Comision de Seguimiento de CTE, abril 2005.

ASTROFISICA

ESTELAR

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Temas a desarrollar:

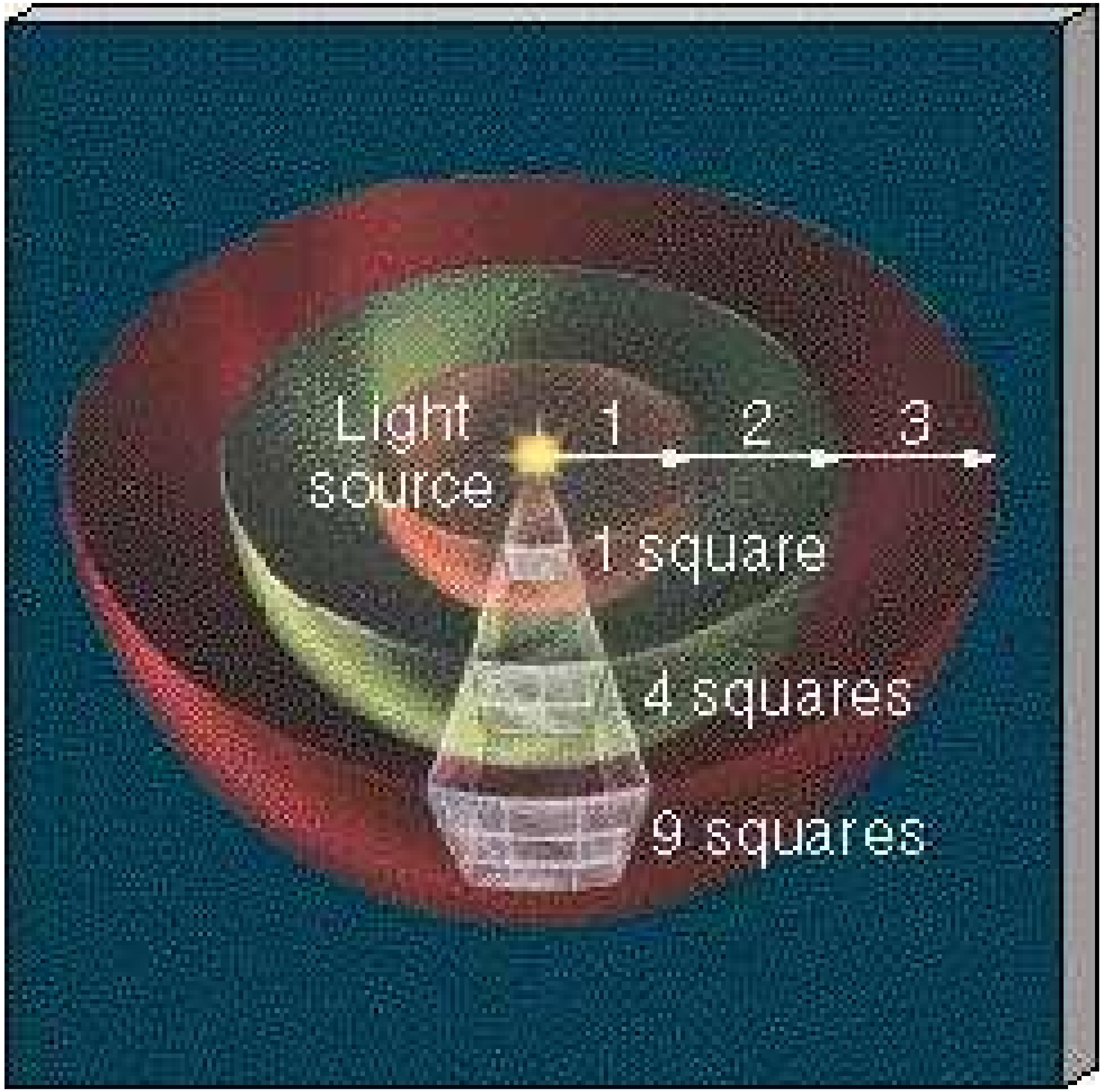
- Distancia, Luminosidad, Temperatura, Radio, Masa
- Espectros, composición
- Estructura
- Energía
- Evolución
- Estados finales (objetos compactos)
- Medio interestelar y origen de las estrellas

Métodos para determinar las propiedades 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

LUMINOSIDAD

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



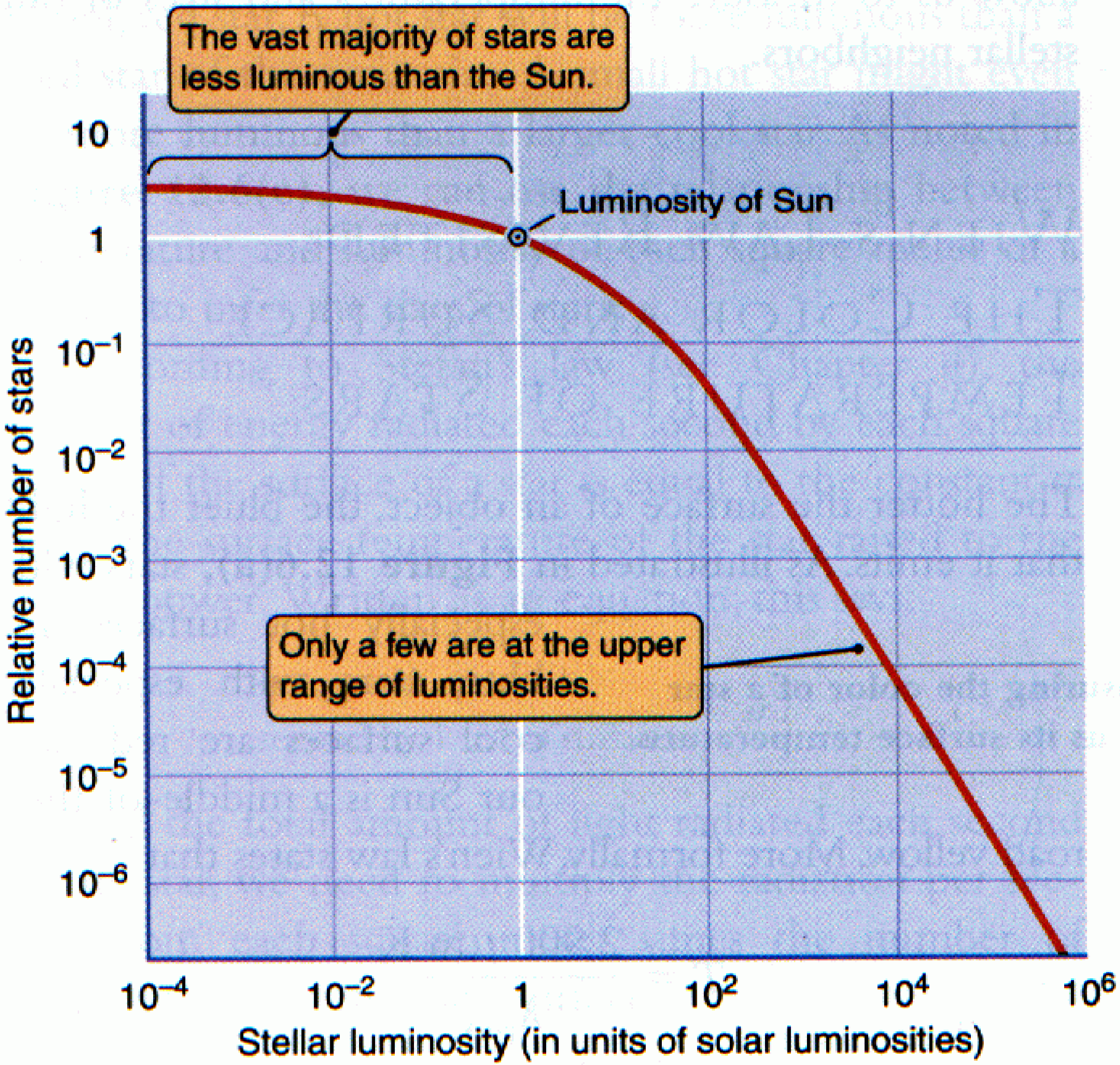


Figure 12.5 *The distribution of luminosities of known stars within 1,000 pc (3,260 ly) of Earth.*

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.*

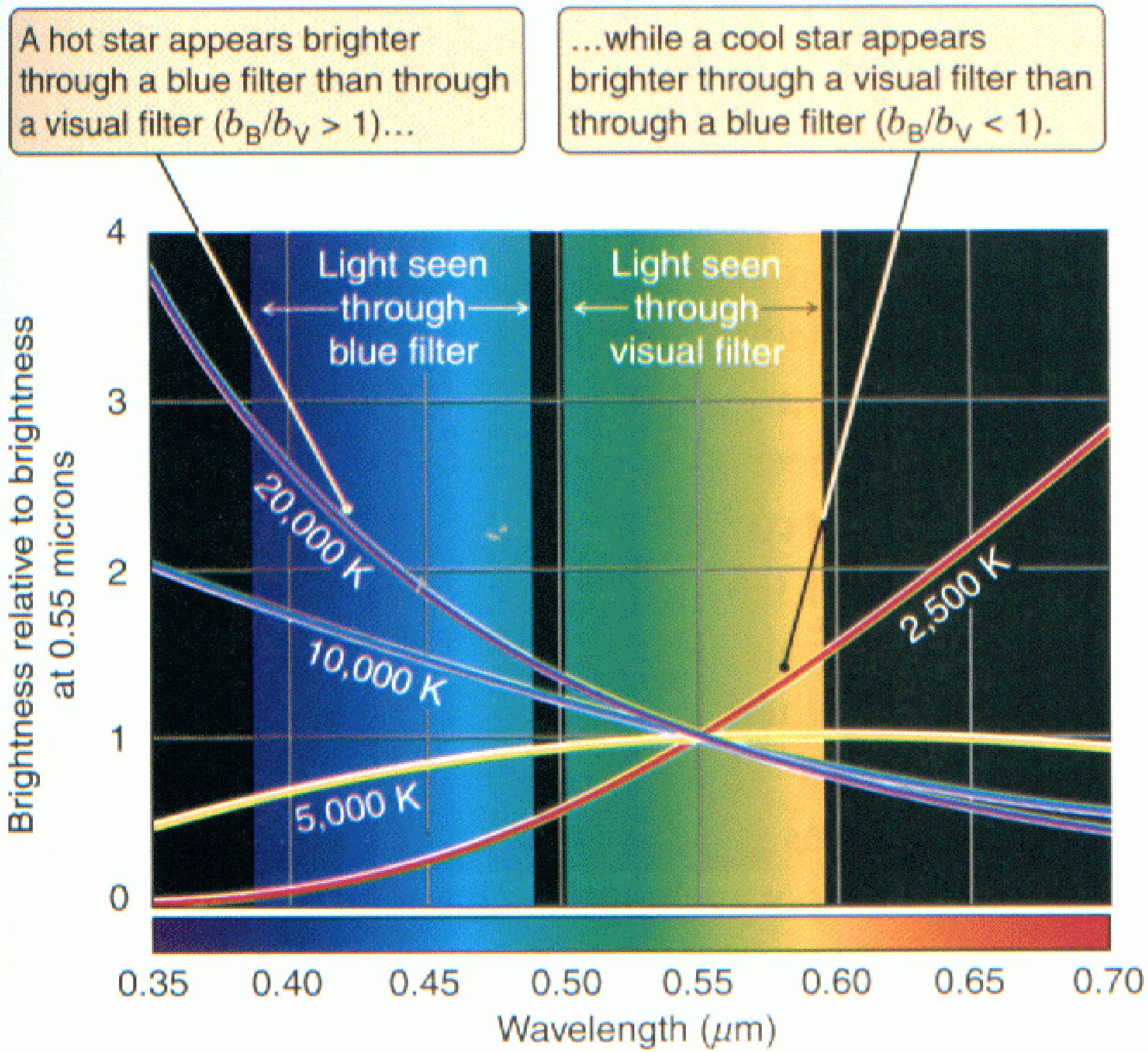


DIAGRAMA H-R

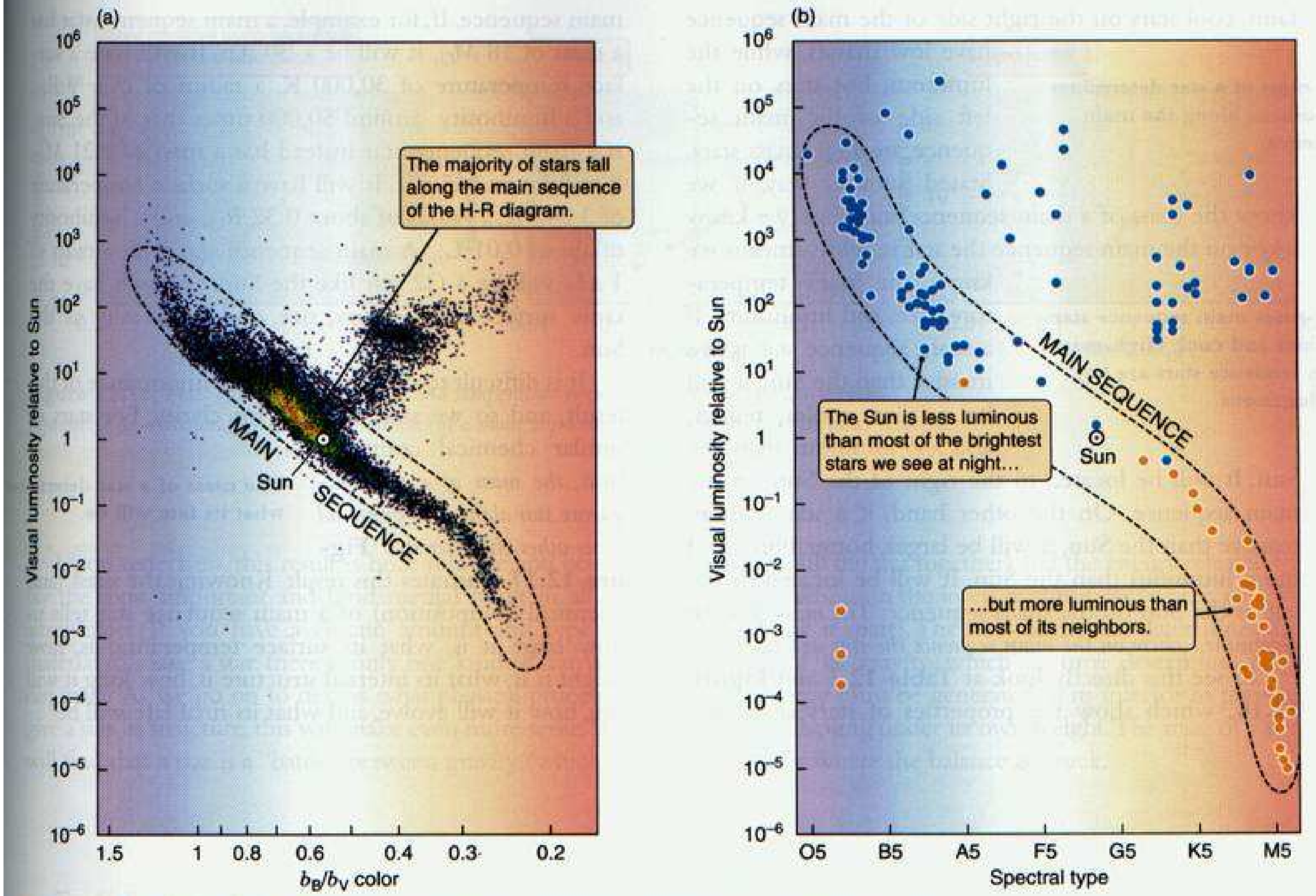
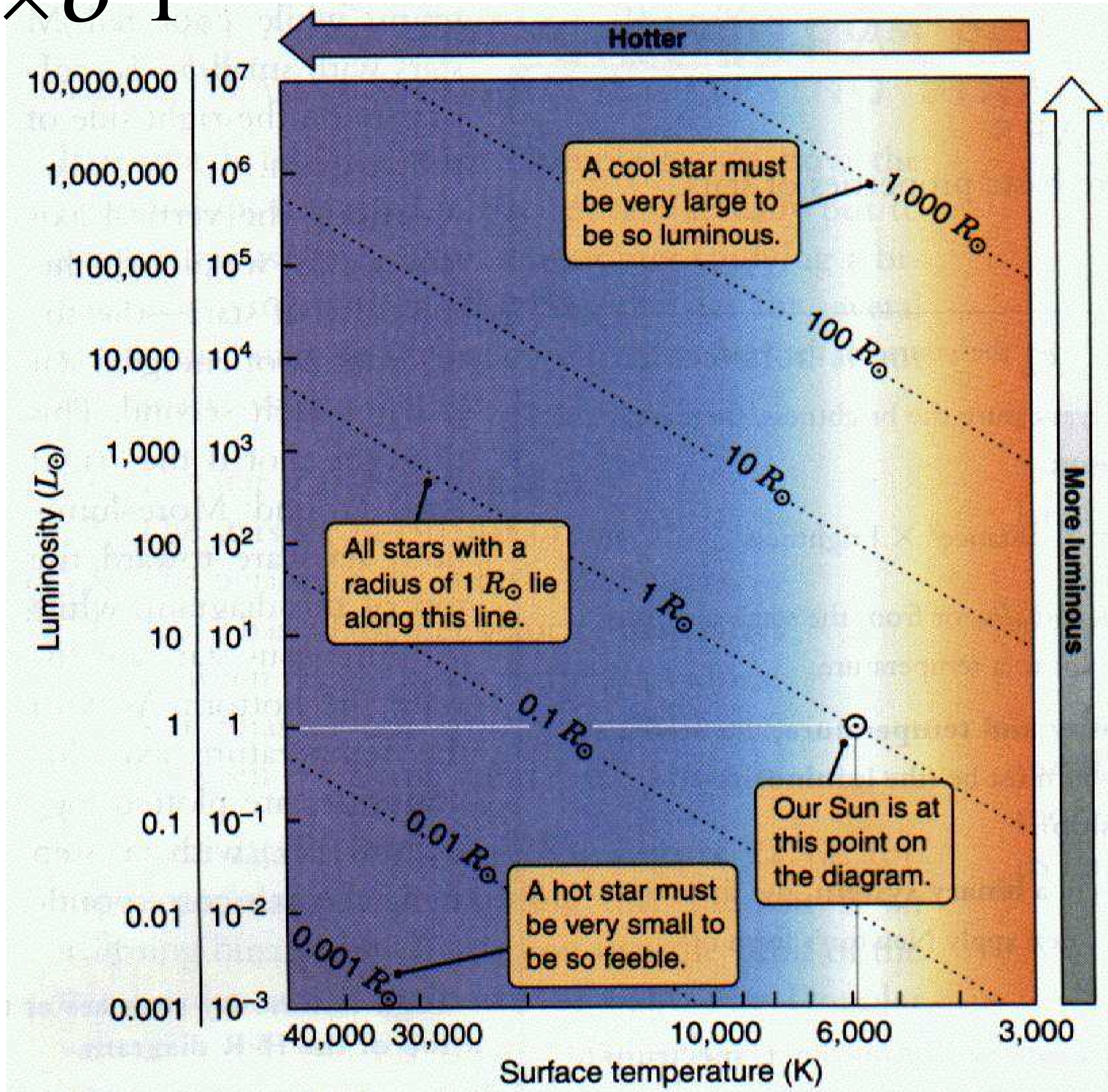


Figure 12.15 (a) *An H-R diagram for 16,600 stars obtained by the* Hipparcos *satellite. Most of the stars lie in a band running from the upper left of the diagram toward the lower right called the main sequence. (Dot color represents number of stars.)* (b) *An H-R diagram for two different samples of 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).

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

RADIOS



MASAS

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

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

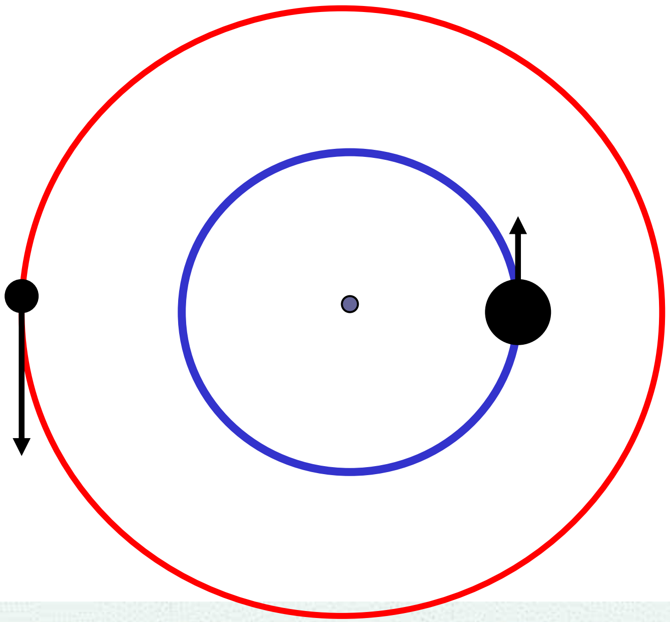
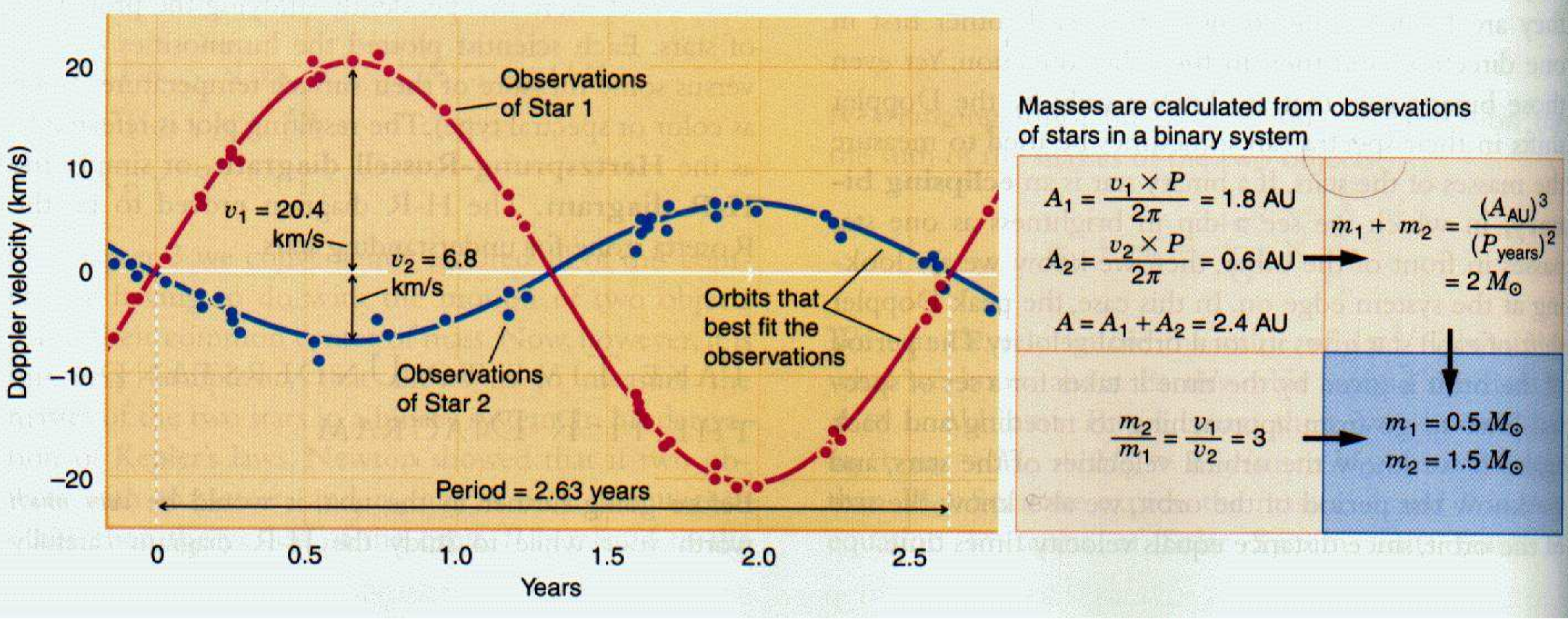


Figure 12.13 *Doppler velocities of the stars in an eclipsing binary are used to measure the masses of the stars.*



SECUENCIA PRINCIPAL

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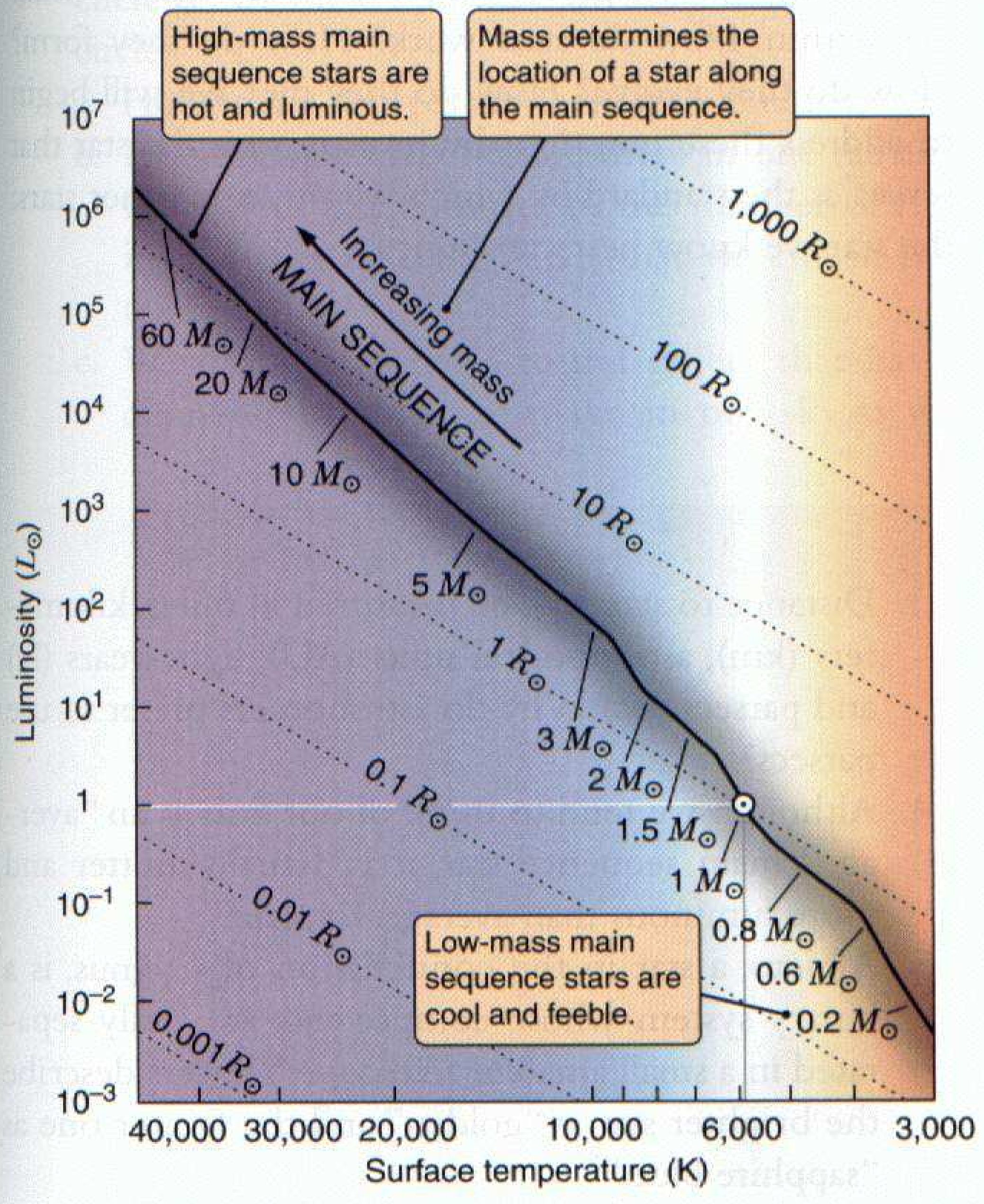
SECUENCIA DE MASAS

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



ESPECTROS

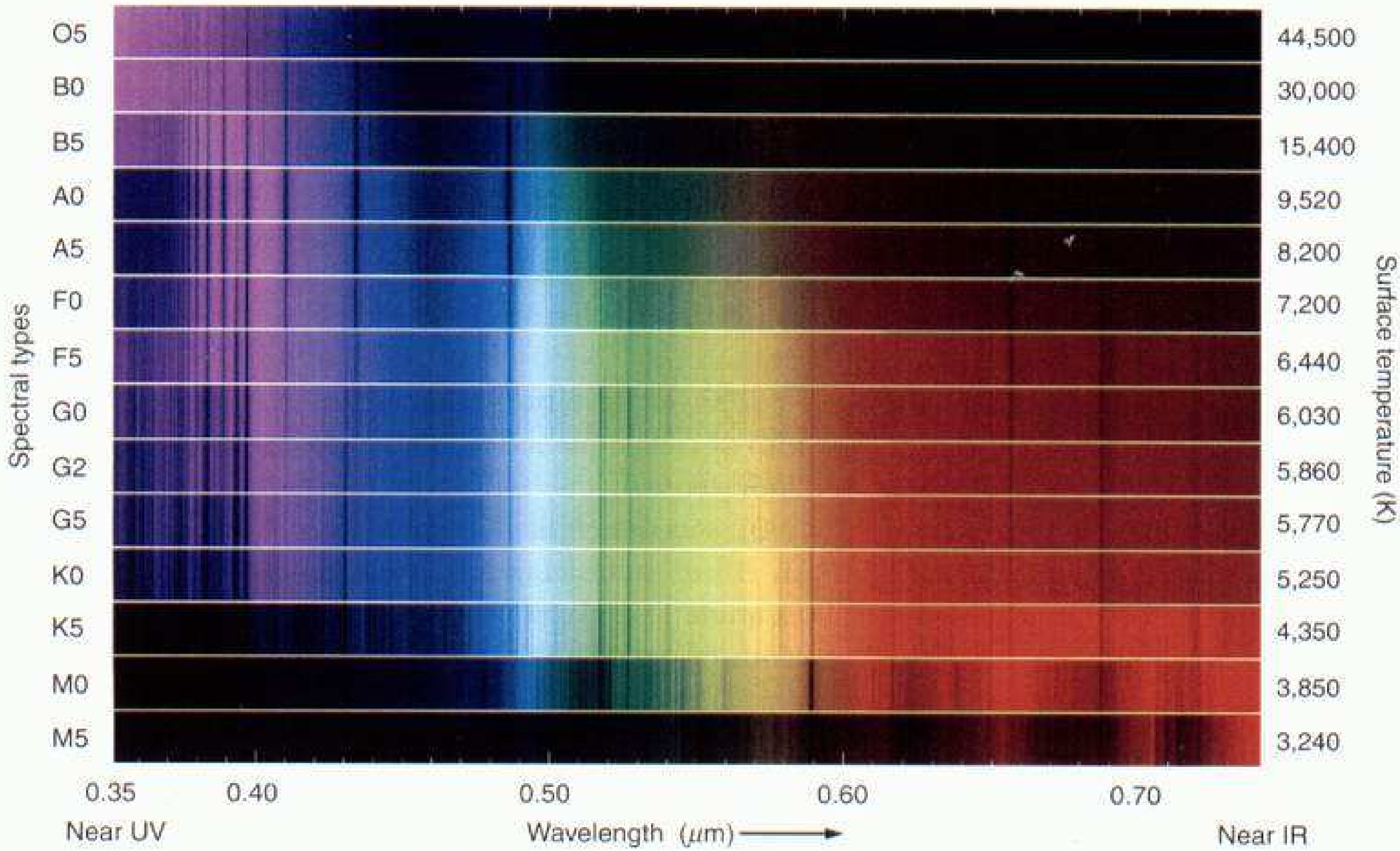


Figure 12.9 *Spectra of stars with different spectral types, ranging from hot blue O stars to cool red M stars. Hotter stars are brighter at shorter wavelengths. The dark lines are absorption lines.*

CLASIFICACION ESPECTRAL

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

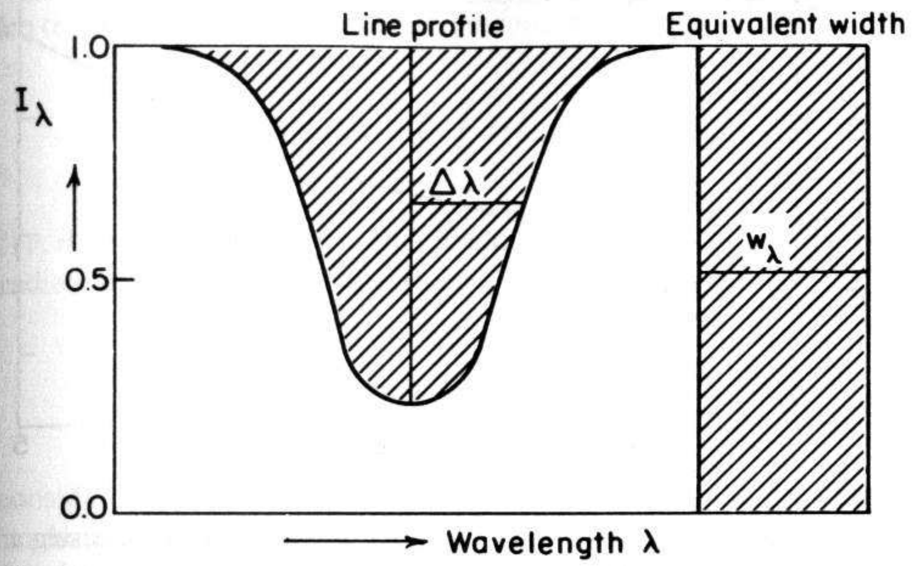
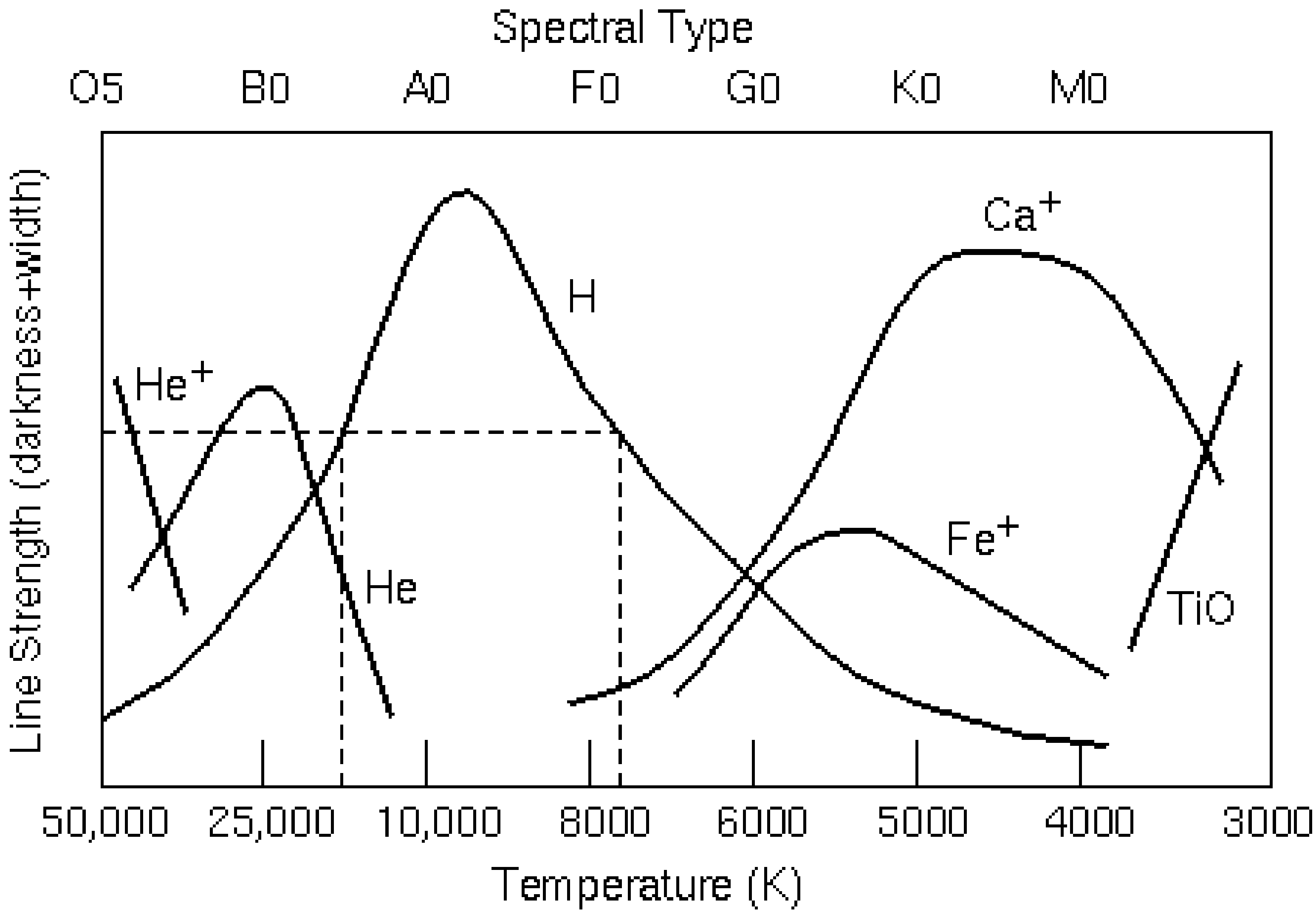


FIGURE 7.13. Profile and equivalent width W_λ of a Fraunhofer line. The intensity of the continuum has been made equal to 1. The area under the line profile is equal to that of a completely "black" strip in the spectrum of width W_λ, usually measured in milliangstroms (after A. Unsöld (Un69)).

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.

Cuando tenemos materia embebida en radiacion podemos definir:

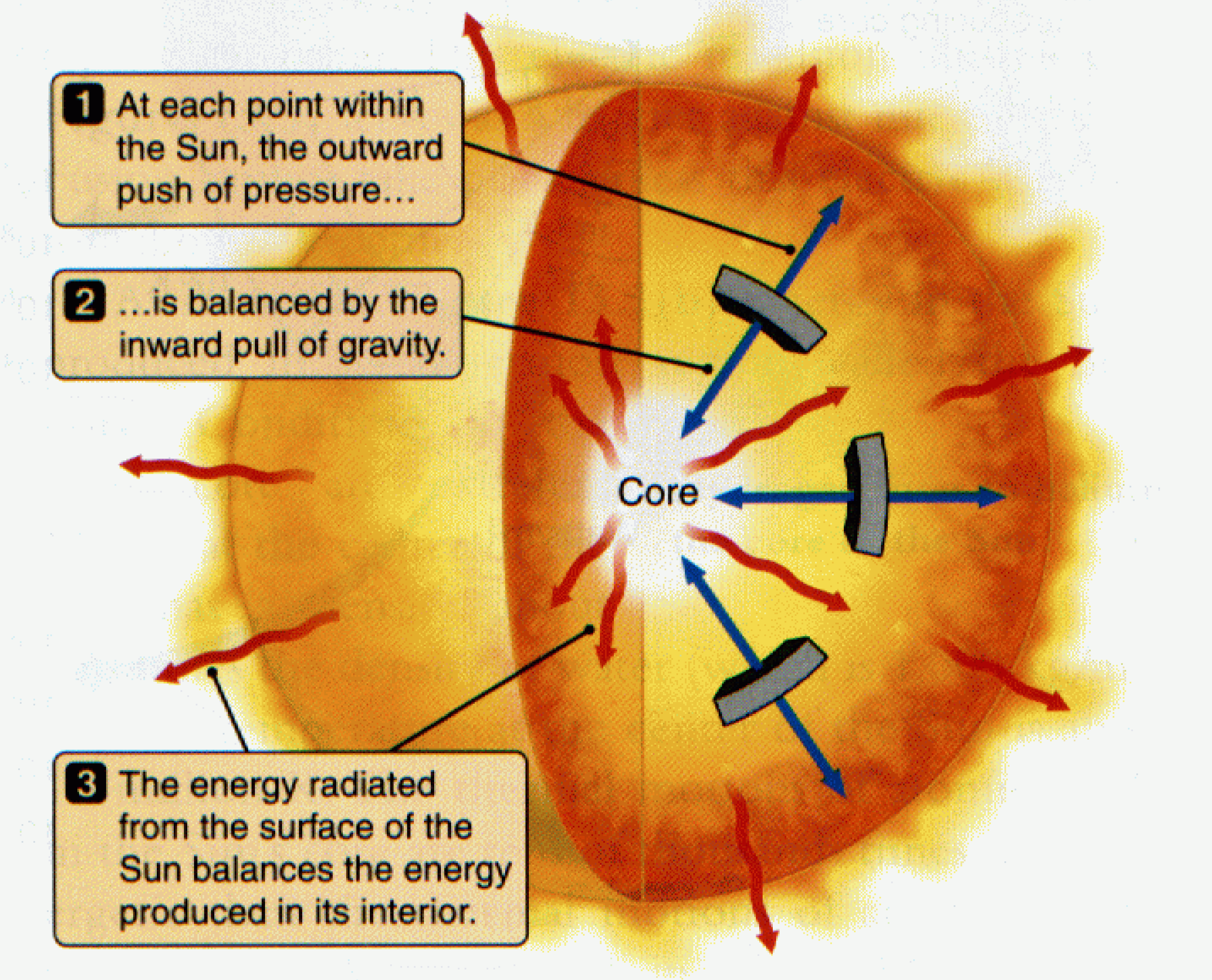
- •Temperatura efectiva (L,R)
- •Temperatura de color (UBV)
- •Temperatura cinetica (velocidad)
- •Temperatura de excitación (lineas)

- •Equilibrio termodinamico (equilibrio fotones-materia)
- •OPACIDAD

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

ESTRUCTURA

Figure 13.1 *The structure of the Sun is determined by balances between forces and in the outward flow of energy.*



$$P_{Centro} = G\frac{4}{3}\pi \times \rho^2 \times \frac{R^2}{2}$$

Quién soporta esta presion?

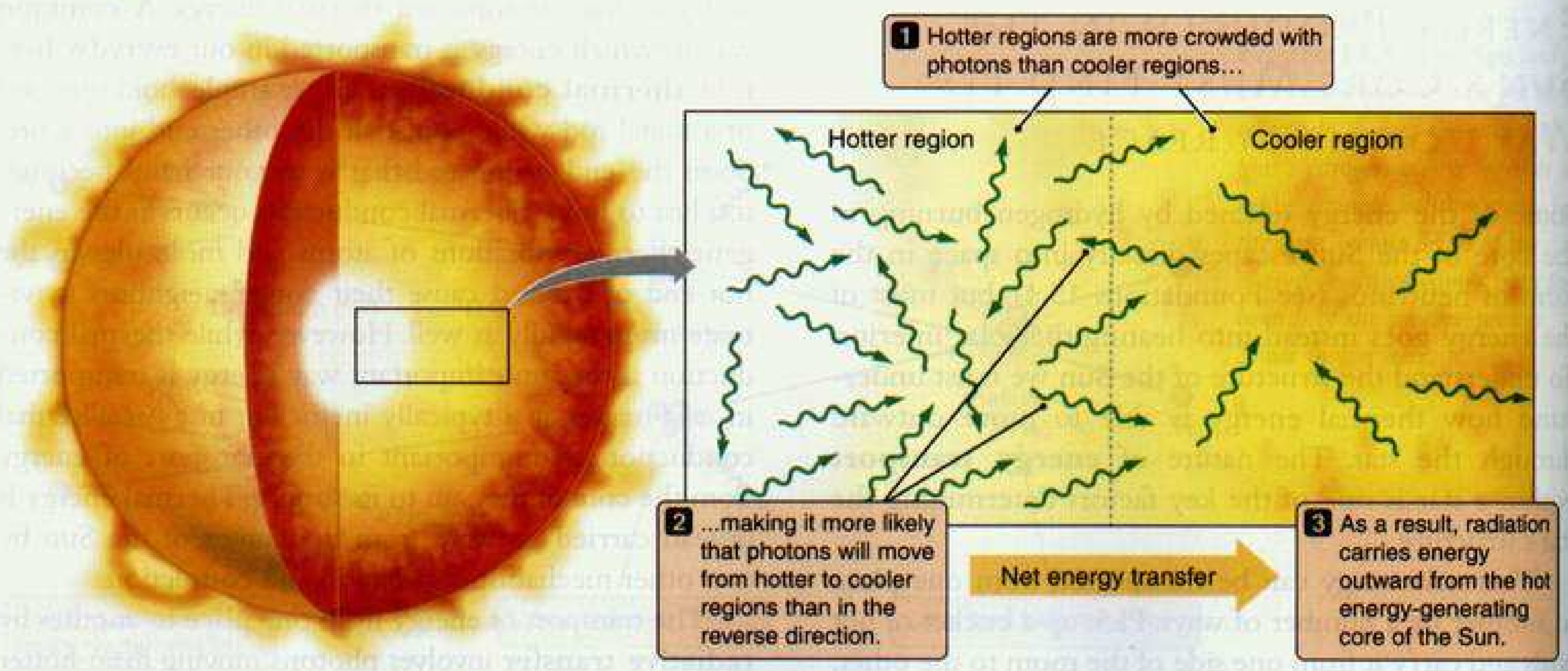
- Presion del gas (peso molecular medio)
- Presion de radiacion (fotones)
- Presion de gas degenerado (electrones)

Stellar theory[a]

Conservation of mass	$\frac{\mathrm{d}M_r}{\mathrm{d}r} = 4\pi\rho r^2$	(9.60)	r M_r ρ	radial distance mass interior to r mass density
Hydrostatic equilibrium	$\frac{\mathrm{d}p}{\mathrm{d}r} = \frac{-G\rho M_r}{r^2}$	(9.61)	p G	pressure constant of gravitation
Energy release	$\frac{\mathrm{d}L_r}{\mathrm{d}r} = 4\pi\rho r^2\epsilon$	(9.62)	L_r ϵ	luminosity interior to r power generated per unit mass
Radiative transport	$\frac{\mathrm{d}T}{\mathrm{d}r} = \frac{-3}{16\sigma}\frac{\langle\kappa\rangle\rho}{T^3}\frac{L_r}{4\pi r^2}$	(9.63)	T σ $\langle\kappa\rangle$	temperature Stefan–Boltzmann constant mean opacity
Convective transport	$\frac{\mathrm{d}T}{\mathrm{d}r} = \frac{\gamma-1}{\gamma}\frac{T}{p}\frac{\mathrm{d}p}{\mathrm{d}r}$	(9.64)	γ	ratio of heat capacities, c_p/c_V

[a]For stars in static equilibrium with adiabatic convection. Note that ρ is a function of r. κ and ϵ are functions of temperature and composition.

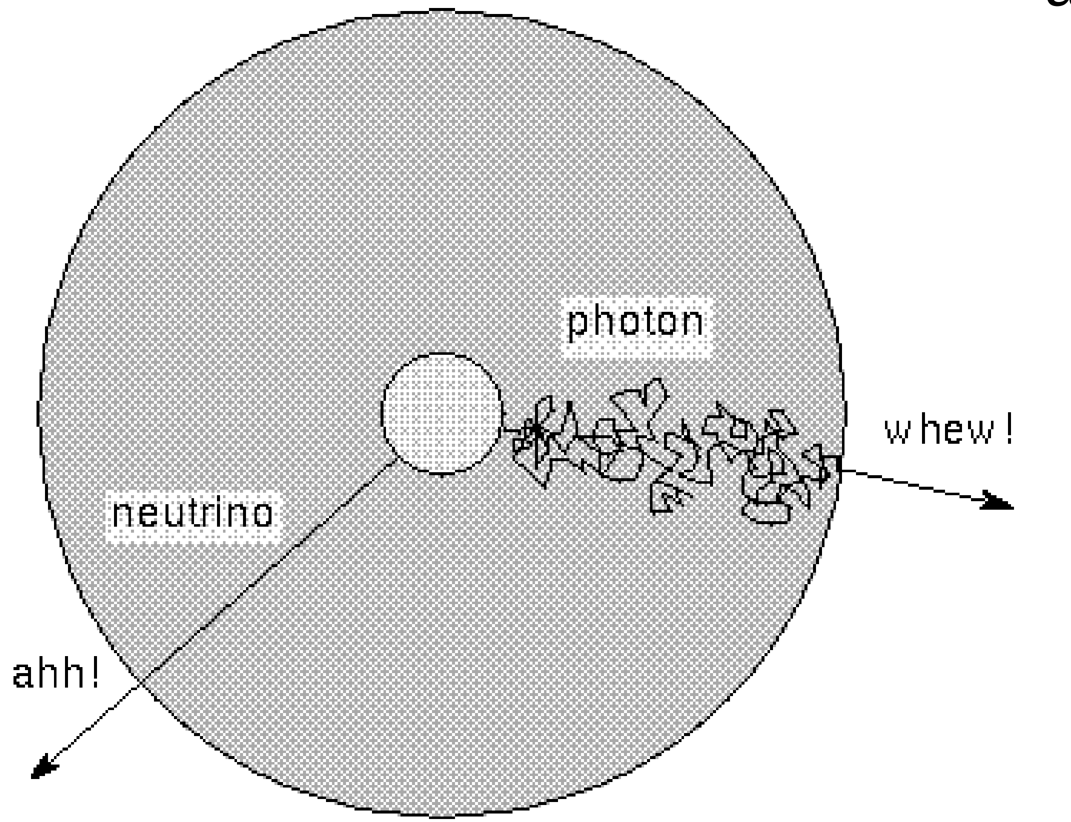
Figure 13.5 *Higher-temperature regions deep within the Sun produce more radiation than lower-temperature regions farther out. While radiation flows in both directions, more radiation flows from the hot regions to the cooler regions than from the cooler regions to the hot regions. In this way, radiation carries energy outward from the inner parts of the Sun.*



transformacion gamma - visible

$$CLM = \frac{1}{\kappa\rho} = \frac{1}{\alpha}$$

La OPACIDAD del medio es una medida de la dificultad que experimenta la radiacion (fotones) en atravesarlo



Photons take tortuous paths out of the Sun's interior.
Neutrinos pass right on through in just two seconds.

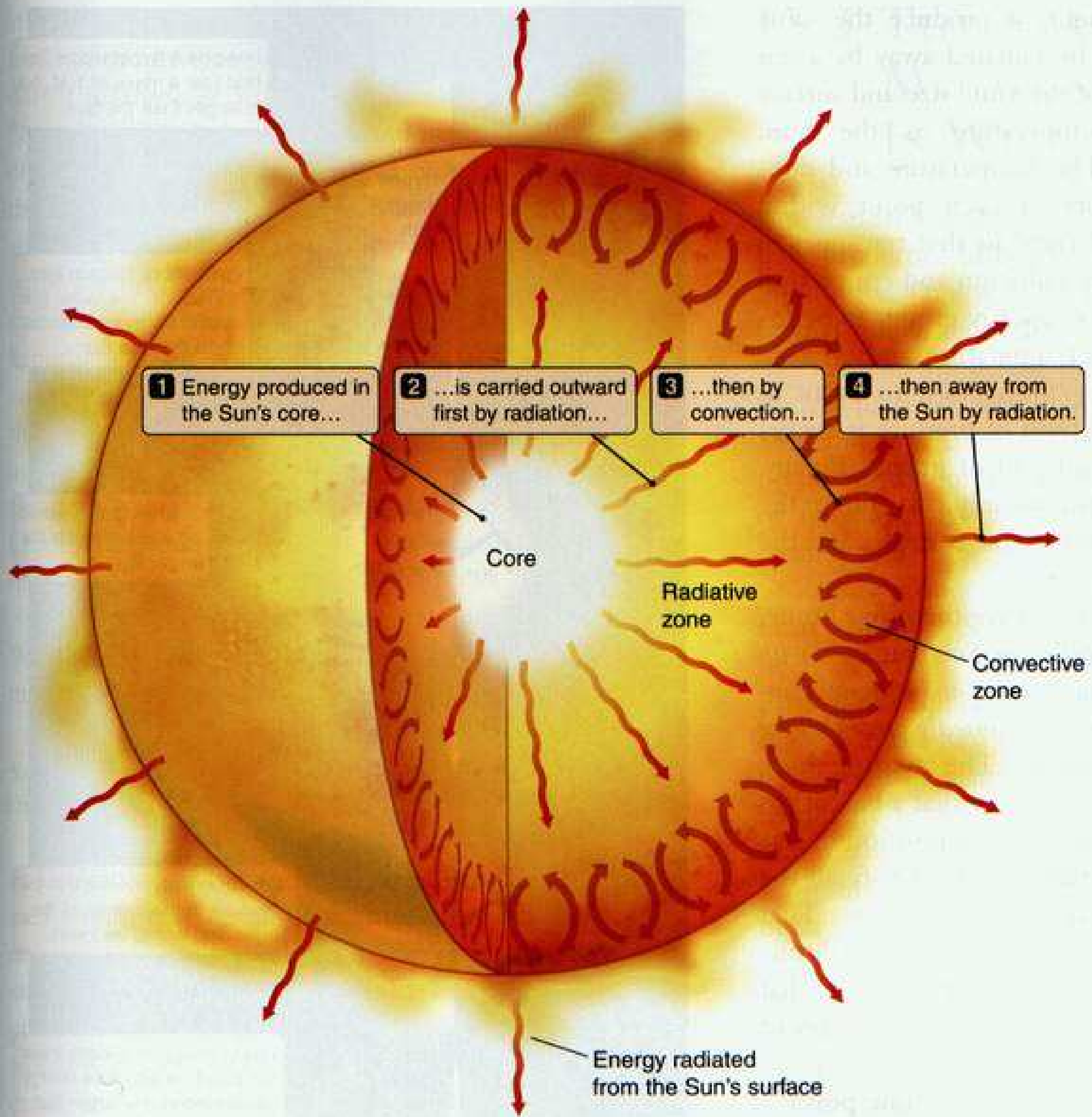
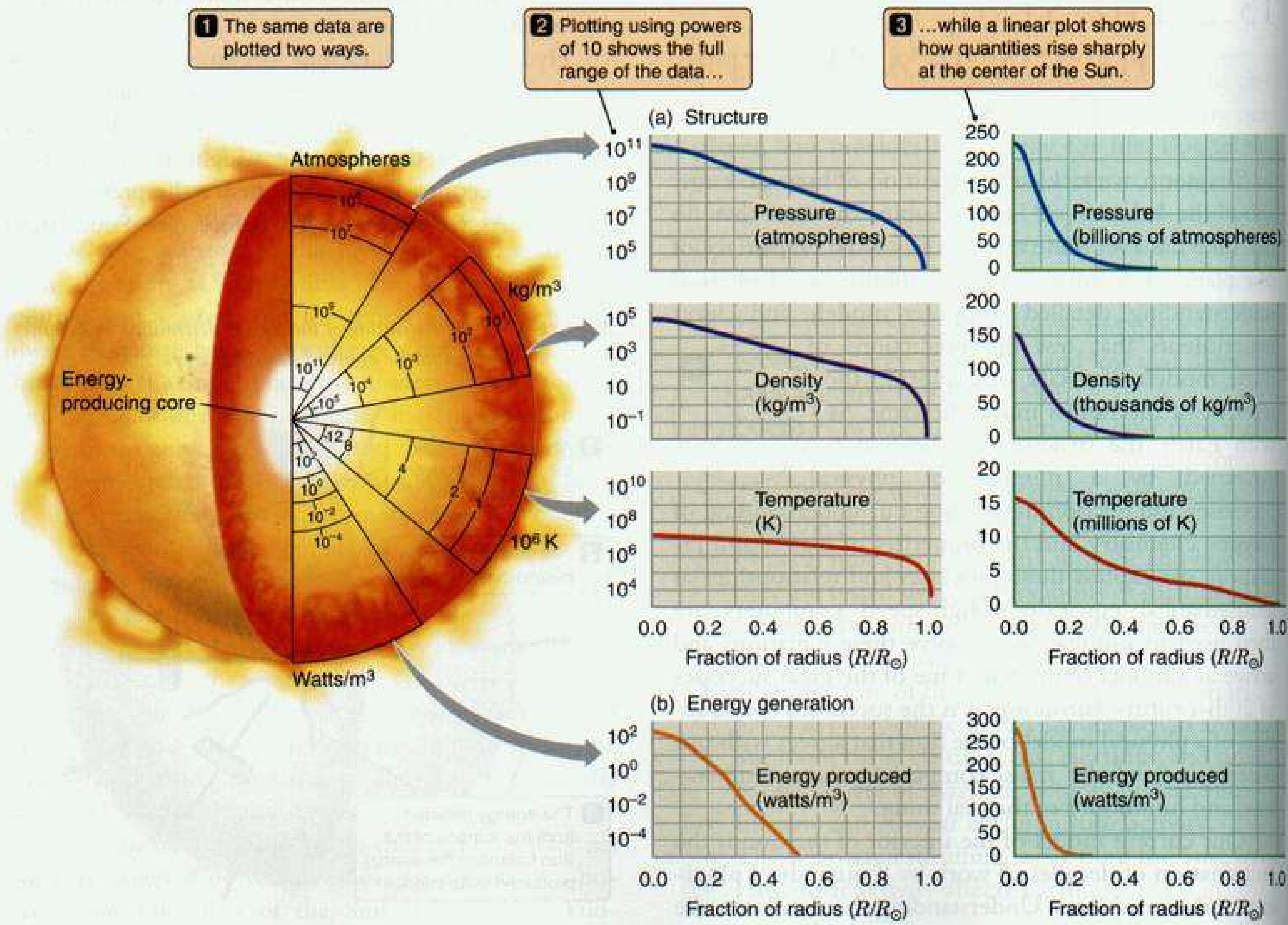


Figure 13.6 *The interior structure of the Sun is divided into zones on the basis of where energy is produced and how it is transported outward.*

SOL

Figure 13.2 *A cutaway figure showing the interior structure of the Sun.* (a) *Temperature, density, and pressure increase toward the center of the Sun.* (b) *Energy is generated in the Sun's core.*



INTERIOR
- núcleo
- zona radiativa
- zona convectiva

ATMÓSFERA
- fotósfera
- cromósfera
- corona

VIENTO SOLAR

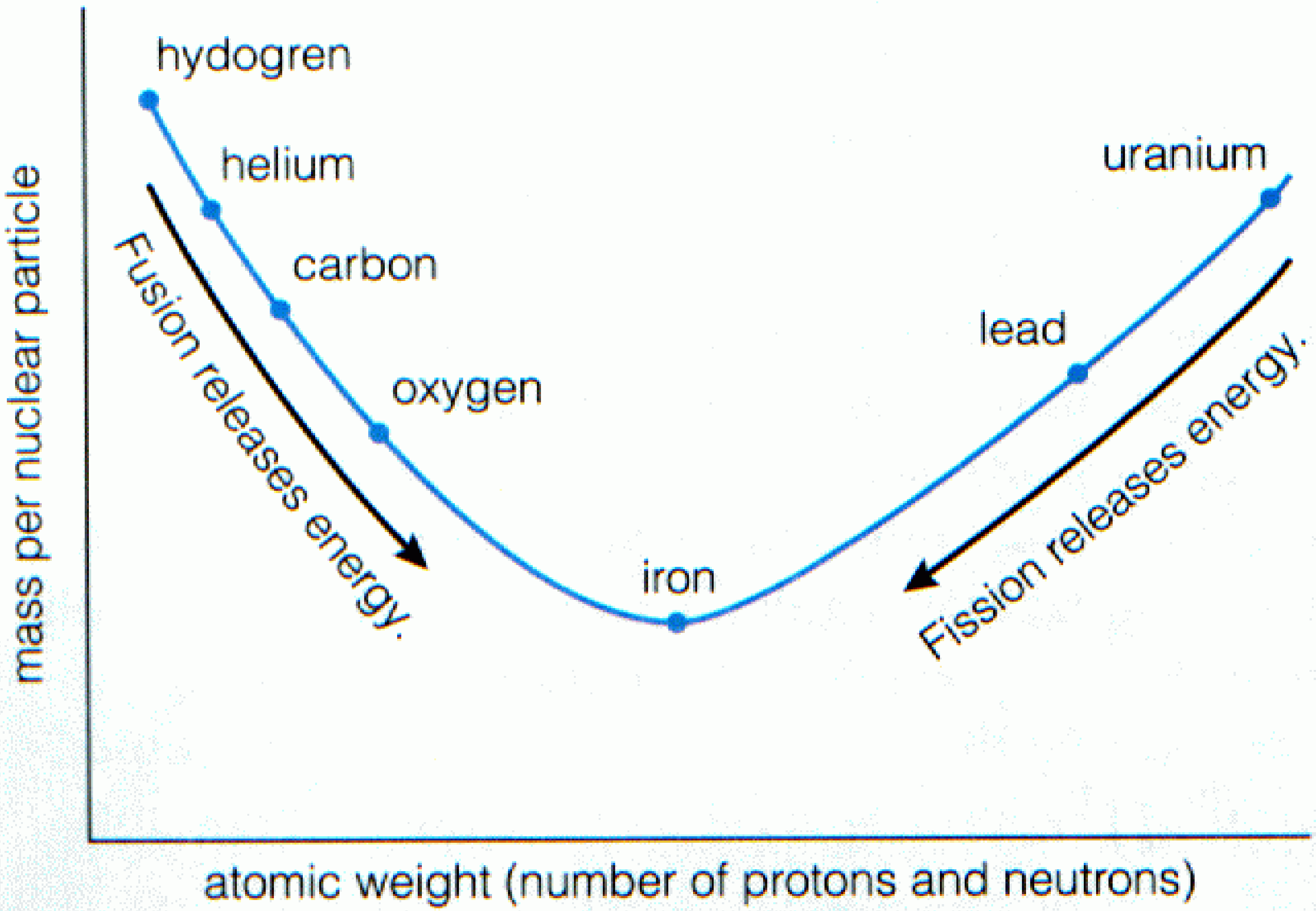
Fraccion de masa que se convierte en energia

$$\frac{\Delta m}{m(4H)} = 0.007$$

Energia generada

$$\varepsilon = \Delta m \times c^2$$

FIGURE 16.18 Overall, the average mass per nuclear particle declines from hydrogen to iron and then increases. Selected nuclei are labeled to provide reference points. (This graph shows the most general trends only; a more detailed graph would show numerous up-and-down bumps superimposed on the general trend.)



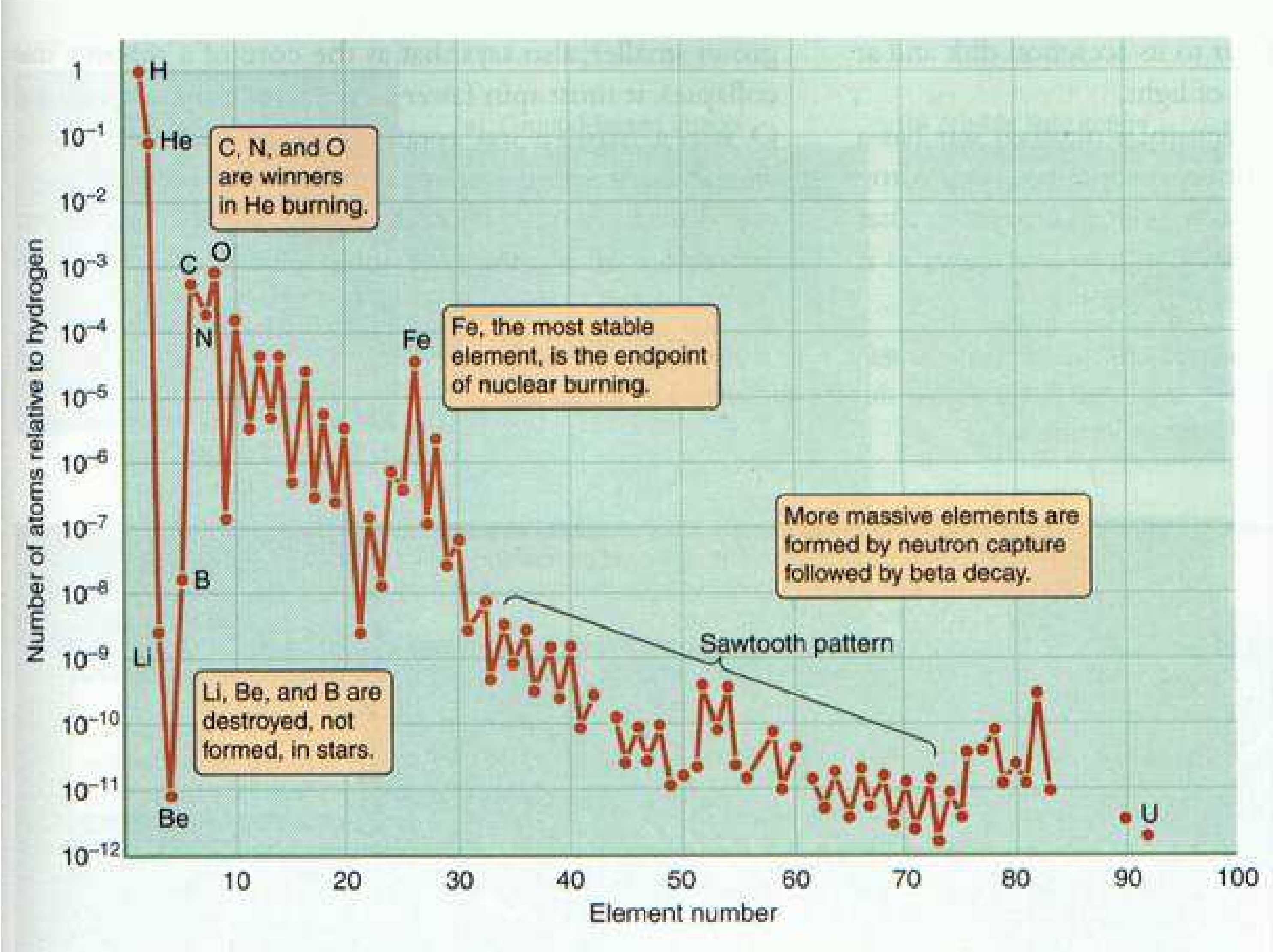


Figure 16.12 *The relative abundances of different elements on Earth are plotted against the mass of the nucleus. This pattern can be understood as a result of the process of nucleosynthesis in stars.*

Li, Be, B

EVOLUCION ESTELAR

$$T_{nuclear} = \frac{0.007 \times 0.1 \times (Masa) \times c^2}{L}$$

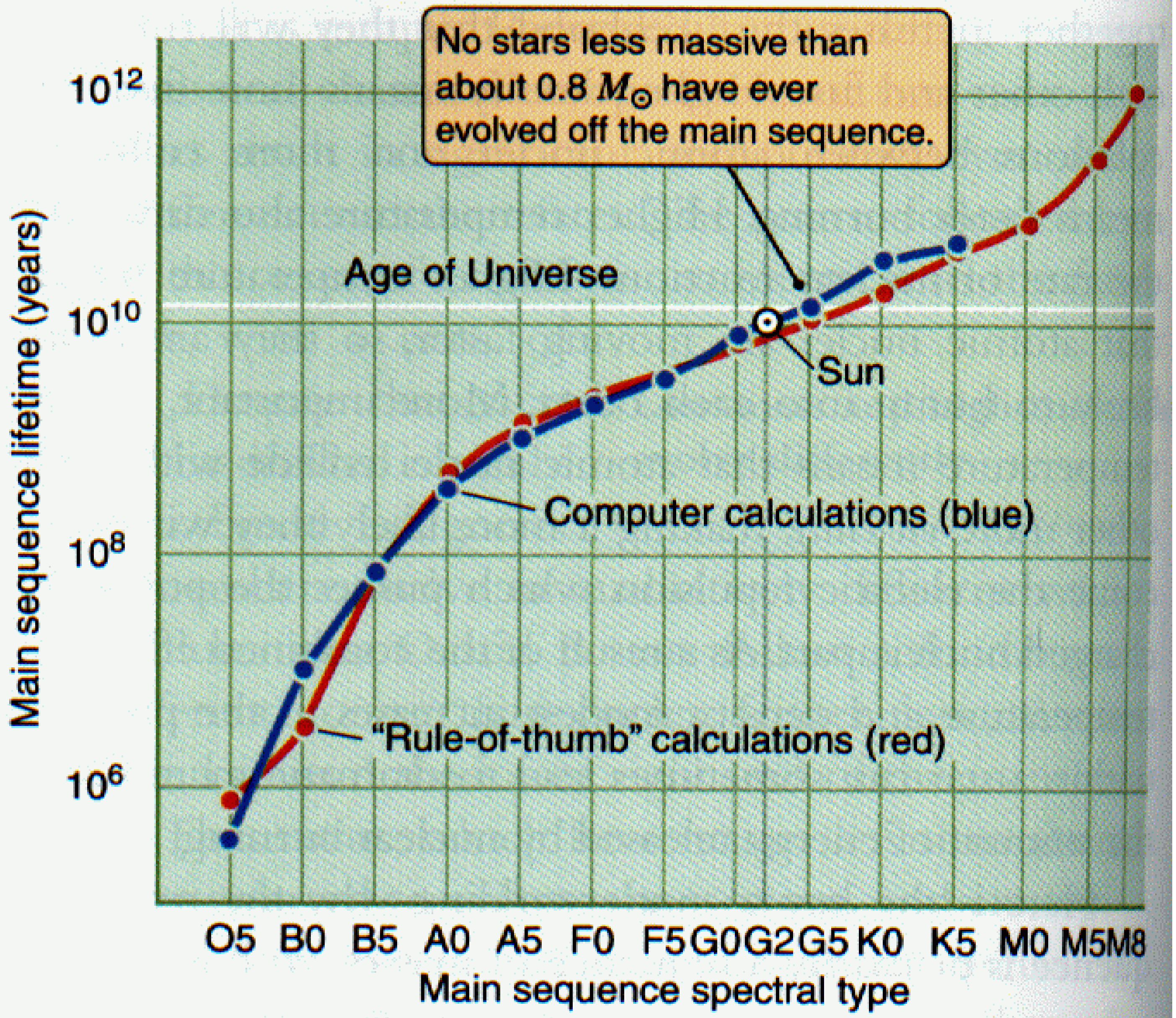


Figure 15.1 *The main sequence lifetimes of stars.*

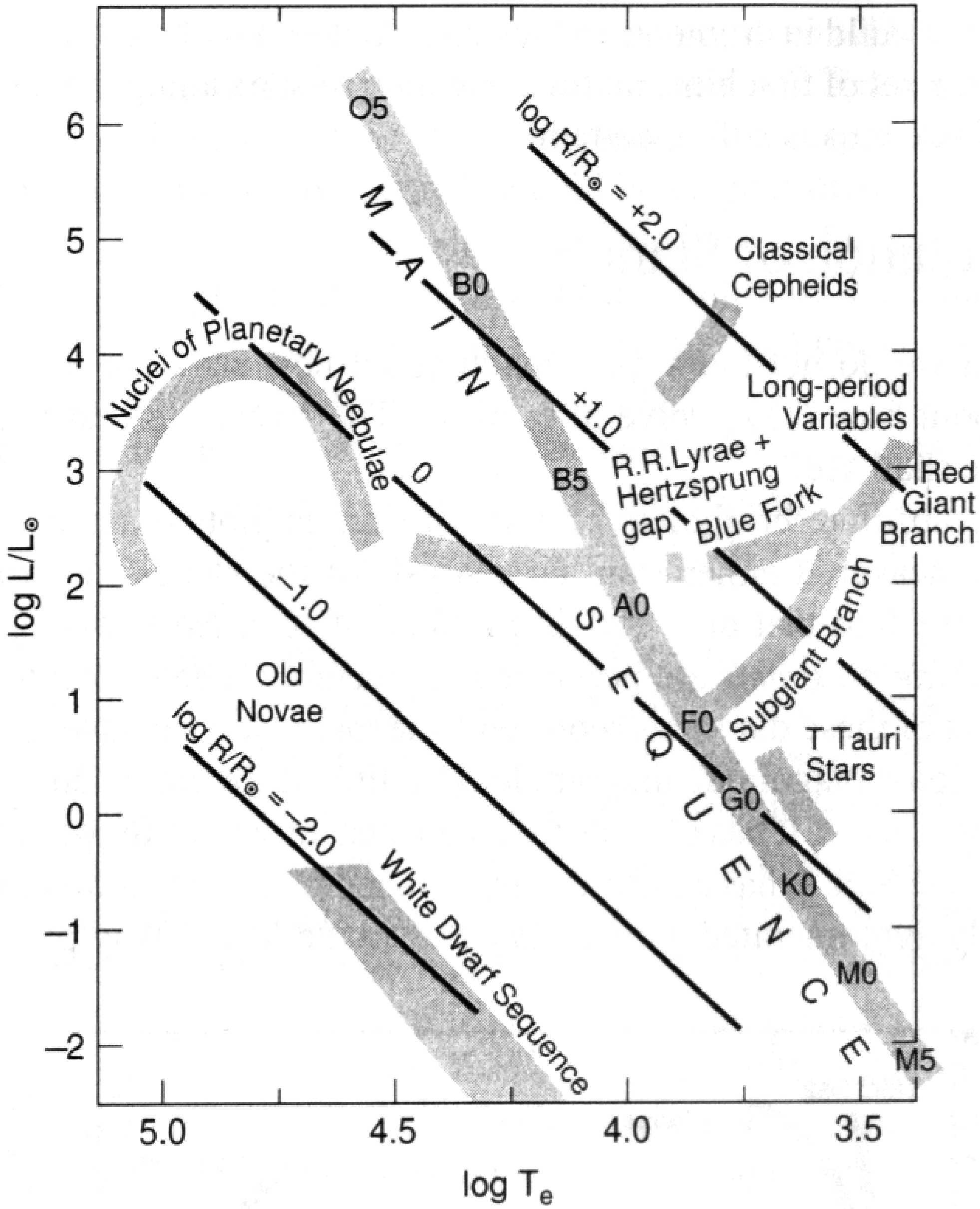


FIGURE 1.4. Schematic Hertzsprung–Russell diagram. The lines of constant slope represent stars having identical radii (see Section 4:13).

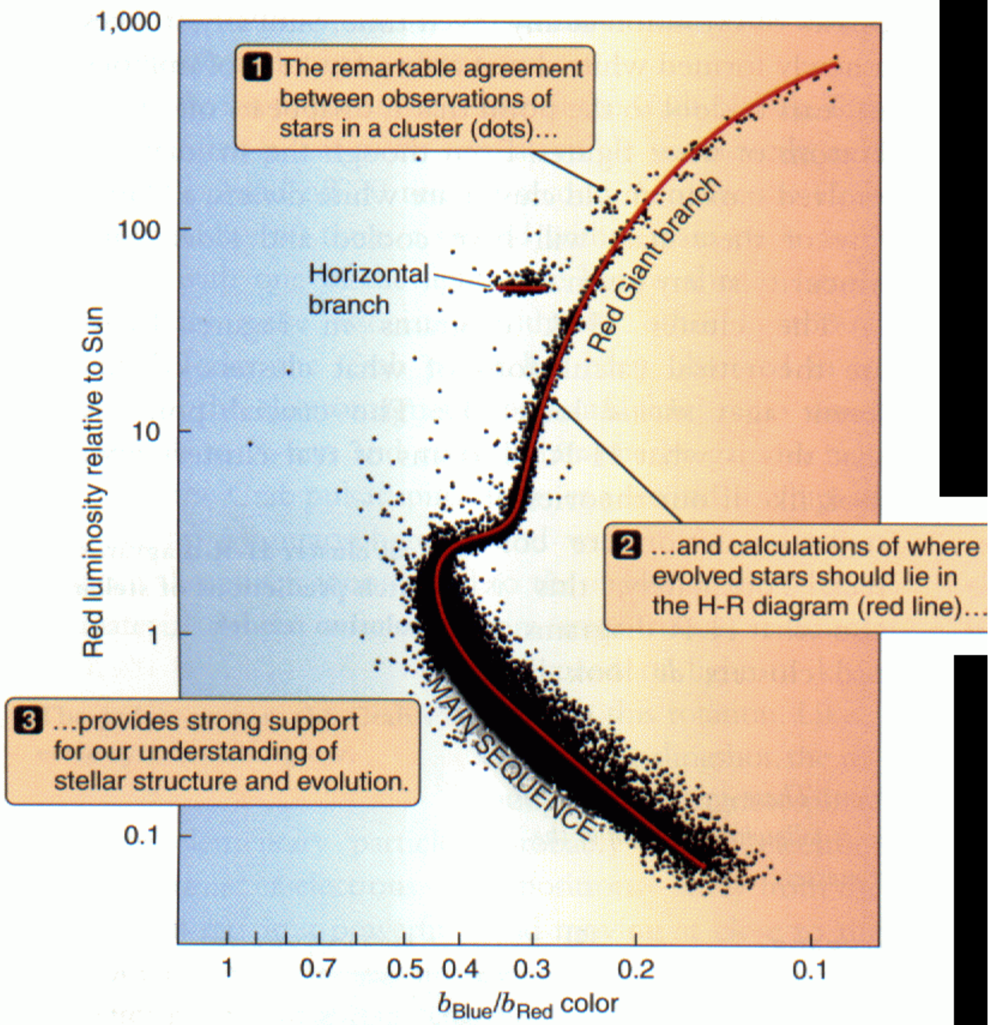
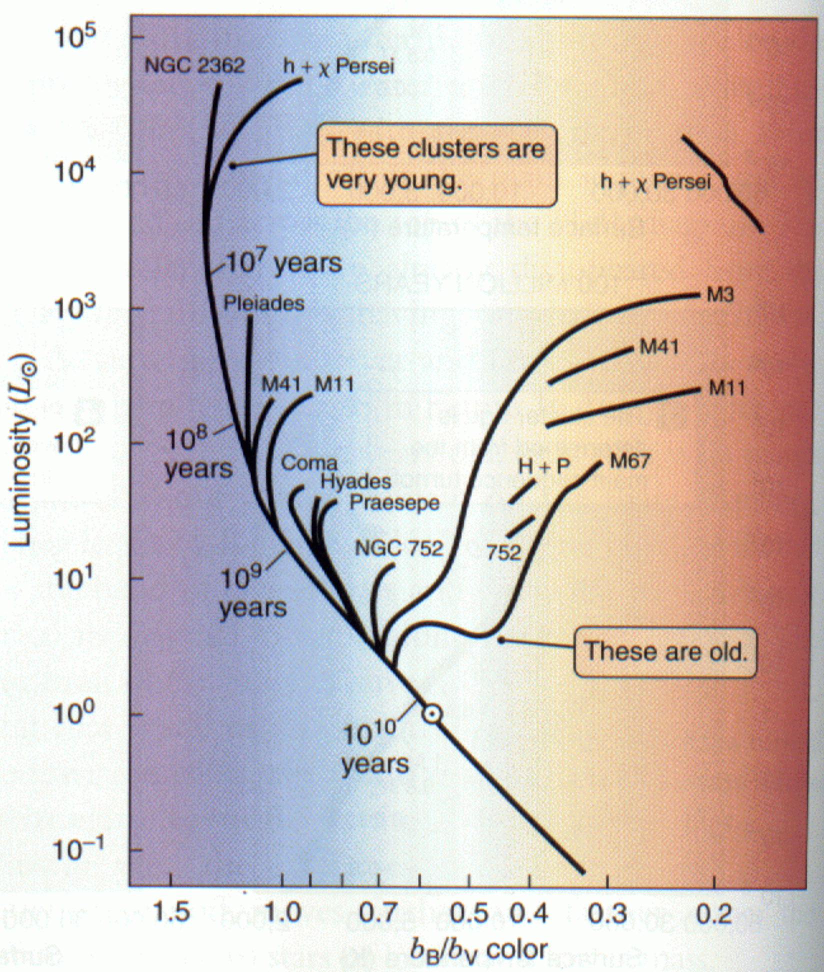


Figure 16.17 *The observed H-R diagram of the cluster 47 Tucanae agrees remarkably well with the theoretical calculation* (solid line) *of the H-R diagram of a 12-billion-year-old cluster.*

Figure 16.18 *H-R diagrams for clusters having a range of different ages. The ages associated with the different main sequence turnoffs are indicated.*



Gigante roja

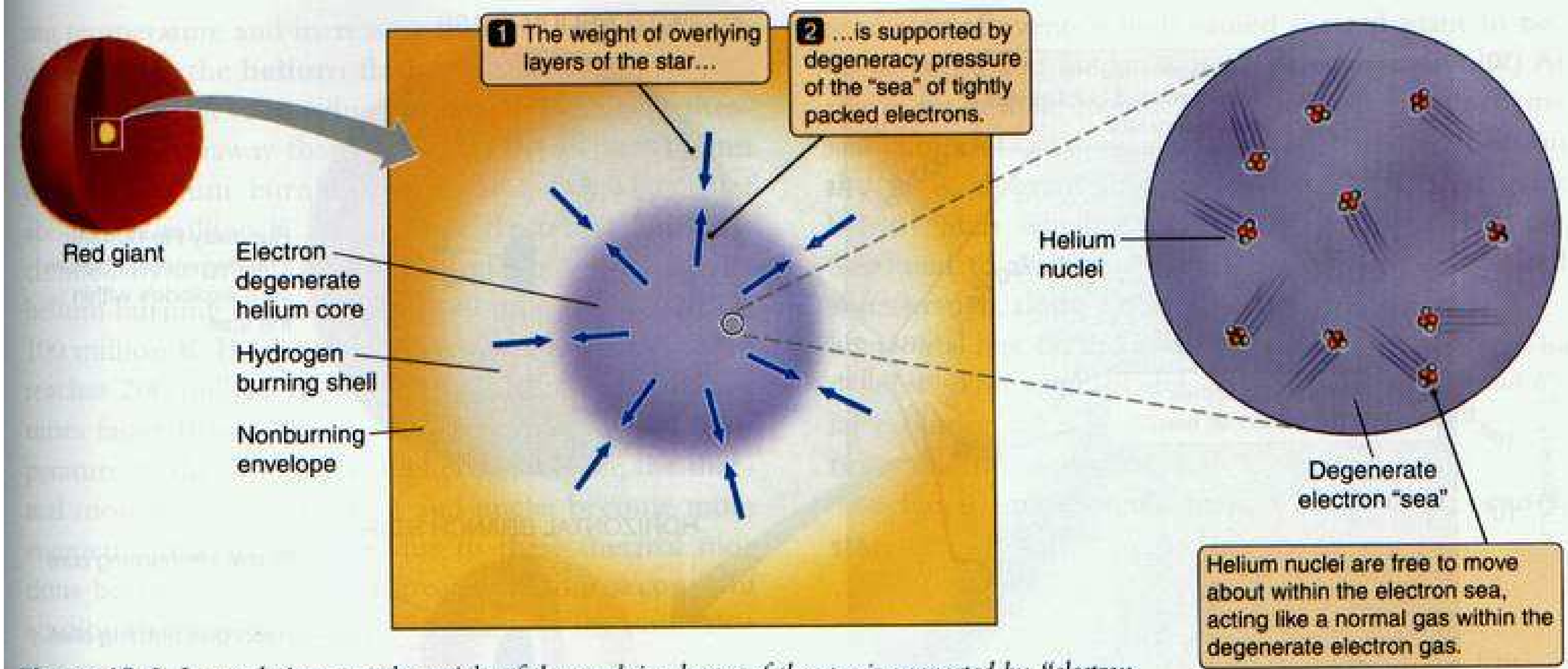


Figure 15.6 *In a red giant star the weight of the overlying layers of the star is supported by "electron degeneracy pressure" in the core arising from the fact that electrons are packed together as tightly as allowed by quantum mechanics. Even so, atomic nuclei in the core of the star are able to move freely about within the sea of degenerate electrons, and so behave as a normal gas.*

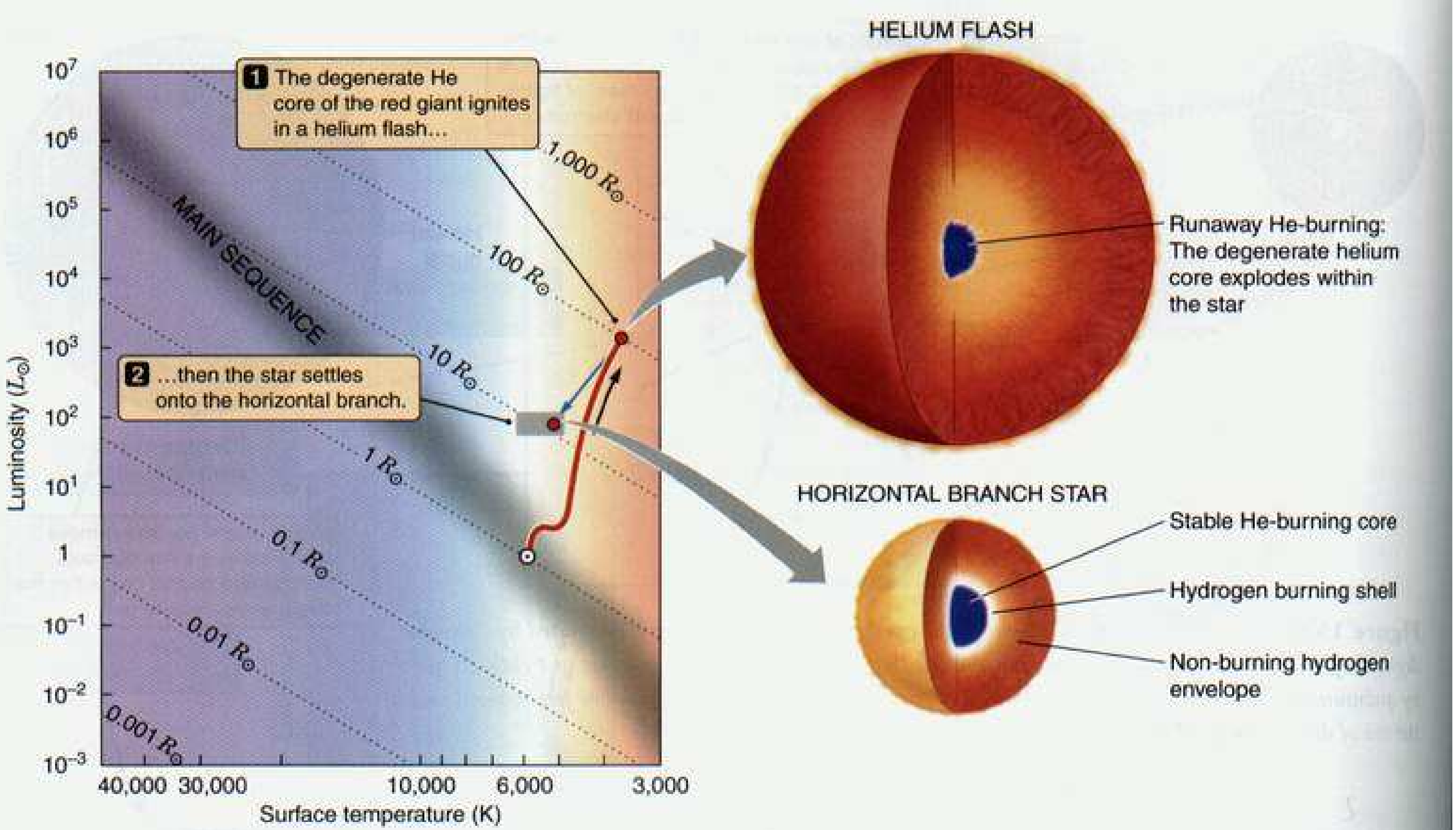


Figure 15.8 *When the core temperature of the red giant reaches about 10^8 K, He begins to burn explosively in the degenerate core, leading to the helium flash. After a few hours the core of the star begins to inflate, ending the helium flash. Over about the next 100,000 years (a relatively short time), the star settles onto the horizontal branch, where it burns He in its core and H in a surrounding shell.*

which appears on the H-R diagram as a cooling white dwarf star.

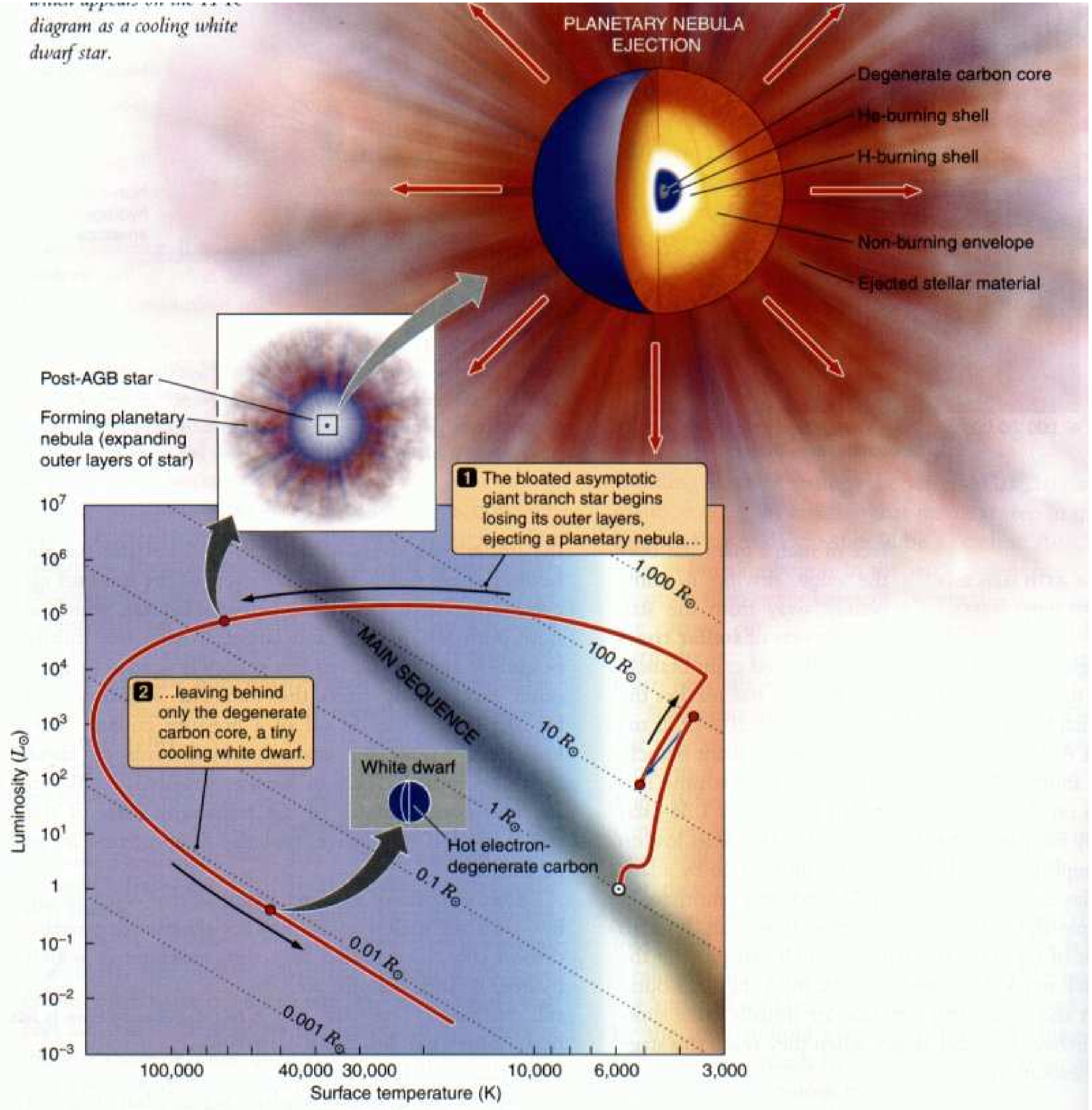
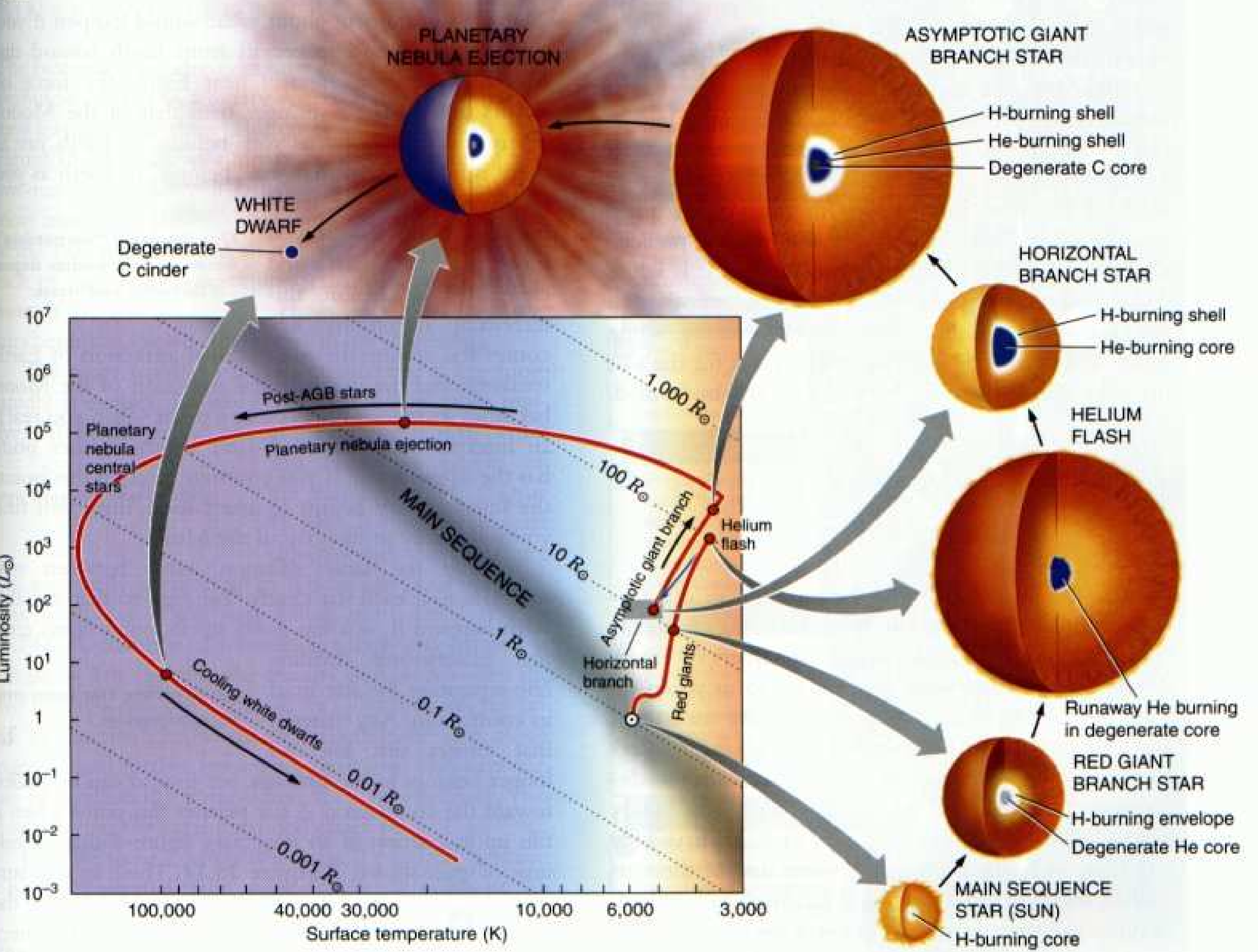


Figure 15.13 *This H-R diagram summarizes the stages in the post–main sequence evolution of a one-solar-mass star.*



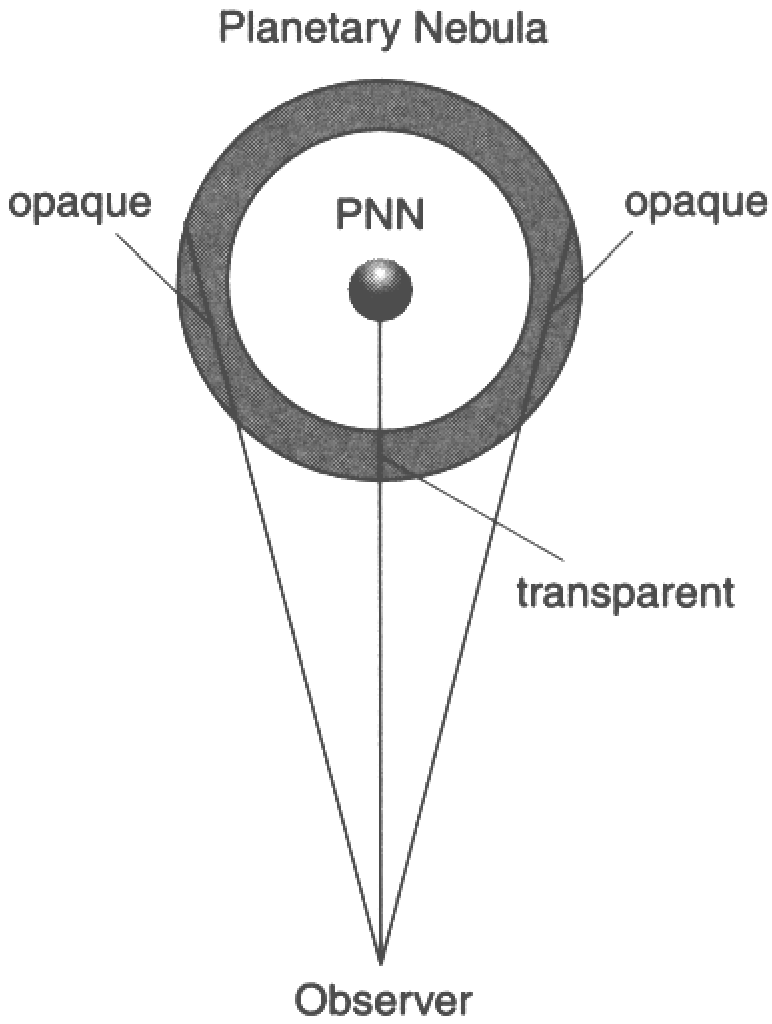
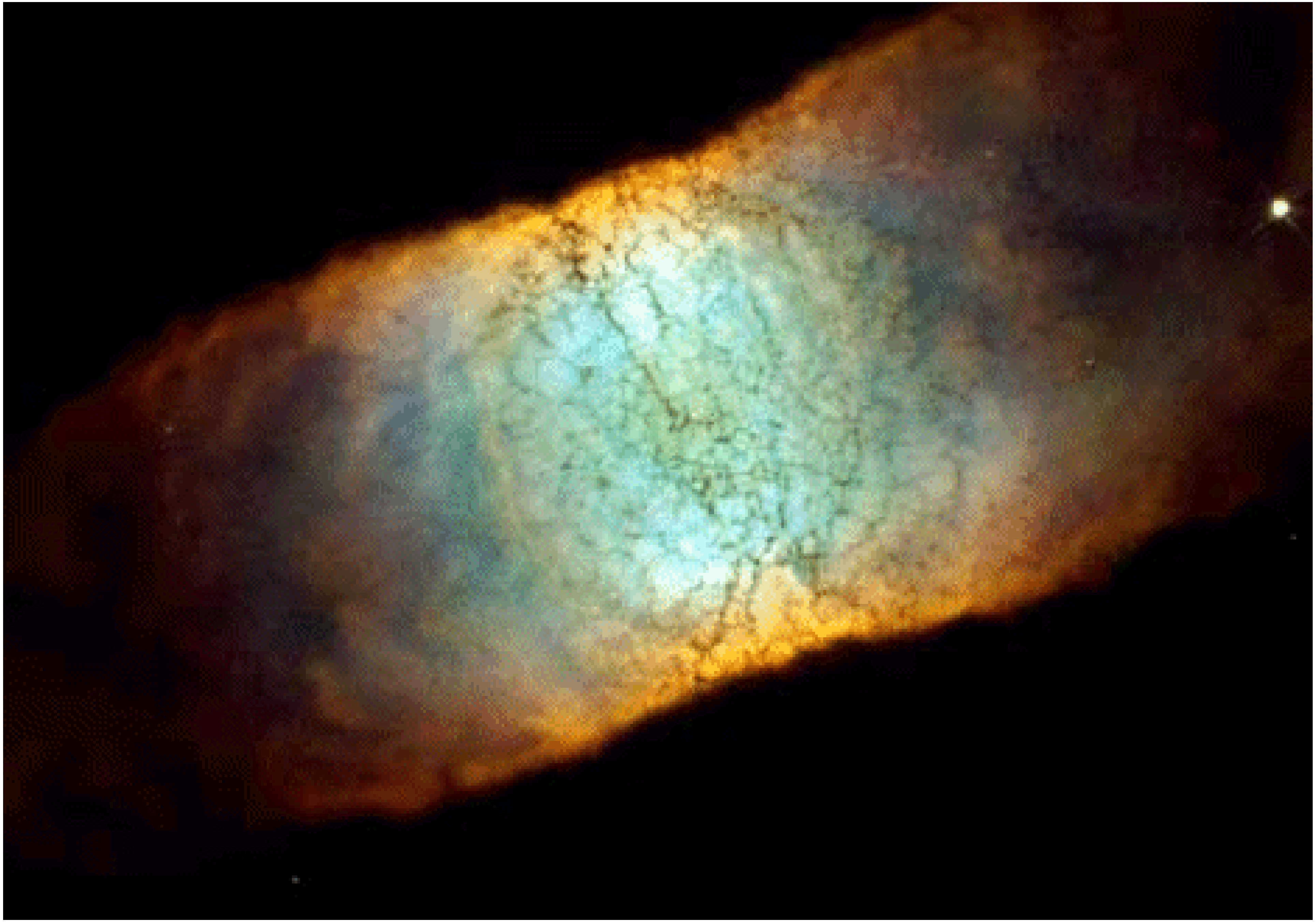
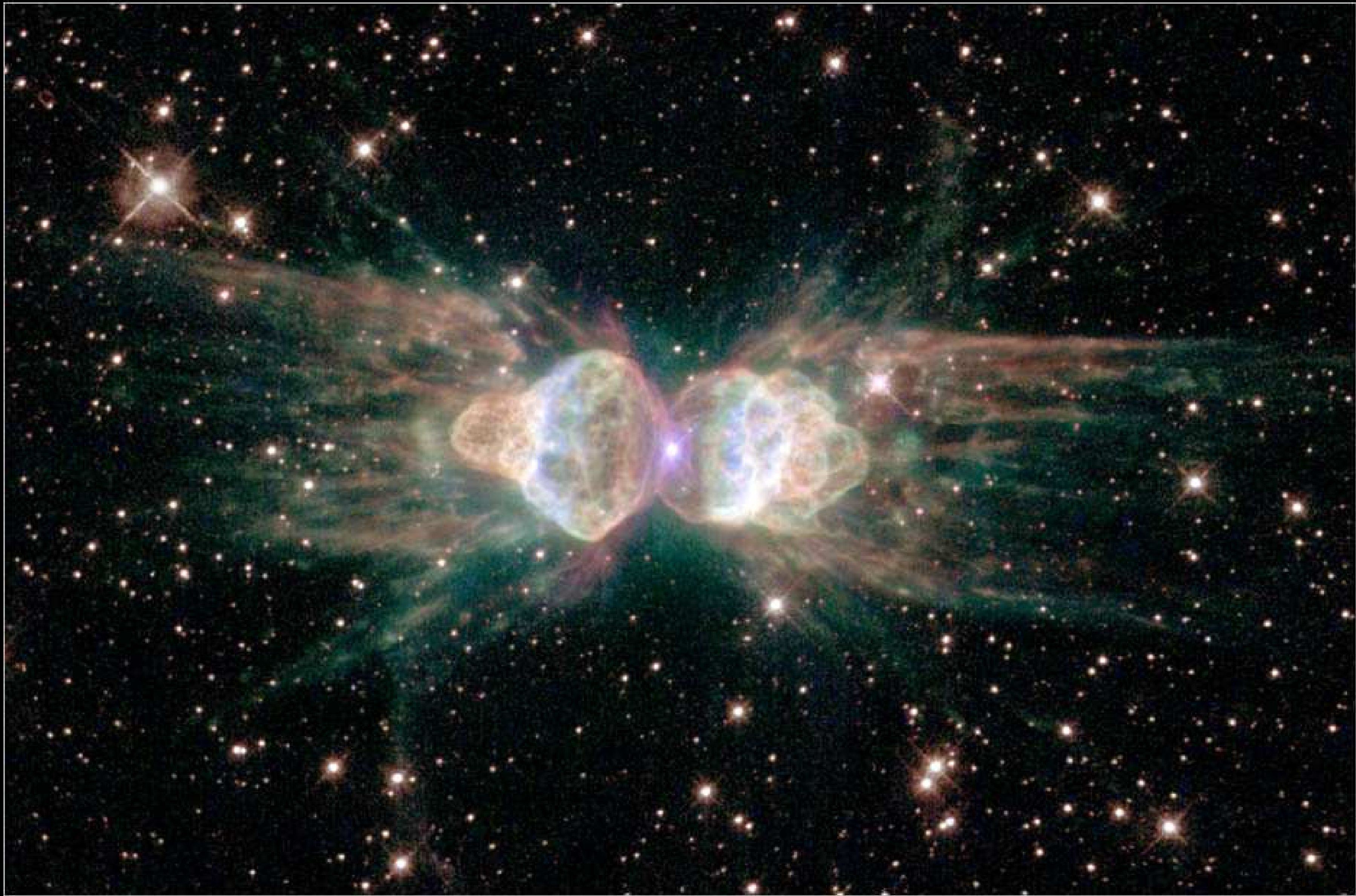


Figure 8.12 Sketch of a planetary nebula and its nucleus (PNN).



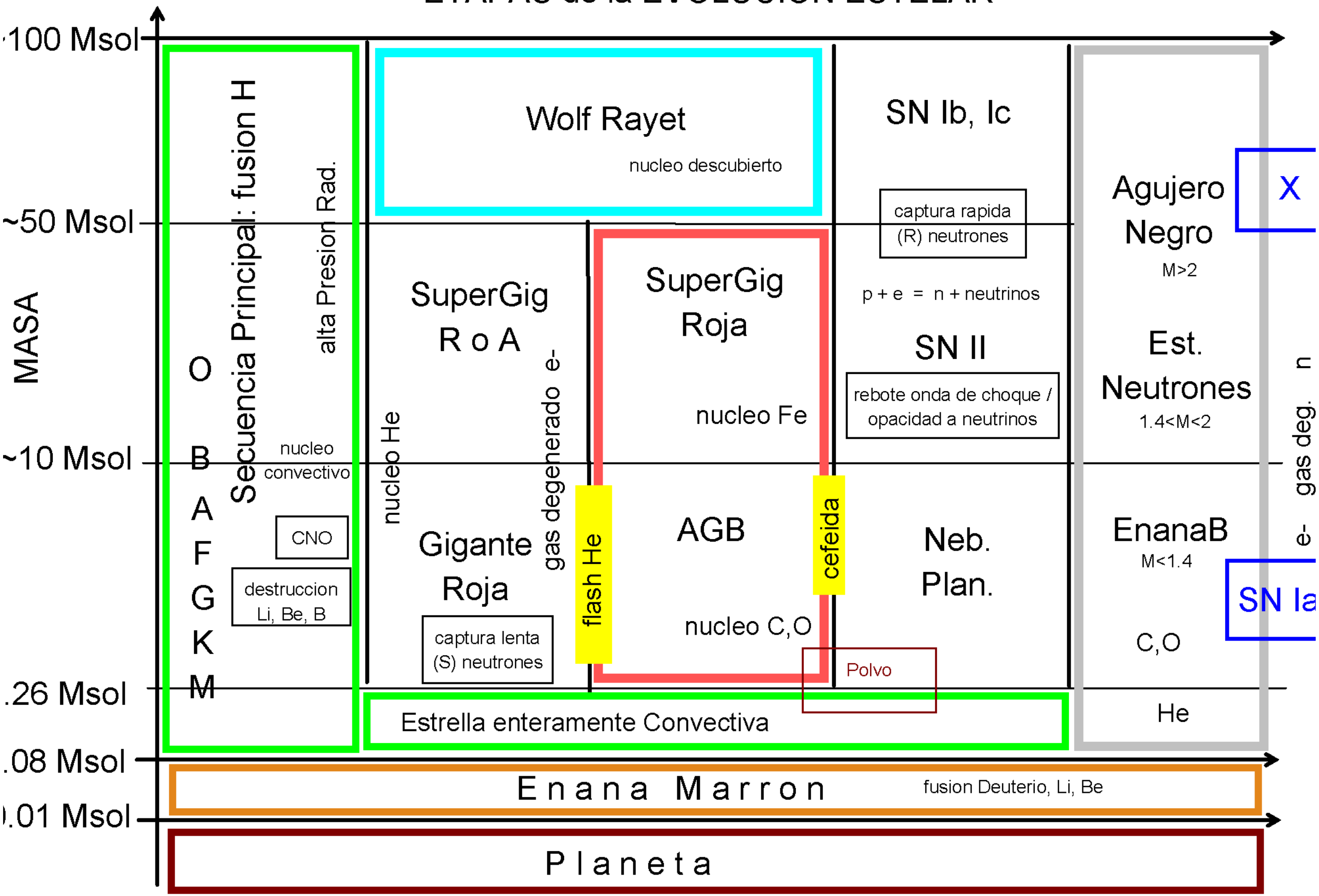
Planetary Nebula Mz 3



Hubble Heritage

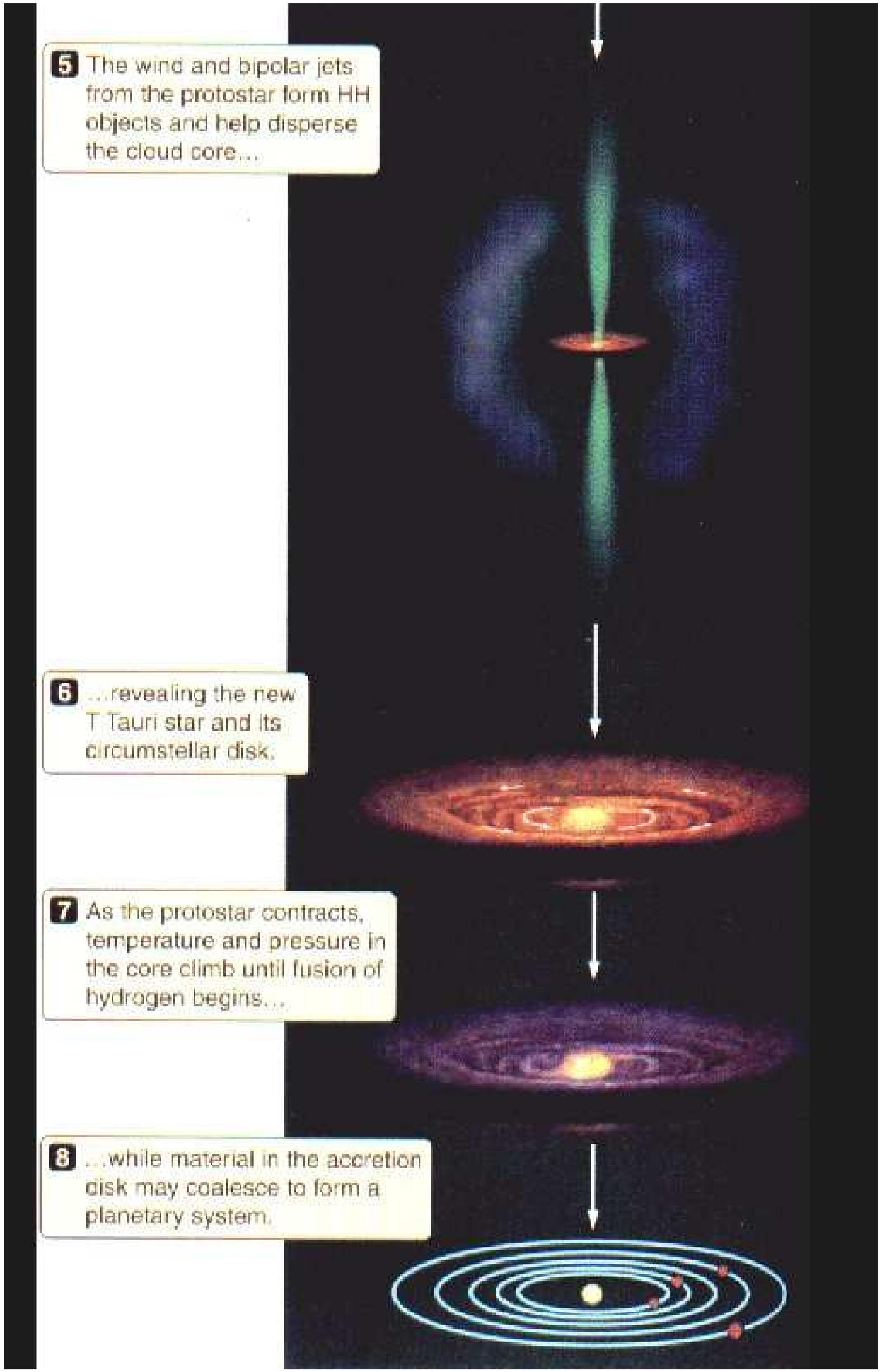
NASA, ESA, and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope WFPC2 • STScI-PRC01-05

ETAPAS de la EVOLUCION ESTELAR



FORMACION ESTELAR

Bow Shock Around LL Orionis



- Flujo bipolar
- T Tauri y disco
- Litio alto
- Fusion H
- Planetas

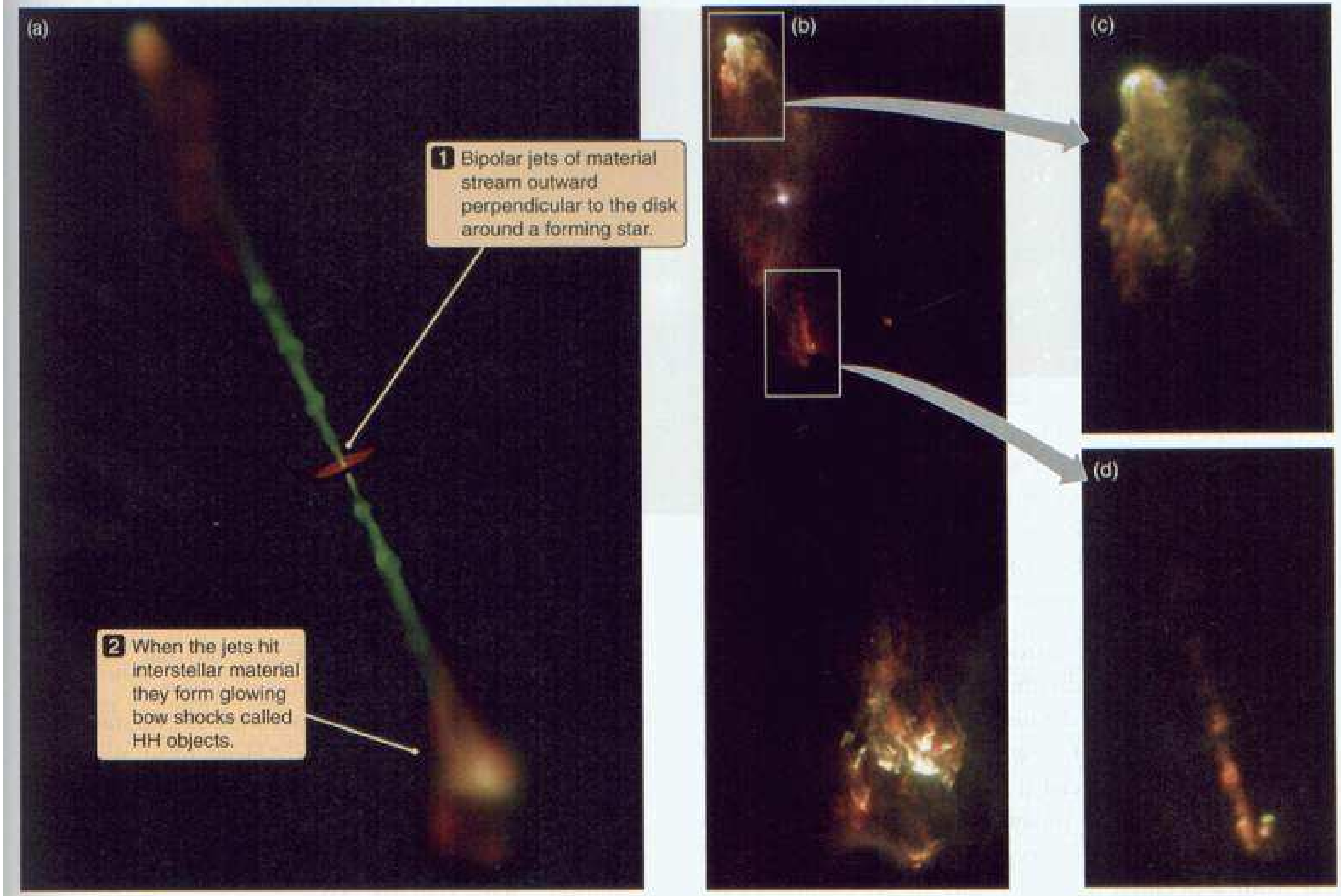
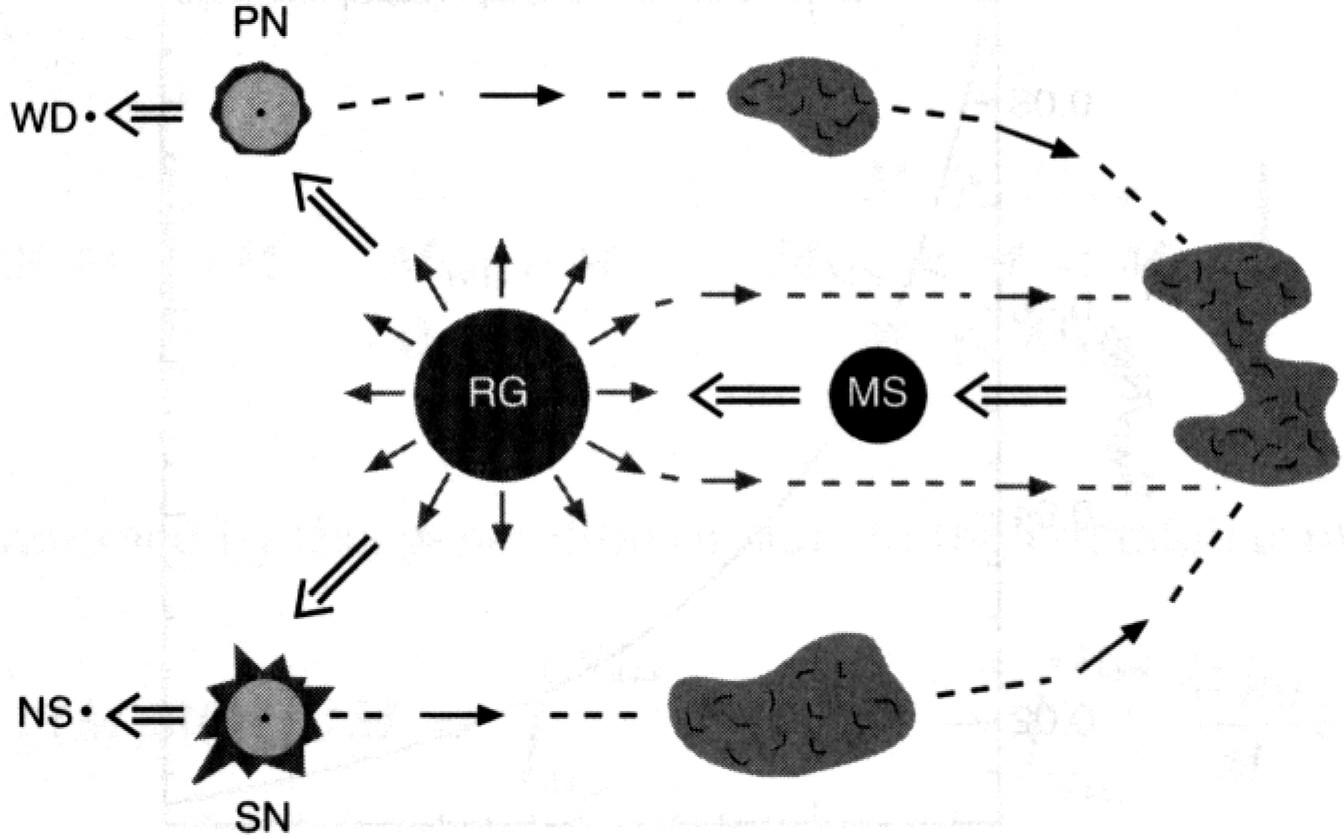


Figure 14.20 (a) *Jets from protostars slam into surrounding interstellar gas, heating the gas and causing it to glow.* (b) *This HST image shows the bow shocks formed at the ends of a bipolar jet from a protostar. Enlargements of the bow shock* (c) *and jet* (d) *are shown at right. Only one side of the jet itself can be seen because the other side is hidden behind the dark cloud in which the star is embedded.*

Objetos Herbig Haro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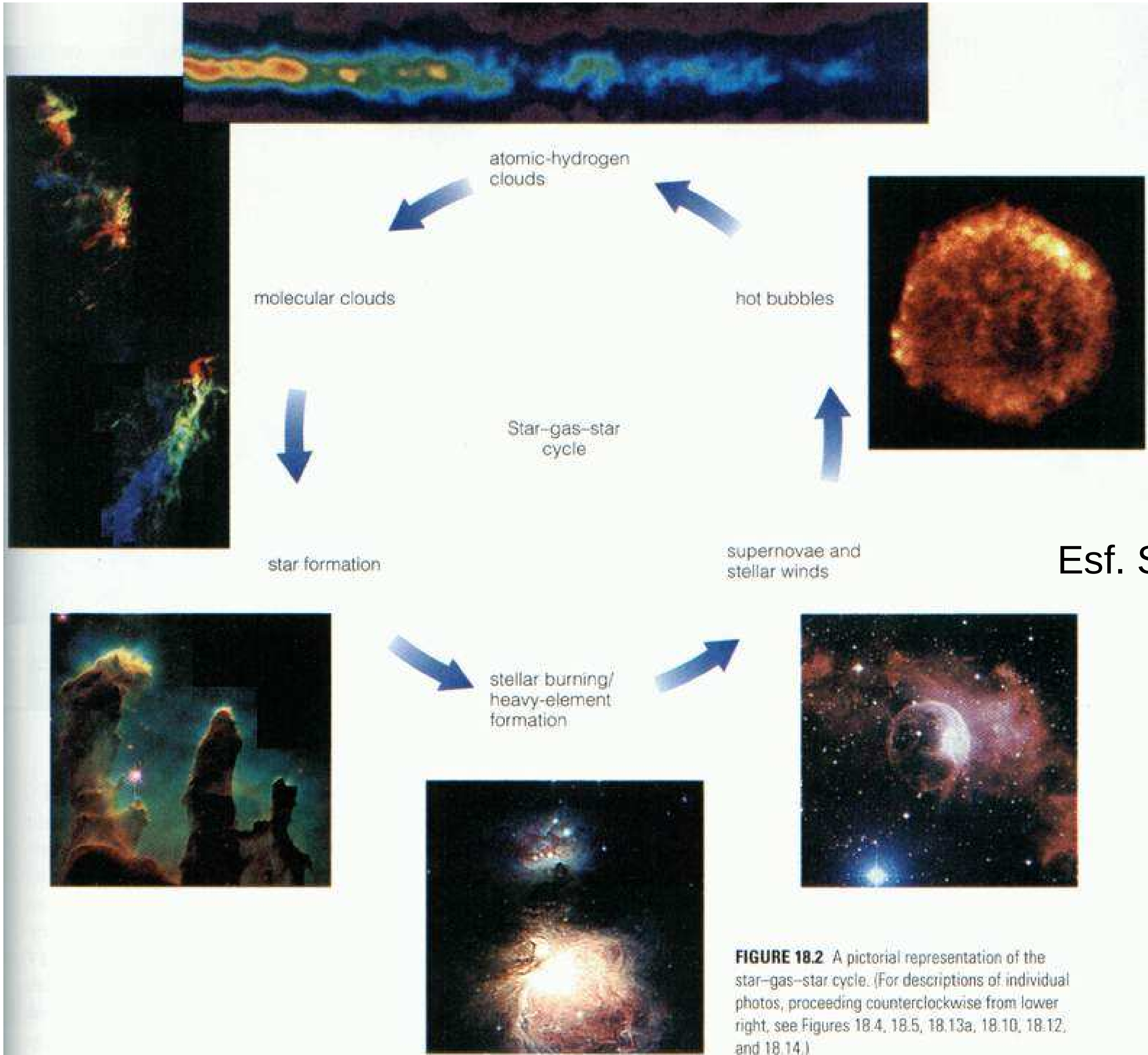

FIGURE 18.2 A pictorial representation of the star–gas–star cycle. (For descriptions of individual photos, proceeding counterclockwise from lower right, see Figures 18.4, 18.5, 18.13a, 18.10, 18.12, and 18.14.)

Esf. Stromgren

BIBLIOGRAFIA

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- El Nuevo Cosmos, Unsold
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- Astronomy Notes: www.astronomynotes.com
- Astronomia: uma visao geral, Antonio Mario Magalhaes (no planet.)
- Astronomia e Astrofisica: www.if.ufrgs.br/ast
- Hubble Heritage Home Page: fotografias con descripcion
- Clear Skies: www.swin.edu.au/astronomy (ppt)
- Laboratorios para PC: CLEA
- Programas: HRCalc, SClock20