Paulo Santos presents...

Astrophysical constraints on Ungravity inspired models

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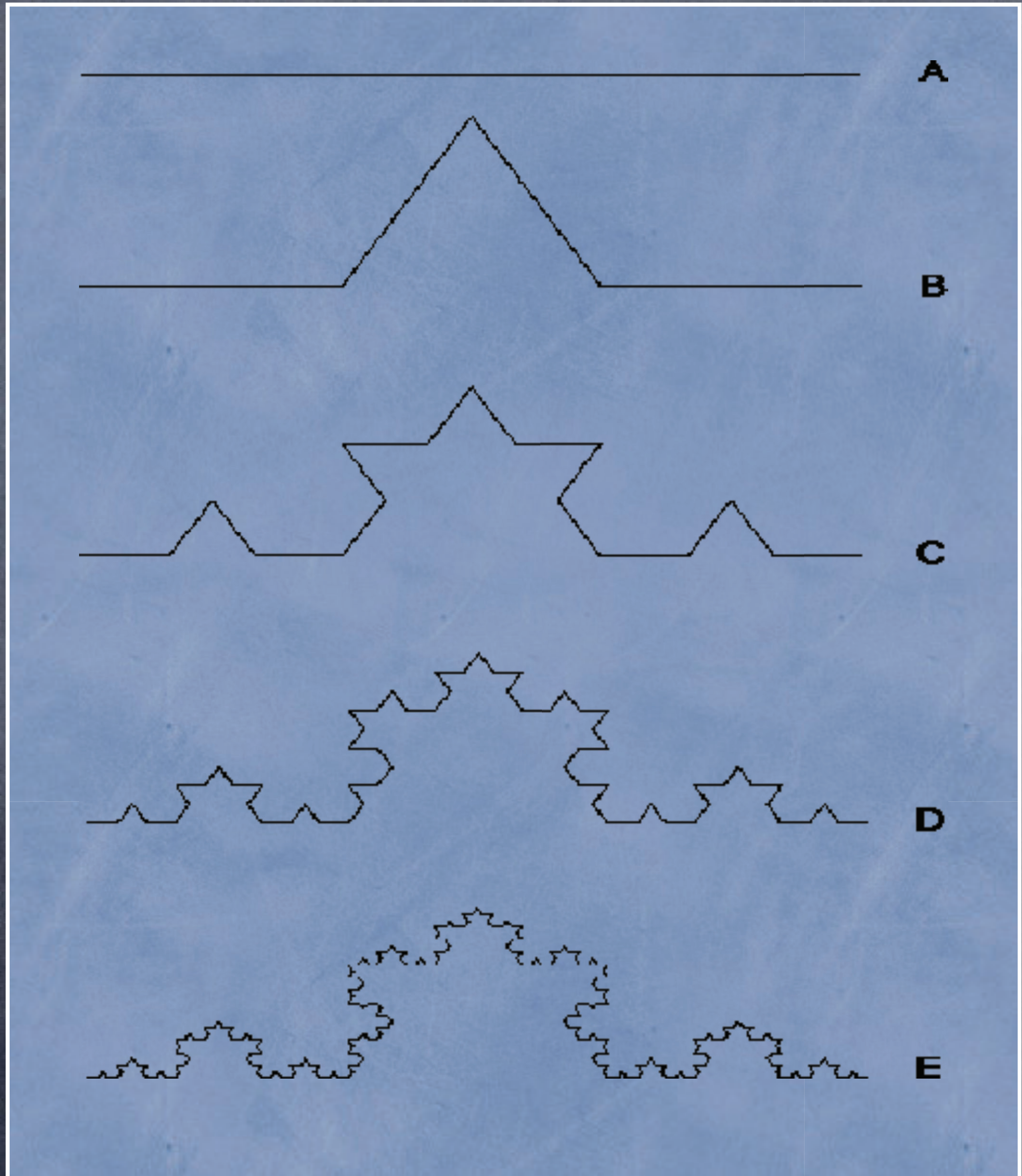
Astrophysical constraints on Ungravity inspired models

Based on work with the same title presented in Physical Review D 80, 022001 (2009)
[arXiv:0905.1602v2 [astro-ph.SR]]

What are Unparticles?

(H. Georgi, 2007)

- Massive Scale Invariant Objects



How to interpret Unparticles?

- Non-integer number of particles
- Tower of continuous mass fields

Ungravity

(H. Goldberg and P. Nath, 2007)

$$V(r) = -\frac{G_U M m}{r}\left[1 + \left(\frac{R_G}{r}\right)^{2d_U - 2}\right]$$

with:

$$R_G = \frac{1}{\pi \Lambda_U}\left(\frac{M_{Pl}}{M_*}\right)^{1/(d_U - 1)} \times \left[\frac{2(2-\alpha)}{\pi}\frac{\Gamma(d_U + \frac{1}{2})\Gamma(d_U - \frac{1}{2})}{\Gamma(2d_U)}\right]^{1/(2d_U - 2)}$$

Ungravity matching the Newtonian potential

(O. Bertolami, J. Páramos and P. Santos, 2009)

- To match the Newtonian potential for the non-interacting cases - $d_U = 1$, $R_G = 0$ (for $d_U > 1$) and $R_G = \infty$ (for $d_U < 1$) - we have:

$$G_U = \frac{G}{1 + \left(\frac{R_G}{R_0}\right)^{2d_U - 2}}$$

- For d_U close to unity:

$$V(r) = -\frac{GMm}{2r}\left[1 + \left(\frac{R_G}{r}\right)^{2d_U - 2}\right]$$

How to test Ungravity?

(O. Bertolami, J. Páramos and P. Santos, 2009)

- Astrophysical constraints using a modified Lane-Emden equation applied to the Sun.

Usual Lane-Emden Equation

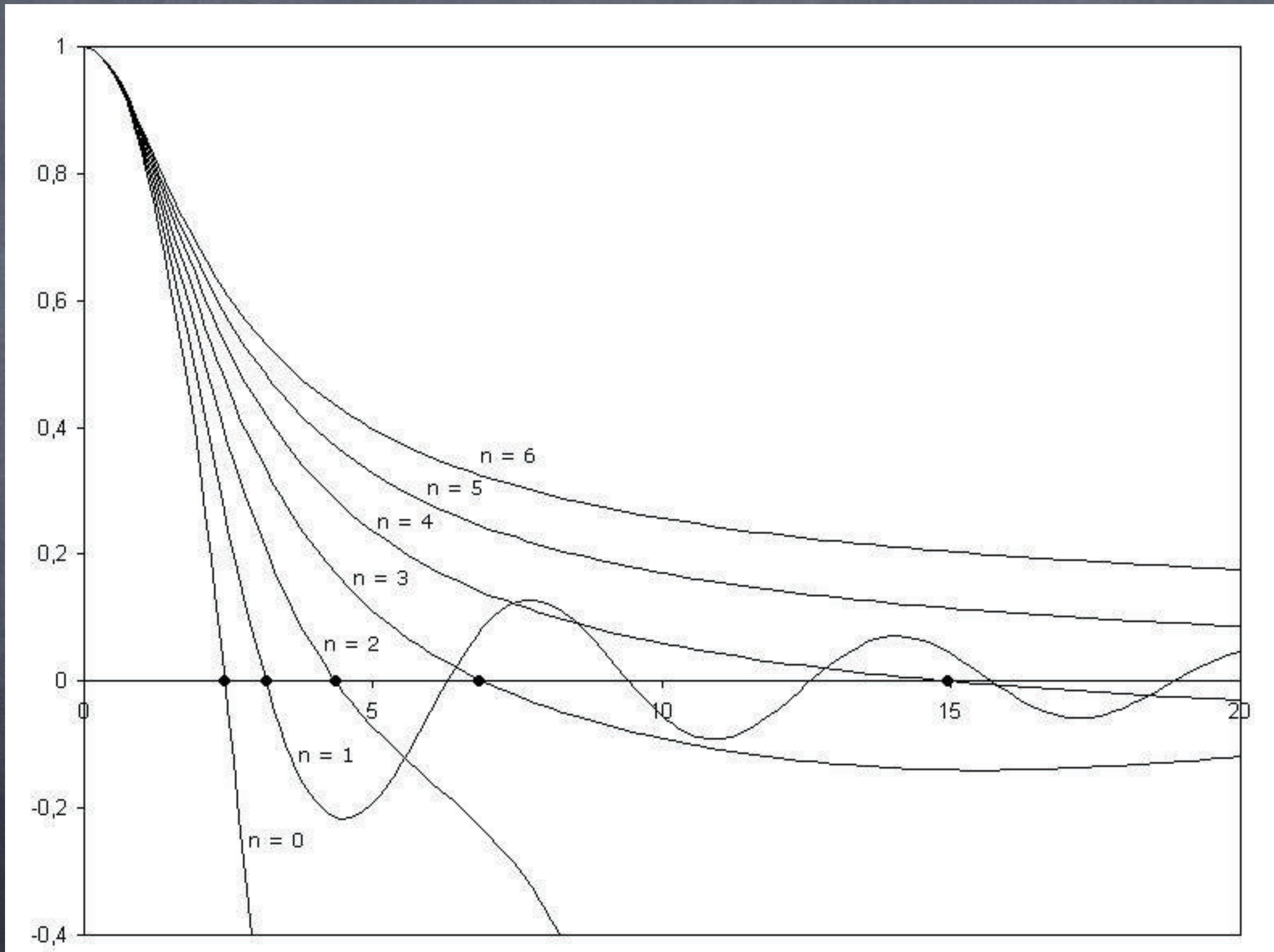
(Wikipedia, for example...)

- Hydrostatic Equilibrium: $$\frac{d}{dr}\left(\frac{r^2}{\rho}\frac{dP}{dr}\right) = -G\frac{dM(r)}{dr}$$

- Mass Conservation: $$\frac{dM(r)}{dr} = 4\pi\rho(r)r^2$$

- Lane-Emden Equation: $$\frac{1}{\xi^2}\frac{d}{d\xi}\left(\xi^2\frac{d\theta_0}{d\xi}\right) = -\theta_0^n$$

A plot of Θ as a function of ξ



Modified Lane-Emden Equation (I)

(O. Bertolami, J. Páramos and P. Santos, 2009)

- Hydrostatic Equilibrium:

$$\frac{r^2}{\rho}\frac{dP(r)}{dr} = -\frac{GM(r)}{2}\left[1 + (2d_U - 1)\left(\frac{R_G}{r}\right)^{2d_U - 2}\right]$$

- Mass Conservation:

$$M(\xi) = -4\pi\left(\frac{(n+1)K}{2\pi G}\right)^{3/2}\rho_c^{(3-n)/2n}\xi^2\frac{d\theta}{d\xi}$$

Modified Lane-Emden Equation (II)

(O. Bertolami, J. Páramos and P. Santos, 2009)

- Modified Lane-Emden Equation:

$$\frac{1}{\xi^2}\frac{d}{d\xi}\left(\xi^2\frac{d\theta}{d\xi}\right) = -\frac{\theta^n}{2}\left[1+(2d_U-1)\left(\frac{\xi_G}{\xi}\right)^{2d_U-2}\right] -$$

$$(2d_U-1)(d_U-1)\frac{1}{\xi}\frac{d\theta}{d\xi}\left(\frac{\xi_G}{\xi}\right)^{2d_U-2}$$

Temperature Method

(O. Bertolami, J. Páramos and P. Santos, 2009)

- 6% is the observational uncertainty for the Sun's temperature - $|T_r - 1| = 6\%$

- Newtonian Temperature / Ungravity Temperature:

$$T_{c0} \propto \left[\xi_{10} \left(\frac{d\theta_0}{d\xi} \right)_{\xi=\xi_{10}} \right]^{-1} \quad , \quad T_c \propto \left[\xi_1 \left(\frac{d\theta}{d\xi} \right)_{\xi=\xi_1} \right]^{-1}$$

- Ratio:

$$T_r \equiv \frac{T_c}{T_{c0}} = \frac{\xi_{10}}{\xi_1} \frac{\frac{d\theta_0}{d\xi}}{\frac{d\theta}{d\xi}}$$

Lower Bound on M*

(O. Bertolami, J. Páramos and P. Santos, 2009)

$$\frac{M_*}{M_{Pl}} > \left[\pi \Lambda_U R_6(d_U)\right]^{1-d_U} f(d_U, \alpha)$$

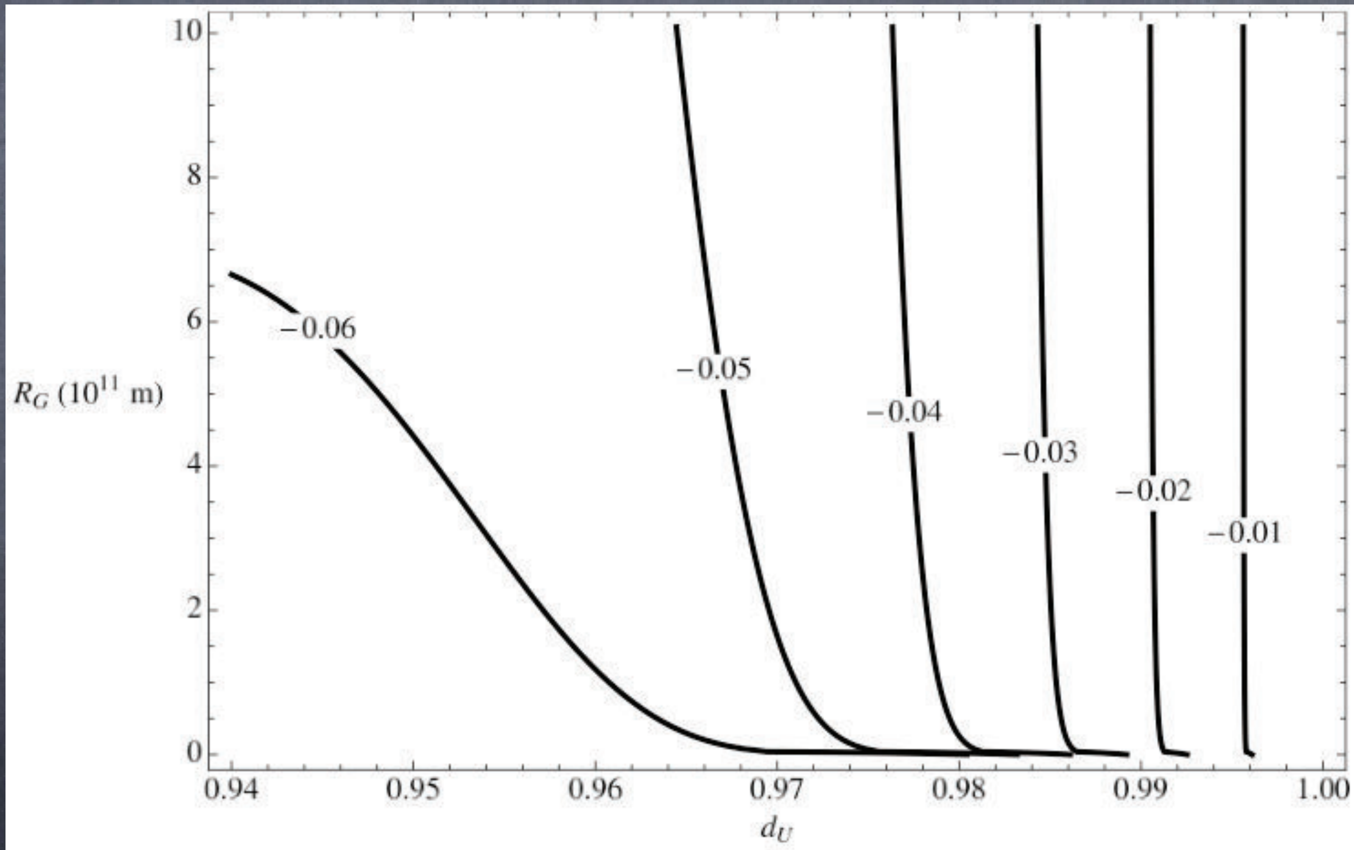
with:

$$f(d_U, \alpha) = \sqrt{\frac{2(2-\alpha)}{\pi} \frac{\Gamma(d_U + \frac{1}{2})\Gamma(d_U - \frac{1}{2})}{\Gamma(2d_U)}}$$

Results

Constraining d_U and R_G (I)

(O. Bertolami, J. Páramos and P. Santos, 2009)

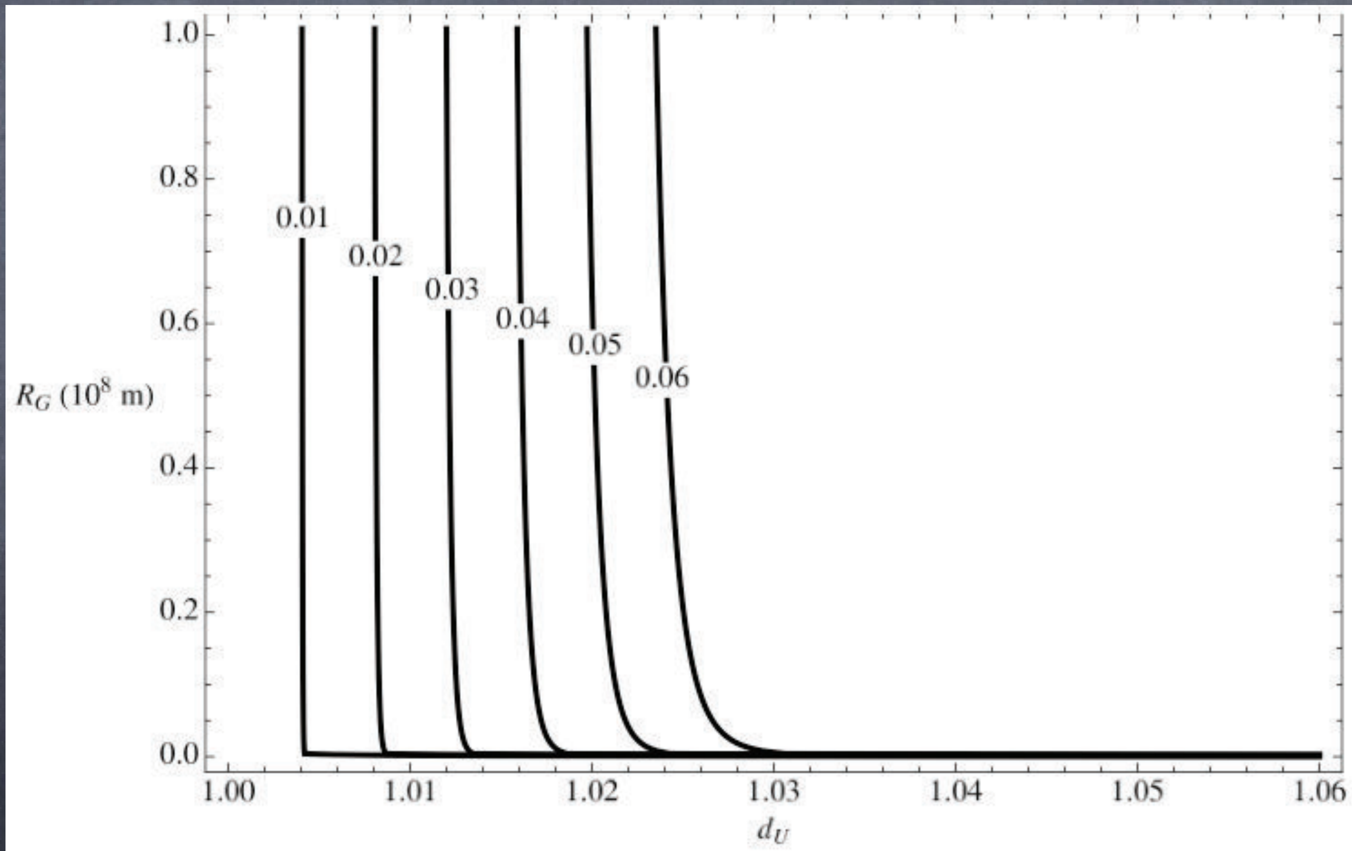


Contour plot of T_r–1 as a function of log R_G and d_U

Results

Constraining d_U and R_G (II)

(O. Bertolami, J. Páramos and P. Santos, 2009)

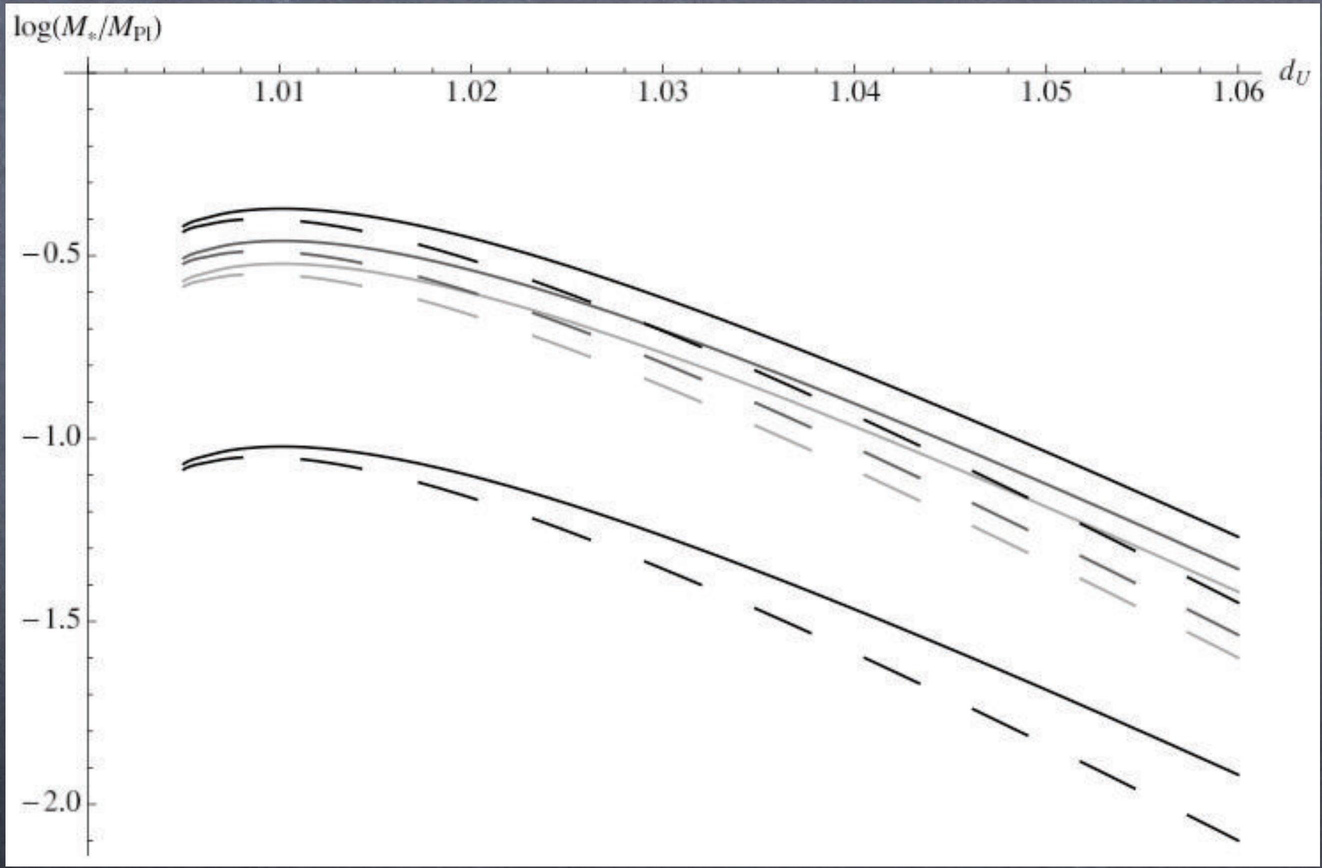


Contour plot of T_r–1 as a function of log R_G and d_U

Results

Constraining M* (I)

(O. Bertolami, J. Páramos and P. Santos, 2009)

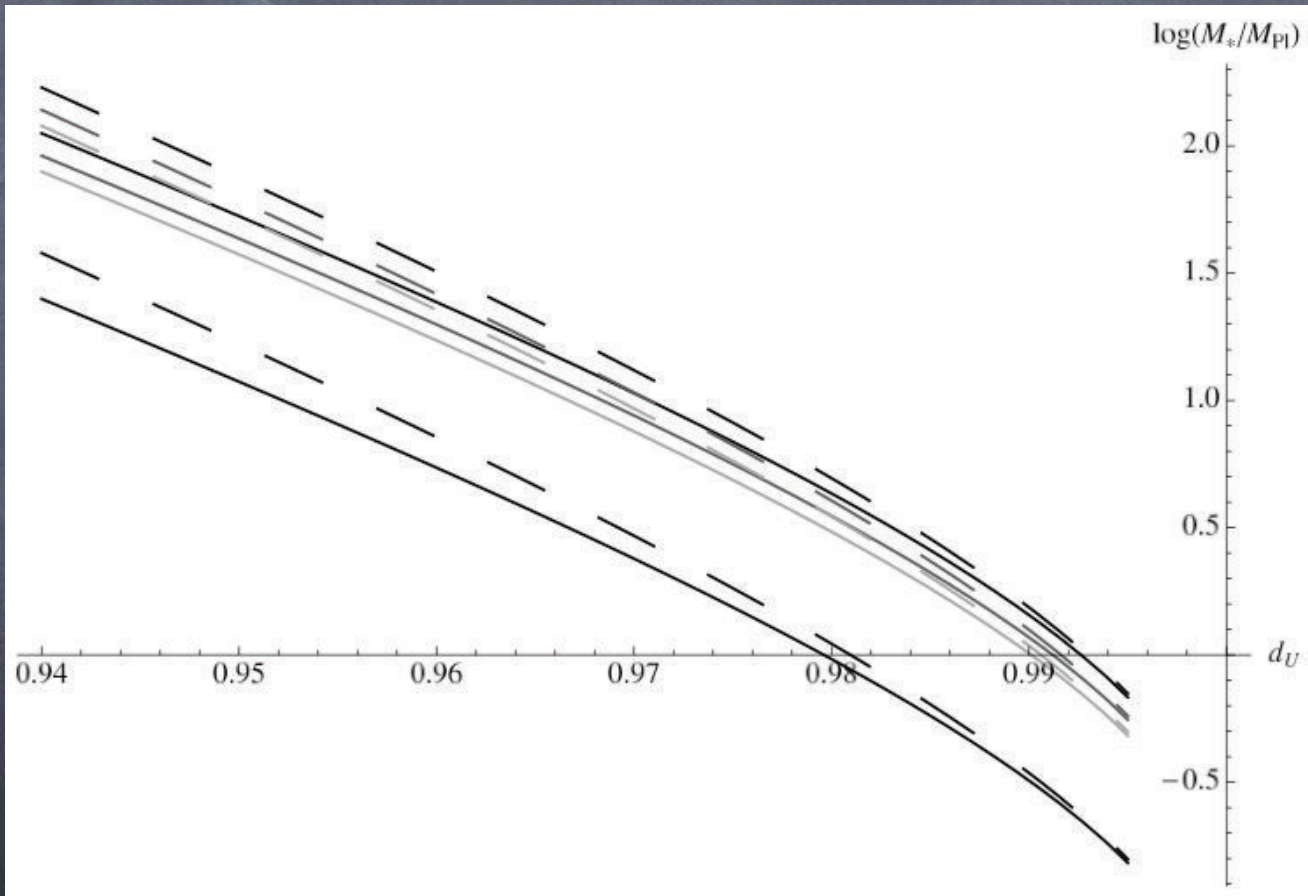


Lower bound of $\log(M_*/M_{Pl})$ for $\alpha=0$ (black), $\alpha=2/3$ (dark grey), $\alpha=1$ (light grey), $\alpha=1.9$ (black, lower curve) and $\Lambda_U=1$ TeV (solid), $\Lambda_U=10^3$ TeV (dashed)

Results

Constraining M* (II)

(O. Bertolami, J. Páramos and P. Santos, 2009)



Lower bound of $\log(M_*/M_{Pl})$ for $\alpha=0$ (black), $\alpha=2/3$ (dark grey), $\alpha=1$ (light grey), $\alpha=1.9$ (black, lower curve) and $\Lambda_U=1$ TeV (solid), $\Lambda_U=10^3$ TeV (dashed)

Previous Constraints

Method	Range of d_U	Lower bound on M_*
Astrophysical Constraints [1]	1 - 2	10^{19} TeV ($1 \leqslant \Lambda_U \leqslant 10^3$ TeV)
Cosmological Constraints [2]	1.1- 2	10 - 10^3 TeV ($\Lambda_U = 1$ TeV)
Ungravity Constraints [3]	2 - 2.2	10^3 - 10^{10} TeV ($1 \leqslant \Lambda_U \leqslant 10^3$ TeV)

[1] S. Das, S. Mohanty and K. Rao, 2008
[2] J. McDonald, 2009
[3] H. Goldberg and P. Nath, 2009

Conclusions

(I)

- Our method allows for obtaining lower bounds for M_*: $(10^{-2} - 10^{-1})\ M_{Pl}$ for $d_U \gtrsim 1$ and $(10^{-1} - 10^{2})\ M_{Pl}$ for $d_U \lesssim 1$, in both cases for $\Lambda_U = 1$ TeV, 10^3 TeV
- The result for $d_U \gtrsim 1$ is at least as stringent as those previously obtained

Conclusions
(II)

- The $d_U \lesssim 1$ case was not examined so far
- The objection for $d_U \lesssim 1$ of quick divergence is only true for $d_U \ll 1$

$$(r/R_G)^{2-2d_U} \approx 1 + 2(d_U - 1)\log(r/R_g)$$