Section 3.
Stellar properties

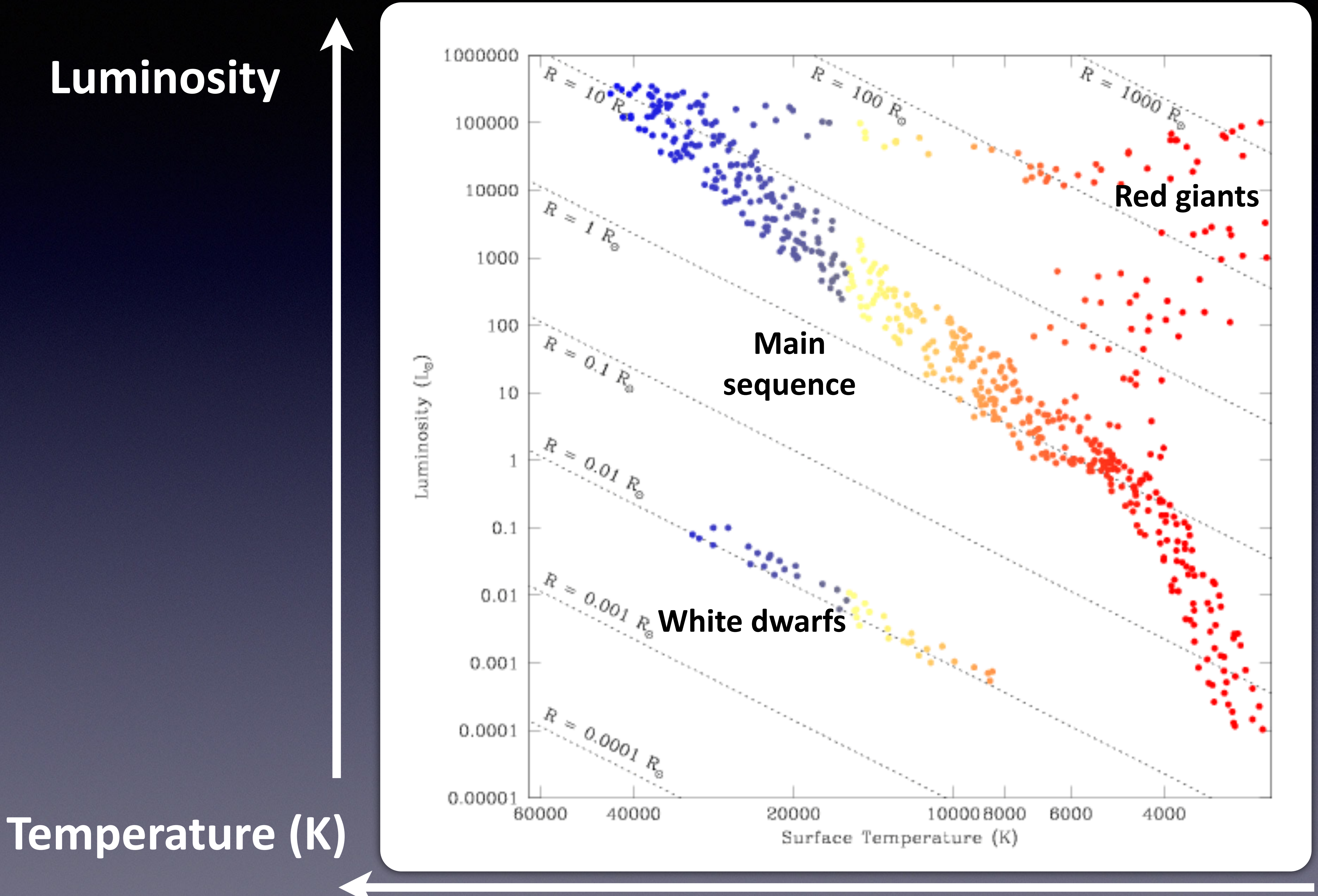
3.1 Luminosity of the stars

3.2 Opacities in the stars

Let's understand these questions with the words of physics

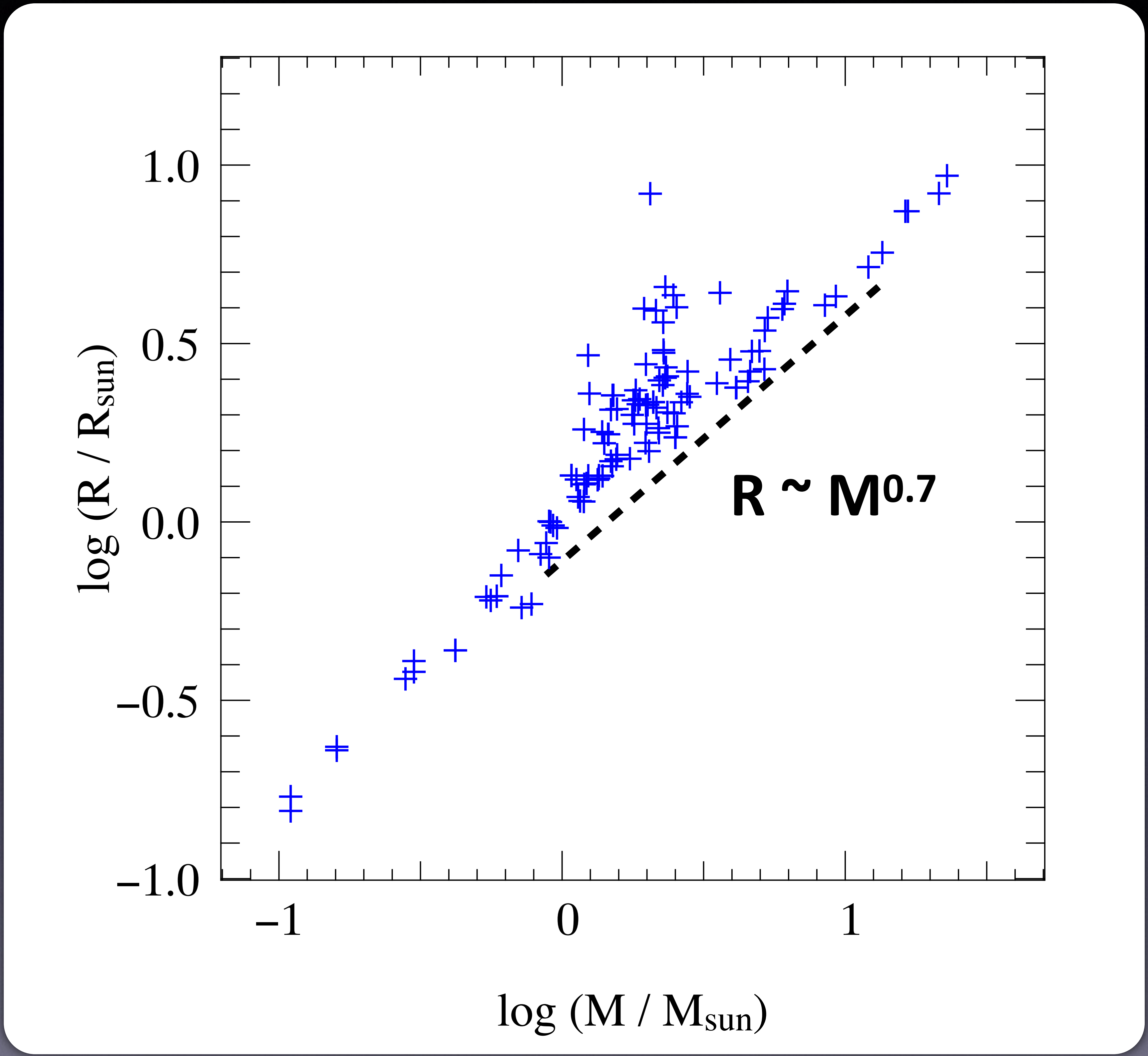
- Why are stars so luminous?
- Why do stars show $L \sim M^4$?
- Why do stars evolve?
- Why does the destiny of stars depend on the mass?
- Why do some stars explode?
- Why don't normal star explode?
- Why does stellar core collapses?
- Why is the energy of supernova so huge?
- ...

Hertzsprung-Russel diagram



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

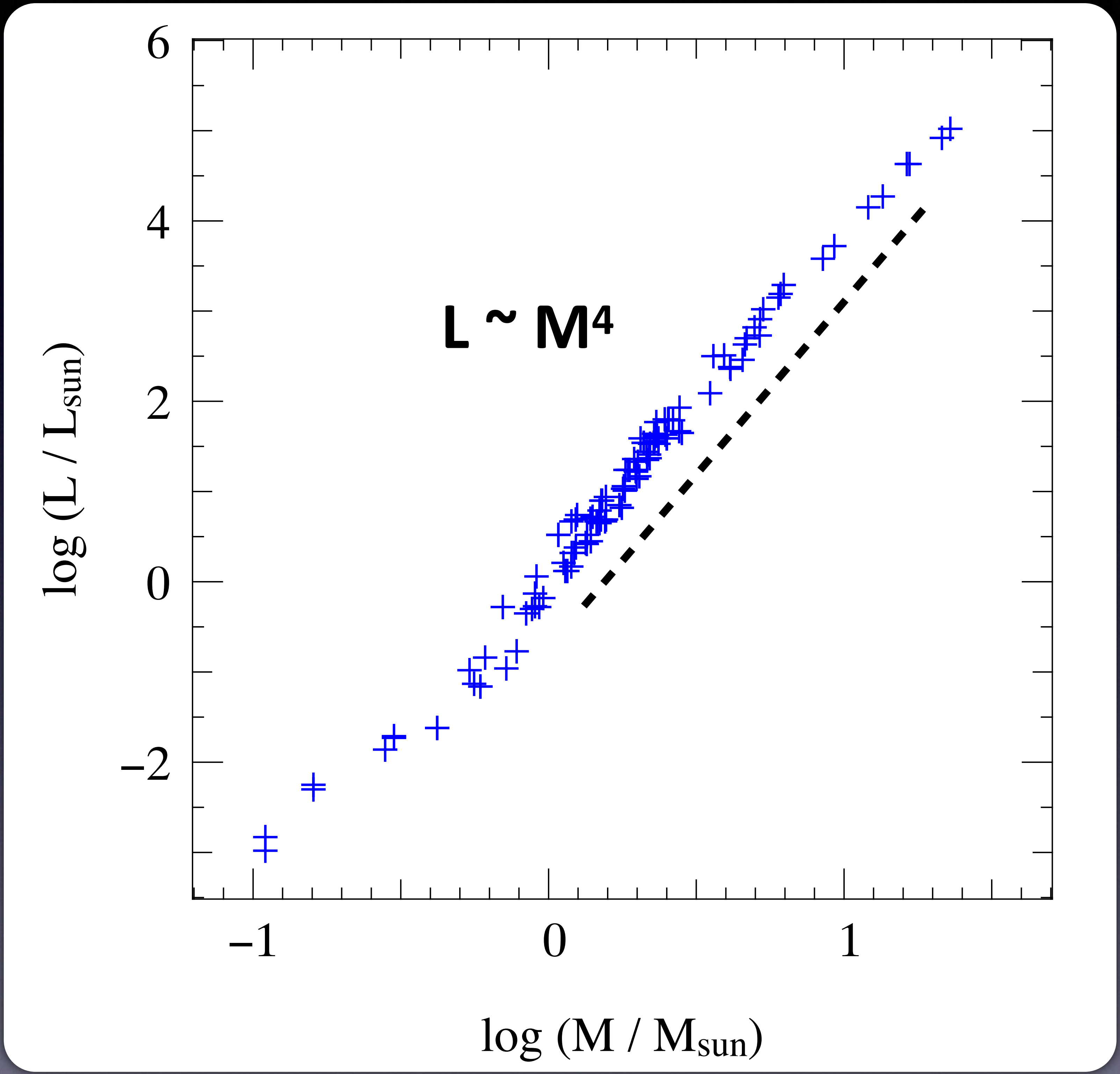
Mass - radius relation for the main sequence



Outcome of
the central property
of the star

Lecture Note by Pols

Mass - luminosity relation of the main sequence stars



Star with M = 10 Msun
=> L ~ 10^4 Lsun
=> Lifetime
~ $1/10^3$ of the Sun
~ 10^{10} yr (100億年)/10^3
~ 10^7 yr (1000万年)

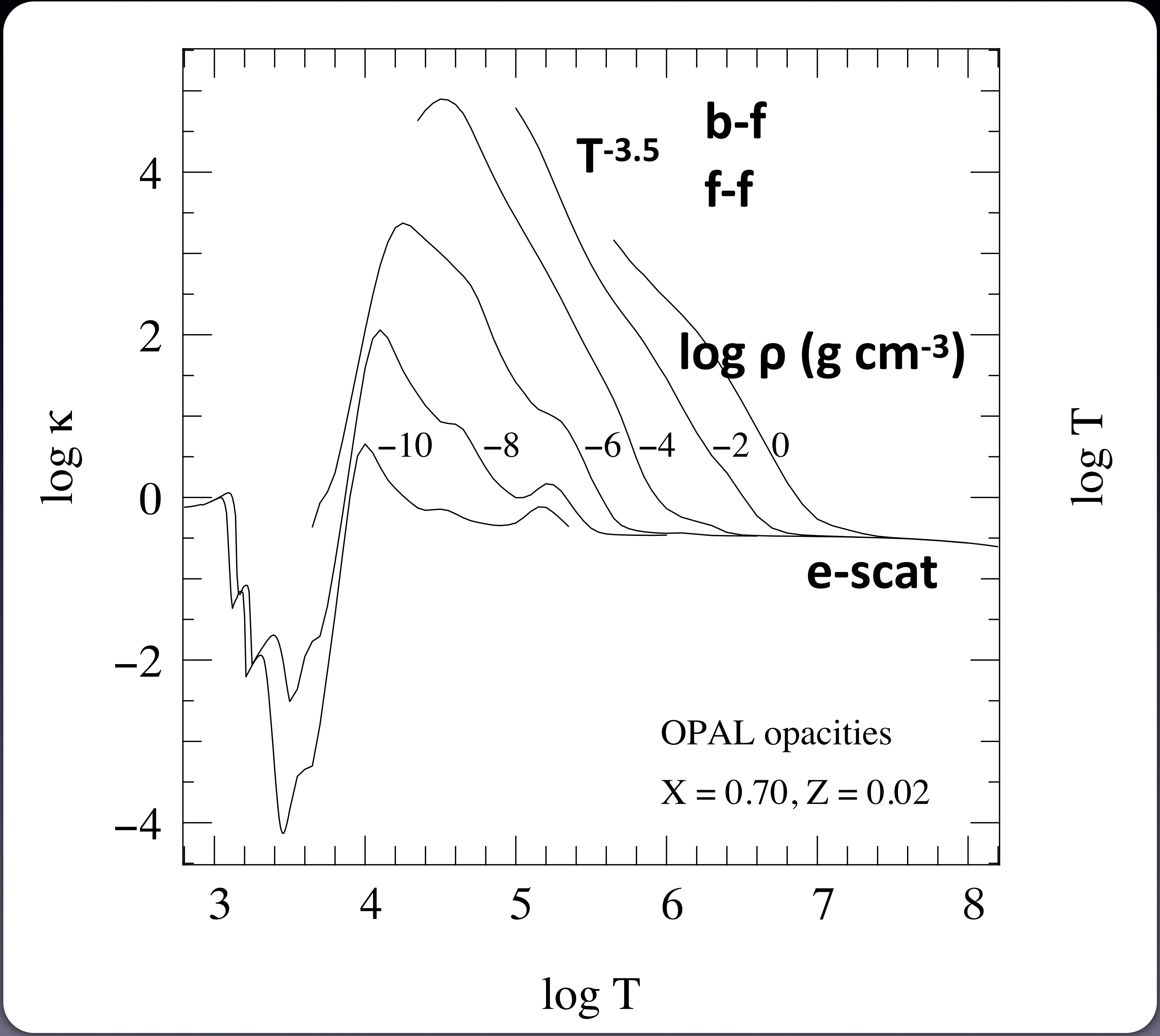
More massive stars
have shorter lifetime

Lecture Note by Pols

Why do stars show L~M^4?

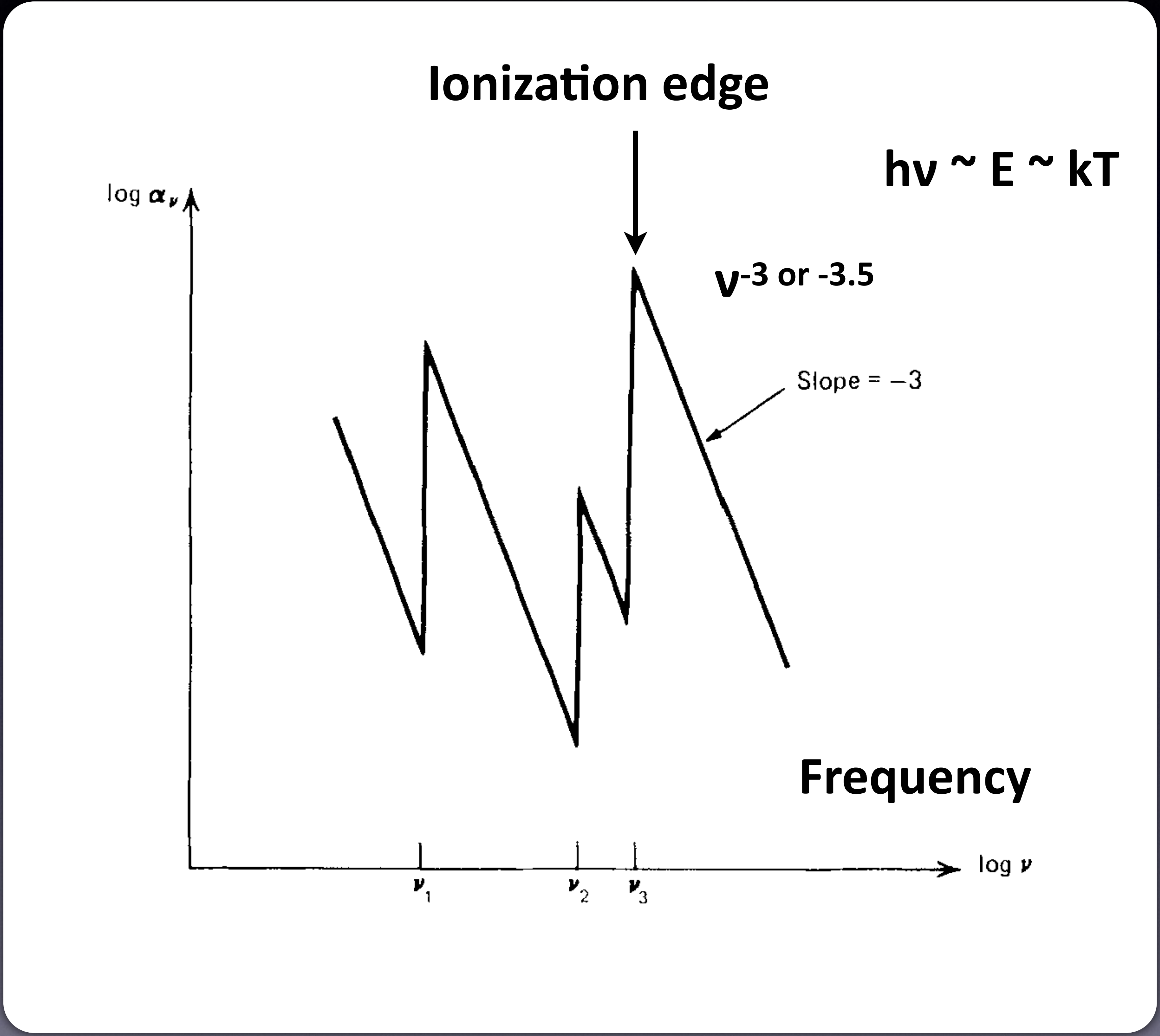
Why do more massive stars have higher temperature?

Opacity inside the stars



Lecture Note by Pols

Bound-free opacity



Rybicki & Lightman

Assignment 1 (microphysics => stellar properties)

Derive that the dependence of free-free opacity in stellar interior can be approximated as $\kappa \propto \rho T^{-3.5}$

Hint: In equilibrium, the rate for free-free absorption matches with that of free-free emission (thermal bremsstrahlung), i.e. $j_\nu = \alpha_\nu B_\nu(T)$
* Kirchhoff's law

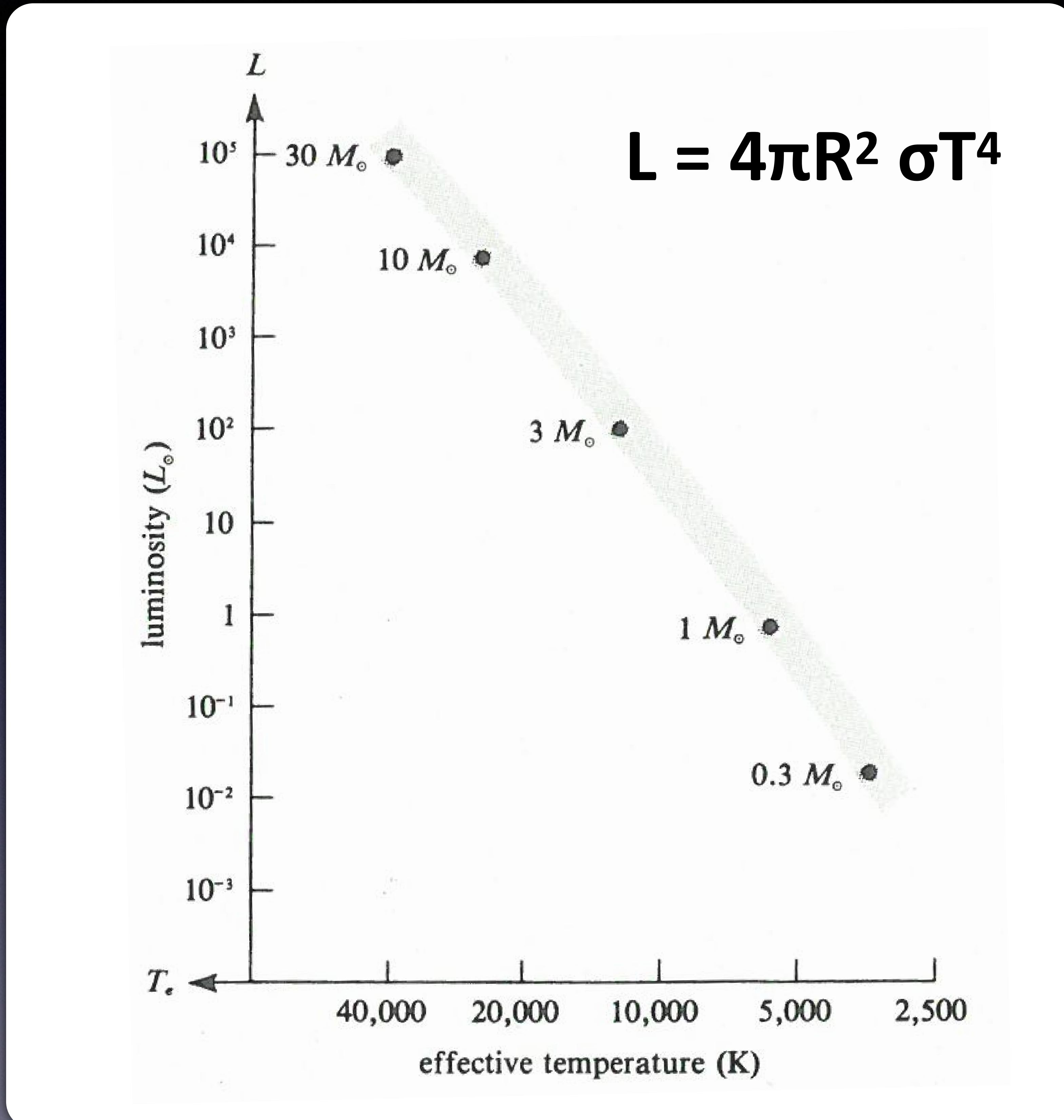
レポート課題 1 (microphysicsが星の性質を決める)

恒星内部における自由-自由吸収の密度・温度依存性が
近似的に次のように表せられることを示せ $\kappa \propto \rho T^{-3.5}$

ヒント：平衡状態では自由-自由吸収のrateと自由-自由放射 (熱的制動放射)のrate
はつり合う $j_\nu = \alpha_\nu B_\nu(T)$
* キルヒホッフの法則

Hertzsprung-Russel diagram

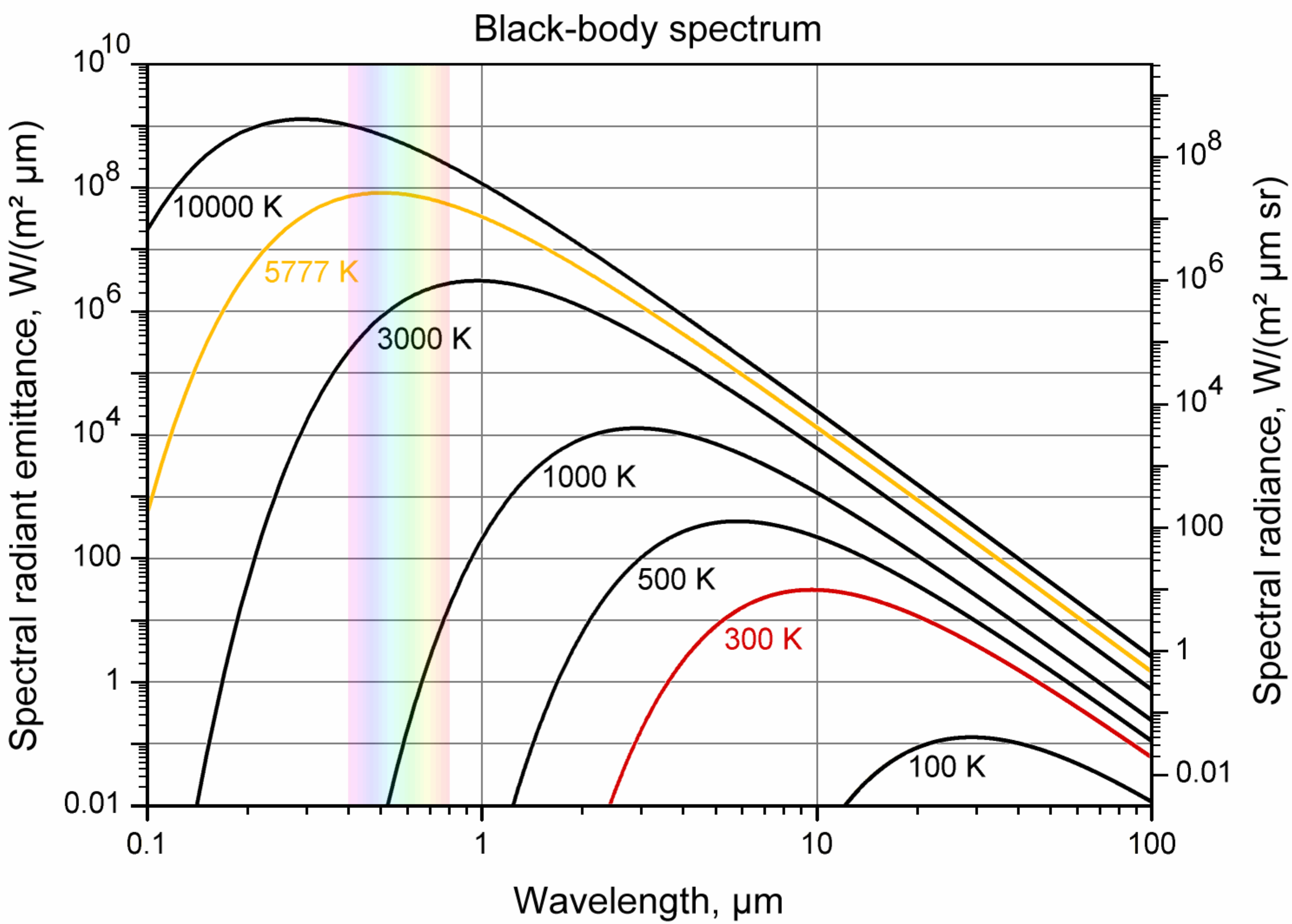
L



T (K)

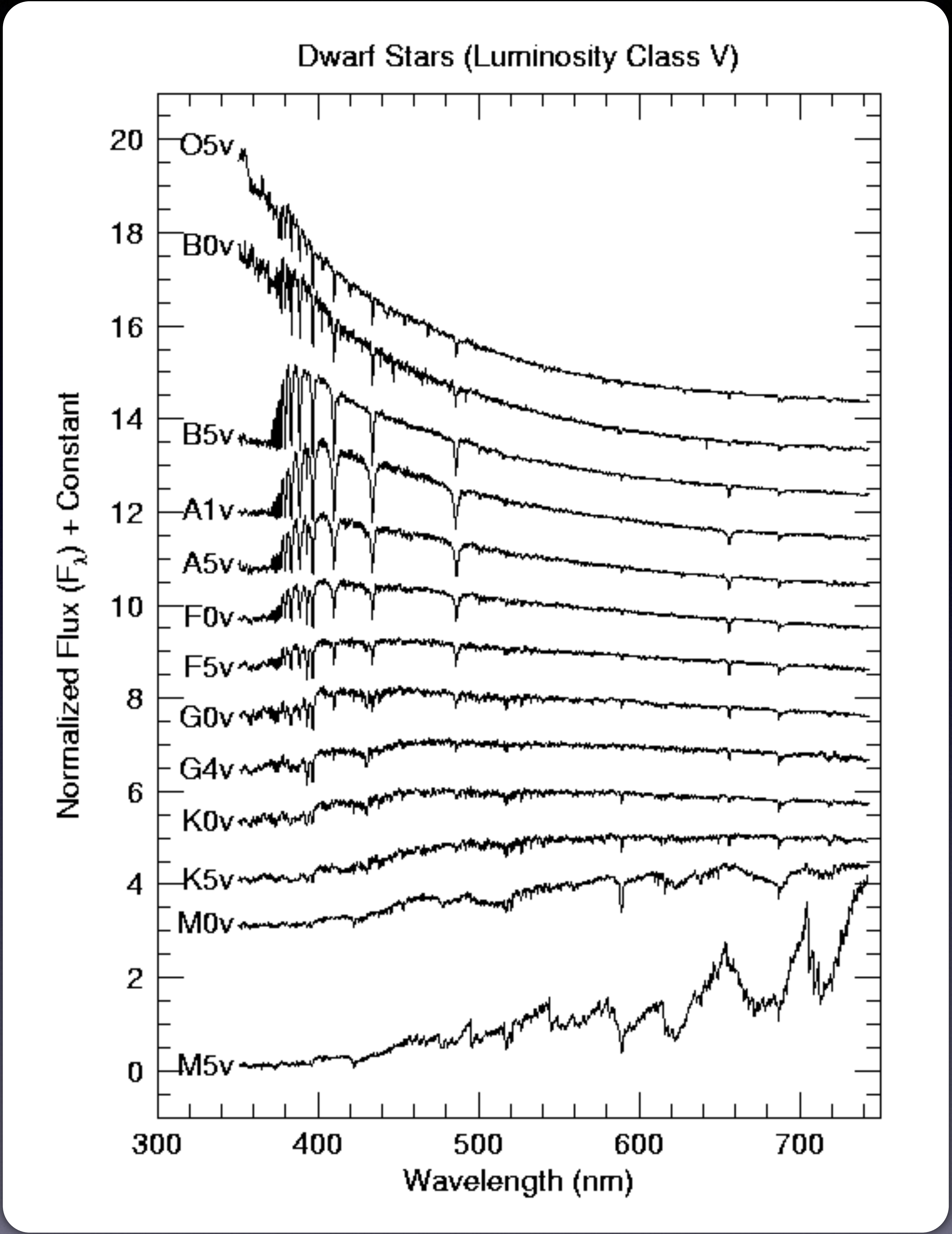
Introduction to Astronomy (F. Shu)

Blackbody radiation



Stellar spectrum

Type	M (Msun)
O	20-60
B	3-18
A	2-3
F	1.1-1.6
G	0.9-1.05
K	0.6-0.8
M	0.08-0.5



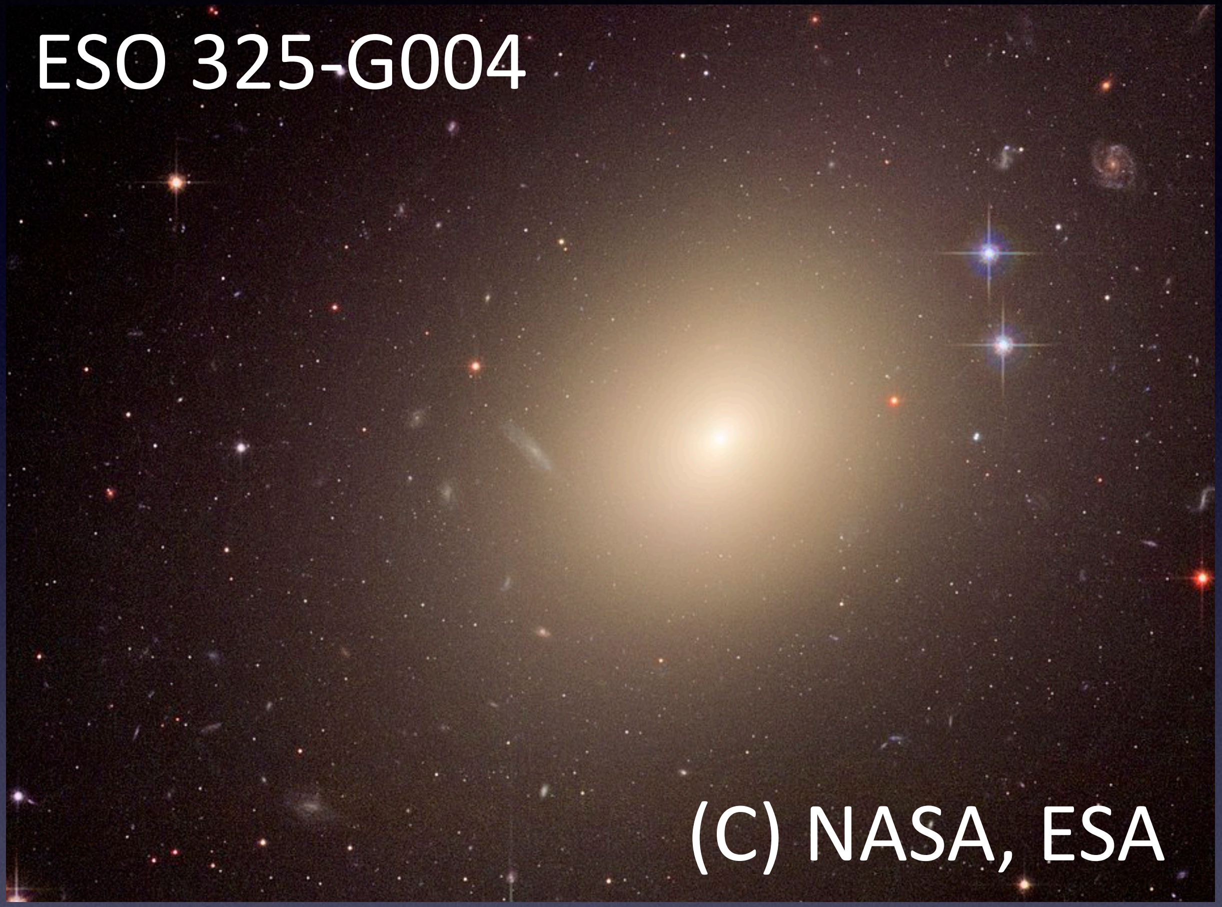
http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit1/SpTypes/index.html

Applications to galaxy studies

Spiral galaxy

- Star forming
- More “young" stars
- More massive stars
- Blue (high T radiation)

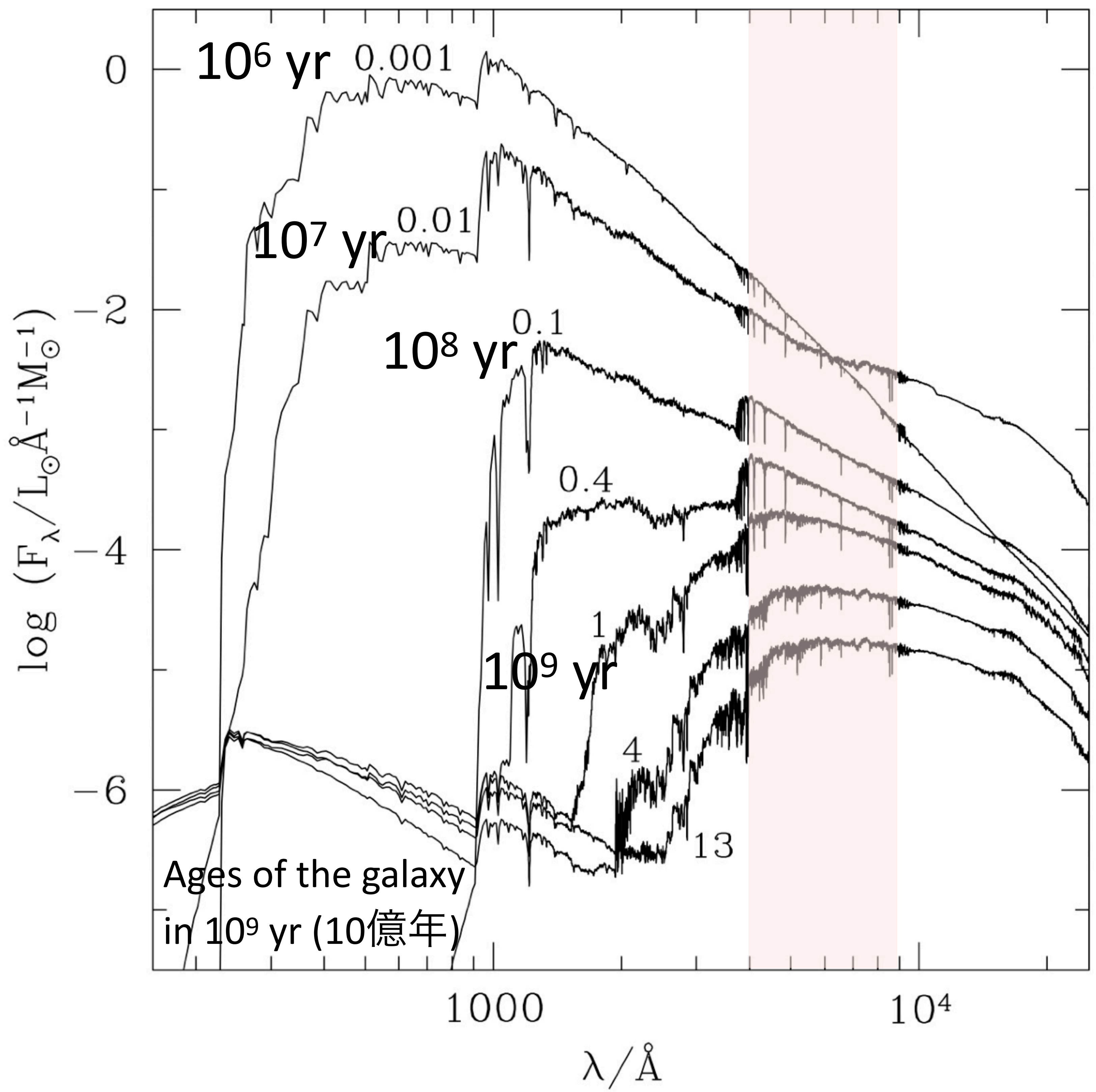
Elliptical galaxy



- No star formation
- Old stars
- Less massive stars
- Red (low T radiation)

Spectral models for galaxies

Bruzual & Charlot 2003



Summary: Stellar properties

- Opacities in the stars
  - Thomson scattering
  - free-free and bound-free absorption
- Luminosity of the stars
  - $L \sim E/t_{esc},$ where $t_{esc} \sim (R/c)\,\tau$ ($\Leftarrow\!=\; \tau = \kappa\rho R$)
  - $L \sim M^{3\text{-}5}$
- Stellar properties
  - More massive stars have
    - Higher luminosity $L \sim M^4$ (shorter lifetime $t \sim M^{-3}$)
    - Higher temperature $T_{eff} \sim M^{0.5}$
  - Foundation to determine the galaxy spectra

Thermodynamics

Electromagnetism

Classical mechanics

Statistical mechanics

Astrophysics

Hydrodynamics

Quantum mechanics

Relativity

Nuclear physics