Not so Hidden Fields in Cosmology

Subodh P. Patil

University of Geneva

DESY, Hamburg
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Based on:

I. Antoniadis, S.P.Patil; arXiv:1410.8845

I. Antoniadis, S.P.Patil; arXiv:1510.xxxxx

I. Antoniadis, R. Durrer, S.P.Patil; in preparation

Introductory Remarks

Hidden fields, by definition do not couple at all to the visible sector (i.e. us). However they still gravitate.

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- In 'large' numbers, can consistently generate distinct signatures whose absence can bound the hidden field content of the Universe. (Pt II)

The Effective Strength of Gravity

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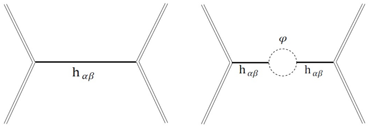
- Positive/negative energy solution attracted/ repulsed from source, effectively anti-screening it. Gravity appears to have gotten 'stronger'.
- N.B. There are many subtleties and caveat emptors when dealing with running quantities in EFT of gravity. (cf. Anber, Donoghue, arXiv:1111.2875; Bjerrum-Bohr et al, arXiv:1505.04974)

The Strong Coupling Scale

More concretely, *every* massive species contributes to lowering the scale at which strong gravitational effects become important.



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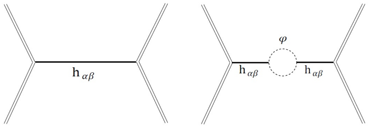

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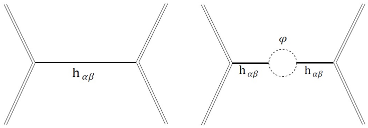

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- In the limit $p^2 \gg M^2$, theory becomes conformal;

$$\langle T(-p)T(p)\rangle \sim \frac{c}{16\pi^2}p^4\log\frac{p^2}{\mu^2}$$

- $c := N = \frac{4}{3}N_\phi + 8N_\psi + 16N_V$ Duff, Nucl. Phys. B 125, 334 (1977)

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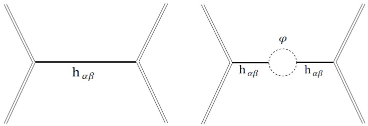

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- Comparison with the free propagator $1/(p^2M_{pl}^2)$ implies that the perturbative expansion fails at $p = M_{**}$ where $M_{**} \sim \frac{M_{pl}}{\sqrt{N}}$.

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Generalized to curved backgrounds, places bounds on maximum allowed curvature.

- $S = \frac{M_{pl}^2}{2}\int d^4x\sqrt{-g}\,R + \int d^4x\sqrt{-g}\left[c_1 R^2 + c_2 R^{\mu\nu}R_{\mu\nu}\right] + \ldots$
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$$S = \frac{M_{pl}^2}{8}\int d^4x\sqrt{-g^0}\left[\dot{h}_{ij}\dot{h}_{ij} - \frac{1}{a^2}\partial_k h_{ij}\partial_k h_{ij}\right]$$

- ... but also get contributions from higher curvature terms s.t.

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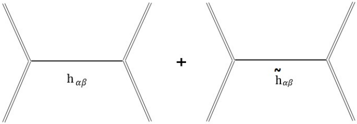
- Expansion breaks down when $H^2 \sim M_{pl}^2/N$.
- Corollary: it is not possible to consistently *infer* a scale of inflation H greater than $M_{pl}/\sqrt{N}$.

The Stength of Gravity

The *strength* of gravity M_* is an independent quantity[1]. Provided we are below M_{**} , any universally coupled species will also affect the *effective strength* of gravity depending on the process in question (equivalence principle, in general violated).

- KK gravitons do so universally for all conserved sources.



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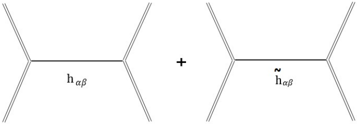

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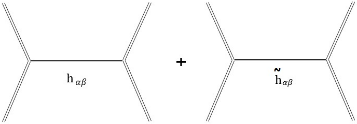

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- $M_*^2 = M_{pl}^2/N_*$, N_* counts the number of species with masses below the momentum transfer of the process in question.

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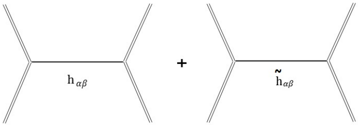

- For KK gravitons with mass M , we have tree level exchange:

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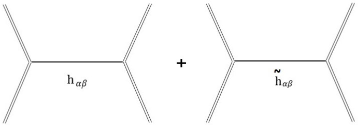

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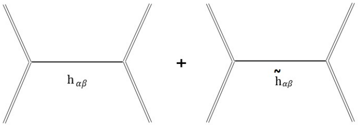

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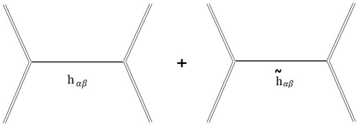

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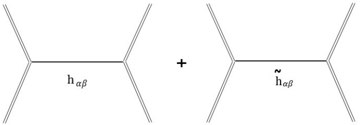

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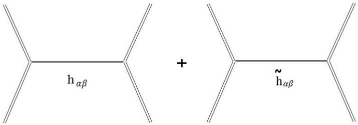

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- Non-minimal couplings do the same. $M_* = M_{pl}/N_*$, N_* a (process dependent) weighted index.

The Stength of Gravity and the Scale of Inflation

It is widely understood that any detection of primordial tensor modes in the CMB determines the scale of inflation. Or does it?

- In foliation were inflaton fluctuations are gauged away (comoving/ unitary gauge):

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The Stength of Gravity and the Scale of Inflation

It is widely understood that any detection of primordial tensor modes in the CMB determines the scale of inflation. Or does it?

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- e.g. $r_* = 0.1$ implies $V_*^{1/4} = 7.6\times 10^{-3}M_{pl}/\sqrt{N_*}$. *Uncertain up to unknown N_* .*

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- Can you really have KK gravitons with masses less than H^2? Higuchi's bound? $m_{KK}^2 \geq 2H^2$, else a ghost propagates.
  Kleban, Mirbabayi, Porrati, arXiv:1508.01527
- One would have a new no go theorem for compactifications were Higuchi's bound to apply to KK gravitons. Explicit constructions show it doesn't (higher dimensional Einstein gravity is a healthy theory.)
  Antoniadis, Patil, arXiv:1510.xxxxx

A Maximally Boring Universe?

Lets say as per the standard picture $M_* = M_{pl}$ all the way up to M_{**} . LHC Run II turns up nothing new. DM is completely non-interacting. We see nothing beyond what is consistent with Gaussian, scale invariant perturbations...

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- ... the non-observation of which could bound the field content of the hidden universe.

Some of the material covered in the second part of the seminar is as of yet unpublished, and so is omitted here. Once published, these slides will be updated....

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