

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?
- ...

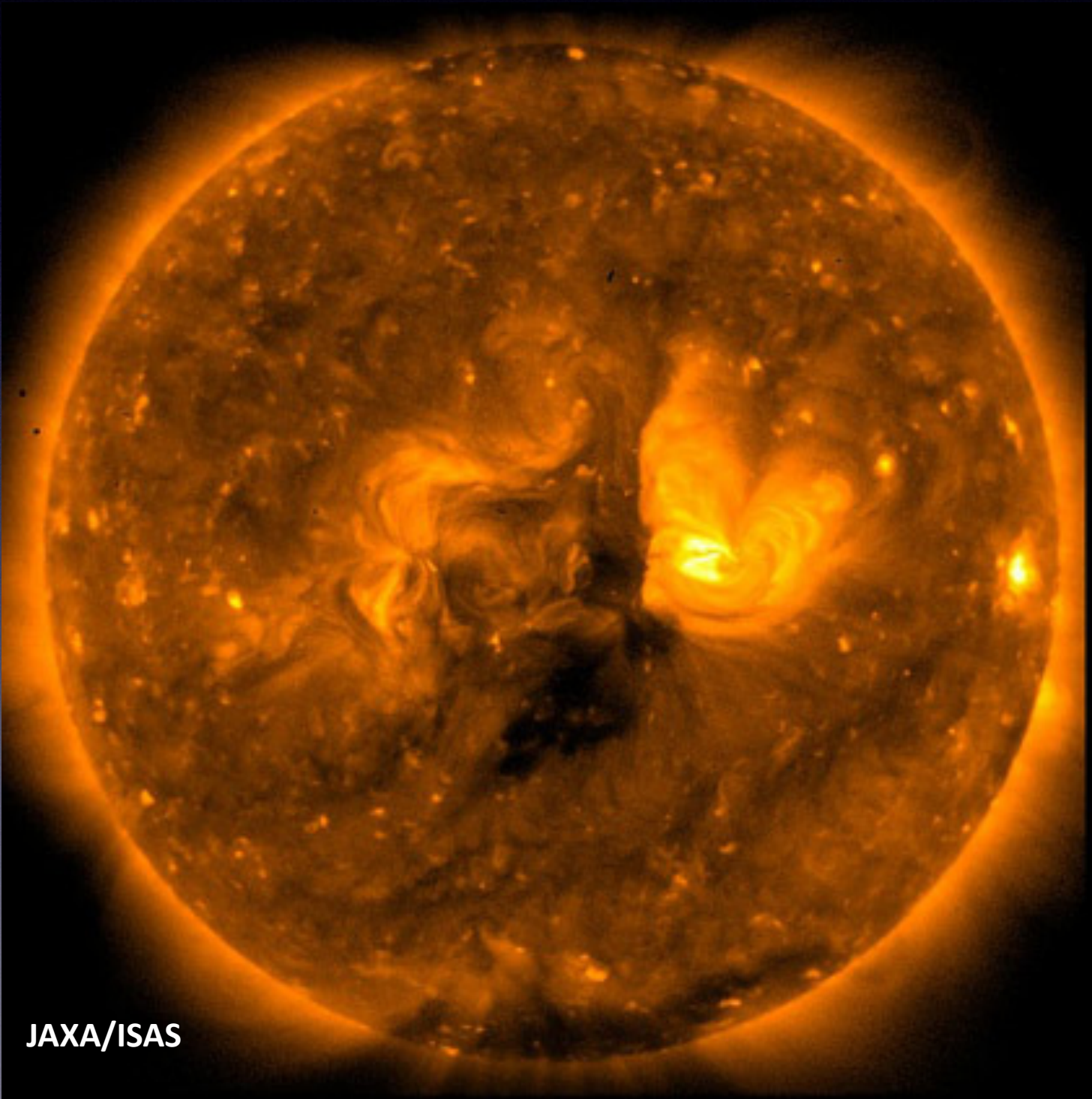
Our sun

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

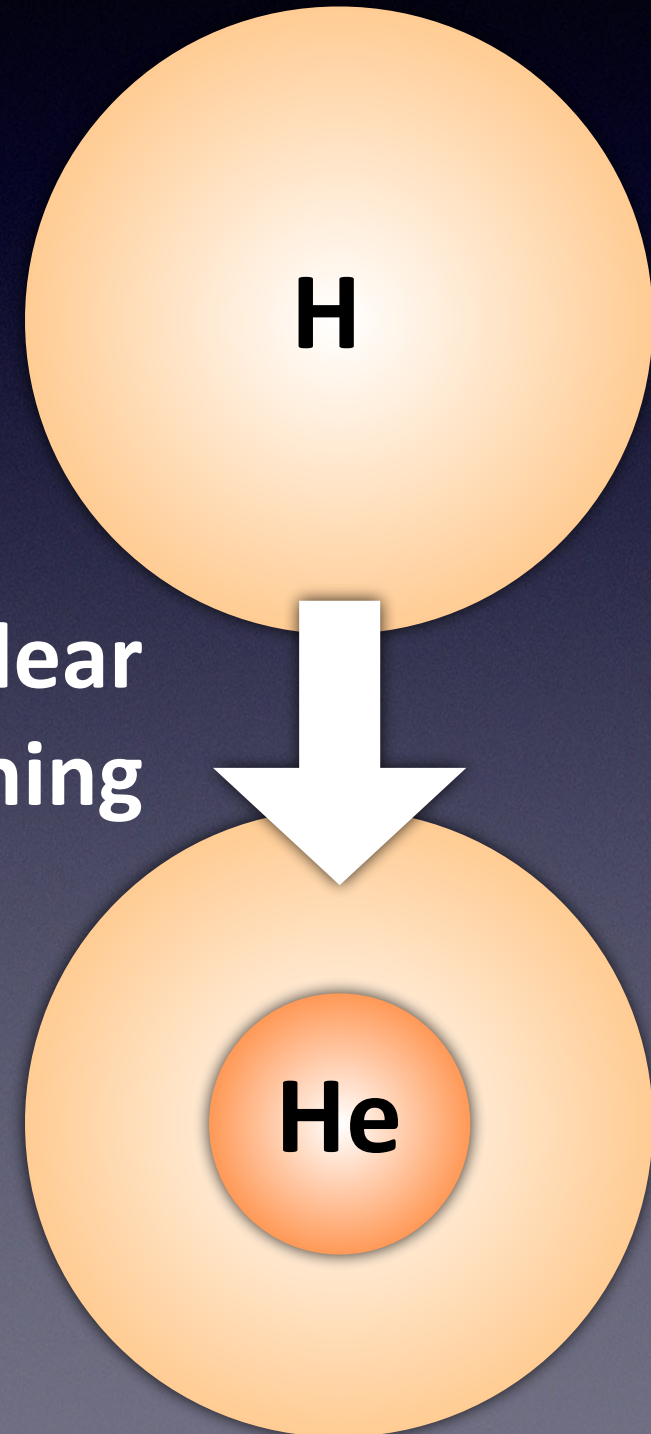
Electronic power consumption in Japan

$$1.5 \times 10^{19} \text{ J / year}$$

==> Japanese power consumption for $2 \times 10^7 \text{ yr}$
= solar radiation in 1 second



Nuclear
burning



Energy source

A. Chemical reaction

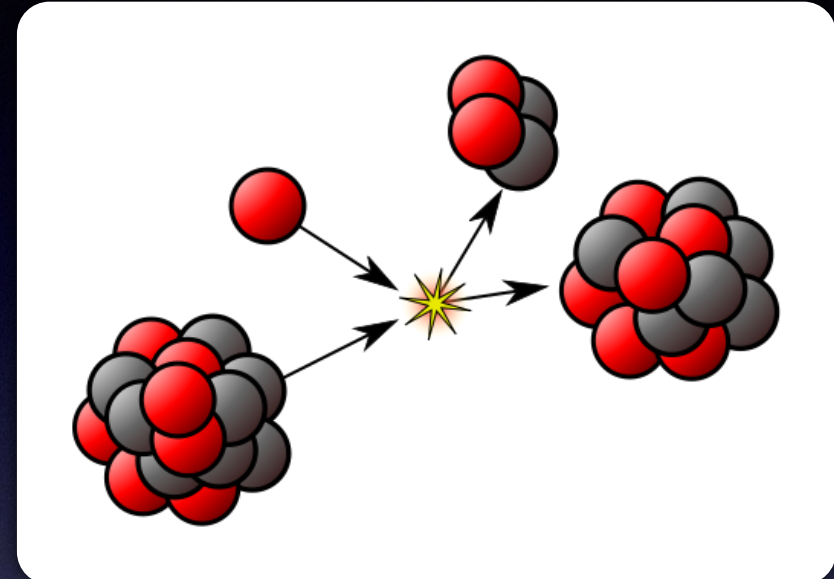


<https://www.britannica.com/science/chemical-reaction>



Reaction of atoms/molecules
= No change in nucleus

B. Nuclear reaction



Change in nucleus
= Production of new elements

Solar luminosity for 10^{10} yr

Binding energy of nuclei

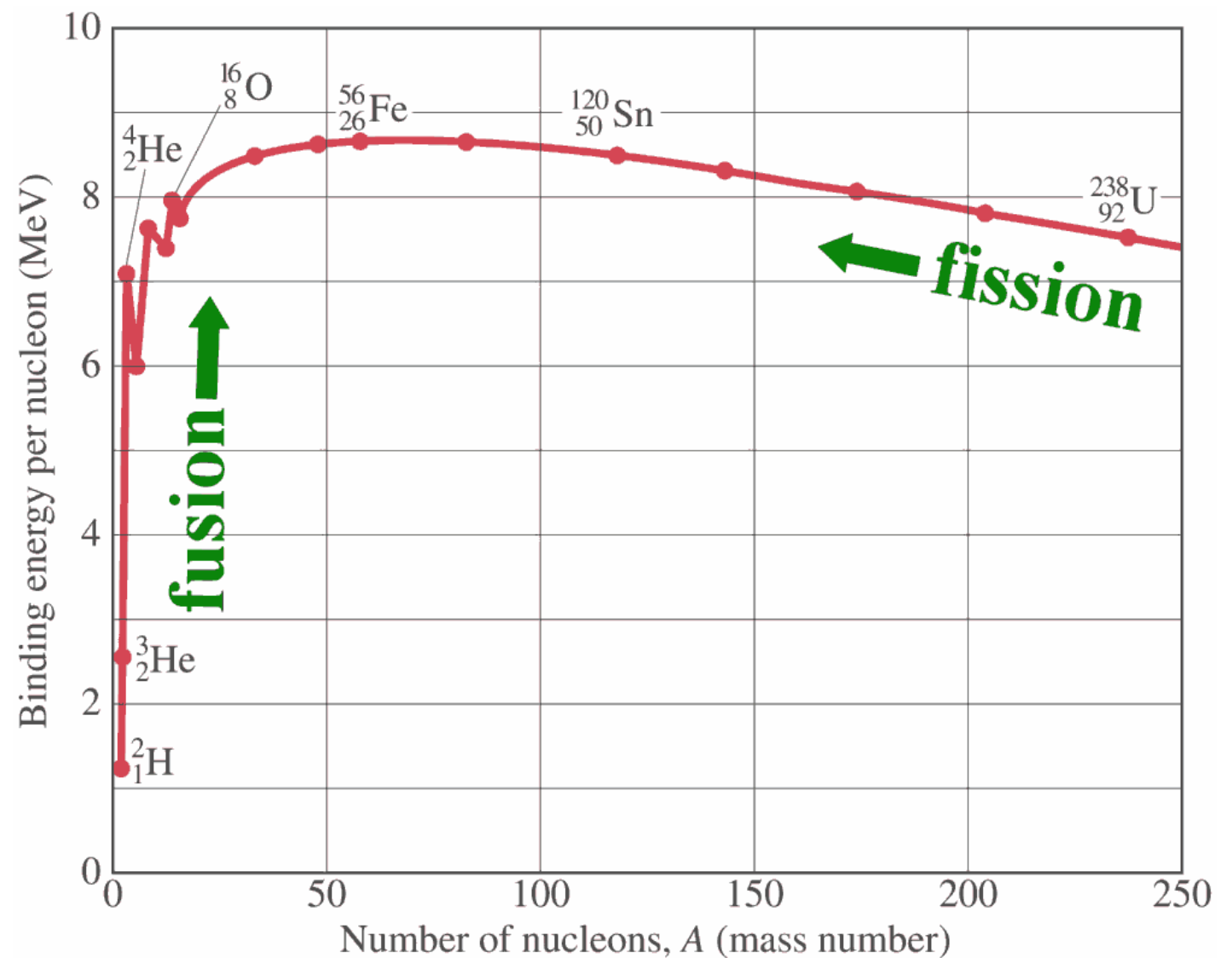
$$E_b = [Nm_N + Zm_p - m_i] c^2$$

P + n

Nuclei

Higher binding energy
= strongly “bound”
= more stable
= “lighter”

Fe is the most stable nucleus



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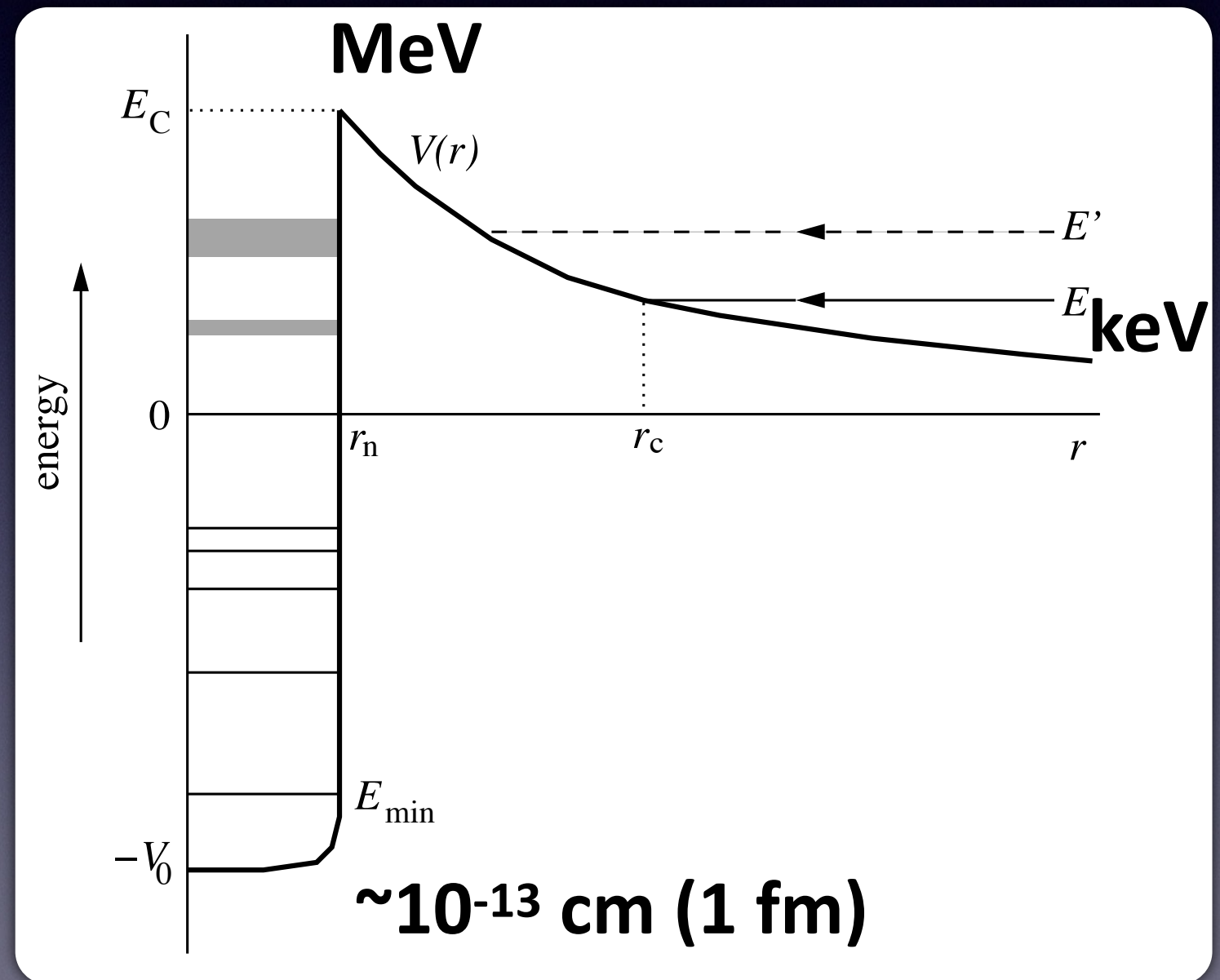
**What is going on at the center of the star?
How does nuclear burning occurs?**

Nuclear burning

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

Typical energy of the gas $E \sim kT \sim 10^3 \text{ eV (keV)} \leq 10^7 \text{ K}$

=> Tunnel effects



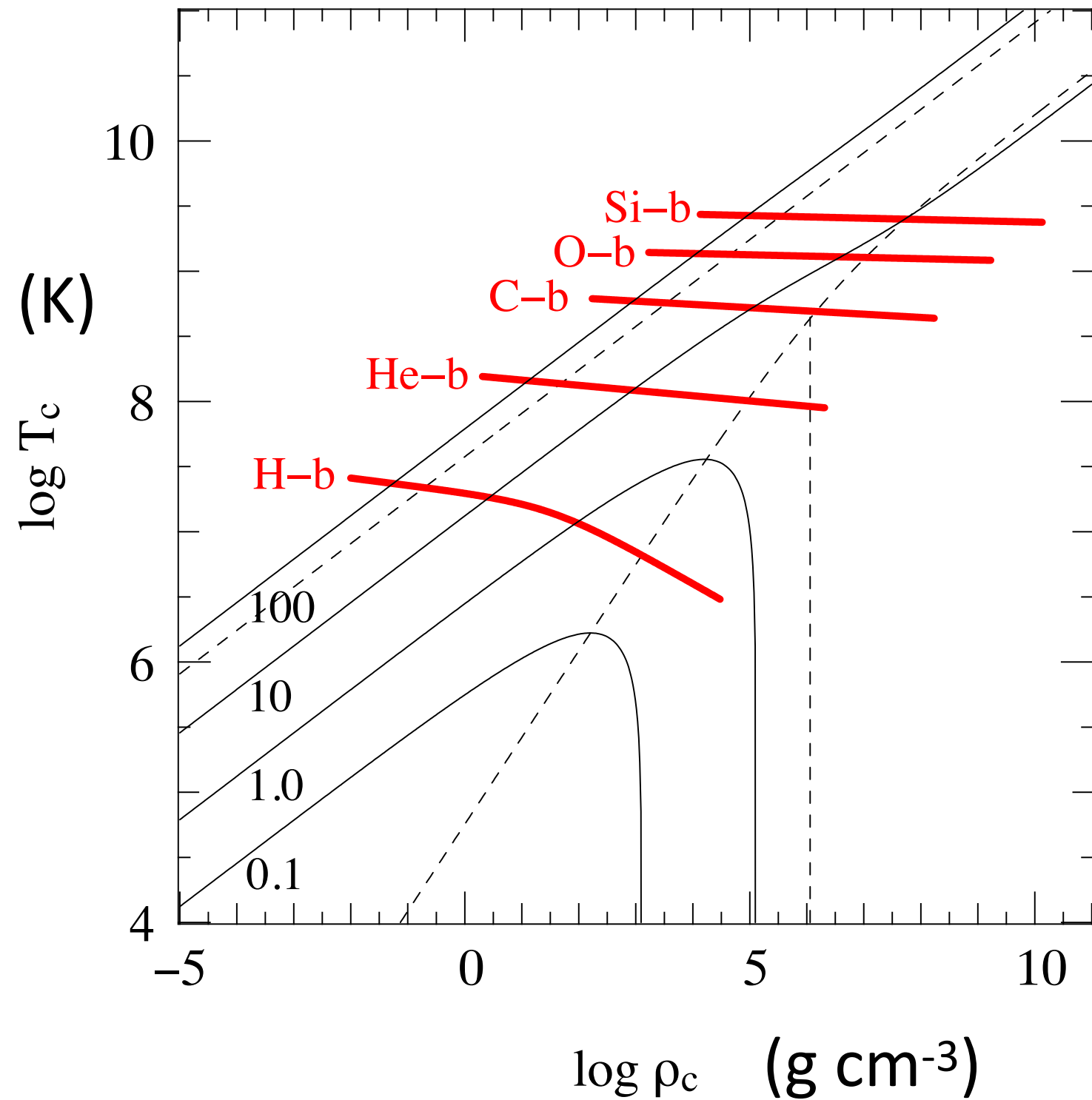
Condition of H-burning

Fusion
reactor

$\sim 10^8$ K



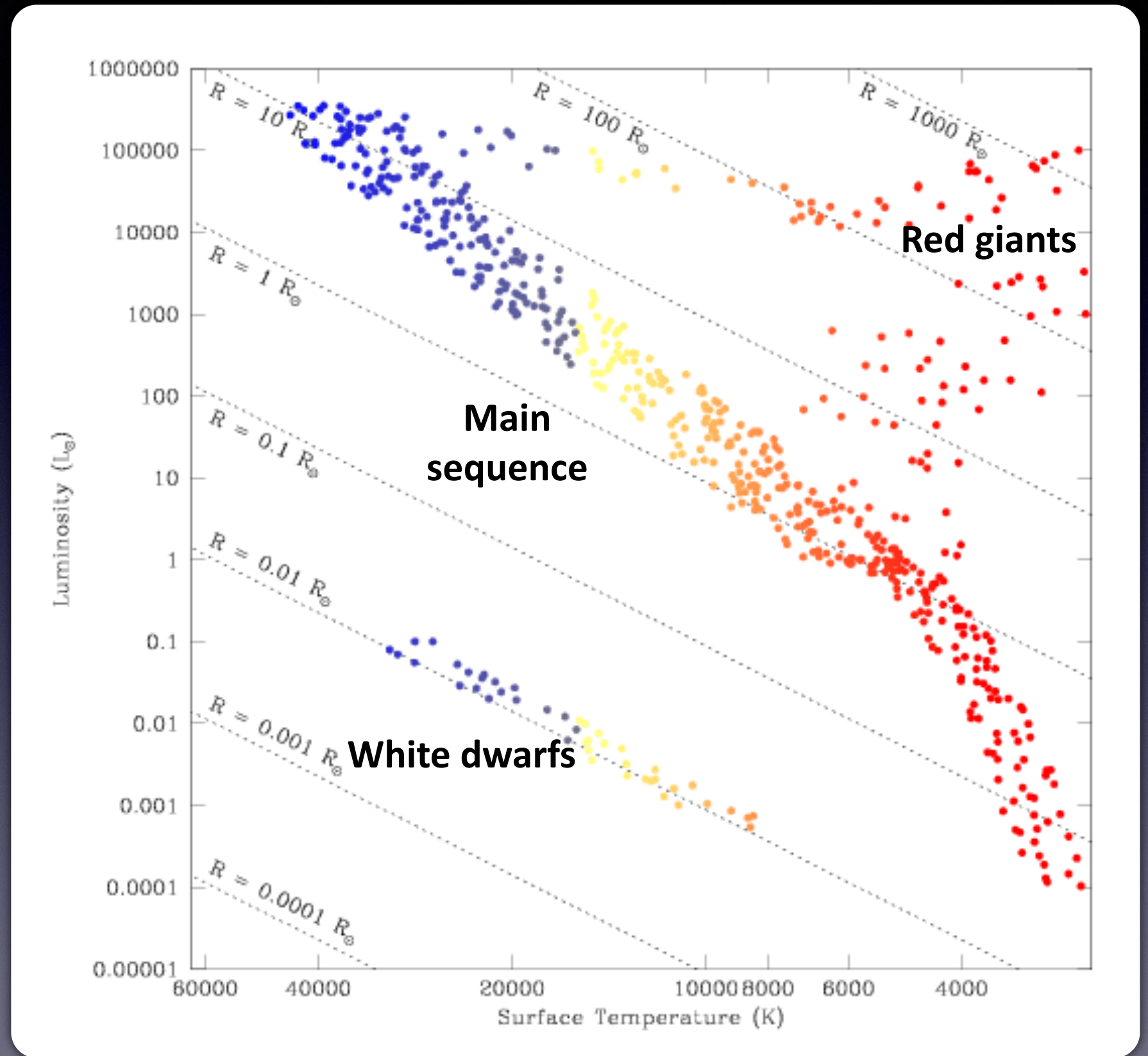
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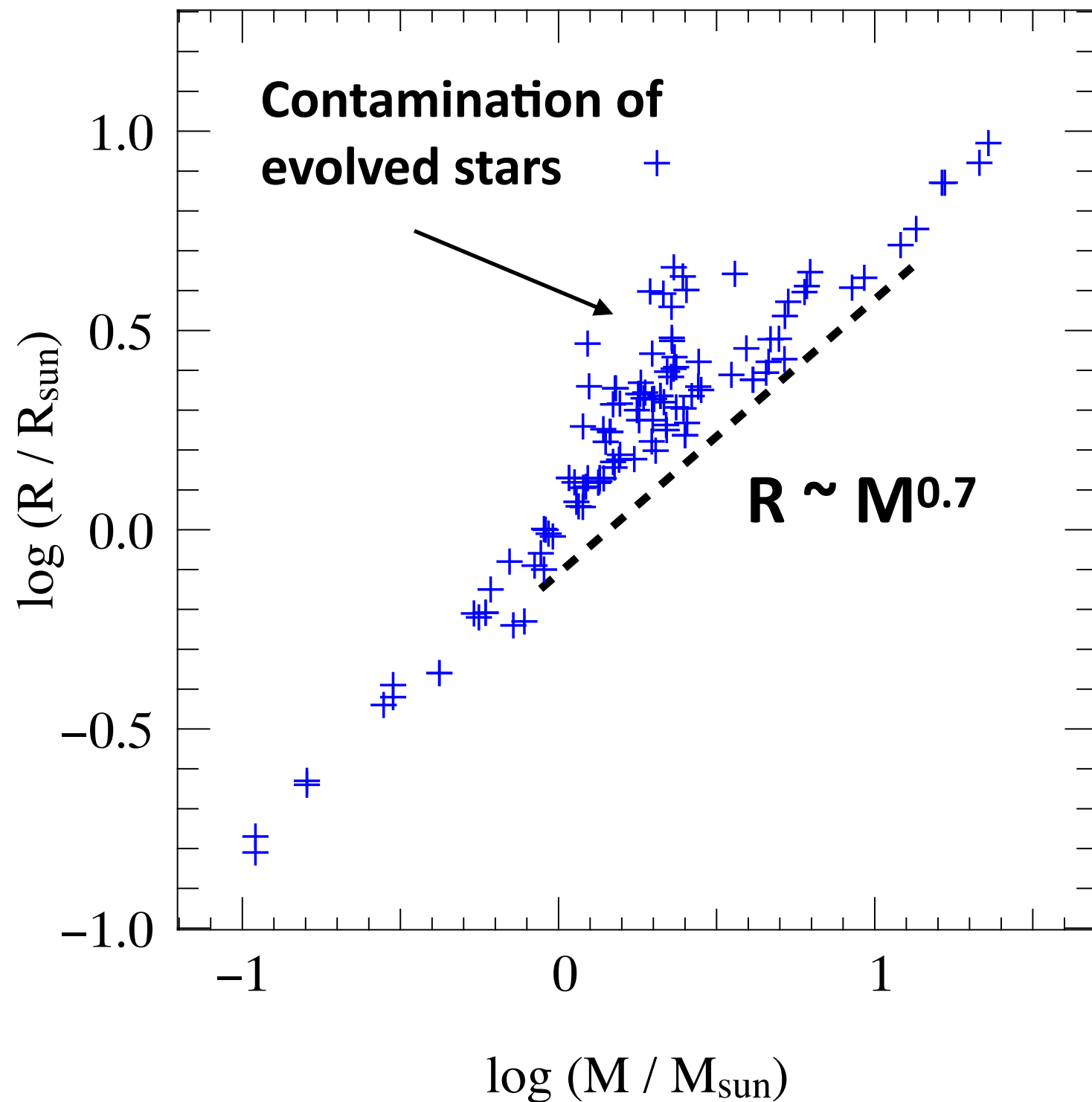
Hertzsprung-Russell diagram

Luminosity

Temperature (K)



Mass - radius relation for the main sequence



**Outcome of
the central property
of the star**

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 $T \Rightarrow R \sim M$
 - Observed mass-radius relation ($R \sim M^{0.7}$)