Title: Effective field theory framework in QG

Date: Oct 25, 2012 03:00 PM

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Abstract: Gravity Induced Grand Unification
Motivated by the lack of evidence for physics beyond the Standard Model in the TeV region, we discussed an alternative path for grand unification. We show that simple grand unification models based on e.g. SU(5) can work successfully even without low scale supersymmetry. In particular quantum gravitational effects could easily modify the unification conditions for the gauge and Yukawa couplings.
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Testing the consistency of quantum gravity with low-energy properties of the standard model
Testing quantum gravity is possible by using, e.g. the available data on the properties of the standard model. I will discuss how a parameterisation of quantum gravity fluctuations in terms of metric fluctuations can be used to test the compatibility of quantum gravity with the observed low-energy properties of the standard model, such as the existence of fermions with masses much below the Planck mass.
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The Asymptotic Safety program
The effective average action approach to Quantum Einstein Gravity (QEG) is discussed as a natural framework for exploring the scale dependent Riemannian geometry and multifractal micro-structure of the effective spacetimes predicted by QEG. Their fractal properties are related to the functional RG flow on theory space, and the special role of the running cosmological constant is emphasized. The prospects of an experimental verification will also be discussed.

Introductory remarks for the session on Effective Field Theory Framework in Quantum Gravity

PI October 25, 2012

What is renormalizability good for?

Desiderata: consistency, predictivity, wide applicability.

Old point of view: only renormalizable QFTs make sense and are useful.

"G 't Hooft turned the Weinberg-Salam frog into a beautiful prince"

Modern point of view: renormalizability is unnecessary and insufficient.

(Renormalizability not sufficient for a theory to make sense at all energies, not necessary for a theory to be useful)

Insufficient

SM is perturbatively renormalizable
Still it is not an UV complete theory

- U(1) sector
- Higgs sector

Sufficient condition UV completion

UV complete QFT is described by a complete RG trajectory.
For UV completion in perturbative framework need asymptotic freedom (e.g. QCD).
More generally need some fixed point (asymptotic safety).

$\rightarrow$ Reuter's talk

Predictivity

Let us restrict our attention to the perturbative case.

In a renormalizable theory only a finite number of parameters have to be determined from experiment, the others can be calculated. Renormalizable theories are highly predictive.

In a non-renormalizable theory the *local* terms in the action have uncalculable coefficients. Such parameters have to be determined from observations. Does this mean that the theory has no predictive power at all?

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EFT

Suppose we knew the TOE. It describes particles with vastly different masses.
In a collider with energy E we can only produce particles with mass $m < E$.
We can describe all the physics that is accessible at the collider in terms of an effective field theory where the heavy modes have been integrated out.
The effective Lagrangian for the light fields will contain all possible terms that are permitted by the symmetries. It will be nonrenormalizable.
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General EFT recipe

- fix the level of precision that is required in the calculation
- fix the ratio E/M. This determines the order of the expansion that will be required
- at the given order in the expansion, determine all the terms in the action that can contribute to the given process. By power counting there can only be finitely many.
- if the fundamental theory is known, their coefficients can in principle be calculated
- otherwise, measure them with as many experiments.
- use the EFT Lagrangian to compute the amplitudes to the desired precision

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Energy expansion

There can be more observable quantities than undetermined parameters so the theory is predictive within its low energy domain of validity.
Nonlocal terms are independent of high energy physics and therefore can be correctly calculated in the EFT.
One does not need to know the fundamental theory.

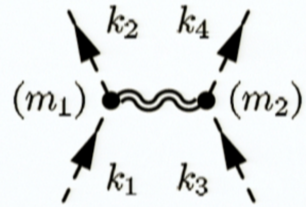
Chiral perturbation theory

Strong interactions at low energy described by chiral model

$$S = \int dx \left[\frac{f_\pi^2}{4} tr(U^{-1}\partial U)^2 + \ell_1 tr((U^{-1}\partial U)^2)^2 + \ell_2 tr((U^{-1}\partial U)^2)^2 + O(\partial^6) \right]$$

Expansion parameter E/f_π.
For low energy meson physics need f_π, ℓ_1, ℓ_2 and perhaps a few others. One loop in f_π, tree level in ℓ_1, ℓ_2.
Successfully describe a rich phenomenology.

Newtonian potential



$$\sim \; Gp^2 \;\rightarrow\; \frac{Gm_1 m_2}{\mathrm{q}^2}$$

$$V(r) = \int \frac{d^3 q}{(2\pi)^3} \frac{Gm_1 m_2}{\mathrm{q}^2} e^{i\mathrm{qr}} = -\frac{Gm_1 m_2}{r}$$

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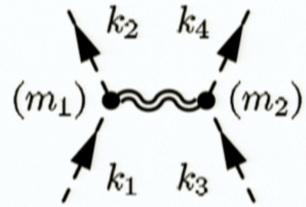

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Leading quantum correction

For dimensional reasons the leading correction is

$$V(r) = -\frac{Gm_1 m_2}{r}\left[1 + \alpha\frac{G(m_1 + m_2)}{rc^2} + \beta\frac{G\hbar}{r^2 c^3} + \dots\right]$$

and

$$\int \frac{d^3q}{(2\pi)^3}\log\left(\frac{\mathrm{q}^2}{\mu^2}\right)e^{i\mathrm{qr}} = -\frac{1}{2\pi^2 r^3}$$

Clearly distinct from contributions of local counterterms that give analytic corrections to the amplitude. E.g.

$$\int \frac{d^3q}{(2\pi)^3}\ell e^{i\mathrm{qr}} = \ell\delta(r)$$

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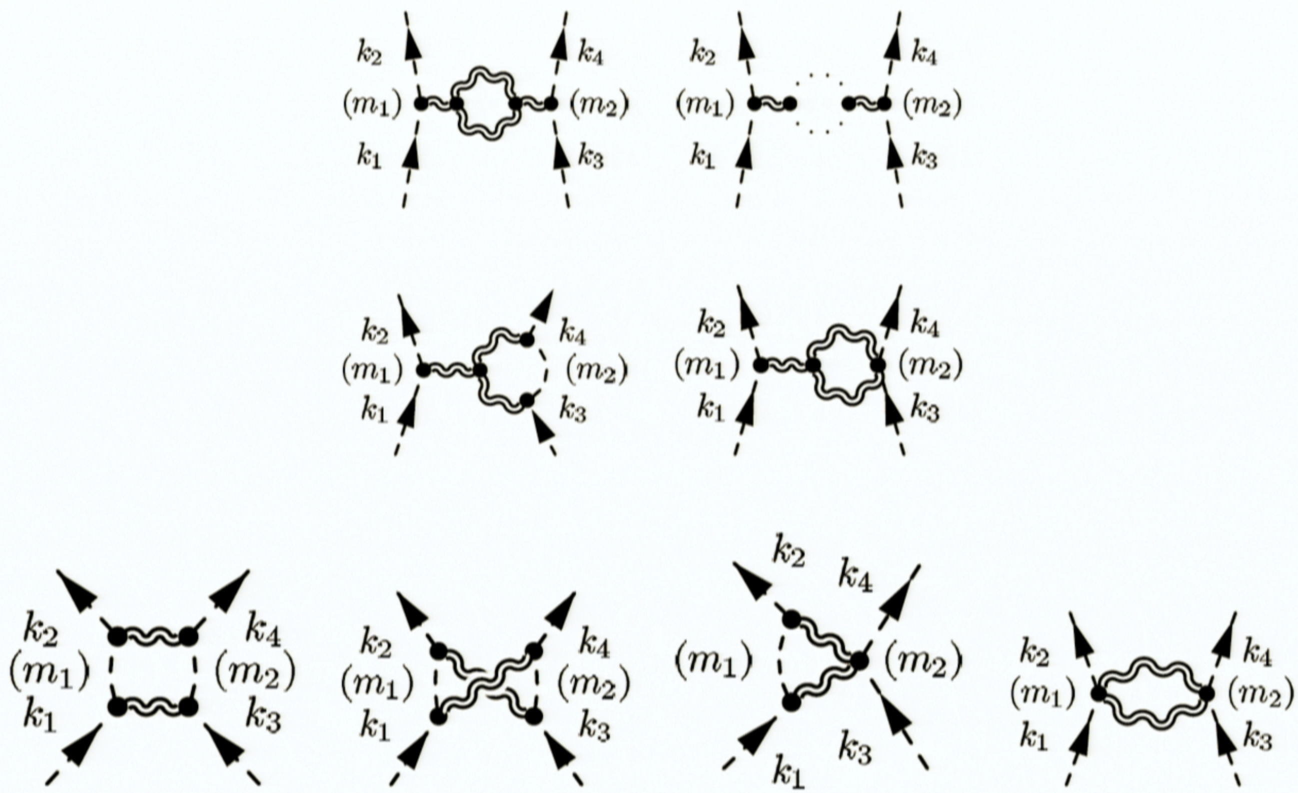
One loop graphs



(from Bjerrum Bohr, Donoghue, Holstein, 2002)

Evaluation

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- H.W. Hamber, S. Liu, Phys. Lett. B357, 51 (1995)
- A. Akhundov, S. Bellucci, A. Shiekh, Phys. Lett. B395, 16 (1997)
- N.E.J. Bjerrum-Bohr (2002) Phys. Rev. D66, 084023
- I.B. Khriplovich, G.G. Kirilin (2002) J. Exp. Theor. Phys. 95, 981-986 (Zh. Eksp. Teor. Fiz. 95, 1139-1145 (2002))
- N.E.J. Bjerrum-Bohr, J.F. Donoghue, B.R. Holstein Phys. Rev. D68, 084005; Erratum-ibid.D71, 069904 (2005)
- N.E.J. Bjerrum-Bohr, J.F. Donoghue and B.R. Holstein Phys. Rev. D 67, 084033 (2003) [Erratum-ibid. D 71 (2005) 069903
- I.B. Khriplovich, G.G. Kirilin (2004) J. Exp. Theor. Phys. 98, 1063-1072

The hardest fact

$$V(r) = -\frac{Gm_1 m_2}{r}\left[1 + 3\frac{G(m_1+m_2)}{rc^2} + \frac{41}{10\pi}\frac{G\hbar}{r^2} + \dots\right]$$

Probably the most reliable result in quantum gravity.

$M = M_\odot$	$\frac{GM_\odot}{rc^2}$	$\frac{G\hbar}{r^2c^3}$
$r = R_\odot$	10^{-6}	10^{-88}
$r = r_{S\odot}$	0.5	10^{-76}

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Alternative evaluation

A. Satz, A. Codello, F.D. Mazzitelli, Phys.Rev. D82, 084011 (2010)

$$\Gamma \sim \frac{1}{32\pi^2} \int d^4x \sqrt{g} \left[\frac{1}{60} R \log\left(\frac{-\Box}{\mu^2}\right) R + \frac{7}{10} R_{\mu\nu} \log\left(\frac{-\Box}{\mu^2}\right) R^{\mu\nu} \right]$$

$$V(r) = -\frac{G m_1 m_2}{r} \left[1 + \frac{43}{30\pi} \frac{G\hbar}{r^2} + \dots \right]$$

Conclusions

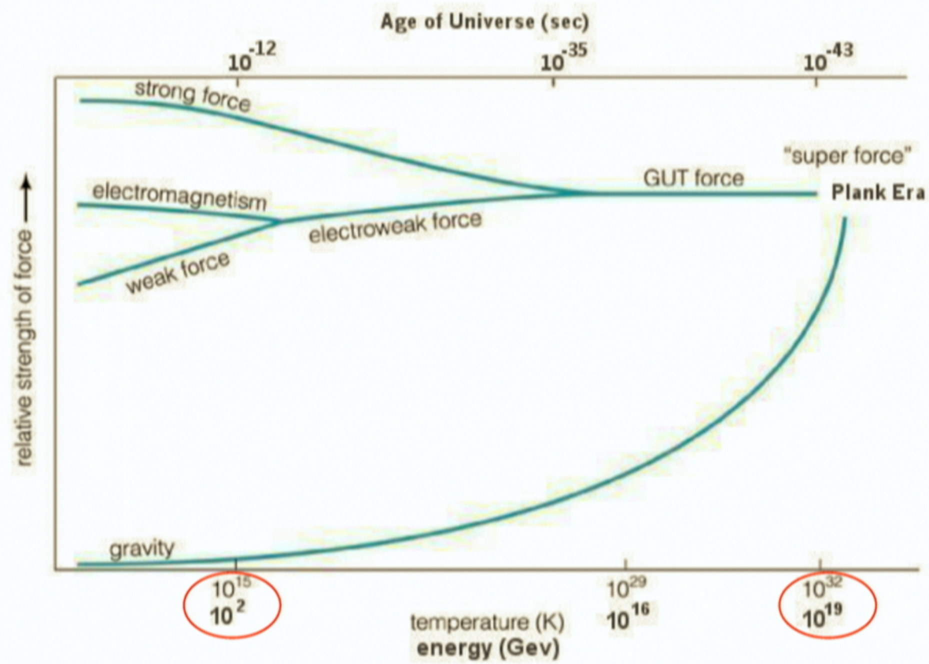
- this is a quantum theory of gravity!
- (no clash between QM and GR)
- experimentally indistinguishable from classical GR
- consistent and predictive QFT
- agrees with all experimental data
- same status as SM
- open issues in the UV, IR, strong field
- motivation for further work is not to have a UV complete theory but to have a theory that makes predictions at the Planck scale and beyond

University of Sussex

Gravity induced Grand Unification

Xavier Calmet

Classical picture of Grand Unification



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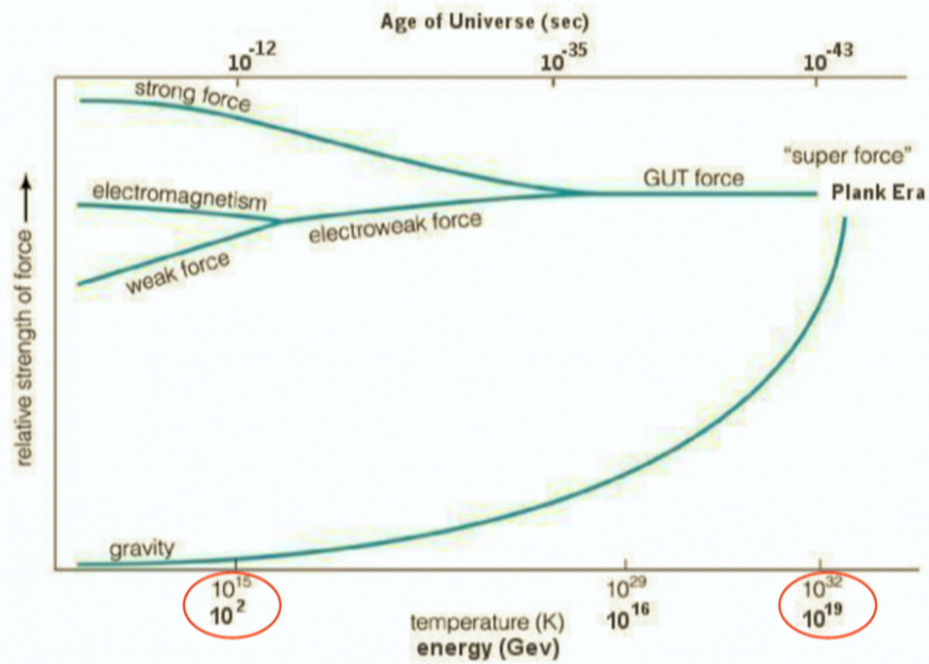

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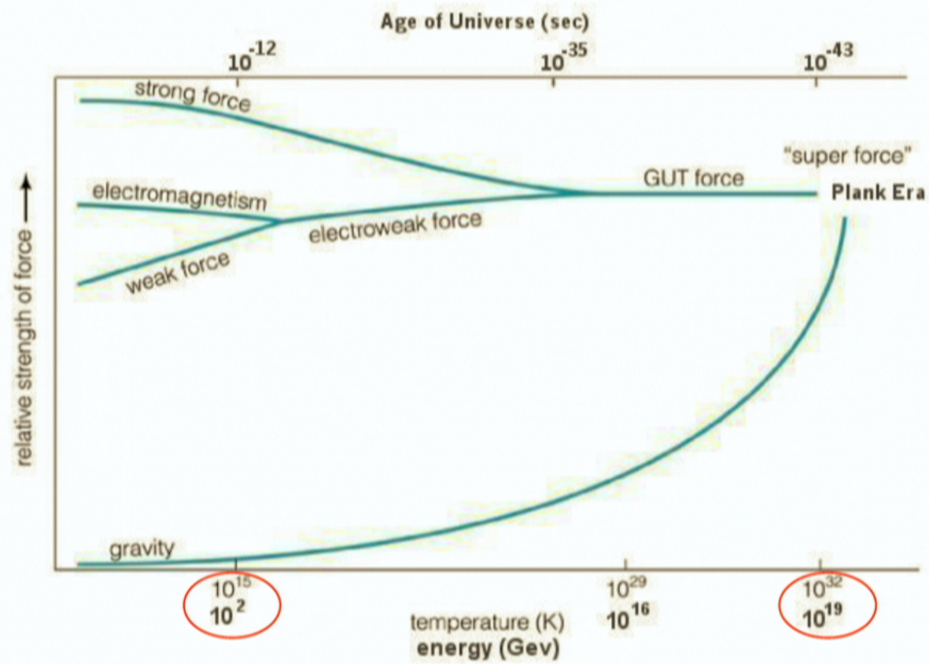
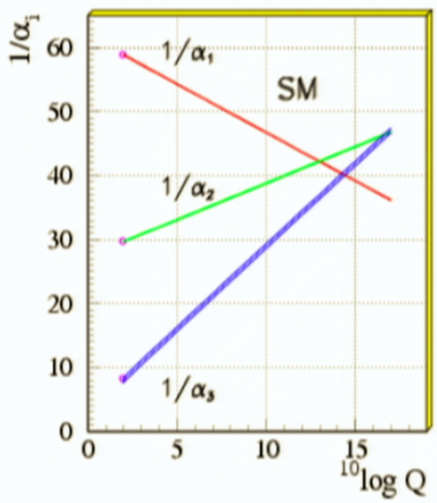
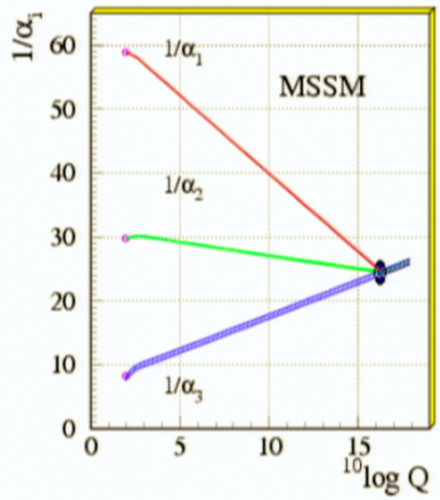


Unification of the couplings of the Standard Model?

One of LEP's most impressive





Standard Model does not work

But the minimal Supersymmetric (SUSY) Standard Model works beautifully

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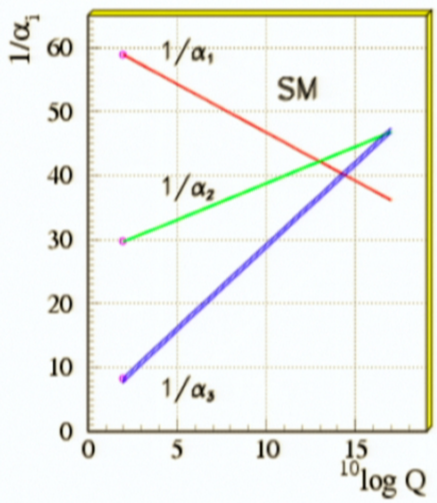

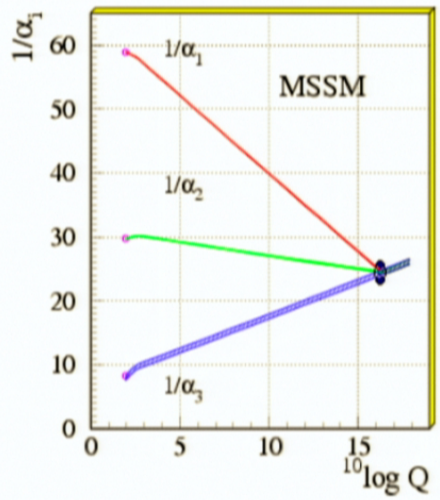

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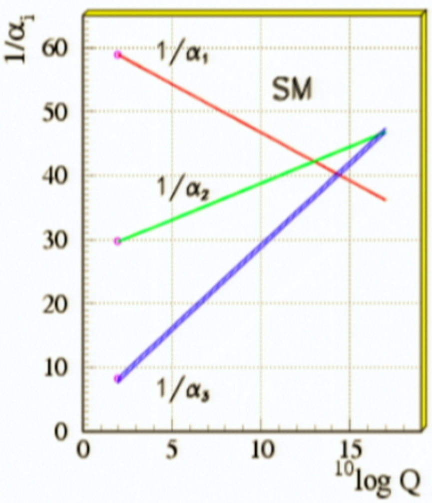

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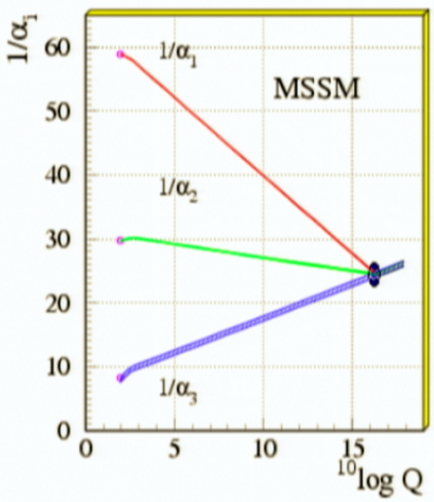

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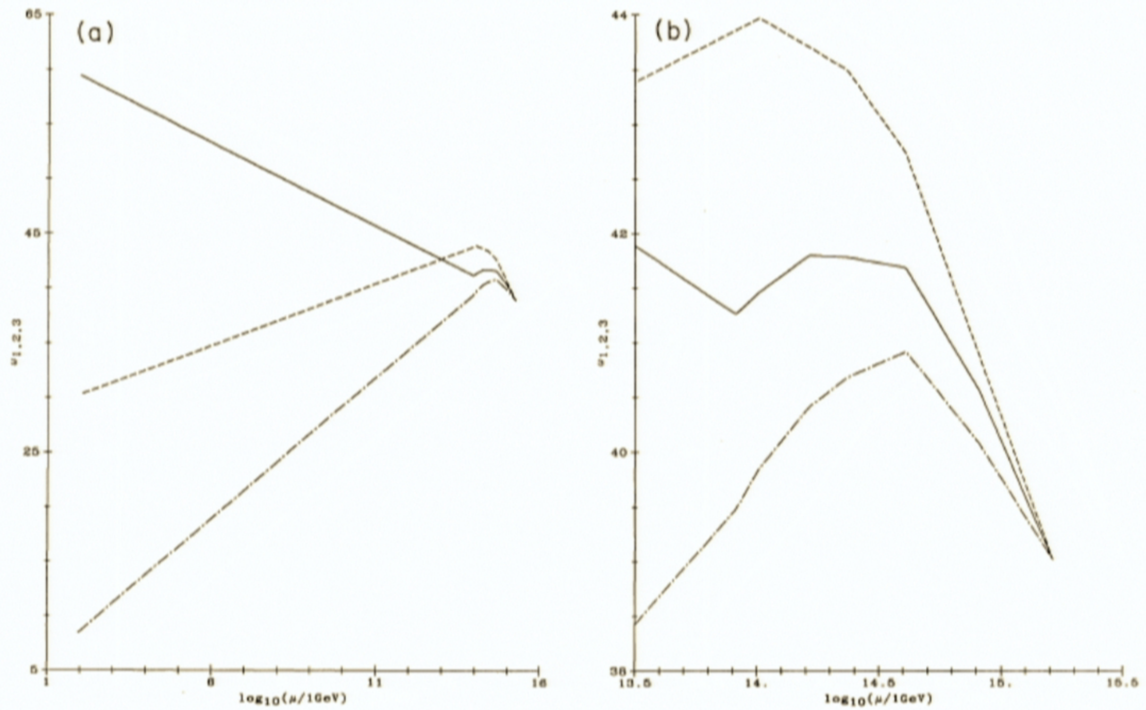
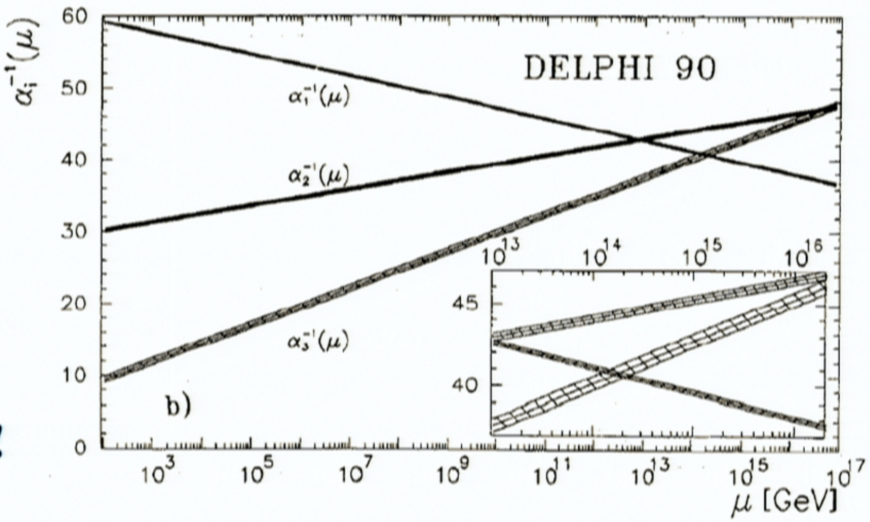
But this is not unique! E.g. Lavoura & Wolfenstein PRD 48, 264 (1993)



SO(10) with 210, 126, 10: one can lower the mass of some Higgses to get unification but not too much proton decay

There are four options:
- **Modify the low energy regime**
- **Intermediate step unification**
- **Modify the running in the high energy regime**
- **Modify the unification condition**

LHC:
NO SIGN
OF BSM
PHYSICS!!!



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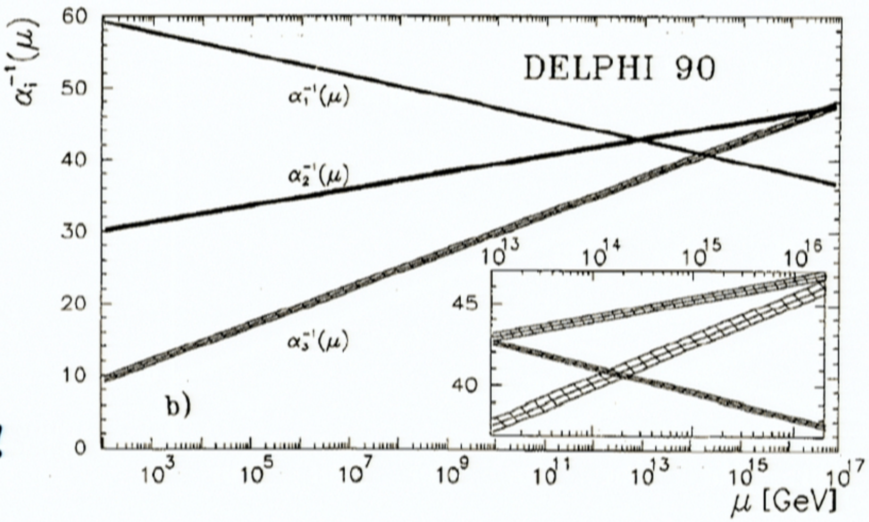

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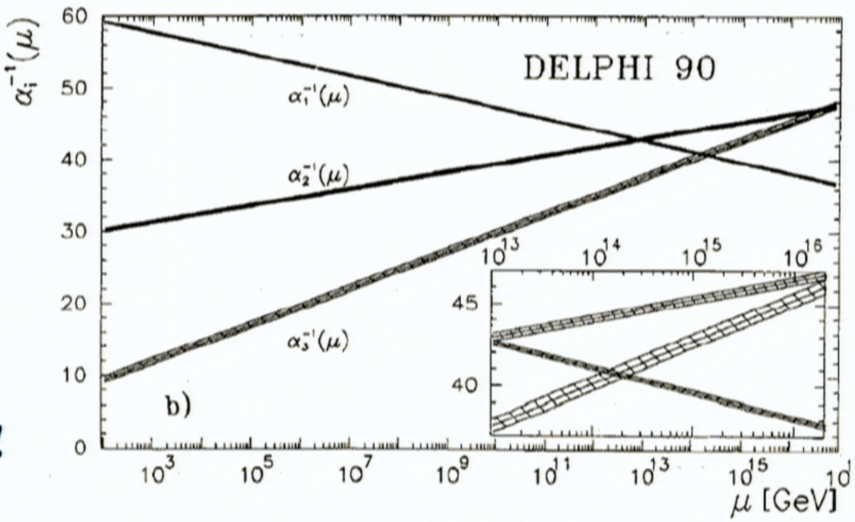

Gravity changes the unification condition

- Let us look again at operators discussed already by Hill (1984); Shafi and Wetterich (1984); Hall and Sarid (1991).

$$\frac{c}{\hat{\mu}_*}\mathrm{Tr}\left(G_{\mu\nu}G^{\mu\nu}H\right)$$

$$\hat{\mu}_* = \mu_*/\sqrt{8\pi} = \hat{M}_{\mathrm{Pl}}/\eta \text{ with } \hat{M}_{\mathrm{Pl}} = 2.43 \times 10^{18}\,\mathrm{GeV}$$

- New effect: running of the Planck mass.
- H: Higgs field in the adjoint of GUT group.
- Let us look at a toy model to make our point: SU(5)

$$\langle H\rangle = M_X\,(2,2,2,-3,-3)/\sqrt{50\pi\alpha_G}$$

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$$-\frac{1}{4}(1+\epsilon_1)\,F_{\mu\nu}F^{\mu\nu}_{\mathrm{U}(1)}-\frac{1}{2}(1+\epsilon_2)\,\mathrm{Tr}\left(F_{\mu\nu}F^{\mu\nu}_{\mathrm{SU}(2)}\right)$$
$$-\frac{1}{2}(1+\epsilon_3)\,\mathrm{Tr}\left(F_{\mu\nu}F^{\mu\nu}_{\mathrm{SU}(3)}\right)$$

- with:

$$\epsilon_1=\frac{\epsilon_2}{3}=-\frac{\epsilon_3}{2}=\frac{\sqrt{2}}{5\sqrt{\pi}}\frac{c\eta}{\sqrt{\alpha_G}}\frac{M_X}{\hat{M}_{\mathrm{Pl}}}$$

- After field and coupling constants redefinitions

$$A^i_\mu\to(1+\epsilon_i)^{1/2}A^i_\mu \qquad\qquad g_i\to(1+\epsilon_i)^{-1/2}g_i$$

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How big can N be?

- Typical GUT model involves a lot of scalar fields to reproduce SM in the low energy regime.

particle physics model	$N = N_0 + N_{1/2} - 4N_1$
no running of G_N	
standard model	1
$SU(5)$ w/ $\mathbf{5}$, $\mathbf{24}$	−17
$SU(5)$ w/ $\mathbf{5}$, $\mathbf{200}$	159
$SU(5)$ w/ $\mathbf{5}$, $\mathbf{24}$, $\mathbf{75}$	58
$SU(5)$ w/ $\mathbf{5}$, $\mathbf{24}$, $\mathbf{75}$, $\mathbf{200}$	258
$SO(10)$ w/ $\mathbf{10}$, $\mathbf{16}$, $\mathbf{45}$	−35
$SO(10)$ w/ $\mathbf{10}$, $\mathbf{16}$, $\mathbf{210}$	130
$SO(10)$ w/ $\mathbf{10}$, $\mathbf{16}$, $\mathbf{770}$	690
SUSY-$SU(5)$ w/ $\mathbf{5}$, $\overline{\mathbf{5}}$, $\mathbf{24}$	165
SUSY-$SU(5)$ w/ $\mathbf{5}$, $\overline{\mathbf{5}}$, $\mathbf{24}$, $\mathbf{75}$	390
SUSY-$SU(5)$ w/ $\mathbf{5}$, $\overline{\mathbf{5}}$, $\mathbf{200}$	693
SUSY-$SO(10)$ w/ $\mathbf{10}$, $\mathbf{16}$, $\overline{\mathbf{16}}$, $\mathbf{45}$, $\mathbf{54}$	432
SUSY-$SO(10)$ w/ $\mathbf{10}$, $\mathbf{16}$, $\overline{\mathbf{16}}$, $\mathbf{210}$	765
SUSY-$SO(10)$ w/ $\mathbf{10}$, $\mathbf{16}$, $\overline{\mathbf{16}}$, $\mathbf{770}$	2445

Uncertainty due to new operator is bigger than two loop effects!!!

E.g. the uncertainty in α_1 at the unification scale due to the new operator is of the order of 2.1% whereas the two loop correction is of the order of 1.7%

One interpretation: this is a problem for low scale SUSY theories! Indeed you would have to explain why these operators are not present!

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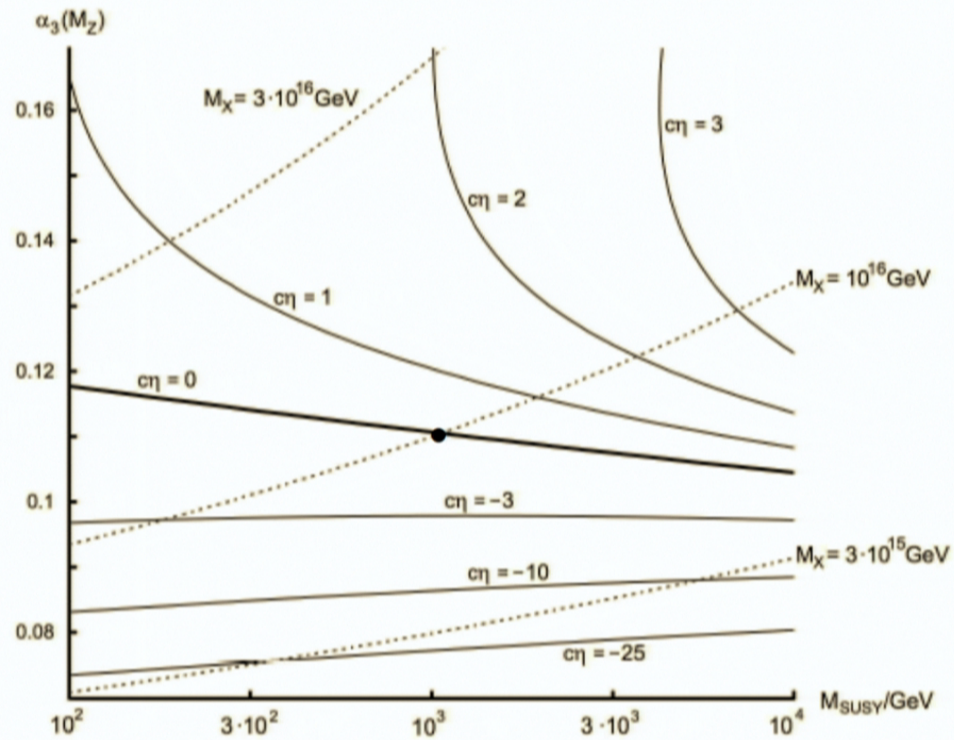
Usual solution: $\alpha_3(M_Z)=0.117$, $M_{SUSY}=1$ TeV

$$\eta = \sqrt{1+\frac{N}{12\pi}}$$

Each point on this picture satisfies unification



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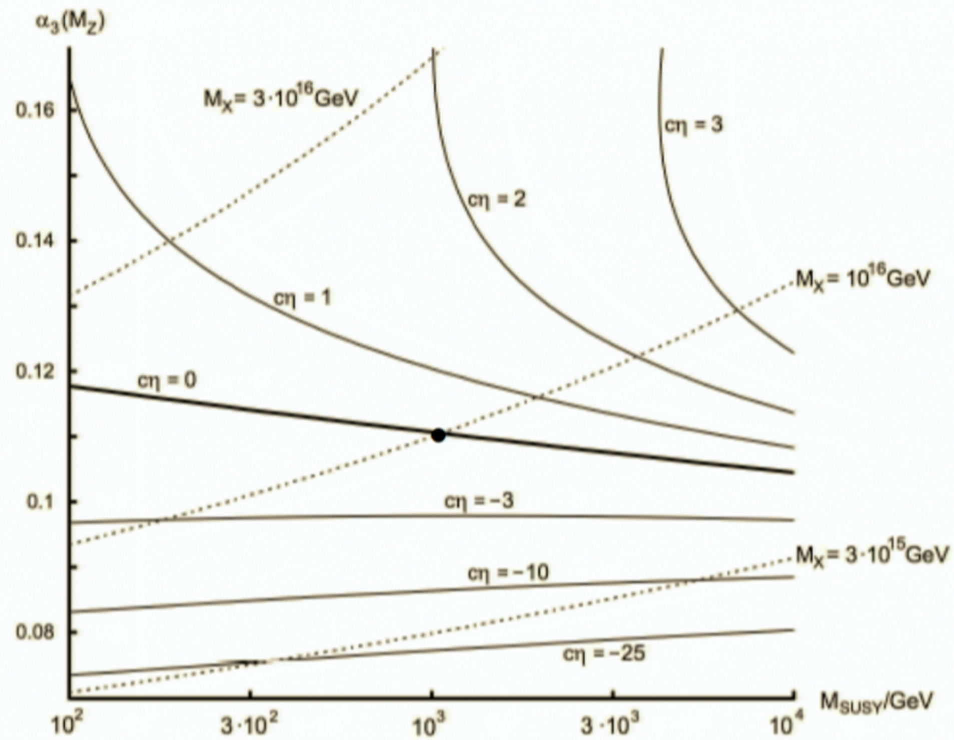

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Grand unification through gravitational effects

- The same operators can however lead to numerical unification of the couplings in models where you naively do not expect it.
- Generically speaking there are many dimension five operators:

$$\mathcal{L} = \frac{c_i}{4M_{Pl}} H_i^{ab} G^a_{\mu\nu} G^{b\mu\nu}$$

- We find that unification without supersymmetry can easily be obtained.
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Yukawa couplings

- Usual term in SU(5)

$$\begin{aligned}\mathcal{L} &= \{G_d \bar{\Psi}^c_{jR} \Psi^j_{kL} H^k(5) + G_u \varepsilon_{jklmn} \bar{\Psi}^{c\,jk}_L \Psi^{lm}_L H^n(5)\} + h.c. \\ &= -\frac{2M_w}{\sqrt{2}g_2}[G_d(\bar{d}d + \bar{e}e) + G_u 8(\bar{u}u)]\end{aligned}$$

- Lead to the unification of down type quark masses with that of charged leptons

$$m_d(M_X) = m_e(M_X) = -\frac{2M_w}{\sqrt{2}g_2} G_d$$

Yukawa couplings

- Dimension 5 terms

Ψ and f are fermion fields in **10** and **5** respectively scalar fields in the **24** and **5** representations

$$\begin{aligned} \mathcal{O}_5 &= \frac{a_1}{\hat{\mu}_\star}\{\phi_{mn}\bar{f}^{mk}H^l_k\Psi^n_l\} \\ &+ \frac{a_2}{\hat{\mu}_\star}\{\phi_{mn}H^{mk}\bar{f}^l{}_k\Psi^n_l\} \\ &+ \frac{a_3}{\hat{\mu}_\star}\varepsilon^{mnpql}\{\Psi_{mn}\Psi_{pq}H_k\phi^k_l\}, \end{aligned}$$

- New unification condition:

$$m_d(M_X)[1+\frac{3}{2}\zeta_1-\zeta_2] = m_e(M_X)[1+\frac{3}{2}\zeta_1+\frac{3}{2}\zeta_2]$$

$$\zeta_i = \frac{-2\sqrt{2}}{5G_d g_u}\frac{M_X}{\bar{M}_{Pl}}a_i\eta$$

Conclusions

- Quantum gravity can help to unify the gauge couplings and Yukawa couplings.
- It spoils predictions done using low energy data.
- LEP does not favor SUSY unification: Extrapolation from low energy data is too naïve.
- If no BSM is discovered, gravity induced unification should be taken very seriously
- Impossible to make any prediction without knowing the full details of the unification group and symmetry breaking pattern.
- Thanks for your attention.

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Testing the consistency of quantum gravity with low-energy properties of the standard model

Astrid Eichhorn

Perimeter Institute, Waterloo

Experimental search for quantum gravity - the hard facts
25th October, 2012

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

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- construct dedicated experiments

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  - existence of semiclassical gravity regime

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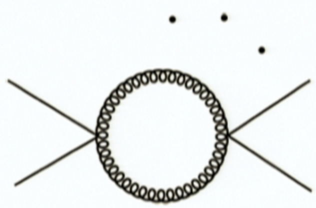

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$\rightarrow$ not clear if properties of the standard model "survive" the coupling to a model of quantum gravity

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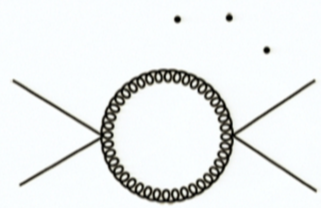

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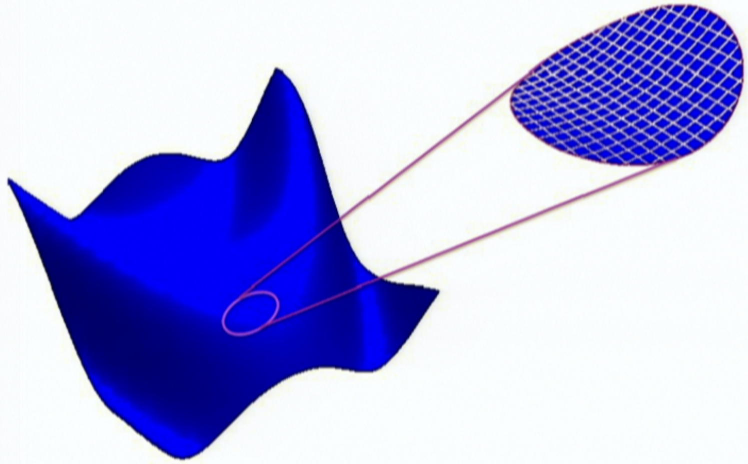
Effective-field theory setting



many candidates for microscopic dynamics

assume: for $E < M_{Planck}$ quantum gravity fluctuations can be parameterised as metric fluctuations

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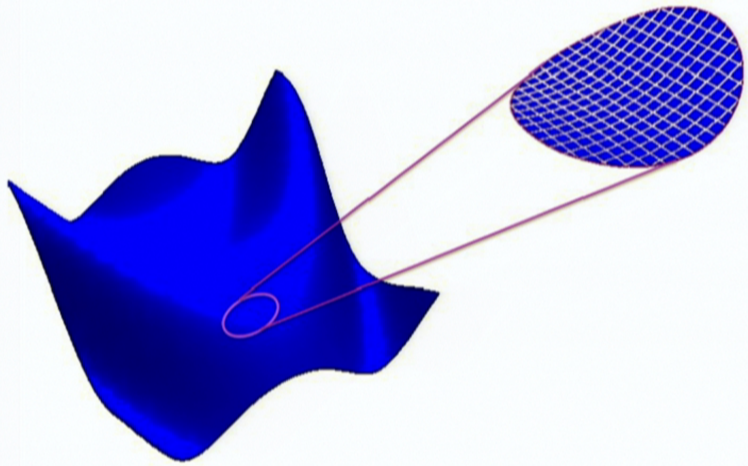

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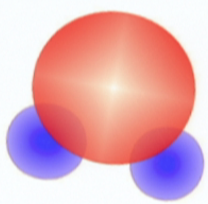

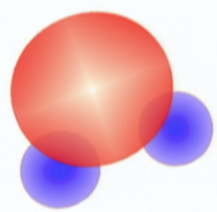

microscopic model: determines parameters of effective description

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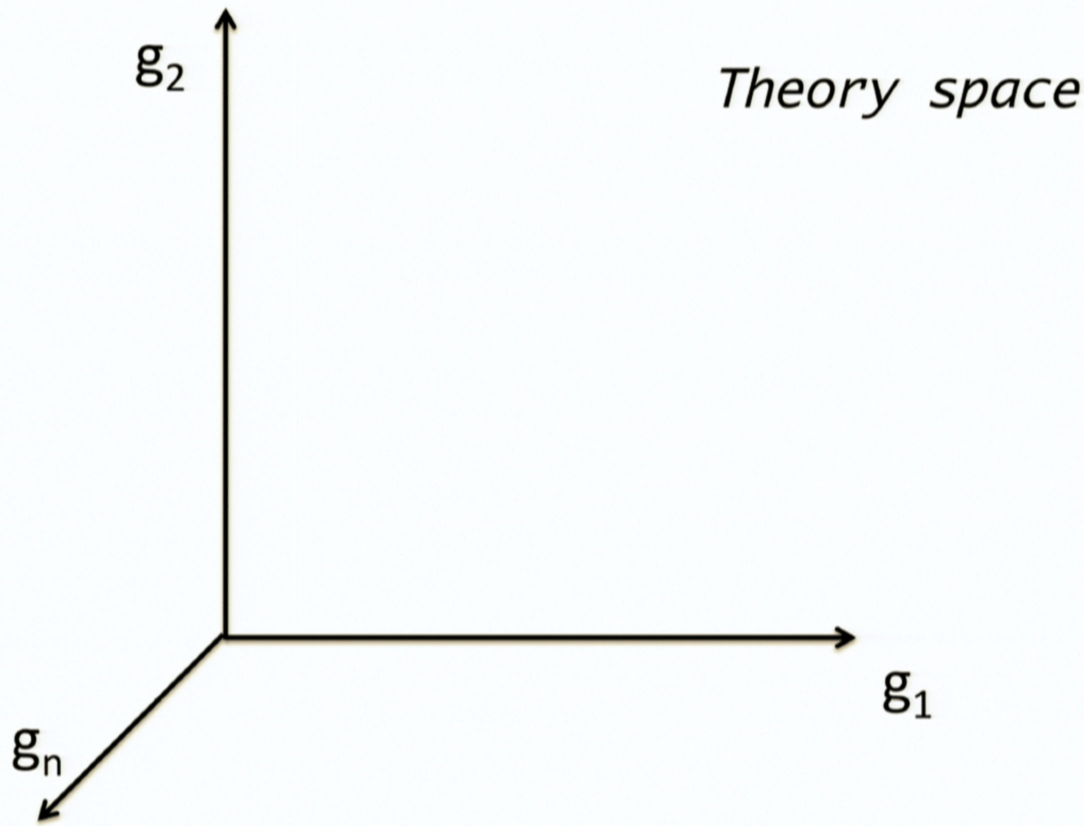

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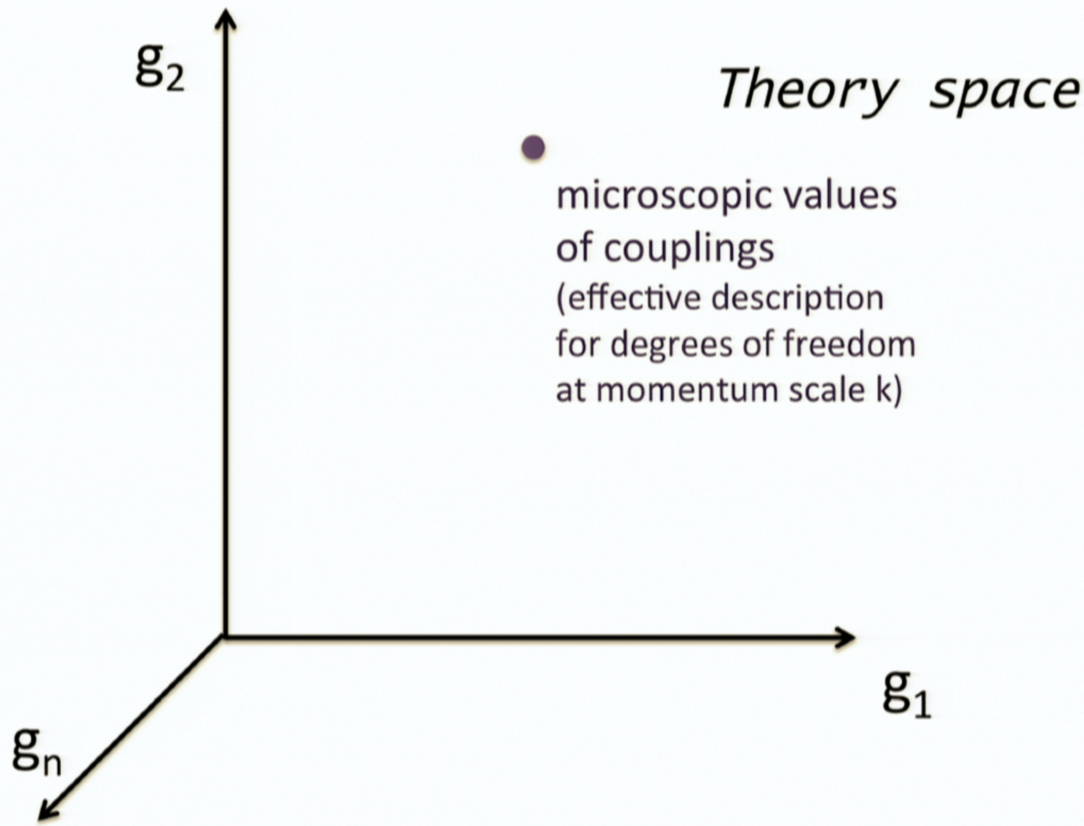
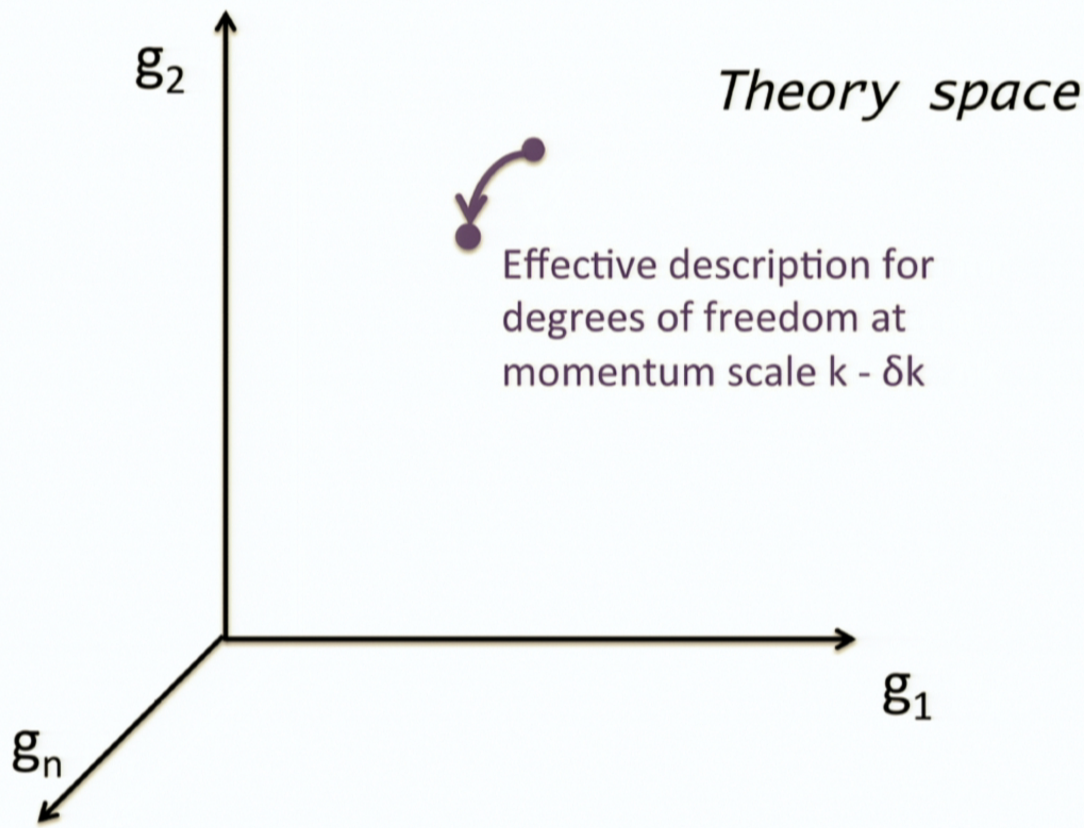
$$\int_{p>k} \mathcal{D}\phi e^{-S} = e^{-\Gamma_k}$$



Effective-field theory setting

$$\int_{p>(k-\delta k)} \mathcal{D}\phi e^{-S} = e^{-\Gamma_{k-\delta k}}$$

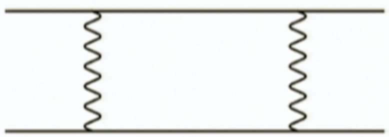


Existence of light fermions

observation: $m_{\text{fermion}} \ll M_{\text{Planck}}$

Is quantum gravity compatible with this observation?

in the standard model: gluonic fluctuations generate strong correlations between fermions and lead to chiral symmetry breaking
(most of our own mass is due to this process)



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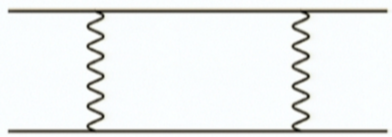

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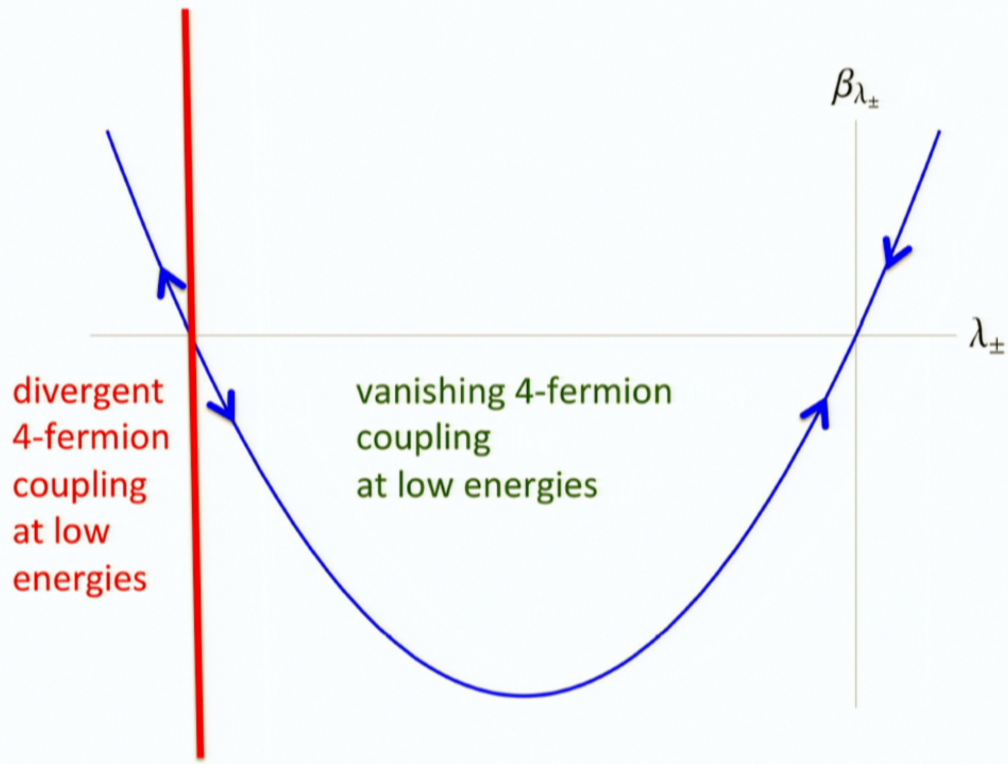
observation: metric fluctuations are similar to gluonic fluctuations

Will metric fluctuations generate fermion masses?
If so, then $m_{\text{fermion}} \sim M_{\text{Planck}}$
NOT COMPATIBLE WITH OBSERVATIONS!!

RG flow for four-fermion couplings in gravity

chiral symmetry breaks if four-fermion couplings $\lambda_{\pm}(k)$ diverge at a finite scale

$$\beta_{\lambda_{\pm}} = k\partial_k \lambda_{\pm}(k)$$



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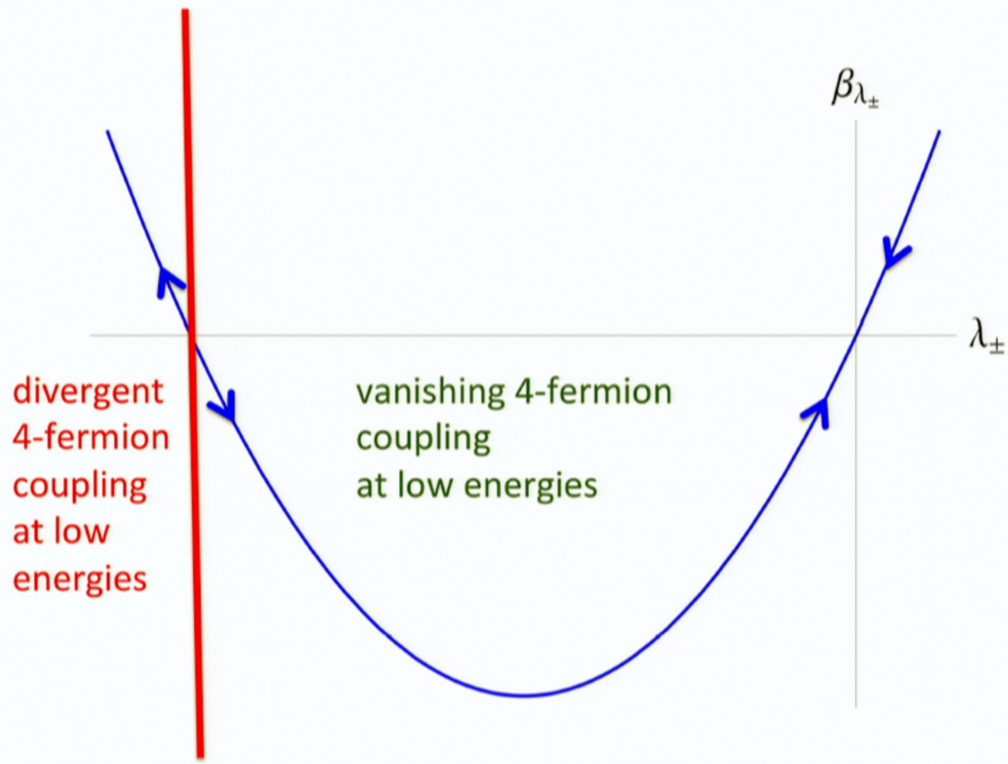
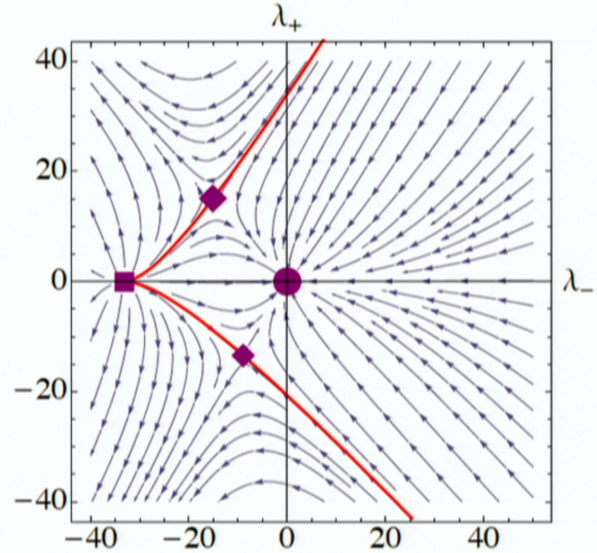


Existence of light fermions

within truncated RG flow:

$$\Gamma_k = \int d^4x\sqrt{g}\left[\frac{1}{16\pi G_N(k)}(-R+2\bar{\lambda}(k))\right] + \Gamma_{gf} + \Gamma_{gh}$$
$$+\int d^4x\sqrt{g}\, i\bar{\psi}^i\gamma^\mu\nabla_\mu\psi^i \qquad +$$
$$\lambda_\pm(k)\int d^4x\sqrt{g}\left(\left(\bar{\psi}^i\gamma_\mu\psi^i\right)^2 \mp \left(\bar{\psi}^i\gamma_\mu\gamma_5\psi^i\right)^2\right)$$

[A.E., H. Gies, New J.Phys. 13 (2011) 125012 and J.Phys.Conf.Ser. 360 (2012) 012057]



Asymptotic safety compatible with the existence of light fermions

parameter space for quantum gravity models restricted

challenge: "translate" microscopic model into effective language and determine what the microscopic values of the couplings are

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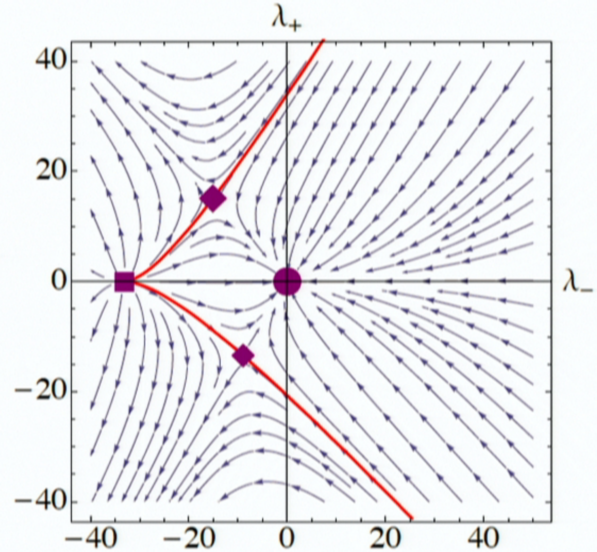

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Summary and Outlook

- use available data to rule out quantum gravity theories
- Existence of light fermions ($m_f \ll M_{\mathrm{Planck}}$) non trivial
- Light fermions can exist within asymptotic safety
- Parameter space for quantum gravity models restricted

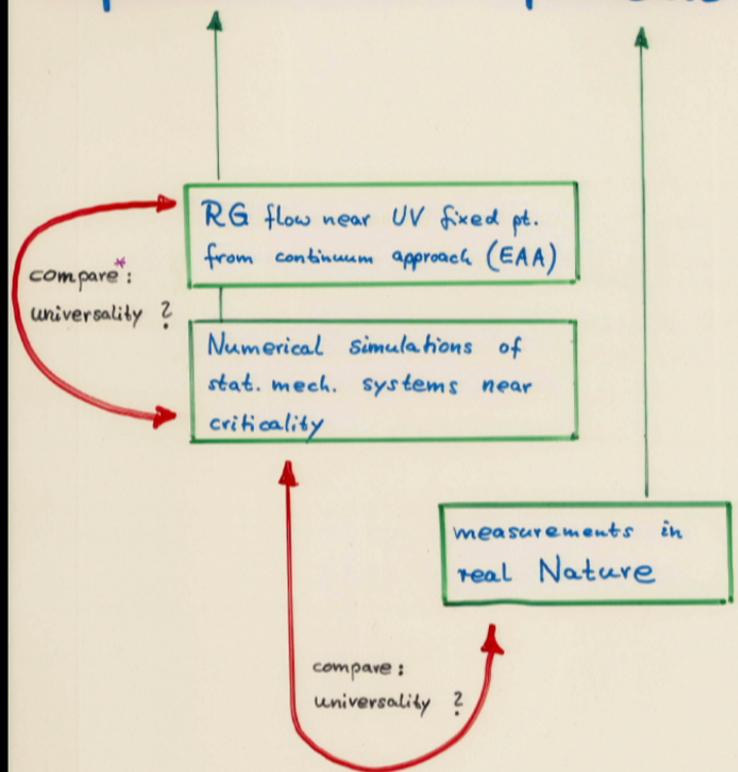
The Asymptotic Safety Program

or

Experiments without Experiments

Martin Reuter

Experiments without Experiments



* Critical exponents, dimensions, potential of the conf. factor, ...

- Relation continuum ⟷ lattice formulation is well understood for the other 3 fundamental interactions in the Standard Model.

  Prime example: Yang-Mills theory

- Most natural research strategy:

  Apply the very same concepts of statistical field theory and their generalized notions of renormalization and renormalizability to the 4^{th}, gravity, as well.

- In case we succeed in reliably identifying a certain universality class, and find two or more representatives (**EAA** Γ_k ; stat. systems: **CDT, EDT, Regge**, ⋯ ; ⋯) chances are very good that this universality class is also relevant to Nature.

  General experience: There are "very few" only.

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Two ways of applying the effective average action

(1) Use RG flow of $\Gamma_k[\langle \text{grav. field} \rangle, \cdots]$
in order to give a meaning to ("define", "non-perturbatively renormalize", "take the continuum limit of", ⋯) a functional integral

$$" \int \mathcal{D}g_{\mu\nu}\, e^{-S[g_{\mu\nu}]} "$$

- Rigorous, in principle
- Γ_k = interpolating functional ;
  effective field theory properties are inessential.

(2) Exploit that $\Gamma_k \sim$ eff. field theory at scale k.

- Much less rigorous (cutoff identification, ⋯)
- Sometimes efficient "shortcut" avoiding much more demanding (as to yet, impossible) exact calculations.

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Concrete implementation:
the gravitational average action

(M.R., 1996)

- Fix a set of fields Ψ supposed to carry the degrees of freedom: $\Psi = (g_{\mu\nu})$, $\Psi = (e^a_\mu, \omega_\mu^{ab})$, ...
- Fix a group $\mathcal{G}$ of (gauge) symmetries acting on Ψ.
- Define "theory space" to consist of all invariant fctl's:

$$\mathcal{T} = \left\{ A[\Psi] \,\middle|\, \text{action functional } A \text{ is inv. under } \mathcal{G} \right\}$$

- Fix a coarse graining scheme on $\mathcal{T}$ (background covariant continuum analogue of Kadanoff's block spin idea)
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  β: vector field on $\mathcal{T}$ obtained by applying infinitesimal coarse graining steps to all $A \in \mathcal{T}$

$$A \xrightarrow[\text{RG step}]{\text{infinites.}} A + \underbrace{\beta(A)}_{\in T_A \mathcal{T}}$$

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- Compute "RG trajectories" $\Gamma_\cdot : \mathbb{R} \to \mathcal{T}$, $k \mapsto \Gamma_k$ as integral curves of β:

$$\frac{d}{d\ln k}\Gamma_k = \beta(\Gamma_k)$$

"FRGE"
"flow eq."

concretely: $\beta(\Gamma_k) = \frac{1}{2}\mathrm{STr}\left[\left(\Gamma_k^{(2)} + \mathcal{R}_k\right)^{-1} k\partial_k \mathcal{R}_k\right]$; $\Gamma_0 = \Gamma$, $\Gamma_\infty \sim S$

- Determine fixed points of the flow: $\beta(A_*) = 0$

- Linearize flow about A_*: $\Gamma_k = A_* + \delta\Gamma_k$

$$\frac{d}{d\ln k}\delta\Gamma_k = \begin{bmatrix}\text{stability}\\ \text{matrix}\end{bmatrix}_{A_*}\delta\Gamma_k$$

$\Longrightarrow$ • eigenvectors = "scaling fields"

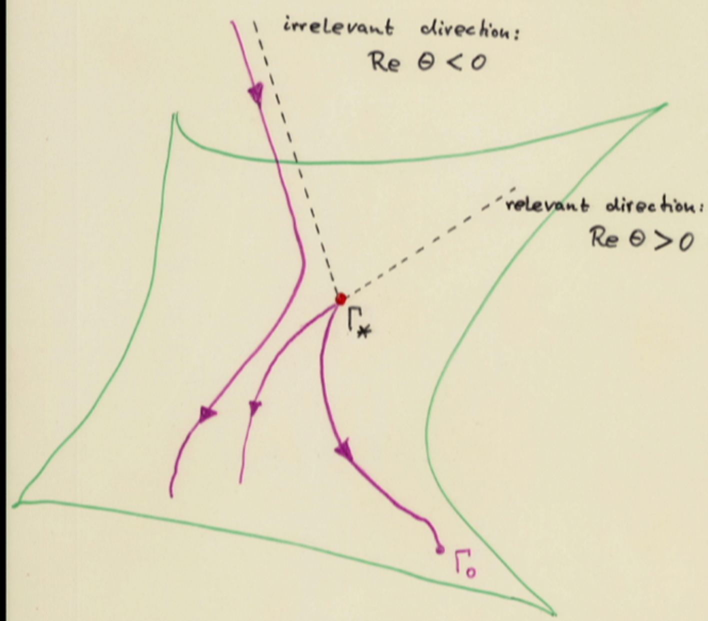
• eigenvalues = "critical exponents" Θ_i

$$(\delta\Gamma_k)_i \sim k^{-\Theta_i}$$

- Try to find <u>complete</u> RG trajectories for which the limits $k\to\infty$ (UV) and $k \to 0$ (IR) exist. Every one of them defines a quantum theory.

- The Asymptotic Safety construction: perform UV limit at a fixed point: $\Gamma_k \longrightarrow A_*$ for $k \to \infty$.

The UV-critical hypersurface $\mathcal{S}_{UV}$:



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= # free parameters in the a.s. quantum field theory

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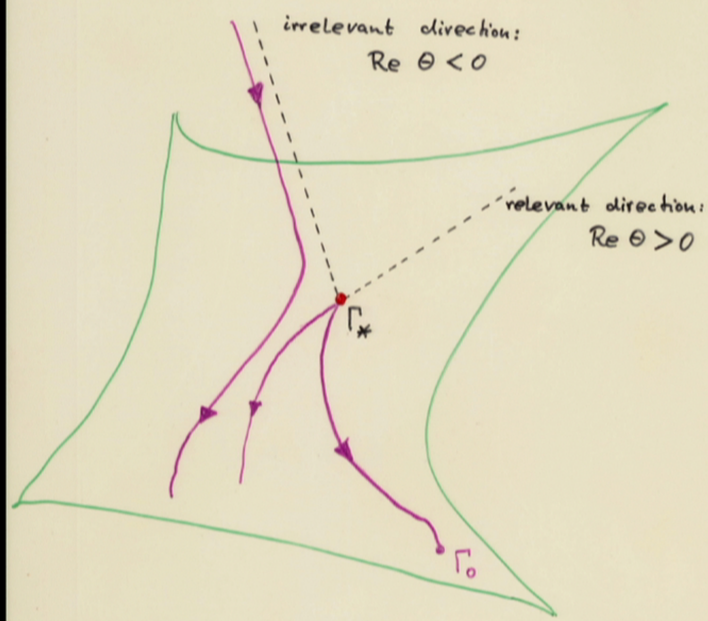

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- Bare ("classical") action is a <u>prediction</u> rather than an input !

- <u>The Reconstruction Problem:</u>

Construct an UV-regularized fctl. integral

$$\int \mathcal{D}_{\Lambda} g_{\mu\nu}\, e^{-S_{\Lambda}[g_{\mu\nu}]} \quad \text{which reproduces } \underbrace{\Gamma_k}_{\text{solution to FRGE}} .$$

$\Lambda \to \infty$

Bare trajectory $\Lambda \mapsto S_\Lambda$ is given by

$$\underset{\text{UV cutoff}}{S_\Lambda} = \underbrace{\Gamma_{k=\Lambda}}_{\substack{\text{independent}\\ \text{of the UV-scheme;}\\ \text{solution to FRGE}}} + \underbrace{\begin{bmatrix}\text{correction term depending}\\ \text{on UV-regulator scheme}\end{bmatrix}_\Lambda}_{\substack{\text{Is to be computed}\\ \text{with lattice regularization}\\ \text{when } \Gamma_k\text{-flow is}\\ \text{compared to}\\ \text{lattice RG flow, say!}}}$$

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$$\int \mathcal{D}_{\underset{\hookrightarrow \infty}{\Lambda}} g_{\mu\nu}\, e^{-S_\Lambda [g_{\mu\nu}]}$$ which reproduces $\underbrace{\Gamma_k}_{\text{solution to FRGE}}$.

Bare trajectory $\Lambda \mapsto S_\Lambda$ is given by

$$\underset{\text{UV cutoff}}{S_\Lambda} = \underbrace{\Gamma_{k=\Lambda}}_{} + \underbrace{\begin{bmatrix}\text{correction term depending} \\ \text{on UV-regulator scheme}\end{bmatrix}_\Lambda}_{}$$

independent of the UV-scheme; solution to FRGE

Is to be computed with lattice regularization when Γ_k-flow is compared to lattice RG flow, say!

- Bare ("classical") action is a <u>prediction</u> rather than an input!

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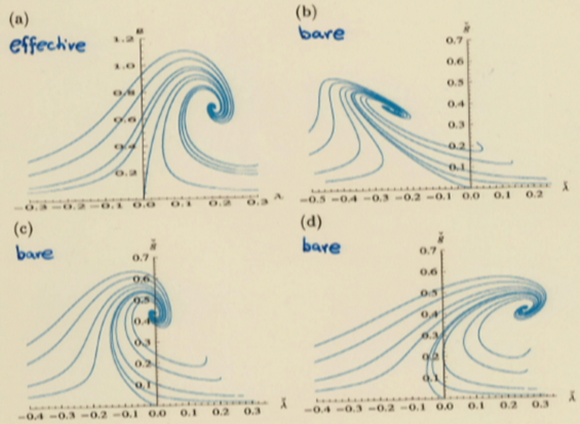

Figure 4: The diagram (a) shows the phase portrait of the effective RG flow on the (g, λ)-plane. The other diagrams are its image on the $(\check{g}, \check{\lambda})$-plane of bare parameters for three different values of Q, namely (b) $Q = +1$, (c) $Q = -0.1167$ where $\check{\lambda}_* = 0$, and (d) $Q = -1$, respectively.

E. Manrique, M.R., 0811.3888

Summary

- From the point of view of our continuum approach to Asymptotic Safety there is little difference between trying to explain "data" from numerical experiments on stat. mech. models of gravity, or from real experiments in Nature.
- It is therefore a crucial, well-posed (no experimental guidance needed yet!) and realistic (most tools known) intermediate research goal to establish contact among different theoretical approaches.
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