TIFR Annual Report 2004-05
THEORETICAL PHYSICS

String Theory and Mathematical Physics

Highlights

Quantum corrections are shown to convert a singular classical geometry into a black hole geometry with a smooth horizon. The entropy of the black hole matches precisely with macroscopic counting.

The AdS_5 big and small blackhole saddle points have been identified with those of the large N holographic gauge theory, in the phase where the eigenvalue distribution of the unitary matrix has a gap. This indicates that the phase transition at the closing of the gap is a crossover point from a blackhole description to that in terms of excited strings.

The semiclassical limit of the gauge-gravity correspondence, in a specific sector of four-dimensional Yang-Mills theory preserving half the supersymmetries, has been derived.

Correlation functions of bulk and boundary operators on extended D-branes of $c = 1$ noncritical string theory were obtained.

By higher loop calculations it has been confirmed that the deconfining transition in Yang Mills theory on S^3 is of first order.

It has been shown that weakly coupled gauge theory undergoes a single first order phase transition from a "black string" to a "black hole" like phase.

The existence of meta-stable localized bubbles of gluon plasma –" plasma balls" – in large N confining gauge theories, undergoing first order deconfinement transitions, have been proposed.

The qualitative structure of the phase diagrams of a class of large N gauge theories on circles in 1 dimension and on tori in 2 dimensions have been determined.

A matrix model incorporating the full unbroken symmetry of the $c = 1$ string was proposed.

Fermion bilinear terms in the world volume action for a $D3$ brane were derived in the presence of background flux.

The attractor mechanism for blackholes has been shown to work even in the absence of supersymmetry.

Sen's rotating black hole solution was shown to be supersymmetric.

TEXT

AdS and conformal field theory

The Hawking-Moss instanton in asymptotic AdS3 was conjectured and a new world-sheet CFT found. The partition function of the dual field theory was studied and it was shown how the phase transition can be understood from that partition function. [Norihiro Iizuka with Shiraz Minwalla]

$AdS_5 \times S^5$ and matrix models

A phenomenological matrix model was proposed to study string theory in $AdS_5 \times S_5$ in the canonical ensemble. The model reproduces all the known qualitative features of the theory. In particular, it gives a simple effective potential description of Euclidean black hole nucleation and the tunnelling between thermal AdS and the big black hole. There exists a critical temperature at which the Euclidean small black hole undergoes a Gross-Witten phase transition. The phase transition is identified with the Horowitz-Polchinski point where the black hole horizon size becomes comparable to the string scale. A formula for the partition function of the small black hole is presented at the crossover point. [Spenta R. Wadia with L. Alvarez-Gaume, C. Gomez and Hong-Liu.]

AdS and Yang-Mills

Any gravitational theory on AdS_5 undergoes a thermal phase transition at a temperature of order the inverse AdS radius. The high temperature phase is dominated by a big black hole at the center of AdS space. This black hole nucleation process may then be reinterpreted (via the AdS/CFT correspondence) as a thermal phase transition in Yang Mills theory on S^3. In earlier work it was shown that in all free gauge theories, all of whose fields lie in the adjoint, the deconfinement transition is always of first order. However the transition is very finely tuned; in particular coupling constant corrections to this story could either weaken the phase transition into a second order transition, or strengthen it into a more usual, 'stable' first order phase transition. Which way this goes depends on a number that is computed by a set of 2 and 3 loop vacuum graphs in the relevant field theory. This long and intricate computation has now been performed for pure Yang Mills theory. It was discovered that the weak coupling phase transition was strengthened to stable first order, a result that leads to a rather simple conjecture for the phase diagram of pure large N Yang Mills on S^3 as a function of coupling. [Shiraz Minwalla with O. Aharony, J. Marsano,K. Papadodimas and M. Van Raamsdonk]

The thermal behaviour of supersymmetric Yang Mills theories on tori was investigated. It had been observed some time ago, using the AdS/CFT correspondence, that such theories undergo thermal phase transitions at strong coupling. This phase transition is the gauge theory mirror of the Gregory-Laflamme transition between black strings and black holes in the bulk dual. This has led to the demonstration that weakly coupled gauge theory on a torus also undergoes a similar thermal phase transition that is amenable to detailed analyis. It appears that the weakly coupled gauge theory undergoes a single first order phase transition from a "black string" to a "black hole" like phase. This result is particularly interesting as it gives a clue to how the strongly coupled theory (hence the dual gravitational system) - might behave (this is a topic of much current controversy within the gravitational community). [Shiraz Minwalla with O. Aharony, J. Marsano, K. Papadodimas, M. Van Raamsdonk and T. Wiseman]

The existence of meta-stable localized bubbles of gluon plasma – plasma balls – was postulated in large N confining gauge theories that undergo first order deconfinement transitions. Plasma-balls are almost homogeneous lumps at just above the deconfinement energy density, which decay over a time scale of order N^2 by thermally radiating hadrons at the deconfinement temperature. It is argued that, in gauge theories whose dual string theory may be studied in the gravitational approximation, plasma-balls map to a family of classically stable localized black holes, which are constructed numerically in a specific background, in the large ball limit. These black holes shrink as they decay by Hawking radiation; towards the end of this process they resemble ten dimensional Schwarzschild black holes, which are proposed to be dual to small plasma-balls. This work may find 'practical' applications in the study of the physics of localized black holes from a dual viewpoint. It is also noted that plasma-ball-like meta-stable configurations may exist in QCD in the real world at high enough baryon density, though with relatively short lifetimes. [Shiraz Minwalla, under preparation]

The qualitative structure of the phase diagrams has been determined of a class of large N gauge theories on circles in 1 dimension and on tori in 2 dimensions. These theories typically undergo phase transitions as various parameters (tori radii, couplings) are varied. The order parameters for these phase transitions are the $Z_N \times Z_N$ symmetries associated with large gauge transformations around the cycles of the tori. When the gauge theories in question admit a gravitational description, these phase transitions have a dual bulk description as transitions between distinct black hole solutions. [Shiraz Minwalla, under preparation]

Black holes

For a large class of states in string theory, quantum stringy corrections can modify a classically singular geometry around these states and result in a black hole geometry with a

regular horizon. The qunatum corrected entropy of these black holes is in precise agreement with microscopic counting. [Atish Dabholkar]

An attempt was made to find the stationary rotating black hole solutions using the supersymmetric attractor mechanism. The rotating black hole solution without any alpha prime corrections was found. This was compared with Sen's rotating black hole solution, thereby demonstrating the supersymmetric nature of his solution which was not known. The final aim is to generate the rotating black hole solution incorporating the alpha prime corrections. [Ashik Iqubal with Atish Dabholkar, Ashoke Sen, Norihiro Iizuka]

The attractor mechanism was studied, where black hole solution shows extremality but does not show BPS property, and find that in a certain case, it does work even without using supersymmetry at all. [Norihiro Iizuka with Kevin Goldstein, Rudra P. Jena and Sandip P. Trivedi]

c=1 Matrix Models

An explicit demonstration has been given of the equivalence between the Normal Matrix Model (NMM) of the $c = 1$ theory at the self-dual radius and the Kontsevich Penner (KP) model of the same string theory. Some observations are also made on the relation between loop expectation values in the NMM to condensates of the closed string tachyon, and discussed the implications for open-closed duality. As in the $c < 1$ case the Kontsevich-Miwa transform between the parameters of the two theories appears to encode open-closed string duality, though some interesting differences are found with the $c < 1$ case. Brief comments are made on two different possible origins of the Kontsevich model in connection to string theory. [Anindya Mukherjee with Sunil Mukhi]

Calabi-Yau compactifications

While conventional Calabi-Yau compactifications still leave a high number of moduli-fields, the existence of flux can greatly reduce this number of free parameters. It has been known that the "complex structure moduli" are fixed in the presence of RR- and NSNS-fluxes, but here explicit examples have been considered where a potential for the Kaehler moduli is generated by these fluxes via non-perturbative effects. Kaehler moduli can also be fixed by introducing D-branes with appropriate open string NS-fieldstrengths. Combination of RR- and NSNS-fluxes as well as open-string fields have been investigated in order to eliminate all closed string moduli. [Lars Goerlich]

Conifolds

The physics of closed string tachyons in nonsupersymmetric orbifold singularities and mild topology change via flip transitions therein was studied with David Morrison. Following this, embeddings of flip regions in nonsupersymmetric conifolds have been studied with a view to understanding the geometry in the vicinity of the singularity and strong topology change here. [K. Narayan]

D-branes

D3/D7 brane inflation models and cosmological solutions were studied using their uplifted descriptions in 11-dim M-theory with higher derivative contributions. [K. Narayan with Keshav Dasgupta, Pisin Chen, Marina Shmakova and Marco Zagermann.]

D-branes in noncritical string theory were investigated in the background where strings propagate in two spacetime dimensions. The branes that extend along the Liouville direction in spacetime, known as FZZT branes, were analysed and explicit expressions obtained for correlation functions of bulk and boundary operators. A matrix model incorporating the full unbroken symmetry of the $c = 1$ string was proposed. [Sunil Mukhi with Debashis Ghoshal and Sameer Murthy]

The fermion bilinear terms in the world volume action for a $D3$ brane were derived in the presence of background flux. In six-dimensional compactifications non-perturbative corrections to the superpotential can arise from an Euclidean $D3$-brane instanton wrapping a divisor in the internal space. The bilinear terms give rise to fermion masses and are important in determining these corrections. The three-form flux was found to generically break a $U(1)$ subgroup of the structure group of the normal bundle of the divisor. In an example of compactification on T^6/Z_2, twelve of the sixteen zero modes originally present are lifted by the flux. [Sandip Trivedi with Prasanta K. Tripathy]

Noncommutative field theory

Exact bosonization of free non-relativistic fermions in one space dimension has been studied earlier by Dhar, Mandal and Wadia. The bosonization of these authors is done in terms of a non-commutative field theory of phase space density of the fermions. The present motivation for revisiting this problem is the recent work on bubbling half-BPS geometries by Lin, Lunin and Maldacena. The hope is that one may be able to study some aspects of quantum gravity since the quantization of the dual fermi system is known exactly. One new result we have in this connection is that we have obtained an action for the collective field (which lives on the

droplet boundaries in the classical limit) which is manifestly invariant under time-dependent reparametrizations of the boundary. Work is now going on to appropriately fix this gauge symmetry and quantize the collective field. However, already there are strong indications that the standard collective theory fails to reproduce the details of exact bosonization. [Avinash Dhar]

Recently there has been some interest in the half-BPS sector of N=4 super Yang-Mills theory (preserving an O(4) x O(4) symmetry) and the corresponding sector of supergravity in AdS_5 preserving the same symmetries. The former theory is known to be a theory of free fermions in a harmonic potential whose semiclassical phase space configurations are droplets of fermi fluid. It has been observed that a similar droplet picture appears in the supergravity solutions. In the present work, the correspondence is derived in the semiclassical approximation using a collective coordinate quantization of the supergravity. As a byproduct it is found that, in this sector, supergravity becomes noncommutative and that two of the supergravity coordinates becomes noncommutating. The possibility of topology change within noncommutative supergravity is explored. [Gautam Mandal]

Tachyonic Interactions

Off-shell interactions necessary to analyze the endpoint of condensation near certain spacetime instabilities in string theory were computed. [Atish Dabholkar]

Mathematical Physics

Work was mainly concentrated on developing further the generalisation to vector bundles of our earlier work on CFT on an arbitrary curve. It was found that, for topological reasons, the generalisation works for genus at least 2. This is the case of interest in geometry, but some investigations were made to remove this restriction by reformulating the problem through covering spaces. [A.K. Raina]