Name: ______________________________ Form: ______

GCSE

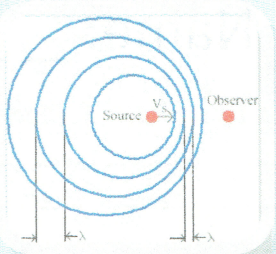
Astronomy

Club

4.3 Galaxies and Cosmology

Cosmology

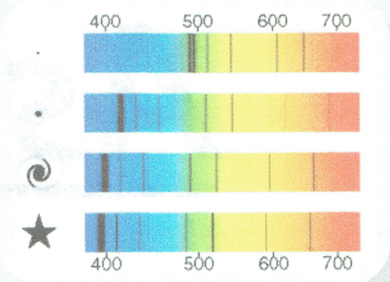
a) Recall the Doppler principle for radial velocities



Radial velocity means: the rate of change of distance between an object (often a star or galaxy) and a point (usually the Earth)

Use the diagram on the right to explain the Doppler principle: The Doppler effect is observed whenever a source of waves is moving with respect to an observer. As the source approaches, the object experiences an apparent upward shift in frequency (+ vice versa). The source always emits a wave of the same frequency but the distance may change. For a given period of time, the same number of waves must arrive. Moving towards the observer, the waves seem to arrive more often – a higher pitch – and vice versa.

b) Demonstrate an understanding that light from distant galaxies is shifted to longer wavelengths (redshift)



Referring to the diagram, explain how red-shift occurs explain how light from different galaxies at different distances from Earth are red-shifted by different amounts: The bottom spectrum is typical of a nearby star. The black lines are where certain wavelengths have been absorbed. By looking for these lines in other objects' spectra, their position depends on their radial velocity. The faster something is moving away from us, the more the lines will be shifted towards the red end. The further away the object is, the more redshift, so it is moving away faster.

c) Use the equation: $(\lambda-\lambda_0)/\lambda_0=v/c$ to determine the radial velocity of a galaxy

Calculate the radial velocity of the most distant galaxy in the diagram in section b).

λ = ~~41~~ 510
λ_0 = 415
c = 3×10^8
v = ??

Equation: $\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$

Rearranged: $v = \frac{\Delta\lambda\, c}{\lambda_0}$

Insert values: $= \frac{95}{415} \times 3\times10^8$

Answer: v = 6.9×10^7 unit: m/s

Calculate the radial velocity of the second-most distant galaxy in the diagram in section b).

λ = 505
λ_0 = 485
c = 3×10^8
v = ??

Equation: $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

Rearranged: $v = \frac{\Delta\lambda\, c}{\lambda_0}$

Insert values: $= \frac{20}{485} \times 3\times10^8$

Answer: v = 1.2×10^7 unit: m/s

d) Demonstrate an understanding that for galaxies in the Local Group blueshift is possible

Explain what is meant by blueshift and how it could come about for a galaxy in the Local Group: A blueshift is the opposite of a redshift – it is a decrease in wavelength. It is caused when an object/source is moving towards an observer – the wavelength of the photons are shortened. For example the Andromeda Galaxy is moving towards the Milky Way. On smaller scales, gravity can overcome the force causing the expansion of the universe.

Blueshift does not occur for galaxies in distant Superclusters because: on a larger scale, the expansive force overcomes gravity so they will always appear redshifted to us

e) Recall what quasars are

A Quasar is: a quasi-stellar radio source. A very energetic + distant object. Most likely a compact but very luminous region in the centre of a massive galaxy surrounding a supermassive black hole. Mass falling into the disc around a black hole produces the energy. Sometimes called an Active Galactic Nucleus

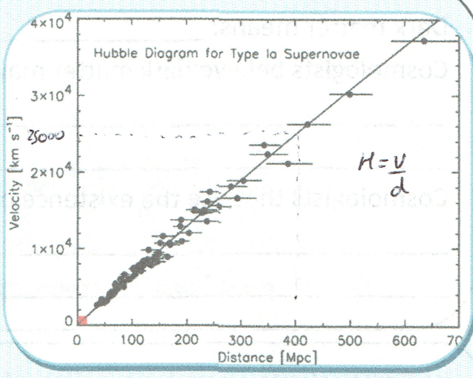
We observe Quasars as very young objects because: they are high redshift objects which means they are very distant. Their light (EM radiation) takes incredibly long times to reach us and suggests most quasars were formed around 12bn years ago

f) Describe the discovery of quasars by astronomers

Quasars were discovered in ~~1959~~ 1963 by Cyril Hazard. He used a radio telescope to analyse the spectrum of Radio Source 3C 273. He realised it was a very different object to any seen before because: it seemed to be a star from its spectrum but its redshift was such that it would be too distant to see. The conclusion had to be that it was a much bigger, brighter object that had a spectrum like that of a star.

A quasar is called a quasar because: it is short for quasi-stellar radio source. Their EM spectra are similar to those of stars (quasi-stellar) and contain a lot of radio.

g) Demonstrate an understanding of the relationship between distance and redshift of distant galaxies (Hubble's Law) and use the formula: v = Hd



$H = \frac{25000}{400} = 62.5$ km/s/MPc

Measure the gradient of this graph to determine Hubble's constant H.

1)Use your value of H and the formula above to calculate the radial velocity of a galaxy which is 360Mpc away.

H= 62.5
d= 360
v= ??

Equation: $v = Hd$

Insert values: 62.5×360

Answer: v= 2.25×10^4 unit: km/s

1)Use your value of H and the formula above to calculate how far away a galaxy with a radial velocity of 0.7×10^4km/s is.

H= 62.5
v= 7000
d= ??

Equation: $v = Hd$

Rearranged: $d = v/H$

Insert values: $7000/62.5$

Answer: d= 112 unit: MPc

h) Describe how astronomers use the value of the Hubble Constant to determine the age of the Universe

The Hubble constant has units of inverse time. The inverse of the Hubble constant is known as the Hubble time. The current value for the Hubble constant is 67.8 km/s/MPc. The inverse gives 4.55×10^{17} s = 14.4bn years. This is slightly longer than the accepted age of the universe (around 13.8 bn years) as the expansion hasn't been linear.

i) Demonstrate an understanding of the existence and significance of cosmic microwave background (CMB) radiation

Explain the origin of CMB radiation: After the Big Bang, the Universe cooled, atoms were formed, and the Universe became transparent. It is known as the recombination epoch. The oldest light in the Universe emerged.

Explain how expansion resulted in what was originally gamma rays to become microwaves: It stretched and cooled (by using up energy) the high-energy radiation.

The relative even spread of CMB across the sky is significant because: it suggest it originated in a fairly uniformly distributed hot gas that then expanded. No model other than the Big Bang has yet explained the fluctuations, and is thus considered the best explanation.

j) Describe how CMB radiation was discovered (1964)

Arno Penzias and Robert Wilson were using a microwave telescope and noticed a constant microwave background noise wherever they pointed their telescope. After excluding any other explanation, they concluded that: this was a cosmic microwave background, and a remnant of the Big Bang. This was because measurements at a range of frequencies showed it was a thermal blackbody spectrum, as predicted as early as 1948.

k) Describe recent observations of CMB radiation, including the Wilkinson Microwave Anisotropy Probe (WMAP), and their significance to cosmologists

Recent observation of CMB radiations have discovered that: the afterglow is nearly uniform in all directions but the tiny residual variations show a very specific pattern.

This is significant because: it is the same as expected of a fairly uniformly distributed hot ~~gast~~ gas with small thermal ~~Th~~ variations in a very tiny (quantum) space which then expanded to the size of the Universe today

l) Demonstrate an understanding of the possible nature and significance of dark ~~matter~~ energy

Dark ~~matter~~ energy means: an unknown form of energy hypothesised to permeate all of space.

~~Cosmologists believe dark matter may take the form of:~~

Cosmologists theorise the existence of dark ~~matter~~ energy because: they need some means of explaining the acceleration of the expansion of the Universe (as observed). It would be a sort of strong negative pressure that acts repulsively

m) Demonstrate an understanding of the significance of dark energy

Dark matter means: matter that can't be seen with telescopes but may be most of the matter in the Universe.

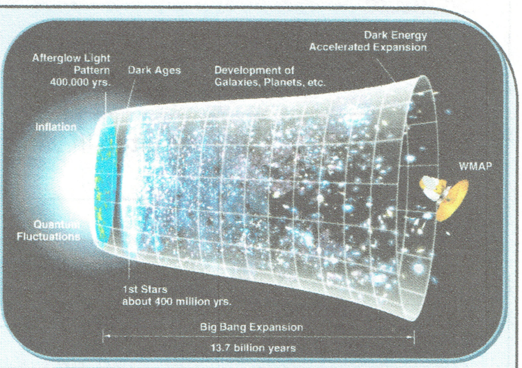
Cosmologists theorise the existence of dark energy because: of its gravitational effects on matter, radiation and the large scale structure of the Universe. It is likely composed of weakly interacting massive particles (WIMPs), a cold relic of the early universe. They have not been detected yet.

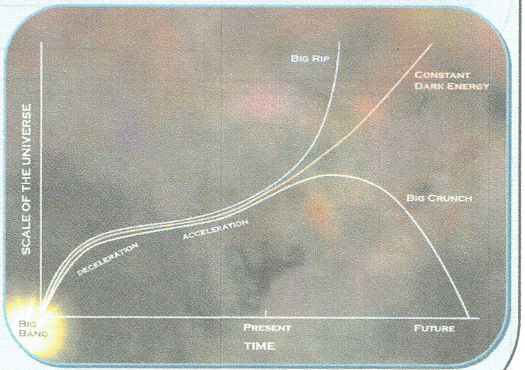
n) Demonstrate an understanding of the observational evidence for an expanding Universe

Evidence	How evidence demonstrates an expanding universe
Red-shift of distant galaxies.	Initially, redshifts interpreted as Doppler effect, but then found that redshift increased with distance. This was re-interpreted as the expansion of space itself, stretching the photons and increasing their wavelength.
CMB radiation	The 'hot' photons emitted at the time of recombination have been redshifted like the photons to longer wavelengths and are now detected as microwaves ('cold')

o) Demonstrate an understanding of the past evolution of the Universe and the main arguments in favour of the Big Bang

p) demonstrate an awareness of the different evolutionary models of the Universe (past and future) and why cosmologists are unable to agree on a model.





On a separate piece of paper;

1. Write a description of each stage of the past evolution of the universe. Wikipedia: "chronology of the Universe"
2. Discuss the main arguments in favour of the Big Bang and explain how they support the Big Bang theory. "Big Bang"
3. Describe the Standard Model of Big Bang Cosmology and compare it to some other models of the expansion of the universe so far. "Physical Cosmology" and "Big Bang"
4. Explain what the Big Rip, Big Freeze and Big Crunch are and describe which one cosmologists think is most likely to happen. "Ultimate fate of the Universe"