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Costas Kounnas Memorial Day

Corfu
4 Sep 2022

Our scientific collaboration

Main theme:

effective d=4 supergravities

from (strings) compactifications

12 papers (<cit>~140) from 1987 to 2005

With continuing friendship, and scientific interactions until Planck 2015 in Ioannina

Aspects touched: susy breaking, mass sum rules, string threshold effects & dualities, gaugings from fluxes, dynamical determination of parameters

In Berkeley (1987-1988)

Effective Superhiggs and Strm2 From Four-dimensional Strings** #13

Sergio Ferrara (CERN and UCLA), Costas Kounnas (LBL, Berkeley and UC, Berkeley), Massimo Porrati (UCLA), Fabio Zwirner (LBL, Berkeley) (Apr, 1987)

Published in: *Phys.Lett.B* 194 (1987) 366-374

DOI cite 60 citations

Superstrings with Spontaneously Broken Supersymmetry and their Effective Theories #11

Sergio Ferrara (CERN and UCLA), Costas Kounnas (Ecole Normale Superieure), Massimo Porrati (UC, Berkeley and LBL, Berkeley and INFN, Padua), Fabio Zwirner (UC, Berkeley and LBL, Berkeley and INFN, Padua) (Aug, 1988)

Published in: *Nucl.Phys.B* 318 (1989) 75-105

DOI cite 306 citations

CERN & ENS part I (1991)

All loop gauge couplings from anomaly cancellation in string effective theories #4

Jean-Pierre Derendinger (Neuchatel U.), Sergio Ferrara (CERN), Costas Kounnas (Ecole Normale Superieure), Fabio Zwirner (CERN) (Sep 3, 1991)

Published in: *Phys.Lett.B* 271 (1991) 307-313

DOI cite 144 citations

On loop corrections to string effective field theories: Field dependent gauge couplings and sigma model anomalies #5

J.P. Derendinger (CERN and Neuchatel U.), S. Ferrara (CERN), C. Kounnas (CERN and Ecole Normale Superieure), F. Zwirner (CERN) (Jun, 1991)

Published in: *Nucl.Phys.B* 372 (1992) 145-188

DOI cite 371 citations

CERN & ENS part II (1994)

Mass formulae and natural hierarchy in string effective supergravities #5

Sergio Ferrara (CERN), Costas Kounnas (CERN), Fabio Zwirner (CERN) (May, 1994)

Published in: *Nucl.Phys.B* 429 (1994) 589-625, *Nucl.Phys.B* 433 (1995) 255-255 (erratum) • e-Print: hep-th/9405188 [hep-th]

pdf DOI cite 219 citations

Towards a dynamical determination of parameters in the minimal supersymmetric standard model #6

Costas Kounnas (CERN), Fabio Zwirner (CERN), Ilarion Pavel (Ecole Normale Superieure) (May, 1994)

Published in: *Phys.Lett.B* 335 (1994) 403-415 • e-Print: hep-ph/9406256 [hep-ph]

pdf DOI cite 77 citations

CERN & ENS part III (2004)


Superpotentials in IIA compactifications with general fluxes #2

Jean-Pierre Derendinger (Neuchatel U.), Costas Kounnas (Ecole Normale Superieure and CERN), P.Marios Petropoulos (Ecole Polytechnique), Fabio Zwirner (CERN and Rome U. and INFN, Rome) (Nov, 2004)

Published in: *Nucl.Phys.B* 715 (2005) 211-233 • e-Print: hep-th/0411276 [hep-th]

pdf links DOI cite 236 citations

And now to today's physics

(unfinished unpublished work with G. Dall'Agata)

Motivation:

two big unanswered long-standing questions

- Stability of D=4 ~Minkowski background
- Dynamical generation of scale hierarchies

can be quantitively addressed in D>4 local susy broken classically by compactification (Scherk-Schwarz, fluxes)

First step:

compute V_1 as function of those background fields that are classically undetermined (no-scale moduli)

V_1 in the REDUCED theory

- Finite # of d.o.f.: those massless for unbroken susy
- $V_{1,red}$ controlled by Str M^n and generically divergent

N=0: Str $M^0 \neq 0$ ($n_B \neq n_F$) => quartic divergence

N=1: Str $M^2 \neq 0$ => quadratic divergence

N=4: Str $M^4 \neq 0$ => logarithmic divergence

N=8: Str M^4 = Str $M^6 = 0$ => finite $V_{1,red} < 0$

=> no locally stable Mink or dS vacuum

Disappointing result, but reduced theory does not capture the full physics of the compactified theory!

V_1 in the COMPACTIFIED theory

- Infinite towers of KK modes (and additional string modes, exponentially decoupling at large volume)
- Non-local susy breaking in the extra dimensions => V_1 is automatically finite for N>0 [Rohm 1984]

Strategy

Focus on those Scherk-Schwarz susy breaking

models that do not require localized defects

⇩

keep maximal control on the effective theory

Two versions of Scherk-Schwarz

- Explicit breaking of d>4 susy by twisted boundary conditions w.r.t. an internal global R-symmetry
- Spontaneous breaking of d>4 susy where twisted b.c. equivalent to VEV of internal spin connection

=> quantized "geometrical fluxes"

Step-by-step understanding:

(i) Start first with D=5 pure sugra on the circle S^1 to understand better how finite V_1 relates with $V_{1,red}$

(ii) Generalize to truly spontaneous breaking (d≥7) e.g. to d=11 sugra as in Scherk-Schwarz 1979

Scherk-Schwarz of N>0 on S^1

$$V_1 = \frac{1}{2}\int \frac{d^4p}{(2\pi)^4} \sum_{n=-\infty}^{+\infty} \sum_{\alpha} (-1)^{2J_\alpha} (2J_\alpha + 1) \log\left(p^2 + m_{n,\alpha}^2\right)$$

$$m_{n,\alpha}^2 = \frac{(n + s_\alpha)^2}{R^2}$$

n is KK level, R is S^1 radius, s_α are Scherk-Schwarz shifts

(neglecting for simplicity susy-preserving masses)

Adapting [Delgado-Pomarol-Quiros 1999], V_1 is finite:

$$V_1 = -\frac{3}{128\,\pi^6 R^4} \sum_{\alpha} (-1)^{2J_\alpha} (2J_\alpha + 1) \left[\mathrm{Li}_5(e^{-2\pi i s_\alpha}) + \mathrm{Li}_5(e^{2\pi i s_\alpha})\right]$$

$\mathrm{Li}_n(x) = \sum_{k=1}^{\infty} x^k/k^n$ are the polylogarithm functions and $\mathrm{Li}_5(1) = \zeta(5) \simeq 1.037$.

Relating V_1 with $V_{1,red}$ (n=0 only)

$V_1 \rightarrow V_{1,red}$ for $|s_\alpha| \ll 1 \leftrightarrow m_{0,\alpha}^2 \ll 1/R^2$
if we cutoff divergent $V_{1,red}$ with $\boldsymbol{\Lambda} \sim 1/R$

$$V_{1,red} = \frac{1}{32\,\pi^2}\,\mathrm{Str}\,\mathcal{M}_0^2\,\Lambda^2 + \frac{1}{64\,\pi^2}\,\mathrm{Str}\,\mathcal{M}_0^4\,\log\frac{\mathcal{M}_0^2}{\Lambda^2}$$

$$\mathrm{Str}\,\mathcal{M}_n^p \equiv \sum_\alpha (-1)^{2J_\alpha}\,(2J_\alpha+1)\,m_{n,\alpha}^p$$

And for $|s_\alpha| \ll 1$:

$$\left[\mathrm{Li}_5(e^{-2\pi\,i\,s_\alpha}) + \mathrm{Li}_5(e^{2\pi\,i\,s_\alpha})\right] = \cancel{2\zeta(5)} - 4\pi^2\,\zeta(3)\,s_\alpha^2 + \frac{\pi^4}{3}\left[\frac{25}{3} - 4\,\log(2\pi)\right]\,s_\alpha^4$$

cancels for N>0

$$-\frac{2}{3}\,\pi^4\,s_\alpha^4\,\log s_\alpha^2 + \ldots .\ O(s_\alpha{}^6)$$

Indeed: $\Lambda \simeq 0.6/R$ for quadr div, $\Lambda \simeq 2.7/R$ for log div

Ex 1: twisted pure N=2, d=5 sugra on S^1

- Single twist parameter a, $V_1 < 0$
- $V_{1,min}$ at fixed R for a=1/2 (mod.1)

$$Str\ \mathcal{M}_0^2 = Str\ \mathcal{M}_n^2 = Str\ \frac{s_\alpha^2}{R^2} = -8\,\frac{a^2}{R^2} < 0$$

Ex 2: twisted pure N=4, d=5 sugra on S^1

- Two twist parameters $a_{1,2}$, $V_1 < 0$
- $V_{1,min}$ at fixed R for $a_1 = a_2 = 1/2$ (mod.1)

$$Str\ \mathcal{M}_0^4 = Str\ \mathcal{M}_n^4 = Str\ \frac{s_\alpha^4}{R^4} = 72\,\frac{a_1^2\,a_2^2}{R^4} > 0$$

Ex 3: twisted pure N=6, d=5 sugra on S^1

- Three indep twists $a_{1,2,3}$, $V_1 < 0$
- $V_{1,min}$ at fixed R for $a_{1,2,3}$=1/2 (mod.1)

$$Str\ \mathcal{M}_0^6 = Str\ \mathcal{M}_n^6 = Str\ \frac{s_\alpha^6}{R^6} = -1440\ \frac{a_1^2\, a_2^2\, a_3^2}{R^6} < 0$$

Ex 4: twisted pure N=8, d=5 sugra on S^1

- Four ind twists $a_{1,2,3,4}$, $V_1 < 0$
- $V_{1,min}$ at fixed R for $a_1=a_2=a_3=a_4$=1/2 (mod.1)

$$Str\ \mathcal{M}_n^8 = Str\ \frac{s_\alpha^8}{R^8} = 40320\ \frac{a_1^2\, a_2^2\, a_3^2\, a_4^2}{R^8} < 0$$

Lessons from computing V_1 on S^1

- No qualitatively new features wrt $V_{1,red}$
- In particular, $V_1 = -k/R^4$ with $k > 0$
- No quantisation of twist parameters
- Leading contribution repeats at each KK level

  Must move to "geometrical fluxes", where:
- Susy breaking spontaneous in the full theory
- Twist parameters quantized
- At least three internal dimensions required

=> KK spectrum much more challenging to get

Technical points to be addressed

- Classify twisted 3-tori with the help of wallpaper groups (discrete subgroups of E_2 that contain two independent translations); combine if possible
- Determine the full KK spectrum: powerful tools developed [Malek-Samtleben 2020] in exceptional field theory (duality-covariant formulation of d>4 supergravity), applied so far mostly to AdS vacua
- Generalise the simple sums on S^1 described today

…work in slow progress…