Course of General Astronomy

Gulu University

Naples FEDERICO II University

4

Spectral Classification & HR Diagram

Black Body light: (From previous Lectures)

- Wavelength of the emission maximum

$$\lambda = \frac{2.8979 \times 10^{-3}}{T}$$

λ in meters

T in Kelvin

- overall emitted Flux

$$F = \sigma T^4$$

F in Watt and

σ=5.67×10^{-8} W K^{-4} m^{-2}

•Flux at different λ (Planck's law)

$$F(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{\Delta}{e^{\frac{hc}{\lambda kT}} - 1}$$

k=1.3806×10^{-23} j/ K

The Stars: (T* and R* are surf. temperature and radius)

•Overall Flux at star surface (emitted power by 1 m^2 of star)

$$F_* = \sigma T_*^4$$

(From previous Lectures)

•Total Luminosity (emitted power by the whole star surface)

$$L_* = 4\pi R_*^2 F_* = 4\pi R_*^2 \sigma T_*^4$$

•Total Flux at Earth (received power by 1 m^2 telescope far **d** from the star)

$$f = \frac{L_*}{4\pi d^2} = \frac{4\pi R_*^2}{4\pi d^2} F_* = \frac{R_*^2}{d^2} \sigma T_*^4$$

Observations using filters:

(From previous Lectures)

If we observe the star through a blue filter:

$$f_B = \frac{R_*^2}{d^2} \frac{2\pi hc^2}{\lambda_B^5} \frac{\Delta_B}{e^{\frac{hc}{\lambda_B kT_*}} - 1}$$

If we observe the star through a yellow filter:

$$f_G = \frac{R_*^2}{d^2} \frac{2\pi hc^2}{\lambda_G^5} \frac{\Delta_G}{e^{\frac{hc}{\lambda_G kT_*}} - 1}$$

Observations using filters:

(From previous Lectures)

Their ratio is :

$$\frac{f_B}{f_G} = \frac{\lambda_G^{\;5}}{\lambda_B^{\;5}} \frac{\Delta_B}{\Delta_G} \frac{e^{\frac{hc}{\lambda_G k T_*}} - 1}{e^{\frac{hc}{\lambda_B k T_*}} - 1}$$

We have the stars Thermometer !!

Different colours ↔ different temperatures:

(From previous Lectures)

The strange antique astronomers

Hipparcos (II century B.C.): first astronomical catalogue

Stars classified in 6 ***class*** (*magnitudo*) on the base of their luminous stimulus:

•***I magnitude***: brightest stars visible at naked eyes

•…………………………

•***VI magnitude***: dimmest stars visible at naked eyes

The classification depends by:

1. flux at Earth $f = \mathbf{L_\star / 4\pi d^2}$
2. eye response (logarithmic detector, at constant differences in magnitude correspond constant ratios in fluxes)

Apparent Magnitude:

Pogson (II half of 1800): mathematical definition

$$m = -2.5 \log f + c$$

• *c (zero constant)*: fixed so that for North Star should be $m_P = 2.12$

• $m_{Sun} = -26.78$ e $m_{Sirius} = -1.46$

Coloured Filters: b and v magnitude

$$\mathbf{b} = -2.5 \log f_b + c_b \qquad \mathbf{v} = -2.5 \log f_v + c_v$$

Colour Index (*temperature*):

$$\mathbf{b}\text{-}\mathbf{v} = -2.5 \log (f_b / f_v) + \text{costant}$$

m depends from:

- luminosity *(intrinsic)* of star $\mathbf{L}_\star$
- distance **d** of star

Absolute Magnitude M:

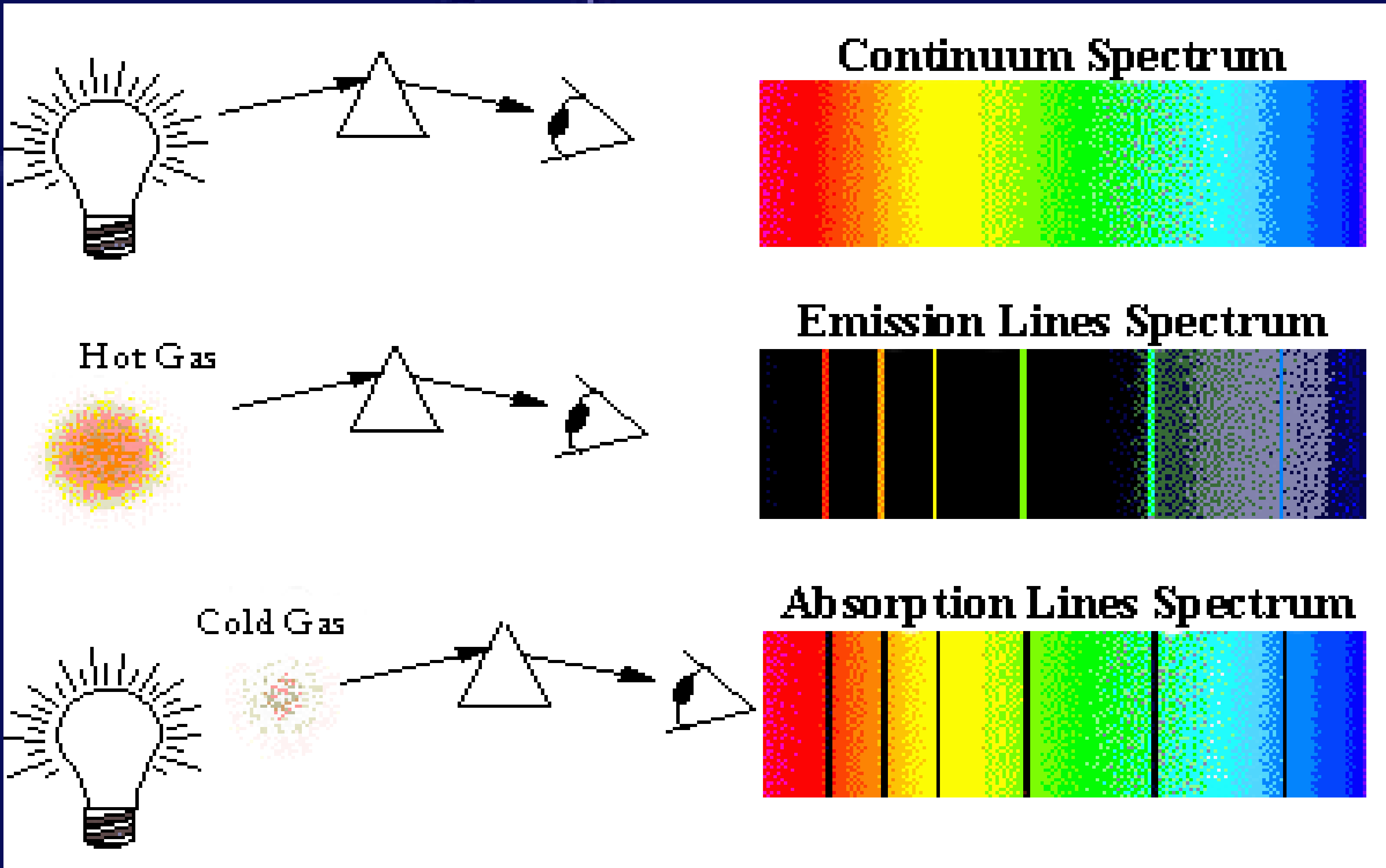
$$M = -2.5 \log L_\star + C$$

- ***C*** : fixed so that m ed M should coincide for stars at d=10 *pc*

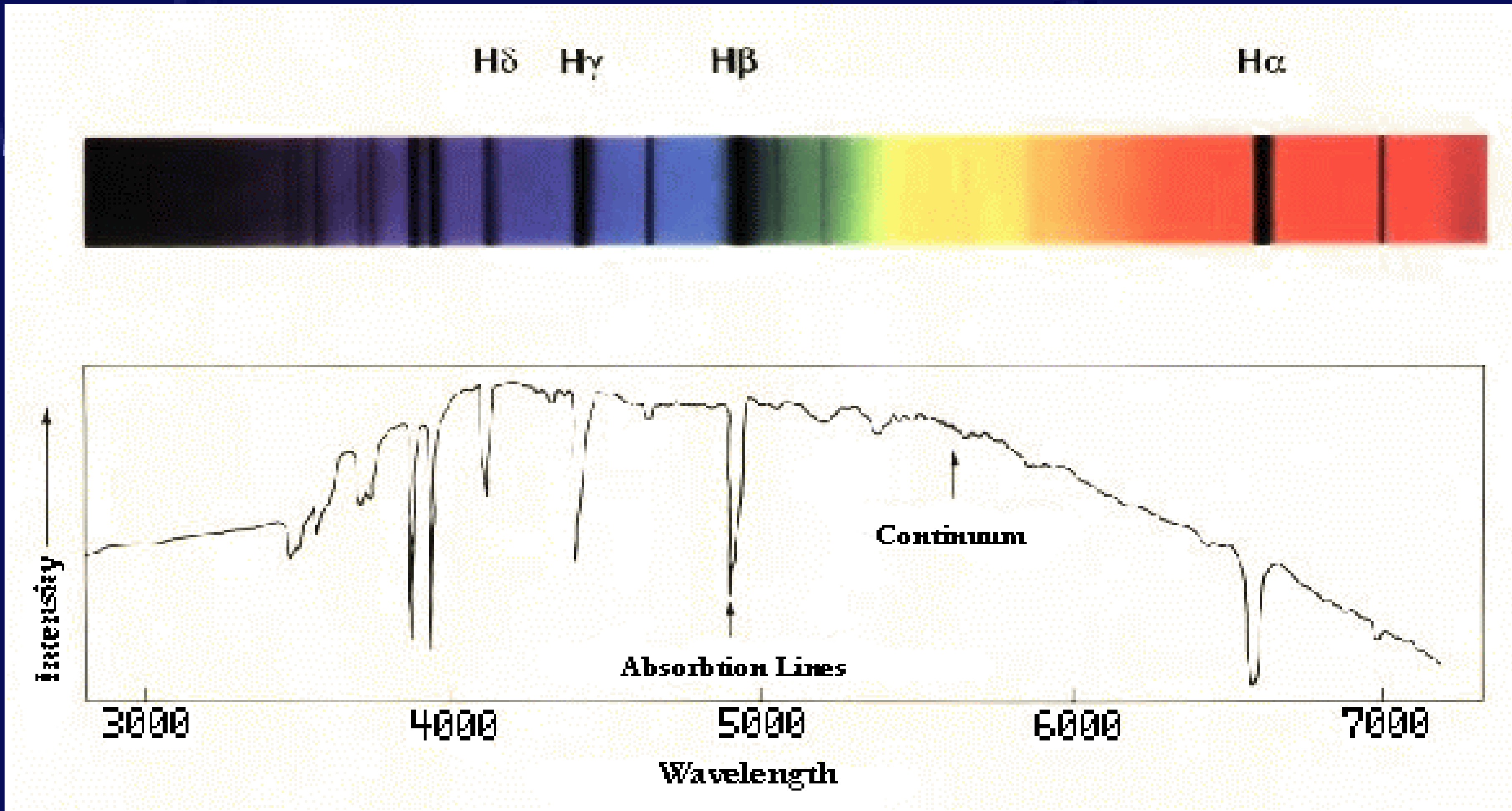
$$M = m + 5 - 5 \log d \qquad \text{(d in pc)}$$

$m - M = 5 \log d - 5$ *distance modulus*

Spectra:


Continuum Spectrum
Hot Gas
Emission Lines Spectrum
Cold Gas
Absorption Lines Spectrum

Stellar Spectra:



Spettral Classification:

STELLAR SPECTRA …

Black Body + Absorption lines of different elements

??? … it's better to classify

(father Angelo Secchi started)

Spectral Class

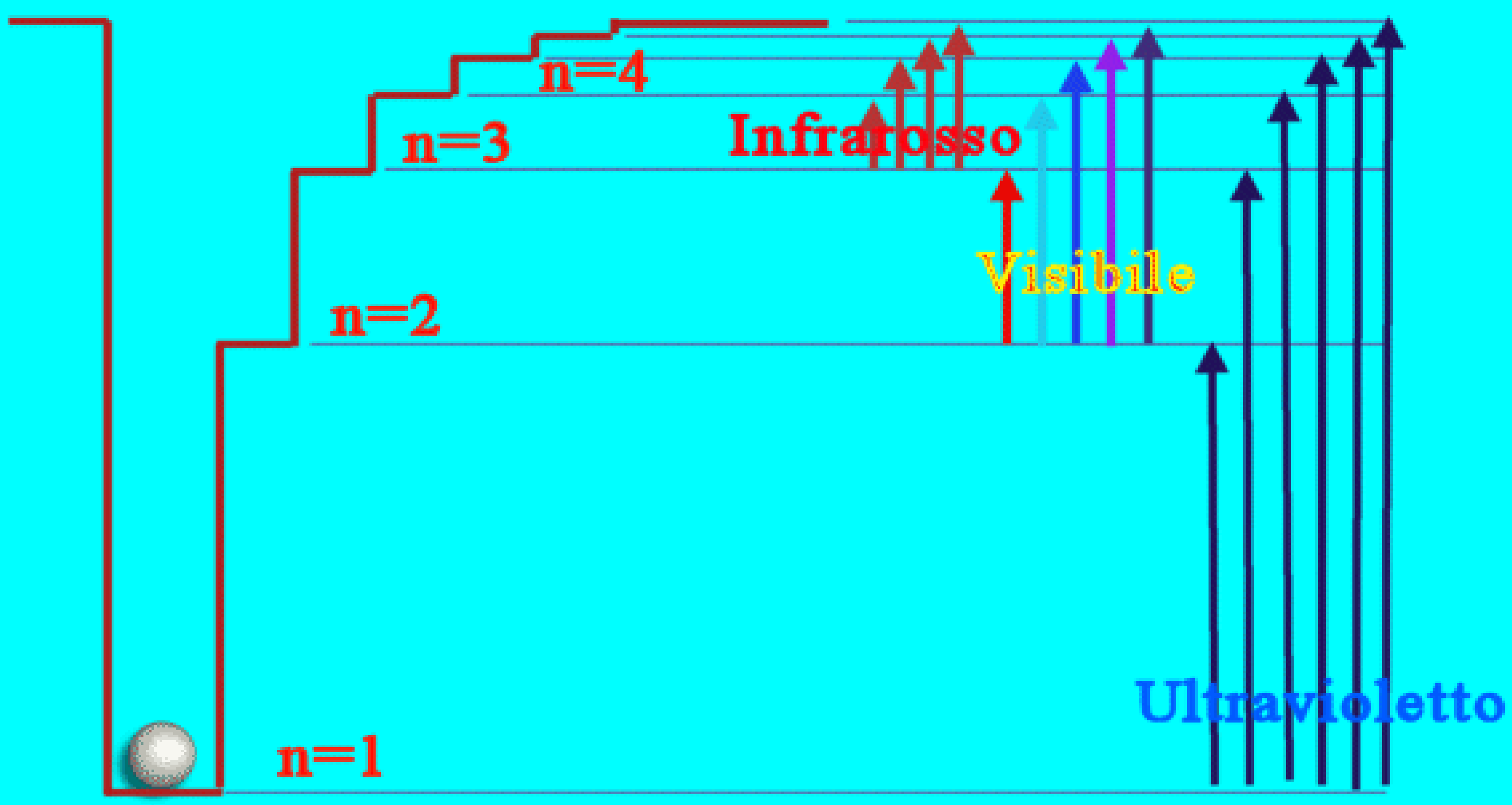
ABCDEFGHIJKLMNOPQRS

← strong H lines   missing H lines →

- 1920: development of quantum mechanics …

Helium stars, hydrogen stars … and mango stars ?

Energy levels of hydrogen atom



Predominant Factor : **TEMPERATURE**

Spectral Type:

Spectral Type ⇆ Temperature

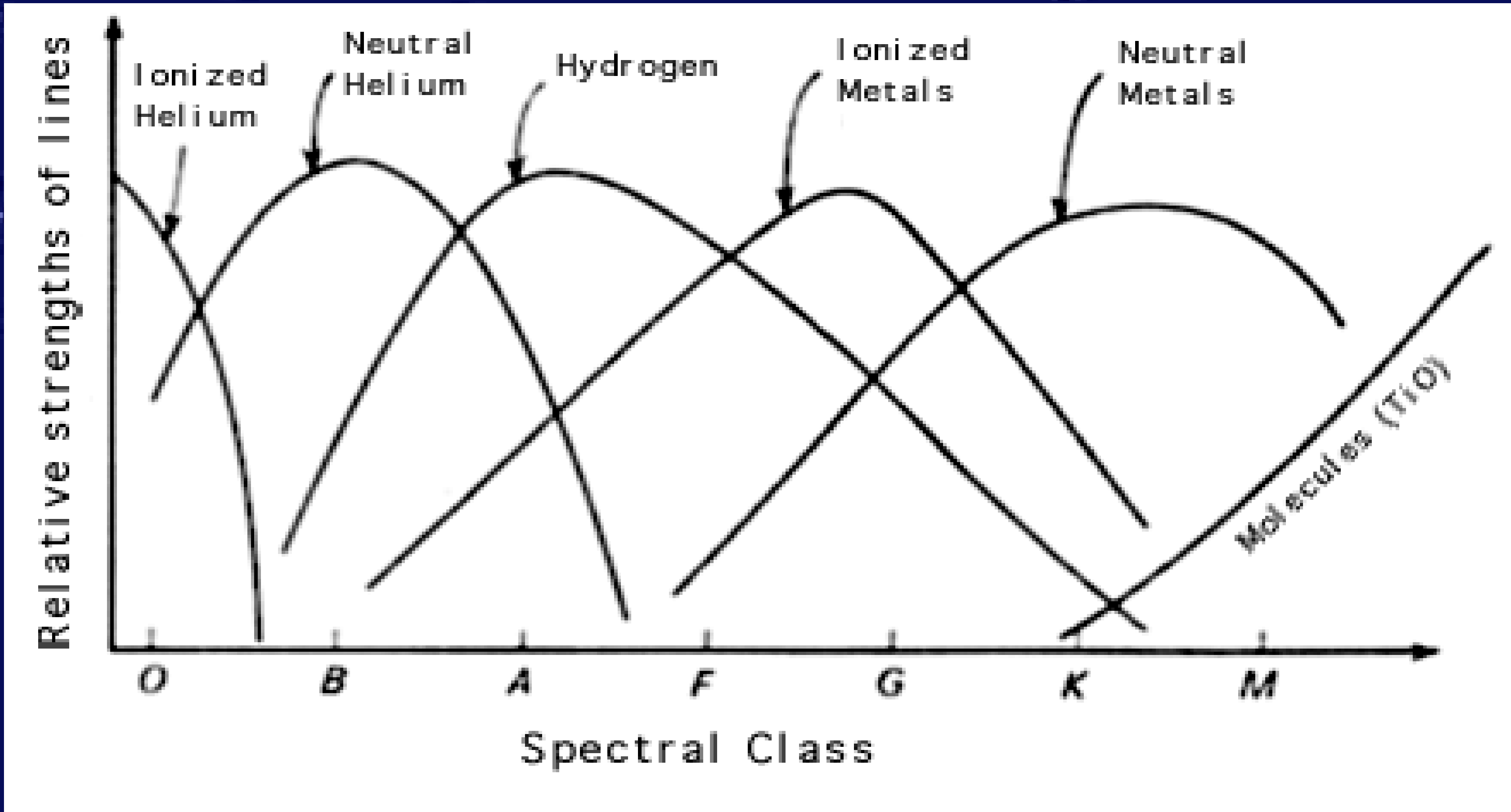
O B A F G K M

Every class is divided in 10 under type:

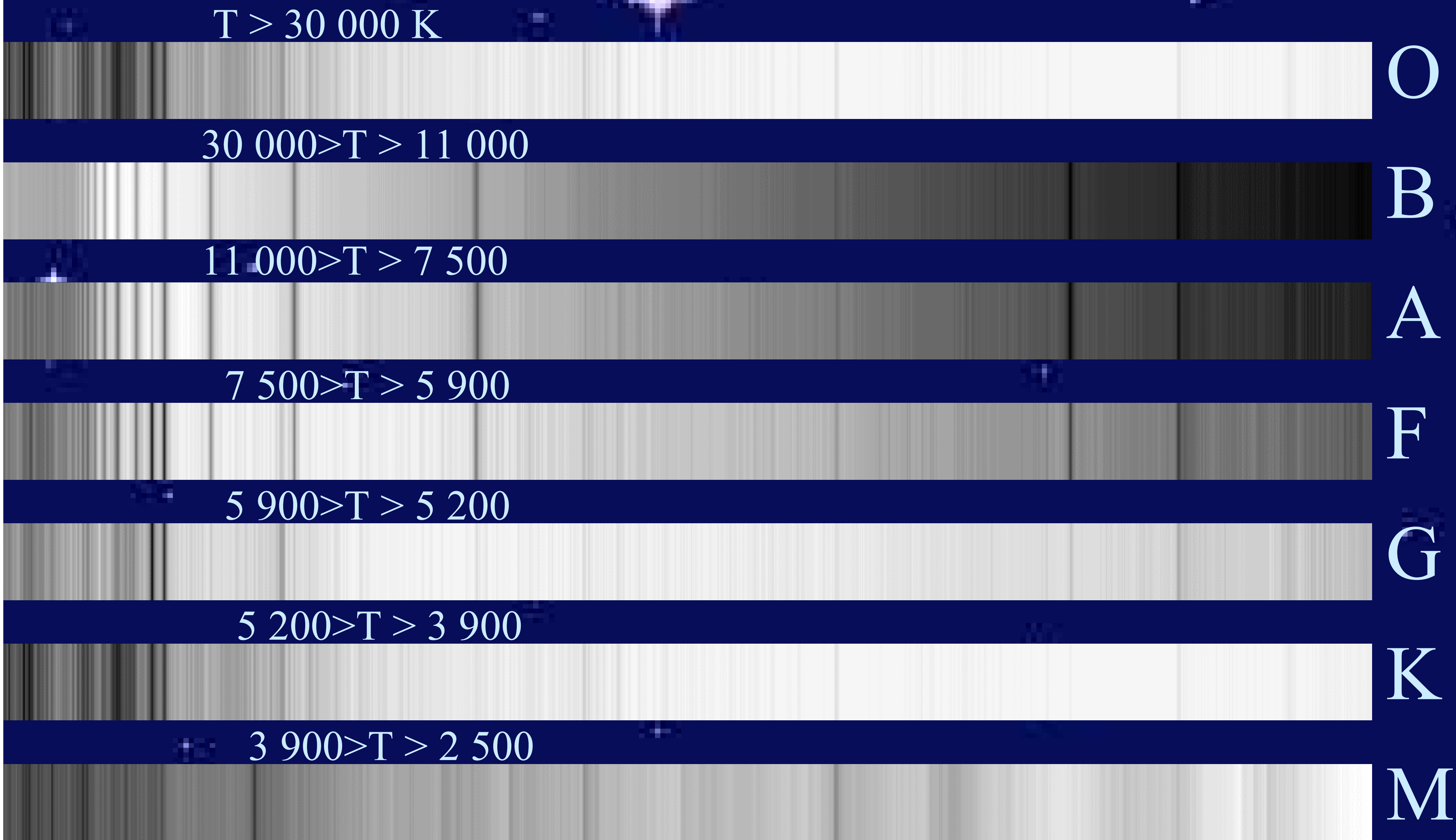
G0, G1, G2. ………,G9

(the Sun is G2)

Spectral Type (2) :



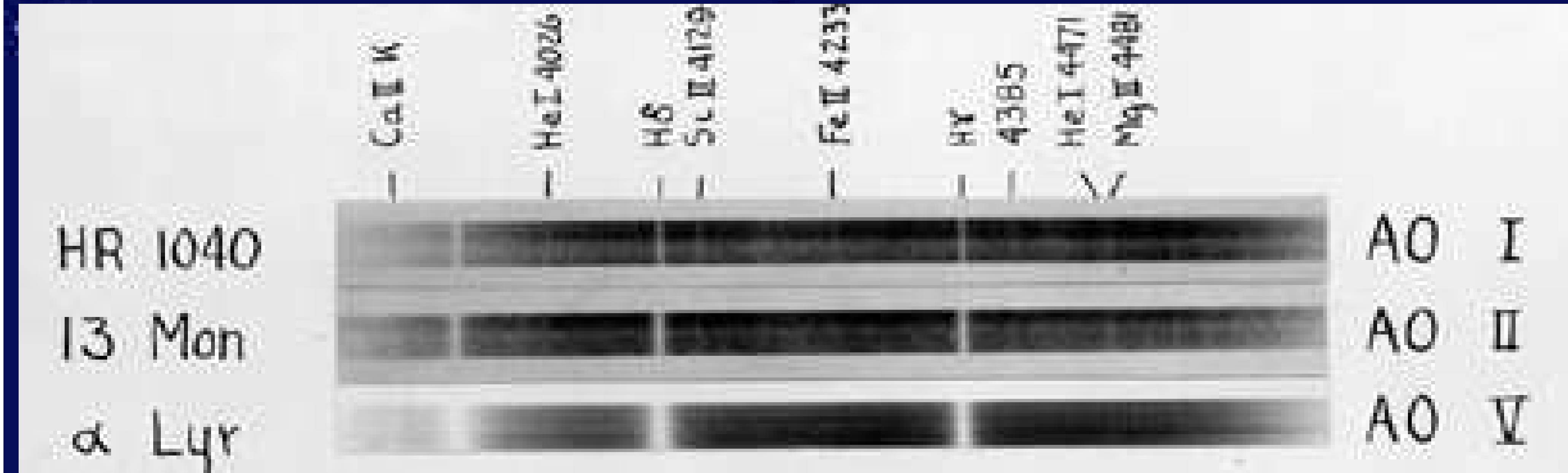
Spectral Type (3):



The Shape of Absorption Lines

At same temperature (Spectral Type) … the line shape can be:

- very ***broad*** (diffuse and less deep)
- ***narrow*** and very deep



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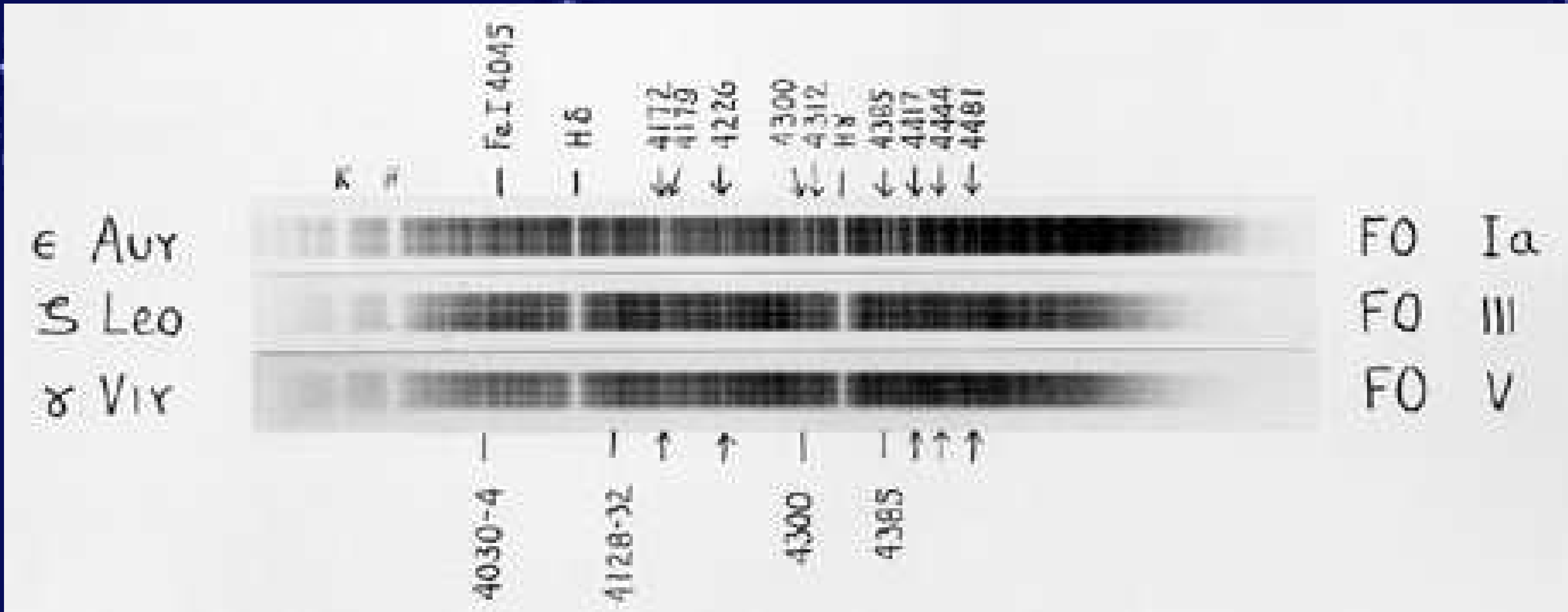


It's better …. To classify !

Luminosity Classes

Parameter broadening of spectral lines:

SURFACE PRESSURE ≈ **g**

≈ Mass/(Radius)^2

The mass doesn't change much !

Line Shape	Class	Name
Very marrow ⇒	I_a O	*bright super supergiant*
	I_a	*bright supergiant*
	I_b	*normal supergiant*
	II	*bright giant*
	III	*red giant*
	IV	*sub-giant*
	V	*main sequence dwarf*
	VI	*sub- dwarf*
Very broad ⇒	VII	*white dwarf*

Why these names:

$L=4\pi R^2\sigma T^4$

Sun : G2 V star

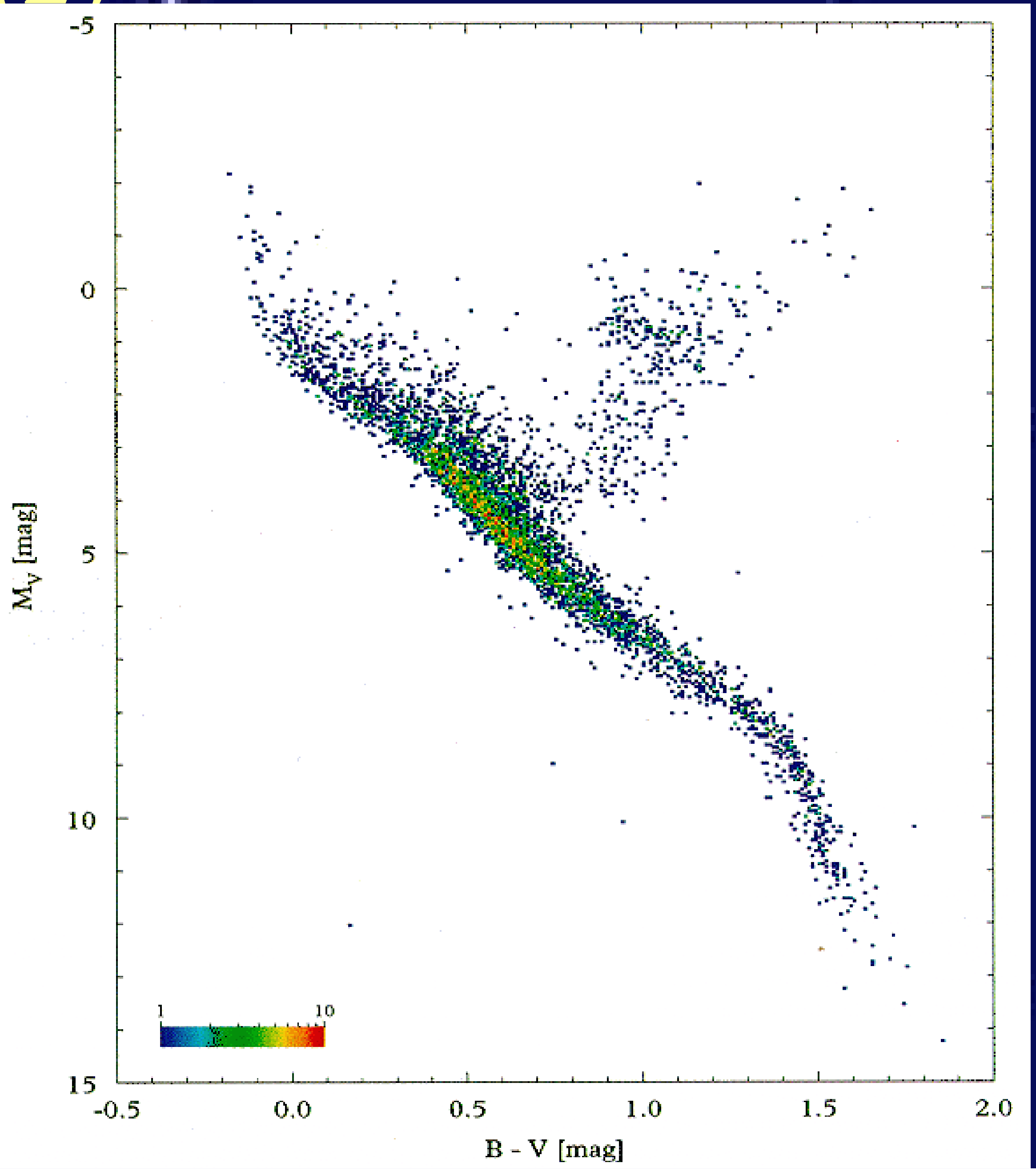
H-R Diagram

- **H**: Danish astronomer E. HERTZSPRUNG (1911)
- **R**: U.S. astronomer H. RUSSEL (1913)

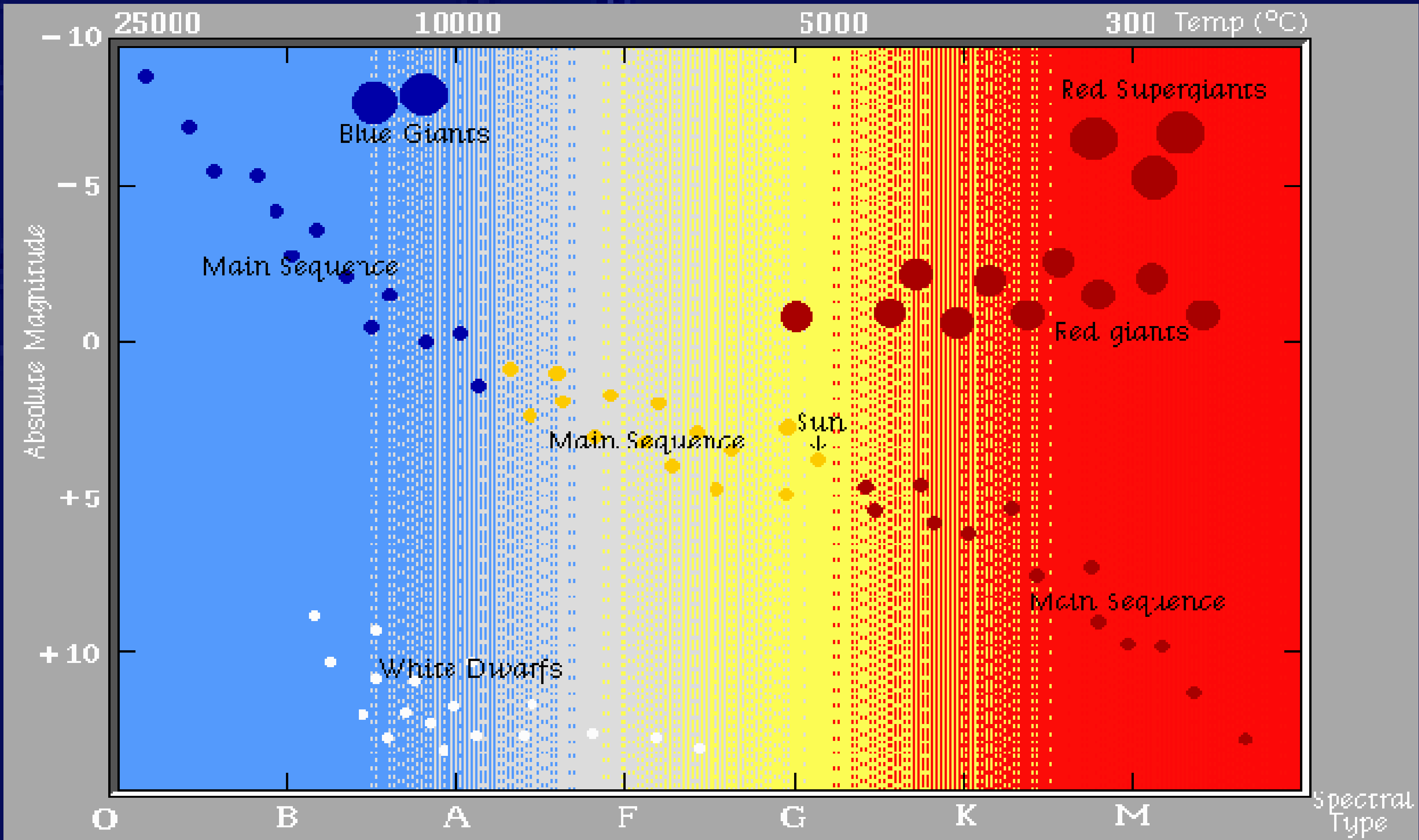
Diagram
LUMINOSITY – TEMPERATURE
(for the stars)

$$L_* = 4\pi R_*^2 \sigma T_*^4$$

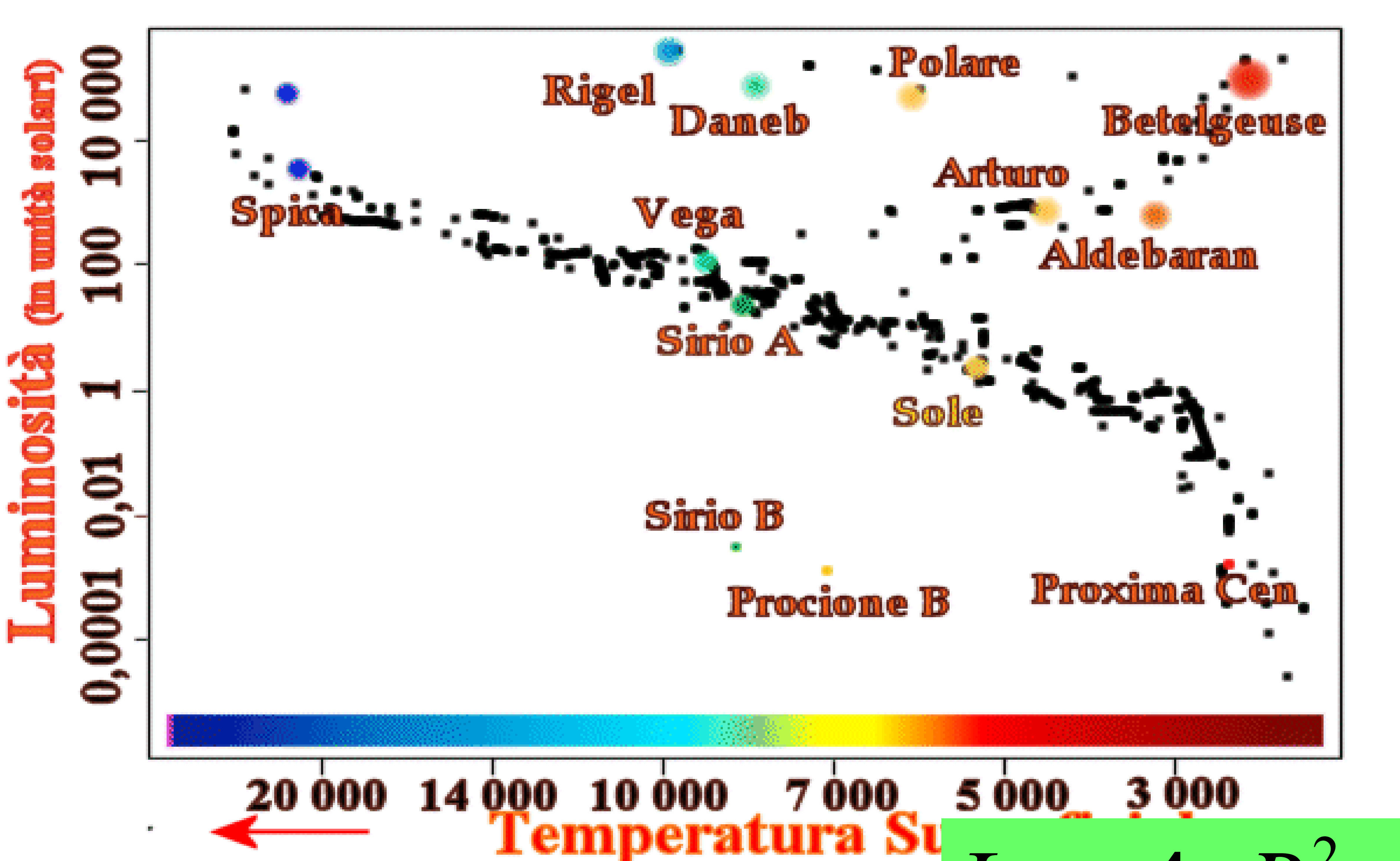
H-R Diagram (2)



H-R Diagram (3), schematic

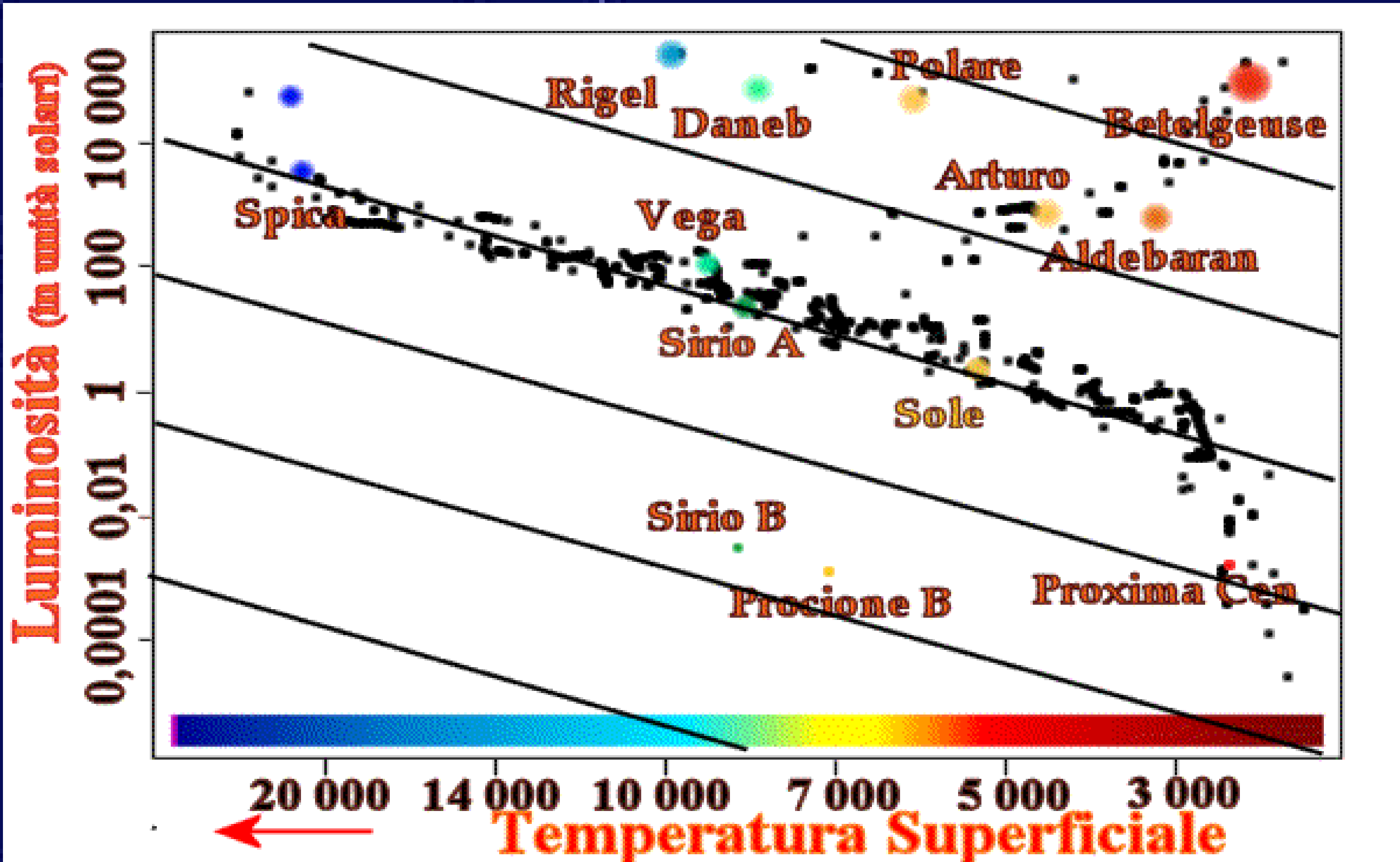


H-R Diagram (4)



$$L_* = 4\pi R_*^2 \sigma T_*^4$$

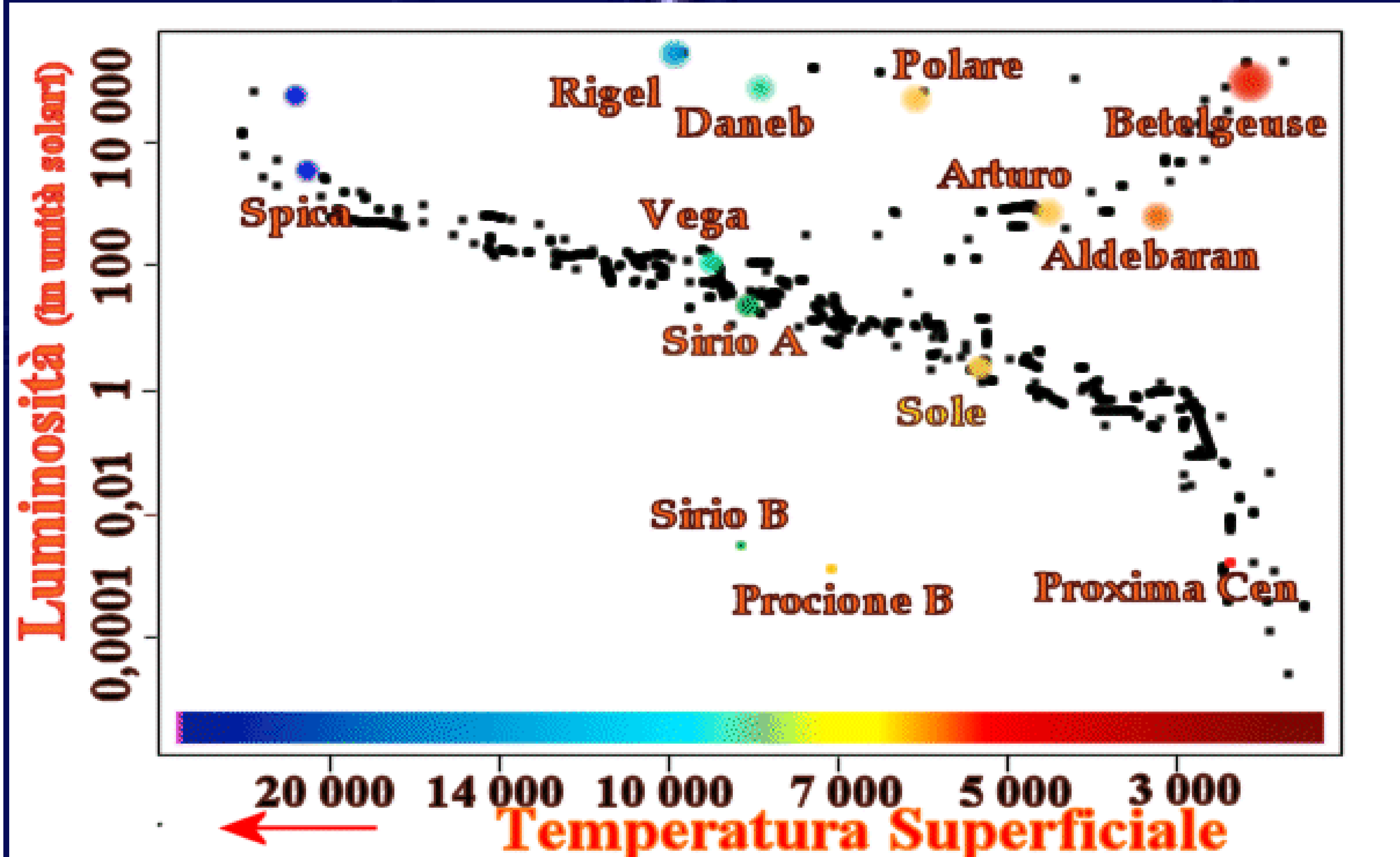
H-R Diagram : equal radius lines



Each star at its own place

In the washdishes there isn't place for…

But in H-R Diagram … there is !



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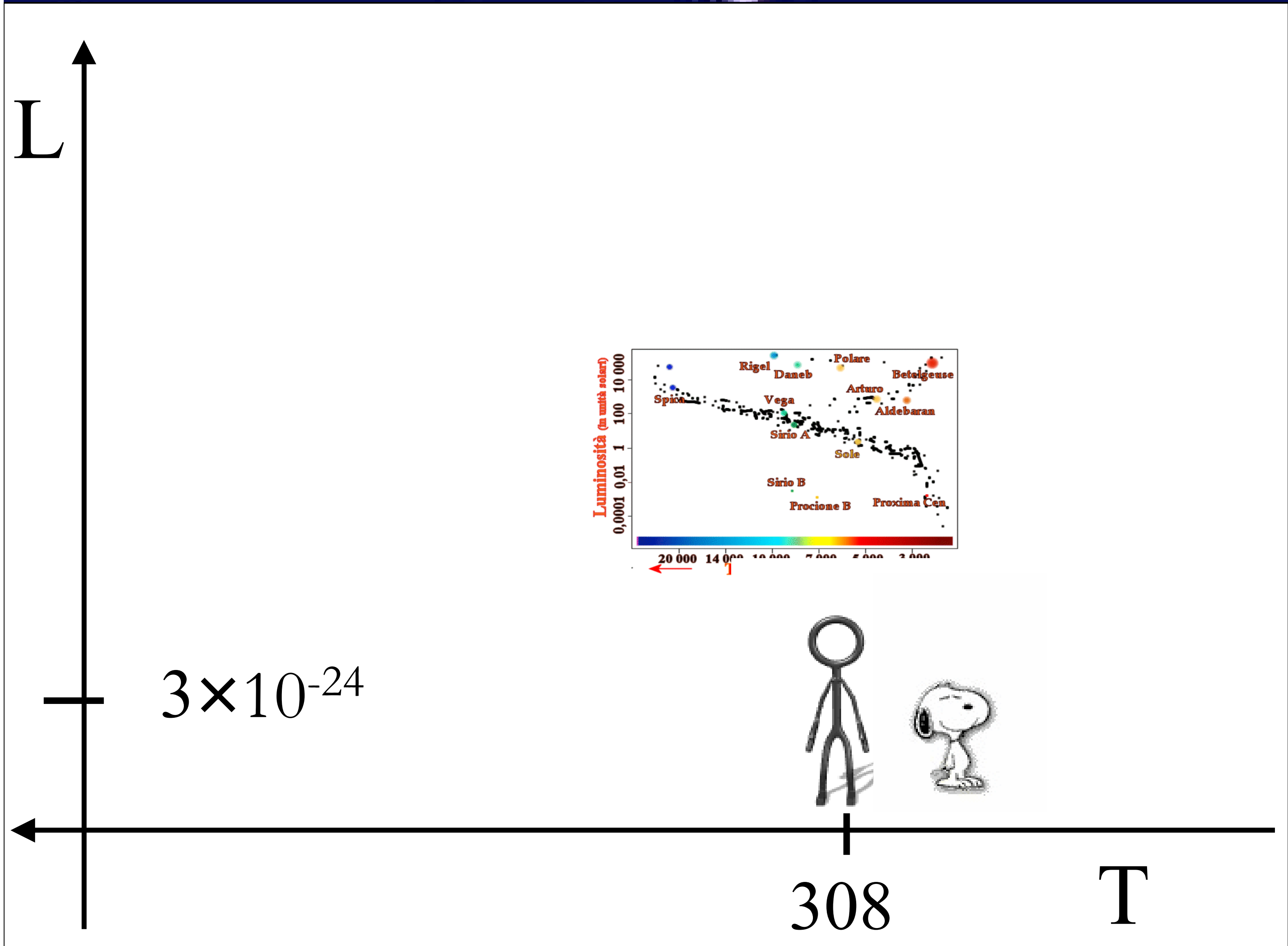


Global properties of stars:

- Temperature:

  3 000 → 50 000 K

- Radius:

  0,01 → 1000 solar radius

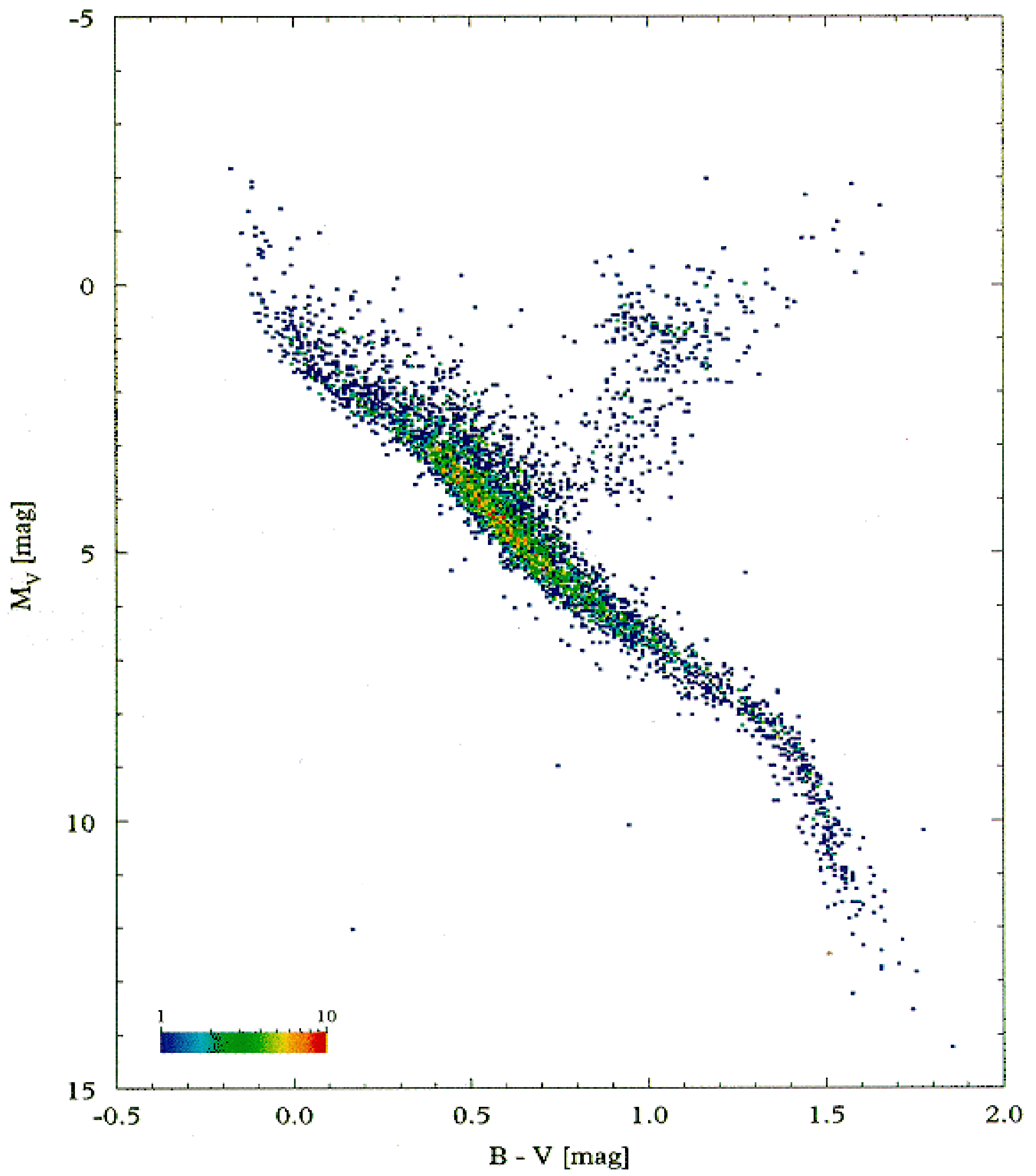
- Masses:

  0,1 → 50 solar mass

- Luminosity:

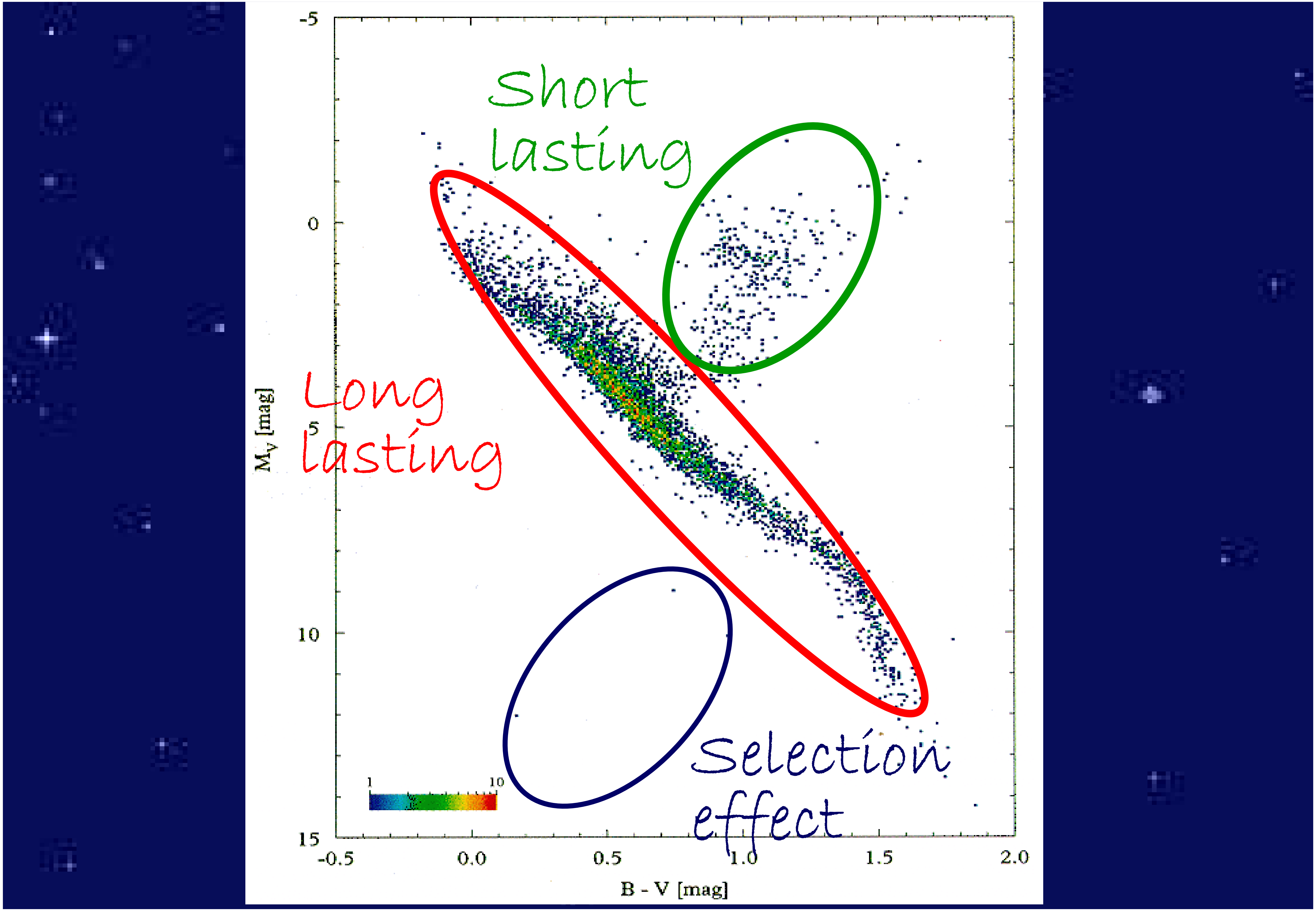
  0,0001 → 1 000 000 solar luminosity

Why the Main Sequence is so crowded ?




If an Extraterrestrial has just one minute to study the human been, as can he do?
neff

Observing all of us simultaneously !!



Short
lasting
Long
lasting
Selection
effect
M_V [mag]
B - V [mag]
-5
0
5
10
15
-0.5
0.0
0.5
1.0
1.5
2.0
1
10