Physics 777

Lecture 0

Introduction of the Sun
Big Bear Solar Observatory

Disk Photometer

- 65 cm Vacuum Reflector
- 25 cm Vacuum Refractor
- 15 cm Singer Full Disk Telescope
- 7.5 cm Photometric Full Disk Telescope
- 15 cm Earthshine Telescope

TON

Seeing Sensor

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
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 $R_\odot$. 

Big Bear Solar Observatory
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

![Graphs showing temperature, pressure, and density variations with height in the solar atmosphere.](image)
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

Sunspots
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 $T=80,000 \text{ K}$
- 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

diameter:
860,000 mi
1,392,000 km

Filament
Plage
Sunspot
Sunspot:
Penumbra
Umbra

Pore

Granule ——— Intergranular Lane

size:
40,000 x 27,000 mi
65,000 x 43,000 km
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

Longitudinal Zeeman Effect

Transverse 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

Magnetogram

Doppler velocity

Pore
Granule
Filament
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

4 June 1946: Hα photograph

Source: High Altitude Observatory Archives
Solar Eclipse

The Moon covers the Sun

Coronal Hole

Coronal Streamers

Prominences

Prominence

Coronal Hole
Solar Corona at Eclipse, 3 Nov 1994, Putre, Chile. High Altitude Observatory, NCAR, Boulder, Colorado, USA.
Fig. 14. White-light eclipse photographs of the corona taken during the eclipses of (a) 2 November 1980 and (b) 1 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. Kriger, 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
Halpah 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

BBSO  Feb–17–2000  180144UT
Two Ribbon Flare

16:31 16:38 16:51
Light Curves of Flares

![Diagram showing light curves of flares in different wavelengths.](image)

**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

(Lin et al. 2004)
Another CME

18 Aug 1980: White Light

Source: High Altitude Observatory/Solar Maximum Mission Archives
The Sun-Earth Connection
Space Weather Effects

- Galactic Cosmic Rays
- Surface and Interior Charging
- Magnetic Attitude Control
- Ionosphere Currents
- Radio Wave Disturbances
- Electricity Grid Disruption
- Earth Currents
- Computer and Memory Upsets and Failures
- Solar Flare Protons
- Astronaut Safety
- Atmospheric Drag
- Plasma Bubble
- Signal Scintillation
- Airline Passenger Radiation
- Rainfall Water Vapor
- Telecommunication Cable Disruption

Big Bear Solar Observatory
Two Major Effects of Space Weather

- Geo-Magnetic Storm
- SEP (Solar Energetic Particle)
LFFF (Linear Force Free Field) Extrapolation, 2/17/2000

Big Bear Solar Observatory
LASCO C3 Movie, 2/17/2000
ACE Data, 2/17/2000
LFFF Extrapolation, 7/14/2000

Big Bear Solar Observatory
ACE Data, 7/14/2000

The graph shows the evolution of various solar parameters over time. The X-axis represents time in UTC, with specific intervals marked for clarity. The Y-axis depicts different parameters such as Bt in nT and Dst index. The GSE System is used for orientation, with X and Z axes indicating directions from the Earth to the Sun and towards the North of the ecliptic, respectively. Several time points (t1, t2, t3) are marked on the graph to highlight significant changes or events. The data provides insights into solar activity and its impact on the Earth's magnetic field.
Cartoon to Demonstrate two Events (top, 2/17/2000, bottom, 7/14/2000)