

15.1 Spectral shifts: a low-speed astronomical estimate

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS redshift • rest wavelength

Objective

Spectral shifts: a low-speed astronomical estimate. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

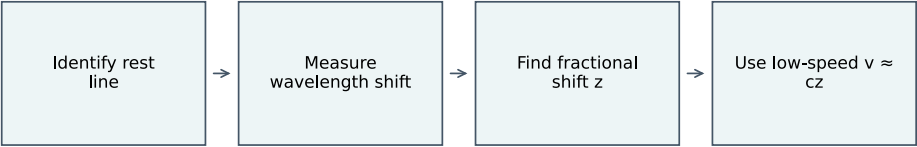
1 Key knowledge and worked examples

■ What would explain this observation?

- A recognizable spectral line appears at a longer wavelength in a distant source. Its shift can provide evidence of recession along the line of sight.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- Relative source-observer motion changes observed frequency or wavelength. For light at a relative speed much smaller than c , the magnitude of the fractional wavelength shift is approximately v/c . Recession corresponds to longer wavelength, and approach to shorter wavelength.
- **redshift** : Shift of an identified line toward longer wavelength; **rest wavelength** : Wavelength of the line measured with no relative source motion.



■ Choose evidence that can test it

- Compare a identified line with its laboratory rest wavelength. Use $z = (\text{observed} - \text{rest})/\text{rest}$, then v approximately cz in the stated low-speed model. Do not apply this approximation without checking the regime or treating a cosmological redshift as a simple exact velocity.
- Use attributed spectra with calibration and line identification. Compare several lines for a consistent shift. State uncertainty and distinguish relative line-of-sight motion from an unmeasured transverse component.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a 500 nm rest line is observed at 501 nm. $z = (501 - 500)/500 = 0.002$. With $c = 3.0 \times 10^8$ m/s, v approximately 6.0×10^5 m/s away. The sound-source denominator formula is not the required SL light approximation.

Example:

A 600 nm rest line is observed at 601.2 nm. Find $z = (\text{observed} - \text{rest})/\text{rest}$. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- The approximate shift relation does not show that light travels faster from an approaching source. A single unidentified line cannot safely establish a redshift.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

An observed redshift means light speed increased. This claim is false: The approximate shift relation does not show that light travels faster from an approaching source. A single

unidentified line cannot safely establish a redshift.

Key:

Spectral shifts: a low-speed astronomical estimate: Compare a identified line with its laboratory rest wavelength. Use $z = (\text{observed} - \text{rest})/\text{rest}$, then v approximately cz in the stated low-speed model. Do not apply this approximation without checking the regime or treating a cosmological redshift as a simple exact velocity.

2 Practice

2.1 What does an identified line shifting to a longer wavelength suggest in the stated model? Choose one answer.

- **A** Recession along the line of sight
- **B** Light speed increased
- **C** The source frequency must be zero

[1]

2.2 A 600 nm rest line is observed at 601.2 nm. Find $z=(\text{observed}-\text{rest})/\text{rest}$. Show the relation, substitution and units.

[2]

2.3 Decide whether this claim is true and justify: An observed redshift means light speed increased.

[2]

2.4 Shift of an identified line toward longer wavelength: write the technical term.

[1]

3 Exam-style questions

3.1 A 500 nm rest line is observed at 499 nm. Find z and low-speed radial velocity using $c=3\times10^8$ m/s. Explain sign and limit.

[4]

Solutions

2.1 A Compare a identified line with its laboratory rest wavelength. Use $z = (\text{observed} - \text{rest}) / \text{rest}$, then v approximately cz in the stated low-speed model. Do not apply this approximation without checking the regime or treating a cosmological redshift as a simple exact velocity.

2.2 $z = (601.2 - 600) / 600 = 0.002$.

2.3 False. The approximate shift relation does not show that light travels faster from an approaching source. A single unidentified line cannot safely establish a redshift.

2.4 redshift. redshift means Shift of an identified line toward longer wavelength.

3.1 $z = -0.002$; $v \approx cz = -6 \times 10^5$ m/s, approaching under the positive-away convention. This small- $|z|$ kinematic approximation does not cover every origin of redshift.