
CV – BAILLEUL Ismaël

Birth date	Dec. 2, 1979
Administrative address	Institut de Recherche Mathématiques de Rennes 263 Avenue du Général Leclerc, 35042 Rennes, FRANCE
<i>email</i>	ismael.bailleul@univ-rennes1.fr
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Personal status	Married, two children (9 years old and 12 years old)

A – Academic career

- 2015 **Habilitation à diriger les recherches**, *Contributions to stochastic differential geometry and rough paths theory*. Jury: J.-C. Breton, S. Gouezel, P. Friz, M. Hairer, Th. Lévy, X.-M. Li, L. Zambotti.
- 2011 – **Maitre de conférence (lecturer then reader)**, Université Rennes 1, France.
- 2007 - 2011 **Postdoc**, Statistical Laboratory, Cambridge Univ., England.

B – Scientific activity

1. A bird's eye view on my research themes

One can describe shortly as follows the different research domains that I have explored so far.

(2004 –) Stochastic differential geometry. *Relativistic diffusions, in relation with small and large scale Lorentzian geometry. Study of hypoelliptic diffusions and their heat kernels.*

(2007 – 2011) Smoluchowski's coagulation equation. *Interacting particle systems, numerical schemes for computing sensitivity.*

(2012 –) Rough paths theory. *Development of the flow-approach to the subject, applications to random flows, homogenisation of fast/slow systems and mean field type dynamics, links with random dynamical systems.*

(20015 –) Singular stochastic PDEs. *Development of paracontrolled calculus, based on semi-group technics.*

The following three paragraphs give some details on the three research directions that I keep exploring presently. References refer to the publication list from Section 2.

- **Stochastic differential geometry.** My first works in stochastic differential geometry are related to my PhD work (2003-2006), in which I fully described the asymptotic behaviour of the unique natural diffusion in Minkowski spacetime [1-2-3]. The situation is different in a general Lorentzian manifold, where metric tensors can be used to define a whole class of intrinsic diffusions. I described a number of properties of the latter and studied the explosion problem for them [7-9-10-11]. The

Riemannian analogue of relativistic diffusions was introduced in [19], where kinetic Brownian motion is defined, and where we show that it provides an interpolation family between geodesic and Brownian flows. These diffusions are examples of hypoelliptic, non-subelliptic, diffusions. I studied heat kernels of subelliptic diffusion on non-compact manifolds in [26], and the small time behaviour of bridges of such diffusions, fluctuations and large deviations in [21-22]. The study of kinetic Brownian motion started in [19] was developed in the PhD thesis work of my student P. Perruchaud, who studied this object in the infinite dimensional setting of the diffeomorphism space of a compact domain/manifold. We proved an interpolation result between the geodesic flow, related to PDEs from hydrodynamics in the present setting, and a Brownian-like flow. Ongoing works address the difficult question of getting small time estimates for the heat kernel of kinetic Brownian motion.

KEYWORDS: *Stochastic differential geometry, coupling method, Lorentzian geometry, sub-Riemannian geometry, Malliavin calculus, global analysis, geometric mechanics.*

- **Rough paths theory.** I developed from 2012 onward a personal approach to T. Lyons' rough paths theory, based on the notion of approximate flow introduced for that purpose [12-13]. This approach encompasses the theory of stochastic flows [16] within its setting. Different questions were studied in [14-15-17-28-33], and the link with random dynamical systems was established in [27]. Another link with the mathematics of mean field-type dynamics was made in [31-32], and the first steps in the direction of a theory of rough differential inclusions made in [34]. Together with M. Gubinelli, I developed in [18] a general approach of rough transport equations that was followed by a number of works by other researchers.

KEYWORDS: *Rough paths, mean field type rough dynamics, dynamics on pathspace, rough flows, homogenisation for fast/slow systems.*

- **Singular PDEs.** The period (2013-2015) has seen the birth and explosion of the study of singular stochastic partial differential equations, especially under the impulse of M. Hairer and M. Gubinelli. Together with F. Bernicot, I developed Gubinelli & co.'s paracontrolled approach way beyond its initial scope [20-23-24-29] and was able to prove that it has a scope comparable to Hairer's theory of regularity structures [35-37].

KEYWORDS: *Singular stochastic partial differential equations, paracontrolled calculus, smigroup methods, renormalisation.*

2. Publications

I published or submitted 44 works. They are all available on my webpage

<https://perso.univ-rennes1.fr/ismael.bailleul/research.html>

where each of them is described shortly.

Publication list. The works are presented here in chronological order. They are all accessible on my webpage

<https://perso.univ-rennes1.fr/ismael.bailleul/research.html>

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- [1] **Poisson boundary of a relativistic diffusion**
I. Bailleul
Probab. Th. & Rel. Fields, **141**(1) (2008), 283–329.
 - [2] **Une preuve simple d'un résultat de Dufresne**
I. Bailleul
Séminaire de Probabilités de Paris, Vol. **XLI** (2008), 203–213.
 - [3] **Poisson boundary of a random walk on Poincaré group**
I. Bailleul and A. Raugi
ESAIM, P & S, **14** (2010) 16–52.
 - [4] **Coupling algorithm for calculating sensitivities in Smoluchowski equation**
I. Bailleul, M. Kraft, P. Man and J. Norris
SIAM Journal on Scientific Computing, **32**(2) (2010), 635–655.
 - [5] **A stochastic algorithm for sensitivity in Smoluchowski equation**
I. Bailleul, M. Kraft, P. Man
SIAM Journal on Numerical Analysis, **48**(3) (2010), 1064–1086.
 - [6] **Sensitivity for Smoluchowski equation**
I. Bailleul
J. of Physics A., **44**(24) (2011).
 - [7] **A stochastic approach to relativistic diffusions**
I. Bailleul
Annales de l'Institut H. Poincaré, **46**(3) (2010), 760–795.
 - [8] **Spatial coagulation with bounded coagulation rate**
I. Bailleul
J. of Evolution Equations, **11**(3) (2011), 675–686.
 - [9] **Non-explosion criteria for relativistic diffusions**
I. Bailleul and J. Franchi
Ann. Probab., **40**(5) (2012), 2168–2196.
 - [10] **A probabilistic view on singularities**
I. Bailleul
J. Math. Phys., **52** (2012), 023520.
 - [11] **General relativistic Boltzmann equation**
I. Bailleul and F. Debbasch
Classical and Quantum Gravity, **29**(6) (2012), 065020.1-10.
 - [12] **Flows driven by rough paths**
I. Bailleul
Revista Iberoam. Math., **31**(3) (2015), 901–934.
 - [13] **Flows driven by Banach space valued rough paths**
I. Bailleul
Séminaire de Probabilités de Paris, Vol. **XLVI** (2014), 195–205.
 - [14] **Rough integrators on Banach manifolds**
I. Bailleul
Bull. Sc. Math., **151**, (2019), 51–65.

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- [15] **Regularity of the Itô-Lyons map**
I. Bailleul
Confluentes Mathematici, **7**(1), (2015), 3–11.
- [16] **Rough flows**
I. Bailleul and S. Riedel
A paraître dans *J. Math. Soc. Japan*, (2019), 64 pages.
- [17] **The inverse problem for rough controlled differential equations**
I. Bailleul and J. Diehl
SIAM J. Opt. Control, **53**(5), (2015), 2762–2780.
- [18] **Unbounded rough drivers**
I. Bailleul and M. Gubinelli
Ann. Fac. Sc. Toulouse, **26**(4), (2017), 795–830.
- [19] **Kinetic Brownian motion**
J. Angst, I. Bailleul and C. Tardif
Elec. J. Probability, **20**(110), (2015), 40 pages.
- [20] **Heat semigroups and singular PDEs**
I. Bailleul and F. Bernicot
J. Func. Anal., **270**, (2016), 3344–3452.
- [21] **Small time fluctuations for Riemannian and sub-Riemannian diffusion processes**
I. Bailleul, J. Norris and L. Mesnager
To appear in *Ann. Sci. Ec. Norm. Super. (4)*, (2020), 42 pages.
- [22] **Large deviation principle for bridges of sub-Riemannian diffusions**
I. Bailleul
Séminaire de Probabilités, **XLVIII**, (2016), 189–198.
- [23] **Space/time paraproducts for paracontrolled calculus, 3d-PAM and Burgers equations**
I. Bailleul, F. Bernicot and D. Frey
Ann. Sci. Ec. Norm. Super. (4), 51(6): (2018), 1399–1457.
- [24] **Paracontrolled calculus**
I. Bailleul
Journées EDP, (2016), 12 pages.
- [25] **Rough flows and homogenization in stochastic turbulence**
I. Bailleul and R. Catellier
J. Diff. Eq., **263**(8), (2017), 4894–4928.
- [26] **Diffusion in small time in incomplete sub-Riemannian manifolds**
I. Bailleul, J. Norris
To appear in *Analysis & PDE*, (2022), 24 pages.
- [27] **Random dynamical systems, rough paths and rough flows**
I. Bailleul, S. Riedel, M. Scheutzow
J. Diff. Eq., **262**, (2017), 5792–5823.
- [28] **Non-explosion for rough differential equations**
I. Bailleul, R. Catellier
To appear in *Ann. Fac. Sc. Toulouse*, (2022), 39 pages.

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- [29] **High order paracontrolled calculus**
I. Bailleul, F. Bernicot
Forum of Math. Sigma, **7**: e44, (2019).
- [30] **Quasilinear generalised parabolic Anderson model equation**
I. Bailleul, A. Debussche, M. Hofmanova
Stoch. Part. Diff. Eq.: Anal. and Computations, (2018), 24 pages.
- [31] **Solving mean field rough differential equations**
I. Bailleul, R. Catellier, F. Delarue
Elec. J. Probab., **25**(21):1–51, (2020).
- [32] **Propagation of chaos for mean field rough differential equations**
I. Bailleul, R. Catellier, F. Delarue
Annals of Probability, **49**(2):944–996, (2021).
- [33] **On the definition of a solution to a rough differential equation**
I. Bailleul
Ann. Fac. Sc. Toulouse, **30**(3):463–478, 2021.
- [34] **Young and rough differential inclusions**
I. Bailleul, A. Brault, L. Coutin
Rev. Mat. Iberoamericana, **37**(4):1489–1512, 2021.
- [35] **Paracontrolled calculus and regularity structures (1)**
I. Bailleul, M. Hoshino
J. Math. Soc. Japan, **73**(2):553–595, 2021.
- [36] **Kinetic Brownian motion on the diffeomorphism group of a closed Riemannian manifold**
J. Angst, I. Bailleul, P. Perruchaud
Submitted to *Ann. Éc. Polytechnique*, (2019), 45 pages.
- [37] **Regularity structures and paracontrolled calculus**
I. Bailleul, M. Hoshino
Ann. Éc. Polytechnique, **8**:1275–1328, 2021.
- [38] **Paracontrolled calculus for quasilinear singular PDEs**
I. Bailleul et A. Mouzard,
To appear in *Stochastic Partial Differential Equations: Analysis and Computations*, (2022), 32 pages.
- [39] **A tourist’s guide to regularity structures and singular stochastic PDEs**
I. Bailleul et M. Hoshino
To appear in *Forum of Mathematics, Sigma*, (2022), 81 pages.
- [40] **Locality for singular stochastic PDEs**
I. Bailleul et Y. Bruned
arXiv:2101.11949 & arXiv:2109.00399, 24 pages, (2021).
- [41] **Parametrization of renormalized models for singular stochastic PDEs**
I. Bailleul et Y. Bruned
arXiv:2106.08932, 14 pages, (2021).
- [42] **Analysis of the Anderson operator**
I. Bailleul et V. N. Dang et A. Mouzard
arXiv:2201.04705, 52 pages, (2022).

- [43] **Singular stochastic wave equations**
I. Bailleul et K. Chouk et T. Oh et T. Robert
Preprint, (2022).
- [44] **Topological methods for singular stochastic PDEs**
I. Bailleul et H. Eurlly
Preprint, (2022).

Even though they are not to be considered on an equal footing with the preceding works, I would like to mention here the following lecture notes that I have written for a *Part III cours in Cambridge* (2009-2011)

- **Advanced probability** (95 pages)

and a Master 2 course on rough paths in Rennes

- **A flow-based approach to rough paths** (63 pages).

The two lecture notes are available on my webpage

<https://perso.univ-rennes1.fr/ismael.bailleul/teaching.html>

3. Doctoral and scientific supervision.

So far I have supervised two PhD students and one postdoc.

PhD supervision

- P. Perruchaud (2016–2019) : joint supervision with J. Angst (Univ. Rennes 1) PhD subject: *Kinetic Brownian motion on the space of diffeomorphisms of a compact manifold*. Now postdoc at Notre-Dame (United States), with L. Nicolaescu. Publications
 - P. Perruchaud, *Homogenisation for anisotropic kinetic random motions*, arXiv:1811.08415, to appear in *Elec. J. Probab.*
 - I. Bailleul, J. Angst, P. Perruchaud, *Kinetic Brownian motion on the space of diffeomorphisms of a compact manifold*, arXiv:1905.04103, submitted to *Annales de l'Institut Fourier*.
- A. Mouzard (2018–2021) : full supervision. Title : *Paracontrolled calculus for stochastic singular PDEs on manifolds*. Publications :
 - I. Bailleul and A. Mouzard, *Paracontrolled calculus for quasilinear singular PDEs*, 32 pages, arXiv:1912.09073, to appear in *Stochastic PDEs: analysis and computations*, (2022).
 - A. Mouzard, *Weyl law for the Anderson Hamiltonian on a two-dimensional manifold*, 40 pages, arXiv:2009.03549, (2020), to appear in *Annales Institut Henri Poincaré, B*, (2022).
 - A. Mouzard, *2D random magnetic Laplacian with white noise magnetic field*, 20 pages, arXiv:2101.05020, (2021), to appear in *Stochastic Processes and their Applications*, (2022).
 - A. Mouzard and I. Zacchuber, *Strichartz inequalities with white noise potential on compact surfaces*, 29 pages. arXiv:2104.07940, submitted to *Analysis & PDEs*.
- H. Eurlly (2021–2024) : encadrement à 100%. Titre : *Paracontrolled calculus*.
 - I. Bailleul and H. Eurlly and T. Robert, *Topological methods for singular stochastic PDEs*, preprint (2022).

Post-doctoral supervision

- R. Catellier (2014-2016). Title : *Applications of rough differential equations*. Publications [25] and [28] in Section 2. Now Maître de conférence in Université de Nice from Septembre 2016 onward.

4. Early achievements track record

Invited presentations to international conferences

- 2022 – AMS-SMF-EMS joint meeting, Grenoble.
- 2021 – Conférence "*Stochastic Pathwise Analysis and their Applications*", CIRM, Marseille.
 - Conférence "*Stochastics and Geometry*", BIRS Banff, Canada.
- 2020 – Conférence "*Higher Structures emerging from Renormalisation*", Erwin Schrödinger Institute, Vienne.
 - Oberwolfach meeting "*New Directions in Rough Path Theory*", Allemagne.
- 2019 – Meeting Paths between Probability, PDEs, and Physics, Imperial College, Londres.
 - New Directions in Stochastic Analysis: Rough Paths, SPDEs and Related Topics, Berlin.
- 2017 – Oberwolfach meeting on Geometry of Random Processes.
 - Workshop on Algebraic Renormalisation in SPDEs, Bergen.
- 2016 – Conférence Singular Phenomena and Singular Geometries, Pisa. Mini-course on Kinetic Brownian motion.
 - Workshop "Stochastic Partial Differential Equations", Simons Centre for Geometry and Physics, New York.
 - Oberwolfach meeting Rough Paths, Regularity Structures and Related Topics.
- 2015 – Stochastic Analysis Meeting, Osaka.
 - Conference EquaDiff, Lyon.
- 2014 – ASC-IMS 2014 Conference, Sydney.
 - Stochastic Processes and Applications 2014 Conference, Buenos Aires.
 - Workshop Rough paths: theory and applications, Institute for Pure and Applied Mathematics, Los Angeles.
- 2011 – 5th International Conference on Stochastic Analysis and its Applications, Bonn.

In addition to these talks in conferences, I have given numerous talks in Europe (Berlin, Bergen, Cambridge, Genève, Londres, Luxembourg, Oxford, Swansea, Warwick, York), worldwide (Kyushu University, Kyoto, Osaka, Stony Brook, Vancouver) or in France (Brest, Dijon, Lyon, Nancy, Paris, Rennes, Strasbourg, Toulouse).

Grants

- 2021 One year sabbatical at Pacific Institute of Mathematical Sciences, Vancouver, Canada.
- 2017-2020 **Principal investigator** of the **ANR grant Singular** (116k€). This funding obtained within the Jeune Chercheuse Jeune Chercheur (JCJC) scheme of the National Agency of Research (ANR) involves P. Gassiat (Univ. Dauphine), C. Labbé (Univ. Dauphine) et J. Unterberger (Univ. Nancy). This project aims at exploring a number of questions about the class of singular stochastic partial differential equations.

2011-2015 **Principal investigator** of the **ANR grant RelDiff** (36k€). Individual ANR funding obtained within the Retour Post-doctorant scheme of the ANR. Its subject was the exploration of the interaction between small and large scale geometric properties of relativistic spacetime models and properties of diffusion processes associated with these geometries.

Involvement in a research net

2019–2022 Membre of the research group (CNRS GDR) Rough Paths
 2018–2021 Membre of the research group (CNRS GDR) Renormalisation
 2017-2020 P.I. of the ANR grant Singular (116k€)
 2011-2015 P.I. of the ANR grant RelDiff (36k€)
 2008–2013 Membre of the ANR Proba-Geo

Institutional responsibilities

PhD referee

- Yvain Bruned, *Equations singulières de type KPZ*, PhD supervised by L. Zambotti (2015), Sorbonne Université.
- Antoine Brault, *Flots rugueux et inclusions différentielles perturbées*, PhD supervised by L. Coutin and A. Lejay (2018), Toulouse.

PhD defense jury

- Rémi Catellier, *Perturbations irrégulières et systèmes différentiels rugueux*, PhD supervised by M. Gubinelli (2014), Paris Dauphine.
- Frank Gabriel, *Champs d'holonomies et matrices aléatoires : symétries de tressage et de permutation*, PhD supervised by Th. Lévy, Sorbonne Université.
- Marco Furlan, *Controlled Structures for Partial Differential Equations*, PhD supervised by M. Gubinelli (2018), Paris Dauphine.
- Olga Lopusanschi, *Chemins rugueux issus de processus discrets*, PhD supervised by L. Zambotti et D. Simon (2018), Sorbonne Université.
- Angelo Rosello, *Limites d'échelles pour des modèles cinétiques stochastiques*, PhD supervised by A. Debussche (2020), Université de Rennes.

Services to the mathematical community

- Co-organiser of a session '*Rough paths*' during the meeting Journées MAS 2021.
- Co-organiser of the conference "*Stochastic differential geometry and mathematical physics*", Rennes, July 2021, within the setting of the semester on "*Mathematical physics*" by the Centre Lebesgue.
- Co-organiser of the conference "*Random PDEs*", in CIRM, April 2019.
- Crash course on "*Rough differential equations*", GDR Renormalisation meeting, Clermont-Ferrand, Nov. 2018, and Campinas, Brasil, Jul. 2020. Crash course on singular stochastic PDEs, UBC, Vancouver, Nov. 2021.
- Co-organiser of the workshop "*Rough paths*", Toulouse, Oct. 2017.

- Invited mini-course on Kinetic Brownian motion, during the workshop "*Singular phenomena, singular geometries*", Pisa, 2016.
- Organiser/chairman of the "*Stochastic differential geometry*" session, SPA meeting, Buenos Aires 2014.
- Co-organiser of the workshop "*Stochastic differential geometry*", within the semester "*Perspectives in Analysis and Probability*", organised by the Centre Lebesgue, 2013.
- Reviewer for the journals: *Annals of Applied Probability*, *Annals of Probability*, *Annales Henri Lebesgue*, *Annales de l'Institut H. Poincaré A/B/C*, *Bulletin des Sciences Mathématiques*, *Bulletin de la Société Mathématique de France*, *Classical and Quantum Gravity*, *Communications in Mathematical Physics*, *Communications in Pure and Applied Mathematics*, *Electronic Journal of Probability*, *Forum of Mathematics Pi*, *Journal of Differential Equations*, *Journal of Dynamical and Control Systems*, *Journal of Dynamics and Differential Equations*, *Journal de l'École Polytechnique*, *Journal of the European Mathematical Society*, *Journal of Evolution Equations*, *Journal of Functional Analysis*, *Journal of the London Mathematical Society*, *Journal of Mathematical Physics*, *Journal of Physics A*, *Mathematical Control and Related Fields*, *Physica A*, *Probability Theory and Related Fields*, *Proceedings of the Royal Society A*, *Potential Analysis*, *Results in Mathematics*, *SIAM Journal of Mathematical Analysis*, *Stochastics and Dynamics*, *Stochastic Partial Differential Equations: analysis and computations*, *Stochastic Processes and their Applications*, *Transaction of the American Mathematical Society*, *Vietnam Journal of Mathematics*.
- Reader/referee of the book "*Nonlinear Markov processes and kinetic equations*", de V. Kolokolsov, for Cambridge University Press.

Expertise

- Panel reviewer for DFG German Research Foundation, 2020.
- Panel reviewer for EPSRC, 2014, 2021.
- Reviewer for FWF Austrian Science Fund, 2018.
- Member of the hiring jury for the maître de conférence position 4064 in Université Paris 7, 2012.