Hertzsprung-Russell Activity

- Use the HR Diagram provided to graph the stars on “bright~.pdf”
- Add temperatures from the chart below

Class	Color	Prominent Spectral Lines	Surface Temp. (K)
O	Blue	Ionized helium, hydrogen	> 25,000 K
B	Blue-white	Neutral helium, hydrogen	11,000 – 25,000 K
A	White	Hydrogen, ionized sodium and calcium	7,500 – 11,000 K
F	White	Hydrogen, ionized and neutral sodium and calcium	6,000 – 7,500 K
G	Yellow	Neutral sodium and calcium, ionized calcium, iron, magnesium	5,000 – 6,000 K
K	Orange	Neutral calcium, iron, magnesium	3,500 – 5,000 K
M	Red	Neutral iron, magnesium, and neutral titanium oxide	< 3,500 K

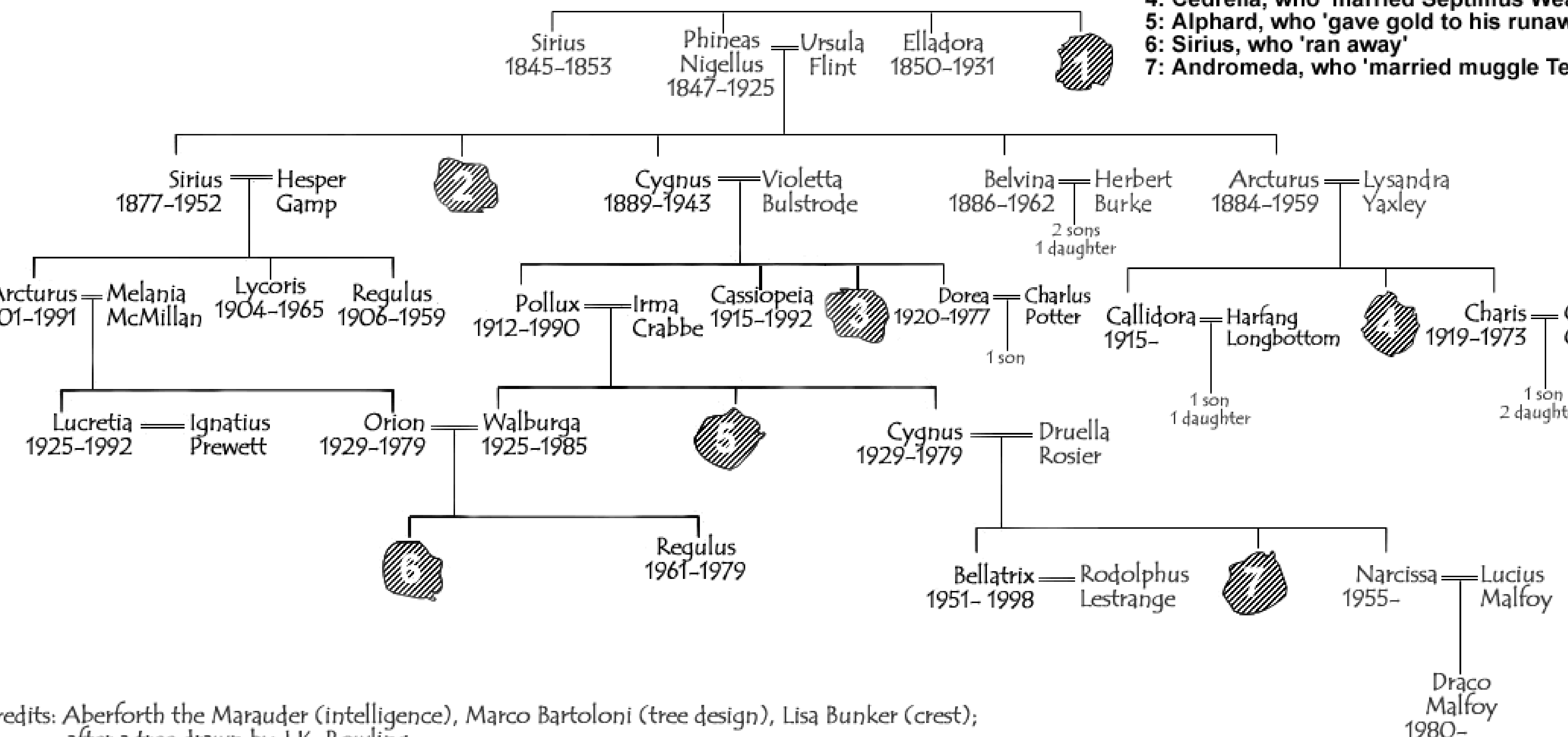
The Noble and Most Ancient House of

BLACK

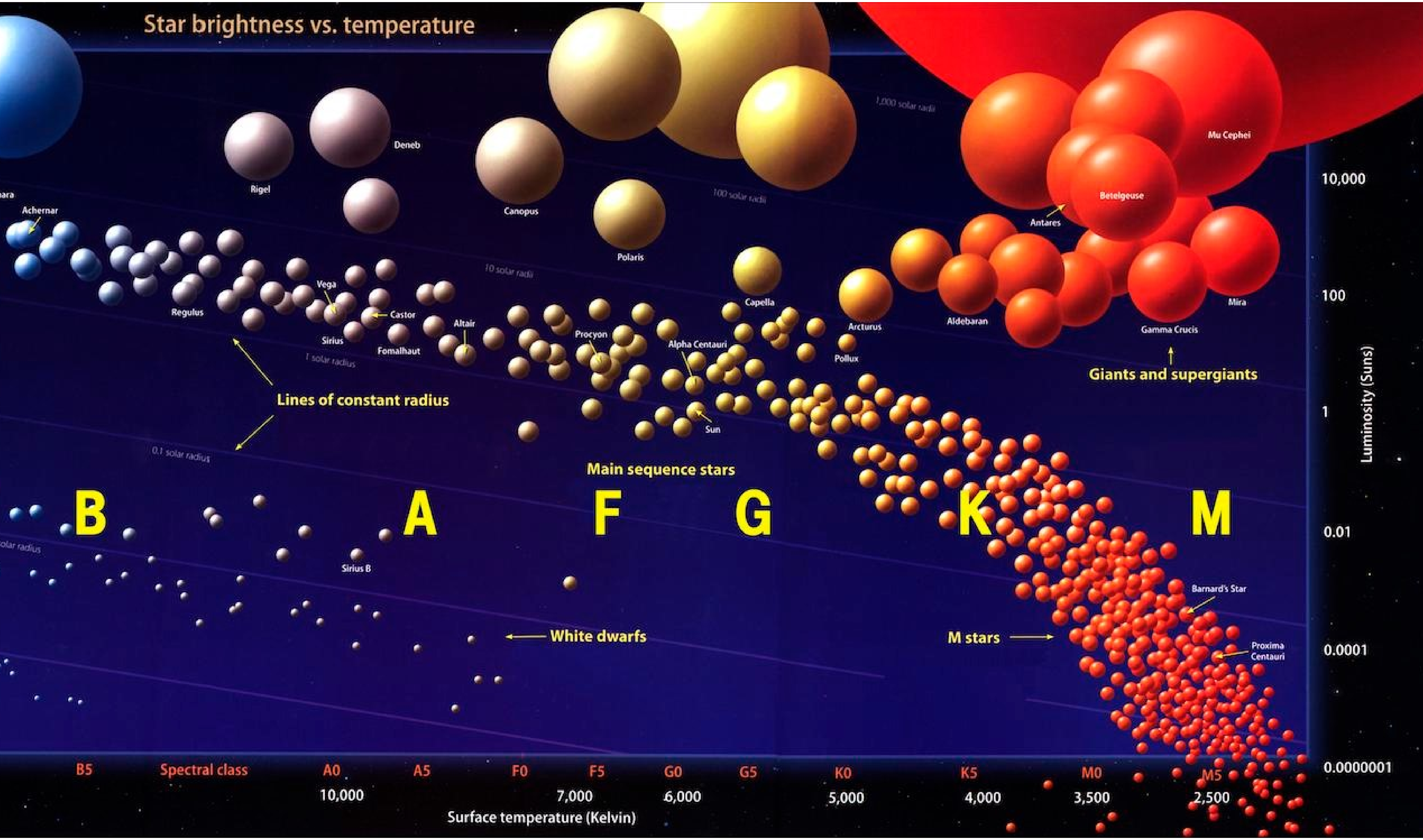
(there are many stories between the lines)

Key (removed from tree)

1: Isla Black, who 'married muggle Bob
2: Phineas, who 'supported muggle rigl
3: Marius, 'a squib'
4: Cedrella, who 'married Septimus Wea
5: Alphard, who 'gave gold to his runaw
6: Sirius, who 'ran away'
7: Andromeda, who 'married muggle Te



redits: Aberforth the Marauder (intelligence), Marco Bartoloni (tree design), Lisa Bunker (crest);
after a tree drawn by J.K. Rowling.



Star brightness vs. temperature
1,000 solar radii
100 solar radii
10 solar radii
1 solar radius
0.1 solar radius
Achernar
Rigel
Deneb
Canopus
Polaris
Mu Cephei
Betelgeuse
Antares
Mira
Gamma Crucis
Aldebaran
Arcturus
Pollux
Capella
Alpha Centauri
Procyon
Sun
Altair
Fomalhaut
Sirius
Castor
Vega
Regulus
Sirius B
Barnard's Star
Proxima Centauri
Lines of constant radius
Main sequence stars
Giants and supergiants
White dwarfs
M stars
B
A
F
G
K
M
Luminosity (Suns)
10,000
100
1
0.01
0.0001
0.0000001
B5
Spectral class
A0
A5
F0
F5
G0
G5
K0
K5
M0
M5
10,000
7,000
6,000
5,000
4,000
3,500
2,500
Surface temperature (Kelvin)

Stefan-Boltzmann law

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

- Ex: Betelgeuse has a radius of 3.1E11 m and a temperature of 2800K. Find its luminosity

$$L = 5.67\times10^{-8} 4\pi\left(3.1\times10^{11}\right)^2\left(2800\right)^4$$

$$L = 4.21\times10^{30} W$$

- Ex 2: Sol has a radius of 696,000 km and a temperature of 5,778 K. Find its luminosity

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

$$L = 5.67 \times 10^{-8} 4\pi \left(6.96 \times 10^{8}\right)^2 (5778)^4$$

$$L = 3.85 \times 10^{26} W$$

- Ex 3: How luminous is Betelgeuse compared to the Sun?

- 11000 L_s

- Ex 4: Rigel has a power output of 117490 L_s. If it has a radius of 78 r_s, find its temperature compared to Sol.

$$\frac{L_R}{L_S} = \frac{\sigma A_R T_R{}^4}{\sigma A_S T_S{}^4} \qquad \frac{L_R}{L_S} = \frac{\sigma 4\pi r_R^2 T_R{}^4}{\sigma 4\pi r_S^2 T_S{}^4}$$

$$\frac{T_R{}^4}{T_S{}^4} = \frac{L_R}{L_S}\frac{r_S^2}{r_R^2} \qquad \frac{T_R}{T_S} = \sqrt[4]{\frac{117490 L_s}{L_s} \times \frac{r_s^2}{(78 r_s)^2}}$$

$$T_R = 2.1 T_S$$

- I’ve got a fever!

- How high a fever would you have, to get twice the apparent brightness from a trillionth the distance as the Sun? The Sun has 4×10^{18} times your area.

$$L = \sigma A T^4 \qquad b = \frac{L}{4\pi d^2}$$

$$b = \frac{\sigma A T^4}{4\pi d^2} \qquad T = \sqrt[4]{\frac{4\pi d^2 b}{\sigma A}}$$

- How high a fever would you have, to get twice the apparent brightness from a trillionth the distance as the Sun? The Sun has 4x10^{18} times your area.

$$\frac{T_b}{T_s} = \sqrt[4]{\frac{4\pi d_b^{\,2} b_b}{\sigma A_b}\,\frac{\sigma A_s}{4\pi d_s^{\,2} b_s}} = \sqrt[4]{\frac{d_b^{\,2}}{d_s^{\,2}}\,\frac{b_b}{b_s}\,\frac{A_s}{A_b}}$$

$$\frac{T_b}{T_s} = \sqrt[4]{\frac{\left(10^{-12} d_s\right)^2}{d_s^{\,2}}\,\frac{2b_s}{b_s}\,\frac{\left(4\times 10^{18}\right)A_b}{A_b}} = 0.053$$

Brightness

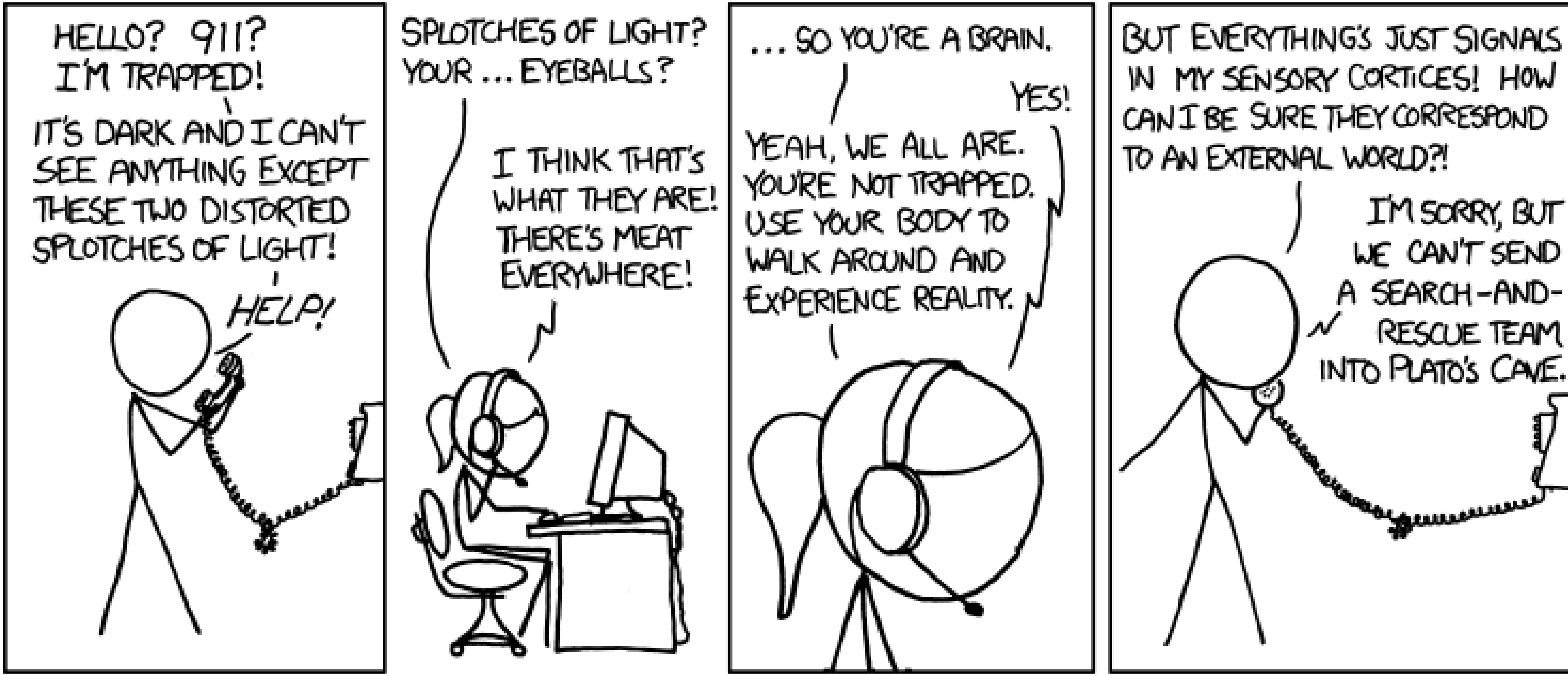
$$b = \frac{L}{4\pi d^2}$$

- Apparent Brightness “b” depends on distance and luminosity
- Ex 5a: show that the brightness of the sun is 1360 $W \cdot m^{-2}$

- Ex: Find the brightness of our nearest star: Proxima Centauri

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

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


HELLO? 911? I'M TRAPPED!
IT'S DARK AND I CAN'T SEE ANYTHING EXCEPT THESE TWO DISTORTED SPLOTCHES OF LIGHT!
HELP!
SPLOTCHES OF LIGHT? YOUR ... EYEBALLS?
I THINK THAT'S WHAT THEY ARE! THERE'S MEAT EVERYWHERE!
... SO YOU'RE A BRAIN.
YES!
YEAH, WE ALL ARE. YOU'RE NOT TRAPPED. USE YOUR BODY TO WALK AROUND AND EXPERIENCE REALITY.
BUT EVERYTHING'S JUST SIGNALS IN MY SENSORY CORTICES! HOW CAN I BE SURE THEY CORRESPOND TO AN EXTERNAL WORLD?!
I'M SORRY, BUT WE CAN'T SEND A SEARCH-AND-RESCUE TEAM INTO PLATO'S CAVE.

Which bunsen burner is hottest?

Wien’s displacement law

$$\lambda_{\max} T = 2.9 \times 10^{-3} m \cdot K$$

Maximum radiation is given off at a wavelength inversely proportional to temperature

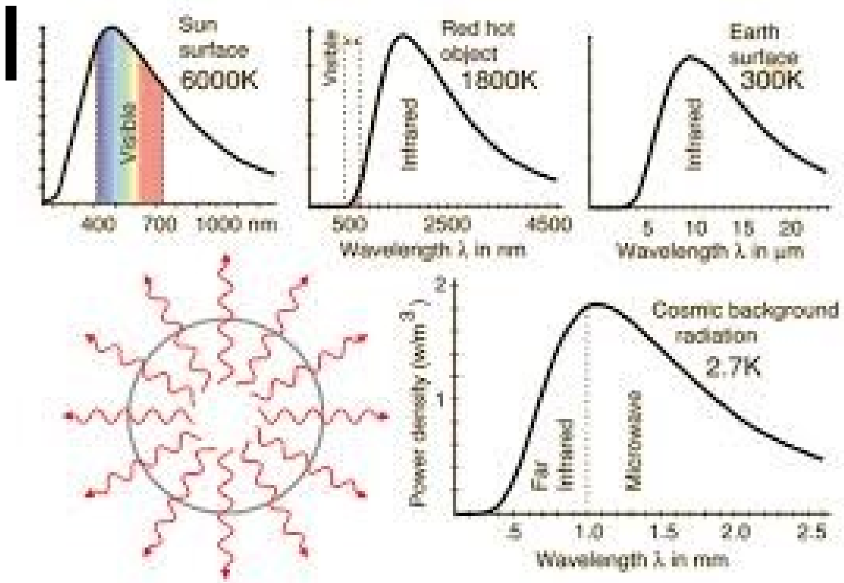
Ex: Show that your peak wavelength is in the infra

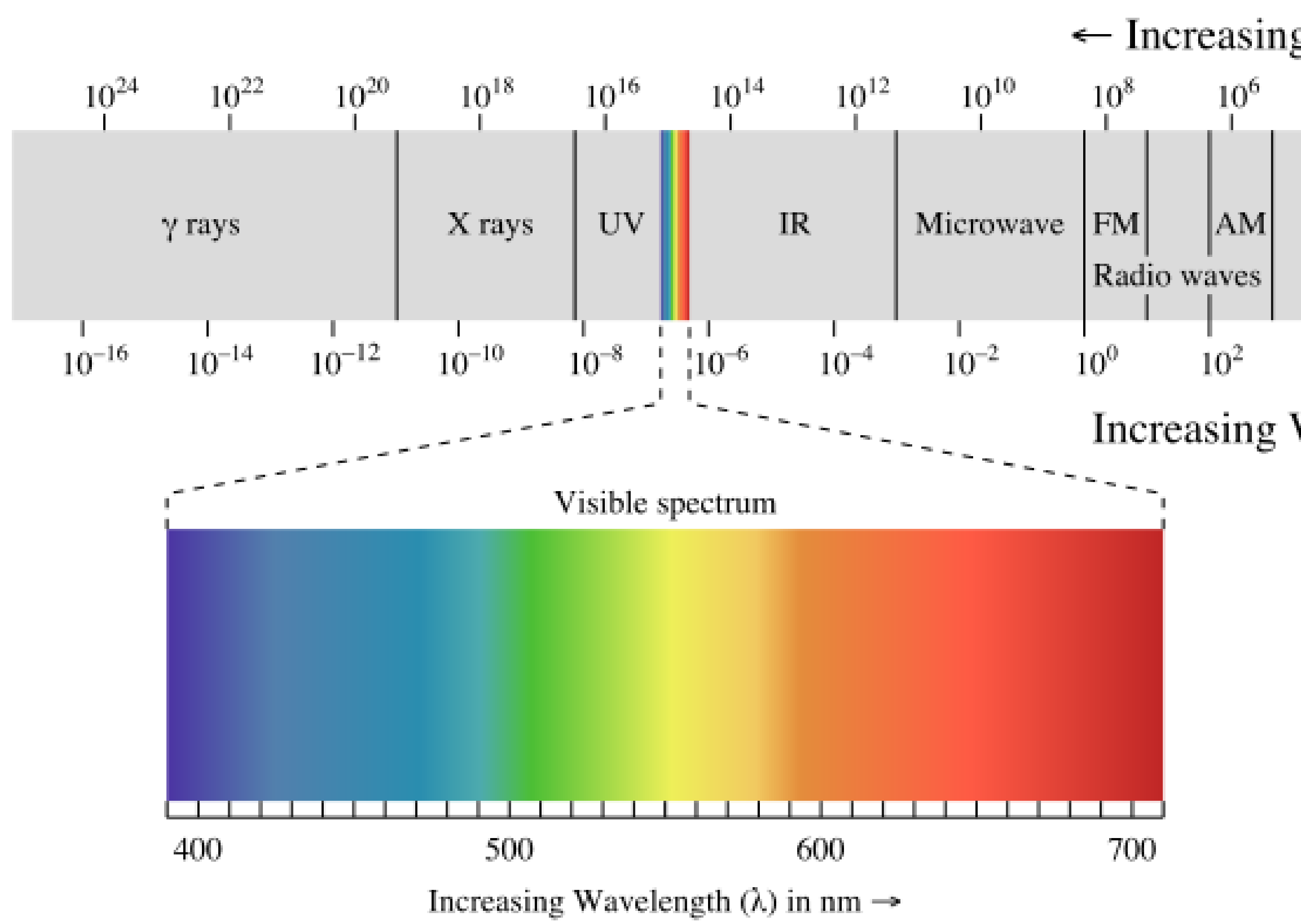
$$\lambda_{max} T = 2.9\times10^{-3} m\cdot K$$

$$\lambda_{max} = \frac{2.9\times10^{-3} m\cdot K}{T}$$

$$\lambda_{max} \cong \frac{3\times10^{-3} m\cdot K}{3\times10^{2} K}$$

$$\lambda_{max} \cong 10^{-5} m$$





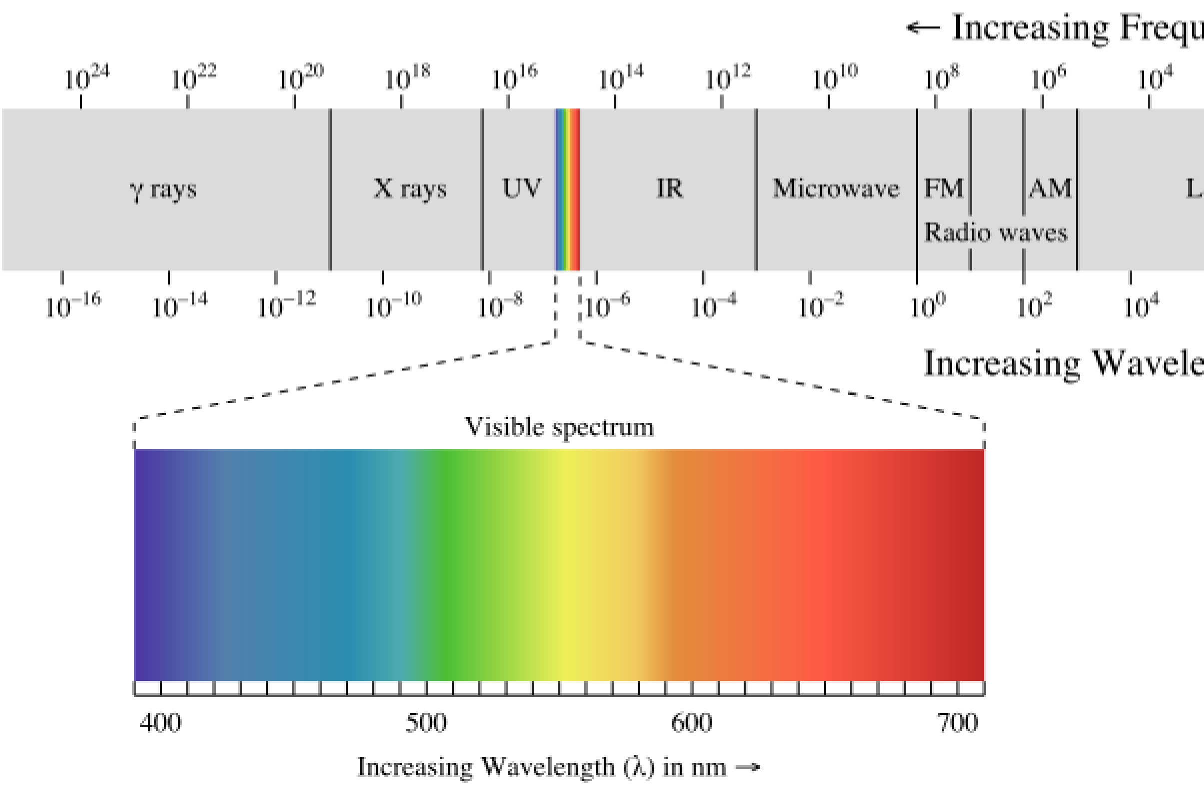
Ex: If peak wavelength is 400 nm find temperature according to Wien's displacement law. Star?

$$\lambda_{\max} T = 2.9 \times 10^{-3} m \cdot K$$

$$T = \frac{2.9 \times 10^{-3}}{\lambda_{\max}}$$

$$T = \frac{2.9 \times 10^{-3}}{400 \times 10^{-9}}$$

$$T = 7250K$$



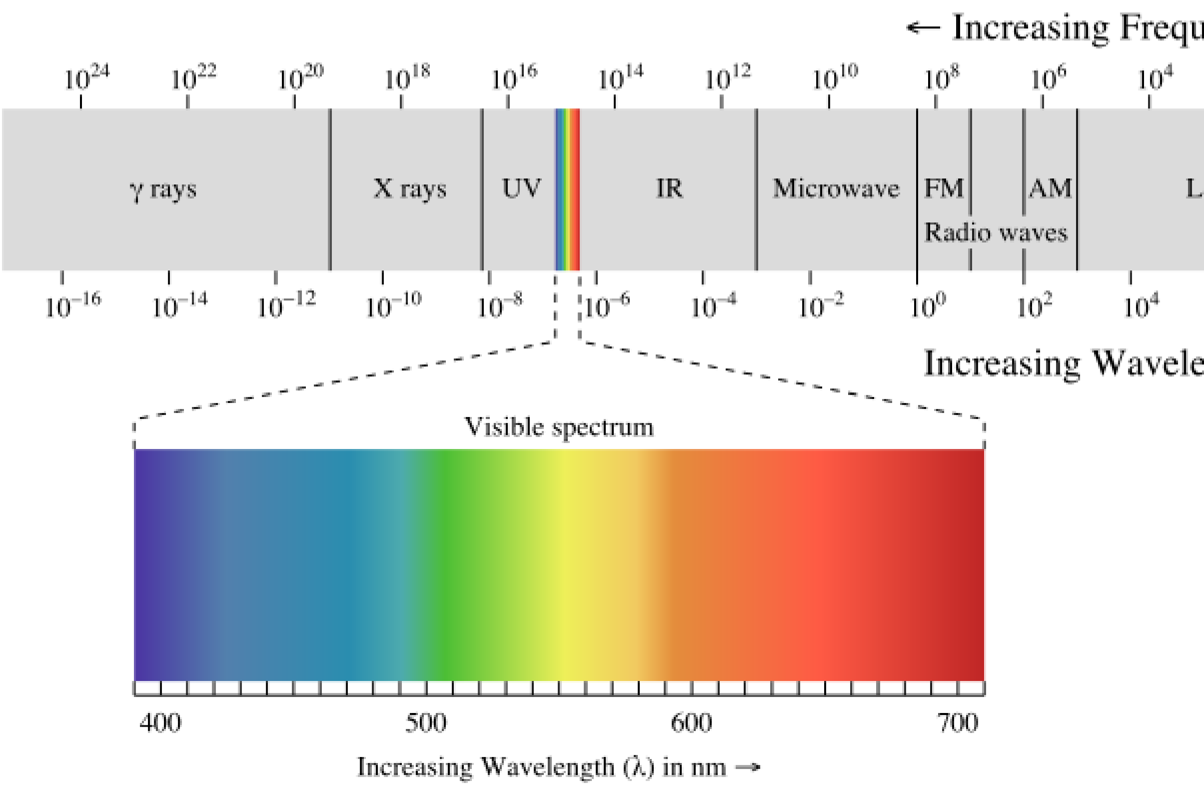
Ex: Find the temperature of the "coldest" star

$$\lambda_{max}T = 2.9\times10^{-3}m\cdot K$$

$$T = \frac{2.9\times10^{-3}}{\lambda_{max}}$$

$$T = \frac{2.9\times10^{-3}}{700\times10^{-9}}$$

$$T = 4100K$$



Ex: Find the power radiated per square meter for the previous example

$$\frac{L}{A} = \sigma T^4 \quad = 5.67\times10^{-8}\left(7250\right)^4$$

$$\frac{L}{A} = 1.6\times10^{8}\,W\cdot m^{-2}$$

Ex: find the distance for a star with a parallax of 0.23"

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

$$d(parsec) = \frac{1}{0.23 arc - second}$$

d=4.3pc

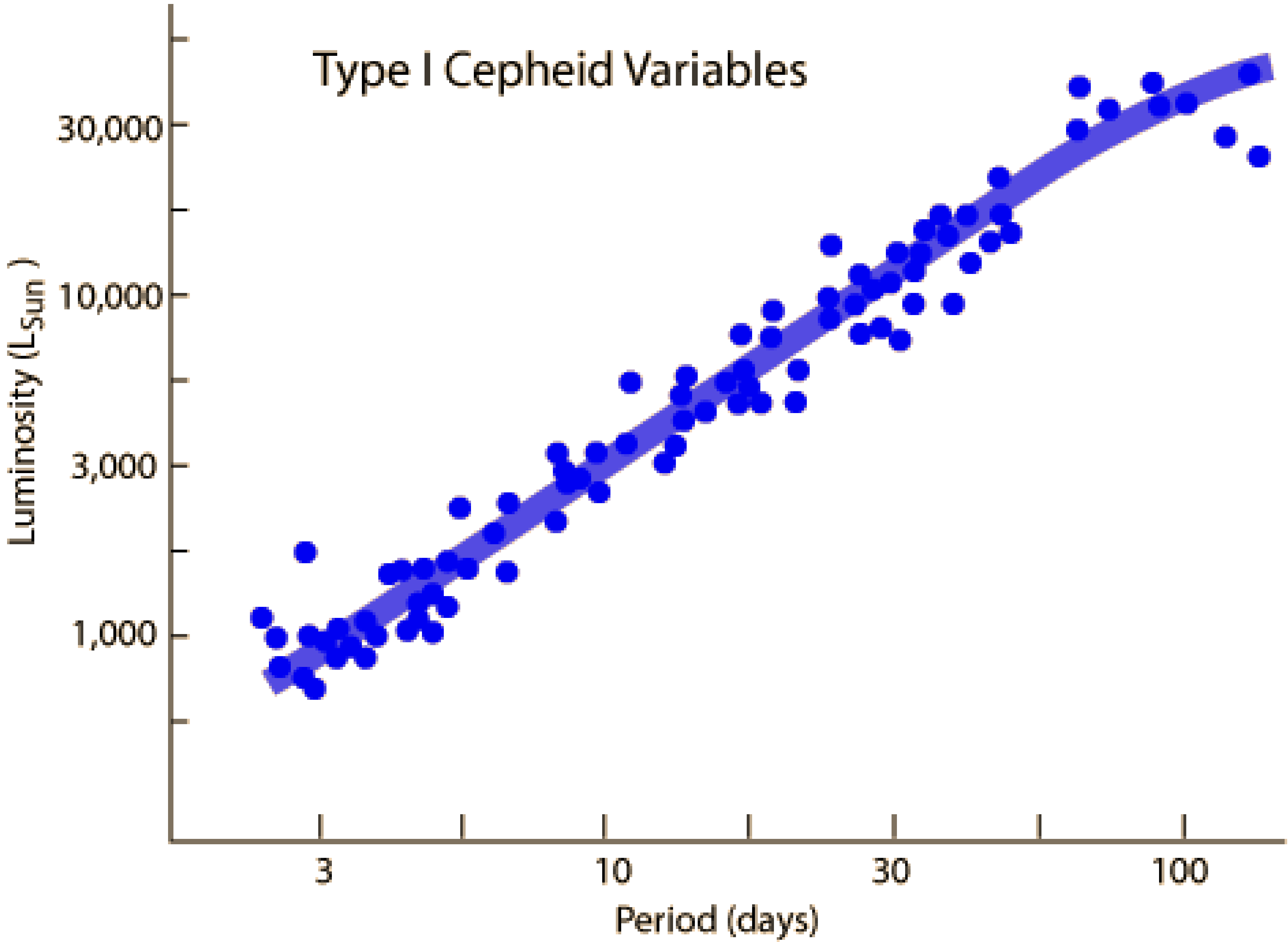
Ex: find the parallax of proxima centauri

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

p=1/1.3pc

p=0.77"

Star Visual	Apparent Magnitude	Distance(pc)	Absolute Magnitude	Luminosity (rel. to Sun)
Sun	-26.74	4.84813×10^{-6}	4.83	1
Sirius	-1.44	2.6371	1.45	22.5
Arcturus	-0.05	11.25	-0.31	114
Vega	0.03	7.7561	0.58	50.1
Spica	0.98	80.39	-3.55	2250
Barnard's Star	9.54	1.8215	13.24	1/2310
Proxima Centauri	11.01	1.2948	15.45	1/17700



Type I Cepheid Variables
30,000
10,000
3,000
1,000
Luminosity (L Sun)
3
10
30
100
Period (days)

Kepler's Laws

- First Law:
  - The planets' orbits are ellipses with the Sun at one focus (ellipse activity)
- Second Law:
  - The planet sweeps out equal area in equal time
- Third Law:
  - The square of the period is proportional to the cube of the radius

$$T^2 \alpha r^3$$