



Introduction

Swampland
picture

Thermalization
in de Sitter

Thermal de
Sitter and the
Swampland

Thermal de Sitter and the Swampland

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Based on 2010.09760

Strings 2021



An observation!

dS is different!

- More difficult to construct in string theory
- Unique and strange thermal properties

Unique features should be related!

Swampland \leftrightarrow Thermal properties

TCC time = scrambling time!

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Trans-Planckian Censorship Conjecture (TCC)

$$\frac{a_f}{a_i} \cdot l_{pl} < \frac{1}{H_f} \rightarrow \tau < \frac{1}{H} \ln\left(\frac{1}{H}\right) \quad (\text{TCC time})$$

See [2010.09760](#) for a brief review of motivations and consequences

Non-trivial evidence from string theory:

- Implies $\frac{|\nabla V|}{V} > \frac{2}{\sqrt{(d-1)(d-2)}}$ in the asymptotics ([1909.11063](#))
- Implies distance conjecture with $\lambda = \frac{1}{\sqrt{(d-1)(d-2)}}$ conjectured in [2004.00030](#), derived in [2010.09760](#)



Thermalization in de Sitter

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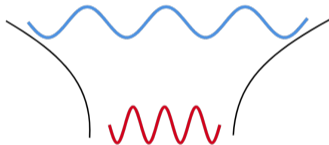
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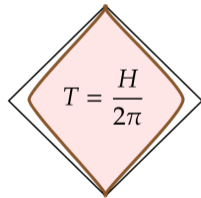
Flat-slicing coordinates

As trans-Planckian modes become sub-Planckian, they are in a thermal state called Bunch-Davies



Static coordinates

Any deviation from thermal equilibrium gets scrambled and thermalized by the stretched horizon



Thermalization time: $\sim \frac{1}{H} \ln\left(\frac{1}{H}\right)$



dS complementarity and the Swampland

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Thermal de Sitter and the Swampland

Swampland conditions suggest dS space cannot be viewed as an equilibrium thermal background. This, however, does not mean that the dS space does not have any statistical interpretation.

Couple of strange features of thermal de Sitter:

- The number of particles $\sim \mathcal{O}(1)$.
- The apparatus must be of the size of observable universe!

Stay tuned!

A fundamental tension between unitarity and long-lived de Sitter!