AQA A-Level Physics

9.3 Cosmology

Flashcards

What is the Doppler effect?

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The change in wavelength and frequency of a wave as the source moves away or towards the observer.

As the source moves towards the observer, the waves are compressed and wavelength decreases. As the source moves away from the observer, the waves spread out and the wavelength increases.

What is red shift?

What is red-shift?

Red shift (z) is the shift in wavelength and frequency of waves from a retreating source towards/beyond the red end of the electromagnetic spectrum. Cosmological red shift is evidence for the Big Bang.

The formula for red-shift can only be used when v is much smaller than c (the speed of light).

$$\overbrace{z}^{\text{Red shift}} = \frac{\overbrace{\Delta f}^{\text{change in frequency}}}{\underbrace{f}_{\text{original frequency}}} = \frac{\overbrace{v}^{\text{velocity of object}}}{\underbrace{c}_{\substack{\text{speed of light} \\ 3 \times 10^8 ms^{-1}}}} = \frac{-\overbrace{\Delta \lambda}^{\text{change in wavelength}}}{\underbrace{\lambda}_{\text{original wavelength}}}$$

State Hubble's law

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The velocity of receding galaxies is proportional to their distance from Earth.

$$v = H_0 d$$

v = velocity of a retreating galaxy ($km\ s^{-1}$)

d = Distance from Earth (Mpc)

H_0 = Hubble's Constant = 65 $km\ s^{-1}\ Mpc^{-1}$

Use Hubble's law to estimate the age of the universe.

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Time = distance / velocity = 1 / H_0 (since $v = H_0 d$)

The units of Hubble's constant must be converted to SI units

65 km s^{-1} Mpc^{-1} x10^3 gives **H_0 = 65,000 m s^{-1} Mpc^{-1}**

Divide by 1 Mpc (**3.08 x 10^{22} m**) to get the units for H_0 as s^{-1}

H_0 = 2.11 x 10^{-18} s^{-1} so **1 / H_0 = 4.74 x 10^{17} s**

Age (convert to years) = 4.74 x 10^{17} / 3600 / 24 / 365 = **1.5 x 10^{10} years (or 15 billion years).**

Draw a simplified light curve for a binary star system.

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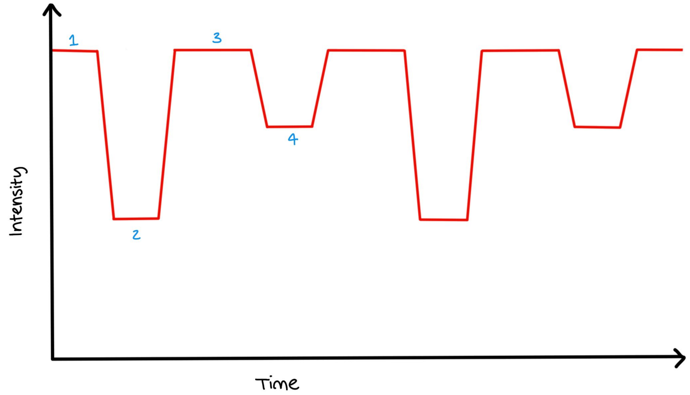
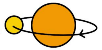
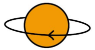
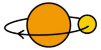
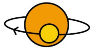


1: no eclipse, so brightness is maximum 

2: larger star is in front of smaller star, blocking all of its light – Primary minimum 

3: no eclipse, so brightness is maximum 

4: smaller star is in front of larger star, partially blocking its light – secondary minimum 

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A quasar is a nucleus of an active galaxy; a supermassive black hole surrounded by a disc of matter. As matter falls into the black hole, jets of radiation are emitted from the poles of the quasar.

Large optical red shift shows quasars are the most distant observable objects. From the inverse square law for intensity we know they are extremely powerful, with the same energy output as several galaxies. They were initially found to be powerful radio sources but with further telescope developments we now know they emit all wavelengths of EM radiation.

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Scientists believe that, 13.8 billion years ago, the universe exploded from an extremely hot and dense point and is still expanding now.

CMBR (Cosmological Microwave Background Radiation) is the heat signature left behind from the big bang. The EM radiation released in the explosion shifted from extremely high energy waves into the microwave region as the universe expanded, stretching out the waves. CMBR has a black body distribution with a peak that corresponds to a temperature of 2.7K. There was nuclear fusion of hydrogen into helium which explains the large abundance of helium in today's universe.

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During the Big Bang, Hydrogen was converted into Helium via nuclear fusion. The expansion of the universe caused it to cool, meaning it was no longer hot enough to fuse elements. About ¼ of all Hydrogen was converted into Helium, resulting in a ratio of H:He of 3:1. The observed distribution of matter now is 73% hydrogen, 25% helium and 2% everything else, which follows the predicted ratio.

What are exoplanets?

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Exoplanets are planets that are not in our solar system.

Direct observations of exoplanets are difficult as their light is often obscured by the stars they orbit. Also they tend to be too close together for the telescope to resolve them.

How can we detect exoplanets?

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1. **Radial Velocity Method:** A star and a planet will orbit their common centre of mass, this means the star will have tiny variations in its distance from Earth, shown by tiny red and blue shifts in its spectrum.
2. **Transit method:** As a planet moves between the star it orbits and the Earth, the star's brightness appears to decrease slightly. We can detect this and use it to calculate the diameter of the planet. Unfortunately there is a low chance of this orbit being in the right place for us to measure this, so it is mostly only useful for detecting planets with small orbits (they are more likely to cross the star's disc).

Draw the light curve for an exoplanet transiting in front of its star

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