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Photocopy Master Sheets

Years 9-10

The Universe

Disk filename = "20.Universe"

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Topics Available

Year 7-8 General Science

Disk Filename	Topic Name
01.Energy	Energy
02.Forces	Forces
03.Matter	Solids, Liquids & Gases
04.Mixtures	Separating Mixtures
05.Elements	Elements & Compounds
06.Cells	Living Cells
07.Life	Living Things
08.LifeSystems	Plant & Animal Systems
09.Astronomy	Astronomy
10.Earth	The Earth
11.Ecosystems	Ecosystems

Year 9-10 General Science

Disk Filename	Topic Name
12.Waves	Wave Energy (inc. Light)
13.Motion	Forces & Motion
14.Electricity	Electricity
15.Atoms	Atoms & Elements
16.Reactions	Compounds & Reactions
17.DNA	Cell Division & DNA
18.Evolution	Evolution of Life
19.Health	Health & Reproduction
20.Universe	The Universe
21.EarthScience	Earth Science
22.Resources	Resources & Technology

Year 11-12 Science Courses

Biology

Preliminary Core

Local Ecosystem
Patterns in Nature
Life on Earth
Evolution Aust. Biota

HSC Core

Maintain. a Balance
Blueprint of Life
Search for Better Health

Options

Communication
Genetics:Code Broken?

Chemistry

Preliminary Core

Chemical Earth
Metals
Water
Energy

HSC Core

Production of Materials
Acidic Environment
Chem.Monit.&Mngment

Options

Shipwrecks, Corrosion...
Industrial Chemistry

Earth & Envir. Science

Preliminary Core

Planet Earth...
Local Environment
Water Issues
Dynamic Earth

HSC Core

Tectonic Impacts
Environs thru Time
Caring for the Country

Option

Introduced Species

Physics

Preliminary Core

World Communicates
Electrical Energy...
Moving About
Cosmic Engine

HSC Core

Space
Motors & Generators
Ideas to Implementation

Options

Quanta to Quarks
Astrophysics

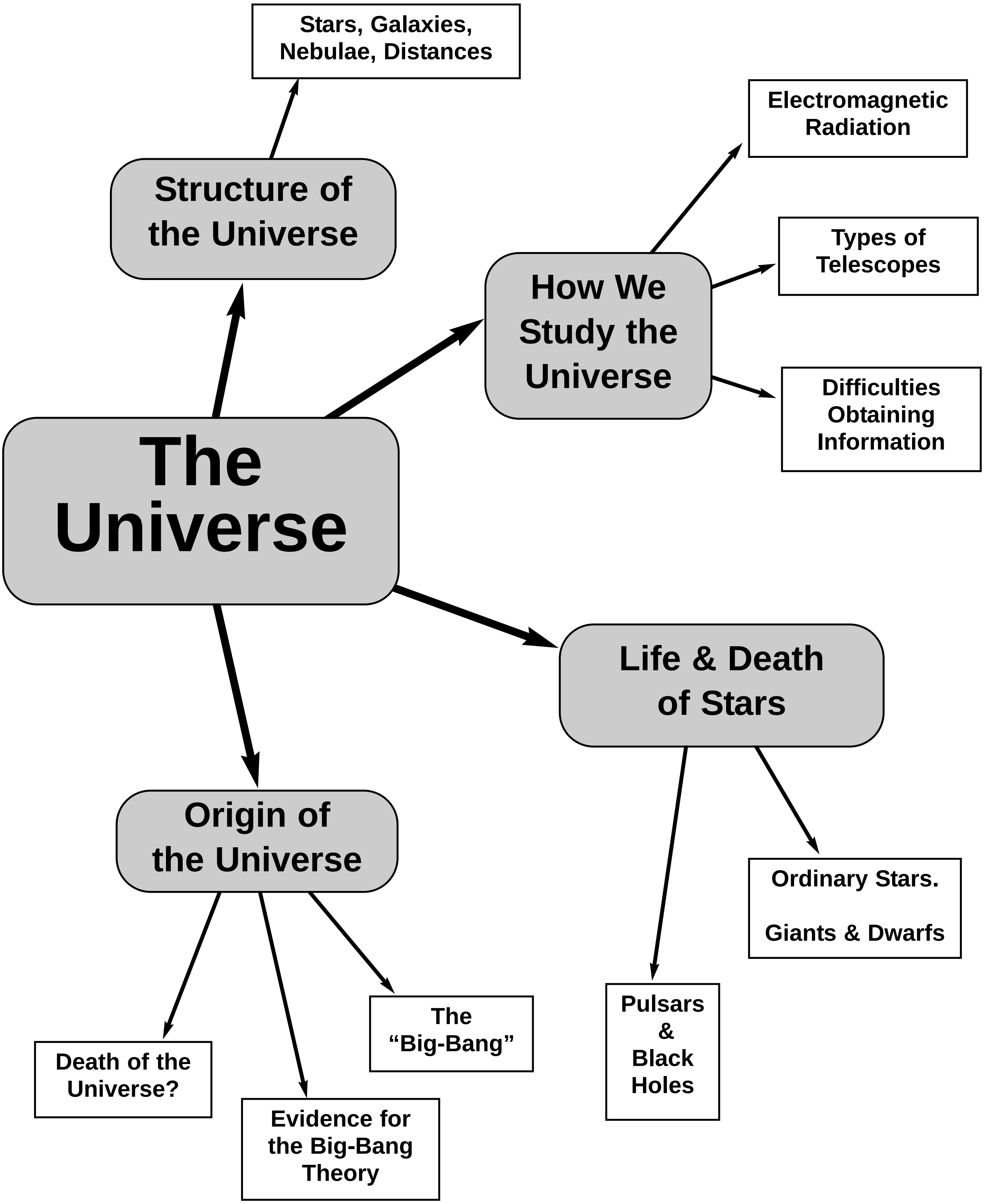
All Topics Available as PHOTOCOPY MASTERS and/or KCiC

Photocopy Masters (PDF files)
Black & White, A4 portrait-orientation for clear, economical photocopying.

KCiC = Key Concepts in Colour
Full colour, formatted for on-screen study and data projection. PDF + Powerpoint®

"Mind-Map" Outline of Topic

In this topic we return to the Astronomy branch of Science.
You previously studied Earth's "neighbourhood", the Solar System.
Here, you will study the wider Universe of stars, galaxies and how it all began.



Make your own "Mind-Map" TITLE PAGE.
Cut out the boxes. Sort them into an appropriate lay-out on a page of your workbook, then glue them down. Add connecting arrows and colour in.

The Universe

Structure of the Universe

Types of Telescopes

How We Study the Universe

Origin of the Universe

Difficulties Obtaining Information

Life & Death of Stars

Ordinary Stars. Giants & Dwarfs

Pulsars & Black Holes

Stars, Galaxies, Nebulae, Distances

Electromagnetic Radiation

The "Big-Bang"

Evidence for the Big-Bang Theory

Death of the Universe?

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Death of the Universe?

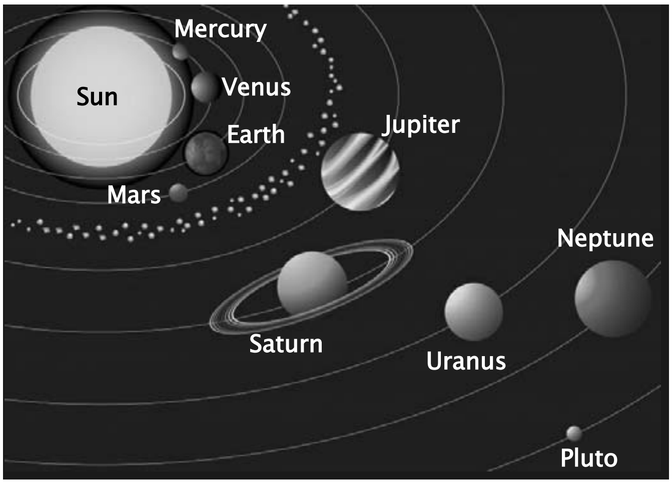
The Science of Astronomy

"Astronomy" comes from a Greek word which means literally "to look at the stars". The modern science of Astronomy includes the study of everything beyond the Earth. In practice, this usually ends up divided into 2 distinct areas of study: study of our Solar System, and study of the Universe beyond.

The Solar System ("solar" = Sun) (Revision)

Our Sun is a star. It is a huge ball of hot, glowing gases.

In orbit around the Sun are 8 major planets, several minor planets and many smaller bodies such as asteroids and comets. The gravity of the Sun holds all these objects in orbit around it.



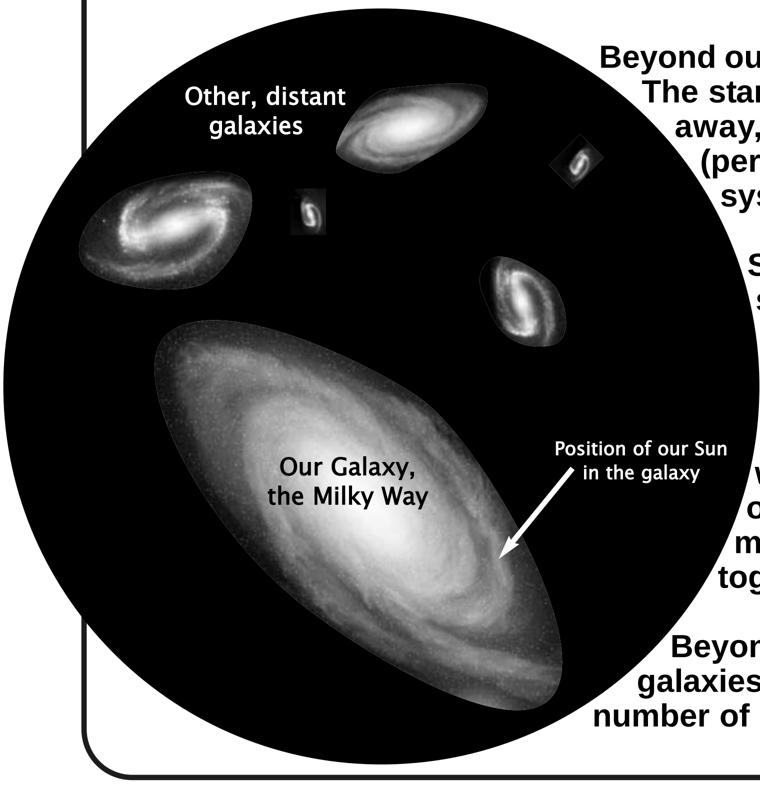
The Earth is one of the major planets, although certainly not the largest.

Most of the major planets also have moons. A moon is a minor planet which orbits around another planet, rather than directly around the Sun.

Our moon, the Moon, is one of the largest. Together, the Earth-Moon pair are often considered a "double planet".

Until recently, the planet Pluto was considered one of 9 planets. Pluto has now been re-classified as a "minor planet", along with a few other medium-sized members of the system.

The Universe Beyond



Beyond our Solar System are billions of other suns. The stars are just like our Sun, but much further away, so they appear very small. Many (perhaps most of them) have their own solar systems of orbiting planets.

Stars are gathered together in huge swirling clumps called "galaxies". Our Sun is just one of over 200 billion stars in our galaxy, the "Milky Way".

The stars (and their solar systems) within a galaxy all swirl around each other in orbit. The gravity of all the material in the galaxy holds everything together.

Beyond our galaxy there are billions of other galaxies. The distances involved, and the total number of stars & planets is literally astronomical!

The Stars

On a clear night the sky is full of stars.**
Each star is another Sun similar to ours.
Each one is a nuclear furnace burning furiously at millions of degrees.
The stars appear very small because they are much, much further away.

**They're there in the day too, but the glare of the Sun makes it impossible to see them with the naked eye.

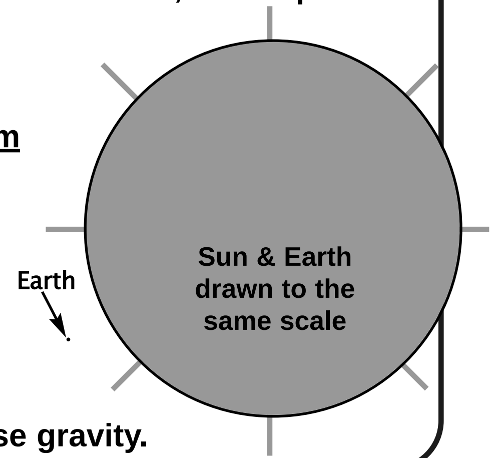
The Sun

Our Sun is a star. A rather small-sized, quite normal star.

Although it is 150 million km away we can feel its warmth so it must be very hot. In fact, we know that it is about 5,000^{o}C at the surface. Deep down inside, its temperature is over 10 million ^{o}C !

It's big too.
The Sun is over one million km in diameter.

The Sun is not solid... no substance can be solid at such temperatures.



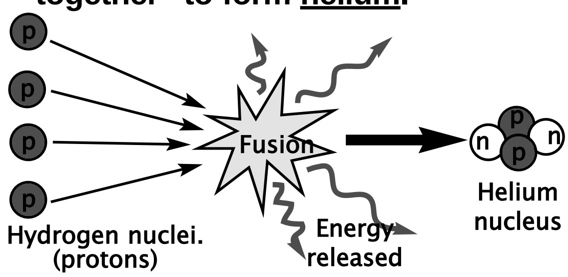
In fact, the Sun is a huge ball of hot glowing gas (mostly hydrogen & helium) held together by its immense gravity.

Energy in a Star

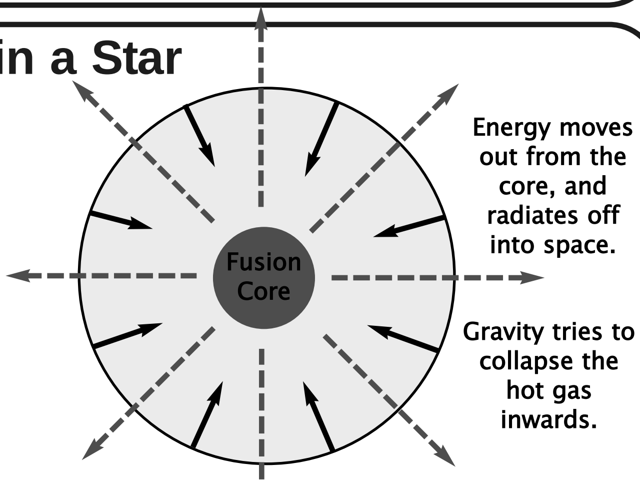
The huge amount of heat and light energy coming from the Sun, and other stars, comes from nuclear reactions occurring deep in the star's "core".

The reactions are called nuclear fusion.
("fusion" means to join, or melt, together)

There are many fusion reactions, but the most common is when hydrogen atoms are slammed together so that they "fuse together" to form helium.



Hydrogen ➡ Helium

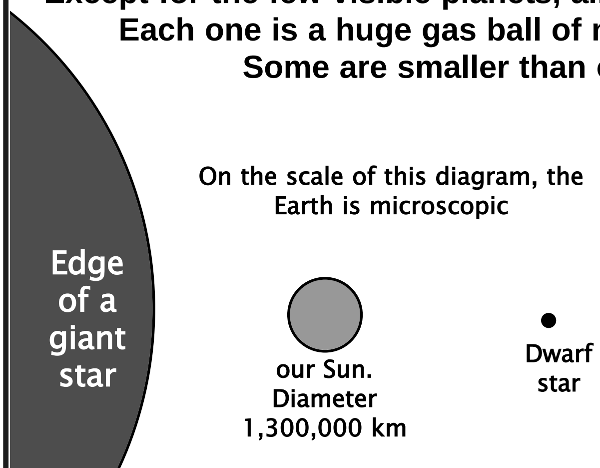


The huge pressure and temperature in the core slams the hydrogen nuclei so hard that they fuse together.

Nuclear transformations occur and a tiny amount of matter is converted into pure energy. The result is a helium nucleus and a huge release of heat and nuclear radiation.

Stars Are Not All the Same

Except for the few visible planets, all the points of light in the night sky are stars. Each one is a huge gas ball of nuclear reactions held together by gravity. Some are smaller than our Sun, and some are much larger.



Every star, including the Sun, is like a huge nuclear bomb. It would explode, except it is so huge that gravity holds the hot gas in a ball.

The size of every star is the balance between the explosive energy release in the core, and the crushing force of gravity trying to collapse it.

As well as there being many different sized stars, there are also different colours. These colours are not obvious to the naked eye, (although you can spot some red-ish stars) but when astronomers analyse the starlight for the exact frequencies of light, they find many differences.

Colour of a star is related to the surface temperature. "Cooler" stars are red. Slightly hotter stars (like our Sun) are yellow. Hotter still, a star becomes "white hot", while the very hottest stars are blue.

As the technology to study stars improves, we are finding that many stars have their own solar system of planets. Perhaps most stars do.

Distance to the Stars

When we talk distances in the Solar System we can use kilometres, although the numbers do get pretty big. For example, the distance from Earth to Sun is about 150 million km. At space rocket speeds, (25,000 km/hr) that would take about 1 year to cover.

The next nearest star to our solar system is over 30 million million km away. At the speed of the Space Shuttle it would take about 150,000 years to get there.

To measure such enormous distances, astronomers use the "light-year".

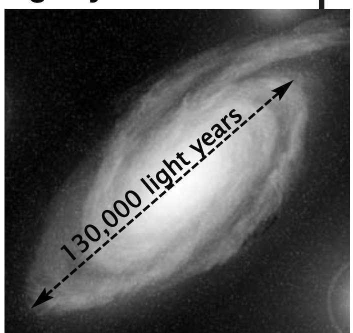
This is the distance that a beam of light can travel in one year. Since light moves at 300,000 km/second, a light-year is almost 10 million million km.

In Light-Years to...

...the nearest star ***(beyond the Sun)***
= just over 3 light-years.

...all our "neighbourhood" stars
= about 500 light-years.

...across the galaxy
= 130,000 light-years



...the next major galaxy
= 1 million light-years

...all our "neighbour" galaxies
= about 500 million light-years

... to the furthest known galaxies
= over 10 billion light-years

Nebulae

("Nebulae" is plural. The singular is "nebula" which means "a cloud" or "mist")

Before telescopes were invented, early astronomers had to rely on naked eye observations. They noticed that there were some objects in the night sky which were vague "blobs", or clouds. Some glowed with light, so they were called "bright nebulae", while others were dark, opaque clouds called "dark nebulae". With modern technology, we now know what they are:

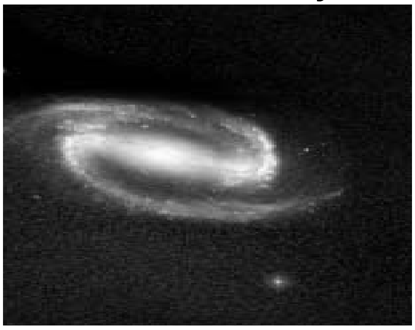
Bright Nebulae = Galaxies or Star Clusters

Bright, glowing nebulae are galaxies or clusters of stars which are so far away that our eyes cannot pick out individual stars. We see just a vague, blurry, glowing cloud.

The most familiar bright nebula is the "Milky Way". This band of milky light across the night sky is the bulk of stars in our galaxy seen edge-on. A telescope reveals that the "cloud" is really millions of individual stars, at great distances.

Our Sun and the Solar System rotate right around the galaxy every 200 million years or so.

Beyond our galaxy are billions of others. It's usually millions of light years from one to the next.



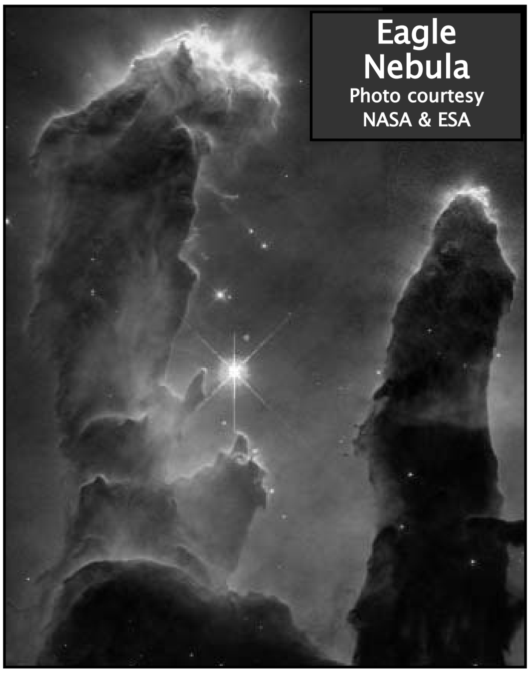
This means that when we look at them (with a telescope) we are seeing light that left there millions or even billions of years ago.

We see them, not as they are now, but as they were in the distant past... we are looking back in time!

Dark Nebulae = Star Nurseries

Dark nebulae really are clouds. Made of gas and dust, they fill vast volumes of space within our galaxy. The dust is thought to be the "ashes" from an exploded giant star.

These clouds are the places where new stars and solar systems are made. Our solar system is thought to have formed in a cloud like this, about 5 billion years ago.



Eagle Nebula
Photo courtesy NASA & ESA

The ash and dust of a dark nebula may be the remnant of a "supernova"... the explosion of a massive star.

The Universe is mostly made of hydrogen and helium; the smallest atoms of all.

When stars explode there is a whole flurry of nuclear fusion reactions. This creates bigger and bigger atoms such as iron, silicon and even lead and gold.

These steps in star formation will be explained later in this topic.

This is how we think the Earth came to be made of iron, silicon, oxygen, etc, with traces of heavy atoms like lead.

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Worksheet 1
Stars & Galaxies

Student Name..

Fill in the blank spaces.

Our Sun is a a).................... All the stars in the night sky are like the Sun, but look a lot smaller because they are b)........... ....

The surface temperature of the Sun is about c).............. ^oC, but deep in the core it is over d)............................ degrees.

The Sun is a hot, glowing ball of (mostly) e).......................... & .... gases. The heat is generated by nuclear f)......................... reactions in the core. The most important reaction fuses g).......................... nuclei together to form h)......................... The size of any star is a balance between the energy release in the core (which tries to i)............................... the star) and the force of j).......................... collapsing it.

Some stars are bigger than others, and they have different k)....................... according to their l)............................... Cooler stars are m).................... and very hot stars are n)...........................

Distances between stars is usually measured in "o)...................................." which is the distance that p).................... can travel in q).......................

"Nebula" means r).....................
A "bright nebula" is a s)............................ or a cluster of stars at such distance that we cannot see individual stars.

A "dark nebula" is a cloud of t).............. and .... within our galaxy. This could be the remnant from a u)................................. explosion of a massive star. These clouds are the places where v)..

Worksheet 2
Stars & Galaxies II

Student Name..

Answer the following questions.

1.

a) What is a star made from?

b) The <u>size</u> of a star is a balance between 2 things. Explain this statement.

c) What process releases the energy of a star? Give a specific example.

d) What causes different stars to be different colours?

2. a) What is a light-year?

b) "When we look at distant galaxies, we are looking back in time."
Explain this statement.

3.

a) What important process occurs inside the "dark nebulas"?

b) If the Universe is mostly hydrogen, how come the Earth is iron, silicon, etc?

How We Study the Universe

Everything we know about the distant Universe has been gathered by studying the light, and other radiations, which stars and galaxies emit.

Electromagnetic (EM) Radiation

EM radiation can travel through outer space as waves at the speed of light.

Radio

Microwaves

Infra-Red

Light

Ultra Violet

X-rays

Gamma Rays

Frequency getting higher

Wavelength getting shorter

Traditionally, Astronomers studied the Universe by observing the visible light from the stars. Until the 1600's they used naked eye observations, then came telescopes.

Light Telescopes

The first telescopes used for Astronomy were less powerful than this child's toy, yet they led to many important discoveries (mainly) about the Solar System and its planets.

CCD's & Computers

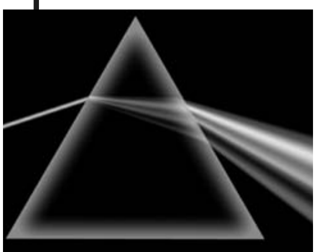
**Modern astronomers never look through their telescopes.
The light is collected by electronic detectors called CCD's, (simple CCD's are in your digital camera) and processed by computers.**

(CCD stands for "Charged-Couple Device")

**Astronomers don't even have to be near the telescope! It can be on board a satellite in space, sending data back to Earth automatically.
The astronomer's job is to analyse the data and decide where to look and what to look at next.**

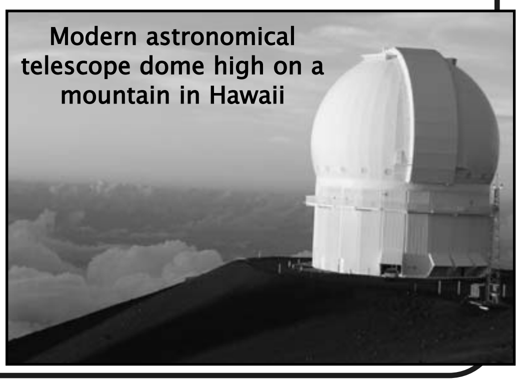
Photos & Spectra

Telescopes got bigger and more powerful, but the great leap forward came in the 19th century. Astronomers began to take photographs through the telescopes, rather than just observe by eye.



**They also began to analyse starlight by studying the spectrum of different light frequencies coming from the stars.
This allowed much more to be learned about the Universe.**

It became possible to measure the distances to the stars, how hot they are and even their chemical make-up. This will be explained next.

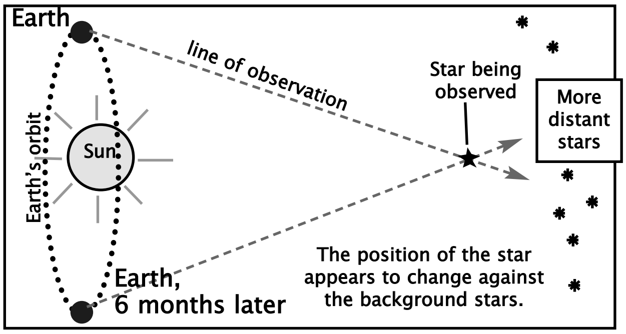


Modern astronomical telescope dome high on a mountain in Hawaii

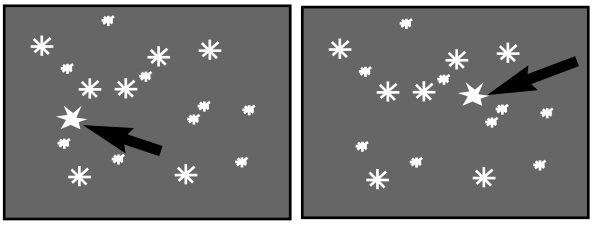
Information in the Light

Measuring Distances

If the exact same part of the sky is photographed at times 6 months apart, some of the stars seem to change position slightly. The diagram explains.
(This is not apparent to the naked eye at all.)



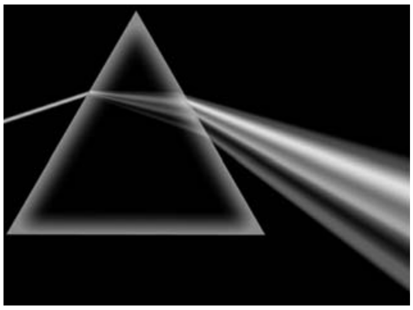
Here is what 2 photos, 6 months apart, might show. The arrowed star seems to have moved slightly.



This apparent movement is called "parallax". Careful measurements of the photos allows calculation of how far away the star is.

Measuring Temperatures

About the same time as photography for astronomy developed, astronomers began to pass the light from individual stars through a prism, then photograph the colour spectrum of light.



It was immediately clear that different stars emitted different mixtures of colours of light.

Some stars emit a lot of red light, others give off more yellow, or blue, and so on.

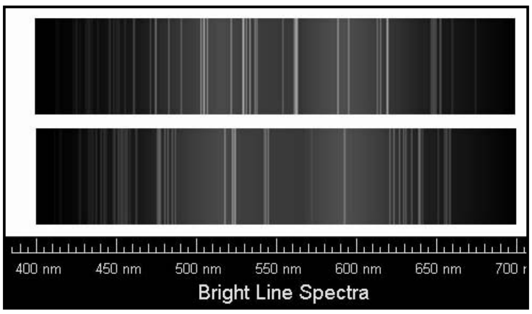
Experimental laboratory measurements soon gave the explanation. Objects which are "red-hot" emit radiation at different frequencies (colours of light) according to their temperature.

Astronomers could now tell, quite accurately, the surface temperature of each star. They could calculate energy output, and begin figuring out what was happening inside the star.

More Information in the Light - Chemistry

Spectral Lines

The light spectrum from a star is never a simple "rainbow" of colours. It always contains many fine black lines, or bright lines, at particular frequencies.



These lines are the "fingerprints" of particular types of atoms. The spectral lines in starlight reveal which chemical elements are present in the star.

Each type of atom absorbs or emits light at precise frequencies to make its own unique spectral pattern.

Helium's Discovery

In the 19th century experiments were going on to learn the spectral "fingerprints" of each known chemical element. These were then matched against the spectral lines of light from stars.

Some strong spectral lines in sunlight could not be matched to any known element. It was realised that there was an unknown element in the Sun. It was later discovered on Earth and named "helium", from Greek "helios" = Sun.

Other Types of Telescopes

Until the middle of the 20th century, all astronomy was done with visible light. Then it was accidentally discovered that stars, galaxies and nebulae give off a lot of radio wave radiation.

Radio Astronomy

Using huge receiving dishes, astronomers began studying the radio signals from space. They soon found that radio waves give information not available with visible light.

For example, radio waves can penetrate through the clouds of gas and dust in a dark nebula. Astronomers cannot see inside a nebula with a light telescope, but with a radio telescope they can analyse radio signals and get a "picture" of what is going on inside the cloud.

We now know that new stars are being born inside the dark nebulae.

Why Stop at Radio?

Soon it was clear that outer space is awash with EM radiation of every possible type, and each type had its own advantages for study.

Studying X-ray and gamma ray emissions gives information about violent events occurring near black holes, where matter is being torn apart.

Microwave telescopes have given us information about the very beginnings of the Universe, while an ultra-violet telescope is excellent for spotting star explosions. Modern Astronomy uses every available radiation for study.

Difficulties Getting Information

The biggest problem in gathering radiation from space to study the Universe can be stated in one word... "AIR". The Earth's atmosphere interfers with light rays, and completely blocks many EM radiations so they cannot be studied from the surface.

Twinkle, Twinkle, Little Star

To the naked eye, the "twinkling" of the stars is part of their beauty and charm. Twinkling is actually due to the light rays being jiggled and deflected as they come through the shifting atmosphere.

To astronomers, twinkling starlight is a curse which limits the clarity and accuracy of their measurements and observations.

Optical telescopes are always built on top of high mountains. That puts them above the densest and most unstable part of the atmosphere so they get a clearer view.

Hubble Space Telescope, photographed from the Space Shuttle

Satellite Astronomy

Light rays might be jiggled by the atmosphere, but many EM radiations are completely blocked. It is impossible to do any useful astronomy at ground level using infra-red, X-ray, gamma and parts of the microwave and UV spectrum.

The solution is obvious, but expensive! A lot of modern astronomy is done from satellites in space.

For some types of observation this is the only solution, and it has revealed some amazing things!

Technology Transforms Science

Every now and then in the history of Science a technological development completely transforms the Science and boosts its rate of discovery.
In Astronomy this happened when telescopes were invented over 300 years ago.
Then it happened to Astronomy again in the second half of the 20th centrury.

Rocket Science

During World War II great advances were made in the technology of using rockets as weapons. The German V-2 delivered 1 tonne of explosives over a range of 300 km at a speed of 3,000km/hr.

At the end of the war, captured German scientists were used by both USA and USSR to develop long range rockets to carry nuclear weapons. Luckily, the “Cold War” never turned hot.

Then came the “Space Race” in which these countries competed to launch satellites and astronauts into orbit and to the Moon.

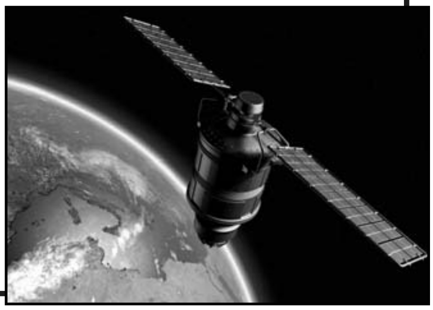
Revolution in Astronomy

The developments in rocket and space technology had many impacts on other technologies and even on everyday life.

Astronomy was revolutionised, again!

Observatories were put into space. Above the atmosphere, optical telescopes get a perfectly clear view. Microwave, infra-red and x-ray telescopes become possible.

A thousand times more data has been collected in 20 years of space astronomy than in the previous 100 years.



Impacts of Space Science

The “Space Race” between the USA and USSR lasted for about 30 years.
In that time enormous resources were applied to scientific research, not just in rocketry, but in electronics, communications, fabrics and plastics and even food preservation. Many developments became “spin-offs” to society.

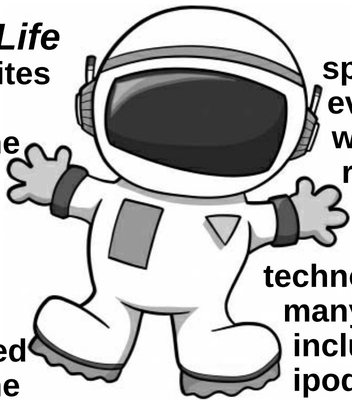
Impacts of Satellites on Everyday Life

Today there are over 1,000 satellites in orbit. They provide telephone links, television programs and the internet. Satellites monitor our weather and allow a GPS unit to provide navigation.

Plastics & Fabrics

Many new materials were invented during space research. One of the earliest was “teflon”, the non-stick coating on kitchen pots and pans.

Modern fabrics used for swimwear, sneakers and snow-ski clothing as well as carbon-fibre for tennis racquets and racing bikes were all developed for space suits and other space equipment.



Electronics

One of the major areas of space research was to make everything as small and light-weight as possible for the rocket launch.

This led to new, compact technologies in electronics. The many spin-offs we now enjoy include personal computers, ipods and mobile phones.

Health Sciences

Keeping astronauts alive in the hostile environment of space led to new discoveries in physiology and to new electronic devices to measure health and fitness. Many of these findings and devices are now in routine use in modern hospitals.

Worksheet 3

How We Study the Universe

Student Name...

Fill in the blank spaces.

To learn about the Universe we rely totally on a).. radiation which travels to Earth from outer space.

Traditionally, astronomers observed the b)........................ from the stars by eye. In the 1600's the c)........................... was invented. A big step forward was when d)........................... of the sky could be taken. This allowed the e)...................... to some stars to be measured.

By passing starlight through a prism, a f)............................... of the light could be photographed. This reveals information about the g).......................... of a star and even its h)......................... composition.

In the 20th century it was discovered that a lot of i)............................ waves come in from space. Radio astronomy can discover things that a light telescope cannot see, such as what is happening inside a dark j)........................

Modern astronomy uses every type of k)............................... radiation including l)....................... and ....

The biggest problem for studying the Universe is that the Earth's m).................................. blocks some radiations. Light waves pass through, but are jiggled by the air. This reduces the n)............................ of any measurements. A lot of astronomy is done by o)............................ in orbit.

Worksheet 4

Studying the Universe Questions

Student Name...

1.
List the seven (7) types of EM radiation, from lowest to highest frequency.

2.
a) What is "parallax"?

b) What can be calculated from the parallax detected in photographs of stars?

3.
What is a star "spectrum"?

4.
What measurement can be made by analysing the amount of red, yellow, blue, etc light in a star spectrum?

5.
What are "spectral lines" and what can they tell us about a star?

6.
Launching satellites is ultra-expensive.
a) Why is it worth the cost to put a light telescope in orbit?

b) Why is it worth the cost to put an infra-red, or X-ray, telescope in orbit?

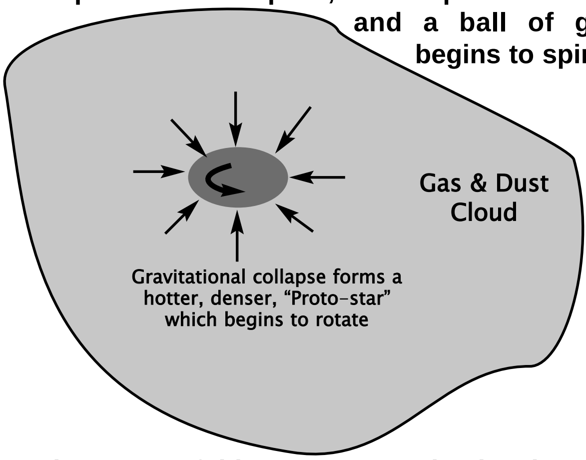
A Star is Born

A typical star lives for about 10 billion years, so obviously we cannot watch any star go through its life. However, by studying many stars, all at different stages of their life cycle, we can piece together the full story.

A Cloudy Start

Stars are created in the dark nebulae... vast clouds of (mainly) hydrogen gas which fill great volumes of space.

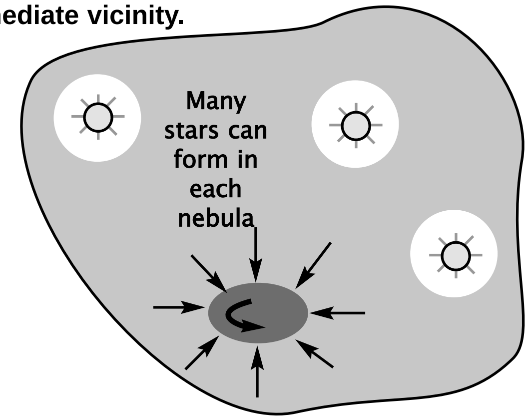
Slight irregularities in parts of the cloud contract due to gravity. As the zone of contraction becomes denser, gravity causes further, faster collapse. As it collapses, the temperature rises and a ball of gas begins to spin.



In the centre of this "proto-star" the density, and the temperature rise, slamming hydrogen atoms together harder and harder.

Fusion Begins

The gas-ball becomes a star when hydrogen fusion ignites in the core. As the new star begins to shine, its radiation blows away the gas in its immediate vicinity.



If the nebula contains the "dust" of heavier atoms from an exploded star, the heavier atoms may clump together to form planets. This is how our Solar System began 5 billion years ago.

Stars now settle into a life which is a constant battle between the raging explosion in their core and the immense force of gravity crushing inwards.

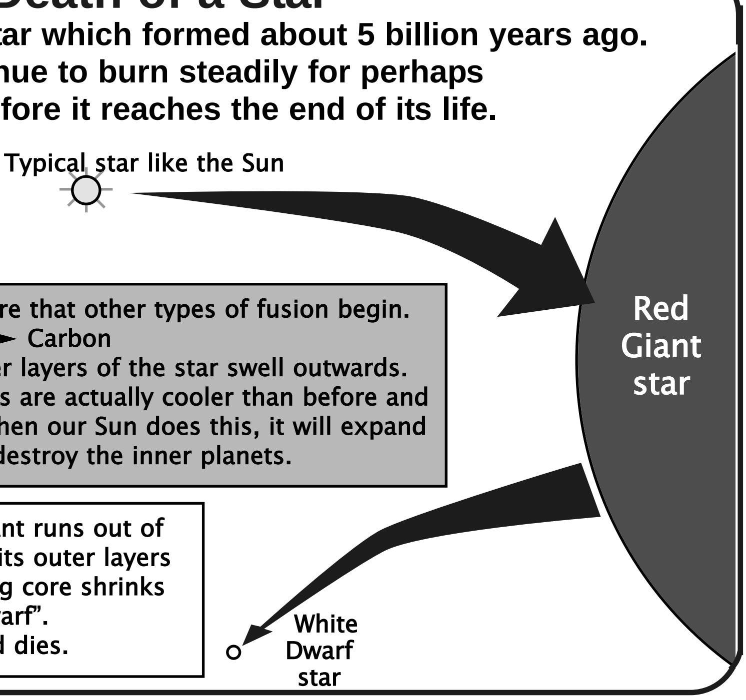
How long the star lives depends on how big it is

Life & Death of a Star

Our Sun is a typical, average star which formed about 5 billion years ago. We believe it will continue to burn steadily for perhaps another 5 billion years, before it reaches the end of its life.

10 billion years of steady fusion.

Hydrogen → Helium



Eventually, there is so much helium in the core that other types of fusion begin.
e.g. Helium → Carbon
This releases much more energy, so the outer layers of the star swell outwards. Although huge and very bright, the outer layers are actually cooler than before and emit a lot of red light. This is a "Red Giant". When our Sun does this, it will expand out to about the Earth's orbit and destroy the inner planets.

After perhaps 100 million years, the red giant runs out of fusion fuel. Stuttering explosions may blow its outer layers away to form a new, dusty nebula. The dying core shrinks under gravity to form a "White Dwarf".
It's still hot, but gradually cools and dies.

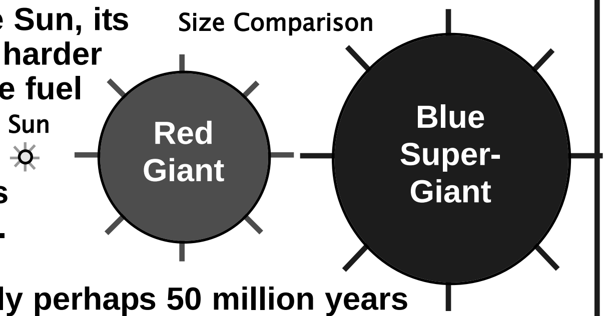
The Short & Violent Life of a Superstar

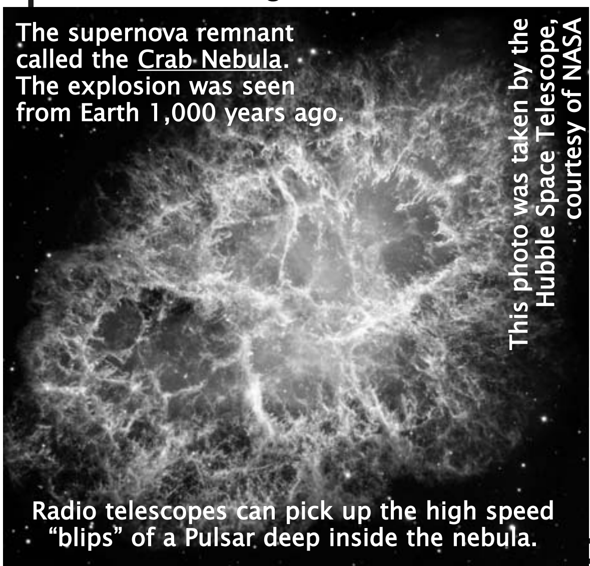
The vast majority of stars are born about the same size as our Sun and have long, stable lives before they briefly flare up to Red Giants, then shrink down to White Dwarfs and fade away. A few stars are born big. The bigger they are, the shorter their life, and the more violent and spectacular their death.

Big Mass = Short Life

If a star is more than 10 times bigger than the Sun, its crushing gravity rams the atoms in its core harder together. Fusion reactions run faster and the fuel is used up very quickly.

The star is very large, very bright and radiates a lot of blue light. This is a "Blue Supergiant".




The supernova remnant called the Crab Nebula. The explosion was seen from Earth 1,000 years ago.

This photo was taken by the Hubble Space Telescope, courtesy of NASA

Radio telescopes can pick up the high speed "blips" of a Pulsar deep inside the nebula.

After only perhaps 50 million years (compared to 10 billion for the Sun) the giant's fuel is exhausted. Energy production in the core shuts down quite suddenly. Gravity takes over and enormous masses of material collapse inwards. The pressure and in-falling matter sets off one final, cataclysmic fusion explosion.

This "supernova" explosion out-shines the whole galaxy for a few days. Debris expands outwards creating a new nebula of gas and dust containing many heavy elements. Later this nebula may be the birth place of a new star with planets like ours.

What Happened to the Core?

The supernova story is not finished. The outside of the star was blown away, but what happened to the star's core? It depends on how big it was.

Neutron Stars = Pulsars

If the core is less than 3 times the mass of our Sun, gravity and the pressure of the explosion, collapses it inwards to form a super-dense ball of neutrons only about 20 km in diameter.

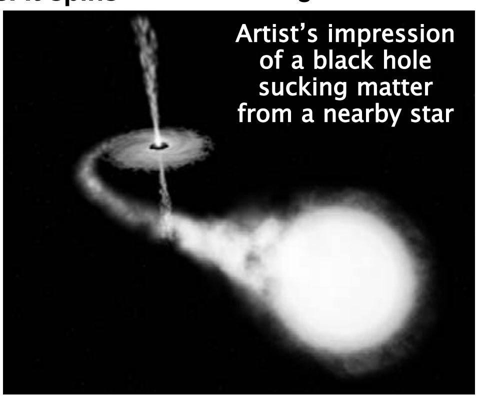
Two tight beams of radiation are created by its tortured, twisted magnetic fields. It spins rapidly, so the beams of radio, light and x-rays sweep around like a demented lighthouse.

As the beams sweep the Earth, we pick up pulses of radiation. Neutron stars are also called "Pulsars" because of this. (The first pulsar radio signals detected were thought to be possible communications from intelligent aliens!)

Black Holes

If the core is more than 3 times the mass of the Sun, it keeps collapsing in on itself. Matter is crushed to an infinite density and the core becomes a "singularity" or "black hole".

Any matter nearby is sucked into its immense gravitational field. Even light waves cannot escape... that's why it's black.


Artist's impression of a black hole sucking matter from a nearby star

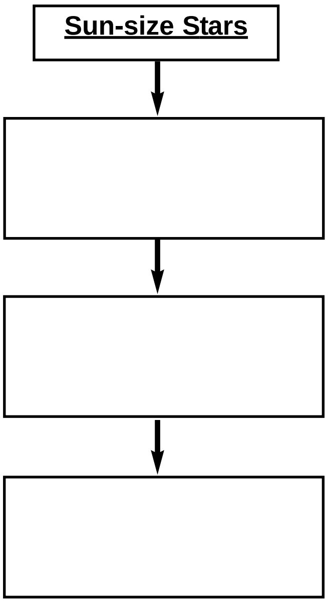
In-falling matter swirls around the "event horizon" and is torn apart before disappearing. Twisted magnetic fields eject "jets" of matter at high speed.

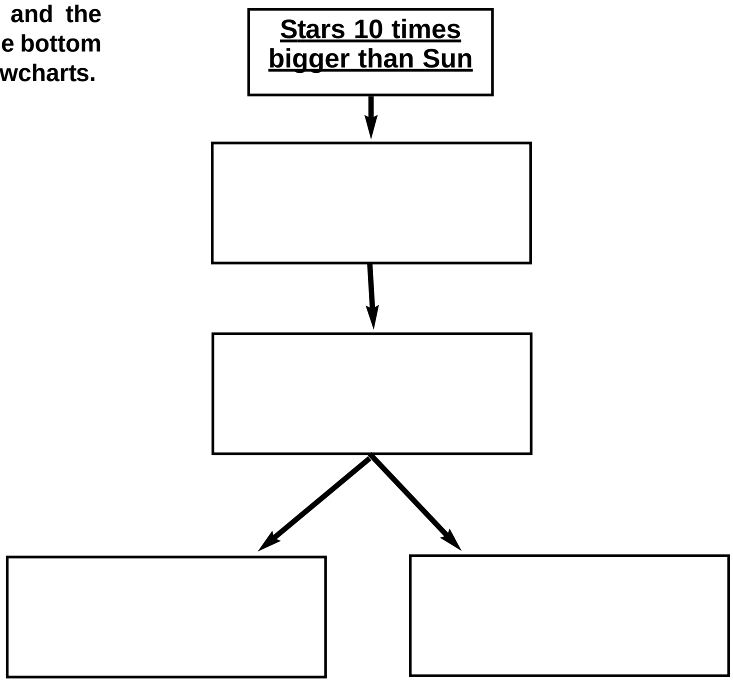
We think every galaxy has super-massive black holes in its centre. We can't see them, but pick up X-rays from the jets.

Worksheet 5
Flowcharts of Star Lives

Student Name...

These flowcharts summarise the lives of stars and the stages they go through. Cut out the captions at the bottom and glue them into the boxes to complete the flowcharts.





Supernova Explosion.

White Dwarf Star, gradually cooling off.

If core more than 3X the mass of the Sun... Black Hole.

Red Giant Star.
Helium ⟶ Carbon

If core less than 3X the mass of the Sun... Neutron Star.

10 billion years of steady fusion.
Hydrogen ⟶ Helium

Blue Supergiant.

Worksheet 6
Life & Death of Stars

Student Name...

Fill in the blank spaces.

Stars form in the dark a)......................... when a region of the cloud (mostly b)............................. gas) begins to collapse under the force of c).................. As the gas collapses inwards, the density and the d)......................... rise as the atoms are slammed together.

The gas cloud becomes a star when e)............................... begins in the core.

Sun-sized stars now settle into many f).............................. of years of stable fusion reactions, mainly g)...................... fusing into h)..........................

Eventually, new types of fusion begin in the core which force the i)....................... to rise. The star expands to become a “j)..” When the fuel finally runs out, the star shrinks to a “k)................................” star and slowly cools and dies.

Very large stars burn much hotter and are “l)...” stars. Their fuel runs out quickly. When the core dies, the m)............................ of the star collapse inwards. This sets off a final fusion explosion called a n).. The core then collapses to form a o)..................... star or even a “p)...............................”

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How the Universe Began

By about 100 years ago, telescope technology began to reveal the vastness of the Universe. It seemed to have no limits, and many astronomers thought that perhaps the Universe was infinite in space and in time, with no beginning and no end. From about the 1920's new evidence suggested a different idea. Modern observation of the Universe using every type of telescope available, causes most astronomers to accept a theory called

The Big Bang Theory

Summary of the Main Points

1. About 14 billion years ago, the entire Universe began in a tiny point, or "singularity" of pure energy.

2. It exploded outwards, expanding the fabric of space itself.

3. At first the Universe was filled with nothing but seething energy, but as space expanded, it cooled until particles of matter could be formed from pure energy. With further cooling, particles formed atoms... mostly simple hydrogen.

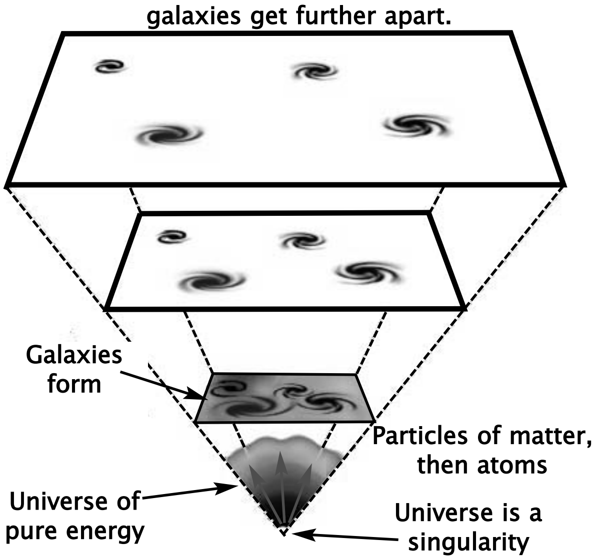
4. Gradually, the great clouds of gas condensed to form stars, clustered in huge groups... the galaxies.

5. The Universe continues to expand today. As space expands, the distances between galaxies continues to increase.

(There is no visible expansion within a galaxy because gravity holds the stars together.)

Expanding Space

You must NOT think of the galaxies flying off into infinite space around them. Rather, they are being carried further apart as space itself expands.



What was there before the Big Bang?
Meaningless question: there was no space or time before. In fact there was no "before" because time did not exist until the BB.

Is This For Real?

It sounds like fantasy. Whoever made this up needs help!

How Science Works

Science works by proposing models and theories to explain the facts we observe about nature and the Universe.

Scientific theories are accepted only if they fit the facts. Theories are subject to "falsification". Scientists will test every aspect of a theory. If it is proven false, it will be rejected. Big Bang theory certainly explains many facts and, so far, has survived the falsification test.

Status of the Big Bang Theory

The Big Bang Theory is the best explanation of the Origin of the Universe that we have. It fits the most amazing facts about the Universe. It also raises a lot of new questions, and certain aspects of it cannot yet be verified or falsified.

It is currently accepted, but with some caution. It is likely that the finer details of the Theory will be modified as new evidence is discovered.

Evidence for the Big Bang

The name "Big Bang Theory" was invented in 1949 as a scornful, sarcastic name for a whacky theory. The astronomer who coined the name thought the whole idea was ridiculous. Since then, the evidence has mounted...

The Universe IS Expanding

When we look into deep space we see all the distant galaxies racing away from us. The more distant they are, the faster they are moving away.

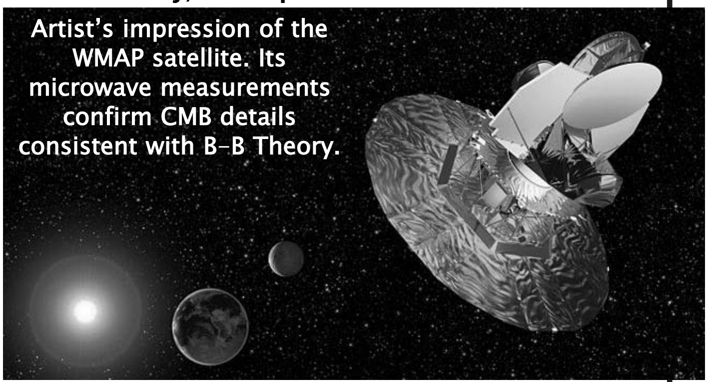
This is consistent with the idea of an outward expansion of the Universe.

Calculations show that the rate of the expansion points back to a time (about 14 billion years ago) when the entire Universe was in one point.

How do we measure the movement of distant galaxies? Their radiations (light, radio, etc) show a "*Red-Shift*" of wavelength and frequency. (The Red-Shift is explained below.)

The Cosmic Microwave Background (CMB)

If the Big Bang actually happened, scientists calculated that the entire Universe should be awash with microwave radiation of a particular frequency. This radiation is like the "afterglow" of the early, hot explosion.



Artist's impression of the WMAP satellite. Its microwave measurements confirm CMB details consistent with B-B Theory.

The CMB radiation has been discovered, confirmed and found to be exactly as predicted.

This is powerful evidence for the theory.

The Red-Shift

The light (or radio waves) from a distant galaxy left it billions of years ago. During those billions of years, the waves have been travelling through space which has been expanding. This has "stretched" the waves to longer wavelengths. For visible light, longer waves are towards the red end of the colour spectrum.

The Doppler Effect

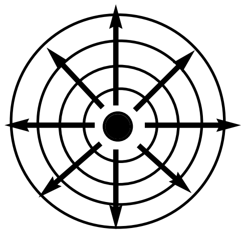
This effect is well known and understood. It affects all types of waves.

If a stationary object is emitting waves, they are the same in all directions around it.

However, if the object is moving, the waves in front get "bunched up" and their wavelength is shortened. The waves behind get "stretched" and the wavelength is lengthened.

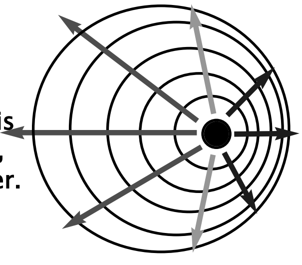
For visible light waves, longer waves are red, shorter waves are blue.

If galaxies were moving towards us, we would see a "Blue-Shift" in the light. Every distant galaxy, in every direction, shows a red-shift in its radiation. This is powerful evidence of expansion of the Universe.



Wave crests spreading out evenly from a stationary object. The wavelength is the same in all directions

Light Waves Spreading Out From a Moving Galaxy



More Evidence for the Big Bang

Links to Accepted Theories

One of the best accepted scientific theories of all time is <u>Einstein's Theory of Relativity</u>.

This theory has been confirmed over and over by experiments and observation. Despite many attempts to find "holes" in it, it has survived every falsification process of Science.

Relativity theory explains how pure energy of the Big Bang could form particles of matter.

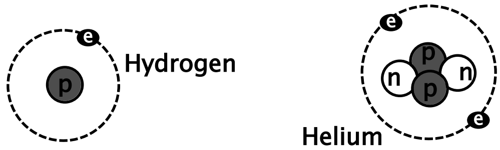
The mathematical equations which describe space and time in Relativity are in agreement with an expanding Universe. In fact, it was these equations which led to the Big Bang idea before any evidence of expansion was found.

When a strongly accepted theory (Relativity) points to, and agrees with, another idea (BB) it suggests it's true.

Composition of the Universe

If all the known principles of atomic physics, energy, etc are applied to the BB idea, it is possible to predict which kinds of particles, and which types of atoms should have formed in the early Universe.

The prediction is that, before there were any stars, the Universe should have been 75% hydrogen atoms and the rest helium, with just a trace of lithium.



This prediction is in good agreement with the observed composition of stars and nebulae. Don't forget that astronomers can measure chemical composition from the light spectra.

Future of the Universe?

What does the Big Bang Theory predict for the future?

Expansion Forever?

There is no evidence that the expansion of the Universe is slowing down.

If this is so, then the Universe will expand forever. After about 300 billion years all the star fusion that can occur will have happened. All stars will have died. Energy will become "evened out" and the Universe uniformly cold.

This scenario is called the "Heat Death of the Universe".

The Big Crunch?

If there is enough matter in the Universe, then gravity will eventually slow down the expansion, stop it, then pull the Universe back in on itself.

Perhaps all matter will collapse back into one all-powerful black hole.

Repeating Cycles?

If the "Big Crunch" happened, maybe then a new Big Bang would happen to create a new Universe?

Maybe our Universe is just one of an endless series of universes that go bang, crunch, bang, crunch...

So far, we do not have enough evidence to choose between these possible scenarios.

Worksheet 7
Origin of the Universe

Student Name...

Fill in the blank spaces.

The currently accepted theory for the origin of the Universe is the a).......... .... Theory. The evidence suggests the Universe began almost b)....... .... years ago at a single point (or a “c)..............................”) of pure d)........................ which exploded outwards.

Space itself expanded outwards, with the early Universe filled with e)..............., but then matter formed from energy. Most of the matter was f)....................... atoms in huge clouds.

As the Universe cooled, g)................... began to form in the gas clouds. Huge clusters of stars formed h)....................... Today, the galaxies are moving apart as space continues to i)..............................

The main evidence for this theory is the “j)............-Shift” of radiation from distant galaxies. This change of wavelength of the light indicates that the galaxies are all k)................ ....

More evidence comes from the CMB which is the l).................... .... which is the “afterglow” from the early Universe.

The theory is also consistent with other accepted theories. For example, Einstein’s Theory of m).......................... which explains how matter could form from pure n)....................... and predicts that o)................... & .... atoms should be the most common.(as they are)

We cannot yet predict what might happen in the future. The Universe may p)..................... forever, or gravity may win in the end. In this case the Universe would q)........................ again to a “Big r)........................”.

Worksheet 8
Evidence for the Big Bang

Student Name...

1.
a) What is the “Red-Shift” of light from distant galaxies?

b) What is thought to be the reason for the Red-Shift?

c) How is this evidence of an expanding Universe?

d) What would a “Blue-Shift” mean?

2.
a) What does “CMB” stand for?

b) What technology has allowed CMB to be studied?

c) How does CMB support the Big Bang theory?

3.
a) What are the 2 most common elements in the Universe?

b) How do we know that?

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Topic Test
The Universe

Student Name ....

Score = /23

Answer all questions in the spaces provided.

1. (8 marks)
Match each description to an item from the list. To answer, write the letter (A,B,C, etc) of the list item beside the description.

Description matches with	List Item
a) Nuclear process which powers all stars.	....
b) Swirling mass of billions of stars.	....
c) The distance light can travel in one year.	....
d) Place where stars are created.	....
e) Explosion of a giant star.	....
f) Last stage of life of a regular sized star.	....
g) Another name for a neutron star.	....
h) Main evidence of the Big Bang Theory.	....

List Items Not all will be used. Some may be used more than once.

A. pulsar	F. supernova
B. dark nebula	G. light year
C. fusion	H. black hole
D. red giant	I. red-shift
E. white dwarf	J. galaxy

2. (4 marks)
a) Which two opposing effects control the size of a star?

b) Complete the "equation" which summarises the main process releasing energy in most stars.

.... ⟶ ....

3. (4 marks)
a) Give an outline of how astronomers determine which chemical elements are in a star.

b) Light waves cannot pass through a "dark nebula", yet astronomers can find out what is happening deep inside. Suggest how they might get this information.

c) Why are many observatories either on high mountains or on board satellites?

4. (4 marks)
An astronomer has detected 3 stars. Each star's light spectrum is dominated by a different frequency (colour) of light. The dominant colours are yellow, red & blue.

a) Which colour star is hottest?

b) Which colour star is most likely to explode in a supernova?

c) The red star is discovered to be very large. Is this star quite young, or getting quite old?

d) What type of star might the large red star become at a later stage?

5. (3 marks)
According to the Big Bang Theory:
a) approximately when did the Universe begin?

b) how were particles of matter first formed?

c) which chemical element was formed in the greatest amounts?

Answer Section

Worksheet 1

a) star b) much further away.
c) 5,000 d) 10 million
e) hydrogen &helium
f) fusion g) hydrogen
h) helium i) expand / explode
j) gravity k) colours
l) temperature m) red
n) blue o) light-years
p) light q) 1 year
r) cloud s) galaxy
t) gas and dust u) supernova
v) new stars form.

Worksheet 2

1.
a) Hot, glowing gases, mainly hydrogen.
b) The huge release of energy inside a star tries to expand/explode it, but gravity tries to collapse it. Final size is the balance between these 2 forces.
c) Nuclear fusion
e.g. hydrogen helium
d) Their temperature. Cooler stars are red, while very hot stars are blue.
2.
a) A light-year is the <u>distance</u> that light can travel in 1 year.
b) The light may have taken a billion years to get here, so what we see now is what the galaxy looked like a billion years ago when the light started out.
3.
a) Formation of new stars.
b) Some nebula are the remains of an exploded giant star. The dust contains many heavier atoms formed by fusion in the star or during the supernova explosion. Our Solar System formed from such a nebula.

Worksheet 3

a) electromagnetic b) light
c) telescope d) photographs
e) distance f) spectrum
g) temperature h) chemical
i) radio j) nebula
k) electromagnetic
l) infra-red & X-rays (or any others)
m) atmosphere n) accuracy
o) satellites

Worksheet 4

1.
radio, microwaves, infra-red, light, ultra-violet, X-rays, gamma rays
2.
a) Parallax is the apparent change of position of a star when viewed from a slightly different angle.
b) Parallax allows the distance to a star to be measured.
3.
The spectrum is a “rainbow” of the light frequencies obtained by passing the light through a prism.
4.
The temperature of the star.
5.
They are fine bright, or dark, lines in the spectrum “rainbow”. They reveal the types of atoms in the star.
6.
a) Light astronomy suffers from the “twinkling” as light comes through air. In orbit above the atmosphere the images can be much clearer and more detailed.
b) Some EM radiations are totally blocked by the atmosphere, so the only way to make observations is from a satellite.

Worksheet 5

Sun Sized
↓
10 billion yrs steady fusion
↓
Red Giant
↓
White Dwarf

10x bigger
↓
Blue Supergiant
↓
Supernova
↙ ↘
Neutron Star Black Hole

Worksheet 6

a)nebulae b) hydrogen
c) gravity d) temperature
e) fusion f) billions
g) hydrogen h) helium
i) temperature j) Red Giant
k) White Dwarf l) Blue Supergiant
m) outer layers n) supernova
o) neutron p) black hole

Worksheet 7

a) Big Bang b) 14 billion
c) singularity d) energy
e) energy f) hydrogen
g) stars h) galaxies
i) expand j) Red
k) moving away or moving apart
l) Cosmic Microwave Background
m) Relativity n) energy
o) hydrogen & helium
p) expand q) contract
r) Crunch

Worksheet 8

1.
a) The light's wavelength is stretched longer towards the red end of the spectrum.
b) Distant galaxies are all moving away from us.
c) For everything to be moving away, the Universe must be expanding.
d) Blue-shift would mean things were moving towards us.
2.
a) Cosmic Microwave Background
b) Space satellites. Microwave radiation is partly blocked by air, so detailed study must be done from space.
c) Theory predicted the CMB should be there at particular (red-shifted) wavelengths. The fact that it IS there is evidence that theory is correct.
3.
a) Hydrogen & helium
b) From the spectral lines in light spectra from stars and galaxies.

Topic Test

1.
a) C b) J c) G d) B
e) F f) E g) A h) I

2.
a) The outwards expansion of energy release and the force of gravity.
b) hydrogen ⟶ helium

3.
a) They pass light from star through prism to get the spectrum. The fine spectral lines in it identify which atoms are present.
b) From radio astronomy, because radio waves may be able to pass through the nebula.
c) To get above the air which blocks some radiations, and makes light "twinkle" so images cannot be totally clear.

4.
a) Blue
b) Blue
c) Old (it's a Red Giant)
d) White dwarf

5.
a) Almost 14 billion years ago.
b) Atomic particles formed from pure energy. Later the particles (protons, electrons, neutrons) formed atoms.
c) Hydrogen