The Universe

Hubble's Expanding Universe

Part 1 – How far away are the stars?

For many years astronomers believed that our galaxy, the Milky Way, was the only galaxy in the universe. In fact they thought that the Milky Way was the whole universe. We now know that it is just one of millions of galaxies and the universe is much bigger than previously imagined.

All the stars in the universe are different. Some give off large amounts of light (they are highly luminous), others do not emit as much light. A small star that is relatively close to us may appear the same brightness as a larger star that is much further away. Because of this, you cannot judge the distance of a star by its apparent brightness.

In the 1920s, Edwin Hubble detected objects called variable stars in fuzzy patches known as nebulae. These variable stars expanded and contracted regularly in a pulsating manner and were similar to other celestial objects known as the Cepheid variable stars (sometimes spelt as Cephoid). It had been shown that there was a tight correlation between the time taken for one complete pulse and the luminosity of the star (how much light is actually emitted by the star). Hubble, by measuring the period of these stars, was able to calculate the luminosity of the variable stars. By comparing this calculated luminosity with their apparent brightness in the sky, he could judge their distance away from the earth. He showed that these nebulae were not clouds within our own galaxy, but were external galaxies far beyond the edge of the Milky Way.

Questions

1. Explain the difference between luminosity and apparent brightness.
2. Why is it not possible to judge the distance of a star from earth by how bright it appears in the sky?
3. Why were variable stars given this name?
4. What does the 'period of a variable star' mean?
5. Describe the correlation that helped Hubble estimate the distance of a star from the earth.
6. What was Hubble's conclusion from these observations?

Part 2 – Red shift

Pure white light is made up of all the colours in the spectrum. It is a continuum containing every frequency of visible electromagnetic radiation. The light reaching us from the stars does not contain every colour component, but only a number of individual frequencies. These frequencies of light are actually emitted by the gases that make up the star. We know which gases are present in a star, so we can predict which frequencies are emitted. When we actually measure the frequencies of the light emitted, we find that they are usually lower than expected. They have been shifted towards the red end of the spectrum.

Red shift is thought to occur because the star is moving away from us. The wave is stretched as it is formed, giving it a longer wavelength than usual. The longer the wavelength of a light wave, the lower its frequency. The faster the star is moving away from us, the more the wave is stretched and the larger the red shift. [A similar effect occurs with sound waves, known as the Doppler shift. A car moving towards you makes a higher pitch noise than a car moving away from you (think of the sound you make when you mimic a car whizzing past). This effect is due to the waves being compressed as the car approaches and stretched as it moves away.]

Hubble measured the red shift of many galaxies and used the information to calculate how quickly the galaxies were moving away from the earth. He also measured the distance the galaxy was from the earth. He found that the further the galaxy was away, the faster it appeared to be moving. He concluded from this that the universe is expanding outwards in all directions. The galaxies on the far side of the universe are moving in the opposite direction to us. Other galaxies are also spreading out from us as the universe expands. You can observe this expansion by drawing dots all over a balloon and blowing it up – every dot moves away from every other dot as the space inside expands.

Questions

1. How does the light reaching us from the stars differ from pure white light?
2. How can we predict which frequencies of light a star might emit?
3. What observable difference is there between the predicted and measured frequencies?
4. Describe the similarity between the Doppler Effect and red shift.
5. Sketch a graph to show how the speed of a galaxy compares to its distance from us.
6. What were Hubble's conclusions?

Answers to Part 1 – How far away are the stars?

1. Luminosity is a measure of the amount of light actually emitted by the star. The apparent brightness indicates how bright it appears in the sky (a car headlight in the distance may appear less bright than a torch that is close to you, but the headlamp has a higher luminosity because it is actually giving off more light).

2. A star that appears bright in the sky could be a smallish star that is relatively close by or a massive star that is relatively far away.

3. Variable stars expand and contract regularly in a pulsating manner.

4. The time taken for it to expand and contract again (or go through one complete cycle). This time is known as the period of the star.

5. The correlation is between the time taken for one complete pulse (the period) and the luminosity of the star (how much light is actually emitted). If the period is measured, the luminosity can be calculated. By comparing this calculated luminosity with the apparent brightness of the variable star, Hubble could judge its distance away from the earth.

6. Hubble concluded that these nebulae were not clouds within our own galaxy, but were external galaxies far beyond the edge of the Milky Way.

Answers to Part 2 – Red shift

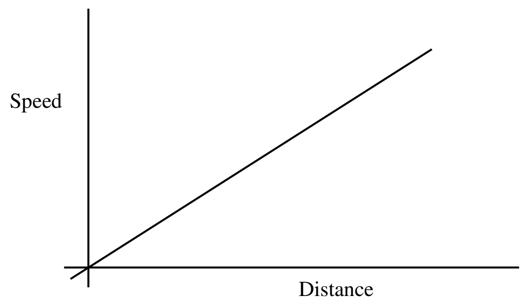
1. Pure white light is made up of all the colours in the spectrum. It is a continuum containing every frequency of visible electromagnetic radiation. The light reaching us from the stars does not contain every colour component, but only a number of individual frequencies.

2. The light is emitted by the gases that make up the star. We know which gases are present in a star, so we can predict which frequencies are emitted.

3. When we actually measure the frequencies of the light emitted, we find that they are usually lower than expected. They have been shifted towards the red end of the spectrum.

4. In both red shift and the Doppler effect, the wave is stretched as it is formed, giving it a longer wavelength than usual. The longer the wavelength, the lower its frequency. The faster the object creating the wave is moving away from us, the more the wave is stretched and the larger the effect. The sound heard has a lower pitch than expected and the light seen is closer to the red end of the spectrum.

5.



6. Hubble concluded from this that the universe is expanding outwards in all directions. The galaxies on the far side of the universe are moving in the opposite direction to us. Other galaxies are also spreading out from us as the universe expands.