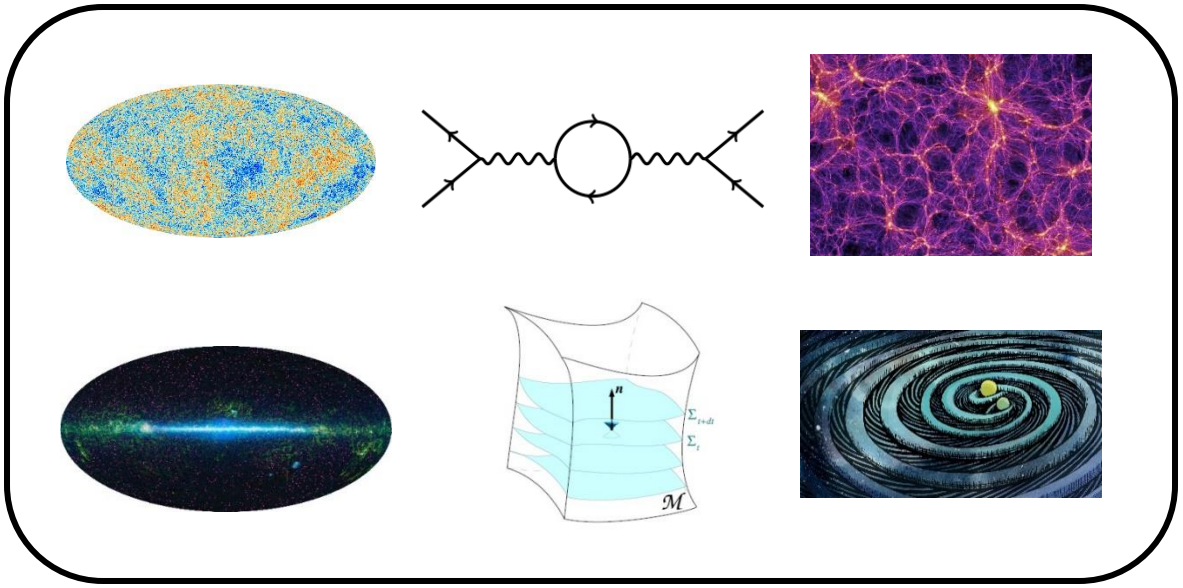
Testing gravity on all scales



Johannes Noller

ICG, University of Portsmouth
DAMTP, University of Cambridge

GR23, Beijing, 05/07/2022

Gravity across scales

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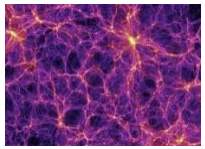
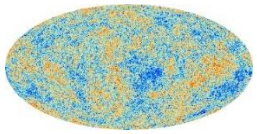
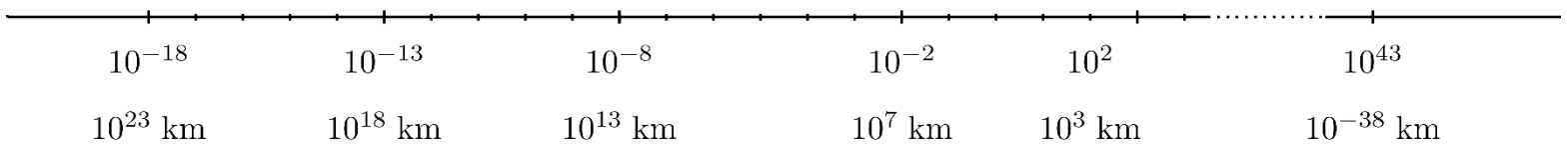
Gravity across scales







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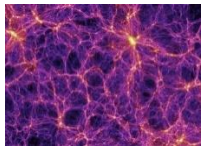

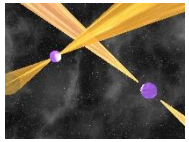

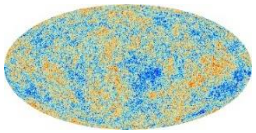

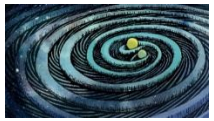

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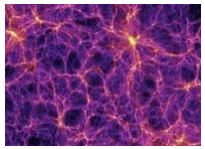
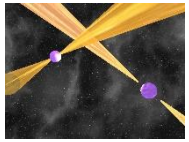
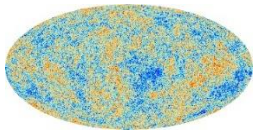
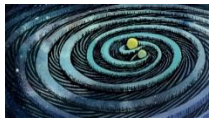
Gravity across scales



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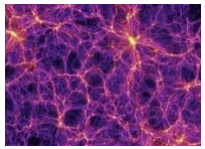
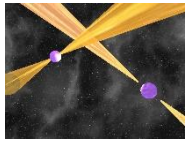

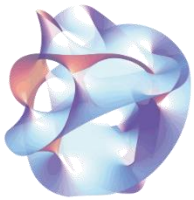
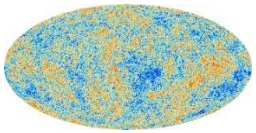


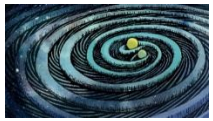

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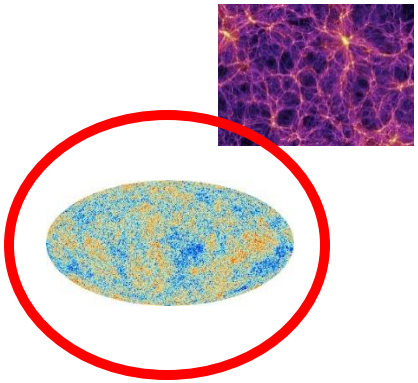

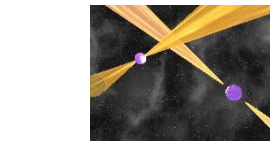

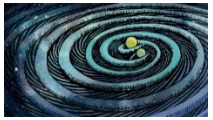

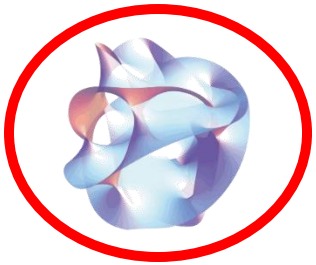

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'Positivity bounds from multiple vacua and their cosmological consequences'

Melville, **JN** *'22, 2202.01222*

The Galileon

The theory:

$$\mathcal{L} = -\frac{1}{2}c_2 \nabla_\mu \phi \nabla^\mu \phi - \frac{c_3}{\Lambda^3} \nabla_\mu \phi \nabla^\mu \phi \nabla_\nu \nabla^\nu \phi + \dots$$

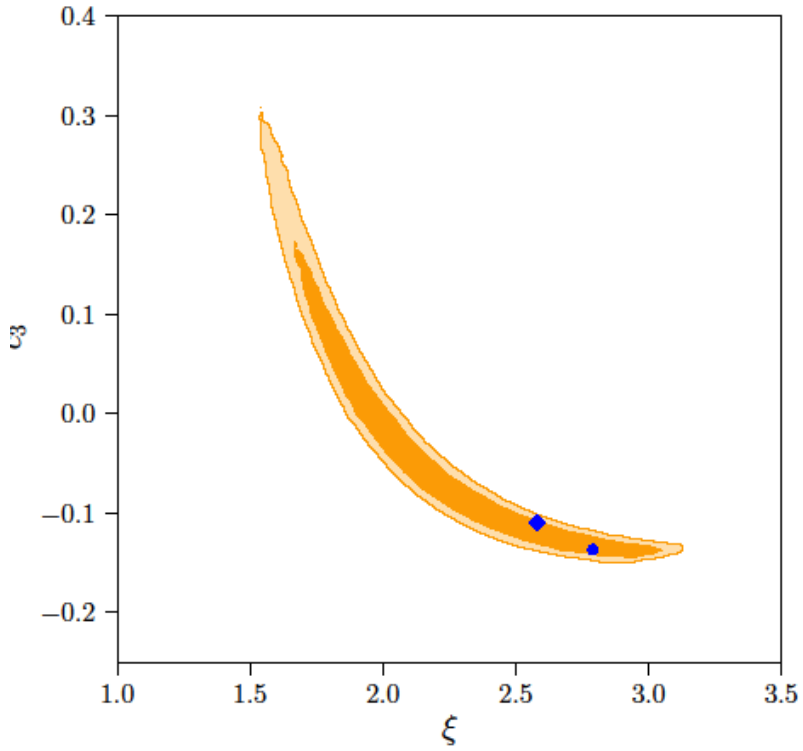
Nicolis, Rattazzi, Trincherini, '08, Deffayet, Esposito-Farese, Vikman '09

Cosmological vacua:

$$\frac{\dot{\phi} H}{\Lambda^3} = \text{constant}$$

De Felice, Tsujikawa, '10

The Galileon



Melville, **JN** *'22*

cf. Renk, Zumalacarregui, Montanari Barreira '17

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'Trivial' vacua:

$$\bar{\phi} = 0$$

'Galileid' vacua:

$$\bar{\phi} = \frac{\Lambda^3}{2}\left(-\alpha t^2 + \beta |\mathbf{x}|^2\right)$$

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Careful with 'naive' application of theoretical priors!

Deffayet, Pujolas, Sawicki, Vikman '10, Barreira, Li, Sanchez, Baugh, Pascoli '13, Traykova, Bellini, Ferreira, Garcia-Garcia, **JN**, *Zumalacarregui '21, Aoki, Mukohyama, Namba, '21*

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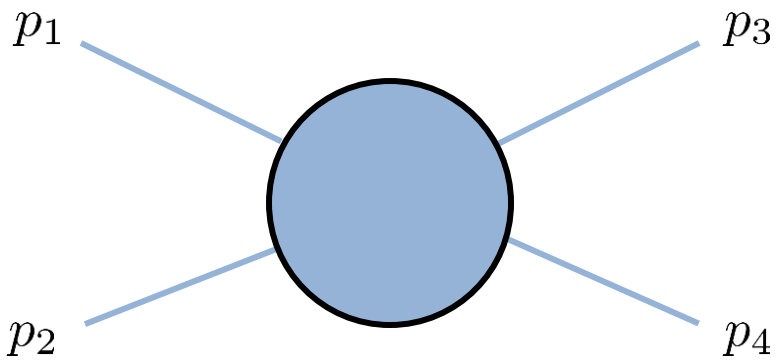
Positivity bounds

Theoretical bounds that any
unitary, local and causal
gravitational theory has to satisfy



Scattering amplitude: $\mathcal{A} = c_{ss} s^2 + \ldots$, where $s = -(p_1 + p_2)^2$

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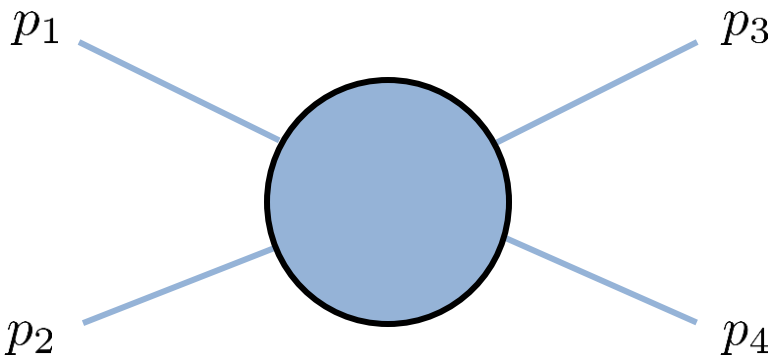

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$$c_{ss} = \frac{1}{2\pi i} \oint_{\mathcal{C}} ds \frac{\mathcal{A}(s)}{s^3} = \ldots = \frac{4}{\pi} \int_0^\infty ds \frac{\sigma(s)}{s^2}$$

Cauchy's theorem

positive(!)

Positivity bounds

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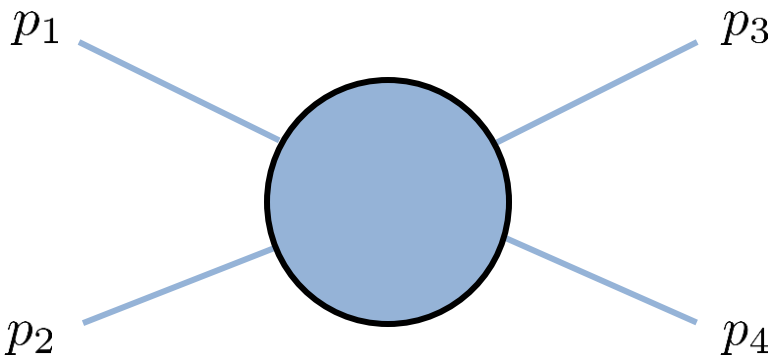

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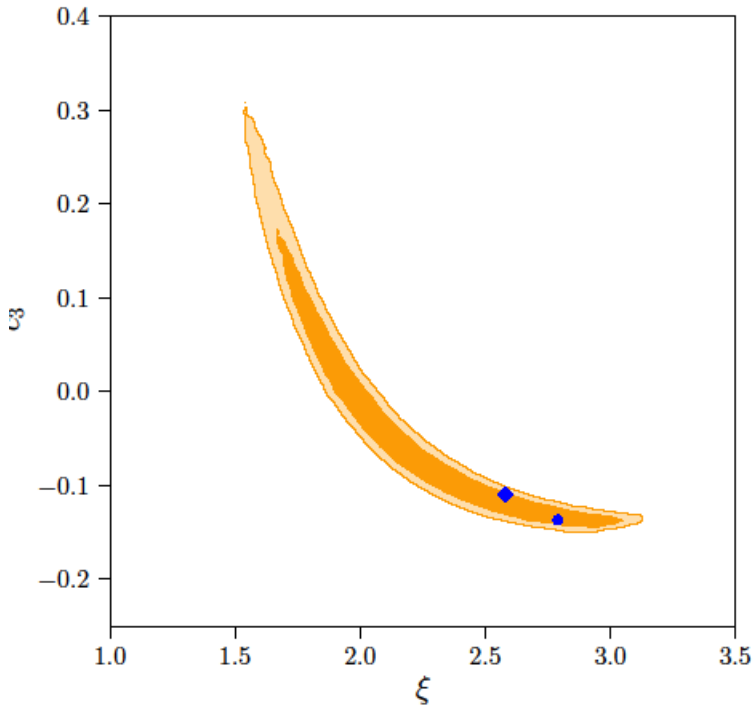
Cosmological positivity bounds: *Adams, Alberte, Aoki, Arkani-Hamed, Baumann, Bellazzini, Bonifacio, Cheung, de Rham, Dubovsky, Grall, Green, Herrero-Valea, Hinterbichler, Huang, Lee, Lewandowski , Melville, Momeni, Mukohyama, Namba, Nicolis, Noller, Porto, Rattazzi, Remmen, Riva, Rosen, Rumbutis, Serra, Sgarlata,Timiryasov, Tokareva, Tolley, Trincherini, Wang, Zhang, Zhou + many, many others!*

Positivity bounds without boosts: *Grall, Melville '21*

The Galileon



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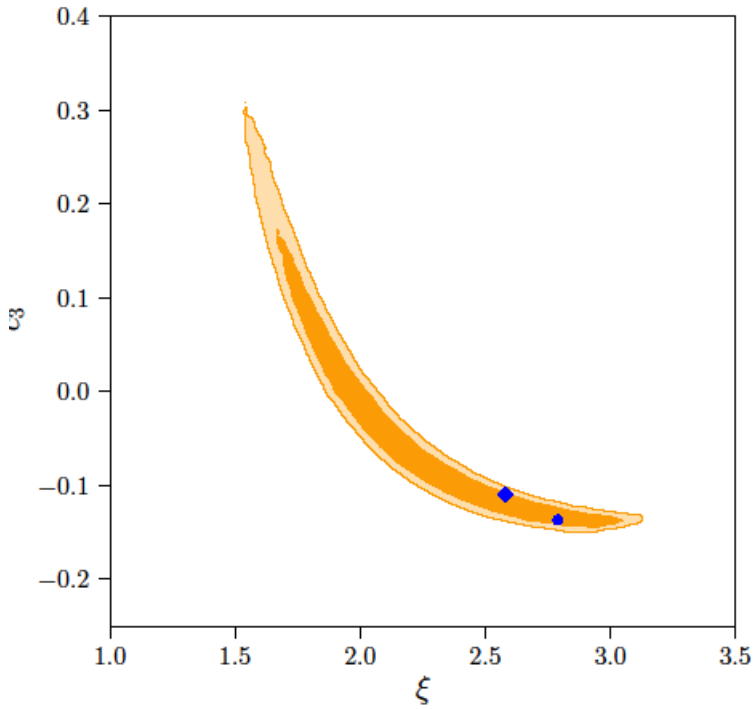

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Galileid vacuum:

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Cosmological vacuum:

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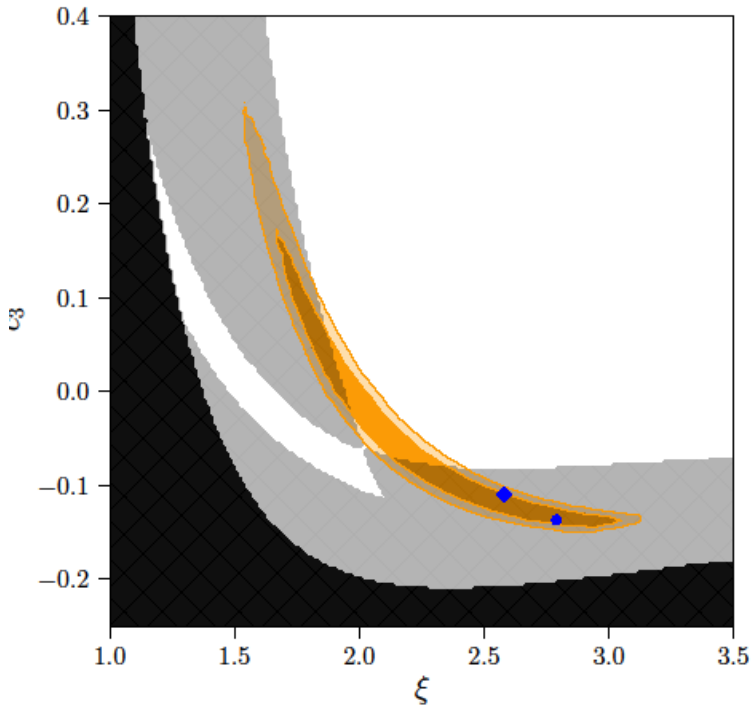
Mapping:

$$\beta \sim -\xi, \quad \alpha/\beta \sim -\dot{H}_i/H_i^2.$$

The Galileon



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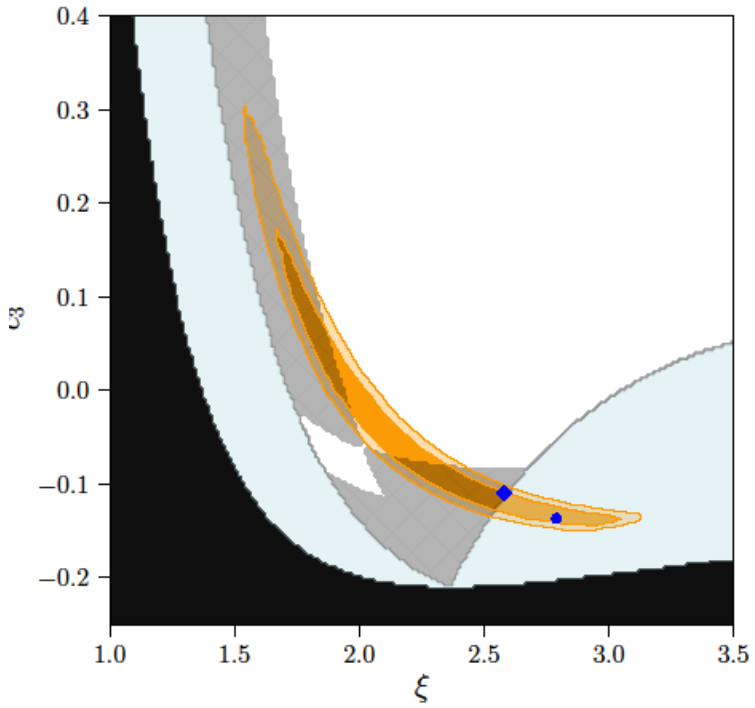

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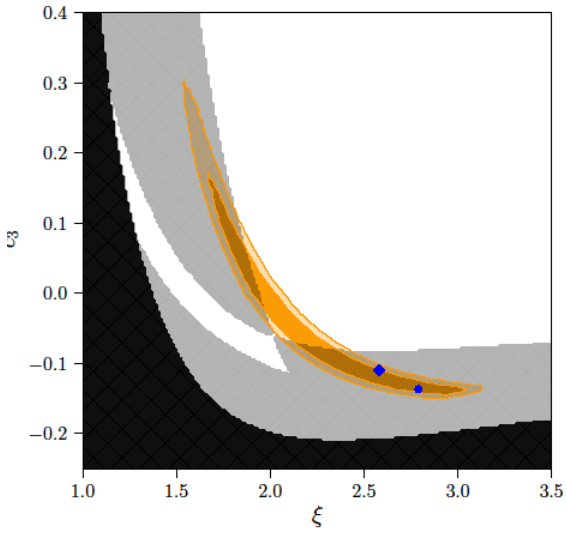
Testing gravity on all scales



Positivity bounds are powerful theoretical priors for observational tests of gravity/cosmology

Observational tests as probes of gravity's UV features

Thank you!