

Trans-Planckian Censorship

Masahito Yamazaki

(Kavli IPMU, Univ. Tokyo)

KEK theory workshop

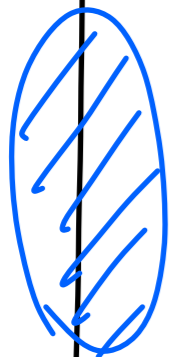
Dec 16 / 2019

Swampland

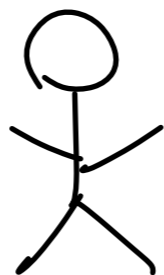


Renormalization & EFT

energy scale



← low-energy effective field theory



LHC! Belle II!

Renormalization & EFT

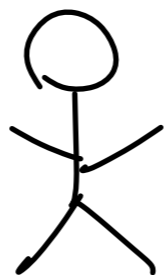
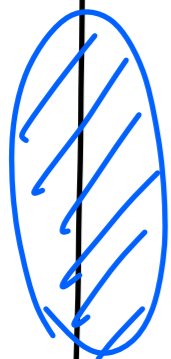
energy scale

Λ_{cutoff}

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

↑ suppressed

low-energy effective field theory



LHC! Belle II!

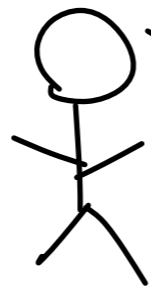
Renormalization & EFT

energy
Scale



M_{pl}

Λ_{cutoff}

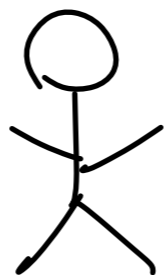


QFT, string, ...

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

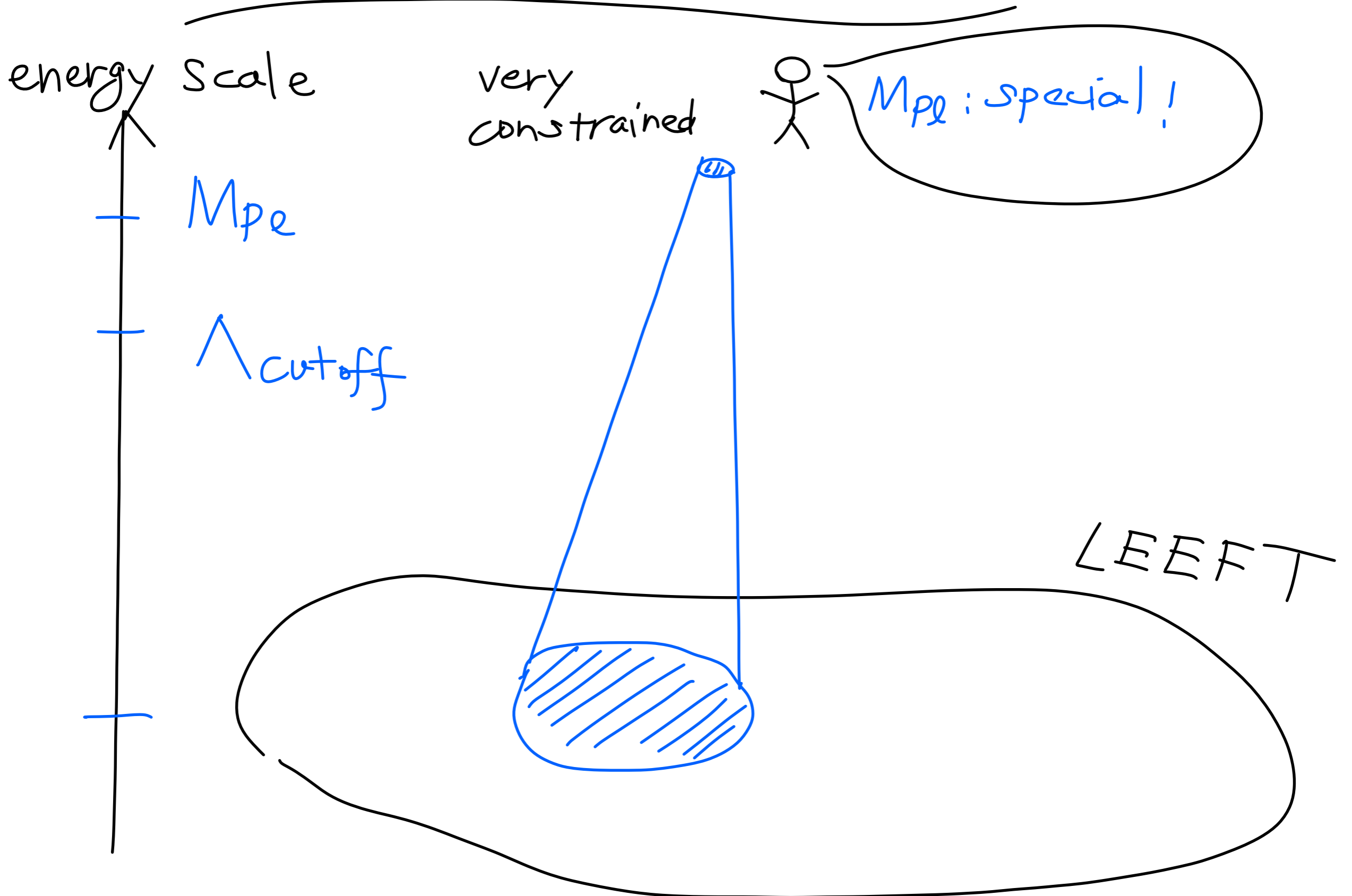
↑ Suppressed

low-energy effective field theory

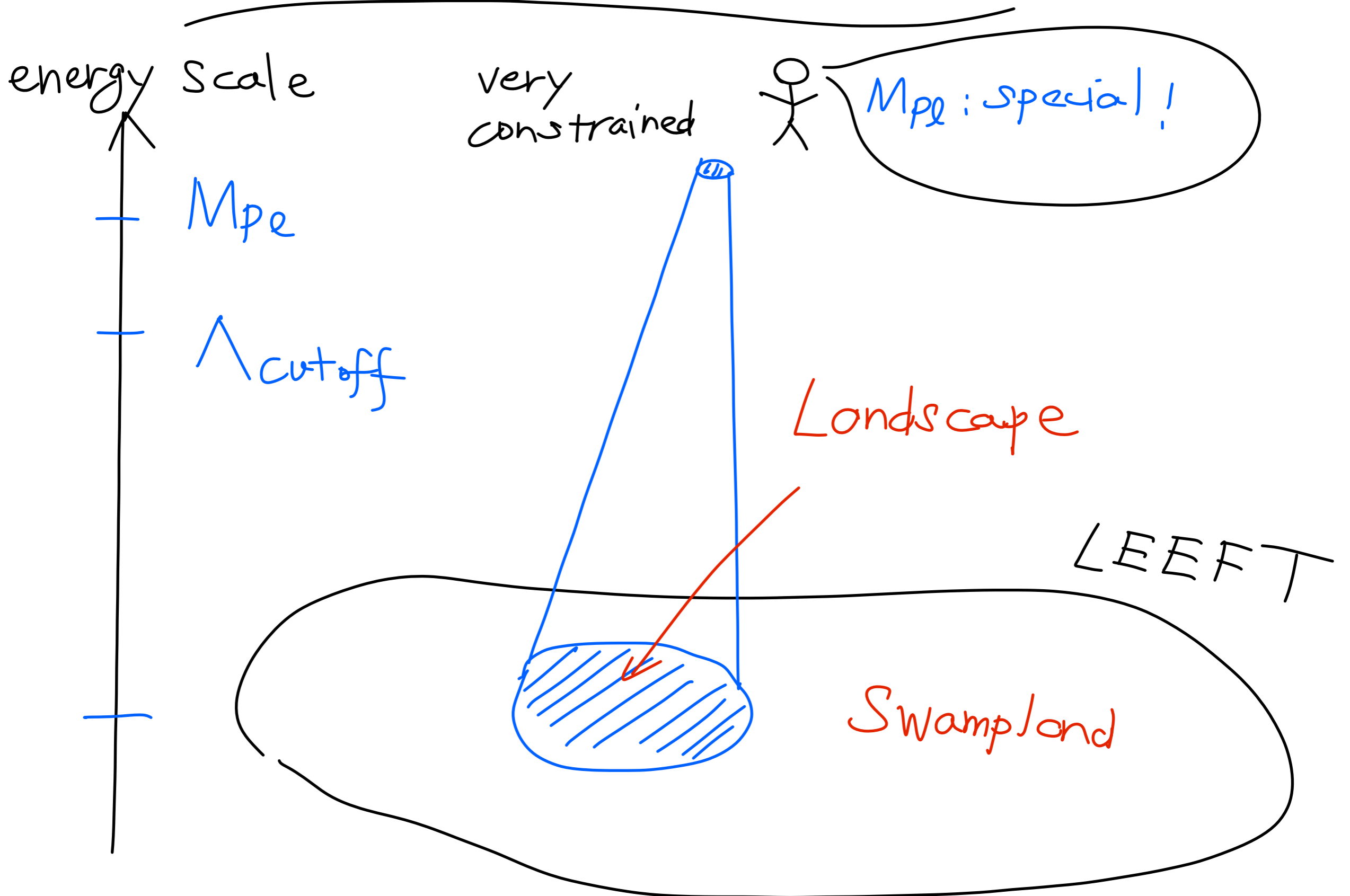


LHC! Belle II!

Renormalization & EFT



Renormalization & EFT

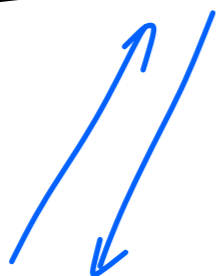


Swampland Conjectures :

Necessary Conditions for existence of
UV completion

Swampland Conjectures:

Necessary Conditions for existence of
UV completion



semiclassical
GR



string
theory



phenomenology
experiments

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](https://arxiv.org/abs/1911.10445) [hep-th] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)



Saito (Yamaguchi)



Shirai (IPMU)

Trans-Planckian

"Problem"

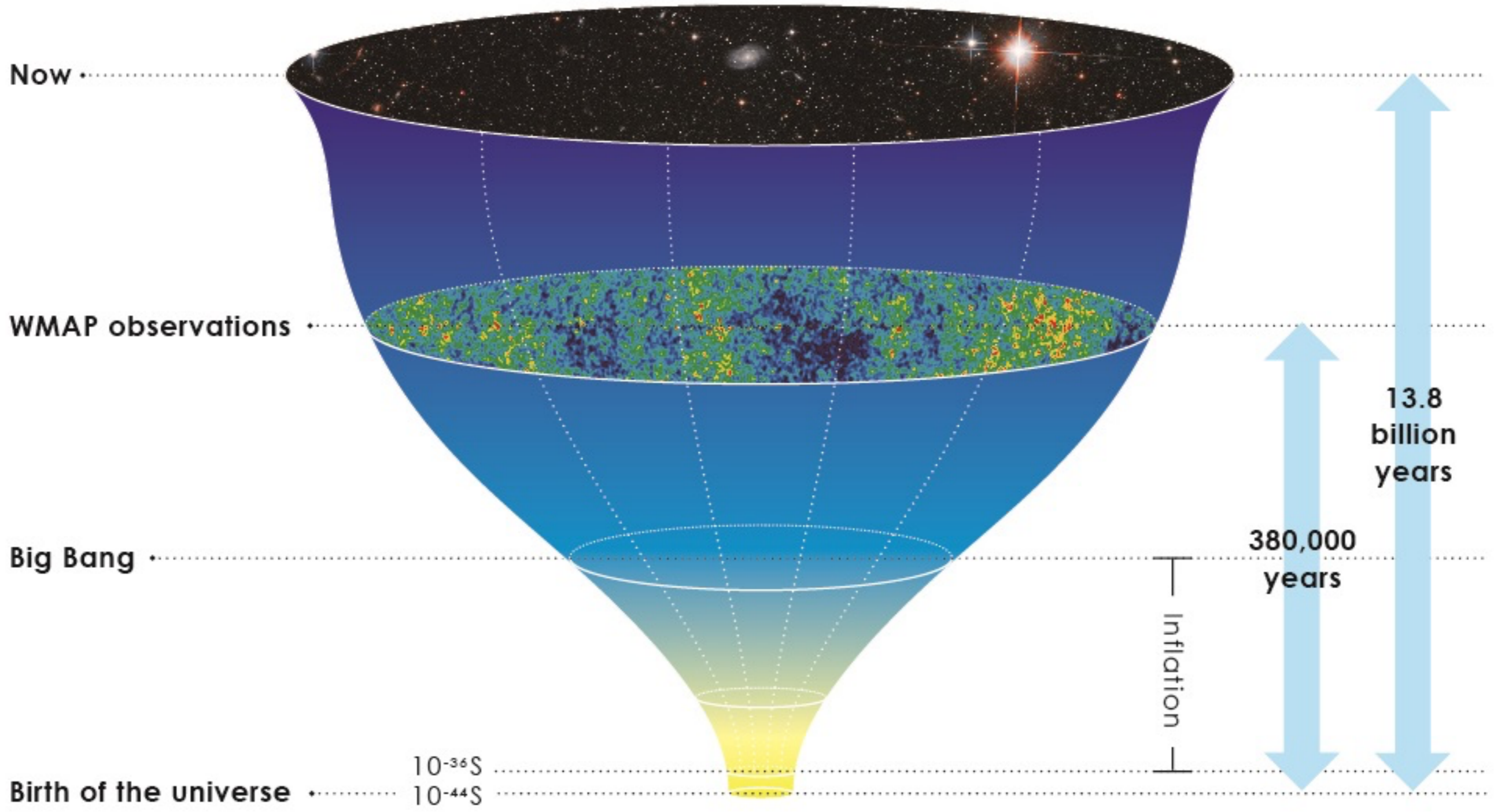
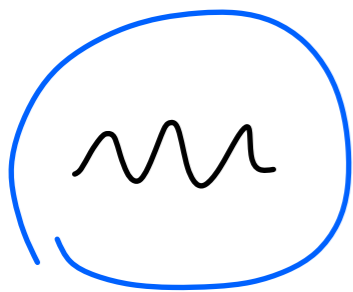


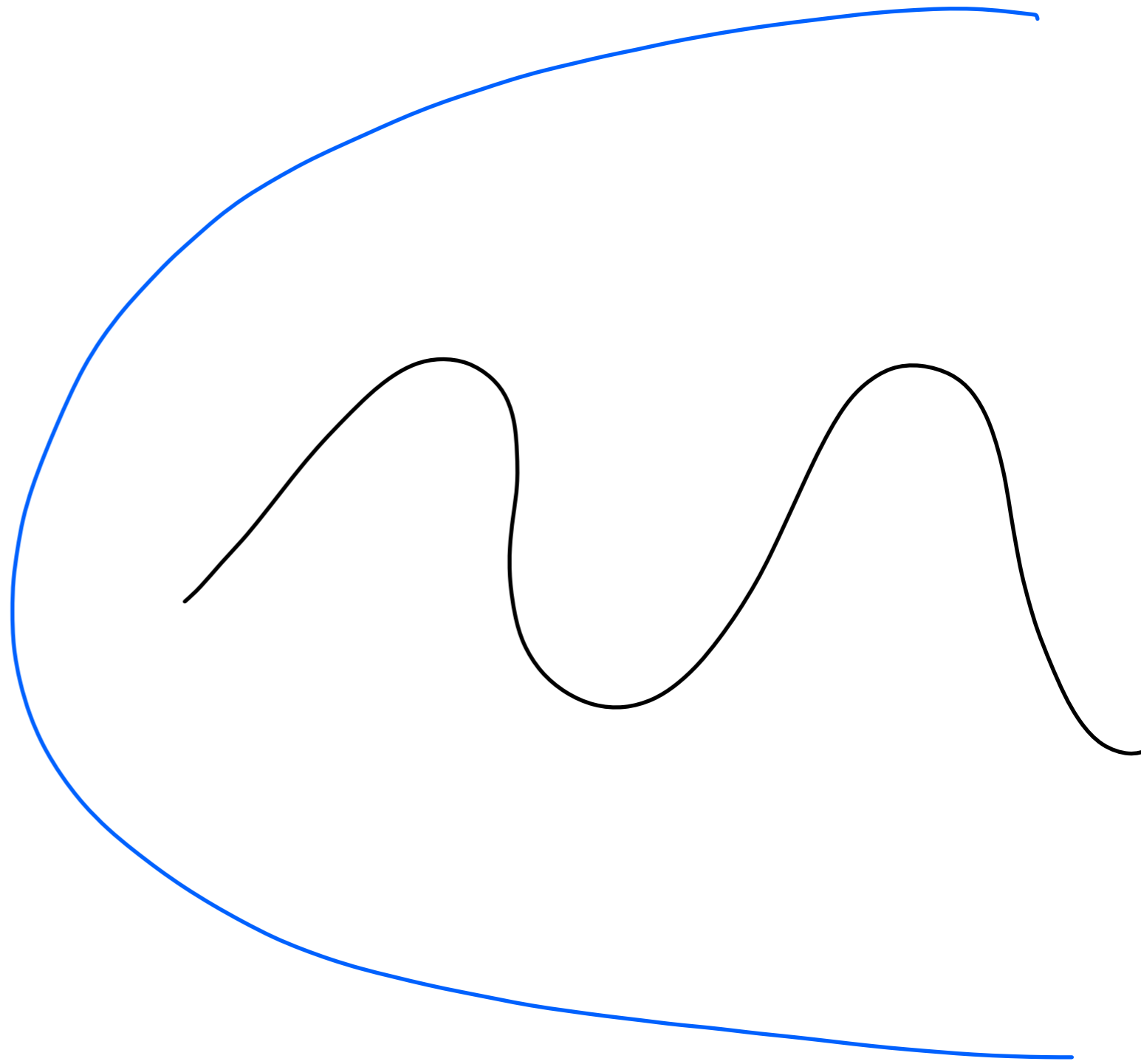
Figure from <https://www.u-tokyo.ac.jp/content/400031453.jpg>

macroscopic
fluctuation

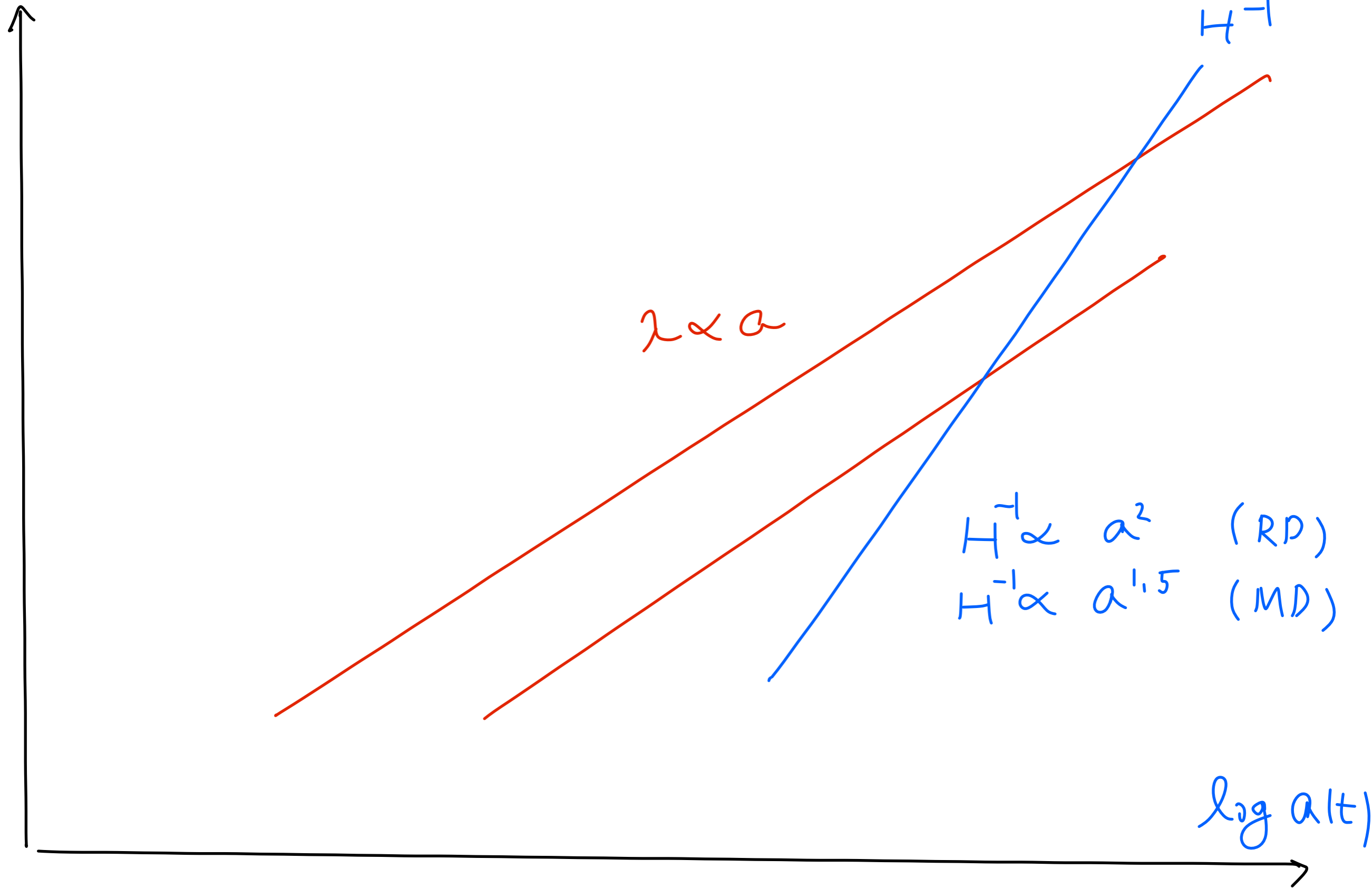
tiny
quantum
fluctuation



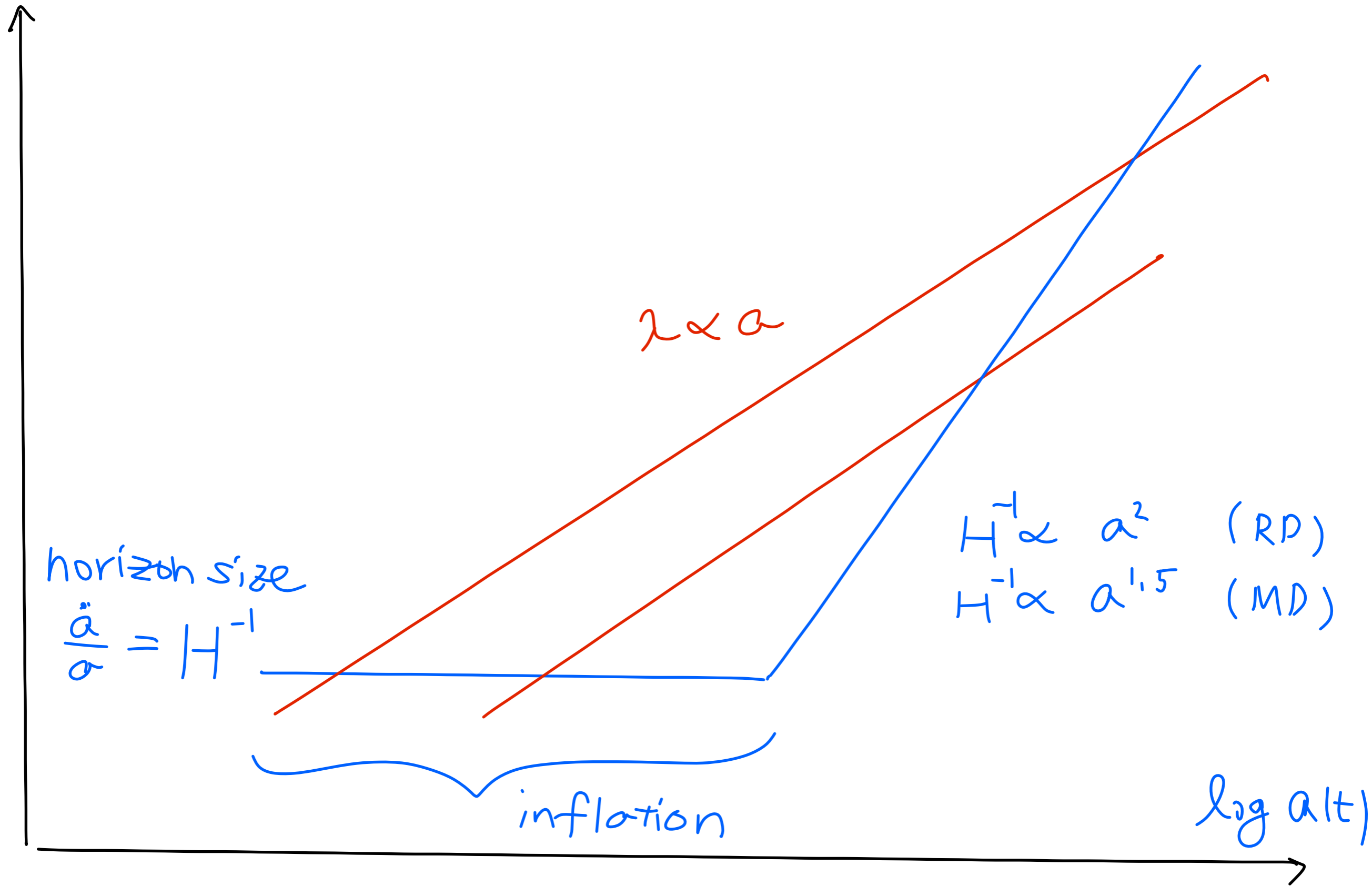
exponential
expansion



log(physical scale)



log(physical scale)



log(physical scale)

horizon crossing

$\lambda \propto a$

horizon exit

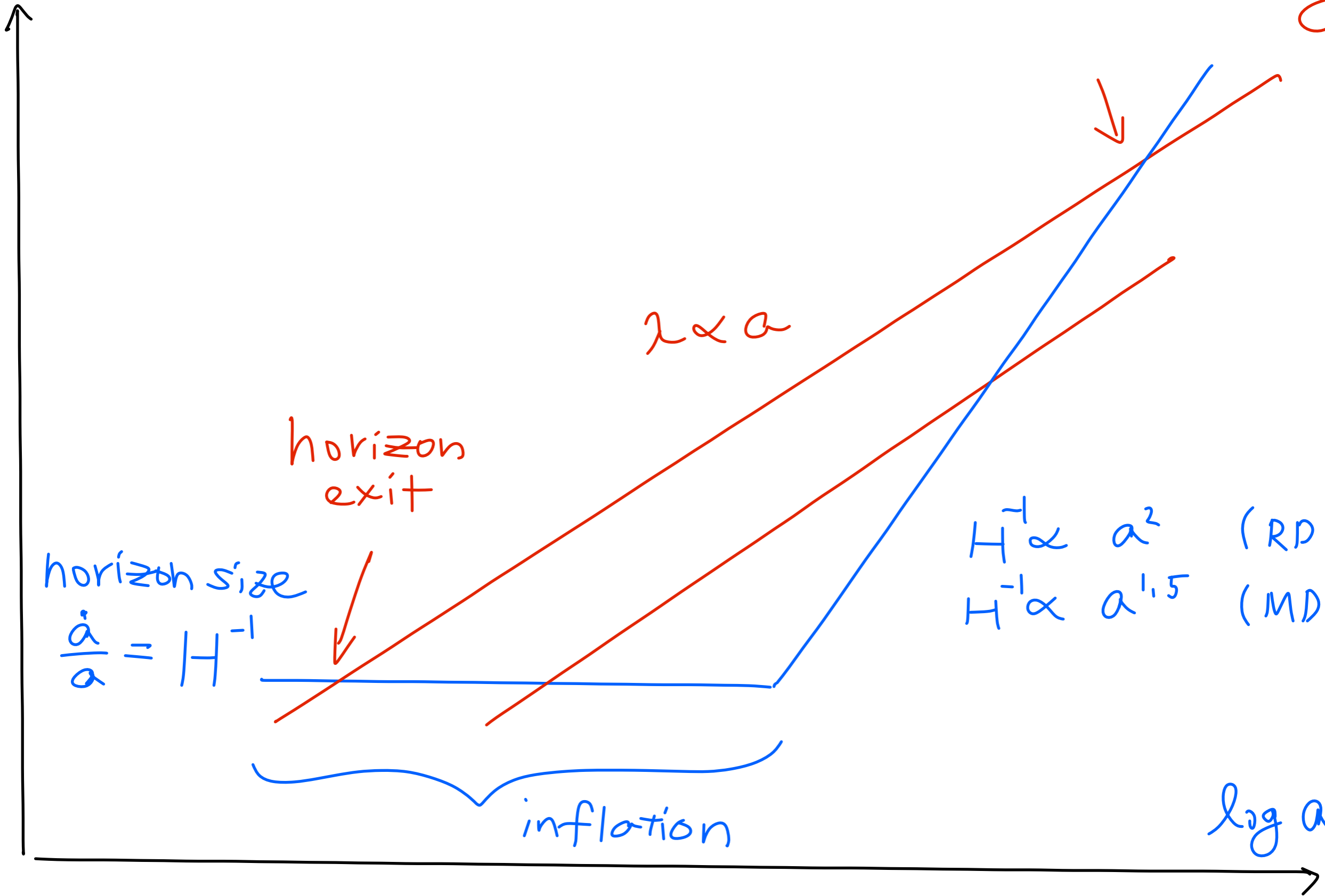
horizon size

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

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

inflation

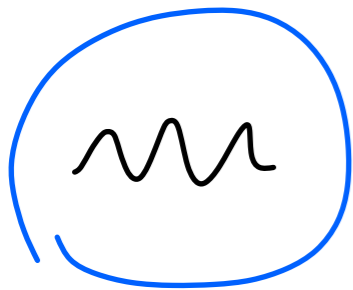
log a(t)



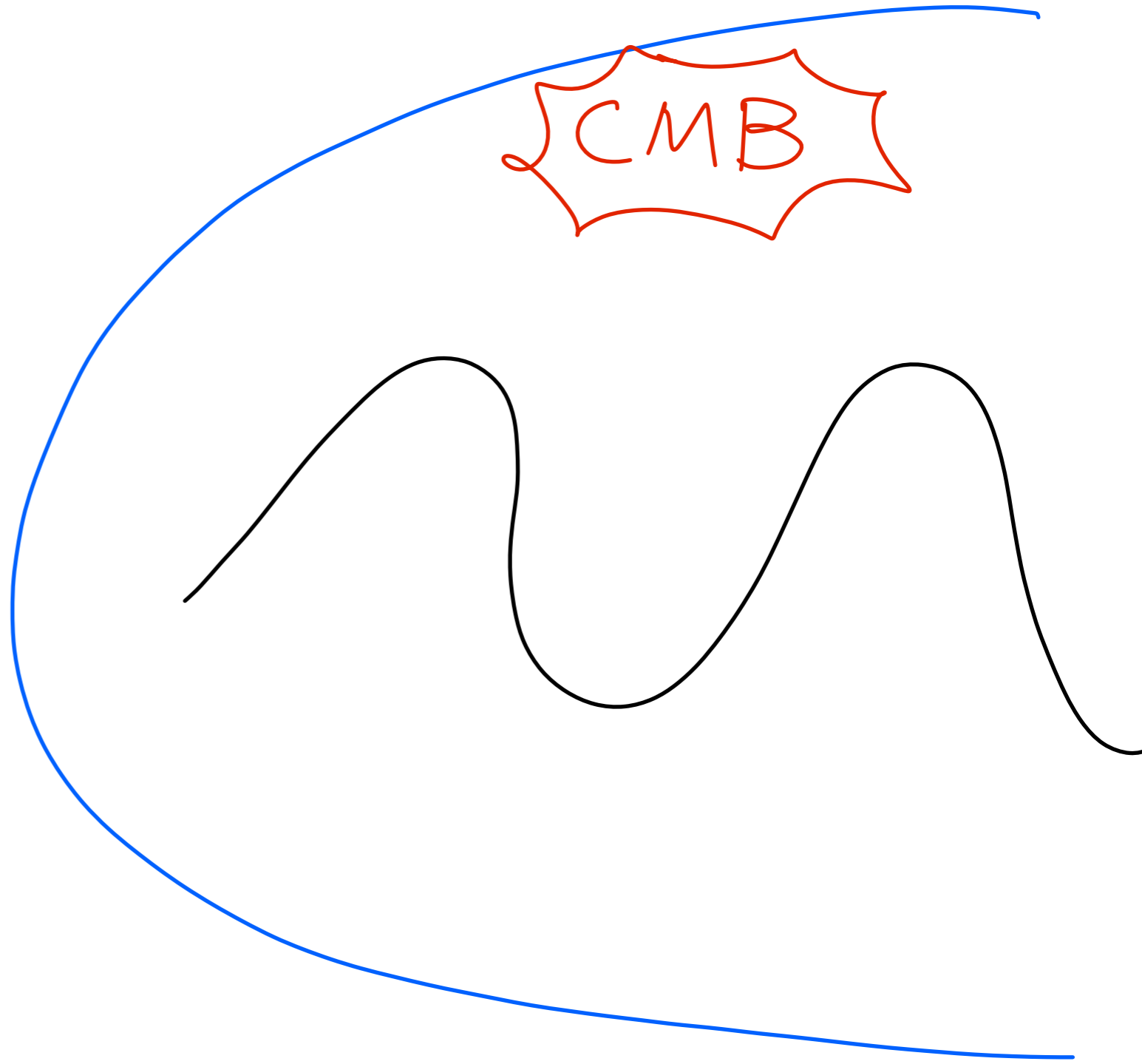
macroscopic
fluctuation

CMB

tiny
quantum
fluctuation



exponential
expansion



log(physical scale)

horizon crossing

$\lambda \propto a$

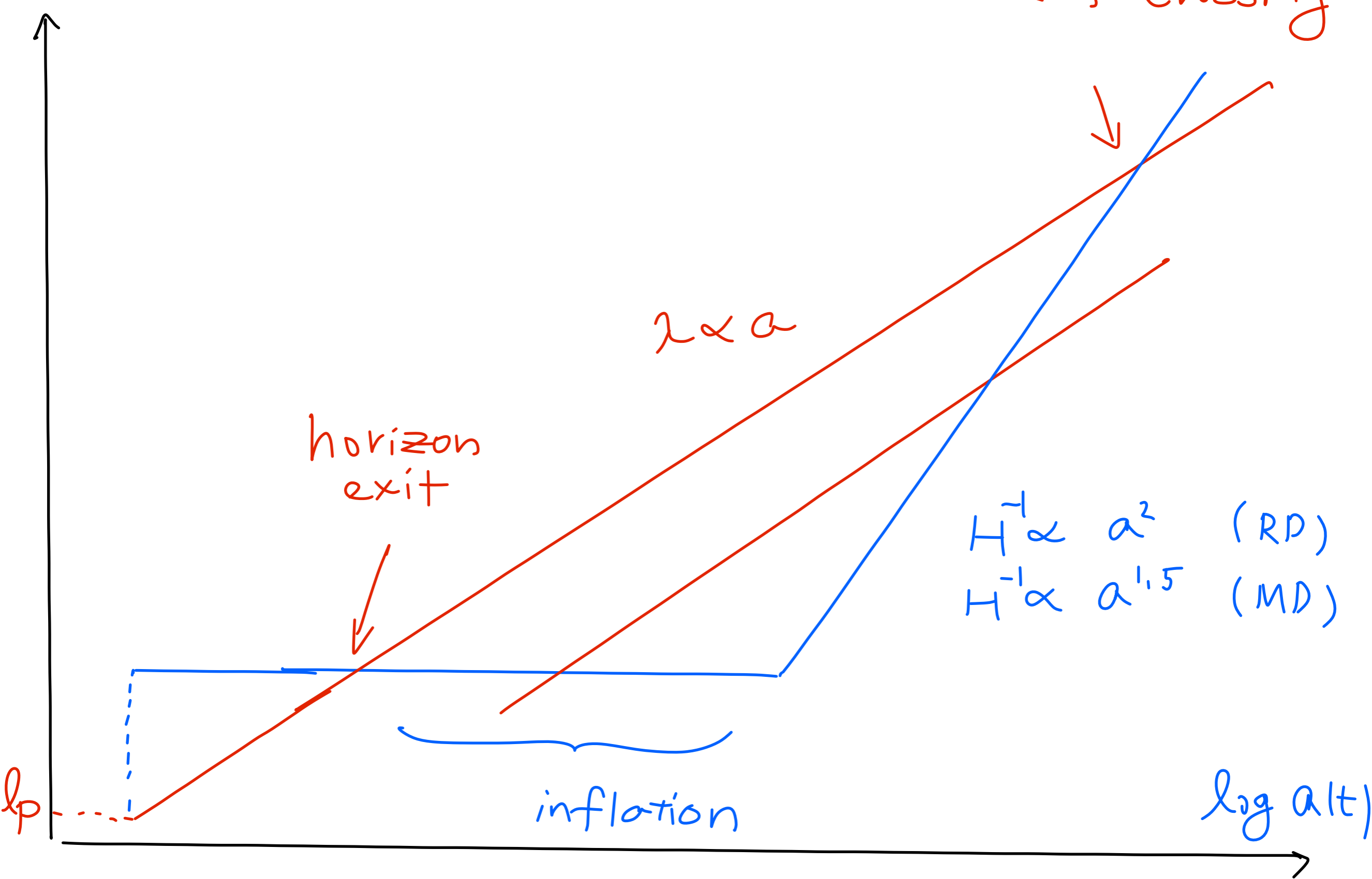
horizon exit

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

inflation

log a(t)

l_p



transplanckian

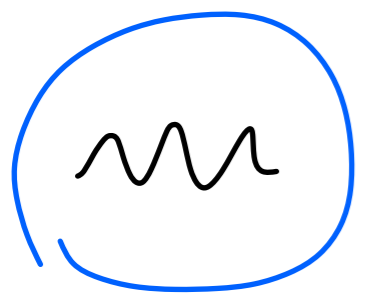
mode

$$l \lesssim lp$$

tiny

quantum

fluctuation

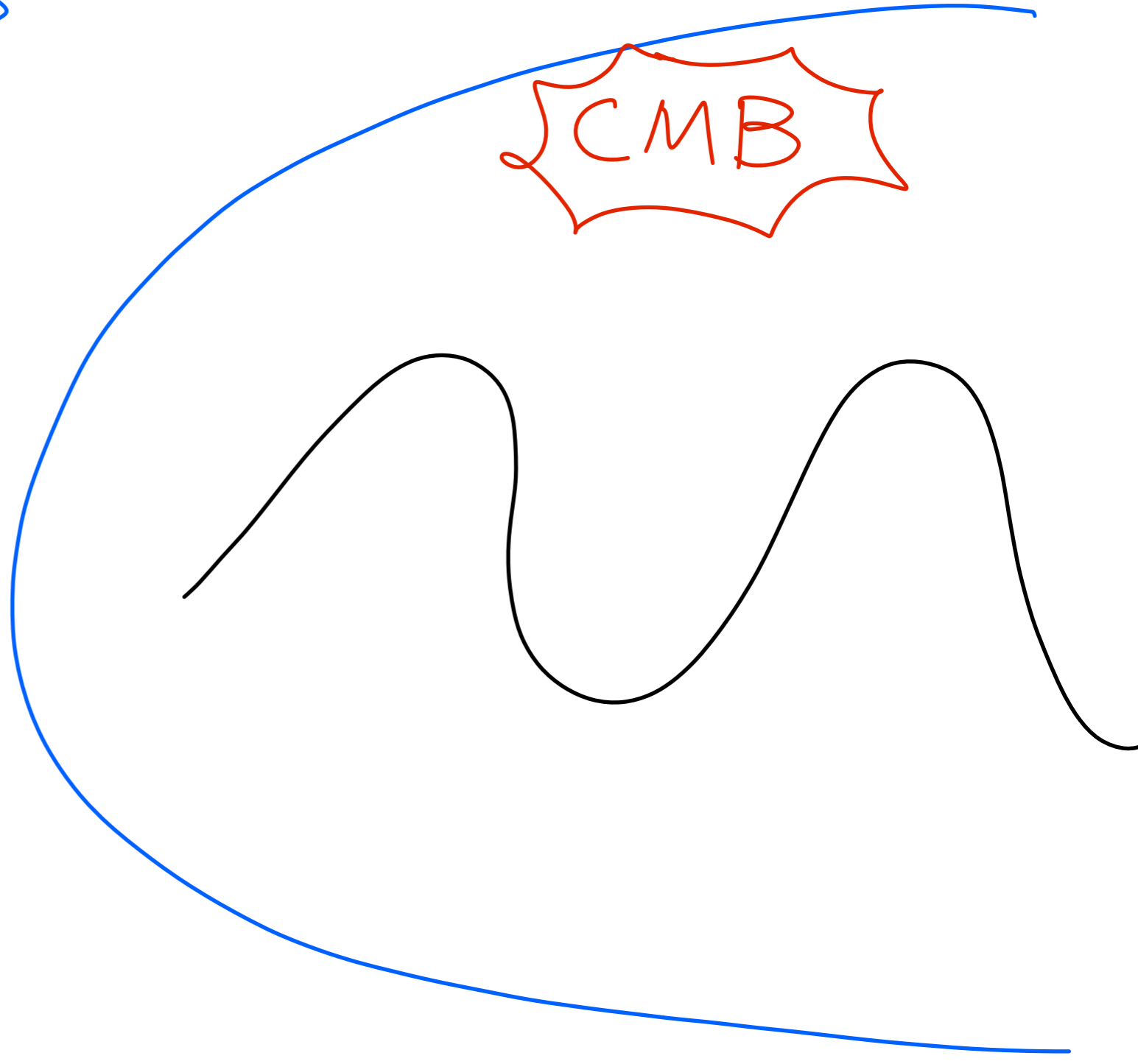


exponential

expansion

macroscopic

fluctuation

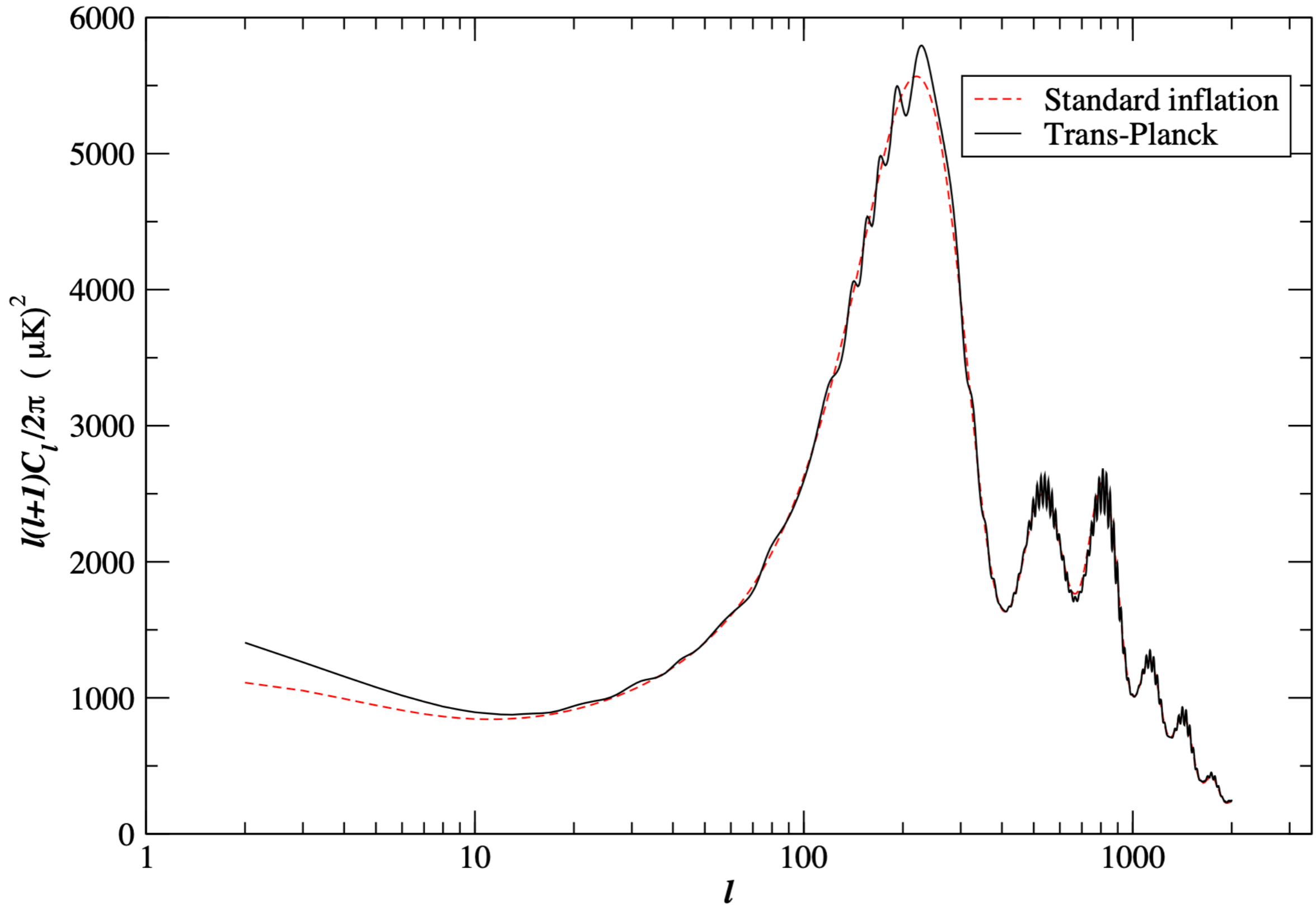


Trans-Planckian "Problem":

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

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

e^N N : e-folding

TCC \Rightarrow metastable dS has lifetime

$$T \lesssim H^{-1} \ln(M_{\text{pl}}/H)$$

TCC \Rightarrow metastable dS has lifetime

$$T \lesssim H^{-1} \ln(M_{\text{pl}}/H)$$

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

\Rightarrow no metastable dS

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

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

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

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

↑
 $\mathcal{O}(1)$ number

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

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

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

↑
 $\mathcal{O}(1)$ number

Problem with Higgs / pion / axion

[Denef-Hebecker-Wrase, Murayama-Yangida-MY
Choi-Chwoy-shin, Hamaguchi-Ibe-Moroi ('18)]

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](#)

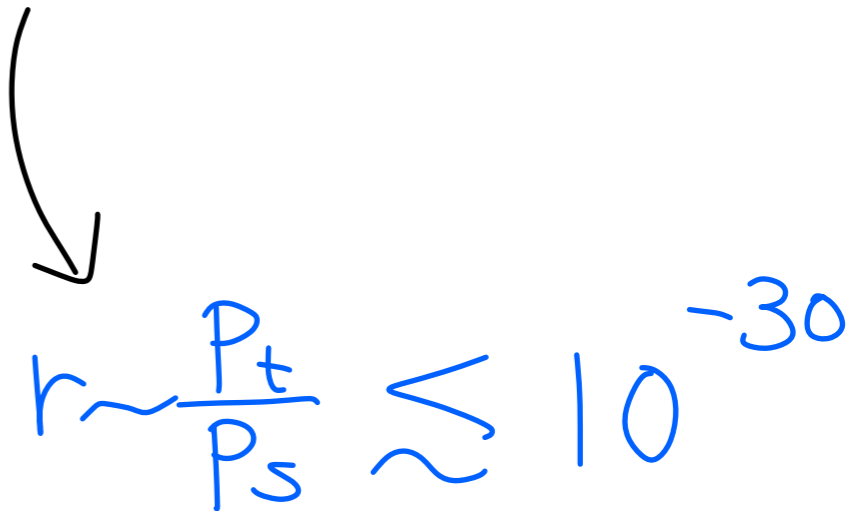
2. Trans-Planckian Censorship and the Swampland

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](#)
[ADS Abstract Service](#)

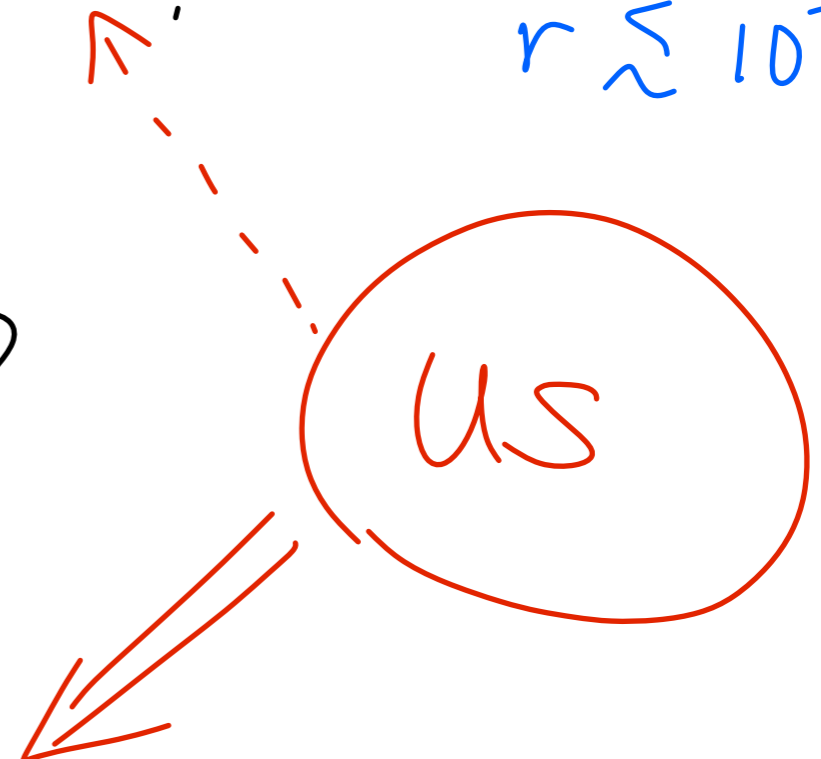
[レコードの詳細](#) - [Cited by 38 records](#)


$$r \sim \frac{P_t}{P_s} \lesssim 10^{-30}$$

Questions Raised on TCC:

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

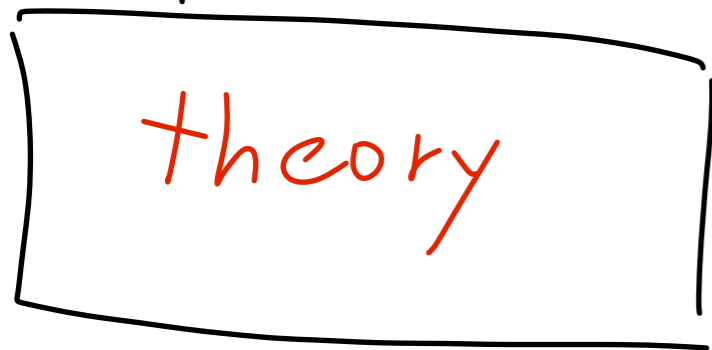
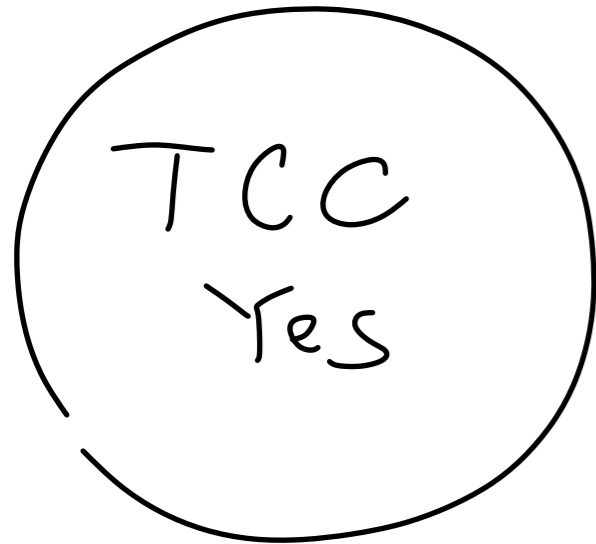
Questions Raised on TCC:

- * Implications if true? eg. $r \lesssim 10^{-8}$
 $r \lesssim 10^{-3}$
 $r \lesssim 10^{-30}$
 - * Checks, Derivations?
 - * Is TCC a swampland conjecture?
- 

Problems w/ TCC

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

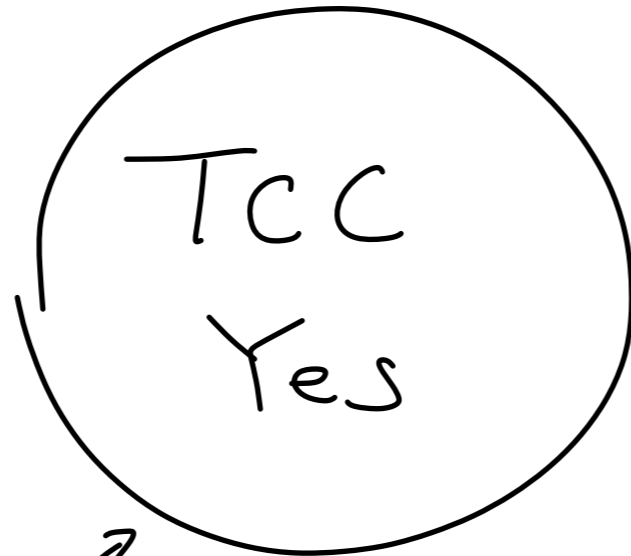
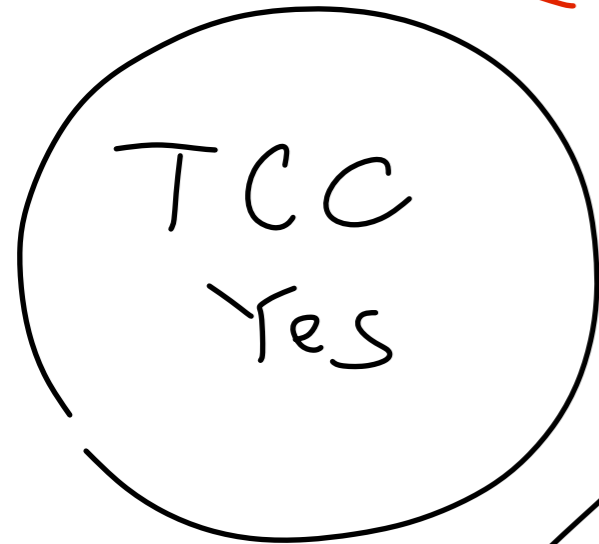
Scenario



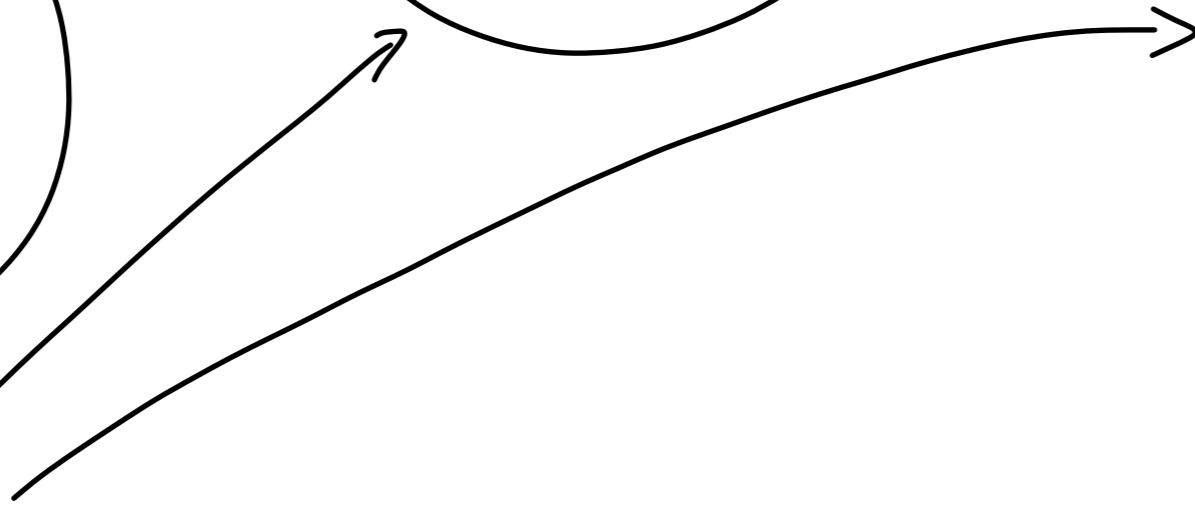
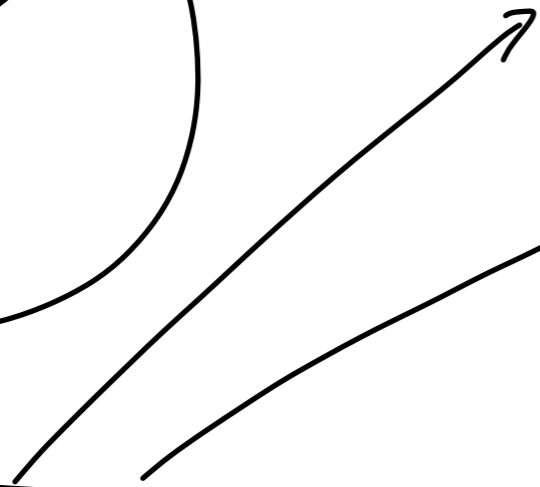
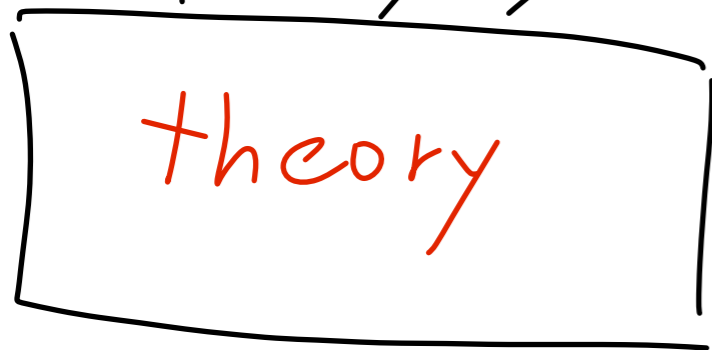
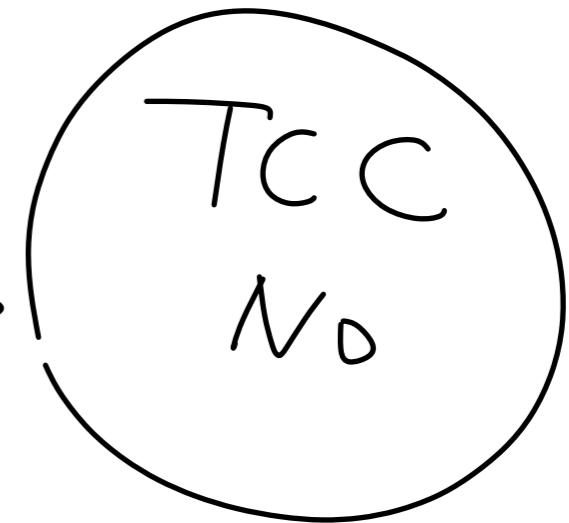
Basic Problem w/ TCC: $\frac{a}{a_i} \leq \frac{M_{pe}}{H}$

scenario 2

scenario 1



scenario 3

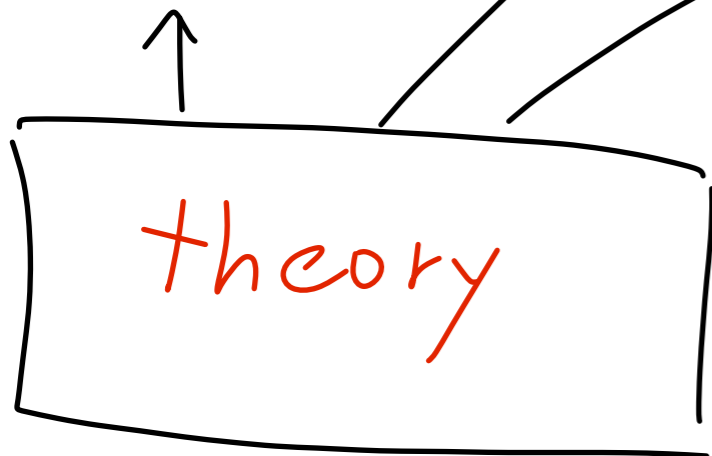
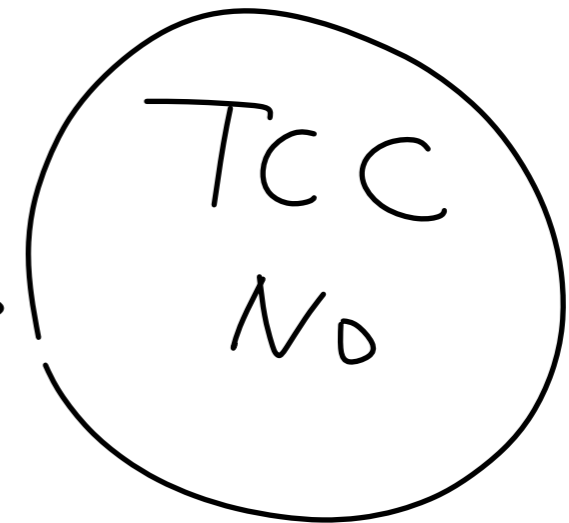
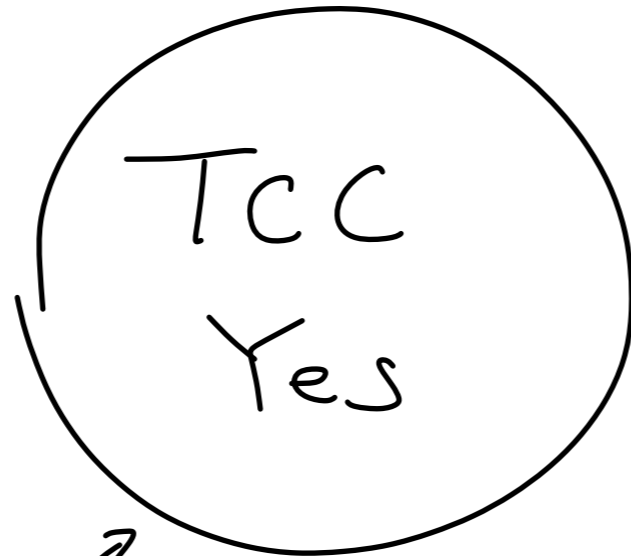
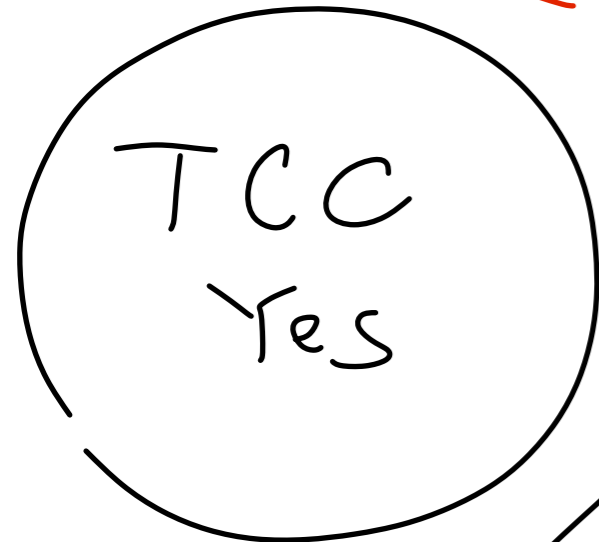


Basic Problem w/ TCC: $\frac{a}{a_i} < \frac{M_{pl}}{H}$

scenario 2

scenario 3

scenario 1



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

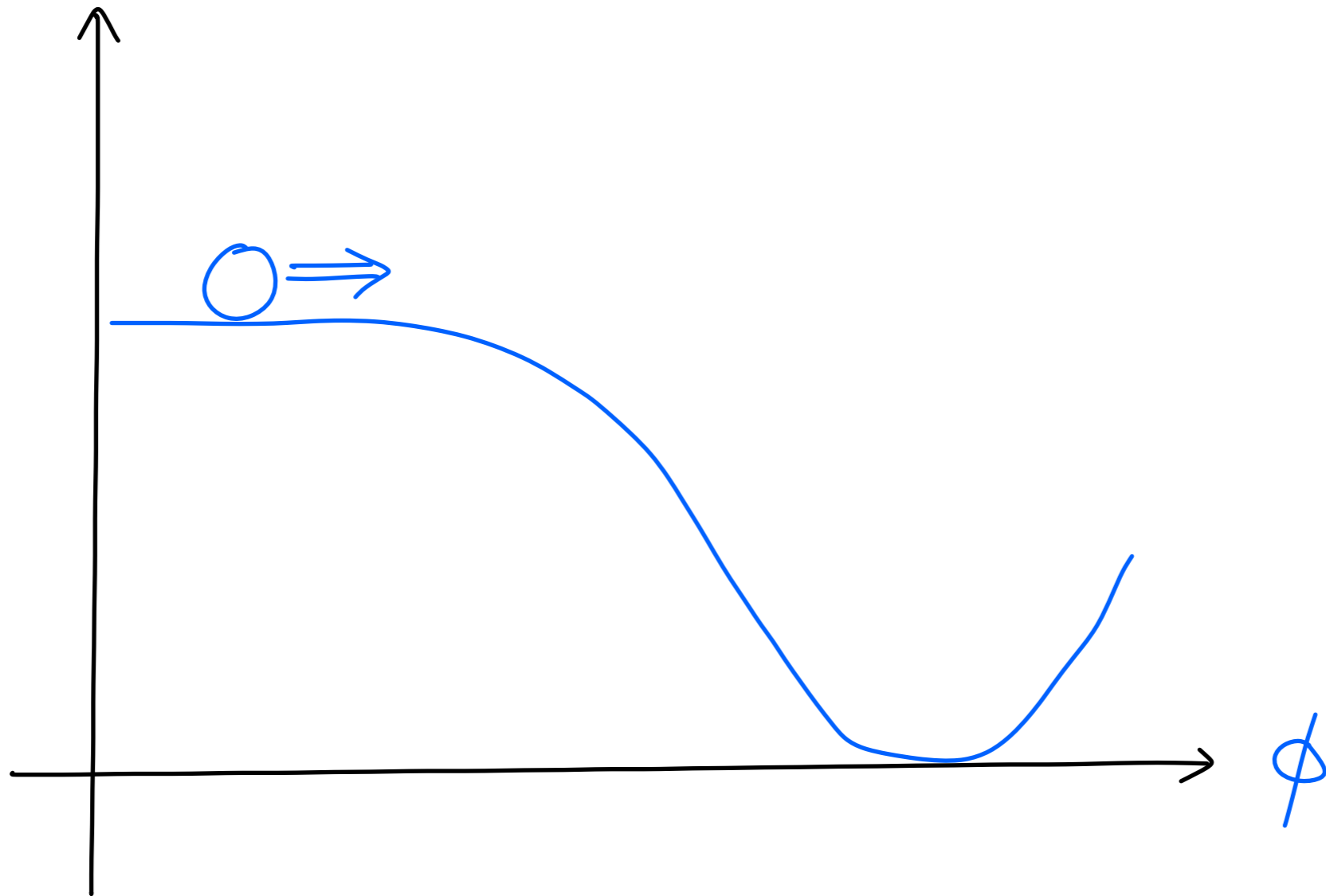
1. What happens if TCC

indeed applies *universally* ?

(universal TCC)

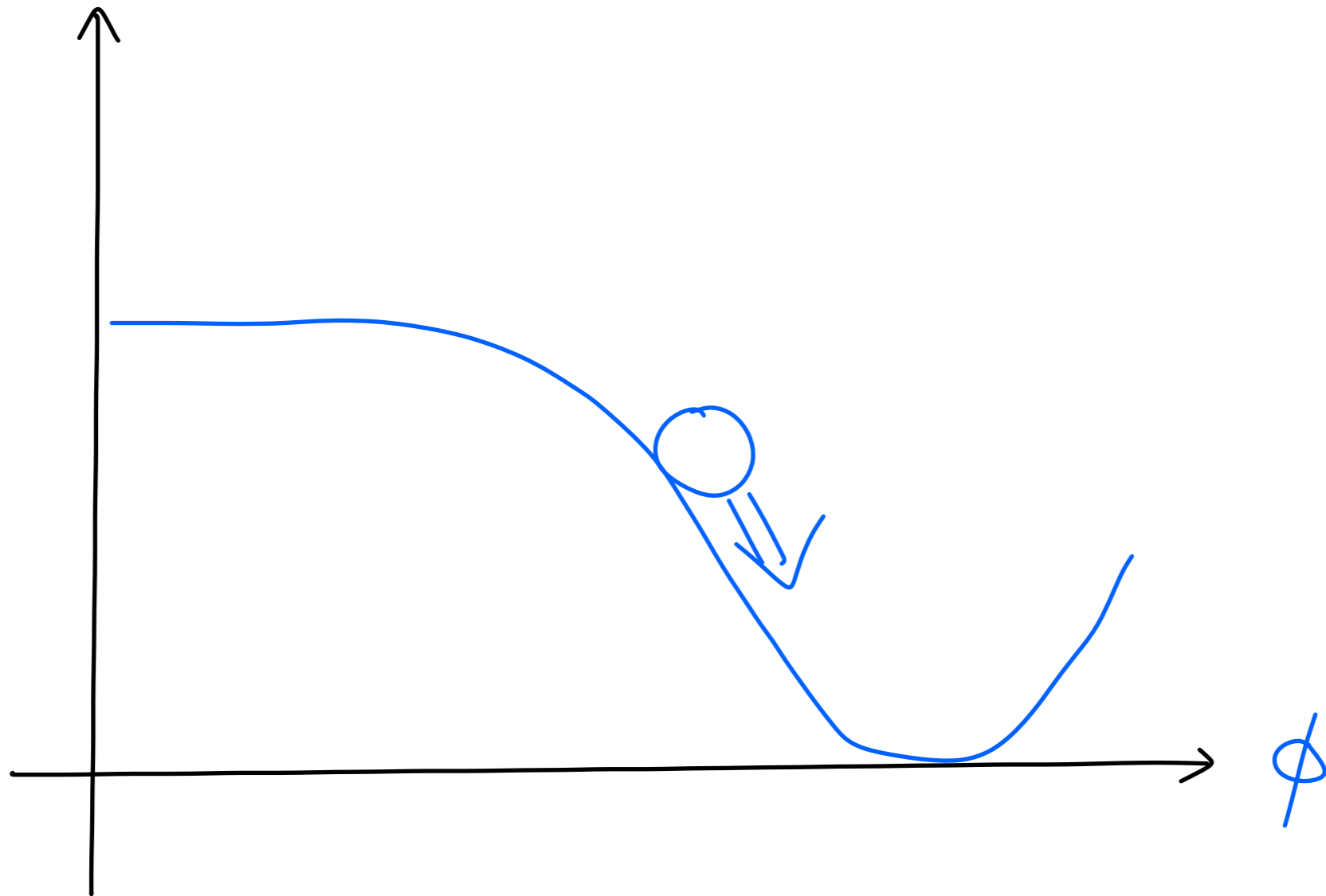
inflation

$V(\phi)$



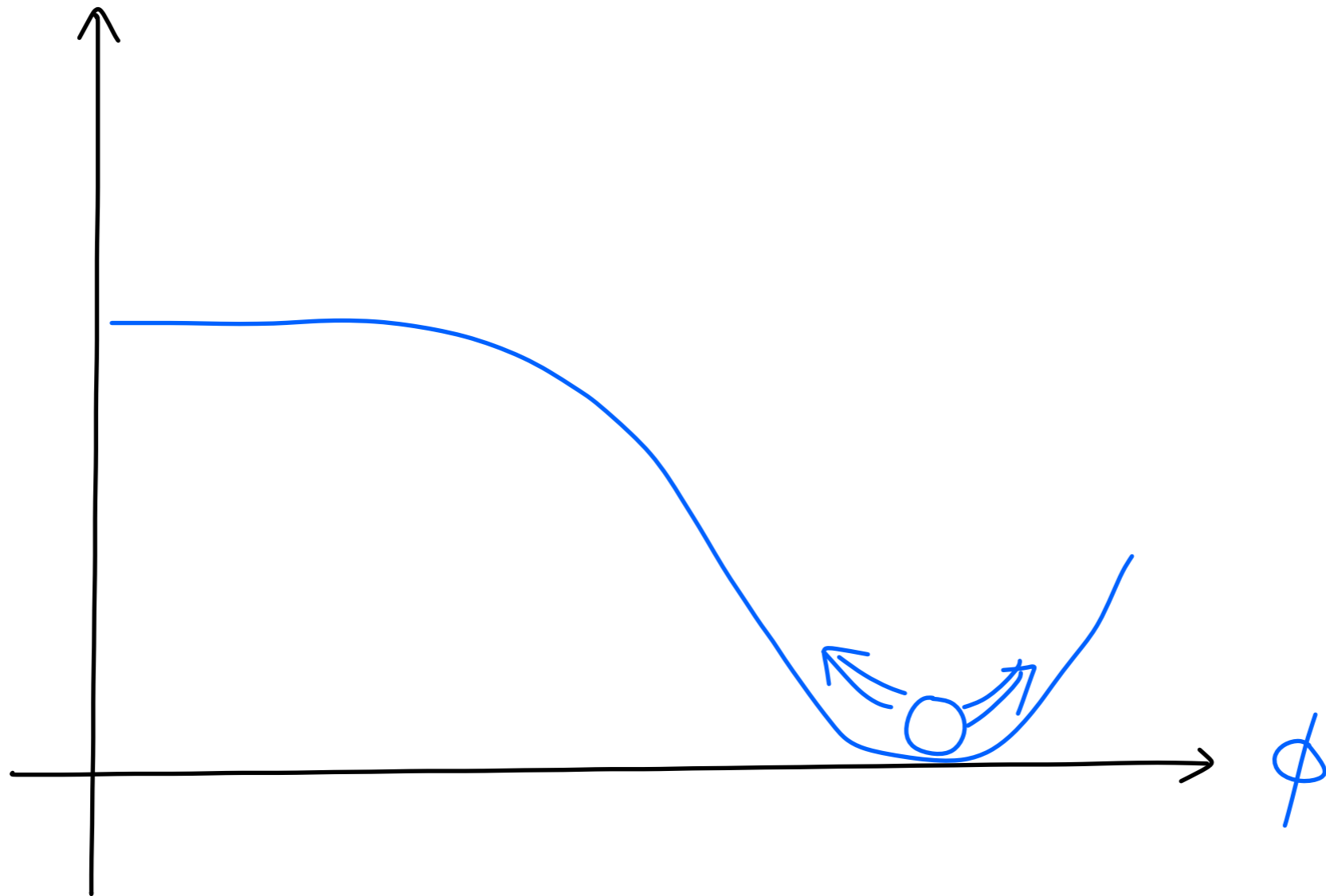
inflation

$V(\phi)$



inflation

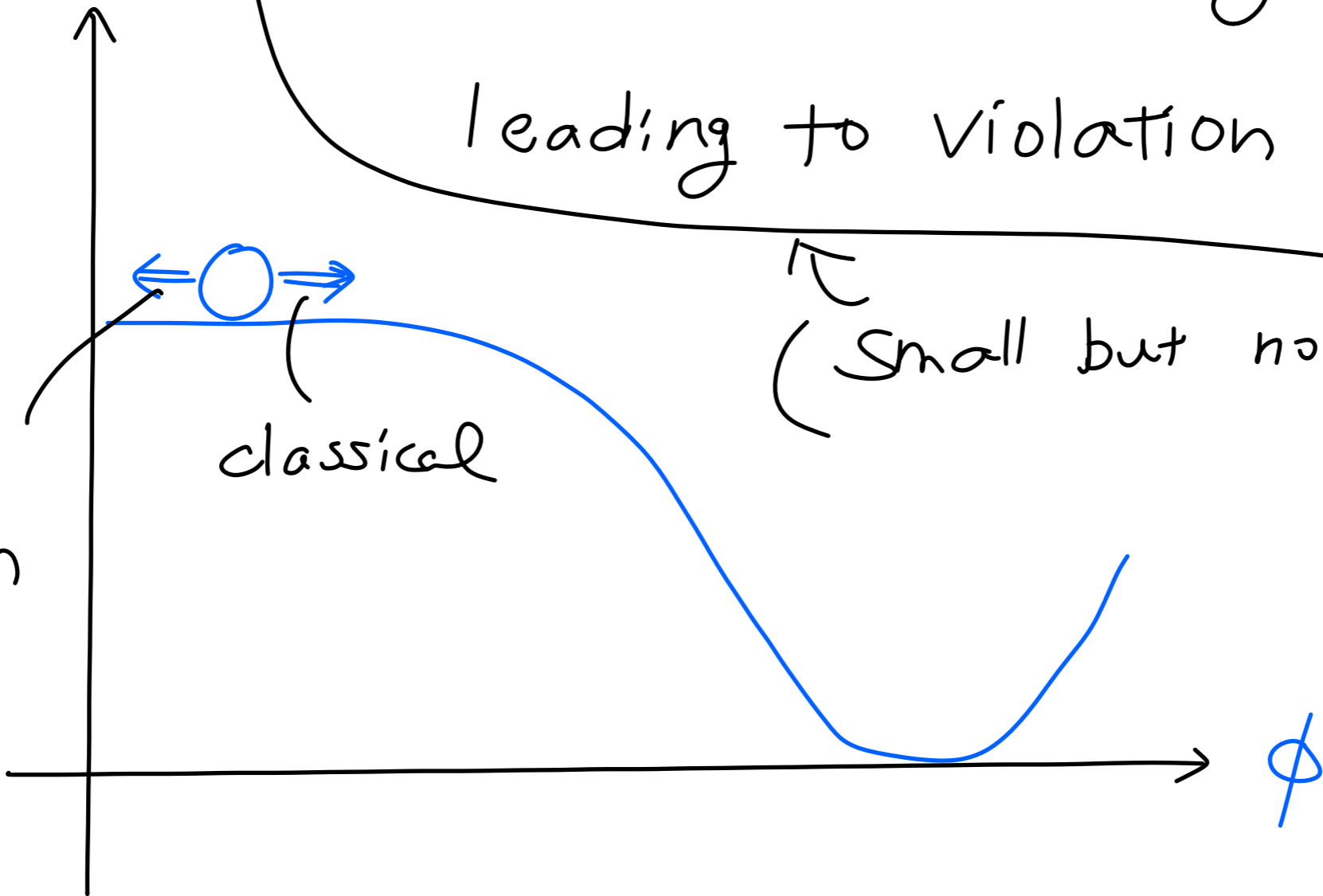
$V(\phi)$



inflation

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

$V(\phi)$



(Small but non-zero p)

quantum fluctuation

classical

ϕ

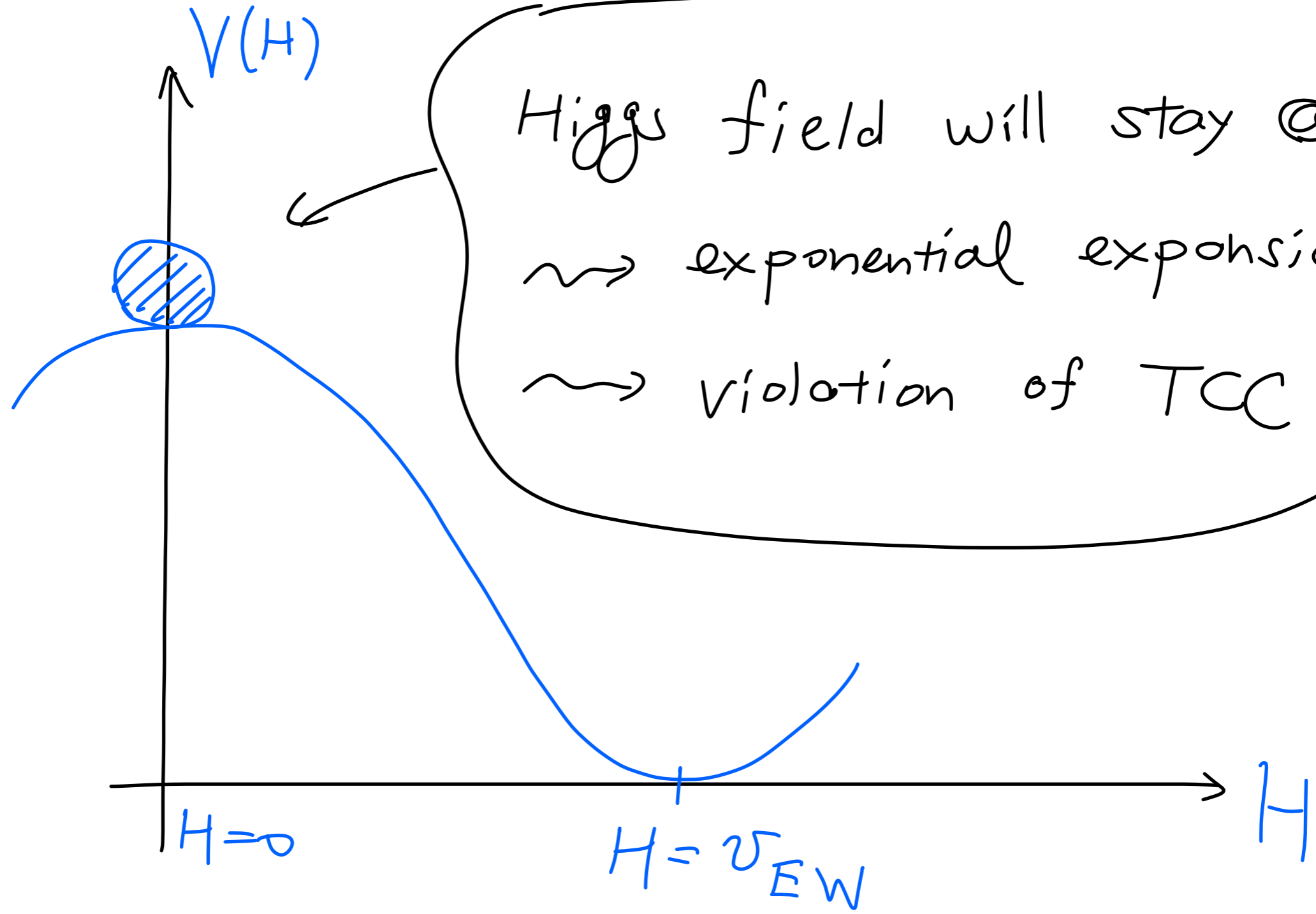
2. If quantum fluctuations are

problematic, why not only

classical locus?

(classical TCC)

Higgs



Higgs field will stay @ top
~> exponential expansion
~> 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

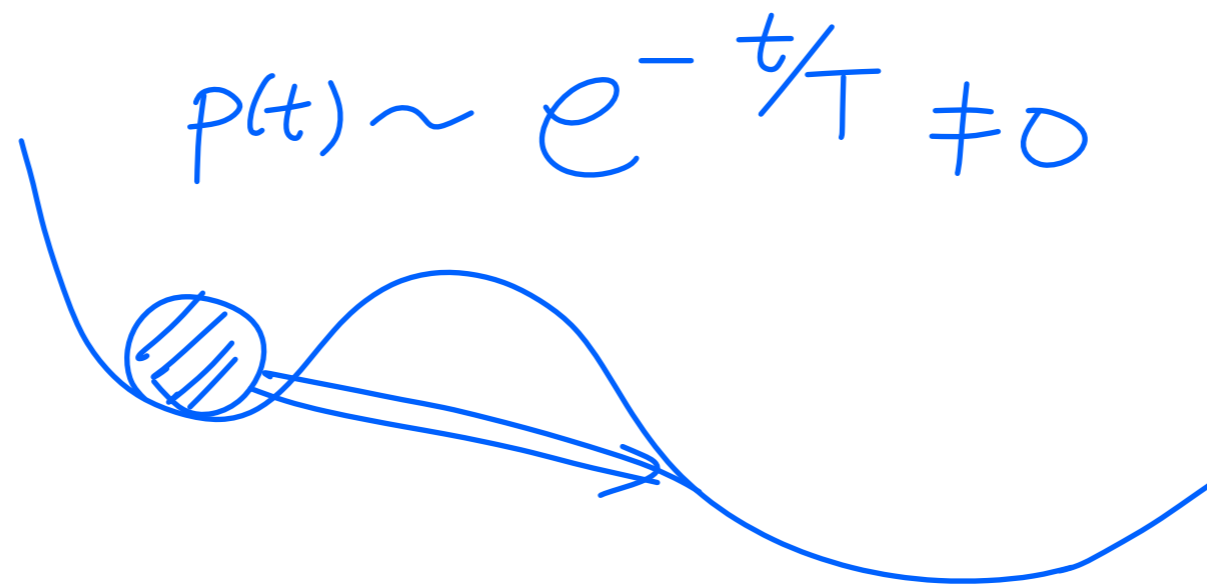
(observational TCC)

(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



4. Allow TCC violation with

"small" probabilities?

(probabilistic TCC)

4. Allow TCC violation with

"Small" probabilities ?
↑
how small?
why?

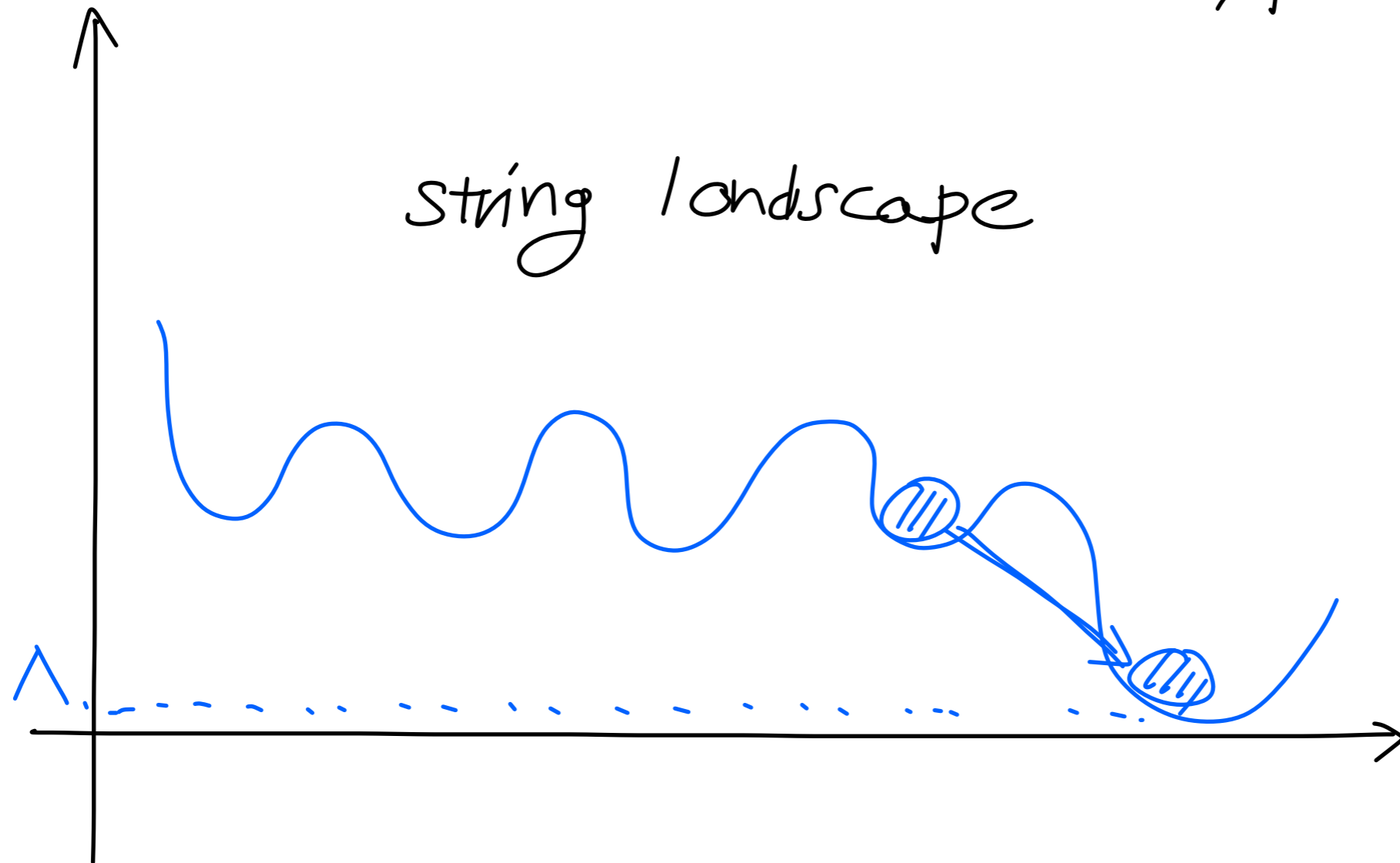
(probabilistic TCC)

4. Allow TCC violation with

"Small" probabilities?
how small?
why?
which probability?
"measure problem"

(probabilistic TCC)

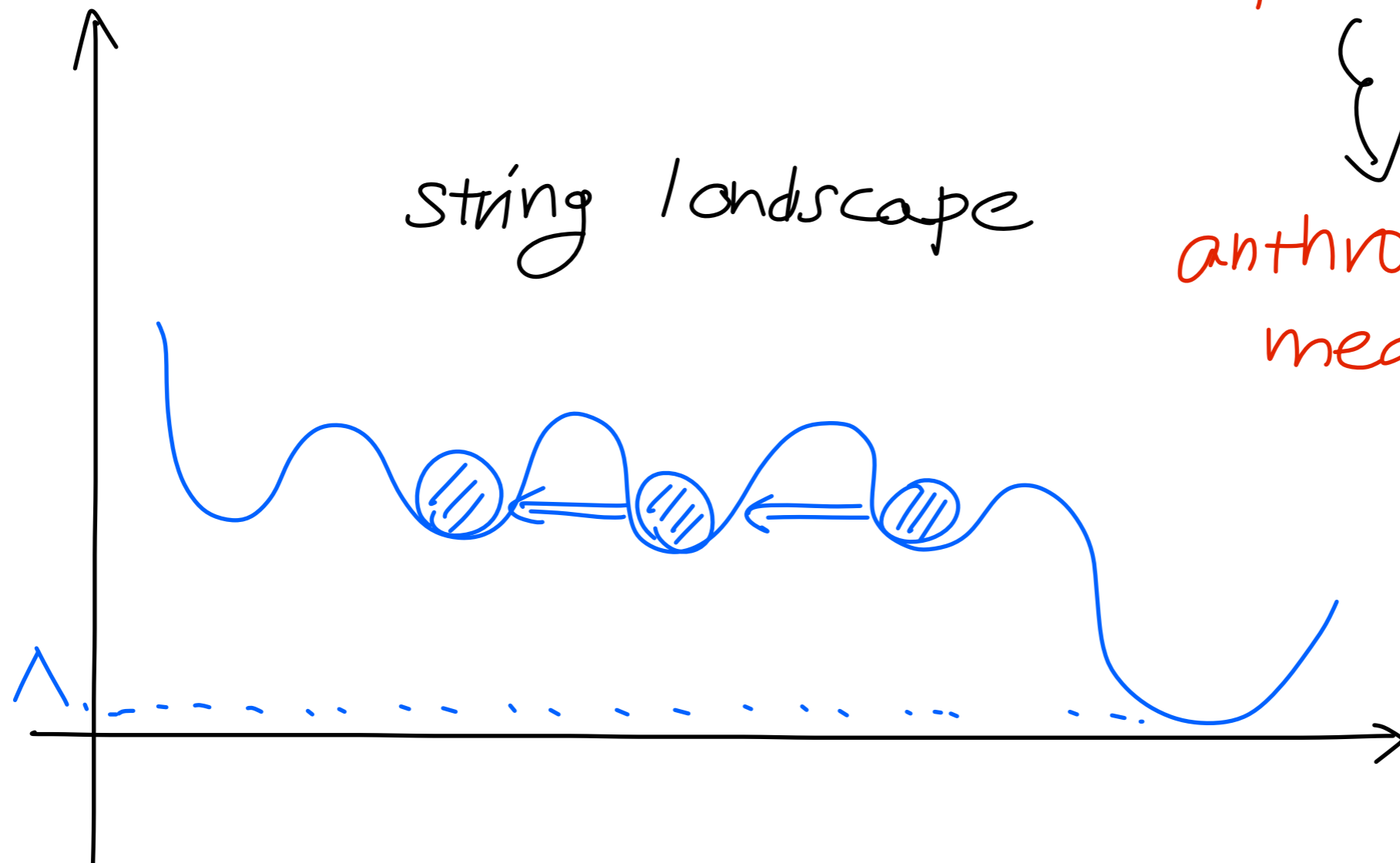
We ourselves can be very *atypical/unlikely*,
while probabilistic prediction
assumes typicality



We ourselves can be very **atypical**

while probabilistic prediction

assumes **typicality**



anthropic
measure?

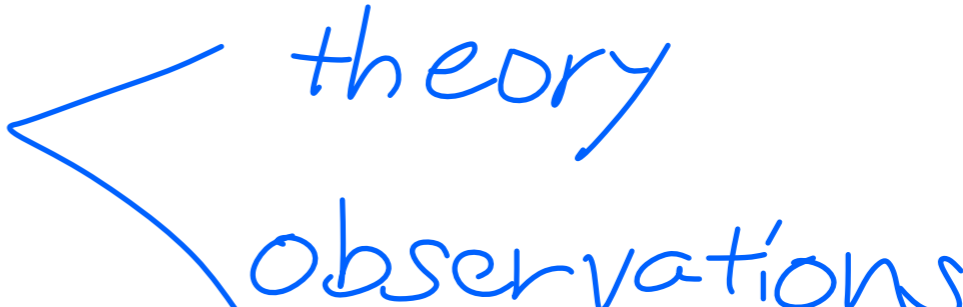
Summary



* Non-trivial if TCC
is a swampland conjecture

If not, resurrection of the
trans-Planckion problem?

* Ideas on QG can be

tested against  theory
observations

* A Swampland conjecture is a
constraint on theory, not scenarios

~> other possible (unobservable) Universes
affects observable predictions

(General Lesson on QG ??)