Luminosity: Light Given Off in all Directions

Luminosity (L): Total light emitted from the source in Joules/second (Watts)

Intrinsic to the Star

$$L = 4\pi r^2 \sigma T^4$$

$\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

r = radius (m)

T = temperature (K)

Stefan-Boltzmann constant

Luminosity of the Sun

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$$L = 4\pi r^2 \sigma T^4$$

$\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

$r = 6.955 \times 10^{8}$ m

$T = 5777$ K

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Stefan-Boltzmann constant

$r = 6.955 \times 10^{8}$ m

$T = 5777$ K

$L = 3.8 \times 10^{26}$ Watts (Joules/s)

Luminosity of the Betelgeuse

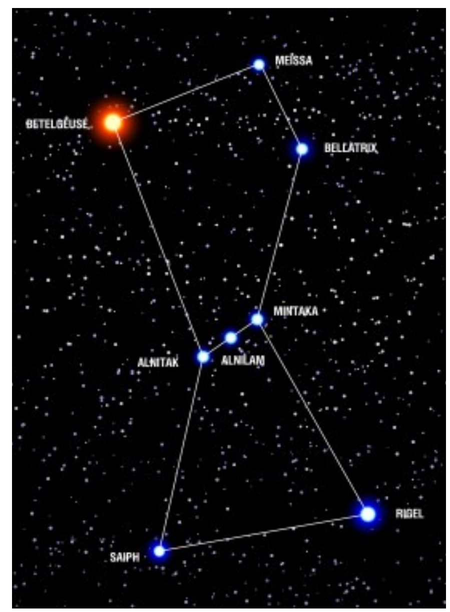
Luminosity (L): Total light emitted from the source in Joules/second (Watts)

$$L = 4\pi r^2 \sigma T^4$$

$\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

$r = 6.2 \times 10^{11}$ m

$T = 3500$ K



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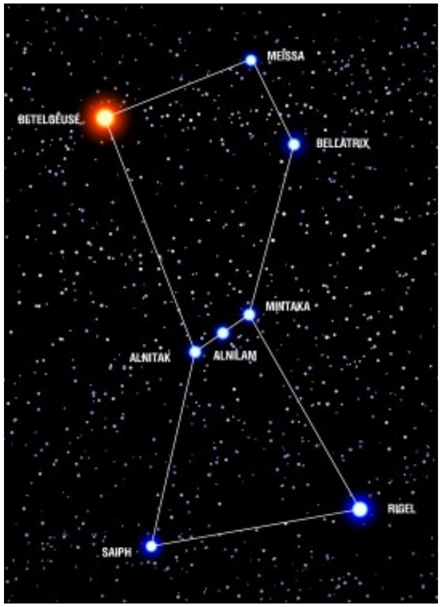
$L = 4.1 \times 10^{31}$ Watts (Joules/s)



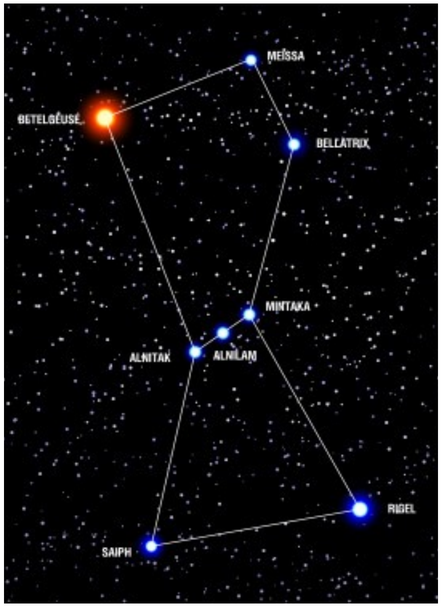
Luminosity of the Betelgeuse Compared to the Sun

$L_{Betelgeuse} = 4.1 \times 10^{31}$ Watts

$L_{sun} = 3.8 \times 10^{26}$ Watts

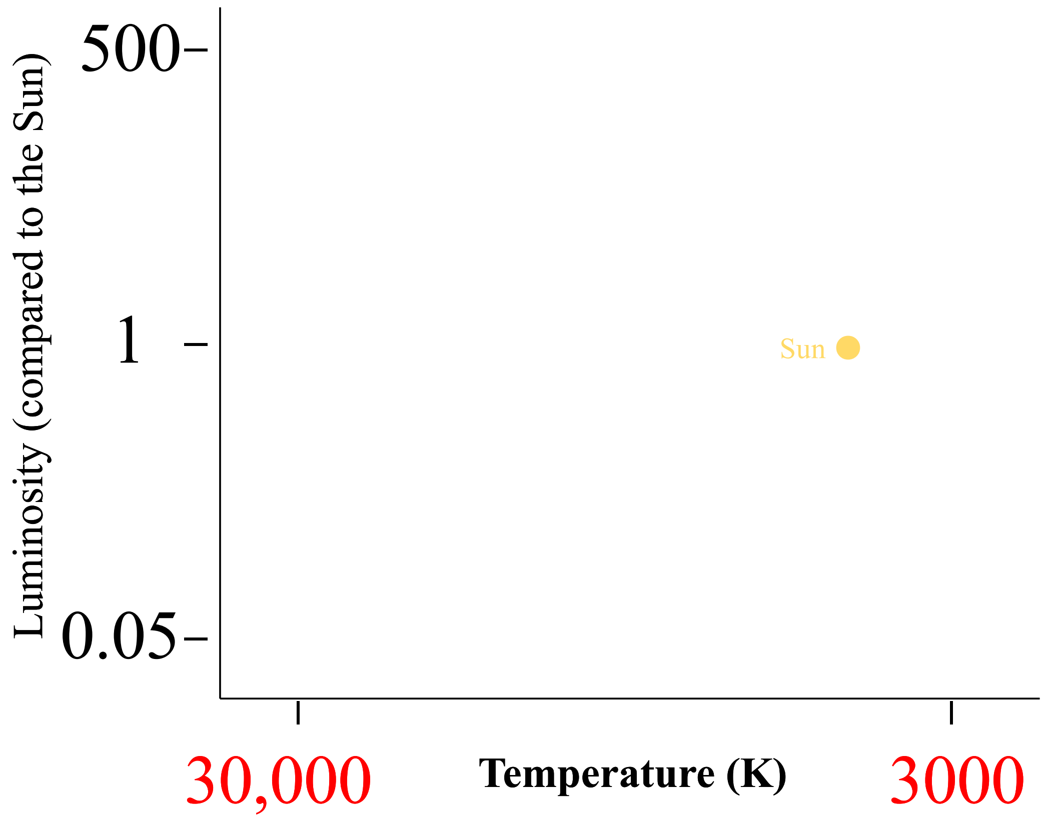
Luminosity Ratio: $\dfrac{4.1 \times 10^{31} \text{ Watts}}{3.8 \times 10^{26} \text{ Watts}} = 108{,}000$

Betelgeuse is over 100,000 brighter than the Sun!



Comparisons with the Sun on the H-R Diagram

What if star "1" has same radius (R_{*1}) as Sun but $T_{*1} = 2\,T_{sun}$? Where will it live on the H-R diagram?



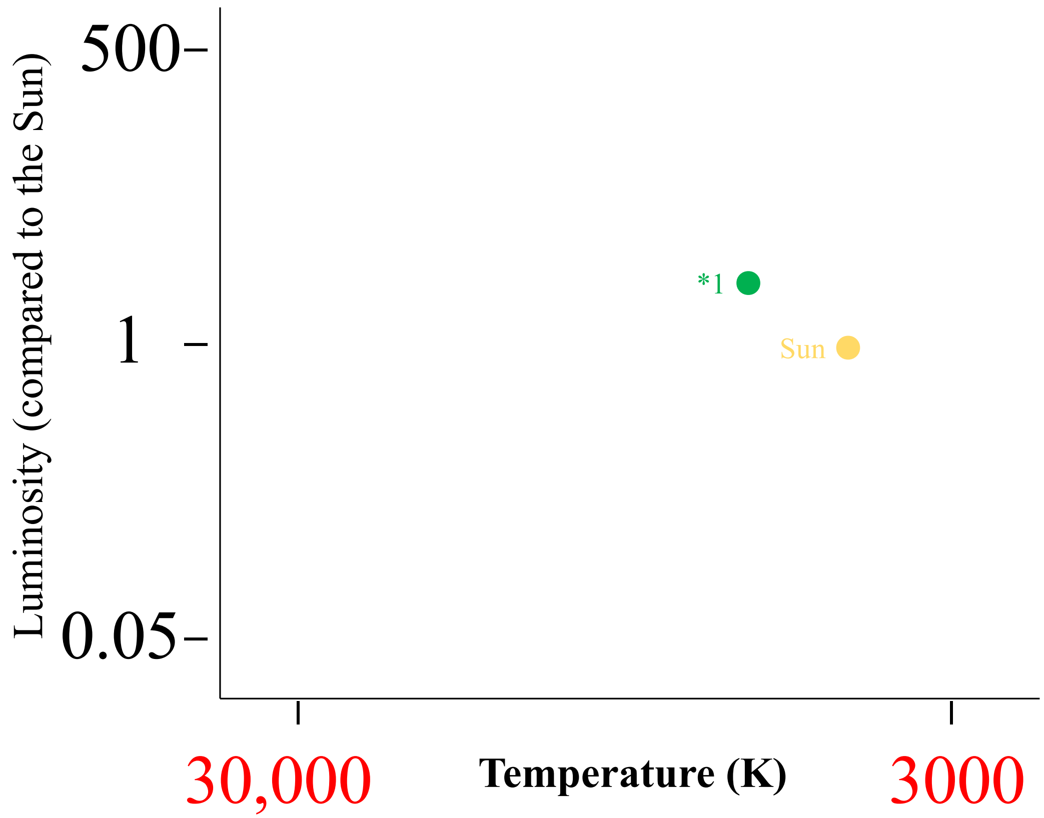
What if star "1" has same radius (R_{*1}) as Sun but $T_{*1} = 2\ T_{sun}$?

$$\frac{L_*}{L_{sun}} = \left(\frac{R_*}{R_{sun}}\right)^2 \left(\frac{T_*}{T_{sun}}\right)^4$$

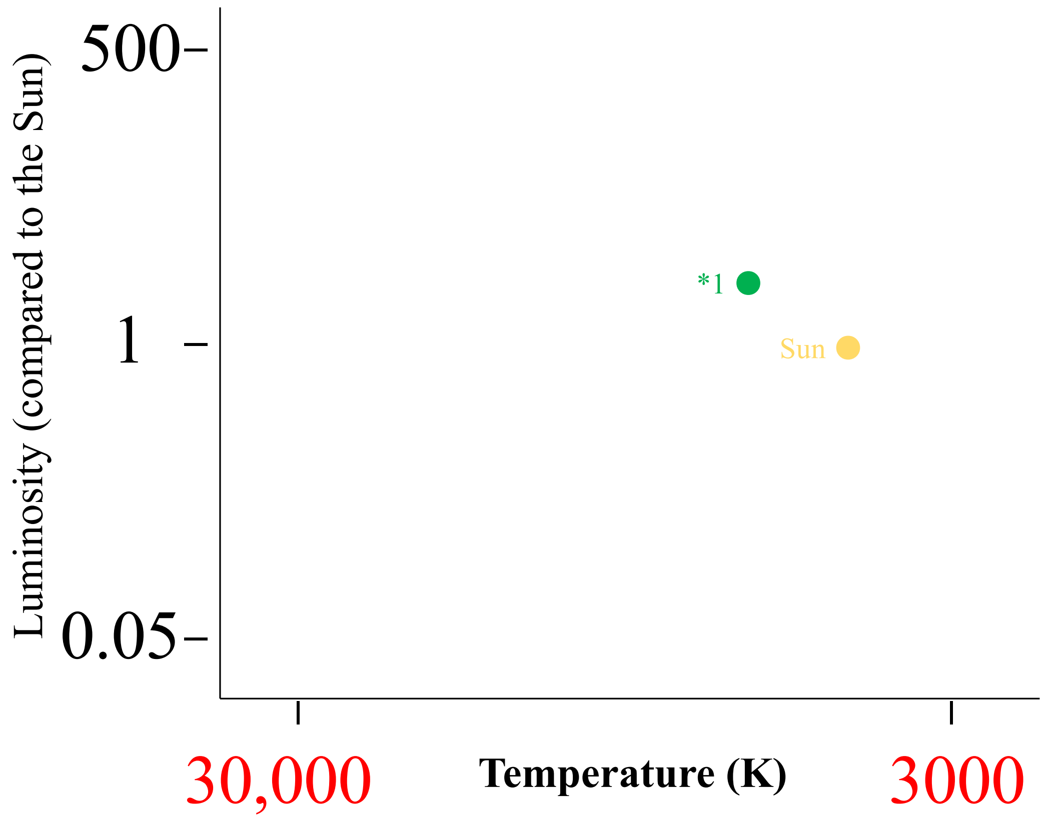
$$\frac{L_*}{L_{sun}} = \left(\frac{R_*}{R_{sun}}\right)^2 \left(\frac{12000}{6000}\right)^4 = \left(\frac{1}{1}\right)^2 (2)^4 = 16$$

Star 1 is 16 times brighter than the Sun!

What if star "1" has same radius (R_{*1}) as Sun but $T_{*1} = 2\ T_{sun}$?



What if star "2" has same radius (R_{*2}) as Sun but $T_{*2} = 4\ T_{sun}$?



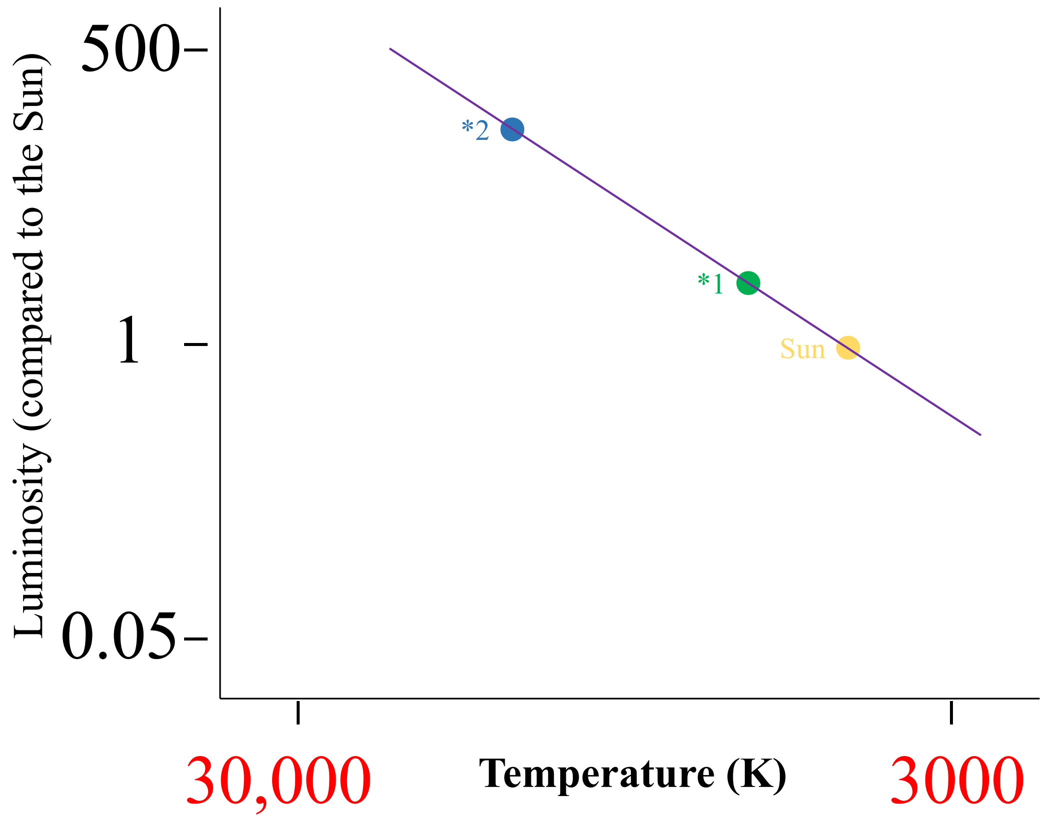
What if star "2" has same radius (R_{*2}) as Sun but $T_{*2} = 4\ T_{sun}$?

$$\frac{L_*}{L_{sun}} = \left(\frac{R_*}{R_{sun}}\right)^2 \left(\frac{T_*}{T_{sun}}\right)^4$$

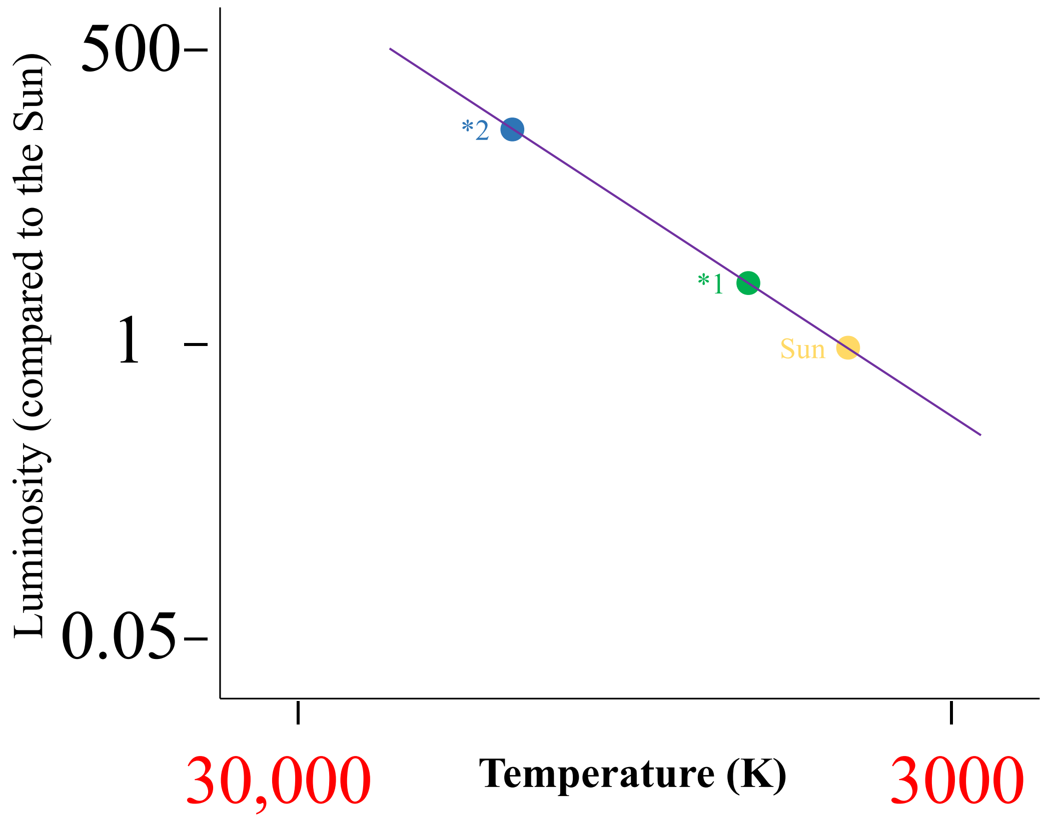
$$\frac{L_*}{L_{sun}} = \left(\frac{R_*}{R_{sun}}\right)^2 \left(\frac{24000}{6000}\right)^4 = \left(\frac{1}{1}\right)^2 (4)^4 = 256$$

Star 2 is 256 times brighter than the Sun!

What if star "2" has same radius (R_{*2}) as Sun but $T_{*2} = 4\ T_{sun}$?

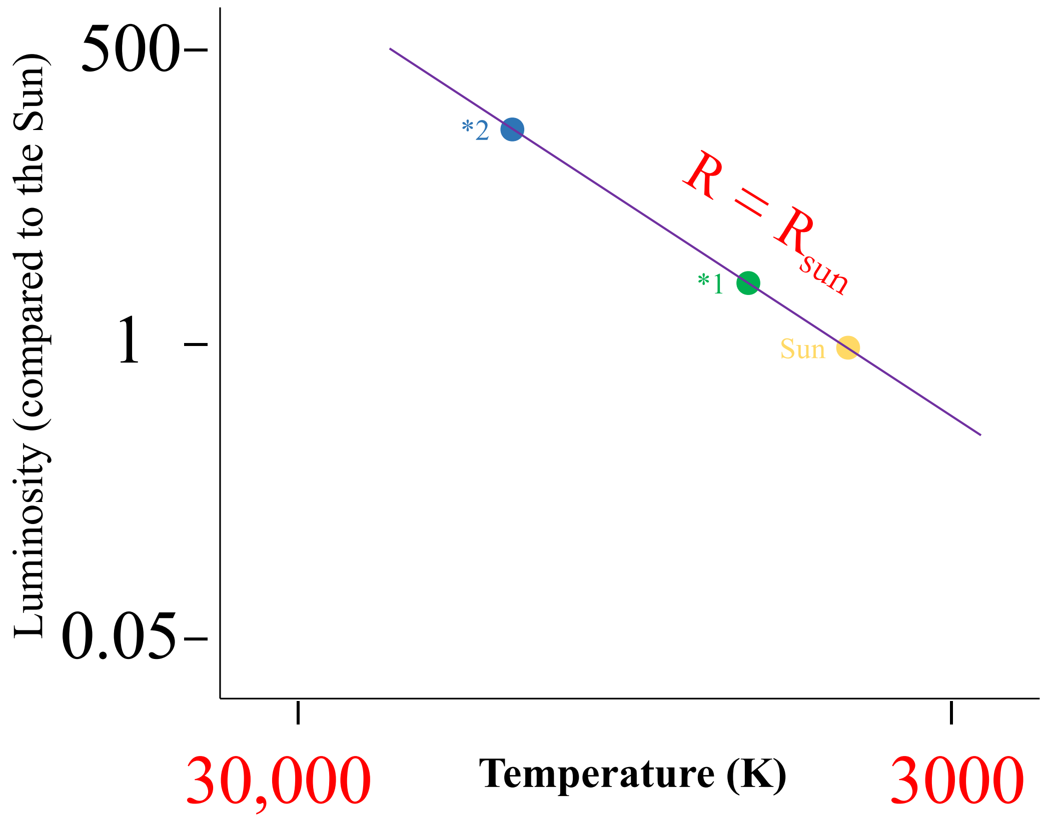


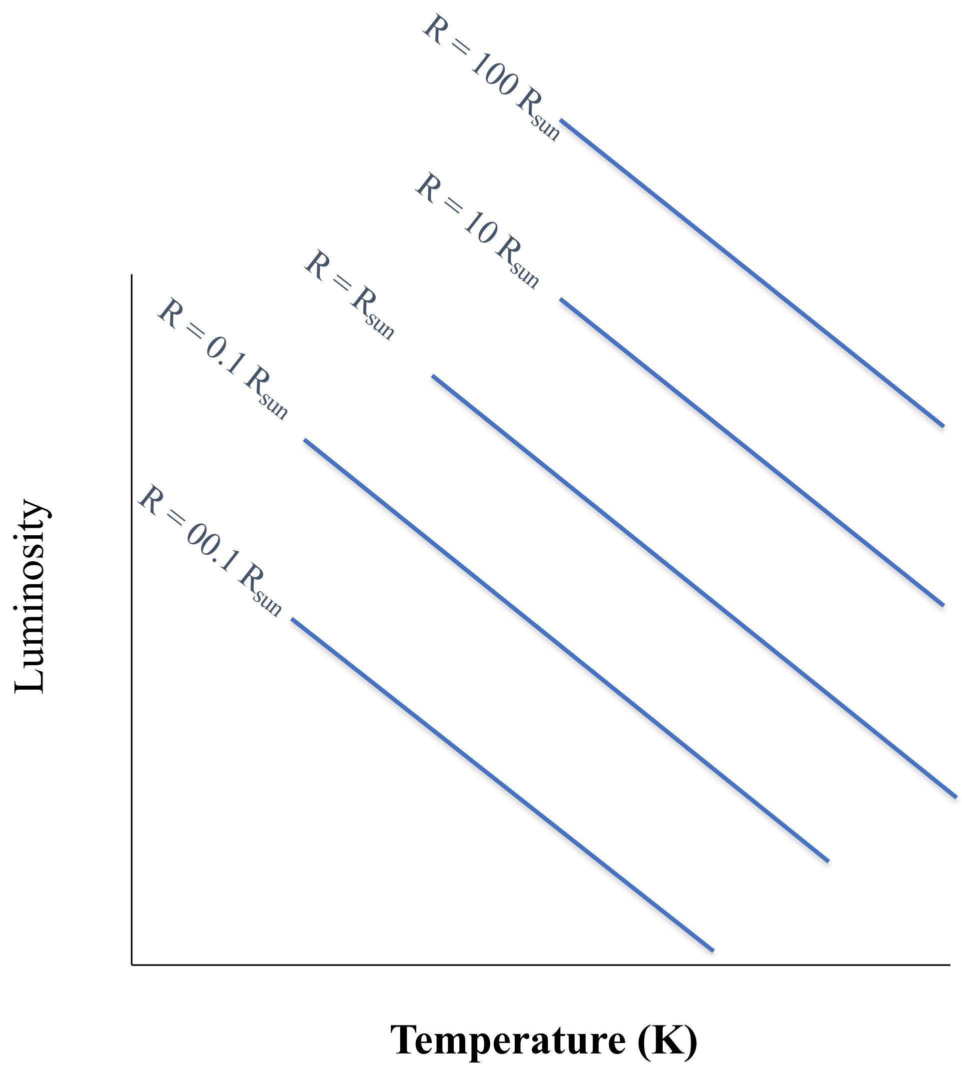
What is true about all the stars that fall on the line connecting these 3 stars?



What is true about all the stars that fall on the line connecting these 3 stars?

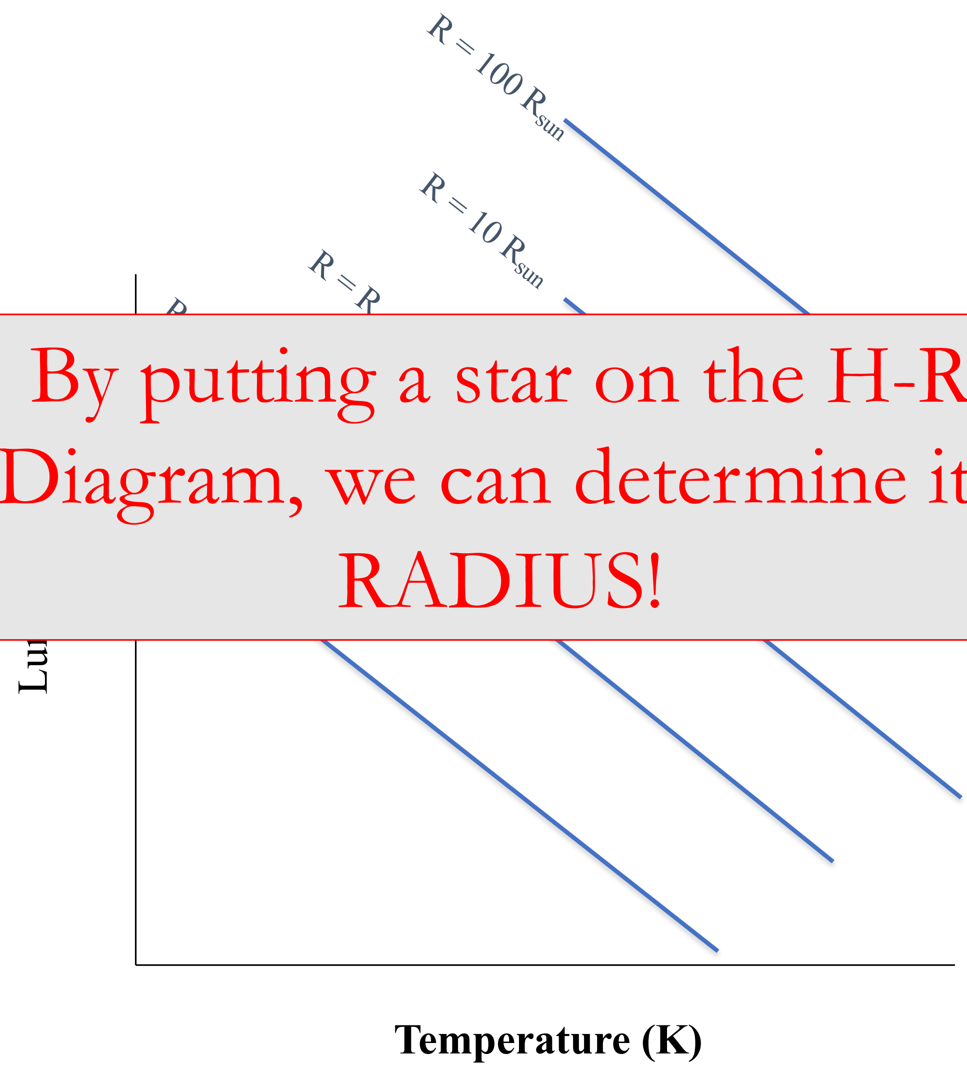
All stars on this line have the same radius.



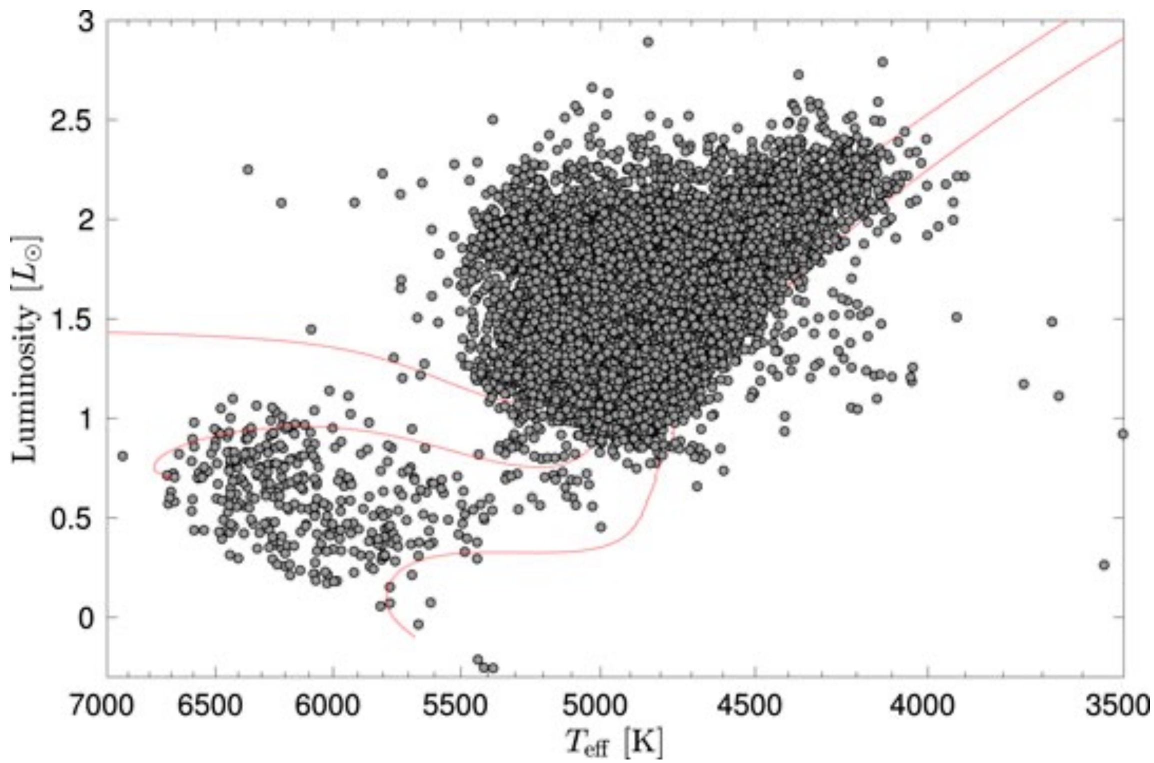


R = 100 R_sun
R = 10 R_sun
R = R_sun
R = 0.1 R_sun
R = 00.1 R_sun
Luminosity
Temperature (K)

By putting a star on the H-R Diagram, we can determine its RADIUS!



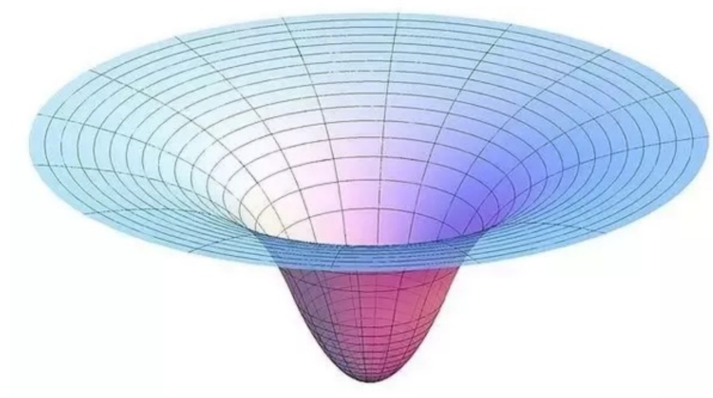
Asteroseismology



Mass-Luminosity Relation

Arthur Eddington

- (1882-1944)
- English astrophysicist
- Made Albert Einstein famous by organizing solar eclipse expeditions in 1919 to test (and prove correct) theory of General Relativity



1924: Mass-Luminosity Relationship

Arthur Eddington quantified the relationship between stellar masses and their luminosities *for main-sequence stars*:

$$L = M^{3.5}$$

L_* and M_* in units of the Sun's luminosity and the Sun's mass

Question: if we increase M by 10 times, do we increase L by 10 times?

1924: Mass-Luminosity Relationship

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Question: if we increase M by 10 times, do we increase L by 10 times?

We increase L by $10^{3.5}$

We increase L by 3162 times!

Mass-luminosity Relationship

If $M_* = 10\ M_\odot$ find L

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

Mass-luminosity Relationship

If $M_* = 2.5\ M_\odot$ find L

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

$$L = M^{3.5}$$

$$L = 2.5^{3.5}$$

$$L = 25\ L_\odot$$

Mass-luminosity Relationship

If $L_* = 10\ L_{sun}$ find M

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Mass-luminosity Relationship

If $L_* = 10\ L_{sun}$ find M

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

$$M = L^{1/3.5}$$

$$M = 10^{1/3.5}$$

$$L = 2M_{\odot}$$

Mass-luminosity Relationship

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

Find Luminosity:

- If Mass is 0.1 M_{sun}
- If Mass is 20 M_{sun}
- If Mass is 100 M_{sun}

Find Mass:

- If Luminosity is 0.01 L_{sun}
- If Luminosity is 1 L_{sun}
- If Luminosity is 100 L_{sun}

Mass-luminosity Relationship

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

Find Luminosity:

- If Mass is 0.1 M_{sun} = 0.0003 L_{sun}
- If Mass is 20 M_{sun}
- If Mass is 100 M_{sun}

Find Mass:

- If Luminosity is 0.01 L_{sun}
- If Luminosity is 1 L_{sun}
- If Luminosity is 1000 L_{sun}

Mass-luminosity Relationship

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

Find Luminosity:

- If Mass is 0.1 M_{sun} = 0.0003 L_{sun}
- If Mass is 20 M_{sun} = 35777 L_{sun} = 35000 L_{sun}
- If Mass is 100

Find Mass:

- If Luminosity is 0.01 L_{sun}
- If Luminosity is 1 L_{sun}
- If Luminosity is 1000 L_{sun}

Mass-luminosity Relationship

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

Find Luminosity:

- If Mass is 0.1 M_{sun} = 0.0003 L_{sun}
- If Mass is 20 M_{sun} = 35777 L_{sun} = 35000 L_{sun}
- If Mass is 100 M_{sun} = 10,000,000 L_{sun}

Find Mass:

- If Luminosity is 0.01 L_{sun}
- If Luminosity is 1 L_{sun}
- If Luminosity is 1000 L_{sun}

Mass-luminosity Relationship

$$\frac{L_*}{L_{sun}} \approx \left(\frac{M_*}{M_{sun}}\right)^{3.5}$$

Find Luminosity:

- If Mass is 0.1 M_{sun} = 0.0003 L_{sun}
- If Mass is 20 M_{sun} = 35777 L_{sun} = 35000 L_{sun}
- If Mass is 100 M_{sun} = 10,000,000 L_{sun}

Find Mass:

- If Luminosity is 0.01 L_{sun} = 0.27 M_{sun} = 0.3 M_{sun}
- If Luminosity is 1 L_{sun}
- If Luminosity is 1000 L_{sun}

Mass-luminosity Relationship

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Find Mass:

- If Luminosity is 0.01 L_{sun} = 0.27 M_{sun} = 0.3 M_{sun}
- If Luminosity is 1 L_{sun} = 1 M_{sun}
- If Luminosity is 1000 L_{sun} = 7.2 M_{sun} = 7 M_{sun}