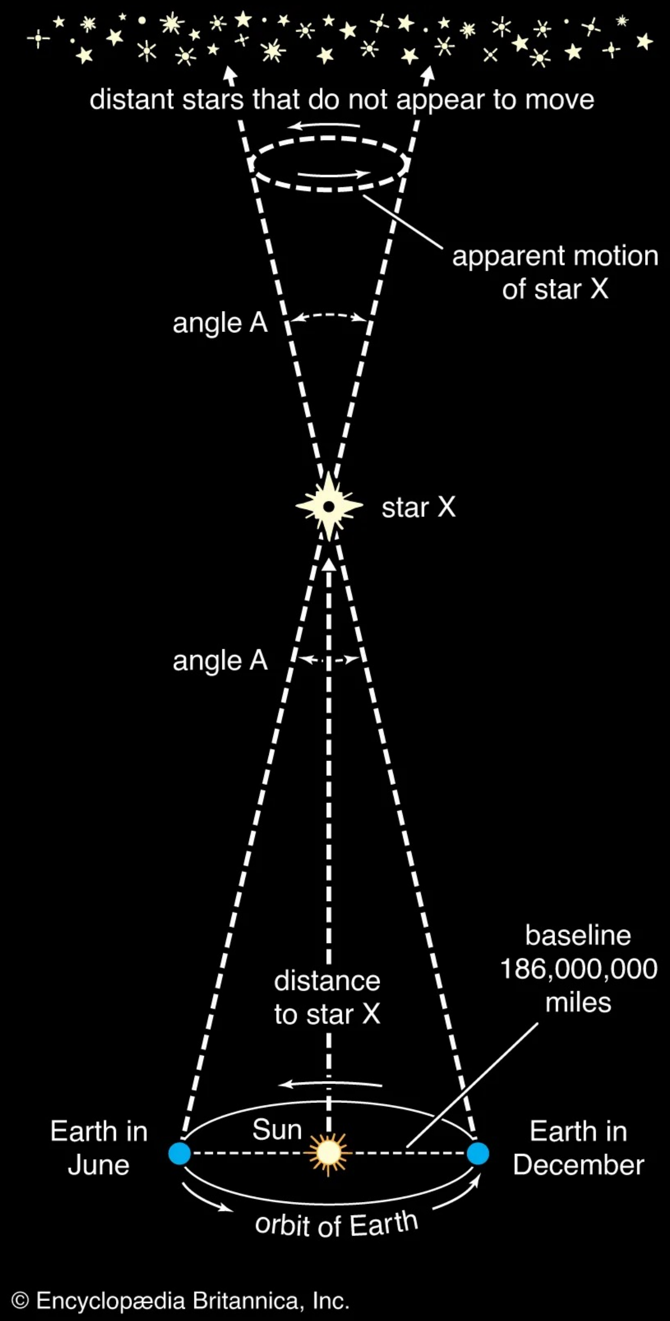
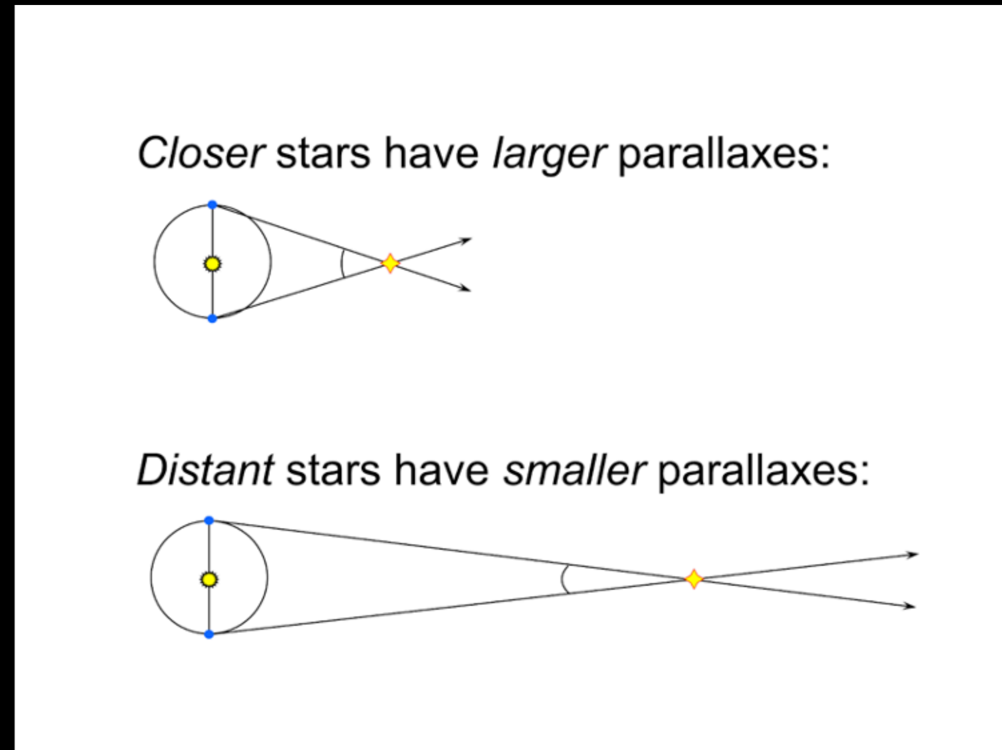
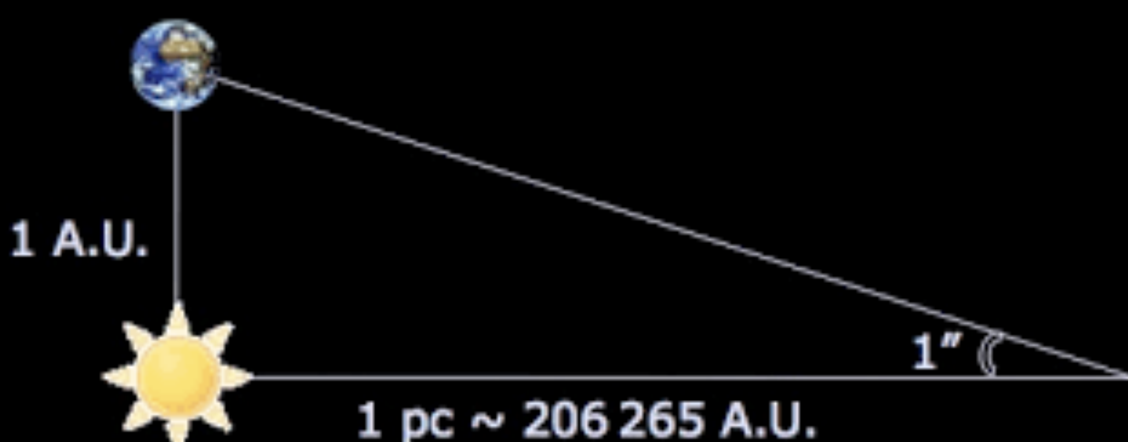


The most direct method to measure the distance to nearby stars is through the use of parallax. The Earth's motion around the Sun every year produces a very small shift in nearby star's position in the sky compared to distant, background stars. This shift is always less than one arcsec for any star, which is very small (where a circle is 360 degrees, one degree is 60 arcminutes, one arcminute is 60 arcsecs).



Source: Ohio State University



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

d = *distance to star in parsecs*

p = *parallax angle of star in arcseconds*

Distance is measured in parsecs, where one parsec equals 3.26 light-years (the distance light travels in one year).

DISTANCES LIGHT YEAR / PARSEC

Earth / Moon	1.3 light seconds
Sun / Earth	8 light minutes
Sun / Neptune	4 light hours
Sun / Proxima Centuri (Nearest Star)	4.2 light years
Sun / Polaris	433 light-years
Sun / Centre of Milky Way	100,000 light years
Milky Way / Andromeda Galaxy	2.537 million light years

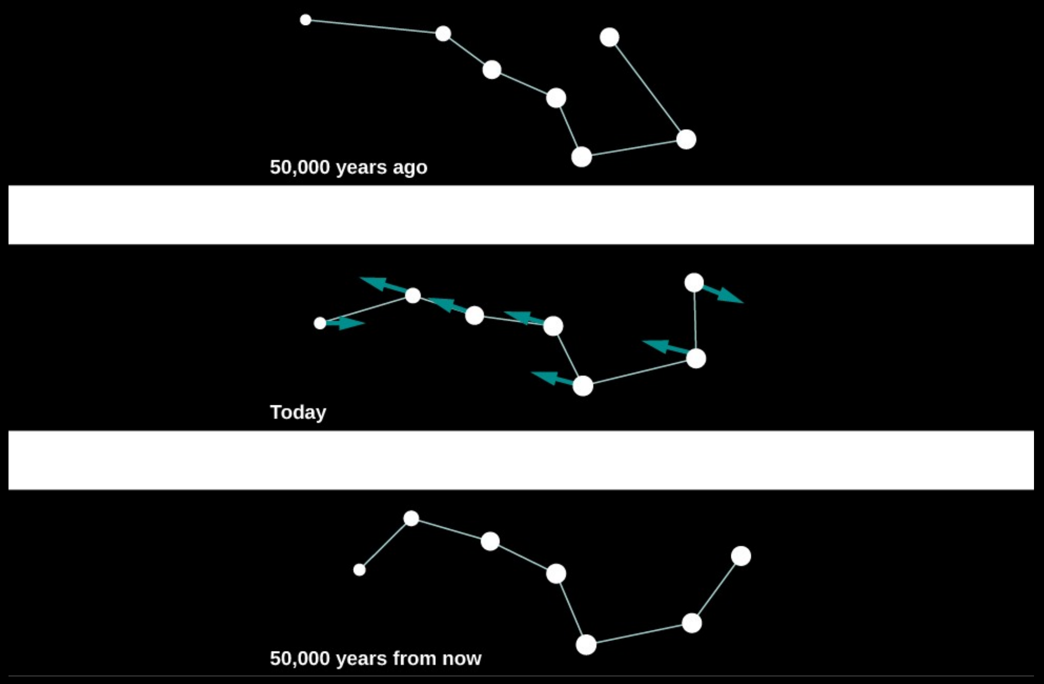
Speed of Light =
300,000,000
metres per second

Light Year =
9460 billion km

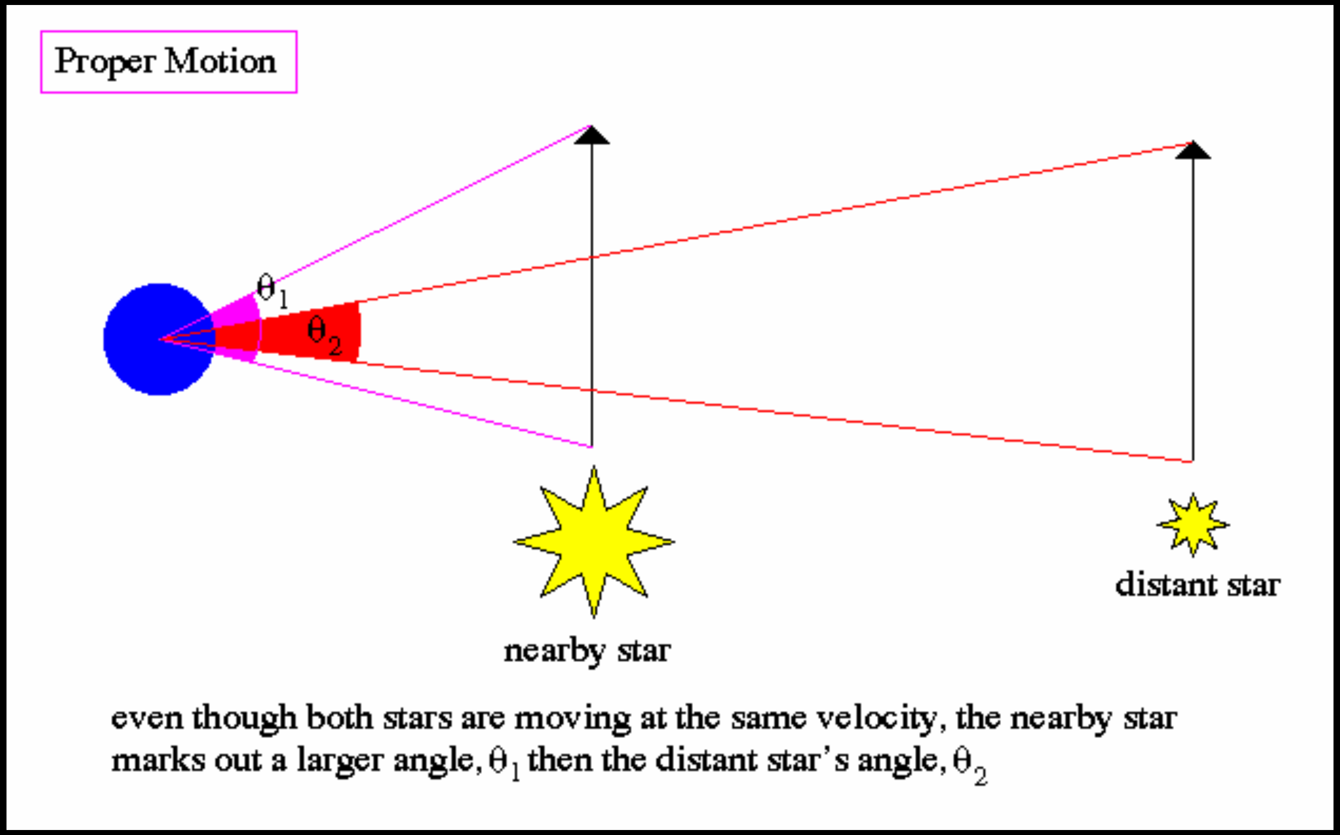
(Distance that light travels in a year)

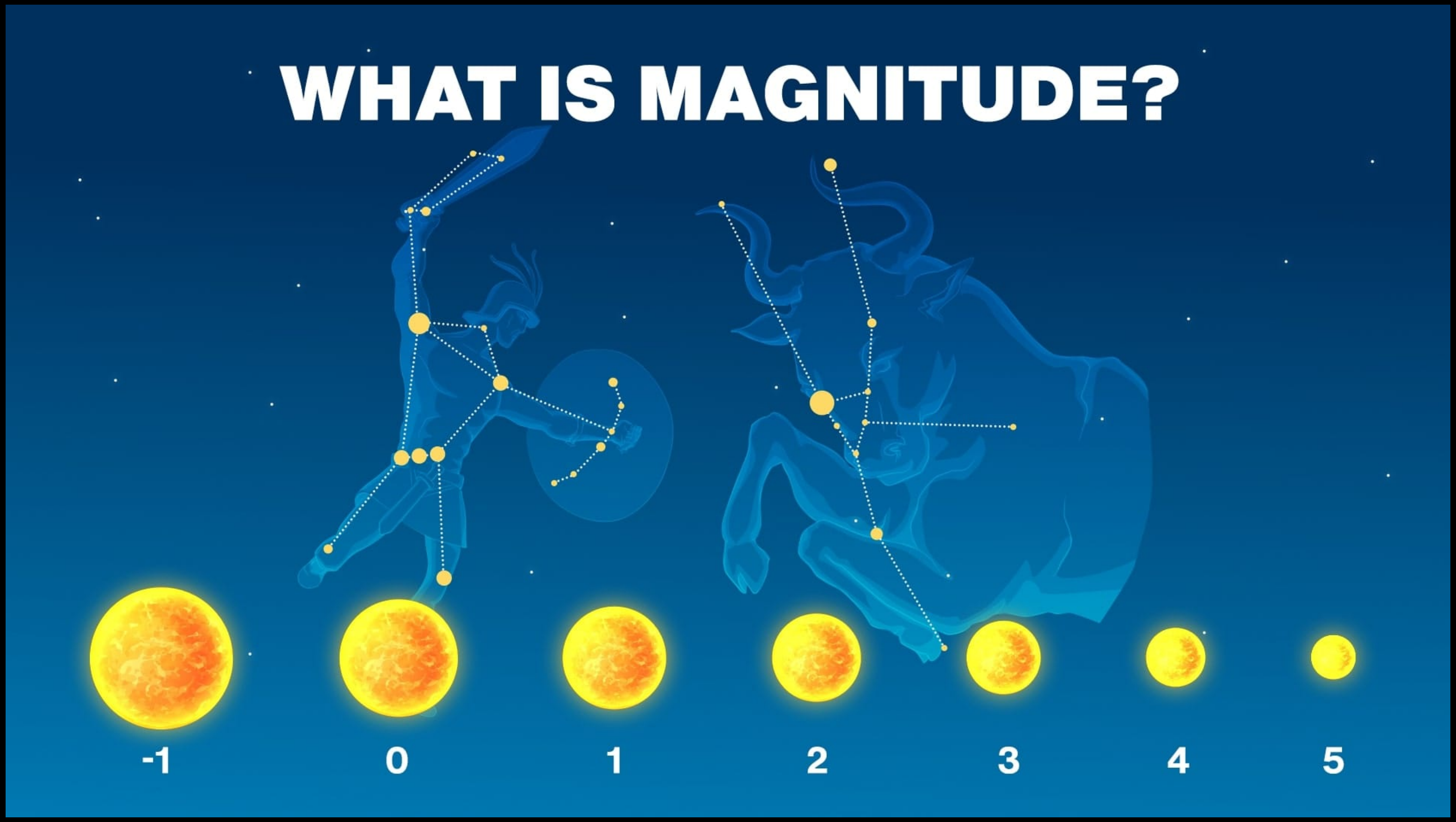
Parsec =
3.26 Light Years

space fm

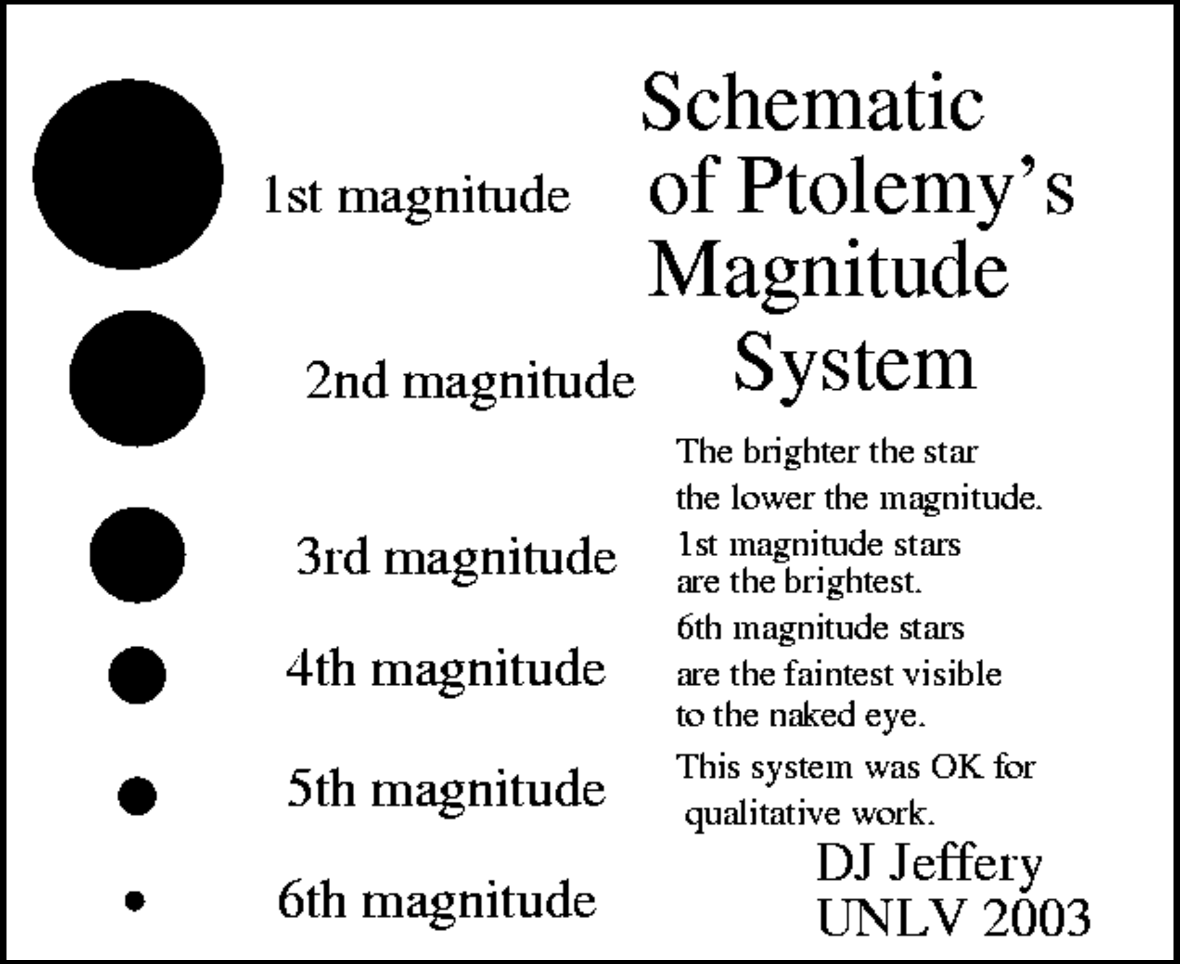


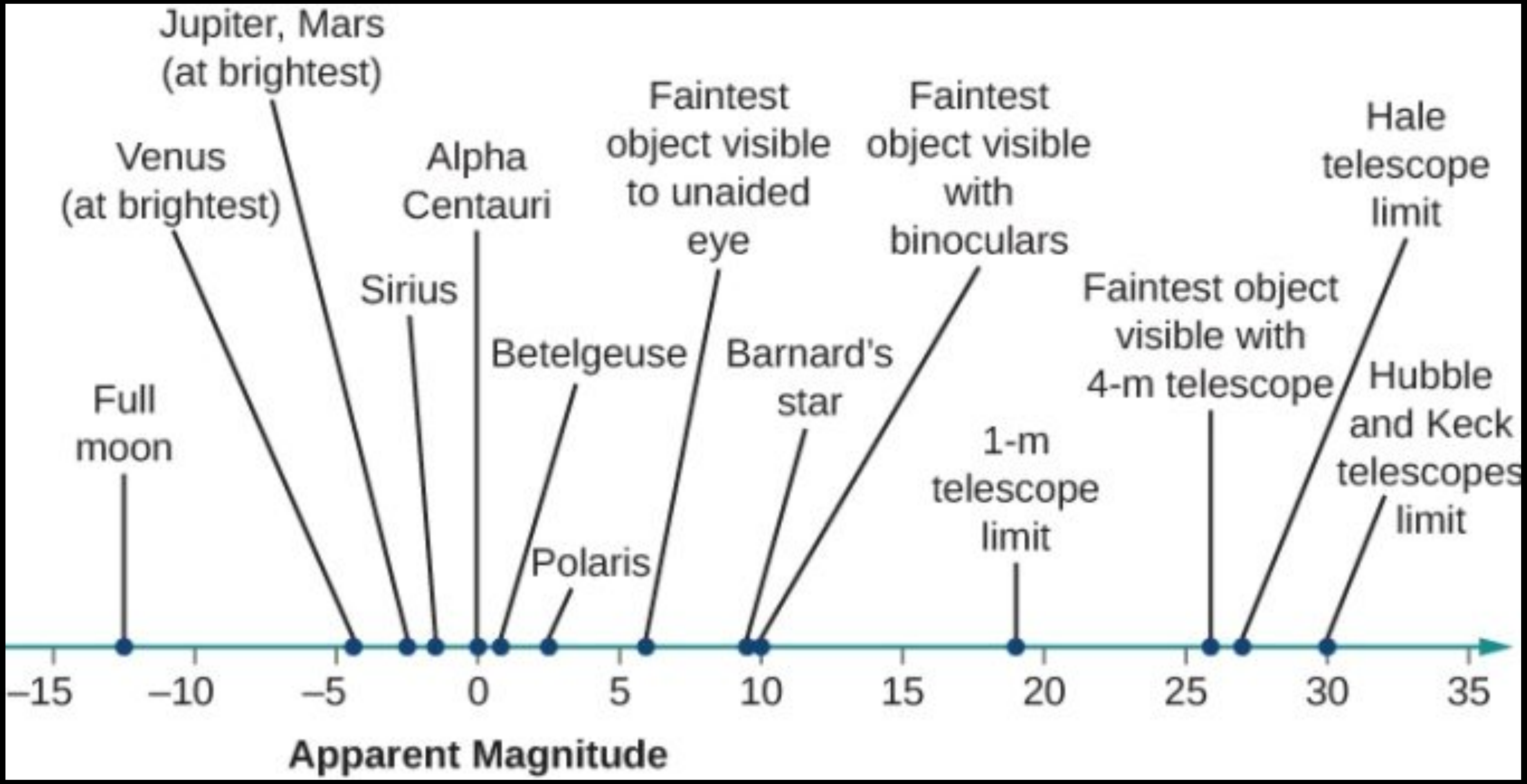
Although the stars appear fixed in the sky, they are actually moving through space at very high velocities. Their extremely large distances makes this motion almost undetectable. This motion is called proper motion, and can also be used to judge the distance to stars.



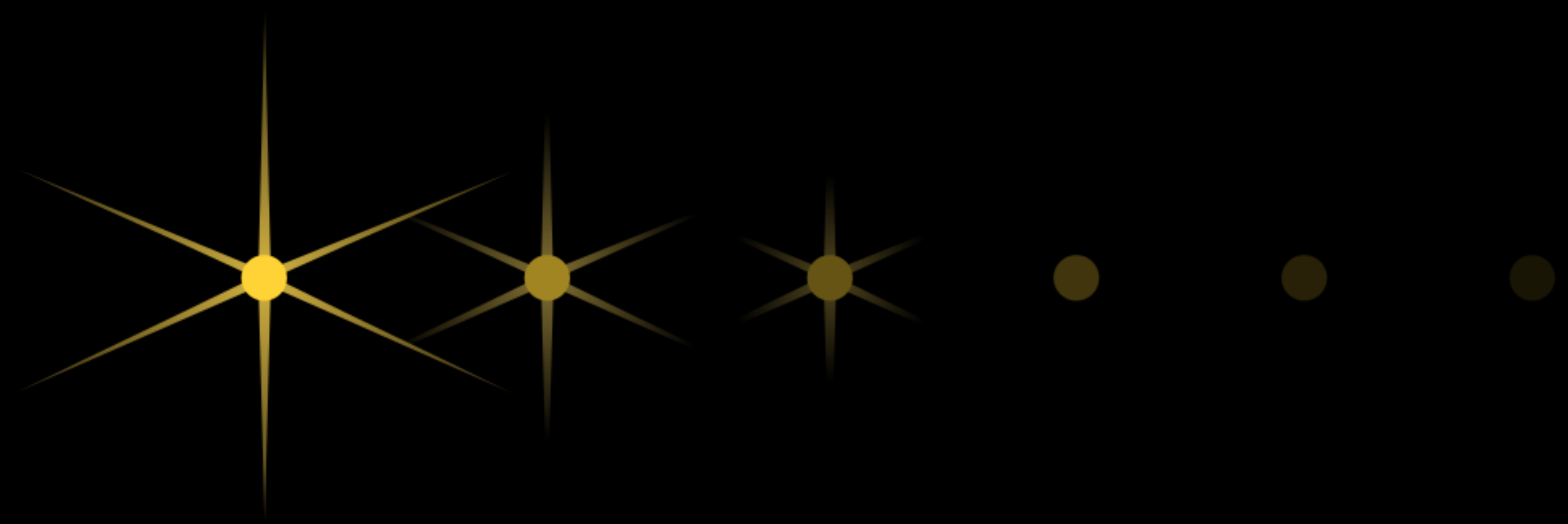


The measure of the brightness of a star is, for historical and physiological reasons, called its apparent magnitude. The human eye detects light in a logarithmic fashion, meaning that changes occur in powers of 10 rather than in a linear manner. So ancient astronomers divided stars into six classes or magnitudes where the brightest are first magnitude, the faintest are sixth magnitude. Later measurements showed that a change in 5 magnitudes is equal to a 100 increase in brightness.


1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
5th magnitude
6th magnitude
Schematic of Ptolemy's Magnitude System
The brighter the star the lower the magnitude.
1st magnitude stars are the brightest.
6th magnitude stars are the faintest visible to the naked eye.
This system was OK for qualitative work.
DJ Jeffery
UNLV 2003


Jupiter, Mars (at brightest)
Venus (at brightest)
Alpha Centauri
Faintest object visible to unaided eye
Faintest object visible with binoculars
Hale telescope limit
Sirius
Betelgeuse
Barnard's star
Faintest object visible with 4-m telescope
Full moon
Hubble and Keck telescopes limit
1-m telescope limit
Polaris
–15
–10
–5
0
5
10
15
20
25
30
35
Apparent Magnitude

Magnitude	1	1.5	2	2.5	3	3.5
Brightness (RGB values)	255	160	102	64	40	26
Relative brightness	1.000	0.631	0.398	0.251	0.158	0.100

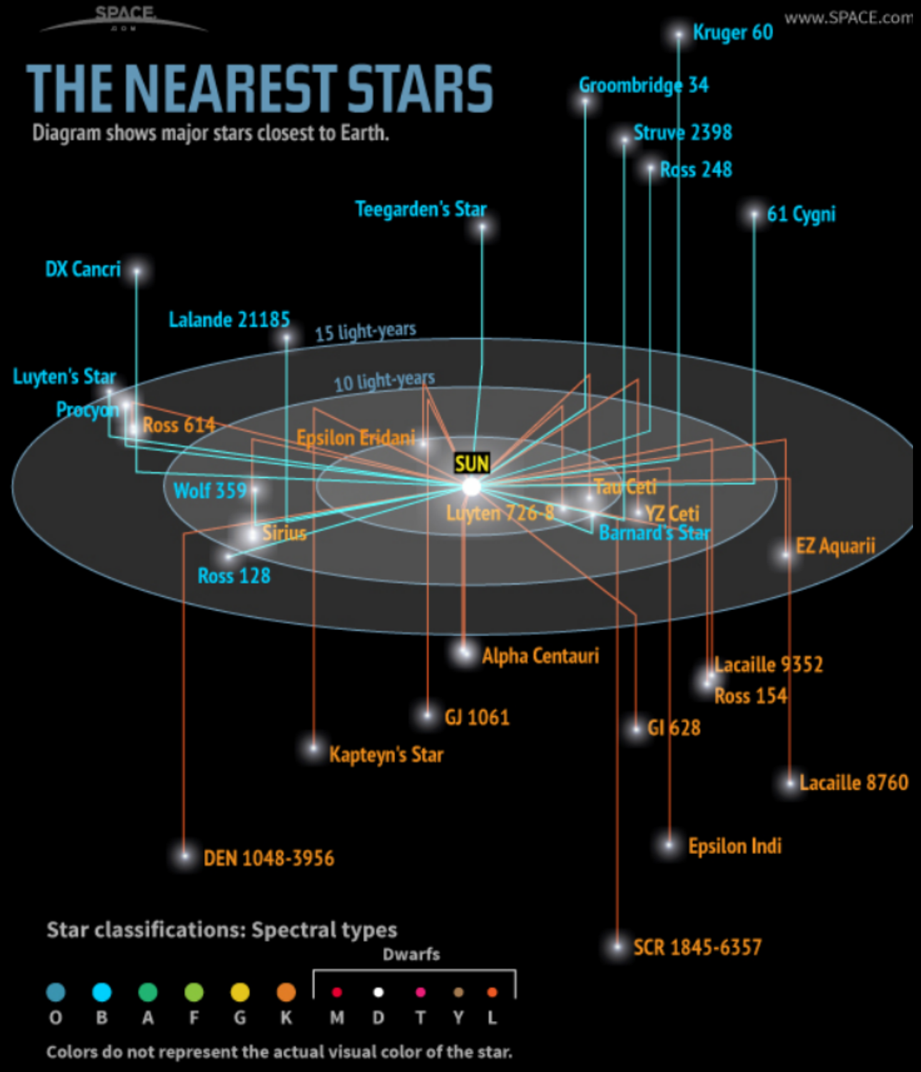


The magnitude system works out such that a change in 1 in magnitude corresponds to a change in 2.512 in brightness. The formula is as follows:

$$b_1/b_2 = 2.512^{(m_2-m_1)}$$

where b_1 and b_2 are the brightnesses of two stars (ergs per sec) and m_1 and m_2 are the magnitudes of the two stars. If you know the brightness of the stars, and want to determine their relative magnitudes, this formula is the inverse of the one above:

$$m_2-m_1 = 2.5\ \log(b_1/b_2)$$



Stars have different absolute luminosities. So the brightest stars in the sky are not necessarily the closest stars.

The nearest stars make-up what is called the solar neighborhood, shown below. Note that the nearest stars are mostly small dim stars. These types of stars are hard to see at great distances. The twenty brightest stars are mostly supergiant stars; which are rare, but very bright.

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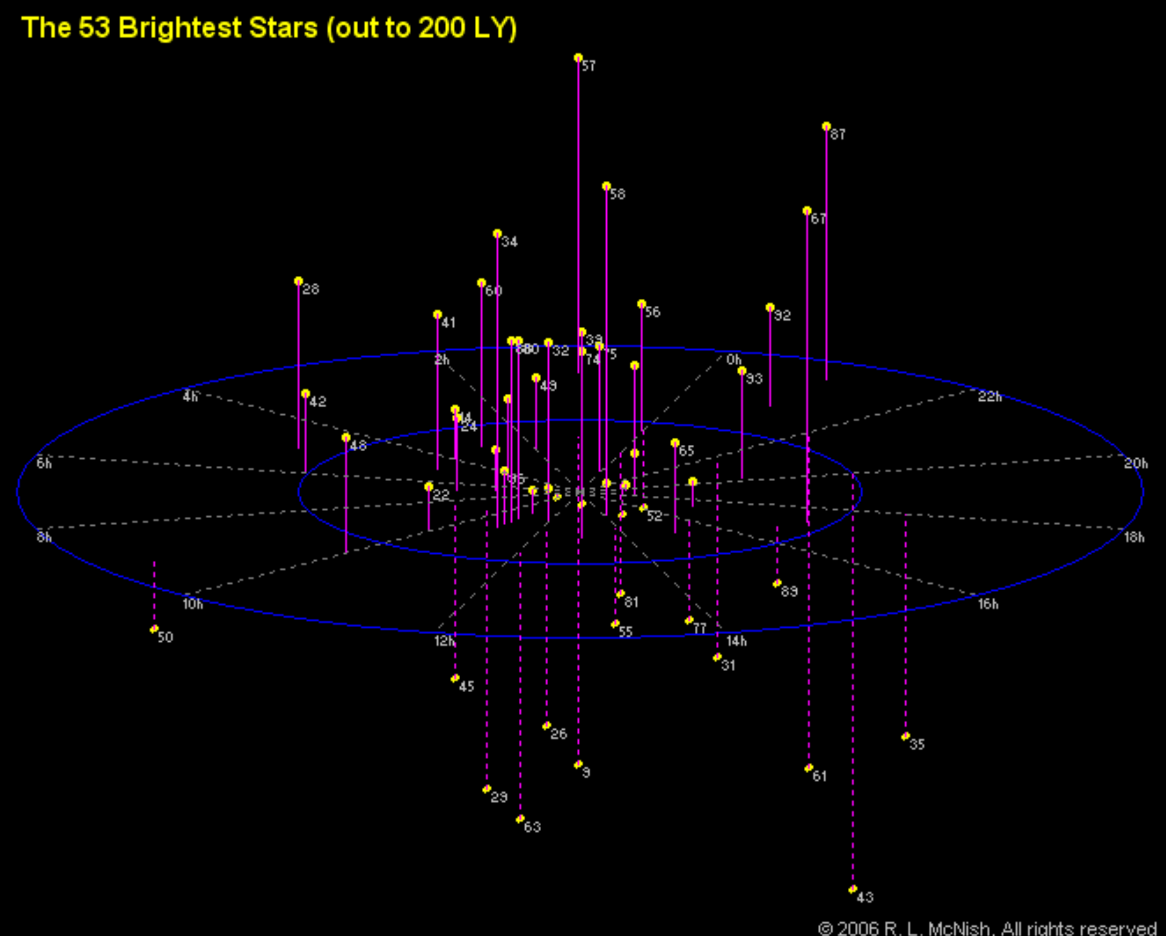
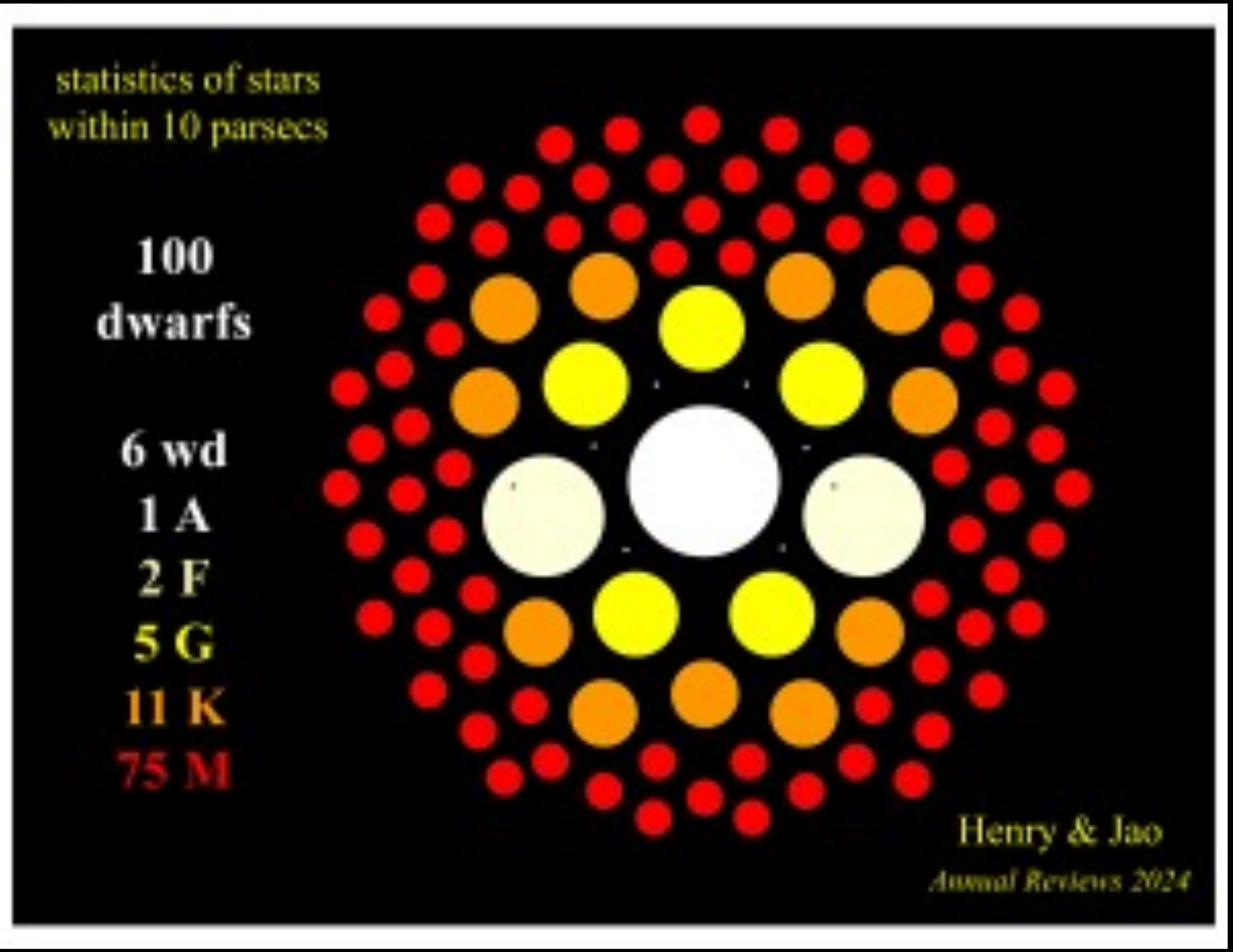
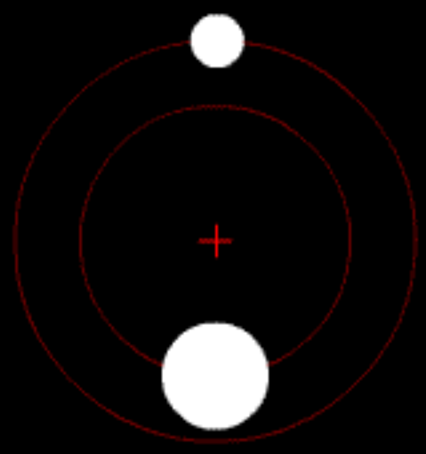
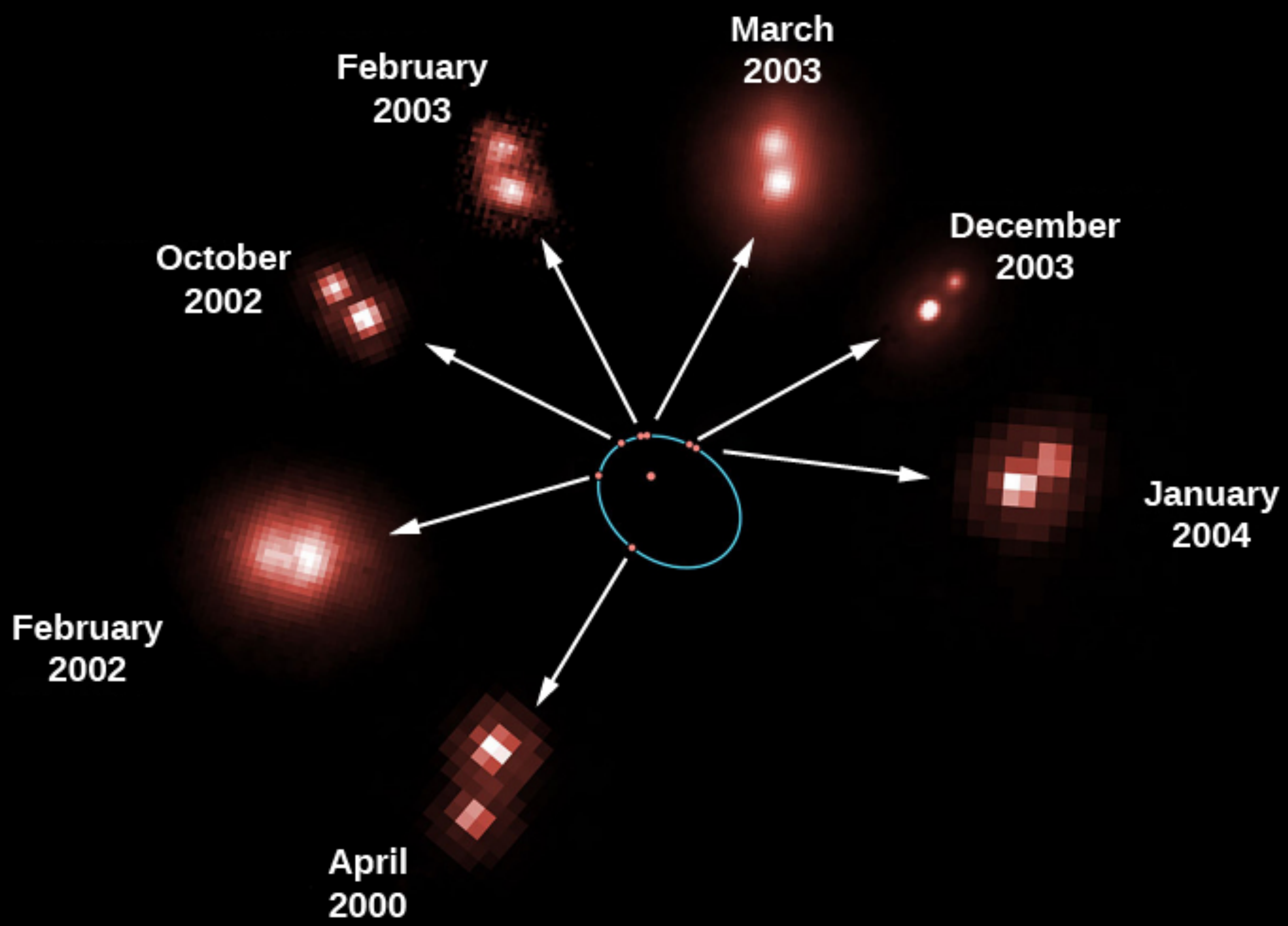


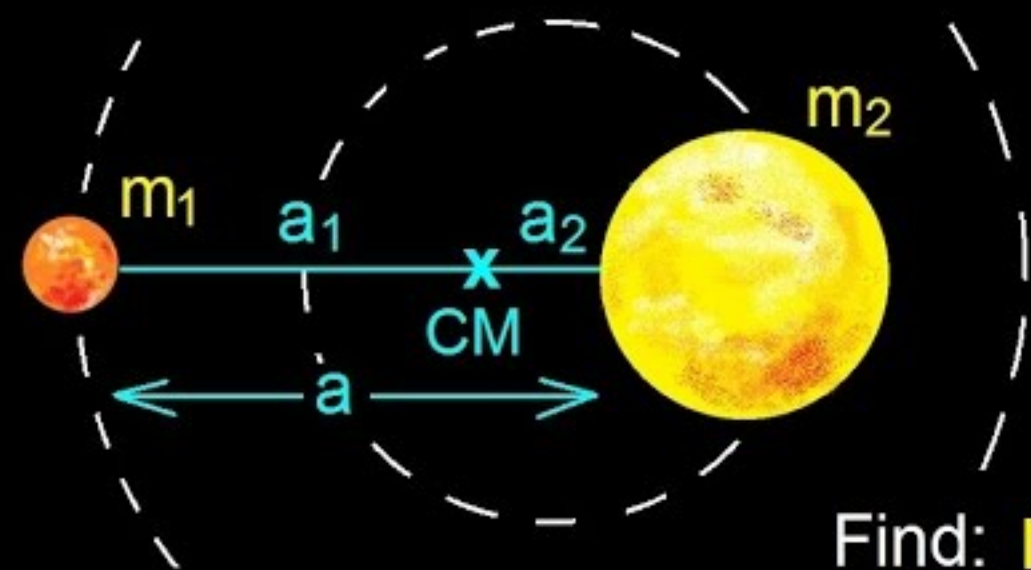

statistics of stars
within 10 parsecs
100
dwarfs
6 wd
1 A
2 F
5 G
11 K
75 M
Henry & Jao
Annual Reviews 2024



Two stars in a binary system are bound by gravity and revolve around a common center of mass. Kepler's 3rd law of planetary motion can be used to determine the sum of the mass of the binary stars if the distance between each other and their orbital period is known.



Determining the Masses of a Binary Star (Example)



$$\frac{m_1}{m_2} = \frac{a}{a_1} - 1$$

$$m_1 + m_2 = \frac{P^2}{a^3}$$

Given: $P = 10$ years

$a = 6$ AU

$a_1 = 4.5$ AU

Find: $m_1 = ?$

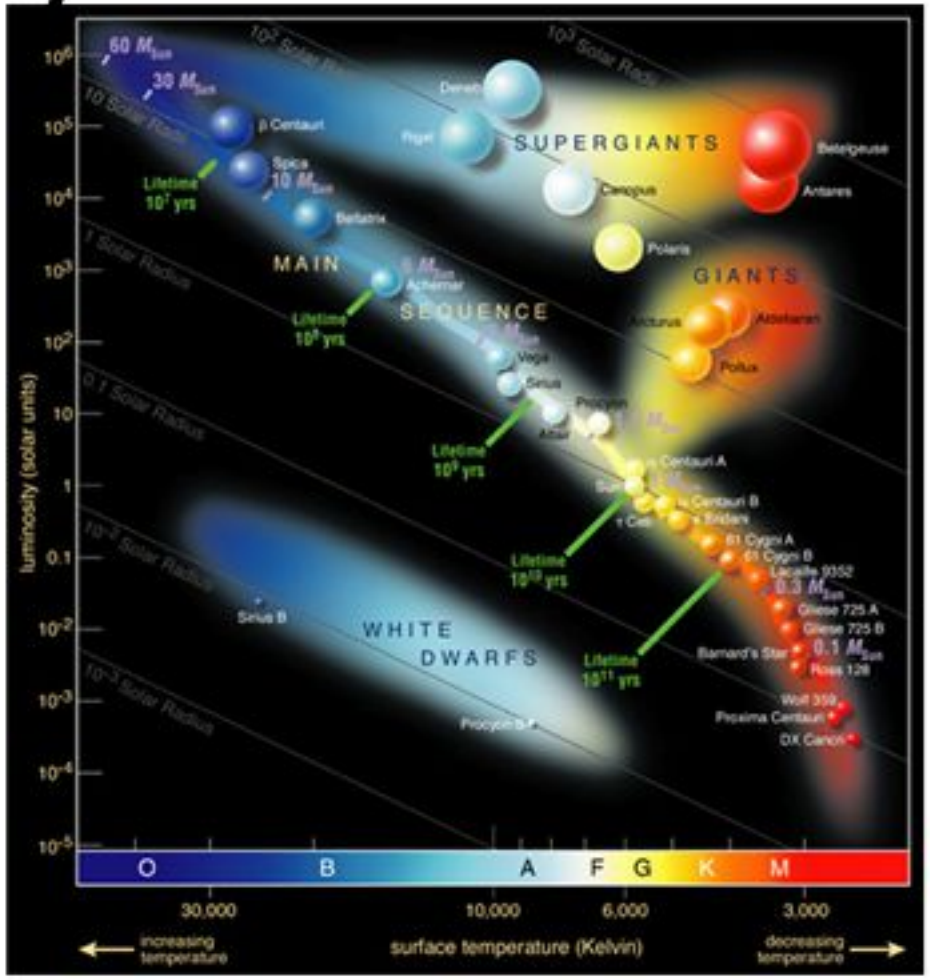
$m_2 = ?$

Mass-Luminosity Relation

- Find approximately

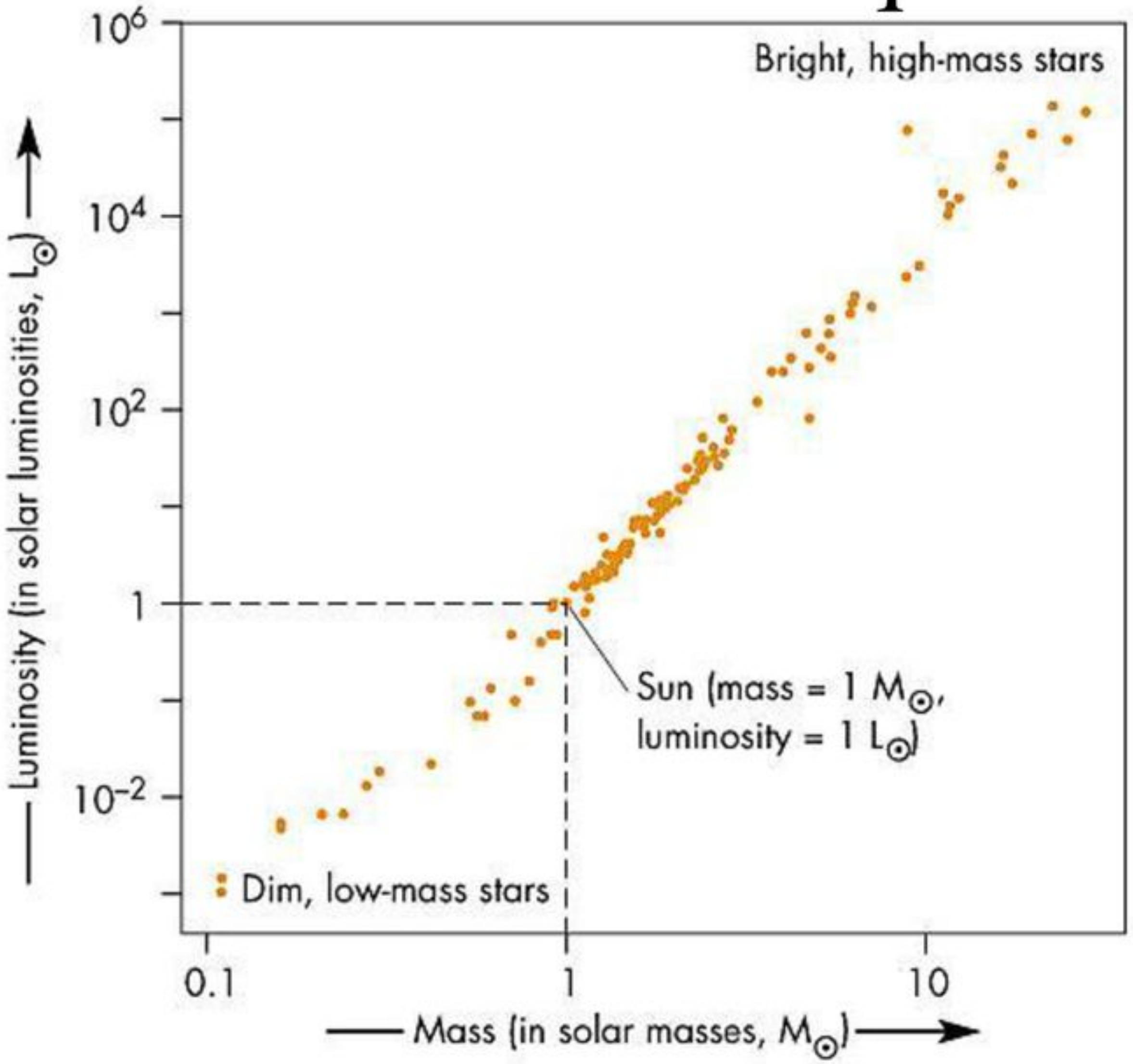
$$\left(\frac{L}{L_\odot}\right) = \left(\frac{M}{M_\odot}\right)^{3.5}$$

- Borne out by models: Mass compresses star increasing rate of fusion
- If amount of Hydrogen available for fusion is near constant fraction, big stars run out sooner
- OB stars are young!



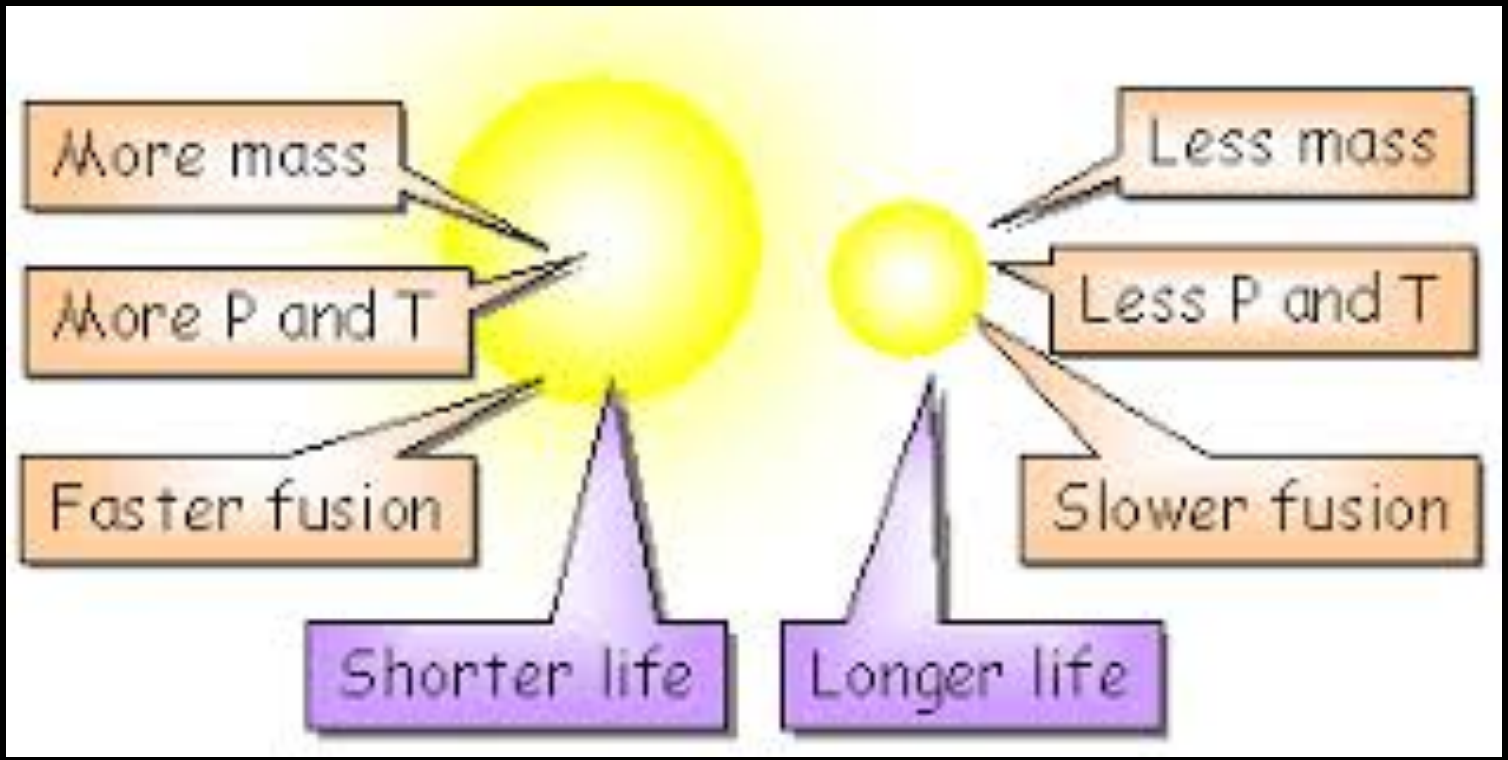
Duke UNIVERSITY

Mass-Luminosity relation on the main sequence



$$\frac{L}{L_\Theta} \approx \left(\frac{M}{M_\Theta} \right)^{3.5}$$

This relationship is called the mass-luminosity relation for stars, and it indicates that the mass of a star controls the rate of energy production, which is thermonuclear fusion in the star's core. The rate of energy generation, in turn, uniquely determines the stars total luminosity.



More mass
More P and T
Faster fusion
Shorter life
Less mass
Less P and T
Slower fusion
Longer life

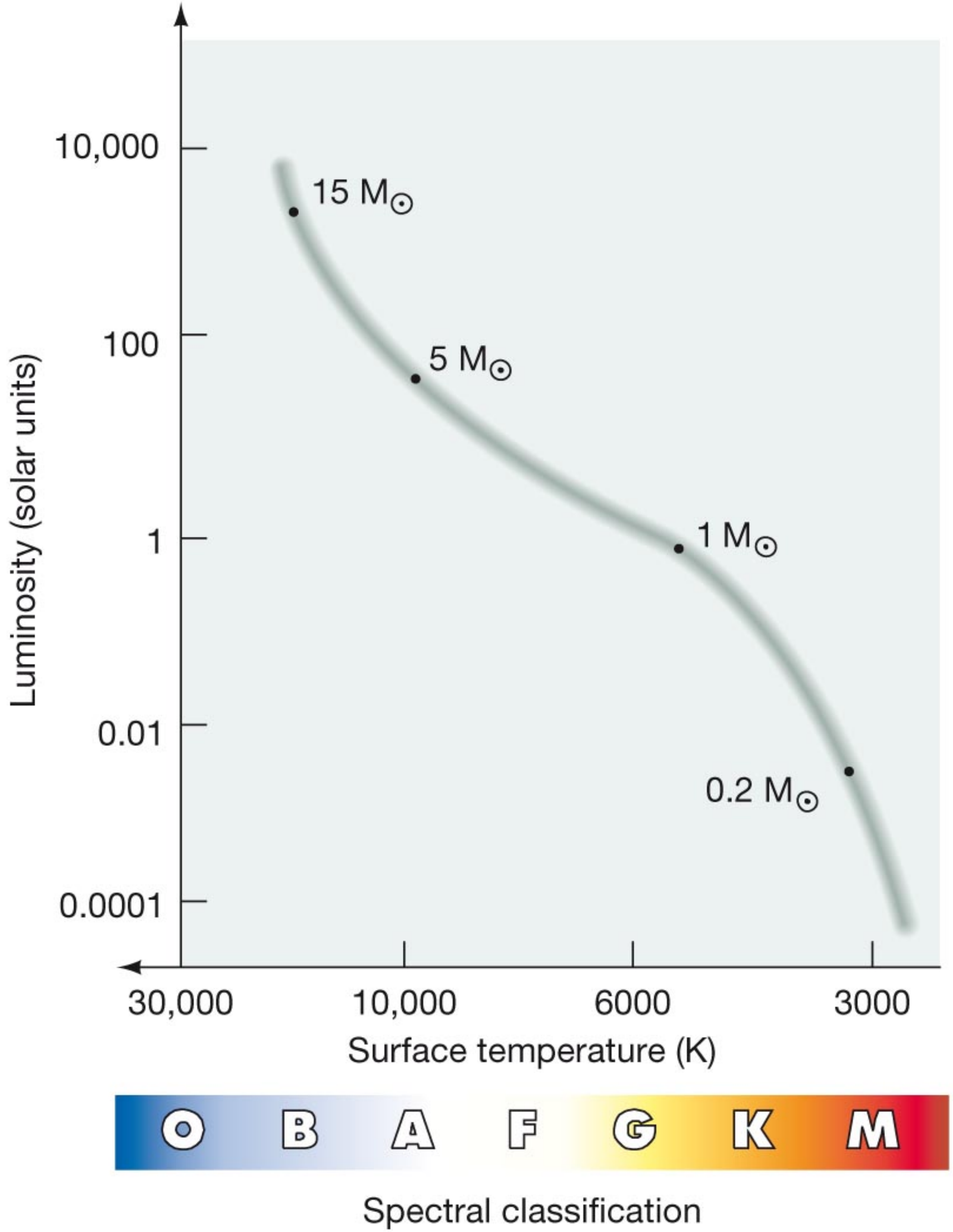


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TABLE 17.5 Measuring the Stars

Stellar Property	Measurement Technique	"Known" Quantity	Measured Quantity	Theory Applied	Section
Distance	stellar parallax spectroscopic parallax	astronomical unit main sequence	parallactic angle spectral type apparent magnitude	elementary geometry inverse-square law	17.1 17.6
Radial velocity		speed of light atomic spectra	spectral lines	Doppler effect	17.1
Transverse velocity	astrometry	distance	proper motion	elementary geometry	17.1
Luminosity		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

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