Worksheet answers

Part 1: Evolution of the Universe

Locate and open the interactive learning object, *Timeline of the Universe*, to answer the following questions.

1. How old is the Universe?

   The Universe is thought to be 13.7 billion years old.

2. What was created in the Big Bang?

   Space, time and energy were all created in the Big Bang.

3. What came before the Big Bang*?*

   The Big Bang theory offers no explanation of what came before. Many astronomers believe there was nothing. Everything, including all matter and energy we see today in the Universe, and even time itself, were created in the Big Bang.

   Other scientists believe there may have been another 'Universe' before the current one. However these theories are likely to be be impossible to prove.

4. What was the early Universe like? How has it changed since the Big Bang?

   The early Universe was extremely hot, dense and small. After the Big Bang it expanded rapidly and cooled.

5. Why weren't atoms formed until 380 000 years after the Big Bang?

   Until 380 000 years after the Big Bang, the Universe was too hot for atoms to be stable. After 380 000 years the Universe was cool enough (about 4000 K) for charged electrons and protons to combine and form neutral atoms.

6. Why is the Universe cooling as it expands?

   The Universe had a fixed amount of energy when it was created. As the Universe expands, this heat energy is spread over an increasing volume of space. This means that the size of the Universe increases, energy density decreases and the average temperature of the Universe decreases.

7. Why would hydrogen and helium be among the first atoms to form in the Universe?

   Hydrogen and helium are the simplest elements in the period table. They require the least energy to form and were the first atoms to be stable as the Universe cooled.

8. What is cosmic microwave background radiation?

   Cosmic microwave background radiation is electromagnetic radiation that has travelled freely in the Universe since 380 000 years after the Big Bang. At that time background radiation had a much smaller wavelength, but its wavelength has increased as the Universe has expanded.

9. What does the WMAP image of cosmic microwave background radiation tell us about the early Universe?

   The WMAP image shows variations in cosmic background radiation temperature. Red regions are slightly warmer; blue are cooler. Temperature differences are extremely small: only about a hundred thousandth of a degree. Cosmologists believe that variations in temperature indicate regions of different matter density in the early Universe.

10. The WMAP image shows what the Universe was like 380 000 years after the Big Bang. How is it possible for scientists to 'look back in time'?

    Light travels at 300 000 km s^{-1}, so it takes time for light to travel from objects to us. It takes about eight minutes for light to travel from the Sun to Earth, so when we look at the Sun we are seeing it as it was eight minutes ago. In this sense we are looking back eight minutes in time.

    Light from distant galaxies can take billions of years to reach Earth, so when we look at them we see them as they were billions of years ago.

11. How do gravity and gas pressure interact in the process of galaxy formation?

    Gravity and gas pressure played an essential role in forming the first stars and galaxies. Gravitational force acted on matter, puling it together to form giant gas clouds. As particles of matter came closer together they collided more often, causing gas pressure and temperature in to increase.

    The densest regions became so hot that thermonuclear reactions were triggered and the first stars lit up in early galaxies.

12. If the Universe continues to expand at an accelerating rate, what do you think Earth's inhabitants will see when they look up into the sky billions of years from now?

    In a billion years or so Earth's inhabitants may have to find somewhere else to live as the Sun expands and becomes brighter.

    Most galaxies will move further apart as the Universe continues to expand. A few galaxies will be closer and easier to see, most notably our Local Group of galaxies. In about 4 billion years, the Milky Way and Andromeda galaxies are expected to collide and merge to form a new galaxy.

    From our galaxy (the Milky Way) most galaxies will appear to be moving away with increasing speed. Eventually (in 100 billion years or so) they will be moving away so fast that light from them never reaches us and they recede out of sight.

Research questions

1. Why can't astronomers determine the size of the Universe?

    Much of the Universe is blocked from our view by gas, dust and material in Milky Way — but this is not the major problem to overcome. Light has to travel across vast distances of space. This takes time. Beyond a certain distance insufficient time has elapsed since the Big Bang for that light to reach us. The Universe is expanding at an increasing rate, so we will probably never see this light, or know how big the Universe is.

2. What did Hubble discover about the Universe?

    Hubble discovered a relationship between a galaxy's distance from Earth and the speed it moves away from us. This became known as Hubble's law and led to the realisation that the Universe is expanding. Hubble also showed that most galaxies he observed were outside the Milky Way.

3. Hubble used redshift and blueshift measurements of light from distant galaxies to make his discovery. What do we mean by the terms redshift and blueshift, and what do these measurements tell us about a galaxy?

    Redshift: Light waves travelling towards us from a galaxy moving away from Earth are stretched. This causes wavelengths to move towards the red end of the electromagnetic spectrum. This is known as redshift.

    Blueshift: Light waves travelling towards us from galaxies moving towards Earth are shortened. Their wavelengths move toward the blue end of the spectrum.

Measurements of redshift and blueshift show that:

- *Most galaxies are moving away from Earth, because their light is redshifted. This occurs because the Universe is expanding.*
- *Light from a few galaxies is blueshifted. These galaxies are moving towards Earth.*
- *The amount of redshift or blueshift can be used to determine how fast galaxies are approaching or receding.*

4. Hubble first determined the age of the Universe to be 2 billion years. Why was this result rejected and what caused him to make such an error?

   Hubble greatly underestimated the distance to remote galaxies he observed. This led him to conclude that the Universe was only about 2 billion years old. Geologists knew this wasn't correct because their measurements had estimated the Earth's age to be between 3 and 5 billion years old.

5. Penzias and Wilson pointed their antenna at the sky and discovered a 'noise' while they were researching reflected radio signals. How did they come to the conclusion that it was cosmic microwave background radiation?

   Penzias and Wilson first eliminated known sources of radio signals, such as interference from New York City. The remaining signal filled the sky and was detected day and night. With no known sources capable of producing such widespread 'noise' they needed to look elsewhere. The source of the signal originated from beyond the Milky Way and was eventually identified as cosmic microwave background radiation.

6. How do cosmologists explain the increasing rate of expansion of the Universe?

   Cosmologists believe that dark energy causes the Universe to expand, by making matter repel other matter. At present, however, they don't know what dark energy really is.

7. Astronomers think that 25% of the Universe is made up of dark matter, although they don't know what dark matter is. What evidence is there that dark matter exists?

   Astronomers use various methods to calculate the mass of galaxies. They find only 20% of the mass needed to prevent galaxies from flying apart, given their speed of rotation. This 'missing' mass is believed to be dark matter.

8. Astronomy, astrophysics and cosmology all contribute to increasing our understanding of the Universe. What are they and what do astronomers, cosmologists and astrophysicists do?

   Astronomy is the branch of science that deals with celestial objects, space and the physical Universe as a whole. It includes both cosmology and astrophysics.

   Astronomers may study general astronomy, the Sun, radio astronomy or x-ray astronomy as well as astrophysics, cosmology and other space related fields.

   Cosmology is the study of the properties of the Universe as a whole.

   Cosmologists study the evolution of the Universe since the Big Bang, its future and ultimate fate. They typically study data and images of the most distant galaxies because they provide information on what the early Universe was like.

   Astrophysics is the study of the physical or chemical properties of celestial objects.

   Astrophysicists use different disciplines of physics to study the Universe, such as mechanics, electromagnetism, thermodynamics, quantum mechanics, relativity, particle physics and atomic and molecular physics.