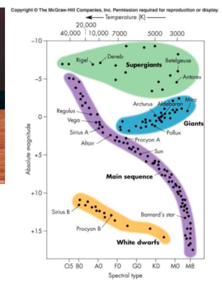
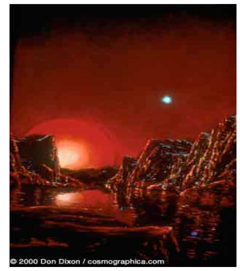
The meaning of the Main Sequence

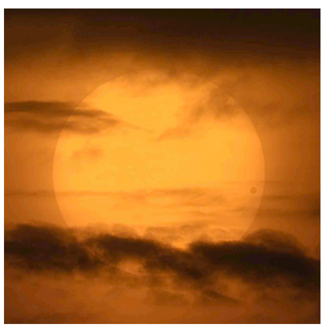


The Main Sequence is a long-lived phase of stellar evolution. Stars spend a much longer time here than in other parts of the HR diagram



Back to the Sun: its interior structure

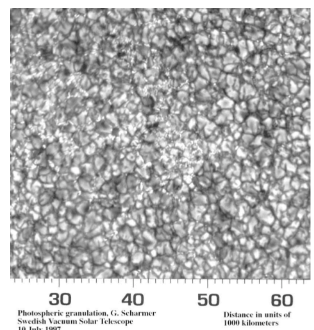
The Sun is a key to understanding the stars because we can get such detailed information about it



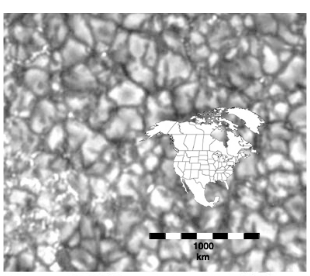
First hint: solar granulation as evidence of convection

Convection=boiling
Motion of hot fluid in
A gravitational field

demo



The scale of solar granulation

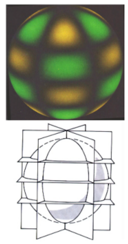


Photospheric granulation, G. Scharmer
Swedish Vacuum Solar Telescope
10 July 1997

How can we know the structure of the Sun below the photosphere?

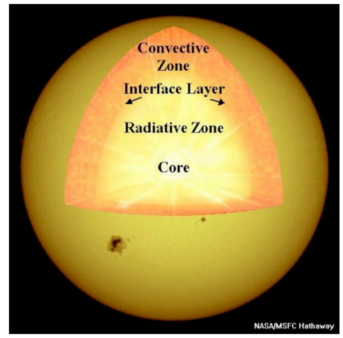
- Application of the laws of physics (equations of stellar structure), find solution consistent with mass and radius of Sun
- Measure “eigenmodes” of the Sun (see how fast it jiggles)
- Results for how the sun is put together

Helioseismology: the study of the eigenmodes of the Sun. Hear the "Singing Sun"

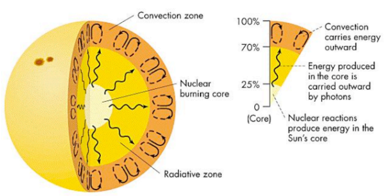


http://solar-center.stanford.edu/singing/singing.html

Our knowledge of the solar interior



Stellar interior slides from textbook (17.1)



Gravity tends to squeeze a star into ever-smaller object. What resists this tendency?

The gravitational force acting to cause the star to contract is balanced by the high pressure in the interior of the Sun or another star. At each point in the stellar interior, the pressure must equal the weight of the overlying material. In physics, this condition is called *hydrostatic equilibrium*

demo

Physical properties 1: density

Units: mass/volume

Grams/cc

(1) water…1 grams/cc

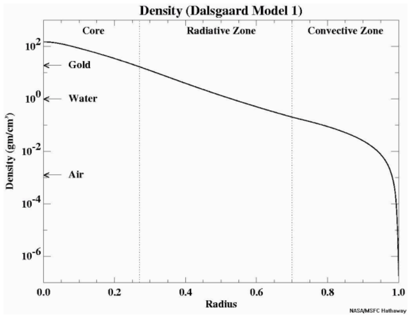
(2) rock… about 3 grams/cc

(3) Lead…11.3 grams/cc

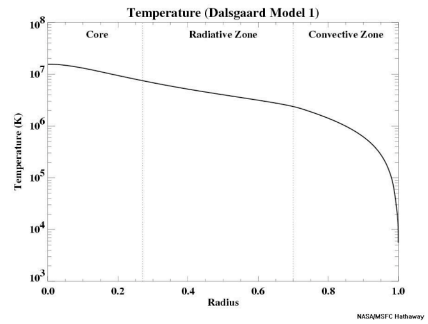
Physical properties 2: temperature

- Units: degrees centigrade
- Temperature Kelvin: degrees C above absolute zero
- Temperature of this room: 295K
- Boiling point of water: 373 K
- Surface temperature of Sun 5800K

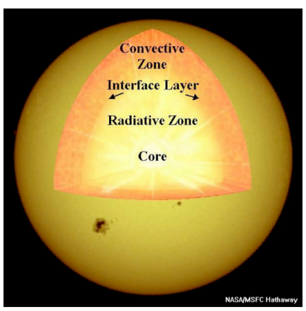
Distribution of density inside the Sun



Distribution of temperature inside the Sun



The interior of the Sun is a region of *extreme* physical conditions



Next topic: what is the luminosity of the Sun telling us?

- Luminosity = 3.847×10^{26} Watts
- What fuel cycle could provide this?
- What fuel cycle could provide this for the lifetime of the Sun?

Say it with equations! (easy ones)

- Luminosity = power =energy/time
- Energy=powerXtime
- Time=energy/power

Let's see how long we could keep the Sun shining with a known, powerful energy source

Coal

- Coal runs civilization
- Energy content: 24 MegaJoules/kilogram=
- 2.4×10^{7} Joules/kg
- If the Sun were made of coal, how long could it "burn", providing its current power or luminosity?

Power and the Sun

- Mass of Sun = $2X10^{30}$ kilograms
- Total energy content of "coal Sun"=$(2X10^{30})X(2.4X10^{7})$ =$4.8X10^{37}$ Joules
- Time the Sun could "keep this up" = energy/luminosity =$4.8X10^{37}/3.8X10^{26}$=$1.3X10^{11}$ seconds
- Is this a lot or a little????

A strong conclusion: energy drawn from coal burning, or any other chemical reaction, is *grossly* inadequate to power the Sun over geological timescales

Some vastly more powerful energy source (than chemical reactions) must be occurring in the Sun and stars