Locally Localized Shock Waves

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N. Kaloper, L.S., JHEP 0508:070,2005 [hep-th/0507191]

Karch-Randall model

Karch & Randall, 2001

=Randall-Sundrum model with
subcritical brane tension

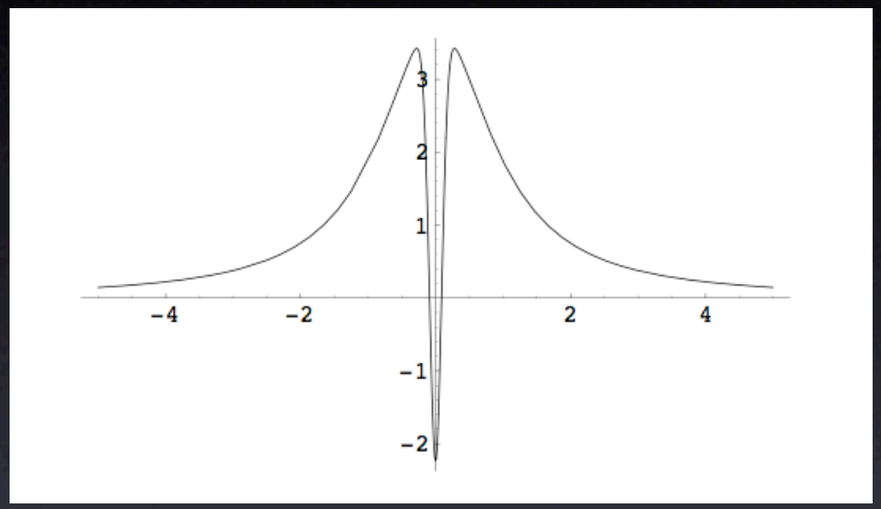
Anti-de Sitter 4d background

Why is it interesting?

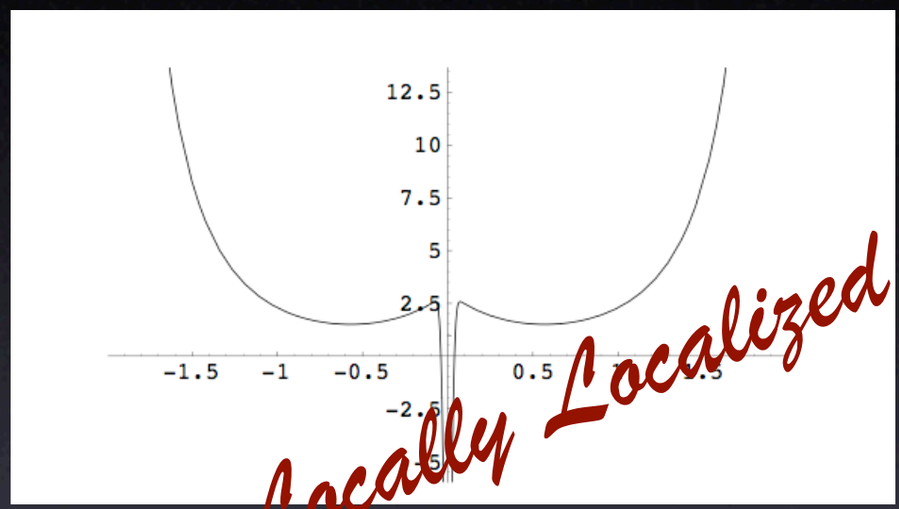
There is no 4d zero mode
of the graviton!

No massless graviton??

Bulk with infinite volume ➡ 4d graviton is a resonance



Randall-Sundrum volcano potential



Karch-Randall volcano potential

Locally Localized Gravity

ℓ =AdS_4 radius
L=AdS_5 radius
} *Ultralight graviton* with $m \sim L/\ell^2$

+ a tower of intermediate mass gravitons, $m_n \sim n/\ell$

+ a tower of heavy gravitons, $m > 1/L$

OK, but...

- How does the potential of a localized source look like?
- How does the graviton couple to matter? (i.e. what is the value of Planck mass?)
- Do we ever see the fifth dimension?

Field of a ultrarelativistic particle

Aichelburg & Sexl, 1971

- Mass μ, momentum $p = \mu v / \sqrt{1-v^2}$
- Limit $v \to 1$, $\mu \to 0$, p finite
- All other terms of the form $\mu^n v / \sqrt{1-v^2}$ vanish for $v \to 1$

Linear equations!

Always possible to find the metric for an ultrarelativistic source: SHOCK WAVE

Locally Localized Shock Waves

Kaloper & LS, 2005

The metric:

$$ds^2 = \Omega^2(|z|)\left[\frac{4\,du\,dv}{(1-uv/\ell^2)^2} - \frac{4\delta(u)\,f\,du^2}{(1-uv/\ell^2)^2} + \ell^2\left(\frac{1+uv/\ell^2}{1-uv/\ell^2}\right)^2(d\chi^2+\sinh^2\chi\,d\phi^2)+dz^2\right]$$

$$\Omega(|z|) = \left[L/[\ell\sin(\tfrac{|z|+z_0}{\ell})]\right]$$

...with...

$$f\,(y,\,\chi) = -\frac{p\,\ell}{2\pi M_5^3 L^2}\int_0^\infty dq\,q\tanh(\pi\,q)\,\times$$
$$\times\sin^2(|y|+y_0)\,\frac{P^{-2}_{iq-1/2}(-\cos(|y|+y_0))}{P^{-1}_{iq-1/2}(-\cos(y_0))}P_{iq-1/2}(\cosh\chi)$$

$$y = z/\ell,\ y_0 = z_0/\ell = \arcsin(L/\ell)$$

Four different regimes!

1. $\mathcal{R} \ll L$: 5d gravity in flat space
2. $L \ll \mathcal{R} \ll \ell$: 4d gravity in flat space (mediated by ultralight graviton)+small corrections from KK modes with $m < 1/\mathcal{R}$

→ running of Planck mass!

$$\frac{1}{M_4^2} = \frac{1}{M_5^3\, L}\left(1 + \mathcal{O}\left(L^2/\ell^2\right)\right)\left(1 + \frac{L^2}{\mathcal{R}^2} + \ldots\right)$$

Cf. Randall-Sundrum

Four different regimes! (Part II)

3. $\ell << \mathcal{R} << \ell^3/L^2$: ultralight graviton dominance. Shockwave as in *massless* 4d AdS gravity.

(Naive guess: mass shows up at $\mathcal{R} \sim 1/m \sim \ell^2/L$.) *Wrong!*

Planck mass:

$$M_4^2 = \frac{2M_5^3\ell}{2\nu+1}\frac{[-\partial_\nu P_\nu^{-1}(-\cos(y_0))]}{P_\nu^{-2}(-\cos(y_0))}\Big|_{\nu=\nu_0} = M_5^3 L\left(1+\frac{5}{12}(\frac{L}{\ell})^2+\ldots\right)$$

$$\nu_0 = [\sqrt{9+4\ell^2 m^2}-1]/2$$

Four different regimes! (Part III)

4. $\mathcal{R} >> \ell^3/L^2$: the mass shows up

(and the 5th dimension too!)

$$f\left(\mathcal{R} > \ell^3/L^2\right) = \frac{4}{3}\frac{p}{\pi M_4^2}\, e^{-\left(2+m^2\ell^2/3\right)\mathcal{R}/\ell}$$

As in massless gravity in AdS_4

As in massive theory in AdS_5!

Conclusions

- Shock wave: first exact solution for a localized source in locally localized gravity
- Different regimes studied
- Expression of 4d Planck mass
- What happens at ultralarge distances?
- CFT interpretation??