Gravitational Waves, Black Holes and Fundamental Physics

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Book of Abstracts

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1 Talks

1.1 Tuesday, 14

Cosmic Archaeology with black hole binaries

Raffaella Schneider *Department of Physics, Sapienza University of Rome*
Jan 14, 09:15 am, 45 min

Abstract

The existence of massive stellar black hole binaries, with primary black hole (BH) masses greater than 30 -35 Msun was proven by the detection of the gravitational wave (GW) event GW150914 during the first LIGO/Virgo observing run (O1), and successively confirmed by seven additional GW signals discovered by independent analyses of the O1 and O2 data. Recently reported O3 alerts suggest that similar events may have been detected. Building on well established observed galaxy scaling relations and on our current understanding of stellar evolution at different metallicities, we find that these systems may be the relics of stellar populations forming in low-mass dwarf galaxies before the end of cosmic reionization. At the other extreme of the mass spectrum of astrophysical black holes, the existence of a population of almost 200 bright quasars at z > 6 poses crucial questions about their formation and growth processes. Observationally, the most distant quasars provide joint constraints on the mass of black-hole 'seeds' and their accretion efficiency. Depending on their birth environmental conditions in the first halos collapsing at very high redshifts, black hole seeds can be light, heavy or with intermediate masses. Using ab-initio structure formation models, we investigate the relative role of different populations of black hole seeds in the formation histories of the first super-massive black holes and how these formation scenarios may be constrained by future electromagnetic and gravitational wave observations. In particular, future gravitational wave facilities, such as LISA and the Einstein Telescope, will be able to improve our knowledge of these ancient systems, fully exploiting their potential as cosmic archaeology probes.

Growth of supermassive black hole seeds in ETG star-forming progenitors via gaseous dynamical friction: perspectives for GW detections

Lumen Boco *SISSA*
Jan 14, 10:00 am, 15 min

Abstract

In this talk I will discuss a novel mechanism to grow supermassive black hole seeds in star-forming ETG progenitors at $z > 1$. This envisages the migration and merging of stellar compact remnants, via gaseous dynamical friction, toward the central regions of such galaxies. I will show that this process can build up central BH masses of order $10^4 - 10^6 M_\odot$ in a timescale shorter than 10^8 yr, providing heavy seeds before standard disk accretion takes over to become the dominant process for further BH growth. I will discuss the perspectives to detect the merger events between the migrating stellar remnants and the accumulating central supermassive BH via gravitational wave emission with future ground and space-based detectors such as the Einstein Telescope (ET) and the Laser Interferometer Space Antenna (LISA).

Merger rate of stellar black hole binaries above the pair-instability mass gap

Alberto Mangiagli *University of Milan - Bicocca*

Jan 14, 10:15 am, 15 min

Abstract

In current stellar evolutionary models, the occurrence of pair-instability supernovae plays a key role in shaping the resulting black hole (BH) mass population, preventing the formation of remnants between about $[60, 120] M_\odot$. We develop a simple approach to describe BHs beyond the pair-instability gap, by convolving the initial mass function and star formation rate with the metallicity evolution across cosmic time and SEVN, a code to evolve single stars up to $M < 350\, M_\odot$. Under the ansatz that the underlying physics of binary formation does not change beyond the gap, we then construct the cosmic population of merging BH binaries. We found that LIGO/Virgo at design sensitivity will detect between $\simeq [0.4, 7]\, \mathrm{yr}^{-1}$ with both mass components above the gap, considering the most pessimistic and optimistic scenario. Similarly, the expected rate for third generation ground-based detectors, like Einstein Telescope, ranges between $[10, 460]\, \mathrm{yr}^{-1}$. Moreover, at lower frequencies, LISA can individually detect these binaries up to thousands of years from coalescence. The number of multiband events, i.e. merging in less than four years, is expected to be in the range [1, 20]. While ET will detect all these events, LIGO/Virgo is expected to detect $< 50\%$ of them. Finally the undetected systems are expected to contribute to the stochastic background in the LISA band. We estimate that this background may be in principle detected with a signal-to-noise ratio between $\simeq 2.5$ and $\simeq 80$. Our work has been accepted for publication: A. Mangiagli et al., ApJL 883, L27

Detection and parameter estimation for accreting stellar-origin black-hole binaries and their electromagnetic counterpart

Laura Sberna *Perimeter Institute*

Jan 14, 10:30 am, 15 min

Abstract

We study the impact of mass accretion in the evolution of LIGO-like black hole binaries. Based on simulated catalogues of binary populations, we estimate that a fraction of the events will have a detectable imprint of Eddington-level accretion, when detected by LISA or by LISA and ground-based detectors (multiband). Accretion can also induce bias in the binary parameters, such as the masses and the coalescence time. For these events, the sky location is well determined and allows for targeted searches for electromagnetic counterparts, e.g. with the ATHENA mission or SKA.

Tidal Deformability of Black Holes Immersed in Matter

Francisco Duque *GRiT/CENTRA, Instituto Superior Técnico, Universidade de Lisboa*

Jan 14, 10:45 am, 15 min

Abstract

The tidal deformability of compact objects by an external field has a detectable imprint in the gravitational waves emitted by a binary system, which is encoded in the so-called Tidal Love Numbers (TLNs). For a particular theory of gravity, the TLNs depend solely on the object's internal structure and, remarkably, they vanish for black holes in general relativity. This fact has gathered attention recently since a non-zero measurement of the TLNs for a would-be black hole could provide evidence of new physics in the strong-field regime. However, in realistic astrophysical scenarios, a compact object will be surrounded by a non-vacuum environment. It is, therefore, crucial to evaluate if the effect on tidal deformability due to this environmental matter is comparable to the ones characterizing deviations to GR or exotic compact objects (ECOs), such as boson stars, gravastars, and wormholes. In this work, we compute the TLNs for model configurations of black holes immersed in matter and apply our results to astrophysically motivated black hole + accretion disk systems. Our results pose some questions regarding the possibility of testing strong-field gravity using TLNs.

BMS with applications

Béatrice Bonga *Radboud University*

Jan 14, 11:30 am, 45 min

Abstract

This will be an overview talk about the Bondi-Metzner-Sachs group, which is the symmetry group of asymptotically flat spacetimes. After having reviewed its main properties, I will discuss some applications such as the memory effect. Next, I will discuss the BMS algebra in other contexts such as higher dimensions and black hole horizons. The latter is conjectured to be key in solving the information loss paradox. Finally, I will venture beyond asymptotic flatness to include superrotations or a positive cosmological constant.

LISA Data Challenges: Status and future prospects

Nikolaos Karnesis *APC*

Jan 14, 14:15, 45 min

Abstract

The LISA Data Challenges (LDC) where established as a common ground with the aim of engaging the community to the open LISA data analysis questions. Since the first LDC, a lot of experience has been gained, and significant progress has been achieved. In this talk I will review this progress, and I will present the purpose and individual goals of the current LDCs. The status and future prospects will be discussed, and a small tutorial on the software usage will be given as well.

Force-free electrodynamics near rotation axis of a Kerr black hole

Troels Harmark *Niels Bohr Institute*

Jan 14, 15:00, 15 min

Abstract

Despite their potential importance for understanding astrophysical jets, physically realistic exact solutions for magnetospheres around Kerr black holes have not been found, even in the force-free approximation. Instead approximate analytical solutions such as the Blandford-Znajek (split-)monopole, as well as numerical solutions, have been constructed. In this talk we consider a new approach to the analysis and construction of such magnetospheres. We consider force-free electrodynamics close to the rotation axis of a magnetosphere surrounding a Kerr black hole assuming axisymmetry. This is the region where the force-free approximation should work the best, and where the jets are located. We perform a systematic study of the asymptotic region with (split-)monopole, paraboloidal and vertical asymptotic behaviors. Imposing asymptotics similar to a (split-)monopole, we find that demanding regularity at the rotation axis and the event horizon restricts solutions of the stream equation so much that it is not possible for a solution to be continuously connected to the static (split-)monopole around the Schwarzschild black hole in the limit where the rotation goes to zero. This provides independent evidence to the issues discovered with the asymptotics of the Blandford-Znajek (split-)monopole in Ref. [1] from which it follows that its perturbative construction is inconsistent.

Constraints on an Effective Field Theory extension to gravity using gravitational-wave observations

Richard Brito *Sapienza University of Rome*

Jan 14, 15:15, 15 min

Abstract

Gravitational-wave observations of coalescing binary black holes allow for novel tests of the strong-field regime of gravity. Using the detections of the LIGO and Virgo collaborations, we place the first constraints on higher-order curvature corrections that arise in the effective-field-theory extension of general relativity where higher-order powers in the Riemann tensor are included in the gravitational-field action. We construct gravitational-wave templates that describe the quasi-circular inspiral stage in this modified theory of gravity, and use Bayesian-selection methods to constrain this theory with respect to General Relativity. We focus on the two lowest-mass gravitational-wave events observed to date (GW151226 and GW170608), but describe a general strategy for updating constraints with more events.

Rotating black hole in a higher order scalar tensor theory

Christos Charmousis *LPT*

Jan 14, 15:30, 15 min

Abstract

We will discuss an analytic hairy black hole in a subclass of scalar tensor theories.

The sound of DHOST

Antoine Lehébel *University of Nottingham*

Jan 14, 16:15, 15 min

Abstract

In generic higher-order scalar-tensor theories which avoid the Ostrogradsky instability, the presence of a scalar field significantly modifies the propagation of matter perturbations, even in weakly curved backgrounds. This affects notably the speed of sound in the atmosphere of the Earth. It can also generate instabilities in homogeneous media. I will use this to constrain the viable higher-order scalar-tensor models.

Hearing the strength of gravity (with the Sun)

Ippocratis Saltas *CEICO - Czech Academy of Sciences*

Jan 14, 16:30, 15 min

Abstract

Generic extensions of General Relativity aiming to explain dark energy typically introduce fifth forces of gravitational origin. In this talk, I will explain how helioseismic observations can provide a powerful and novel tool towards precision constraints of fifth forces, as predicted by general theories for dark energy, and I will discuss the implications for cosmology.

The IR limit of Horava Gravity

Mario Herrero-Valea *SISSA*

Jan 14, 16:45, 15 min

Abstract

Horava Gravity is a renormalizable theory of Quantum Gravity which is expected to flow to GR in the low energy limit. This naive expectation is obstructed by a strongly coupled interaction when the parameters of the Lagrangian flow to the general relativistic values. However, when closely studied, only self-interactions of the extra scalar mode of the theory are strongly coupled. When matter is coupled to HG, scattering amplitudes naturally flow to the results given by GR. In other words, matter remains weakly coupled and interacting only through Lorentz invariant operators. I will discuss the implications of this behavior for HG as a realistic model of gravitational interactions.

1.2 Wednesday, 15

Multi-messenger signals from merging neutron stars

Francois Foucart *University of New Hampshire*
Jan 15, 09:15, 45 min

Abstract

The first detection of a binary neutron star star system through gravitational waves and electromagnetic signals (gamma-ray burst, kilonova, radio) recently demonstrated the feasibility and usefulness of multi-messenger astronomy. In this talk, I will provide an overview of the physics of neutron star-neutron star and black hole-neutron star mergers, and of what we can learn from gravitational waves and electromagnetic signals powered by these events. I will also discuss uncertainties in existing models of merging neutron stars, and how these uncertainties still place important limits on our ability to reliably extract information from the observation of merging compact objects.

BMS flux-balance equations as constraints on the gravitational radiation

Ali Seraj *ULB, Brussels*
Jan 15, 10:00, 15 min

Abstract

Asymptotically flat spacetimes admit infinite dimensional BMS symmetries which complete the Poincare symmetry algebra with super-translation and super-Lorentz generators. We show that each of these symmetries lead to a flux-balance equation at null infinity, which we compute to all orders in the post-Minkowskian expansion in terms of radiative multipole moments. The ten Poincare flux-balance laws generalize the previously known balance equations to all orders in the post-Minkowskian expansion. The rest of BMS balance laws are novel in the literature and impose infinite number of constraints on the gravitational waveforms. We show that the balance equations for quadrupolar super-translation and super-Lorentz generators give non-trivial constraints at 3PN and 2.5PN order, respectively. Our analysis also confirms the surface charge expression for the angular momentum at null infinity derived previously from the sub-leading soft graviton theorem.

Gauge-invariant approach to the parameterized post-Newtonian formalism

Manuel Hohmann *University of Tartu*

Jan 15, 10:15, 15 min

Abstract

The parameterized post-Newtonian (PPN) formalism is an invaluable tool to assess the viability of gravity theories using a number of constant parameters. These parameters form a bridge between theory and experiment, as they have been measured in various solar system experiments and can be calculated for any given theory of gravity. The practical calculation, however, can become rather cumbersome, if the field equations involve couplings to additional fields. In addition, the PPN formalism relies on the choice of a particular gauge (or coordinate system), which is determined only after solving the field equations. These difficulties can be overcome by applying a gauge invariant formalism, which is conventionally used in cosmological perturbation theory. The particular nature of the PPN formalism requires perturbations of at least quadratic order to be considered, as well as a different treatment of space and time directions. In my talk I show how to develop such kind of formalism for gravity theories in metric and tetrad formulation and give prospects on how to generalize this treatment to higher perturbation orders necessary

for calculating high precision orbital motion.

Modelling black hole binaries in the intermediate-mass-ratio regime.

Mekhi Dhesi *University of Southampton*

Jan 15, 10:30, 15 min

Abstract

We are working to provide accurate modelling of the dynamics and gravitational-wave signatures of black hole inspirals in the intermediate-mass-ratio regime (IMIRIs) (1:100-1:1000). In doing so we hope to bridge the gap between the accurate modelling of extreme-mass-ratio inspirals achieved through black hole perturbation theory, and that of comparable-mass inspirals using numerical relativity. Neither approach works well for IMRIs due to the inability to treat the smaller black hole as a perturbation of the larger and yet disparate length scales remain, preventing computational efficiency in numerical relativity. IMRIs remain an important open problem in the field as such binary systems are not unlikely sources for Advanced LIGO and LISA and their observation would provide us with fundamental insight into black hole formation and astrophysical populations.

Our team at Southampton will work with the numerical relativity group at the Albert Einstein Institute to tackle the problem through a combination of black-hole perturbation and numerical relativistic techniques. This talk will give an overview of a new approach to IMRI modelling: matching an approximate analytic solution near the small black hole to a fully nonlinear numerical solution in the bulk of the spacetime. Preliminary results will be presented from a scalar toy model which tests the implementation of such a matching procedure.

Well-posedness of characteristic formulations of GR

Thanasis Giannakopoulos *Instituto Superior Técnico*

Jan 15, 10:45, 15 min

Abstract

Characteristic formulations of General Relativity (GR) have advantages over more standard spacelike foliations in a number of situations. For instance, the Bondi-Sachs formalism is at the base of codes that aim to produce gravitational waveforms of high accuracy, exploiting the fact that null hypersurfaces reach future null infinity and hence avoid systematic errors of extrapolation techniques. Furthermore, characteristic formulations in asymptotically anti-de Sitter spacetimes are widely used in the field of numerical holography, which can provide insights for the behavior of strongly coupled matter. Well-posedness of the resulting PDE systems, however, remains an open question. The answer to this question affects the accuracy of the results and the reliability of the conclusions drawn from numerical studies based on such formulations. A numerical solution can converge to the continuous one only for well-posed PDE systems. The well-posedness of the initial value problem of such systems is characterized by strong hyperbolicity. We find that the PDE systems arising from the aforementioned formulations are only weakly hyperbolic, due to a shared pathological structure in both the asymptotically flat and anti de-Sitter cases. We present numerical tests that demonstrate this problem at the practical level.

Black holes in Gauss-Bonnet theories – models and stability

Daniela Doneva *University of Tuebingen*

Jan 15, 11:30, 45 min

Abstract

We discuss black holes in Gauss-Bonnet gravity focusing on the case of a massive scalar field as well as nonzero charge. Different forms of the coupling function are examined putting an emphasis on the case of scalarization. The stability of the obtained solutions is also discussed.

The Black Hole Perturbation Toolkit

Niels Warburton *University College Dublin*

Jan 15, 14:15, 45 min

Abstract

As we face the task of modelling small mass-ratio binaries for LISA we, as a community, need to spend more time developing waveform models and less time writing and re-writing codes. Currently there exist multiple, scattered black hole perturbation codes developed by a wide array of individuals or groups over a number of decades. This project brings together some of the core elements of these codes into a Toolkit that can be used by anyone. The Black Hole Perturbation Toolkit, hosted at https://bhptoolkit.org, is a collection of open-source software and data for black hole perturbation theory calculations. In this talk I will overview the motivation for the Toolkit, give examples of the current code and data, show how you can contribute, and discuss

where we plan to take the BHPToolkit in the near future.

Teukolsky formalism for nonlinear Kerr perturbations

Stephen Green *Albert Einstein Institute Potsdam*
Jan 15, 15:00, 15 min

Abstract

We develop a formalism to treat higher order (nonlinear) metric perturbations of the Kerr spacetime in a Teukolsky framework. We first show that solutions to the linearized Einstein equation with nonvanishing stress tensor can be decomposed into a pure gauge part plus a zero mode (infinitesimal perturbation of the mass and spin) plus a perturbation arising from a certain scalar (”Debye-Hertz”) potential, plus a so-called ”corrector tensor.” The scalar potential is a solution to the spin -2 Teukolsky equation with a source. This source, as well as the tetrad components of the corrector tensor, are obtained by solving certain decoupled ordinary differential equations involving the stress tensor. As we show, solving these ordinary differential equations reduces simply to integrations in the coordinate r in outgoing Kerr-Newman coordinates, so in this sense, the problem is reduced to the Teukolsky equation with source, which can be treated by a separation of variables ansatz. Since higher order perturbations are subject to a linearized Einstein equation with a stress tensor obtained from the lower order perturbations, our method also applies iteratively to the higher order metric perturbations, and could thus be used to analyze the nonlinear coupling of perturbations in the near-extremal Kerr spacetime, where weakly turbulent behavior has been conjectured to occur. Our method could also be applied to the study of perturbations generated by a pointlike body traveling on a timelike geodesic in Kerr, which is relevant to the extreme mass ratio inspiral problem.

Eikonal QNMs of black holes beyond GR

Kostas Glampedakis *University of Murcia*
Jan 15, 15:15, 15 min

Abstract

In this talk we study the quasi-normal modes of spherically symmetric black holes in modified theories of gravity, allowing for couplings between the tensorial and scalar field degrees of freedom. Using the eikonal approximation and a largely theory-agnostic approach, we obtain

analytical results for the fundamental mode of such black holes.

On black hole spectroscopy using overtones

Swetha Bhagwat *La Sapienza University*

Jan 15, 15:30, 15 min

Abstract

Validating the no-hair theorem with a gravitational wave observation from a compact binary coalescence presents a compelling argument that the remnant object is indeed a black hole described by the classical general theory of relativity. Validating this theorem relies on performing a spectroscopic analysis of the post-merger signal and recovering the frequencies of either different angular modes or overtones (of the same angular mode). For an equal mass binary black hole systems, the angular modes apart from $l = m = 2$ are not adequately excited but the overtones provide a prospect to perform this test. We discuss some challenges associated with performing as well as interpreting the results of the tests performed using black hole overtones. We investigate the robustness of modelling the post-merger signal of binary black hole coalescence as a superposition of overtones as well as study the bias expected in recovered frequencies as a function of the start time of the analysis. We provide a computationally cheap procedure to pick an optimal time to start the spectroscopic analysis of post-merger signal. Further, we find that resolving the frequencies of the overtones can be particularly challenging and requires high ringdown SNRs; for instance, the Rayleigh resolvability criterion suggests that for an event like GW150914, an SNR ~ 200 is necessary to resolve the overtone frequencies.

Spontaneous scalarization in generalised scalar-tensor theory

Nikolas Andreou *University of Nottingham*

Jan 15, 16:15, 15 min

Abstract

Spontaneous scalarization is a mechanism that endows relativistic stars and black holes with a nontrivial configuration only when their spacetime curvature exceeds some threshold. The standard way to trigger spontaneous scalarization is via a tachyonic instability at the linear level, which is eventually quenched due to the effect of non-linear terms. At this work (Phys. Rev. D 99, 124022 (2019) and arXiv:1904.06365) we identify all of the terms in the Horndeski action that contribute to the (effective) mass term in the linearized equations and, hence, can cause or contribute to the tachyonic instability that triggers scalarization. We acknowledge networking support by the COST Action GWverse Grant No. CA16104.

Numerical investigation of superradiant instabilities

Alexandru Dima *SISSA*

Jan 15, 16:30, 15 min

Abstract

We present a numerical investigation of the superradiant instability in spinning black holes surrounded by a plasma with density increasing when moving closer to the black hole. We try to understand whether superradiant instabilities are relevant or not for astrophysical black-holes surrounded by matter.

Causal structure of black holes in generalized scalar-tensor theories

Nicola Franchini *SISSA*

Jan 15, 16:45, 15 min

Abstract

A modified causal structure of black holes in theories beyond general relativity might have implications for the stability of such solutions. In this talk, we explore the horizon structure of black holes as perceived by scalar fields for generalized scalar-tensor theories, which exhibit derivative self-interactions. This means that the propagation of perturbations on nontrivial field configurations can be superluminal and that the matter fields and gravitational perturbations do not necessarily experience the same causal structure. Upon linearization, and imposing stationarity of the metric and of the scalar field, we prove that Killing horizons of the background metric are always Killing horizons of the effective metric as well.

1.3 Thursday, 16

Testing the no-hair theorem with LIGO and Virgo

Maximiliano Isi *MIT*

Jan 16, 09:15, 45 min

Abstract

Gravitational waves may allow us to experimentally probe the structure of black holes, with important implications for fundamental physics. One of the most promising ways to do so is by studying the spectrum of quasinormal modes emitted by the remnant from a binary black hole merger. This program, known as black hole spectroscopy, could allow us to test general relativity and the nature of black holes, including the no-hair theorem—the statement that astrophysical black holes are fully described by their mass and spin according to the Kerr metric. I will discuss the prospects for carrying this out with existing ground-based detectors by relying on the shortest-lived tones of the dominant quadrupolar mode (aka 'overtones'), as well as our recent results from the analysis of GW150914.

Coalescence of Exotic Compact Objects

Miguel Bezares *SISSA*

Jan 16, 10:00, 15 min

Abstract

The direct detection of gravitational waves (GWs) by the LIGO and VIRGO interferometric detectors has begun a new era of GW astronomy, allowing us to study the strong regime of gravity through GW signals produced by coalescence of compact objects. In this talk, I will present our numerical studies on coalescence of binary Exotic Compact Objects (ECOs) performed by solving the Einstein equations with different types of exotic matter: boson stars, dark boson stars and Neutron Stars that contain a small fraction of dark matter particles clustered inside. These binaries lead to different dynamics and gravitational waves emission during their coalescence,

which might be crucial to distinguish them with current/future LIGO and Virgo observations.

Quantum gravity predictions for black hole interior geometry

Daniele Pranzetti *Perimeter Institute*
Jan 16, 10:15, 15 min

Abstract

In this talk I will show how to derive an effective Hamiltonian constraint for the Schwarzschild geometry starting from the full loop quantum gravity Hamiltonian constraint and computing its expectation value on coherent states sharply peaked around a spherically symmetric geometry. I then use this effective Hamiltonian to study the interior region of a Schwarzschild black hole, where a homogeneous foliation is available. I show how, for several geometrically and physically well motivated choices of coherent states, the classical black hole singularity is replaced by a homogeneous expanding Universe. The resultant geometries have no significant deviations from the classical Schwarzschild geometry in the pre-bounce sub-Planckian curvature regime, evidencing the fact that large quantum effects are avoided in these models. In all cases, we find no evidence of a white hole horizon formation. However, various aspects of the post-bounce effective geometry depend on the choice of quantum states and, in particular, to the numerical value of the Immirzi parameter.

Post merger signal from black hole mimickers

Alexandre Toubiana *APC/IAP*
Jan 16, 10:30, 15 min

Abstract

Black holes mimickers, e.g. neutron stars or boson stars, are compact objects with similar properties to black holes. The gravitational wave signal emitted by a binary of such putative objects during the inspiral phase is difficult to distinguish from the one emitted by a black hole binary. Nevertheless, significant differences might appear in the post merger signal. Inspired by the known behavior of black holes, neutron stars and boson stars we propose a toy model that captures potential characteristics of such systems composed by such mimickers. This model can be exploited to assess how well such signal could be recovered with gravitational waves observations from earth based detectors using standard templates. By analyzing the residuals,

i.e. the difference between the injected signal and the best fit template, one can also develop strategies to extract the new physics described by these new signals.

Importance of the tidal heating in binary coalescence

Sayak Datta *IUCAA*

Jan 16, 10:45, 15 min

Abstract

With the observation of the multiple binary inspirals, we begin to question whether the components of the binary are black holes or some exotic compact objects (ECO). The black holeness or the deviation from it can be tested in several ways. The distinguishing feature of a black hole from other exotic compact objects is the presence of the horizon. This surface acts as a one-way membrane, that absorbs energy. Due to this different behavior from ECOs in the late stages of an inspiral black holes exchange energy, these backreact on the orbit, transferring energy and angular momentum from their spin into the orbit. This effect is called tidal heating. In Phys.Rev. D99 (2019) no.8, 084001 we argued that the tidal heating can be used as a test for the presence of the horizon, and for that, we introduced horizon parameter (H). Using H we showed that in LISA, presence or absence of the horizon can be tested accurately as well as precisely. In arXiv:1910.07841 we compute the orbital dephasing and the gravitational-wave signal emitted by a point particle in circular, equatorial motion around a spinning supermassive object to the leading order in the mass ratio. We showed that the absence of absorption by the central object can affect the gravitational-wave signal dramatically, especially at high spin. As result it allows us to put an unparalleled upper bound on the reflectivity of exotic compact objects, at the level of O(0.01)%. This can be used even in near equal mass binaries to search for the horizon.

The first image of a black hole

Luciano Rezzolla *Institute for Theoretical Physics*

Jan 16, 11:30, 45 min

Abstract

I will briefly discuss how the first image of a black hole was obtained by the EHT collaboration. In particular, I will describe the theoretical aspects that have allowed us to model the dynamics of the plasma accreting onto the black hole and how such dynamics was used to generate synthetic

black-hole images. I will also illustrate how the comparison between the theoretical images and the observations has allowed us to deduce the presence of a black hole in M87 and to extract information about its properties. Finally, I will describe the lessons we have learned about strong-field gravity and alternatives to black holes.

A VISual approach to science communication

Marcos Valdes *Scuola Normale Superiore*
Jan 16, 16:15, 45 min

2 Posters

Quantum constitutive equations for finite temperature Dirac fermions under rotation

Victor E. Ambrus *West University of Timisoara*

Abstract

The experimental confirmation of the polarization of the Lambda hyperons observed in relativistic heavy ion collisions experiments [1] has renewed the interest in anomalous transport of fermions due to the spin-orbit coupling (e.g., through the chiral vortical effect [2]). Using a non-perturbative technique [3], exact expressions are derived for the thermal expectation values of the stress-energy tensor, charge current and (anomalous) axial current for the case of massless rigidly-rotating fermions at finite chemical potential [4]. Compared to the relativistic kinetic theory analogue, the quantum corrections are expressed as constitutive equations in terms of local kinematic quantities, such as the vorticity and acceleration.

References: [1] STAR collaboration, Nature 548 (2017) 62. [2] D. E. Kharzeev, J. Liao, S. A. Voloshin, G. Wang, Prog. Part. Nucl. Phys. 88 (2016) 1. [3] V. E. Ambrus, E. Winstanley, Phys. Lett. B 734 (2014) 296. [4] V. E. Ambrus, E. Winstanley, arXiv:1908.10244 [hep-th].

Kicking Q-balls and boson stars: stimulated emission of radiation by confined structures

Lorenzo Annulli *CENTRA - IST*

Abstract

Scalar fields can give rise to confined structures, such as Q-balls or boson tars, which can serve as interesting models for cold dark-matter. The existence and stability of objects in a given theory is relevant for a wide range of topics, from planetary science to a description of fundamental particles. Taking as starting point a theory describing a time-dependent scalar field, in this talk, I study two different theories, yielding localized objects with a static energy-density profile, but where the scalar is time-periodic. The first theory describes a nonlinearly-interacting scalar in flat space, yielding solutions known as Q-balls, non-topological solitons which arise in a large family of field theories admitting a conserved charge Q, associated with some continuous internal symmetry. The second theory add the gravitational interaction to the picture, the resulting objects are known as boson stars. As a starting point, I build thin- and thick-wall Q-balls and Newtonian boson stars, and compute their proper oscillation modes. Moreover, I would like to show the dynamical behaviour and the emission of radiation from these objects when excited by external matter in their vicinities. Particularly, I compute energy fluxes, total radiated energy and linear momentum during this process.

The study of the dynamics of such objects is interesting for a number of reasons. As dark matter candidates, it is important to understand the stability of such configurations, and the way they interact with surrounding bodies (stars, black holes etc). For example, when a star crosses one of these objects, it may change the local properties to the extent that the configuration simply collapses or disperses. It is also important to quantify the gravitational drag that bodies are subjected to when immersed in scalar structures.

Novel Wormhole Solutions in Einstein-Scalar-Gauss-Bonnet Theories

Georgios Antoniou *University of Nottingham*

Abstract

Novel wormholes are obtained in Einstein-scalar-Gauss-Bonnet theory for several coupling functions. The wormholes may feature a single-throat or a double-throat geometry. The scalar field may asymptotically vanish or be finite, and it may possess radial excitations. The domain of existence is fully mapped out for several forms of the coupling function.

Smarr formulas for Einstein-Maxwell-dilaton stationary spacetimes with line singularities

Igor Bogush *Lomonosov Moscow State University*

Abstract

We generalize the recent derivation http://arxiv.org/abs/arXiv:1908.10617 of the Smarr formulas for Einstein-Maxwell stationary axisymmetric asymptotically locally flat spacetimes with line singularities to the Einstein-Maxwell-dilaton (EMD) theory with an arbitrary dilaton coupling constant. The line singularities include the Dirac and Misner strings for spacetimes with magnetic and NUT charges. Multiple black holes sitting on the symmetry axis and joined by struts are also included. Both the horizons and the line singularities are described as rods in Weyl coordinates and they are treated in a similar way. The derivation is based on Tomimatsu's approach to express the Komar integrals as the integrals over the symmetry axis and is directly applicable to rotating spacetimes. It is shown that the dilaton does not contribute to the bulk mass and angular momentum, while the dilaton exponents before Maxwell terms mutually cancel in the integrals over the rods, so the final Smarr relations preserve their form in the Einstein-Maxwell theory. They hold for each rod separately. In the case of Misner and Dirac string, they connect the mass, the angular momentum and the area of the string and include a spacelike analogue of the surface gravity. We apply this formalism to new rotating EMD black holes endowed with both electric and magnetic charges and the NUT charge. Thermodynamical interpretation is discussed.

A Bifocal Coordinate System in General Relativity

Nikolaos Chatzarakis *Aristotle University of Thessaloniki*

Abstract

Following the generalised form of non-stationary axisymmetric space-time (Chandrasekhar 1983), we assume a bifocale elliptic symmetry and attempt to show that this particular metric can be a solution to Einstein's field equations. We discuss the form of the metric and the curvature implied, as well as its possible physical meaning and applications.

A covariant simultaneous action for branes

Giovany Cruz *CINVESTAV*

Abstract

A covariant simultaneous action for branes in an arbitrary curved background spacetime is considered. The term 'simultaneous' is imported from variational calculus and refers to the fact that extremization of the action produces at once both the

first and second variation of a given geometrical action for the brane. The action depends on a pair of independent field variables, the brane embedding functions, through the canonical momentum of a reparametrization invariant geometric model for the brane, and an auxiliary vector field. The form of the action is analogous to a symplectic potential. Extremization of the simultaneous action produces at once the equations of motion and the Jacobi equations for the brane geometric model, and it also provides a convenient shortcut towards its second variation. In this note, we consider geometric models depending only on the intrinsic geometry of the brane worldvolume, and discuss briefly the generalization to extrinsic geometry dependent models. The approach is illustrated for Dirac-Nambu- Goto [DNG] branes. For a relativistic particle, a simultaneous action was introduced by Bazanski, that served as an inspiration for

the present work.

Gravity-induced quantum anomalies through gravitational wave polarization

Adrian del Rio Vega *Instituto Superior Tecnico - Universidade de Lisboa*

Abstract

Axial-type anomalies predicted by quantum field theory in curved spacetime are determined by the Chern-Pontryagin invariant of the spacetime background. I will show that this geometric quantity is non-zero in spacetimes admitting gravitational radiation that propagates to future null infinity with an excess of one polarization mode over the other. I will further argue that typical scenarios where this gravitational asymmetry occurs include mergers of precessing binary black holes or in head-on collisions of black holes with misaligned spins, since these systems are not even under parity transformations. Some applications in the context of the electric-magnetic duality anomaly will be discussed.

Strong cosmic censorship in charged black holes with a positive cosmological constant

Kyriakos Destounis *University of Tübingen*

Abstract

”The strong cosmic censorship conjecture has recently regained a lot of attention in charged and rotating black holes immersed in de Sitter space. Such spacetimes possess Cauchy horizons in the internal region of the black hole. The stability of Cauchy horizons is intrinsically connected to the decay of small perturbations exterior to the event horizon. As such, the validity of strong cosmic censorship is tied to how effectively the exterior damps fluctuations.

Recent studies have shown that charged cosmological black holes, such as the Reissner-Nordstr”om-de Sitter solution, appear to be serious counter-examples of strong cosmic censorship. In this talk, we will present the first consistent test of strong cosmic censorship in Reissner-Nordstr”om-de Sitter black holes under minimally coupled scalar-field fluctuations and conclude that the conjecture is violated for near-extremal black-hole charges.

We will also present another test to the conjecture by utilizing a scalar field fluctuation non-minimally coupled to the Einstein tensor propagating on Reissner-Nordstr”om-de Sitter black

holes. Such non-minimal derivative coupling is characteristic of Horndeski scalar-tensor theories. Although the introduction of higher-order derivative terms in the energy-momentum tensor increases the regularity requirements for the stability of the Cauchy horizon, we are still able to find a small, but finite, region in the black hole's parameter space where strong cosmic censorship is violated.

The talk will be based on:

1. V. Cardoso, J. L. Costa, K. Destounis, P. Hintz and A. Jansen, ""Quasinormal modes and Strong Cosmic Censorship"", [Phys. Rev. Lett. 120, no. 3, 031103 (2018)],[1711.10502],

2. K. Destounis, R. D. B. Fontana, F. C. Mena and E. Papantonopoulos, ""Strong Cosmic Censorship in Horndeski Theory"", [JHEP 10 (2019) 280],[1908.09842].

Gravitational waves in Teleparallel theories of gravity

Viktor Gakis *National and Technical University of Athens and University of Malta*

Abstract

The Teleparallel equivalent of General Relativity, where the connection is curvatureless, offers an alternative but equivalent way of describing gravity. In accordance to GR-based modified theories such as $f(R)$ there are also torsion or non-metricity teleparallel modifications like $f(T)$, where T the torsion scalar and $f(Q)$, where Q is the non-metricity scalar both of them playing a role analogous to the curvature scalar R. In principle GR-based modifications and Teleparallel-based ones are not equivalent theories. In this talk we will present a gravitational wave analysis of some prominent Teleparallel Modified theories and how they differ from GR and $f(R)$ gravities and how they are constrained after GW170817. The talk will be based on 10.1103/PhysRevD.97.124064, 10.1103/PhysRevD.100.044008 and arXiv:1907.10057.

Duality of conformally and kinetically coupled scalar-tensor theories

Dmitry Gal'tsov *Moscow state University*

Abstract

We show that the non-minimal conformally-coupled (CC) scalar-tensor theory and the Palatini theory with kinetic coupling of the scalar to the Ricci tensor (PKC) are the same. This is demonstrated by showing that both theories coincide in the Einstein frame. Using this duality as generating technique, we construct the PKC counterpart to the BBMB black hole of the CC theory. It turns out to be not a black hole, but a regular solution. So, in a sense, the regulating property of PKC is stronger that that of CC. We also construct dual cosmological solutions to these theories. Both begin cosmological expansion from Minkowski space. The indicated duality extends to all values of the coupling constant of the first theory, as well as to the theory with an arbitrary function of the scalar and the scalar curvature without derivatives.

Rotating Solitonic Vacuum in TMST

Lucas Gardai Collodel *Tübingen University*

Abstract

In the context of a special class of tensor-multi-scalar theories of gravity for which the target-space metric admits as a Killing field a generator of a one-parameter group of point transformations under which the theory is invariant, we present rotating vacuum solutions, namely with no matter fields. These objects behave like nontopological solitons, whose primary stability is due to the conserved charge arising from the global symmetry. We consider theories with two and three scalar fields, different Gauss curvatures and quartic interaction coefficients. As it occurs for boson stars, their angular momentum is quantized. Ergoregions appear for compact enough solutions in the two scalars theory but are absent in the three scalars case for the two first nonzero winding numbers.

The Ultra-relativistic Expansion of General Relativity

Dennis Hansen *ETH Zürich*

Abstract

In this talk I will discuss the ultra-relativistic expansion of general relativity. The ultra-relativistic expansion in the speed of light captures very strong gravitational field effects and extreme astrophysical phenomena in a simplifying setting compared to full GR. Surprisingly it also turns out that the ultra-relativistic expansion is closely related to the non-relativistic expansion, which will be elaborated on. Based on upcoming work arXiv:20XX.YYYY.

Tidal effect on scalar cloud:numerical simulations

Taishi Ikeda *Instituto Superior Tecnico*

Abstract

Axion and axion-like particle are the candidates of the dark matter. Due to the super-radiant instability, these fields are amplified, and can localize around Kerr BH, as axion clouds. Since the axion clouds emit gravitational waves, it is important to analyze several properties of the axion cloud around BHs. Here, we study the axion cloud around binary BH (BBH). The axion cloud around a BH of BBH feels a tidal force due to the companion BH, and the force changes the time evolution of the cloud. Here, using numerical simulation, we discuss the time evolution of the axion cloud under the tidal force.

Time-domain metric reconstruction using the Hertz potential

Oliver Long *University of Southampton*

Abstract

Historically the Teukolsky equation corresponding to gravitational perturbations is solved for the Weyl scalars. However, reconstructing the metric from these scalars involves solving a fourth order PDE to obtain the Hertz potential and then another second order PDE to construct the metric perturbation. Solving the (adjoint) Teukolsky equation for the Hertz potential directly simplifies the metric reconstructions procedure to just one second order PDE. We discuss using this method in the time domain with a point particle source and its foreseeable application in self-force calculations.

Holographic Bound on Remnant Boundary Area of Black Hole Merger

Partha Sarathi Majumdar *School of Physical Sciences, Indian Association for the Cultivation of Science*

Abstract

Using concomitantly the Generalized Second Law of black hole thermodynamics and the holo-

graphic Bekenstein entropy bound embellished by Loop Quantum Gravity corrections to quantum black hole entropy, we show that the boundary area of the remnant from the binary black hole merger in GW150914 is bounded from below. This lower bound is more general than the bound from application of Hawking's classical area theorem for black holes, since it does not depend on whether the remnant is a black hole or some other more exotic compact object.

Thermally Quasi-stable Radiant Black Holes

Partha Sarathi Majumdar *School of Physical Sciences, Indian Association for the Cultivation of Science*

Abstract

We use loop quantum gravity inspired holographic thermal stability criteria to establish the existence of regions in parameter space of charged rotating black holes away from extremality, where partial fulfillment of the stability criteria is possible. Physical implications of our results will be discussed.

A parametrized ringdown approach for black-hole spectroscopy of spinning black holes

Andrea Maselli *Sapienza University of Rome*

Abstract

Black-hole spectroscopy is arguably the most promising tool to test gravity in extreme regimes and to probe the ultimate nature of black holes with unparalleled precision. These tests are currently limited by the lack of a ringdown parametrization that is both robust and accurate. We develop an observable-based parametrization of the ringdown of spinning black holes beyond general relativity, which is perturbative in the spin, but it can be made arbitrarily precise through a high-order expansion. It requires $\mathcal{O}(10)$ ringdown detections, which should be routinely available with the planned space mission LISA and with third-generation ground-based detectors. In this talk I will present a preliminary analysis of the projected bounds on parametrized ringdown parameters with LISA and with the Einstein Telescope, and discuss extensions of our model that can be straightforwardly included in the future.

Rotating and non rotating, non singular compact objects

Anupam Mazumdar *University of Groningen*

Abstract

I will discuss the physics of non singular compact objects which is primrily made up of gravitons, and it is as compact as that of the Buchdahl star. I will discuss how to construct such a system within higher derivative theories of gravity which incorporates nonlocal effects at the level of gravitational ingeractions. I will construct in fact both static and rotating solutions in this regard and discuss various observational consequences.

New frontiers in cosmology using gravitational waves

Suvodip Mukherjee *IAP/GRAPPA*

Abstract

Cosmic microwave background and large scale structure missions have played a crucial role in constructing the standard model of cosmology. The upcoming missions in astrophysics and cosmology are going to explore the Universe over a wide range of redshifts using both electromagnetic waves and gravitational waves. I will introduce a few new frontiers in cosmology which will open-up from the gravitational wave missions and which will be capable to probe a broad range of topics in fundamental physics. In the first part of my talk, I will discuss the provision of precision measurement of Hubble constant using gravitational wave sources with or without electromagnetic counterpart by exploiting the spatial correlation of the astrophysical gravitational wave sources with the galaxy distribution. In the latter part of my talk, I will discuss the imprints of cosmological density field on the strain of the astrophysical gravitational waves and will introduce new cross-correlation techniques between electromagnetic sector and gravitational wave sector to measure the imprints of cosmological perturbations from the upcoming missions. These new techniques are going to open an era of multi-messenger cosmology and will open a discovery space to understand the theory of gravity, nature dark energy and the properties of dark matter in a unique way which was not possible until now.

Formation and Abundance of Primordial Black Holes

Ilia Musco *ICC, University of Barcelona / University of Geneva*

Abstract

Primordial black holes can form in the early Universe from the collapse of cosmological perturbations after the cosmological horizon crossing. They are possible candidates for the dark matter as well as for the seeds of supermassive black holes observed today in the centre of galaxies. If the perturbation is larger than a certain threshold, depending on the equation of state and on the specific shape of the perturbation, a black hole is formed. In this talk I will discuss the dependence of PBH formation from the initial shape of the curvature profile showing the relation between the threshold amplitude and the initial shape of the inflationary power spectrum of cosmological perturbations, taking into account also possible primordial non-Gaussianity. Although the abundance of PBHs could vary by several order of magnitudes depending on the model of inflation, it looks that the threshold of PBH formation is rather solid against non linearities.

Probing black holes with X-rays and gravitational waves

Sourabh Nampalliwar *Eberhard Karls University of Tuebingen*

Abstract

Einstein's theory has been the standard theory of gravity for nearly a century. Alternatives to and extensions of it have been proposed to address various issues. With advances in technology, these theories are becoming testable, especially in the strong field regime around black holes. In this talk, I will describe a theory agnostic approach to probe the nature of black holes. I will provide the latest constraints obtained with X-rays (e.g., using XMM-Newton, NuSTAR) and gravitational waves (e.g., using LIGO).

Beyond the Post-Newtonian expansion using Non-relativistic Gravity

Niels Obers *Nordita and Niels Bohr Institute*

Abstract

I will discuss an action principle for non-relativistic gravity, as has recently been obtained from a covariant large speed of light expansion of Einstein's theory of gravity. This action reproduces Newtonian gravity as a special case, but goes beyond it by allowing for gravitational time dilation while retaining a non-relativistic causal structure. As a consequence, it can be shown that the three classical tests of general relativity (perihelion precession, deflection of light and gravitational redshift) are passed perfectly by this extension of Newtonian gravity. I will present the underlying symmetry principle of the action as well as the extension to any order in the 1/c expansion of GR. Finally I will comment on the relation to the PN expansion and discuss how this novel expansion may be useful in astrophysical settings.

Total probability for fermion pair production in external fields on de Sitter space-time

Diana-Cristiana Popescu *The West University of Timisoara*

Abstract

We are illustrating a procedure for computing the total probabilities corresponding to the processes of fermion pair production in electric fields and in the field of a magnetic dipole on de Sitter space-time. The total probabilities are preserving the dependence on the expansion parameter, proving the fact that the results are consistent with the ones obtained for probability densities. The number of fermions is also obtained in terms of the expansion parameter.

Wormholes in R^2-gravity

Pradyumn Sahoo *Birla Institute of Technology and Science-Pilani, Hyderabad Campus*

Abstract

We propose, as a novelty in the literature, the modelling of wormholes within the particular case of the $f(R,T)$ gravity, namely $f(R,T) = R + \alpha R^2 + \lambda T$, with R and T being the Ricci scalar and trace of the energy-momentum tensor, respectively, while α and λ are constants. Although such a functional form application can be found in the literature, those concern to compact astrophysical objects, such that no wormhole analysis has been done so far. The quadratic geometric and linear material corrections of this theory make the matter content of the wormhole to remarkably be able to obey the energy conditions.

Stationary vector clouds around Kerr black holes

Nuno M. Santos *CENTRA, Instituto Superior Técnico, University of Lisbon*

Abstract

Kerr black holes are known to support massive bosonic test fields whose phase angular velocity fulfills the synchronization condition, i.e. the threshold of superradiance. The presence of these real-frequency bound states at the linear level, commonly dubbed stationary clouds, is intimately linked to existence of Kerr black holes with bosonic hair at the non-linear level. These configurations are very similar to the atomic orbitals of the electron in a hydrogen atom. In fact, they are finite on and outside the black hole's event horizon, decay exponentially at spatial infinity and can be labeled by four quantum numbers: n, the number of nodes of the radial function; l, the orbital angular momentum; j, the total angular momentum; and m, the projection of the total angular momentum along the black hole's axis of rotation. The existence of stationary test-field configurations is only allowed for specific values of the black hole's mass M and angular momentum per unit mass a. Such quantization follows from the regularity of the bound states and results in an existence line in the two-dimensional Kerr parameter space defined by (M, a). While the phenomenology of stationary scalar clouds has been widely addressed in the literature over the last years, little is known about the physical properties of their vector counterparts. Following the recent demonstration of the separability of the Proca equation in Kerr spacetime, we compute the existence lines of such stationary vector clouds in a (M, a) diagram for Kerr black holes and compare them with those of stationary scalar clouds, discussing the role played by the intrinsic angular momentum.

Signatures of Unimodular Gravity

Raquel Santos Garcia

Abstract

Unimodular Gravity is an infrared modification of General Relativity where the cosmological constant is replaced by an integration constant, thus free from radiative corrections and effectively solving one piece of the cosmological constant problem. Apart from this, both theories enjoy the same classical dynamics, dictated by Einstein equations, and they were thought to be equivalent for any other matter. We show that, contrary to this common lore, Unimodular Gravity and General Relativity are two different gravitational theories once loop corrections are taken into account. Due to the presence of different gauge groups, gravitons run inside loop corrections in a different manner. We show this phenomenon in a simple example and discuss

its possible consequences.

Physics Beyond General Relativity: Theoretical and Observational Constraints.

Sudipta Sarkar *IIT Gandhinagar*

Abstract

The study of the effects of higher curvature terms is a major research theme of contemporary gravitational physics. In this talk, I will present a comprehensive study of the higher curvature gravity and various observational and theoretical constraints. The inclusion of these terms leads to exciting new possibilities, e.g., gravitational and electromagnetic perturbations following different geodesics; leading to a time delay. Such a time delay was observed between the gravitational wave event GW170817 and its electromagnetic counterpart GRB 170817A. I describe how this effect can be used to constrain the coupling of the higher curvature term.

Formation and evolution of the first Supermassive Black Hole Seeds

Federica Sassano *Sapienza University of Rome*

Abstract

In the last decade, many observations of bright quasars at $z > 5$, have revealed the existence of Supermassive Black Holes (SMBHs), giants of billion solar masses shining close to their Eddington limit. The mechanism of their formation at these early epochs represents currently an open problem in galaxy evolution. Several scenarios have been proposed to overcome this problem, such as the Super-Eddington accretion onto stellar Black Hole seeds, with typical masses of $100 M_{\odot}$, or the existence of more massive seeds, such as the Direct Collapse Black Holes with masses picked around $10^5 M_{\odot}$. Intermediate mass black holes forming from the runaway collapse into dense stellar cluster, with mass of $\sim 10^3 M_{\odot}$, actually represent another potential solution. Following the early growth and coalescence of BH seeds in cosmological simulations, I will discuss the formation sites of these seeds and their relative contribution to the formation of the central Black Hole mass. The resulting theoretical predictions constrain the detectability of gravitational wave signals produced by binary BH seeds mergers with future third generation gravitational telescopes, such as the Einstein telescope and the Laser Interferometer Space Antenna (LISA).

GWxLSS: chasing the progenitors of merging binary black holes.

Giulio Scelfo *SISSA, INFN, IFPU*

Abstract

Cross-correlations between galaxy catalogs and gravitational wave maps can provide useful information regarding open questions in both cosmology and astrophysics. The detection of binary black hole mergers through gravitational waves by the LIGO-Virgo instrument sparked the discussion on whether they have astrophysical or primordial origin. According to a model whose popularity revived after the first gravitational waves detections, primordial black holes of stellar mass could constitute a fraction of the dark matter. The possibility to infer the nature of the binary black hole progenitors can be studied through GWxLSS cross-correlations, whose formalism can be applied in several contexts.

Continuation of Schwarzschild exterior without a black hole in first order gravity

Sandipan Sengupta *Indian Institute of Technology Kharagpur*

Abstract

We present a smooth extension of the Schwarzschild exterior geometry, where the singular interior is superceded by a vacuum phase with vanishing metric determinant. Unlike the Kruskal-Szekeres continuation, this explicit solution to the first-order field equations in vacuum has no singularity in the curvature two-form fields, no horizon and no global time. The underlying non-analytic structure provides a distinct geometric realization of 'mass' in classical gravity. We also find that the negative mass Schwarzschild solution does not admit a similar extension within the first-order theory. This is consistent with the general expectation that degenerate metric solutions associated with the Hilbert-Palatini Lagrangian formulation should satisfy the energy conditions.

Searching tidally disrupted white dwarfs to find intermediate mass black holes

Martina Toscani *Università Degli Studi di Milano*

Abstract

My poster is focused on two topics. The main one is related to intermediate mass black holes (IMBHs). Some recent observations suggest that IMBHs exist in our Universe. Yet, none of them has been confirmed so far. A possible way to prove the existence of these elusive objects can be the study of tidal disruption events of white dwarfs (WDs). Indeed, if a WD wanders too close to an IMBH, it gets tidally disrupted, producing a gravitational wave (GW) burst with a frequency around the decihertz. Anyway, this signal is not very strong and decreases quickly with distance, so it is unlikely that the future space interferometers will be able to detect it. For this reason, it is more significant to study the GW background associated to this type of source, taking into account that the natural environment for these holes are globular clusters and, since there are many globular clusters per galaxy, we expect many sources of this type through all the Universe. We derive this background for different values of the parameters involved in the problem and we compare our estimates with the sensitivity curves of the decihertz interferometers LISA, TianQin, ALIA and DECIGO. The second part of my poster instead will describe GR-PHANTOM, a 3D general relativistic smoothed particle hydrodynamics code, where I have implemented a feature for the calculation of the gravitational wave signal emitted by a source. Thus, this code could be an useful tool to study astrophysical events that produce both electromagnetic and gravitational signals.

General Relativistic Study of the Structure of Highly Magnetized Neutron Stars

Orlenys Troconis *International Centre for Theoretical Physics (ICTP-Trieste)*

Abstract

Neutron stars are one of the most compact and densest astrophysical objects known in nature, they result from the supernova explosion of a massive star. Many of the neutron stars have very strong magnetic fields, which lead to the emission of radio and X-ray radiation. This work is devoted to study the effects of strong magnetic fields in the structure of neutron stars, within the framework of the general relativity theory. We study the formal aspects of the magnetic field in the stellar structure and gravitational equations using two different approaches, which allow us to introduce new quantities and their possible physical interpretation. By other hand, we study the theoretical formalism describing rotating and highly magnetized neutron stars within the context of Einstein-Maxwell's equations. Specifically, for magnetized neutron stars, we study poloidal magnetic fields and static configurations. We discuss about the relevant physical quantities describing these objects and the contribution of the electromagnetic energy to the total gravitational mass. we found the spacetime describing rotating and magnetized neutron stars, the distribution of the different terms that contribute to the total gravitational

mass and the mass-radius relation. The results show that for stars with magnetic fields $\sim 10^{18}\,G$ the electromagnetic effects increase the mass in 10.1% with respect to the configuration without magnetic field. The studies performed in this work are key for the understanding the astrophysical objects known as a Soft-Gamma Ray Repeaters and Anomalous X-Ray Pulsars, which are understood as being one class of neutron stars called as magnetars.

Dilatonic black holes and the weak gravity conjecture

Kunihito Uzawa *Kwansei Gakuin University*

Abstract

We discuss the weak gravity conjecture (WGC) from black hole entropy in the Einstein-Maxwell-dilaton system or string theory. The WGC is strongly motivated by theorems forbidding global symmetries which arise in the vanishing-charge limit, and implies the fact that not only all non-BPS black holes but also extremal one without supersymmetry should be able to decay. It is shown that the large extremal black holes are unstable to decay to smaller extremal ones in the Einstein-Maxwell theory at least. We would demonstrate whether the WGC is satisfied or not in the string theory by computing corrections to the Bekenstein-Hawking entropy of a dilatonic black hole.

Moving black holes: energy extraction, absorption cross-section and the ring of fire

Rodrigo Vicente *CENTRA - IST*

Abstract

We consider the interaction between a plane wave and a (counter-moving) black hole. We show that energy is transferred from the black hole to the wave, giving rise to a *negative* absorption cross-section. Moving black holes absorb radiation *and* deposit energy in external radiation. Due to this effect, a black hole hole of mass M moving at relativistic speeds in a cold medium will appear to be surrounded by a bright ”ring” of diameter $3\sqrt{3}GM/c^2$ and thickness $\sim GM/c^2$.

New solutions in tensor-multi-scalar theories of gravity

Stoytcho Yazadjiev

Abstract

In this talk I will present new solutions describing neutron stars and black holes in the tensor-multi-scalar theories of gravity. Some astrophysical implications of the solutions will be also discussed.