Ciencias de la Tierra y el Espacio, 2003.

ESTRELLAS

Dr. Tabaré Gallardo

Instituto de Física - Dpto. de Astronomía

Facultad de Ciencias

- Distancia, Luminosidad, Temperatura, Radio, Masa
- Espectros, composición
- Estructura
- Energía
- Evolución
- Estados finales (objetos compactos)
- Medio interestelar y origen de las estrellas

Métodos para medir las propiedades básicas de las estrellas

distancia	midiendo paralaje
luminosidad	$L = 4\pi \times (\text{distancia})^2 \times F_{\text{recibido}}$
temperatura superficial	midiendo color o $T = \text{cte}/\lambda_{\text{max}}$
radio	$L = 4\pi \times R^2 \times \sigma T^4$
masa	sistema binario
composición	líneas espectrales - modelo

DISTANCIAS

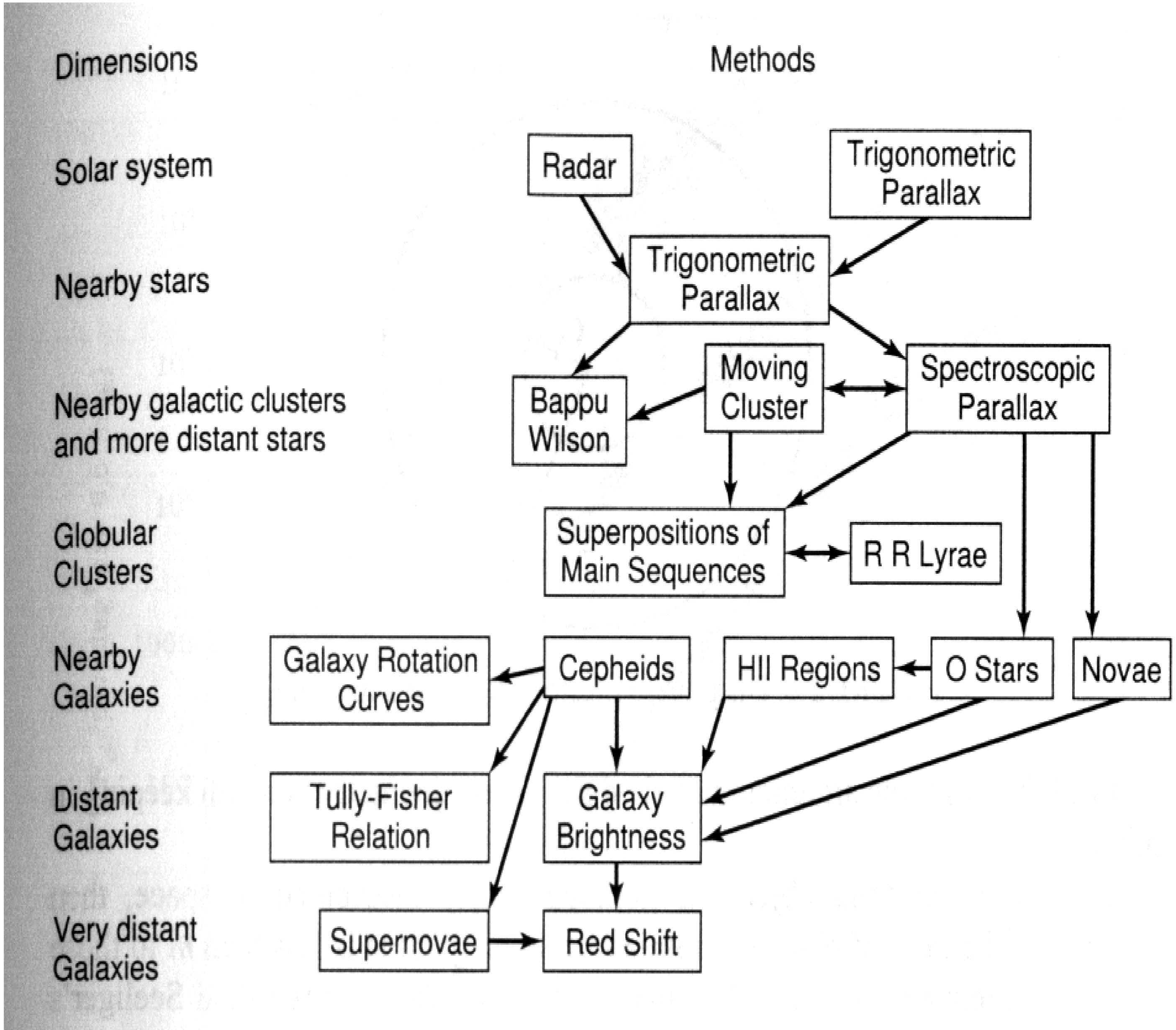
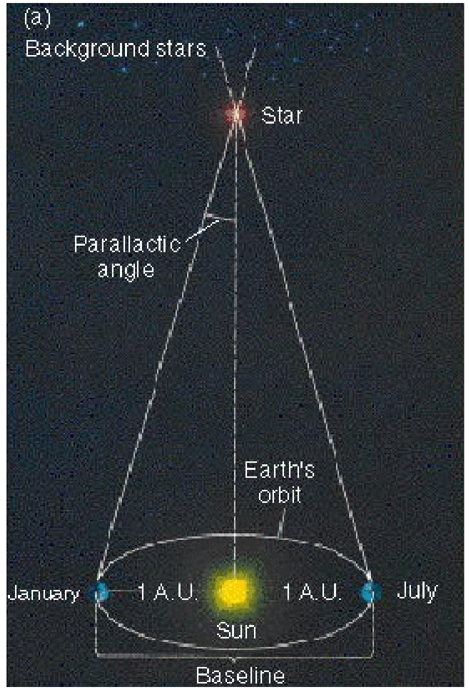


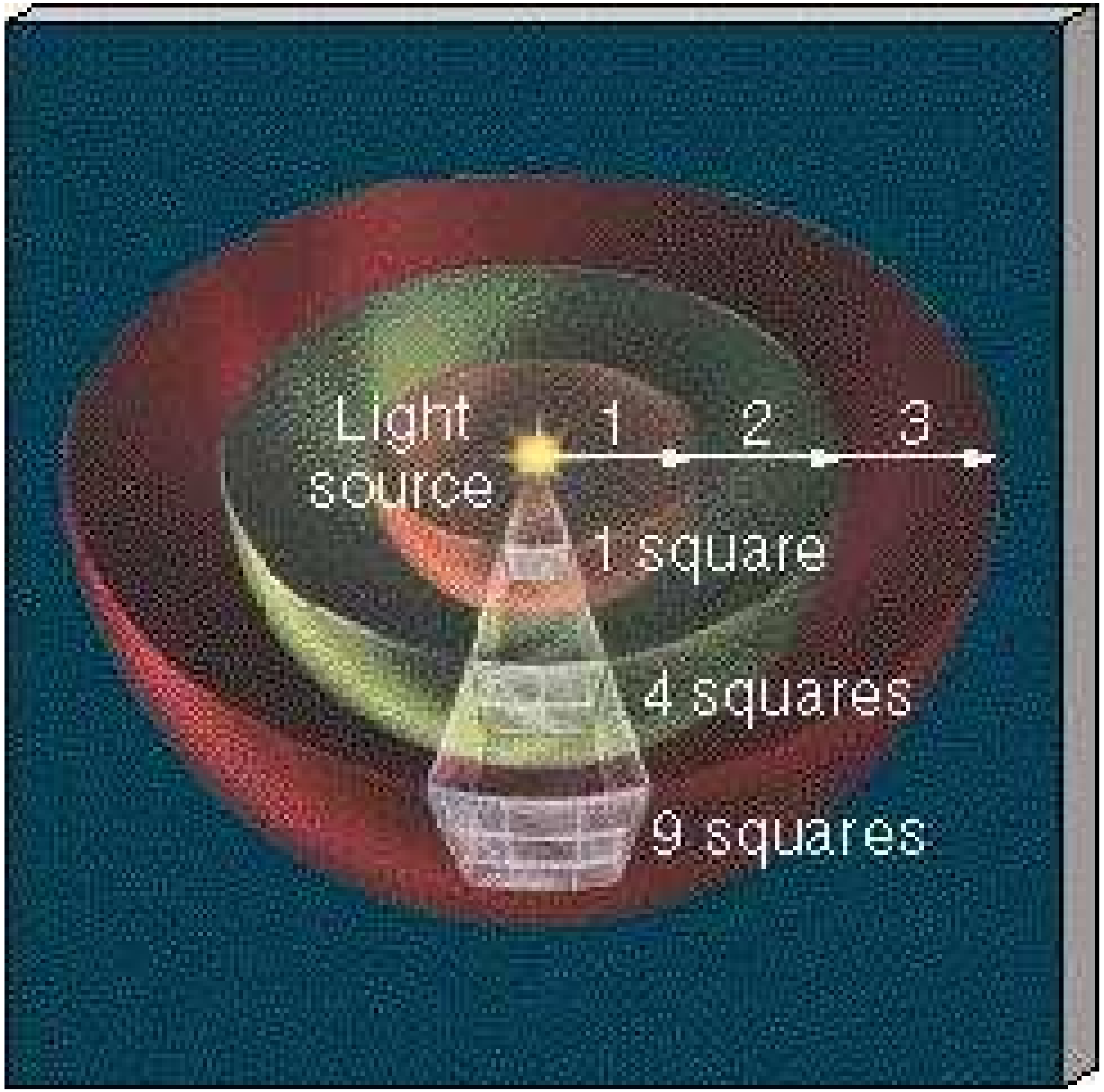
FIGURE 2.5. Flow chart of distance indicators.

$$d = \frac{1\,\mathrm{UA}}{\tan p}$$



LUMINOSIDAD

$$L = 4\pi \times r^2 \times F(r) = cte$$



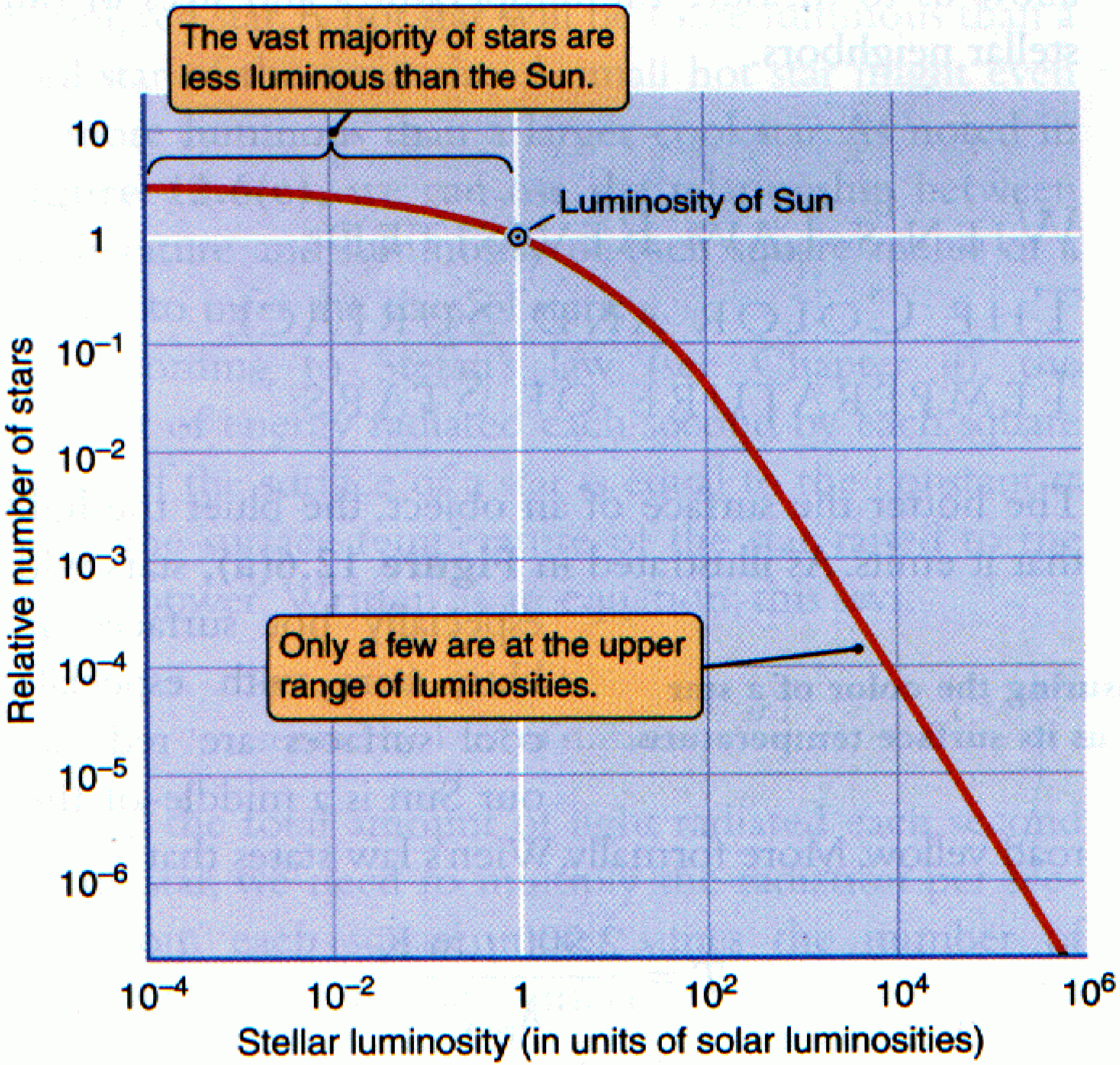


Figure 12.5 *The distribution of luminosities of known stars within 1,000 pc (3,260 ly) of Earth.*

Magnitud aparente: Pogson

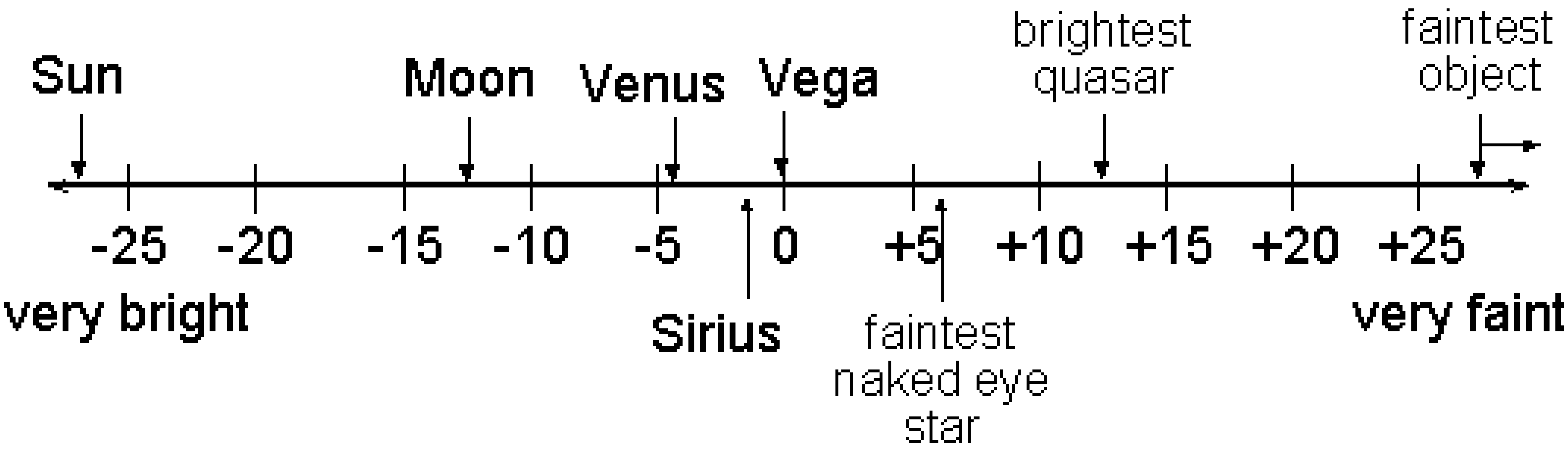
$$m - m_o = -2.5 \times \log \frac{F}{F_o}$$

$$\frac{F}{F_o} = 100 \Rightarrow m - m_o = -5$$

Se define en filtros U B V R I o bolometrica (integrada en todo el espectro)

Indice de Color:

$$B - V = -2.5 \times \log \frac{F_B}{F_V} + cte$$



Apparent brightnesses of some objects in the magnitude system.

El vinculo de la magnitud aparente con la distancia se obtiene a partir de la relacion flujo - distancia

$$L = 4\pi \times r^2 \times F(r) = cte$$

Magnitud absoluta M:

$$m - M = -2.5 \times \log \frac{F(r)}{F(10\,pc)}$$

$$\frac{F(r)}{F(10\,pc)} = \left(\frac{10\,pc}{r} \right)^2$$

$$\Rightarrow m - M = -5 \times \log \frac{10}{r}$$

TEMPERATURAS

Figure 12.7 *A star's* b_B/b_V *color depends on its temperature. The Plank spectra shown here are adjusted so they have the same brightness at 0.55 microns.*

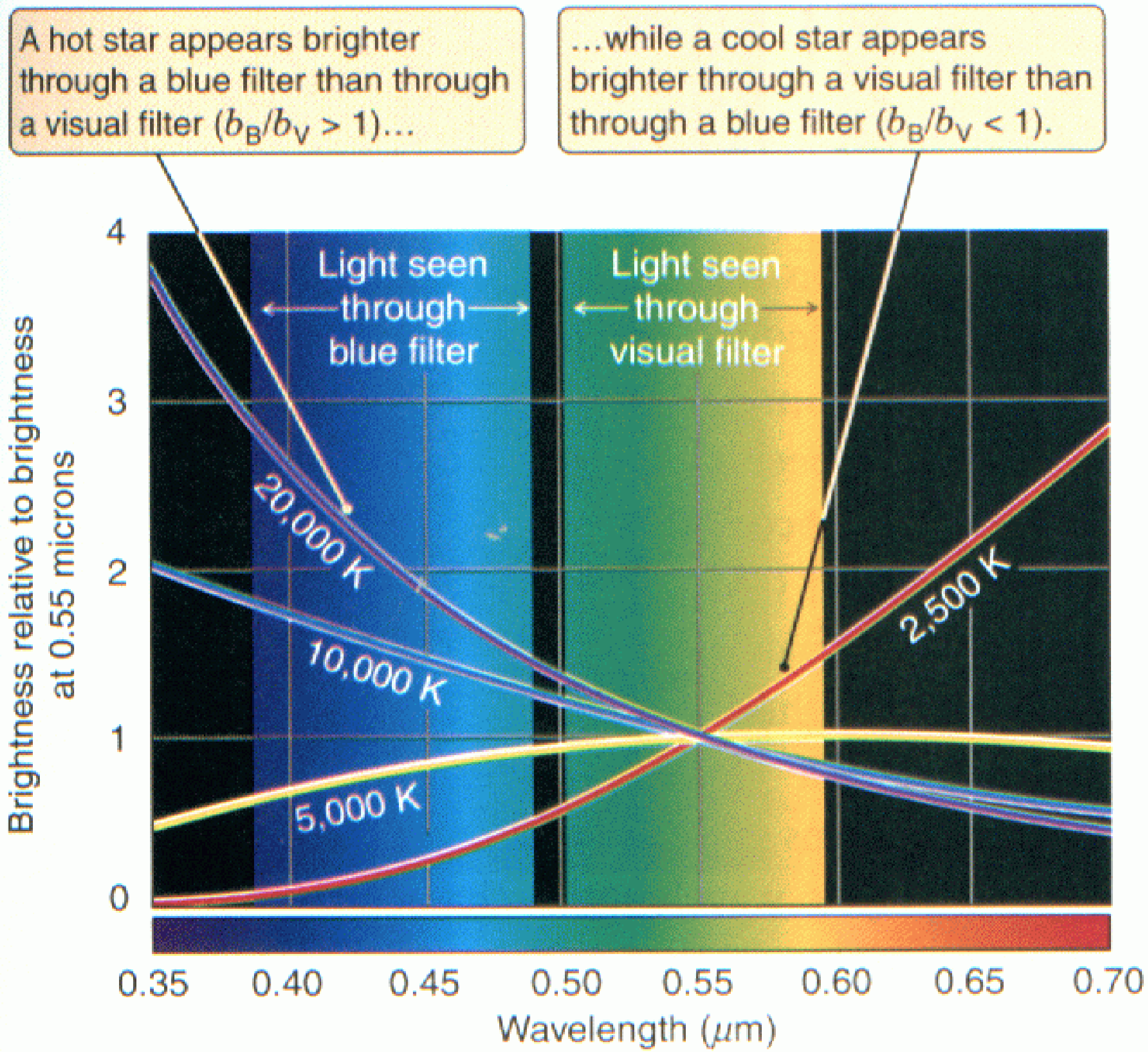


DIAGRAMA H-R

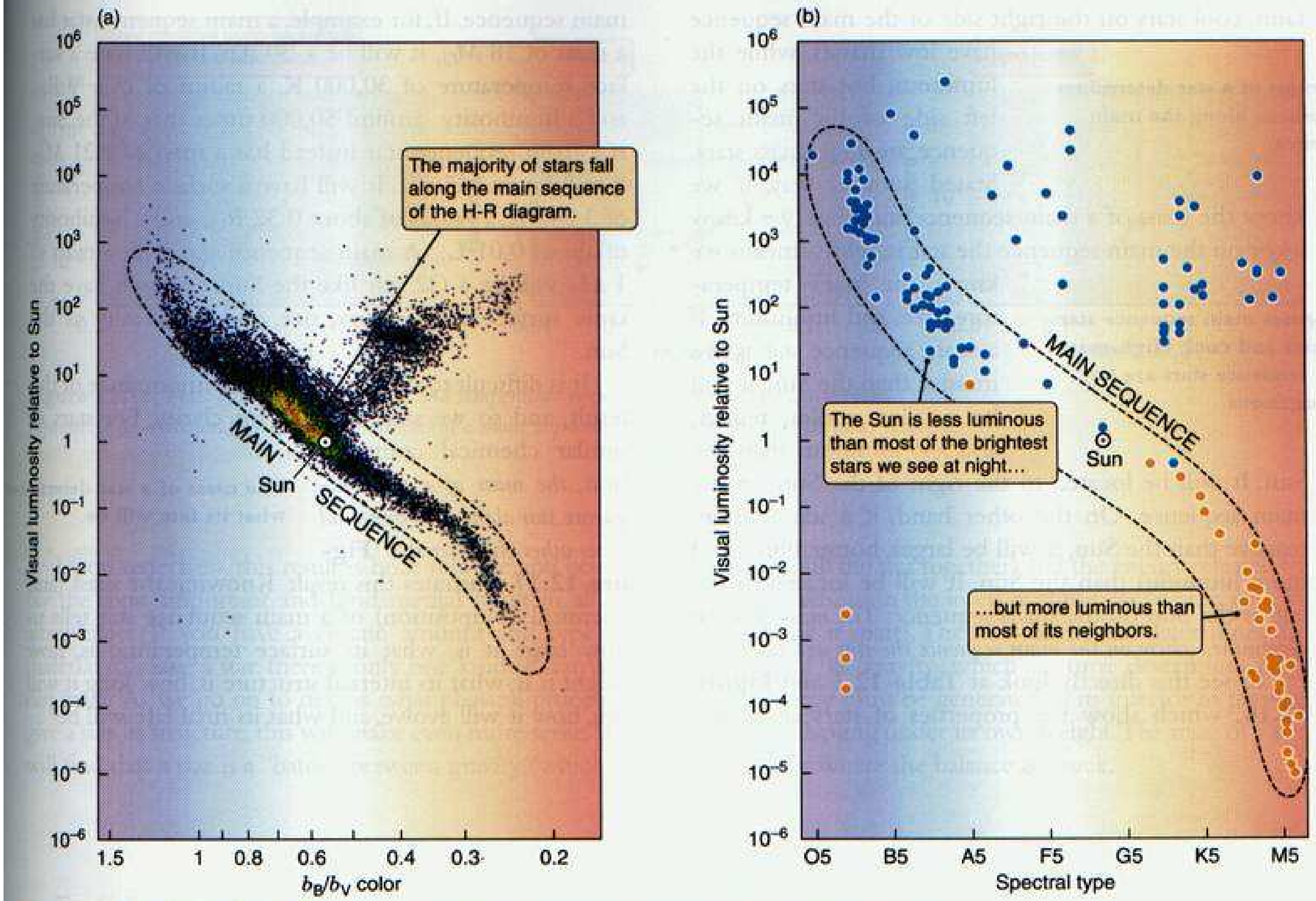
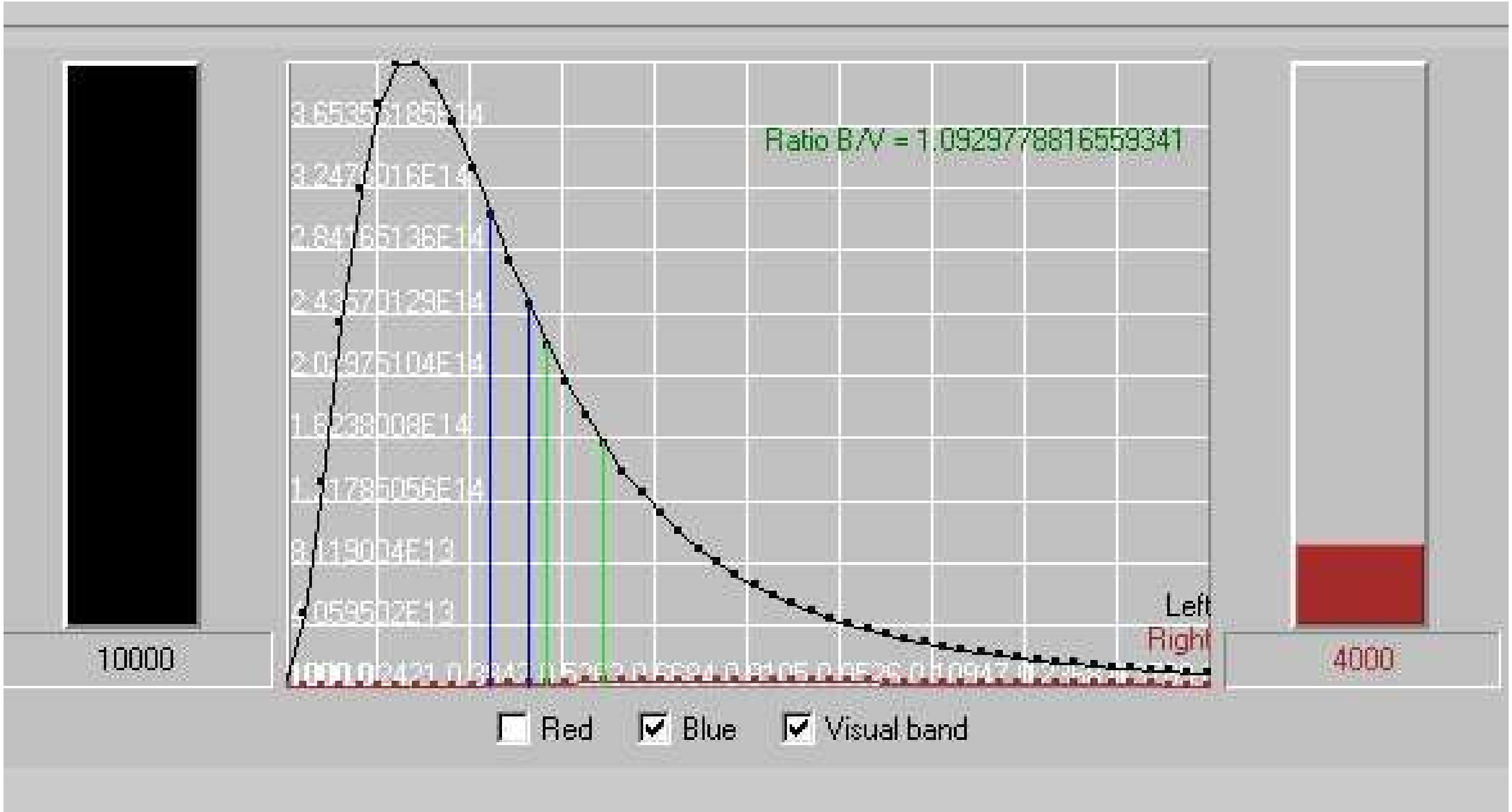


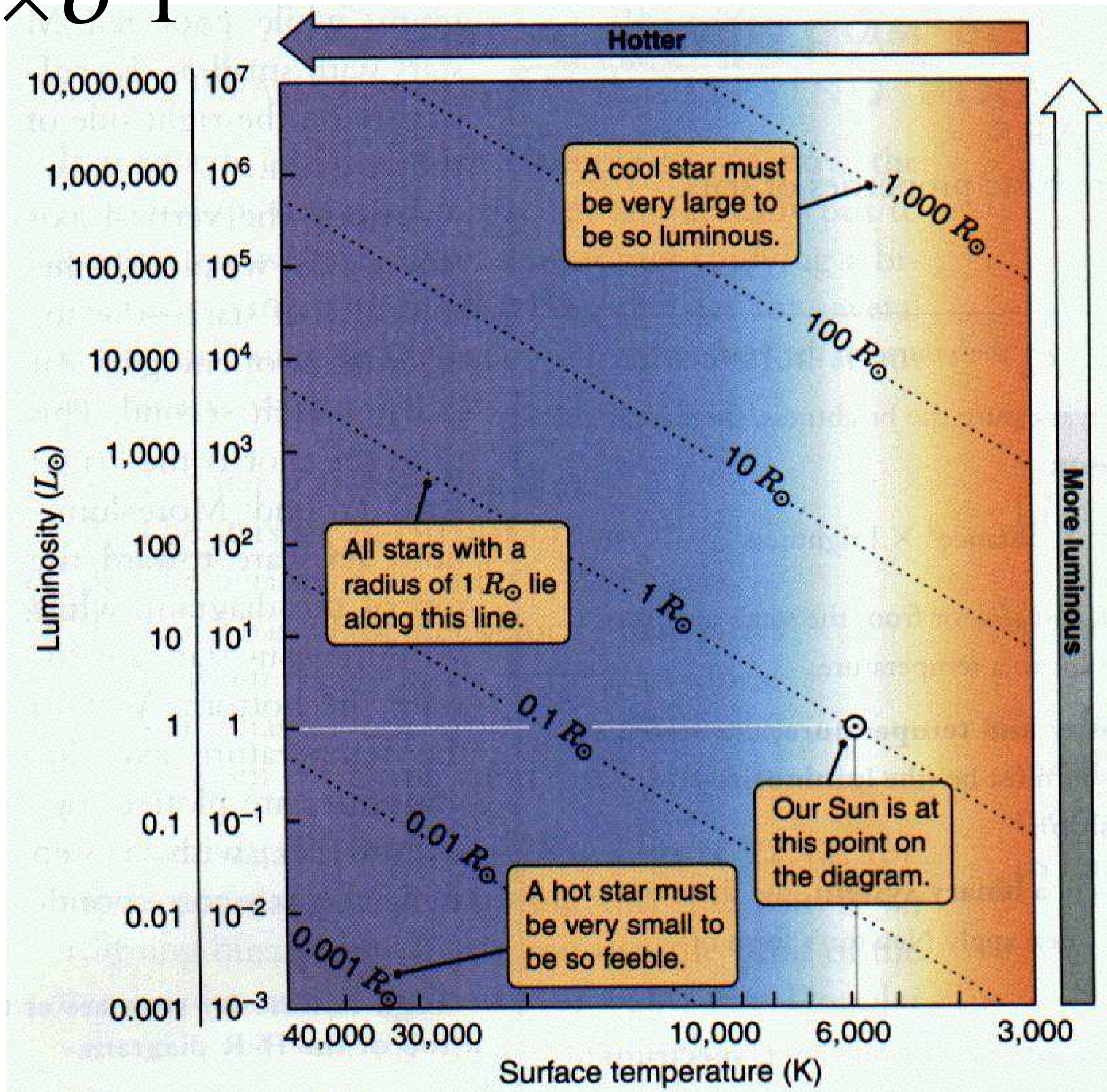
Figure 12.15 (a) *An H-R diagram for 16,600 stars obtained by the* Hipparcos *satellite. Most of the stars lie in a band running from the upper left of the diagram toward the lower right called the main sequence. (Dot color represents number of stars.)* (b) *An H-R diagram for two different samples of stars. The red symbols show the H-R diagram for 46 stars that are especially close to the Sun. The blue symbols show the 97 brightest stars in the sky. Note that since these are observational H-R diagrams they are plotted against observed quantities,* b_B/b_V *color in* (a) *and spectral type in* (b).

Comparacion de Flujo emitido



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

RADIOS



MASAS

$$\frac{A_1}{A_2} = \frac{V_1}{V_2} = \frac{m_2}{m_1}$$

$$m_1 + m_2 = \frac{(A_1 + A_2)^3}{P^2}$$

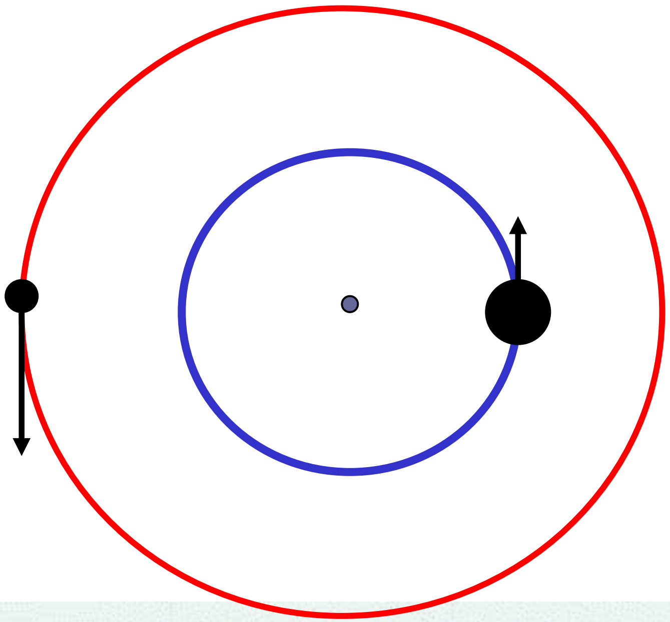
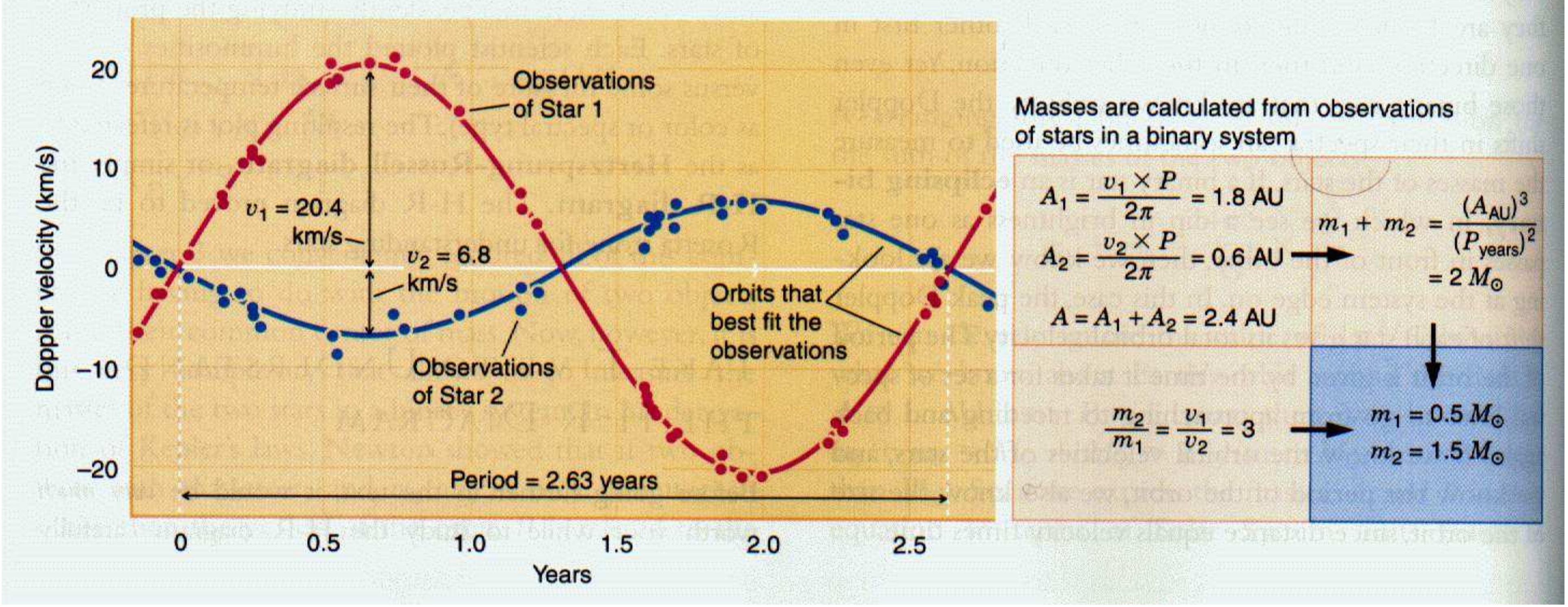


Figure 12.13 *Doppler velocities of the stars in an eclipsing binary are used to measure the masses of the stars.*

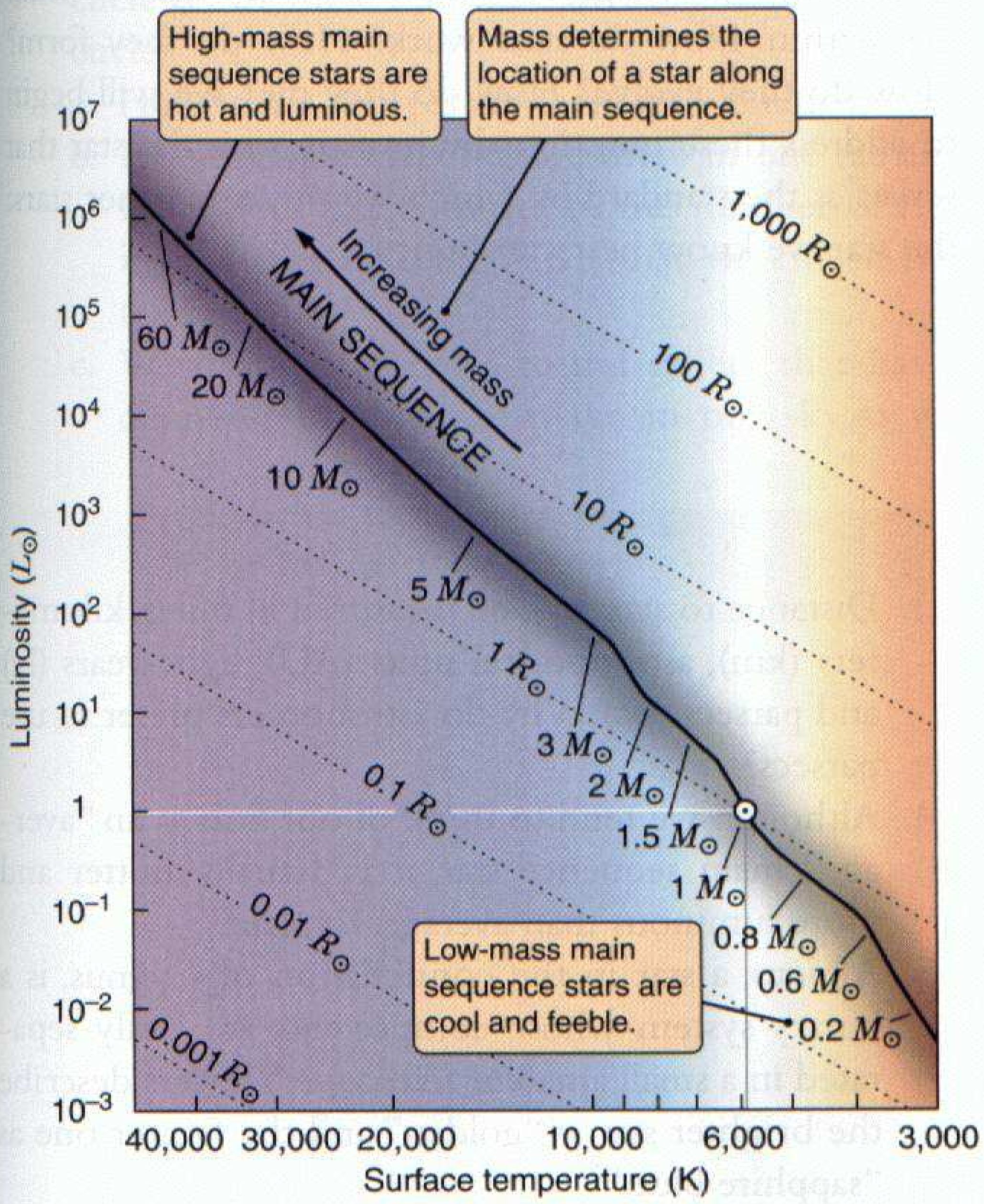


SECUENCIA PRINCIPAL

=

SECUENCIA DE MASAS

Figure 12.17 *The main sequence of the H-R diagram is a sequence of masses.*



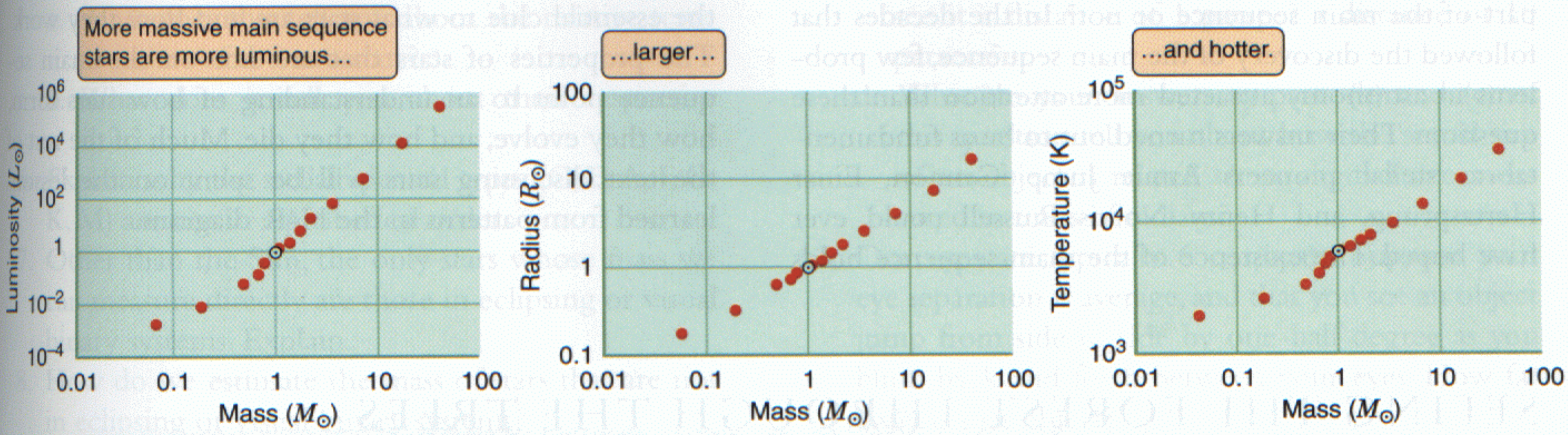


Figure 12.16 *Plots of luminosity, radius, and temperature versus mass for stars along the main sequence. The mass (and chemical composition) of a main sequence star determines all of its other properties.*

ESPECTROS

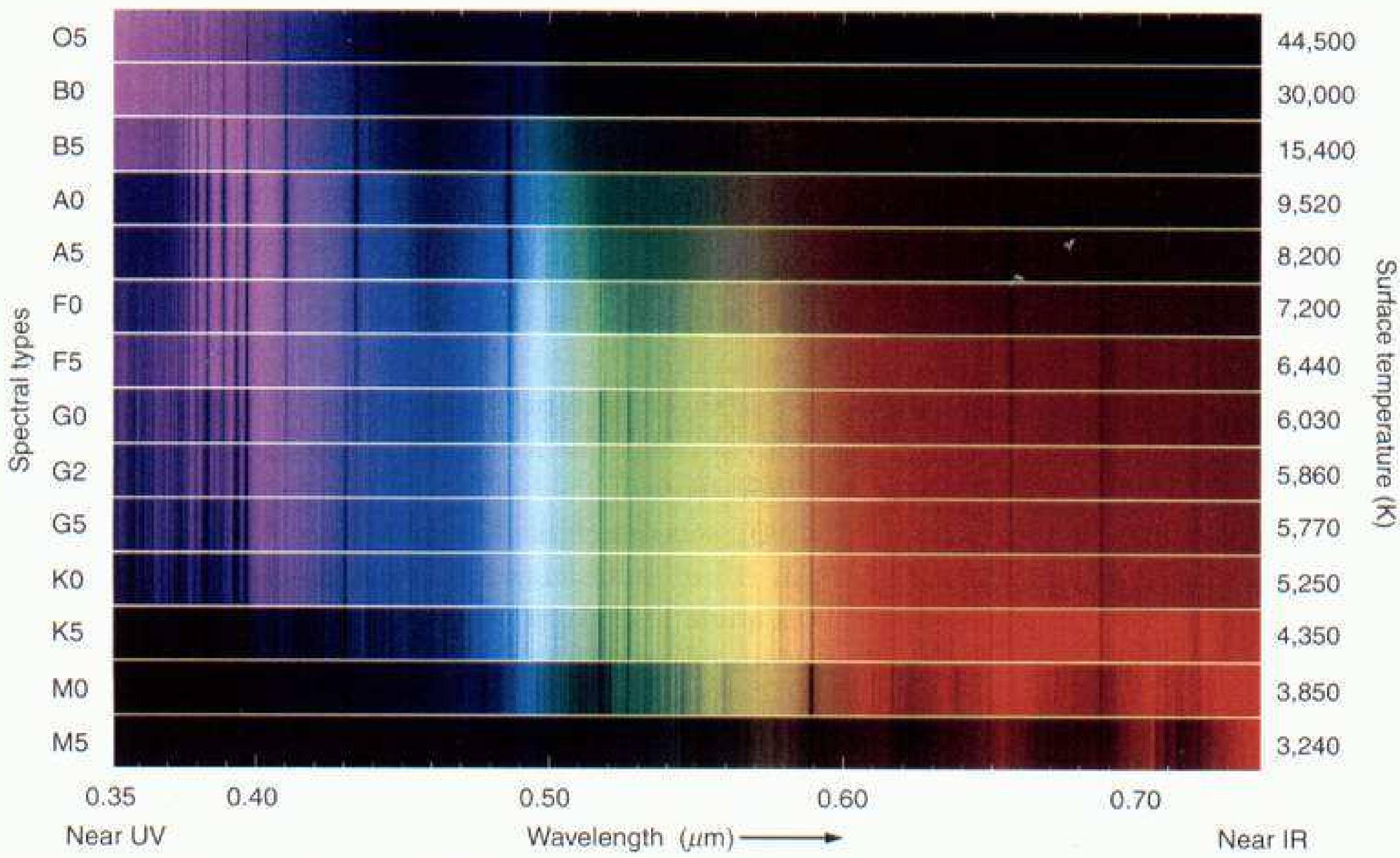


Figure 12.9 *Spectra of stars with different spectral types, ranging from hot blue O stars to cool red M stars. Hotter stars are brighter at shorter wavelengths. The dark lines are absorption lines.*

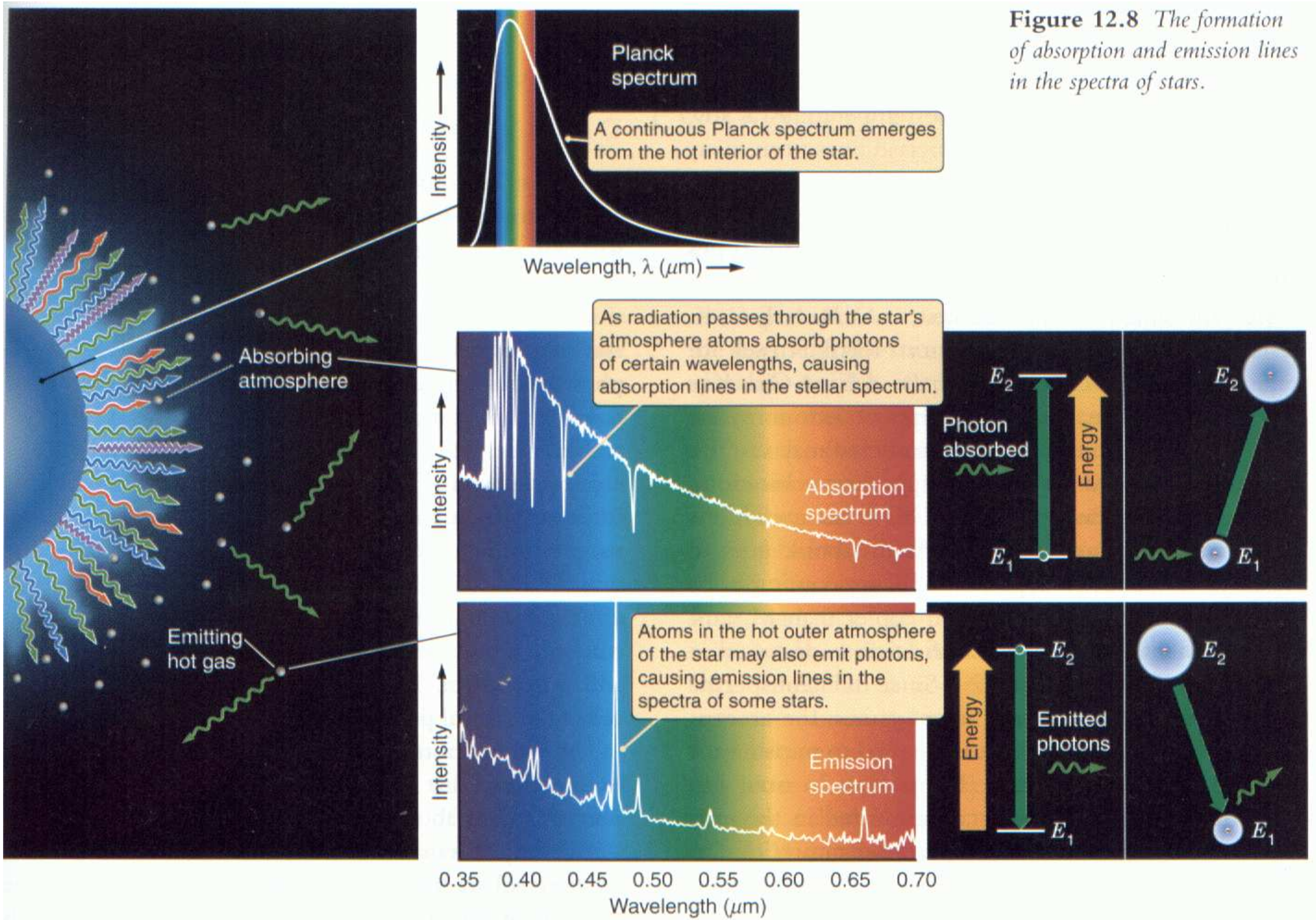


Figure 12.8 *The formation of absorption and emission lines in the spectra of stars.*

CLASIFICACION ESPECTRAL

- Lineas presentes, ausentes, fuertes, debiles: Harvard (OBAFGKM)
- Perfil de las lineas: Yerkes (clases de luminosidad, I, II, III,IV,V)

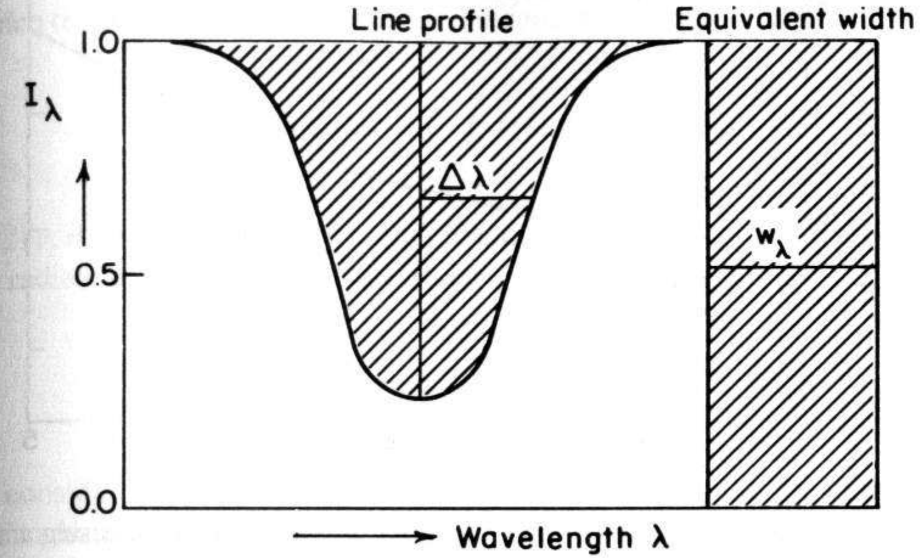
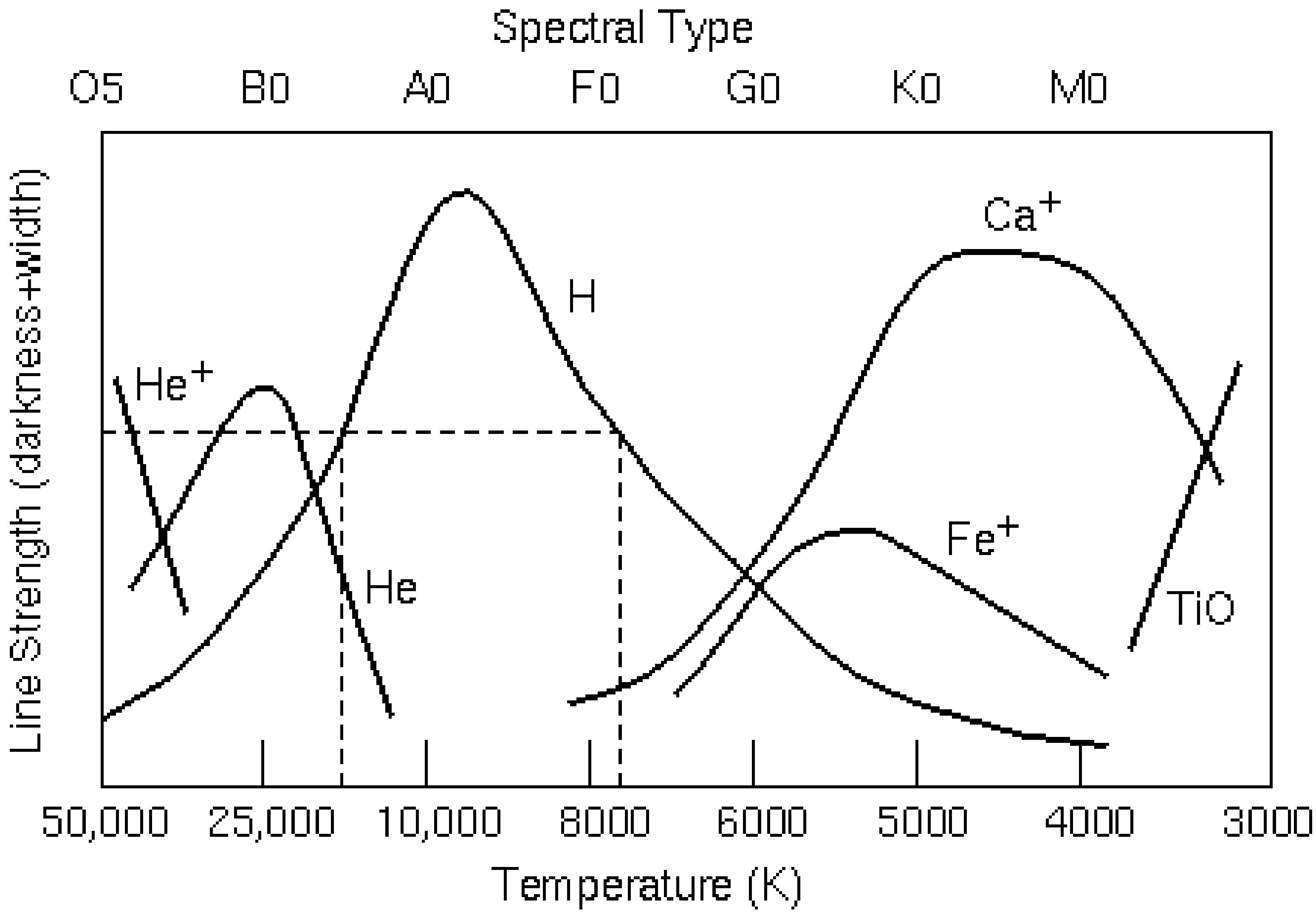


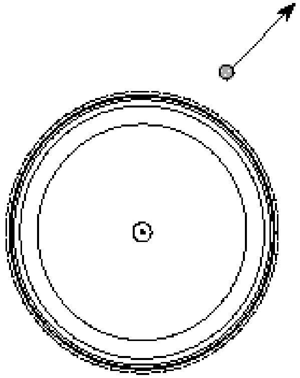
FIGURE 7.13. Profile and equivalent width W_λ of a Fraunhofer line. The intensity of the continuum has been made equal to 1. The area under the line profile is equal to that of a completely "black" strip in the spectrum of width W_λ, usually measured in milliangstroms (after A. Unsöld (Un69)).

COMPOSICION QUIMICA

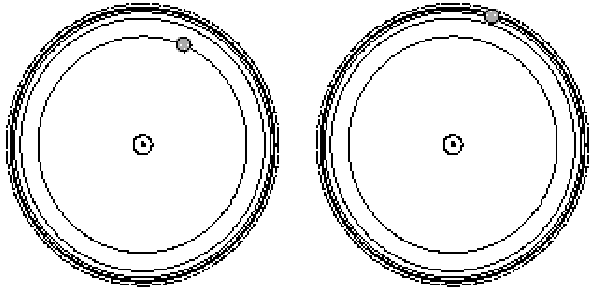
- X=fraccion de H
- Y=fraccion de He
- Z=el resto "metales"



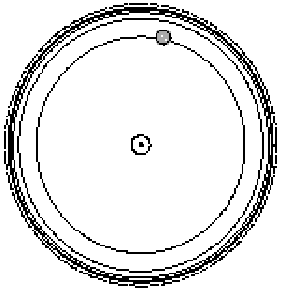
Cross-referencing different line strengths narrows the possible temperature range. A given strength for the Hydrogen line could mean two possible temperatures (hot or warm). If Helium line is present, then the choice is the hot temperature. If the ionized Calcium line is present (and Helium not present), then the choice is the warm temperature.



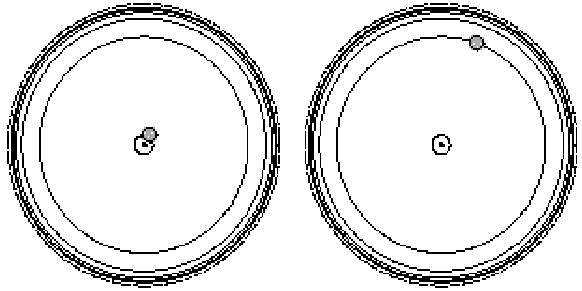
Ultra-hot **O-type** star: electron not bound to atom: no H lines



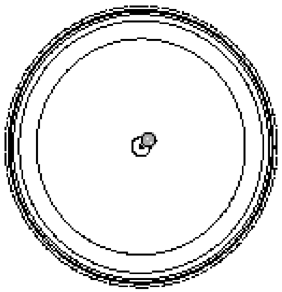
Very hot **B-type** star: some H atoms have electron in prime **2nd energy level**, other atoms have electron in *higher* energy levels: detectable H lines



Hot **A-type** star: most H atoms have electron in prime **2nd energy level**: very strong, dark H lines.



warm **F & G-type** star: some H atoms have electron in prime **2nd energy level**, other atoms have electron in *ground state*: detectable H lines



Cool **K & M-type** star: electron is stuck in *ground state* : no H lines.

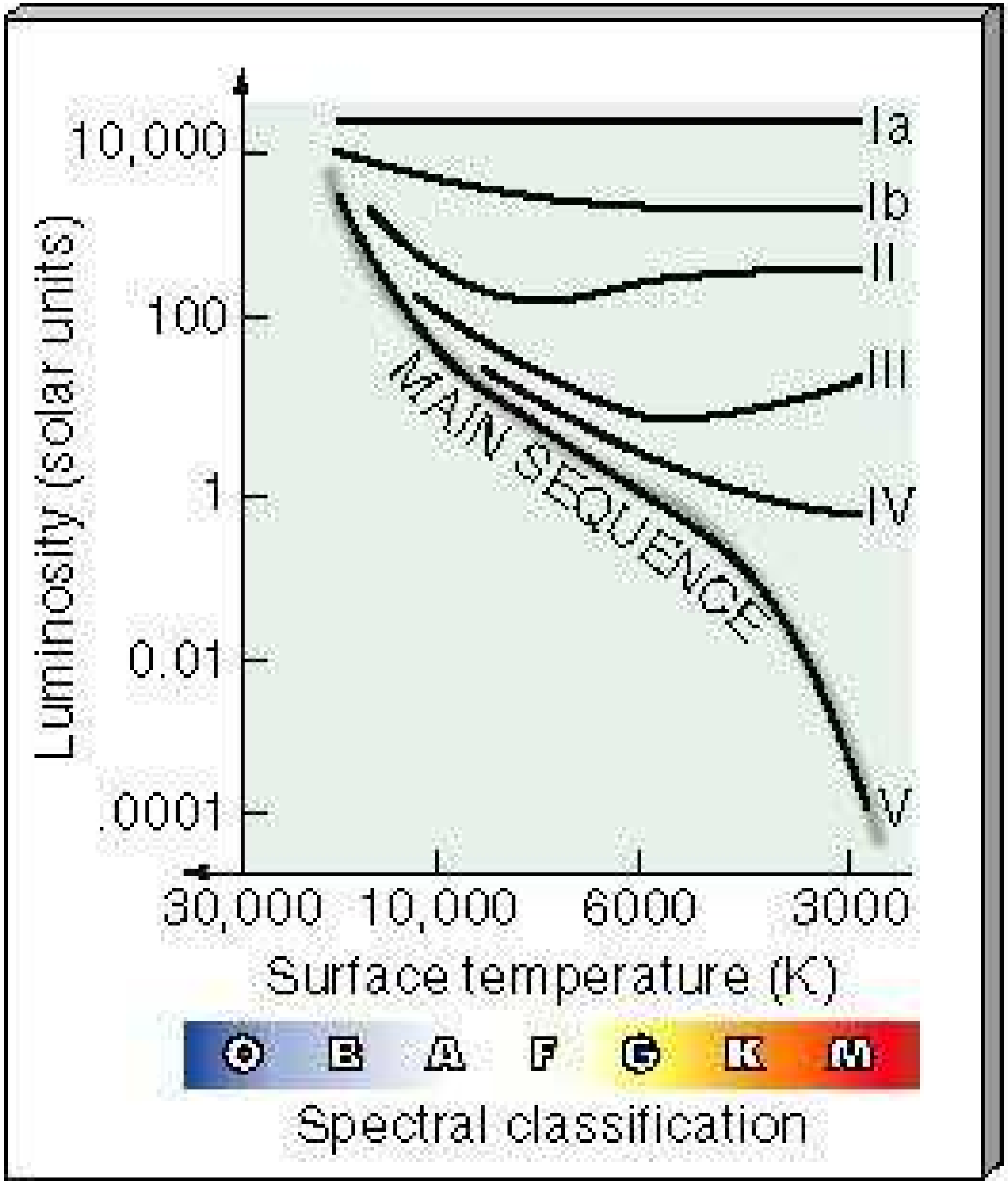
To produce strong, dark hydrogen absorption lines in the **visible band**, the electron must be in the **2nd energy level**. Most stars are too hot or too cool to have atoms in the proper setup so they have weak, light hydrogen lines.

Other elements behave in the same way: star needs to have just the right temperature to produce dark lines of the other elements.

Type	Main Characteristics	Subtypes	Spectral Criteria
Q	Nova: sudden brightness increase by 10 to 12 magnitudes		
P	Planetary nebula: hot star with intensely ionized gas envelope		
W	Wolf-Rayet stars: hot stars		Broad emission of OIII to OVI, NIII to NV, CII to CIV, and HeI and HeII.
O	Hot stars, continuum strong in UV (O5 to O9)		OII λ 4650 dominates
			HeII λ 4686 dominates } emission lines
			Lines narrower } emission lines
			Absorption lines dominate; only HeII, CII in emission
			SiIV λ4089 at maximum
			OII λ 4649, HeII λ 4686 strong
B	Neutral helium dominates	B0	CIII/4650 at maximum
		B1	HeI λ 4472 > OII λ 4649
		B2	HeI lines are maximum
		B3	HeII lines are disappearing
		B5	Si λ 4128 > He λ 4121
		B8	λ 4472 = Mg λ 4481
		B9	HeI λ 4026 just visible

A	Hydrogen lines decreasing from maximum at A0	A0	Balmer lines at maximum
		A2	CaII K = 0.4 Hδ
		A3	K = 0.8 Hδ
		A5	K > Hδ
F	Metallic lines becoming noticeable	F0	K = H + Hδ
		F2	G band becoming noticeable
		F5	G band becoming continuous
		F8	Balmer lines slightly stronger than in Sun
G	Solar-type spectra	G0	Ca λ 4227 = Hδ
		G5	Fe λ4325 > Hγ on small-scale plates
K	Metallic lines dominate	K0	H and K at maximum strength
		K2	Continuum becoming weak in blue
		K5	G band no longer continuous
M	TiO bands		TiO bands noticeable
			Bands conspicuous
			Spectrum fluted by the strong bands
			Mira variables, Hγ, Hδ
R, N	CN, CO, C_2 bands		CN, CO, C_2 bands appear instead of TiO.
			R stars show pronounced H and K lines.
S	ZrO bands		ZrO bands

Clases de luminosidad



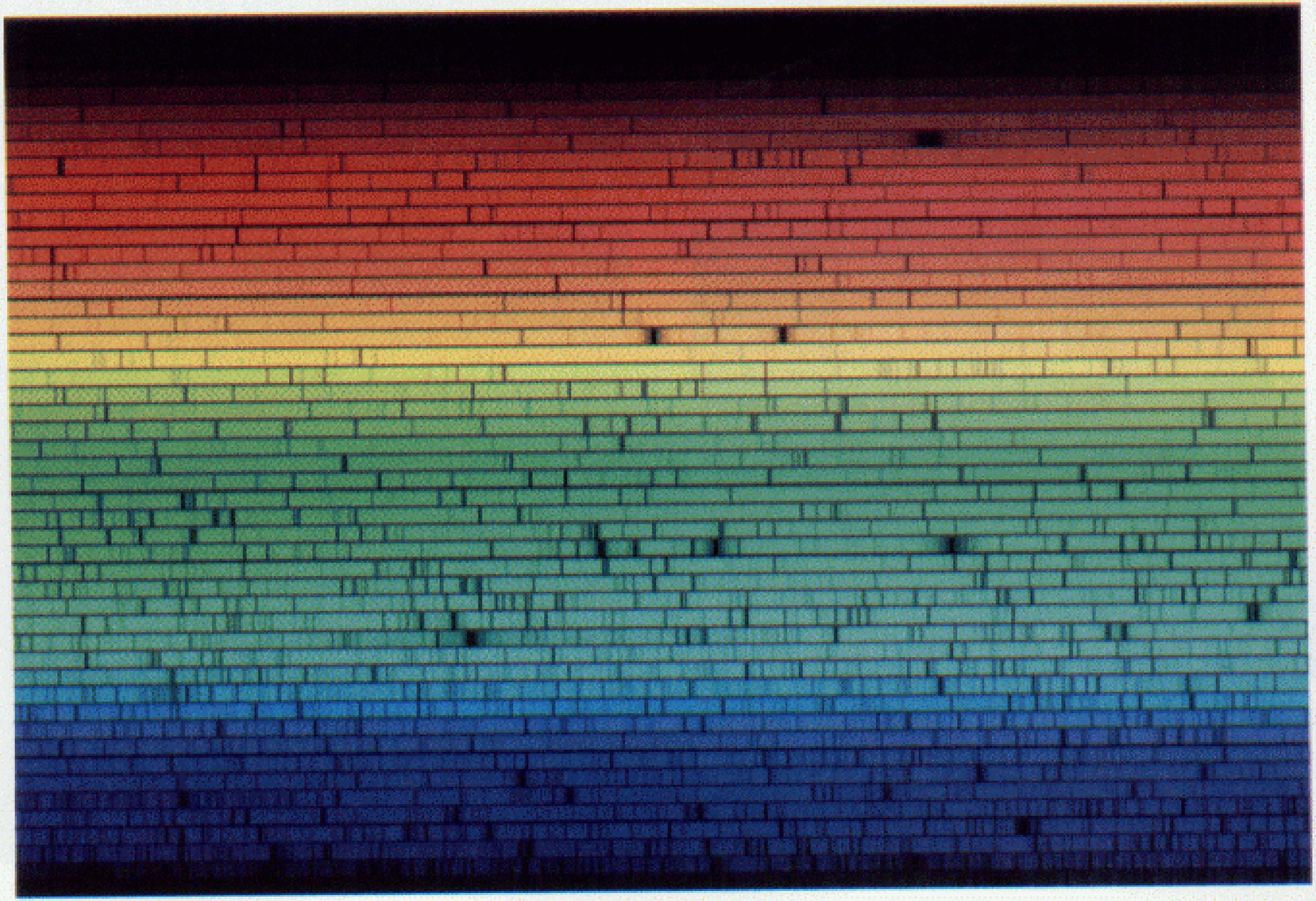
Cuando tenemos materia embebida en radiacion podemos definir:

- Temperatura efectiva (L,R)
- Temperatura de color (UBV)
- Temperatura cinetica (vel)
- Temperatura de excitación (lineas)

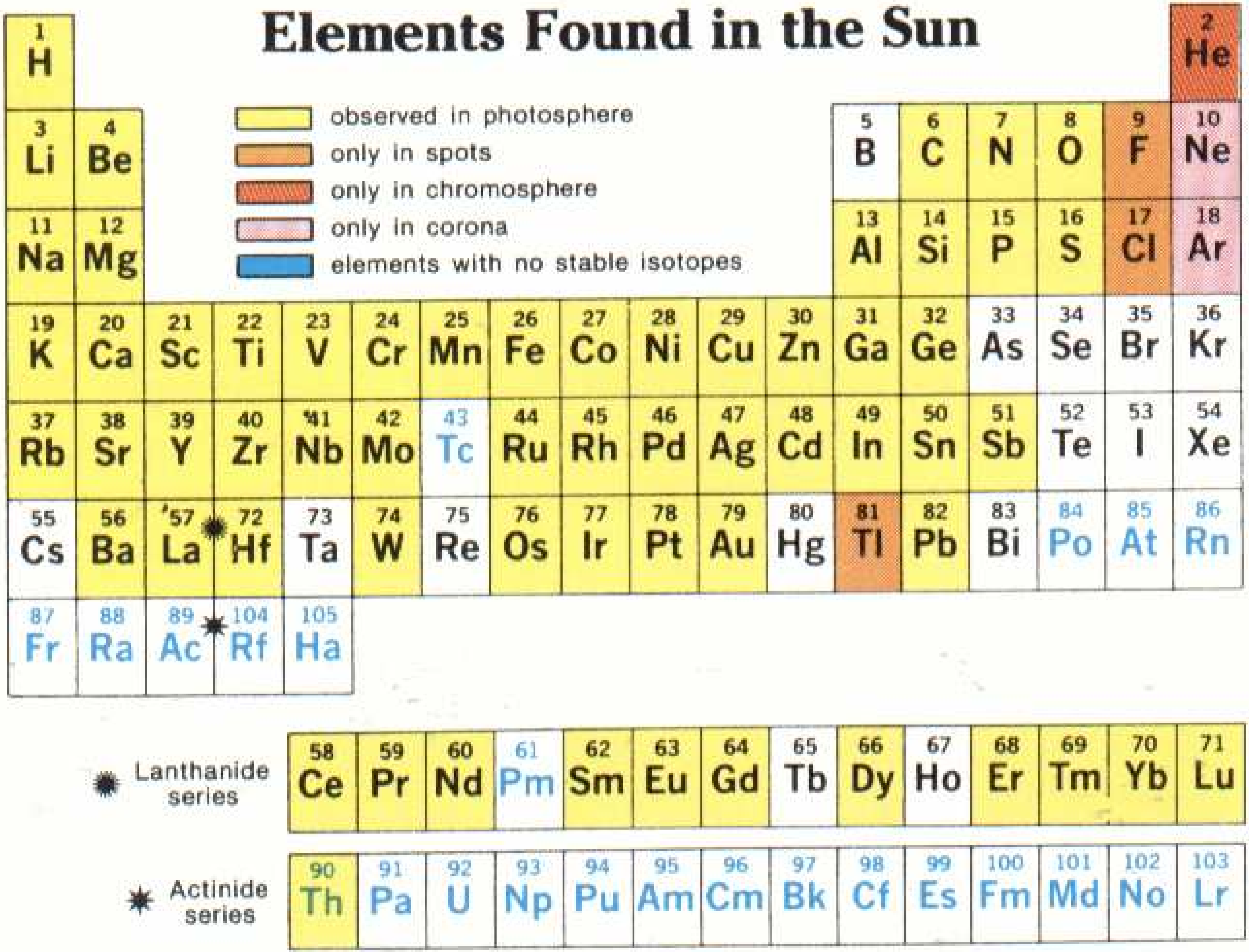
- Equilibrio termodinamico (equilibrio fotones-materia)
- OPACIDAD

Ejemplo: atmosfera terrestre invadida por radiacion solar e IR terrestre.

Figure 13.12 *A high resolution spectrum of the Sun, stretching from 0.4 μm* (lower left corner) *to 0.7 μm* (upper right corner), *showing a wealth of absorption lines.*



Elements Found in the Sun



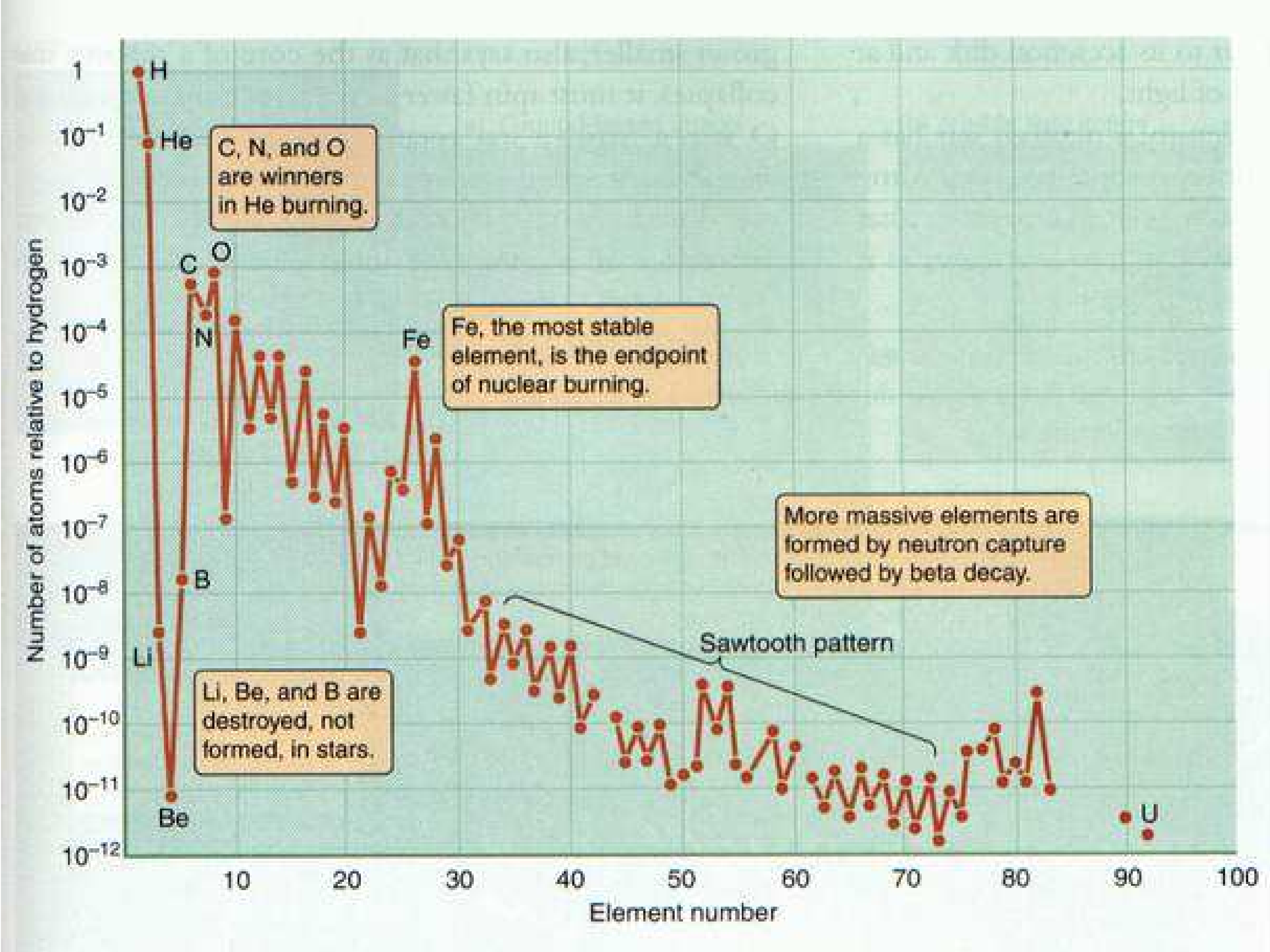


Figure 16.12 *The relative abundances of different elements on Earth are plotted against the mass of the nucleus. This pattern can be understood as a result of the process of nucleosynthesis in stars.*

[redacted]

¿Por qué?