The Color of Stars

As you learned in FYI: *Spectral Lines*, energy is released in the form of electromagnetic radiation when the atoms that make up an object collide with one another. Because the atoms can move at almost any speed, the energy released through collisions can be at any energy or wavelength, and a continuous spectrum of electromagnetic radiation is produced.

The amount of light a star produces at each wavelength is proportional to the star's surface temperature. Hotter stars have atoms that are moving at a faster average speed, so their collisions result in the production of higher-energy photons. This means these stars emit more blue photons than red photons and appear blue. Similarly, cooler stars have atoms that are moving at a slower average speed, so their collisions result in the production of more low-energy photons than high-energy photons. These stars appear red. Stars at middle temperatures, like our sun, emit mostly green or yellow photons. When the brightness of electromagnetic radiation from a star is plotted versus its wavelength, it produces a smooth curve like the one shown in Figure 4-20.

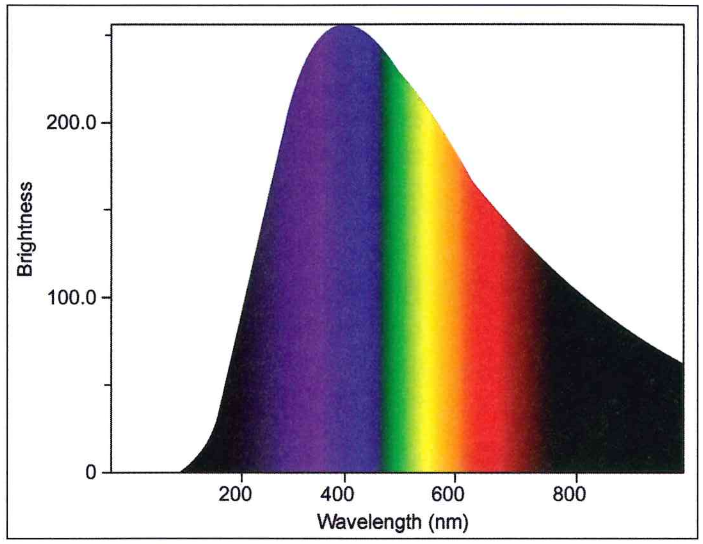


Figure 4-20: Graph of a star's brightness plotted versus its wavelength

All astronomical objects emit electromagnetic radiation, and most of them will have a continuous spectrum with or without additional spectral lines. The shape of the graph of the continuous spectrum, often called a **blackbody curve**, is roughly the same for all objects, but the peak of the curve for a hotter object is higher (brighter) than that of a cooler object, and it peaks at a shorter wavelength than that of a cooler object.

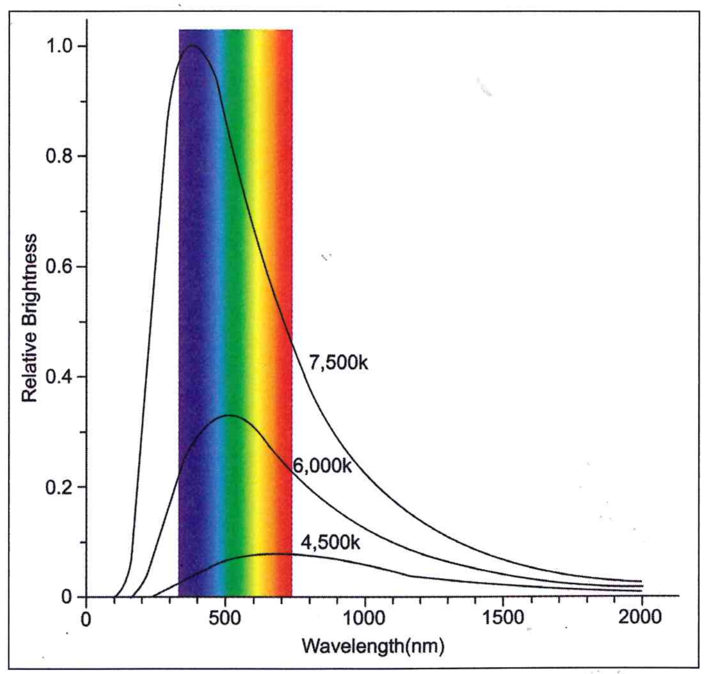


Figure 4-21: Graph of the blackbody curves for three different temperatures of objects

The peak wavelength of cool objects, such as human beings and very cool stars, lies in the infrared region, not in the visible portion of the electromagnetic spectrum—this is why you don't glow in the dark! Very hot stars peak in the ultraviolet region. Because the amount of radiation emitted by an object is greatest at the peak wavelength, this wavelength is dominant in determining the overall color of an object.

Color and temperature are related by a simple mathematical formula known as **Wien's Law**.

This law states that the wavelength of maximum brightness, λ max (measured in centimeters), is equal to a constant ($C = 0.29$ cm $\cdot$ K) divided by the temperature of the object (measured in degrees Kelvin).

Example: Calculate the wavelength of maximum brightness for two stars—one with a temperature of 3,000 K and one with a temperature of 15,000 K. What color will each of these stars appear to be?

$$\lambda \text{ max} = \frac{C}{T(K)} = \frac{0.29}{3{,}000 \text{ K}} = 9.67 \times 10^{-5} \text{ cm} = 967 \text{ nm}$$

$$\lambda \text{ max} = \frac{C}{T(K)} = \frac{0.29}{15{,}000 \text{ K}} = 1.93 \times 10^{-5} \text{ cm} = 193 \text{ nm}$$

The 3,000 K star has a peak wavelength in the infrared region of the electromagnetic spectrum. Since our eyes can only detect visible light, this star will appear red. The 15,000 K star has a peak wavelength in the ultraviolet, and will therefore appear blue.

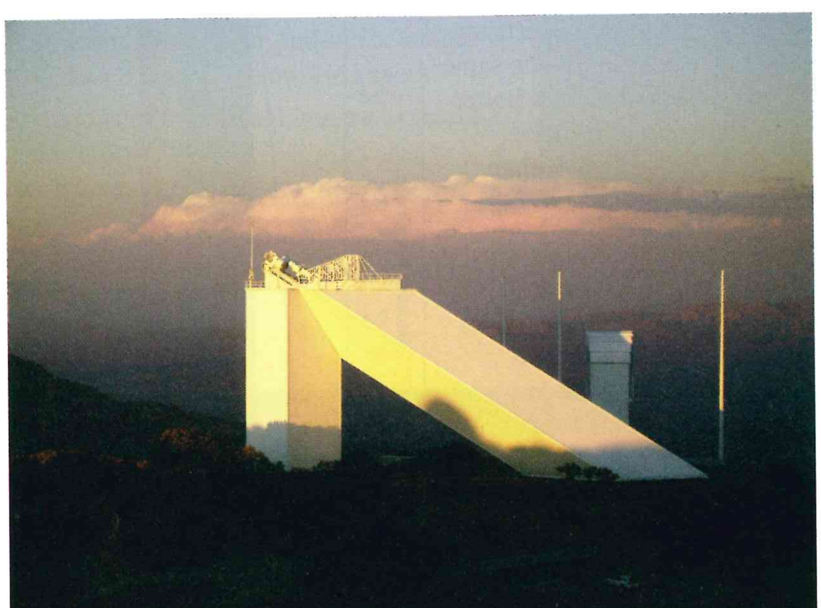
A second important radiation law that relates the temperature of any object to the total energy it emits is called the **Stefan-Boltzmann Law**, which states that the total energy emitted by an object is equal to a constant number (σ) times the temperature of the object raised to the fourth power:

$$E = \sigma T^4$$

This means that temperature is a dominating factor in the energy output of stars. The sun's surface temperature is about 5,800 K. The Stefan-Boltzmann Law says that if a star has twice the surface temperature of the sun, it will emit not twice, not four times, not eight times, but 16 times more energy ($2^4 = 16$).

Checking In

1. Explain why the peak wavelength of a continuous spectrum relates to the surface temperature of the emitting object.
2. If a star has a surface temperature of 2,900 K (half the surface temperature of the sun), how would its energy output compare to that of the sun?



An image of the McMath-Pierce solar telescope on Kitt Peak in Arizona