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Department of Theoretical Physics

String Theory and Mathematical Physics

The inside outs of AdS3/CFT2: exact AdS wormholes with entangled CFT duals

It has long been know in a system can be understood as arising from a pure state in a larger system obtained by adding another copy of the original system. The two systems do not have a mutual interaction but are linked by the fact that their wavefunctions are entangled. The entanglement is precisely described and its extent is dictated by the requirement that the density matrix of system 1, after tracing over system 2, should be the thermal density matrix. It has been known for a while that such an entangled pair of systems, the so-called thermofield double, has a geometric dual given by the maximally extended manifold of eternal black hole, with two asymptotically AdS regions and the interior of the black hole. In recent times, it has been suggested that such a dual map for black hole spacetimes could be somewhat special, and generic black holes may not have a field theory dual. We show that the duality between the thermofield double in two dimensions and an eternal black hole can be generalized to a large class of examples where the thermofield double is deformed by independent conformal transformations on the two sides. The corresponding geometric duals were obtained by extending the conformal transformations into a large diffeomorphism inside the bulk. The duality was verified by matching the holographic stress tensor with that of the field theory. It was also shown that the entanglement entropy of a certain interval was reproduced correctly from holography in terms of geodesics that pass through the black hole interior. The dynamical entanglement entropy has an interesting behaviour which is a linear rise modulated by a conformal transformation. There results provided evidence for a recent conjecture by Maldacena and Susskind that quantum entanglement may be generically represented by spacetimes connected by a wormhole (EPR = ER).
[Gautam Mandal, R. Sinha and N. Sorokhoibam].

Unitarity, Crossing Symmetry and Duality of the S-matrix in large N Chern-Simons theories with fundamental matter

Explicit computations and conjectures for $2 \to 2$ scattering matrices are presented in large N U(N) Chern-Simons theories coupled to fundamental bosonic or fermionic matter to all orders in the t Hooft coupling expansion. The bosonic and fermionic S-matrices map to each other under the recently conjectured Bose-Fermi duality after a level-rank transposition. The S-matrices may be regarded as relativistic generalization of Aharonov-Bohm scattering. They have unusual structural features: they include a non- analytic piece localized on forward scattering, and obey modified crossing symmetry rules. It was conjectured that these unusual features are properties of S-matrices in all Chern-Simons matter theories. The S-matrix in one of the exchange channels in our paper has an anyonic character; the parameter map of the conjectured Bose-Fermi duality may be derived by equating the anyonic phase in the bosonic and fermionic theories.
[Shiraz Minwalla, Spenta R. Wadia, S. Jain, M. Mandlik, and S. Yokoyama with T. Takimi (HRI)]

Poles in the S-Matrix of Relativistic Chern-Simons Matter theories from Quantum Mechanics

An all orders formula for the S-matrix for $2 \to 2$ scattering in large N ChernSimons theory coupled to a fundamental scalar has recently been conjectured. A scaling limit of the theory in which the pole in this S-matrix is near threshold was found. It was argued that the theory must be well described by non-relativistic quantum mechanics in this limit, and the relevant Schroedinger equation was determined. It was demonstrateted that the S-matrix obtained from this Schroedinger equation agrees perfectly with this scaling limit of the relativistic S-matrix; in particular the pole structures match exactly. This matching provided a nontrivial consistency check of the conjectured field theory S-matrix.
[Shiraz Minwalla, Y. Dandekar, and M. Mandlik]

Conformal Invariance and the Four Point Scalar Correlator in Slow-Roll Inflation

The four point correlation function for scalar perturbations in the canonical model of slow-roll inflation was calculated in the leading slow-roll approximation where the calculation can be done in de Sitter space. The calculation used techniques drawn from the AdS/CFT correspondence to find the wave function at late times. The four point function was then computed from the wave function. The obtained answer agreed with an earlier result in the literature, obtained using different methods. The analysis revealed a subtlety with regard to the Ward identities for conformal invariance, which arises in de Sitter space and has no analogue in AdS space. This subtlety arose because in de

Sitter space the metric at late times was a genuine degree of freedom, and hence to calculate correlation functions from the wave function of the Universe at late times, it was necessary to fix gauge completely. The resulting correlators wer then invariant under a conformal transformation accompanied by a compensating coordinate transformation which restored the gauge.
[Sandip P. Trivedi, A. Ghosh, N. Kundu, and S. Raju]

Constraints from Conformal Symmetry on the Three Point Scalar Correlator in Inflation

Symmetry considerations were used to derive Ward identities which relate the three point function of scalar perturbations produced during inflation to the scalar four point function, in a particular limit. The derivation assumed approximate conformal invariance, and the conditions for the slow roll approximation, but was otherwise model independent. The Ward identities implied that the three point function must be suppressed in general, being of the same order of magnitude as in the slow roll model. They also fix the three point function in terms of the four point function, upto one constant which was argued to be generically generically suppressed.
[Sandip P. Trivedi and A. Shukla with N. Kundu (HRI)]

On The Entanglement Entropy For Gauge Theories

A definition for the entanglement entropy of a gauge theory on a spatial lattice was proposed. The definition applied to any subset of links in the lattice, and was valid for both Abelian and Non-Abelian gauge theories. For Z_N and $U(1)$ theories, without matter, this definition agreed with a particular case of the definition given by Casini, Huerta and Rosabal. It was also argued that in general, both for Abelian and Non-Abelian theories, our definition agreed with the entanglement entropy calculated using a definition of the replica trick. The definition, however, did not agree with some standard ways to measure entanglement, like the number of Bell pairs which could be produced by entanglement distillation.
[Sandip P. Trivedi, S. Ghosh, and R. M. Soni]

A Strongly Coupled Anisotropic Fluid From Dilaton Driven Holography

A system consisting of 5 dimensional gravity with a negative cosmological constant coupled to a massless scalar, the dilaton was considered. A black brane solution which arises when the dilaton satisfies linearly varying boundary conditions in the asymptotically $AdS5$ region was constructed. The geometry of this black brane broke rotational symmetry while preserving translational invariance and corresponded to an anisotropic phase of the system. Close to extremality, where

the anisotropy is big compared to the temperature, some components of the viscosity tensor became parametrically small compared to the entropy density. The quasi normal modes were studied in considerable detail and no instability close to extremality was found. The equations for fluid mechanics for an anisotropic driven system in general, working upto first order in the derivative expansion for the stress tensor, were obtained and additional transport coefficients which appear in the constitutive relation were identified. For the fluid of interest it was found that the parametrically small viscosity can resulted in a very small force of friction, when the fluid was enclosed between appropriately oriented parallel plates moving with a relative velocity

[Sandip P. Trivedi, Sachin Jain, and N. Kundu, with K. Sen, and A. Sinha (IISC)]

Stable Bianchi III attractor in $U(1)_R$ gauged supergravity

Bianchi attractors are homogeneous and anisotropic extremal black brane horizons. The $AdS_3 \times \mathbb{H}^2$ solution is a special case of Bianchi type IIIin a $U(1)_R$ gauged supergravity. For a wide range of values for certain free parameters in gauged supergravity, it was shown that there exist a large class of solutions that satisfy conditions for the attractor mechanism to hold. The response of the solution against linearized fluctuations of the scalar field was investigated. The sufficient conditions for the attractor mechanism ensured that there existed a solution for the scalar fluctuation which died out at the horizon. Furthermore, the gauge field and metric fluctuations that are sourced by scalar fluctuations were solved for and it was demonstrated that they were well behaved near the horizon. Thus, an example of a stable Bianchi attractor in gauged supergravity was constructed. The Killing spinor equations of gauged supergravity was also analysed in the background of our solution. It was demonstrated that a radial Killing spinor consistent with the Bianchi III symmetry breaks all supersymmetry.

[K. Inbasekar and R. Samanta]