Islands in Multiverse Models.

[2108.01278]

Bright ideas for a dark universe. DESY-TH Workshop.

Sergio Ernesto Aguilar Gutiérrez

ITF - KU Leuven
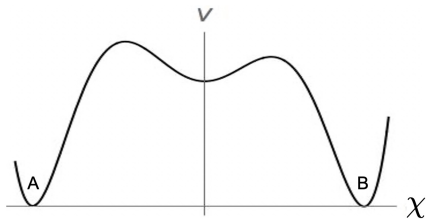
In collaboration with:
Aidan Chatwin-Davies, **Thomas Hertog**, **Natalia Pinzani-Fokeeva**, & **Brandon Robinson**

September 21, 2021

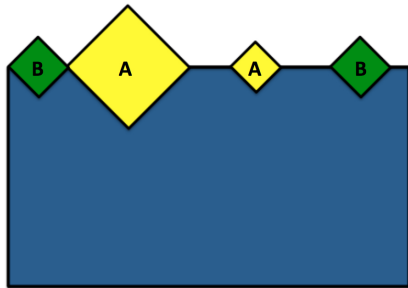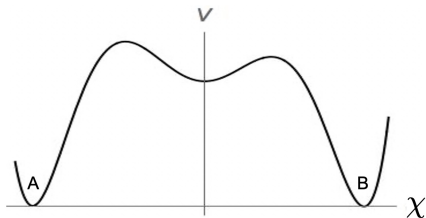# Setting

Universe undergoing false vacuum eternal inflation can be seen as a mosaic of bubble universes separated by inflatory regions.

Universe undergoing false vacuum eternal inflation can be seen as a mosaic of bubble universes separated by inflatory regions.

Motivation: Measure problem

- Version of the information paradox in the multiverse.
- The history of states leading to $\langle \mathcal{O} \rangle$ follows ∞ number of bubbles.
- Reproducing probabilities for local observables require a surface beyond there's no instance of observation $\rightarrow$ **highly cutoff dependent**.
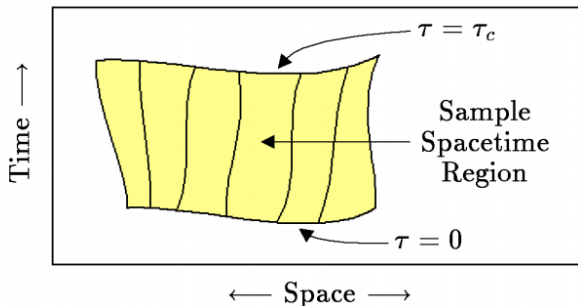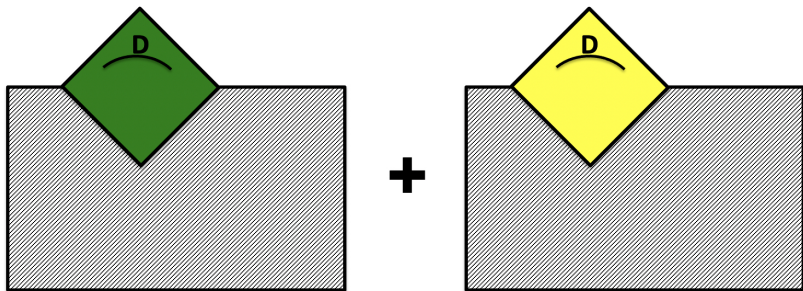

Figure: [Guth, Vanchurin; 2011]

Previous ideas

- *Lessons from semiclassical quantum cosmology*: Bubbles can be replaced by a superposition of saddle point geometries; histories that follow a single bubble reproduce local observables.
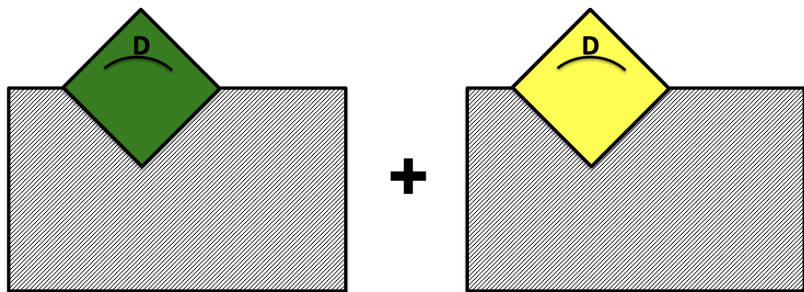
Previous ideas

- *Lessons from semiclassical quantum cosmology*: Bubbles can be replaced by a superposition of saddle point geometries; histories that follow a single bubble reproduce local observables.

- No information about unbservable structure outside one's bubble.
- Fine grained information from coarse graining! - just like the **entanglement islands**.
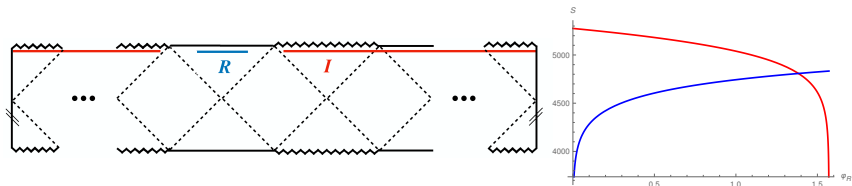
- Entanglement entropy in R,

$$S(\rho_R) = \min_I \operatorname{ext} \left[S_{\mathsf{CFT}}(R \cup I) + \frac{\mathsf{Area}(\partial I)}{4 G_N} - S_{\mathsf{ct}}(\partial I) \right].$$

- JT gravity in dS_2 in presence of CFT matter in its vacuum state.

Model

- Entanglement entropy in R,

$$S(\rho_R) = \min_I \operatorname{ext}_I \left[S_{\text{CFT}}(R \cup I) + \frac{\text{Area}(\partial I)}{4 G_N} - S_{\text{ct}}(\partial I) \right].$$

- JT gravity in dS_2 in presence of CFT matter in its vacuum state.
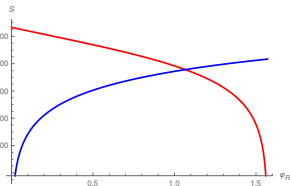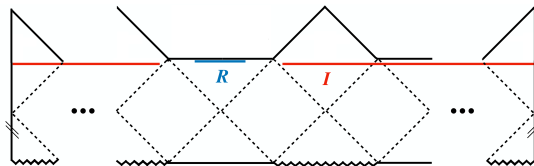
- dS_2^n background; an n-fold extension of dS_2.

And we glued patches of different curvature

- Flat bubbles in dS_2^n.

- AdS_2 bubbles.

Discussion
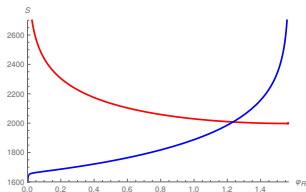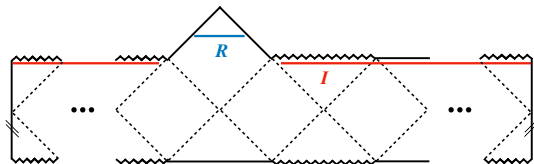
- Particular patches covered by the islands don't matter, only the endpoints.

- Generically, islands have to cover all structure outside R to purify the quantum state in $I \cup R$.

- We considered other cases, with multiple islands, or intervals where certain approximations are not valid, which required exact calculations.

- S_{dS} is the maximum entropy, the Hilbert space for the degrees of freedom is bounded, regardless of the information outside R.

- We pointed out similarities with coarse-graining in quantum cosmology.