Stellar Properties

1. Distance (nearby stars) (17.1)
2. Luminosity/ Absolute mag. (17.2)
3. Apparent brightness/appar. mag. (17.2)
4. Surface Temp./Core Temp. (17.3)
5. Spectral Type & color (17.3)
6. Size (radius) (17.4)
7. Luminosity Class (17.6, p.456)
8. Mass (17.7,17.8)
9. Radial & Tangential velocity (17.1)
10. Composition (17.3)
11. Distance (far away stars) (17.6)
12. Lifetime & age (17.8)
13. Position on H-R diagram (17.5)

EXERCISE

In groups of 2-3, figure out the following for each property listed to the right:

a) Value for the Sun
b) Range of values for other stars
c) How its measured
d) Theory behind interpretation of measurement.

Table 17-5
Measuring the Stars

TABLE 17.5 Measuring the Stars

Stellar Property	Measurement Technique	"Known" Quantity	Measured Quantity	Theory Applied	Section
Distance	stellar parallax	astronomical unit	parallactic angle	elementary geometry	17.1
Distance - far	spectroscopic parallax	main sequence	spectral type apparent magnitude	inverse-square law	17.6
Radial velocity	spectroscopy	speed of light atomic spectra	spectral lines	Doppler effect	17.1
Transverse velocity	astrometry	distance	proper motion	elementary geometry	17.1
Luminosity	photometry	distance main sequence	apparent magnitude spectral type	inverse square law	17.2 17.6
Temperature	photometry spectroscopy		color spectral type	blackbody law atomic physics	17.3 17.3
Radius	direct indirect	distance	angular size luminosity temperature	elementary geometry radius–luminosity–temperature relationship	17.4 17.4
Composition	spectroscopy		spectrum	atomic physics	17.3
Mass	observations of binary stars	(distance)	binary period binary orbit orbital velocity	Newtonian gravity and dynamics	17.7

Table 17-6
Key Properties of Some Well-Known Main-Sequence Stars

TABLE 17.6 Key Properties of Some Well-Known Main-Sequence Stars

Star	Spectral Type	Mass, M (Solar Masses)	Central Temperature (10^6 K)	Luminosity, L (Solar Luminosities)	Estimated Lifetime (M/L) (10^6 years)
Spica B*	B2V	6.8	25	800	90
Vega	A0V	2.6	21	50	500
Sirius	A1V	2.1	20	22	1000
Alpha Centauri	G2V	1.1	17	1.6	7000
Sun	G2V	1.0	15	1.0	10,000
Proxima Centauri	M5V	0.1	0.6	0.00006	16,000,000

**The "star" Spica is, in fact, a binary system comprising a B1III giant primary (Spica A) and a B2V main-sequence secondary (Spica B).*

1. Distances to nearby stars

a) Value for Sun.*

93,000,000 miles or 150,000,000 km.

This is only 1.5 X 10^{-5} LY.

b) Range of values for other stars.

Closest: 4.3 LY for Proxima Centauri. (4.22 LY)

Farthest: Stars exist in galaxies which have distances out to the edge of the observable universe (about 10,000,000,000 LY).

However, the technique of “Stellar Parallax” is limited by the resolution of our imagers. It can only be measured out to 200 pc (600 LY) from the ground, The Hipparcos satellite “measured parallaxes to over 200 pc, encompassing over a million stars.” Hipparcos measured 118,000 stars with a median precision of +-1 mas corresponding distances to 3300 LY, another million stars were measured with lower precision.

c) How its measured

Image a star (on film or CCD) at least two times from two positions as far apart as possible. The more images at different positions, the better. A nearby star will appear to move relative to background stars (or an absolute coordinate system).

d) Theory behind interpretation of measurement.

The theory is simple geometry, not physics. $D = 1/\pi$ where D is distance (in parsecs) and π is the parallax angle (in arcseconds).

* green text means information from Astronomy Today 5th Ed.

Figure 17-2: The Solar Neighborhood

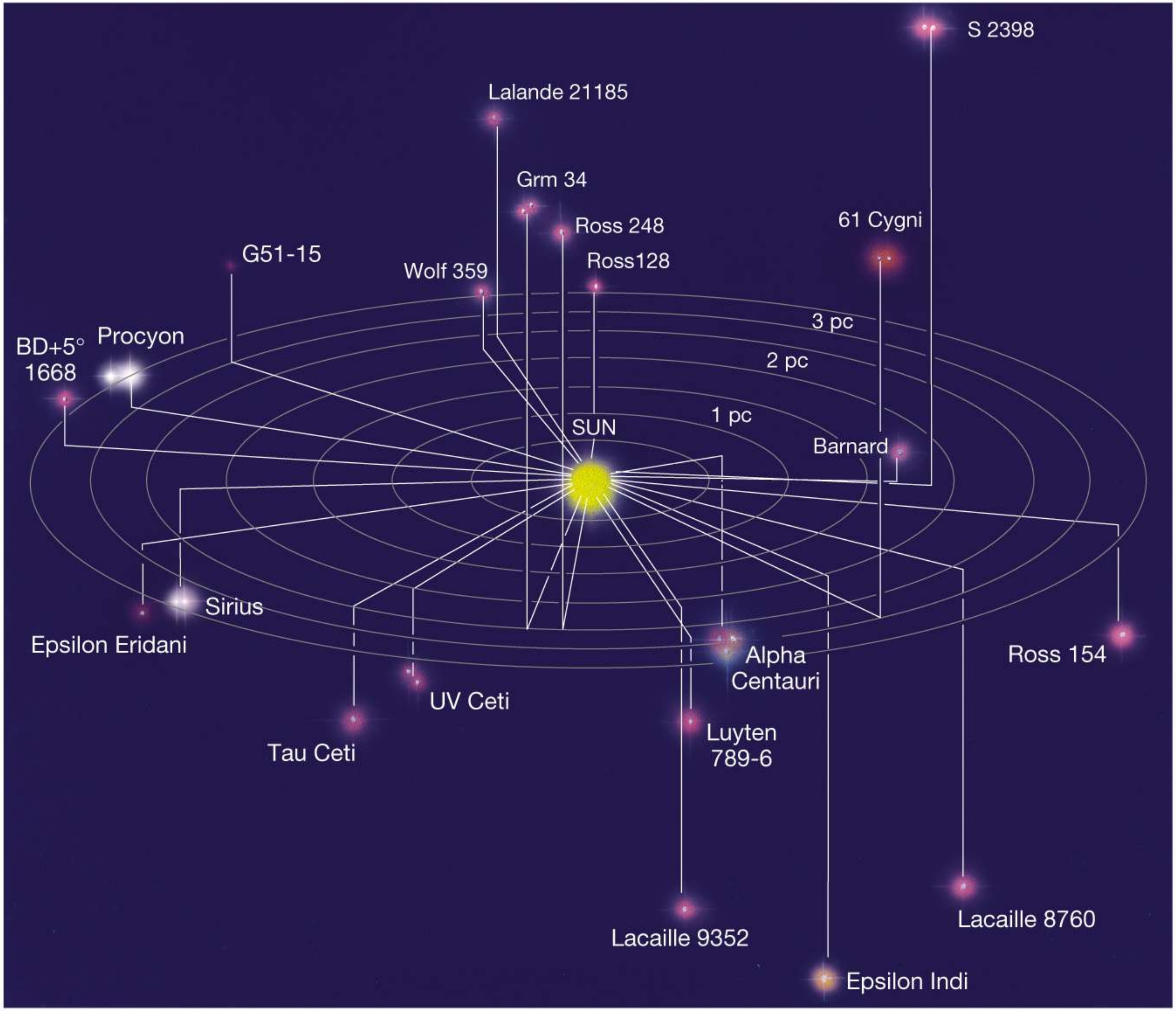
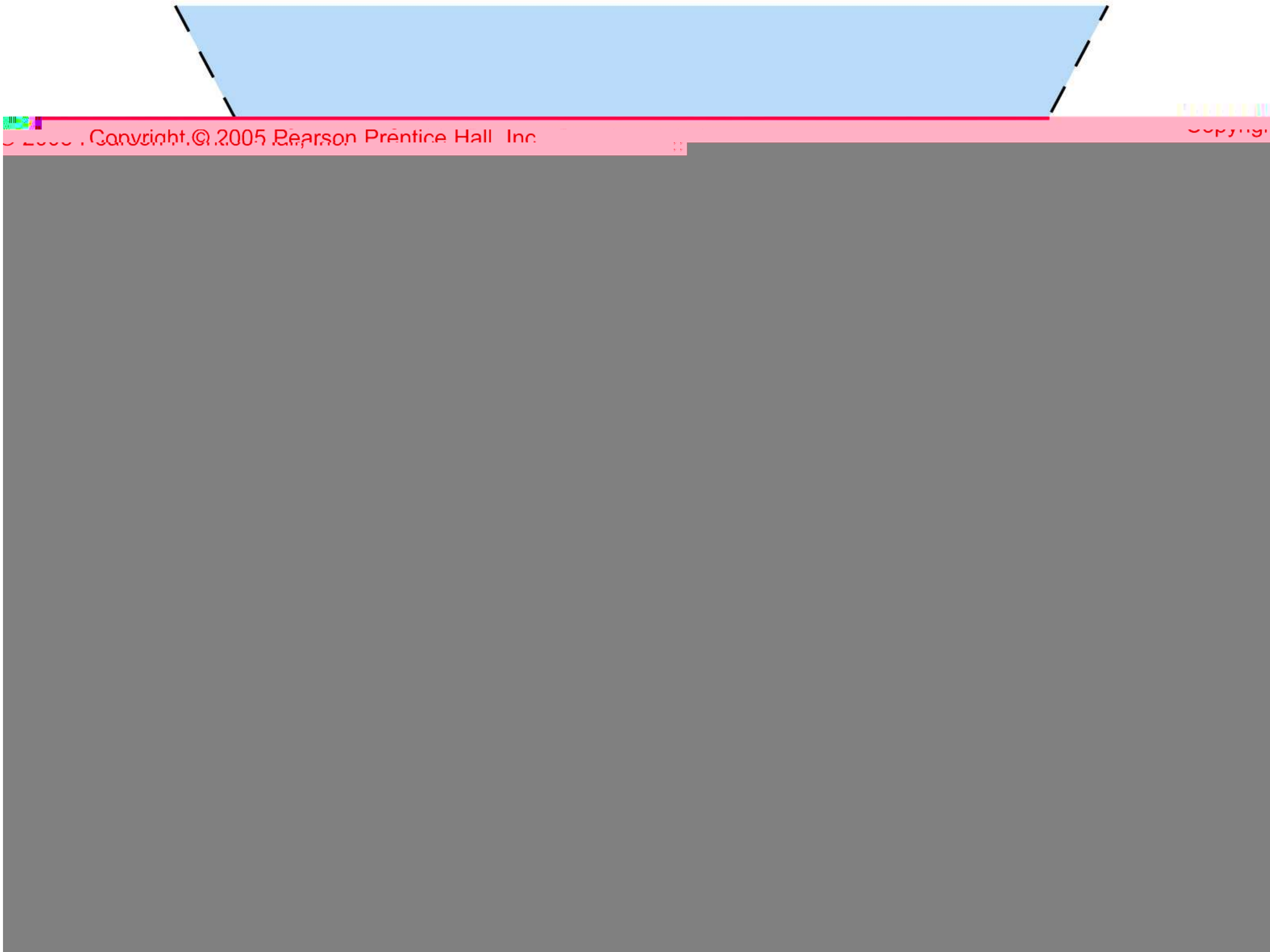


Figure 17-17
Stellar Distances



Apparent brightness / apparent magnitude

a) Values for the Sun

m = -26.7

b) Range of values for other stars

Sun is brightest (-26.7), we can observe others as faint as m=+30.0.

Next brightest star is -1.5 (Sirius).

Planets can appear even brighter, and the Moon is -12.5.

c) How its measured

Use photometry to get a flux (counts per second). Apparent magnitude is then given by m = -2.5 log (flux/reference flux).

d) Theory behind interpretation of measurement.

The counts that we receive in a detector tell us the intensity or flux of photons at the Earth.

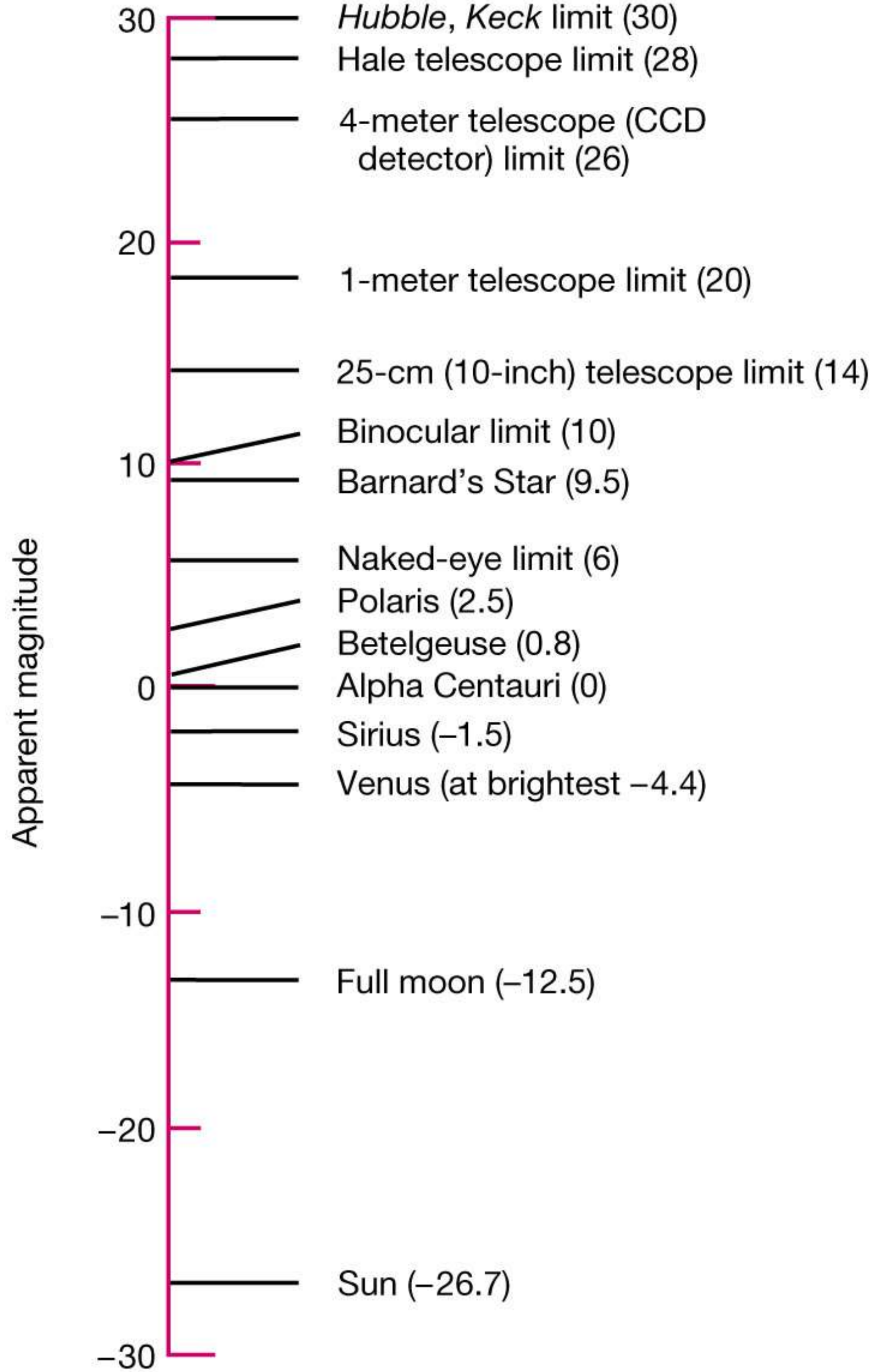


Figure 17-7
Apparent Magnitude

Surface and core temperature

a) Values for the Sun

Tcore= 15x10^6 K

Tsurface= 5800 K

b) Range of values for other stars

Tsurface ranges from 3000 to 50000 K for main sequence stars.

Tcore ranges from $9\text{x}10^6$ to $25\text{x}10^6$.

c) How its measured

Tsurf: a) use multi-color photometry (ie. image through color filters). The colors correlate with surface temperature (blue=hot, red=cool). b) take a spectrum and measure the strengths of many different absorption lines.

Tcore: MANY observables used: radius, surface temp, surface density, total mass (from planet orbits), total luminosity. This information is fed into a computer that uses laws of physics to make a stellar model. The model will include temperature at the core.

d) Theory behind interpretation of measurement.

Tsurf: a) blackbody law – for a blackbody, each temperature produces a unique continuous spectrum with a unique peak wavelength (λmax). The shape of this spectrum across the filter bandwidths determines the colors measured. b) atomic physics – the strength of absorption lines created by a given element depend on the gas temperature.

Tcore: structural equations (like hydrostatic equilibrium), and nuclear physics

Figure 17-9
Blackbody Curve

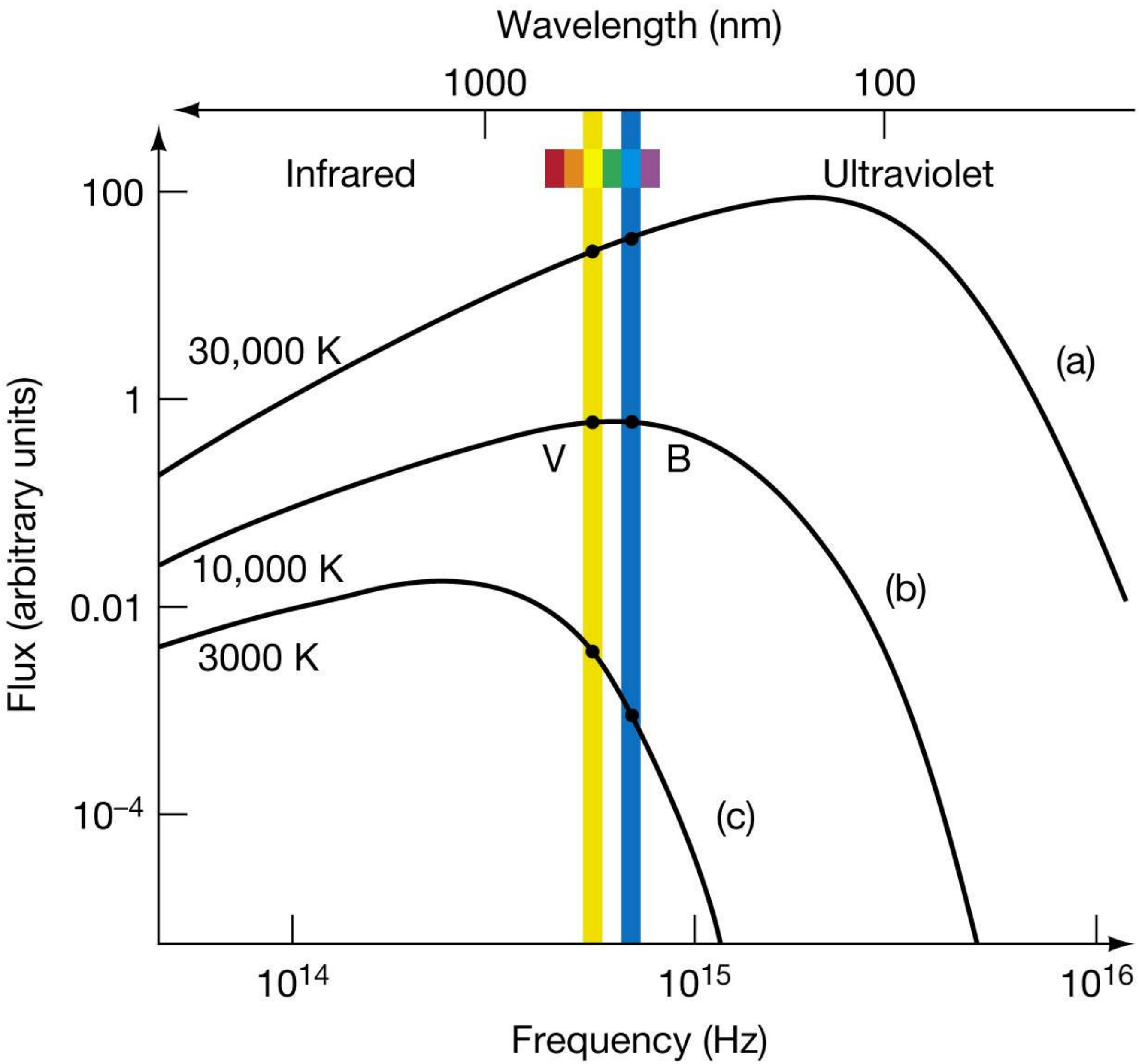
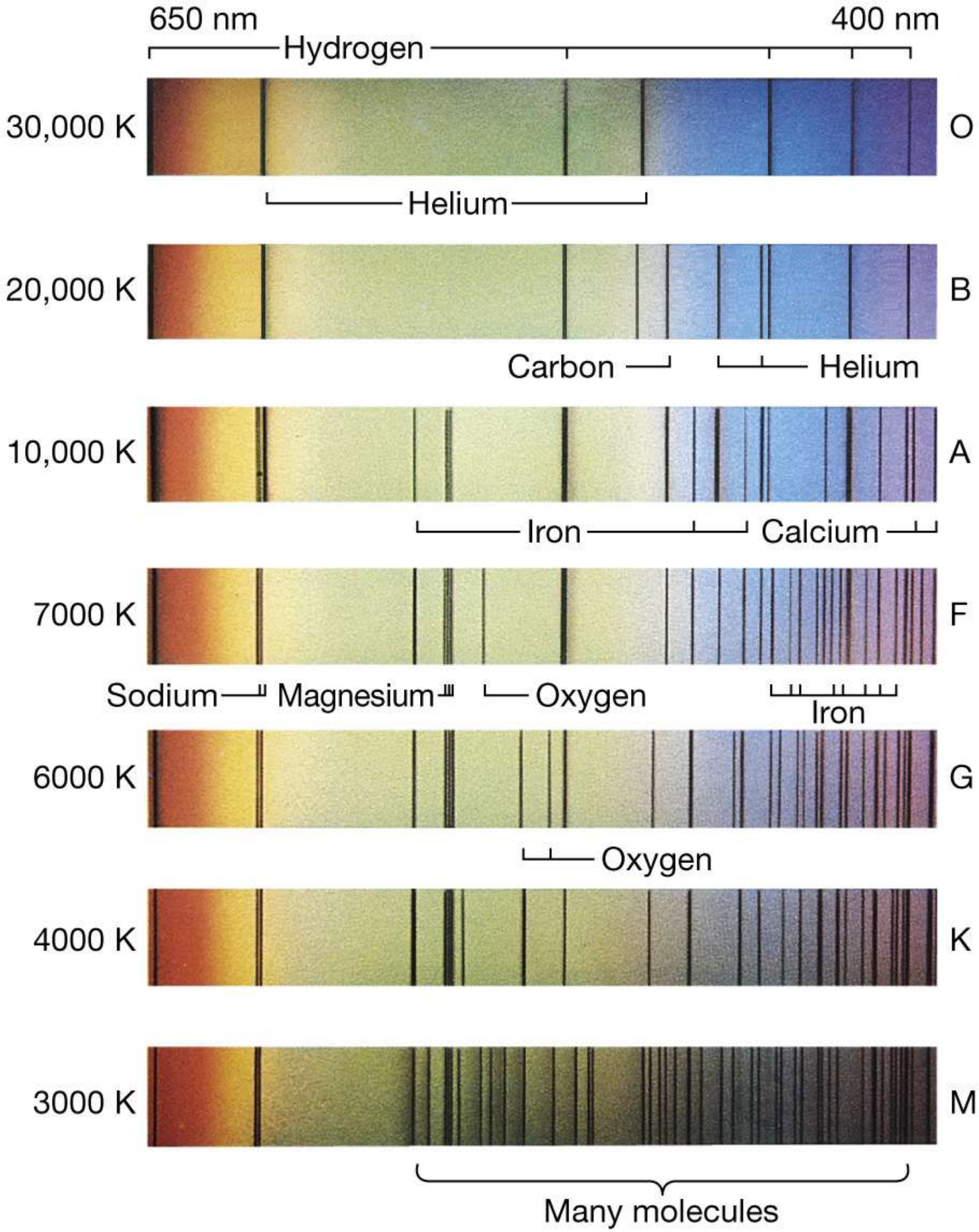


Figure 17-10
Stellar Spectra



Core temperature is found by creating a stellar model. You observe things like radius, total mass, and luminosity, and these will constrain the model. The model requires several physics equations and knowledge of the temperature and density required for nuclear fusion.

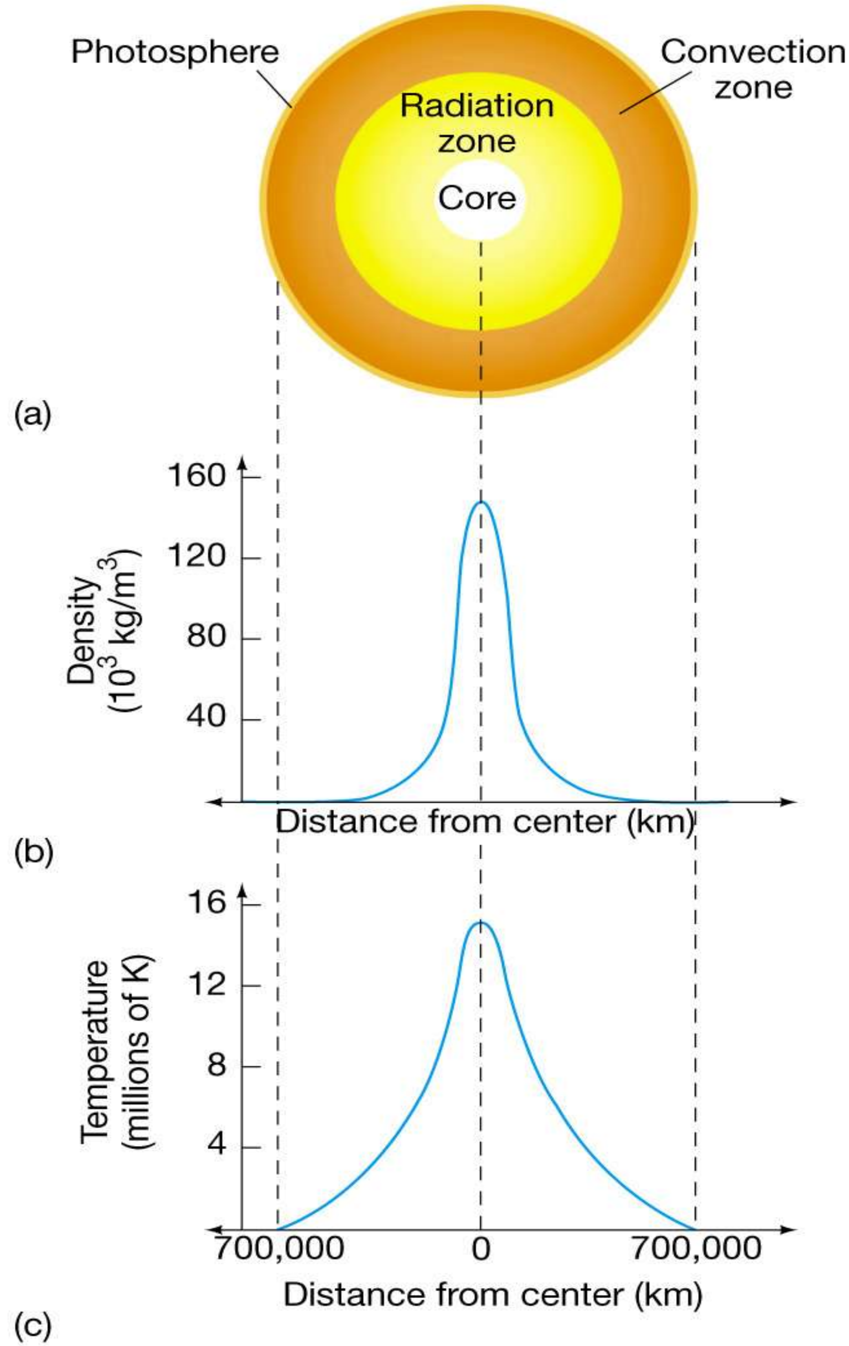


Table 17-1
Stellar Colors and Temperatures

TABLE 17.1 Stellar Colors and Temperatures

$\frac{\text{B flux}}{\text{V flux}}$	Approximate Surface Temperature (K)	Color	Familiar Examples
1.3	30,000	blue-violet	Mintaka (δ Orionis)
1.3	30,000	blue-violet	Mintaka (δ Orionis)
1.2	20,000	blue	Rigel
1.00	10,000	white	Vega, Sirius
0.72	7000	yellow-white	Canopus
0.55	6000	yellow	Sun, Alpha Centauri
0.33	4000	orange	Arcturus, Aldebaran

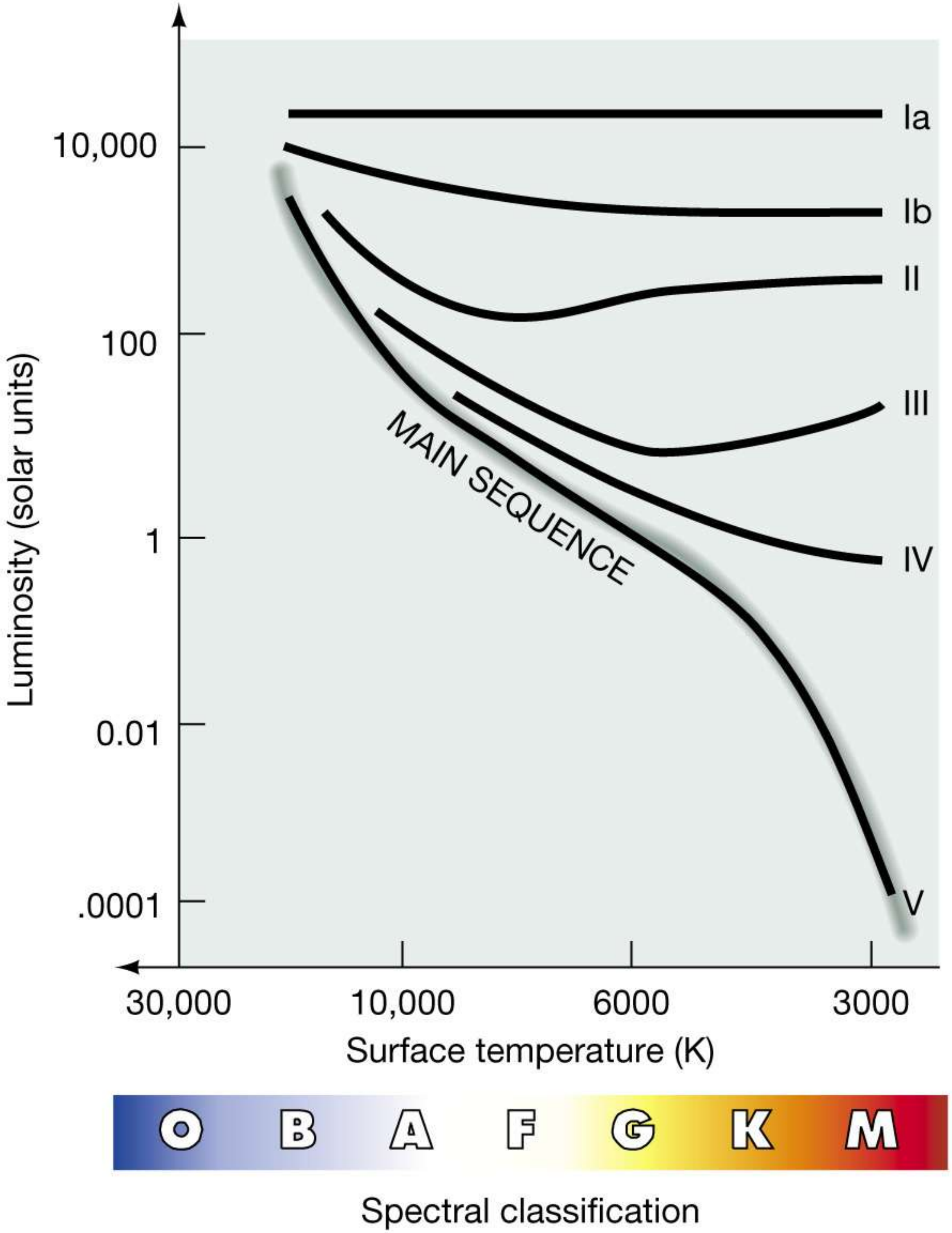


Figure 17-18
Luminosity Classes

Table 17-4
Variation in Stellar Properties within a Spectral Class

TABLE 17.4 Variation in Stellar Properties within a Spectral Class

Approximate Surface Temperature (K)	Luminosity (solar luminosities)	Radius (solar radii)	Object	Example
4900	0.3	0.8	K2V main-sequence star	ε Eridani
4500	110	21	K2III red giant	Arcturus
4300	4000	140	K2Ib red supergiant	ε Pegasi

Mass

a) Values for the Sun

Msun = 2x10^30 kg

b) Range of values for other stars

0.08 Msun - ~50 Msun

c) How it's measured

Observations of binary stars. Example: for eclipsing binaries, get the period from the light curve (photometry), get the mass ratios and the true speeds from the doppler effect (spectra).

Or, for visual binaries (those where two stars can be resolved), one can get the relative masses from the relative sizes of the orbits.

$$m_1/m_2 = r_2/r_1 \quad \text{or } m_1/m_2 = v_2/v_1$$

d) Theory behind interpretation of measurement.

Kepler's 3rd law (with Newton's modification):

$$P^2=4\pi R^3/G(m_1+m_2)$$

Figure 17-19
Visual Binary

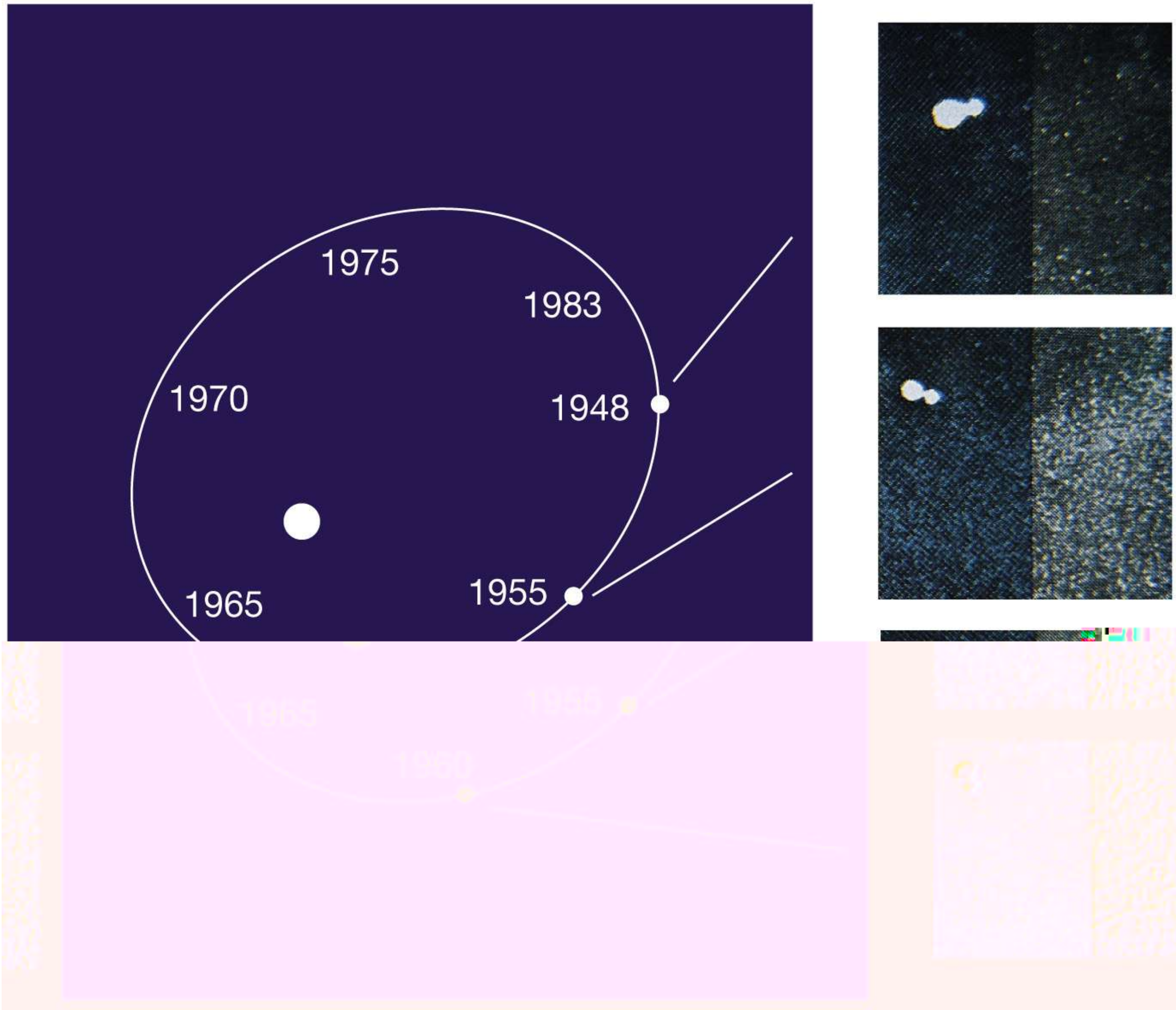


Figure 17-24
Stellar Radii and Luminosities