Doppler effect

International Baccalaureate · IB Diploma · Physics · SL

Scope and prerequisites

This handout covers selected SL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

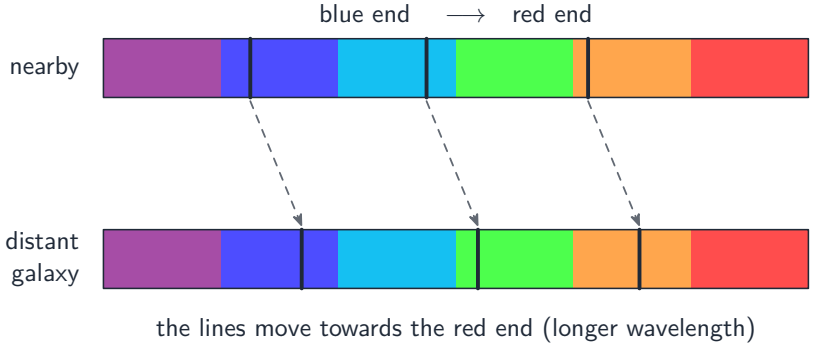
Spectral shifts: a low-speed astronomical estimate

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.



Every line shifts towards longer wavelength: $z = \Delta\lambda/\lambda$, and $v \approx cz$ at low speed

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■ 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 0.005

- A 500 nm rest line is observed at 502.5 nm.
- Find z. Redshift does not mean the speed of light increased.

■ **Write from a blue shift of 0.001**

- A 600 nm rest line is observed at 599.4 nm.
- $z = (599.4 - 600) \div 600 = -0.001$, so $v \approx 0.001c = 3.0 \times 10^5$ m s^{-1} TOWARD the observer – the sign carries the direction.

■ **Write from a unit check on z**

- A worksheet quotes $z = 0.002$ "nanometres".
- $z = \Delta\lambda \div \lambda$ is a ratio with NO units: quote v as a fraction of c first (0.002c), converting to metres per second only at the end.