ASTRO 100/G – Experiment 4

Spectroscopy

Links to Lectures 5, 16, 18, and 21

Much of the information we can deduce about the composition, temperature and gravity of stars comes from examining the spectra of light they emit as every body/element is characterised by their unique spectrum.

This is because hot objects emit a **continuous spectrum** – the peak intensity of which depends on its temperature (T) according to Wien's Law. The hotter an object is, the shorter its peak wavelength (λ_{peak}), and therefore (counterintuitively) the bluer it appears to be.

$$\lambda_{\text{peak}} = \frac{3 \times 10^6}{T}$$

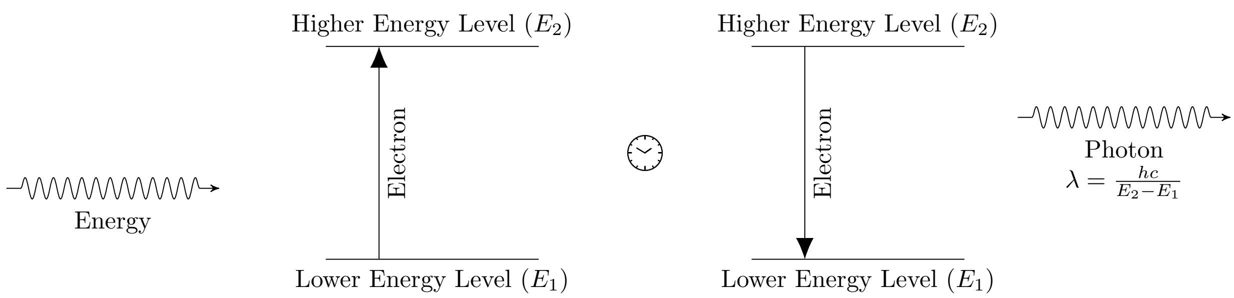
When white light interacts with a prism – such as the triangular one in front of you – it **refracts** and spreads out into a continuum of colour, commonly called a rainbow. Depending on the wavelength of the light, it will refract more or less (i.e. colors with the shorter wavelength will refract more, and vice-versa).

Different elements in a star's atmosphere – or along the line-of-sight – absorb and emit light at specific wavelengths (or colours) forming spectral lines. When energy is absorbed by an element, the electrons orbiting around the atom get excited and will start moving up and down energy levels; when the electrons drop back down to a lower energy level, the excess energy is emitted in the form of light producing **emission spectra**. This is shown as a picture at the bottom of this page. On the contrary, light absorbed by a gas excites the electrons to a higher energy level leaving an absorption spectrum. The relationship between the energy of the emitted photon (E), its wavelength (λ), and its frequency (f) is

$$E = hf = \frac{hc}{\lambda} \ ,$$

where h is called Planck's constant ($h = 6.626 \times 10^{-34}$), and c is the speed of light ($c = 3 \times 10^8$ metres per second, or about one billion kilometres per hour). The lamps on the bench are gas discharge tubes – this means they excite the atoms by applying electricity across a sample of the gas. This electricity provides the energy to excite the electrons. In a real star, the excitation is provided by the core – the core of the star is a violent nuclear furnace. In the Sun, the total energy per second is about 10^{26} Joules – that's about one million billion billion times the energy in a single 100W light bulb, per second.

Since every element is sensitive to slightly different wavelengths of light (because they all have unique electron configurations), they each have their own unique "fingerprint" of spectral lines. Therefore studying these lines can tell us about the temperature of a gas and its composition.



At the end of this lab, students will be able to:

- **Qualitatively describe** how white light is refracted by a prism.
- **Recall** how the energy of a photon is related to wavelength.
- **Recall** the order of visible colours, infrared, and ultraviolet in a spectrum, ordered by wavelength.
- **Contrast** a continuous spectrum, an emission spectrum, and an absorption spectrum.