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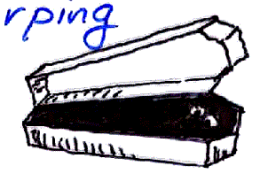
Warped Brane Worlds from 6D ~~Warped~~ Gauged Supergravity

OUTLINE

* MOTIVATION
* 6D SUPERGRAVITIES
* Salam-Sezgin Model
* Branes and Warping
* Self Tuning?
* Where's Waldo?
  (spot the fine tuning...)



MOTIVATION

* Poor Man's Calabi-Yau:
  - chiral fermions, supersymmetry, moduli, moduli stabilization by fluxes, anomaly cancellation....
  - explicit metrics, general solutions
* Brane-Worlds with Back-Reaction
  - generalizes co-dimension 1 examples to co-dimension 2, in a supersymmetric context
  - brane supersymmetry breaking
* Maybe string theory predicts we live here?

6D SUGRAS

* ROMANS SUPERGRAVITY:
  - nonchiral
  - string pedigree
  - AdS-like potential

$$\frac{\mathcal{L}}{e_6} = -\frac{1}{2}R - \frac{1}{2}(\partial\phi)^2 - \frac{1}{12}e^{-2\phi}G_{MNP}^2 - \frac{1}{4g^2}e^{-\phi}F_{MN}^2 \pm c\hat{g}^2 e^{\phi} + \cdots$$

* Salam-Sezgin SUPERGRAVITY:
  - chiral (and anomalous in original version)
  - Green-Schwarz anomaly cancell'n.
  - dS-like potential
  - string pedigree?
    - new 6D sugra (Kerimo + Lü)
    - truncation (Cvetic et al)

S-S SOLUTION

* Ansatz: ϕ = constant

$F_{mn} = f \epsilon_{mn}$ ($n=1$ monopole)

$ds^2 = g_{\mu\nu} dx^\mu dx^\nu + g_{mn} dy^m dy^n$

maximal symmetry: R r — Salam Sezgin

* Stabilization and a Surprise:

$$e_6 \left[-\tfrac{1}{2} R - \tfrac{1}{4g^2} e^{-\phi} F^2 - 2g^2 e^{\phi} \right]$$

$$-\frac{1}{r^2}\left[-\frac{2}{r^2} + \frac{e^{-\phi}}{g^2 r^4} + g^2 e^{\phi} \right]$$

▶ $t = g^2 r^2 e^{\phi}$ fixed

$$-\frac{g^2 e^{\phi}}{r^2}\left(1 - \frac{1}{g^2 r^2 e^{\phi}}\right)^2$$

▶ $s = \frac{r^2}{g^2 e^{\phi}}$ flat

▶ 4D space flat!

* 4D $N=1$ SUSY: — Aghababaie, CB, Parameswaran, Quevedo

$f_{ab} = S\,\delta_{ab} + \ldots$ $\quad K = -\ln(S+S^*) - \ln(T+T^*+V)$

$\xi_{FI} = \text{const}$

** Pope, Guvens, Gibbons: MOST GENERAL NONSINGULAR, MAX 4D sym **

"BRANE" SOLNS

— Navarro — Carroll Guica

* UNWARPED SOLUTION:

$$\frac{g}{\hat{g}} = \frac{N}{1-\epsilon}$$

↳ Scalar Potential
↳ Background F_{mn}
Deficit angle

"Rugby Ball" — A.B.P.Q.

eg: SUSY ADD

* WARPED SOLUTIONS: — A.B., Cline, Firouzjahi, P., Q., Tasinato + Zavala

$$e^{\phi} = \frac{c}{2r} \qquad F_{mn} = \frac{-A}{r^3}\epsilon_{mn}$$

$$ds^2 = 2r\,\eta_{\mu\nu} dx^\mu dx^\nu + h(r) d\theta^2 + \frac{dr^2}{h(r)}$$

$$h(r) = \frac{2M}{r} - \frac{\hat{g}^2}{4} r - \frac{A^2}{r^3}$$

$r_- \le r \le r_+$ $\quad h(r_\pm) = 0$ conical singularity

* TOPOLOGICAL CONSTRAINTS:

$$A\left(\frac{1}{r_-^2} - \frac{1}{r_+^2}\right) = \frac{2N}{\hat{g}}$$

↳ at most one can vanish

$\epsilon(r_+)$ given in terms of $\epsilon(r_-)$

* MOST GENERAL SOLUTION HAS FLAT 4D SPACE!

nonsingular warp
" dilaton
axisymmetric
4D maximal symmetry

Gibbons, Guven + Pope

BRANE PROPERTIES

* What kinds of 3-branes can source these geometries?

if $S_\pm = -\frac{T_\pm}{2}\int_{r_\pm} e^{\lambda_\pm \phi}\sqrt{-\det\gamma}$

then: ϕ nonsingular $\Rightarrow$ $\lambda_\pm = 0$

$T_\pm = 2\pi\epsilon(r_\pm)$

* Coupling to F_{MN}?

$$\Delta S_\pm = q_\pm \int_{r_\pm} *F\, e^{\xi_\pm \phi}$$

- introduces δ-function to F_{mn}
- topological constraint resembles tension constraint

$$\frac{q_+ - q_-}{2\pi} + \frac{1}{g} = \frac{N}{g(1-\epsilon)}$$

WHY FLAT?

* INTEGRATE KK MODES OUT AT TREE LEVEL:

$$\lambda_{eff} = \sum_i T_i + \int_{X_2} e_2 [R + \ldots.]$$

$R = R_{sing} + R_{smooth}$ $\quad R_{sing} = c\sum_i T_i\,\delta^2(x-x_i)$

- R_{sing} cancels $\sum_i T_i$ in λ_{eff} - Chen, Luty + Ponton
- other bulk terms also cancel when other e.o.m. are used.

* RELIES ON CLASSICAL SCALE INVARIANCE OF BULK ACTION
  - Would fail if $\lambda \neq 0$
  - Special case of Weinberg's self-tuning mechanism:

$$g^{\mu\nu}\frac{\delta S}{\delta g^{\mu\nu}} = \frac{\delta S}{\delta \phi}$$ for "dilaton" ϕ

  - Likely not specific to 6D (or 5D)
    - Arkani-Hamed, Dimop., Kaloper, Sundrum
    - Kachru, Schulte + Silverstein

[5D:

when brane placed at singularity, its tension makes 4D cc = 0

OPEN ISSUES

* SOLUTIONS REQUIRE RELATIONS AMONGST BRANE COUPLINGS (CHARGES):
  - tensions related
  - magnetic fluxes related
  - both have a topological origin
  - if so, stable against integration over modes with $\lambda \ll r$?

[TANTALIZING SUSY ADD NUMEROLOGY:
$M_6 \simeq M_W \Rightarrow M_{KK} \simeq 10^{-3}\,eV$ = Bulk susy breaking scale = C.C. scale]

* WHAT HAPPENS IF T ON ONE BRANE CHANGES DUE TO INTERNAL PHYSICS?

* QUANTUM CORRECTIONS:
  - SCALE INVARIANCE IS CLASSICAL
  - m_{KK}^4 = right answer
  - LARGER BRANE CONTRIBUTIONS?

UV: Local in 6D: $\delta\mathcal{L}_{eff} \simeq (M^4 R + M^2 R^2 + R^3 + \ldots)$

$\rightarrow \quad \delta\rho_{eff} \simeq M^4 + M^2 m_{KK}^2 + m_{KK}^4 + \ldots$

Renorm of EINSTEIN? → M^4

Dangerous → $M^2 m_{KK}^2$