 1.2. An illustrative model for the variation of the temperature with height in the solar atmosphere (Athay, 1976).

Temperature, Pressure and Density

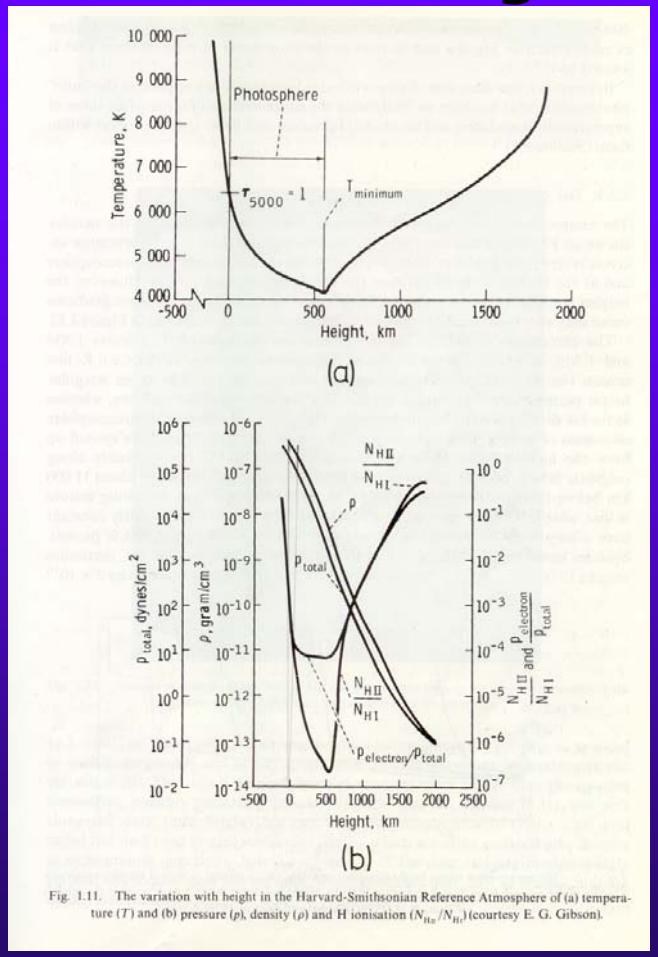


Fig. 1.11. The variation with height in the Harvard-Smithsonian Reference Atmosphere of (a) temperature (T) and (b) pressure (p), density (ρ) and H ionisation ($N_{H\,II}/N_{H\,I}$) (courtesy E. G. Gibson).

BBSO White Light Image of Sun 8/20/1999

Sun's Temperature:

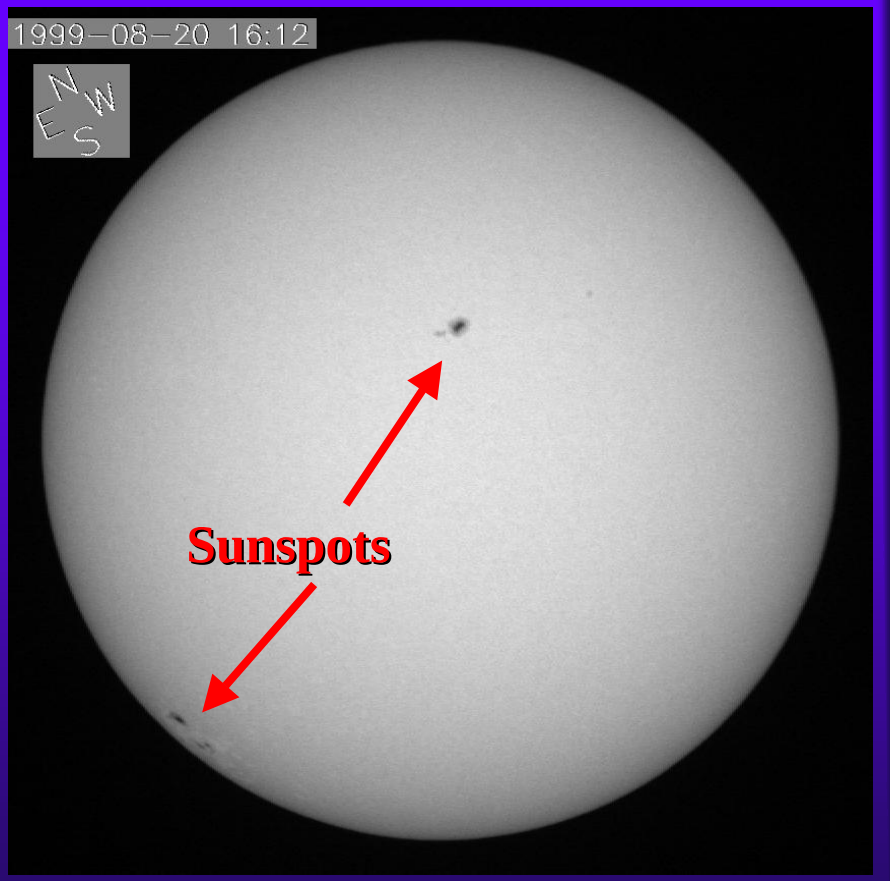
- Center: 15,000,000 K
- Surface: 4,000 K
- Corona: 5,000,000 K

Energy Source:

- Nuclear Fusion

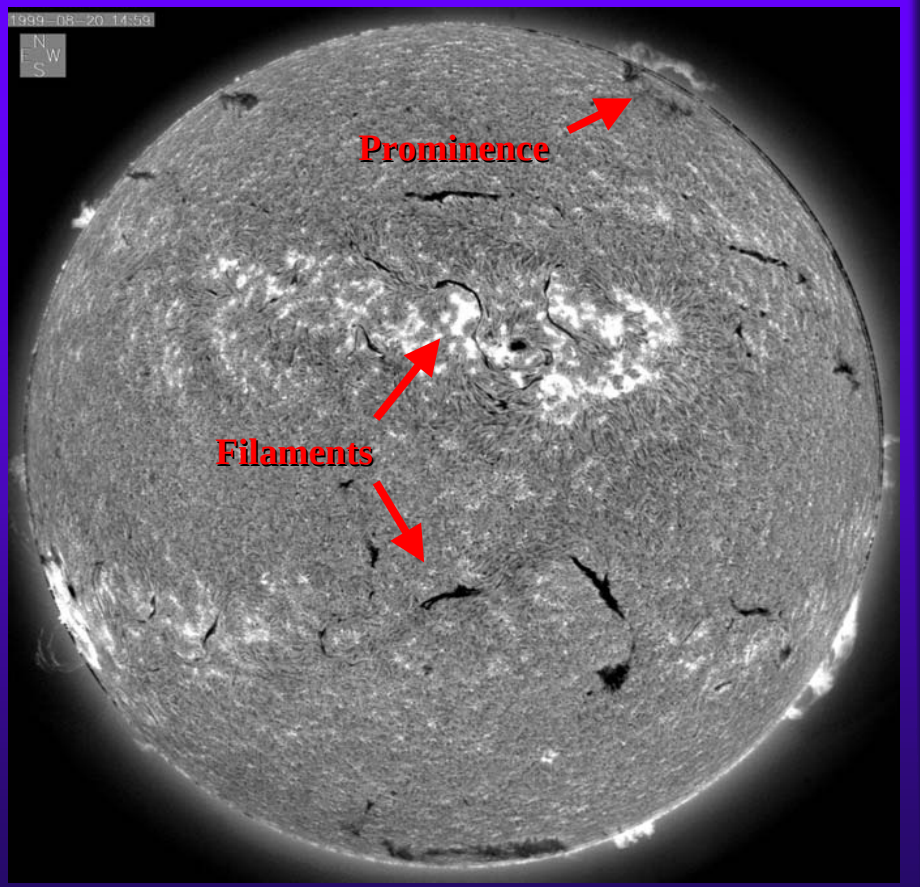
Energy Transport:

- Radiative to 0.7 R
- Convective 0.7-1.0 R



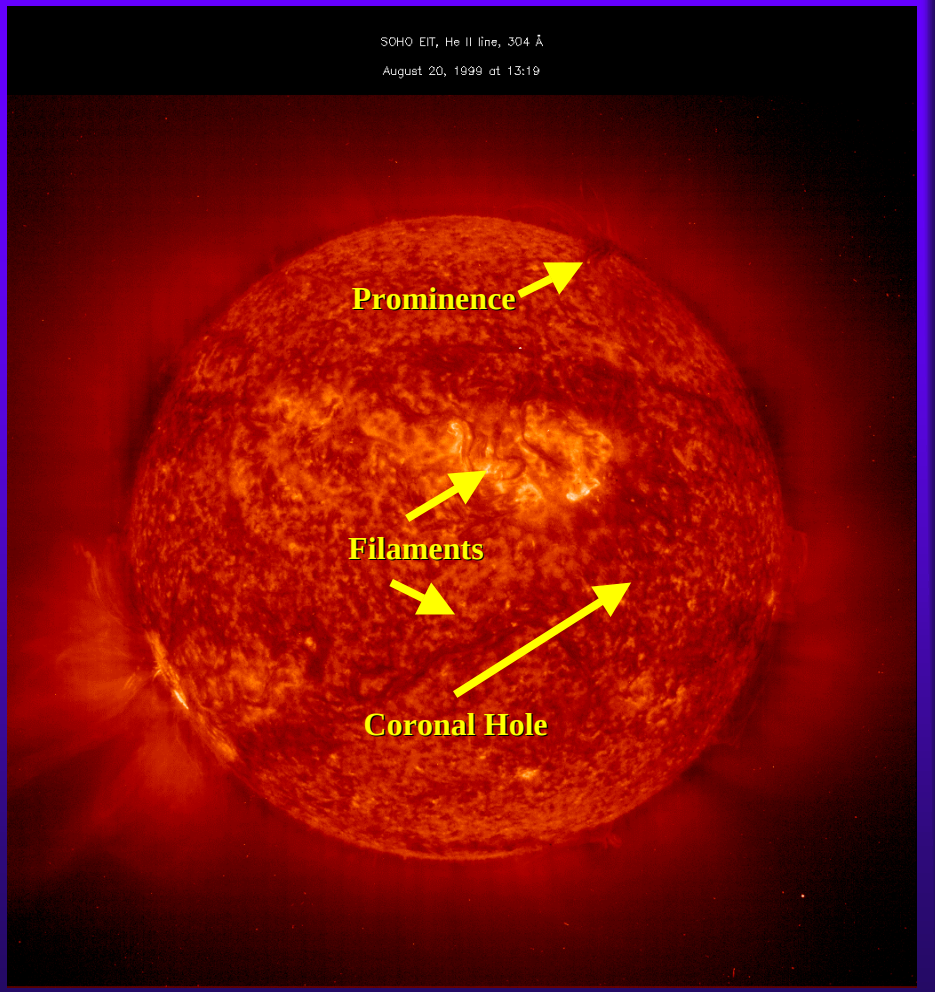
BBSO Hα Image of the Sun

- Image from 8/20/1999 – same day as the white light image
- Filaments and Prominences are cold, dark magnetized material held in magnetic basket above the Sun's visible surface –suspended in the corona
- Prominence bright against dark backdrop
- Hα sensitive to T=10,000 K – the chromosphere



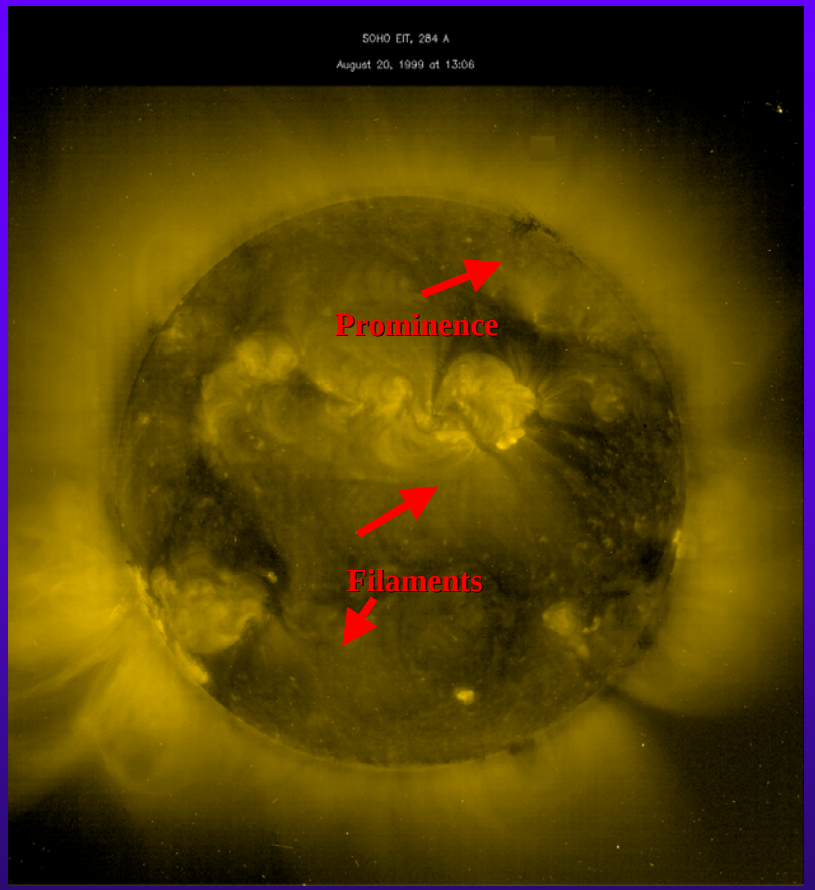
Sun in UV (304 Å) – SOHO/EIT

- 8/20/1999
- Satellite data used in concert with BBSO to understand Sun
- Still see filaments and prominences at T=80,000 K
- See Coronal holes
- See Brightness at Limb



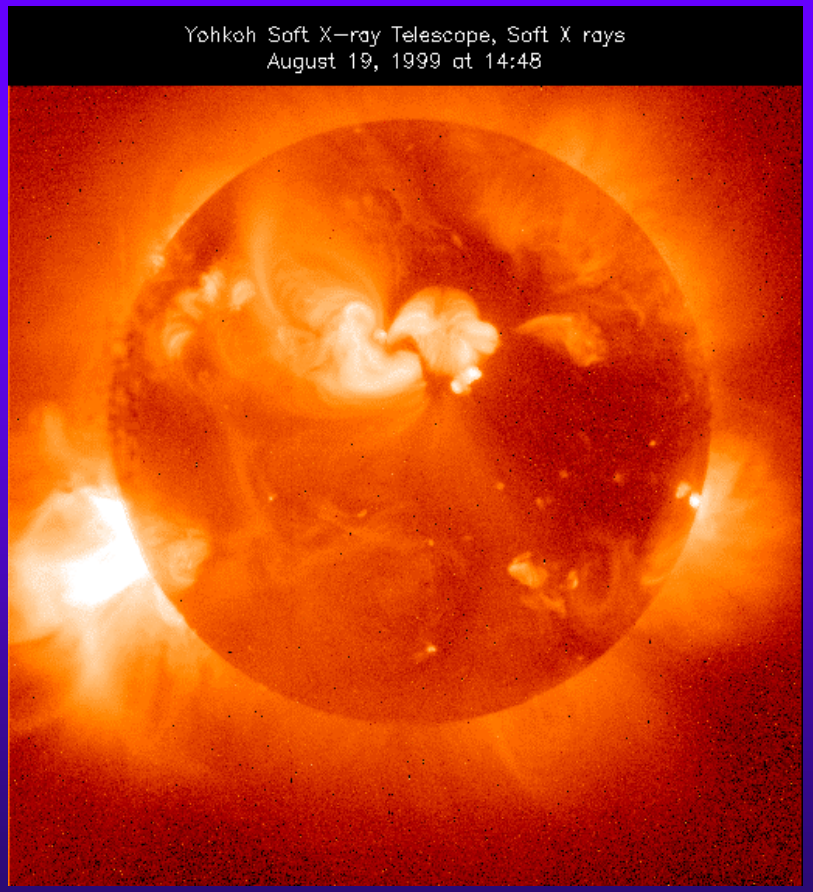
Sun in EUV (284 Å) – SOHO/EIT

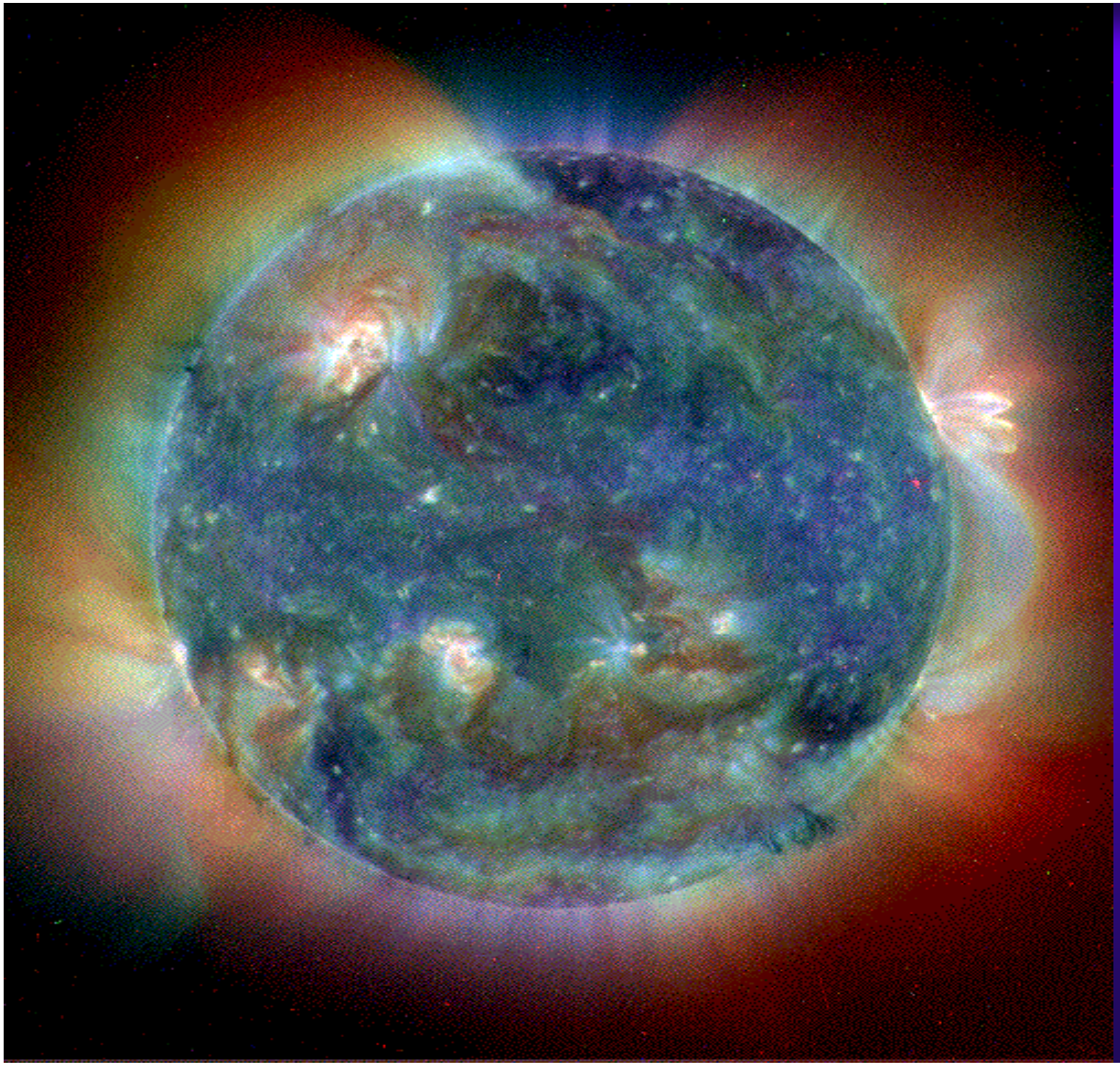
- 8/20/1999
- See prominences and filaments dark against the now bright corona
- Temperature sensitivity near 1,500,000 K
- Filaments and prominences fading as corona brightens



Sun in X-Ray (YOHKOH)

- 8/19/1999
- Prominences and filaments now gone, but corona is very bright
- Temperature sensitivity about 4,000,000 K
- Higher temperature means sampling higher in the solar atmosphere





Multi-
Temperature
Vision
of the Sun

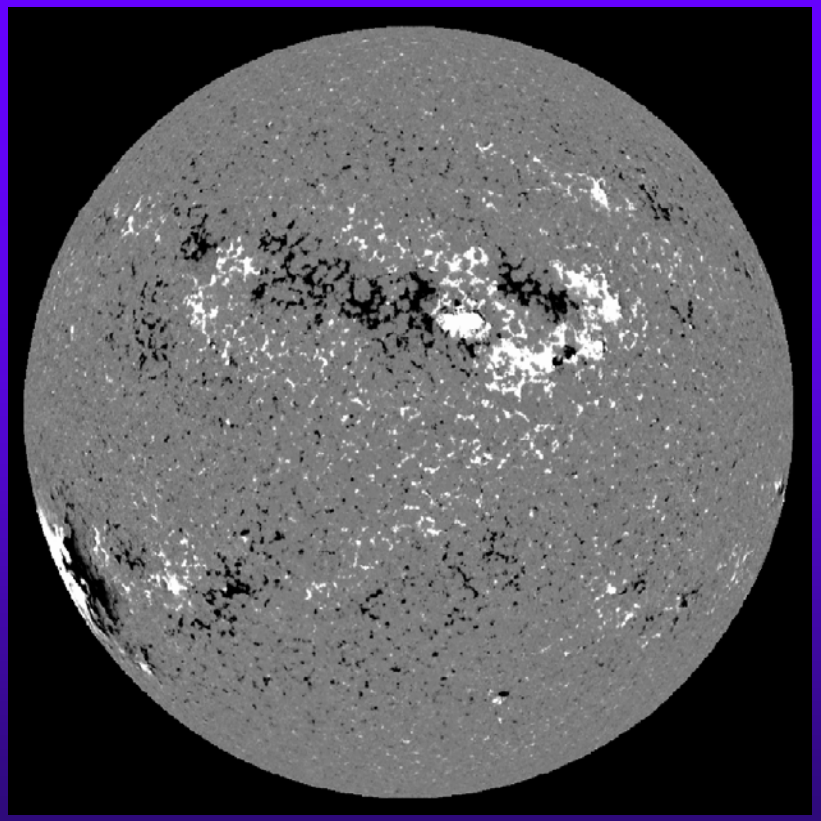
Blue:
EIT 171 A
T=1.0 MK

Green:
EIT 195 A
T=1.5 MK

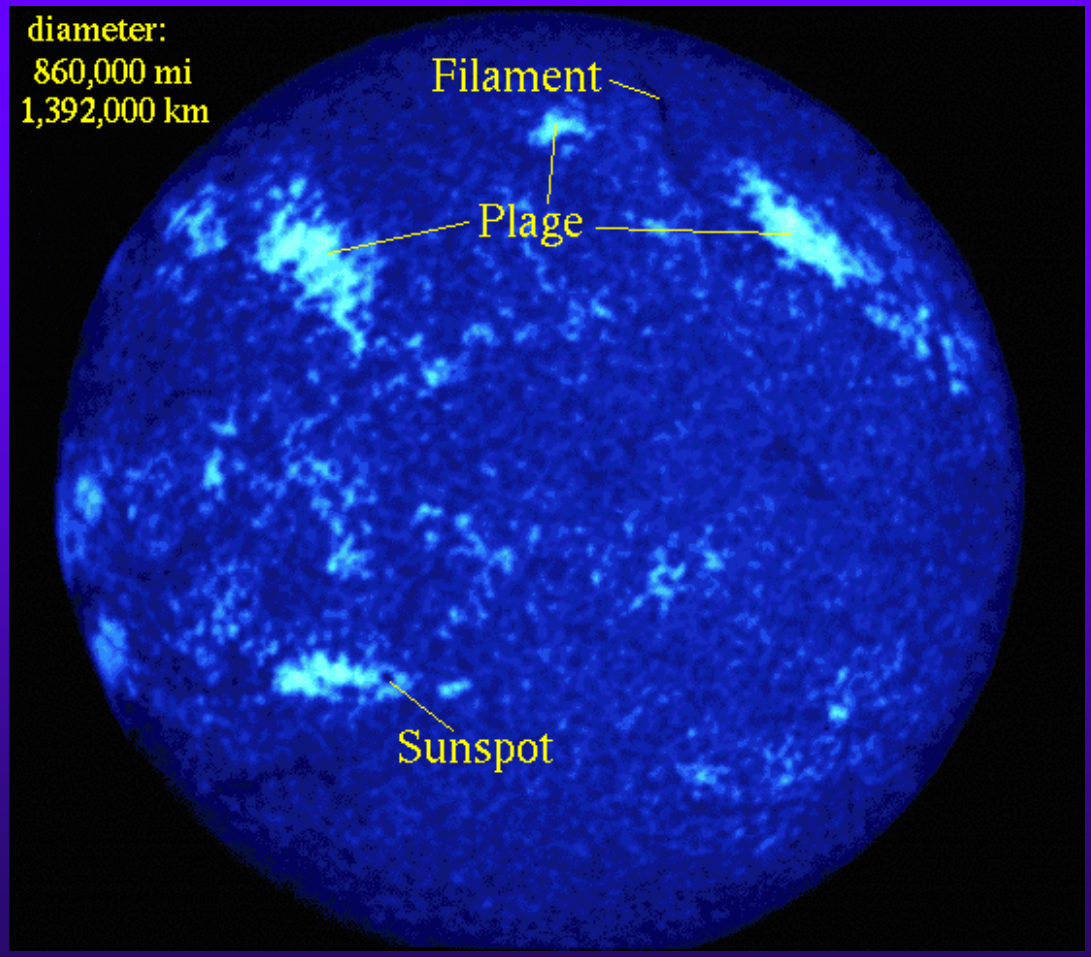
Red:
EIT 284 A
T=2.0 MK

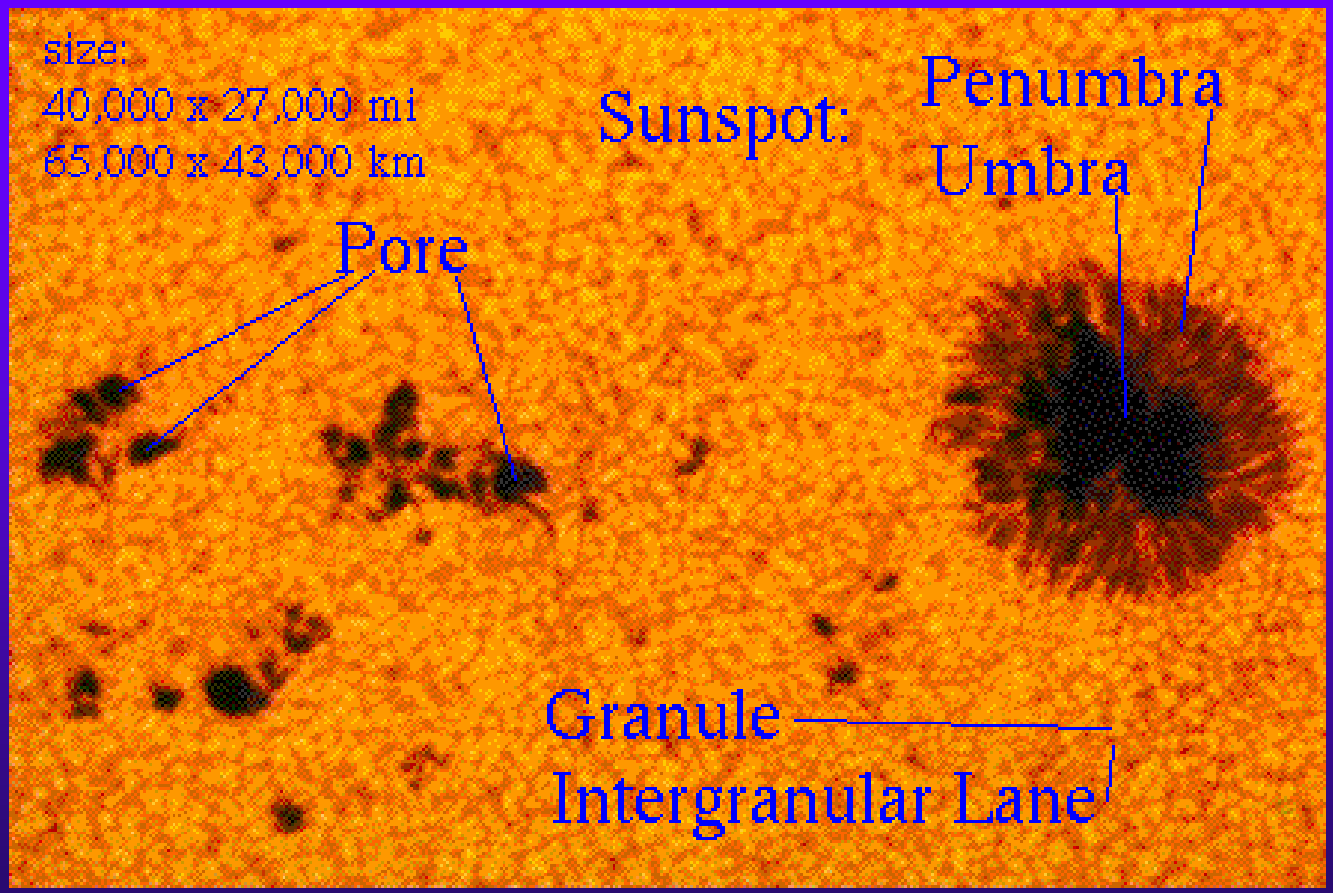
Sun's Magnetic Field -- KPNO

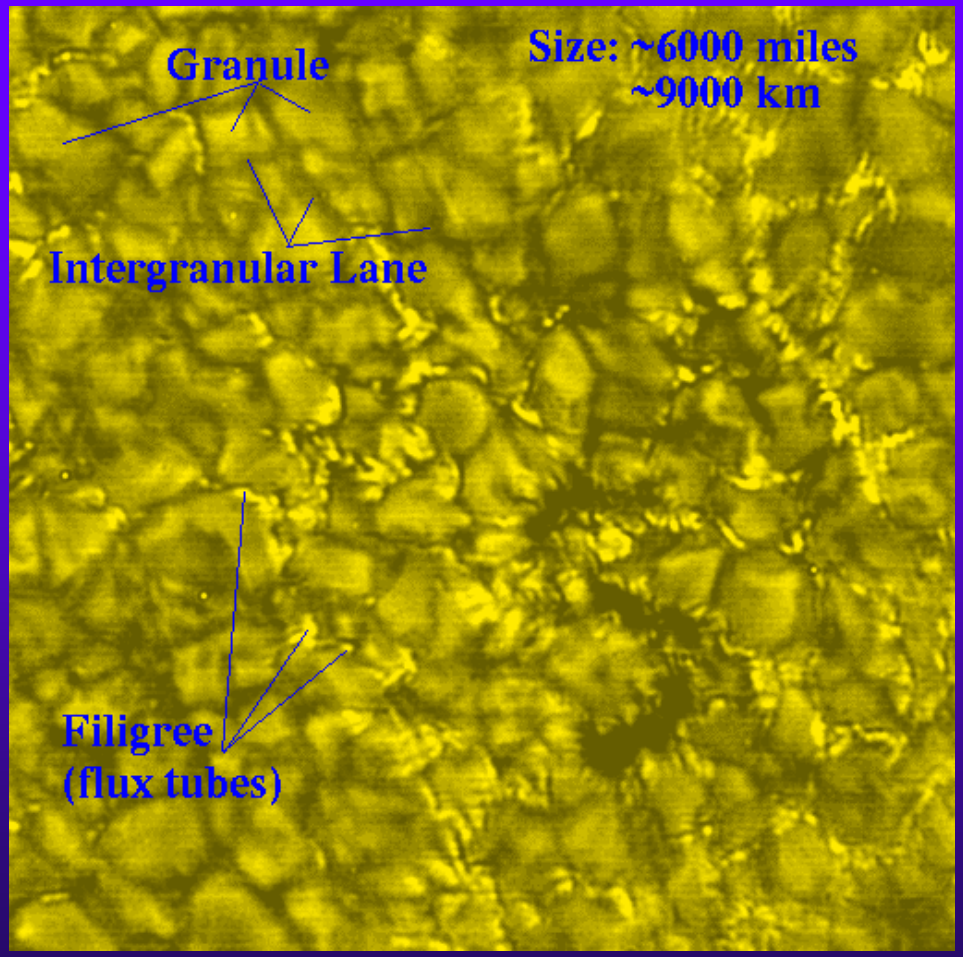
- 8/20/1999
- Magnetogram with bright and dark regions being opposite polarities of the line-of-sight magnetic field
- Filaments/Prominences along the neutral line between opposing polarities



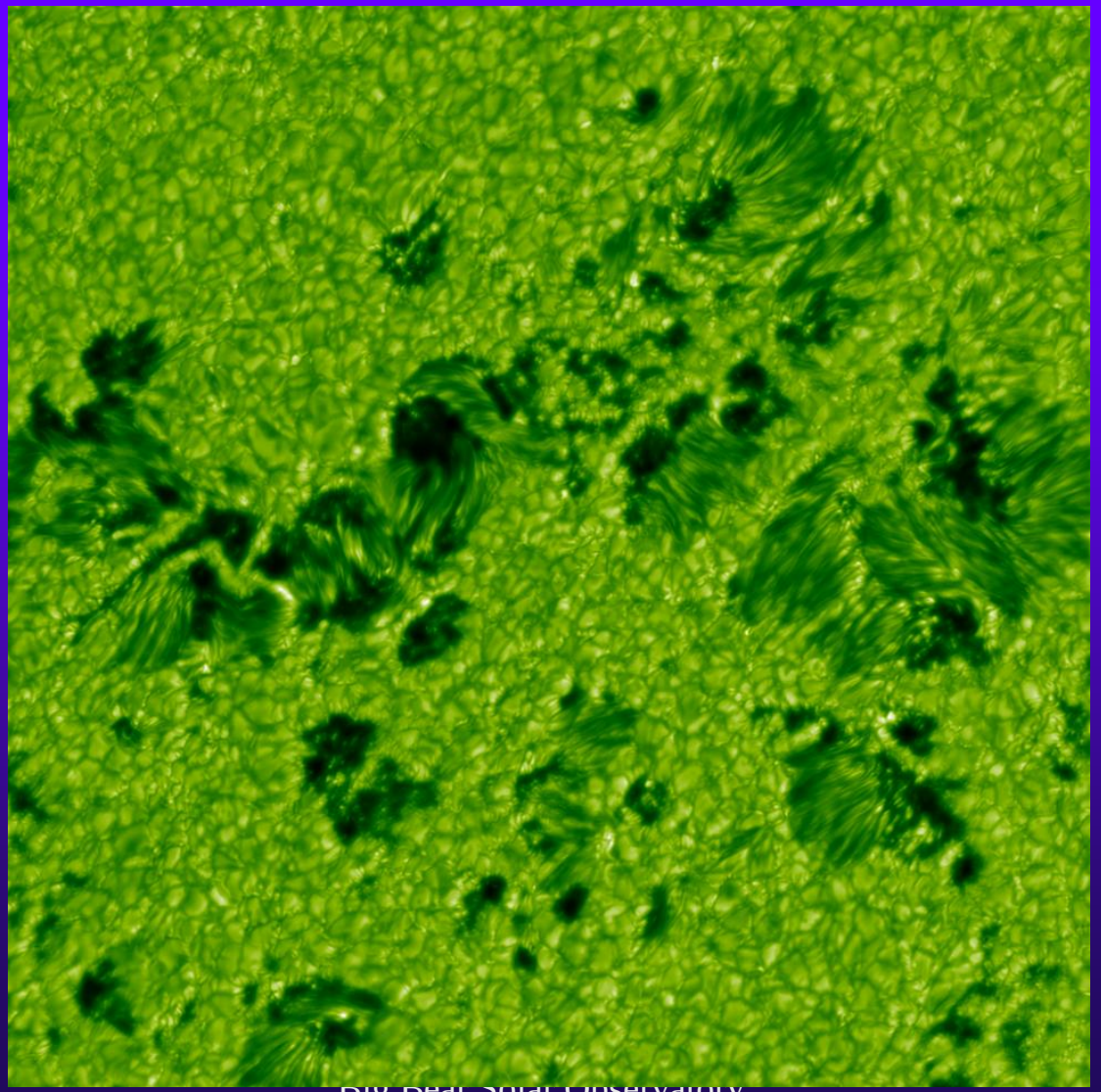
CaK Image




size:
40,000 x 27,000 mi
65,000 x 43,000 km
Sunspot:
Penumbra
Umbra
Pore
Granule
Intergranular Lane


Granule
Size: ~6000 miles
~9000 km
Intergranular Lane
Filigree
(flux tubes)

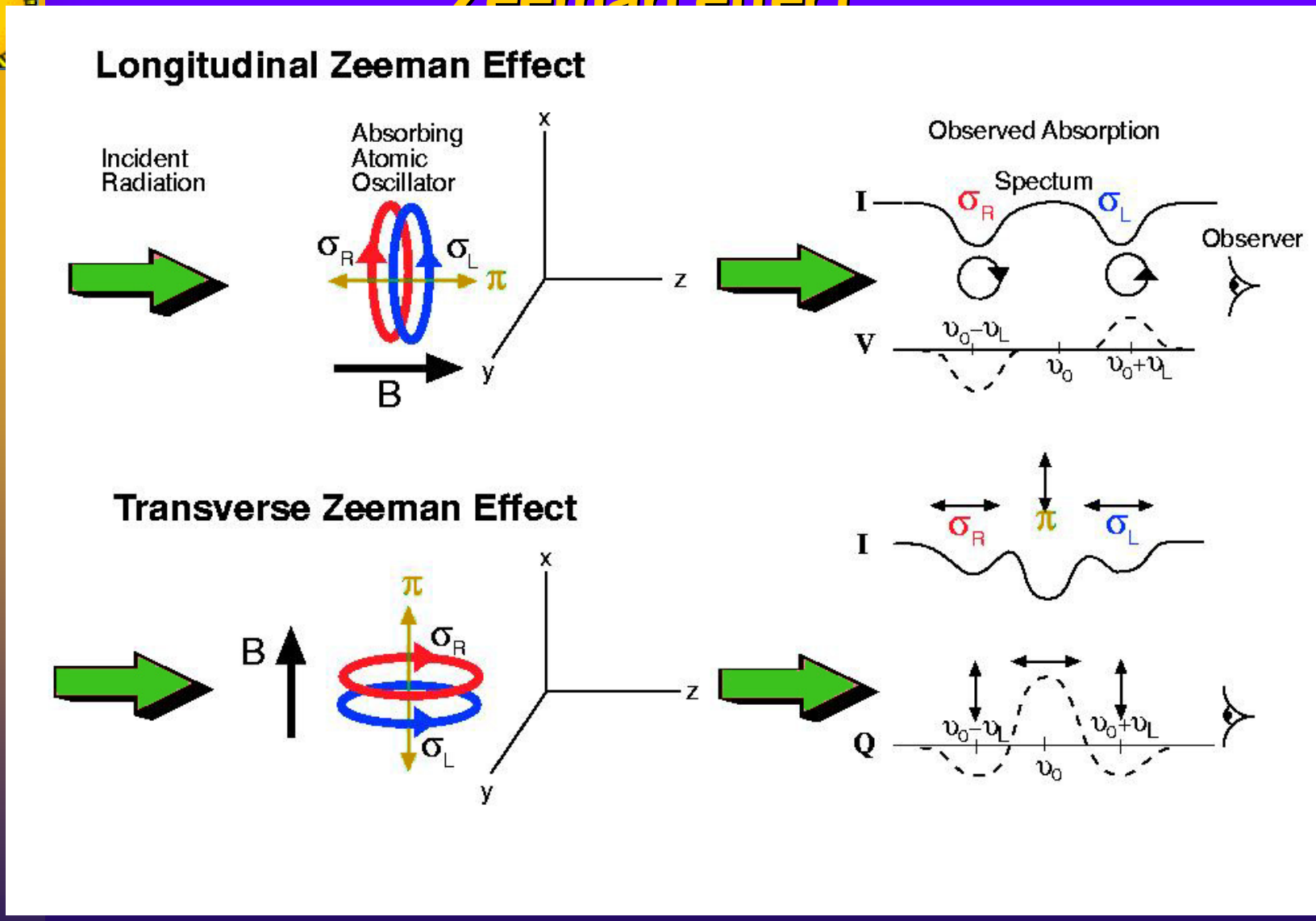
High Resolution Observations of a very strange spot



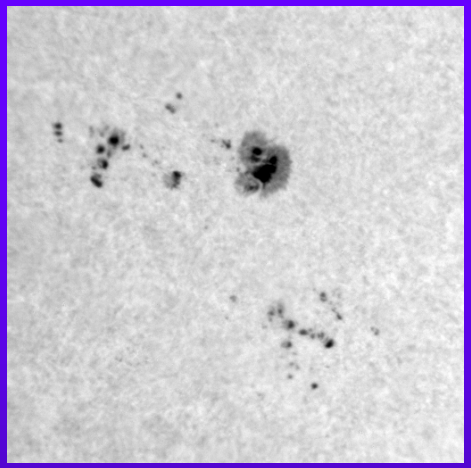
Convection and Oscillation

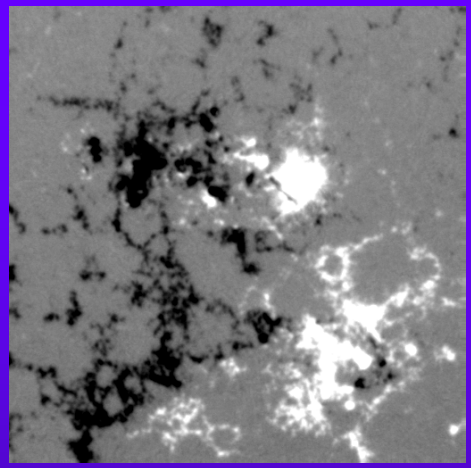
- Granulation
- Mesogranule?
- Supergranulation
  - Network Magnetic Fields
  - Intranetwork Magnetic Fields
- Giant Cells?
- 5 Minute Oscillation (3 minute in chromosphere

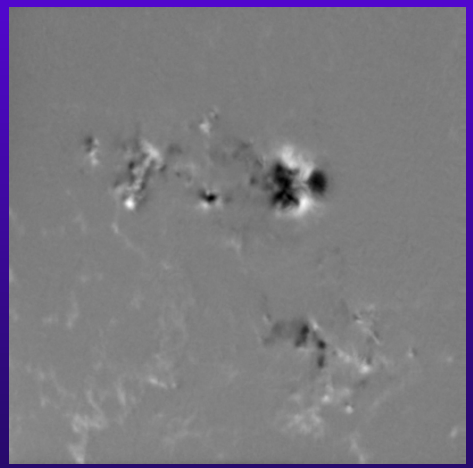
Measurement of Magnetic Fields: Zeeman effect

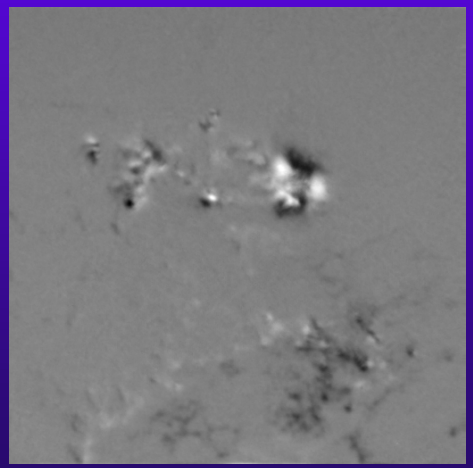


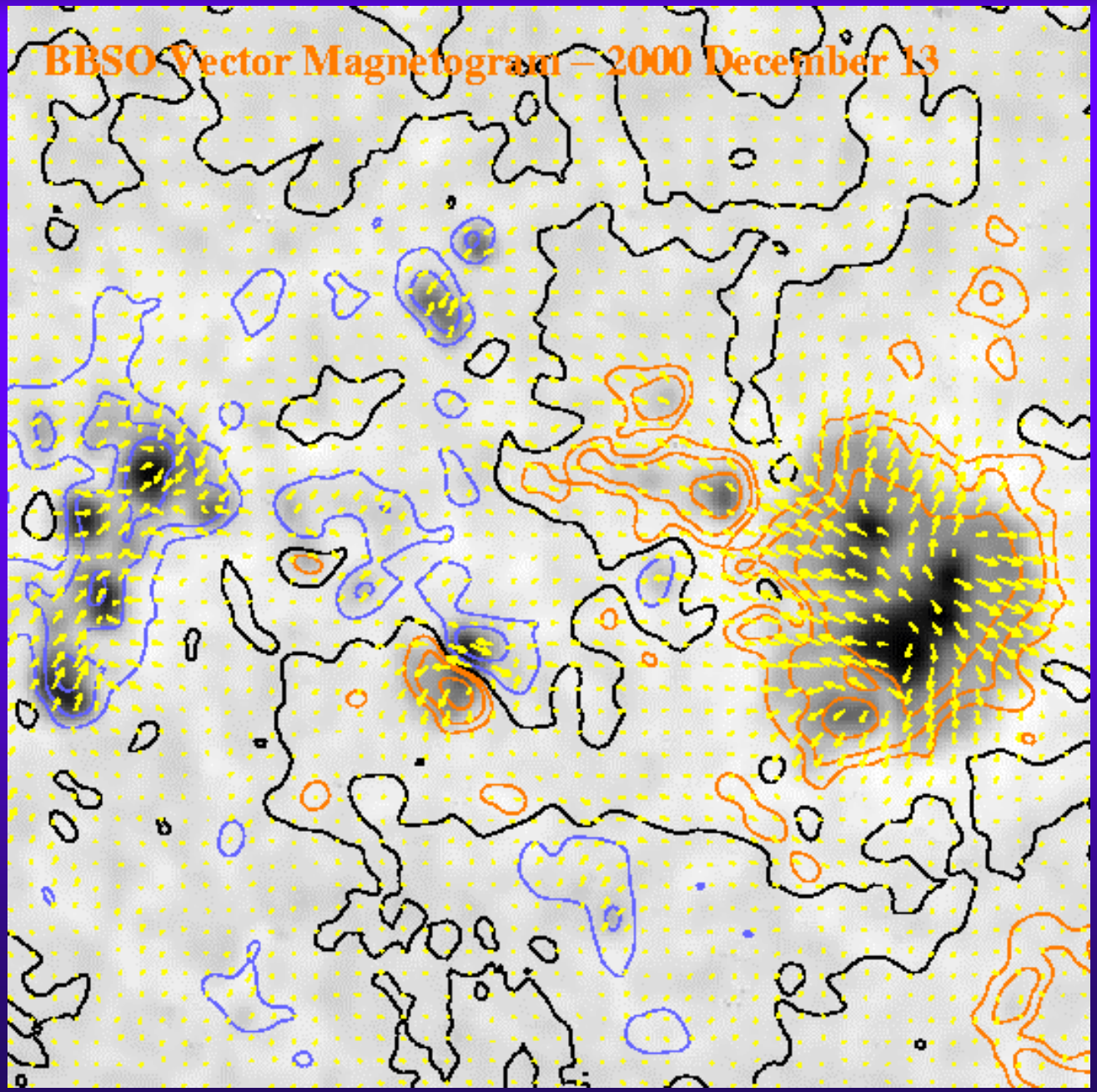
BBSO Vector Magnetogram December 13, 2000 (I, V, Q and U)



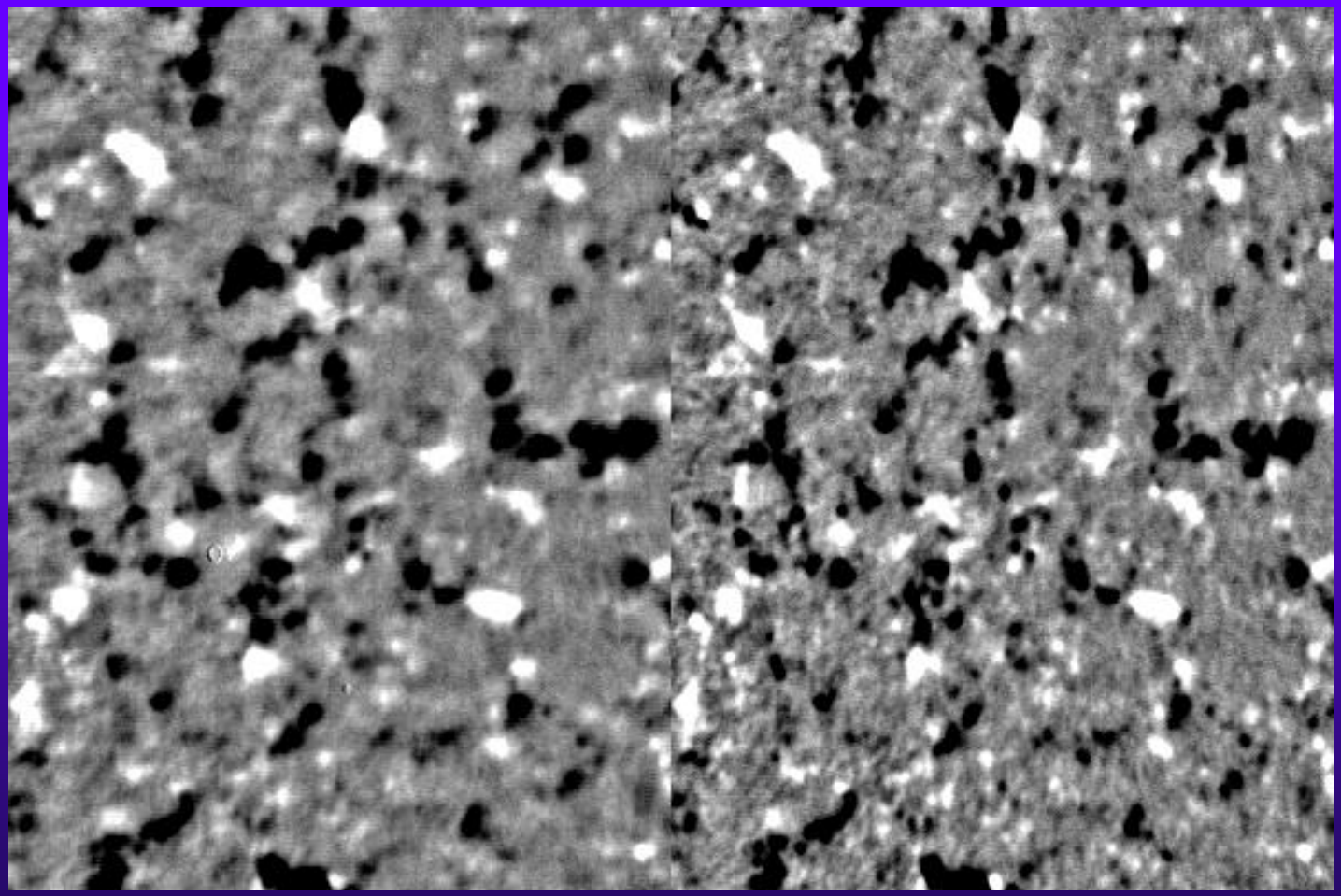


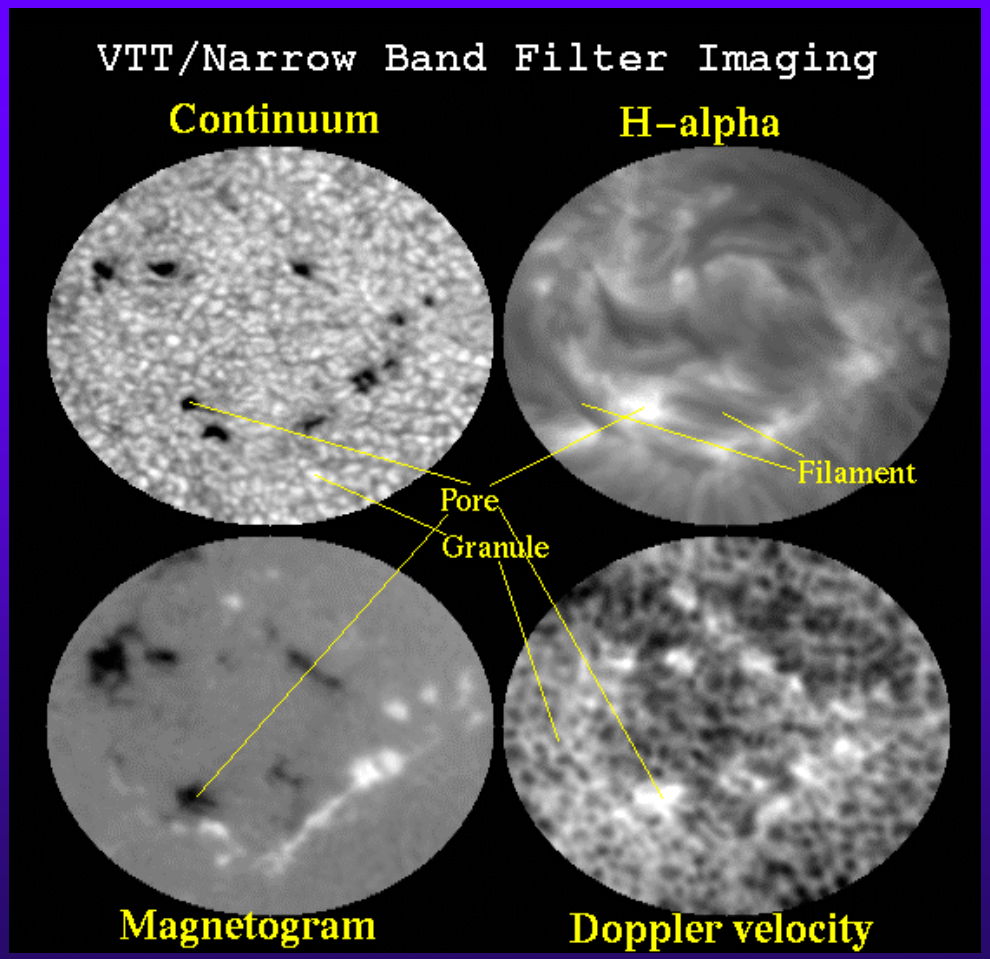




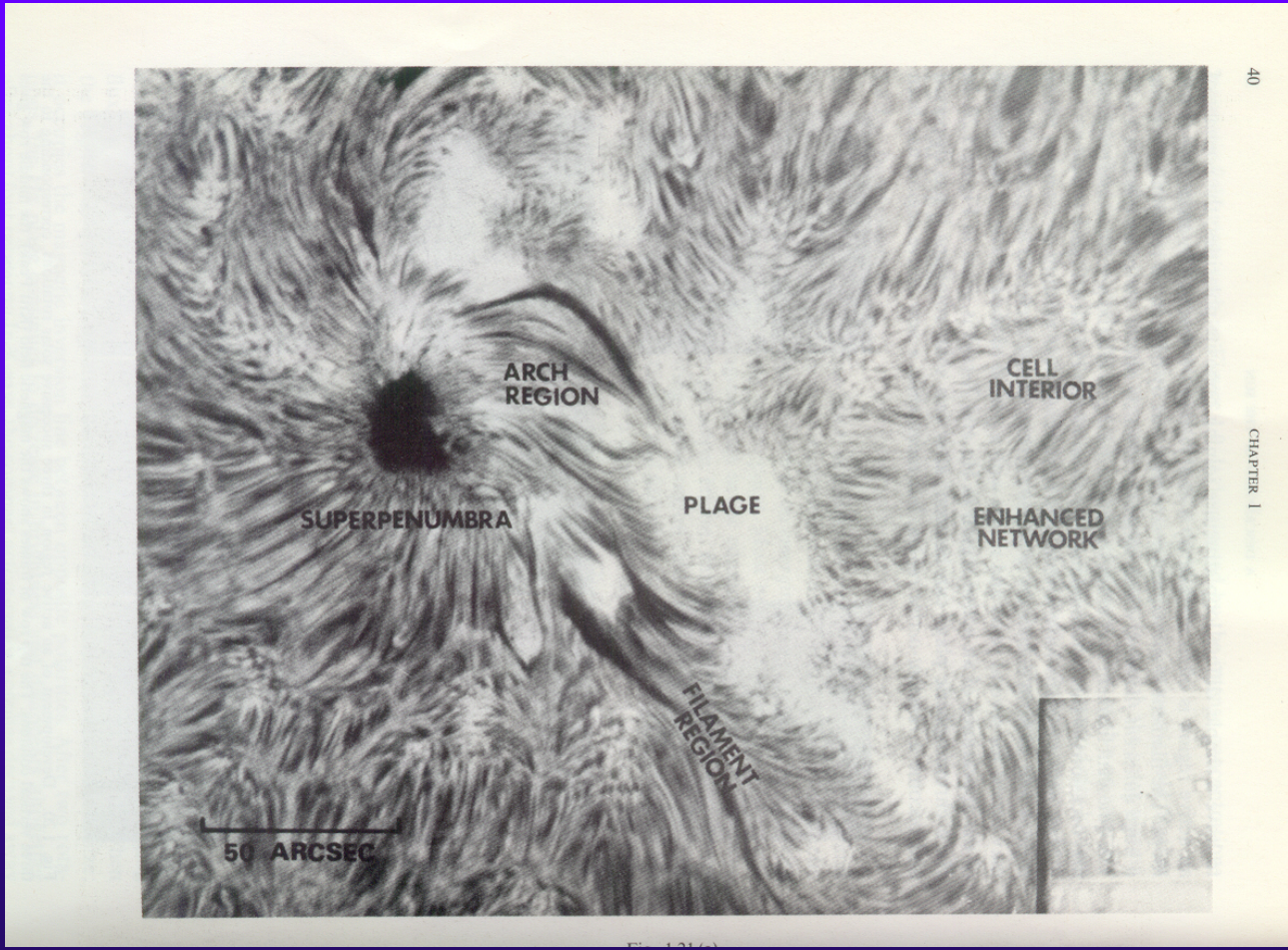

BBSO Vector Magnetogram – 2000 December 13

Quiet Sun Magnetic Fields




VTT/Narrow Band Filter Imaging
Continuum
H-alpha
Filament
Pore
Granule
Magnetogram
Doppler velocity

High Resolution Halpha Image



Spicules

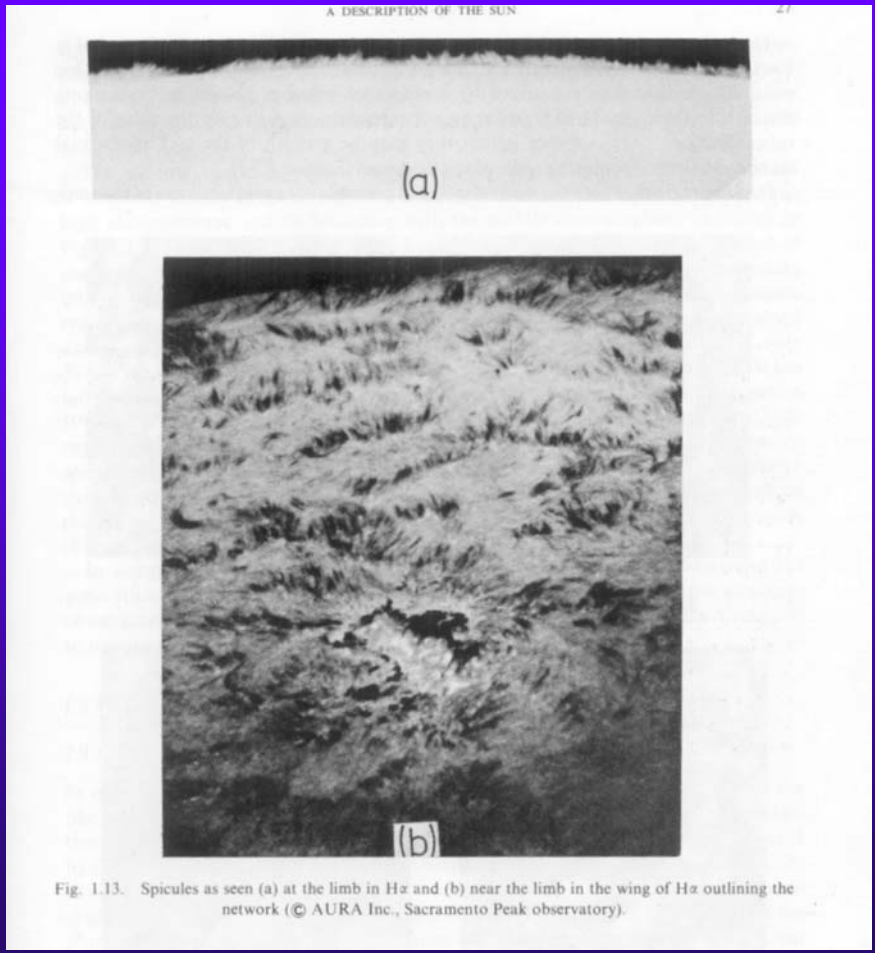


Fig. 1.13. Spicules as seen (a) at the limb in Hα and (b) near the limb in the wing of Hα outlining the network (© AURA Inc., Sacramento Peak observatory).

Filaments and Prominences

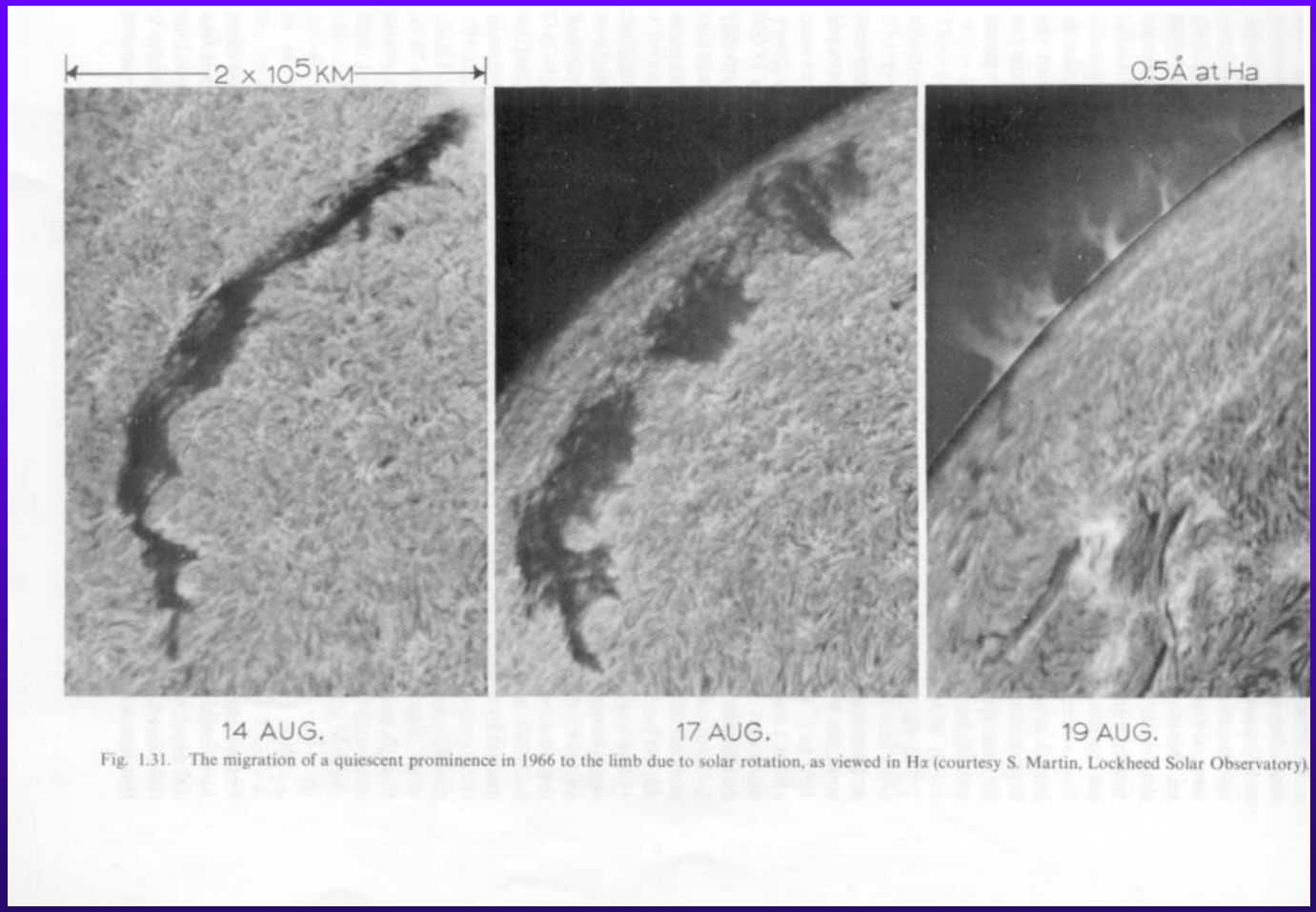
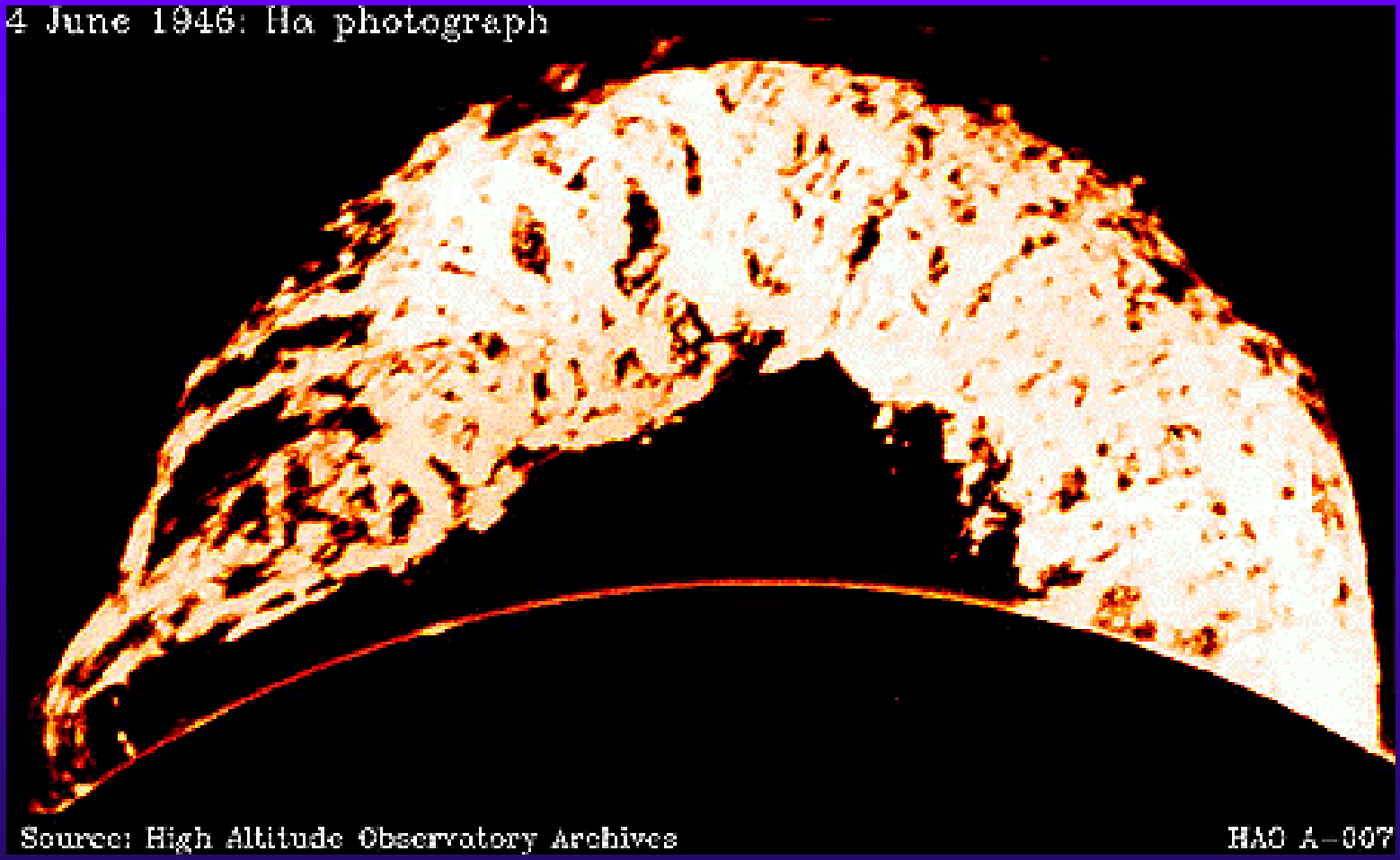
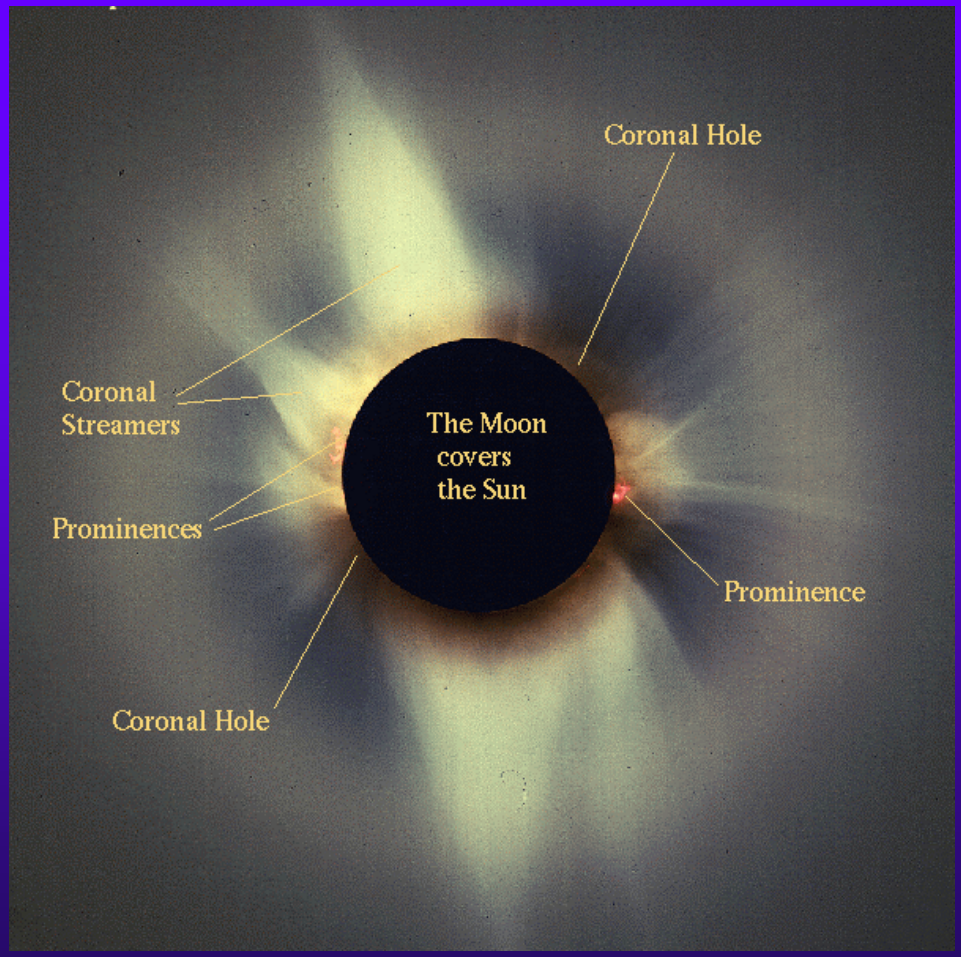


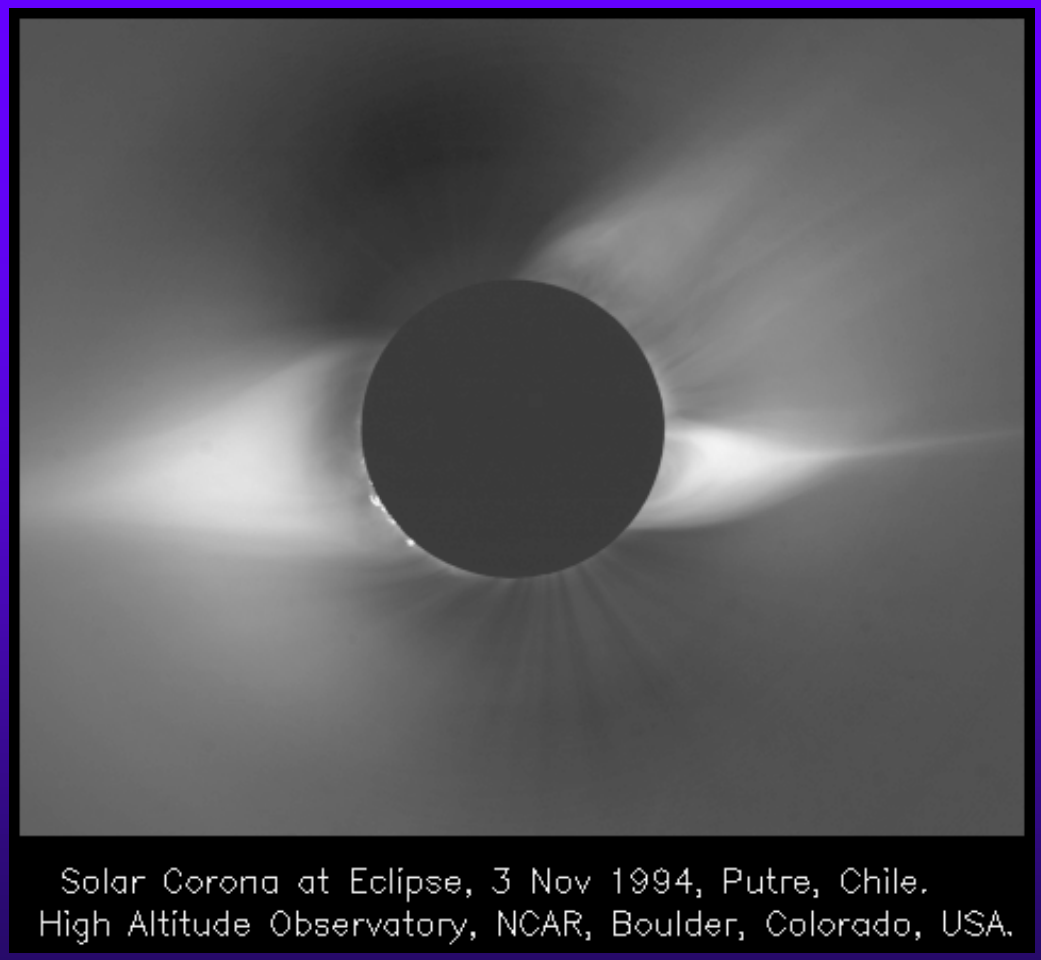
Fig. 1.31. The migration of a quiescent prominence in 1966 to the limb due to solar rotation, as viewed in Hα (courtesy S. Martin, Lockheed Solar Observatory).

A Huge Prominence



Solar Eclipse





Solar Corona at Eclipse, 3 Nov 1994, Putre, Chile.
High Altitude Observatory, NCAR, Boulder, Colorado, USA.

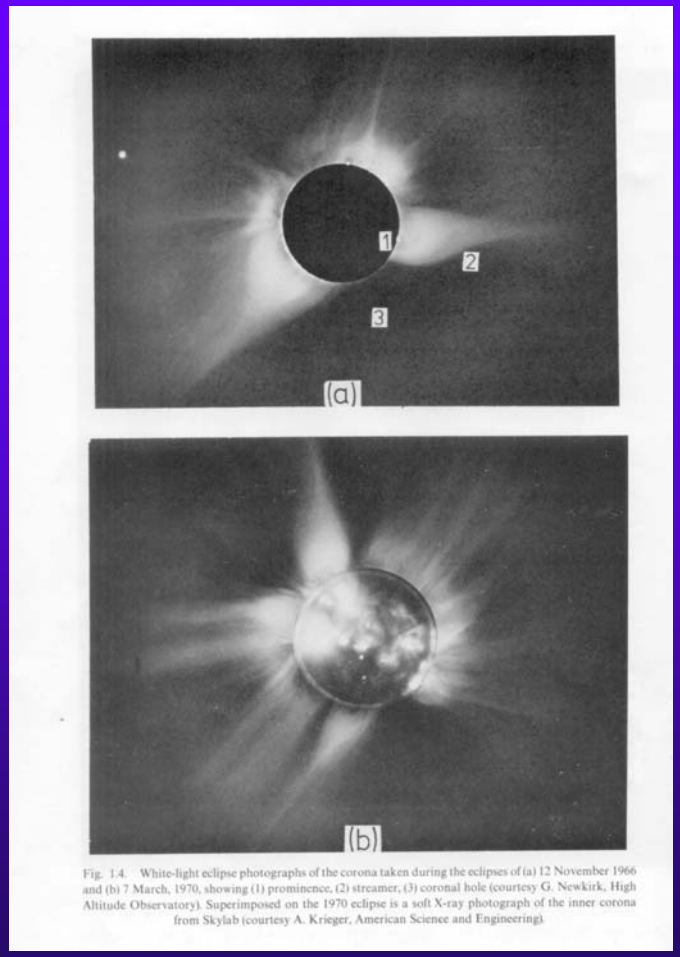
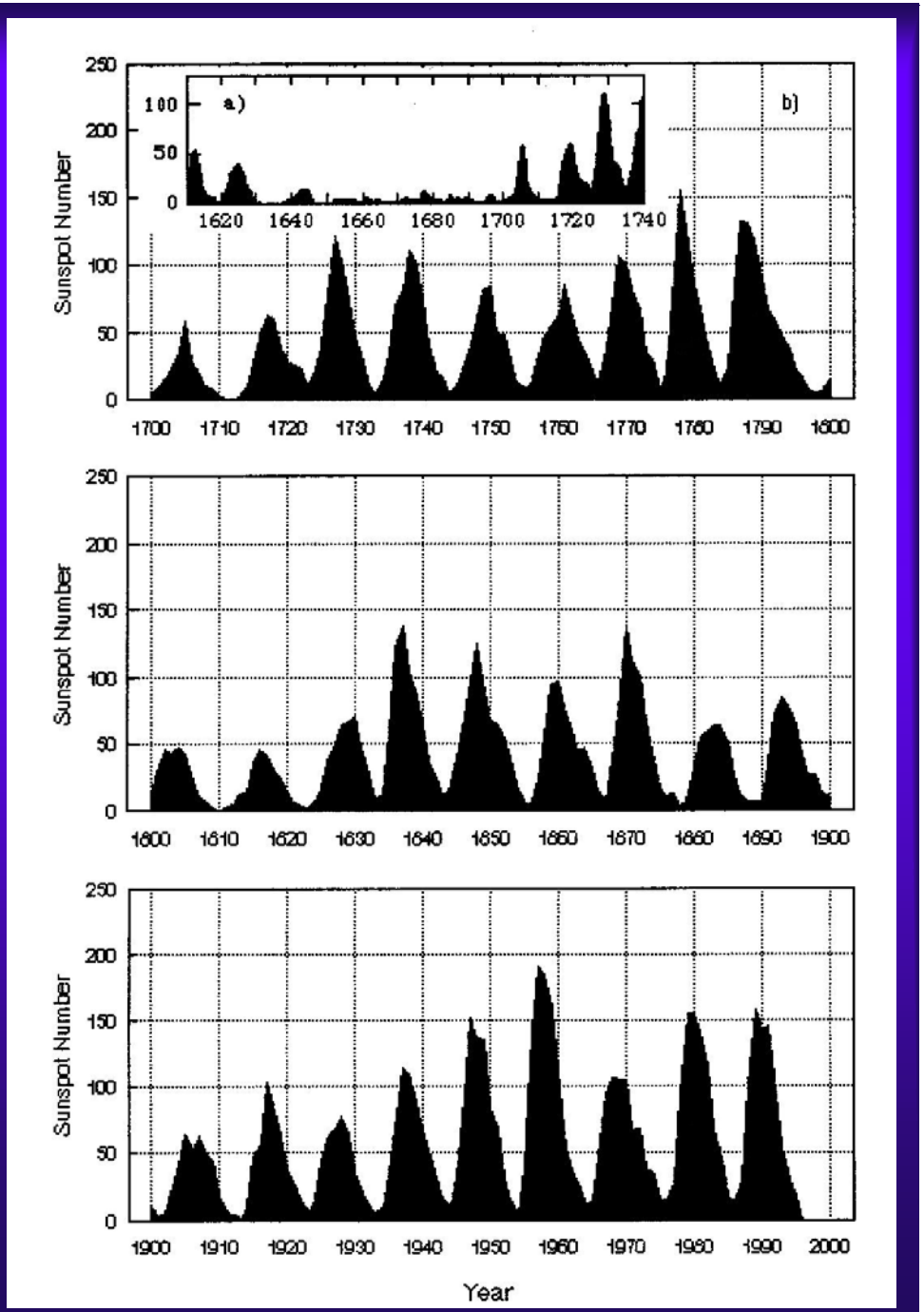


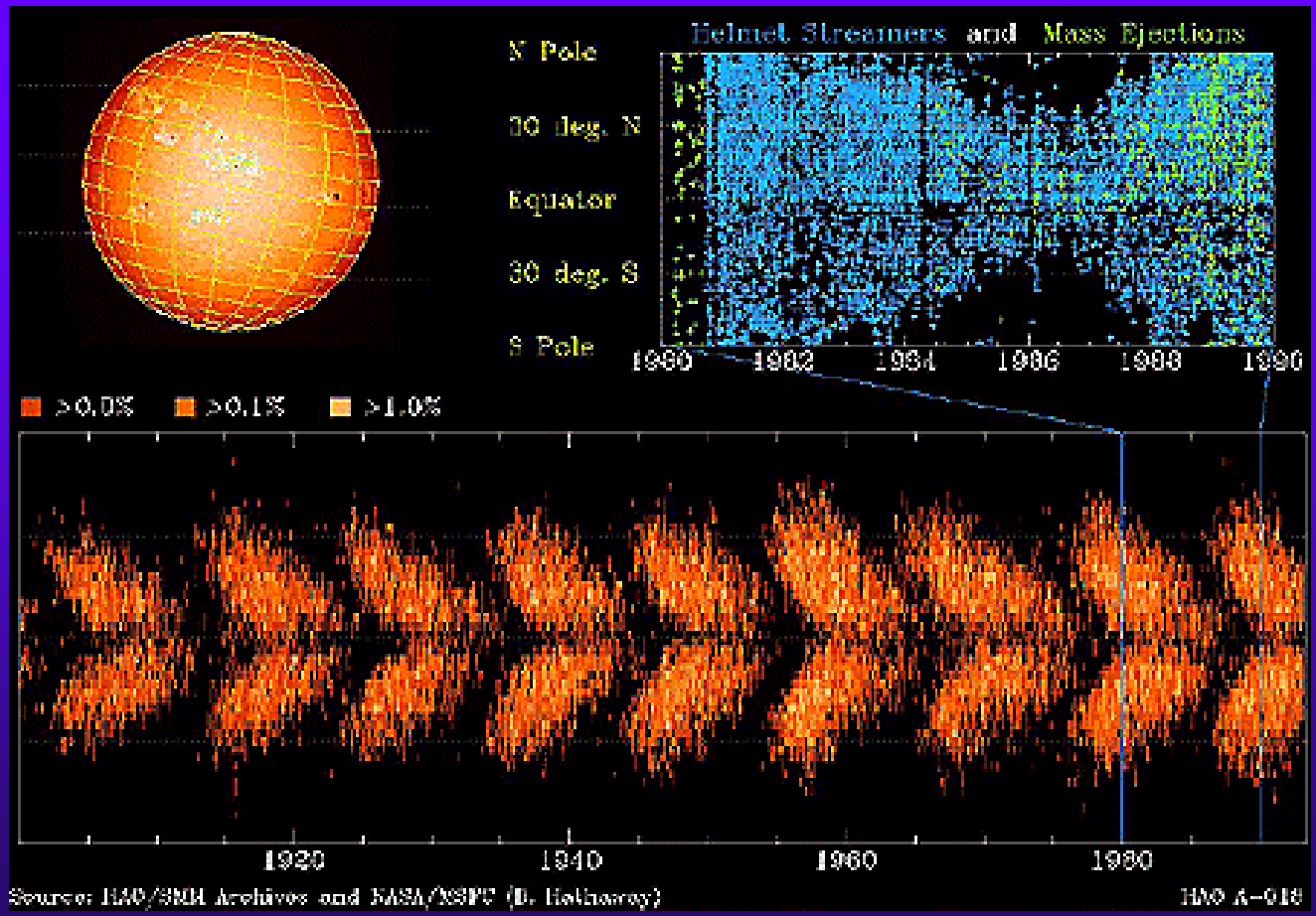
Fig. 1.4. White-light eclipse photographs of the corona taken during the eclipses of (a) 12 November 1966 and (b) 7 March, 1970, showing (1) prominence, (2) streamer, (3) coronal hole (courtesy G. Newkirk, High Altitude Observatory). Superimposed on the 1970 eclipse is a soft X-ray photograph of the inner corona from Skylab (courtesy A. Krieger, American Science and Engineering).

Solar Cycle:

- Sunspot number 1620 –1996

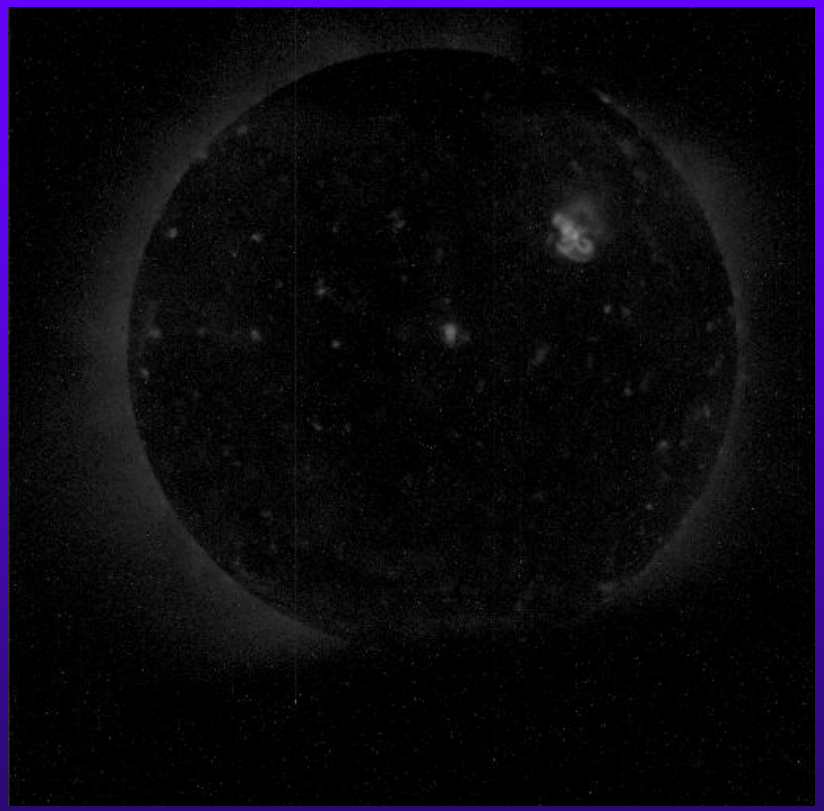


Butterfly Diagram

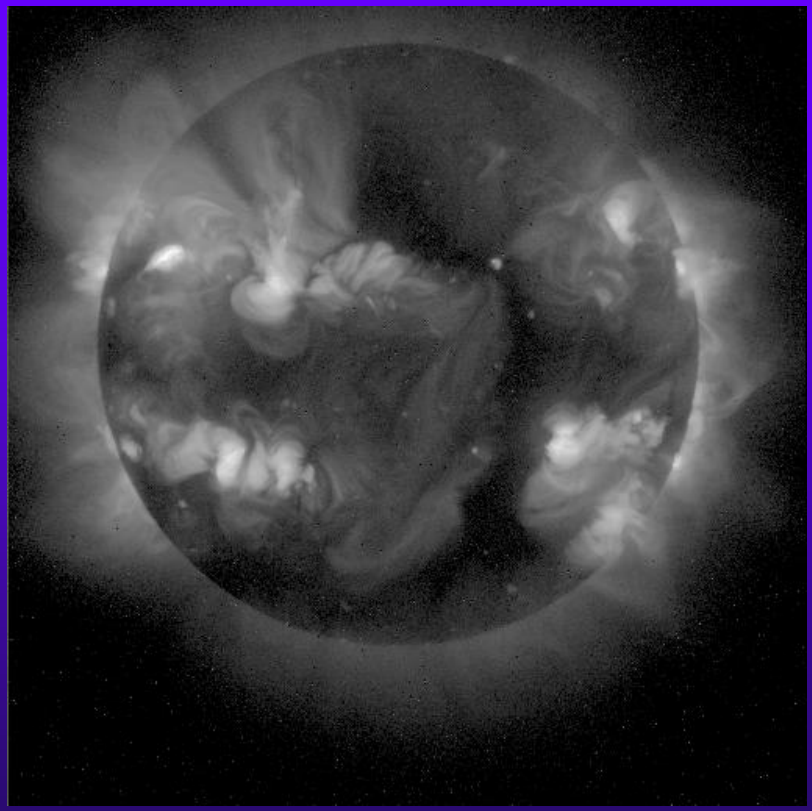


The Sun in X-Ray Light

Solar Activity Minimum --1996



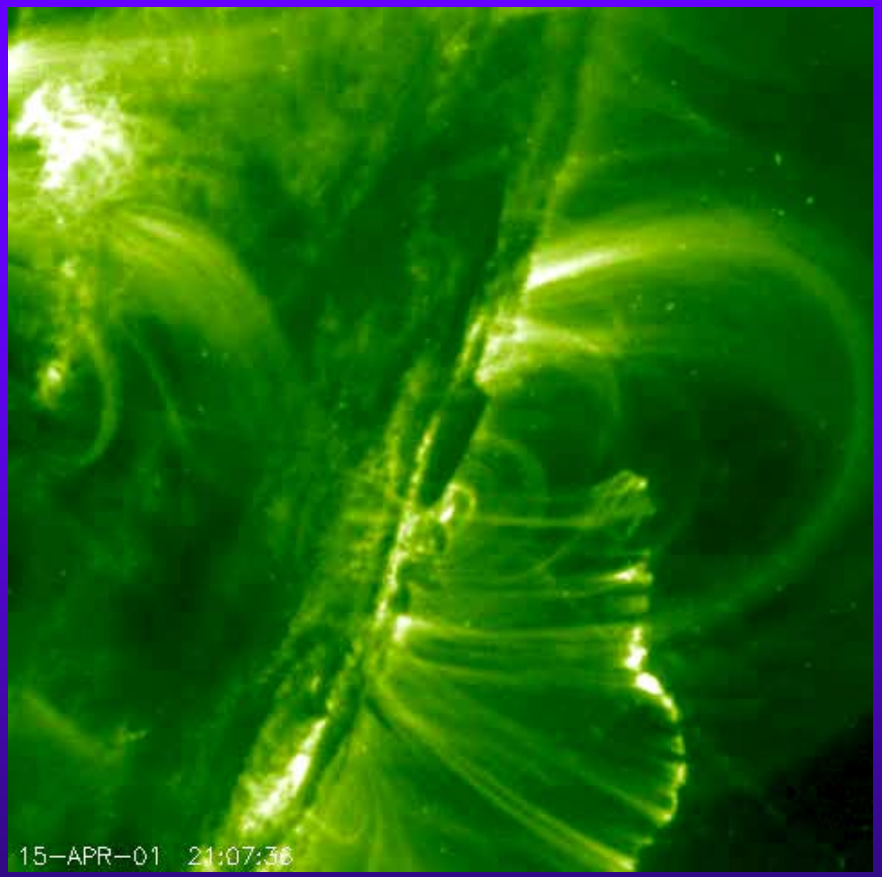
Solar Activity Maximum--2000



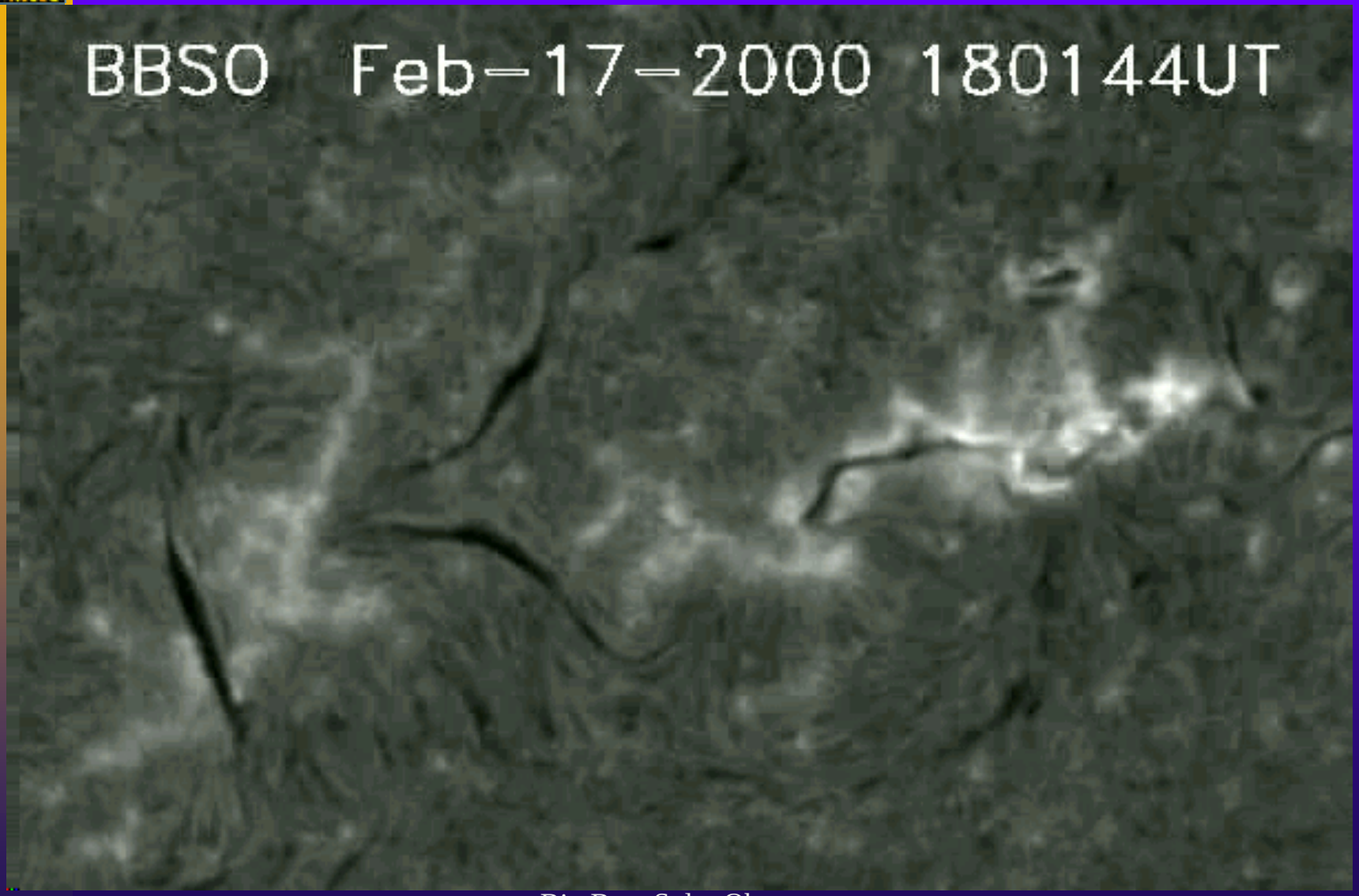
Prominence Eruption in Halpha BBSO

- 4/15/2001
- Prominence eruption
- Coronal Mass Ejection (CME) may accompany some filament/prominence eruptions
- Earth-directed CMEs can have geomagnetic effects

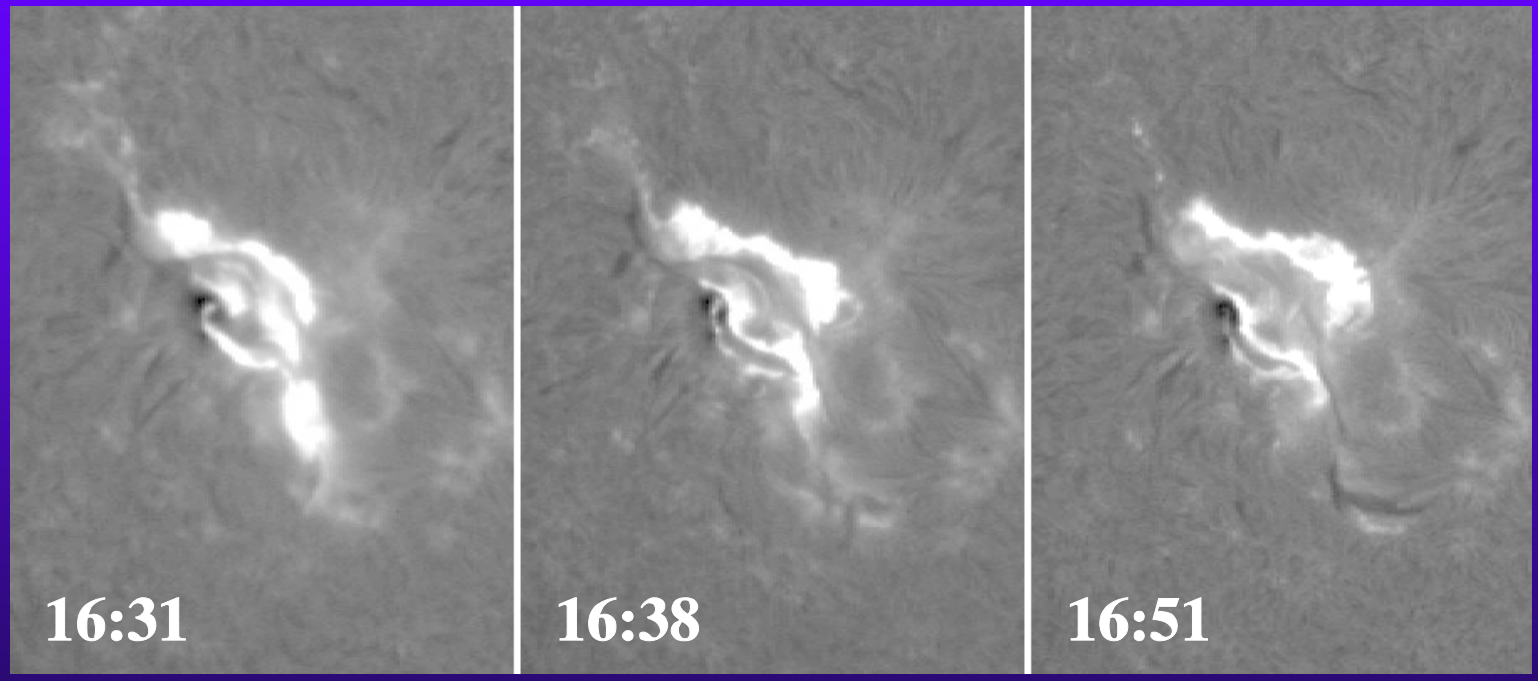
April 15, 2001 Prominence Eruption



Sympathetic Flares of 2/17/2000



Two Ribbon Flare



Light Curves of Flares

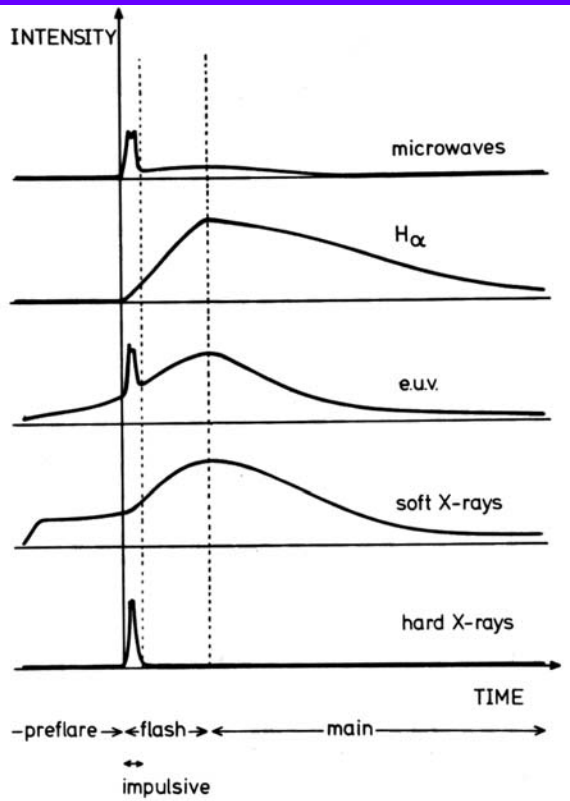
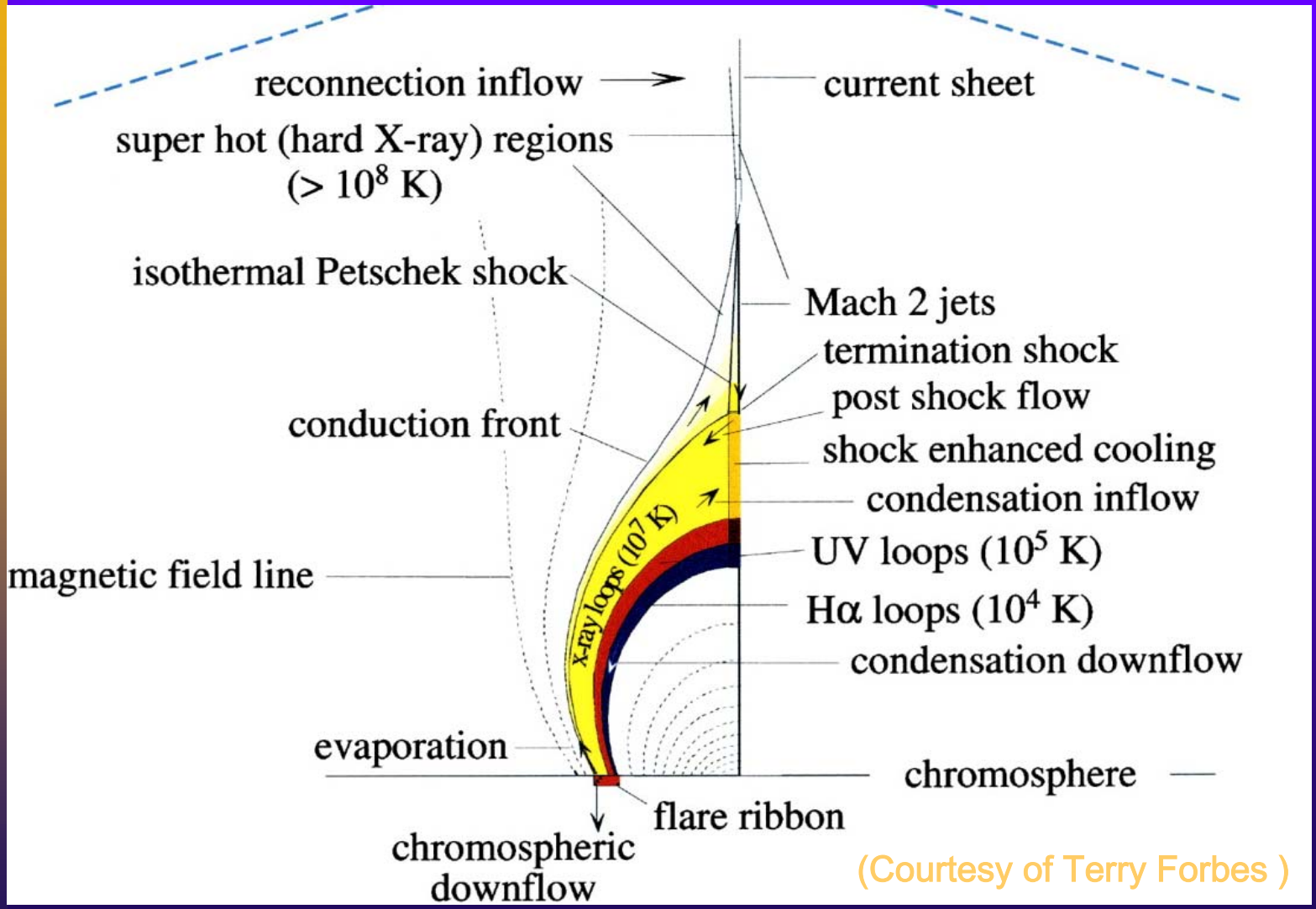


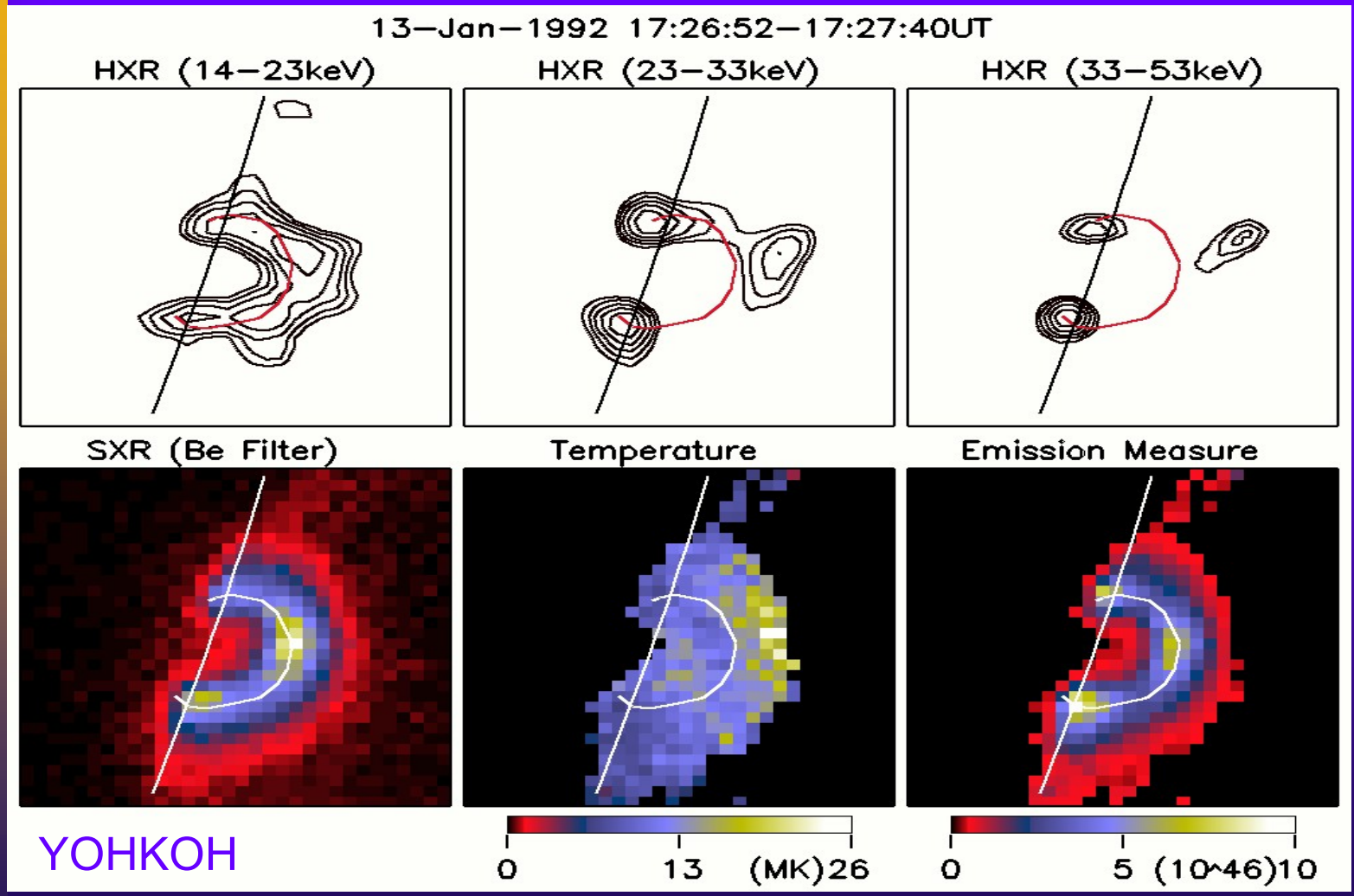
Fig. 1.36. A schematic profile of the flare intensity in several wavelengths (see, e.g., Kane, 1974; Lin, 1974). There is a great variation in the duration and complexity of the various phases. In a large event the pre-flare phase lasts typically 10 min, the impulsive phase a minute, the flash phase 5 min, and the main phase an hour.

“observe” magnetic reconnection in a standard flare configuration

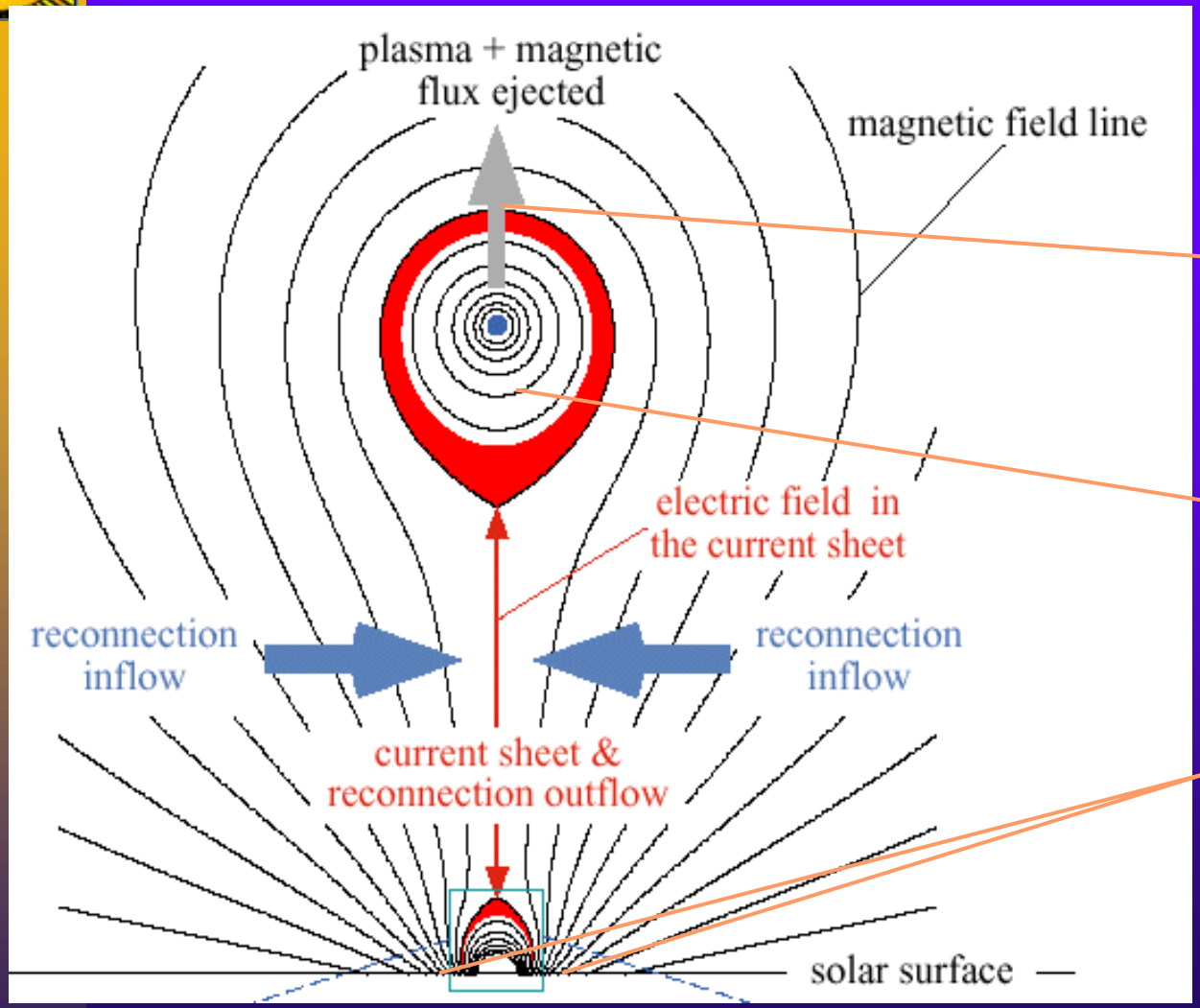


(Courtesy of Terry Forbes)

Masuda flare: hard X-ray source above the loop top
(Masuda et al. 1994)



A schematic flux rope model for CME and flare

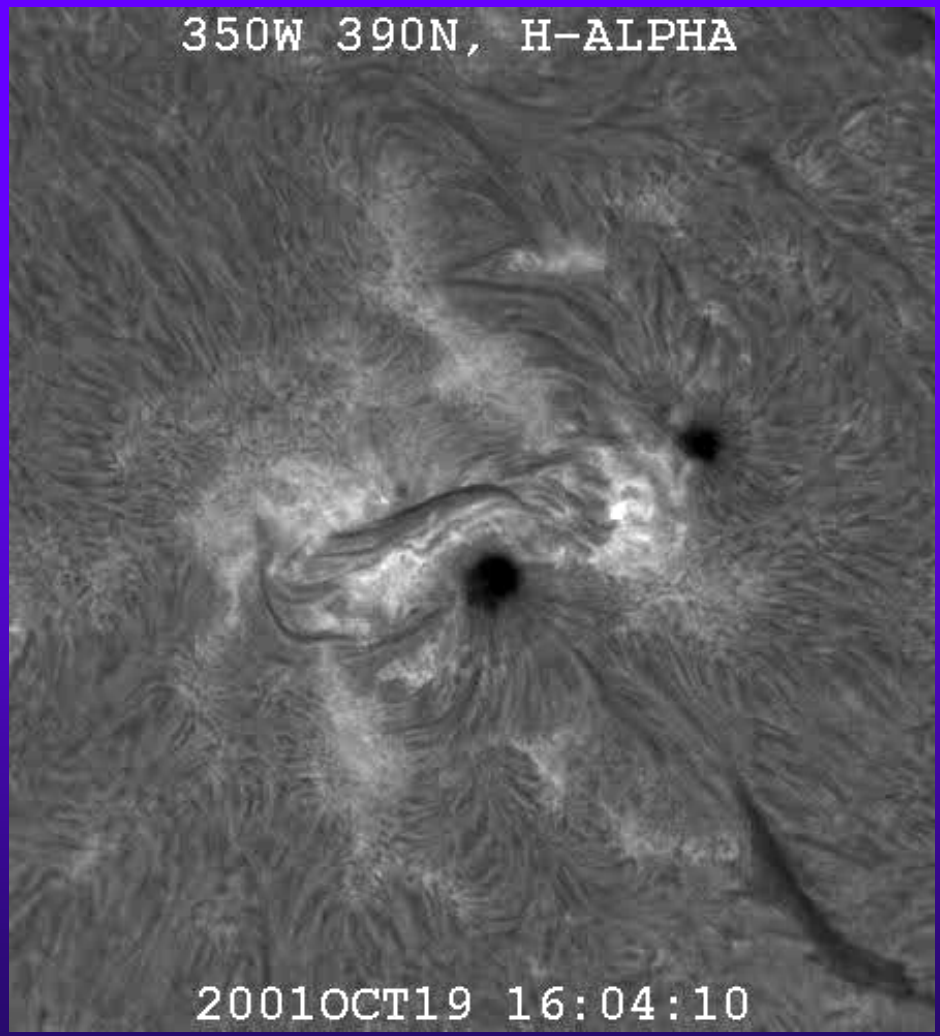


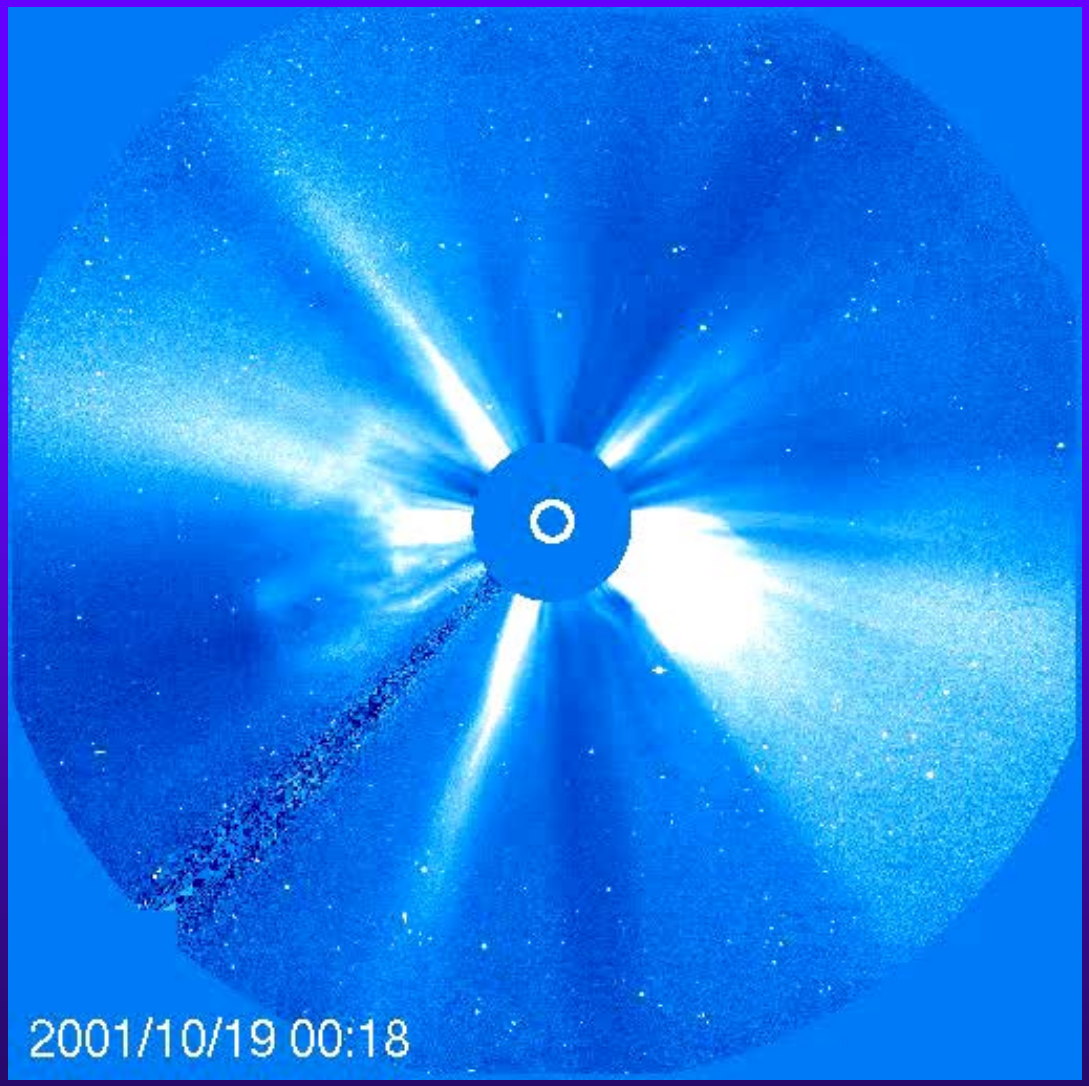
CME

filament

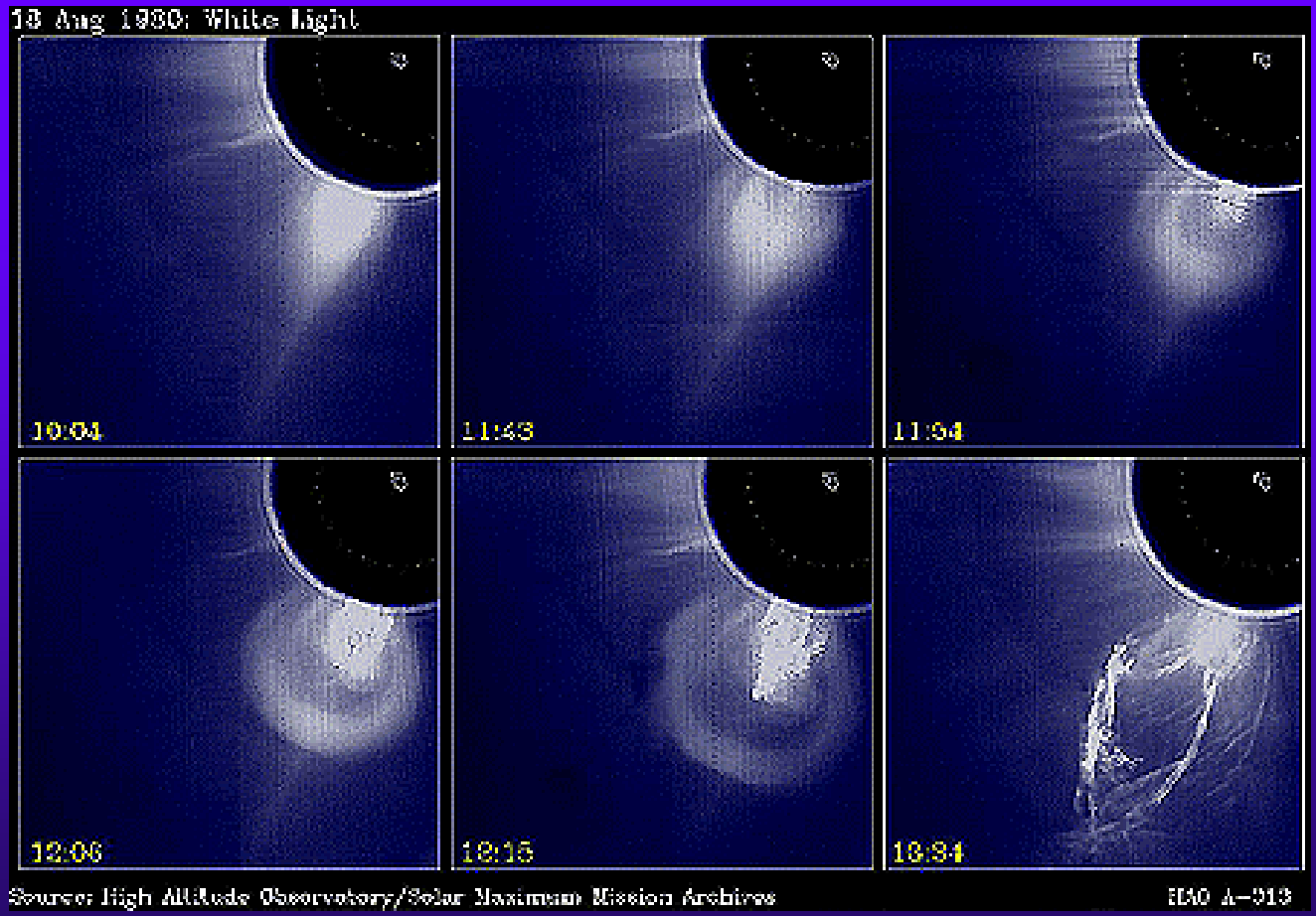
two-ribbon flare

(Lin et al. 2004)

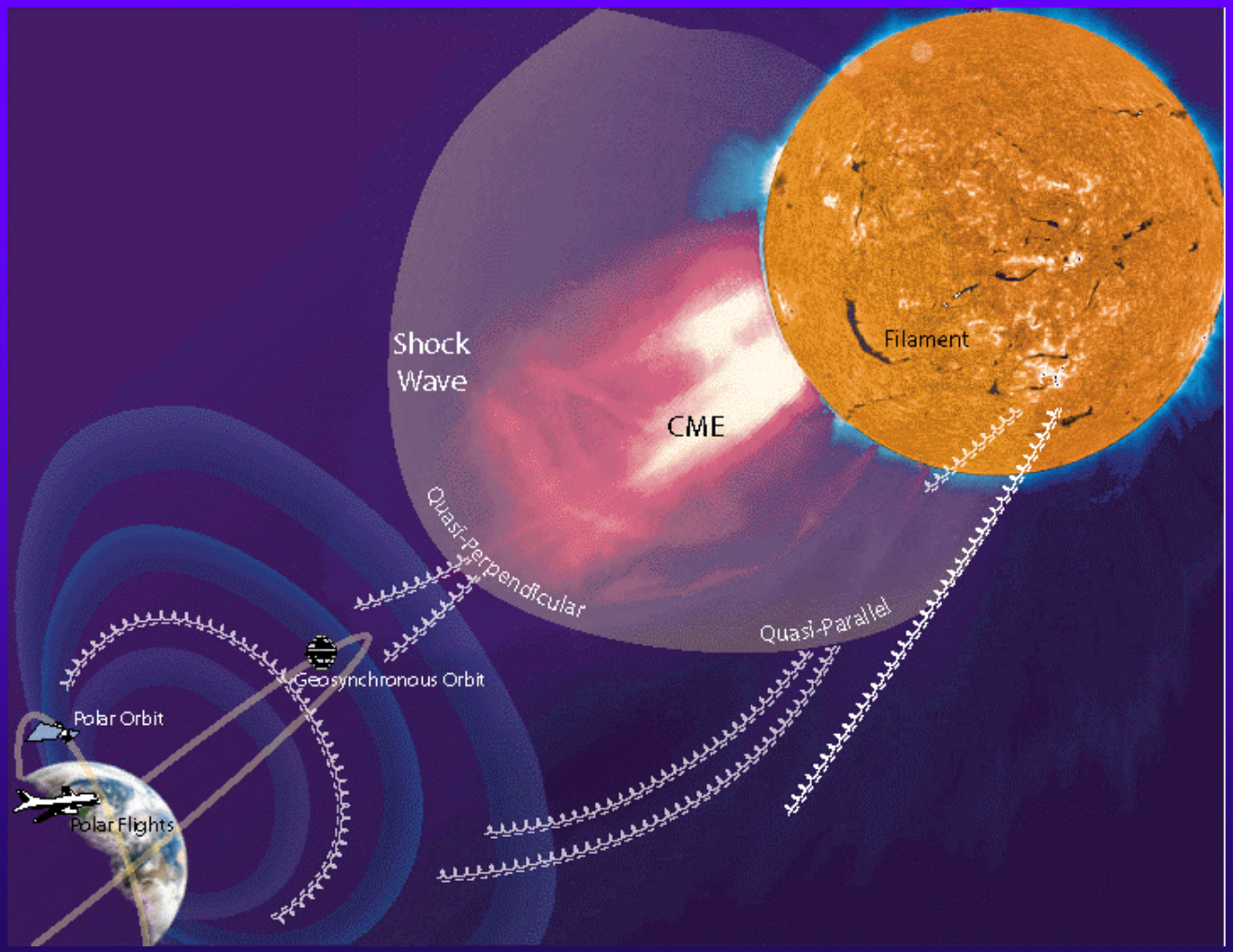

350W 390N, H-ALPHA
2001OCT19 16:04:10


2001/10/19 00:18

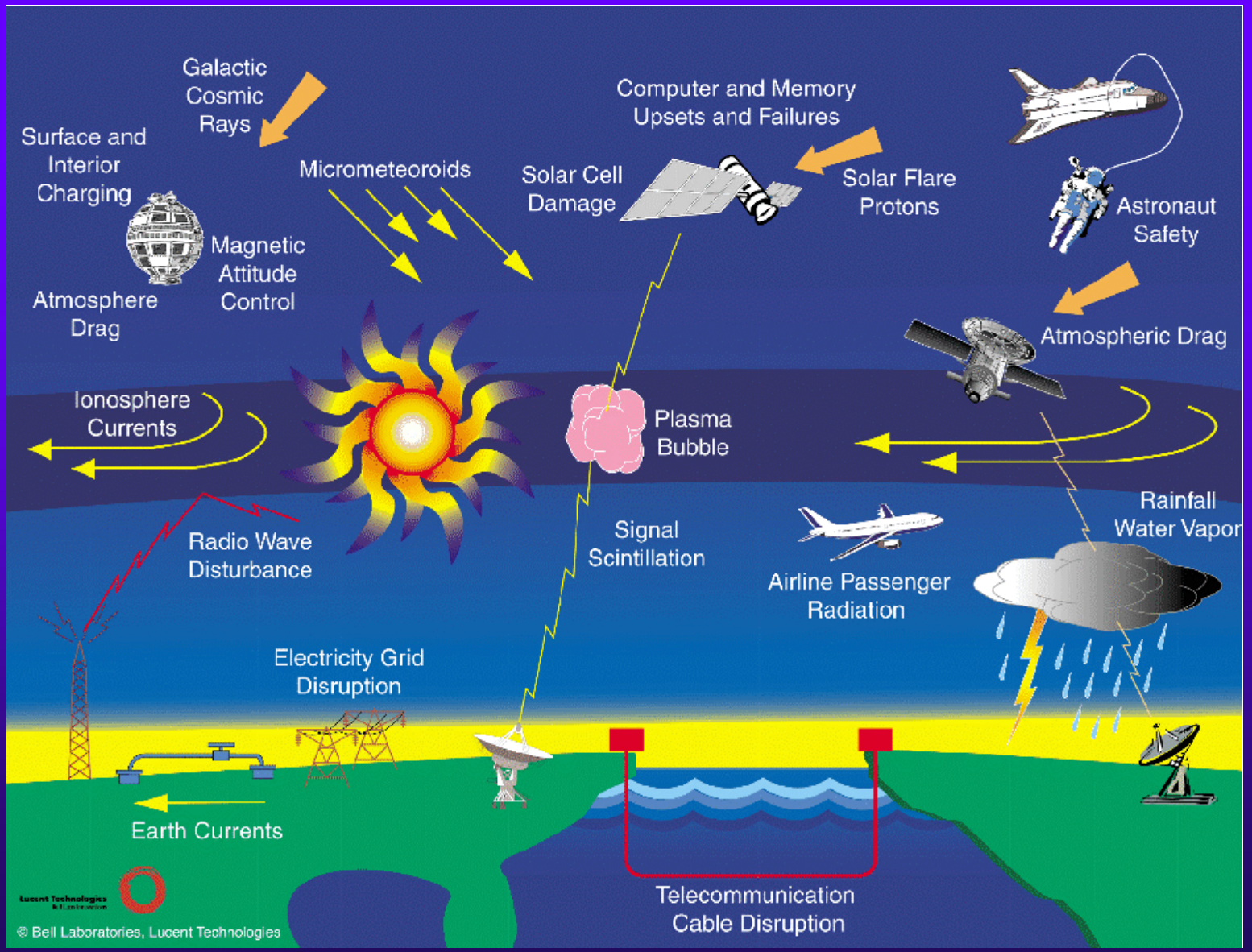
Another CME


18 Aug 1980: White Light
10:04
11:43
11:54
12:06
12:15
12:34
Source: High Altitude Observatory/Solar Maximum Mission Archives
EAO A-913

The Sun-Earth Connection



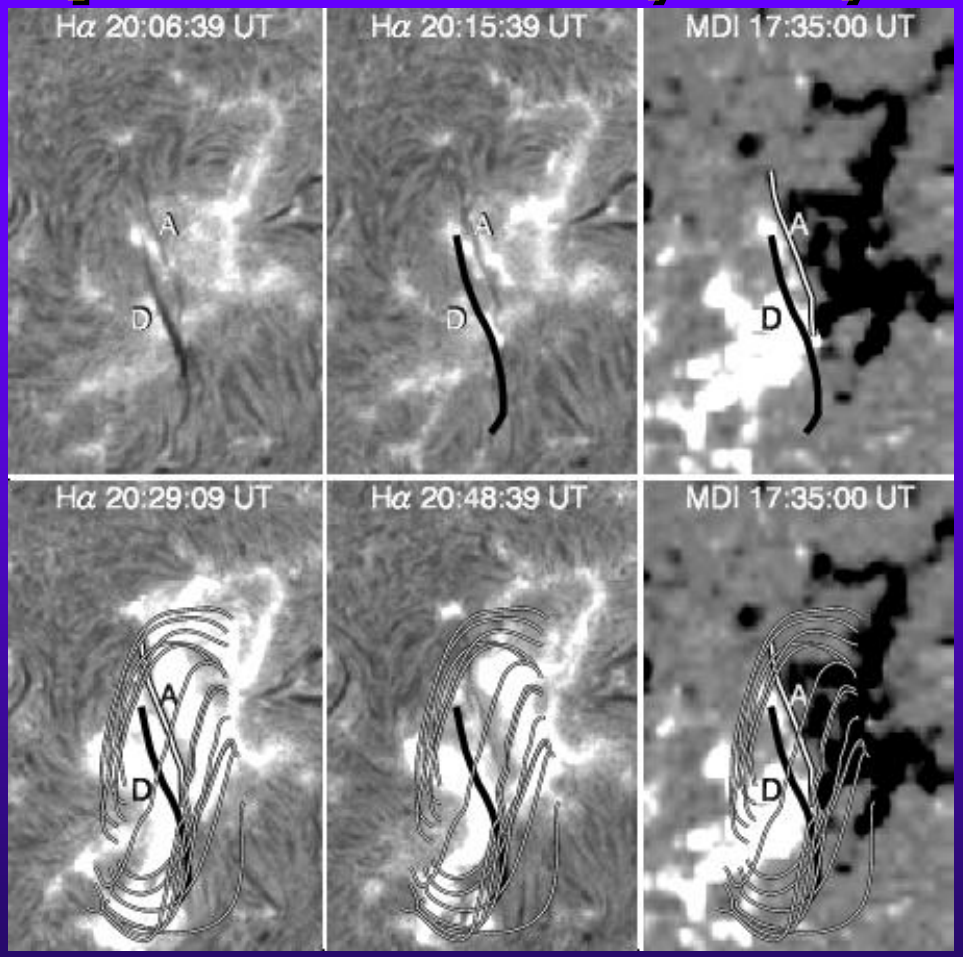
Space Weather Effects



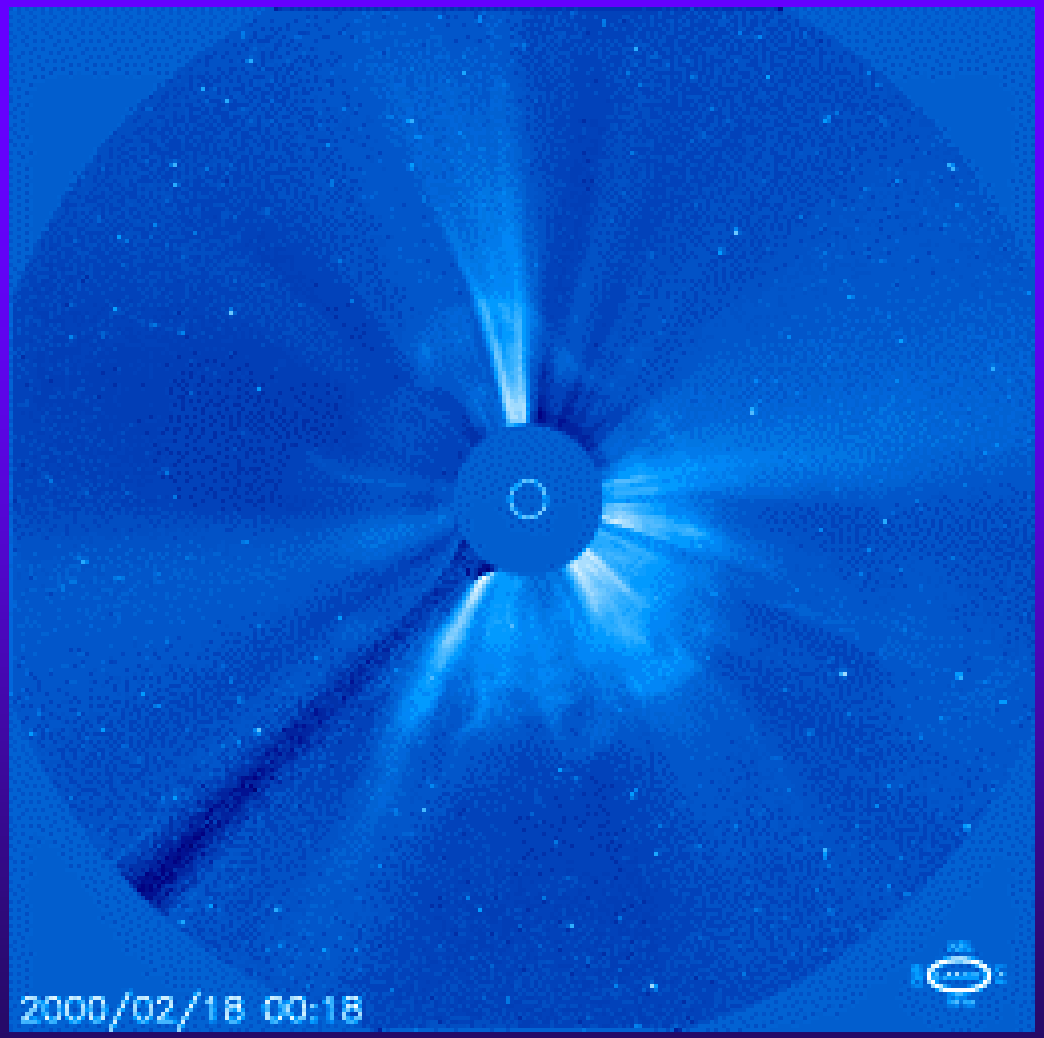
Two Major Effects of Space Weather

- Geo-Magnetic Storm
- SEP (Solar Energetic Particle)

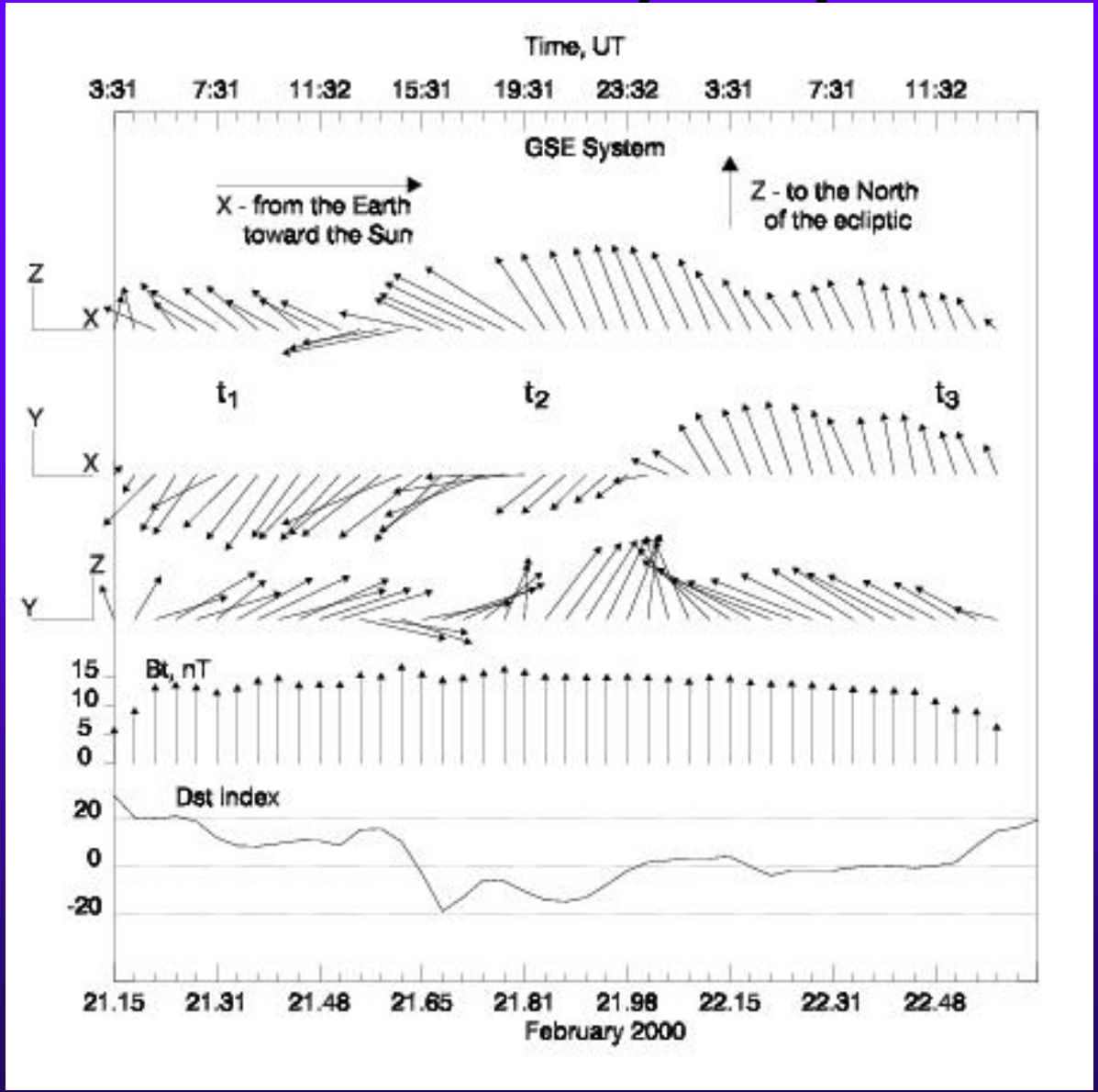
LFFF (Linear Force Free Field) Extrapolation, 2/17/2000



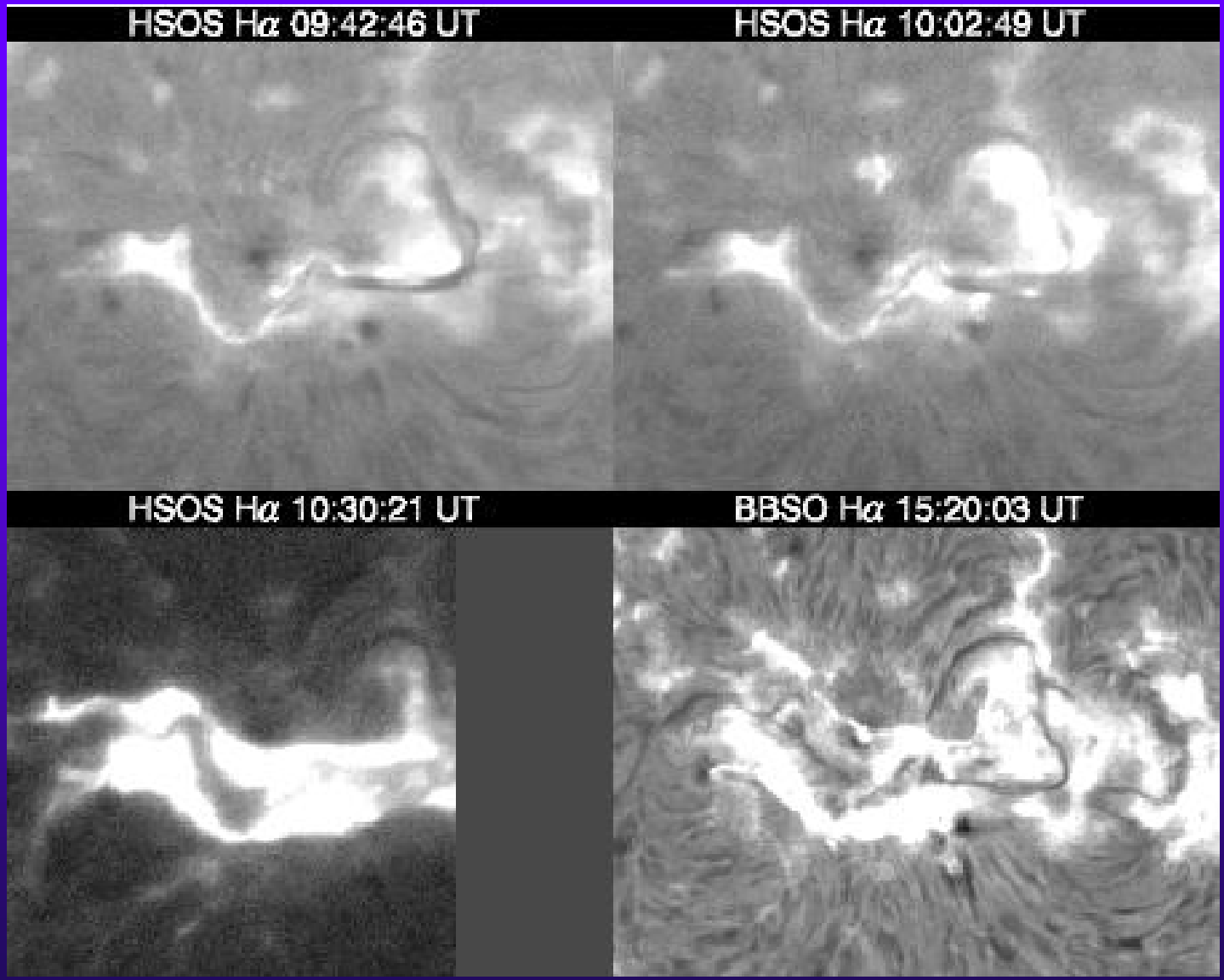
LASCO C3 Movie, 2/17/2000



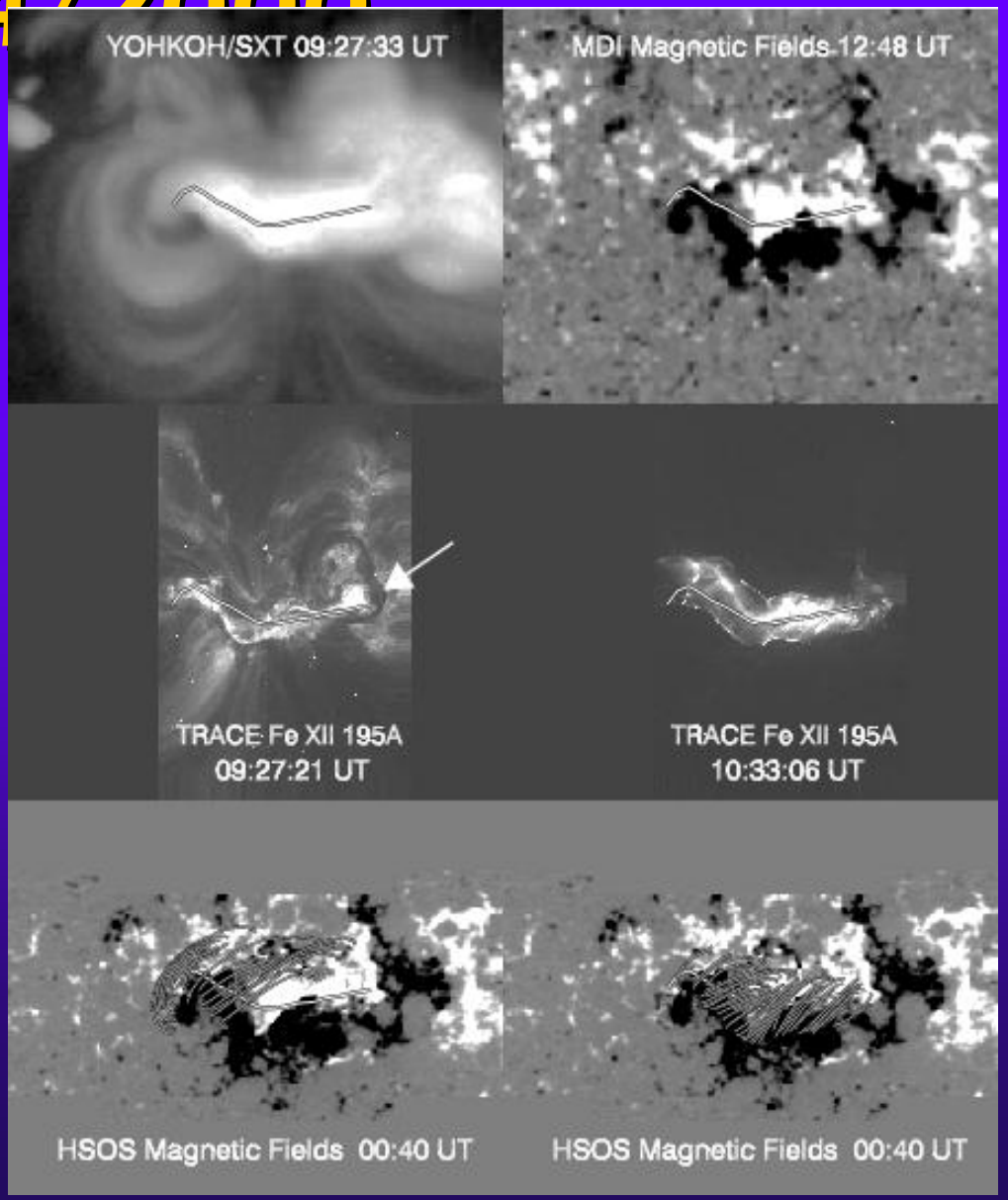
ACE Data, 2/17/2000



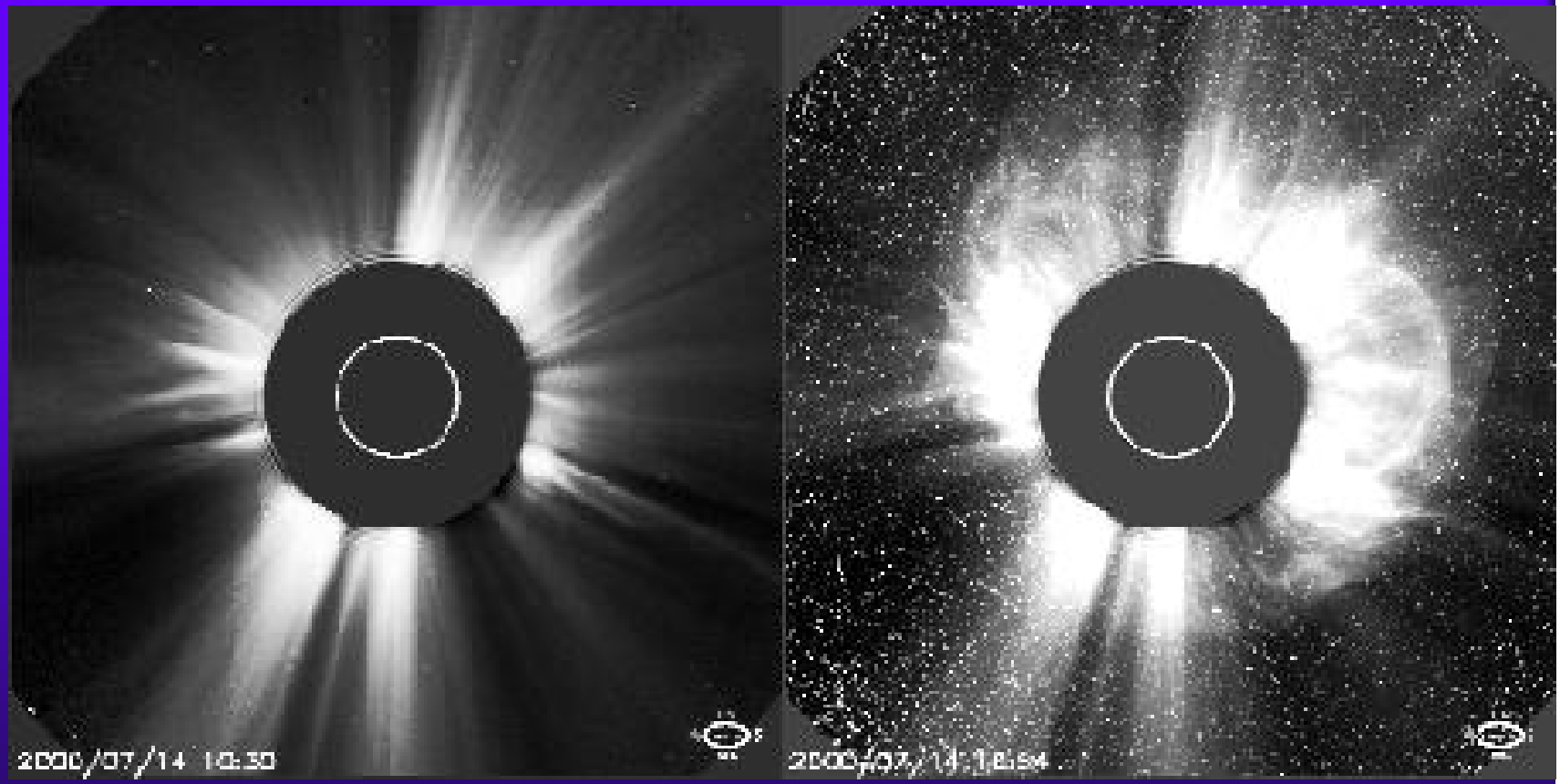
Halpha, 07/14/2000



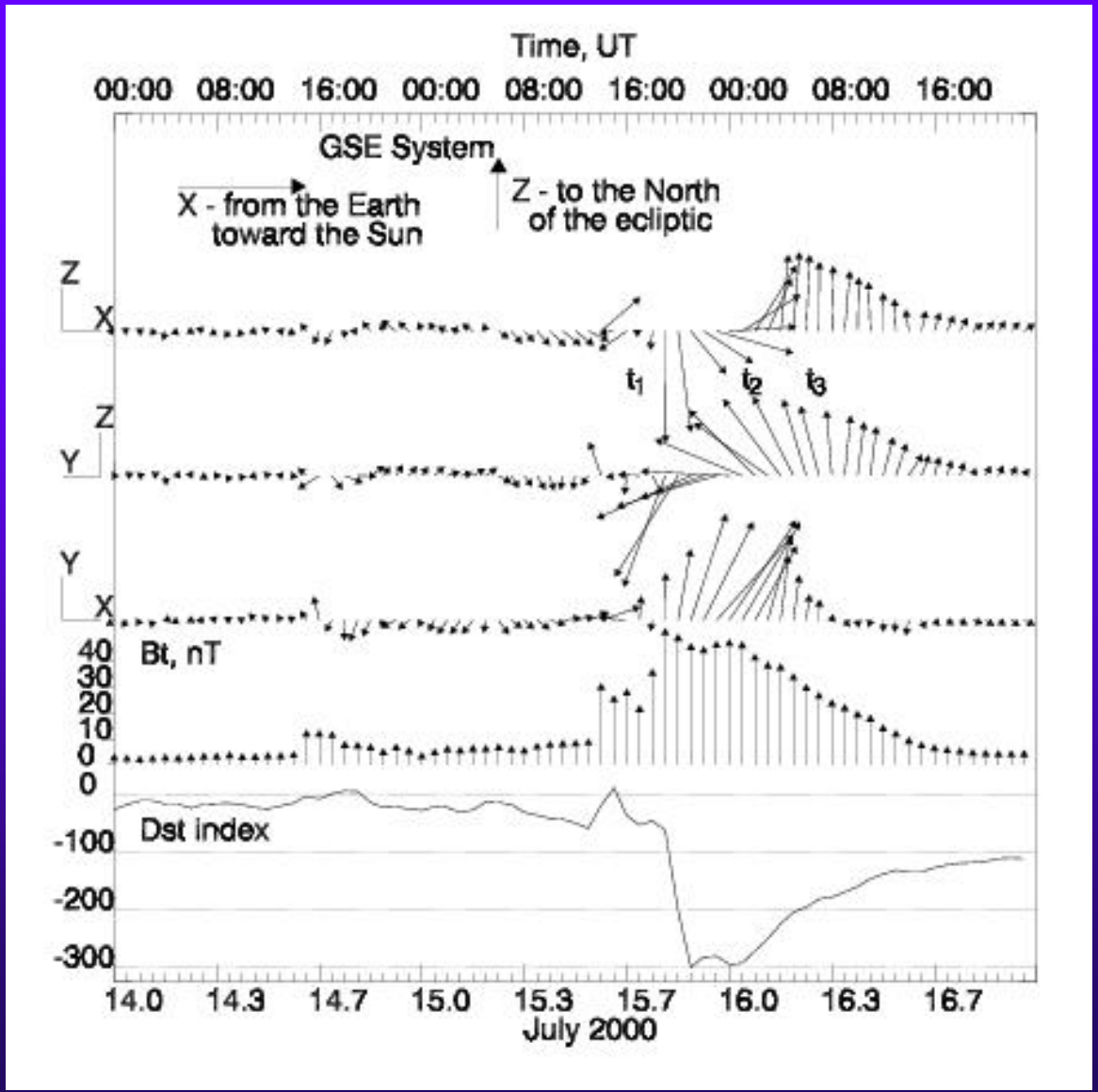
LFFF Extrapolation, 7/14/2000



LASCO C2, 7/14/2000



ACE Data, 7/14/2000



Cartoon to Demonstrate two Events (top, 2/17/2000, bottom, 7/14/2000)