TIFR Annual Report 2009-10
THEORETICAL PHYSICS

String Theory and Mathematical Physics

Highlights

New black hole solutions, with charged scalar condensates, were constructed in global AdS spaces were constructed in a perturbative expansion in the charge of the solutions. The properties of these solutions were explored and their implications for dual field theory dynamics discussed

Gauged matrix quantum mechanics was studied in the limit of a large number of flavours. It was demonstrated that the phase diagram of this system includes two phase transitions, one of second and the next of third order. The results were shown to be in excellent agreement with numerical simulations.

A novel Higgs mechanism was used to determine the leading higher-derivative corrections to Bagger-Lambert-Gustavsson field theories related to membrane worldvolumes in M-theory and evidence for a universal answer was obtained.

A Nambu-Jona-Lasinio type four-fermion coupling at the z=3 Lifshitz-like fixed point in 4 dimensions was shown to be asymptotically free and to generate a mass scale dynamically. The RG flows in the space of couplings of this system were shown to include a new fixed point (apart from the z=3 Lifshitz fixed point and the free field fixed point) characterized by z=1 scaling and a violation of Lorentz invariance, which cannot be tuned away by adjusting a parameter.

The relation between 4d N = 2 supersymmetric gauge theories and 2d Toda CFT was explored.

Gauge theory dual of a phase transition between black holes and black strings was studied analytically. Renormalizable, asymptotically free Four-fermi theories with Lifshitz scaling were constructed.

Non-supersymmetric AdS compactifications in string theory and possible

connections betwen gravity in AdS space and condensed matter systems at critical points were studied.

TEXT

Large N Yang Mills theories with D adjoint scalar fields in 0 and 1 dimensions

Large N Yang Mills theories with D adjoint scalar fields in 0 and 1 dimensions were systematically studied in a large D expansion. The functional integral was shown to possess a non-trivial saddle point at large D which was characterized by a mass gap for the adjoint scalars. This allowed us to integrate out the adjoint scalars in a 1/D expansion around the saddle point. For d=1, regarded as a circle, this procedure led to an effective action for the Wilson line around the circle. For this system, an analogue of the confinement/deconfinement transition was found which consisted of a second order phase transition from a uniform to a non-uniform eigenvalue distribution of the Wilson line, closely followed by a Gross-Witten-Wadia transition characterized by the appearance of a gap in the eigenvalue distribution. The double phase transition could be regarded as a continuation of a Gregory-Laflamme transition. Our methods involved large values of the dimensionless 'tHooft coupling. The analysis was quantitatively supported by earlier numerical work for D=9.

[Gautam Mandal, Manavendra Mahato and Takeshi Morita]

The same model was also studied with a chemical potential associated with R symmetry charge. It was discovered that condensation of the adjoint scalars protects the system from this instability. The contribution of the chemical potential to the phase structure was also elucidated. [Takeshi Morita]

Hawking Radiation and Anomaly

A new interpretation of the Hawking radiation was proposed by Wilczek et al. They showed that the radiation can be regarded as a contribution through a gravitational anomaly. It was pointed out that the derivation of Wilczek involves an ambiguity. A modification of their method by using a conformal anomaly was proposed, and the old ambiguity circumvented [Takeshi Morita]

Aspects of monopole operators in N=6 Chern-Simons theory

The supersymmetric index was computed in a monopole background in the d=3, N=6 supersymmetric Chern-Simons theories proposed by ABJM to describe the dynamics of $M2$-branes at an orbifold singularity. In the Lorentzian description the spectrum of BPS fluctuations that contribute to the index was obtained by an explicit computation. The simplest U(1) x U(1) monopole background was considered and scalar, fermion and gauge BPS fluctuations were studied. The index computed over these modes turns out to be in agreement with the corresponding gravity index.

[K. Madhu with S. Kim (Seoul)]

Membranes in M-theory

Higher-derivative corrections to the Bagger-Lambert-Gustavsson field theory were investigated and obtained to lowest non-trivial order in the Planck length. The answer is consistent with universality at least over all maximally supersymmetric theories in this class. Extensions of this procedure to ABJM field theory describing membranes at $C4/Z_n$ orbifolds were investigated.
[Sunil Mukhi and Costis Papageorgakis with Bobby Ezhuthachan (HRI, Allahabad)]

Asymptotically free four-fermi theory in 4 dimensions at the z=3 Lifshitz-like fixed point

It was shown that a Nambu-Jona-Lasinio type four-fermion coupling at the Lorentz violating z=3 Lifshitz-like fixed point in 4 dimensions is asymptotically free and generates a mass scale dynamically. This result is nonperturbative in the limit of a large number of fermion species and the theory is ultra-violet complete. A scenario is presented, which uses this mechanism of mass generation, in which a composite Higgs field arises from a condensate of the fermions and couples to quarks and leptons of the standard model, leading to dynamical electroweak symmetry breaking. Such a scenario could eliminate the need for a fundamental Higgs degree of freedom and the associated hierarchy problem. [A. Dhar, G. Mandal and S.R. Wadia].

Renormalization group flows in a Lifshitz-like four fermi model

RG flows were studied in the above model. It was shown that the phase diagram includes, besides the z=3 Lifshitz fixed point and the free field fixed point, a new fixed point characterized by z=1 scaling and a violation of Lorentz invariance, which cannot be tuned away by adjusting a parameter. In the broken symmetry phase, the model flows from the z=3 Lifshitz-like fixed point in the UV to this new fixed point in the IR.

[A. Dhar, G. Mandal and P. Nag]

Small Hairy Black Holes in Global AdS Spacetime.

Small charged black holes in global AdS spacetime were studied in the presence of a charged massless minimally coupled scalar field. In a certain parameter range these black holes suffer from well known superradiant instabilities. It was demonstrated that the end point of the resultant tachyon condensation process is a hairy black hole which was constructed analytically in a perturbative expansion in the black hole radius. At leading order this solution is a small undeformed RNAdS black hole immersed into a charged scalar condensate that fills the AdS 'box'. These hairy black hole solutions appear in a two parameter family labelled by their mass and charge. Their mass is bounded from below by a function of their charge; at the lower bound a hairy black hole reduces to a regular horizon free soliton which can also be thought of as a nonlinear Bose condensate. The microcanonical phase diagram of our system at small mass was also computed. It was demonstrated that the system exhibits a second order 'phase transition' between the RNAdS black hole and the hairy black hole phases.
[J. Bhattacharyya, S. Bhattacharyya, R. Loganayagam, S. Minwalla and V. Umesh with P. Basu (UBC, Canada)]

Small Hairy Black Holes in global $AdS_5 \times S^5$

Small hairy black holes were studied in a consistent truncation of $\mathcal{N} = 8$ gauged supergravity that consists of a single charged scalar field interacting with the metric and a U(1) gauge field. Small very near extremal RNAdS black holes in this system are unstable to decay by superradiant emission. The end point of this instability is a small hairy black hole that was

constructed analytically in a perturbative expansion in its charge. Unlike their RNAdS counterparts, hairy black hole solutions exist all the way down to the BPS bound, demonstrating that $\mathcal{N} = 4$ Yang Mills theory has an $\mathcal{O}(N^2)$ entropy at all energies above supersymmetry. At the BPS bound these black holes reduce to previously discussed regular, supersymmetric horizon free solitons. Numerical methods were used to continue the construction of these solitons to large charges. It was found that the line of soliton solutions terminates at a singular solution S at a finite charge. At leading order in their charge, the thermodynamics of the small hairy black holes constructed in this paper turn out to be correctly reproduced by modeling these objects as a non interacting mix of an RNAdS black hole and the supersymmetric soliton in thermal equilibrium.

[S. Bhattacharyya and S. Minwalla with K. Papadodimas (Amsterdam)]

Holography of Charged Dilaton Black Holes

It was shown that extremal black branes with zero entropy arise quite generically in gravity systems. This was achieved by studying gravitational systems with a scalar field, like the dilaton, which couples to the gauge kinetic energy term. The mass of extremal branes arises entirely from coloumb repulsion, and therefore they might be of some interest in studying strongly coupled and correlated systems which arise in condensed matter physics. The transport properties of this system were computed. The electrical conductivity of the extremal black branes displays power-law growth with temperature, after turning on a magnetic field this results in a power -law growth of the resistivity, which is some what reminiscent of the behaviour seen in the strange-metal phase Various other computed transsport properties show a Weidemann-Franz like relation to the electrical conductivity.
[S. Trivedi and S. Prakash with K. Goldstein (Witwatersrand) and S. Kachru (KITP)]

On The Stability Of Non-Supersymmetric AdS Vacua

A large class of perturbatively stable non-supersymmetric AdS vacua in string theory were constructed. Earlier constructions of such vacuua were unstable to small fluctuations, and so unsatisfactory. Non-perturbative decays of these vacuua , which arise due to brane-nucleation, were also

investigatted. A useful set of criteria to test for their existence was determined. Using these criteria we were able to show that in some but not all of the newly construced vacua have instabilities. Whether these arise in all cases remains an open question. These non-perturbative instabilities are argued to have catastrophic consequence for the putative field theory dual which would decay near-instantaneously. [P. Narayan and S. Trivedi]