Everpresent Λ Cosmology

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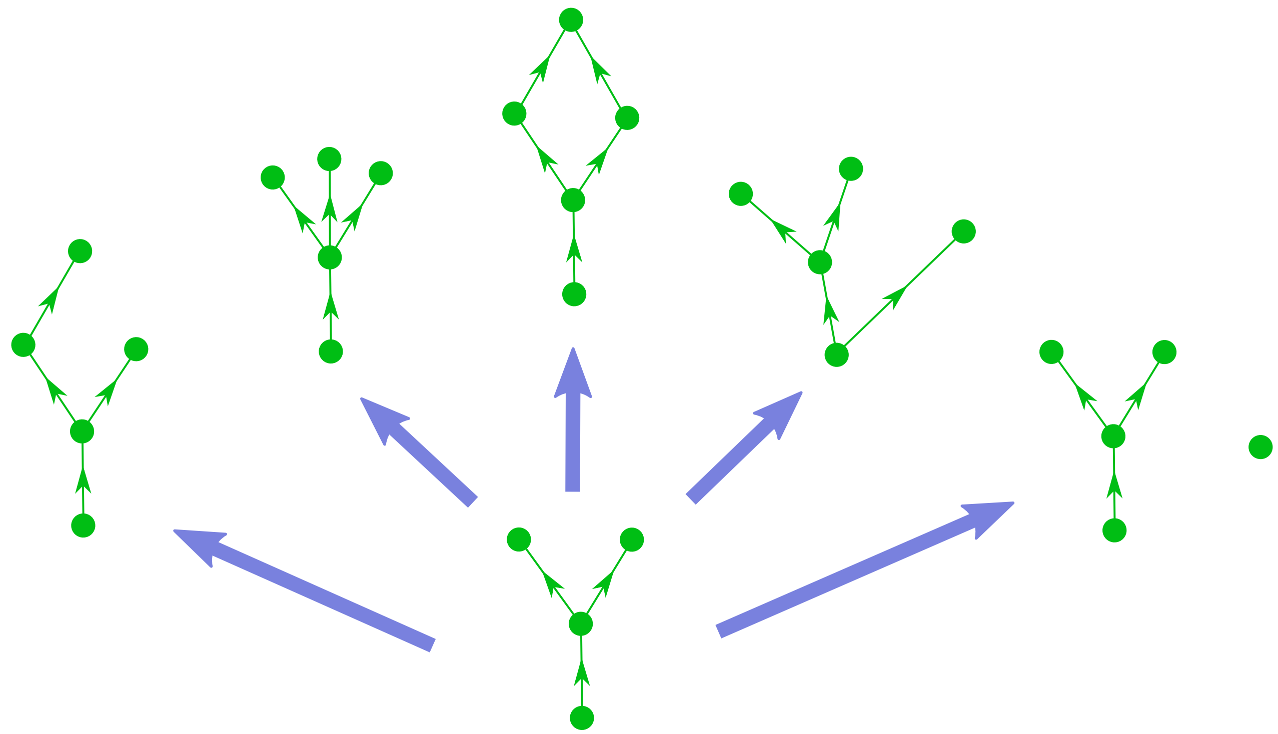
Causal Set Theory: Growing by Number

In classical dynamical models, a causal set **grows element by element** sequentially. At stage 1, the first element is born, and subsequently at each stage n we have an n-element causal set.



Dynamics ingredient: number of elements plays a similar role to time

Causal Set Theory: Fundamental Discreteness

$$\langle N \rangle = V$$
$$\delta N = \sqrt{V}$$

Causal sets that are approximated by continuum manifolds have a **number-volume correspondence** such that: the number of elements N within any arbitrary region with volume V is statistically proportional to V. The **Poisson distribution** ensures this correspondence with minimal variance.

Kinematics ingredient: number-volume correspondence according to the Poisson distribution

Everpresent Λ

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Everpresent Λ

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$$\mathcal{Z}(\Lambda) \sim \int \mathcal{D}g_{\mu\nu} \exp\left(iS_G[g] - i\Lambda \int d^4x \sqrt{-g} \right)$$

Therefore, spacetime volume V and Λ are quantum mechanically conjugate

$$\frac{\delta\Lambda}{8\pi G} \cdot \delta V \geq \frac{\hbar}{2}$$

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A causal set with fixed N can be approximated by continuum spacetimes with mean $\langle V \rangle = N$ and standard deviation $\delta V = \sqrt{N} \sim \sqrt{V}$. Also: $N, V \gg 1$

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$$\delta\Lambda\;\delta V \sim 1 \xrightarrow[\text{}]{\text{Assume } \langle\Lambda\rangle = 0} \Lambda \sim \delta\Lambda \sim 1/\delta V = 1/\sqrt{V} \sim H^2 \sim 10^{-121}!$$

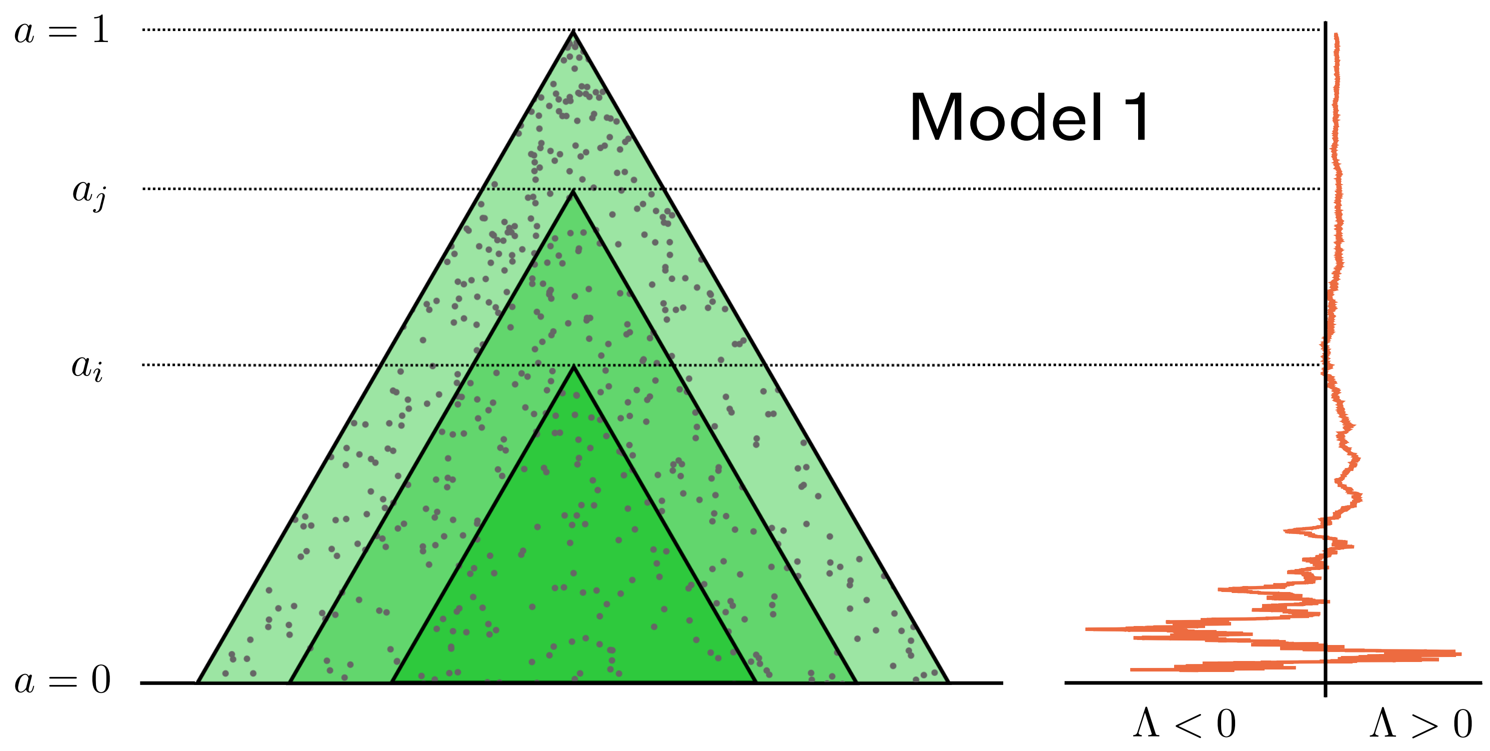
A Phenomenological Model of Everpresent Λ

Ahmed, Dodelson, Greene, and Sorkin, “Everpresent Λ”, PRD 69, no. 10 103523, 2004.

$$|\Lambda| \sim 1/\sqrt{V}$$

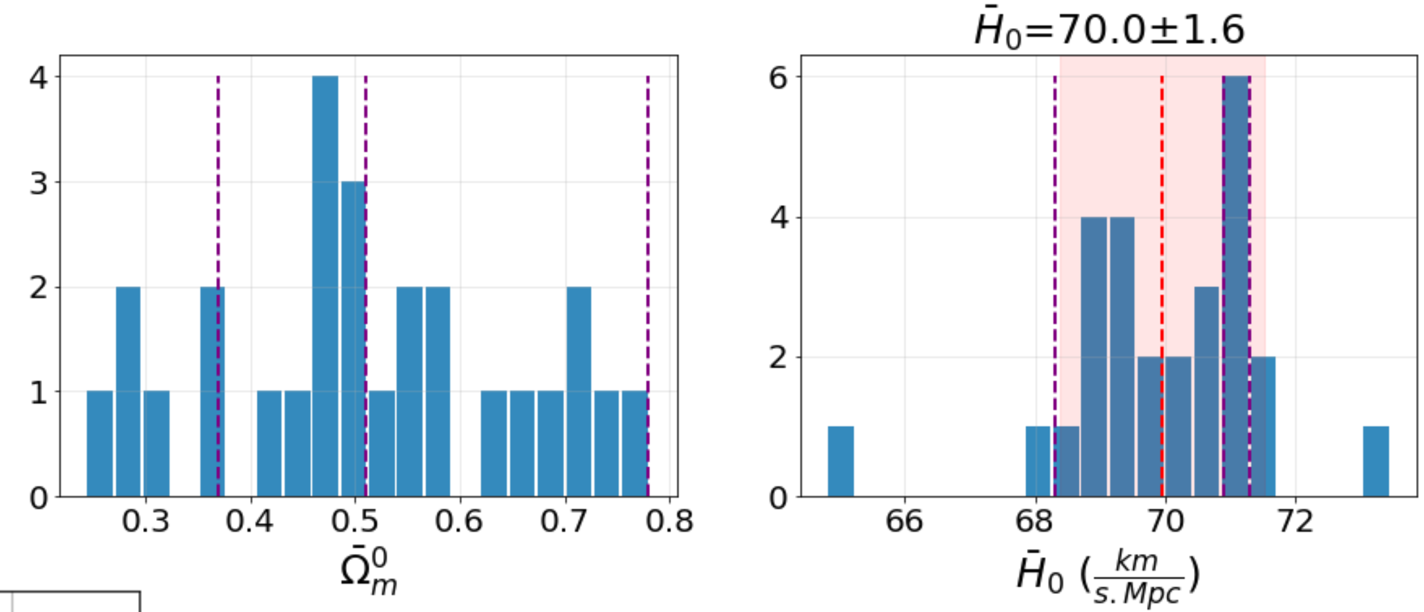
Each causal set element contributes a random variable with standard deviation α to S_Λ:

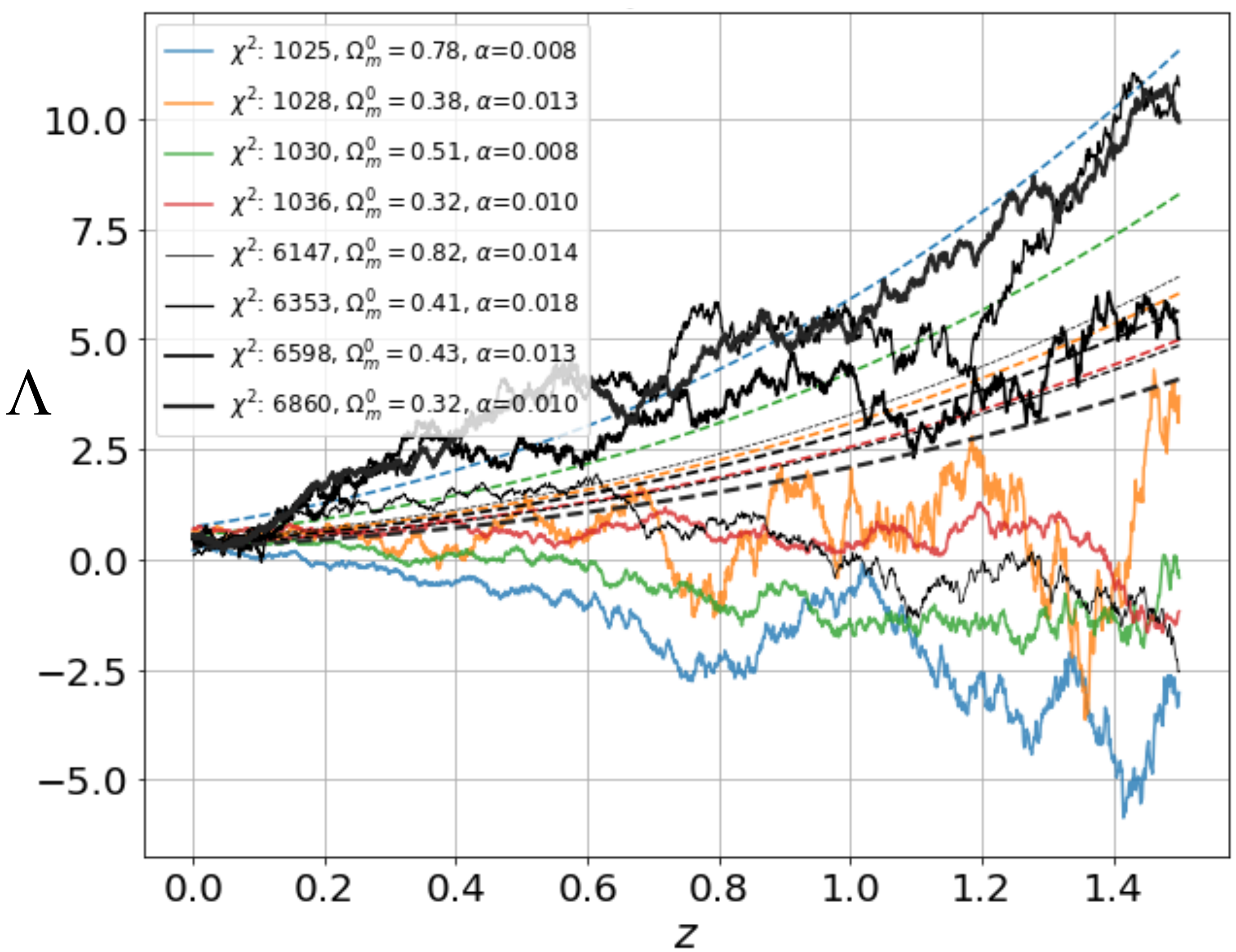
$$S_\Lambda|_{1\ element} = \begin{cases} \alpha, & p = \frac{1}{2} \\ -\alpha, & p = \frac{1}{2} \end{cases}$$



Type Ia Supernovae

Out of a sample of 20,000 seeds, 3 Everpresent Λ histories (dashed lines) yielded a better χ^2 (1025, 1028, 1030) than ΛCDM (1033).





Dark energy densities that are smaller than matter density at small redshifts (colored) are favored over those with comparable or larger dark energy densities (black).

Das, Nasiri, YKY, in preparation.

Summary & Outlook

- Everpresent Λ: a fluctuating cosmological constant from spacetime discreteness
- Many open questions remain: e.g. why is the mean 0?
- Improvements: CMB data fit, quantum modifications, stochastic differential equations, incorporation of inhomogeneities