12th Iberian Gravitational Waves Meeting

Monday 6 June 2022 - Wednesday 8 June 2022

University of Minho, Campus Gualtar, Pedagogical Complex II (CP2), Room B1

Book of Abstracts

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Contents

The stochastic gravitational wave background from close hyperbolic encounters of primordial black holes in dense clusters 1 1

Simulations for highly eccentric black holes binaries 6 1

Maximum mass and stability of a differentially rotating neutron star 7 1

Active monitoring of stray light at Advanced Virgo: new instrumented baffles. 8 2

The gravitational wave signal from primordial magnetic fields in the Pulsar Timing Array frequency band 9 2

Action-Angle formalism for Geodesic motion in Kerr spacetime 10 3

Implications for first-order cosmological phase transitions and the formation of primordial black holes from the third LIGO-Virgo observing run 11 3

Probing primordial non-Gaussianities with anisotropies of the SGWB 12 4

Implications of the quantum nature of the black hole horizon on the gravitational-wave ringdown 13 4

Where is the ringdown? Gravitational waves in scalar-tensor theories. 16 5

Multi-messenger NS mergers: using GWs and photon light-curves to understand their properties 17 5

Primordial black hole formation with full numerical relativity 18 6

Impact of ultralight bosonic dark matter on the dynamical bar-mode instability of rotating neutron stars 19 7

How neutron star mergers and astrophysical observations could constrain dark matter properties 20 7

Search for gravitational waves from black hole hyperbolic encounters in LIGO-Virgo 21 . 7

Applications of the close-limit approximation: horizonless compact objects and scalar fields 22 8

A numerical-relativity gravitational-wave catalogue of spinning Proca-star collisions 23 . 8

Gravitational waves cosmology: from theory to observations 24 9

Hierarchical approach to matched filtering using a reduced basis 26 9

A comparison of GstLAL performance in gaussian data and LIGO detectors data. 27 . . . 10

Universal relations for rotating Boson Stars 29 . . . 10

Some ongoing Efforts for Evolving Einstein Field Equations on Hyperboloidal Slices 30 . 11

Parity violating gravitational waves at the end of inflation 31 . . . 11

GWTC-3: Parameter Estimation Formalism & Results 32 . . . 12

Darboux covariance: a hidden symmetry of perturbed Schwarzschild Black Holes 33 . . . 12

Quasi-Equilibrium Configurations of Compact Binaries Composed of Two Fluids 34 . . . 13

Comparison of eccentric numerical relativity simulations to small mass-ratio perturbation theory 35 . . . 13

Prospects for detecting long-duration transient gravitational waves from glitching pulsars with current and future detectors 36 . . . 14

Constraining ΛCDM cosmological parameters with Einstein Telescope mock data 37 . . . 14

Numerical Simulations of Dark Matter Admixed Neutron Stars Binaries 38 . . . 15

Tracking the origin of black holes with the stochastic gravitational wave background popcorn signal 39 . . . 15

Rapid Online Estimation of Astrophysical Source Category and Compact Binary Parameters 41 . . . 16

The LISA Data Challenges 42 . . . 17

All-sky searches for continuous gravitational-wave signals from unknown isolated and binary neutron stars in O3 LIGO-Virgo data 43 . . . 17

Gravitational-wave parameter inference with the Newman-Penrose scalar 44 . . . 18

Narrowband searches for continuous and long-duration transient gravitational waves from known pulsars in the LIGO-Virgo third observing run 45 . . . 18

Search for Proca star mergers in GWTC-3 46 . . . 19

Accept Test 47 . . . 19

Welcome 49 . . . 19

LISA: Space-based GW Astronomy 50 . . . 20

LISA: Space-based GW Astronomy 51 . . . 20

Action-Angle formalism for Geodesic motion in Kerr spacetime 52 . . . 20

Coffee Break 53 . . . 21

Testing General Relativity with gravitational waves from compact binary coalescences 54 21

Tests of Gravity Theories with Pulsar Timing 55 . . . 21

Black holes in fundamental field environments 56 21

Hunting and interpreting intermediate-mass compact objects 57 22

Developing Gans for Gravitational Waves 58 22

Searching for Primordial Black Holes with Gravitational Waves 59 22

Gravitational waves from strong first-order phase transitions 60 22

RECENT RESULTS AND FUTURE CHALLENGES FOR CONTINUOUS GRAVITATIONAL WAVE SEARCHES WITH A NETWORK OF TERRESTRIAL GRAVITATIONAL WAVE DETECTORS 61 23

Closing Remarks 62 23

1

The stochastic gravitational wave background from close hyperbolic encounters of primordial black holes in dense clusters

Authors: Juan García-Bellido[1]; Sachiko Kuroyanagi[1]; Santiago Jaraba[1]

[1] *IFT UAM-CSIC*

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The inner part of dense clusters of primordial black holes is an active environment where multiple scattering processes take place. Some of them give rise from time to time to bounded pairs, and the rest ends up with a single scattering event. The former eventually evolves to a binary black hole (BBH) emitting periodic gravitational waves (GWs), while the latter with a short distance, called close hyperbolic encounters (CHE), emits a strong GW burst. We make the first calculation of the stochastic GW background originating from unresolved CHE sources. Unlike the case for BBH, the low-frequency tail of the SGWB from CHE is sensitive to the redshift dependence of the event rate, which could help distinguish the astrophysical from the primordial black hole contributions. We find that there is a chance that CHE can be tested by third-generation ground-based GW detectors such as Einstein Telescope and Cosmic Explorer.

Which topic best fits your talk?:

Cosmological Sources of GW

6

Simulations for highly eccentric black holes binaries

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Motivated by the characterization of detected black hole binaries which challenge the quasi-circular interpretation, we describe Numerical Relativity simulations of highly eccentric black hole binaries carried out with the codes Einstein Toolkit and GRAthena++. We consider initial data consisting of equal and unequal masses, and aligned spins. We report a preliminary comparison to Effective One Body waveforms, carried out with the code TEOBResumS, with which we find good agreement.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

7

Maximum mass and stability of a differentially rotating neutron star

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Simulations of BNS mergers have shown that the result of the merger could be a prompt collapse or will have an intermediate meta-stable product which is a massive differentially rotating neutron star; before the final collapse to a black hole or a neutron star. The outcome of the merger depends on a number of factors such as the mass of the progenitors, their mass ratio, timescales under consideration, equation-of-state (EoS), the strength of magnetic fields, neutrino loss, etc. This delayed collapse might have significant consequences on the expected gravitational-wave(GW) signal, in constraining EoS, and on the post-merger astrophysical phenomenon like gamma-ray burst models, which could be very insightful. One of the approaches to study this is by estimating the maximum possible mass of this differentially rotating short-lived remnant, which is one of the important factors in determining the final remnant of the merger. I will talk about the maximum mass that can be achieved and its stability given polytropic equation of states.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

8

Active monitoring of stray light at Advanced Virgo: new instrumented baffles.

Author: Giada Caneva Santoro[None]

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As part of the phase I upgrade of the Advanced Virgo interferometer, a new instrumented baffle was installed last year at EGO. This novel and innovative control device surrounds the suspended end mirror of the Virgo's input mode cleaner cavity and is equipped with photosensors in order to monitor the stray light inside the experiment, a persistent source of noise at interferometers. It serves as a demonstrator of the technology designed to instrument the baffles in the main arms as part of the phase II upgrade in the near future. We present an update on the status of the new detector and its integration into the regular Virgo operations in preparation for the new Observation Run O4, along with results on the measured scattered light distribution inside the cavity. The sensitivity of the baffle is discussed and the data is compared to scattered light simulations.

Which topic best fits your talk?:

GW Experimental Results

9

The gravitational wave signal from primordial magnetic fields in the Pulsar Timing Array frequency band

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The NANOGrav, Parkes, and European pulsar timing array (PTA) collaborations have reported evidence for a common-spectrum process that can potentially correspond to a stochastic gravitational wave background (SGWB) in the 1–100 nHz frequency range. I will present the scenario in which this signal is produced by magnetohydrodynamic (MHD) turbulence in the early universe, induced by a non-helical primordial magnetic field at the energy scale corresponding to the quark confinement phase transition. I will present the results of MHD simulations studying the dynamical evolution of the magnetic field and the resulting SGWB. The SGWB output from the simulations can be very well approximated by assuming that the magnetic anisotropic stress is constant in time, over a time interval related to the eddy turnover time. The analytical spectrum derived under this assumption features a change of slope at a frequency corresponding to the GW source duration that is confirmed with the numerical simulations. The SGWB signal can be compared with the PTA data to constrain the temperature scale at which the SGWB is sourced, as well as the amplitude and characteristic scale of the initial magnetic field. The generation temperature is constrained by PTA to be in the 2-200 MeV range, the magnetic field amplitude must be > 1% of the radiation energy density at that time, and the magnetic field characteristic scale is constrained to be > 10% of the horizon scale. The turbulent decay of this magnetic field will lead to a field at recombination that can help to alleviate the Hubble tension and can be tested by measurements in the voids of the Large Scale Structure with gamma-ray telescopes like the Cherenkov Telescope Array.

Which topic best fits your talk?:

Cosmological Sources of GW

10

Action-Angle formalism for Geodesic motion in Kerr spacetime

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Extreme mass ratio inspirals (EMRIs) are sources of gravitational waves that we expect to be observed by LISA. These binary sources are composed of a primary supermassive black hole and a secondary much lighter compact object. Hence, the mass ratio between the secondary and the primary is very small allowing us to approach the contribution of the secondary object to the binary system as a perturbation to a Kerr black hole background. The dissipation due to radiation reaction is actually slow when compared to the orbital motion of the secondary around the primary. This allows us to use a two timescale approach to model an EMRI. The slow time scale is concerned with the evolution of the constants of motion, which correspond to the action variables of the system, while the fast time scale is concerned with the orbital phases of the secondary, which correspond to the angle variables of the system. Therefore, expressing the geodesic motion on a Kerr background in action angle variables comes as a natural way to describe it. In our work, we use the Lie series approach of the canonicacal perturbation theory to simplify the system, which allows us to have the respective Hamiltonian expressed purely in terms of actions. As a result all the important quantities, such as the characteristic frequencies of motion, are in closed form. Since the Lie approach is based on a canonical transformation, we have an invertible mapping between the original coordinates and the action-angle ones.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

11

Implications for first-order cosmological phase transitions and the formation of primordial black holes from the third LIGO-Virgo observing run

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Abstract:
We place constraints on the normalised energy density in gravitational waves from first-order strong phase transitions and then from the formation of primordial black holes using data from Advanced LIGO and Virgo's first, second and third observing runs. First, adopting a broken power law model, we place 95 % confidence level upper limits simultaneously on the gravitational-wave energy density at 25 Hz from unresolved compact binary mergers and strong first-order phase transitions. We then consider two more complex phenomenological models, limiting at 25 Hz the gravitational-wave background due to bubble collisions and the background due to sound waves at 95 % confidence level for phase transitions occurring at temperatures above 1e8 GeV. We then do a similar search assuming a background sourced by the formation of primordial black holes and unresolved compact binary mergers. For a very generic spectrum describing the primordial black hole background, we place 95% confidence level upper limits on the gravitational-wave energy density at 25 Hz.

Which topic best fits your talk?:

Cosmological Sources of GW

12

Probing primordial non-Gaussianities with anisotropies of the SGWB

Author: Lucas Pinol[None]

Co-authors: Ema Dimastrogiovanni ; Matteo Fasiello

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Primordial non-Gaussianities of the scalar(tensor)-tensor-tensor type supporting a non-trivial squeezed component are known to induce anisotropies in the stochastic gravitational wave background. I will explain how to compute such anisotropies by making use of the in-in formalism for cosmological correlation functions.
After illustrating the general method and explaining why the minimal single-field slow-roll scenario cannot lead to observable anisotropies, I will apply it to two interesting multifield models of inflation. First, I will make contact with previous results on anisotropies due to the presence of an extra spin-2 field during inflation. Secondly, I will show how to calculate the 1-loop scalar-tensor-tensor three-point function in the context of so-called supersolid inflation. The corresponding gravitational wave anisotropy is induced atop a gravitational signal that may be sufficiently large for detection.

Based on https://arxiv.org/pdf/2203.17192.pdf

Which topic best fits your talk?:

GW Theory and Fundamental Physics

13

Implications of the quantum nature of the black hole horizon on the gravitational-wave ringdown

Authors: Anupam Mazumdar[1]; Elisa Maggio[None]; Sumanta Chakraborty[2]; Paolo Pani[3]

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Motivated by capturing putative quantum effects at the horizon scale, we model the black hole horizon as a membrane with fluctuations following a Gaussian profile. By extending the membrane paradigm at the semiclassical level, we show that the quantum nature of the black hole horizon implies partially reflective boundary conditions and a frequency-dependent reflectivity. This generically results into a modified quasi-normal mode spectrum and the existence of echoes in the post-merger signal. On a similar note, we derive the horizon boundary condition for a braneworld black hole that could originate from quantum corrections on the brane. This scenario also leads to a modified gravitational-wave ringdown. We discuss general implications of these findings for scenarios predicting quantum corrections at the horizon scale.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

16

Where is the ringdown? Gravitational waves in scalar-tensor theories.

Author: Josu Aurrekoetxea[1]

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[2] *King's College London*

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We study the generation of gravitational waves in scalar-tensor gravity with 3+1 numerical relativity. We show that new scalar gravitational waves are excited, generated by the dilatonic part of the scalar field, which obeys a massive wave equation. Whilst tensor ringdown waveforms extracted at a distance from the source agree with those expected from quasinormal mode (QNM) calculations, the scalar mode shows a radically different behaviour, consisting of a non-exponentially decaying inverse chirp that crosses through the QNM frequency prediction. This is a consequence of the dispersive nature of the new (massive) scalar mode, which obscures the ringdown phase when mixing with louder transient responses of the collapse as it propagates. In order to alleviate the dispersion and classify the different stages of the collapse, we rewind the extracted signals evolving them back with a massive wave equation in flat space, which allows us to clearly identify the ringdown phase and extract the QNMs, in agreement with the expected values from perturbative calculations.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

17

Multi-messenger NS mergers: using GWs and photon light-curves to understand their properties

Authors: M. Angeles Perez-Garcia[1]; C. Albertus Torres[1]; D. Barba et al.[1]

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When two Neutron Stars (NSs) merge a multi-wavelength emission including Gravitational waves (GWs) and electromagnetic (EM) waves is expected. In Kilonova (KN) events, the light curves are powered by the radioactive decay of ejecta products. In this contribution we discuss how some GW observable quantities may help disentanble uncertainties in the stellar radius and Equation of State (EoS), being complementary to information from the KN light-curve. In addition, observing parameters such as inclination angle and distance are key, since they modulate the signal. The new MAAT Integral Field Unit on the OSIRIS spectrograph at the 10.4m Gran Telescopio CANARIAS (GTC) is designed for this task in the 360-1000 nm spectral range. Together with UV and near-IR spectra, it could provide some relevant features of NSs in the coalescing binary and thus add further constraints on the nuclear matter EoS. https://arxiv.org/abs/2204.00022

Pérez-García M 1 , Albertus C 1 , Barba D 1 , Bulla M 3 , Pérez E 4 , Sagués-Carracedo A 3 , Izzo L 2 , Dhawan S 5 , Prada F 4
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4 Instituto de Astrofísica de Andalucía (CSIC), Granada, Spain
5 Kavli Institute for Cosmology, Institute of Astronomy, Cambridge, United Kingdom

Which topic best fits your talk?:

GW Theory and Fundamental Physics

18

Primordial black hole formation with full numerical relativity

Author: Eloy de Jong[1]

Co-authors: Eugene Lim [1]; Josu Aurrekoetxea [2]

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I will talk about studying the formation of black holes from subhorizon and superhorizon perturbations in a matter dominated universe with 3+1D numerical relativity simulations. We find that there are two primary mechanisms of formation depending on the initial perturbation's mass and geometry – via direct collapse of the initial overdensity and via post-collapse accretion of the ambient dark matter. We find that the duration of the collapse process is roughly one Hubble time, that the PBH mass at formation time is around 1% of the Hubble mass and that the subsequent accretion rates are high. I will also comment on the influence of non-sphericity on the collapse.

Which topic best fits your talk?:

Cosmological Sources of GW

19

Impact of ultralight bosonic dark matter on the dynamical bar-mode instability of rotating neutron stars

Authors: Davide Guerra[None]; Fabrizio Di Giovanni[None]; José Antonio Font Roda[None]; Miquel Miravet-Tenés[None]; Nicolás Sanchis-Gual[None]; Pablo Cerdá Durán[None]

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We investigate the effects ultralight bosonic field dark matter may have on the dynamics of unstable differentially-rotating neutron stars prone to the bar-mode instability. To this aim we
perform numerical simulations in general relativity of rotating neutron stars accreting an initial spherically symmetric bosonic field cloud, solving the Einstein-(complex, massive) Klein-Gordon-Euler and the Einstein-(complex) Proca-Euler systems. We find that the presence of the bosonic field can critically modify the development of the bar-mode instability of neutron stars, depending on the total mass of the bosonic field and on the boson particle mass. In some cases, the accreting bosonic field can even quench the dominant ‘ = m = 2 mode of the bar deformation by dynamically forming a mixed (fermion-boson) star that retains part of the angular momentum of the original neutron star. However, the mixed star undergoes the development of a mixed bar that leads to significant gravitational-wave emission, substantially different to that of the isolated neutron star. Our results indicate that dark-matter accretion in neutron stars could change the frequency of the expected emission of the bar-mode instability, which would have an important impact on ongoing searches for continuous gravitational waves.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

20

How neutron star mergers and astrophysical observations could constrain dark matter properties

Authors: Constança Providência[1]; Edoardo Giangrandi[None]; Oleksii Ivanytskyi[2]; Tim Dietrich[3]; Violetta Sagun[1]

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[3] *Nikhef*

Corresponding Author: edoardogiangrandi@gmail.com

We study the impact of asymmetric fermionic Dark Matter (DM) on Neutron Stars (NS). We show how the DM component affects the star's evolution and properties, e.g. mass, radius and tidal deformability parameter. We present the conditions under which the DM particles tend to create an extended diluted halo or a dense core inside a NS. The presence of DM in both configurations affects how a NS is tidally disrupted in a merger, leading to modifications of the tidal deformability parameter which can be further constrained by future gravitational wave detections. Using the constraints coming from GW170817 event along with the existing astrophysical constraints we set a new limit on the mass and fraction of the DM particles.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

21

Search for gravitational waves from black hole hyperbolic encounters in LIGO-Virgo

Author: Gonzalo Morras[None]

Co-authors: Juan García-Bellido [1]; Savvas Nesseris [1]

[1] *IFT, UAM-CSIC*

Corresponding Author: gonzalomorras28@gmail.com

There is evidence and theoretical reasons to believe that Black Holes are densely clustered. Black holes in dense clusters will gravitationally scatter off each other in hyperbolic encounters, emitting gravitational waves that can be observed by current detectors. In this talk I will talk about the properties of the gravitational waves that are emitted in close encounters and the signal we expect to observe in the network of gravitational wave detectors currently on Earth. Using the properties of the signal, I will detail the data processing techniques, both standard and with Machine Learning methods that can be used to make the signal stand above the detector noise. Finally, I will talk about how we applied these methods to search from these hyperbolic encounters in the publicly available LIGO-Virgo data and the results that we obtained.

Which topic best fits your talk?:

GW Experimental Results

22

Applications of the close-limit approximation: horizonless compact objects and scalar fields

Author: Lorenzo Annulli[1]

[1] *CIDMA, Gr@v, University of Aveiro*

Corresponding Author: lorenzo.annulli@gmail.com

The ability to model the evolution of compact binaries from the inspiral to coalescence is central to gravitational wave astronomy. Current waveform catalogues are built from vacuum binary black hole models, by evolving Einstein equations numerically and complementing them with knowledge from slow-motion expansions. Much less is known about the coalescence process in the presence of matter, or in theories other than general relativity. In this talk, I will show how to use the Close Limit Approximation as a powerful tool to understand the head-on collision of two equal-mass, compact but horizonless objects, showing the appearance of 'echoes'. I will also apply the Close Limit Approximation to investigate the effect of colliding black holes on surrounding scalar fields, showing that observables obtained through perturbation theory may be extended to a significant segment of the merger phase, where in principle only a numerical approach is appropriate.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

23

A numerical-relativity gravitational-wave catalogue of spinning Proca-star collisions

Author: Nicolas Sanchis-Gual[None]

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We have performed a systematic study of the dynamics and the emission of gravitational radiation in head-on collisions of dynamically robust spinning vector boson stars, {\it aka} Proca stars. We find that the wave-like nature of bosonic stars has large impact on the gravitational-wave emission. The energy emitted in gravitational waves critically depends on the difference between the oscillation frequencies of the primary and secondary stars $\Delta\omega/\mu = (\omega_1 - \omega_2)/\mu$ in a non-monotonic way. In the unequal-mass case we observe a periodic modulation of the radiated energy as a function of ω_2/μ of the secondary star with fixed ω_1/μ that we relate to constructive and destructive interference due to the interaction of the Proca field with itself.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

24

Gravitational waves cosmology: from theory to observations

Author: Nicola TAMANINI[1]

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Gravitational-wave (GW) cosmology has recently been established as a new observationally-driven research field, and is expected to expand rapidly in the future thanks to the increasing number of ever more accurate GW observations. In this talk I will briefly review the theory behind these observations, including the methods employed to test models beyond general relativity, and I will then survey the current status of GW cosmological results obtained with the LIGO and Virgo interferometers. If time remains I will also present the results expected with future detectors such as LISA and 3G interferometers.

Which topic best fits your talk?:

Cosmological Sources of GW

26

Hierarchical approach to matched filtering using a reduced basis

Author: Rahul Dhurkunde[1]

[1] *AEI Hannover*

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Searching for gravitational waves from compact binary coalescence (CBC) is performed by matched filtering the observed strain data from gravitational-wave observatories against a discrete set of waveform templates designed to accurately approximate the expected gravitational-wave signal,

and are chosen to efficiently cover a target search region. The computational cost of matched filtering scales with both the number of templates required to cover a parameter space and the in-band duration of the waveform. Both of these factors increase in difficulty as the current observatories improve in sensitivity, especially at low frequencies, and may pose challenges for third-generation observatories. Reducing the cost of matched filtering would make searches of future detector's data more tractable. In addition, it would be easier to conduct searches that incorporate the effects of eccentricity, precession or target light sources (e.g., subsolar). We present a hierarchical scheme based on a reduced basis method to decrease the computational cost of conducting a matched-filter based search. Compared to the current methods, we estimate without any loss in sensitivity, a speedup by a factor of ~10 for sources with signal-to-noise ratio (SNR) of at least =6.0, and a factor of ~6 for SNR of at least 5. Our method is dominated by linear operations which are highly parallelizable. Therefore, we implement our algorithm using graphical processing units (GPUs) and evaluate commercially motivated metrics to demonstrate the efficiency of GPUs in CBC searches. Our scheme can be extended to generic CBC searches and allows for efficient matched filtering using GPUs.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

27

A comparison of GstLAL performance in gaussian data and LIGO detectors data.

Author: Andre Guimaraes[1]

[1] *Louisiana State University*

Corresponding Authors: andrerg01@gmail.com, aguima1@lsu.edu

In this study we explore the differences of results of GW searches with the GstLAL pipeline applied to real LIGO data and simulated Colored-Gaussian data.
This difference is quantified with a measure derived from the Kolmogorov–Smirnov test, and is used to find out significant differences depending on template bank parameters.
We find that regions representative of high chirp mass are roughly 6 times more well behaved than those of low chirp mass according to the chosen measure.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

29

Universal relations for rotating Boson Stars

Author: Jorge Castelo Mourelle[None]

Corresponding Author: jorge.castelo@rai.usc.es

Boson stars are hypothetical but widely considered exotic compact objects known as "black-hole mimickers"whose mergers may produce gravitational-wave emissions observable by current ground-based detectors like Advanced LIGO and Virgo.

We need ways to tell different types of compact bodies apart, and universal relations are excellent tools for this purpose since they allow us to know the external gravitational field of particular types

of compact stars. Therefore, having universal relations for rotating boson stars would help us to identify these objects and lift possible degeneracies with other compact stars.

We show that the moment of inertia I, the (dimensionless) angular momentum χ, and the quadrupole moment Q of rotating boson stars obey a universal relation, valid for a wide set of boson-star models. Further, the obtained $I-\chi-Q$ relation clearly differs from its famous neutron star counterpart. In GW observations, this provides an unequivocal diagnostic tool to distinguish boson stars from ordinary compact stars or other celestial bodies. Such universal (i.e. model-independent) relations also provide a valuable tool to probe the strong gravity regime of general relativity and to constrain the equation of state of matter inside compact stars.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

30

Some ongoing Efforts for Evolving Einstein Field Equations on Hyperboloidal Slices

Author: Shalabh Gautam[1]

Co-authors: Edgar Gasperin Garcia [2]; Sukanta Bose [3]; Alex Vano-Vinuales [2]

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[3] *IUCAA*

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One of the challenges in numerical relativity is to include future null infinity in the computational domain with a well-posed formulation. Success will not only enable us to evolve any system of astrophysical interest, e.g. binary black holes and extracting the gravitational wave signal at future null infinity, with any desired accuracy, but also help in studying various phenomena of fundamental interest. One proposal is to use hyperboloidal slices. In this talk, I will present our ongoing efforts for obtaining a well-posed formulation of the Einstein Field Equations on hyperboloidal slices, all in spherical symmetry. The natural extension will be to generalize these methods to full 3d.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

31

Parity violating gravitational waves at the end of inflation

Authors: António Manso[1]; Mar Bastero Gil[1]

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Vector particle-inflaton interactions of the type $\phi F\tilde{F}$, have provided interesting phenomenology to tackle some of current problems in cosmology, namely the vectors could constitute the dark matter component. It could also lead to possible signatures imprinted in a gravitational wave spectrum.

Through this coupling, a rolling inflaton induces an exponential production of the transverse polarizations of the vector field, having a maximum at the end of inflation when the inflaton field velocity is at its maximum. Moreover, these gauge particles, already parity asymmetric, will source the tensor components of the metric perturbations, leading to the production of parity violating gravitational waves. In this work we examine the vector particle production with an attempt to mimic its backreaction effects on the inflation evolution. Furthermore, we fully integrate the gauge particle amplitudes spectrum during this production epoch, studying the behavior until $\epsilon_H = 2$, at the onset of reheating. Finally, we calculate the gravitational wave spectrum solely relying on the vector mode WKB expansion in its regime of validity.

Which topic best fits your talk?:

Cosmological Sources of GW

32

GWTC-3: Parameter Estimation Formalism & Results

Author: Jose Nuno[None]

Co-author: Collaboration LVK

Corresponding Authors: jn2527@gmail.com, jose.nuno@ligo.org

As a member of the LVK Collaboration, I will review the third Gravitational Wave Transient Catalog (GWTC-3) describing the signals detected with Advanced LIGO and Advanced Virgo up to the end of their third observing run. I will focus on the parameter estimation part of the catalog, giving details on the main inference methods and checks we do to assess whether a given result is reasonable. I will then show this formalism in action with two events GW200322_091133 and GW191219_163120 both in the wider context of the Catalog and individually based on their inference results.

Which topic best fits your talk?:

GW Experimental Results

33

Darboux covariance: a hidden symmetry of perturbed Schwarzschild Black Holes

Author: MICHELE LENZI[1]

Co-author: Carlos F. Sopuerta [1]

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Perturbation theory of vacuum spherically-symmetric spacetimes is a crucial
tool to understand the dynamics of black hole perturbations. In spherical symmetry the equations for the perturbations can be decoupled in terms of (gauge-invariant) master functions that satisfy 1+1 wave equations. By working in a completely general perturbative gauge, we determine and characterize the full space of master equations describing the dynamics of vacuum spherically-symmetric spacetimes. The outcome of the study is that for each parity we have two branches of solutions with similar features. One of the branches includes the known results: In the odd-parity case, the most general master function is an arbitrary linear combination of the Regge-Wheeler and the

Cunningham-Price-Moncrief master functions whereas in the even-parity case it is an arbitrary linear combination of the Zerilli master function and another master function that is new to our knowledge. The other branch is very different since it includes an infinite collection of potentials which in turn lead to an independent collection master of functions. In the case of perturbed Schwarzschild black holes, all these master equations are shown to be connected via Darboux transformations thus revealing the presence of a hidden symmetry, Darboux covariance, which preserves the spectrum of quasinormal modes and the continuous spectrum associated with black hole scattering processes. This picture is further shown to share a deep connection with the Korteweg-de Vries equation and inverse scattering methods which leads to an infinite hierarchy of conserved quantities.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

34

Quasi-Equilibrium Configurations of Compact Binaries Composed of Two Fluids

Author: Hannes Rüter[None]

Co-author: Violetta Sagun [1]

[1] *University of Coimbra*

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We discuss the construction of quasi-equilibrium configurations of compact binaries, in which each component of the binary is modeled as a mixture of two ideal fluids. We will consider in particular the application to neutron stars, where the two-fluid description is used for example for superfluid neutron stars or dark-matter admixed neutron stars.
Quasi-equilibrium configurations provide the best form of initial data for numerical raltivity simulations and are therefore an important ingredient for simulations of compact binaries. They hence form the basis for future two-fluid simulations of neutron star binaries.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

35

Comparison of eccentric numerical relativity simulations to small mass-ratio perturbation theory

Authors: Antoni Ramos-Buades[1]; Harald Pfeiffer[1]; Maarten Van De Meent[1]

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During the third observing run of the LIGO and Virgo detectors a few gravitational wave (GW) signals from binary black hole (BBH) mergers with unequal masses have been detected. As detectors' sensitivity continues to increase, more systems with more asymmetric masses are expected to be detected, and therefore modelling of BBHs at all mass ratios is of preeminent relevance. Here we investigate two approaches to modeling BBH: 1) small mass-ratio (SMR) perturbation theory, and 2) numerical relativity (NR). We extend recent work on combining information from quasi-circular non-spinning NR simulations of BBHs with results from SMR perturbation theory to nonspinning eccentric BBHs. We produce a dataset of long and accurate eccentric non-spinning NR simulations with the Spectral Einstein Code (SpEC) from mass ratios 1 to 10, and eccentricities up to 0.7. We analyze these NR simulations, develop tools to map points in parameter space between eccentric NR and SMR configurations, and provide constraints on unknown higher order terms in the SMR expansion of the energy and angular fluxes, as well as the periastron advance in the limited parameter space in mass ratio covered by the NR simulations.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

36

Prospects for detecting long-duration transient gravitational waves from glitching pulsars with current and future detectors

Author: Joan Moragues[1]

Co-authors: David Keitel ; Luana Michela Modafferi

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Pulsars are rotating neutron stars that emit electromagnetic radiation. Even though pulsars slow down while they lose energy, they can suffer glitches: spontaneous increases of their rotational frequency. These glitches can also lead to the emission of long-duration transient gravitational waves (GWs). An increase in the sensitivity of GW detectors is indispensable for measuring new types of GWs. Existing ground-based detectors are currently being improved for the next observation run (O4) and a new generation of detectors will be built, like the Einstein Telescope, which will improve sensitivity by an order of magnitude and also open up lower frequencies for observation. We present detection prospects for long-duration transient gravitational waves from glitching pulsars by comparing data of known pulsars with the sensitivity of current and future GW detectors. We review methods to perform a post-glitch GW search, and reanalyze the ATNF pulsar catalog together with the ATNF and Jodrell glitch catalogs to extrapolate to the detectability of future glitches. In particular, we perform a specific prediction for Crab-like and Vela-like pulsars: from the setup of our O3 matched-filter analysis, we can determine a realistic sensitivity for future searches and comparing the maximum strain of an emitted GW with the expected sensitivity curve we can see how likely we are to detect long-duration transient GW signals from glitching pulsars in the future.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

37

Constraining ΛCDM cosmological parameters with Einstein Telescope mock data

Author: Matteo Califano[1]

[1] *Scuola Superiore Meridionale - University of Naples "Federico II"*

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We investigate the capability of Einstein Telescope to constrain the cosmological parameters of the non-flat ΛCDM cosmological model. Two types of mock datasets are considered depending on whether or not a short Gamma-Ray Burst is detected and associated with the gravitational wave event using the THESEUS satellite. Depending on the mock dataset, different statistical estimators are applied: one assumes that the redshift is known, and another one marginalizes over it assuming a specific prior distribution. We demonstrate that (I) using mock catalogs collecting gravitational wave events to which a short Gamma-Ray Burst has been associated, Einstein Telescope may achieve an accuracy on the cosmological parameters of $\sigma_{H_0} \approx 0.40$ km s^{-1} Mpc^{-1}, $\sigma_{\Omega_{k,0}} \approx 0.09$, and $\sigma_{\Omega_{\Lambda,0}} \approx 0.07$; while {\em (ii)} using mock catalogs collecting also gravitational wave events without a detected electromagnetic counterpart, Einstein Telescope may achieve an accuracy on the cosmological parameters of $\sigma_{H_0} \approx 0.04$ km s^{-1} Mpc^{-1}, $\sigma_{\Omega_{k,0}} \approx 0.01$, and $\sigma_{\Omega_{\Lambda,0}} \approx 0.01$. These results show an improvement of a factor 2-75 with respect to earlier results using complementary datasets.

Which topic best fits your talk?:

Cosmological Sources of GW

38

Numerical Simulations of Dark Matter Admixed Neutron Stars Binaries

Author: Mattia Emma[None]

Co-authors: Violetta Sagun [1]; Francesco Pannarale [2]; Tim Dietrich [3]; Federico Schianchi [4]

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The multi-messenger detection of GW170817, GRB170817A, and AT2017gfo originating from the merger of two neutron stars have been a scientific breakthrough. Under the assumption that dark matter accumulatesin and around neutron stars, multi-messenger observations of compact binary mergers will provide a new way to search for and constrain the nature of dark matter. In this context, we extended the numerical-relativity code BAM to enable the simulation of neutron stars that contain ordinary baryonic matter, but also a mirror dark matter component. We performed single star tests to verify our code changes and perform the binary neutron star simulations using a two-fluid approach. Despite the drawback that our simulations are based on superimposed initial configurations, we find that the presence of dark matter reduces noticeably the lifetime of the remnant and changes the amount of ejected material. Consequently, electromagnetic signals that arise due to the merger of binary neutron star mergers admixed with dark matter will be different than those from 'pure' neutron stars. Given the increasing sensitivity of gravitational-wave interferometers and other observational
facilities, our analysis gives a new perspective on how to probe the presence of dark matter.

Which topic best fits your talk?:

GW Theory and Fundamental Physics

39

Tracking the origin of black holes with the stochastic gravitational wave background popcorn signal

Author: Sachiko Kuroyanagi[1]

Co-authors: Juan García-Bellido [1]; Matteo Braglia [1]

[1] *IFT UAM-CSIC*

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Unresolved sources of gravitational waves (GWs) produced by the merger of a binary of black holes at cosmological distances combine into a stochastic background. Such a background is in the continuous or popcorn regime, depending on whether the GW rate is high enough so that two or more events overlap in the same frequency band. These two regimes respectively correspond to large and small values of the so-called duty cycle. We study the detection regime of the background in models of Primordial Black Holes (PBHs) and compare it to the one produced by black holes
of stellar origin. Focusing on ground-based detectors, we show that the duty cycle of the PBH-origin background is larger than that of astrophysical black holes because of differences in their mass function and the merger rate. Our study opens up the possibility to learn about the primordial or astrophysical nature of black hole populations by examining the statistical properties of the stochastic background.

Which topic best fits your talk?:

Cosmological Sources of GW

41

Rapid Online Estimation of Astrophysical Source Category and Compact Binary Parameters

Author: Verónica Villa-Ortega[1]

Co-authors: Thomas Dent [2]; Andrés Curiel Barroso

[1] *IGFAE, Universidade de Santiago de Compostela*

[2] *University of Santiago de Compostela*

Corresponding Author: veronica.villa.ortega@usc.es

Since the detection of GW170817, multi-messenger astronomy involving gravitational waves has become a reality. A challenge for low-latency searches, like PyCBC Live, is to rapidly identify and disseminate candidate alerts, in order to allow immediate followup searches by electromagnetic (EM) and neutrino observatories.
To help observatories to choose which events to prioritize, LIGO-Virgo alerts for Compact Binary Coalescence (CBC) sources include estimates of probabilities for the source to contain neutron star or black hole components. During the later part of the third observing run (O3), a method to rapidly classify sources between different CBC categories was developed for PyCBC Live. This fast classification uses the chirp mass recovered by the search as input, given the difficulty of measuring the mass ratio with high accuracy for lower-mass binaries. The accuracy of the estimated source chirp mass is improved by correcting for the bias due to cosmological redshift, using an estimate of the source distance derived from the search. We present results for simulated signals, and for confirmed candidate events identified in low latency over O3.

Our chirp-mass based method is available for use in the fourth observing run (O4), for which the production of an accurate but rapid parameter estimation (PE) analysis still remains a significant challenge. Our next step towards this for PyCBC Live is to use the optimized Signal-to-Noise-Ratio

(SNR) point estimate given by the pipeline, in addition to an approximation to the likelihood dependence on masses and spins, to produce rapid PE samples and credible regions that could eventually be used to contribute to EM followup searches.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

42

The LISA Data Challenges

Author: Ivan Martin Vilchez[1]

Co-author: Carlos F. Sopuerta [2]

[1] *Institute of Space Sciences (ICE, CSIC and IEEC)*

[2] *ICE-CSIC*

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Part of the work necessary prior to launch of the LISA mission is the establishment of ground segment data processing and analysis pipelines. A critical piece of this work is being done in the LISA Data Challenges (LDCs) group of the LISA Consortium. The LDCs consist of simulated LISA data to be analyzed by the participants, serving as the test bench for any LISA data analysis pipeline. In this talk I will describe what they consist of and their current status. I will also show our group's contribution to the first round and talk about our plans for the currently ongoing ones.

Which topic best fits your talk?:

Modelling and Machine Learning Algorithms

43

All-sky searches for continuous gravitational-wave signals from unknown isolated and binary neutron stars in O3 LIGO-Virgo data

Author: Rodrigo Tenorio[1]

[1] *Universitat de les Illes Balears*

Corresponding Author: rodrigo.tenorio@ligo.org

Continuous gravitational waves are long-standing forms of gravitational radiation. They are expected to be emitted by rapidly-spinning non-axisymmetric neutron stars. Detecting such a signal would allow probing the physical properties of matter under extreme conditions. We present the results of the latest all-sky search in early O3 Advanced LIGO data for continuous gravitational waves from unknown neutron stars in binary systems and four searches in full O3 Advanced LIGO and Advanced Virgo data for continuous gravitational waves from unknown isolated neutron stars.
The searches are focused around the most sensitive frequency band of the current generation of advanced detectors, covering different parameter-space regions in order to establish a favorable trade-off between sensitivity and computing cost. No detections are reported. The sensitivity of each search is estimated and we achieve the most sensitive results to date across the analyzed parameter space.

Which topic best fits your talk?:

GW Experimental Results

44

Gravitational-wave parameter inference with the Newman-Penrose scalar

Authors: Isaac Chun Fung Wong[1]; Juan calderon bustillo[None]

Co-authors: Nicolas Sanchis-Gual ; Samson Leong [1]; Alejandro Torres-Forné [2]; Koustav Chandra [3]; Jose A. Font [4]; Carlos Herdeiro ; Eugen Radu [5]; Tjonnie Li [1]

[1] *Department of Physics, the Chinese University of Hong Kong*

[2] *University of Valencia*

[3] *Department of Physics, Indian Institute of Technology, Bombay*

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Detection and parameter inference of gravitational-wave signals rely on the comparison between the detector strain data $d(t)$ and the gravitational-wave strain waveform templates $h(t)$. The strain waveform templates ultimately rely on solving the Einstein's equations via numerical relativity simulations. However, the simulations commonly output the Newman-Penrose scalar $\psi_4(t)$ that is related to the strain by $\psi_4(t) = \mathrm{d}^2h(t)/\mathrm{d}t^2$. Therefore, the obtention of the strain templates involves a double time-integration of the $\psi_4(t)$ that introduces artefacts which need to be eased manually. By taking the second order finite differences on the detector strain data and deriving the corresponding noise statistics, we develop a framework to perform the gravitational-wave data analysis directly using the $\psi_4(t)$ templates. We demonstrate the framework by recovering numerically simulated signals from head-on collisions of Proca stars injected in Advanced LIGO noise, and we show that a significant bias in the parameter estimation could be induced by excessively aggressive filtering of the integration artefacts. Our framework removes the need of the integration process to obtain the strain from the numerical relativity simulations and therefore avoids the associated systematic errors.

Which topic best fits your talk?:

45

Narrowband searches for continuous and long-duration transient gravitational waves from known pulsars in the LIGO-Virgo third observing run

Author: David Keitel[None]

Co-author: Collaboration LVK

Corresponding Author: david.keitel@ligo.org

Isolated neutron stars that are asymmetric with respect to their spin axis are possible sources of detectable continuous gravitational waves. This paper presents a fully-coherent search for such signals from eighteen pulsars in data from LIGO and Virgos third observing run (O3). For known pulsars, efficient and sensitive matched-filter searches can be carried out if one assumes the gravitational radiation is phase-locked to the electromagnetic emission. In the search presented here, we relax

this assumption and allow the frequency and frequency time-derivative of the gravitational waves to vary in a small range around those inferred from electromagnetic observations. We find no evidence for continuous gravitational waves, and set upper limits on the strain amplitude for each target. These limits are more constraining for seven of the targets than the spin-down limit defined by ascribing all rotational energy loss to gravitational radiation. In an additional search we look in O3 data for long-duration (hours-months) transient gravitational waves in the aftermath of pulsar glitches for six targets with a total of nine glitches. We report two marginal outliers from this search, but find no clear evidence for such emission either. The resulting duration-dependent strain upper limits do not yet surpass indirect energy constraints for any of these targets.

Which topic best fits your talk?:

GW Experimental Results

46

Search for Proca star mergers in GWTC-3

Authors: Alejandro Torres-Forńe[None]; Juan Calderón Bustillo[None]; Samson Leong[None]; Carlos Herdeiro[None]; Eugen Radu[None]; Isaac C. F. Wong[None]; Jośe A. Font[None]; Koustav Chandra[None]; Nicolas Sanchis-Gual[None]; Tjonnie G. F. Li[None]

Vector boson stars, also known as Proca stars, are self-gravitating lumps of dark matter sourced by an ultralight vector bosonic particle. We find 4 short signals in the latest gravitational wave catalogue GWTC-3, including the events GW190426, GW190521, and GW200220 and a trigger S200114f; and compare them to a catalogue of ˜800 numerical simulations of head-on mergers of such exotic compact binaries. Our result shows that GW190521 and S200114f are more favoured to be Proca stars mergers than binary black holes merger; whereas GW200220 and GW190426 are not. On top of that, the mass of the ultralight bosons inferred from these signals are consistent with each other, at around 9⊠10ˆ{-13} eV, except for the trigger S200114f which slightly deviates from that.

Which topic best fits your talk?:

Cosmological Sources of GW

47

Accept Test

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This is just a test to confirm Accept message is sent

Which topic best fits your talk?:

GW Experimental Results

49

Welcome

Which topic best fits your talk?:

50

LISA: Space-based GW Astronomy

In 2015, the merger signal from a pair of binary black holes arrived at Earth and was observed by the Advanced LIGO detectors. The signal had travelled for around 1 billion years to arrive at Earth, and its detection marks the beginning of Gravitational Wave astronomy. In recent years and the decade to come, the LIGO, Virgo and Kagra detector network, has made, and will make, many more such detections, opening our 'ears'to events in the Universe not visible through electromagnetic detections.
The Laser Interferometer Space Antenna (LISA) is a gravitational wave observatory in space, targeting the millihertz frequency band where a large number of astrophysical and cosmological sources of gravitational waves is expected. In 2013, the European Space Agency selected the science theme 'The Gravitational Universe', which focuses on this rich science and in 2016, a call was issued by ESA for missions to address this science, and the LISA Consortium responded to that call with the LISA mission. ESA then selected the proposal in 2017 and the LISA mission began.
This talk will introduce Gravitational Waves and the techniques used to detect them in space. It will review the LISA mission as a whole, highlight the outstanding science that it will deliver. We will also look at the technical aspects of the design, as well as the strong heritage from the LISA Pathfinder mission, all of which gives us a glimpse at the exciting future of Gravitational Wave astronomy.

51

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Which topic best fits your talk?:

52

Action-Angle formalism for Geodesic motion in Kerr spacetime

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Extreme mass ratio inspirals (EMRIs) are sources of gravitational waves that we expect to be observed by LISA. These binary sources are composed of a primary supermassive black hole and a secondary much lighter compact object. Hence, the mass ratio between the secondary and the primary is very small allowing us to approach the contribution of the secondary object to the binary system as a perturbation to a Kerr black hole background. The dissipation due to radiation reaction is actually slow when compared to the orbital motion of the secondary around the primary. This allows us to use a two timescale approach to model an EMRI. The slow time scale is concerned with the evolution of the constants of motion, which correspond to the action variables of the system, while the fast time scale is concerned with the orbital phases of the secondary, which correspond to the angle variables of the system. Therefore, expressing the geodesic motion on a Kerr back- ground in action angle variables comes as a natural way to describe it. In our work, we use the Lie series approach of the canonicacal perturbation theory to simplify the system, which allows us to have the respective Hamiltonian expressed purely in terms of actions. As a result all the important quantities, such as the characteristic frequencies of motion, are in closed form. Since the Lie approach is based on a canonical transformation, we have an invertible mapping between the original coordinates and the action-angle ones.

Which topic best fits your talk?:

53

Coffee Break

54

Testing General Relativity with gravitational waves from compact binary coalescences

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In recent years, several tests have been proposed to constrain possible deviations from General Relativity through gravitational-wave observations of compact binary coalescences. Such tests challenge a number of "standard"assumptions regarding the source dynamics, the polarisation content and propagation of the signals, as well as the nature of the compact objects involved in the coalescence. I will present an overview of the results obtained so far and discuss future prospects.

55

Tests of Gravity Theories with Pulsar Timing

Which topic best fits your talk?:

56

Black holes in fundamental field environments

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There are several well-motivated scenarios in which fundamental fields could be present around black holes at a sufficient level to impact on the gravitational waveform of a merger. However, developing templates for the impact of such fields is challenging - in particular one issue that requires more attention is how to select and impose appropriate initial conditions for the field that represent their state at the late, dynamical, strong field phase of the merger. A correct specification will be crucial in obtaining sufficiently accurate waveforms and in avoiding degeneracies with other effects. I will describe the recent and ongoing work in this direction.

57

Hunting and interpreting intermediate-mass compact objects

58

Developing Gans for Gravitational Waves

Corresponding Author: fp4303@gmail.com

59

Searching for Primordial Black Holes with Gravitational Waves

Corresponding Author: juan.garciabellido@gmail.com

Which topic best fits your talk?:

60

Gravitational waves from strong first-order phase transitions

Corresponding Author: david.weir@helsinki.fi

Many theories of physics beyond the Standard Model, at the electroweak scale and above, predict first-order phase transitions that would have taken place in the very early universe. A first-order phase transition involves the nucleation, expansion and collision of bubbles of the new phase. The bubbles of the new phase interact with the hot plasma of the early universe as they expand, setting up expanding heated shells of plasma which also collide and interact, even after the bubbles have merged. The motion of the plasma after the transition, consisting initially of sound waves from the heated shells, can later become nonlinear and turbulent. Both the initial collisions of the bubbles and heated shells, and the subsequent dynamics of the plasma, are sources of gravitational waves.
For a phase transition at or around the electroweak scale, the length scales involved mean that these gravitational waves may be detectable by future missions such as LISA. They can indirectly provide a probe of particle physics beyond the Standard Model, complementary to future colliders. The stronger the phase transition, the better the chance of being observed (or constrained) by gravitational wave detectors. However, strong transitions are also relatively poorly understood as they are likely to lead to nonlinear effects, including turbulence. Such effects are an active area of theoretical and simulational research.
In this talk I will discuss some recent work to understand strong thermal first-order phase transitions and how they source gravitational waves.

61

RECENT RESULTS AND FUTURE CHALLENGES FOR CONTINUOUS GRAVITATIONAL WAVE SEARCHES WITH A NETWORK OF TERRESTRIAL GRAVITATIONAL WAVE DETECTORS

Corresponding Author: pia.astone@roma1.infn.it

Following the historic discovery of the signals from coalescing black hole and neutron star (NS) binaries, a new frontier in gravitational wave (GW) research is the detection of sources emitting periodic continuous waves (CWs).
Fast rotating NSs, emit a nearly monochromatic CW signal, whose frequency is proportional to the spin frequency.
An electromagnetic (EM) counterpart of CWs is expected, for example in the case of young rotation-powered pulsars, accreting NSs in binary systems and new-born magnetars. EM-silent NSs are also potential CW sources.
The detection of GWs from these sources is a high priority task for the LIGO/Virgo/KAGRA collaborations. The most recent efforts and results, together with future challenges, will be presented in this talk.

62

Closing Remarks

Which topic best fits your talk?: