Trans-Planckian Censorship

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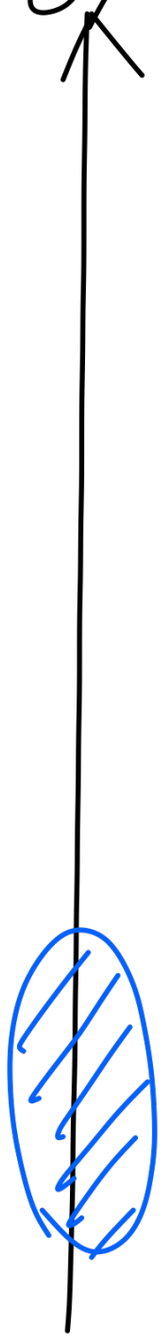
KEK theory workshop

Dec 16 / 2019

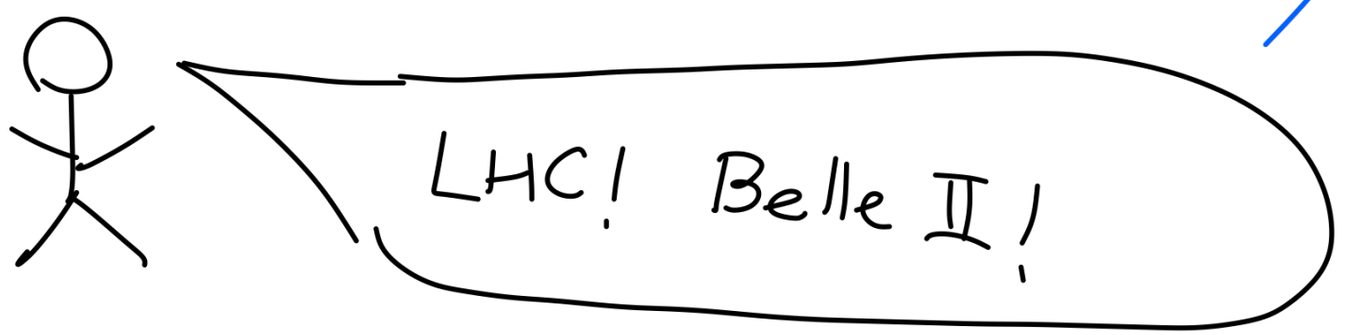
Swampland

Renormalization & EFT

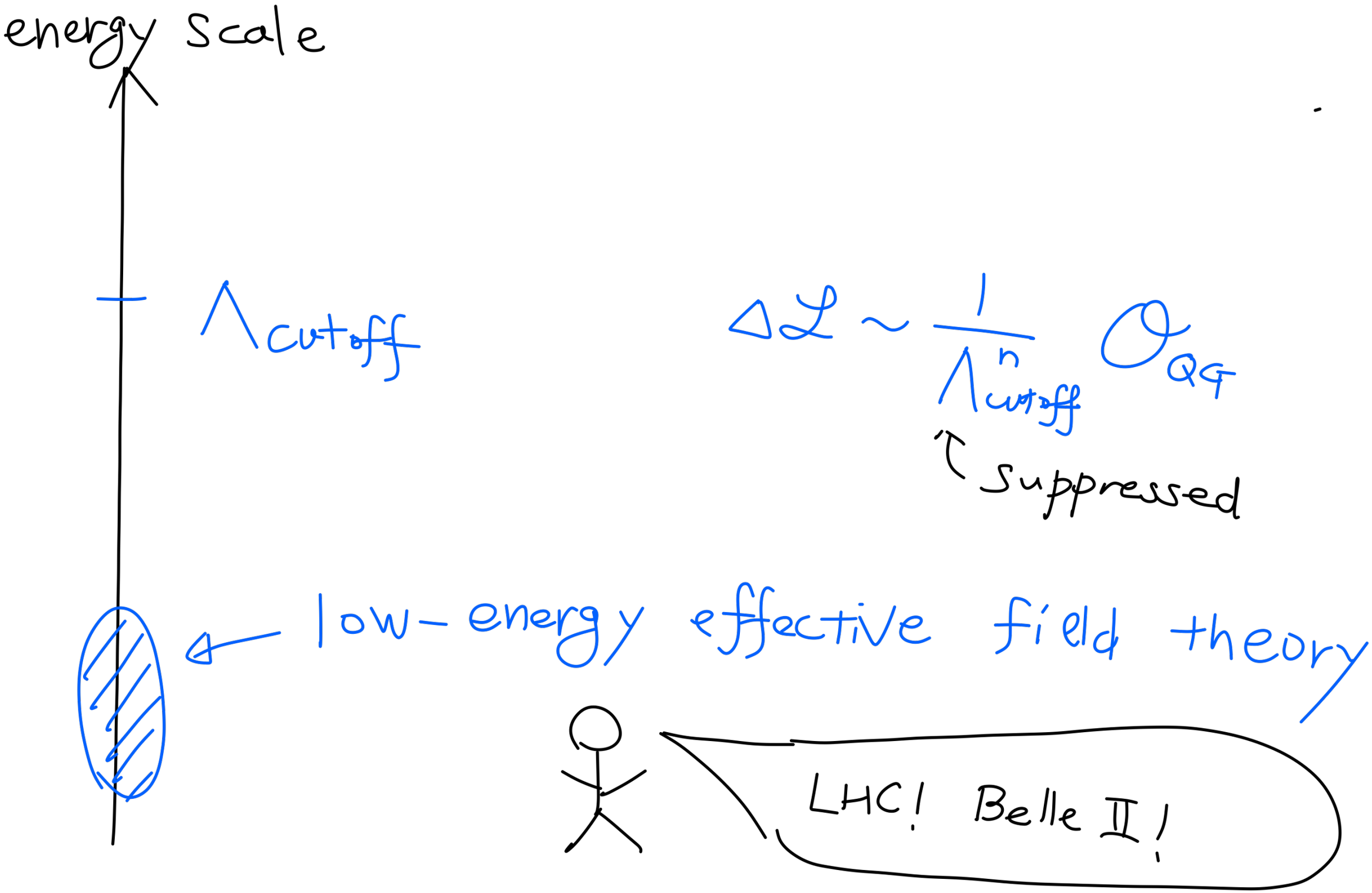
energy scale



← low-energy effective field theory

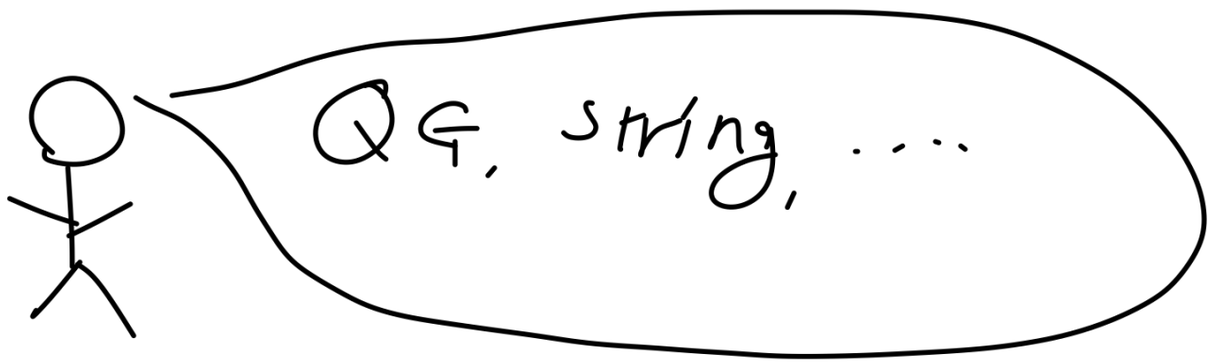


Renormalization & EFT



Renormalization & EFT

energy scale

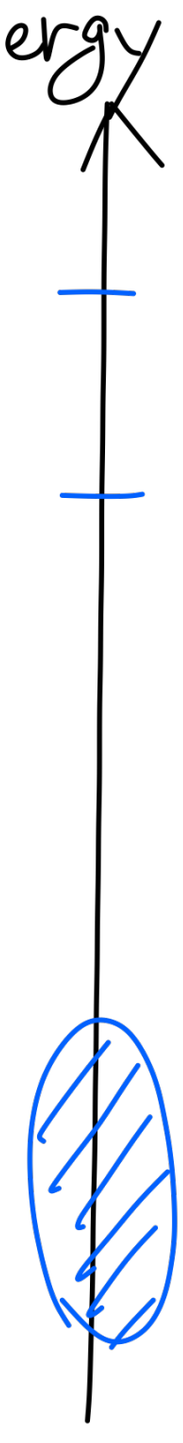


M_{Pe}

Λ_{cutoff}

$$\Delta\mathcal{L} \sim \frac{1}{\Lambda_{cutoff}^{n}} \mathcal{O}_{QG}$$

↑ suppressed



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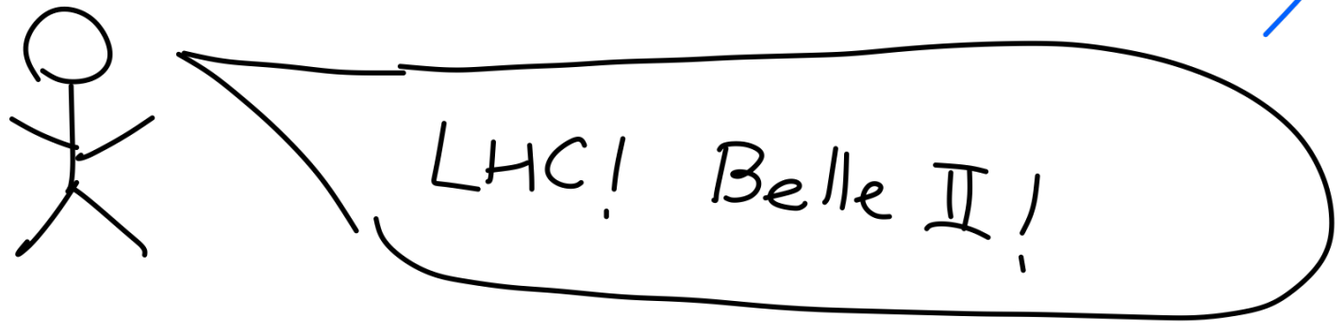
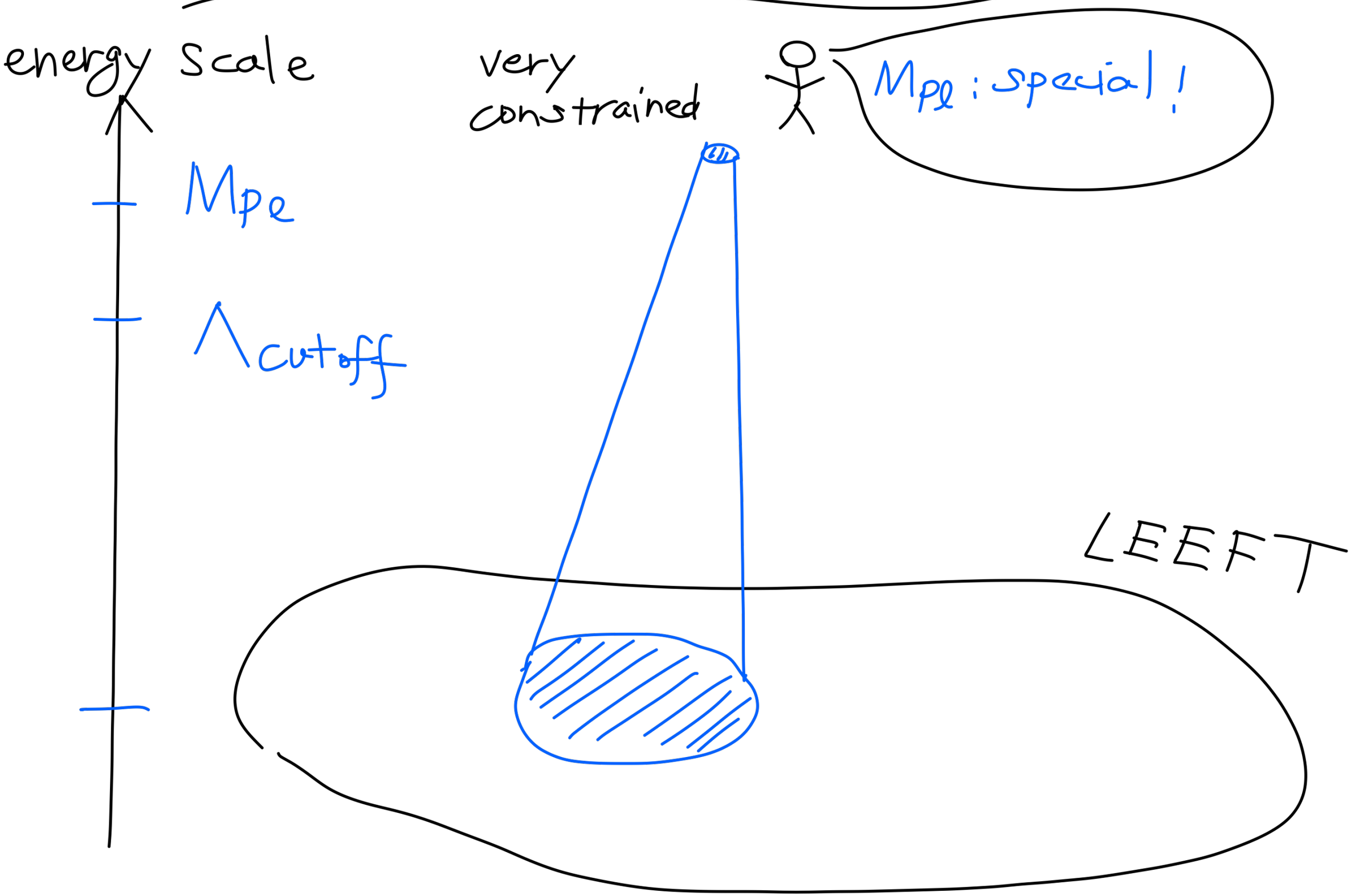
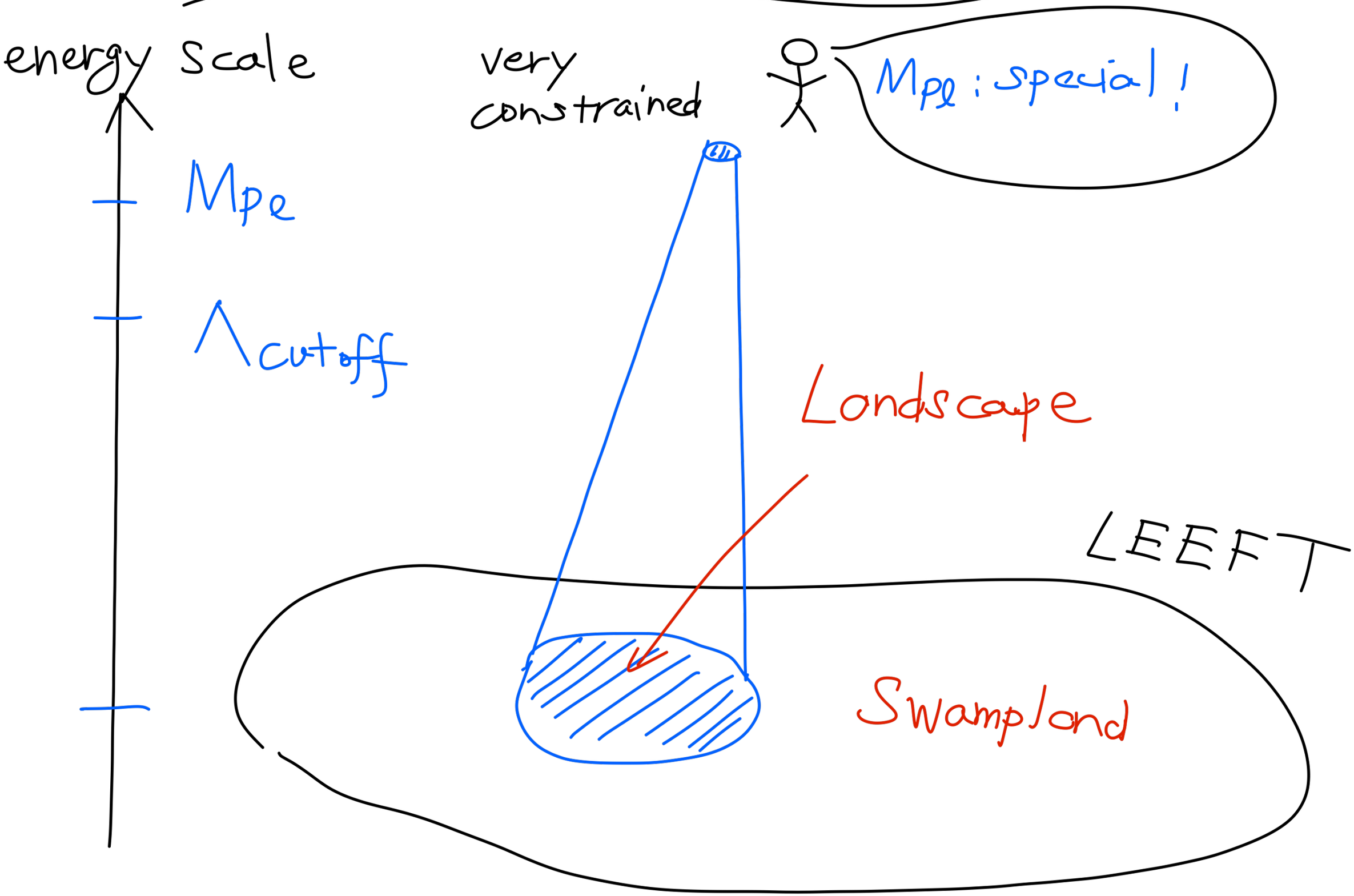


Renormalization & EFT



Renormalization & EFT



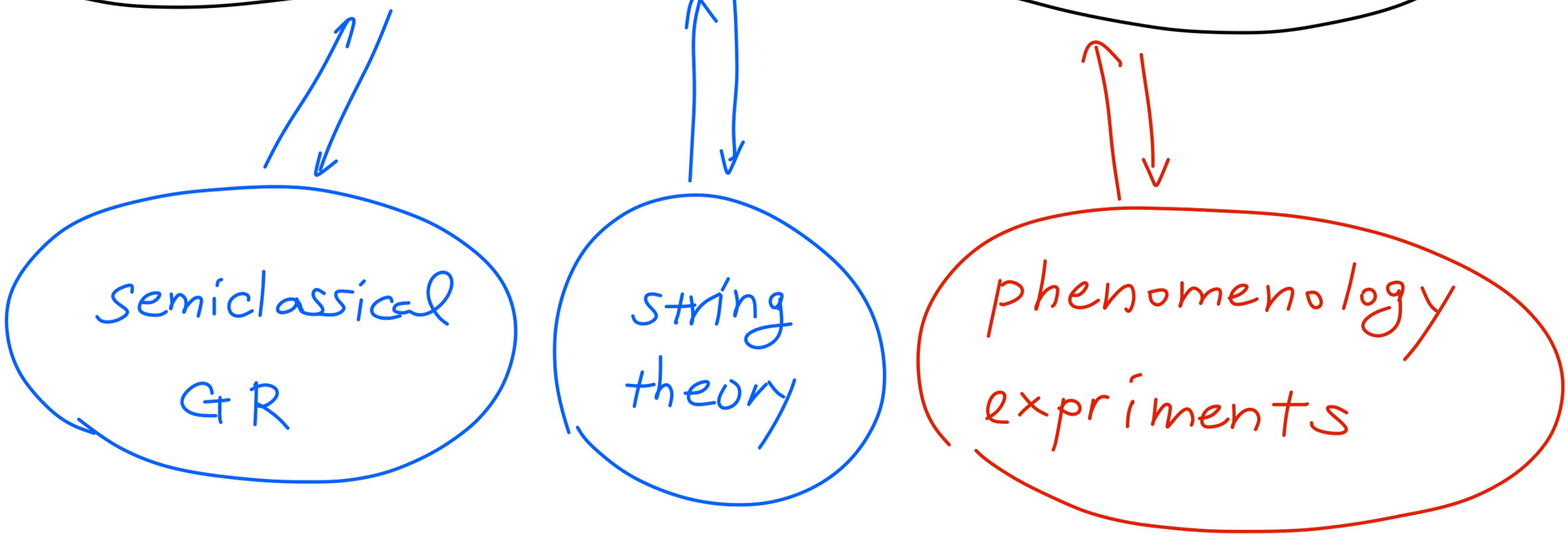
Swampland Conjectures :

Necessary Conditions for existence of

UV completion

Swampland Conjectures :

Necessary Conditions for existence of UV completion



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

Today:

1. **Is Trans-Planckian Censorship a Swampland Conjecture?**
   Ryo Saito, Satoshi Shirai, Masahito Yamazaki. Nov 23, 2019. 12 pp.
   IPMU-19-0170
   e-Print: **arXiv:1911.10445 [hep-th]** | **PDF**

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

Saito (Yamaguchi)

Shirai (IPMU)

Trans-Planckian "Problem"

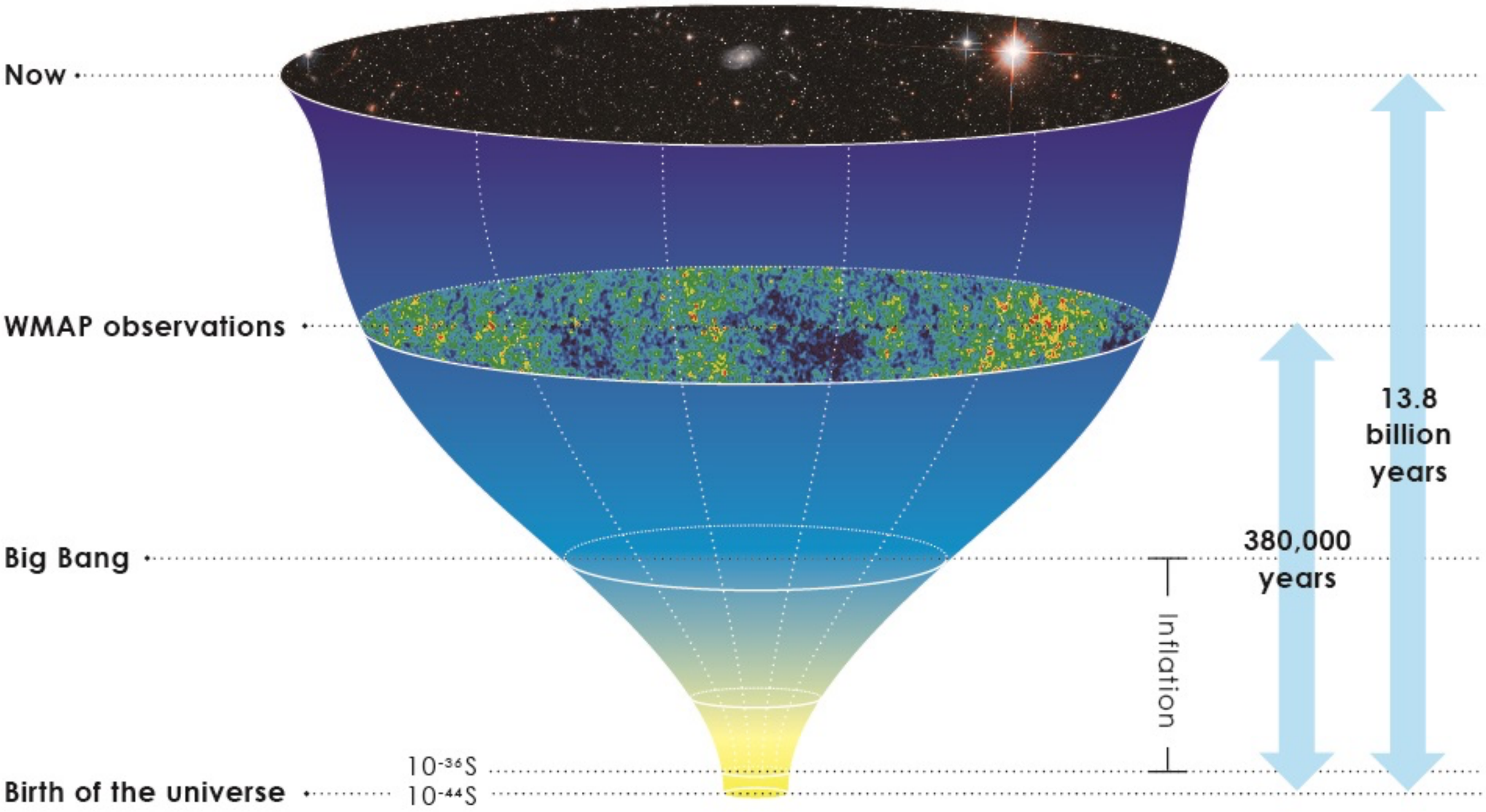
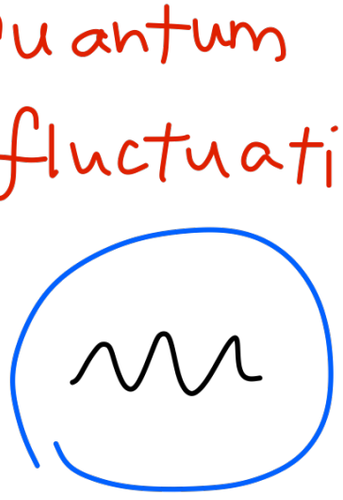


Figure from https://www.u-tokyo.ac.jp/content/400031453.jpg

macroscopic
fluctuation

tiny
quantum
fluctuation



exponential
expansion

log(physical scale)

horizon size
H^{-1}

$\lambda \propto a$

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

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

log a(t)

log(physical scale)

$\lambda \propto a$

horizon size

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

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

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

inflation

log a(t)

log(physical scale)

horizon crossing

$\lambda \propto a$

horizon exit

horizon size

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

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

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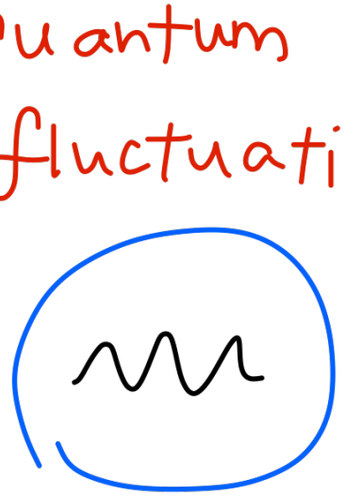
inflation

log a(t)

macroscopic
fluctuation

CMB

tiny
quantum
fluctuation



exponential
expansion

log(physical scale)

horizon crossing

$\lambda \propto a$

horizon exit

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

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

l_p

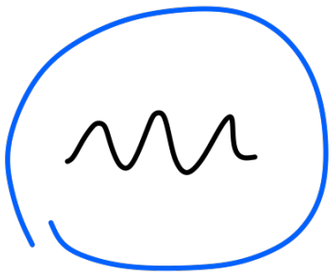
inflation

log a(t)

transplanckian mode

$\ell \lesssim \ell_p$

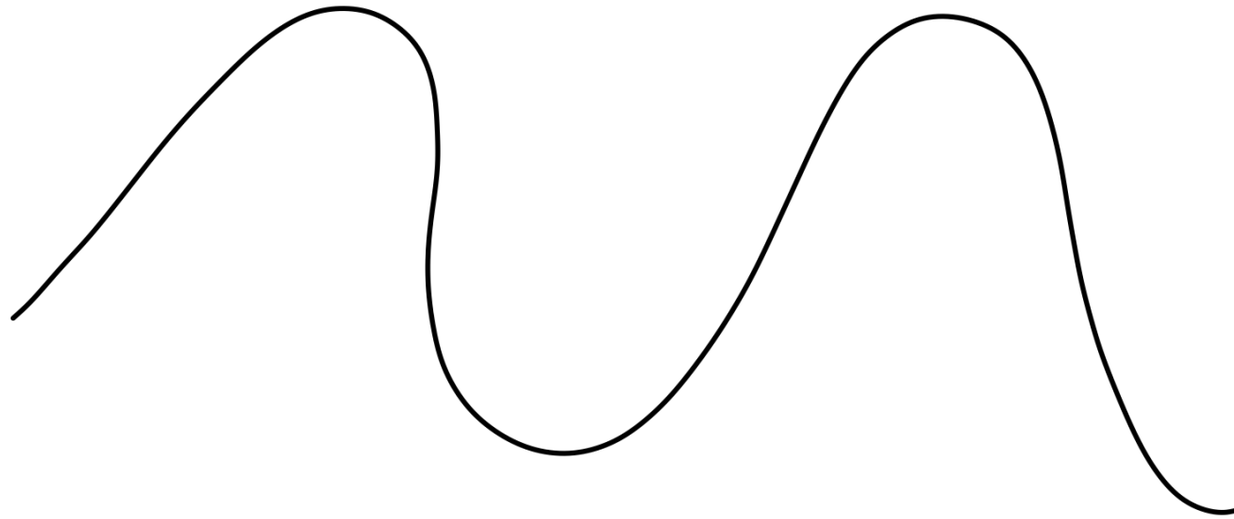
tiny quantum fluctuation



exponential expansion

macroscopic fluctuation

CMB

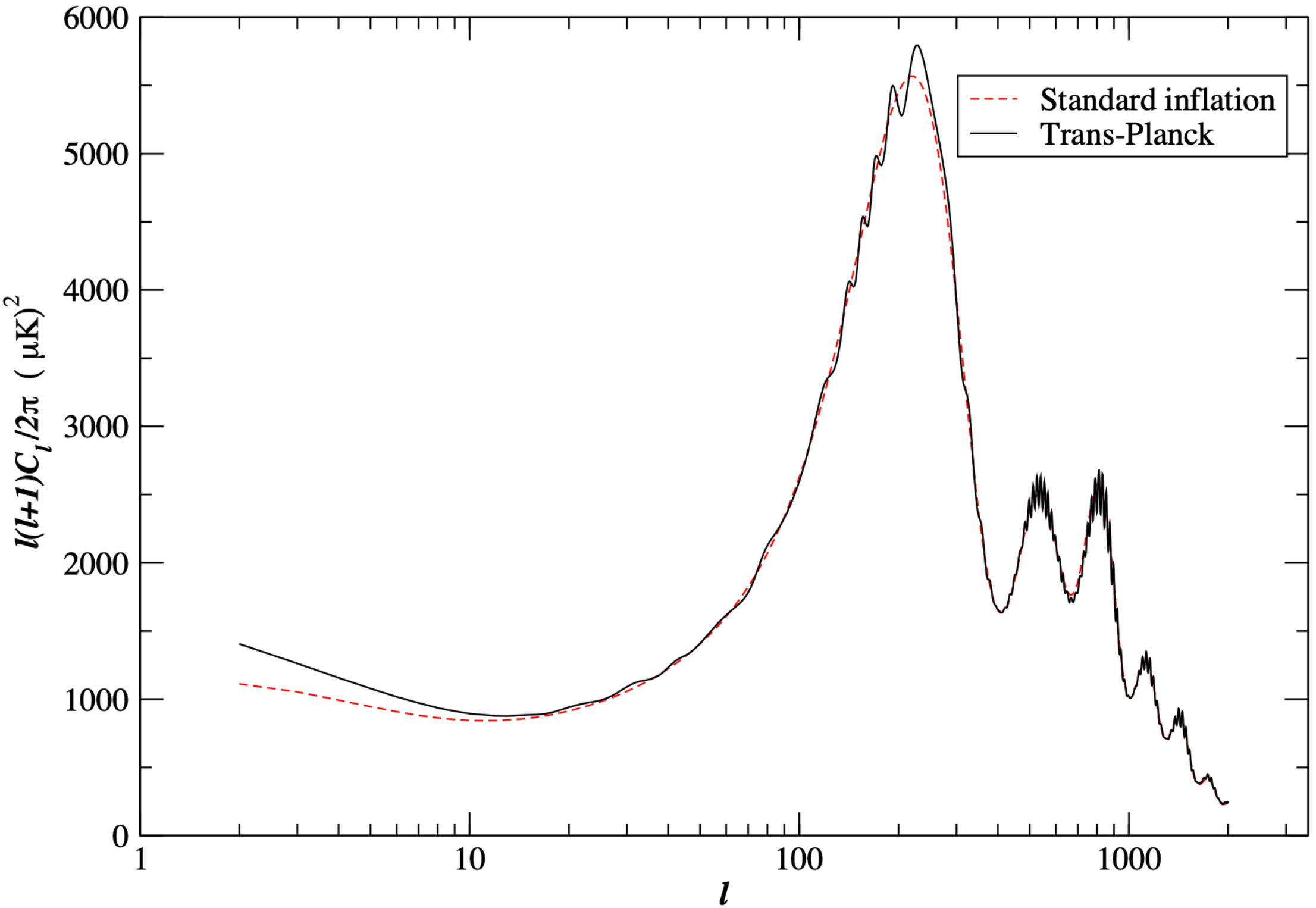


Trans-Planckian "Problem":

Can we observe trans-Planckian modes?

If so, breakdown of EFT?

※ Similar problem for BHs



[Martin-Ringeval] astro-ph/0310382

Trans-Planckian

Censorship

Trans-Planckian Censorship Conjecture (TCC, [Bedroya-Vafa '19])

Horizon-crossing of transPlanckian modes never happens in QG landscape

$$l_p \underbrace{\frac{a(t)}{a(t_i)}} \lesssim \frac{1}{H}$$

$\downarrow$

e^N $\quad N$: e-folding

TCC $\Longrightarrow$ metastable dS has lifetime

$$T \lesssim H^{-1} \ln\left(M_{Pl}/H\right)$$

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$$T \lesssim H^{-1} \ln\left(M_{Pl}/H\right)$$

---

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

$\Longrightarrow$ no metastable dS

$$\text{TCC} \Longrightarrow \frac{|V'|}{V} \geq \frac{2}{\sqrt{(d-1)(d-2)}} \quad \text{at } \infty$$

TCC $\Longrightarrow$ $\dfrac{|V'|}{V} \geq \dfrac{2}{\sqrt{(d-1)(d-2)}}$ at ∞

---

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

$\dfrac{|V'|}{V} \geq c$ everywhere

$\uparrow$ $O(1)$ number

TCC $\Longrightarrow$ $\dfrac{|V'|}{V} \geq \dfrac{2}{\sqrt{(d-1)(d-2)}}$ at ∞

---

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

$\dfrac{|V'|}{V} \geq c$ everywhere

$\uparrow$ $O(1)$ number

Problem with Higgs / pion / axion

[Denef-Hebecker-Wrase, Murayama-Yanagida-M ⋎
Choi-Chwoy-Shin, Hamaguchi-Ibe-Moroi ('18)]

HEP　　2 のレコードが見つかりました。

1. **Trans-Planckian Censorship and Inflationary Cosmology**
Alek Bedroya (Harvard U.), Robert Brandenberger (McGill U.), Marilena Loverde (YITP, Stony Brook), Cumrun Vafa (Harvard U.). S
e-Print: **arXiv:1909.11106 [hep-th] | PDF**

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**
Alek Bedroya, Cumrun Vafa (Harvard U.). Sep 24, 2019. 35 pp.
e-Print: **arXiv:1909.11063 [hep-th] | PDF**

References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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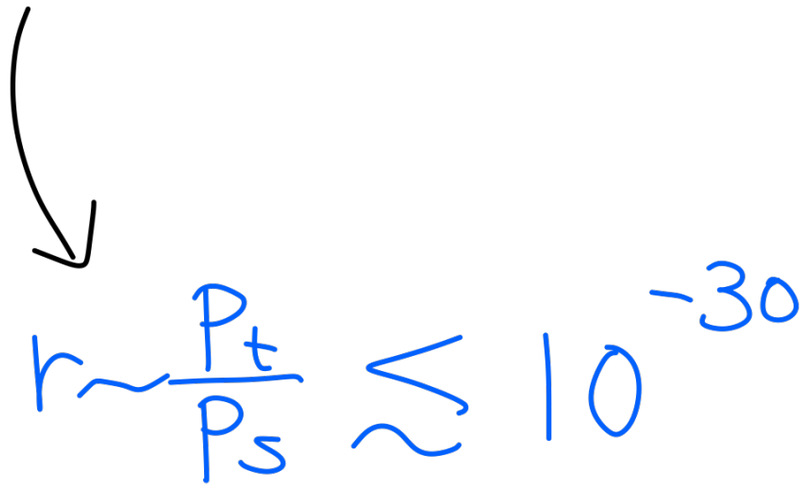
レコードの詳細 - Cited by 38 records



Questions Raised on TCC :

* Implications if true ? eg. $r \lesssim 10^{-30}$, $r \lesssim 10^{-8}$, $r \lesssim 10^{-3}$

* Checks, Derivations ?

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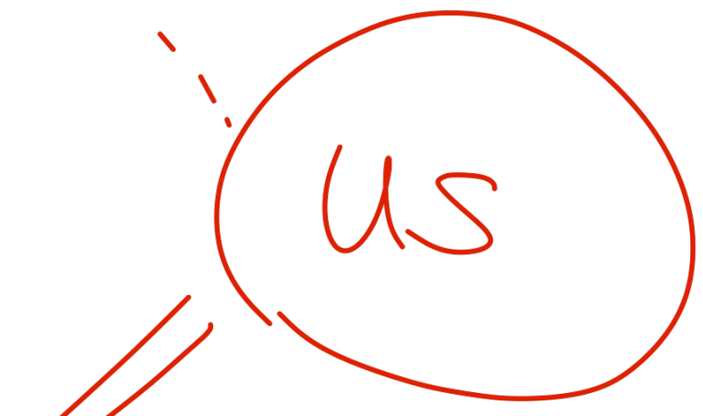
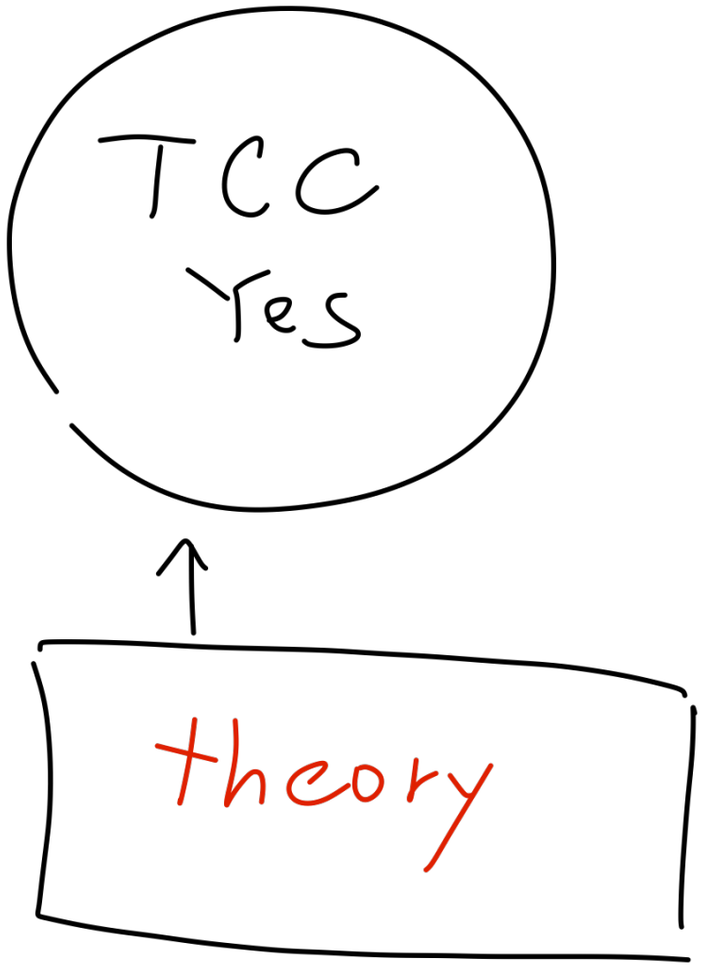


* Is TCC a swampland conjecture?

Problems w/ TCC

Basic Problem w/ TCC: $\frac{a}{a_i} \lesssim \frac{M_{pe}}{H}$

scenario



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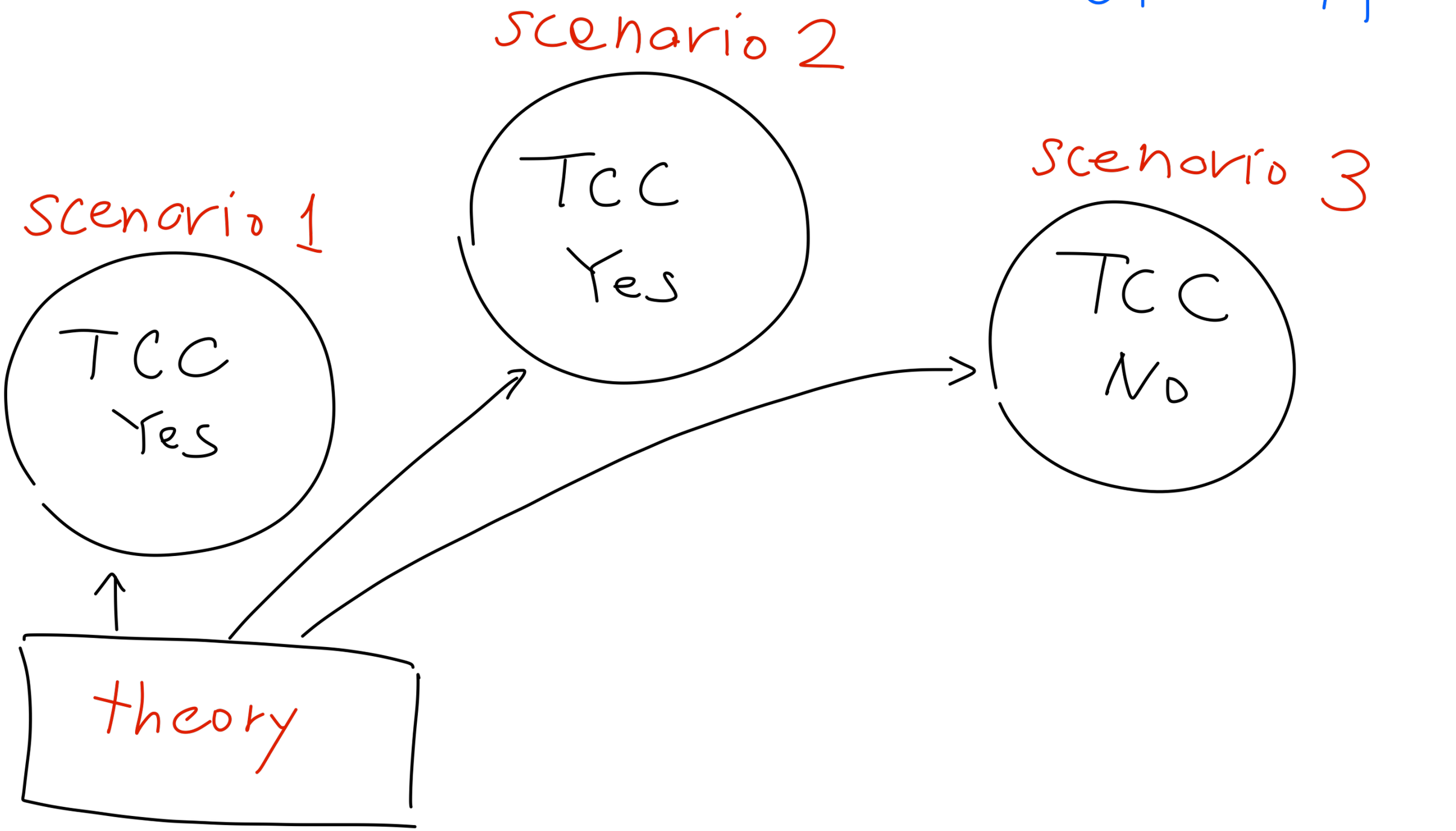


Basic Problem w/ TCC: $\frac{a}{a_i} \lesssim \frac{M_{Pl}}{H}$

scenario 1

TCC Yes

scenario 2

TCC Yes

scenario 3

TCC No

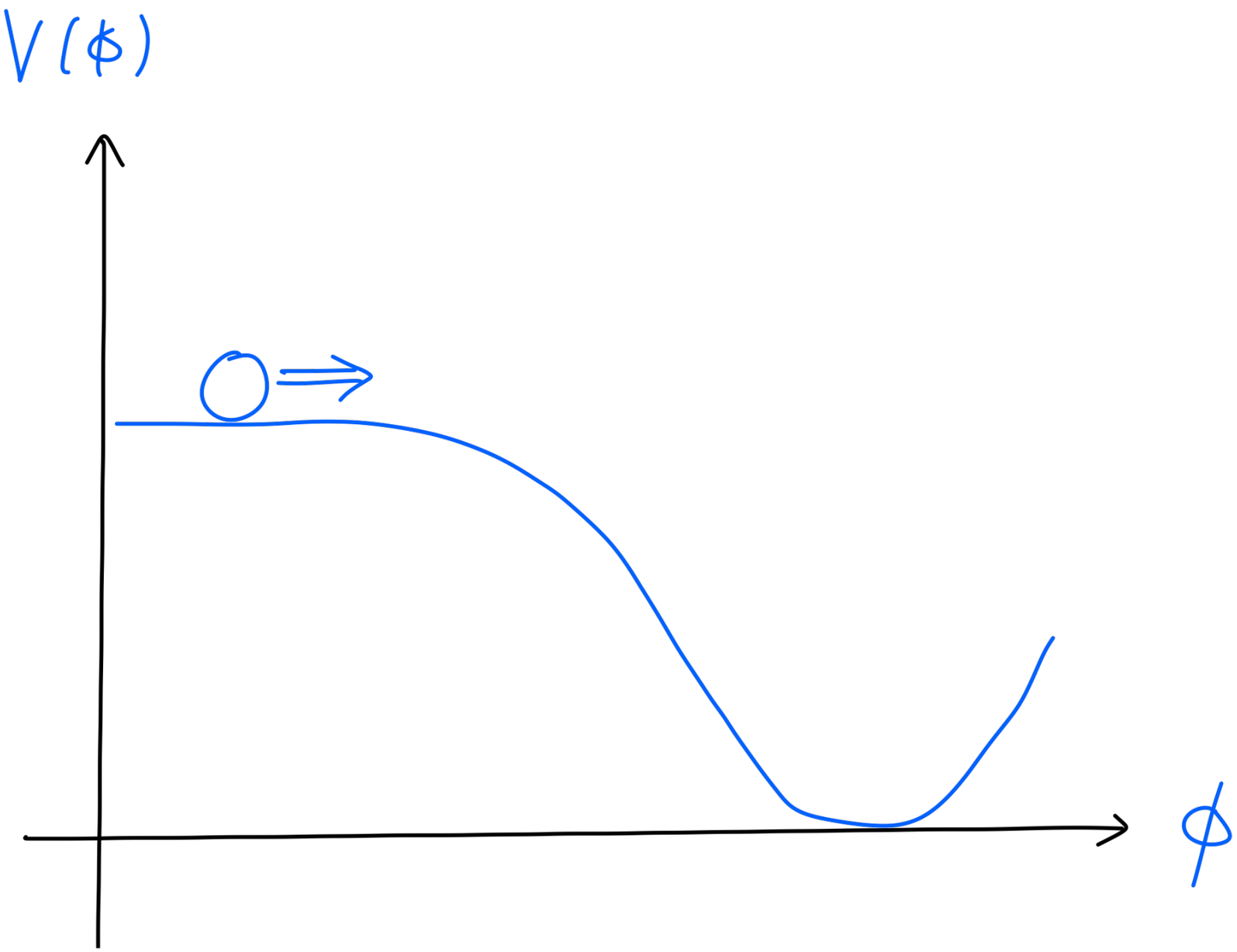
theory

a swampland conjecture should apply to ALL scenarios in a given theory

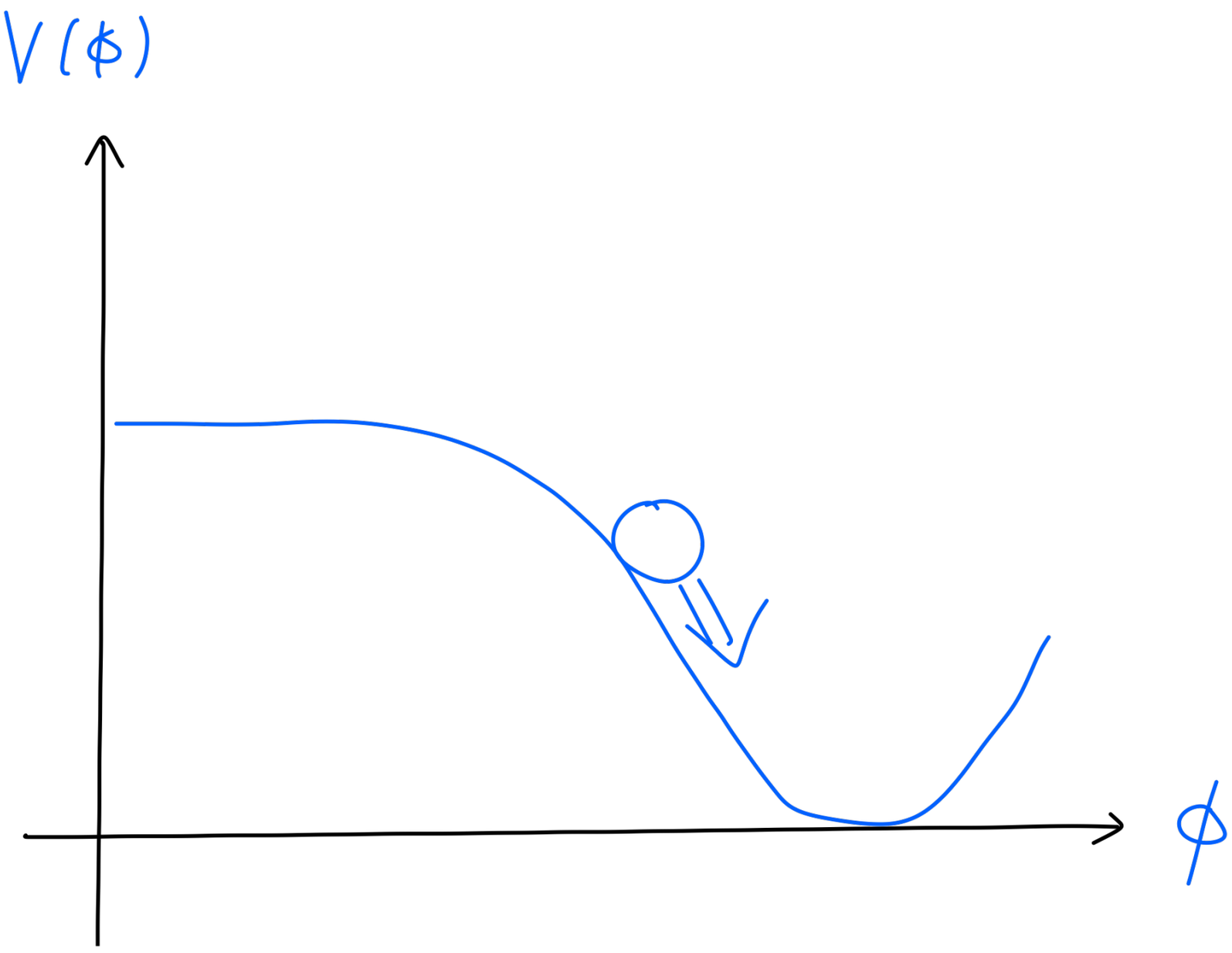
1. What happens if TCC indeed applies universaly ?

(universal TCC)

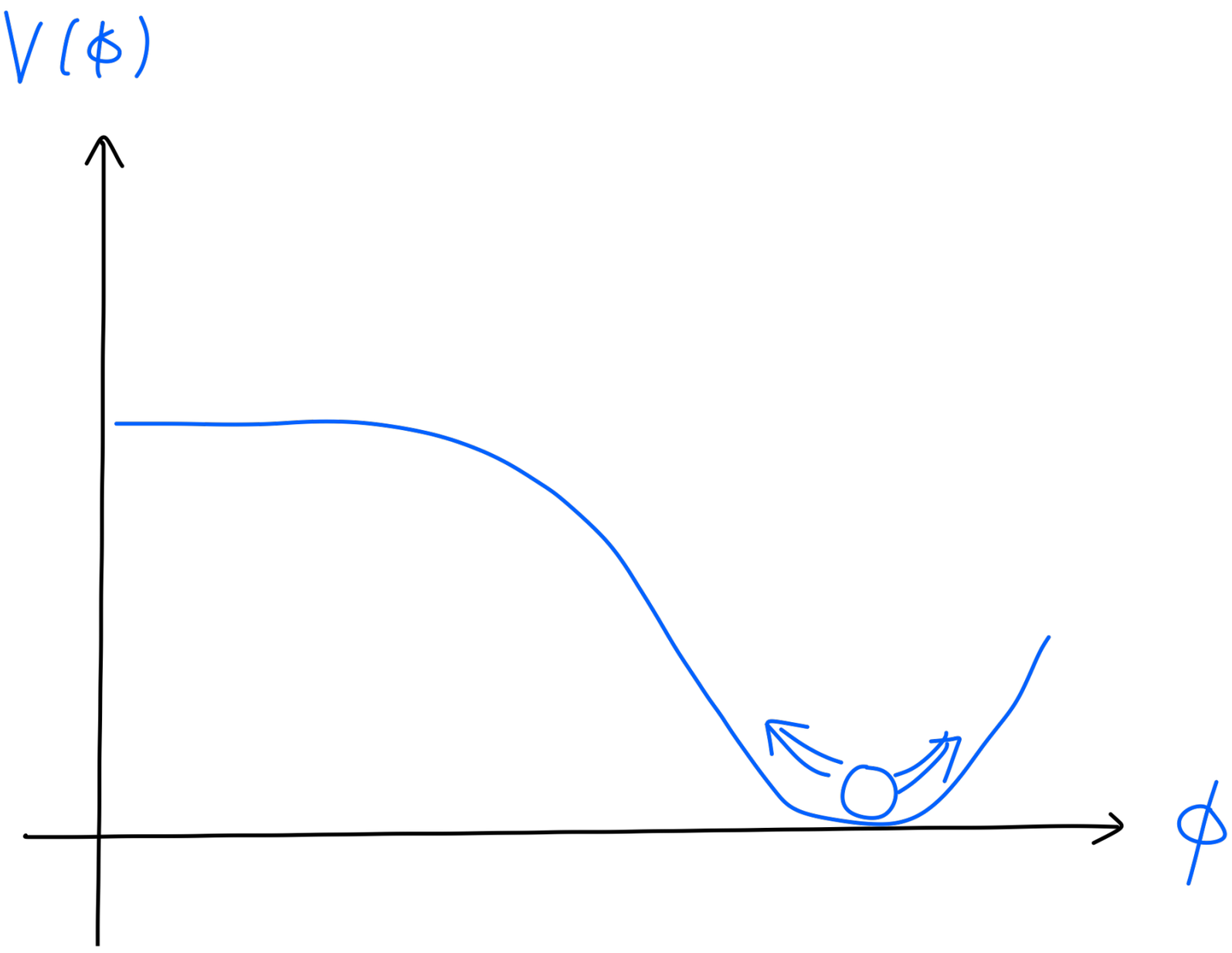
inflation



inflation



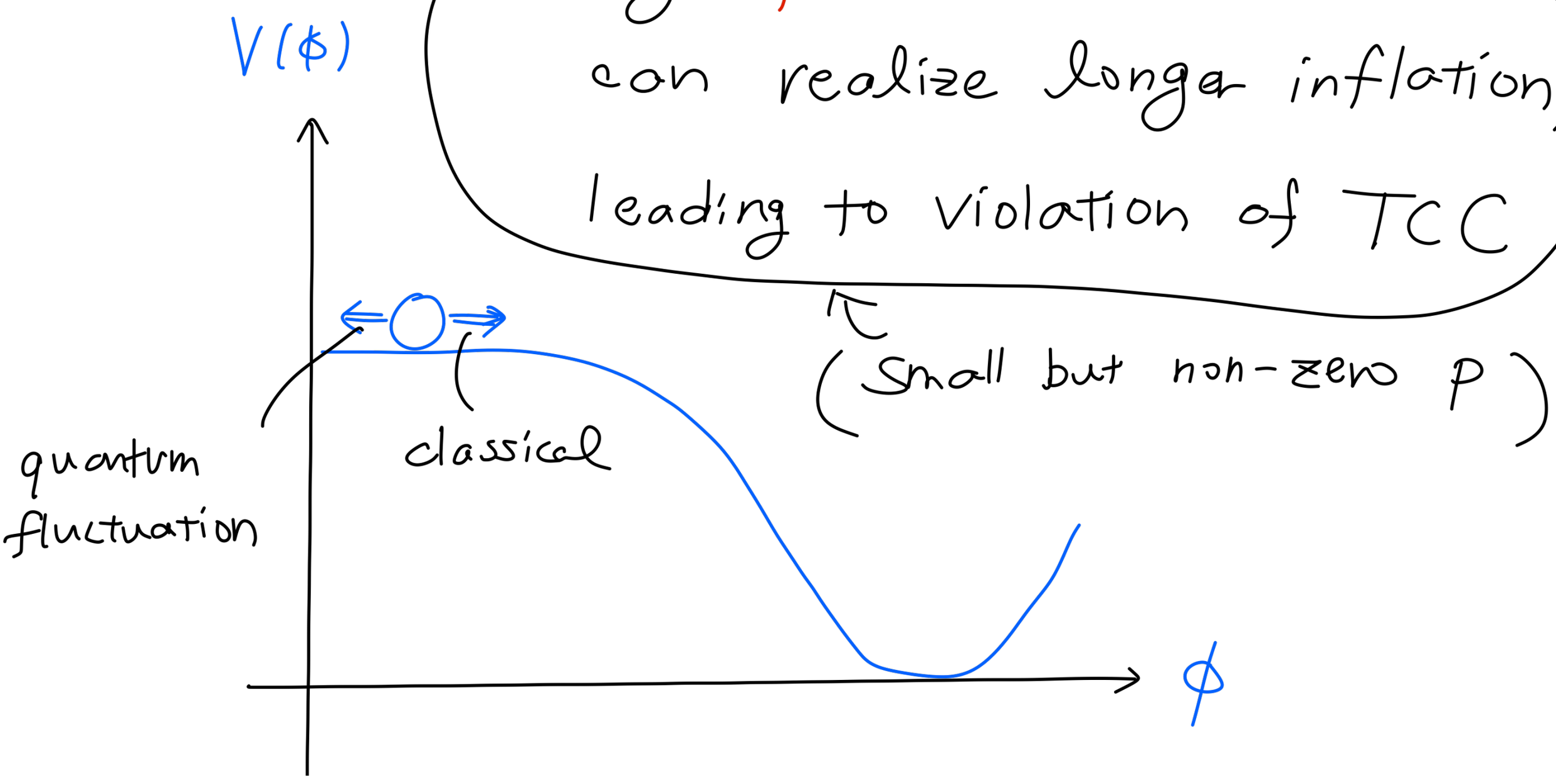
inflation



inflation

Large quantum fluctuations
can realize long inflation,
leading to violation of TCC

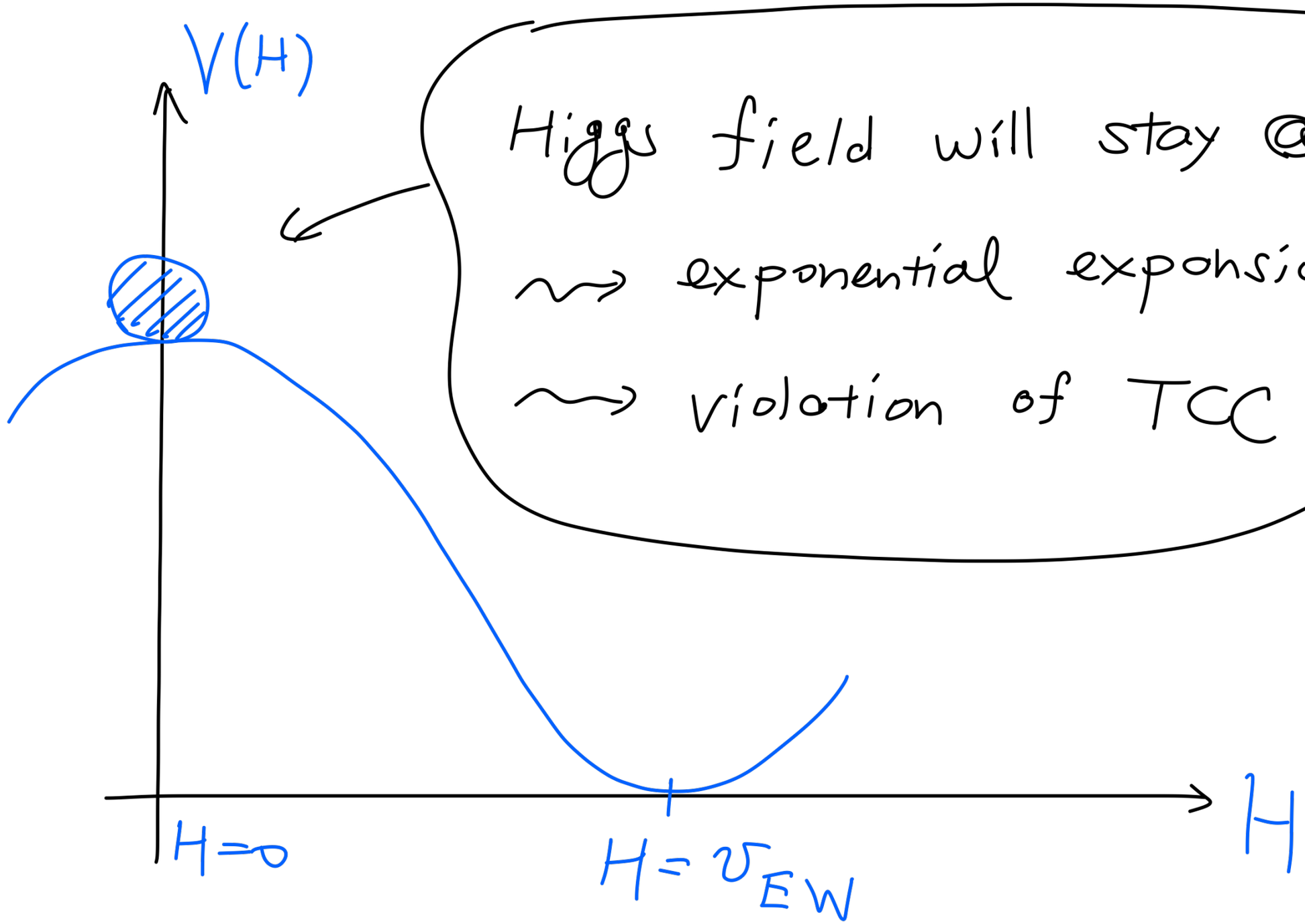
(small but non-zero p)



2. If quantum fluctuations are problemotic, why not only classical locus ?

(classical TCC)

Higgs



Higgs field will stay @ top

⇝ exponential exponsion

⇝ 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-consistant

scenario for a given theory

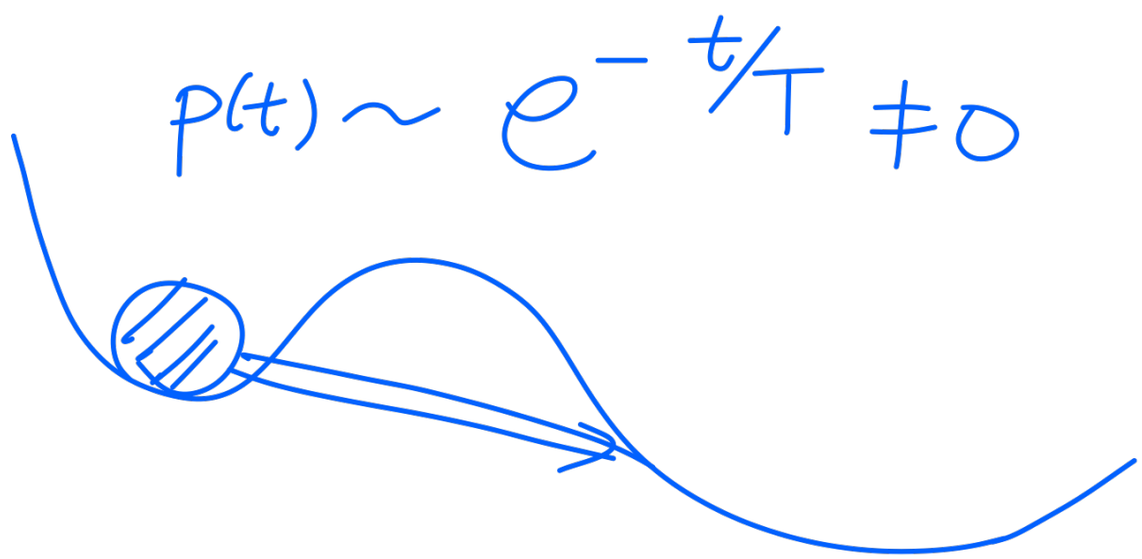
(observational TCC)

(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



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?

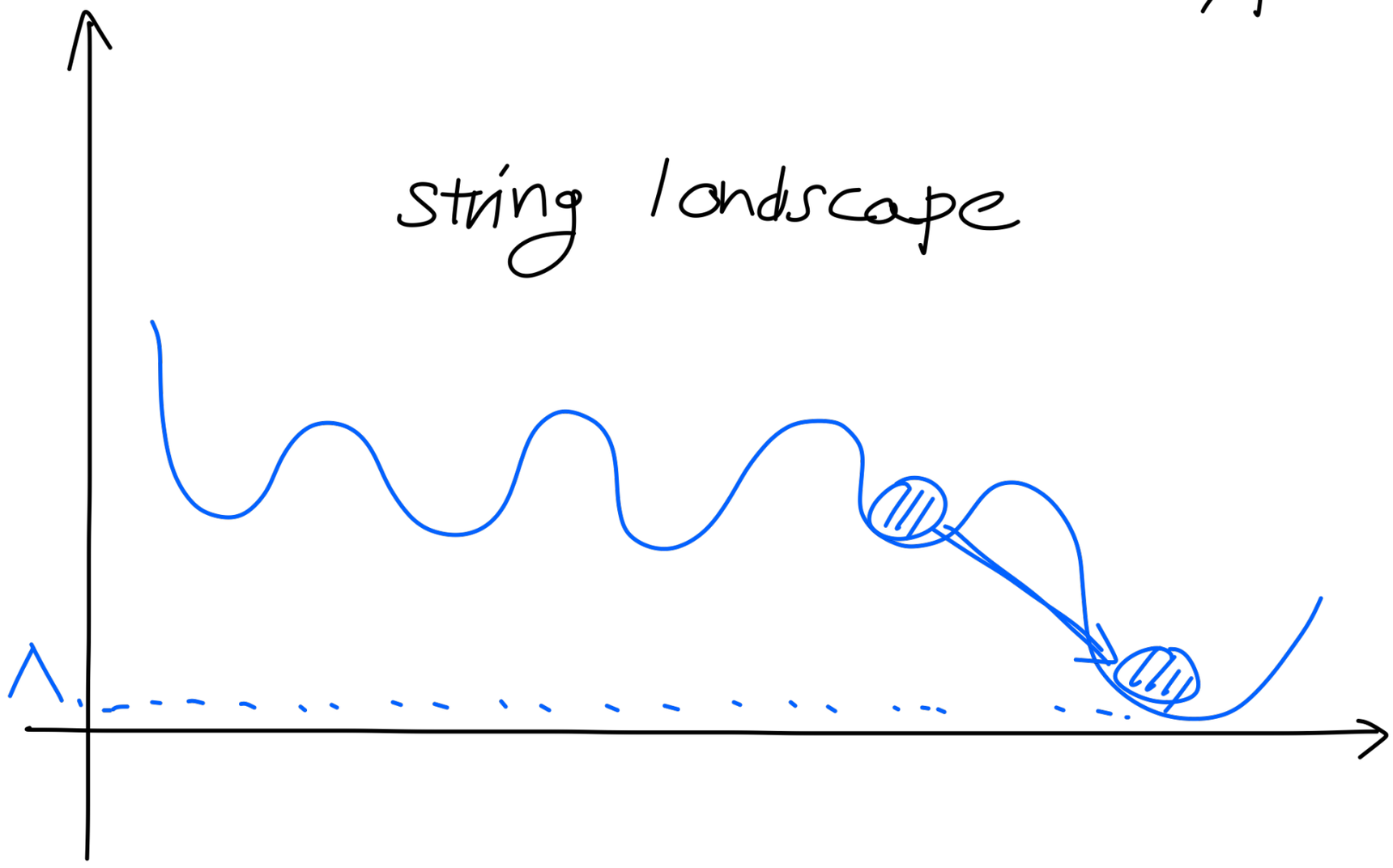
which probability? "measure problem"

(probabilistic TCC)

We ourselves can be very atypical / unlikely,

while probabilistic prediction

assumes typicality



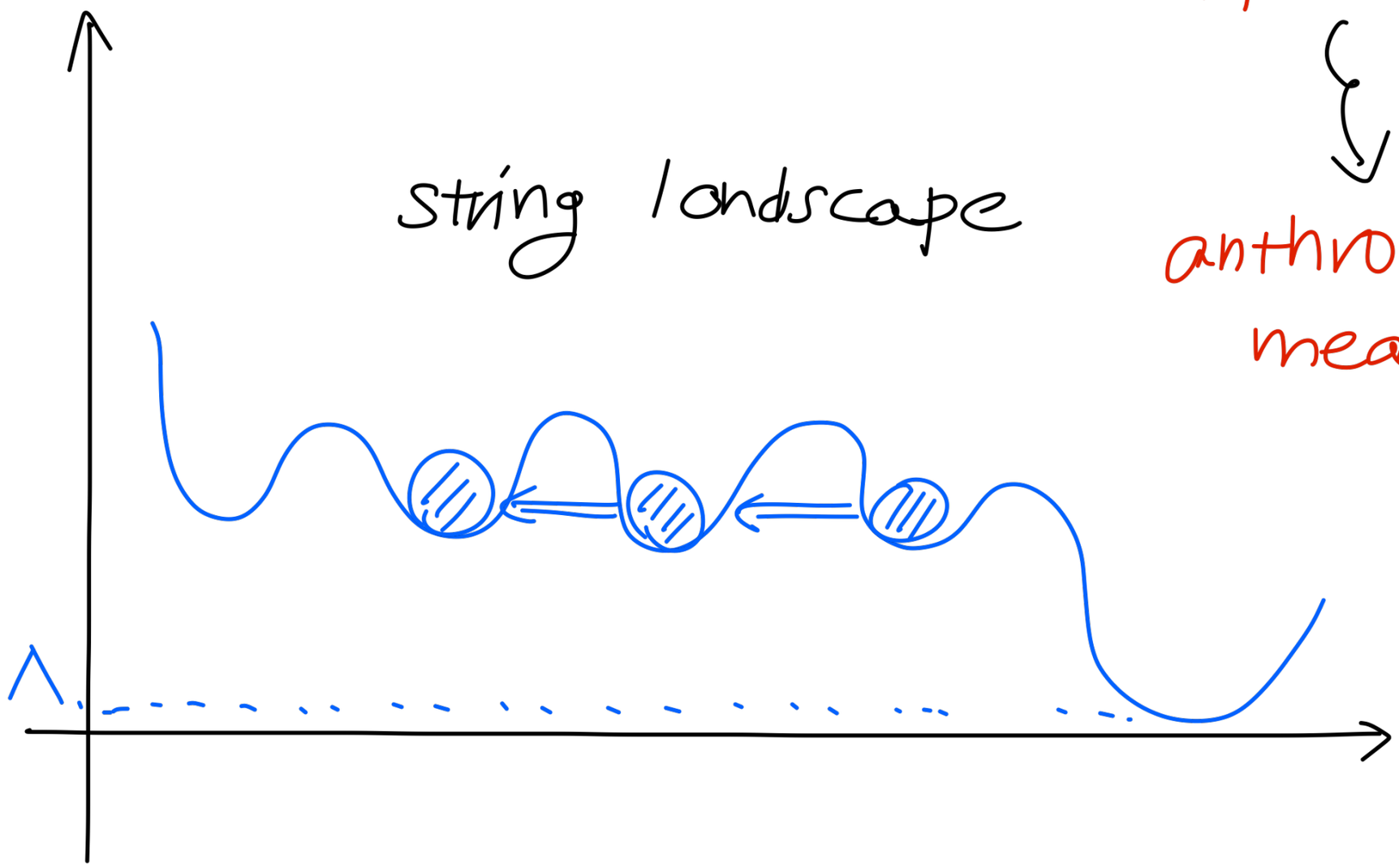
We ourselves can be very atypical

while probabilistic prediction

assumes typicality

⇓

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 $\begin{cases} \text{theory} \\ \text{observations} \end{cases}$

* A swampland conjecture is a

constraint on theory, not scenarios

⇝ other possible (unobservable) Universes

affects observable predictions

(General Lesson on QG ??)