

TIFR Annual Report 2010 - 11

Department of Theoretical Physics

String Theory and Mathematical Physics

Highlights

Using the AdS/CFT correspondence, a complete theory of superfluid hydrodynamics for s-wave superfluids was obtained generalizing classic earlier results by Landau, Tiza and Putterman. A new class of small hairy black holes was found in $\text{AdS}_5 \times S^5$. The hydrodynamic properties of strongly coupled $\text{SU}(N)$ Yang-Mills theory of the D1-brane was studied at finite temperature and at a non-zero density of R-charge in the framework of gauge/gravity duality.

The phase diagram of adjoint scalar QCD was computed analytically in two dimensions and compared with lattice results for 4d Yang-Mills in a box and with holographic results from D-branes.

The stability of non-supersymmetric AdS compactifications of string theory was investigated. Dilatonic black branes were constructed and applied to condensed matter-like systems. A string theory model of quintessence was proposed.

$\text{SU}(N)$ Chern-Simons theory in (2+1)d coupled to massless fundamental fermions was studied as an example of a soluble CFT at large- N . This theory naturally realizes W -infinity as a symmetry algebra. This theory is conjectured to be dual to a Vasiliev type higher-spin theory in (3+1)d. The $N=4$ superconformal index was studied using localization techniques.

The origin of the novel Higgs mechanism for multiple membranes in M-theory was clarified and it was shown to be a subtle variant of the phenomenon of topological mass generation.

A generalisation of an algebro-geometric proof of the trisecant identity to simple rank- r vector bundles was obtained.

New gravitational backgrounds were constructed that, via gauge/gravity duality, describe quantum field theories with multi-scale dynamics.

The interpolating function for ABJM theory was obtained by comparing integrability and perturbative calculations at one loop for all classes of giant magnons in CP^3 .

A model of quintessence was proposed in string theory based on the idea of axion monodromy.

Text

Black Holes, AdS/CFT and Fluid Dynamics

Small hairy black holes were studied in a consistent truncation of $N=8$ gauged supergravity. The end point of their instability is a small hairy black hole that was constructed analytically in a perturbative expansion in its charge. Numerical methods were used to continue the construction of these solitons to large charges and a line of soliton solutions was found to terminate at a singular

solution S at a finite charge. It was conjectured that a one parameter family of singular supersymmetric solutions, which emerges out of S , constitutes the BPS limit of hairy black holes at larger values of the charge. A rich family of rotating hairy black holes is predicted, including new hairy supersymmetric black holes. [Jyotirmoy Bhattacharya, Sayantani Bhattacharyya, R. Loganayagam, Shiraz Minwalla, V. Umesh, with Pallab Basu (UBC Vancouver) and Kyriakos Papadodimas (Amsterdam)]

Herzog's analysis of AdS black hole instabilities was generalised by perturbing away from infinite charge. Thereby explicit expressions were obtained for the metric, gauge field and scalar field dual to an arbitrary superfluid flow at first order in the derivative expansion. This construction allows to read off the leading dissipative corrections to the perfect superfluid stress tensor, current and Josephson equations. Purely within fluid dynamics a consistent new generalization was presented of the well-known equations of Landau-Lifshitz and Clark-Putterman to a set of superfluid equations parameterized by 14 dissipative parameters. All the dissipative constants were computed for the gravitational superfluid. [Jyotirmoy Bhattacharya and Shiraz Minwalla, with Sayantani Bhattacharyya (HRI Allahabad)]

The hydrodynamic properties of strongly coupled $SU(N)$ Yang-Mills theory of the D1-brane was studied at finite temperature and at a non-zero density of R-charge in the framework of gauge/gravity duality. The gravity dual description involves a charged black hole solution of an Einstein-Maxwell-dilaton system in 3 dimensions. The thermal and electrical conductivity as well as the bulk viscosity were evaluated as a function of the chemical potential conjugate to the R-charges of the D1-brane. The ratio of bulk viscosity to entropy density was shown to be independent of the chemical potential and equal to $1/4\pi$. The thermal conductivity and bulk viscosity were found to obey a relationship similar to the Wiedemann-Franz law. At the boundary of thermodynamic stability, the charge diffusion mode becomes unstable and the transport coefficients exhibit critical behaviour. It was observed that the transport coefficients of the D1-brane theory are related to those of the M2-brane by an overall proportionality constant. [Manavendra Mahato and Spenta Wadia, with Justin David and Soumyadip Thakur (IISc. Bangalore)]

Superconformal indices

The spectrum of BPS operators/states in $N=2$ superconformal $U(N)$ Chern-Simons-matter theories with adjoint chiral matter fields, with and without superpotential, was studied. The superconformal indices and conjectures on the full supersymmetric spectrum of the theories in the large N limit with up to two adjoint matter fields are presented. The results suggest that some of these theories may have supergravity duals at strong coupling, while some others may be dual to higher spin theories of gravity at strong coupling. [Shiraz Minwalla, Prithvi Narayan, Tarun Sharma and V. Umesh, with Xi Yin (Harvard)]

A geometrical meaning of the $N=4$ superconformal index was proposed. With this interpretation, the $N=4$ superconformal index can be realized as the partition function on a Scherk-Schwarz deformed background. To calculate the functional integral, the localisation method was applied by adding a suitable exact term whose critical points turn out to be the space of flat connections. The one-loop evaluation over the space of flat connections reduces to the matrix integral by which the $N=4$ superconformal index is expressed. [Satoshi Nawata]

New supergravity solutions

A solution generating technique was used to construct new solutions in Type IIB supergravity that are deformations of the Klebanov-Strassler solution. Starting with a solution describing wrapped D5

branes, which due to the presence of a dimension 8 operator is not UV complete, the rotation turns off the dimension 8 operator, making the UV well-defined. In addition to the scale of the gaugino condensate the solution generated is characterized by having another scale, set by the size of the VEV of a dimension 6 operator. This VEV Higgses the quiver gauge group of Klebanov-Strassler to a single gauge group. It is natural to regard the D5 brane system as an effective theory valid below the scale of the dimension 6 VEV, an interpretation that is supported by the detailed study of the rotated solutions. [Daniel Elander with Jerome Gaillard, Carlos Nunez and Maurizio Piai (Swansea)]

Confinement in low-dimensional Yang-Mills theory

Yang Mills theories in dimensions d up to two, with D adjoint scalars, were considered. In the limit of large D , it was shown that bilinears of the adjoint scalar condense in a non-trivial vacuum, leading to a dynamical generation of mass. Using this method, phase diagrams of these theories were computed at weak coupling analytically. In $d=1$, these calculations were compared with earlier numerical work; these compared well, and in some cases, corrected the numerical results. For $d=2$, the analytically derived phase diagram provided evidence of a "cascade" of phase transitions found in previous lattice studies for four dimensional YM theories in a box. Strong coupling calculations of these gauge theories were performed using gauge-gravity duality and a comprehensive phase diagram was presented for two-dimensional adjoint scalar QCD [Gautam Mandal, with Takeshi Morita (University of Crete)]

Lifshitz-type field theories

A proposal is investigated which treats "maximal attainable" velocities for all particles as parameters and minimizes the vacuum energy of the system with respect to them. The hope is that the minimum is attained when all the velocities are equal. This is expected to address the problem of four-fermi Lorentz symmetry violating theory of violating Lorentz symmetry even at low energies. [Avinash Dhar and Gautam Mandal, with Holger Nielsen (Niels Bohr Institute)].

Beyond Standard Model and AdS/CFT

Various scenarios of beyond the standard model physics involving strong coupling physics are being studied. Some of these can be mapped by AdS/CFT on to 5-d theories in AdS-type of background geometry. Of particular interest are geometries that may be dual to walking technicolour theories. These 5-d scenarios are being investigated. [Avinash Dhar]

Dyonic Dilaton Black Branes

The thermodynamic and transport properties of dyonic black branes obtained in the presence of a dilaton and axion were studied. The entropy of these black branes is typically vanishing. It was found that the electric conductivity transforms suggestively under $SL(2,R)$ and the transport coefficients in general satisfy Weidemann-Franz type relations. [Shiroman Prakash and Sandip Trivedi, with Kevin Goldstein (Witwatersrand), Nori Iizuka (CERN) and Shamit Kachru (SLAC)]

Quintessence in String Theory

A model of quintessence was proposed in string theory based on the idea of axion monodromy. The quintessence field is an axion whose shift symmetry is broken by the presence of 5-branes which are placed in highly warped throats. This gives rise to a potential for the axion field which is slowly varying, even after incorporating the effects of moduli stabilization and supersymmetry breaking. The resulting time dependence in the equation of state of Dark Energy is potentially detectable,

depending on the initial conditions. The model has many very light extra particles which live in the highly warped throats, but these are hard to detect. A signal in the rotation of the CMB polarization can also possibly arise. [Yoske Sumitomo and Sandip Trivedi, with Sudhakar Panda (HRI)]

Membranes in M-theory

The novel Higgs mechanism relates conformal Chern-Simons field theories in $2+1$ d to (non-conformal) Yang-Mills theories. It was shown that this is possible due to an incompatibility between diagonalising the mass matrix and preserving the Lorentz metric on field space in the Chern-Simons theory. In this situation a variant of a well-known duality between topological and dynamical mass, due to Deser and Jackiw, applies and gives rise to a massless final theory. General conditions for the novel Higgs mechanism to hold were obtained. It was also shown that in a certain gauge, the equations of motion for difference-Chern-Simons theories are identical to the Hitchin equations. [Sunil Mukhi]

Mathematical Physics

A study of rank one connections on an abelian variety was carried out and its moduli space constructed. [Ashok Raina and Indranil Biswas with J. Hurtubise (McGill)]

An earlier algebro-geometric proof of the trisecant identity for Riemann theta functions associated to a compact Riemann surface of arbitrary genus was generalised. The earlier result took as mathematical data a degree $g-1$ line bundle and some axioms based on the Operator Product Expansion of free fermions. The generalisation consists of replacing the line bundle by a rank r , simple bundle and keeping the axioms of the OPE. A 'non-commutative Wick theorem' is shown to hold. Moreover, the techniques of schemes with nilpotent elements can be extended to study the corresponding currents of the system. [Ashok Raina]

Integrability in AdS₄

The example of the AdS/CFT correspondence to ABJM theory is described at all values of the coupling by an integrable structure which contains one unfixed interpolating function. This function is understood at strong coupling by comparing results from the integrable structure to perturbative string calculations. This was done at one loop for all classes of giant magnons in CP^3 . For this purpose a description of the string as an algebraic curve was used and it was shown how to implement the various proposed cutoff schemes using this technology. [M.C. Abbott, with I. Aniceto (Lisbon) and D. Bombardelli (Porto)]