Atelier API ”Ondes gravitationnelles et objets compacts”

mercredi 10 décembre 2025 - vendredi 12 décembre 2025

Observatoire de Paris - site de Meudon

Recueil des résumés

Contents

Contributed talks / 1

From the accretion processes to the electromagnetic signatures of supermassive binary black holes

Auteur: Raphaël Mignon-Risse[1]

Co-auteurs: Peggy Varniere [2]; Fabien Casse [3]

[1] *CNRS/LAM*

[2] *CNRS/APC*

[3] *U. Paris Cité/APC*

Despite the re-birth of multi-messenger astronomy, no unambiguous electromagnetic (EM) counterpart to binary black hole (BBH) pre-/post-merger has been reported. Indeed, stellar-mass BBHs are expected to be gas-poor ; however, this should not be the case of supermassive BBHs, whose GWs will be detectable with LISA (2035+). Detecting the EM pre-merger counterpart would allow for optimal follow-up. Nonetheless, the accretion properties onto BBHs and the related EM signatures are not firmly identified because, until recently, very few numerical codes were able to model accretion and emission around BBHs in General Relativity (GR).

The picture has evolved in the last few years. In this talk, I will present results obtained with e-NOVAs ("extended Numerical Observatory for Violent Accreting systems"; Varniere+18), a GR-magnetohydrodynamical (Casse+17) + GR ray-tracing code (Vincent+11) recently extended to dynamical spacetimes and now incorporating analytical BBH spacetimes. I will study the circumbinary disk evolution and its EM observables, emphasizing the various plausible sources of variability and the contribution from relativistic effects: those could be the smoking-guns of BBHs. Finally, I will mention on-going developments of e-NOVAs allowing us to address the robustness of other, complementary EM signatures associated with the BH's individual disks.

Contributed talks / 2

Beyond circles: stationary axisymmetric black holes and the breaking of circularity

Auteur: Jacopo MAZZA[1]

[1] *IJCLab*

Circularity is an accidental symmetry of the Kerr metric, one that is widely assumed when searching for rotating black hole solutions in modified gravity as well as when constructing models of Kerr mimickers. Though extremely enticing, circularity is often an excessively restrictive assumption, and understanding the consequences of its loss is thus crucially relevant. In this seminar, I wish to present some recent results on the subject: After describing in detail what this symmetry entails, I will show how to construct stationary and axisymmetric spacetimes exhibiting a controlled breaking of circularity; then, I will describe the impact of circularity breaking on the hole's horizon, focusing in particular on the laws of black hole mechanics. This discussion is thus going to be pertinent for anyone with an interest in compact astrophysical objects and their phenomenology, in general relativity and beyond.

Contributed talks / 3

The Supermassive Black Hole Binary Candidate 3C 66A

Auteurs: Jeong-Uk Kim[1]; Paloma Thevenet[2]

Co-auteurs: Bong Won Sohn [3]; Guang-Yao Zhao [4]; Suk-Jin Yoon [5]

[1] *Yonsei University, KASI*

[2] *Observatoire de Paris*

[3] *KASI*

[4] *MPIfRA*

[5] *Yonsei University*

The blazar 3C 66A is known for its optical flux periodicity and complex jet kinematics. Using 22/43 GHz KaVa (KVN and VERA array) observations and 43 GHz VLBA (Very Long Baseline Array) archival data, we have found that its pc-scale jet has a twisted structure and that the inner jet undergoes periodic swings every 13 years. In this talk, we will describe the peculiar characteristics of 3C 66A and delve into possible interpretation scenarios. The multiwavelength flux variability and jet orientation changes hint at a supermassive black hole binary (SMBHB) in which orbital motion and disk-orbit misalignment lead to jet precession. However, combinations of other mechanisms such as Lense-Thirring disk precession and jet instabilities could also account for the properties of 3C 66A, underscoring the challenge in robust SMBHB candidate identification.

Contributed talks / 4

Detectability of the spin parameters of SgrA* using multiple S stars

Auteur: Karim Abd El Dayem[1]

[1] *Observatoire de Paris (LESIA)*

Context. The orbits of S stars around the Galactic Center black hole, Sgr A, *offer a unique opportunity to probe the relativistic regime of gravity and test the no-hair theorem. While the Schwarzschild precession has been detected with S2, the detection of spin-induced (Kerr) effects—Lense–Thirring and quadrupole moment terms—remains a major observational challenge.*
Aims. We aim to quantify the time needed to detect the spin parameters of Sgr A—magnitude and orientation—by exploiting astrometric and spectroscopic monitoring of multiple S stars with current (GRAVITY+, ERIS) and future facilities (MICADO).
Methods. Using the post-Newtonian integrator, we simulate long-term astrometric observations of individual and combined S-star systems, including S2, S29, S38 and S55, and the recently discovered S301. We quantify spin detectability through $\chi 2$ minimization and forecast the evolution of spin-parameter uncertainties over the coming decades.
Results. We show that S301 has spin sensitivity comparable to a star identical to S2 but ten-times closer to Sgr A, *and that combining its data with those of other stars of diverse orientations (S2, S29, S38, S55) reduces parameter degeneracies and accelerates spin*
detection. Quantitative forecasts indicate that the spin magnitude can be constrained to $\sigma\chi$ ⊠ *0.1 by 2032, 0.05 by 2034, and 0.03 by 2036 when only fitting the spin magnitude* χ*, with comparable results when fitting all spin parameters. Astrometry provides the dominant leverage, while spectroscopy adds substantial value only if radial-velocity precision reaches 2 km/s, as expected with MICADO. Overall, spin detectability is robust given sufficient monitoring and knowledge of orbital parameters. The black hole orientation is a critical factor, along with multi-star, multi-instrument datasets, which together offer the most promising path forward.*
Conclusions. The joint monitoring of multiple S stars with GRAVITY+ and MICADO will enable robust measurement of the spin of Sgr A within the next decade. Astrometry remains indispensable for achieving this goal, while high-precision spectroscopy will serve as a critical complement once the required velocity accuracy is reached.

Contributed talks / 5

Slowly rotating black holes in scalar-tensor theories of gravity

Auteur: Hugo Candan[1]

[1] *LUTH, Observatoire de Paris PSL & IJCLab, Université Paris-Saclay*

We are entering an era of high-precision measurements of black holes, either through gravitational waves (LVK, and soon LISA) or direct imaging (EHT). It is therefore interesting to study black hole spacetimes within both General Relativity (GR) and alternative theories, to confront them with observations. In GR, the Kerr spacetime, which describes rotating black holes, is the most general astrophysically relevant solution. However, in modified gravity theories, very few rotating solutions are known, even though real black holes always possess non-zero spin. Finding exact rotating solutions is known to be a very complicated task, but approximate analytical solutions can be obtained in the slow-rotation regime. Here, we present a general method to compute first-order slowly rotating black holes in a class of modified theories of gravity.

Review talk / 6

Overview of the post-Newtonian formalism

Auteur: David Trestini[1]

[1] *University of Southampton*

In this talk, I will give an overview of the Blanchet-Damour formalism for post-Newtonian waveforms. I will cover the treatment of motion, radiation, and radiation reaction.

Contributed talks / 7

Dynamics of Spinning, Eccentric Binary Black Holes at Second Post-Newtonian Order

Auteurs: Laura Bernard[1]; Sashwat Tanay[1]; Tom Colin[1]

[1] *LUX*

We present an analytical solution for the dynamics of spinning binary black holes on eccentric orbits at second post-Newtonian (2PN) order, extending the 1.5PN results of Cho and Lee. For the orbital angular momentum **L** and the individual spins **S1** and **S2**, we exploit the separation of timescales between orbital motion and precession to construct a hybrid solution that combines the 1.5PN oscillatory structure with complete 2PN secular corrections. For the orbital variables (r, φ), we derive their equations of motion and, using an ansatz method analog to Klein, construct a quasi-Keplerian parametric solution. This parametrization introduces generalized Keplerian elements that remain approximately constant over orbital timescales while incorporating 2PN spin-spin corrections.

Contributed talks / 8

Multi-messenger observations of binary neutron star mergers: synergies between the next generation gravitational wave interferometers and wide-field, high-multiplex spectroscopic facilities

Auteurs: Sofia Bisero[1]; Susanna Vergani[2]; Eleonora Loffredo[3]; Marica Branchesi[4]; Nandini Hazra[5]; Ulyana Dupletsa[6]

[1] *IRFU, CEA Paris-Saclay*

[2] *LUX, Observatoire de Paris, Université PSL, Sorbonne Université, CNRS, 92190 Meudon, France*

[3] *INAF –Osservatorio Astronomico d'Abruzzo, 64100 Teramo, Italy*

[4] *Gran Sasso Science Institute (GSSI), I-67100 L'Aquila, Italy*

[5] *National Centre for Nuclear Research, Pasteura 7, PL-02-093 Warsaw, Poland*

[6] *Institute of High Energy Physics - Austrian Academy of Sciences, 1010 Vienna, Austria*

Next generation gravitational wave (GW) interferometers such as the Einstein Telescope (ET) will explore a significantly larger volume of the Universe, detecting up to 10^5 binary neutron star system mergers (BNS) per year beyond the Local Universe. Identifying the faint optical-NIR electromagnetic (EM) counterparts of these GW signals within vast sky localization regions, among a huge number of contaminants, will be highly challenging. Spectroscopy, the definitive tool to identify and characterise EM counterparts, is likely to become the bottleneck of GW MM science. New observational strategies will be necessary and they have to be prepared well in advance of ET operations.
I will present the latest results of the simulations I carried out within the Division 4 of the ET Observational Science Board and the Time Domain Working group of the Wide-field Spectroscopic Telescope (WST) science team to assess the impact of next generation Integral Field and Multi-Object Spectroscopy (IFS and MOS) on the detection, identification and characterization of EM counterparts of ET BNS. I will discuss possible observing strategies, provide estimates of the number of galaxies within the GW error volume, and outline key observational challenges together with the potential mitigation strategies.

Contributed talks / 9

Results and current activities of the Multimessenger observations Division of the Einstein Telescope Observing Science Board

Auteur: Susanna Diana VERGANI[1]

[1] *CNRS-Observatoire de Paris*

Results of the Multimessenger observations Division of the Einstein Telescope Observing Science Board

The Einstein Telescope is the European Next Generation gravitational wave (GW) interferometer. Despite the fact that it will be operational from the late 2030's, its revolutionary capabilities require that the preparation of the multimessenger follow-up of the GW events (in terms of useful observing strategies and facilities) must be started well in advance.
As a co-coordinator of this Division, in this talk I will present the current activities of the Division as well as the results of the work that we carried out for the Einstein Telescope Blue Book, with the predictions of the characteristics of the GW electromagnetic (EM) counterparts from the gamma-rays to the radio domain, as well as the requirements for their detections that should drive the development of new EM facilities and the use of the current ones.

Contributed talks / 10

The SVOM Core Program : first results

Auteur: Susanna Diana VERGANI[1]

[1] *CNRS-Observatoire de Paris*

SVOM (Space-based multi-band astronomical Variable Objects Monitor) is a Sino-French mission launched in June 2024. Its Core Program is dedicated to the detection and study of Gamma-Ray Bursts (GRBs). I will show how the set of SVOM instruments as well as the observing strategy compare with previous mission, present the first results and show the new questions they are opening on the study of GRBs.

Contributed talks / **11**

Gravitational scattering of solitonic boson stars: Analytics vs Numerics

Auteurs: Tamanna Jain[1]; Thibault Damour[2]; Ulrich Sperhake[3]

[1] *LPENS*

[2] *IHES, Paris*

[3] *DAMTP, Cambridge*

We study the scattering of boson-star binaries, taking into account three effects: point-mass gravitational, tidal, and short-range scalar-field interactions. We compare analytic results to the scattering angle extracted from four sequences of numerical-relativity simulations at fixed energy and varying impact parameter. The very good agreement exhibits the attractive (repulsive) effect of in-phase (out-of-phase) binaries. For small impact parameters, where the stars approach more closely before separating to infinity, the short-range scalar-field interaction is found to dominate.

Review talk / **12**

Measuring the cosmic expansion rate with gravitational wave "dark sirens": prospects and challenges

Auteur: Sayantani BERA[1]

[1] *CPT, Aix-Marseille University*

The measurement of the current expansion rate of the Universe, known as the Hubble constant (H0), has garnered significant interest lately, owing to the vastly different estimates obtained when probing different cosmological epochs. In particular, high-redshift measurements of the cosmic microwave background and the local low-redshift measurements using supernovae are statistically inconsistent with each other, giving rise to the unresolved discrepancy commonly known as the "Hubble Tension". Gravitational waves emitted by merging compact binaries, detected routinely nowadays, offer a unique way to measure cosmological distances across different redshift epochs. If their redshifts can be determined independently, there is a prospect of measuring H0 directly with such sources by leveraging the distance-redshift relation. In this talk, I will discuss how redshifts are statistically inferred for events without an associated electromagnetic counterpart, the so-called dark sirens, which constitute the majority of detections by the LIGO-Virgo-KAGRA detector network. I will review the latest cosmological results from the GWTC-4.0 public gravitational wave transient catalog focusing on the methods employed, their limitations and future challenges for dark siren cosmology.

Review talk / **13**

Unveiling the equation of state of dense matter

Auteur: Lami Suleiman[1]

[1] *Deutsches Elektronen Synchrotron*

Observations of neutron stars can expand our understanding of strong interaction and help us explore the properties of dense matter in thermodynamic conditions unreachable in laboratories on Earth. In this overview, we discuss the field of extremely dense matter and particularly how gravitational waves combined with other astrophysical detections can constrain the equation of state of dense and neutron-rich matter. We expand on the techniques used to do so, the caveats and various approximations they rely on, and finally comment on the prospects for dense matter exploration with future detections.

Contributed talks / **14**

Testing planar matter distributions at the GC

Auteurs: Arianna Foschi[1]; Frederic Vincent[None]; Guy Perrin[None]; Thibaut Paumard[None]

[1] *Observatoire de Meudon*

The surroundings of the supermassive black hole at the center of our galaxy, Sagittarius A*, are mostly unknown and for this reason many studies have tried to constrain the presence of an extended mass around it, with the aim of simulating either dark matter distribution or stellar clusters. However, all these works focus on spherically symmetric distributions of matter, while observations suggest that matter clusters in disks or rings around compact objects. In this talk I will present our findings regarding the effect that a planar distribution of matter will have on S-stars, compared to the spherically symmetric case. The final aim is to show whether the current upper limit on the extended mass around SgrA* obtained by GRAVITY changes when a disk of matter is considered.

Contributed talks / **15**

Dynamical tidal response of Schwarzschild black holes

Auteurs: Austin Joyce[1]; Daniel Glazer[1]; Luca Santoni[2]; Maria Rodriguez[3]; Oscar Combaluzier–Szteinsznaider[4]

[1] *Chicago University*

[2] *APC-CNRS*

[3] *Utah State University*

[4] *APC (Astroparticules et Cosmologie)*

The response of a black hole to an external tidal field is encapsulated in the so-called Love numbers. While these are well known in the context of static and linear perturbations, future developments of gravitational-wave astronomy will require more precise results, taking subleading effects into account.

In the talk, I will show how to compute the response of a Schwarzschild black hole to a time-dependent external tidal gravitational field, up to second-order in frequency, using the framework of the point-particle effective field theory (EFT). In addition to the known logarithmic running of the dynamical Love numbers, I will present the derivation of the scheme-dependent finite terms.

The result is obtained by matching the renormalized one-point function in the EFT to the solution of the linearized Einstein equations in general relativity. On the general-relativistic side, the linearized equations of motion are solved perturbatively in a small-frequency expansion, while, on the EFT side, we include gravitational interactions and employ dimensional regularization to obtain a renormalized solution.

Review talk / 16

Gravitational waves from Numerical relativity

Auteur: Santiago Jaraba[1]

[1] *Observatoire astronomique de Strasbourg - CNRS*

Numerical relativity (NR) provides the most accurate description of compact binary coalescences and other strong-field phenomena producing gravitational waves (GW). In this talk, I will review the history, main formalisms and current status of NR waveform generation. We will begin with binary black holes, discussing general aspects including GW extraction, as well as addressing current challenges in the field (high mass ratios, eccentricity, spin effects) and other frontier topics such as hyperbolic encounters and dynamical captures. We will then turn to systems involving neutron stars, covering tidal effects, post-merger signatures and their relevance for dense matter equations of state. The talk will conclude with an outlook on the role of NR in the era of next-generation GW detectors.

17

Welcome and API review

Co-auteurs: Frederic Vincent [1]; Laura Bernard [2]

[1] *Observatoire de Paris / LESIA*

[2] *LUX - CNRS / Observatoire de Paris-PSL*

Review talk / 18

On the Kerr magnetosphere models and the motion of charged particles: the role of symmetries

Auteur: Jibril BEN ACHOUR[1]

[1] *ENS de Lyon / Arnold Sommerfeld Center (Munich)*

Black holes accrete and eject matter, giving rise to a complicated spectral signature which rise several open questions (low quiescent luminosity, mechanism supporting the emitted jets). They are known to provide a large reservoir of accessible (rotational) energy allowing to accelerated charged particles at very high energy through various mechanisms. In all these processes, the electromagnetic field supported by the rotating black hole plays a major role. In this talk, I will review the most simple models of magnetospheres around the Kerr black hole. In particular, I will explain how the (hidden) symmetries known as the Killing tower of the Kerr geometry naturally encodes some of the allowed electromagnetic vacuum configurations. In particular, I will review the Carter and the Wald construction to describe the magnetosphere and discuss the property of the non-linear rotating Michel solution. Then, I will discuss the status of the motion of the charged particles in

these magnetosphere models. A interesting target is to obtain an analytic form for the acceleration of charged particles, which is possible only under certain circumstances. I will review the condition under which this can be achieved and discuss possible interesting applications to understand the jets structure and high energy emission.

Review talk / **19**

Making sense of LISA data

LISA is a signal-dominated instrument that will observe thousands of sources, from binaries in our galaxy to massive black hole binaries at very high redshift. However, the same aspect that makes LISA data so rich also makes it difficult to analyse. I will discuss the challenges that LISA data analysis poses and the ways we can overcome them. In particular, I will focus on two aspects: the global fit, including how we approach parameter estimation for galactic binaries and its difficulties; and low-latency parameter estimation for massive black hole binaries, which is important for electromagnetic follow-ups.