Solution

Physics 213 **Problem 3** **Week 5**

Stellar Radii

In this problem you will use Wien's displacement law, and the Stefan-Boltzman law to calculate the radius of a distant star. Astronomers often use these techniques, because most stars are so distant that the actual size is not resolvable by our best telescopes, due to diffraction.

Here are a few possibly useful facts:

The peak wavelength of the spectrum emitted by our Sun is ~480 nm.
The radius of our Sun is 7×10^8 m.
The peak wavelength of the spectrum emitted from the "dog-star" Sirius is 294 nm.
By measuring the brightness of Sirius, and measuring how far away it is, we calculate that Sirius outputs about 23 times as much power as the Sun.

a). Calculate the temperature of Sirius, and of the Sun.

By Wien's displacement law, $\lambda T = 0.0029$ m-K, we have $T_{Sirius} = 0.0029/294\text{ nm} = 9880$ K.

Similarly, we have $T_{sun} = 0.0029/480\text{nm} = 6040$ K.

b) Derive a general relationship between the radii of two stars, if you know the relative power output, and the temperatures of the stars.

Since $J = \sigma_{SB}T^4$, and $P = 4\pi R^2 J$, we have $P = 4\pi R^2 \sigma_{SB}T^4$. Let the two stars be "A" and "B".

Then $P_A/P_B = (R_A/R_B)^2 (T_A/T_B)^4$, and $R_A/R_B = (P_A/P_B)^{0.5} (T_B/T_A)^2 = (P_A/P_B)^{0.5} (\lambda_A/\lambda_B)^2$

c) What is the radius of Sirius?

$R_{Sirius} = R_{sun} (P_{Sirius}/P_{sun})^{0.5}(T_{sun}/T_{Sirius})^2$

$= 7 \times 10^8 \text{ m } (23)^{0.5} (6040/9880)^2$

$= 1.8 R_{sun} = 1.3 \times 10^9$m