Astronomy

Earth, Moon and Sun

Earth

- The Earth is 70% water on the surface
    - The only planet to have liquid water on its surface
- It has a magnetic field that protects it from harmful solar radiation
- It has a substantial atmosphere
- The earth is an oblate spheroid with an average diameter of 13000 km
    - It is 42 km flatter at the poles
- Early astronomers had evidence that the earth was round:
    - The Moon is round.
    - The shadow of the Earth on the Moon during a lunar eclipse is round.
    - Travellers going north or south see different stars not visible from elsewhere.
    - Travellers recording shadows at different angles on the same date.
    - Tall ships appearing to 'sink' as they move over the horizon

Eratosthenes

- He found out the town of Syrene, when the sun was at the zenith on the summer solstice a stick casts no shadow
    - This is because it was at the tropic of cancer
- He calculated from measuring shadows at Alexandra that the sun did not quite reach the zenith
    - It was 7.5 degrees off
    - This is approximately 1/50th of a circle
- He then multiplied the distance between Alexandra and Syrene by 50 to estimate the size of the earth

Rotation

- The rotation period of the earth is 23 hours and 56 minutes which is referred to as a sidereal Day
- It rotates 15 degrees in 1 hour
    - 1 degree in 4 minutes

Tropics - A region where the sun is directly overhead in the zenith at least once a year and lie between 23.5 N (tropic of cancer) and S (tropic of Capricorn).

Equator - Lies exactly between the Poles. The sun is directly above the equator twice a year on the equinoxes

Latitude -how far north or south you are measured in degrees from the equator

Longitude - how far east and west you are measured in degrees from the Greenwich meridian up to 180 degrees

Pole - The pole is a point on the earth at the axis of rotation

Zenith - The point directly above the observers head

Horizon - The furthest visible point of the Earth's surface from the observer's position

Meridian - An imaginary line intersecting the Pole to the observer's zenith

Telescopes

Refractor

- A convex lens is used at the end of the tube to bring the image into a focus at a point
- Another convex lens called an eyepiece is then used at the opposite end to magnify the image
- Lenses are heavy and difficult to support

Reflector

- Collects light at one end of the tube and reflects it off a concave mirror to bring it to a focus
- A secondary mirror at the focus reflects the light into an eyepiece
- Mirrors can be manufactured and engineered to a much higher precision than lenses so most professional telescopes are reflectors

- Imperfections in mirrors or lenses can result in the loss of light and atmospheric turbulence can have an adverse effect on resolution
    - This can be solved using adaptive optics
- For the increase in length of the telescope it collects the square of that more light

Atmosphere

Benefits

- Oxygen allows humans and animals to breathe.
- The atmosphere protects us from harmful ultraviolet radiation from the Sun
- Makes the climate and temperature of Earth consistent
- The atmosphere spreads out and scatters light from the Sun
- Protects us from micro meteorite collisions from space

Drawbacks

- The atmosphere holds in some "greenhouse" gases that retain the heat of the Sun. These are necessary for life to continue on Earth however gases made as a result of human actions are causing the atmosphere to heat up which causes climate change.
- Clouds regularly obscure good astronomical viewing
- The atmosphere refracts light which means the position and clarity of star viewing is less accurate
    - Makes the stars twinkle
- Pollution from light and chemicals obscure observations
- The atmosphere reflects most radiation making observations at some wavelengths weaker.

Blue Sky

- The longer wavelengths get bounced around more by the atmosphere

Light Pollution

- Light pollution from obtrusive lighting causes sky glow which obscures faint stars
- The main sources of light pollution are:
    - Commercial and sports floodlights
    - Urban streetlamps and motorway lights
    - Domestic and industrial security lights

    - Lights above car parks and shopping centres

Wavelengths

- The longest radio waves are reflected back into space by the ionosphere
- Some shorter wavelengths are absorbed by water vapour and oxygen
- Most infra-red radiation is absorbed by water vapour and carbon dioxide
- Ultra-violet radiation is absorbed by ozone and at shorter wavelengths, oxygen
- X-rays and gamma rays are absorbed by oxygen and nitrogen
- There is an optical window where visible light can get through
- There is a radio window where some radio waves can get through

Observatory locations

- Observatories are built in remote locations far away from light pollution
- They are also built on high mountains so there is less atmosphere to obscure viewing
- Also they are located in areas that have good, dry weather and fewer clouds, so typically nearer the tropics or Equator
    - This is especially important for infrared observations as water vapour absorbs infra-red radiation
- Some telescopes are in space. This gives the advantages:
    - No atmosphere to blur images or reduce resolution
    - No light pollution
    - No adverse weather pollution
    - Longer observing periods (always dark)
    - Able to observe other wavelengths such as X-rays
- But there are also drawbacks:
    - Reduced lifetime
    - Difficult maintenance
    - More expensive to build and launch

Van Allen Belts

- Two doughnut shaped rings of high-energy particles held in place by the Earth's magnetic field
- The compact inner belt contains high-energy protons formed by collisions between cosmic rays and the atmosphere
- It is positioned between 0.1 and 1.5 Earth-radii
    - This means it poses a problem for astronauts and scientific instruments in this sector
- The outer belt consist mainly of electrons and other charged particles emitted by the sun as a result of solar activity
- It is positioned between 3 and 10 Earth-radii
- The inner belt was discovered in 1958 using a Geiger counter on board the *Explorer 1*
    - This was confirmed by the *Explorer 3* and *Sputnik 3*
- The outer belt was discovered in 1958 by *Pioneer 3*
    - This was confirmed by *Pioneer 4* the following year

Moon

- It has a diameter of 3500 km
- It orbits at a distance of 380 000 km

- The gravity is 6 times less than the earth
- The moon always shows us the same side
    - This is because the rotational period of the moon is the same as its orbital period
        - The rotational and orbital period is 27.3 days
        - The interval between to new moons is 29.5 days as the Earth is also orbiting the Sun
- The far side of the moon was first observed by *Luna 3*
    - It was seen to have very different characteristics to the near side
        - There are far fewer maria and it is more heavily cratered

Features

- The main features of the moon are the large dark-grey smooth seas (*maria*) and the lighter-grey highlands (*terrae*)
- The *maria* where formed from lava lakes created by large impacts
    - They are much younger than the highlands as implied by fewer craters
- Rillies are cracks or clefts on the lunar surface
    - They are geological faults caused by collapsed lava tubes
- Wrinkle ridges are ridges of *Maria* usually hundreds of kilometres long. They are not thought to be mountains because they are only 200 metres tall
    - They are thought to be lava tunnels that have contracted and cooled

Apollo

- Six missions landed on the Moon between 1969 and 1972
    - They collected lunar soil and rock
    - They deployed experiments
- Apollo 11 was the first to land on the Moon
- The astronauts deployed the Apollo Lunar Surface Experiments Package (ALSEP)
    - Several of these included Laser Ranging Retroreflectors (LRRR) that were used to determine the distance to Earth using radar
    - They collected data on:
        - The structure of the moon
        - The composition and pressure of the atmosphere
        - The intensity and direction of the solar wind
        - Minute changes in lunar gravity
        - The presence of micrometeorites
        - Lunar dust

Origin

- The main theory for the formation of the moon is the Giant Impact Hypothesis in which the Earth is hit by a Mars sized object and the material ejected formed into the moon
    - This is supported by the relative abundances of isotopes of oxygen in moon rocks
        - The same as on Earth suggesting they formed in the same region of space
    - The lack of water and other volatile compounds suggesting a collision involving so much energy they were vaporised
    - The discovery of KREEP-rich rocks in as predicted by this model
- However, over theory have been suggested
    - The earth and moon could have formed at the same time and place

    - The moon could be a captured object
    - A rapidly spinning Earth could have ejected material to form the moon
- When it was first formed the moon was a lot closer and it span a lot quicker
    - However, it moved away at a rate of 4 cm a year and tidal forces have slowed its spin

The Sun

- The sun is 75% hydrogen and 25% helium
- The visible surface photosphere had a temperature of 5800K
- The relatively thin (2000 km) chromosphere (a thin ring of pink colour only observable just before an eclipse) and corona make up the atmosphere
- The corona has a temperature of 2 000 000 K
- The core reaches temperatures of over 15 000 000 K

Rotation

- It rotates slower at the poles than the equator
    - The rotation period of the poles is 36 days against the 25 at the equator
- Astronomers can record the rotation of the sun using the Sun spots

Sun Spots

- Small (actually the size of Earth) dark spots on the photosphere
- They are areas that are cooler than the surrounding area
- They travel around the surface in groups between 40 N and S
- They consist of a central region called an umbra and an area called a penumbra
    - Temperatures of the umbra is normally 4 000 K and the penumbra, 5 600 K
- Sunspots are caused by local changes in the sun's magnetic field
    - When the field in stronger the conventional abilities of the area diminish so it cools down
- Solar flares emanate from Sun Spots producing more solar particles
- They are good evidence of the solar cycle which occurs every 11 years
- If you plot the latitude of sun spots against the time you get a butterfly diagram

Features

- Prominences are clouds and formations of bright gases expelled from the sun and stretch large distances from its surface
- Flares are violent ejections of solar material from the Sun's photosphere
    - They may be brief or last hours
    - They originate from sun spots and are caused by the suns magnetic field
    - They have been known to interfere with communications on Earth
- Granules are the cell-like grainly like structures on the surface of the sun
    - Plasma rises to the surface and then dissipates back after forming a granule up to 1 000 km across lasting up to 20 minutes

Fusion

- The proton-proton chain involves the fusing of nucleus with mass being lost at each stage releasing large amounts of energy

Wavelengths

- A H-alpha filter can be used to view the sun
- The increased contrast allows solar features to be visible

Interactions

Lunar Phases

- The moon waxes from new to full and wanes back

Eclipses

- Solar eclipses are possible because the sun and moon appear the same size in the sky
    - This is because the moon is 400 times smaller than the sun and the sun is 400 times further away from us than the moon
- During a total eclipse the corona is visible
- An annual eclipse is one were the focus of the umbra is above the earth's surface so the moon appears too small to cover the sun
- A hybrid eclipse is where it appears annual in some locations and total in others due to the tilt of the Earth

- During a lunar eclipse the Earth's shadow passes over the moon and it can turn red from the light passing through the Earth's atmosphere

Time

- The apparent sun moves at different speeds at different times due to our orbit and the inclination of our axis
- So for out time keeping we create a mean sun that moves at a consistent speed
- The difference between the apparent solar time and the mean solar time is the equation of time

Aurorae

- Particles caught in the Van Allen belts move along the field lines toward the north and south poles and observers in these locations experience aurorae
- They are caused by the atoms of the atmosphere being excited by the radiation and then de-exciting to emite light

Planetary Systems

Size of the Solar System

Planets

- Mercury
- Venus
- Earth
- Mars
- Jupiter
- Saturn
- Uranus
- Neptune

Dwarf Planets

- Ceres (Asteroid Belt)
- Pluto (Kuiper belt)
- Haumae (Kuiper belt)

- Makemake (Kuiper belt)
- Eris (Scattered Disc)

Asteroids

- Any rock bigger than 10m in diameter
- Have no coma

Comets

- Balls of rock and ice
- Very eccentric orbits often retrograde
- Have a coma

Centaur

- Across between Asteroids and comets
- Their orbits are eccentric but they stay inside the solar system
- Some have a coma
    - Hidalgo
    - Chiron

TNO (Trans-Neptunian Objects)

- Objects orbiting the sun beyond Neptune

Kuiper Belt

- The Kuiper belt is beyond Neptune
- It is a belt of millions of small particles
- It is between 30 – 50 AU away from the sun
- It is the possible origin of short period comets
- Where it thins it becomes known as the scattered disc

Oort cloud

- A theoretical huge cloud (50,000 AU) that surrounds the solar system
- It is the possible origin of long period comets
- It may be the remnants of the planetary nebula

Orbits

The earth orbits the sun on the elliptical plane. The orbits of the other planets are slightly inclined to the ecliptic. Mercury is the greatest with +7 degrees.

This means that the planets appear to move across the sky in the zodiac band.

Sometimes the planets appear to move backwards. This is called retrograde motion.

Ecliptic - The path the sun takes through the celestial sphere in a year

Zodiac Band - An area eight degrees either side of the ecliptic which contains the constellations of the zodiac and the planets.

Perihelion - When an object is closest to its focus

Aphelion - When an object is furthest from its focus

Greatest Elongation - When an inferior planet is at a position forming a right angle between the earth and the sun. This is the best time for viewing the planet as it is from our perspective furthest from the sun

Conjunction - When a superior planet is on the opposite side of the sun or when an inferior planet is in front of the sun

Opposition - When a superior planet is on the opposite side of the earth to the sun. This is when it is best to view the planet.

Transit - When a smaller body passes in front of a larger one

Occultation - When a body is hidden by another

Characteristics of the planets

Planet	Orbital Period (years)	Average Temperature	Diameter (1000 km)	Rotation Period (days)	Distance from Sun (AU)
Mercury	0.24	170	4.0	59	0.38
Venus	0.62	470*	12.1	243 (retrograde)	0.72
Earth	1.0	15	12.8	1.0	1.0
Mars	1.9	-50	6.8	1.0	1.5
Jupiter	11.9	-150	143	0.41	5.2
Saturn	29.5	-180	121	0.43	9.5
Uranus	84	-210	51	0.72	19.1
Neptune	165	-220	50	0.67	30.0

*Venus is an exception to this trend because its dense atmosphere full of greenhouse gasses insulate it. This is a good demonstration of the greenhouse effect and what global warming could turn earth into

Space Probes

Manned Disadvantages

Space adaptation Syndrome – The lack of gravity causes disorientation, headaches, poor concentration and vomiting

Physical Problems – Lack of gravity causes the muscles to deteriorate and bones become weaker

Communication Delays – On longer missions the astronauts would take a long time to communicate with control

Radiation Issues – Without the Earth's protective shielding the prolonged exposure to solar radiation could cause cancer

Psychological Problems – Living and working with the same people in a confined environment could cause fatigue, irritability and low motivation

Time Factor – Most missions take too long for humans

Life Support – Humans need a lot more room and resources than a probe such as oxygen and water which you have to take – extra weight

Unmanned Disadvantages

Adaptation – Probes cannot improvise and perform new experiments

Independence – They are reliant on control to get them out of trouble

Case Studies

Moons

Mars

- Mars has two small moons:
  - Deimos and Phobos
- They are irregular in shape
  - Typical of asteroids
- They are captured bodies from the asteroid belt

Neptune

Triton (largest)

- Highly-inclined retrograde orbit
  - Captured asteroid or
  - Collided with Neptune or another moon

Dark Proteus

- Orbits at equator
- Created at the same time as Neptune

Nereid

- Highly eccentric orbit
  - 360 days long
- Captured from Kuiper Belt

Origins

- A moon may form in the same area of space as the planet e.g. Jupiter's Galilean Moons
- A moon may be captured by the planet e.g. Phobos and Deimos of Mars
- A moon may be a ruminants from a collision with the planet e.g. Earth's Moon

Ring Systems

- Ring systems are all extremely wide
  - Up to hundreds of thousands of km across
- Ring systems are very thin
  - Less than 1.5 km thick
- Ring systems have notable gaps
  - Saturn's Cassini Division
- Some ring systems are incomplete
  - Neptune and Uranus have strange ring arcs
- They are believed to be short-lived by most astronomers
- Shepherd moons are small moons that orbit close to the rings
  - They influence the shape and gaps of the ring

Origins

- Formed from debris left over from formation of planet
- Formed from debris of large impacts between moons
- Formed from a moon torn apart through tidal forces
- Formed from material ejected from the surfaces of moons by meteoritic impacts

Comets

- As a comet approaches the sun some ice evaporates and jets of gas and dust produce a spherical coma around the nucleus
- Two tails are also produced:
    - The dust tail which is produced due to the radiation pressure from the sun
        - This is very bright due to the reflective ice particles
        - Is curved due to the dust particles following their own orbit
    - The Ion tail consists of gas ionised by the solar winds that then de-excite to emit light
        - This is straighter and more blue than the dust tail
- Comets have very eccentric, inclined and sometimes retrograde orbits
- Short period comets originate in the Kuiper Belt
- Long period comets originate in the Oort Cloud

Meteors

Meteoroid - In space

Meteor - In atmosphere

Meteorite - On ground

Micrometeorite - Really small meteorite

- A meteor with a magnitude of -3 or more is called a fireball
- The majority of meteoroids form from the dust trail of comets
- If the earth passes through the wake of a comet then we can see meteors appearing to diverge from a point on the sky called a radiant
- These meteor showers usually occur annually and in the same place and so are named after the constellation they appear in

PHOs

Near Earth Objects – bodies those trajectory may bring them closer to the earth than 0.3 AU

Potentially Hazardous Objects - bodies that have objects that bring them closer than 0.05 AU to the earth

- PHOs with diameters larger than 1 km pose a threat
- The Torino Scale categorises the risk of PHOs like the Richter Scale for earthquakes

Evidence

- Moon craters
- Earth craters
- Venus and Uranus spin wrong because of impacts
- Moon was formed from Earth after impact
- Comet Shoemaker-Levy 9 collided with Jupiter

Discoveries

Heliocentric Solar System

- Ancient astronomers such as Ptlomey believed that the sun orbited the Earth in a geocentric model

- Copernicus put forward the Heliocentric model because observations of the planets seemed to show that this was more likely
- Galileo discussed and spread this idea
    - He was convinced because he discovered moons around Jupiter and the phases of Venus
- Kepler corrected the Heliocentric model from circular orbits to elliptical ones and set laws that governed how the objects moved

Tycho

- Worked with Kepler and succeeded him
- He is known as the greatest naked eye astronomer
- He gathered evidence to prove Copernicus and Kepler right
- Attempted to combine the heliocentric and geocentric models unsuccessfully

Galileo

- Galileo was the first person to use a telescope for astronomical purposes
- He discovered four of the moons of Jupiter
- He observed the phases of Venus and sun spots
- He sent time in prison and house arrest for his views

Kepler's Laws

- Planets have elliptical orbits with the sun at one focus
- The imaginary line from a planet weeps out equal areas in equal intervals of time
- The orbital period of a planet squared is equal to its distance from the sun cubed

Ceres

- Predicted by the Titus-Bode law that proposed there was a pattern to the distance of the planets
- Giuseppe Piazzi first observed Ceres and it was classified as a minor planet

Uranus

- William Herschel discovered Uranus from Bath in 1781
- It had been previously observed but mistaken for a star
- They did not compare its position between dates
- Herschel did this and originally thought it was a comet but further observations confirmed it was a planet

Neptune

- Neptune was predicted to exist to explain the 'wobbles' in Uranus' orbit
- Adams and le Verrier calculated its orbit and it was observed by Galle and D'Arrest

Pluto

- Edward Pickering and Percival Lowell suggested that another planet might be affecting the motion of Uranus
- Having obtained their calculations Clyde Tombaugh located the planet photographically at the Lowell Observatory in Arizona in 1930

Gravity

- Gravity is the force that holds planets in orbit
- Gravity decreases with distance according to the inverse square law
    - That the gravity decreases by the square of the increase in distance
        - If A is twice as far away from B then the gravity is 4 times less

Exoplanets

Methods of discovery

Astrometry

- Measuring the position of the start very accurately, any minute wobble in a stars position can be due to the tiny pull of a planet

Transit Method

- If an exoplanet moves across the disc of the star they cause a very small drop in brightness

Radial Velocity Method

- The wobbling of star also causes the wavelength of the light to be slightly re-shifted on a regular timescale as the star moves away and towards us
- Spectroscopy is able to detecting these small shifts in wavelengths and this technique has proved most successful at detecting exoplanets

Goldilocks Zone

- This is the area surrounding a star in which a planet can have liquid water
- In our solar system it is thought that this zone is between 0.75 AU and 3 AU
- This habitable zone changes depending on the size of the star

Water

- Is thought to have two principle origins:
    - Outgassing of hydrogen and oxygen form volcanos that combined to produce steam
    - Deposited by comets
- The Philae lander is searching for signs of water on comets

Extra-terrestrial life

- The drake Equation uses a lot of factors to estimate the number of civilisations within our galaxy that would be able to communicate with use
- We use space probes to search for extra-terrestrial life
- We also use spectral analysis of planetary atmospheres above rocky exoplanets
- We also analyse radio waves to try to detect signals that may have orginated from extra-terrestrial life
- Extra-terrestrial life could bring cures to disease or bring disease
- They could bring knowledge and share discoveries we have not yet made

Stars

Constellations

Appearance

Constellation - An area of the sky containing a pattern of stars. There are 88.

Asterism - A pattern of stars in the sky, e.g. the Plough

Open cluster - a group of young stars, e.g. the Pleiades

Globular cluster - a group of old stars tightly packed around the galactic nucleus that resemble a fuzzy ball, e.g. M13

Nebulae - a dense cloud of gas and dust that appear like faint fuzzy patches of light

Double Stars - Stars that appear close to each other. Some are binary stars that are close and orbit each other. Whereas others just appear close because of the angle we see them at.

Labelling Constellations

Drawing Constellations

Pointer Stars

Seasonal Stars

Observing the Night Sky

Right Ascension & Declination

Right Ascension is measured from the vernal equinox (were the sun appears to cross the celestial equator) in a similar way to longitude. Right Ascension is sweeps eastward like bearings on a compass. It is measured in hours, minutes and seconds with 15 degrees equal to one hour.

Declination is measured from the celestial equator in a similar fashion to latitude. It is measure in degrees.

The Right Ascension and Declination of stars, nebulae and galaxies are fixed but the Sun, moon and planets are not due to their orbits.

Polaris

The declination of Polaris is 90 degrees this means that it appears to stay in a fixed position in the sky. The angle of Polaris is equal to the latitude of the observer.

Circumpolar Stars

Circumpolar Star - A star that does not dip below the horizon from the perspective of the observer

You can find out if a star is circumpolar using the following formula:

Declination of Star >= 90 - latitude

This is because the latitude is the distance the horizon is away from Polaris and as long as the stars declination is higher than this then it will be circumpolar.

Any constellation that is not circumpolar is a **seasonal constellation**. This means that they might only be visible for a few months of the year like Orion.

Galaxies and Cosmology

Milky Way

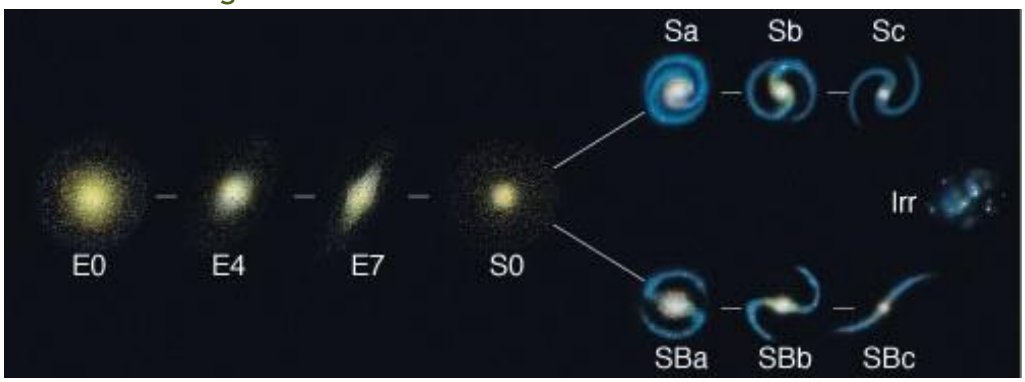
- With the naked eye it looks like a furry light irregular column in the sky
- Only a bright long area can be seen without binoculars to pick out individual stars
- Using binoculars the haziness clears and you can make out small stars
- Using a telescope it can be seen that the milky way comprises of countless stars
- The milky way forms the plane into our own galaxy

- Our galaxy has a disk of spiral arms about 1,500 light years (1-2 kpc) thick and between 100,000 – 150,000 (30kpc) light years across
- We are in a spiral arm called the Orion arm about 10kpc from the nucleus
- There is a central bulge that we cannot view very well due to cosmic dust but we can observe infrared and radio signals
    - It is believed that a supermassive black hole called Sagittarius A is emitting this radiation
- The halo contains mainly globular clusters in a spherical distribution about the galactic centre
- The galaxy contains large amounts of interstellar dust and gas that obscures visible light
    - This prevents us from effectively mapping our galaxy
    - However, hydrogen also pervades the galaxy and emits electromagnetic radiation at a specific frequency of 1420MHz and corresponding wavelength of 21cm when its electron reverses its spin which can penetrate the dust
    - This radio signal allows us to determine the radial velocity of different parts of the galaxy and therefore its rotation using the Doppler effect
- It takes 226 million years to make one galactic orbit
- The milky way is an Sb type galaxy

Galaxies

- Spiral galaxies appear as flattened disk-shaped systems with spiral arms
    - Such as Andromeda Galaxy and M81
- Barred spiral galaxies are similar with a bright bar running through the nucleus
- Elliptical galaxies are relatively smooth showing a gradual decrease in brightness from the centre outwards
- Irregular galaxies have little structure or symmetry possibly due to interaction with other galaxies; these do not fit into the tuning fork
    - Such as Small Magellanic Cloud in Tucana

Hubble's Tuning Fork



Active Galaxies

- Many galaxies emit vast amounts of radiation in other wavelengths other than visible light
- The source of the energy is thought to be a extremely small active galactic nucleus
- Here the amount of material spinning around a black hole forms an accretion disk
- The heat caused by its speed and the effect of it falling into the black hole produces enormous amounts of radiation

Seyfert Galaxies

- These spiral galaxies have extremely compact but bright nuclei, strong emission lines in their spectra and show strong and often variable emission of radiation in IR and X-Ray wavelengths

Radio Galaxies

- Intense sources of radio waves (more than a million times more than a normal galaxy)
- Radio waves often originate from symmetrical pairs of ‘lobes’ that lie on opposite sides of the galaxy

Quasars

- Compact appearance makes them appear like stars but they emit huge quantities of energy in all regions of the spectrum
- Their high redshifts reveal that quasars are some of the most distant objects in the universe

Blazars

- Also appear star-like but are much closer than quasars
- Galaxies with jets pointing towards us and emit strongly in all of the spectrum
- Difficult to compare blazars as we see them differently depending on their angle

Groups