

## Background information

### Year 10, unit 3: Our universe

In the Australian Curriculum: Science, students are introduced to the solar system in year 5 – ‘The Earth is part of a system of planets orbiting around a star (the Sun)’, and then in year 7 they study phenomena associated with Earth’s place in space – ‘Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the Sun, Earth and the Moon’.

The year 8 and 9 content descriptions in the Earth and space sciences strand focus on the Earth (rocks, minerals and plate tectonics). It is therefore worthwhile spending time in the first lesson reviewing what students know and remember from earlier years.

The content descriptions in this unit take students beyond the solar system to study the big bang theory and other phenomena including galaxies, stars and black holes, as well as looking at the technologies that make new discoveries possible.

### Understanding the universe

Cosmology is the scientific study of the large-scale properties of the universe as a whole. It involves the formation of theories and hypotheses about the universe that can be tested with observations. Depending on observations, theories will be abandoned, revised or extended to accommodate new data. The prevailing theory about the origin and evolution of our universe is called the Big Bang theory.

The following websites provide a good explanation of the Big Bang theory accompanied by images and videos:

‘The Big Bang’, NASA Science: Astrophysics website,

<http://nasascience.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/> (2012)

‘Big Bang’ Universe Forum, Harvard-Smithsonian Centre for Astrophysics website,

<http://www.cfa.harvard.edu/seuforum/bigbanglanding.htm> (2004)

### Changing ideas

Scientists’ estimates of the size and age of the universe have changed over time as new technologies have allowed more data to be gathered.

Astronomical distances are so vast they are measured in light years. A light year is the distance travelled by light in one year. Light travels at approximately 300,000 km/sec, so a light year is calculated as  $9.4605284 \times 10^{12}$  kilometres (using a more precise speed).

The table below summarises how understanding has changed over time. More details can be obtained from:

‘Cosmic Times downloads’, Goddard Space Flight Centre website (scroll down to ‘Century Timeline’ and choose Appendix A),

<http://cosmictimes.gsfc.nasa.gov/teachers/curriculum/downloads.html> (2010)

Year	Age of universe (years)	Size of universe (light years)	Further information
1919	Infinite	300 000	Solar eclipse confirms Einstein's theory of gravity. Astronomers thought the universe was infinitely old and unchanging.
1929	2 billion	280 million	Hubble determined distances to furthest galaxy to be 140 million light years and showed the universe is expanding thus disproving Einstein's prediction that the universe was static. The rate of expansion was named the Hubble Constant.
1955	6 billion	4 billion	<p>New data from a 200-inch telescope at Mt Palomar, San Diego leads to changes in the size estimate. Scientists debate steady state and Big Bang theories.</p> <p><b>Steady state theory</b></p> <ul style="list-style-type: none"> <li>• Universe has no beginning or end.</li> <li>• New matter can be created spontaneously as the universe expands.</li> <li>• Expansion of the universe and creation of new matter is balanced via a negative energy so it does not change its look over time.</li> <li>• Universe looks the same from every point.</li> </ul> <p><b>Big Bang theory</b></p> <ul style="list-style-type: none"> <li>• Universe is expanding from a state of high density and pressure.</li> <li>• Hydrogen and helium were formed as the universe cooled.</li> <li>• There should be left over radiation with a temperature of ~5 kelvin.</li> </ul>
1965	10–25 billion	25 billion	The furthest objects discovered are quasars. Penzias and Wilson discover cosmic microwave background (CMB). Peebles and Dicke estimate the temperature of the radiation.
1993	12–20 billion	30 billion	Quasars continue to define the size of the universe. It is expected that the expansion of the universe will slow down because of gravitational attraction between objects.
2006	13.7 billion	94 billion	<p>The Hubble Key Project calculated the age of the universe to be 13.7 billion years and this was confirmed by the Wilkinson microwave anisotropy probe (WMAP) satellite. In 1997, observations of supernovae in distant galaxies showed the expansion is speeding up. The concept of dark energy is developed to explain what powers the expansion.</p> <p>See the video <i>2011 Nobel Prize: Dark energy</i>, YouTube (1:39 min), explaining the expanding universe.  <a href="http://www.youtube.com/watch?v=v6o2bUPdxV0">http://www.youtube.com/watch?v=v6o2bUPdxV0</a></p>
Recently	13.7 billion	94 billion	<p>Dark energy is confirmed. Scientists come up with the composition of the universe to be: ~70% dark energy, ~25% dark matter, ~5% normal matter. Dark matter is particularly elusive as it does not emit, absorb or reflect light, but only makes itself apparent through its gravitational attraction. Colliding galaxies provide a mapping of dark matter in that region of space. For an image and explanation of mapping see 'Abell 2744: Pandora's cluster revealed', Chandra X-ray Observatory website,  <a href="http://chandra.harvard.edu/photo/2011/a2744/">http://chandra.harvard.edu/photo/2011/a2744/</a> (2011)</p>

## Exploring star life cycles

Technological advances are allowing scientists to begin to understand the process by which stars evolve, live and die.

Approximately 13.7 billion years ago the universe came into existence along with mainly hydrogen and some helium and lithium. During the first 10 billion years, stars were born and galaxies were formed.

Stars form deep inside clouds of interstellar gas (mainly hydrogen) and dust called nebulae. Over a few million years, during which the gas cloud has been collapsing on itself, the internal temperature of the core has been increasing. When it reaches a few million degrees the process of hydrogen fusion begins and a new star is born.

Eventually, stars run out of fuel and begin to die. The final fates of stars depend on their size. Low-mass stars like our sun end up as a white dwarfs. More massive stars are ripped apart by massive explosions called supernovae which synthesise the natural elements. Eventually they become neutron stars so dense that a teaspoon full of material weighs 100 million tons.

For even more massive stars there is a different fate. The neutron star formed by the supernova is unable to support the weight of the collapsing material, and the star's central region becomes a black hole.

The shockwave of an exploding supernova as it passes through the outer shell of the dying star creates the conditions by which the heavier elements in the periodic table are formed.

Approximately five billion years ago a shockwave from a supernova event encountered a giant molecular cloud of cloud and dust. This triggered the fragmentation of the cloud and the subsequent collapse of one of the fragments, resulting in the birth of our sun and solar system.

The following website provides more detailed information and images on the life cycles of stars:

'Stars', NASA Science: Astrophysics website,

<http://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve/> (2012)

## Observing the universe

Much of the information about the universe is gathered by telescopes (either land-based or orbiting). Information is also obtained from probes, such as *Voyager*, that have been sent into space and which send messages back to Earth.

The data gathered by scientists comes from across the electromagnetic spectrum. Each region of the electromagnetic spectrum is focused on, and specific instruments are used to gather data. Data from different regions of the spectrum can then be combined to provide information about the universe.

The following table summarises the spectral regions, the instruments used to retrieve information and the information they provide.

Electromagnetic region	Instrument (examples)	Information provided
radio waves	Radio telescopes: Parkes Murchison Widefield Array (MWA) Australian Square Kilometre Array Pathfinder (ASKAP) Canberra Deep Space Communication Complex	The composition, structure and motion of celestial objects, eg pulsars, star-forming regions, supernova remnants and quasars.
microwaves	Wilkinson Microwave Anisotropy Probe (WMAP)	Identified microwave background radiation that supports the Big Bang theory.
infra-red waves	Cassini spacecraft James Webb Space Telescope (JWST) Spitzer Telescope	Planets, cool stars, nebulae, galaxies and sees through dust in nebula.
reflected near infra-red waves	Hubble Space Telescope's Near Infrared Camera and Multi-Object Spectrometer	Rock and soil types, cloud altitudes.
visible	Hubble Space Telescope Keck Anglo-Australian Telescope Gemini	Spectral signatures – elemental composition of objects, structure and evolution of galaxies and can see individual stars.
ultraviolet waves	Evolution Explorer (GALEX) spacecraft Hubble Space Telescope (HST) World Space Observatory	Formation of stars, structure and evolution of galaxies and auroras.
x-rays	Chandra Observatory	White dwarf stars, neutron stars, black holes, Sun's corona, pulsars and supernovae remnants.
gamma rays	Swift satellite MESSENGER gamma ray spectrometer (GMS) Fermi Gamma-ray Space Telescope	Black-hole birth, elements on other planets, stars, supernovae and pulsars.

Adapted from 'Tour of the electromagnetic spectrum', Mission: Science NASA website, <http://missionscience.nasa.gov/ems/index.html> (2011)