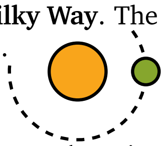
2. Space

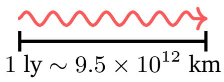
Cosmology

The **Earth** is one of 8 planets in our solar system which orbits a star in the middle—the **Sun**. The **Sun** is one of many ($\sim 100,000$ million) stars in our galaxy, the **Milky Way**. The entire universe contains ~ 100 billion galaxies.



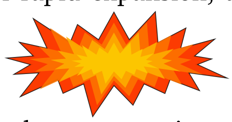
Distances

Distance in space may be measured in light-years (or minutes, seconds, etc.), one light-year (ly) the distance travelled by light at $c = 3 \times 10^8$ ms^{-1} in one year.



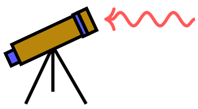
The Big Bang theory

The **Big Bang theory** is the prevailing model for the origin of the universe. It states that the universe began almost 14 billion years from an extremely small concentration of matter and energy and a brief period of rapid expansion, and has been expanding ever since.



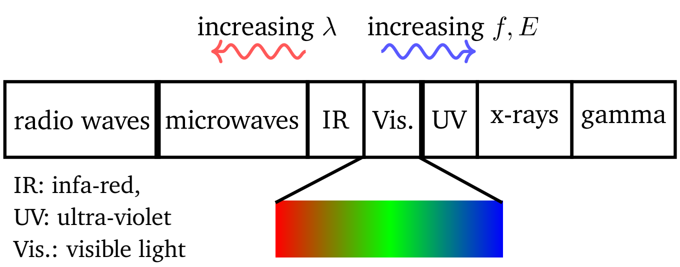
Observations

Astronomers use telescopes to detect electromagnetic radiation from astronomical objects to obtain information about, for example, their distance, size and composition. Different telescopes are used to detect radiation from different parts of the electromagnetic spectrum.



Electromagnetic spectrum

All light is electromagnetic radiation (waves) that resides on a spectrum according to its frequency ν and wavelength λ which are related by $c = \lambda f$. The energy E of electromagnetic radiation increases with f.



The spectrum of light from stars can be used to determine their composition by matching lines of *absorption* with lines from the *emission* spectra of known elements.

A **spectroscope** uses a prism to display the colours comprising a light source. The continuous spectrum shown under Vis. above would be seen for a source of white light.

Exercise 2.1. Match the following objects to their definition

Object	Definition
	A large body orbiting a star
	The star at the centre of our solar system
	A star and its orbiting planets
	A small planet-like object
	A body orbiting a planet
	All matter and energy that we know of
	A ball of burning gas that emits EM radiation
	Small rocky bodies that orbit the Sun
	A planet not part of our solar system
	A large collection of many stars and their planets

Example 2.2. Since light travels at c and there are 3.15×10^7 $(60 \times 60 \times 24 \times 365)$ seconds on one year, 1 ly $= (3.15 \times 10^7$ s$) \times (3 \times 10^8$ ms$^{-1}) = 9.5 \times 10^{15}$ m.

Notable distances: Sun-Earth (8.5 light min.), Sun-nearest star (4.3 ly) and the Milky Way's diameter ($120,000$ ly).

Exercise 2.3. Match the following pieces of evidence for the Big Bang theory to their explanation

Hydrogen to Helium ratio	Uniform background radiation from the early universe
Cosmic Microwave Background	Light from distant galaxies is shifted towards the red end of the spectrum as they are moving away (Doppler effect), so the universe is expanding
Red shift of galaxies/stars	The ratio of these two elements matches that predicted by the model

Example 2.4. Visible light has a wavelength range from ~ 400 nm (blue) to ~ 700 nm (red), x-rays $\lesssim 1$ nm and gamma-rays $\lesssim 1$ pm ($1\text{nm} = 10^{-9}$m, $1\text{pm} = 10^{-12}$m).

Exercise 2.5. Look-up the emission spectrum of hydrogen gas (the Balmer series). Sketch this below and comment on how these lines would appear in an absorption spectrum. How many lines fall within the visible range?

Space Exploration

Space exploration has the potential to further our understanding of the universe and facilitate the development of many useful technologies (e.g. satellite communications) but carries certain risks and economic costs which must be considered when planning space missions.

Challenges of space travel include: attaining high velocities to cover vast distances, manoeuvring spacecraft in zero friction environments (e.g. to dock) and maintaining sufficient energy to operate life support systems on a spacecraft (arrays of solar cells may be used for this purpose).

Example 2.6. *Manned* space exploration has particular risks to human life, for example during fuel loading and ignition at take-off, exposure to harmful radiation during flight, muscle atrophy, suit failure leading to fatal depressurisation, and burn-up on re-entry.

Exercise 2.7. When a space shuttle enters the Earth's atmosphere a lot of heat is generated. Explain why this is and how the effect may be reduced or protected against.

Example 2.8. Ion drive (producing a small unbalanced force over a long period) and 'catapulting' from a fast moving planet-masses may provide sufficiently high velocities.

Satellites

Satellites are immensely useful tools for scientific research on both our own planet and atmosphere as well as our solar system and the wider universe. They are also essential for many important terrestrial technologies including GPS, satellite imagery, telecommunications and weather forecasting.

Satellites can be either orbiting, at relatively low altitudes ($\gtrsim 200\,\mathrm{km}$) and high speeds ($\gtrsim 8,000\,\mathrm{ms}^{-1}$), or **geostationary**, meaning they orbit at the same speed the Earth rotates i.e. once every 24 hours.

Exercise 2.9. List common uses of orbiting (polar) and geostationary orbits.

Example 2.10. Geostationary satellites have much higher ($\sim 36,000\,\mathrm{km}$) and slower ($\sim 3,000\,\mathrm{ms}^{-1}$) orbits than satellites with polar orbits. Note that a geostationary satellite is still orbiting, but remains a fixed point above the Earth's surface due to matching the planets rotation.