

The Expanding Universe

- The ongoing increase in distances between galaxies over cosmic time
- Space itself is expanding — galaxies are not flying through static space
- No center, no edge, no explosion into pre-existing space
- For science educators, students, and science communicators
- 15-slide journey: foundations, evidence, misconceptions, current research



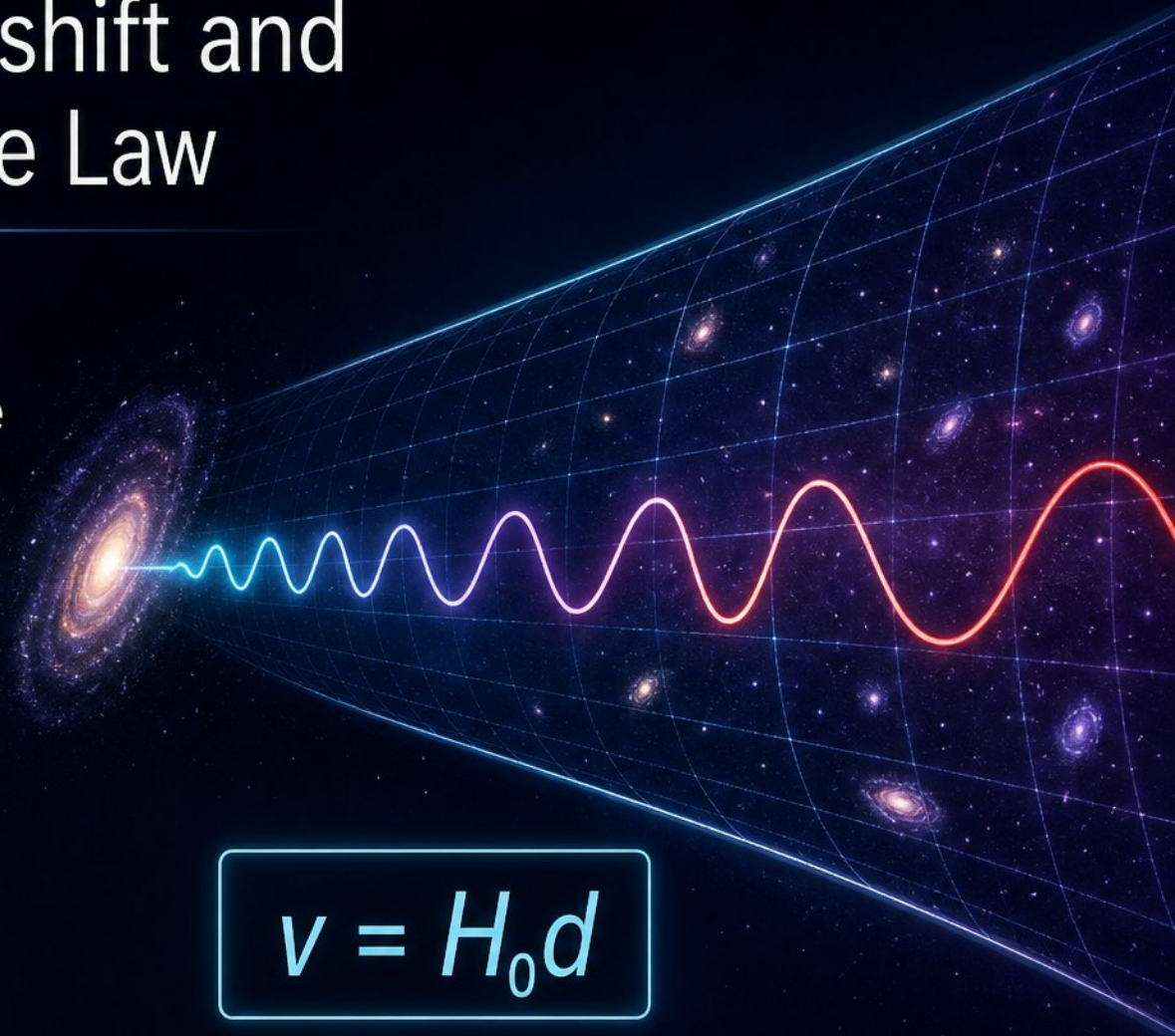
What Expansion Really Means

- Expansion changes the scale of space itself, not galaxies moving through static space
- Cosmological redshift: light stretched by expanding space, distinct from ordinary Doppler shift
- Observable only beyond ~100 million light-years; gravitationally bound systems do not expand
- Foundation for the Hubble–Lemaître law: recession velocity proportional to distance

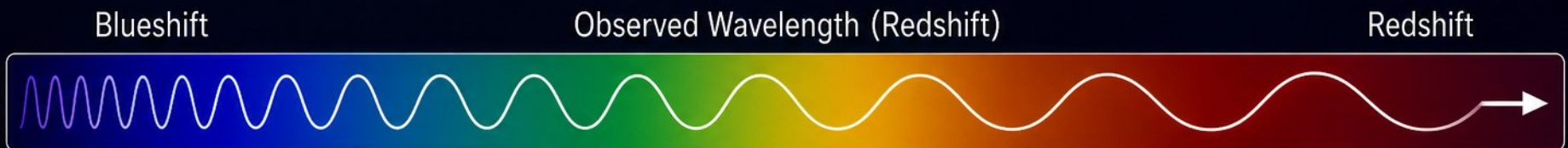


Core Concepts: Redshift and the Hubble–Lemaître Law

- Redshift stretches light as space expands, not motion through space
- Higher redshift means greater distance and more stretching
- Hubble–Lemaître law: $v = H_0 d$
- H_0 measures present-day expansion rate (~ 70 km/s/Mpc)
- Distant galaxies can recede faster than light without violating relativity



$$v = H_0 d$$



Discovery Timeline: From Relativity to Hubble

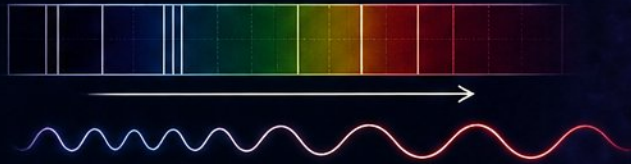
- **1922:** Friedmann derives expanding universe solutions from general relativity

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

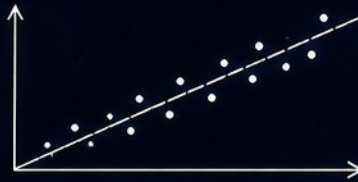
- **1927:** Lemaître derives the expansion law and tests it against observations



- **1912–1924:** Slipher measures redshifts of spiral nebulae



- **1929:** Hubble confirms distance–velocity relation observationally

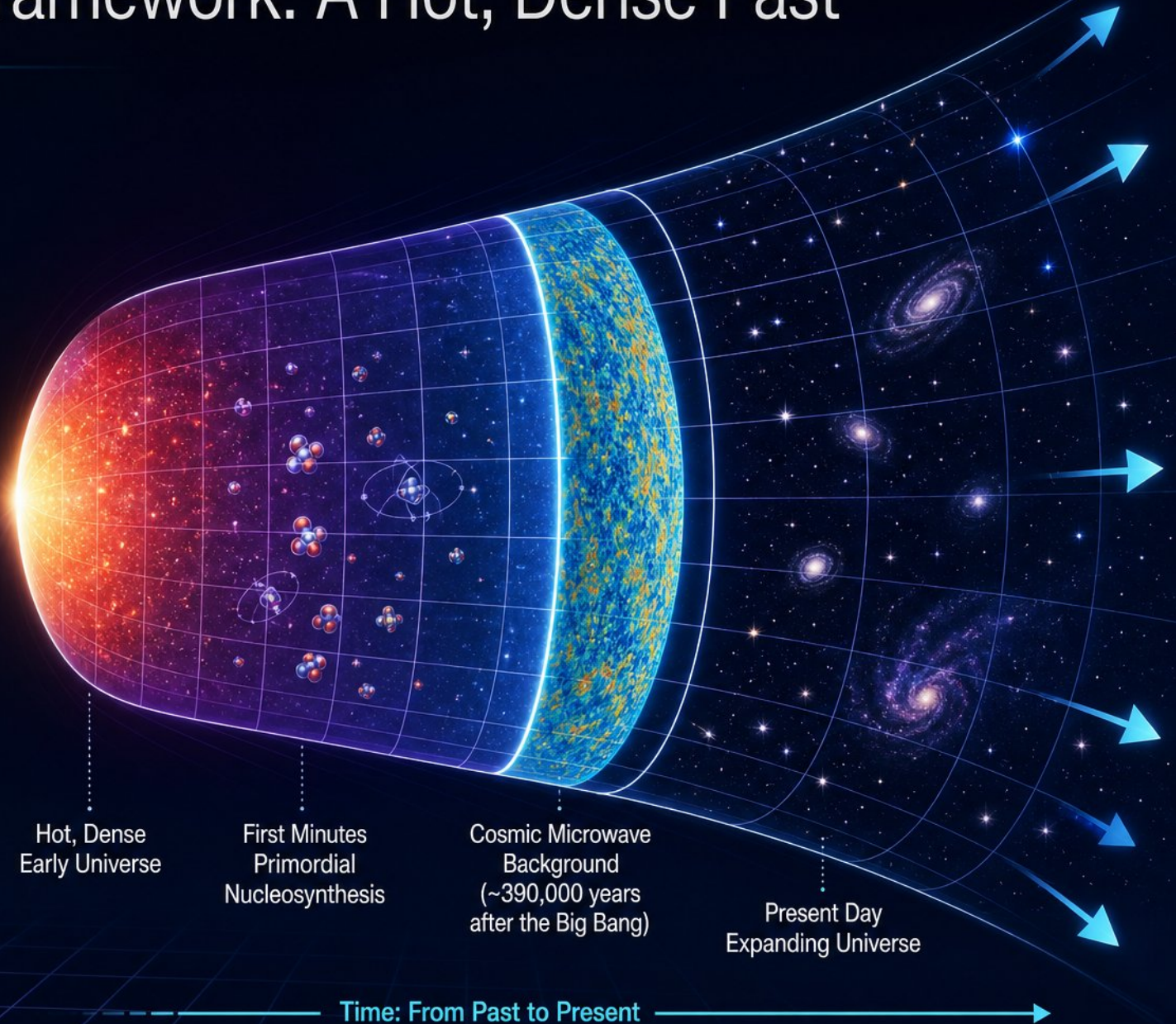


- Hubble remained cautious about interpreting redshifts as cosmic expansion



The Big Bang Framework: A Hot, Dense Past

- Extrapolating expansion backward implies a hotter, denser early state
- Cosmic microwave background: relic radiation from ~390,000 years after the Big Bang, cooled to 2.7 K
- Primordial nucleosynthesis: first minutes forged hydrogen and helium in observed proportions
- Big Bang was not an explosion in space—it was the beginning of space itself expanding



Accelerating Expansion and Dark Energy



- 1998 discovery: distant Type Ia supernovae revealed accelerating cosmic expansion



- Dark energy: unknown force driving acceleration, acting repulsively on large scales



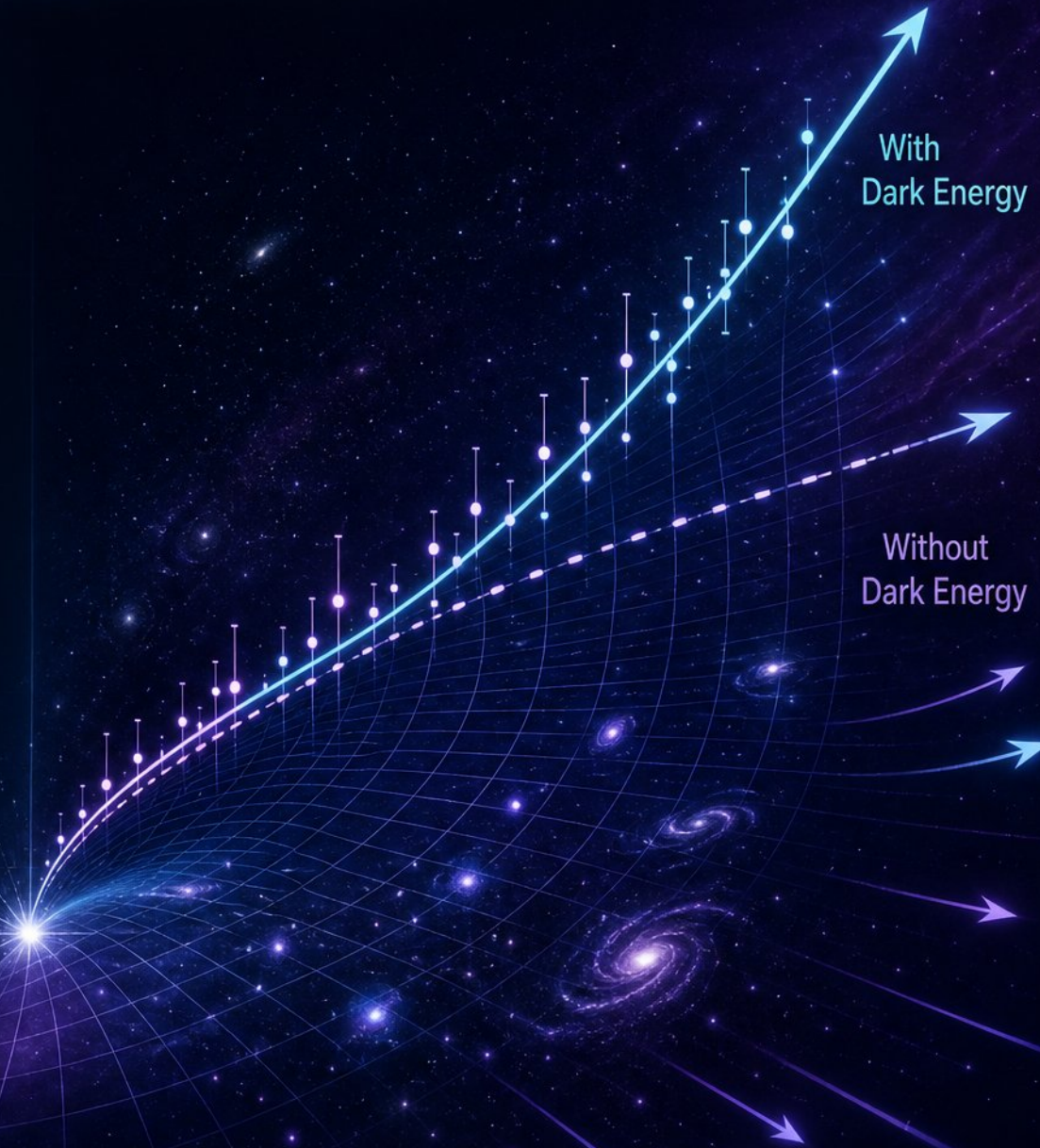
- Key evidence: supernova distances, baryon acoustic oscillations, large-scale structure surveys



- Dark energy is a placeholder name for an unexplained phenomenon

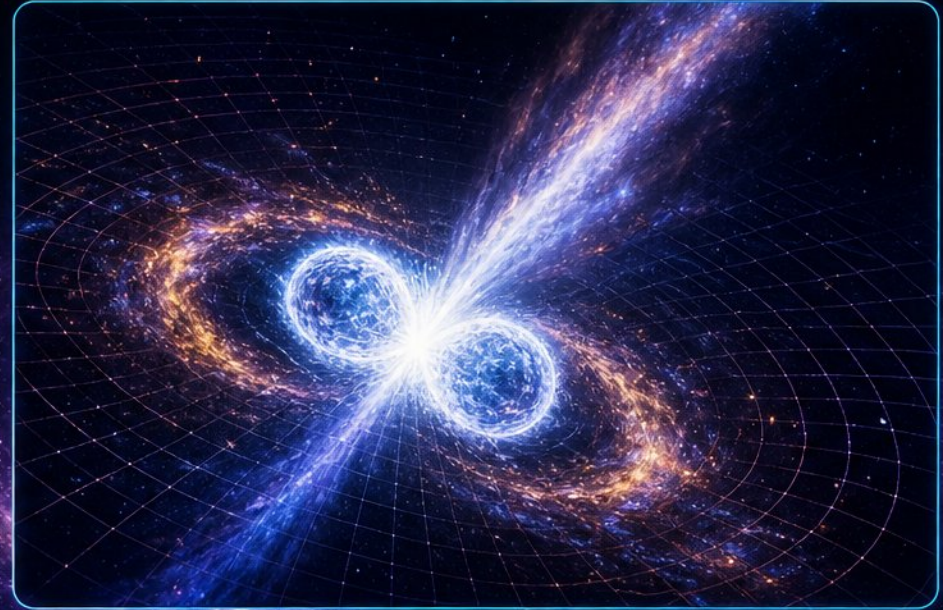


- Recent DESI data hint dark energy may evolve over time, not remain constant



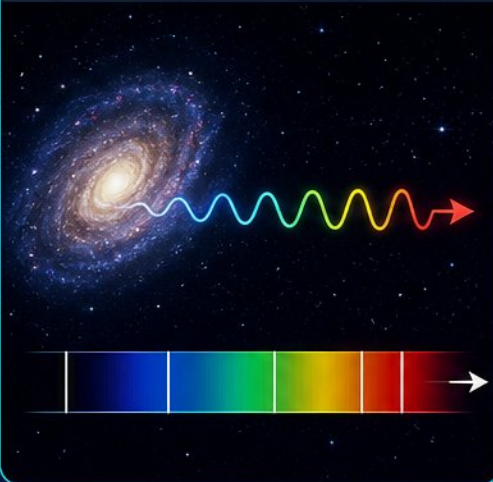
Gravitational Waves and Multi-Messenger Astronomy

- Gravitational waves encode distance directly — independent standard sirens
- GW170817: first standard siren H_0 measurement (2017)
- GW data help resolve the Hubble tension
- LIGO, Virgo, LISA, Einstein Telescope expand this window

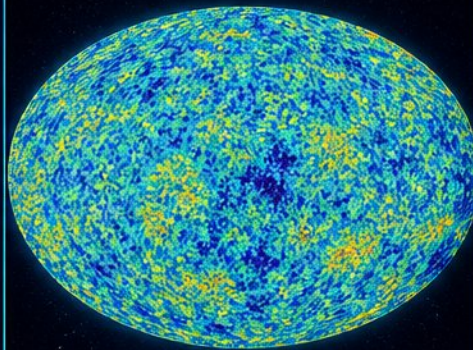


Observational Pillars of Expansion

GALACTIC REDSHIFTS



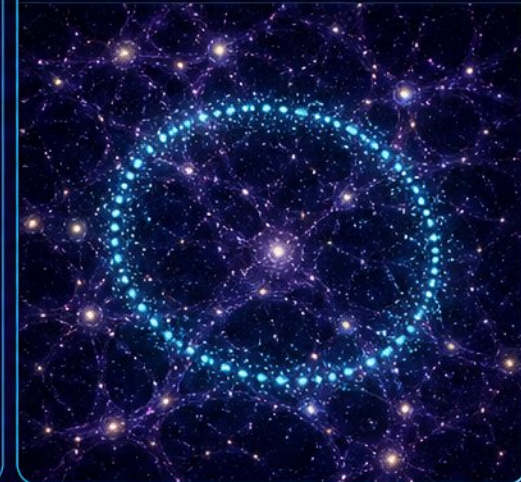
COSMIC MICROWAVE BACKGROUND



PRIMORDIAL NUCLEOSYNTHESIS



LARGE-SCALE STRUCTURE AND BAO



- Galactic redshifts: expansion stretches light waves
- Cosmic microwave background: relic radiation, uniform 2.7 K
- Primordial nucleosynthesis: matching hydrogen and helium abundance
- Large-scale structure: galaxies cluster around the BAO standard ruler
- Independent methods converge on one consistent expansion history

Common Misconceptions and How to Correct Them



Misconception: Big Bang as an explosion, universe with a center or edge



Misconception: Galaxies growing in size or moving through static space



Fact: Expansion is stretching of space itself, not motion through space



Fact: No center or edge; every observer sees galaxies receding



Fact: Galaxies, stars, atoms stay bound by gravity and electromagnetism



Strategy: Use conceptual bridges; avoid misleading analogies like firecracker explosion



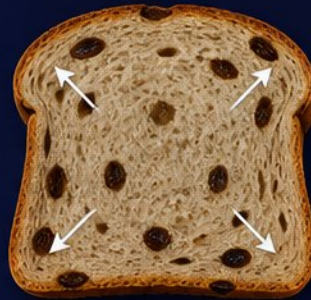
Analogies, Tools, and Scaffolded Activities

- - Compare raisin bread, balloon, and elastic band analogies
- - Tools: Rubin Observatory investigation, WWT Hubble Lab, NASA
- - Scaffold from hands-on redshift activities to real data
- - Always explain analogy limits at each grade level

THREE EVERYDAY ANALOGIES

All show expansion without a center.

RAISIN BREAD



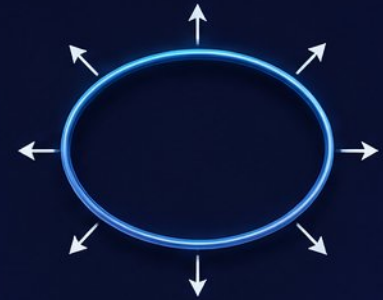
As the dough rises, raisins move farther apart.

BALLOON



As the balloon inflates, points on the surface move apart.

ELASTIC BAND



As the band stretches, all parts get farther apart.

ANALOGY LIMITS — REMEMBER:



The universe does not expand into anything.



There is no center of expansion.



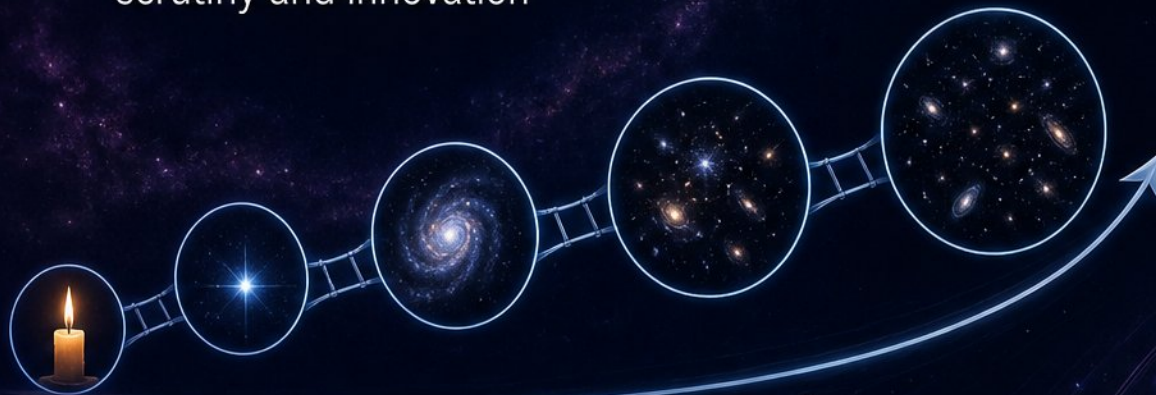
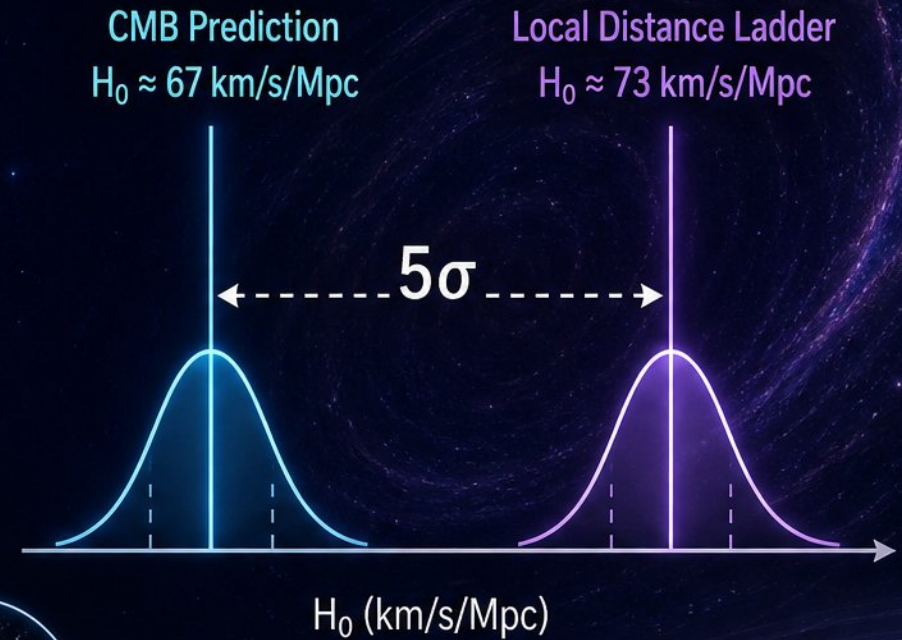
The universe has no edge; it has no boundary.

EXPANSION WITHOUT A CENTER
NO EDGE



The Hubble Tension: A Real Scientific Puzzle

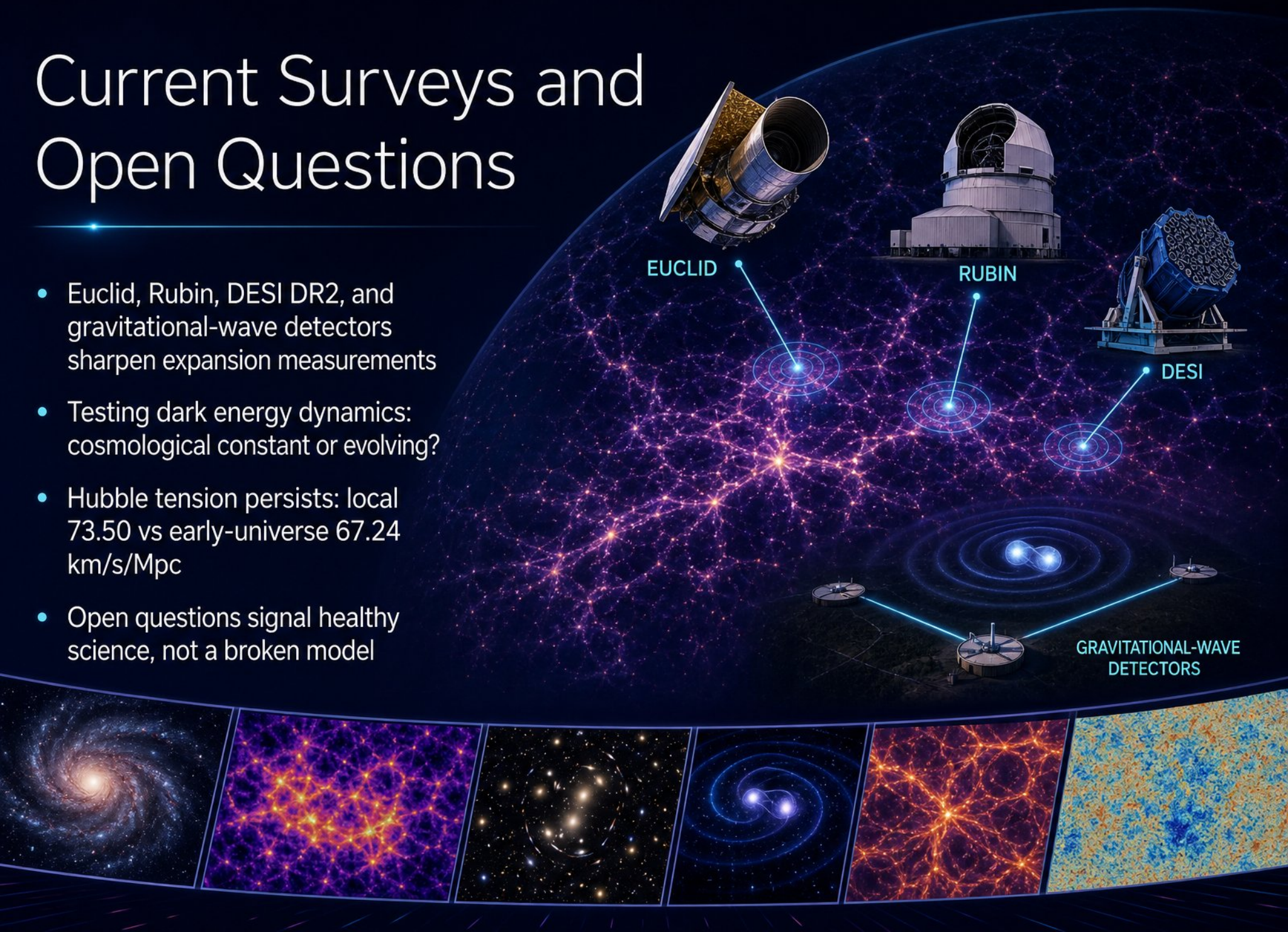
- Local distance ladder: $H_0 \approx 73$ km/s/Mpc
- CMB prediction: $H_0 \approx 67$ km/s/Mpc
- Discrepancy exceeds 5σ , a genuine puzzle
- Possible causes: new early- or late-universe physics
- Healthy disagreement drives scientific scrutiny and innovation



THE COSMIC DISTANCE LADDER

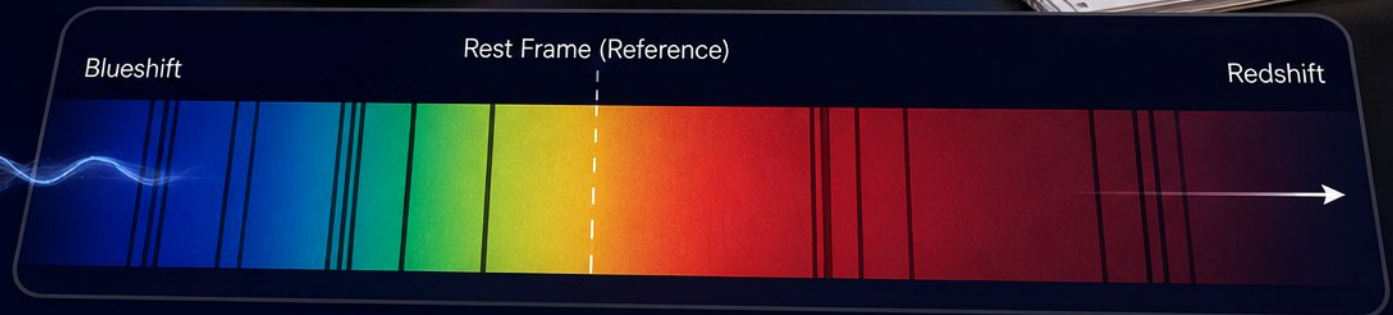
Current Surveys and Open Questions

- Euclid, Rubin, DESI DR2, and gravitational-wave detectors sharpen expansion measurements
- Testing dark energy dynamics: cosmological constant or evolving?
- Hubble tension persists: local 73.50 vs early-universe 67.24 km/s/Mpc
- Open questions signal healthy science, not a broken model



Modelling Expansion in the Classroom

- - Hands-on models: balloon, elastic band, raisin bread
- - Scaffold from analogies to real data
- - Students calculate redshift with supernova spectra
- - Plot Hubble diagrams using actual galaxy data
- - Facilitate discussion to surface misconceptions



Key Ideas for Science Communication

- The universe is expanding, not exploding; space itself stretches
- No center, no edge, no expansion into anything
- Avoid misleading phrases like “Big Bang explosion” and “galaxies moving through space”
- Use strong analogies, but always state their limits
- Expansion is among the best-supported ideas in modern cosmology



Summary and Action Plan

- 
- Recap the journey: expansion foundations, discovery timeline, evidence, and current research

- 
- Action plan for educators:
 - identify misconceptions early
 - use analogies with limits
 - connect to real data



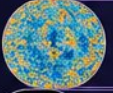
RECAP AND ACTION PLAN



FOUR OBSERVATIONAL PILLARS



Galactic redshift



Cosmic microwave background



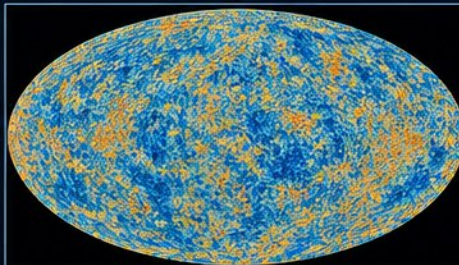
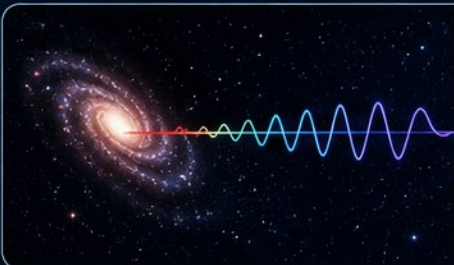
Nucleosynthesis



Large-scale structure

- 
- Follow live science: current surveys and the Hubble tension enrich teaching

OBSERVATIONAL EVIDENCE MOSAIC



PersonWise.

PersonWise • AI digital-human course platform



Scan the code or click anywhere to watch this course live, with voice Q&A

personwise.ai/t/8b93100a/public