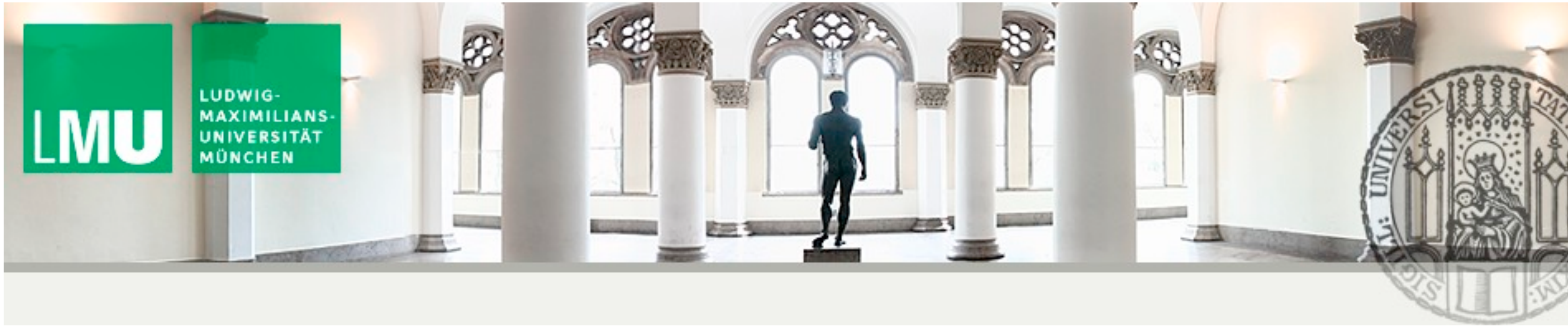


Costas Kounnas: scientific and personal memories

Dieter Lüst, LMU and MPI München

Event in Honour of Costas Kounnas: ENS Paris, 3rd. July 2023

Costas made several very profound and important contributions to theoretical physics !

Problems relevant for the understanding of the universe.

Paired with mathematical depth and rigour.

So let us remind us about a few of his most original contributions.

Supersymmetry and supergravity and their implications in nature




Volume 133B, number 1,2 PHYSICS LETTERS 8 December 1983

NATURALLY VANISHING COSMOLOGICAL CONSTANT IN $N = 1$ SUPERGRAVITY

E. CREMMER
Ecole Normale Supérieure, Paris, France

and

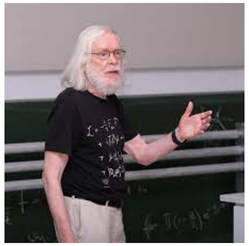
S. FERRARA, C. KOUNNAS and D.V. NANOPOULOS
CERN, Geneva, Switzerland

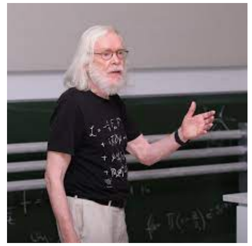
Received 5 September 1983

For $N = 1$ supergravity theories we show that the choice of a particular class of Einstein spaces for the Kähler manifold of the hidden sector leads to a vanishing cosmological constant without unnatural fine tuning. The total scalar potential from the hidden and physical sector is positive definite. The resulting low energy softly broken global supersymmetry for the matter fields is thus the same as in the case of factorized superpotential models with a flat Kähler metric.

The almost vanishing value of the cosmological constant is an old, interesting, but unsolved problem in gravity and more recently in supergravity theories. The experimental upper limit on that quantity is found

planation in the framework of a supersymmetric theory, such as the smallness of non-perturbative effects in QCD which are parametrized by θ_{QCD} ($\theta_{QCD} < 10^{-9}$!) [7].



Nuclear Physics B247 (1984) 373–395

NO-SCALE SUPERSYMMETRIC GUTs

John ELLIS, C. KOUNNAS[1] and D.V. NANOPOULOS

CERN, Geneva, Switzerland

Received 26 March 1984

We construct locally supersymmetric GUTs in which radiative corrections determine all the mass scales which are hierarchically smaller than the Planck mass: $m_{3/2} = \mathrm{O}(m_W) = \exp(-\mathrm{O}(1)/\alpha_t) m_P$, etc. Such no-scale GUTs are based on a hidden sector with a flat potential guaranteed by SU(1, 1) conformal invariance. This is extended to include observable chiral fields in an $\mathrm{SU}(n, 1)/\mathrm{SU}(n) \times \mathrm{U}(1)$ structure reminiscent of $N \geqslant 5$ extended supergravity theories. Tree-level supersymmetry breaking is present only for the gravitino, and for the light gaugino masses through non-minimal kinetic terms reminiscent of $N \geqslant 4$ extended supergravity theories. Radiative corrections generate squark and slepton masses which are phenomenologically acceptable, and the right value of m_W is obtained if $m_t \approx 50$ GeV in the simplest such model.

1. Introduction

Nuclear Physics B250 (1985) 385–426

VECTOR MULTIPLETS COUPLED TO $N=2$ SUPERGRAVITY: SUPER-HIGGS EFFECT, FLAT POTENTIALS AND GEOMETRIC STRUCTURE

E. CREMMER, C. KOUNNAS and A. VAN PROEYEN[1]

Laboratoire de Physique Théorique, Ecole Normale Supérieure, Paris, France*

J.P. DERENDINGER and S. FERRARA

CERN, Geneva, Switzerland

B. de WIT[2]

NIKHEF-H, Amsterdam, The Netherlands

L. GIRARDELLO[3,4]

Dipartimento di Fisica and INFN, Università di Milano, Milano, Italy

Received 24 September 1984

We obtain general properties of $N=2$ gauged extended supergravity coupled to vector multiplets, which can gauge an arbitrary group. General formulas for masses and curvatures are derived. Particular attention is devoted to the scalar potential of the theory which determines the



Nuclear Physics B318 (1989) 75–105
North-Holland, Amsterdam

SUPERSTRINGS WITH SPONTANEOUSLY BROKEN SUPERSYMMETRY AND THEIR EFFECTIVE THEORIES*

Sergio FERRARA

CERN, Geneva, Switzerland
and
Department of Physics, UCLA, Los Angeles, USA

Costas KOUNNAS

LPT, Ecole Normale Supérieure, Paris, France

Massimo PORRATI and Fabio ZWIRNER**

Department of Physics, UCB, Berkeley, USA
and
Lawrence Berkeley Laboratory, Berkeley, USA

Received 21 September 1988

Construction of string theories in four space-time dimensions



Nuclear Physics B2
North-Holland, An

FOUR-DIMENSIONAL SUPERSTRINGS

I. ANTONIADIS*

CERN, Genève, Switzerland

C.P. BACHAS

Centre de Physique Théorique, Ecole Polytechnique, 91128 Palaiseau Cedex, France

C. KOUNNAS**

Lawrence Berkeley Laboratory, Berkeley, California 94720, USA

Received 30 December 1986

We solve completely the constraints of factorization and multiloop modular invariance for closed string theories in which all internal quantum numbers of the string are carried by free periodic and antiperiodic world-sheet fermions. We derive a simple set of necessary and sufficient rules, and illustrate how they can be used to find the spectrum, one-loop amplitudes and low-energy lagrangian of many realistic four-dimensional chiral models. We prove that modular invariance and factorization ensure the presence of a massless graviton and the correct connection between spin and statistics. We also prove that the existence of a massless spin-$\frac{3}{2}$ state ensures the absence of tachyons and the vanishing of the one-loop cosmological constant.

Moduli stabilisation and flux vacua with non-vanishing cosmological constant

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Nuclear Physics B 715 (2005) 211–233

NUCLEAR PHYSICS B

Superpotentials in IIA compactifications with general fluxes

J.-P. Derendinger [a], C. Kounnas [b,c,1], P.M. Petropoulos [d,2], F. Zwirner [c,e]

[a] *Physics Institute, Neuchâtel University, Breguet 1, CH-2000 Neuchâtel, Switzerland*
[b] *Laboratoire de Physique Théorique, Ecole Normale Supérieure, 24 rue Lhomond, F-75231 Paris cedex 05, France*
[c] *CERN, Physics Department, Theory Division, CH-1211 Geneva 23, Switzerland*
[d] *Centre de Physique Théorique, Ecole Polytechnique, F-91128 Palaiseau, France*
[e] *Dipartimento di Fisica, Università di Roma 'La Sapienza', and INFN, Sezione di Roma, P.le A. Moro 2, I-00185 Rome, Italy*

Received 16 December 2004; accepted 25 February 2005

Available online 25 March 2005

Often I was working also on related subjects
(construction of 4-dimensional strings, effective supergravity actions, supersymmetry breaking, fluxes, ..)
and I enjoyed various very nice collaborations with Costas:

Threshold corrections and topological free energy of string compactifications







Nuclear Physics B365 (1991) 431–466
North-Holland

NUCLEAR
PHYSICS B

DUALITY-INVARIANT PARTITION FUNCTIONS AND AUTOMORPHIC SUPERPOTENTIALS FOR (2,2) STRING COMPACTIFICATIONS*

S. FERRARA, C. KOUNNAS**, D. LÜST and F. ZWIRNER***

CERN, CH-1211 Geneva 23, Switzerland

Received 17 June 1991

We define the topological free energy for string compactifications, which is relevant for the discussion of perturbative as well as non-perturbative effects in string theory. This moduli-dependent functional, originating from the integration over massive string modes, is determined by automorphic functions of the target-space duality group. We explicitly construct these automorphic functions for symmetric orbifold and Calabi–Yau compactifications.

1. Introduction

Cosmological and axionic string backgrounds

CERN-TH.6494/92
LPTENS 92-16

Cosmological String Backgrounds from Gauged WZW Models

Costas Kounnas

Ecole Normale Supérieure, Paris, France

and

Dieter Lüst ⋆

CERN, Geneva, Switzerland

Abstract

We discuss the four-dimensional target-space interpretation of bosonic strings based on gauged WZW models, in particular of those based on the non-compact coset space $SL(2,\mathbf{R}) \times SO(1,1)^2/SO(1,1)$. We show that these theories lead, apart from the recently broadly discussed black-hole type of backgrounds, to cosmological string backgrounds, such as an expanding Universe. Which of the two cases is realized depends on the sign of the level of the corresponding Kac-Moody algebra. We discuss various aspects of these new cosmological string backgrounds.

  

CERN-TH.6975/93
HUB-IEP-93/3
LPTENS 93/31
hep-th/9308124

A Large Class of New Gravitational and Axionic Backgrounds for Four-dimensional Superstrings

E. Kiritsis, C. Kounnas*

CERN, Geneva, SWITZERLAND

and

D. Lüst

Humboldt Universität zu Berlin
Fachbereich Physik
D-10099 Berlin, GERMANY

ABSTRACT

A large class of new 4-D superstring vacua with non-trivial/singular geometries, spacetime supersymmetry and other background fields (axion, dilaton) are found. Killing symmetries are generic and are associated with non-trivial dilaton and antisymmetric tensor fields. Duality symmetries preserving N=2 superconformal invariance are employed to generate a large class of explicit metrics for non-compact 4-D Calabi-Yau manifolds with Killing symmetries.

Flux vacua and domain walls

   




Preprint typeset in JHEP style - PAPER VERSION

LPTENS/07/32
LMU-ASC 50/07
MPP-2007-98
CPTH-RR060.0707

AdS_4 flux vacua in type II superstrings and their domain-wall solutions

Costas Kounnas[◇], **Dieter Lüst**[♣♡], **P. Marios Petropoulos**[♠] **and Dimitrios Tsimpis**[♣]

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♣ *Arnold-Sommerfeld-Center for Theoretical Physics*
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Teresienstraße 37, 80333 München, Germany

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Föhringer Ring 6, 80805 München, Germany

♠ *Centre de Physique Théorique, Ecole Polytechnique, CNRS – UMR 7644*
91128 Palaiseau, France

E-mail: kounnas@lpt.ens.fr, luest@theorie.physik.uni-muenchen.de,

Higher curvature gravity and de Sitter space









Page 1 / 14

Fortschr. Phys. **64**, No. 2–3, 176–189 (2016) / DOI 10.1002/prop.201500100

Fortschritte der Physik
Progress of Physics

Original Paper

Aspects of quadratic gravity

Luis Alvarez-Gaume[1,], Alex Kehagias[2,3], Costas Kounnas[4], Dieter Lüst[1,5,6], and Antonio Riotto[3]*

Received 13 December 2015, accepted 13 December 2015
Published online 27 January 2016

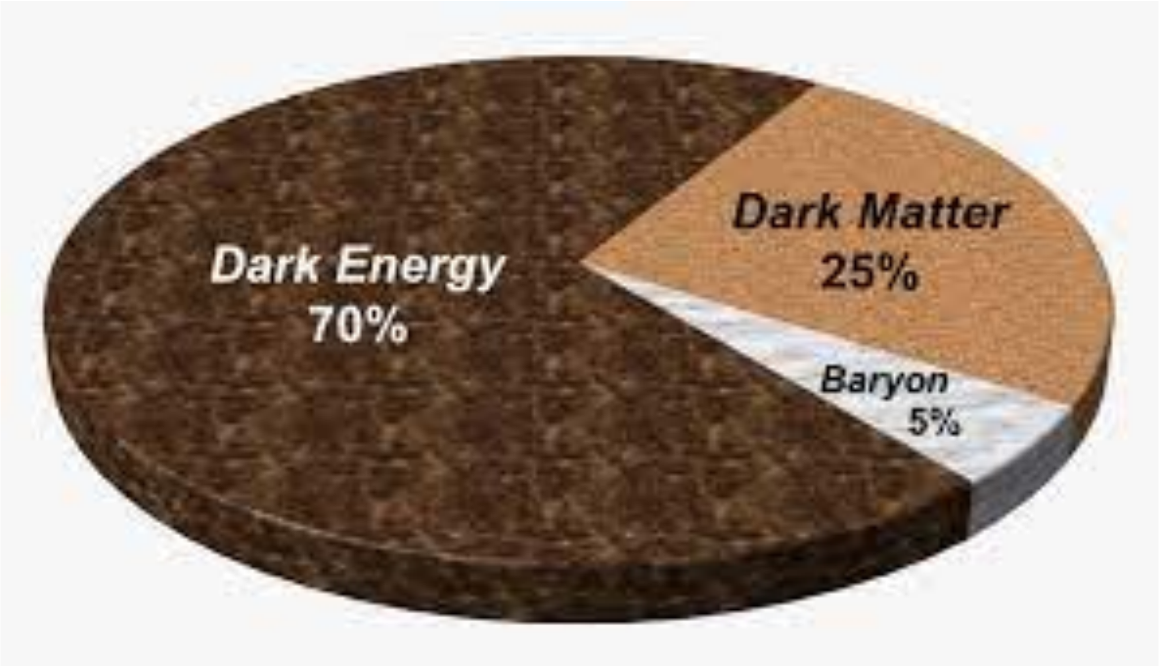
We discuss quadratic gravity where terms quadratic in the curvature tensor are included in the action. After reviewing the corresponding field equations, we analyze in detail the physical propagating modes in some specific backgrounds. First we confirm that the pure R^2 theory is indeed ghost free. Then we point out that for flat backgrounds the pure R^2 theory propagates only a scalar massless mode and no spin-two tensor mode. However, the latter emerges either by expanding the theory around curved backgrounds like de Sitter or anti-de Sitter, or by changing the long-distance dynamics by introducing the standard Einstein term. In both cases, the theory is modified in the infrared and a propagating graviton is recovered. Hence we recognize a subtle interplay between the UV and IR properties of higher order gravity. We also calculate the corresponding Newton's law for general quadratic curvature theories. Finally, we discuss how quadratic actions may be obtained from a fundamental theory like string- or M-theory. We demonstrate

Riemann, the Ricci or the Weyl tensor. Note that, as we will discuss, if only the scalar curvature and its square are included in the gravity action, then, contrary to some people's belief, these theories are indeed physical and do not contain ghost like modes. In fact, the $R+R^2$ theory, known as the Starobinsky model [8], propagates besides the usual massless graviton, an additional massive spin-0 state, known as the "scalaron field" or the so called "no-scale field". After a field redefinition [9], one obtains a scalar field minimally coupled to standard Einstein gravity with a potential making the $R+R^2$ theory particularly appealing for cosmological inflation [10]. The $R+R^2$ theory can also be embedded in supergravity [11], and there is a large amount of recent work on the inflationary predictions of the supersymmetric $R+R^2$ theory [12, 13]. In addition, quadratic gravity theories have also been discussed in particle physics on the basis of their properties under scale transformations. [14].

Although in higher curvature gravity and its solutions [15], a linear Einstein term was assumed to be always

Let me come back to the problem of the cosmological constant.

Energy budget of the universe (cosmic pie):



Dark energy:

$$\Lambda_{cc} \simeq 10^{-122} M_p^4 \simeq (2.31\ meV)^4$$

Small cosmological constant:

Anthropic „explanation“:

[S. Weinberg (1987)]

String landscape: Statistical „explanation“

[R. Bousso, J. Polchinski (2000); M. Douglas (2001), KKLT (2001), …]

General quantum gravity arguments against de Sitter vacua

[G. Dvali, C. Gomez (2014);
G. Obied, H. Ooguri, L. Spodyneiko, C. Vafa (2018)]

Stability and other issues for KKLT in string theory

[I. Bena, G. Giecold, M. Grana, N. Halmagyi (2011);
I. Bena, E. Dudas, M. Grana, S. Lüst (2018);
I. Bena. J. Blabäck. M. Grana, S. Lüst (2020);
S. Lüst, L. Randall (2022)]

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S. Lüst, L. Randall (2022)]

The smallness of the cosmological constant may be linked to the existence of a very large extra dimension of micron size:

Swampland distance conjecture:

[H. Ooguri, C. Vafa (2007)]

Small constants in nature $\leftrightarrow$ large distances in field space of string theory

The Dark Universe

[M. Montero, C.Vafa, I.Valenzuela (2022)]

Consider (meta-stable) vacua with positive cosmological constant and assume that the ADC is still valid :

Cosmological Constant distance conjecture:

[D.L. , E. Palti, C.Vafa (2019)]

The limit of small positive cosmological constant leads to a light tower of states with mass scale m:

$$m \sim \lambda^{-1}\ \Lambda_{cc}^{\alpha}\ M_p^{1-4\alpha} \sim \lambda^{-1}\ 10^{-122\alpha}\ M_p$$

Bounds on the tower mass scale m :

Lowest possible mass from the Higuchi bound (unitarity):

$$m \geq (\Lambda_{cc})^{1/2} \ / M_p$$

Highest possible mass from one-loop potential in string theory (contribution from light modes):

$$m \leq (\Lambda_{cc})^{1/4}$$

So we get: $$\frac{1}{4} \leq \alpha \leq \frac{1}{2}$$

Dark Universe: the tower of states is given by the KK modes of n large, dark dimensions.

Three parameters: $n\,,\ \alpha\,,\ \lambda$

$\alpha = 1/4$ $n = 1$ $\lambda \sim 10^{-3}$

Radius of dark dimension:	$R \sim \lambda \Lambda_{cc}^{-1/4} \sim 1 \mu m$
KK mass scale:	$m_{KK} \simeq \lambda^{-1} \Lambda_{cc}^{1/4} \sim 10^{-1}\ eV$
Related species scale:	$\Lambda_{QG} \simeq 10^{10}\ GeV$

The Dark Universe and SUSY Breaking

[L. Anchordoqui, I. Antoniadis, N. Cribiori, D.L. , M. Scalisi (2023)]

Supergravity scalar potential:

$$V = M_{\rm P}^2 \, e^K (|DW|^2 - 3|W|^2) \, , \qquad M_{3/2}^2 = e^K |W|^2$$

Spontaneous SUSY Breaking $\quad F_\phi = e^{K/2} DW \simeq M_{SUSY}^2 / M_P$

$$\Lambda_{cc} = V \approx 0 \;\Rightarrow\; M_{SUSY} \simeq \sqrt{M_P \; M_{3/2}}$$

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Gauge mediation: $\quad M_{\rm soft} \simeq M_{SUSY} \geq \mathcal{O}(\rm TeV)$

$$M_{3/2} \geq \mathcal{O}(10^{-3} \rm eV)$$

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$$M_{3/2} \geq \mathcal{O}(10^{-3}{\rm eV})$$

Gravity mediation: $\quad M_{\rm soft} \simeq M_{SUSY}^2 / M_P \geq \mathcal{O}(\rm TeV)$

$$M_{3/2} \geq \mathcal{O}(\rm TeV)$$

Gravitino conjecture :

$$m = \lambda_{3/2}^{-1} \left(\frac{M_{3/2}}{M_{\mathrm{P}}} \right)^{\beta} M_{\mathrm{P}} \qquad (\frac{1}{4} \leq \beta \leq 2)$$

[A. Antoniadis, C. Bachas, D. Lewellen, T. Tomaras (1988);
N. Cribiori, M. Scalisi, D.L. ; A. Castellano, A. Font. A. Harraez, L. Ibanez (2021)]

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Combine with the dark dimension: assume one common KK tower with $\alpha = 1/4$

$$\Lambda_{cc} = \left(\frac{\lambda}{\lambda_{3/2}} \right)^4 \left(\frac{M_{3/2}}{M_{\mathrm{P}}} \right)^{4\beta} M_{\mathrm{P}}^4$$

or

$$\Lambda_{cc} = \left(\frac{\lambda}{\lambda_{3/2}} \right)^4 \left(\frac{M_{\mathrm{SUSY}}}{M_{\mathrm{P}}} \right)^{8\beta} M_{\mathrm{P}}^4$$

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or

$$\Lambda_{cc} = \left(\frac{\lambda}{\lambda_{3/2}} \right)^4 \left(\frac{M_{\rm SUSY}}{M_{\rm P}} \right)^{8\beta} M_{\rm P}^4$$

This can be viewed as the leading term of a more general power series expansion:

$$\Lambda_{cc} = M_{\rm P}^4 \sum_{k=1}^{\infty} c'_k \left(\frac{M_{\rm SUSY}}{M_{\rm P}} \right)^{2k}$$

β	$M_{3/2} \times (\lambda_{3/2})^{-\frac{1}{\beta}}$ GeV^{-1}	$M_{\rm SUSY} \times (\lambda_{3/2})^{-\frac{1}{2\beta}}$ GeV^{-1}
$1/2$	2.5×10^{-36}	2.5×10^{-9}
1	2.5×10^{-9}	7.8×10^{4}
$3/2$	2.5×10^{0}	2.5×10^{9}
2	7.8×10^{4}	4.4×10^{11}

$$\beta = 1 \; : \quad M_{SUSY} = \mathcal{O}(\Lambda_{cc}^{1/8}) = \mathcal{O}(1 - 10 \text{ TeV})$$

This is the relevant case for gauge mediation.

$$\beta = 2 \; : \quad M_{3/2} = \mathcal{O}(\Lambda_{cc}^{1/8}) = \mathcal{O}(1 - 10 \text{ TeV})$$

This is the relevant case for gravity mediation.

Microscopic realisation: String compactifiction on an anistropic two-torus with Scherk-Schwarz boundary conditions:

$$V = M_{\rm P}^2\, e^K (|DW|^2 - 3|W|^2)\,, \qquad M_{3/2}^2 = e^K |W|^2$$

$$W = \text{const} \quad , \quad K = -\log\left((-i(\phi - \bar{\phi}))^3 + \xi\right)$$

$$M_{3/2} = \frac{|W|}{\sqrt{(2\text{Im}\,\phi)^3 + \xi}} = \frac{|W|}{(2\text{Im}\,\phi)^{\frac{3}{2}}} + \mathcal{O}(\xi)$$

$$V = 6 M_{\rm P}^2 \xi \frac{|W|^2}{(2\text{Im}\phi)^6} + \mathcal{O}(\xi^2) = \frac{6 M_{\rm P}^2 \xi}{|W|^2} (M_{3/2})^4 + \mathcal{O}(\xi^2)$$

$$m_{KK} = 1/R$$

(In 4D Planck units)

Two-torus: $\text{Im}\phi = R^{2/3} \quad \Rightarrow \quad \alpha = 1/4\,, \;\; \beta = 1$

This is just a variant of the supersymmetry breaking mechanism considered in this paper:

This is just a variant of the supersymmetry breaking mechanism considered in this paper:

Volume 261, number 4 PHYSICS LETTERS B 6 June 1991

Superstring phase transition at high temperature

I. Antoniadis

Centre de Physique Théorique de l'Ecole Polytechnique, F-91128 Palaiseau Cedex, France

and

C. Kounnas

Laboratoire de Physique Théorique de l'Ecole Normale Supérieure [1], *24 rue Lhomond, F-75231 Paris Cedex 05, France*

Received 26 February 1991

We analyse the phase transition of superstring at high temperature. We derive the exact effective potential of the "T-winding" mode which becomes tachyonic above the Hagedorn temperature. We show that in the heterotic case a phase transition occurs which, from the world-sheet point of view, is a generalization of the Kosterlitz–Thouless transition. We derive the conformal field theory describing the new phase and we find that the central charge of the system $\hat{c}$ is lowered by two units. The resulting high-temperature phase then corresponds to a non-critical superstring in $(7+1)$ dimensions. Moreover, the new vacuum exhibits a miraculous "space-like" supersymmetry which leads to the vanishing of the free energy, at least up to the one-loop level. We

Costas as a person :

Unique character

Enthusiastic physicist

Outstanding mentor

Faithful and reliable colleague and collaborator

Warm, helpful and charming person

Person, who liked to enjoy his life and his many friends

Very good friend of mine


Λίθος


Samaria


2185 m
ü.M.


POUR LE
VOISINAGE
SILENCE
FUMEZ


evian


Strings 2002
Cambridge, July 15-20


ERKELEY

Thank you Costas for your outstanding work in science and for being a very nice person and very good friend.