Closing remarks

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Plan of the talk

General considerations: a look at the past

- Originally string theory meant just what you can compute in string perturbation theory in the five consistent ten dimensional string theories: Type II A,B, Type I and two Heterotic strings.
- In the 80ties connection with particle phenomenology done mostly using the heterotic string.
- String theory is an extension of field theory.
- In the limit of $\alpha' \to 0$ one gets gauge theories unified with (super)gravity: both of them are included in string theory.
- In 1995 it became clear that the five string theories are all part of a unique 11-dim theory: M theory.
- Non-perturbative effects and especially the D branes played an essential role in understanding and formulating M theory.
- In 1997 the Maldacena conjecture was formulated:
  exact equivalence between
  $\mathcal{N} = 4$ super Yang-Mills and Type IIB string theory on $AdS_5 \times S^5$
- Very important tool: use classical gravity to study strongly coupled gauge theories.

- Connection with particle phenomenology done also with the other string theories and D branes: intersecting and magnetized branes.
- Moduli stabilization with closed string fluxes, but still a huge number of consistent vacua: Landscape problem.
- Problem.... anthropic principle and/or a lot more to understand.
- Use of the gravity dual has given a way to compute quantities in strongly interacting theories.
- Application to QCD, quark-gluon plasma, condensed matter systems: models or theory ?
- From theory of everything to theory for everything.
- Nowadays string theory touches many different things.
- As in soccer also in string theory one must learn to play a tutto campo: away from narrow specialization
  ....if you want to follow what is going on.

- This meeting has given a clear idea of the Italian activity in the framework of string theory.
- All recent developments in string theories have been discussed in this meeting.
- There is an active italian community (well connected internationally) working along various aspects of string theory!

Dynamical supersymmetry breaking(DSB)

[Auzzi, Bertolini, Girardello and Morales]

- One of the most promising possibility for an extension of the Standard Model(SM) (for solving the hierarchy problem and possibly to be observed at LHC) is the Minimal Supersymmetric Standard Model (MSSM) or some of its extensions.
- Introduce for each particle of the SM its supersymmetric partner: gluinos, squarks, Higgsinos etc.
- Since one does not observe fermion-boson degeneracy, one needs to break supersymmetry.
- In the MSSM or in its extensions, one introduces soft breaking terms by hand: explicit breaking.
- One would, however, like to deduce these susy breaking terms from dynamical or spontaneous susy breaking.
- Susy can be broken by non-perturbative effects, but they are difficult to compute...

- Using Seiberg duality, Intriligator, Seiberg and Shih showed the existence of long lived metastable vacua in SQCD in the region $N_c + 1 < N_f < \frac{3}{2} N_c$ where susy is broken.
- They are perturbative in the magnetic formulation.
- Study of metastable vacua in the conformal window: $\frac{3}{2} N_f < N_c < 2 N_f$ [Girardello].
- Study of metastable vacua in $\mathcal{N} = 2$ theories deformed with a cubic superpotential.
- Flavour symmetries can be gauged and coupled to external susy sectors to realize gauge mediation $\rightarrow$ susy breaking and gaugino masses [Auzzi].
- Study of gauge mediation models.
- There are two sectors: the visible one and a hidden one.
- Susy is broken in the hidden one.
- Susy breaking is transported in the visible sector by messenger fields [Bertolini].
- Intersecting brane setups exhibiting DSB [Morales].

AdS/CFT

[Bassetto, Bigazzi, Cadoni, Dall'Agata, Fagnocchi, Orselli, Penati and Ricci]

- The work in this direction is based on the Maldacena conjecture ($AdS_5 \times S^5$):
  $\mathcal{N} = 4$ super Yang-Mills $\equiv$ Type IIB string theory on $AdS_5 \times S^5$
- It is based on the near horizon limit of a D3 brane classical solution.
- It is an exact duality.
- Compare the spectrum of anomalous dimensions of the composite operators in the gauge theory with the energy of the string states.
- Very strong evidence, but difficult to prove because there is no regime where both theories are perturbative.
- In the Penrose limit of BMN one gets a maximally supersymmetric pp-wave background where two theories can be compared.
- New Penrose (decoupling: $\lambda \to 0$) limits are derived where one can compute both in gauge and string theory
- Very good agreement [Orselli].

- Computation of various Wilson loops in perturbative $\mathcal{N} = 4$ super Yang-Mills and comparison with matrix models and QCD_2 [Bassetto].
- Consistent truncation of type IIB supergravity. The 5dim gauged supergravity captures the holographic dual of a universal sector of single trace operators existing in any 4dim superconformal field theory [Dall'Agata].
- Integrability and two loop corrections to the energy of a spinning string in AdS_5 [Ricci].
- New duality: AdS_4/CFT_3:
  $\mathcal{N} = 6$ Chern-Simon theory (ABJM) (living in the world-volume of a M2 brane) $\equiv$ M-theory on $AdS_4 \times S^7/Z_k$
  $\mathcal{N} = 6$ Chern-Simon theory (ABJM) $\equiv$ type IIA on $AdS_4 \times CP^3$
- It is based on the near horizon limit of a M2 brane in M theory.
- Study of RG flow and of the IR behaviour of $\mathcal{N} = 2$ Chern-Simon theory Matter Theory [Penati].

- Extension of the gauge/gravity correspondence to non-conformal QCD-like theories.
- Consider the D3/D7 system, solve analytically the gravitational equations of motion and study the thermodynamics of the system that is providing a holographic description of the quark-gluon plasma [Bigazzi].
- Consider the Reissner-Nordstroem black hole of Einstein-Maxwell-dilaton gravity in 4dim AdS space. Phase transition at a certain temperature [Cadoni].
- Gravity description of condensed matter systems[Fagnocchi].

Higher spins

- In string theory no massless particle with spin larger than 2.
- Why then talk about higher spins ?
- String theory contains a fundamental constant α' and in terms of it one can compute the spectrum of string states: $m^2 \sim \frac{N}{\alpha'}$.
- In the limit $\alpha' \to \infty$ all string states become massless.
- Study theories with higher spins for studying this limit of string theory.
- World-line formalism for particles with higher spins[Bastianelli].
- What can we learn from string theories on higher spins[Taronna]?

Other directions

- Gravity and non-commutative geometry [Balachandran]
- Black holes and non-perturbative completion of $\mathcal{N} = 8$ supergravity [Ferrara].
- Non-abelian vortex classical solution [Gudnason]
- Based on typeI/Heterotic duality it is possible to perform in a precise way exotic instanton calculations. Important contribution to string phenomenology [Lerda].
- A and B topological string amplitudes are related to correlation functions in 2-dim CFT [Pasquetti]

Final remarks

- String theory has provided us with a consistent quantum theory unifying gauge theories with gravity.
- Too many consistent(?) vacua: Landscape problem.
- Not a single vacuum explaining our world.
- But is it not too much to expect this with the present knowledge of string theory?
- Lessons from the past???
- On the other hand, string theory has been very successful in contributing with new ideas and mechanisms that have generated important and new research directions : supersymmetry, extra-dimensions, 2-dim CFT, treatment of strongly interacting theories etc.
- Given that it is not so difficult believe that it will continue to do so also in the future.
- and hopefully in the near future there will be some more work for reaching a better understanding of its deep structure.