Rencontre du groupe de travail ”méthodes d’analyse des données” du GdR Ondes Gravitationnelles Description

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A test for LISA foregrounds Gaussianity and stationarity. II. Extreme-mass-ratio inspirals

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Extreme Mass Ratio Inspirals (EMRIs) are key targets expected to be observed by the Laser Interferometer Space Antenna (LISA) mission. Unresolvable EMRI signals contribute to forming a gravitational wave background (GWB).
Characterizing the statistical features of the GWB from EMRIs is of great importance, as EMRIs will ubiquitously affect large segments of the inference scheme.
In this work, we apply a frequentist test for GWB Gaussianity and stationarity, exploring three astrophysically-motivated EMRI populations. We construct the resulting signal by combining state-of-the-art EMRI waveforms and a detailed description of the LISA response with first-generation time-delay interferometry variables.
Depending on the brightness of the GWB, our analysis demonstrates that the resultant EMRI foregrounds show varying degrees of departure from the usual statistical assumptions that the GWBs are both Gaussian and Stationary.
If the GWB background is non-stationary with non-Gaussian features, this will challenge the robustness of Gaussian-likelihood model, when applied to global inference results, e.g. foreground estimation, background detection, and individual-source parameters reconstruction.

Contributed talks / 2

Reconstructing gravitational wave polarizations with bivariate signal processing and deep generative models

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This work addresses the inverse problem of the reconstruction of the impinging gravitational-wave (GW) polarizations $(h_+, h_\times)$ from the interferometric detector measurements. It is specifically focused on situations where the polarization pattern is non-stationary and evolves over the duration of the signal. For instance, this is the case for GW signals from compact binaries coalescence (CBC) subject to precession of their orbital plane; precession may be due to misaligned component spins. The GWTC-3 catalog (LIGO Scientific Collaboration et al., 2023) includes several such binaries like GW200129_065458.

Two new approaches are proposed that improve upon the methods available in the literature such as BayesWave (Cornish and Littenberg, 2015). BayesWave defines the GW signal model as a combination of wavelets with independent or constant elliptical polarization. It is therefore unable to capture both polarizations correctly or accurately.

1. The first approach builds on a previous work (Cano, 2022), that is based on the geometrical parametrization of the polarization content through Stokes parameters (Flamant, 2018). The regularization of the inversion is performed using a term to penalize the misalignment between reconstructed and predefined target Stokes parameters. This earlier work is restricted to constant Stokes parameters and suffers for the same limitations as BayesWave. The new approach enforces a variable but smooth evolution of the signal Stokes parameters in the reconstructed polarizations (Pilavci et al., 2024).
2. The second approach is based on the plug-and-play (PnP) method (Hurault, 2023) that exploits a deep generative model. PnP methods constitute the current state-of-the-art in image processing and consist in learning a prior from image examples. We apply this technique here on spectrograms of GW simulated signals.

The two proposed approaches are complementary. They resort to different levels of priors for the regularization. These priors are exploited in different ways in practice. The first approach is rather model-agnostic and encodes desirable characteristics of GW signals such as regularity or smoothness of the polarization evolution. In contrast, the second approach ensures that reconstructed GWs belong to the true GW spectrogram distribution learnt from the numerical model.

References

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Contributed talks / 5

Addressing gaps in LISA data

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In this talk, we will discuss the impact of data gaps on parameter estimation in the context of the Laser Interferometer Space Antennae (LISA). Data gaps, for LISA, are unavoidable: whether it is due to antennae repointing due to drift in the orbit, or instrumental malfunctions that are then masked, it is paramount that we can account for data gaps in our parameter estimation pipelines. In this talk, we will discuss a number of general methods that can be used to account for data gaps in LISA data. We will discuss advantages and disadvantages for dealing with data gaps in the frequency domain, time domain and, if time allows, the time-frequency domain.

Contributed talks / 6

Inferring astrophysics and cosmology with individual compact binary coalescences and their gravitational-wave stochastic background

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This work introduces a method to infer the Hubble constant H0 by combining dark siren gravitational wave sources (without electromagnetic counterparts) with the stochastic gravitational wave background (SGWB). Traditional H0 measurement techniques, such as the local distance ladder and cosmic microwave background observations, face significant challenges and yield conflicting results. Gravitational Waves dark sirens can measure the Hubble constant by using a calibration given by the source mass spectrum. The proposed framework integrates SGWB data, which contains signals from numerous unresolved sources, to determine the mass spectrum and hence H0. This method leverages complementary information from both sources. Although preliminary analysis has not shown yet a significant improvement in the H0 precision with projected O5 sensitivity, considering also the other population parameters unknown might result in an improvement.

Reviews / 7

LISA data analysis

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Status of LISA data analysis

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PTA data analysis (remote)

Status of PTA data analysis

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Matched Filtering

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Population inference

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