Properties of Stars

Names, Distances, Motions, Brightness,
Spectral Classification, Chemical Abundances,
Radial Velocity, Mass and Luminosity

Reading: Chapter 16

Star Names


η Carinae and the Homunculus Nebula

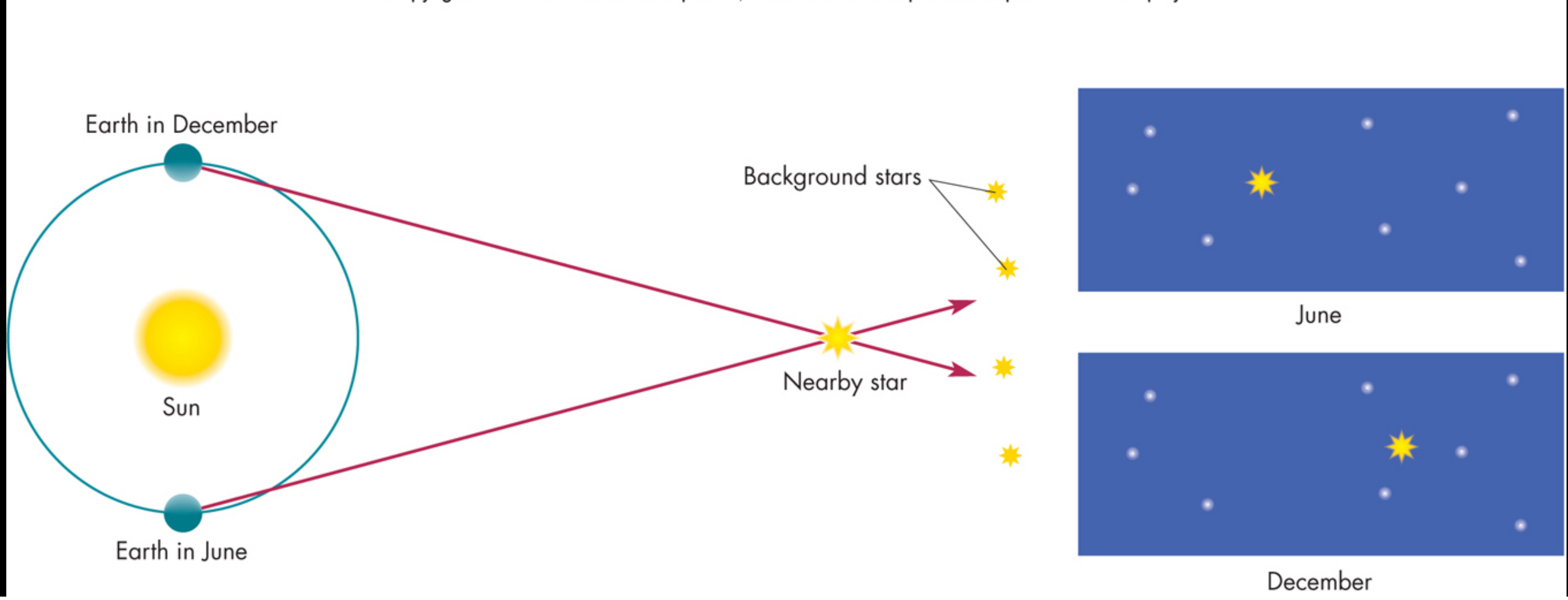
- Arabic names:
  - Altair, Aldebaran, Rigel, …
- Greek names:
  - Sirius, Canopus, …
- Bayer designation:
  - α Aquilae, α Tauri, β Orionis, α Canis Majoris, η Carinae
- Catalog name/number:
  - HIP 32349 (Sirius), IRAS 10431-5925 (η Carinae), HIP 11767 (Polaris)

Distance to Stars

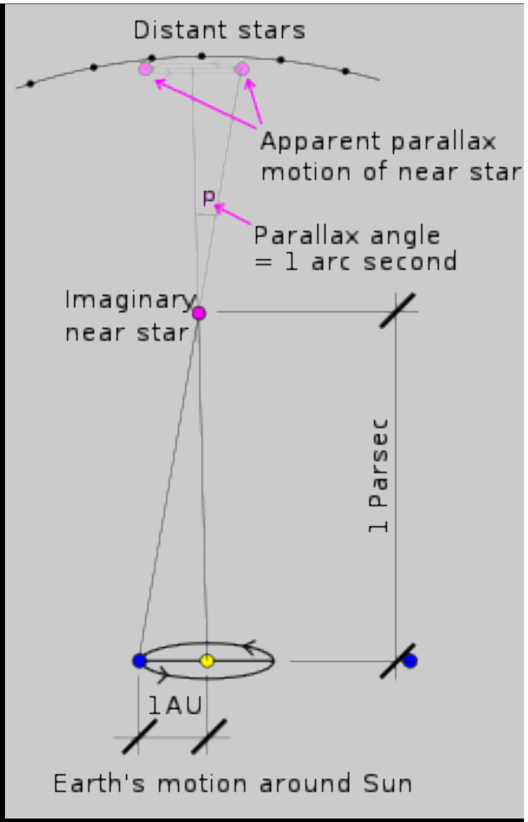
In 1668 James Gregory proposed that the brightness of stars could be used to determine their distances. See Homework #6 for how well that works.

Parallax measurements made using Earth's orbit as the baseline (2 AU) first succeeded in 1838 (Bessel, Struve, Henderson).

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Parsecs and Light Years



Distances are commonly stated in "parsecs" (pc), defined as the distance at which the parallax would be 1 arc second. Then

$$\text{Distance (in parsecs)} = \frac{1}{\text{Parallax (in arc seconds)}}$$

Distances are also stated in "*light years*" (ly), the distance traveled by light in 1 year.

$$1 \text{ pc} = 3.09 \times 10^{16} \text{ m} = 3.26 \text{ ly}$$

Hipparcos

Hipparcos ("High precision parallax collecting satellite") was launched by ESA in 1989. It made high precision measurements of star positions until 1993.

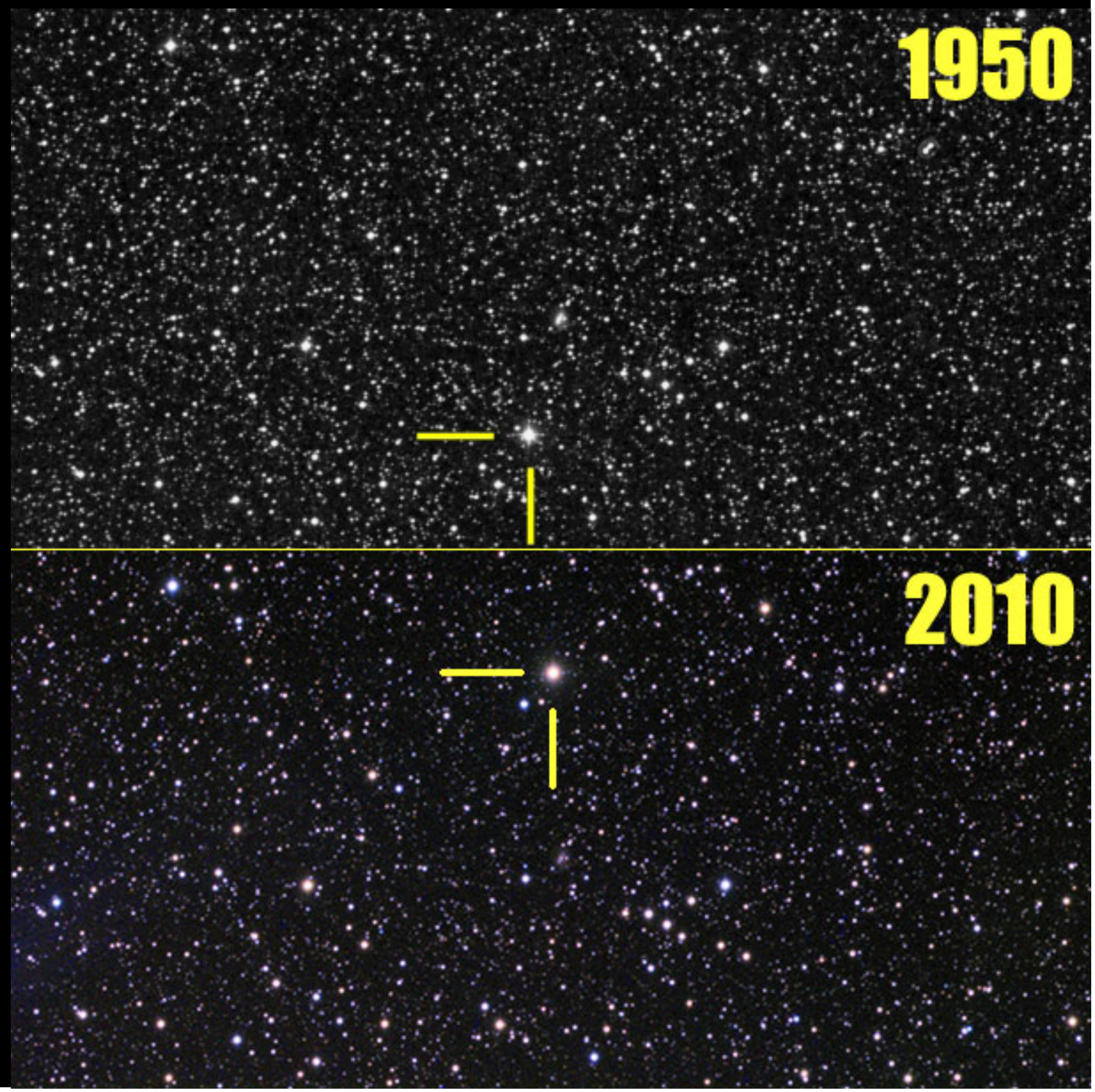
Precision of 0.001”

Catalog of more than 100,000 high-precision star positions published in 1997.

Hipparcos made it possible to determine accurate distances via parallax, and to measure *proper motion.*

Proper Motion

Stars do move over time!

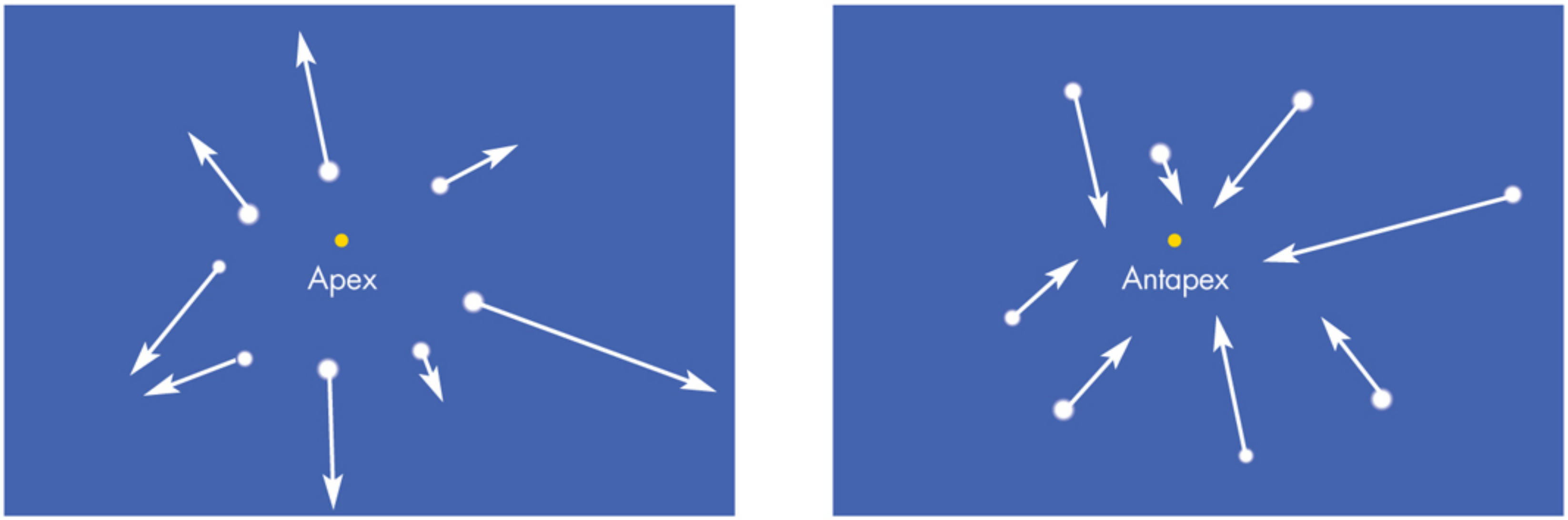


Barnard's Star
(5.98 ly away)
moves 1° in 350 yr

Bad Astronomy: Runaway Star!

Solar Motion

Because the Sun is moving toward Hercules, the proper motion of the stars in that direction is directed out from a point called the “Apex”. (Herschel, 1783)



A View of the stars toward which the Sun is moving **B** View of the stars away from which the Sun is moving

Antapex is in the constellation Columba.

Brightness

Herschel made systematic measurements of the relative brightness of stars, turning the classification scheme of Ptolemy and Hipparchus into a well defined quantitative measurement.

"*Apparent Magnitude*" is how bright the star appears to us on Earth.

"*Absolute Magnitude*" is how bright the star really is.

(Absolute Magnitude is the apparent magnitude of the star if it were at a distance of 10 pc)

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Luminosity

Luminosity is a measure of the total amount of electromagnetic radiation emitted by a star.

Absolute Magnitude is the brightness of just visible light.

The two are related, and both measure intrinsic "brightness".

Apparent Magnitude measures how bright the object appears to the observer.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Table 16.1

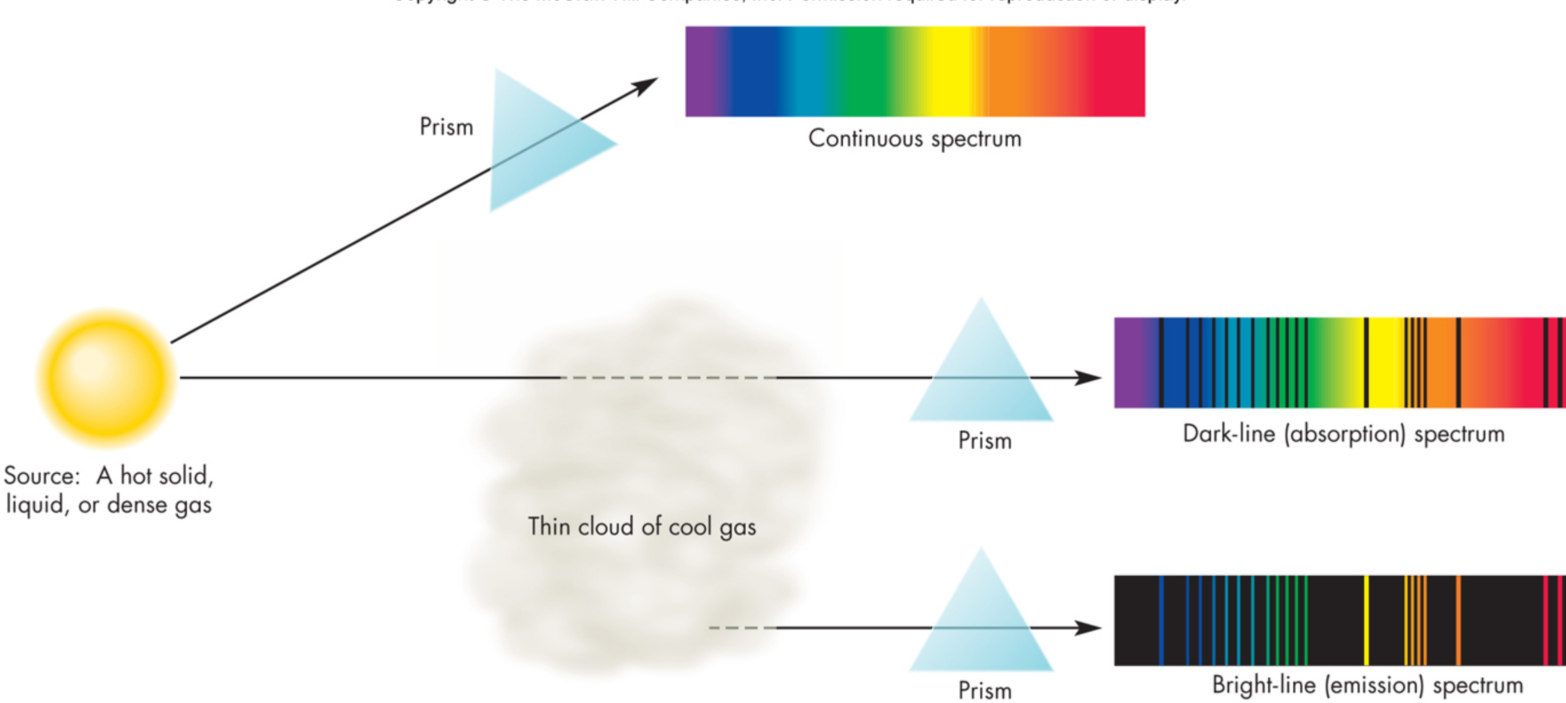
Some Apparent Magnitudes

OBJECT	APPARENT MAGNITUDE
Sun	−26.5
Full Moon	−12.5
Venus (at brightest)	−4.0
Jupiter, Mars (at brightest)	−3.0
Sirius (brightest star)	−1.4
Polaris	2.0
Uranus	5.5
Naked eye limit (dark location)	6.5
Neptune	7.8
Limit with binoculars	10.0
Pluto	15.0
Limit for large telescope	24.0
Limit for *Hubble Space Telescope*	29.0

Stellar Spectra: Kirchhoff's Laws

1. Hot solid, liquid, or dense gas produces a continuous spectrum
2. Hot thin gas produces emmission-line spectrum
3. Cool thin gas in front of continuous spectrum source produces an absorption-line spectrum.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

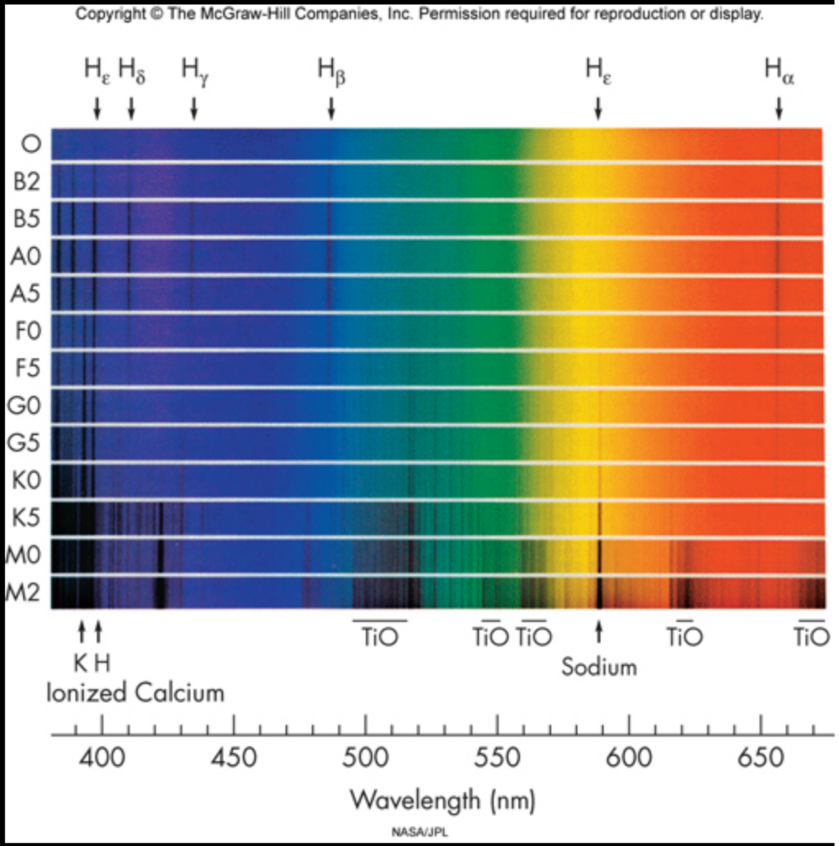


Reason? Quantum Physics and Atoms!

Spectral Classification

Originally just a classification scheme using letters A to O, depending on presence or absence of certain spectral lines.

Later realized that differences are due to temperature, and letters had to be re-arranged. Also added 10 subclasses.



O B A F G K M

/ \

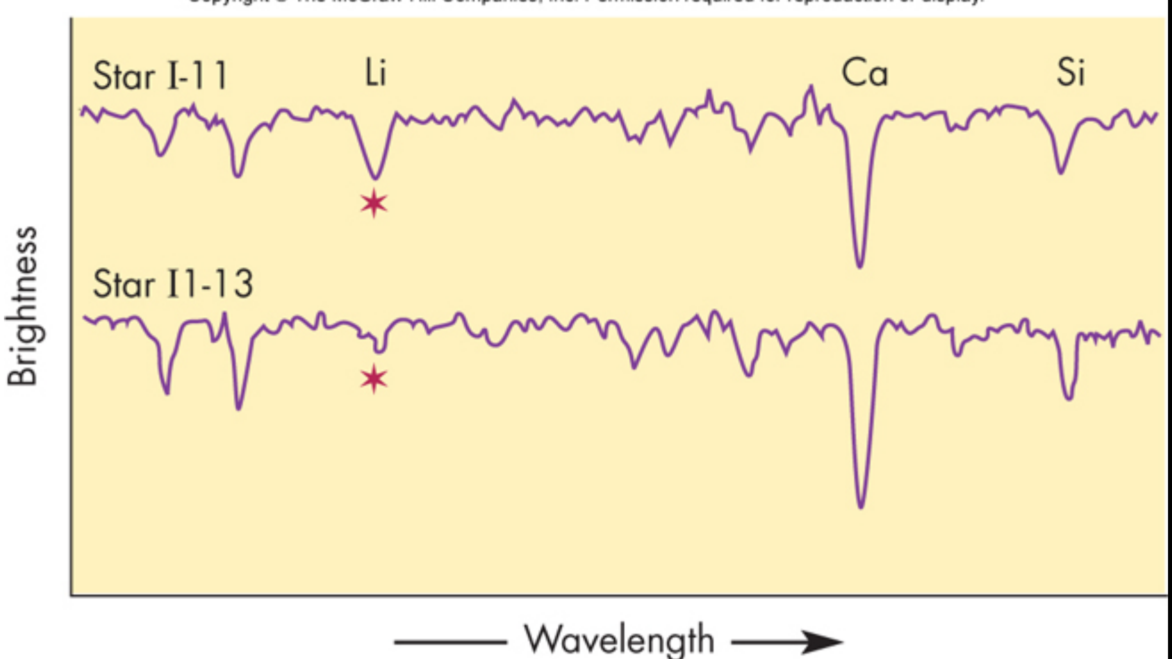
High Temp ← F0 F1 F2 F3 F4 F5 F6 F7 F8 F9 → Low Temp

Chemical Abundance

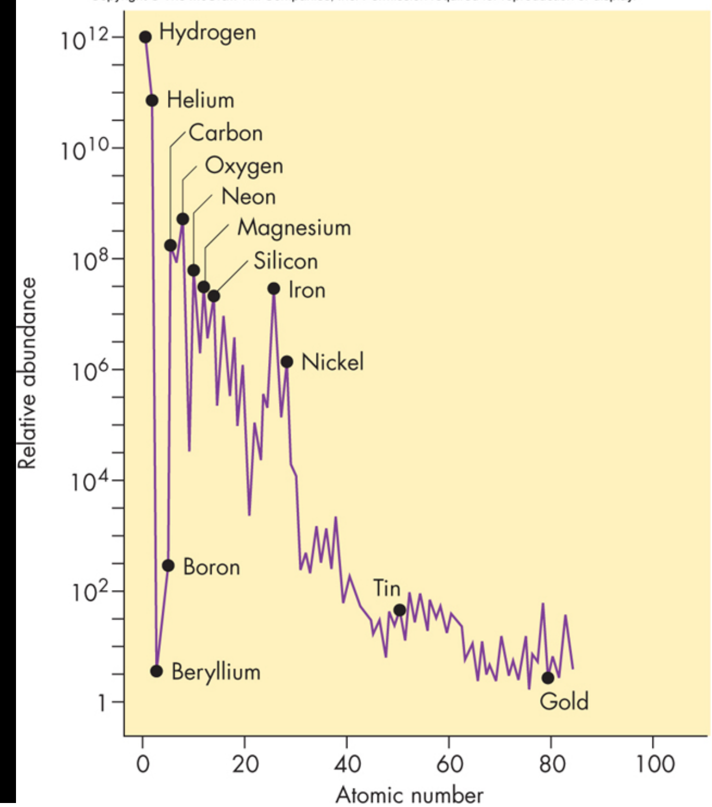
Each element has a unique “fingerprint” of spectral lines.

The relative amount of each element in a star can be determined from the relative strength of absorption lines.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



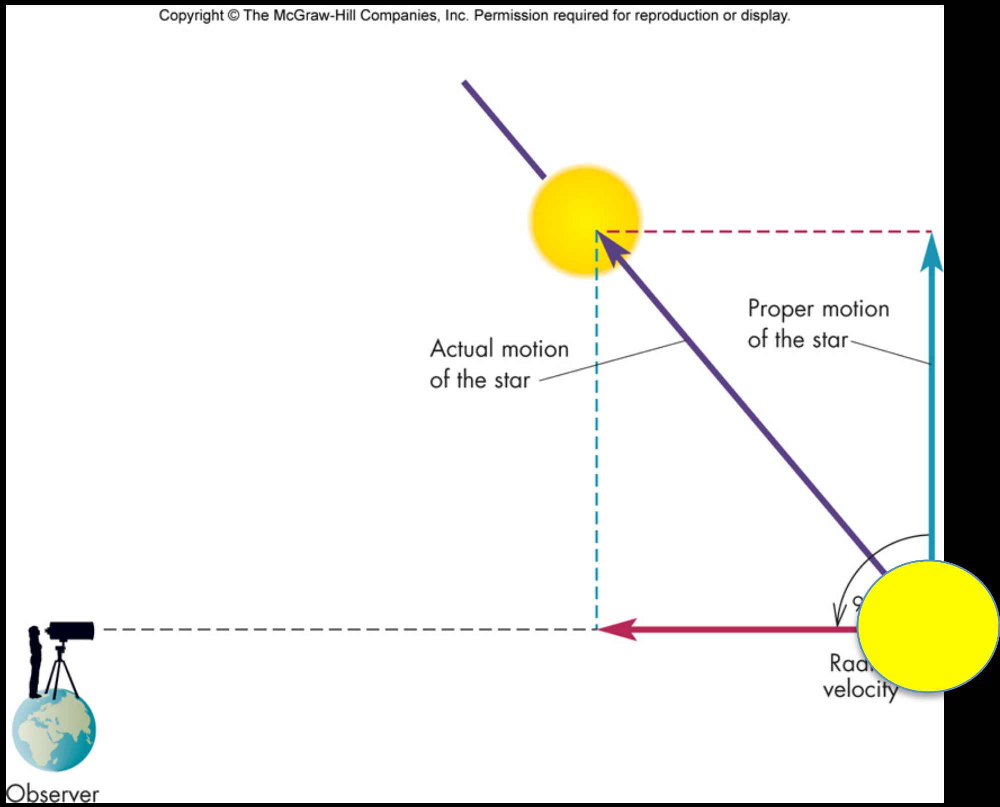
Radial Velocity

The Doppler effect causes spectral lines to shift toward red if the star is moving away from the observer, and toward blue if the star is moving toward the observer. The amount of Doppler shift can be used to compute the velocity of the star in the direction from star to observer.

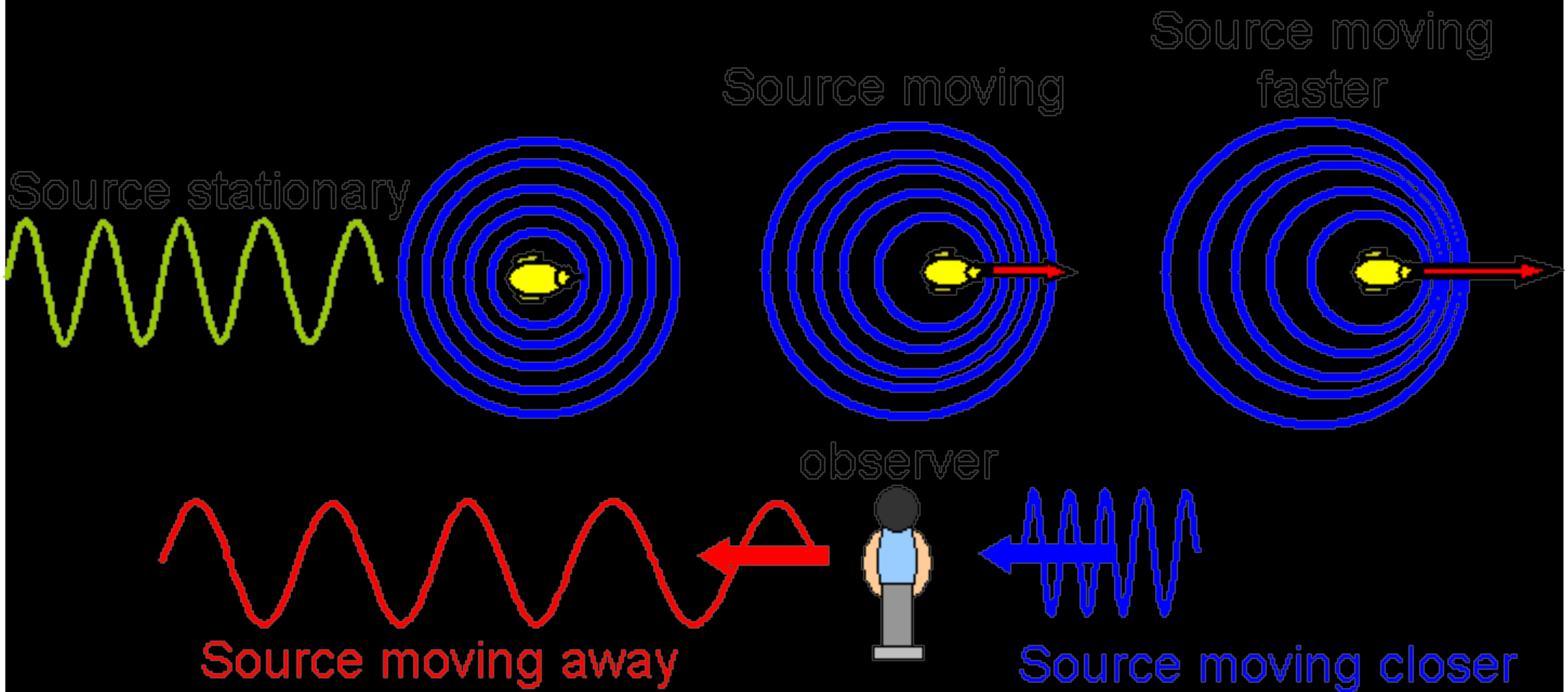
[Animation]

Radial velocity is perpendicular to proper motion!

Figure 16.16 is confusing!
The star is in the wrong place.
The radial velocity should be blue.



Dopper Effect



Source moving away	$\Longrightarrow$	longer wavelength	=	"Red Shift"
Source moving towards	$\Longrightarrow$	shorter wavelength	=	"Blue Shift"

Animation...

H-R Diagrams

Hertzprung (1905) and Russell (1913) independently observed a correlation between spectral type and absolute magnitude.

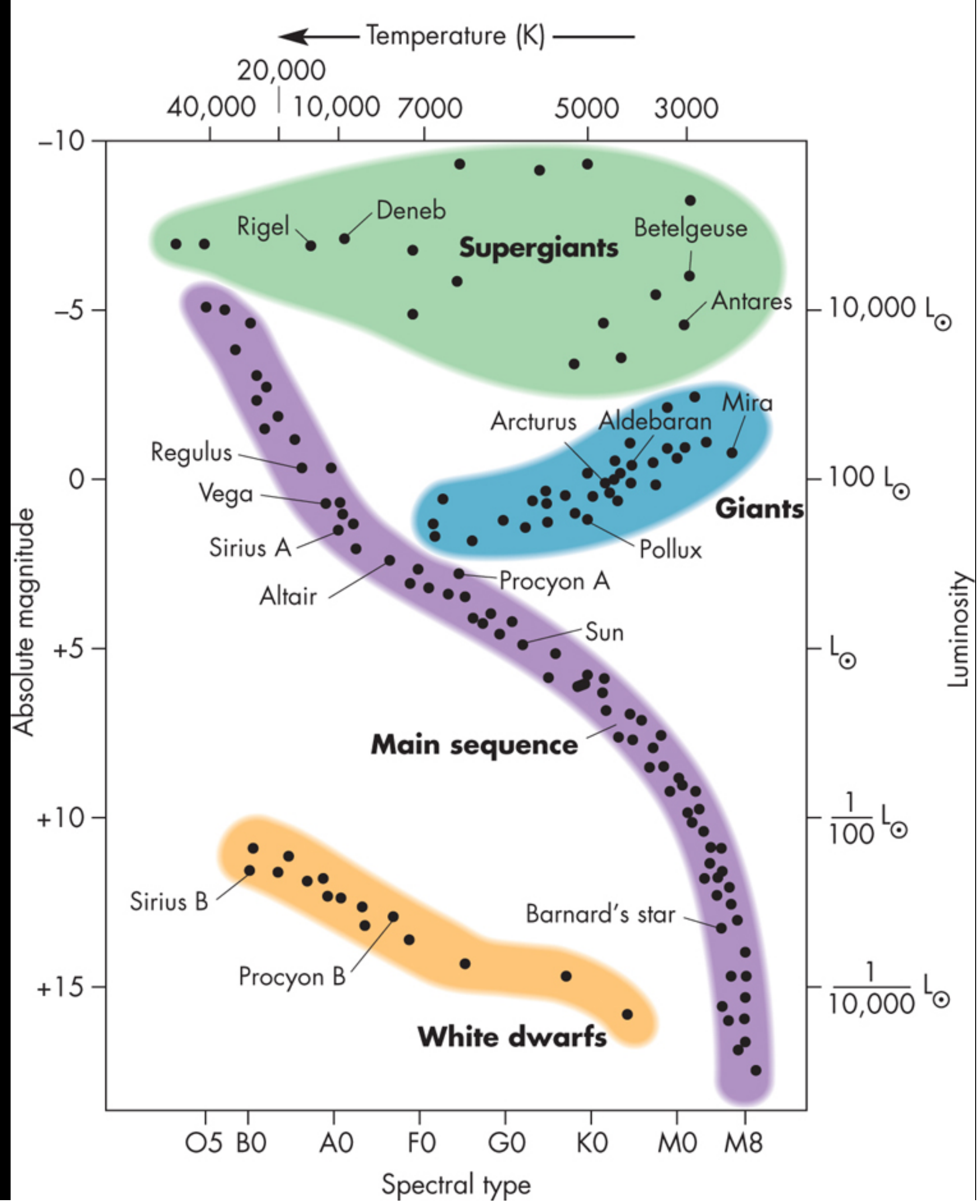
An H-R diagram is a "scattter plot" with a dot for each star in the dataset (catalog).

Temperature may be used in place of spectral type.

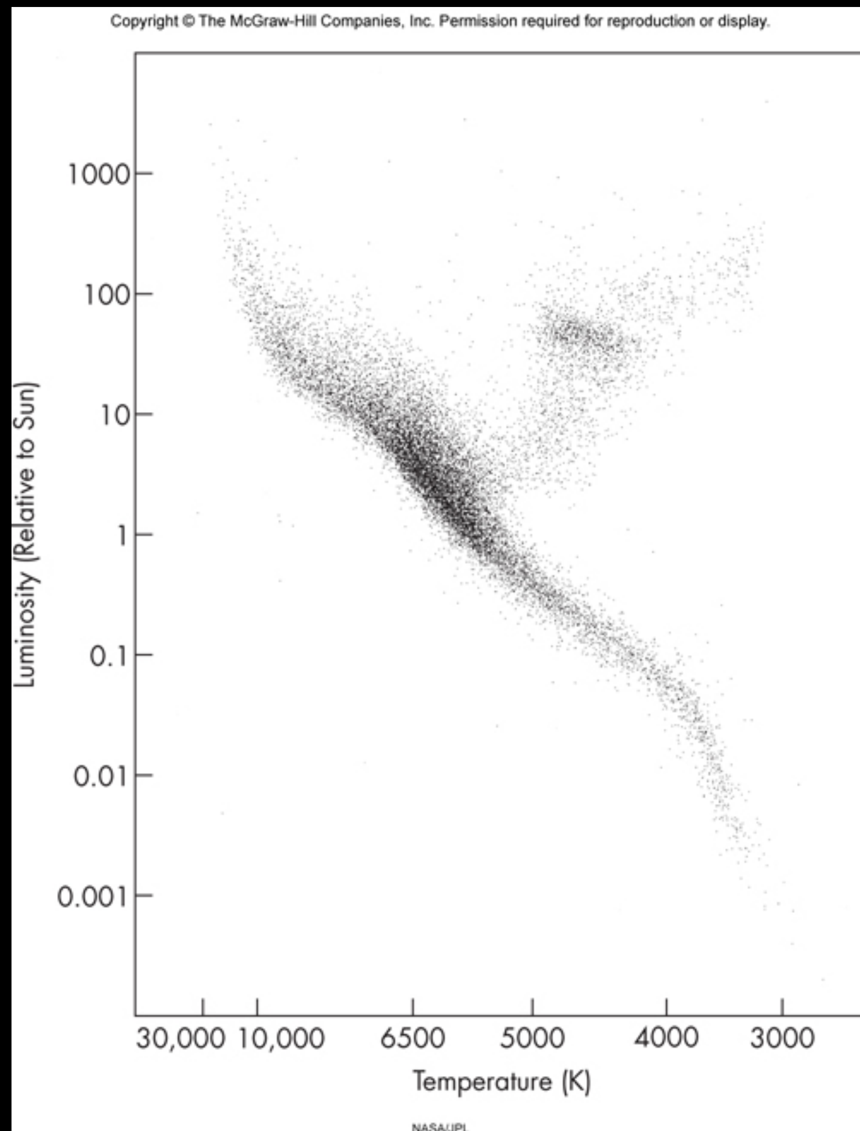
Luminosity may be used in place of absolute magnitude.

Most stars end up on the
"Main Sequence"

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Hipparcos H-R Diagram



Mass –vs- Luminosity

Mass of a star can be determined if it is part of a binary pair (Kepler III).

Luminosity determined from Absolute Magnitude.

Plotting the two for Main Sequence stars shows a strong correlation:

$$\frac{L}{L_\odot} = \left(\frac{M}{M_\odot}\right)^{3.5}$$