Roger A. Freedman • Robert Geller • William J. Kaufmann III

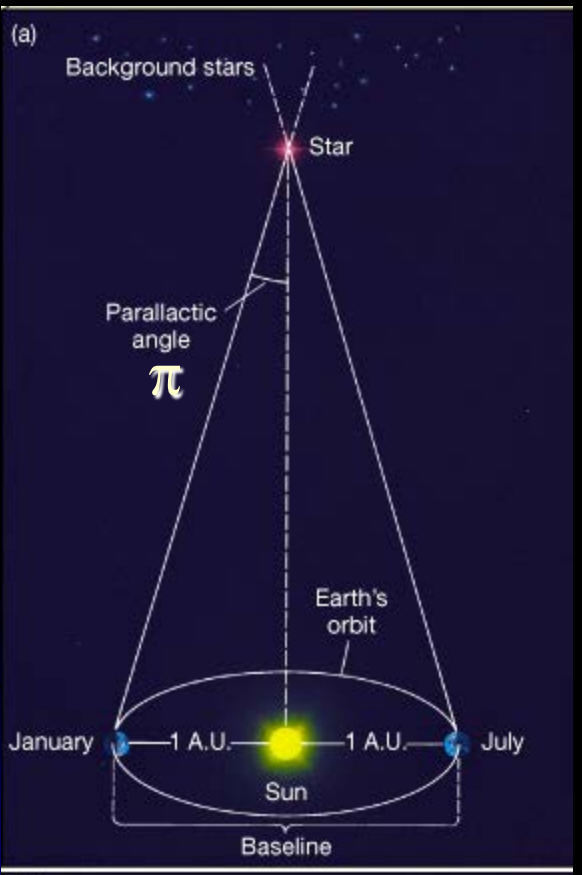
Universe

9th Edition

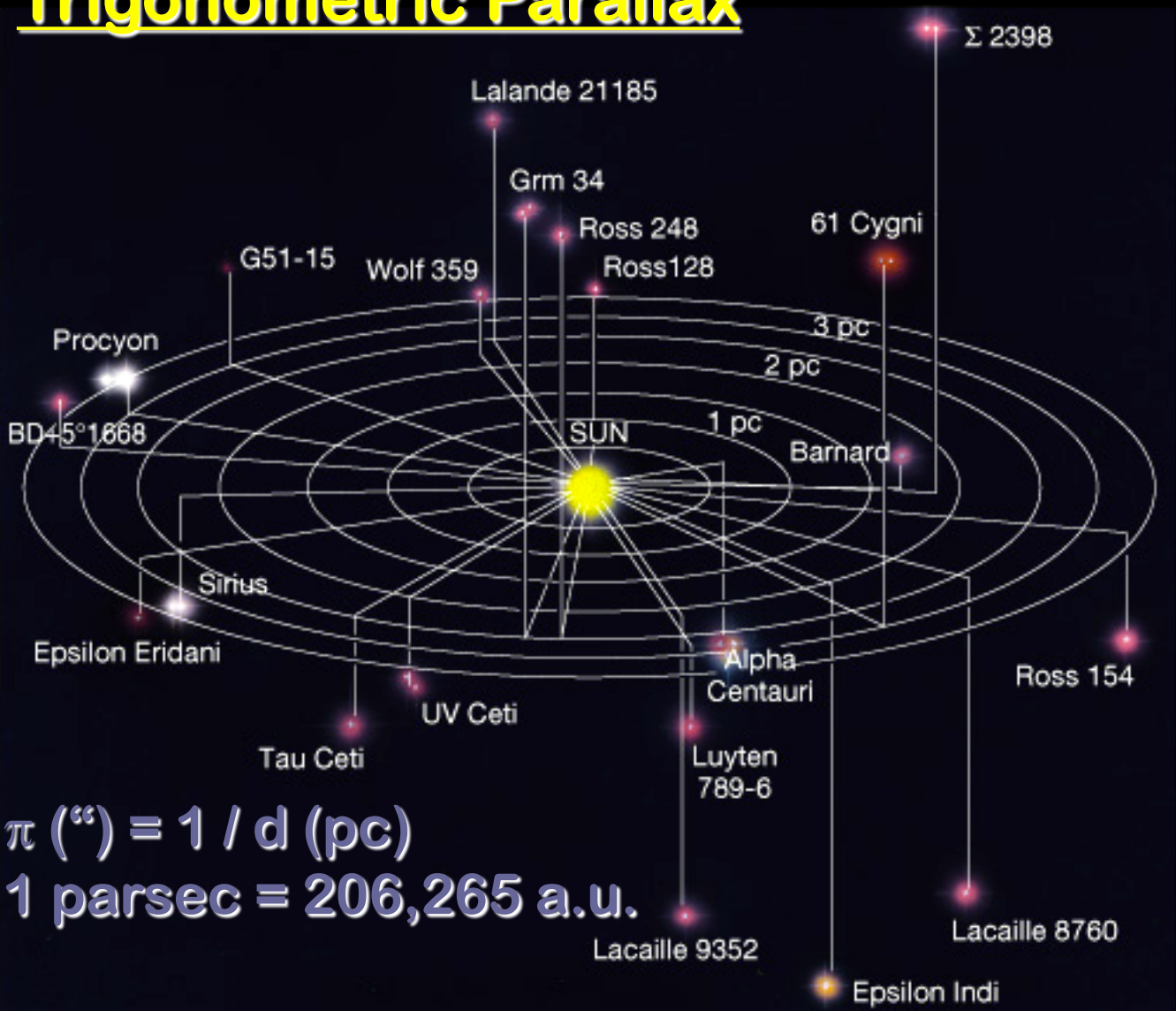
CHAPTER 17

The Nature of Stars

Stellar Distances & the Solar Neighborhood



Trigonometric Parallax



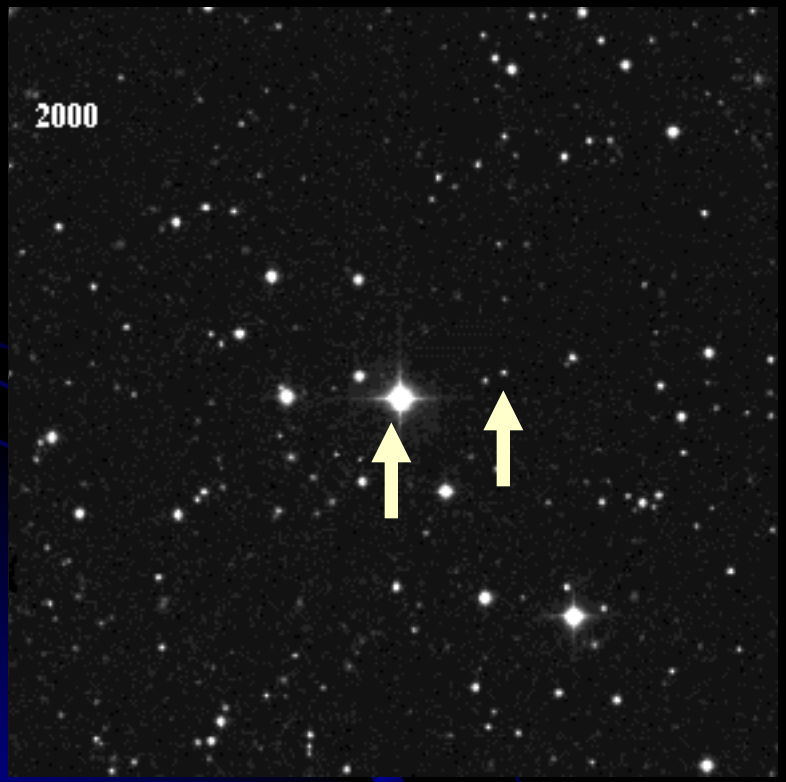
π (") = 1 / d (pc)

1 parsec = 206,265 a.u.

Stellar Motions

Proper Motion

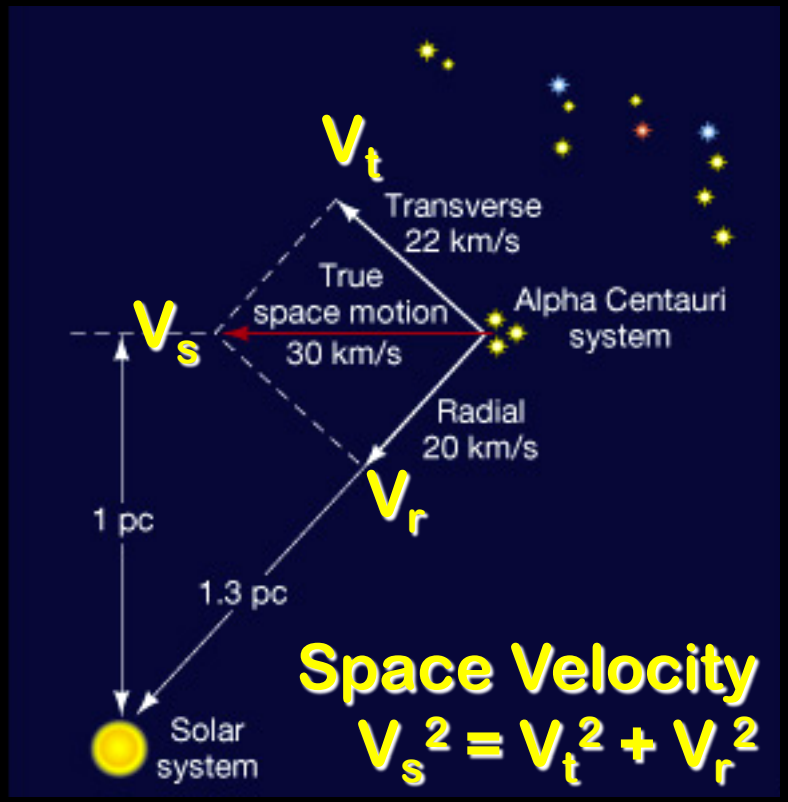
Angular velocity μ ("/yr)



Velocities

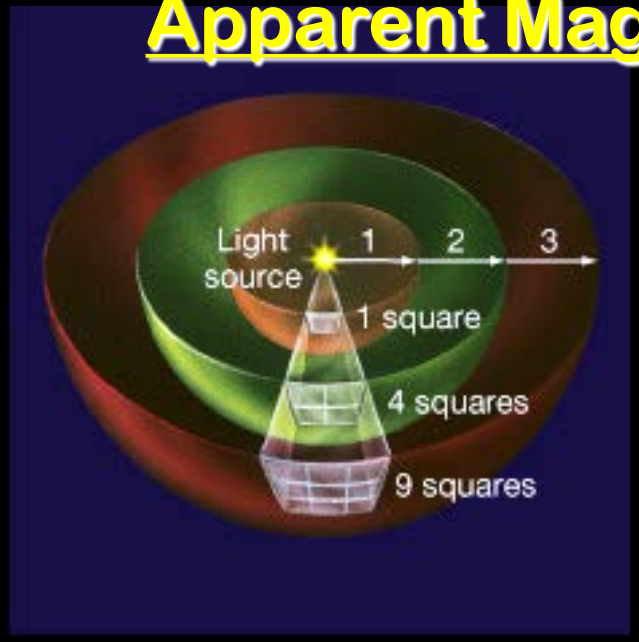
Tangential $V_t = 4.74\ \mu\ d$

Radial $V_r = c\ \delta\lambda / \lambda_o$



Brightness & Color

Apparent Magnitude



$$F = L / 4\pi d^2$$

$$m = -2.5 \log F + c$$

Hipparchus (c. 120 B.C.)	
mag. diff.	flux ratio
0	$2.5^0 = 1$
1	$2.5^1 = 2.5$
2	$2.5^2 = 6.3$
3	$2.5^3 = 15.6$
4	$2.5^4 = 39$
5	$2.5^5 = 100$

Absolute Magnitude (M) ⇒ L

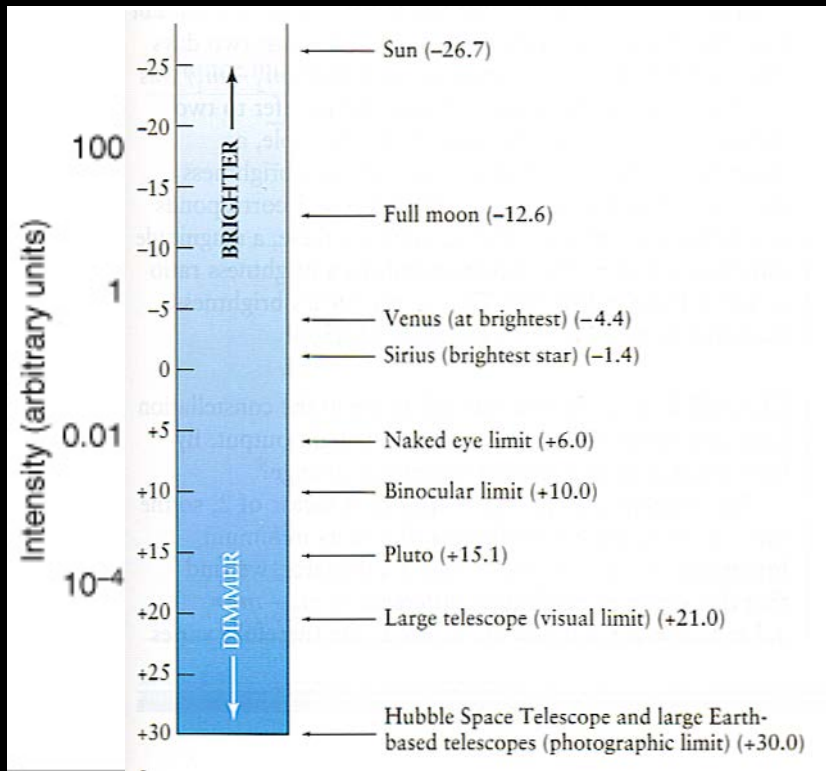
apparent magnitude at 10 pc

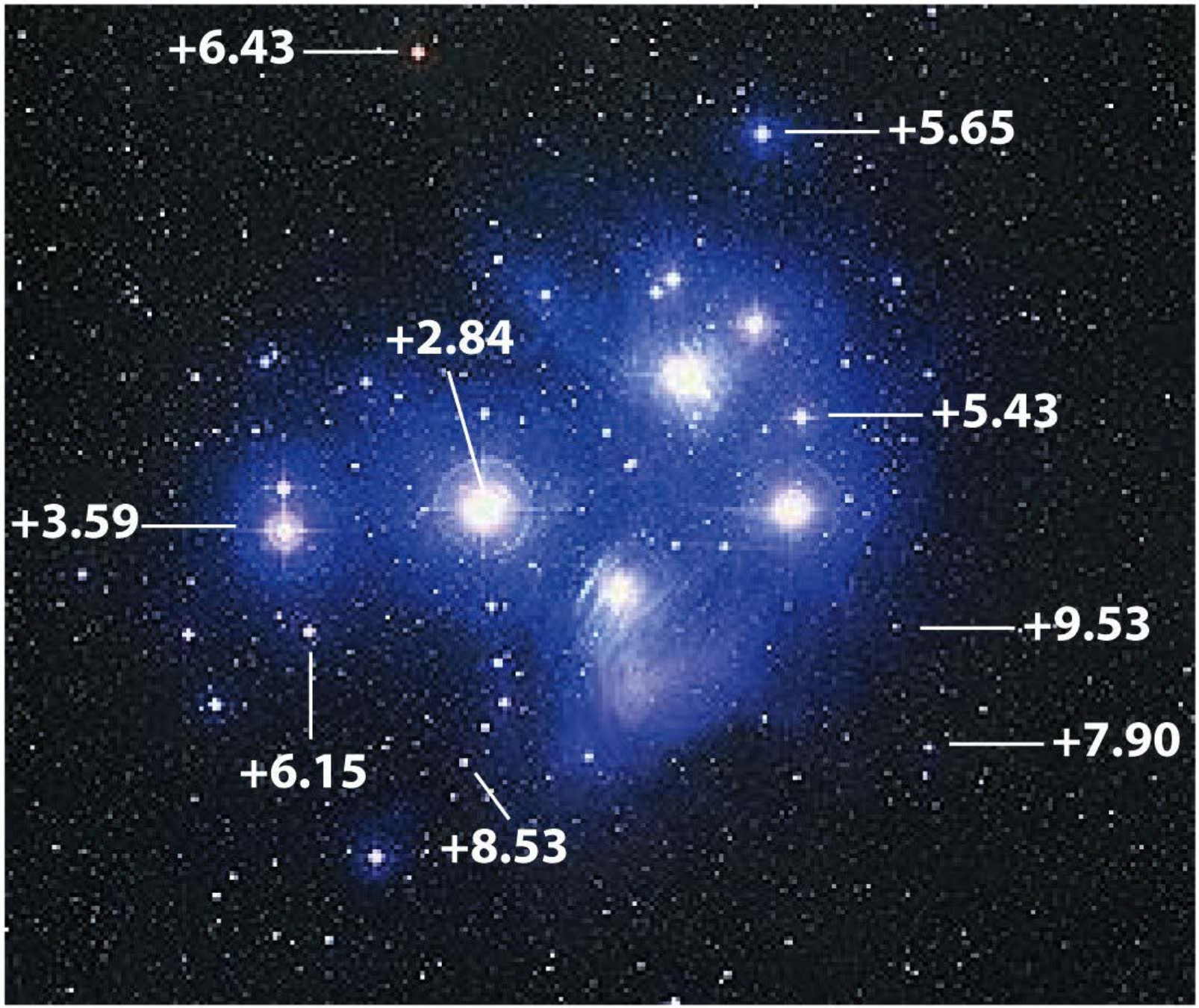
Distance Modulus ⇒ d

(m-M): 5 log d - 5

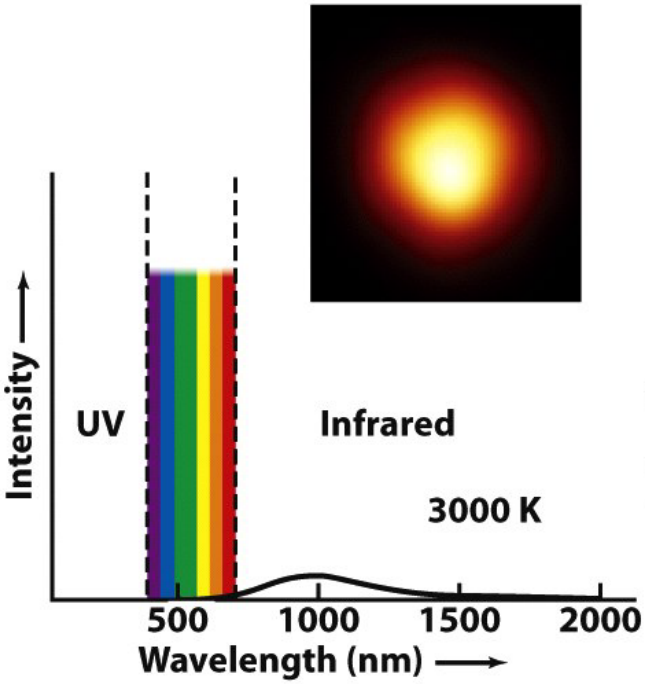
Color Index ⇒ T

B - V, R - I, V - I, etc.

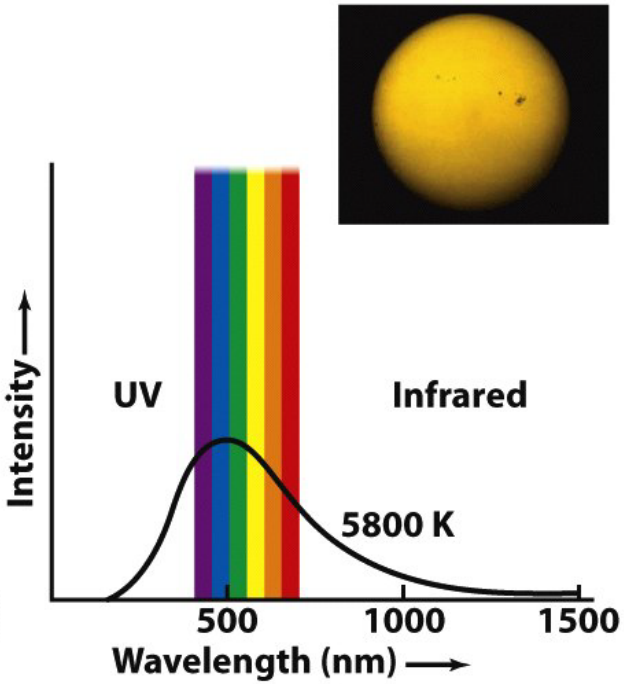




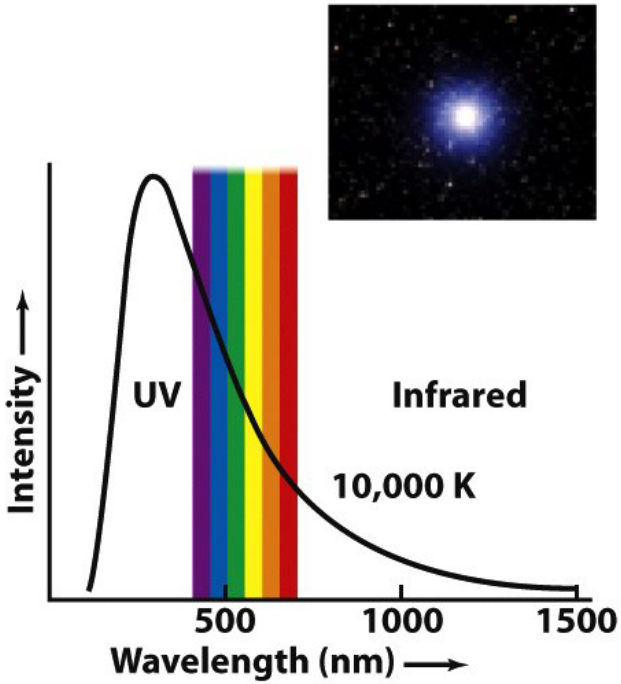
Apparent magnitudes of stars in the Pleiades



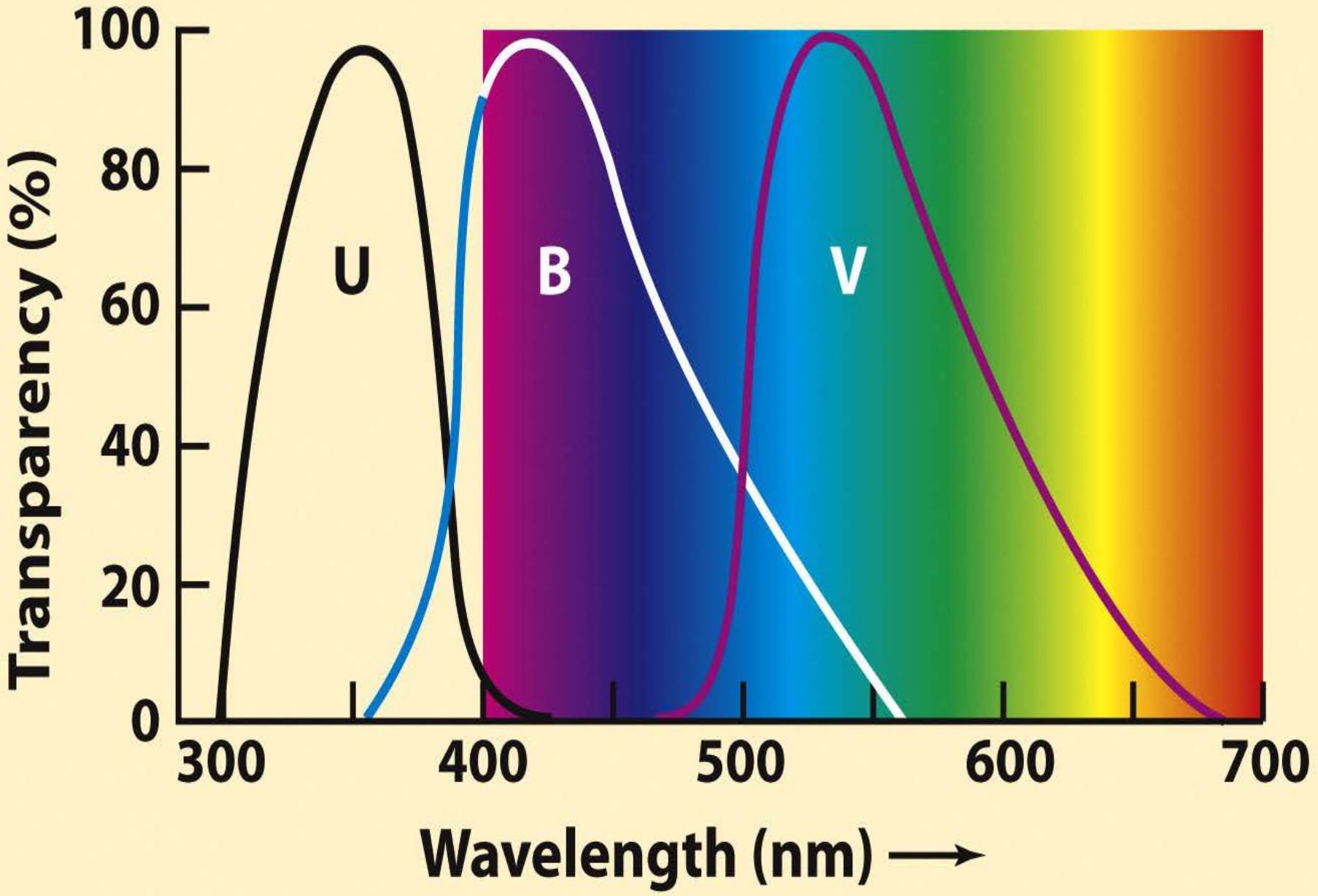
(a) A cool star with surface temperature 3000 K emits much more red light than blue light, and so appears red.

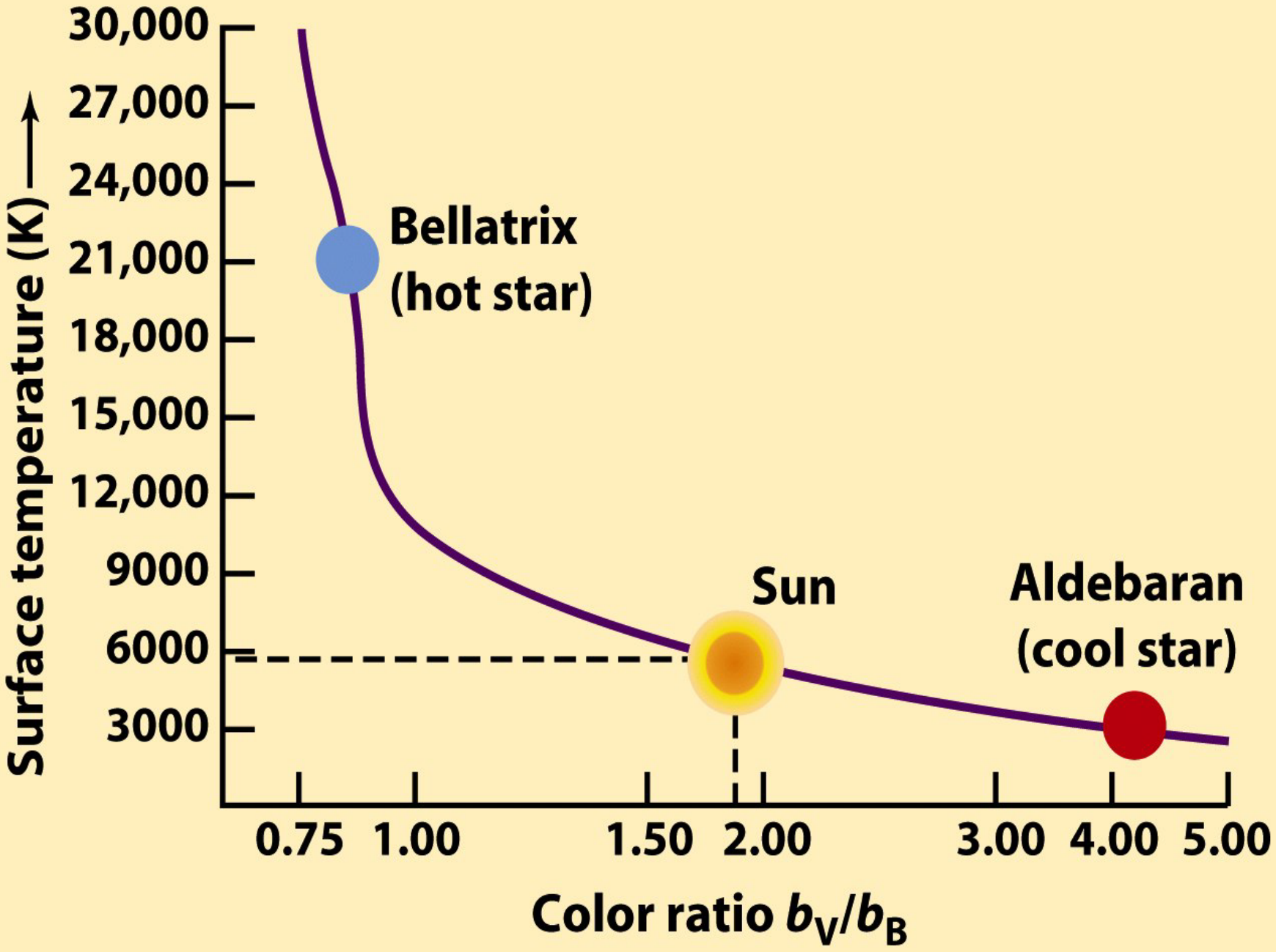


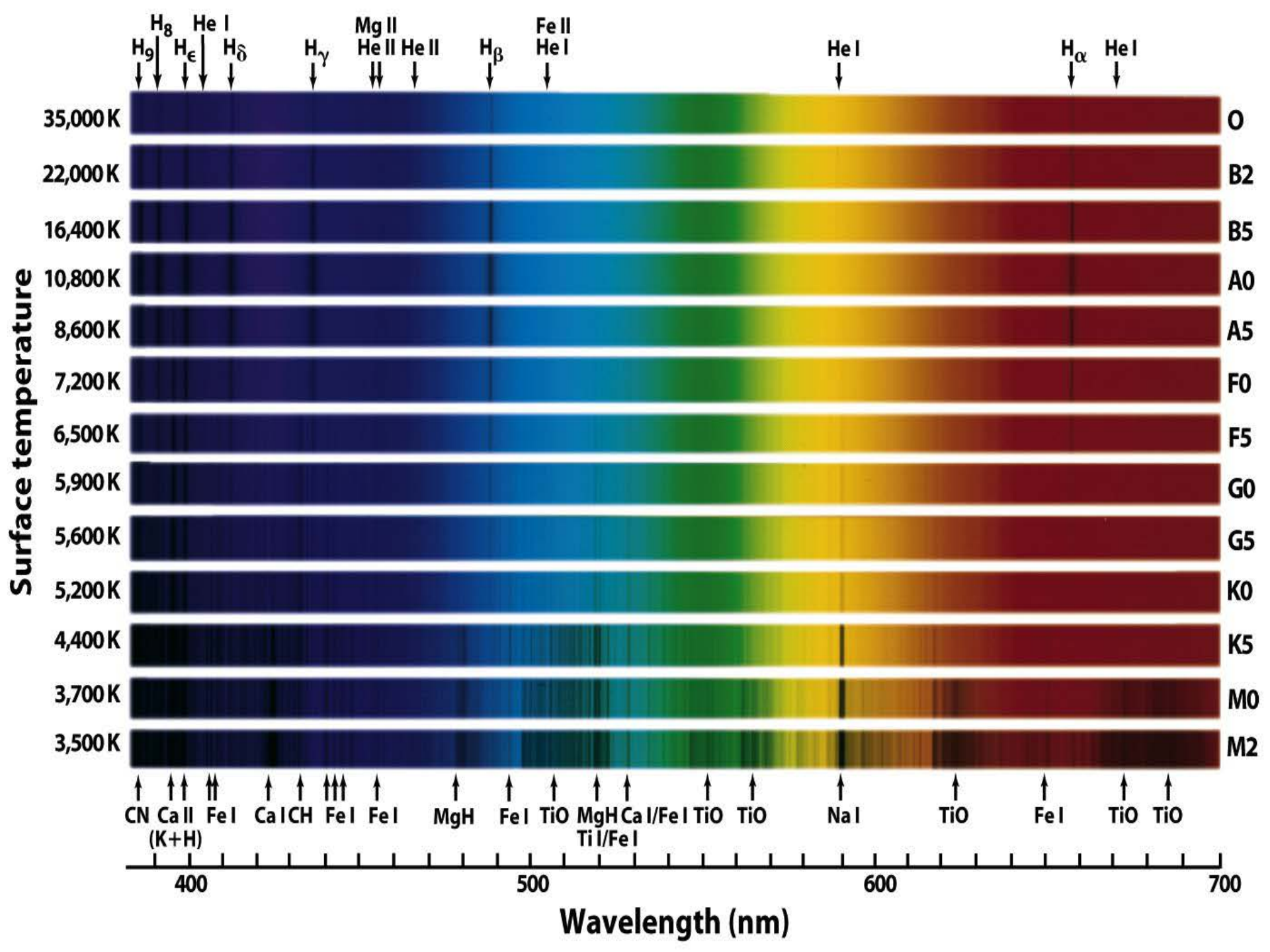
(b) A warmer star with surface temperature 5800 K (like the Sun) emits roughly equal amounts of all visible wavelengths, and so appears yellow-white.

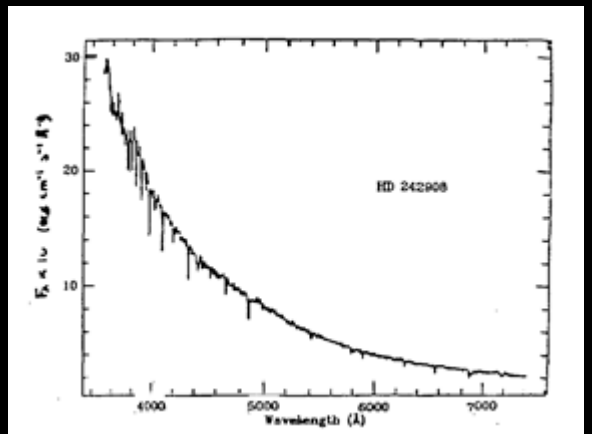


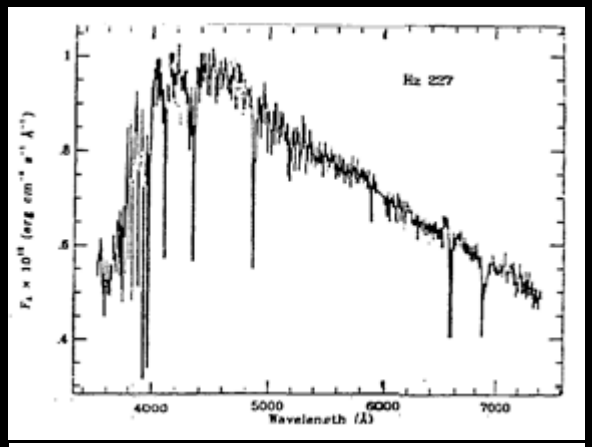
(c) A hot star with surface temperature 10,000 K emits much more blue light than red light, and so appears blue.

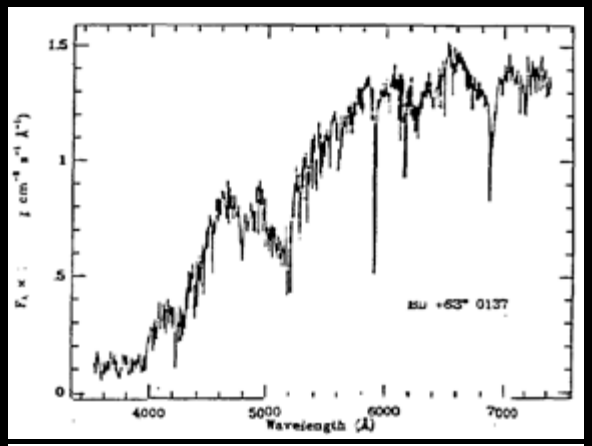

100
80
60
40
20
0
Transparency (%)
U
B
V
300
400
500
600
700
Wavelength (nm) ⟶

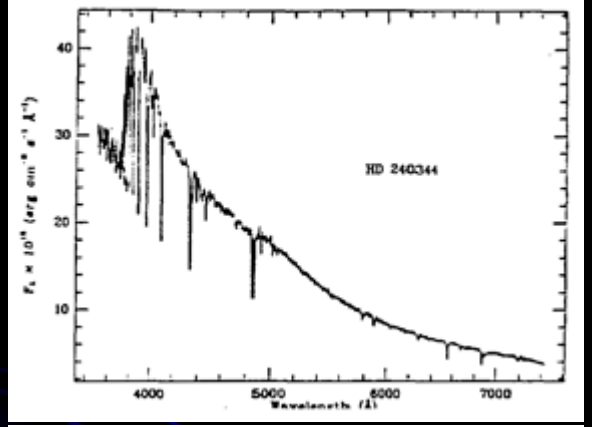

30,000
27,000
24,000
21,000
18,000
15,000
12,000
9000
6000
3000
Surface temperature (K)
Bellatrix
(hot star)
Sun
Aldebaran
(cool star)
0.75
1.00
1.50
2.00
3.00
4.00
5.00
Color ratio b_V/b_B

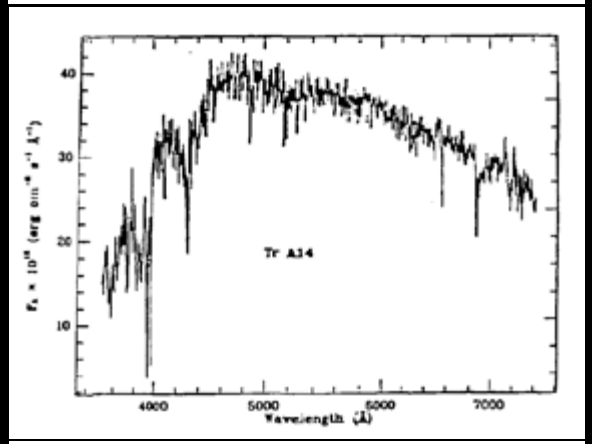

H8
He I
H9
Hε
Hδ
Hγ
Mg II
He II
He II
Hβ
Fe II
He I
He I
Hα
He I
35,000 K
22,000 K
16,400 K
10,800 K
8,600 K
7,200 K
6,500 K
5,900 K
5,600 K
5,200 K
4,400 K
3,700 K
3,500 K
O
B2
B5
A0
A5
F0
F5
G0
G5
K0
K5
M0
M2
Surface temperature
CN
Ca II
(K+H)
Fe I
Ca I
CH
Fe I
Fe I
MgH
Fe I
TiO
MgH
Ti I/Fe I
Ca I/Fe I
TiO
TiO
Na I
TiO
Fe I
TiO
TiO
400
500
600
700
Wavelength (nm)

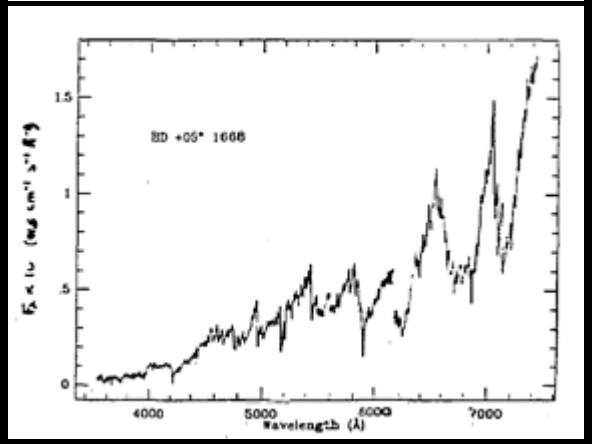

HD 242908
Wavelength (Å)

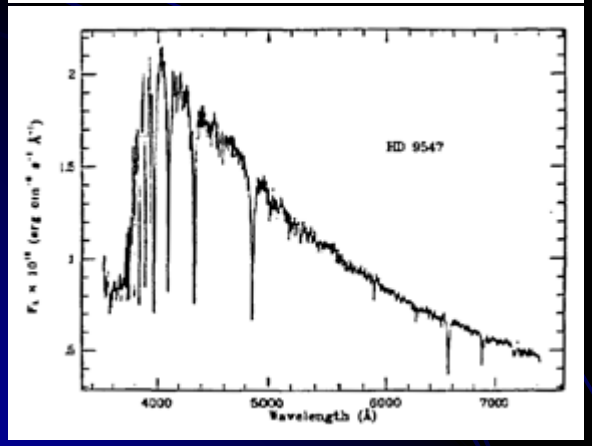

Hz 227
Wavelength (Å)

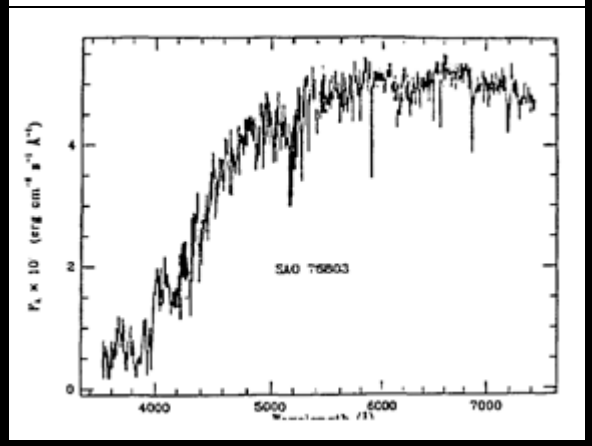

BSD +63° 0137
Wavelength (Å)


HD 240344
Wavelength (Å)


Tr A34
Wavelength (Å)


BD +05° 1668
Wavelength (Å)


HD 9547
Wavelength (Å)

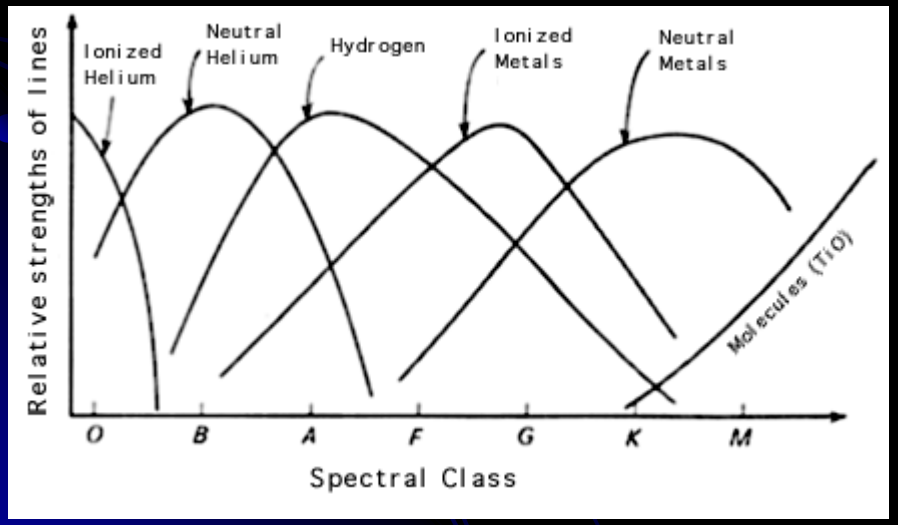

SAO 76803
Wavelength (Å)

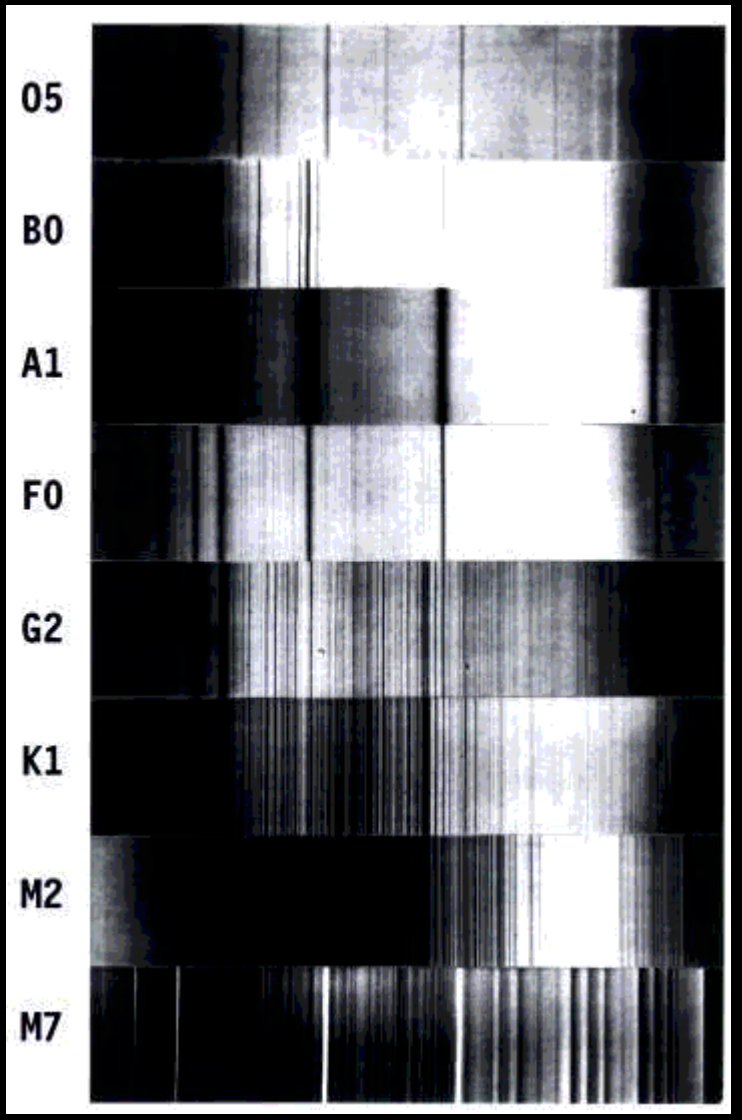
Stellar Spectra

Morgan, Keenan & Kellman, 1941
MKK classification scheme

Annie J. Cannon
1863-1941

- O - He lines
- B - weak H
- A - strong H
- F - H, wk metals
- G - ionized metals
- K - neutral metals +
- M - molecules
- L, T, Y - brown dwarfs





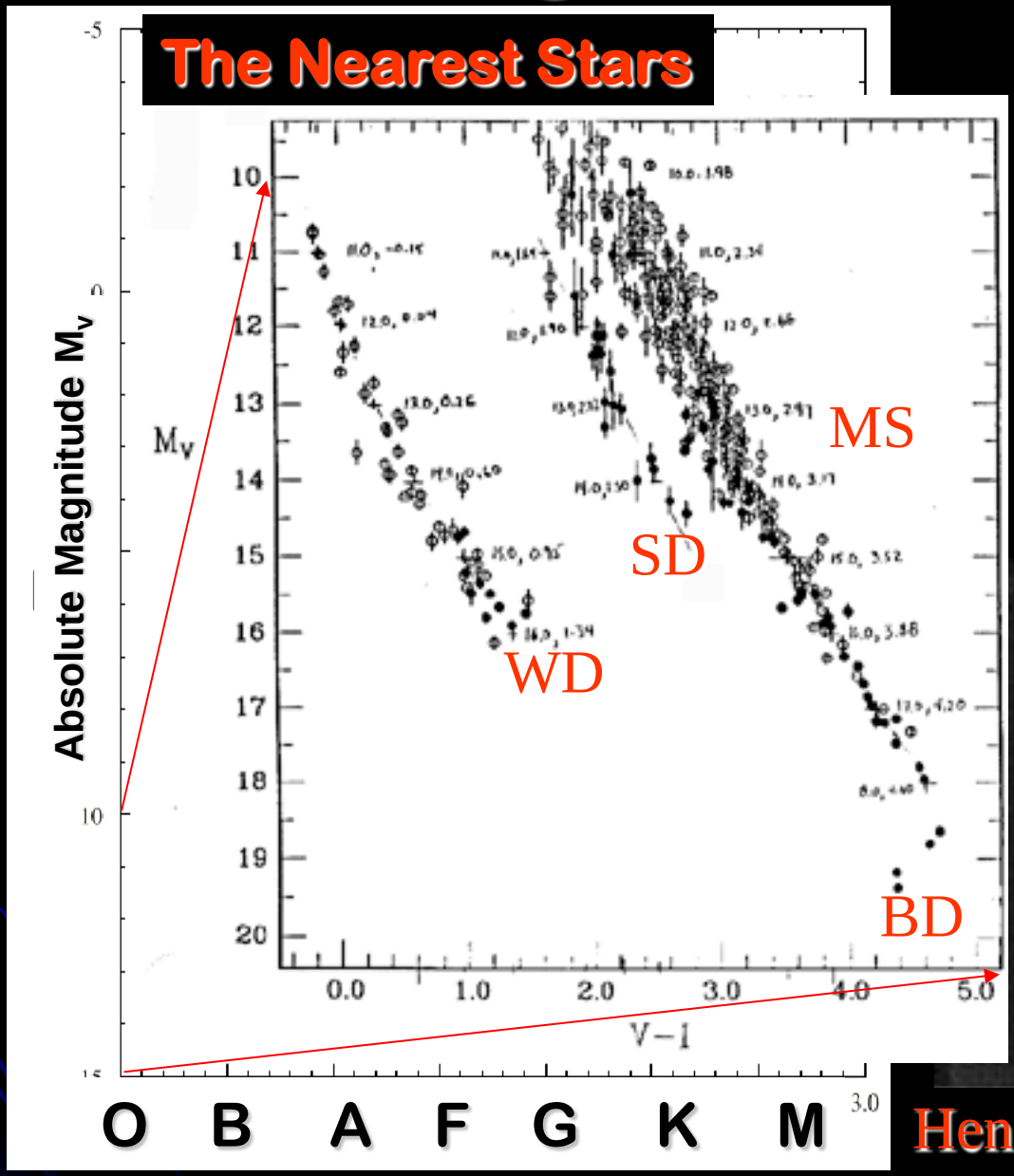
H-R Diagram

The Nearest Stars

"Spectroscopic Parallax"

spectrum ⇒
M_v ⇒
$m-M_v$ ⇒
distance

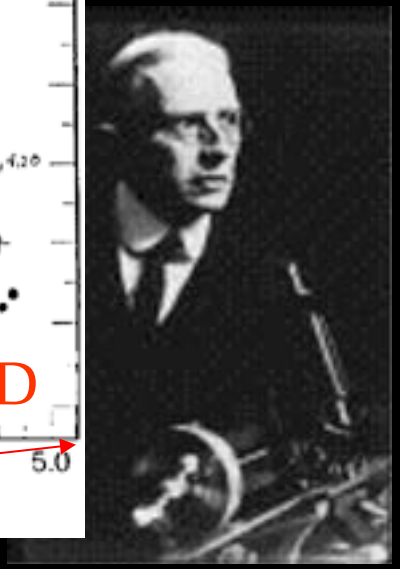
Ejnar Hertzsprung
1873-1967



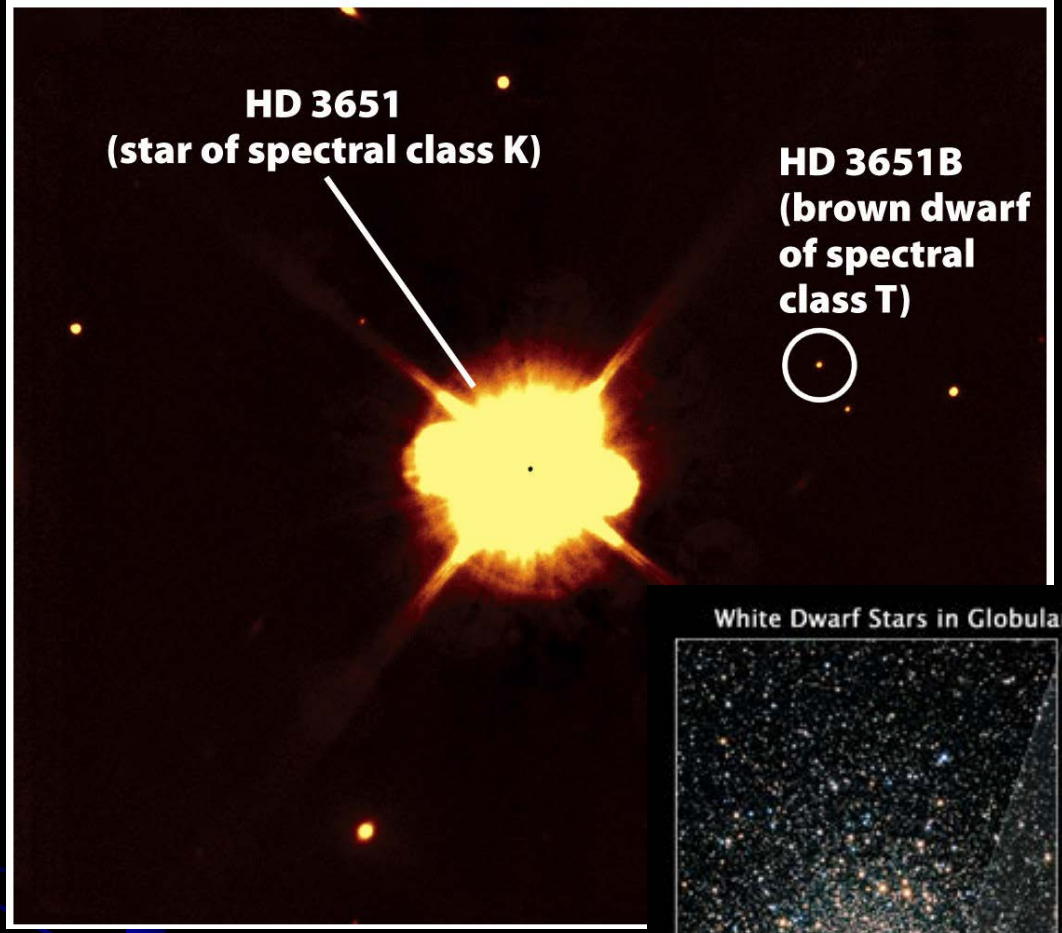
Stellar radii

$V, \pi \Rightarrow F, d$

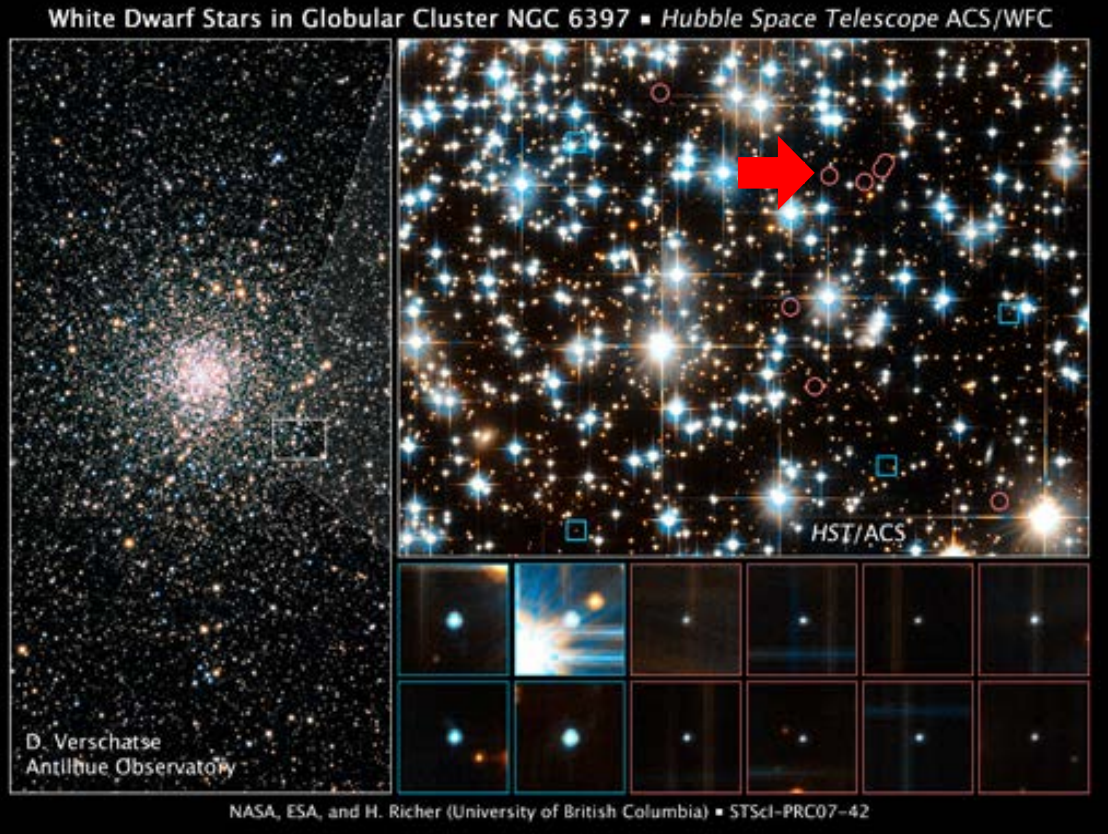
$F_{obs} = \sigma T^4 \frac{4\pi R^2}{4\pi d^2}$



Henry N. Russell
1877-1957



Stars have an enormous range in luminosity



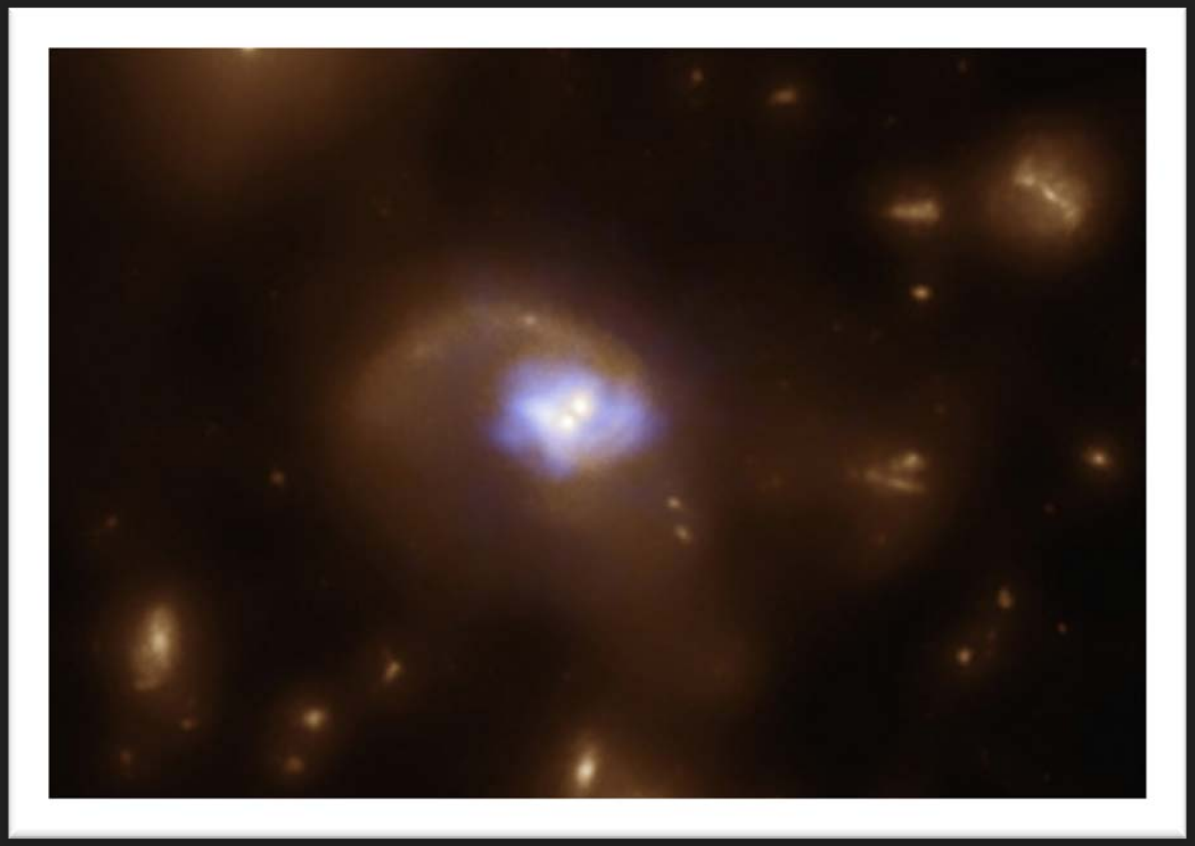
What causes stellar spectra to be so different?

A. Age of the star
B. Composition of the star
C. Temperature of the star
D. Velocity of the star

Physics and Space Sciences Department Colloquium:

Observational Signatures of Recoiling Supermassive Black Holes

Dr. Andy Robinson
Rochester Institute of Technology



TOMORROW
Friday, March 22, 2013
4:00-5:00P.M.
Olin Physical Sciences
Room 140

Stellar Spectra Explained: TEMPERATURE

	HOT (>20kK)	WARM (5-20kK)	COOL (<5,K)
Hydrogen	weak, ionized	strong, excited	weakly excited
Helium	medium, excited	weak, excited	absent
"Metals"	weak, ionized	medium, excited	strong, excited
Molecules	absent, dissociated	weak, excited	strong, excited

Excitation

Ludwig Boltzmann
1804-1906

Ionization

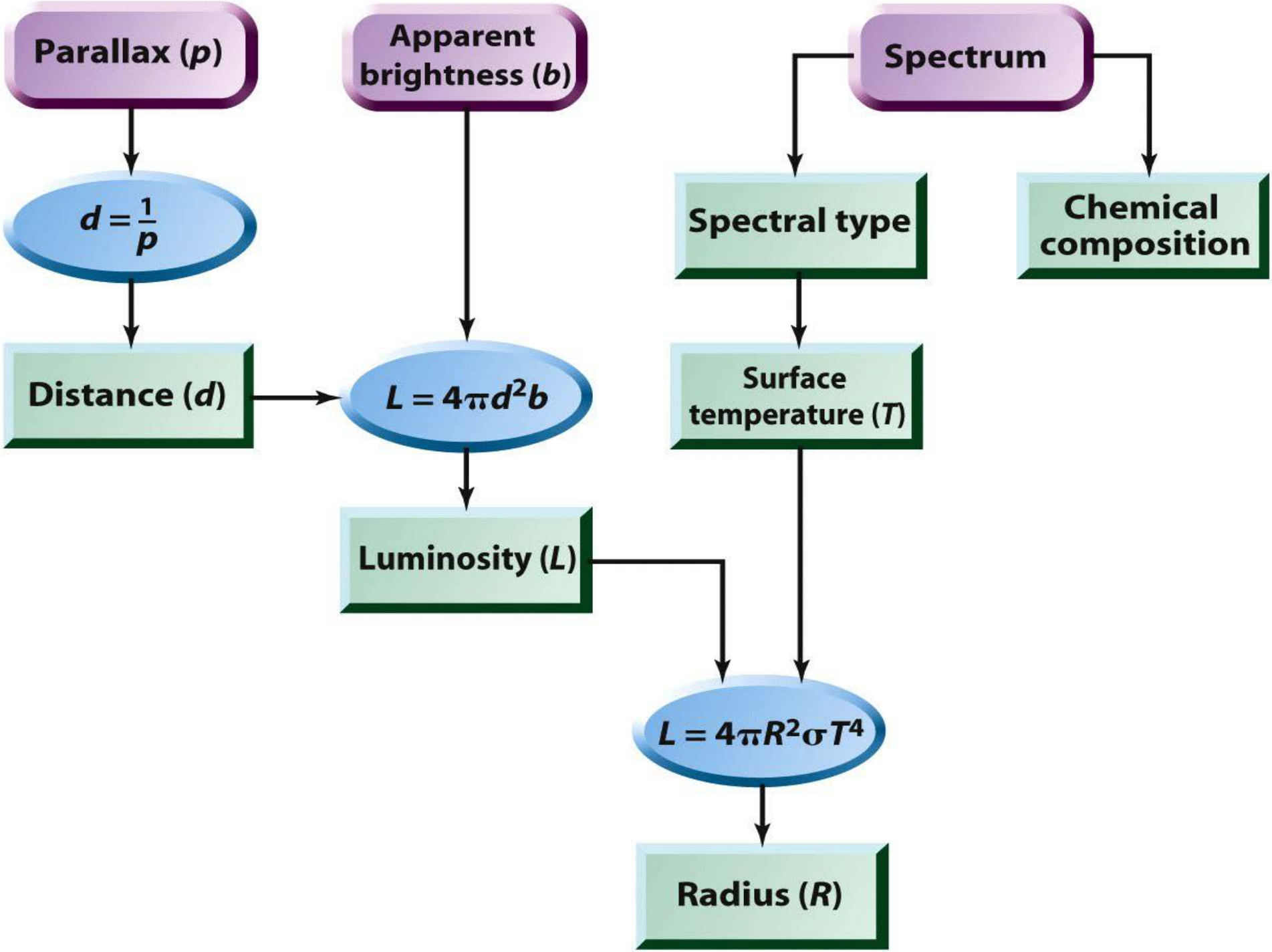
H ionizes at ~13 kK (warm)

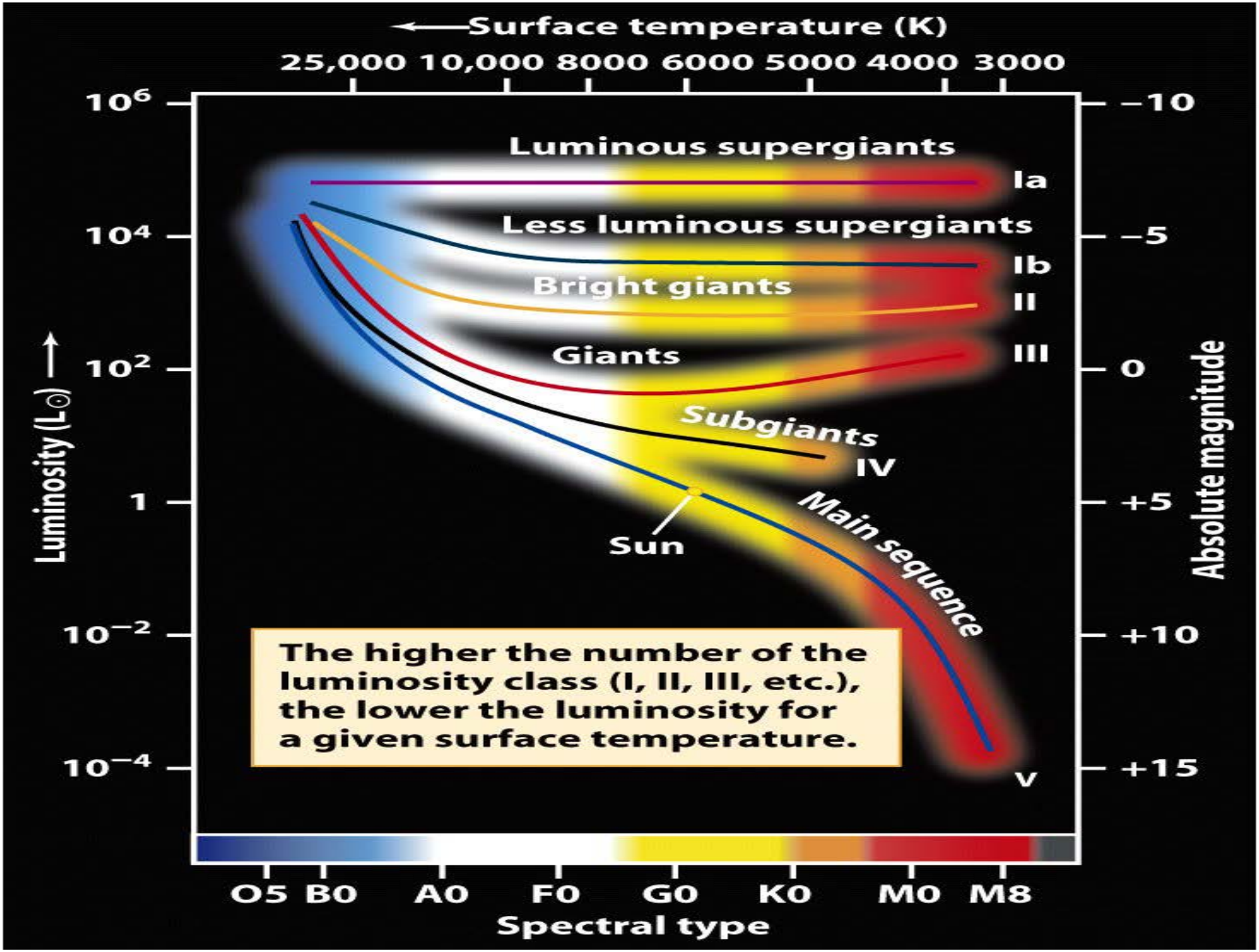
He ionizes at ~50 kK (hot)

Metals ionize at ~7 kK (cool)

Molecules break ~ 4 kK (way cool)

Meghnad Saha
1893-1956


Parallax (p)
Apparent brightness (b)
Spectrum
$d = \frac{1}{p}$
Spectral type
Chemical composition
Distance (d)
$L = 4\pi d^2 b$
Surface temperature (T)
Luminosity (L)
$L = 4\pi R^2 \sigma T^4$
Radius (R)

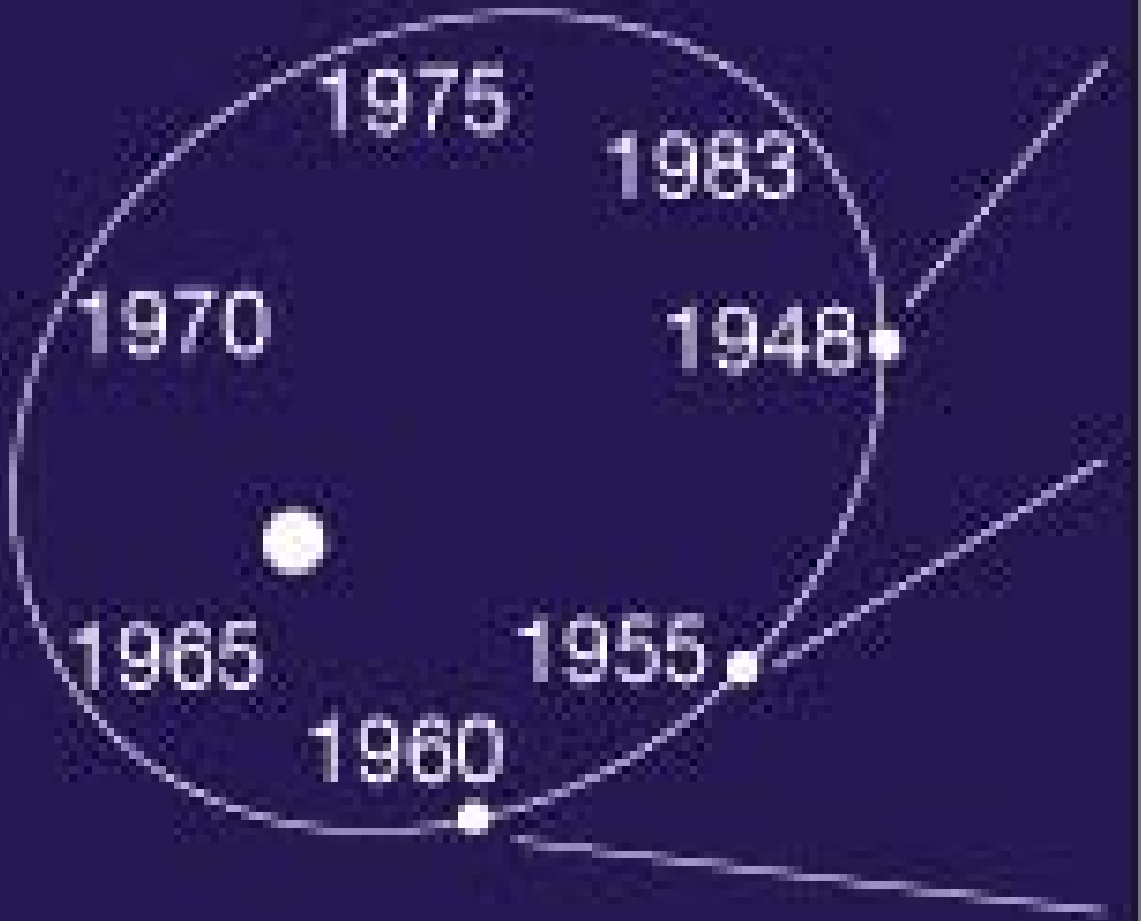

Surface temperature (K)
25,000 10,000 8000 6000 5000 4000 3000
10^6
10^4
10^2
1
10^{-2}
10^{-4}
Luminosity ($L_\odot$)
−10
−5
0
+5
+10
+15
Absolute magnitude
Luminous supergiants
Ia
Less luminous supergiants
Ib
Bright giants
II
Giants
III
Subgiants
IV
Main sequence
Sun
V
The higher the number of the luminosity class (I, II, III, etc.), the lower the luminosity for a given surface temperature.
O5 B0 A0 F0 G0 K0 M0 M8
Spectral type

Binary Stars

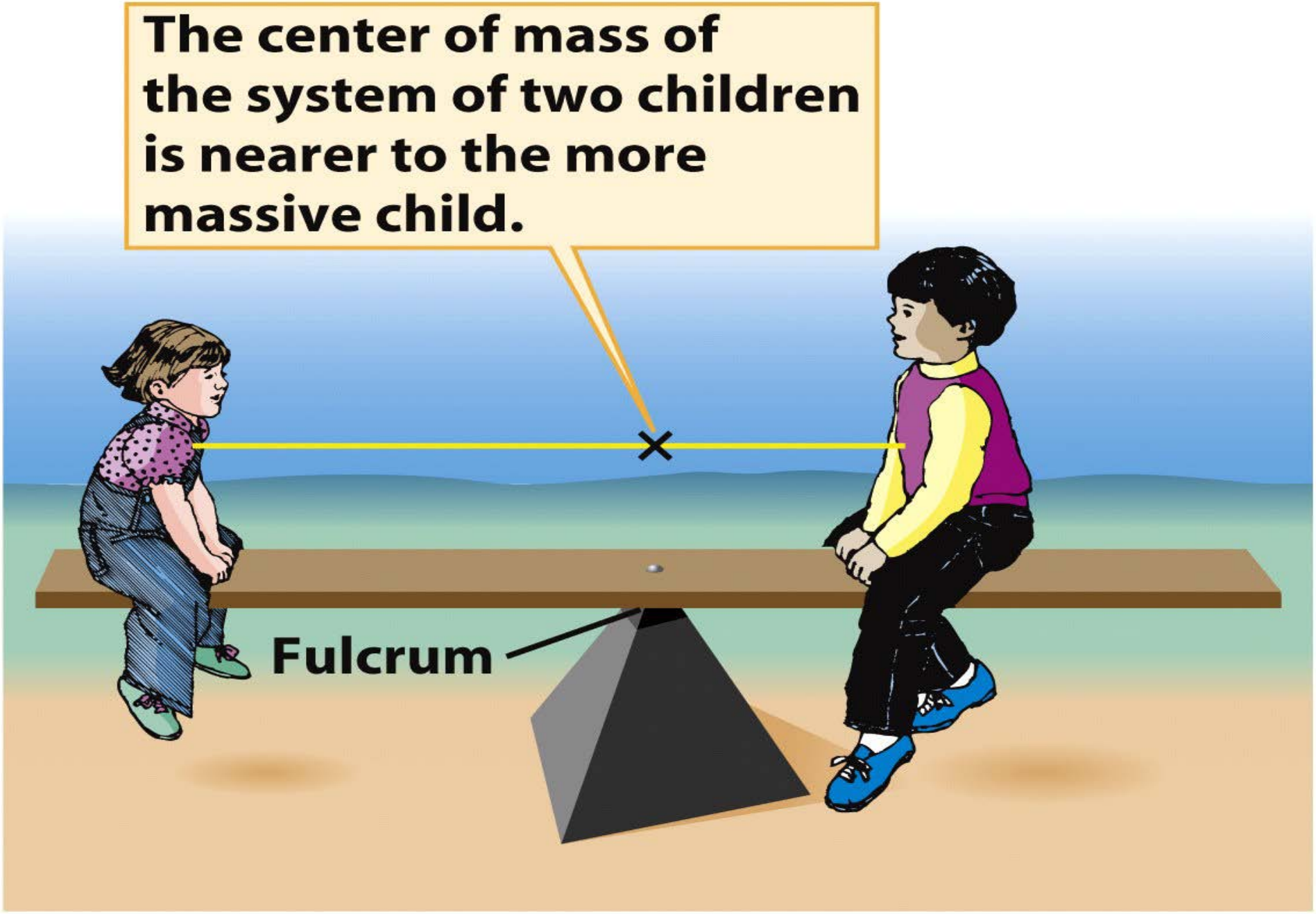
$(m_1 + m_2)\, P^2 = a^3$

$m_1 r_1 = m_2 r_2$

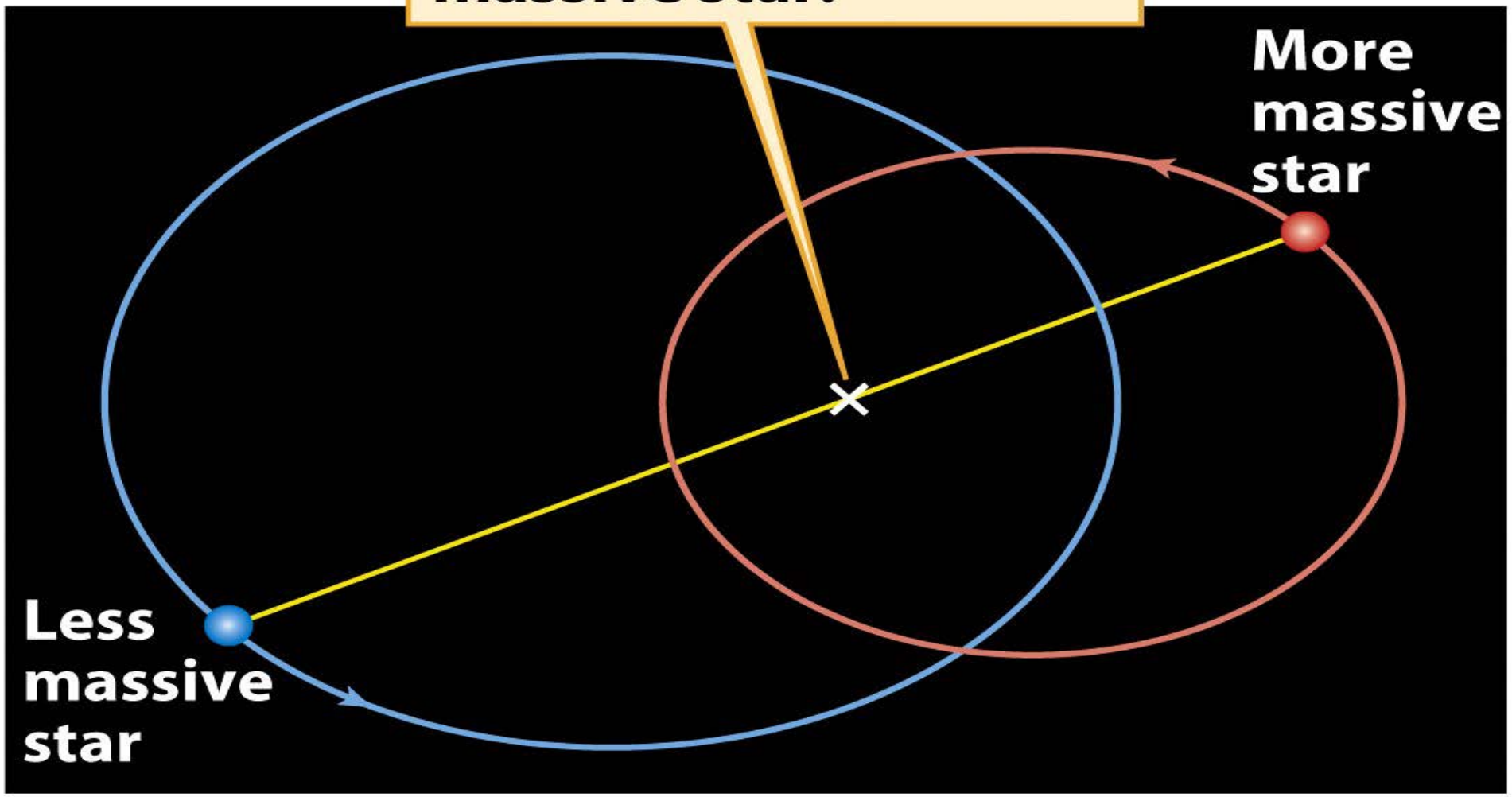
Visual*



*but what is the inclination?



A “binary system” of two children

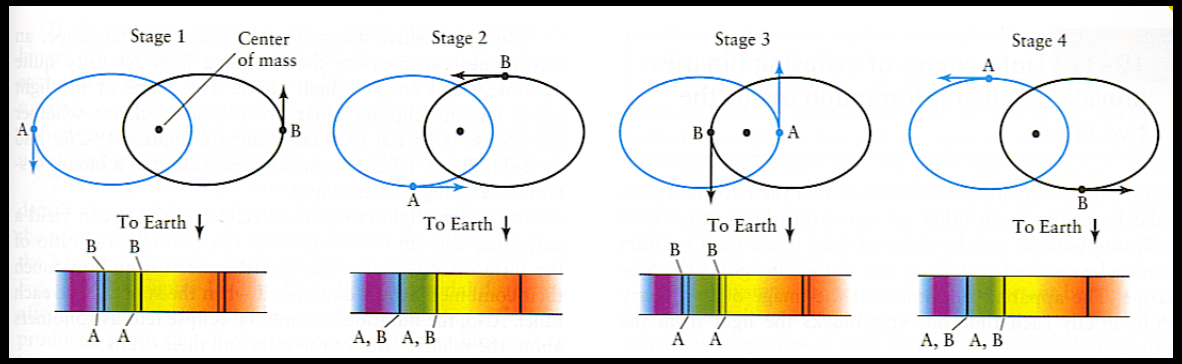


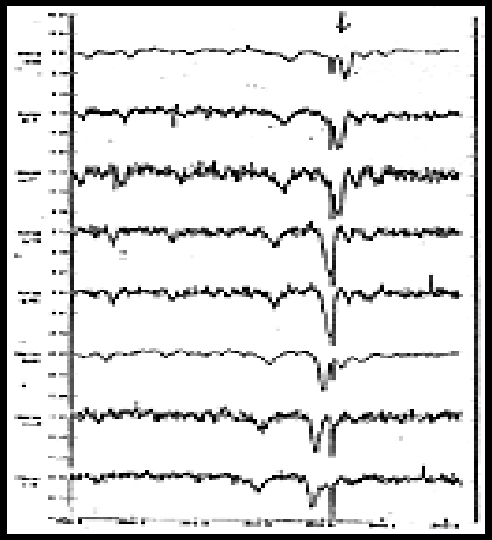
A binary star system

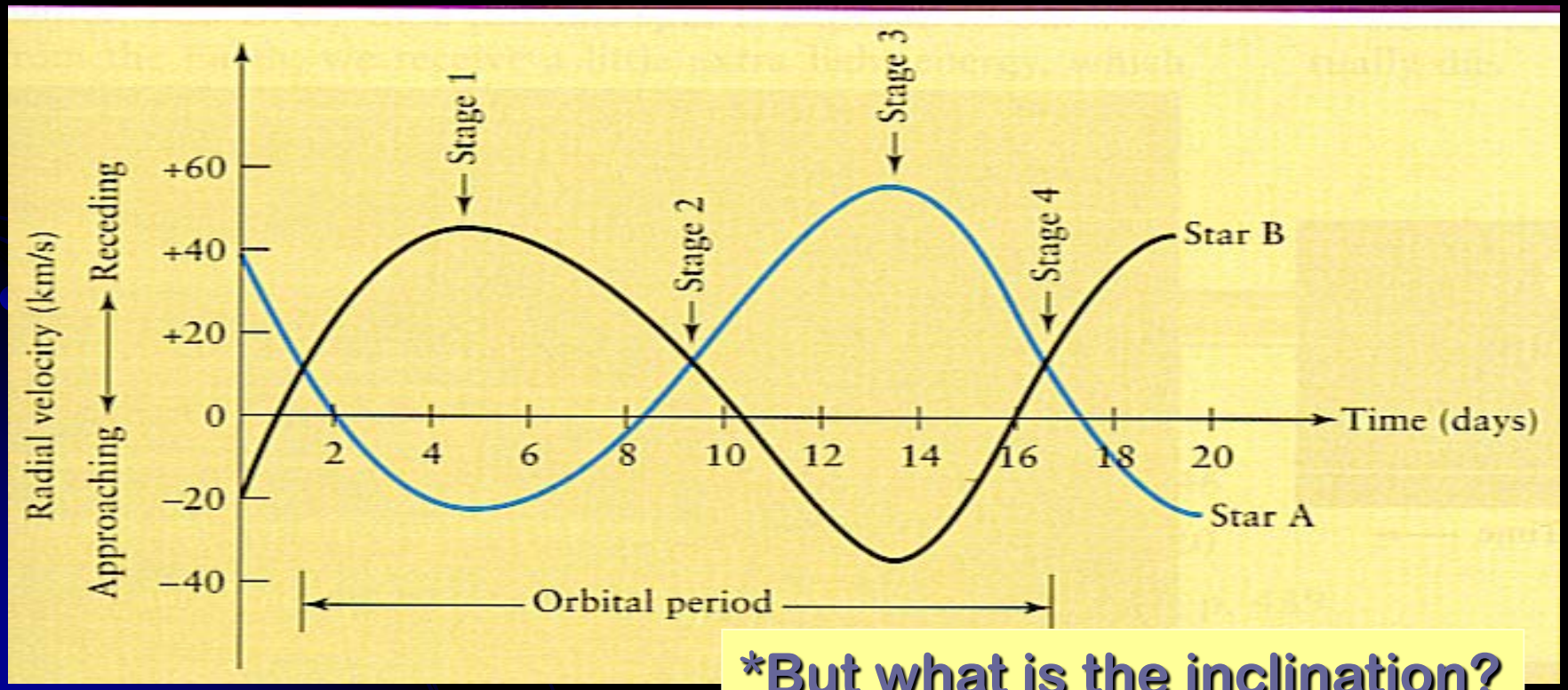
Binary Stars

Spectroscopic*

$$m_1 v_1 = m_2 v_2$$







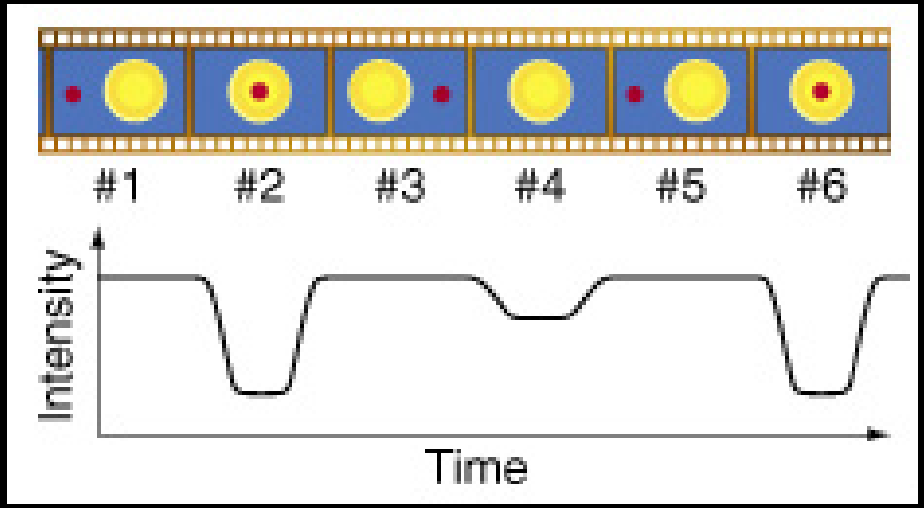
*But what is the inclination?

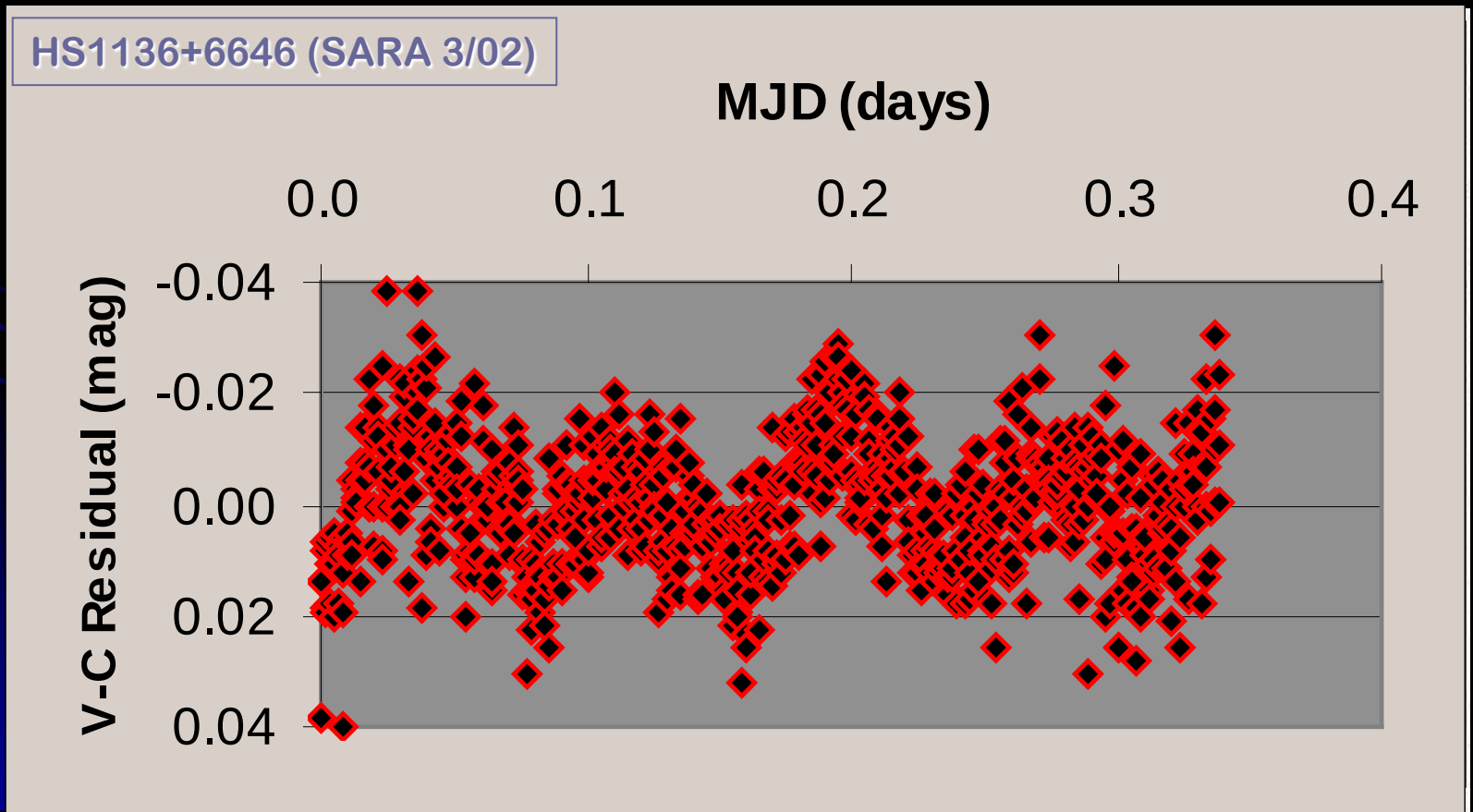
Binary Stars

Eclipsing

$t_2 - t_1 \Rightarrow R_2$

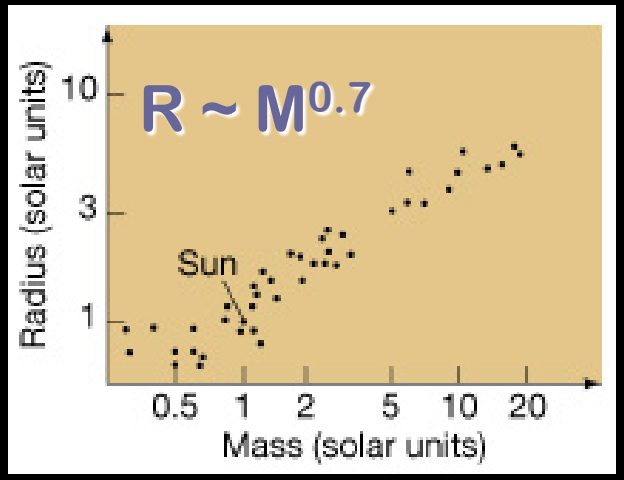
$t_3 - t_1 \Rightarrow R_{15}$



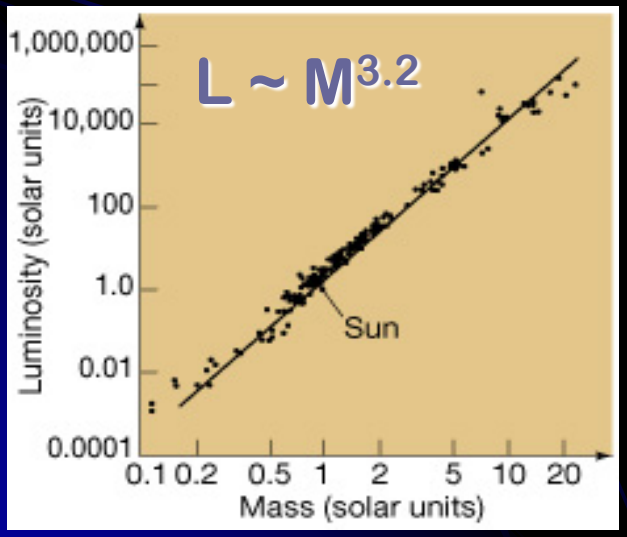


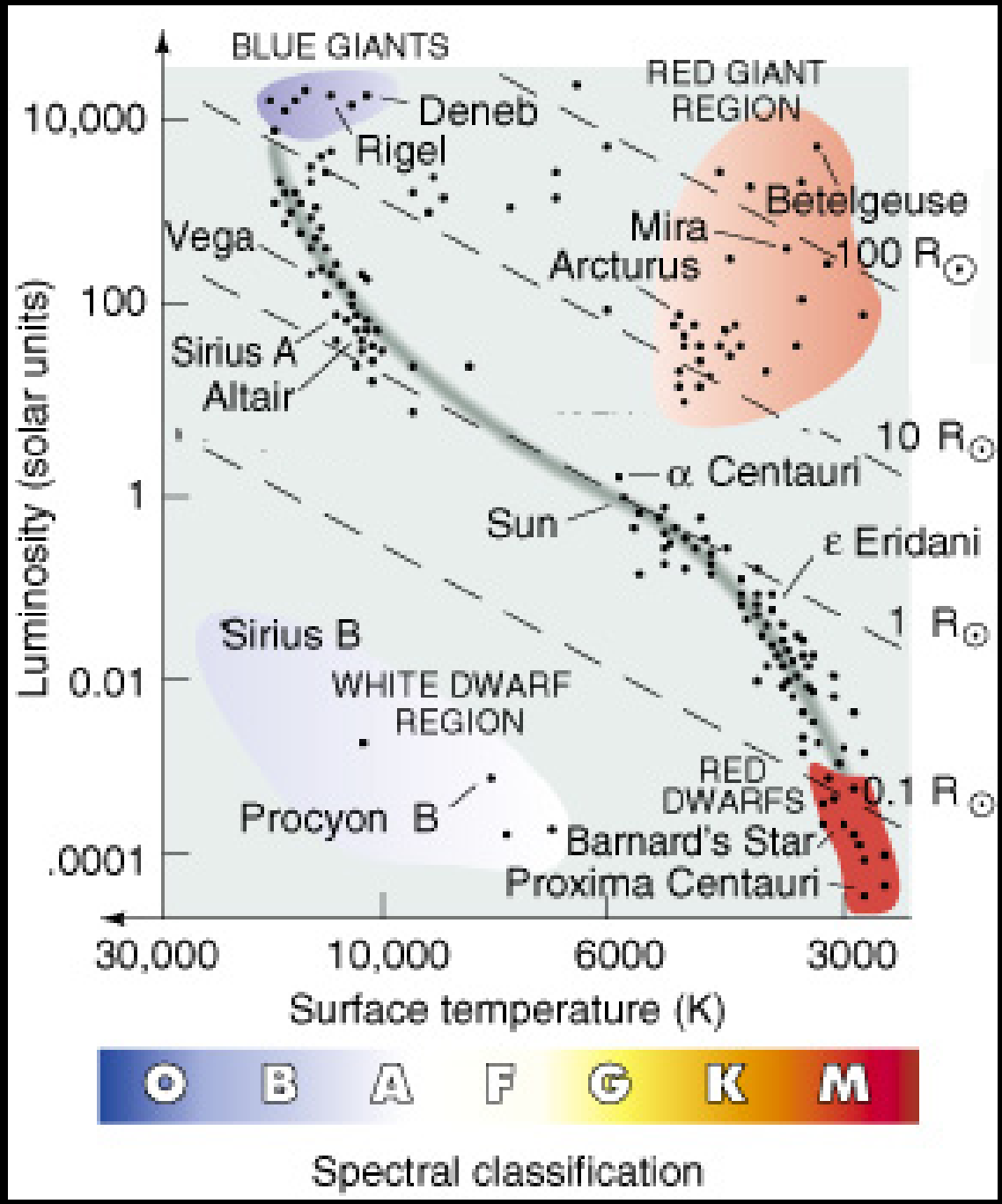
Physical Data

M-R Relation



M-L Relation






Launch-CY2011
Launch-CY2012
Launch-CY2013
XMM-Newton (ESA)
Swift
Suzaku (JAXA)
Fermi
INTEGRAL (ESA)
RXTE
(Decommissioned—2012)
GALEX
Planck (ESA)
Herschel (ESA)
NuSTAR
WISE
(Decommissioned—2011)
Hubble
Chandra
Kepler
Spitzer
SOFIA
NASA Astrophysics
Advisory Subcommittee