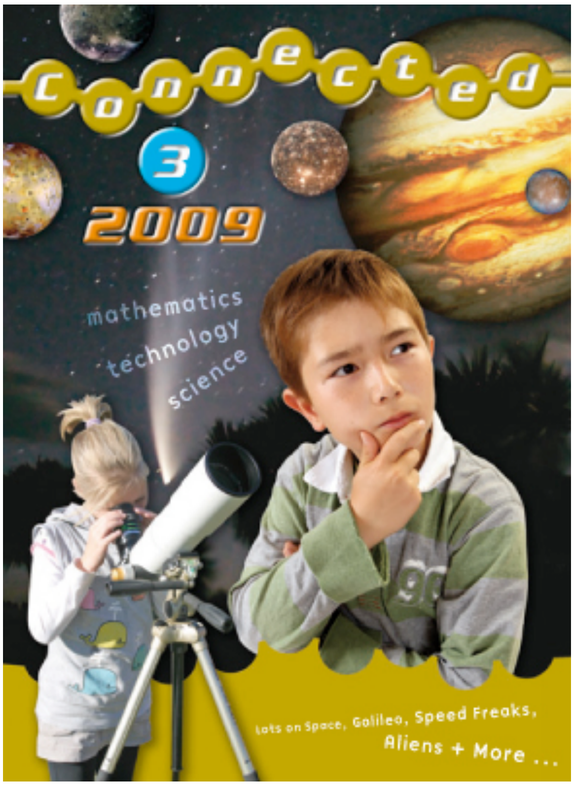
Teacher Support Materials



Connected 3 2009

Contents and curriculum links

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General themes in *Connected 3 2009*

1. The International Year of Astronomy

The United Nations has made 2009 the International Year of Astronomy (IYA2009) to celebrate the beginnings of modern astronomy, when Galileo first looked at the sky with a telescope 400 years ago. The six articles and one story relate to IYA2009's vision of looking at the sky with a sense of wonder (if possible, through a telescope/binoculars) in order to appreciate that:

- we are part of the universe
- the same physical laws apply in space as they do on Earth
- astronomy and other fundamental sciences affect our daily lives.

2. Looking up – our connections to space

"Eye Spy" and "Aotearoa's Star" invite students to look up and identify particular stars and patterns of stars in the southern night sky and to recognise them as part of their environment (and also their history). Although other space bodies appear to be so different from Earth, there are many things Earth shares with them. For example, although the Moon lacks water and an atmosphere, its surface is similar to Earth's. Other planets also have moons. The pattern of small bodies orbiting large ones is repeated through our solar system and in the galaxies. Our bodies are also made of the same stuff as stars and planets. "Aotearoa's Star" explains that stars are the universe's factories, taking the raw material of hydrogen gas and making all the elements that we are familiar with on our planet.

Although space is a very different environment, the same physical laws apply there as they do on Earth. The effect of gravity is predictable on Mars and on Earth, and light behaves in the same way, whether it is reflected from Venus's clouds or absorbed by Mercury. "Speed Freaks" makes the point that the same laws of physics that apply to speed and motion on Earth also apply in space.

3. Science is exploration – and space is the biggest "laboratory"

By looking into space, we have been able to discover things about our own planet. When Galileo used his telescope and discovered moons orbiting Jupiter, he was able to use this information to confirm that Earth orbits the Sun. We have recently sent up space probes to send back close-up images of Jupiter's moons – a remarkable feat – and we are discovering more about what conditions are needed for life on other worlds.

Science also involves imaginative exploration, a point made by "Close Up", a science fiction story about how a space expedition fails to detect alien life because the life form was not what the expedition expected. Now that hundreds of extrasolar planets (planets orbiting other stars) have been found, the idea of discovering extraterrestrial life elsewhere seems possible. (New Zealand and Japanese astronomers are involved in the search for new planets through the Microlensing Observations in Astrophysics, or MOA project, at Mt John Observatory in Tekapō.)

One of the most likely places to search for life is Mars and, over the next few years, dozens of missions are planned for the red planet. There is a lot of debate about whether to send manned or unmanned missions to Mars. This theme is worth exploring with students as it challenges them to think about the different requirements and likely science dividends for each type of mission.

Astronomical distances are difficult to grasp. Using several comparative models of size and scale will help students to appreciate ratios. The solar system can be modelled in the classroom using a scale of 10 centimetres for an astronomical unit (AU) or on a rugby field using a 1 metre scale. An AU is the distance from the Earth to the Sun or 149 598 000 kilometres.

4. Science and society (understanding about science)

A key theme in *Connected 3 2009* is that astronomy/science discoveries and new technologies have changed the way people think, especially about our place in the universe. In 400 years, we have moved from thinking the Earth was at the centre of the universe to discovering that neither the Earth nor human beings are at the centre of the solar system, our galaxy, or the universe.

We have also changed the way we gain knowledge because we no longer rely only on reasoning, imagination, and our own senses. We now have powerful equipment to help us see better, think better, and collect more data that we can analyse in ways that weren't previously possible. We have been able to send machines to places where humans cannot venture.

However, it has not always been smooth sailing, as "Galileo's Legacy" makes clear. People don't always want, or are not ready, to hear what scientists tell them. (Global warming is an excellent modern example of this struggle.) Sometimes equipment fails as described in "Mission to Jupiter". Sometimes scientists get it wrong or miss seeing something important, as the astronauts do in "Close Up". Scientists make mistakes, have their own prejudices, and are just as subject to peer pressure as other groups. The difference is that scientists invite criticism from their peers and that arguments are eventually settled with good data.

Galileo wrote in common Italian rather than in the usual academic Latin because he wanted ordinary people to have access to scientific information. The Internet serves a similar purpose today, but people can find it just as hard to distinguish the "truth".

You could use any item in *Connected 3 2009* to introduce the concept that the source of any information is important in forming a judgment about how reliable it is. Direct your students' attention towards noticing writers' qualifications, experience, and reputation, and the application of peer review (for example, publishing in journals that are peer-reviewed by other scientists in the same field). Encourage them to seek out authoritative views.

5. Advances in technology

"Galileo's Legacy" and "Mission to Jupiter" provide contexts for exploring technology. "Galileo's Legacy" relates to ideas in the Nature of Technology strand. The focus for learning is the characteristics of technology component from this strand. This story can be used as a starting point for developing learning experiences in the other components of technology. "Mission to Jupiter" offers an opportunity to discuss the importance of models and prototypes in the context of space exploration.

Ministry of Education resources

- *Making Better Sense of Planet Earth and Beyond*, Science Focus: Astronomy (levels 1–4), pp. 91–126, which includes activities

- BSC Book 8 *The Moon: Orbits, Appearances, and Effects* (levels 3–4), Book 20 *Our Star, the Sun: Life and Time in a Solar System* (levels 1–2), and Book 27 *Exploring Space: Discovering Our Place in the Universe* (levels 3–4)
- BSC *Space: A Picture Pack for Levels 1–4* and *Space Posters: A Set of Posters for Levels 1–4*
- *Connected 3 2003* includes items on the following themes: the origins, development, and eventual extinction of various classes of star; the Matariki/Pleiades star cluster; the festival of Matariki and celebrations involving stars and other celestial bodies; the origins and behaviour of shooting stars; understanding and working with very big numbers; astronomical mathematics; and the historical development of telescopes.

Web resources

- **The International Year of Astronomy** at http://www.astronomy2009.org
- **The International Year of Astronomy in New Zealand** at http://www.astronomy2009.org.nz
- **European Space Agency (ESA)** at http://www.esa.int/esaCP/index.html (See especially ESA Education on the right navigation.)
- **NASA** at http://www.nasa.gov
- **NASA Kids' Club** at http://www.nasa.gov/audience/forkids/kidsclub/flash/index.html
- **Solar System lesson finder** at http://solarsystem.nasa.gov/educ/lessons.cfm
- **Space Telescope Science Institute (STScI)** at http://www.stsci.edu (See especially News and Outreach on the top navigation and follow the links to Education.)
- **Astronomy Picture of the Day** at http://apod.nasa.gov/apod (This site is a marvellous source of images and brief descriptions.)
- **The Internet Encyclopedia of Science (David Darling)** at http://www.daviddarling.info/encyclopedia/ETEmain.html (This site has excellent sections on astronomy, astrobiology, and space flight.)
- **Chignecto-Central Regional Schools Board** at http://schools.ccrsb.ednet.ns.ca/tins/science/grade9.html (This site lists several other relevant websites.)

Eye Spy

Possible achievement objectives

Note: All achievement objectives are quoted from The New Zealand Curriculum (2007).

Science

Students will:

Nature of Science

Understanding about science (UaS)

- L3/4: Appreciate that science is a way of explaining the world and that science knowledge changes over time.

Planet Earth and Beyond

Astronomical systems (AS)

- L3/4: Investigate the components of the solar system, developing an appreciation of the distances between them.

Physical World

Physical inquiry and physics concepts (PI&PC)

- L1/2: Seek and describe simple patterns in physical phenomena.

Key ideas

- The invention of the telescope helped scientists learn more about space and changed their theories about how the objects in space behave.
- The Earth is a small part of the solar system, which is part of the Milky Way Galaxy, which is part of the universe.
- In the universe, there are many different kinds of objects, including stars, planets, moons, and meteorites.
- Earth shares common features with the other objects, and the same laws that apply to Earth also apply to them.
- From Earth, we can most readily see some nearer objects and those further ones that are brighter (because they have more size or mass).

Shared learning goals

We are learning to:

- name and describe some of the different kinds of objects in the universe (AS)
- name and describe the planets and some major constellations that we can see in the New Zealand night sky (AS)
- explain some of the changes visible in our night sky (for example, the Moon's phases or the planets' movements) (AS)
- explain some of the features that these objects have in common and the laws that they obey (AS, PI&PC).

Developing the ideas

Looking outwards

This section relates to the following learning goals. We are learning to:

- **name and describe some of the different kinds of objects in the universe (AS)**
- **explain some of the changes visible in our night sky (for example, the Moon's phases or the planets' movements) (AS)**
- **explain some of the features that these objects have in common and the laws that they obey (AS, PI&PC).**

NB: "Eye Spy" refers to four readily visible planets: Saturn, Jupiter, Mars, and Venus. It also refers to Mercury, which is occasionally visible at dusk or dawn.

"Eye Spy" identifies the main visible components of the universe in order of increasing distance from earth and size (mass):

- the Moon
- planets
- stars
- the Milky Way Galaxy and other galaxies. (Note, however, that the Milky Way is actually one of the bigger spiral galaxies and is much larger than the nearest visible galaxies, the Large and Small Magellanic Clouds.)

Focus question

- *Did you notice any repeating patterns in the descriptions of the Moon, the planets, stars, and galaxies?*

Answers could include:

- that our moon orbits the earth in the same way that the planets orbit the Sun, or, to put it generally, smaller bodies orbit larger ones
- that celestial bodies can be described in a hierarchical progression from small, single entities to large clusters. The Sun is one of about 200 billion stars in the Milky Way Galaxy, which is one of billions of galaxies in the universe. A common analogy is to think of the galaxy as a city of stars. The Sun, with its family of planets, is one of about 200 billion inhabitants living in the suburbs of the galaxy about two-thirds distant from the universe's CBD. Any students who have amused themselves by writing their address in the universe (Ms Sunny Light, 2 Rocky Road, Wellington, Aotearoa New Zealand, Planet Earth, Solar System, Milky Way Galaxy, the Universe) will already have encountered this idea.

Looking at our own night sky

This section relates to the following learning goal. We are learning to:

- **name and describe the planets and some major constellations that we can see in the New Zealand night sky (AS).**

“Eye Spy” encourages students to find the visible objects described for themselves and to notice differences between them – how they move and their colour and brightness, for example. You could use further activity 1 (below) to guide students’ observations of the night sky.

Focus question

- *How can we tell if a celestial object is close to earth?*

Brightness can be an indicator of closeness, but *a key distinction is the difference between apparent size and brightness and actual size and brightness*. For example, the Moon appears big and bright, but it is actually the smallest of the objects easily visible from Earth. It appears bright because it is close. It seems almost as big as the Sun, but this is because it is 400 times closer than the Sun, which is actually much larger.

Another way of detecting the closeness of an object to Earth is to see how quickly it moves across the sky. The Moon moves rapidly against the background stars, rising and setting 50 minutes later each day; planets move more slowly relative to the stars, while stars appear constant (although they do rise 4 minutes earlier each day). You can notice the same effect, which is called parallax, when you are travelling on a highway. The trees by the side of the road seem to whiz by, but mountains in the distance stay relatively still.

The movement of the stars can be simply illustrated using further activity 3 (below).

The idea that appearances (apparent movement or brightness) can be misleading is reinforced in “Speed Freaks”, where the travellers on Earth find that apparently stationary stars are moving very quickly indeed.

Focus questions

- *What is a constellation?*
- *What are some of the important constellations in New Zealand’s night sky?*

Astronomers have a different name for constellations: they call them asterisms. A constellation is a grouping of heavenly bodies (usually stars) that appear to the observer to make a pattern in the sky or to be related to each other. In reality, the stars in a constellation observed from earth may be many light years apart. Four constellations important to New Zealand are named on pages 6–9.

While the Southern Cross (its astronomical name is Crux) is always visible in our sky, Scorpius, Orion, and the Pleiades (or Matariki) take turns. Scorpius is in our night sky throughout the winter months, and Orion is prominent during summer. When Matariki rises in June at midwinter, it announces the Māori New Year.

The Southern Cross, Scorpius, and Orion constellations are the main “lighthouses” of the southern sky, which we can use to navigate our position both on Earth and relative to other constellations. Each of these three constellations is part of the Milky Way.

Rocky objects

This section relates to the following learning goal. We are learning to:

- **explain some of the features that these objects have in common and the laws that they obey (AS, PI&PC).**

Focus questions

- *What are some of the geological features of rocky planets, such as the Earth, Mars, Venus, and Mercury or other rocky objects such as the Moon?*
- *What do you think scientists can tell from observing these features?*

Rocky planets display a variety of features such as craters, mountain ranges, and gorges or valleys.

The geological features of rocky planets allow scientists to work out whether:

- volcanoes may have erupted in the past
- there may have been tectonic or crustal movement
- the planet may once have had free-flowing water.

The Moon is the only one of the rocky objects close enough for us to see features with the naked eye, that is, without binoculars or a telescope. (Students should also be encouraged to use binoculars if these are available.) Mountains, craters, valleys, and "seas" can be distinguished. The seas are in fact large basaltic plains formed by very old volcanic eruptions. The rock in the lunar seas contains a lot of iron, so they reflect less light and look darker than surrounding highlands. The surface of the Moon could be examined in more detail using further activity 2 (below).

Like the Moon and the other planets, the Earth also has craters. Meteor Crater and Chicxulub crater are famous examples. But most Earth craters are not usually recognisable because they have been eroded by weather or changed by geological processes. Astronomers use the number of craters to work out the age of the planets and moons. A very cratered surface indicates an old, barren, inactive planet.

Earth craters:

- Meteor Crater at http://neo.jpl.nasa.gov/images/meteorcrater.html
- Chicxulub crater at http://nationalatlas.gov/articles/geology/features/chixulub.html

Further activities

1. Tracking the Moon/planets/stars

Students could do a series of "skyscape" sketches over a period of time.

This can be a long- or a short-term project depending on the focus. Changes in the position of the Moon can be observed over a week; planets over a month; stars over several months, for example, once each term. The most important thing to remember is that all observations must be carried out at the same time, so allow for daylight saving.

Tell the students to find a position in or near their homes where they have a good view of the object(s) selected for observation. Remember that some objects are only visible in some parts of the sky at certain times. Observations must be made from the same position and should include foreground features, such as lamp posts and chimneys as well as the main bright stars. The students may also like to sketch in any meteors they see – they should use arrows to show their direction. Explain that what they are doing is more than drawing – they are working as scientists do when collecting data.

This would also be an opportunity to make connections to the Nature of Science strand, perhaps discussing why observational drawings are important, or asking the students to think about advances in technology from Galileo's time: "In what ways other than drawings can we now record observations?"

Some supporting materials are described below, but put the emphasis on the students drawing what they can see.

Check the Royal Astronomical Society of New Zealand at http://www.rasnz.org.nz and Stardome Observatory at http://www.stardome.org.nz to see what your students will be able to observe at particular times of the year.

The best star guides to use are those published in the annual *New Zealand Astronomical Yearbook*, available from Stardome, which also publishes monthly online guides.

Planispheres are useful but often difficult for beginners.

You can also create and download a star guide from John Walker's Your Sky website at http://www.fourmilab.ch/yoursky

The fields for making a star guide are fully explained on the Your Sky site: click on the "Explain controls" link. Any students who are digital natives may enjoy creating and comparing star guides for their own and other places or for their own night sky in different seasons.

Select a nearby city: Auckland, Wellington, or Christchurch.

At the top, choose "View horizon at this observing site".

Date and time: Universal time is 12 hours behind New Zealand standard time: 7 p.m. (19:00:00) NZST = 07:00:00 UT.

Viewpoint: Azimuth: Choose either 0 for North (default) or South and 180 degrees (you will want to produce both views) and leave the field of view at the default setting of 45°.

Observing site options: Deselect the other two boxes and select "Moon and planets" only. Under "Constellations", choose "Outlines" and "Names".

Display options: Set the "Show stars brighter than magnitude" at 3 and select the "Names" box. (You can change this later – the higher the number, the more stars are marked.) Deselect the other surrounding boxes. Select the "Terrain at horizon" box and the "With scenery" box. Set colour at black on white.

Click on "Update".

2. Identifying features on the moon

Use a map or diagram of the Moon's features to discuss these. There are several Moon map options on the Internet, including a printable option at Space.com at http://www.space.com/images/skywatchers_moon_map.gif

3. Why don't we see the same stars all the time?

Have the class stand in a circle representing the stars. Choose one person to be the Sun in the middle and another to be a planet orbiting the Sun. (This is Earth's yearly motion.) Ask the "planet" to name the persons (stars) she can see (facing outwards) from various positions in her orbit. This illustrates why we see different stars at different times of the year.

Now ask the “planet” to stand in one spot and rotate – this is the Earth’s daily motion. As she slowly orbits, get the “planet” to name the person (star) she sees directly in front of her only while facing away from the Sun. This illustrates why the stars seem to move from night to night. Ask the students why the “planet” should not name the persons (stars) she sees in front of her when she is facing the Sun. The students should be able to explain that, in the daytime, we don’t see the stars as they are blotted out by the brilliance of the Sun’s light. Be sure to emphasise that they are still there though.

Aotearoa's Star

Possible achievement objectives

Note: All achievement objectives are quoted from *The New Zealand Curriculum* (2007).

Science

Students will:

Material World

Properties and changes of matter (P&CoM)

- L3/4: Group materials in different ways, based on the observations and measurements of the characteristic chemical and physical properties in a range of different materials.
- L3/4: Compare chemical and physical changes.

The structure of matter (TSoM)

- L4: Begin to develop an understanding of the particle nature of matter and use this to explain observed changes.

Physical World

Physical inquiry and physics concepts (PI&PC)

- L3/4: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, **identify and describe the effect of forces (contact and non-contact) on the motion of objects**; identify and describe everyday examples of sources of energy, forms of energy, and energy transformations.

Key ideas

- Stars live and die on very long time scales.
- Stars are chemical factories, which produce all the elements that make up the Earth and all living things.

Shared learning goals

We are learning to:

- develop an understanding that Earth's elements come from the stars (P&CoM, PI&PC).

Developing the ideas

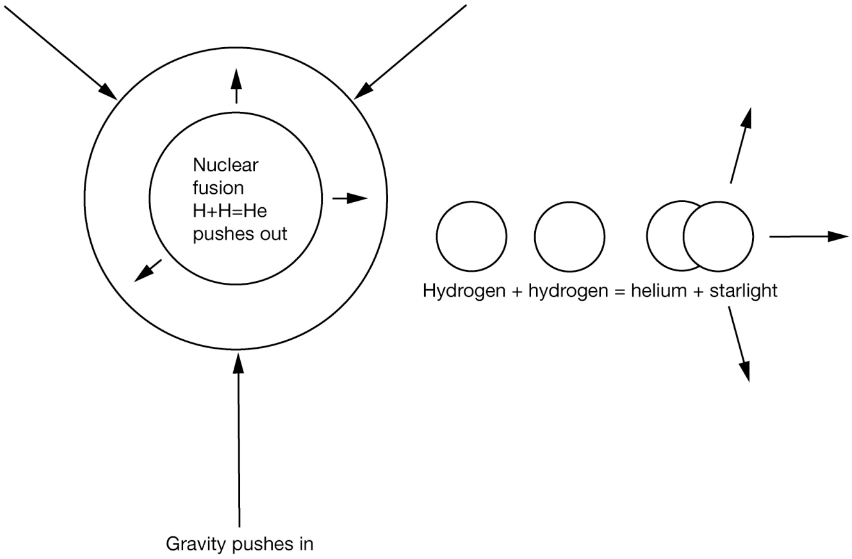
Without stars, there would be no planets and no life. This is why astronomers say that we are made of stardust or are children of the stars, meaning that we consist of the elements that the stars have made.

Focus question

- *Have you ever been caught in the middle of a large crowd? How did it feel?*

If the students remember feeling hot or pressured, this is similar to what happens to hydrogen atoms in the core of a star, where the temperature and pressure are very high. Gravity forces the hydrogen atoms together so strongly that they fuse. When that happens, a new element called helium is formed and a little bit of energy is released. We call that energy starlight.

Figure 1: How helium is formed



Stars also make other elements, such as oxygen and carbon. Only very massive stars like Eta Carinae can make really heavy elements, such as gold, uranium, and platinum, and they produce them only when they are dying in a huge supernova explosion. Elements such as gold are rare and precious because the massive stars that make them are very rare. You could use further activity 1 to introduce the idea of how many elements have been discovered and classified on Earth.

The article explains how all these elements are blasted off into space, where they will be used as the raw materials for the next round of star making and planet building.

But what causes a star to explode? When it runs out of fuel, the star collapses inwards (implodes) because it cannot resist gravity. The force is so great that the implosion rebounds, and this forces the elements out into interstellar space.

Further activities

1. The periodic table in tune

You will need to introduce the idea that scientists have developed a table listing in a systematic way all of the elements so far found on Earth. The periodic table currently contains 117 elements. The table allows scientists to classify and compare different forms of chemical behaviour.

You could help the students to sing the first 20 elements of the periodic table to the tune of "Michael Finnegan":

> Hydrogen, helium, lithium, beryllium
>
> Boron, carbon, nitrogen, and oxygen
>
> Fluorine, neon, sodium, magnesium

Aluminium, silicon
Phos-phor-us.

Sulphur, chlorine, argon, potassium
And the last one is cal-ci-um.

The most famous element song is one by Tom Lehrer. There are many versions of this on the Web. Your students may enjoy comparing two of these versions:

- Chemistry element song at http://www.youtube.com/watch?v=DYW50F42ss8&feature=related
- The element song at http://www.youtube.com/watch?v=GFIvXVMbII0

2. Supernova implosion and ejection demonstration

Implosion

Adapted from the NASA website at http://bigexplosions.gsfc.nasa.gov/documents/activities/SupernovaExplosions.pdf

Purpose: To show what happens at the end of a massive star's life as it becomes a supernova.

Practise doing this before you try it with your students! You will need:

- a hot plate or camping stove
- a couple of aluminium cans
- a bowl of very cold iced water
- tongs and/or very good oven mitts.

Heat a few tablespoons of water in a can until you see a steady stream of steam coming out the top. Quickly take the can and turn it upside down into the bowl of water. The can will immediately implode with a satisfying crunch!

This happens because at first the can is in equilibrium: the pressure of the air outside pushing down is equal to the pressure of the steam inside pushing up. When the can is put into the water, the steam condenses, and since air cannot get inside to compensate, the pressure outside forces the can to collapse. This is what happens to the core of the star. When nuclear fusion stops, there is nothing to stop gravity crushing the star.

Explosion and ejection

Adapted from the Harvard website at http://chandra.harvard.edu/graphics/edu/formal/demos/ejection.pdf

Purpose: To show how, when a star has collapsed inwards, the materials rebound or are flung outwards. This activity is best done outside.

You will need (depending on whether you are doing the activity in groups):

- one or more tennis balls
- one or more basketballs or soccer balls.

When a star has collapsed inwards, how do the materials get out, and why are they flung out so far and so fast? “Aotearoa’s Star” explains that when the core of the star collapses and bounces back, it collides with itself and with its outer atmosphere. You will need to clarify with your students that astronomers use the term “atmosphere” to describe the outer layers of a star, which are not involved in nuclear reactions at the core. Be careful that students do not think that stars have an atmosphere in our sense of breathable air and clouds.

Use the tennis ball to represent the star’s atmosphere and the basketball to represent the core. Check how high they bounce by dropping them separately. Then put the tennis ball on top of the basketball, hold them out in front and let go of both balls at the same time. When they hit the floor, the tennis ball will suddenly rebound with much more energy than when bounced on its own – that is why it is safer to do this outside!

When the core of the star implodes, it contracts catastrophically, just like the imploding can. The outer atmospheric layers are following the core, but because they are less dense, they take a little longer to contract than the core. The material in the core comes together with such force that it rebounds. When the core (basketball) rebounds, the atmospheric layers (tennis ball) are still falling inwards. The rebounding core meets the incoming atmosphere with enough energy to literally blow the outer layers away. This is the supernova explosion.

Further references

See Supernova on the NASA site at
http://www.nasa.gov/worldbook/supernova_worldbook.html

See an animation of a supernova at
http://oposite.stsci.edu/pubinfo/pr/1998/08/content/sn1987.mov

Galileo’s Legacy

Possible achievement objectives

Technology

Students will:

Nature of Technology

Characteristics of technology (CoT)

- L2: Understand that technology both reflects and changes society and the environment and increases people’s capability.
- L3: Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.
- L4: Understand how technological development expands human possibilities and how technology draws on knowledge from a wide range of disciplines.

Characteristics of technological outcomes (CoTO)

- L4: Understand that technological outcomes can be interpreted in terms of how they might be used and by whom and that each has a proper function as well as possible alternative functions.

Technological Knowledge

Technological products (TP)

- L3: Understand the relationship between the materials used and their performance properties in technological products.

Key ideas

- Technology produces outcomes that have an impact on the world.
- Technological developments are inseparable from social influences.
- Developing technological outcomes is a purposeful, innovative human activity.
- The function that an outcome is designed for is called its “proper” function. If the outcome is used successfully for a purpose other than what it was designed for, this is known as an “alternative” function.
- Alternative functions can become future proper functions.
- The development of a technological outcome involves the creative generation and testing of ideas. These ideas lead to a conceptual design for the potential outcome.
- Technological outcomes are made from materials. It is important to understand how a material’s composition relates to the way the material performs and to how it can be manipulated (shaped, joined, and/or finished).
- Materials are carefully selected and all work together to ensure that the outcome is fit for purpose.

Shared learning goals

Nature of Technology

Characteristics of technology (CoT)

For students working at **level 2**. We are learning to:

- identify some of the factors that influenced how Galileo developed the telescope
- identify how the development of the telescope changed the way people do things
- describe how the development of the telescope has had a positive and/or negative impact on society and/or the environment.

For students working at **level 3**. We are learning to:

- describe how society influenced the way that Galileo worked
- explain why instruments used to observe things have changed over time
- describe other examples of technological developments that have changed society and/or the physical environment over time
- identify the knowledge that Galileo used to develop his telescope.

For students working at **level 4**. We are learning to:

- describe how the telescope has expanded human possibilities
- discuss the short- and long-term impacts of Galileo's discoveries
- discuss what the writer means when describing Galileo as "innovative"
- discuss the importance of innovation in technological practice.

Characteristics of technological outcomes (CoTO)

For students working at **level 4**. We are learning to:

- describe how Galileo adapted the "spyglass" to produce his telescope
- use the terms "proper function" and "alternative function" in relation to Galileo's development of the telescope.

Technological Knowledge

Technological products (TP)

For students working at **level 3**. We are learning to:

- identify the structural and sensory qualities of the materials used by Galileo to produce his telescope
- explain how the materials selected worked together to allow it to function.

Developing the ideas

A purposeful and innovative human activity

The reasons for the development of technological outcomes are always linked to social, cultural, and environmental factors. The outcomes themselves impact upon the society and physical environment in which they are used.

"Galileo's Legacy" provides a context in which to discuss these ideas. The teacher's focus should be guided by the appropriate achievement objectives (see above) and by the characteristics of technology indicators of progression. Go to http://www.techlink.org.nz/curriculum-support/indicators/nature/index.htm

You could also read:

- "Easy as Child's Play" (*Connected 2 2002*)
- "First Light: The History of Telescopes" (*Connected 3 2003*)
- "A New Life for Old Machines" (*Connected 3 2007*).

These articles contain ideas about innovative solutions that have been influenced by societal and environmental issues. They also refer to the impacts the technological outcomes have or may have on the people and the environment they are designed for.

Provide the students with other examples of technological outcomes, past and contemporary, and guide the students in analysing what influenced the development of the outcome. Explore the impacts, positive and/or negative, the outcome has had on societies and/or the environment.

Further reading about the ideas in the component characteristics of technology and other suggestions for learning experiences can be found at the Techlink website at http://www.techlink.org.nz/curriculum-support/papers/nature/char-tech/index.htm

Further activity

Please note that this activity is aimed at students who are working at levels 3–4 of the curriculum. Students need to have robust understandings of characteristics of technology, characteristics of technological outcomes, technological products, and technological modelling at level 2 before attempting the activity.

Divide the class into groups and supply them with examples of technological outcomes (such as an egg beater, a torch, a chair on wheels, a stapler, a fountain pen, a packet of "heat-and-eat" noodles, an old suitcase, a typewriter). Ask each group to choose one outcome and imagine how it could be used or adapted to perform another function.

Ask the groups to develop functional models to explore and test their ideas. They can use these functional models to produce a conceptual design (a detailed drawing with specifications, a 3 D scale model, and/or a prototype) for their "new" technological outcome.

The students can:

- describe the designed function of their chosen technological outcome as its "proper function" and describe their idea for a new function as the original outcome's "alternative function"
- describe their design ideas (either by 2 D and/or 3 D drawing or by using manipulative media such as plasticine, cardboard, or wire)
- investigate and evaluate their design ideas using functional modelling
- explain what information they gathered when modelling
- explore and research potential materials to use in their outcome

- understand the relationship between the structural/sensory qualities of the suggested materials and the materials' performance properties
- investigate their designed outcome by producing and evaluating a prototype.

Further references

Further reading about the ideas in the technology components characteristics of technological outcomes, outcome development and evaluation, technological products, and technological modelling can be found in the explanatory papers on Techlink at http://www.techlink.org.nz/curriculum-support/papers/index.htm These papers also contain other suggestions for learning experiences.

Tracking Jupiter's Moons

Possible achievement objectives

Science

Students will:

Planet Earth and Beyond

Astronomical systems (AS)

- L3/4: Investigate the components of the solar system, developing an appreciation of the distances between them.

Nature of Science

Understanding about science (UaS)

- L3/4: Identify ways in which scientists work together and provide evidence to support their ideas.

Physical World

Physical inquiry and physics concepts (PI&PC)

- L3/4: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, **identify and describe the effect of forces (contact and non-contact) on the motion of objects**; identify and describe everyday examples of sources of energy, forms of energy, and energy transformations.

Key ideas

- Smaller objects orbit larger ones.
- The force of gravity and the law of motion affect the orbits of objects.
- The closeness to, or distance from, the central mass it orbits determines how fast an orbiting body will move and the length of its orbit or period of revolution
- Scientists need to work together with other experts (for example, technologists and engineers) to deal with the huge challenges of space exploration.

Shared learning goals

We are learning to:

- explain why smaller objects orbit larger ones (AS, PI&PC)
- explain what influences the period of revolution of an orbiting object (PI&PC)
- discuss examples of the way scientists work together (UaS).

Developing the ideas

Smaller orbiting larger

This section relates to the following learning goal. We are learning to:

- **explain why smaller objects orbit larger ones (AS, PI&PC).**

Jupiter is the largest planet in the solar system and one of four gas giants. It is about 1300 times the volume of Earth but only a quarter as dense because it is made of gas. Gas giants do not have a solid surface as do the solar system's rocky planets, Mars, Earth, Venus, and Mercury.

Smaller objects orbit larger ones because of:

- the force of gravity (the gravitational attraction between the two bodies, which increases with mass and decreases with distance)
- the law of motion, which states that a body will remain at rest or continue moving in a straight line unless acted on by a force (Newton's first law of motion).

The first of the further activities should help the students grasp the concept of orbits. Note that orbital motion is sometimes described as "falling" because the force of gravity is what makes objects fall back to Earth.

Help the students to expand their understanding of the concept of orbits by thinking about Newton's first law of motion (also called the law of inertia).

Focus questions

- *What do you think makes objects move?*
- *What do you think stops them moving?*
- *What might happen if a car collides with a stationary one in front of it and the passengers in the moving car are not wearing their seatbelts? Can you explain why?*

Newton's law explains:

- the tendency of objects to stay still unless they receive some kind of push (energy) to get started, for example, the movement of a car being powered by its engine
- the tendency for objects to keep moving unless they are forced to do something different, for example, a moving car needing brakes to stop.

Newton's law explains why we wear seatbelts in cars to prevent us from continuing to move at the speed of the car we are in if it hits a stationary object in front of it.

On Earth, friction and our atmosphere slow moving things down eventually. In space, moving objects will just keep moving.

Periods of revolution

This section relates to the following learning goals. We are learning to:

- **explain what influences the period of revolution of an orbiting object (AS, PI&PC)**
- **discuss examples of the way scientists work together (UaS).**

"Tracking Jupiter's Moons" gives students the orbital periods of four of Jupiter's moons. (Jupiter has 63 confirmed moons.)

In space, the *closer an orbiting body is to the central mass that it orbits, the faster it will move and the shorter its orbit* or period of revolution. (The same concept is explored in

"Speed Freaks".) To reinforce this point, students could attempt further activity 4, based on data for Saturn's moons.

Tracking Jupiter's moons is not as difficult as it sounds. Given co-operative weather, this is well within the capability of an able, motivated student with a modest telescope or stable binoculars. (Ideally, binoculars should be mounted.) See the suggestions for making regular observations of celestial objects in "Eye Spy".

Focus question

- *Can you think of a way to determine Jupiter's rotational period, that is, the time it takes to spin on its axis (its "day")?*

The colourful cloud bands on Jupiter and the Great Red Spot (GRS), which can be seen to the upper left of the planet, are the clue. Scientists use these as markers to determine how long it takes Jupiter to spin. They can see that it spins more rapidly at the poles than at the equator.

The GRS has been observed for over 300 years and is exactly what it looks like, a hurricane. Although Jupiter shares some common features with Earth, its atmosphere is very different from our own. It is largely made of hydrogen and helium, which are colourless gases. The colours in Jupiter's clouds come from chemicals in the atmosphere, which react differently to sunlight or are affected by constant lightning storms in the upper atmosphere.

Focus question

- *What tools or technologies have scientists used to discover and identify more about Jupiter's moons?*

Discussing Galileo's observations of Jupiter's moons is a good opportunity to cover advances in optical research and technology, which should be familiar to any students who wear glasses. (Those who wear contact lenses may be interested to know that they are a development of space science technology, originally developed to protect astronauts' eyes.) Tools and technological advances include:

- early optical telescopes, such as Galileo's
- more powerful modern telescopes
- different kinds of telescopes, for example, those that monitor radio signals or the Hubble Space Telescope, which can make observations that are not distorted by Earth's atmosphere
- space probes that can take cameras and other instruments onto or close to the planet or its moons and transmit data back to Earth
- modern computing technologies that enable the huge amount of data from, for example, a space probe, to be processed and analysed.

Astronomers today marvel at how Galileo was able to distinguish the orbits of the Jovian satellites with such precision, using such poor lenses. Galileo was able to distinguish the moons from the planet because he was seeing a magnified image: starlight passing through his lens was bent in a particular way to achieve this.

An interesting story relevant in this context concerns the problems with the Hubble Space Telescope's optics, which originally gave blurry images. NASA had to use the space shuttle to deliver corrector lenses, in effect, glasses, and the astronauts had to space-walk to fit them. You could also make the UaS connection that scientists and other experts have to share their expertise and work in collaboration on the complex challenges of space exploration.

Further activities

1. Discovering orbital motion

Have students stand in pairs holding one hand. One represents a planet and the other represents the planet's moon. On a given signal, the "planet" will turn slowly around on the same spot. The moon will try to go in a straight line. Both must stay holding hands. The moon will discover that, although it wants to go straight ahead, the gravitational force of the planet keeps it in orbit.

2. First law of motion

Use books or a bench for a horizontal surface that can be inclined and toy cars or balls to show that:

- (when the surface is flat) an object needs a force to start it moving from rest
- (after the surface is inclined) an object needs a force to stop it once it is moving – the balls and cars keep moving on the sloped surface and onto the horizontal surface beyond it.

Note that on Earth, moving objects are stopped through friction, including air resistance. Planets are not in contact with a surface (or air) and keep moving.

3. Period of revolution

Stick a small ball of plasticine onto one short edge of a metre-long stick and one onto that of a ruler. Stand them up (ball on top) side by side on a flat surface, holding them near the top. Release both at the same time.

The shorter stick will hit the ground first because it has less distance to fall. This is similar to the movement of the planets, which are "falling" around the Sun. Mercury, at only 58 million kilometres from the Sun, has an orbital period of just 88 days. Jupiter, 778 million kilometres distant, takes nearly 12 years to orbit the Sun.

4. Saturn's moons

A follow-up activity could be to use the orbital periods of some of Saturn's main moons to work out their order of distance from the planet and to express this as a diagram, with the moons ranged outwards from the central mass of Saturn.

The orbital periods of some of the larger moons are listed (mixed up) below. (Your students may be impressed by the thought that Saturn has 53 officially named moons and many more that are not as yet named.)

Moon	**Orbital period in days**
Dione	2.7
Atlas	0.6
Iapetus	79
Tethys	1.9
Janus	0.7

Hyperion	22
Pandora	0.62
Helene	2.7
Epimetheus	0.69
Enceladus	1.4
Titan	15.9
Pan	0.57
Calypso	1.9
Mimas	0.9
Rhea	4.5
Prometheus	0.61
Phoebe	548
Telesto	1.9

Note: Phoebe goes backwards, possibly because it is a captured asteroid. The moons are listed in correct order of distance below.

Moon	**Distance (kms) from Saturn**
Pan	133 570
Atlas	137 640
Prometheus	139 350
Pandora	141 700
Epimetheus	151 422
Janus	151 472
Mimas	185 520
Enceladus	238 020
Tethys	294 660
Calypso	294 660
Telesto	294 660
Dione	377 400
Helene	377 400
Rhea	527 040
Titan	1 221 850
Hyperion	1 481 000
Iapetus	3 561 300
Phoebe	12 952 000

Note that Tethys, Calypso, and Telesto all have the same orbital period. Calypso and Telesto travel around Saturn in the same orbit as Tethys but about 60 degrees ahead of and behind it. (This is a resonance effect.)

Visit the website for NASA's Cassini Equinox Mission to view images of Saturn's main moons at http://saturn.jpl.nasa.gov/science/moons

5. Colours in Jupiter's clouds

You will need:

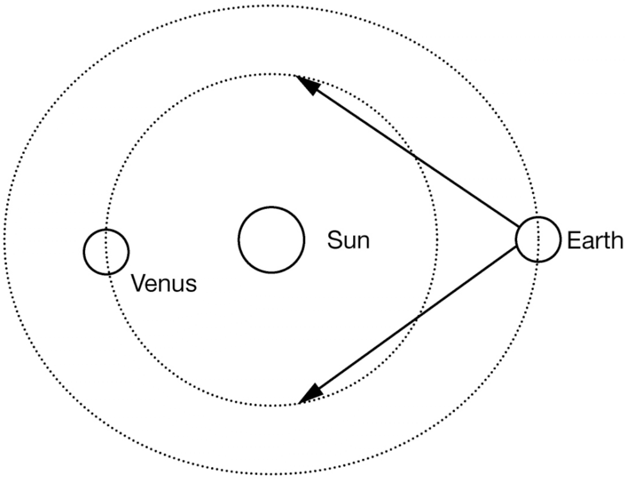
- photosensitive paper from photographic suppliers (keep it covered)
- cardboard the same size as the paper
- double-sided sticky tape
- a semi-darkened classroom.

Cut out any shape within the cardboard rectangle. Fasten double-sided tape onto the back of the cardboard rectangle. Quickly stick the cardboard rectangle onto the glossy side of the paper and take it outside into the sunlight or expose it to a lamp for a minute or two. Bring it back inside and peel off the cardboard. The cut-out shape will show as a dark patch because light chemically activates molecules on the glossy surface of the paper. This is similar to what happens on Jupiter: sunlight and lightning react with different chemicals in the clouds, giving different colour effects.

6. The phases of Venus

Galileo was able to confirm that Venus was between the Earth and the Sun because Venus has phases, rather like the phases of the Moon. Note that we do not see Venus in full phase, because this happens when Venus is behind the Sun, and it is extremely difficult to see Venus as a crescent. It is very easy to see Venus at half phase.

Figure 2: Venus's phases



Venus is invisible to us on Earth when it is behind the Sun, but where the arrow points, it is visible as a half moon. When it is directly between Earth and the Sun, it is also invisible because its dark side is facing us.

Further references

Newton's laws of motion

Georgia Louviere's website (based on a teacher training programme sponsored by the Centre for Research on Parallel Computation and the National Science Foundation) has simple relevant animations. Go to http://teachertech.rice.edu/Participants/louviere/Newton/law1.html

See also the University of Tennessee Astronomy 161 page on Newton at http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html

Speed Freaks

Possible achievement objectives

Science

Students will:

Nature of Science

Understanding about science (UAS)

- L3/4: Appreciate that science is a way of explaining the world and that science knowledge changes over time.
- L3/4: Identify ways in which scientists work together and provide evidence to support their ideas.

Planet Earth and Beyond

Astronomical systems (AS)

- L3/4: Investigate the components of the solar system, developing an appreciation of the distances between them.

Physical World

Physical inquiry and physical concepts (PI&PC)

- L3/4: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, **identify and describe the effect of forces (contact and non-contact) on the motion of objects**; identify and describe everyday examples of sources of energy, forms of energy, and energy transformations.

Key ideas

- Everything is in motion.
- Motion is relative (to an observer or some fixed object).
- The speed of light is constant.
- Within science programmes, such as the NASA space exploration missions, science knowledge may advance very rapidly and scientists work together with other experts to achieve the mission outcomes.

Shared learning goals

We are learning to:

- explain why objects in the solar system, and the Milky Way Galaxy itself, rotate (AS, PI&PC)
- understand more about the model of the Big Bang and the expanding universe (UaS, AS)
- understand more about motion and the speed of light (PI&PC)
- discuss examples of how scientists work with other experts in areas of rapidly developing scientific knowledge (UaS).

Developing the ideas

"Speed Freaks" draws on our fascination with speed as well as providing an appropriate context for introducing and discussing the key aspects of contemporary standard cosmology, such as the Big Bang, the expanding universe, and the relationship between energy and matter expressed in Einstein's famous equation $E=mc^2$. Students are likely to recognise the terms even if they are not familiar with their meanings.

Focus questions

- *Has anybody heard the term the Big Bang? What do you think it means?*
- *Has anybody heard of the scientist Albert Einstein before – what do you know about him?*
- *What do you know about the speed of light?*

In unpacking the different sections and the ideas introduced in this article, you could also draw the students' attention to how scientists explain the world. The *Big Bang* is a model of how the universe has developed, based on: observations; accepted understandings, such as the law of gravity; and the thinking of many scientists. Edwin Hubble, after whom the space telescope is named, observed that galaxies are moving away from the Earth and galaxies that are farther from us are moving faster. Scientists infer that this expansion began with a giant explosion from an unknown hot and dense condition in the past. The term Big Bang is credited to Fred Hoyle, a scientist who did not at the time believe this model was correct but whose work subsequently contributed to thinking about the Big Bang.

When discussing *Einstein's equation*, you could make the connection for the students (communicating in science) that scientific ideas can be expressed mathematically. If you and your students would like to find out more about Einstein, the Nobel Prize site includes a biography of Einstein at http://nobelprize.org/nobel_prizes/physics/laureates/1921/einstein-bio.html

The American Institute of Physics site includes a brief overview of Einstein's quest to find the most general laws of physics that would bring together other theories in a "unified field" theory. Go to http://www.aip.org/history/einstein/philos1.htm

More for super science sleuths

Scientists are continuing to investigate whether a unifying theory or set of laws is possible. One investigation involves an amazing machine, the Large Hadron Collider, which is a literally massive example of scientific co-operation. This huge underground installation crosses the border between Switzerland and France. Your students may enjoy the Large Hadron rap – accessed online over 5 million times. Go to http://www.youtube.com/watch?v=j50ZssEojtM

The author of "Speed Freaks" explains our planet's *orbital motion* as a consequence of the solar system forming from a spinning cloud of gas and dust. Gravity is still the main factor at work. The cloud was set spinning when, through gravitational attraction, matter started to fall towards the dense centre. The more the cloud collapsed, the faster it began to spin. The same effect can be seen when an ice skater draws her arms towards her body to spin faster.

A good introduction to the key idea that *motion is relative to an observer* or fixed point is provided on the School for Champions website at http://www.school-for-champions.com/science/motion.htm

Further activities

1. Expanding universe

Draw galaxies on a balloon and then blow it up. The galaxies will move away from each other as the balloon expands. Note however, that with drawings on a balloon, the galaxies also get bigger. This is NOT what happens in space. It is the space between the galaxies that expands.

2. Speed of sound

On Earth, we can't measure the speed of light, but it is possible to measure the speed of sound on Earth. This experiment can be done as a class or in groups. You will need:

- at least 3 people
- several balloons
- a funnel
- flour
- a stopwatch
- a pin
- a pencil and paper to record results
- access to a rugby field or a similar area.

Use the funnel to put about a tablespoon of flour into each of the balloons. Blow the balloons up and tie a knot in the end. A rugby field is 100 metres long. One person with a stopwatch should stand at one end. One person with the balloons and a pin should stand at the other end, next to a third person who will give a signal (such as dropping an arm) when the balloon is popped.

The timekeeper starts the stopwatch as soon as they see the signal and stops it as soon as they hear the bang. (Have a few practices first.) Take several recordings. Even if the timing is not perfect, the students should notice that they see the flour before they hear the bang.

To calculate the speed (v), you have to find out how far the sound has travelled (distance in metres, d) and how long it took in seconds (t): $v = d/t$. For example: if the bang was timed at 0.3 seconds, $v = 100\text{m}/0.3 = 1000/3 = 333.3\text{m/s}$. Ask the students if it was a good idea to take several recordings and why. Compare the results between different groups: are the average results pretty much the same?

Close Up

Possible achievement objectives

Science

Students will:

Living World

Ecology (Ec)

- L3/4: Explain how living things are suited to their particular habitat and how they respond to environmental changes, both natural and human-induced.

Life processes (LP)

- L3/4: Recognise that there are life processes common to all living things and that these occur in different ways.

Planet Earth and Beyond

Earth systems (ES)

- L4: Develop an understanding that water, air, rocks and soil, and life forms make up our planet and recognise that these are also Earth's resources.

Astronomical systems (AS)

- L3/4: Investigate the components of the solar system, developing an appreciation of the distances between them.

Nature of Science

Understanding about science (UaS)

- L3/4: Identify ways in which scientists work together and provide evidence to support their ideas.

Material World

Chemistry and society (C&S)

- L3/4: Relate the observed, characteristic chemical and physical properties of a range of different materials to technological uses and natural processes.

Key ideas

- Liquid water is a key condition for life to develop.
- Extraterrestrial life may be very different to life on Earth and will be suited to very different habitats and environments from those on Earth.
- Scientists/astronomers are searching for planets that might support extraterrestrial life.

Shared learning goals

We are learning to:

- describe the conditions necessary for life as we know it on Earth (Ec, LP, ES)
- explain the importance of liquid water to life forms (Ec, LP, ES)

- describe what an alien creature might be like, given a set of different conditions from those on Earth (LP)
- describe some of the challenges facing the scientists and astronomers searching for extraterrestrial life (AS, C&S, UaS).

Developing the ideas

“Close Up” is set in the future, when a space crew is sent to investigate a planet that has shown some signs of life – microscopic life as it turns out! The life we may find on other worlds may very likely be microbial, but this story introduces the exciting possibility of intelligent microbial life.

Finding any extraterrestrial form of life is a huge challenge and a very significant focus of a large number of space missions both within and outside the solar system.

The constituents necessary for life as we know it

This section relates to the following learning goals. We are learning to:

- **describe the conditions necessary for life as we know it on Earth (Ec, LP, ES)**
- **explain the importance of liquid water to life forms (Ec, LP, ES).**

Focus questions

- *What are the main constituents necessary for life as we know it?*
- *Do you think that any one of the things you have suggested is more important than the others? Why?*

Answers include:

- a source of energy (for Earth, our star the Sun, or for extrasolar planets, a star)
- a rocky planet, the right distance from the Sun/star (the “goldilocks” zone, which is not too hot and not too cold)
- an atmosphere to protect life from deadly radiation
- most of all, liquid water.

Water has unique properties, which make it easy for the carbon compounds to form on which all life is based. These unique properties also help to regulate and moderate climates. For example, water is densest at 4°C so, when planets freeze over, life can still exist in the liquid water below the ice. Water stores energy well, keeping continents warmer in winter and cooler in summer. Water absorbs carbon dioxide, a greenhouse gas, and stops the planet heating up too quickly, which would make the water evaporate. (A small amount of carbon dioxide in the atmosphere is useful to stop things from getting too cold, however. Carbon dioxide is released into the atmosphere when rocks are eroded and also through volcanic activity. For this reason, most scientists believe that planets supporting life have to be geologically active.)

Most ET searches are therefore based on the search for liquid water. Oxygen is not strictly necessary for life. Scientists know of microbes that do not require oxygen, for example, cyanobacteria. (Cyanobacteria, which formed the earliest fossils, stromatolites, were responsible for oxygenating the Earth’s atmosphere). However, oxygen could be an important biosignature (a marker for life) on some planets, as it is on Earth.

The challenges for searchers

This section relates to the following learning goals. We are learning to:

- **describe some of the challenges facing the scientists and astronomers in the search for extraterrestrial life (AS, C&S, UaS)**
- **describe what an alien creature might be like, given a set of conditions different from those on Earth (LP).**

Focus question

- *What are some of the challenges for scientists looking for ET life forms?*

As "Close Up" illustrates, *knowing what to look for* is one of the challenges. Scientists expect life forms to be adapted to their habitat and also that differences in gravity, atmospheric composition, energy sources and so on will influence the appearance of any developing life forms. On the other hand, many living things share such physical characteristics as organs for seeing, breathing, moving, and so on. This allows scientists to make an educated guess at what life on other planets *may* look like by looking at the physical characteristics of extremophiles and other life forms existing in extreme habitats on Earth.

For scientists on Earth, finding planets that may support extraterrestrial life is a huge challenge. The *greatest challenge is distance*. Refer your students back to "Eye Spy". The closest visible star to Earth is the brightest pointer to the Southern Cross, Alpha Centauri. It comprises two main stars similar in size to our Sun and is just over four light years away, yet we see it only as a small point of light. If it were 30 light years away, we would not see it at all!

Next, have your students consider *how difficult it is to see* a small, faint object right next to a bright one and how much more difficult it is when these objects are further away. Most telescopes do not have the resolution to directly image a planet, so astronomers have to use other clever techniques to help them find planets around stars. Most of these techniques are directed towards finding very massive planets close to their host stars. These planets are often referred to as "hot Jupiters" – they are usually much larger than Jupiter, and they are so close to the star that they orbit it in just a few days. Is it likely that they will harbour life?

New Zealand astronomers are using a technique called gravitational microlensing, which is probably the best technique we have at present to find Earth-like planets at a distance. To find out more about this New Zealand–Japanese initiative, your students could visit the MOA (Microlensing Observations in Astrophysics) site at http://www.phys.canterbury.ac.nz/moa

Although several hundred extrasolar planets (or "exoplanets") have been discovered over the past decade, most of these planets are very unlike Earth, and it is difficult to see how they could sustain life. The challenge for planet finders is therefore to find Earth-like planets.

Finding *intelligent* life: the Search for Extra Terrestrial Intelligence (SETI) is even more difficult. Radio astronomers conduct searches by "listening" for signals, which may indicate intelligent life. This involves a huge amount of computer processing time. SETI was the first scientific group to make use of ordinary people's computers. When not in use, they are linked to the SETI programme, which uses them to analyse data. Some students may like to link to the SETI@home project.

Students should also be encouraged to think about the *logistical implications* of people travelling to other planets and to consider the comparative advantages and disadvantages of manned or unmanned space missions.

Use further activity 2 (below) to help students think further on what an alien life form might be like.

Further activities

1. Materials for better, stronger spaceships

Space is a dangerous environment, and space vehicles have to be light enough to be sent into orbit but strong enough to withstand micrometeorites piercing their shell. This experiment shows how scientists may be able to use the properties of crystals to help design better shields for spaceships.

You and the students will need:

- a darkened room
- a brick
- a hammer
- peppermint ring-shaped lollies.

Put a lolly on the brick and hammer it sharply – the students should see a blue-green flash of light (triboluminescence) as the sugar crystals in the lolly break. (The students can experiment to see if their friends can see the same thing when they bite one of the lollies!) Triboluminescence (try–bo–loom-in-essence), the light given off by crystals under pressure, may be used to detect or warn of weak spots in the spaceship's outer shield.

2. Design an alien

Note that living things are suited to their particular habitat, so the first thing the students have to decide is what sort of planet their alien lives on and what its habitat is. Then they can design the correct physical characteristics for the alien. Ask them to consider:

- **Gravity:** Small planets with low gravity could sustain much taller plants and animals – a giraffe-like animal could have a neck twice as long as Earth giraffes, and insects could be much bigger, since the weight of their exoskeletons would not be such a problem. Conversely, massive planets would favour tough, low plants and large animals with strong, thick skeletons.
- **Energy source:** Is the star distant or close? Is the planet tilted so it has seasons? Is the orbit stable or variable? If the planet spends long periods far from its star, life forms might be cryogenic, or able to withstand supercool conditions for long periods. Our eyes are optimised to see light from the yellow Sun. Animals that live in dimmer environments would need bigger eyes, and animals in brighter environments might need protection or eyes that can retract.
- **Temperature:** Think about thick fur, shields for eyes and noses, and absorbent colours in ultra-cold climates.

- **Atmosphere**: The alien's lungs might be bigger or smaller depending on the amount of available oxygen. If the planet is covered by water, the alien's breathing apparatus may need to be extended.
- **Water and landmass**: How much of the planet is covered in water? Does the water exist only in smaller pools? Is the water salty? Are there volcanoes? (For various reasons, astrobiologists believe vulcanism is an important factor for conditions suitable for life.) Could the alien exist in the atmosphere, rather than on the planet's surface? (Bacteria have been found in Earth's atmosphere, and some scientists believe that sulphur-eating microbes may exist in Venus's atmosphere.)

3. Showing the resolution of a lens

Resolution is the ability to distinguish detail. It is the most important feature of a telescope and of most astronomical instruments (including our own eyes).

You and the students will need:

- a torch
- black paper
- a pin
- scissors
- a ruler
- masking or sticky tape
- a pencil
- a glass of water.

Cut a circle of paper to fit over the end of the torch and secure it with tape. Use the pin to make two holes in the centre of the paper about the width of a pencil lead apart. Turn the torch on and put it on a table with the beam facing out. Suggest that the students experiment with standing close to the torch and, keeping their eyes on the two dots, slowly walking backwards until the two dots merge into one. You all know there are two dots, but the person who has backed away can no longer see them from further off.

The closer you are to an object and the bigger the lens (telescope), the easier it is to see detail.

Now try looking straight into the light beam through a glass of water. The water bends (refracts) the light, making it difficult to see the image clearly. This is what happens with our atmosphere, which is why the Hubble Space Telescope can resolve images better than bigger telescopes on Earth.

Cut out another circle of paper, making one larger hole with a pencil and a pinhole as close as possible to it. Repeat the first exercise. You will see how difficult it is to resolve the smaller light beam when "blinded" by the light from the bigger hole.

4. Logic puzzle

Ask your students to consider this scenario. 2030: The space probe has just come back from Europa with a sample of one of the life forms found in the great ocean under Europa's icy surface. Experiments on board have shown that these microscopic Euro-amoebas reproduce by splitting in two, which they do every five minutes. If it takes 4 hours to fill one jar beginning with two Euro-amoebas, how long will it take for a second jar to be filled beginning with just one?

(Answer: 4 hours 5 minutes.)

Further resources

The NASA Astrobiology Roadmap outlines pathways for research and exploration for life on other worlds at http://astrobiology.arc.nasa.gov/roadmap

Visit SETI@home at http://setiathome.ssl.berkeley.edu

Mission to Jupiter

Possible achievement objectives

Science

Students will:

Physical World

Physical inquiry and physical concepts (PI&PC)

- L3/4: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, **identify and describe the effect of forces (contact and non-contact) on the motion of objects**; identify and describe everyday examples of sources of energy, forms of energy, and energy transformations.

Planet Earth and Beyond

Astronomical systems (AS)

- L3/4: Investigate the components of the solar system, developing an appreciation of the distances between them.

Nature of Science

Understanding about science (UaS)

- L3/4: Identify ways in which scientists work together and provide evidence to support their ideas.

Technology

Students will:

Nature of Technology

Characteristics of technological outcomes (CoTO)

- L3: Understand that technological outcomes are recognisable as fit for purpose by the relationship between their physical and functional natures.

Technological Knowledge

Technological modelling (TM)

- L3: Understand that different forms of functional modelling are used to inform decision making in the development of technological possibilities and that prototypes can be used to evaluate the fitness of technological outcomes for further development.

Technological products (TP)

- L4: Understand that materials can be formed, manipulated, and/or transformed to enhance the fitness for purpose of a technological product.

Key ideas

- The technique of gravity assist can be used to power and speed unmanned space probes to explore the other planets in the solar system and their moons.

- Scientists are working together with other experts to explore the other planets and their moons to expand their understanding of the solar system.

Shared learning goals

We are learning to:

- discuss what we might learn from space probes (AS, UaS)
- name and describe some methods of powering unmanned space probes and debate the safety of these (PI&PC)
- describe the gravity assist technique (PI&PC)
- explain the importance of modelling or prototyping in developing unmanned space probes (CoTO, TM, UaS)

Developing the ideas

Getting launched

This section relates to the following learning goals. We are learning to:

- **discuss what we might learn from space probes (AS, UaS).**

Focus questions

- *Why do you think scientists are using unmanned space probes like* Galileo *to investigate our solar system?*
- *What kind of information could a space probe send back to earth?*

As with unmanned vessels exploring the deep sea, unmanned spacecraft can go safely where humans at present cannot. The probes can observe objects in the solar system more closely than observations made from Earth and can carry out other forms of monitoring, such as the testing of soil and rock samples by the probes that landed on Mars.

The space probes can send back electronic data and images. The difference between *Galileo's* high- and low-gain antennas may be explained by comparison with dial-up and broadband Internet speed and capacity. The volume of data and the speed of recovery are important to scientists for many reasons, including research programmes not taking lifetimes to complete.

A prime focus for the *Galileo* mission was to examine the Jovian moons. Scientists were particularly interested in Europa because earlier images of this moon had shown a relatively unmarked surface. Ask the students why that is important. (Refer back to the notes for "Eye Spy".) An unmarked surface is usually a sign of geological activity to astronomers. Since Europa has an icy surface, the lack of markings suggests that something might have melted the ice recently, that is, within the past few hundred thousand years. Information gathered from the images taken and from data collected by *Galileo* indicates that Europa probably has a salty ocean beneath its cracked and frozen surface. It even has a very thin oxygen atmosphere. However, scientists do not know how thick the ice cover is: it could be anything from 3 to 100 kilometres deep.

Europa is a very long way from the Sun, so why isn't it frozen solid? It is very close to Jupiter, so tidal gravitational force pushes and pulls on the moon as it orbits. All that friction results in heat, as you can see if you rub your hands together. Io, which is much closer to Jupiter than Europa, experiences these tidal effects much more strongly.

Gravity assist

This section relates to the following learning goals. We are learning to:

- **name and describe some methods of powering unmanned space probes and debate the safety of these (PI&PC)**
- **describe the gravity assist technique (PI&PC).**

Focus question

- *Can you think of some of the ways scientists might power a space probe on its journey and to do its work?*

Power sources can include launch by a fuelled rocket that then drops away from the probe, some form of fuelled propulsion built into the probe itself, solar power from fold-out reflective panels, and "gravity assist".

A large force is needed to overcome gravity. A *rocket* must reach a speed of 11.2 kilometres/second, so spacecraft need to be as light as possible and carry the least amount of fuel. However, once in space, there is no way to refuel.

By using the *gravity assist manoeuvre,* which essentially involves approaching a planet at exactly the right speed and angle, spacecraft can get some of their energy needs from the planet. (Remind the students that planets orbit the Sun at incredible speeds – see "Speed Freaks".)

Gravity assist is sometimes called the slingshot effect because it is similar to what happens when a stone is released from a slingshot: the stone goes much further and at a greater speed than if it were just thrown. As with a slingshot, using gravity assist requires skill and precision to make the spacecraft go in the right direction.

Focus question

- *Why do you think gravity assist is so important?*

The main reason is *cost*. Without gravity assist, spacecraft visiting the outer planets would take far too long to get there and require far too much fuel to be able to lift off. The most expensive aspect of space flight is getting enough energy to overcome the force of gravity. Refer the students back to Newton's first law of motion (see the notes for "Tracking Jupiter's Moons"). This law is also called the law of inertia because, to set a stationary object in motion, a force is needed.

Galileo also used a form of *nuclear energy* because solar panels would not be a functional solution for its power needs so far from the Sun. A tiny quantity of radioactive plutonium was used, less in fact than was used by the earlier *Voyager* mission. However, Earth was one of the planets used to slingshot *Galileo* through gravity assist, bringing the probe into a fast and close-range orbit around Earth. Some people were worried that an accident could cause *Galileo* to crash on Earth and protested vigorously over the use of nuclear power. The students may like to discuss whether or not it was legitimate to use nuclear power to get the probe down into Jupiter's atmosphere: did the gains outweigh the risk? Who should make such decisions?

Working together

This section relates to the following learning goals. We are learning to:

- **explain the importance of modelling or prototyping in developing unmanned space probes (CoTO, TM, UaS).**

“Mission to Jupiter” describes one of NASA’s most successful missions, successful in spite of tremendous technological hiccups along the way. It should be emphasised that the mission’s scientists and technologists were able to repair faulty equipment and even make improvements based on a thorough knowledge and understanding of physics – no “new” science was needed.

The difficulties *Galileo* experienced highlight the problem-solving aspect of science and technology. They also underline why a pre-production or prototype phase is so important, allowing technical glitches to be ironed out before the final craft is built and launched. With space missions, there is neither time nor money for second chances, so it is important that new technologies are tested as far as possible on Earth.

Earth-based testing may be one reason why the idea of gravity assist, or the slingshot effect, was so slow to catch on, at least in the West. The Russians used it first in 1959 with *Luna 3*. Michael Minovitch, a young mathematician working at the Jet Propulsion Laboratory, first suggested it to NASA in 1961, but it wasn’t used until 1973. *Pioneer 10* approached Jupiter at 9.8 kilometres a second, and gravity assist was used to accelerate it to a speed of 22.4 kilometres a second and send it on its way beyond the planets to the outer solar system. *Pioneer 10* was last heard from in 2003. (The *Pioneer* probes had plaques designed to show human figures and Earth’s position, in case of discovery by extraterrestrial beings.)

The end

When *Galileo’s* mission ended, it was deliberately set on a collision course with Jupiter. Ask the students why they think it was purposely destroyed and not allowed to decay where it was. The reason was to prevent *Galileo* contaminating Europa’s surface with microbes from Earth. If life is found on Europa at a later date, we could not be sure that it came from Europa and not Earth. (Note that bacteria in a camera left on the Moon for 31 months survived.)

Further activities

1. Gravity assist

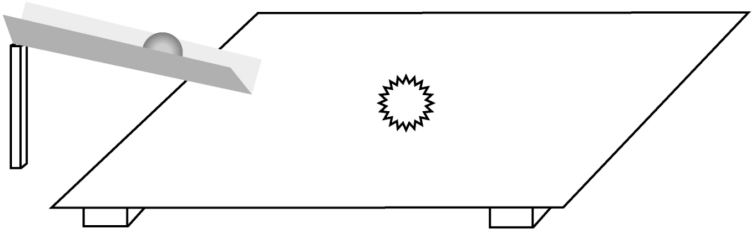
Adapted from the NSF Teach Engineering site at
http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_solar/cub_solar_lesson07_activity1.xml

You will need:

- a 25-cm-thick piece of transparent “plastic glass” or thick cardboard to serve as a baseboard (If using cardboard, mark where the magnet is.)
- 4 small pieces of wood or books to serve as corner supports for the baseboard
- 1 or 2 strong magnets to represent the planet
- several steel ball bearings to represent spacecraft (get different sizes)

- 2 pieces of cardboard about 20 cm long and 6–8 cm wide, bent in half lengthways to represent the launch ramp
- a few blocks and some plasticine to hold the ramp in place.

Figure 3: Gravity assist



Set the board up as illustrated, starting with one magnet stuck *underneath* in the middle. First, roll the ball bearing close to the magnet and observe how its path is changed by the magnetic field. This shows the same change in the pathway as when a spacecraft approaches a planet. Several factors affect the angle of the spacecraft's path (called the deflection angle) after it passes near a planet. Experiment with different-sized ball bearings, changing the elevation of the ramp and therefore the speed at which the ball bearing will be travelling. Add another magnet (that is, increase the mass or gravity of the "planet"). Move the ramp further away and try placing it at different angles (that is, change the flightpath of the "spacecraft") and see what happens.

Students should note that the mass and initial speed of the ball (the spacecraft), the mass of the magnet (the planet), and the "miss" distance are all contributing factors that affect the spacecraft's path as it performs a gravity assist manoeuvre.

Note: Technically, because the spacecraft takes energy from the planet, a corresponding amount of energy is removed from the planet, thus slowing it down. However, because the planet is so much larger, the energy lost is miniscule compared to its total energy, so energy the spacecraft gains makes no real difference to the planet.

2. Rocket power

Mini rocket: Have the students try using a film canister. Put in half a fizzy indigestion tablet and a little bit of water. Quickly put the lid on and put it upside down on the ground. Count the seconds until it blasts off. Experiment with different quantities. Don't forget to record the results.

Baking-soda rocket: Use as a holder a plastic bucket with a hole in the bottom large enough to hold a small plastic bottle with a cork by its neck. Put some vinegar in the bottle. Load baking soda into a tissue. Put the tissue with the baking soda in the bottle, bung in the cork, place the bottle into the hole in the bucket upside down, and run!

Plastic-bottle rocket: Pour two cups of water into a large plastic fizzy drink bottle. Put in a stopper with a long tube in the top attached to a bicycle pump. Put the bottle upside down in a holder and gently pump once or twice to seal up any holes. Continue to pump until the rocket launches itself.

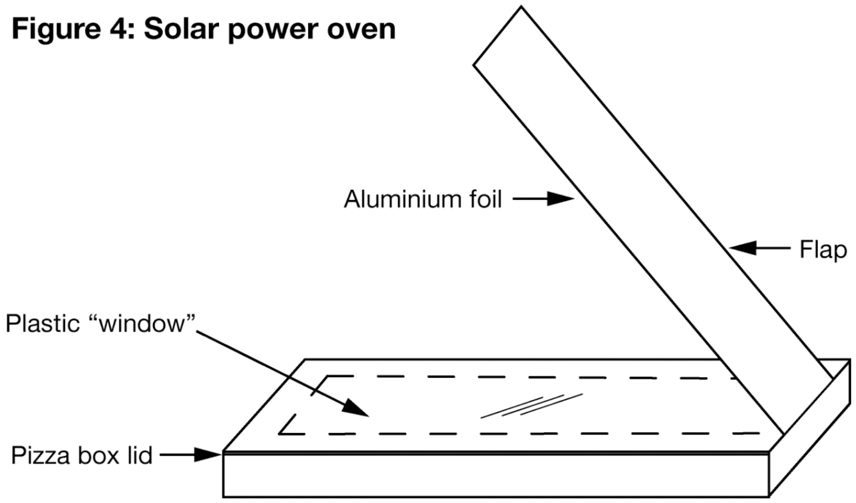
3. Solar power oven

The pizza box oven activity for students is adapted from the Solar Now site, which encourages further improvisation at http://www.solarnow.org/pizzabx.htm

You will need:

- a recycled pizza box
- clear heavy plastic
- black construction paper
- a wooden dowel or pencil or ruler
- a pen, a ruler, scissors, glue, a blob of reusable adhesive.

Figure 4: Solar power oven



On the lid of the box, draw a line 2 cm from the edges. Cut along three sides of the line, leaving the back uncut. Fold this flap back gently. Cut out a square of aluminium foil to fit over the inside of the flap and glue it on. Open the remaining part of the lid. Cut out a square piece of plastic a little bigger than the hole and glue it into place underneath the hole so that the hole is covered, with no air gaps.

Line the bottom of the box with foil glued into place. Cover the foil with black construction paper and tape into place. Close the lid of the box and prop the flap up with a bit of dowel or a pencil – a blob of reusable adhesive will keep it in place. Face the oven to the Sun, and experiment with the angle of the flap to get the maximum reflection onto the "oven window". Use it to heat muffins or hotdogs.

Further resources

Apollo 13 is a brilliant film (1995) about the ill-fated mission to the Moon, which almost cost the lives of three astronauts. It is useful in the context of this article, firstly to show the difference in technologies now 40 years old. There is more computing power in a modern laptop (and possibly an MP3 player or mobile) than was used to put men on the Moon. The Apollo physicists used slide rules for calculations. This movie is also useful to contrast the difference in risk between manned and unmanned missions.

View and discuss the Pioneer plaque image at
http://en.wikipedia.org/wiki/File:Pioneer_plaque.svg

See the NASA site for comprehensive coverage of the *Galileo* mission, exciting images, and even some of the sounds recorded by the mission, such as lightning on Jupiter. Go to http://solarsystem.nasa.gov/galileo