# No New Below-Planck-Scale-Solution to the Hierarchy Problem.

G.D., A. Vilenkin, PRD70(2004) 63501, hep-th/0304043;

G.D., PRD 74.025018, hep-th/0410286

Does this imply no new non-Wilsonian physics?

with Cesar Gomez

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Lagrangian:

$$\mathcal{L} = \mathcal{L}_{SM} + H^2\left(m^2 - \frac{F^2}{M_p^2}\right)$$
$$-\lambda H^4 - C_{\alpha\beta\gamma} J_T^{\alpha\beta\gamma} Q(H)$$

where:

$C_{\alpha\beta\gamma} \leftarrow$ 3-form

$$F \equiv \partial_\alpha C_{\beta\gamma\delta} \varepsilon^{\alpha\beta\gamma\delta}$$

$$Q \equiv M_p^2 \left\{ \left(\frac{H\bar{q}_L q_R}{M_p^4}\right)^n - \left(\frac{\bar{q}_L q_R \bar{q}_L q_R}{M_p^6}\right)^k \right\}$$

Massless 3-form

$$C_{\alpha\beta\gamma} \to C_{\alpha\beta\gamma} + \partial_{[\alpha}\Omega_{\beta\gamma]}$$

propagates no degrees of freedom. It can be sourced by 2-brane or an axionic domain wall

$$Q \int dx_\alpha \wedge dx_\beta \wedge dx_\gamma \, C^{\alpha\beta\gamma}$$

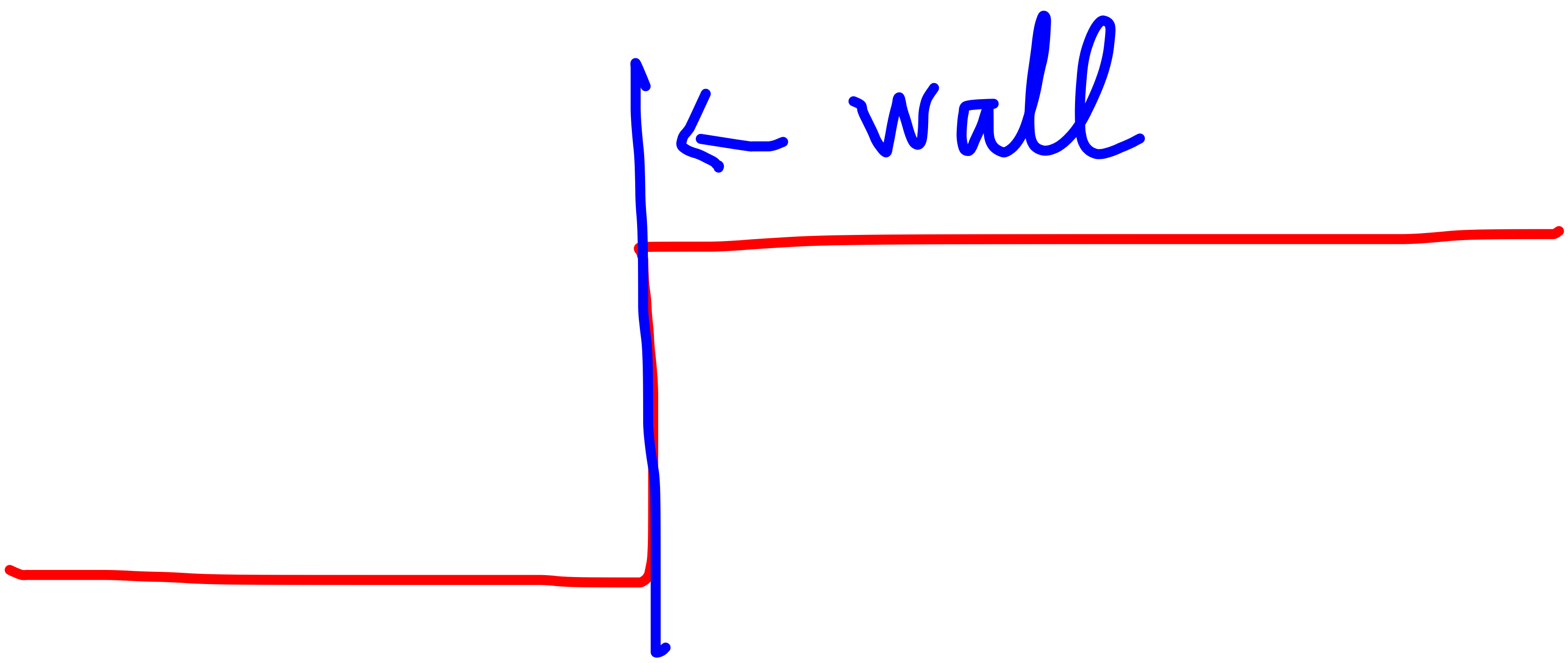
$$\updownarrow$$

$$[\partial_\mu a \, \varepsilon^{\mu\alpha\beta\gamma}] \, C_{\alpha\beta\gamma}$$

$$F_{\mu\nu\alpha\beta} \equiv \partial_{[\mu} C_{\nu\alpha\beta]}$$

$$\mathcal{L} = -F^2$$

$$\partial^\mu F_{\mu\nu\alpha\beta} = Q \int dx_\nu \wedge dx_\alpha \wedge dx_\beta$$




$$\Delta F = Q$$

$Z_{2n}$ - symmetry

$$(H\bar{q}_L q_R) \to e^{i\frac{\pi}{n}}(H\bar{q}_L q_R)$$

$$C_{\alpha\beta\gamma} \longrightarrow -C_{\alpha\beta\gamma}$$

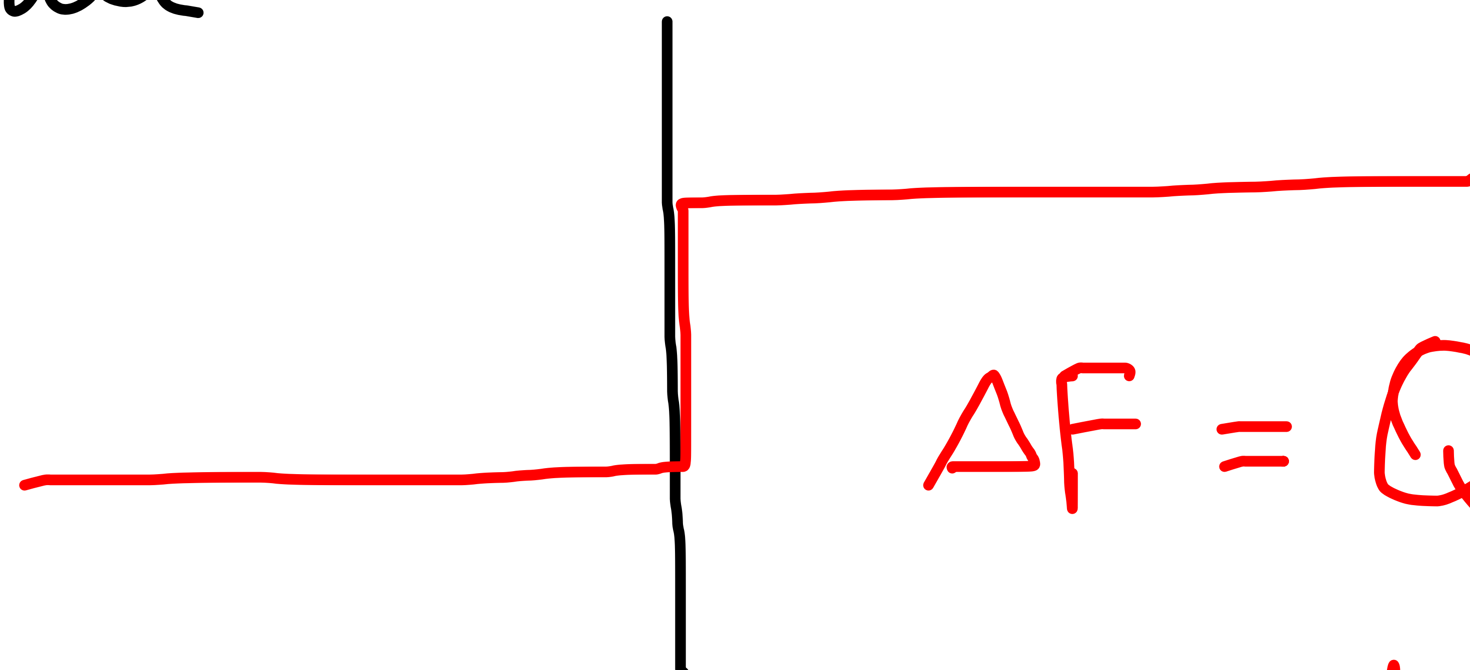
Brane (or axionic domain wall) current

$$J_{\alpha\beta\gamma} \equiv \varepsilon_{\alpha\beta\gamma\mu}\partial^\mu a$$

Heavy axion (mass $\sim M_p$)

This theory has $\infty$ number of vacua separated by axionic domain walls.

F changes across the wall



$\Delta F = Q(H)$

and so does VEV of H! But, the step is controlled by H.

The VEV $H_*$ for which $Q(H_*) = 0$ is attractor:

The number of vacua with $H \to H_*$ diverges.

Since $\langle \bar{q}_L q_R \rangle = \Lambda_{QCD}^3$

So
$$H_* = M_P \left( \frac{\Lambda_{QCD}}{M_P} \right)^{4\frac{k}{h} - 2}$$

For $\frac{k}{n} \sim \frac{5}{7}$, $H_* \sim 100\,\text{GeV}$.

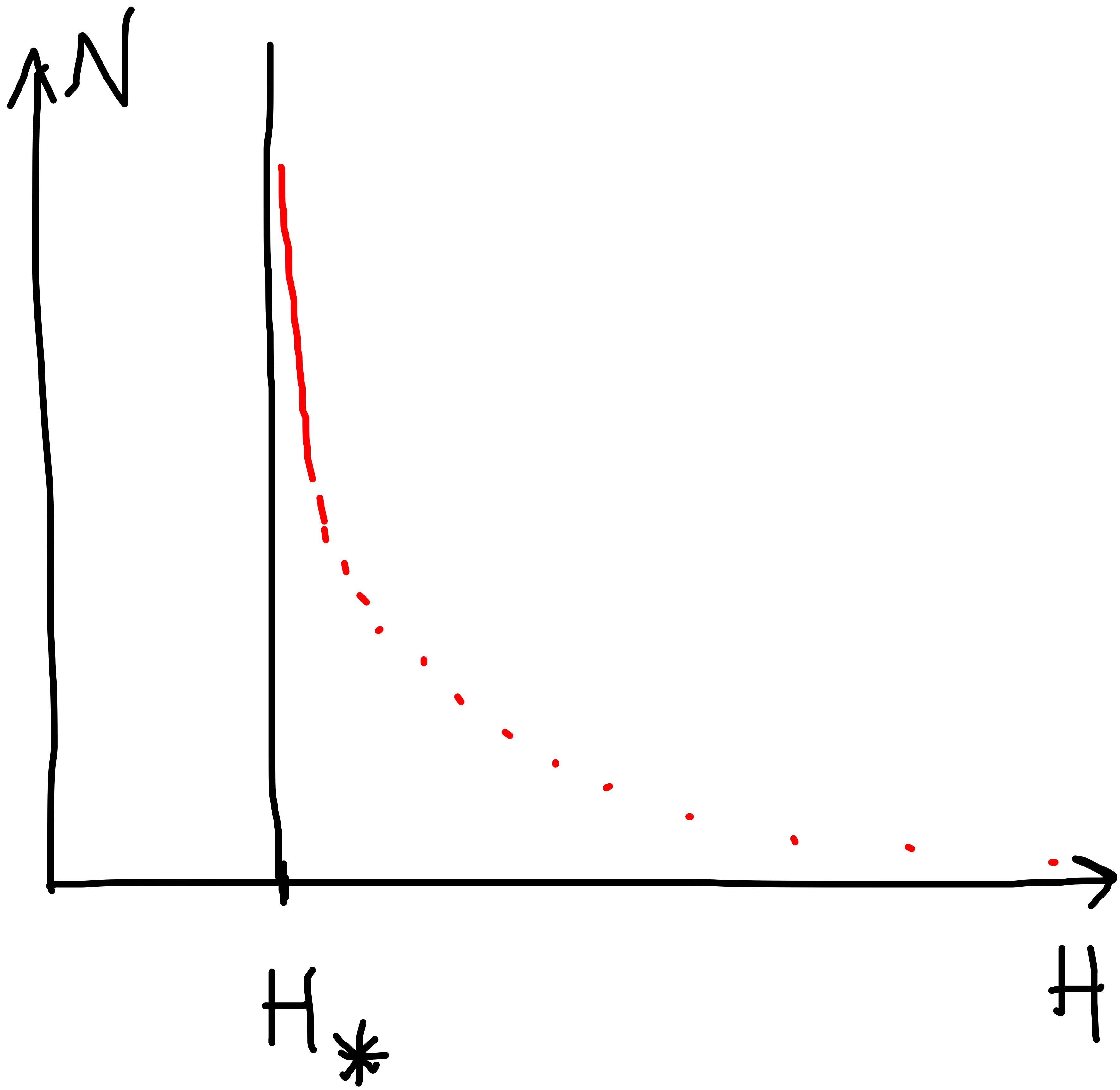
From vacuum $H$ one step towards $H_*$ is

$$\delta H \sim (H_* - H)\,\varepsilon$$

$$\varepsilon \sim 10^{-484}$$

Number of vacua near $H_*$

$$N \sim 10^{484} \ln(H - H_*)$$



N
H
H*

We have promoted the hierarchy problem into a problem of <u>vacuum super-selection</u>.

No new physics is required around the weak scale.

However there is no <u>free lunch</u>.

The $Z_{2n}$ symmetry must be a family symmetry, because

$$H\bar{q}_L q_R \to e^{i\frac{\pi}{n}} H\bar{q}_L q_R$$

in order to allow the Yukawa couplings

Secondly, there is a propagating $\frac{1}{M_p}$-coupled massless axion in this theory.

This is a Stückelberg field $B_{\mu\nu}$, which ensures gauge invariance of the coupling with brane current.

$$C_{\alpha\beta\gamma} \to C_{\alpha\beta\gamma} + \partial_{[\alpha}\Omega_{\beta\gamma]}$$

$$\left(C_{\alpha\beta\gamma} - \partial_{[\alpha}B_{\beta\gamma]}\right)J^{\alpha\beta\gamma}$$

$$B_{\mu\nu} \to B_{\mu\nu} + \Omega_{\mu\nu}$$

Constraint

$$\chi^{\mu\nu}\partial^{\alpha}\left(C_{\mu\nu\alpha} - \partial_{\mu}B_{\nu\alpha}\right)$$

$$C_{\alpha\beta\gamma}\,J_{T}^{\alpha\beta\gamma}$$

$B_{\mu\nu}$ propagates massless waves

$$\Box\left(\left(1-\frac{H^2}{M_p^2}\right)F\right)=\partial_z\left(Q(t)\,\delta(z)\right)$$

$$F(z,t)=\frac{1}{\left(1-\frac{H^2}{M_p^2}\right)}\Big[\theta(z)\,Q(t-z)$$

$$-\,Q(t+z)\,\theta(-z)+f_0\Big]$$

We can extend this mechanism for solving doublet-triplet splitting problem in GUTs.

SU(5) Higgs, $\Sigma$, $5_H$

$$\bar{5}\left[\Sigma^2+\mu\Sigma+M^2-\frac{F^2}{M_p^2}\right]5$$

$$\Sigma = \mathrm{diag}\left[2,2,2,-3,-3\right]M_G$$

In usual (Wilsonian) UV-completion one integrates in some new weakly coupled physics at distances $L < L_*$

Examples:

weakly-coupled Higgs, SUSY, . . . .

Characteristic property of such Wilsonian UV-completion is that high energy scattering cross section diminishes

$$\sigma \sim \frac{\alpha^2}{s} \equiv r_*^2(s)$$

$r_*(s) \equiv$ scattering radius

It has been realized recently that UV-completion of the SM may not be Wilsonian.

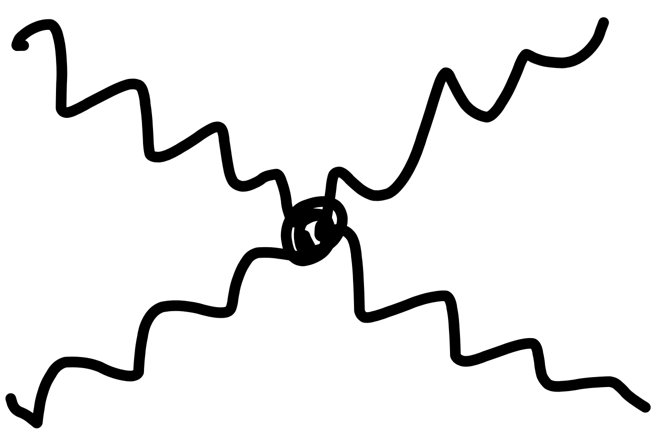
G.D. & Gomez; + Giudice Kehagias

In some theories no one or two-particle states exist at

$$L \ll L_*$$

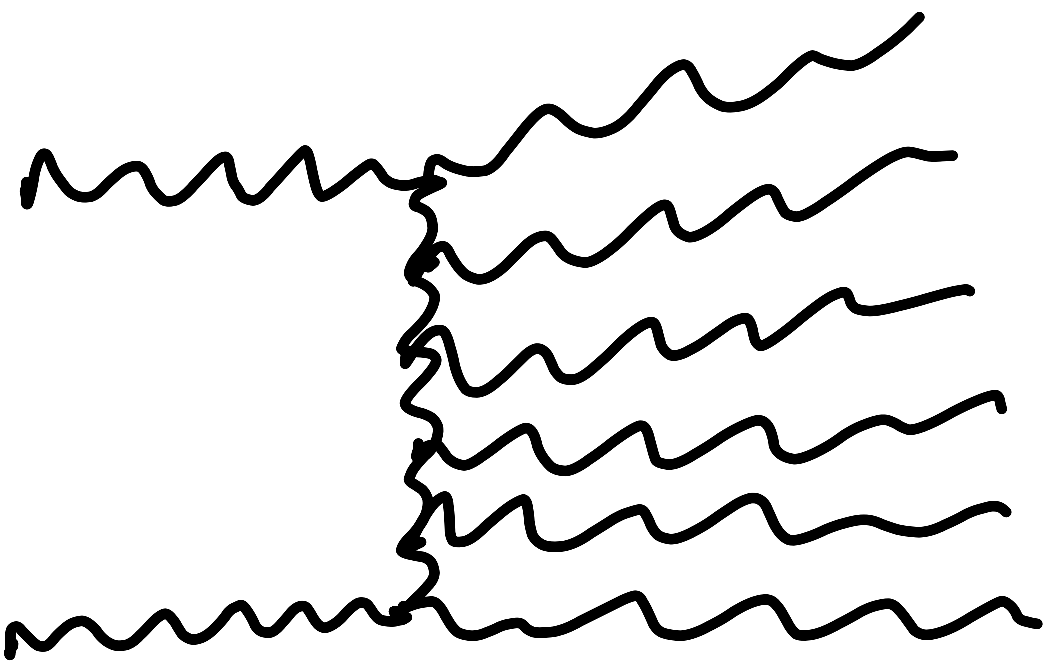
.

Above the cutoff the naive coupling becomes strong



$$\alpha_{\text{naive}} \sim \frac{s}{M_p^2}$$

But, in reality the theory becomes a theory of many **soft quanta**

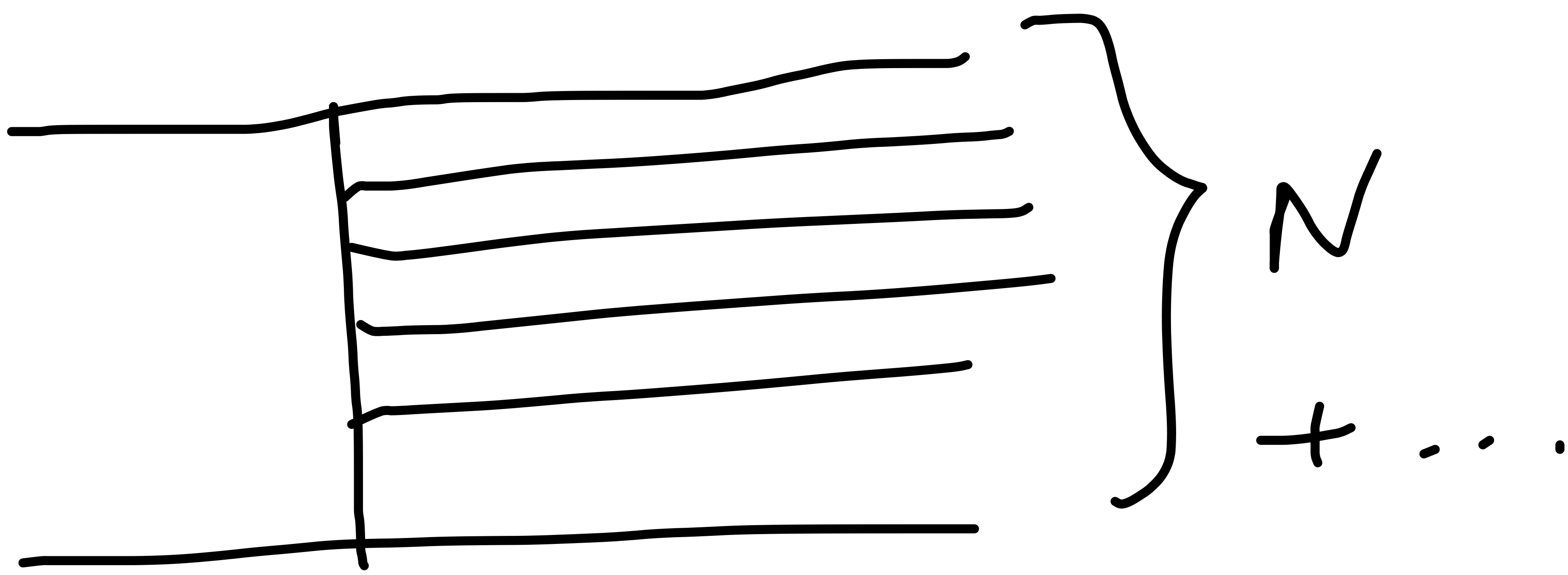


$N = \alpha_{haire}$

$$\alpha = \frac{1}{N} = \frac{M_p^2}{s} \ !$$

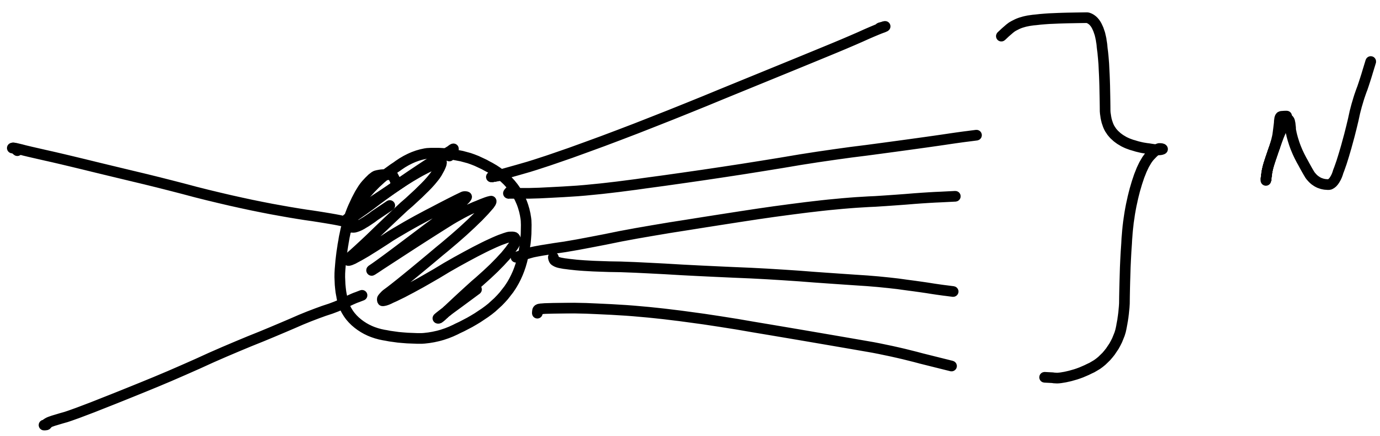
# 2 → N graviton scattering

GD, Gomez, Isermann, Lüst, Stieberger, hep-th/1409.7405




In our kinematic regime loops are suppressed by $\sim \frac{1}{N}$

for $2\to N$ amplitude we get

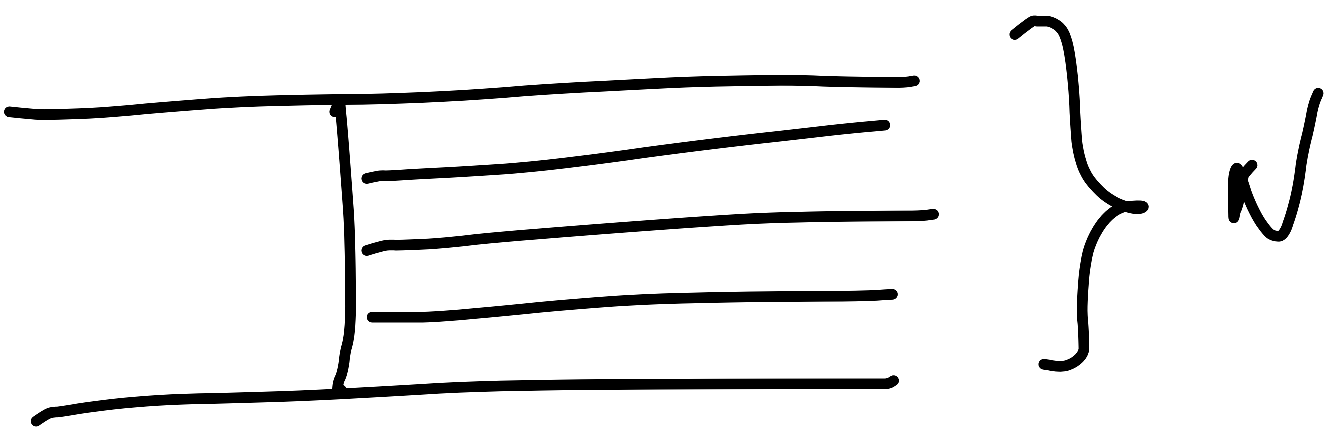



$$\sigma_{2\to N} = \frac{s}{M_p^4}\left(\frac{1}{N}\right)^N N! = \frac{s}{M_p^4} e^{-N}$$

This exactly matches the black hole entropy factor!

Our result are UV-insensitive:

We get the same result in field theory




and string theory