



Spring School on Superstring Theory and Related Topics | (SMR 4209)

23 Mar 2026 - 31 Mar 2026
ICTP, Trieste, Italy

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Poster Presentation**A Worldsheet Odyssey: String Cobordisms via Non-Compact CFTs****Edoardo Anastasi¹, Miguel Montero¹, Angel Uranga¹, and Chuying Wang¹***¹Instituto de Física Teórica IFT-UAM/CSIC*

The cobordism conjecture [1] proposes that any two consistent theories of Quantum Gravity can be connected via a domain wall. We study the realization of cobordism domain walls separating different string theories in terms of interpolations between their 2d worldsheet CFTs. We use this to provide microscopic descriptions of the domain wall between 10d type 0A and 0B theories, and type IIA and IIB theories. The construction admits a descriptions in terms of supercritical strings. Our interpolations involve passing through non compact CFTs, allowing for physical transitions changing the 2d topological phase.

[1] J. McNamara, C. Vafa, *Cobordism Classes and the Swampland*, arXiv:1909.10355.

Quantum entanglement in interacting 1+1D massless Lifshitz field theory with arbitrary anisotropy

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We consider renormalizable Lifshitz field theory with various choices of interactions and an arbitrary anisotropy index, z , to compute the entanglement entropy. The choices of interaction include quartic self-interaction, Yukawa-type fermionic interaction and non-abelian Yang-Mills-like interaction. We develop the Rokhsar-Kivelson family of ground states for each of the chosen interacting LFTs and formalise the path integral using the associated Kernels. These are further utilised in the well-known replica technique to derive the entanglement entropy. For each case, we analyse the behaviour of entanglement entropy with the anisotropy of the theory.

References:

[1] Massless Lifshitz field theory for arbitrary z , J.K. Basak, A. Chakraborty, C.-S. Chu, D. Giataganas and H. Parihar, JHEP 05 (2024) 284

Running Love Numbers of Charged Black Holes

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Loops of virtual particles in quantum field theory induce a non-vanishing tidal response in charged black holes. We compute the static tidal response of unspinning electrically and magnetically charged black holes using perturbative formalism developed in [1].

Since gravitational and electromagnetic tidal perturbations are coupled, we generalize the notion of Love numbers to Love matrices. We derive the coupled equations of motion for the metric and electromagnetic fluctuations around purely electric and magnetic backgrounds. For large charged black holes, which are described by the Effective Field Theory (EFT) of gravity, we compute the full set of Love matrices induced by an arbitrary tower of F^{2n} operators.

We find that, although quantum corrections break electromagnetic duality of Maxwell theory, the Love matrices in electric and magnetic backgrounds are related by a Z_2 symmetry under electric-magnetic exchange. Going beyond EFT, we compute the Love matrices of small magnetic black holes. We show that the running of the Love matrices is governed by the running of the $U(1)$ gauge coupling, and we derive the correspondence between Love and $U(1)$ beta functions for arbitrary spherical harmonics.

Our results indicate that the QFT-induced tidal response of magnetic black holes saturates in the strong-field regime, with potential implications for gravitational-wave probes of nearly extremal black holes charged under an Abelian dark sector.

A detailed derivation can be found in [2].

[1] S. Barbosa, S. Fichet, L. de Souza, JCAP 07 (2025) 071.

[2] S. Barbosa, S. Fichet, L. de Souza, arXiv: 2602.00349.

Black Holes and Black Strings from M-Theory on Calabi Yau Threefolds with Four Kähler Parameters

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Using toric geometry and $\mathcal{N} = 2$ supergravity, we study 5D black branes in M-theory compactified on a Calabi–Yau threefold with four Kähler parameters. We analyze BPS and non-BPS black holes from M2-branes on non-holomorphic 2-cycles, identifying allowed electric charge regions and computing their entropy, temperature, and stability via the recombination factor. We then examine 5D black strings from M5-branes on dual 4-cycles, finding stable and unstable states depending on magnetic charges in the moduli space.

- [1] A. Belhaj, H. Belmahi, A. Bouhouch, S. E. Ennadifi, M. B. Sedra, "Black Holes and Black Strings in M-theory on Calabi-Yau threefolds with four Kähler parameters", *Eur.Phys.J.C* 85 (2025) 8, 901

Electroweak effects on the proton structure from holographic Pomerons

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In this work we use the BPST Pomeron [1] to fit experimental data of the proton $F_2(x, Q^2)$ [2] structure function within the Bjorken parameter range $0.01 \leq x \leq 0.1$ and the squared of the virtual momentum transfer $Q^2 \leq 3000 \text{ GeV}^2$ where electroweak effects are relevant. Moreover, we investigate the proton anti-symmetric structure function $xF_3(x, Q^2)$ [3] using the Holographic A-Pomeron [4, 5] within the ranges $0.01 \leq x \leq 0.1$ and $1000 \text{ GeV}^2 \leq Q^2 \leq 8000 \text{ GeV}^2$ where γZ interference effects become dominant. In both cases we obtain values of χ^2 per degree of freedom very close to the unity, signalling a remarkably good level of agreement between the holographic Pomerons and the experimental data. Also, we compare the holographic Pomerons parametrizations with the structure functions F_2 and xF_3 obtained with NNPDF4.0 [6].

[1] R. C. Brower, M. Djuric, I. Sarcevic and C. I. Tan JHEP 11 (2010)

[2] F. D. Aaron *et al.* [H1 and ZEUS], JHEP **01** (2010), 109

[3] H. Abramowicz *et al.* [H1 and ZEUS], Eur. Phys. J. C **75** (2015)

[4] N. Kovensky, G. Michalski and M. Schvellinger, JHEP 10 (2018)

[5] M. Schvellinger and D. Jorin, Phys.Rev.D 106 (2022)

[6] R. D. Ball *et al.* [NNPDF], Eur. Phys. J. C **82** (2022)

Instantons in String Theory

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This work investigates instantonic solutions in string theory arising from the D3-D(-1) brane system, with the aim of establishing a precise correspondence between superstring field theory and Yang–Mills instantons. We analyze the equations of motion of open superstring field theory around the D3-D(-1) bound state and study marginal deformations associated with the size modulus of the instanton. A central focus is the perturbative construction of solutions in string field theory and the identification of obstructions at higher orders. While the deformation corresponding to a finite instanton size is unobstructed at second order, we show that non-trivial effects arise at third order, reflecting subtle contributions from supermoduli space and highlighting the limitations of the on-shell worldsheet approach. These obstructions can be consistently resolved by including appropriate background gauge fields, allowing for the definition of a well-behaved instanton profile. Building on this framework, the thesis aims to derive a genuinely non-perturbative effective equation governing the expansion in the instanton size parameter within the ADHM parametrization. We propose an ansatz compatible with the Yang–Mills instanton equations, explicitly accounting for the decoupling between massless and massive string modes in the low-energy effective field theory. This approach provides a systematic bridge between superstring field theory and the ADHM construction, clarifying the role of D-instantons as finite-size, non-perturbative objects and extending the correspondence to include higher-order corrections.

- [1] J. Polchinski, *String Theory, Vol. 1: An Introduction to the Bosonic String*, Cambridge University Press, Cambridge (1998).
- [2] J. Polchinski, *String Theory, Vol. 2: Superstring Theory and Beyond*, Cambridge University Press, Cambridge (1998).
- [3] JM. Cho, J. P. Gomide, J. Scheinpflug, X. Yin, *On the $AdS_5 \times S^5$ Solution of Superstring Field Theory*, arXiv:2507.12921 [hep-th] (2025)
- [4] L. Mattiello, *On Instantons and Finite-Size D-Branes in String Theory*, PhD Thesis, Ludwig-Maximilians-Universität München (2019).
- [5] S. Donaldson, *The ADHM construction of Yang-Mills instantons*, arXiv:2205.08639 [hep-th] (2022).
- [6] E. Witten, *Small instantons in string theory*, Nucl. Phys. **B460** (1996) 541-559, [hep-th/9511030].

The (no) boundary proposal and excited states in de Sitter holography

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In the AdS/CFT framework, vacuum and excited states are systematically described by imposing arbitrary Dirichlet boundary conditions at the AdS boundary. Furthermore, there are explicit relations connecting the quantum states to their corresponding dual Euclidean AdS geometries, in line with the Hartle-Hawking (HH) construction. The ground state therefore corresponds to the dominant saddle point under trivial conditions on the asymptotic boundary, which is the exact Euclidean AdS geometry. In contrast, the situation in de Sitter spacetime differs significantly, as there is no natural region analogous to the AdS boundary. Thus, the Hartle Hawking approach precisely defines the ground state as a path integral over smooth (Euclidean) geometries ending on a spatial Cauchy surface, with no additional boundary or past singularity, known as the no boundary proposal. In this work, we revisit the no boundary proposal to describe excited states within the framework of de Sitter Holography. Specifically, we investigate the possibility of defining a family of excited states by introducing an additional boundary in the Euclidean region and imposing arbitrary Dirichlet boundary conditions on it. As a result, we demonstrate that the computation of n point correlation functions is consistent with the presence of excited states, and furthermore, show that cosmological late-time observables in these states undergo non-trivial modifications. Based on: Botta-Cantcheff, M., Cruz, F.L. & Martínez, P.J. The (no) boundary proposal and excited states in de Sitter holography. *J. High Energ. Phys.* **2025**, 173 (2025). [https://doi.org/10.1007/JHEP09\(2025\)173](https://doi.org/10.1007/JHEP09(2025)173)

Flowery Horizons & Bulk Observers: $sl^{(q)}(2, \mathbb{R})$ Drive in 2d Holographic CFT

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Abstract

We explore and analyze bulk geometric aspects corresponding to a driven two-dimensional holographic CFT, where the drive Hamiltonian is constructed from the $sl^{(q)}(2, \mathbb{R})$ generators. In particular, we demonstrate that starting with a thermal initial state, the evolution of the event horizon is characterized by distinct geometric transformations in the bulk which are associated to the conjugacy classes of the corresponding transformations on the CFT. Namely, the bulk evolution of the horizon is geometrically classified into an oscillatory (non-heating) behaviour, an exponentially growing (heating) behaviour and a power-law growth with an angular rotation (the phase boundary), all as a function of the stroboscopic time. We also show that the explicit symmetry breaking of the drive is manifest in a flowery structure of the event horizon that displays a $U(1) \rightarrow \mathbb{Z}_q$ symmetry breaking. In the $q \rightarrow \infty$ limit, the $U(1)$ symmetry is effectively restored. Furthermore, by analyzing the integral curves generated by the asymptotic Killing vectors, we also demonstrate how the fixed points of these curves approximate a bulk Ryu-Takayanagi surface corresponding to a modular Hamiltonian for a sub-region in the CFT. Since the CFT modular Hamiltonian has an infinitely many in-equivalent extensions in the bulk, the fixed points of the integral curves can also lie outside the entanglement wedge of the CFT sub-region.

- [1] J. Das and A. Kundu, JHEP **05** (2025) 035, doi:10.1007/JHEP05(2025)035, arXiv:2412.18536 [hep-th].
- [2] X. Wen, R. Fan, and A. Vishwanath, arXiv:2211.00040 [cond-mat.str-el] (2022).
- [3] J. de Boer, V. Godet, J. Kastikainen, and E. Keski-Vakkuri, J. High Energ. Phys. **2023**, 087 (2023).

Jones index from Rényi entropies in the Ising conformal field theory

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The Jones index originated in the study of von Neumann algebra subfactors to characterize the inclusion of one algebra within another. Recently, it has emerged in the physics literature as a probe for the completeness of a quantum field theory and as a tool to study RG flows [1, 2]. By quantifying the size of the observable algebra relative to the full theory, the index serves as a diagnostic tool for identifying the presence of generalized symmetries and modular invariance [1, 3]. In this work, we further explore this notion by studying Rényi mutual information for $n \geq 2$ and two interval regions associated with subalgebras of the Ising and the free Majorana CFTs in (1+1) dimensions. By mapping the calculation to a genus $(n - 1)$ partition function, we derive expressions for the partition function of each submodel on higher genus Riemann surfaces. This approach necessitates a classification of all possible modular or non-modular invariant partition functions constructed from representations of the $c = 1/2$ Virasoro algebra at any genus. Using these results, we compute the Jones index for each submodel via a limiting procedure on an asymmetric mutual information function called crossing asymmetry introduced in [1].

- [1] V. Benedetti, H. Casini, Y. Kawahigashi, R. Longo and J. M. Magan, “Modular invariance as completeness”, *Phys. Rev. D* **110**, 125004 (2024), [arxiv:2408.04011](#).
- [2] V. Benedetti, H. Casini and J. M. Magan, “Selection rules for RG flows of minimal models”, *Phys. Rev. D* **111**, 065024 (2025), [arxiv:2412.16587](#).
- [3] H. Casini and J. M. Magan, “On completeness and generalized symmetries in quantum field theory”, *Mod. Phys. Lett. A* **36**, 2130025 (2021), [arxiv:2110.11358](#).

Black Hole Weak Gravity Conjecture and the Strong-Field Regime

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In [1] we analyze several aspects of the Weak Gravity Conjecture (WGC), ranging from the infrared regime, where the dynamics of spacetime and matter at distances larger than the Planck length can be described by an effective field theory, to the strong-field regime, in which the electromagnetic sector becomes dominant. In particular, we point out that the WGC implies that sufficiently small extremal black holes necessarily lie in the strong-field regime of electrodynamics, and therefore probe the UV completion of the Maxwell sector.

To investigate the WGC bounds implied by such small extremal black holes, we revisit black hole decay in generic field theories in asymptotically flat spacetime. We derive a necessary and a sufficient condition for any black hole to decay, the latter amounting to a bound on the growth of charge relative to mass. We then apply these decay conditions to extremal black holes arising in some models of ultraviolet completions for the Maxwell sector, thereby classifying which models are compatible with black-hole decay in the strong-field regime. The decay conditions are also used to show that the black hole WGC implies positivity of the $U(1)$ gauge coupling beta function. This provides an independent argument that classically stable (embedded-Abelian) colored black holes cannot exist.

Acknowledgments: This work was supported in part by the São Paulo Research Foundation (FAPESP), grant 2021/10128-0. The work of LS and SB was supported by grant 2023/11293-0 and 2025/05571-3 of FAPESP.

[1] S. Barbosa, S. Fichet, L. de Souza, JHEP 10 (2025) 145.

Spacetimes with Symmetry in Modified Theories of Gravity

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Spacetime symmetries play a crucial role in our understanding of Gravitational theories. The idea of *reduction of Lagrangians* by a specified symmetry group is attractive for several reasons: i) when dealing with complicated theories of gravity (e.g. the higher-derivative gravity models) one can bypass the variation of the full Lagrangian and the subsequent substitution of the metric ansatz into the field equations and replace it by a reduced Lagrangian evaluated directly on this ansatz, which typically yields the reduced field equations much faster (the *Weyl trick*); ii) the reduced Lagrangians can be viewed as interesting mini/midi-superspace models that may be used in applications where the full phase space is difficult to deal with; iii) one can scan for special theories that are tuned to possess desired symmetries so that they display a reduced order of derivatives in the field equations. Although it is usually used heuristically by many researchers, the Weyl trick has a rigorous mathematical formulation in terms of the *principle of symmetric criticality (PSC)*, which consists of two conditions on the infinitesimal symmetry group action that must be satisfied to obtain the correct solutions. In order to analyze every possibility of PSC being satisfied, one needs a complete classification of all infinitesimal group actions in four spacetime dimensions; this is realized in [1], the *Hicks classification*, where the author makes use of Lorentzian Lie algebra-subalgebra (isometry-isotropy) pairs to classify them. With this classification at hand, all the ingredients for a successful symmetric reduction are studied [2]: group actions compatible with PSC are identified, the relations among them are studied, and the subsequent invariant metrics are derived. The next natural step, which is currently a work in progress, is to carry out a similar analysis for the PSC-non-compatible cases.

- [1] Jesse W. Hicks, "Classification of spacetime with Symmetry"(2016), *All Graduate Theses and Dissertations, Spring 1920 to Summer 2023*. 5054.
- [2] G. Frausto, I. Kolář, T. Málek, C. Torre, "Symmetry reduction of gravitational Lagrangians", *arXiv: 2410.11036v3* (2025).

Gravitational origin of index saddle degeneracy and one-form symmetry

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Abstract

We study the gravitational origin of the logarithmic term arising in the superconformal index of four-dimensional $\mathcal{N} = 1$ SCFTs, both in the Cardy-like limit [1] and in the large- N limit, focusing on its interpretation in terms of discrete symmetries and saddle degeneracy. On the field-theory side, this contribution is associated with the spontaneous breaking of an electric \mathbb{Z}_N one-form symmetry, which leads to the appearance of N degenerate saddle points contributing equally to the index.

We analyze the gravitational realization of this saddle degeneracy by studying the infinite-volume limit of a supersymmetric non-extremal AdS_5 black hole solution, and reproduce the $\log N$ term by working within an appropriate 5d consistent truncation of type IIB supergravity [2].

- [1] D. Cassani and Z. Komargodski, EFT and the SUSY Index on the 2nd Sheet, *SciPost Phys.* 11 (2021) 004.
- [2] D. Cassani, G. Dall’Agata and A.F. Faedo, Type IIB supergravity on squashed Sasaki-Einstein manifolds, *JHEP* 05 (2010) 094.

Statistical mechanics	Rényi analogue
Inverse temperature: β	Replica parameter: n
Hamiltonian: H	Modular Hamiltonian: $H_A = -\log \rho_A$
Partition function: $Z(\beta) = \text{Tr} \left[e^{-\beta H} \right]$	Replica partition function: $Z(n) = \text{Tr}_A \left[e^{-n H_A} \right]$
Free energy: $F(\beta) = -\beta^{-1} \log Z(\beta)$	Replica free energy: $F(n) = -n^{-1} \log Z(n)$
Energy: $E(\beta) = -\partial_\beta \log Z(\beta)$	Replica energy: $E(n) = -\partial_n \log Z(n)$
Thermal entropy: $S(\beta) = \beta^2 \partial_\beta F(\beta)$	Refined Rényi entropy: $\tilde{S}^{(n)} = n^2 \partial_n F(n)$
Heat capacity: $C(\beta) = -\beta \partial_\beta S(\beta)$	Capacity of entanglement: $C^{(n)} = -n \partial_n \tilde{S}^{(n)}$

Capacity of Entanglement in RST gravity

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Introducing Entanglement Entropy (EE) and Information Theory into the context of the BHIP has improved both the conceptual understanding of the problem and the tools for its partial resolution in simplified models of Black Hole evaporation.

Capacity of Entanglement (CoE) is a related quantum information measure and, like the EE, can be defined through the Rényi Entropy. In the replicated space it is the analogue of Heat Capacity of thermodynamic systems [1]. The purpose of this project is to understand the Replica Wormholes construction in 2D dilatonic theories of gravity, extending the work of [1] from JT to RST gravity [2]. This theory has asymptotically flat spacetimes and this simplifies many technical difficulties present in JT gravity, mainly the ones related to the welding problem.

- [1] K. Kawabata, T. Nishioka, Y. Okuyama and K. Watanabe - **Replica wormholes and capacity of entanglement** - arxiv: 2105.08396
 [2] T. Hartman, E. Shaghoulian and A. Strominger - **Islands in Asymptotically Flat 2D Gravity** - arxiv: 2004.13857

Abstract template for the ICTP Spring School in Supergravity and related topics.

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Motivated by issues of static patch holography in de Sitter space and the understanding of an observer's experience in dynamical quantum gravity, we study quantum mechanical systems coupled to Euclidean JT gravity in anti-de Sitter space. We derive exact expressions for the two-point and n -point functions of a quantum mechanical observer on a worldline on the disk topology, for which we also propose a holographic interpretation. The main consequence of coupling quantum mechanics to gravity is the fluctuation of the global mode corresponding to the total Euclidean time for which the observer lives, which is suppressed in the classical gravity limit. Moreover, we analyze the partition function of a quantum mechanical system on the double trumpet. In this setup, we show that the partition function of the observer coupled to quantum gravity is computed as an integral over temperatures of the standard quantum mechanical partition function with a measure that is determined by the gravity theory, which becomes peaked at a fixed temperature in the $G_N \rightarrow 0$ limit, thus recovering standard quantum mechanics.

Black Holes and the Attractor Mechanism in One Parameter Calabi-Yau Compactifications

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Extremal BPS black holes in $\mathcal{N} = 2$ supergravity provide a controlled setting to study the attractor mechanism, whereby vector-multiplet scalars are driven to fixed values at the horizon determined by the electric–magnetic charges, independently of their asymptotic moduli [2]. In compactifications of type IIA/IIB string theory on one-parameter Calabi–Yau threefolds, these scalars admit a geometric interpretation as complex-structure moduli governed by special Kähler geometry and an effective prepotential encoding the topological data of the internal space [1]. Within this framework we investigate several attractor flows in moduli space and their relation to horizon quantities such as the central charge and the entropy, with particular emphasis on the role of periods, monodromy, and their numerical realization. The emerging picture connects the near-horizon fixed points of the flows to regions near the large-complex-structure (LCS) point in the Calabi–Yau moduli space and suggests a refined probe of its structure via extremal black holes [3]. Several nontrivial features of the flows, together with novel representative numerical solutions for black hole metrics, are outlined, whereas detailed constructions and explicit models are left for discussion in the poster.

[1] S. Bellucci, S. Ferrara and A. Marrani, eds., Supersymmetric mechanics. Vol. 2: The attractor mechanism and space time singularities, vol. 701, 2006.

[2] S. Ferrara, R. Kallosh and A. Strominger, N=2 extremal black holes, Phys. Rev. D **52** (1995)

[3] M. Delgado, M. Montero and C. Vafa, Black holes as probes of moduli space geometry, JHEP **04** (2023) 045

Area spectrum and black hole thermodynamics

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The role of horizon area quantization on black hole thermodynamics is investigated in this article. The coefficient appearing in the quantization of area is fixed by an appeal to the saturated form of Landauer's principle. Then, by considering the transition between discrete states of the event horizon area, which in turn is equivalent to transitions between discrete mass states of the black hole, the change in mass can be obtained. The change in mass is then equated to the product of the Hawking temperature and the change in entropy of the black hole between two consecutive discrete states, applying the first law of black hole thermodynamics. This gives the corrected Hawking temperature. In particular, we apply this technique to the Schwarzschild black hole, the quantum corrected Schwarzschild black hole, the Reissner-Nordström black hole, which is a charged black hole, and the rotating Kerr black hole geometry, and obtain the corrected Hawking temperature in each of these cases. We then take a step forward by inserting this corrected Hawking temperature in the first law of black hole thermodynamics once again to calculate the entropy of the black hole in terms of the horizon area of the black hole. This leads to logarithmic and inverse corrections to the entropy of the black hole.

- [1] J.D.Bekenstein, *Lettere al Nuovo Cimento* **4**, 737-740 (1972).
- [2] J. D. Bekenstein, *Lett. Nuovo Cimento* **11**, 467-470 (1974).
- [3] V. Mukhanov, "*Pis. Eksp. Tear. Fiz.* 44 (1986) 50 [*JETP Letters* 44 (1986) 631]; in *Complexity, Entropy and the Physics of Information, SFI Studies in the Sciences of Complexity, Vol. III, ed. W.H. Zurek (Addison-Wesley, New York, 1990)*".
- [4] J.D. Bekenstein and V.F. Mukhanov, *Phys. Lett. B* **360**, 7-12 (1995).
- [5] B. Bagchi, A. Ghosh and S. Sen, *General Relativity and Gravitation* **56**, 108 (2024).

On Thermodynamics of Charged Black Holes via Extended Space-time Derivatives

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Inspired by non-commutative geometry in string theory, we propose extended derivatives in black hole physics by incorporating a real antisymmetric tensor of rank 2 carrying similarities of certain stringy fields. Using gauge theory formulation of gravity via de Sitter group theory, we first find the associated black hole solutions by solving the Einstein field equations. Then, we study the thermodynamic properties by approaching the stability analysis, the criticality, and the phase transitions. Concretely, we investigate the P - V criticality behavior of the obtained solution. We compute and examine the Gibbs free energy revealing comparable attitudes with the Van der Waals phase transitions. Combining such results, we provide constraints on the deformed parameter B and the charge Q with the help of CUDA numerical methods exploited in machine learning computations. Precisely, we show that there are suitable ranges for such parameters where the obtained black holes behave like the Van der Waals fluid systems.

Iyer-Wald ambiguities and gauge covariance of Entropy current in Higher derivative theories of gravity

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In [1, 2], the authors have been able to argue for an ultra-local version of the second law of black hole mechanics, for arbitrary diffeomorphism invariant theories of gravity non-minimally coupled to matter fields, by constructing an entropy current on the dynamical horizon with manifestly positive divergence. This has been achieved by working in the horizon-adapted coordinate system. In this work, we demonstrate that the local entropy production, as measured by the divergence of the entropy current, is covariant under affine reparametrizations that preserve the gauge invariance of horizon-adapted coordinates. We explicitly derive a formula for how the entropy current transforms under such coordinate transformations. This extends the analysis of [3] to arbitrary diffeomorphism-invariant theories of gravity non-minimally coupled to matter fields. We also study the Iyer-Wald ambiguities of the covariant phase formalism that generically plague the components of the entropy current.

- [1] S. Bhattacharyya, P. Dhivakar, A. Dinda, N. Kundu, M. Patra and S. Roy, *JHEP* **09** (2021), 169 doi:10.1007/JHEP09(2021)169 [arXiv:2105.06455 [hep-th]].
- [2] P. Biswas, P. Dhivakar and N. Kundu, *JHEP* **12** (2022), 036 doi:10.1007/JHEP12(2022)036 [arXiv:2206.04538 [hep-th]].
- [3] S. Bhattacharyya, P. Jethwani, M. Patra and S. Roy, *Phys. Rev. D* **108** (2023) no.10, 104032 doi:10.1103/PhysRevD.108.104032 [arXiv:2204.08447 [hep-th]].
- [4] A. Kar, P. Dhivakar, S. Roy, B. Panda and A. Shaikh, *JHEP* **07** (2024), 016 doi:10.1007/JHEP07(2024)016 [arXiv:2403.04749 [hep-th]].
- [5] P. Biswas, A. Kar and A. Shaikh, “Zeroth law of black hole thermodynamics for higher derivative Proca theories,” [arXiv:2509.09516 [hep-th]].

Poster Abstract

 $c = 1$, $R = 1$ and $N \gg 1$: ZZ instantons in 2D String Theory and Matrix Integrals

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We explore the non-perturbative aspects of $c = 1$ string with compactified Euclidean time, its $0 + 0$ dimensional matrix model duals (at self-dual radius), and $0 + 1$ dimensional Matrix Quantum Mechanics (free fermion) description. We calculate the instanton normalizations, disk two-point function, and annulus one-point function in worldsheet formalism using string field theory insights. We further match them with the corresponding predictions from the matrix model descriptions.

Further, Instanton contributions in 2d string theory are known to include subtle numerical factors ζ_n closely related to a contour prescription in multi-instanton string amplitudes. Both ingredients appear to be ambiguous due to a degeneracy between $(1, n)$ -ZZ instantons and n $(1,1)$ -ZZ instantons in the linear dilaton background. We resolve this ambiguity using insights from the dual matrix quantum mechanics where the multipliers n can be derived from an integral representation of the scattering phase and follow from the median resummation prescribed by resurgence theory. We evaluate multi-instanton string amplitudes in the theory compactified on a circle of finite radius for arbitrary number of instantons and show that they reproduce the matrix model predictions provided the Lorentzian contour prescription is used for their evaluation. We also show that the non-perturbative free energy matches the structure of the D-instanton induced string field theory effective action, which suggests the vanishing of contributions from worldsheet topologies of negative Euler number.

References

- [1] Rishabh Kaushik. “ $c = 1$, $R = 1$ and $N \gg 1$: ZZ instantons in 2D string theory and matrix integrals”. In: *JHEP* 08 (2025), p. 177. DOI: 10.1007/JHEP08(2025)177. arXiv: 2501.14023 [hep-th].
- [2] Sergei Alexandrov and Rishabh Kaushik. “Multi-instantons in 2d string theory”. In: (Sept. 2025). arXiv: 2509.03293 [hep-th].

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Association Rules Machine Learning Calabi-Yau Manifolds

Semi-universality of CFT_d entropy at large spin

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The thermal partition function, Z , of a CFT_d on S^{d-1} is parameterized by the inverse temperature β along with $\lfloor d/2 \rfloor$ angular velocities ω_i . In this paper, we investigate the behaviour of this partition function when n of the ω_i are scaled to unity (the largest allowed value) at fixed values of the other $(\lfloor d/2 \rfloor - n)$ angular velocities. We argue that $\ln Z$ develops a simple pole in $(1 - \omega_i)$ for each ω_i that is scaled to unity. The residue of this product of poles is a theory dependent (so non-universal) function of β and the fixed angular velocities. The inverse Laplace transformation of this partition function constrains the functional form of the field theory entropy as a function of charges in a limit in which angular momenta and the twist are scaled as follows. While n special angular momenta $J_1 \dots J_n$ are scaled to infinity, the twist and the other angular momenta – collectively denoted x_i – are also taken to infinity but at the slower rate that ensures that the scaled charges $x_i / (J_1 J_2 \dots J_n)^{\frac{1}{n+1}}$ are held fixed. In this limit, we demonstrate that the scaled entropy $S / (J_1 J_2 \dots J_n)^{\frac{1}{n+1}}$ depends only on the $\lfloor d/2 \rfloor - n + 1$ scaled charges defined above (the precise form of this dependence is non-universal). We verify our predictions (and compute all non-universal functions) in the case of free scalar theories (which show surprisingly rich behaviour) as well as large N , strongly coupled $\mathcal{N} = 4$ Yang Mills theory. The last theory is analyzed in the bulk via the AdS/CFT correspondence. In the scaling limit described above, its phase diagram displays sharp phase transitions between black hole, grey galaxy, and thermal gas phases.

2-loop free energy of M2 brane in $\text{AdS}_7 \times S^4$ and surface defect anomaly in (2,0) theory

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$\frac{1}{2}$ -BPS surface operator viewed as a conformal defect in rank N 6d (2,0) theory is expected to have a holographic description in terms of a probe M2 brane wrapped on AdS_3 in the $\text{AdS}_7 \times S^4$ M-theory background. The M2 brane has the effective tension $T_2 = \frac{2}{\pi}N$ so that the large tension expansion corresponds to the $1/N$ expansion. The value of the defect conformal anomaly coefficient in $SU(N)$ (2,0) theory was previously argued to be $b = 12N - 9 - 3N^{-1}$. Semiclassically quantizing M2 brane it was found in [1] that the first two terms in b are indeed reproduced by the classical and 1-loop corrections to the M2 free energy. Here we address the question if the 2-loop term in the M2 brane free energy reproduces the N^{-1} term in b . Remarkably, despite the general non-renormalizability of the standard BST M2 brane action we find that the 2-loop correction to the free energy of the AdS_3 M2 brane in $\text{AdS}_7 \times S^4$ is UV finite (modulo power divergences that can be removed by an analytic regularization). Moreover, the 2-loop correction vanishes in the dimensional and ζ -function regularizations. This result appears to be in disagreement with the non-vanishing of the coefficient of the N^{-1} term in the expected expression for the anomaly coefficient b . We discuss possible resolutions of this puzzle, including the one that the M2 brane probe computation may be capturing the surface defect anomaly in the $U(N)$ rather than the $SU(N)$ boundary 6d CFT.

Based on [2].

- [1] N. Drukker, S. Giombi, A. A. Tseytlin and X. Zhou, “Defect CFT in the 6d (2,0) theory from M2 brane dynamics in $\text{AdS}_7 \times S^4$,” *JHEP* **07** (2020) 101, doi:10.1007/JHEP07(2020)101, arXiv:2004.04562 [hep-th].
- [2] M. Beccaria, S. A. Kurlyand and A. A. Tseytlin, “2-loop free energy of M2 brane in $\text{AdS}_7 \times S^4$ and surface defect anomaly in (2,0) theory,” arXiv:2511.22306 [hep-th], report number: Imperial-TP-2025-SK-03 (Nov 2025).

Abstract template for Spring School on Superstring Theory and Related Topics

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Exceptional field theory is a powerful reformulation of ten or eleven dimensional supergravity that makes symmetry under exceptional groups manifest. Using this formalism, it is possible to have an elegant description of consistent truncations of higher dimensional supergravities to lower dimensional theories. We firstly focus on consistent truncations of ten dimensional supergravity on $\text{AdS}_5 \times S^5$ as a starting point for future possible generalization to less supersymmetric vacua. To this end, we use the so-called Scherk-Schwarz reduction ansatz, for which the consistency of the truncation has already been proven. The fluctuations around the AdS background are then encoded into a L_∞ algebra that can be mapped via homotopy transfer to a cyclic L_∞ algebra associated to the conformal boundary of AdS and from this algebra it is possible to compute the CFT correlation functions.

Schur Connections: Chord Counting, Line Operators, and Indices

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Recently, an intriguing correspondence was conjectured in [1] between Schur half-indices of pure 4d $SU(2)$ $\mathcal{N} = 2$ supersymmetric Yang-Mills (SYM) theory with line operator insertions and partition functions of the double scaling limit of the Sachdev-Ye-Kitaev model (DSSYK). Motivated by this, we explore a generalization to $SU(N)$ $\mathcal{N} = 2$ SYM theories. After introducing Schur half-indices, we construct a q -oscillator representation for Wilson lines, from which we can compute the half-index as an expectation value in the Fock space of the oscillators. This q -oscillator perspective further suggests an interpretation in terms of generalized colored chord counting, and maps the half-index to a purely combinatorial quantity. Finally, we prove these equivalences by explicitly solving the spectral problem for the Wilson lines, with the resulting basis of eigenfunctions corresponding to those appearing in the half-index. This work is based on [2].

[1] D.Gaiotto, H.Verlinde, JHEP 06 (2025) 163.

[2] O.Lewis, M.Mezei, M.Sacchi, S.Schäfer-Nameki, arXiv2506.17384.

Large- D -Inspired Black Hole Effective Theory

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Using large- D expansion, we develop a horizon effective theory for Einstein–dilaton black holes in 5 dimensions, which reduces the bulk dynamics to evolution equations for two collective fields: horizon mass density and momentum density. This construction provides a efficient approximation to study long-wavelength dynamics near first-order phase transitions in QCD-motivated holographic models, with the dilaton potential deformation acting as an equation of state input that controls both thermodynamics and stability. Linearization of the effective equations yields the expected hydrodynamic modes (shear diffusion and sound) and gives a clear criterion for the onset of spinodal instability, signaling the breakdown of homogeneous states and the emergence of phase separation dynamics. The same framework admits static interface (domain-wall) solutions, linking interface existence to thermodynamic coexistence conditions and enabling a lightweight study of phase interfaces. We also outline an extension including a Maxwell field to explore finite-density phase structure in the (T, μ) plane.

- [1] M. Järvinen and D. Weissman, arXiv:2405.17553 [hep-th].
- [2] R. Emparan, T. Shiromizu, R. Suzuki, K. Tanabe, and T. Tanaka, arXiv:1504.06489 [hep-th].
- [3] R. Gregory and R. Laflamme, Phys. Rev. Lett. **70**, 2837 (1993).
- [4] P. Kovtun, D. T. Son, and A. O. Starinets, Phys. Rev. Lett. **94**, 111601 (2005).
- [5] M. Attems, arXiv:2012.15687 [hep-th].

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Wilson loop chiral ring expansions in 5d
gauge theories

Index Saddles with $AdS_3 \times S^3$ Asymptotics

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It is now well-known that four-dimensional index saddles upon uplifting gives rise to five-dimensional index saddles. In many cases, four-dimensional index saddles are constructed by doing analytical continuation on four-dimensional non-extremal rotating black holes. However it is less appreciated how non-extremal five-dimensional charged rotating black holes can be obtained from non-extremal four-dimensional charged rotating black holes. In this paper we explore the circle of ideas; we show that the five-dimensional Cvetic-Youm black hole can be obtained by zooming in on the four-dimensional four-charge black hole. Next we consider the uplift of the five-dimensional index saddles obtained from analytic continuation of the Cvetic-Youm black hole to six dimensions and construct index saddles for the six-dimensional black string. Upon taking a decoupling limit, we construct index saddle with $AdS \times S^3$ asymptotics.

Entanglement spreading and emergent locality in Brownian SYK chains

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1 Abstract

The Ryu-Takayanagi (RT) formula and its interpretation in terms of quantum error correction (QEC) imply an emergent locality for the spread of quantum information in holographic CFTs, where information injected at a point in the boundary theory spreads within a sharp light cone corresponding to the butterfly velocity. This emergent locality is a necessary condition for the existence of a geometric bulk dual with an RT-like formula for entanglement entropy. In this paper, we use tools from QEC to study the spread of quantum information and the emergence of a sharp light-cone in an analytically tractable model of chaotic dynamics, namely a one-dimensional Brownian SYK chain. We start with an infinite temperature state in this model and inject a qudit at time $t=0$ at some point p on the chain. We then explicitly calculate the amount of information of the qudit contained in an interval of length 2 (centered around p) at some later time $t=T$. We find that at strong coupling, this quantity shows a sharp transition as a function of t from near zero to near maximal correlation. The transition occurs at $v_B T$, with v_B being the butterfly velocity. Underlying the emergence of this sharp light-cone is a non-linear generalization of the diffusion equation called the FKPP equation, which admits sharp domain wall solutions at late times and strong coupling. These domain wall solutions can be understood on physical grounds from properties of operator growth in chaotic systems. We also study some conditions on the spectrum of holographic CFTs. We further discuss some bounds on 4-point functions of holographic CFTs.

Blackish Holes with Stringy Backreaction

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Recent studies have demonstrated that an *ad hoc* Dirichlet boundary condition, placed outside but close to an event horizon, for probe degrees of freedom in an otherwise black hole geometry is capable of capturing non-trivial level-correlations of the corresponding spectrum of the probe sector. Much of the interesting physics stems from a hierarchy of scales that is present in the quantum spectrum, in terms of two quantum numbers that characterize it. In this work, we establish an explicit connection with the hierarchy of these scales with a *radial localization* or the absence of it of the probe scalar WKB-wavefunction. Subsequently, this scale separation can be traced back to the hierarchy between the local red-shift and the classical light-traversing time in a geometry that produces a Rindler-throat. The classical null ray takes a logarithmically divergent time to reach the Dirichlet wall, and interestingly, we explicitly demonstrate that the scalar quantum spectrum arising from the Rindler throat yields a Dip-time of the corresponding spectral form factor, which scales with a universal power of the light traversing time. Armed with these, we further consider a *dressed effective model* where the Dirichlet boundary condition is inserted in a ten-dimensional supergravity geometry, where classical string sources back-react. We demonstrate that, as a result of this backreaction, the quantum-dynamical time-scales, *e.g.* the Dip time of the corresponding spectral form factor can be further enhanced with factors of the string length, thereby making the Dirichlet wall configuration better mimic the true black hole. In the dual field theory, the geometry corresponds to thermal states of a large N gauge theory in the Veneziano limit, where both the number of colour and the flavour degrees of freedom are large.

ISCOs and weak gravity conjecture bound in higher derivative theories of gravity

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The weak gravity conjecture (WGC) suggests that any consistent theory of quantum gravity must contain a state whose charge to mass ratio is greater than unity in appropriate units [1]. We [2] study circular orbits of charged particles in spherically symmetric AdS black holes in higher derivative theories of gravity, and their limiting ISCOs (innermost stable circular orbits). The dual interpretation is in terms of heavy-light double twist conformal field theory (CFT) operators in the large spin limit, whose anomalous dimensions can be extracted from the binding energy of charged probes in the bulk, in a certain large orbit limit. Demanding the positivity of the anomalous dimensions, leads to an exact bound for the charge to mass ratio \hat{q} of probe particles in the black hole backgrounds, which matches with the WGC bound. We find that \hat{q} increases with the higher derivative coupling parameters, which is explicitly checked in the Gauss-Bonnet gravity. For existing computations with probe particles in AdS backgrounds, the anomalous dimension and the WGC bound we find, particularly in Gauss-Bonnet theories, are in agreement in appropriate limits with the recent computations for Schwarzschild AdS [3], charged AdS [4] and neutral Gauss-Bonnet black holes in AdS [5]. Finally, we show that the ISCOs exist until the limit set by the WGC bound, with their radius decreasing with coupling parameters, which we check explicitly for the case of Gauss-Bonnet black holes in AdS.

- [1] N. Arkani-Hamed, L. Motl, A. Nicolis, C. Vafa, J. High Energy Phys. **06** (2007) 060
- [2] A. Paul and C. Bhamidipati, Physics Letters B **868**, 139702 (2025).
- [3] D. Berenstein, Z. Li, J. Simon, Class. Quantum Gravity **38** (2021) 045009.
- [4] U. Moitra, Phys. Rev. D **109** (2024) L041903.
- [5] M. Dodelson, A. Zhiboedov, J. High Energy Phys. **12** (2022) 163

On the stabilizer complexity of Hawking radiation

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We study the complexity of Hawking radiation for an evaporating black hole from the perspective of the stabilizer theory of quantum computation. Specifically, we calculate Wigner negativity – a magic monotone which can be interpreted as a measure of the stabilizer complexity, or equivalently, the complexity of classical simulation – in various toy models for evaporating black holes. We first calculate the Wigner negativity of Hawking radiation in the PSSY model directly using the gravitational path integral, and show that the negativity is $O(1)$ before the Page transition, but becomes exponentially large past the Page transition. We also derive a universal, information theoretic formula for the negativity which interpolates between the two extremes. We then study the Wigner negativity of radiation in a dynamical model of black hole evaporation. In this case, the negativity shows a sharp spike at early times resulting from the coupling between the black hole and the radiation system, but at late times when the system settles down, we find that the negativity satisfies the same universal formula as in the PSSY model. Finally, we also propose a geometric formula for Wigner negativity in general holographic states using intuition from fixed area states and random tensor networks, and argue that a python’s lunch in the entanglement wedge implies a stabilizer complexity which is exponentially large in $\frac{1}{8G_N}$ times the difference between the areas corresponding to the outermost and minimal extremal surfaces.

Hidden symmetries from extra dimensions

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In Kaluza-Klein compactifications, some symmetries of the higher dimensional theory are preserved in lower dimensions, others are broken, and occasionally, there are symmetry enhancements. The symmetries that are enhanced by toroidal compactifications were recently shown to define a symmetry principle with constrained parameters that fixes the action *before* dimensional reduction [1, 2]. Here [3] we show the opposite: symmetries of the higher dimensional theory that are broken in the reduction process, can actually be realized *after* dimensional reduction as a global symmetry principle with constrained parameters that fixes couplings in the lower dimensional theory. We implement this principle in pure gravity, half-maximal supergravity and the circle reduction of 11 dimensional supergravity to Type IIA superstring theory. As a further application, we show that it can be used to constrain the quartic Ramond-Ramond couplings in Type IIA superstring theory from the four-point $\zeta(3) \alpha'^3 t_8 t_8 R^{(-)4}$ interactions.

[1] W. H. Baron, D. Marques and C. A. Nunez, Phys. Rev. Lett. **130** no.6, 061601 (2023).

[2] W. H. Baron, D. Marques and C. A. Nunez, JHEP **12**, 006 (2023).

[3] M. Ciafardini, D. Marques, C. A. Nunez, and A. Pereyra Grau, JHEP **02**, 072 (2025).

Root- $T\bar{T}$ Deformations on Causal Self-Dual Electrodynamics Theories

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The self-dual condition, which ensures invariance under electromagnetic duality, manifests as a partial differential equation in nonlinear electromagnetism theories. The general solution to this equation is expressed in terms of an auxiliary field, τ , and Courant-Hilbert functions, $\ell(\tau)$, which depend on τ . Recent studies have shown that duality-invariant nonlinear electromagnetic theories fulfill the principle of causality under the conditions $\frac{\partial \ell}{\partial \tau} \geq 1$ and $\frac{\partial^2 \ell}{\partial \tau^2} \geq 0$.

In this paper, we investigate theories with two coupling constants that also comply with the principle of causality. We demonstrate that these theories possess a new universal representation of the root- $T\bar{T}$ operator. Additionally, we derive marginal and irrelevant flow equations for the logarithmic causal self-dual electrodynamics.

Towards non-relativistic supersymmetric localization

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Supersymmetric localization is a powerful technique for obtaining exact results from the path integral of supersymmetric field theories defined on compact manifolds [1, 2, 3]. A crucial ingredient of localization is the formulation of supersymmetric theories in curved space, which requires preserving part of the supersymmetry present in flat space. In the relativistic case, this problem was systematically addressed in the seminal work of Festuccia and Seiberg [4].

Motivated by recent progress in non-relativistic field theories, we study the analogous problem for supersymmetric theories coupled to Newton-Cartan geometry [5]. In particular, it is known that in Lorentzian signature the preservation of supersymmetry in four-dimensional theories with R -symmetry is equivalent to the existence of a conformal null Killing vector in the background geometry [6, 7]. This condition is naturally realized on three-dimensional manifolds obtained via null reduction ([8]) of a pseudo-Riemannian geometry.

In this work, I have shown that torsional Newton-Cartan geometries provide consistent backgrounds where supersymmetry is preserved in curved space. I have shown that the gauge theory obtained via the null reduction of four-dimensional $\mathcal{N} = 1$ supersymmetric Yang-Mills is Q -exact, i.e., can be written as the supersymmetric variation of a scalar quantity. Finally, I will comment on the realization of supersymmetric localization in this context.

- [1] V. Pestun, *Commun.Math.Phys.* **313** (2012) 71-129.
- [2] B. Willett, DOI: 10.1088/1751-8121/aa612f.
- [3] A. Kapustin, B. Willett, I. Yaakov, *JHEP* 1003:089,2010.
- [4] G. Festuccia, N. Seiberg, *JHEP* 1106:114,2011.
- [5] J. Hartong, N. A. Obers, G. Oling, DOI: 10.3389/fphy.2023.1116888.
- [6] C. Klare, A. Tomasiello, A. Zaffaroni, DOI: 10.1007/jhep08(2012)061.
- [7] D. Cassani, C. Klare, D. Martelli, A. Tomasiello, A. Zaffaroni, *Commun.Math.Phys.* **327** (2014) 577-602.
- [8] C. Duval, G. Burdet, H. P. Künzle, M. Perrin; *Phys. Rev.* **D31**, 1841.

Effective Potential for Boundary Gauge Theories Dual to BPS Black Holes in AdS₅

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Motivated by recent progress [1] in understanding supersymmetric black holes [2], we develop a systematic construction of the off-shell free energy for BPS black holes in AdS₅. In certain limits, this off-shell free energy can be reorganized in terms of an effective energy and an effective entropy, with the entropy naturally appearing as the variable conjugate to an effective BPS temperature. Using this formulation, we study the resulting BPS phase diagrams in both the standard two-derivative theory and in the presence of four-derivative corrections, which introduce notable modifications to the phase structure. Building on the AdS/CFT correspondence, we also propose [5], for the first time, phenomenological effective potentials in the boundary gauge theory dual to BPS black holes in AdS₅. The saddle points of the effective potential capture the various locally stable and unstable phases of the gauge theory at finite temperature and chemical potential. These potentials reduce on-shell to the HHZ potential [3] and allow us to identify a boundary effective energy and a boundary effective entropy, the latter being conjugate to an effective boundary temperature. Within this framework, the Hawking–Page transition temperature aligns with the confinement–deconfinement transition temperature, unlike in earlier on-shell analyses [4] where the two did not coincide. Our bulk effective entropy also differs from previously suggested conjugate quantities and leads to a more consistent thermodynamic interpretation. Overall, the rearranged BPS variables naturally yield a non-zero effective energy and a well-defined entropy conjugate, pointing toward a more coherent set of thermodynamic variables for supersymmetric systems. While the results are promising, further consistency checks will be important to establish this framework fully.

- [1] N. Ezroua, F. Larsen, Z. Liu and Y. Zeng, JHEP **09**, 033 (2022).
- [2] Z. W. Chong, M. Cvetič, H. Lu and C. N. Pope, Phys. Rev. Lett. **95**, 161301 (2005)
- [3] S. M. Hosseini, K. Hristov and A. Zaffaroni, JHEP **07**, 106 (2017)
- [4] S. Choi, J. Kim, S. Kim and J. Nahmgoong, [arXiv:1811.08646 [hep-th]].
- [5] D. Sahu and C. Bhamidipati, [arXiv:2502.01519 [hep-th]].

Higher spin swampland conjecture for massive AdS₃ gravity

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In this paper, we propose a version of the Swampland Weak Gravity Conjecture (WGC) [1] for higher-spin (HS) massive topological AdS₃ gravity [2]. We demonstrate that the conjecture can be formulated in terms of mass M_{hs} , charge Q_{hs} and coupling constant g_{hs} of 3D gravity coupled to higher spin fields as $M_{\text{hs}} \leq \sqrt{2} Q_{\text{hs}} g_{\text{hs}} M_{\text{Pl}}$. To the best of our knowledge, this question has not been explored in the literature. While the WGC has been studied in a distinct setup, where the gravitational and gauge sectors remain decoupled by considering 3D gravity in addition to a U(1) gauge field, it has not yet been established for massive AdS₃ gravity in the Chern-Simons formulation coupled to higher-spin fields. In our paper [3], we aim to bridge this gap by formulating a super-extremality bound for the higher-spin BTZ black hole, extending the WGC framework to this context to regulate the discharge of unstable higher spin BTZ black holes.

[1] N. Arkani-Hamed, L. Motl, A. Nicolas, and C. Vafa, J. High Energy Phys. 06, 060 (2007).

[2] S. Deser, R. Jackiw, and S. Templeton, Ann. Phys. 140, 372 (1982).

[3] R. Sammani and E.H. Saidi, SciPost Phys. 18, 173 (2025).

The Holographic Principle Beyond Anti-de Sitter

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The holographic principle has profoundly shaped our understanding of quantum gravity, with its most celebrated realization being the Anti-de Sitter/Conformal Field Theory (AdS/CFT) correspondence.

One of the most prominent realizations of AdS₃/CFT₂ was provided by the seminal work [1], which derives the following holographic relation:

$$\begin{array}{l} \text{Pure NS-NS strings on} \\ \text{AdS}_3 \times S^3 \times \mathbb{T}^4 \\ \text{with } k = 1 \end{array} \iff \text{Sym}(\mathbb{T}^4). \quad (1)$$

Building on these foundations, recent progress suggests that aspects of the duality may extend beyond AdS spaces, offering new perspectives on more general curved backgrounds and black hole geometries. In particular, [2] conjectures that a specific current-current deformation of type IIB string theory on AdS₃ × S³ × T⁴ with $k = 1$ unit of NS-NS flux is dual to a single-trace $T\bar{T}$ -deformed symmetric-orbifold CFT of T⁴:

$$\begin{array}{l} J^+ \bar{J}^+ \text{-deformation of} \\ \text{pure NS-NS strings on} \\ \text{AdS}_3 \times S^3 \times \mathbb{T}^4 \text{ with } k = 1 \end{array} \iff \begin{array}{l} \text{single-trace } T\bar{T}\text{-deformed} \\ \text{Sym}(\mathbb{T}^4) \end{array}. \quad (2)$$

The interest in this current–current worldsheet deformation is twofold. On the one hand, it leads to a target-space geometry that interpolates between AdS₃ × S³ × T⁴ and a linear-dilaton space-time, arising in the fivebrane decoupling limit of the NS5–F1 system. On the other hand, the deformation admits an exact reformulation in terms of a gauged Wess–Zumino–Witten (WZW) model, providing full control over the worldsheet theory.

This poster presents a concrete and fully tractable realization of this holographic duality in the tensionless limit of string theory. An exact, non-perturbative worldsheet description of the string dynamics is obtained via the gauged WZW construction, and an explicit holographic dictionary is established through a comparison between the spectra of the bulk theory and the deformed boundary CFT, highlighting the role of *large gauge transformations*.

- [1] L. Eberhardt, M. R. Gaberdiel, and R. Gopakumar, “Deriving the AdS₃/CFT₂ correspondence”, *J. High Energy Phys.* **02**, 001 (2020).
- [2] A. Dei, B. Knighton, K. Naderi, and S. Sethi, “Tensionless AdS₃/CFT₂ and single-trace $T\bar{T}$ ”, *J. High Energy Phys.* **11**, 001 (2024).

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From BTZ Perturbations to super-Schwarzian Modes

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Universal modular properties of the Generalised Gibbs ensemble

Chern-Simons Propagators in AdS₃

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The embedding space formalism for AdS as known in the literature [1, 2] offered a manifestly covariant framework for constructing and evaluating AdS correlators for parity-even theories, but not for parity-odd theories like the Chern-Simons theories in 3 dimensions. In our work, we modify this formalism to incorporate the parity-odd structures, which also helps us to write a general form of the propagator for higher-spin fields. Based on insights from this formalism, we introduce parity-odd spin-1 harmonic functions in AdS₃ and study their properties. We also introduce the “Chern-Simons operator” which relates the parity-odd harmonics to the parity-even counterpart and thus, create a simultaneous eigenfunction of this operator and the vector Laplacian. Subsequently, we use these harmonic functions to construct the bulk-to-bulk propagators of the pure abelian, massive abelian, and Maxwell Chern-Simons theories (in covariant gauge). Using those propagators, we find the bulk-to-boundary and boundary-to-boundary propagators, which we then verify with the known results in the literature [3, 4].

- [1] M. S. Costa, V. Gonçalves and J. Penedones, JHEP **09**, 064 (2014).
- [2] Ankur, D. Carmi and L. Di Pietro, JHEP **10**, 089 (2023).
- [3] J. R. David, B. Sahoo and A. Sen, JHEP **07**, 058 (2007).
- [4] R. Bhat, J. R. David and S. Dutta, [arXiv:2511.13549 [hep-th]].

Probing the Novel Attractor Mechanism in AdS_5

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The attractor mechanism is a phenomenon observed in BPS blackhole solutions in Supergravity models in 4D and 5D, which posits that the values of moduli at the blackhole horizon are purely functions of the blackhole charges. Boruch et. al. proposed a novel attractor mechanism for 4D Euclidean saddles in [2]. These Euclidean saddles were subsequently lifted to 5D in [1]. In this work, we investigate the properties of the attractor mechanism in 5D euclidean saddles. We probe the behaviour of the central charge and the monotonicity properties of the moduli in this setting. These features are compared to those of the classic attractor mechanism and some applications for these are discussed in the context of blackhole thermodynamic.

[1] J. Boruch, R. Emparan, L. V. Iliesiu, and S. Murthy, JHEP 06 (2025) 145

[2] J. Boruch, L. Iliesiu, S. Murthy, and G. J. Turiaci, JHEP 04 (2025) 087.

Massless Multiplets in free tensionless String Field Theory

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String Field Theory(SFT) provides one framework for writing a consistent interacting quantum field theory of massive particles of arbitrary spin[1]. As a first step towards that, we want to understand the free higher spin states in SFT[2]. In this poster, we will demonstrate the construction of basis at any given level of tensionless SFT which would finally give us Fronsdal action for higher spin massless particles along with the massless gauge transformations.

[1] A. Sen and B. Zwiebach, [arXiv:2405.19421 [hep-th]]

[2] A. Sagnotti and M. Tsulaia, Nucl. Phys. B **682** (2004), 83-116 doi:10.1016/j.nuclphysb.2004.01.024 [arXiv:hep-th/0311257 [hep-th]]

Planar Abelian Mirror Duals of 3d $\mathcal{N} = 2$ Chern-Simons-Matter Theories

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We study mirror symmetry in three-dimensional quantum field theories with reduced supersymmetry, focusing on $\mathcal{N} \leq 2$ Chern–Simons–matter theories. Unlike the well-understood $\mathcal{N} = 4$ case, where mirror symmetry admits a geometric realization via Type IIB branes and $SL(2, Z)$ duality, reduced supersymmetry lifts moduli spaces and obscures any canonical brane picture. Despite this, we show that mirror-like dualities persist beyond $\mathcal{N} = 4$. Guided by symmetry principles—most notably the exchange of flavor and topological symmetries—we develop a systematic framework to construct mirror duals of non-Abelian $\mathcal{N} = 2$ theories. We analyze unitary and symplectic gauge groups, track renormalization group flows under real mass deformations, and match gauge-invariant operators across dual descriptions. Our framework naturally extends to non-supersymmetric theories, suggesting a broader notion of three-dimensional mirror symmetry as a duality between order and disorder operators.

- [1] S. Benvenuti, R. Comi, S. Pasquetti, G. Pedde Ungureanu, S. Rota, A. Shri, *Phys. Rev. D* **112.10**, L101703 (2025).
- [2] S. Benvenuti, R. Comi, S. Pasquetti, G. Pedde Ungureanu, S. Rota, A. Shri, *JHEP* (**10**), 211 (2025).
- [3] S. Benvenuti, R. Comi, S. Pasquetti, G. Pedde Ungureanu, S. Rota, A. Shri, arXiv: 2505.02913 [hep-th].

Symplectic Grassmannian description of the Coulomb branch three and four point amplitudes

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Based on [1], we present a formulation of the three- and four-point amplitudes on the Coulomb branch of $\mathcal{N} = 4$ SYM as integrals over the symplectic Grassmannian. We demonstrate that their kinematic spaces are equivalent to symplectic Grassmannians $SpGr(n, 2n)$. For the three-point case, we express the amplitude as an integral over the symplectic Grassmannian in a specific little group frame. In the four-point case, we show that the integral yields the amplitude up to a known kinematic factor. Building on the four-dimensional analysis, we also express the six-dimensional $\mathcal{N} = (1, 1)$ SYM amplitude in terms of four-dimensional variables in a form that makes its symplectic Grassmannian structure manifest.

- [1] V.C. Cortes, Y. El Maazouz, S. Hegde, and A. Suthar, Symplectic Grassmannian description of the Coulomb branch three and four point amplitudes, arXiv:2505.03705.

Hamiltonian Cobordism

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We study states charged under global symmetries detected by the Cobordism Conjecture [2], aiming to understand when such states can be realized as smooth, finite-energy configurations in asymptotically flat spacetime, consistent with general relativity's initial-value constraints [3,4]. Under standard energy conditions, we find that states associated with bordism generators that **do not admit positive scalar curvature (psc) metrics** cannot be constructed smoothly: they must be singular, involve matter violating energy conditions, or lead to the collapse of spacetime. Consequently, such symmetries only become manifest in the UV.

In contrast, bordism groups of spin manifolds admitting psc metrics detect **approximate global symmetries in the IR**, which are broken in the UV but whose appearance signals the need for energy-condition-violating matter to realize them dynamically. We introduce the notion of **psc-bordism**, showing that not only the boundary manifolds but the bordisms themselves must admit psc metrics, and we analyze their structure via Stolz's exact sequence [5-11]. This leads to a **dynamical refinement of the Cobordism Conjecture**, establishing a precise connection between cobordism, geometry, and physical consistency in quantum gravity.

- [1] M. Delgado, M. Montero, G. Tazzoli, Hamiltonian Cobordism (soon to be published)
- [2] McNamara and C. Vafa, Cobordism Classes and the Swampland, 1909.10355.
- [3] R. Arnowitt, S. Deser and C. W. Misner, Dynamical structure and definition of energy in general relativity, Phys. Rev. 116 (1959) 1322.
- [4] E. Bertschinger, "Lecture notes: Hamiltonian Formulation of General Relativity.", 2005
- [5] A. Lichnerowicz, Spineurs harmoniques, Comptes Rendus de l'Académie des Sciences de Paris 257 (1963) 7.
- [6] N. Hitchin, Harmonic spinors, Advances in Mathematics 14 (1974) 1.
- [7] S. Stolz, Concordance classes of positive scalar curvature metrics. preprint, unpublished, 1998
- [8] S. Stolz, Positive scalar curvature – constructions and obstructions, 2202.05904.
- [9] M. Gromov and H. B. Lawson, The classification of simply connected manifolds of positive scalar curvature, Annals of Mathematics 111 (1980) 423.
- [10] S. Stolz, Simply connected manifolds of positive scalar curvature, Annals of Mathematics 136 (1992) 511.
- [11] J. W. Milnor, Remarks concerning spin manifolds, Differential and Combinatorial Topology (A Symposium in Honor of Marston Morse), Princeton Univ. Press, Princeton N.J. (1965) 55.
- [12] D.-E. Diaconescu, G. W. Moore and E. Witten, E(8) gauge theory, and a derivation of K theory from M theory, Adv. Theor. Math. Phys. 6 (2003) 1031 [hep-th/0005090]

QM bootstrap: from bounds to equations

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Quantum mechanical bootstrap methods typically impose positivity to obtain bounds on the spectrum in matrix [1,2] and one-dimensional [3] quantum mechanics. We study a one-dimensional quantum mechanical system whose spectrum coincides with that of bilinear operators of the Sachdev-Ye-Kitaev model. We show that positivity bounds from the naive application of the quantum mechanical bootstrap are insufficient to determine the eigenvalues. Instead, by considering fractional powers of operators, we obtain constraint equations that *directly determine the spectrum*, converging to exact eigenvalues as the truncation order increases. We briefly discuss how this strategy may extend to broader classes of quantum-mechanical spectral problems. arXiv:2602.xxxxx

[1] H. W. Lin, “Bootstraps to strings: solving random matrix models with positivity,” JHEP, vol. 06, p. 090, 2020. arXiv: 2002.08387 [hep-th].

[2] X. Han, S. A. Hartnoll, and J. Kruthoff, “Bootstrapping Matrix Quantum Mechanics,” Phys. Rev. Lett., vol. 125, no. 4, p. 041 601, 2020. arXiv: 2004.10212 [hep-th].

[3] D. Berenstein and G. Hulsey, “Bootstrapping more QM systems,” J. Phys. A, vol. 55, no. 27, p. 275 304, 2022. arXiv: 2109.06251 [hep-th].

Electromagnetic radiation and conservation of energy in de Sitter and asymptotically flat spacetimes

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The idea of conservation laws has a long and profound history, being a concept that cuts across all areas of physics. At the mathematical level, conservation laws are deeply connected to the existence of continuous symmetry transformations in the variational principle. This crucial fact was elucidated by Emmy Noether in 1918 [1].

In general, we tend to identify energy as the conserved charge associated with invariance under time translations. In the 1960s, Bondi, van der Burg, Metzner, and Sachs (BMS) introduced the notion of asymptotic symmetry, which made it possible to study radiative situations in asymptotically flat spacetimes [2]. One of the most important results of their work was the energy balance equation, which shows that the mass of a gravitational system decreases over time in the presence of radiation. The generalization of BMS ideas to electromagnetism, where the dynamics are governed by Maxwell's equations, has been studied in recent years [3–5].

We will present generalizations of the above results to spacetimes with a positive cosmological constant (de Sitter-type spacetimes) [6]. In particular, we will address different ideas related to the notion of energy in flat and de Sitter spaces, highlighting their similarities and profound differences. We will show in detail the electromagnetic radiation flux and energy conservation in spacetimes with boundaries, and finally, we will define the news tensor in the electromagnetic context.

[1] E. Noether, *Nachr. Königl. Ges. Wiss. Göttingen Math.-Phys. Kl. 2*, 235 (1918).

[2] H. Bondi, M. G. J. van der Burg, and A. W. K. Metzner, *Proc. R. Soc. Lond. A* 269, 21 (1962);

R. K. Sachs, *Proc. R. Soc. Lond. A* 270, 103 (1962);

R. K. Sachs, *Phys. Rev.* 128, 2851 (1962).

[3] H. A. González, O. Labrín, and O. Mišković, *J. High Energy Phys.* 2023, 1 (2023).

[4] H. A. González, O. Labrín, and O. Mišković, *Phys.Rev.D* 111 (2025).

[5] A. Strominger, *Lectures on the Infrared Structure of Gravity and Gauge Theory* (Princeton University Press, Princeton, 2018).

[6] B. Bonga, C. Bunster, and A. Pérez, *Phys.Rev.D* 108 (2023).