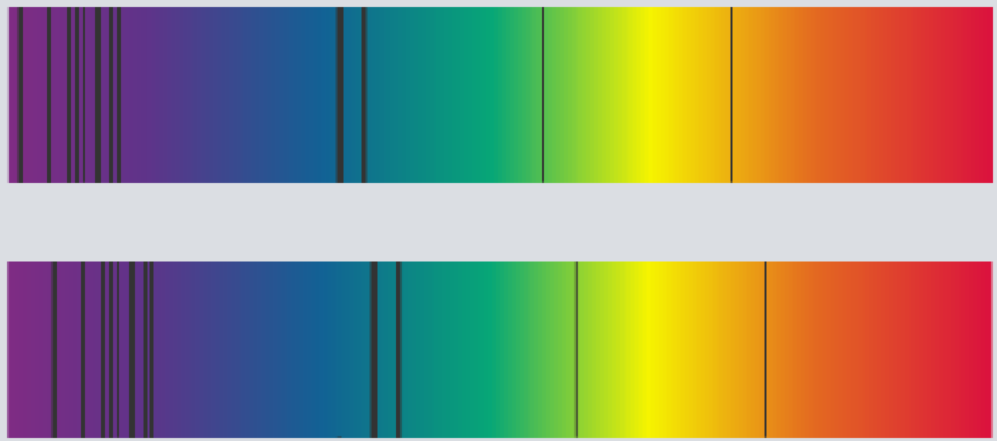
Observing the Universe



Black body radiation and Wien's law

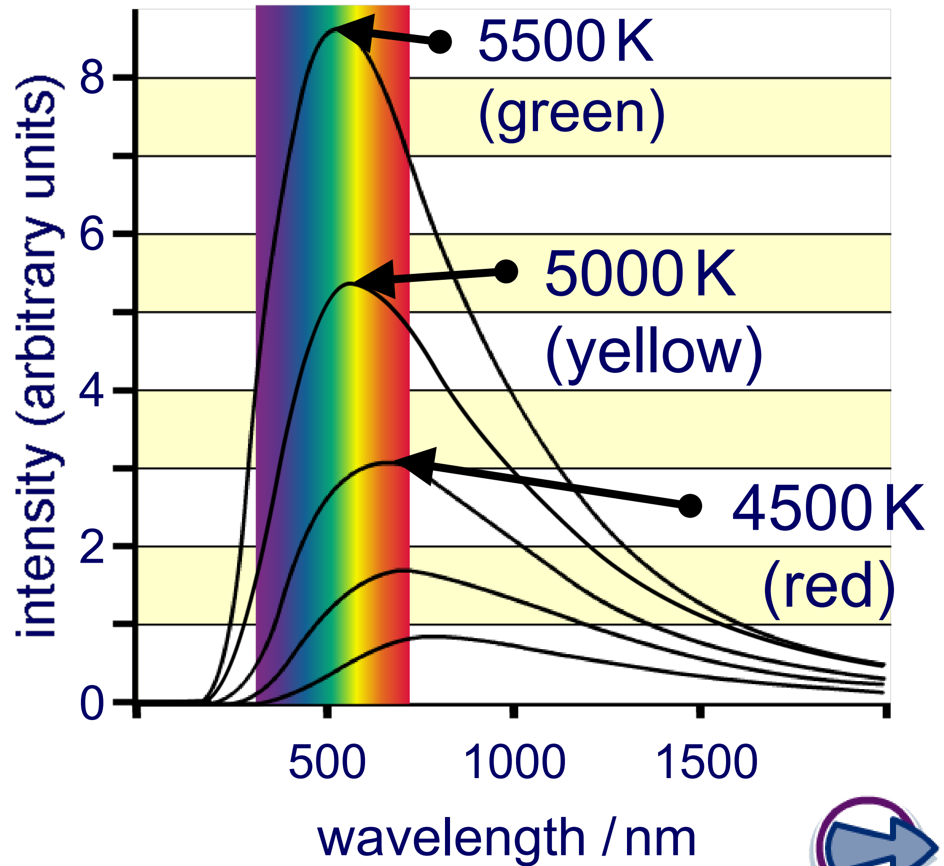
A **black body** is a theoretical object that absorbs all the light that hits it, so it appears perfectly black when cold. When heated above absolute zero, it emits light across the whole electromagnetic spectrum, in a distribution that looks like this:

Wien's displacement law states that the hotter the black body, the shorter the peak wavelength of the curve:

$$\boldsymbol{\lambda_{max} T = \text{constant}}$$

This can be given a value:

$$\lambda_{max} T = 2.9 \times 10^{-3}\,\text{m K}$$



Black body temperatures

When metal is heated, it glows red, then orange, then yellow, then white hot. You can get a sense of how hot it is just by looking at it. This is a good way of remembering how a black body behaves.

Wien's displacement law can be used to estimate the temperature of a star from the peak wavelength of its light.

Q. Estimate the temperature of an orange star with a peak wavelength of 600 nm.

A. $\lambda_{max} T = 2.9 \times 10^{-3}\,\text{m K}$

$$T = \frac{2.9 \times 10^{-3}}{600 \times 10^{-9}} = \mathbf{4800\,K}$$

Absorption spectra

When an electron moves between energy levels in an atom, it releases or absorbs a photon. When moving up energy levels, only a **single photon** of the relevant energy can be absorbed. It is not possible for an electron to ‘store up’ energy from smaller quanta until it has enough to jump.

If a continuous spectrum of light is shone at a transparent material, a few discrete frequencies are absorbed, while the rest are transmitted. This forms an **absorption spectrum**.

Some of the light produced by a star will be absorbed in this way by its outer layers, so the spectrum of a star tells us its composition.

these lines in a star’s spectrum indicate the presence of hydrogen

Spectral classification

Stars can be classified by the absorption lines in their spectra, which correspond to particular temperatures and colors.

Class	Prominent lines	Color	Surface temp /K
O	He^+, He, H	blue	25000–50000
B	He, H	blue	11000–25000
A	H, ionized metals	blue-white	7500–11000
F	ionized metals	white	6000–7500
G	metals	yellow-white	5000–6000
K	neutral metals	orange	3500–5000
M	neutral atoms	red	<3500

Q. Which of these classes does our Sun belong to? **Class G**

Doppler effect and red shift

When an ambulance drives past you, its siren sounds higher pitched as it approaches, and lower pitched as it moves away. This is the **Doppler effect**. The same thing happens to the light emitted by very fast moving objects, such as distant stars, and can be seen in their spectra. This is **red shift**.

absorption lines of the Sun

similar star red shifted

The amount of red shift can be calculated using this formula:

$$z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

Where *z* is red shift, $\Delta\lambda$ is the difference between the observed and emitted wavelengths, λ is the emitted wavelength, *v* is the relative velocity of the source, and *c* is the speed of light.

Binary stars

Quasars

Edwin Hubble

Edwin Hubble was the first scientist to observe that other galaxies existed outside the Milky Way. He announced this discovery in 1925, and went on to study the **red shift** of these distant galaxies.

He observed that almost all galaxies showed a shift towards the red end of the spectrum, meaning that they were moving away from the Milky Way. He then observed that the **further away** a galaxy was, the **greater** its red shift.

This was the first observational evidence to support the Big Bang theory, by demonstrating that the Universe is expanding.

Hubble's law

Hubble found that the speed of a receding galaxy is directly proportional to its distance. This became **Hubble's law**.

$$v = H_0 d$$

Where H_0 is known as **Hubble's constant**.

Hubble used this to estimate the age of the Universe by calculating how much time had passed since the receding galaxies would all have been at distance zero.

$$\textbf{time} = \text{distance/speed} = \frac{1}{H_0}$$

How accurate do you think his estimation was?

What assumptions did he make?

Estimating the age of the Universe

Questions