Curriculum Vitae

INFORMATION PERSONNELLES

Nom de Famille, prénom: BLANCHET, Luc
Identifiant ORCID https://orcid.org/0000-0003-1142-9534
Date de naissance: 3 Janvier 1956
Nationalité: Française
Site web: http://www2.iap.fr/users/blanchet/

ÉTUDES ET DIPLÔMES

1990 : Thèse d'Habilitation, *Contribution à l'étude du rayonnement gravitationnel émis par un système isolé*, Université Pierre et Marie Curie

1984 : Thèse de Doctorat, Etude de la *structure des champs gravitationnels radiatifs et de leurs couplages avec les sources matérielles (directeur de thèse*: Thibault Damour), Université Pierre et Marie Curie

1982 : Diplôme d'études approfondies en Physique Théorique, Université Pierre et Marie Curie (Paris VI)

1981 : Diplôme d'études approfondies en Astrophysique, Université Denis Diderot (Paris VII)

1980 : Diplôme d'ingénieur de l'École Polytechnique, Paris

POSITION ACTUELLE

depuis 2023 Directeur de Recherche émérite

2017 – 2023 Directeur de Recherche classe exceptionnelle (DRCE)
Centre National de la Recherche Scientifique (CNRS)
Groupe de Gravitation et Cosmologie (GReCO),
Institut d'Astrophysique de Paris,
98 bis boulevard Arago, 75014 Paris, France

POSITIONS PRÉCÉDENTES

2008 – 2017 Directeur de Recherche CNRS (1ère classe)
GReCO, Institut d'Astrophysique de Paris

1999 – 2008 Directeur de Recherche (2ème classe)
GReCO, Institut d'Astrophysique de Paris

1990 – 1999 Chargé de Recherche (1ère classe)
DARC, Observatoire de Paris-Meudon,

1989 – 1990 Ingénieur Recherche & Developpement (en détachement du CNRS)[1]
Société Européenne de Propulsion, Vernon, France

1985 – 1989 Chargé de Recherche (2ème classe)
Département d'Astrophysique Relativiste et Cosmologie (DARC)
Observatoire de Paris-Meudon

1984 – 1985 Post-Doctorant, California Institute of Technology,
Theoretical Astrophysics Including Relativity (TAPIR),
Los Angeles, États-Unis

ENCADREMENT DE DOCTORANTS ET POST-DOCTORANTS

Doctorants

1997 – 1999 : Guillaume Faye,[2] *Equations du mouvement des binaires compacts en relativité générale*
1999 – 2001 : Philippe Canitrot, *Analyse du signal d'ondes gravitationnelles dans le détecteur VIRGO*

---

1 Cette activité a été évaluée par la commission interdisciplinaire de valorisation de la recherche du C.N.R.S. en 1991.
2 Guillaume Faye est chercheur permanent au C.N.R.S. (Physique Théorique) depuis 2004.

2000 – 2002 : Olivier Poujade,[3] *Itération post-Newtonienne du champ intérieur d'un système isolé*
2002 – 2006 : Samaya Nissanke,[4] *Effets de réaction de rayonnement dans la dynamique des binaires de TN*
2007 – 2010 : Alexandre Le Tiec,[5] *Approximation de limite proche pour la coalescence de trous noirs*
2010 – 2013 : Sylvain Marsat[6], *Effets de spins dans la dynamique et la radiation des binaires compactes*
2013 – 2016 : Laura Bernard,[7] *Quelques aspects phénoménologiques de la RG et de ses extensions*
2015 – 2018 : Tanguy Marchand, *Ondes gravitationnelles des binaires compactes et modèles alternatifs*
2018 – 2021 : François Larrouturou, *Champ gravitationnel des binaires compactes à un ordre PN élevé*
2018 – 2021 : Quentin Henry, *Effets de structure interne dans la dynamique des binaires d'étoiles à neutrons*
depuis 2020 : David Trestini, *Ondes gravitationnelles en théorie Tenseur-Scalaire*

Post-Doctorants
2013 – 2016 : Alejandro Bohé,[8] *Equations du mouvement des binaires au 4ème ordre post-Newtonien*

ENSEIGNEMENT

Universités et institutions françaises
1986 – 1989 : Travaux dirigés de relativité générale, Master de physique théorique (Paris VI)
1988 – 1989 : Cours d'introduction à la relativité générale, Master champs/particules (Université d'Orsay)
1993 – 1999 : Cours d'introduction à la relativité générale, Master d'astrophysique (Paris VII)
2000 – 2003 : Cours de gravitation newtonienne, École doctorale d'astrophysique (Paris VI et Paris VII)
2003 – 2005 : Cours d'électromagnétisne maxwellien, Sciences de la terre et de l'espace (Paris VII)
2006 – 2007 : Cours de relativité générale, Master de Physique (Université d'Orsay)
2003 – 2013 : Cours de relativité générale, Master de l'École Normale Supérieure (Paris)
2015 : Cours de relativité générale avancée, École doctorale de physique théorique (Paris)
2017 : Cours sur les ondes gravitationnelles, CEA–Saclay
2016 – 2020 : Nombreuses présentations didactiques sur la détection et l'analyse des ondes gravitationnelles par les expériences LIGO et VIRGO

Ecoles de physique internationales
1995 : École de physique des Houches, France, *Relativistic gravitation and gravitational radiation*
1999 : Como school of Physics, Italy, *Gravitational waves*
2001 : Bad Honnef international school of Physics, Germany, *Gravity experiments in space*
2003 : École de physique de Cargèse, France, *Black holes in Astrophysics*
2006 : Institut Henri Poincaré, France, *Gravitational waves, relativistic astrophysics and cosmology*
2008 : École thématique du CNRS, Orléans, France, *Mass and motion in General Relativity*
2013 : VIRGO-EGO Physics school, Rome, Italy, *Gravitational waves – theory and experiments*
2014 : General Relativity @ 99, Bad Honnef, Germany, *Analytical approximation methods in GR*
2017 : School on Gravitational Waves for Cosmology and Astrophysics, Benasque, Spain, *GW theory*
2017 : École de physique des particules, Gif-sur-Yvette, France, *GR and modified gravitation*
2017 : Mini-school on gravitational waves, ULB, Brussels, *Analytical methods for gravitational waves*
2018 : The dawn of Gravitational Astronomy, Sao Paulo, Brazil, *Introduction to Post-Newtonian theory*
2018 : Mexican school on Mathematical Physics, Cancun, *Post-Newtonian analysis of gravitational waves*
2019 : YITP Asian-Pacific Winter School, Kyoto, Japan, *Perturbative methods in GR*
2019 : ICTS School on Gravitational Astrophysics, Bangalore, India, *Introduction to Gravitational waves*
2019 : School on Gravitational Astrophysics, Bad Honnef, Germany, *Post-Newtonian theory*
2020 : Institut Henri Poincaré, France, *Gravitational Waves: a New Messenger to Explore the Universe*
2021 : Galileo Galilei Institute, Italie, *Gravitational Scattering, Inspiral, and Radiation*
2021 : CIRM, Marseille, *Theory of Gravitation and Variation in Cosmology*

---

3 Olivier Poujade est ingénieur de recherche au C.E.A. depuis 2004.
4 Samaya Nissanke est professeur d'Astronomie à l'université d'Amsterdam depuis 2012.
5 Alexandre Le Tiec est chercheur permanent au C.N.R.S. (Astrophysique) depuis 2013.
6 Sylvain Marsat est chercheur permanent au C.N.R.S. (Physique des Particules) depuis 2021.
7 Laura Bernard est chercheuse permanente au C.N.R.S. (Physique Théorique) depuis 2018.
8 Alejandro Bohé est ingénieur au C.N.E.S. depuis 2018.

ORGANISATION DE CONFÉRENCES SCIENTIFIQUES

2012 – 2017 : co-organisateur des conférences *Hot Topics in General Relativity and Gravitation,* Vietnam
2010 – 2021 : co-organisateur du cycle de conferences *Rencontres de Moriond sur la Gravitation*, Italy
2017 : co-organisateur du colloque IAP *The Era of Gravitational Wave Astronomy*, France

SUBVENTIONS

2010 – 2015 Agence Nationale de la Recherche (ANR-10-BLAN-0507)
Alternative Theories for Dark Matter and Dark Energy

PUBLICATIONS

116 articles dans des revues internationales avec comité de lecture, 9 contributions à des livres, 43 articles dans des comptes-rendus de conférences, 6 articles pour le grand public, environ 12000 citations SPIRES, h=62

RESPONSABILITÉS INSTITUTIONNELLES

2004 – 2008 : Membre du conseil d'administration de l'Institut d'Astrophysique de Paris
2004 – 2008 : Membre nommé du comité national du CNRS dans la section Astroparticules
2005 – 2008 : Membre élu du bureau du forum scientifique VIRGO-EGO (VESF)
depuis 2016 : Membre du comité scientifique du GDR du CNRS sur les ondes gravitationnelles

ACTIVITÉS D'EXPERTISE SCIENTIFIQUE

1990 – 1991 : Membre du groupe Théorie de l'expérience STEP
1994 – 1996 : Membre des groupes de travail des expériences PHARAO et ACES
1993 – 2004 : Membre du groupe de Physique Fondamentale du C.N.E.S.
2003 – 2006 : Member of the Fundamental Physics Advisory Group (FPAG) of E.S.A.
2008 – 2016 : Member of the Steering Technical Advisory Committee (STAC) of the VIRGO experiment
2010 – 2020 : Membre du comité scientifique du programme national GRAM du C.N.R.S.
2013 – 2016 : Membre du groupe Théorie de l'expérience STE-QUEST
2013 : Président du comité d'évaluation AERES du laboratoire SYRTE
2013 – 2017 : Président du groupe de Physique Fondamentale du C.N.E.S.

APPARTENANCE À DES SOCIÉTÉS SCIENTIFIQUES

2012 : Membre correspondant du Bureau des Longitudes
depuis 2017 : Membre titulaire du Bureau des Longitudes
2019 : Fellow of the International Society of General Relativity and Gravitation (ISGRG)
depuis 2020 : Vice-président du Bureau des Longitudes

DISTINCTIONS

2002 : *Prix Langevin de Physique* de l'Académie des Sciences
2016 : *Special Breakthrough Prize in Fundamental Physics* pour la détection des ondes gravitationnelles
2018 : *Prix CNES – Astrophysique et Sciences Spatiales* de l'Académie des Sciences
2020 : *Prix Jean Ricard* de la Société Française de Physique
2023 : *Médaille Einstein* de la *Société Albert Einstein* de Berne (Albert-Einstein Gesellschaft – AEG)

RESUMÉ DES TRAVAUX SCIENTIFIQUES[9]

Les travaux scientifiques se répartissent sur trois axes principaux ayant pour dénominateur commun l'utilisation de la théorie classique de la relativité générale :

1. Le rayonnement gravitationnel des systèmes binaires d'étoiles compactes;
2. L'interprétation théorique des tests expérimentaux du principe d'équivalence;
3. Les formulations alternatives pour le problème de la matière noire en astrophysique.

Le travail sur le thème 1. (rayonnement gravitationnel), que j'ai poursuivi depuis le début de ma thèse de 3ème cycle dirigée by Thibault Damour en 1982, a reçu à partir de 2015 toute sa justification avec la détection directe sur Terre par la collaboration LIGO-Virgo des ondes gravitationnelles émises lors de la fusion de systèmes binaires de trous noirs et d'étoiles à neutrons. Les prédictions théoriques post-newtoniennes que j'ai développées pour le signal d'ondes gravitationnelles des systèmes binaires (phase orbitale et forme d'onde à l'approximation 4.5PN ~ $(v/c)^9$ au-delà de la formule du quadrupôle d'Einstein) jouent un rôle crucial pour la détection et l'analyse du signal des ondes gravitationnelles dans les détecteurs (au sol LIGO-Virgo-Kagra et plus tard LISA dans l'espace), est à la base des formalismes effectifs tels que EOB (effective-one-body), et est important pour la comparaison avec les études de relativité numérique.

1. Gravitational waves from compact binary systems

- *The Multipolar-post-Minkowskian formalism* [4,5,6,7,11,12,22,23,93,110,111]. A non-linearity or post-Minkowskian (PM) expansion is combined with a multipolar (M) expansion parametrized by appropriate sets of source multipole moments, yielding the most general solution of the Einstein field equation in the exterior zone of an isolated system. In particular the solution recovers the Bondi-Sachs-Penrose formalism for the asymptotic structure of GW fields at infinity from matter sources in GR.
- *Matching to an isolated post-Newtonian source* [6,7,16,24,35,44]. The MPM solution is matched to the post-Newtonian (PN) field in the near and interior zones of the source. This is achieved by a matching equation, within a specific variant of the theory of matched asymptotic expansions, which yields unique expressions for the (PN-expanded) multipole moments of the source.
- *Gravitational radiation reaction and flux-balance equations* [3,6,12,21,96]. The gravitational radiation reaction contributions in the inner PN metric and equations of motion of the source are obtained up to 4PN order, and general flux-balance equations for energy, angular momentum, linear momentum and center-of-mass position are derived.
- *Computation of gravitational wave tails and related non-linear effects* [11,22,23,88,112]. We obtain high order non-linear tail effects in the propagation of GWs from the matter system to an observer located at infinity. In the case of compact binaries the non-linear tails, "tail-of-tails" [23] and even "tail-of-tail-of-tails" [88] in the radiation field have been computed to 4.5PN order. The contribution of "tails-of-memory" at 4PN order has been obtained in [112]. Tail effects are directly measured by LIGO/VIRGO detectors [14,15].
- *Post-Newtonian equations of motion of compact binaries* [25-29,31,34,37,39,87,89,91-95,100]. Equations of motion of compact binary systems have been obtained to order 4PN beyond the Newtonian acceleration. Dimensional regularization is systematically used to treat ultra-violet (UV) divergences due to the model of point particles as well as infra-red (IR) ones. Explicit expressions of all conserved quantities have been provided as well as reduction to the frame of the center of mass and to circular orbits.
- *Conservative part of the dynamics and high accuracy comparisons with gravitational self-force calculations* [60,63,69,79,80]. The accuracy of the PN approximation has been evaluated thanks to high precision comparisons with numerical calculations of the gravitational self-force (GSF) for compact binaries in the small mass ratio limit. Conservative terms at high half integer PN approximations are also investigated.
- *First law of binary black hole mechanics* [69,72,91]. This interesting relation holding for compact binaries moving on circular orbits has been discovered from high PN calculations and then proved to any order in the general case and used in high order comparisons between the PN and the GSF. The relation has been generalized to include spins and shown to work also in the presence of non-linear tail effects.
- *GW templates of inspiralling compact binaries* [8,13,17-20,32,33,40-42,45,53-55,59,71,82,88, 115,116]. The complete GW energy flux has been derived to order 4.5PN for circular binary orbits, and all the fluxes of conserved quantities (energy, angular momentum, linear momentum and center-of-

9 Les citations [n] se réfèrent à la liste de publications de rang A (dénotées [An]) disponible sur le site : http://www2.iap.fr/users/blanchet/

mass position) have been derived to order 3PN for general orbits. The complete gravitational waveform has been provided in a form suitable for data analysis to 3PN order. The dominant GW mode *lm = 22* for circular orbits have been computed to order 4PN.

- *Gravitational recoil of coalescing compact binaries* [47,61,62]. The loss of linear momentum by gravitational radiation and the resulting gravitational recoil (or "kick") of black-hole binary systems without spins has been investigated to 2PN order, including the contributions due to the merger and ringdown phases using different techniques.
- *Initial conditions for the numerical calculation of the coalescence of two black holes* [38]. We propose a particular deformation of the Brill-Lindquist solution, which solves the Hamiltonian constraint equation of GR in the symmetric case, and agrees with the metric generated by two black holes up to the 2PN order.
- *High order spin-orbit effects in the equations of motion and gravitational radiation field of compact binaries* [49,50,67,74-77]. Spin-orbit effects (due to the intrinsic rotation of the two black holes) have been derived in the equations of motion and radiation field to next-to-next-to-leading order which means 4PN. All expressions for the equations of motion, conserved quantities, spin precession equations, near zone metric, GW flux, in the general case or reduced to the center-of-mass frame and to circular orbits, have been provided for GW data analysis.
- *High-order tidal effects in the dynamics of neutron star binaries* [99, 102, 103]. We compute the equations of motion and the orbital phase evolution of spinless neutron star binaries including tidal effects up to the next-to-next-to-leading order beyond the dominant mass quadrupole tidal effect.
- *From harmonic to Bondi-Newman-Unti coordinates* [104,114]. We transform the metric of an isolated matter source in the multipolar post-Minkowskian approximation from harmonic coordinates to radiative Newman-Unti coordinates. We describe non-linear tails GW losses and the GW memory effect in terms of the Bondi shear, and mass and angular momentum aspects.
- *The current-type quadrupole moment and GW mode 21 up to 3PN order* [105]. We define the current-type multipole moments of an isolated system in *d* dimensions (needed for later application of dimensional regularization) and apply it to the waveform of (non-spinning) compact binary systems at the 3PN level, as well as the corresponding phase evolution and GW mode.
- *The renormalized mass-type quadrupole moment of compact binaries at 4PN order* [101,107,108]. Central to the extension of GW templates to 4PN order is the mass quadrupole moment of compact binaries which has been achieved with systematic use of dimensional regularization for treating both UV and IR divergences.
- *Gravitational waves in scalar-tensor theory to one-and-a-half post-Newtonian order* [109]. We compute the gravitational waves generated by compact binary systems in a class of massless scalar-tensor (ST) theories to the 1.5 post-Newtonian (1.5PN) order beyond the standard quadrupole radiation in general relativity (GR). Using and adapting to ST theories the multipolar-post-Minkowskian and post-Newtonian formalisms originally defined in GR, we obtain the tail and non-linear memory terms associated with the dipole radiation in ST theory. The multipole moments and GW flux of compact binaries are derived for general orbits including the new 1.5PN contribution, and comparison is made with previous results in the literature. In the case of quasi-circular orbits, we present ready-to-use templates for the data analysis of detectors, and for the first time the scalar GW modes for comparisons with numerical relativity results.

2. Theoretical aspects of tests of the equivalence principle

- *A class of non-metric couplings to gravity* [10]. Motivated by discussions on the STEP experiment testing the equivalence principle in Earth orbit, we propose a class of non-metric couplings between matter fields and the gravitational field which naturally violates the Einstein equivalence principle at the level 10^{-15}.
- *Relativistic effects in the time and frequency transfer for the* PHARAO-ACES *atomic clock experiment in space* [30]. The accuracy of the PHARAO clock is such that it requires taking into account new terms in the time-frequency transfer from the orbit to the ground station. We obtain a formula valid to order c^{-3}, which is now used in the data analysis of the ACES experiment and should permit the test of the gravitational redshift with precision 10^{-6}.
- *Quantum tests of the EP with the* STE-QUEST *experiment* [81]. The STE-QUEST space mission will test the weak EP thanks to quantum atomic wave interferometry, by comparing the free-fall of two different atoms (rubidium and potassium) in Earth orbit. We investigate the specific interest of quantum test of the EP, that look for the behaviour of quantum matter waves in the presence of gravity, as compared to classical tests using classical macroscopic materials, such as in the MICROSCOPE experiment.
- *Redshift test with the* STE-QUEST *experiment* [86]. The STE-QUEST space mission will perform tests

of the gravitational redshift in the field of the Sun and the Moon to high precision by frequency comparisons of clocks attached to the ground and separated by intercontinental distances. Here we analyze the Sun/Moon redshift tests using a generic EP violating theoretical framework, with clocks minimally modelled as two-level atoms.

3. Alternative approaches to dark matter in astrophysics

- *Interpretation of MOND in terms of a mechanism of gravitational polarization* [51, 52, 57, 58]. We show that Milgrom's MOdified Newtonian Dynamics (MOND) enjoys a remarkable property, now known as the dielectric analogy, which yields an elegant model in which dark matter is viewed as a medium of gravitational dipole moments, polarizable in the gravitational field of ordinary matter. The model recovers the cosmological mode Λ-CDM at large scales (including first-order cosmological perturbations) and, under certain hypothesis, the phenomenology of MOND at small galactic scales.
- *Testing MOND in the Solar System* [65]. We show that the so-called external field effect in MOND yields an abnormal quadrupolar correction in the Newtonian gravitational potential of the Sun induced by the presence of the Galaxy. This effect is responsible for a supplementary secular orbital precession of outer planets of the Solar System and is severely constrained by modern planetary ephemerides.
- *Modified gravity approach based on a violation of Lorentz invariance* [68]. We investigate a particular case of generalized Einstein-Aether theories in which the vector field is hypersurface orthogonal. In adapted coordinates the theory admits a purely geometrical formulation but violates local Lorentz invariance. Such pure modified gravity theory without dark matter reproduces the observed phenomenology of dark matter in galaxies, however it has no viable cosmology.
- *Phenomenology of dark matter via a bimetric extension of GR* [83]. This relativistic model is a tentative for improvement of the concept of dipolar dark matter. It reproduces the cosmological model Λ-CDM at cosmological scales, but is very complicated, and contains ghosts. Attempts have been made [84-85, 90] to reformulate the model within the ghost-free massive bimetric gravity, but the model fails to reproduce the phenomenology of MOND at galactic scales [113].

4. Miscalleneous

- *Detecting the General Relativistic Orbital Precession of the Exoplanet* HD 80606b [98]. We prove that it will soon be possible to detect the orbital relativistic precession due to GR on the orbit of the exoplanet HD 80606b. This exoplanet has a high eccentricity orbit (which increases the GR effect) and is known by radial velocity measurements and by the successive transits on the parent star as well as the occultations or eclipses. The method is based on the significant variation of the time interval between an eclipse and its subsequent transit as the orbit is precessing. The GR effect should be measurable by comparing events already observed on HD 80606b in 2010 with the *Spitzer* satellite together with those to be observed in the future with the *James Webb Space Telescope*.