

Red shift and the expanding universe

AQA GCSE Separate Physics 8463 only | Foundation and Higher | Paper 2

20 parts | 40 marks | Both tiers | Timing estimated/untrialled

Specification points covered

4.8.2: increased wavelength, recession and the distance trend; evidence that space is expanding
4.8.2: evidence for the Big Bang model; an initially very small, extremely hot and dense universe
4.8.2: later supernova evidence, accelerating recession and remaining unknowns; evaluating theories

An observatory is preparing a public exhibit from its archive. Check model spectral fingerprints, compare a survey of distant galaxies and help the team separate observations from conclusions.

Original PhysicsUK practice, not official AQA. Both tiers complete the same 20 parts / 40 marks. Separate Physics only; no required-practical completion claim. Figure 1 is qualitative: green in the solution highlights H, not its actual light colour. Use the tables for exact values.

1 Checking the exhibit vocabulary

The team uses red-shift measurements and the Big Bang model in its exhibit. Start by checking the meaning of the terms.

1(a) State what red-shift means in terms of the observed wavelength of light. **[1 mark]**

Answer / mark points: The observed wavelength is increased compared with the corresponding emitted/laboratory wavelength. [1] A colour name alone is not a wavelength comparison.

1(b) The Big Bang model begins with a very small region. State the two other physical conditions of this early universe. **[1 mark]**

Answer / mark points: Extremely hot and very dense. [1 for both] "Very bright" or "full of stars" does not replace either condition.

1(c) A laboratory lamp is made fainter, but all its spectral lines stay at their original wavelengths. A trainee calls this red-shift. Explain why the claim is wrong. **[2 marks]**

Answer / mark points: The wavelengths have not increased, so no red-shift has been measured. [1] A reduction in brightness/intensity is not a change in wavelength. [1] Do not use faintness alone to decide recession speed.



2 Comparing spectral fingerprints

Figure 1 shows selected absorption features of the same model source in the laboratory and two distant galaxies. The marks show wavelength positions, not physical colours. Compare corresponding lines from left to right; this is not a scale for numerical readings.

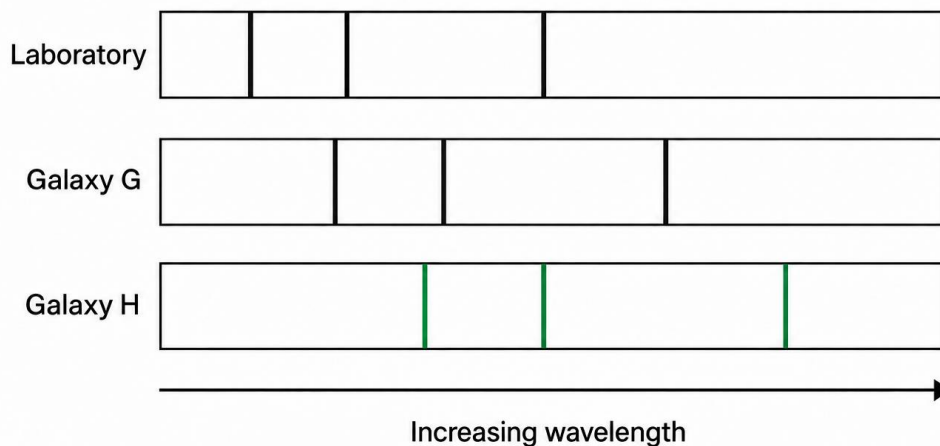


Figure 1

2(a) Compare the wavelengths of the features in galaxy G with the corresponding laboratory features. [1 mark]

Answer / mark points: All three corresponding features in G are at longer wavelengths. [1] Refer to corresponding features, not just the rightmost line in isolation.

2(b) Compare the recession speeds of G and H. Explain your answer using the spectral features. [3 marks]

Answer / mark points: Both sets of features have increased wavelengths, indicating that both galaxies recede from us. [1] H has the greater red-shift for corresponding features. [1] H therefore recedes faster than G. [1] Faster means a greater recession speed, not that its speed has been measured increasing with time.

2(c) Only one dark feature is detected in a faint third galaxy. Explain why the team should seek several matching features before making a confident comparison with the laboratory pattern. [2 marks]

Answer / mark points: One isolated line might be matched to the wrong laboratory feature. [1] Several corresponding features showing a consistent shifted pattern give a more reliable identification/comparison. [1] The pattern stretches; its gaps need not remain exactly unchanged.



3 Auditing the wavelength data

Table 1 gives exact values for the three corresponding features P, Q and R in the model. All values are wavelengths in nm. Use these data, not measurements from the diagram.

Table 1

Feature	Laboratory / nm	G / nm	H / nm
P	450	495	540
Q	500	550	600
R	600	660	720

3(a) For feature Q, calculate the wavelength increase for G and for H relative to the laboratory value. **[2 marks]**

Answer / mark points: G: $550 - 500 = 50$ nm. [1] H: $600 - 500 = 100$ nm. [1] These are changes in wavelength, not the observed wavelengths themselves.

3(b) Calculate the wavelength increase of feature R for H. Compare it with the 100 nm increase of feature Q for H. **[2 marks]**

Answer / mark points: R: $720 - 600 = 120$ nm. [1] It is greater than Q's 100 nm increase (by 20 nm). [1] The longer-wavelength feature has a larger absolute change in this model.

3(c) A technician redraws H by adding 90 nm to EVERY laboratory wavelength. Use features P and R to explain why this does not match Table 1. **[2 marks]**

Answer / mark points: For P, $540 - 450 = 90$ nm, so the rule fits P. [1] For R, the change is 120 nm, not 90 nm, so that same-addition rule fails. [1] The exact data use a consistent 20% increase for H, not a constant added wavelength. No red-shift equation is required.



4 Testing a distance trend

Table 2 is a simplified survey of distant galaxies. Every row uses the SAME feature, measured at 500 nm in the laboratory. Distances were estimated independently. A light-year is a unit of distance. Use the trend, without calculating a galaxy speed.

Table 2

Galaxy	Distance / million light-years	Observed wavelength / nm
R	120	505
S	240	510
T	360	515
U	480	520

4(a) Use Table 2 to put R, S and T in order of increasing recession speed, starting with the slowest. **[1 mark]**

Answer / mark points: R, S, T. [1] The common feature has increasing wavelength shifts of 5, 10 and 15 nm. Do not rank the galaxies alphabetically without using the data.

4(b) Describe how the wavelength shift and inferred recession speed change as distance increases in this survey. **[2 marks]**

Answer / mark points: More distant galaxies have a greater wavelength increase/red-shift for the same feature. [1] They are therefore inferred to recede faster. [1] This is a comparison across different galaxies.

4(c) Another distant galaxy W has this same feature at 530 nm. Using the survey trend, compare its expected recession speed and distance with U. **[2 marks]**

Answer / mark points: W has a greater shift (30 nm versus U's 20 nm), so is inferred to recede faster. [1] The survey trend suggests W is farther away than U. [1] No exact distance is asked for or needed.

4(d) A writer says Table 2 proves that each individual galaxy is speeding up with time. Explain why the table alone cannot establish this. **[2 marks]**

Answer / mark points: It compares different galaxies at different distances. [1] It does not track a change in one galaxy's recession speed with time. [1] A speed–distance trend is not by itself a speed–time record.



5 Checking what the evidence means

The exhibit writer must describe expansion accurately and show how the team checks its conclusions. Use the spectral evidence and the survey when answering.

5(a) The draft says expanding space means every galaxy must itself be growing in size. Correct this interpretation of the survey. **[2 marks]**

Answer / mark points: The evidence supports increasing separation of distant galaxies/expansion of space between them. [1] It does not establish that the galaxies themselves are growing in size. [1] Keep object size separate from separation.

5(b) Explain why tracing the expansion backwards supports a smaller earlier universe. State why these wavelength data alone do not measure its initial temperature. **[2 marks]**

Answer / mark points: If separations increase as the universe expands, earlier separations were smaller. [1] The wavelength comparisons do not directly measure the initial temperature; “extremely hot” is part of the Big Bang model, not a thermometer reading from this table. [1] Do not describe an explosion into an already empty surrounding space.

5(c) Describe one check the team could use before accepting its wavelength results, and explain how the check increases confidence in the conclusion. **[2 marks]**

Answer / mark points: Example: check the wavelength calibration using a known laboratory source. [1] This can reveal a systematic wavelength offset that could mimic a shift. [1] Alternatively, an independent team repeats the measurements [1] to test whether the trend is reproducible rather than an instrument/analysis error [1]. Accept qualified peer review of the method/data [1] to find errors or unsupported interpretations [1]. Award one linked check–reason pair only, maximum 2. More observers voting for a theory is not a scientific check.

6 Reviewing later observations

A separate review of supernova observations from 1998 onwards suggests that distant galaxies are receding ever faster. The review lists dark mass and dark energy as aspects of the universe that are not yet fully understood.

6(a) Explain what the supernova review means by “receding ever faster”. **[1 mark]**

Answer / mark points: Its recession speed increases with time: its recession accelerates. [1] Do not answer merely that a farther galaxy is faster, or that light travels faster.

6(b) A previous model predicted constant recession speeds. Explain how scientists should respond if repeated new observations instead favour accelerating recession. **[2 marks]**

Answer / mark points: Reassess/refine the model so its predictions can account for the new evidence. [1] Test the revised explanation against the new observations and the earlier evidence for expansion, rather than ignoring either set. [1] Acceleration does not remove the evidence that space expands.

6(c) A visitor says naming dark mass and dark energy means scientists have explained everything about the universe. Evaluate this claim using the review. **[2 marks]**

Answer / mark points: The review identifies these as aspects that are not fully understood; names do not supply a complete physical explanation. [1] Such uncertainties do not erase the separate observational evidence for expansion/the supported parts of the model. [1] No detailed mechanism for either dark mass or dark energy is required.

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7 Writing the evidence argument

The exhibit draft says: “Our galaxy spectra and distance survey prove the whole Big Bang theory. They also prove that each galaxy is speeding up with time.” Write a scientifically accurate replacement.

7(a) Use Figure 1 and Table 2 to explain how observations support expansion and the Big Bang model, and evaluate the draft’s two uses of “prove”. Structure your answer around: what is observed; what is inferred about recession and the past; what these data do not establish. **[6 marks]**

Answer / mark points: Original PhysicsUK best-fit levels rubric, not an official AQA mark scheme. Level 3 (5–6): a coherent evidence-to-inference explanation links corresponding longer wavelengths to recession, greater shifts at greater distances to expanding space, and backwards expansion to a smaller past universe/Big Bang support. It evaluates both certainty about the whole model and the missing speed–time evidence. Use 6 for a complete linked account; 5 for a minor omission. Level 2 (3–4): some correct linked observations and conclusions with a relevant limitation, but incomplete coverage or reasoning. Level 1 (1–2): isolated relevant statements with little linkage. 0: no relevant physics. Judge the whole response; do not allocate six automatic keyword ticks. Example: G and H show corresponding features at longer wavelengths than the laboratory reference, so they are receding. H’s greater shift indicates faster recession. The survey shows greater shifts for more distant galaxies, supporting expansion of space. Tracing expansion backwards suggests a much smaller earlier universe, consistent with the Big Bang model of a very small, extremely hot and dense beginning. These observations support the model but do not prove every detail or directly measure the initial temperature. The table compares different galaxies, not changes of speed with time, so accelerating recession requires additional evidence such as the separate supernova observations.

Review and improve

Require the full evidence-to-inference link rather than “it is red”. More distant galaxies receding faster and recession speeding up with time are different statements. Red-shift supports expansion and the Big Bang model; it does not directly measure the initial temperature or explain dark mass and dark energy.

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