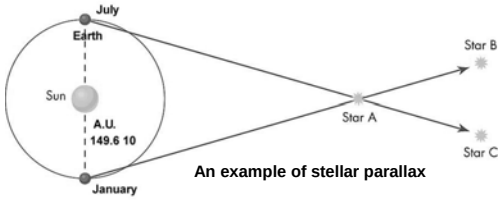
Cosmology

The modern view of the universe

Stellar Parallax

- Copernicus said stellar parallax couldn't be seen because the stars were so far away.
  - A strictly ad hoc explanation of his inability to verify what his theory demanded was true.



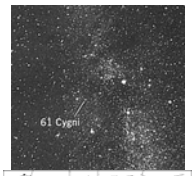
An example of stellar parallax

Stellar Parallax seen

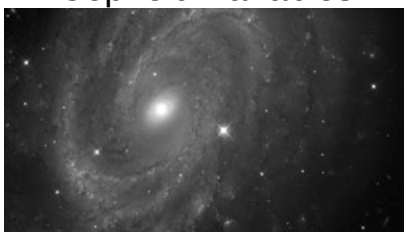
- In 1838 Friedrich Bessel found parallax and used it to measure stellar distances.
- The star 61 Cygnus A had a parallatic angle of 0.2 arc seconds.
- .

The universe is seen to be vast

- 61 Cygnus A was therefore 100,000 times more distant than Saturn
- Prior belief: The stars were as far beyond the planets as the planets were beyond the sun.

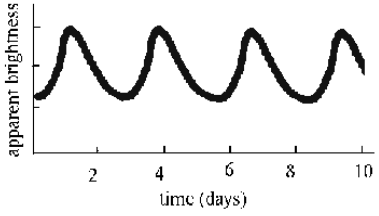


Cepheid Variables



- Stars that vary in brightness every few days
  - Caused by a tug of war between gravity and the outward pressure of star light

Cepheid Variables



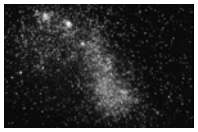
- Time between dimmest to brightest depends on strength of light pressure – i.e., how bright a star really is.

Cepheid Variables

- The absolute brightness of the star—how big it is—can be determined by the amount of time between the peaks of brightness.
- The relative brightness is measured by its appearance in the telescope.
- Absolute and relative brightness are related by the formula:
  - Relative brightness = absolute brightness/square of distance

Distance as measured by Cepheid variables

- In 1912, Henrietta Leavitt (American astronomer) used Cepheids to measure the distance to the Large and Small Magellanic Clouds (Nebulae in the southern sky discovered by Magellan).
- Found them 1000 times more distant than 61 Cygnus A.
- Therefore they had to contain millions of stars and be billions of light years across.

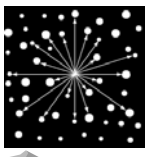


Is the Universe Finite or Infinite?

- Ancient astronomers and philosophers concluded that it was finite.
  - Anything else was unthinkable for them.
- However, Newton's physics leads one to think *infinite*.
  - Absolute space can stretch out in all directions indefinitely, like Euclidean geometry.
  - With the Earth no longer in the centre, there was no special reason to think of limits.
  - Universal gravitation attracted everything to everything else – no centre was implied.

Olbers' Paradox

- Heinrich Olbers, Swiss astronomer, in 1826 asked
  - Why is it dark at night?
- Look out in any direction whatsoever in the sky. If the universe goes on forever, your line of sight will hit a star sooner or later.
  - Nights should be as bright as days.



The Galaxy

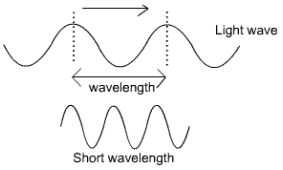
- Our word "galaxy" comes from γαλα = milk in Greek.
  - and γαλακτινοσ = milky.
- Hence, Galaxy = Milky Way
  - What we call the Milky Way was *the* Galaxy. There was only one, so far as astronomy was concerned.
  - It was a whitish blotch in the sky.
- A much later idea was that we are part of the Milky Way.
- But if so, is our galaxy the only one?
  - Are distant nebulae really galaxies – other universes?

Edwin Hubble

- American astronomer
  - The 20th century Tycho Brahe.
  - Took observational astronomy to new heights.
- Worked at the Mount Wilson Observatory, Los Angeles(1923), using the new 100 inch telescope.
- Resolved the *Andromeda nebula* into a galaxy of stars and determined their distance using cepheid variables.
  - **Showed that the universe was a million times more vast than the distance to the nearest star and included a great many galaxies, the Milky Way being merely the nearest.**

Redshift

- The colour of light from stars is determined by their material compostion. Starlight is emitted in precise colours, i.e., exact wavelengths.
- However, Hubble found that light from the spiral galaxies was shifted slightly to the red end of the spectrum, i.e. longer wave lengths.



Red light has the longest wavelengths of visible light.

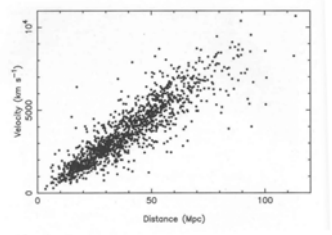
Redshift, 2

- The stretching of the wavelengths of distant starlight suggests that the light source is moving away from us.
  - The speed of motion is determined by the amount of redshift.
- For stars with distances already determined, Hubble found that the more distant ones had greater redshift.
  - If that is generally true, then the amount of redshift could be used as a measure of distance for other stars.

Hubble's Constant

- Hubble found that every galaxy had red shift, and the farther the galaxy, the more the shift.
- Hubble proposed a fixed relationship between distance and redshift, known now as Hubble's constant:
  - H_0 = distance/(redshift)

Hubble's Constant, 2



Later research has mostly confirmed Hubble's theory that the farther a galaxy is away, the faster it is moving away from us.

The Big Bang

- If the universe is expanding, it must have been (much) smaller in the past.
  - It must have had a beginning.
- George Le Maitre – Jesuit priest/astronomer used general relativity to construct a model of the universe which began as a "primeval atom" which exploded.
- Given the nickname (derisively), the Big Bang.

Cosmic Background Radiation

- If there was a Big Bang, there would be a faint microwave radiation left over, of about 3 degrees Kelvin.
  - If that radiation could be detected it would be direct evidence for the Big Bang theory.

Cosmic Background Radiation, 2

- In 1964, Arno Penzias and Robert Wilson, two engineers at Bell Labs in New Jersey discovered this radiation when trying to get rid of noise from an antenna aimed at telecommunications satellites.

Penzias, Wilson, and their noisy radio antenna.

Black Holes

- When a large star burns out it falls in on itself.
  - If big enough, it becomes so dense that the curvature of space around it becomes infinite. Not even light can escape.
- It becomes a *black hole* (as predicted by general relativity).
- The universe itself is like a black hole.
  - Maybe the universe *is* a black hole *in some other universe*.

Dark Matter

- One of the really shocking discoveries of astronomy in the last few decades is that according to the best calculations that astrophysics can make, there must be a very large amount of matter in the universe that cannot be seen through telescopes, maybe as much as 90% of the matter in the universe.
  - It matters because it will determine whether the universe goes on forever or not.

The Big Crunch

- Will the universe stop expanding? If so, then what?
  - If the amount of matter in the universe is *above a critical amount*, it will stop expanding one day and begin to contract, due to gravity.
- The result will be *The Big Crunch.*
  - If not it will expand forever and gravity cannot rein it in.