ISAPP Summer School on Gravitational Waves 2021

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POSTER SESSION BOOKLET OF THE ABSTRACTS

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POSTER ROOM 1 - LOCATION 01

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Effective one-body approach for eccentric black hole binaries in the extreme mass ratio limit

In this poster we recall the main ideas of the Effective One Body (EOB) model and we discuss the EOB approach to binaries with eccentric and hyperbolic orbits in the large mass ratio limit. We show two examples where we compare the quadrupolar analytical EOB waveforms with the numerical waves obtained using Teukode, a 2+1 time-domain Teukolsky solver. The agreement between the waveforms and the flexibility of the EOB model let us think that this is a promising approach to describe the EMRIs (Extreme Mass Ratio Inspirals) that will be detected by LISA.

POSTER ROOM 1 - LOCATION 02

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A search of the Stochastic Gravitational Waves Background from Compact Binary Coalescences

Gravitational astronomy began in 2015 with the first direct observation of a gravitational wave whose existence was predicted by Albert Einstein in 1916 as a consequence of his general relativity theory. Despite the very low amplitude of these waves, the most violent events in the universe can be detected on Earth using very sensitive interferometers. The LIGO experiments in the United States and Virgo in Italy have been operating since the 2000s. It was not until 2015 after major improvements placing the detectors in advanced configurations that the first coalescence of two black holes was detected. The analysis of the following events provides a better understanding of these systems, their estimated merger rates suggest that the majority of the population of coalescences in the universe is not resolved, the sources being too distant and therefore too weak. All of these events contribute to the astrophysical gravitational wave background. Such a background could be detected by the cross-correlation of data from the detectors that make up the global network of interferometers. The current contribution of the detected population to this background, in terms of gravitational wave energy density, is not representative of the universe's total one. Moreover, the astrophysical background forms a foreground to the cosmological stochastic background, which is the result of the superposition of gravitational waves emitted at the primordial times of the universe. The future detectors sensitivity improvement will increase the detection rate, hence the necessity to develop and upgrade data analysis tools. This poster describes the stochastic gravitational waves background (sgwb) and illustrates some data analysis aspects of a sgwb detection method which tries to take advantage of the information given by a compact binary coalescence pipeline.

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The Hunt for Very High Energy Emission from Gravitational Wave Events

One of the main issue with Gravitational Waves (GW) follow-up astronomy is the poor localization of the events in the sky. GW localizations can span tens to thousands of degrees in the sky as shown in Fig.1. Several techniques have been developed in order to facilitate follow-up observations and maximize the probability of counterpart detection. In the following, the techniques used by the High Energy Stereoscopic System (H.E.S.S.) are presented [1]. These techniques either exploit the localization information provided by the GW interferometers or use additional external information in order to correlate local distribution of the galaxies in the Universe with GW localization information.

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Measuring the expansion history of the Universe from cosmic chronometers in the LEGA-C survey

Massive and passive galaxies can be used as cosmic chronometers to study the expansion history of the Universe. In particular, by following their differential age evolution over different cosmic epochs it is possible to obtain direct measurements of the Hubble parameter, H(z). However, robust age estimates require deep spectroscopy to break internal degeneracies between stellar population parameters (e.g. age and chemical content). In this work, we take advantage of the high quality of LEGA-C survey Data Release 2 data in terms of spectral resolution and signal-to-noise ratio to constrain the physical properties of a population of 140 massive and passive galaxies at z~0.7. From the analysis of the age-redshift relation of this sample, we obtain a new measurement of H(z), assessing in detail its robustness and dependence on systematic effects. We use these data also to extract information on cosmological parameters, in particular on Ω_m and H_0, that we discuss in the framework of the current H_0 tension.

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Multimessenger Bayesian inference of binary neutron star mergers

The joint detection of the gravitational wave GW170817, of the short γ-ray burst GRB170817A and of the kilonova AT2017gfo, generated by the the binary neutron star merger observed on August 17, 2017, is a milestone in multi-messenger astronomy and provides new constraints on the neutron star equation of state. Employing a novel specialized pipeline, we perform Bayesian inference on GW170817 and its kilonova counterpart AT2017gfo. GW170817 is analyzed using effective-one-body, phenomenological and post-Newtonian models with different cutoff-frequencies of 1024Hz and 2048Hz. We find that the former choice minimizes systematics on the reduced tidal parameter, while a larger amount of tidal information is gained with the latter choice. We study AT2017gfo using semi-analytical, multi-components models that also account for non-spherical ejecta. Observational data favor anisotropic geometries to spherically symmetric profiles and favor multi-component models against single-component ones. Using the dynamical ejecta parameters inferred from the best-fitting model and numerical-relativity relations connecting the ejecta properties to the binary properties, we constrain the binary mass ratio and the reduced tidal parameter. Finally, we combine the predictions from AT2017gfo with those from GW170817, constraining the radius of a neutron star of 1.4 MΘ to 12.2±0.5 km (1σ level)

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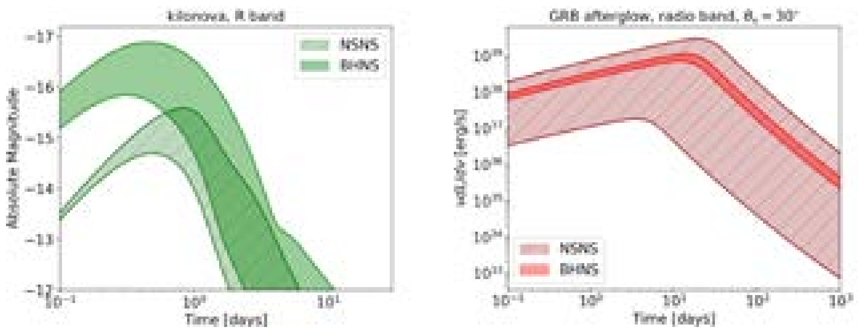
Distinguishing Binary Neutron Star From Black Hole - Neutron Star Mergers with Electromagnetic Counterparts

The discovery of the gravitational wave (GW) signal GW170817, compatible with a coalescing binary neutron star system (NSNS), by the LIGO and Virgo collaboration (LVC) and the following detection of the associated multi-wavelength electromagnetic (EM) counterparts marked the beginning of the multi-messenger astronomy era (Abbott et al. 2017). Recently LVC detected the second NSNS merger (GW190425, although the presence of a black hole [BH] in the binary can not be excluded, see LVC 2020). This event is particularly interesting because the inferred component mass range ($M_1 \in 1.6 - 2.52 M_\odot$ and $M_2 \in 1.12 - 1.68 M_\odot$) is compatible with a system hosting a massive NS or a low-mass stellar BH (in the so-called "mass gap" [Lattimer & Prakash 2001]). No EM counterpart was associated with this event. This could be due to the larger distance and less informative sky-localisation with respect to GW170817 event. NSNS mergers are always expected to be accompained by EM counterparts (Radice et al. 2020). Theoretically, a BHNS merger can produce EM counterparts if the NS is tidally disrupted outside the BH event horizon (Shibata & Taniguchi 2011). Tidal disruption is favoured in binaries with low mass ratio $q = M_1/M_2$, large NS tidal deformability $\Lambda_{\rm NS}$ and high BH spin (Kawaguchi et al. 2016). The unbound material originated from NS disruption, known as "ejecta", produces the kilonova (KN) emission (Lattimer & Schramm 1974, Metzger 2019), while the accretion of material on the merger's remnant can induce the launch of a relativistic jet, powering short gamma-ray burst (sGRB) (Eichler et al. 1989) and GRB afterglow emission (Sari et al. 1998). The binary chirp mass $M_{\rm c} = (M_1 M_2)^{3/5}/(M_1 + M_2)^{1/5}$ is one of the most precisely measured parameter from the GW signal. If there is no "mass gap" between NS and BH mass distributions, there exists an interval of "ambiguous" values of $M_{\rm c}$, in which the nature of the binary can not be deduced from the GW signal alone (Mandel 2015). In this essay we analyse the properties of the KN and the GRB afterglow emission of NSNS and BHNS mergers in this "ambiguous" chirp mass range. We assume two different equations of state (EoS): SFHo, with a maximum mass for a non-rotating NS of $M_{\rm NS}^{\rm max} = 2.058 M_\odot$, and DD2, for which $M_{\rm NS}^{\rm max} = 2.423 M_\odot$. We neglect the NSs' spin and we consider non-spinning BHs. We adopt a semi-analytical KN model with three ejecta components, whose propagation and emission are computed following Barbieri et al. (2020) (in part based on Perego et al. 2017). In order to evaluate dynamical ejecta and disk mass from a NSNS merger we use fitting formulae calibrated on general-relativistic hydrodynamical (GRHD) simulations (Radice et al. 2018; Salafia et al. 2020 in prep.). For BHNS mergers we adopt the formulae in Kawaguchi et al. (2016) to evaluate the dynamical ejecta mass $M_{\rm dyn}$. The disk mass is then calculated as $M_{\rm disk} = \max[M_{\rm out} - M_{\rm dyn}, 0]$, where $M_{\rm out}$ is the NS material remaining outside the BH (Foucart et al. 2019). For the KN light curves we consider emission in the K (2143 nm), R (657 nm) and B (443 nm) bands. We find that KN from BHNS mergers can be far more luminous with respect to the NSNS case, in particular for small chirp masses (including the inferred value for GW190425). The difference in the KN brightness mostly emerges from the different ejecta mass produced during the merger. These results have already been published in a Letter (Barbieri et al. 2019). For the GRB afterglow emission we adopt a semi-analytical model, assuming the jet launch and structure presented in Barbieri et al. (2020). We consider emission in the radio (1.4×10^9 Hz), optical (4.6×10^{14} Hz) and X (2.4×10^{17} Hz) bands. We also consider three different viewing angles: 0°, 30° and 60° (contrarily to the KN, the GRB afterglow is strongly dependent on this parameter). The differences in the GRB afterglow light curves arise from the different produced disk masses. We find that GRB afterglow light curve ranges from NSNS mergers have a wider spread with respect to the BHNS case. In particular for small chirp masses BHNS GRB afterglows are very luminous (large disk masses), while the majority of NSNS configurations produce dimmer emission (although few cases can be as luminous as or even brighter than BHNS light curves). Our results could be applied in the case of detection of an EM counterpart associated with a GW190425-like ("ambiguous") event. As an example, with the observed KN light curve and the knowledge of the system chirp mass, we could be able to distinguish the nature of the merging system (see Barbieri et al. 2020). Finally, we also study the maximum distances at which the GW signal, the KN and GRB light curves are detectable ("horizons") for different NSNS configurations. For which concerns GW detection, we assume the current O3 detector network (LIGO Livingston, LIGO Hanford and Virgo) and a detection threshold signal-to-noise ratio of 12. For which concerns KN/GRB detection we assume limiting magnitudes/fluxes of typical EM follow-up campaigns. We find that for GW170817-like events the GW, KN (R band) and GRB afterglow (radio band, $\theta_{\rm v} = 30°$) horizons are, respectively, ~ 292 Mpc, ~ 288 Mpc and ~ 197 Mpc, while for GW190425-like events the horizons are ~ 330 Mpc, ~ 197 Mpc and ~ 112 Mpc, respectively. The horizons that we find for GW170817-like events are consistent with all the signals having been detected from that event, indeed they are all larger than the GW170817 inferred distance (40^{+8}_{-14} Mpc). The GW horizon for GW190425-like events is consistent with the GW signal having been detected from that event (GW190425 inferred distance is 159^{+69}_{-72} Mpc). For which concerns the EM signals, we find that GW190425 was too distant for GRB afterglow detection, while in principle the KN could have been detected. However, as already mentioned, the absence of EM counterparts is probably due to the less informative sky-localisation.



(a) (b)

Figure 1: (a) Light curve ranges in the R band for kilonovae produced by NSNS (hatched) and BHNS (filled) mergers with a chirp mass $M_{\rm c} = 1.4 M_{\odot}$, assuming SFHo EoS. (b) Light curve ranges in the radio band for GRB afterglow emission produced by NSNS (hatched) and BHNS (filled) mergers with a chirp mass $M_{\rm c} = 1.4 M_{\odot}$, assuming SFHo EoS and a viewing angle $\theta_{\rm v} = 30°$.

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Neutron stars interpreted as primordial black holes in injected data

Gravitational wave-forms from coalescences of binary black hole systems and binary neutron star systems with low tidal effects can hardly be distinguished if the two systems have similar masses. In what follows we investigate a procedure to favour a model between binary neutron star merger and primordial binary black hole merger by using a Bayes factor in simulated wave-forms that we superimpose to realistic detector noise.

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Stochastic Gravitational-Wave Background Search for Galactic Neutron Stars

Individual galactic rotating neutron stars (NSs) are promising sources of continuous gravitational waves (CWs), which arise from deviations from spherical symmetry on the surface of these stars. Likewise, an ensemble of NSs, each emi˛ing CWs, is a source of a stochastic gravitational-wave background (SGWB), which can be searched for by using cross-correlation techniques that could con-strain the properties of the NS population, such as the degree of deformation (ellipticity). In this work, we focus on modeling and searching for an anisotropic SGWB produced by the NS population inside the Galaxy. Moreover, we plan to set constraints on those ensemble properties and produce sky-maps of these sources. Finally, we estimate the margin of improvement of such a search when considering third-generation detectors.

POSTER ROOM 2 - LOCATION 09

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Testing BAYESTAR accuracy

BAYESTAR is the algorithm used by the LIGO-Virgo collaboration (LVC) to localise GW signal sources. It is used for the low-latency localisation, and is extremely important for the EM counterpart detection. This work aims to test the BAYESTAR's accuracy. We simulated compact binary coalescence (CBC) signal in a gaussian and stationary noise, then compute the signal to noise ratio time series with PyCBC (one of the detection pipeline used by LVC) and eventually localise the signal with BAYESTAR. To evaluate the accuracy, we performed a PP-plot test and a Kolmogorov - Smirnov test on these plots.

We found an overestimation of the localisation uncertainties, thus we tested several hypothesis to find its origin. It turns out that it is due to a hard coded factor used in BAYESTAR, indicating that the last may have to be tuned carefully from one pipeline to another.

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Electromagnetic properties of binary neutron star and black hole - neutron star mergers detected with gravitational waves

During the recently concluded third observing run (O3) of the Laser Interferometer Gravitational wave Observatory (LIGO) and Virgo advanced detector network, the LIGO and Virgo Scientific collaborations (LVC) issued several public alerts about candidate detections of binary black hole mergers, plus a smaller number of candidate binary neutron star and black hole - neutron star mergers. The aim of this work is i) to provide the detection rates and the horizons for the observation of these sources (starting from published binary population synthesis results) in the gravitational, electromagnetic and joint multi-messenger channels, considering current facilities; and ii) to find the ranges of peak magnitude/luminosity and time for the different electromagnetic counterparts of the gravitational-wave-detectable population, in order to provide a useful contribution to the organization of the electromagnetic follow-up campaigns. I adopt a semi-analytical approach to model the emissions which are expected from these sources (in accordance to the properties of their ejecta and their remnants). I consider prompt and afterglow emission from short gamma-ray burst (SGRB) jets launched by the merger remnants, and kilonova (i.e. r-process nuclear-decay-powered) emission from the merger dynamical ejecta and from accretion disk winds produced in the post-merger phase. I compare my results with the detections from LVC O3, together with past SGRB and kilonova observations, in order to calibrate the model's parameters. After its validation, the actual use of this model will be its application to future facilities (e.g. the next LVC observing run O4, the Einstein Telescope, Cosmic Explorer, and future electromagnetic telescopes), with the aim of constructing quantitative predictions to be used as a means to optimize future campaigns, and eventually constrain population parameters through their comparison to observed samples.

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Realization of the control systems of a small scale suspended interferometer for quantum noise reduction in gravitational wave detectors

Quantum noise is one of the most important noises limiting the sensitivity of interferometric gravitational wave (GW) detectors. The frequency independent squeezing (FIS) technique adopted by the current generation of GW detectors allowed the quantum noise reduction at high frequency (shot noise above 200 Hz), but on the other hand, this technique shown up the drawback effect of increasing radiation pressure noise at low frequency (below 100 Hz): thus demonstrating the importance of introducing frequency dependent squeezing (FDS).

The upgrades of the 2nd generation of GW detectors lead these instruments to face the limit due by the quantum nature of light: the Standard Quantum Limit (SQL). Their sensitivity can be improved by injecting squeezed vacuum states which have a reduced uncertainty on a quadrature at the expenses of the other quadrature, without breaking Heisenberg principle. Nevertheless, SQL can be overcome by injecting squeezed vacuum states with a frequency-dependent squeezing (FDS) angle: thus, achieving a broadband quantum noise reduction.

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Study of optical techniques to reduce the impact of fundamental noises in graviational wave detector

During the O3 run, both LIGO and VIRGO implemented frequency-independent squeezing in order to reduce the shot noise in the high-frequency region. But because of the Heisenberg uncertainty principle, the radiation pressure noise in the low frequency increased. During the next upgrade of Advanced Virgo, a frequency-dependent squeezing vacuum will be injected into the interferometer for noise reduction across the whole spectrum. This can be realized by reflecting the frequency-independent squeezing with a detuned Fabry-Pérot cavity, referred to as the «filter cavity».

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MBTA False Alarm Rate computation for single detector triggers

The search for gravitational wave events is a difficult process due to how faint the signal is. Because of this the detected events were required to be found in coincidence in at least two detectors in order to be selected as candidates. With time the sensitivity of the search increased thanks to upgrades of the detectors and analysis pipelines, resulting in a higher confidence in the detected events and therefore enabling the search of candidates within single detector triggers to increase statistics. The work presented here aims to identify astrophysical events within single detector triggers by assigning them a false alarm rate.

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Calibration of Advanced Virgo and verification of the reconstructed gravitational wave signal with a photon calibrator

Virgo is a power-recycled Michelson interferometer with two arms of 3 km length, designed to detect gravitational waves (GWs) in a frequency range from 10 Hz to 10 kHz.
One needs to calibrate the interferometer (ITF), and to recontruct the de-tector strain signal h(t), from which GW signals are detected. The photon calibrator (PCal) is a particular mirror actuator which uses the radiation pres-sure of an auxiliary laser to drive the motion of the ITF mirror. Since the LIGO-Virgo Observing run O3 (2019/2020), the PCal is used as reference to calibrate the Virgo detector and to validate h(t). The PCal setup is being modified to further reduce its calibration uncertain-ties for the LIGO-Virgo-KAGRA run O4 to be started mid 2022. During O3, the PCal calibration uncertainty was 1.73% and contributed for about half of the final h(t) uncertainty.

The goal for O4 is to reduce this uncertainty under 1%. To do so, we are:
•Modifying the optical setup to reduce power calibration variation cor-related with humidity as seen during O3. It has been shown that this correlation mainly came from the beam splitters used on the setup.
•Using InGaAs photodiodes instead of silicon photodiodes, in order to re-duce the photodiode sensing noise thanks to a more powerful pickoff and new electronics, and to reduce correlation between photodiode response and temperature.
•Using an integrating sphere on the PCal reflection bench to measure the reflected power directly, without additional optical elements on the beam path.
•Reducing laser power noise, which creates mirror movement noise.

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Cosmology in the dark: On the importance of source population models for gravitational-wave cosmology

From the knowledge of the source mass distribution of compact binary coalescences, we can obtain a statistical measurement of the source's redshift. With additional information about the luminosity distance we can transform this in a constraint of the cosmology of our universe. In this scenario no information from galaxy catalogs is required. We outline here a method that performs a joint fit of the cosmological parameters H_0 and $\Omega_{m,0}$, as well as the source mass population. More specifically, we assume a power law with an additional gaussian component (which is suggested by the current observations [7]). We then study the convergence of the parameter estimation and compare this to other existing methods. For our assumed model on the likelihood, we find that we enter the $1/\sqrt{N}$ regime for about 500 detected events. Moreover, we describe the bias introduced by fixing source mass population parameters to incorrect values or assuming an incorrect mass model. We find that mass features such as the maximum mass are strongly correlated with H_0. Finally, we perform an end-to-end analysis where we simulate a power law and run a full parameter estimation with bilby for 200 events.

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Maximum mass and stability of a differentially rotating neutron star

Neutron stars (NS) are exotic state of matter with the highest possible density and compactness in the observable universe. They are of high interest because they play a crucial role in governing many astrophysical phenomena, for eg., their merger is a primary source of gravitational waves (GWs), they are potential sources for electromagnetic and neutrino emissions, they are central engines for short gamma-ray bursts, their merger produces some of the very heavy elements in the Universe, they are Einstein's laboratory for testing GR in the strong-field regime. But the governing equation of state (EoS) for such an extreme state is unknown. Yet, we know that one of the most important characteristics of a neutron star is, its maximum allowed mass and even though it is the most important prediction of the general relativistic theory of stellar structures, its limiting value is still an unclear picture from many decades.

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MBTA Offline Analysis for CBC Detections in LIGO-Virgo Data

The Multi-Band Template Analysis (MBTA) is a pipeline suited for searching for gravitational waves (GWs) emitted by coalescing compact binary systems (CBCs) in LIGO-Virgo data. It has been used ever since the first generation of interferometric GW detectors in its online configuration, and over the past years it has been improved to provide contributions to GW transient catalogues by developing an offline configuration. MBTA performs a template-based search by splitting the analysis in two frequency bands to reduce computational costs. It has been used in both its offline and online configuration to analyze data from the third observing run (O3) in the standard search, investigating for signals emitted by coalescing Binary Black-Holes (BBHs), Neutron Star Binaries (BNSs) and Neutron-Star-Black-Hole Binaries (NSBHs). At the moment, MBTA is contributing in the Sub-Solar Mass (SSM) search, seeking for signals emitted by compact binaries with at least one component with mass smaller than the mass of the sun.

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Accelerating Waveform Surrogate Models Construction Using PN Expansions Residuals

Gravitational waves data analysis techniques are computationally expensive even in modern computer architectures requiring a vast amount of memory and execution time to run. In order to overcome these obstacles new approaches have been put forward to enhance and accelerate the various procedures, such as surrogate modeling. This work in progress is based on the recent work of Khan and Green (2020) and tries to accelerate training processes by initially altering the waveforms through the subtraction of specific terms from the PN expansion that is used for modeling it, mainly using the calculated residuals. The residual calculations will be made both in the frequency and time domain. Although this project is still in very early stage, we expect training space of various procedures to be reduced, along with the coefficients needed to represent the waveform model. We also expect to conclude that the training procedure for the altered waveform will produce equivalently accurate outcome

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Using Omicron to improve PyCBC's search sensitivity

Data from gravitational waves (GW) detectors is contaminated with glitches, which complicate the detection of astrophysical signals. Understanding glitches is important to claim the astrophysical nature of a gravitational-wave candidate. The idea of this project is to use the Q-transform, implemented in the Omicron software, to identify and reject glitches triggering CBC templates in the PyCBC search. We define a metric which measures the deviation between the power distribution in the time-frequency plane and the expected CBC chirp. We reanalyze ~1 week of O3 data and explore the improvement of the sensitivity of PyCBC with this Omicron-derived metric.

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Broadband quantum noise reduction in Advanced Virgo Plus using frequency dependent squeezing

Quantum noise is limiting the sensitivity of ground based gravitational wave detectors both at high frequency, in the form of shot noise, and low frequency, in the form of radiation pressure noise. In the last observing run, the injection of frequency independent squeezing improved Virgo and LIGO sensitivities at high frequency, slightly worsening the performance at low frequency. A broadband quantum noise reduction can be achieved using frequency dependent squeezing, i. e. rotating the vacuum squeezed ellipse below 100 Hz by reflecting the squeezed vacuum off a Fabry–Perot cavity, called filter cavity. The frequency-dependent squeezed quadrature turning with rotation frequency around a few tens of Hz using a hundred-meter scale cavity has been proven (Phys. Rev. Lett. 124, 171101). Once the frequency dependent squeezing is produced, it has to be injected into the interferometer. This interface is not trivial, since it requires the installation of additional benches and a 285 meter long cavity (in Advanced Virgo Plus) and also to couple the rotating squeezed vacuum with the detector. In order to optimise the performance of this new technique, it is necessary to reduce losses. One important reduction factor I dealt with was the replacement of the two Output Mode Cleaners with a new, higher Finesse one. In addition, I am in charge of mitigating stray light on the most critical benches (squeezing and detection), both because they reduce squeezing performance and because of the sensitivity of the detector itself..

POSTER ROOM 3 - LOCATION 21

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Binary systems of compact objects

For a binary system of compact objects, such as black holes and/or neutron stars, there exists a remarkable differential identity that relates (1) the properties of the individual bodies (masses, spins, quadrupolar deformations) and (2) the binary's property (binding energy, orbital frequency, angular momentum). This identity is called the first law of mechanics (because it resembles the first law of thermodynamics). The purpose of my PhD is to derive a systematic, analytical method to derive this first law for extended, spinning compact objets (using the multipolar point particle model) moving on circular orbits (using an exact spacetime helical isometry). This work is 100% pen and paper and contributes to the understanding of compact object binary mechanics, which is crucial for GW astrophysics.

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Characterization of light scattering point defects in gravitational waves detector mirrors

The high reflective mirrors of the gravitational waves detector LIGO & Virgo present in the coating many micrometer size defects that scattered the light in the interferometer. This scattered light induces a loss of the laser power of the order of a few tens of parts per million (ppm) and a phase noise because of the recombination with the main beam after reflection on the tube walls. This phenomenon limits the sensitivity of the detector and impacts the ability to detect astrophysical events. A reduction of the scattered light is thus required in order to improve the optical performances of the coatings for the new mirrors of the Advanced LIGO and Virgo plus upgrade. For this purpose a dedicated research line is in progress at LMA since 2018. We studied the point defects for each material tantala and silica separately with monolayers deposited onto micropolished fused-silica substrates. We analyzed the impact of different parameters, such as the thickness, as well as the effect of a post-deposition annealing. The samples were measured with a dark-field detection system in order to compare the density and the size distribution of the defects. We pointed out that even if one material has a much larger defect density, both materials share some similarities. Moreover we noticed an outstanding improvement of the coating quality thanks to the post-deposition annealing.

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Mechanical and structural properties of amorphous coatings for mirrors of gravitational waves detectors

The recent detection of gravitational waves opens the doors for a different kind of observation of the Universe, posing new challenges on the limits of current devices for high precision measurements. Gravitational waves detectors need exceptionally high sensitivity, mostly limited by the mirror thermal noise. Mechanical losses of these materials often depend on the sample composition, as well as on the deposition and postdeposition treatments affecting the atomic structure and morphology, such as annealing at high temperature and doping. Moreover, a possible correlation between macroscopic effects (mechanical losses and optical properties) and structural changes at atomic level has not been completely identified yet. A characterization campaign is carrying out for a-SiO_2 and Ti:Ta_2O_5 through different techniques, that are X-ray Absorption Spectroscopy (XAS), X-ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FT-IR) to characterize the structure and a Gentle Nodal Suspension (GeNS) system for the substrate and coating mechanical losses.

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Characterization of the seismic field at Virgo and improved estimates of Newtonian-noise suppression by recesses

Fluctuations of gravitational forces cause so-called Newtonian noise (NN) in gravitational-wave (GW) detectors expected to limit their low-frequency sensitivity in upcoming observing runs. Seismic NN is produced by seismic waves passing near a detector's suspended test masses. It is predicted to be the strongest contribution to NN. Modeling this contribution accurately is a major challenge. Arrays of seismometers were deployed at the Virgo site to characterize the seismic field near the four test masses. In this poster, we present results of a spectral analysis of the array data from one of Virgo's end buildings to identify dominant modes of the seismic field. Some of the modes can be associated with known seismic sources. Analyzing the modes over a range of frequencies, we provide a dispersion curve of Rayleigh waves. We find that the Rayleigh speed in the NN frequency band 10 Hz - 20 Hz is very low (< 100 m/s), which has important consequences for Virgo's seismic NN. Using the new speed estimate, we find that the recess formed under the suspended test masses by a basement level at the end buildings leads to a 10 fold reduction of seismic NN.

POSTER ROOM 3 - LOCATION 25

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Stability of hypermassive neutron stars

Remnants of neutron star mergers and supernovae (SN) explosions are often neutron stars (NS), which, initially, rotate differentialy. Differential rotation may support significantly larger masses than rigid rotation. The limit of mass for differentially rotating NS was shown to be even 4 times larger than their non-rotating counterparts. Those objects are called hypermassive neutron stars. Some of the hypermassive configurations are, however, dynamically unstable.
The fate of the SN remnant or NS-NS merger remnant has an impact on the GW signal of those events, yet it is hard to predict whether the proto-NS will collapse to BH promptly or will be stabilised for some time by the differential rotation.
In our work we explore the equilibrium solutions of differentially rotating neutron stars for different models of matter and different rotation profiles. We try to estimate the threshold of stability and find a stability criterion not de-pendent on the EOS or rotation profile. I will present initial results of our study.

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MIMO representation of LSC of Advanced Virgo

Advanced Virgo is a complex system which is designed to detect gravitational waves. In order to detect such signals, its optical cavities must be controlled in length. Multiple Input Multiple Output (MIMO) approach is used to obtain a characterization of these control loops. Then this technique is extended to provide noise projection of the controls of the main length degrees of freedom (DoF) of advanced Virgo configuration for O4. Having a MIMO model of the system would also allow to implement optimal filters and therefore reduce further the re-injection of noise from these control loops onto DARM.

POSTER ROOM 3 - LOCATION 27

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Non-linear effects at 1.5 post-Newtonian order in massless scalar-tensor theories

Scalar-tensor theories are an interesting playground to probe potential non-GR effects in gravitational wave emission from compact binary systems. Due to no-hair theorems for single black holes, no weak-field effect is expected for binary BH systems, so at least one NS must be involved. Unlike in GR, the leading-order GW emission is dipolar. In this work, we investigate non-linear effects at 1.5PN order, in particular Christodoulou memory.

POSTER ROOM 3 - LOCATION 28

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Spin Precession In Compact Binary Inspirals & TEOBResumSP

Spin precession in compact binary inspirals is introduced. TEOBResumSP is highlighted as a state of the art effective-one-body waveform approximant to generate precessing waveforms. A comparison with the approximant NRSur7dq4 is presented including modes up to ŝ = 4 with precession strength up to χp = 0.69. Further work improving the ringdown section by testing the evolution of the Euler angles of the system past merger is ongoing. The (5,5) mode will also be incorporated.

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A cryogenic & superconducting inertial sensor for the Einstein Telescope and the Lunar Gravitational Wave Antenna

In the next future, 3rd generation GW detectors will be constructed. Their sensitivity to GWs will improve by about 2-3 orders of magnitude at 10 Hz. This means that we will need better controls and better sensors. Moreover, these new GW detectors will be cooled down to cryogenic temperatures. It is in this frame that CSIS is being developed: given that it will work at cryogenic temperatures, it could be used to monitor the final suspension stages of the Einstein Telescope (ET) . However, it could also be deployed on the Moon, in order to exploit it as a detector to reveal GWs with the Lunar Gravitational-Wave Antenna (LGWA), a recently proposed low-frequency gravitational-wave detector on the Moon's surface.

CSIS revolutionizes the (cryogenic) inertial sensor field by obtaining a displacement sensitivity at 0.5 Hz of 3 order of magnitude better than current state-of-art. It will also allow LGWA to be sensitive below 1 Hz and down to 1 mHz.

Moreover, CSIS seismic data could also be employed to get new insights about the Moon's interior… and the selenphysics (the Moon's geophysics)..