E.5

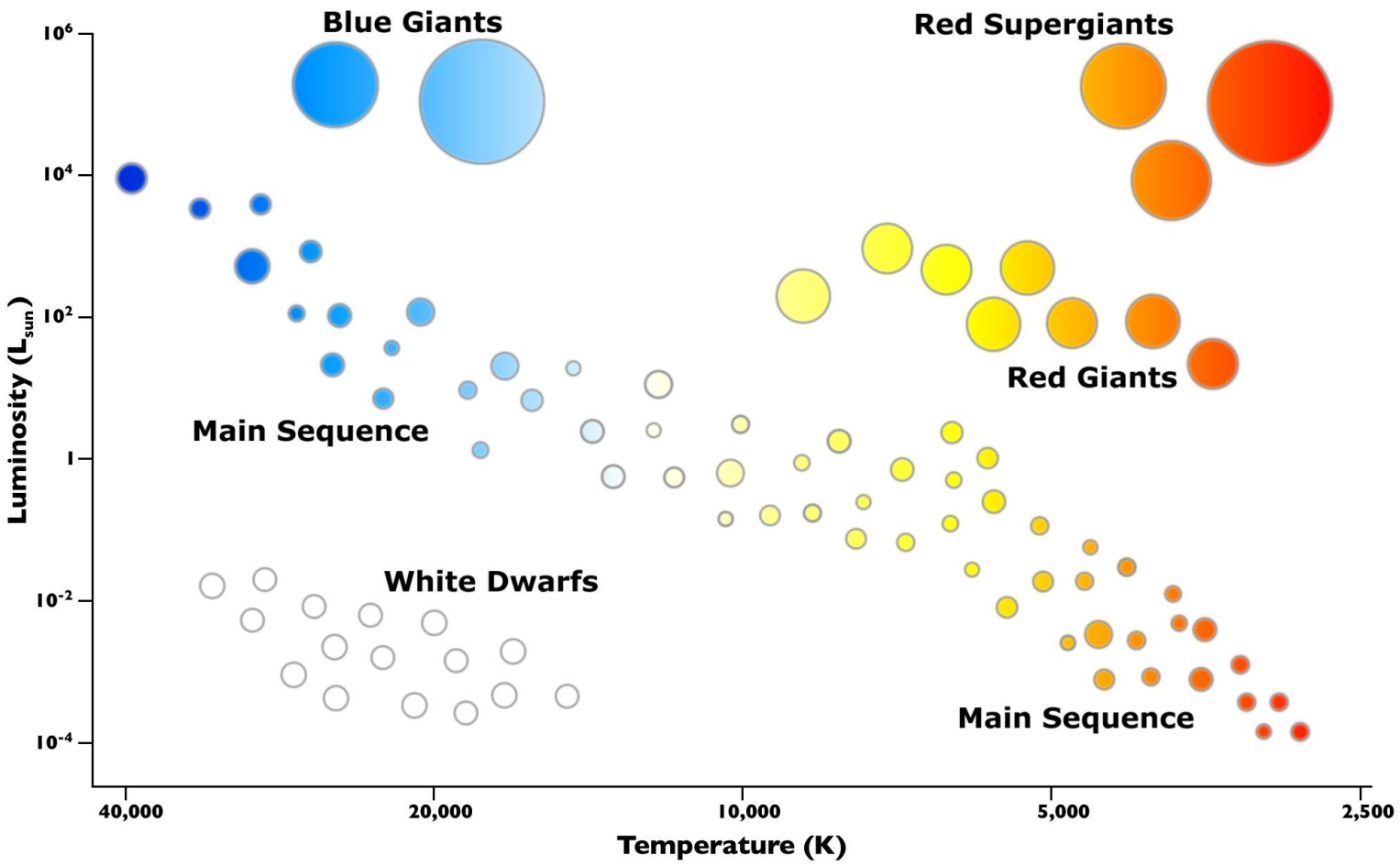
Organizing the Stars

IB PHYSICS | ASTROPHYSICS

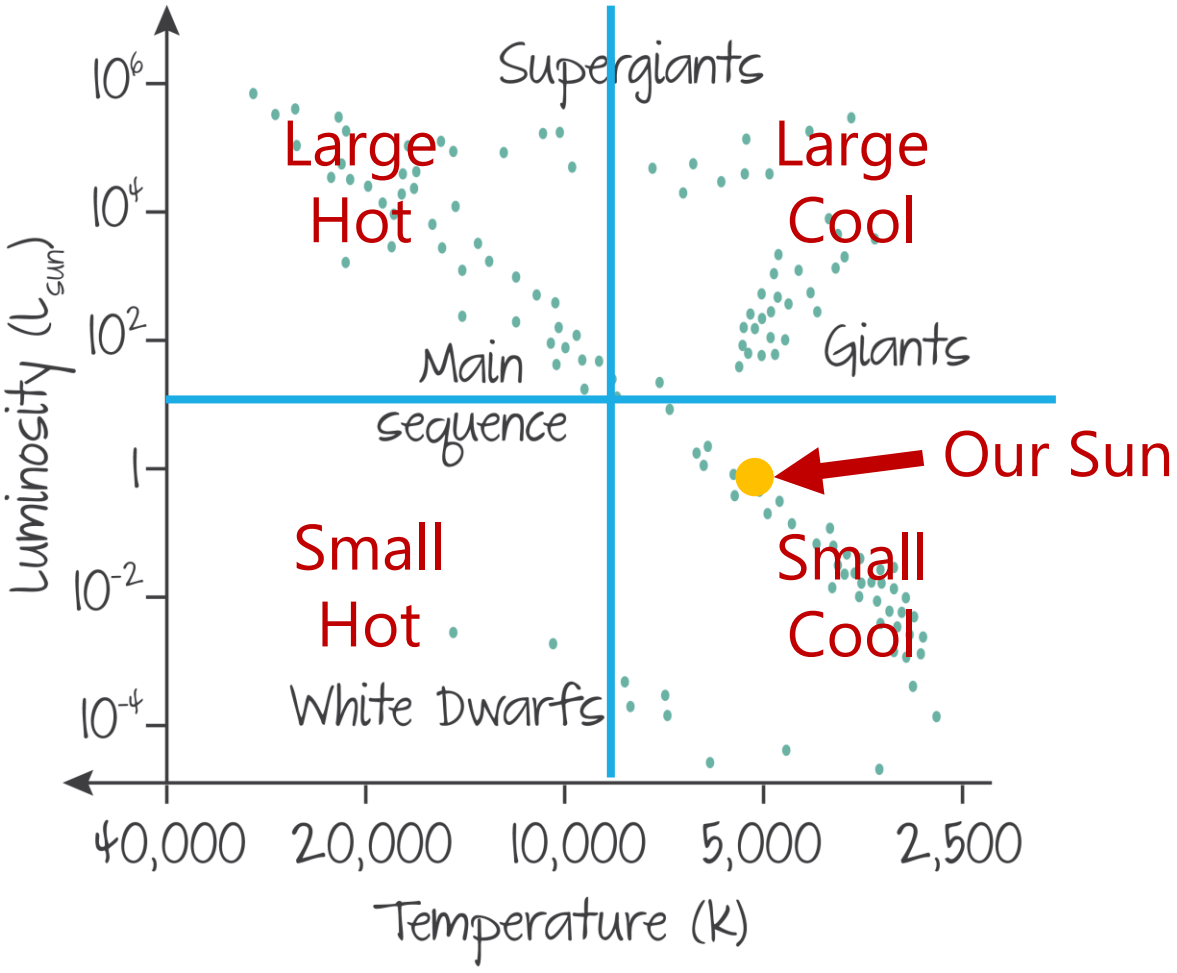
H-R Diagrams

L_{sun}

$L_{\odot}$



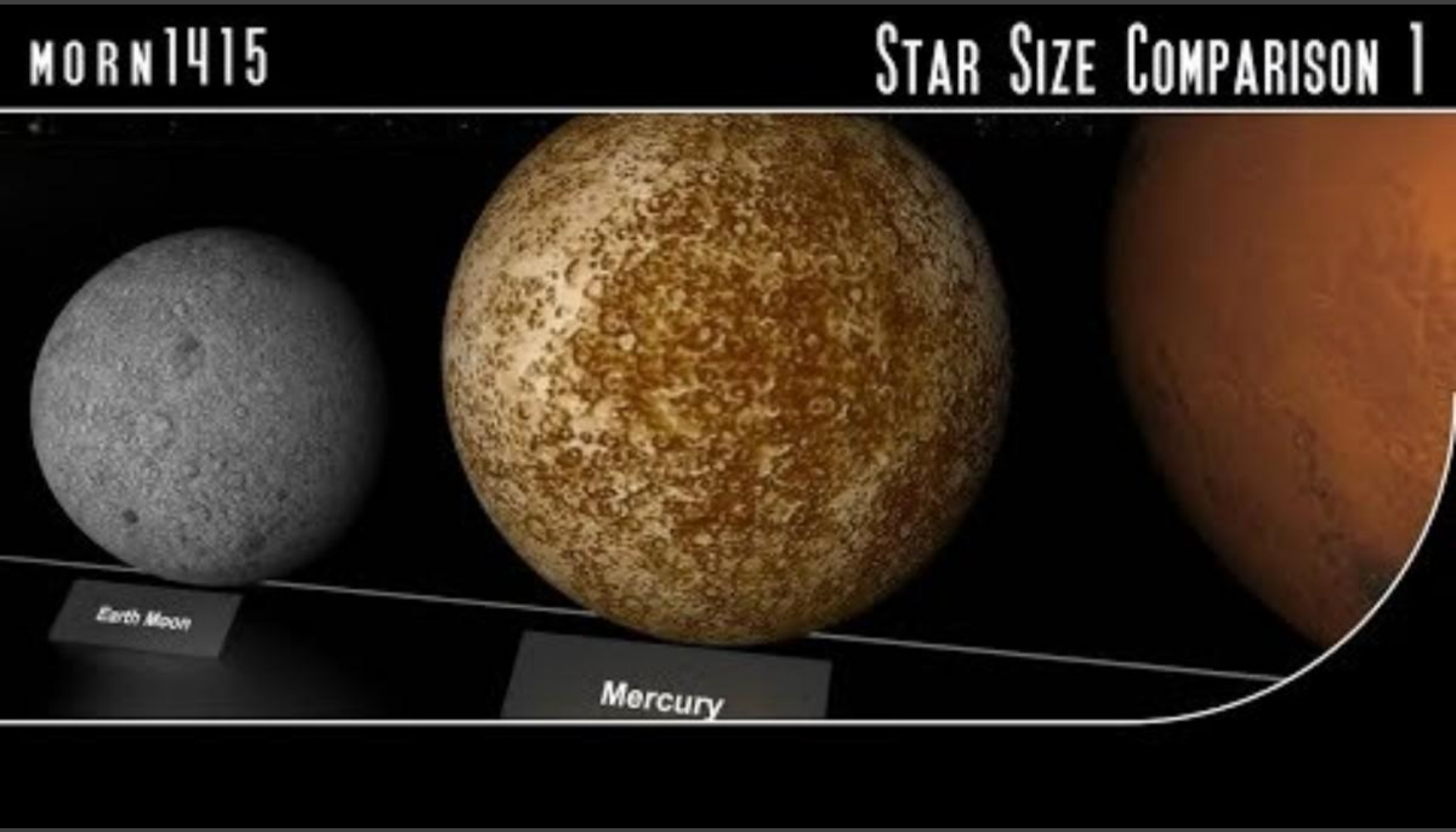
H-R Diagrams


Supergiants
Large
Hot
Large
Cool
Giants
Main
sequence
Our Sun
Small
Hot
Small
Cool
White Dwarfs
Luminosity (L_{sun})
10^6
10^4
10^2
1
10^{-2}
10^{-4}
40,000
20,000
10,000
5,000
2,500
Temperature (K)

H-R Diagrams

Twinkle, twinkle, little star! How I wonder
where on the Hertzsprung-Russell diagram you are...

Sizes of Stars



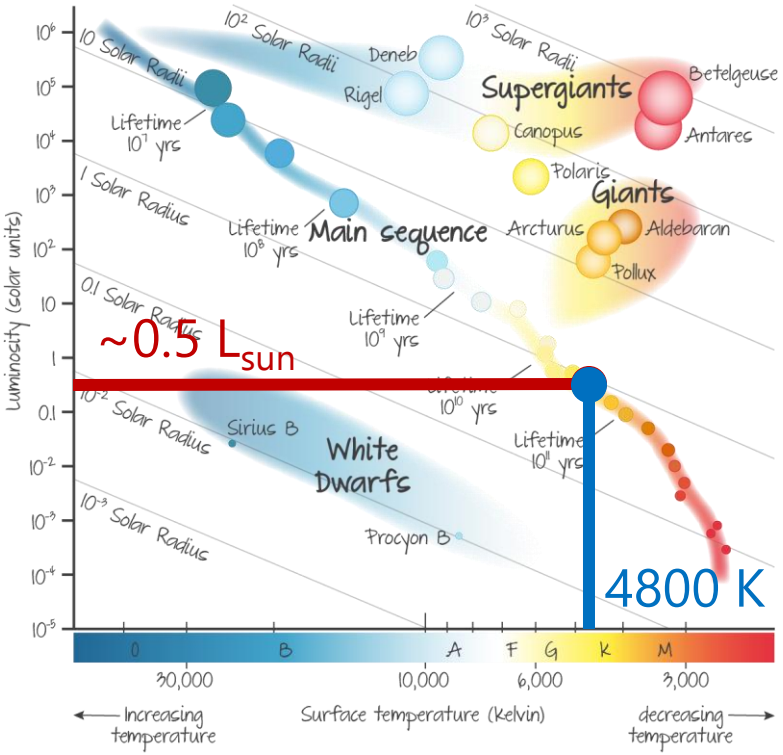
Equation Reminders

B.1

B.1 Thermal energy transfers	
	$\rho = \frac{m}{V}$
	$\overline{E_k} = \frac{3}{2} k_B T$
	$Q = mc\Delta T$
	$Q = mL$
	$\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{\Delta x}$
	$L = \sigma A T^4$ ← Luminosity
	$b = \frac{L}{4\pi d^2}$ ← Brightness
	$\lambda_{max} T = 2.9 \times 10^{-3}\,\text{mK}$ ← Temperature

H-R Diagram for Calculating Distance

The maximum wavelength of a distant star is measured to be 600 nm, suggesting that it has a temperature of ~4800 K. If this star has a brightness of 2.3×10^{-12} W m^{-2}, what is its distance from Earth?



$$L_{sun} = 3.84 \times 10^{26} \text{ W}$$

$$L_{star} = 0.5 \times (3.84 \times 10^{26})$$

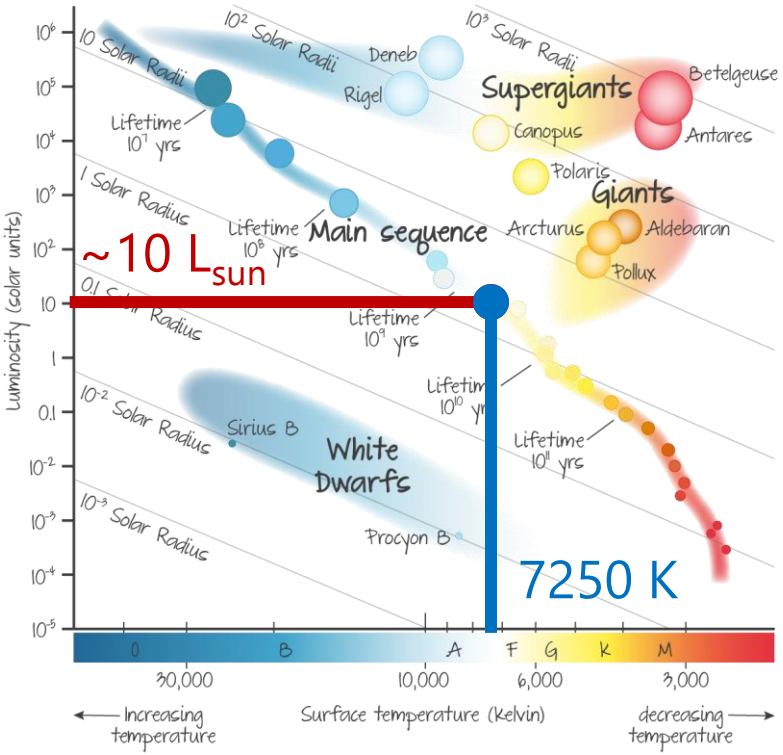
$$= 1.92 \times 10^{26} \text{ W}$$

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

$$d = \sqrt{\frac{1.92 \times 10^{26}}{4\pi(2.3 \times 10^{-12})}} = \boxed{2.58 \times 10^{18} \text{ m}}$$

Try This

The maximum wavelength of a distant star is measured to be 400 nm. If this star has a brightness of 0.5×10^{-12} W m^{-2}, what is its distance from Earth?



$$L_{sun} = 3.84 \times 10^{26} \text{ W}$$

$$T = \frac{2.90 \times 10^{-3}}{400 \times 10^{-9}}$$

$$T = 7250 \text{ K}$$

$$L_{star} = 10 \times (3.84 \times 10^{26})$$

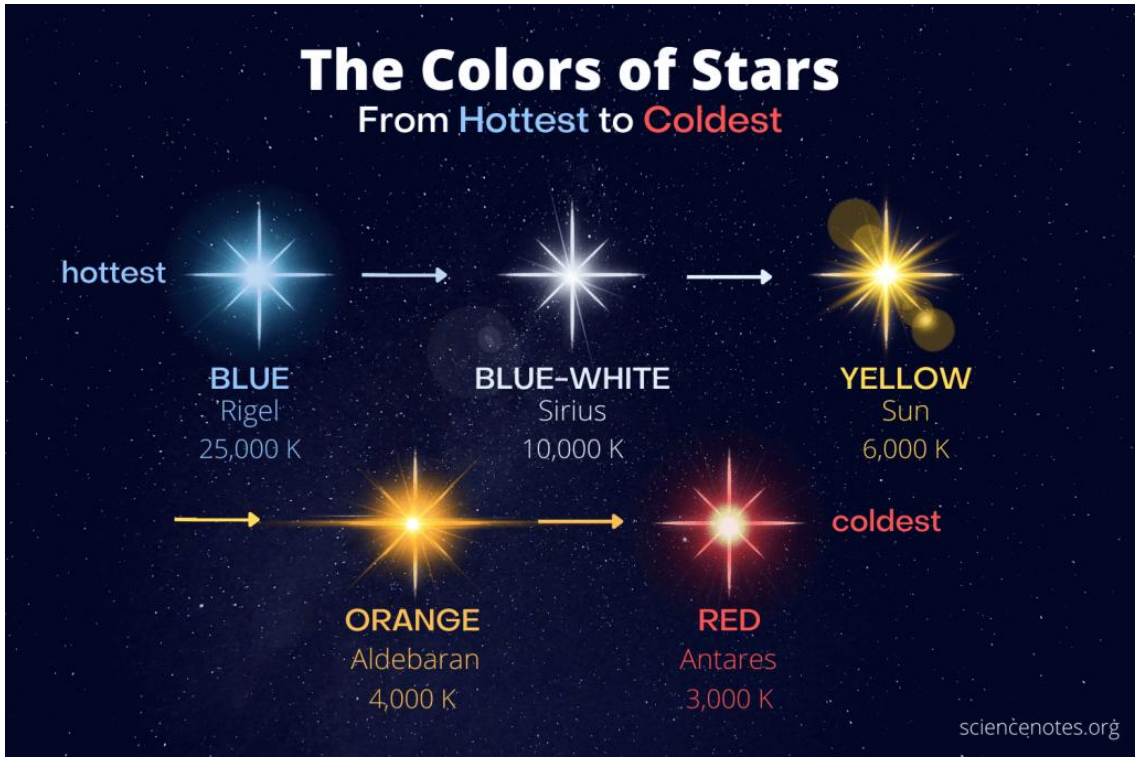
$$= 3.84 \times 10^{27} \text{ W}$$

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

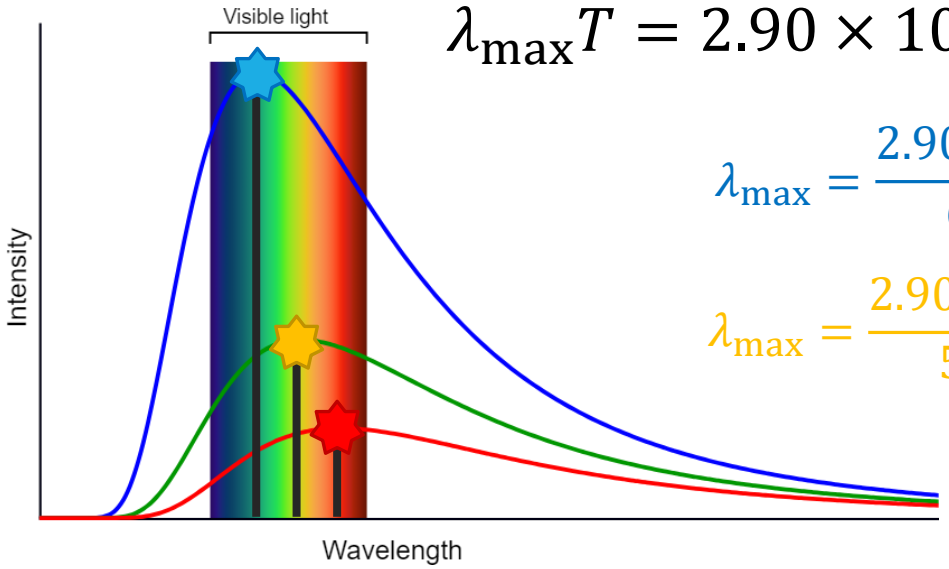
$$d = \sqrt{\frac{3.84 \times 10^{27}}{4\pi(0.5 \times 10^{-12})}} = 2.47 \times 10^{19} \text{ m}$$

Star Color

The color that a star appears is dependent upon its temperature



Wien's Displacement Law



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

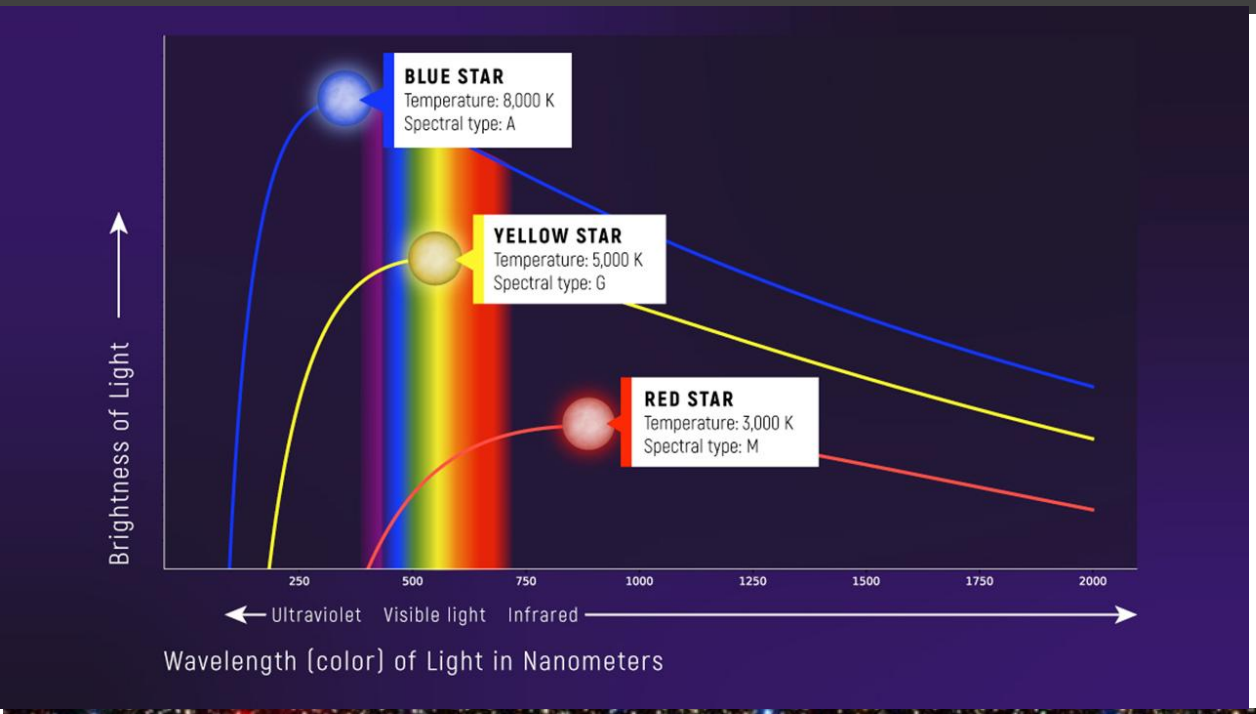
$$\lambda_{max} = \frac{2.90 \times 10^{-3}}{6000} = 4.83 \times 10^{-7}\ \text{m} = 483\ \text{nm}$$

$$\lambda_{max} = \frac{2.90 \times 10^{-3}}{5000} = 6.3 \times 10^{-7}\ \text{m} = 630\ \text{nm}$$

$$\lambda_{max} = \frac{2.90 \times 10^{-3}}{4000} = 6.3 \times 10^{-7}\ \text{m} = 630\ \text{nm}$$

Temperature (T)	6000 K	5000 K	4000 K
Max Wavelength (λ_{max})	**483 nm**	**630 nm**	**700 nm**

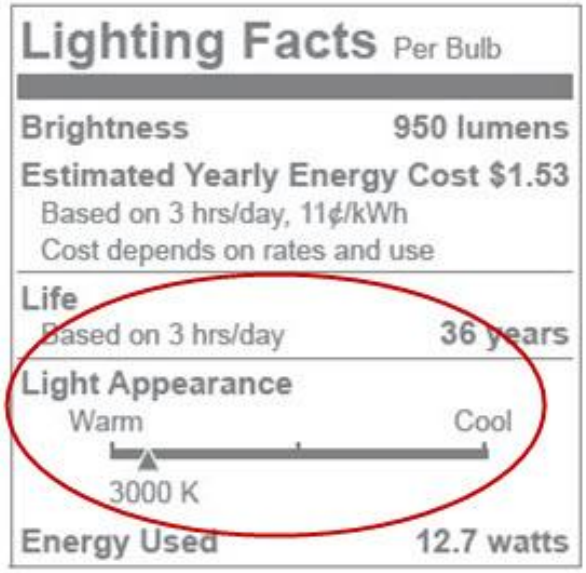
Why no green or purple stars?

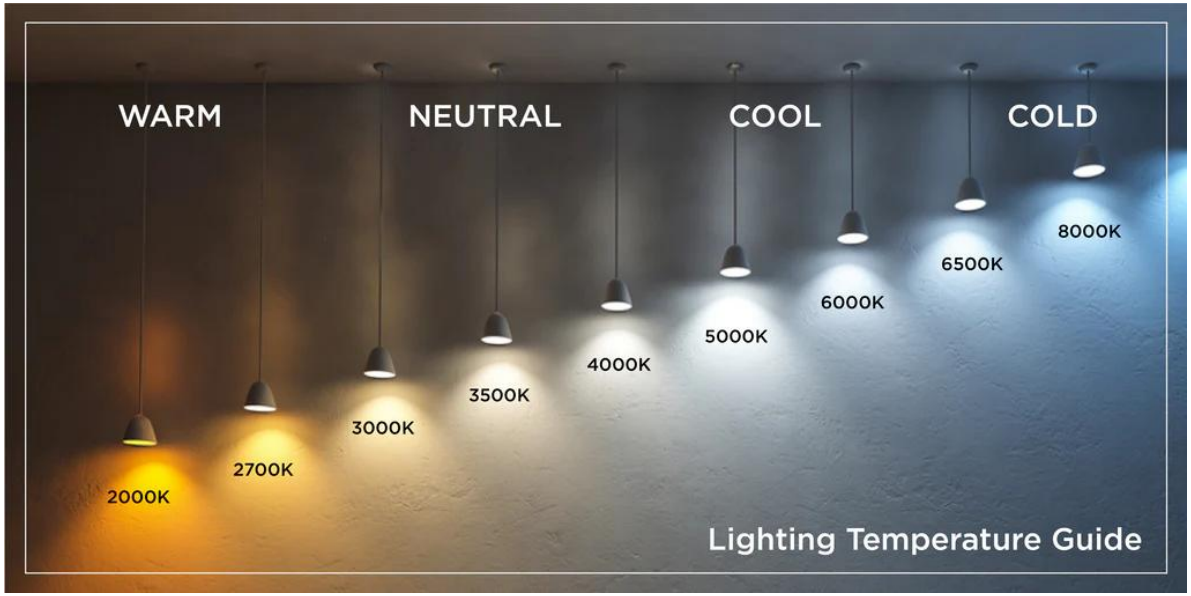


All the colors together

White

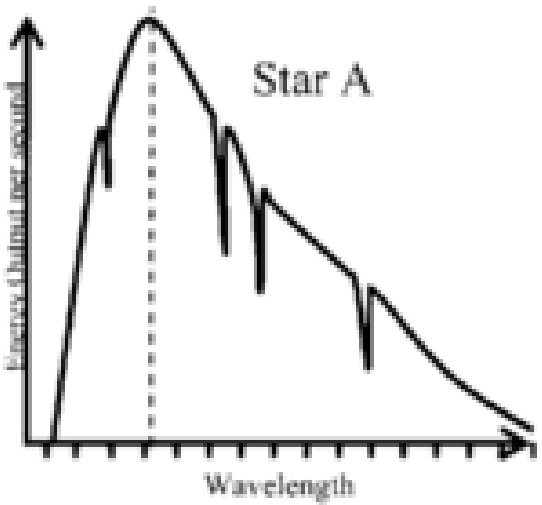
Light Bulbs and Color

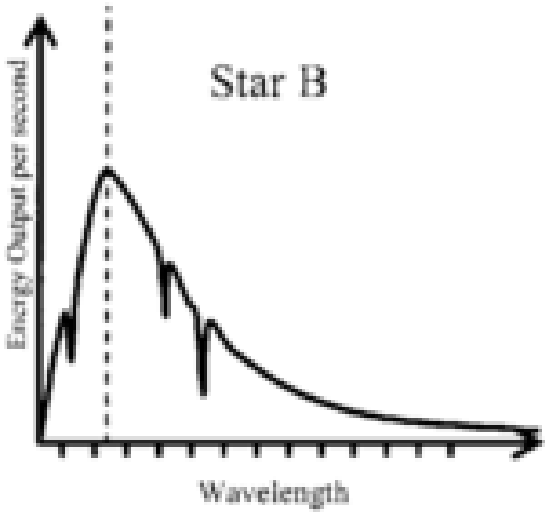


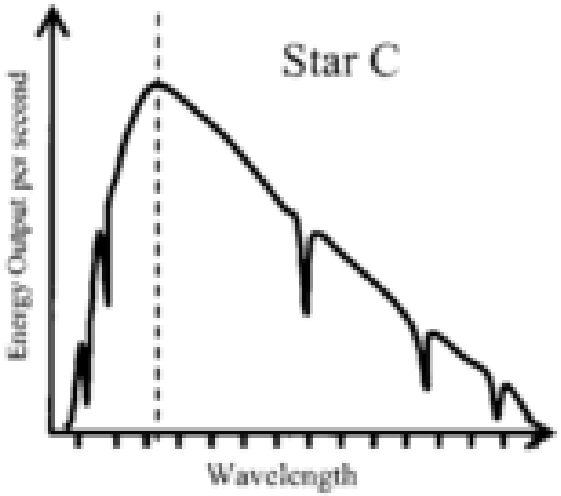


Lightbulbs are sold based on this temperature/color relationship

The Curve isn't Smooth…



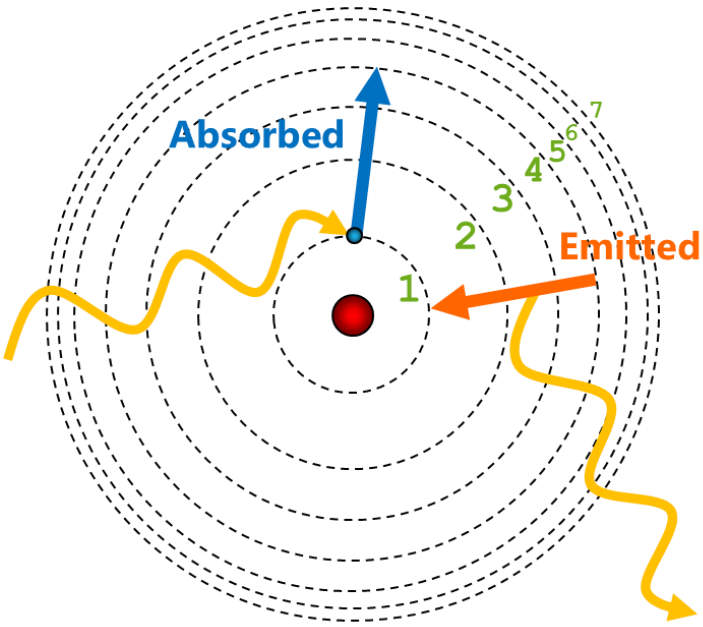


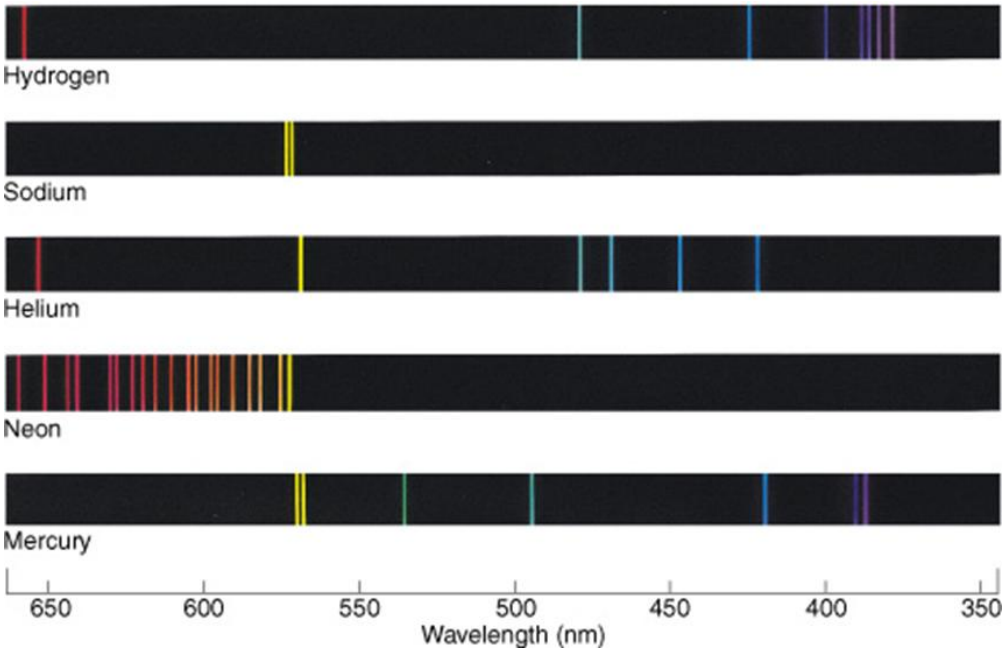


A star's spectrum is missing specific wavelengths….

Remember Light Spectra?

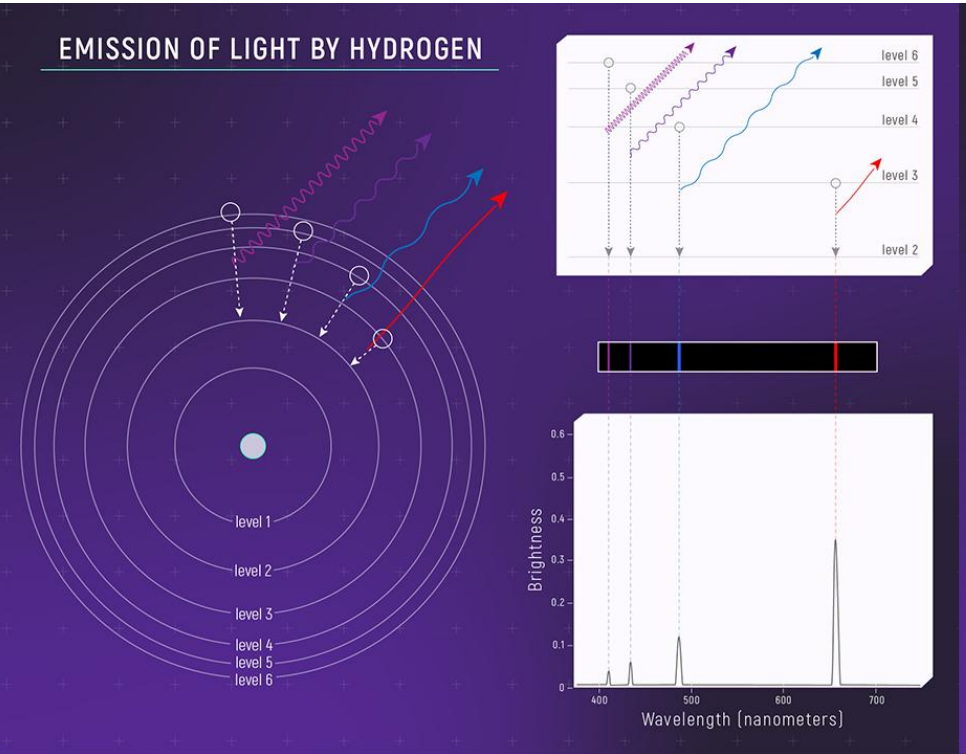
Each element has specific wavelengths that match the electron energy level drops

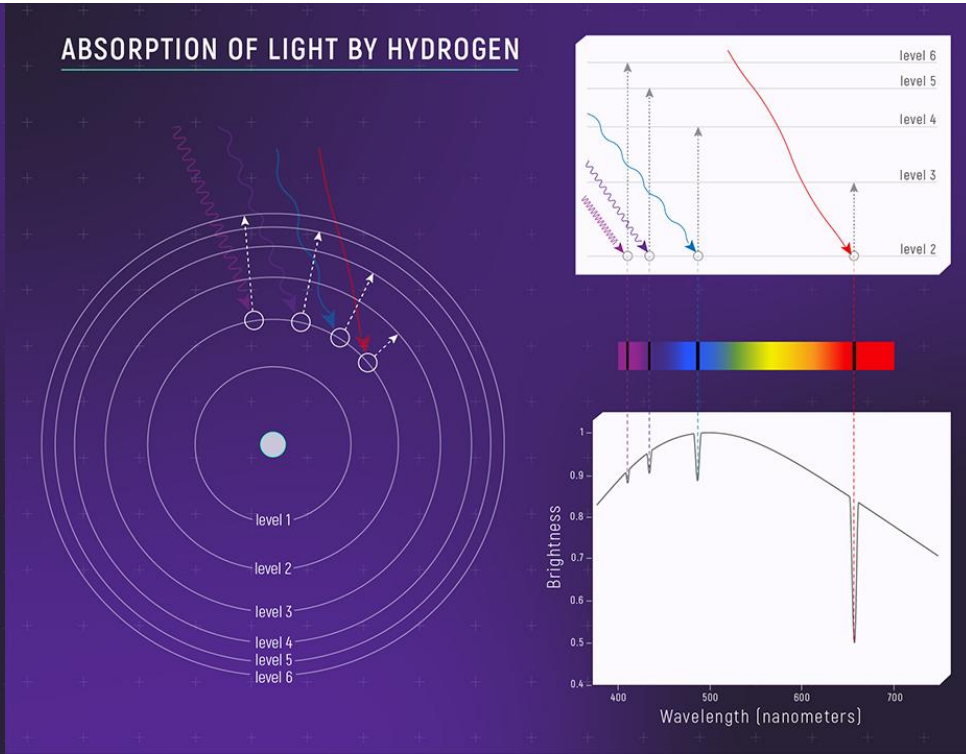




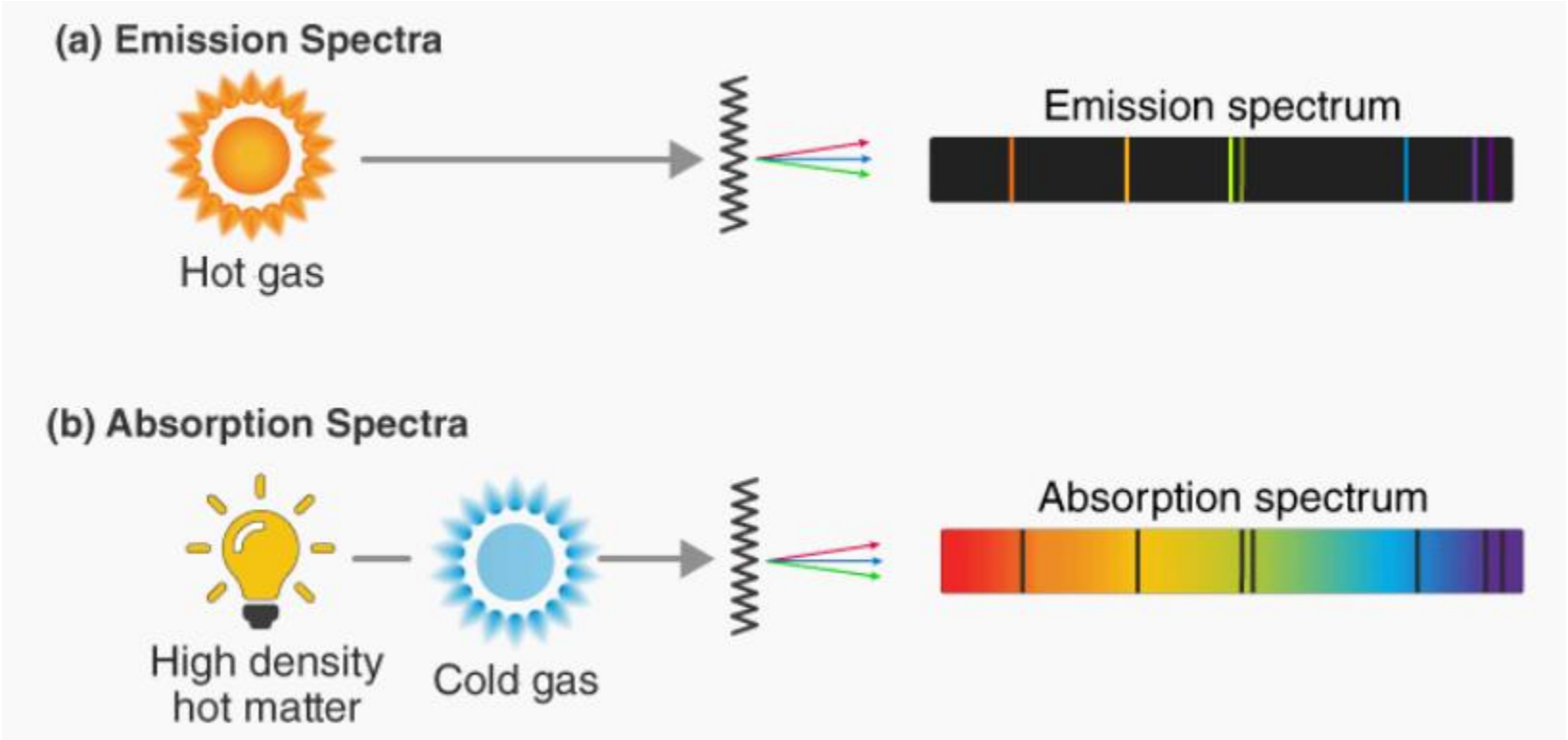
Light Spectra and Electrons

Electrons _emit_ energy when they fall down and they _absorb_ energy to jump up

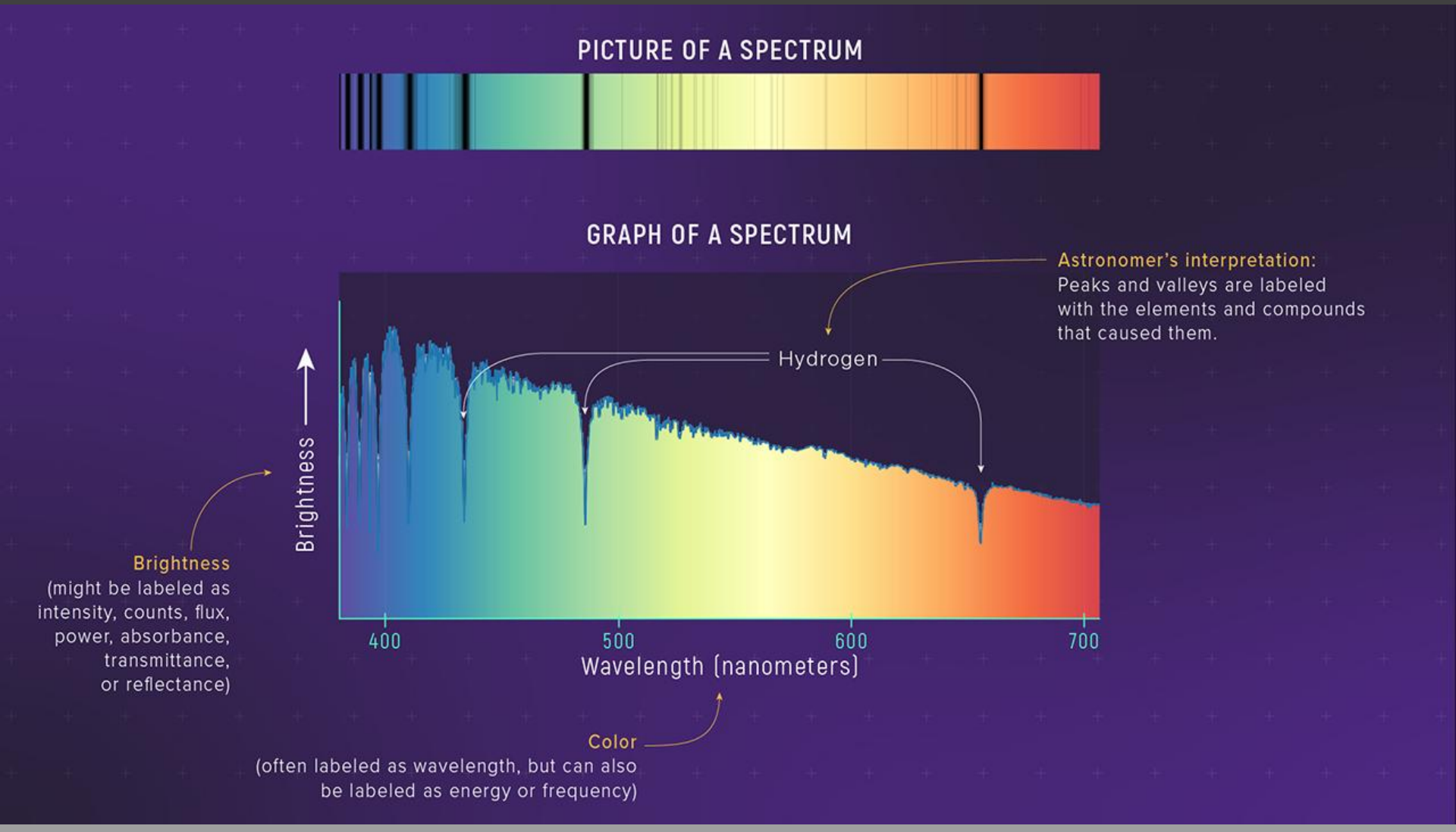




Emission and Absorption

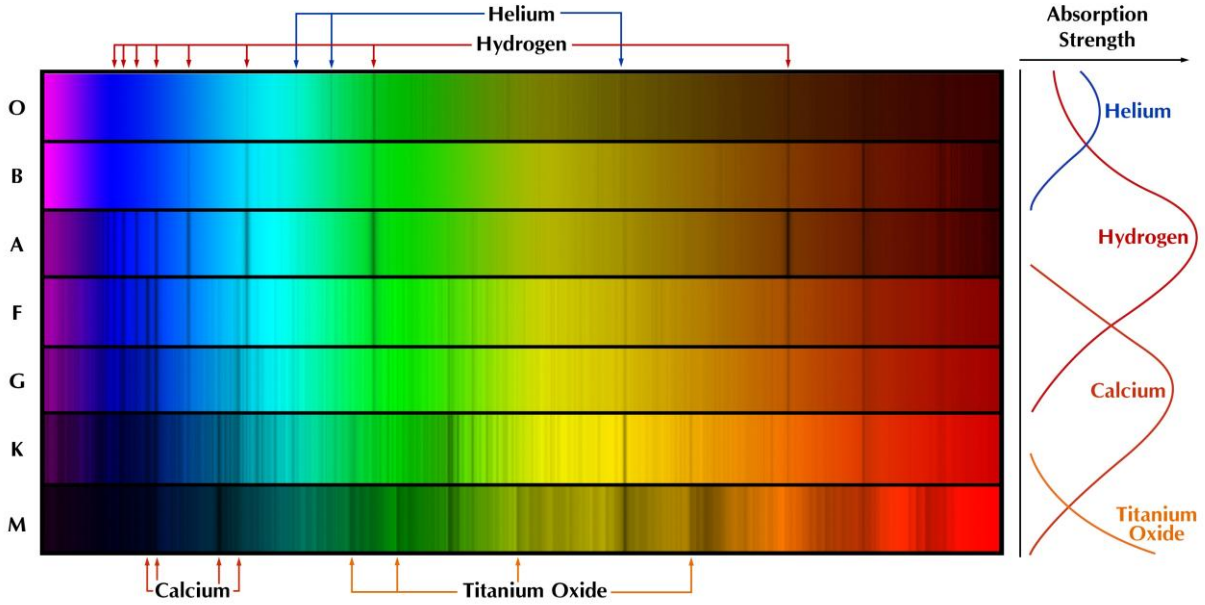


Stellar Spectrum



Stellar Spectra

Studying the Spectra of Stars can help determine what the stars are made of



Are these **Emission Spectra** or **Absorption Spectra**?

Lesson Takeaways

B.2

- ❑ I can place a star on an axis showing luminosity vs temperature
- ❑ I can describe the organization of the Hertzsprung-Russell Diagram
- ❑ I can use the main sequence to calculate the distance of a star from its wavelength and brightness
- ❑ I can identify the chemical makeup of a star from its absorption spectrum