Gravitational wave data science with the Laser Interferometer Space Antenna (LISA)

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Research Group: Geometry, Analysis & Gravitation

Project description:

The principal goal of the space-based LISA gravitational wave detector is to observe the extreme mass ratio inspiral (EMRI) of stellar-size black holes orbiting supermassive black holes. Detection and parameter estimation require accurate gravitational waveforms associated with generic orbits, that are most efficiently computed within a perturbative expansion. We will combine novel numerical methods with time-domain numerical computation to construct high-precision waveforms. The prospective student will join our LISA group and will be trained on gravitational-wave source modelling using novel numerical and AI data analysis schemes. Theoretical high-precision waveform templates are necessary for extracting the extremely weak waveform signals from noisy detector data. Thus, part of the focus will be on the development of novel collocation methods and time-symmetric integration methods for numerically evolving PDEs with time-domain gravitational self-force computation in a radiation gauge to construct high-precision gravitational waveforms.

The student will use our templates to perform gravitational-wave data analysis for the LISA detector via novel deep learning techniques and traditional match filtering techniques. Match filtering relies on computationally intensive MCMC methods that take weeks and need to be repeated for each detection. In contrast, our template database will be used to train a deep neural network for detecting gravitational wave signals (via classification) and estimating astrophysical source parameters (via regression). Deep neural networks for gravitational wave data analysis only need to be pre-trained once, and then enable detection and parameter estimation in milliseconds. This will allow real-time detection of gravitational signals, enabling astronomers to point telescopes to the source and observe electromagnetic counterparts.

The proposed research is aimed at computationally exploring the theory of black holes, in order to improve our understanding of fundamental physical laws and reveal how nature operates on scales where our current understanding breaks down. As detectors improve their sensitivity and range, the rate of events inside their observable volume will increase cubically. Keeping up with this increase in signals necessitates the use of AI in space data science, which is expected to form a new paradigm in multi-messenger astronomy.

Further information:

How to apply

Entry requirements

Fees and funding