Chapter 11: Characterizing Stars

A. Distances

1. Trigonometric Parallax

$$d = 1/p$$

Distance (d) is determined in parsecs (pc), where 1 parsec = 3.26 light years.
Parallax angle (p) is measured in seconds of arc (").
A star at a distance of 1 parsec will show a parallax of 1".

a. Nearest star (Proxima Centauri) has p = 0".76.

b. Barnard's Star has p = 0".55.

c. Smallest parallaxes have p = 0".03 (d = 33 parsecs)

B. Stellar Motions

1. Space Velocity has two components:

a. Transverse velocity: motion perpendicular to the line of sight. Measured quantity is in units of seconds of arc per year (proper motion).

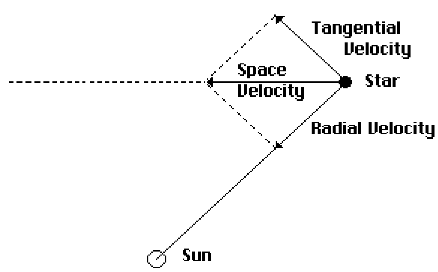
i. Measured by taking photographs spaced by several decades and measuring the angular change and converting the angular change into km/s using the distance.

$$V_T = 4.7\mu d$$

μ is the proper motion, and d is the distance in parsecs.

b. Radial velocity: motion along the line of sight. Measured with a spectroscope, using the Doppler effect.

c. Radial and transverse velocities are combined to find the true space velocity.



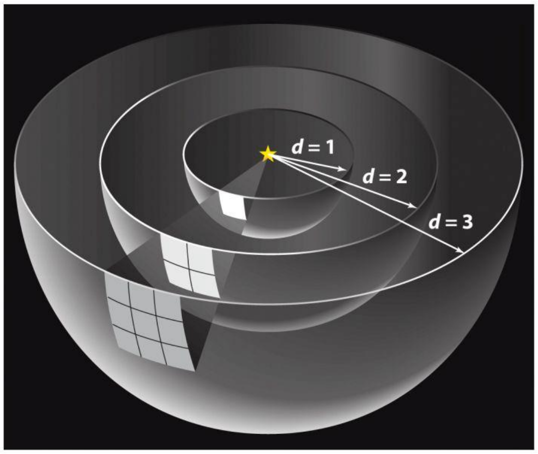
C. Luminosity and Brightness

1. Luminosity: total energy output of a star.

2. Apparent Brightness: depends on a star's luminosity and distance.

   a. Inverse Square Law: brightness is proportional to the inverse of the distance squared.

$$\text{brightness} \propto \frac{1}{d^2}$$



   b. More precisely:

$$\text{brightness} = \frac{L}{4 \pi d^2}$$

3. Magnitude Scale: a means of measuring apparent brightness.

   a. originally established by the Greek astronomer Hipparchus.

   b. brightest star was designated first magnitude.

   c. faintest star was designated sixth magnitude.

   d. one magnitude corresponds to a brightness difference of 2.5.

   e. Modern magnitude scale defines 5 magnitudes as being equivalent to a factor of exactly 100 in apparent brightness.

$$(2.512)^5 = 100$$

   f. Objects brighter than magnitude 0 are given negative magnitudes.

Examples:		
	Sirius:	-1.44
	Full Moon:	-12.6
	Sun:	- 26.7

g. Limiting magnitudes (faintest stars that can be seen):

i. human eye:	+6
ii. binoculars:	+10
iii. 8 inch telescope:	+14
iv. Hubble Space Telescope:	+30

h. Magnitude scale is a reverse scale!

4. Absolute Brightness: apparent brightness a star would have if placed at a distance of 10 parsecs (32.6 light years).

a. Depends only on luminosity, since we are dealing with a common distance.

b. Determined by:

i. measuring a star's flux.

ii. measuring its distance.

iii. applying the inverse square law.

c. Relation between distance, apparent magnitude and absolute magnitude.

$$m - M = 5 \log d - 5$$

m – M is called the distance modulus.

Concept Test

Star G has an apparent magnitude of +5.0 and an absolute magnitude of +4.0.
Star H has an apparent magnitude of +4.0 and an absolute magnitude of +4.0.
Which star will appear brighter in the night sky?

a) Star G
b) Star H
c) They will appear the same.

Which star is emitting the greater amount of energy?

a) Star G
b) Star H
c) They are the same.

D. Temperatures and Colors:

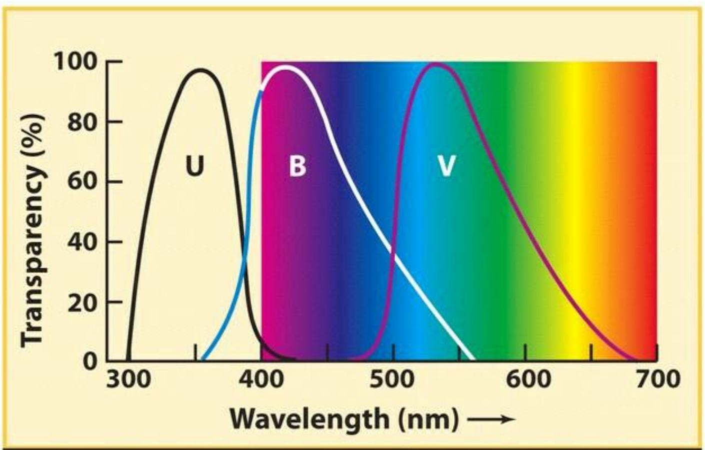
1. Temperature: determined by measuring the black body curve at several wavelengths using photometry (UBV photometry most commonly used).

2. Color Index: a method that astronomers use to determine temperatures of stars.

   a. Observe star's brightness through three filters:

Ultraviolet filter(U):	300 - 390 nm
Blue filter (B):	390 - 490 nm
Visual filter (V):	500 - 590 nm

Brightness' are expressed as magnitudes.



   b. Color Ratios b_U/b_B and b_V/b_B (a measure of a star's temperature)

Hot stars have color ratios less than one.

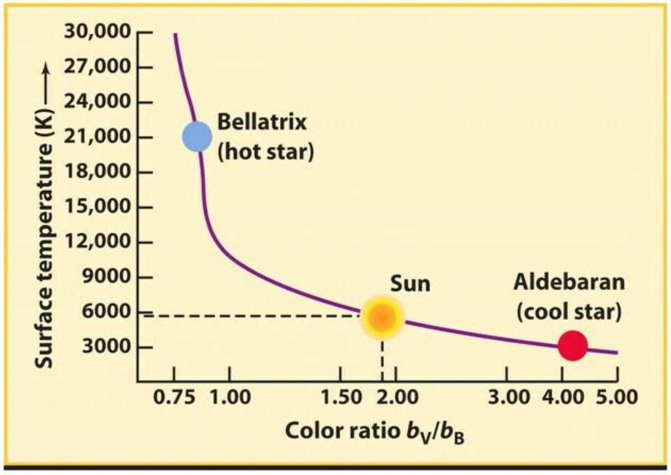
Cool stars have color ratios greater than one.

UBV Filters

Concept Test

Star G has a color ratio b_V/b_B of –0.5 and star H has a color ratio b_V/b_B of +1.0.
Which star is hotter?

a) Star G
b) Star H
c) They are the same.



Color Ratios

E. Spectral Classification: process of arranging spectra by temperature.

1. Spectra are arranged into seven main categories:

O, B, A, F G, K, M

Hot ----------> Cool

"Oh Be A Fine Guy/Girl Kiss Me"

2. Each letter category is subdivided into ten numerical subcategories.

Example: A0, A1, A2,..., A9

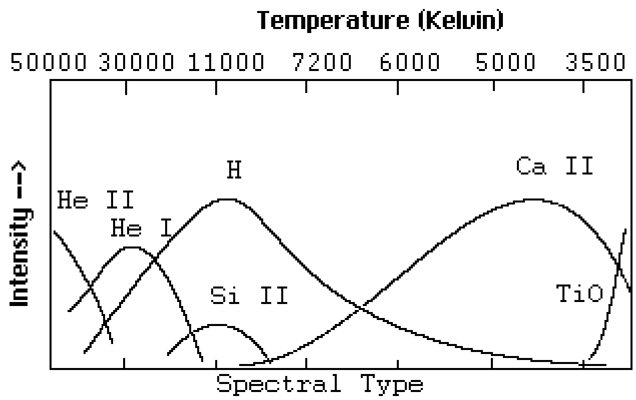
Note: Not all letter categories have exactly ten subcategories.

3. Spectra are classified by the strengths of the lines of hydrogen, helium, and heavier metals.

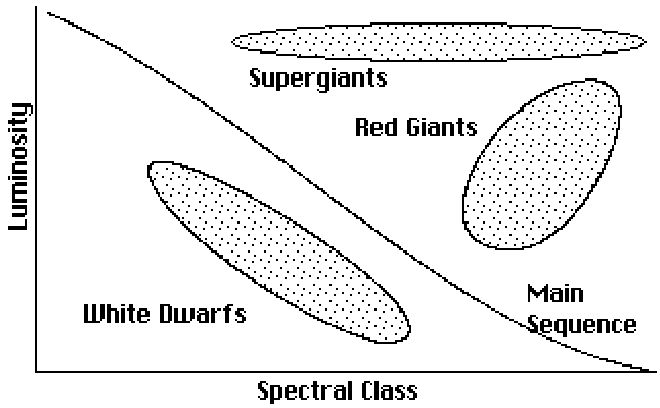
table 19-2 The Spectral Sequence				
Spectral class	Color	Temperature (K)	Spectral lines	Examples
O	Blue-violet	30,000–50,000	Ionized atoms, especially helium	Naos (ζ Puppis), Mintaka (δ Orionis)
B	Blue-white	11,000–30,000	Neutral helium, some hydrogen	Spica (α Virginis), Rigel (β Orionis)
A	White	7500–11,000	Strong hydrogen, some ionized metals	Sirius (α Canis Majoris), Vega (α Lyrae)
F	Yellow-white	5900–7500	Hydrogen and ionized metals such as calcium and iron	Canopus (α Carinae), Procyon (α Canis Minoris)
G	Yellow	5200–5900	Both neutral and ionized metals, especially ionized calcium	Sun, Capella (α Aurigae)
K	Orange	3900–5200	Neutral metals	Arcturus (α Boötis), Aldebaran (α Tauri)
M	Red-orange	2500–3900	Strong titanium oxide and some neutral calcium	Antares (α Scorpii), Betelgeuse (α Orionis)
L	Red	1300–2500	Neutral potassium, rubidium, and cesium, and metal hydrides	Brown dwarf Teide 1
T	Red	below 1300	Strong neutral potassium and some water (H_2O)	Brown dwarf Gliese 229B

Note: Astronomers refer to all elements other than hydrogen and helium as "metals".

4. The previous diagram can be represented by a graph like the following:



F. Hertzsprung-Russell Diagram: Plot of Luminosity vs. Temperature.



1. Color-Magnitude diagram: often spectral types are used instead of temperatures and magnitudes instead of luminosity.

2. Spectroscopic Parallaxes: distance is determined knowing the apparent and absolute magnitudes.

    a. HR diagram provides the absolute magnitude.

        i. Measure temperature and find absolute magnitude from HR diagram.

3. Luminosity Class: width of absorption lines tells astronomers about the density of the atmosphere which reveals where on the HR diagram a star belongs.

    a. Narrow lines: Giants or supergiants. The extended atmospheres have lower densities which in turn result in narrower lines.

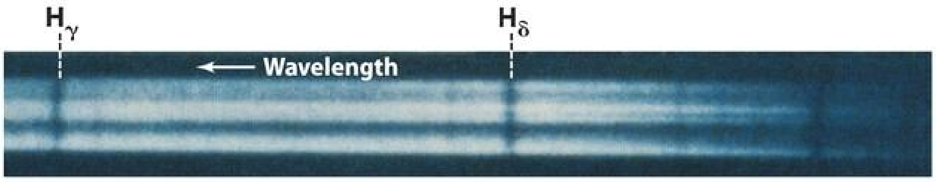
    b. Wide lines: White dwarfs. High density atmospheres produce wider lines.

    c. Luminosity classes:

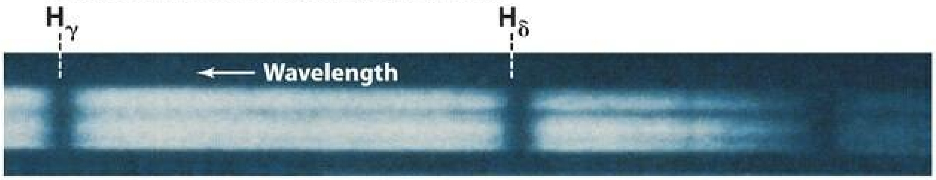
Ia	Bright Supergiants
Ib	Supergiants
II	Bright Giants
III	Giants
IV	Subgiants

V   Main-sequence

D   White Dwarfs



(a) A supergiant star has a low-density, low-pressure atmosphere: its spectrum has narrow absorption lines



(b) A main-sequence star has a denser, higher-pressure atmosphere: its spectrum has broad absorption lines

d. Giants vs. Dwarfs

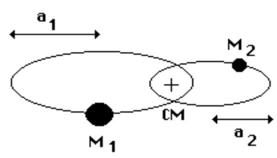
Supergiants	- radii greater than 100 times Sun's radius.
Giants	- radii 10 to 100 times Sun's radius.
Dwarfs	- radii 0.01 to 10 times Sun's radius.

G. Stellar Mass: Determines the position of a star on the HR diagram.

1. Composition: Other factor that determines a star's structure and evolution.

2. Masses derived from binary star systems using Kepler's 3rd law and the distance of each star from the center of mass

$(M_1 + M_2)\,P^2 = A^3$, $M_1 A_1 = M_2 A_2$



a. Visual binaries: can be resolved separately.

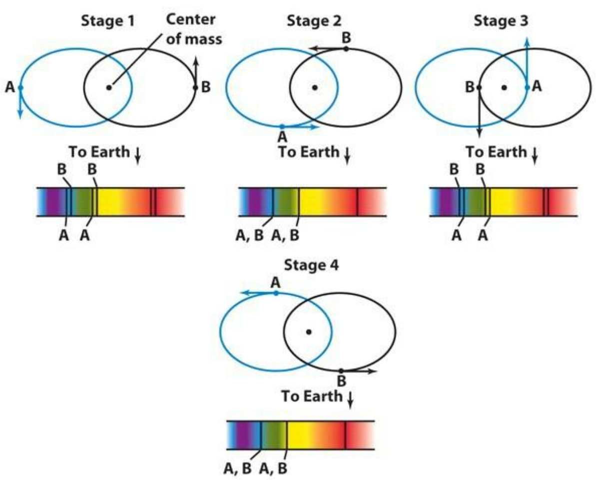
b. Eclipsing binaries: orbital planes are edge on to our line of sight.

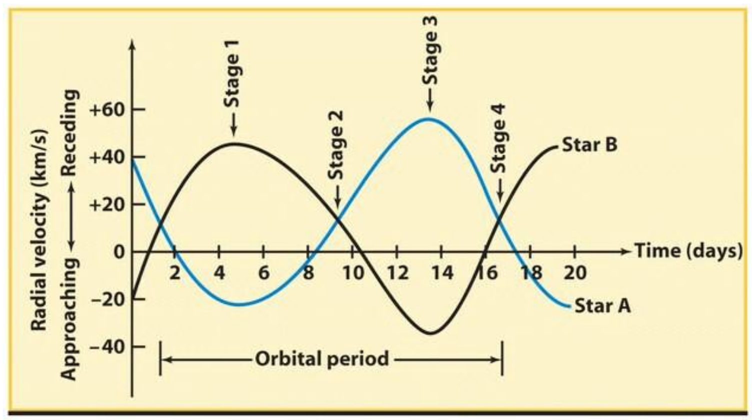
i. Relative temperatures and sizes can be determined from the light curve.

c. Spectroscopic binaries: very distant, unresolveable. Use Doppler shifts to determine period of motion.

i. Information about stellar radii are determined from the radial velocity curve.

ii. If the binary is also an eclipsing binary we can determine the masses of each star





d. Optical doubles: chance superpositions. They hold no information about stellar masses.

3. Properties that depend on mass.

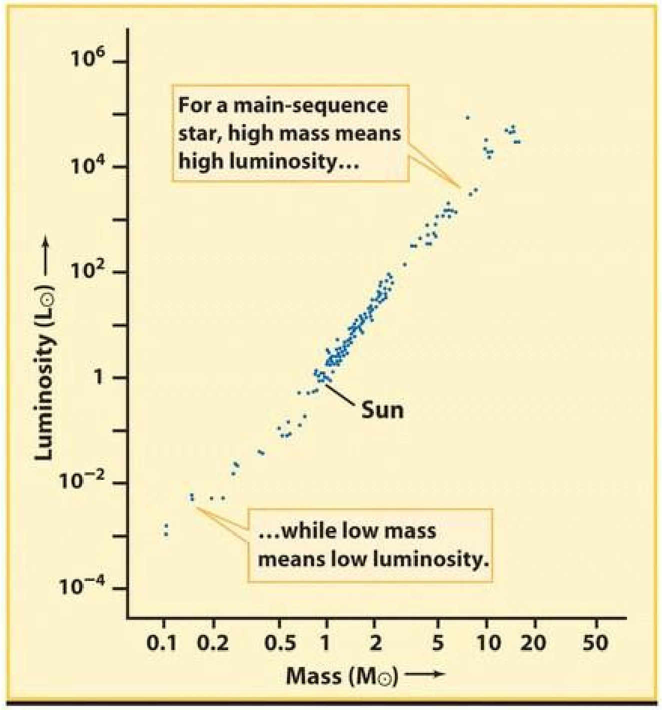
a. Luminosity

b. Radius

c. Lifetime (more on this in chapter 12)

4. Mass-Luminosity Relationship: L^3 proportional to mass.

a. Holds true for main sequence stars.
b. Determined from observations of binary stars where Newton's form of Kepler's 3^{rd} law has been applied.



Mass-Luminosity Relationship