GCSE Physics Revision Notes: Astrophysics

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1. Satellites & Orbits

Satellites are objects that orbit a larger object in space.

The Moon is Earth's natural satellite and we have launched many artificial satellites.

Uses of satellites

Communications, TV - Intelsat
Weather forecasting – Meteosat
Navigation – Global Positioning Satellites GPS,
Remote Sensing - Radarsat
Military spy satellites - Big Bird
Search & Rescue - Sarsat
Astronomy – Hubble Space Telescope

Satellite Launch

Satellites are launched by rockets. The speed must reach 27400 km / hour to achieve orbit, where speed balances the pull of Earth's gravity.

Orbits

Low Earth orbit, LEO, is from 200km to 2000km above Earth.

Geosynchronous orbit is at a height of 36000 km. At this height the satellite takes 24 hours to orbit Earth, the same as the Earth's 24-hour rotation. The satellite stays above the same point on Earth. TV satellites are in synchronous orbit.

Earth's gravitational pull decreases with distance.

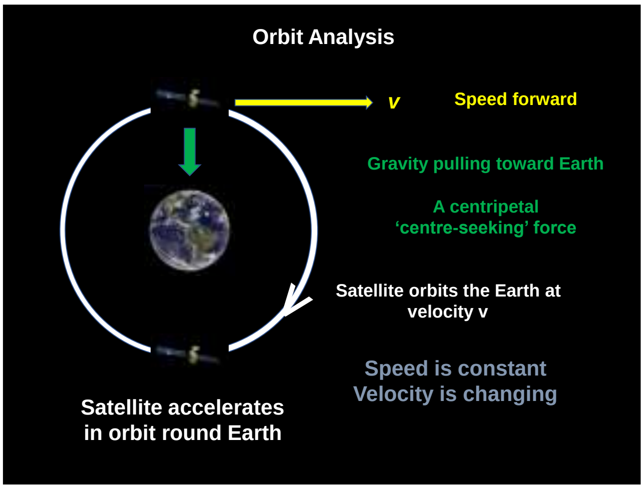
The higher the orbit, the lower is the speed necessary to balance the pull of Earth's gravity.

Speed in LEO is around 27000 km / hour.

Speed in synchronous orbit is around 11000 km / hour

Forces acting on a Satellite

Two forces dictate a satellite orbit: **satellite speed** and Earth's **gravitational pull.**



Speed is how fast something is moving, distance ÷ time

Velocity is the rate at which an object changes position,

Change of position ÷ time

Acceleration is the rate of change of velocity with time.

Change of velocity ÷ time

A satellite in orbit is accelerating around Earth but its speed remains the same.

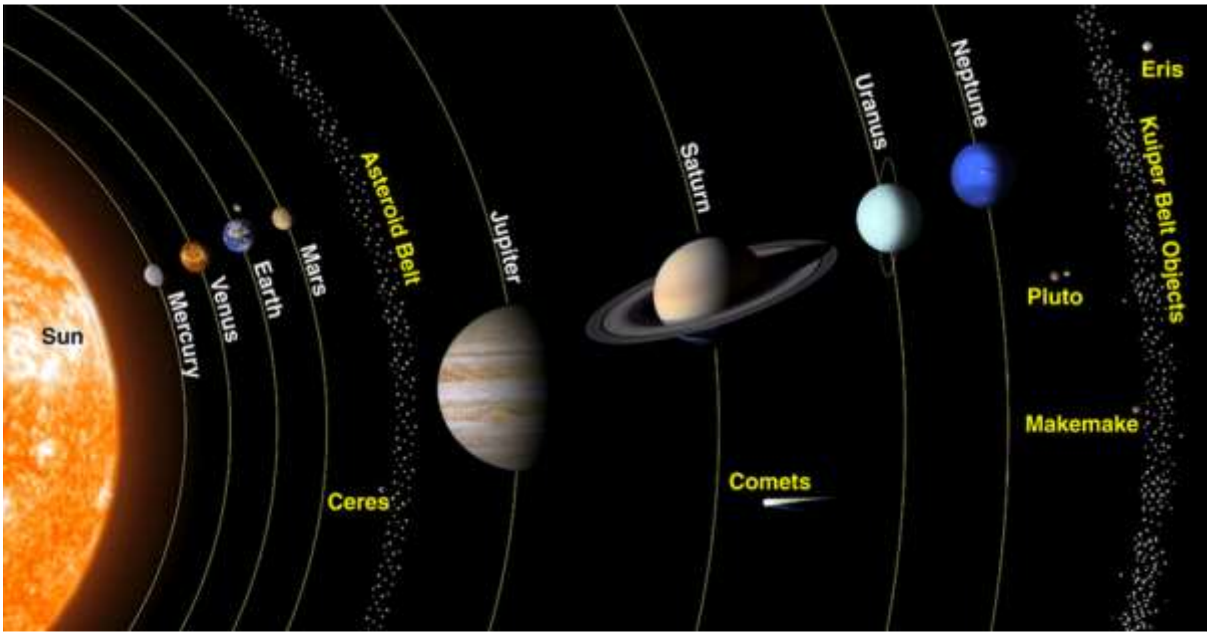
2. Solar System

Our Solar System contains one star, the **Sun and 8 planets**.

Sun **4 small rocky planets** **4 giant gas planets**

Between Mars and Jupiter are the **asteroids**, millions of space rocks that did not come together to form a planet. **Ceres**, the biggest asteroid, is classed as a dwarf planet.

Beyond Neptune is the **Kuiper Belt** of millions of icy objects, **comets.** Within the Kuiper belt are icy **dwarf planets** including **Pluto.**



Far beyond Pluto, at the edge of the solar system, there are millions more comets in the **Oort Cloud.**

Dwarf Planets

After its discovery in 1930, Pluto was recognised as a planet.
In later years its size was re-assessed until it was smaller than our Moon.

The discovery of large objects in the Kuiper Belt led to a re-appraisal of Pluto’s status.

In 2006, Pluto was re-classified as a **dwarf planet**.

A dwarf planet is an object that orbits the sun but **has not cleared the debris** around it. Pluto’s **highly elliptical orbit** and small size also makes it different to the eight mainstream planets.

Other Kuiper Belt objects are now classed as dwarf planets, including Eris, Sedna, Haumea, Makemake. Ceres in the asteroid belt is also a dwarf planet .

Location of the Solar System

The Solar System is in the **Milky Way Galaxy**. It is in a spiral arm about two-thirds of the way from the centre of our galaxy.

Solar System

The Milky Way contains **200 000 000 000 stars** (two hundred billion).

We have so far discovered nearly **4000 planets** in our part of the galaxy.

In the universe there are an estimated **2 trillion galaxies** (2 000 000 000 000) each with billions of stars – and probably billions of planets.

3. Life Cycle of Stars

Creation

Stars are born in huge clouds of gas and dust known as **nebulae**.
The gas is about **80% hydrogen** and 20% helium.

The gas begins to collapse under the force of gravity. As the gas collapses, it is compressed and becomes hotter.

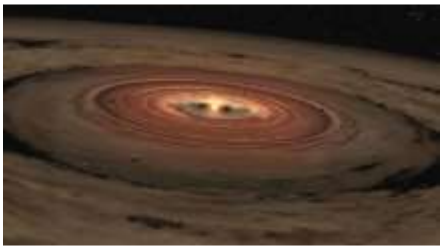
After 100 000 years, the collapsing ball of gas becomes hot enough, 100 000ºC, to glow.
It is a **protostar**.

After about one million years, the centre of the collapsing gas reaches 10 million degrees C. Atoms of **hydrogen fuse to create helium**, a nuclear reaction that gives out enormous amounts of energy.
$E = mc^2$.

The centre (core) of a star is a constantly exploding hydrogen bomb. This is the power source of the star.

The outer layers of the star (the shell) do not reach the critical temperature and remain collapsing inwards under gravity.

The two forces – **radiation pressure and gravity** – balance each other and the star is created.



Gas and dust left over from star birth can form planets, again under the force of gravity.

Our sun is around 5 billion years old.
The planets were formed some 4.6 billion years ago.

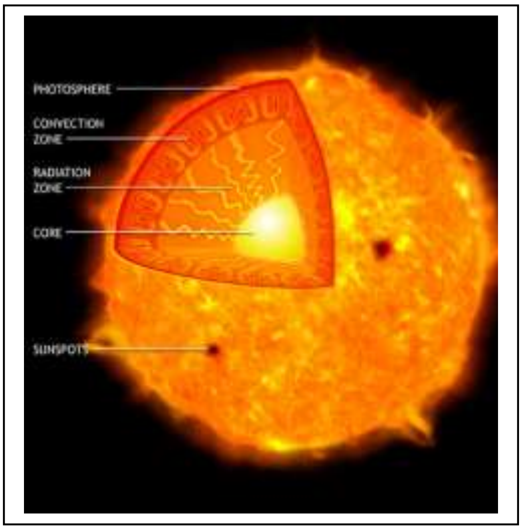
Main Sequence Stars

Stars are powered by hydrogen fusion reactions at their core. The energy is transferred to the surface by radiation, then convection. The energy is radiated from the surface mainly as heat and light.

Sun size stars have a surface temperature of 10 000ºC to 5000ºC. They are white to yellow.

The Sun's surface temperature is 5800ºC.

Much bigger stars, with a mass up to 100 times the sun, are hot and blue. With surface temperatures of 15000ºC, These huge stars can shine 60000 times brighter than the sun.



Sun size stars burn their hydrogen steadily and can last around 10 billion years.

Massive stars burn hydrogen much faster and may last only 10 to 100 million years.

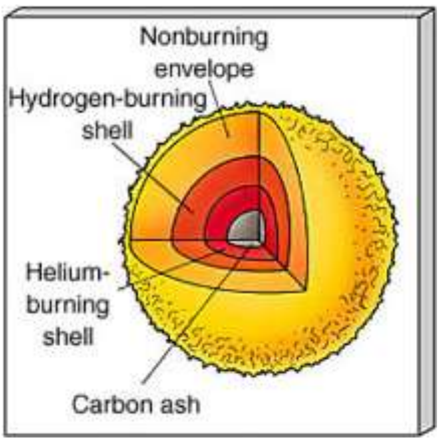
Death of Sun-size Stars

After billions of years, stars have converted almost all their hydrogen to helium. Fusion at the core stops.

With no force pushing out from the core, the star begins to collapse under gravity. This collapse heats up the centre of the star, and it is refuelled – for a while.

Hydrogen in the shell becomes hot enough to fuse to helium.
Helium in the core is now hot enough to fuse to make carbon.
These new reactions push the star out to become bigger. The heat is spread over a large surface and the star goes cool and red. It becomes a **red giant star.**

The Sun will become a red giant in around 5 billion years time.



The outer layers of the star continue to push out. The shell expands into space, to make a badly named ‘planetary nebula’.

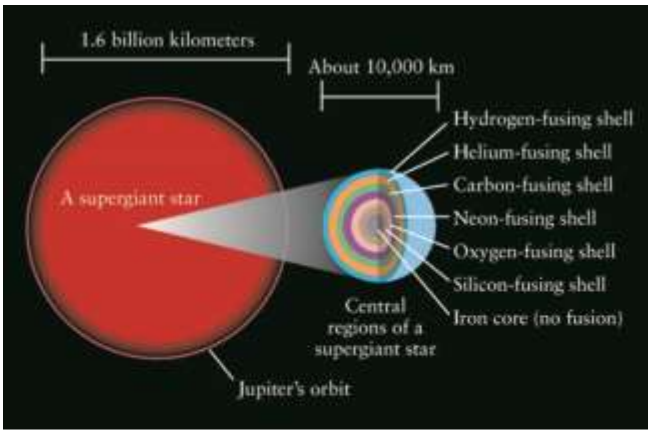
The core of the star is exposed. It is no glowing under its gravitational collapse. It is a dead **white dwarf star**, which will fade away over billions of years.

Death of Massive Stars

Massive hot blue stars die a spectacular death. When their hydrogen is used up, they expand to become **red supergiant stars.** These can be a billion km across.

In the shell, hydrogen fuses to helium. In the core, helium fuses to make carbon, just as in sun sized stars.

However the temperature in the core becomes so high that more fusion reactions produce heavier elements – oxygen, nitrogen, silicon, all the first 26 elements up to iron.



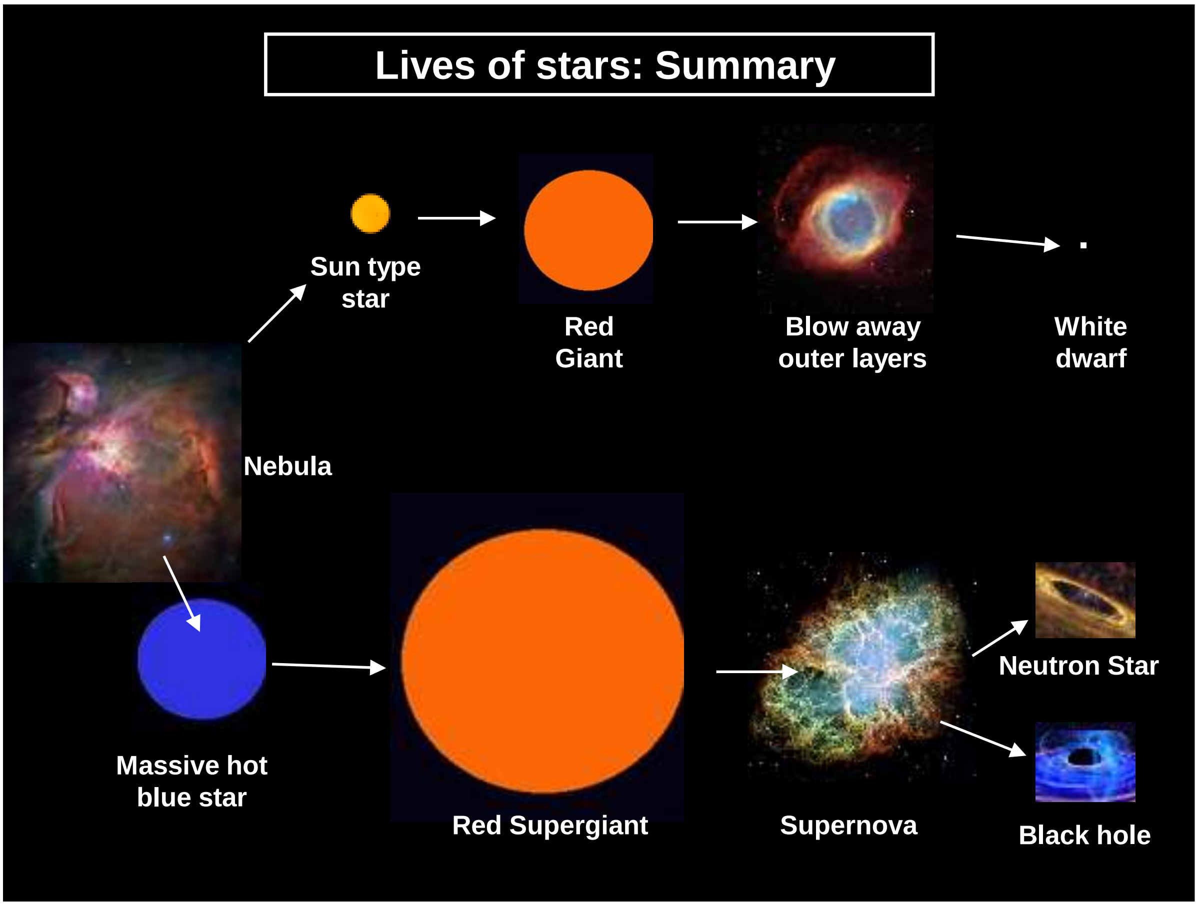
The iron core is not hot enough to fuse to heavier elements. The iron core grows so big it cannot support the supergiant star. The star collapses under its own gravity, crushing the core. The collapsing shell collides with the dense core and bounces off in a huge explosion**, a supernova**.

If core of the star is around three times the sun's mass, it is crushed by gravity to become a dense **neutron star**. One teaspoonful of neutron star would weigh 10 billion tons!

Black holes

However if the collapsed core weighs in at five times the mass of the sun, gravity collapses the neutron star into a single point, a singularity. This tiny, massive particle has gravity so great that nothing can escape from it, not even light. An area of darkness forms around the singularity – a **black hole.**

As material falls into a black hole, it gives out high energy **X-rays**. Black holes can be detected by X-Ray telescopes. X-ray telescopes are carried on satellites because short wavelength X-rays cannot penetrate Earth's atmosphere



Creation of Elements
In a **main sequence** star**, hydrogen** fuses to make **helium.**

In a red giant star, **helium** fuses to make elements up to **carbon** in atomic number.

In a **red supergiant star,** a series of fusion reactions creates **carbon – nitrogen oxygen – neon – silicon – all the first 26 elements up to iron.**

Even at the high temperature of a red supergiant core, the iron cannot fuse to heavier elements.

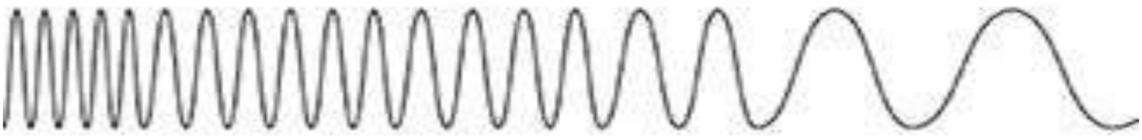
But when the star explodes as a supernova, **heavier elements** are created – copper, gold, silver – all the elements up to Atomic number 92, Uranium.

The materials thrown out in a supernova can create new planets. Stars are the factories where elements are made from hydrogen.

4. <u>Redshift & Big Bang</u>

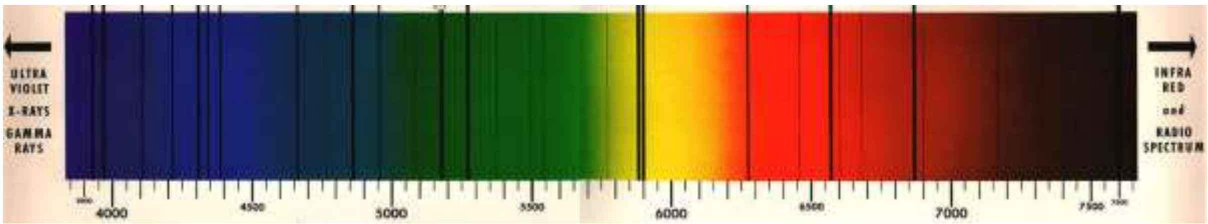
Spectroscopy

A spectrometer splits starlight into its component colours:
red, orange, yellow, green, blue, indigo, violet.



Blue = shorter wavelength ---------------------------------------red = longer wavelength

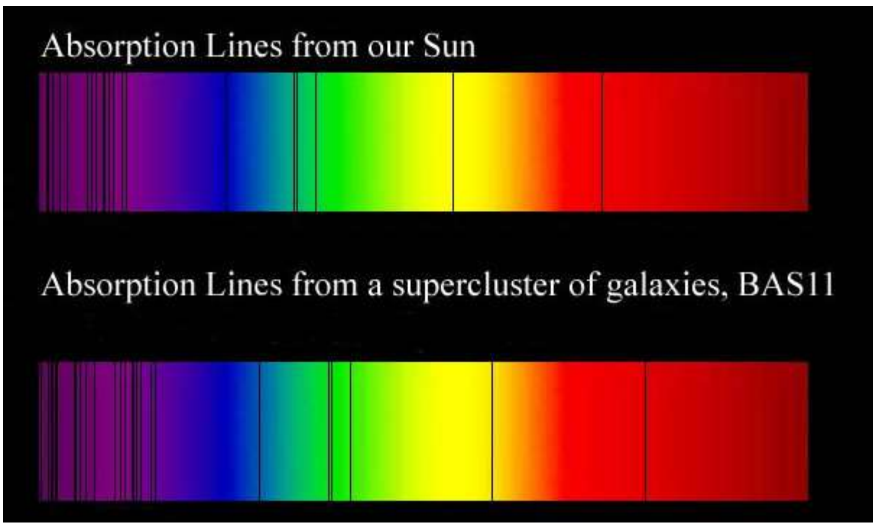
In a star's spectrum, dark vertical lines are seen in the coloured spectrum. These are absorption lines, where each element in the star absorbs light of particular wavelengths.



We can identify elements in stars from their lines in spectra, like a barcode.

Galaxy Spectra

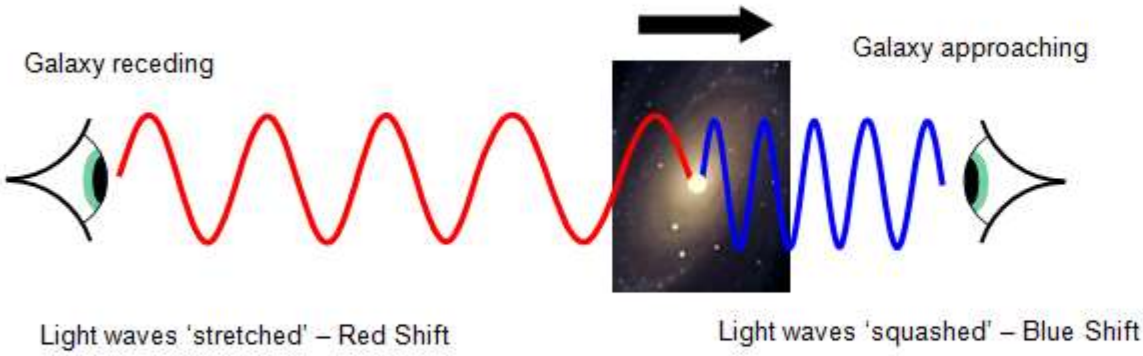
Distant galaxies are too far away to resolve individual stars. But the light from a galaxy still shows absorption lines from stars inside it.



The lines from the galaxy are not at the usual wavelength. They are all at a longer wavelength, towards the red part of the spectrum. This is redshift.

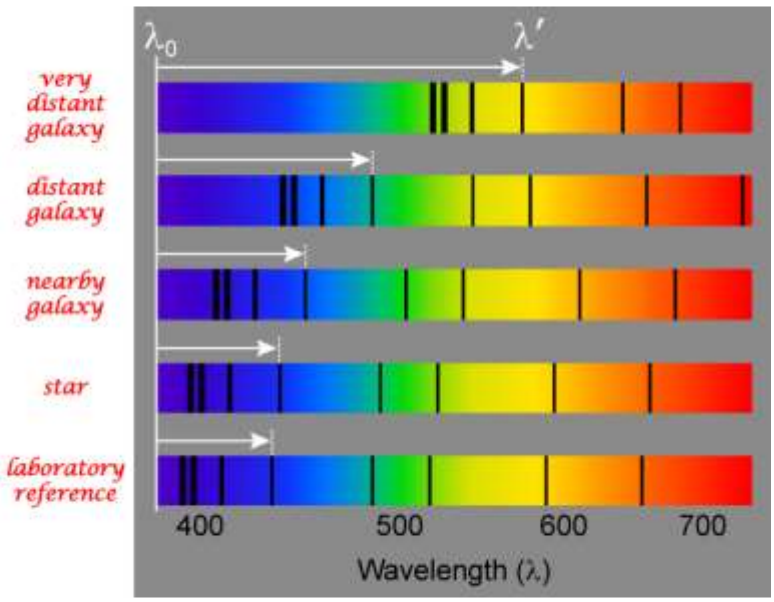
Doppler redshift

Redshift is caused by **movement of an object away from us.** As the object moves away, the light waves are 'stretched' and become longer.



An approaching galaxy shows **blueshift**, where waves are 'squashed'. Only the nearby Andromeda Galaxy shows a blueshift. All other galaxies show **redshift** – they are moving away from us.

The **greater the redshift**, the **faster** the galaxy is moving away – and the **further away** it is.



In fact, the galaxies are not moving away. Instead **space is getting bigger** and taking the galaxies with it. We live in an **expanding universe**.

In the past, the universe was smaller. Calculations show that **13.8 billion years ago**, the universe was small, hot and dense. This tiny universe suddenly became bigger in the **'Big Bang'**, the creation of the universe.

The universe has been expanding ever since.

Cosmic Microwave Background, CMB

Scientists using radio telescopes have discovered the ‘echo’ of the Big Bang.

It is a long wavelength microwave signal that comes from all over the sky, the **Cosmic Microwave Background Radiation** (CMBR). The radiation has been redshifted in its 13.8 billion year journey through an expanding universe from visible light to longer wavelength microwaves.

Radio telescopes are large in diameter because radio wavelengths are so long. The UK’s Jodrell Bank radio telescope has a dish 76 metres wide.

Dark Energy

In the last 20 years, observations of supernovae explosions have indicated that the **expansion rate of the universe is increasing** – the universe is getting bigger faster.

There seems to be an ‘anti-gravity’ force at work. It has been named **Dark Energy** but we do not know what it is.

Dark Matter

Calculations show that there is not enough mass in the stars, dust, gas, etc in galaxies to hold them together. There is not enough mass to create the gravity needed to hold clusters of galaxies together.
This ‘missing mass’ is called **Dark Matter** and we do not know what it is made of.
We now believe that Dark Matter played a key role in shaping the universe.

Dark Matter makes up about 25% of the universe.
Dark Energy makes up about 70% of the universe.

Everything we can see – stars, galaxies, dust, planets – makes up only 5% of the universe.

We do not know what 95% of the universe is!   Will you find out?