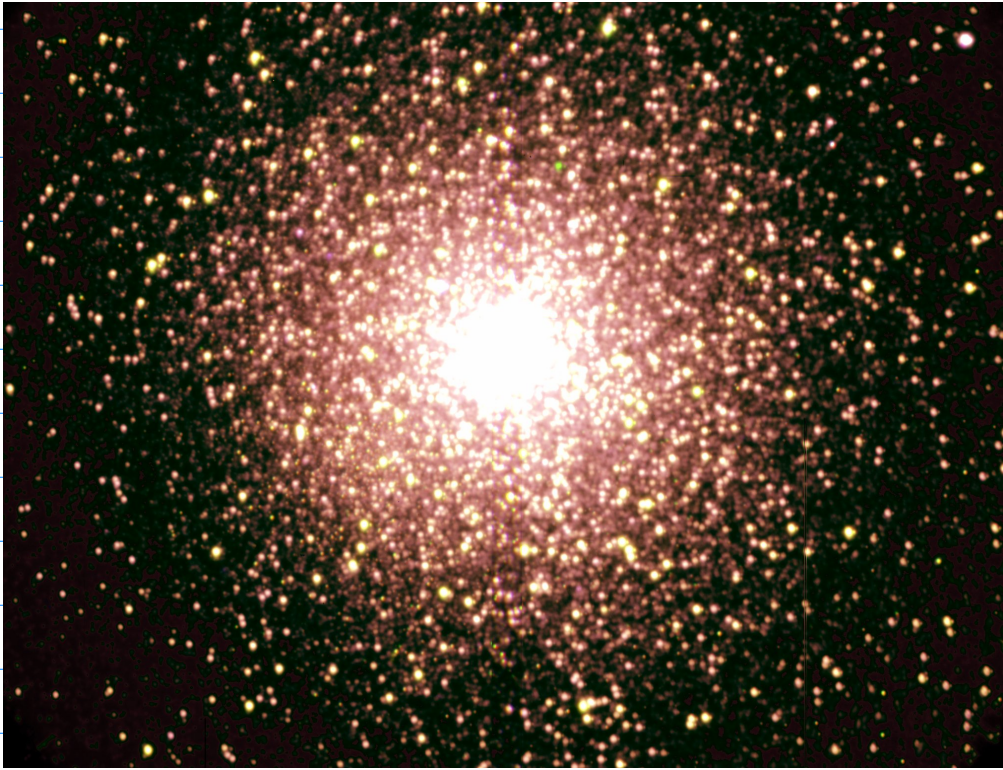


FOR DISTANCES BEYOND 100 MILLION LY THE ASTRONOMERS USE THE METHOD OF GLOBULAR CLUSTERS



ASTRONOMERS NOTICED 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 (AND THE DISTANCE OF THE GALAXY IN WHICH THEY RESIDE) FROM

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

IN 1929 AMERICAN ASTRONOMER EDWIN HUBBLE

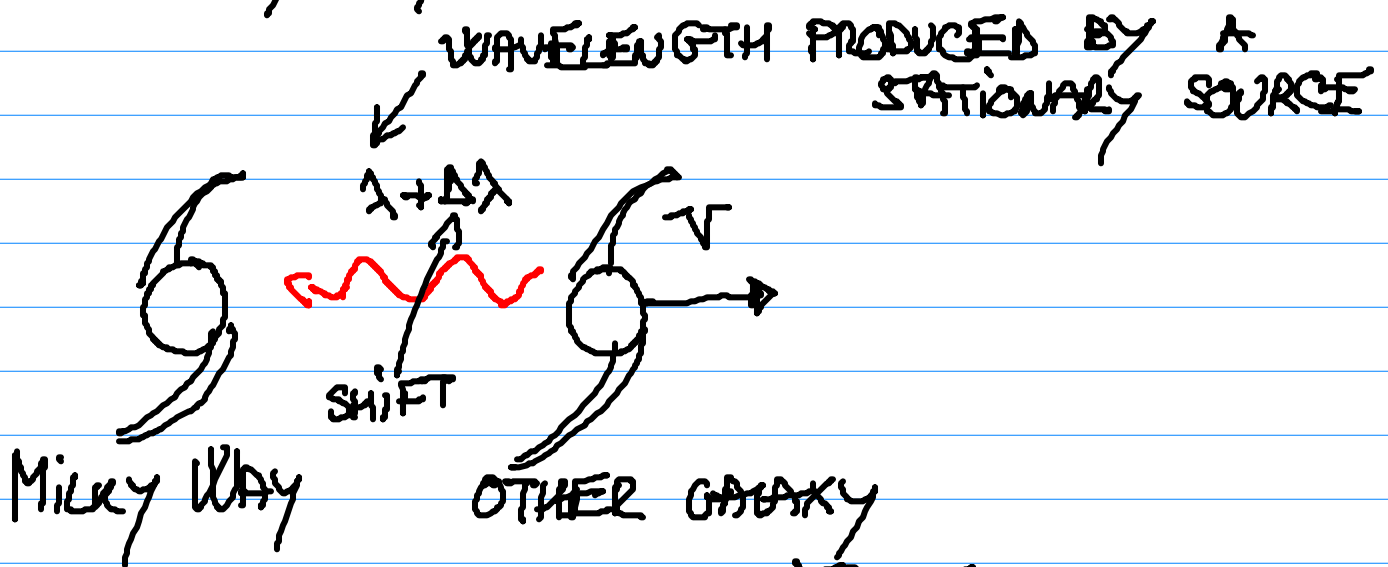


DISCOVERED A RELATIONSHIP BETWEEN THE DISTANCE OF A GALAXY AND ITS RECESSION VELOCITY.

HE USED THE DATA ON RECESSION VELOCITIES OF GALAXIES OBTAINED BY ANOTHER AMERICAN ASTRONOMER, VESTO SLIPHER. SLIPHER MEASURED THE SHIFT OF WAVELENGTHS IN THE SPECTRA OF GALAXIES AND ASSUMING THAT THE SHIFT RESULTS FROM THE DOPPLER EFFECT HE WAS ABLE TO DEDUCE THEIR SPEED RELATIVE TO



# THE Milky Way.



MEASURE  $\rightarrow \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$   $\leftarrow$  REDUCE

$c$   $\leftarrow$  SPEED OF LIGHT

## 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.

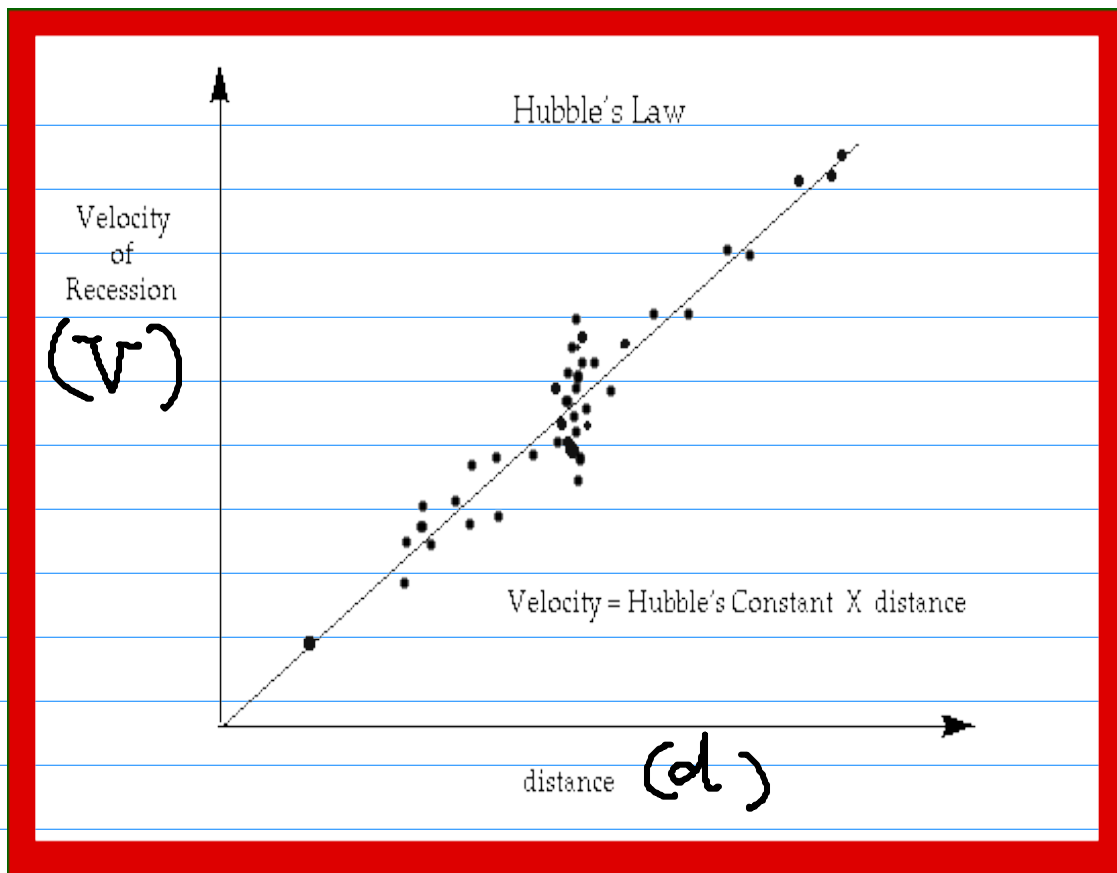
EXCEPT FOR THE CLOSEST OF THE GALAXIES (E.G. ANDROMEDA) THE SPECTRA OF OTHER, MORE DISTANT, GALAXIES WERE REDSHIFTED.

HUBBLE USED SLIPHER'S DATA ON RECESSION 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



THE CURRENT VALUE OF HUBBLE'S CONSTANT IS

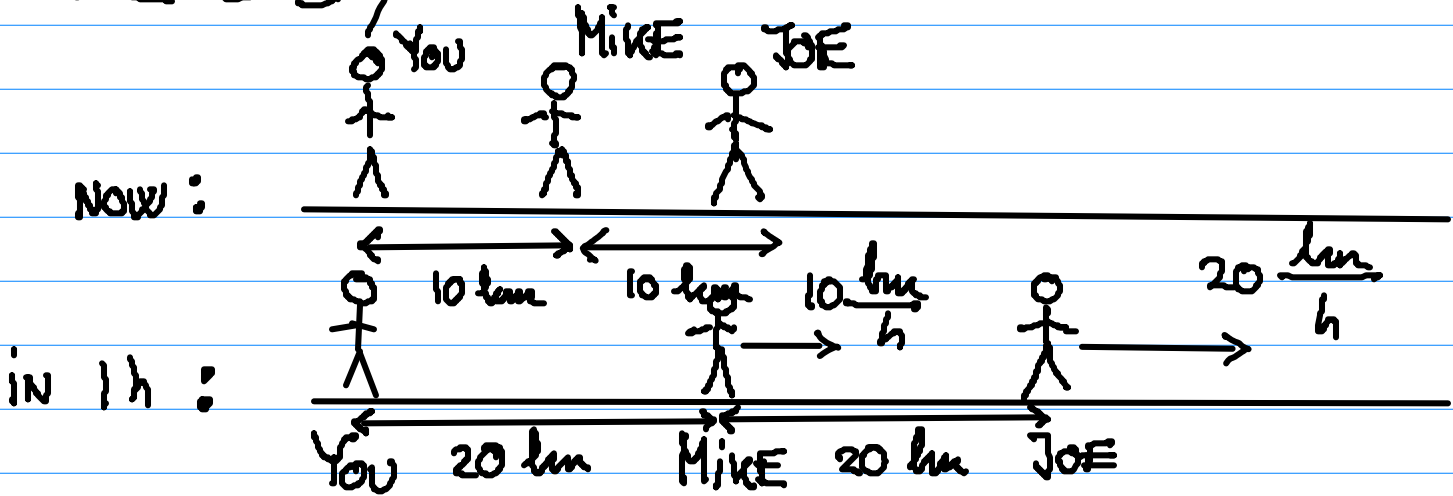
$$H = 70 \frac{\text{km/s}}{\text{Mpc}}$$

$$1 \text{ Mpc} = 10^6 \text{ pc} = 3.26 \times 10^6 \text{ ly}$$

$$1 \text{ pc} = 3.26 \text{ ly}$$

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



$$\text{RECESSION VELOCITY} = (\text{A CONSTANT}) \cdot \text{DISTANCE}$$

$$\parallel$$

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