1 Surveying the Stars

1.1 Star Magnitudes

- One **light year** is the distance light travels through space in 1 year.
- The sun and nearby stars are in a **spiral arm** of the Milky Way galaxy.
- **Galaxies** are assemblies of stars prevented from moving away from each other by their **gravitational attraction**.
- The most distant galaxies near the edge of the **observable universe** were formed shortly after the Big Bang.
- **Parallax**: nearby stars shift in position against the background of more distance stars as the Earth moves in its orbit,
- The **astronomical unit** is the mean distance from the centre of the Sun to the Earth.
- The **parallax angle** θ is the angle subtended to the star by the line between the Sun and the Earth.

$$\theta \approx \tan\theta = \frac{R}{d}$$

- One **arc second** is $\frac{1^\circ}{3600}$
- One **parsec** is defined as the distance to a star which subtends an angle of 1 arc second to the line from the centre of the Earth to the centre of the Sun.

$$d \text{ (parsec)} = \frac{R \text{ (au)}}{\theta \text{ (arc seconds)}}$$

Star Magnitudes

The brightness of a star depends on the **intensity** of the star's light on earth - intensity is the light **energy per second per unit surface area** received from the star at **normal incidence** on a surface.

The **Hipparcos scale** define a difference of 5 magnitudes as a hundredfold change in the intensity of light received from the star.

- The **apparent magnitude** m of a star in the night sky is a measure of its brightness - its intensity.

$$m_y - m_x = 2.5 \log \frac{I_X}{I_Y}$$

- The **absolute magnitude** M of a star is defined as the star's apparent magnitude m, if it was at a distance of 10 parsecs away from the earth.

$$m - M = 5\log\frac{d}{10}$$

1.2 Classifying Stars

Stars differ in **colour and brightness**. Stars that appear white appear in their true colours when viewed through a telescope, because a telescope **collect more light** than the unaided eye, and activating the colour-sensitive cells in the retina.

- The thermal radiation from a hot object at constant temperature consists of a **continuous range of wavelengths**.
- The **distribution of intensity** with wavelength changes as the temperature of the hot object is increased.
- A **black body** is defined as a body that is a perfect absorber of radiation, and therefore emits a continuous spectrum of wavelengths.
- A **black body radiation curve** shows the intensities of the wavelengths emitted by a black body.

Law's of Thermal Radiation

Wien's Displacement Law

The wavelength at peak intensity is inversely proportional to the absolute temperature of the object.

$$\lambda_{\max}T = b$$

where $b = 0.0025\text{m K}$

It is used to calculate the **absolute temperature of the photosphere** (the light-emitting outer layer) of a star.

Stefan's Law

The total energy per second emitted by a black body is proportional to its **surface area** and to T^4.

$$P = \sigma A T^4$$

where the **Stefan constant** $\sigma = 5.67 \times 10^{-8}\text{Wm}^{-2}\text{K}^{-4}$.

The power output of a start is sometimes called the **luminosity** of the star.

Stellar Spectral Classes

The spectrum of light from a star is used to classify it.

Spectral class	Intrinsic colour	Temperature	Absorption lines
O	Blue	25K - 50K	He^+, He, H
B	Blue	11K - 25K	He, H
A	Blue-white	7.5K - 11K	H, ionised metals
F	White	6K - 7.5K	Ionised metals
G	Yellow-white	5K - 6K	Ionised & neutral metals
K	Orange	3.5K - 5K	Neutral metals
M	Red	2.5K - 3.5K	Neutral atoms & TiO

The spectrum of light from a star contains **absorption lines** due to an atmosphere of hot gases surrounding the star above its photosphere.

- Atoms of the gas **absorb light of certain wavelengths**.
- The light that passes through these hot gases is therefore **deficient of this wavelengths**, its spectrum therefore contains **absorption lines**.

The wavelengths of absorption lines are **characteristics of the elements in the corona of hot gases** surrounding a star. The wavelengths of these absorption lines can be used to identify the **elements present in the star**.

Balmer lines are **hydrogen absorption lines** correspond to excitation of hydrogen atoms from the $n = 2$ state to higher energy levels. They are only visible in O, B, A class stars.

- Hydrogen atoms in $n = 2$ state exist in hot stars.
- Such atoms absorb visible photons at certain wavelengths, producing absorption lines.

Note hydrogen atoms in $n = 1$ state does not absorb visible photons, as they do not have sufficient energy to cause excitation from $n = 1$.

1.3 The Herzsprung-Russell Diagram

The power output (luminosity) of the sun is given by

$$P = 4\pi r^2 I$$

Star diameters are determined by comparing the absolute magnitude of the star with that of the sun.

- A **dwarf star** is a star that is much smaller in diameter than the sun.
- A **giant star** is a star that is much larger in diameter than the sun.

Note Stefan's law gives the power output across the entire spectrum, absolute magnitudes relate to the visible spectrum.

Compare a star X with the sun

$$
\begin{aligned}
P_X &= \sigma A_X {T_X}^4 \\
P_S &= \sigma A_S {T_S}^4 \\
\frac{A_X}{A_S} &= \frac{P_X}{P_S} \div \left(\frac{T_X}{T_S}\right)^4 \\
&= \frac{\text{power output ratio}}{(\text{temperature ratio})^4}
\end{aligned}
$$

- Same surface temperature + unequal absolute magnitudes
  $\implies$ the one greater power output has the larger surface area.
- Same absolute magnitude + unequal surface temperatures
  $\implies$ the hotter star has a smaller surface area.

Features of the The HR Diagram

- **Absolute magnitude** is plotted on the y-scale.
- **Temperature** is plotted in the x-scale.

The main features are as follows

- The **main sequence** is a heavily populated diagonal belt of stars, ranging from cool low-powered stars ($M = +15$) to very hot high powered stars ($M = 5$).
- **Giant stars** have absolute magnitudes $-2 < M < 2$, emit more power than the sun, and are 10 to 100 times larger. **Red giants** are cooler than the sun.
- **Supergiant stars** have absolute magnitude $-10 < M < -5$, they are relatively rare, and are much brighter and larger than giant stars, with diameters up to 1000 times of the sun.
- **White dwarf** stars have absolute magnitude $+10 < M < +15$ and are hotter than the sun, they are much smaller and emit much less power than the sun.