11.5.1: Color and Astronomy

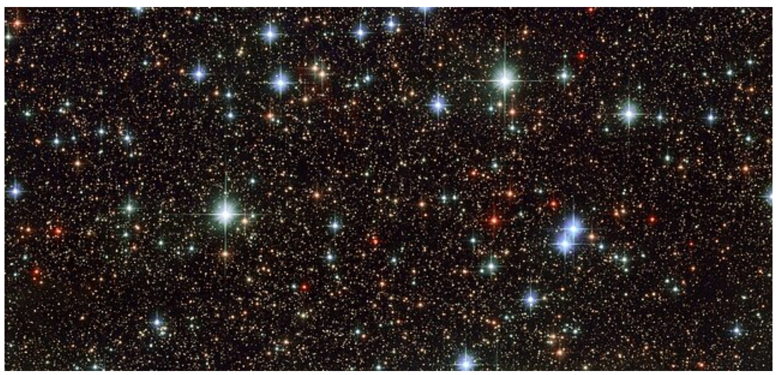
Beyond its ability to provides us with a richer visual experience, the color of objects can be used in astronomy to help gather information about them. In particular, there is a link between the frequency of the light emitted by an object and the temperature of that object. The phrases 'red hot' and 'white hot' spring to mind as an example of the linguistic relationship between color and temperature.

Thermodynamics is a branch of physics that concerns itself with heat energy and how it is transferred between objects. Simple experiments show that the color emitted at the highest intensity is well correlated to the temperature of the object. Simply stated, as the temperature of the object increases, the wavelength it emits decreases. German physicist Wilhelm Wien discovered an experimental relationship between temperature and wavelength known as Wien's Law:

$$\lambda_{peak} = \frac{2.897 \times 10^{-3} \text{ meter-Kelvin}}{\text{T}}$$

In this expression T is the temperature of the object in Kelvin.

The image below was taken by the Hubble Space Telescope and shows a region of the Milky Way Galaxy known as the Sagittarius Star Cloud.



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We can use our understanding of electromagnetic waves, intensity and color to help make sense out of the image. Knowing that the stars are all located at a similar distance from the earth, we can conclude that the brighter (more intense) stars are emitting more energy per second than their dimmer companions. Furthermore, we can use Wien's Law to help categorize the approximate temperature of these stars. Since blue light has a shorter wavelength than red light, stars that appear blue-white are at a higher temperature than stars that appear reddish. The temperature of the star has an effect on which elements can be fused, and this information can be used to establish an approximate mass of the star. In the chapter on nuclear physics, the relationship between temperature and nucleosynthesis will be explored further.

To get a more accurate reading of the peak intensity color emitted by the star, filters are used that block all but a narrow range of wavelengths. The intensities of various wavelengths are compared to a reference star and a value is then determined.

Star Color	Approximate Temperature
Blue	25,000 Kelvin
White	10,000 Kelvin
Yellow	6000 Kelvin
Orange	4000 Kelvin
Red	3000 Kelvin

Observations show that the hottest visible stars have surface temperatures over 40,000 Kelvin and the lowest detectable temperatures are about 2000 Kelvin. Our Sun emits yellowish-green light with a surface temperature around 6000 Kelvin. It looks yellow from the surface of the planet because the shorter (bluer) wavelengths interact more with the molecules in the atmosphere, causing them to be randomly scattered, leaving the longer (yellow) wavelengths of light to travel straight to our eyes. This also explains why the sky appears blue.

Understanding the behavior of charges and the electromagnetic waves they produce has led to vast technological advances and the ability to examine the universe and make sense out of what we see. In the chapter on optics, differences in wave speeds will allow us to understand how the lenses in our eyes work, as well how to build microscopes and telescopes to expand the scales at which we can gather information.
