Cosmology

Definitions

Planet	a rocky or gaseous body, usually spherical, which orbits a central star. Reflects light from stars but does not produce its own light. The Earth is an example of a planet. A **dwarf planet** is a object which orbits a star but is too small to classify as a planet and too large to classify as an asteroid.
Moon	a rocky body which orbits a planet. Reflects light from stars but does not produce its own light. Our Moon is an example of a moon.
Asteroid	a rocky body which orbits a star, but is too small to be classified as a planet, or orbits a planet and is too small to be classified as a moon. Unlikely to be spherical in shape.
Star	a massive ball of gas which is undergoing nuclear fusion. Produces vast quantities of light and heat through this process. The **Sun** is a star.
Solar System	a system consisting of a central star and all objects which are gravitationally bound to it, including planets (and their moons), asteroids and comets
Exo-planet	a planet which is in orbit around a star other than our own
Galaxy	a collection of several million stars and their planets, gravitationally bound and moving through the Universe as a single system. The Milky Way is our galaxy.
Universe	everything we know to exist everywhere, all stars planets and galaxies.

Scale of the Universe

Earth to the Moon	384,400 km	1.3 light seconds	
Earth to the Sun	150 million km	8 light minutes	1 Astronomical Unit
Solar System Radius		approx. 2 light years	(objects under Suns influence)
Nearest Star		4 light Years	
Diameter of Galaxy		100,000 light years	
Diameter of observable Universe		approx. 93 billion light years	

1 light year = 365.25 x 24 x 60 x 60 x 300,000,000 = 9.5 x 10^{15}m

Life of the Universe

Origin – Expansion - Future

Origins	Evidence points to all the matter that has been observed in the universe having originated from a common dense origin. We think of this event as a Big Bang at the start of the universe (it really was more of a rapid expansion)
Expansion	There is evidence to show that almost all galaxies in the observable universe are moving away from us (this does not mean that we are at the centre but rather that almost all galaxies are moving away from each other. If this is the case the universe must be expanding.
Future	Will the Universe continue to expand forever? Will the Universe ever stop expanding? Will the Universe begin to collapse into a Big Crunch?
Age	Based on the observed expansion of the Universe it is estimated to be 13.8 billion years old.

Space Exploration

Space exploration may refer to sending people into Earth's orbit or to the Moon, future plans to explore other planets or the sending on automated probes to carry out this exploration for us. Mankind has sent a variety of space probes to the Moon, Mercury, Venus and Mars. Probes have been sent past the gas giants too, taking decades to reach their destinations and send back their findings. The voyager spacecraft are even now leaving our solar system behind them as they race off into the vast emptiness of space beyond the limits of our solar system.

Space exploration may also refer simply to the use of satellites, placed in orbit around the Earth.

Benefits of Space Travel

Besides the most direct application of space travel, to find out more about the Universe and our place in it, there are many other benefits. Some are more obvious than others, such as the use of satellites, and some benefits and technologies exist because they were develop to support the space program. Areas that have benefited include:

Light Emitting Diodes	Anti icing systems	Freeze drying
Infrared thermometers	Chemical detection	Water purification
Artificial limbs	Video enhancement	Solar cells
Invisible braces	Firefighting equipment	Powdered lubricants
Scratch resistant lenses	Temper foam	Mine safety
Space blankets	Cordless Vacuums	Food safety

Satellites

The Moon is a natural satellite. Mankind has launched many artificial satellites since the first artificial satellite, Sputnik 1, was launched in 1957. Their main uses include:

Communications Satellites	allow for worldwide audio and video communications with minimum delay, includes telephone & television
Weather Satellites	monitor global and local weather systems for use in weather forecasting and early warning of natural disasters
Space Telescopes	allow for astronomical observations without the interference of the Earth's atmosphere or light pollution. These include telescopes which can see well beyond the visible spectrum, as astronomers observe the universe across the whole EM spectrum. Examples include the current Hubble Space Telescope and the upcoming James Webb Telescope, due to be launched in 2019.
Space exploration & Scientific discovery	Scientists and astronauts can learn a great deal from working and carrying out experiments in space, particularly due to the microgravity in which they operate. Currently the main location for this is the International Space Station, ISS.
Global Positioning Systems	makes use of triangulation to determine the users location
Environmental Monitoring	monitoring land and sea temperatures, climate and climate change, as well as atmospheric composition

A satellites orbit depends on its distance from the centre of the Earth. The greater its altitude the longer its period of orbit. A geostationary satellite is placed in orbit so that it remains above the exact same point on the Earths surface. It therefore requires an orbital period of exactly 24 hours. To achieve this it must be placed at an altitude of 36,000 km.

Risk of Space Travel

There are of course also risks associated with space travel and there have been a few accidents and disasters as well as successes. Astronauts and spacecraft designers must take these into account for both manned and unmanned missions.

Rocket Propulsion	There are always underlying risks when using rocket propulsion and the fuel involved, miscalculations or accidents can lead to wrong and even dangerous trajectories or even explosions
Micrometeorites	Small pieces of rock in orbit or crossing the paths of satellites or spacecraft can do a great deal of damage
Solar flares and Radiation	There is a constant risk of high levels of ionising radiation from the Sun
No Atmosphere	There is no air and so no oxygen in space. All astronauts require specialised self-contained breathing and support systems to survive
Space Junk	Man made debris, including old disused satellites, are in orbit around the Earth and lie in the path of new space missions. Collisions in space have disastrous consequences
Re-entry into the Atmosphere	Gravitational potential energy is converted into kinetic energy as a space craft re-enters the atmosphere. Due to air resistance a great deal of heat energy is also generated. This can lead to extreme changes in temperatures. (See heat topic $\mathbf{E_H = cm\Delta T}$ and $\mathbf{E_H = ml}$)

Challenges in space exploration

Distance	distances in space are huge. Even a trip to Mars would require at least 3 months just to travel there, that doesn't include the return trip or any time spent on the planet! A possible solution is to reach large velocities in order to reduce the duration of expeditions.
Velocity	the velocities required (see above) can be difficult to obtain. Currently slingshot methods are used, using the gravitational field of a planet or asteroid to accelerate the spacecraft, reducing fuel requirements. Another option is a proposed ion drive, which would provide a small but constant acceleration throughout the journey allowing for a gradual build up to a large velocity.
Manoeuvring	There is no friction in space (and so an object in motion will stay in motion). Additionally, all objects in space will be moving relative to one another, therefore any delicate manoeuvres, such as docking with the ISS must be done extremely carefully, with thrusters required to stop as well as start motion.
Energy	Energy supplies are limited in space, so spacecraft and satellites must be self sufficient. This is mostly achieved by the use of solar arrays, which convert light energy from the sun into electricity.

Newton’s Laws and space travel

Newton’s Frist Law

“An object will remain at rest or continue to travel with constant speed, and in the same direction, unless acted upon by an unbalanced force”

Once a spacecraft is moving in the vacuum of space it will continue to move and will not slow down. This means that everything in orbit around the Earth is at risk of high velocity collisions with other objects in similar orbits. Additionally, thrust must be provided to slow or halt the motion of a spacecraft, as there is no frictional force to assist with this process.

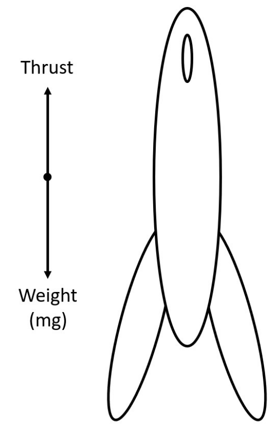
Newton’s Second Law

“The acceleration of a body is proportional to the ***unbalanced force*** *acting upon it and inversely proportion to the objects mass”*

The acceleration of the rocket is determined using F = ma, However, the unbalanced force here is given by:

Unbalanced force = thrust - weight

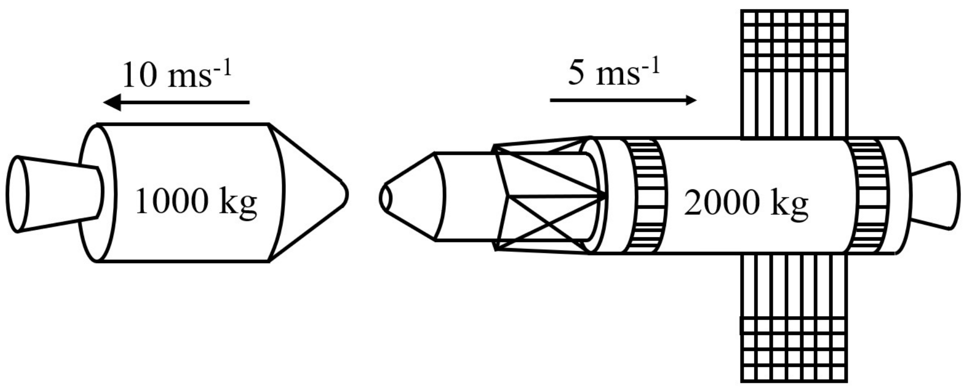
Remember to always calculate the unbalanced force in order to use F = ma correctly.



Newton’s Third Law

“If object A exerts a force on object B, then object B exerts an equal and opposite force on object A”

Releasing or ejecting any part of a spacecraft will result in this equal and opposite force, meaning that **both** objects will experience a change in motion. The acceleration of the object will less mass will be greater that the acceleration of the object with greater mass.



Observing the Universe

Astronomy

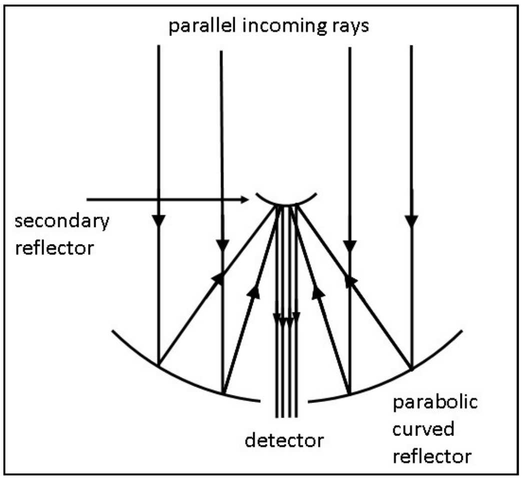
Astronomer use all 7 parts of the electromagnetic spectrum to observe the universe. Different parts of the spectrum help us in identifying and finding different pieces of evidence.

For example visible light is not able to penetrate the dense clouds of dust that are spread throughout the galaxy. To observe stars within or behind these clouds astronomers observe the Infrared radiation emitted by the stars, since their visible light will not reach us.

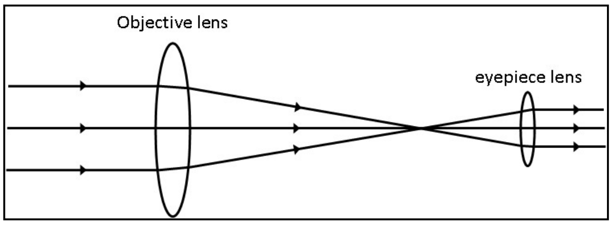
Telescopes

There are 2 main types of telescopes. The principles for both for visible light can generally be applied to most of the other parts of the electromagnetic spectrum.

Reflecting Telescope



Refracting Telescope

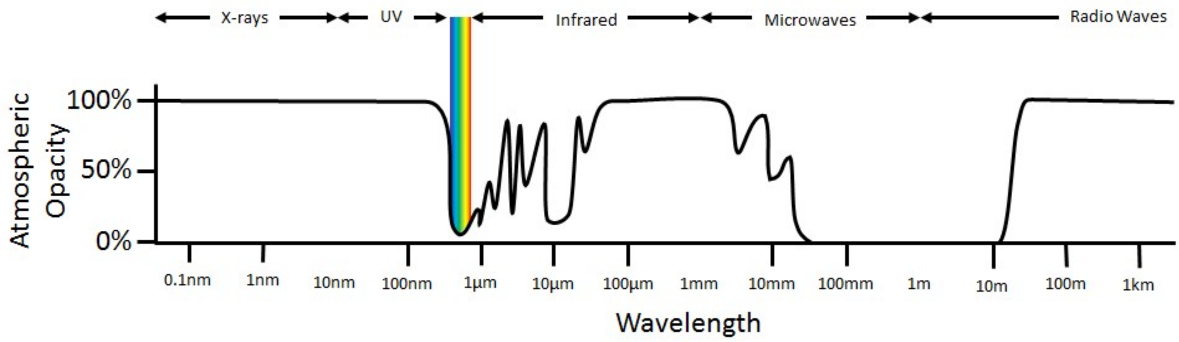


The larger the primary mirror or objective lens, the more light can be captured and therefore the better the image received.

The majority of modern telescopes use curved reflectors as large lenses are very heavy, easily damaged and difficult to transport, especially into space.

Opacity of the Atmosphere

The atmosphere is not transparent at all wavelength of the Electromagnetic spectrum. Some parts of the spectrum never reach the Earth's surface. To these types of radiation the atmosphere is said to be opaque.



Radio Astronomy

Radio waves are barely affected by Earth's atmosphere. Observations can be made during the day and even on cloudy days!

A special technique called interferometry allows 2 telescopes to act as one large telescope with an equivalent size of the separation between them. This allows for very high resolution images. This is also why radio telescopes are often seen arranged in large arrays, as opposed to individually. Two telescopes on opposite sides of the Earth will have an equivalent dish the size of the Earth! Imagine the effective size of a radio telescope in space paired with one on Earth!

Radio waves are **emitted** by stars and galaxies, as well as newly identified classes of objects, such as radio galaxies, quasars, pulsars, and masers.

Radio waves are **detected** using a curved reflector with **aerial**/antenna.

Microwave Astronomy

Most microwave frequencies are blocked by the Earth's atmosphere. For this reason space based telescopes are used. Astronomer have detected microwaves from all directions in space, this is known as the Cosmic Microwave Background and is a remnant of the Big Bang. These microwaves are electromagnetic waves which have lost their energy since they were **emitted** after the Big Bag, shifting from infrared radiation into the microwave part of the spectrum.

Similar to radio waves, Microwaves can also be **detected** using a curved reflector with **aerial**/antenna

Infrared Astronomy

Infrared radiation is mostly blocked by the Earth's atmosphere. It is absorbed by the moisture in the air. To overcome this, infrared observatories are placed in dry climates and at high altitude locations. This includes at the top of mountains and occasionally in the back of specially modified jumbo jets. Heat is a part of Infrared section of the Electromagnetic spectrum. Infrared telescopes (and their surroundings) must be super cooled to prevent them from detecting themselves, as **all warm objects emit some form of infrared radiation**.

Heat radiation lies in the far infrared region of the spectrum. The emitted wavelength can be used to determine the temperature of the source. Your body emits infrared radiation! Even cold objects emit infrared radiation with a longer wavelength.

Infrared radiation is **detected** using similar methods as visible light. Detectors similar to those found in digital cameras can detect near infrared radiation. Modifications and slightly different digital detectors are required for far infrared detection. In the simplest of cases a **blackened thermometer** or **photodiode** can be used.

Visible Spectrum Astronomy

Visible astronomy is almost as old as mankind itself. Visible light is able to pass through the atmosphere, provided the sky is clear of clouds. Visible light is however distorted by the atmosphere, it refracts when entering different gas densities at different altitude and temperatures. Again observatories are often found at high altitudes and away from populated areas, since light pollution will have a negative effect on observations.

Space based telescopes will produce much better images as they can totally remove the atmospheric distortion.

Visible light is **emitted** by **stars**. This allows us to observe them as well as the galaxies and star clusters that they make up. Planets, moons and nebulae (clouds of gas in space) all reflect light from nearby stars allowing us to observe them too. By observing visible light we can determine the composition of stars and nebulae (see spectroscopy section)

Visible light is classically **detected** using **photographic film** but is now most likely detected using an electronic detector such as a CCD or a CMOS detector like those found in modern digital cameras as well as the **retina** of the human eye, of course. [for interest] A CCD works by “counting” the incoming photons of light; the brighter the light the more photons; the more photons the more electrons produced. These electrons can then be counted.

Ultraviolet Astronomy

Ultraviolet light is absorbed by the atmosphere. All ultraviolet observations must be made using space based telescopes. These are very similar in design and construction as visible telescopes beside some modifications to filters

Ultraviolet radiation is mostly **emitted** by **very hot young stars**, although our sun produced UV too. UV radiation is ionising.

Ultraviolet light can be **detected** by special films, similar to photographic film and **fluorescent materials**. Digital detectors also exist, with similar construction to those for visible light.

X-ray Astronomy

X-rays are also blocked by the Earth’s atmosphere. X-rays do not reflect as easily as lower frequency waves. Reflections must be at very large angles (measured from the normal) such that the barely graze the surface of the reflector. As a result X-ray telescopes must be very long. This makes X-ray telescopes difficult to launch into space as they require particularly powerful rockets to overcome their mass.

X-rays are **emitted** by **incredibly hot gases and objects** with temperatures from about one million kelvin (K) to hundreds of millions of kelvin.

X-rays are **detected** using **photographic film**. Digital detectors now also exist for X-ray radiation.

Gamma-ray Astronomy

Gamma rays are blocked by the Earth's atmosphere. They are also possible to reflect and detectors are very different from the other parts of the electromagnetic spectrum. They are more likely to rely on specially designed "masks" which cast a gamma ray shadow on the sensor allowing us to determine direction but not much detail. Gamma rays can also be **detected** using a **Geiger tube**, in this case no direction or detail of the source is provided.

Gamma rays are **emitted** by pulsars, black holes, active galaxies and unidentified objects responsible for high energy gamma ray bursts.

Spectroscopy

Continuous Spectrum

White light consists of a combination of all of the colours in the visible spectrum. A spectrum which consists of all these wavelengths is known as a continuous spectrum.

Emission and Absorption Line Spectra

The light emitted by stars (which are hot) can tell us a great deal about their composition. Hydrogen gas, for example only produces specific emission lines at specific wavelengths of light. These wavelengths relate to specific colours.

The emission lines for helium, lithium and beryllium etc. are all different and unique to that element, like a fingerprint. By observing the emission lines of stars we can determine their composition. The spectrum produced by a star can be observed using a spectroscope, which, like a prism, separates the colours of visible light.

When white light passes through a cold gas, the elements in the gas absorb light of specific wavelengths (and therefore colours). These lines are identical in wavelength to the emission lines and again identify the elements present.

These diagrams all show the emission and absorption lines for Hydrogen.