String theory and related fields

IGFAE Retreat

Highlights from 2018

Seniors:

- Alfonso V. Ramallo
- José L. Miramontes
- José D. Edelstein
- Javier Mas

Postdocs:

- Daniele Musso
- Gustavo Arciniega
- Riccardo Borsato

PhD students:

- Anxo F. Biasi
- José M. Penín
- Alejandro Vilar
- Ana Garbayo
- David Vázquez Rodríguez
- Filip Jurukovic

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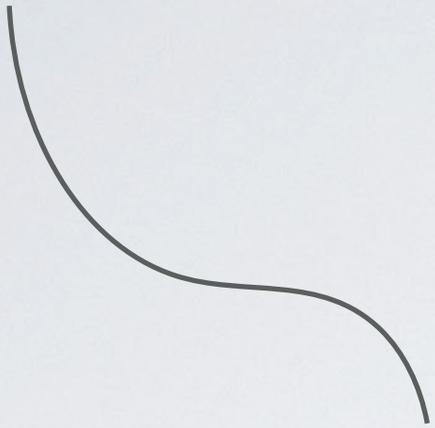
XUNTA DE GALICIA

IGFAE

Instituto Galego de Física de Altas Enerxías

Main avenues of research

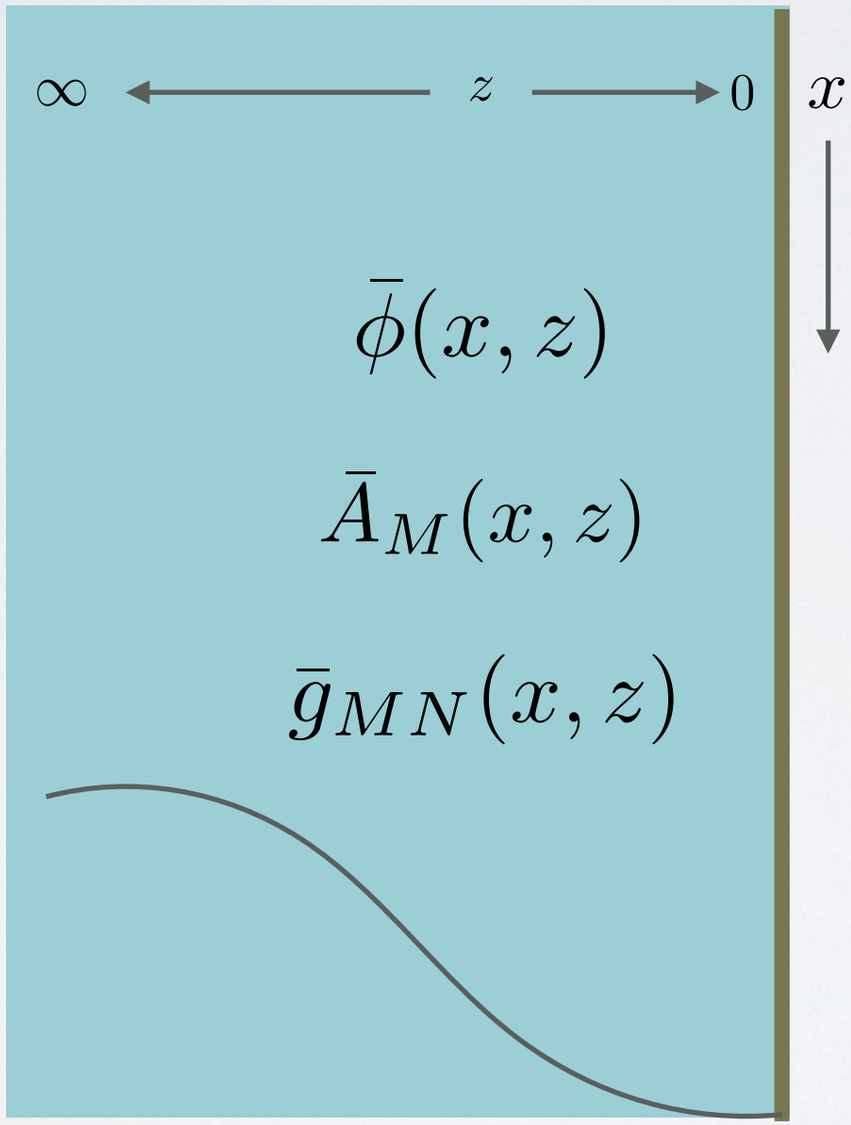
- Holographic tools for strongly coupled quantum systems
    - non-perturbative phenomena in QCD-like theories
    - models for lower dimensional (condensed matter)
        - topological phases, quantum criticality
        - phonons and translational symmetry breaking
    - time dependent processes (needs numerical Relativity)
        - dynamical phase transitions
        - driven systems and quenches
        - thermalization at strong coupling
- Strings on integrable **deformations of $AdS_5 \times S_5$**
- Higher-curvature corrections to General Relativity: towards an effective theory of **Quantum Gravity**



holographic tools for strongly coupled quantum systems

The holographic duality maps **quantum problems at strong coupling** and large number of degrees of freedom in 4d QFTs into a **classical** field theory of **gravity in 5d** with certain boundary conditions (**AdS**).

Geometries $\Longleftrightarrow$ States



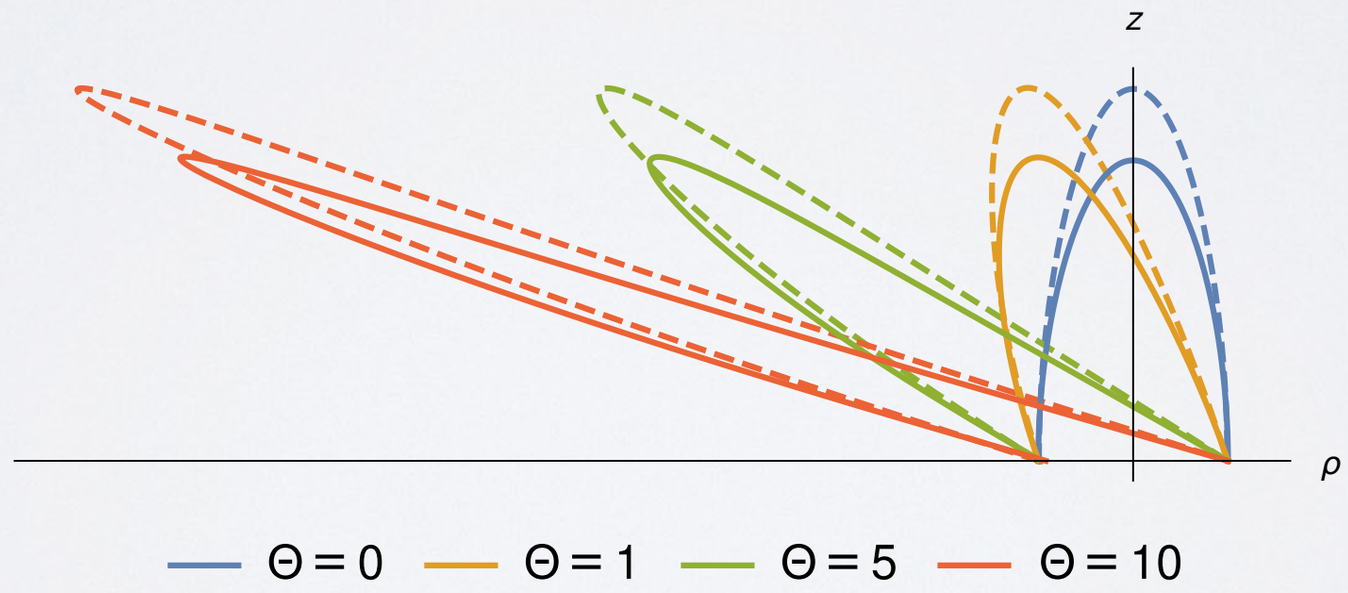
$|\mathcal{O}, \mathcal{J}_\mu, \mathcal{T}_{\mu\nu}>$

top-down versus bottom-up

- We construct a black hole geometry generated by the **intersection of D3-branes and flavor D5-branes** along a 2+1 dimensional subspace. The solution is analytic and dual to a 2+1 dimensional defect in a 3+1 dimensional gauge theory. The smeared background can be regarded as a holographic multilayered system.

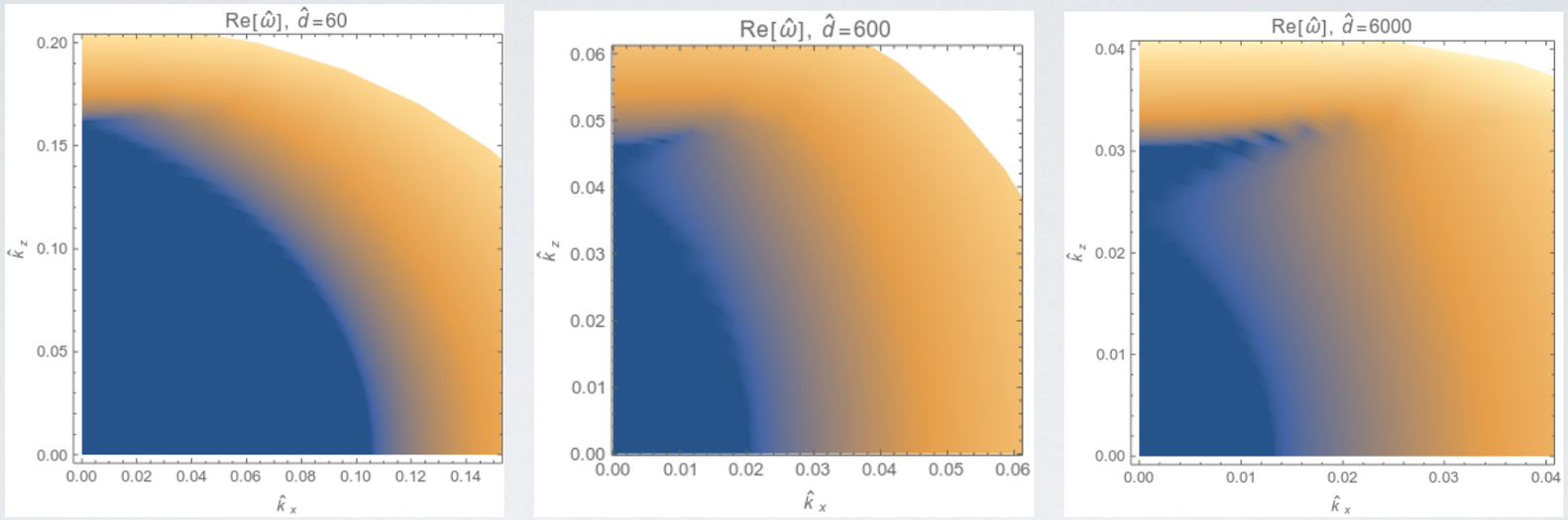
J. M. Penín, **A.V. Ramallo**, D. Zoakos
Anisotropic D3-D5 black holes with unquenched flavors, JHEP 1802 (2018) 139

- We study **non-commutative massive** unquenched **Chern-Simons matter** theory using its gravity dual. We construct a new background by a TsT-transformation.



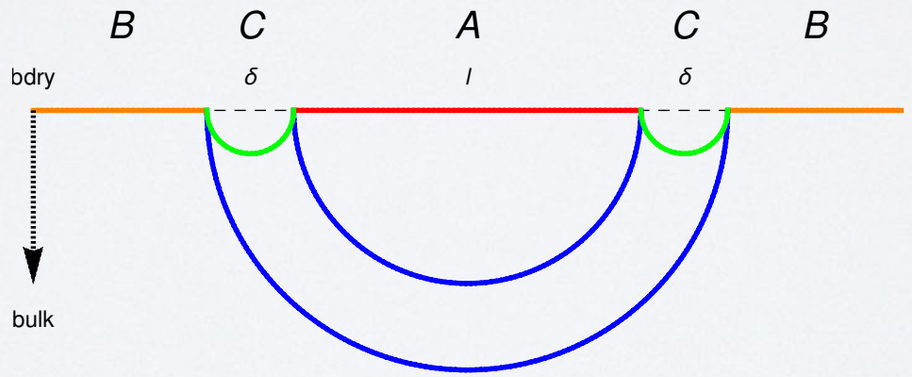
Y. Bea, N. Jokela, A. Pönni, **A.V. Ramallo**
Non-commutative massive unquenched ABJM, Int. J. Mod. Phys. A33 (2018) 1850078

- We studied the **low-energy collective behavior of spatially anisotropic dense fluids** in four spacetime dimensions by using a top-down holographic model.



G. Itsios, N. Jokela, J. Järvelä, **A.V. Ramallo,** Low-energy modes in anisotropic holographic fluids, 1808.07035

- We characterized the **RG flow of quantum information** in a **Chern-Simons theory coupled to massive fermions**. We studied the flow of mutual information between strips and the corresponding information transitions.



V. Balasubramanian, N. Jokela, A. Pönni, **A.V. Ramallo,** Information flows in a strongly interacting field theory, 1811.09500

- We construct a gravity dual to a system with **multiple (2+1)-dimensional layers in a (3+1)-dimensional ambient theory**. The solution is supersymmetric, has an intrinsic mass scale and exhibits anisotropy.

N. Jokela, **J. M. Penín**, **A.V. Ramallo**, D. Zoakos, Gravity dual of a multilayer system, 1901.02020

- We write down an effective **low-energy holographic theory of charge density waves**. We capture the low energy dynamics of **phonons coupled to conserved currents**. The model allows to study **quantum critical ground states breaking translations spontaneously**.

A. Amoretti, D. Areán, B. Goutéraux, **D. Musso**, Effective holographic theory of charge density waves, Phys. Rev. D 97 (2018) 086017

- In contrast to metals with weak disorder, the resistivity of weakly-pinned charge density waves is governed by incoherent, diffusive processes which do not drag momentum. We **compute analytically the DC resistivity for a family of holographic charge density wave quantum critical phases** and discuss its temperature scaling.

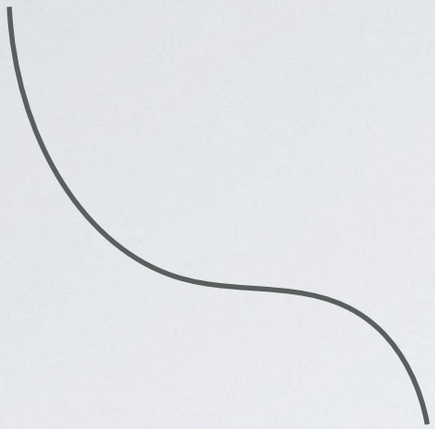
A. Amoretti, D. Areán, B. Goutéraux, **D. Musso**, DC resistivity of quantum critical, charge density wave states from gauge-gravity duality, Phys. Rev. Lett. 120 (2018) 171603

- Study the **emergence of Nambu-Goldstone modes due to broken translational symmetry**. Purely spontaneous breaking yields a massless phonon which develops a mass upon introducing a perturbative explicit breaking as well as **space-dependent order parameters**.

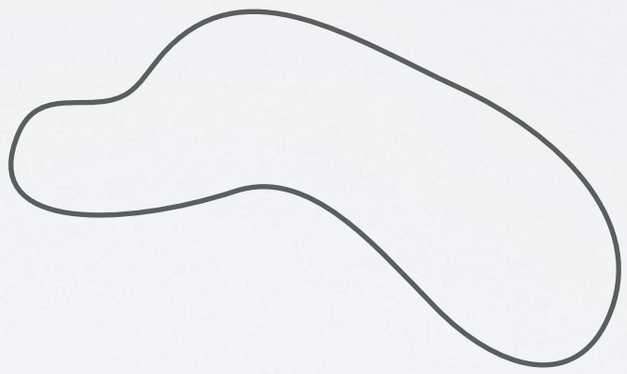
D. **Musso**, Simplest phonons and pseudo-phonons in field theory, 1810.01799

- Study the i**nterplay of slowly fluctuating translational order with quantum criticality** in a strongly-coupled metallic phase.

A. Amoretti, D. Areán, B. Goutéraux, **D. Musso**, A holographic strange metal with slowly fluctuating translational order, 1812.08118



holographic tools for strongly coupled systems: time dependent processes

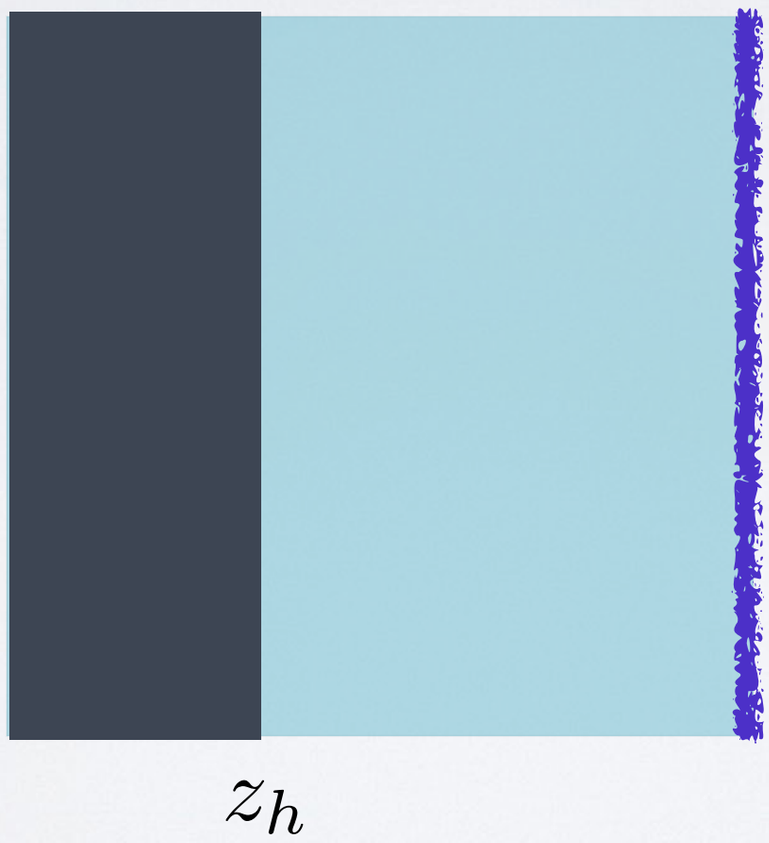


- We investigate **deconfinement** and **decoherence** at strong coupling, *i.e.* under what initial conditions **a pure excited state evolves into a final mixed state.**

- The dual process to decoherence involves the evolution (and eventual **collapse**) **of a regular metric into a black hole**. The Hawking temperature is T_{QFT}.

Black hole formation ⟺ Thermalization

deconfined plasma



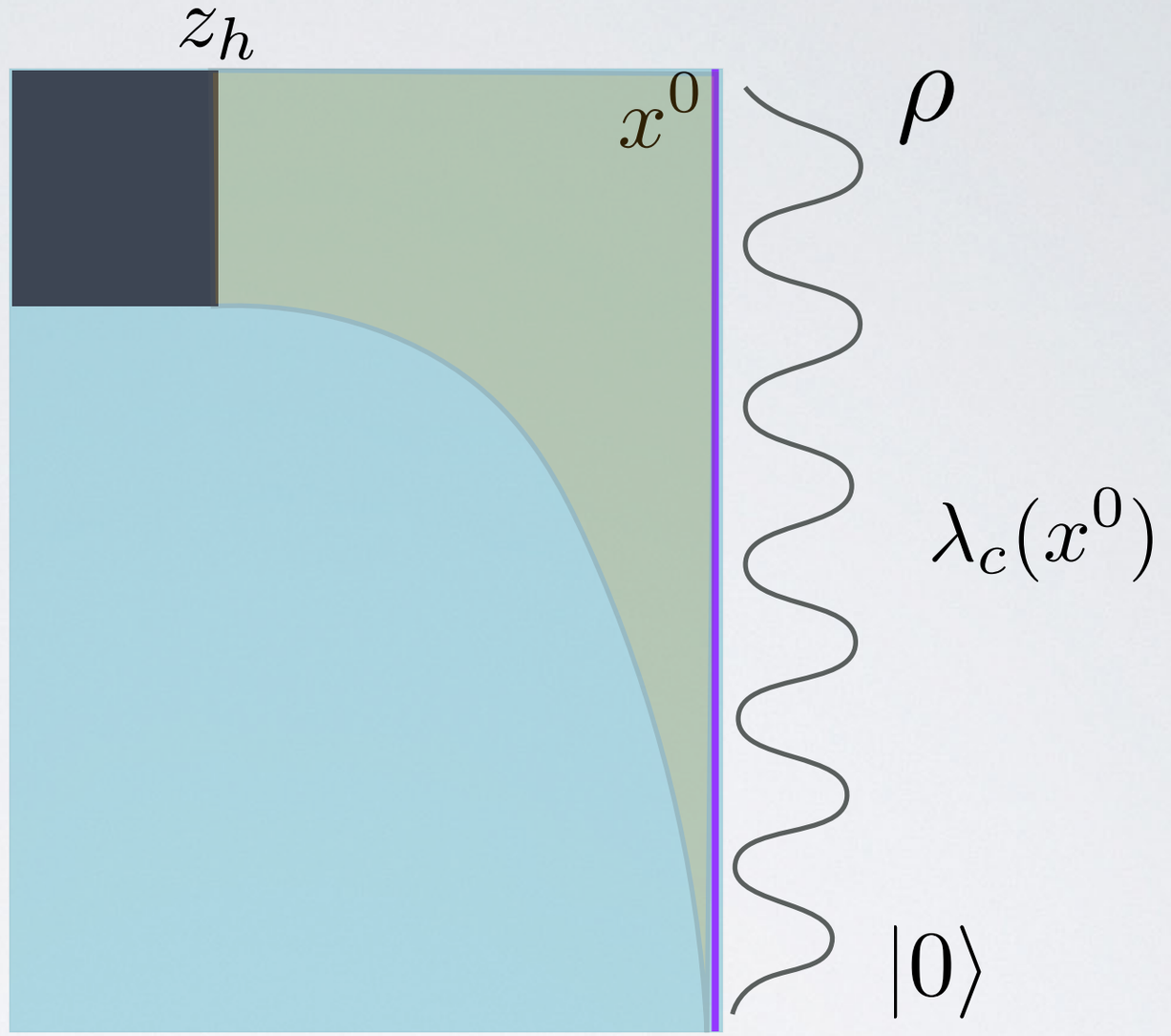
$|\Psi\rangle$

$$\rho = \sum_n e^{-E_n/kT} |\psi_n\rangle\langle\psi_n|$$

- **Time dependent processes** (heavy ions, relaxation problems, jet quenching) are mapped to **dynamical gravitational** problems demanding **numerical simulation.**

- We started investigating the case of **time dependent couplings** (quenches): take an initial state and drive a coupling **periodically in time**.

periodic driving



- Scrutinize ranges of frequencies and amplitudes for which **the system retains coherence** (Floquet state) and find **parametric resonances**: the system absorbs energy until it collapses into a black hole.

A. Biasi, P. Carracedo, **J.Mas., D. Musso**, A. Serantes
Floquet scalar dynamics in global AdS, JHEP 1804(2018)137

- In 2018 we started to explore other periodically driven systems:

  - at laser drivings of Hall states

    A. Garbayo, J. Mas, A.V. Ramallo
    Floquet dynamics in D3-D5 flavored systems, work in progress

  - gravitational wave driving of a strongly coupled system

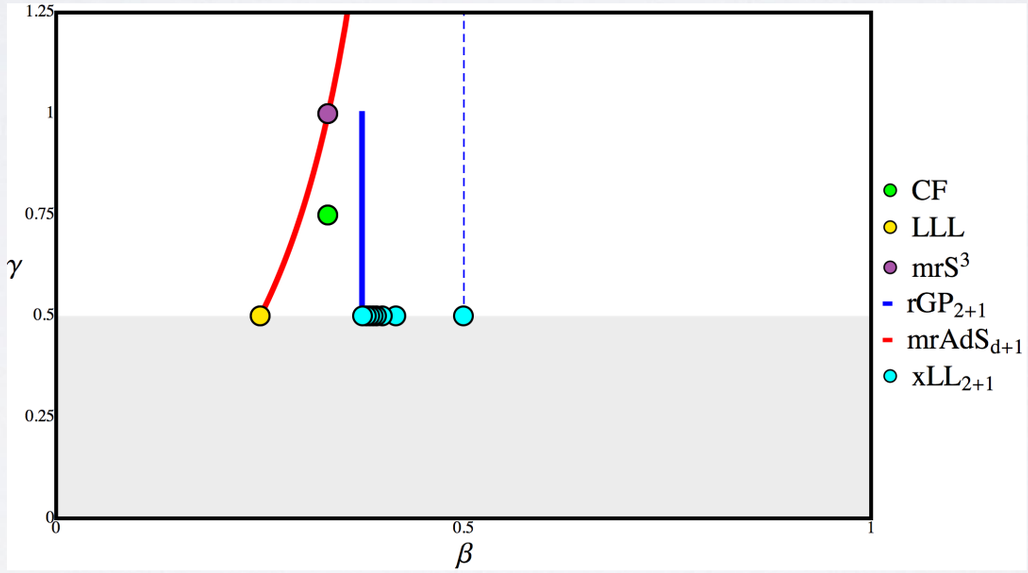
    A. Biasi, J. Mas, A. Serantes
    Gravitational wave driving at strong coupling, work in progress

- A broader family of **confined** (completely resonant) **systems** whose mildly **non-linear wave dynamics** was studied is given by:

$$i\dot{\alpha}_n = \sum_{\substack{m,k,l=0 \\ n+m=k+l}}^{\infty} C_{nmkl}\bar{\alpha}_m\alpha_k\alpha_l = \sum_{m=0}^{\infty}\sum_{k=0}^{n+m} C_{nmk,n+m-k}\bar{\alpha}_m\alpha_k\alpha_{n+m-k}$$

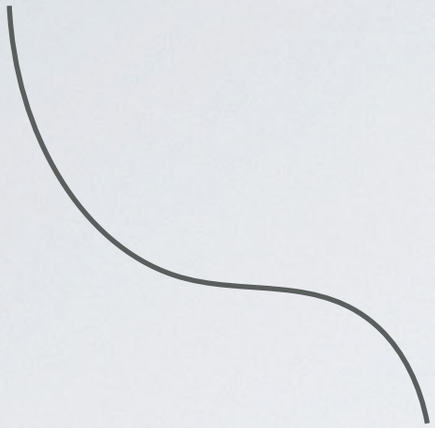
A. Biasi, P. Bizon, O. Evnin, Solvable cubic resonant systems, 1805.03634

- **Formation of singularities** in finite time, characterization and classification of systems with regular solutions, instability, turbulence and chaos are studied.



A. Biasi, P. Bizon, B. Craps, O. Evnin, Two infinite families of resonant solutions for the Gross-Pitaevskii equation, Phys. Rev. E 98 (2018) 032222

A. Biasi, B. Craps, O. Evnin, Energy returns in global AdS_4, 1810.04753



higher-curvature corrections: towards a consistent quantum gravity

- In the framework of a two-parameter family of **quadratic theories** exhibiting T-duality, which includes (but goes beyond) String Theory

$$\mathcal{I} = \int d^3x \sqrt{-\mathrm{G}}\, e^{-2\Phi} \left[\mathcal{L}^{(0)} + \gamma_+ \mathcal{L}^{(1)}_+ + \gamma_- \mathcal{L}^{(1)}_- \right]$$

  we showed that the **temperature and entropy of a BTZ black hole are invariant under T-duality**. Interestingly enough, the AdS/CFT correspondence enforces quantization conditions on these parameters.

  For generic (albeit quantized) values of the parameters, it suggests that **T-duality might be an interesting tool to constrain consistent low-energy effective actions** while entailing **physical equivalences outside String Theory**.

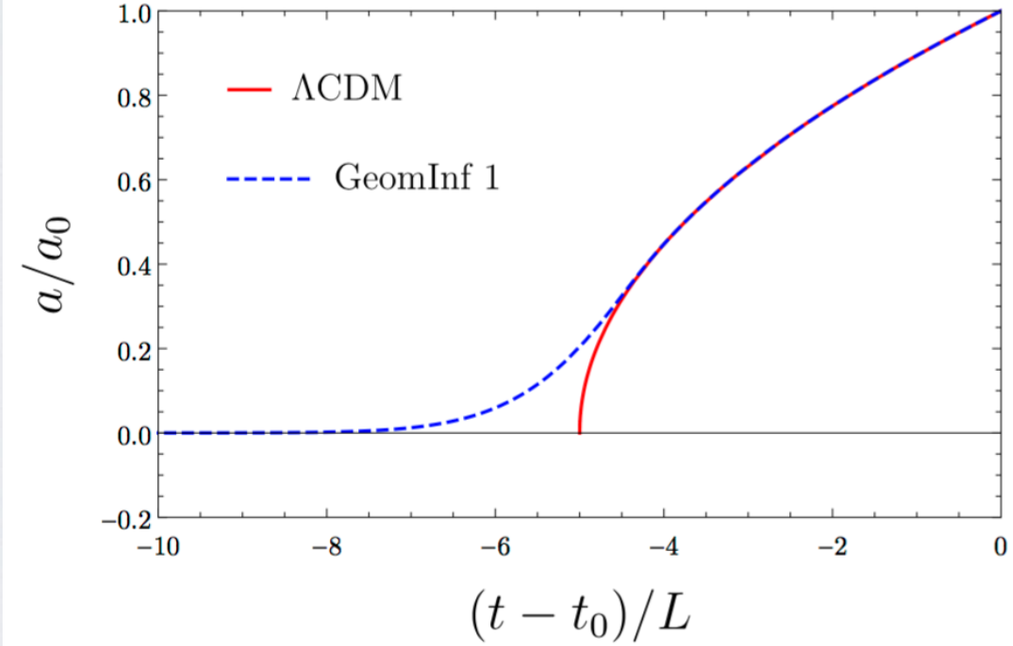
J. D. Edelstein, K. Sfetsos, J. A. Sierra-García, **A. Vilar López**
T-duality and high-derivative gravity theories: the BTZ black hole/string paradigm
JHEP 1806 (2018) 142

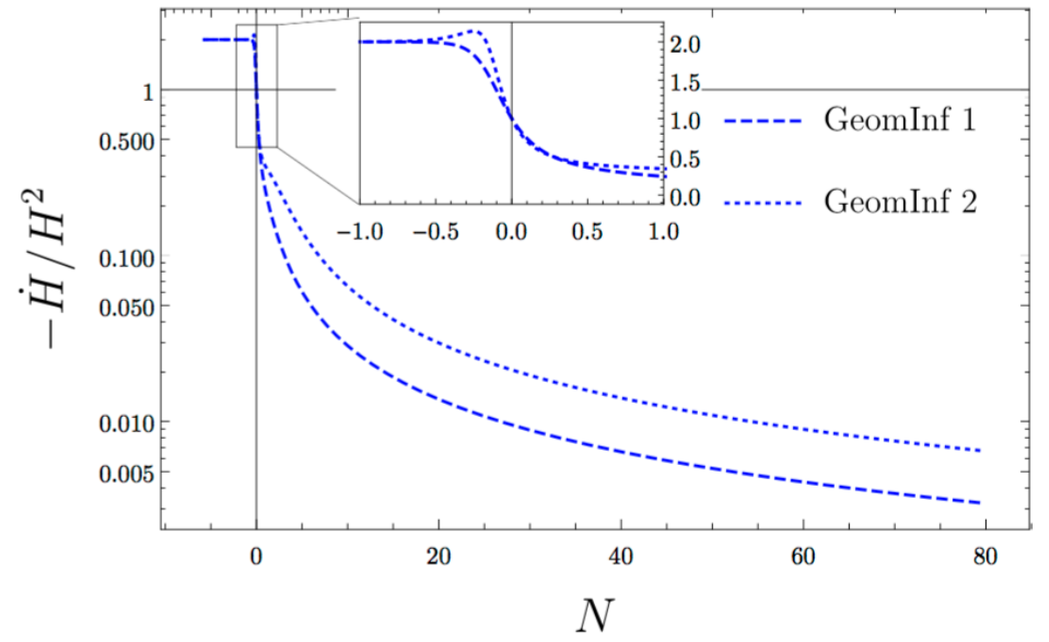
J. D. Edelstein, K. Sfetsos, J. A. Sierra-García, **A. Vilar López**
T-duality equivalences beyond string theory, to appear

- While studying higher-curvature gravity actions we realized that there is a family with gorgeous properties: (i) just gravitons in vacuum, (ii) non-hairy black holes and, most importantly, **(iii) well-behaved cosmology!**

$$S = \int \frac{d^4x\sqrt{|g|}}{16\pi G}\left\{-2\Lambda + R + \sum_{n=3}^{\infty}\lambda_n L^{2n-2}\mathcal{R}_{(n)}\right\}$$

G. Arciniega, **J. D. Edelstein**, L. G. Jaime
Towards purely geometric inflation and late time acceleration, 1810.08166





G. Arciniega, P. Bueno, P. A. Cano, **J. D. Edelstein**, R. A. Hennigar, L. G. Jaime
Geometric inflation, 1812.11187

- We investigate the **phase diagram** of a general class of 4d exact regular hairy planar black holes. For some particular values of the parameters these can be embedded in **ω-deformed N=8 gauged supergravity**.

- We construct the hairy soliton that is the ground state of the theory and show that **there exist first order phase transitions**.

A. Anabalón, D. Astefanesei, D. Choque, **J. D. Edelstein**, Phase transitions of neutral planar hairy AdS black holes, to appear

more to come…