Vainshtein in the UV

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Motivation

Theories for dark energy and inflation usually treated as effective theories tested against observations

They often rely on dominance of non-linear derivative interactions

Quantum features at strong coupling?

UV initial conditions?

UV completion?

Aim: An understanding within a non-perturbative Wilsonian framework

Cosmology with derivative interactions

P(X) theories, galileons, ...

$$\mathcal{L} \sim \frac{1}{2}(\partial\phi)^2 + \frac{(\partial\phi)^4}{\Lambda^4} + \ldots + \frac{(\partial\phi)^2\Box\phi}{\Lambda^3} + \ldots$$

strong coupling scale

Vainshtein screening

$$\delta\mathcal{L} = -\frac{1}{2}Z^{\mu\nu}\left[\bar{\phi}\right] \cdot \partial_\mu\delta\phi\partial_\nu\delta\phi - \frac{1}{2}m^2[\bar{\phi}^2] \cdot \delta\phi^2 + \frac{1}{M_{pl}}\delta\phi\delta T$$

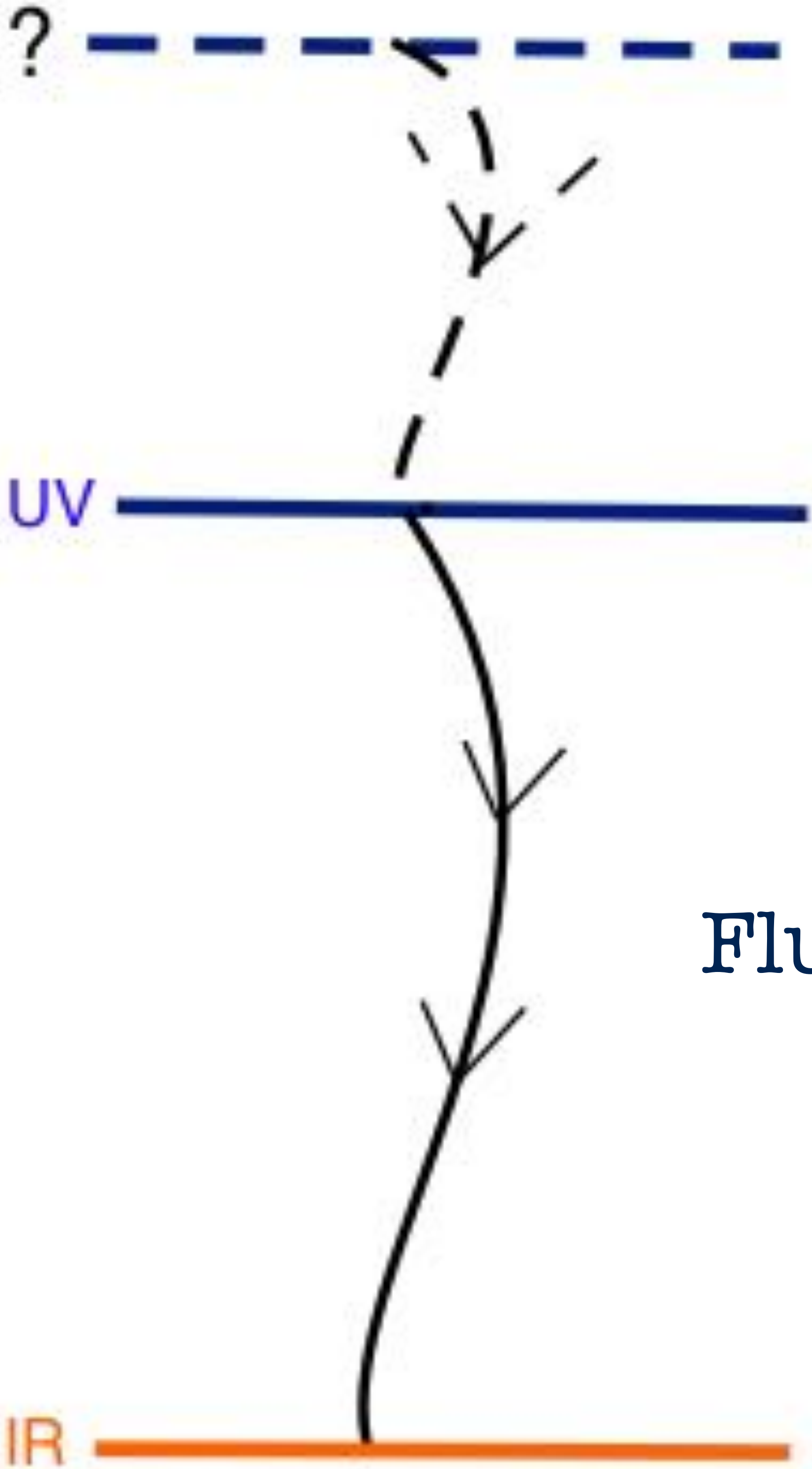
$\gg 1$

$\frac{1}{\sqrt{Z}}\frac{1}{M_P}$

Implications of strongly-coupled configurations at the quantum level? *

* Previous analysis on quantum stability: C. de Rham & R. H. Ribeiro (2014), arXiv: 1405.5213

The Wilsonian framework for QFTs



UV completion?

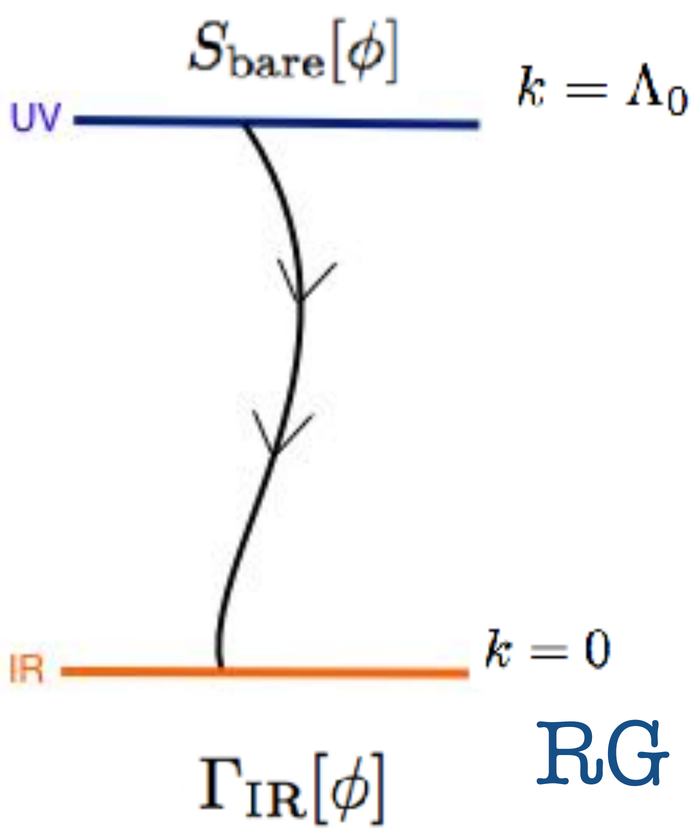
$S_{\text{bare}}[\phi]$ Effective theory at cut-off Λ_0

Fluctuations integrated out iteratively

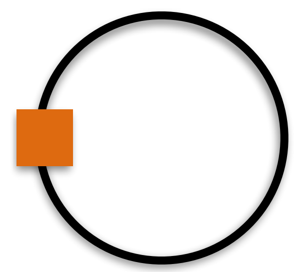
$\Gamma_{\text{IR}}[\phi]$ All fluctuations are integrated out

From UV to IR à la Wilson

The tool: An Exact Renormalisation Group equation for the coarse-grained effective action*



$$\frac{\partial}{\partial k}\Gamma_k[\phi] = \frac{1}{2}\cdot$$



$$= \frac{1}{2}\mathrm{Tr}\left[\frac{\partial_k R_k}{\Gamma_k^{(2)} + R_k}\right]$$

Wilsonian regulator

RG flow of interaction couplings from UV to IR

Critical points of the RG flow: UV completion?

Asymptotic Safety?

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*C. Wetterich (1993), T. R. Morris (1994)

Asymptotic Safety

Irrelevant coupling: $[g] = -d$

As $E \to \infty$:

Naive dimensional analysis: $g \cdot E^d \to \infty$

Asymptotic safety: $g(E) \cdot E^d \to \text{constant}$

In principle, of non-perturbative nature

Derivatively coupled scalars: UV completion?

Can P(X) theories be UV completed through asymptotic safety ?

Critical points equation: Non-linear, differential equation for P(X) and its derivatives w.r.t X

$$\partial_k P(X) = 0 = \mathcal{F}[P, P_X, P_{XX}, P_{X^3}]$$

P(X) theories: Their non-perturbative RG flow possesses **no UV fixed point** irrespective the form of P(X)

Theory is trivial

Can only be treated as EFT up to some UV cut—off

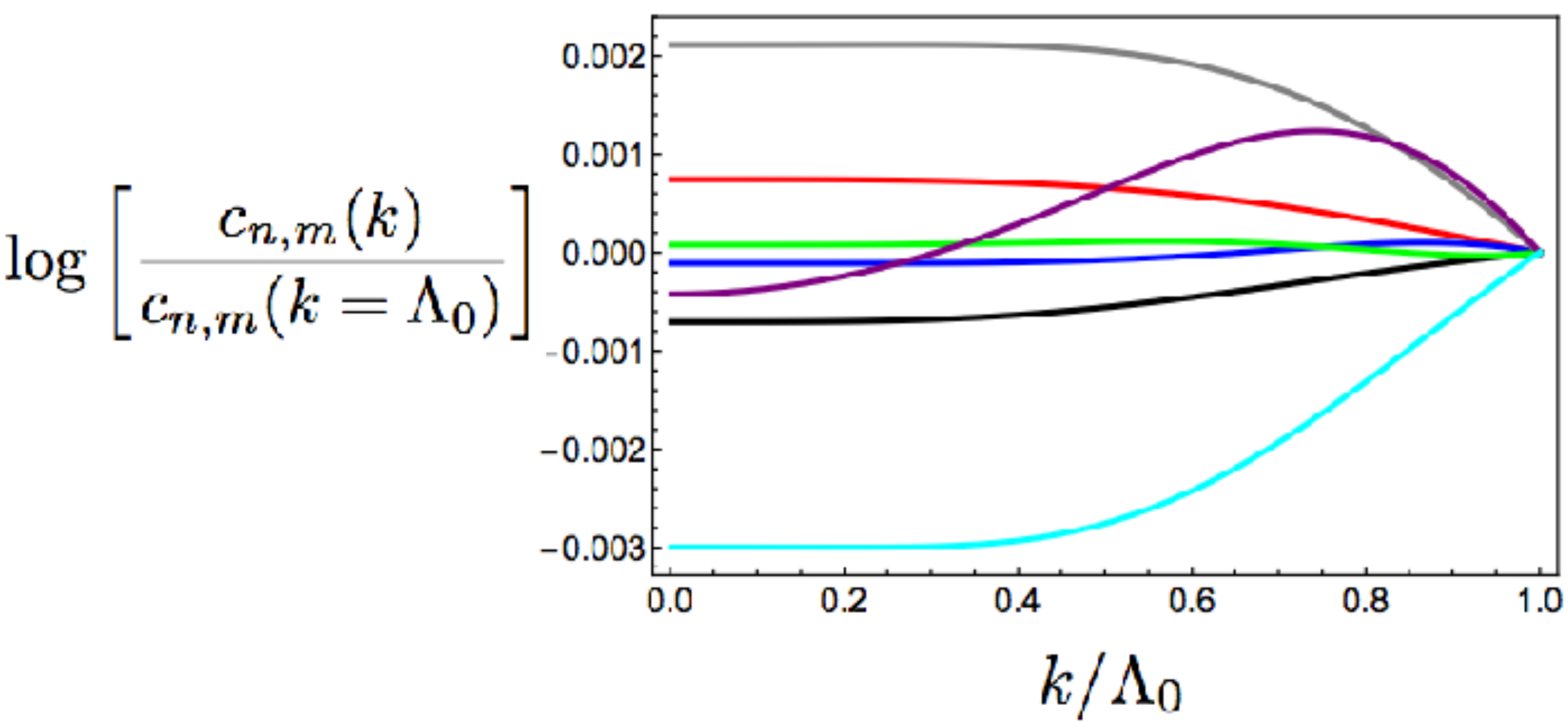
Derivatively coupled scalars: UV completion?

But, what about higher-order derivative interactions?

$$P_k(X,B) \approx \sum_{n,m}^{n+m=11} c_{n,m}(k) X^n B^m$$

$$X \equiv (1/2)(\partial\phi)^2$$
$$B \equiv \Box\phi$$

Results persist under higher-order corrections: No apparent UV completion beyond EFT



Running couplings from the UV cut–off to IR (numerical)

So far, background configurations (gradients) were still assumed to be in the perturbative regime.

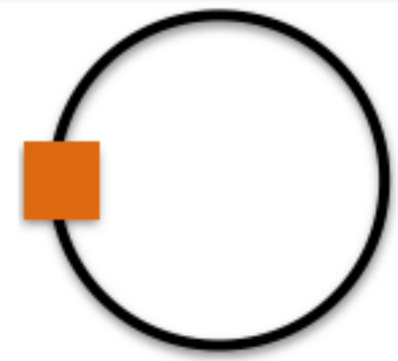
What can we say about strongly-coupled configurations?

RG flow for strongly—coupled configurations

Large derivative configuration: $P_k(X,B) \approx Z_1(k)X + \frac{c_{n,m}(k)}{\Lambda^{4n+3m-4}} X^n B^m$

Dominant operator

$X \equiv (1/2)(\partial\phi)^2 \quad B \equiv \Box\phi$

As $\frac{|X|}{\Lambda^4}, \frac{|B|}{\Lambda^3} \gg 1$ $\Rightarrow$ $\frac{\partial}{\partial k}\Gamma_k[\phi] = \frac{1}{2}\cdot$  $\longrightarrow 0$

Absence of running: $\Gamma_k[\phi] \approx S_{\text{classical}}[\phi]$

A (scale invariant) fixed point of the RG flow at strong coupling as $\Lambda \to 0$

A hint of classicalisation?*

*G. Dvali et al. (2010)

Implications

(Non-perturbative) UV completion:

No UV completion — theory is trivial

EFT approach the only path

Should one worry about the absence of a UV completion?

Lack of fundamental control upon UV initial conditions

Still, all our realistic theories are EFTs

"Freeze" of the RG flow for large-derivative configurations:

Strong sensitivity on the UV initial conditions

A window to UV physics?

Summary

Understanding the initial conditions and short-scale properties of dark energy theories is an important task

No apparent Wilsonian UV completion for sufficiently general, derivatively coupled scalar fields beyond EFT

Suppression of the RG flow for strongly coupled configurations: Theory is fixed to its classical, UV boundary

Thank you!