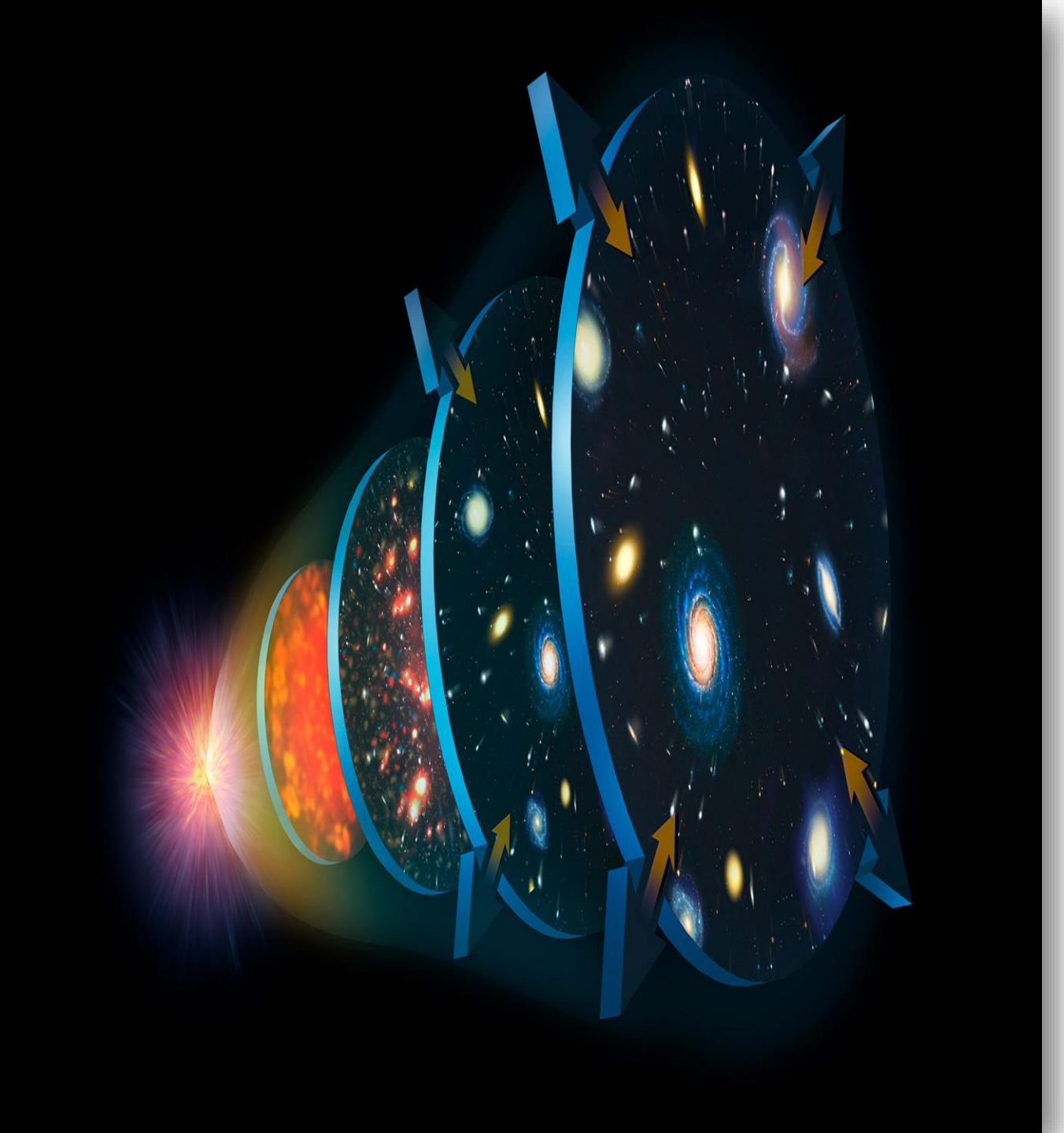


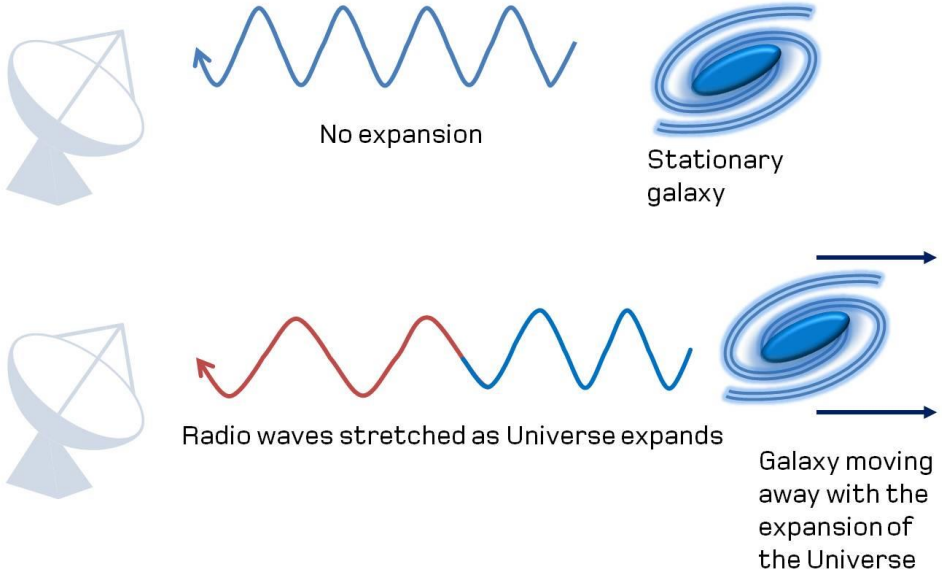
Case Study of Cepheid Stars to Estimate the Age of the Universe

Age of The Universe?!

- In 1929, Edwin Hubble was observing the light from distant galaxies and found it to be redshifted (stretched). He concluded that these galaxies are moving away from us in what's known as the expansion of the universe. He derived a mathematical form to calculate the speed of these moving galaxies:

$$v = H \cdot d$$

Where H is Hubble's Constant, and d is the distance to the galaxy.



The beginning of expansion

- Hubble's finding led to a major question: As the galaxies are moving away from each other, there must be a point in the past in which all these galaxies were condensed together then began to move.
- This introduced the topic of the Big Bang, which raised another question: when did the big bang occur?

Calculating the time

- If we take two galaxies d distance apart and moving away from each other with speed v, the time they took to reach this distance starting from the same point (the Big Bang in this case) can be found as following

$$T = \frac{d}{v}$$

From Hubble's Law,

$$v = H \cdot d$$

Then,

$$T = \frac{d}{H \cdot d} = \frac{1}{H}$$

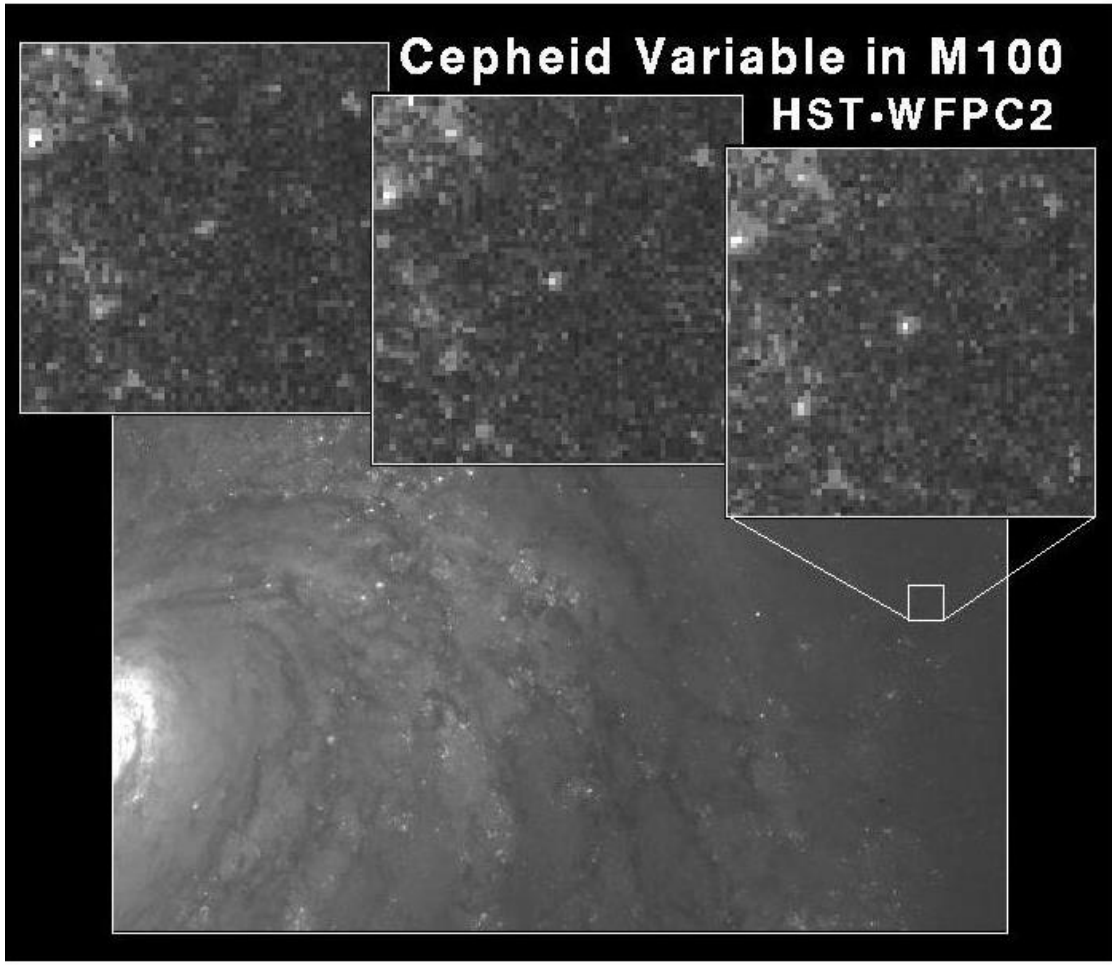
So, if we get the value of Hubble's Constant, the time of the big bang can be calculated giving a good estimation to the age of the universe.

Cepheids

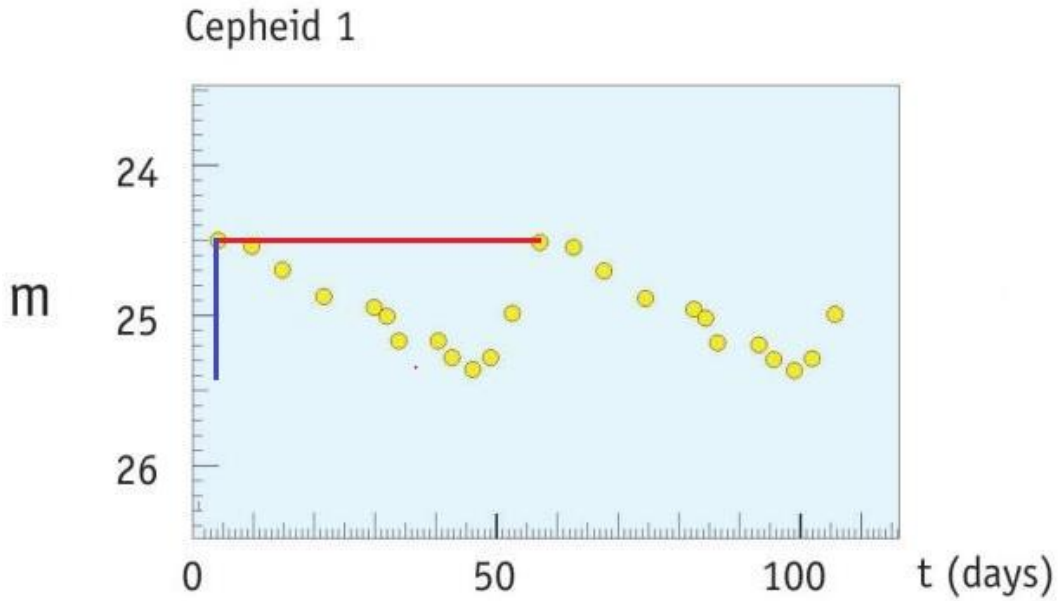
To find the value of H, we need a kind of stars called “Variable Stars.”

They have regularly varying luminosity that can be used to know their distance from earth.

From these stars are the 12 Cepheids in the M 100 galaxy.



The following graph is a representation of the varying brightness, which is referred to as apparent magnitude (m) of the first star in 100 days.
The red line represents the time between two successive crests that represent the pulsation period of the star, while the blue line represent the difference between the maximum and minimum apparent magnitude of the star.



From the period, the absolute magnitude M of the star (representation of luminosity) is calculated from the relation

$$M = -2.78 \log (P) - 1.35$$

And from the maximum and minimum apparent magnitude, the average is calculated as

$$< m > = \frac{m_{max} + m_{min}}{2}$$

Now with the absolute and apparent magnitude, we can calculate the distance, in parsec, to the star from the formula (Parsec =3.086 × 10^13 km)

$$d = 10^{(m-M+5)/5}$$

- The previous steps were used to calculate the distance to the 12 stars through an excel spread sheet

A	B	C	D	E	F	G	H
	Period	m_max	m_min	<m>	M	d (parsec)	d (Mega parsec)
Cepheid 1	54	25.5	24.5	25	-6.1660547	17108460.46	17.10846046
Cepheid 2	48	25.9	24.8	25.35	-6.0238506	18826523.38	18.82652338
Cepheid 3	44	26.3	25	25.65	-5.9187984	20594900.03	20.59490003
Cepheid 4	40	26	25	25.5	-5.8037268	18228265.9	18.2282659
Cepheid 5	30	27.1	25.8	26.45	-5.4563971	24059102.24	24.05910224
Cepheid 6	24	27.1	25.8	26.45	-5.1869873	21251884.67	21.25188467
Cepheid 7	28	27.3	25.7	26.5	-5.3730993	23692989.69	23.69298969
Cepheid 8	27	26.4	25	25.7	-5.3291913	16063428.81	16.06342881
Cepheid 9	26	27	25.9	26.45	-5.2836259	22219034.41	22.21903441
Cepheid 10	25	26.1	25	25.55	-5.2362732	14363313.67	14.36331367
Cepheid 11	24	27.1	25.5	26.3	-5.1869873	19833412.77	19.83341277
Cepheid 12	22	27	25.5	26.25	-5.0819351	18466602.91	18.46660291
						Averge distance	19.55899324

The average distance to the stars can be a good representation to the distance to the M 100 Galaxy. So, we only need the speed of the galaxy to calculate the Hubble Constant.

Fortunately, the velocity of the Virgo Cluster, of which M100 is a member, has been measured earlier to be 1400 km/s.

$$H = \frac{v}{d} = \frac{1400}{19.559} = 71.578 \;\; km/s/Mparsec \tag{1}$$

To convert Mpc to km,

$$H = \frac{71.578}{3.086 \times 10^{19}} = 2.319 \times 10^{-18} \;\; km \tag{2}$$

From Hubble Law, the time in seconds

$$T = \frac{1}{H} = \frac{1}{2.319 \times 10^{-18}} = 4.3 \times 10^{17} \;\; s \tag{3}$$

$$Time \;\; in \;\; years = 13.63 \;\; Billion \;\; year \tag{4}$$

These steps got the age of the universe to be 13.63 billion years while the recent estimation of scientists is that the universe ages between 12 and 14 billion years.

Actually, the presence of humans on earth was only 100,000 years ago. We are really tiny compared to the history of the universe, which I believe is the history of humans themselves.