Contact & Personal information

Pierre Del Moral, *Date of birth:* January 7th, 1965 (Nationality: French).
Married with two children: Timothy (1989), and Tiffany (1993).
Languages (fluent): French, English, Spanish.
Address : INRIA Team ASTRAL; 200 Avenue de la Vieille Tour, 33405 Talence, France
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Education

- Higher Degree of Research, (H.D.R.) in Math., U.P.S. Toulouse (2002).
- Ph. D. Signal processing LAAS-CNRS & U.P.S., Toulouse (1994).
- Master of Science, theory track, U.P.S., Toulouse; major of promotion (1989):

Pure Mathematics (Cohomology, Hyperbolic Geometry, Algebraic Geometry & Dynamical Systems).

Professional history

- Since 2007: Directeur de Recherches INRIA (DR2 2007-2011, DR1 2011-2023, DR0 since 2024).
- 2018-2019: Scientific collaborator (Stress Test Chair) CMAP Polytechnique Palaiseau.
- 2014-2016: Professor (School of Mathematics - INRIA secondment), UNSW Sydney.
- 2011-2014: Professor (PCC, Part-time) CMAP Polytechnique Palaiseau.
- 2004-2007: Professor (Dieudonné Lab.) Université de Nice, Parc Valrose.
- 1995-2004: Chargé de Recherche (CR2-1995 & CR1-1998, Math-Phys. Sec. 01), Lab. Stats. Prob. U.P.S., Toulouse.
- 1994-1995: Lecturer in Mathematics. Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, Toulouse.
- 1993-1995: Research Engineer, DIGILOG-STERIA.

International visiting positions

- 2025/2026: Invited Professor, CUHK, Hong-Kong [3 months].
- 2024: Nelder Fellow, Imperial College, London [2 months].
- 2022: Heilbronn Invited Professor, Univ. Bristol [2 months].
- 2018: Invited Professor, FGV Rio, Brasil [2 months].
- 2017: Simons CRM Invited Professor, HEC Montreal [2 months].
- 2016: Invited Professor, Imperial College, Maths Dpt. [2 months].
- 2013: Invited Professor, CSIRO Sydney [1 months].
- 2003: Invited Professor, Purdue Univ. (Maths Dpt, CNRS secondment) [1 year].
- 2002: Invited Professor, Melbourne University (Electrical Eng. Dept.), Australia [1 months].
- 2001: Invited Professor, Princeton Univ. (ORFE Dpt, CNRS secondment) [3 months].
- 1995: Invited researcher, Russian Academy of Science [2 months].

Editorial activities

- Since 2018, AE Foundations of Data Science.
- Since 2001, AE Stochastic Analysis and Applications.
- 2019-2025, AE Annals of Applied Probability.
- 2006-2011: Co-editor-in-Chief of ESAIM: Proceedings with J. F. Gerbeau & E. Cancès.
- 2009-2013: AE Applied Mathematics and Optimization.
- 2009-2018: AE Revista de Matemàtica: Teoria y Aplicaciones.
- 2006-2009: AE Stochastic Processes and their Applications.
- 2010: ESAIM M2AN Special volume edition with Nicolas Hadjiconstantinou on Probabilistic methods in scientific computing and numerical analysis. (⇝ An introduction to probabilistic methods).

Seminars & Conferences

- Distinguished lecturer IMS-APRM 2026 Hong-Kong
- Medallion lecturer - World Congress in Probability and Statistics. Fields Institute Toronto (2016).
- **Plenary lectures:** MCQMC 2012, International Conf. on Monte Carlo and QMC Methods, Sydney Australia (2012); Stochastic Processes and their Applications, Melbourne (July 2002); Journées MAS Clermont-Ferrand (August 2012).
- **Colloquium lectures:** Heilbronn Colloquium, Bristol (September 2022), Maxwell Institute Colloquium Edinburgh, Bayes Center, (October 2019 & December 2023), Maxwell Colloqium.University of Edinburgh, Scotland, (February 2015), Colloque a l'Assemblee generale du departement MIA (Mathematique et Informatique Appliquees), INRA Agde meeting (October 2005), Centre de Mathématiques et leurs Applications, E.N.S. Cachan (May 2004), Colloquium Department of Mathematical Sciences University of Alberta, Edmonton (April 1999).
- ⇝ Web-link to around 200 invited-conferences

Research

My research interests lie at the frontier of various scientific disciplines such as applied mathematics, probability theory, Bayesian inference, molecular and quantum physics, as well as advanced signal processing, information sciences and scientific computing.

• Since my PhD thesis in the early 1990s, the main part of my research has focused on the analysis of nonlinear/normalized Feynman-Kac-Schrödinger semigroups and their mean-field particle interpretations in terms of branching genetic-type algorithms and genealogical tree based models. This novel particle methodology allows to design new classes of interacting particle samplers for sampling conditional distributions on path spaces. It also provides a rigorous and unifying mathematical framework to design and analyze the convergence of a variety of heuristic-like killing/regeneration algorithms that have been used in molecular chemistry and quantum physics since the early 1950s.

The earlier work on this subject appears to have been done at Los Alamos National Labs (USA) with the pruned-enriched Rosenbluth method based on the seminal work by M.N. Rosenbluth and A.W. Rosenbluth (J. Chem. Phys-1955). The multilevel branching/splitting scheme by Harris and Kahn. (Natl. Bur.-1951) also provides a somehow related weighted simple branching process simulation of rare events. The origins of Quantum Monte Carlo methods are often attributed to Fermi and Richtmyer who developed in 1948 a mean-field particle interpretation of neutron-chain reactions, but the first heuristic-like and genetic type particle algorithm (a.k.a. Resampled or Reconfiguration Monte Carlo methods) for estimating ground state energies of quantum systems (in reduced matrix models) is due to Hetherington in (Phys. Rev.-1984), see also the branching random walk method introduced by J.B. Anderson in (J. Chem-Phys. 1975). These Monte Carlo methods are also closely related to the popular genetic algorithm, a mutation-selection random search metaheuristic that appears in the literature on evolutionary computation in computer science as well as in operations research and machine learning.
In all of these papers, genetic-type particle samplers are presented as natural killing/regeneration algorithms to find an optimal solution or to sample molecular conformations or high energy particle distributions without a single convergence estimate to ensure the performance or the consistency of the method.

• I started working on the numerical and mathematical aspects of these challenging Monte Carlo methods in the early 1990s, with the development of the first heuristic genetic particle scheme for solving nonlinear filtering and tracking problems. These early studies were developed in collaboration with G. Rigal and G. Salut at LAAS-CNRS. During my career, a central part of my research activities is also to promote industrial transfers and partnerships.
My first article on the mathematical foundations of these genetic-type particle samplers was published in 1996 in the journal Markov Processes and Related Fields (MPRF-1996). In this article, we present the first formalized mean-field particle model that incorporates all the heuristic algorithms discussed above. It provides the first rigorous proof of the convergence of particle filters towards the optimal filter, and also discusses the unbias properties of a novel class of un-normalized particle measures. This work opened a series of research questions in the field of stochastic analysis of mean field particle samplers and their applications. Since that time, most of my research has focused on the theoretical and numerical aspects of this class of particle algorithms.

• In the last three decades these mean field genetic-type particle methodologies have led to a revolution in statistical machine learning and information sciences. They have become one of the crucial and most used numerical techniques in nonlinear filtering, statistical inference as well as rare event simulation, with a more recent renewed interest in population dynamics and quasi-invariant measure computations. The scope of this class of mean field particle samplers has expanded, opening up unexpected applications in a variety of fields, to name a few: *Molecular simulations, Schrödinger operators ground state computation, analysis of directed polymers, signal processing and information sciences, stochastic optimization and optimal control problems, genealogical tree analysis.* This genetic-type particle sampling methodology is now used in engineering, statistics, artificial intelligence as well as in physics under various names. They also have been successfully applied in biology, risk analysis, computer vision, signal processing, tracking, optimal control, econometrics, finance, robotics, and statistical inference. A discussion on these application domains can be found in my research books (cf. Chapter 12 in (FK-2004) and Section 2.6 in (CRC-2013)), see also the wikipedia list of genetic algorithm applications.

• Unlike traditional importance sampling type Monte Carlo methods and Markov chain Monte Carlo samplers, this class of interacting particle samplers is based neither on the law of large numbers for independent samples nor on the convergence decays to equilibrium of a Markov chain. In the end of the 1990s, much of the classical literature on the propagation of chaos properties of mean field particle systems yields exceedingly pessimistic mean error estimates that grows exponentially fast w.r.t. the time horizon. An exponential type bias estimate of the form e^{7t}/N, where N is the number of particles and t the time horizon, would induce an error bound at $t \geq 27$ larger than the number of particles in the visible universe; up to $t = 6$ we can eventually use all sand grains on earth. These exponential bounds are clearly impractical from any numerical perspective. To address this problem, we presented in end the late 1990s the first uniform propagation of chaos estimates with respect to the time horizon for mean field particle systems (IHP- 2001)/(CRAS-1999), both articles were submitted in 1998, [cf. preprint LSP-CNRS No. 03-1998]. This type of result is essential to develop particle algorithms with a degree of precision that does not depend on the time horizon. More refined time-uniform estimates for both discrete and continuous time mean field-type killing/duplication particle systems were published in 2000 in the review article (Sém-Proba.-2000), including time-uniform large deviations rates in (DM-Dawson-2005), and increasing propagations of chaos for particle blocks in chapter 8 in (FK-2004) w.r.t. entropy criteria and total variation norms. Time-uniform type extensions of the classical Hoeffding, Bernstein and Bennett exponential concentration inequalities for independent random sequences to interacting particle

systems are also presented in (AAP-2011), (FTML-2011) and (CRC-2013)

• To better understand the mathematical foundations of genetic-type mean field particle samplers we developed a fairly complete stochastic analysis with precise information on the stability of Feynman-Kac distribution semigroups as well as sharp asymptotic results for mean field interacting processes, including time-uniform strong and increasing propagation-of-chaos, non asymptotic coalescent tree based Taylor-type expansions with respect to the number of particles, convergence of empirical processes, exponential concentration estimates as well as large deviation principles for weak and strong topologies and uniform w.r.t. the time horizon, Donsker-type fluctuation theorems and Berry Essen estimates, ...

All of these contributions were the first results of this type in the literature on mean field interacting particle systems. A detailed presentation of these theoretical and numerical contributions is provided in the invited monograph I wrote for the Springer Series in Applied Probability in 2004 on Feynman-Kac formulae, and the more recent monograph on Mean field simulation published by Chapman & Hall/CRC in 2013. Most of this research program is built across various disciplines on active collaborations with international recognized and leading scientific experts in different scientific disciplines, to a name a few: *R. Carmona, D. Dawson, A. Guionnet, J. Jacod, M. Ledoux, T. Lyons, P. Protter in probability theory, as well as researchers in signal processing, statistics and information sciences such as B.D.O Anderson, C. Andrieu, A.N. Bishop, A. Doucet, A. Jasra, L. Murray, E. Moulines, S.S. Singh, B.N.G Vo, N. Whiteley, and many others*.
All our mathematical contributions rely on the development of new tools and techniques in combinatorics, operator theory, linear algebra, dynamical systems as well as functional and stochastic analysis.

• For instance, one of our deepest results on the uniform propagation of chaos estimates with respect to the time horizon developed in the early 2000 is based on a stochastic version of the Alekseev-Gröbner interpolation formula. Recently, we further developed this novel stochastic perturbation methodology in various directions, including in the context of McKean-Vlasov diffusions (Section 1.2 and Theorem 2.7 in (AAP-2020)), interacting jump processes (Theorem 5.7 in (EJP-2020)). We also used these techniques in the context of Ensemble Kalman models and related stochastic Riccati equations (Theorem 1.3 in (IHP-2020), Theorem 2.3 in (EJP-2019)).
Our more recent article on this subject (SPA-2022, see also Arxiv-2019 and CRAS Note 2020) also deduces a stochastic flow interpolating formula from a novel backward Itô-Ventzell formula. A more detailed review on the historical development of this novel stochastic perturbation theory, with precise reference pointers is provided in Section 8 in (SPA-2022).
In the context of Feynman-Kac semigroups and their particle approximations, these stochastic interpolation techniques require to quantify with some precision the stability properties of possibly random and time varying Feynman-Kac semigroups on probability spaces. The stability of these measure valued processes, including the discrete time nonlinear filtering equation and the Kushner-Stratonovich stochastic partial differential equation is a popular topic and well known difficult problem in signal processing and applied probability.

• We extended our earlier studies in this field mainly valid on compact spaces ((CRAS-1999), (SemProba-2000), (IHP-2001), (Annales-Fac-Toulouse-2002), (ESAIM-2003)) to discrete and continuous time varying models, including Neumann and Dirichlet boundary semigroups on general state spaces. These recent contributions are presented in (EJP-2020).
We developed a Lyapunov stability analysis of positive semigroups (AAP-2023) including absorption and/or reflection boundary models in the companion article (SAA-2023). We provided a complete analysis of coupled quantum harmonic oscillators in (CMP-2023). These linear/gaussian models play the same role in quantum mechanics as the Kalman-Bucy filter in signal processing. We also developed in the article (SIAM-PTA 2021) a novel interpretation of the smoothing solution in terms of a nonlinear diffusion flow. These models are the continuous time version of the backward Feynman-Kac models on path spaces we developed in 2010 in a joint work with A. Doucet and S.S. Singh in (M2AN-2010).
The more recent article (Arxiv-2024) presents a novel and general mathematical framework with easily checked Lyapunov stability conditions that ensure a novel uniform-in-time convergence of Diffusion Monte Carlo estimates towards the top of the spectrum of Schrödinger operators.

• In parallel with this research program on Feynman-Kac formula and their mean field particle interpretations, we developed various methodologies related to sequential Monte Carlo, adaptative rare event samplers, island particle algorithms, as well as self-interacting Markov chain models. For instance, the rigorous mathematical analysis of self-organized particle algorithms, often refereed as meta-heuristics in Operation Research literature, is part of another long term research program we started in 2002 (see for instance LSP-2002-06). We started developing the mathematical foundations of a new class of self-interacting Markov chains in a series of articles ((PRS-2004),(SAA-2006), (LSP preprint 2002), (ESAIM-2007),(ESAIM-2007),(Bernoulli-2011),(ArXiv-2023)). Elephant Random Walk (Phys. Rev-2004) and the interacting urn process (CUP-2009). arising in mathematical physics.

• Since 2016 my research mainly focuses on the mathematical foundations of Ensemble Kalman filters (abbreviated EnKF). The EnKF is a class of interacting particle system methodologies for solving nonlinear filtering and partial differential equations arising in fluid mechanics and geophysical models. In contrast with particle filters, the mean field interaction depends on the sample covariance of the particles. These particle techniques were introduced by Evensen in the seminal article Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics, Journal of Geophysical Research, vol. 10, pp. 143-162 (1994). In the last three decades the EnKF methodology has become one of the most used numerical techniques for solving high dimensional forecasting and data assimilation problems in a variety of applications including ocean and atmosphere sciences, fluid mechanics, image inverse problems, weather forecasting, environmental and ecological statistics and oil reservoir simulations. Despite the widespread usage of

this methodology to solve nonlinear and high dimensional filtering and inverse problems, little is known about their mathematical foundations.

The first rigorous analysis of discrete generation EnKF appeared in 2011 in the independent works (Le-Gland-2011), and (Mandel-2012). Unfortunately, even for stable signals, the non-asymptotic analysis developed in these aforementioned articles yields exceedingly pessimistic and impractical estimates that grow exponentially fast with respect to the time horizon as well as when the time step tends to zero when applied to continuous time models. To better understand the obstacles to the mathematical analysis of this class of particle models, we should recall that the EnKF is defined by a system of particles with an interaction diffusion function that depends on the sample covariance matrices of the system. This quadratic-type nonlinearity of the diffusion function already shows that conventional techniques developed in nonlinear Markov processes theory and McKean Vlasov diffusions are not suited to analyze the convergence of these particle algorithms nor to analyze the stability properties these models. In the last decade, laying the mathematical foundations of the EnKF methodology has been one of my principal research axis.

• We developed with my co-authors a rather complete mean field theory, including non asymptotic and uniform propagation of chaos estimates w.r.t. time, fluctuation and stability theorems for the sample means and the sample covariances. We also provided exponential decays to equilibrium and a precise description of invariant measures of stochastic Riccati diffusions. We restricted our attention to linear/Gaussian models as well as the extended Kalman filter, the only classes of filtering models where the EnKF is consistent with the optimal filter or with the well known extended Kalman filter. Our analysis applies to discrete and continuous time models, including nonlinear models with transient signals/observations.

• We made the following crucial observation concerning the evolution of the sample mean and the sample covariance of the EnKF filters: As the Kalman filter is coupled through the gain with an offline Riccati equation, the EnKF stochastic evolution also satisfies a coupled of nonlinear diffusion equation of the same form with orthogonal fluctuation/perturbation martingales (see for instance Theorem 3.1 in (AAP-2018), Section 3 in (EJP-2019), Section 4 in (MCSS-2023), as well as Theorem 3.1 in (AAP-2023)/(Arxiv-2021) in the context of discrete time EnKF). Note however that in the multivariate case, the sample covariance matrices satisfy a stochastic Riccati equation involving matrix valued martingales which require us to develop in (EJP-2019) and (IHP-2020) an appropriate and more sophisticated stochastic analysis in matrix spaces.

The article (AAP-2018) provides the first uniform propagation of chaos estimates w.r.t. the time parameter, as soon as the signal is stable. Uniform quantitative estimates for Extended Ensemble Kalman filters are presented in (EJP-2018). The stability analysis of various perturbation and projection methodologies of Kalman semigroups used in practice is also discussed in (SPA-2018). As expected the stability analysis and the uniform convergence of the EnKF with possibly unstable and multivariate transient signals is more involved.

• To understand these difficulties, we shown in (AAP-2019) that even for elementary one-dimensional problems, the stochastic Riccati diffusions describing the random evolution of the sample variances of the EnKF may exhibit surprisingly heavy tailed or Gaussian tailed invariant distributions, depending on the class of EnKF one uses as well as on the number of samples. To handle multivariate and possibly unstable signals, we extended the stability theory developed by Kalman and Bucy in the mid-1960s to Ensemble Kalman particle models. These contributions are presented in the articles (EJP-2019) and (IHP-2020), see also the review articles (MCSS-2023) as well as (Adv-AP-2022).

• All the mathematical contributions discussed above also rely on the development of new tools in random matrix theory, Riccati matrix equations and linear algebra. We wrote a book (FTML-2018) on Wishart matrix moments, we also present new Floquet representations of both continuous and discrete time Riccati flows in (IJC-2021) and (SIAM-2022) (Arxiv-version-2021), as well as a novel Taylor expansion of the matrix square root function (JMAA-2018), In the article (SIAM-2019) we also developed a more refined analysis of the stability of time varying and possibly random linear processes.

• Most of the studies discussed above are restricted to continuous time EnKF. For obvious reasons, any numerical integration of these models including all known filtering sensors are defined by discrete-time models. The analysis of discrete generation EnKF is more involved. In contrast with continuous-time models, discrete generation EnKF are not defined by a single coupled diffusion process but in terms of coupled two-step prediction-updating process (a.k.a. forecasting-analysis steps in EnKF and data assimilation literature). Furthermore, the Gaussian-nature of the diffusion models arising in the analysis of continuous-time EnKF theory is also lost and involves more sophisticated Riccati matrix equations and non-central Wishart transitions. This research projet is more complex and risky than it at first appears. The analysis of discrete time Riccati equations is rather delicate. As mentioned in (Bitmead-1985) "The (discrete time) Riccati equation is a difficult beast whose behavior can often be counter intuitive". As also noted in (Anderson-1972) in both of the pioneering articles (Kalman-1960) and (Deyst-1968) there was a crucial and commonly error made in the proof which invalidated these results including the ones in the seminal book (Jazwinski-1970). To handle the structure and the statistical difficulty of discrete time models, we started developing new stochastic perturbation tools in (AAP-2023). This article presents a rather complete analysis of the long time behavior of EnKF for one-dimensional models, including uniform estimates for transient signals.

• Since 2024, I have started developing new operator-theoretic tools to study entropic optimal transport problems, including Sinkhorn algorithms and Schrödinger bridges. These models play an increasingly important role in machine learning and generative modelling. The article (Arxiv-dec.24) we present a refined analysis of a finite-dimensional recursive formulation of the iterative proportional fitting procedure for general Gaussian multivariate models. The articles (Arxiv-1-March-25) and (Arxiv-2-March-25) present a novel semigroup contraction analysis based on Lyapunov techniques and transportation cost inequalities. In (Arxiv-April-25) provides entropic continuity bounds for conditional expectations and covariance matrices.

Head of Teams & Projects managements

• 2009-2013: INRIA project-team ALEA in Bordeaux.
• 2009-2010: Proba-Stats Team, Bordeaux Maths Institute. AERES Eval.report.
• 2011: PEPII project, Bordeaux Maths Inst. & the Ecology, Evolution Lab., ENS Paris (Bernard Cazelles).
• 2009-2011: ARC INRIA EPS, INRA (J.P. Gauchi & J.P. Vila), École vétérinaire d'Alfort and the LUBEM Quimper).
• 2009: Associated-team 2AS, ALEA & the Maths Dept. of Wuhan Univ. in China (Prof. Wu Li Ming).
• 2008-2009: Aquitaine Regional Council Project on Monte Carlo methods by interacting Markov chains.
• 2006: Research project, Nice-Sophia Antipolis Univ. & INRA dpt. MIA (J.P. Gauchi & J.P. Vila).
• 1998-2001: CNRS Maths-STIC research project Particle methods U.P.S., Lab. Stats. Prob. Toulouse, INRIA Rennes (F. Le Gland) & Sup Telecom Paris (E. Moulines).
• 1996-1999: INTAS-RFBR, European Prog. on Idempotent Analysis, Russian Academy of Sciences (V.P. Maslov).
• ⇝ Web-link to research management.

Committees

• Since 2023: MaThRad Advisory Board, (PI A. Kyprianou).
• 2018-2024: Bureau du Comité des Projets, INRIA Bordeaux.
• 2018-2023: Advisory Board, UKRI/EPSRC Centre for Doctoral Training in Mathematics, Mac-Migs Prog..
• 2015: Research Evaluation Committee: Math. & Comp. Sci. Australian Government, Australian Research Council.
• 2013-2014: Scientific expert for the European Commission.
• 2010-2011: Ministère de la Recherche: Committees PES 2010 & PES 2011, CNU 25/26.
• 2010: Ministère de la Recherche, dept. des affaires européennes et internationales.
Working group *Information, communication, nanotechnologies, China*, INRIA head C. Laugier.
• 2003-2004: AERES evaluation of the Math. Dept. Clermont Ferrand Univ. (head V. Giovangigli).
• 2010-2011: Team leader with Xavier Warin, *stochastic models and uncertainties*, EDF-INRIA Strategic action
• 2009-2010: facilitation INRIA committee 2009-2010 on Applied Maths, Calculus and Simulation (head Bernard Espiau).
• Recruitment committees: INRIA Bordeaux (2009 & 2010), Toulouse LSP & INSA (2000-2004), Bordeaux I & II (2009-2011), Nice Lab. Dieudonné (2004-2007), Lille (2010), Rennes IRMAR (2010), Luxembourg (2013-1014), Sydney UNSW (2015), Pau Univ. (2023).
• ⇝ Web-link to research management.

Research Grants & Projects

• 2019-2024: ANR Quamproc (PI L. Michel).
• 2010-2013: ANR VIROSCOPY (PI S. Clémençon).
• 2009-2012: ANR PROPAGATION, INRIA ALEA, DCNS-SIS & THALES (PI Fr. Caron).
• 2009-2012: ANR MODECOL, CNRS, La Rochelle Univ. & INRIA (PI C. Mony).
• 2008-2011: ANR PREVASSEMBLE, with ENS Paris (PI O. Talagrand) & Météo France Toulouse (PI C. Baehr).
• 2006-2009: ANR Chaire d'Excellence 2006, for the visit of P. Diaconis in Nice University.
• 2007-2010: ANR NEBBIANO CNRS, Nice-Sophia Antipolis Univ. & INRIA (PI T. Furon).
• 2017-2018: Australian ARC/Linkage Project 17, Remote sensing - high-speed catamarans, UNSW Sydney.
• 2005-2007: ARC INRIA RARE.
• 2005-2007: International prog. INRIA EPI ARMOR, ASPI, GERAD Montreal Univ. & Montreal HEC.
• 1999-2005: MITACS Network on Prediction in Interacting Systems.
• 1996-2001: TMR Network on Stochastic Analysis and Applications, head T. Lyons.
• ⇝ Web-link to research grants.

Technological transfers & Industrial contracts

• Since 2020: Partnership EPI ASTRAL & Naval Group on filtering and tracking aspects of warships and combat systems.
• 2018-2021: Underwater terrain-aided navigation using multi-sensor fusion EPI ASTRAL, ONERA & Naval Group.
• 2010-2014: Risk analysis of nuclear reactor vessel ruptures. EPI ALEA INRIA & EDF Chatou.
• 2011-2012: Modal parameter estimation using interacting Kalman filters. EPI ALEA & I4S & Dassault Aviation.
• 2011-2012: Deconvolution of signals by advanced Bayesian and Monte Carlo methods, EPI ALEA INRIA & CEA-CESTA.
• 2011-2012: Uncertainty propagations in numerical codes. EPI ALEA INRIA & IFREMER Brest.
• 2010-2012: Monte Carlo methods for financial American option pricing EPI ALEA INRIA & EDF Clamart team OSIRIS.
• 2009-2010: Multi-target filtering and tracking. EPI ALEA INRIA & DCNS-SIS/Naval Group.
• 2009-2010: Antenna array configuration, electromagnetic scattering inversion EPI ALEA INRIA & CEA-CESTA.
• 1990-1994: Particle filters, RADAR /SONAR/ GPS signal-processing, DRET-DIGILOG- LAAS/CNRS contract.
• ⇝ Web-link to industrial & technological transfers

Conferences & Workshops organizations

• Journées MAS Bordeaux 2010, co-organized with B. Bercu, B. de Saporta & D. Féral.
• Workshop on stochastic models and bayesian inference in epidemiology Bordeaux November 2011, co-organized with Bernard Cazelles, ENS Paris.
• Workshop on Evolutionary Algorithms - Challenges in Theory and Practice, Bordeaux March, 2010.
• Workshop on rare event simulation, ARC EPS (Ecomicrobiologie Prévisionnelle Statistique) & ANR VIROSCOPY, Bordeaux October 2010 & Workshop ARC EPS, Bordeaux March 2010.
• Workshop on numerical methods in Finance, co-organized with N. Oudjane, Bordeaux June 2010.
• Workshop on Stochastic Algorithms with the Chinese INRIA associated team 2AS Bordeaux June 2009.
• Rencontres INRIA & EDF INRIA CQFD and the R&D Clamart (ICAME team), January 2009.
• Journées de Probabilités et Statistique de Bordeaux INRIA & CEA CESTA, October 2008.
• Journées MAS, Lille Sept. 2006. Session on particle methods in physics and stochastic engineering.
• Conferences on particle filters *(Probability, Stats & Information Sciences)*:

- Workshop on multi-targets tracking, Bordeaux May 2009.
- Particle systems & filtering. Institut H. Poincaré, June 2001 (co-organized with R. Carmona & J. Jacod)
- Cambridge. Departement of Maths Cambridge Univ. December 1999 (co-org. with D. Crisan & A. Doucet)
- Rennes, CNRS/IRISA, June 1998 (co-organized with F. LeGland)
- Toulouse, LSP/CNRS. December 1996 & Avril 1997.

• Co-organization with P. Diaconis & S. Holmes of around 20 workshops and seminars at the Laboratoire J. A. Dieudonné, Nice Univ. in 2006-2007 projet ANR Chaire d'Excellence 2006; such as the workshop on Rare Event Simulation (co-organized with G. Rubino & B. Tuffin), Nice Univ. April 2007.
• Satellite conference of the VI World Congress Bernoulli Society for Mathematical Statistics and Probability, (co-organized with F. Le Gland, E. Moulines, D. Nualard, & Ch. Robert) Barcelona, July 2004.
• Machine Learning Summer School 2011. Bordeaux, September 2011.
• 41-ième Journées de Statistiques. Bordeaux May 2009 (organization committee).
• Member of the scientitic committee for the organisation of the Journées MAS SMAI 2008 in Rennes.

University lectures:

• 2014-2016: UNSW Sydney Australia, 2 courses on stochastic processes (MATH5835) & Advanced Monte Carlo methods (MATH5805) and a tutorial in Statistics (72h/year).
• 2011-2014: Professeur chargé de cours Polytechnique, CMAP (58h/year); (2007-2011) : Bordeaux Univ., Simulation et Algo. stochastiques, Master I & II Mathématiques & Master MIMSE. Course and tutorials (66h).
• 2011: CSC Doctorate School, Luxembourg University. Evolutionary particle methods: an introduction with applications (12h); (2009) Post-graduate course on stochastic algo. (November), La Havana Univ.
• 2004-2007: Nice, Sophia-Antipolis Univ. (185h/year):
Integration, probability and statistics (Master I Math) Course and tutorials; Financial Maths. (L3 Mass, et École Polytechnique Universitaire Nice-Sophia Antipolis), Course and tutorials; Stochastic Engineering (Master 2 MASS), Course and tutorials; Dynamical systems, (L3 MASS) tutorials.
• 2003: Purdue University: Introduction to probab. 3rd and 4th year univ. (60h).
• Post-graduate courses on particle methods (30h/course): (2000-2001) Princeton Univ. + (2003-2004) Paul Sabatier Univ. Toulouse + (2018) Fundação Getulio Vargas Rio + (2021) Vega Inst. Found., Moscow State Univ. (Zoom-online).
• 1996-2002: Paul Sabatier Univ. Toulouse. Simulation & Stochastic Algorithms. DESS & INSA (30h/year).
• 1994-1995: Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, Toulouse; 2 tutorials on Harmonic analysis, Stats-Proba. and Markov chains (30h/tutorial).
• ⇝ Web-link to lecture notes & math/scilab programs.

Summer schools:

• ICCAIS 2022 tutorial on Ensemble Kalman and Particle filters. Hanoi, Vietnam (November 2022) (3h); Summer School, Institute for Advanced studies in mathematics of Harbin China, (Zoom-online) Series of lectures on advanced Monte Carlo methods (July 2021) (6h); Greek Stochastics meeting, Corfu, Greece (August 2019) (4h).
• Mini-courses on Feynman-Kac formulae and particle methods: Univ. of Edinburgh, Scotland, (February 2015 and December 2023) (4h) + Summer School Proba & Stats. Ho Chi Minh City Vietnam (July 2014) (4h)+ CIRM Luminy (March 2013) (6h) + Academy of Math. and Systems Science, Summer School Probability Beijing, China (July 2013) (6h) + CNRS-INLN Sophia-Antipolis, (December 2012) (10h) + Summer School ENS Lyon (June 2012) (6h).
• Sino-French Summer Institute 2011. On the concentration of interacting particle processes. Academy of Science Beijing, China (June 2011) (6h)
• 10th Machine Learning summer school, An introduction to particle methods. Ile de Ré (September 2008) (6h).
• The 24th Finnish Summer School on Probability Theory. Interacting Particle Approximations of Feynman-Kac Formulae with Applications. Lahti, Academy of Finland through the Rolf Nevanlinna institute (June 2002) (6h).

Supervision (former affiliations)

• **Master students:** Luc de Montella (ENSTA 2021); Greg Durrett (MIT, USA, 5 months research internship INRIA 2009); Angèle Niclas (ENS Lyon. 5 months research internship UNSW (Australia) in 2017); Hu Peng (Paris VI, Financial Maths 2009); Ding Weng (Master Paris VI, Financial Maths 2010); Audrey Dubourg (Bordeaux, IT projet 2009); François Giraud (2009, ENS Bretagne); Philippe Fraysse (2008, ENS Cachan Bretagne).

• **PhD students:** Luc de Montella (EPI ASTRAL INRIA & Naval Group) 2022-2025; Camille Palmier, ONERA-Palaiseau (2018-2021); Antoine Campi, Météo France (2012-2015); Christelle Vergé, ONERA Palaiseau & École Polytechnique Palaiseau (2012-2015); Paul Lemaître, INRIA & EDF Chatou (2010-2014); Peng Hu, INRIA (2009-2012); François Giraud, INRIA & CEA CESTA (2009-2013). Aurélie Le Cain INRIA & CEA CESTA (2008-2012); Michele Pace, INRIA (2008-2011); Christophe Baehr (2004-2008); Mathias Rousset, Paul Sabatier Univ. (2004-2007).

• **Post-doc students:** E. Tantar (2009-2010); A. Tantar (2009-2010); M. Lei (2009-2010); S. Hu (2009-2010).

• **PhD reports:** Benjamin Dufée (IRISA), Hai-Dang Dau (Oxford Univ.), Qiming Du (Dauphine Univ.), Romain Ravaille (Saint Etienne Univ.), Adrien Todeschini (IMB Bordeaux), Christophe Avenel (INRIA Rennes), Olivier Bardou (INRIA Sophia Antipolis), Agnès Lagnoux Renaudie (Univ. Paul Sabatier, Toulouse), Florent Malrieu (Univ. Paul Sabatier, Toulouse), Nadia Oudjane (IRISA), Anastasia Papavasiliou (Princeton Univ.), Vivien Rossi (IRISA de Rennes), Sylvain Rubenthaler (Paris VI), Florian Simonatos (INRIA Rocquencourt), Ghislain Verdier (INRA, Montpellier), Denis Villemonais (Polytechnique CMAP).

• **HDR reports:** Alain Durmus (Ecole Polytechnique), Bertrand Cloez (INRAE Montpellier), Christian Musso (ONERA Palaiseau), Rama Cont (Polytechnique CMAP, CNRS), Fabien Campillo (IRISA de Rennes and INRIA Sophia Antipolis), Djalil Chafai (ENVT & LSP Toulouse), Manuel Davy (LAGIS-CNRS, Villeneuve d'Ascq), Madalina Deaconu (INRIA Nancy), Florent Malrieu (IRMAR, Univ. Rennes), Sylvain Rubenthaler (Lab. J.A. Dieudonné, Nice Univ.).

Publications

⇝ *Web-link to a full list of papers updated on September 2025 including 193 publications in journals, books and conference proceedings mainly in mathematical science, probability theory with some more discipline-based journals in statistics, engineering, signal processing, information sciences, machine learning, biology and in physics.*
The publication activity and citation impact can be found on my Google scholar profile; see also my Scopus author profile based on 154 of my 189 published articles. Our joint article Sequential Monte Carlo Samplers in collaboration with A. Doucet and A. Jasra published in JRSS B in 2006, is also one of the ten-most-cited articles published ten years earlier in the Google Scholar classic papers, category Physics & Mathematics (Proba. & Stat. Section)

Selected research monographs

• Mean field simulation for Monte Carlo integration. Chapman & Hall/CRC Press. Monographs on Statistics & Applied Probability (2013). [⇝ Web-link to CRC book]

• Feynman-Kac formulae. Genealogical and interacting particle approximations. Springer New York. Series: Probability and Applications (2004). [⇝ Web-link to Springer book]

Selected pedagogical books

• Stochastic Processes: From Applications to Theory. Joint book with S. Penev. Chapman & Hall/CRC Press (2014). [⇝ Web-link CRC book]

• Modèles et Méthodes Stochastiques. Une introduction avec applications. Joint book with C. Vergé. Springer Series : Maths & Applications. SMAI, vol. 75 (2014). [⇝ Web-link to Springer book]

Selected recent articles (2016-2025)

• A Lyapunov approach to stability of positive semigroups: An overview with illustrations. Joint work with M. Arnaudon & E.M. Ouhabaz. **Stochastic Analysis and Applications** (2024) & On the Stability of Positive Semigroups. Joint work with E. Horton & A. Jasra. **Annals of Applied Probability** (2023).

These 2 articles present an extension of V-norm contraction methods, associated to functionally weighted Banach spaces for Markov semigroups, to positive semigroups, including time-inhomogeneous models on non-necessarily compact spaces with Neumann and Dirichlet boundary conditions. These semigroups arise in a variety of areas of applied mathematics, including nonlinear filtering, rare event analysis, branching processes, physics and molecular chemistry.
The first article presents a self-contained overview of Lyapunov-based approaches with a variety of illustrations ranging from conventional Markov semigroups on general state spaces with geometric and sub-geometric convergence to equilibrium to more sophisticated conditional stochastic processes. The analysis applies to processes possibly restricted to some non-necessarily bounded domains, including locally Lipschitz and smooth hypersurface boundaries, Langevin diffusions as well as coupled harmonic oscillators.

• Coupled Quantum Harmonic Oscillators and Feynman-Kac path integrals for Linear Diffusive Particles. Joint work with E. Horton. **Communications in Mathematical Physics** (2023).

The article presents a new solvable class of quantum harmonic oscillators for a linear diffusive particle and a quadratic energy absorbing well associated with a semi-definite positive matrix force. Under controllability conditions, for non necessarily reversible models with possibly transient free particle diffusions, the ground state and the zero-point energy are explicitly computed in terms of the unique positive fixed point of a continuous time algebraic Riccati matrix equation.
The article also provides sharp non asymptotic estimates of the exponential decays to equilibrium of Feynman-Kac semigroups in terms of Wasserstein distances or Boltzmann-relative entropy. For reversible models we develop a series of functional inequalities including de Bruijn identity, Fisher's information decays, log-Sobolev inequalities, and entropy contraction estimates.

• A theoretical analysis of one-dimensional discrete generation ensemble Kalman particle filters. Joint work with E. Horton. **Annals of Applied Probability** Vol. 33, No. 2, pp. 1127-1172 (2023).

The article presents a novel self-contained and complete stochastic perturbation analysis of the fluctuations, the stability, and the long-time performance of discrete generation ensemble Kalman particle filters, including time-uniform and non-asymptotic mean-error estimates that apply to possibly unstable signals.
The stochastic Riccati difference equations considered in this work are also of interest in their own right, as a new class of stochastic rational difference equation.

• Backward Itô-Ventzell and stochastic interpolation formulae. Joint work with S.S. Singh. **Stochastic Processes and their Applications**, vol. 154, pp. 197–250 (2022).

The article presents a novel backward Itô-Ventzell formula and an extension of the Alekseev-Gröbner interpolating formula to stochastic diffusion flows. We also present some natural spectral conditions that yield direct and simple proofs of time uniform estimates of the difference between the two stochastic flows when their drift and diffusion functions are not the same, yielding what seems to be the first results of this type for this class of anticipative models. We also illustrate the impact of these results in the context of diffusion perturbation theory, comparisons for solutions of stochastic differential equations, interacting diffusions and discrete time approximations.

• A second order analysis of McKean-Vlasov semigroups. Joint work with M. Arnaudon. **Annals of Applied Probability**, vol. 30, no. 6, pp. 2613-2664 (2020) & A variational approach to nonlinear and interacting diffusions. Joint work with M. Arnaudon. **Stochastic Analysis and Applications**, vol. 37, no. 5 (2019).

These 2 articles present variational techniques and a second order differential calculus to analyze the regularity and the stability properties of the distribution semigroup associated with McKean-Vlasov type interacting diffusions. These methodologies provide second order Taylor type expansions with remainder for both the evolution semigroup as well as the stochastic flow associated with this class of nonlinear diffusions.
The impact of these results are illustrated with a second order extension of the Alekseev-Gröbner lemma to nonlinear measure valued semigroups and interacting diffusion flows. This second order perturbation analysis provides direct proofs of several uniform propagation of chaos properties w.r.t. the time parameter, including bias, fluctuation error estimate as well as exponential concentration.

• A perturbation analysis of stochastic matrix Riccati diffusions. Joint work with A. N. Bishop & A. Niclas. **Annales de l'Institut Henri Poincaré Probab. & Statist.**, vol. 56, no. 2, pp. 884–916 (2020) & On the Stability of Matrix-Valued Riccati Diffusions. Joint work with A. N. Bishop. **Electronic Journal of Probability** (2019).

These 2 articles are concerned with class of stochastic matrix Riccati diffusions arising in signal processing and data assimilation. In this context, the Riccati diffusion represents the flow of the sample covariance matrices associated with McKean-Vlasov-type interacting Kalman-Bucy filters. Under rather natural observability and controllability conditions, we derive new time-uniform moment and fluctuation estimates and exponential contraction inequalities.
Our approach combines spectral theory with nonlinear semigroup methods and stochastic matrix calculus and it applies to filtering problems with unstable signals. We also derive non-asymptotic Taylor-type expansions of stochastic matrix Riccati flows with respect to the number of particles. Also presented are refined moment estimates and sharp bias and variance estimates. These expansions are also used to deduce a functional central limit theorem at the level of the diffusion process in matrix spaces.

• A duality formula and a particle Gibbs sampler for continuous time Feynman-Kac measures on path spaces. Joint work with M. Arnaudon. **Electronic Journal of Probability**, 25, pp. 1-54 (2020) & On particle Gibbs samplers (discrete time). Joint work with R. Kohn & F. Patras. **Annals Institut H. Poincaré Probab. & Statist.** vol 52, no. 4, pp. 1687-1733 (2016).

These 2 articles show the equivalence between Particle Markov-chain Monte Carlo methodologies (JRSS-B-2010) and the Gibbs-Glauber sampling of a many-body Feynman-Kac target distribution on path space with a frozen ancestral line. We also presents a novel stochastic differential calculus based on geometric combinatorial techniques to derive explicit non-asymptotic Taylor type series of the semigroup of a class of particle Markov chain Monte Carlo models around their invariant measures with respect to the population size of the auxiliary particle sampler. These results provide sharp quantitative estimates of the convergence properties of conditional particle Markov chain models with respect to the time horizon.

Selected articles (2004-2014)

• A Lognormal Central Limit Theorem for Particle Approximations of Normalizing Constants. Joint work with J. Bérard & A. Doucet. **Electronic Journal of Probability**. vol.19, article no. 94, pp. 1-28 (2014).

The article analyses the log-normal fluctuations of particle approximations of unnormalized Feynman-Kac semigroups when both the number of particles and the time horizon tends to infinity. Special classes of models are also discussed, including particle absorption models in time-homogeneous environment and hidden Markov models in ergodic random environment, for which more explicit descriptions of the limiting bias and variance can be obtained.

• Snell envelope with small probability criteria. Joint work with P. Hu & N. Oudjane. **Applied Mathematics and Optimization.** vol. 66, no. 3, pp. 309-330 (2012) & On the Robustness of the Snell envelope. Joint work with P. Hu, N. Oudjane & B. Remillard. **SIAM Journal on Financial Mathematics.** vol. 2, no. 1, pp. 587-626 (2011).

These 2 articles analyze the robustness properties of the Snell envelope backward evolution equation for the discrete time optimal stopping problem. We consider a series of approximation schemes, including cut–off-type approximations, Euler discretization schemes, interpolation models, quantization tree models, and the stochastic mesh method of Broadie and Glasserman. We also propose a new approach based on genealogical tree approximations in the specific case where the criteria to optimize is associated with a small probability or a rare event.

• On the Stability and the Approximation of Branching Distribution Flows, with Applications to Nonlinear Multiple Target Filtering. Joint work with F. Caron, M. Pace & B.N. Vo. **Stochastic Analysis and Applications.** vol. 29, no. 6, pp. 951-997 (2011) & Particle approximations of a class of branching distribution flows arising in multi-target tracking. Joint work with F. Caron, A. Doucet & M. Pace. **SIAM J. on Control and Optimization.** vol. 49, no 4, pp. 1766-1792 (2011).

The first article analyzes the exponential stability properties of a class of measure-valued equations arising in nonlinear multi-target filtering problems. We also prove the uniform convergence properties w.r.t. the time parameter of a rather general class of stochastic filtering algorithms, including sequential Monte Carlo type models and mean field particle interpretation models. We illustrate these results in the context of the Bernoulli and the Probability Hypothesis Density filter. The second article analyzes an original particle scheme to approximate numerically branching intensity measures. Under appropriate regularity conditions, we obtain uniform and non-asymptotic estimates and a functional central limit theorem.

• Convergence of U-statistics for interacting particle systems. Joint work with F. Patras & S. Rubenthaler. **Journal of Theoretical Probability.** vol. 24, pp. 1002-1027 (2011).

The article extends the theory of U-statistics for i.i.d. random variables to continuous time and mean field type interacting particle systems. We also present Taylor-type non asymptotic expansions as well as Wick-type theorems.

• Concentration Inequalities for Mean Field Particle Models. Joint work with E. Rio. **Annals of Applied Probability**. vol. 21, no. 3, pp. 1017-1052 (2011).

The article analyses the fluctuations and the time-uniform concentration properties of a general class of discrete generation and mean field particle interpretations of nonlinear measure valued processes. These concentration inequalities generalize the classical Hoeffding, Bernstein and Bennett inequalities for independent random sequences to interacting particle systems. We illustrate these results in the context of McKean-Vlasov-type diffusion models, McKean collision-type models of gases and a class of Feynman-Kac distribution flows arising in machine learning and molecular chemistry.

• A non asymptotic variance theorem for unnormalized Feynman-Kac particle models. Joint work with F. Cérou & A. Guyader. **Annales de l'Institut Henri Poincaré Probab. & Statist.**, vol. 47, no. 3, pp. 629-649 (2011).

The article presents a non-asymptotic theorem for interacting particle approximations of unnormalized Feynman-Kac models. It also presents an original stochastic analysis-based on Feynman-Kac semigroup techniques combined with coalescent tree-based functional representations of particle block distributions.

• A Backward Particle Interpretation of Feynman-Kac Formulae. Joint work with A. Doucet & S.S. Singh. **M2AN**. vol 44, no. 5, pp. 947-976 (2010).

The article presents a novel particle interpretation of Feynman-Kac measures on path spaces based on a backward Markovian representation combined with a traditional mean field particle interpretation of the flow of their final time marginals. We also provide uniform convergence results w.r.t. the time horizon parameter as well as functional central limit theorems and exponential concentration estimates.

• Self Interacting Markov chains. Joint work with L. Miclo. **Stochastic Analysis and Applications.** vol. 24, no. 3, pp. 615-660 (2006) & On convergence of chains with time empirical self-interactions. Joint work with L. Miclo. **Proceedings of the Royal Society A.** vol. 460, pp. 325–346 (2004).

These 2 articles presents a new class of self-interacting Markov chains (LSP preprint 2002). We present sharp convergence rates, and exhibit different types of decays to equilibrium, depending on the level of interaction. Self-interacting approximations of quasi-invariant distributions on general state spaces including sharp convergence rates are also discussed. The Elephant Random Walk by Schütz and Trimper (Phys. Rev-2004) and the self interacting urn-type process introduced by Aldous, Flannery, and Palacios in (CUP-1988) can be seen as particular examples of self-interacting random walks.

Selected articles (1996-2003)

• Particle approximations of Lyapunov exponents connected to Schrödinger operators and Feynman-Kac semigroups. Joint work with L. Miclo. **ESAIM: Probabilités et Statistiques.** t. 7, pp. 171-208 (2003).

The article presents an interacting particle system methodology for the numerical solving of the Lyapunov exponent of Feynman-Kac semigroups and for estimating the principal eigenvalue of Schrödinger generators. We provide precise time-uniform estimates and we analyze the fluctuations of continuous time particle models.

• On contraction properties of Markov kernels. Joint work with M. Ledoux & L. Miclo. **Probability Theory and Related Fields**. vol. 126, no.3, pp. 395-420 (2003).

The article presents Lipschitz contraction properties of general Markov kernels on spaces of probability measures equipped with entropy-like distances. Universal quantitative bounds are deduced from Dobrushin's ergodic coefficient.

• Annealed Feynman-Kac Models. Joint work with L. Miclo. **Com. in Math. Physics**. vol. 235, no. 2, pp.191–214 (2003).

The articles is concerned with the concentration properties of annealed Feynman-Kac models in distribution space. We characterize the concentration regions in terms of a variational problem involving a competition between the potential function and the mutation kernel. When the temperature parameter is evanescent with time, the probability mass tends to concentrate on regions with minimal potential values.

• Genealogies and Increasing Propagations of Chaos for Feynman-Kac and Genetic Models. Joint work with L. Miclo. **Annals of Applied Probability**, vol. 11, No. 4, pp. 1166-1198 (2001).

The article presents a novel path-valued interacting particle systems model for the genealogical structure of genetic algorithms. We connect the historical process and the distribution of the whole ancestral tree with a class of Feynman-Kac formulae on path space. We also prove time-uniform versions of propagation of chaos for appropriate particle block sizes.

• The Monte-Carlo Method for filtering with discrete-time observations. Joint work with J. Jacod & P. Protter. **Probability Theory and Related Fields**. vol. 120, no. 3, pp. 346–368 (2001).

The article is concerned with continuous time filtering problems with observations delivered at regularly spaces times. We discuss a state-observation particle filter that applies to situations where the likelihood function is intractable, or expensive to calculate. These particle filters combine particle filter methodologies with Approximate Bayesian Computation techniques.

• On the stability of interacting processes with applications to filtering and genetic algorithms. Joint work with A. Guionnet. **Annales de l'Institut Henri Poincaré Probab. & Statist.**, vol. 37, No. 2, pp. 155-194 (2001).

The article presents a novel approach to study the asymptotic stability of a class of measure valued processes arising in biology, in the theory of genetic type algorithms and in advanced signal processing. Simple sufficient conditions are given for exponential decays and time-uniform convergence for the interacting particle numerical scheme. These qualitative properties are the first time-uniform convergence result for mean field type interacting particle systems.

• A Central Limit Theorem for Non Linear Filtering using Interacting Particle Systems. Joint work with A. Guionnet. **Annals of Applied Probability.** vol. 9, no. 2, pp. 275-297 (1999).

The first article on the fluctuations of particle filter approximations of McKean-type probability measures on path spaces. The article proves a Central Limit Theorem for the occupation measures of the interacting particle systems from the origin up to any given time horizon.

• On the Convergence and the Applications of the Generalized Simulated Annealing. Joint work with L. Miclo. **SIAM Journal on Control and Optimization**, vol. 37, no. 4, pp. 1222–1250 (1999).

The article is concerned with the convergence of the generalized simulated annealing with time-inhomogeneous communication cost functions using Log-Sobolev inequalities and semigroup techniques. We illustrate these results in the context of genetic type algorithms, with a simple proof of the convergence toward the global minima of the fitness function.

• Measure Valued Processes and Interacting Particle Systems. Application to Non Linear Filtering Problems. **Annals of Applied Probability**, vol. 8 , no. 2, pp. 438-495 (1998).

The article presents a general class of interacting particle approximations of discrete time and measure-valued dynamical systems. We also provide new classes of particle filters with conditional mutations driven by the observations.

• Large Deviations for Interacting Particle Systems. Applications to Non Linear Filtering Problems. Joint work with A. Guionnet. **Stochastic Processes and their Applications**, vol. 78, no. 1, pp. 69-95 (1998).

The article develops large deviations principles for the empirical measures of a general class of mean field type particle systems, including branching type particle filters.

• Non Linear Filtering: Interacting Particle Solution. **Markov Proc. and Related Fields.** vol. 2, no. 4, pp. 555–580 (1996).

The article presents the first rigorous proof of particle filters. It also provides the first proof of the unbiasedness properties of unnormalized particle measures.