Astronomy (PY 101)

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Project III: Mass-Luminosity Relation for Main Sequence Stars

The luminosity L of a star of radius R and surface temperature T can be expressed in terms of the luminosity $L_\odot$ (= 3.85×10^{26} W) of the Sun, its radius $R_\odot$ (= 6.96×10^8 m) and its surface temperature $T_\odot$ (= 5778 K) as

$$\frac{L}{L_\odot} = \left(\frac{R}{R_\odot}\right)^2 \left(\frac{T}{T_\odot}\right)^4 .$$

Because of the strong dependence on temperature, one might think that a hotter star is always brighter than a colder star. This turns out not to be true. For example, the luminosity of the red giant star Mira (with a radius $R = 5.3 \times 10^{10}$ m and a surface temperature $T = 3,000$ K) is $L \simeq 415\ L_\odot$, while the luminosity of the white dwarf star Sirius B (with a radius $R = 7 \times 10^6$ m and a surface temperature $T = 24,000$ K) is $L \simeq 0.03\ L_\odot$.

In fact, the luminosity of a star depends strongly on its mass $\mathcal{M}$. The data shown below presents stellar luminosities (expressed in terms of solar luminosity $L_\odot$) for various stellar masses (expressed in terms of solar mass $\mathcal{M}_\odot = 1.99 \times 10^{30}$ kg).

Luminosity ratio $L/L_\odot$	$\log(L/L_\odot)$	Mass ratio $\mathcal{M}/\mathcal{M}_\odot$	$\log(\mathcal{M}/\mathcal{M}_\odot)$
0.01	−2.0	0.26	−0.585
0.1		0.51	
1		1.00	
10		1.90	
100		3.70	
1000		7.30	
10000		14.0	
100000		28.0	

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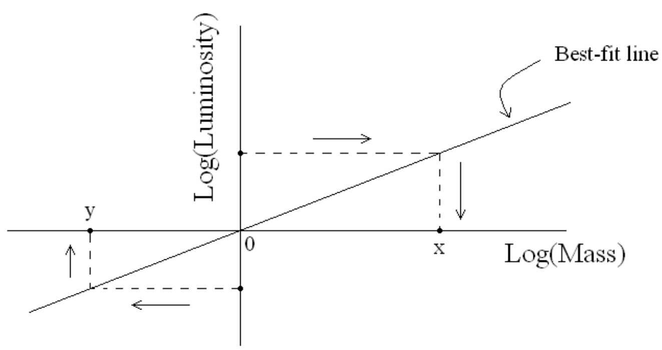
Part 1: Complete the data table above by computing the logarithms of luminosity L and mass $\mathcal{M}$.

Part 2: Plot $\log(L/L_{\odot})$ versus $\log(\mathcal{M}/\mathcal{M}_{\odot})$ on a graph, and draw a straight line which best fits the data points.

Part 3: Using the best-fit line on your graph, estimate the masses of Sirius A ($L/L_{\odot} = 24$) and ϵ Eridani ($L/L_{\odot} = 0.32$):

$$\left(\frac{\mathcal{M}}{\mathcal{M}_{\odot}}\right)_{\text{Sirius A}} = \underline{\hspace{6cm}}$$

$$\left(\frac{\mathcal{M}}{\mathcal{M}_{\odot}}\right)_{\epsilon \text{ Eridani}} = \underline{\hspace{6cm}}$$



Mass Ratio = $10^{x} > 1$

Mass Ratio = $10^{y} < 1$