Section 2.
Stellar structure and properties (I)

2.1 Hydrostatic equilibrium

2.2 Nuclear burning

Goals of this lecture

- Standard properties of stars
  - Stellar structure and properties
  - Stellar evolution
- Origin of the elements in the Universe
  - Nucleosynthesis in stars and supernovae
  - Explosion mechanism of supernovae
- Topics in time-domain astronomy
  - Radiation from explosive phenomena
  - Multi-messenger astronomy

Our sun

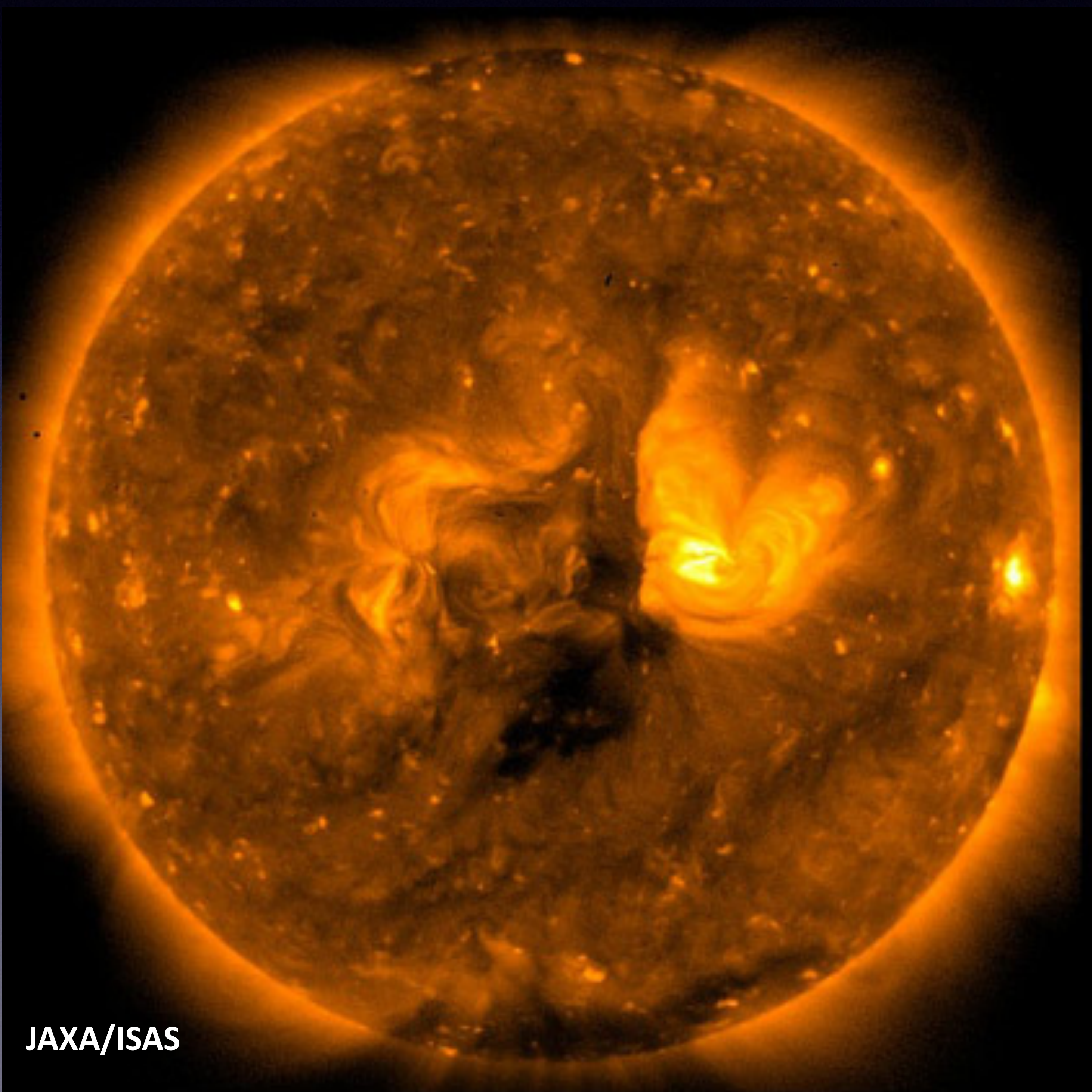
$L = 4 \times 10^{33}$ erg/s = 4×10^{26} J/s (W)

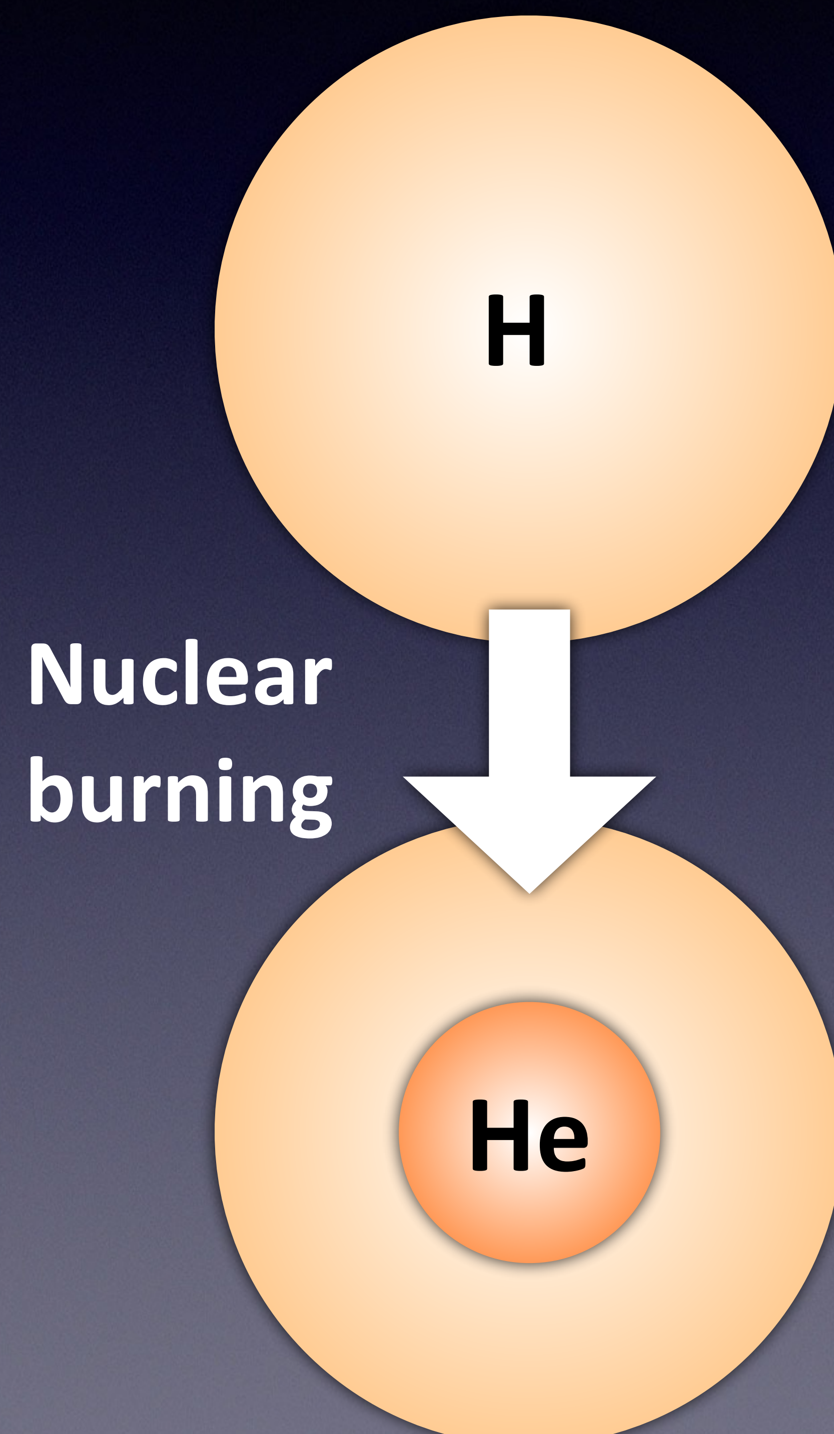
Electronic power consumption in Japan

1.5×10^{19} J / year

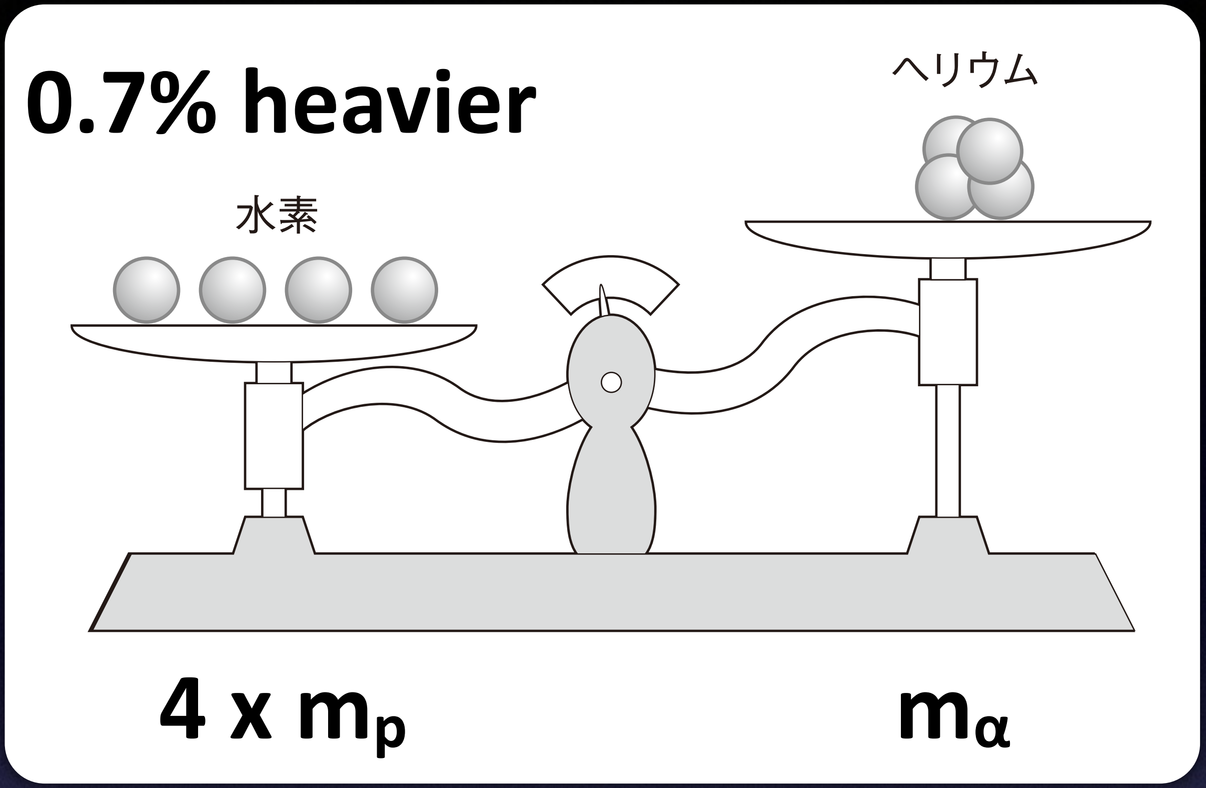
==> Japanese power consumption for 2×10^{7} yr

= solar radiation in 1 second





Energy source: $E = mc^2$



Q1: How much energy is released for one nucleon? (核子あたり)

$E = \Delta mc^2$

Solar mass：2×10^{33} g

Q2: How much energy does the Sun can produce?
(assume 10% of solar mass can be used for nuclear burning)

Q3: How many years the sun can keep shining?

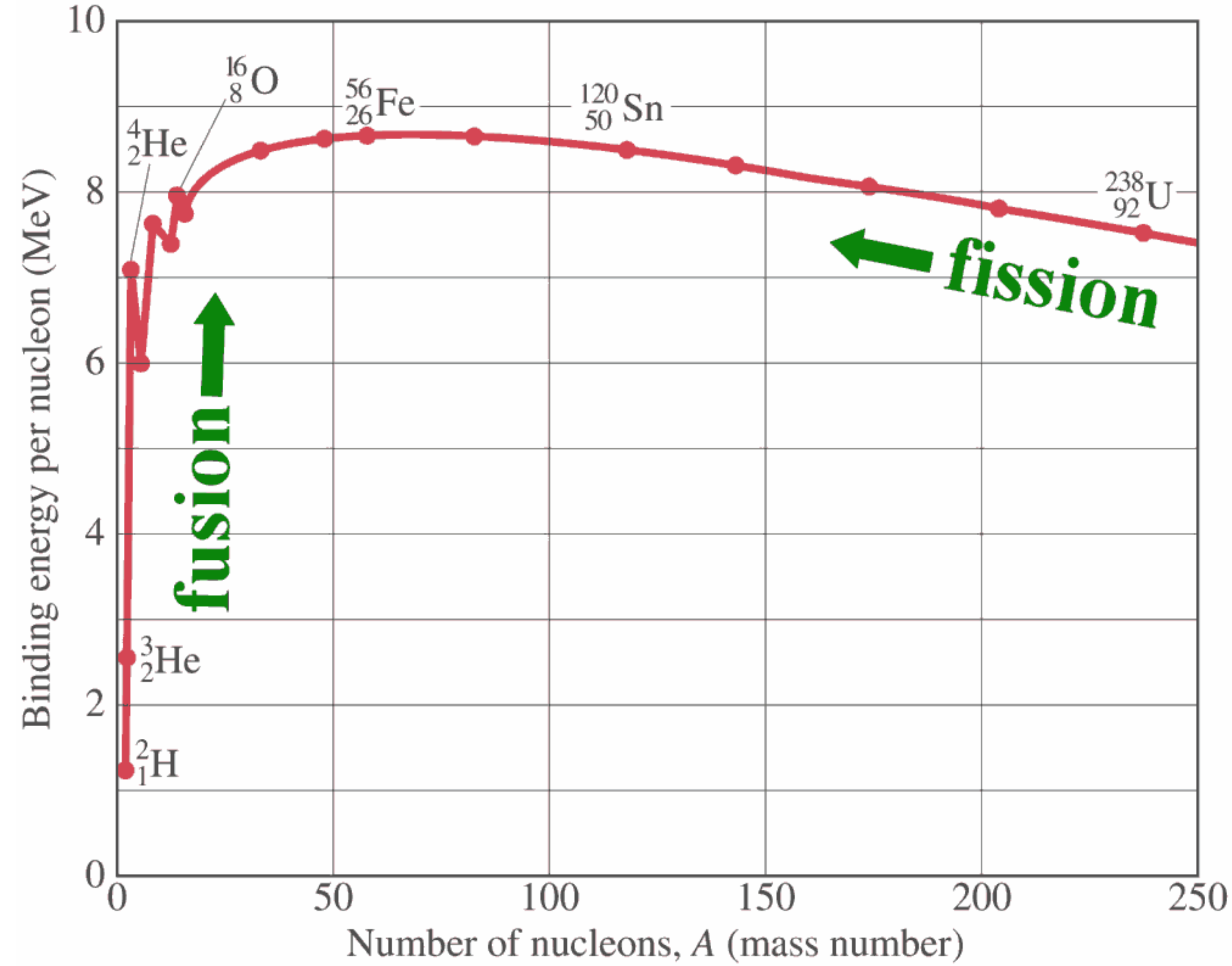
$L = 4 \times 10^{33}$ erg/s　　　1 yr ~ 3×10^{7} sec

Binding energy of nuclei

$$E_b = [\underbrace{N m_N + Z m_p}_{\text{P + n}} - \underbrace{m_i}_{\text{Nuclei}}]\, c^2$$

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

Fe is the most stable nucleus



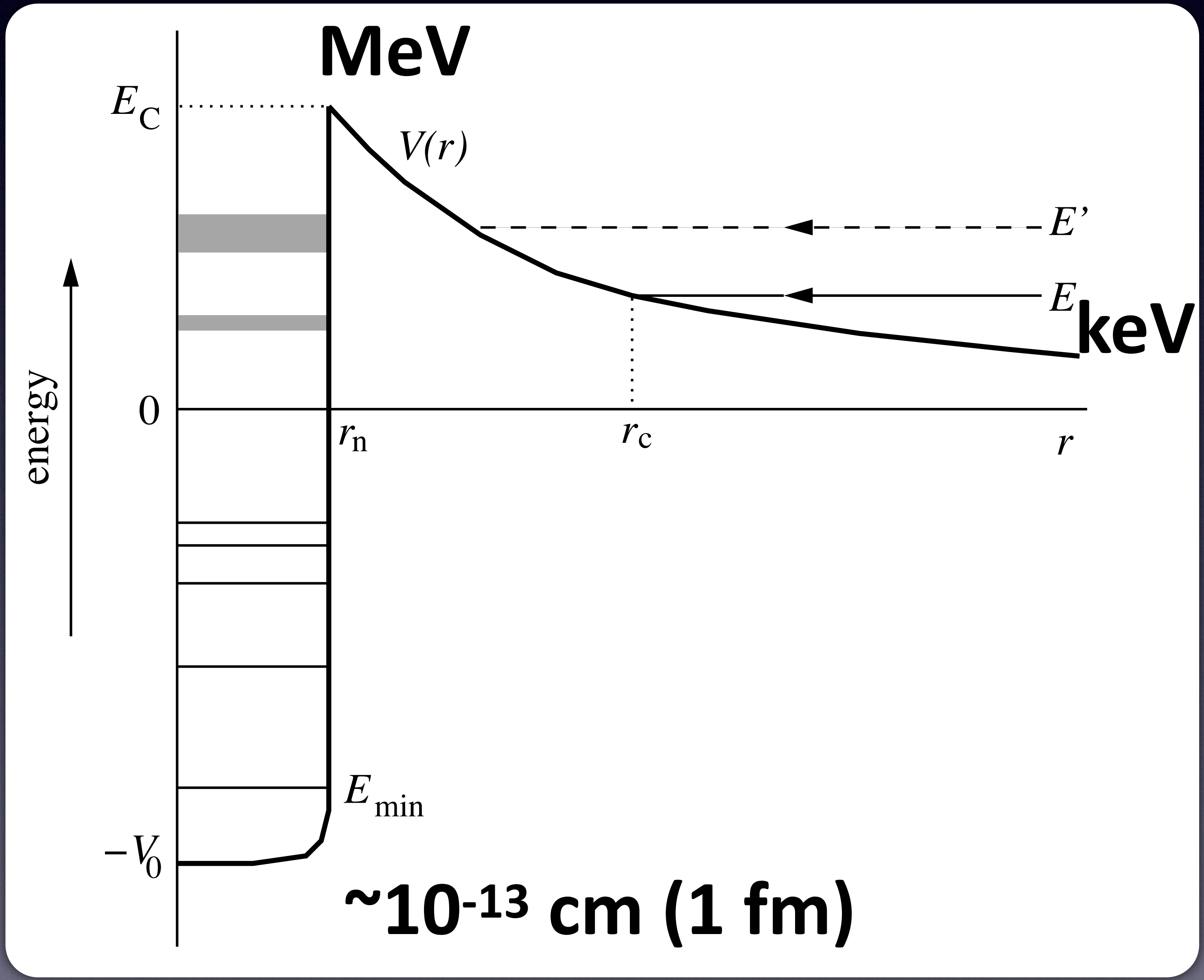
What is going on at the center of the star?
How does nuclear burning occurs?

Nuclear burning

Coulomb barrier $E \sim (Z_1 Z_2 e^2)/r \sim 10^6$ eV (MeV)

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

=> Tunnel effects



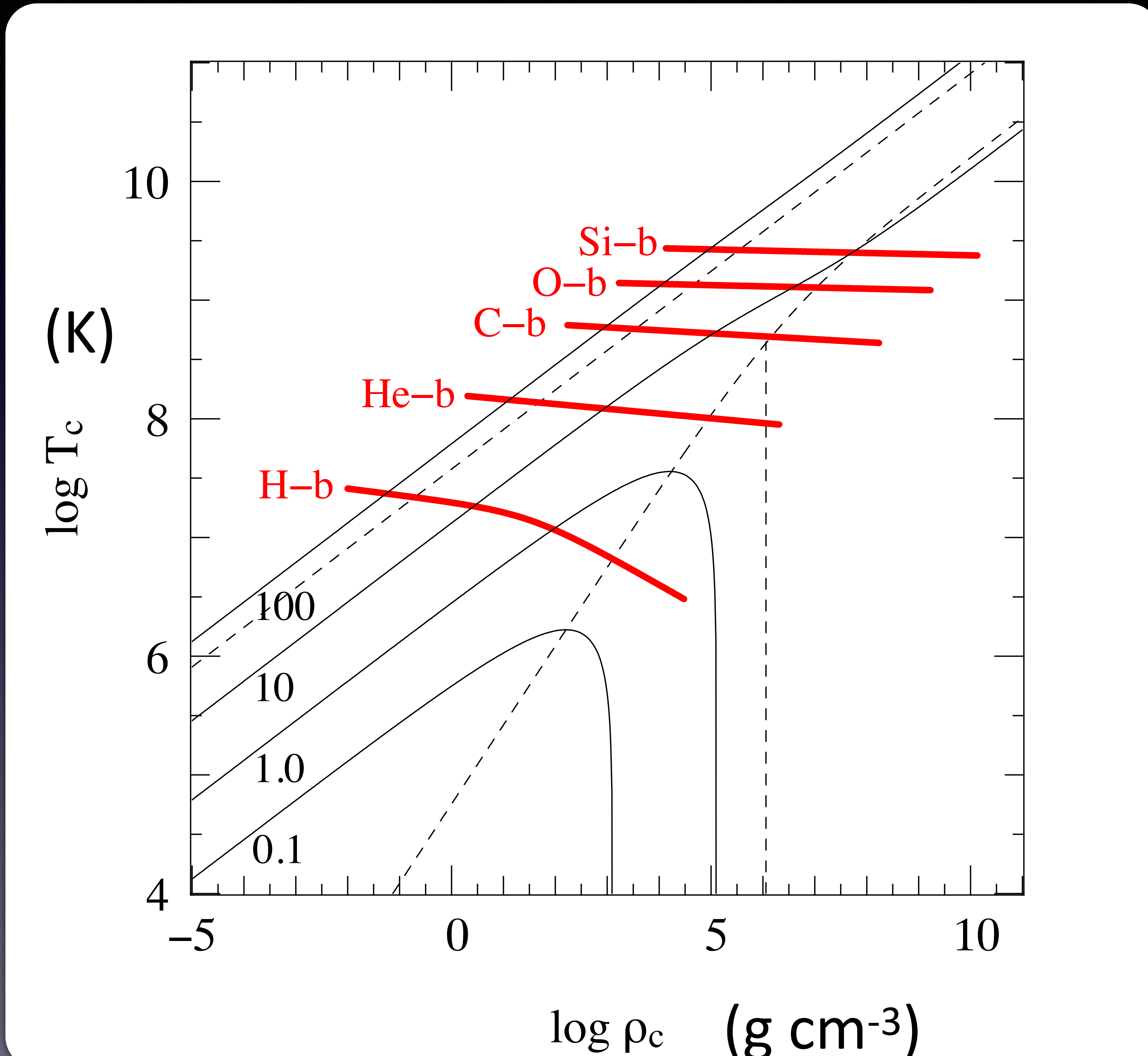
Textbook by Pols

Condition of H-burning

Fusion reactor

~10^8 K

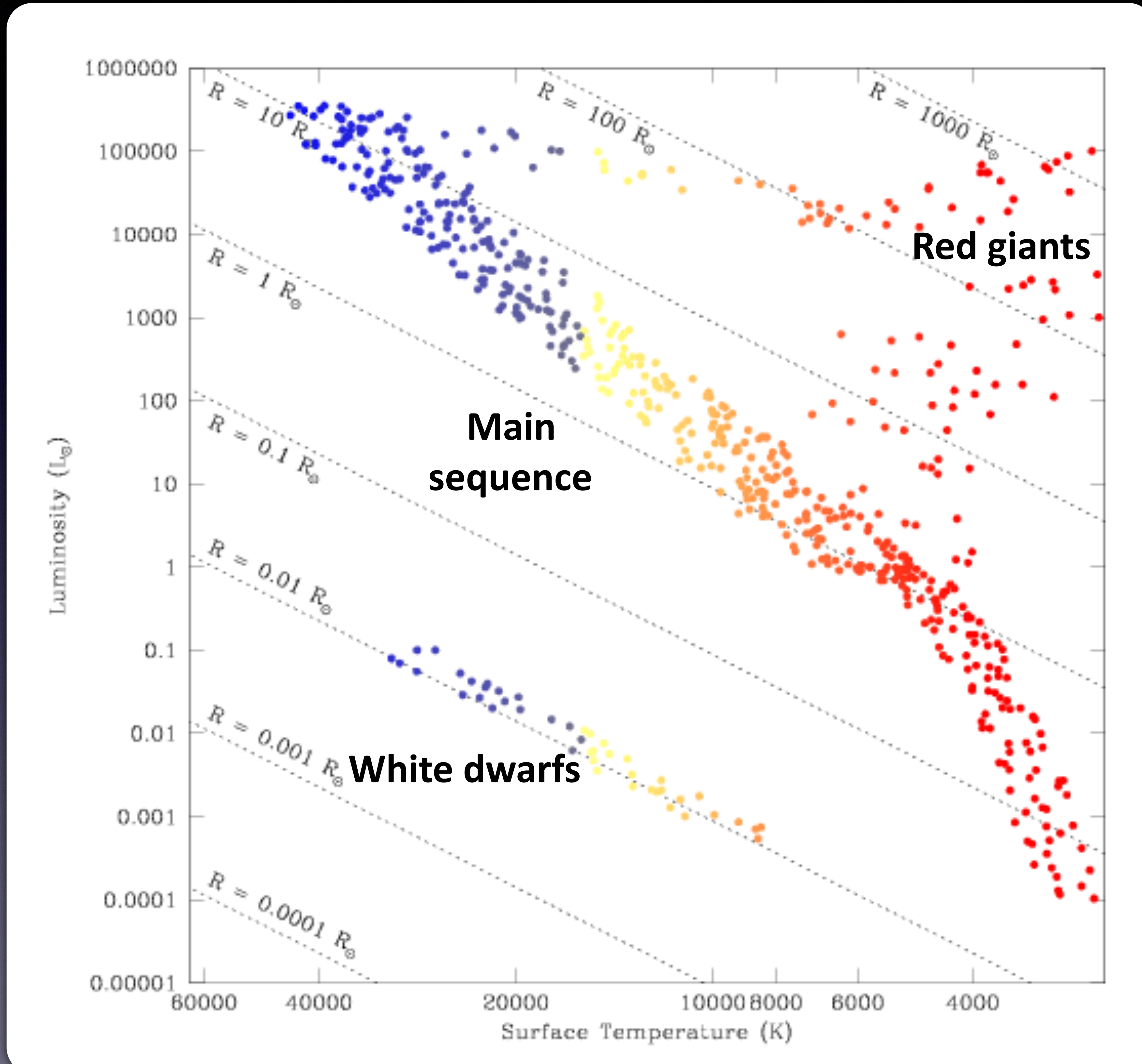
-10



Lecture Note by Pols

Hertzsprung-Russel diagram

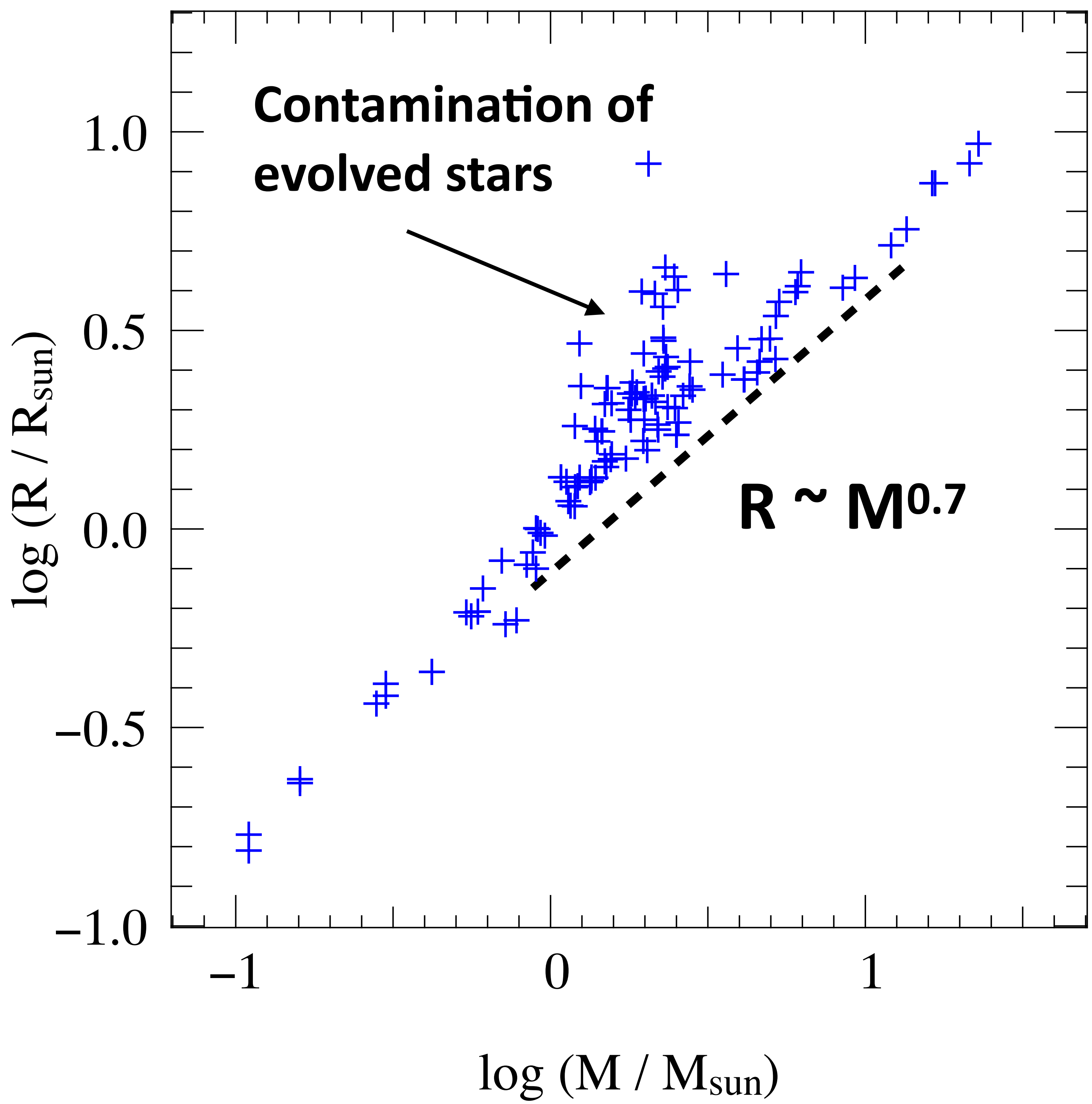
Luminosity



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 and properties (I)

- 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 ($R \sim M^{0.7}$)