

Cosmic Homogeneity: Inflation

WHAT: Sudden growth of the cosmic horizon

WHEN: 10^{-35} s ABB

WHERE: everywhere

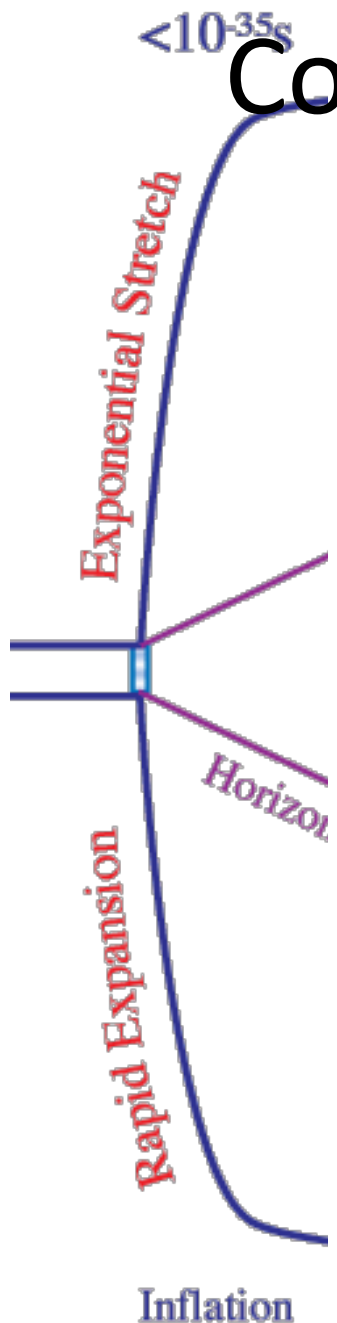
★ Space inflated (multiplied) in scale by a factor of 10^{50} between $t = 10^{-35}$ and 10^{-33} s ABB.

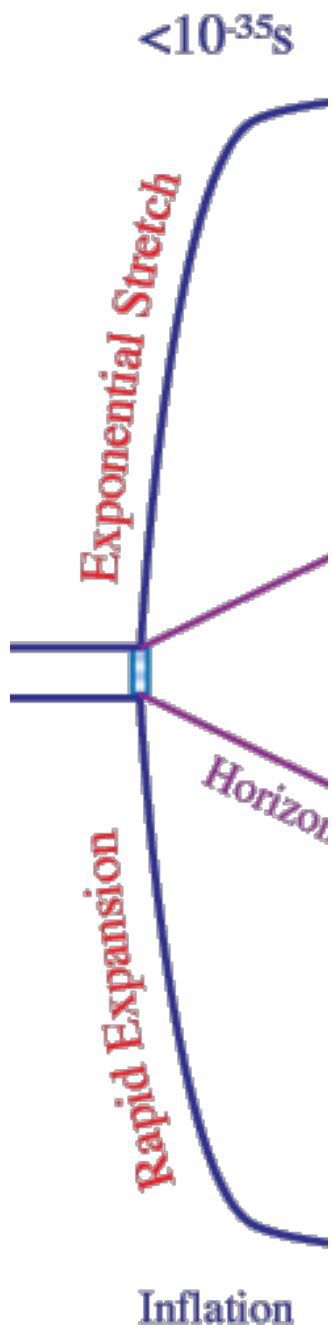
★ the horizon (radius of spheres of influence) ballooned from $10^{-28.5}$ km to $10^{+23.5}$ km ≈ 100 x the radius of today's visible universe l.y.

★ Size of proton grew from 10^{-13} cm to 10^{32} km = 10^{19} l.y. !

★ Regions once in close touch suddenly lost touch and no longer influence each other's evolution (and never will)

★ However, these regions shard (still share) their "inherited genes"- physical properties, forces, & processes





Inflation resolves problems

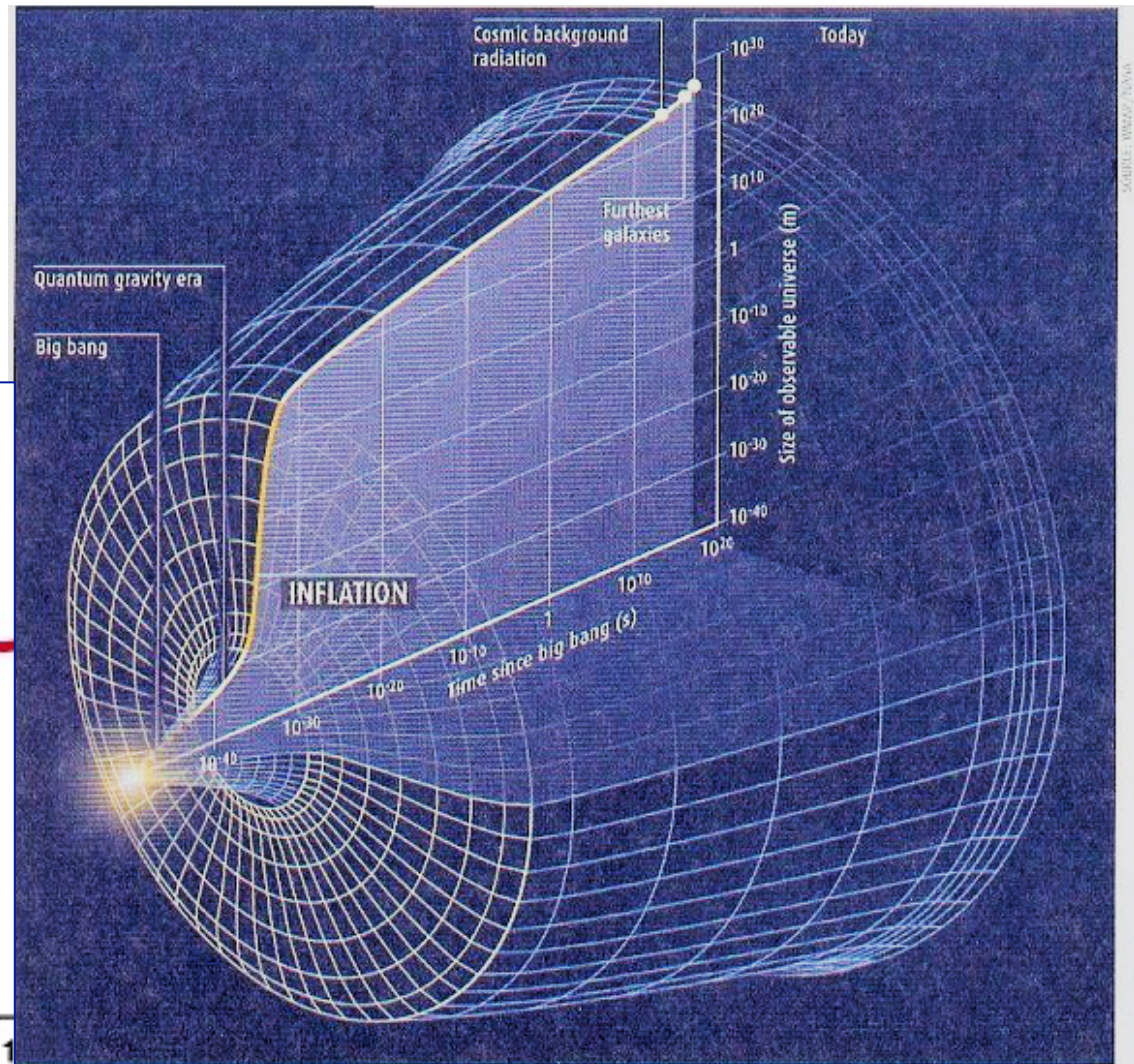
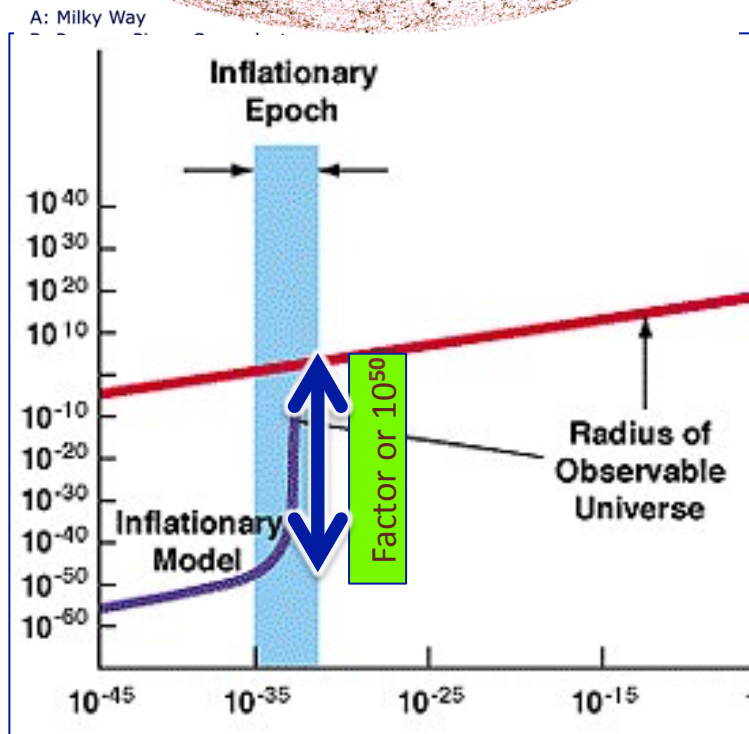
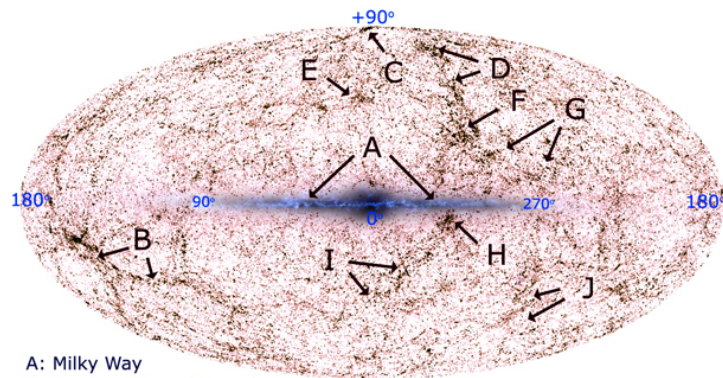
WHAT: Expansion by 10^{50} in 10^{-33} sec

WHEN: 10^{-35} s to 10^{-35} s ABB

WHERE: everywhere

- ★ **Horizon Problem:** Inflation insured that every part of the visible universe, even 180 degrees apart, were once in thermal contact, and would have the same temperature.
- ★ **Smoothness Problem:** The number of particles in the initial unit that became our visible universe after inflation was much smaller. So Inflation prevents clumping from being larger than observed (rather than being too smooth).
- ★ **Flatness Problem:** The inflation decreased the curvature of space-time by a factor of 10^{50} . That made it flat to all practical purposes.

Cosmic Homogeneity: Inflation

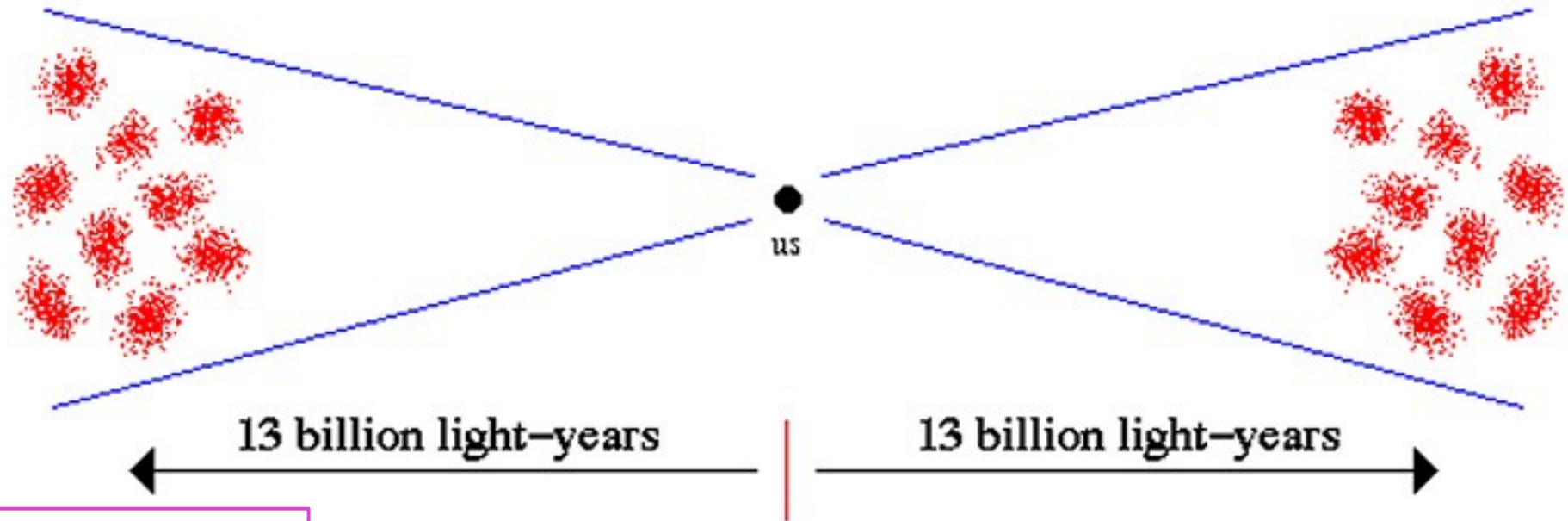


Who Needs Inflation?

Why does each part of the sky look much the same?

Horizon Problem

the number and size of density fluctuations on both sides of the sky are similar, yet they are separated by a distance that is greater than the speed of light times the age of the Universe, i.e. they should have no knowledge of each other by special relativity



Horizon Solution

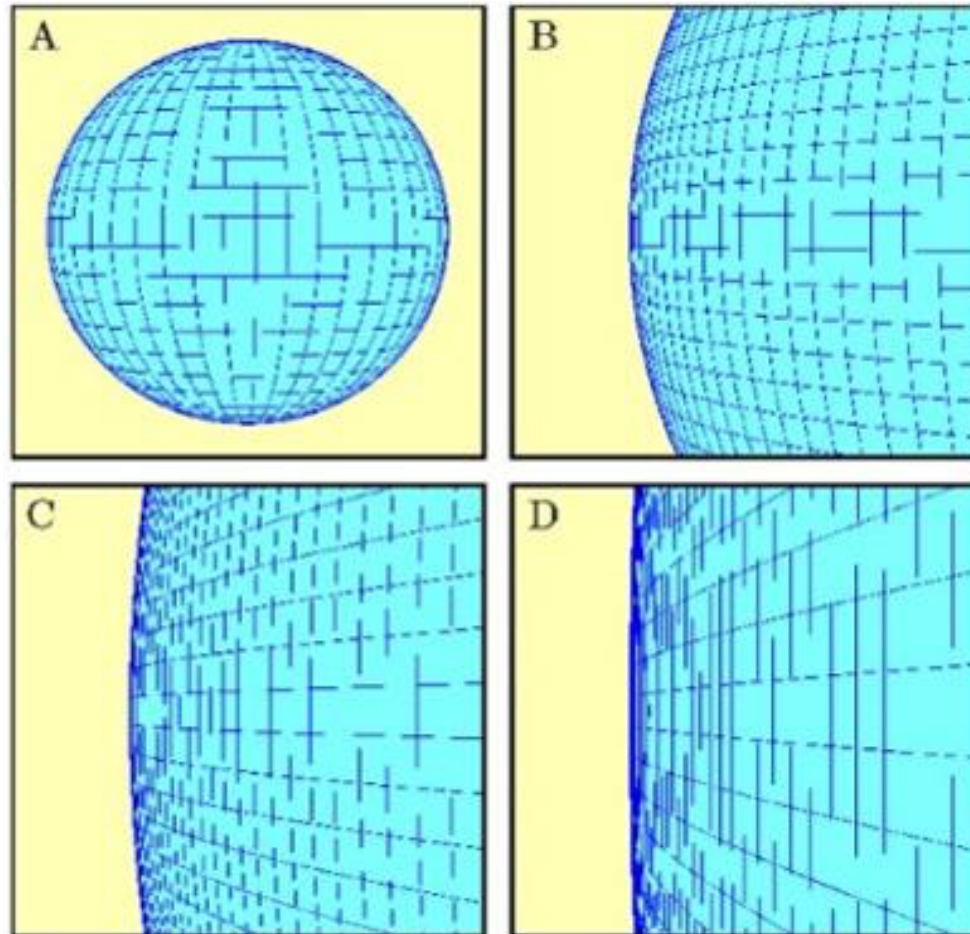
at some time in the early Universe, all parts of spacetime were causally connected, this must have happened after the spacetime foam era, and before the time where thermalization of matter occurred.

Who Needs Inflation?

Why is the Universe Flat? Inflation helps!

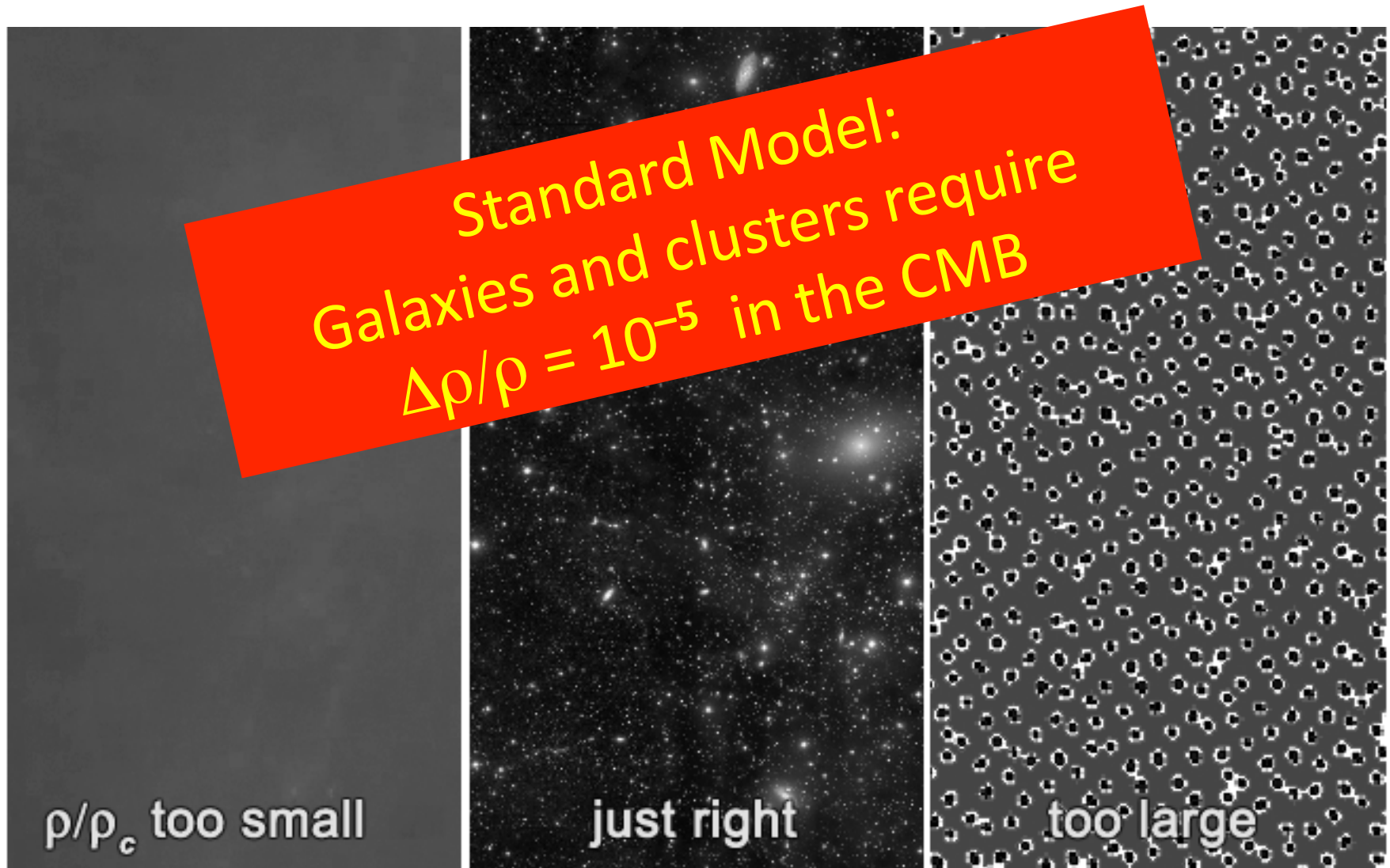
Flatness Problem

Lots of
inflation
decreases
the curvature
of the
universe



Who Needs Inflation?

Inflation set just the right ripple contrast in the CMB



Who Needs Inflation?

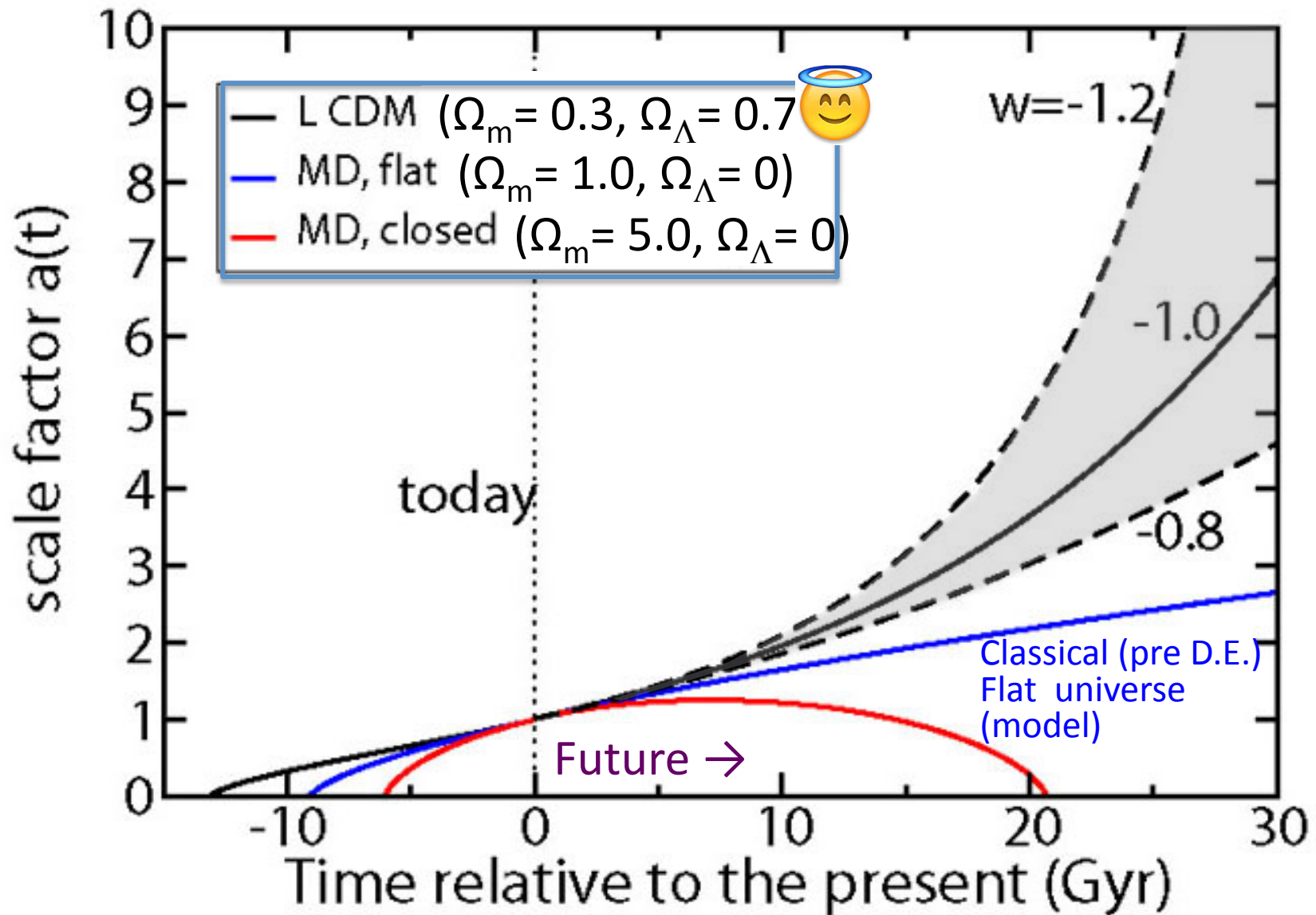
Us! No galaxies then no stars, planets, or life

Anthropic Principle

theories of the universe are constrained by the necessity to allow human existence.



Looking Ahead: Cosmic Outcomes



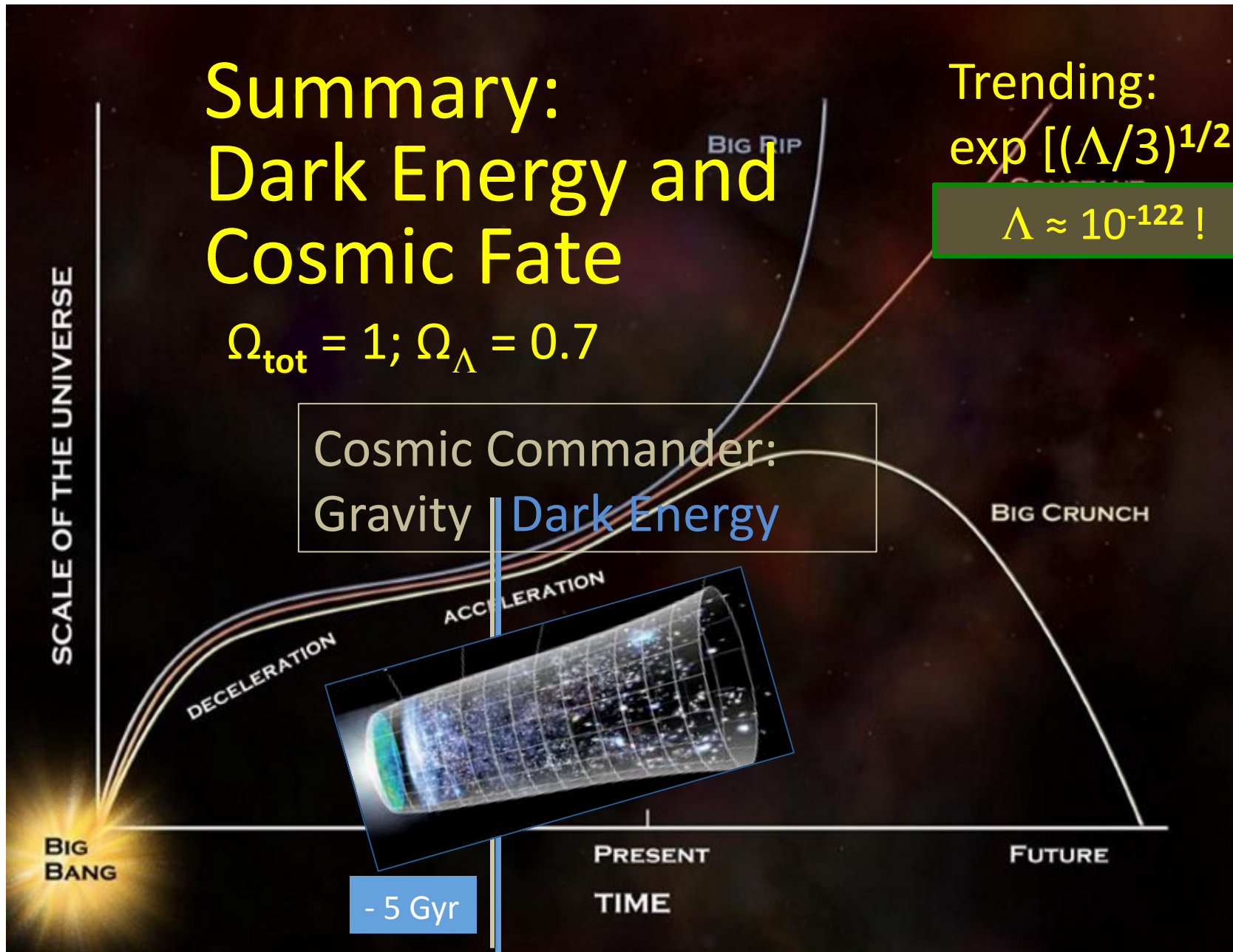
Summary: Dark Energy and Cosmic Fate

$$\Omega_{\text{tot}} = 1; \Omega_{\Lambda} = 0.7$$

Trending:
 $\exp [(\Lambda/3)^{1/2} t]$

$$\Lambda \approx 10^{-122} !$$

Cosmic Commander:
Gravity | Dark Energy



Dark Energy in Our Universe

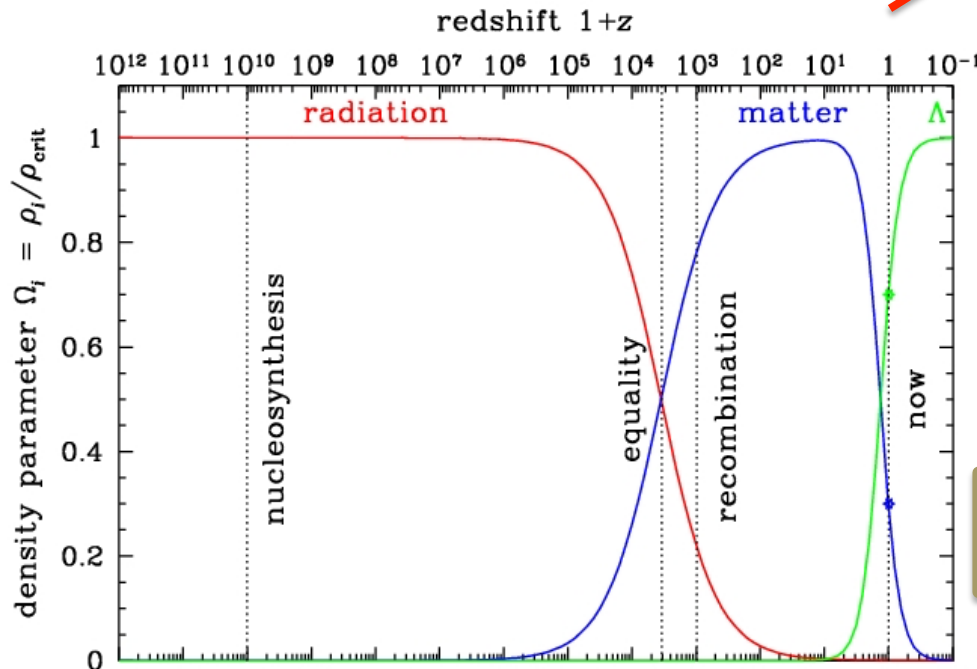
$$(\Omega_{\text{mass-energy}} > 0)$$

Before long mass will lose all of its cosmic influence

~~Attraction
contraction~~

Repulsion
expansion

$$\text{acceleration} = -GM/r^2 + \Lambda \cdot r / 3$$

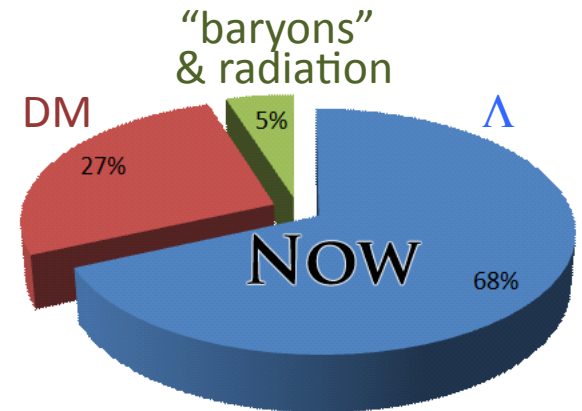
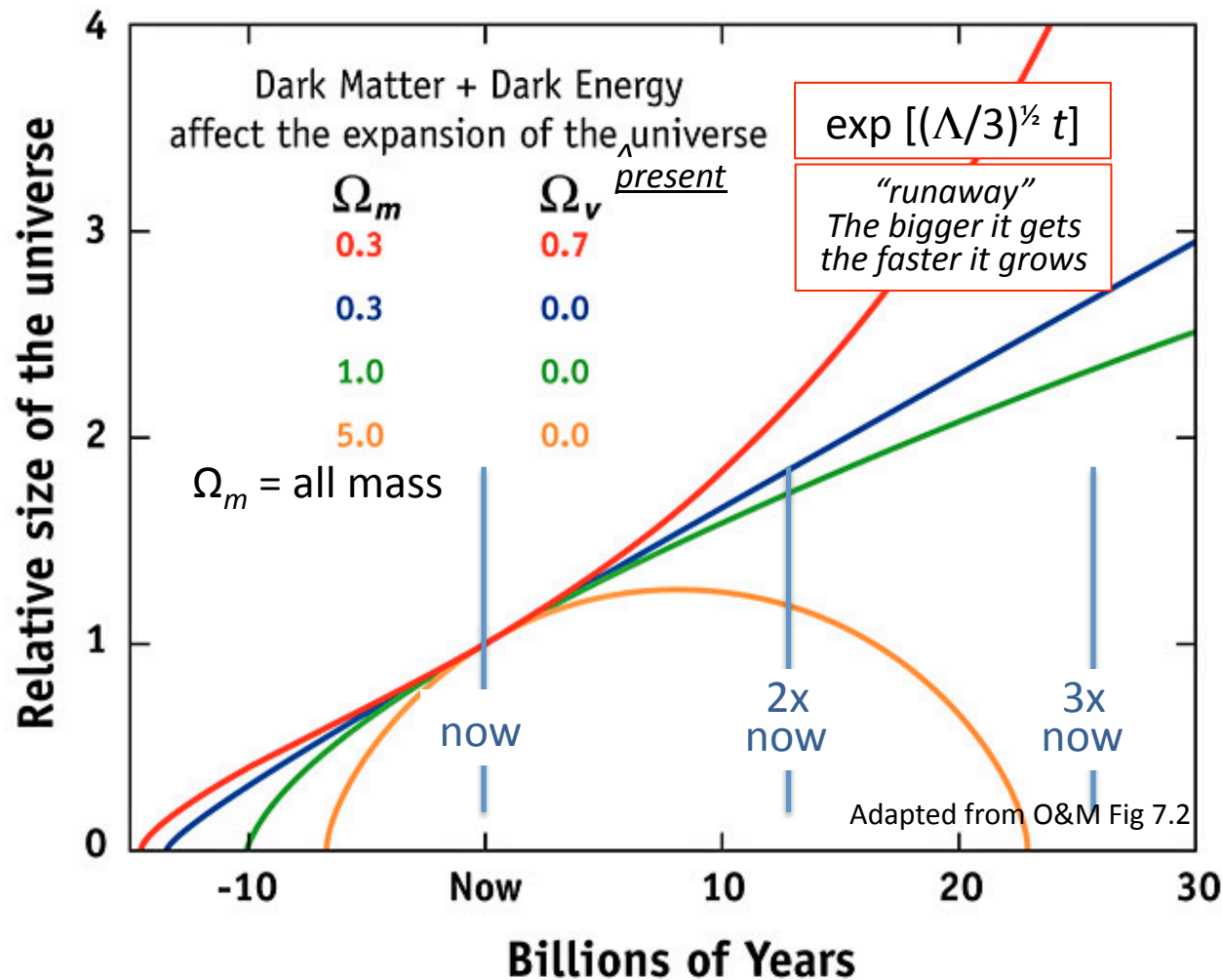


The expansion “runs away” as r increases a few billion years from now.

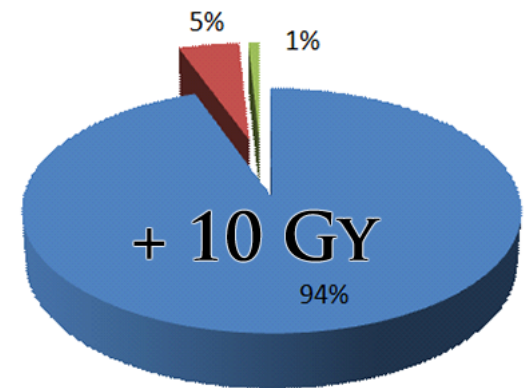
Once this happens the size scale of the Universe will increase exponentially:

$$\text{separation} \propto \exp [(\Lambda / 3)^{1/2} t]$$

Long-term Cosmic Outcomes



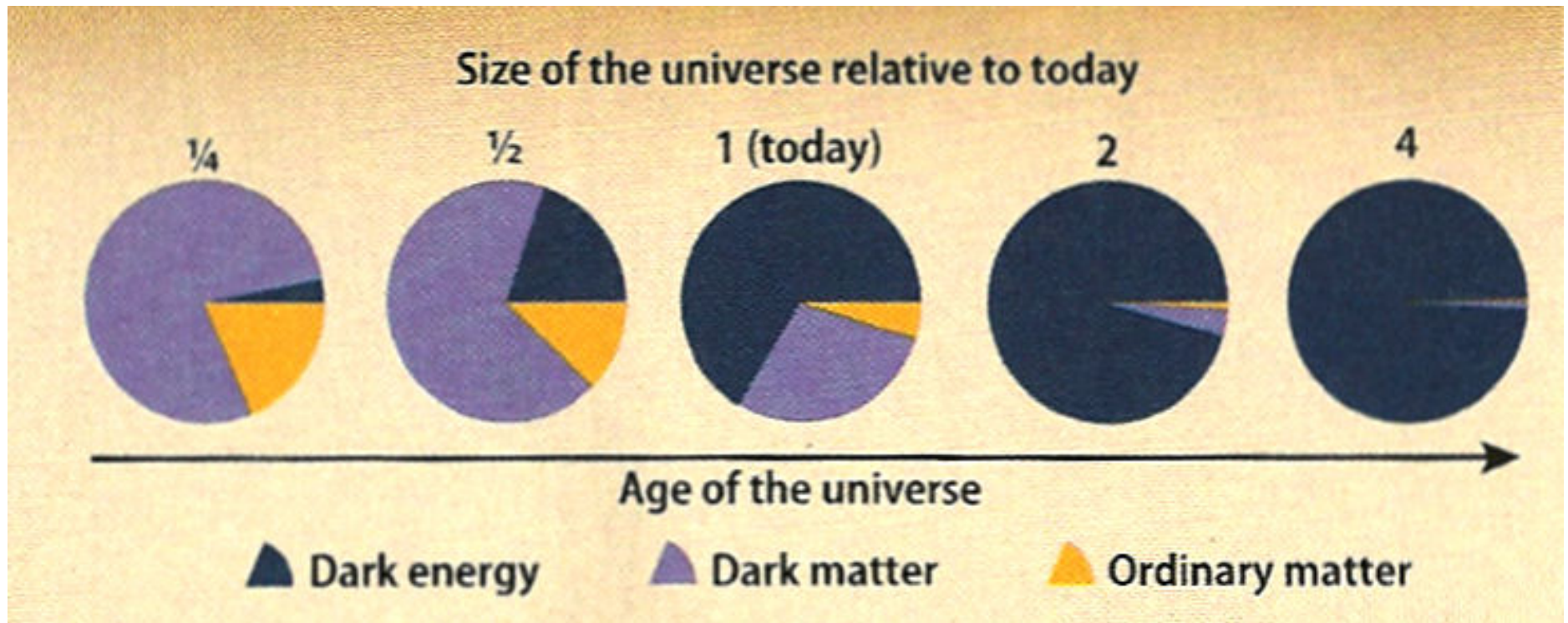
Gravity now plays a minor role



Gravity won't matter much longer

Long-term Cosmic Outcomes

What do you expect?



Surely you just made DE up.



Do you really believe this stuff?

Alternates to Dark Energy: Quintessence and Modified Gravity

Chasing Prescience

Quintessence: pervasive cosmic repulsive force field with gentle form and very gradual change in structure (text page 256)
imagine an almost stationary energy fluid roughly similar (and possibly related) to dark matter

*“quintessence” means the fifth essence of existence
–after earth, sky, fire, and water*

Modified gravity: GR’s description of gravity needs modification so that the force of gravity loses its influence over cosmic distances



Coming up

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More searches and more failures

“Quintessence” an idea du jour

A little more grounded since 2013

They’re in all galaxies, but how and why?

That again?

Puzzles and Future Frontiers