Title: Town Hall - Fundamental aspects of Modified gravity

Speakers: Adam Solomon, Andrew Tolley, Astrid Eichhorn, Sergey Sibiryakov

Collection/Series: 50 Years of Horndeski Gravity: Exploring Modified Gravity

Subject: Cosmology, Strong Gravity, Mathematical physics

Date: July 18, 2024 - 4:00 PM

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Abstract:

Lead: Jerome Quintin

Fundamental Aspects of Modified Gravity

Town hall — 50 Years of Horndeski Gravity
Perimeter Institute

Panelists

- Adam Solomon (McMaster & PI)
- Andrew Tolley (Imperial)
- Astrid Eichhorn (Southern Denmark U., CP3-Origins)
- Sergey Sibiryakov (McMaster & PI)

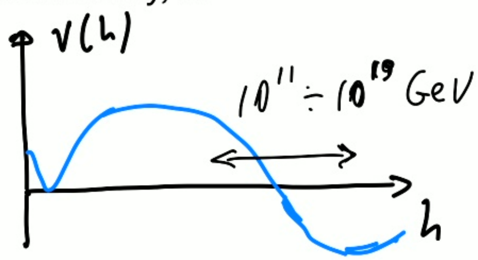
top-down vs bottom-up
or
fundamental (quantum gravity) vs EFTs

What has produced more successful modified gravity theories?
(theory side and observational side)

What is now the best way forward?

1. Top-down vs bottom-up approaches, or fundamental (quantum gravity) theories vs effective field theories — what has yielded more successful modified gravity theories, from theoretical and observational perspectives? What is now the best way forward in the upcoming decades?

	top-down	**bottom-up**
player's guide	theoretical control, clear principles / symmetries, compatibility w. particle physics / QFT ?? insights: *inflation, SM Higgs metastability, ...*	data driven, clear principles / symmetries, compatibility w. particle physics / QFT ?? insights: *dark matter, ...*
pitfalls	getting to signatures can be hard, untestable / ruled out	EFT may not admit UV completion, statistical flukes / systematics



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top-down vs bottom-up
or
fundamental (quantum gravity) vs EFTs

What has produced more successful modified gravity theories?
(theory side and observational side)

What is now the best way forward?

2. How confident are we that a potentially UV-complete theory of gravity has to be Lorentz invariant, local, causal, unitary, etc.? Which assumptions or principles are more robust vs which ones may well break down in the far UV or far IR, i.e., in experimentally or observationally poorly constrained extreme regimes where GR is most likely to be modified?

quantum gravity (almost) certainly **violates** one of those

But we must recover them with enough precision in the low-energy EFT

Typically hard: example of Lorentz violation

↖

we know because we have a comprehensive EFT framework (aether, khrono-metric, LV SM extension)

To do: develop similar EFT's to test unitarity / causality / locality violation

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How confident are we that a potentially UV-complete theory of gravity has to be:

- **Lorentz invariant?**
- local?
- causal?
- unitary?

Which assumptions or principles are more robust vs which ones may well break down in the far UV or far IR, i.e., in experimentally or observationally poorly constrained extreme regimes where GR is most likely to be modified?

3. Is modified gravity the best approach to solve the (old and/or new) cosmological constant problem?

Hard to tell gravity apart from matter. Perhaps at the inerface

The eventual solution (if not anthropics) will be crazy enough (UV/IR mixing, non-locality, acausality ...)

Recall *Linde (1988):*

$$S = \int dx \sqrt{-g(x)} \int d\tilde{x} \sqrt{-g(\tilde{x})} \left[\mathscr{L}\big(\phi(x)\big) - \mathscr{L}\big(\tilde{\phi}(\tilde{x})\big) \right]$$

symmetry: $x \leftrightarrow \tilde{x}$, $\phi \leftrightarrow \tilde{\phi}$ $\qquad + \Lambda \quad - \Lambda$

classical eqs. unchanged; prediction: DE must be dynamical

but how to make sense quantum mechanically ??

$\Longrightarrow$ topology-changing transition in quantum gravity ?? *Coleman (1988), ...*