Swampland constraints on small Dirac Neutrino Yukawa couplings

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Based on [2403.09775] + [2406.14609]

w/ Fernando Marchesano and Luis Ibáñez

Exploring infinite distance limits

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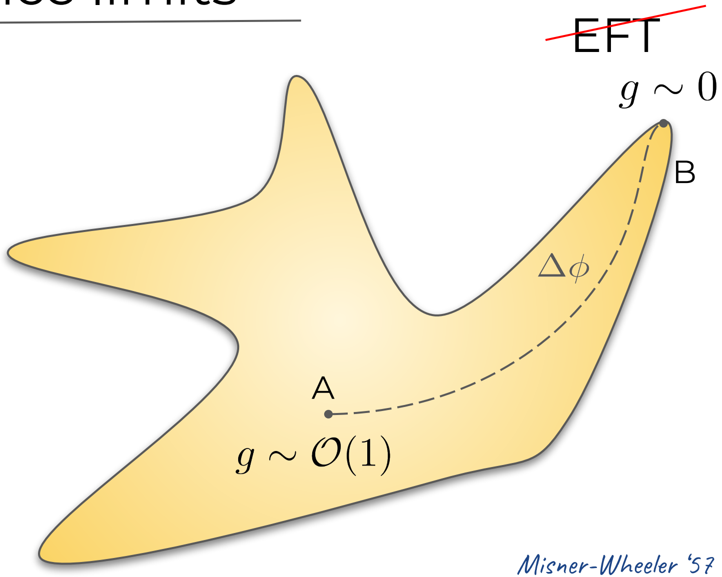

NGS: *Misner-Wheeler '57*, *Banks-Dixon '88*, *Banks-Seiberg '11*

(t)WGC: *Arkani-Motl-Nicolis-Vafa '06*, *Heidenreich-Reece-Rudelius 16' 19'*, *Montero-Shiu-Soler 16'*, *Andriolo-Junghans-Noumi-Shiu 18'*

SDC: *Ooguri-Vafa '05*

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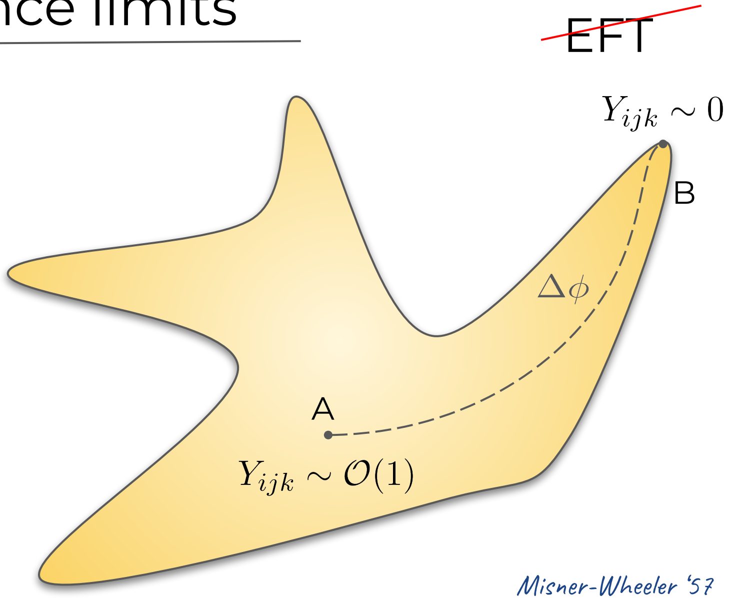

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Cribiori-Farakos '23
Palti '20

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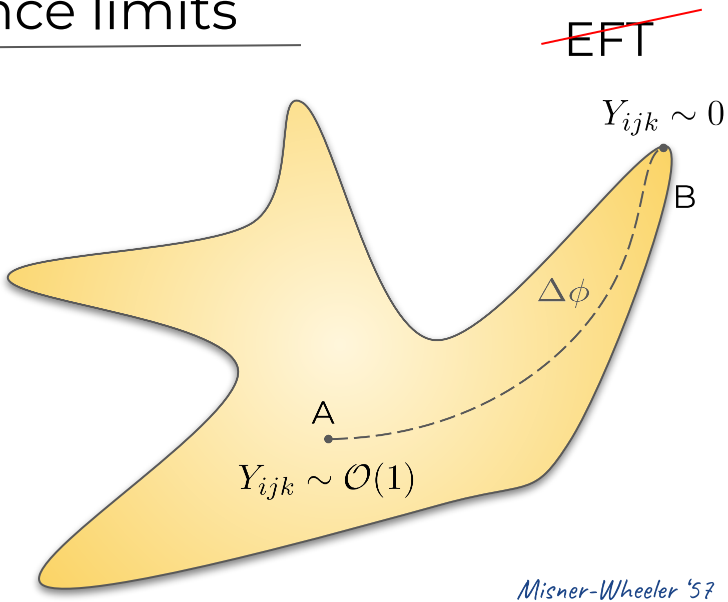
There is no obvious reason what goes wrong!



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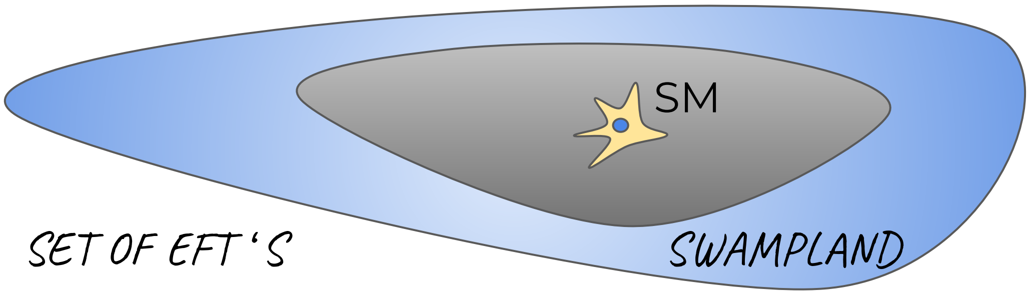

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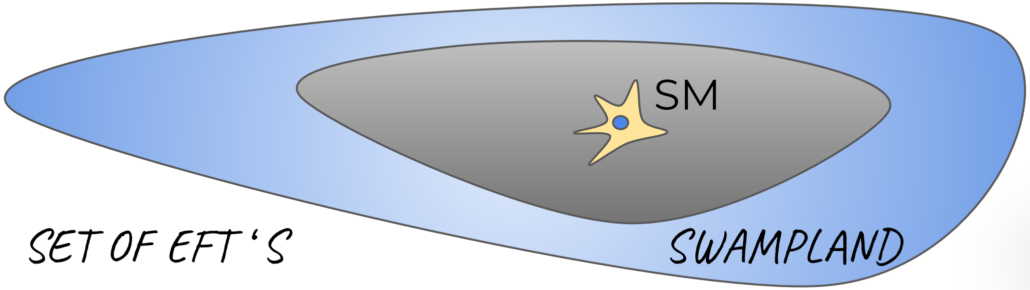

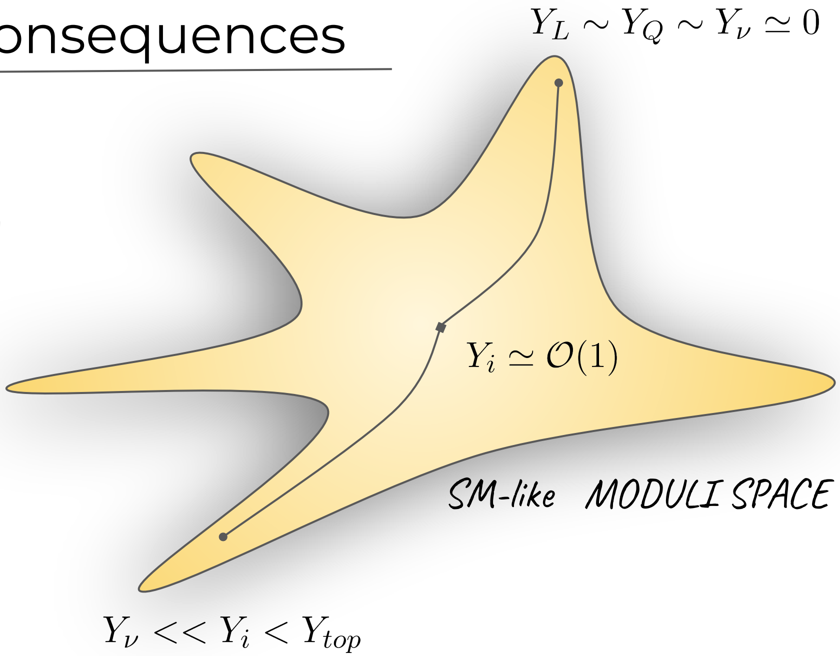

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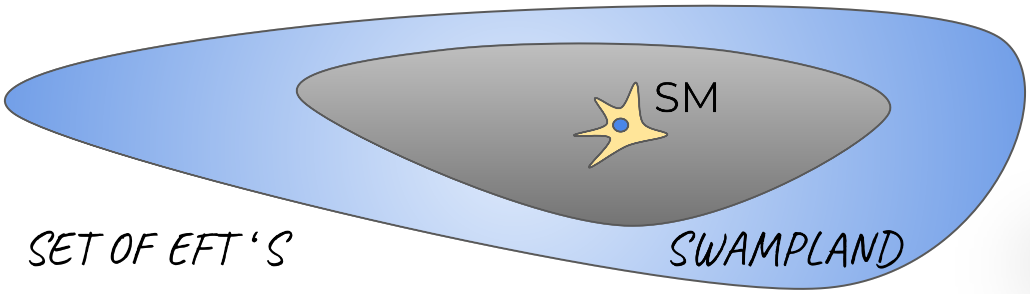

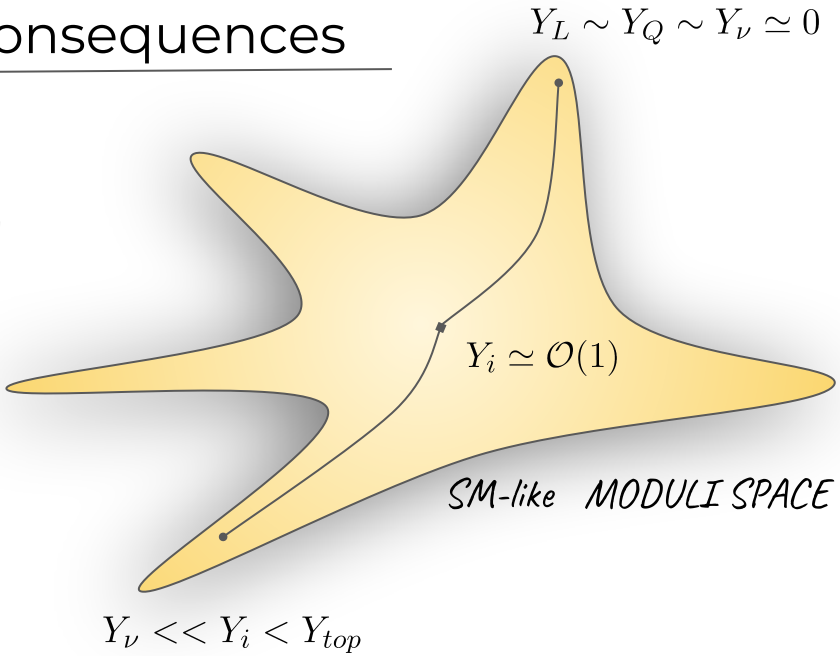

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For instance if neutrinos are Dirac

$$Y_\nu \sim 10^{-12}$$

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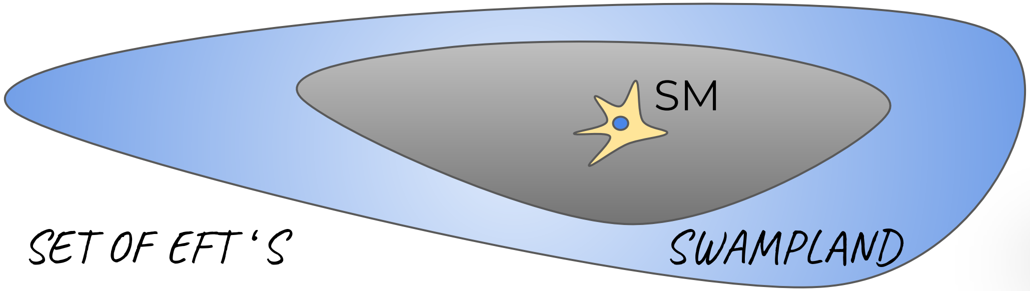

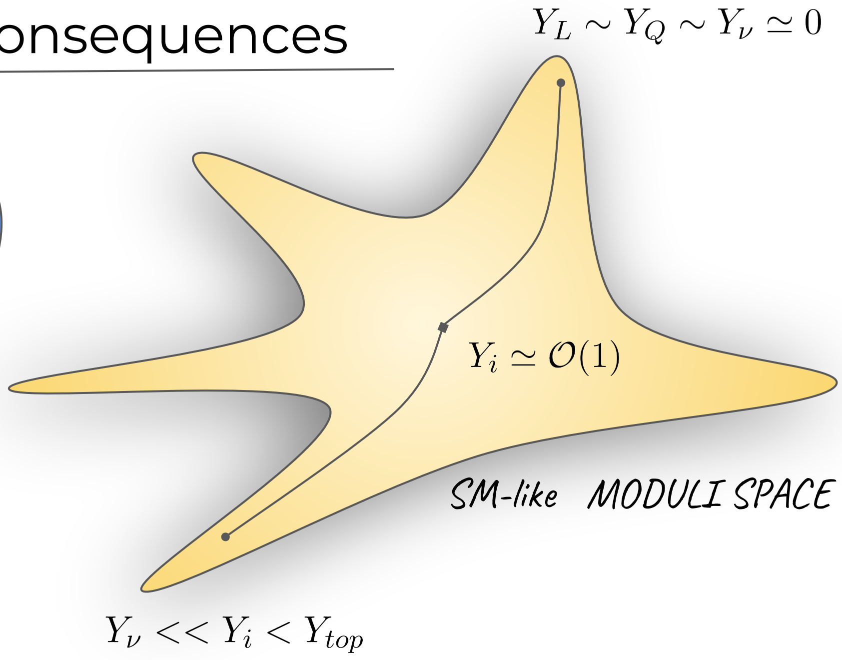

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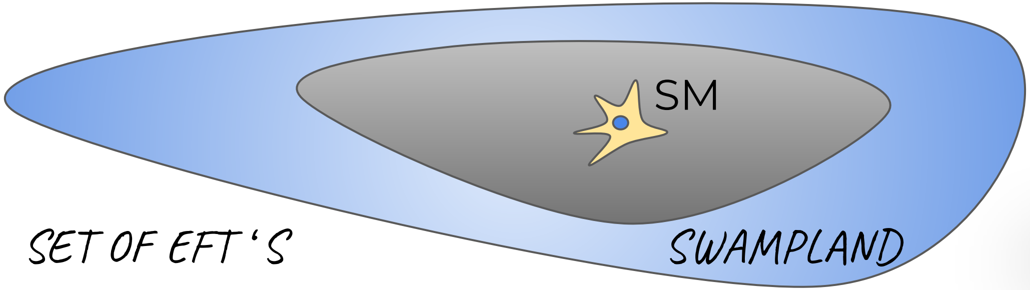

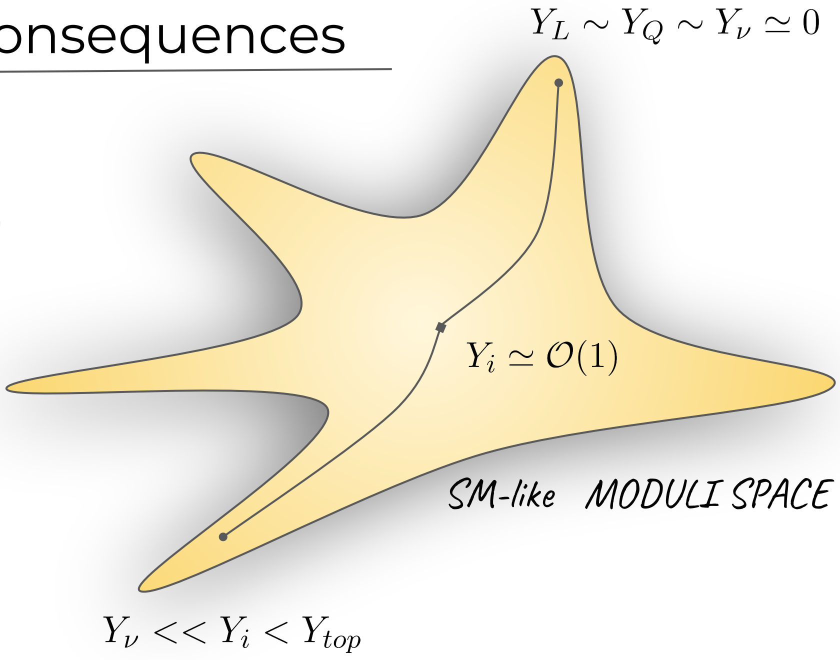

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This limit MUST be explored!

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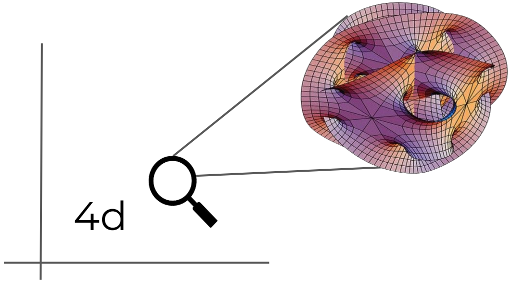
Compactify Type IIA string theory on a CY orientifold

SUSY is broken from N=2 to N=1

How does it work?



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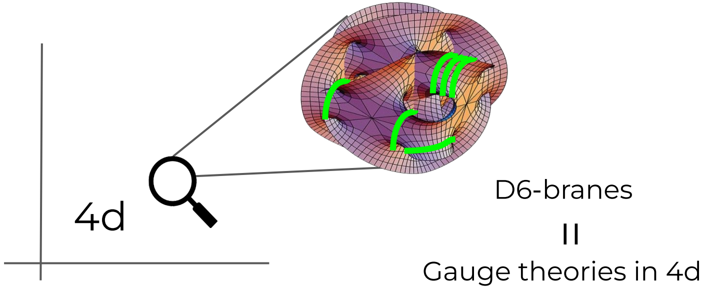

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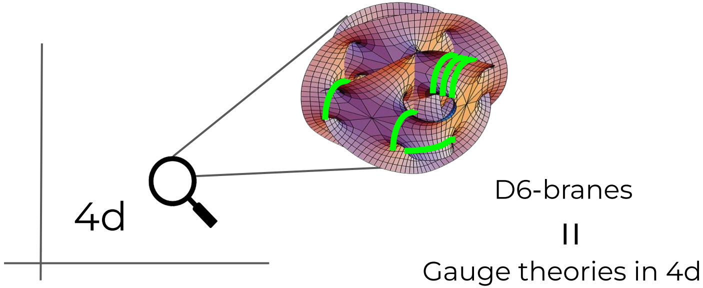
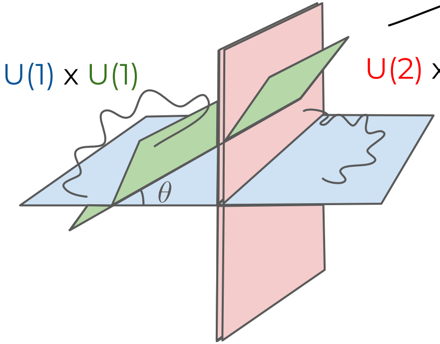


Berkooz-Douglas-Leigh '96



Massless + massive chiral fields

$$\ell_s^2\ m_{\alpha\beta}^2 \simeq n_1\,|\theta_{\alpha\beta}^1| + n_2\,|\theta_{\alpha\beta}^2| + n_3\,|\theta_{\alpha\beta}^3|$$

Gonions

Aldazabal-Franco-Ibañez-Rabadan-Uranga '00

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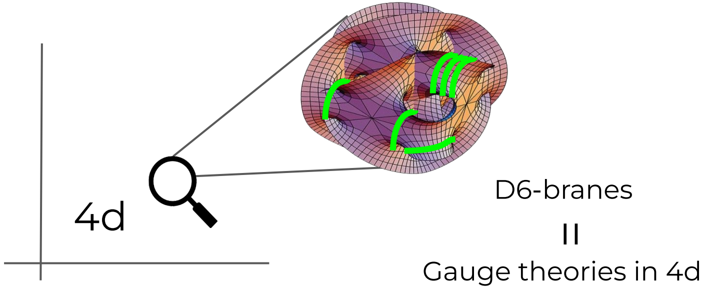

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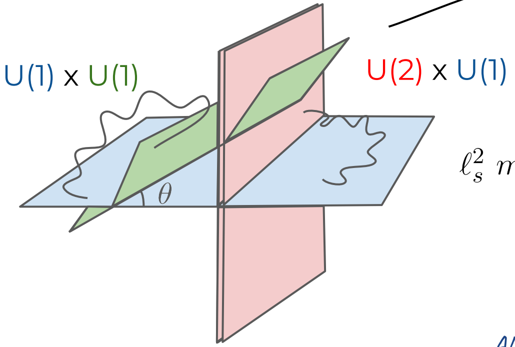

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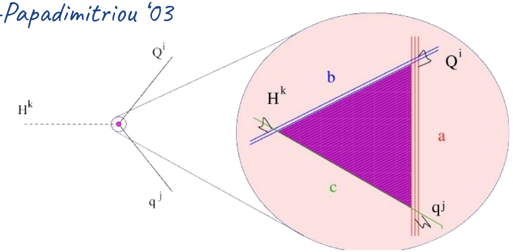
Yukawa couplings arise in triple D6-branes intersections

Cremades-Ibañez-Marchesano '03 '04
Aldazabal-Franco-Ibañez-Rabadan-Uranga '00
Cvetic-Papadimitriou '03



Some results

MANY MORE IN FERNANDO'S TALK

Focus on c.s moduli

$$Y_{ijk} = B\, e^{\phi_4/2}\Theta_{ijk}^{1/4}$$

$$\Omega_c \equiv C_3 + ie^{-\phi}\mathrm{Re}\Omega = (\xi^K + iu^K)\alpha_K$$

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$$u^K = u_0^K + e^K\lambda, \quad \lambda \to \infty$$

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see also Castellano-Herraez-Ibañez '23

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Scales:

$$Y_\nu \sim 6.9 \cdot 10^{-13}$$

$$m_{\text{gon},\nu} \simeq m_{KK} \simeq 500eV$$

$$M_s = Y_\nu M_P = 700\,\text{TeV}$$

Let’s take a different angle approach… as an exercise.. and see if we can learn something

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The Emergence Proposal

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Heidenreich-Reece-Rudelius 17’
Grimm-Palti-Valenzuela 18’
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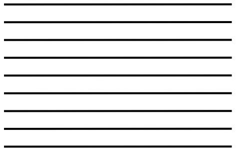
Castellano-Herráez- Ibáñez 22’ 23’
Blumenhagen-Gligovic-Paraskevopoulou 23’
Blumenhagen-Cribiori-Gligovic-Paraskevopoulou 23’
…….

There has been a lot of work in this recently, different ideas, proposals… But let me just be naive..

A very intriguing feature of gonions is that they do not have a KK-like gap



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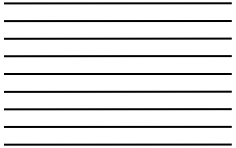

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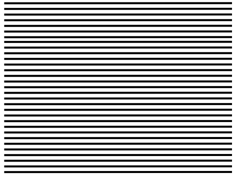

$$m_n = n^{1/p} m_0$$

Castellano-Herráez-Ibáñez 21'

Actually, a tower with density p reproduces effectively the same mass levels of p Kaluza-Klein towers

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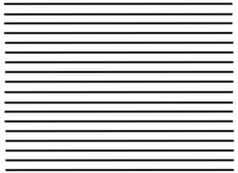

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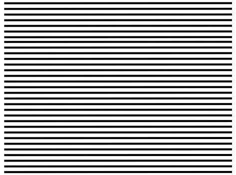

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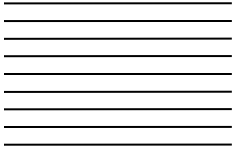

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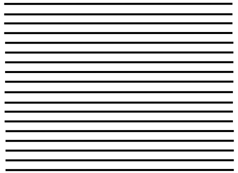

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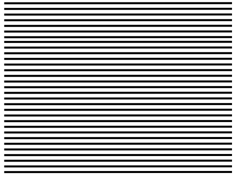

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And now the let's put Emergence into play...

Is Emergence sensitive of this p=2 of a single gonion tower?

Dvali 07' Dvali-Redi 07'
Dvali-Gomez 08'

The quantum gravity cut off $\Lambda \simeq \frac{M_P}{N^{1/2}}$

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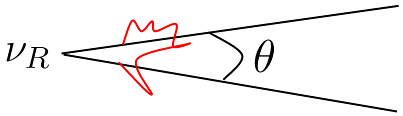

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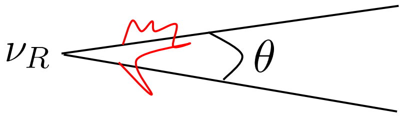

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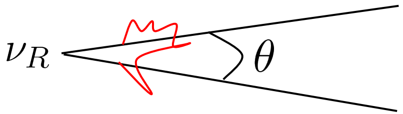

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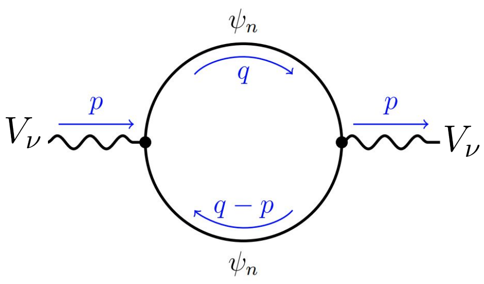
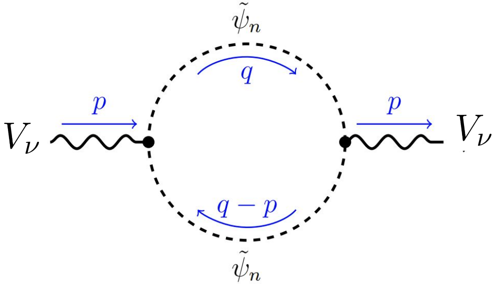
Gonion density

$$\delta\left(\frac{1}{g_\nu^2}\right) \simeq q^2 \sum_{k=1}^{N} \log(\Lambda^2/m_k^2) \sim N \simeq \left(\frac{M_s}{m_{\rm gon}}\right)^2 \simeq u$$





Dvali 07'   Dvali-Redi 07'
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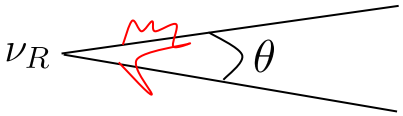
The quantum gravity cut off $\Lambda \simeq \frac{M_P}{N^{1/2}}$ $m_{\rm gon} \simeq u^{-1} M_P$ $\Lambda \simeq u^{-1/2} M_P \simeq M_s$

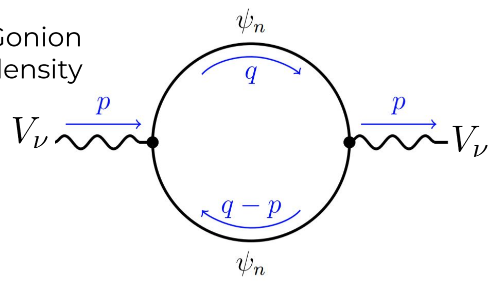


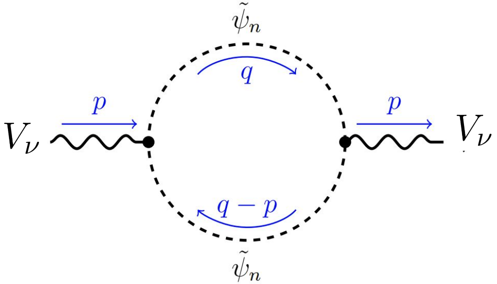
$$\Lambda = N^{1/2} m_{\rm gon}$$

Gonion density

$$\delta\left(\frac{1}{g_\nu^2}\right) \simeq q^2 \sum_{k=1}^{N} \log(\Lambda^2/m_k^2) \sim N \simeq \left(\frac{M_s}{m_{\rm gon}}\right)^2 \simeq u$$

Gonion density





Same charge for the whole tower

Unlike BPS states

Dvali 07' Dvali-Redi 07'
Dvali-Gomez 08'

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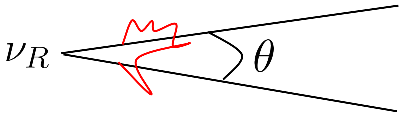

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Gonion density

Same charge for the whole tower

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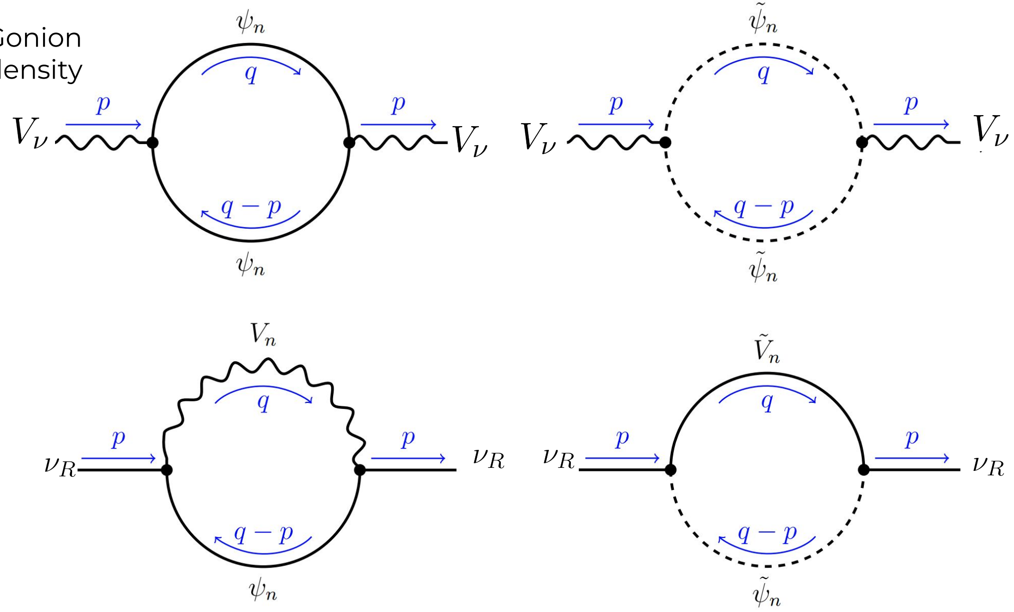
$$\delta(K_{\nu_R}) \simeq \sum_{k=1}^{N} \log(\Lambda^2/m_k^2) \sim N \simeq \left(\frac{M_s}{m_{\text{gon}}}\right)^2 \simeq u$$



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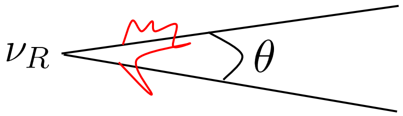

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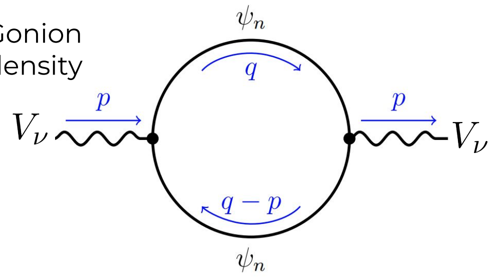

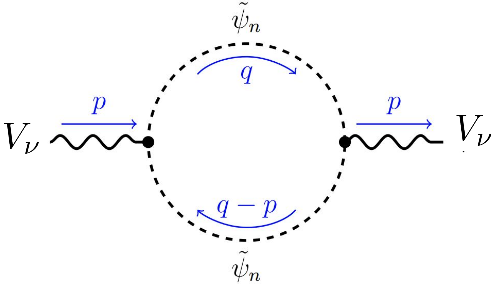

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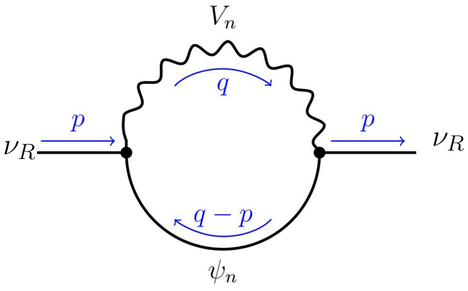

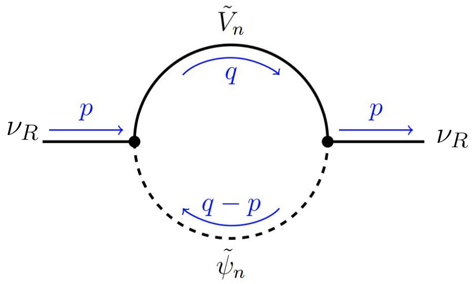

$$Y_\nu \simeq \frac{1}{u^{1/2}}$$

Replicates the same singular behaviour

Conclusions

Different test are provided in 2403.09775

Yukawa couplings approaching zero are at infinite distance

This is very powerful, it helps us to relate different things

$$Y \simeq R^{\alpha} \simeq m_{\text{light}}^{\beta} \simeq \Lambda_{\text{QG}}^{\gamma} \simeq \Lambda_{\text{cc}}^{\delta} \ldots \qquad M_P = 1$$

For the Neutrino setting, we find hierarchies among the SM Yukawas and SWAMPY predictions

$$Y_{SM} >> Y_{\nu} \simeq m_{\text{KK}}^{1/2} \simeq m_{\text{gon}}^{1/2} \simeq \Lambda_{\text{QG}} \ldots \qquad M_P = 1$$

Gonion towers are very interesting ... and non-trivially Emergence captures their features

They are very intriguing for this tower-ology science 

THANK $Y_\nu \, O\bar{\nu}\nu$