

**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

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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)

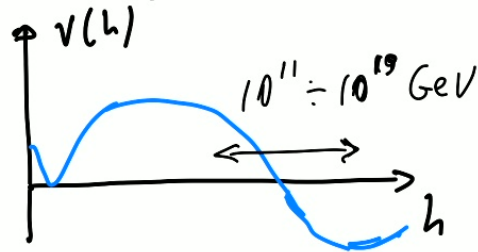
What is now the best way forward?

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

#### player's guide

theoretical control,  
clear principles / symmetries,  
compatibility w. particle physics / QFT  
?? insights: *inflation, SM Higgs metastability, ...*



#### pitfalls

getting to signatures can be hard,  
untestable / ruled out

### bottom-up

data driven,  
clear principles / symmetries,  
compatibility w. particle physics / QFT  
?? insights: *dark matter, ...*

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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 interface

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

Recall *Linde (1988)*:

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

symmetry:  $x \leftrightarrow \tilde{x}, \phi \leftrightarrow \tilde{\phi}$

+  $\Lambda$  -  $\Lambda$

I

classical eqs. unchanged; prediction: DE must be dynamical

but how to make sense quantum mechanically ??

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

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