

Size

•Materials

Calculator

•Introduction

Stars, except the sun, are too far away to directly measure their radius. Therefore, astronomers use an indirect technique to estimate the size of stars. In this lab, you will use this technique to explore the variation of size in different types of stars.

The **Stefan-Boltzman law** describes how much energy is emitted per second per square meter of a blackbody's surface,

$$F = \sigma T^4, \quad (1)$$

where F is energy flux, $\sigma = 5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$ is the Stefan-Boltzman constant, and T is the surface temperature of the blackbody. This equation applies very well to stars, whose spectra are quite similar to that of a perfect blackbody. A star's luminosity is the amount of energy emitted per second from its entire surface. In the case of stars, we can safely assume a spherical emission surface with area $4\pi R^2$, where R is the radius of the star. The luminosity is therefore

$$L = 4\pi R^2 \sigma T^4. \quad (2)$$

Since we are interested in finding the size of stars, we would like an equation expressing R in terms of the other variables. A useful way of expressing the numbers in this kind of problem is to use ratios referring to the sun. For the sun,

$$L_{\odot} = 4\pi R_{\odot}^2 \sigma T_{\odot}^4, \quad (3)$$

where $L_{\odot} = 3.8 \times 10^{26} \text{ W}$, $R_{\odot} = 6.96 \times 10^8 \text{ m}$, and $T_{\odot} = 5776 \text{ K}$. Dividing equation (2) by equation (3) and solving for R/R_{\odot} , we get

$$R/R_{\odot} = (T_{\odot}/T)^2 (L/L_{\odot})^{1/2}. \quad (4)$$

We now have the tool needed to calculate the size of stars. In order to use this equation, we need two pieces of information for each star:

the surface temperature and the luminosity. The surface temperature is determined by the spectral class. See the table below for the relationship between surface temperature and spectral class. *Remember, an A1 star is hotter than an A7 star.*

Spectral Class	Temperature (K)
O	30,000 - 50,000
B	11,000 - 30,000
A	7,500 - 11,000
F	5,900 - 7,500
G	5,200 - 5,900
K	3,900 - 5,200
M	2,500 - 3,900

To find the luminosity, we can use measurements of the absolute magnitude, M . Absolute magnitude is a quantity that describes the brightness of a star (see the Luminosity lab) and determines luminosity via the formula

$$M - M_{\odot} = 2.5 \times \text{Log}(L/L_{\odot}). \quad (5)$$

M_{\odot} is the absolute magnitude of the sun, and is equal to $+4.8$. We want to know the luminosity given the absolute magnitude, so we'll rewrite the equation in the form

$$L/L_{\odot} = 10^{(M_{\odot} - M)/2.5}. \quad (6)$$

Notice that there is *not* an absolute value sign around $(M_{\odot} - M)$. It is important to use the correct sign for the star's magnitude, M , as very *bright stars have negative absolute magnitudes*.

•Procedure

Use equation (6), the table, and equation (4) to find the radii in terms of the solar radius for each star in the chart on the following page. To get temperature, make an estimate given the table above. For example, G2 star: $(5900 \text{ K} - 5200 \text{ K})/10 = 70$ so $G2 = 5900 \text{ K} - 140 \text{ K} = 5760 \text{ K}$. Fill in the blanks in the chart as you go. Answer the questions in the section below.

•Questions

- 1) Are all of the stars in the chart that are hotter than the sun bigger than the sun?
- 2) Are all of the stars in the chart that are more luminous than the sun bigger than the sun?

Star	Spectral Type	Temperature	M	L/L_{\odot}	R/R_{\odot}
Alpha Centauri A	G2		4.4		
Arcturus	K2		-0.3		
Betelgeuse	M2		-5.6		
Capella	G2		0.0		
Deneb	A2		-7.1		
Proxima Centauri	M5		15.4		
Sirius	A1		1.5		
Spica	B1		-2.0		
Vega	A0		0.5		
Wolf 359	M6		16.7		

- 3) Do all stars with the same luminosity have the same size? Give an example.
- 4) Do all stars with the same temperature have the same size? Give an example
- 5) What, if anything, strikes you about Betelgeuse? What type of star do you think it is?
- 6) How does size vary with temperature (i.e. to what power does size depend on temperature)? How does size vary with luminosity?
- 7) According to equation (2), luminosity is related to temperature. How so? Does this explain your answer to question 5)?

For credit, turn in your calculations and answers to all questions.