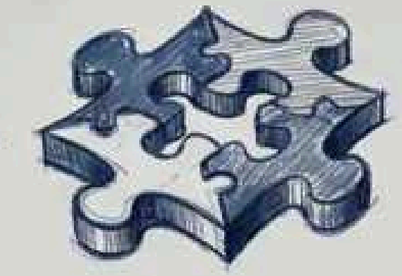
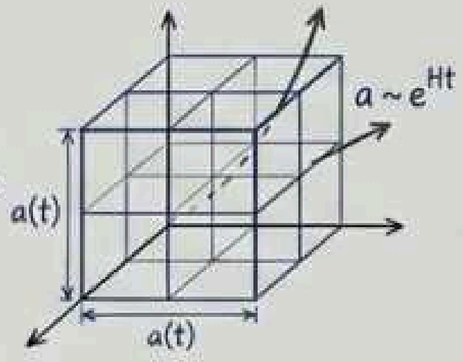
Three defining questions drive modern cosmology.

¶ 6.1

Simple Big Bang Theory



Unsolved Problems:
Where did the simple Big Bang theory break down?



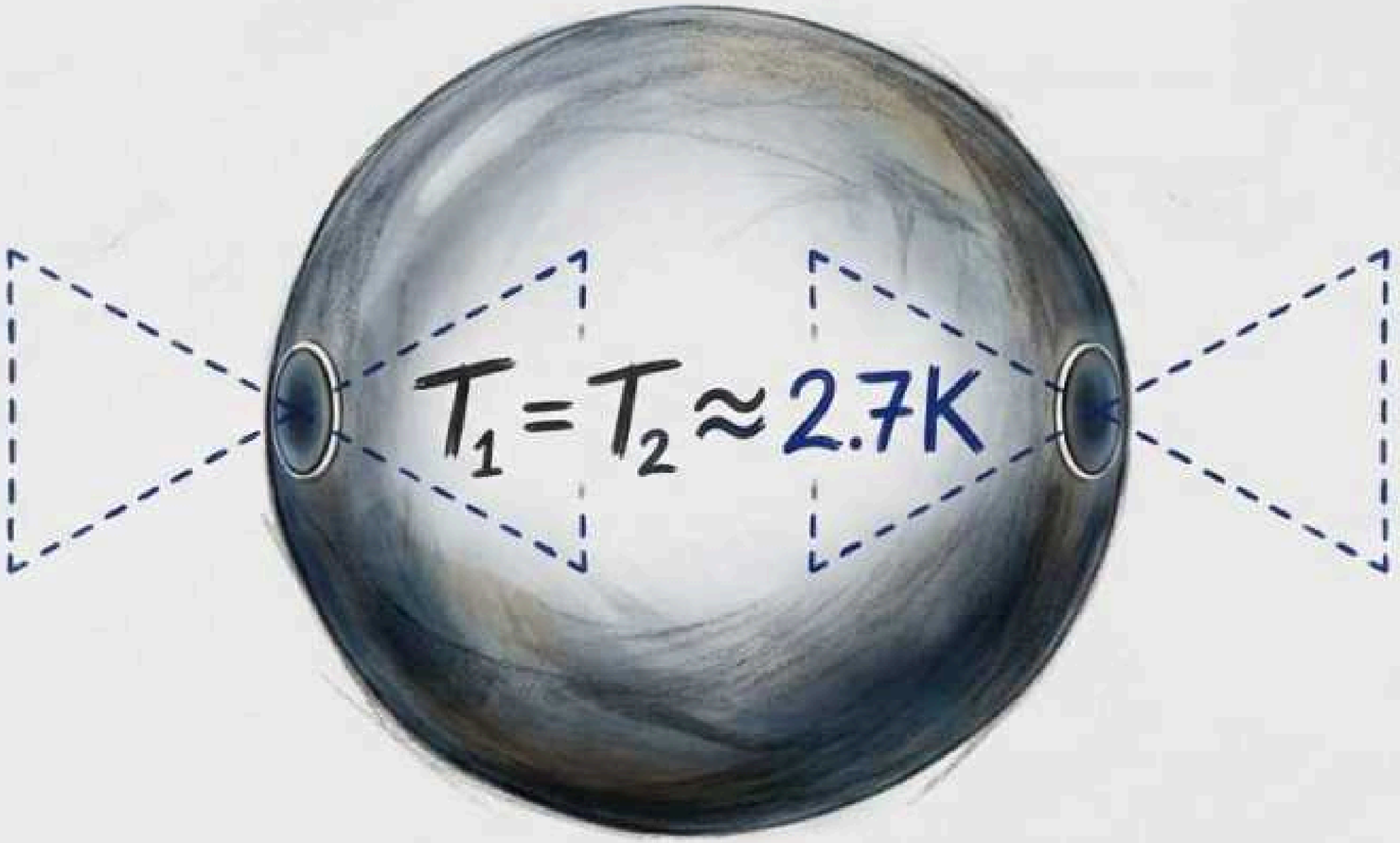
The Elegant Fix:
How does Cosmic Inflation attempt to solve them?



The Unknown:
What are the deepest open questions remaining today?

The Cosmic Microwave Background matches too perfectly.

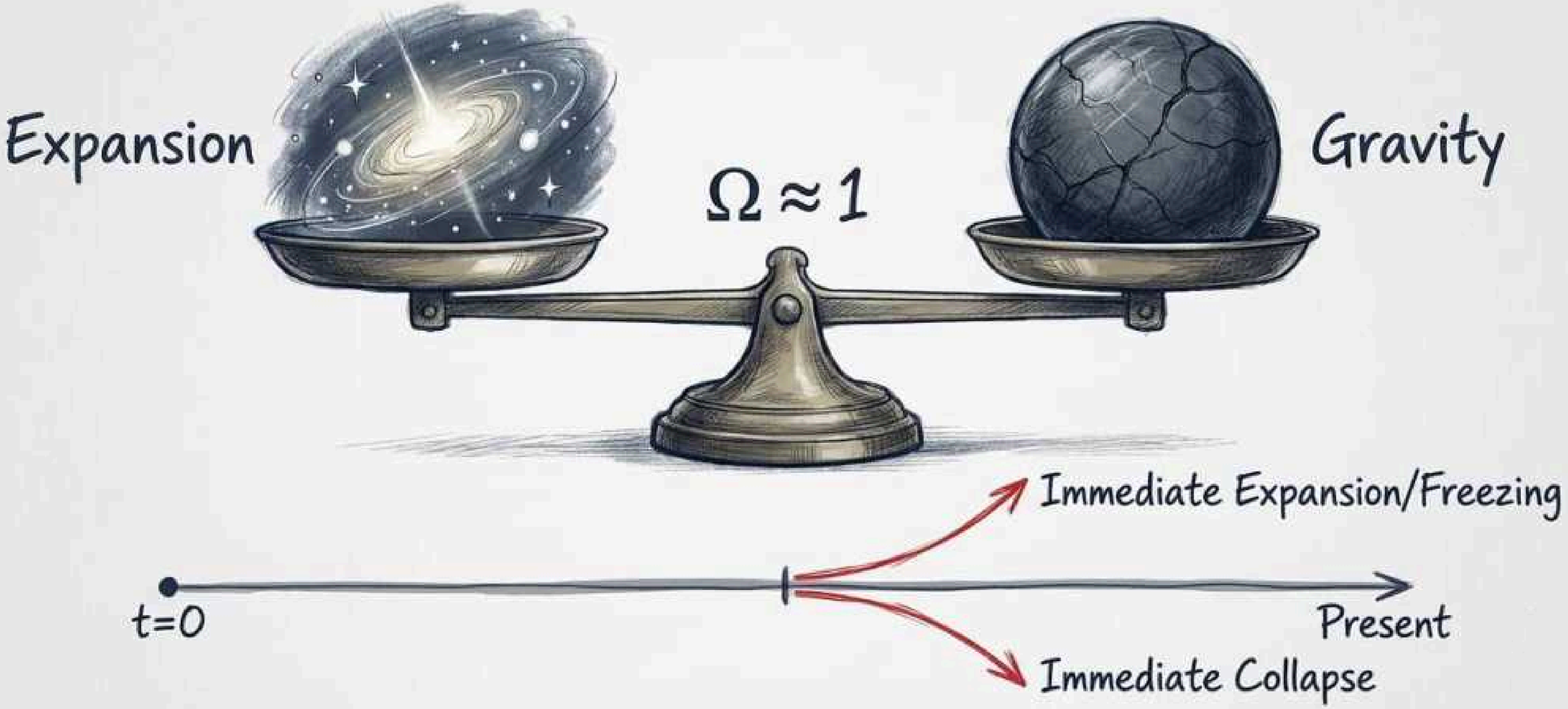
¶ 6.2



The Horizon Problem: These regions were too far apart in the 1970s Big Bang model to have ever exchanged heat or light. How did they come to the exact same temperature?

The universe started in a state of precarious, perfect balance.

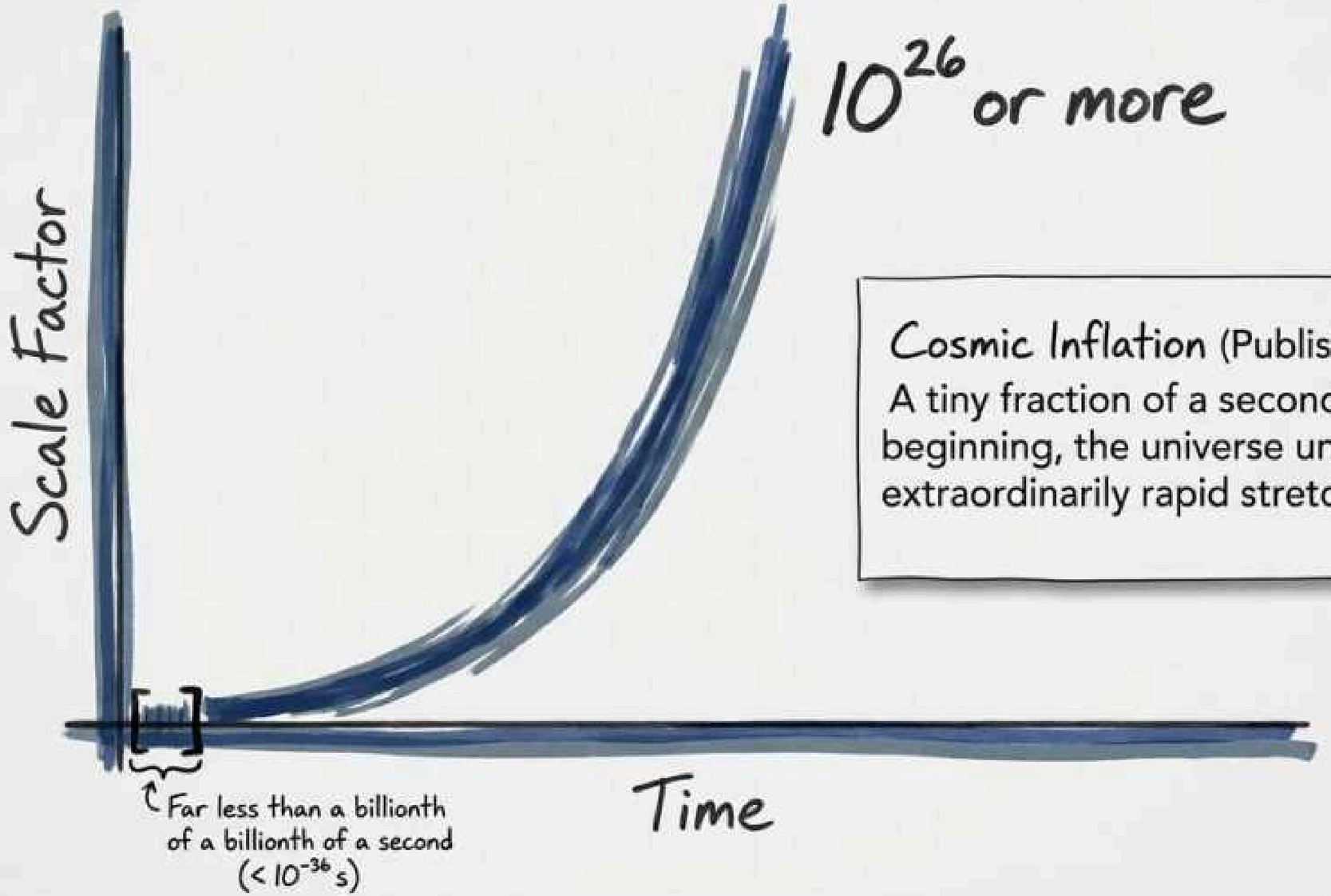
¶ 6.3



The Flatness Problem: Space on large scales is perfectly flat. Why was the initial density so finely tuned to this critical value?

¶6.4

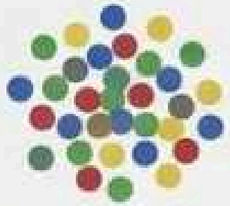
In 1980, Alan Guth proposed an era of violent, exponential expansion.



Cosmic Inflation (Published 1981):
A tiny fraction of a second after the beginning, the universe underwent an extraordinarily rapid stretching of space.

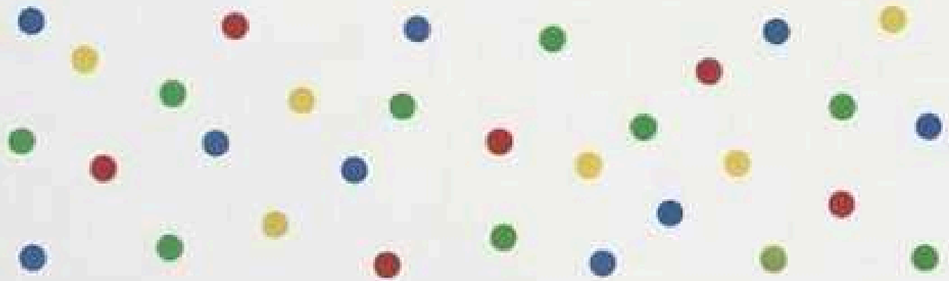
Inflation geometrically erases the early universe's puzzles. ¶6.5

Solving Horizon



Thermal Equilibrium

Inflation

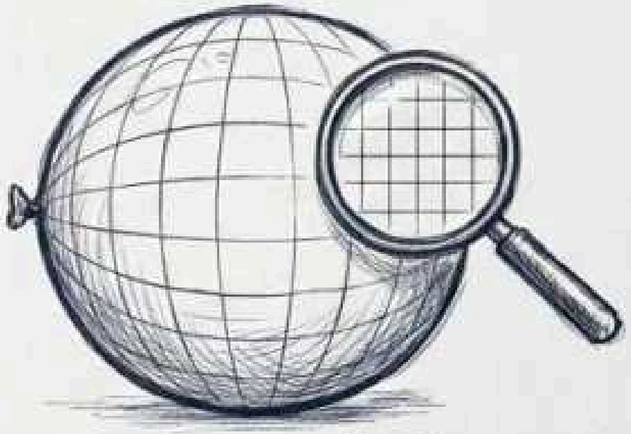


Regions were close enough to share heat, then stretched apart.

Solving Flatness

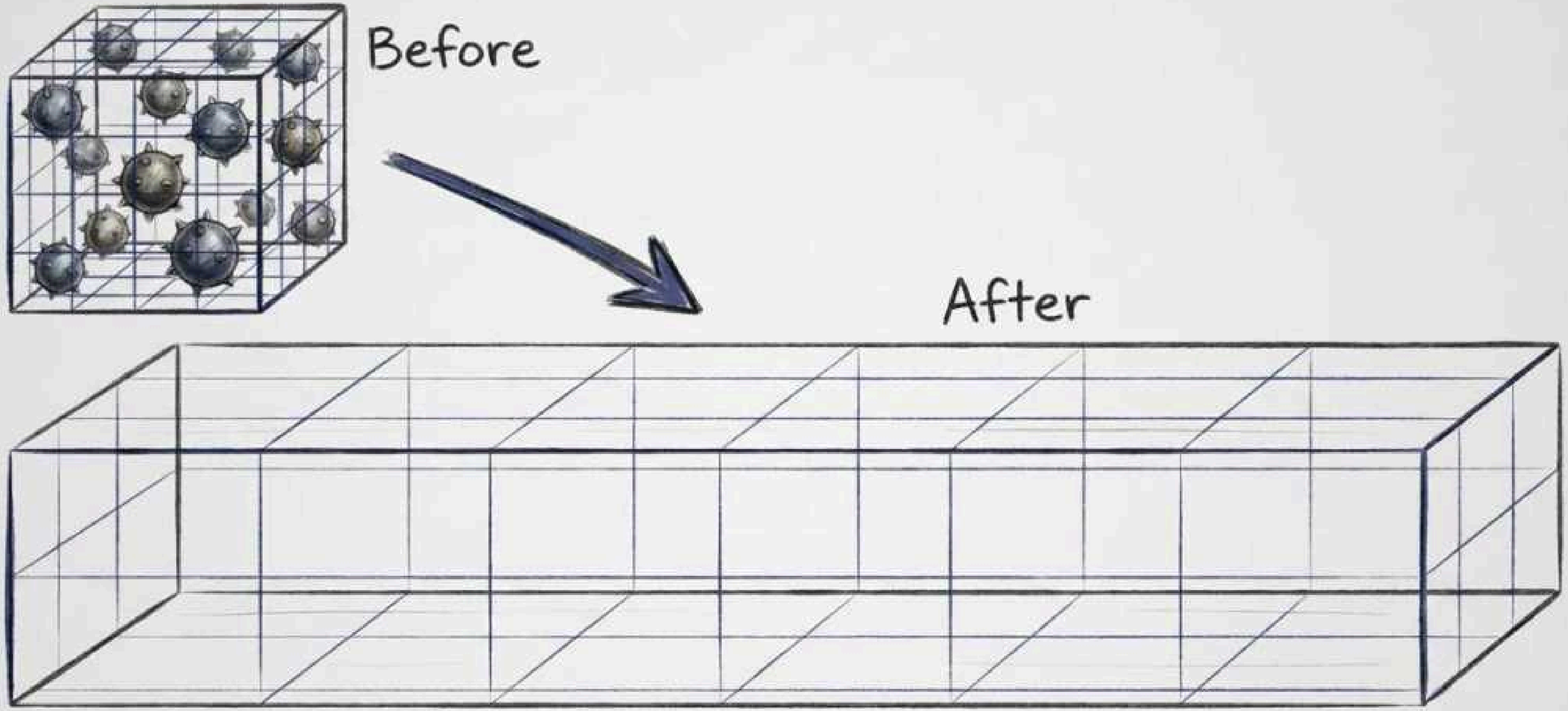


Inflation



Massive expansion flattens space, regardless of its starting shape.

Massive expansion dilutes heavy theoretical particles to zero. ¶ 6.6

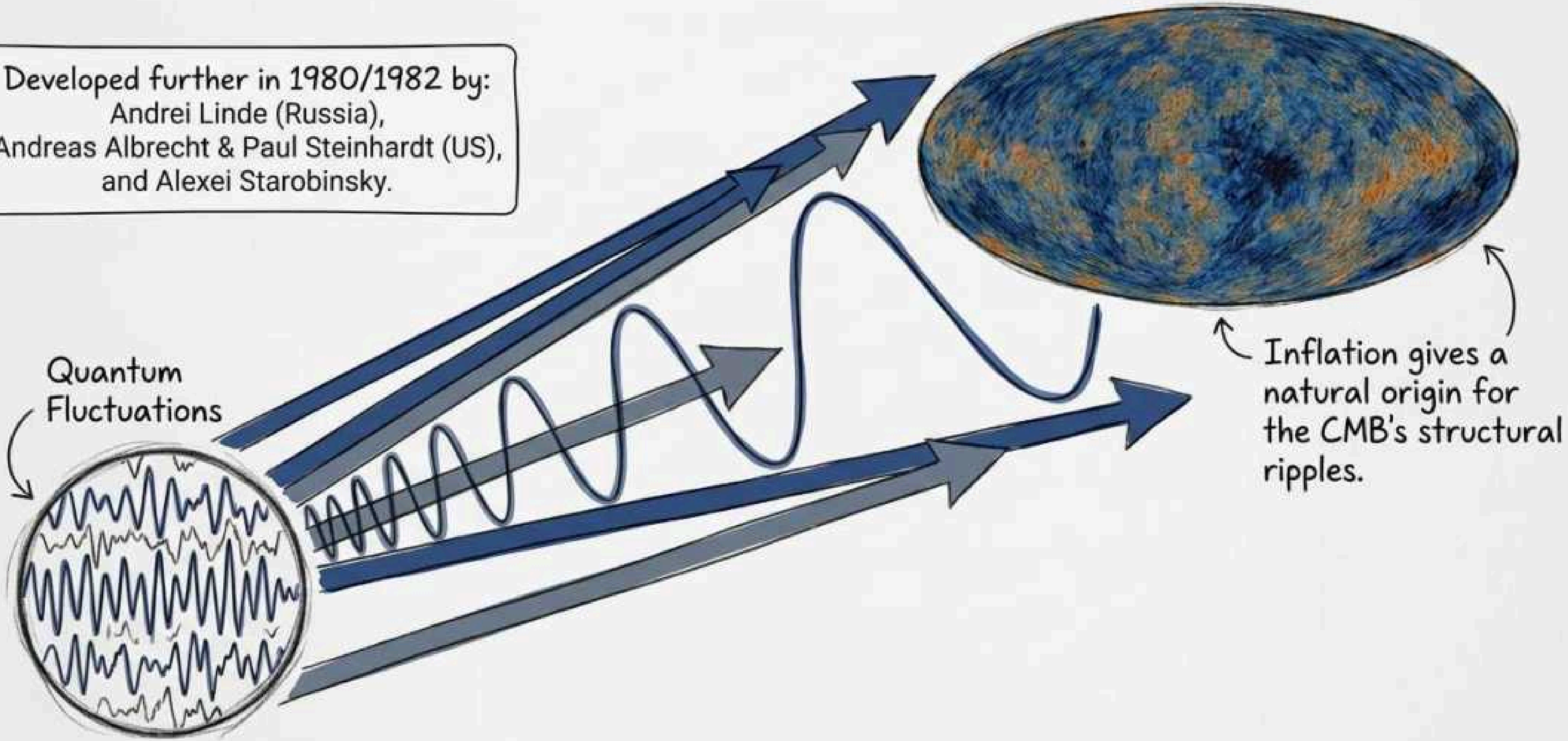


The Monopole Problem: Particle physics predicts the hot early universe produced heavy magnetic monopoles. Inflation dilutes them so thoroughly that we are unlikely to ever see even one.

Microscopic quantum jitters stretched into macroscopic cosmic ripples.

¶ 6.7

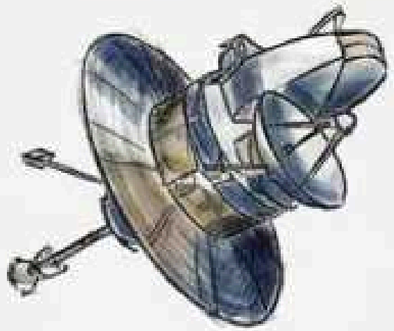
Developed further in 1980/1982 by:
Andrei Linde (Russia),
Andreas Albrecht & Paul Steinhardt (US),
and Alexei Starobinsky.



Satellites confirm the structural predictions of inflation.

¶ 6.8

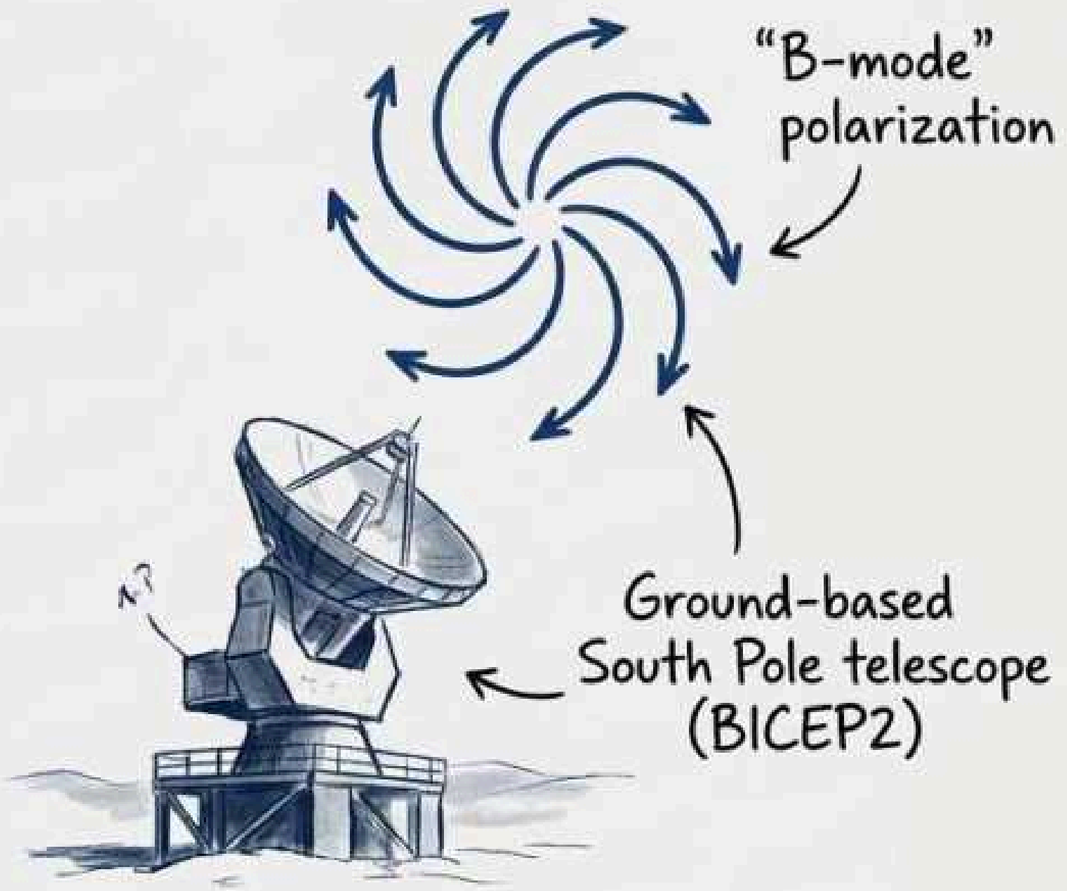
Diagnostic Matrix

The Prediction	The Observation Tool	The Result
Ripples are almost (but not quite) the same strength on all scales.		✓
Space should be very nearly flat.		✓

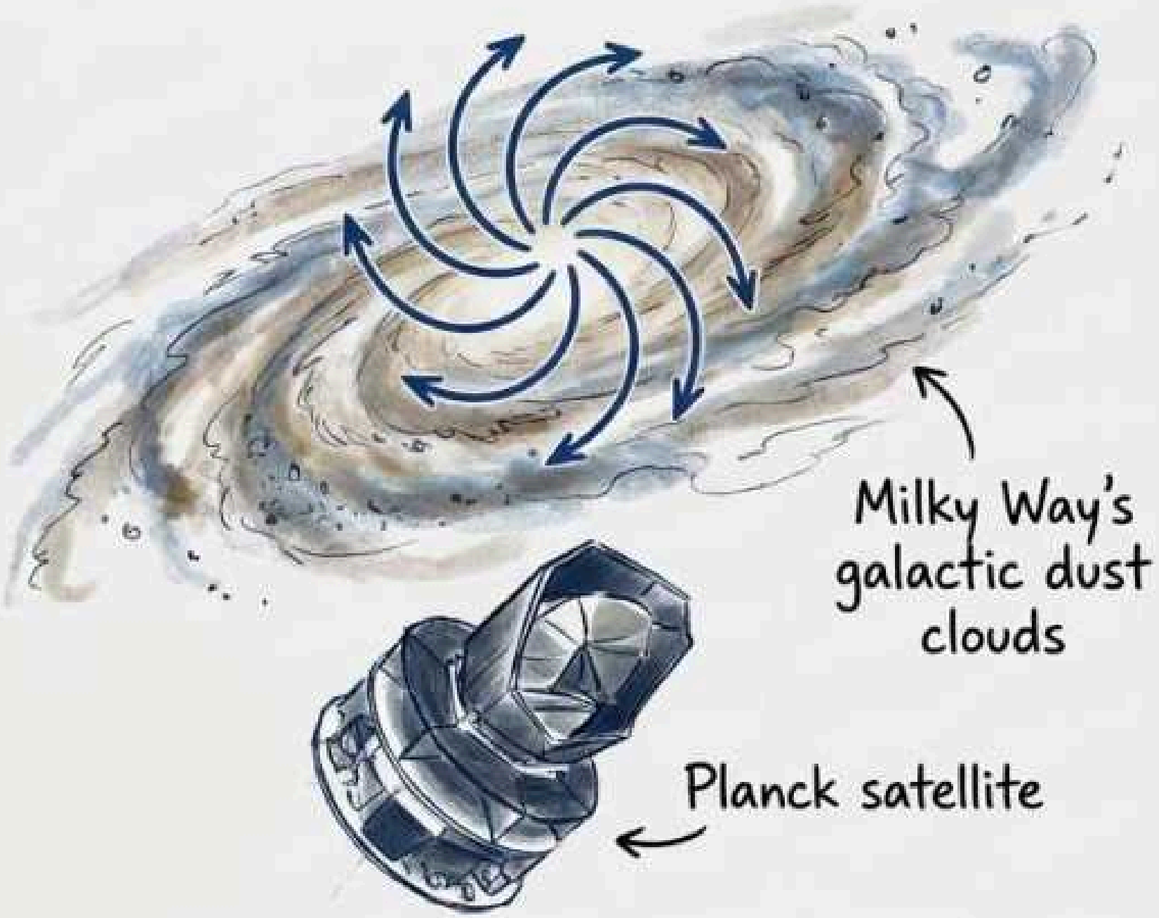
While not confirmed directly, these observational matches make inflation the leading theory of the very early universe.

The BICEP2 episode: A mirage in the microwave background

¶ 6.9



2014 Claim: Twisting polarization pattern detected—direct evidence of gravitational waves from inflation.



2015 Reality: Joint analysis reveals the signal was mostly caused by galactic dust.

The scientific method self-correcting in real-time.

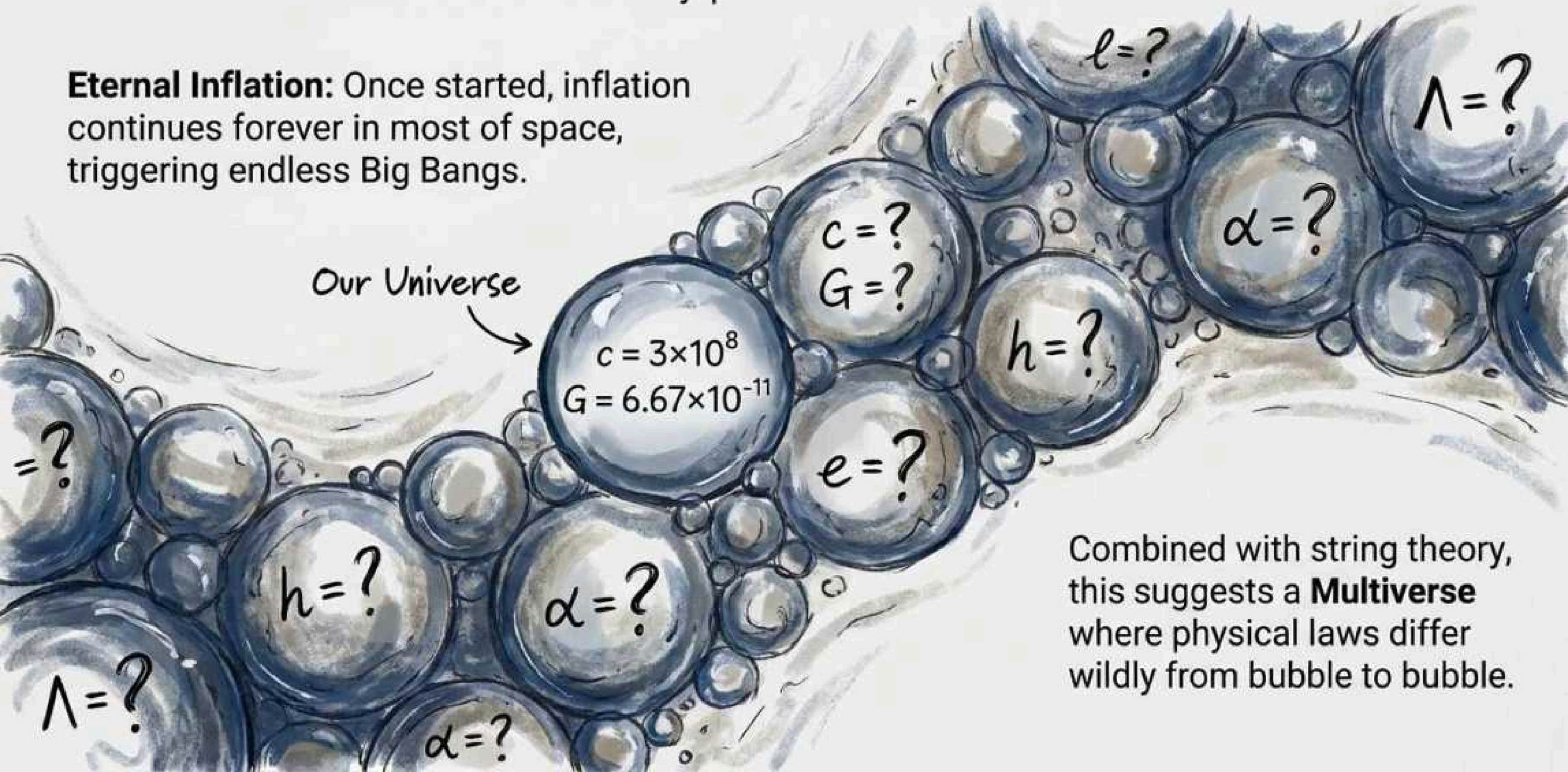
¶ 6.10



Eternal inflation inevitably predicts endless bubble universes.

¶ 6.11

Eternal Inflation: Once started, inflation continues forever in most of space, triggering endless Big Bangs.



Combined with string theory, this suggests a **Multiverse** where physical laws differ wildly from bubble to bubble.

The multiverse forces a debate on the limits of observable science.

The Case For

- ✓ Follows naturally from mathematically successful theories.
- ✓ Elegantly explains why our specific universe appears finely tuned for life.

The Case Against

- ✗ Led by critics like Paul Steinhardt (an original founder of inflation).
- ✗ A theory that predicts every possible outcome predicts nothing.
- ✗ Other universes may permanently reside outside observable reality.

¶ 6.13

The Hubble Tension breaks our understanding of cosmic expansion.

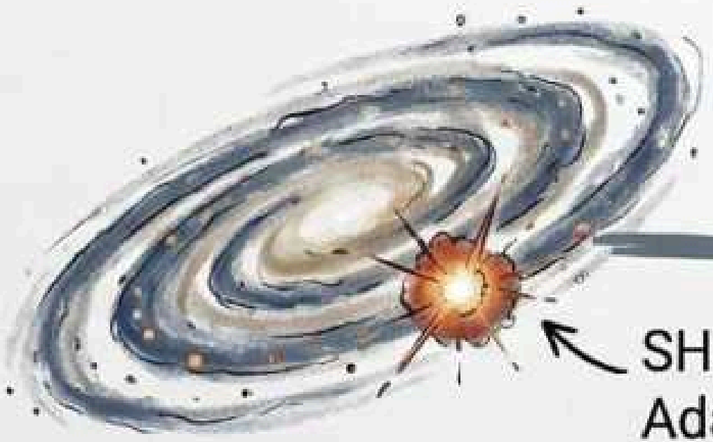
Top Track:
Early Universe
(CMB)



$H_0 \approx 67$

The Tension: A small but statistically significant, unbridgeable gap.

Bottom Track:
Late Universe
(Distance Ladder)



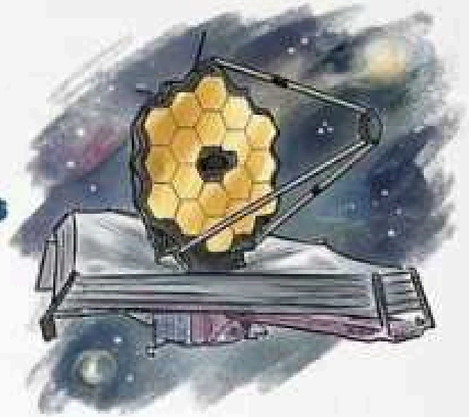
$H_0 \approx 73$

SH0ES team /
Adam Riess

What explains the gap in the Hubble constant?

Why the Gap?

Hidden Measurement Errors?



Less likely—JWST recently confirmed the accuracy of the Cepheid measurements.

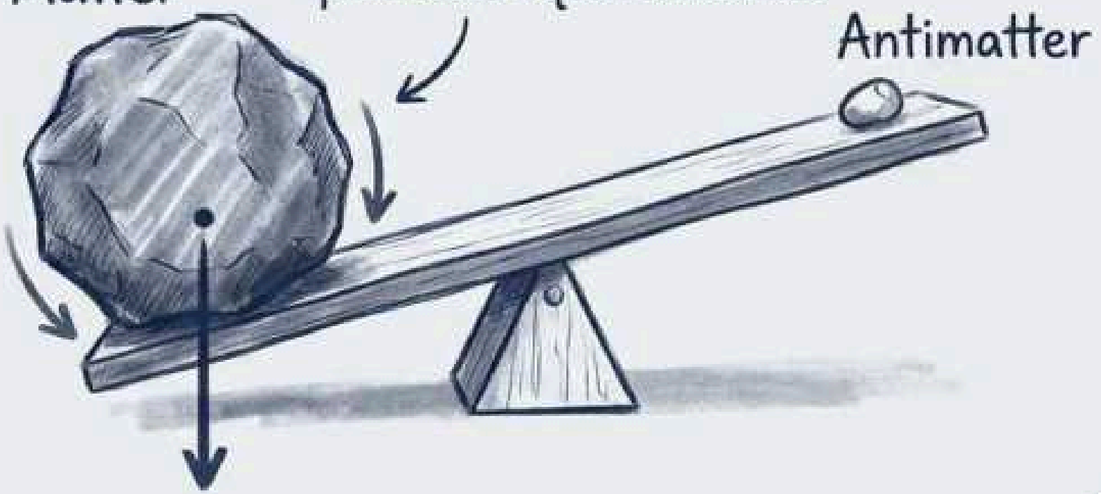
Middle-Ground Methods?

Some alternative local methods using different star types yield intermediate values around 70.

Entirely New Physics?

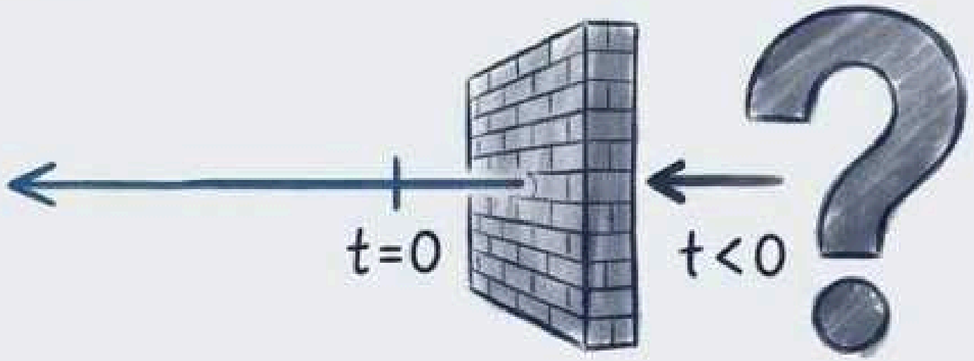
The most profound possibility. Could dark energy be changing its behavior over cosmic time?

The deepest unresolved questions in modern science.





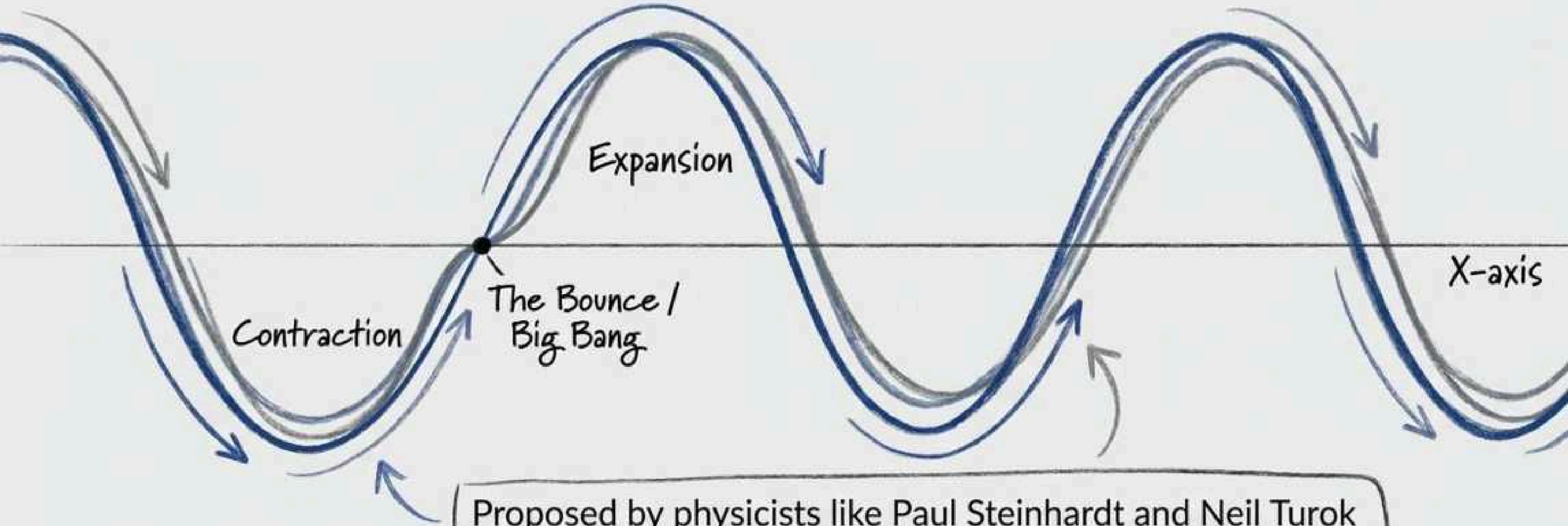
What exactly are they?



What came before inflation, and does the word 'before' even make sense?

Alternatives exist: The cyclic and bouncing universe models.

¶ 6.16

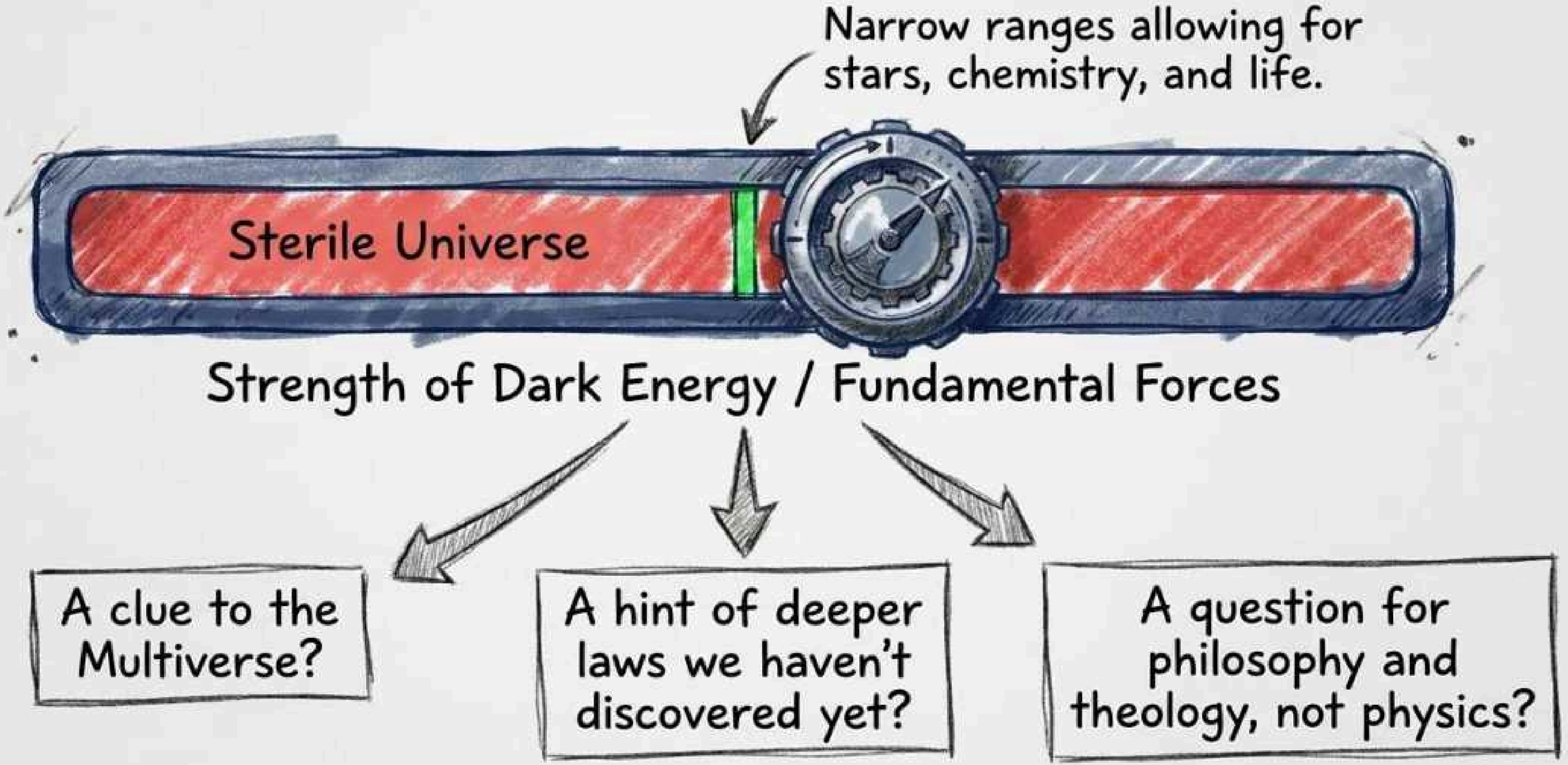


Proposed by physicists like Paul Steinhardt and Neil Turok to explain observations without requiring cosmic inflation.

Currently, evidence does not clearly favor these models, but they crucially keep the scientific debate open.

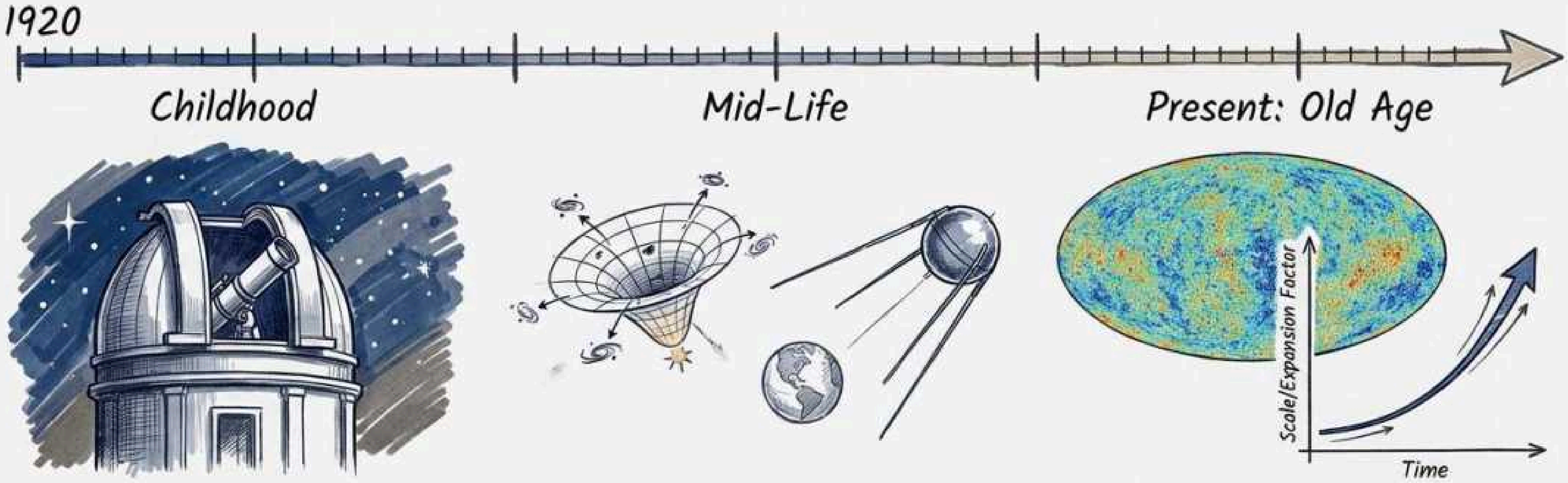
The fine-tuning of the cosmos remains fiercely debated.

¶ 6.17



Unprecedented progress within a single human lifetime.

¶ 6.18

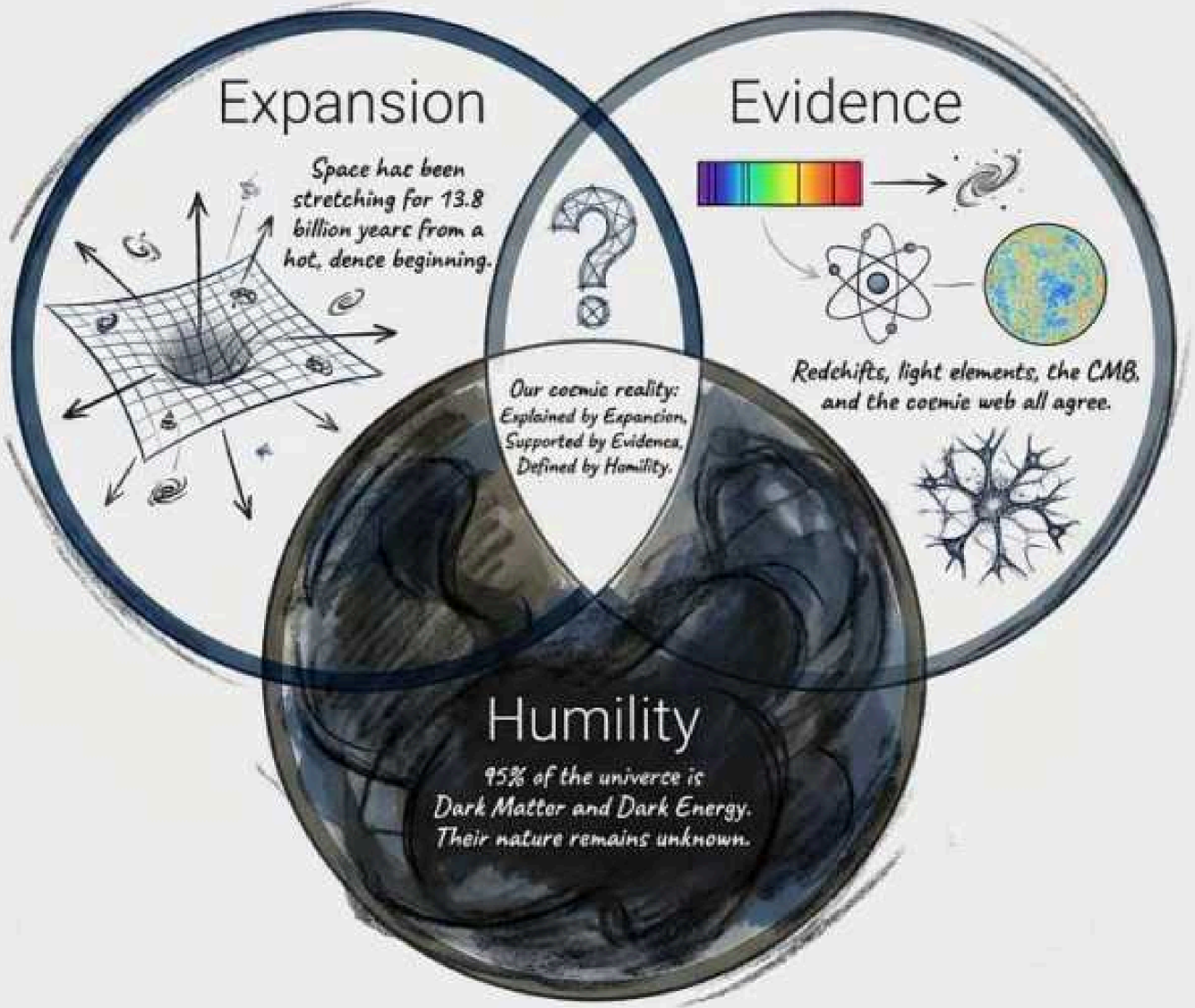


1920: Astronomers still debating if other galaxies even existed.

Present: We now map the Big Bang's afterglow, measure the universe's age to within 1%, and observe accelerating expansion.

The three big ideas defining our cosmic reality.

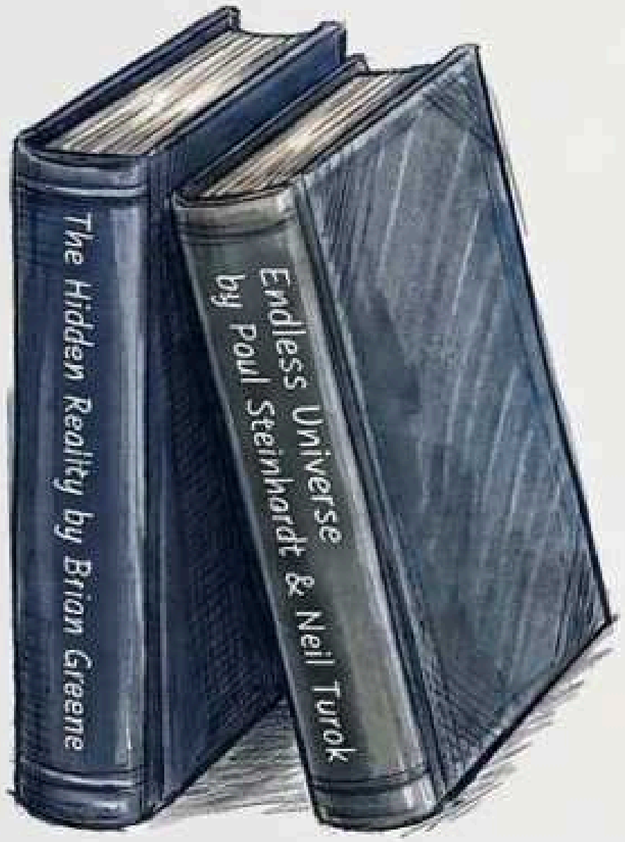
¶ 6.19



Where to continue your exploration of the cosmos.

¶6.20

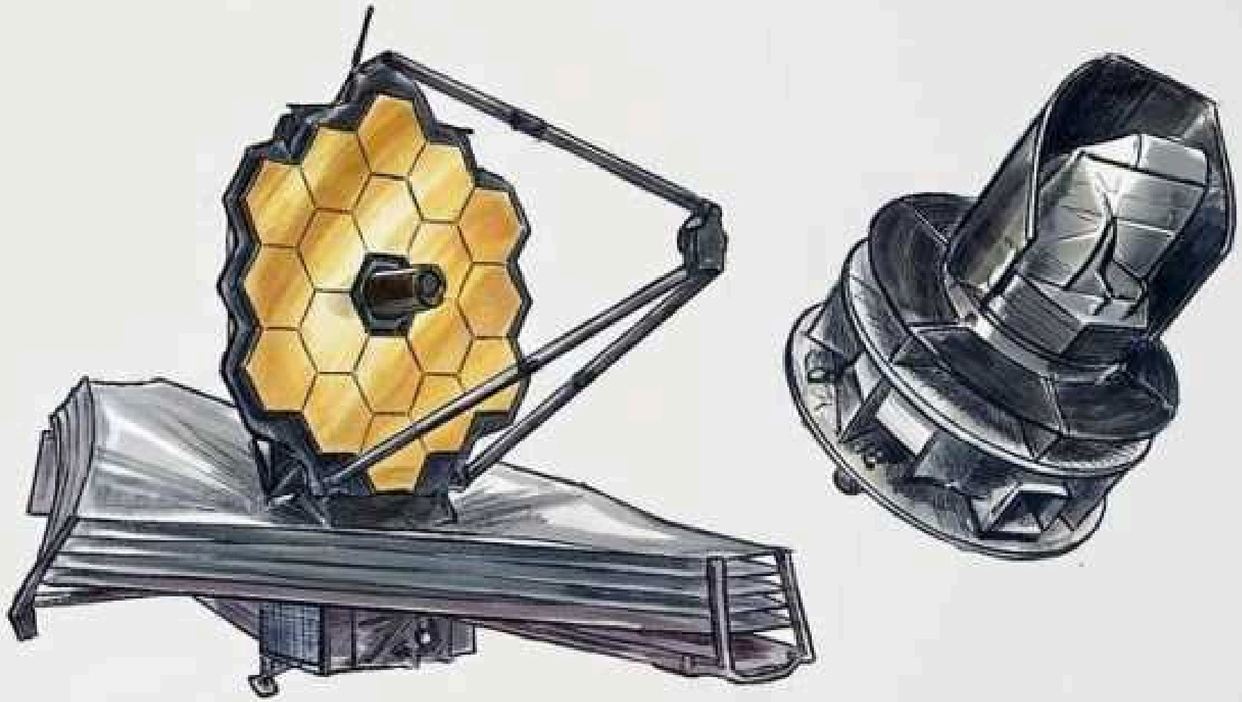
Reading Material



by Brian Greene
(Focus: The Multiverse)

Endless Universe
(Focus: Cyclic Alternatives)

Mission Data



Visit the official JWST and Planck mission websites for the absolute latest images and public data.

Closing Exercise: Synthesizing the Big Bang.

¶ 6.21

Write a short paragraph explaining to a friend how we know the universe had a hot beginning, using at least three independent lines of evidence from this course.

☐ *Evidence 1* ☐ *Evidence 2* ☐ *Evidence 3*

Thank you for studying Astronomy 210 B with Anderson Academy.
Prepare for the final exam and tripos.