



Science Meeting – Scientific Report

Scientific report (one single document in WORD or PDF file) should be submitted online within two months of the event. It should not exceed seven A4 pages.

Proposal Title: Supersymmetry Breaking in String Theory

Application Reference N°: Science Meeting 5338

1) Summary (up to one page)

In the standard construction of string theory, supersymmetry (a symmetry relating particles of integer spin to particles with half-integer spin, SUSY for short) is a basic ingredient to obtain consistent models. However, since supersymmetry has not been observed so far, any string set-up aiming at addressing phenomenological issues, both in particle physics and in cosmology, has to address supersymmetry breaking.

Understanding how supersymmetry is actually broken in Nature, in a fully controlled and consistent way, is a very difficult and open problem. As already said, supersymmetry is so deeply rooted in string theory that it is difficult to break it without spoiling many desirable features, or at least without losing analytical control. For instance, the stability of non-SUSY solutions or frameworks in string theory is often an unresolved issue.

Supersymmetry breaking in string theory is a wide topic and can be approached from very different and complementary directions.

This workshop aimed at putting together the different communities working on various aspects of SUSY breaking in string theory, to draw a sort of state of the art of the different approaches and to try to build bridges among them.

The main topics according to which talks were organised are

- SUSY breaking in D-brane models
- SUSY breaking in warped space-times

- SUSY breaking and moduli stabilization
- de Sitter vacua in string theory
- SUSY breaking in realistic model building

2) Description of the scientific content of and discussions at the event (up to four pages)

The aim of this workshop was to explore the many different ways SUSY breaking can be implemented in string theory, to strengthen links among them, and discuss future developments. The structure of the workshop was designed on purpose to facilitate and stimulate discussions among researchers working on different aspects of the problem.

Each day had a theme, following the list above. The morning sessions consisted of one review talk by two speakers on the theme of the day, followed by a long discussion led by two experts in which all participants were invited to actively participate. In the afternoon, after some time for free discussions, there were typically two talks by Early Stage Researchers (ESR), postdocs or PhD students working in the field.

The first two sessions were devoted to explore specific ways in which supersymmetry breaking can be implemented in string theory, while the last three sessions focused on how these mechanisms are used for addressing concrete problems, like moduli stabilisation, the construction of de Sitter vacua in string theory, and realistic model building, with a specific focus on F-theory. More precisely:

- *SUSY breaking in D-brane models.*
The session focused on type II string theories, where the natural way to obtain realistic 4-dimensional models is to use D-branes at singularities, intersecting D-branes, non-perturbative stringy effects known as exotic instantons. This last topic was discussed in great detail since exotic instantons play a crucial role in obtaining consistent SUSY breaking mechanisms. The discussion focused in particular on the dependence of the dynamics of these models on the internal six-dimensional space (compact versus non compact spaces): exotic instantons in the context of string compactifications or in the context of holographic models inspired by the AdS/CFT.
- *SUSY breaking in warped space-times.*
The session put a lot of attention on the role of anti D-brane in the construction of supersymmetry breaking scenario in warped space-times and string compactification scenarios, as well as in the context of *holographic* models (and in the difference between them). There is some on-going discussion in the community on the pros and cons of such constructions, on their consistency and on the extent to which we do or do not have a complete understanding of their dynamics. Different viewpoints

were put forward and the morning discussion was particularly lively and fruitful.

- *SUSY breaking and moduli stabilization*
The session enjoyed an overview talk on the two main approaches to construct viable string inspired models, namely Heterotic string models and the Large Volume Scenario (LVS) models in type II string. This offered participants the opportunity to have a rather comprehensive update on the two different approaches and an overview on solved and still open problems, which are different, both quantitatively and qualitatively, in the two cases. In fact, people working on Heterotic models and LVS usually are not so much in touch and this day we had was a great opportunity to let the two community share methods, achievements as well as to appreciate what is more difficult (respectively easier) in one or the other scenario.
- *de Sitter vacua.*
The session focused on how to obtain de Sitter vacua in string theory or string inspired models. De Sitter vacua are inherently incompatible with supersymmetry, hence the way supersymmetry is broken is a necessary ingredient to even start discussing them. The review talks were a beautiful wrap-up on how de Sitter vacua can be obtained both in string theory as well as in supergravity, and on the relation between the two. In particular explaining to what extent string theory and supergravity may also put different constraints on the landscape of de Sitter vacua. The search for de Sitter vacua has also inspired new approaches to string theory where supersymmetry is broken in different ways, which are worth-wile exploring more.
- *SUSY breaking in realistic model building.*
The session focused on so-called local models. In this approach one supposes that closed string moduli are somehow fixed and/or frozen, and focus on the dynamics of the D-brane open strings, on which the Standard Model “lives”. Much progress have been recently obtained in the context of F-theory which, in short, corresponds to the non-perturbative regime of type IIB string theory (and it is related by string dualities to other set-ups). For this reason the focus in this last day was on F-theory, although both the review talks and the subsequent discussion covered (and compared) also other approaches, like intersecting D-brane models and D-branes at singularities (which can be seen as the weak coupling counter-part of F-theory).

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

While it is certainly hard to assess what the results of a workshop can be, we can safely say the workshop was very successful. The strength of the workshop has been to have a critical mass of scientists actively working on connected topics and have them lively interact. In fact, the feedback from all participants on the format we choose was extremely positive, precisely because the discussion sessions were very lively and different viewpoints were abundantly discussed and compared. Also young researchers profited from such informal atmosphere, which makes it easier for them to take an active part to the discussions, something which is usually uncommon in workshops and conferences.

For all these reasons the discussions we had during this workshop, and the possibility to put into contact people having different expertise but similar goals are likely to give rise to new collaborations and new ideas.

Possible developments for the future can include a better understanding of the infra-red dynamics of anti D-brane models, systematic constructions of de Sitter models in string theory, which are also relevant for the very recent discoveries of BICEPS2, the programme of F-theory is still on-going and the new developments of differential and algebraic geometry can be of benefit for both F-theory and Heterotic string models

Annex 4a: Programme of the meeting

MONDAY

- 8:30-9:15 Registration
9:15-9:30 Welcome
9:30-11:00 **Review talk:** S. Franco - F. Morales
SUSY breaking in D-brane models
11:00-11:30 Coffee Break
11:30-13:00 **Discussion Session.** Leaders: G. Honecker – A. Lerda
13:00-14:00 Lunch
14:00-16:00 Free Discussions
16:00-16:30 Coffee Break
16:30-17:30 **Short talks** I. Garcia-Extbarria
TBA
P. McGuirk
Soft terms from bent branes
17:30 Wine Reception

TUESDAY

- 9:00-10:30 **Review talk:** S. Kuperstein – T. Van Riet
SUSY breaking in warped spacetimes
10:30-11:00 Coffee Break
11:00-12:30 **Discussion Session.** Leaders: N. Halmagyi – G. Shiu
12:30-14:00 Lunch
14:00-16:00 Free Discussions
16:00-16:30 Coffee Break
16:30-17:30 **Short talks:** D. Junghans
New insights into anti-brane backreaction
S. Massai
SUSY breaking on conifolds: all is not lost

WEDNESDAY

- 9:00-10:30 **Review talk:** R. Valandro – L. Anderson
SUSY breaking and moduli stabilization
10:30-11:00 Coffee Break
11:00-12:30 **Discussion Session.** Leaders: J. Gray
12:30-14:00 Lunch
14:00-16:00 Free Discussions
16:00-16:30 Coffee Break
16:30-17:30 **Short Talks:** D. Marsh
On the decoupling of supersymmetry breaking in stabilised type IIB compactifications
M. Rummel

Probability of Vacuum Stability in Type IIB Multi-Kähler Moduli Models

THURSDAY

- 9:00-10:30 Review Talk. G. Torroba – D. Cassani
De Sitter vacua in String Theory and Supergravity
- 10:30-11:00 Coffee Break
- 11:00-12:30 Discussion Session. Leaders: M. Cicoli – U. Danielsson
- 12:30-14:00 Lunch
- 14:00-16:00 Free Discussions
- 16:00-16:30 Coffee Break
- 16:30-17:30 Short Talks. D. Blaback
Searching for accelerated universes using genetic algorithms
M. Krippendorf
Explicit de Sitter Vacua for Global String Models with Chiral Matter
- 19:30 Dinner at St John's College, Wordsworth Room

FRIDAY

- 9:00-10:30 **Review Talk.** E. Palti – T. Weigand
SUSY breaking in realistic model building
- 10:30-11:00 Coffee Break
- 11:00-12:30 **Discussion Session.** Leaders: M. Bianchi – J. Conlon
- 12:30-14:00 Lunch

Annex 4b: Full list of speakers and participants

Speakers

Lara Anderson
Johan Blåbäck
Davide Cassani
Sebastian Franco
Inaki Garcia-Extebarria
Daniel Junghans
Sven Krippendorf
Stanislav Kuperstein
David Marsh
Stefano Massai
Paul McGuirk
Francisco Morales
Eran Palti
Markus Rummel
Gonzalo Torroba
Roberto Valandro
Thomas Van Riet
Timo Weigand

Participants

Riccardo Argurio
Matteo Bertolini
Massimo Bianchi
Andreas Braun
Michele Cicoli
Joe Conlon
Ulf Danielsson
Emilian Dudas
James Gray
Nick Halmagyi
Gabriele Honecker
Moritz Kuntlzer
Craig Lawrie
Alberto Lerda
Michela Petrini
Flavio Porri
Gianfranco Pradisi
Sakura Schafer-Nameki
Garry Shiu
Wieland Staessens