Atelier API ”Ondes gravitationnelles et objets compacts”

mardi 8 octobre 2024 - jeudi 10 octobre 2024

Observatoire de Paris - site de Meudon

Recueil des résumés

Contents

Contributed talks / **1**

Revisiting 2PN Hamiltonian mechanics of binary black holes

Auteurs: Laura Bernard[1]; Manuel Alva Morales[2]; Sashwat Tanay[1]; Tom Colin[1]

[1] *LUTH, Paris Observatory*

[2] *Trujillo Natl. U.*

Accurate modeling of binary black hole (BBH) dynamics is crucial for the detection of gravitational waves emitted by them. We focus on the so-called "orbit-averaged" spinning BBH system at the second post-Newtonian (PN) order. We discover that it is a Hamiltonian system and we present its Hamiltonian. We then establish that it is an integrable system (one that possesses action-angle variables (AAVs)) owing to the already-known constants of motion. We then construct its AAVs and hence its AAV-based solution. Using these AAVs, we locate some of its separatrices and resonances. Additionally, for the non-integrable 2PN system (without any orbit-averaging), we construct the solution for the magnitude of the position vector of the black holes in the so-called quasi-Keplerian spirit, despite the non-integrability of the system.

Contributed talks / **2**

Relativistic effects on the orbits of the closest stars to the black hole at the center of the Galaxy

Auteur: Karim Abd El Dayem[1]

[1] *Observatoire de Paris (LESIA)*

Auteur correspondant karim.abdeldayem@obspm.fr

In this presentation, we investigate the detection of the spin and quadrupole moment of the black hole at the center of the galaxy called Sgr A. *These parameters affect the astrometric and spectroscopic observations of stars in the close vicinity of the black hole (S stars). Here, we consider putative stars that are closer to Sgr A*, and thus much more affected by the spin effects. Such stars might exist if they are too faint to have been already detected by GRAVITY. It is possible that either future observations of this instrument, or of its update GRAVITY+ that is under development, might detect such faint inner stars. In order to reach our objectives, we use different relativistic models in order to generate the orbit of S stars and analyze how they can be affected by the spin and quadrupole moment of Sgr A*. This, allows us to study the detectability of these quantities enabling us to test the no-hair theorem and thus general relativity.

Contributed talks / **3**

EFT-based methods for classical gravity

Auteur: Stavros Mougiakakos[1]

[1] *LUTH, Observatoire de Paris, Meudon*

Auteur correspondant stavros.mougiakakos@obspm.fr

In this talk, we will review applications of EFT approaches in perturbative analytical approaches in GR. Specifically, we will discuss the Post-Newtonian (PN) and the Post-Minkowskian (PM) world-line Effective Field Theory (EFT) formalisms. Finally, we will discuss possible avenues towards the application of these methods in the Self-Force expansion based on recent work.

Contributed talks / 4

ET-WST synergy for next generation gravitational wave multi-messenger observations

Auteurs: Sofia Bisero[1]; Susanna Vergani[1]; Marica Branchesi[2]; Eleonora Loffredo[2]; Nandini Hazra[2]; Ulyana Dupletsa[2]

[1] *GEPI, Observatoire de Paris, Université PSL, CNRS*

[2] *Gran Sasso Science Institute*

Auteur correspondant sofia.bisero@obspm.fr

The Einstein Telescope (ET), next generation gravitational wave (GW) interferometer, will explore a large volume of the Universe detecting up to ~ 10^5 binary neutron star system mergers (BNS) beyond z ~ 3, clearly revolutionizing GW multi-messenger (MM) astrophysics. Given the huge amount of EM counterpart candidates that will be provided by optical-NIR photometric observations within the large GW signal error regions, the bottleneck of GW MM science will be to gather the spectroscopic data required to discriminate against counterpart candidates, identifying and characterizing them. New observational strategies will be necessary and they have to be prepared well in advance of ET operations.
I will present the results of the simulations I carried out within the Wide-Field Spectroscopic Telescope science team and the MM Division of the ET Observational Science Board to assess the impact of next generation Integral Field and Multi-Object Spectroscopy (IFS and MOS) on the detection, identification and characterisation of EM counterparts of ET BNS. I will also give an estimate of the number of galaxies that can be found within the error volume of ET BNS detections, with a view to perform a galaxy-targeted research with WST IFS and MOS.

Contributed talks / 5

Hamiltonian normal forms for the post-Newtonian binary problem

Auteur: Christopher Aykroyd[1]

Co-auteurs: Adrien Bourgoin [1]; Christophe Le Poncin-Lafitte [1]

[1] *SYRTE, Observatoire de Paris*

Auteur correspondant christopher.aykroyd@obspm.fr

Since their onset, post-Newtonian schemes have been consistently effective in describing binary orbits, achieving progressively higher order expansions. Their aim is to essentially produce 'matter-only' equations of motion by elimination of the metric degrees of freedom. In the ADM framework, this corresponds to the computation of a matter-only Hamiltonian.
Yet despite these advancements, systematical tools for analytically solving the resulting equations often lag behind, and ad-hoc methods are frequently limited to secular or (quasi-)circular approximations. In this talk, I will describe a structural approach for solving the matter-only equations of motion of a perturbed two-body system in a canonical formalism using Lie series. This framework allows a comprehensive analytical description of the orbital evolution in coordinate-time, including both secular and oscillatory contributions, thereby complementing traditional methods. I will derive parametric generator solutions for typical Hamiltonian terms, including local conservative PN contributions and a certain class of non-gravitational perturbations. As an application, I will reproduce established 2PN results and expand on existing Hamilton-Jacobi solutions to incorporate short-term oscillations. Future research will extend this framework to include non-conservative forces and spin dynamics.

Contributed talks / **6**

Binary neutron star mergers in massive scalar-tensor theory: post-merger properties and gravitational wave signature

Auteur: Alan Tsz Lok Lam[1]

Co-auteurs: Hao-Jui Kuan ; Kenta Kiuchi [1]; Masaru Shibata [1]

[1] *Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam*

Auteur correspondant tszlok.lam@aei.mpg.de

We study binary neutron stars in the framework of Damour-Esposito-Farese-type scalar-tensor theory of gravity with a massive scalar field using numerical relativity simulations, focusing on the properties of post-merger remnant. We found that the threshold mass for prompt collapse is raised in the presence of the excited scalar field. Our simulation results also suggest the existence of long-lived ϕ–mode in hypermassive neutron stars due to the presence of the massive scalar field which enhances the quasi-radial oscillation in the remnant. We investigate the descalarization condition in hypermassive neutron stars and discover a distinctive signature in post-merger gravitational waves.

Contributed talks / **7**

On the finite-size imprints on waveforms of binary neutron star mergers

Auteur: Hao-Jui Kuan[None]

Co-auteurs: Alan Tsz Lok Lam [1]; Kenta Kiuchi [2]; Masaru Shibata [2]

[1] *Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam*

[2] *Max Planck Institute for Gravitational Physics*

Auteur correspondant hao-jui.kuan@aei.mpg.de

Gravitational waves provide a pure probe for fundamental physics that manifests in coalescing binaries, supplementing the electromagnetic counterparts to form multimessenger signals. Precise measurement of waveforms can help us learn about the yet-fully-explored tidal response of neutron stars in late inspiral stages and about effects beyond general relativity (GR). In particular, the waveform of GW170817 has yielded certain constraints on the nuclear equation of state and the tolerance of non-standard gravitational models. However, the waveform detected in that event is only up to 500 Hz or so, and thus, future observation of higher-frequency bands is promising to further our understanding of these two aspects. In this talk, I will discuss how the tidally-excited fundamental mode of neutron stars may affect the late-time binary waveform by using a harmonic model for dynamic tides and a post-Newtonian treatment of orbital motion. In addition, I will also discuss the imprints of non-GR effects while focusing on massive scalar-tensor theories. Since we are interested in high scalar masses, such effects can only be noticeable in the band of several hundred Hz, for which a numerical survey is a unique way to model it. As a first step, we construct quasi-equilibrium sequences of binary neutron stars to estimate the size of scalar effects for different theory parameters.

Contributed talks / **8**

Constraint the mass of boson clouds at the Galactic Center

Auteur: Arianna Foschi[1]

[1] *Observatoire de Meudon*

Auteur correspondant arianna.foschi@tecnico.ulisboa.pt

The motion of S2, one of the stars closest to the Galactic Center (GC), has been measured accurately and used to study the compact object at the centre of the Milky Way. It is commonly accepted that this object is a supermassive black hole but the nature of its environment is open to discussion. In this talk I'm going to show how the motion of S2 can be used to investigate the possibility that dark matter in the form of an ultralight scalar field "cloud" clusters around SgrA*. I will present some previous results on mass distribution at the GC, explain the theoretical setup, the tools used to fit the available data and finally the results and the constrains we can get from the Galactic Center on the mass of both scalar and vector clouds.

Contributed talks / **9**

Tidal contributions to the gravitational waveform amplitude to the second-and-a-half post-newtonian order

Auteur: Eve Dones[1]

[1] *LUTH - Observatoire de Paris*

Auteur correspondant eve.dones@obspm.fr

The study of tidal effects between compact objects such as neutron stars is particularly promising to better understand their physics. Including these effects in our waveform models could allow us to probe their internal structure, but also possibly to distinguish signals coming from black holes, neutron stars or even more exotic objects. This will be of paramount importance when interpreting the multiple signals expected with the arrival of third-generation gravitational wave detectors.
The tidal interaction affects both the dynamics and the gravitational wave emission processes of compacts binaries resulting in a change in the orbital phase and the gravitational wave amplitude that are directly observable.
In this talk, I will present how we completed the computation of gravitational-waveform amplitude modes using the the post-Newtonian-multipolar-post-Minkowskian formalism and wrote them in form suitable for effective-one-body template building.

Contributed talks / **10**

Initial data for binary systems

Auteur: Philippe Grandclément[1]

[1] *LUTH*

Numerical relativity enables to simulate the full coalescence of binary compact objects. Using appropriate initial data for such evolutions is crucial. This is not an easy task: not only should those data describe as accurately as possible the physical situation one wishes to simulate, but they also must verify a subset of Einstein's equations known as the constraint equations. I will adopt an historical approach, and move my way through the decade long history of the initial value problem in general relativity, starting from the original work of Misner, Brill and Lindquist in the 60s to the state-of-the-art, currently used, refined data.

Engrenage / **11**

Hands-on session on the Engrenage code.

Auteur: Katy Clough[None]

Engrenage is a spherically symmetric BSSN code designed for teaching Numerical Relativity (NR), which is the solution of the Einstein Equations of General Relativity (GR) using numerical methods. The code includes a scalar field (obeying the Klein Gordon equation for a minimally coupled spin 0 field) as the matter source of the metric curvature. It currently includes two physical examples - a black hole and a real scalar boson star (or oscillaton).

Invited talks / **12**

Nonlinear dynamics of compact object mergers beyond General Relativity

Auteur: Maxence Corman[None]

In recent years, gravitational wave observations of compact objects have provided new opportunities to test our understanding of gravity in the strong-field,highly dynamical regime. To perform model-dependent tests of General Relativity with these observations, one needs accurate inspiral-merger-ringdown waveforms in alternative theories of gravity.
In this talk, we consider two generally applicable, but approximate methods for treating modifications to full general relativity that have been used to study binary black hole mergers and other phenomena in this regime, and compare solutions obtained by them to those from solving the full equations of motion. We use shift-symmetric Einstein-scalar-Gauss-Bonnet gravity as a benchmark theory to illustrate the differences between these methods for several spacetimes of physical interest. We will also discuss the nonlinear dynamics of black hole-neutron star binaries which have the potential to place strong constraints on modifications to general relativity that arise at small curvature length scales.

Invited talks / **13**

Exploring collapsar scenarios in numerical relativity

Auteur: Masaru Shibata[None]

By performing longterm magneto/viscous radiation hydrodynamics simulations in general relativity for the collapse of rapidly rotating massive stars, we explore the collapsar scenarios. I will first show that stellar explosion with the explosion energy of 10^51—10^52 erg can be induced even after the formation of a black hole if a massive torus surrounding the black hole, which becomes the engine of the energy injection, is formed. I then show results of magnetohydrodynamics simulations and a condition for jet generation during the stellar collapse via the Blandford-Znajek mechanism. An issue of this jet generation mechanism, over-energy production problem, is pointed out and then I suggest an acceptable scenario.

Contributed talks / **14**

The Gravitation team at APC

Auteur: Quentin Baghi[1]

[1] *APC | Université Paris Cité*

Auteur correspondant baghi@apc.in2p3.fr

TBA

Contributed talks / **15**

TBA

Auteur: Kumeet Kulkarni[None]

TBA

Engrenage / **18**

Hands-on session on the Engrenage code.

Auteur: Katy Clough[None]

Engrenage is a spherically symmetric BSSN code designed for teaching Numerical Relativity (NR), which is the solution of the Einstein Equations of General Relativity (GR) using numerical methods. The code includes a scalar field (obeying the Klein Gordon equation for a minimally coupled spin 0 field) as the matter source of the metric curvature. It currently includes two physical examples - a black hole and a real scalar boson star (or oscillaton).

Contributed talks / **19**

Opening remarks

Auteur correspondant laura.bernard@obspm.fr

Contributed talks / **20**

Concluding remarks and flash talks