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The Doppler Effect & Redshift

Physics

Context

- At Nat 5 we learned that the only way to alter the frequency of a wave eminating from ~~the~~ a source was to change the source.
- The Doppler effect is an example of a way we can change the source - if the source is moving, it will either produce wavefronts that are closer together or further apart, hence changing the observed frequency.

Definitions

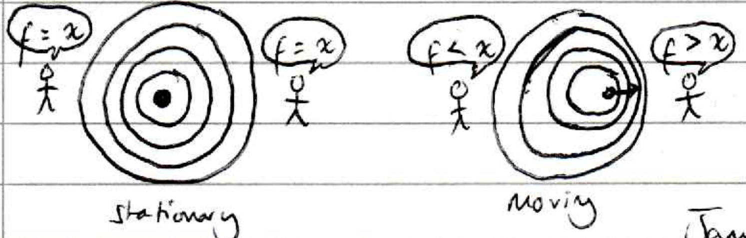
- Frequency - the number of waves that pass a point every second
- Wavelength - the length of one wave, or between two identical points one wave apart.

Equations

- Doppler effect - $f_o = f_s\left(\frac{v}{v \pm v_s}\right)$
- Redshift - $z = \frac{\Delta\lambda}{\lambda_{rest}}$, $z = \frac{v}{c}$

Technique

- As shown in the diagram below, when a source is moving towards you it appears to 'catch up' with its own waves, producing a higher frequency.
- Therefore, a source moving away produces a lower observed frequency.



- For example: an ambulance has a siren emitting a 380 Hz frequency. The ambulance drives away from James and towards Jack at a speed of $26\,ms^{-1}$. What frequencies do they hear respectively?

- The source is moving towards Jack, so he will hear a higher frequency. We find this by taking away in the formula:
- $f_{Jack} = f_S\left(\frac{v}{v - v_S}\right)$

  $f_{Jack} = 380\left(\frac{340}{340-26}\right)$

  $f_{Jack} = 380 \times 1.0828... = 410\ Hz$
- Similarly for James, but adding so we get a lower frequency

  $f_{James} = 380\left(\frac{340}{340+26}\right) = 350\ Hz$
- Now an example for redshift: a galaxy is moving away from earth at $600\ kms^{-1}$. If the light it emits has a rest wavelength of 410 nm what will be the observed wavelength on earth?
- First use $z = \frac{v}{c}$, $z = \frac{600\ 000}{3.0 \times 10^8} = 0.002$

  now $z = \frac{\Delta\lambda}{\lambda_{rest}}$, $0.002 = \frac{\Delta\lambda}{410}$ $\Delta\lambda = 0.82nm$
- As the galaxy is moving away its redshifted light will have a longer wavelength, of:
- $410 + 0.82 = 411nm$

Things to Remember

- For Doppler Effect - <u>take away towards</u>
- To describe redshift, make sure you say the light observed is redder ~~of~~ or of longer wavelength than the rest <u>wavelength</u>

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Evidence for the Big Bang & Hubble's Law

Physics

Context

- For Higher you are required to know the different pieces of evidence that indicate the Big Bang
- There are four main examples, including Hubble's Law which relates to redshift.

Equations

- Hubble's Law - $v = H_0 d$
- Age of the Universe - $t = \frac{1}{H_0}$

Technique

- In the 1920s and 30s Edwin Hubble discovered that there was a relationship between the speed a galaxy was moving away from Earth and its distance from Earth.
- By plotting this data on a graph he found that the two were directly proportional, and that their ratio was a constant - Hubble's constant.
- If we assume that all galaxies are moving away from the origin of the universe, then:
- $t = \frac{d}{v}$ and since $v = H_0 d$

  $t = \frac{d}{H_0 d} \Rightarrow t = \frac{1}{H_0}$
- Other pieces of evidence for the Big Bang are redshift itself, Cosmic Background Radiation, and the abundance of light elements like hydrogen and helium.
- A more obscure piece of evidence is Olber's Paradox, which asks why given the abundance of stars, the night sky is still dark. This is because due to the universe's expansion light from these stars is redshifted into obscurity.

Things to Remember

- Just the evidence: Hubble's law, redshift, CMBR, abundance of H_2 & He, and Olber's Paradox.

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The End of the Universe, Dark Matter & Energy

Physics

Context

- Due to behaviours in the universe we cannot understand, scientists have postulated the existence of Dark Matter and Dark Energy.
- We know that the amounts of the matter in our universe are roughly 4% matter, 23% dark matter, 72% dark energy.
- However, the exact values are mere speculation and we are not sure how our universe will meet its end, due to our uncertainty around dark matter and energy.

Definitions

- Dark matter - a different type of matter that we cannot see but predict exists as galaxies do not have the required mass to hold together otherwise.
- Dark energy - a force we cannot see or detect but predict exists to explain the acceleration of the universe's expansion.

Technique

- If we did not have dark matter, the rotational speed of galaxies would cause all the mass to fly out.
- Dark matter, which interacts with gravity but not light, is postulated to be offering the gravitational force required to keep galaxies from deforming.
- Similarly, the universe is not only expanding, but accelerating in its expansion. Since gravity would oppose this, we thing Dark Energy is causing the force behind this acceleration.
- Whether Dark Energy or gravity wins out in the end will decide the future of our universe - if it expands forever our universe will become a cold waste land, if it collapses due to gravity we'll all be crunched

- Thing to Remember
- Dark matter is to do with galaxies, dark energy to do with the expanding universe.
- Both are undetectable.