# 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.

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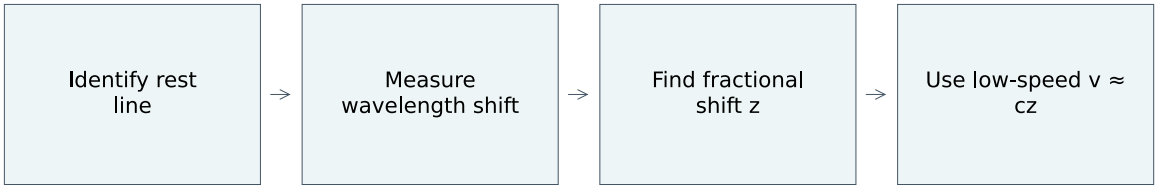
### Build the model

- 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.

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## Work from known quantities

- Known: a 500 nm rest line is observed at 501 nm. z = (501−500)/500 = 0.002.
- With c=$3.0\times10^8$ m/s, v approximately $6.0\times10^5$ 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.

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## 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]

## Solutions

**2.1 A** A known line found at a longer wavelength is redshifted, which in this model means the source is receding along the line of sight. The speed of light is constant, and a shifted line still has a nonzero frequency.

**2.2** z=(601.2−600)/600=0.002.

**2.3** False. 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.

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

**3.1** z=−0.002; v≈cz=$-6\times10^5$ m/s, approaching under the positive-away convention. This small-|z| kinematic approximation does not cover every origin of redshift.