COSMIC DISTANCE LADDER

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HOW DO ASTRONOMERS MEASURE DISTANCE?

INTRODUCTION

Measuring distance across the Universe is fundamental to astronomy. Without knowledge of distance it’s virtually impossible to study the physical properties of celestial objects

The cosmic distance ladder is the succession of methods which is used for similar purpose

WHY LADDER??

It’s called a ladder for good reason — each rung or measurement technique relies upon the previous step for calibration. The greater the distance measured, the more steps astronomers have used to get there.

HISTORY

Very first measurement was the radius of earth.

Erathosthenes was an ancient greek astronomer who first used this method. He read it somewhere that in the town of Syene during the summer solstice if one see in the well the reflection of sun can be seen. He decided to test the same in his town in Alexandria but he found that the reflection was not seen.

Explanation:
During the summer solstice the earth's axis of rotation is tilted directly towards the sun. As the earth rotates there is a constant line of latitude where sun is directly verticly upwards. This line is called Tropic of Cancer.

Method used:

He measured the tilt of sunrays with the vertical and found it to be 7 degrees. With this and the distance between the syene and alaxandria he meaured the approximate radius of the earth

STEPS

Friedrich Bessel measured the parallax of 61 Cygni, providing the first direct measurement of a star's distance (~11.4 light years).

1.STELLAR PARALLAX

- Direct method for measuring distance to nearby stars.
- Based on apparent shift in a star's position as Earth orbits the Sun.
- Works for stars up to ~10,000 light years away.
- Satellite missions like Hipparcos improve accuracy by avoiding atmospheric distortion.

2.STANDARD CANDLE

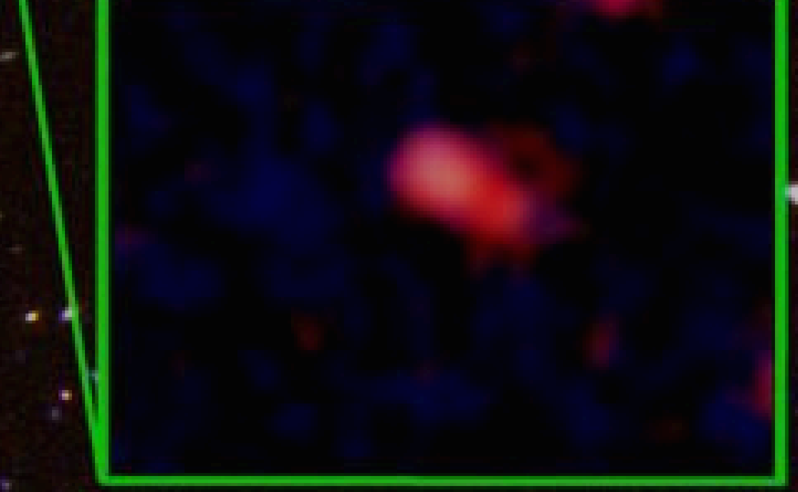
The accuracy of standard candles depends on calibrating their luminosity using parallax for nearby Cepheids and Gaia data.

- Uses stars with known luminosity to estimate distance by comparing apparent and absolute magnitude.
- Cepheid variables are key standard candles: their brightness period relation allows distance estimation.
- Can measure distances up to ~100 million light years using telescopes like Hubble.

3.TYPE 1A SUPERNOVAE

In 1998, two independent teams (Perlmutter et al. & Riess et al.) found that distant Type Ia supernovae were dimmer than expected. This led to the discovery of dark energy and earned the 2011 Nobel Prize in Physics.

- Explosions of white dwarfs with consistent peak luminosity.
- Serve as bright, reliable standard candles to measure distances up to 1 billion light years.
- Based on the light curve shape which is uniform across all Type Ia events.



4.REDSHIFT

Edwin Hubble discovered that galaxies are receding from us and that their speed increases with distance — known as Hubble's Law.

- Light from distant galaxies shifts toward the red as the universe expands.
- Hubble’s Law: Greater redshift = Greater distance.
- High redshifts (e.g., $z = 8.2$) correspond to objects billions of light years away and from the early universe.
- Caused mainly by cosmic expansion, not just motion (Doppler effect).

CONCLUSION

"The cosmic distance ladder has helped us measure distances from our solar backyard to galaxies over 13 billion light years away — but every rung we climb raises new questions."

What if the universe is expanding in ways we don't yet understand?

Could the next rung reveal what dark energy really is — or something entirely unexpected?

These are some of the interesting questions which keep the discussion open for understanding our universe in a better way!!

THANK YOU

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