(1)Magnitude and Color of Stars

(2)background on the Sun

Magnitude System

- Definition relative to Vega:

$$m_1 - m^*_{vega} \equiv -2.5 log_{10} \frac{\int f_1(\lambda) d\lambda}{\int f^*_{vega}(\lambda) d\lambda}$$

$$m_{1,F} - m^*_{vega,F} \equiv -2.5 log_{10} \frac{\int f_1(\lambda) A_F(\lambda) d\lambda}{\int f^*_{vega}(\lambda) A_F(\lambda) d\lambda}$$

Magnitude System

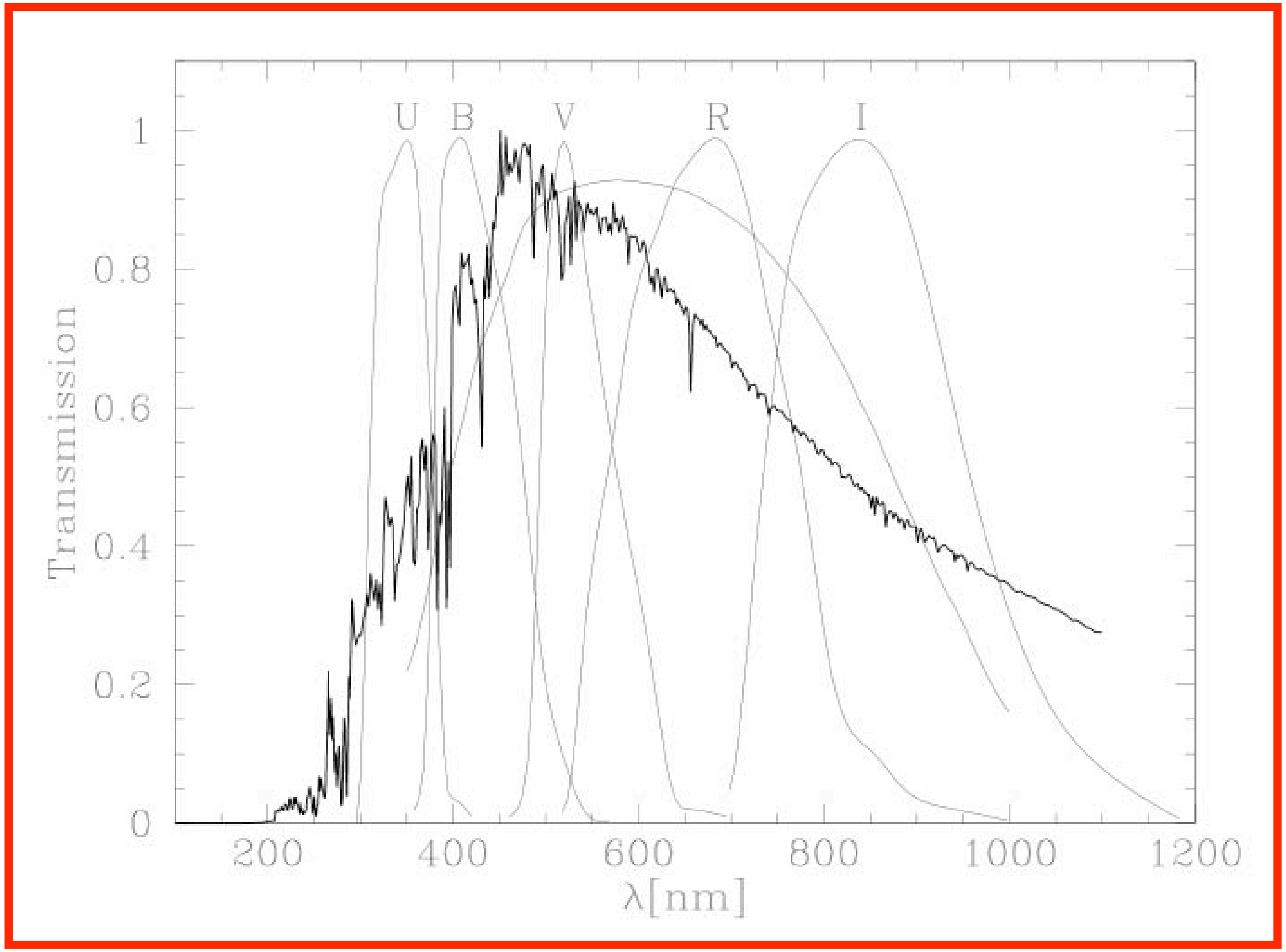
- Normalization

$$m_X = -2.5\log_{10}\left[\frac{\int_{\lambda_a}^{\lambda_b} F(\lambda)S_X(\lambda)d\lambda}{F_{X,\lambda,0}\int_{\lambda_a}^{\lambda_b} S_X(\lambda)d\lambda}\right]$$

$$F_{\{U,B,V,R,I\},\lambda,0} = \{4.27, 6.61, 3.64, 1.74, 0.832\} \times 10^{-9}\ erg\ cm^{-2}\ s^{-1} \text{Å}^{-1}$$

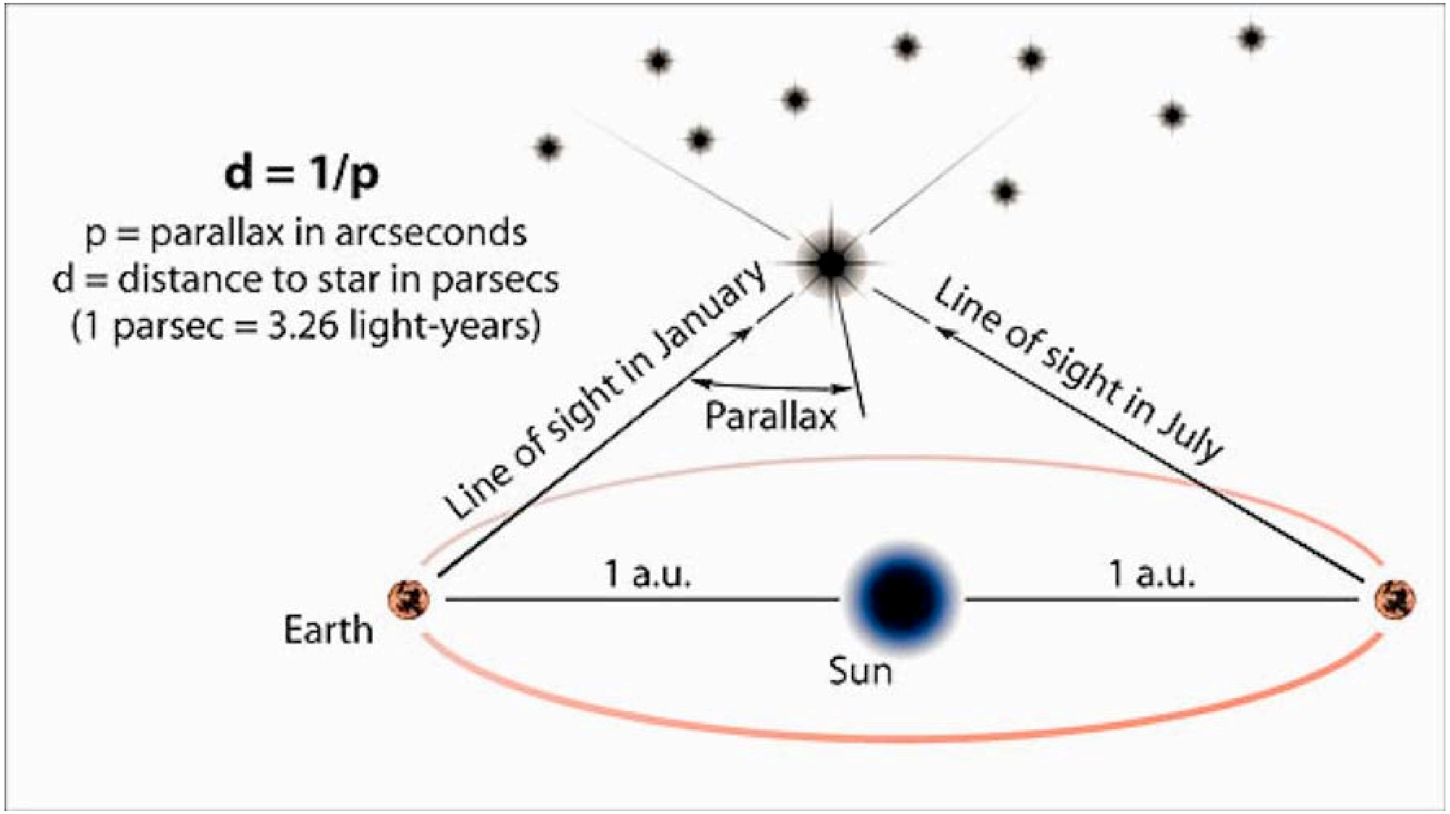
Filters and Solar spectrum

- Example: G2 i.e., solar like spectrum



Absolute Magnitude

- Absolute magnitude = magnitude at distance of 10 pc



Temperature & Color

- Effective Temperature:

  Each Surface element of a black body emits: σT^4.

  Total Emission from from a black body star at temperature T is: $L=4\pi R^2\sigma T^4$.

  Stars are not black bodies! However, we define the effective temperature Teff to be the temperature such that:

  $L=4\pi R^2\sigma T_{eff}^4$ or $T_{eff} = L/4\pi R^2\sigma\ ^{1/4}$

Temperature & Color

- Color Temperature:

$$B_\nu(T) \propto \frac{2h\nu^2}{c^2}\frac{1}{\exp(h\nu/kT)-1}$$

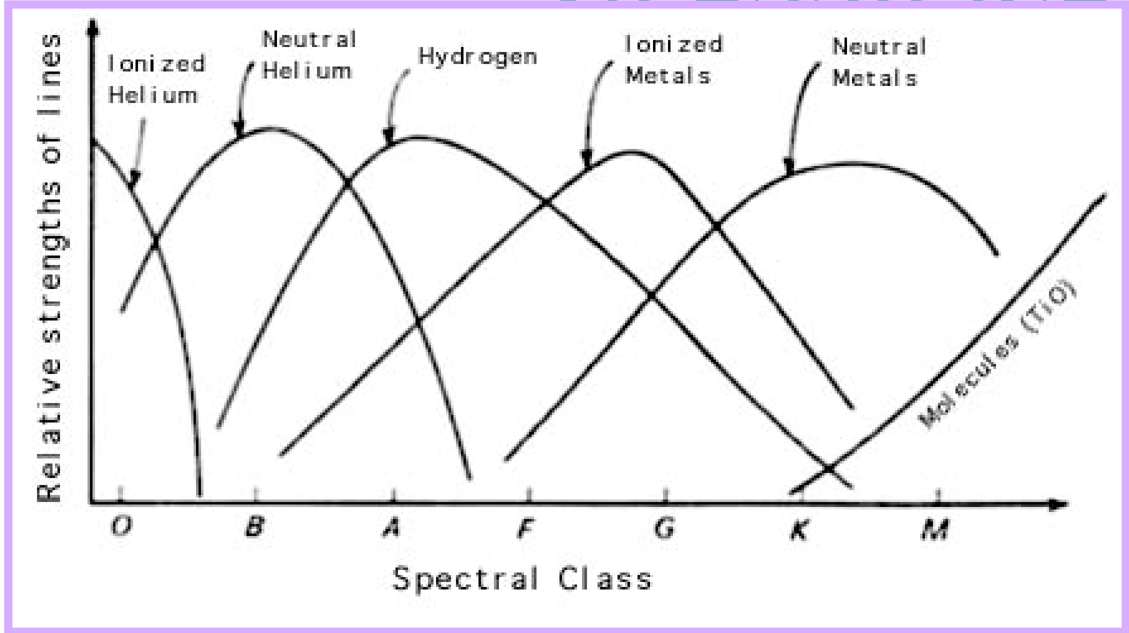
$$m_B - m_V \equiv (B-V) = -2.5\log\left(\frac{\int_{\lambda_a}^{\lambda_b} B(\lambda)S_B(\lambda)d\lambda / \int_{\lambda_a}^{\lambda_b} S_B(\lambda)d\lambda}{\int_{\lambda_a}^{\lambda_b} B(\lambda)S_V(\lambda)d\lambda / \int_{\lambda_a}^{\lambda_b} S_V(\lambda)d\lambda}\right) + 2.5\log\left(\frac{F_{B,\lambda,0}}{F_{V,\lambda,0}}\right)$$

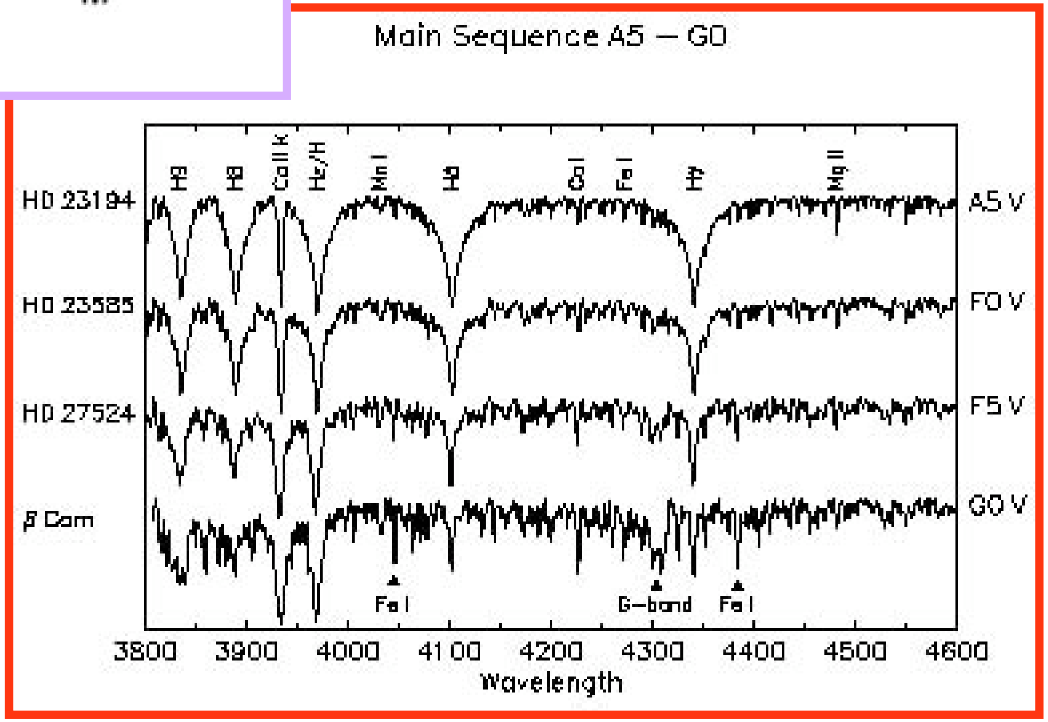
- T_{color} B V is the Black Body temperature that gives the observed B V.

Spectral Classification

- Stars can also be classified according to spectral lines that appear in spectrum
  - Hi ionization state of metals
    - > high T e.g., 50,000°K for O stars
  - Molecular lines in spectrum
    - > Low T e.g., 3000°K for M stars
- Types: hot O B A F G K M cold
  - Subtypes 0 9

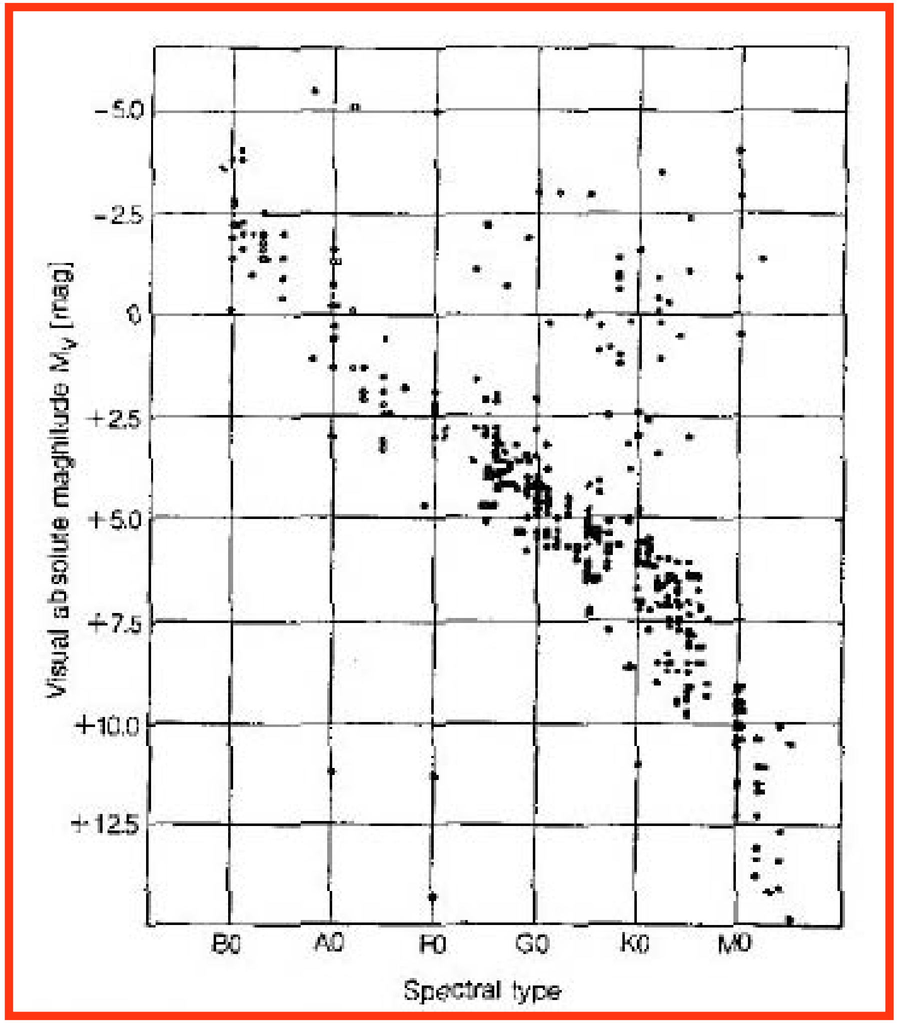
Ionization States vs. Classification





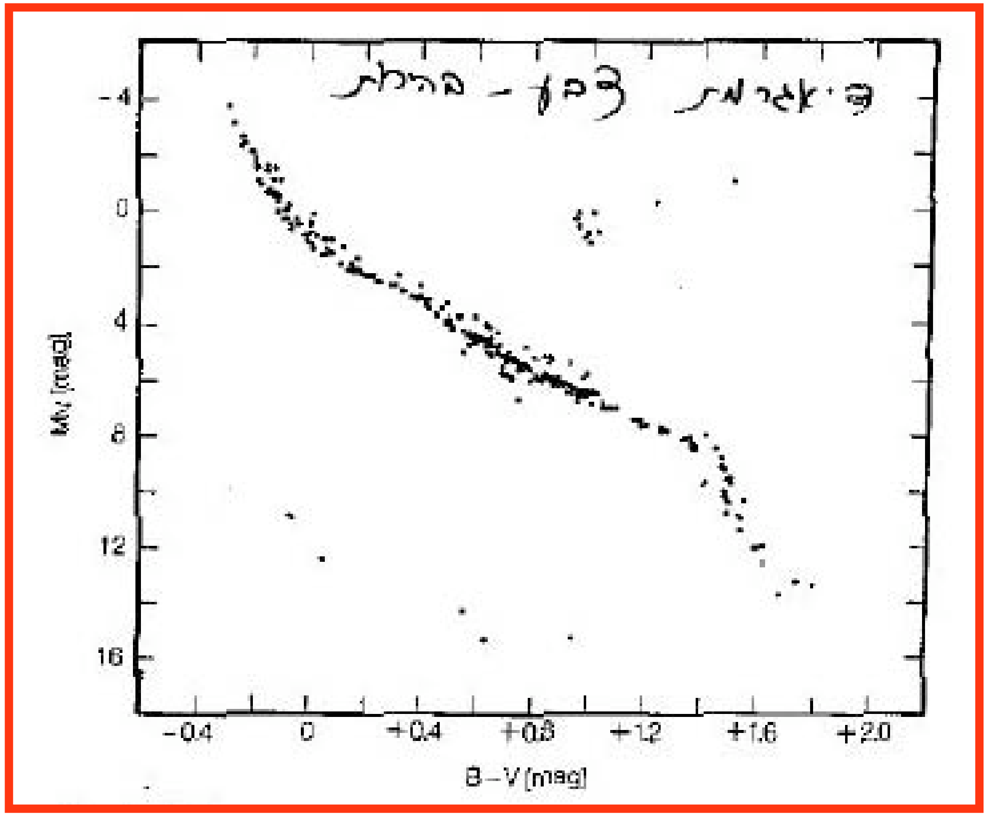
HR DIAGRAM

- Hertzprung   Russel Diagram:



Color Magntidue diagram

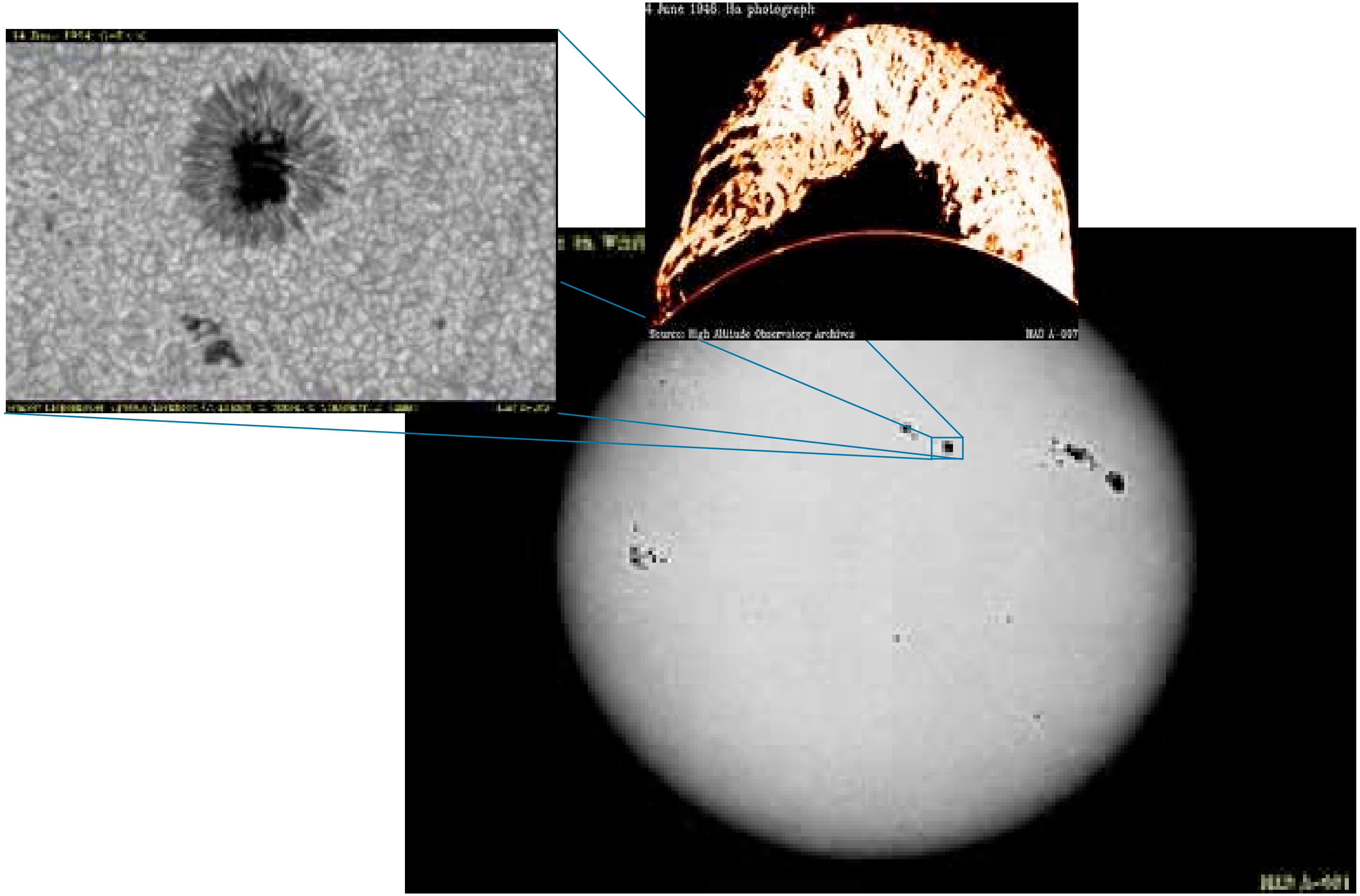
- Uses B V i.e., color tempeture :



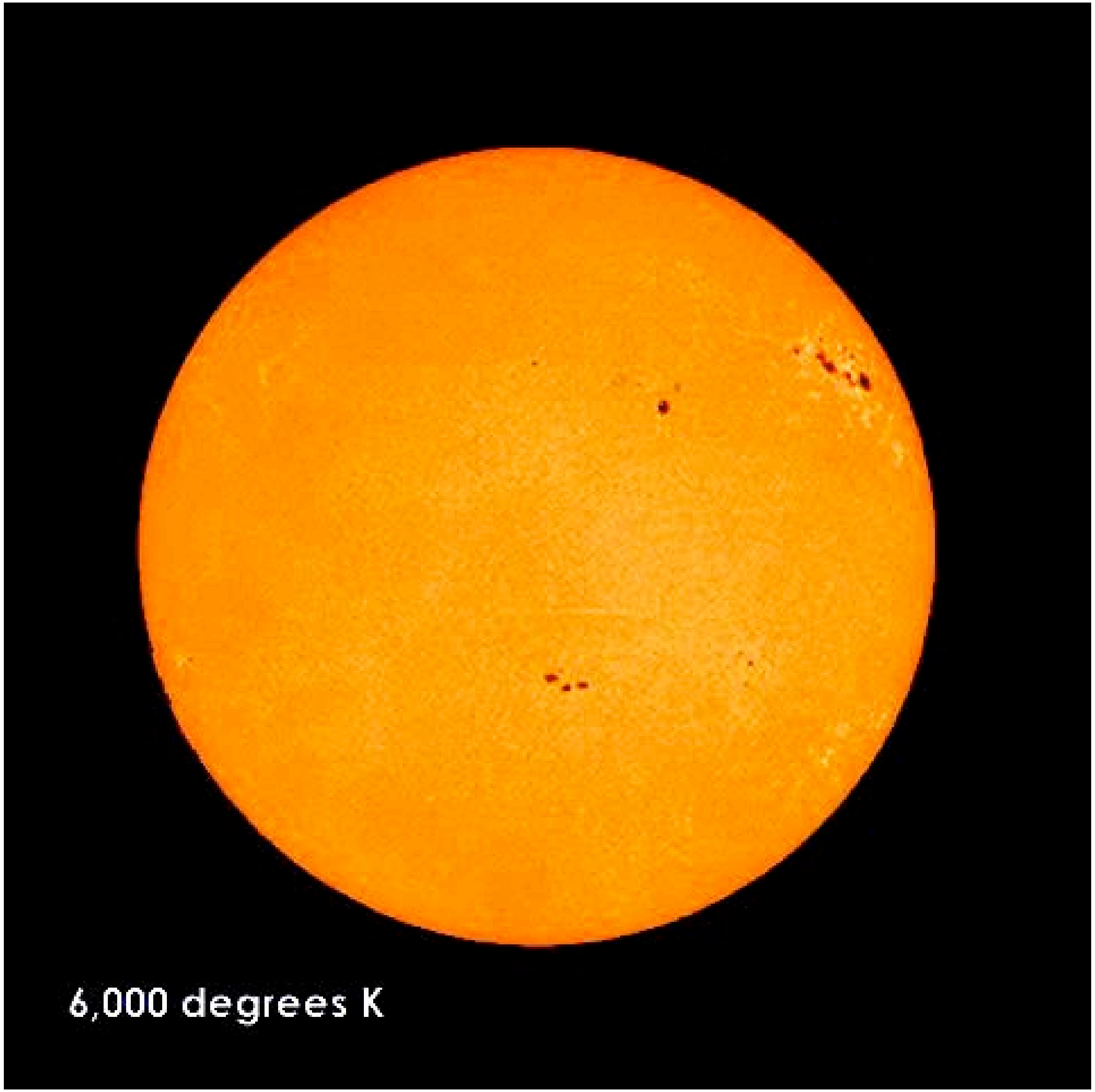
What do stars really look like?

- One really good example: Sun
  - Look at various wavelengths:
    - Radio, IR, Optical, UV, X rays
  - Resolve disk spatial information
  - Look at sun in other forms:
    - “Listen” to acoustic oscillations.
    - Measure □’s from nuclear reactions
    - Measure charged particles in solar wind

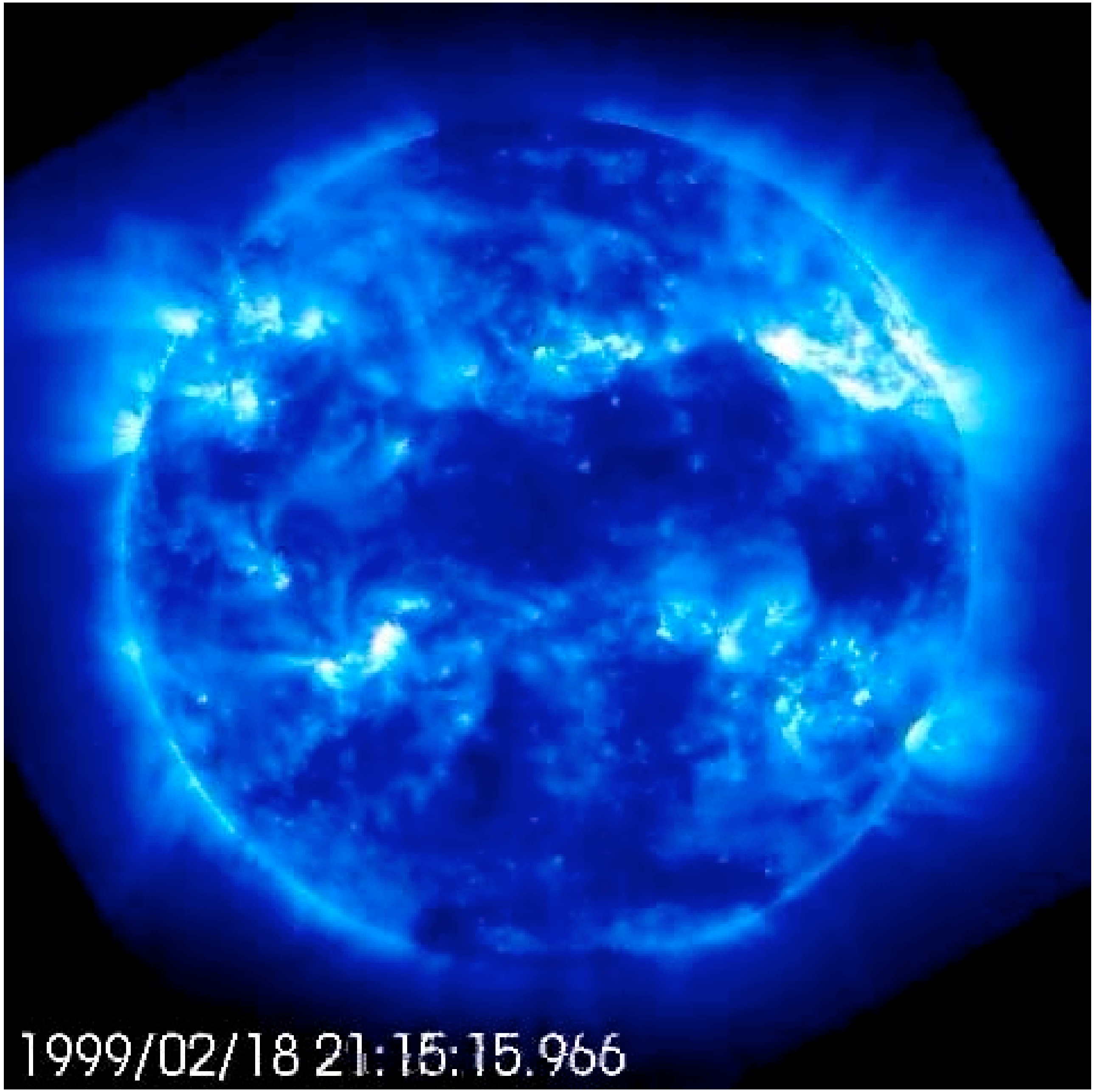
The sun in optical wavelenths



The Sun in observed as observed with "electro-magnetic" Radiation:



The active sun at nonthermal wavelenths (x-rays)



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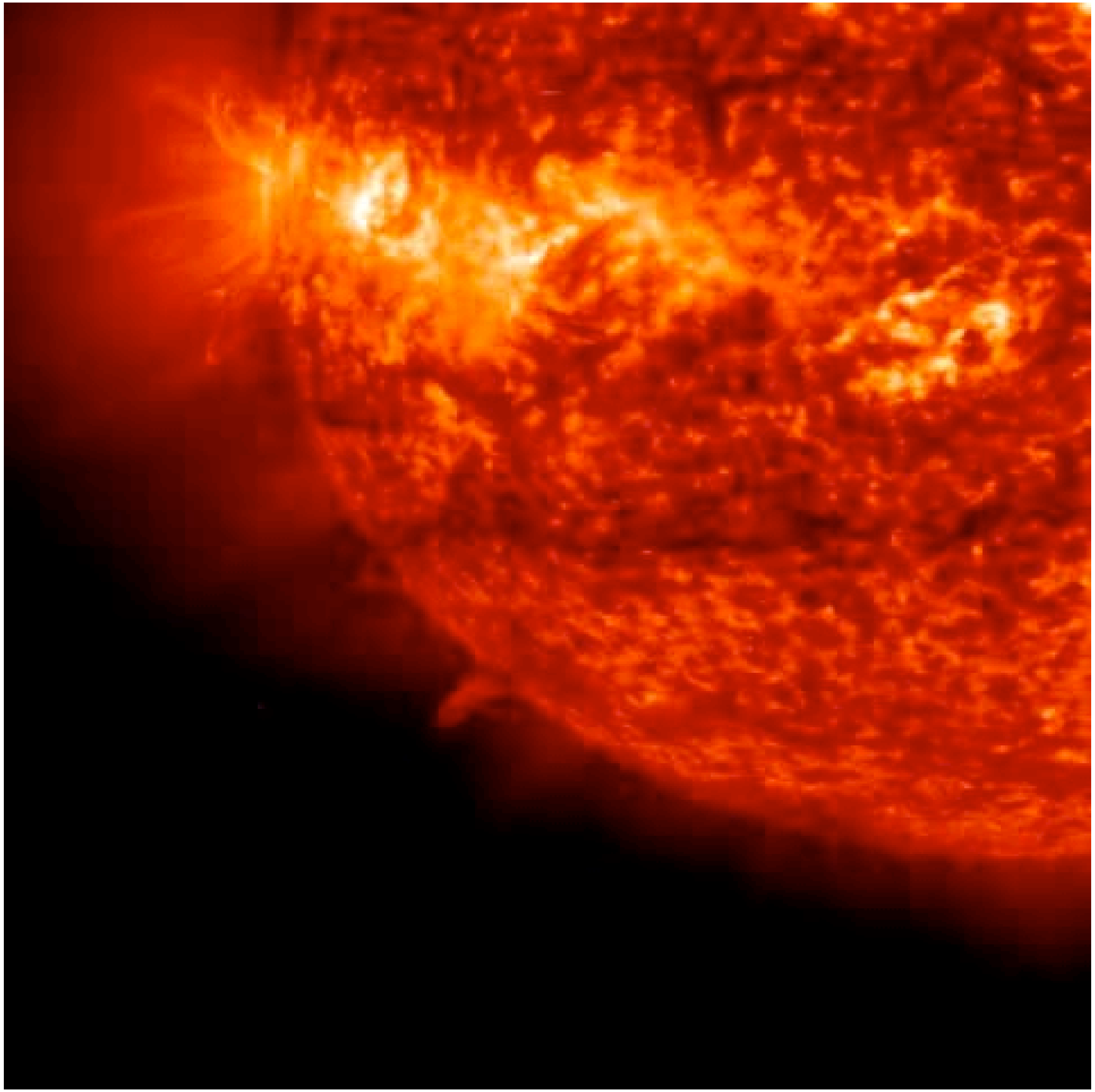
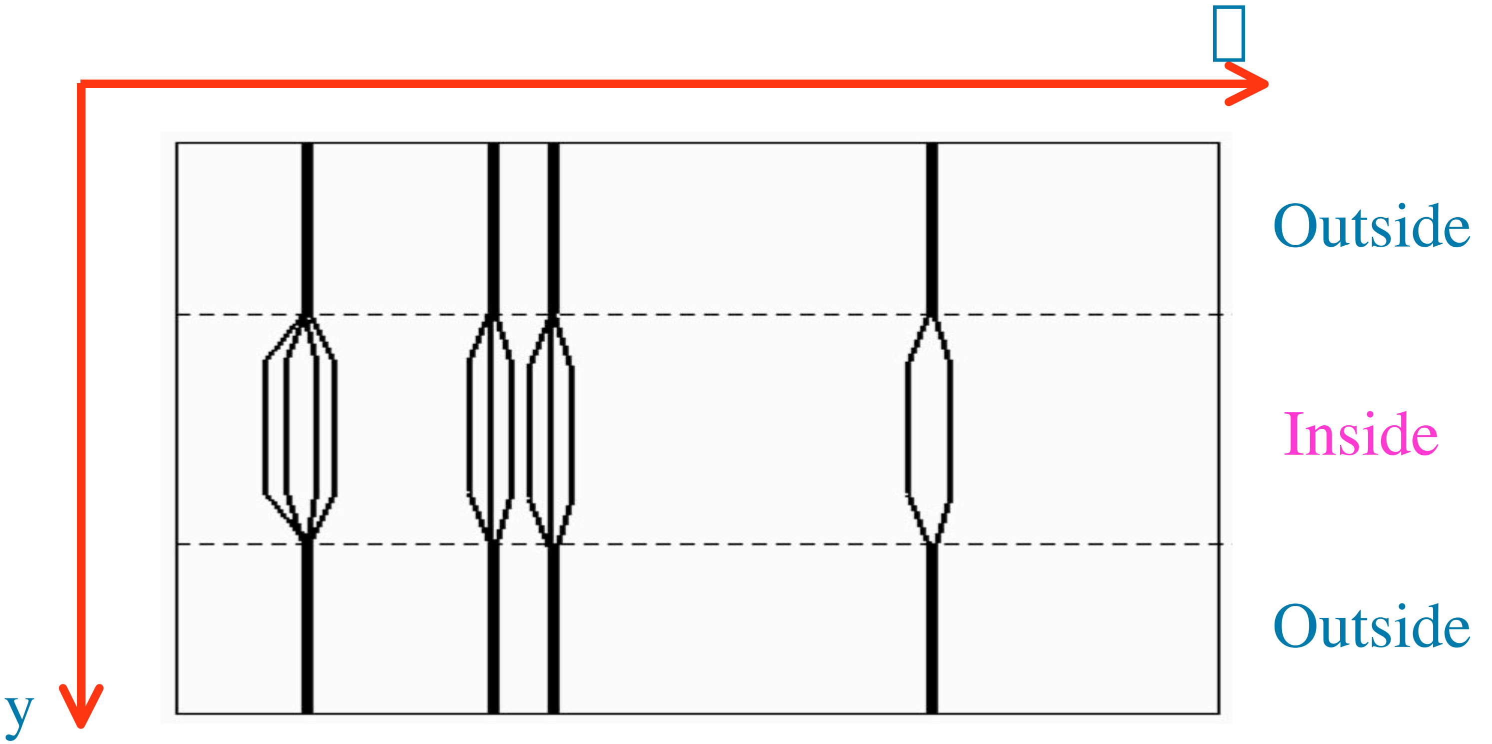
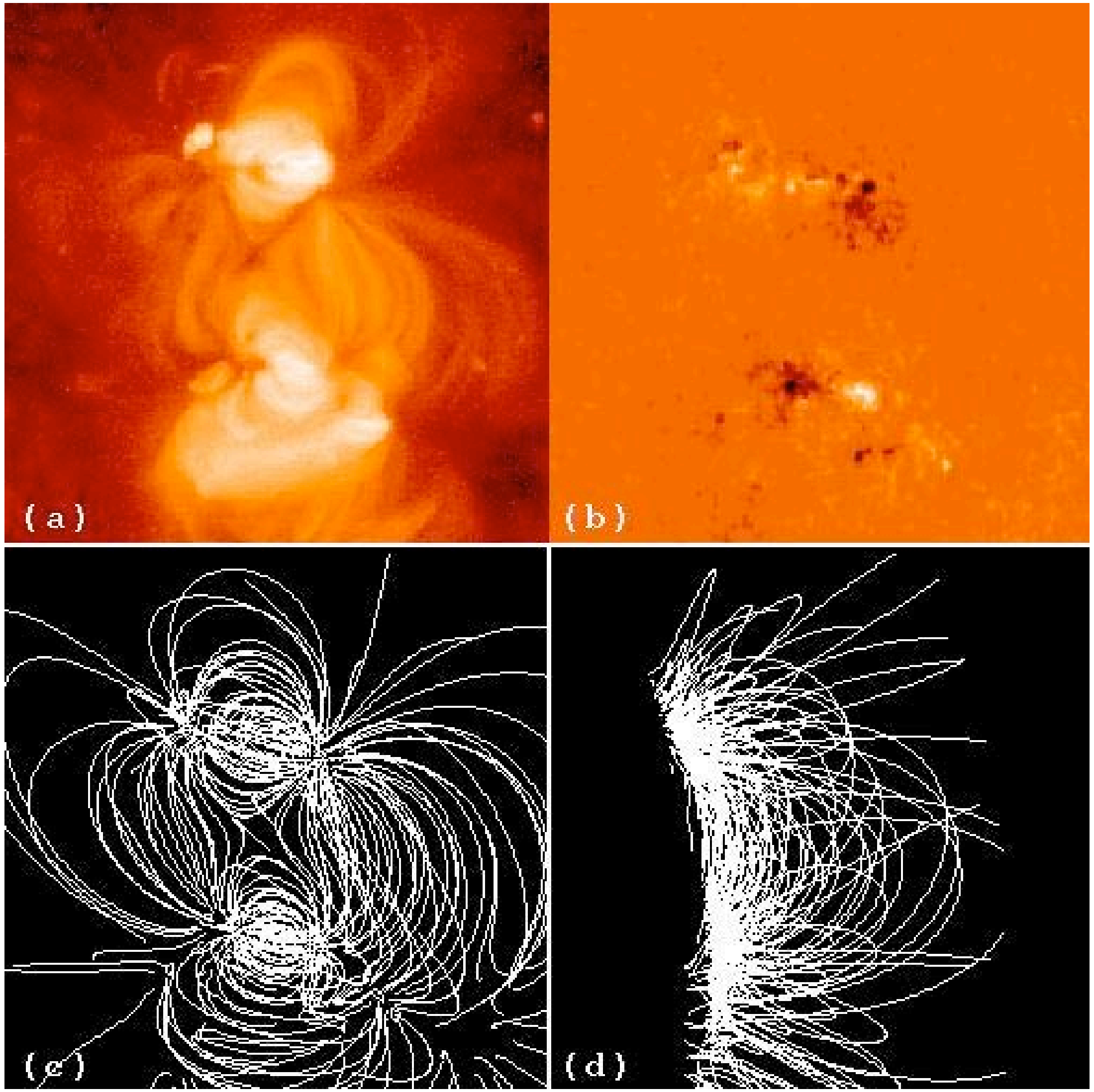


Magnetic fields and Zeeman

Zeeman splitting of spectral lines inside sun spot is an indication to strong magnetic fields

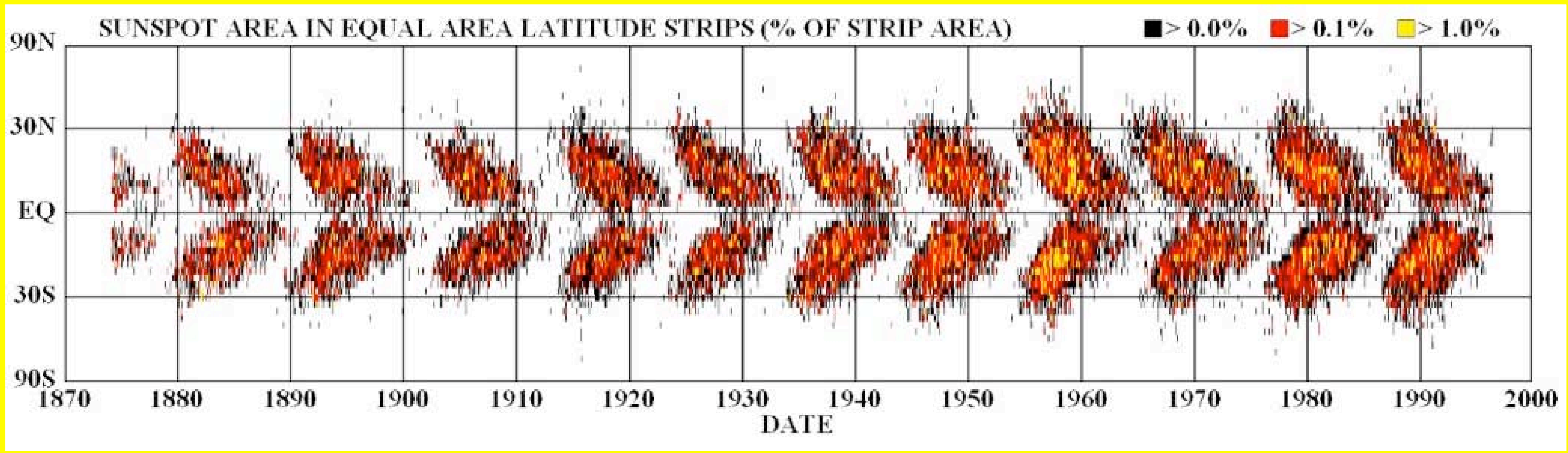


Sunspots and Magnetic fields



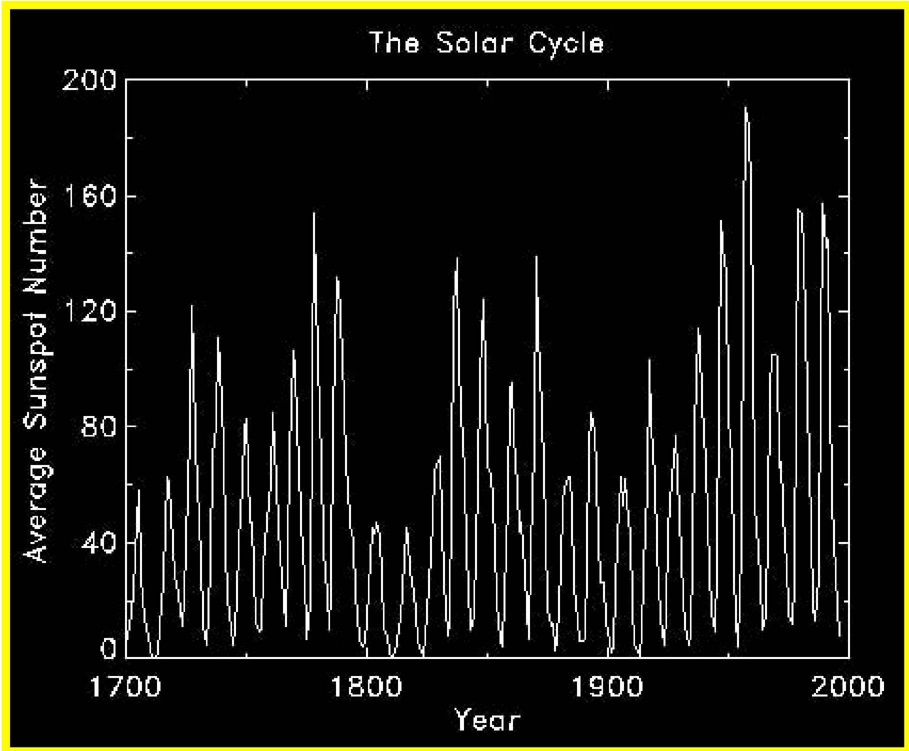
Magnetic Activity of the Sun

- The sun spot and local magnetic activity have a quasi period of 11 yrs on average
- Dipole magnetic field switches polarity with same period.
- Additional activity: Solar Wind and there for aurora's on Earth etc.



Long term variability

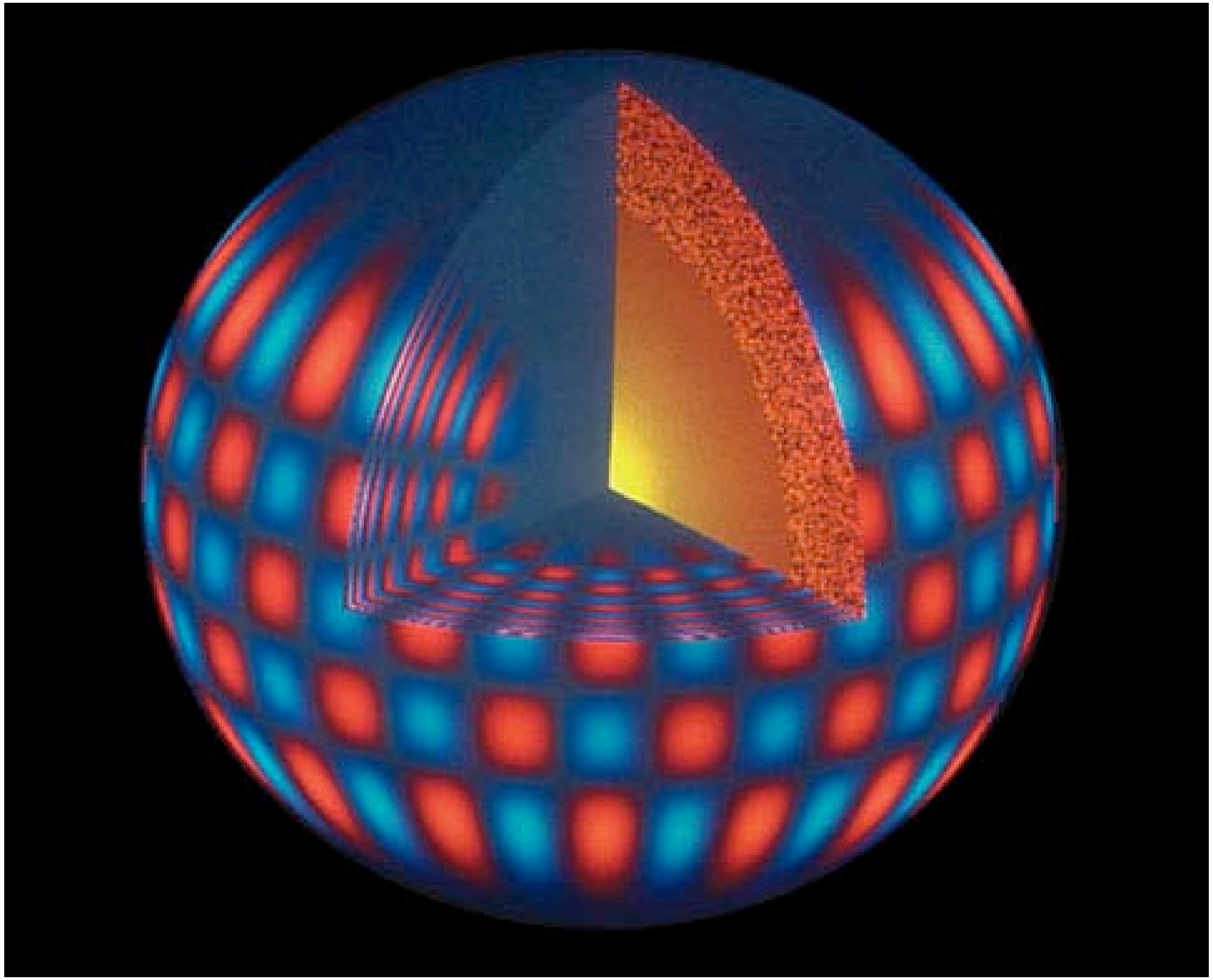
- Sun also has long irregular variations in sunspot/magnetic/ nonthermal activity e.g., Maunder Minimum during 1650 1700



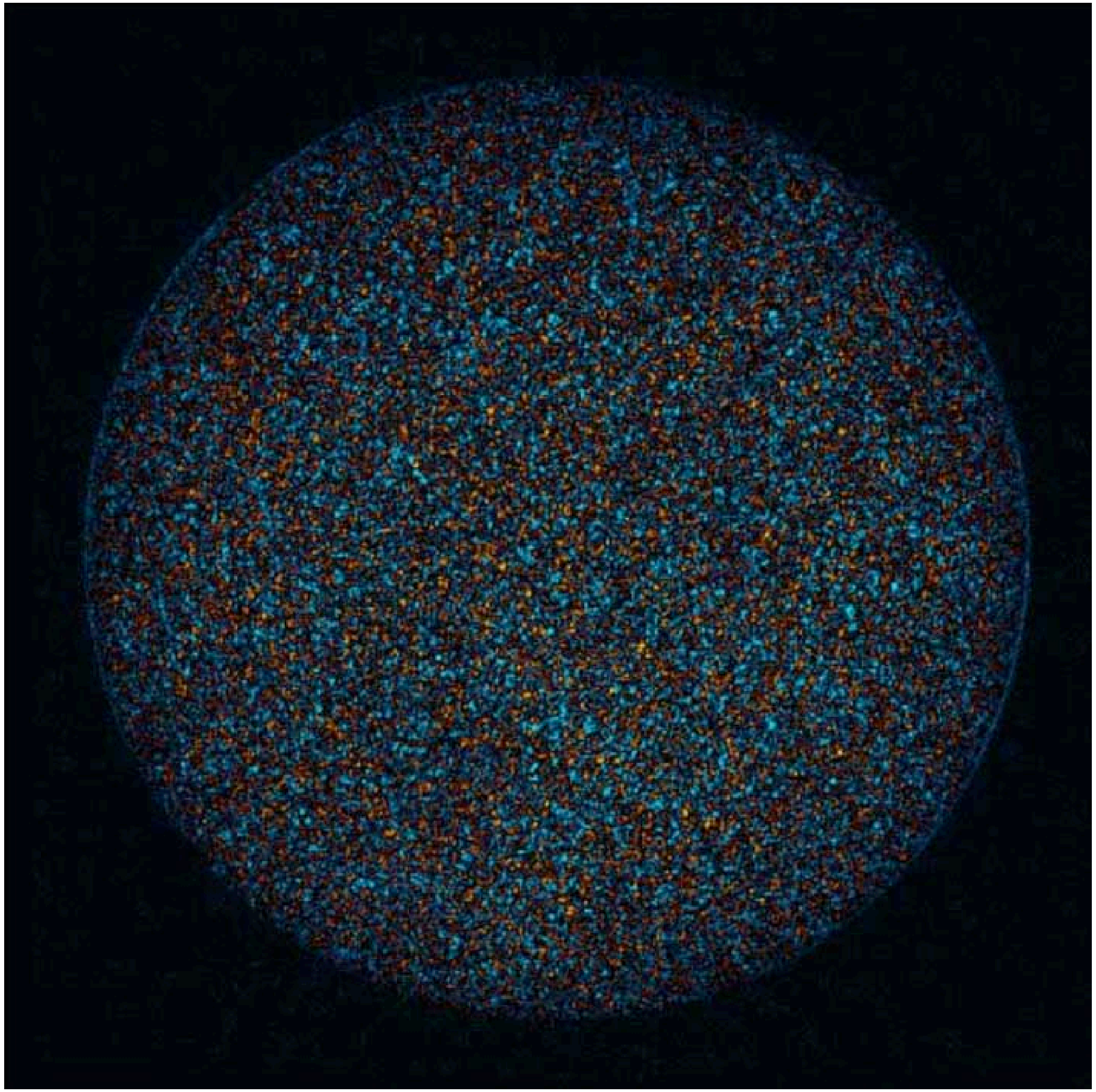
Listening to the sun: Helioseismology

- Since the sun has a wave source   the convection layer, it *vibrates*.
- By measuring the frequencies of oscillation, the structure of the sun can be inferred e.g., *the run of the speed of sound* .

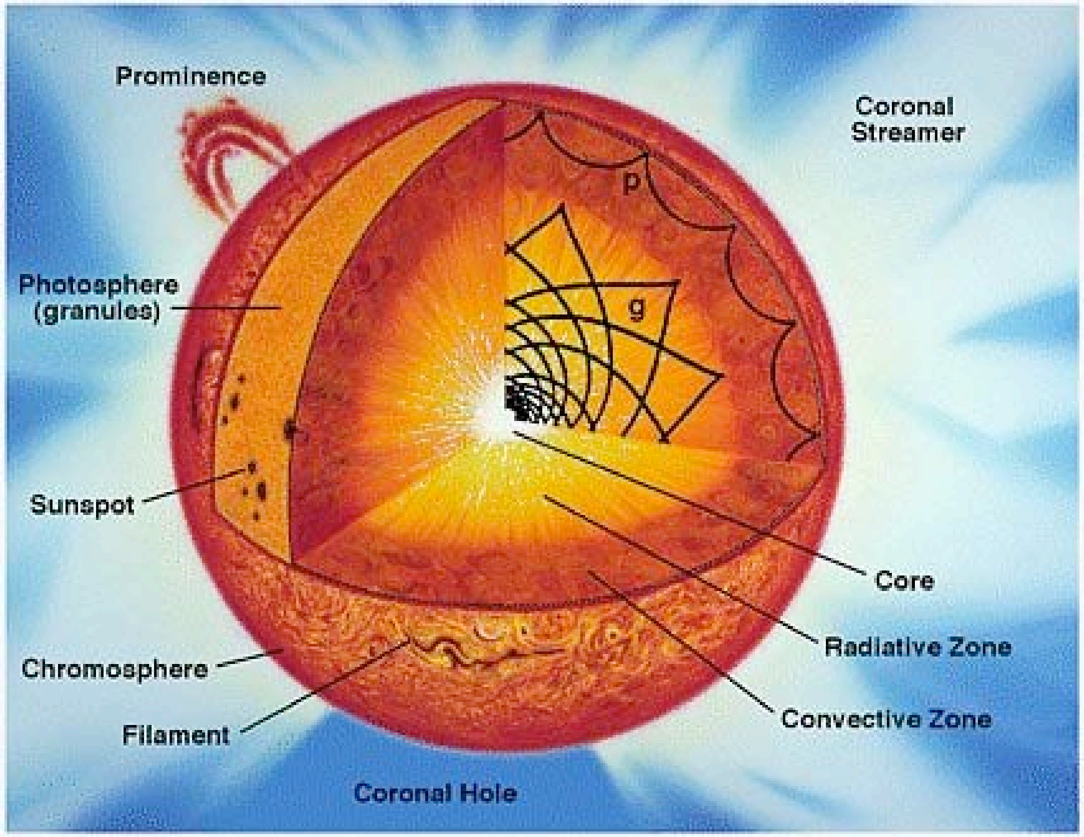
Sample "Eigenmode"

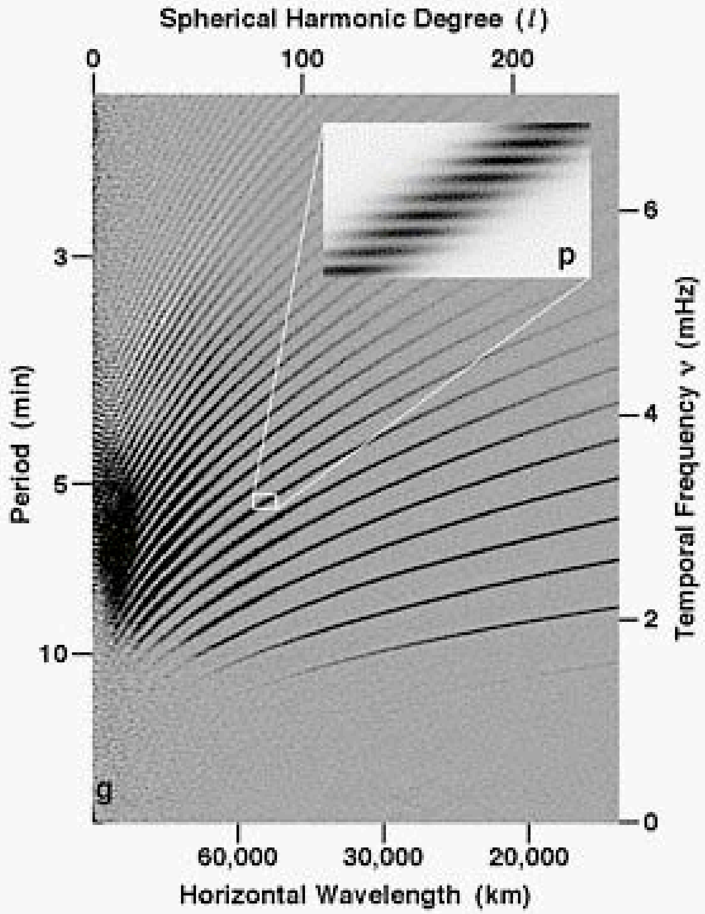


An "Acoustic Snapshot" (Dopplergram)

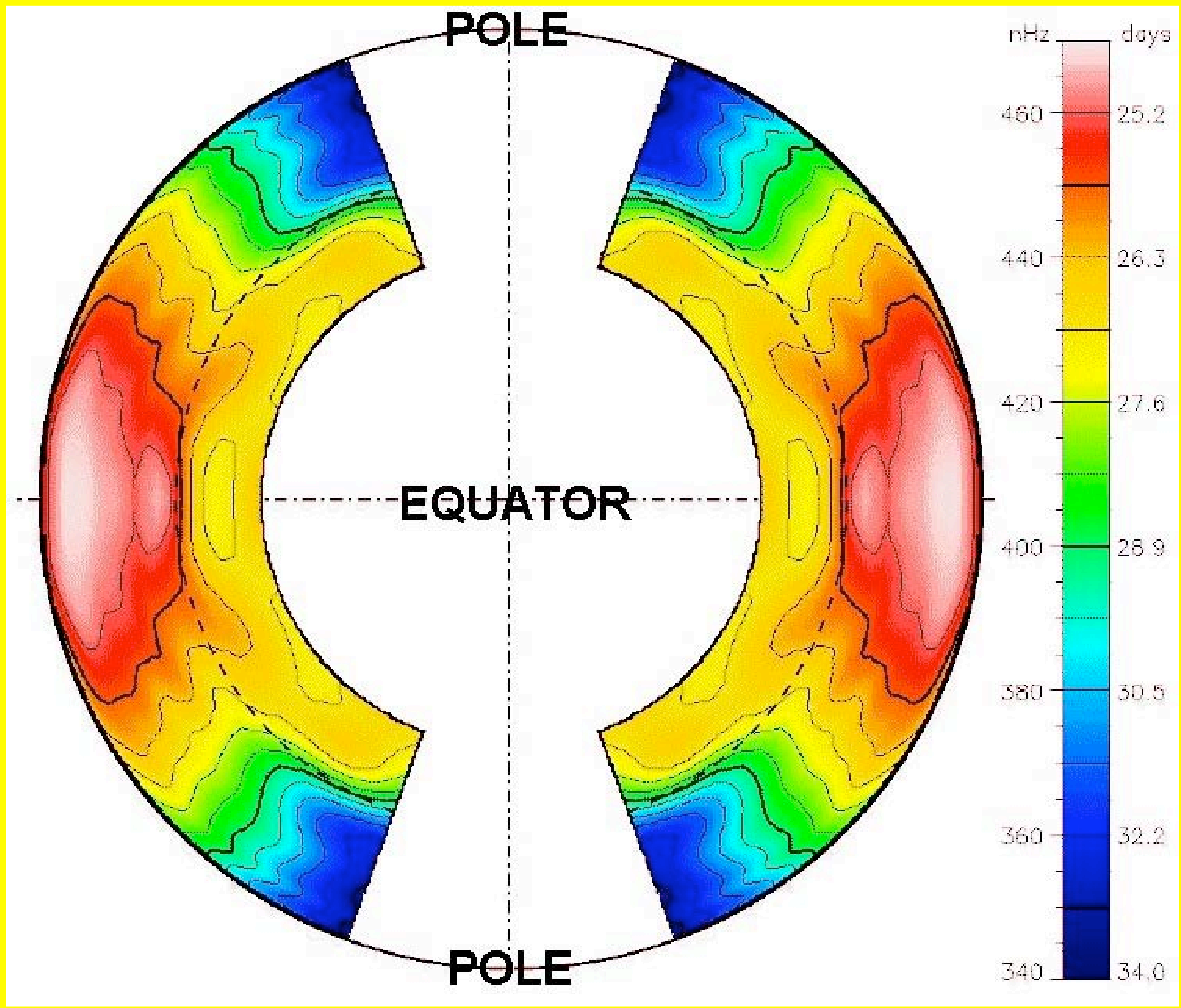


The Observed modes

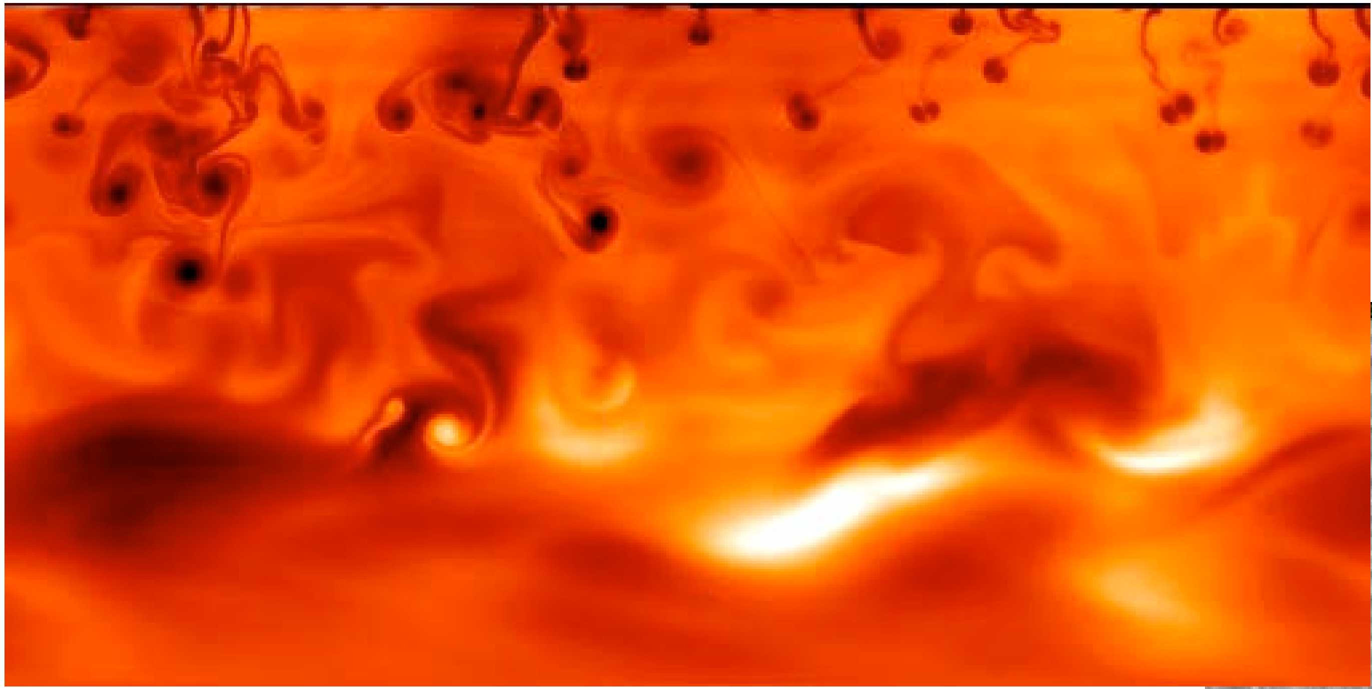


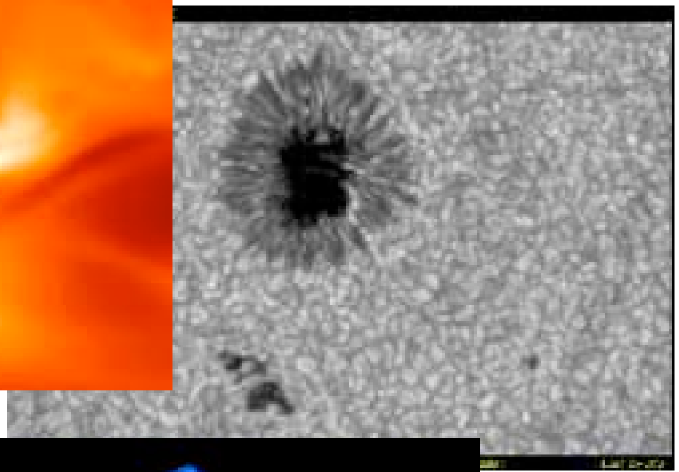


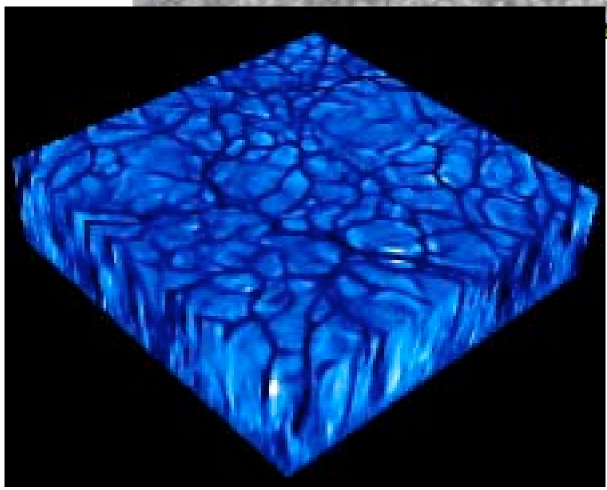
The Solar Differential Rotation



Outer part is convective

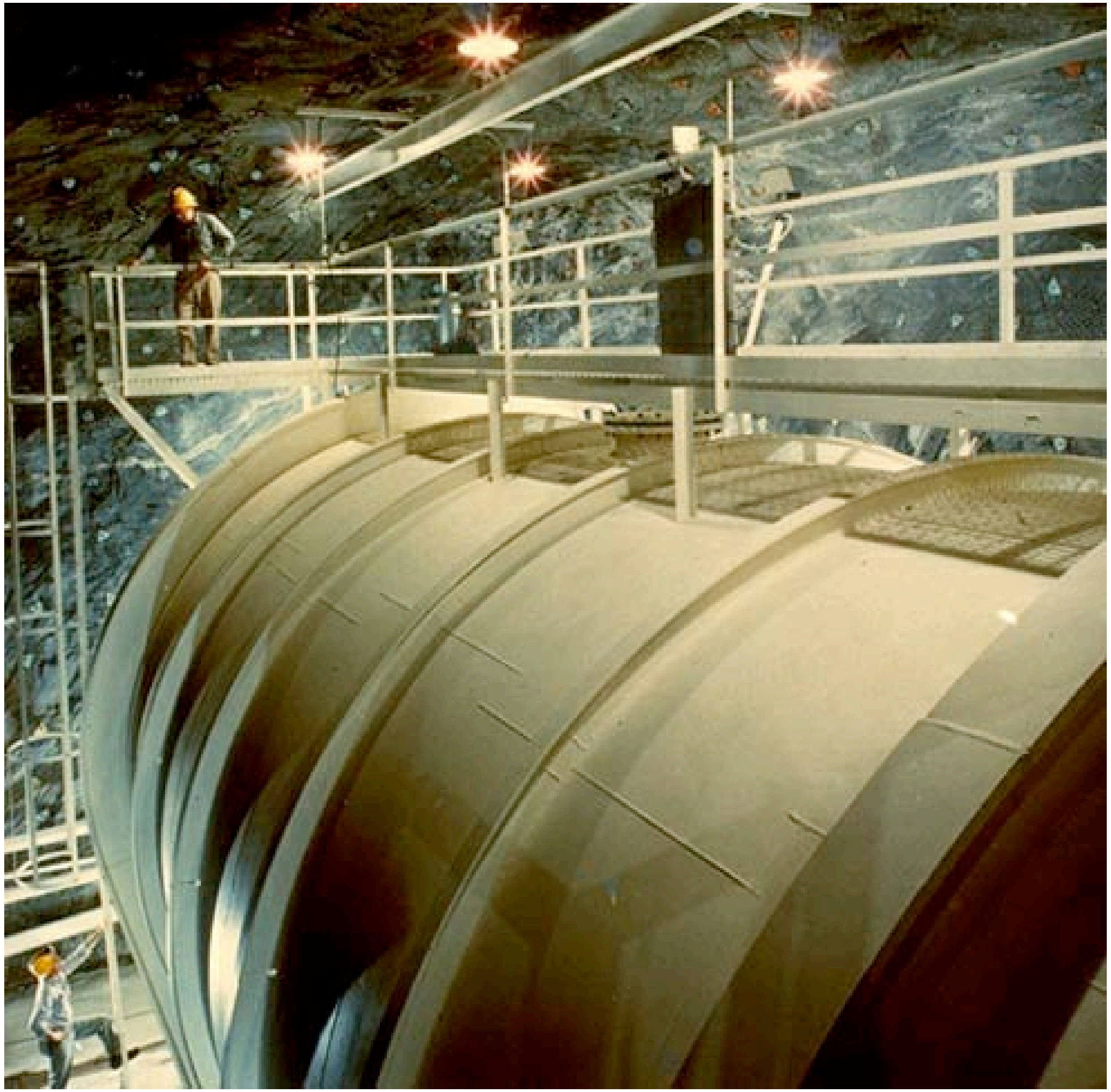






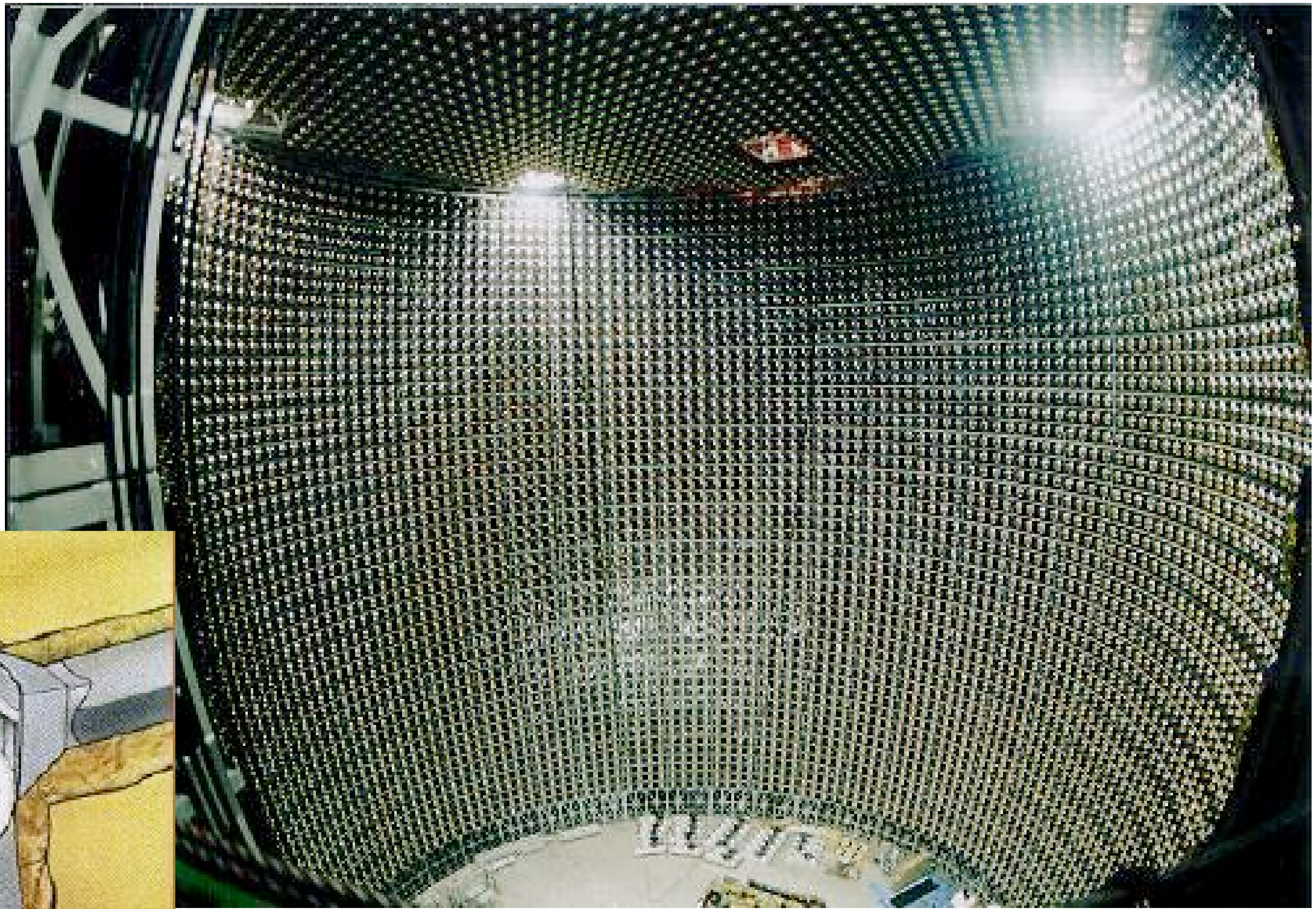
- Hot gas elements rise + Cold gas elements fall = heat trasport called convection

Sun generates energy through thermonuclear reactions!

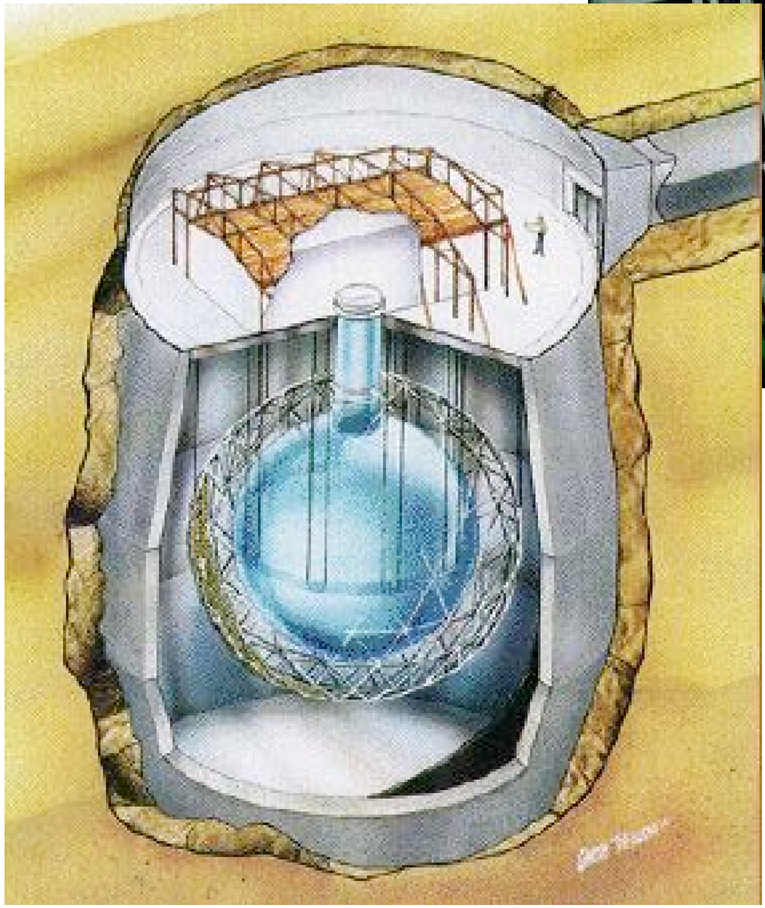


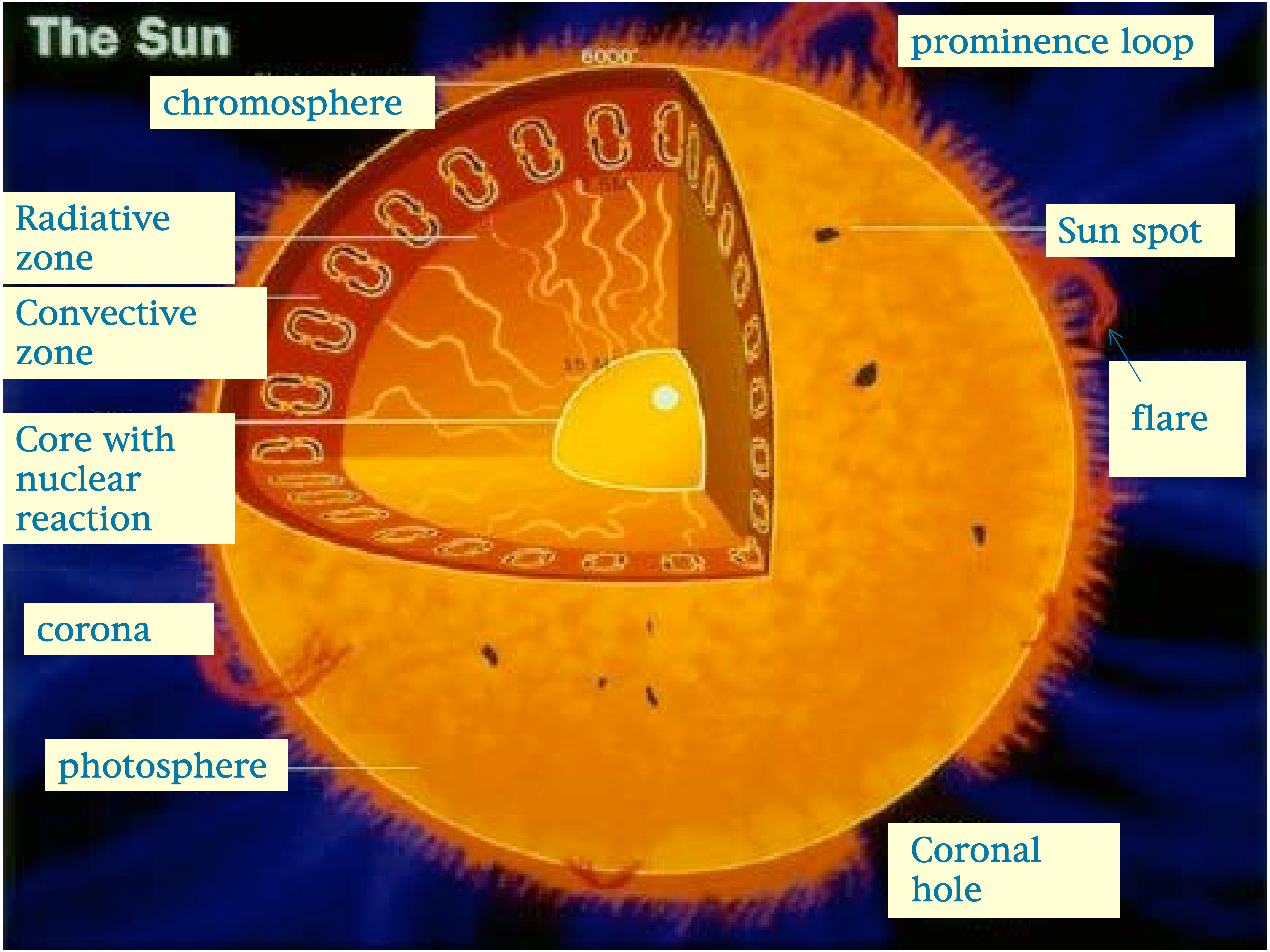
Homestake Gold Mine Neutrino Experiment ($\nu_x + Cl^{37} \rightarrow Ar^{37} + e^-$)

Super-Kamiokande
Neutrino Detector



Sudbury Neutrino
Observatory





The Sun
chromosphere
prominence loop
Radiative zone
Convective zone
Sun spot
Core with nuclear reaction
flare
corona
photosphere
Coronal hole
6000°