Title: Coupling variations and equivalence principle violations in string inspired scenarios

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Abstract: I will describe how and why coupling variations and violations of the equivalence principle are generally expected in string theory and focus on two main scenarios/realizations: the Damour-Polyakov and the runaway dilaton.

Coupling variations, equivalence principle violations and the runaway dilaton

Federico Piazza

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Plan of the Talk

- Alpha variations and EP violations in scalar tensor theories
- The runaway dilaton

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Coupling variations and extra forces

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$\phi =$dark energy) $$\frac{d\ln\alpha_{EM}}{d\phi}\sqrt{3(1+w)(1-\Omega_m)}$$

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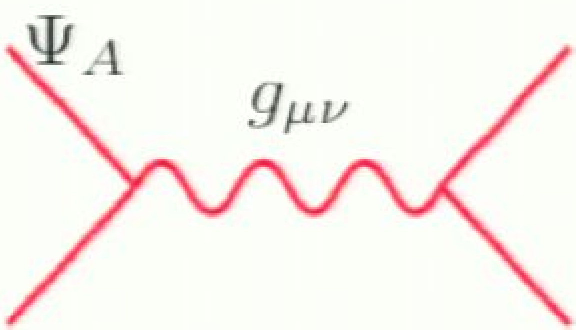

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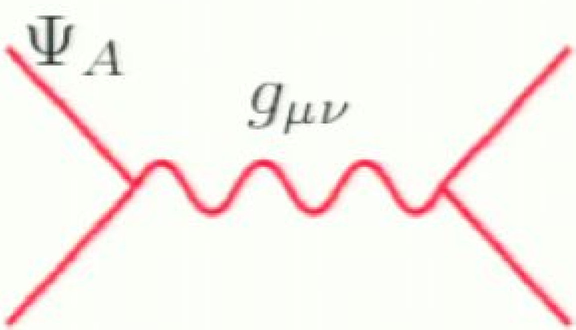

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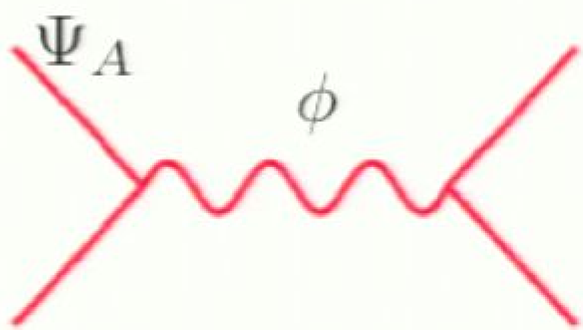

Effective Newton Constant

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$\sim MeV,$ independent (EW) origin

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Dominated by collective Coulomb binding.
Bethe-Weizacker formula:

$$m_{QED} \simeq \alpha_{EM} \frac{Z(Z-1)}{(N+Z)^{1/3}} 100\,\mathrm{MeV}$$

Responsible for Composition Dependent effects.

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(Bertotti et. al. 2003)

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e.g. Dvali Zaldarriaga

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$$c_{\text{had}} = 0 \quad \Rightarrow \quad \frac{d \ln \alpha_{EM}}{d\phi} \lesssim 10^{-4}$$

e.g. Dvali Zaldarriaga

However...

In scenarios where couplings are unified at some scale M_{GUT}, Λ_{QCD} inherits a $\phi-$dependence:

$$\Lambda_{QCD} \simeq M_{GUT}\, e^{-\beta/\alpha_{GUT}}$$

$$c_{\mathrm{had}} = \frac{d\ln\Lambda_{QCD}}{d\phi} \simeq \ln\frac{M_{GUT}}{\Lambda_{QCD}}\,\frac{d\ln\alpha}{d\phi}$$

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$$c_{\rm had} \simeq 30 \frac{d \ln \alpha_{EM}}{d\phi}$$ ⇒ $$\frac{d \ln \alpha_{EM}}{d\phi} \lesssim 10^{-5}$$

e.g. Damour Polyakov 1994

Damour FP Veneziano 2002

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$d\phi$

e.g. Dvali Zaldarriaga

Future experiments (composition-dependent)

MICROSCOPE	10^{-15}
STEP	10^{-18}

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Damour F.P. Veneziano 2002

quintessence/k-essence models:

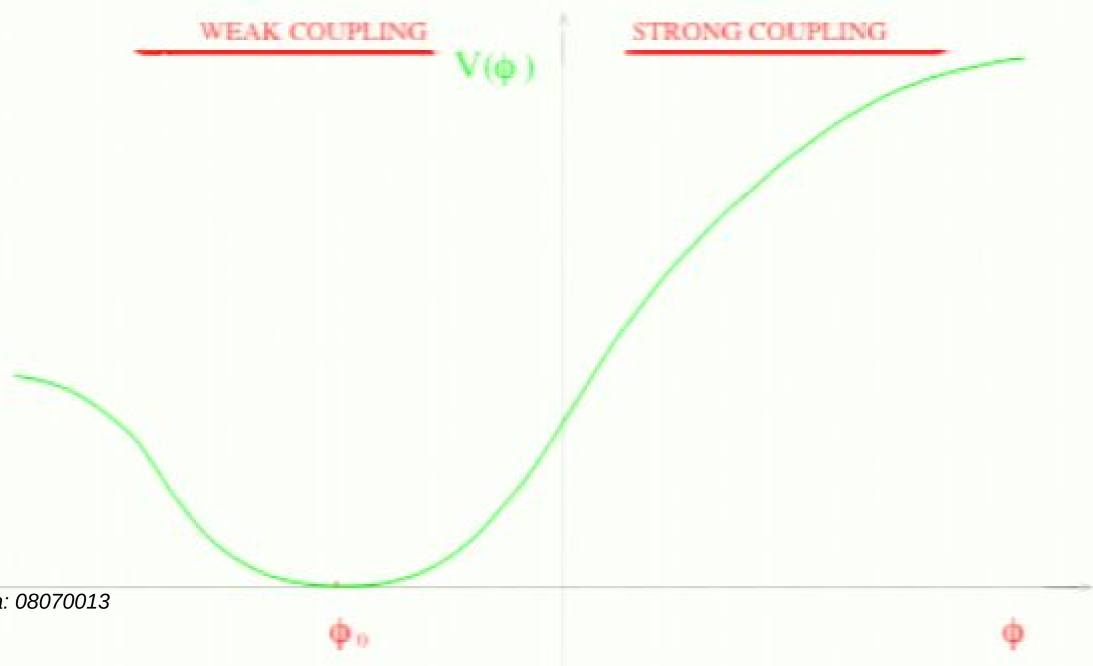
Gasperini F.P. Veneziano 2001
F.P. Tsujikawa 2004

more recently:
Chiba et al. 2007

Gravity and String: “conventional wisdom”

$$S = \frac{M_s^2}{2} \int d^4x \sqrt{-g}\, e^{-\phi} [R + (\nabla\phi)^2 - \frac{1}{4M_s^2} F_{\mu\nu}^2 + \ldots]$$

The dilaton can stabilize with a potential of non-perturbative origin (Taylor Veneziano ‘88)



$$\alpha_{GUT} \simeq e^{\langle\phi\rangle}$$

$$\langle\phi\rangle \simeq -3$$

A toy model (Veneziano 2001)

Gravity + (rank N_1) gauge fields + $N_{1/2}$ fermions + N_0 scalars. Cut off Λ

$$S_0 = \frac{1}{2}\int d^D x\sqrt{-g}\left[\kappa_0^{-2} R - g_0^{-2}\sum_{k=1}^{N_1} F^k_{\mu\nu}F^{k\mu\nu}\right] + + \sum_{i=1}^{N_0} S_{\mathrm{scalar}}[\varphi_i] + \sum_{k=1}^{N_{1/2}} S_{\mathrm{fermion}}[\psi_i]$$

$$\kappa_0^{-2} \implies \kappa^{-2} \simeq \kappa_0^{-2} + \Lambda^{D-2}\mathcal{O}(N) + \dots$$

$$g_0^{-2} \implies g^{-2} \simeq g_0^{-2} + \Lambda^{D-4}\mathcal{O}(N) + \dots$$

Effective couplings

What does that say about string effective action?

$$\Gamma = \frac{M_s^2}{2}\int d^4x\sqrt{-g}\left[B_g(\phi)R + -B_\phi(\phi)(\nabla\phi)^2 - M_s^{-2}B_F(\phi)F^2 + \ldots\right]$$

Cut-off -> $\Lambda \sim M_s$, bare inverse coupling-> $g_0^{-2} \sim e^{-\phi}$

Renormalized inverse coupling-> $g^{-2} \sim B_F(\phi)$

$$B_i(\phi) \underset{\phi\to\infty}{=} C_i + b_i e^{-\phi}$$

$$C_i = \mathcal{O}(10^2)$$
$$b_i = \mathcal{O}(1)$$

ne theory allows a strong coupling, ``runaway" scenario

It's like a ``version at infinity" of Damour-Polyakov

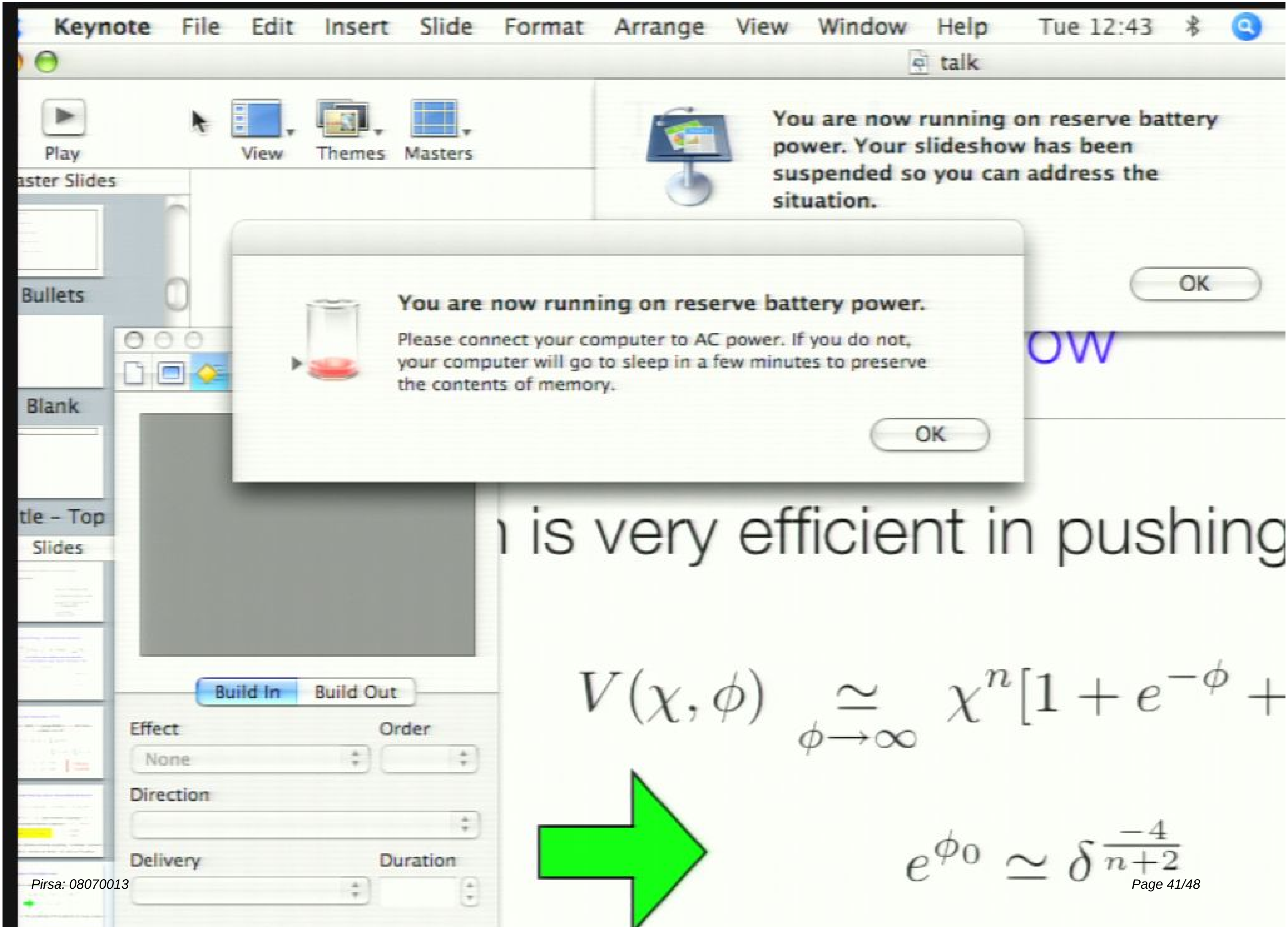
The value of the dilaton now

Inflation is very efficient in pushing $\phi \to \infty$

$$V(\chi, \phi) \underset{\phi \to \infty}{\simeq} \chi^n [1 + e^{-\phi} + \mathcal{O}(e^{-2\phi}]$$

$$e^{\phi_0} \simeq \delta^{\frac{-4}{n+2}}$$

$\simeq 10^{-5}$ is the amplitude of fluctuations on large scales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talk
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Slides
You are now running on reserve battery power. Your slideshow has been suspended so you can address the situation.
OK
You are now running on reserve battery power.
Please connect your computer to AC power. If you do not, your computer will go to sleep in a few minutes to preserve the contents of memory.
OK
ow
is very efficient in pushing
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Effect
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Expected EP violations

$$c_{\rm had} \simeq 40 \cdot \delta_H{}^{\frac{4}{n+2}} \quad \stackrel{n=2}{\simeq} 10^{-4}$$

$$\stackrel{n=4}{\simeq} 10^{-3}$$

Ok with tested composition independent violations

(Bertotti et al: $c_{\rm had} \lesssim 3\ 10^{-2}$)

Expected EP violations

$$\left(\frac{\Delta a}{a}\right) \simeq 10^{-4} \cdot \delta_H{}^{\frac{8}{n+2}} \quad \overset{n=2}{\simeq} 10^{-12}$$

$$\overset{n=4}{\simeq} 10^{-9}$$

Composition dependent: n=4 ruled out. n=2 very close to present experimental limits

EP violations and alpha variations in the runaway dilaton scenario

If the dilaton plays a major contribution today (e.g. quintessence):

$$\frac{d\ln\alpha_{EM}}{H_0\,dt} \simeq \pm 3.5\times 10^{-6}\sqrt{1+q_0-3\Omega_m/2}\sqrt{10^{12}\frac{\Delta a}{a}}$$

$$\frac{\Delta a}{a}\sim 10^{-12} \implies \frac{d\ln\alpha_{EM}}{dt}\sim 10^{-16}\mathrm{yr}^{-1}$$

- Close to present experimental limits
- Difficult to accomodate a $\sim 10^{-5}$ variation at $z\sim 1$

(see however Chiba et al. 2007)