Red-shift

4.8.2 · Space physics · revision notes

Red-shift is the observed increase in the wavelength of light from most distant galaxies. You need to explain what it shows about how galaxies are moving, why it is evidence for an expanding universe and the Big Bang theory, and what is still not understood, such as dark mass and dark energy. GCSE Physics only, not in Combined Science.

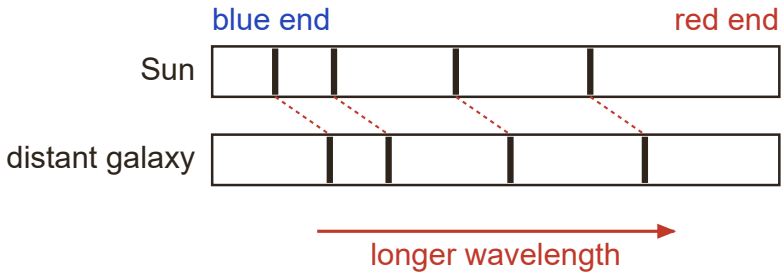
Key facts

- Red-shift: an observed increase in the wavelength of light from most distant galaxies
- Further away → moving away faster → bigger red-shift
- Big Bang theory: the universe began from a very small region that was extremely hot and dense
- Since 1998: supernova observations suggest distant galaxies are receding ever faster
- Red-shift → the galaxy is moving away from us
- Red-shift is evidence that space itself (the universe) is expanding
- Red-shift supports the Big Bang theory
- Not yet understood: dark mass and dark energy

Notes

What red-shift is

- Light from most distant galaxies is observed to have longer wavelengths than expected. This observed increase in wavelength is called **red-shift**.
- In the spectrum of a galaxy, the pattern of dark lines is the same as in the Sun's spectrum, but every line is shifted towards the red (longer wavelength) end.



Same pattern of lines, shifted towards the red end: red-shift.

- Red-shift happens because the galaxy is moving away from us: the light waves are stretched out, so the wavelength increases and the frequency decreases.
- The further away a galaxy is, the faster it is moving away and the bigger its red-shift.



Further away → moving away faster → bigger red-shift.

Evidence for an expanding universe and the Big Bang

- Distant galaxies in every direction are moving away from us, and the most distant ones are moving fastest. This is evidence that space itself (the universe) is expanding.
- If the universe is expanding, it must have been smaller in the past. Tracing the expansion back suggests the universe began from a very small region that was extremely hot and dense.
- This is the **Big Bang theory**. The observed red-shift supports it.
- Scientists arrived at this theory from observations: they measured red-shifts, proposed an explanation that fits them, and checked it against more data. Theories can change if new evidence does not fit.

What is still not understood

- Since 1998, observations of supernovae suggest that distant galaxies are moving away **ever faster**: the expansion of the universe is speeding up.
- Scientists do not know what causes this. The unknown cause is called **dark energy**.
- Galaxies also seem to contain much more mass than we can see. This unseen mass is called **dark mass** (dark matter). It is detected only by the effect of its gravity.
- So there is still much about the universe that is not understood.

How to answer each type of question

State what red-shift is and what it shows

1 to 2 marks | **Grade 4**

1. Define it: an observed increase in the wavelength of the light from a distant galaxy.
2. Say what it shows: the galaxy is moving away from us.

Example. The light from a distant galaxy shows red-shift.
Describe what is meant by red-shift and what it tells you about the galaxy.

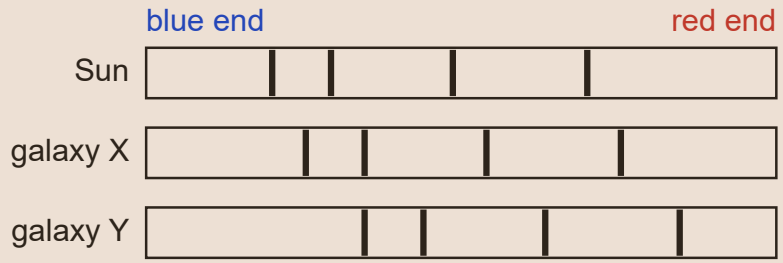
Model answer. The wavelength of the light we observe from the galaxy is increased (shifted towards the red end of the spectrum) (1). This shows that the galaxy is moving away from us (1).

Compare the red-shifts of two galaxies

2 marks | **Grade 5**

1. Check the line pattern: the same pattern moved to longer wavelengths means red-shift.
2. The galaxy with the bigger shift is moving away faster.
3. It is also further away.

Example. Astronomers compare the spectra of two galaxies, X and Y, with the spectrum of the Sun. Both galaxies show the same pattern of dark lines as the Sun. The lines for galaxy Y are shifted further towards the red end of the spectrum than the lines for galaxy X.



What can you conclude about galaxy Y compared with galaxy X?

Model answer.

Galaxy Y is moving away from us faster (1).
Galaxy Y is further away (1).

Use data on the distance and speed of galaxies

2 to 4 marks | **Grade 6**

1. Describe the trend: the further away the galaxy, the faster it is moving away.
2. Check for direct proportion: speed ÷ distance is about the same for each galaxy, so doubling the distance doubles the speed.
3. Use the proportion to make a prediction, and give the unit.

Example. Astronomers measured the distance of four galaxies and the speed at which each is moving away from us.

Galaxy	Distance (million light years)	Speed moving away (km/s)
A	90	2000
B	180	3900
C	270	6000
D	360	7900

(a) Describe the relationship between the distance of a galaxy and the speed at which it is moving away.
(b) Galaxy E is 720 million light years away. Estimate the speed at which it is moving away.

Model answer.

(a) The further away the galaxy, the faster it is moving away (1). The speed is approximately directly proportional to the distance (1).
(b) 720 million light years is twice the distance of galaxy D (1), so the speed is about 2 × 7900 = 15 800 km/s (1). Allow answers from 15 600 to 16 000 km/s found using any of the galaxies.

Explain how red-shift is evidence for the Big Bang

3 to 4 marks | **Grade 7**

1. Red-shift shows that distant galaxies are moving away from us.
2. The further away they are, the faster they are moving away.
3. So space itself is expanding.
4. So the universe was smaller in the past, and began from a very small, extremely hot and dense region.

Example. Explain how the red-shift of light from distant galaxies provides evidence for the Big Bang theory.

Model answer. Light from most distant galaxies is red-shifted, so they are moving away from us (1). The further away a galaxy is, the bigger its red-shift, so the faster it is moving away (1). This shows that space itself (the universe) is expanding (1). So the universe must have been smaller in the past, which suggests it began from a very small region that was extremely hot and dense (1).

Explain what is still not understood about the universe 2 marks **Grade 8**

1. Name the observation that is not explained, e.g. galaxies receding ever faster.
2. Name the idea proposed (dark energy or dark mass) and say that scientists do not know what it is.

Example. Since 1998, observations of supernovae have suggested that distant galaxies are moving away from us ever faster.
Explain why this shows that there is still much about the universe that scientists do not understand.

Model answer. Scientists do not know what is causing the expansion of the universe to speed up (1).
The unknown cause has been called dark energy, but nobody yet knows what dark energy is (1).

Don't lose marks

- Saying the galaxy or its light turns red. Red-shift means the wavelength increases, so the lines in the spectrum move towards the red end.
- Saying the frequency increases. When the wavelength increases, the frequency decreases.
- Describing the Big Bang as an explosion of matter into empty space from one point. The theory says the universe began from a very small, extremely hot and dense region, and space itself is expanding.
- Thinking that because distant galaxies in every direction are moving away from us, we must be at the centre. Every galaxy would see the others moving away.
- Mixing up dark mass and dark energy: dark mass is unseen mass; dark energy is the unknown cause of the expansion speeding up.

More tips

Memory tricks

- Red light has the longest wavelength of visible light, so 'red-shift' means 'shifted to a longer wavelength'.
- Further, faster, more red: all three go together.
- Picture dots drawn on a balloon as it is blown up: every dot moves away from every other dot, dots that are further apart separate faster, and no dot is the centre.
- Spectrum check: same pattern of lines, all moved towards the red end, means the galaxy is moving away.

Exam technique

- Use the phrase 'observed increase in wavelength' when you define red-shift.
- For Big Bang evidence, build a chain with 'so': red-shift → moving away → further away means faster → space is expanding → the universe began very small, hot and dense.
- When describing data, say whether the relationship is directly proportional, not just 'as one goes up, the other goes up'.
- For 'not understood' questions, name dark mass and dark energy and say that scientists do not yet know what they are.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4

Describe what red-shift is

Red-shift is an observed increase in the wavelength of light from most distant galaxies.

Grade 5

Explain what red-shift shows about galaxies

A red-shifted galaxy is moving away from us, and a bigger red-shift means it is further away and moving faster.

Grade 5

Describe the Big Bang theory

The universe began from a very small region that was extremely hot and dense.

Grade 6

Use galaxy data to describe a relationship

The speed a galaxy moves away is roughly directly proportional to its distance, so you can use this to make predictions.

Grade 7

Explain red-shift as evidence for expansion

More distant galaxies move away faster, which shows that space itself is expanding and supports the Big Bang theory.

Grade 8

Explain what is not yet understood

Since 1998, galaxies have been observed receding ever faster, and dark mass and dark energy are still not understood.

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