teachers guide

Cosmology 3
The future of the Universe

Components

NAME	DESCRIPTION	AUDIENCE
The future of the Universe teachers guide	This guide contains presentation notes and questions to promote discussion about possible scenarios for the future of the Universe.	teachers
The future of the Universe presentation	The presentation describes the science that informs predictions for the future of the Universe. It highlights our limited knowledge of the shape, density and composition of the Universe, and the degree of uncertainty in our capacity to predict its future.	students
The future of the Universe fact sheet	The fact sheet summarises major ideas discussed in the presentation.	students

Purpose

To describe and explain the science that informs our predictions about the future of the Universe.

Outcomes

Students:

- understand that our knowledge of the Universe is limited by the speed of light and the age of the Universe; and
- understand that the future of the Universe depends on its density and the effect of gravity on its mass; and
- understand that scientific theories are re-evaluated following the discovery of new evidence.

Activity summary

ACTIVITY	POSSIBLE STRATEGY
Students speculate on the future of the Universe, based on their understanding of the Big Bang (causing the Universe to expand) and gravity (causing the Universe to contract). Teacher summarises ideas on the whiteboard.	small group or whole class discussion
Students discuss factors that might limit our knowledge of the Universe and hinder our ability to predict its future.	small groups
Teacher shows slides 1–5 of the presentation, *The future of the Universe*, and asks students to reconsider their ideas in light of the new information. Teacher shows slides 6–7 and discusses density and the need for us to know the density of the Universe.	small group discussion or whole class sharing of ideas
Students speculate on possible futures of the Universe if its density is greater than, less than, or equal to the critical density.	small groups
Teacher shows slides 9–14, which provide answers. Students speculate on which possibility they think is most likely.	small group discussion or whole class sharing of ideas
Teacher shows slide 15-16 and asks students to speculate about what makes up the missing mass (95% of the Universe).	small groups or whole class
Teacher shows slides (17–20) and initiates a discussion of dark matter and dark energy. Finally, slide 21 presents a fourth possible scenario for the future of the Universe.	teacher-led discussion
Teacher distributes the fact sheet, *The future of the Universe*.	

Information for teachers

The future of the Universe is the third of three presentations that enable teachers and students to explore and explain cosmological concepts, discoveries and theories.

The presentation is designed to facilitate a conversation with students about aspects of the future of the Universe and a discussion of scientific evidence and theories that underpin modern cosmology. Presenters' notes are included to provide background information for teachers and suggested discussion points.

The presentation contains six main sections.

SECTION	CONTENTS
Key ideas	There are limits to how much we can know about the Universe. Predictions about its future are based on the amount of it we can observe. Predictions about the future of the Universe assume that the laws of physics apply equally to all parts of it.
The future of the Universe depends on its density and the effect gravity has on matter.	
Three scenarios for the future of the Universe	closed Universe open Universe flat Universe
The density of the Universe will determine its future	
Composition of the Universe	radiation, ordinary matter, dark matter, dark energy
A fourth scenario for the future of the Universe	

The fact sheet, *Future of the Universe*, summarises major ideas in the presentation and is a useful handout for students after viewing and discussing the presentation.

The following notes accompany the presentation, *The future of the Universe* (notes are only provided for slides that require additional information).

SLIDE	NOTES
1	This presentation has been constructed using information drawn from a number of sources. The major source is Universe 101 Big Bang Theory http://map.gsfc.nasa.gov/universe/. It is highly recommended reading for physics teachers.
5	The Cosmological Principle tells us that the Universe has uniform composition and density in all directions. General relativity can therefore be used to compute the effects of gravity on that matter. Since gravity is a property of spacetime, this is equivalent to computing the dynamics of spacetime itself.
6	The two assumptions are derived from the Cosmological Principle, which can be stated as: Viewed on a sufficiently large scale, the properties of the Universe are the same for all observers.
8	**Teaching/discussion point** This is a useful place to involve students in discussion about the balance between Big Bang expansion and the effects of gravity on matter. In small groups, students could be encouraged to speculate on the future of the Universe if gravity is too strong, too weak or just right. **Answers** If the density of the Universe is greater than critical density, gravity will eventually stop its expansion and then reverse it. The Universe will eventually collapse back in on itself and end in the 'Big Crunch'. If the density of the Universe is less than critical density, the Universe will continue to expand forever. Eventually it will cool down and end in the 'Big Chill'. If the density of the Universe equals critical density it will continue to expand at an ever-decreasing rate. Gravity will eventually stop its expansion, but only when infinite time has passed. The problem for cosmologists attempting to predict the Universe's future is that its density hasn't been determined.
9	The key idea in the following three scenarios is that there is a direct link between the geometry of the Universe and its likely future. The image shows gravity distorting the geometry of spacetime and giving it a curvature like the surface of a sphere. In a closed Universe: • a space traveller could start a journey in one direction and, if allowed sufficient time, ultimately return to his/her starting point; and • the sum of the angles of a triangle exceeds 180 degrees and there are no parallel lines – all lines eventually meet.

SLIDE	NOTES
10	A closed, high density Universe will expand for several billion years then ultimately contract and collapse under its own weight.
11	The image shows the geometry of spacetime with a curvature similar to the surface of a saddle. In an open Universe: • a space traveller starting a journey in one direction would never return to his/her starting point; and • the angles of a triangle sum to less than 180 degrees and lines that don't meet are never equidistant – they have a point of least distance but otherwise grow apart. The geometry of an open Universe is said to be hyperbolic.
12	An open, low density Universe will expand at an ever-decreasing rate. However, its expansion will occur at a faster rate than for a flat Universe (see next slides) because the effect of gravity is not as strong.
13	If the density of the Universe is equal to critical density, the geometry of spacetime will be flat. In a flat Universe: • a space traveller starting a journey in one direction would never return to his/her starting point.; and • the sum of the angles of a triangle is 180 degrees and parallel lines continuously maintain the same distance apart.
14	A flat, critical density Universe will continue to expand at an ever-decreasing rate. However, its rate of expansion will be less than that of an open Universe.
16	Prior to Zwicky's discovery, astronomers believed that the Universe was dominated by visible matter: protons, neutrons and electrons. Within a galaxy, astrophysicists can measure the rate of rotation of stars around the galactic centre. They observed that outer stars rotated too fast to be held in place by gravity from the amount of matter they could see in the galaxy. They estimated that about 4–5 times more matter is needed to explain the observation. In addition, the motion of galaxies within a cluster suggested that they are bound by a total gravitational force due to 5–10 times as much matter as could be seen within them. Astrophysicists explained these results by proposing that every galaxy is surrounded by a halo of dark matter. **Teaching point** In Physics unit 3APHY, students should understand the relationship between gravitational and centripetal forces and how the orbital velocity of a satellite relates to the mass of the object it orbits. This knowledge could be applied to enable them to understand Zwicky's findings.
17	Since Zwicky's discovery, astronomers began to recognise that dark matter dominated the Universe. Dark matter: • was inferred from effects of gravity on visible matter and background radiation (gravitational lensing); • has never been observed directly; and • could possibly include massive neutrinos, WIMPS (weakly interacting massive particles) or MACHOS (massive astrophysical compact halo objects). Who says physicists don't have a sense of humour?
18	In the 1990s, astronomers observing distant supernovae found evidence that the Universe is expanding at an increasing rate. They discovered that the acceleration of more distant galaxies is less than that of galaxies closer to Earth (ie younger galaxies). From this, they inferred that the Universe is expanding at an accelerating rate. This inevitably led to ask what was causing this increasing expansion? Slides 18-20 introduce the concept of dark energy as the likely explanation.
21	The red curve shows a Universe in which a large proportion of matter in the form of dark energy is causing its expansion to speed up. There is growing evidence that our Universe is following the red curve.

Technical requirements

The guide and fact sheet require Adobe Reader (version 5 or later), which is a free download from www.adobe.com. The presentation is provided in two formats: Microsoft PowerPoint and Adobe PDF.