Asymptotic Safety and Matter

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Why Should Matter Matter? - I

matter influences the RG of Yang-Mills Theory $SU(N_c)$
one loop beta function:

$$\beta(g) = -\left(\frac{11}{3} N_c - \frac{2}{3} N_F\right) \frac{g^3}{16\,\pi^2} + \mathcal{O}\left(g^5\right)$$

- N_c: number of colours
- N_F: number of fundamental Dirac fermions
- fermions contribute with opposite sign

$$N_{F,\text{critical}} = \frac{11}{2} N_c$$

matter can spoil asymptotic freedom in Yang-Mills

Why Should Matter Matter? - II

one loop β-function of Newton's coupling g:

$$\beta_g = (2+\eta)\, g$$
$$\eta = -(21 - n_{\text{scalar}} - 2\, n_{\text{fermion}} + 4\, n_{\text{vector}})\, \frac{g}{6\,\pi} + \mathcal{O}(g^2)$$

- non-gaussian fixed point for $\eta = -2$
- matter fields contribute with different signs at one-loop level
- $\rightarrow$ potential destabilisation of the fixed point through matter

Can asymptotic safety be spoiled?

Matter Couples to Gravity

matter couples into the asymptotic safety scenario

- feedback of non-self interacting matter (scalars, Weyl, Maxwell, RS) into the Einstein-Hilbert β-functions of gravity $\rightarrow$ constraints on the number of matter fields compatible with AS scenario in 4D [1]
- recent upgrade that uses a bi-metric setup [2]
- fixed point can be spoiled through
  - disappearance
  - repulsiveness
  - unphysical coupling values (negative g)
  - loss of predictivity

[1] Percacci Perini 10.1103/PhysRevD.67.081503
[2] Dona Eichhorn Percacci ARXIV:1311.2898

$f(R)$ gravity with minimal matter

Setup

- $d = 4$
- minimally coupled + non-self interacting matter
- real scalars, Dirac fermions, Maxwell vectors
- gravity in the polynomial $f(R)$ approximation (up to R^5)
- single-metric approximation

- beta functions are singular for $\lambda = 1/2$

Pure Gravity

- physical solution established up to R^{70} order [3]
- $\lambda \approx 0.156$ and $g \approx 0.852$
- convergence pattern in the couplings
- three relevant eigendirections:
  - one complex conjugate pair (visible at EH)
  - one purely real (introduced at R^2)
- convergence pattern in the eigenvalues

[3] Falls Litim Nikolakopoulos Rahmede hep-th/1301.4191, Falls Litim Nikolakopoulos Schroeder to appear

Scalars and Gravity

- tested up to R^5
- fixed point candidate with $g > 0$ visible for all n_{scalar}
- three relevant eigenvalues persist
- at finite n_{scalar}: relevant cc eigenvalue pair turns real

many scalar limit

- $\lambda \to 1/2$
- $g \sim 1/n_{\text{scalar}} \to 0+$
- increasing relevant eigenvalue $\sim \sqrt{n_{\text{scalar}}}$

- large scalar limit available $\to$ one EV grows large, hinting a failure of the approximation

Many Scalars in R^3 - Relevant Directions

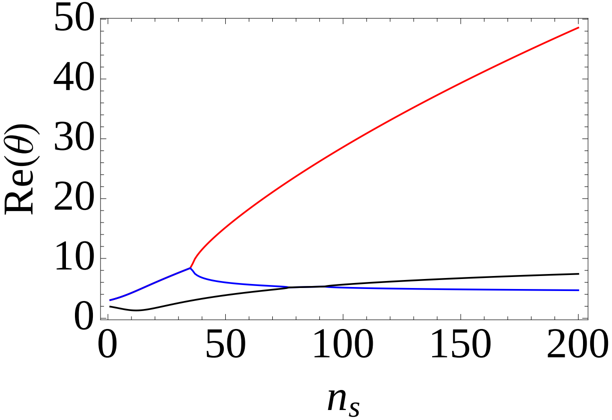

Figure: Real part of the critical exponent θ for different number of scalar fields n_s

Fermions and Gravity

- tested up to R^5
- continuously deformed pure gravity fixed point ends at finite $n_{\text{fermion}} = \mathcal{O}(1)$
- interplay with other matter types alters this bound!
- three relevant eigenvalues persist

many fermion limit

- no physical limit for R and R^2
- physical limit opens for R^3 and higher
  - $\lambda \neq 1/2$ remains finite and $g \sim 1/n_{\text{fermion}}$
  - three (two at R^3) relevant and real directions

Fermions - Critical Exponents in R^4

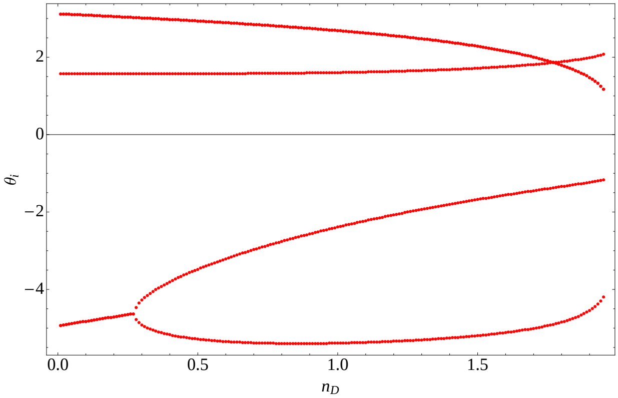

Figure: The spectrum of critical exponents θ_i is given as a function of the number of fermion fields n_D for the deformed pure gravity line in the R^4 approximation.

Vectors and Gravity

- tested up to R^5
- continuously deformed pure gravity fixed point ends at finite $n_{\text{vector}} = \mathcal{O}(100)$
- at least two relevant eigenvalues
- eigenvalues can turn from irrelevant to relevant with increasing n_{vector} - predictivity?

many vector limit

- exists for all approximations + consistent with Einstein-Hilbert
- $\lambda \to 3/8$ and $g \sim 1/n_{\text{vector}}$
- two or three relevant directions consistently

Vectors - Critical Exponents in R^4

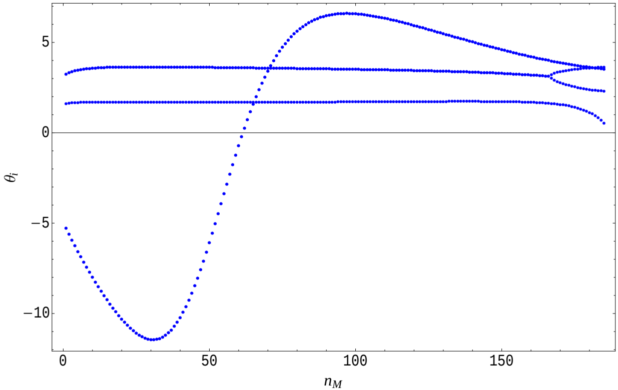

Figure: The spectrum of critical exponents θ_i is given as a function of the number of vector fields n_M for the deformed pure gravity line in the R^4 approximation.

Conclusions

examined minimally coupled matter in $f(R)$ gravity up to R^5

- confirmed physical fixed points close to pure gravity
- bounds for fermions $\mathcal{O}(1)$ and vectors $\mathcal{O}(100)$
- approximation breakdown in the many scalar limit
- physical many fermion limit (R^3 and beyond)
- physical many vector limit
- higher curvature invariants stabilise the many matter limit

- matter interplay - first results: alteration of fermion bounds