Section 2.
Stellar structure

2.1 Hydrostatic equilibrium

2.2 Nuclear burning

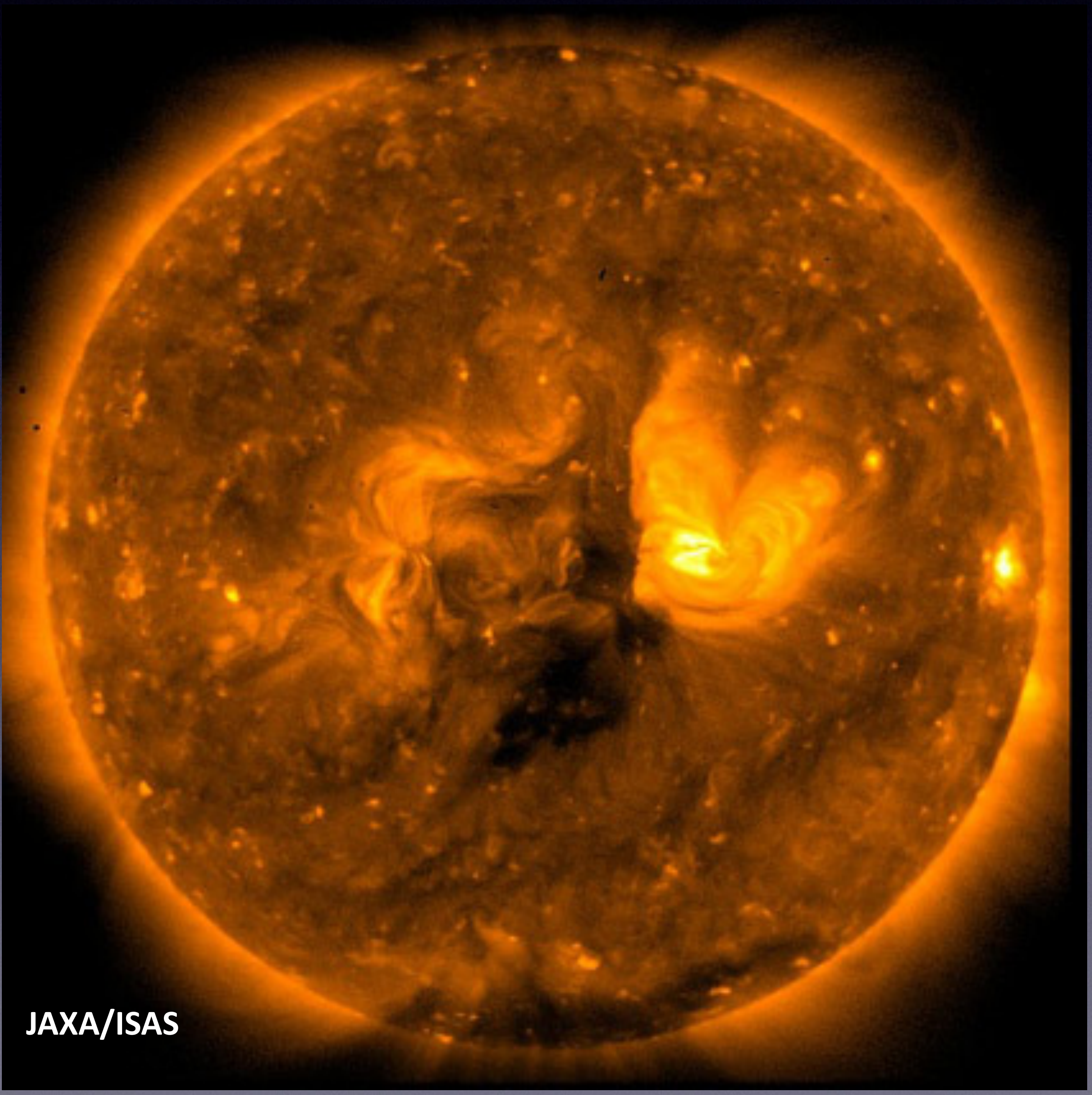
Let's understand these questions with the words of physics

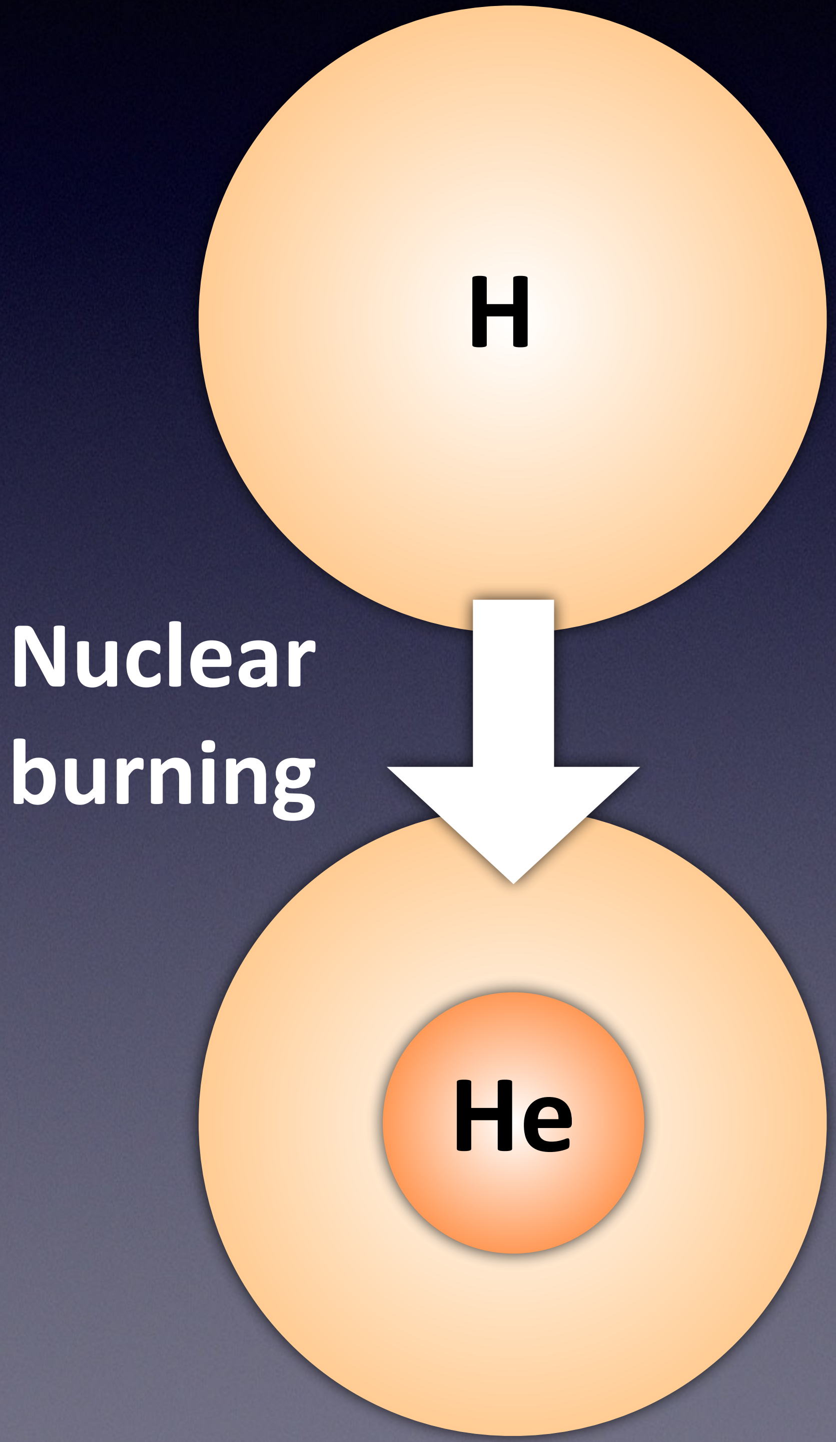
- Why are stars so luminous?
- Why do stars show $L \sim M^4$?
- Why do stars evolve?
- Why does the destiny of stars depend on the mass?
- Why do some stars explode?
- Why don't normal star explode?
- Why does stellar core collapses?
- Why is the energy of supernova so huge?
- …

Our sun

$L = 4 \times 10^{33}$ erg/s = 4×10^{26} J/s (W)

Electronic power consumption in Japan
1.5×10^{19} J / year
==> Japanese power consumption for 2×10^7 yr
= solar radiation in 1 second





Energy source

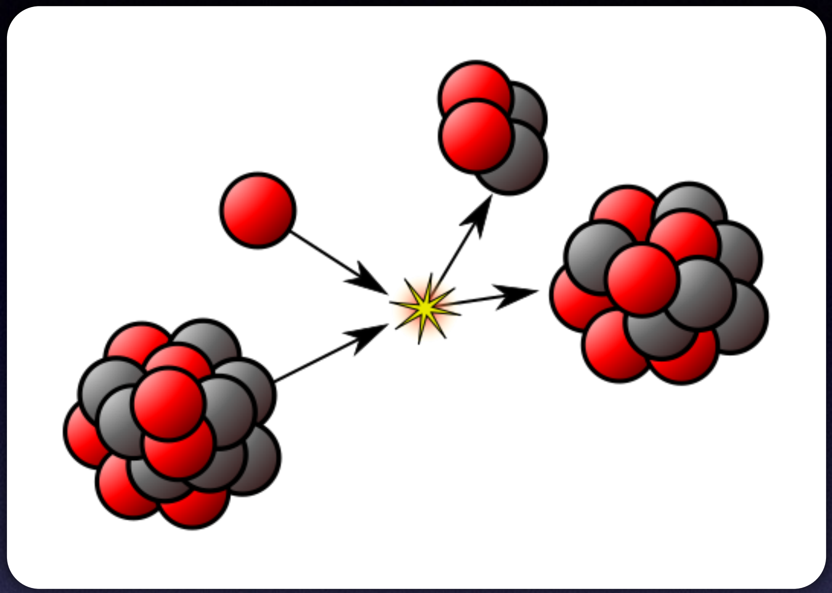
A. Chemical reaction

https://www.britannica.com/science/chemical-reaction

(ex.) $C + O_2 \rightarrow CO_2$

Reaction of atoms/molecules
= No change in nucleus

B. Nuclear reaction



(ex.) H + H + H + H -> He

Change in nucleus
= Production of new elements

Solar luminosity for 10^{10} yr

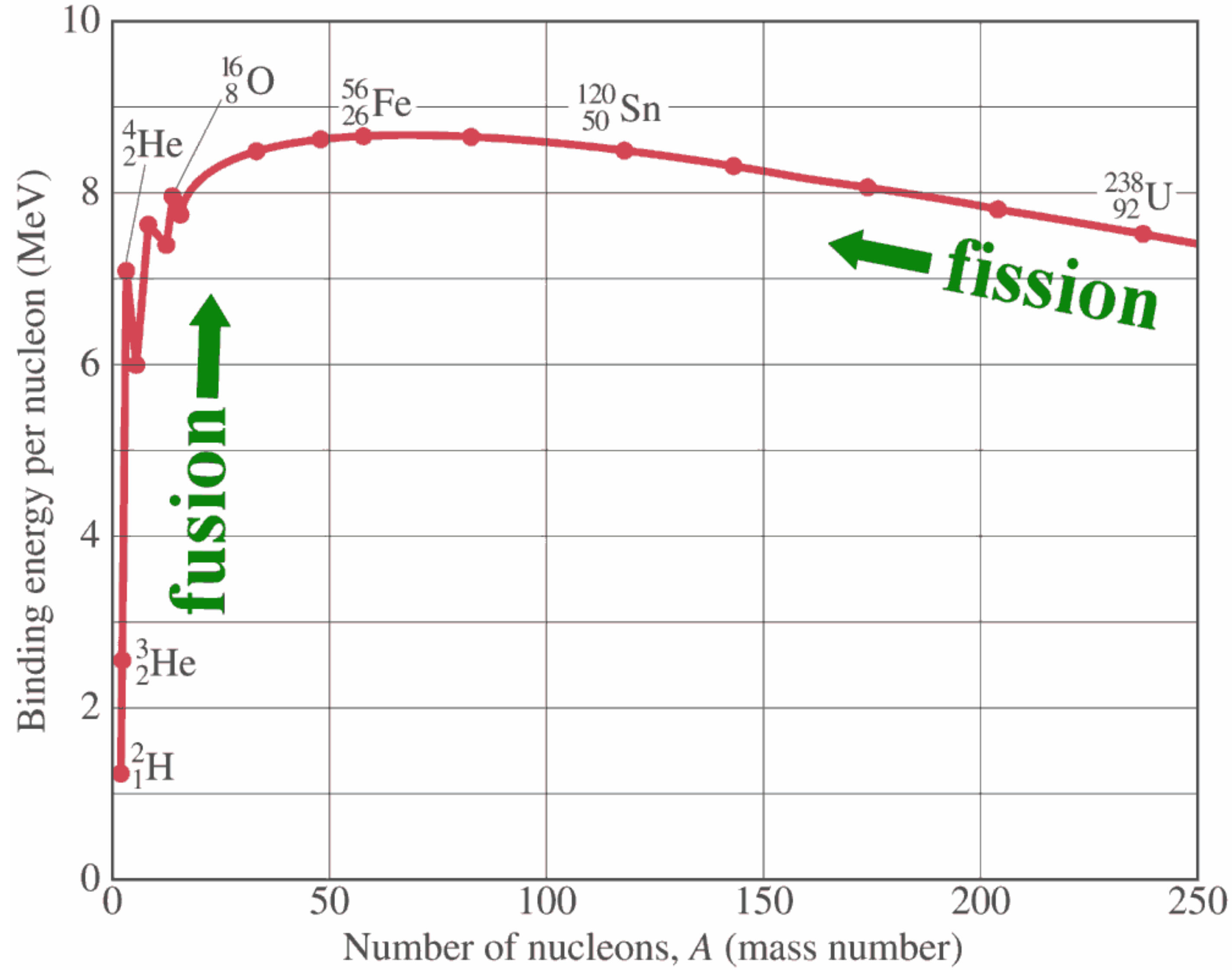
Binding energy of nuclei

$$Eb = [Nm_N + Zm_p - m_i]\, c^2$$

P + n   Nuclei

Higher binding energy
= strongly "bound"
= more stable
= "lighter"

Fe is the most stable nucleus



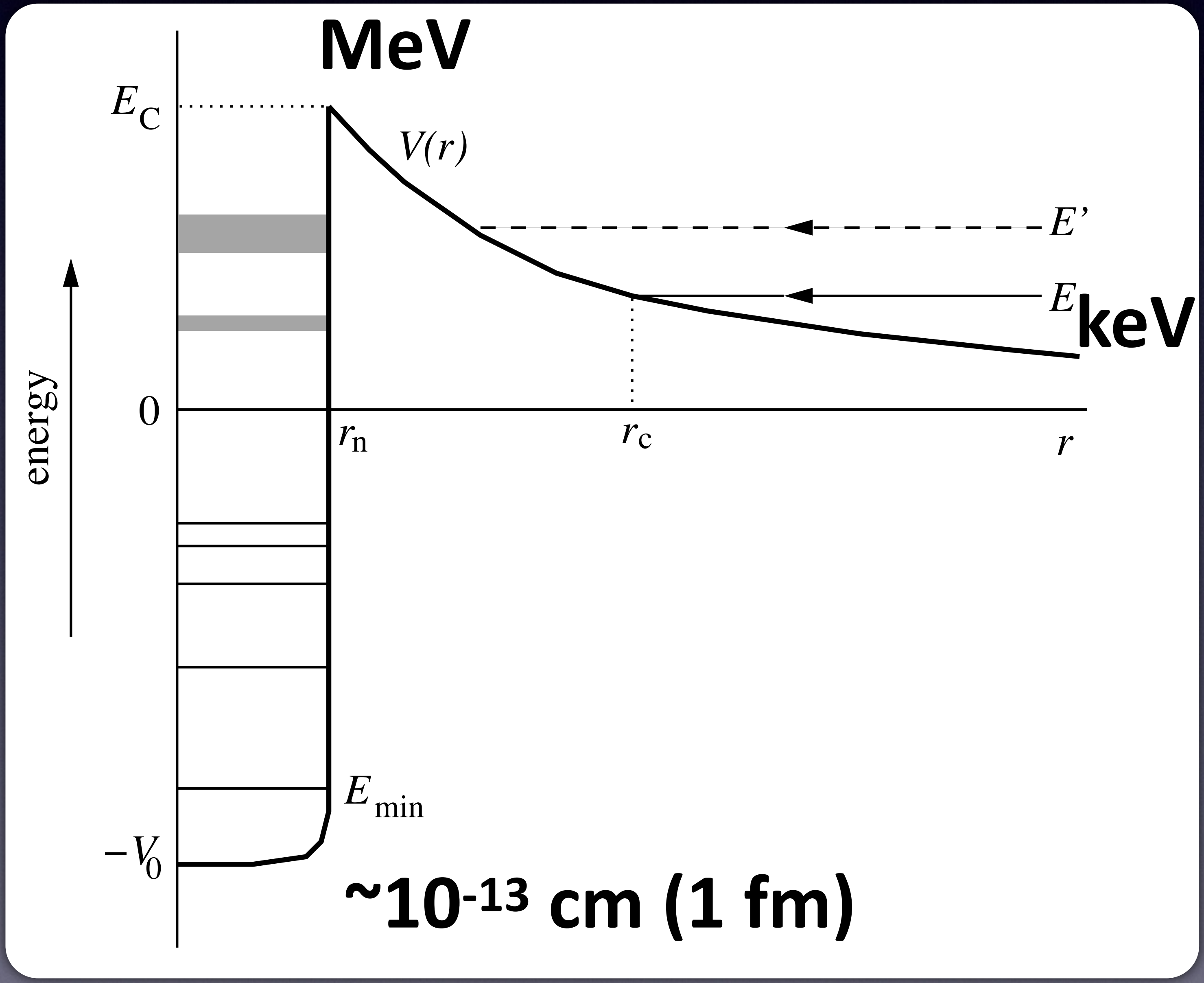
What is going on at the center of the star?
How does nuclear burning occurs?

Nuclear burning

Coulomb barrier E ~ $(Z_1Z_2e^2)/r \sim 10^6$ eV (MeV)

Typical energy of the gas E ~ kT ~ 10^3 eV (keV) <= 10^7 K

=> Tunnel effects



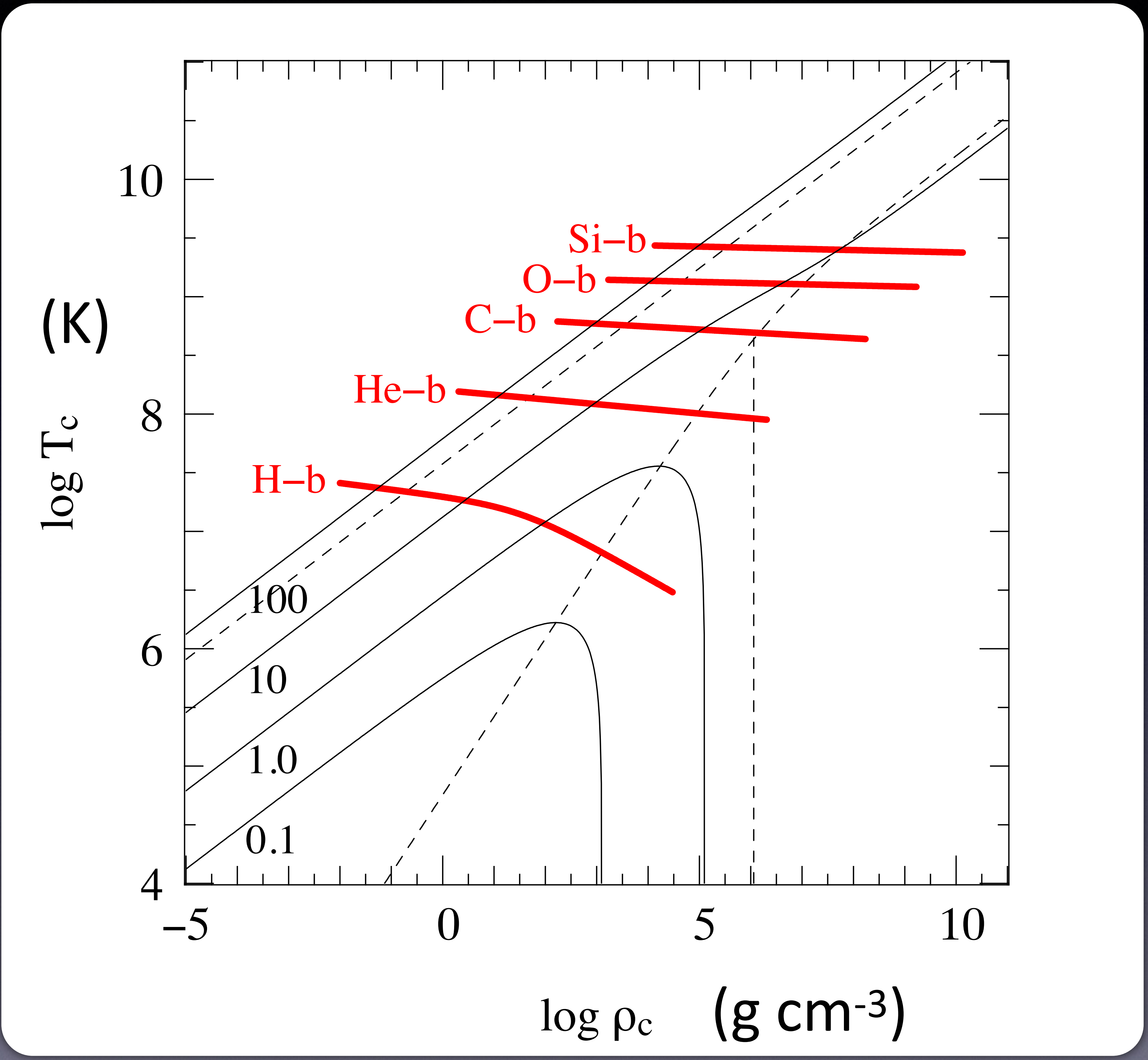
Textbook by Pols

Condition of H-burning

Fusion reactor

~10^8 K

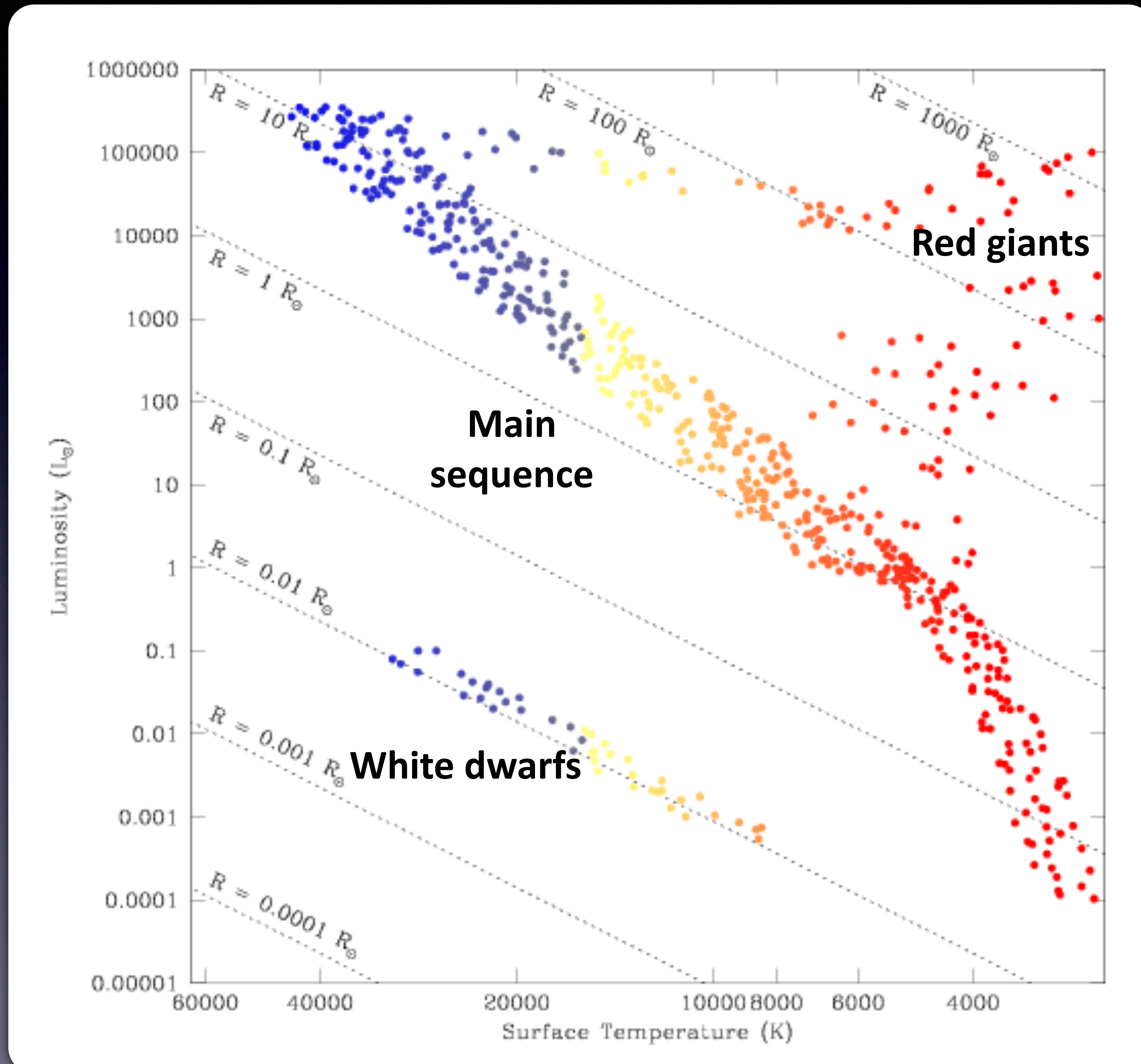
-10



Lecture Note by Pols

Hertzsprung-Russel diagram

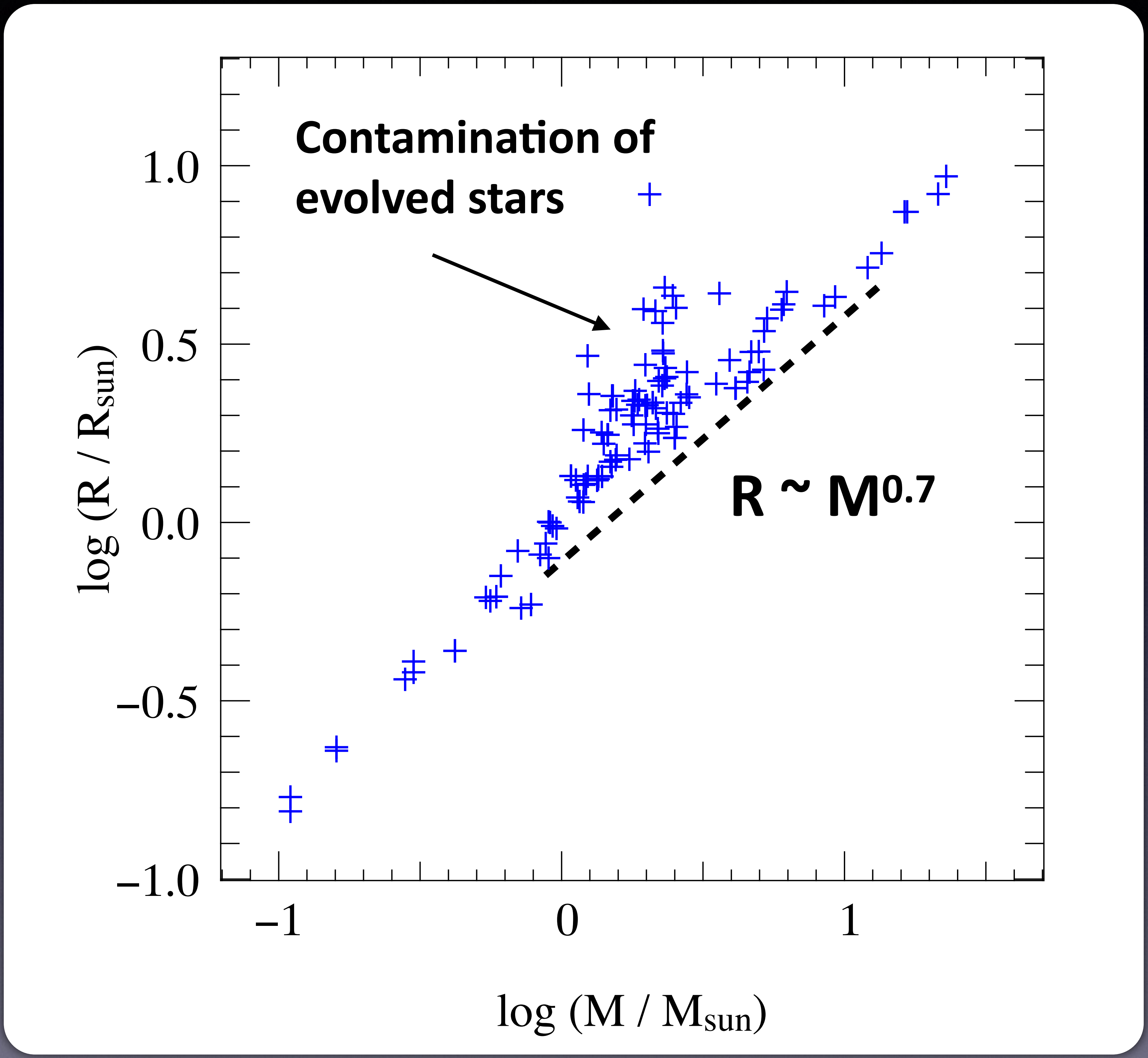
Luminosity



Temperature (K)

http://astronomy.nmsu.edu/geas/lectures/lecture23/slide04.html

Mass - radius relation for the main sequence



Outcome of
the central property
of the star

Lecture Note by Pols

Summary: Stellar structure

- Energy source of the stars
  - Nuclear burning
  - $E = mc^2$
- Stellar structure
  - Hydrostatic Equilibrium
  - Central temperature of the stars $T \sim 10^7$ K
  - Require tunnel effects for nuclear burning
- Stellar properties
  - Almost constant central T => $R \sim M$
  - Observed mass-radius relation ($R \sim M^{0.7}$)