Corfu, September 4, 2022

Kounnas Memorial:

Elias Kiritsis

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Introduction

- I have met Costas at the (in)famous Santa Barbara String Conference in 1986.

- At the time I was a second year graduate student.

- We immediately took a liking to each-other.

- Costas was at the time in Berkeley.

- When I finished, and went to Berkeley for my first postdoc, Costas had left (also Sagnotti, Zwirner,Porrati).

- But when after three years I decided I wanted to return to Europe, I received a postdoc offer from ENS.

- It was clear, that Costas was instrumental in this.

• When I moved to ENS (September 1991) we started discussing physics with him and Paul Windey.

• But I started collaborating with him, later, when we went both to CERN.

• Costas went to CERN as junior staff member in early 1992.

• I followed him in November 1992.

♠ During the roughly 6 years we stayed at CERN we interacted a lot and collaborated in many papers.

♠ Out of the 23 papers we wrote together,21 were written during the period we were both at CERN.

• And a little anecdote on my interaction with Costas at CERN.....

CERN

A LARGE CLASS OF NEW GRAVITATIONAL AND AXIONIC BACKGROUNDS FOR FOUR-DIMENSIONAL SUPERSTRINGS

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Received 17 September 1993

A large class of new 4D superstring vacua with nontrivial/singular geometries, space–time supersymmetry and other background fields (axion, dilaton) are found. Killing symmetries are generic and are associated with nontrivial dilaton and antisymmetric tensor fields. Duality symmetries preserving $N = 2$ superconformal invariance are employed to generate a large class of explicit metrics for noncompact 4D Calabi–Yau manifolds with Killing symmetries. We comment on some of our solutions which have interesting singularity properties and cosmological interpretation.

• This paper was not my idea, and I do not know if it was Costas' or Dieters'.

• There were many things done in this paper:

♠ We found a sequence of string theory solutions with Kähler metric and U(N) isometries.

♠ The first ($N = 1$) was the by that time knowncigar solution (Witten's paper from 1992).

♠ The higher N were generalizations that were shown 10 years later by Hori+Kapustin to correspond to the world-sheet theories of wrapped NS5-branes.

♠ We had shown for the first time that a duality known in Susy sigma models

$$chiral \quad multiplets \quad \leftrightarrow \quad twisted \quad multiplets$$

was equivalent to Bucher duality.

♠ We used it to write explicit metrics for non-compact CY manifolds with isometries and to perform explicit duality transformations.

♠ We knew that compact CY cannot have isometries so we did not pay much attention to this.

♠ But mathematicians use these metrics with some identifications to resolve singularities, and in this way they break the isometries globally (but not locally).

♠ Therefore our duality transformations are also valid for compact CY.

♠ A version of these results was published in a two-volume compendium on CY manifolds edited by Yau
Published in: AMS/IP Stud.Adv.Math. 1 (1996) 427-441.

♠ The Mirror symmetry work of Strominger+Yau+Zaslow is a slightly refined version of our work, tuned to the regular manifolds.

• Somehow our work was not particularly noticed by the CY community.

Topology Change

• I had just finished a paper with A. Giveon, where we worked out the deformed SU(2) WZW model with the J^3 radius R deformation.

• I tried to see if one can find an exact solution to the strings equations by making $R \to R(t)$.

• I found several solutions, which turned out to be T-dual to $SU(2)/U(1) \times SL(2,R)/U(1)$ giving them and exact CFT incarnation.

• At that time we had discussions with Gabriele Veneziano on his pre-big-bang cosmology and his "dilaton bounce": this was a region around the "big-bang" where the theory crossed a non-controllable regime.

• Costas realized that our solutions were examples of topology change: singular geometrically but with non-singular string description, hence the title.

• This rimed with similar ideas of Vafa-Brandenberger.

Dynamical topology change in string theory

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Received 21 April 1994
Editor: L. Alvarez-Gaumé

Abstract

Exact string solutions are presented, providing backgrounds where a dynamical change of topology is occurring. This is induced by the time variation of a modulus field. Some lessons are drawn concerning the region of validity of effective theories and how they can be glued together, using stringy information in the region where the topology changes.

Infrared Regularization and String Thresholds

• Costas had for a long time the idea to replace space in string theory with sphere (SU(2)-WZW model) and use it to calculate thresholds using boosted lattices

• Sometime earlier, a paper calculating for the first time string-one-loop moduli-dependent thresholds to gauge couplings come out (Dixon+Kaplunovsky+Louis) and received a lot of attention.

• In this calculation, the authors had to regulate the IR divergences by hand, breaking modular invariance.

• Our setup could also regulate the IR divergences naturally as the space was compact.

• By making a boost in the $SU(2)_L, SU(2)_R \times G)$ lattice, we could introduce exactly in the CFT, background fields that would give as the gauge coupling corrections including the universal part, bur also the Einstein term renormalization.

• We derived general formulae for both gauge couplings and the Einstein term one-loop thresholds.

• We subtracted properly the IR divergences while preserving modular invariance.

• We derived several R non-renormalization theorems at non-maximal supersymmetry.

• By expanding the partition sums that appeared in the thresholds, we gave explicit formulae for the thresholds.

• In the special case of D+K+L we confirmed their result.

• We have also found PDEs for the regulated thresholds in terms of the IR cutoff and the moduli as parameters.

Infrared regularization of superstring theory and the one-loop calculation of coupling constants

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Received 12 January 1995; accepted 30 March 1995

Abstract

Infrared regularized versions of 4-D $N = 1$ superstring ground states are constructed by curving the spacetime. A similar regularization can be performed in field theory. For the IR regularized string ground states we derive the exact one-loop effective action for non-zero U(1) or chromomagnetic fields as well as gravitational and axionic-dilatonic fields. This effective action is IR and UV finite. Thus, the one-loop corrections to all couplings (gravitational, gauge and Yukawas) are unambiguously computed. These corrections are necessary for quantitative string superunification predictions at low energies. The one-loop corrections to the couplings are also found to satisfy infrared Flow Equations.

• Alas, we did not look at other special cases to write the results in a nicer way.

• A few months later, Harvey and Moore, used our formulae and calculated the full thresholds in the presence of enough susy, and obtained nice holomorphic functions out of the series we derived (and which looked non-holomorphic).

• They interpreted this special result as due to contribution from BPS states only, giving rise to the concept of BPS-saturated amplitudes.

More Thresholds

• One of the problems that was central with thresholds at the time was the "decompactification problem" :

♠ One needed large thresholds to match the gauge couplings (heterotic) but large thresholds meant large compact space (incompatible with data).

• Costas' idea was to protect the thresholds using susy at small copmpactification radii.

Solving the decompactification problem in string theory

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Received 24 June 1996

Editor: L. Alvarez-Gaumé

Abstract

We investigate heterotic ground states in four dimensions in which $N = 4$ supersymmetry is spontaneously broken to $N = 2$. The $N = 4$ supersymmetry is restored at a decompactification limit corresponding to $m_{3/2} \to 0$. We calculate the full moduli-dependent threshold corrections and confirm that they are suppressed in the decompactification limit, as expected from the restoration of $N = 4$ supersymmetry. This should be contrasted with the behaviour of the standard $N = 2$ ground states, where the couplings blow up linearly with the volume of the decompactifying manifold. This mechanism provides a solution to the decompactification problem for the gauge coupling constants. We also discuss how the mechanism can be implemented in ground states with lower supersymmetry.

• "Learning" from the Harvey+Moore paper, again with Marios Petropoulos and Giannis Rizos we did a careful, and wide analysis of thresholds in many cases, and derived holomorphic formulae for them

Universality properties of $N = 2$ and $N = 1$ heterotic threshold corrections

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• And we generalized them further in vacua with spontaneously broken susy:

String threshold corrections in models with spontaneously broken supersymmetry ⋆

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• In a different direction, with more collaborators, we decided to look at R^2 thresholds in models with at least N=2 susy in 4d.

• We found all BPS saturated cases and rewrote the thresholds in terms of helicity super-traces that filter BPS states.

• The helicity super-traces proved central in later computations of black-hole entropy in string theory.

R^2 corrections and non-perturbative dualities of $N = 4$ string ground states

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Abstract

We compute and analyse a variety of four-derivative gravitational terms in the effective action of six- and four-dimensional type II string ground states with $N = 4$ supersymmetry. In six dimensions, we compute the relevant perturbative corrections for the type II string compactified on $K3$. In four dimensions we do analogous computations for several models with $(4,0)$ and $(2,2)$ supersymmetry. Such ground states are related by heterotic-type II duality or type II–type II U-duality. Perturbative computations in one member of a dual pair give a non-perturbative result in the other member. In particular, the exact CP-even R^2 coupling on the $(2,2)$ side reproduces the tree-level term plus NS 5-brane instanton contributions on the $(4,0)$ side. On the other hand, the exact CP-odd coupling yields the one-loop axionic interaction $aR \wedge R$ together with a similar instanton sum. In a subset of models, the expected breaking of the $SL(2,Z)_S$ S-duality symmetry to a $\Gamma(2)_S$ subgroup is observed on the non-perturbative thresholds. Moreover, we present a duality chain that provides evidence for the existence of heterotic $N = 4$ models in which $N = 8$ supersymmetry appears at strong coupling. © 1998 Elsevier Science B.V.

Supersymmetry breaking

• In 1989 Costas together with S. Ferrara, F. Zwirner and M. Porrati invented the string models with Sherk-Schwartz-like supersymmetry breaking.

• Their construction was at the level of partition function and involved a (L,R) boost in the combined compactification and supersymmetry lattice.

• It was not entirely clear though what the CFT was in conventional terms, and how to compute amplitudes.

• By 1997 we realized that the CFT description of these theories was in terms of freely acting orbifolds acting both by translating a compactification lattice and twisting the susy part.

• The advantage was that now one could compute amplitudes.

• We also made some non-perturbative conjectures on the spectrum of BPS specta following a similar conjecture for the N=4 case by Dijkgraf+Verlinde[2].

Perturbative and non-perturbative partial supersymmetry breaking: $N = 4 \longrightarrow N = 2 \longrightarrow N = 1$

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Costas

- There are two words that describe the essence of Costas:

♠ Generosity!

♠ Passion!

- All the people who knew him would easily recognize both.

- Although at times he could be difficult, I am extremely grateful to him as he treated me as his child, he taught me a lot of physics I did not know and he helped me in my academic carrier.

- And this he did for many other young physicists.

The Photos

CERN circa 1997-1998:+Marie Noëlle

CERN circa 1996:+Ioannis Bakas

CERN circa 1997:+Luis Alvarez-Gaumé

CERN circa 1995-6:as Kounocles +Kiritotle+John Ellis +Mathias Staudacher

CERN circa 1997:+Dieter Lust+Elena Gianolio+Cinzia DaVia

Kolymbari 2001: with Eliezer Rabinovici at Crete Regional Meeting

Paris 2001: with Ignatios Antoniadis, John Iliopoulos, Miguel Virasoro and Giorgio Parisi

Kolymbari 2004, Van-Proeyen RTN Meeting: with Niels Obers

Kolymbari 2004, Van-Proeyen RTN Meeting: with Nikos Toumbas and Marios Petropoulos

Kolymbari 2004, Van-Proeyen RTN Meeting: at Falassarna beach with Fabio Zwirner, Jean Pierre Derendinger and Dieter Lust

Kolymbari 2004, Van-Proeyen RTN Meeting: with Jean Pierre Derendinger and Luis Alvarez Gaume

Corfu 2005: with Kelley Stelle, Anna Ceresole and Dieter Lust

Cyprus 2012: with Elena Gianolio

Cyprus 2012: with Sergio Ferrara and John Ellis

Cyprus 2012: with Paul Windey, Elena Gianolio and Dieter Lust

Kolymbari 2013, Crete Regional Meeting: with Costas Bachas and Eliezer Rabinovici

Nauplion 2015, Crete Regional Meeting: with Andy Strominger

Costas flying .....

THANK YOU!

pp-waves

String propagation in gravitational wave backgrounds

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Received 3 November 1993

Superstring gravitational wave backgrounds with spacetime supersymmetry

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Received 20 April 1994

• These works were after Witten+Nappi paper on the WZW model of the Heisenberg group (a central extension of the ISO(2) group).

• In the first paper the idea was to simplify the CFT dynamics by showing the theory is euivalent to some free bosons, two forming a continuous orbifold with twist p_+.

• THis opbservation was enough to proceed to solve the model, but we did not go all the way.

• In the second paper (with Dieter also) we implemented space-time supersymmetry in such pp-wave backgrounds.

• Much later pp-waves returned to fashon after the BMN limit in AdS/CFT (Berenstein+Maldacena+Nastase)

• With G. D'Appollonio and M. Bianchi we solved complete the CFTs both in the closed sector and the open sector, using the continuous orbifold idea.

Detailed plan of the presentation

- Title page 0 minutes
- Introduction 2 minutes
- CERN 5 minutes
- Topology Change 7 minutes
- IR regularisation and string thresholds 10 minutes
- More thresholds 13 minutes
- Supersymmetry breaking 15 minutes
- Costas 16 minutes
- Photos 19 minutes

- pp-waves 21 minutes