Trans-Planckian Censorship

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Swampland
Renormalization & EFT

energy Scale

a low-energy effective field theory

LHC! Belle II!
Renormalization & EFT

energy scale

$\Delta \mathcal{L} \sim \frac{1}{\Lambda_{\text{cutoff}}}$

\uparrow suppressed

Low-energy effective field theory

LHC! Belle II!
Renormalization & EFT

energy

Scale

$M_{\text{pe}}$

$\Lambda_{\text{cutoff}}$

$\Delta L \sim \frac{1}{\Lambda_{\text{cutoff}}}$

QG, string, ...

Low-energy effective field theory

LHC! Belle II!
Renormalization & EFT

energy

Scale

$M_{pl}$

Very constrained

$\Lambda_{cut off}$

$M_{pl}$ is special!
Renormalization & EFT

energy

Scale

M_{\text{pl}}: \text{special!}

very constrained

\Lambda_{\text{cutoff}}

Landscape

Swampland

LEEFT
Swampland Conjectures: Necessary Conditions for existence of UV completion
Swampland Conjectures: Necessary Conditions for existence of UV completion

- semiclassical GR
- string theory
- phenomenology experiments

Arrow connections indicate relationships or dependencies between the concepts.
Murayama - Yanagida - Y 1809. 00478
Fukuda - Saito - Shirai - Y 1810. 06532
Ibe - Yanagida - Y 1811. 04664
Y 1904. 04976
Shirai - Y 1904. 10577
Kusenko - Takhistov - Yamada - Y 1908. 10930
Y 1910. 08691
1. Is Trans-Planckian Censorship a Swampland Conjecture?
IPMU-19-0170


References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service

Saito (Yamaguchi)   Shirai (IPMU)
Trans-Planckian

"Problem"
tiny quantum fluctuation

exponential expansion

macroscopic fluctuation
$\log(\text{physical scale})$

$\lambda \propto a$

$H^{-1} \propto a^2$ (RD)
$H^{-1} \propto a^{1.5}$ (MD)

$\log a(t)$
$\log(\text{physical scale})$

$\frac{a}{\sigma} = H^{-1}$

$2 \propto a$

$H \propto a^2$ (RD)
$H^{-1} \propto a^{1.5}$ (MD)

inflation

$\log a(t)$
\[ \log(\text{physical scale}) \]

- Horizon crossing
- \( \lambda \propto a \)
- Horizon exit
- Horizon size: \( \frac{a}{\dot{a}} = H^{-1} \)
- Inflation
- \( H^{-1} \propto a^2 \) (RD)
- \( H^{-1} \propto a^{1.5} \) (MD)

\[ \log(\text{alt}) \]
tiny quantum fluctuation

exponential expansion

macroscopic fluctuation

CMB
transplanckian mode
\[ l \lesssim l^* \]
tiny quantum fluctuation

expontential expansion

macroscopic fluctuation

CMB
Trans-Planckian "Problem":
Can we observe trans-Planckian modes?
If so, breakdown of EFT?

* Similar problem for BHS
Trans-Planckian Censorship
Trans-Planckian Censorship Conjecture
(TCC, [Bedroya-Vafa 19])

Horizon-crossing of trans-Planckian modes never happens in QG landscape

\[ l_p \frac{a(t)}{a(t_i)} \lesssim \frac{1}{H} \]

\[ e^{N} \quad N: \text{e-folding} \]
$T_{CC} \Rightarrow$ metastable $dS$ has lifetime

$T \lesssim H^{-1} \ln \left( \frac{M_{\text{pe}}}{H} \right)$
$TCC \implies$ metastable $dS$ has lifetime

$T \lesssim H^{-1} \ln \left( \frac{M_{\text{pl}} e}{H} \right)$

cf. $dS$ swampland conjecture [Obied-Ooguri-Spodyneiko-Vafa (18)]

$\implies$ no metastable $dS$
\[ TCC \implies \frac{|V'|}{\sqrt{V}} \geq \frac{2}{\sqrt{(d-1)(d-2)}} \quad \text{as } n \to \infty \]
\[ \text{TCC} \quad \Rightarrow \quad \frac{|V'|}{V} \geq \frac{2}{\sqrt{(d-1)(d-2)}} \quad \text{at } \infty \]

cf. dS swampland conjecture

\[ \frac{|V'|}{V} \geq c \quad \text{everywhere} \]

\[ \text{O(1)} \text{ number} \]

[Obied-Ooguri-Spodyneiko - Vafa ('18)]
\[ TCC \implies \frac{|V'|}{V} \geq \frac{2}{\sqrt{(d-1)(d-2)}} \text{ at } \infty \]

cf. dS swampland conjecture [Obed-Ooguri-Spodyneiko - Vafa ('18)]

\[ \frac{|V'|}{V} \geq c \]

\( O(1) \) number

Problem with Higgs/pion/axion

[Denef- Hebecker- Wrase, Murayama- Yanggida - MY]

[Choi- Chwoy- Shin, Hamaguchi- Ibe- Moroi ('18)]
1. Trans-Planckian Censorship and Inflationary Cosmology
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service
   レコードの詳細 - Cited by 27 records

2. Trans-Planckian Censorship and the Swampland
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service
   レコードの詳細 - Cited by 38 records

\[ \frac{r}{P_t} \lesssim 10^{-30} \]
Questions Raised on TCC:

* Implications if true? e.g. $r \leq 10^{-3}$

* Checks, Derivations?
Questions Raised on TCC:

* Implications if true?  $r \leq 10^{-3}$  $r \leq 10^{-8}$  $r \leq 10^{-3}$

* Checks, Derivations?

* Is TCC a swampland conjecture?
Problems w/ TCC
Basic Problem w/ TCC: \( \frac{a}{a_i} \sim \frac{M_{p\ell}}{H} \)

Scenario

TCC

Yes

\[ \uparrow \]

theory
Basic Problem w/ TCC: \( \frac{a}{a_i} \sim \frac{M_{pl}}{H} \)

Scenario 1

TCC Yes

TCC Yes

Scenario 2

TCC No

Scenario 3

theory
Basic Problem w/ TCC: $\frac{a}{a_i} \sim \frac{M_{pl}}{H}$

Scenario 1
- TCC: Yes

Scenario 2
- TCC: Yes

Scenario 3
- TCC: No

A swampland conjecture should apply to all scenarios in a given theory.
1. What happens if TCC indeed applies universally?

(universal TCC)
inflation

$V(\phi)$

\[ V(\phi) \]

\[ \phi \]
inflation

$V(\phi)$
inflation

$V(\phi)$
Large quantum fluctuations can realize longer inflation, leading to violation of TCC (small but non-zero $\rho$).
2. If quantum fluctuations are problematic, why not only classical locus?

(classical TCC)
Higgs field will stay at top
\[\rightarrow\] exponential expansion
\[\rightarrow\] violation of TCC
3. We require that TCC is obeyed in our Universe,

(implicit in many follow-up papers)
3. We require that TCC is obeyed in our Universe, by requiring at least one TCC-consistent scenario for a given theory (observational TCC) (implicit in many follow-up papers)
This is fine (we are atypical)

However, the prediction $T \lesssim H^{-1} \ln H^{-1}$ is gone since decay is probabilistic

$p(t) \sim e^{-t/T} \neq 0$
4. Allow TCC violation with "small" probabilities?

(probabilistic TCC)
4. Allow TCC violation with "small" probabilities?

How small? Why?

(probabilistic TCC)
4. Allow TCC violation with

"Small" probabilities ?

how small? why?

which probability?

"measure problem"

(probabilistic TCC)
We ourselves can be very atypical/unlikely, while probabilistic prediction assumes typicality.

string landscape
We ourselves can be very atypical while probabilistic prediction assumes typicality. String landscape. Anthropic measure?
Summary
Non-trivial if TCC is a swampland conjecture

If not, resurrection of the trans-Planckion problem?
* Ideas on QG can be tested against observations
A swampland conjecture is a constraint on theory, not scenarios.

Other possible (unobservable) Universes affects observable predictions.

(General Lesson on QG??)