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. Original classroom practice for IB HL; not an official IB paper.

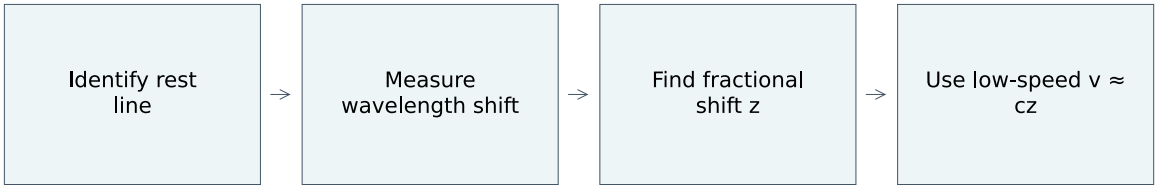
1 Key knowledge and worked examples

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.

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 = (observed−rest)/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.

In the lab: 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

- Known: a 500 nm rest line is observed at 501 nm. z = (501−500)/500 = 0.002.
- With c=3.0×10^8 m/s, v approximately 6.0×10^5 m/s away.
- The sound-source denominator formula is not the required SL light approximation.

Your turn: A 600 nm rest line is observed at 601.2 nm. Find z=(observed−rest)/rest.

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.

Not true: An observed redshift means light speed increased. Light speed in vacuum is the same for all observers. Redshift is a change in observed wavelength from relative motion (or expanding space), not light travelling faster or slower.

Key:

- Relative source-observer motion changes observed frequency or wavelength.
- Compare a identified line with its laboratory rest wavelength.
- Watch for: the approximate shift relation does not show that light travels faster from an approaching source.

Write from a redshift of 0.004

- A 400 nm rest line is observed at 401.6 nm.
- Find z. Redshift does not mean the speed of light increased.

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** The source frequency must be zero
- **C** Light speed increased [1]

2.2 A 600 nm rest line is observed at 601.2 nm. Find z=(observed−rest)/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]