Outlook:
Is Supersymmetry enough?

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SUSY 2018
Barcelona, July 2018

Why Supersymmetry?

Theoretical:

1) It is the most general symmetry of the S-matrix

2) Nima's argument: spins in nature so far:

$$1/2 \;,\; 1 \;, \qquad ,2$$

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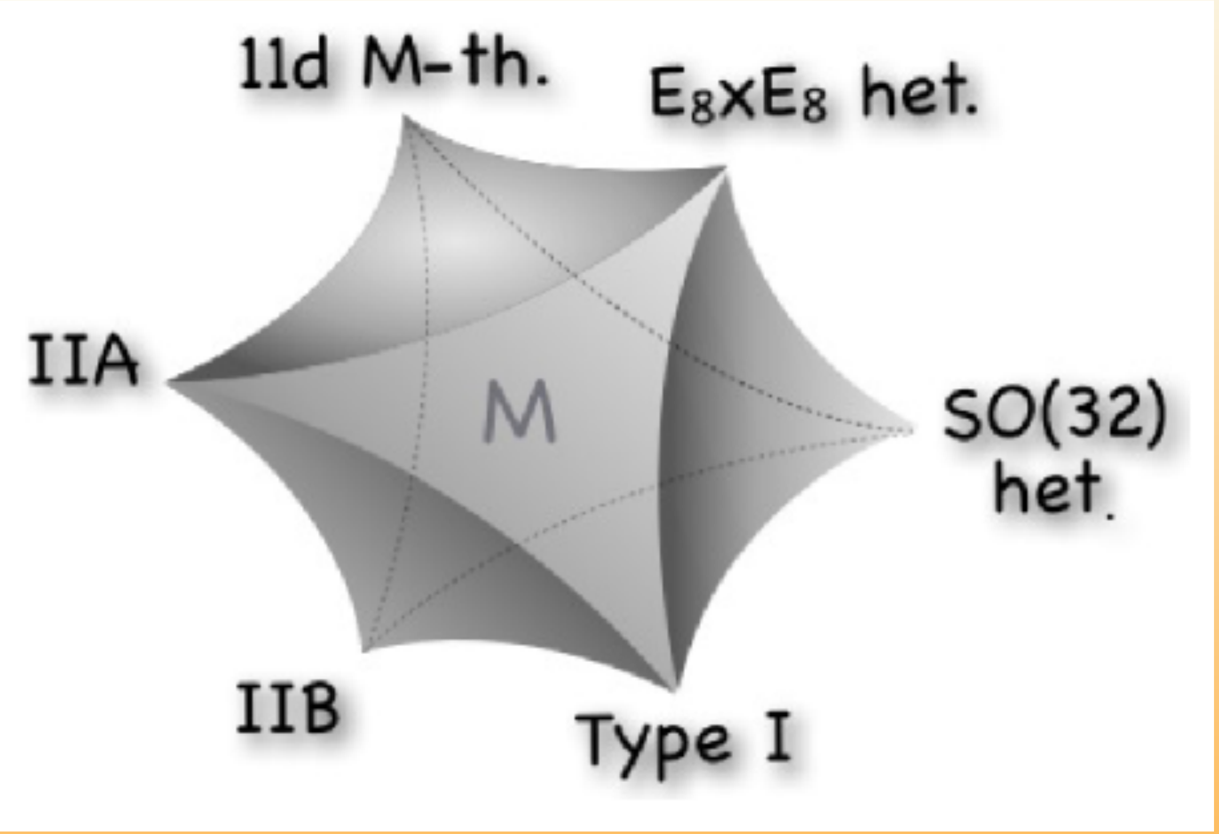
2) Nima's argument: spins in nature so far:

0 , 1/2 , 1 , 3/2 ,2

3) It is a fundamental ingredient of String Theory

String-M-Theory

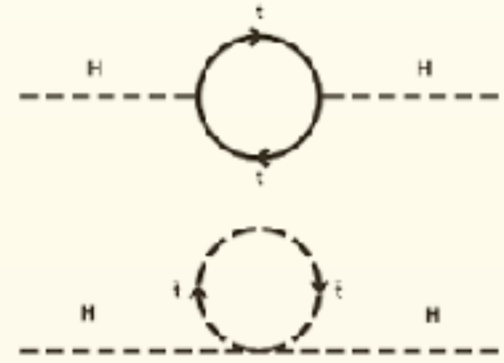


Maximal supersymmetry: 32 SUSY generators

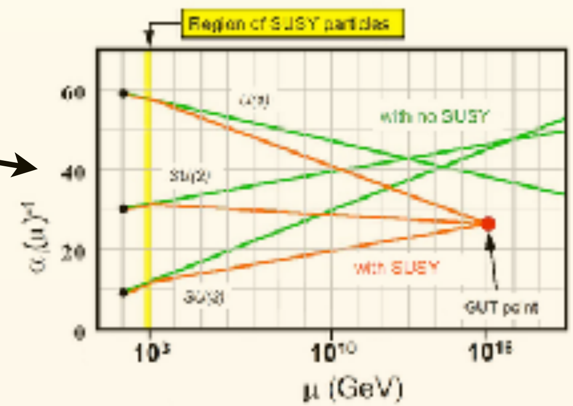
Compactified to 4D: N=1 may survive (or not)

But SUSY recovered at sufficiently high energy

Low energy Supersymmetry:



- 1) Stabilizes the Higgs mass
- 2) Accurate gauge coupling unification

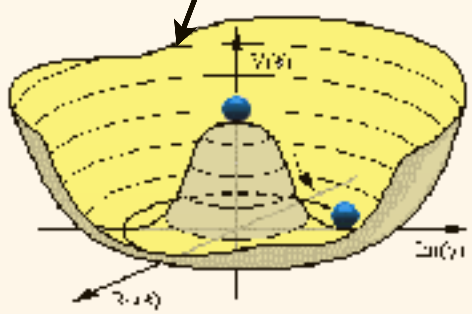


- 3) Neutralinos candidates for dark matter

- 4) Predicts the existence of fundamental scalars (and the Higgs looks like one)

$$\lambda = \frac{m_H^2}{M_W^2}\frac{g_2^2}{4} \simeq 0.27$$

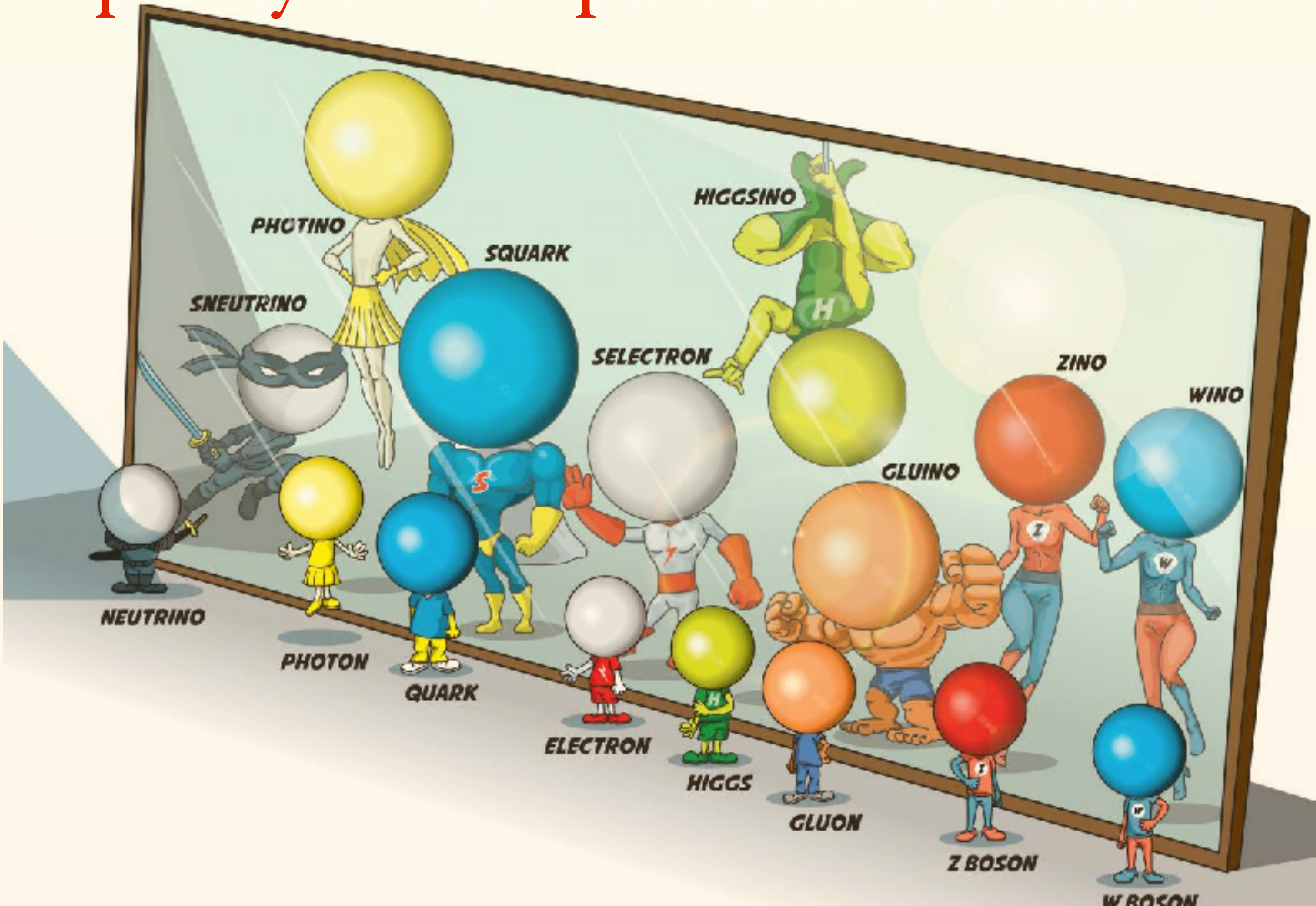
$$(compared\ to\ g_1^2 = 0.11\ ,\ g_2^2 = 0.42)$$



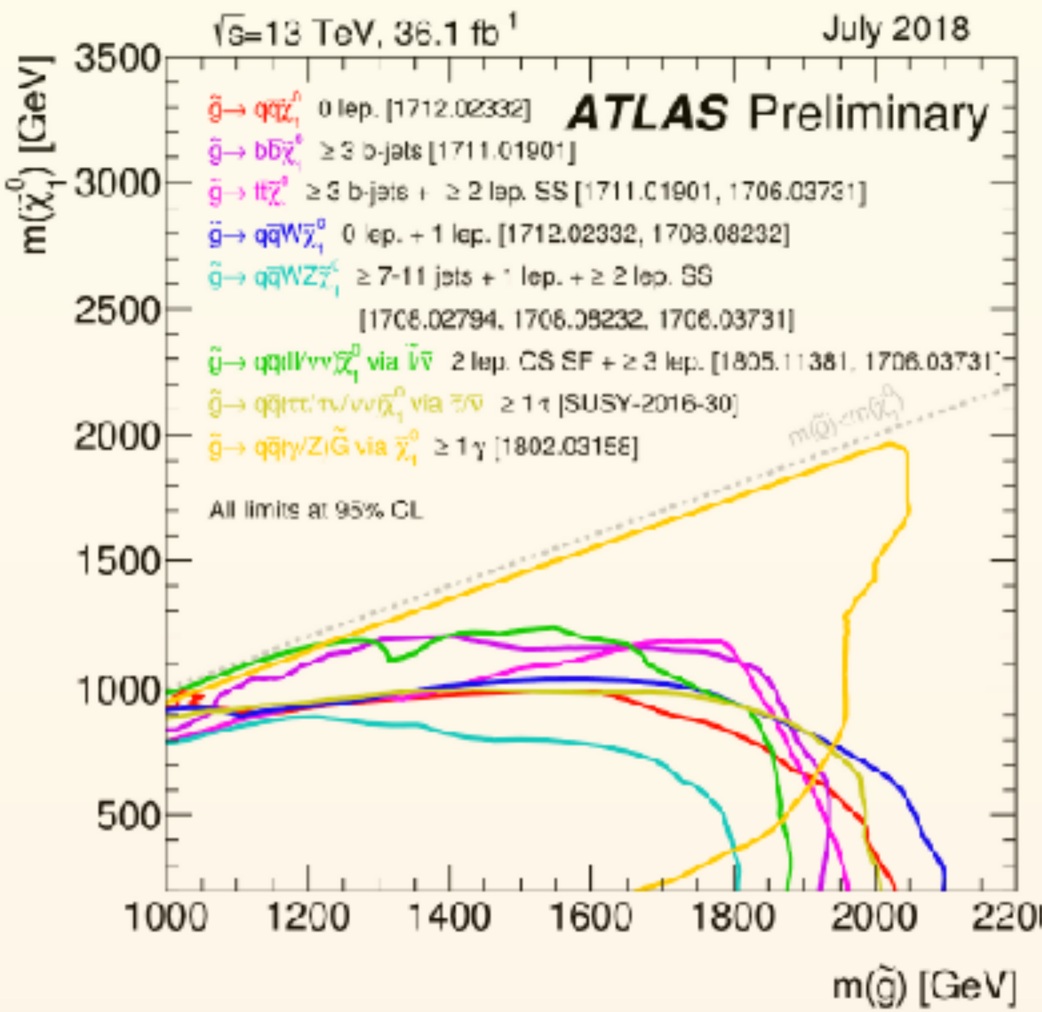
$$125\ GeV \leq 135\ GeV$$

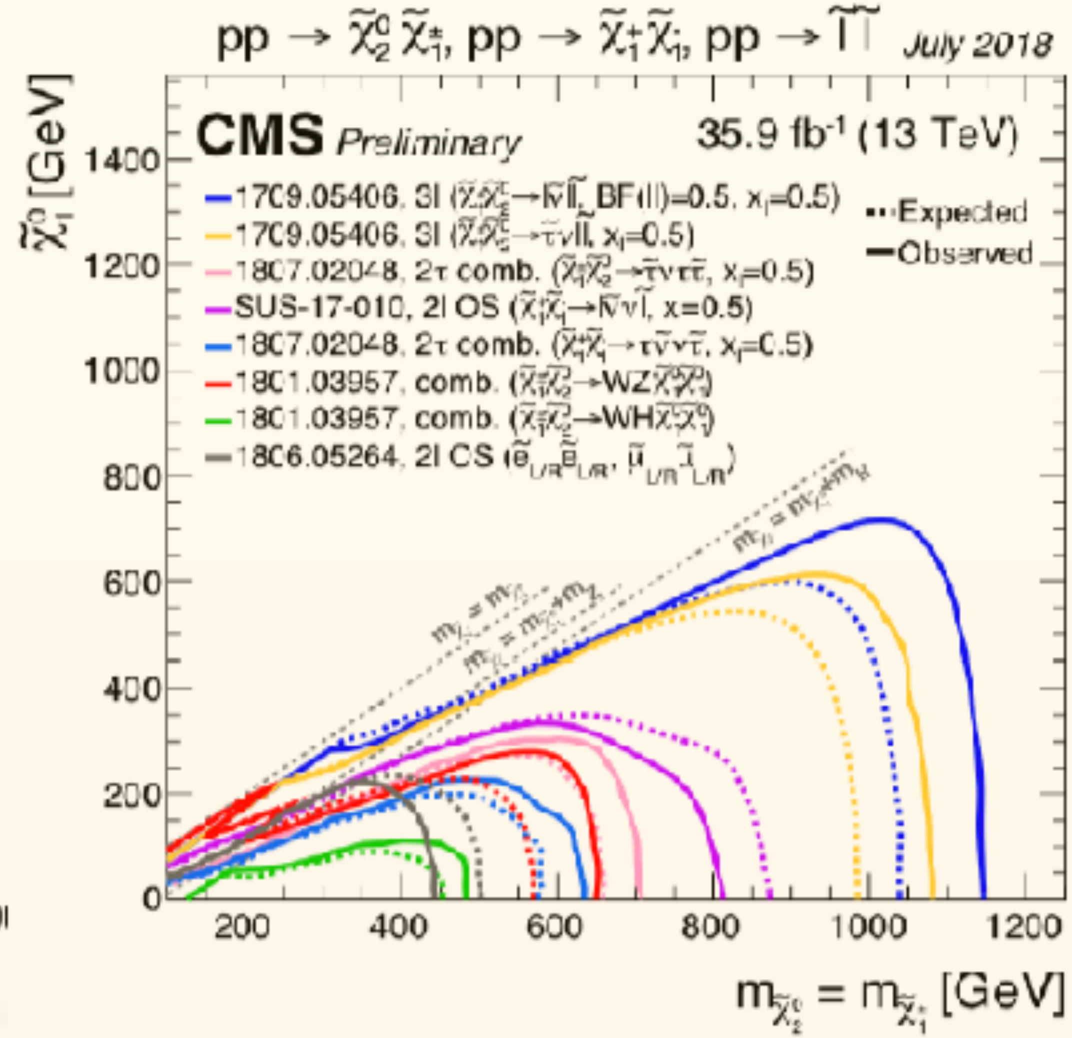
Consistent with SUSY!!

...plenty of new particles to discover



$m_{\tilde{g}} \gtrsim 2\ TeV$ $m_{\chi_1} \lesssim 0.8\ TeV$

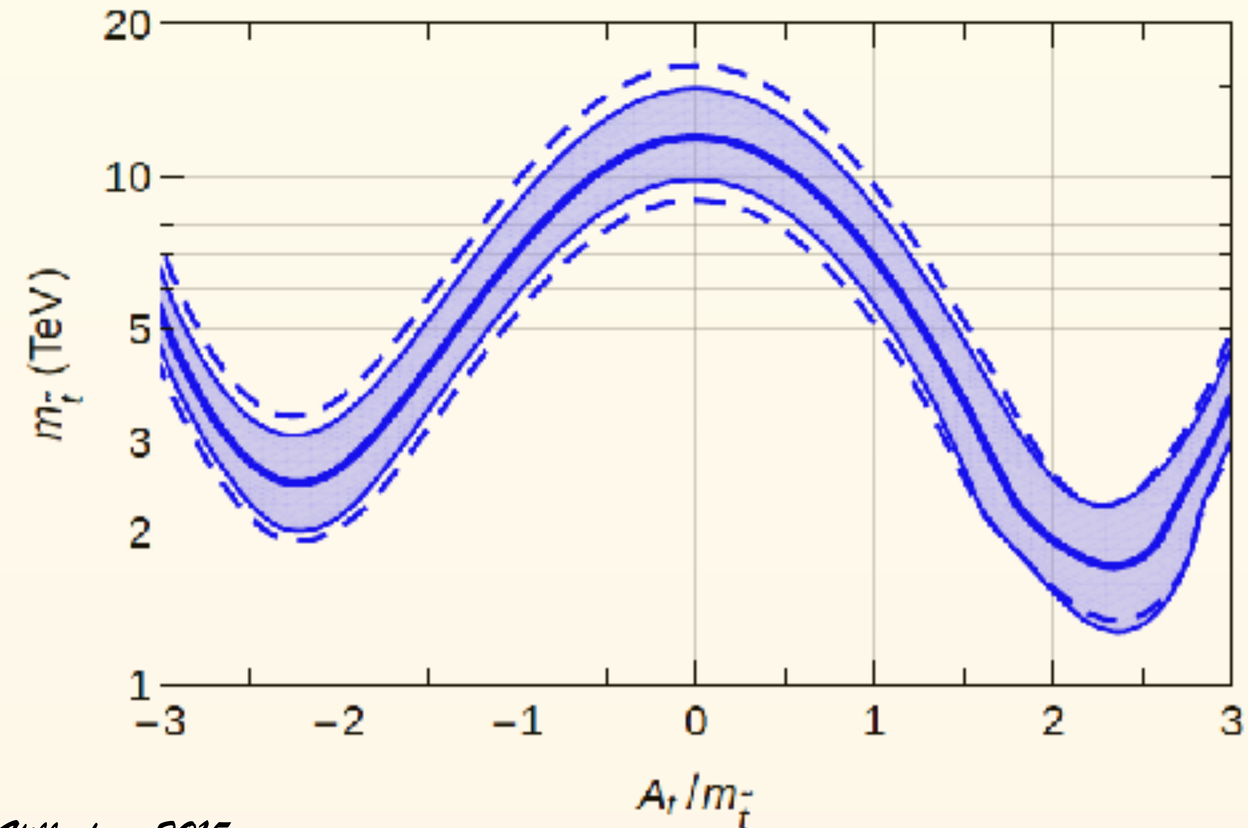




No trace so far!!

See M. Reece talk

$m_H \simeq 125\ GeV$



Pardo,Villadoro 2015

Figure 5: *Allowed values of the OS stop mass reproducing $m_h = 125$ GeV as a function of the stop mixing, with $\tan\beta = 20$, $\mu = 300$ GeV and all the other sparticles at 2 TeV. The band reproduce the theoretical uncertainties while the dashed line the 2σ experimental uncertainty from the top mass. The wiggle around the positive maximal mixing point is due to the physical threshold when $m_{\tilde{t}}$ crosses $M_3 + m_t$.*

Independently of LHC limits,

implies heavy sparticles….

My expectations 35 years ago.....

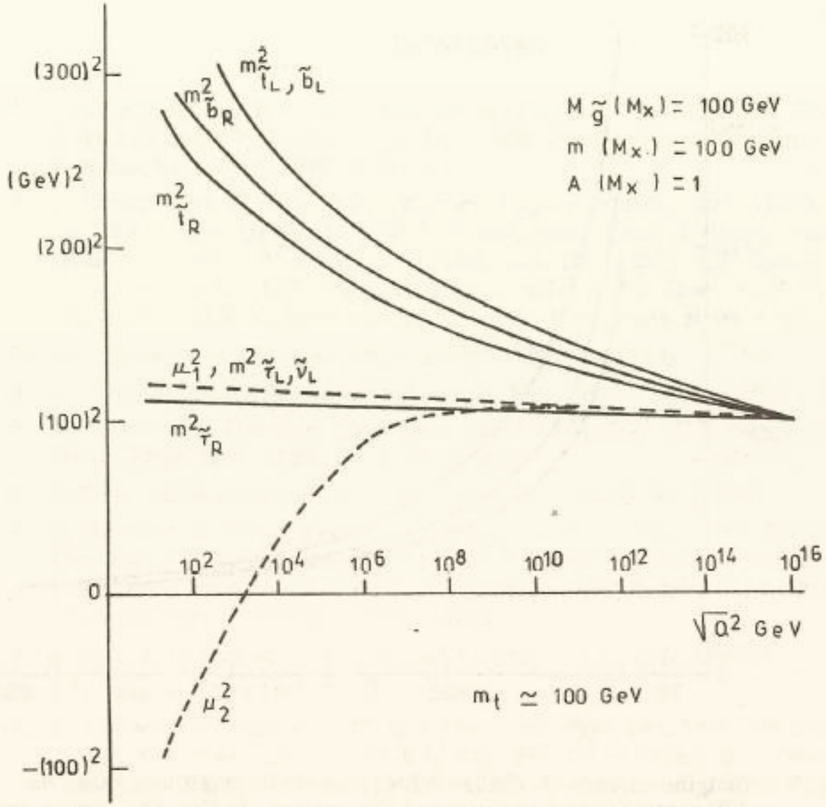


Figure 1. Evolution of the $(\text{mass})^2$ of scalars as a function of the scale. The results correspond to the boundary conditions at $M_x : m = M_t = M_{\tilde{g}} = 100 GeV$. $Su(2) \times U(1)$ is broken at the right energy for a top quark mass $m_t \simeq 100 GeV$.

can manage to break SU(2) x U(1) with smaller gaugino masses. In any case the lower bound for the top quark mass applies:

$$m_t \gtrsim 55\ GeV$$

If renormalized gluino masses are lighter than $\sim 100\ GeV$, one needs $m_t \gtrsim 100\ GeV$ (in general even larger values) in order to get SU(2) x U(1) breaking at the appropriate scale.

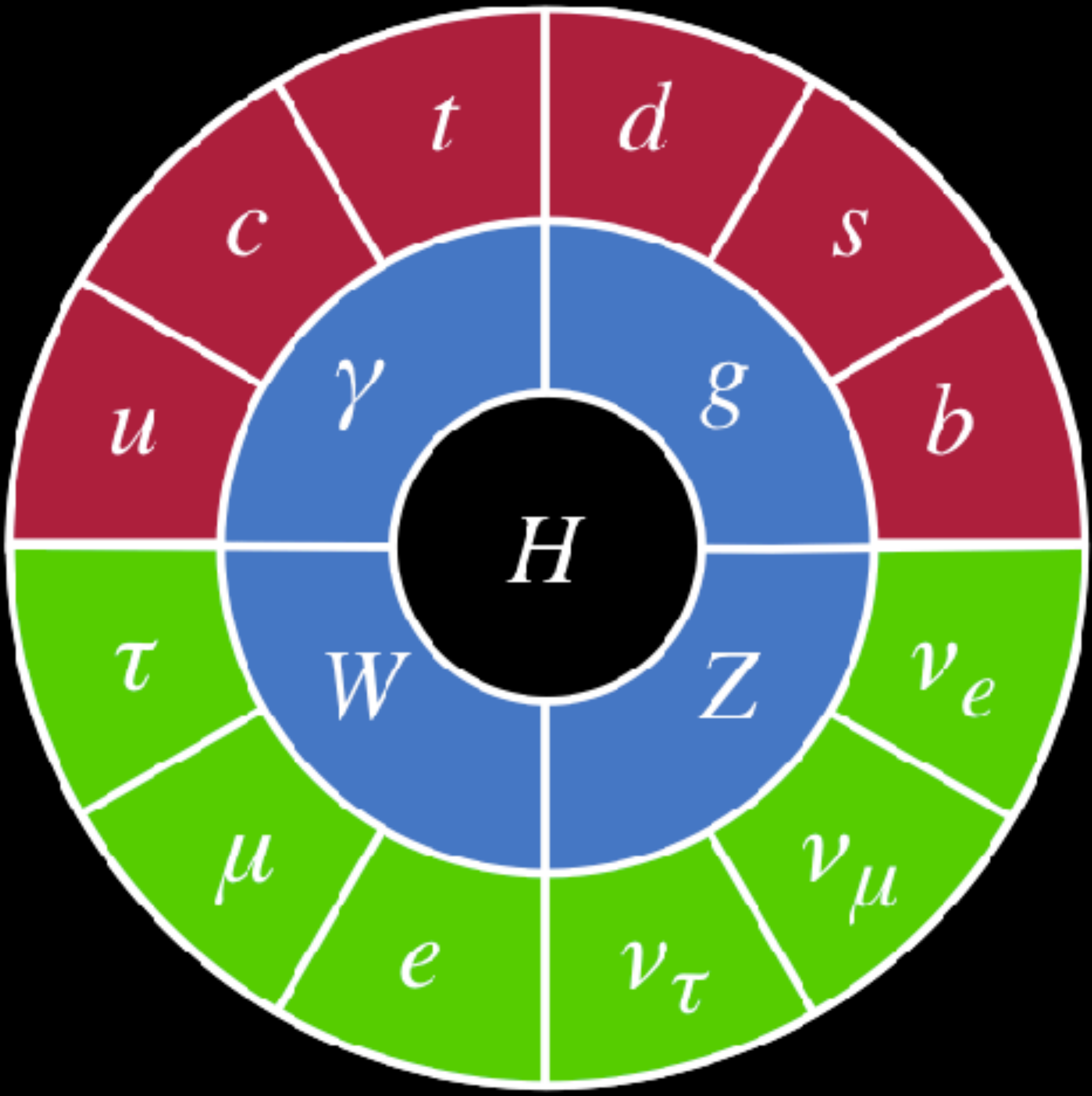
The supersymmetric particle spectrum in this supergravity scheme is very similar to the one in radiative global susy-GUT's.[6-8] Since all the squarks and sleptons of different families will be (approximately) degenerate there are negligible flavor changing neutral currents. The only novel feature at low energies is the existence of the trilinear scalar couplings associated to each Yukawa coupling. These may have interesting phenomenological consequences.

Let us finally remark that this scheme for SU(2) x U(1) breaking is indeed very similar to the one proposed in Reference 3 in the context of global susy-

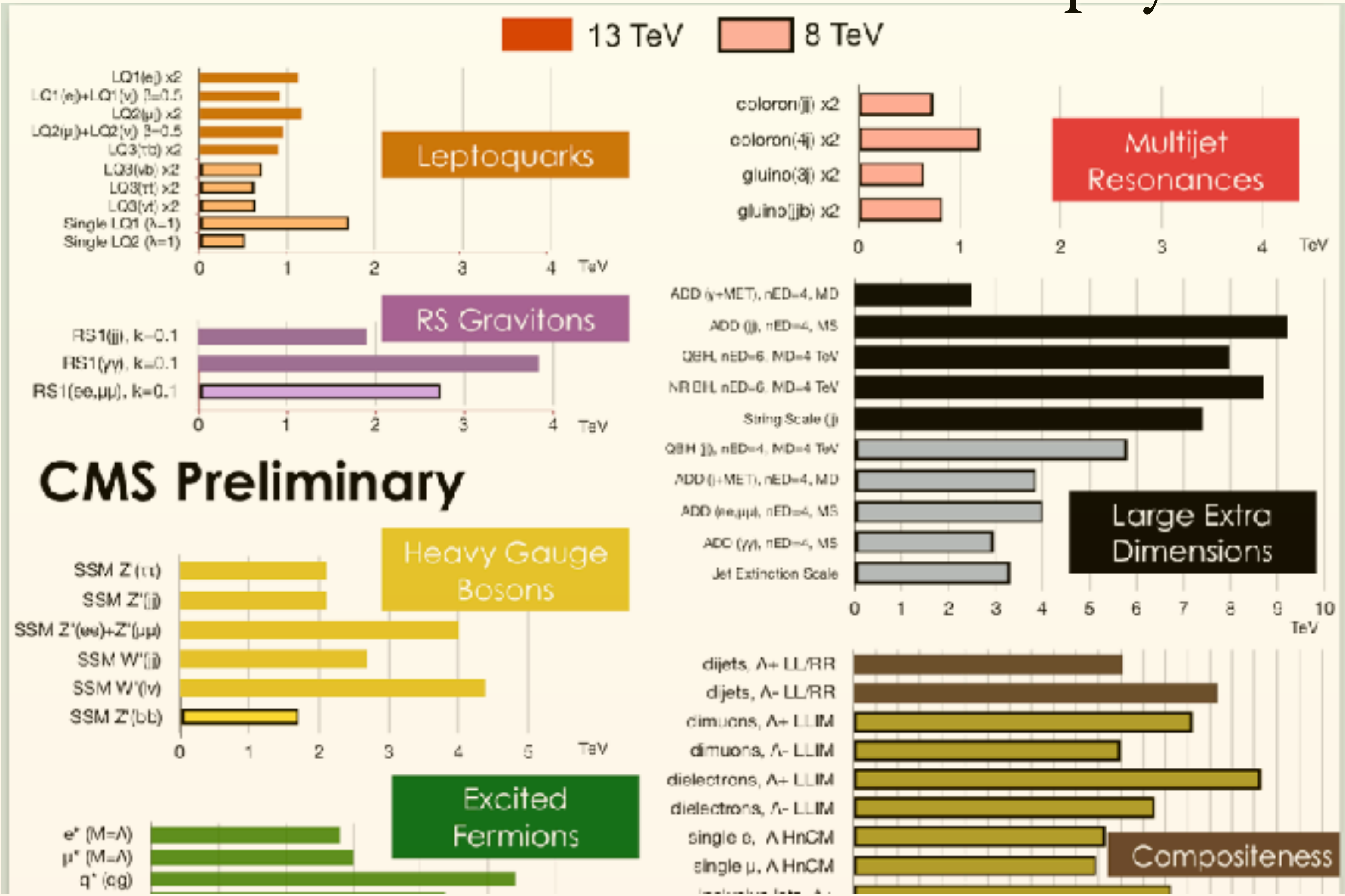
$$m_{\tilde{q}}, M_{gluino}, \ldots \sim 300\ GeV$$

L.I in proceedings of
'Problems in Unification and
Supergravity' , La Jolla, January 1983

The SM rules!



No hint either for alternative new physics



But negative experimental results are also very important!

(Recall Michelson-Morley: NO aether)

SUSY (be patient)

SUSY (non-minimal)

RPV

Technicolor

Relaxion

Composite

LED

Clockwork

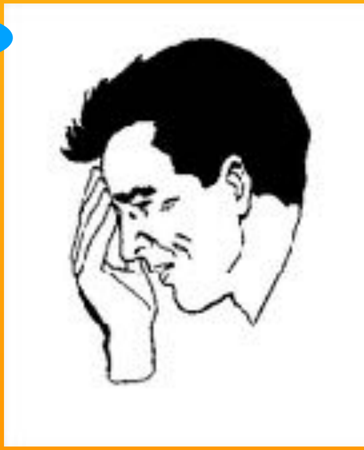
Twin H

Conformal

LST

Agravity

RS



See Delgado and Reece talks

SUSY
(non-minimal)

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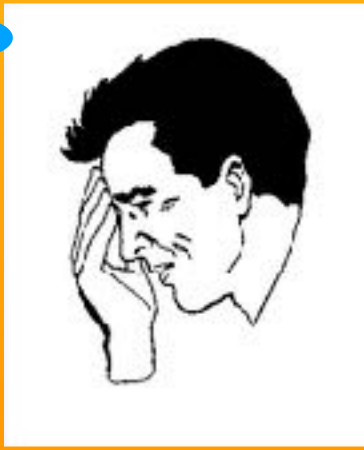


It is important to pursue the quest…

See Delgado and Reece talks

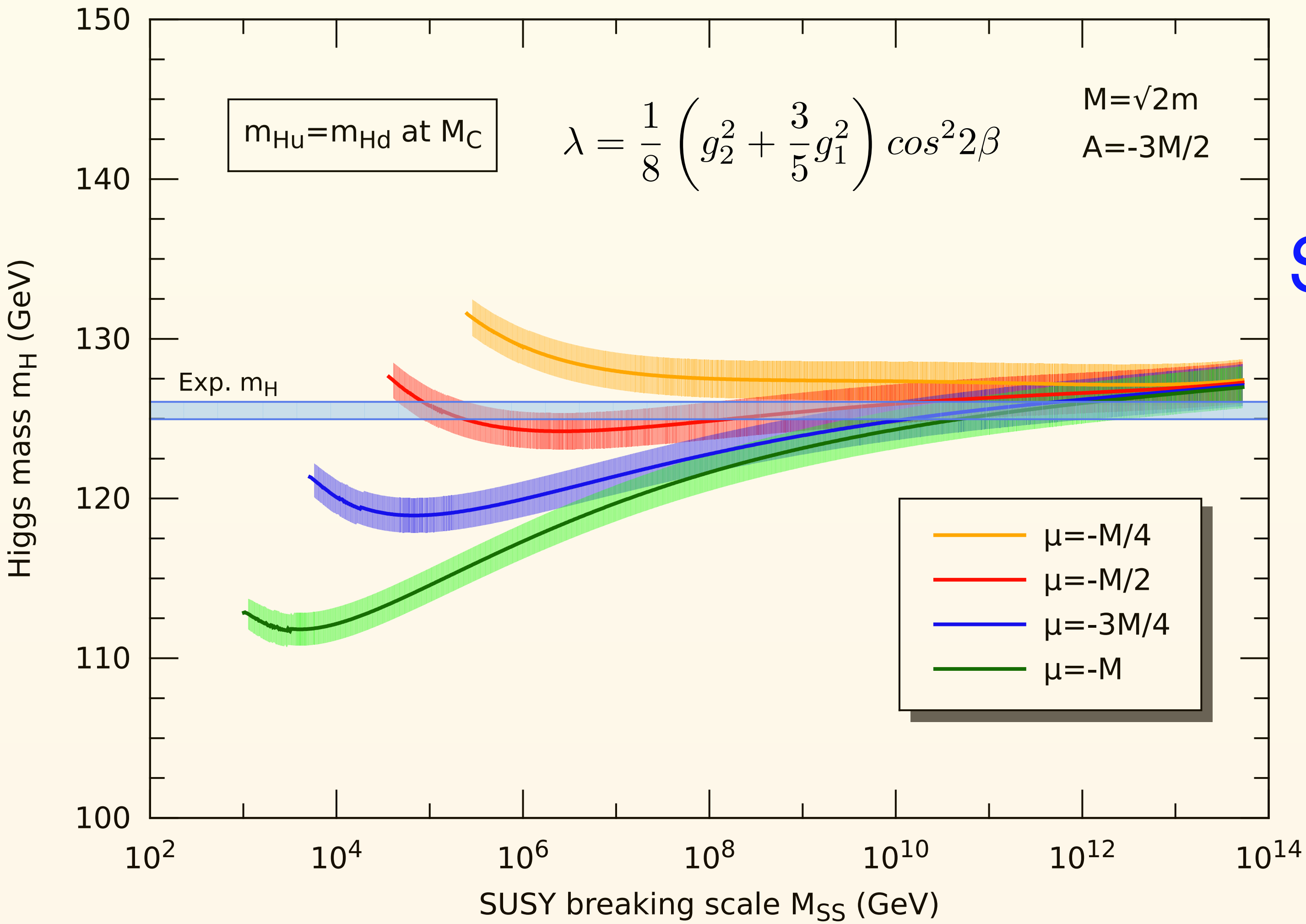
21 Increasingly Crazy Approaches to the Hierarchy Problem

N. Craig,
Paris 2018

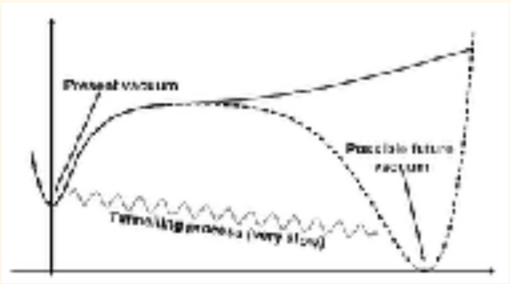
1. Supersymmetry
2. Global symmetry
3. Discrete symmetry
4. RS/Technicolor
5. LED/10^{32}xSM
6. LST/Clockwork
7. Classicalization
8. Disorder
9. Anthropics
10. Relaxation
11. NNaturalness
12. Conformal symmetry
13. Asymptotic fragility
14. Agravity
15. Lee-Wick Theory
16. Non-compact SM
17. Weak gravity conjecture
18. Non-commutative QFT
19. Weak scale from CC
20. AdS magic
21. Self-organized criticality
22. …

Simple option: High Scale SUSY?

Arkani-Hamed, Dimopoulos '04
Hall, Nomura '09



Stabilizes Higgs potential at high scales



L.I. and Valenzuela 2013

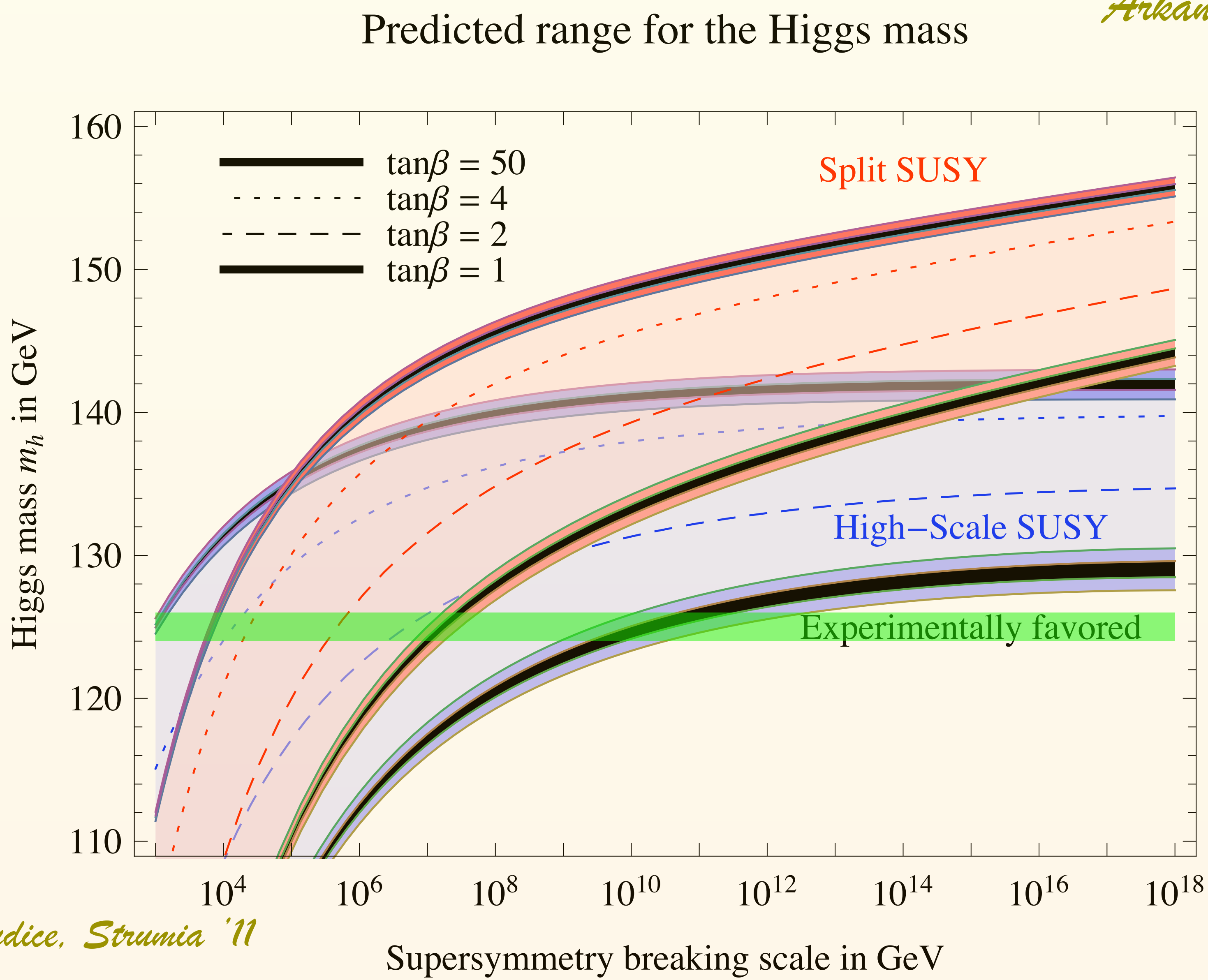
$$For\ M_{SS} \ \geq\ 10^{10}\ GeV \rightarrow m_H \ =\ 126 \pm 3\ GeV$$

Arkani-Hamed, Dimopoulos, 04

Giudice, Romanino '04

Hall and Nomura '11

Arvanitaki et al '12



Giudice, Strumia '11

But fine-tuning then required….

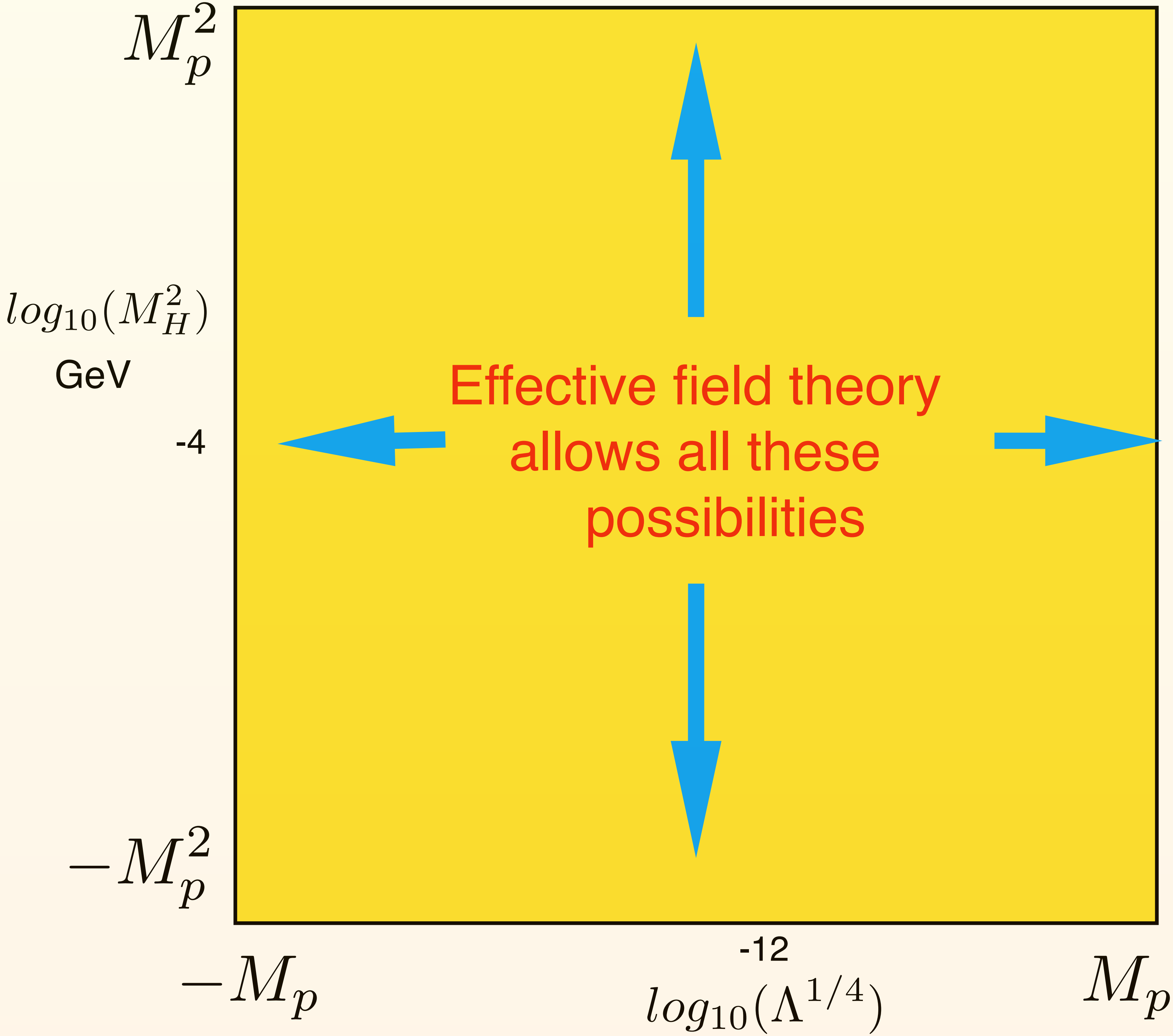
Perhaps SUSY is not enough…..

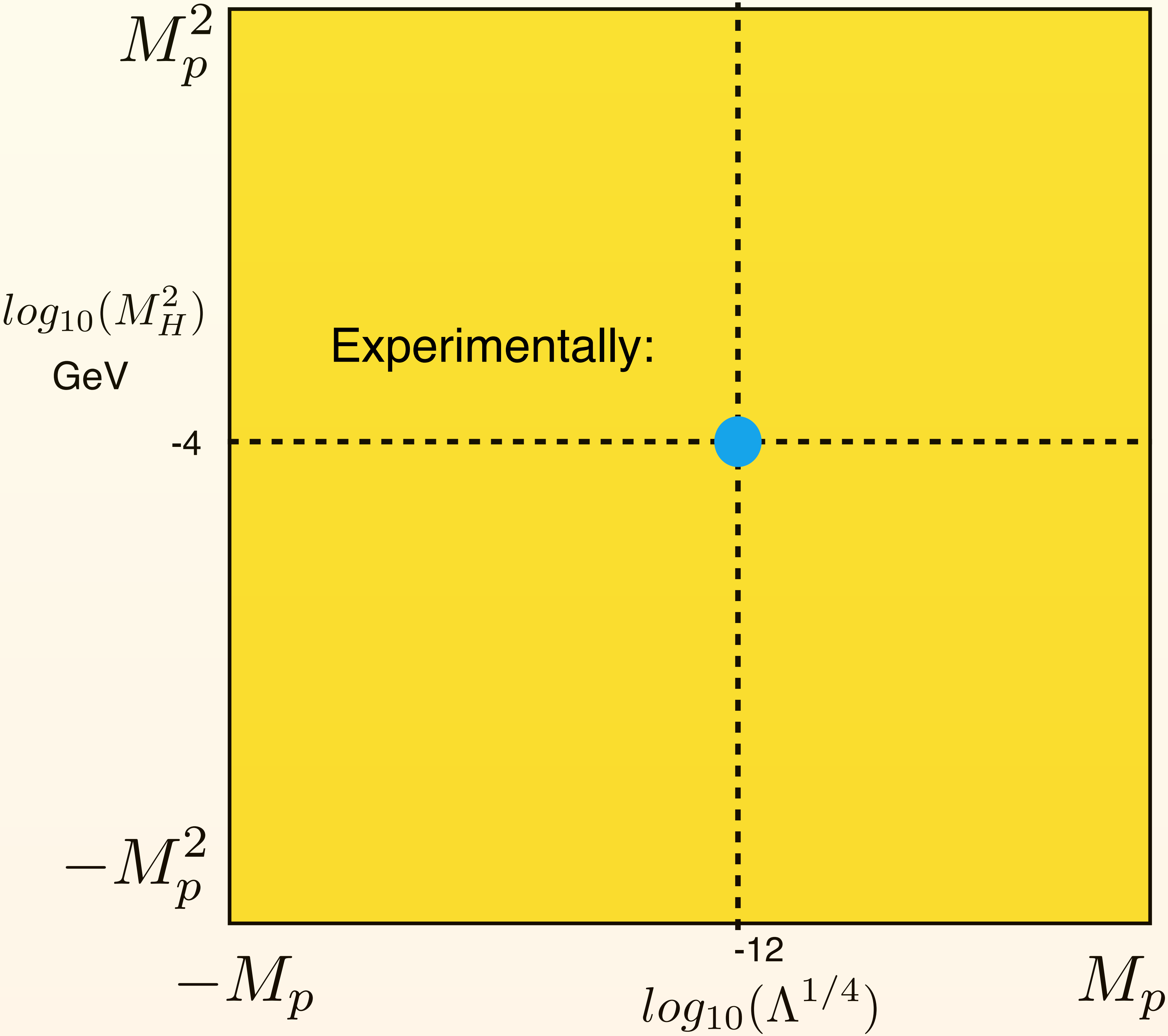
Back to basic questions:

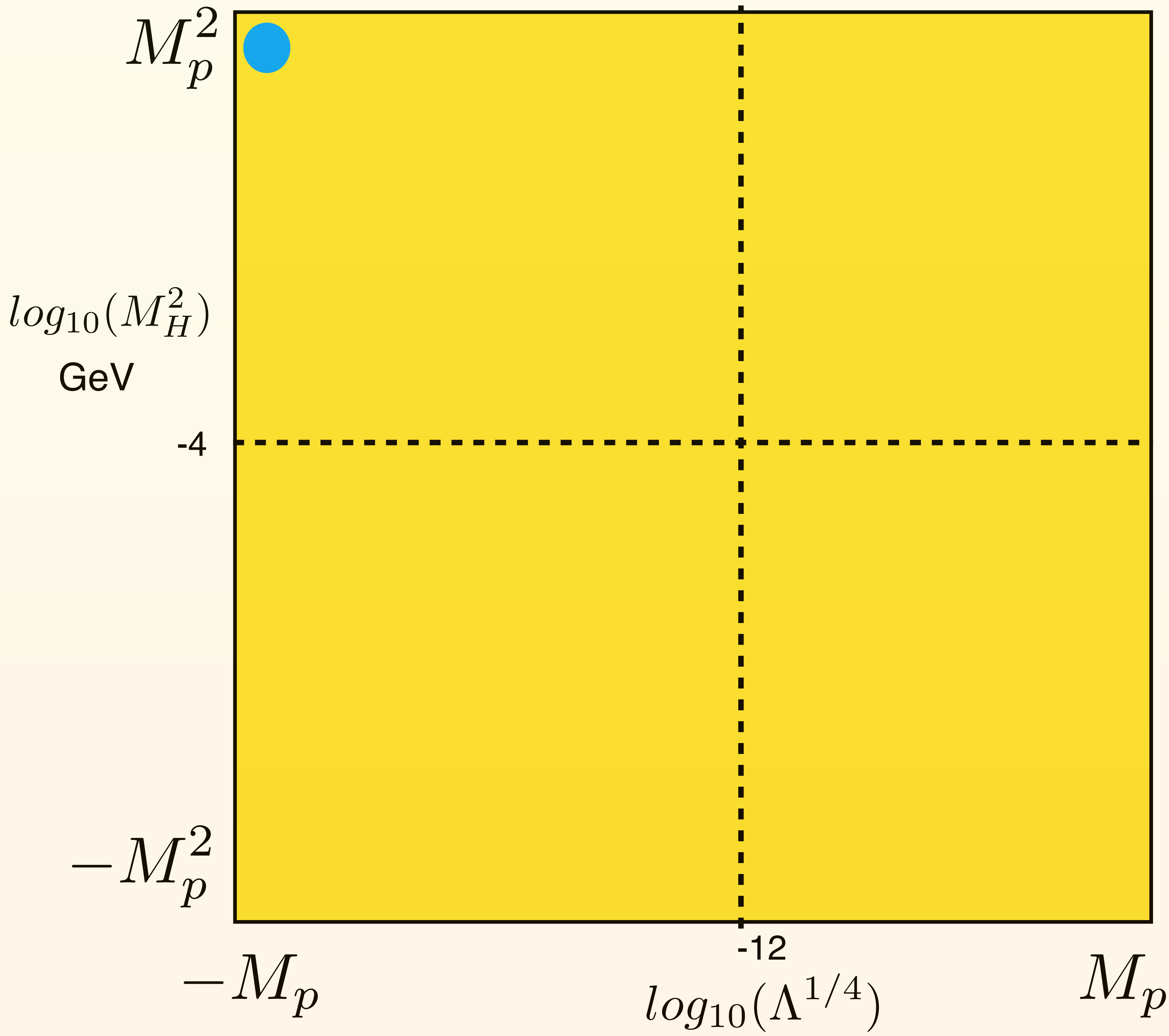
- 1) Why there are three generations?
- 2) Why there is a Higgs?
- 3) Why the EW scale is so small compared to the Planck scale?
- 4) Why the c.c. is so small?
- 5) Is there a reason why $m_\nu \simeq \Lambda_4^{1/4}$?
- 6) Is the naturally criterium right?

The two most offending physical quantities:

$$The\ m_H^2 - \Lambda_4\ plane$$

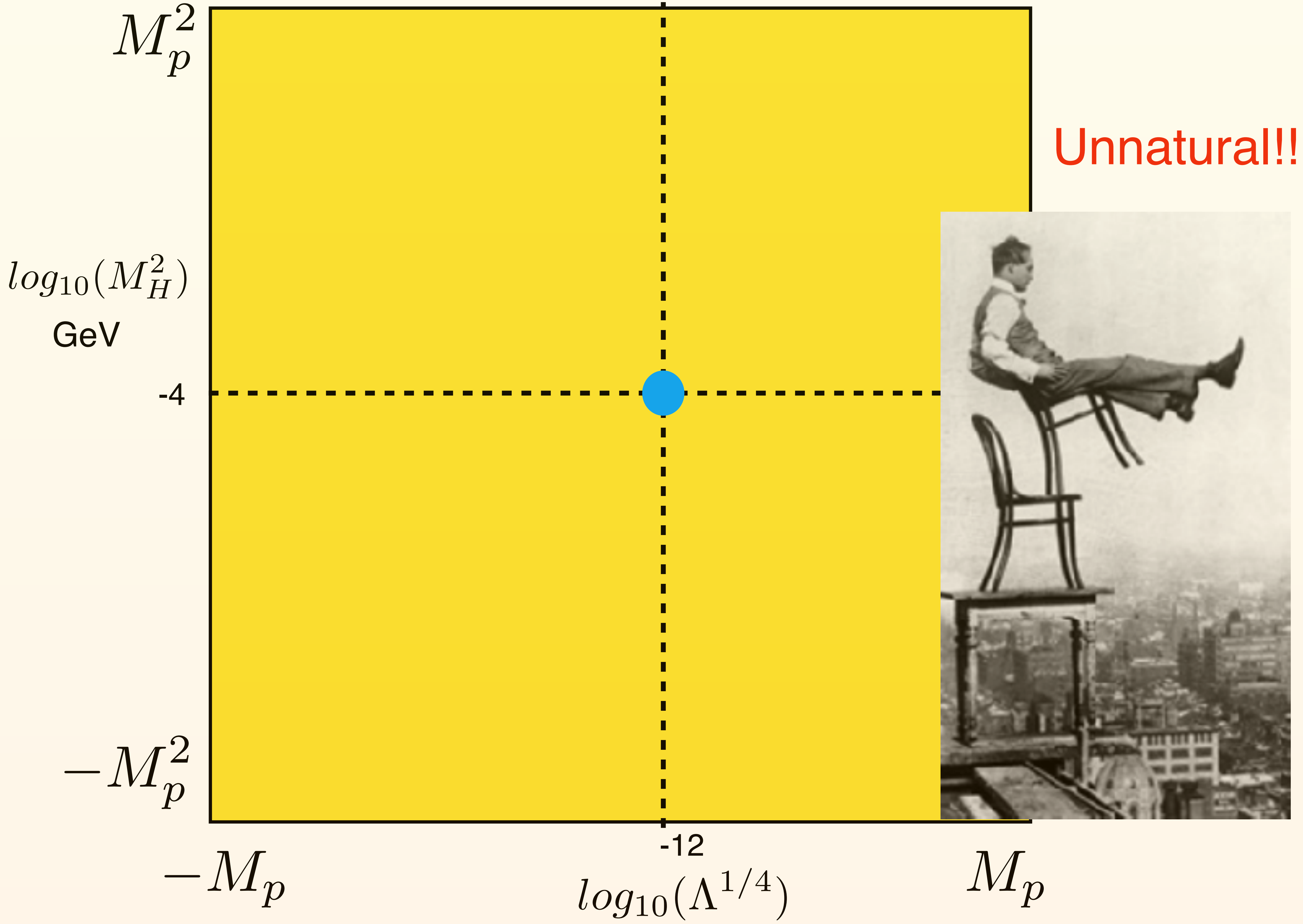

M_p^2
$log_{10}(M_H^2)$
GeV
-4
$-M_p^2$
Effective field theory allows all these possibilities
$-M_p$
-12
$log_{10}(\Lambda^{1/4})$
M_p


M_p^2
$log_{10}(M_H^2)$
GeV
Experimentally:
-4
$-M_p^2$
-12
$-M_p$
$log_{10}(\Lambda^{1/4})$
M_p



Quantum Effects!

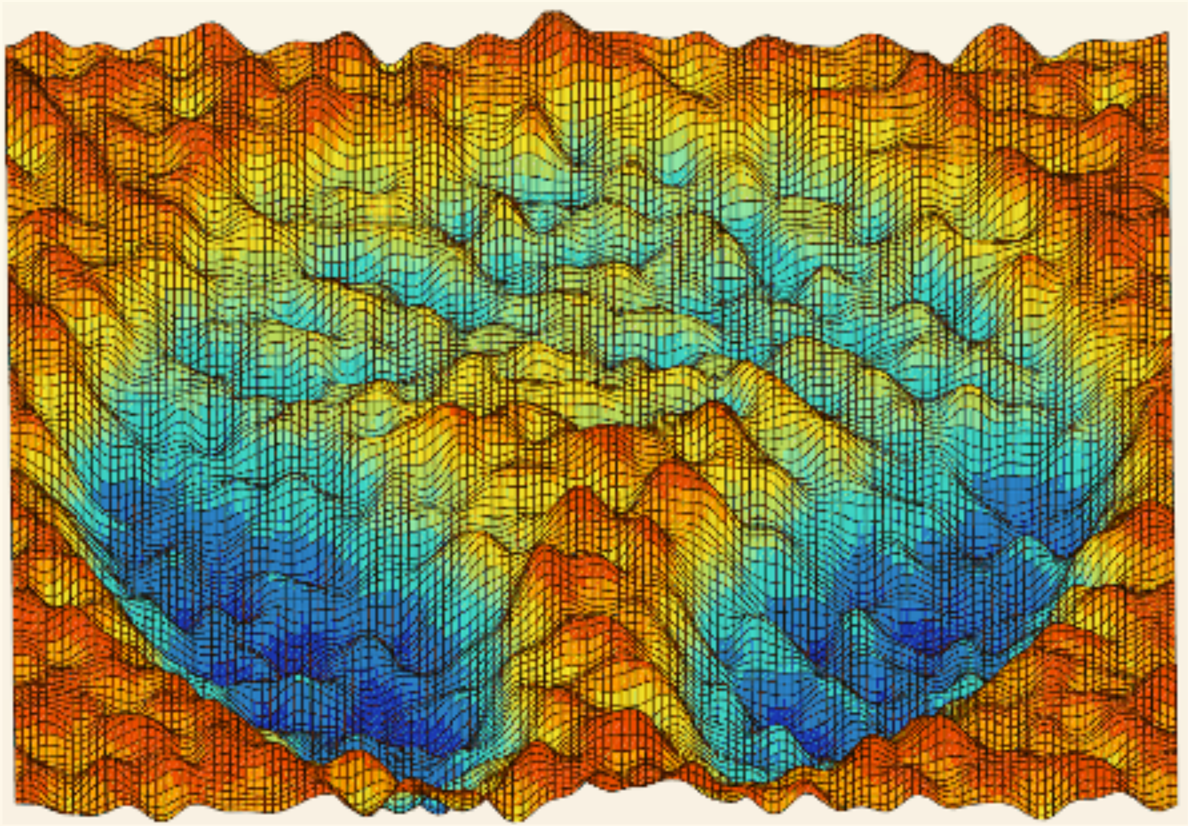
m_H^2 *and* Λ_4 *unstable*



M_p^2
$log_{10}(M_H^2)$
GeV
-4
$-M_p^2$
-12
$-M_p$
$log_{10}(\Lambda^{1/4})$
M_p
Unnatural!!

Leading idea for the cosmological constant problem:

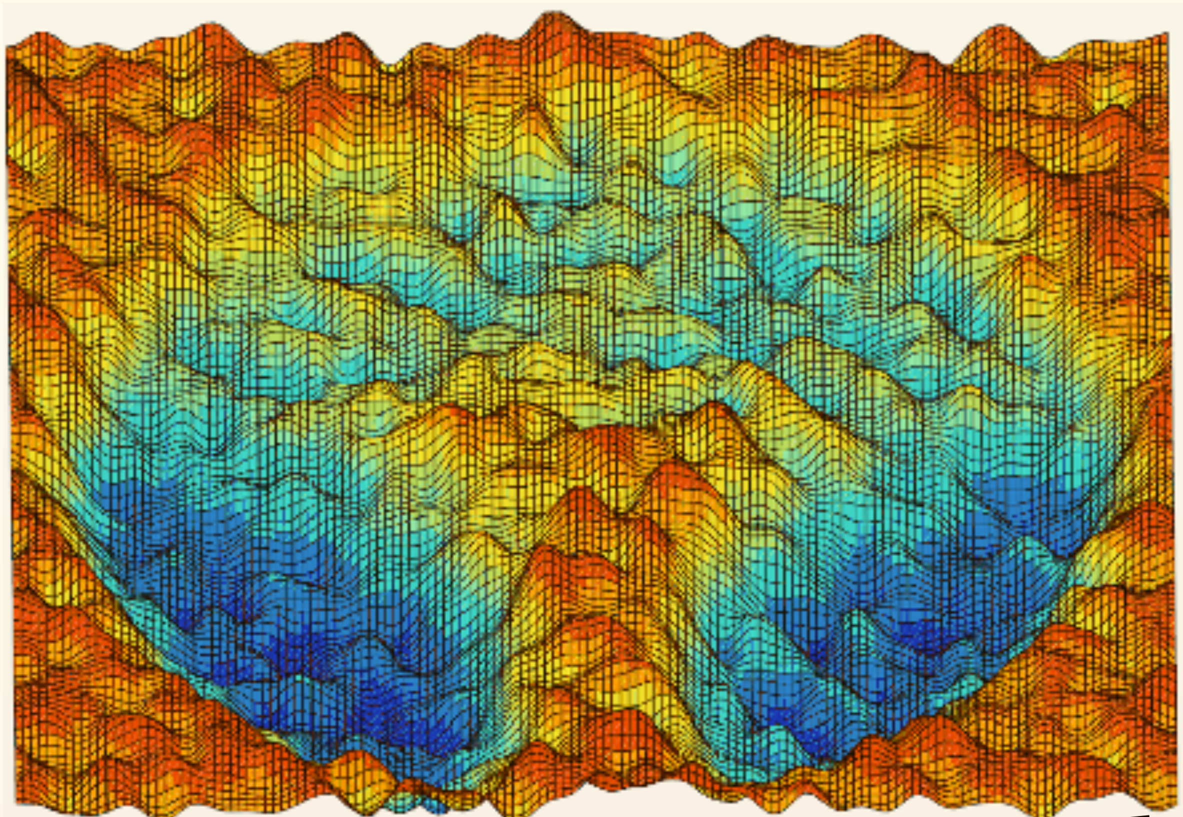
The String Landscape



10^{272000} $4D\ F - theory\ vacua\ estimated$

Taylor, Wang 2015

The String Landscape



Quantized fluxes

$$V = \sum_a G_a |F_4^a|^2 \ - \ \Lambda_0$$

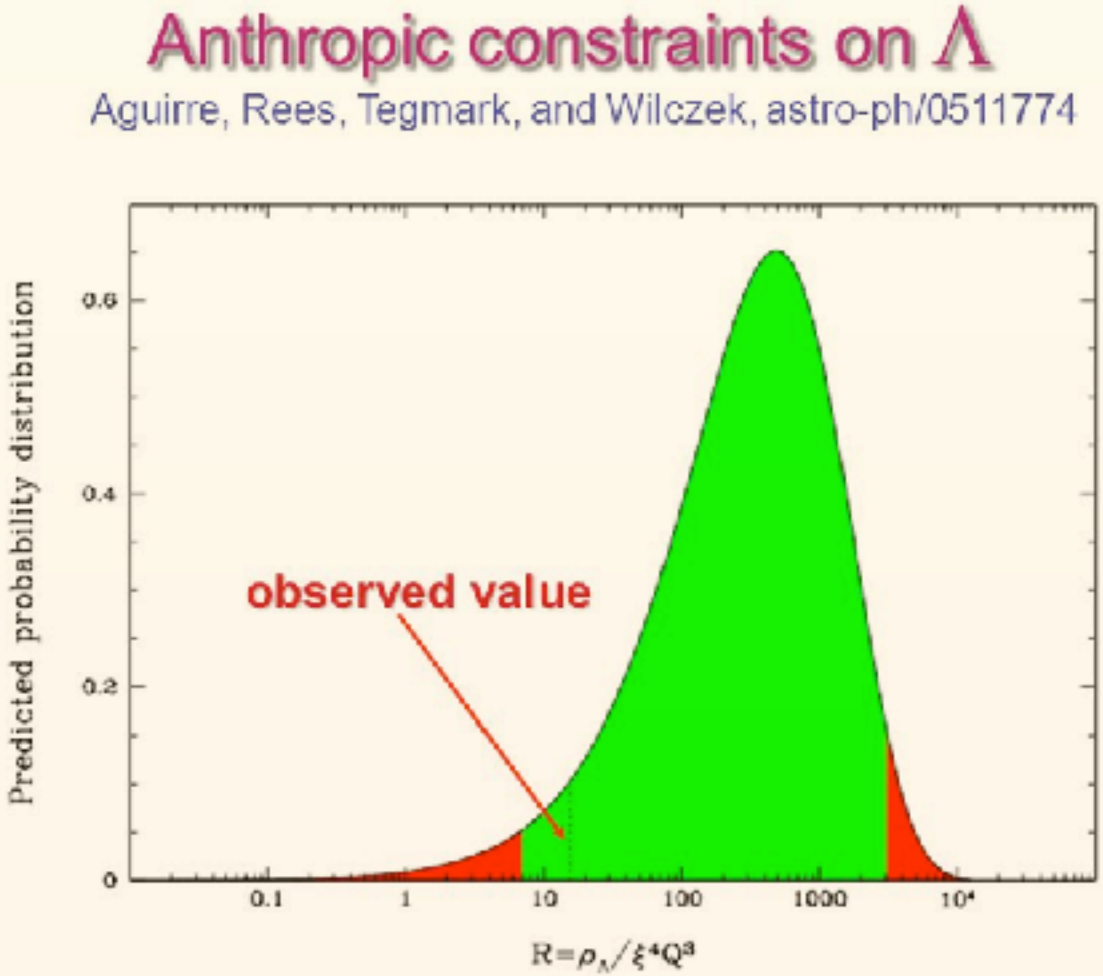
Bousso, Polchinski 2000

→ very likely vacua exist with small c.c. matching cosmological observations

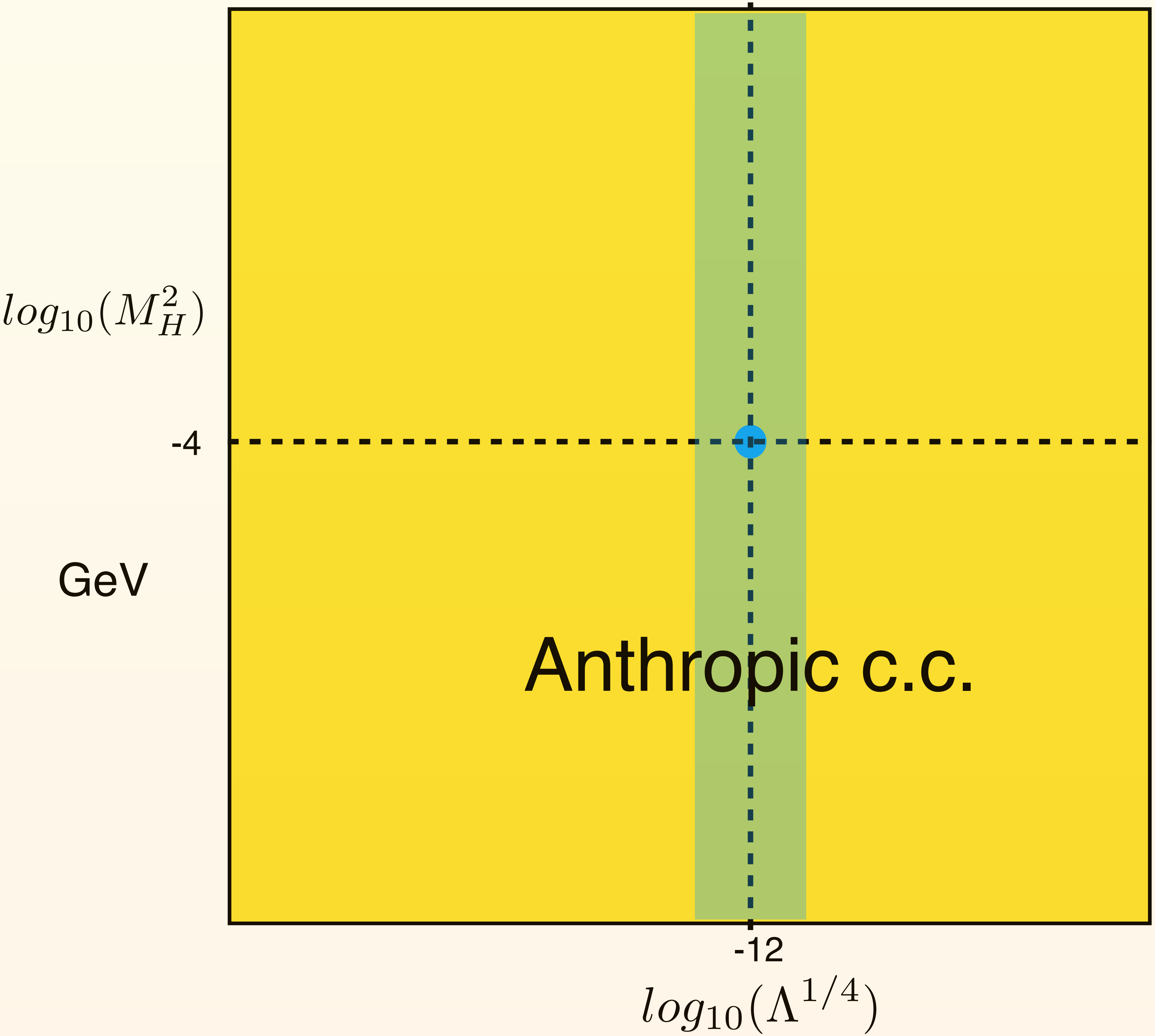
Existence of this huge landscape combined with anthropic arguments provides for an understanding of the size of the c.c.

Galaxy formation constraints the c.c.

Weinberg 1987



Probability distribution of the c.c.

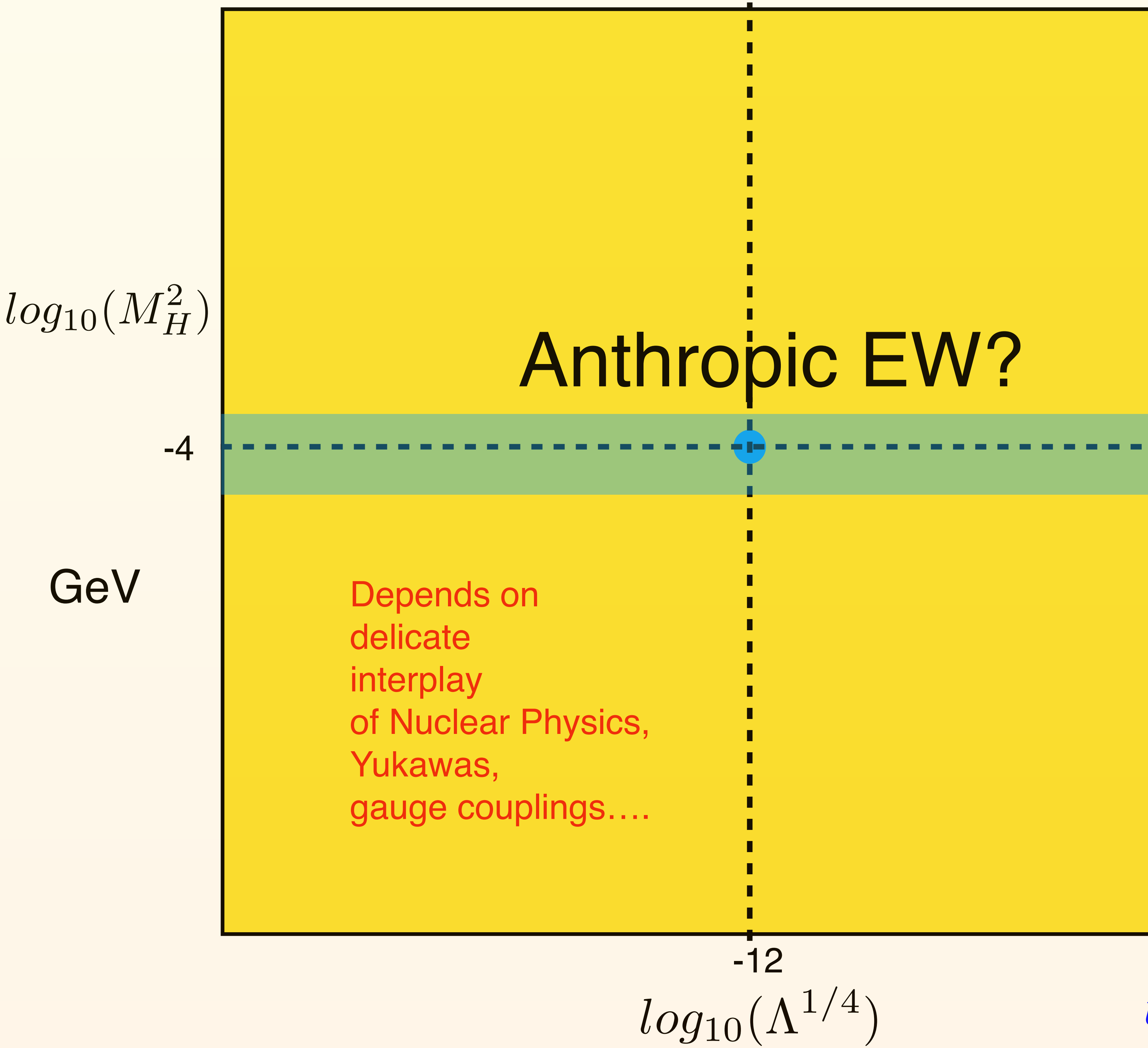


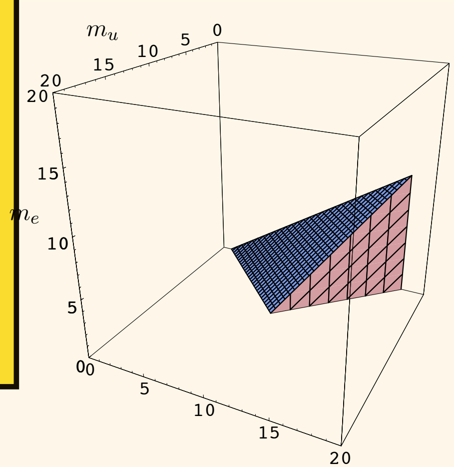
$log_{10}(M_H^2)$
-4
GeV
Anthropic c.c.
-12
$log_{10}(\Lambda^{1/4})$

Damour, Donoghue 2007

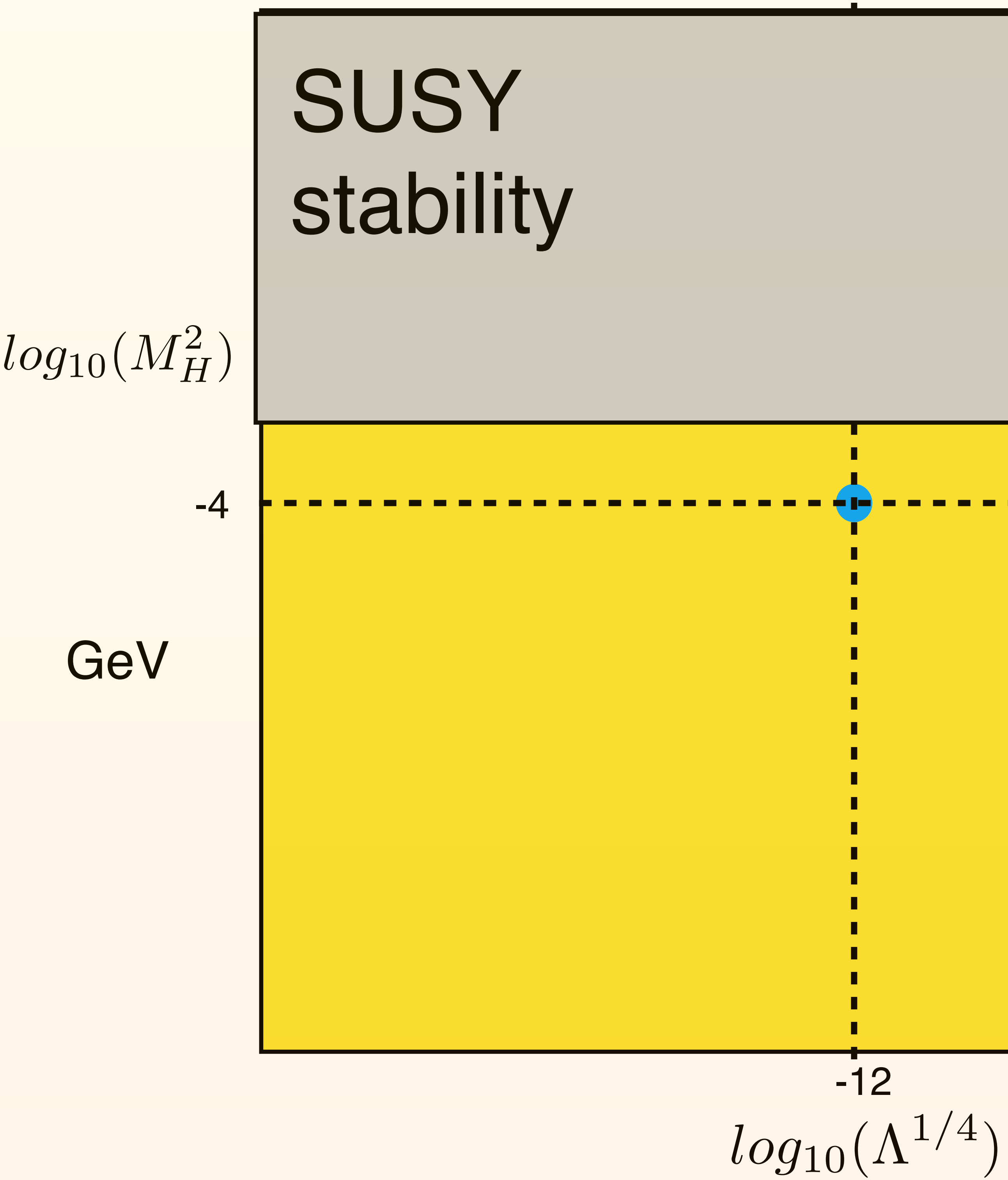
Donoghue et al 2009

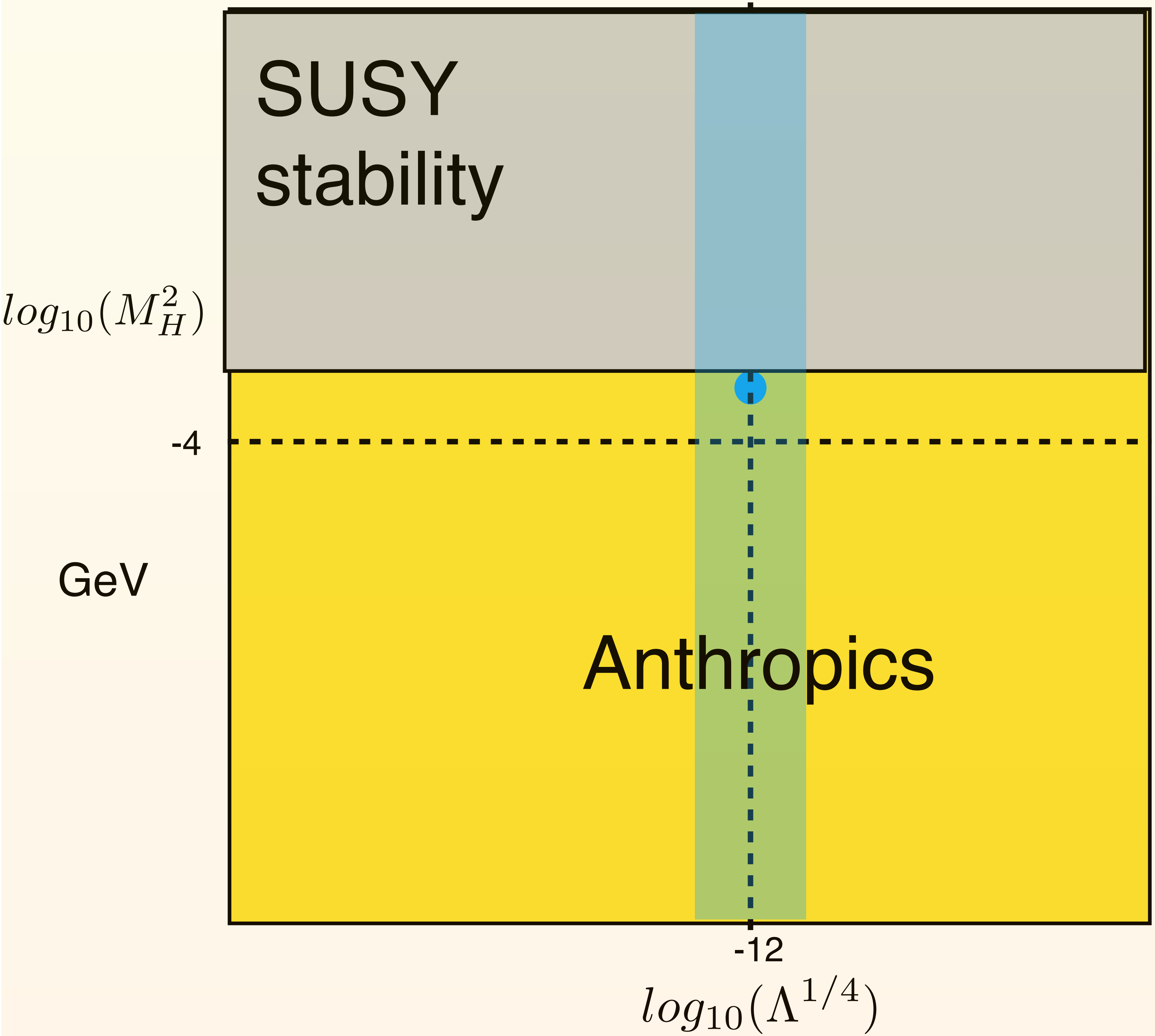
Meissner 2014



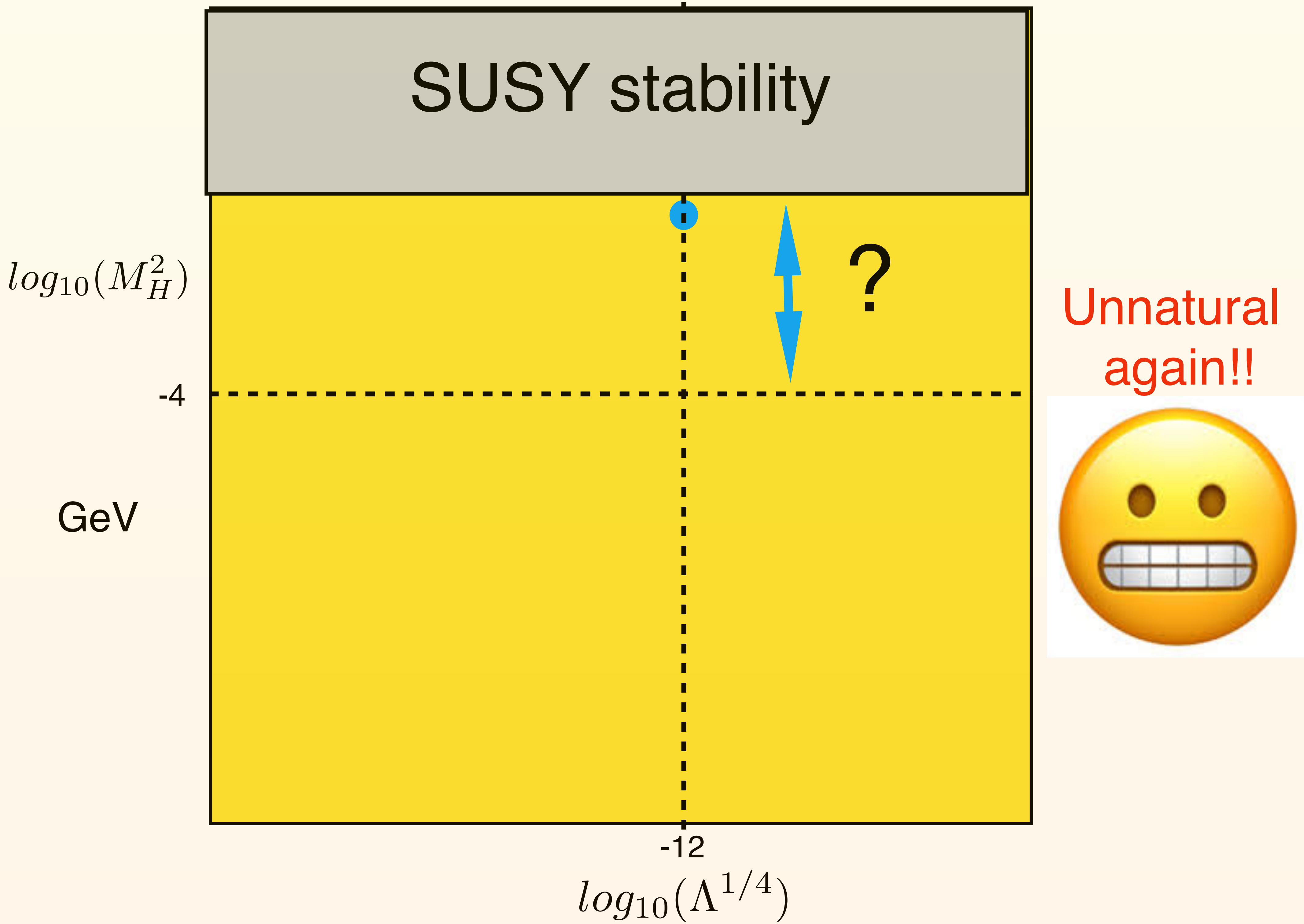


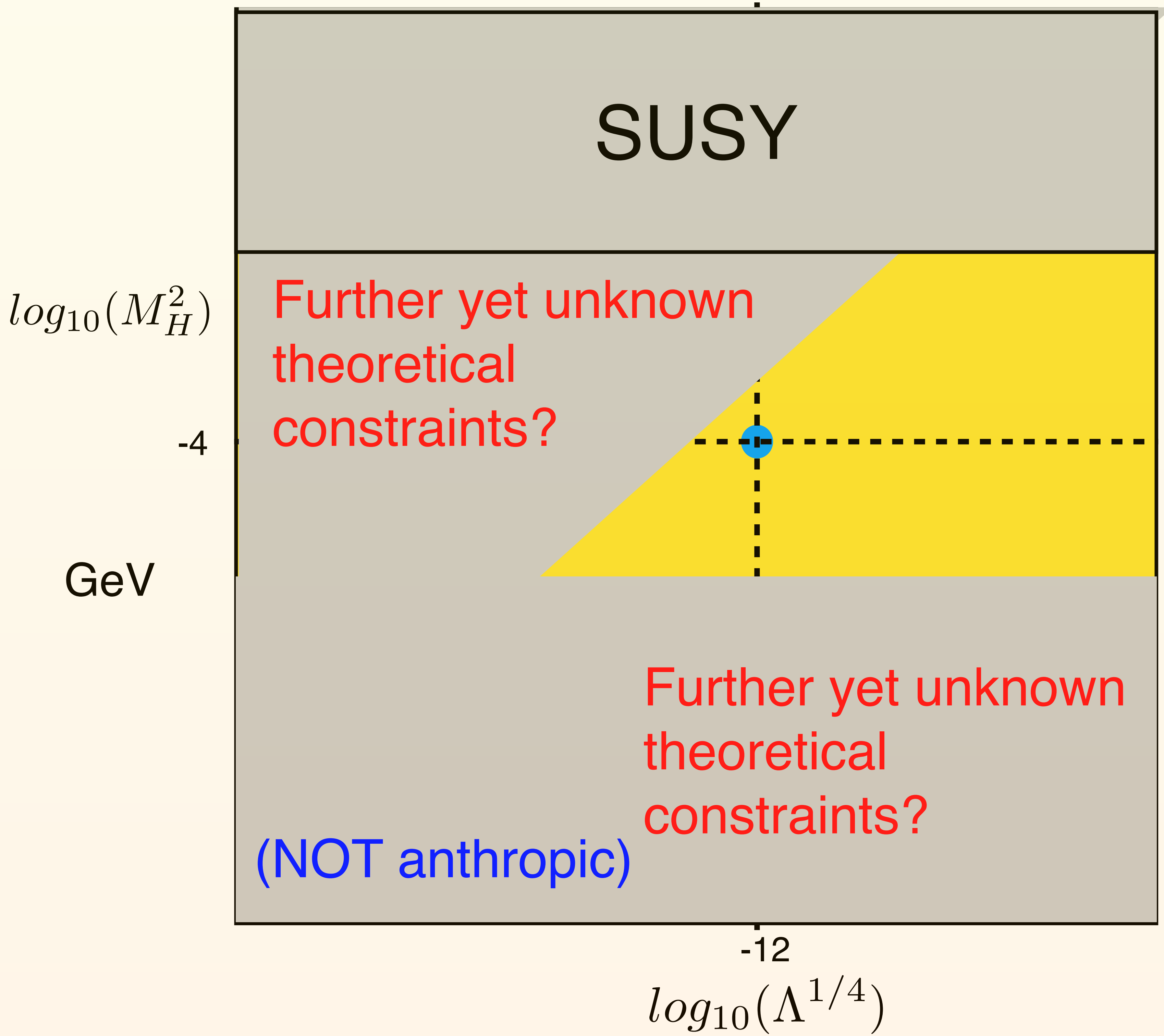
bounds on m_u, m_d, m_e

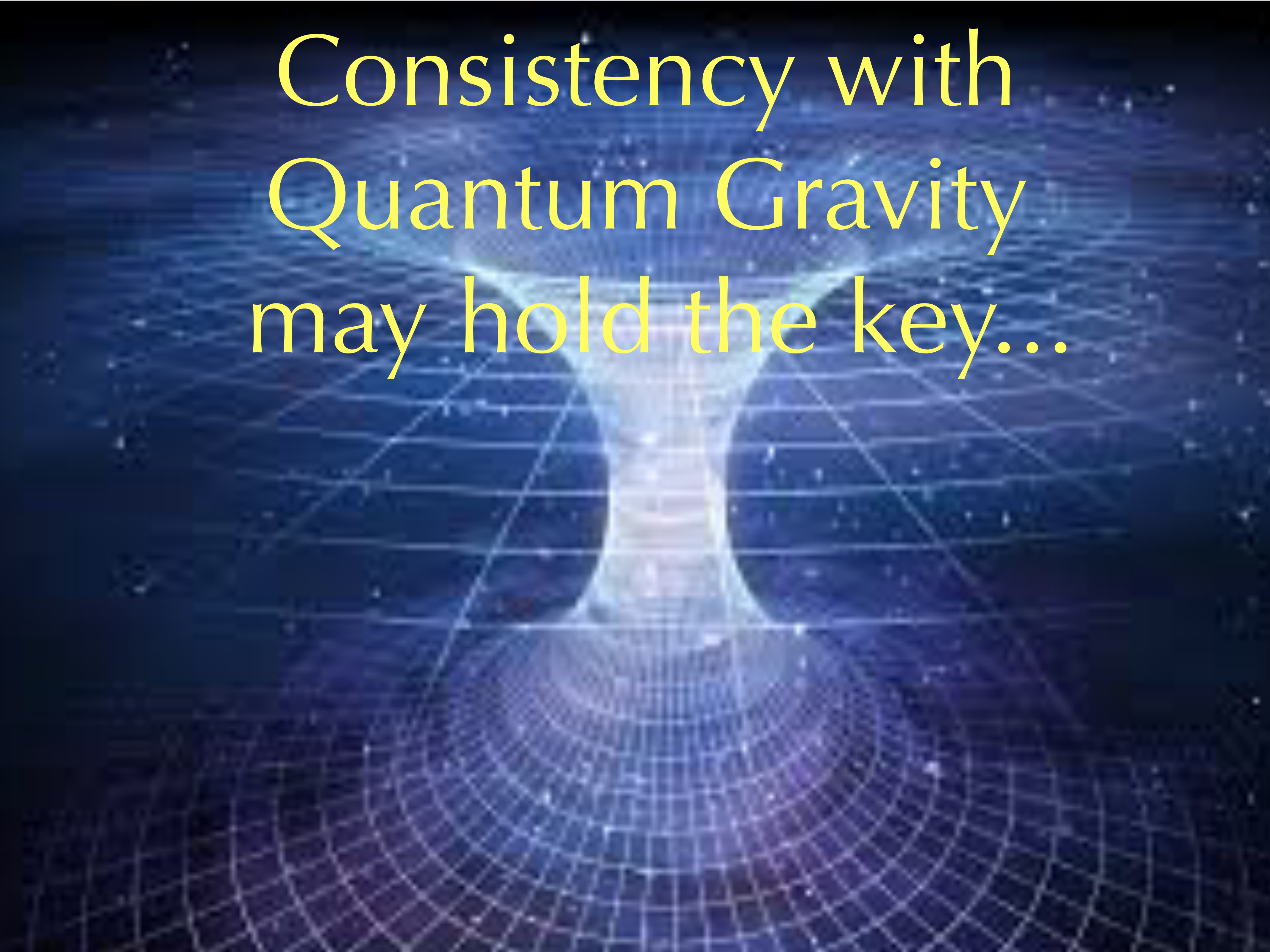

SUSY
stability
$log_{10}(M_H^2)$
-4
GeV
-12
$log_{10}(\Lambda^{1/4})$



SUSY
stability
$log_{10}(M_H^2)$
-4
GeV
Anthropics
-12
$log_{10}(\Lambda^{1/4})$

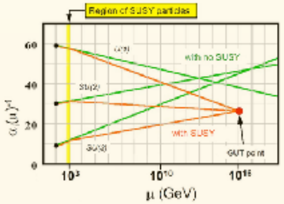

SUSY stability
?
Unnatural again!!
$log_{10}(M_H^2)$
-4
GeV
-12
$log_{10}(\Lambda^{1/4})$


SUSY
$log_{10}(M_H^2)$
Further yet unknown theoretical constraints?
-4
GeV
Further yet unknown theoretical constraints?
(NOT anthropic)
-12
$log_{10}(\Lambda^{1/4})$


Consistency with
Quantum Gravity
may hold the key...

Quantum Gravity versus Particle Physics

- We normally assume that the SM is unified with quantum gravity at the Planck scale



- Also asume that no trace of such quantum gravity embedding, other than boundary conditions, e.g. coupling unification, remains

- So we can ignore quantum gravity effects at low energies

- The tacit assumption is the belief that any field theory you can think of can consistently be coupled to quantum gravity.

- It has been realized in the last decade that this is NOT TRUE , e.g

$$\int dx^4 \sqrt{g}\; g_{\mu\nu}\partial^\mu\phi\partial^\nu\phi^* \;\neq\; \int dx^4\; \delta_{\mu\nu}\partial^\mu\phi\partial^\nu\phi^*$$

- Most field theories cannot be consistently coupled to quantum gravity, they belong to the

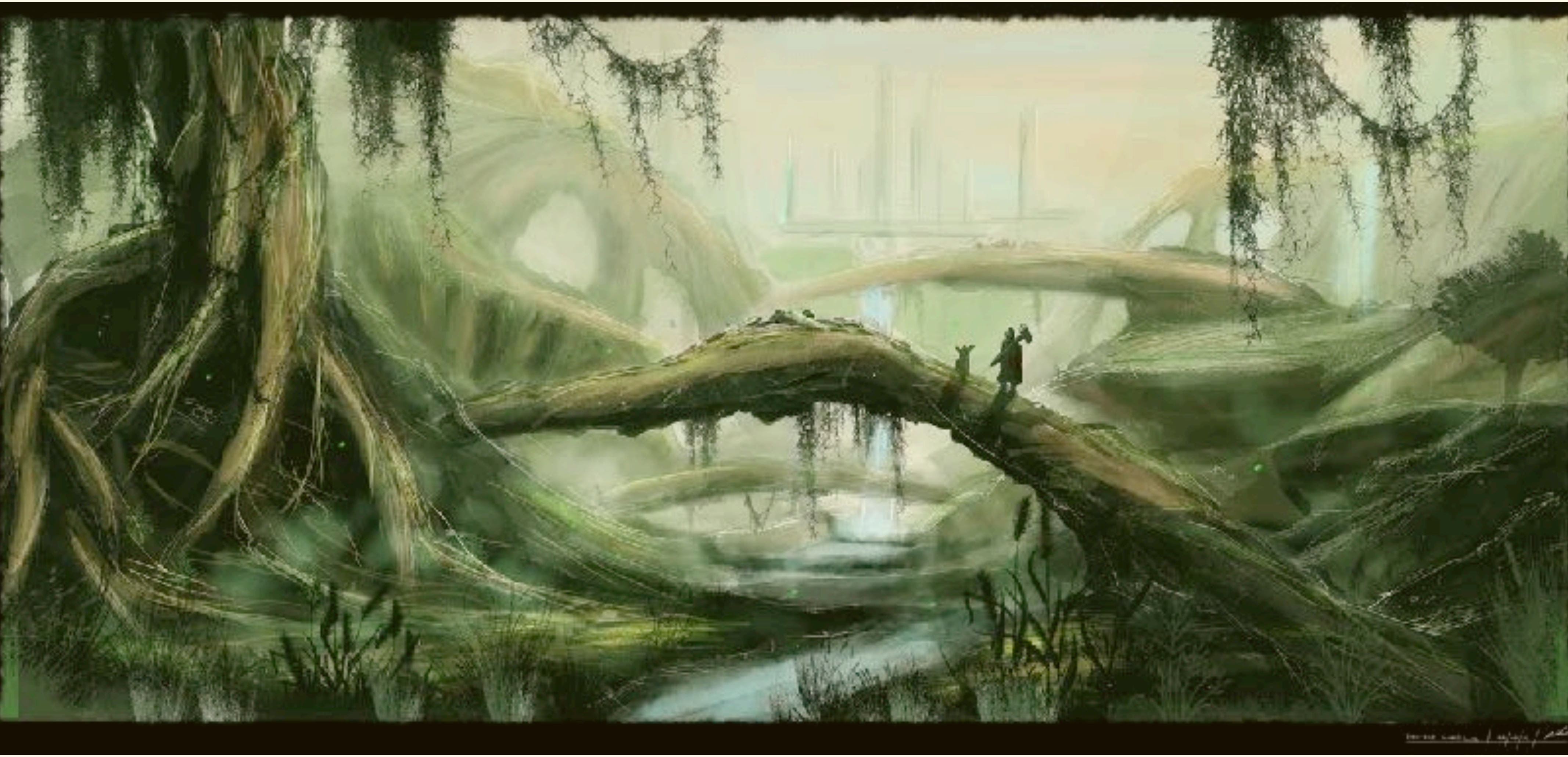
SWAMPLAND

C. Vafa 2005

The Swampland

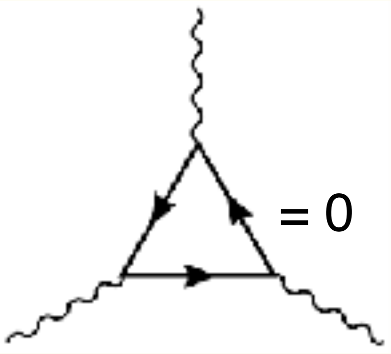
The space of field theories which cannot be embedded into a consistent theory of quantum gravity

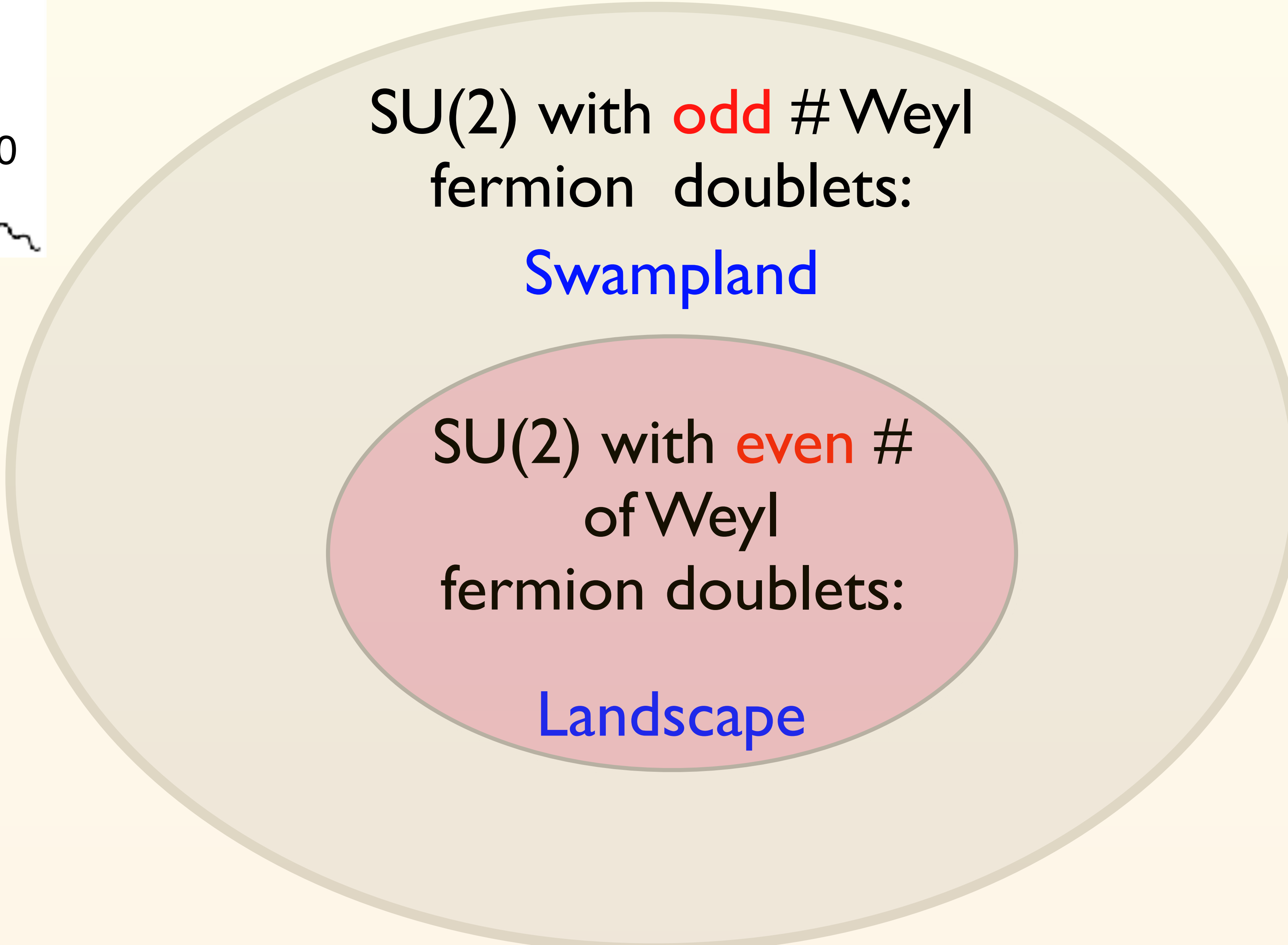
La Ciénaga



The space of field theories which cannot be embedded into a consistent theory of quantum gravity

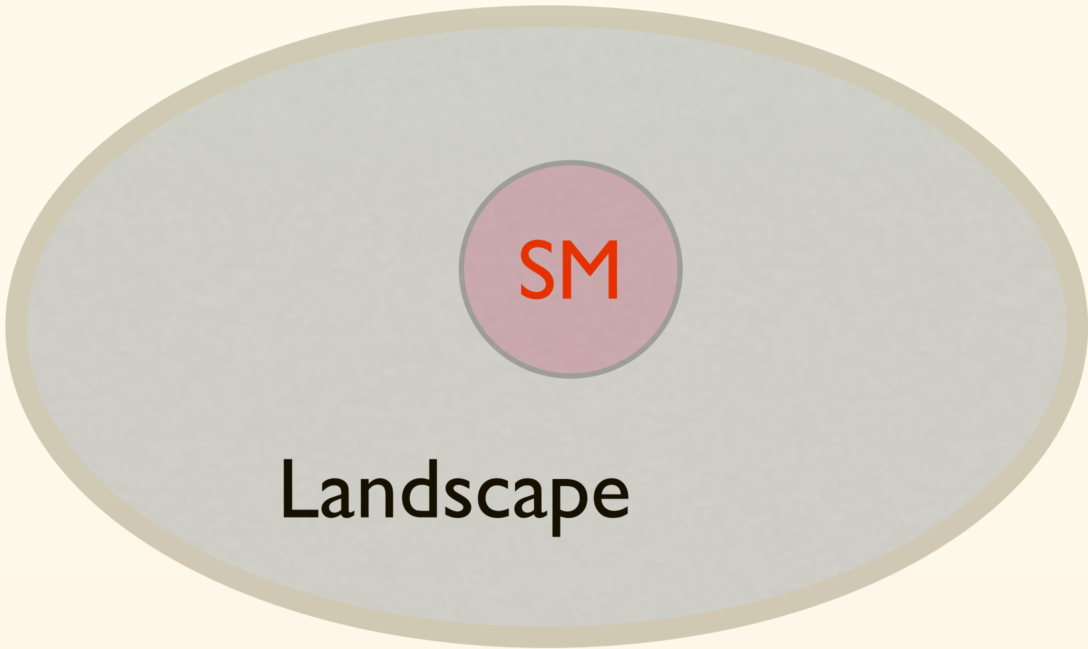
Analogy in QFT: sometimes inconsistency takes some time to be realised....

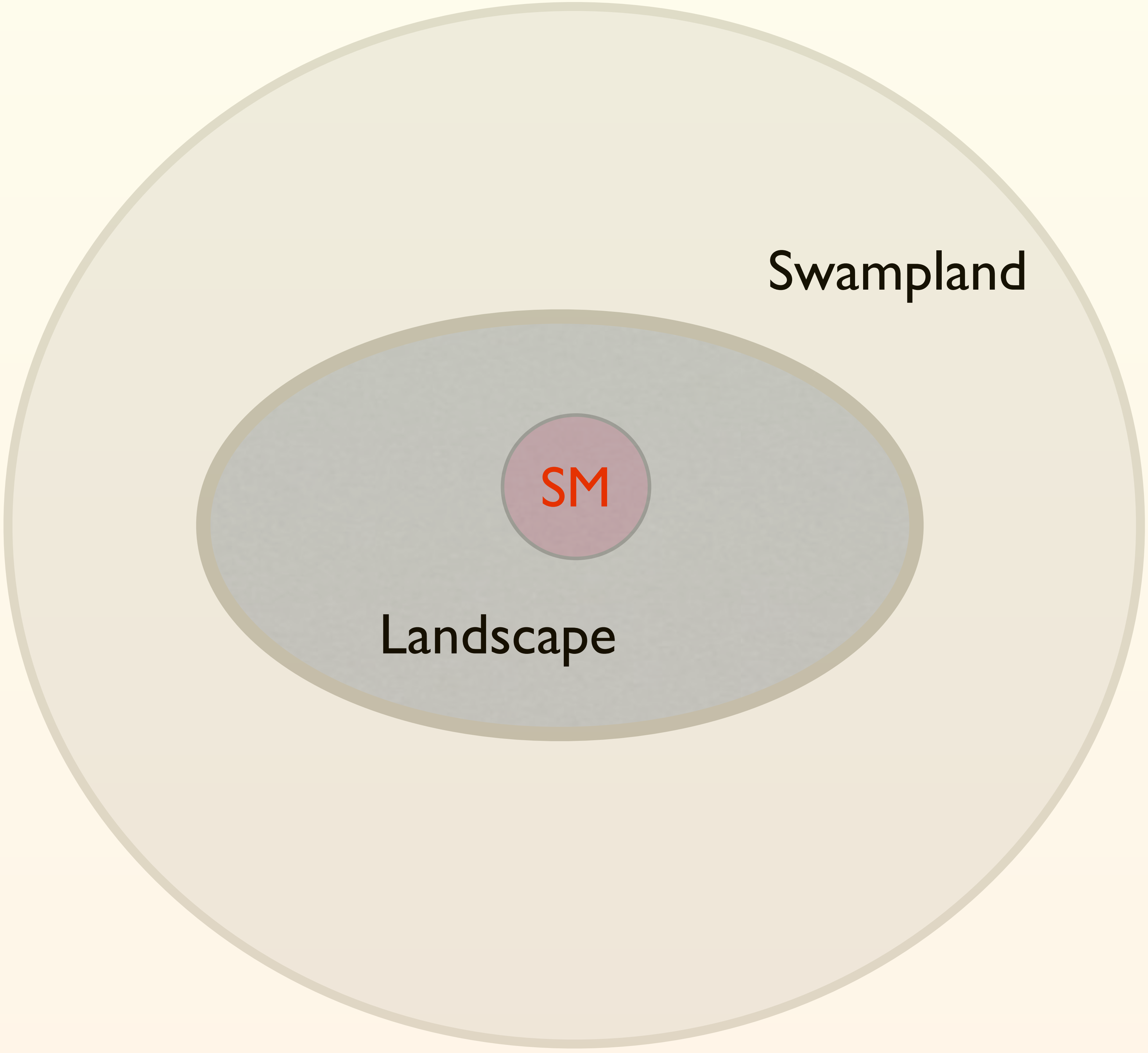


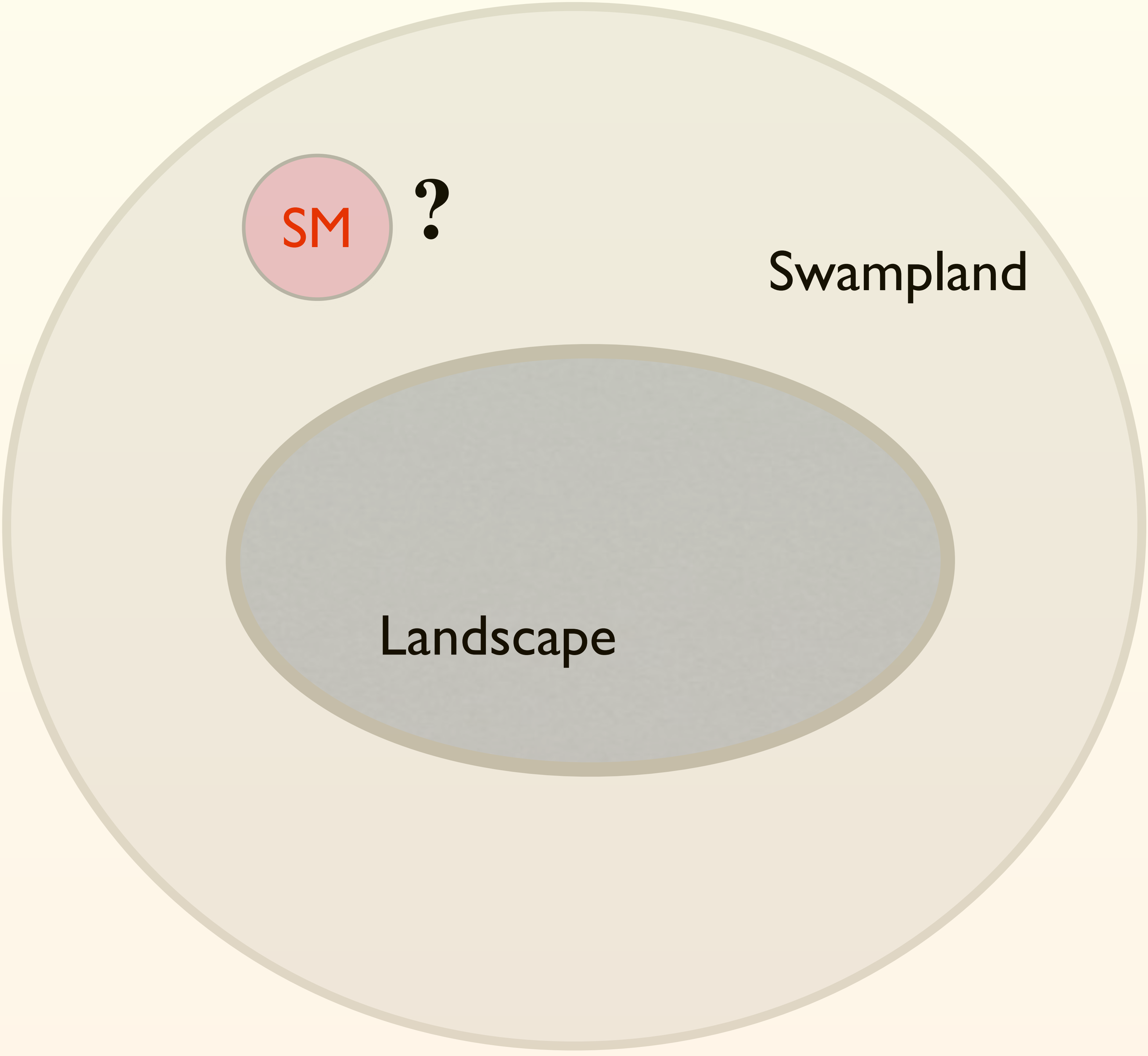


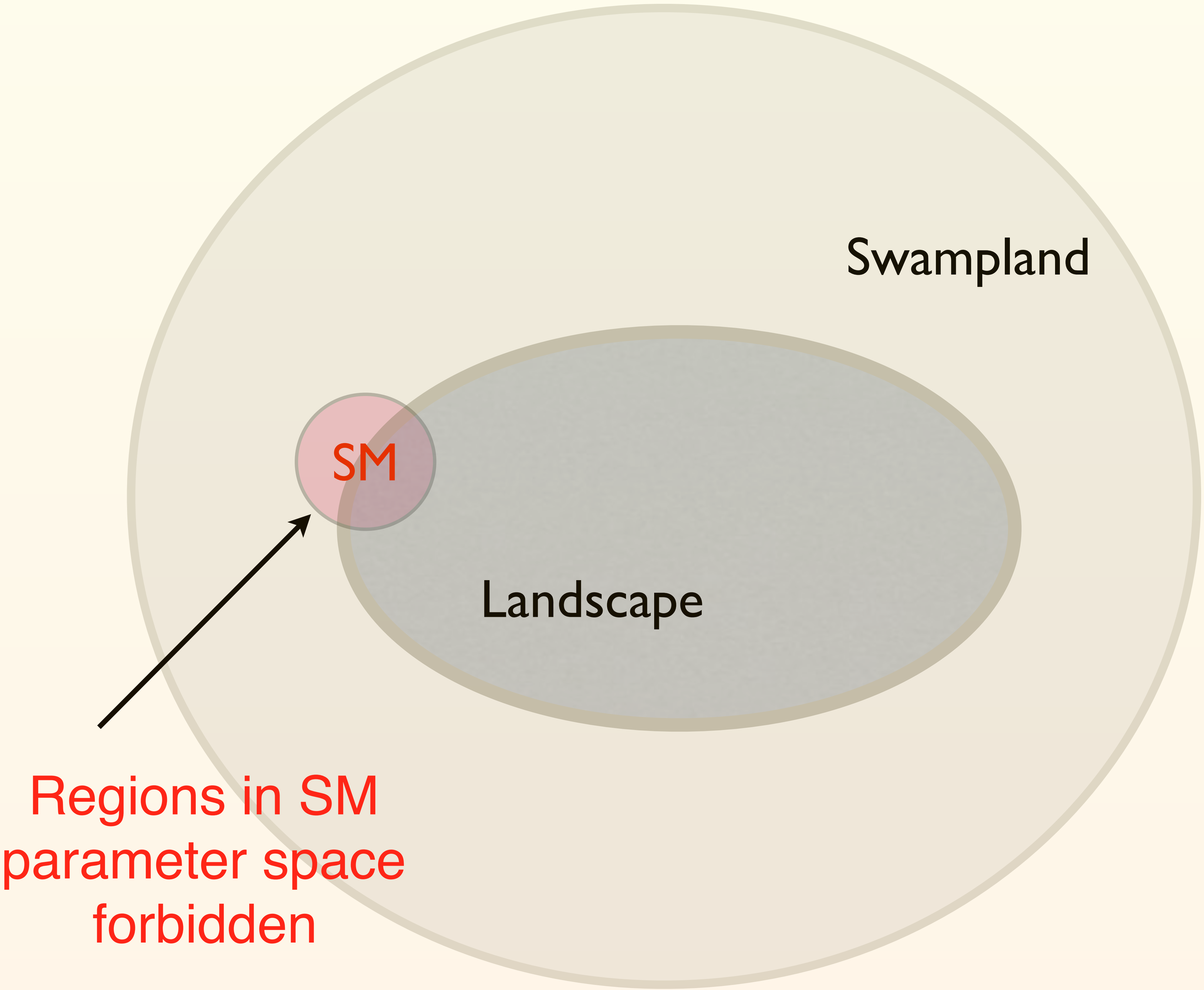
Witten global quantum anomaly 1982

SM


SM
Landscape


Swampland
SM
Landscape


SM
?
Swampland
Landscape


Swampland
SM
Landscape
Regions in SM
parameter space
forbidden

Some Swampland Criteria

- These are conjectures, many of them suggested by black-hole quantum physics

- No counterexample to these criteria has been found within string theory

Recent Review: *Brennan, Carta, Vafa . arXiv:1711.00864*

See C. Cheung talk

Some Swampland Conjectures

1) There are no exact global symmetries

Motivated by black-hole physics (no-hair).

Proven in string theory

2) All possible charges must appear in the full spectrum

$$\frac{1}{4g^2}\int F_{\mu\nu}F^{\mu\nu} + \frac{1}{2\kappa}\int \sqrt{G}R \quad \longrightarrow \quad \text{Inconsistent !}$$

Motivated by black-hole physics. Gauge bosons imply existence of charged particles.

3) No free parameters in the theory

All couplings are scalar fields.

e.g N=2 pure supergravity cannot exist (has no scalars)

$$N = 2: \;\; g^{\mu\nu}, \psi^{\mu}_{3/2}, A^{\mu}$$

Gravity as the weakest force

Arkani-hamed, Motl, Nicolis, Vafa 2006; Ooguri,Vafa 2007

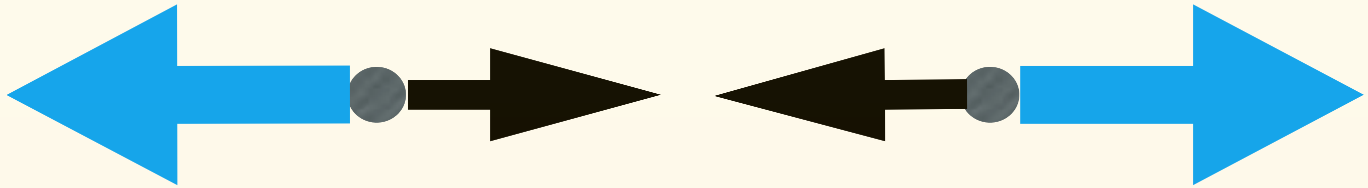
"In any UV-complete theory gravity must be the weakest force"

WGC for a U(1)

- In any UV complete U(1) gauge theory there must exist at least one charged particle with mass M such that:

$$\frac{M}{M_p} \leq g$$

Consider two particles with mass m and charge q :



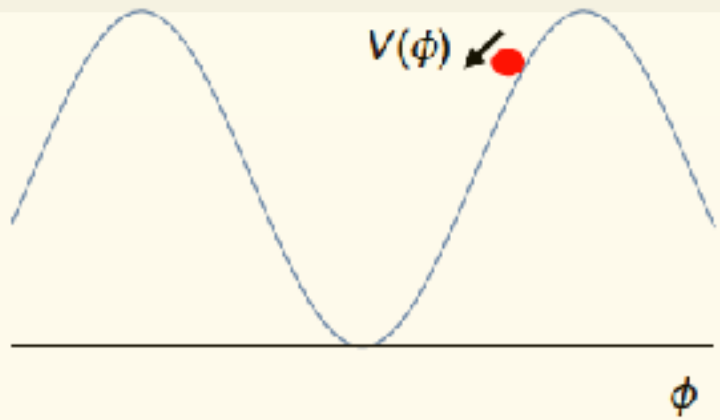
$$F_G = \frac{1}{M_p^2}\frac{m^2}{r^2} \qquad F_q = \frac{q^2}{r^2}$$

$$F_G \leq F_q \longrightarrow m \leq q M_p$$

e.g. electron

E.g., applications of the WGC to Cosmology

$Axion\ inflation:$



$$V(\phi) = \Lambda^4\left(1 - \cos\frac{\phi}{f}\right) + \ldots$$

$Inflation\ needs\ f > M_p$

$$\gamma \longrightarrow Axion$$

$$m \leq g\, M_p$$

$$m \to S_{inst}, \quad g \to \frac{1}{f}$$

$$S_{inst} \leq \frac{1}{f} M_p$$

$Potential\ under\ control\ S_{inst} > 1$ ➡ $f \lesssim M_p$

$Natural\ inflation,\ N-flation, \ldots inconsistent\ with\ WGC$

Heidenreich, Reece, Rudelius 2015
Montero, Uranga, Valenzuela 2015

Also constraints on relaxions

Generalizes to higher rank tensors and branes in ST

$$A^{\mu} \longrightarrow C^{\mu..\rho} \quad ; \quad M,\ mass \longrightarrow T,\ tension$$

$$\frac{T}{M_p} \leq g$$

$(g\ dimensionful)$

Ooguri and Vafa 2016: *arXiv:1610.01533*

The equality is only achieved
for SUSY BPS states

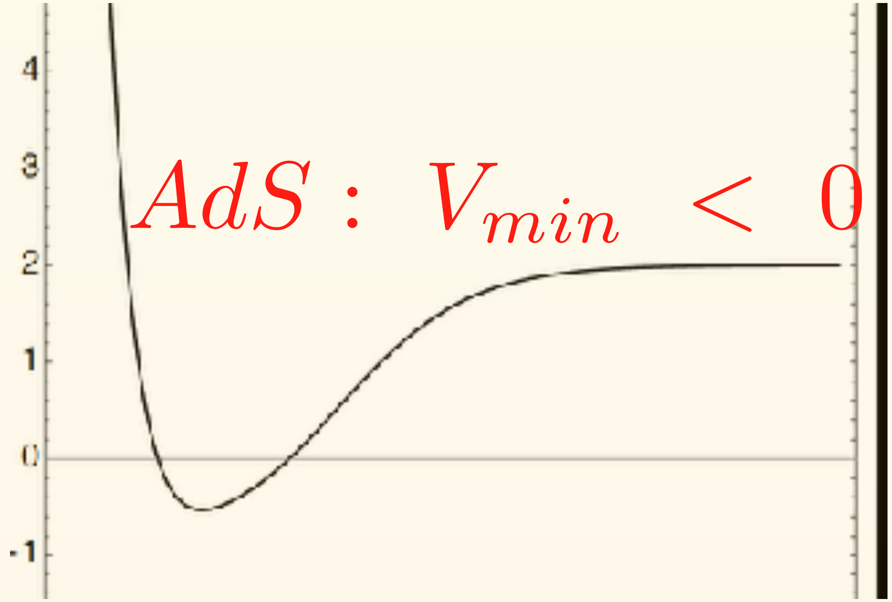
$$\frac{T}{M_p} < g$$

for non-SUSY

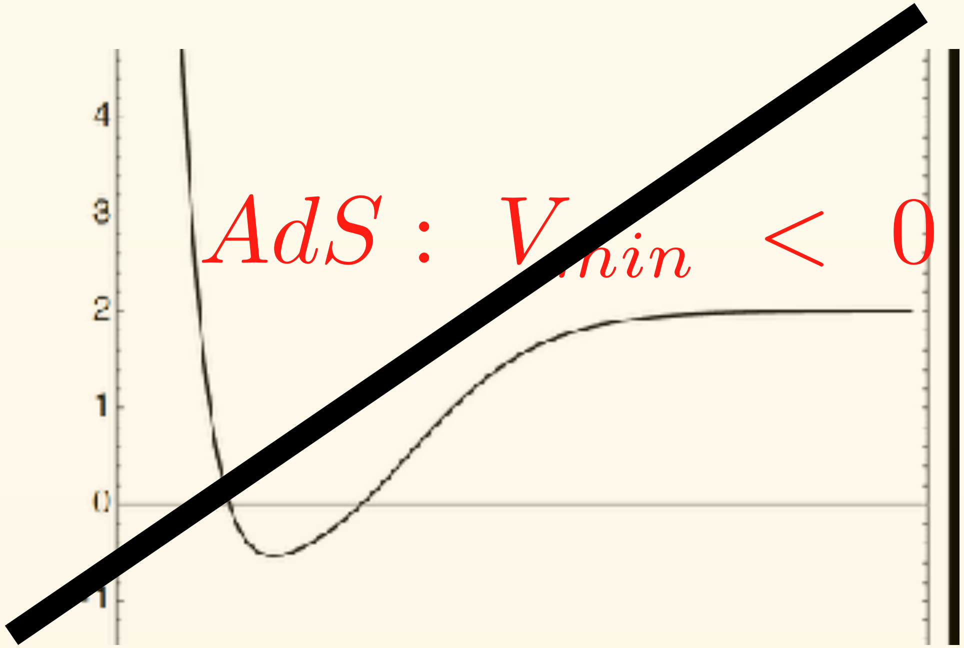
Strong
Corolarium !!

 (also Banks 2016, Freivogel, Kleban 2016)

Non-SUSY AdS flux vacua are unstable and cannot have CFT dual



Non-SUSY AdS flux vacua are unstable and cannot have CFT dual



There cannot be stable non-SUSY AdS vacua in quantum gravity

(If you find one in your theory, then it is inconsistent with quantum gravity)

Caveat: often not obvious to be sure of full stability....

Consequences for the SM

If we have a consistent theory, it is consistent in any background:

If SM consistent, any compactification should be consistent

Ooguri,Vafa 2016

The SM should not have any AdS (stable) lower dimensional vacua

The Standard Model Landscape in lower dimensions

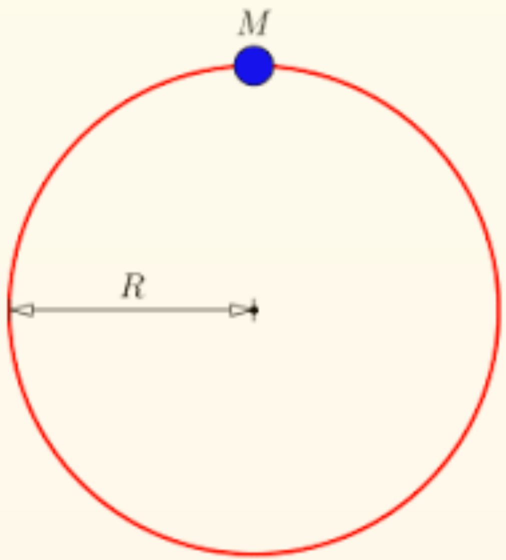
There is a SM landscape of vacua
(even without any string theory arguments)

Arkani-Hamed, Dubovsky, Nicolis, Villadoro 2007: hep-th:0703067;

Arnold, Fornal, Wise 2010: hep-th:1010.4302;

We will see this 'AdS phobia' puts constraints on neutrino masses, the c.c., the EW hierarchy....

SM compactified to 3D on a circle

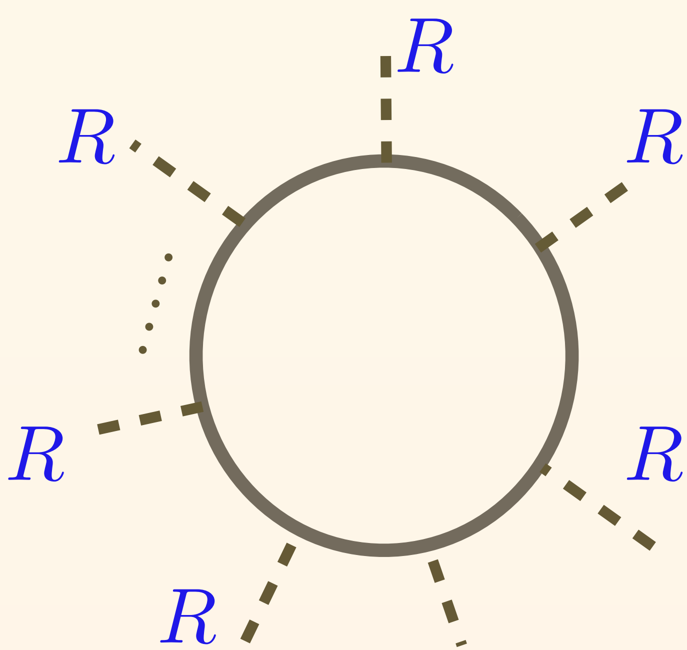


A Compact Dimension

$$Radius\ R\ is\ a\ massless\ scalar\ field$$

For $R \gg 1/m_e$

only $\gamma,\ g^{\mu\nu},\ \nu_i$ relevant



$$V_{boson} \sim -\frac{1}{R^6}$$

$$V_{fermion} \sim \frac{1}{R^6}$$

One-loop Casimir potential

(massless fields)

The SM + gravity on a circle S^1

Arkani-Hamed et al. 2007

Consider the lightest sector : $\gamma, g_{\mu\nu}, \nu_{1,2,3}$

The radius potential :

One – loop Casimir energy

$$V(R) \simeq \frac{2\pi r^3 \Lambda_4}{R^2} - 4\left(\frac{r^3}{720\pi R^6}\right) + \sum_i (2\pi R)(-1)^{s_i} n_i \rho_i(R)$$

From 4D c.c.

$\gamma, g_{\mu\nu}$

ν_i

$$\rho(R) = \mp \sum_{n=1}^{\infty} \frac{2m^4}{(2\pi)^2} \frac{K_2(2\pi R m n)}{(2\pi R m n)^2}$$

ν_i *with periodic b.c. contributes positively!!*

$The\ SM\ +\ gravity\ on\ a\ circle\ S^1$

$Consider\ the\ lightest\ sector:\ \gamma, g_{\mu\nu}, \nu_{1,2,3}$

$The\ radius\ potential:$

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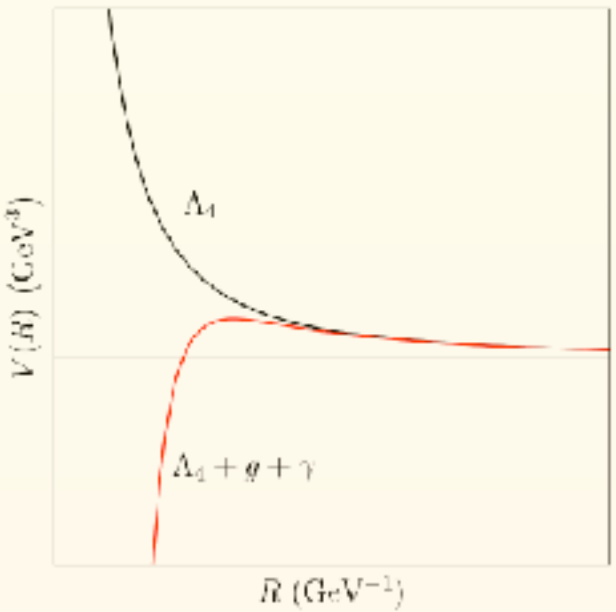
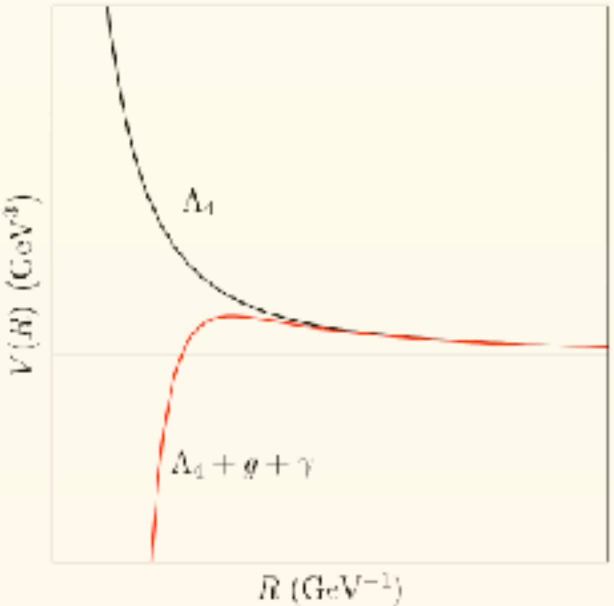
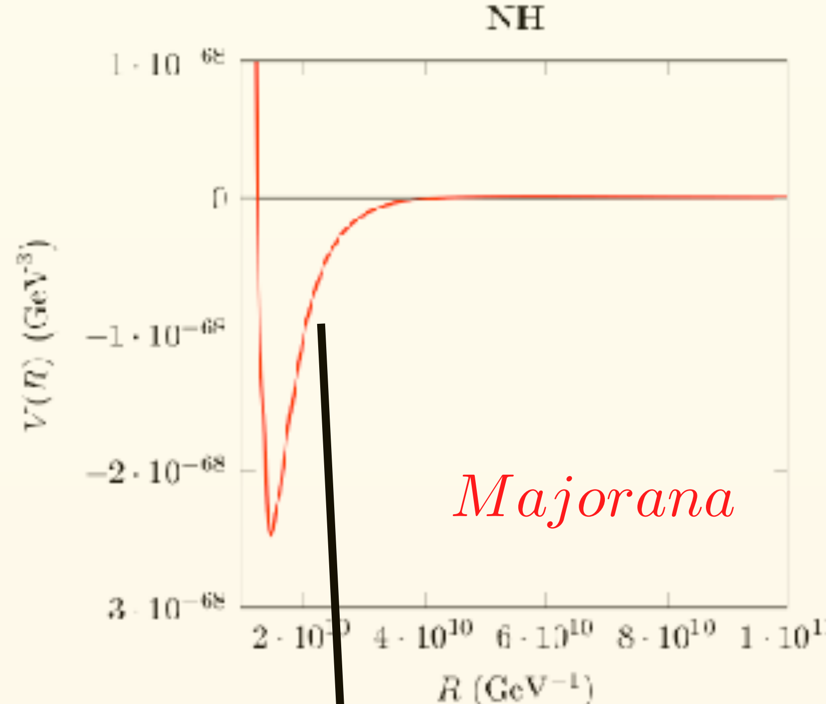
$\nu_i\ with\ periodic\ b.c.\ contributes\ positively!!$

Important: Effect of heavier particles suppressed like $e^{-(m_f/m_\nu)}$



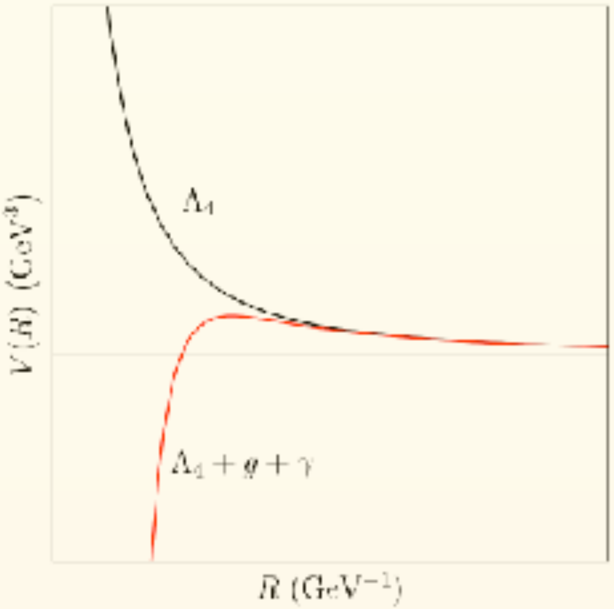
$V(R)$ (GeV^4)
Λ_4
$\Lambda_4 + g + \gamma$
R (GeV^{-1})

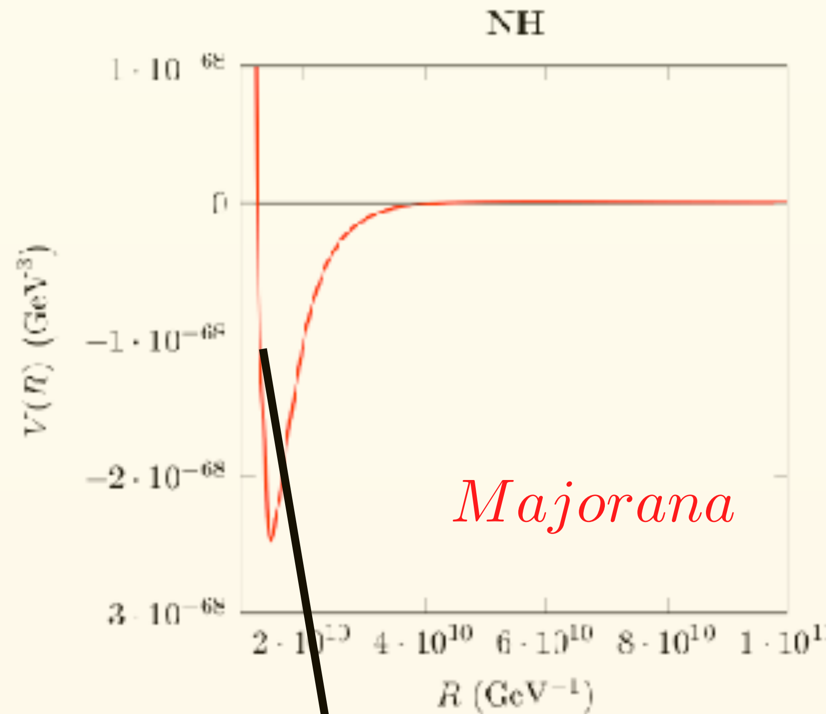




$$(-2-2+2)\left(\frac{r^3}{720\pi R^6}\right)$$

γ $\quad g_{\mu\nu}$ $\quad \nu_1^M$



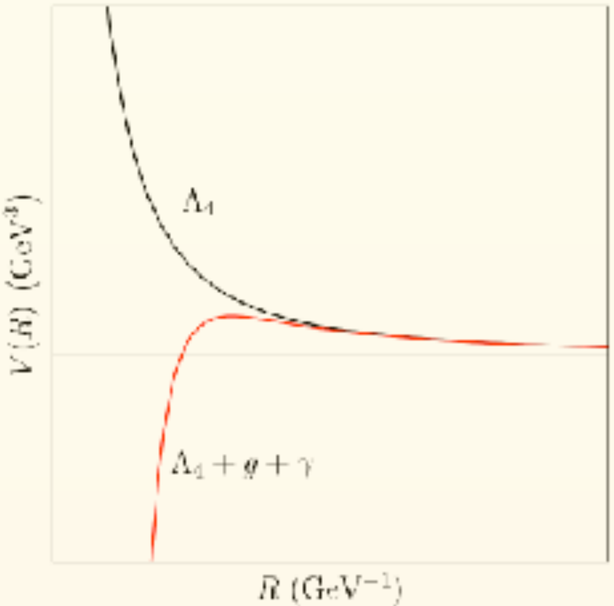


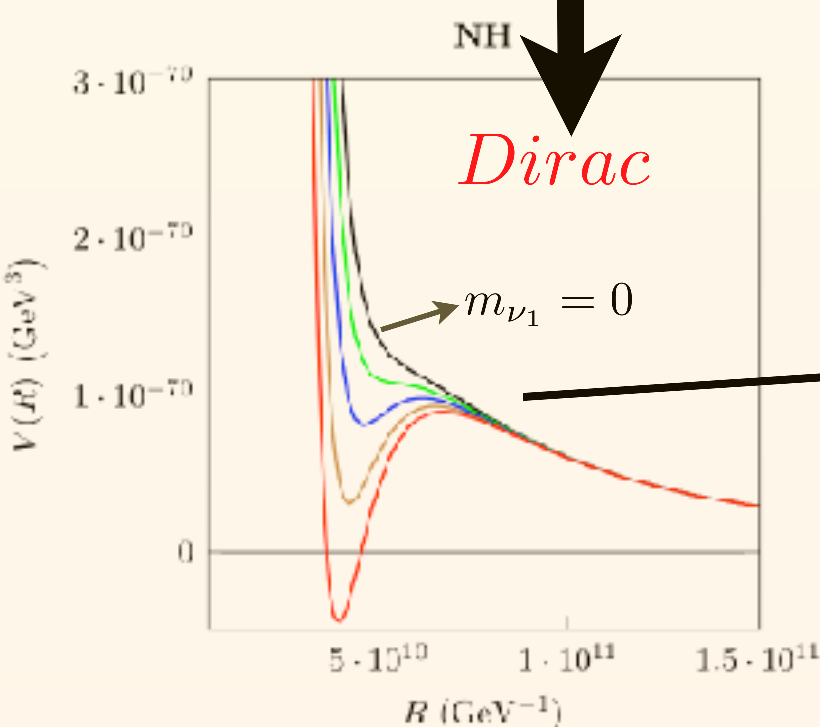
$$(-2 - 2 + 6)\left(\frac{r^3}{720\pi R^6}\right)$$

γ $\quad g_{\mu\nu}$ $\quad \nu^M_{1,2,3}$

$Majorana\ \nu_1\ forbidden!!$

Oguri,Vafa 2016

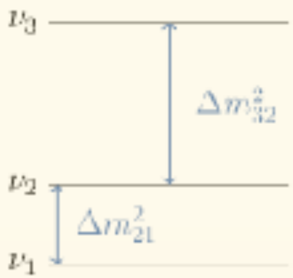


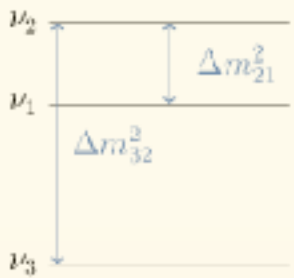


$$(-2 - 2 + 4)\left(\frac{r^3}{720\pi R^6}\right)$$

γ $g_{\mu\nu}$ ν_1^D

Constraints on neutrino masses





$$\Delta m^2_{21} = (7.53 \pm 0.18) \times 10^{-5}\ \text{eV}^2,$$
$$\Delta m^2_{32} = (2.44 \pm 0.06) \times 10^{-3}\ \text{eV}^2\ (\text{NH}),$$
$$\Delta m^2_{32} = (2.51 \pm 0.06) \times 10^{-3}\ \text{eV}^2\ (\text{IH}).$$

Majorana: ruled out!!

$$\textit{There is always an AdS vacuum for any } m_{\nu_1}$$

Dirac:

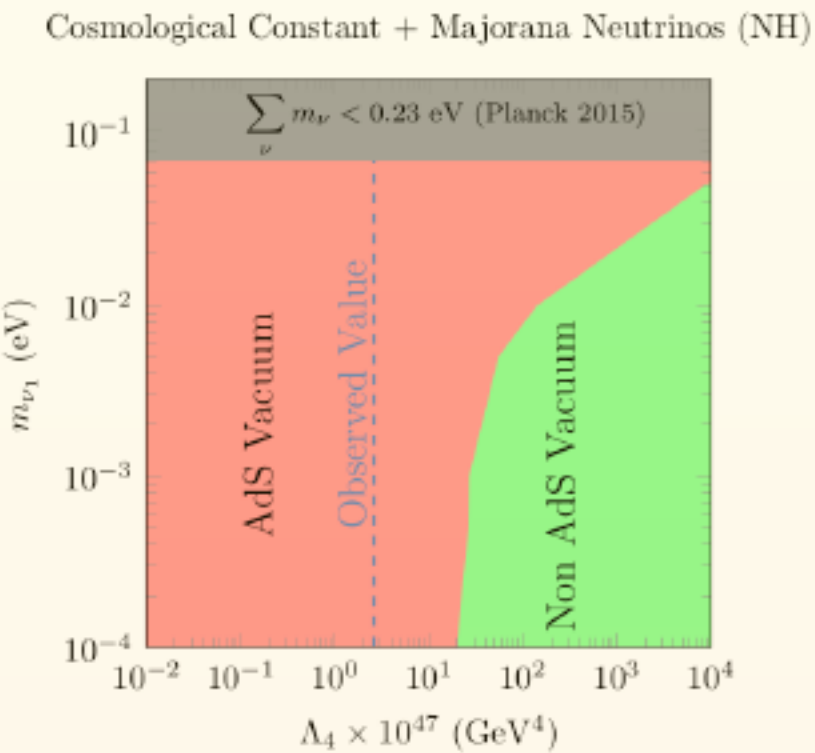
	NH	IH
No vacuum	$m_{\nu_1} < 6.7$ meV	$m_{\nu_3} < 2.1$ meV
dS_3 vacuum	$6.7 \text{ meV} < m_{\nu_1} < 7.7$ meV	$2.1 \text{ meV} < m_{\nu_3} < 2.56$ meV
AdS_3 vacuum	$m_{\nu_1} > 7.7$ meV	$m_{\nu_3} > 2.56$ meV

$$m_{\nu_1} < 7.7\ \text{meV}\ (\text{NH})$$
$$m_{\nu_1} < 2.1\ \text{meV}\ (\text{IH})$$

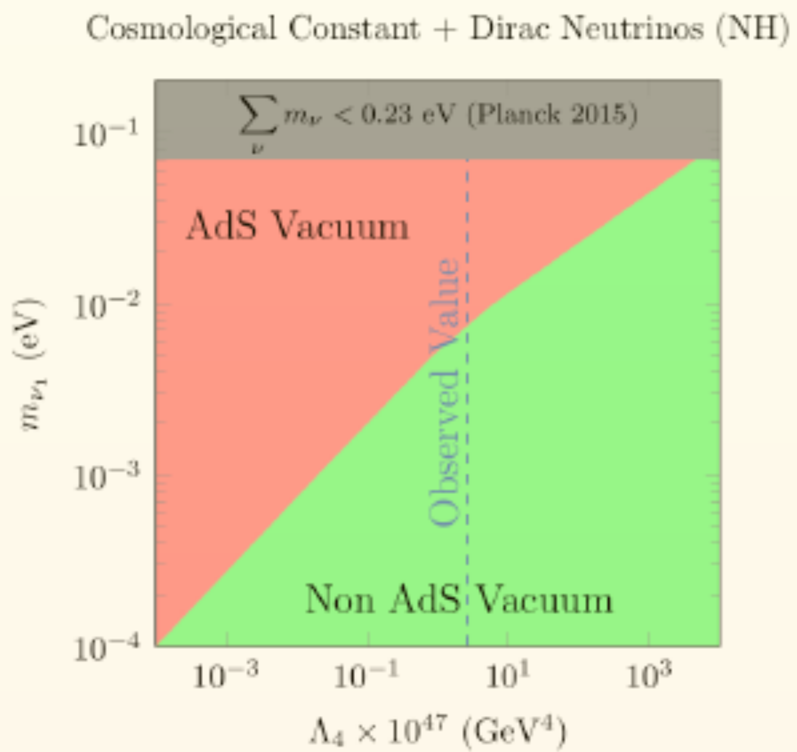
L.I, Martin-Lozano, Valenzuela 2017
Hamada, Shiu 2017

See Martin-Lozano parallel talk

Lower bound on the cosmological constant



Majorana



Dirac

$$\Lambda_4 \geq \frac{a(n_f)30(\Sigma m_i^2)^2 - b(n_f, m_i)\Sigma m_i^4}{384\pi^2}$$

To avoid AdS

$$\Lambda_4 \gtrsim m_\nu^4$$

Explains coincidence!!

L.I,Martin-Lozano, Valenzuela 2017

First particle physics argument for a non-vanishing c.c. (independent of cosmology)

Hierarchy Problem, Naturality and the Swampland

SM without a Higgs is in the Swampland

No lepton masses, quarks dynamical mass

$Below\ \Lambda_{QCD}:$ $4n_g^2\ Goldstone\ bosons$

$$U(2n_g)_L \times U(2n_g)_R \longrightarrow U(2n_g)_{L+R}$$

$$(N_F - N_B) = \underbrace{8n_g}_{\text{Leptons}} - (\underbrace{4n_g^2}_{\text{GB}} - 1 - \underbrace{3}_{\text{W,Z}} + \underbrace{2}_{g^{\mu\nu}} + \underbrace{2}_{\gamma}) = 4n_g(2 - n_g)$$

$Above\ \Lambda_{QCD}:$ $Quarks\ deconfine$

$$(N_F - N_B) = \underbrace{32n_g}_{\text{quark/leptons}} - \underbrace{24}_{\text{Gauge}} - \underbrace{2}_{g^{\mu\nu}}$$

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$$U(2n_g)_L \times U(2n_g)_R \longrightarrow U(2n_g)_{L+R}$$

$$(N_F - N_B) = \overset{\text{Leptons}}{8n_g} - (\overset{\text{GB}}{4n_g^2} - 1 - \overset{\text{W,Z}}{3} + \overset{g^{\mu\nu}}{2} + \overset{\gamma}{2}) = 4n_g(2 - n_g) \quad < 0$$

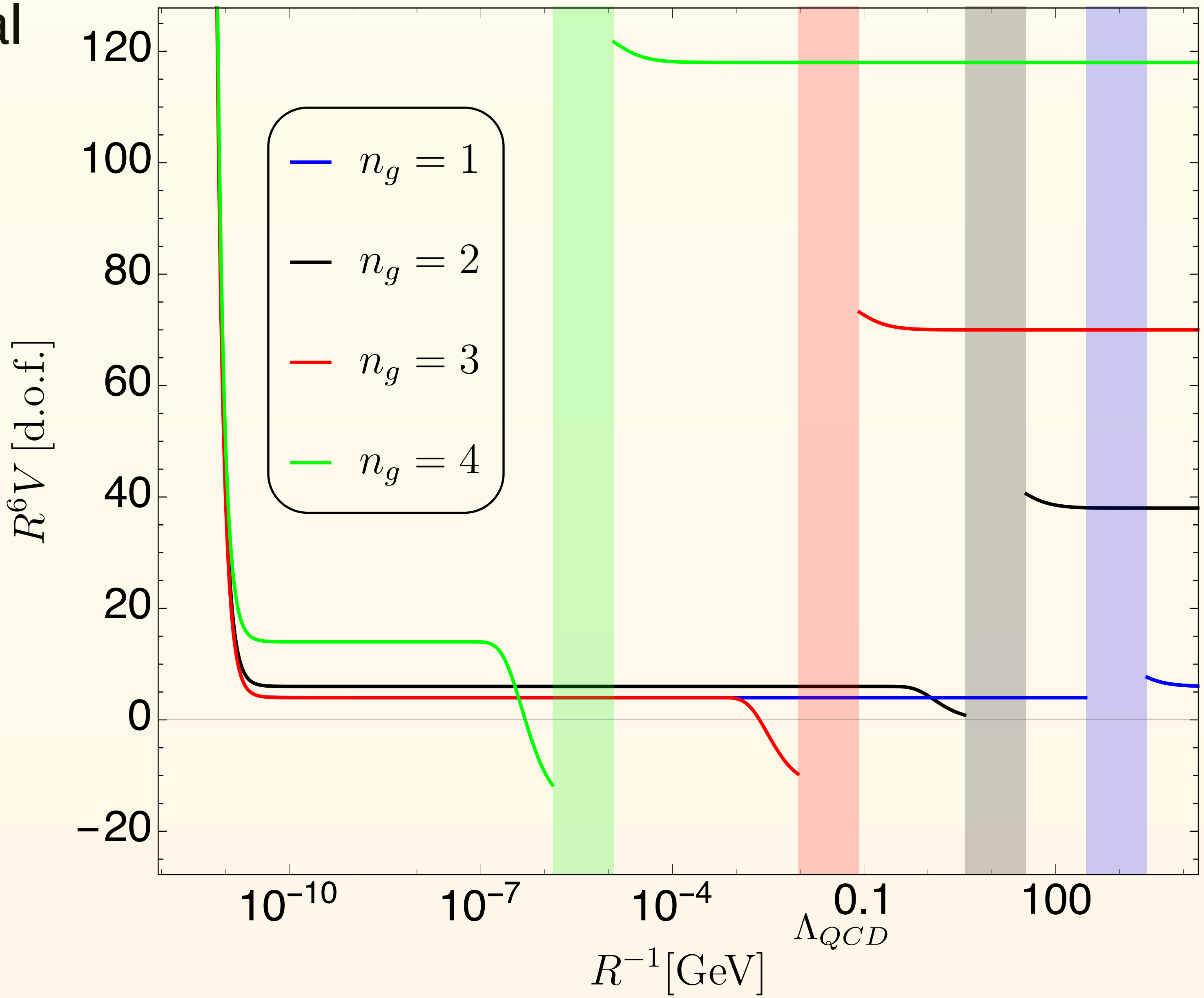
$\textit{Above}\ \Lambda_{QCD}:$ $\quad$ *Quarks deconfine*

$$(N_F - N_B) = \overset{\text{quark/leptons}}{32n_g} - \overset{\text{Gauge}}{24} - \overset{g^{\mu\nu}}{2} \quad > 0$$

- An AdS vacuum necessarily develops for $n_g \geq 3$

E.Gonzalo, L.I. 2018

3D potential

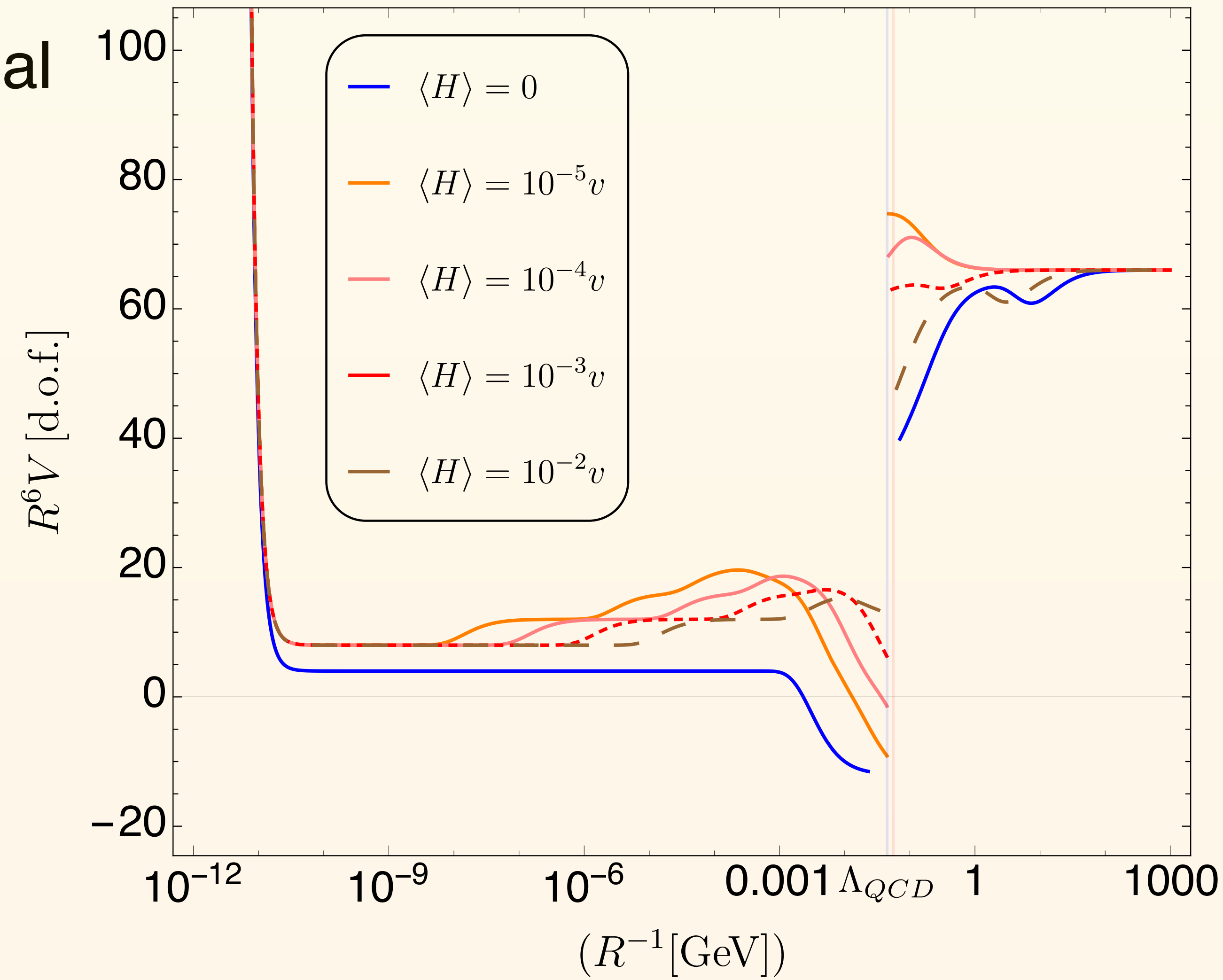


Higgs is needed….if the number of generations is 3 or more

Lower bound on Higgs vev

As we turn the Higgs vev on, with SM Yukawa fixed,
the goldstones start becoming heavy: fewer bosons

3D potential



$h = < H >$

$$To\ avoid\ AdS\ vacua: \qquad |H| \gtrsim \Lambda_{QCD}$$

Hierarchy problem and the swampland

Dirac neutrinos(NH):

$$m_{\nu_1} = Y_\nu < H >$$

$$m_{\nu_1} \lesssim 4.12 \times 10^{-3} eV = 1.6 \Lambda_4^{1/4}$$

Hierarchy problem and the swampland

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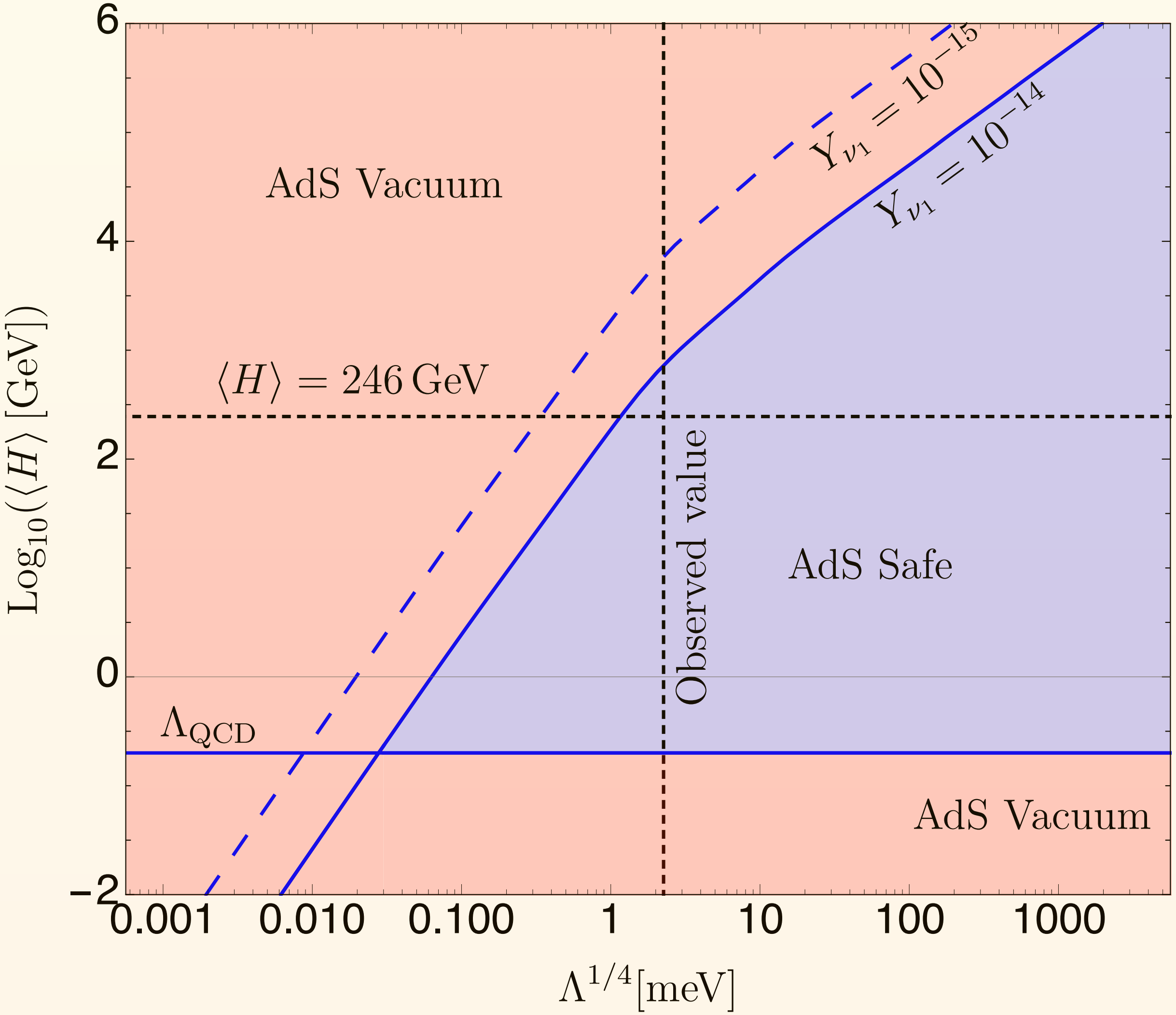


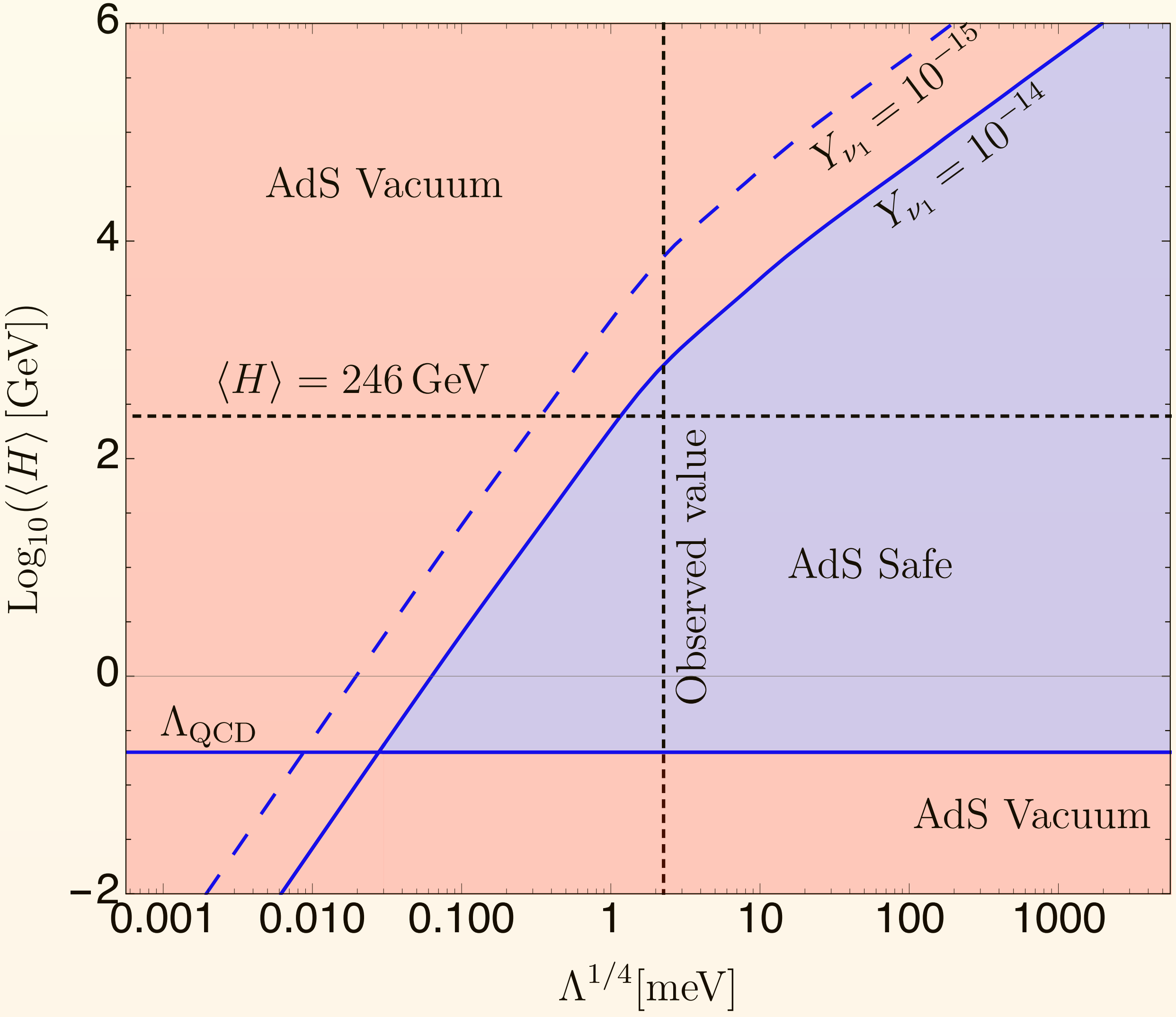
$< H > \lesssim 1.6 \frac{\Lambda_4^{1/4}}{Y_\nu}$

EW scales above 1 TeV in the Swampland!!

(For fixed Y_ν and Λ_4)

Hierarchy problem and the swampland

Dirac neutrinos(NH):



$$m_{\nu_1} = Y_\nu < H >$$

$$m_{\nu_1} \lesssim 4.12 \times 10^{-3} eV = 1.6 \Lambda_4^{1/4}$$

$$< H > \lesssim 1.6 \frac{\Lambda_4^{1/4}}{Y_\nu}$$

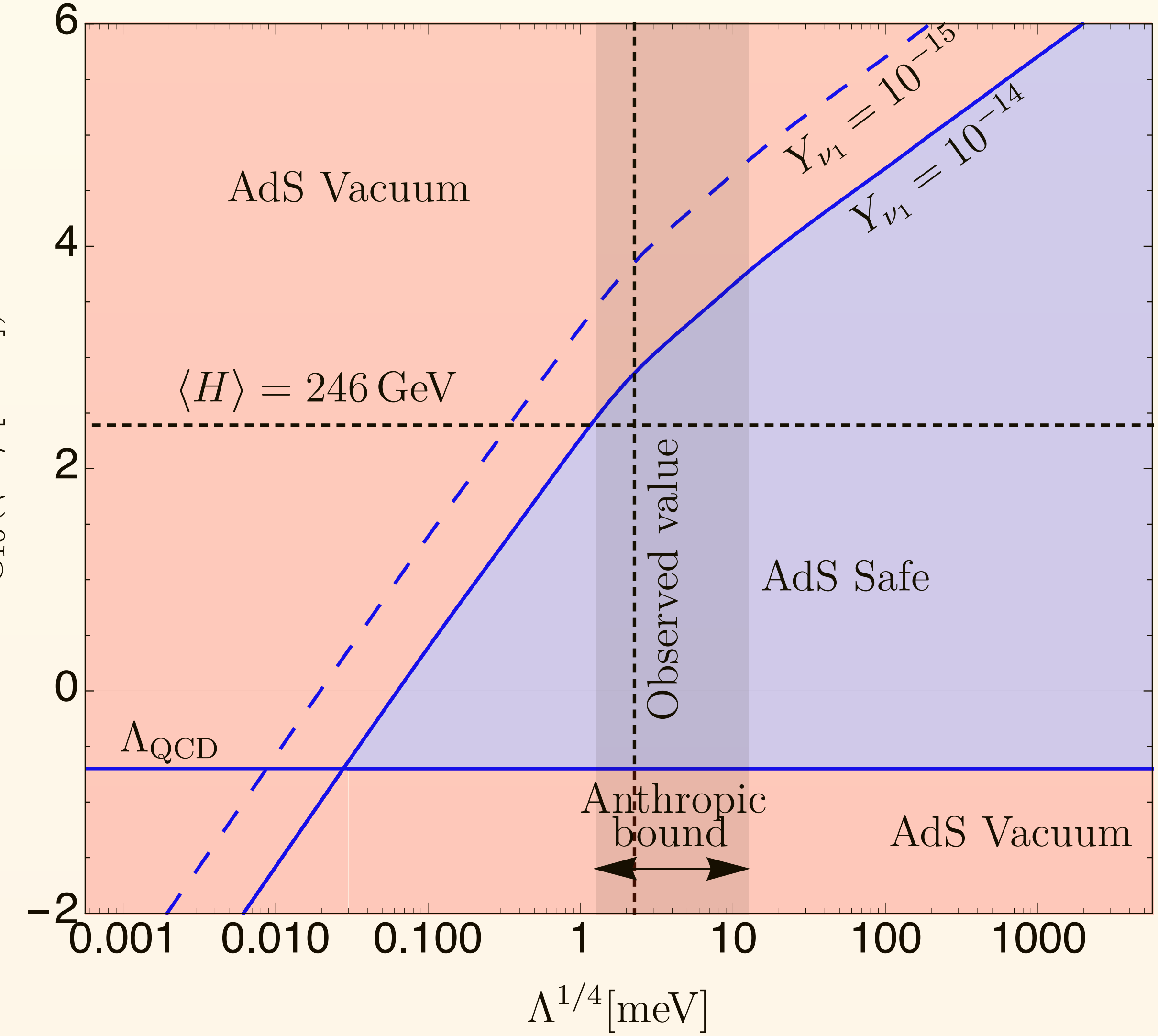
EW scales above 1 TeV in the Swampland!!

No real fine-tuning……

EW scale tied up to Λ_4

Hierarchy problem and the swampland

Dirac neutrinos(NH):



$$m_{\nu_1} = Y_\nu < H >$$

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EW scales above 1 TeV in the Swampland!!

No real fine-tuning……

EW scale tied up to Λ_4

L.I.,Martin-Lozano, Valenzuela 2017; E.Gonzalo, L.I. 2018

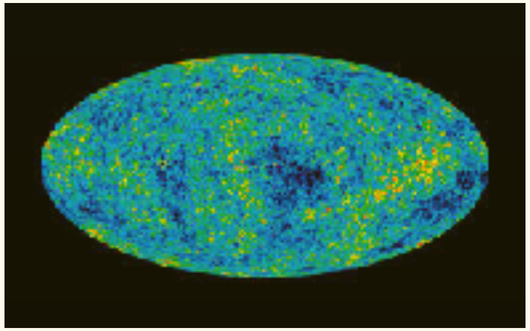
$$H_{ex} + \Delta H \leq \frac{a\Lambda_4^{1/4}}{h_{\nu_1}}$$

$$\frac{|\Delta H|}{|H|} \leq \frac{(a\Lambda_4^{1/4} - m_{\nu_1})}{m_{\nu_1}}$$

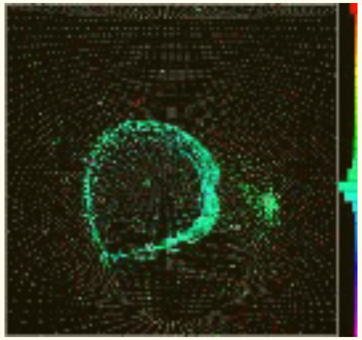
EW fine-tuning is related to the proximity between neutrino masses and the c.c.!

L.I.,Martin-Lozano, Valenzuela 2017; E.Gonzalo, L.I. 2018

EW fine-tuning



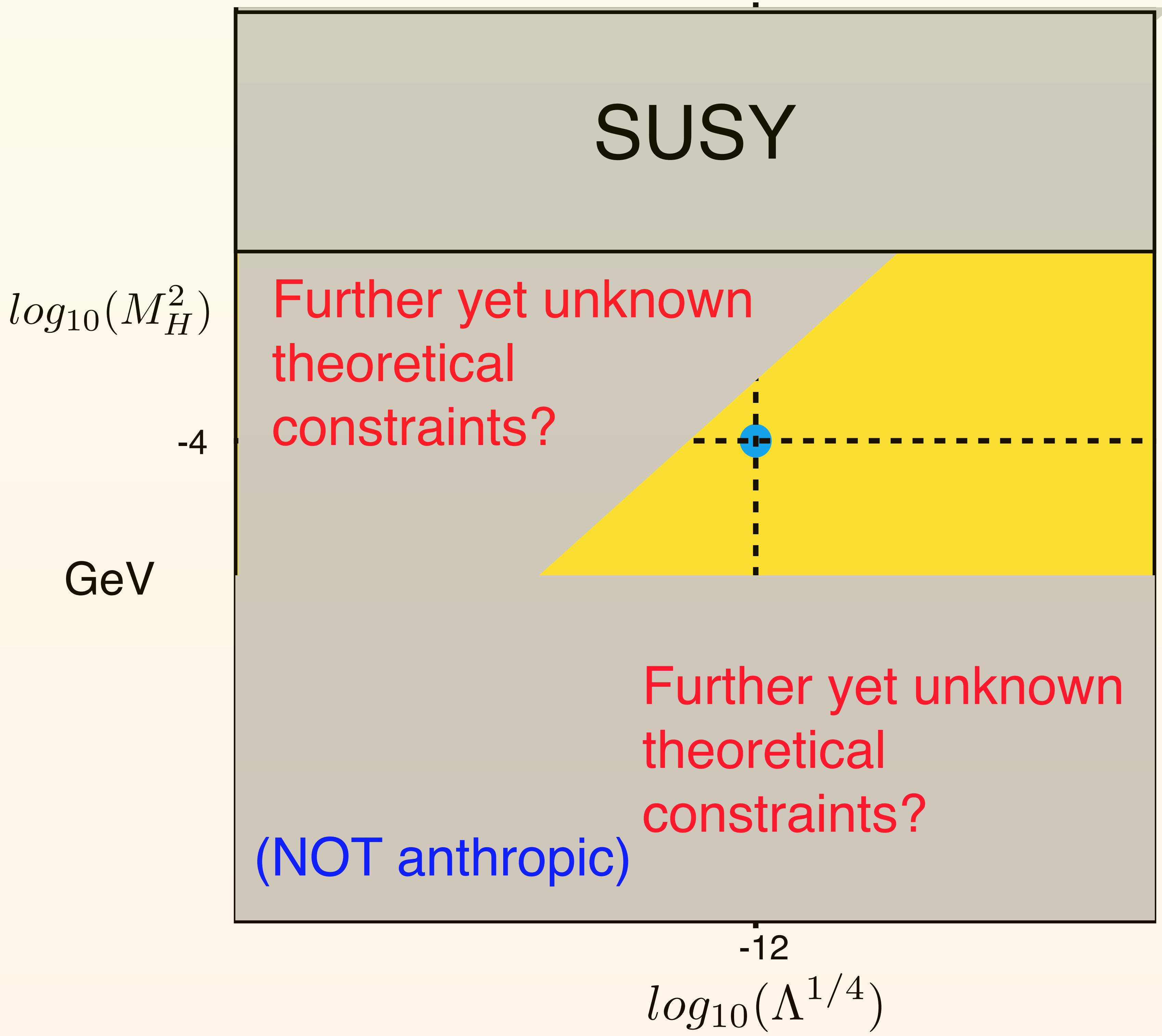
Dark Energy

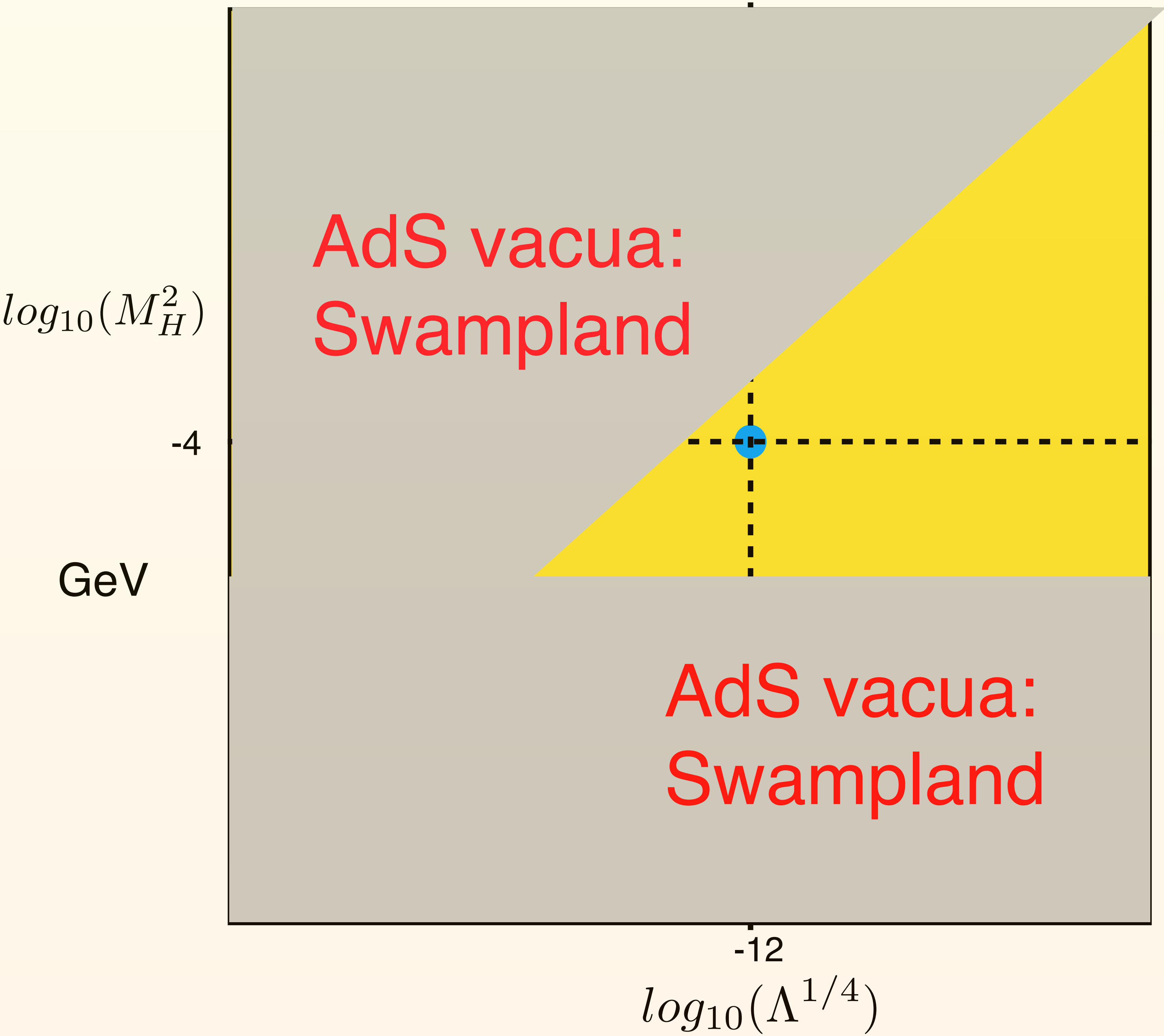


Neutrino Physics

$$\frac{|\Delta H|}{|H|} \leq \frac{(a\Lambda_4^{1/4} - m_{\nu_1})}{m_{\nu_1}}$$

Surprising connection of neutrino physics with the hierarchy prolem!


SUSY
$log_{10}(M_H^2)$
-4
GeV
Further yet unknown theoretical constraints?
Further yet unknown theoretical constraints?
(NOT anthropic)
-12
$log_{10}(\Lambda^{1/4})$



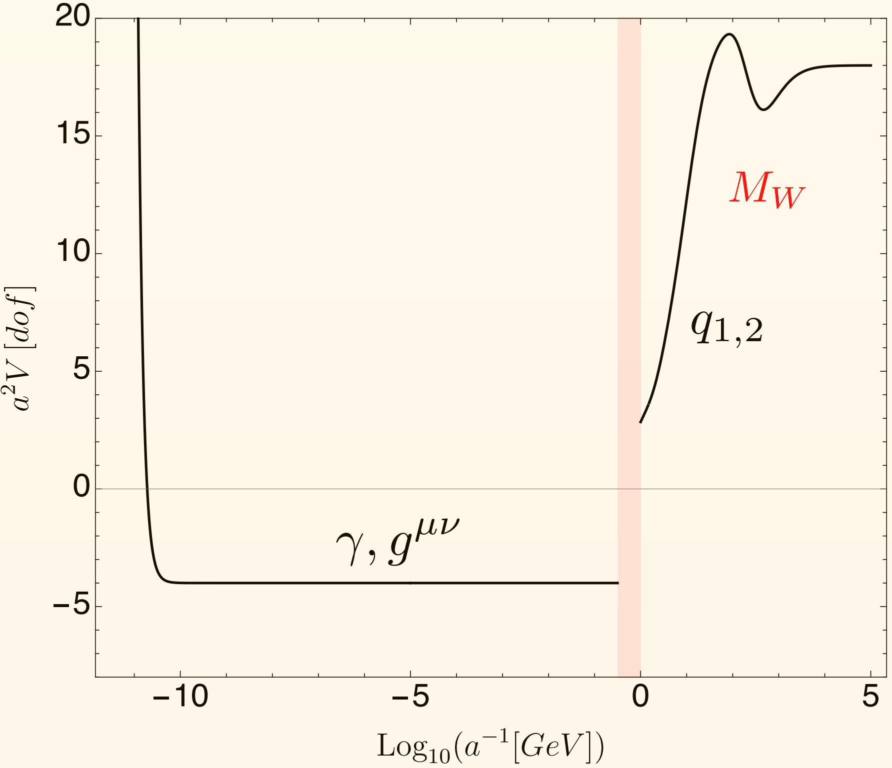
AdS vacua:
Swampland
$log_{10}(M_H^2)$
-4
GeV
AdS vacua:
Swampland
-12
$log_{10}(\Lambda^{1/4})$

Is there a role for SUSY here?

SM

T^2/Z_N *new SM stable*

AdS vacua exist



AdS minimum forms

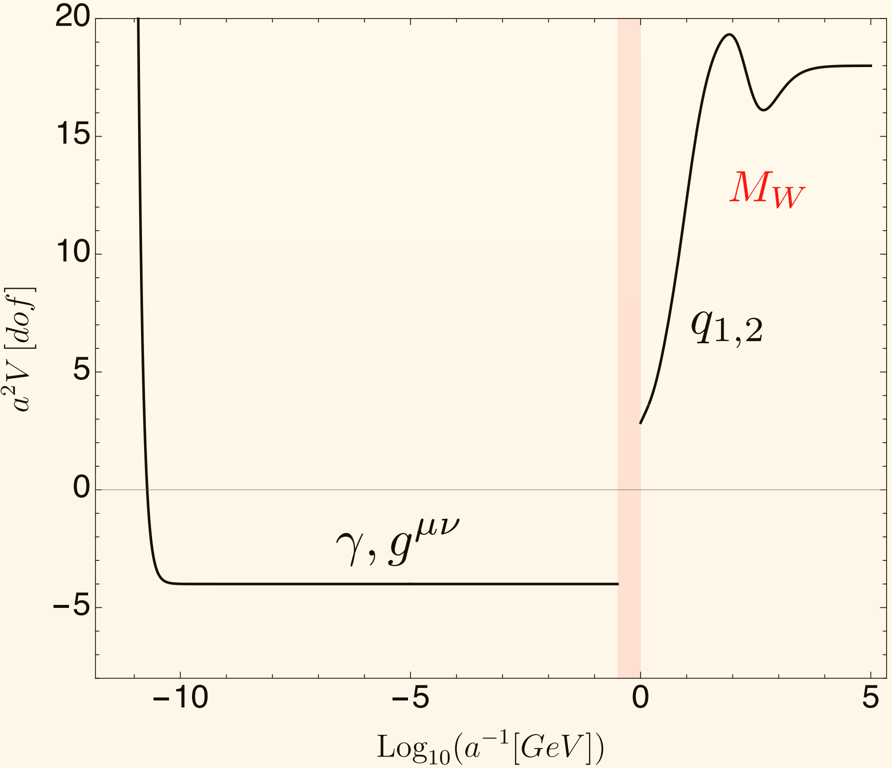
SM in Swampland!

Gonzalo, Herraez, L.I. 2018

SUSY survives the test

SM

A T^2/Z_4 SM stable vacuum exists

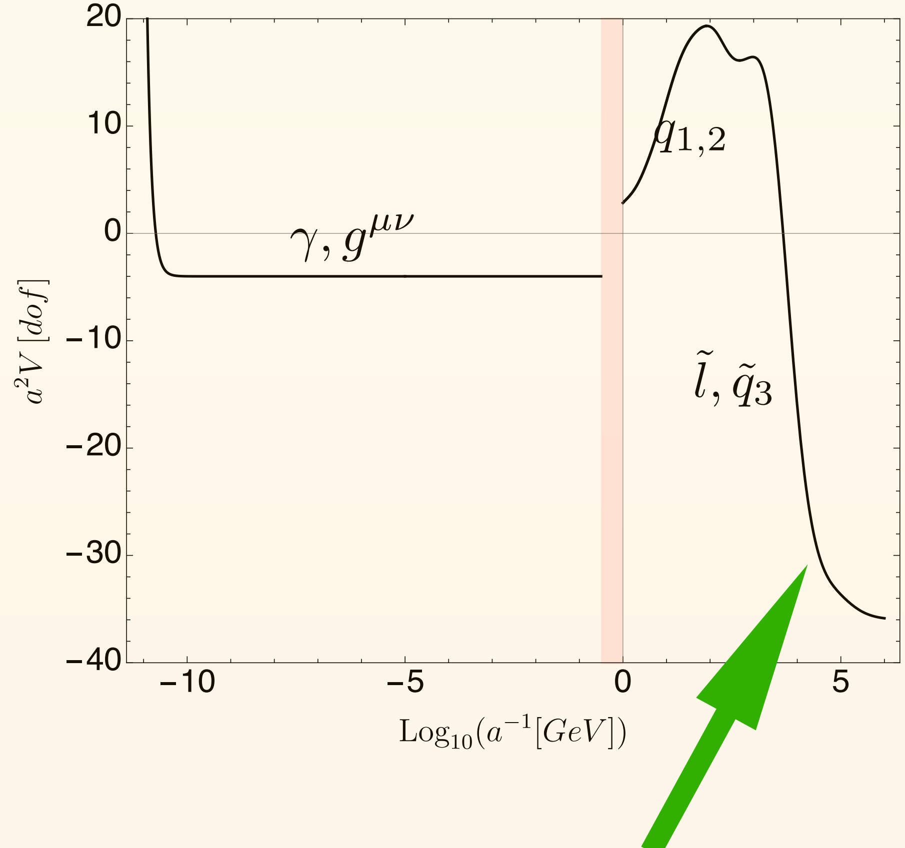


AdS minimum forms

SM in Swampland!

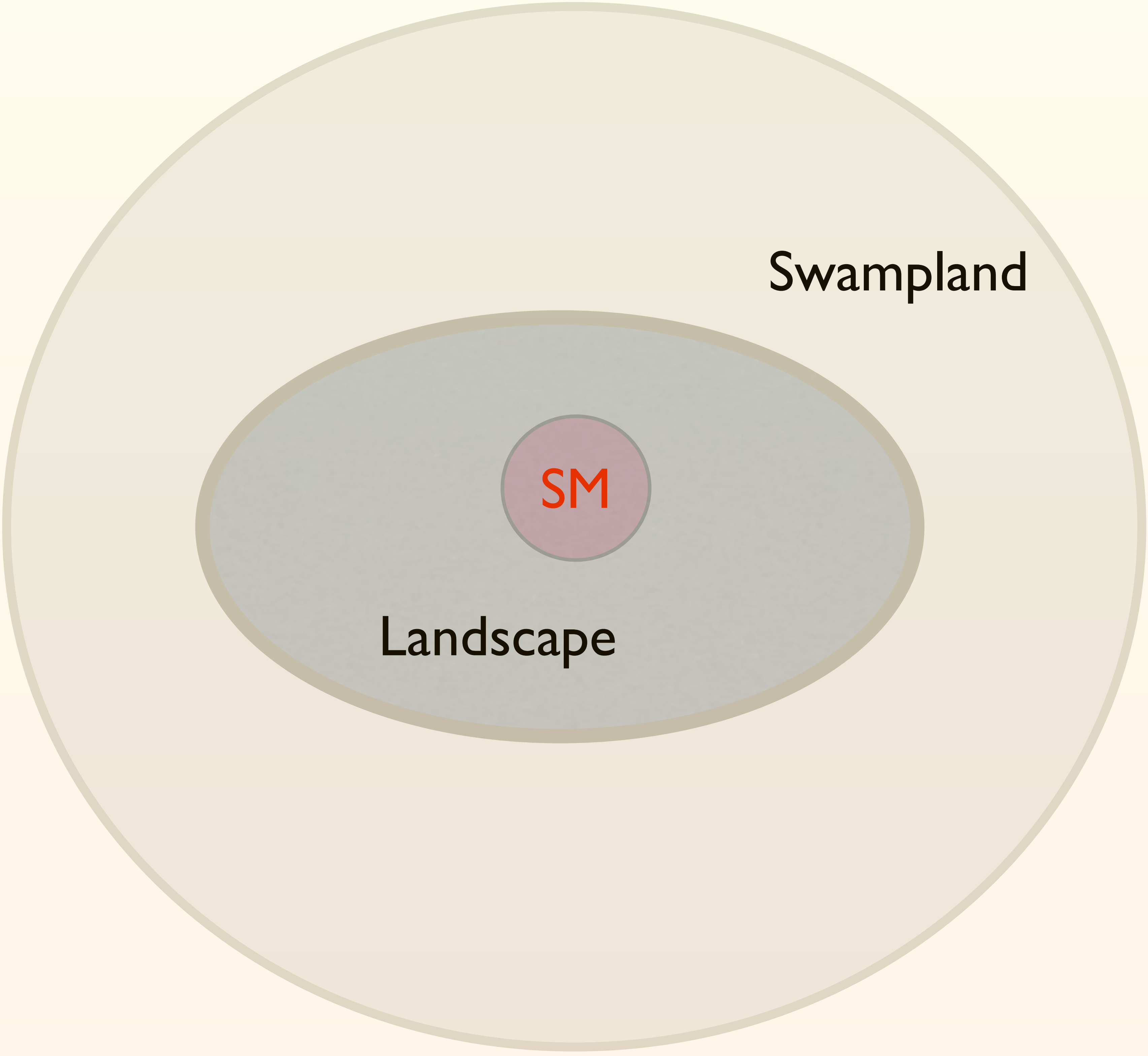
Gonzalo,Herraez,L.I. 2018

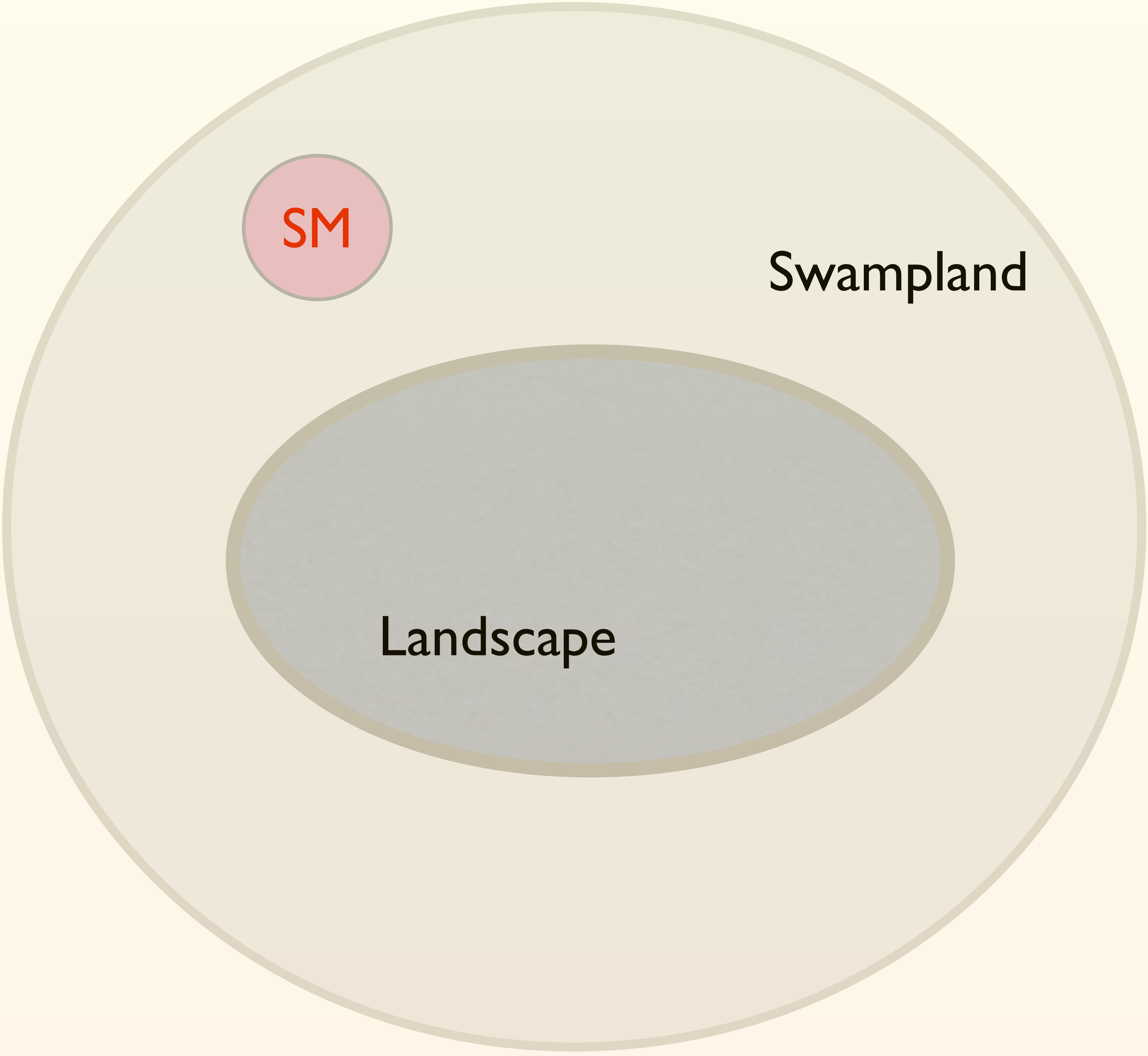
MSSM

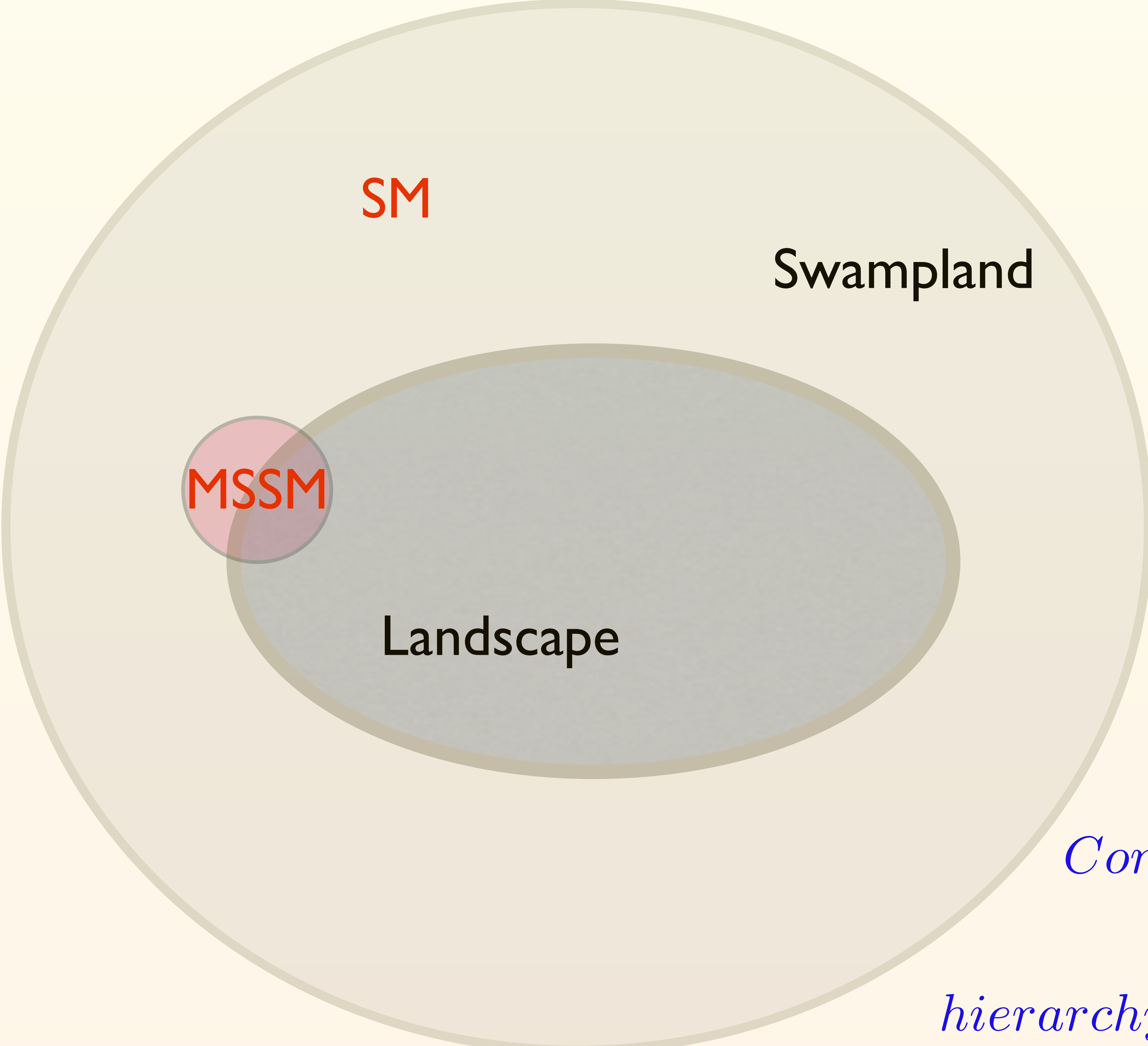


AdS minimum **unstable**

Due to (negative) contribution of sleptons and some squarks


Swampland
SM
Landscape


SM
Swampland
Landscape



Constraints on $\nu' s, \Lambda_4$ and hierarchy still apply

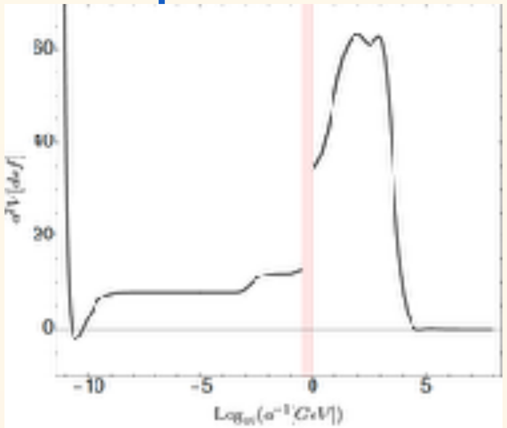
MSSM consistent with Swampland:

- 1) MSSM scale must be below $10^{10} - 10^{12} GeV$ to avoid a second SM minimum

- 2) Charge/color breaking minima in 4D and lower D must lie above the SM Higgs vacuum to avoid additional AdS. This implies a relatively heavy spectrum at the few TeV level.

- 3) There may be sum rule constraints on the SUSY spectrum, In particular, maintaining the Higgs upper bound requires:

$$\sum_{B,F}(m_B^2 - m_F^2) > 0$$



This is violated if e.g. $m_{\tilde{g}} \gg m_{\tilde{q}}$ but also depend e.g. on $m_{sgoldstino}, m_{3/2}, ..$

Gonzalo,Herraez,L.I. 2018

Keeps SM away
from the Swampland

Explains residual
fine-tuning

SUSY+WGC*
Symbiosis

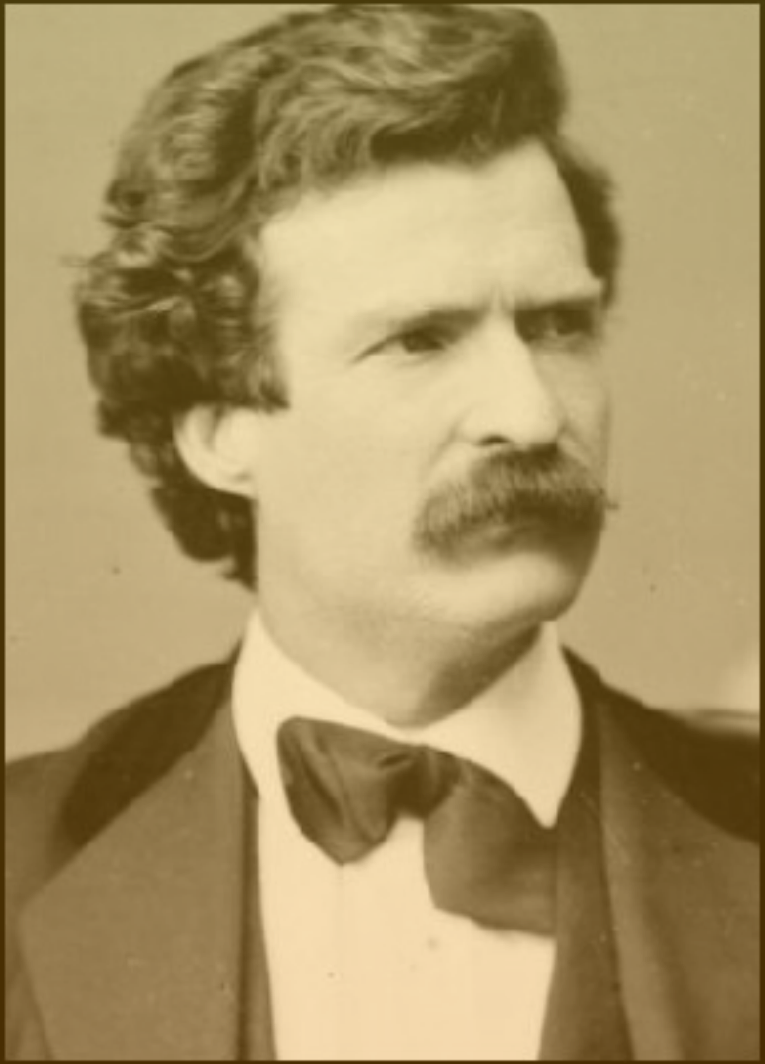
Gauge coupling unification
Dark matter candidates
Consistent with Higgs mass

Constrains on neutrino masses

$$\Lambda_4^{1/4} \gtrsim m_{\nu_i}$$

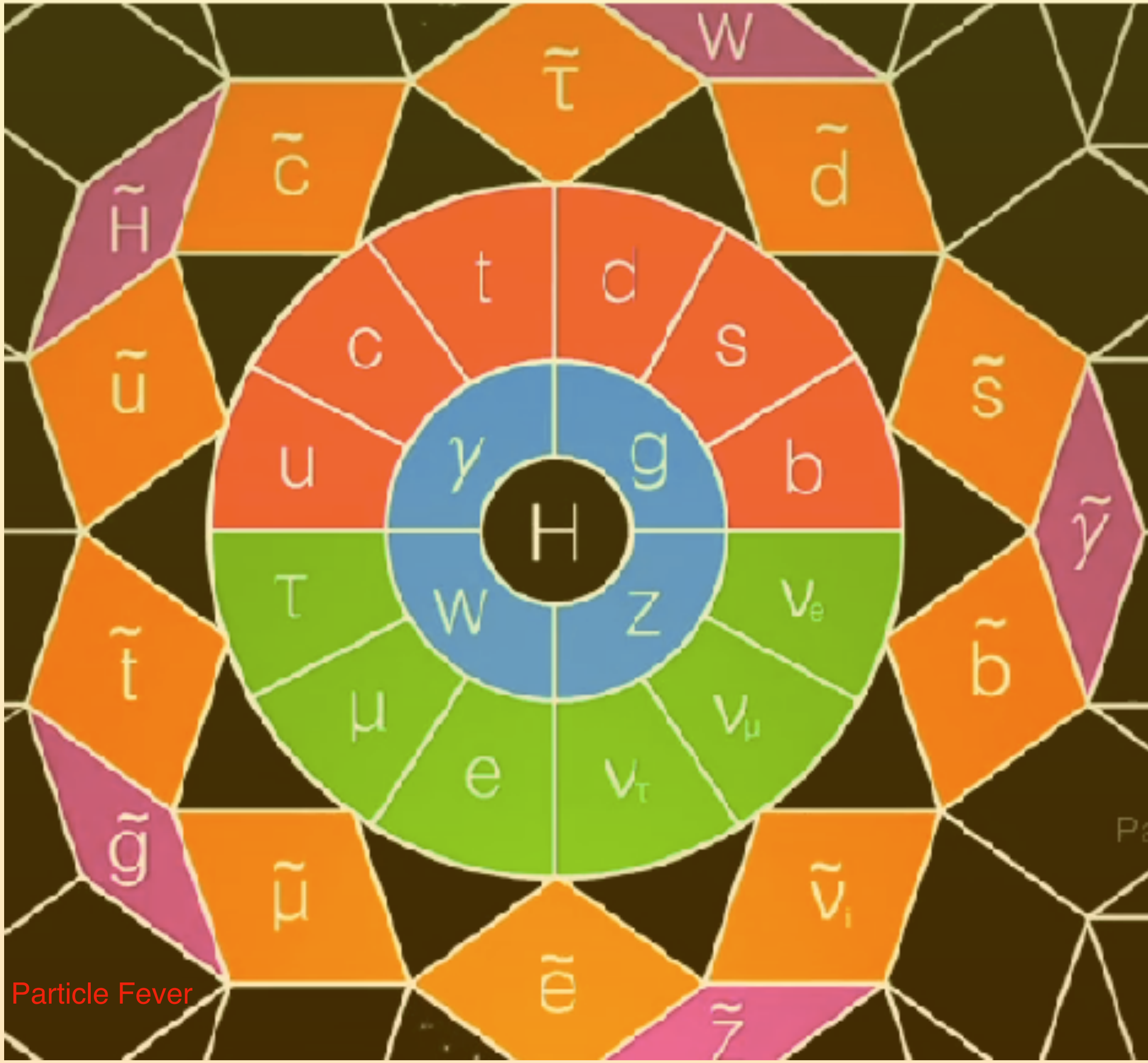
Requires existence of a Higgs for 3 or more gen.
May lead to constraints on SUSY masses

*Should try to gather more evidence for these conjectures and their application to the SM !!



The reports of my death have been greatly exaggerated.

- Mark Twain -



Particle Fever

"Reports of my death have been greatly exagerated"

SUSY

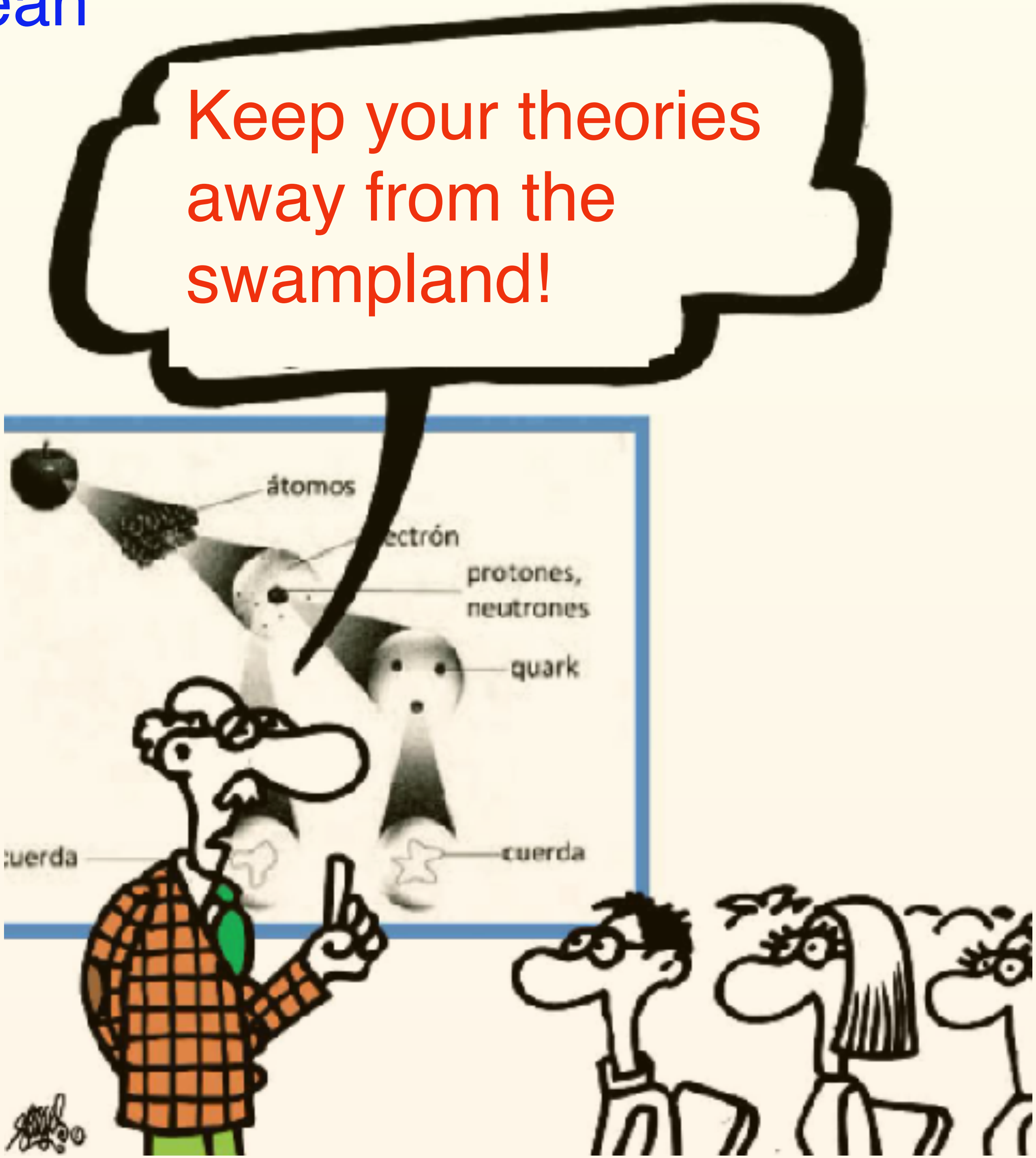
ADDRESS PUZZLES OF EW SCALE

Experimental:
LHC,HL-LHC,
ILC, FCC,….
$Also\ \nu's, DM, Cosmo..$

Model-building:
SUSY, and alternatives

Revisit the concept of naturally UV-IR connection, Swampland

In the mean time….



Thank you !!

Instituto de Física Teórica UAM-CSIC presents:

Vistas over the Swampland

Madrid, 19-21 September 2018

https://workshops.ift.uam-csic.es/swampland

Swamp lookouts

N. Arkani-Hamed (IAS - Princeton)
T. Banks (Santa Cruz & Rutgers U.)
R. Blumenhagen (MPI - Munich)
T. Crisford (DAMTP - Cambridge)
U. Danielsson (Uppsala U.)
A. Hebecker (Heidelberg U.)
M. Kleban (New York U.)
D. Lüst (LMU & MPI - Munich)
M. Montero (ITP - Utrecht)
E. Palti (MPI - Munich)
M. Reece (Harvard U.)
G. Remmen (UC - Berkeley)
T. Rudelius (IAS - Princeton)
G. Shiu (UW - Madison)
P. Soler (Heidelberg U.)
C. Vafa (Harvard U.)
I. Valenzuela (ITP - Utrecht)
T. Van Riet (KU Leuven)

Swamp rangers

L. E. Ibáñez
F. Marchesano
A. M. Uranga

Instituto de Física Teórica UAM-CSIC

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UAM Universidad Autónoma de Madrid

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