

Asymmetric Binaries meet Fundamental Astro-Physics

Report of Contributions

Contribution ID: 1

Type: **not specified**

Registration

Wednesday, 20 September 2023 14:40 (10 minutes)

Contribution ID: 2

Type: **not specified**

Welcome and practical information

Wednesday, 20 September 2023 14:50 (10 minutes)

Contribution ID: 4

Type: **not specified**

State of the art in gravitational self-force and the post-adiabatic inspiral in Schwarzschild

Wednesday, 20 September 2023 15:00 (30 minutes)

I will discuss what is the current state of the art for gravitational self-force waveforms and the ingredients that go into them. I will discuss how the second-order metric perturbation is used to calculate the amplitude, flux and phase of a gravitational wave and how the slowly-evolving first-order metric perturbation contributes to sourcing perturbations at second order. I will demonstrate the validity of the model as compared to numerical relativity simulations and effective-one-body theory, noting the interesting result that the small-mass ratio approximation remains valid for near-comparable mass ratio binaries in the non-spinning case for quasicircular orbits.

Presenter: DURKAN, Leanne (The University of Texas at Austin)

Session Classification: Self Force

Contribution ID: 5

Type: **not specified**

Adiabatic radiation reaction to the constants of motion in Kerr

Wednesday, 20 September 2023 15:30 (30 minutes)

I review how to compute the adiabatic radiation reaction to the constants of motion including the Carter constant in Kerr spacetime. I also talk about extending these ideas to post-adiabatic order, i.e., one order higher in the mass ratio, which would significantly simplify the construction of the gravitational wave waveform necessary for the observation of extreme mass-ratio in-spirals.

Presenter: TANAKA, Takahiro (University of Kyoto)

Session Classification: Self Force

Contribution ID: 6

Type: **not specified**

Secondary spin in asymmetric binaries

Wednesday, 20 September 2023 16:00 (30 minutes)

Accurate models of large mass-ratio black hole binary systems must include post-geodesic corrections which account for forces driving the small body away from the geodesic. One such effect is called the spin-curvature force which occurs when the secondary spin associated with the smaller black hole couples to the curvature of the background spacetime. In recent years, considerable progress has been made in quantifying the effect of secondary spin on gravitational waves in asymmetric binaries. In this talk, I will review the principles governing spinning bodies in curved space time, outline progress that has been made in the domain of secondary spin corrections in recent years and discuss remaining open questions in the field.

Presenter: DRUMMOND, Lisa (MIT)

Session Classification: Self Force

Contribution ID: 7

Type: **not specified**

Discussion

Wednesday, 20 September 2023 17:00 (1 hour)

Presenters: LOUSTO, Carlos (Rochester Institute of Technology); WARBURTON, Niels (University College Dublin)

Session Classification: Self Force

Contribution ID: 8

Type: **not specified**

Oligochromatic extreme-mass ratio inspirals.

Friday, 22 September 2023 09:30 (30 minutes)

In this talk I will explain that, although polychromatic EMRIs (the EMRIs we have been talking about until now) have a very low event rate at our Galactic Centre, but that early EMRIs, i.e. EMRIs which are far away from plunging, do contribute and since they are so close to us, the SNR can reach extreme values.

Presenter: AMARO SEOANE, Pau (Universitat Politècnica de València)

Session Classification: Astro & Data

Contribution ID: 9

Type: **not specified**

Search, recovery or destroy a waveform template: how important are eccentricity evolution and post-adiabatic terms for asymmetric binaries?

Friday, 22 September 2023 10:00 (30 minutes)

Extreme mass-ratio inspirals (EMRIs) arguably stand out among the sources observable by LISA. Indeed, an EMRI waveform is a treasure cove of information on the binary because the gravitational wave is extremely sensitive to even the smallest perturbation. Detecting such a signal would allow us to test General Relativity with unprecedented precision, unique to EMRIs. Such incredible scientific potential comes with a price: modeling accurate waveforms is a challenging task in terms of analytic computations, numerical simulations, and data analysis. One may then wonder: when can we use approximate models? What is the impact of waveform systematic errors on parameter estimation? In this talk, I will (partially) address these questions by presenting the results of a Bayesian statistical analysis on systematic biases. In particular, the work assesses the importance of first-order post-adiabatic (1PA) terms for extreme and intermediate-mass ratio binaries. We employ state-of-the-art 1PA waveforms for circular equatorial orbits in Schwarzschild spacetime, which include the flux corrections due to second-order self-force and secondary spin. Finally, we also investigate the impact of mismodeling the evolution of eccentric orbits for adiabatic waveforms.”

Presenter: PIOVANO, Gabriel (University College Dublin)

Session Classification: Astro & Data

Contribution ID: 10

Type: **not specified**

Testing General Relativity with LISA observations

Friday, 22 September 2023 10:30 (30 minutes)

The future gravitational wave observations of the Laser Interferometer Space Antenna (LISA) mission have a huge scientific potential to test General Relativity. The key to unlocking such potential is to develop accurate and fast beyond vacuum waveforms and an efficient data analysis pipeline. This talk will illustrate how to do this with Extreme Mass Ratio Inspiral (EMRI) systems. We will present a full Bayesian analysis to test General Relativity with EMRI systems endowed with a scalar field. We will show that observing a “golden” EMRI can constrain the scalar charge tighter than ground-based gravitational wave detectors. Finally, we will outline the key challenges we will face when testing General Relativity with LISA data.

Presenter: SPERI, Lorenzo (AEI)

Session Classification: Astro & Data

Contribution ID: 11

Type: **not specified**

Discussion

Friday, 22 September 2023 11:30 (1 hour)

Presenter: CHUA, Alvin (University of Singapore)

Session Classification: Astro & Data

Contribution ID: 12

Type: **not specified**

Environmental effects and matter systematics for low-frequency gravitational wave astronomy

Thursday, 21 September 2023 09:00 (30 minutes)

Despite the groundbreaking discoveries of the LIGO-Virgo-KAGRA collaboration, the full frequency spectrum of the gravitational wave sky is still largely unknown. The Einstein Telescope will push observations on Earth down to the seismic noise, while LISA will open a window on the mHz gravitational wave band from space. At the same time, pulsar timing arrays, which have just detected a stochastic background signal, will keep exploring the gravitational wave universe at nHz frequencies. This forthcoming wealth of data requires not only waveform templates of exquisite precision, but also to revisit the commonly held assumption that gravitational wave signals are insensitive to the surrounding ambient medium. I will present examples in which the matter environment may affect, directly and indirectly, the gravitational wave signals from various sources for pulsar timing arrays, LISA and possibly ET. I will argue that a complete understanding and modeling of these effects is crucial for making gravitational astronomy a precision science in the next decade.

Presenter: BARAUSSE, Enrico (SISSA)

Session Classification: Environmental Effects

Contribution ID: 13

Type: **not specified**

Detecting disk-induced environmental effects

Thursday, 21 September 2023 09:30 (30 minutes)

Gravitational-wave observations of extreme mass ratio inspirals (EMRIs) hold incredible potential to probe gravity, astrophysical and exotic environments. One of the main effects of astrophysical environments is the torque exerted by gas disks of active galactic nuclei, which force the EMRI to “migrate” (mostly) inward like a planet. We present a Bayesian model-independent framework to detect and characterise these effects with LISA. We will also explore a new, potentially detectable interaction between magnetised stars and the disk.

Presenter: SBERNA, Laura (AEI)

Session Classification: Environmental Effects

Contribution ID: 14

Type: **not specified**

Dynamical tidal resonances in EMRIs

Thursday, 21 September 2023 10:00 (30 minutes)

Resonances are ubiquitous in nature. In this talk, I will focus on resonances due to the interaction of two stellar-mass black holes orbiting a central massive black hole. Such tidal resonances will generically occur for Extreme Mass Ratio Inspirals (EMRIs), if nearby compact objects exist. By probing their influence on the EMRI waveform, we can in principle extract information about the environmental tidal field of the EMRI system, albeit at the cost of a more complicated EMRI waveform model.

Presenter: BONGA, Beatrice (Radboud University)

Session Classification: Environmental Effects

Contribution ID: 15

Type: **not specified**

Discussion

Thursday, 21 September 2023 10:50 (1 hour)

Presenters: SPIEKSMAN, Thomas (Niels Bohr Institute); CARDOSO, Vitor (Niels Bohr Institute)

Session Classification: Environmental Effects

Contribution ID: 16

Type: **not specified**

Detecting scalar charge with EMRIs

Thursday, 21 September 2023 13:30 (30 minutes)

I will first discuss under which circumstances can black holes carry a scalar charge and what this implies for how that charge scales with the mass of the black hole. I will then use this insight to argue that EMRIs are an ideal system for searches of new fundamental scalars. I will lay out the framework for modelling EMRIs in this context and present some first forecasts on LISA's ability to measure scalar charge. This message and any attachment are intended solely for the addressee and may contain confidential information. If you have received this message in error, please contact the sender and delete the email and attachment. Any views or opinions expressed by the author of this email do not necessarily reflect the views of the University of Nottingham. Email communications with the University of Nottingham may be monitored where permitted by law.

Presenter: SOTIRIOU, Thomas (University of Nottingham)

Session Classification: Beyond GR & ECO

Contribution ID: 17

Type: **not specified**

Using EMRIs to detect scalar fields with LISA

Thursday, 21 September 2023 14:00 (30 minutes)

The description of Extreme Mass Ratio Inspirals (EMRIs) in modified theories of gravity can be very complex. However, for a vast class of theories with additional scalar fields, great simplifications occur. At leading order in the binary mass ratio, the primary scalar charge is suppressed, so that the background spacetime is simply described by the Kerr metric. Moreover, the imprint of the scalar field on the waveform is fully captured by two parameters: the scalar charge carried by the secondary and the scalar field mass. Using these simplifications, I will show how the two parameters affects the EMRI dynamics, how such changes get imprinted on the emitted signals, and the extremely promising results on the LISA ability to detect new fundamental fields.

Presenter: BARSANTI, Susanna (Sapienza University)

Session Classification: Beyond GR & ECO

Contribution ID: 18

Type: **not specified**

Self-Force in Scalar-Tensor Theories of Gravity: Perturbative Approach Beyond Linear Order

Thursday, 21 September 2023 14:30 (30 minutes)

For precise measurements of EMRIs with LISA data, first-post-adiabatic accuracy EMRI models will be required. Great effort is being expended in pursuing first-post-adiabatic models in General Relativity. However, to test our fundamental theory of gravity, we also need models in alternative theories. Scalar fields are ubiquitous in alternative theories of gravity. In this talk, we provide a framework for modelling EMRIs to first-post-adiabatic accuracy in general scalar-tensor theories of gravity. In our perturbative approach, the background spacetime can be treated as Kerr, as discussed in the preceding talks and Ref. [PRL. 125, 141101]. Additionally, we produce an ansatz for the action of a point scalar charge experiencing a self-force. From these assumptions, we derive field equations for the metric and scalar field perturbations to second order. Moreover, we derive the equations of motion of the compact object to second order. Crucially, our formalism builds on inputs from the General Relativity calculation, and the additional contributions are no more challenging to calculate than the General Relativity self-force contribution.

Presenter: SPIERS, Andrew (University of Nottingham)

Session Classification: Beyond GR & ECO

Contribution ID: 19

Type: **not specified**

Extreme mass-ratio inspirals into black holes surrounded by scalar clouds

Thursday, 21 September 2023 15:20 (30 minutes)

Scalar clouds can form through superradiant instabilities of massive scalar fields around spinning black holes and can also serve as a proxy for dark matter structures around black holes. They can potentially be detected through a number of signatures, including the possibility that they can affect the dynamics of binary black hole systems. In this talk, I will discuss recent work aiming at studying extreme-mass-ratio systems in which a small compact object inspirals around a supermassive black hole surrounded by a scalar cloud. In particular, I will present the first steps towards studying those systems in a fully relativistic setup (i.e. making use of tools from black hole perturbation theory).

Presenter: BRITO, Richard (Instituto Superior Tecnico)

Session Classification: Beyond GR & ECO

Contribution ID: 20

Type: **not specified**

Testing the horizon of black holes with gravitational waves

Thursday, 21 September 2023 15:50 (30 minutes)

Gravitational waves open the possibility to investigate the nature of compact objects and probe the existence of horizons in black holes. This is of particular interest given some quantum-gravity models which predict the presence of horizonless and singularity-free compact objects. Such exotic compact objects can emit a different gravitational-wave signal relative to the black hole case. In this talk, I derive the characteristic oscillation frequencies of horizonless compact objects in the ringdown. Finally, I describe how parametrised tests on general relativity can allow for tests of the black hole paradigm.

Presenter: MAGGIO, Elisa (AEI)

Session Classification: Beyond GR & ECO

Contribution ID: 21

Type: **not specified**

Gravitational wave based Tests of binary black hole nature: current and future prospects

Thursday, 21 September 2023 16:20 (30 minutes)

Gravitational wave observations through the first three observational runs of ground-based detectors can reveal such sources' various astrophysical and fundamental physics aspects. Even though the current detections do not show evidence for alternate compact objects, the data can still not rule out their existence entirely. This talk aims to provide a status update on black hole mimicker tests and their observational signatures, starting from existing bounds from current detectors to future space-based detectors. Moreover, we discuss some recent developments focusing on spin-induced multipole-based tests.

Presenter: KRISHNENDU, N.V. (International Centre for Theoretical Sciences)

Session Classification: Beyond GR & ECO

Contribution ID: 22

Type: **not specified**

discussion

Thursday, 21 September 2023 17:10 (1 hour)

Presenters: YUNES, Nico (University of Illinois at Urbana-Champaign); PANI, Paolo (Sapienza University)

Session Classification: Beyond GR & ECO