Gauge Invariant Probability Proposal for Eternal Inflation

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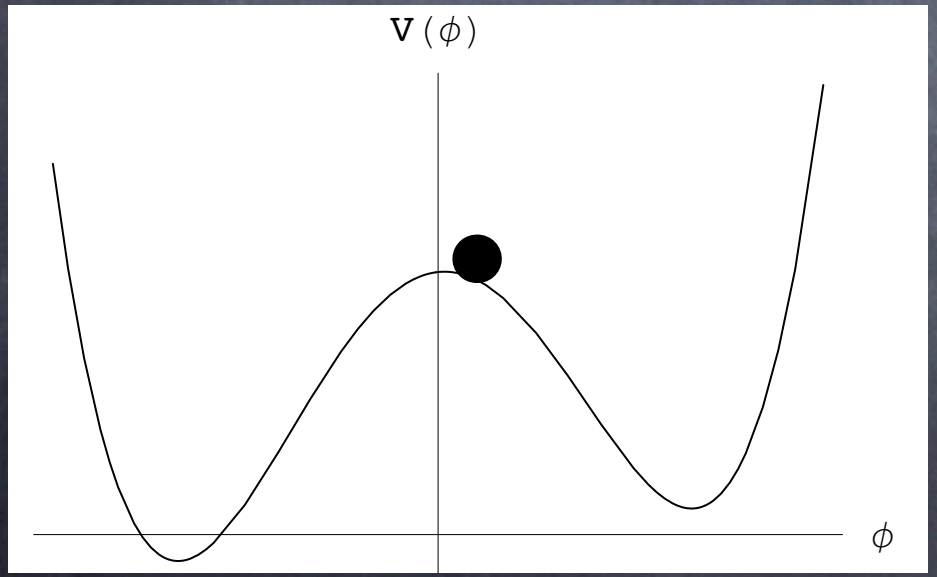
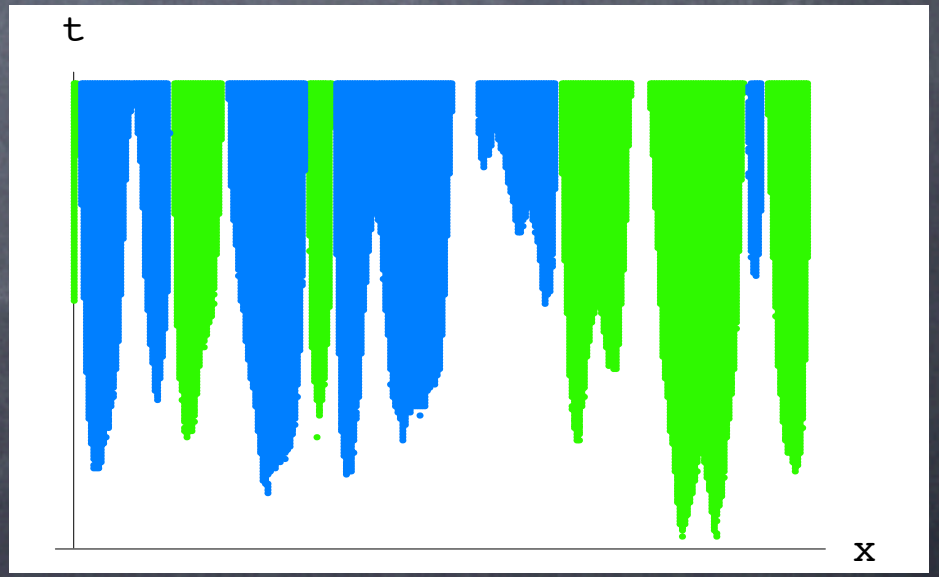
Eternal Inflation

- Fluctuations of the Inflaton may drive it to different vacua in different places

A. Vilenkin PRD 27, 2848 (1983)
A.D. Linde PLB 175, 395 (1986)
A. A. Starobinsky, Field Theory, Quantum Gravity and Strings (1986)
Overview: A. Guth astro-ph/0002156





Probabilities

- Different vacua have different properties
  - String Landscape
- MUST understand what is likely/unlikely if we are to make predictions
  - What is the Prob. for a randomly picked galaxy to have a given cosmological const.?
  - Naive approach: $P(\Lambda) = \frac{Vol(\Lambda)}{Vol(Total)}$

Probability Challenges

- There are an infinite number of spatially infinite pocket universes
  Vanchurin, Vilenkin, Winitzki
  gr-qc/9905097
- Time cut-off introduces gauge artifacts
  - Young pocket universes are favored
  - Shrinking volume gauge
    S. Winitzki
    gr-qc/0504084
- Spherical cut-off method
  A. Vilenkin
  hep-th/9806185
  - Can not handle different pocket universes

Infinite Pocket Universes and Probability

- Consider multiple different vacua
- Take a constant parameter (cosmo. const.)
- "Which pocket uni. has more galaxies" is meaningless: both have countably infinite
- If only two pockets exist then a randomly picked galaxy may be in either: P=1/2

Picking Pockets

- More generally: N pockets -> P=1/N
- The question reduced to: what is the probability of a randomly picked pocket universe having a given cosmo. const.?
- Still have an infinite number of pockets

World Line Method

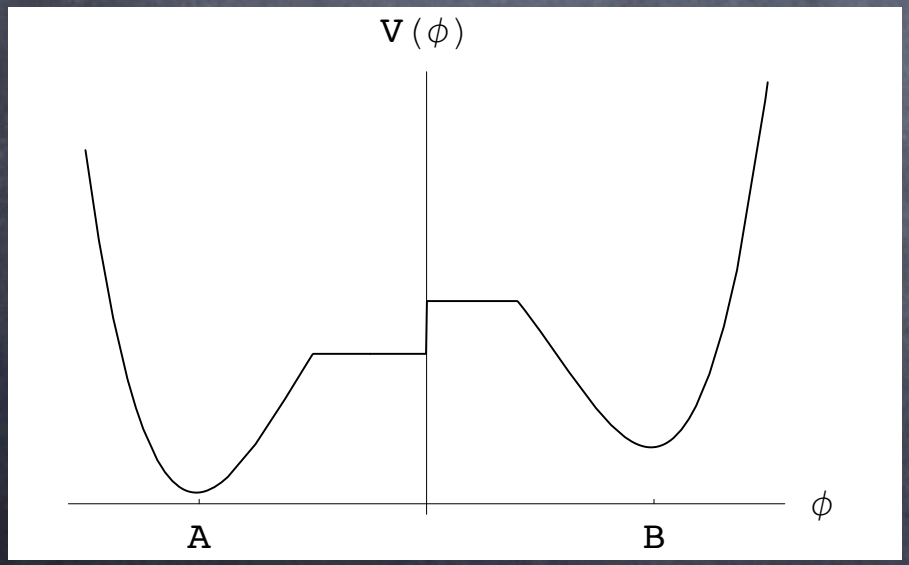
- Pick an eternally inflating region
- Pick N points in region -> follow world lines
- Each line eventually enters thermal region
- Do not over-count pocket universes: N->N′

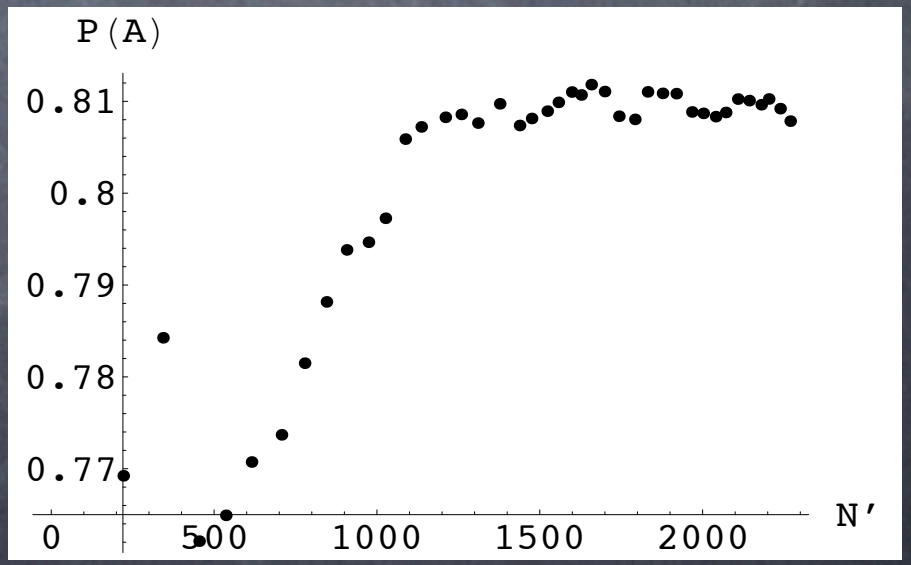
$$P(\Lambda) = \frac{N_\Lambda}{N'}$$

- Check convergence as N′ -> Infinity

Toy Model Example

- Use toy model with discrete time steps and discrete Hubble volumes
- Assign hopping probabilities





Probability $\neq$ Anthropic

- Consider 3 vacua: $\Lambda_0, \Lambda_{us}, \Lambda_{EW}$
- If $P_{us} \gg P_0, P_{EW}$ Model and Observations are consistent
- If $P_0 \gg P_{us}, P_{EW}$ Model is ruled out
- If $P_{EW} \gg P_{us}, P_0$ ignore EW pockets and compare P_{us} with P_0

Conclusions

- Volume can be misleading for probabilities
- Follow the (finite number of) worldlines to calculate probabilities for pocket universes.
- Some models (landscapes) may be falsifiable without recourse to anthropic reasoning.