Universal properties in quantum gravity (?)

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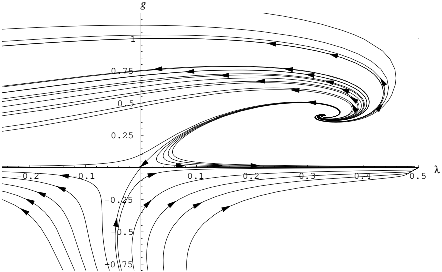
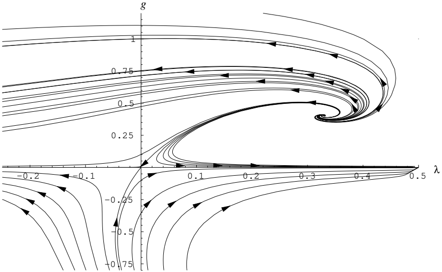
Motivations



Reuter & Saueressig, 2001

Scheme dependence in asymptotic safety **Weinberg, 1979; Reuter, 1998**.

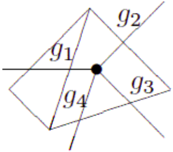
Motivations



Reuter & Saueressig, 2001

Scheme dependence in asymptotic safety **Weinberg, 1979; Reuter, 1998**.

Is the smoothness of spacetime the effect of a phase transition?



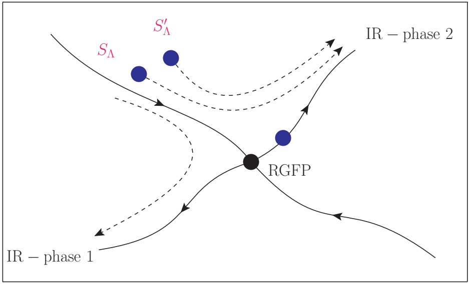
Lesson from other QFTs: part 1

- Quantum field theories with different microscopical degrees of freedom share the same critical behaviors

- They fall into the same universality class

- Characterization done by studying the critical exponents

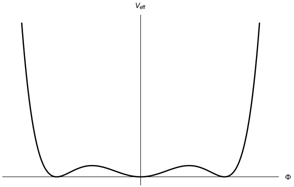
- One to one correspondence with RG fixed points



Lesson from other QFTs: part 2

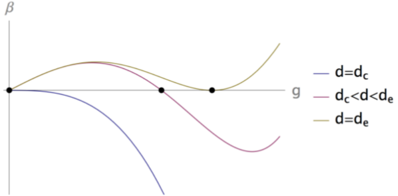
- Analytic continuation of theories far from their critical dimension

Multicritical scalar field theories



Interesting physics if continued **below** the critical dimension until $d = 2$

Y-M gauge theories



Interesting physics if continued **above** the critical dimension
Gies 2003; Morris 2005.
(predictions for gravity: $d_e \sim 5.73$ and $d_e = 7$
Gies et al., 2015; Falls, 2015)

How to identify universality classes?

• Require possible analytical continuation in a dimensional range

• Identify a critical dimension d_c

• At d_c the perturbative expansion of the theory is controlled by a set of marginal operators.

For a metric field content one has:

$$\mathcal{O} \sim \mathcal{R}^n \qquad d_c = 2n\,.$$

- $d_c = 2$ Kawai-Ninomiya universality class **Kawai, Ninomiya, Aida, Kitazawa, Nishimura, Tsuchiya, ..., 1993-1997**
- $d_c = 4$ Stelle universality class **Stelle, 1976**
- $d_c = 6$?

2d Gravity

Linear splitting
(ex. **Jack and Jones, 1990**)

$$g_{\mu\nu} = \bar{g}_{\mu\nu} + \frac{Z_h}{\sqrt{G}} h_{\mu\nu}$$

$$S[g] = \int \sqrt{g} \left(-\frac{Z_G}{G} R + Z_\Lambda \Lambda \right)$$

central charge = 19

$$\beta_G = \varepsilon G - \frac{19 - c}{24\pi^2} G^2$$

Exponential splitting
(ex. **Aida, Kitazawa, Kawai, Ninomiya, 1994**)

$$g_{\mu\nu} = \hat{g}_{\mu\nu} e^{-\phi} = \bar{g}_{\mu\rho} \left(e^h \right)^\rho_{\ \nu} e^{-\phi}$$

$$S[g] = \int \sqrt{\bar{g}} \left(\hat{R} L(\phi) - \frac{1}{2} \hat{g}^{\mu\nu} \partial_\mu \phi \partial_\nu \phi \right)$$

central charge = 25

$$\beta_G = \varepsilon G - \frac{25 - c}{24\pi^2} G^2$$

2d: Jack and Jones ('90)

- Einstein Gravity + Cosmological constant
- $S^{(2)}$ **not** elliptic: Insert a projector

$$P^{-1}_{\mu\nu,\rho\sigma} = -2\left(I_{\mu\nu,\rho\sigma} + \frac{1}{\varepsilon} g_{\mu\nu} g_{\rho\sigma}\right) \qquad \Rightarrow \text{ Kinematic pole}$$

$$\boxed{\varepsilon \longrightarrow \bar{\varepsilon}}$$

$$\beta_G = \varepsilon G - \left(\frac{(5d-9)d+48}{48\pi} + \frac{(d-2)(d-4)}{8\pi\bar{\varepsilon}}\right) G^2$$

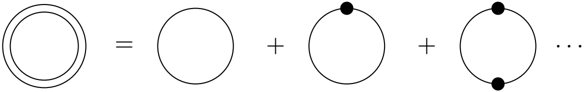
identifying $\bar{\varepsilon}$ with dimensional regulator
central charge = 19

keeping ε and $\bar{\varepsilon}$ independent
central charge = 25

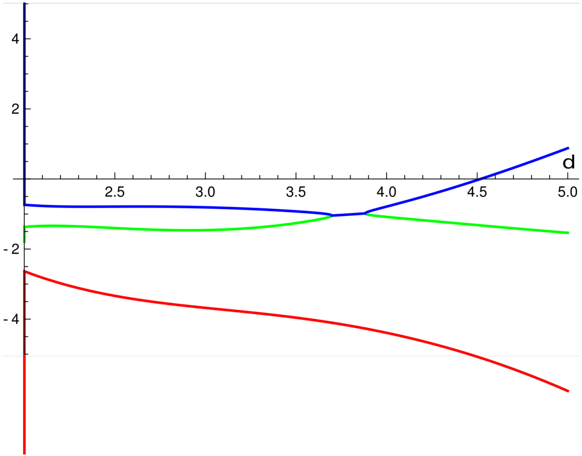
Deformation of the theory

• In order to continue the theory to $d = 4$ we should take into account the role of higher derivatives operators

$$S_{int}[g] = \int \sqrt{g}\left[\alpha_1 R^2 + \alpha_2 R_{\mu\nu}R^{\mu\nu} + \alpha_3 R_{\mu\nu\rho\sigma}R^{\mu\nu\rho\sigma}\right]$$



Analytic continuation



Summary and Outlook

- A classification of metric universality classes is important for the quantum gravity program

- Qualitative features of asymptotic safety results could be traced to specific higher order operators

- Stay tuned for more results

Thank you!