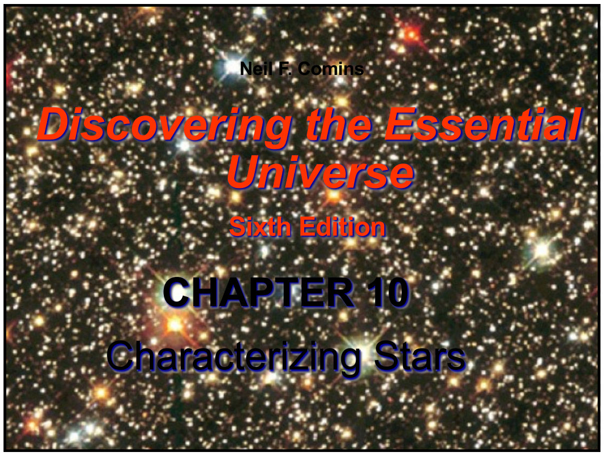
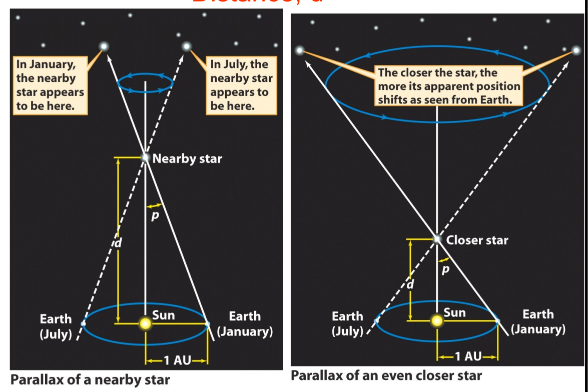


1

Distance, d



2

Careful measurements of the parallaxes of stars reveal their distances

Relation between a star's distance and its parallax

$$d = \frac{1}{p}$$

d = distance to a star, in parsecs

p = parallax angle of that star, in arcseconds

- Distances to the nearer stars can be determined by parallax, the apparent shift of a star against the background stars observed as the Earth moves along its orbit
- Parallax measurements made from orbit, above the blurring effects of the atmosphere, are much more accurate than those made with Earth-based telescopes
- Stellar parallaxes can only be measured for stars within a few hundred parsecs

3

If a star's distance is known, its luminosity can be determined from its brightness

Inverse-square law relating apparent brightness and luminosity

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

b = apparent brightness of a star's light, in W/m^2

L = star's luminosity, in W

d = distance to star, in meters

- A star's luminosity (total power of light output), apparent brightness, and distance from the Earth are related by the inverse-square law
- If any two of these quantities are known, the third can be calculated

4

Determining a star's luminosity from its apparent brightness

$$\frac{L}{L_\odot} = \left(\frac{d}{d_\odot}\right)^2 \frac{b}{b_\odot}$$

$L/L_\odot$ = ratio of the star's luminosity to the Sun's luminosity

$d/d_\odot$ = ratio of the star's distance to the Earth-Sun distance

$b/b_\odot$ = ratio of the star's apparent brightness to the Sun's apparent brightness

5

Astronomers often use the magnitude scale to denote brightness

Introduced by Hipparchus 129 BC

The **apparent magnitude,** m, is an alternative quantity that measures a star's apparent brightness

A 1st mag star is 100 times brighter than a 6th mag star (definition).

Then a 1st mag star is $\sqrt[5]{100}$ = 2.512 times brighter than a 2nd mag star and $(2.512)^2$ times brighter than a 3rd mag star and …

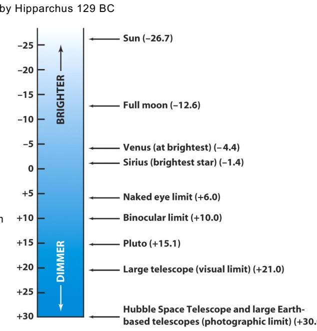
$$m_2 – m_1 = 2.5 \log (b_1/b_2)$$

The **absolute magnitude,** M, of a star is the apparent magnitude it would have if viewed from a distance of 10 pc

$$m – M = 5 \log (d) - 5$$

M of Sun?

M = -5 log (d) + 5 + m
M = -5 log (1/206265) +5 + (-26.7)
M = 4.8



Some apparent magnitudes

6

Distance Modulus

- Consider a star with apparent magnitude, m, and absolute magnitude, M. Then
- m – M = 5 log (d) – 5
- Note that d is in pc
- Further, if d = 10 pc then

  m – M = 5 log (10) – 5

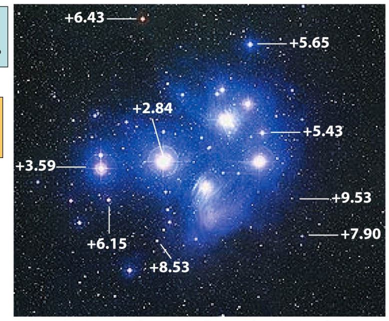
  m – M = 5 – 5

  = 0
- m – M is called the distance modulus

7

What would be the apparent magnitude of the Sun at d = 120 pc?

m–M = 5 log(d) – 5
m = 5 log(120)–5+4.8
m = 10.2



Apparent magnitudes of stars in the Pleiades

d = 120 pc

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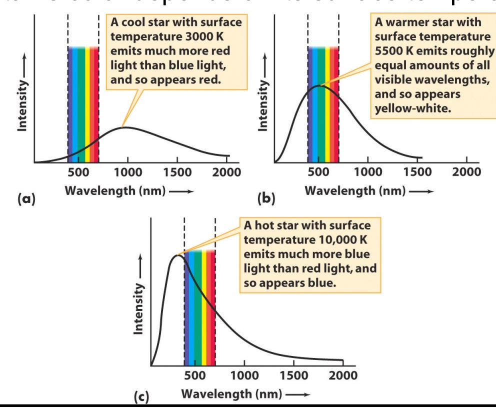
A star's color depends on its surface temperature



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The spectra of stars reveal their chemical compositions as well as surface temperatures

- Stars are classified into spectral types (subdivisions of the spectral classes O, B, A, F, G, K, and M), based on the major patterns of spectral lines in their spectra

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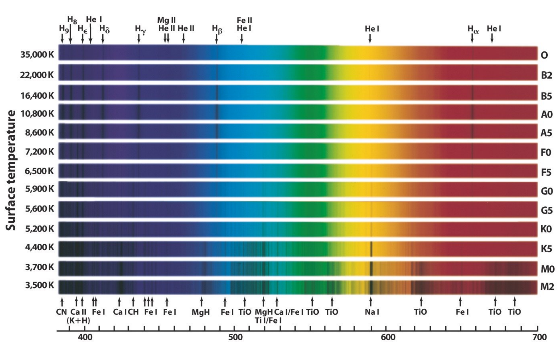
Spectra of stars with different T



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Relationship between a star's luminosity, radius, and surface temperature

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

L = star's luminosity, in watts

R = star's radius, in meters

σ = Stefan-Boltzmann constant = 5.67×10^{-8} W m^{-2} K^{-4}

T = star's surface temperature, in kelvins

Stars come in a wide variety of sizes

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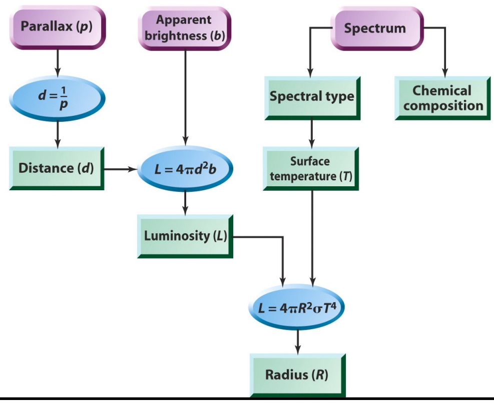
Finding Key Properties of Nearby Stars



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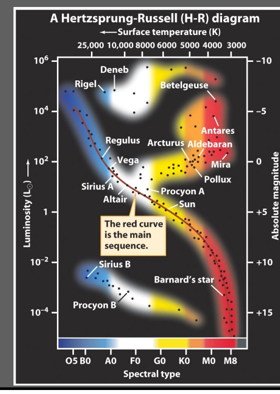
Hertzsprung-Russell (H-R) diagrams reveal the different kinds of stars

- The H-R diagram is a graph plotting the absolute magnitudes of stars against their spectral types—or, equivalently, their luminosities against surface temperatures
- The positions on the H-R diagram of most stars **(90%)** are along the main sequence, a band that extends from high luminosity and high surface temperature to low luminosity and low surface temperature



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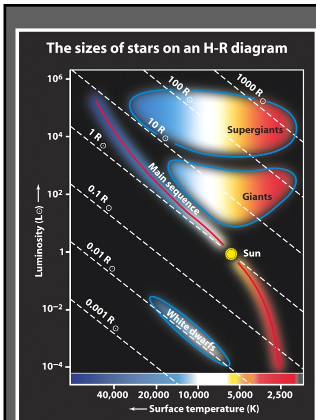

$L = 4\pi R^2 \sigma T^4$

$R = [L/(4\pi\sigma T^4)]^{1/2}$

On the H-R diagram, giant and supergiant stars lie above the main sequence, while white dwarfs are below the main sequence

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Orion

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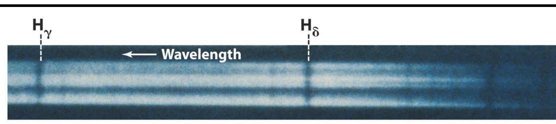
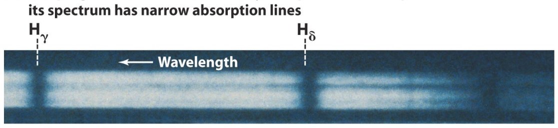


(a) A supergiant star has a low-density, low-pressure atmosphere: its spectrum has narrow absorption lines



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

By carefully examining a star's spectral lines, astronomers can determine whether that star is a main-sequence star, giant, supergiant, or white dwarf

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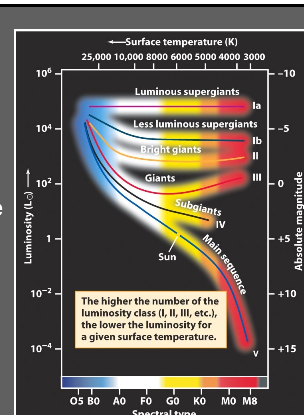
Using the H-R diagram and the inverse square law, the star's luminosity and distance can be found without measuring its stellar parallax



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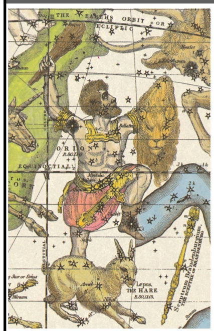
Surface temperature, T



- Ancient peoples looked at the stars and imagined groupings made pictures in the sky and gave them meaning.
- But they were on the wrong track.
- Today we look at the colours and get the surface temperature and the energy flux per m^2.
- With the parallax and apparent brightness we get the luminosity and the radius.
- The life and death of stars

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Orion

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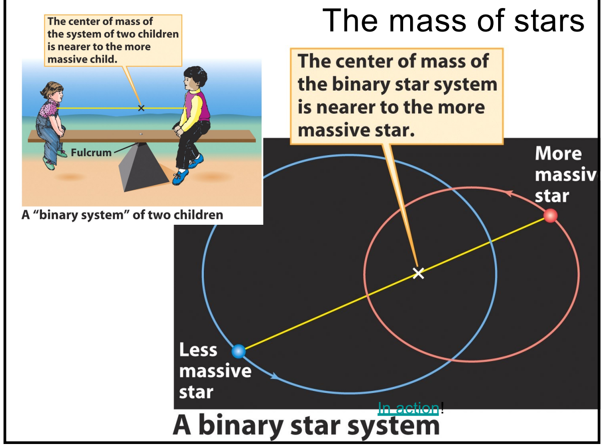
The mass of stars



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Binary star systems provide crucial information about stellar masses

- Binary stars are important because they allow astronomers to determine the masses of the two stars in a binary system
- The masses can be computed from measurements of the orbital period and orbital dimensions of the system

$$M_1 + M_2 = \frac{a^3}{P^2}$$

M_1, M_2 = masses of two stars in binary system, in solar masses

a = semimajor axis of one star's orbit around the other, in AU

P = orbital period, in years

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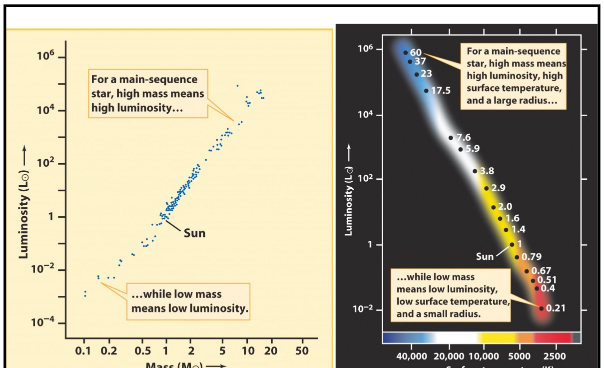

$L/L_{sol} = (M/M_{sol})^{3.5}$ With: $E/E_{sol} = Lt/(L_{sol}\, t_{sol}) = fMc^2/(fM_{sol}\, c^2)$ f: fraction of mass converted into energy

Lifetime on main sequence: $t/t_{sol} = M/M_{sol})^{-2.5}$

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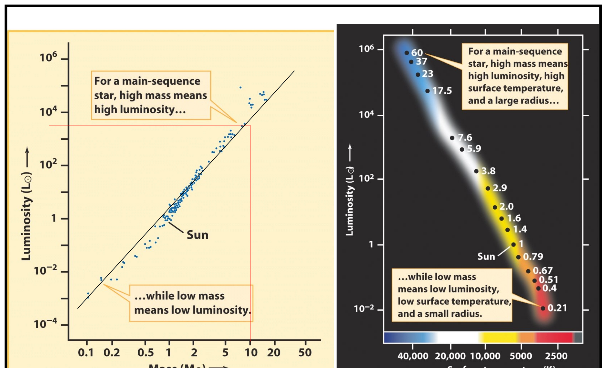

$L/L_{sol} = (M/M_{sol})^{3.5}$ Lifetime on main sequence: $t/t_{sol} = M/M_{sol})^{-2.5}$

$E/E_{sol} = Lt/(L_{sol}\, t_{sol}) = fMc^2/(fM_{sol}\, c^2)$

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