The PhD Students of Ignatios

Stefan Hohenegger
(IP2I Lyon)

Ignatios Fest (Planck 2022)

(03/June/2022)

PhD Students of Ignatios

Karim Benakli (1994)

Hervé Partouche (1997)

Boris Pioline (1998)

Alexandre Laugier (2002)

Marc Tückmantel (2005)

Tristan Maillard (2006)

Stefan Hohenegger (2008)

Panteleimon Tziveloglou (2011)

Binata Panda (2012)
with Alok Kumar

Ahmad Zein Assi (2013)

Rob Knoops (2016)

Chrysoula Markou (2018)

Ioannis Mitsoulas (2019)
with Ioannis Bakas

Yifan Chen (2019)
with Karim Benakli

Osmin Lacombe (2021)

François Rondeau (in prep.)

Anthony Guillen (in prep.)

Topics:

1) Supersymmetry

2) (String) Dualities

3) Moduli Stabilisation with Magnetic Fluxes

4) BPS Amplitudes and Topological String Theory

5) de Sitter Vacua in SUGRA and Cosmology

6) Extra Dimensions and String Phenomenology

Supersymmetry

Karim Benakli (1994, Paris 11)

Title: Quelques aspects de la brisure de la supersymetrie en theorie des cordes
(Some aspects of supersymmetry breaking in string theory)

Hervé Partouche (1997, École Polytechnique)

Title: Dualité en théorie des cordes

work with: Tomasz Taylor

Alexandre Laugier (2002, École Polytechnique)

Title: Aspects phénoménologiques et brisure de supersymétrie en théorie des cordes à basses échelles
(Phenomenological aspect and supersymmetry breaking in string theory at low scale)

Marc Tuckmantel (2005, ETH Zurich and CERN)

Title: Aspects of supersymmetry breaking in string theory

work with: Karim Benakli, Antonio Delgado, Mariano Quirós

Panteleimon Tziveloglou (2011, Cornell University and CERN)

Title: Aspects of Effective Supersymmetric Theories

work with: Nicola Ambrosetti, Emilian Dudas, Dumitru Ghilencea, Jean-Pierre Derendinger

Chrysoula Markou (2018, LPTHE)

Title: Nonlinear supersymmetry, spontaneous supersymmetry breaking and extra dimensions

work with: Jean-Pierre Derendinger

1) Supersymmetry Breaking:

Different mechanisms and aspects considered:

-) fractional electric charged particles (FEC particles) [Antoniadis, Benakli 1992]

Single gauge group G that confines the FEC and is responsible for SUSY breaking

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extended $\mathcal{N} = 2$ supersymmetry

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extended $\mathcal{N} = 2$ supersymmetry

-) Split Supersymmetry scenarios

mass of the scalars (squarks, sleptons) at the (high) SUSY breaking scale
mass of the fermions (gauginos) near the electroweak scale

[Arkani-Hamed, Dimopoulos 2004; Giudice, Romanino 2004; Antoniadis, Dimopoulos 2004]

- type I compactifications with internal magnetic flux
- D-branes at angles

[Antoniadis,Tuckmantel 2004]
[Antoniadis, Benakli, Delgado, Quirós, Tuckmantel 2005,2006]

2) Nonlinear Supersymmetry:

D-brane configurations break SUSY in the bulk, but lead to a non-linear realisation on the D-brane world-volume, i.e. transformation of Goldstino λ

$$\delta\lambda_\alpha = \frac{\xi_\alpha}{\kappa} - i\kappa\left(\lambda\sigma^\mu\bar{\xi} - \xi\sigma^\mu\bar{\lambda}\right)\partial_\mu\lambda_\alpha \qquad \text{and} \qquad \delta\bar{\lambda}^{\dot{\alpha}} = \frac{\bar{\xi}^{\dot{\alpha}}}{\kappa} - i\kappa\left(\lambda\sigma^\mu\bar{\xi} - \xi\sigma^\mu\bar{\lambda}\right)\partial_\mu\bar{\lambda}^{\dot{\alpha}}$$

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Invariant action with standard kinetic term [Akulov, Volkov 1973]

$$S_{\mathrm{AV}} = -\frac{1}{2\kappa^2}\int d^4x\,\det(A) \quad \text{with} \quad A_\mu{}^\nu = \delta_\mu^\nu + i\kappa^2\,\lambda\overleftrightarrow{\partial}_\mu\,\sigma^\nu\,\bar{\lambda}$$

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Extension implies universal coupling to matter stress energy momentum tensor

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-) dim. eight operators: free parameter in four fermion coupling

-) model dependent operators for D-branes with angles [Antoniadis, Benakli, Laugier 2001] [Antoniadis, Tuckmantel 2004]

-) nonlinear MSSM [Antoniadis, Dudas, Ghilencea, Tziveloglou 2008, 2011]

-) coupling to SUGRA [Antoniadis, Markou 2015]

(String) Dualities

Hervé Partouche **(1997, École Polytechnique)**

Title: Dualité en théorie des cordes

work with: Constantin Bachas, C. Fabre, Tomasz Taylor

Boris Pioline **(1998, École Polytechnique)**

Title: Aspects non perturbatifs de la théorie des supercordes

work with: Tomasz Taylor

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Duality in 6 dimensions (strong-weak)

Type IIA on $K3$ $\longleftrightarrow$ Heterotic on T^4

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Compactification to 4 dimensions on T^2

-) used to calculate non-perturbative contributions to type II couplings

$$\tilde{I}_{II} = \frac{\tilde{F}_1}{2(\mathrm{Im}S)^2}\left(\partial_\mu\partial_\nu\bar{S}\partial^\mu\partial^\nu\bar{S} + \partial_\mu\partial_\nu S\,\partial^\mu\partial^\nu S\right)$$

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-) triality including type I on T^6

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$\mathcal{N}=2$ duality in 4 dimensions:

Type II on CY3 $\longleftrightarrow$ Heterotic on $K3\times T^2$

Embedding of pure $\mathcal{N}=2$ SYM Seiberg-Witten theory in string theory

[Antoniadis, Partouche 1995]

2) Structure of $\mathcal{N}=2$ supersymmetric gauge theories:

hyperKähler quotient construction of $\mathcal{N}=2$ supersymmetric gauge theories:

tests of type II/heterotic duality in the vector multiplet sector [Kachru, Vafa 1995]

idea: extend tests to the hypermultiplet sector [Antoniadis, Pioline 1996]

Continued work and solution 20 years later

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Spontaneous breaking of $\mathcal{N}=2$ global supersymmetry for abelian vector multiplets:

-) Fayet-Iliopoulos term for 'magnetic' $U(1)$

-) partial breaking to $\mathcal{N}=1$

[Antoniadis, Partouche, Taylor 1995]

Moduli Stabilisation with Magnetic Fluxes

Tristan Maillard (2006, ETH Zurich and CERN)

Title: Aspects of moduli stabilization in string theory

work with: Karim Benakli, Alexandre Laugier, Alok Kumar

Binata Panda (2012, Inst. Phys. Bhubaneswar)

Title: Phenomenology with Magnetized D-branes

work with: Alok Kumar

String vacua depend on continuous parameter characterising e.g. the shape and size of the internal manifold (vevs of moduli)

different mechanisms to fix vevs and provide isolated string ground states

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Examples: type I on T^6 or type II on $T^6/\mathbb{Z}_2$ orientifold compactifications with magnetised D9-branes

[Antoniadis, Maillard 2004]

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4 main ingredients of the construction:

1) oblique (= non-commutative) magnetic fluxes

fixes off-diagonal components of the metric

2) magnetised D9-branes can lead to negative 5-brane tension

3) non-linear part of the DBI-action

needed to fix the overall volume

4) non-vanishing vevs for scalar fields on some of the branes

needed for consistent model building and more general supersymmetric vacuum configurations

Stabilise complex structure and Kähler moduli and cancel 5-brane tadpole

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Minimal example of supersymmetric SU(5) GUT model [Antoniadis, Kumar, Panda 2007, 2009]

Non-linear SUSY of the effective D-brane action with internal magnetic fields

[Antoniadis, Derendinger, Maillard 2008]

BPS Amplitudes and Topological String Theory

Stefan Hohenegger **(2008, TU Wien and CERN)** with Maximilian Kreuzer

Title: Topological Amplitudes and String Effective Couplings

work with: Kumar Narain, Emery Sokatchev

Ahmad Zein Assi **(2013, École Polytechnique and CERN)**

Title: Topological amplitudes and the string effective action

work with: Ioannis Florakis, Stefan Hohenegger, Kumar Narain

Topological couplings in the string effective action

[Antoniadis, Gava, Narain, Taylor 1993]

$$\mathcal{I}_g = \int d^4x \, F_g(\phi) \, R^2 \, T^{2g-2}$$

with

$R_{\mu\nu\rho\tau}$......Riemann tensor

$T_{\mu\nu}$.........graviphoton field strength tensor

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F_g calculated exactly as g -loop amplitude in type II on CY-3fold ($\mathcal{N}=2$)

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holomorphic anomaly equation: [Bershadsky, Cecotti, Ooguri, Vafa 1993]

$$\partial_{\bar{i}} F_g = \frac{1}{2} C_{\bar{i}\bar{j}\bar{k}} \, e^{2K} \, G^{j\bar{j}} \, G^{k\bar{k}} \left(\sum_{h=1}^{g-1} D_j F_h \, D_k F_{g-h} + D_j D_k F_{g-1} \right)$$

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Anti-holomorphic moduli derivatives

Lower genus top. Amplitudes

Generalisation along different lines:

1) $\mathcal{N}=4$ Topological Amplitudes

[Antoniadis, SH, Narain 2006]

Higher derivative couplings in type II on $K3\times T^2$ lead to twisted $\mathcal{N}=4$ correlator

$$\int d^4x\, F_g^{(1)}\, R^4\, T^{2g-2}$$

leads to

$$F_g^{(1)}=\int_{\mathcal{M}_g}\left\langle\left|\prod_{a=1}^{3g-3}G^-(\mu_a)\right|^2\int|J_{K3}|^2\int|J_{T^2}|^2\right\rangle$$

$$\int d^4x\, F_g^{(2)}\, R^2\, (\partial\partial\phi)^2\, T^{2g-2}$$

leads to

$$F_g^{(2)}=\int_{\mathcal{M}_{g+1}}\left\langle\left|\prod_{a=1}^{3g-1}G^-(\mu_a)\, J_{K3}^{--}(\mu_{3g})\,\psi_3(\alpha)\right|^2\right\rangle$$

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Holomorphic anomaly equation generalised to harmonicity relations, e.g. for the contribution in heterotic string theory on T^6 [Antoniadis, SH, Narain, Sokatchev 2007]

$$\epsilon^{ijk\ell} D_{ij,A} D_{k\ell,B} F_g^{(2)} = 4 D_{++,A} D_{++,B} F_{g-1}^{(2)} - 4(g+1)\, \delta_{AB}\, F_g^{(2)}$$

2) Refined Topological String

Generalisation to higher derivative couplings

[Antoniadis, SH, Narain, Taylor 2010]

[Antoniadis, Florakis, SH, Narain, Zein Assi 2013]

$$\mathcal{I}_{g,n} = \int d^4x \, F_{g,n} \, R_-^2 \, T_-^{2g-2} \, F_+^{2n}$$

with F_+...(self-dual) part of the field strength of a vector multiplet gauge field

Appear at 1-loop in heterotic and type I string theory compactified on $K3 \times T^2$

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Gauge theory instanton corrections can be calculated from disc-contributions in type I and precisely reproduce the full ADHM action on the Ω-background

[Antoniadis, Florakis, SH, Narain, Zein Assi 2013]

2) Refined Topological String

Generalisation to higher derivative couplings

[Antoniadis, SH, Narain, Taylor 2010]
[Antoniadis, Florakis, SH, Narain, Zein Assi 2013]

$$\mathcal{I}_{g,n} = \int d^4x\, F_{g,n}\, R_-^2\, T_-^{2g-2}\, F_+^{2n}$$

with F_+...(self-dual) part of the field strength of a vector multiplet gauge field

Appear at 1-loop in heterotic and type I string theory compactified on $K3 \times T^2$

For the right choice of F_+ (het: partner of $\bar{T}$ modulus) the field theory limit of $F_{g,n}$ reproduces correctly the perturbative part of the Nekrasov partition function on the Ω-background.

Gauge theory instanton corrections can be calculated from disc-contributions in type I and precisely reproduce the full ADHM action on the Ω-background

[Antoniadis, Florakis, SH, Narain, Zein Assi 2013]

Strong evidence that the $F_{g,n}$ provide a world-sheet description of the refined topological string theory.

de Sitter Vacua in SUGRA and Cosmology

Rob Knoops (2016, KU Leuven) with Antoine Van Proeyen

Title: Phenomenological aspects of supergravity theories in de Sitter vacua

work with: Dumitru Ghilencea, Auttakit Chatrabhuti, Hiroshi Isono

Yifan Chen (2019, LPTHE) with Karim Benakli

Title: Gravity as a playground for supersymmetry breaking

work with: George Leontaris

Osmin Lacombe (2021, Sorbonne Université)

Title: Champs, particules, cordes et applications à la cosmologie

work with: George Leontaris, Hongliang Jiang

François Rondeau (in preparation, LPTHE)

Anthony Guillen (in preparation, LPTHE)

Obtain (metastable) de Sitter vacua in 4dim $\mathcal{N} = 1$ SUGRA with

-) infinitesimally small, tuneable (positive) cosmological constant

-) gravitino mass in the TeV range

Field content of proposed minimal model:

[Villadoro, Zwirner 2005]
[Antoniadis, Knoops 2004]

-) supergravity multiplet

-) vector multiplet for $U(1)_R$ gauge symmetry

-) chiral multiplet (dilaton S) on which $U(1)_R$ acts as a shift: $S \to S - i\, c\, \Lambda$

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Kähler and superpotential take the form

$$\mathcal{L} = \int d^4\theta\, \mathcal{K}(S+\bar{S}) + \int d^2\theta\, W(S) + \int d^2\bar{\theta}\, \bar{W}(\bar{S}) \quad \text{with} \quad \begin{aligned} \mathcal{K} &= -\frac{2}{\kappa^2}\, \ln(s+\bar{s}) \\ W &= \kappa^3\, a\, e^{bs} \end{aligned}$$

Locally stable de Sitter minimum of the scalar potential at

$$b(s_0 + \bar{s}_0) \sim -0.183268 \qquad \frac{a^2}{bc^2} \sim -50.6602$$

Properties maintained under addition of MSSM-like sector

[Antoniadis, Ghilencea, Knoops 2004]

Type IIB/F-theory framework and moduli stabilisation:

intersecting 7-branes generate an F-term potential for the Kähler moduli (logarithmic higher loop corrections) and Fayet-Iliopoulos D-terms associated with anomalous $U(1)$ symmetries

Uplift the potential and generate a dS minimum with all Kähler moduli stabilised

[Antoniadis, Chen, Leontaris 2018,2019]

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Study of inflation within this model

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[Antoniadis, Lacombe, Leontaris 2018]

see also George's talk

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Further study of the role of FI terms in SUGRA and their role in inflation (as well other cosmological applications)

[Antoniadis, Rondeau 2019]

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Higgs Inflation: calculation of relevant Higgs tree-level scattering amplitudes

[Antoniadis, Guillen, Tamvakis 2020]

Extra Dimensions and String Phenomenology

Karim Benakli (1994, Paris 11)

work with: Mariano Quirós

Chrysoula Markou (2018, LPTHE)

Title: Nonlinear supersymmetry, spontaneous supersymmetry breaking and extra dimensions

François Rondeau (in preparation, LPTHE)

First predictions of collider signatures of Kaluza-Klein modes of gauge fields

[Antoniadis, Benakli, Quiros 1999]

Limits on the size of extra dimensions [Antoniadis, Benakli 2000,2001]

Physics of extra dimensions at the LHC [Antoniadis, Benakli 2015]

see also the talk by Mariano

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KK compactification of a 5 dimensional graviton-dilation system on $S^1/\mathbb{Z}_2$ with linear dilation background: [Antoniadis, Markou, Rondeau 2021]

-) Higgs mechanism for KK vector coming from g_{MN}

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Embedding of the Standard Model into D-brane configurations with gauged lepton number: produce KK modes that can explain g-2 discrepancy

Requires that lepton number gauge bosons live on an abelian $U(1)$ brane that extends along at least one large extra dimension [Antoniadis, Rondeau 2021]

[Anchordoqui, Antoniadis, Huang, Lüst, Rondeau, Taylor 2022]

see also the talk by Dieter

On behalf of all students:

Thank you Ignatios!

-) for teaching us about so many different subjects!

-) for always having time for us!

-) for sharing your ideas and thoughts with us!

-) for your constant support and your help in all situations!

-) for being a friend!

We wish you all the best for the future!