Holography@25 (ICTP-SAIFR, São Paulo)
Titles and abstracts

School, 5-13 June 2023

1. J. de Boer
   Some references:
   https://arxiv.org/abs/1409.1231

   https://arxiv.org/abs/1703.02143

   https://arxiv.org/abs/1804.10610

   https://arxiv.org/abs/2012.05770

2. A. Donos
   Some references:

   ArXiv: 0903.3246, 1612.07324

   "Gauge/Gravity duality" by M. Ammon and J. Erdmenger

   "Holographic duality in condensed matter physics" by J. Zaanen, Ya-Wen Sun, Yan Lin and Koenraad Schalm

3. C. Hoyos – *Holographic approach to QCD at large densities and compact stars*
   Some bibliography
   Introduction to the AdS/CFT Correspondence (book by H. Nastase)
   Gauge/Gravity Duality: Foundations and Applications (book by J. Erdmenger and M. Ammon)
   Holographic approach to compact stars and their binary mergers (C. Hoyos, N. Jokela, A. Vuorinen, arXiv: 2112.08422)
   Holographic modeling of nuclear matter and neutron stars (M. Jarvinen, arXiv: 2110.08281)

4. H. Verlinde

5. K. Zarembo - *Integrability in AdS/CFT*

   Some review articles

   https://arxiv.org/pdf/1012.3983.pdf

   https://arxiv.org/pdf/hep-th/9605187.pdf

   https://arxiv.org/pdf/1012.3990.pdf

   https://arxiv.org/pdf/1012.3991.pdf

   https://arxiv.org/pdf/1012.3993.pdf

   https://arxiv.org/pdf/1708.03648.pdf

   https://arxiv.org/pdf/1908.03444.pdf

   https://arxiv.org/pdf/1606.02950.pdf

   https://arxiv.org/pdf/1606.02951.pdf

Colloquia

07/06/2023 J. de Boer - *Quantum gravity, chaos, complexity and statistical physics*
I will give an overview of various recent developments in our understanding of quantum gravity and black holes. In particular, I will focus on (i) the chaotic nature of the quantum gravitational degrees of freedom, (ii) the statistical interpretation of semi-classical gravity and its connection to wormholes, and (iii) the possible role of computational complexity. I will try to connect all of this to famous questions like the information loss paradox and the experience of an infalling observer.

14/06/2023 J. Maldacena - *The entropy of Hawking Radiation*
Black holes are fascinating spacetime configurations predicted by general relativity. When quantum mechanics is taken into account, black holes are found to emit thermal radiation, called "Hawking radiation". Recently an interesting area formula for the quantum entropy of black holes was derived. This also leads to a surprising new way to compute the entropy of Hawking radiation. This result indicates that the black hole formation and evaporation is consistent with standard quantum mechanical laws.

Workshop, 14-17 June 2023

M. Baggioli - *Holography with broken spacetime symmetries and its transition into adulthood*
At ten years old, Holography realized that it could play a useful role for several open questions in condensed-matter physics. Nevertheless, this gift came at the price of giving up many of its original symmetries, even the spacetime ones. During its teenage years, Holography quickly learned how to live without translational invariance and became a valuable tool to construct, improve and verify low-energy effective field theories for systems with broken symmetries. As a wiser adult, Holography is now trying to assess how to make a real impact for scientists who do not live in Anti de Sitter spacetime. In this talk, I will guide you through the early life of holography with broken symmetries and present the successes, the failures and the future of this program.

N. Bobev - *Large N Partition Functions, Holography, and Black Holes*
I will discuss the large N behavior of partition functions of the ABJM theory on compact Euclidean manifolds. I will pay particular attention to the S^3 free energy and the topologically twisted index for which I will present closed form expressions valid to all orders in the large N expansion. These results have important implications for holography and the microscopic entropy counting of AdS_4 black holes which I will discuss. I will also briefly discuss generalizations of these results to the superconformal index, as well as to other 3d SCFTs arising from M2-branes.

D. Correa - *Wilson loops and integrability in Chern-Simons-matter theories*

N. Drukker - *Surface operators and holographic M2-branes*

J. Erdmenger - *Geometric phases, von Neumann algebras and AdS/CFT*

I will explain how geometric phases may be used to characterize the entanglement properties of eternal black holes in AdS/CFT. Geometric phases provide a neat formulation of the factorization puzzle for the Hilbert spaces in the gravity theory and dual field theory. We show that a vanishing geometric phase implies the existence of a well-defined trace functional on the associated von Neumann algebra. We consider the example of Virasoro Berry phases in particular. We find that similar algebraic structures are also realized in simple spin systems. In addition to its relevance for quantum gravity, this analysis therefore also suggests how to experimentally realise geometric phases and its relation to entanglement in table-top experiments. This provides a new example for relations between very different branches of physics that follow from the AdS/CFT correspondence and its generalizations.

Based on 2109.06190, 2202.11717 and 2306.00055

C. Hoyos - *Holographic baryonic matter without flavor branes*
In holographic models flavor is usually realized by introducing additional branes in a dual supergravity background. With this realization one is forced to work in a probe approximation or solve supergravity equations with sources, which typically requires introducing additional phenomenological simplifications. In addition, since there are no fields carrying baryon charge on the branes, baryonic matter is dual to solitonic configurations on the flavor branes, which makes it challenging to describe a state with non-zero baryon density. Here we will show how these issues can be avoided by considering a holographic model where baryon symmetry is already realized in the dual supergravity sector. We construct confining solutions with non-zero baryon density that do not involve solitonic configurations despite the absence of dual fields carrying baryon charge. The model is a three-dimensional field theory cousin of Klebanov-Strassler and shares with it some interesting features like a duality cascade.

H. Lin - *Coherent states and high dimension operators in gauge/gravity correspondence*

J. Maldacena - *Scaling similarity in large N quantum mechanics*

D. Martelli - *A spindle story: from AdS to equivariant localization and back*
The AdS/CFT correspondence has been recently enriched by the construction of a novel type of supersymmetric AdS backgrounds, comprising the spindle and other geometries with orbifold singularities, prompting progress in supergravity, geometry and field theory. In this talk I will recount this story, going through some explicit supergravity solutions and general lessons drawn from them. In particular, I will argue that the theory of equivariant localization is the appropriate mathematical framework to study universal aspects of holography, in the supersymmetric setting.

D. Melnikov - *Entanglement and holographic states in Chern-Simons theory*
I will consider a simple class of states in topological quantum field theories that exhibit properties commonly attributed to the states of theories with a holographic dual. These states satisfy a discrete analog of the minimal area law for entanglement entropy, together with the characteristic inequalities. Similarly to classical geometries, these states are also classical states of the topological theories. I will discuss some applications, including an analog model of a unitary black hole evaporation.

R. Myers - *Complexity equals (Almost) Anything*
Motivated by holographic complexity, we examine a new class of gravitational observables in asymptotically AdS space associated with codimension-one slices or with codimension-zero regions. We argue that any of these observables is an equally viable candidate as the extremal volume for a gravitational dual of complexity.

N. Obers - *Non-relativistic corners in string theory and AdS/CFT*

I will start by showing how certain near BPS limits of N=4 SYM lead to a type of non-relativistic string, indicating its relevance as a corner of the AdS/CFT correspondence. Subsequently, I discuss how these fit in the larger landscape of non-relativistic strings. The original formulation of non-relativistic strings on flat target spacetime was introduced already twenty years ago, but recent progress in our understanding of non-Lorentzian geometries such as Newton-Cartan geometry has enabled to formulate this sector on arbitrary curved nonrelativistic spacetimes. I will show how strings on torsional string Newton-Cartan geometry arise from a limit of relativistic strings. Finally, I will introduce a further limit that leads to a novel class of worldsheet sigma models that not only have a non-relativistic target spacetime but also exhibit non-relativistic worldsheet symmetries, and explain that such sigma models are connected to near BPS limits of the AdS/CFT correspondence.

L. Pando-Zayas - *Logarithmic Corrections to the Entropy of AdS Black Holes*

I will review some recent developments within the AdS/CFT correspondence whereby the Bekenstein-Hawking entropy of certain black holes has been given a microscopic, statistical mechanical foundation in terms of partition functions of the dual field theories. At the quantum level, the entropy of black holes is not exactly equal to one quarter of the area of the event horizon; it receives tiny quantum corrections proportional to the logarithm of the area. I will describe how these logarithmic corrections to the black hole entropy can be computed for certain black holes in AdS and how to match them successfully to a microscopic description based on the AdS/CFT correspondence.

K. Skenderis - *Flat space limit of AdS/CFT for massive amplitudes*

We analyse the flat space limit of AdS and use it to derive massive amplitudes in flat space starting from momentum space CFT correlators involving non-conserved spinning operators.
The flat space limit amounts to taking Δ, L to infinity keeping fixed the mass of the bulk field, where Δ is the dimension of the dual operator and L the AdS radius. We show how the AdS isometries are mapped to Poincar\'{e} ones in this limit, and demonstrate the analysis by deriving the flat space 3-point amplitude involving a complex massive vector field, its complex conjugate and an Abelian gauge field. The corresponding AdS amplitude/CFT 3-point function depends on 3-parameters, which are related to the charge, the gyromagnetic coupling and the quadrupole moment of the massive field.

D. T. Son - *Applied nonrelativistic conformal field theory*

J. Sparks - *Equivariant localization in supergravity*
I will show that supersymmetric supergravity solutions with an R-symmetry Killing vector are equipped with a set of equivariantly closed forms. Various physical observables may be expressed as integrals of these forms, and then evaluated using the Berline-Vergne-Atiyah-Bott fixed point theorem. This will be illustrated with a variety of holographic examples, including on-shell actions, black hole entropies, central charges, and scaling dimensions of operators. The resulting expressions depend only on topological data and the R-symmetry vector, and hence may be evaluated without solving the supergravity equations.

A. Tomasiello - *General bounds on Kaluza–Klein masses*

H. Verlinde -

K. Zarembo - *'t Hooft loops and integrability*
't Hooft loops are disorder operators that exist in any gauge theory. They are beautifully connected to quantization of charge in the field of a magnetic monopole. I will discuss an interplay of holography, S-duality and localization for 't Hooft loops in the N=4 super-Yang-Mills theory.