Exploring the Cosmos since 1790

A Level Physics Astronomy

2020

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ARMAGH OBSERVATORY & PLANETARIUM

EXPLORING THE COSMOS SINCE 1790

Programme 2020

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→ Education → Secondary Schools → A-Level

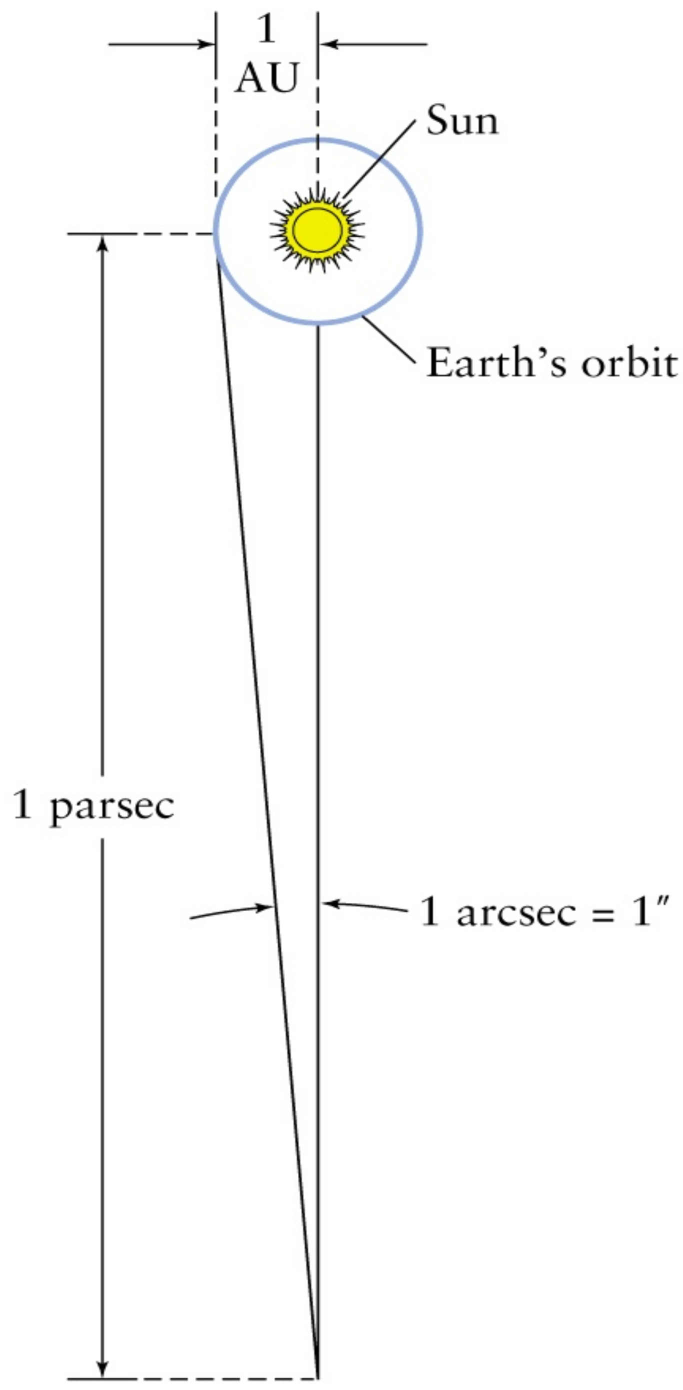
Week	Class	Tutorial	Planetarium
1. Tuesday March 10	Doppler Redshift & Stars	Doppler Redshift for orbit of a planet	Our Solar System
2. Wednesday March 25	Cosmological Redshift & Galaxies	Hubble's Law	Our Galaxy
3. Thursday April 2	Cosmology & the Age of the Universe	Cosmic Scales	Galaxies and Large-Scale Structure

Lecture 1

Doppler Redshift and Stars

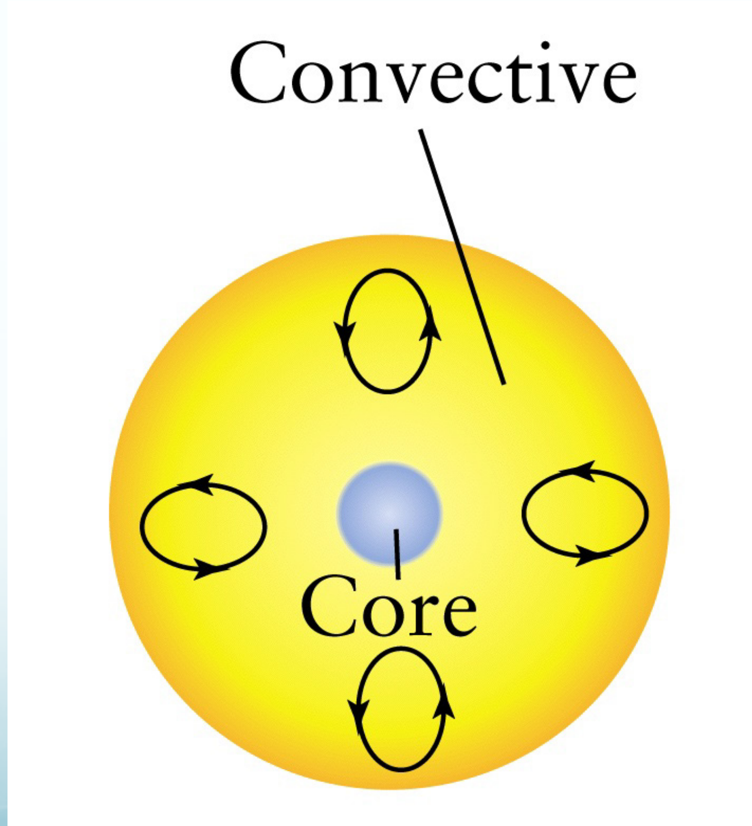
Distances in Astronomy

- Astronomical Unit
  - Average distance from Earth to Sun
  - 1 AU = 1.5×10^{11} m
- Light Year
  - Distance light travels in 1 year
  - 1 lyr = 9.5×10^{15} m
- Parsec
  - Distance to star with a parallax angle of 1 arcsecond on a 1 AU baseline
  - 1 pc = 3.0×10^{16} m



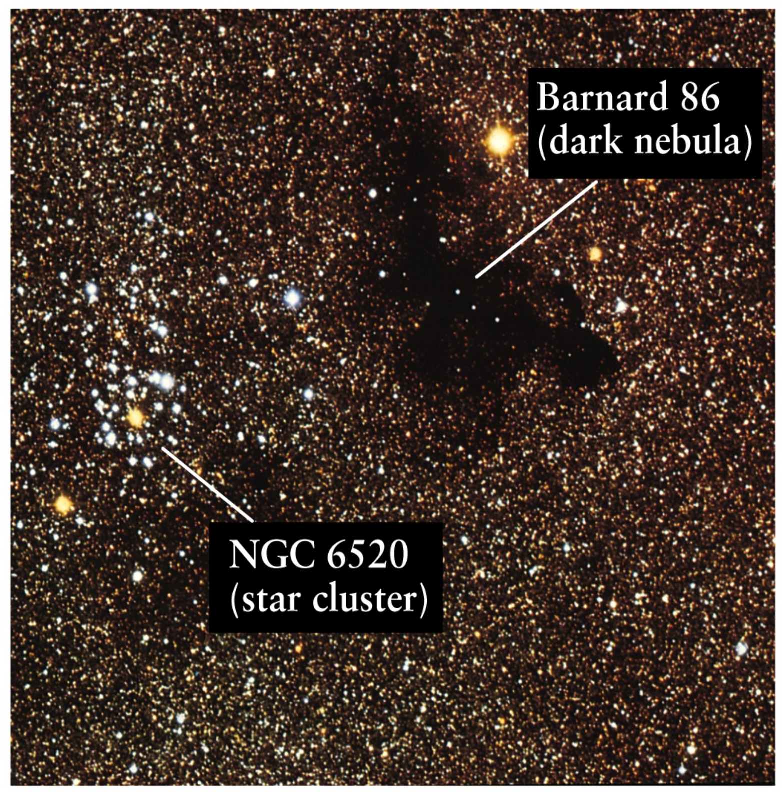
Stars

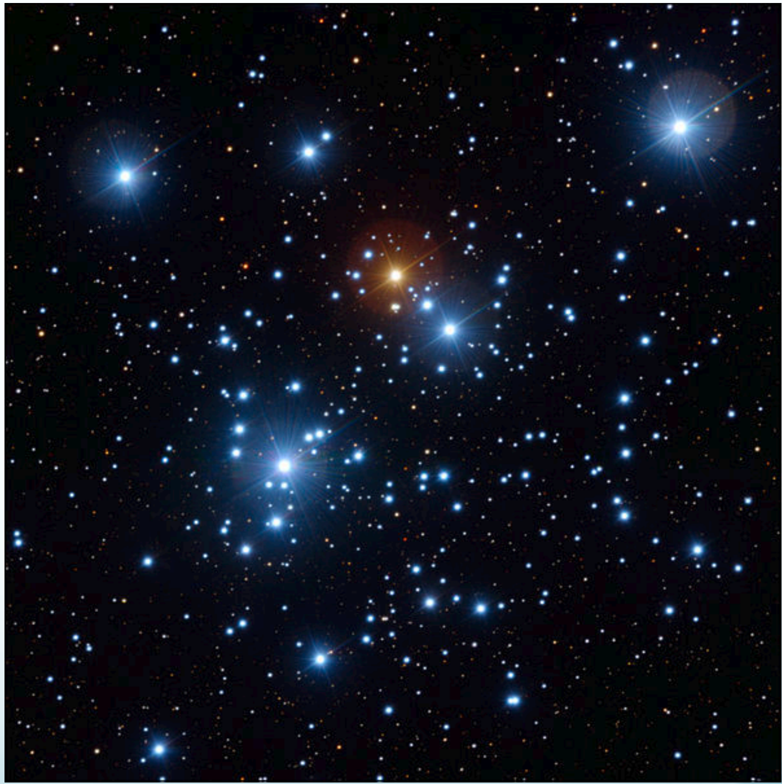
- The basic components of the Universe!
- Balls of gas undergoing nuclear fusion in their cores



Star Clusters

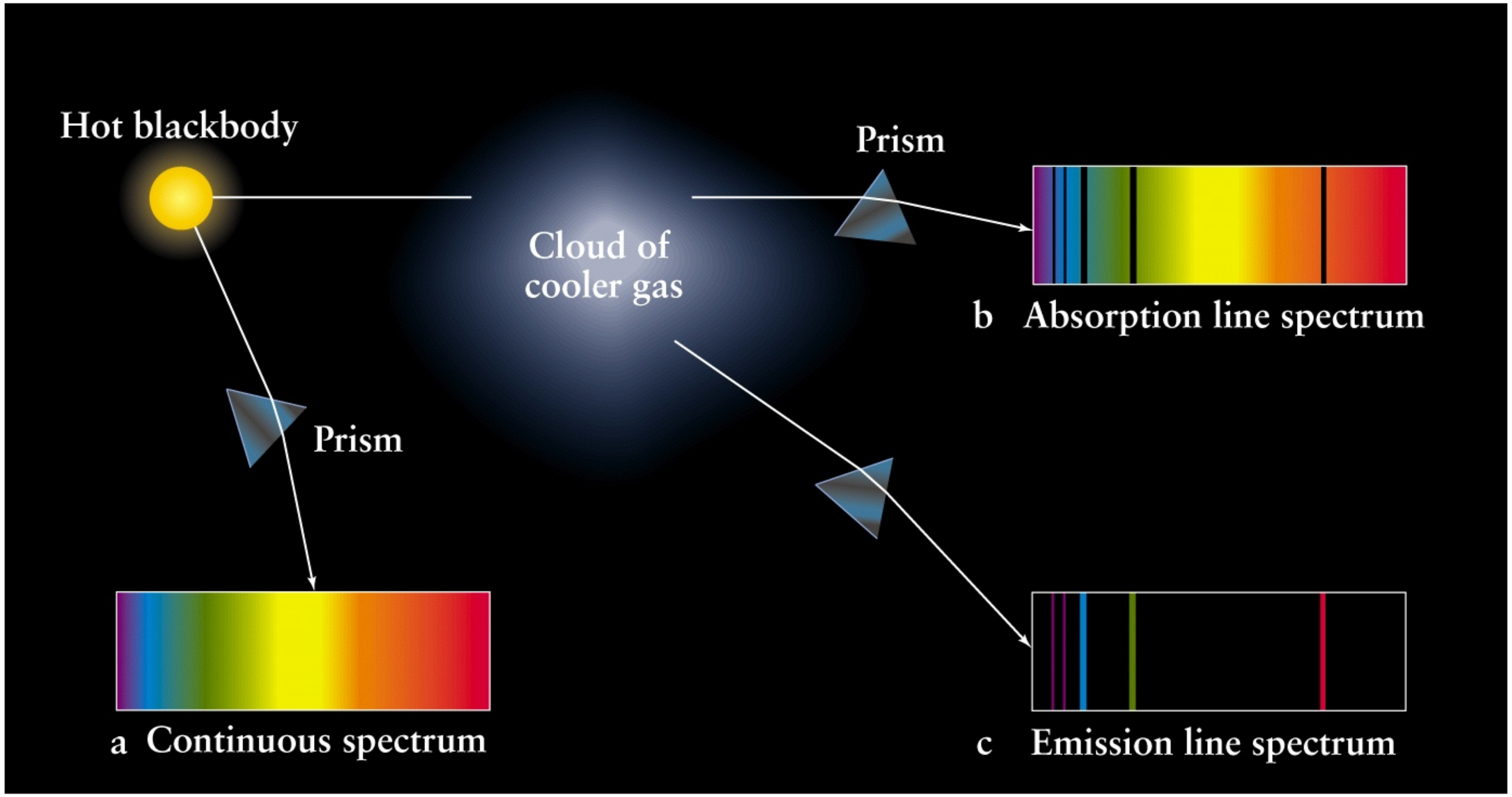
- Stars are often found in clusters





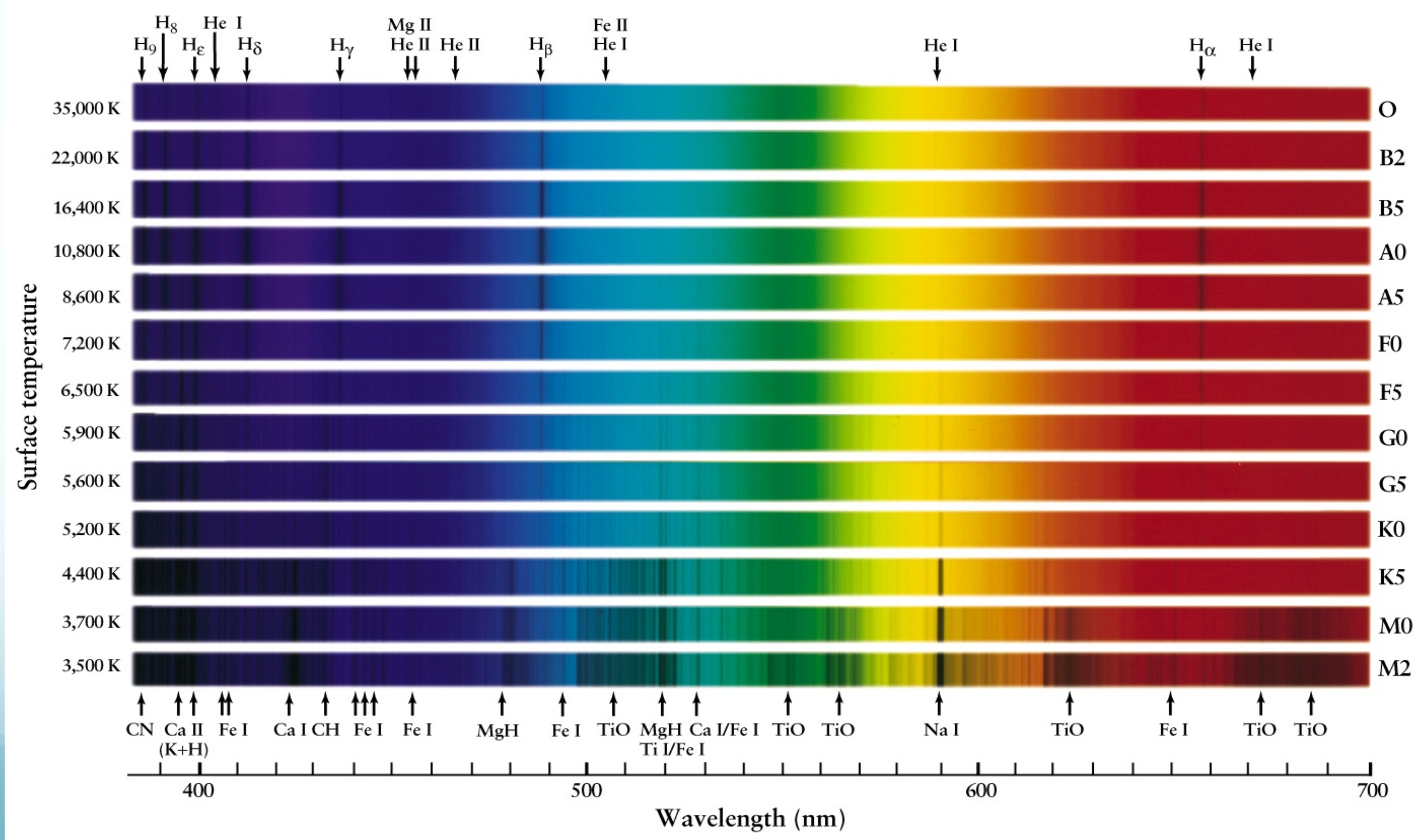
Spectra

- “Continuum” spectrum of stars produces the “colours”
- Absorption – by elements in star surface – dark lines
- Emission – by hot gas – produces bright lines



Spectra of Stars

- Dark lines in the continuum spectrum of stars



Doppler Effect

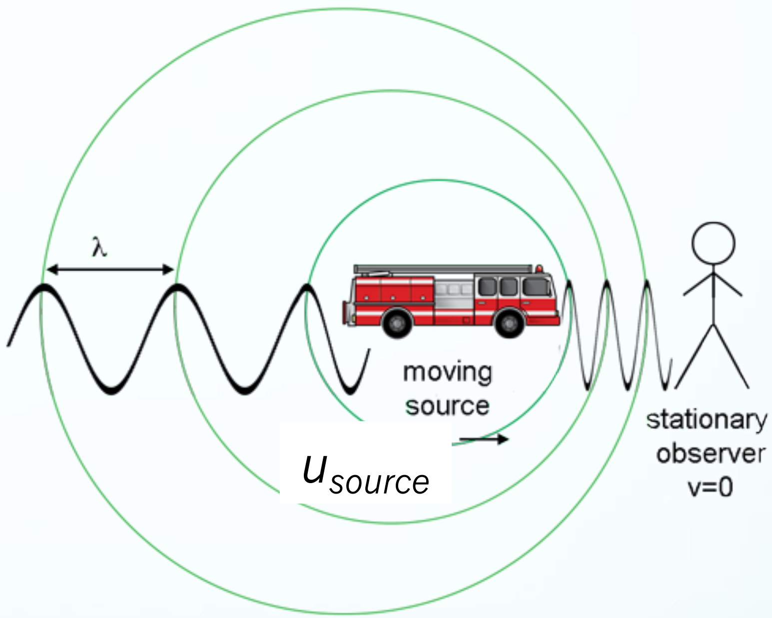
- The change in frequency of a wave when there is relative motion between the source and observer
- Also applies to wavelength
  - Since speed = wavelength x frequency

$$c = \lambda f$$

- When there is a medium (e.g. air, water), the Doppler effect depends on whether the source is moving, the observer is moving, or both.
  - *This is a little tricky. Fortunately you will probably only need to apply the Doppler effect for light rather than sound, which turns out to be a little easier to understand.*

Moving Source, Stationary Observer in a medium

- Approaching:
  - Waves are squashed
  - Frequency increases
    - $f' = \frac{c}{c-u_{source}} f$
- Receding:
  - Waves are stretched
  - Frequency decreases
  - $f' = \frac{c}{c+u_{source}} f$

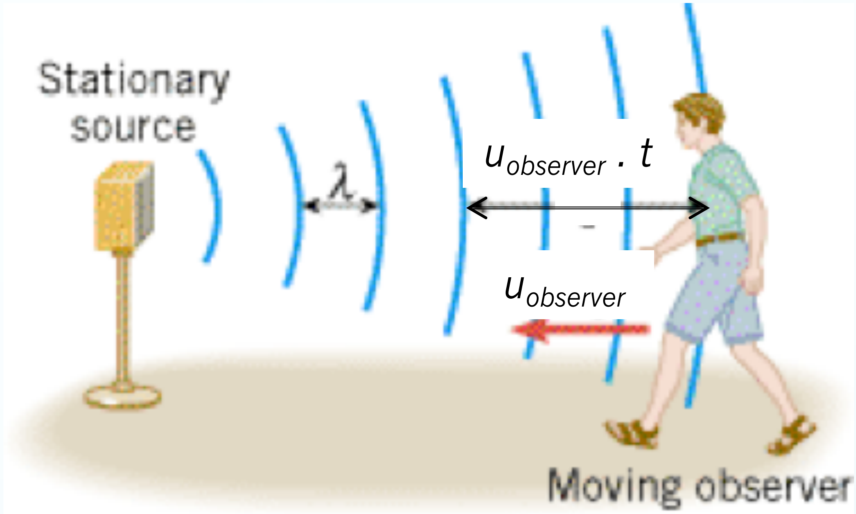


c is the wave speed.
e.g. speed of sound or light.

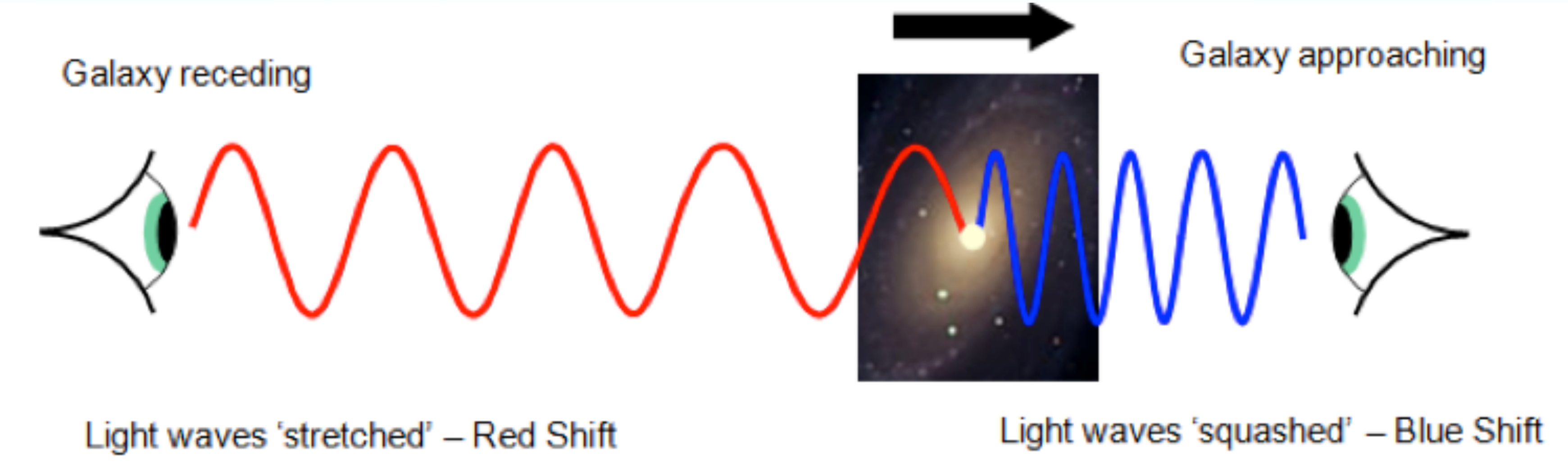
Stationary Source, Moving Observer in a medium

[Not on the syllabus]

- Approaching
  - Wavefronts encountered more frequently
  - Shorter **λ**, Higher ***f***
    - $f' = \frac{c+u_{observer}}{c} f$
- Receding
  - Wavefronts encountered less frequently
  - Longer **λ**, Lower ***f***
    - $f' = \frac{c-u_{observer}}{c} f$



Doppler Effect for Light



- No medium – light travels in a vacuum
- Only the relative speed between source & observer matters
- Approaching: $f' = \frac{c}{c-v} f$ and $\lambda' = (1 - \frac{v}{c})\lambda$
- Receding: $f' = \frac{c}{c+v} f$ and $\lambda' = (1 + \frac{v}{c})\lambda$

This is the most important case you need to learn for A-level Physics!

N.B. These are the same formula as for sound when the source is moving.

The Redshift Parameter, z

- Change in wavelength: $\Delta\lambda = \lambda' - \lambda = \frac{v}{c}\lambda$
- Thus $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
- Define the Redshift Parameter, z, as the fractional change wavelength
  - i.e. $z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
- $z = \frac{v}{c} > 0$ when source is receding: Doppler "redshifted"
- $z = \frac{v}{c} < 0$ when source approaching: Doppler "blueshifted"