An asymptotically safe link between the Planck scale and the electroweak scale

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PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Planck 2018 - from the Planck scale to the electroweak scale

An asymptotically safe link between the Planck scale and the electroweak scale

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recent work with:

Aaron Held (1705.02342, PRD 96 (2017), 086025;
1707.01107, Phys.Lett. B777 (2018) 217-221
1803.04072)

Fleur Versteegen (arXiv:1709.07252, JHEP 1801 (2018) 030)

Nic Christiansen (1702.07724, Phys.Lett. B770 (2017) 154-160)

Yuta Hamada, Johannes Lumma, Masatoshi Yamada (1712.00319, PRD 97 (2018) no.8, 086004)

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electroweak scale

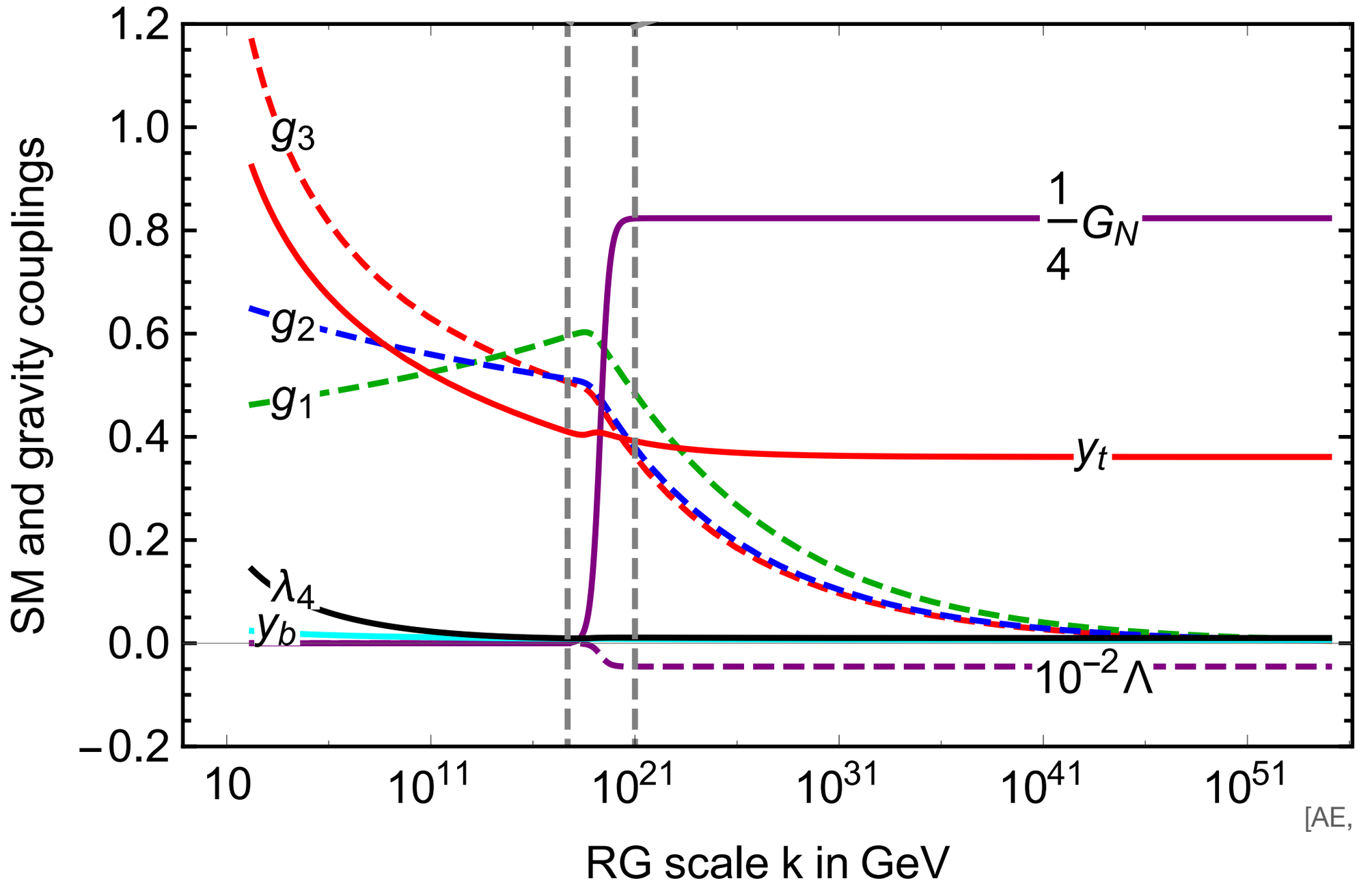
Comparison to measurements

Planck scale:

Quantum gravity fluctuations switch off; Planck-scale values of several SM couplings fixed/bounded

Transplanckian scales:

Asymptotic safety of gravity + matter

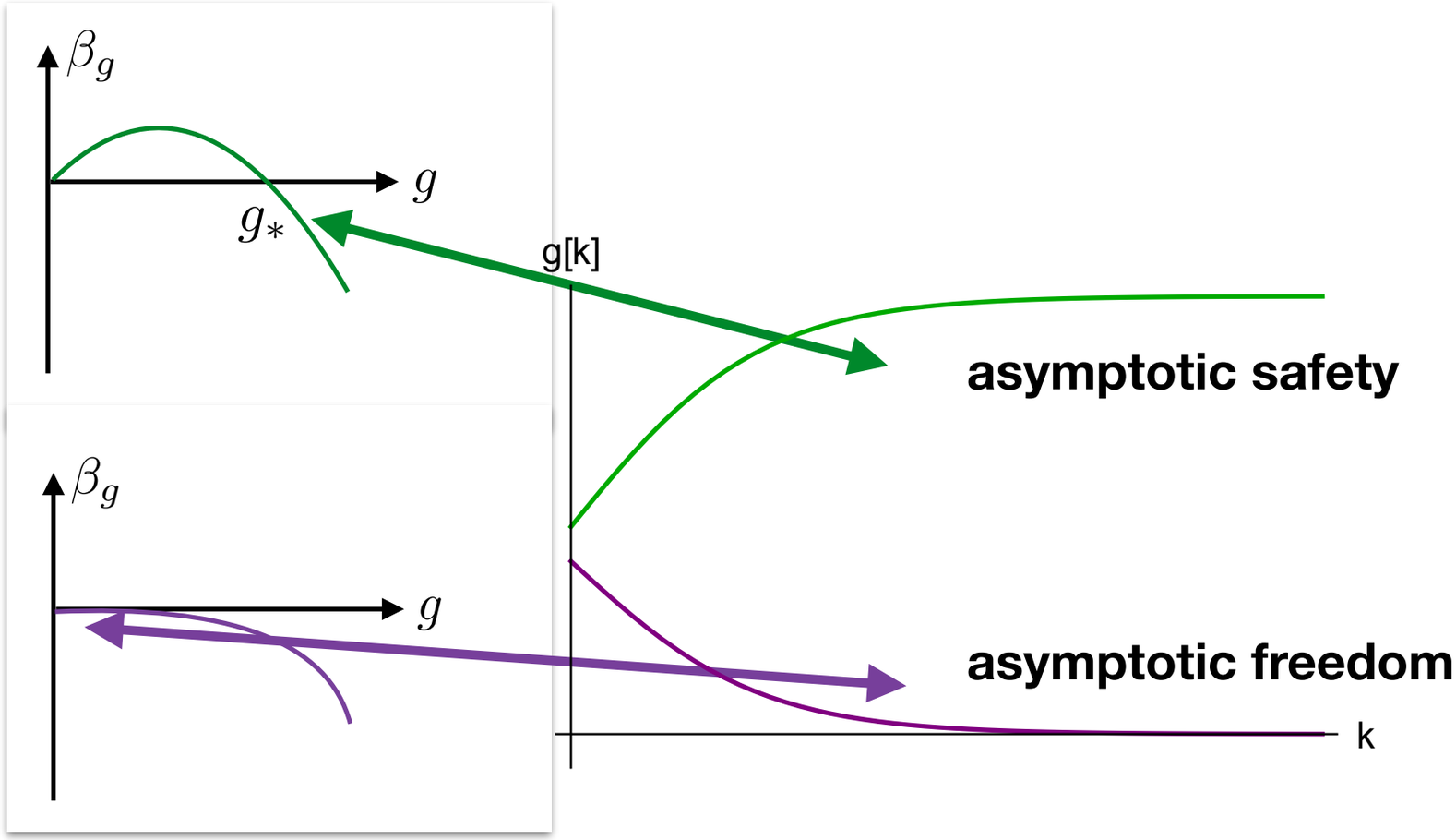


[AE, Held ‘17]

Asymptotic safety

= UV completion through scale-invariant regime

$\longrightarrow$ interacting Renormalization Group fixed point



Asymptotic safety

= UV completion through scale-invariant regime

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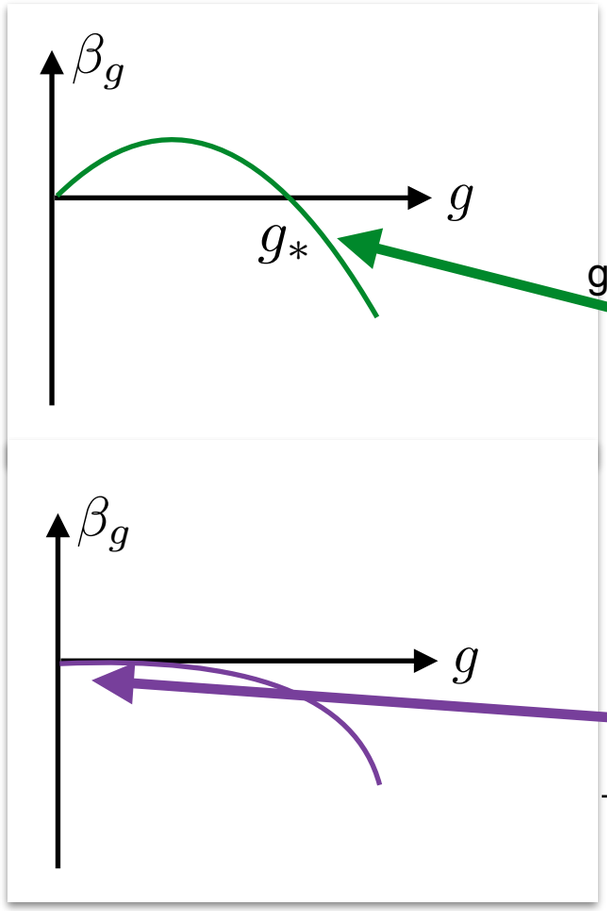
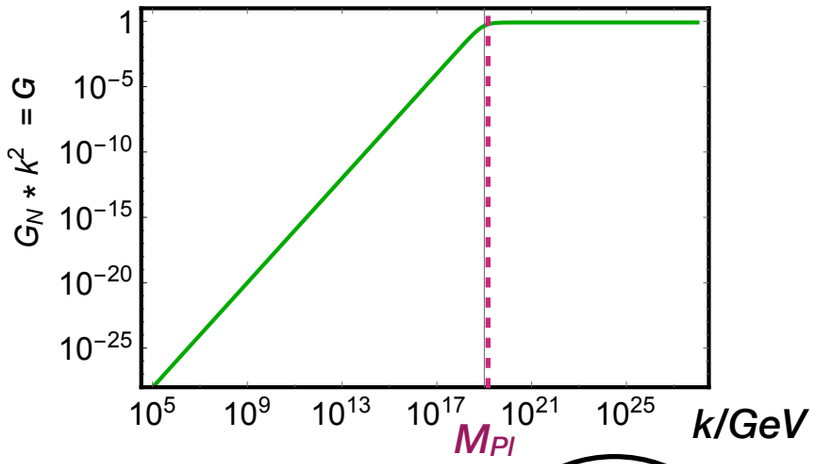
for gravity:

functional RG techniques

[Wetterich, ’93; Reuter ’96]





$$\beta_G = 2G\left(-\frac{23\,G^2}{3\pi} + \dots\right)$$

metric fluctuations

[Codello, Percacci, Rahmede ’08]

indications for AS in QG in truncations of the space of couplings

[AE, Gies, Litim, Morris, Pawlowski, Reuter, Saueressig, Vacca, Wetterich…]

with matter [AE, Pawlowski, Percacci, Saueressig…]

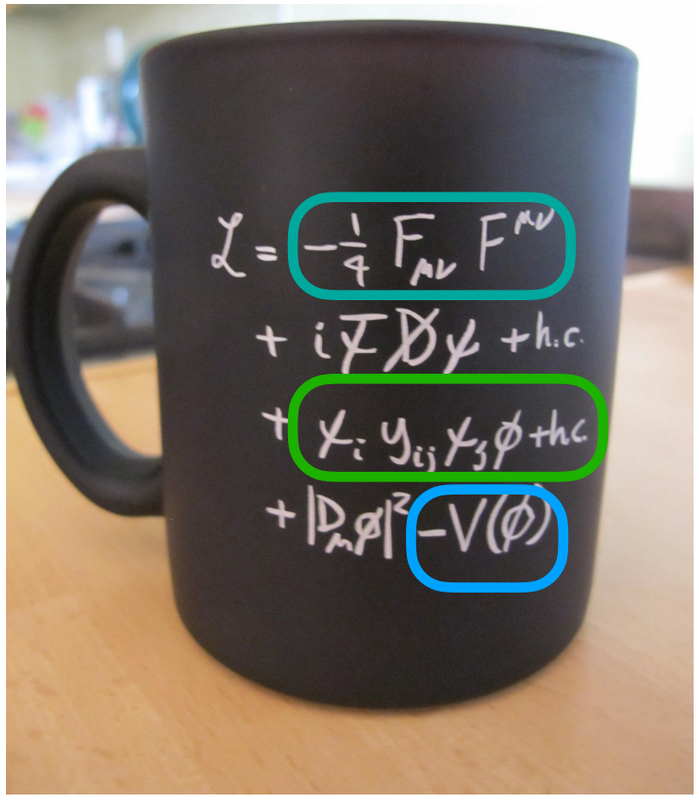
Asymptotically safe gravity - impact on matter

asymptotic safety = UV completion through scale-invariant regime

$\longrightarrow$ **interacting Renormalization Group fixed point**

QG contribution to Standard Model matter couplings (@ 1 loop)

truncations of gravity dynamics $f_i = f_i(G, ...)$



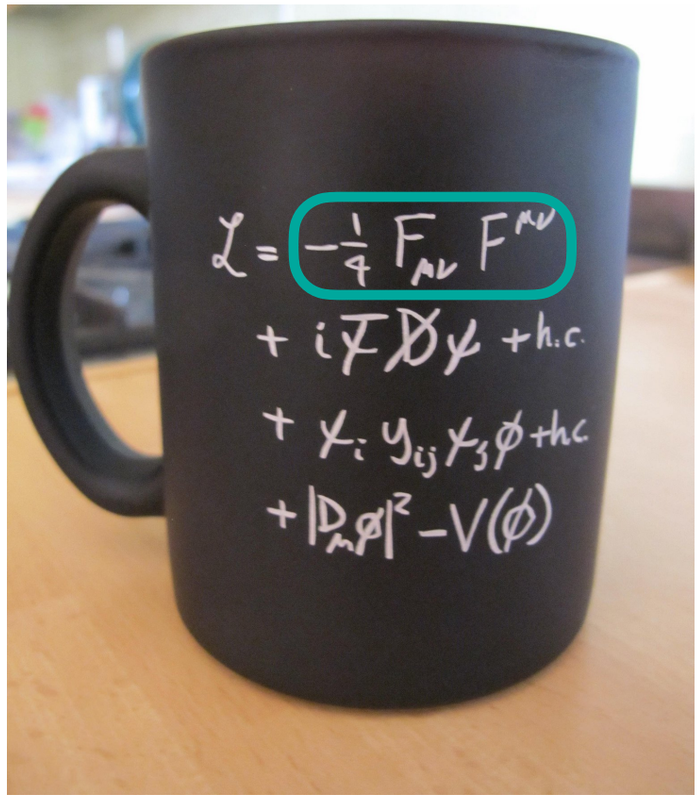
gauge couplings $\beta_{g_i} = f_g\, g_i + \#_i g_i^3 \ldots$

Yukawa couplings $\beta_y = f_y y + \#_y y^3 \ldots$

Higgs quartic $\beta_\lambda = f_\lambda \lambda + \#_\lambda \lambda^2 \ldots$

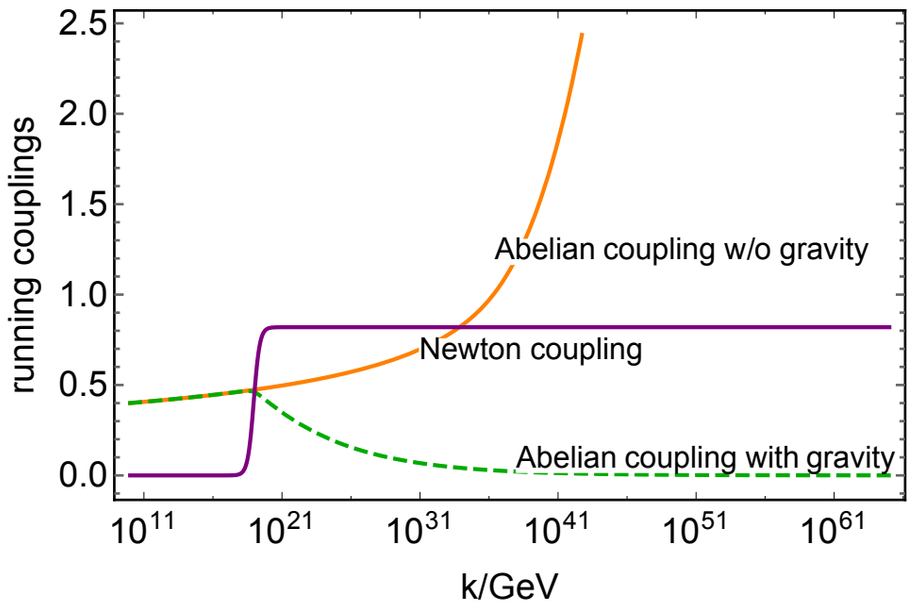
QG effect:
like change in canonical dimension:
triggers asymptotic freedom for $f_i < 0$

Asymptotically safe gravity - impact on matter



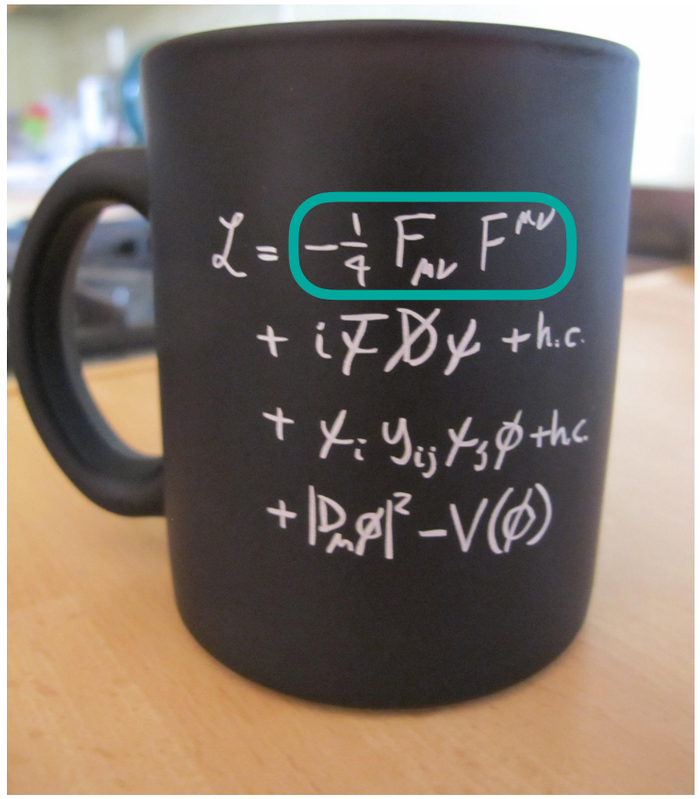
gauge couplings $\beta_{g_i} = f_g\, g_i + \#_i g_i^3$ $\quad f_g < 0$

[Daum, Harst, Reuter ’10; Folkerts, Litim, Pawlowski ’11; Harst, Reuter ’11, Christiansen, AE ’17, AE, Versteegen ’17, Christiansen et al. ’17]



QG effect:
“dimensional reduction”

Asymptotically safe gravity - impact on matter



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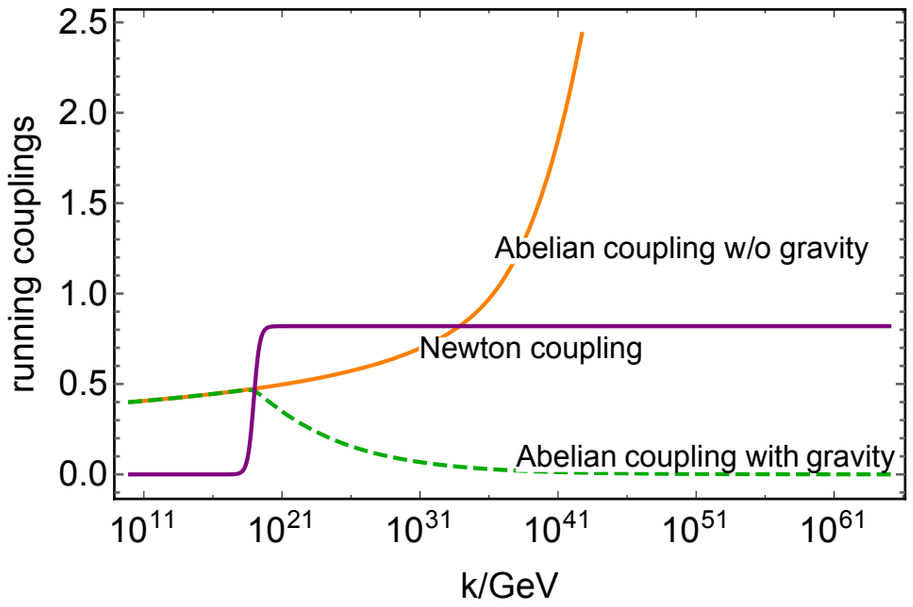


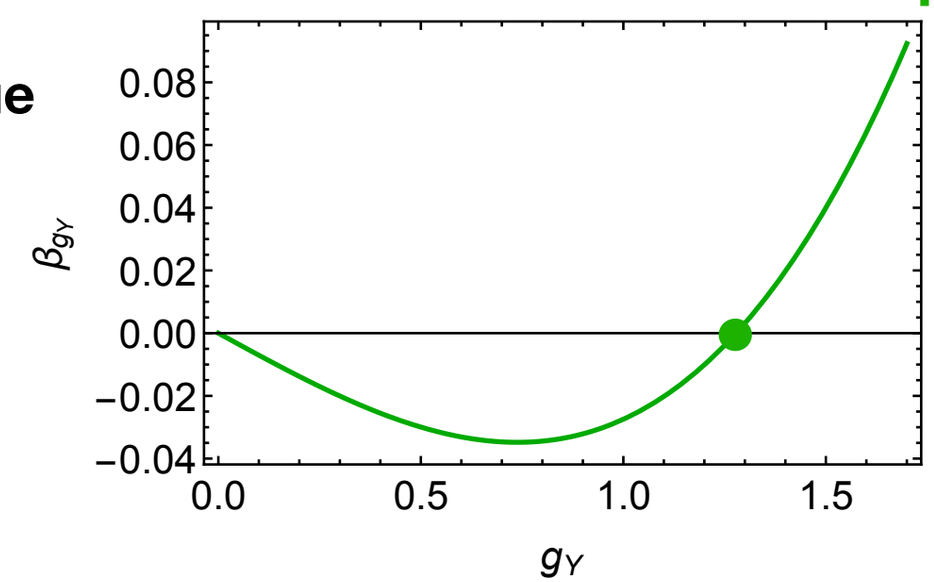
QG effect: “dimensional reduction”

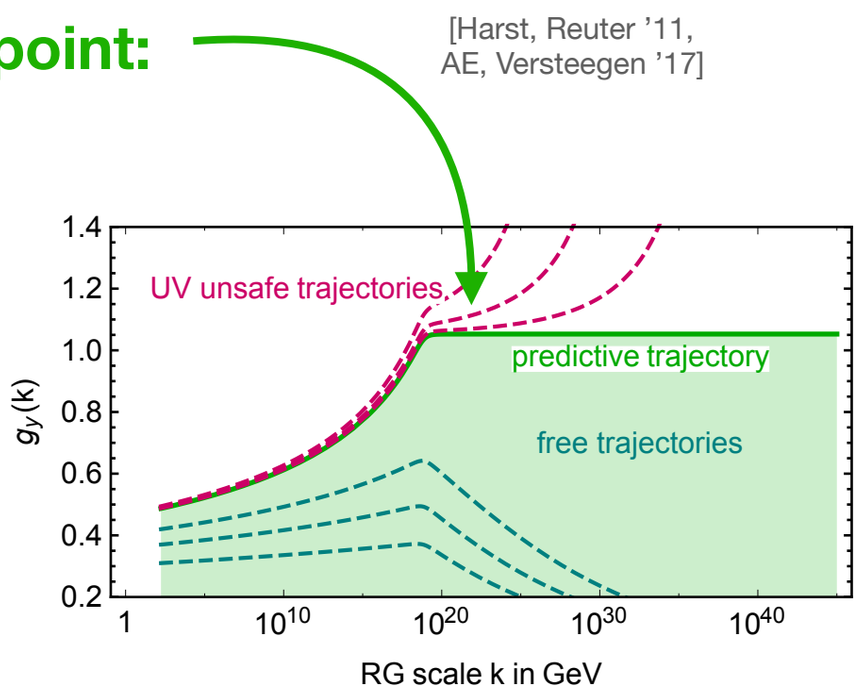
upper bound on Abelian gauge coupling: 35 % above measured value

[AE, Versteegen ’17]

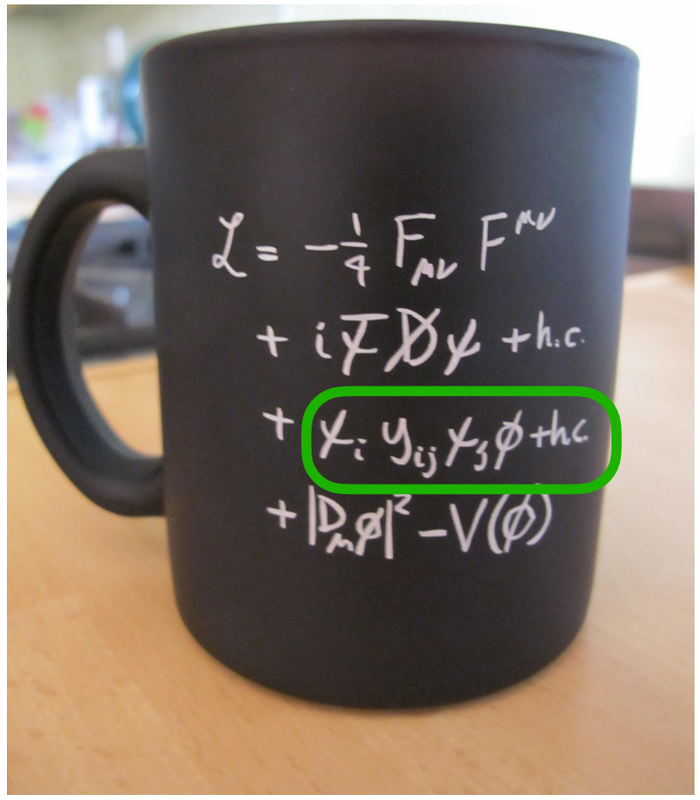
IR attractive fixed point:

[Harst, Reuter ’11, AE, Versteegen ’17]





Asymptotically safe gravity - impact on matter

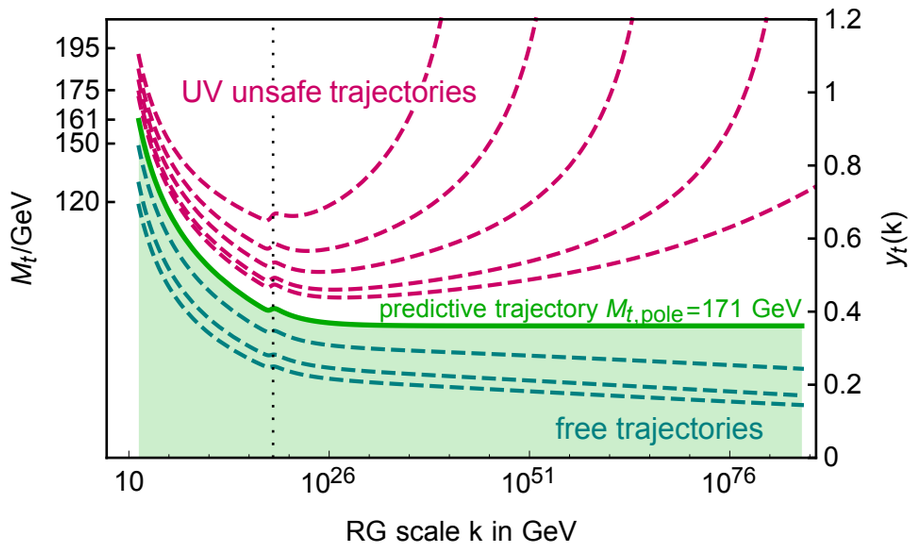


Yukawa couplings

$$\beta_y = f_y y + \#_y y^3$$

$f_y < 0$
restricts micr. grav. parameter space

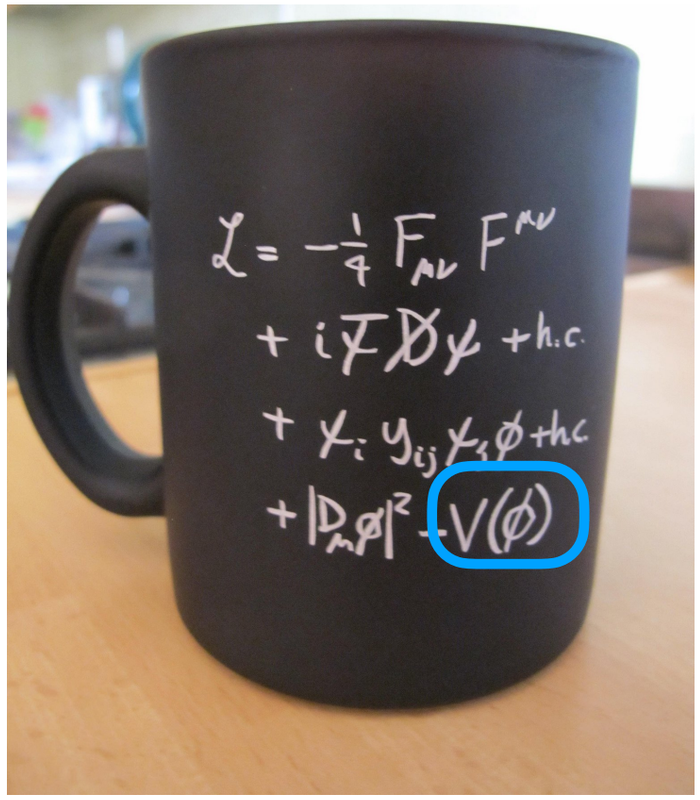
[AE, Held, Pawlowski ’16;
AE, Held, ’17, ’18]



``retrodiction” of top and bottom mass from asymptotic safety

Aaron Held’s talk @ 14.40 (this session)

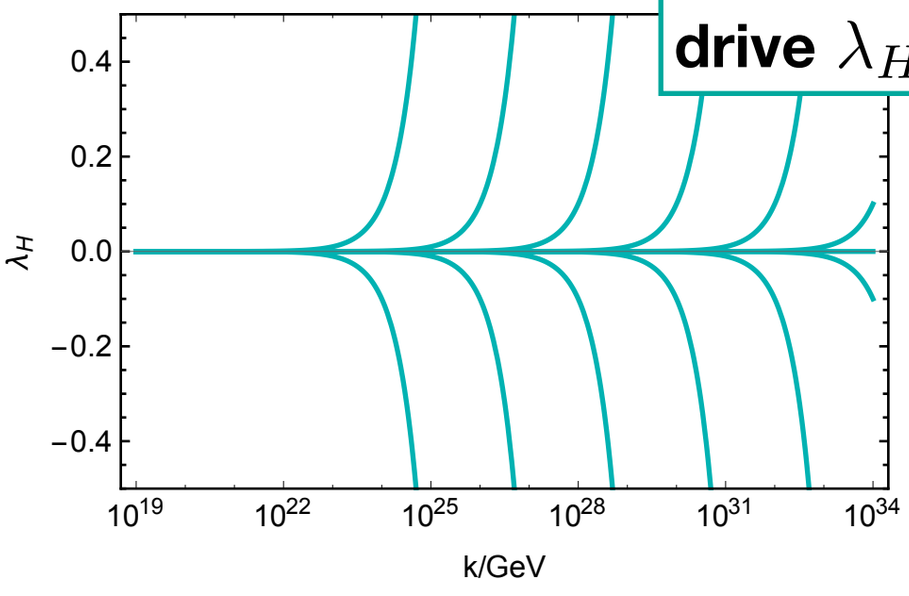
Asymptotically safe gravity - impact on matter



Higgs quartic

$$\beta_\lambda = f_\lambda \lambda + \#_\lambda \lambda^2 \qquad f_\lambda > 0$$

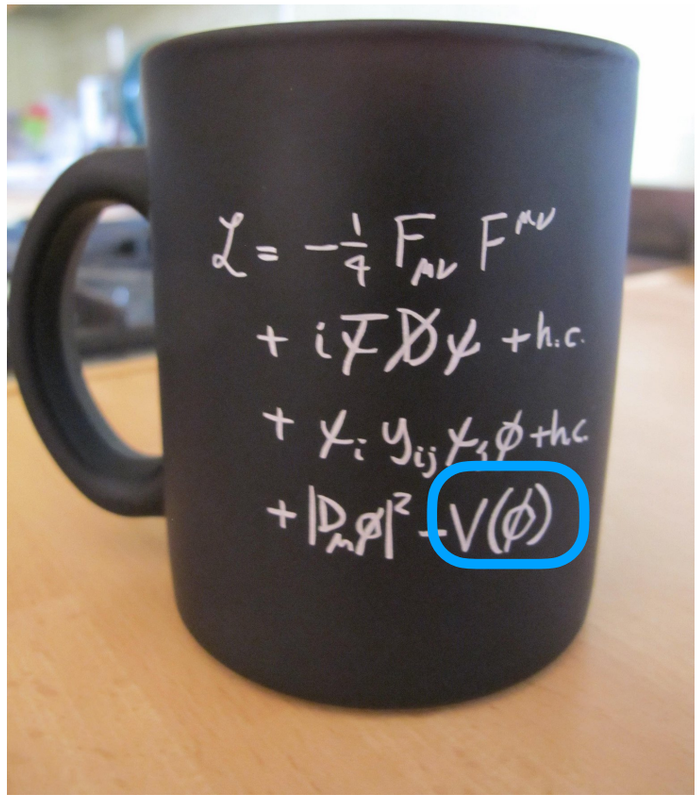
[Narain, Percacci '09,
Zanusso, Zambelli, Vacca, Percacci '10;
AE '12,
Oda, Yamada '15
AE, Hamada, Lumma, Yamada '17]



$M_h \approx 126\,\mathrm{GeV}$ **(top-mass dependence)**

[Shaposhnikov, Wetterich '09; Bezrukov, Kalmykov, Kniehl, Shaposhnikov '12]

Asymptotically safe gravity - impact on matter



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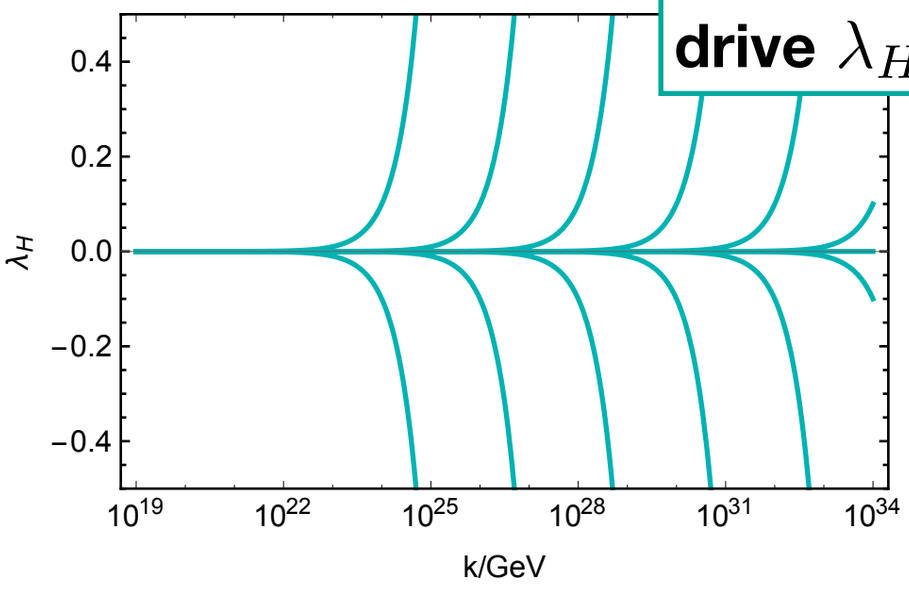

QG fluctuations drive λ_H to zero at M_{Planck}

$M_h \approx 126\,\mathrm{GeV}$ **(top-mass dependence)**

[Shaposhnikov, Wetterich '09; Bezrukov, Kalmykov, Kniehl, Shaposhnikov '12]

extended Higgs sector:

near-flat potential at Planck scale
$\rightarrow$ vanishing Higgs portal coupling $\lambda_{\phi\chi}\,\phi^2\,\chi^2$
to scalar dark matter

[AE, Hamada, Lumma, Yamada '17

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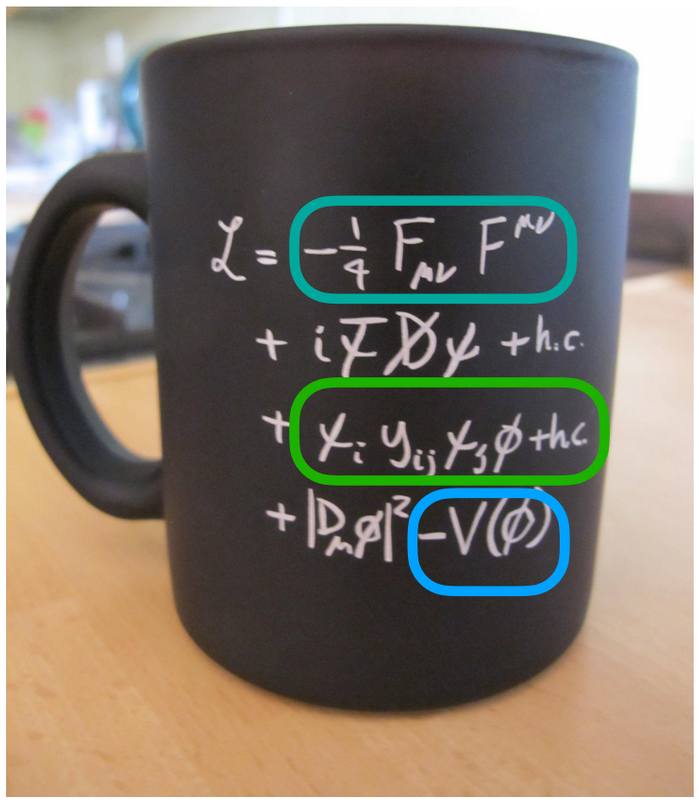

ASQG effects on SM in truncated RG flows

gauge couplings $\beta_{g_i} = f_g\, g_i + \#_i g_i^3$ $\quad f_g < 0$

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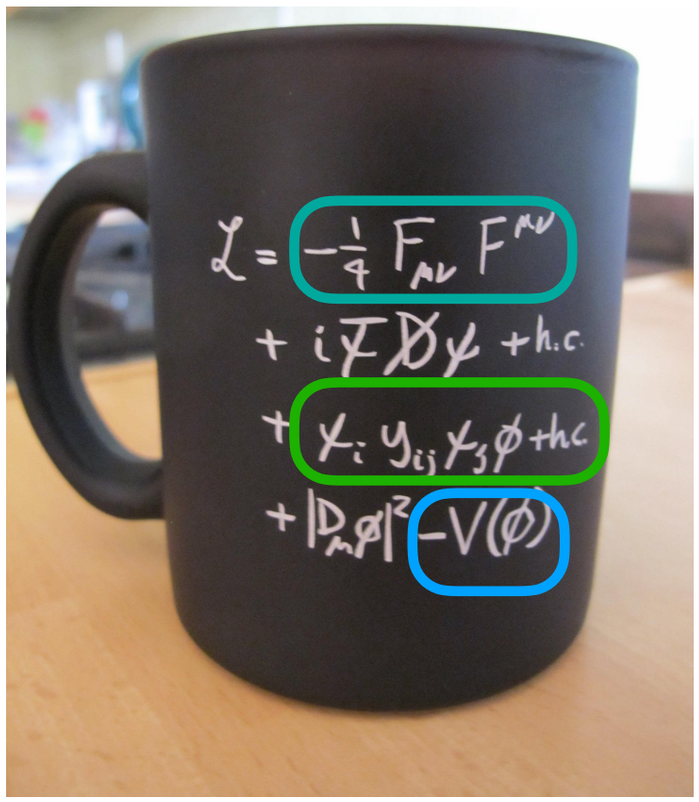

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$\longrightarrow$ **indications that:**

- **asymptotic freedom in non-Abelian gauge couplings preserved**
- **upper bound on Abelian gauge coupling**
- **top & bottom Yukawa `retrodicted"**
- **vanishing Higgs quartic and Higgs portal couplings at Mpl**

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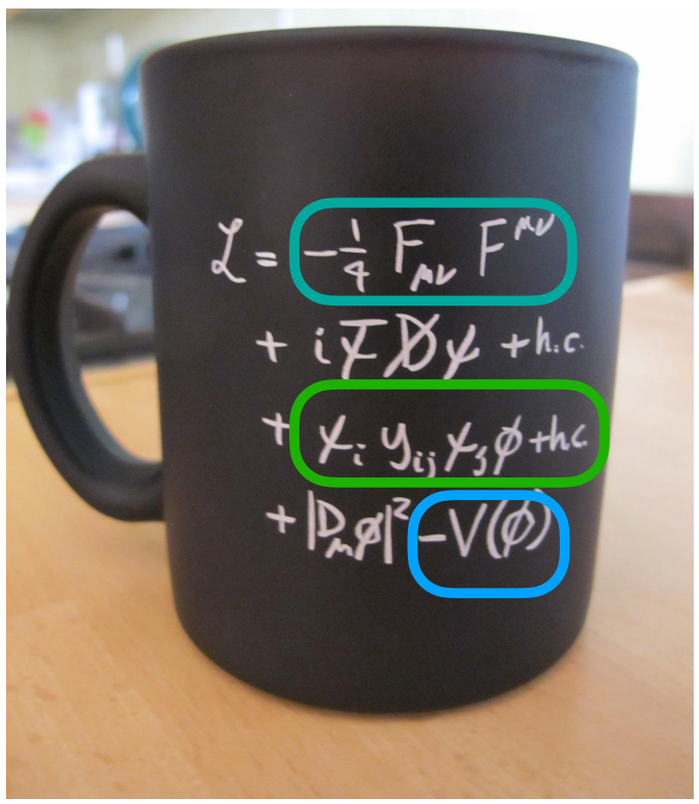

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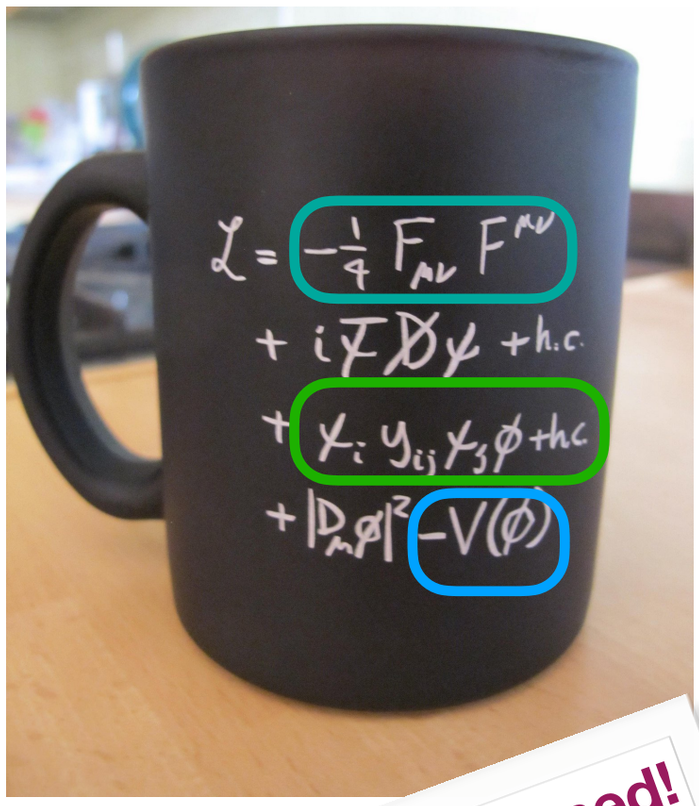

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