NATURALNESS

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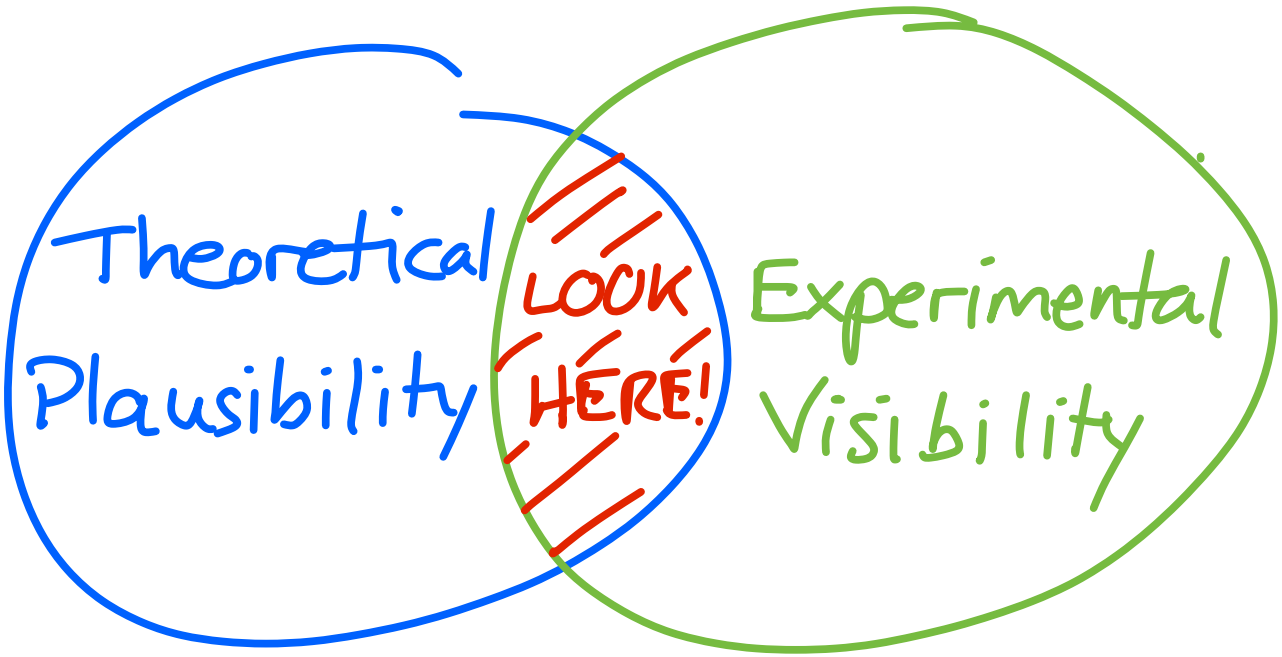
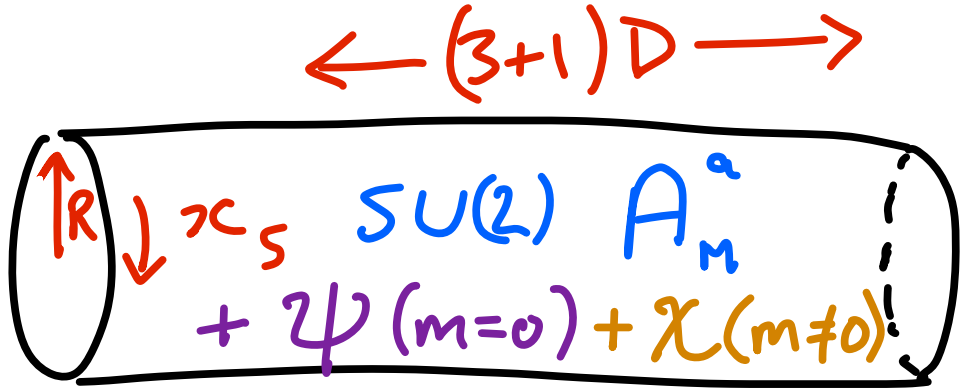
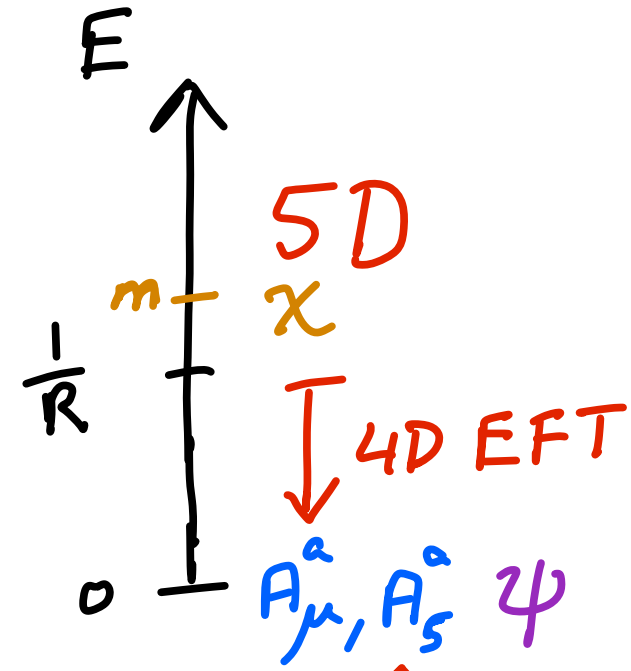
University of Maryland


Theoretical
Plausibility
LOOK
HERE!
Experimental
Visibility

Higher-Dimensional Gauge Theory





$$V_{5D}(A_5) = 0$$

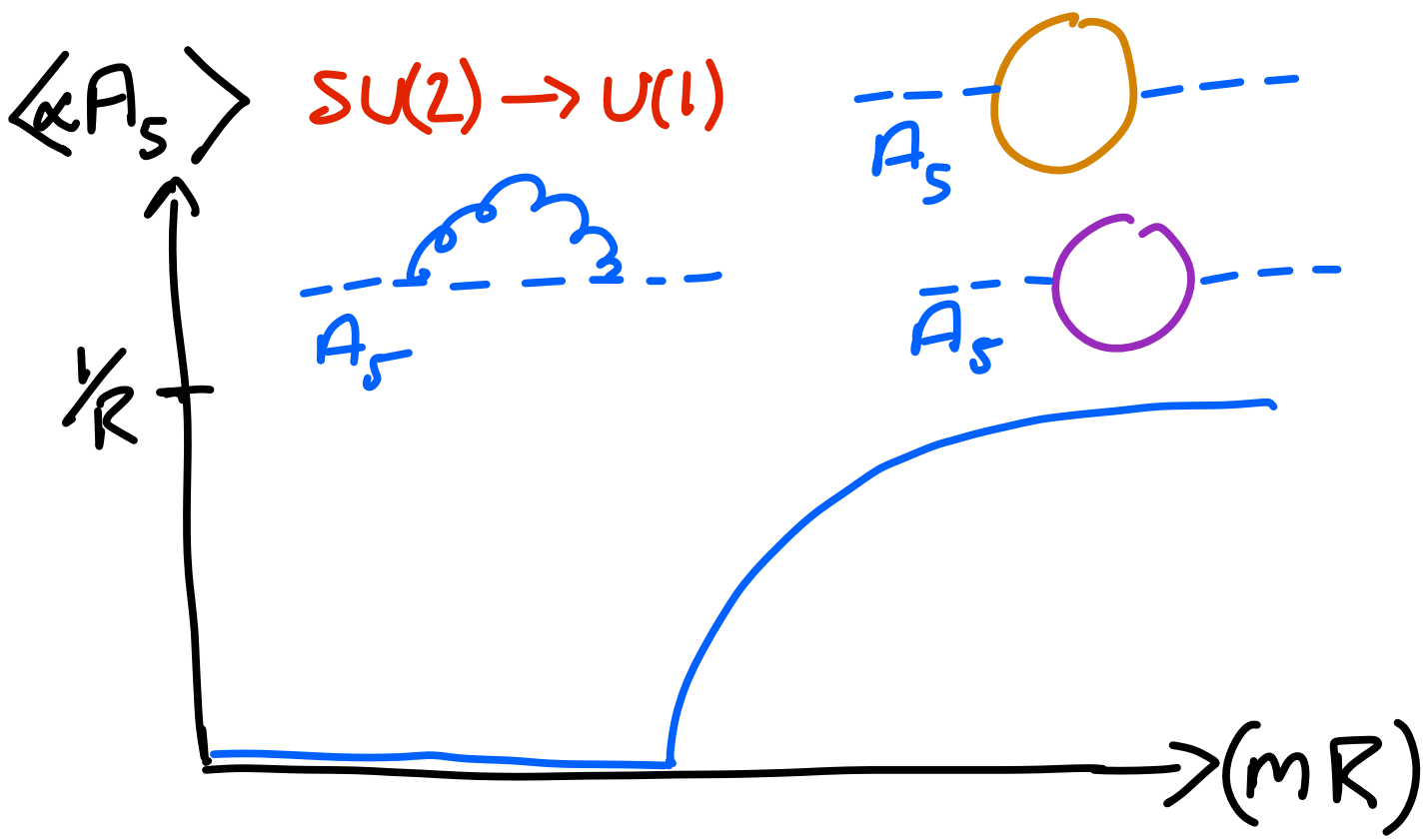
5D Lorentz & Gauge Invariance

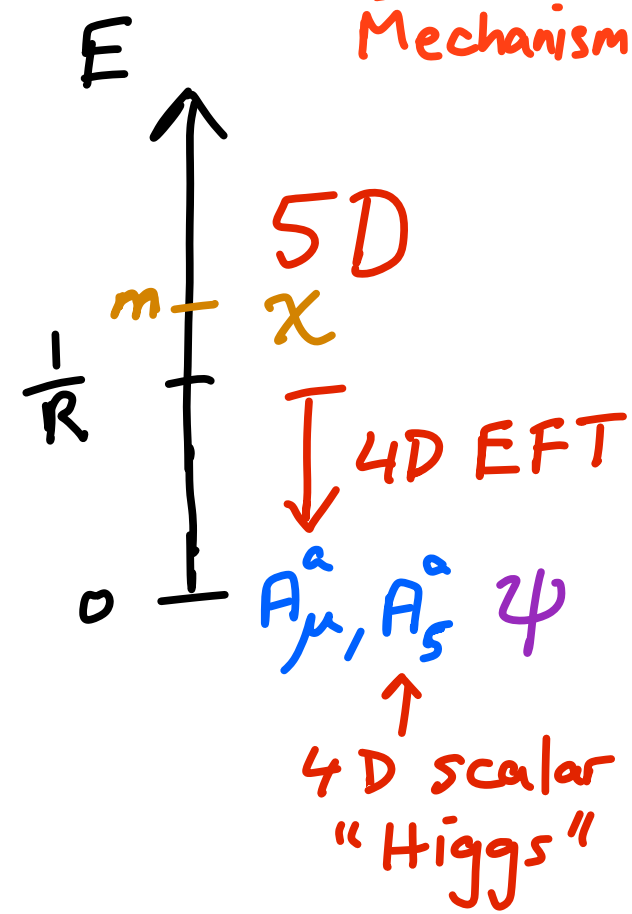
4D scalar "Higgs"

$\Rightarrow$ no short-distance divergent contributions to $V(A_5)$

$\Rightarrow$ FINITE PREDICTIVE RADIATIVE ~~SYMMETRY~~

Hosotani Mechanism





$\langle A_5 \rangle \ll \frac{1}{R} \Rightarrow (A_5 R)^2$ fine-tuning

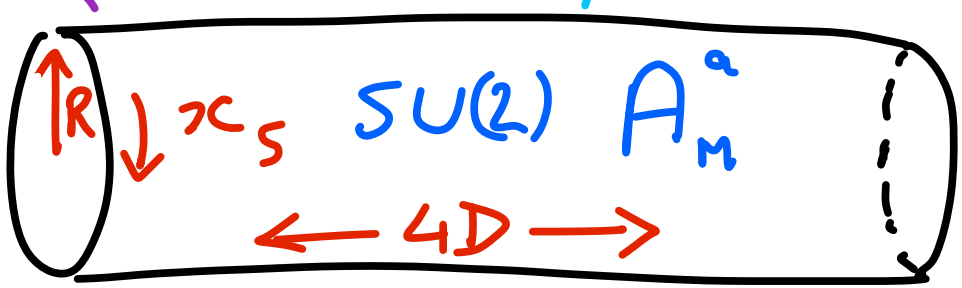
REALISTIC PREDICTIVE DYNAMICS

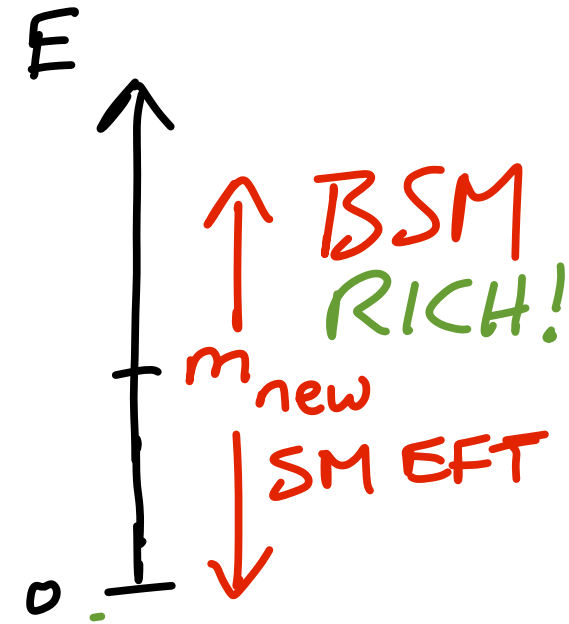
SUSY

fermionic extra dimensions

Strings

extra dimension added to point particle → string





lattice extra dimensions

Little Higgs

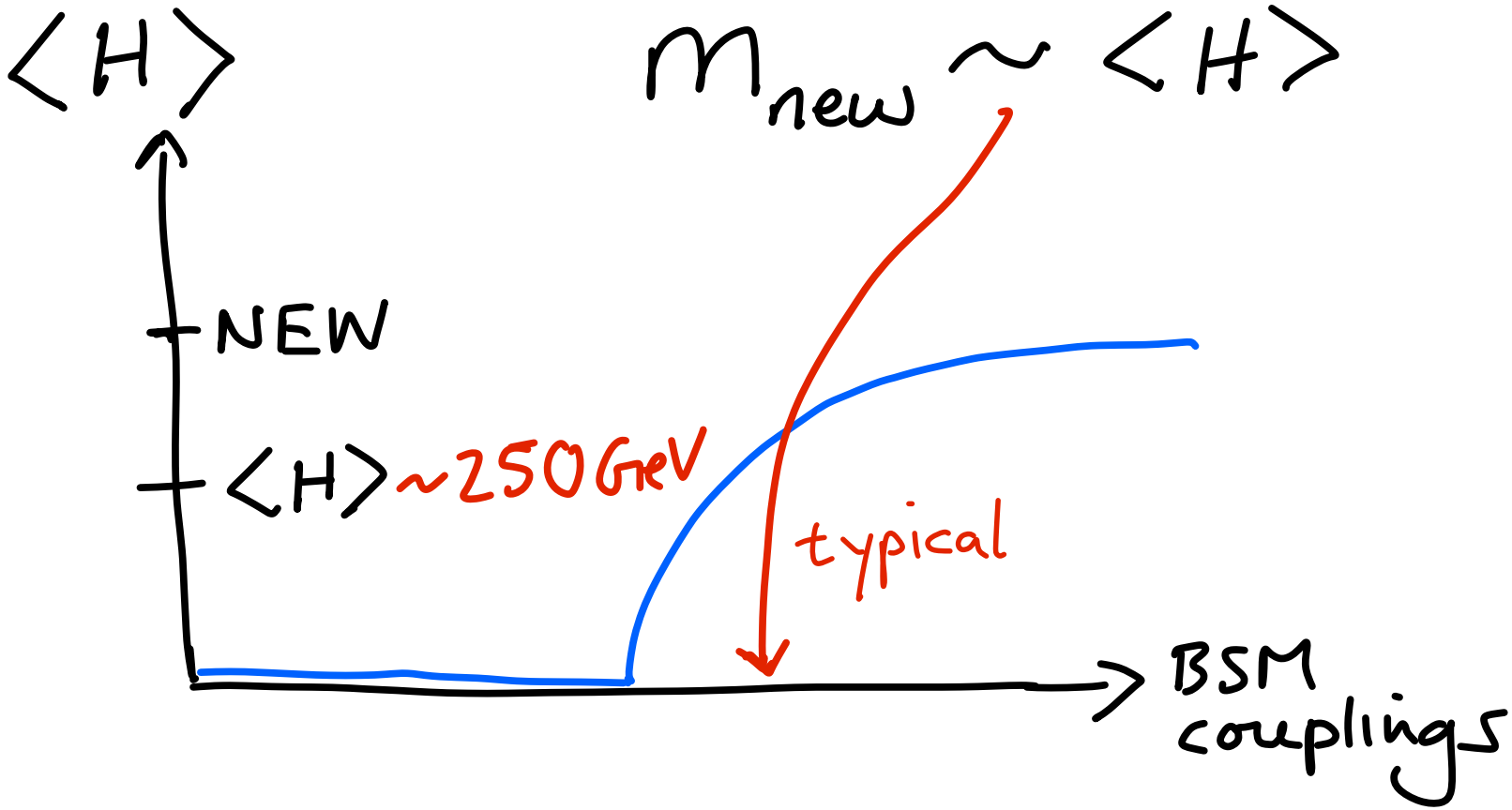
Warped extra dimension

RS1

AdS/CFT

(Partial) Compositeness

NATURALNESS



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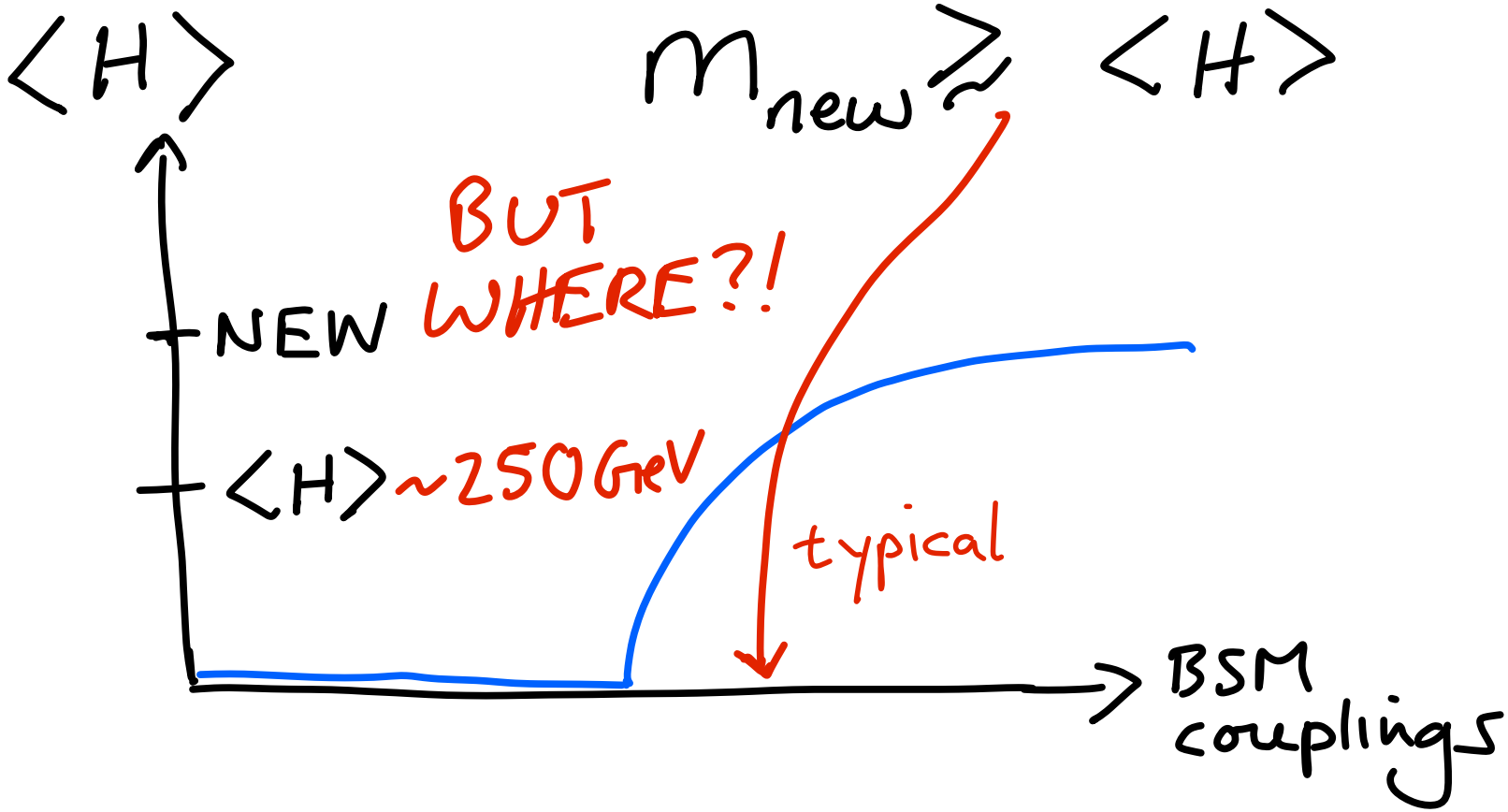
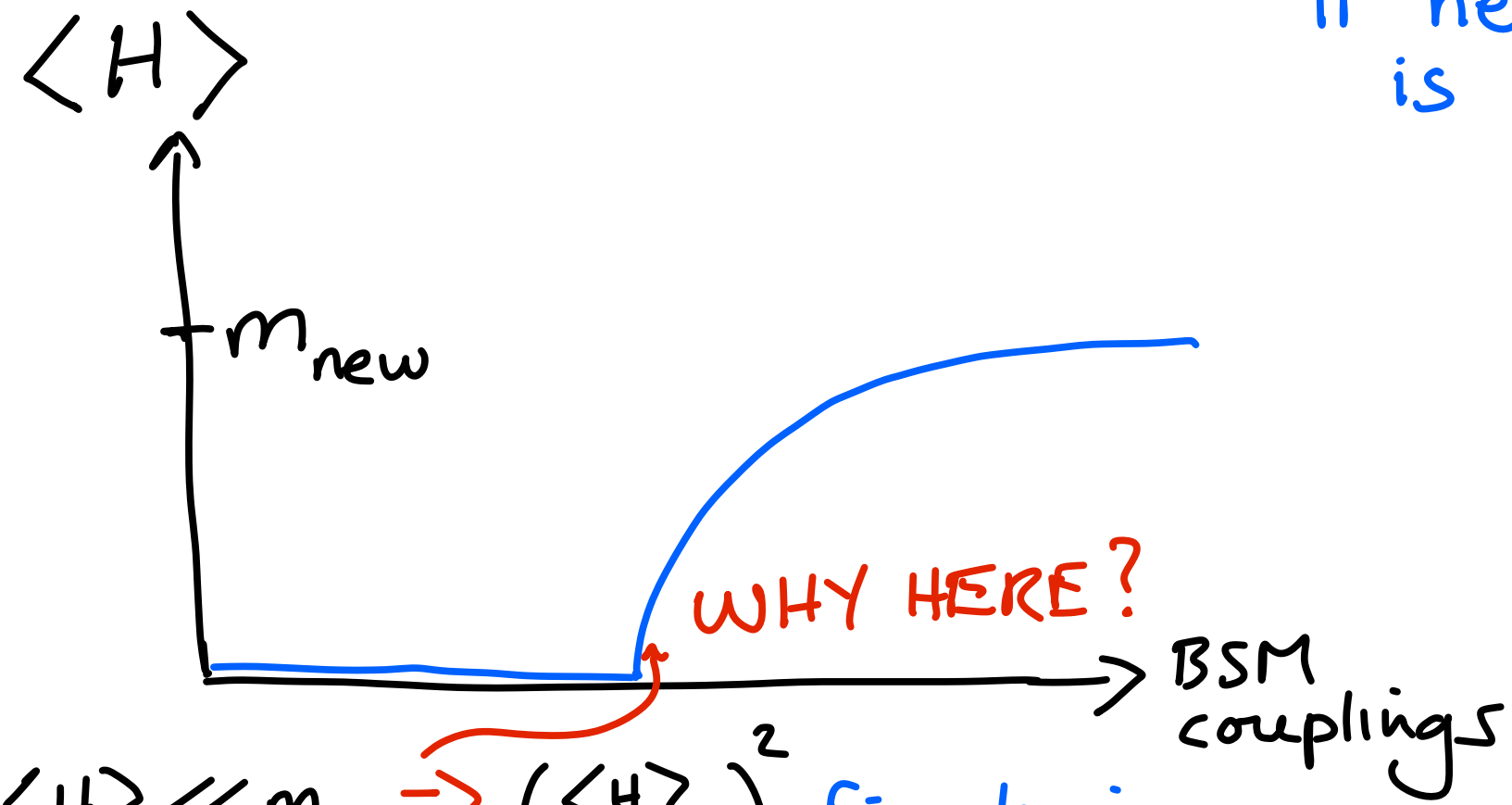


HIERARCHY PROBLEM

if new physics is delayed.



$\langle H \rangle \ll m_{new} \Rightarrow \left(\frac{\langle H \rangle}{m_{new}}\right)^2$ fine-tuning

INTERACTING SCALARS ARE RARE!

We observe:

LOTS of spin ½, 1 fundamental fields

Massless spin 2 (theoretically must be) GRAVITY

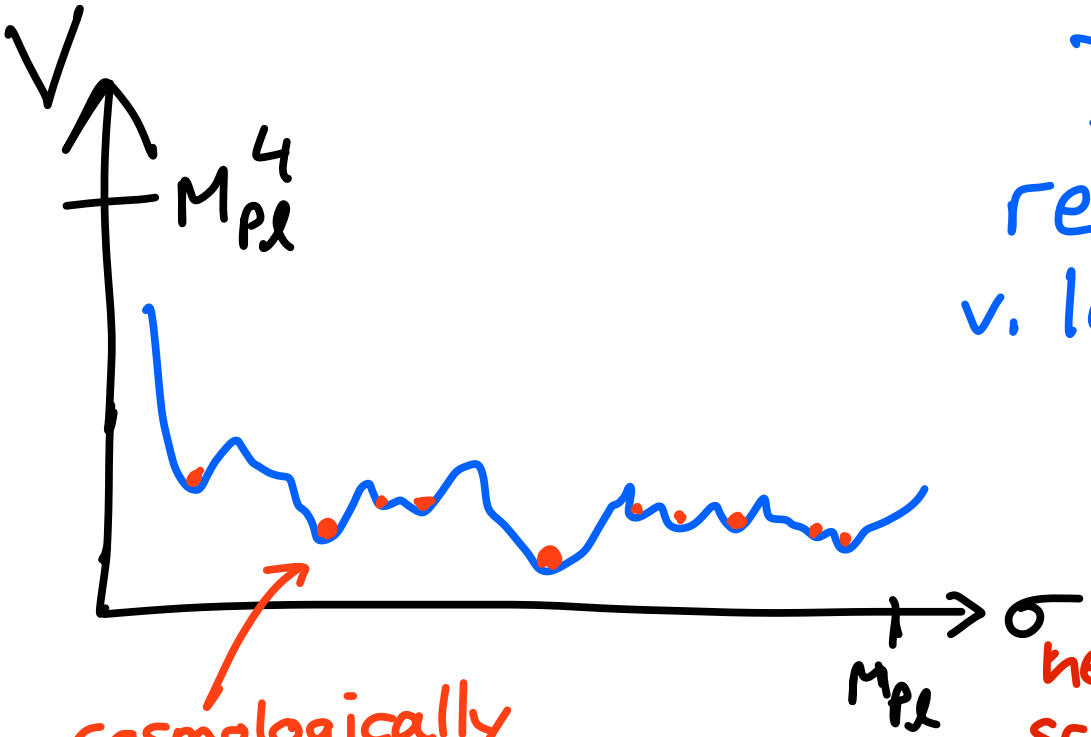
Lots of composite (hadronic) fields of all spins. Includes spin-0 Eg. π^+, but m_{π^+} beautifully NATURAL due to QCD compositeness.

HIGGS BOSON IS EXCEPTIONAL!

LANDSCAPE

MULTIVERSE

Different vacua "i" realized in different v. large patches of spacetime ...



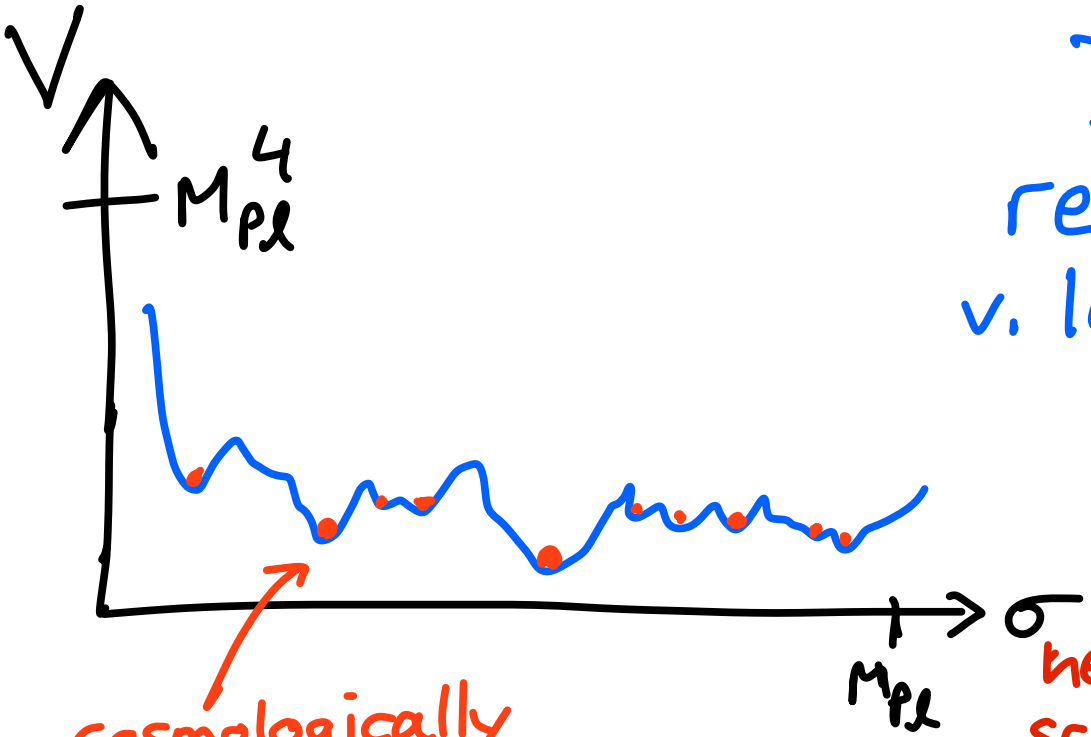
cosmologically metastable vacua

heavy scalars

$$\mathcal{L}_{eff} \supset \left(1/\alpha + \frac{\sigma}{M_{Pl}}\right) F_{\mu\nu}^2$$

LANDSCAPE

MULTIVERSE



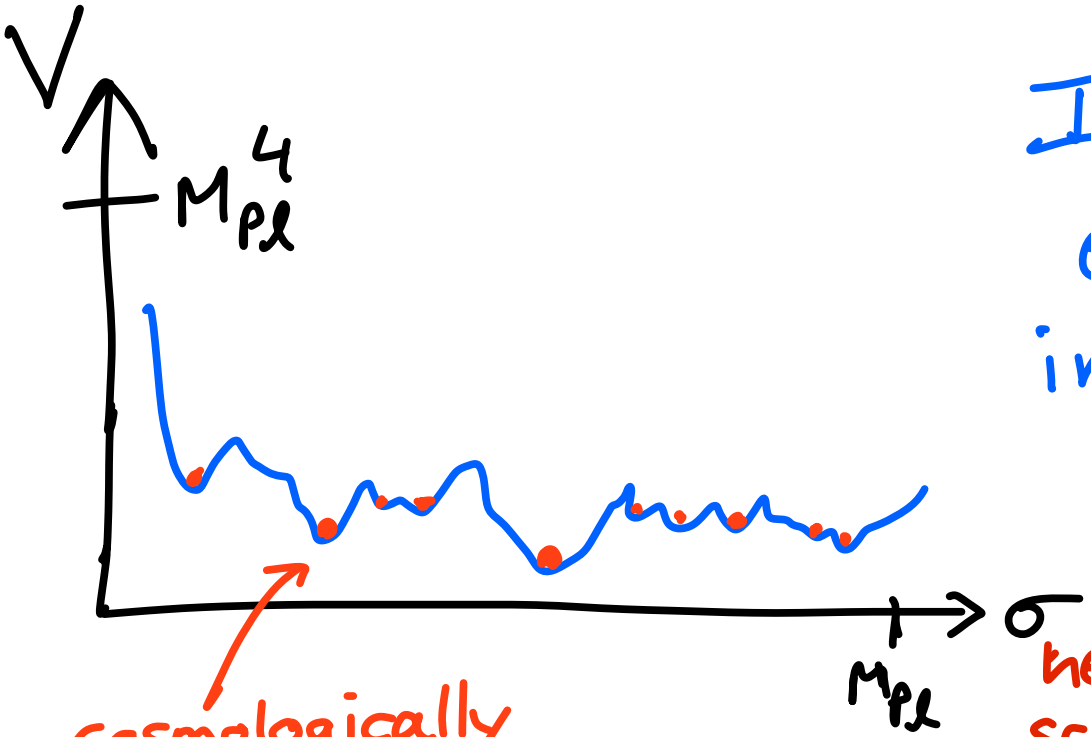
cosmologically metastable vacua

heavy scalars

Different vacua "i" realized in different v. large patches of spacetime, with different effective couplings, $\alpha_{eff,i}$.

$$\mathcal{L}_{eff}^{SM} \supset \underbrace{\left(1/\alpha + \frac{\langle\sigma\rangle_i}{M_{Pl}}\right)}_{\equiv\, 1/\alpha_{eff,i}} F_{\mu\nu}^2$$

ANTHROPIC PRINCIPLE



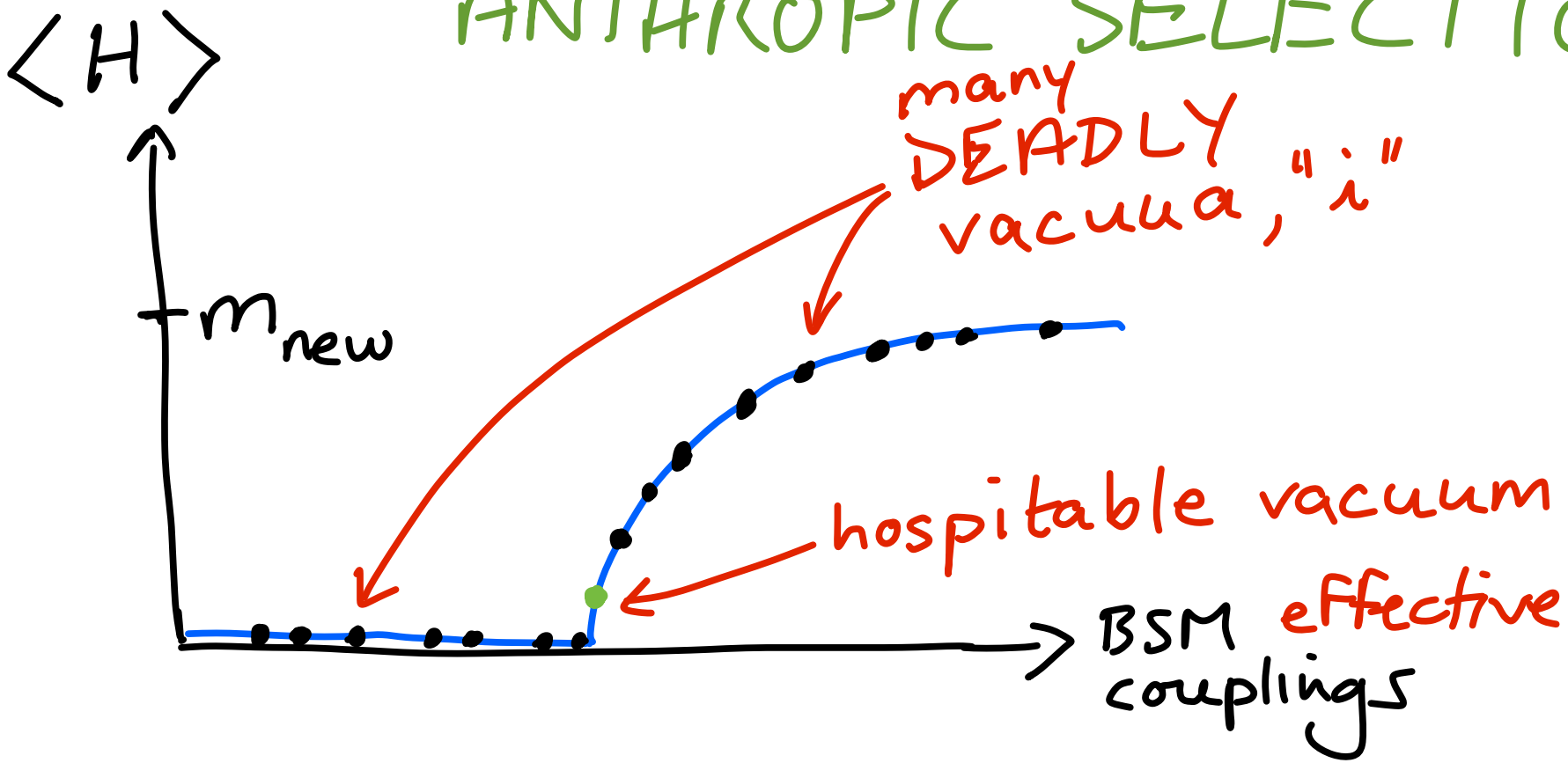
cosmologically metastable vacua

heavy scalars

Intelligent Life evolves in patches in which effective interactions $\alpha_{eff,i}$ are "tuned" to be "hospitable"

$$\mathcal{L}_{eff} \supset \underbrace{\left(1/\alpha + \frac{\langle\sigma\rangle_i}{M_{Pl}}\right)}_{\equiv\, 1/\alpha_{eff,i}} F_{\mu\nu}^2$$

HIERARCHY BY ANTHROPIC SELECTION?



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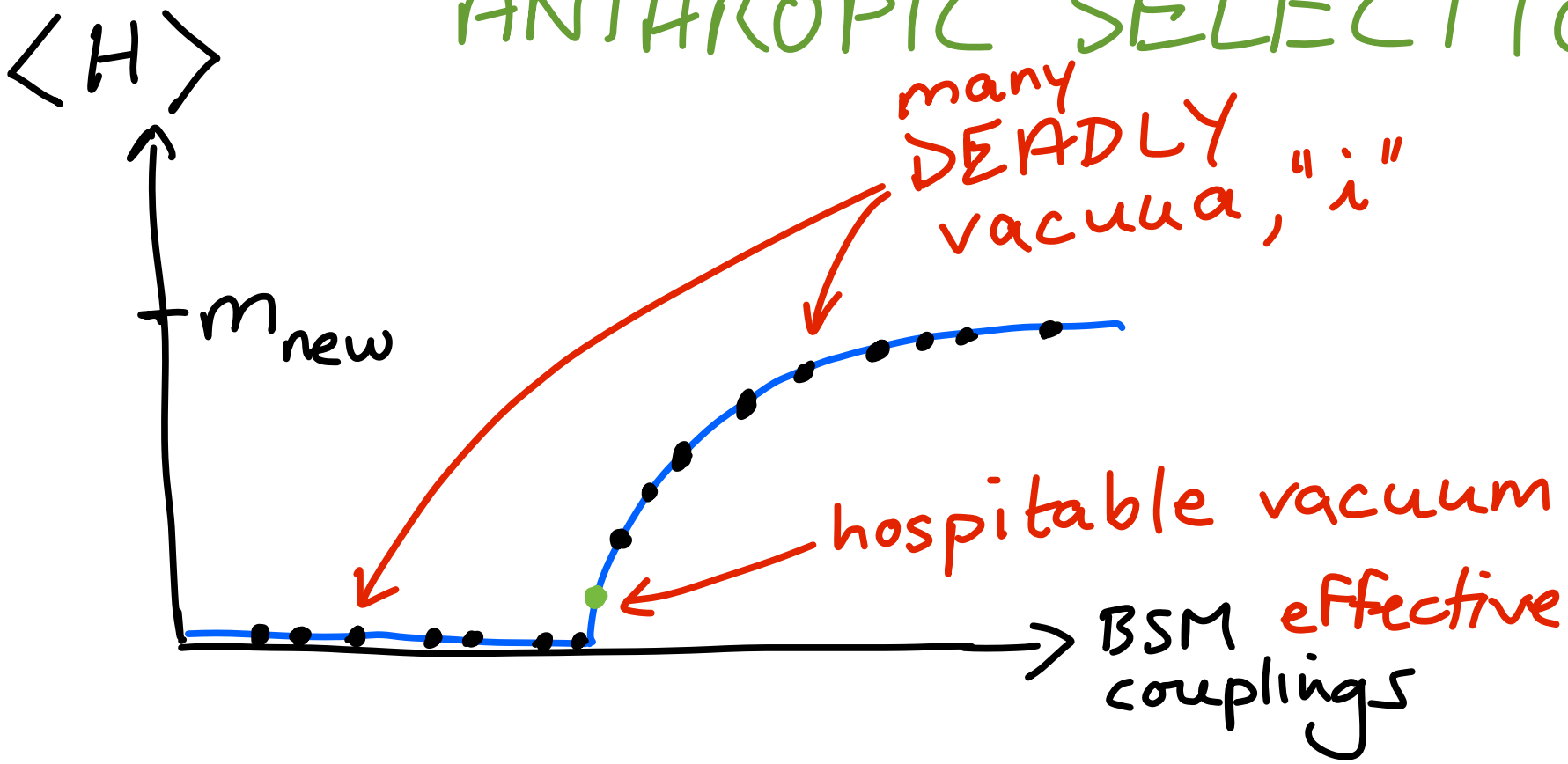
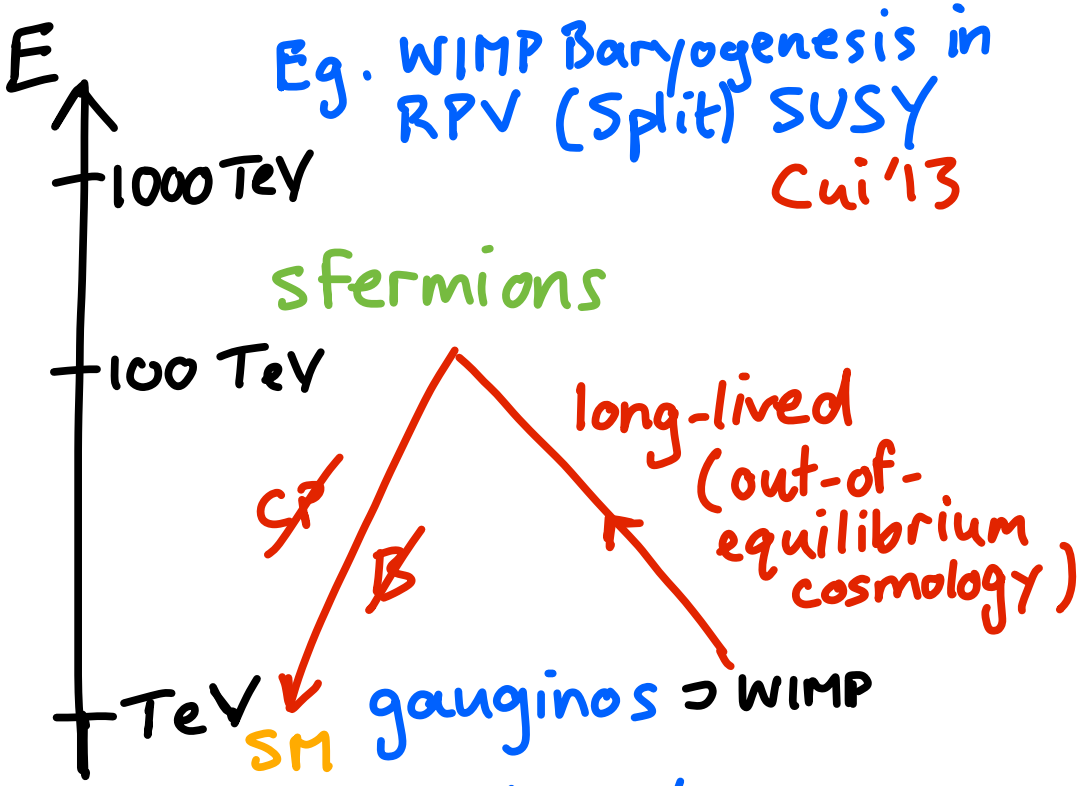
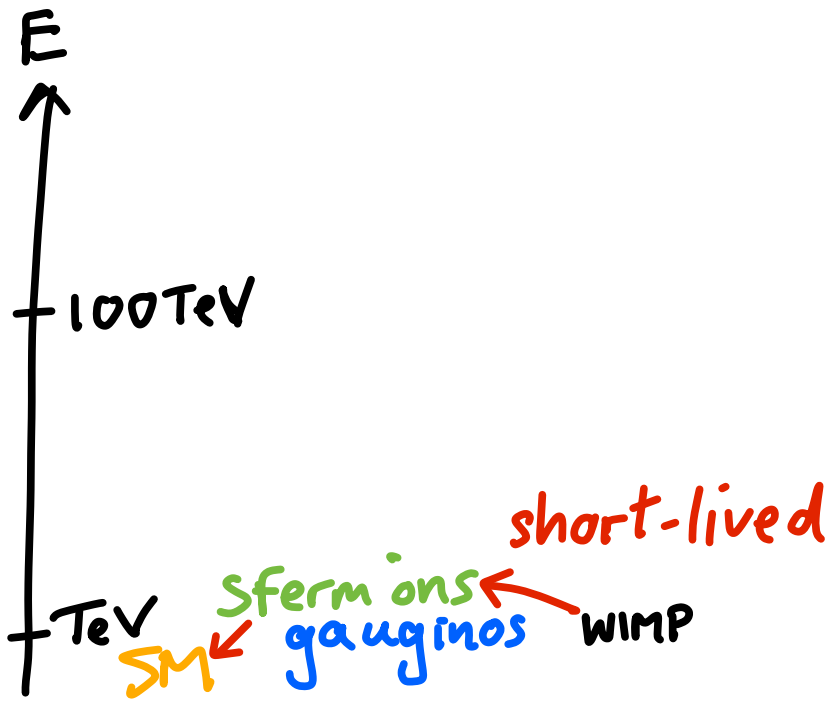


But this may modify, not replace, Naturalness

FRUSTRATED NATURALNESS
(due to Anthropic Selection)



"Meso-tuned" but successful baryogenesis



"Natural", but unsuccessful baryogenesis

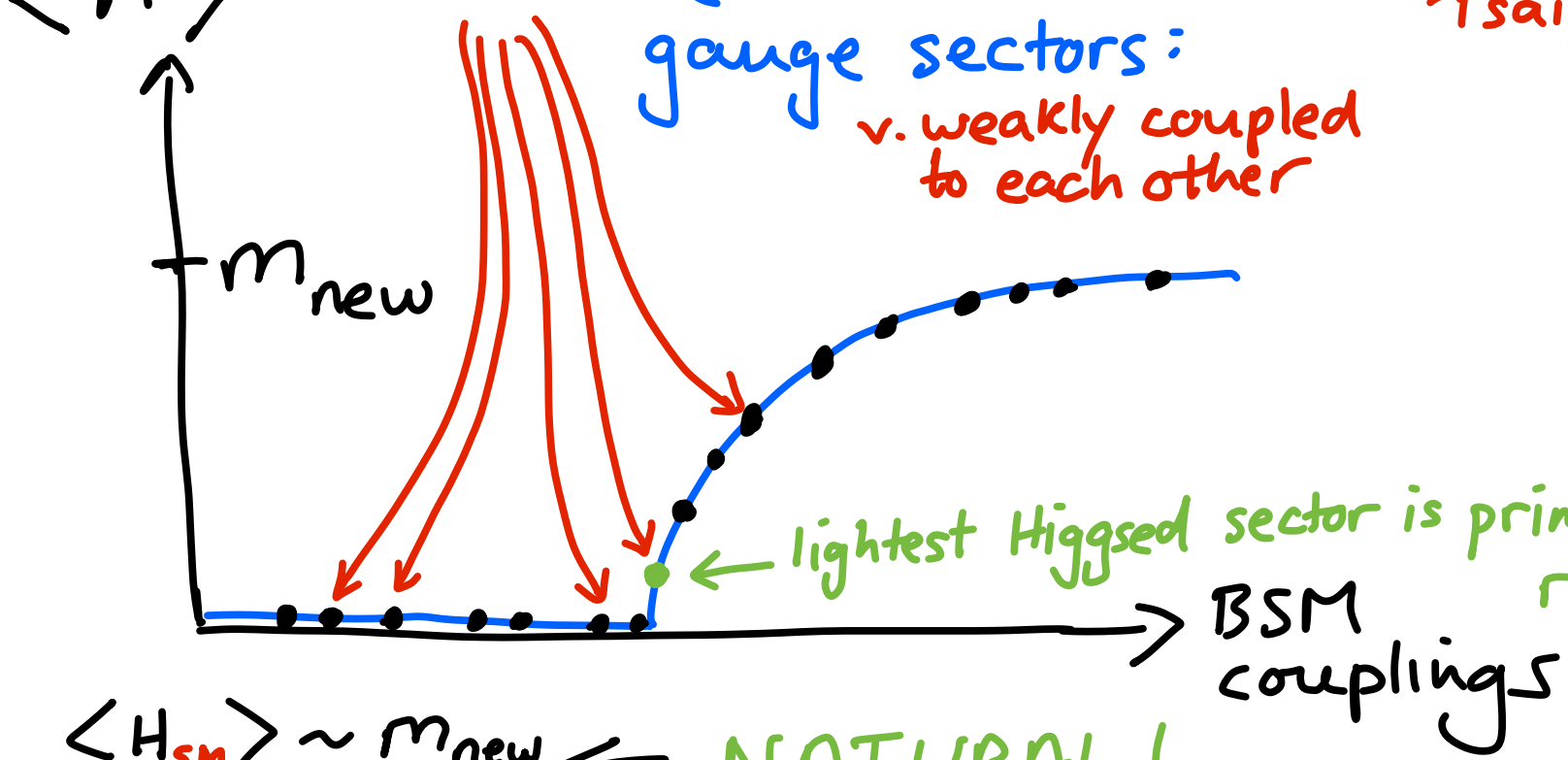
Alternatively, NNATURALNESS

Arkani-Hamed, Cohen, D'Agnolo, Hook, Kim, Pinner '16

Tsai, Sundrum, in progress

$N \gg 1$ (B)SM-like gauge sectors:

v. weakly coupled to each other



lightest Higgsed sector is primarily reheated after inflation $\equiv$ "the SM"

$\langle H_{SM} \rangle \sim m_{new}/\sqrt{N}$ NATURAL!

Eg. $N \sim 10^3$, $m_{new} \sim O(10)$ TeV

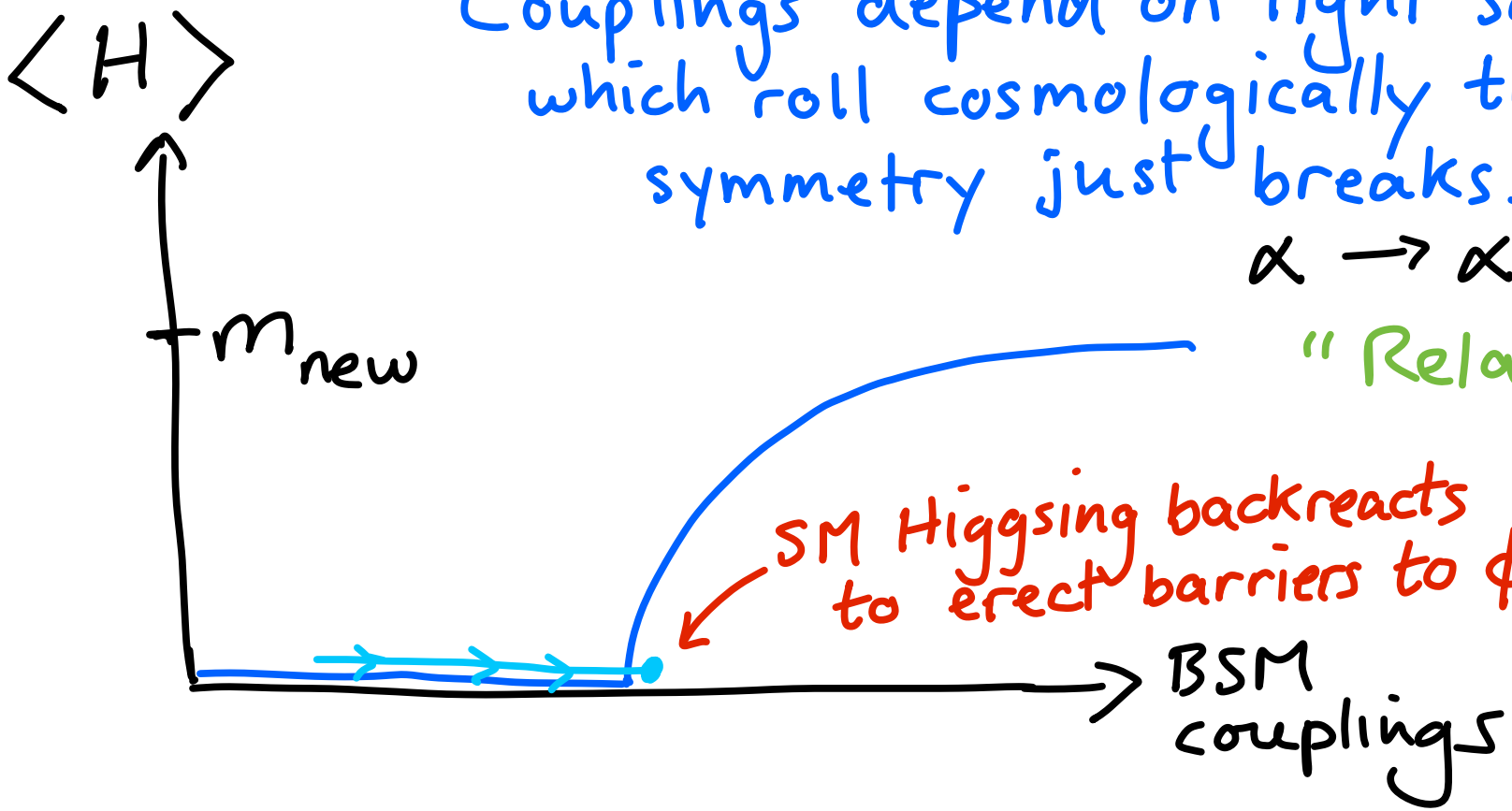
COSMOLOGICAL RELAXATION

Couplings depend on light scalar fields, which roll cosmologically till EW symmetry just breaks.

$\alpha \to \alpha(\phi(t))$

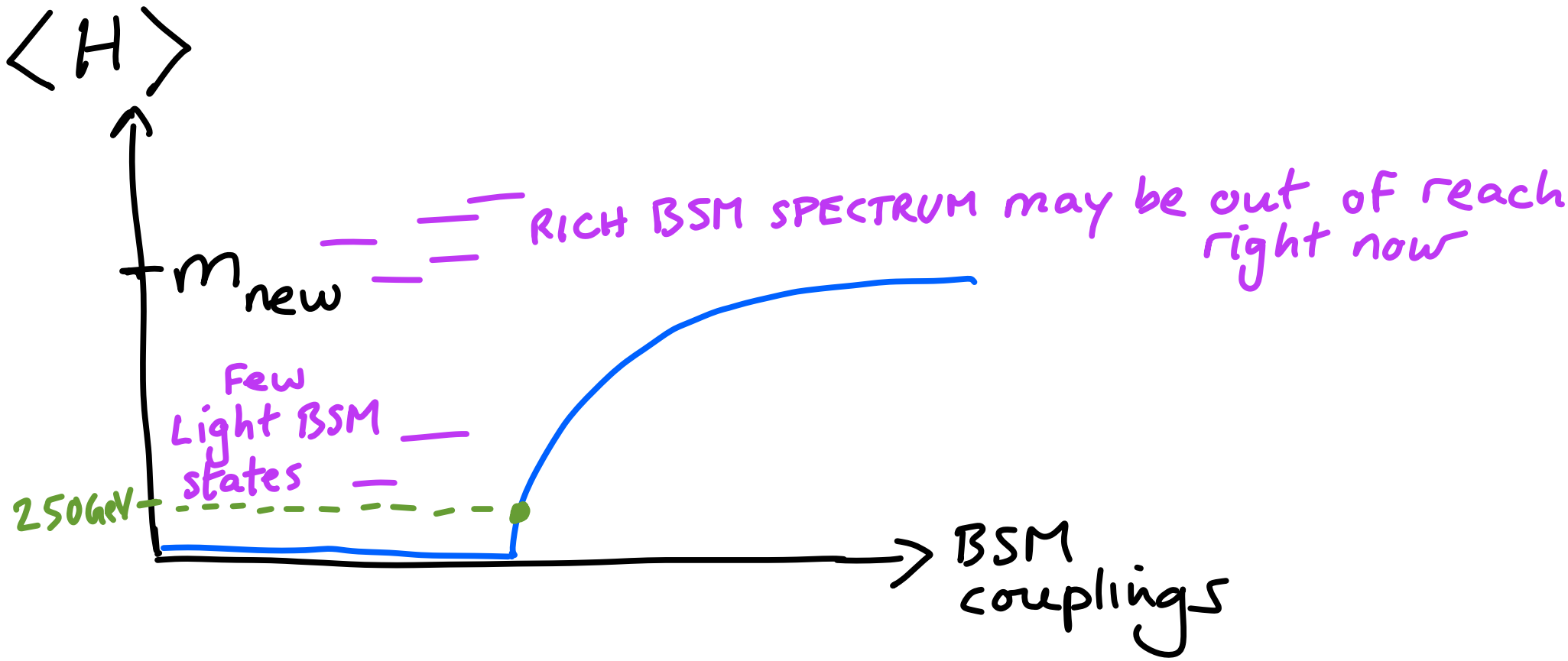
"Relaxion"

Graham, Kaplan, Rajendran '15



SM Higgsing backreacts to erect barriers to ϕ rolling.

LIGHT VESTIGES OF NATURALNESS



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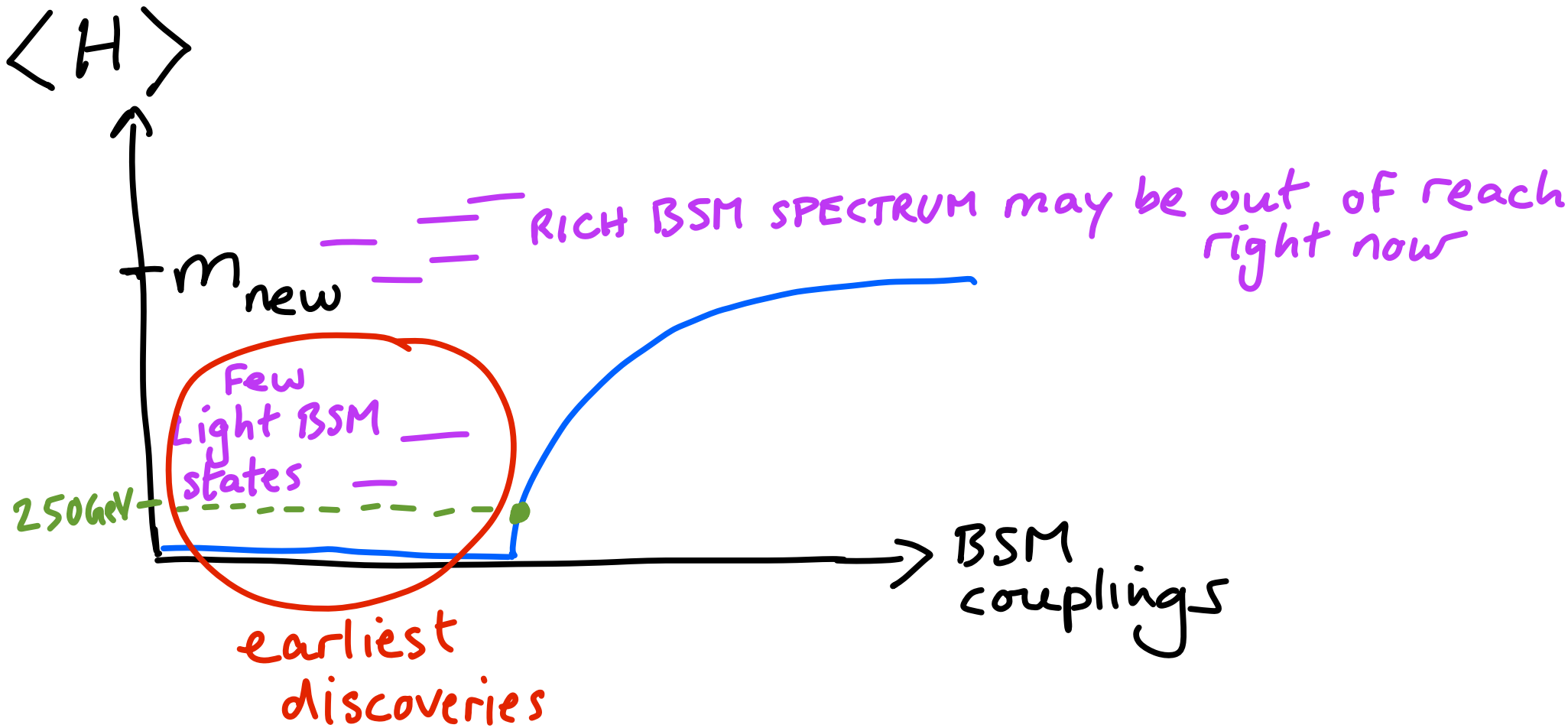
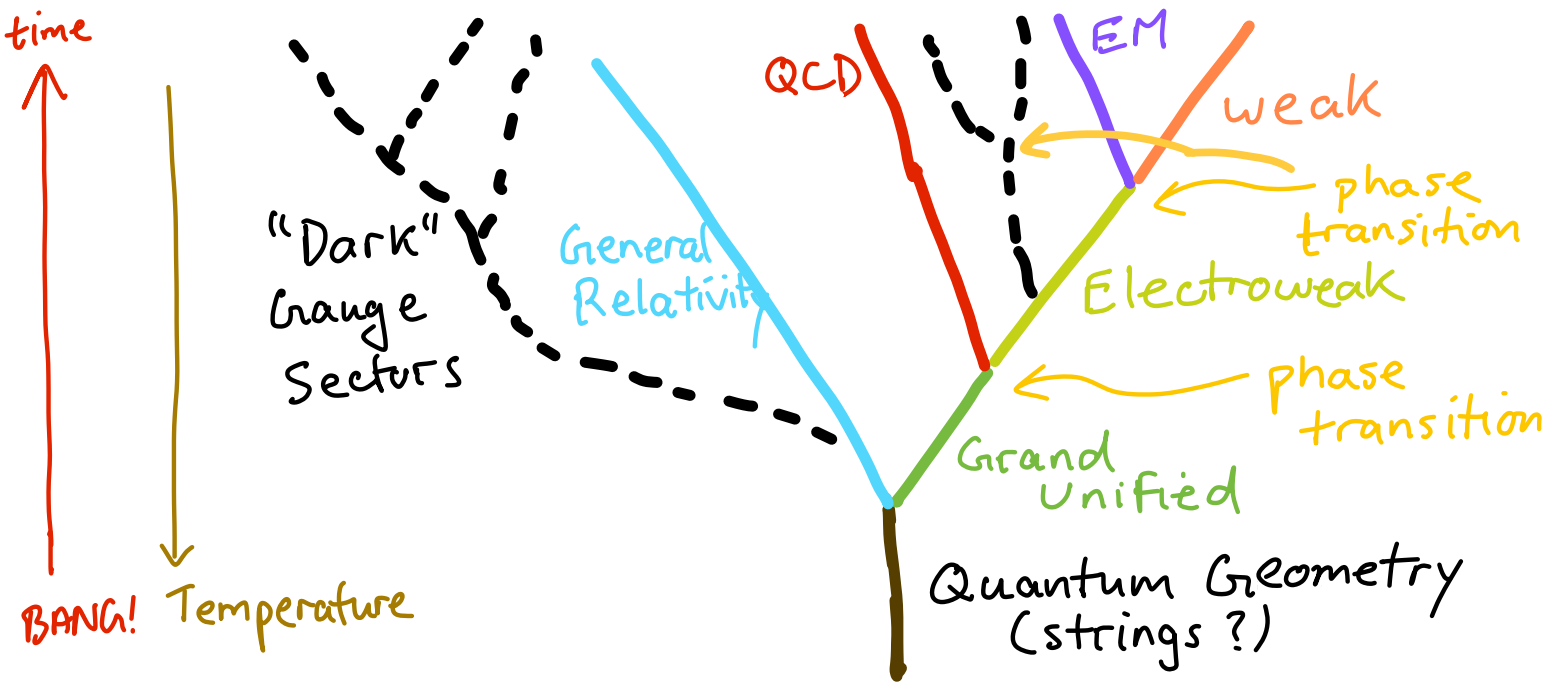
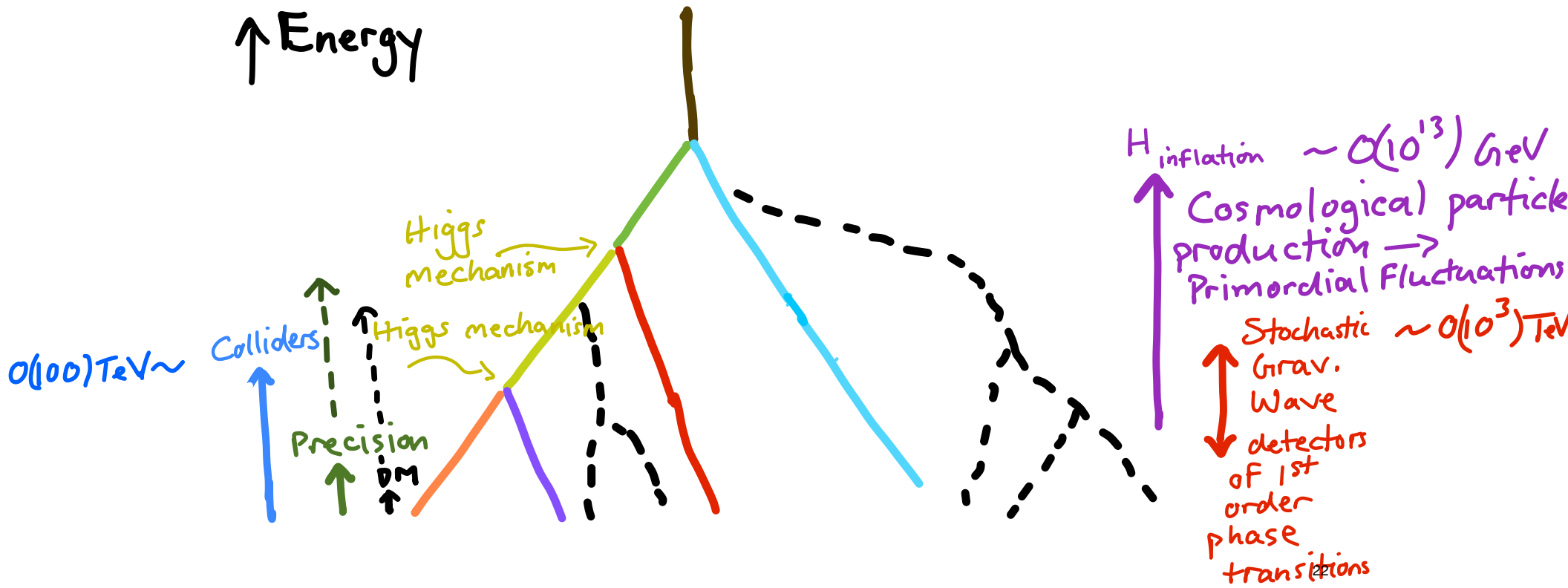


NATURALNESS

⇒ EXPECT WONDERS WITHIN HUMAN REACH!

FAMILY TREE OF FUNDAMENTAL PHYSICS



FAMILY TREE OF FUNDAMENTAL PHYSICS