Abstract: I will discuss the possibilities for a post-standard-cosmological-model phenomenology based on the assumption that our universe was born in a tunneling event from an earlier 'Ancestor' vacuum.
Tunneling from Eternal Inflation to Ordinary Slow Roll Inflation.
A Theoretical Prejudice

"Ordinary" inflation* stretched the universe far beyond the point where all fossils of an earlier epoch were completely obliterated.

The expansion factor could have been as large as

\[
10^{1,000} \\
10^{1,000,000} \\
10^{10^{1,000,000}}
\]

This prejudice is unjustified and is quite possible wrong.

In part it comes from mixing up the two kinds of inflation.*

* "Ordinary" inflation and "Slow Roll" inflation are synonymous in this talk. They are distinct from the earlier epoch of "Eternal" inflation.
• Just how much ordinary inflation did take place? Did it obliterate all evidence of an earlier epoch?

• Can we look back to when the universe may have nucleated from another point on the Landscape? If so, what will we see?

• Can we see into other bubbles?
Quick Cosmology Lesson

FRW Cosmology

\[ ds^2 = -dt^2 + a^2(t) \left\{ dR^2 + \sin^2 R \left( d\theta^2 + \sin^2 \theta \, d\phi^2 \right) \right\} \]

\[ ds^2 = -dt^2 + a^2(t) \left\{ dR^2 + R^2 \left( d\theta^2 + \sin^2 \theta \, d\phi^2 \right) \right\} \]

\[ ds^2 = -dt^2 + a^2(t) \left\{ dR^2 + \sinh^2 R \left( d\theta^2 + \sin^2 \theta \, d\phi^2 \right) \right\} \]
Data inconclusive

- Inflation flattens. Best fit: Curvature slightly negative but zero within 1-sigma error bars.

- Anomalous behavior of lowest primordial fluctuations? Maybe.
What does theory say?

Tunneling on the Landscape
We are here.

Ancestor

Remote Ancestor
\[ \left( \frac{\ddot{a}}{a} \right)^2 = V(\phi) + \frac{\dot{\phi}^2}{2} + \frac{1}{a^2} \]

\[ \ddot{\phi} + \frac{\dot{a}}{a} \dot{\phi} + V' = 0 \]

Eternally inflating ancestor

curvature dominated
\[ a = t \]
Slow roll
\[ a = e^{Ht} \]
Too much Slow Roll inflation would obliterate everything that came before.
Why did slow roll inflation happen?

- Slow roll inflation is highly fine tuned.

- Best answer so far: Anthropic
Negative curvature means greater than the escape velocity.

Given $\delta \rho \rho = 10^{-5}$ too much negative curvature will prevent structure formation.

How to dilute curvature?

A period of slow roll Inflation.
\[ \left( \frac{\Omega_{\Lambda}}{\Omega_{\text{matter}}} \right)^{1.3} + \frac{\Omega_{\text{curvature}}}{\Omega_{\text{matter}}} < \left( \frac{\delta \rho}{\rho} \right)_{dc}^{3} \frac{\rho_{dc}}{\rho_{\text{today}}} \]

At decoupling

\[ \frac{\Omega_{\text{curvature}}}{\Omega_{\text{matter}}} < \left( \frac{\delta \rho}{\rho} \right)_{dc}^{3} \frac{\rho_{dc}}{\rho_{\text{today}}} \]

Or in terms of e-foldings

\[ N_{\text{observation}} > 50 \]
\[ N_{\text{structure anthropic}} > 47.5 \]

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Measure Problem
Measures that

- violently favor large number of e-foldings (typically very bizarre consequences).

- that are more or less neutral with respect to N.

(e.g., Bousso, Harnik, Kribs, Perez, hep-th/0702115, and more recently, Guth and Vilenkin, arXiv:0805.2173)
A very simplified 3-parameter model of Landscape statistics
(slope, width, height)

\[ \text{slope} = x \frac{V}{\Delta \Phi} \]
Fixing $N$ and integrating over the 3 parameters gives a “probability” for the number of e-folds.

$$P(N > 50) \sim 10^{-6}$$

Inflation is fine tuned to about one part in a million.
But imposing Anthropic selection requires $N > 47.5$

The conditional probability is large. $\Pr(N > 50 \mid N > 47.5) \sim 0.9$

This is the only known explanation for inflation.

Note: $\Pr(N > 100 \mid N > 50) \sim 0.1$
Now consider the probability that $N$ is in the window in which we can see back to the onset of inflation. This means $N < 53$.

The window is the red region.

$P(N) = \frac{1}{N^4}$

$P(50 < N < 53) \sim 0.15$
Fossils of a Tunneling Event
Fossil #1

Negative Curvature
\[ R = \text{Co-moving radial distance} \]
Last Scattering
Radiation
Reheating
Slow Roll
Curvature

\[ R = 1 \text{ (radius of curvature)} \]
Fossil 2

Very low I tensor modes
Gravity waves (Tensor modes) are also produced during inflation but their amplitude may be (?) too small to detect.

\[ h \sim H_{SR} < 10^{-7} \]

But there is a mechanism to create strong large-scale tensor modes.
Gravity waves created in the ancestor are inherited in the FRW.
FRW/CFT duality

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LS
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\[ \langle h \ h \rangle = \ell^2 \ H^2_{\text{ancestor}} \]
\[ \langle h h \rangle = H_{\text{amper}}^2 \ell^2 \quad (R \geq 1) \]

\[ \langle h h \rangle = H_{\text{amper}}^2 \ell^2 R^\ell \quad (R < 1) \]
\[ \langle h \ h \rangle = H_{\text{ancolor}}^2 \ell^2 \quad (R \geq 1) \]

\[ \langle h \ h \rangle = H_{\text{ancolor}}^2 \ell^2 R^\ell \quad (R < 1) \]
$I(l+1)C_l/2\pi [\mu K^2]$ vs Multipole moment $l$
could low I tensor modes add to a suppressed low I scalar spectrum to produce observed data?
Polarization

\[ h_{ij} \sim H_{\text{ancestor}} e^{-2R} \]
\[ \varepsilon_{ab} \hat{\mathcal{C}}_a P_{bc} = 0 \quad \text{Gradiant modes} \]

\[ \hat{\mathcal{C}}_b P_{bc} = 0 \quad \text{Curl modes} \]

G-waves and density fluctuations

Only G-waves
Guth, Weinberg, Vilenkin, Garriga, Freivogel, Bousso, Shenker, Sekino, Kleban, Bjorken, ............

But, as with other fossils too much slow roll will dilute the signal to unobservability.