NORDITA

Paolo Di Vecchia

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Nordita

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- Director: Lárus Thorlacius
- Deputy Director: Ulf Wahlgren
- Professors: 6, 1 in particle physics: Paolo Di Vecchia
- Post-docs: 10-12, 3 in particle physics: Kristina Giesel, Alexander Wijns, Diego Chialva.
- Assistant Professors: 3, 1 in particle physics: Stefan Hofmann.
- New Nordita activity: organize programs that last from a couple of weeks to about two months.
- LHC scale physics and dark matter: 1 June- 31 July, organized by Per Osland and Katri Huitu.
- Geometrical aspects of string theory: 15 October- 15 December, organized by Ulf Lindström and Maxim Zabzine.
- Astroparticle Physics. A pathfinder to new physics: 30 March-30 April, organized by Joakim Edsjö, Sten Hannestad, Stefan Hofmann and Tommy Ohlsson.
- Electroweak phase transition:15 June-29 July, organized by Mark Hindmarsh, Stefan Huber and Kari Rummukainen.

Stefan Hofmann

- Why is the cosmological constant so small?
- The cosmological constant is measured through the measurement of the space-time curvature by cosmological observations.
- This assumes that gravity at large distance satisfies the Newton law.
- But if at large distance gravity is much weaker than predicted by the Newton law then one could reach a dynamical solution of the cosmological constant problems.
- because the vacuum energy could effectively decouple from gravity.
- Study of models based on branes where the Newton law is modified at large distances.

Lárus Thorlacius

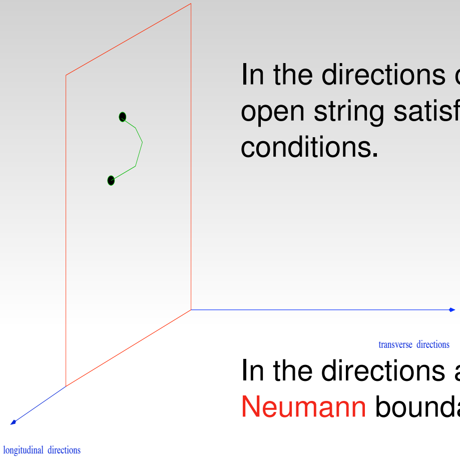
- A black hole in asymptotically flat space-time has a temperature given by the Hawking temperature T_H.
- This is the temperature measured by an asymptotic observer.
- The local temperature measured at finite distance from the black hole will in general be different from T_H and depends on the state of motion of the observer making the measurement.
- Determine the local temperature for observers in free fall outside a static black hole.
- The local free-fall temperature remains finite at the event horizon and in asymptotically flat spacetime it approaches the Hawking temperature at spatial infinity.
- Study of the particular case of a AdS black hole, where T_H grows without bound with increasing black hole mass, but the observers in free fall would nevertheless measure very low ambient temperature near one of these large AdS black holes.

Paolo Di Vecchia

- The strongest motivation for string theory is the fact that it provides a consistent quantum theory of gravity unified with the gauge interactions.
- String theory is a ten dimensional theory containing a dimensional parameter α' (with dimension of a $(\textit{length})^2$) that acts as a physical UV cutoff $\Longrightarrow$ Loop integrals are finite.
- When $\alpha' \to 0$ one recovers ten dimensional perturbative quantum gravity unified with gauge theories (with UV divergences).
- If the energy E available in the experiments is such that $\sqrt{\alpha'}E << 1$ then one will see only the limiting field theory.
- Only if $\sqrt{\alpha'}E \sim 1$ one will see stringy effects.
- Since we see only four non-compact directions, then the additional six must be compactified and small enough to be compatible with experiments.
- But then the four-dimensional physics will depend on the size and shape of the six-dimensional compact manifold.

- This dependence is encoded in the vacuum expectation values of a bunch of scalar fields, called moduli.
- At each order of string perturbation theory their values are arbitrary because their potential is flat.
- In the last few years the introduction of fluxes has allowed to stabilize them at discrete values.
- But we still have a discrete (and huge) quantity of string vacua: "Landscape Problem".
- How do we fix the vacuum we live in?
- Anthropic principle or better understanding needed?
- Two approaches have been proposed to connect string theory to particle phenomenology.
- A top-down one where one starts from string theory with $\frac{1}{\sqrt{\alpha'}} \sim \frac{1}{R_{comp}} \sim M_{Pl}$ and one then extrapolates to low energy making predictions for the physics at present energy.

- A bottom-up: construct string extension of the Standard Model or of the Minimal supersymmetric Standard Model.
- If we want to construct them in an explicit way we must limit ourselves to toroidal compactifications with orbifolds and orientifolds.
- and, most important, we need to have massless open strings corresponding to chiral fermions in four dimensions for describing quarks and leptons.
- The simplest models are those based on several stacks of intersecting branes and/or of their T-dual magnetized branes on $R^{3,1} \times \mathcal{T}^2 \times \mathcal{T}^2 \times \mathcal{T}^2$.
- Dp branes are non-perturbative p-dimensional objects of string theory.
- They have the property of having open strings attached with their end-points to them.

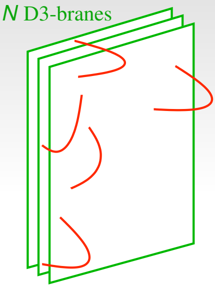


In the directions orthogonal to the brane the open string satisfies Dirichlet boundary conditions.

In the directions along the brane they satisfy Neumann boundary conditions.

- The open strings (gauge theory) live in the (p+1)-dim. volume of a Dp brane, while closed strings (gravity) live in the entire ten dimensional space.

- If we have a stack of N parallel D branes, then we have N^2 open strings having their endpoints on the D branes:



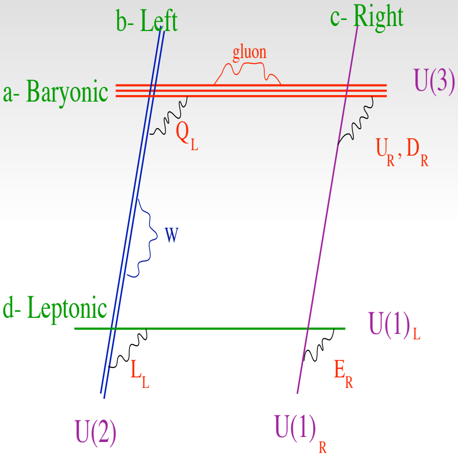
An open string attached to the same stack of D branes transforms according to the adjoint representation of $U(N)$

- The massless strings correspond to the gauge fields of $U(N)$.

- A stack of N D branes has a $U(N) = SU(N) \times U(1)$ gauge theory living on their worldvolume.

- The open strings attached to a stack of parallel D branes describe the gauge degrees of freedom.
- In order to describe quarks and leptons (chiral fermions) we need to have stacks of D branes at angles (intersecting branes) or magnetized branes (branes with a magnetic field in the extra compact dimensions).

A simple phenomenological model



Four stacks of magnetized branes: a, b, c, d.

$SU(3)_a \times SU(2)_b \times U(1)_a \times U(1)_b \times U(1)_c \times U(1)_d$

Marchesano, thesis, 2003

- Given a certain compactification of the extra dimensions one needs to determine the low-energy four-dimensional Lagrangian that describes the Standard Model or its extensions.
- In particular, if the theory is supersymmetric one needs to derive the form of the Kähler metrics, of the superpotential and of the coefficient of the kinetic terms of the gauge bosons as functions of the size and shape of the compact six-dimensional manifold.
- Also the supersymmetry soft breaking terms can be computed.
- This is a direct way to determine the low energy physics starting from ten dimensional string theory.
- In principle this procedure can be carried out also for manifolds more complicated than the torus, but it will be more difficult to obtain explicit results.