Curriculum Vitae

PERSONAL INFORMATION

Family name, First name: BLANCHET, Luc
Researcher unique identifier: ORCID https://orcid.org/0000-0003-1142-9534
Date of birth: January, 03, 1956
Nationality: French
URL for web site: http://www2.iap.fr/users/blanchet/

EDUCATION

1990: Habilitation thesis, *Contribution to the study of gravitational radiation generated by an isolated system*, Université Pierre et Marie Curie
1984: Physics Doctor, *Structure of radiative gravitational fields and their coupling to material sources (*thesis advisor: Thibault Damour), Université Pierre et Marie Curie
1982 : Master in Theoretical Physics, Université Pierre et Marie Curie (Paris VI)
1981 : Master in Astrophysics, Université Denis Diderot (Paris VII)
1980 : Engineer graduated from École Polytechnique, Paris

CURRENT POSITION

since 2023 Directeur de Recherche emeritus
2017 – 2023 Directeur de Recherche exceptional class (DRCE2)
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

PREVIOUS POSITIONS

2008 – 2017 Directeur de Recherche CNRS (1st class)
GReCO, Institut d'Astrophysique de Paris
1999 – 2008 Directeur de Recherche (2nd class)
GReCO, Institut d'Astrophysique de Paris
1990 – 1999 Chargé de Recherche (1st class)
DARC, Observatoire de Paris-Meudon
1989 – 1990 Engineer Research & Development (detached from CNRS)[1]
Société Européenne de Propulsion, Vernon, France
1985 – 1989 Chargé de Recherche (2nd class)
Département d'Astrophysique Relativiste et Cosmologie (DARC)
Observatoire de Paris-Meudon
1984 – 1985 Post-Doc, California Institute of Technology,
Theoretical Astrophysics Including Relativity (TAPIR),
Los Angeles, United States

SUPERVISION OF GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS

PhD students

1997 – 1999 : Guillaume Faye,[2] *Equations of motion of compact binary systems in General Relativity*
1999 – 2001 : Philippe Canitrot, *Analysis of the gravitational wave signal from compact binaries by VIRGO*
2000 – 2002 : Olivier Poujade,[3] *Post-Newtonian iteration of the gravitational field inside an isolated system*
2002 – 2006 : Samaya Nissanke,[4] *Gravitational radiation reaction effects in the dynamics of BH binaries*

1 This activity has been evaluated by the interdisciplinary committee of C.N.R.S. in 1991.
2 Guillaume Faye is permanent researcher at C.N.R.S. (Theoretical Physics) since 2004.
3 Olivier Poujade is research engineer at C.E.A. since 2004.
4 Samaya Nissanke is professor in Astronomy at the University of Amsterdam since 2012.

2007 – 2010 : Alexandre Le Tiec,[5] *Close limit approximation for the coalescence of two black holes*
2010 – 2013 : Sylvain Marsat[6], *Spin effects in the dynamics and radiation of compact binary systems*
2013 – 2016 : Laura Bernard,[7] *Some phenomenological aspects of GR and its extensions*
2015 – 2018 : Tanguy Marchand, *Gravitational radiation of binary systems and alternative models*
2018 – 2021 : François Larrouturou, G*ravitational field of binary black hole systems to high PN order*
2018 – 2021 : Quentin Henry, *Effects of internal structure in the dynamics of neutron stars binaries*
2020 – 2023 : David Trestini, *Ondes gravitationnelles en théorie Tenseur-Scalaire*
depuis 2024 : Emeric Seraille, *Modified dark matter theories*
depuis 2024 : Etienne Ligout, *Stability of binary orbits in post-Newtonian theory*

Post-Doc
2013 – 2016 : Alejandro Bohé,[8] *Equations of motion of compact binaries at the fourth post-Newtonian order*

TEACHING ACTIVITIES

French Universities and institutions
1986 – 1989 : Tutorials in General Relativity, Master in theoretical physics (Paris VI)
1988 – 1989 : Course of Introduction to General Relativity, Master in particle Physics (Orsay University)
1993 – 1999 : Course of Introduction to General Relativity, Master in Astrophysics (Paris VII)
2000 – 2003 : Course on Newtonian gravity, Doctoral school in Astrophysics (Paris VI and Paris VII)
2003 – 2005 : Course on Maxwelian Electromagnetism, 2nd year, Sciences of Earth and Space (Paris VII)
2006 – 2007 : Course on General Relativity, Master in Physics (Orsay University)
2003 – 2013 : Course on General Relativity, Master in Physics, Ecole Normale Supérieure (Paris)
2015 : Course on Advanced General Relativity, Doctoral school in theoretical physics (Paris)
2017 : Course on Gravitational Waves, CEA–Saclay
2016 – 2024 : Many didactic courses and outreach presentations on the detection of GW by LIGO/Virgo

International Physics schools
1995 : Les Houches Physics school, 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 : Cargèse Physics school, France, *Black holes in Astrophysics*
2006 : Institut Henri Poincaré, France, *Gravitational waves, relativistic astrophysics and cosmology*
2008 : Thematic school of 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 : Particle Physics school, Gif-sur-Yvette, France, *General Relativity 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*

ORGANISATION OF SCIENTIFIC MEETINGS
2012 – 2017 : co-organizer of the conferences *Hot Topics in General Relativity and Gravitation*, Vietnam
2010 – 2023 : co-organizer of the cycle of conferences *Rencontres de Moriond on Gravitation*, Italy
2017 : co-organizer of the IAP colloquim *The Era of Gravitational Wave Astronomy*, France

5 Alexandre Le Tiec is permanent researcher at C.N.R.S. (Astrophysics) since 2013.
6 Sylvain Marsat is permanent researcher at C.N.R.S. (Particle Physics) since 2021.
7 Laura Bernard is permanent researcher at C.N.R.S. (Theoretical Physics) since 2018.
8 Alejandro Bohé is space engineer at C.N.E.S. since 2018.

2023 : co-organizer of the scientific day of the bureau des longitudes *Black holes and gravitational waves in Astrophysics*, France

2025 : co-organizer of the scientific day of the bureau des longitudes *100 years ago : discovery of Galaxies and the expansion of the Universe*, France

FELLOWSHIPS AND AWARDS

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

PUBLICATIONS

122 articles in peer-reviewed international journals, 9 contributions to books, 43 articles in conference proceedings, 6 outreach articles for the general public, about 14500 citations SPIRES, h=68

INSTITUTIONAL RESPONSIBILITIES

2004 – 2008 : Member of the administration council of Institut d'Astrophysique de Paris
2004 – 2008 : Nominated member of the national committee on Astroparticles in CNRS
2005 – 2008 : Elected member of the board of the VIRGO-EGO Scientific Forum (VESF)
since 2016 : Member of the scientific committee of the CNRS GDR on gravitational waves

REVIEWING ACTIVITIES

1990 – 1991 : Member of the theory group of the STEP experiment
1994 – 1996 : Member of the working groups of the PHARAO and ACES experiments
1993 – 2004 : Member of the Fundamental Physics group of 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
since 2010 : Member of the scientific committee of the national program GRAM in C.N.R.S.
2013 – 2016 : Member of the theory group of the STE-QUEST experiment
2013 : President of the evaluation committee AERES of the laboratory SYRTE
2013 – 2017 : President of the committee for Fundamental Physics in C.N.E.S.

MEMBERSHIPS OF SCIENTIFIC SOCIETIES

2012 : Corresponding member of the Bureau des Longitudes
since 2017 : Full member of the Bureau des Longitudes
2019 : Fellow of the International Society of General Relativity and Gravitation (ISGRG)
2020 – 2023 + 2025 : Vice-president of the Bureau des Longitudes

DISTINCTIONS

2002 : *Prix Langevin de Physique* of the French Academy of Sciences
2016 : *Special Breakthrough Prize in Fundamental Physics* for the detection of gravitational waves
2018 : *Prix CNES – Astrophysique et Sciences Spatiales* of the French Academy of Sciences
2020 : *Prix Jean Ricard* of the Société Française de Physique
2023 : *Einstein medal of the Albert Einstein society* in Bern (Albert-Einstein Gesellschaft – AEG)

SUMMARY OF SCIENTIFIC WORKS[9]

The scientific works are divided into three main axes having as common denominator the use of the classical theory of general relativity:

1. Gravitational waves from compact binary systems;
2. Theoretical aspects of tests of the equivalence principle;
3. Alternative approaches to dark matter in astrophysics.

The works on topic 1. (gravitational waves), which was pursued since my PhD thesis supervised by Thibault Damour in 1982, received from 2015 on all its justification with the direct detection by the LIGO and Virgo detectors of gravitational waves generated by the inspiral and merger of binary systems of black holes and neutron stars. The post-Newtonian theoretical predictions I developed for the gravitational wave signal of binary systems (orbital phase and waveform with post-Newtonian accuracy 4.5PN ~ $(v/c)^9$ beyond the Einstein quadrupole formula) play a crucial role for the data analysis of gravitational waves with the detectors LIGO-Virgo-Kagra on ground and, later, with LISA in space. They form also the basis of effective phenomenological formalisms such as the EOB (effective-one-body), and are important for comparison with numerical relativity calculations.

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. The extension to 4.5PN order (2PN relative radiation reaction) has been achieved in [120], in a general frame for arbitrary binary orbits. We show that there are crucial non-local contributions due to the recoil of the source to be taken into account at that order for the definition of the center of mass frame.
- *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

9 Citations [n] refer to the list of publication of rank A (denoted [An]) available at: http://www2.iap.fr/users/blanchet/

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-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. The 4PN/4.5PN flux for quasi circular binaries agrees very well with gravitational self force (GSF) calculations developed to second order in the small mass ratio [119].
- *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.
- *Innermost stable circular orbit of arbitrary-mass compact binaries at fourth post-Newtonian order* [122]. We obtain a gauge invariant criterion for the stability of compact binary orbits (generalizing the ISCO of the Schwarzschild metric) and show that it

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, 73]. We show that Milgrom's MOdified Newtonian Dynamics (MOND) enjoys a remarkable property, now known as the dielectric analogy, which yields an elegant model (now called Dipolar Dark Matter) 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. A recent extension of this theory has been shown to be viable in cosmology as well [118].
- *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].
- *Dipolar dark matter based on a fundamental Yang-Mills SU(2) graviphoton* [121]. This is a drastic improvement of the DDM model [51] where the phenomenology of MOND is interpreted as due to a new sector of Particle Physics (with a new non-Abelian Yang-Mills field) emerging in the MOND regime of weak accelerations.

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*.