From Swampland to Phenomenology and Back

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(Univ. Tokyo)
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Moriond EW, 2019

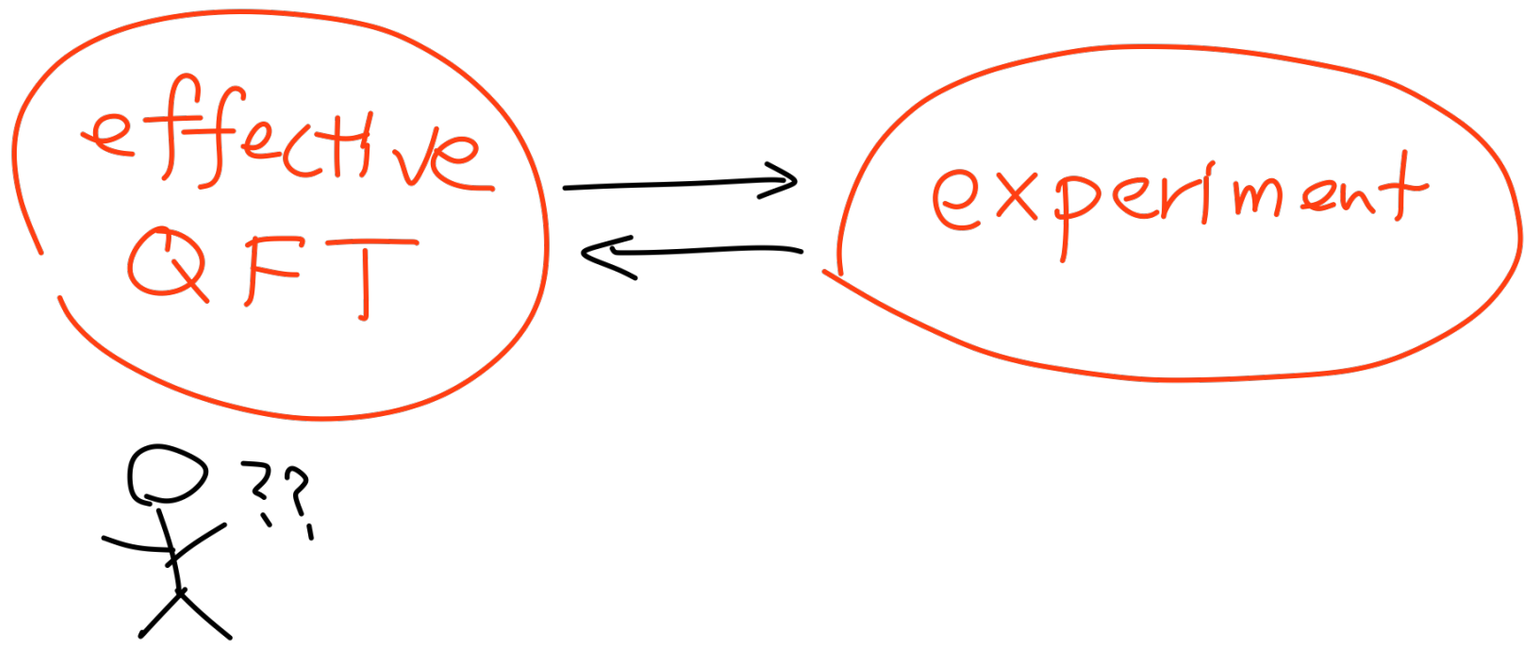
Based on

- H. Murayama - T. T. Yanagida + MY
  1809.00478 [hep-th]

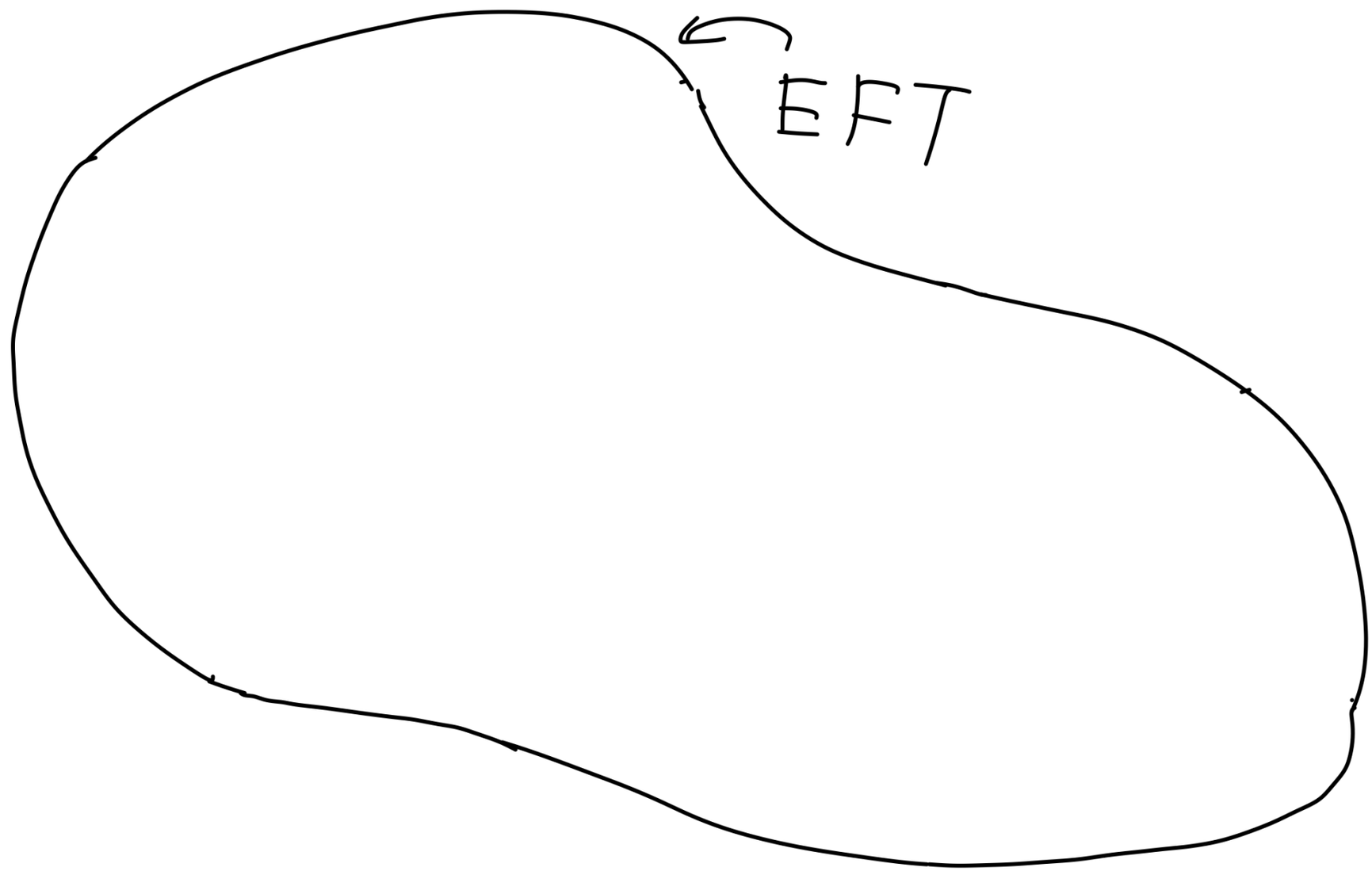
- H. Fukuda - R. Saito - S. Shirai + MY
  1810.06532 [hep-th]

- M. Ibe - T. T. Yanagida + MY
  1811.04664 [hep-th]

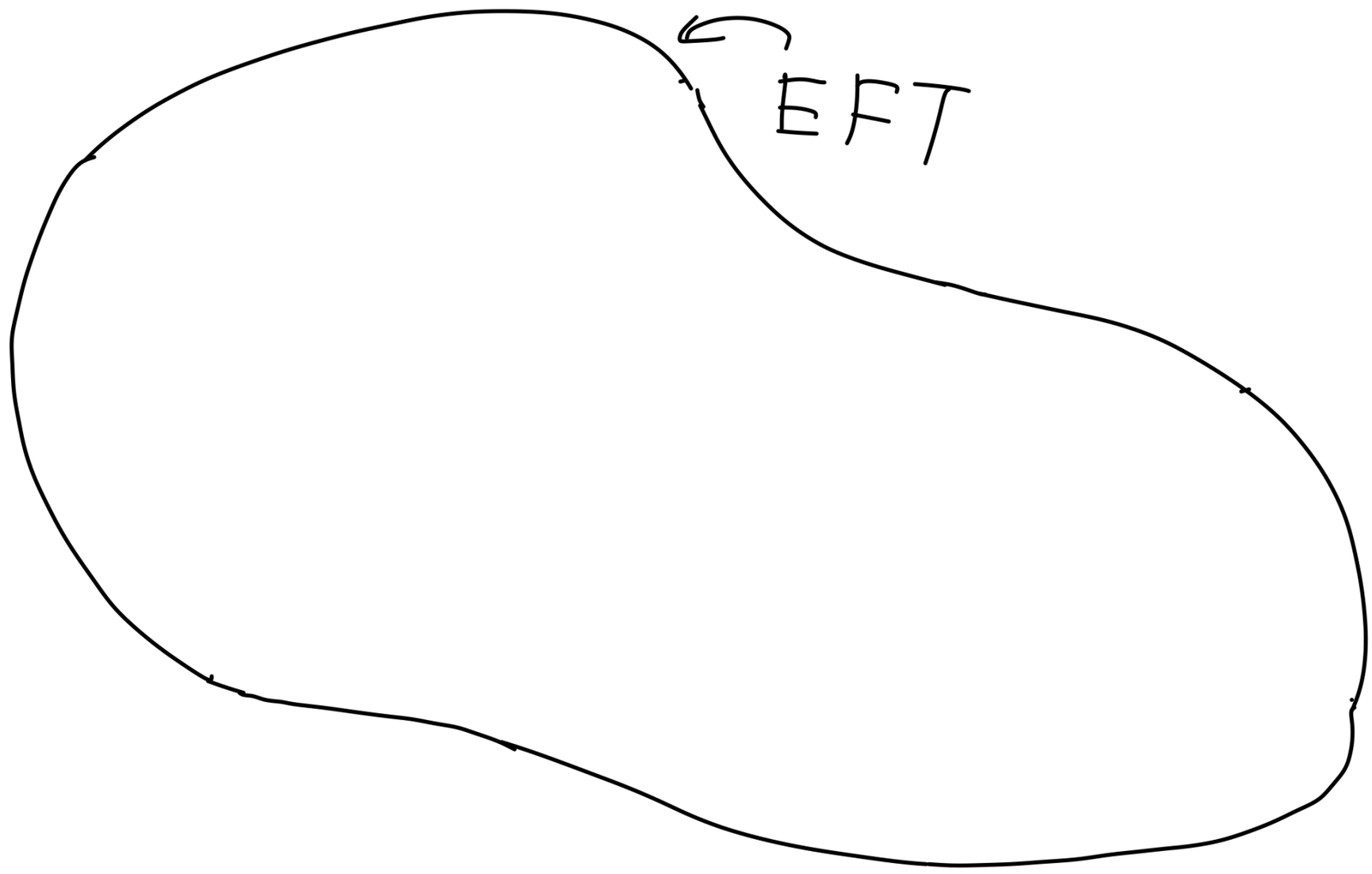
experiment


effective
QFT
experiment
??

effective QFT $\rightleftarrows$ experiment




Quantum Gravity
effective QFT
experiment


EFT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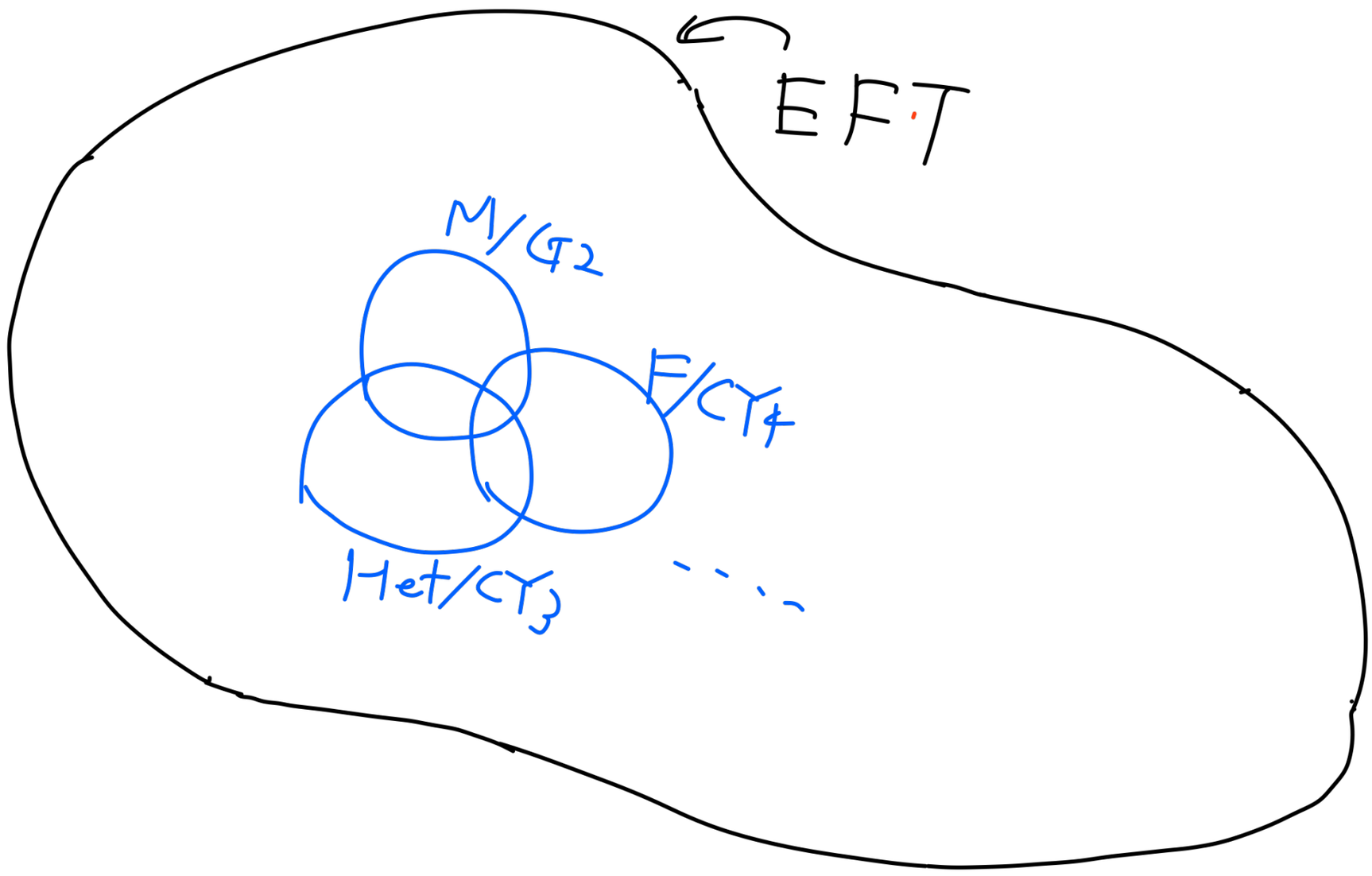
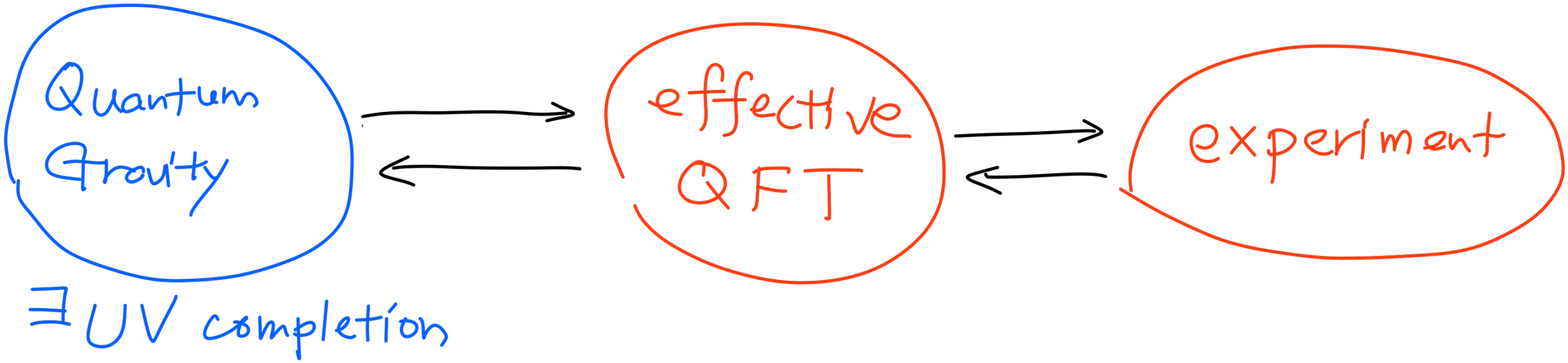

EFT
M/G2
F/CY4
Het/CY3
....


Quantum Gravity
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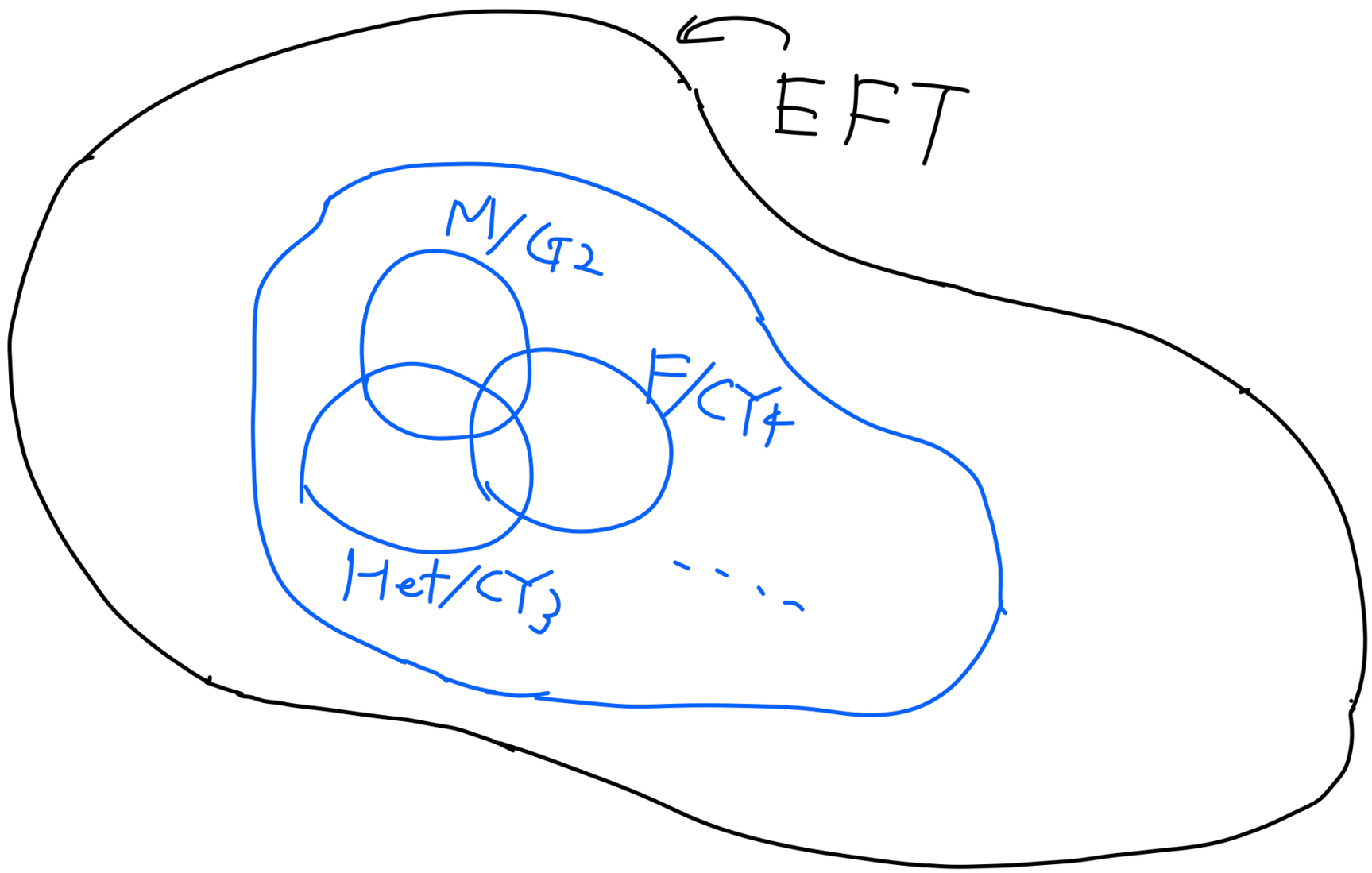
∃ UV completion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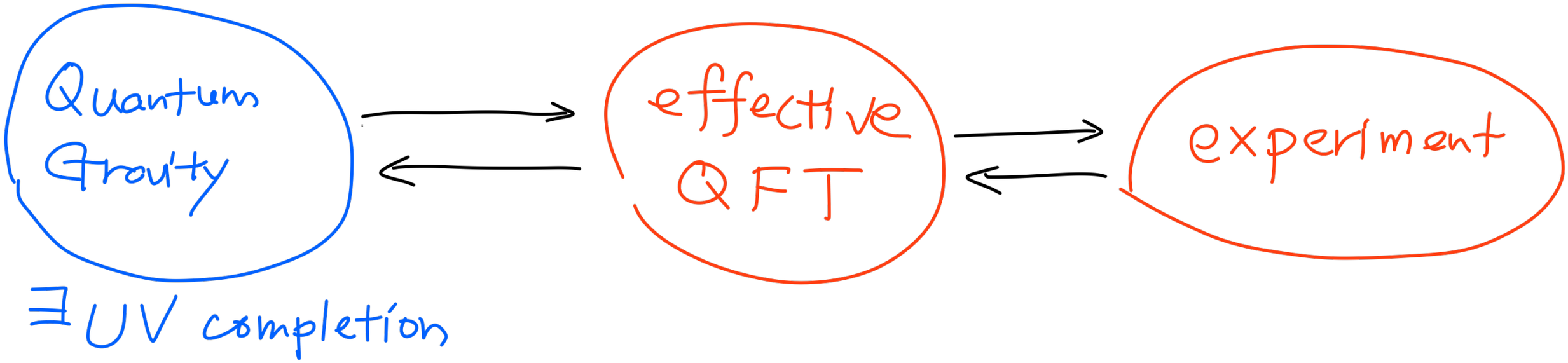
Quantum Gravity
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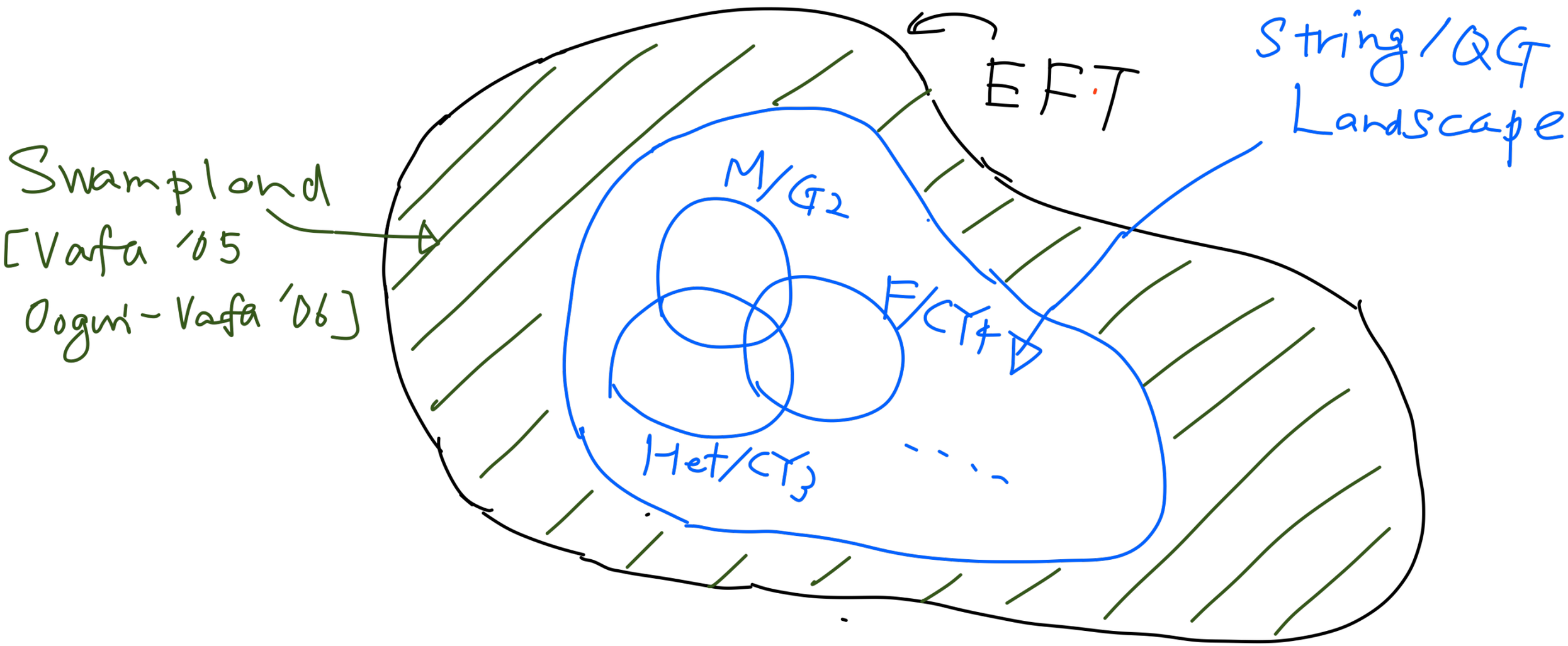
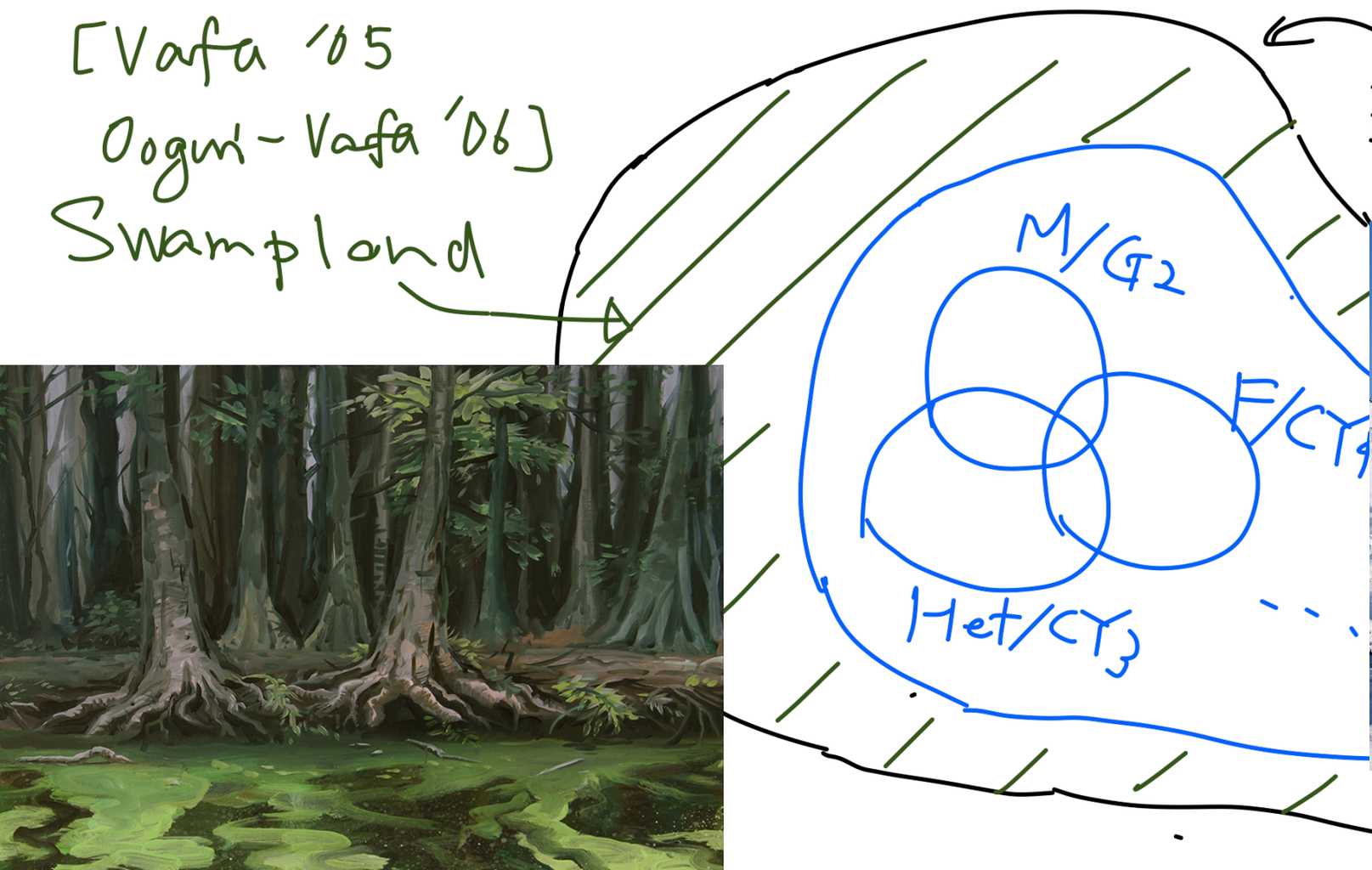

EFT
String/QG Landscape
Swampland
[Vafa '05
Ooguri-Vafa '06]
M/G2
F/CY4
Het/CY3
....

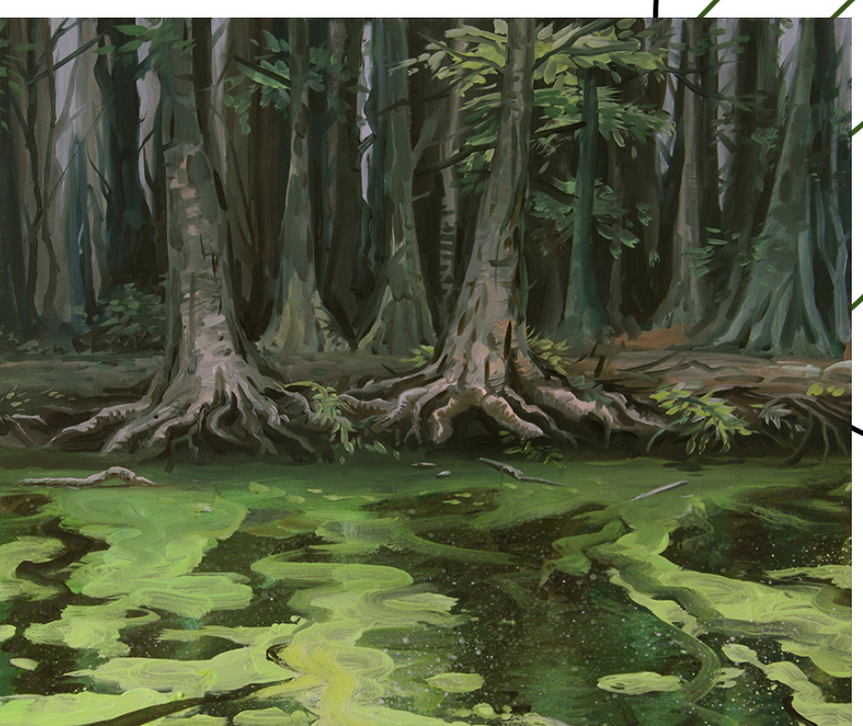
Quantum Gravity $\rightleftarrows$ effective QFT $\rightleftarrows$ experiment

$\exists$ UV completion

[Vafa '05
Ooguri-Vafa '06]
Swampland



String/QG
Landscape



But .... isn't QG difficult ??

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Yes, but we have some clues. ....

- black hole (semiclassical) + ...
- many examples/data from string theory (often quantitative)

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formulate $\boxed{\text{swampland conjectures}}$, i.e. necessary conditions for existence of UV completion

Many conjectures, too many to list here

- no global sym.
- completeness of charge lattice
- weak gravity conjecture
  (sublattice, scalar, ..)
- distance conjecture
- no non-SUSY AdS
- de Sitter conjecture

⋮

[See Palti '19 for recent review]

example

no global sym. conjecture

weak gravity conjecture

conjecture [Reece '18]

$\mathcal{L} \supset m^2 (A_\mu - \partial_\mu \theta)^2$

for Stückelberg photon mass m

$$\Lambda_{UV} \lesssim \min\left(\sqrt{\frac{m M_{pl}}{e}},\ e^{\frac{1}{3}} M_{pl}\right)$$

constraints on light dark photons

(loophole via clockwork?) [Craig, Garcia-Garcia '18]

Jun 2018, Strings 2018, Okinawa

High Energy Physics - Theory

De Sitter Space and the Swampland

Georges Obied, Hirosi Ooguri, Lev Spodyneiko, Cumrun Vafa

(Submitted on 21 Jun 2018 (v1), last revised 17 Jul 2018 (this version, v3))

It has been notoriously difficult to construct a meta-stable de Sitter (dS) vacuum in string theory in a controlled approximation. This suggests the possibility that meta-stable dS belongs to the swampland. In this paper, we propose a swampland criterion in the form of $|\nabla V| \geq c \cdot V$ for a scalar potential V of any consistent theory of quantum gravity, for a positive constant c. In particular, this bound forbids dS vacua. The existence of this bound is motivated by the abundance of string theory constructions and no-go theorems which exhibit this behavior. We also extend some of the well-known no-go theorems for the existence of dS vacua in string theory to more general accelerating universes and reinterpret the results in terms of restrictions on allowed scalar potentials.

Comments: 22 pages, 1 table; added references

Subjects: **High Energy Physics - Theory (hep-th)**

Cite as: **arXiv:1806.08362 [hep-th]**

(or **arXiv:1806.08362v3 [hep-th]** for this version)

Submission history

From: Georges Obied [view email]

[v1] Thu, 21 Jun 2018 18:00:01 UTC (21 KB)

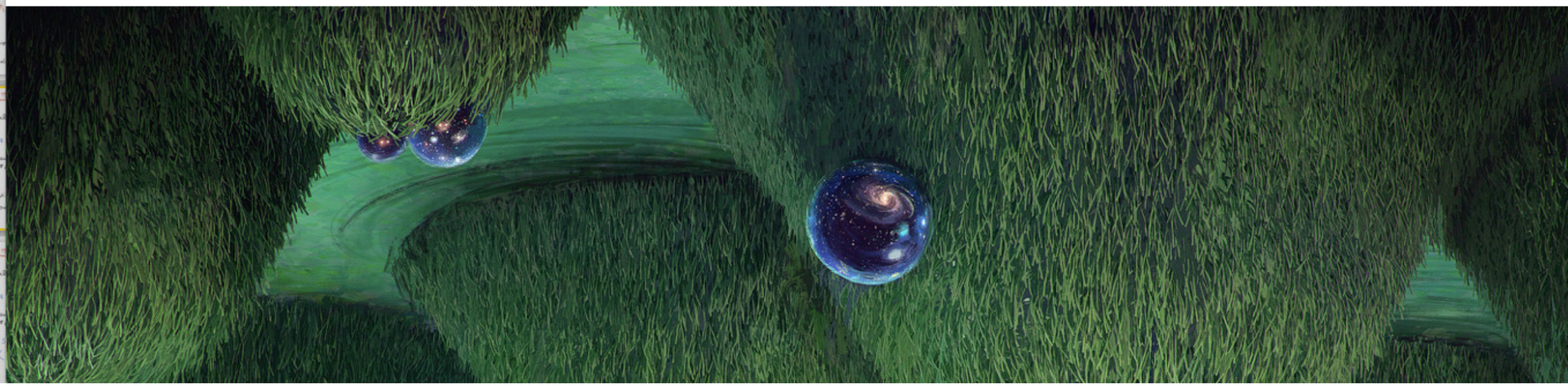
[v2] Wed, 11 Jul 2018 03:22:04 UTC (22 KB)

[v3] Tue, 17 Jul 2018 08:44:22 UTC (22 KB)

THEORETICAL PHYSICS

Dark Energy May Be Incompatible With String Theory

A controversial new paper argues that universes with dark energy profiles like ours do not exist in the "landscape" of universes allowed by string theory.



SPACE

String Theory May Create Far Fewer Universes Than Thought

Some physicists claim the popular landscape of universes in string theory may not exist

By Clara Moskowitz on July 30, 2018 أعرض هذا باللغة العربية

de Sitter swampland conjecture

[Obied - Ooguri - Spodyneiko - Vafa '18]

V : total potential of an EFT

$$M_{pl} \left| \nabla V \right| \geq c \, V$$

M_{pl}: Planck scale $\sim 2 \times 10^{18}$ GeV

c: $\mathcal{O}(1)$ const.

de Sitter swampland conjecture

[Obied - Ooguri - Spodyneiko - Vafa '18]

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$$M_{pl} \, |\nabla V| \geq c \, V$$

M_{pl}: Planck scale $\sim 2 \times 10^{18}$ GeV

c: $O(1)$ const.

$\rightsquigarrow$ de Sitter vacua ruled out

$$(\nabla V = 0, \; \underset{\Lambda}{\underset{\parallel}{V}} > 0)$$

Problem

the conjecture $(|\nabla V| \geq cV)$ rules out

$$\nabla V = 0, \quad \nabla^2 V < 0, \quad V > 0$$

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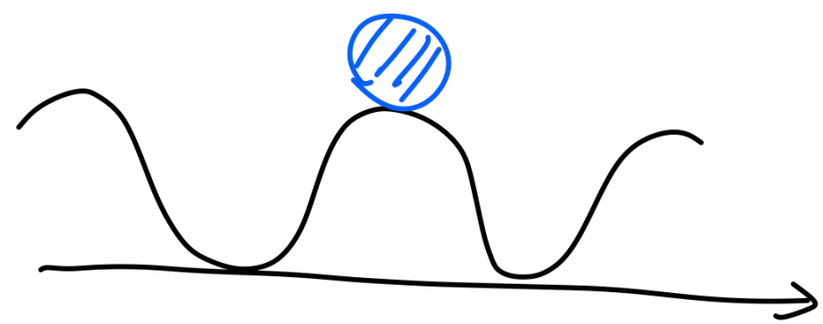
e.g. Higgs

$$V_H(H) = \lambda(H^2 - v^2)^2$$

axion

$$V_a(a) = \Lambda^4\left(1 - \cos\frac{a}{f_a}\right)$$



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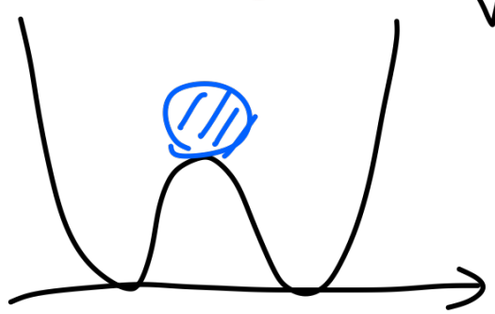
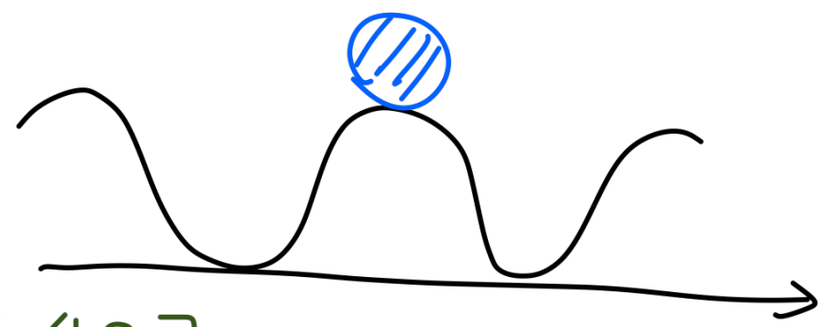


axion $V_a(a) = \Lambda^4\left(1 - \cos\frac{a}{f_a}\right)$



in [Murayama-Yanagida-Y '18]

many loopholes closed

e.g.
- no-go thm against EW modification
- fifth force constraint
- m_p/m_e time dependence ....

See also [Denef-Hebecker-Wrase, Choi-Chwang-Shin, Hamaguchi-Ibe-Moroi '18]

refinement of dS conjecture?

[Murayama - Yanagida - Y '18]

$$M_{pl}|\nabla V| \geq c\, V \quad \text{when} \quad \nabla^2 V > 0$$

[Garg - Krishnan, Ooguri - Shiu - Palti - Vafa '18]

$$M_{pl}|\nabla V| \geq \underset{\text{positive } O(1)}{c}\, V \quad \text{or} \quad \min(\nabla^2 V) \leq -\underset{\text{positive } O(1)}{c'}\, V$$

※ still highly speculative

better motivated in asymptotic region

Consistency w/ inflation

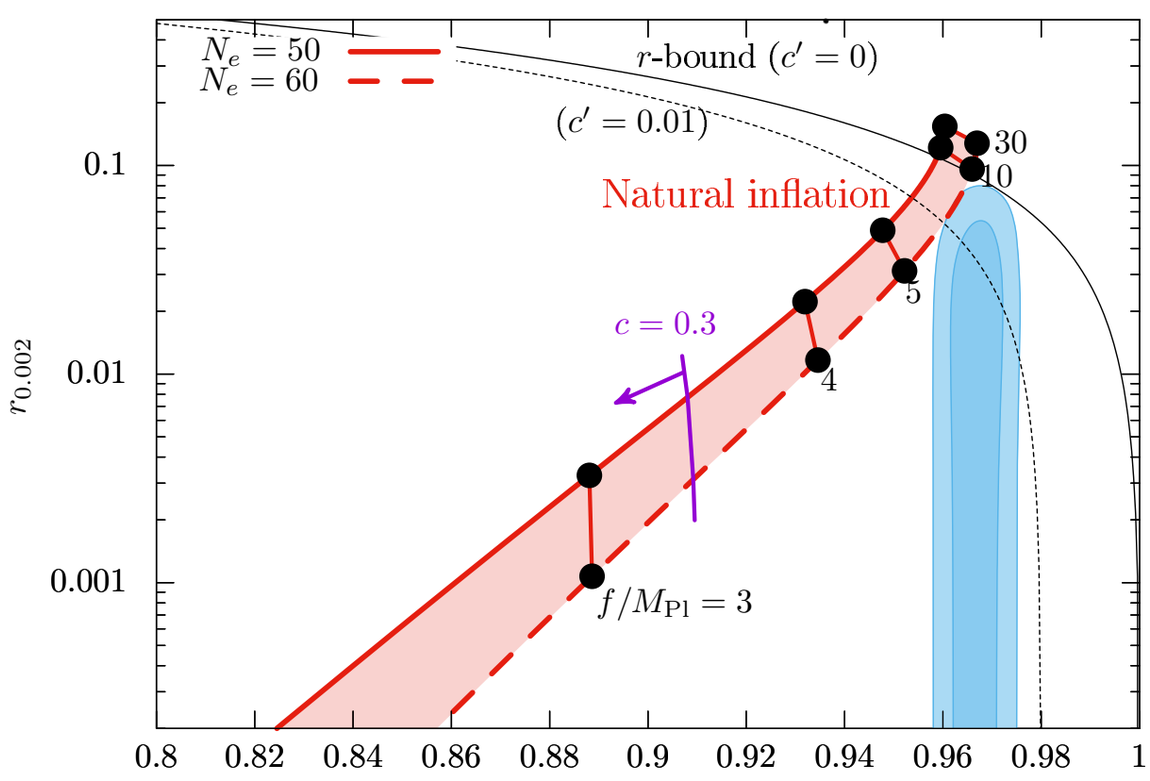
if $c, c' \sim 1$ then [Fukuda-Saito-Shirai-Y '18]

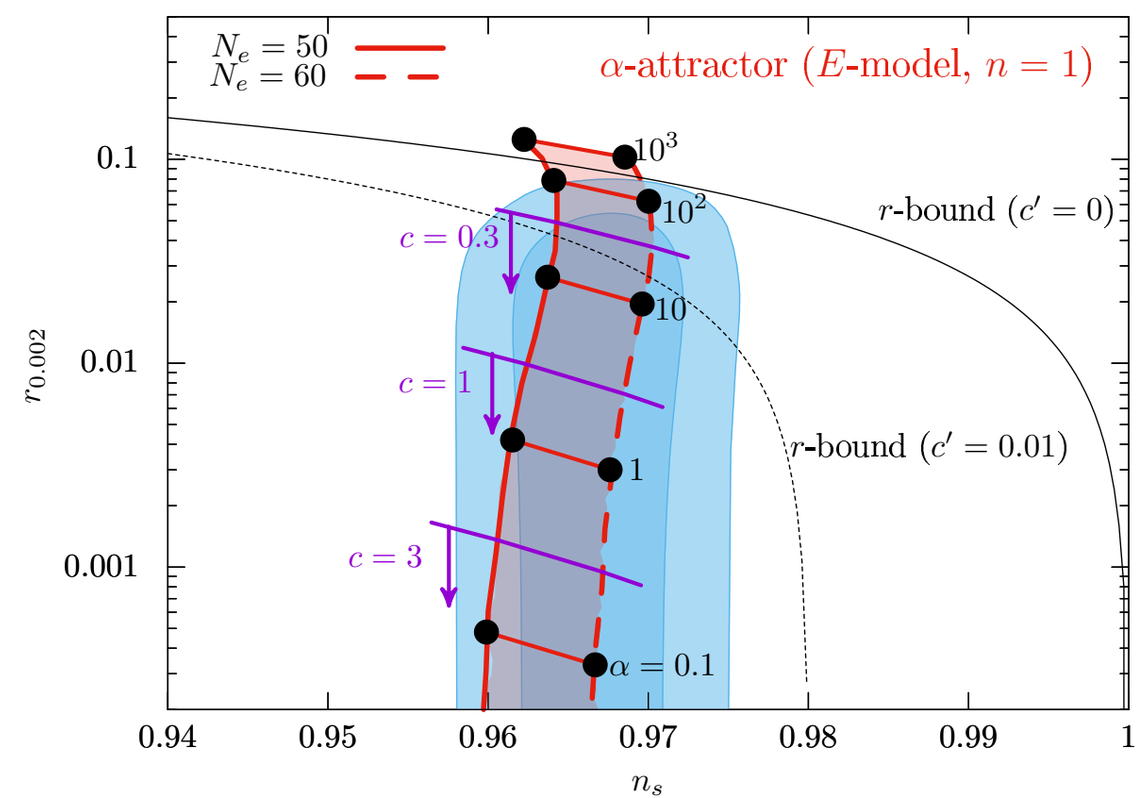
single-field slow-roll
e-fold OK
n_s not good

⇝

multi-field
hilltop curvaton ?
constraints from f_{NL}

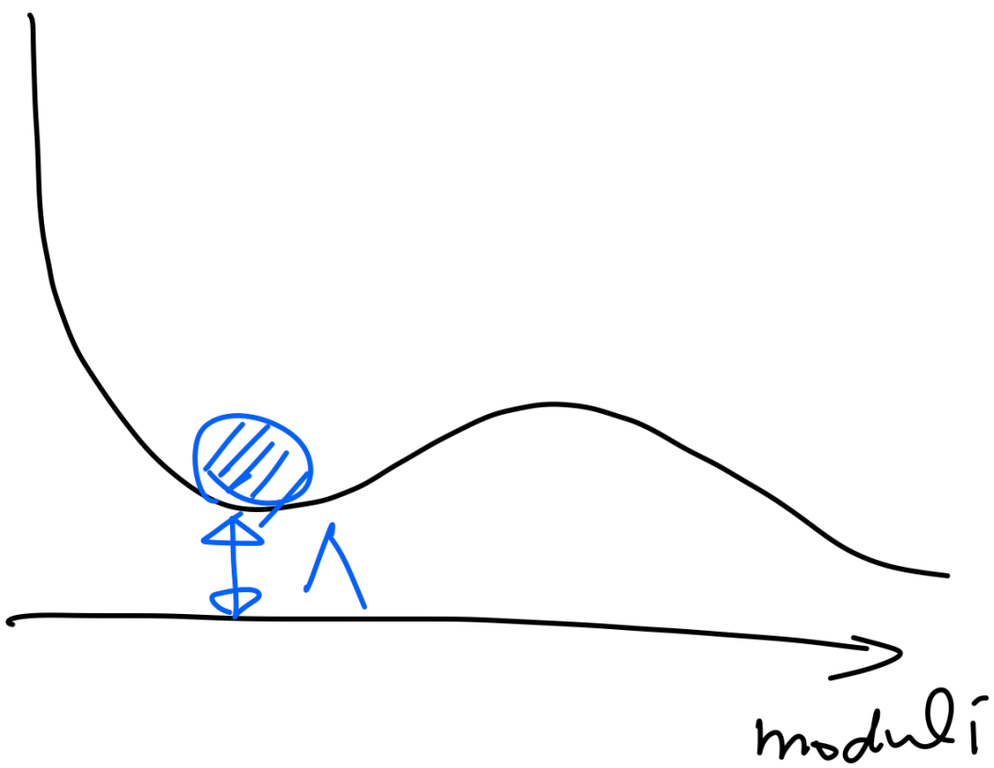
※ we can keep c, c' as parameters and derive constraints





$\Lambda^4 \sim 10^{-120} M_{pl}^4$?

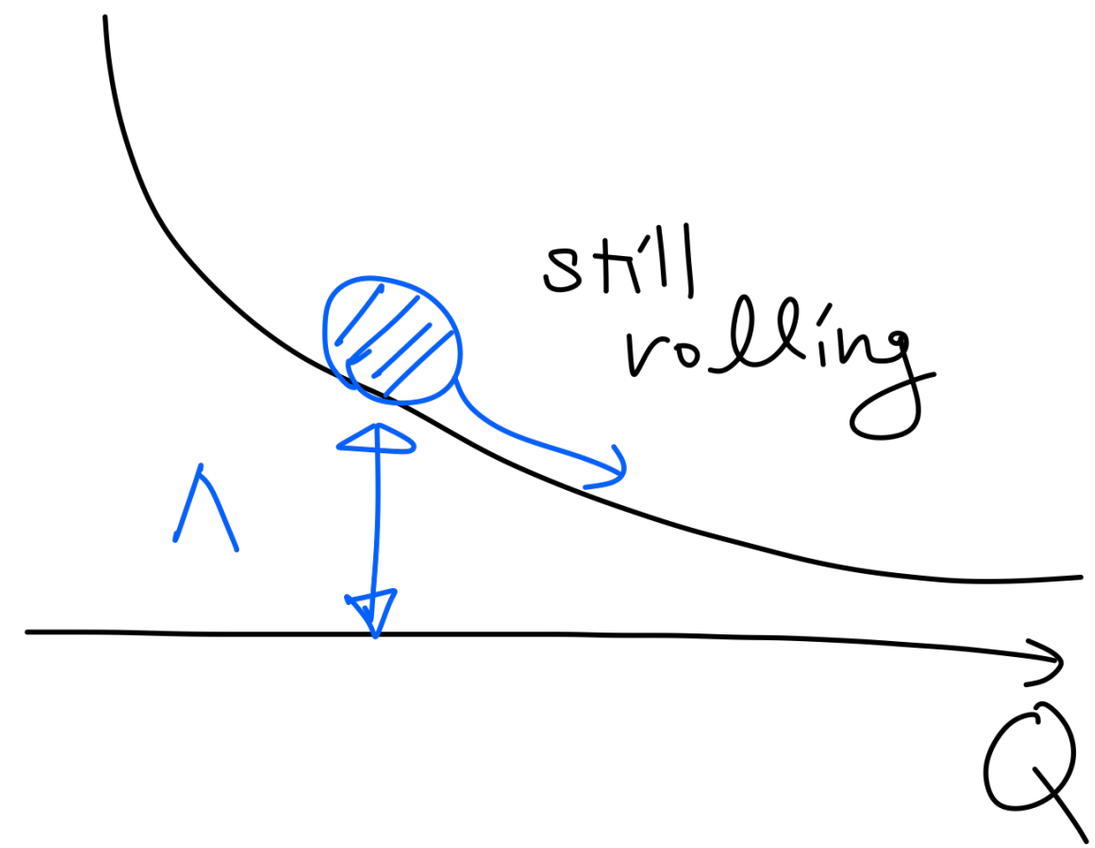
c.c.



refined dS conjecture

↙

quintessence



measure $\omega = \frac{p}{\rho}$!

DES, HSC, DESI, PFS, LSST, WFIRST, Euclid, ...

EW quintessence axion ?

$$\mathcal{L} = \underbrace{\frac{a}{32\pi^2 f_a}}_{\theta\text{-angle}} \mathrm{Tr}\, \underbrace{F^{\mu\nu} F_{\mu\nu}}_{\text{EW } SU(2)}$$

recently
[Ibe-Yanagida-Y '18]
also
[Nomura-Watari-Yanagida '00.
McLerran-Pisarski-Skokov '12]

$$V = \Lambda^4 \left(1 - \cos \frac{a}{f_a}\right)$$

$$\Lambda^4 \sim M_{pl}^4\, e^{-\frac{4\pi}{\alpha_2(M_{pl})}} \sim 10^{-130} M_{pl}^4 \;!!$$

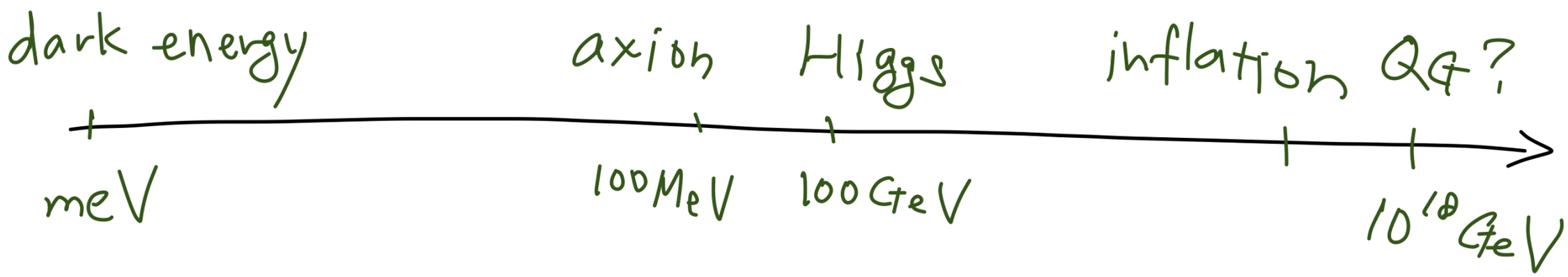
motivated from dS conjecture

[※ close-to-hilltop for $m \sim \frac{\Lambda^2}{f_a} \lesssim H_0$
$f_a \lesssim \mathcal{O}(M_{pl})$
fine-tuning better for SUSY extension]

Summary

- Swampland conjectures :

attempt for extracting universal consequences of QG in low-energy EFT



Summary

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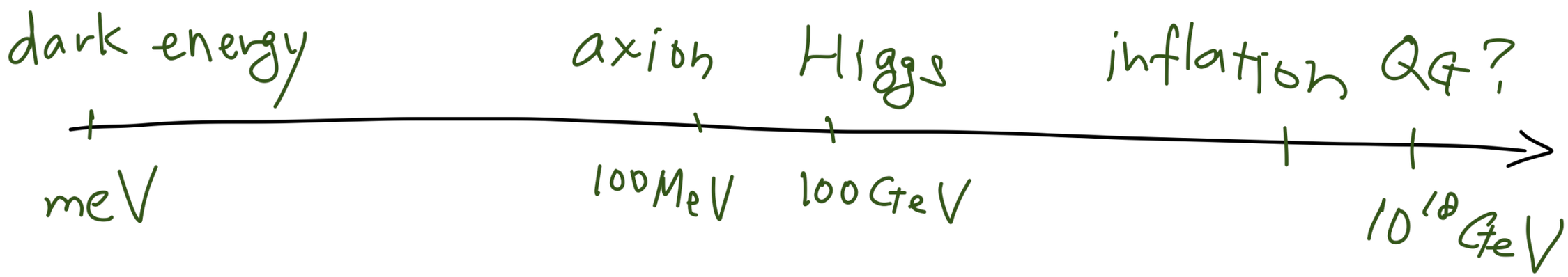
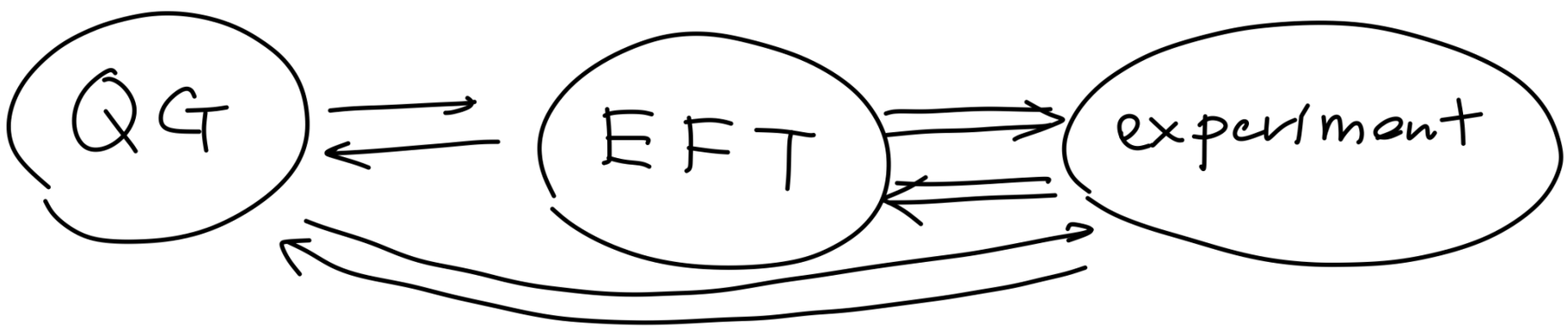
attempt for extracting universal consequences of QG in low-energy EFT



- We can learn from non-discoveries !



QG session in Moriond 20XX ?

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Rencontres de Moriond

March 16 - 23
Electroweak Interactions and Unified Theories

March 23 - 30
QCD and High Energy Interactions

March 16 - 23
Quantum Mesoscopic Physics

March 16-23
Quantum Gravity

March 23 - 30
Gravitation