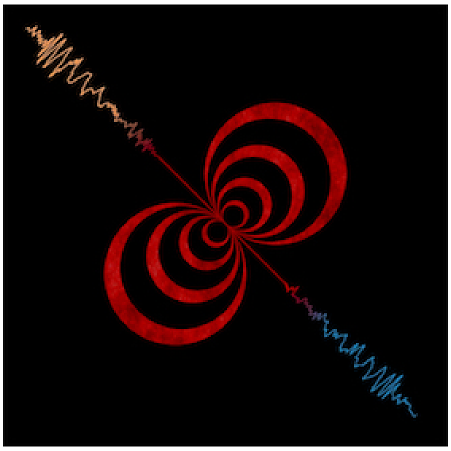
XV Black Holes Workshop

Monday, 19 December 2022 - Tuesday, 20 December 2022

ISCTE - University Institute of Lisbon



Book of Abstracts

Contents

Session 1 / Monday 9:15

J. Lemos: Thermodynamics of Schwarzschild-de Sitter and Nariai spaces in the 50 years of Bekenstein's black hole entropy

In 1972 Bekenstein put forward the idea that a black has an entropy S proportional to its area A in Planck units. Bekenstein's black hole entropy was published in Nuovo Cimento. Hawking, developing quantum field theory calculations in curved spacetime, soon showed that the constant of proportionality in the entropy formula is one quarter, so that $S = A/4$, and that indeed a black hole has temperature. With the Bekenstein-Hawking entropy and the Hawking temperature formulas, the discipline of black hole thermodynamics was born. After 50 years of Bekentein's paper, we are still exploring its extraordinary consequences that led to a better understanding of low energy quantum gravity and with it of how general relativity and quantum theory might unite in a full proper quantum gravity. Here, we use the Euclidean path integral approach to quantum gravity to study the statistical mechanics and thermodynamic behavior of the Schwarzschild-de Sitter and Nariai spaces in the canonical ensemble. For both these spaces one can place two types of heat reservoirs that imply two independent physical settings. In one setting there is an outer reservoir that harbors the black hole horizon, in the other setting there is an inner reservoir that discloses the cosmological horizon. In Schwarzschild-de Sitter, the results related to the outer reservoir are much the same as the ones for pure Schwarzschild found by York in 1986, nevertheless there are a few interesting differences due to the existence of the additional scale parameter associated with the cosmological constant, whereas the problem related to the inner reservoir and the corresponding cosmological horizon has not been explicitly formulated before. In Nariai, there are intriguing surprises. These will be the main focus of the talk.

Collaborators: This work is in collaboration with Oleg Zaslavskii.

Session 1 / Monday 9:30

P. Luz: The effects of intrinsic spin of matter in relativistic cosmology and black holes formation

Using the covariant $1 + 3$ threading spacetime decomposition, we discuss solutions of the Einstein-Cartan theory sourced by a cosmological perfect fluid composed by particles with intrinsic spin. It is shown that, even in the presence of intrinsic spin of matter, the metric tensor is described by a general FLRW solution, however the Weyl tensor might not vanish. The coupling between the intrinsic spin and the Weyl tensor leads to the conclusion that, in the considered model, the universe must either be flat or open. In the open case, we derive a wave equation for the the magnetic part of the Weyl tensor and show how the intrinsic spin of matter leads to the emission of gravitational waves. These results allows us clarify a long misunderstanding in the literature regarding the possibility of considering spin effects to avoid the formation of singularities.

Session 1 / Monday 9:45

P. Fernandes: A new approach and code for spinning black holes in modified gravity

We discuss and implement a spectral method approach to computing stationary and axisymmetric black hole solutions and their properties in modified theories of gravity. The resulting code is written in the Julia language and is transparent and easily adapted to new settings. We test the code on both general relativity and on Einstein-Scalar-Gauss-Bonnet gravity. It is accurate and fast, converging on a spinning solution in these theories with tiny errors ($\sim \mathcal{O}\left(10^{-13}\right)$ in most cases) in a matter of seconds.

Session 1 / Monday 10:00

H. Rüter: Hyperbolic-like encounters of binary black holes with the numerical relativity code SpEC

We present results on the encounter of two black holes that are initially on a hyperbolic-like orbit simulated with the numerical relativity code SpEC. We discuss the dynamical capture scenario as well as the scattering scenario, in which the black holes remain unbound during the encounter. In dynamical captures the binary becomes bound due to the emission of gravitational waves, which poses a possible formation scenario of highly eccentric binary mergers. We present the waveforms for both scenarios and discuss key features like the beaming of radiation and the memory effect.

Session 1 / Monday 10:15

J. G. Rosa: Determining the spin of light primordial black holes with Hawking radiation

We propose a method to determine the mass and spin of primordial black holes (PBHs) in the mass range $5 \times 10^7 - 10^{12}$ kg (Hawking temperatures ~ 10 MeV – 200 GeV), based on measuring the energy of specific features in the photon Hawking emission spectrum, including both primary and secondary components. This is motivated by scenarios where PBHs in this mass range spin up as they evaporate, namely the string axiverse, where dimensionless spin parameters $a \sim 0.1 - 0.5$ can be achieved through the Hawking emission of hundreds or even thousands of light axion-like particles. Measuring the present PBH mass-spin distribution may thus be an important probe of physics beyond the Standard Model. Since the proposed method relies on the energy of the photons emitted by a given PBH, rather than on the associated flux, it is independent of the PBH-Earth distance and, as a byproduct, can also be used to infer the latter.

Session 2 / Monday 11:00

C. Herdeiro: The fate of the light-ring instability

Ultracompact objects with light-rings (LRs) but without an event horizon could mimic black holes (BHs) in their strong gravity phenomenology. But are such objects dynamically viable? Stationary and axisymmetric ultracompact objects that can form from smooth, quasi-Minkowski initial data must have at least one stable LR, which has been argued to trigger a spacetime instability; but its development and fate have been unknown. Using fully non-linear numerical evolutions of ultracompact bosonic stars free of any other known instabilities and introducing a novel adiabatic effective potential technique, we confirm the LRs triggered instability, identifying two possible fates: migration to non-ultracompact configurations or collapse to BHs. In concrete examples we show that typical migration/collapse time scales are not larger than $\sim 10^3$ light-crossing times, unless the stable LR potential well is very shallow. Our results show that the LR instability is effective in destroying horizonless ultracompact objects that could be plausible BH imitators.

Session 2 / Monday 11:15

P. Cunha: Fundamental photon orbits and spacetime instabilities

Generic equilibrium black holes (BHs) and ultra-compact horizonless objects can admit a special set of planar and circular bound null orbits: Light Rings (LRs). These orbits are deeply connected to strong gravitational lensing. For instance, in spherical symmetry, LRs completely determines the photon spheres and the BH shadow image.

In generic equilibrium spacetimes, non-planar bound photon orbits may also exist, dubbed Fundamental Photon Orbits (FPOs), regardless of having full geodesic integrability of the photon motion. FPOs are a natural generalization of the LR orbits.

Recent results in Arxiv:2207.13713 have indicated that horizonless ultracompact objects with LRs, that could potentially mimic BHs, can be effectively destroyed by a LR instability, triggered by the existence of a stable LR inside these objects.

In this talk we remark that stable FPOs can exist within generic spacetimes, even when all LRs are unstable or even in scenarios where no LR exists at all. We illustrate such scenarios in two concrete models: two boson stars in equilibrium and Kerr BHs with Proca hair. The existence of stable FPOs can be conjectured to also trigger new instabilities on the spacetime, similarly to the LR instability. However, a conjectured FPO instability would be much harder to anticipate or diagnose.

Session 2 / Monday 11:30

A. Frassino: Quantum black holes and holographic complexity

In this talk, I will consider quantum effects on some specific black hole solutions and take into account their gravitational backreaction. In particular, I will describe the holographic construction of the quantum BTZ black hole (quBTZ) from an exact four-dimensional bulk solution.

I will present some of the thermodynamic properties of these black holes, focus on the generalized first law and analyze the different complexity proposals for the quBTZ. Our results indicate that Action Complexity fails to account for the additional quantum contributions and does not lead to the correct classical limit. On the other hand, the Volume Complexity admits a consistent quantum expansion and agrees with known limits.

Session 2 / Monday 11:45

L. Annulli: Spin-induced scalarization and magnetic fields

In the presence of certain non-minimal couplings between a scalar field and the Gauss-Bonnet curvature invariant, Kerr black holes can scalarize, as long as they are spinning fast enough. This provides a distinctive violation of the Kerr hypothesis, occurring only for some high spin range. Motivated by the fact that self-gravitating magnetic fields, by themselves, can promote "spin-induced" scalarization, in this talk I will assess if strong magnetic fields, that may exist in the vicinity of astrophysical black holes, could facilitate this distinctive effect. A geometric interpretation for the obtained result is suggested, in terms of the effects of rotation vs. magnetic fields on the horizon geometry.

Session 2 / Monday 12:00

G. Raposo: Elastic stars and compactness bounds

In this presentation I will introduce a rigorous and general framework to study systematically self-gravitating elastic materials within general relativity. I will introduce two classes of elastic equations of state that can be used to explore properties of exotic compact objects. I will discuss the general effects of elasticity on the structure of compact objects, including an analysis on the compactness bounds of compact objects. I will conclude the presentation by discussing how relativistic elasticity can be useful to address issues such as the neutron star structure and the modeling of ultracompact objects.

Session 2 / Monday 12:15

R. Panosso Macedo: Pseudospectrum and quasinormal mode (in)stability

Black hole spectroscopy is as a powerful approach to extract space- time information from gravitational wave observed signals. However, quasinormal mode (QNM) spectral instability under high wave-number perturbations has been recently shown to be a common classical general relativistic phenomenon. I will discuss these recent results on the stability of QNM in asymptotically flat black hole spacetimes by means of a pseudospectrum analysis.

Session 2 / Monday 12:30

P. Garcia: Recent results from the GRAVITY collaboration on SgrA* supermassive black hole

GRAVITY is the most advanced optical-infrared instrument in a ground-based observatory. It sharpens the light of four giant 8 m telescopes with advanced adaptive optics and combines it interferometrically, achieving exquisite precision. It was central to the experimental breakthrough justifying part of the 2020 Physics Nobel Prize.

We will conduct a review of past achievements of the GRAVITY experiment on the Galactic Centre supermassive black hole since the last Workshop. The deep imaging of the galactic centre and the detection of several stars (S29, S38, and S55) further to S2, constrain the extended mass distribution around the supermassive black hole. Using the orbit of S2 and the dynamics of the S cluster the viability of an intermediate mass black hole in the vicinity of SgrA* is analysed and shown to be only plausible for a close orbit.

Session 3 A / Monday 14:30

A. Foschi: Using S2 motion to constrain a scalar field cloud around SgrA*

The motion of S2, one of the stars closest to the Galactic Center, has been well studied and used to set constraints on the compact object at the center of the Milky Way. This central object is well established to be a supermassive black hole but the nature of its environment is unknown. Here, we investigate the possibility that dark matter in the form of an ultralight scalar field clusters around Sgr A* . We used the available data for S2 to perform a Markov Chain Monte Carlo analysis and find the best-fit estimates for a scalar cloud structure. Our results show that observational data are compatible with an extended mass of order 0.1% of the central mass if the cloud is located within the orbit of S2. However, there is only a mild evidence that the model that includes the scalar cloud is preferred over the single black hole setup. Inclusion of the motion of other S-stars to confirm (or reject) this result is in preparation and will be presented in another work.

Session 3 A / Monday 14:45

J. Calderón Bustillo: Measuring the direction of a black-hole gravitational recoil

Gravitational waves (GWs) carry linear momentum. As a consequence, due to the asymmetry of the GW emission, the remnant of a black hole of a black-hole merger can inherit a recoil speed, known as "kick", which can exceed the scape velocity of the host environment. The magnitude of a black-hole kick has fundamental implications in black-hole formation and while its direction is key to understand the plausibility of potential multi-messenger observations of black-hole mergers. In this talk I will report the first measurement of the recoil direction of a remnant black-hole (that of GW190412). In addition, I will discuss the features of GW190412 that enable this measurements and potential applications to multi-messenger observations of black-hole mergers in, e.g., active galactic nuclei.

Session 3 A / Monday 15:00

F. Serrano: Superradiance and Hawking evaporation in the string axiverse

In the string axiverse scenario, light primordial black holes may spin up due to the Hawking emission of a large number of light (sub-MeV) axion-like particles (ALPs). We show that this may trigger superradiant instabilities associated with heavier ALPs during the black hole?s evolution, and study the coupled dynamics of superradiance and evaporation. We find, in particular, that the black hole mass-spin distribution should follow the superradiance threshold condition for black hole masses below the value at which the superradiant cloud forms, for a given heavy ALP mass. Furthermore, we show that the decay of the heavy ALPs within the superradiant cloud into photons may lead to a distinctive line in the black hole?s emission spectrum, superimposed on its electromagnetic Hawking emission.

Session 3 A / Monday 15:15

M. Oi: Constraining regular black holes with S2 star data

Black-hole existence has been widely tested in several contexts, with all observations in agreement with general relativity (GR). However, GR predicts the presence of a curvature singularity at the black-hole core, where the theory breaks down. Consequently, there has recently been increased interest in studying regular black-hole geometries, i.e., objects that are completely regular everywhere. Although their behavior resembles that of a GR solution at great distances from the source, they usually exhibit interesting phenomenological properties at the horizon scale.

In this talk, we present a novel regular black-hole model, characterized by an additional length scale ℓ, which has the strongest possible corrections at great distances compared to the Schwarzschild black hole. Interestingly, our geometry modifies the precession angle proportionally to ℓ, and we find that the orbit becomes retrograde for $\ell > GM$. For this reason, we can impose an upper bound on the deformation parameter using the orbits of the S2 star around the compact radio source SgrA* in the Galactic Center. Finally, we observe that this upper bound is compatible with our thermodynamic stability analysis.

Session 3 A / Monday 15:30

C. Pasiecznik: Eikonal approximation in black hole dynamics and gravitational wave experiments

The Eikonal approximation has provided a simple approach to analyze the scattering angle of particles interacting with a large massive object. With the Eikonal approach, it is possible to study the quantum perturbative scattering amplitudes of a binary system interacting through graviton exchanges. We review the effective field theory treatment of general relativity and the higher order corrections for the bending of light near a massive object via the Eikonal approximation. We explore various probe-limits of the post-Minkowskian order corrections to the scattering angle and evaluate the testability of such corrections using present and near-future gravitational wave experiments. Moreover, we evaluate the testability of these observables pertinent to gravitational binary systems by looking at possible implications of such scattering events in resulting gravitational waves.

Session 3 A / Monday 15:45

J. Pasiecznik: Prospects for gravitational wave detection with CubeSats

We explore the feasibility of using CubeSats for detecting Gravitational Waves (GW). Heavier black hole mergers are dominated by low-frequency emission, however terrestrial gravitational noise contributions prevent the use of ground based low-frequency GW detectors. We present the sources of such noise contributions and the argument for the use of space based low-frequency GW detectors. We analyze the detrimental effect of forces on CubeSats that are in Earth orbit, including that of solar radiation pressure and J2 perturbations. We estimate the ability of measuring the acceleration of test masses (TMs) that are in free fall using CubeSats. By investigating the mass cost reduction of CubeSats, we present benefits of using CubeSats over ground-based detectors and current LISA systems. We discuss constraints associated with miniaturizing the GW detection systems used for LISA. Our investigations lead us to developing a comprehensive argument for using CubeSats for detecting GWs with an analysis of the signal to noise ratio for low-frequency gravitational wave detection.

Session 3 B / Monday 14:30

N. Santos: A little hair can make a big difference: local thermodynamic stability of hairy black holes

The local thermodynamic stability of a black hole (BH) in the canonical ensemble is defined by the positivity of the specific heat at constant global charges. Schwarzschild BHs in thermal equilibrium with the environment are always unstable against small fluctuations of energy, whereas Reissner-Nordström/Kerr BHs with sufficiently large specific electric charge/angular momentum are stable. One could expect that asymptotically-flat hairy BHs branching off from such stable phases would also be, by continuity, locally thermodynamically stable for vanishingly little hair. In this talk, we show the situation changes when the hair grows from the addition of ultralight bosonic matter to Einstein-Maxwell theory. Specifically, we find quasi-bald BHs are locally unstable in this statistical ensemble, regardless of their specific global charges.

Session 3 B / Monday 14:45

T. Fernandes: The canonical ensemble of a d-dimensional Reissner-Nordström black hole in a cavity

We construct the canonical ensemble of a Reissner-Nordström black hole in a cavity for an arbitrary number of dimensions. The system of a charged black hole in a cavity can be described by a partition function given by the Euclidean path integral approach, where we consider the usual Einstein-Maxwell action with the Gibbons-Hawking-York boundary term and an additional boundary term depending on the Maxwell tensor. The spacetime is then Euclideanized and time becomes periodic. The inverse temperature at the boundary is fixed, which corresponds to the total time length at the cavity, and the charge is also fixed, which corresponds to the flux of the Maxwell tensor at the cavity. The zero loop approximation is performed, and the path integral is simplified, which allows us to find the black hole solutions for the fixed temperature and electric charge. We find that, below a critical electric charge, there are three solutions, from which two are stable. Above the critical charge, there is only one solution, which is stable. We find analytical expressions for the points where these solutions meet and for the critical charge. Regarding thermodynamics, the energy, the pressure, the entropy and the electric potential are obtained. The stability of the solutions corresponds to the solutions with positive heat capacity at constant electric charge. The limit of very large cavity is performed, and it is found that, contrarily to the uncharged Hawking black hole, a black hole with sufficient electric charge is stable, connecting thus to previous calculations in the literature, notably by Davies in 1978.

Session 3 B / Monday 15:00

S. Nampuri: Wormholes from automorphic forms in string theory: A black hole counting story

We use the exact statistical degeneracy formula of single-centred 1/4 BPS dyonic black holes in 4D $N = 4$ toroidally compactified heterotic string theory, given in terms of the Igusa cusp form of $Sp(2, \mathbb{Z})$ to write down the gravitational path integral that captures black hole degeneracy as a sum over Euclidean backgrounds including orbifolds of the Euclidean $AdS_2 \times S^2$ attractor geometry. We further show how a rewriting of the degeneracy formula is amenable, at a semi-classical level, to a gravitational interpretation involving 2D Euclidean wormholes. This alternative picture is useful to elucidate different aspects of the gravitational path integral capturing the microstate degeneracies.

Based on arXiv.2211.06873

Session 3 B / Monday 15:15

K. Uzawa: Dynamical branes on expanding orbifold and complex projective space

We construct some new dynamical p-brane solutions to gravity theories on curved backgrounds. These solutions depend on time and are carriers of the p-form field strength. The simplest such solutions have the function of $(p+1)$-dimensional worldvolume spacetime, i.e. dynamical p-branes. We discuss the relations between dynamical branes, a new time-dependent solution on complex projective space $\mathbb{C}\mathrm{P}^n$ and the static p-branes on the orbifold $\mathbb{C}^n/\mathbb{Z}_n$.

Session 3 B / Monday 15:30

A. García-Quismondo: Polymeric quantisation of the interior of a Schwarzschild black hole

In this talk, I will present some recent results concerning the loop quantisation of the interior region of a Schwarzschild black hole within the framework of loop quantum cosmology and a preliminary study of the physical states of the quantum theory. We start from a classical canonical description based on an extension of the phase space of Kantowski-Sachs cosmologies. Following the programme of loop quantum cosmology, we find a quantum representation of the holonomy-flux algebra and promote the constraints of the system to quantum operators on a kinematical Hilbert space. Then, assuming certain reasonable spectral properties for the involved operators, we formally discuss the expression of the physical states annihilated by the constraint operators, which turn out to be completely characterised by a wave function of the black hole mass with support on a very specific set. Finally, we comment on the conditions that guarantee the existence of physical states that describe very massive black holes.

Session 3 B / Monday 15:45

A. Sanna: Effective models of nonsingular quantum black holes

Penrose's singularity theorem proved the utter inevitability of spacetime singularity formation in general relativity during gravitational collapse, where the theory completely loses its predictive powers. It is generally believed that this problem will find a solution in a theory of quantum gravity (QG), whose effects have so far been assumed to act at the Planck length. Instead, this talk explores the possibility that smearing of the singularity may be related to QG effects acting at the event horizon scale. We construct a broad class of non-singular, static and asymptotically-flat black-hole models with a de Sitter core, sourced by an anisotropic fluid which effectively encodes quantum corrections. These corrections are parametrized by a single length-scale ℓ, which represents an effective "quantum hair". Depending on its value, these models interpolate between two-horizon, one-horizon (extremal) or horizonless objects. By analyzing their thermodynamics, we show that models with $\ell \sim R_{\mathrm{S}}$ (where R_{S} is the classical Schwarzschild radius) are thermodynamically preferred over those with $\ell \ll R_{\mathrm{S}}$, supporting the relevance of quantum corrections at horizon scales. We argue that these super-Planckian corrections can have phenomenological signatures, potentially observable in the near future.

Session 4 A / Monday 16:30

H. Witek: CSI: Gravity – investigating fundamental physics with black holes

The detection of 90 gravitational wave signals produced by coalescing black holes or neutron stars have opened a rich discovery space for astrophysics, fundamental physics and cosmology. In particular, they enable qualitatively new tests of gravity in its most extreme regime that unfolds when black holes collide. To link gravitational wave observations to the underlying theory of gravity we need accurate waveform models in and beyond general relativity. In this talk, I will give an overview of recent advances in simulating binary black holes in quadratic gravity theories, and I will highlight new dynamical phenomena that are absent in GR.

Session 4 A / Monday 16:45

Z. Zhong: Piercing of a boson star by a black hole

New light fundamental fields are natural candidates for all or a fraction of dark matter. Self-gravitating structures of such fields might be common objects in the universe, and could comprise even galactic halos. These structures would interact gravitationally with black holes, a process of the utmost importance since it dictates their lifetime, the black hole motion, and possible gravitational radiation emission. We study the dynamics of a black hole piercing through a much larger fully relativistic boson star, made of a complex minimally coupled massive scalar without self-interactions. As the black hole pierces through the bosonic structure, it is slowed down by accretion and dynamical friction, giving rise to gravitational-wave emission. Since we are interested in studying the interaction with large and heavy scalar structures, we consider mass ratios up to $q \sim 10$ and length ratios $L \sim 62$. Somewhat surprisingly, for all our simulations, the black hole accretes more than 95% of the boson star material, even if an initially small black hole collides with large velocity. This is a consequence of an extreme "tidal capture" process, which binds the black hole and the boson star together, for these mass ratios. We find evidence of a "gravitational atom" left behind as a product of the process.

Session 4 A / Monday 17:00

N. Sanchis-Gual: The impact of the wavelike nature of Proca stars on their gravitational-wave emission

I will present a systematic study of the dynamics and gravitational-wave emission of head-on collisions of spinning vector boson stars, known as Proca stars. To this aim we build a catalogue of about 800 numerical-relativity simulations of such systems. We have found that the wave-like nature of bosonic stars has a large impact on the gravitational-wave emission. In particular, we show that the initial relative phase $\Delta\epsilon = \epsilon_1 - \epsilon_2$ of the two complex fields forming the stars (or equivalently, the relative phase at merger) strongly impacts both the emitted gravitational-wave energy and the corresponding mode structure. This leads to a non-monotonic dependence of the emission on the frequency of the secondary star ω_2, for fixed frequency ω_1 of the primary. This phenomenology, which has not been found for the case of black-hole mergers, reflects the distinct ability of the Proca field to interact with itself in both constructive and destructive manners. We postulate this may serve as a smoking gun to shed light on the possible existence of these objects.

Session 4 A / Monday 17:15

M. Vaglio: Parameter estimation on boson-star binary signals with a model-based coherent inspiral template

Compact boson star solutions can be constructed on such a scale that binary systems emit gravitational waves in the same frequency range of stellar-mass black hole binaries. Nonetheless, already at the inspiral stage, the resulting signal is significantly different due to tidal and spin-induced effects which affect the waveform. We constructed a post-Newtonian expanded template for the inspiral of boson star binaries, coherently including beyond-point-particle finite size corrections to the orbital dynamics and gravitational emission, as functions of the component masses and spins and of a single parameter of the model. We performed Bayesian parameter estimation on simulated signals, which show that future facilities will have the sensitivity to disentangle these exotic sources from black holes and to infer constraints on the parameter space of the scalar field theory. The analysis also confirms the validity of our template and our choice of parametrization, showing that including model-based dependence of tidal and spin-induced effects from the stars' first two moments, results in a more accurate recovery of all the parameters.

Session 4 A / Monday 17:30

R. Luna: Kicks in charged black hole binaries

We compute the emission of linear momentum (kicks) by both gravitational and electromagnetic radiation in fully general-relativistic numerical evolutions of quasi-circular charged black hole binaries. We derive analytical expressions for slowly moving bodies and explore numerically a variety of mass ratios and charge-to-mass ratios. We find that for the equal mass case our analytical expression is in excellent agreement with the observed values and, contrarily to what happens in the vacuum case, we find that in presence of electromagnetic fields there is emission of momentum by gravitational waves. We also find that the strong gravitational kicks of binaries with unequal masses affect the electromagnetic kicks, causing them to strongly deviate from Keplerian predictions. For the values of charge-to-mass ratio considered in this work, we observe that magnitudes of the electromagnetic kicks are always smaller than the gravitational ones.

Session 4 A / Monday 17:45

A. Vaño-Viñuales: Towards causal visualization of collapsing hyperboloidal slices

Carter-Penrose diagrams are a useful tool to understand the causal properties of spacetimes. I will consider the spherically symmetric collapse of a massless scalar field in the context of numerical relativity. The evolution takes place on hyperboloidal slices, which are smooth and spacelike, and reach future null infinity. This is the collection of the endpoints of future-directed null geodesics and where global quantities of spacetimes are unambiguously defined. I will describe the process to create dynamical Penrose diagrams of the collapse using numerical data and report on the results' current status.

Session 4 B / Monday 16:30

M. Minamitsuji: General relativistic solutions in the Minimal Theory of Bigravity

We investigate general relativistic (GR) solutions in the Minimal Theory of Bigravity (MTBG). MTBG does not contain potentially problematic scalar and vector polarizations in the gravitational sectors and can be a promissing model for the origin of the cosmic acceleration of the present day. We show that a pair of Schwarzschild-de Sitter spacetimes written in the spatially-flat coordinates is a solution in the self-accelerating branch of MTBG, and derive the conditions under which a slicing of the Schwarzschild-de Sitter solution is solution of the normal branch of MTBG. We also confirm that the self-accelerating branch of MTBG admits static and spherically symmetric GR stellar solutions with regular matter profile written in the spatially-flat coordinates, including neutron stars with arbitrary equations of state. We then study the dynamical processes in the self-accelerating branch of MTBG, i.e., gravitational collapse and propagation of the odd-parity black hole perturbations.

Session 4 B / Monday 16:45

J. Gigante Valcarcel: New black hole solutions with a dynamical traceless nonmetricity tensor in Metric-Affine Gravity

In the framework of Metric-Affine Gravity, the existing correspondence between the Einstein tensor and the energy-momentum tensor of matter provided by General Relativity is extended towards a post-Riemannian description in terms of the torsion and nonmetricity fields, which are sourced by the spin, dilation and shear currents of matter. In this talk, we discuss the dynamical role of the traceless part of the nonmetricity tensor and its intrinsic connection with shears, defining a model which encloses a new black hole solution endowed with shear charges. We show that the extension in the presence of dynamical torsion and Weyl vector leads to the broadest family of static and spherically symmetric black hole solutions with spin, dilation and shear charges in Metric-Affine Gravity so far.

Session 4 B / Monday 17:00

R. Garattini: Yukawa Casimir wormholes

After a brief description of what is a traversable wormhole we describe the connection between traversability, the Casimir effect and Yukawa deformations. With the help of an equation of state we also discuss other different solutions generated by the Casimir source. Speculations on these results are also presented including the effect of an additional electric charge.

Session 4 B / Monday 17:15

M. Brito: Stable excited scalar boson-stars and astrophysical consequences

In this presentation we report on our study of the evolution in time of spherical excited scalar boson stars under the framework of General Relativity. We see that spherically symmetric excited scalar boson stars can be made dynamically stable (up to timescales of $t\mu \sim 10^4$, where μ is the mass of the scalar particle) with a quartic self-interaction, for certain values of the self-interaction constant λ, up to $n = 10$, where n is the number of nodes in the radial function. We also report the compactness of these solutions, which are not compact enough to allow for ISCOs or light rings. We will also discuss the angular velocity of particles in a circular orbit and its relevance for the galactic rotational velocities.

Session 4 B / Monday 17:30

A. Pombo: Virial identities in relativistic gravity

Virial (a.k.a. scaling) identities are integral identities that are useful for a variety of purposes in non-linear field theories, including establishing no-go theorems for solitonic and black holes solutions as well as checking the accuracy of numerical solutions. In this presentation, we provide an algorithm for the derivation of such integral identities. We show that a complete treatment of virial identities in the relativistic gravity must take into account the appropriate boundary term. For General Relativity this is the Gibbons-Hawking-York boundary term. There is, however, a particular "gauge" choice i.e. a choice of coordinates and parametrizing the metric functions, that simplifies the computation of the virial identities in General Relativity, making both the Einstein-Hilbert action and the Gibbons-Hawking-York boundary term non-contributing. Under this choice, the virial identity results exclusively from the matter action. For generic "gauge" choices, however, this is not the case.

Session 4 B / Monday 17:45

A. Rincón: The effects of running gravitational coupling on three dimensional black holes

In the present work, we investigate the consequences of running gravitational coupling on the properties of the three-dimensional BTZ black hole. We take as starting point the functional form of gravitational coupling obtained in the context of asymptotic safe gravity theory. By using the standard scale setting relation where $k \sim \xi/r^n$,we compute the solution of the Einstein field equations. We get and analyze the horizon and the thermodynamic properties of this new class of black hole solutions. The impact of the scale–dependent parameter ξ on the cosmological "constant" and metric functions are briefly discussed. We find that the null energy condition is also violated in this setup when scale-dependent gravity and Newton's coupling (coming from the asymptotic safety scenario of gravity) are simultaneously taken into account.

Session 5 / Tuesday 9:00

R. Brito: Floating orbits, superradiant scattering and the black-hole bomb: 50 years after

This year we celebrate the 50 years of the highly influential paper "Floating Orbits, Superradiant Scattering and the Black-hole Bomb" by William Press and Saul Teukolsky [Nature **238**, 211-212 (1972)]. In this talk I will briefly review the fascinating ideas put forward in this paper and highlight the main implications that it had for black hole physics, astrophysics and even particle physics.

Session 5 / Tuesday 9:15

E. Radu: Curing conical singularities with scalar hair

A number of well-known black object solutions in (electro)vacuum general relativity (GR) are plagued by conical singularities which provide the force balance that allows the existence of such configurations. The basic example is the Bach-Weyl (or double-Schwarzschild) solution, which describes two static black holes in four dimensional vacuum GR, with a deficit angle along the section in between the black holes. A different case is provided by the five dimensional static Emparan-Reall black ring, which contains a conical singularity in the form of a disc that sits inside the ring, supporting it against collapse. We argue that the situation in (electro)vacuum GR is not generic, with the possible existence of balanced solutions in i) more general theories or ii) for different spacetime asymptotics. Focusing on the first case, we consider the static black ring in Einstein-Maxwell-gauged scalar field model and argue that the charged scalar hair can balance it, yielding solutions that are singularity free on and outside the horizon. The four dimensional static two static black hole system can be balanced by a real scalar field with an appropriate self-interaction.

Session 5 / Tuesday 9:30

R. Vicente: First constraints on binary black hole environments from LIGO-Virgo observations

As of now, almost a hundred gravitational-wave (GW) signals have been observed and interpreted as resulting from the coalescence of compact binaries by LIGO-Virgo. While these signals seem to be in perfect agreement with the theory of general relativity (GR) in vacuum, it is crucial to quantify any possible small deviations. By looking at the GW signal, how sure are we that these binaries are evolving in vacuum? Both modifications to the theory of gravity and the presence of environments may manifest themselves by a shift in the evolution of the binary phase. Previous analysis have used this effect to quantify deviations of the observed GWs to vacuum GR waveforms by estimating the (inspiral) phase coefficients of PN order ≥ -1. However, environmental effects (like dynamical friction and accretion) are responsible for coefficients at more negative PN orders. In this talk I will present the first estimation of these phase coefficients for several LIGO-Virgo signals, and translate them into constraints on the density of their environments.

Session 5 / Tuesday 9:45

E. Gasperín: The GBU system close to spatial infinity: a log story

A system of equations that serves as a model for the Einstein field equation in generalised harmonic gauge called the good-bad-ugly system is studied in the region close to null and spatial infinity in Minkowski spacetime. This analysis is performed using H. Friedrich's cylinder construction at spatial infinity and defining suitable conformally rescaled fields. The results are translated to the physical set up to investigate the relation between the polyhomogeneous expansions arising from the analysis of linear fields using the i0-cylinder framework and those obtained through a heuristic method based on Hörmander's asymptotic system.

Session 5 / Tuesday 10:00

E. Giangrandi: Stability and gravitational collapse of dark matter admixed neutron stars

We study the impact of accumulated asymmetric bosonic dark matter on neutron star properties, including tidal deformability, maximum masses, radii, etc. The conditions at which dark matter particles tend to condensate in the core of a star or create an extended halo are presented. We show that at some values of mass, interaction scale, and relative fraction, the dark matter core becomes gravitationally unstable leading to a collapse into a black hole. By analyzing observational data of old neutron stars, we constrain the range of model parameters and the amount of accumulated dark matter. Moreover, we discuss how the ongoing and future X-ray, radio, and GW observations could shed light on dark matter admixed compact stars and put multi-messenger constraints on its effect.

Session 5 / Tuesday 10:15

R. Mishra: Radiative GRMHD simulations of black hole accretion with KORAL

KORAL is a general relativistic radiation magnetohydrodynamics (GRRMHD) code used to study accretion onto compact objects and related phenomena. Radiation is treated using the M1 closure scheme. We present some examples of results obtained with KORAL in our group. We also discuss our ongoing project where we intend to set up a simulation of an optically thin and geometrically thick advection dominated accretion flow (ADAF), relevant for systems such as M87 and Sgr A*. These same initial astrophysical set up will then be evolved in different background space-time geometries. The aim of this work is to enable a determination by the Event Horizon Telescope (EHT) team of the space-time metric of the black holes observed in M87 and Sgr A*.

Session 6 / Tuesday 11:00

G. L. Cardoso: Holographic aspects of four-dimensional asymptotically flat N = 2 black holes

We explore holographic attributes of four-dimensional near-extremal Reissner-Nordstrom black hole solutions in ungauged $N = 2$ supergravity theories at the two-derivative level by recasting them as a specific first-order deformation in solution space, associated with an infinitesimal Harrison transformation, of black holes in an AdS_2 space-time. We further show that the $nAdS_2$ attractor mechanism can be recast as a specific deformation of the BPS flow equations in four dimensions. Additionally, we also discuss time-dependent perturbations of the four-dimensional near-extremal Reissner-Nordstrom solutions from a two-dimensional point of view.

Session 6 / Tuesday 11:15

S. Barsanti: Detecting massive scalar fields with Extreme Mass-Ratio Inspirals and LISA

Extreme Mass Ratio Inspirals (EMRIs), binary systems with a secondary stellar mass compact object inspiralling into a massive black hole, are among the main targets for LISA, as they harbour the potential for precise strong gravity tests. Although the description of these systems in modified theories of gravity can be dramatically complex, for a vast class of theories with additional scalar fields great simplifications occur. At leading order in the binary mass ratio, the background spacetime is simply described by the Kerr metric. Moreover, the imprint of the scalar field on the waveform is fully captured by the scalar charge of the secondary - and by the mass of the scalar field. In this talk I will show how, using these simplifications, the secondary's scalar charge and the scalar field mass affect the EMRI's orbital evolution, and how such changes get imprinted on the emitted waveforms. By analysing such signals, I will finally present the results on the LISA's detectability of the scalar field charge and mass, which render EMRIs encouraging probes of gravity and new fundamental fields.

Session 6 / Tuesday 11:30

B. Juraev: Acceleration and radiation of cosmic rays nearby astrophysical black holes

In many astrophysical scenarios, the charge of the black hole is often neglected due to unrealistically large values of the charge required for the Reissner-Nordstrom spacetime metric. Black holes, however, might have a small electric charge because of various methods for selective accretion. We study how an imaginary small electric charge on a Schwarzschild black hole affects the ionization of a freely falling neutral particle and how the ionized particle thereafter escapes from the black hole. We demonstrate the ultra-high energy of ionized particles and discuss the distinctive signs of particle acceleration by weakly charged black holes. Next, we will look for the radiation of the charged particle in the vicinity of the weakly charged Schwarzschild black hole. We study depending on the sign of Coulomb force radiating charged particle spirals down to the black hole or stabilizes the circular orbit.

Session 6 / Tuesday 11:45

M. Bošković: Probing scalar particles and forces with compact objects

In the highly relativistic regime around compact objects signatures of new physics may be unraveled. Some compact objects may in fact be constructed from beyond Standard Model matter. In particular, boson stars are useful toy models for exotic compact objects that could be produced in the Early Universe. Gravitational wave astronomy may also uncover a signature of a new force-mediating boson that must be suppressed through some sort of screening mechanism near matter sources. In this talk I will discuss the following: (i) how the scalar potential constrains the macroscopic properties of boson stars; (ii) how the coalescence of unequal-mass boson star binaries differs from the black hole binary system and (iii) how the kinetic screening operates in the system of binary compact objects.

Session 6 / Tuesday 12:00

T. Ledvinka: Universality of curvature invariants in critical collapse of axisymmetric gravitational waves

Using the standard methods of numerical relativity we study axisymmetric gravitational waves undergoing gravitational collapse. Because it is known that the 1+log lapse choice breaks down in this situation, we propose a computationally effective alternative to maximal slicing and show that it allows the simulation to proceed until either the gravitational waves disperse or an apparent horizon is formed. We then consider several families of asymptotically flat initial data for which a strength parameter, similarly to the well-known Choptuik's discovery, can be fine-tuned between dispersal into empty space and collapse into a black hole. We find that such near-critical spacetimes exhibit behavior similar to scalar-field collapse: For different families of initial data, we observe universal "echoes" in the form of approximate scaled copies of the same piece of spacetime. In contrast to very regular behavior of spherically symmetric massless scalar field collapse, in critical collapse of gravitational waves the quantities such as extremes of curvature invariants or geodesic time intervals between echoes seem irregular.

(Joint work with A. Khirnov)

Session 6 / Tuesday 12:15

M. Lenzi: Black hole greybody factors from Korteweg-de Vries integrals

Perturbation theory of vacuum spherically symmetric spacetimes is a crucial tool for understanding the dynamics of black hole (BH) perturbations as well as BH scattering phenomena. Since the pioneering work of Regge and Wheeler it is known that the equations for the perturbations can be decoupled in terms of (gauge-invariant) master functions that satisfy 1 + 1 wave equations. However, while in the literature only few master equations are known, the full landscape of master equations was recently shown, clarifying that Einstein equations actually allow for an infinite set of them. Moreover, it turned out that this is a consequence of the presence of an infinite number of symmetries for the dynamics of perturbed non-rotating BHs. Besides, such symmetries can be associated with the infinite hierarchy of Korteweg-de Vries (KdV) equations. As a consequence, there is also an infinite number of conserved quantities, the KdV integrals. After reviewing the landscape of master equations for BH perturbations and how the KdV integrals naturally arise in this context, we show that these integrals fully determine the BH greybody factors. We exploit the fact that the problem of finding the greybody factors in BH scattering using these conserved quantities can be cast as a moment problem, which has been largely studied during the last century in a wide range of mathematical and physical contexts. There are a number of numerical approaches to tackle the moment problem but a natural semi-analytical solution is given in terms of Padé approximants. The results are compared with previous calculations with the WKB approximation. This whole picture is not restricted to applications to scattering by non-rotating BHs. In fact, it can be used to describe a quite wide variety of physical systems, provided they are described by a Schrödinger equation with a bound state-less potential barrier.

Session 6 / Tuesday 12:30

U. Sperhake: The Stochastic background from core collapse supernovae in massive scalar-tensor gravity

In this talk, we model the gravitational collapse of stars in massive scalar-tensor gravity. In this theory, the two tensorial gravitational-wave polarization modes are complemented by a massive breathing mode. This latter mode is triggered by the spontaneous scalarization mechanism discovered by Damour and Esposito-Farese; its radiation exhibits a drastically different behaviour dominated by the dispersive character of the mass term which leads to quasi-monochromatic signals that can last years or even centuries. This smoking-gun effect offers unique opportunities to test this class of theories. We discuss the overlap of numerous such signals arising from multiple supernova events in the local universe and compare the resulting gravitational-wave energy density with present constraints from LIGO-Virgo observations.

Session 7 A / Tuesday 14:30

R. Z. Ferreira: Primordial black holes and axions: a tale of (galactic and extragalactic) light

Primordial black holes with asteroid-like masses (10^{14-18} kg) can still account for all the dark matter. In this talk, I will discuss a new indirect probe of PBH dark matter. I will show that axions with masses in the 0.1eV-MeV range can form in clouds around such PBHs, via superradiance, and ultimately decay, if coupled to photons. The decay products will contribute to the galactic or extragalactic background flux at frequencies between the UV and the gamma-rays, depending on the axion mass. I will show that current data already constraints a large range of parameters and that searches for narrow lines with future experiments such as the Athena X-ray telescope will further test this co-existence of PBH dark matter and axions.

Session 7 A / Tuesday 14:45

M. Zhu: Primordial black holes from bouncing cosmology

The non-singular bouncing cosmology is an alternative paradigm to inflation, where the background energy density vanishes at the bounce point in the context of Einstein's gravity. Therefore, the non-linear effects in the evolution of density fluctuations ($\delta\rho$) may be strong in the bounce phase, which potentially provides a mechanism to enhance the abundance of primordial black holes (PBHs). We present a comprehensive illustration for PBH enhancement in the bounce phase and find that the bounce phase can potentially enhance the PBH abundance sufficiently.

Session 7 A / Tuesday 15:00

J. L. Rosa: Recent developments on observational properties of bosonic stars from hot-spots and accretion disks

In the recent years, our understanding of the galactic centre has grown rapidly with the joint efforts of large international collaborations like the GRAVITY, who detected infrared flares close to the innermost stable circular orbit (ISCO) of the supermassive black-hole at the galactic centre, and the Event Horizon Telescope (EHT), which recently published the first picture of a black-hole shadow from Sgr A*. These observations are consistent with the predictions from General Relativity (GR) in black-hole spacetimes. However, due to the large experimental imprecisions, the data are not able to exclude the possibility of the central massive object in our galaxy not being a black-hole but instead some exotic compact object that mimics the qualitative properties of black-hole exteriors. In this talk, we explore a particular example of such alternative compact objects: bosonic stars (Boson and Proca stars), and the possibility of these observations being consistent with the presence of one of these exotic stars at the galactic centre.

Session 7 A / Tuesday 15:15

I. Sengo: Shadows of Kerr black holes with synchronised Proca hair

We report the results of the first comprehensive study on the shadows of fundamental Kerr black holes with Proca hair. Some of these solutions show striking non-Kerr features, such as chaotic patterns, non-smooth shadow edges, and ghost shadows. We illustrate how fundamental photon orbits can help us understand some of these features. Nonetheless, a wide range of solutions where deviations from Kerr are small can also be found, which allow us to constrain the amount of hair compatible with the Event Horizon Telescope (EHT) data. Unexpectedly, given the (roughly) 10% error bars in the EHT data – and in contrast to their scalar cousin model –, some of the black holes with up to 40% of their energy in their Proca hair are compatible with the current data. We estimate the necessary resolution of future observations to better constrain this model.

Session 7 A / Tuesday 15:30

E. Maggio: Testing general relativity in the nonlinear regime: a parametrized plunge-merger-ringdown waveform model

Gravitational waves provide a unique opportunity to test gravity in the dynamical and nonlinear regime. Here, we propose a parametrised test of general relativity that introduces generic deviations to the plunge, merger and ringdown stages of binary-black-hole coalescences. The novel feature of the model is that it can capture signatures of beyond-GR physics in the merger phase of black-hole binaries observed by the LIGO-Virgo-KAGRA Collaboration. We find that the deviations from the peak gravitational-wave amplitude and frequency can be constrained to about 20% with GW150914. Alarmingly, we find that GW200129_065458 shows a strong violation of general relativity. We interpret this result as a false violation either due to waveform systematics (mismodeling of spin precession) or data-quality issues. This event demonstrates the importance of systematics and glitch mitigation procedures when interpreting tests of general relativity with present gravitational-wave observatories.

Session 7 A / Tuesday 15:45

H. Silva: Tests of general relativity at the merger of black-hole binaries

The coalescence of compact binaries and the gravitational waves produced in this process provide an unique view into gravity in its dynamical, nonlinear regime. Proeminent during a black-hole coalescence is the plunge-merger stage, when the black holes collide at a large fraction of the speed of light and around which the gravitational-wave luminosity peaks. How robust are the predictions of general relativity at this stage? I will present a new parametrized waveform model within the effective-one-body formalism that allows for deviations from general relativity in the plunge-merger-ringdown stage of nonprecessing, quasicircular black-hole binaries. I will discuss the application of this waveform model to analyze the black-hole binary events GW150914 and GW200129. I will use GW200129 to discuss the importance of waveform systematics and of data-quality when interpreting tests of general relativity with present day gravitational-wave observations.

Session 7 B / Tuesday 14:30

R. Konoplya: First few overtones probe the event horizon geometry

It is broadly believed that quasinormal modes (QNMs) cannot tell the black-hole near-horizon geometry, because usually the low-lying modes are determined by the scattering of perturbations around the peak of the effective potential. Using the general parametrization of the black-hole spacetimes respecting the generic post-Newtonian asymptotic, we will show that tiny modifications of the Schwarzschild/Kerr geometry in a small region near the event horizon lead to almost the same Schwarzschild/Kerr fundamental mode, but totally different first few overtones. Having in mind that the first several overtones affect the quasinormal (QN) ringing at its early and intermediate stage [M. Giesler, M. Isi, M. Scheel, and S. Teukolsky, Phys. Rev. X 9, 041060 (2019)], we argue that the near-horizon geometry could in principle be studied via the first few overtones of the QN spectrum, which is important because corrections to the Einstein theory must modify precisely the near-horizon geometry, keeping the known weak field regime. We discuss the connection of this observation with the so called "overtones' instability" recently studied in [J. Jaramillo et. al. Phys. Rev. Lett. 128, 211102 (2022)].

Session 7 B / Tuesday 14:45

F. Duque: The elephant and the flea redux: Stability of the fundamental quasinormal mode in time-domain observations

It was recently shown that small perturbations due, e.g., to environmental effects (the "flea") to the effective potential governing gravitational-wave generation and propagation in black hole exteriors (the "elephant") can lead to arbitrarily large changes in the black hole's quasinormal spectrum. This raises an important question: is the black hole spectroscopy program robust against perturbations? In this talk, we clarify the physical behavior of time-domain signals under small perturbations in the potential, and we show that changes in the amplitude of the fundamental mode in the prompt ringdown signal are parametrically small. This implies that the fundamental quasinormal mode extracted from the observable time-domain signal is stable against small perturbations.

Session 7 B / Tuesday 15:00

V. Gennari: Observing black hole's vibrations

Ringdown offers a unique possibility to study the spacetime in extreme curvature regimes, to test general relativity and better understand the nature of black holes. The ringdown corresponds to the last phase of black hole binary coalescences, when the newly formed black hole relaxes to its stationary Kerr state by emitting gravitational waves. The linear theory of black hole perturbations predicts that the ringdown is made by a sum of different modes of vibration, which are exponentially damped harmonics oscillations. The excitation of different modes depends on the specific process that perturbs the black hole, and for quasi-circular binary coalescences only one fundamental mode dominates the ringdown emission. Besides, asymmetries in the system can excite higher subdominant modes of vibration. The measurement of the frequencies and damping times of these higher modes allows to directly test the black hole paradigm, by comparing the predicted values against the observations. We describe the first time domain analysis with an effective one-body ringdown model on the third catalog of gravitational waves events GWTC-3, to assess the observability of higher modes. We report a marginal detection of one higher mode in one event, for the first time on this event and the second time in ringdown-only analyses. This work sets the bases towards the positive identification and characterisation of higher modes in the ringdown signals with future, more sensitive gravitational wave detectors, and opens the concrete possibility of conducting multimodal tests of general relativity in the strong field regime.

Session 7 B / Tuesday 15:15

V. Boyanov: Pseudospectrum of horizonless compact objects

Recent investigations of the pseudospectrum in black hole spacetimes have shown that quasinormal mode frequencies suffer from spectral instabilities. We extend the pseudospectrum analysis to horizonless exotic compact objects which possess a reflective surface arbitrarily close to the Schwarzschild radius, and find that their quasinormal modes also suffer from an overall spectral instability. Even though all the modes themselves decay monotonically, the pseudospectrum contours of equal resonance magnitude around the fundamental mode and the lowest overtones can cross the real axis into the unstable regime of the complex plane, unveiling the existence of nonmodal pseudo-resonances. A pseudospectrum analysis further predicts that fluctuations to the system may destabilize the object when next to leading-order effects are considered, as the triggering of pseudo-resonant growth can break the order-expansion of black-hole perturbation theory.

Session 7 B / Tuesday 15:30

G. Castro: Rotational tidal Love numbers and their impact on compact object inspirals

The coupling between the angular momentum of a compact object and an external tidal field gives rise to the "rotational" tidal Love numbers, which affect the tidal deformability of a spinning self-gravitating body and enter the gravitational waveform of a binary inspiral at high post-Newtonian order. In this talk I will present an unexpected symmetry of these quantities in slowly-rotating neutron stars and how they are expected to hold for generic compact objects. I will also show how the rotational tidal Love numbers of neutron stars will become relevant in the near-future given the expected accuracy of third-generation detectors, as well as what lessons we should take from this in future studies of tidal deformability of compact objects.

Session 7 B / Tuesday 15:45

G. Creci: Tidal deformability from scattering and the role of analytic continuation

The tidal response of a compact object is a key gravitational-wave observable encoding information about its interior. This link is subtle due to the nonlinearities of general relativity. We show that considering a scattering process bypasses challenges with potential ambiguities, as the tidal response is determined by the asymptotic in- and outgoing waves at null infinity. As an application of the general method, we analyze scalar waves scattering off a nonspinning black hole and demonstrate that the low-frequency expansion of the tidal response reproduces known results for the Love number and absorption. In addition, we discuss the definition of the response based on gauge-invariant observables obtained from an effective action description, and clarify the role of analytic continuation for robustly (i) extracting the response and the physical information it contains, and (ii) distinguishing high-order post-Newtonian corrections from finite-size effects in a binary system. Our work is important for interpreting upcoming gravitational-wave data for subatomic physics of ultradense matter in neutron stars, probing black holes and gravity, and looking for beyond-standard-model fields.

Session 8 A / Tuesday 16:30

M. Reintjes: On the regularity implied by the assumptions of geometry

The *Regularity Transformation (RT-)equations* are an elliptic system of partial differential equations which determines coordinate and gauge transformations that remove apparent singularities in spacetime by furnishing *optimal metric regularity*. The resulting gain of one derivative for connections above their L^p curvature suffices to establish *Uhlenbeck compactness*. By developing an existence theory for the RT-equations we prove optimal regularity and Uhlenbeck compactness in Lorentzian geometry, including general affine connections and connections on vector bundles with both compact and non-compact gauge groups. As an application in General Relativity, our optimal regularity result proves that the Lorentzian metrics of shock wave solutions of the Einstein-Euler equations are non-singular—geodesic curves, locally inertial coordinates and the Newtonian limit all exist in a classical sense. It is currently an open problem whether the RT-equations could provide a general procedure for removing apparent singularities at black hole horizons.

Session 8 A / Tuesday 16:45

M. de Cesare: Evolving black hole with scalar field accretion

I will present a new method to study evolving black holes in general relativity. Approximate analytical solutions are obtained by expanding the Einstein field equations close to the trapping horizon for a dynamical spherically symmetric black hole in the presence of a minimally coupled self-interacting scalar field. This is made possible by a new parametrization of the metric, in which the displacement from the horizon as well as its expansion rate feature explicitly. Our results are valid in a neighbourhood of the horizon and hold for any scalar field potential and spacetime asymptotics. An exact equation for the accretion rate is also obtained, which generalizes the standard Bondi formula. We also develop a dynamical system approach to study near-equilibrium black holes; using this formalism, we focus on a simple model to show that the near-equilibrium dynamics is characterized by simple scaling relations among dynamical variables. Moreover, we show that solutions with purely ingoing energy-momentum flux never reach equilibrium.

Session 8 A / Tuesday 17:00

E. Costa Filho: Abelian-Higgs balls and stars: a UV completion for Proca self-interactions

We consider an Abelian-Higgs type model wherein a complex vector field gains mass via spontaneous symmetry breaking. This model can be considered as a UV completion of a complex Proca model with self-interactions. We study the flat spacetime (“balls”) and self-gravitating (“stars”) solitons describing some of their mathematical and physical properties. The stars reduce to the well-known (mini-)Proca stars in some limits. The full model evades the hyperbolicity problems of the self-interacting Proca models, offering novel possibilities for dynamical studies beyond mini-Proca stars.

Session 8 A / Tuesday 17:15

A. Bokulić: Can nonlinear electromagnetic fields regularize black hole singularities?

Before considering any modifications of classical gravitational theory, the question is whether black hole singularities can be cured by coupling to some type of matter fields. We inspect nonlinear electromagnetic theories as candidates for resolving black hole singularities. This problem was first systematically addressed by Bronnikov, whose no-go theorems are focused on spherically symmetric spacetimes sourced by nonlinear electromagnetic Lagrangians depending on one electromagnetic invariant, $F_{ab}F^{ab}$. We extend Bronnikov?s analysis to a broader class of Lagrangians, those depending on both electromagnetic invariants, $F_{ab}F^{ab}$ and $F_{ab}{*}F^{ab}$. The obtained results significantly narrow down the possibility of regularization using physically plausible Lagrangians.

Session 8 A / Tuesday 17:30

P. Kotlařík: Gravity of static thin discs around black holes

The astrophysical black holes are not isolated bodies. One of the most prominent structures which form in the proximity of the black hole is a thin accretion disc. Whether treated in Newton's theory or in general relativity, in the static and axially symmetric case the gravitational potential is determined by the Laplace equation. Though clear in principle, its solution is only known explicitly for several disc density profiles. We will show some explicit closed-form potentials and, in some cases, also the full metric describing the exact BH+disc "superposition".

Session 8 A / Tuesday 17:45

C. Peterson Bórquez: Numerical evolution of Good-Bad-Ugly-F system as a toy model for hyperboloidal numerical relativity

The numerical solution of a system of hyperbolic PDEs all the way to future null infinity requires the knowledge of asymptotics. The Good-Bad-Ugly-F model is known to mimic the asymptotic properties of Einstein equations in generalized harmonic gauge. In this talk I will present the results of numerical evolution of this system, both in spherical symmetry and full 3D, with the scope of using these ideas to incorporate the hyperboloidal approach in numerical relativity simulations.

Session 8 B / Tuesday 16:30

O. Zaslavskii: Radially moving frames and flows under the black hole horizon

We give brief review of our recent works. We consider several different aspects connected with properties of motion inside the Schwarzschild black hole. We elucidate, how (i) to maximize the survival proper time and (ii) how to make a visible part of the outer universe as large as possible before hitting the singularity. We also consider red(blueshift) of photons that an observer absorbs during its travel. General classification of radially moving frames i suggested and properties of corresponding Lemaitre time are described. The relation between the BSW effect and properties of frames is discussed.

Session 8 B / Tuesday 16:45

D. Silva: Signatures of spherically symmetric distributions of dust

Collapsing stars may be approximated by homogeneous distributions of dust, either in the form of massive spheres or thin shells. Furthermore, using modern mathematical techniques, the dynamics of these systems may be obtained by separating spacetime into interior and exterior regions, focusing on the boundary conditions and thus foregoing solving the field equations for the totality of spacetime. Although these approximations deny the complexities of stellar dynamics, they allow analytic solutions and these still exhibit several signatures associated with absolute contraction. Additionally, these solutions can be obtained for any case, whether starting from a finite or infinite distance, at rest or with initial velocity. One particular case, of increased physical interest, is that of a distribution of matter starting collapse at rest from a finite distance. Using the analytic solution for this case we trace the evolution of collapse and we build the causal structure of spacetime for all observers: the interior, the one falling with the star and the exterior. We also identify the events that emerge with contraction: the formation of the apparent and event horizons, and subsequently of the region of trapped surfaces and singularity at the center. While these features are hidden away from external observers by the event horizon, we show the profile of the redshift for a distant static observer to follow a specific profile. Doing so, contraction is fully characterized for this case.

Session 8 B / Tuesday 17:00

J. Delgado: Epicyclic frequencies for a generic ultracompact object

Recently, it has been shown that the radial stability of a light-ring (LR) in a spacetime generated by a stationary, axisymmetric, asymptotically flat object with a Z2 symmetry determines the possibility and radial stability of timelike circular orbits (TCOs) around the LR. In this paper, we generalise this result by also considering the vertical (angular) stability of the orbits through the study of the radial and vertical epicyclic frequencies. We show that the vertical stability of the LR only determines the vertical stability of the TCOs around it. A relation between the sum of the squared epicyclic frequencies and the Ricci tensor is also provided. With such relation, we show that objects with radially and vertically unstable LRs (TCOs) violate the null (strong) energy condition.

Session 8 B / Tuesday 17:15

C. Caputo: Geodesic chaos-stationary case

Motivated by processes happening around accreting black holes,a series of papers entitled "Free motion around black holes with discs or rings: Between integrability and chaos" were published in order to classify and evaluate the chaotic behaviour that may occur in geodesic motion around static black holes if these are perturbed by gravity of some additional matter. However the static and axisymmetric space-time superpositions, which, at least in the vicinity of sources, is likely not adequate since accreting compact objects are rather supposed to rotate rapidly. Actually, it is interesting to examine how the rotation-induced space-time dragging affects the geodesic dynamics. For this purpose, we use a recently derived metric (Čížek & Semerák 2017) describing a linear perturbation of a Schwarzschild black hole due to a rotating light finite thin disc. The work is still in progress, we will present some preliminary results.

Session 8 B / Tuesday 17:30

J. Redondo Yuste: Binaries in a box

We explore the problem of a scalar charge orbiting inside a cavity within Schwarzschild spacetime. This problem is relevant to study stellar binaries in AdS as well as in theories with massive degrees of freedom. We show that the charge suffers a non-trivial self-force that would alter its orbit. However, for appropriate initial configurations of the field this effect vanishes over an orbital period. We explore the consequences of this on the orbital trajectory by considering a simpler Hamiltonian model. We conclude that the initial field configuration can impact the characteristics of the motion. Despite this back-reaction, we estimate the scale for which we are able to find eternal binaries.

Session 8 B / Tuesday 17:45

J. Novo: Circular orbits from 2D effective metrics

The motion of particles on general $(1+3)$-dimensional spacetimes satisfying a set of assumptions can be described by the geodesics of a 2-dimensional manifold. In this work we resort to these 2-dimensional metrics to study circular geodesics of generic static, spherically symmetric, and asymptotically flat $(1+3)$-dimensional spacetimes containing either non-extremal black holes or horizonless compact objects. This is done by studying the Gaussian curvature of the 2-dimensional manifold as well as the geodesic curvature of circular curves on these. This study considers both null and timelike circular geodesics. The study of null geodesics in this formulation retrieves the known result of the number of light rings (LRs) on the spacetime outside a black hole and on spacetimes with horizonless compact objects. With an equivalent procedure we formulate a similar theorem on the number and location of marginally stable circular orbits of a given spacetime satisfying the previously mentioned assumptions. Some ongoing work concerning the generalization of this technique to rotation spacetimes will also be presented.