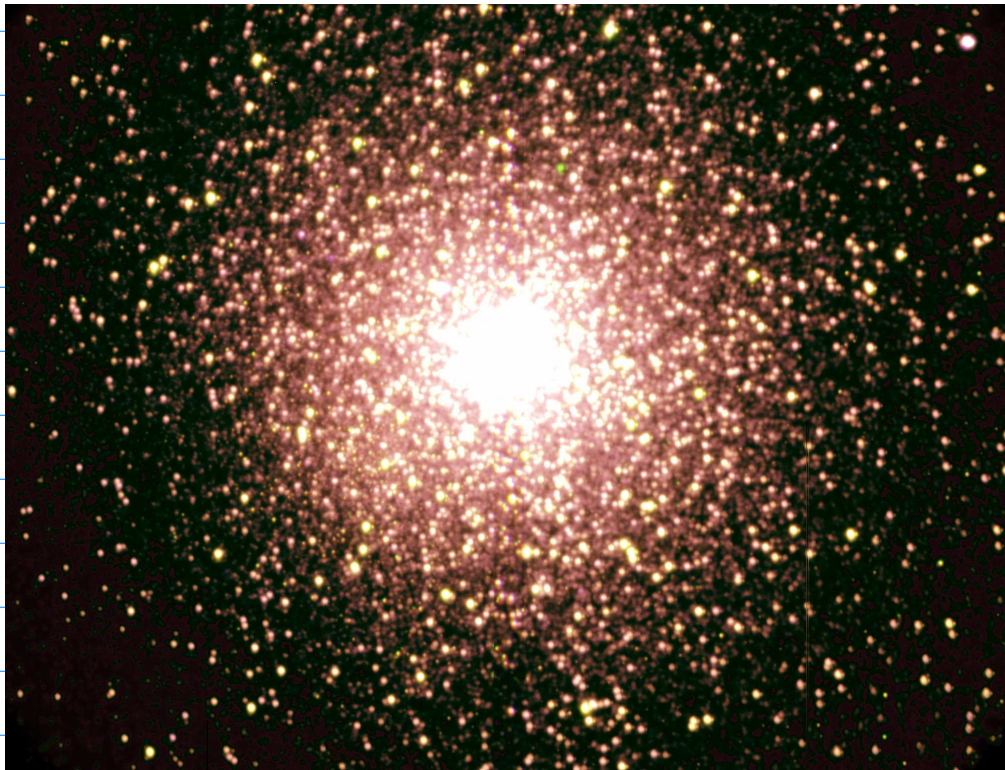FOR THE DISTANCES BEYOND 100 MILLION ly THE
ASTRONOMERS USE THE METHOD OF GLOBULAR
CLUSTERS.

ASTRONOMERS NOTICED THAT THE BRIGHTEST GLOBULAR
CLUSTERS IN NEARBY GALAXIES ALL HAVE THE SAME
LUMINOSITY OF 1,000,000 $M_\odot$. THEN ONE LOCATES
THE BRIGHTEST GLOBULAR CLUSTERS IN MORE DISTANT
GALAXIES, MEASURES THEIR BRIGHTNESS B, AND THEN
DETERMINES THEIR DISTANCE d (AND THE DISTANCE
OF THE GALAXY IN WHICH THEY RESIDE) FROM

$$B = \frac{L = 10^6 M_\odot}{4\pi d^2}.$$

MEASURE   DEDUCE
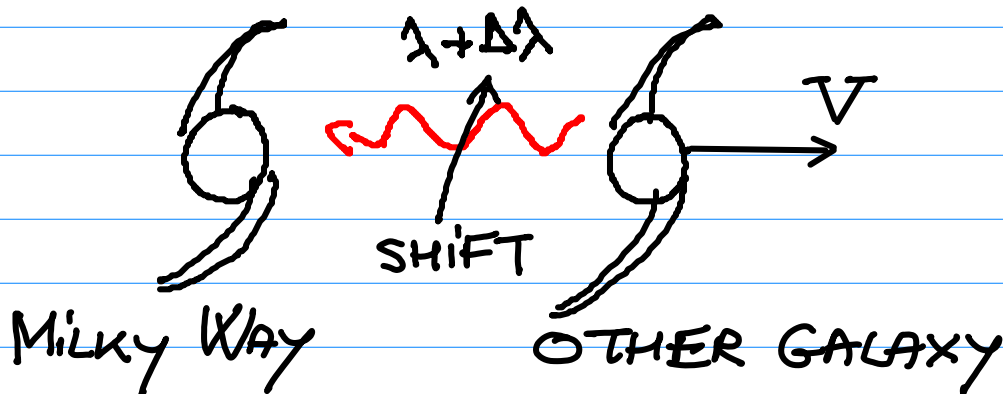
In 1929 American astronomer Edwin Hubble

discovered a relationship between the distance of a galaxy (d) and its recession velocity (V).

He used the data on recession velocities of galaxies obtained by another American astronomer Vesto Slipher. Slipher measured the shift in wavelengths of the spectra produced by stars in the galaxies, and assuming that the shift results from the Doppler effect, he was able to deduce their speed relative to the Milky Way.

WAVELENGTH PRODUCED BY A STATIONARY SOURCE

$\lambda + \Delta\lambda$

SHIFT

V

Milky Way   OTHER GALAXY

MEASURE

DEDUCE

$$Z \equiv \frac{\Delta\lambda}{\lambda} = \frac{V}{C}$$

SPEED OF LIGHT IN VACUUM

Slipher's measurements:

1913 : The light from Andromeda is blueshifted.

1915 : The spectra of 11 out of 15 galaxies were redshifted.

1917 : The spectra of 17 out of 21 galaxies were redshifted.
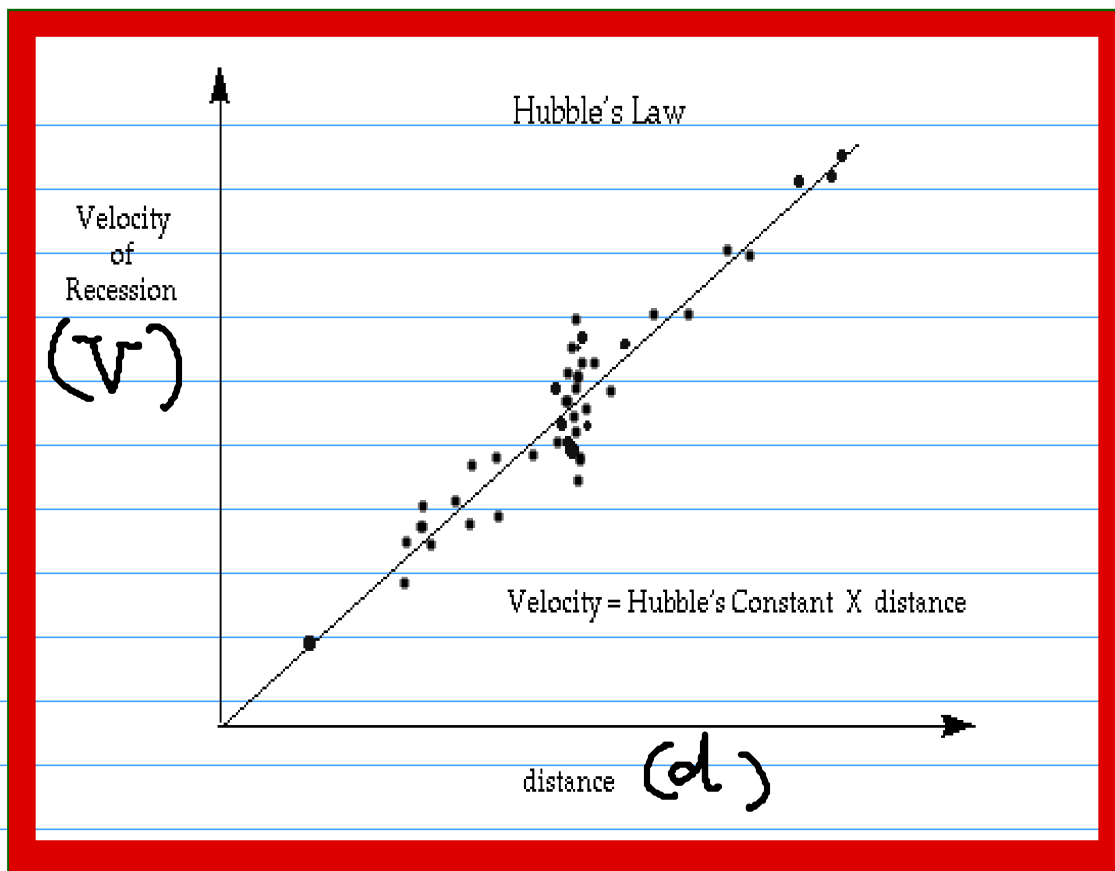
Except for the closest of the galaxies (e.g. Andromeda) the spectra of other, more distant, galaxies were redshifted.

Hubble used Slipher's data on regession velocities of galaxies and he measured their distance using Cepheid variables. Hubble noticed that there is a correlation between the recession velocity and the distance:

$$V = H d$$

HUBBLE'S LAW

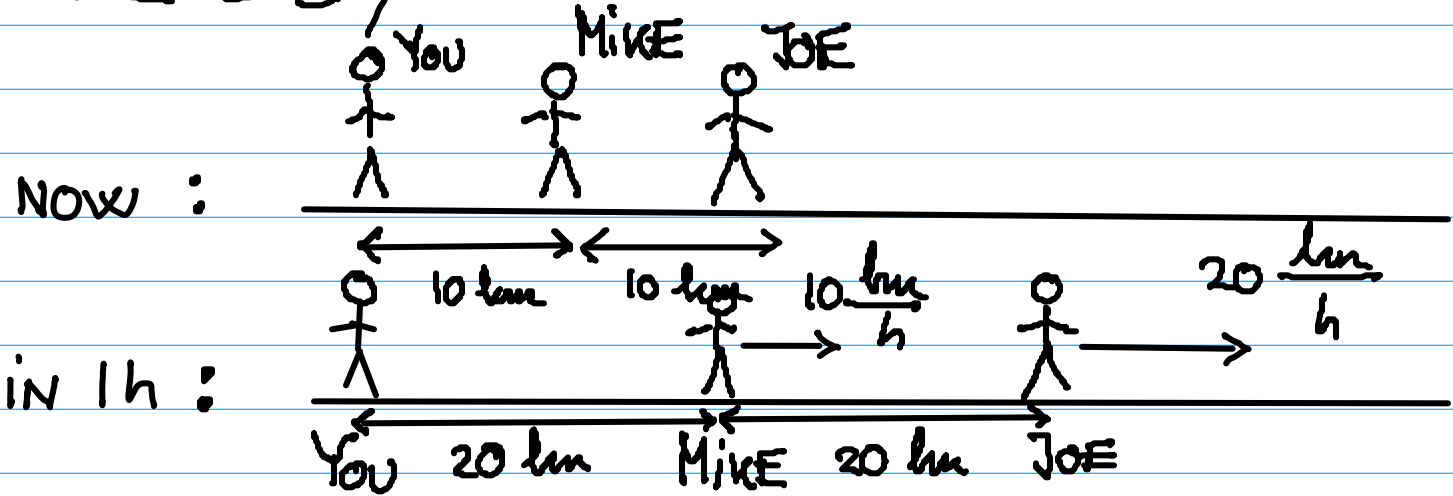the slope of the straight line called Hubble's constant

Hubble's Law

Velocity of Recession (V)

distance (d)

Velocity = Hubble's Constant X distance

THE CURRENT VALUE OF HUBBLE'S CONSTANT IS

$$H = 70 \frac{km/s}{Mpc}$$

$$1 \, Mpc = 10^6 \, pc = 3.26 \times 10^6 \, ly$$

$$1 \, pc = 3.26 \, ly$$

THE HUBBLE'S LAW REVEALS SOMETHING SPECTACULAR ABOUT THE UNIVERSE — IT IS EXPANDING. THE SPACE ITSELF IS EXPANDING.

CONSIDER A ONE-DIMENSIONAL UNIVERSE AND
ASSUME, SAY, THAT THE SPACE IS DOUBLING IN
SIZE EVERY HOUR. THEN

NOW :

in 1h :

RECESSION VELOCITY = (A CONSTANT) · DISTANCE

$$\|$$

$$0.5 \ \text{km/h/km}$$