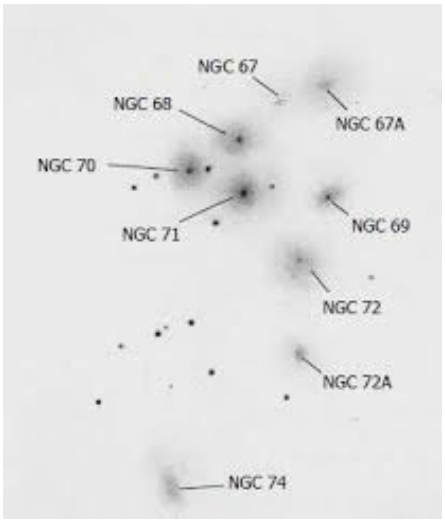
Edwin Hubble was born in Missouri in the year 1864. He was an athlete and an astronomer. It was for his work in astronomy that Edwin became famous.

Applying the Doppler effect to the light coming from galaxies he discovered that ***more distant galaxies have a larger recessional velocity than nearby ones.***

His discovery led onto the fact that space between the galaxies is expanding.

I started observing the cosmos with a new large telescope situated on Mount Wilson in California.

It was the biggest telescope of its time.



At that time of 1919 it was thought that the entire universe was in the Milky Way galaxy.

I measured the distances to these smudges we called nebulae (Latin for clouds) and concluded they they were too far away to be part of the Milky Way.

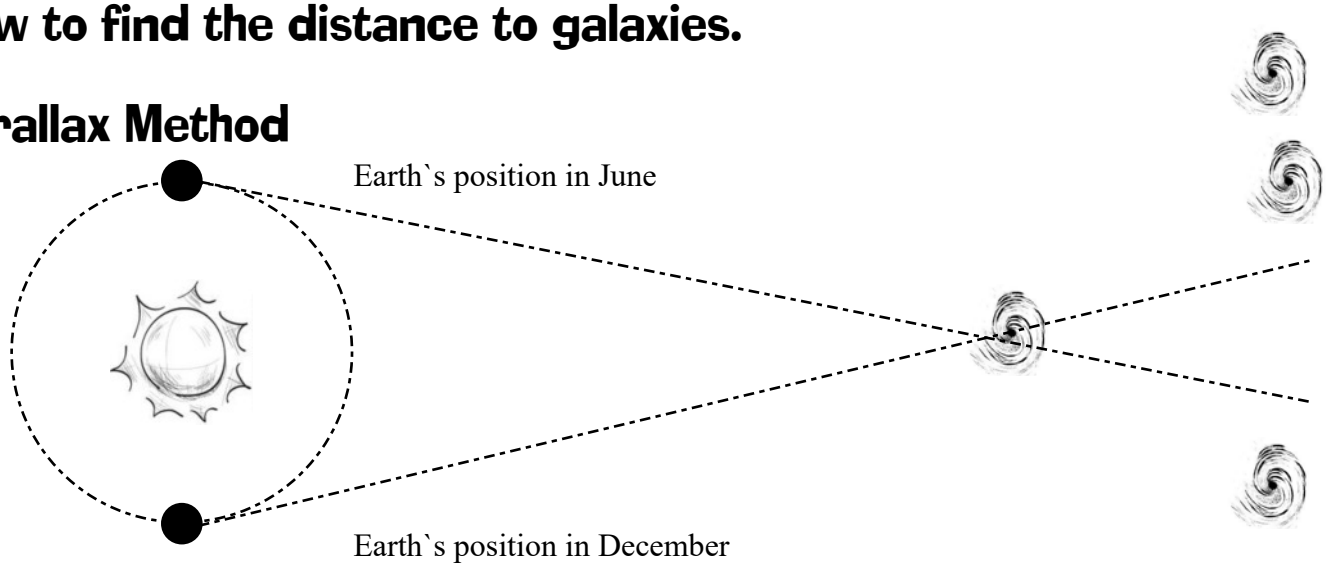
These `clouds in the cosmos` were really galaxies. Galaxies are mega collections of stars.

I actually helped catalogue these galaxies giving them names like NGC 70. I also discovered there were different types of galaxies: spiral, elliptical and lenticular.

You may ask how I worked out the distances to the galaxies. Here are two methods

How to find the distance to galaxies.

Parallax Method



Parallax Method

As you can see between six months the galaxy has apparently moved position against the background.

December June

The angle the galaxy moves through is called the parallax angle. With a bit of trigonometry it can be shown that the smaller this angle the further away the galaxy is.

These shifts are very very small angles.

We can define a new unit of distance called the parsec. This is the distance away a galaxy is that gives an angle of one second of a degree 1/3600 of a degree when the change in position is the distance between the earth and the Sun.

1 Parsec = 3.1×10^{16} metres

1 parsec = 3.26 light years

For galaxies greater than 20 parsecs away it becomes too difficult to use this method.

Cepheid Variables

Fortunately there is a type of star called a cepheid variable. This is a star whose luminosity fluctuates. The period of these fluctuations is linked to its luminosity.

So observing its period of fluctuations in brightness the absolute value of the stars luminosity can be found.

Comparing the stars luminosity with a known star`s luminosity and distance allowed the distance to the star to be calculated.

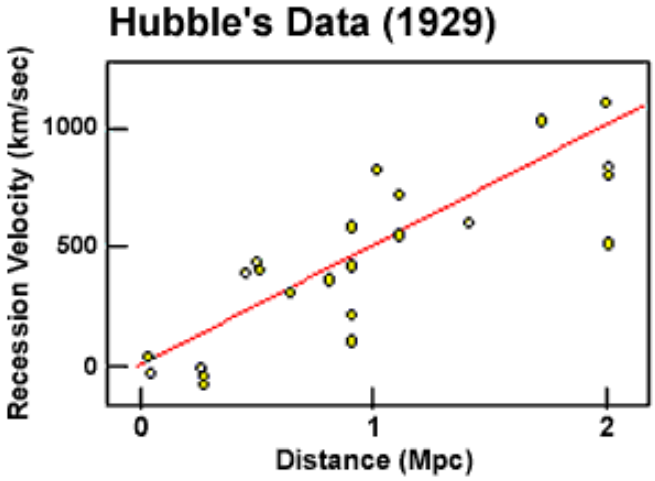
I can thank Henrietta Leavitt as she discovered this method.

Such stars in the galaxies are called STANDARD CANDLES

Now to summarise. I have measured the distances to the galaxies that I am cataloguing and I have recorded each galaxy`s red shifts.

Knowing the red shift of the galaxy I can calculate the velocity it is going away from us.

This is called the galaxy`s recessional velocity



$$recession\ velocity \propto distance$$

$$v \propto d$$

$$v = H_0\ d$$

Hubble`s Constant H_0

Over the years with more sensitive telescopes the Hubble constant has changed.

The accepted value of the Hubble constant is now

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

This number tells us that if a galaxy is at a distance of 1 Mpc then it will be moving away with a velocity of 68 km/s

A galaxy at double the distance 2 Mpc will have a recessional velocity of 136 km/s

For this physics course the Hubble constant is

$$H_0 = 2.34 \times 10^{-18} \text{ s}$$

Calculating the redshift of a galaxy and using my law then the distance of the galaxy can be found.

Hubble`s Constant Calculations

A recessional velocity of a galaxy is found to be 5.0×10^{7} m s^{-1} Using the Hubble equation determine the distance the galaxy is away in metres.

$H_0 = 2.34 \times 10^{-18}$ s^{-1}

A galaxy has a distance of 3.1×10^{22} m from Earth. Use Hubble`s equation to determine the recessional speed of the galaxy.

$H_0 = 2.34 \times 10^{-18}$ s^{-1}

The absorption spectra of a galaxy is observed. One line of the absorption spectra has a wavelength of 500.0 nm. The corresponding line observed in the galaxy is 501.3 nm.

Calculate the redshift ratio

Determine the recessional velocity of the galaxy.

Determine the distanc

Hubble`s Constant and the age of the Universe

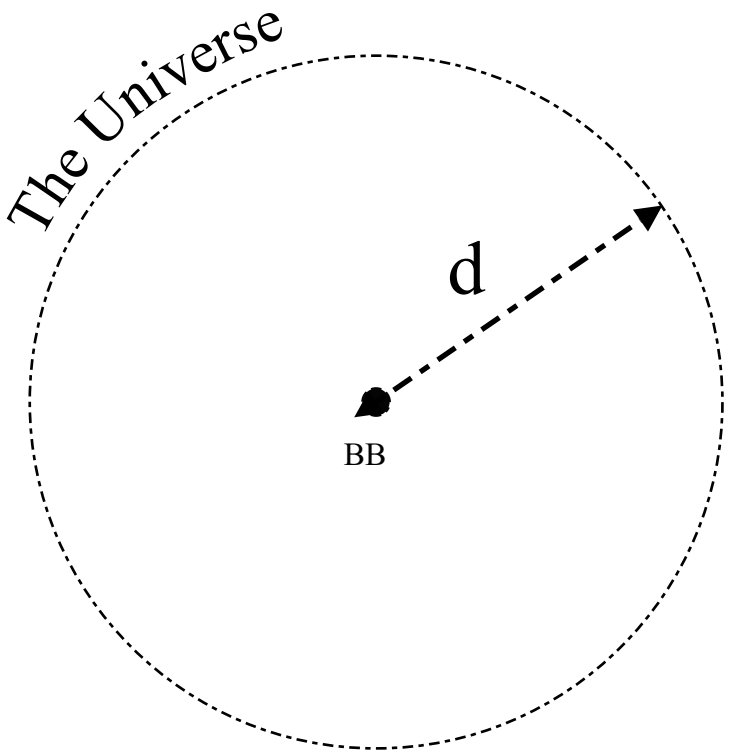
I will now show you how to use the Hubble constant to estimate the age of the Universe.

The diagram below shows a dot where the `big bang` took place.

The circle shows where the expansion has reached now.

Let us say that it is some distance d from the beginning point.

Space has expanded. Let us assume that the speed of the expansion has been the same since the beginning.



$$d = v\,t$$

and

$$V = H_O\,d$$