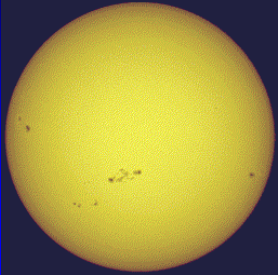


SUN

- > Rotates on its axis
 - > period = 27 d
- > Axis tilted 7.25°
 - > We see more of N pole in September



NASA

SUN

How do astronomers think it got started?

- > A nebula in the ISM
 - > Temp = 100 K
 - > Density = 10 particles/cm³ (H₂O = 10²³ molecules/cm³)
 - > Diameter of gas cloud destined to be the star = ~10¹⁴ km
- > A shock wave from a passing star or distant supernova initiates condensation
 - > Core temp increases to 50,000 K due to Kelvin-Helmholtz (compression) heating; Surface temp still only ~500K
 - > Density increases to ~10¹² particles/cm³
 - > Diameter = 10¹² km (Recall Sun currently 1.4 x 10⁶ km)

©Robert Provan, CSUN

Star Birth

Orion Nebula (M42)



Emission nebula in the ISM

WFPC2 Orion Mosaic STScI-PRC97-13, 1997

Star Birth

Orion Nebula (M42)



WFC2 Orion Mosaic STScI-PRC97-13, 1997

Star Birth



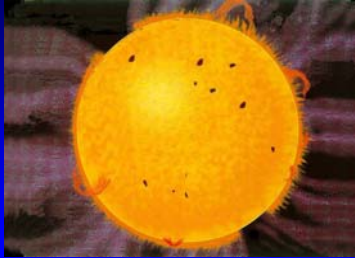
WFC2 Orion Nebula • OMC-1 Region
NICMOS
Protostar visible in IR
Hubble Space Telescope
PRC97-13 • ST ScI QPO • May 12, 1997
R. Thompson (Univ. Arizona), S. Stolovy (Univ. Arizona), C.R. O'Dell (Rice Univ.) and NASA

Star Birth

- > **Protostar stage** – Over a period of $\sim 10^7$ - 10^8 y gravitational collapse of the gases results in Kelvin-Helmholtz (compression) heating
 - > Temp rises to 3000 K
 - > Density increases to $\sim 10^{22}$ particles/cm³
 - > Diameter decreases to 10^7 km (only 10x bigger than current Sun)
- > During gravitational collapse and throughout protostar stage, core continues to heat

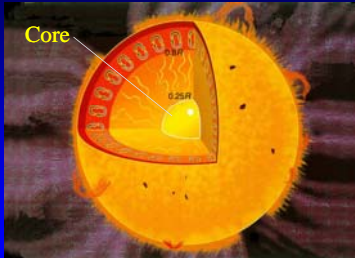
SUN: Structure

Let's open the Sun up and look inside



SUN: Structure

Core




Adapted from a NASA Illustration from *Orbiting Solar Observatory: Our Window on the Sun*

SUN: Structure

- > Core
- > 15,000,000 K

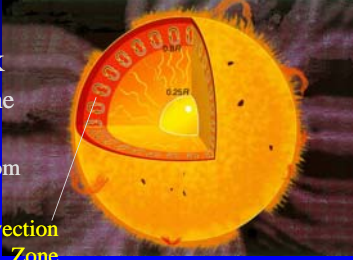
Radiative Zone



Adapted from a NASA Illustration from *Orbiting Solar Observatory: Our Window on the Sun*

SUN: Structure


- > Core
 - > 15,000,000 K
- > Radiative Zone
 - > Opaque
 - > Photon random walk
- > Convection Zone



The diagram shows a cross-section of the Sun. The innermost region is the Core, which is bright yellow and contains the text '15,000,000 K'. Surrounding the core is the Radiative Zone, depicted with a red and orange gradient and containing the text '0.25R'. The outermost layer shown is the Convection Zone, with a darker orange and red gradient. A white line points from the text 'Convection Zone' to the corresponding layer in the diagram.

SUN: Structure

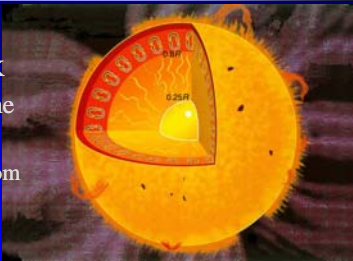
- > Core
 - > 15,000,000 K
- > Radiative Zone
 - > Opaque
 - > Photon random walk
- > Convection Zone
- > Photosphere



The diagram shows a cross-section of the Sun. The innermost region is the Core, which is bright yellow and contains the text '15,000,000 K'. Surrounding the core is the Radiative Zone, depicted with a red and orange gradient and containing the text '0.25R'. The next layer is the Convection Zone, with a darker orange and red gradient. The outermost layer is the Photosphere, shown as a thin, bright yellow layer. A white line points from the text 'Photosphere' to the corresponding layer in the diagram.

SUN: Structure

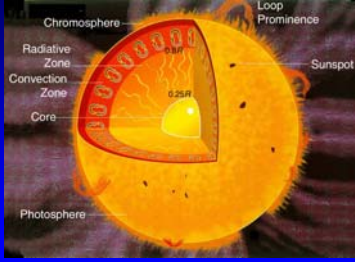
- > Core
 - > 15,000,000 K
- > Radiative Zone
 - > Opaque
 - > Photon random walk
- > Convection Zone
- > Photosphere



The diagram shows a cross-section of the Sun. The innermost region is the Core, which is bright yellow and contains the text '15,000,000 K'. Surrounding the core is the Radiative Zone, depicted with a red and orange gradient and containing the text '0.25R'. The next layer is the Convection Zone, with a darker orange and red gradient. The outermost layer is the Photosphere, shown as a thin, bright yellow layer. A white line points from the text 'Photosphere' to the corresponding layer in the diagram.

SUN: Structure


**R
E
V
I
E
W**



Labels in diagram: Chromosphere, Radiative Zone, Convection Zone, Core, Photosphere, Loop Prominence, Sunspot.

SUN: Structure

- > The Photosphere
- > ~5,800 K



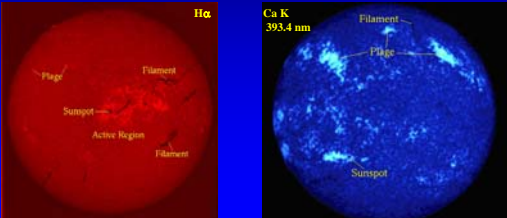
Visible Light

Cue the convection cells!
(Lockheed-Martin Advanced Technology Center/
Swedish Solar Observatory)

High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO

SUN: Structure

- > The Chromosphere
- > 2,000-3,000 km thick



H α

Ca K 393.4 nm

Labels in H α image: Plage, Sunspot, Active Region, Filament.

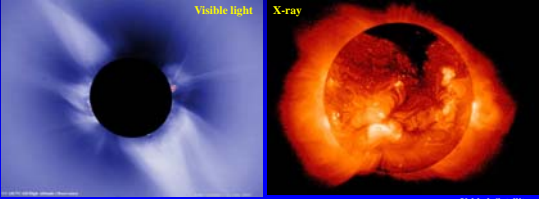
Labels in Ca K image: Filament, Plage, Sunspot.

National Solar Observatory, Sacramento Peak, NM

SUN: Structure

- > The Corona
- > ~1,000,000°C

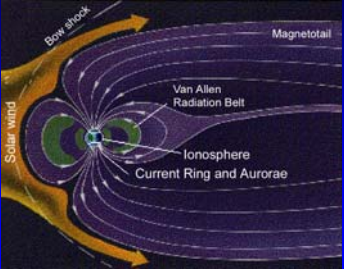
[Cue the Corona in visible \(LASCO/SOHO\)](#)
[Cue the corona in x-ray \(EIT/SOHO\)](#)
[Cue a CME in visible \(LASCO/SOHO\)](#)



UCAR/NCAR/High Altitude Observatory Yohkoh Satellite

LASCO - Large Angle and Spectrometric Coronagraph
EIT - Extreme ultraviolet Imaging Telescope

SUN: Effect of the Solar Wind



Adapted from J. B. Kaler, Stars, Scientific American Library, 1992


SUN: Effect of the Solar Wind

The Aurora Borealis



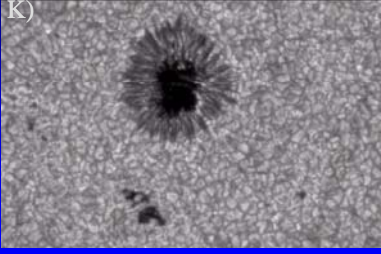
SUN: Sunspots

- ▶ Cool (4300 K) regions



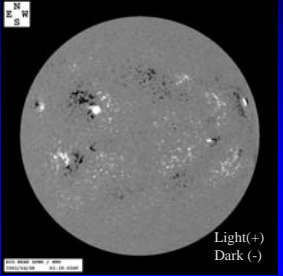
SUN: Sunspots

- ▶ Cool (4300 K) regions



SUN: Sunspots

- ▶ Cool (4300 K) regions
- ▶ Regions of strong magnetic field




Light (+)
Dark (-)

Global Oscillation Network Group/BBSO

SUN: Sunspots

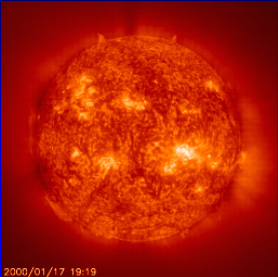
- ▶ Cool (4300 K) regions
- ▶ Regions of strong magnetic field
- ▶ Come in NS pairs



NASA/SkyLab, 1973

SUN: Sunspots

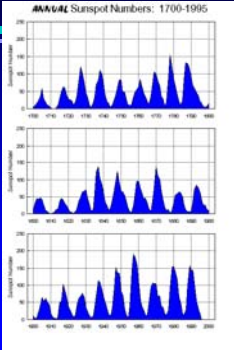
- ▶ Cool (4300 K) regions
- ▶ Regions of strong magnetic field
- ▶ Come in NS pairs



2000/01/17 19:19
Vic Winter, ICSTARS

SUN: Sunspots

- ▶ Cool (4300 K) regions
- ▶ Regions of strong magnetic field
- ▶ Come in NS pairs
- ▶ 11 year cycle/22 year cycle



Average Sunspot Numbers: 1700-1995
