

UV/IR Mixing: Bridging the Graviton & the Higgs Boson

Florian NORTIER

Université Lyon 1, CNRS/IN2P3, IP2I Lyon, Villeurbanne, France

IP2I Seminars, October 13, 2026

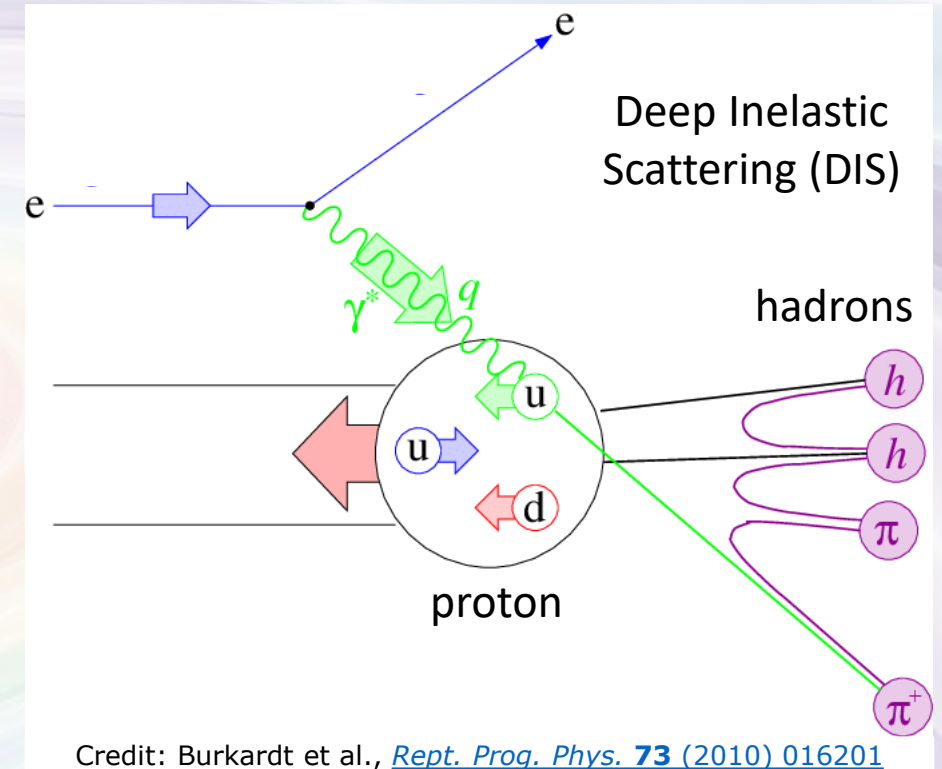
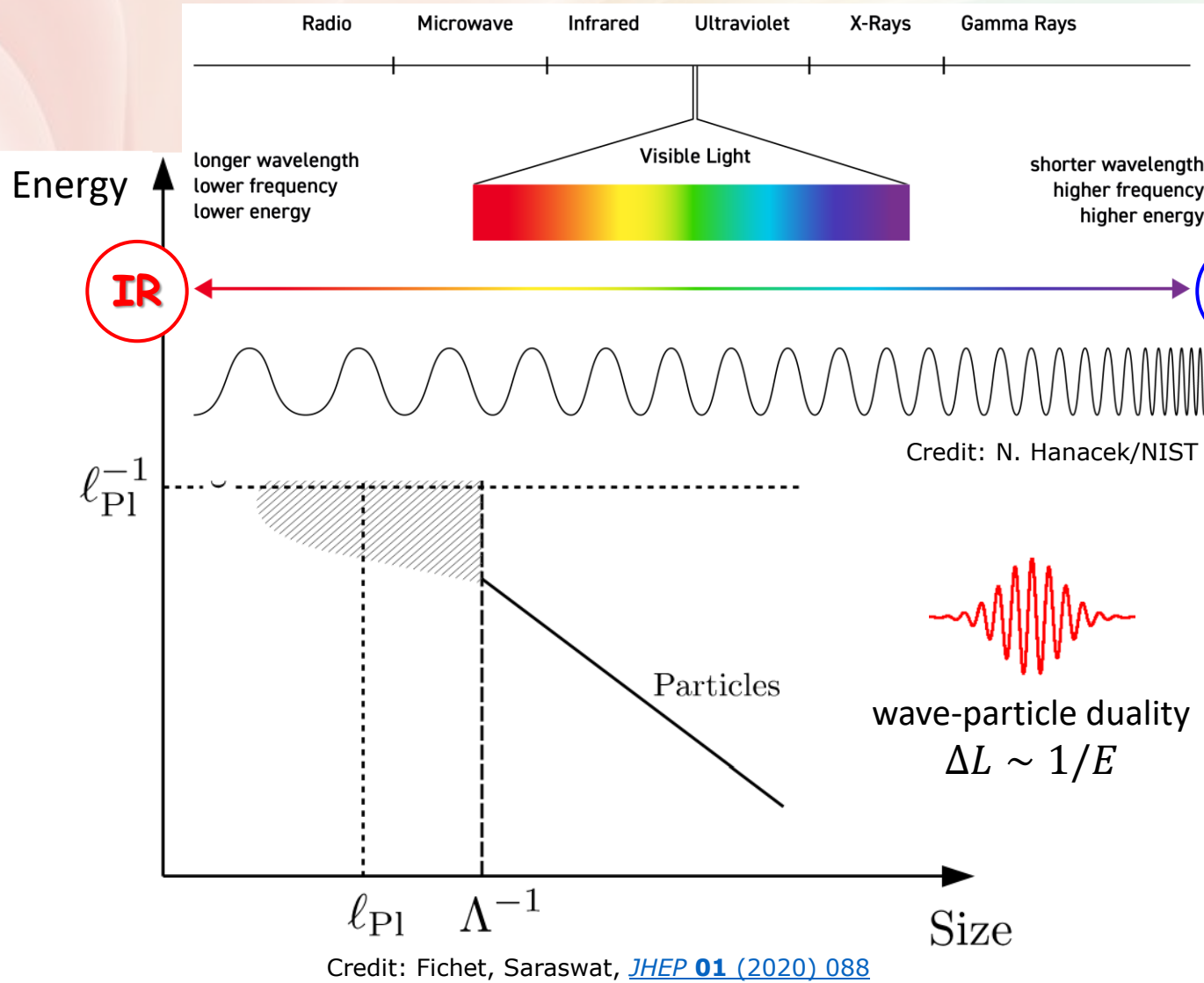
Based on [arXiv:2511.01739](https://arxiv.org/abs/2511.01739) (review + new results)



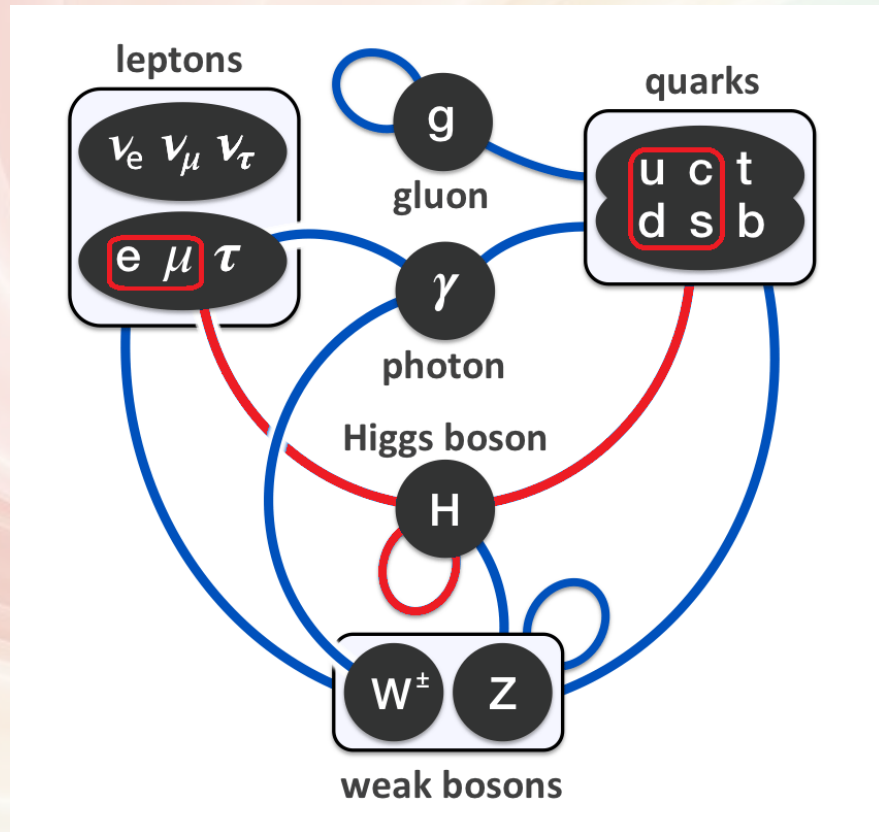
NUCLÉAIRE
& PARTICULES



UV/IR Scales



Particle Physics & EFT



Standard Model (SM)

EFT = Effective Field Theory



Wilsonian EFT
UV/IR decoupling

Wilsonian EFT 'Onion'

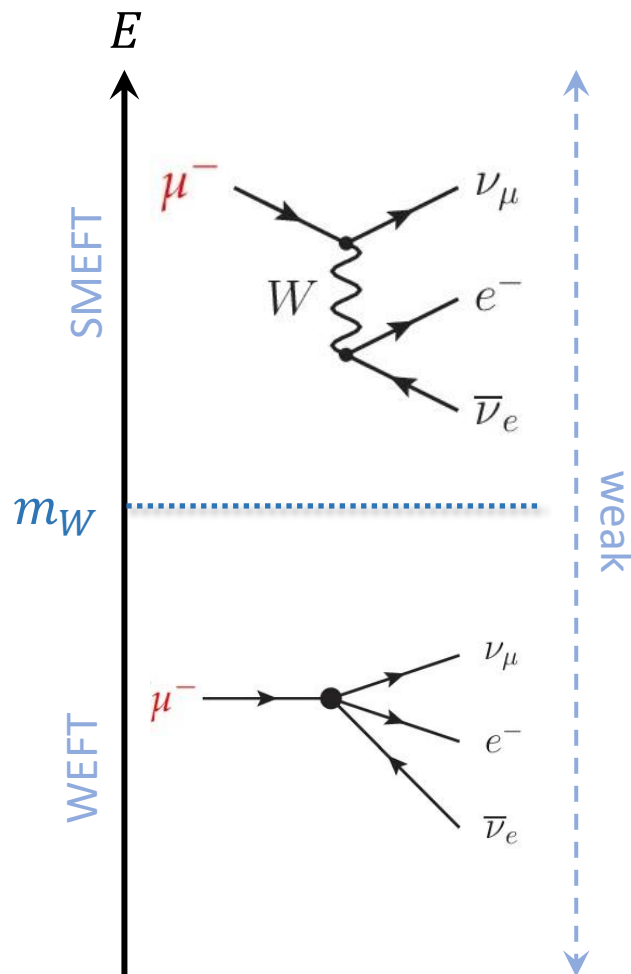
Energy

BSM	Λ	Dragons
SMEFT	100 GeV	$\gamma, g, W, Z, \nu_i, e, \mu, \tau + \text{u, d, s, c, b, t} + \text{h}$
WEFT	5 GeV	$\gamma, g, \nu_i, e, \mu, \tau + \text{u, d, s, c, b}$
WEFT4	2 GeV	$\gamma, g, \nu_i, e, \mu, \tau + \text{u, d, s, c}$
Λ_{QCD}		
ChRT	500 MeV	$\gamma, \nu_i, e, \mu + \text{hadrons}$
ChPT	100 MeV	$\gamma, \nu_i, e, \mu, \pi$
QED	1 MeV	γ, ν_i, e
EH		γ, ν_i γ

Credit: Falkowski, [Eur. Phys. J. C 83 \(2023\) 7, 656](#)

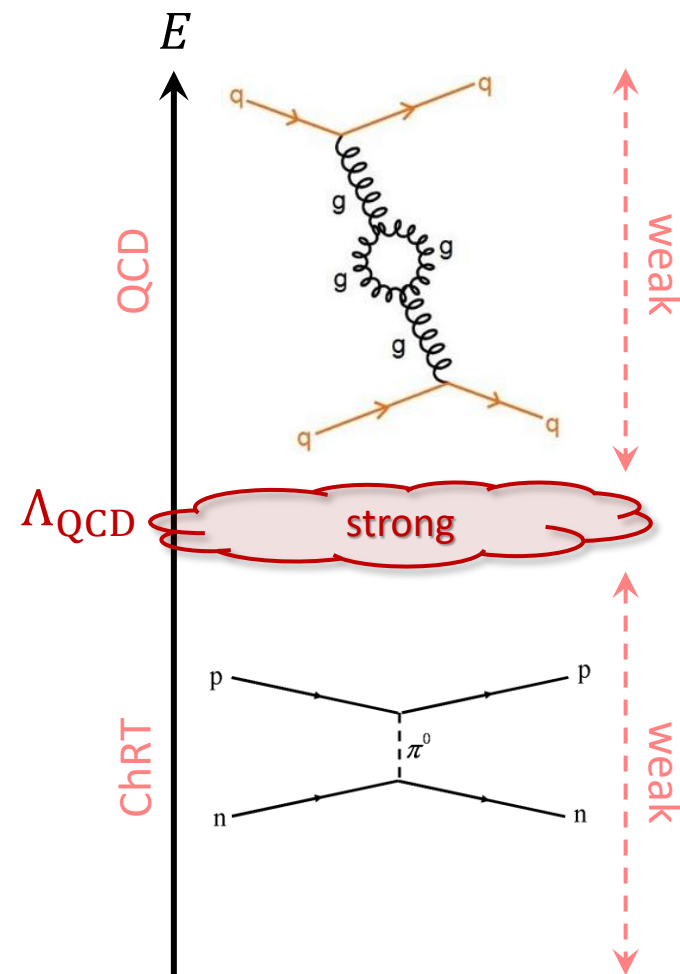
Wilsonian EFT 'Onion'

Species Addition



e.g.: Weak force
UV/IR decoupling

Species Renewal



e.g.: Strong force
UV/IR decoupling

The 'Standard Theory'

SM = EFT

Experimental evidences:

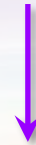
- Gravity/Dark Universe
- Neutrino masses
- Matter-antimatter asymmetry

Theoretical motivations:

- Landau pole (10^{41} GeV)
- Hierarchy problem
- Flavor puzzle
- Strong CP problem
- Inflation
- etc

SMEFT

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{i,d>4} \frac{c_i^{(d)}}{\Lambda_i^{d-4}} \mathcal{O}_i^{(d)}(A_\mu^a, \psi_j^f, H)$$



Weinberg operator
 $d = 5$
 Neutrino masses!

$$\left[\begin{array}{l} \frac{c_\nu}{\Lambda_\nu} (\bar{\ell}_L H^c)(\ell_L^c H) \\ c_\nu \sim 1 \\ \Lambda_\nu \sim 10^{14} \text{ GeV} \end{array} \right]$$

[Review: Falkowski, [Eur. Phys. J. C 83 \(2023\) 7, 656](#)]

GREFT

$$\mathcal{L}_{\text{GREFT}} = -\frac{M_{\text{Pl}}^2}{2} \sqrt{-g} \mathcal{R} \quad \text{Einstein-Hilbert}$$

$$+ a \sqrt{-g} \mathcal{R}^2 + b \sqrt{-g} \mathcal{R}_{\mu\nu} \mathcal{R}^{\mu\nu} + \dots$$

higher-curv.

[Donoghue, [arXiv:gr-qc/9405057](#)]
 [Review: Burgess, [arXiv:gr-qc/0311082](#)]

QFT of **gravitons**
 (spin 2):

$$g_{\mu\nu} = \bar{g}_{\mu\nu} + \frac{h_{\mu\nu}}{M_{\text{Pl}}}$$



J. Donoghue
 Sakurai Prize 2026

Standard (Effective) Theory
 = **GRSMEFT**

Unified framework!

EW + Strong + Gravity

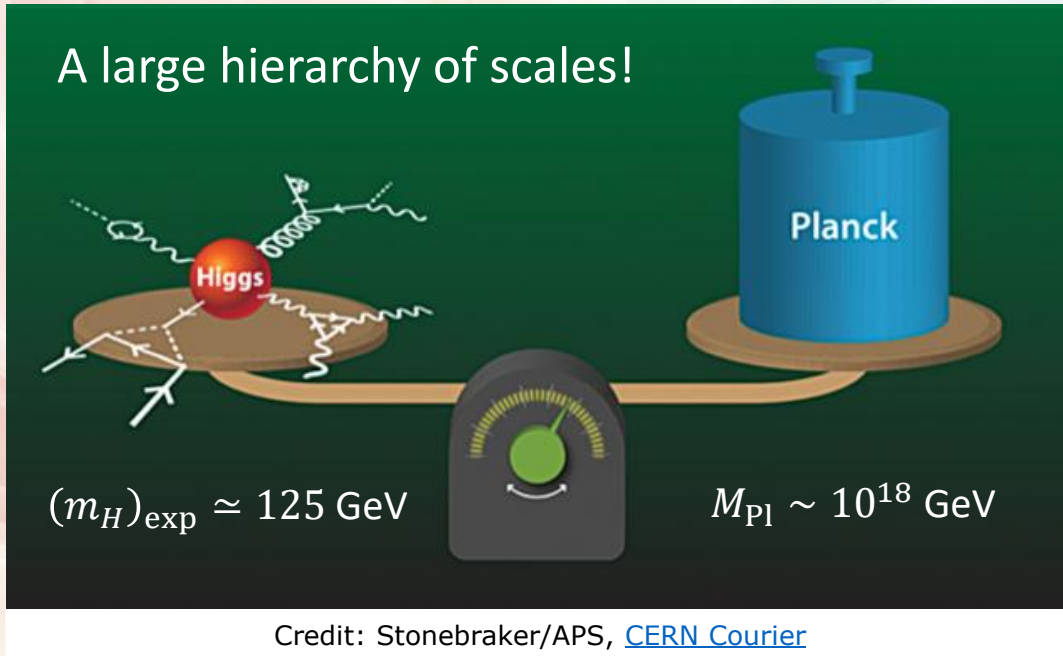
[Ruhdorfer, Serra, Weiler, [arXiv:1908.08050](#)]

Open issues with gravity:

- **Deep UV** (UV completion, singularities)
- **Deep IR** (horizons: black holes, dS, ...)
- Quantum cosmo, topological sector, ...

Almost 50 Years of Hierarchy Problem!

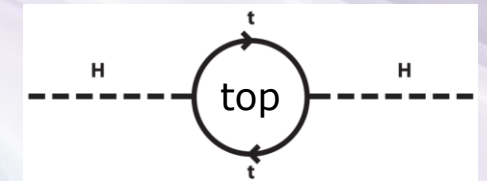
[Susskind, *Phys. Rev. D* **20** (1979) 2619-2625]



$\Lambda_{\text{SM}}?$

$$(m_H)_{\text{exp}}^2 = (m_H)_{\text{R}}^2 + (\delta m_H)_{\text{SM}}^2$$

'Renormalized' mass
Absorbs the unknown ($E > \Lambda_{\text{SM}}$)
Should be computable (UV)



SM radiative corrections
to Higgs mass ($E < \Lambda_{\text{SM}}$):

$$\sim -\frac{3y_t^2}{4\pi^2} \Lambda_{\text{SM}}^2$$

No fine-tuning

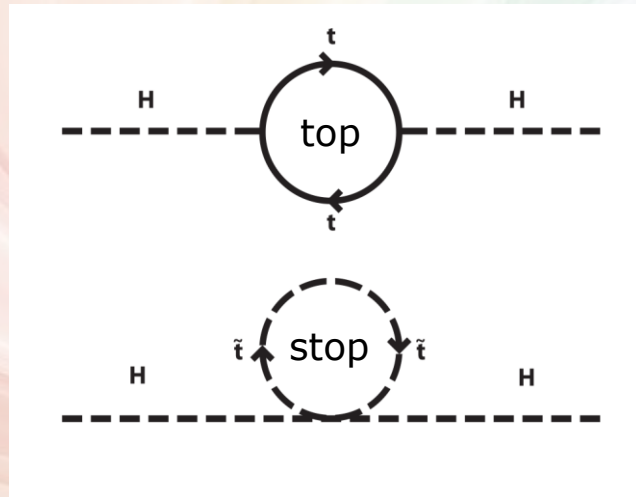


SM cutoff: $\Lambda_{\text{SM}} \lesssim 500 \text{ GeV}$
→ LHC reach!

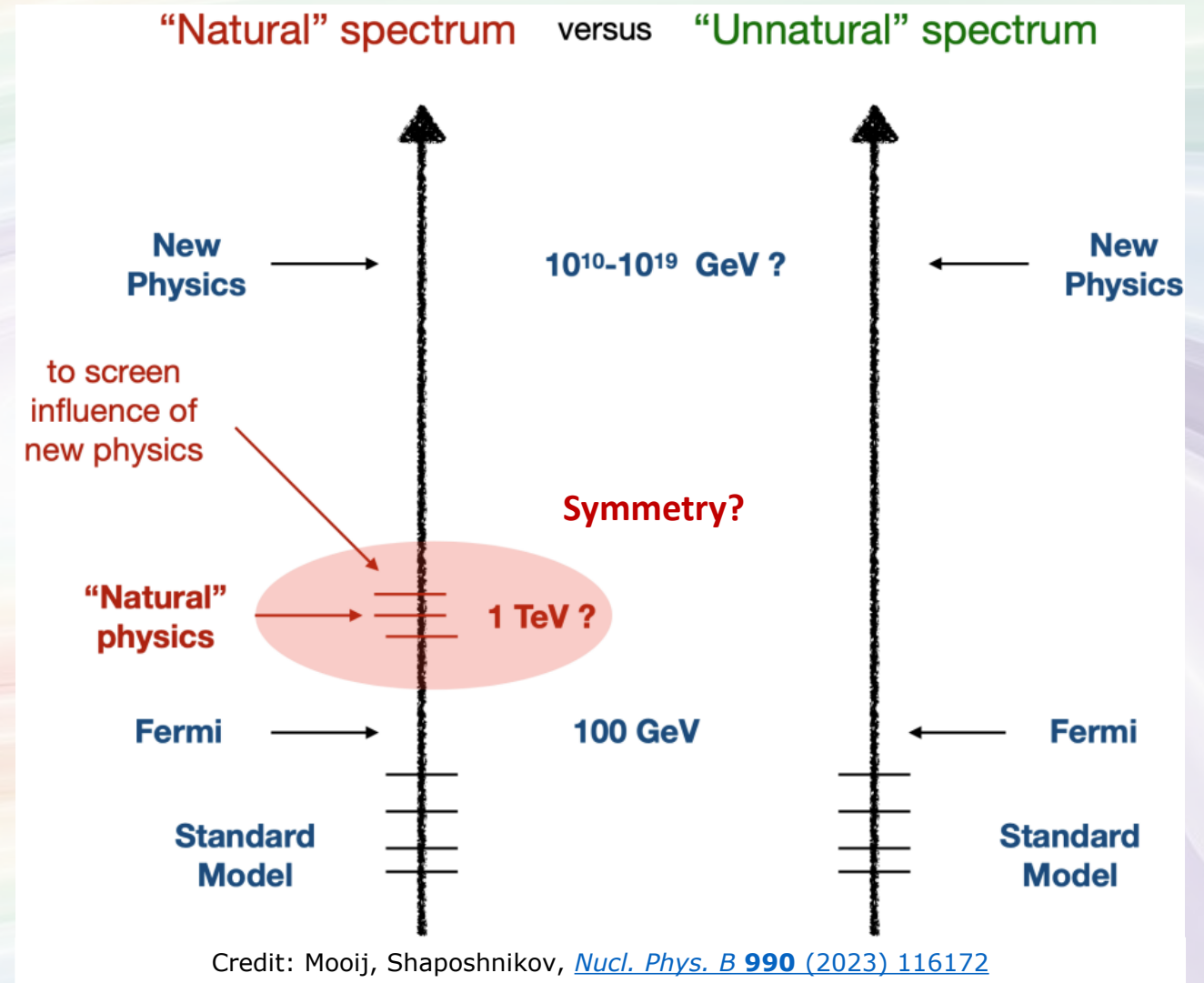
Symmetry-based Solutions

Supersymmetry

[Dimopoulos, Georgi, [Nucl. Phys. B 193 \(1981\) 150-162](#)]



Colored top partners $\lesssim 500$ GeV
→ LHC reach!



LHC → “Naturalness Hits a Snag with Higgs”

[Craig, [APS Physics 13 \(2020\) 174](#)]

"A Krisis?"

[Giudice, [arXiv:1710.07663](https://arxiv.org/abs/1710.07663)]

NEWSFOCUS

Physicists' Nightmare Scenario: The Higgs and Nothing Else

Many fear the LHC will cough up only the one particle they've sought for decades. Some would rather see nothing new at all

Suppose you are a particle physicist. A score of nations has given you several billion Swiss francs to build a machine that will probe the origins of mass, that ineffable something that keeps an object in steady motion unless shoved by a force. Your proposed explanation of mass requires a new particle, cryptically dubbed the Higgs boson, that your machine aims to espy. When, after 2 decades of preparation, you get ready to switch on your rig, you would

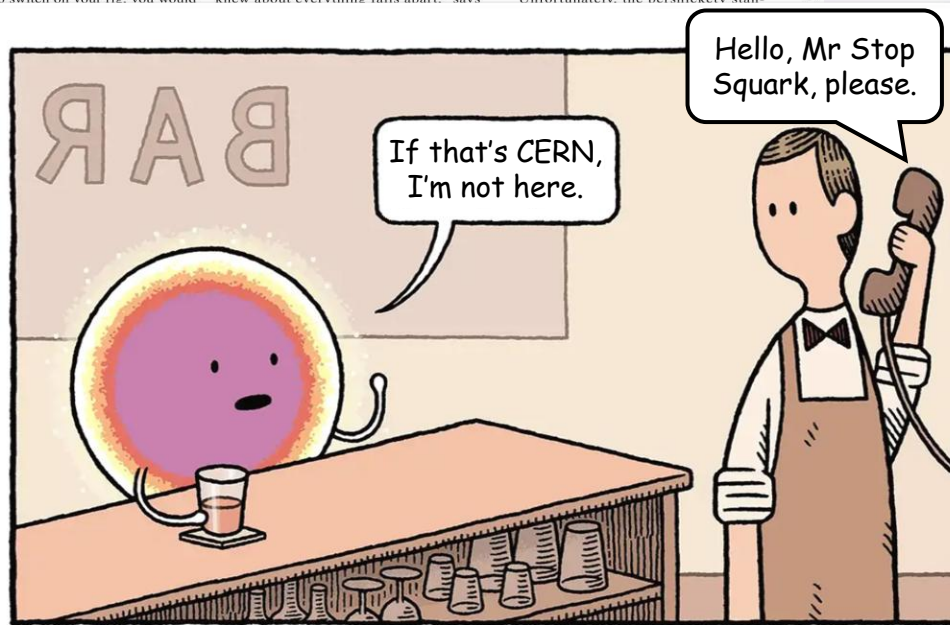
scale," the mind-bogglingly high energy at which gravity pulls as hard as the other forces of nature. The Higgs alone could essentially mark a dissatisfying end to the ages-long quest into the essence of matter.

If, on the other hand, the LHC sees no new particles at all, then the very rules of quantum mechanics and even Einstein's special theory of relativity must be wrong. "It would mean that everything we thought we knew about everything falls apart," says

The particular challenge is to give mass to particles called the W and Z bosons, which convey the weak nuclear force. According to the standard model, the weak force that causes a type of radioactive decay and the electromagnetic force that powers lightning and laptop computers are two facets of the same single thing. The two forces aren't precisely interchangeable: Electromagnetic forces can stretch between the stars, whereas the weak force doesn't even reach across the atomic nucleus. That range difference arises because photons, the quantum particles that make up an electromagnetic field, have no mass. In contrast, the particles that make up the weak force field, the W and Z bosons, are about 86 and 97 times as massive as the proton.

Unfortunately, the persnickety stan-

6, 2015



TOM GAULD for NEW SCIENTIST

CREDIT: CERN

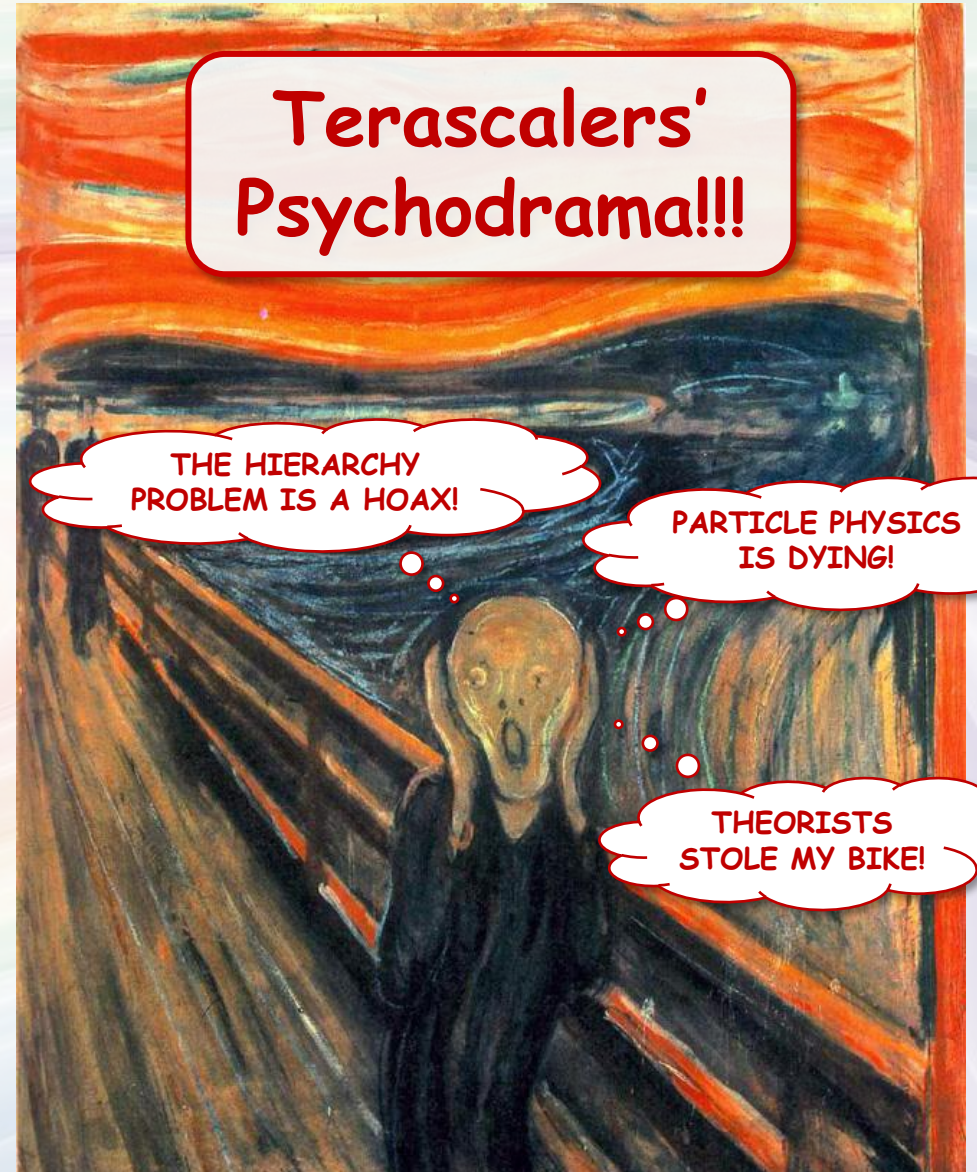
would mean there wouldn't need to be any new physics all the way up to the Planck model: how to give particles mass. Higgs would give physicists little to go on in

Terascalers' Psychodrama!!!

THE HIERARCHY PROBLEM IS A HOAX!

PARTICLE PHYSICS IS DYING!

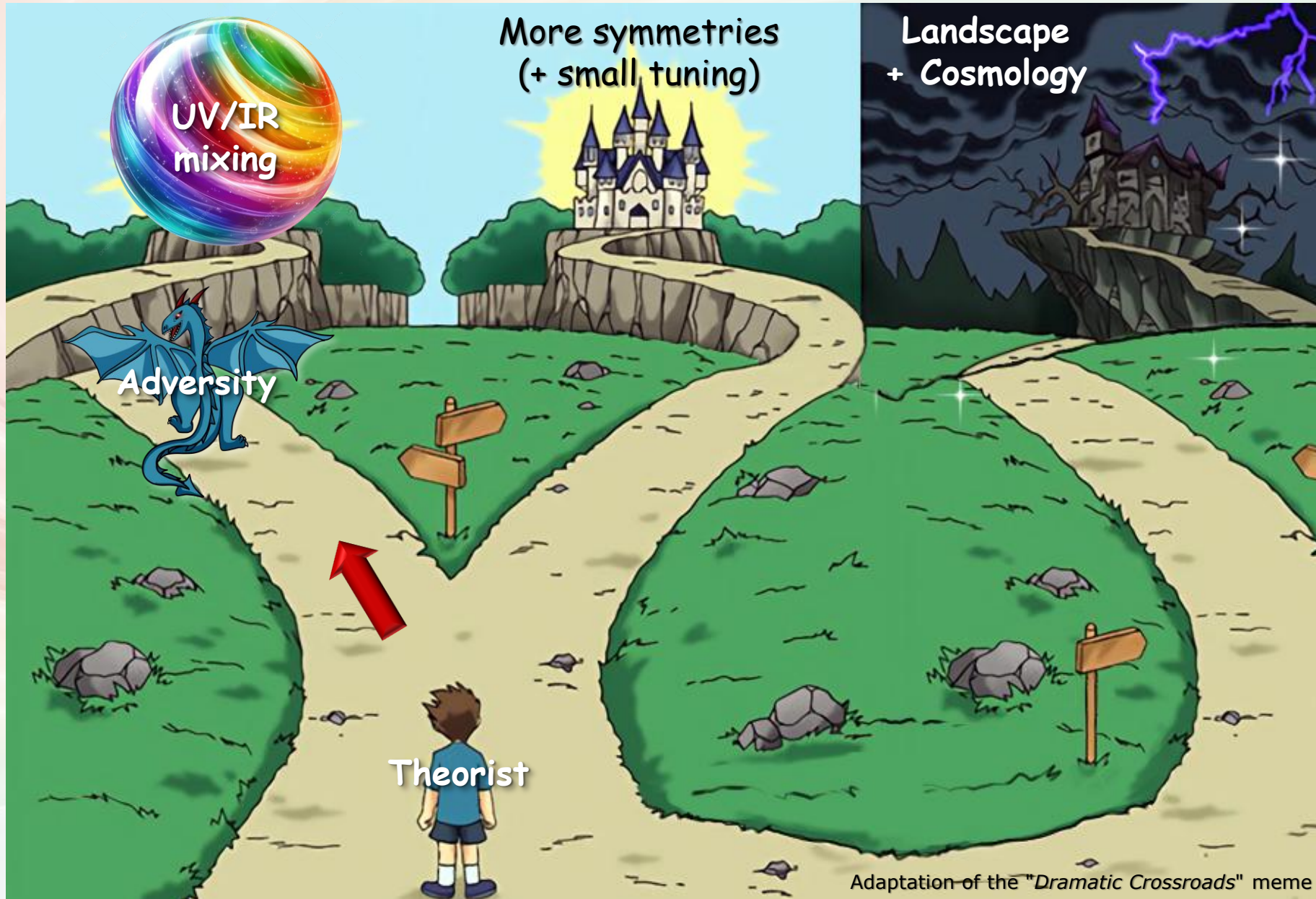
THEORISTS STOLE MY BIKE!



Credit: Munch, *The Scream*, 1893

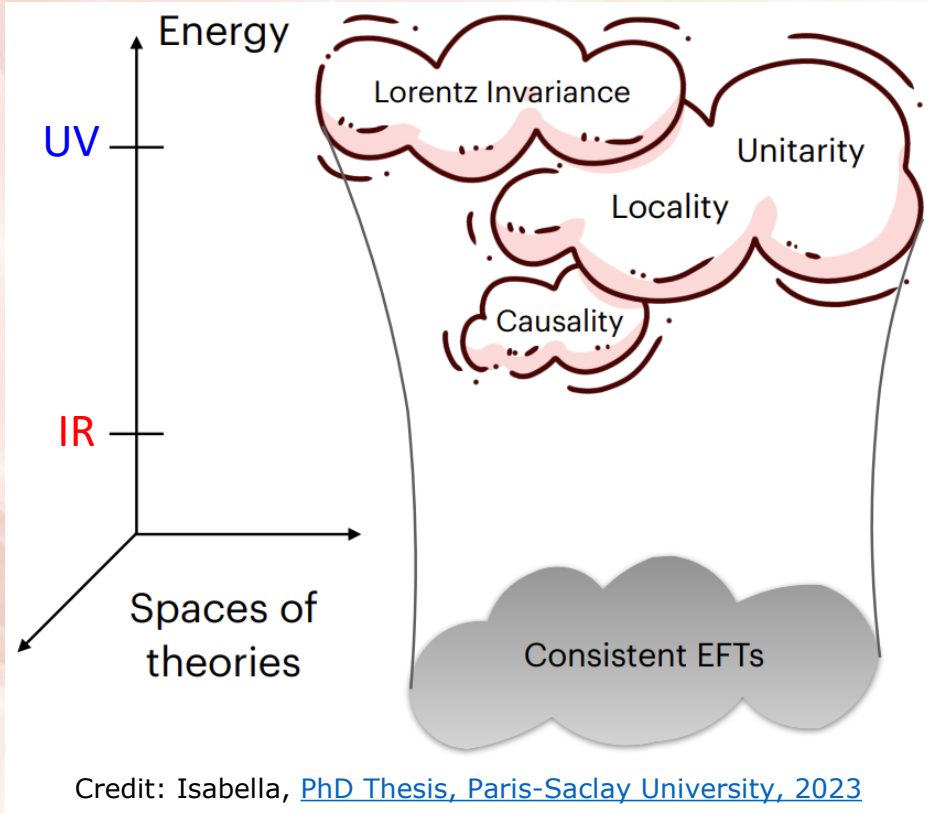
"The Privilege of Experiencing a Krisis"

[Giudice, [arXiv:1710.07663](https://arxiv.org/abs/1710.07663)]



Breaking the Wilsonian Picture

Wilsonian UV-completions



Breaking of locality (microcausality)



'Pandora's box'
of non-local QFT



'Ouroboros' of UV/IR mixing

Credit: McCullough



Drawing from a late medieval Byzantine Greek
alchemical manuscript [[source](#)]

↓
Light scalars?

**UV/IR mixing is a
property of gravity!**

Non-linearities in Gravity

Linearized gravity:

$$g_{\mu\nu} = \eta_{\mu\nu} + \frac{h_{\mu\nu}}{M_{\text{Pl}}}$$

Pointlike mass:

$$M \gg M_{\text{Pl}}$$

$$h \sim \frac{M}{M_{\text{Pl}} r}$$

Schwarzschild radius:

$$R_S \sim \frac{M}{M_{\text{Pl}}^2}$$

General relativity
 (classical non-linearities α_{cl})

$$\mathcal{L}_{\text{GR}} \sim M_{\text{Pl}}^2 \sqrt{-g} \mathcal{R} \sim h \partial^2 h + \sum_{n \geq 2} \frac{h^n \partial^2 h}{M_{\text{Pl}}^{n-1}}$$

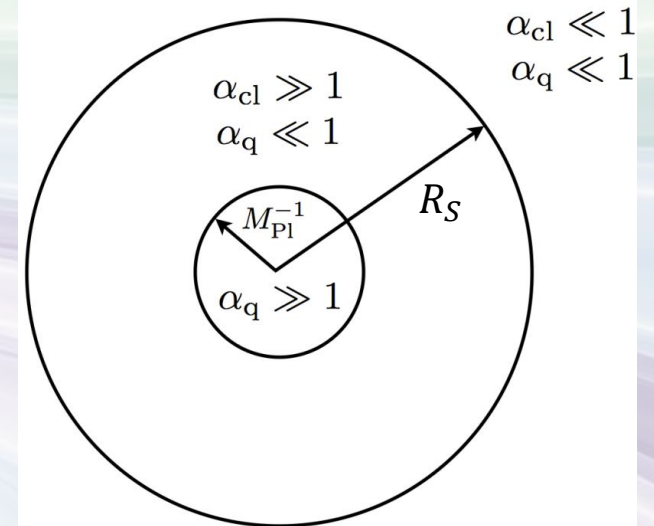
$$\Rightarrow \alpha_{\text{cl}} \sim \frac{h}{M_{\text{Pl}}} \sim \frac{R_S}{r}$$

Higher curvature terms
 (quantum non-linearities α_{q})

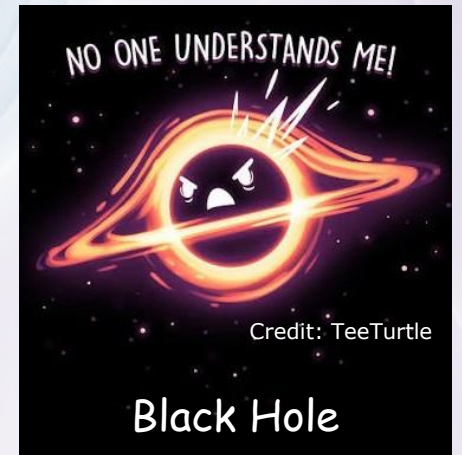
$$\mathcal{L}_{\text{h.c.}} \sim \sqrt{-g} \mathcal{R}^2 + \sqrt{-g} \mathcal{R}_{\mu\nu} \mathcal{R}^{\mu\nu} + \dots$$

$$\sim \sum_{n \geq 2, m \geq 4} \frac{\partial^m h^n}{M_{\text{Pl}}^{m+n-4}}$$

$$\Rightarrow \alpha_{\text{q}} \sim \frac{\partial^2}{M_{\text{Pl}}} \sim \frac{1}{M_{\text{Pl}}^2 r^2}$$

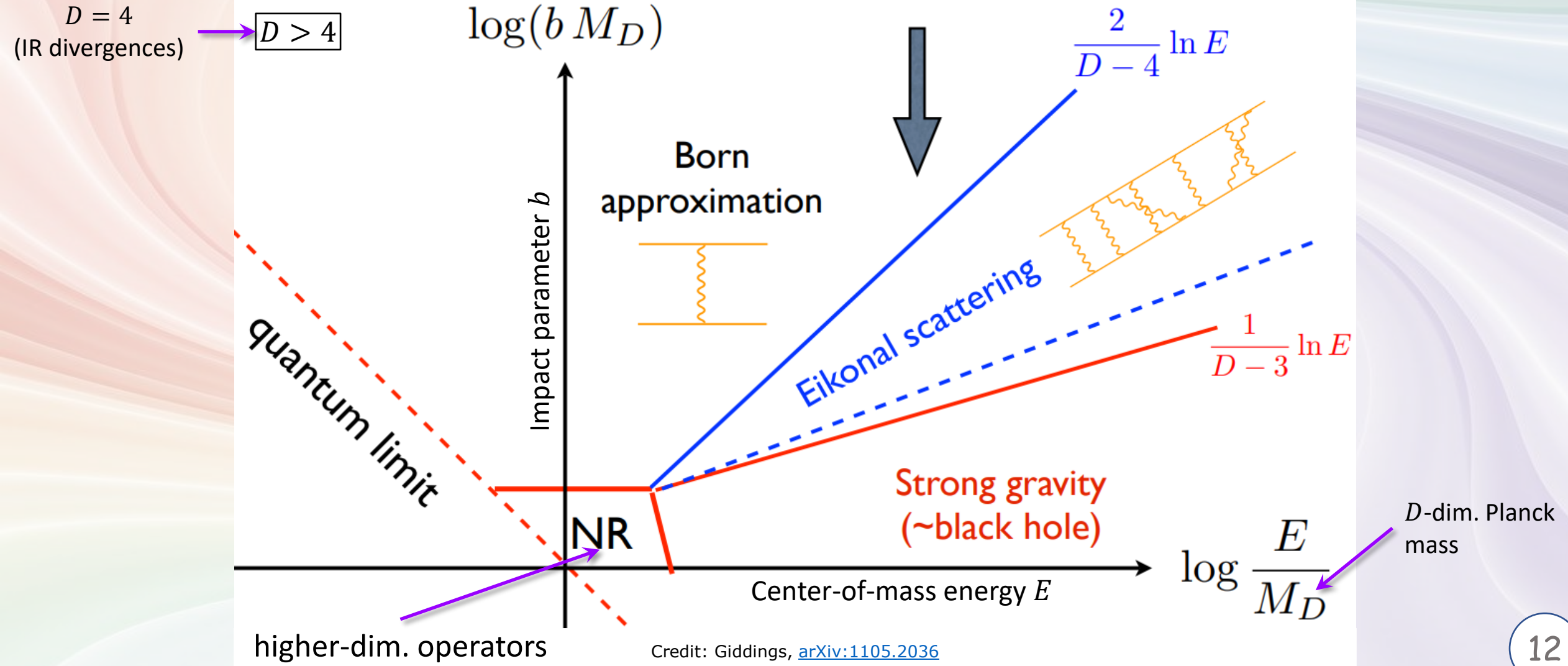


Credit: J. Khoury, [arXiv:1312.2006](https://arxiv.org/abs/1312.2006)



Scattering Regimes in Gravity

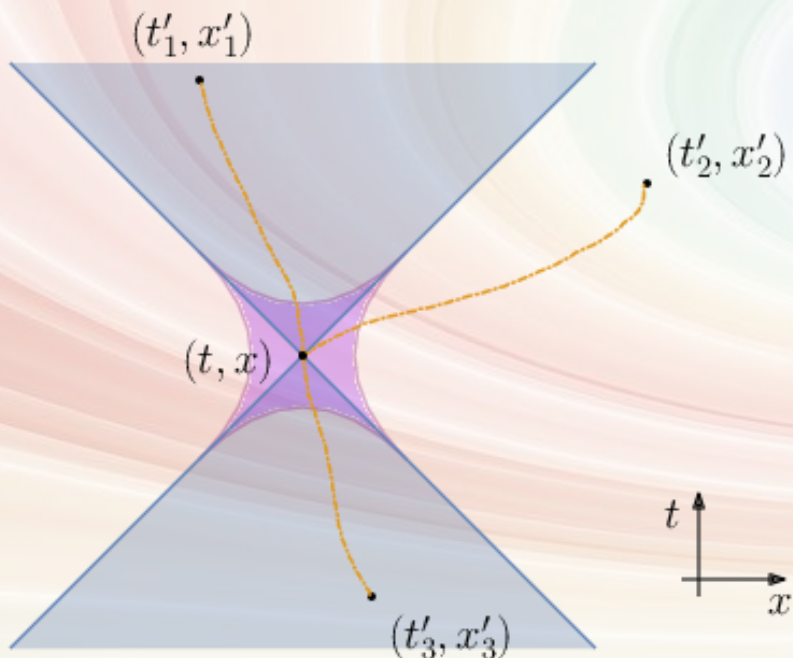
Scattering of 2 particles of mass $m \ll M_{\text{Pl}}$ in asymptotically D -dim. Minkowski spacetime:



The Ultimate Fate of Reductionism

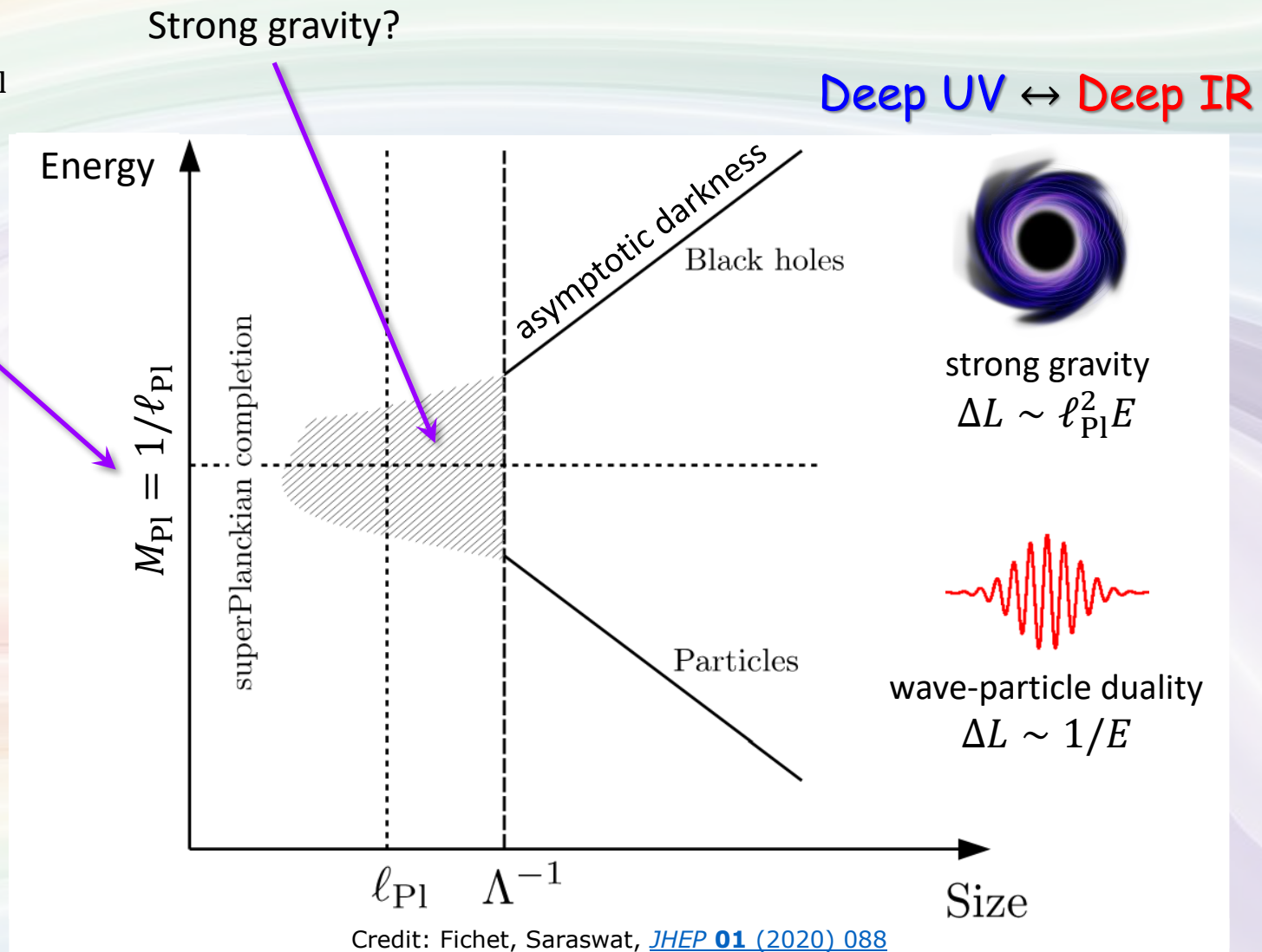
[Aharony, Banks, [arXiv:hep-th/9812237](https://arxiv.org/abs/hep-th/9812237)]
 [Dvali, Gomez, [arXiv:1005.3497](https://arxiv.org/abs/1005.3497)]
 [Dvali et al., [arXiv:1006.0984](https://arxiv.org/abs/1006.0984)]
 [Giddings, [arXiv:1105.2036](https://arxiv.org/abs/1105.2036)]

Planck length $\ell_{\text{Pl}} = 1/M_{\text{Pl}}$
 $\equiv$ Minimal length scale
 $\Rightarrow$ Non-locality!



Credit: Boos, Springer Theses, [arXiv:2009.10856](https://arxiv.org/abs/2009.10856)

'Fuzzy' light cone



$\rightarrow$ Gravity makes the hierarchy problem concrete!

UV/IR Mixing: a Multifaceted "Monster"

Impact on low-energy EFTs??? Light Higgs??? → Several approaches...

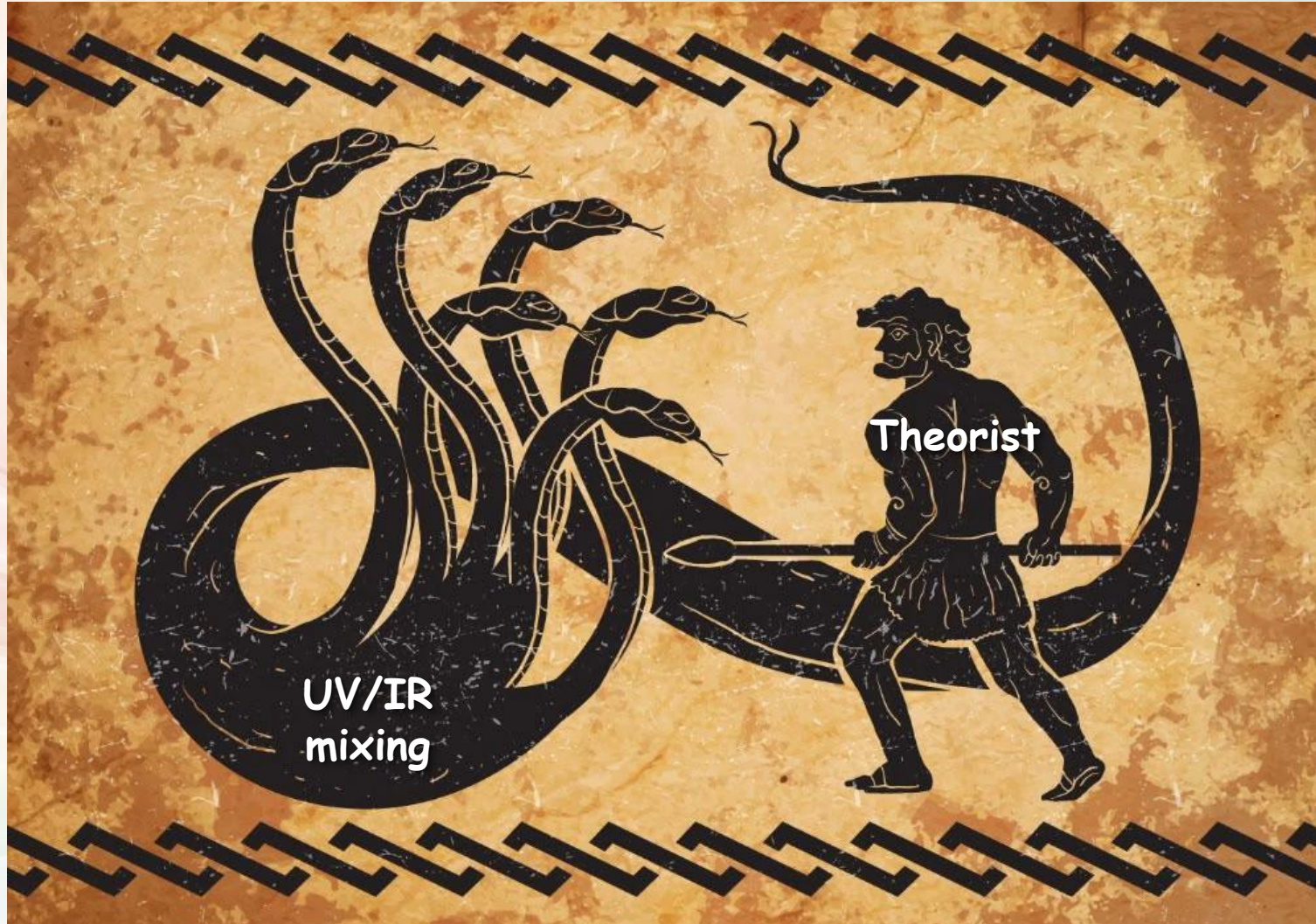
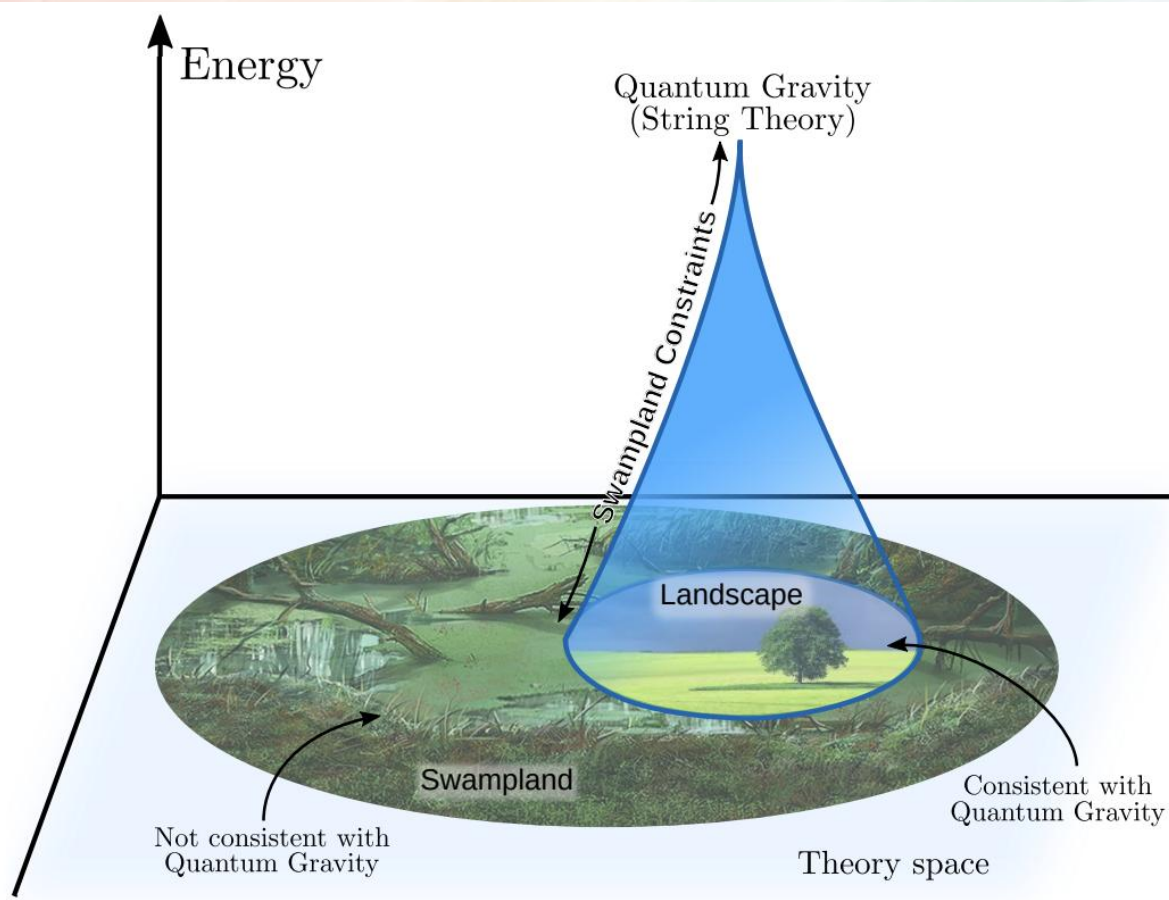


Illustration of the battle between Heracles and the Lernaean Hydra.

Other Faces of UV/IR Mixing

Swampland Program



[van Beest et al, [arXiv:2102.01111](https://arxiv.org/abs/2102.01111)]

Indirect UV/IR mixing / Conjectures!

Non-commutative Geometry



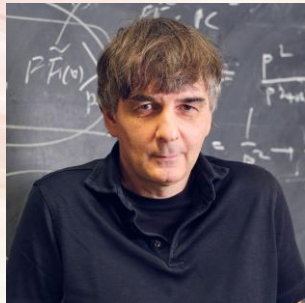
[Craig, Koren, [arXiv:1909.01365](https://arxiv.org/abs/1909.01365)]

[Hersent et al., [arXiv:2210.11890](https://arxiv.org/abs/2210.11890)]

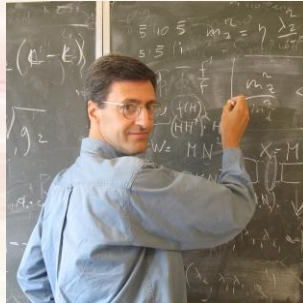
Direct UV/IR mixing / Consistency?

Today's Topic

UV/IR Mixing by Classicalization



G. Dvali



G.F. Giudice



C. Gomez



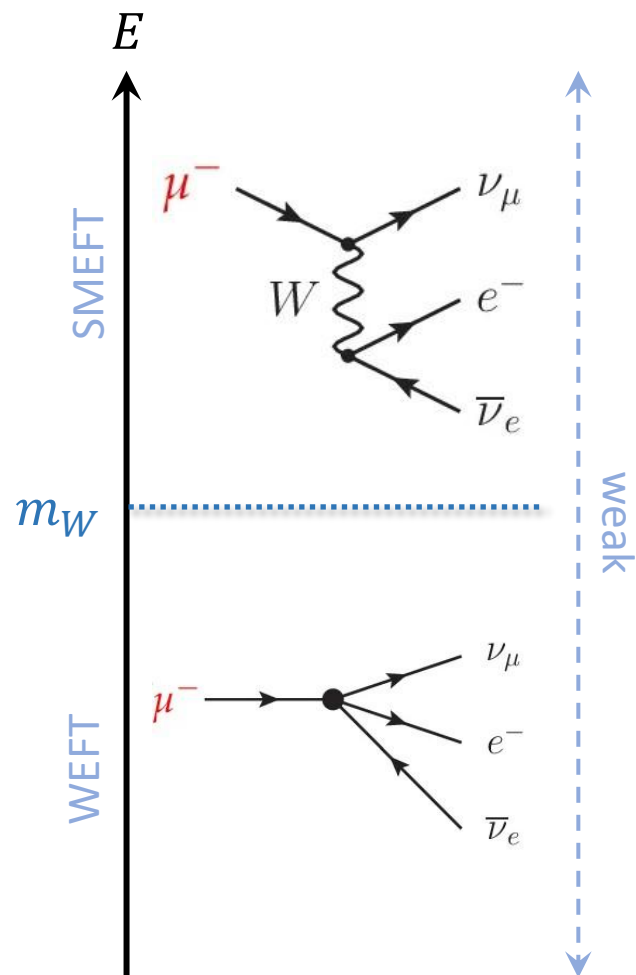
A. Kehagias

Dvali, Giudice, Gomez, Kehagias, *JHEP* **08** (2011) 108, [arXiv:1010.1415](https://arxiv.org/abs/1010.1415)

Dvali, Gomez, Kehagias, *JHEP* **11** (2011) 070, [arXiv:1103.5963](https://arxiv.org/abs/1103.5963)

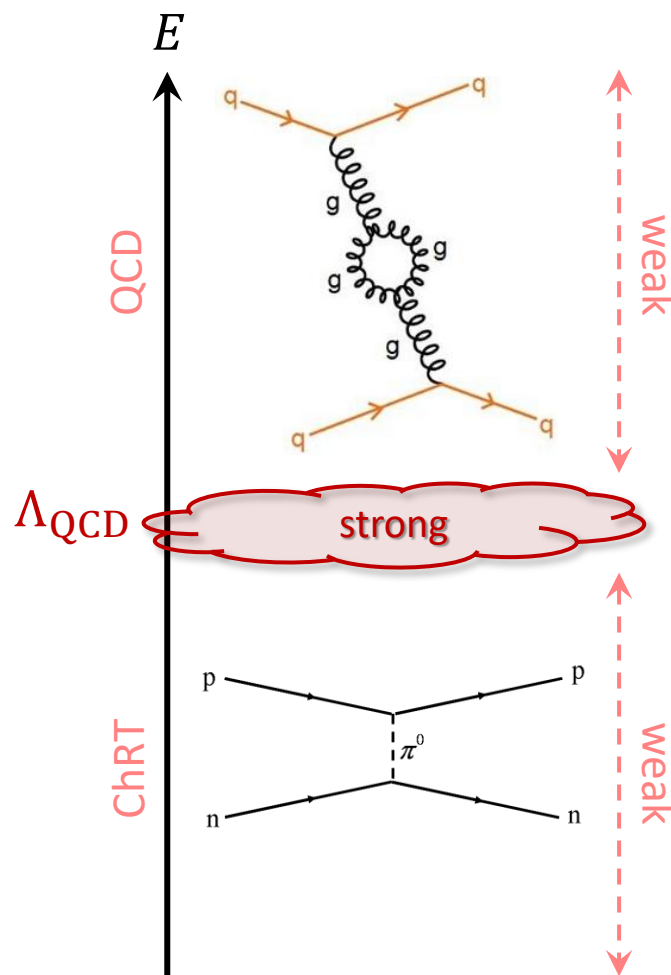
A 3rd Way for UV Completion?

Species Addition



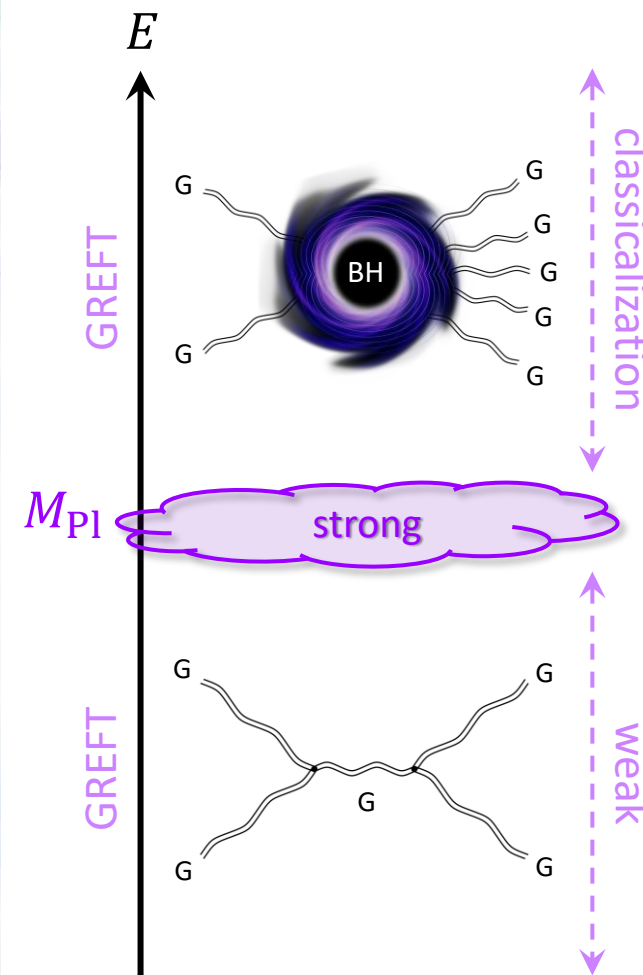
e.g.: Weak force
UV/IR decoupling

Species Renewal



e.g.: Strong force
UV/IR decoupling

Species Recycling



e.g.: Pure gravity?
UV/IR mixing

$\mathcal{O}(1)$ numbers
are fixed at 1

Classicalization in Gravity

[Dvali et al., [arXiv:1103.5963](#)]
[Dvali et al., [arXiv:1409.7405](#)]
[Addazi et al., [arXiv:1611.03643](#)]
[Dvali, [arXiv:2003.05546](#)]

Graviton scattering ($\sqrt{s} \gg M_{\text{Pl}}, b \ll R_{\text{BH}}$)

Individual graviton coupling:

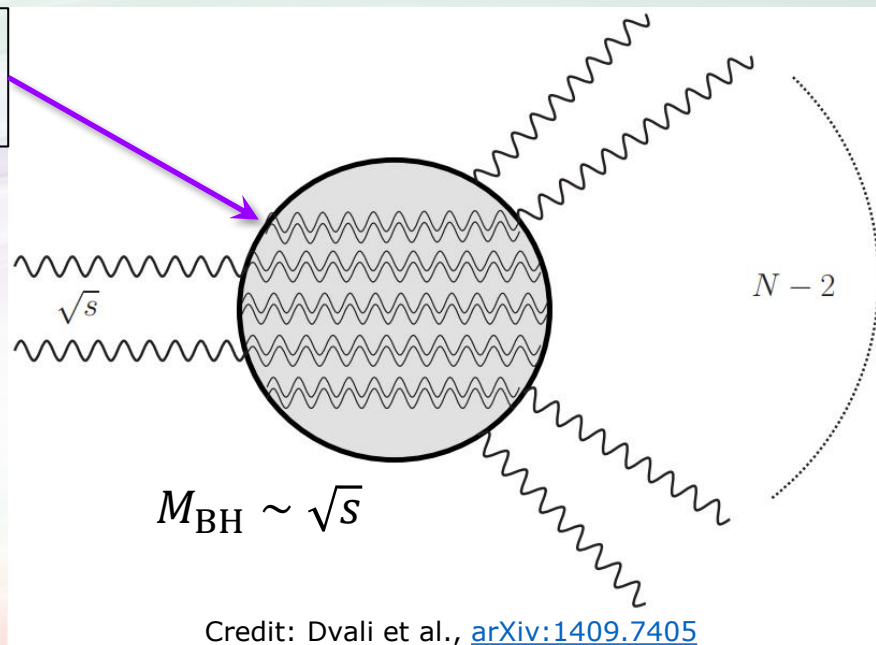
$$\alpha_G(q^2) \equiv \frac{q^2}{M_{\text{Pl}}^2}$$

$$S_{\text{BH}} \sim N_{\odot} \sim M_{\text{BH}} R_S \sim \frac{1}{\alpha_G(1/R_S^2)} \sim \frac{\mathcal{A}}{\ell_{\text{Pl}}^2}$$

$\Rightarrow \text{BH} \equiv \text{Saturn}$

BH $\equiv$ coherent state
($N_{\odot} \gg 1$ gravitons)

UV



IR

for $N_{\odot} \gg 1$

Production of a $N \gg 1$ state in QFT:

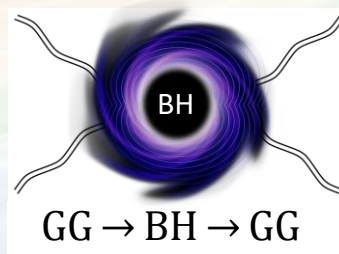
$$|\langle 2|N \rangle|^2 \sim e^{-N} \ll 1$$

unless $N \sim N_{\odot} \sim S_{\text{BH}} \equiv$ entropy of a BH $\equiv$ saturon:

$$|\langle 2|N_{\odot} \rangle|^2 \sim e^{S_{\text{BH}}} \cdot e^{-N} \sim 1$$



overlap with
BH microstates



$$|\langle 2|\mathcal{O}(1) \rangle|^2 \sim e^{-S_{\text{BH}}} \ll 1$$

Classicalization for Scalars?

[Dvali, Pirtskhalava, [arXiv:1011.0114](#)]
 [Brouzakis et al., [arXiv:1109.6174](#)]
 [Rizo, Tetradis, [arXiv:1112.5546](#)]
 [Rizo et al., [arXiv:1206.3785](#)]

Collapsing spherical wave:

$$\phi_0(r, t) = \frac{\psi[\omega(r + t - r_0)]}{r}$$

Frequency ω

Occupation number $A \sim 1$

Non-linearities kick off at r_*

$\mathbb{Z}_2$ -symmetry:
 $\phi(x) \xrightarrow{\mathbb{Z}_2} -\phi(x)$

ϕ^4 -scalar theory:

$$\mathcal{L}_4 = \frac{1}{2} \partial^\mu \phi \partial_\mu \phi - \frac{\lambda}{4} \phi^4$$

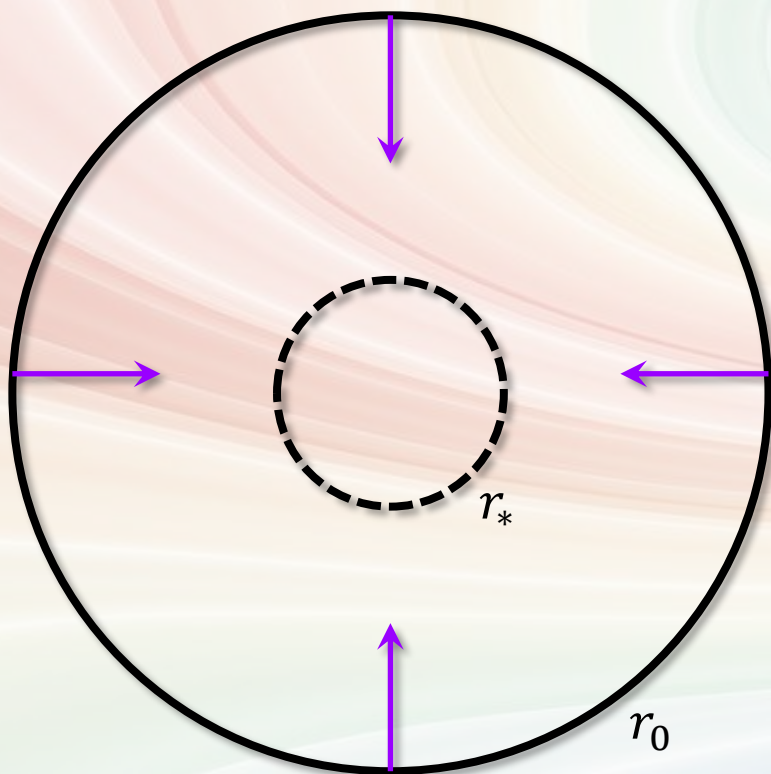
$r_* \sim \frac{\lambda}{\omega}$ $\searrow$ when $\omega \nearrow$
No classicalization

K-essence scalar theory (shift sym.):

$$\mathcal{L}_k = \frac{1}{2} \partial^\mu \phi \partial_\mu \phi \pm \frac{1}{4\Lambda_*^4} (\partial^\mu \phi \partial_\mu \phi)^2$$

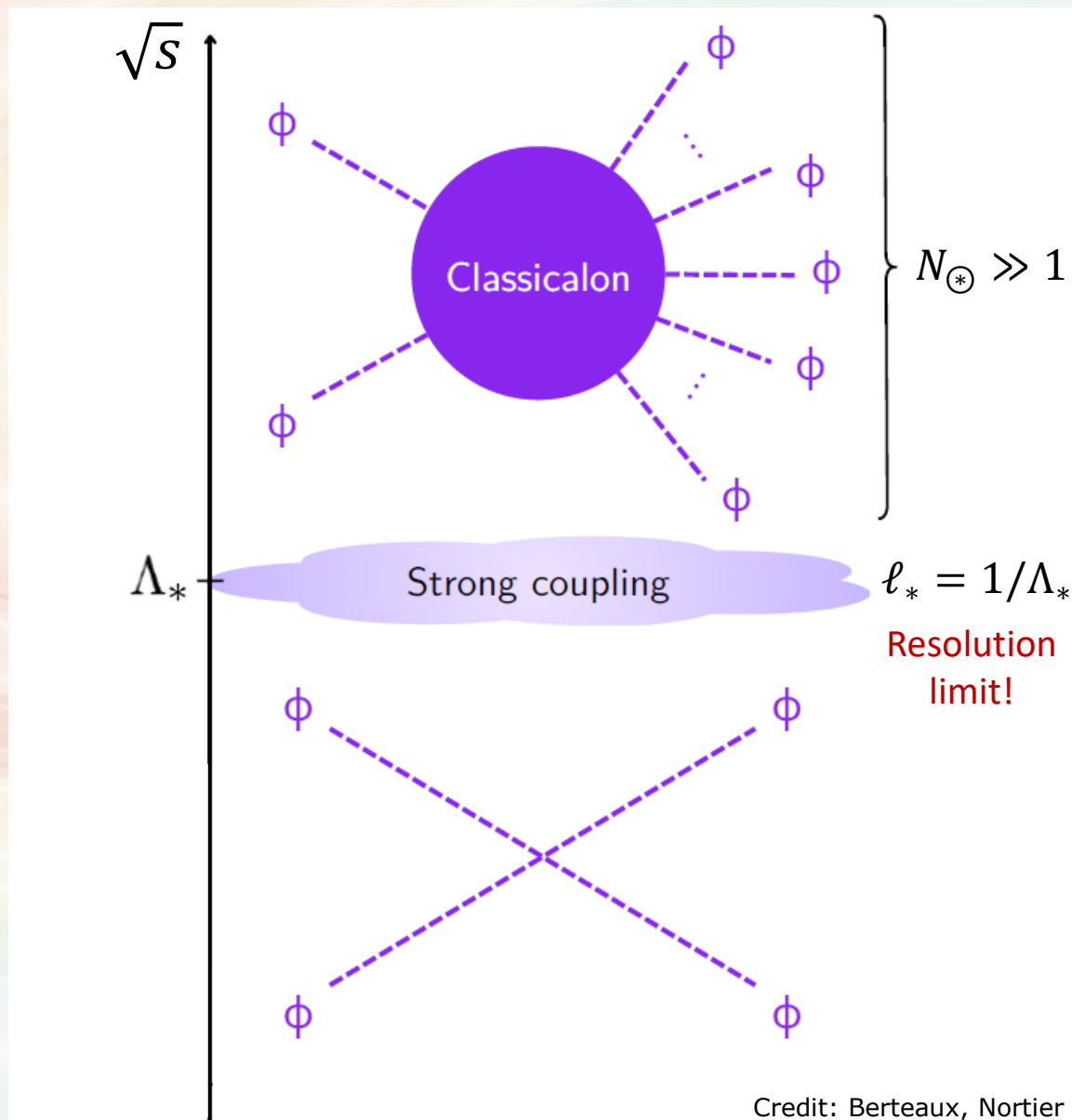
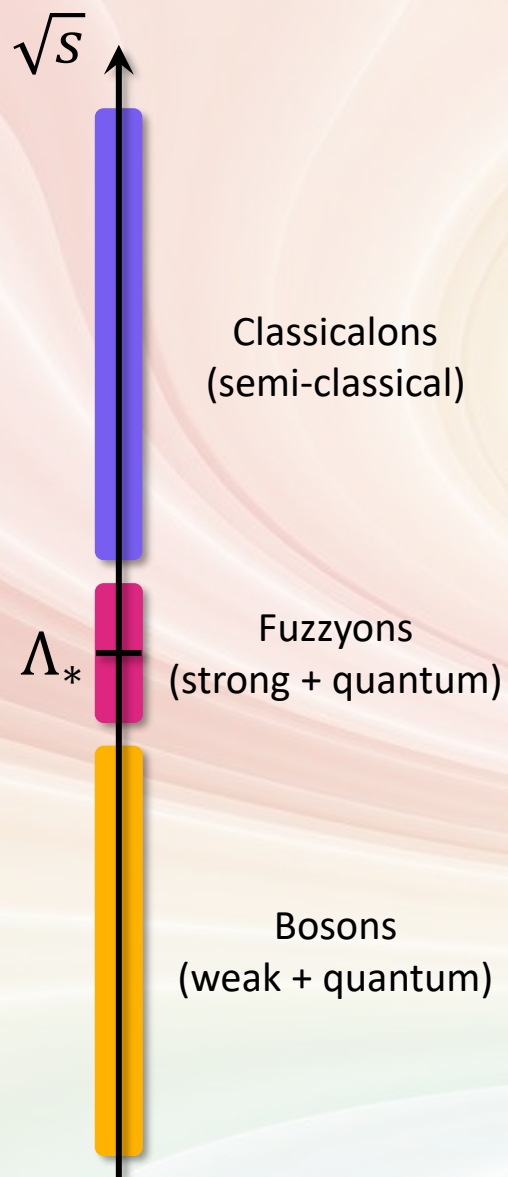
$r_* \sim \frac{1}{\Lambda_*} \left(\frac{\omega}{\Lambda_*} \right)^{\frac{1}{3}}$ $\nearrow$ when $\omega \nearrow$
Classicalization?

depends on self-interaction
 with derivatives $\sim T_{\mu\nu}$



Classicalization for Scalars?

[Dvali et al., [arXiv:1010.1415](#)]
 [Grojean et al., [arXiv:1110.5317](#)]
 [Dvali, [arXiv:1607.07422](#)]
 [Nortier, [arXiv:2511.01739](#)]



Outgoing massless bosons:

$$\omega = |\vec{q}| \sim \frac{1}{R_{\odot}}$$

Individual boson coupling:

$$\alpha_k(q^2) \sim \frac{q^4}{\Lambda_*^4}$$

Classicalization radius:

$$R_{\odot} = \ell_* \left(\frac{M_{\odot}}{4\pi\Lambda_*} \right)^{\frac{1}{3}} \gg \ell_*$$

Classicalon ($N_{\odot} \sim \sqrt{s}R_{\odot}$)
 $\equiv$ **Saturon** ($\alpha_k N_{\odot} \sim 1$)

**Vainshtein screening
in modified gravity!**

Credit: Berteaux, Nortier

Vainshtein Screening

$\mathbb{Z}_2$ -symmetry:

$$\phi(x) \xrightarrow{\mathbb{Z}_2} -\phi(x), \quad J(x) \xrightarrow{\mathbb{Z}_2} -J(x)$$

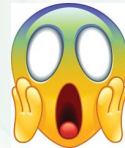
K-essence Lagrangian ($c_2 = \pm 1$):

$$\mathcal{L}_k = \frac{1}{2} \partial^\mu \phi \partial_\mu \phi + \frac{c_2}{4\Lambda_*^4} (\partial^\mu \phi \partial_\mu \phi)^2 + \frac{\phi}{\Lambda_*} T(x)$$

Field equation for the **background** $\bar{\phi}(r)$:

$$\bar{\phi}'(r) - \frac{c_2}{\Lambda_*^4} \bar{\phi}'^3(r) = \frac{1}{4\pi r^2} \cdot \frac{\varepsilon}{\Lambda_*}$$

Smooth real solution if **$c_2 = -1$!**



(see 26)

Quantum fluctuations ($r \ll R_V$):

$$\delta\phi(x) = \phi(x) - \bar{\phi}'(r)$$

$$\delta\phi_Z(x) = \sqrt{Z_\phi} \cdot \delta\phi(x)$$

$$Z_\phi(r) \sim \left[\frac{\bar{\phi}'(r)}{\Lambda_*^2} \right]^2 \gg 1$$

No ghost when **$c_2 = -1$!**

Static pointlike external source:

$$T(x) = -\varepsilon \cdot \delta^{(3)}(\vec{r}), \quad \varepsilon > 0$$

Vainshtein radius ($\bar{\phi}' \sim \Lambda_*^2$):

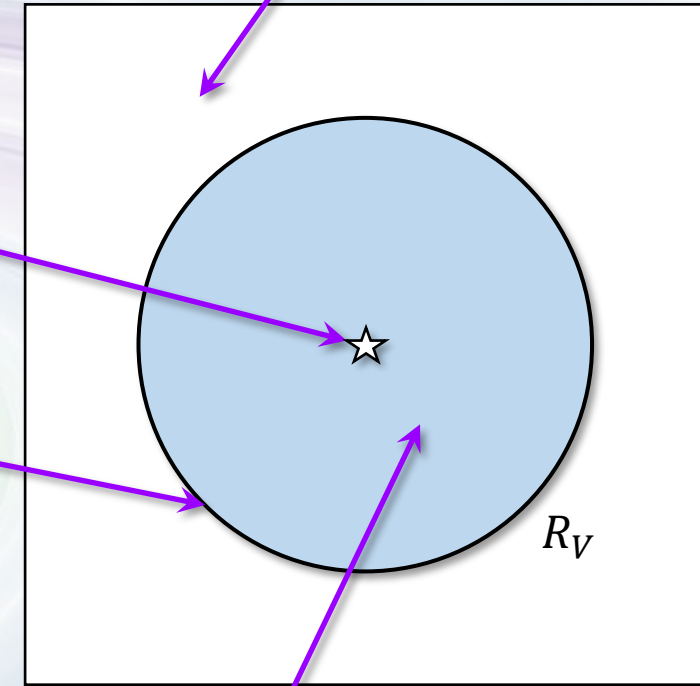
$$R_V = \ell_* \sqrt{\frac{\varepsilon}{4\pi\Lambda_*}}$$

Blueshifted

interaction scale:

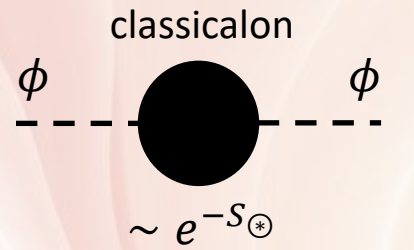
$$\frac{\Lambda_*^{\text{blue}}}{\Lambda_*} = \sqrt{Z_\phi} \gg 1$$

Linear regime $\frac{\bar{\phi}'(r)}{\Lambda_*^2} \sim \left(\frac{R_V}{r}\right)^2 \ll 1$



$\frac{\bar{\phi}'(r)}{\Lambda_*^2} \sim \left(\frac{R_V}{r}\right)^{\frac{2}{3}} \gg 1$ **Non-linear regime**

Classicalization $\Rightarrow$ Little Hierarchy



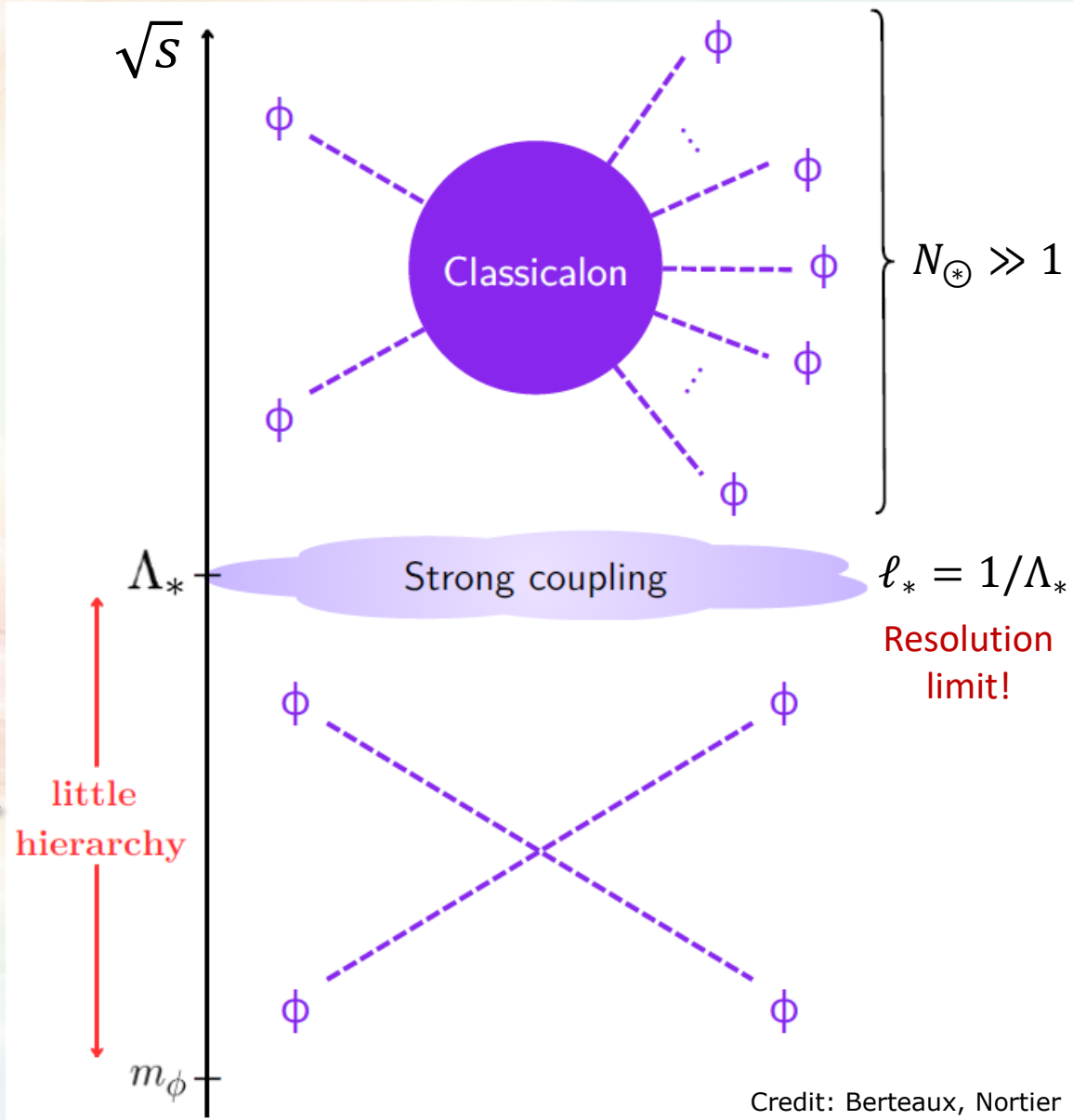
$$S_{\odot} \gg 1$$

$$\sqrt{s} \gg \Lambda_*$$

$$\delta m_{\phi}^2 \sim \Lambda_*^2$$

BUT

To be able to define
the theory



Credit: Berteaux, Nortier

Outgoing massive bosons:

$$\omega^2 - m_{\phi}^2 = |\vec{q}|^2 \sim \left(\frac{1}{R_{\odot}} \right)^2$$

**A new hope for
the Higgs boson?!**

Chameleon-Vainshtein Synergy: Scalar Potential

Add potential ($\mathbb{Z}_2$ -breaking):

$$\phi(x) \xrightarrow{\mathbb{Z}_2} -\phi(x)$$

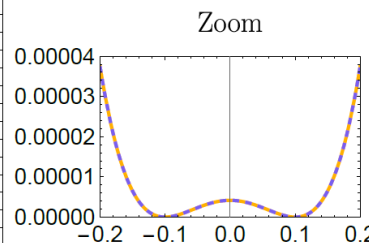
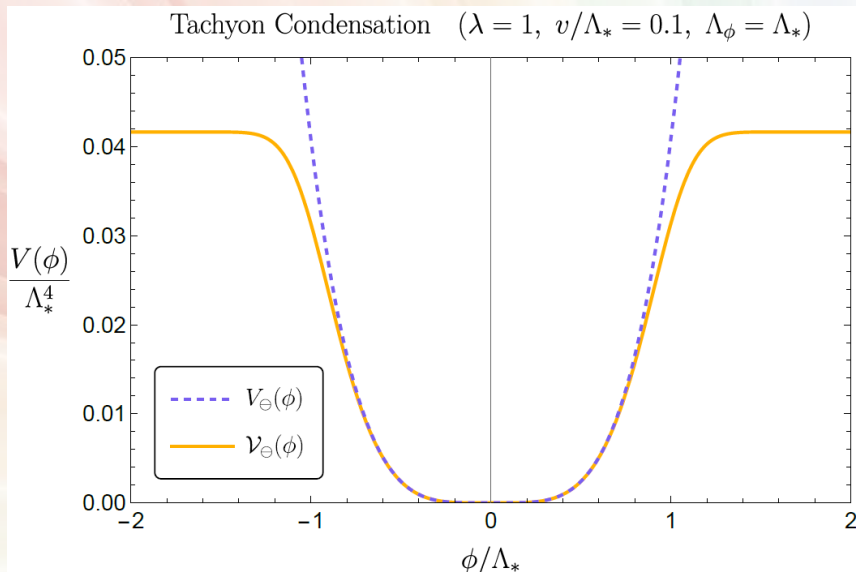
$$V_{\ominus}(\phi) = \frac{\lambda}{4!} (\phi^2 - v^2)^2$$

Conflict with EFT
& Vainshtein screening!

Solution: **Chameleon screening** ($\Lambda_{\phi} \sim \Lambda_* \gg v$):

$$\mathcal{V}_{\ominus}(\phi) = \frac{\lambda}{4!} \Lambda_{\phi}^4 \tanh \left[\frac{(\phi^2 - v^2)^2}{\Lambda_{\phi}^4} \right]$$

$|\bar{\phi}| \gg \Lambda_{\phi} \rightarrow \Lambda_{\phi}^4$
 $|\bar{\phi}| \ll \Lambda_{\phi} \rightarrow V_{\ominus}(\phi)$



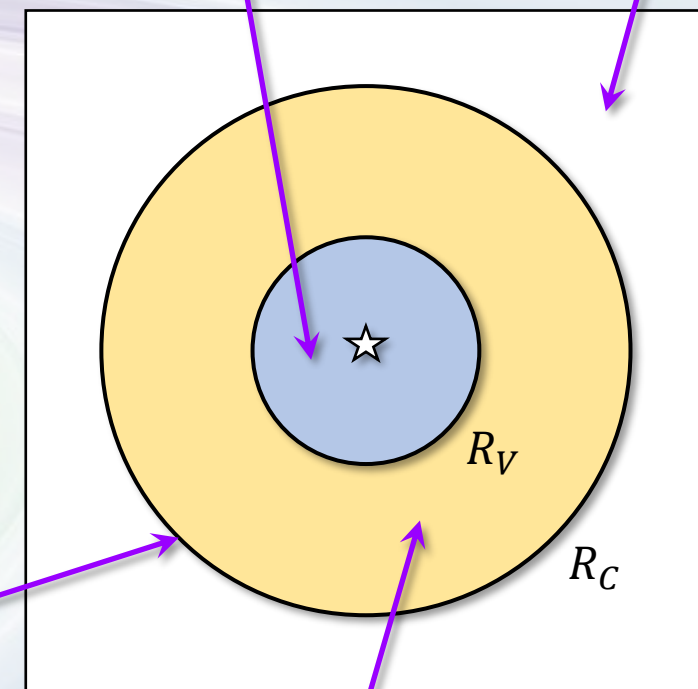
Chameleon radius:

$$\frac{R_C}{R_V} \gg 1$$

Vainshtein screening

$$|\bar{\phi}'| \gg \Lambda_*^2$$

VEV



Chameleon screening

$$|\bar{\phi}| \gg \Lambda_{\phi}$$

Suppressed quantum fluctuations in screening regions:

$$\tanh \left[\left(\frac{\bar{\phi} + \delta\phi}{\Lambda_{\phi}} \right)^4 \right] \xrightarrow{|\bar{\phi}| \gg \Lambda_{\phi}} 1 - 2e^{-2\left(\frac{\bar{\phi}}{\Lambda_{\phi}}\right)^4} \sum_{n=0}^{N_0} \left(\frac{\delta\phi}{\bar{\phi}} \right)^n P_n \left(\frac{\bar{\phi}}{\Lambda_{\phi}} \right) + o \left[\left(\frac{\delta\phi}{\bar{\phi}} \right)^{N_0} \right]$$

Chameleon-Vainshtein Synergy: Yukawa Coupling

Parities ($\mathbb{Z}_2$ -symmetry):

$$\psi_L(x) \xrightarrow{\mathbb{Z}_2} +\psi_L(x), \quad \psi_R(x) \xrightarrow{\mathbb{Z}_2} -\psi_R(x), \quad \phi(x) \xrightarrow{\mathbb{Z}_2} -\phi(x)$$

Yukawa coupling to a fermion:

$$\mathcal{L}_\psi = \frac{i}{2} \bar{\psi} \gamma^\mu \overleftrightarrow{\partial}_\mu \psi - y(\phi \psi_R^\dagger \psi_L + \text{H.c.})$$

Radiative corrections to $\delta\phi_Z$ mass:

$$\frac{\delta m^2(r)}{\Lambda_*^2} \sim \frac{y^4}{16\pi^2} \left(\frac{r}{\ell_*}\right)^2 \gg 1!$$

Chameleon screening ($\Lambda_\psi \sim \Lambda_*$):

$$y \rightarrow y_c[\phi] = y e^{-\left(\frac{\phi}{\Lambda_\psi}\right)^2}$$

No problem with radiative corrections:

$$\frac{\delta m^2(r)}{\Lambda_*^2} \sim \frac{y^4}{16\pi^2} e^{-4\left[\frac{\bar{\phi}(r)}{\Lambda_\psi}\right]^2} \left(\frac{r}{\ell_*}\right)^2 \ll 1!$$

Full classicalization

New kinetic coupling ($\Lambda'_* \sim \Lambda_*$):

$$\mathcal{L}_\psi - \left(\frac{\partial^\mu \phi \partial_\mu \phi}{2\Lambda_*^2}\right) \left(\frac{i\bar{\psi} \gamma^\mu \overleftrightarrow{\partial}_\mu \psi}{2\Lambda'^2_*}\right)$$

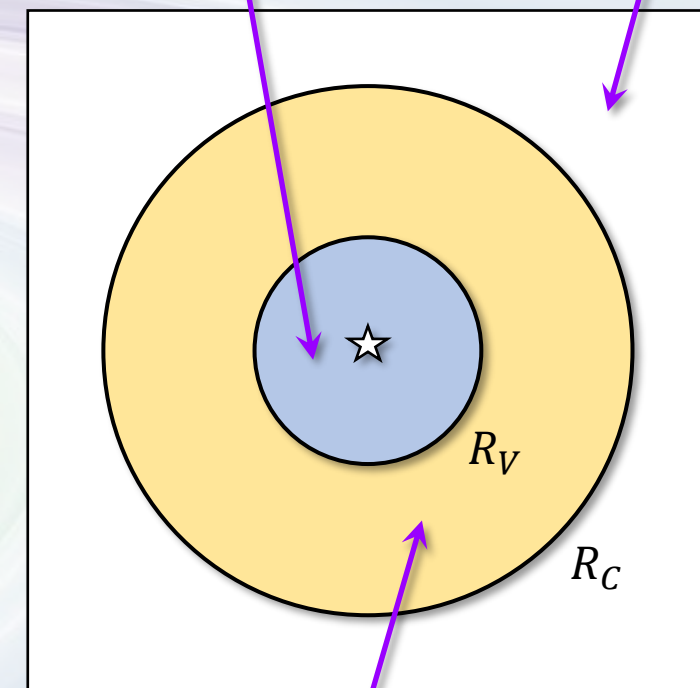
Blueshifted interaction scales:

$$\frac{\Lambda_*^{\text{blue}}}{\Lambda_*} = \sqrt{Z_\phi} \gg 1, \quad \frac{\Lambda'^{\text{blue}}_*}{\Lambda'_*} = \sqrt{Z_\psi} \gg 1$$

Vainshtein screening

$$|\bar{\phi}'| \gg \Lambda_*^2$$

VEV



Chameleon screening

$$|\bar{\phi}| \gg \Lambda_\phi$$

Concerns Regarding UV/IR Mixing...

That "UV/IR mixing"...
yet another flashy
BSM scenario!

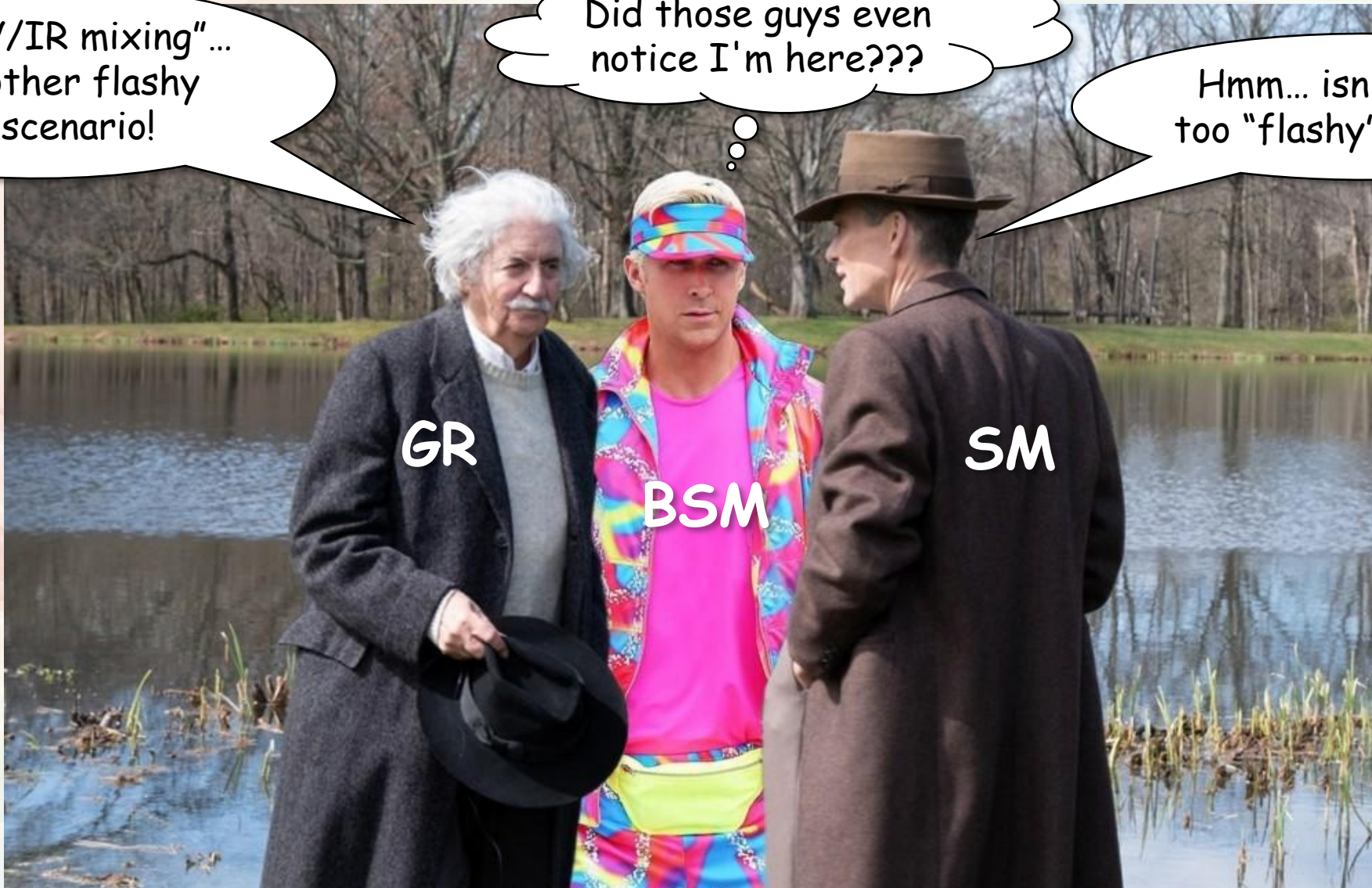
Did those guys even
notice I'm here???

Hmm... isn't it a bit
too "flashy", actually?



Link with
gravity!

Little hierarchy
for free!



No-go theorem?

Locality
Microcausality
Positivity bounds



Adaptation of a "Barbenheimer" meme

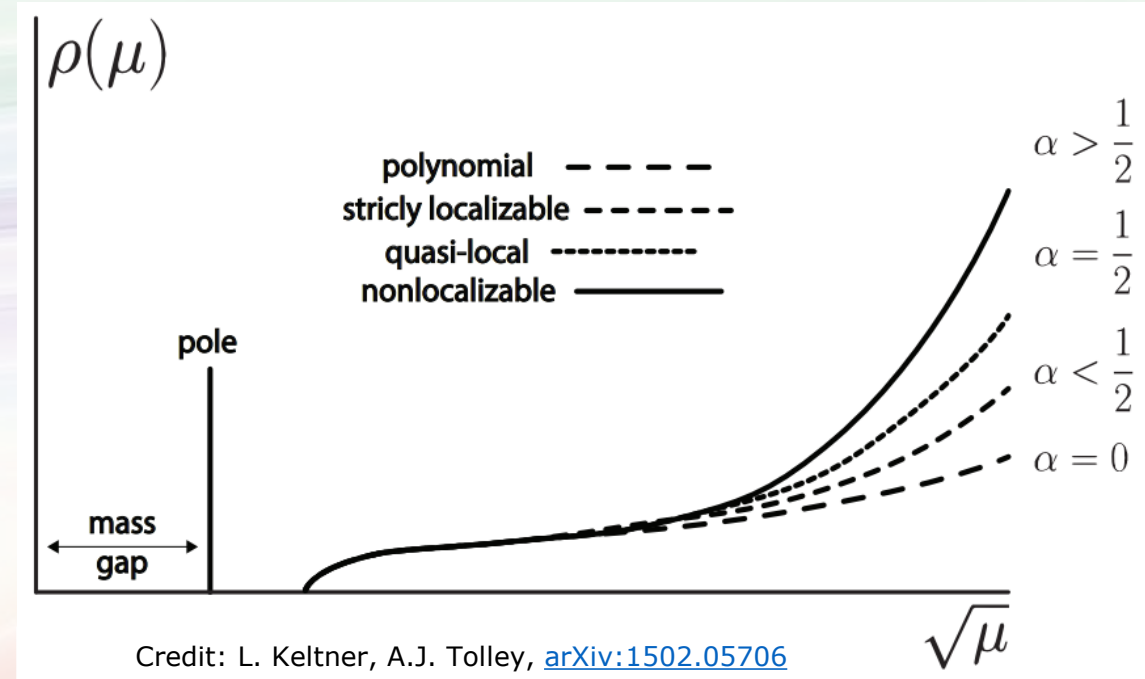
Jaffe's Classification of QFTs

Källén-Lehmann spectral density ($\mu \equiv p^2$), **UV behavior**:

$$\rho(\mu) \leq A\mu^2 e^{\kappa_2 \mu^\alpha}, \quad A, \kappa_2 > 0$$

- $\alpha = 0$: polynomial (e.g. textbook QFT);
 - $0 \leq \alpha < 1/2$: strictly localizable fields;
 - $\alpha = 1/2$: **quasi-local fields** (e.g. little string theory);
 - $\alpha > 1/2$: **non-localizable fields** (e.g. classicalization).
- } **localizable fields;**

$$\rho(\mu) \sim e^{S_{\odot}(\mu)} \equiv e^{\kappa_2 \mu^\alpha}$$



$$\alpha = \frac{\beta + 1}{2} > \frac{1}{2}, \quad R_{\odot} = \ell_* \left(\frac{M_{\odot}}{4\pi\Lambda_*} \right)^{\beta}, \quad \beta > 0$$

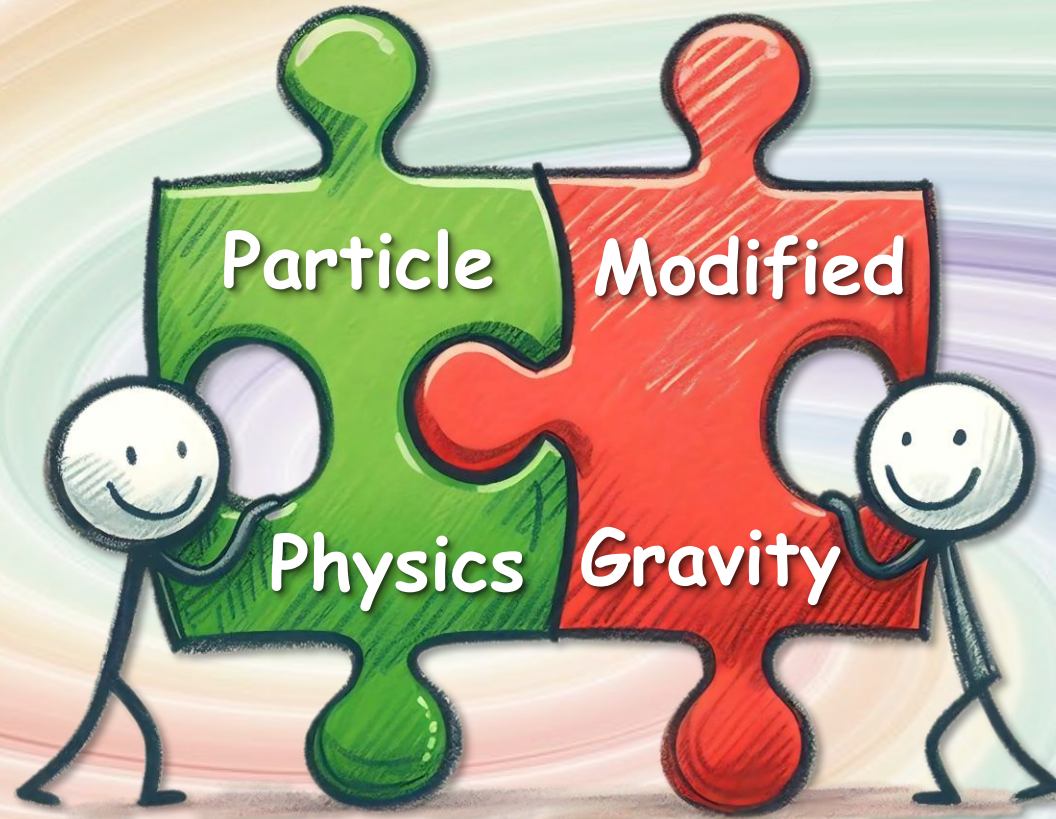
Safe superluminality & Asymptotic causality:

[Babichev et al., [arXiv:0708.0561](https://arxiv.org/abs/0708.0561)]
 [Burrage et al., [arXiv:1111.5549](https://arxiv.org/abs/1111.5549)]
 [Dvali et al., [arXiv:1204.6388](https://arxiv.org/abs/1204.6388)]
 [Keltner, Tolley, [arXiv:1502.05706](https://arxiv.org/abs/1502.05706)]
 [Kaplan et al., [arXiv:2406.06681](https://arxiv.org/abs/2406.06681)]

Non-locality $\Rightarrow$ **Impact on positivity bounds!**

[Tokuda, [arXiv:1902.10039](https://arxiv.org/abs/1902.10039)]
 [Buoninfante et al., [arXiv:2305.16422](https://arxiv.org/abs/2305.16422)]

Last Words...



UV/IR Mixing by Classicalization

Vainshtein screening with gauge interactions??? Higgs??? → Stay tuned!

[Berteaux, Nortier, arXiv:26XX.XXXXXX]

[Ettengruber, Nortier, arXiv:26XX.XXXXXX]

Little Hierarchy → Target for HL-LHC/FCC!!!