Stellar Quantities

IB PHYSICS | ASTROPHYSICS

Measuring Distances

1 light year (ly) = 9.46×10^{15} m

The distance that light travels in an earth year

1 astronomical unit (AU) = 1.50×10^{11} m

The average distance between the earth and the sun

1 parsec (pc) = 3.26 ly

distance at which the mean radius of the earth's orbit subtends an angle of one second of arc.

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Unit conversions

1 radian (rad) $\equiv \frac{180°}{\pi}$

Temperature (K) = temperature (°C) + 273

1 light year (ly) = 9.46×10^{15} m

1 parsec (pc) = 3.26 ly

1 astronomical unit (AU) = 1.50×10^{11} m

1 kilowatt-hour (kWh) = 3.60×10^{6} J

$hc = 1.99 \times 10^{-25}$ J m = 1.24×10^{-6} eV m

Calculating Stellar Quantities

Distance

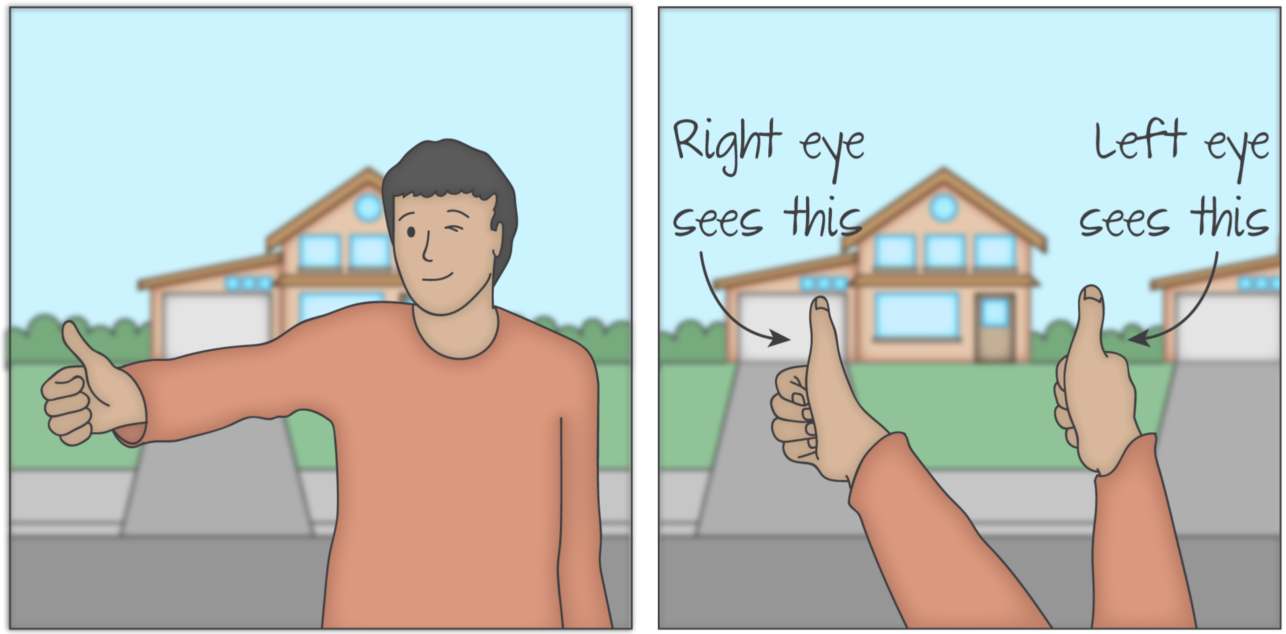
Brightness

Luminosity

Temperature

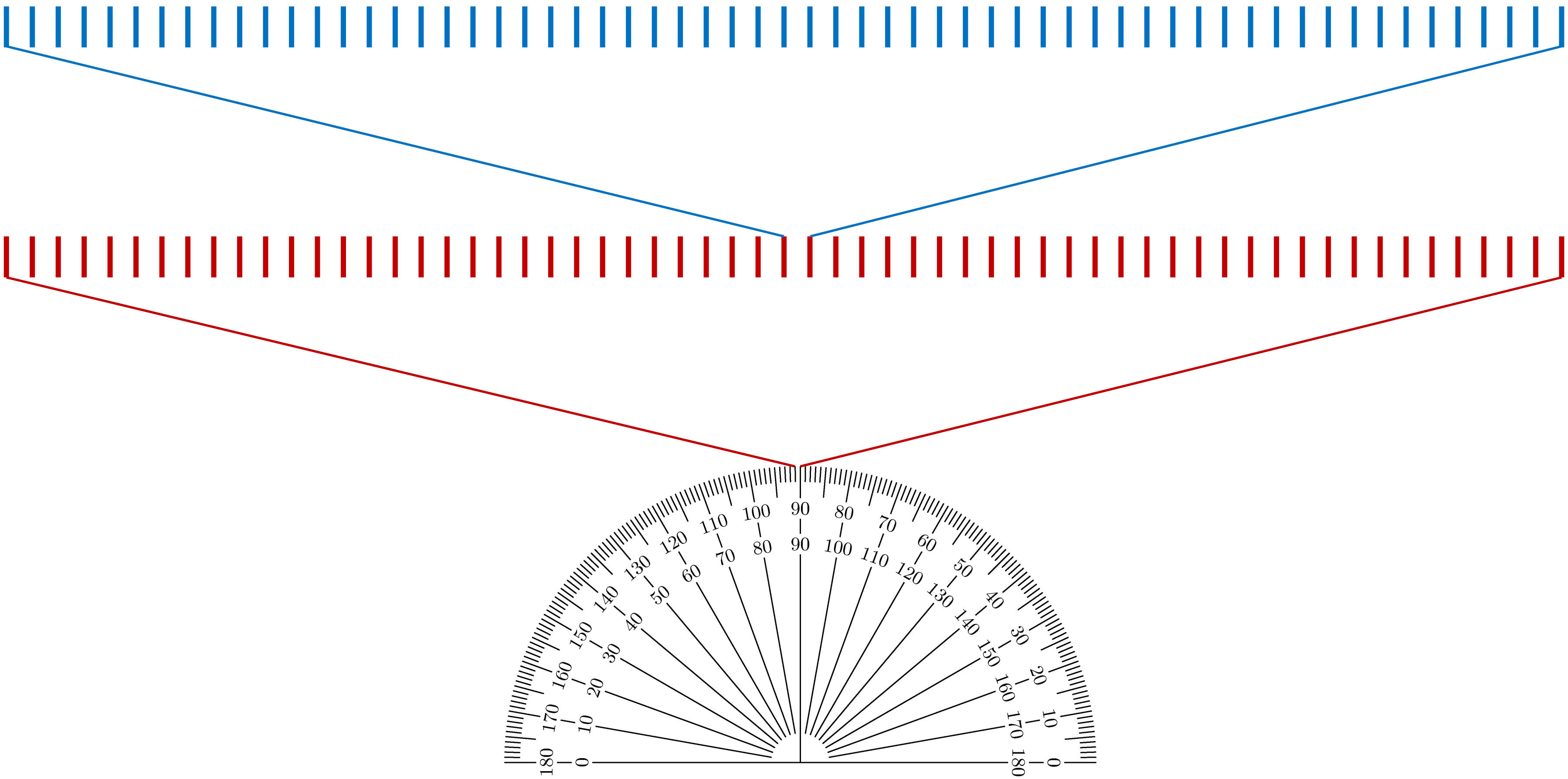
Radius

Stellar Parallax



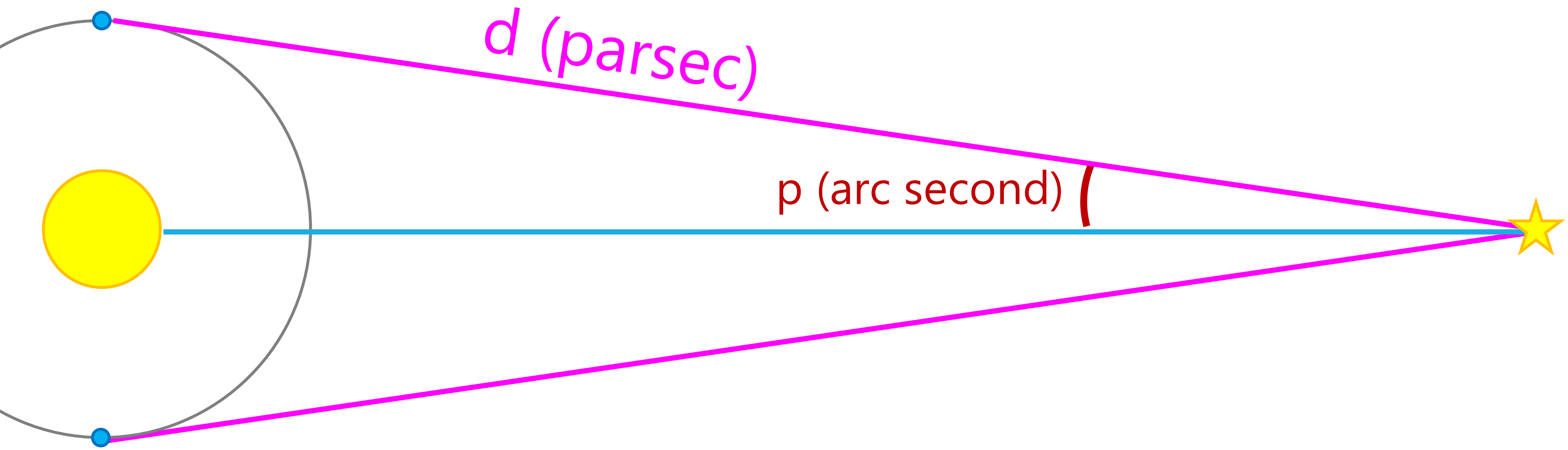
Distance | Brightness | Luminosity | Temperature | Radius

Measuring Angles



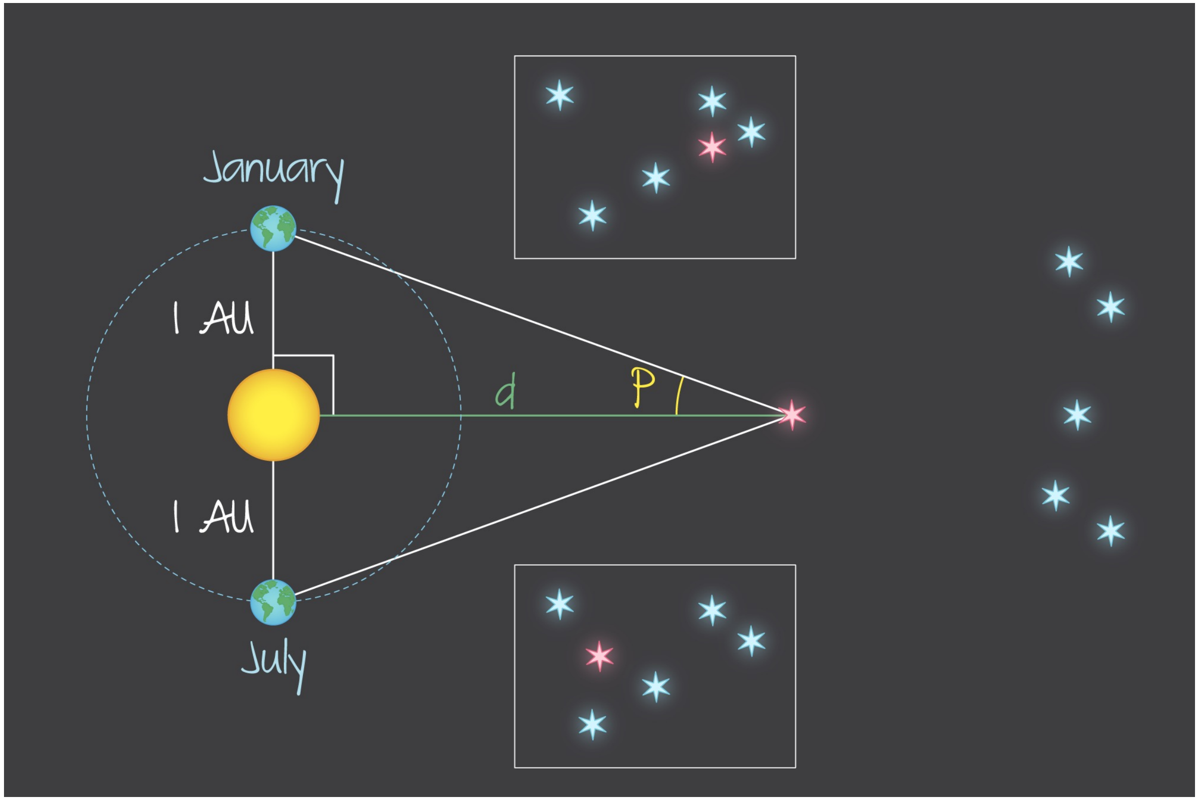
Distance **Brightness** **Luminosity** **Temperature** **Radius**

Stellar Parallax



Stellar Parallax

The angle **must** be measured to a very distant field of other stars



**The parallax method only works for stars that are relatively close to earth*

Try This… | #1

$$d\ (parsec) = \frac{1}{p\ (arc\ second)}$$

The star Betelgeuse has a parallax angle of 7.7×10^{-3} arc seconds. Calculate its distance.

1 light year (ly) = 9.46×10^{15} m

1 parsec (pc) = 3.26 ly

arc-seconds → parsecs → light years → meters

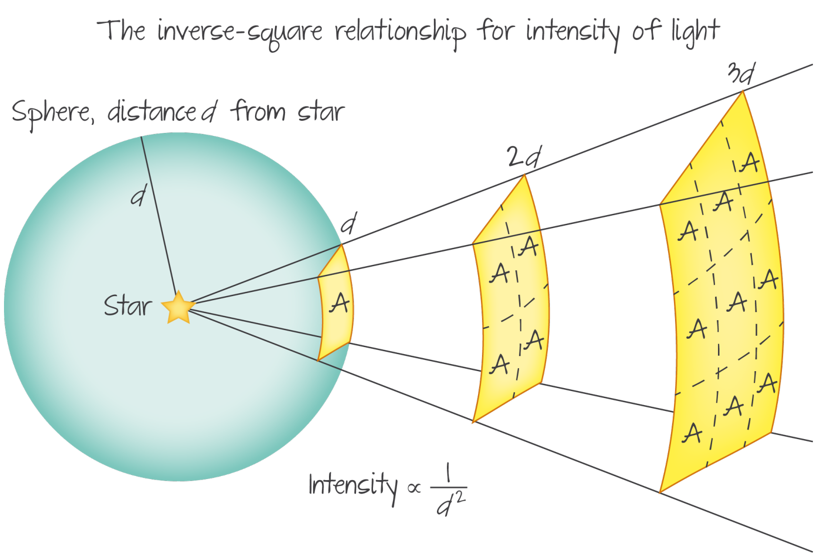
Luminosity vs Brightness

Luminosity		Brightness	

Distance **Brightness** **Luminosity** **Temperature** **Radius**

Brightness

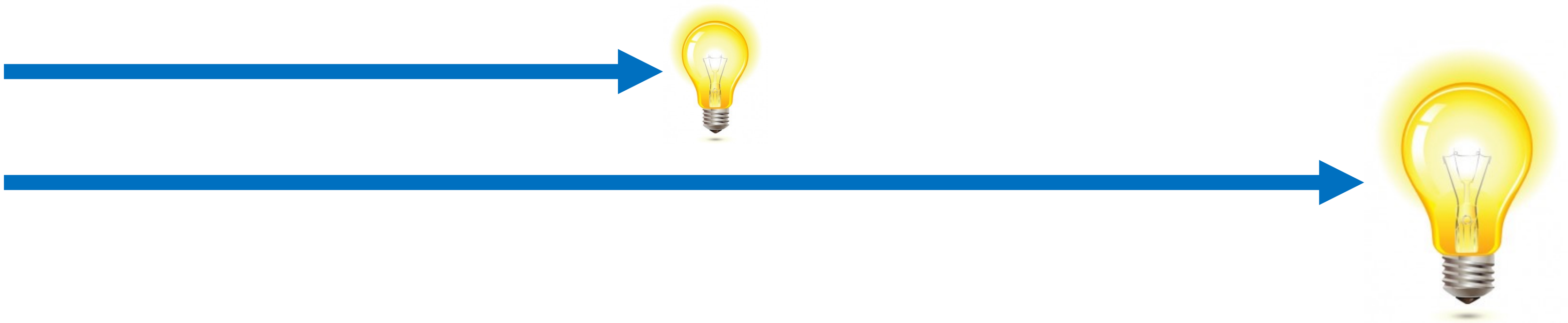
$$b = \frac{L}{4\pi d^2}$$



Distance	Brightness
x	
2x	
3x	
4x	

Same Brightness, Different Stars

It is possible for stars to have the same brightness but have different distances and luminosities



Try This… | #2

The star Betelgeuse has an apparent brightness of 2.0×10^{-7} W m^{-2}. Calculate its luminosity.

$d = 4.0 \times 10^{18}$ m

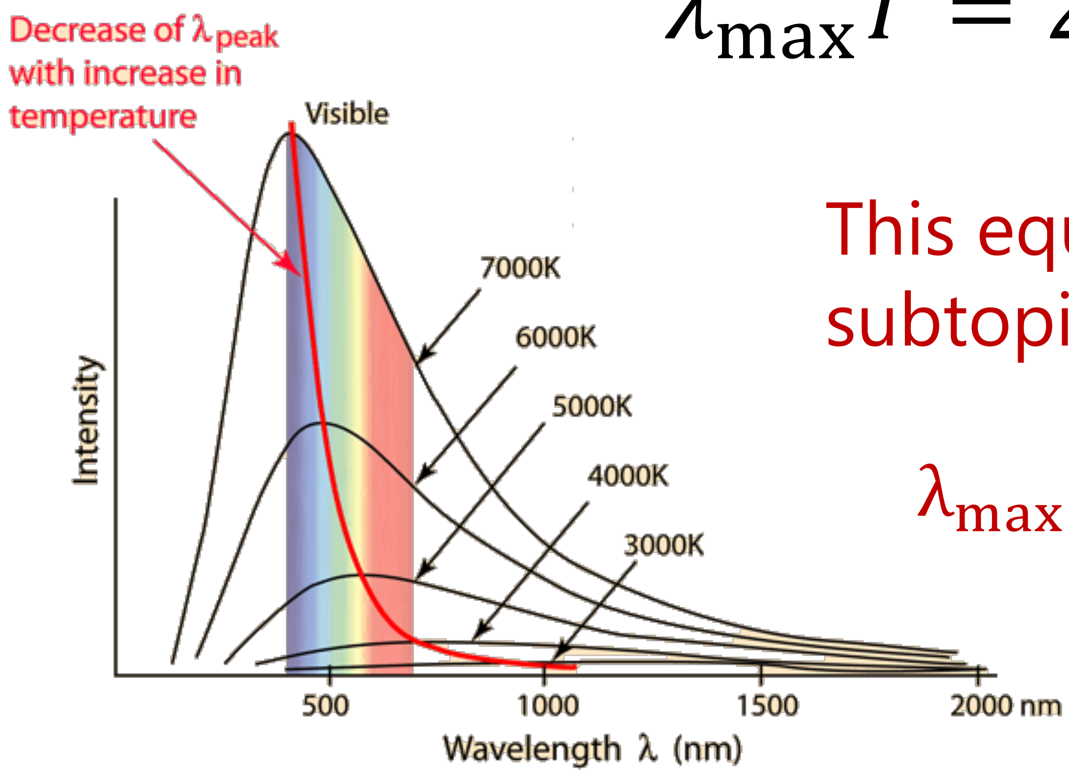
$$b = \frac{L}{4\pi d^2}$$

Calculating Stellar Quantities

- [x] Distance
- [x] Brightness
- [x] Luminosity
- [ ] Temperature
- [ ] Radius

Wien's Displacement Law

$$\lambda_{max}T = 2.90 \times 10^{-3}\text{ mK}$$



This equation shows up in subtopic 8.2 as

$$\lambda_{max}(\text{metres}) = \frac{2.90 \times 10^{-3}}{\text{T (kelvin)}}$$

*Note: This assumes perfect blackbody radiation

Try This… | #3

The star Betelgeuse has a max wavelength of 828.6 nm. What is its surface temperature?

$$\lambda_{\text{max}} T = 2.90 \times 10^{-3}\ \text{mK}$$

Luminosity

$$L = \sigma A T^4$$

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

Try This… | #4

Knowing everything else that we know about Betelgeuse, calculate the average radius of the star.

$L = 4.0 \times 10^{31}$ W

$T = 3{,}500$ K

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Sub-topic D.1 – Stellar quantities	Sub-topic D.2 – Stellar characteristics and stellar evolution
$d\,(\text{parsec}) = \dfrac{1}{p\,(\text{arc–second})}$ $L = \sigma A T^4$ $b = \dfrac{L}{4\pi d^2}$	$\lambda_{\max} T = 2.9 \times 10^{-3}\ \text{m K}$ $L \propto M^{3.5}$
Sub-topic D.3 – Cosmology	**Sub-topic D.5 – Further cosmology (HL only)**
$z = \dfrac{\Delta\lambda}{\lambda_0} \approx \dfrac{v}{c}$ $z = \dfrac{R}{R_0} - 1$ $v = H_0 d$ $T \approx \dfrac{1}{H_0}$	$v = \sqrt{\dfrac{4\pi G\rho}{3}} r$ $\rho_c = \dfrac{3H^2}{8\pi G}$

Distance **Brightness** **Luminosity** **Temperature** **Radius**

All together now!

Brightness (W m^{-2})	1.2×10^{-7} W m^{-2}
Max Wavelength (m)	
Distance (m)	
Luminosity (W)	
Temperature (K)	
Radius (m)	

The brightest star in the sky is known as Sirius and has a parallax angle of 0.379 arc seconds, apparent brightness of 1.2×10^{-7} W m^{-2}, and a max wavelength of 292 nm. Complete this table of stellar properties.