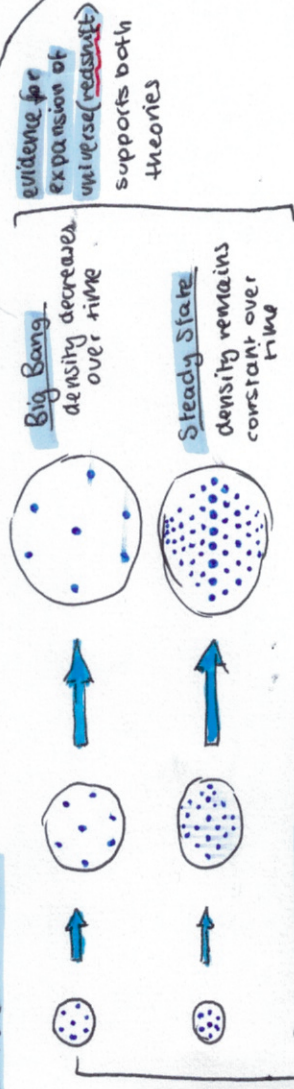


Iniverse Models:

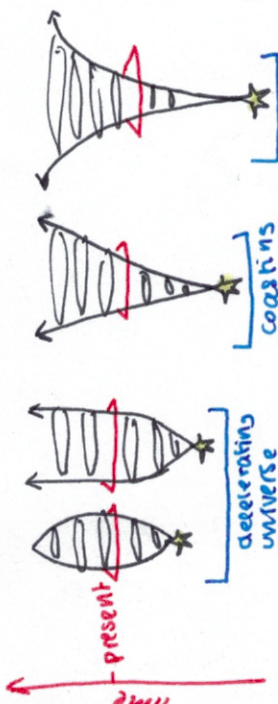


Evidence for Big Bang:

- Quasars** - only found with high redshift which mean very distant and created when universe very young, quasars more common in young universe supports evolutionary nature of Big Bang
- CMBR** - corresponds to a temperature of 2.7K and was the thermal relic of the 'Big Bang', extremely redshifted gamma rays
- Hubble Deep Field Image** - long exposure images of 'empty space', where the FOV was only 2.6' but revealed many thousands of distant and old galaxies, implying that early universe was very different to how it appears today

Evolution of Universe:

- observations of tiny fluctuations in CMB allowed astronomers to study edges of whole universe at time when it was 380,000 yrs old
- tiny temperature fluctuations correspond to different regions of different densities in early universe denser regions where stars and galaxies formed
- revealed that: universe slightly older than previously thought, 25% composed of dark matter, no evidence to invalidate cosmic inflation (rapid uniform expansion of universe)



Cosmology

Weird Stuff:

- Dark Matter and Dark Energy** make up 95% of universe
- difficult to understand as very rarely interact with normal matter particles
- Dark Matter could explain 'gravitational lensing', the apparent bending of light from galaxies to form multiple images of same galaxy
- Dark Matter may exist in form of exotic particle called **WIMPs**
- Dark energy is mysterious force that seems to accelerate the expansion of Universe

observations of galaxies outside the local group shows that light is redshifted

→ redshift is caused by galaxies receding away from us

Redshift equation:

$$\frac{\lambda - \lambda_0}{\lambda_0} = \frac{v}{c}$$

measured wavelength
laboratory wavelength
velocity galaxy is receding at
speed of light

Evidence for expanding universe:

- spectrum of quasar 3C 273 showed a redshift of 16%, so it was receding at 16% of the speed of light
- using increasingly large telescopes, astronomers have confirmed that all distant galaxies in the universe are moving away from us
- the universe is dragging galaxies away from us by expanding

Hubble's Law:



current accepted value: 68 km/s/Mpc
there is a linear relationship between recession velocity and distance

Hubble Length:

interpreted as distance light has travelled in Hubble Time

$$\text{Hubble Length} = c \times \text{Hubble Time}$$

speed of light

Converting to Hubble Time:

$$H_0 = 68 \text{ km/s/Mpc}$$

and

$$1 \text{ Mpc} = 3.1 \times 10^{19} \text{ km}$$

divide both sides of equation by 3.1×10^{19} :
 $1 \text{ km} = 3.2 \times 10^{-20} \text{ Mpc}$

Substitute for 1km in H_0 value:

$$H_0 = 2.2 \times 10^{-18} / \text{s}$$

invert: $T = 4.6 \times 10^{17} \text{ s}$

Hubble Time of $4.6 \times 10^{17} \text{ s}$ is approximately 14 billion years
this can be interpreted as age of universe because this is the length of time it has been expanding for