Pierre and Supersymmetry

Ulrich Ellwanger
LPT Orsay

Around 1982 it was noticed that dotted and undotted indices (so-called Supersymmetry) could solve the hierarchy problem of the Standard Model.

At this time Pierre was in Annecy, and published his first paper on Supersymmetry:

P. Binetruy, P. Sorba and R. Stora, Phys. Lett. **129B** (1983) 85

"SUPERSYMMETRIC S COVARIANT R(ξ) GAUGE"

Pierre and Supersymmetry

Due to his broad view of physics, Pierre was very soon aware of the diverse important formal and phenomenological aspects of this possible extension of the Standard Model

1985 he was in Berkeley and Santa Barbara and collaborated on Supersymmetry with

M. K. Gaillard, S. Mahajan, S. Dawson, I. Hinchliffe, M. Sher,

visited Florida and Chicago in 1986, back to Berkeley and then Annecy (CNRS) where he collaborated with

G. Girardi, R. Grimm, J. Gunion (later with many more)

on many different aspects of Supersymmetry:

Pierre and Supersymmetry

Formal Aspects

Inflation

Supergravity

Cosmology

Flavour Physics

Quintessence

Gaugino Condensates

Superstring Models

Experimental Signatures
GdR SUSY

Susy Breaking

NMSSM

Radiative Corrections

Pierre and Supersymmetry

1990 he came as Professor to Orsay and continued to work on Supersymmetry with

C. Savoy, P. Ramond, G. Dvali, Y. Mambrini, R. Kallosh, A. Van Proeyen, S. C. Davis and A. C. Davis,
including students E. Dudas, E. Pillon, S. Lavignac,
and continuing previous collaborations with M. K. Gaillard, G. Girardi and R. Grimm.

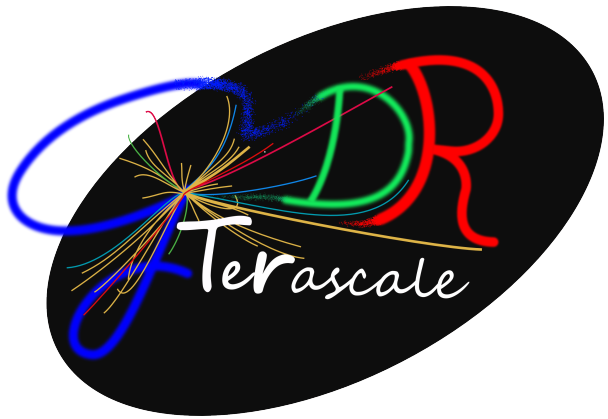
Papers as the only author:

P. Binetruy, "Dilaton, moduli and string/five-brane duality as seen from four-dimensions," Phys. Lett. B **315** (1993) 80

P. Binetruy, "Models of dynamical supersymmetry breaking and quintessence," Phys. Rev. D **60** (1999) 063502 (>200 cites)

1997 he started the

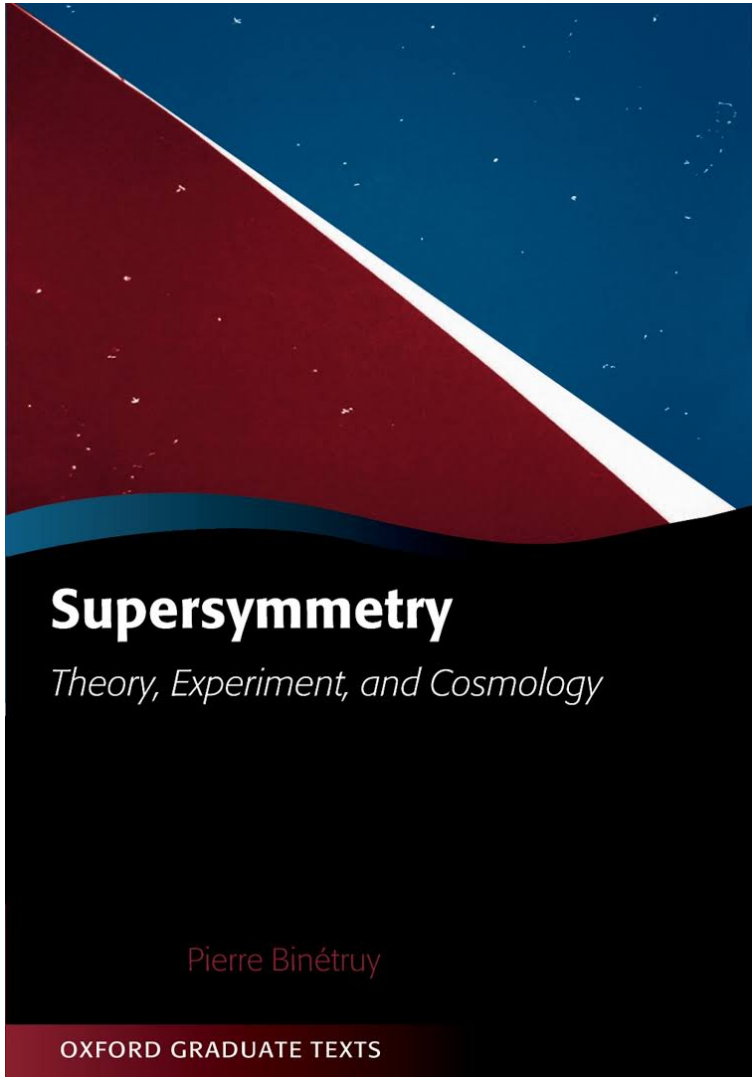
GDR Supersymmetry:
a fruitful and long
lasting series of
meetings between
experimentalists and
theorists on
phenomenological
aspects of
Supersymmetry
(today: GDR
Terascale)



$\rightarrow$ Pierre had a very important impact on the development of Supersymmetry in France

Pierre and Supersymmetry

As a gifted teacher and lecturer he loved to share his insights with students, postdocs and collegues



"Binetruy provides an excellent bullet-point summary of the problems that supersymmetry could solve."

+ many inspiring lectures on Supersymmetry at summer schools, university classes

Pierre and Supersymmetry

... and he asked the important questions:

P. Binetruy, G. L. Kane, J. D. Lykken and B. D. Nelson,
J. Phys. G **32** (2006) 129

"Twenty-five questions for string theorists"

Abstract:
"... Each topic culminates in a set of questions that we believe are amenable to direct consideration by string theorists, and whose answers we think could help connect string theory and phenomenology."

Gauge symmetries and unification

Question 1: What are the properties of string constructions that can provide realistic observable sectors while simultaneously providing large-rank gauge groups in a hidden sector?

Question 2: Can general relations between the mechanism(s) that relax restrictions on the rank of the low-energy gauge group, and the overall low-energy phenomenology of the construction, be identified?

Question 3: If the apparent gauge coupling unification is not a coincidence, is this alone evidence for the existence of a unification-scale GUT?

Question 4: What are the stringy conditions that would guarantee gauge coupling unification occurs rather than just imposing it?

U(1) symmetries and unification, singlets?

Question 5: What are the necessary or sufficient conditions that brane constructions must have for automatic gauge coupling unification to be the result?

Question 6: What are the necessary or sufficient conditions that would guarantee the normalization for the U(1) factor associated with hypercharge in each class of string constructions?

Question 7: Are there any reasons to believe that particular compactifications might automatically produce extra states with the right properties to maintain gauge coupling unification even with $k_Y \neq 5/3$?

Question 8: Under what conditions can true singlets of all gauge symmetries exist and in what sense can they be truly called "matter" (i.e. have Yukawa interactions with SM fields)?

Neutrinos, leptons

Question 9: If right-handed neutrinos are true singlets, do they mix with string moduli?

Question 10: Can a definition of lepton number that distinguishes lepton doublets from Higgs doublets be unambiguously defined for string theory in the absence of an underlying SO(10) gauge structure?

Proton decay, R-parity

Question 11: In a theory where dimension four and five proton decay operators are forbidden, would the observation of proton decay imply the unification (in four dimensions) of quarks and leptons in a simple gauge group, or could observable proton decay arise in such a string theory without grand unification?

Question 12: Would any such R-parity be an exact symmetry of the string theory or could it be an approximate parity? If the latter, how large might the violations be?

Question 13: What string theory conditions are sufficient to guarantee stable states beyond the Standard Model particles?

Generations, flavor symmetries

Question 14: Can constructions be classified by the manner in which generation number is embedded in the string-theoretic properties of the light spectra?

Question 15: How can string selection rules which determine the superpotential be interpreted as low-energy flavor symmetries?

Question 16: Under what circumstances will string-derived flavor symmetries take the form of continuous non-Abelian horizontal symmetries when acting on the low-energy degrees of freedom?

...flavor, CP violation

Question 17: In what basis should we expect the leading-order Kähler potential for massless gauge-charged fields to be diagonal? Under what circumstances might this be a basis that is also diagonal in the low-energy flavor basis?

Question 18: If the Kähler metric is diagonal in some field basis, under what circumstances should the values of the diagonal entries be equal?

Question 19: What are the stringy ways in which complex phases can enter the observable world and can these be related to a theory of flavor or supersymmetry breaking?

Hidden sectors, gaugino masses, μ problem

Question 20: Can compactifications be considered and classified, at a topological level, so as to identify those that give rise to sectors which are truly hidden and/or sequestered from one another?

Question 21: In what classes of string theories are tree level gaugino masses likely to be suppressed?

Question 22: What are the requirements on the fields that we wish to consider Higgs states in order to implement the Giudice-Masiero mechanism to generate a μ-term?

Question 23: Are there other string theory (as opposed to field theory) mechanisms which guarantee the relation $\mu \sim m_{3/2}$ while simultaneously predicting $\mu \to 0$ in the supersymmetric limit?

Right-handed neutrinos, Theory of Everything?

Question 24: If right-handed neutrinos are not true singlets what are the string-theory properties of these fields that make them the only SM fields with a large supersymmetric mass?

Question 25 Is it a reasonable goal to imagine a theory that explains the interlocking relationships between fermion masses, the nature of dark matter, collider experiments and current cosmological observations?

Pierre and Supersymmetry

Whoever had the occasion to discuss physics with Pierre profited from his continuous friendliness and extraordinary knowledge

His broad view of physics will remain inspiring