Stars as black bodies

If you watch the filament of a lamp as the current through it gradually increased you'll see it begin to glow a deep dull red, become brighter and more orange yellow, and eventually appear white. It has gone from warm to 'red hot' to 'White Hot'. As its temperature increases two things happen:

1. The intensity of the radiation it emits increases at all wavelengths.

2. The spectrum of radiation shifts towards higher frequencies This is why the color changes through red to white as more and more of the visible spectrum is included.

An ideal thermal radiator is called a **black body** and emits a characteristic broad-band spectrum of radiation that depends only on its temperature. Surprisingly the stars and filament lamps both behave like ideal black-body radiators. This is very important in astronomy because it means a great deal can be found out about the stars simply by measuring their Spectra.

In particular:

1. The color of a star is related to its surface temperature (through Wien's law), red stars being cooler than yellow stars which are cooler than white or blue stars.

2. The intensity of radiation leaving the surface of a star is related to its temperature (through the Stefan-Boltzmann law) and so its color.

How can stars be black?

A black body absorbs all the radiation that falls upon it, but if it is hot it will also emit all wavelengths. If this wasnot the case black body could never be in thermal equilibrium with their surroundings because they would absorb more energy than they emitted at certain wavelengths and so continue to increase in temperature.

To understand how a star can we black you have to look at its surface. The main body of this star consists of a hot gas dense enough to be opaque to radiation. This means that any photons entering from outside the star will be absorbed and is scattered many times by particles in the gas which makes it an ideal observer.

Any photons coming out from the core of this star (where the nuclear reactions take place) as scatter and are absorbed and reemitted countless number of times before escaping from the **photosphere**, a thin layer near the surface of the star where the gas density drops fairly rapidly and it became transparent. A million years might elapse between the creation of a photon in the core of a star and the emission of its energy into space! The multiple scattering ensure that the photons come to thermal equilibrium with the gas and make their spectrum close to that of a true black body. Without the scattering there would be an abundance of very-high energy, high frequency photons characteristic of nuclear fusion energies.

Color and temperature

Wien's law states that, for a black body spectrum the product of peak wavelength **λp** and temperature **T** in Kelvin is constant:

$$\lambda_p \times T = \text{constant} = 2.898 \times 10^{-3}\ \text{mK}$$

this means we can work out the surface temperature of the stars simply looking at the spectrum of light in the image even with the naked eye. It is clear that some stars are red orange in color and others are yellow or white reddish. Stars are relatively with surface temperature around 3000 Kelvin, yellow stars are closer to 6000 Kelvin and white stars are around 10,000 Kelvin some blue stars have surface temperature in excess of 20,000 Kelvin.

In practice astronomers have to measure the apparent magnitude of the star at more than one wavelength in order to determine the shape of its radiation curve and hence its surface temperature. The human eye responds most strongly to light in the yellow part of their spectrum as do photoelectric photometers or Charge Coupled Devices CDDs which mimic the human eye so this visual magnitude measurement adds it's supplemented by measurements in the blue and possibly ultraviolet region.