The 5th Italian Meeting on Probability and Mathematical Statistics

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Book of Abstracts

(DRAFT)

Plenary Speakers

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Stefano Favaro

Franco Flandoli

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Preface

This volume contains the abstracts of the talks presented at IMPMS 2026, the 5th Italian Meeting on Probability and Mathematical Statistics, held in Palermo, Italy, from June 8 to 12, 2026.

Established in 2017, the Italian Meeting on Probability and Mathematical Statistics series represents an important opportunity for exchange among researchers working in various fields of probability and mathematical statistics, with the aim of promoting academic collaboration and the dissemination of recent research results. A distinctive feature of the meetings is the attention given to early-career researchers conducting their research activities in Italy or abroad.

The first IMPMS meeting was held in Turin in 2017. Since then, the IMPMS meetings have successively taken place in Vietri sul Mare (Salerno) in 2019, Bologna in 2022, and in Rome in 2025.

The fifth edition of the Italian Meeting on Probability and Mathematical Statistics (IMPMS 2026), held in Palermo from June 8 to 12, 2026, was promoted by the PRISMA group (PRobability In Statistics, Mathematics and Applications) of the Italian Mathematical Union (UMI) and organized by the Palermo Association of Mathematics and Computer Science (PAMCS), the Department of Mathematics and Computer Science (DMI), the Department of Economics, Business and Statistics (SEAS), and the Department of Physics and Chemistry "Emilio Segrè" (DiFC).

The event received support from the University of Palermo, the Department of Mathematics of the University of Rome "Tor Vergata", the Department of Mathematics "G. Peano" of the University of Turin, and the Department of Mathematical Sciences "G. Lagrange" (DISMA) of the Polytechnic University of Turin, as well as patronage from the Italian Mathematical Union (UMI), the Italian Statistical Society (SIS), the Association for Applied Mathematics in Economics and Social Sciences (AMASES), and the Sicilian Regional Assembly (ARS).

IMPMS 2026 solicited proposals for contributed sessions in any area of probability and mathematical statistics, each typically comprising four invited speakers and coordinated by one or two organizers. The meeting also offered participants, particularly early-career researchers, the opportunity to present recently published research or preliminary ideas and discuss them with the community. The program included 81 accepted contributed sessions, featuring 320 speakers.

The meeting also featured five plenary talks covering different areas of probability and mathematical statistics. The plenary speakers were Francesca Biagini (Ludwig-Maximilians-Universität München, Germany), Stefano Favaro (University of Turin and Collegio Carlo Alberto, Italy), Franco Flandoli (Scuola Normale Superiore of Pisa, Italy), Silvio Micali (Massachusetts Institute of Technology, USA; 2012 A.M. Turing Award laureate), and Giuseppe Savaré (Bocconi University, Italy).

During the conference, the PRISMA group held a meeting chaired by its President, Antonio Di Crescenzo, at which the President of the UMI, Marco Andreatta, presented the report *The Economic Impact of Mathematical Research in Italy*, prepared by Deloitte Economics.

The official meeting website, containing the detailed program, is available at:

https://probabilitypalermo2026.unipa.it/

We would like to extend our gratitude to all supporting institutions, plenary speakers, authors, speakers, and organizers of contributed sessions for their valuable contributions to the meeting program. Special thanks are due to the members of the Local Organizing Committee, the founding members of PAMCS, Cinzia Cerroni, Head of the DMI of the University of Palermo, Giuliarosa Amerio, Administrative Manager of the DMI, and all members of the department staff for their invaluable dedication and support in organizing the event. A particular acknowledgment is due to Barbara Brandolini, Andrea Consiglio, Angela Sciammetta, Marco Tabacchi, and Michele Tumminello, members of the Local Organizing Committee, for their support and significant contributions to the organization of the meeting, and to Rosario Corso for typesetting this book. Finally, EasyChair proved to be a convenient platform for managing submissions, reviews, and the preparation of the Book of Abstracts of IMPMS 2026.

June 8, 2026 — On behalf of the Steering Committee
Palermo — Giuseppe Sanfilippo

Contributed Sessions

ID	Title	Organizer(s)	Speakers
CS101	Statistical methods for complex spatial data analysis	Nicoletta D'Angelo Matteo Giordano	Matteo Giordano Alessia Caponera Deborah Sulem Marco Tarantino
CS102	Tales of Randomness: A Historical Perspective on SPDEs	Eliseo Luongo Umberto Pappalettera	Marco Romito Enrico Priola Antonio Agresti Mario Maurelli
CS103	Moments, Cumulants and dependence: Classical and Modern Perspectives	Elvira Di Nardo	Elvira Di Nardo Maria Infusino Riccardo Maffucci Pier Inverardi
CS104	SPDEs for physical models	Benedetta Ferrario Margherita Zanella	Giulia Carigi Andrea Di Primio Eliseo Luongo Luca Scarpa
CS105	Regularisation by noise for SPDEs	Luca Scarpa Carlo Orrieri	Marco Bagnara Davide Bignamini Lucio Galeati Theresa Lange
CS106	Collective Phenomena in Financial Markets: Arbitrage, Replication, and Risk	Marco Frittelli	Thilo Meyer-Brandis Alessandro Doldi Marco Maggis Frank Riedel
CS107	Combinatorial structures in probability and mathematical physics	Fabio Deelan Cunden	Elia Bisi Samuel Johnston Giovanni Gramegna Harriet Walsh
CS108	Discrete random structures for Bayesian learning	Giovanni Rebaudo	Martina Amongero Marta Catalano Francesco Gaffi Lorenzo Ghilotti
CS109	Recent Advances in Bayesian Nonparametrics	Beatrice Franzolini	Filippo Ascolani Benedetta Bruni Alice Giampino Giovanni Rebaudo
CS110	Risk measures: static and dynamic aspects	Emanuela Rosazza Gianin Elisa Mastrogiacomo	Matteo Ferrari Marco Tarsia Valeria Bignozzi Asmerilda Hitaj
CS111	Dynamical Aspects of Stochastic PDEs	Antonio Agresti Max Sauerbrey	Zachary Adams Alexandra Blessing Federico Cornalba Tommaso Rosati
CS113	Stochastics in Classical and Quantum Physics	Sonia Mazzucchi Stefania Ugolini	Barbara Rüdiger Luigi Borasi Claudio Dappiaggi Nicolò Drago

CS114	New advances in rough volatility models	Ofelia Bonesini	Giorgia Callegaro Emilio Rossi-Ferrucci Alessandro Bondi Eduardo Abi Jaber
CS115	Stochastic partial differential equations and invariant measures	Davide Bignamini	Francesco De Vecchi Benedetta Ferrario Josef Janák Margherita Zanella
CS116	Neural Networks and Gaussian Processes: Perspectives from Young Researchers	Claudio Macci	Lucia Celli Simmaco Di Lillo Anderson Hernandez Eloy Mosig
CS117	Statistical inference for high-dimensional diffusions	Chiara Amorino	Francisco Pina Francesco Iafrate Radomyra Shevchenko Andrea Zanoni
CS118	Bayesian nonparametrics for network data	Francesco Gaffi	Vince Velkey Beatrice Franzolini Nathaniel Josephs Francesco Sanna Passino
CS119	Statistical Learning through Kernels and Transport	Leonardo Santoro Alessia Caponera	Lorenzo Rosasco Clément Bonet Francesco Mascari Uriel Martinez
CS120	Probabilistic Perspectives on Generative Modeling	Antonio Ocello	Marta Gentiloni-Silveri Le Tuyet Nhi Benjamin Dupuis Antonio Ocello
CS121	Advances in entropic optimal transport	Conforti Giovanni	Lorenzo Dello Schiavo Giacomo Greco Katharina Eichinger Luca Tamanini
CS123	Asymptotic properties of Gaussian fields	Leonardo Maini	Marco Carfagnini Maurizia Rossi Michele Stecconi Anna Vidotto
CS124	Infinite Dimensional Analysis and Malliavin Calculus	Davide Addona	Michele Coghi Paolo De Fazio Simone Ferrari Federica Masiero
CS125	Cooperative and competitive mean-field models – Part I	Federico Cannerozzi Giorgio Ferrari	Roxana Dumitrescu Federico Cannerozzi Salvatore Federico Anna Pajola
CS126	Cooperative and competitive mean-field models – Part II	Federico Cannerozzi Giorgio Ferrari	Jodi Dianetti Giorgio Ferrari Marco Fuhrman Laura Perelli
CS127	Asymptotics of random graphs	Pierfrancesco Dionigi Elena Magnanini	Pierfrancesco Dionigi Elena Magnanini Giacomo Passuello Giulio Zucal

CS128	(Stochastic) Analysis on Spaces of Probability Measures and Applications	Mattia Martini Giacomo Sodini	Alessandro Pinzi Luca Tamanini Alessandro Scagliotti Rhoss Pellat
CS129	New Horizons for Random Fields in Probability and Statistics	Claudio Durastanti	Claudio Durastanti Francesca Pistolato Anna Todino Kartik Waghmare
CS130	McKean-Vlasov SDEs and associated nonlinear PDEs	Daniela Morale Stefania Ugolini	Marta Leocata Leonardo Tarquini Giulia Rui Ernesto Greco
CS131	Directed Polymers and Stochastic Heat Flow	Francesca Cottini	Francesca Cottini Anna Donadini Ziyang Liu Nicola Turchi
CS132	Subordinated Markov processes and applications	Giovanni Amici	Lorenzo Torricelli Patrizia Semeraro Alessandro Mutti Giuseppe D'Onofrio
CS133	Optimal Stopping and Applications	Bruno Buonaguidi	Goran Peskir Pavel Gapeev Andrea Bovo Bruno Buonaguidi
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CS137	Stochastic Models in Fluid Dynamics	Federico Butori Yassine Tahraoui	Francesco Triggiano Umberto Pappalettera Sotirios Kotitsas Yassine Tahraoui
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CS142	Diffusion Processes in Machine Learning	Francesco Iafrate Alessandro De Gregorio	Yuta Koike Shogo Nakakita Lukas Trottner Gitte Kremling

CS143	Optimal Transport Methods for Statistics	Marta Catalano Hugo Lavenant	Emanuele Dolera George Kanchaveli Yoav Zemel
CS144	Probabilistic Analysis of Complex Engineering Networks	Emanuele Mengoli	Ke Feng Nahuel Soprano-Loto Alessia Rigonat Emanuele Mengoli
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Abstracts

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When defaults cannot be hedged: XVA calculations via local risk-minimization

Francesca Biagini[1⋆], Alessandro Gnoatto[2], and Katharina Oberpriller[1]

[1] LMU München, Mathematics Institute, Munich, Germany,
biagini@math.lmu.de, oberpriller@math.lmu.de
[2] University of Verona, Department of Economics, Verona, Italy,
alessandro.gnoatto@univr.it

We consider the pricing and hedging of counterparty credit risk and funding when there is no possibility to hedge the jump to default of either the bank or the counterparty. This represents the situation which is most often encountered in practice, due to the absence of quoted corporate bonds or CDS contracts written on the counterparty and the difficulty for the bank to buy/sell protection on her own default. We apply local risk-minimization to find the optimal strategy and compute it via a BSDE.

Keywords: Default Risk · Market incompleteness· CVA · DVA· FVA· CollVA· xVA· Collateral

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⋆ Keynote Speaker

Bayes and quasi-Bayes empirical Bayes

Stefano Favaro

University of Turin and Collegio Carlo Alberto, Italy,
stefano.favaro@unito.it

Empirical Bayes methods, introduced by Herbert E. Robbins in the 1950s, provide a powerful framework for compound decision problems, with mixture models arising naturally through the marginal distribution of the observations. This talk revisits the nonparametric empirical Bayes paradigm through the classical Poisson compound decision problem, a canonical model for count data and one of the foundational examples in the field.

The first part of the talk will give an overview of nonparametric empirical Bayes, with emphasis on the distinction between f-modeling and g-modeling strategies, their practical behavior, and recent theoretical advances on minimax regret. I will then present a Bayesian g-modeling strategy, motivated by the natural use of priors on the unknown mixing distribution, and discuss why Bayesian procedures, while conceptually natural, may be computationally demanding because of the required posterior calculations.

The main part of the talk will present a quasi-Bayesian g-modeling strategy based on a sequential update of the mixing distribution. This method combines the flexibility of nonparametric g-modeling with substantial computational advantages, making it particularly suitable for large-scale and streaming count data. I will describe its theoretical properties, including consistency, frequentist regret guarantees, and Gaussian approximations leading to credible intervals. Finally, I will discuss a frequentist merging phenomenon between the quasi-Bayesian and Bayesian g-modeling strategies, which shows that the quasi-Bayesian procedure provides a computationally convenient approximation to its Bayesian counterpart.

Keywords: Nonparametric empirical Bayes · Bayesian g-modeling strategy · Quasi-Bayesian g-modeling strategy

Stochastic analysis in turbulent fluid dynamics and fusion plasma

Franco Flandoli

Scuola Normale Superiore di Pisa, Italy,
franco.flandoli@sns.it

Turbulent fluids behave like stochastic processes; therefore it is meaningful to use stochastic analysis to describe them. Two main questions we ask ourselves are: i) where stochasticity comes from, hence how should we insert it into the equations? ii) when does it matter? The talk will review efforts done on these topics, with the special view of application to confined fusion plasma, where turbulence plays a key role. The influence of stochastic models of turbulence on heat flow will be particularly emphasized. These researches, performed with a large group of collaborators mentioned in the talk, are supported by the ERC AdG project NoisyFluid, n. 101053472.

Keywords: Stochastic analysis · Turbulent fluid dynamics · Fusion plasma

Randomness and Computation

Silvio Micali

Massachusetts Institute of Technology, USA,
silvio@csail.mit.edu

We shall review three notable advantages of the integration of Randomness, Computation, and Mathematics: namely,

1. Alternative ways of proving theorems;
2. A rigorous and general theory of pseudorandomness; and
3. An operational notion of distribution equality that power many of the recent advances in Computing Theory.

Keywords: Randomness · Proof Systems · Pseudorandomness · Computational Indistinguishability

From the Monge–Kantorovich problem to optimal transport for random measures

Giuseppe Savaré

Bocconi University, Italy,
giuseppe.savare@unibocconi.it

The Monge–Kantorovich problem, originally posed as the optimal rearrangement of a mass distribution and later relaxed by Kantorovich into a problem of optimal coupling between two probability measures, has grown over the last decades into a rich theory that provides a natural geometric language for probability measures. I will first recall the main ideas of optimal transport and the geometry of the Wasserstein space, working throughout in the L^2 setting, with emphasis on couplings and the role of convex functions. I will then turn to optimal transport for random measures, namely the laws of random variables taking values in a space of probability measures. The theory exhibits striking analogies with the Euclidean case and highlights, on the one hand, the role of random measures admitting a Gaussian lift in the space of maps, and, on the other, the role of the distinguished class of totally convex functions. This offers a new perspective on differential tools already developed in classical optimal transport. I will illustrate this picture through a few examples and comment on some of the questions and perspectives it raises.

Keywords: Monge–Kantorovich problem · Optimal transport · Wasserstein space

Payment-failure times for random Lightning paths

Taki E. M. Abedesselam[1,2]*, Fabio Giacomelli[1,2], Francesco Pasquale[1], and Michele Salvi[1]

[1] University of Rome Tor Vergata, Italy,
abedesselam@ing.uniroma2.it,fabio.giacomelli@uniroma2.it,
{pasquale,salvi}@mat.uniroma2.it
[2] University of Camerino, Italy
{mohamed.abedesselam,fabio.giacomelli}@uincam.it

We study a random process inspired by the payment execution mechanism of the Lightning Network [1], the main layer-two solution on top of Bitcoin [2], represented as a graph in which users correspond to nodes and payment channels to bidirectional weighted edges with capacities. Each channel has a fixed publicly known capacity, while the balance, which specifies how this capacity is distributed between the two endpoints, is private and known only to the channel owners. Each user can make payments directly to adjacent nodes or indirectly through intermediate nodes, where payments will succeed only if all channels along the payment path can handle the required amount. The process we study is as follows: given an undirected graph G, where each edge e has a capacity C_e and each of its endpoints u and v has a balance $b_e(u)$ and $b_e(v)$, such that $C_e = b_e(u) + b_e(v)$, with an initial capacity distributed equally between the endpoints. In each round, a payment of one unit is executed by choosing two nodes u and v, and then selecting a shortest path among all possible shortest paths between them, both uniformly at random. Our goal is to investigate how long it takes for the first payment failure to occur, depending on the topology of the graph and the channel capacities. We first prove almost tight upper and lower bounds as a function of the number of nodes and the edge capacities when the underlying graph is complete. Then, we show how such a random process is related to the edge-betweenness centrality [3] measure and we prove upper and lower bounds for arbitrary graphs as a function of edge-betweenness and capacity. Finally, we validate our theoretical results by running extensive simulations over some classes of graphs, including snapshots of the real Lightning Network.

Keywords: Markov chains · Centrality measures · Lightning Network.

Contributed Session
CS173: Probability for Graph Algorithms organized by Alessandro Straziota and Luca Pepè Sciarria

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* Presenter

Efficient Simulation of Affine Volterra Processes

Eduardo Abi Jaber[1⋆] Elie Attal[1] and Dimitri Sotnikov[1]

Ecole Polytechnique, CMAP, France
eduardo.abi-jaber@polytechnique.edu

We propose simple and efficient schemes for Affine Volterra processes, using integrated kernel quantities and the Inverse Gaussian distribution. The schemes preserve positivity, and can be shown to converge weakly by recasting them as stochastic Volterra equations with a measure-valued kernel. Our method applies to two important examples: Volterra square-root/Heston and Hawkes processes. In the first case, when using a fractional kernel, the scheme with large time steps seems to be more performant as the Hurst index H decreases to -1/2. In the second case, our scheme has deterministic complexity, in contrast with exact methods based on sampling jump times that have random complexity, which opens the door to efficient Monte Carlo methods

Keywords: Volterra processes · Simulation · Hawkes · Heston.

Contributed Session
CS114: New advances in rough volatility models organized by Ofelia Bonesini

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⋆ Presenter

Can the introduction of resetting expedite the first passage of a diffusion process?

Mario Abundo

Dipartimento di Matematica, Università Tor Vergata, Roma, Italy,
abundo@mat.uniroma2.it

We show that the introduction of resetting is able to expedite the first passage of a diffusion process. To this end, we address the problem of minimizing the expected first-passage time (FPT) and the expected first-exit time (FET) of a one-dimensional diffusion process with Poissonian resetting, with respect to the resetting rate r. We first derive a general analytical relationship that expresses the Laplace transform (LT) and the expected value of the FPT (and FET) for the process with resetting in terms of the LT of the FPT (and FET) of the underlying diffusion without resetting. This framework is then applied to determine the optimal resetting rate r that minimizes the expected FPT (and FET). We provide explicit results for drifted Brownian motion and Ornstein-Uhlenbeck (OU) process. For Brownian motion, we extend existing literature by considering the case where the initial position x differs from the resetting position x_R, providing a comprehensive parametric analysis. For the OU process, we provide new insights into the minimization of the expected FPT, a case that has remained largely unexplored. Our results demonstrate how a strategic choice of the resetting rate can effectively regularize and accelerate search processes across one or two boundaries.

Keywords: First-passage time · First-exit time · Diffusion with resetting.

Contributed Session

CS176: Continuous-time random walks and diffusion processes: resetting and transformation for biological modeling organized by Luigia Caputo and Enrica Pirozzi

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(Moment) Lyapunov stability of parabolic SPDEs

Zachary P. Adams

Department of Mathematics and Statistics, Concordia University, Canada,
zachary.adams@concordia.ca

We study the Lyapunov and moment Lyapunov stability of a class of parabolic SPDEs driven by additive noise, including the stochastic Allen-Cahn equation. To do so, we analyze properties of the associated projective process.

Keywords: Lyapunov stability · Projective processes · SPDEs · Large deviation principles.

Contributed Session
CS111: Dynamical Aspects of Stochastic PDEs organized by Antonio Agresti and Max Sauerbrey

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Pathwise uniqueness by noise for stochastic PDEs with singular drift

Davide Addona[1], Davide A. Bignamini[2⋆], Carlo Orrieri[3], and Luca Scarpa[4]

[1] Department of Mathematical, Physical and Computer Sciences, University of Parma, Italy,
davide.addona@unipr.it
[2] Department of Science and High Technology, University of Insubria, Italy,
da.bignamini@uninsubria.it
[3] Department of Mathematics, University of Pavia, Italy,
carlo.orrieri@unipv.it
[4] Department of Mathematics, Politecnico di Milano, Italy,
luca.scarpa@polimi.it

This talk is based on the paper [1]. The main focus is pathwise uniqueness for mild solutions to stochastic PDEs with drift given in differential form. The key example that we want to study is the following SPDE evolving in $H = L^2([0,1]^d)$ with $d \in \{1,2,3\}$

$$dX(t) + A^{\gamma} X(t)\, dt = B(X(t))\, dt + A^{-\rho}\, dW(t)\,, \qquad X(0) = x\,,$$

where $\{W(t)\}_{t\geq 0}$ is an H-cylindrical Wiener process, $-A$ is a suitable realization of the Laplacian in H, $B : D(A^{\mu}) \to D(A^{-\nu})$ is locally θ-Hölder continuous with $\theta \in (0,1)$, $\gamma > 0$ and $\mu, \nu, \rho \geq 0$ are given constants. The singularity of the drift perturbation B allows to achieve novel pathwise uniqueness results for several classes of examples, ranging from fluid-dynamics to phase-separation models, previously studied only in the context of weak uniqueness, see [2,4]. Finally, the technique introduced here also yields significant improvements over the results already known in the non-singular case $B : H \to H$, see [3].

Presenter: Davide A. Bignamini

Keywords: SPDEs, Pathwise uniqueness by noise, Kolmogorov equations.

Contributed Session
CS105: Regularisation by noise for SPDEs organized by Carlo Orrieri and Luca Scarpa

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⋆ Presenter

Bismut-Elworthy type formulae for BSDEs with degenerate noise

Davide Addona[2] and Federica Masiero[1⋆]

[1] Department of Mathematics and Applications, University of Milano Bicocca, Italy,
federica.masiero@unimib.it

[2] Department of Mathematical, Physical and Computer Sciences, University of Parma, Parma, Italy
davide.addona@unipr.it

Keywords: gradient estimates · degenerate noise · backward stochastic differential equations

In this talk we present how to derive Bismut-Elworthy formula under assumptions weaker than non degeneracy of the noise. By Bismut-Elworthy formula we mean a gradient type estimate on the transition semigroup of a stochastic differential equation in a possibly infinite dimensional Hilbert space.
We also present a nonlinear version of the Bismut formula for BSDEs, in analogy to what is done in [3] in the case of non degenerate noise, and we discuss applications to the solution of semilinear Kolmogorov equations.

Our study is motivated by the regularizing properities of the transition semigroup of the stochastic wave equations, studied in [4], and of the stochastic damped wave equation, first studied in [1] and next also in [2].

Contributed Session

CS124: Infinite Dimensional Analysis and Malliavin Calculus organized by Davide Addona

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⋆ Presenter

Numerical approximation of McKean-Vlasov SDEs via stochastic gradient descent

Ankush Agarwal[1], Andrea Amato[2⋆], Stefano Pagliarani[1], and Goncalo dos Reis[3]

[1] Department of Statistical and Actuarial Sciences, University of Western Ontario, Canada, aagarw93@uwo.ca

[2] Department of Mathematics, University of Bologna, Italy, {andrea.amato9, stefano.pagliarani9}@unibo.it

[3] School of Mathematics, University of Edinburgh, United Kingdom, and Centro de Matemática e Aplicações (NOVA Math), Portugal, G.dosReis@ed.ac.uk

We propose a novel approach to numerically approximate McKean-Vlasov stochastic differential equations (MV-SDE) using stochastic gradient descent (SGD) while avoiding the use of interacting particle systems (IPS) and the associated simulation costs required to achieve the "propagation of chaos" limit. The SGD technique is deployed to solve a Euclidean minimization problem, obtained by first representing the MV- SDE as a minimization problem over the set of continuous functions of time, and then approximating the domain with a finite-dimensional subspace. Convergence is established by proving certain intermediate stability and moment estimates of the relevant stochastic processes, including the tangent processes. Numerical experiments illustrate the competitive performance of our SGD based method compared to the IPS benchmarks. This work offers a theoretical foundation for using the SGD method in the context of numerical approximation of MV-SDEs, and provides analytical tools to study its stability and convergence.

Based on a joint work with A. Agarwall, G. Dos Reis and S. Pagliarani in [1].

Keywords: McKean-Vlasov equations · Nonlinear stochastic differential equations · Stochastic gradient descent (SGD) · Convergence · Polynomial approximation

Contributed Session

CS161: Singular SDEs: Well Posedness and Numerics organized by Luca Bondi and Matteo Cagnotti

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⋆ Presenter

Deep Transformers as Mean-field Interacting Particle Systems

Andrea Agazzi*

Institute of Mathematical Statistics and Actuarial Science, University of Bern, Switzerland,
andrea.agazzi@unibe.ch

Transformers are a central architecture in modern deep learning, forming the backbone of large language models such as ChatGPT. In this talk, I will present a mathematical framework for studying how information–represented as "tokens"–evolves through the layers of such neural networks. Specifically, we consider a family of partial differential equations that describe how the distribution of tokens–modeled as particles interacting in a mean-field way–changes with depth. Numerical experiments reveal that, under certain conditions, these dynamics exhibit a metastable clustering phenomenon, where tokens group into well-separated clusters that evolve slowly over time. A rigorous analysis of this behavior uncovers a range of open questions and unexpected connections to various fields of mathematics

Keywords: Deep neural networks· Interacting particle systems· Mean-field· Scaling limits.

Contributed Session
CS180: Mathematics of Neural Networks organized by Stefano Vigogna

* Presenter

Chapter 3: Scaling limits and delayed blow-up by transport noise

Antonio Agresti

Department of Mathematics Guido Castelnuovo, Sapienza University of Rome, Italy,
antonio.agresti92@gmail.com

Transport noise appears in a variety of contexts in applied sciences, especially in fluid dynamics. In the latter, it typically models the effect of small-scale turbulence on large-scale dynamics. As shown in the seminal work of Galeati, and later by Flandoli and Luo, transport noise can provide dissipation effects on the dynamics via a certain scaling limit, thereby leading to regularising phenomena in nonlinear PDEs. The aim of this talk is to provide a guide through the key contributions in this area, up to recent developments in applications to reaction-diffusion equations and the 3D Navier-Stokes equations with small hyperviscosity, in which scaling limits meet and benefit from the maximal L^p-theory of SPDEs.

Keywords: Regularization by noise · Transport noise · Maximal regularity.

Contributed Session
CS102: Tales of Randomness: A Historical Perspective on SPDEs organized by Eliseo Luongo and Umberto Pappalettera

A multi-factorial innovation model with feature-interaction

Giacomo Aletti[1], Irene Crimaldi[2], and Andrea Ghiglietti[3⋆]

[1] Università degli Studi di Milano, Italy
giacomo.aletti@unimi.it
[2] IMT School for Advanced Studies Lucca, Italy
irene.crimaldi@imtlucca.it
[3] Università degli Studi di Milano-Bicocca, Italy
andrea.ghiglietti@unimib.it

We propose in [1] a novel extension of the Indian Buffet Process (IBP) that introduces explicit probabilistic dependence among features in multi-factorial innovation processes. In contrast to classical IBP models [2,3], where feature inclusion events are independent, our model allows the inclusion of a feature to influence the inclusion probabilities of others, providing a framework to study interacting latent factors in a mathematically tractable setting.

We develop a rigorous probabilistic formulation and derive asymptotic results for key quantities, including the total number of observed features D_t, the averaged number of features per agent/item $\overline{T}_t$, the averaged feature inclusion probability $\overline{P}_t$, the averaged number of agents/items per feature $\overline{K}_t$, as well as feature-specific quantities such as inclusion probability $P_t(j)$ and popularity $K_{t,j}$ for an observed feature j. While the asymptotic growth of D_t coincides with that of the classical three-parameter IBP [4], the interacting structure induces novel asymptotic phenomena in both averaged and feature-specific quantities, including power-law behavior and non-linear growth in feature popularity, not observed in the standard IBP.

Our theoretical results include strong laws of large numbers and central limit theorems for these quantities, providing probabilistic guarantees and detailed characterization of the stochastic behavior of the system. This model offers a combination of analytical tractability, interpretability, and flexibility, allowing the study of multi-feature systems with explicit interactions, while extending the asymptotic theory of classical IBP models to settings with dependent feature allocations.

Keywords: Indian Buffet Process · Feature Interactions · Limit Theorems

Contributed Session

CS177: Stochastic Algorithms and Interacting Reinforced Processes organized by Michele Aleandri and Ida Germana Minelli

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⋆ Presenter

Stochastic Volterra Equations on Convex Domains

Aurélien Alfonsi

CERMICS, Ecole Nationale des Ponts et Chaussées, France,
aurelien.alfonsi@enpc.fr

We will present in this talk sufficient conditions on the kernel and on the coefficients to get the existence of a solution that stays in a convex domain. The underlying tool is an approximation scheme that also stays in this domain. Applications include: a comparison result for scalar SVEs, existence of solutions possibly with a jump component, weak second-order approximation schemes for SVEs with multifactor kernels such as the multi-factor approximation of the rough Heston model.

Keywords: Stochastic Volterra Equations · Completely monotone kernels · Rough Heston model.

Contributed Session Recent Advances in Stochastic Volterra Equations
CS157: Recent Advances in Stochastic Volterra Equations organized by Sergio Pulido

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Optimal resource extraction with a random threshold

Mattia Allemandri*, Tiziano De Angelis, and Alessandro Milazzo

School of Management and Economics, Dept. ESOMAS, University of Turin, Turin, Italy,
mattia.allemandri, tiziano.deangelis, alessandro.milazzo@unito.it

We study a problem of resource extraction cast as a stochastic control problem where the depletion time of the resource is modeled by the hitting time for the controlled dynamics of a random (non-observable) threshold. Such a threshold may represent a tipping point, i.e., a critical level below which we expect a drastic disruption of the underlying source, leading to its extinction.

Mathematically, this is formulated as a singular control problem with random time-horizon. The underlying stochastic source X is singularly controlled by the cumulative extraction and it is modeled as a time-homogeneous diffusion process subject to general boundary conditions.

The random time horizon is modeled by the first time X drops below a random threshold, which is independent of the Brownian motion and distributed according to a cdf F. The problem is cast in a Markovian setting by introducing the running infimum of X as an additional state variable, which leads to a 2-dimensional singular control problem with infinite time-horizon.

Under some assumptions on F, we are able to fully characterize the solution of the problem. That is, we show that the optimal strategy consists of extracting resources in such a way that X reflects along a given boundary, which is expressed as a function of the running infimum. Depending on the chosen distribution F, the precise characterization of this boundary requires either solving an auxiliary problem or applying the so-called maximality principle, borrowed from optimal stopping theory, for singular control.

Keywords: resource extraction · tipping point · singular control · incomplete information · maximality principle

Contributed Session
CS153: "Optimal Stopping, Stochastic Control and Stochastic Games II" organized by Andrea Bovo and Alessandro Milazzo

* Presenter

Multivariate additive subordination with applications in finance

Giovanni Amici[1⋆], Laura Ballotta[2], and Patrizia Semeraro[3]

[1] Department of Industrial and Systems Engineering, North Carolina State University, USA,
gamici@ncsu.edu
[2] Faculty of Finance, Bayes Business School (formerly Cass), City St George's, University of London, UK,
l.ballotta@citystgeorges.ac.uk
[3] Department of Mathematical Sciences, Politecnico di Torino, Italy,
patrizia.semeraro@polito.it

We introduce a tractable multivariate pure jump process in which the trading time is described by an additive subordinator. The multivariate process retains the additivity property, and therefore is time inhomogeneous, i.e., its increments are independent but non stationary. We provide the theoretical framework of our process, perform a sensitivity analysis with respect to the time inhomogeneity parameters, and design a Monte Carlo scheme to simulate the trajectories of the process. We then employ the model in the context of option pricing in the FX market. We take advantage of the specific features of currency triangles to extract the joint dynamics of FX log-rates. Extensive tests based on observed market data show that our model outperforms well established pure jump benchmarks. Moreover, we explore applications of our stochastic process to financial optimization problems and propose state-of-the-art derivative-free adaptive sampling algorithms to efficiently compute solutions.

Keywords: Multivariate stochastic processes · Additive subordination · Monte Carlo sampling · Finance · Option pricing

Contributed Session
CS164: Stochastic Processes for Finance organized by Alessandro Mutti and Giuseppe D'Onofrio

⋆ Presenter

Bayesian Nonparametric Community Detection in Stochastic Block Models with Structural Constraints

Martina Amongero[1]* and Pierpaolo De Blasi[2]

[1] ESOMAS Department, University of Torino, Italy
[2] Collegio Carlo Alberto, Torino, Italy
{martina.amongero,pierpaolo.deblasi}@unito.it

Network-structured data are becoming increasingly common across many fields, including the social sciences, biology, physics, and computer science. A central task in network analysis is community detection, which involves partitioning nodes into groups so that nodes within the same group exhibit similar connectivity patterns. A generative model well suited to capturing such communities is the stochastic block model (SBM) [1]. Recent work has applied Bayesian nonparametric methods to jointly infer both community structures and the number of communities in the SBM by placing a prior on the number of blocks and estimating block assignments via collapsed Gibbs samplers [2,3,4]. However, efficiently incorporating structural community constraints through the prior remains an open challenge. In this work, which extends [5], we address this gap by studying the effect of enforcing weak and strong assortativity as well as core–periphery structure on Bayesian nonparametric community detection for the SBM. We identify scenarios in which these constraints improve performance over the standard SBM and illustrate our results using benchmark datasets.

Keywords: Bayesian nonparametrics · community detection · Gibbs-type prior · network · stochastic block model · core-periphery · assortativity

Contributed Session
CS108: Discrete random structures for Bayesian learning organized by Giovanni Rebaudo

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* Presenter

Statistical inference for interacting particle systems driven by the fractional Brownian motion

Chiara Amorino[1], Ivan Nourdin[2], and Radomyra Shevchenko[3,4] ⋆

[1] Universitat Pompeu Fabra, Barcelona, Spain
[2] University of Luxembourg, Esch-sur-Alzette, Luxembourg
[3] LJAD, Côte d'Azur University, Nice, France
[4] Centrale Méditerranée, Nice, France

We consider a system of interacting particles with Lipschitz continuous drift functions, driven by additive fractional Brownian motions with H in $[\frac{1}{2}, 1)$. For this system, we address the drift parameter estimation problem over a fixed time interval, considering different assumptions for the drift. We propose several estimators, demonstrate their consistency and asymptotic normality as the number of particles tends to infinity, and present a numerical study illustrating our findings.

This talk is based on joint work [1] with Chiara Amorino and Ivan Nourdin, and on ongoing work with Chiara Amorino, Augustin Puel, as well as Yasan Odeh.

Keywords: Interacting particle systems · Fractional Brownian motion · Statistical inference for stochastic processes.

Contributed Session
CS117: Statistical inference for high-dimensional diffusions organized by Chiara Amorino

References

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⋆ Presenter

Large deviations for spatial coagulation with diffusion

Luisa Andreis[1]*

Dipartimento di Matematica, Università degli Studi di Torino, Italy,
luisa.andreis@unito.it

Since Smoluchowski introduced his well-known coagulation equation in 1917, there has been an active line of research focused on understanding the properties of the solutions to this equation and related models for coagulation. The framework established by Smoluchowski was later extended, allowing particles to have additional properties beyond their mass, such as spatial location. This lead to the introduction of the Smoluchowski coagulation-diffusion PDE, a system of partial differential equations modelling the evolution in time of mass-bearing Brownian particles which are subject to short-range pairwise coagulation. In 2007, Hammond and Rezakhanlou gave a kinetic limit derivation of such equation via a system of microscopic interacting particles moving as Brownian motion in space, see [1].

In this talk we focus on some recent progress in the study of this particle system. We present the approach based on Poisson Point Processes introduced in [2] to study large deviations of the trajectory of such purely coagulating Markov process in the large volume limit and we explain how this approach can be applied to the study of diffusing particles too. We mention as well how this also provides insight into gelation phenomena and phase transitions for the particle system.
This talk is based on a series of joint works with W. König, M. Kolodjekzyk, H. Langhammer, E. Magnanini and R.I.A. Patterson.

Keywords: Point processes · Smoluchowski PDE · large deviations.

Contributed Session
CS156: Point processes in the continuum organized by Lorenzo Dello Schiavo and Alexander Zass

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* Presenter

Threshold-Driven Streaming Graph: Expansion and Rumor Spreading

Flora Angileri[1⋆], Andrea Clementi[1], Emanuele Natale[2], Michele Salvi[3], and Isabella Ziccardi[4]

[1] Department of Enterprise Engineering "Mario Lucertini", University of Rome Tor Vergata, Italy
flora.angileri@alumni.uniroma2.eu, clementi@mat.uniroma2.it
[2] CNRS, I3S & INRIA, Université Côte d'Azur, Sophia Antipolis, France
emanuele.natale@univ-cotedazur.fr
[3] Department of Mathematics, University of Rome Tor Vergata, Italy
salvi@mat.uniroma2.it
[4] CNRS, IRIF, Université Paris Cité, Paris, France
isabella.ziccardi@irif.fr

We will introduce the *Threshold-driven Streaming Graph* model, which is obtained by performing a randomized distributed algorithm, called RAES, over a dynamic graph evolving with the *streaming node-churn process*. This model captures two key features of modern peer-to-peer networks: a local threshold mechanism that bounds the degree of each vertex, and a node-churn process that regulates how vertices join and leave the network in each round.

Our main result proves good expansion properties of this model, with high probability. As a consequence, we will establish a logarithmic upper bound on the completion time of the well-known PUSH and PULL rumor-spreading protocols. Our analysis will also provide an upper bound to the message-communication overhead, showing that the overall number of exchanged messages at every round t is optimal in expectation and $O(\log n)$ with high probability.

Keywords: Distributed Algorithms · Randomized Algorithms · Dynamic Random Graphs · Graph Expansion · Rumor Spreading.

Contributed Session
CS165: Processes on dynamic random graph organized by Michele Salvi

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⋆ Presenter

Constructing heavy-tailed directed hypergraphs

Giacomo Ascione[1⋆], Piero de Lellis[2], and Roberto Rizzello[2]

[1] Scuola Superiore Meridionale, Napoli, Italy,
g.ascione@ssmeridionale.it
[2] Department of Electrical Engineering and Information Technology, University of Naples Federico II, Napoli, Italy
{pietro.delellis,roberto.rizzello}@unina.it

In recent times, hypergraphs have been frequently used in applications, as for instance in opinion formation [3] and social contagion [2], to describe higher order interactions. For this reason, algorithms to construct hypergraphs with specific characteristics are necessary to better understand, at least numerically, the dynamics on the aforementioned hypergraph. An algorithm for the construction of scale-free directed graphs has been provided in [1]. In particular, the authors obtain a discrete-time stochastic process $(\mathcal{H}_k)_{k\geq 0}$ in the space of directed graphs such that, denoting by $X^i_{\mathsf{in}}(k)$ and $X^i_{\mathsf{out}}(k)$ the number of nodes respectively with indegree and outdegree equal to i, it holds $X^i_\eta(k) = r^i_\eta k + o(k)$ where $r^i_\eta \sim Ci^{-\epsilon_\eta}$ and $\eta \in \{\mathsf{in},\ \mathsf{out}\}$. In this talk we first generalize the approach in [1] to a generic setting for stochastic recursive equations in discrete time and then we use the general results to provide algorithms for the constructions of random sequences of directed hypergraphs $(\mathcal{H}_k)_{k\geq 0}$ such that $k^{-1}X^i_\eta(k) \asymp r^i_\eta$ where $r^i_\eta \sim Ci^{-\epsilon_\eta}$ and $\eta \in \{\mathsf{in},\ \mathsf{out}\}$. In particular, our algorithm allows to avoid self-loops, hence also covering the case of directed graphs with no self-loops that was missing in [1].

Keywords: Hypergraphs · Stochastic recursive equations · Simulation.

Contributed Session
CS158: Stochastic Processes, PDEs and Networks organized by Fausto Colantoni

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⋆ Presenter

Posterior behaviour of the stick-breaking weights for Bayesian infinte mixture models

Filippo Ascolani[1⋆] and Surya Tokdar[2]

[1] Department of Statistical Science, Duke University, United States
filippo.ascolani@duke.edu
[2] Department of Statistical Science, Duke University, United States
surya.tokdar@duke.edu

The stick-breaking representation is a popular way of defining the Dirichlet process by the associated sequence of probability weights. It is particularly appealing when the discrete random measure is convolved with a suitable kernel: in this context, the stick-breaking construction is often truncated and posterior inference can be performed using a finite number of parameters. Despite its relevance, little is known about the posterior distribution of the weights in a mixture framework.

Assuming that the data are generated by a mixture with the same kernel and K^* components, we deduce some asymptotic properties of the stick-breaking weights. In particular, an interesting phase transition is observed: the posterior assigns mass to the first K^* weights up to the parametric rate, while any further improvement requires a logarithmic (with respect to the size of the dataset n) number of components. Thus the model adapts to the correct number of components, but the mixing measure assigns $\mathcal{O}(n^{-1/2})$ mass to additional terms (which can be thought as the price of having a nonparametric specification).

We use such results to shed some light on the clustering properties of Dirichlet process mixtures (e.g. number of clusters) and to provide posterior guarantees for computational methods based on truncation. The mathematical derivations combine prior properties with tools from Bayesian asymptotics and empirical process theory.

Keywords: Bayesian asymptotics · nonparametric models · clustering.

Contributed Session
CS109: Recent Advances in Bayesian Nonparametrics organized by Beatrice Franzolini

⋆ Presenter

node2vec random walks: Regular graphs and recurrence

Luca Avena[1], Gianmarco Bet[1], Lars Schroeder[2⋆], and Clara Stegehuis[2]

[1] Department of Mathematics and Computer Science, University of Florence, Italy,
{luca.avena,gianmarco.bet}@unifi.it
[2] Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, The Netherlands
{l.schroeder,c.stegehuis}@utwente.nl

node2vec random walks are tuneable random walks that come from the popular algorithm node2vec[1] which is used for network embedding. The transition probabilities of the random walks depend on the previous visited node and on the triangles that contain the current and the previous node as shown in Figure 1. In the node2vec algorithm, node2vec random walks are used to sample neighborhoods for each node of the network and by comparing these an embedding of the network into a Euclidean space can be computed. Since the parameters of the random walks can be tuned to create different types of neighborhoods, this approach is very flexible and advantageous over just using simple random walks.

Even though the algorithm is widely used in practice, mathematical properties of node2vec random walks almost have not been investigated and even basic questions such as how the stationary distribution depends on the walk parameters and if the random walk is recurrent are nearly unexplored. In this talk, we study the behavior of node2vec random walks on regular graphs. By going to a higher-order state space, the space of directed wedges, we can prove a simple expression of the stationary distribution on this space which is determined by the transition type of the wedge. We also formalize a pullback mechanism to retrieve the stationary distribution on the original state space. Further, we show that on infinite regular graphs, node2vec random walks are recurrent if and only if the simple random walk is recurrent.

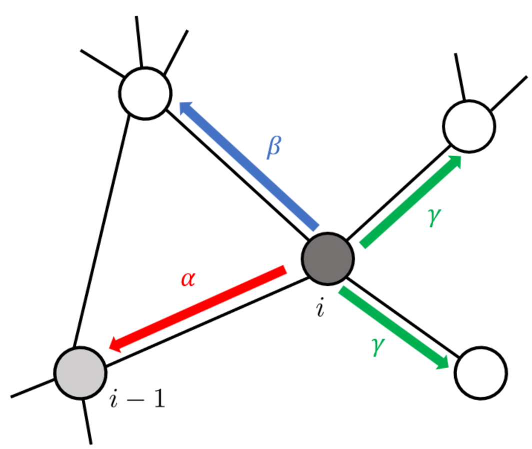

Fig. 1. node2vec transition rates

Keywords: node2vec random walks · Stationary distribution · Regular graphs.

⋆ Presenter

Contributed Session

CS140: Community structure of Complex Networks organized by Riccardo Michielan and Lars Schroeder

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Parametric local volatility: exact prices lead to sound continuous Markovian models

Lorenzo Torricelli[1], Michele Azzone[2⋆], and Marco Vitelli[1]

[1] Department of Statistical Sciences, University of Bologna, Italy
lorenzo.torricelli2@unibo.it, marco.vitelli3@unibo.it
[2] Department of Mathematics, Politecnico di Milano, Milano, Italy
michele.azzone@polimi.it

Local volatility models ([3]) are generally seen as insufficient for handling the many nuances of modern derivative markets. By reverse-engineering a family of no-arbitrage call price functions, this research questions a number of claims in this direction.

We introduce a class of continuous Markovian asset pricing models with closed-form option prices, leading – by construction – to identifiable risk-neutral marginal distributions, and then specialize to a significant instance where the SDE well-posedness can be shown, the generalized beta local volatility (GBLV) model. The GBLV finite-dimensional distributions coincide with those of a known discontinuous martingale model that exhibits an at-the-money implied volatility skew divergence. These findings contrast with the commonly accepted wisdom that LV is unsuitable for capturing the implied volatility surface's singular behavior as time-to-maturity approaches zero ([1]), and that option prices from jump models cannot be fitted to continuous Markov models ([4]). Such claims, typically regarded as valid for the *whole* local volatility class, ultimately hinge on auxiliary assumptions, most notably, regularity of the diffusion coefficient at initial time. By directly embedding in the risk-neutral distributions the desirable properties an implied volatility surface should have, an LV model is freed from the constraints that make it unsuitable for capturing certain phenomena. The program we follow in order to achieve this is quite simple. We begin by specifying a time-consistent family of no-arbitrage implied risk-neutral distributions, inspired by the GBA of [2], a jump model exhibiting ATM power-law skew divergence. We then formally derive the corresponding LV process and show that it admits a unique strong solution. Through the lenses of explicit option prices it can be thus demonstrated that local volatility models can very well be consistent with the ATM short maturity skew blow-up and possess the same marginals as a jump option pricing model and be well-posed despite having a singular diffusion coefficient. As a consequence, the GBLV model does not suffer from several of the commonly exposed drawbacks of continuous Markovian models.

Keywords: Local volatility · explicit option prices · implied volatility surface · generalized beta distribution.

Contributed Session
CS164: Stochastic Processes for Finance organized by Alessandro Mutti and Giuseppe D'Onofrio

⋆ Presenter

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Poisson Hail on a Wireless Ground

François Baccelli[1], Ke Feng[2⋆], and Sergey Foss[3]

[1] INRIA-ENS Paris and Telecom Paris, France
francois.baccelli@inria.fr
[2] CNRS-ETIS, France
ke.feng@ensea.fr
[3] School of MACS, Heriot-Watt University and Sobolev Institute of Mathematics, UK
S.Foss@hw.ac.uk

We introduce a new model which incorporates three key ingredients of a large class of wireless communication systems: (1) spatial interactions through interference, (2) dynamics of the queueing type, with users joining and leaving, and (3) carrier sensing and collision avoidance as used in, e.g., WiFi [1]. In systems using (3), rather than directly accessing the shared resources upon arrival, a customer is considerate and waits to access them until nearby users in service have left. This new model can be seen as a missing piece of a larger puzzle that contains such dynamics as spatial birth-and-death processes [2], the Poisson hail model [3], and wireless dynamics as key other pieces [4]. We show that, under natural assumptions, this model can be represented as a Markov process on the space of counting measures.

The main results are then two-fold. The first is on the shape of the stability region and, more precisely, on the characterization of the critical value of the arrival rate that separates stability from instability. We show that, for natural values of the system parameters, the implementation of sensing and collision avoidance stabilizes a system that would be unstable if immediate access to the shared resources would be granted. In other words, for these parameters, renouncing greedy access makes sharing sustainable, whereas indulging in greedy access kills the system.

Keywords: Dynamic networks · stochastic geometry · wireless queueing analysis.

Contributed Session
CS144: Probabilistic Analysis of Complex Engineering Networks organized by Emanuele Mengoli

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⋆ Presenter

Chapter 4: The nonsmooth Kraichnan model

Marco Bagnara[1], Michele Coghi[2], Lucio Galeati[3], Francesco Grotto[4], and Mario Maurelli[4⋆]

[1] Department of Mathematics, Imperial College, London, United Kingdom,
m.bagnara@imperial.ac.uk

[2] Dipartimento di Matematica, Università degli Studi di Trento, Trento, Italy
michele.coghi@unitn.it

[3] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, L'Aquila, Italy
lucio.galeati@univaq.it

[4] Dipartimento di Matematica, Università di Pisa, Pisa, Italy
{francesco.grotto,mario.maurelli}@unipi.it

The nonsmooth Kraichnan model [6] is a linear stochastic transport model in which the velocity field is Gaussian, white in time, incompressible, isotropic, and spatially rough. Introduced as a toy model for turbulent transport, it allows explicit computations and has become a benchmark for predictions such as Richardson pair dispersion and intermittency.

In mathematics, it stands out as one of the few transport models exhibiting both well-posedness and spontaneous stochasticity, as shown in the early 2000s by Le Jan and Raimond [7], and independently by E and Vanden-Eijnden [5]. More recently, renewed interest has followed rigorous results on anomalous dissipation and anomalous regularization (e.g. [8,4,3]), as well as related regularization-by-noise results (e.g. [2,1]).

In this talk, we will review these mathematical developments and highlight key open problems in stochastic turbulent transport.

Keywords: Kraichnan model · Turbulent transport · Regularization by noise

Contributed Session

CS102: Tales of Randomness: A Historical Perspective on SPDEs organized by Eliseo Luongo and Umberto Pappalettera

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⋆ Presenter

Refined uniqueness results for 2D Euler and gSQG with rough Kraichnan noise

Marco Bagnara[1⋆] and Lucio Galeati[2]

[1] Department of Mathematics, Imperial College London, UK,
m.bagnara@imperial.ac.uk

[2] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, Italy
lucio.galeati@univaq.it

We prove strong well-posedness results for the stochastic 2D Euler equations in vorticity form and generalized SQG equations, with L^p initial data and driven by a spatially rough, incompressible transport noise of Kraichnan type. Previous works addressed this problem with noise of spatial regularity $\alpha \in (0, 1/2)$, in a setting where a rougher noise yields a stronger regularization. We remove this limitation by allowing any $\alpha \in (0, 1)$, covering the same range of parameters for which anomalous regularization effects are known to occur in passive scalars. In particular, this covers the physically relevant case $\alpha = 2/3$, associated with the Richardson-Kolmogorov scaling of energy cascade.

Keywords: 2D Euler equations · generalized SQG equations · rough Kraichnan noise · regularization by noise.

Contributed Session

CS105: Regularisation by noise for SPDEs organized by Luca Scarpa and Carlo Orrieri

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⋆ Presenter

Infection models on dense dynamic random graphs

Simone Baldassarri

Gran Sasso Science Institute (GSSI), L'Aquila, Italy,
simone.baldassarri@gssi.it

The focus of this talk will be Susceptible-Infected-Recovered (SIR) models on dense dynamic random graphs, in which the joint dynamics of vertices and edges are co-evolutionary, i.e., they influence each other bidirectionally. In particular, edges appear and disappear over time depending on the states of the two connected vertices, on how long they have been infected, and on the total density of susceptible and infected vertices. I will present our main results, which establish functional laws of large numbers for the densities of susceptible, infected, and recovered vertices, jointly with the underlying evolving random graphs in the graphon space. The talk will also include numerical illustrations showing that our model exhibits multiple epidemic peaks, as observed in real-world epidemics.

This talk is based on a joint work with P. Braunsteins, F. den Hollander and M. Mandjes.

Keywords: SIR dynamics · Graph dynamics · Co-evolution.

Contributed Session
CS165: Processes on dynamic random graphs organized by Michele Salvi

On spectral gaps of stochastic wave equations

Nikolay Barashkov[1*], Giacomo Di Gesu[2], and Petri Laarne[3]

[1] Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany,
barashkov@mis.mpg.de
[2] Dipartimento di Matematica, Università di Roma La Sapienza giacomo.digesu@uniroma1.it
[3] Department of Mathematics and Computer Science, University of Palermo, Palermo, Italy
petri.laarne@helsinki.fi

We will discuss Spectral Gap of Stochastic Wave equations with additive noise, and it's relation to the heat equation case. Our methods combine techiques from Hypocoercivity in an infinite dimesional setting, with techniques from singuarl SPDE's.

Keywords: First keyword · Second keyword · Another keyword.

Contributed Session

CS162: Singular stochastic analysis and stochastic quantization organized by Alberto Bonicelli and Francesco De Vecchi

* Presenter

Almost conditionally identically distributed random variables

Marco Battiston[1⋆] and Lorenzo Cappello[2]

[1] School of Mathematical Sciences, Lancaster University, UK,
m.battiston@lancaster.ac.uk
[2] Department of Economics and Business,
Universitat Pompeu Fabra,
Data Science Center, Barcelona School of Economics, Spain
lorenzo.cappello@upf.edu

Almost conditional identically distributed (a.c.i.d.) random variables, [2], are generalizations of conditional identically distributed (c.i.d.), [3], and exchangeable, [1], ones. This class of random variables naturally arises in applications in statistics, such as in recursive algorithms, contamination models and heteroskedastic observations. The definition of almost conditional identially distributed random variables depends on a sequence of parameters that quantifies departure from exchangeability and conditional identical distribution. An alternative definition of these processes is as measure-valued almost supermartingales.

In this talk, I will first introduce this new class of random variables, illustrating some specific examples in statistics. Secondly, I will present new limit theorems that extend those for exchangeable and c.i.d. random variables to the more general setting of a.c.i.d. random variables. Specifically, asymptotic exchangeability, a Strong Law of Large Numbers and three different Central Limit Theorems, involving respectively the predictive, empirical and asymptotic directing distributions of the process, are presented. Also, necessary and sufficient conditions for the asymptotic directing measure of the sequence to be absolutely continuous with respect to a given sigma-finite measure are described. These theorems have statistical applications, especially in Bayesian predictive inference.

Keywords: Almost Conditional Identical Distribution · Conditional Identical Distribution · Exchangeability · Almost Supermartingale · Bayesian Statistics.

Contributed Session
CS155: Asymptotic results for predictive distributions organized by Lorenzo Cappello

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⋆ Presenter

Non-chaotic interacting particle systems

Carlo Bellingeri

IRIMAS, Université de Haute-Alsace, France,
carlo.bellingeri@uha.fr

Propagation of chaos is a well-known technique formally introduced in the physics literature by Marc Kač in the 50s to simplify the study of Boltzmann equation and giving rise, for instance, to the mathematically more tractable Vlasov-like equations. In the following years, this approach has been repeatedly applied to both deterministic and stochastic particle systems, and it is nowadays part of the standard tools used in stochastic processes and statistical mechanics to prove Law of Large Numbers results. However, with the more and more interest of the current research in studying complex systems, the assumption of chaotic initial data is too stringent with regards to describing real-world phenomena.

In this talk, I am going to present recent results on Law of Large Numbers of the empirical measure without assuming any hypothesis on the initial datum but the convergence at time zero. The biggest challenge would be to tackle equations with non-linear coefficients and replace the standard topology in the space of probabilities induced by the Wasserstein distance, with a weaker notion of convergence but more suitable for non-chaotic systems.

Keywords: Interacting particle systems · Propagation of chaos · Non-linear PDEs.
Contributed Session
CS168: Scaling limits for stochastic processes organized by Pascal Moyal

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Wick integrals

Carlo Bellingeri[1] and Emilio Ferrucci[2⋆]

[1] IRIMAS, Université de Haute-Alsace, France
carlo.bellingeri@uha.fr
[2] SISSA, Trieste, Italy
emilio.ferrucci@sissa.it

We introduce the *Wick integral*

$$\int_s^t f(X_u) \diamond \mathrm{d}X_u$$

for a class of stochastic processes X which are not necessarily Gaussian, in the regime of bounded $2 > q$-variation. The integral is defined for a class of integrands which contains polynomials, and has the property of being centred if X is such. In the case of $1/2 < H$-fractional Brownian motion, the Wick integral agrees with the divergence operator in Malliavin calculus. It satisfies a correction formula with the Young integral $\int f(X)\mathrm{d}X$ and an Itô formula which have infinitely many correction terms, given by integration against the cumulant functions of X, and reduce to familiar identities in the Gaussian case [3]. These results are obtained by first developing diagram formulae for Appell polynomials [2]. Our theory applies to a range of processes taking values in bounded Wiener chaos, such as the Rosenblatt process.

Keywords: Wick product · Appell polynomials · stochastic integral · Itô formula · Rosenblatt process

Contributed Session
CS150: Rough analysis organized by Carlo Bellingeri

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⋆ Presenter

Some results on general Λ-quantiles

Felix-Benedikt Liebrich[1*] and Fabio Bellini[2]

[1] Amsterdam School of Economics, University of Amsterdam, Netherlands,
f.b.liebrich@uva.nl
[2] Department of Statistics and Quantitative Methods, University of Milan-Bicocca, Italy
fabio.bellini@unimib.it

Lambda-quantiles are a generalisation of classical quantiles and have originally introduced in the financial literature by Frittelli et al. [1]. They are obtained by replacing the fixed probability level $\lambda \in [0,1]$ in the usual definition of a quantile with a functional parameter $\Lambda\colon \mathbb{R} \to [0,1]$. When Λ is decreasing, Λ-quantiles are known to share many properties with classical quantiles, and they have thus received growing attention in recent years in financial and insurance applications as well as from a decision-theoretic perspective.

In this talk, we advocate the use of general, possibly non-monotonic functional parameters Λ. Under minimal assumptions, we examine how the choice of Λ affects the mathematical properties of the resulting functional. In particular, we study aggregation behaviour, weak continuity, mixture representations, and generalised ordinal covariance properties. Additionally, we show that the latter also provides an axiomatic characterisation of a broad class of Λ-quantiles, even when the functional parameter is not monotone.

Keywords: Quantiles · Ordinal covariance · Weak continuity.

Contributed Session
CS174: Probability, Risk and Decision Theory organized by Fabio Bellini

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* Presenter

Disappointment aversion and expectiles

F. Bellini[1]*, F. Maccheroni[2], T. Mao[4], R. Wang[3], and Q. Wu[5]

[1] Department of Statistics and Quantitative Methods, University of Milano-Bicocca
fabio.bellini@unimib.it
[2] Department of Decision Sciences, Bocconi University
fabio.maccheroni@unibocconi.it
[3] Department of Statistics and Finance, University of Science and Technology of China
tmao@ustc.edu.cn
[4] Department of Statistics and Actuarial Science, University of Waterloo
ruodu.wang@uwaterloo.ca
[5] Center for Algorithms, Data, and Market Design at Yale , Yale University
qinyu.wu@yale.edu

Keywords: Expectiles · Decision Theory · Disappointment aversion

The central result of the theory of choice under uncertainty is Von Neumann and Morgenstern's expected utility theorem, stating that an economic agent whose preference relation among discrete probability measures satisfies suitable rationality axioms, is represented by an expected utility, i.e. by the expected value of a monetary utility function of outcomes.

A remarkable extension of expected utility is Gul's (1991) theory of *disappointment aversion*, based on a slight weakening of the independence axiom of the vNM theory.

Our first contribution is to point out the connection between the representing functional of Gul's preferences and the probabilistic notion of *expectile*, a one-parameter family of functionals introduced by Newey and Powell (1987) for asymmetric least squares regression. Indeed, it turns out that the Gul's functional is an *expectiled utility*, depending on two parameters: a vNM utility function u and a disappointment-aversion parameter β.

Further, we recast Gul's theory in a Savage framework where the preference is defined over acts with general, possibly non-monetary outcomes, relying on the notion of *subjective mixture* of acts with general outcomes introduced by Ghirardato et al. (2003).

We introduce a novel axiom of *disappointment hedging*, that is a stronger version of the axiom of ambiguity hedging introduced by Ghirardato et al. (2003), and we show in our main result that a preference relation over Savage acts is probabilistically sophisticated, invariant biseparable, and disappointment hedging if and only if it is an expectiled utility.

Contributed Session
CS174: Probability, Risk and Decision Theory organized by Fabio Bellini

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* Presenter

Bayesian calculus and predictive characterizations of extended feature allocation models

Mario Beraha[1], Federico Camerlenghi[1], and Lorenzo Ghilotti[2⋆]

[1] University of Milano–Bicocca, Department of Economics, Management, and Statistics, Milano, Italy, {mario.beraha,federico.camerlenghi}@unimib.it
[2] Duke University, Department of Statistical Science, Durham, NC, United States, lorenzo.ghilotti@duke.edu

We introduce and study a unified Bayesian framework for extended feature allocations which flexibly captures interactions – such as repulsion or attraction – among features and their associated weights. We provide a complete Bayesian analysis of the proposed model and specialize our general theory to noteworthy classes of priors. This includes novel priors based on (i) determinantal point processes, which yield promising results in a spatial statistics application, and (ii) shot noise Cox processes, illustrated on genetics and ecological examples. Within the general class of extended feature allocations, we further characterize those priors that yield predictive probabilities of discovering new features depending either solely on the sample size or on both the sample size and the distinct number of observed features. These predictive characterizations, known as "sufficientness" postulates, have been extensively studied in the literature on species sampling models starting from the seminal contribution of the English philosopher W.E. Johnson for the Dirichlet distribution. Within the feature allocation setting, existing predictive characterizations are limited to very specific examples; in contrast, our results are general, providing practical guidance for prior selection.

Keywords: Indian buffet process · Bayesian nonparametrics · Sufficientness postulates · Point processes.

Contributed Session
CS108: Discrete random structures for Bayesian learning organized by Giovanni Rebaudo

⋆ Presenter

Strong disorder for Stochastic Heat Flow and 2D Directed Polymers

Nicola Turchi

Department of Mathematics and Applications, University of Milano-Bicocca, Italy,
nicola.turchi@unimib.it

The Critical 2D Stochastic Heat Flow (SHF) serves as the universal measure-valued solution to the singular 2D stochastic heat equation. This talk focuses on the asymptotic behavior of the SHF in the large-time, large-disorder regime.

We establish a sharp form of local extinction, identifying the precise rate at which the distribution collapses. Furthermore, we characterize the spatial scales governing the phase transitions between extinction and averaged behavior, as well as vanishing versus diverging mass. Parallel results are derived for 2D directed polymer partition functions.

These findings offer crucial insights into the 2D SHE regularized via space-time discretization. We show that for any regime of supercritical disorder strength β (including fixed $\beta > 0$), the solution exhibits superdiffusive fluctuations. The proof relies on, and introduces, novel refinements of change of measure and coarse-graining techniques.

Keywords: Change of Measure · Coarse-Graining · Directed Polymer in Random Environment · Disordered Systems · Size Bias · Stochastic Heat Equation · Stochastic Heat Flow

Contributed Session
CS131: Directed Polymers and Stochastic Heat Flow organized by Francesca Cottini

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On consistency of optimal portfolio choice for state-dependent exponential utilities

Edoardo Berton[1⋆], Marco Maggis[2], and Marzia De Donno[3]

[1] Department of Mathematics, Politecnico di Milano, Italy,
edoardo.berton@polimi.it
[2] Department of Mathematics, Università degli Studi di Milano, Italy
marco.maggis@unimi.it
[3] Department of Mathematics for Economic, Financial and Actuarial Sciences, Università Cattolica del Sacro Cuore, Italy
marzia.dedonno@unicatt.it

In an arbitrage-free simple market, we demonstrate that for a class of state-dependent exponential utilities, there exists a unique prediction of the random risk aversion that ensures the consistency of optimal strategies across any time horizon. Our solution aligns with the theory of forward performances, with the added distinction of identifying, among the infinite possible solutions, the one for which the profile is the actual optimizer of the system of preferences specified *a priori*.

Keywords: time consistency · state-dependent utility · portfolio choice · exponential utility · forward performance.

Contributed Session
CS169 : Applications of probability to economics, finance, and insurance organized by Elena Bandini and Alessandro Calvia

⋆ Presenter

Localized geometry detection in scale-free random graphs

Gianmarco Bet[1*], Riccardo Michielan[2], and Clara Stegehuis[3]

[1] Department of Mathematics and Computer Science "Ulisse Dini", University of Florence, Italy, gianmarco.bet@unifi.it
[2] Gran Sasso Science Institute, L'Aquila, Italy
[3] University of Twente, the Netherlands

We consider the problem of detecting whether a power-law inhomogeneous random graph contains a geometric community, and we frame this as a hypothesis-testing problem. More precisely, we assume that we are given a sample from an unknown distribution on the space of graphs on n vertices. Under the null hypothesis, the sample originates from the inhomogeneous random graph with a heavy-tailed degree sequence. Under the alternative hypothesis, $k = o(n)$ vertices are given spatial locations and connect following the geometric inhomogeneous random graph connection rule. The remaining $n - k$ vertices follow the inhomogeneous random graph connection rule. We propose a simple and efficient test based on counting normalized triangles to differentiate between the two hypotheses. We prove that our test correctly detects the presence of the community with high probability as $n \to \infty$, and identifies large-degree vertices of the community with high probability.

Keywords: Community detection · network geometry · scale-free graphs · weighted triangles.

Contributed Session
CS140: Community structure of Complex Networks organized by Riccardo Michielan and Lars Schroeder

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* Presenter

Convergence of subgraph densities in ERGMs

Alessandra Bianchi[1], Francesca Collet[2], Elena Magnanini[3*], and Giacomo Passuello[4]

[1] Department of Mathematics Tullio-Levi-Civita, University of Padova, Italy
alessandra.bianchi@unipd.it
[2] Department of Computer Science, University of Verona, Italy
francesca.collet@univr.it
[3] WIAS, Berlin
magnanini@wias-berlin.de
[4] Delft Institute of Applied Mathematics (DIAM), Delft University of Technology, Netherlands
g.passuello@tudelft.nl

Exponential Random Graphs are a class of network models that can be seen as the generalization of the dense Erdős–Rényi random graph. They are defined, with a statistical mechanics approach, by introducing a Hamiltonian, a function that biases the occurrence of certain features, such as the number of edges or triangles. In this talk we will primarily focus on the so-called edge triangle model, where the Hamiltonian of the system only collects edge and triangle densities, properly tuned by real parameters. Using tools from statistical mechanics and large deviation theory, we establish limit theorems and concentration inequalities for subgraph densities (mainly focusing on edge and triangle density) in the replica-symmetric regime [1], where the limiting free energy of the model is known together with its phase diagram. Part of the results are concerned with a mean-field approximation[2], which allows for explicit computations and provides insights into the behavior of the original model in certain parameter region where rigorous results are hardly achievable. A generalization of the model in which vertices are allowed to carry a type will also be discussed [3].
This talk is based on joint work with A. Bianchi, F. Collet, and G. Passuello.

Keywords: random graphs · subgraph densities · graphons.

Contributed Session
CS127: Asymptotics of random graphs organized by Pierfrancesco Dionigi and Elena Magnanini

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* Presenter

Mixing trichotomy for random walks on directed stochastic block models

Alessandra Bianchi

Department of Mathematics, University of Padova, Italy,
alessandra.bianchi@unipd.it

In this talk, we will analyze the convergence to equilibrium of a simple random walk on a directed version of the classical Stochastic Block Model with m communities. We show that the mixing behavior of the walk exhibits a trichotomy governed by the parameter α, which controls the strength of inter-community interactions. In the subcritical regime (large α) the dynamics displays cutoff at at the entropic timescale $T^* \sim \log(n)/\log\log(n)$. In the supercritical regime (small α) the mixing is driven by rare inter-community transitions, leading to a metastable behavior. After an abrupt jump at timescale T^*, the distance to equilibrium decays smoothly at an exponential rate on the timescale $1/\alpha$. At criticality (when $1/\alpha \sim T^*$), an intermediate behavior emerges, characterized by an interplay between entropic mixing and inter-community transitions. Joint work with G. Passuello and M. Quattropani [1].

Keywords: mixing time · random digraphs · random walks · cutoff phenomenon.

Contributed Session
CS140: Community structure of Complex Networks organized by Riccardo Michielan and Lars Schroeder

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Multivariate Robust Extremiles

Valeria Bignozzi[1⋆], Luca Merlo[2], Lea Petrella[1], and Nicola Salvati[3]

[1] MEMOTEF Department, Sapienza University of Rome, Italy
{valeria.bignozzi, lea.petrella}@uniroma1.it
[2] Department of Human Sciences, Link Campus University, Italy
l.merlo@unilink.it
[3] Department of Economics and Management, University of Pisa, Italy
nicola.salvati@unipi.it

This contribution extends the concept of univariate extremiles introduced by Daouia *et al.* 2019 [1] to a robust multivariate framework. Among the possible multivariate generalizations, we adopt the approach based on the multivariate M-quantiles proposed by Kokic *et al.* 2002 [2].

The proposed formulation ensures that multivariate extremiles lie within the convex hull of the data while allowing for different levels of robustness. We prove the main mathematical and statistical properties of these robust multivariate extremiles and assess their empirical performance through a series of examples on artificial data.

In the presence of covariates, the methodology can be further extended to define multivariate extremile regression, providing a flexible and robust tool for multivariate conditional analysis.

Keywords: Multivariate risk measures · Quantiles · Robustness.

Contributed Session
CS110: Risk measures: static and dynamic aspects organized by Emanuela Gianin and Elisa Mastrogiacomo

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⋆ Presenter

Extreme value statistics for partial orders

Elia Bisi[1], Fabio Deelan Cunden[2,3], Giovanni Gramegna[3,4⋆], and Marilena Ligabò[2]

[1] Dipartimento di Matematica e Informatica, Università degli Studi di Firenze, Italy
elia.bisi@unifi.it
[2] Dipartimento di Matematica, Universitá degli Studi di Bari, I-70125 Bari, Italy
{fabio.cunden,marilena.ligabo}@uniba.it
[3] INFN, Sezione di Bari, I-70126 Bari, Italy
[4] Dipartimento di Fisica, Universitá degli Studi di Bari, I-70165 Bari, Italy
giovanni.gramegna@uniba.it

The study of extreme values of real random variables and their limiting laws is a cornerstone of probability theory [1]. In many probability models, however, the natural state space is high dimensional and only partially ordered. In such settings, most pairs of elements are incomparable [2], and the classical notions of extrema no longer apply. This motivates replacing ordinary minima and maxima with their order-theoretic counterparts, meet and join, that remain meaningful under partial comparability [3].

We study extreme value phenomena for random samples from partially ordered sets. In particular, we consider the majorization and unordered majorization on finite-dimensional probability simplices, where the order is induced by linear stochastic transformations [4]. These partial orders are relevant in many contexts, ranging from economics [5] to thermodynamics and quantum information [6].

Given independent random elements, we consider their meet or join, and how these objects behave in the limit as the sample size and the dimension of the space grows. We describe regimes in which meets and joins typically collapse to extreme (bottom and top) elements, as well as scaling regimes where nondegenerate limits appear, describing the order of fluctuations close to the boundary.

Keywords: Extreme Values · Majorization · (Quantum) Resource theories

Contributed Session

CS107: Combinatorial structures in probability and mathematical physics organized by Fabio Deelan Cunden

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⋆ Presenter

Can one hear the shape of a random matrix?

Elia Bisi[1]*, Fabio Deelan Cunden[2], Ivailo Hartarsky[3], and Stephan Wagner[4]

[1] Dipartimento di Matematica e Informatica, Università degli Studi di Firenze, Italy
elia.bisi@unifi.it
[2] Dipartimento di Matematica, Univerisità degli Studi di Bari, Italy
fabio.cunden@uniba.it
[3] Université Claude Bernard Lyon 1, CNRS, Centrale Lyon, INSA Lyon, Université Jean Monnet, ICJ UMR5208, France
hartarsky@math.univ-lyon1.fr
[4] Institute of Discrete Mathematics, TU Graz, Austria
stephan.wagner@tugraz.at

Consider a random matrix X whose entries are i.i.d. in the cells of a Young diagram (its 'shape') and zero elsewhere. When the shape is the dilation by a factor N of a fixed Young diagram λ, the Wishart-type matrix XX^* (suitably rescaled) has, as $N \to \infty$, a limiting spectral distribution F^λ characterised by its moments. These moments enumerate λ-plane trees, a class of directed plane trees with vertex labelling compatible with λ, for which we provide explicit enumerative formulae. We show that one cannot 'hear the shape of a random matrix', in the sense that there exist distinct Young diagrams yielding the same limiting spectral distribution. We establish that the classes of 'isospectral' Young diagrams are those with the same diagonal profile.

Based on the article in preparation [1].

Keywords: Random matrix · Limiting spectral distribution · Young diagram · Plane tree · Isospectrality.

Contributed Session
CS107: Combinatorial structures in probability and mathematical physics, organized by Fabio Deelan Cunden

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* Presenter

A mild rough Gronwall lemma with applications to non-autonomous evolution equations

Alexandra Blessing

Department of Mathematics and Statistics, University of Konstanz, Germany,
alexandra.blessing@uni-konstanz.de

We derive a Gronwall type inequality for mild solutions of non-autonomous parabolic rough partial differential equations (RPDEs). This inequality together with an analysis of the Cameron-Martin space associated to the noise, allows us to obtain the existence of moments of all order for the solution of the corresponding RPDE and its Jacobian when the random input is given by a Gaussian Volterra process. Applying further the multiplicative ergodic theorem, these integrable bounds entail the existence of Lyapunov exponents for RPDEs. We illustrate these results for stochastic partial differential equations with multiplicative boundary noise. This talk is based on a joint work with Mazyar Ghani Varzaneh and Tim Seitz.

Keywords: rough partial differential equations · mild Gronwall lemma · Lyapunov exponents · rough boundary noise.

Contributed Session
CS111: Dynamical Aspects of Stochastic PDEs organized by Antonio Agresti and Max Sauerbrey

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Random evolution on combinatorial and metric graphs

Stefano Bonaccorsi[1*], Francesca Cottini[2], and Delio Mugnolo[3]

[1] Università degli Studi di Trento, Italy,
stefano.bonaccorsi@unitn.it
[2] F.C., Sorbonne Université, Paris, France
francesca.cottini@sorbonne-universite.fr
[3] D.M., FernUniversität in Hagen, Germany
{delio.mugnolo@fernuni-hagen.de

We consider a family of graphs $\{G_k,\ k = 1, \dots, N\}$, each associated to the (discrete or continuous) *Laplacian* operator $\mathcal{L}_k$ acting on the function defined on the vertices (edges) of the graph.

Given a stochastic mechanism of switching the graphs during time, we get that the evolution is lead by an operator $\mathcal{L}_{X_k}$ (selected from the set $\{\mathcal{L}_1, \dots, \mathcal{L}_N\}$ according to some Markov chain X_k) during the (random) time interval $[T_k, T_{k+1})$

$$\{\, \partial_t\, u(t,x) = \mathcal{L}_{X_k} u(t,x), \qquad t \in [T_k, T_{k+1}), u(0,x) = f(x). \tag{1}$$

We can associate to (1) the (random) evolution operator

$$S(t) = e^{(t-T_n)\mathcal{L}_{X_n}} \prod_{k=0}^{n-1} e^{(T_{k+1}-T_k)\mathcal{L}_{X_k}}, \qquad t \in [T_n, T_{n+1}).$$

Our main problem can be stated as follows:

(**P**) under which condition the random evolution operator $S(t)$ converges? towards which limit?

Contributed Session
CS158: Stochastic Processes, PDEs and Networks organized by Fausto Colantoni

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* Presenter

Lévy processes as weak limits of rough Heston models

Alessandro Bondi[1⋆] and Martin Forde[2]

[1] Department of AI, Data and Decision Sciences, Luiss University, Rome, Italy
abondi@luiss.it
[2] Department of Mathematics, King's College London, UK
martin.forde@kcl.ac.uk

We show weak convergence of the marginals for a re-scaled rough Heston model to a Normal Inverse Gaussian (NIG) Lévy process. In particular, we introduce a scaling technique that does not depend on the Hurst parameter in the fractional kernel. We later extend our approach to the case where the variance is an affine Volterra process with jumps, and establish weak convergence of the finite-dimensional distributions of the integrated variance to a deterministic time-change of the first-passage time process to lower barriers for a more general class of spectrally positive Lévy processes.

Keywords: Affine Volterra processes with jumps · Rough Heston model · Fast mean reversion · Lévy processes hitting times.

Contributed Session
CS 114: New advances in rough volatility models, organized by Ofelia Bonesini

⋆ Presenter

A non-local singular McKean SDE

Luca Bondi[1,2⋆], Elena Issoglio[1], and Francesco Russo[2]

[1] University of Torino, Italy,
[2] ENSTA, Palaiseau, France
luca.bondi@unito.it
elena.issoglio@unito.it, francesco.russo@ensta.fr

We are interested in studying the well-posedness of the non-local singular McKean SDE

$$\begin{cases} dX_t = F(K * v(t, X_t))b(t, X_t)dt + dW_t \\ v(t, \cdot) \text{ is the law density of } X_t \\ X_0 \sim v_0(x)dx, \end{cases} \tag{1}$$

where W is a d-dimensional Brownian motion, b is a function of time taking values in a d-dimensional Besov space of negative index $-\beta \in (-1/2, 0)$, denoted by $\mathcal{C}^{-\beta}$. $K, v_0 : \mathbb{R}^d \to \mathbb{R}$ are probability density functions which are also elements of $\mathcal{C}^{\beta+}$ and $F : \mathbb{R} \to \mathbb{R}$ is a differentiable non-linearity. SDE (1) is only formal due to the singularity of the drift coefficient $F(K * v)b$. Thus we must rely on a notion of solution for singular SDEs that is framed through the *rough martingale problem*, see [3] and also [2] for a recent survey paper. The solution to a rough martingale problem is a probability measure $\mathbb{P}$ which corresponds to the law of X, solution to the SDE (1). Our approach for proving existence and uniqueness of such a measure relies on the well-posedness of the non-local singular non-linear Fokker-Planck PDE

$$\begin{cases} \partial_t v = \frac{1}{2}\Delta v - \operatorname{div}(vF(K * v)b), \\ v(0) = v_0, \end{cases} \tag{2}$$

studied in [1]. We prove in fact that the unique solution $\mathbb{P}$ to (1) admits $v(t)$, solution to (2), as its time marginals. Namely $\mathbb{P}$ is called the *probabilistic representation* of v solution to (2). This presentation is based on the work [1].

Keywords: McKean SDE with distributional coefficients · Fokker-Planck PDE · Probabilistic representation.

Contributed Session
CS161: Singular SDEs: Well Posedness and Numerics organised by Luca Bondi and Matteo Cagnotti

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⋆ Presenter

Rough differential equations for volatility

Ofelia Bonesini[1], Emilio Ferrucci[2⋆], Ioannis Gasteratos[3], and Antoine Jacquier[4]

[1] London School of Economics and Political Science, UK
O.Bonesini@lse.ac.uk
[2] SISSA, Italy
emilio.ferrucci@sissa.it
[3] Technische Universität Berlin
i.gasteratos@tu-berlin.de
[4] Imperial College London
a.jacquier@imperial.ac.uk

We introduce a canonical way of performing the joint lift of a Brownian motion W and a low-regularity adapted stochastic rough path $\mathbf{X}$, extending [1]. Applying this construction to the case where $\mathbf{X}$ is the canonical lift of a one-dimensional fractional Brownian motion (possibly correlated with W) completes the partial rough path of [2]. We use this to model rough volatility with the versatile toolkit of rough differential equations (RDEs), namely by taking the price and volatility processes to be the solution to a single RDE. We argue that our framework is already of interest when W and X are independent, as correlation between the price and volatility can be introduced in the dynamics. The lead-lag scheme of [3] is extended to our fractional setting as an approximation theory for the rough path in the correlated case. Continuity of the solution map transforms it into a numerical scheme for RDEs. We numerically test this framework and use it to calibrate a simple new rough volatility model to market data.

Keywords: rough volatility · rough paths · rough differential equations · Wong-Zakai approximations.

Contributed Session
CS114: New advances in rough volatility models organized by Ofelia Bonesini

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⋆ Presenter

Rough Volatility, Path-Dependent PDEs and Weak Rates of Convergence

Ofelia Bonesini[1⋆], Antoine Jacquier[2], and Alexandre Pannier[3]

[1] Department of Mathematics, London School of Economics and Political Science, UK,
o.bonesini@lse.ac.uk
[2] Department of Mathematics, Imperial College London, UK,
Alan Turing Institute, London, UK
a.jacquier@imperial.ac.uk
[3] LPSM, Université Paris Cité, Paris, France
pannier@lpsm.paris

In the setting of stochastic Volterra equations, and in particular rough volatility models, we show that conditional expectations are the unique classical solutions to path-dependent PDEs. The latter arise from the functional Itô formula developed by Viens and Zhang (2019). We then leverage these tools to study weak rates of convergence for discretised stochastic integrals of smooth functions of a Riemann-Liouville fractional Brownian motion with Hurst parameter $H \in (0, \frac{1}{2})$. These integrals approximate log-stock prices in rough volatility models. We obtain the optimal weak error rates of order 1 if the test function is quadratic and of order $(3H + \frac{1}{2}) \wedge 1$ if the test function is five times differentiable; in particular these conditions are independent of the value of H. This result significantly relaxes the requirements on payoff functions compared to previous work, breaking away from the polynomial setting and providing conditions independent of H for general smooth payoffs.

Keywords: Rough volatility · Path-dependent PDEs · Weak rates · Stochastic Volterra equations

Contributed Session
CS157: Recent Advances in Stochastic Volterra Equations organized by Sergio Pulido

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⋆ Presenter

Flowing Datasets with Wasserstein over Wasserstein Gradient Flows

Clément Bonet[1⋆], Christophe Vauthier[2], and Anna Korba[3]

[1] Ecole Polytechnique, CMAP, Institut Polytechnique de Paris, France,
clement.bonet.mapp@polytechnique.edu
[2] Université Paris-Saclay, Laboratoire de Mathématique d'Orsay, France,
christophe.vauthier@universite-paris-saclay.fr
[3] ENSAE, CREST, Institut Polytechnique de Paris, France,
anna.korba@ensae.fr

Many applications in machine learning involve data represented as probability distributions. The emergence of such data requires radically novel techniques to design tractable gradient flows on probability distributions over this type of (infinite-dimensional) objects. For instance, being able to flow labeled datasets is a core task for applications ranging from domain adaptation to transfer learning or dataset distillation. In this setting, we propose to represent each class by the associated conditional distribution of features, and to model the dataset as a mixture distribution supported on these classes (which are themselves probability distributions), meaning that labeled datasets can be seen as probability distributions over probability distributions. We endow this space with a metric structure from optimal transport, namely the Wasserstein over Wasserstein (WoW) distance, derive a differential structure on this space, and define WoW gradient flows. The latter enables to design dynamics over this space that decrease a given objective functional. We apply our framework to transfer learning and dataset distillation tasks, leveraging our gradient flow construction as well as novel tractable functionals that take the form of Maximum Mean Discrepancies with Sliced-Wasserstein based kernels between probability distributions.

Keywords: Wasserstein gradient flows · Optimal transport · Labeled Datasets.

Contributed Session
CS119: Statistical Learning through Kernels and Transport organized by Leonardo Santoro and Alessia Caponera

References

1. C. Bonet, C. Vauthier, A. Korba, Flowing Datasets with Wasserstein over Wasserstein Gradient Flows. *International Conference on Machine Learning*, 2025.

⋆ Presenter

On the Stochastic Sine-Gordon Model from the Viewpoint of Quantum Field Theory

Alberto Bonicelli[1], Beatrice Costeri[2], Claudio Dappiaggi[2⋆], and Paolo Rinaldi[2]

[1] Laboratoire de probabilités, statistique et modélisation, Sorbonne Université, France
bonicelli@lpsm.paris

[2] Department of Physics, University of Pavia & INFN – Sezione di Pavia & INdAM – Unità di Pavia, Italy,
beatrice.costeri01@universitadipavia.it, claudio.dappiaggi,paolo.rinadli@unipv.it

We discuss the stochastic sine–Gordon model in $1+1$ dimensions from the perspective of interacting (algebraic) field theory, following the approach developed first in [3] and then in [2]. The guiding idea is to realize the random field as an element of a suitable algebra of functional-valued distributions, so that tools from microlocal analysis can be systematically employed to control products, singularities, and the emergence of counterterms. Within this framework, renormalization is implemented in an Epstein–Glaser spirit, *i.e.* by local and causal constructions rather than by choosing a specific regularization scheme.

In the ultraviolet-cutoff theory, we construct correlation functions and moments of the stochastic sine–Gordon field as convergent power series in the coupling, and we analyze their stability under the removal of auxiliary parameters. A key outcome is a robust perturbative construction that also admits a controlled classical limit $\hbar \to 0^+$, thereby connecting the stochastic dynamics with the corresponding interacting field theory. Finally, we briefly comment on the bosonization link between sine–Gordon and Thirring: while our focus is entirely on the sine–Gordon analysis of [2], this correspondence provides a natural bridge to the spinorial setting investigated in [1].

Keywords: Singular Stochastic Partial Differential Equations · Sine-Gordon Model · Algebraic Quantum Field Theory.

Contributed Session
CS113: Stochastics in Classical and Quantum Physics organized by Sonia Mazzucchi and Stefania Ugolini

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⋆ Presenter

Stochastic Differential Equations and the Martin-Siggia-Rose Formalism: An Algebraic-Analytic Correspondence

Alberto Bonicelli[1], Claudio Dappiaggi[2], Nicoló Drago[3★], and Sonia Mazzucchi[4]

[1] Laboratoire de Probabilité, Statistique et Modélisation, Sorbonne Université, Paris, France
[2] Department of Physics, University of Pavia, Pavia, Italy
[3] Department of Mathematics, University of Genova, Italy, nicolo.drago@unige.it
[4] Department of Mathematics, University of Trento, Trento, Italy

The Martin-Siggia-Rose (MSR) formalism is a path-integral approach widely used in the physics literature to compute expectation values and correlation functions associated with stochastic differential equations (SDEs). Despite its effectiveness, the formalism has long lacked a fully rigorous mathematical foundation. This issue has been partially addressed in [1] by employing techniques from the algebraic approach to quantum field theory, which provides a robust framework for a rigorous treatment of path-integral formulations and for the solution theory of ordinary, partial, and stochastic differential equations. Within this framework, we establish—at the level of perturbation theory—a precise correspondence between correlation functions and expectation values computed either directly from the SDE or via the MSR formalism. Time permitting, we will also discuss a complementary, more analytical approach to the MSR formalism based on the theory of infinite dimensional Fresnel path integrals, following [2].

Keywords: Stochastic differential equations · Martin-Siggia-Rose formalism · functional integration.

Contributed Session
CS113: Stochastics in Classical and Quantum Physics organized by Sonia Mazzucchi and Stefania Ugolini

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2. Bonicelli A., Drago N., Mazzucchi S.: in preparation.

★ Presenter

A stochastic approach to time-dependent BEC

Luigi Borasi[1⋆], Luigi Borasi, Francesco Carlo De Vecchi[2], and Stefania Ugolini[2]

[1] Department of Mathematics, University of Wuppertal, Germany,
borasi@uni-wuppertal.de
[2] Department of Mathematics, Universitá degli Studi di Pavia, Italy
francescocarlo.devecchi@unipv.it
[3] Department of Mathematics, Universitá degli Studi di Milano, Italy
stefania.ugolini@unimi.it

We propose a stochastic description of the time dependent quantum Bose-Einstein condensate at zero temperature, within the context of Nelson stochastic mechanics. We describe an infinite particle limit of interacting diffusions which corresponds to the mean field limit in the related quantum system. We are able to extend the framework of Nelson stochastic mechanics to nonlinear systems in particular to the case of the nonlinear Schrödinger equation. We also propose how to extend to this nonlinear case the Guerra-Morato variational approach. Our work can also be seen in the context of a mean field limit of McKean–Vlasov processes in a general situation where the drift is a very singular function depending non-trivially on all the particles.

Presenter: Luigi Borasi

Keywords: Nelson stochastic mechanics · McKean-Vlasov SDE · Mean-field · Entropy · Stochastic calculus of variation.

Contributed Session
CS113: Stochastics in Classical and Quantum Physics organized by Sonia Mazzucchi and Stefania Ugolini

⋆ Presenter

Conformal classification with tight marginal coverage in noisy settings

Teresa Bortolotti[1⋆], Y. X. Rachel Wang[2], Xin Tong[3], Alessandra Menafoglio[1], Simone Vantini[1], and Matteo Sesia[4]

[1] MOX, Department of Mathematics, Politecnico di Milano, Milano, Italy, teresa.bortolotti@polimi.it
[2] School of Mathematics and Statistics, University of Sydney, Sydney, Australia,
[3] Faculty of Business and Economics, University of Hong Kong, Hong Kong, China,
[4] Departments of Data Sciences and Operations, and of Computer Science, University of Southern California, California, USA

Conformal prediction is a nonparametric method widely applied in regression, classification, and outlier detection, providing valid predictive inference with finite-sample coverage guarantees. Marginal coverage, in particular, is a fundamental objective in conformal inference, ensuring that prediction sets contain the correct label for a predefined proportion of future test points. However, these guarantees rely on the assumption of data exchangeability, which is often violated in real-world applications due to distribution shifts, outliers, and label noise. In Bortolotti et al. (2025), we address the limitations of conformal classification in the presence of label contamination and propose novel adaptive methodologies that automatically adjust for noise to restore marginal coverage. Our theoretical guarantees are derived under the assumption that the contamination mechanism is known. We show how label noise induces a systematic inflation of coverage and, leveraging tools from empirical process theory, we derive correction factors that restore nominal marginal guarantees. The resulting adaptive calibration procedures provide valid and informative prediction sets even in challenging classification settings with many classes or severe class imbalance. To make the framework fully data-driven, we complement our theoretical results with a practical strategy to estimate the contamination process from noisy data. Specifically, we propose a procedure based on the identification of anchor points, i.e., observations for which the conditional probability of a class is close to one. These points allow us to consistently estimate the class-dependent contamination matrix without requiring access to clean data. The estimated contamination mechanism is then plugged into the adaptive calibration step. The effectiveness of our approach is demonstrated through extensive experiments on synthetic and real-world datasets, including CIFAR-10H and BigEarthNet. Our findings highlight the importance of accounting for label contamination in conformal classification and provide a robust framework for reliable predictive inference in noisy settings.

Keywords: conformal inference · classification · label noise · marginal validity.

Contributed Session
CS139: Conformal prediction: theory and methods organized by Stefano Favaro and Simone Vantini

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⋆ Presenter

Continuous-Time Dynamic Contracting With Limited Commitment

Andrea Bovo

Department of Economics and Management, University of Brescia, Italy,
andrea.bovo@unibs.it

This talk studies a problem arising in a Principal-Agent framework, analysed from the Principal's perspective. The problem is formulated as a finite-horizon optimal stochastic control problem for a possibly degenerate process with absorption at the boundary. The controlled process represents the contract offered by the Principal, whose objective is to maximise over all admissible contracts offered to the Agent. Properties of the value function are obtained using both probabilistic and analytical techniques. In particular, we establish the existence of a classical solution of the related Hamilton-Jacobi-Bellman equation which allows to characterise explicitly the optimal contract offered by the Principal. Finally, we underline properties of the optimal contract and discuss their economic implications.

Keywords: Optimal stochastic control · Optimal stopping · Principal-agent models.

Contributed Session
CS133: Optimal Stopping and Applications organized by Bruno Buonaguidi

Conditional Coverage in Conformal Prediction: Tradeoffs and Insights

Sacha Braun[1★], Eugène Berta[1], David Holzmüller[1], Francis Bach[1], and Michael I. Jordan[3]

[1] Sierra team, Inria Paris, France,
{sacha.braun, eugene.berta, francis.bach} @inria.fr
[2] Soda team, Inria Paris-Saclay, France
david.holzmuller@inria.fr
[3] Departments of EECS and Statistics, UC Berkeley, USA
jordan@cs.berkeley.edu

Reliable decision-making relies on predictive sets that capture the true outcome with a specified probability. In this talk, I will explore conformal prediction, a statistical approach that delivers rigorous finite-sample guarantees. While standard conformal methods provide valid marginal coverage, they do not ensure coverage conditional on specific inputs. I will present a framework to quantify conditional miscoverage and discuss strategies to improve conditional reliability, including the tradeoff between set size and conditional coverage. We will explore how conformal based strategies can be applied to estimate highest density regions, bypassing density estimation. The talk will highlight both theoretical insights and practical implications for building trustworthy predictive systems.

Keywords: Conformal prediction · Conditional coverage · Standardized residuals.

Contributed Session
CS139: Conformal prediction: theory and methods organized by Stefano Favaro and Simone Vantini

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★ Presenter

Ergodicity of a Stochastic Energy Balance Model for Global Temperature

Jochen Bröcker[1], Piermarco Cannarsa[2], Giulia Carigi[3⋆], Tobias Kuna[4], and Cristina Urbani[5]

[1] School of Mathematical, Physical, and Computational Sciences and Centre for the Mathematics of Planet Earth, University of Reading, UK j.broecker@reading.ac.uk
[2] Dipartimento di Matematica, Universita' di Roma "Tor Vergata" cannarsa@axp.mat.uniroma2.it
[3] Department of Statistics, Indiana University, USA gcarigi@iu.edu
[4] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Universitá degli Studi Dell'Aquila tobias.kuna@univaq.it
[5] Dipartimento di Scienze Tecnologiche e dell'Innovazione, Universitas Mercatorum, cristina.urbani@unimercatorum.it

A simple yet extremely valuable approach to the study of the climate system comes from the use of Energy Balance Models (EBMs). Such models describe the key features of the zonally averaged temperature on the Earth's surface. The classical EBM can be improved by increasing the vertical resolution. This talk presents a two-layer energy balance model that allows for vertical exchanges between a surface layer and the atmosphere. Considering random perturbations of the model will allow to better study its long-time average behaviour. Thanks to the weak Harris' theorem we will establish exponential ergodicity. This is a first step to study the model dependence on different forcing scenarios via response theory.

Keywords: Energy balance model · Stochastic partial differential equations · Ergodicity.

Contributed Session
CS104: SPDEs for physical models organized by Margherita Zanella and Benedetta Ferrario

⋆ Giulia Carigi

A multiscale analysis of mean-field transformers in the moderate interaction regime

Giuseppe Bruno[1⋆], Federico Pasqualotto[2], and Andrea Agazzi[1]

[1] Department of Mathematics and Statistics, University of Bern, Switzerland
giuseppe.bruno@unibe.ch
[2] Department of Mathematics, University of California San Diego, USA
fpasqualotto@ucsd.edu
[3] Department of Mathematics and Statistics, University of Bern, Switzerland
andrea.agazzi@unibe.ch

We study the inference-time evolution of token representations in deep residual streams of encoder-only transformers through the mean-field interacting particle system framework introduced in [1,2]. Motivated by recent context-scaling practices in large language models, where the inverse temperature parameter β grows with the number of tokens N, we analyze the *moderate interaction* regime [4] and show that the dynamics exhibits a multiscale structure that reconciles several previously observed behaviors into a unified picture.

Starting from the continuous-depth limit of a layer-normalized self-attention dynamics, we analyze the associated continuity equation on $\mathcal{P}(\mathbb{S}^{d-1})$ as the inverse temperature $\beta = \beta_N$ diverges with N. Our main technical result identifies a fast *alignment phase* on an $O(1)$ timescale: under mild assumptions on the parameter matrices and on the initial particle distribution, the mean-field dynamics converges to a linear transport equation in which the token distribution collapses onto a low-dimensional subspace dictated by the spectral properties of the matrix $VK^\top Q$.

We then show that, once aligned, the next-order behavior emerges on an $O(\beta)$ timescale and is governed by a heat flow on the aligned manifold under additional structural assumptions on (Q, K, V). Finally, on exponentially long timescales in β, we describe a *pairing phase* where clusters sequentially merge along geodesics, captured by an effective finite-dimensional ODE for the closest pair of clusters. Numerical experiments illustrate all three phases and their separation of timescales.

Keywords: Transformers · mean-field limit · interacting particle systems · multiscale analysis · clustering · transport equation · heat equation on manifolds.

Contributed Session
CS179: Interacting Particles and Optimization in Machine Learning organized by Andrea Agazzi

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⋆ Presenter

Malliavin Calculus for rough stochastic differential equations

Fabio Bugini[1], Michele Coghi[2⋆], and Torstein Nilssen[3]

[1] Department of Mathematics, Technical University of Berlin, Italy
fabio.bugini@tu-berlin.de
[2] Department of Mathematics, University of Trento, Italy,
michele.coghi@unitn.it
[3] Department of Mathematical Sciences, University of Agder, Norway
torstein.nilssen@uia.no

In this work we show that rough stochastic differential equations (RSDEs), as introduced by Friz, Hocquet, and Lê (2021), are Malliavin differentiable. We use this to prove existence of a density when the diffusion coefficients satisfies standard ellipticity assumptions. Moreover, when the coefficients are smooth and the diffusion coefficients satisfies a Hörmander condition, the density is shown to be smooth. The key ingredient is to develop a comprehensive theory of linear rough stochastic differential equations, which could be of independent interest.

Keywords: Malliavin calculus · rough paths · linear rough-stochastic equations · Hoermander theorem.

Contributed Session
CS124: Infinite Dimensional Analysis and Malliavin Calculus organized by Davide Addona

⋆ Presenter

Nonlinear Rough Fokker–Planck equations

Fabio Bugini[1⋆], Peter K. Friz[1,2], and Wilhelm Stannat[1]

[1] Department of Mathematics, Technical University of Berlin, Germany,
[2] Weierstrass Institute for Applied Analysis and Stochastics, Berlin, Germany,
fabio.bugini@tu-berlin.de, friz@math.tu-berlin.de, stannat@math.tu-berlin.de

We present a well-posedness result for Fokker–Planck equations, which describe the evolution of the conditional law of McKean–Vlasov SDEs in the presence of common noise. Such an evolution is governed by a nonlinear, nonlocal SPDE in the space of measures. The well-posedness of such SPDEs is a difficult problem, and the best result to date is due to Coghi and Gess [1], which however comes with dimension-dependent regularity assumptions.

In this talk, we show how rough path techniques can circumvent these entirely. We consider a mixed rough and stochastic setting, which allows us to derive well-posed rough (deterministic) counterparts of the nonlinear Fokker–Planck equations under dimension-independent regularity assumptions. Importantly, the rough Fokker–Planck equations are seen, upon randomisation, to coincide with the classical nonlinear SPDEs. Therefore, and somewhat contrarily to common belief, the use of rough paths leads to substantially less regularity demands on the coefficients when compared to methods rooted in classical stochastic analysis.

Joint work with Peter K. Friz and Wilhelm Stannat [2].

Keywords: Fokker-Planck equations · Rough paths · McKean-Vlasov equations.

Contributed Session
CS150: Rough Analysis organized by Carlo Bellingeri

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⋆ Presenter

Modeling Vagueness in Large Language Models: A Hybrid Logical-Probabilistic Perspective on Moral Classification and Constrained Generation

Luana Bulla[1,2]*

[1] University of Bologna, Italy
[2] National Centre of Research (CNR), Italy
luana.bulla@unibo.it

Real-world decision-making scenarios are characterized by vagueness, plural interpretations, and partially conflicting information. In natural language processing, these features become particularly evident in tasks involving moral or value-based judgments, where annotations reflect heterogeneous and context-dependent perspectives rather than single ground-truth labels [1]. This contribution examines how such forms of structured uncertainty can be formally modeled by integrating probabilistic and logical approaches within Large Language Models (LLMs).

We first analyze moral value classification as a many-valued problem, where labels should not be interpreted as deterministic assignments but as distributions over admissible interpretations. Inter-annotator disagreement is thus treated not as noise, but as an observable manifestation of epistemic variability. To capture this structure, we introduce a generalized agreement metric, F1-kappa, which extends the classical F1-score by normalizing performance against its expected value under a probabilistic baseline, analogously to Fleiss' kappa [2]. This formulation enables direct comparison between human and model performance while accounting for label multiplicity, annotator diversity, and class imbalance. From a semantic standpoint, the resulting framework can be interpreted as defining a probabilistic layer over a many-valued labeling space, thereby bridging categorical evaluation and distributional reasoning.

In a second step, we address the complementary problem of controlling generative models under structural constraints [3]. While LLMs approximate probabilistic semantics through next-token prediction, they lack intrinsic guarantees of syntactic or logical well-formedness. We propose a hybrid decoding framework in which formal grammars act as symbolic constraints over stochastic generation. Constrained decoding can be formally characterized as restricting the support of the underlying probability distribution to strings belonging to a language defined by a context-free grammar. This hybridization preserves probabilistic flexibility while ensuring compliance with predefined structural or semantic requirements.

Taken together, these two directions illustrate a broader methodological claim: modeling vagueness in AI systems requires moving beyond purely statistical or purely symbolic paradigms. Many-valued annotations, probabilistic normalization of agreement, and grammar-constrained generation provide complementary tools for integrating logical structure with uncertainty quantification. This hybrid perspective offers a principled approach to reasoning and decision-making under vagueness, aligning formal evaluation methods with the intrinsic indeterminacy of complex linguistic and moral domains.

Keywords: Natural Language Processing · Machine Learning · Large Language Models · Moral Value Detection · Inter-annotator metric · Constrained-decoding

* Presenter

Luana Bulla

Contributed Session

CS172: Uncertainty, Vagueness, and Decision Support: Logical and AI Approaches organized by Arianna Pavone and Gianmarco La Rosa

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The Wiener Disorder Problem with Random Post-Disorder Drift

Bruno Buonaguidi

Department of Statistical Sciences, Catholic University of the Sacred Heart, Italy,
bruno.buonaguidi@unicatt.it

We consider a one-dimensional Wiener process with zero drift initially, which changes at some random and unobservable moment, referred to as the disorder time. We observe the evolution of the process in real time with the goal of detecting the disorder time as precisely as possible. Unlike Shiryaev's seminal work from the 1960s on the Wiener disorder problem, which assumes a known and fixed value of the post-disorder drift, we assume that the post-disorder drift is a discrete random variable with a known distribution. This formulation is particularly useful when the post-disorder regime is unknown, but past data and/or expert opinions can be used to construct a prior distribution for the new drift. Under the additional assumptions that (a) the disorder time is exponentially distributed and (b) the disorder time, the initial Wiener process with zero drift, and the post-disorder drift are independent, we show that the solution to our problem can be expressed in terms of a stopping time which minimizes a linear combination of the probability of a false alarm and the expected detection delay since the onset of the disorder. This stopping time can be characterized as the first moment at which the coordinate processes of the posterior probability that the disorder has already occurred - given the observed path of the Wiener process - enter a region shaped by a curved boundary, where the latter is the unique solution to a certain integral equation.

Keywords: Disorder (change-point) problem · Optimal stopping · Random drift · Sequential analysis · Sequential detection · Wiener process (Brownian motion).

Contributed Session
CS133: Optimal Stopping and Applications organized by Bruno Buonaguidi

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Background Vlasov equations and Young measures for passive scalar and vector advection equations under special stochastic scaling limits

Federico Butori[1⋆], Freanco Flandoli[1], Eliseo Luongo[2], and Yassine Tahraoui[1]

[1] Scuola Normale Superiore di Pisa, Italy
federico.butori@sns.it
{franco.flandoli,yassine.tahraoui}@sns.it
[2] Fakultät für Mathematik, Universität Bielefeld, 33501 Bielefeld, Germany
eluongo.@math.uni-bielefeld.de

In the last few years it was proved that scalar passive quantities subject to suitable stochastic transport noise, and more recently that also vector passive quantities subject to suitable stochastic transport and stretching noise, weakly converge to the solutions of deterministic equations with a diffusion term. In the background of these stochastic models, we introduce stochastic Vlasov equations which give additional information on the fluctuations and oscillations of solutions: we prove convergence to non-trivial Young measures satisfying limit PDEs with suitable diffusion terms. In the case of a passive vector field, the background Vlasov equation adds completely new statistical information to the stochastic advection equation. This talk is based on a joint work with Franco Flandoli, Eliseo Luongo and Yassine Tahraoui [1].

Keywords: Young Measures · Transport Noise · Stretching Noise · Passive Scalars · Magnetohydrodynamics.

Contributed Session
CS171: Methods in stochastic fluid dynamics: a young researchers' perspective organized by Theresa Lange and Lorenzo Marino

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⋆ Presenter

Optimal Annuitization under Partially Observable Mortality

Matteo Buttarazzi[1⋆], Tiziano De Angelis[2], and Gabriele Stabile[3]

[1] School of Management and Economics, Dept. ESOMAS, University of Torino, Corso Unione Sovietica, 218 Bis, 10134, Torino, Italy,
matteo.buttarazzi@unito.it

[2] School of Management and Economics, Dept. ESOMAS, University of Torino, Corso Unione Sovietica, 218 Bis, 10134, Torino, Italy; Collegio Carlo Alberto, Piazza Arbarello 8, 10122, Torino, Italy,
tiziano.deangelis@unito.it

[3] Department MEMOTEF, University of Rome Sapienza, Via del Castro Laurenziano, 9, Rome, Italy,
gabriele.stabile@uniroma1.it

This paper studies the optimal timing of annuitization when individual mortality is only partially observable. Annuities provide insurance against longevity risk by converting wealth into a lifelong income stream, but the decision to annuitize is typically irreversible and depends crucially on one's life expectancy. While insurers price annuities using objective mortality tables, individuals base their decisions on a subjective mortality force. We assume that the individual is uncertain about their mortality and instead relies on partial information about their health status.

Building on recent work on optimal annuitization ([3], [2] and [1]), we consider an individual who invests wealth in a financial fund modelled as a geometric Brownian motion and chooses when to irreversibly convert all wealth into a life annuity. The individual's mortality force follows a two-state piecewise deterministic process, switching from a low to a high level at an unobservable random time that represents a serious and permanent health deterioration. The individual does not directly observe the change in mortality when it occurs. Instead, they receive noisy information about their health status over time. As a consequence, the individual must form and continuously update beliefs about whether the mortality force has already switched from the low to the high state. Mathematically, this translates into including as a state variable the posterior probability of the occurrence of the change in mortality.

The annuitization problem is formulated as an optimal stopping problem under partial information. The stopping region is shown to be connected and free of isolated boundary points, which ensures continuous differentiability of the value function. The optimal strategy is of a threshold type: the state dynamics is two dimensional and it includes a wealth process and the posterior belief process of the agent about the occurrence of the health shock. Annuitization becomes optimal when wealth crosses a belief-dependent threshold, either from below or from above, depending on the model parameters. We then analyse the qualitative behaviour of the free boundary, studying in particular its monotonicity properties with respect to beliefs about deteriorating health. Our results bridge optimal annuitization and quickest detection theory, highlighting how health uncertainty and learning dynamics significantly shape retirement timing decisions.

Keywords: Optimal stopping · Optimal annuitization · Partial information · Change point detection.

⋆ Presenter

Matteo Buttarazzi, Tiziano De Angelis, and Gabriele Stabile

Contributed Session

CS152: Optimal stopping, stochastic control and stochastic games I organized by Alessandro Milazzo and Tiziano De Angelis

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Martingale Problems with Distributional Drift via Regularisation: Convergence of the Euler Scheme

Matteo Cagnotti[1⋆] and Elena Issoglio[1]

Department of Mathematics "G. Peano", University of Turin, Italy,
matteo.cagnotti@unito.it
elena.issoglio@unito.it

This talk addresses the numerical approximation of solutions to martingale problems that encode the dynamics of the formal SDE

$$dX_t = b(t, X_t)\,dt + dW_t, \qquad b \in C_T\mathcal{C}^{-\beta}(\mathbb{R}^d),\ \beta \in (0, \tfrac{1}{2}).$$

In this setting, the drift cannot be evaluated pointwise, and standard arguments used to prove convergence of the Euler scheme are not directly applicable. The martingale-problem formulation makes it possible to avoid writing the singular drift term in classical form.

A central feature of the analysis is a construction of time integrals of distributions along martingale-problem solutions, namely quantities of the form

$$\int_0^t g(s, X_s)\,ds, \qquad g \in C_T\mathcal{C}^{-\beta}(\mathbb{R}^d),\ \beta \in (0, \tfrac{1}{2}).$$

Here this construction is used as the main analytic device in the error analysis. In particular, I will discuss quantitative stability estimates for these integral functionals, showing that perturbations of the integrand can be controlled along singular trajectories. This provides a substitute for the pointwise comparison arguments that underlie the classical error analysis for SDE schemes.

The approximation analysis is organised in two separate steps. First, one compares the martingale-problem solution associated with the singular drift b to the solution associated with a heat-mollified drift b^m. This is the part where the integral-along-solutions construction is used: the stability estimates for these distributional integral functionals provide quantitative control of the error generated by replacing b with b^m.

Second, for each fixed m, one studies the Euler-Maruyama discretisation of the regularised equation where the drift is smooth and the scheme is classically well defined. The discretisation error is analysed at the level of the regularised dynamics, via stochastic sewing estimates, independently of the singular formulation. The final convergence rate is then obtained by optimising the choice of the mollification scale as a function of the time step.

Under suitable assumptions, this yields quantitative weak and strong convergence bounds with explicit dependence on the spatial regularity of the drift and on the discretisation scale. I will also briefly comment on a randomised time-freezing variant, mainly to indicate how the same approach can be adapted to alternative numerical schemes for specific classes of drifts.

This talk is based on the results proved in [1].

Keywords: Singular SDEs · Martingale Problem · Numerical Approximation.

Contributed Session

CS161: Singular SDEs: Well Posedness and Numerics organized by Luca Bondi and Matteo Cagnotti

⋆ Presenter

Matteo Cagnotti and Elena Issoglio

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Efficient simulation of a new class of Volterra-type SDEs

Ofelia Bonesini[1], Giorgia Callegaro[2⋆], Martino Grasselli[2,4], and Gilles Pagès[3]

[1] Department of Mathematics, London School of Economics and Political Science, London, UK
o.bonesini@lse.ac.uk
[2] Department of Mathematics, University of Padova, Padova, Italy
gcallega,grassell@unipd.it
[3] LPSM, Sorbonne Université, Paris, France
gilles.pages@upmc.fr
[4] Léonard de Vinci, Pole Universitaire, Research Center, Paris la Défense, France

We propose a new theoretical framework that exploits convolution kernels to transform a Volterra-type path-dependent (non-Markovian) stochastic process into a standard (Markovian) diffusion process. Remarkably, it is also possible to go back, i.e., the transformation is reversible.

We discuss existence and path-wise regularity of solutions for our class of stochastic differential equations. In the fractional kernel case, when $H \in (0, \frac{1}{2})$, where H is the Hurst coefficient, we propose a numerical simulation scheme which exhibits a remarkable strong convergence rate of order 1/2, which constitutes a bold improvement when compared with the performance of available Euler schemes, whose strong rate of convergence is H.

Keywords: Volterra stochastic differential equations · Markov process · Fractional Integrals · Euler Scheme · Strong error rate.

Contributed Session
CS114: New advances in rough volatility models organized by Ofelia Bonesini

⋆ Presenter

Stationary Mean Field Games on networks with sticky transition condition

Fabio Camilli

Dipartimento di Ingegneria e Geologia, Università “G. d’Annunzio” Chieti-Pescara
fabio.camilli@unich.it

I consider stochastic Mean Field Games on networks with sticky transition conditions. In this setting, the diffusion process governing the agent’s dynamics can spend finite time both in the interior of the edges and at the vertices. The corresponding generator is subject to limitations concerning second-order derivatives and the invariant measure breaks down into a combination of an absolutely continuous measure within the edges and a sum of Dirac measures positioned at the vertices. Additionally, the value function, solution to the Hamilton-Jacobi-Bellman equation, satisfies generalized Kirchhoff conditions at the vertices.

Keywords: Mean Field Games · sticky transition condition · networks.

Contributed Session
CS158: Stochastic Processes, PDEs and Networks organized by Fausto Colantoni

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Critical Points and Euler characteristic for Time-Dependent Spherical Random Fields

Valentina Cammarota[1]

Dipartimento di Scienze Statistiche, Sapienza University of Rome, Italy,
valentina.cammarota@uniroma1.it

We study the fluctuations over time for critical points, and Euler characteristic of the excursion sets, of general isotropic Gaussian random fields on the sphere.

Keywords: Random fields · Sphere cross time · Critical points · Excursion set.

Contributed Session
CS170: Advances in the Geometry of Random fields organized by Francesca Pistolato

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Correlation Structure for Random Waves

Riccardo Maffucci[1⋆], Valentina Cammarota[2], Domenico Marinucci[3], and Maurizia Rossi[4]

[1] Department of Mathematics, University of Turin, Italy,
riccardowalter.maffucci@unito.it
[2] Department of Statistical Sciences, University of Roma La Sapienza, Rome, Italy
[3] Department of Mathematics, University of Roma Tor Vergata, Rome, Italy
[4] Department of Mathematics and Applications, University of Milano-Bicocca, Milan, Italy

Arithmetic Random Waves are the eigenfunctions of the Laplacian on the torus in $d \geq 2$ dimensions. Their geometry has been extensively investigated in the last two decades, starting from the seminal papers [2,3].

We will discuss [1] the correlation of various functionals including nodal length, boundary length of excursion sets, and the number of intersection of nodal sets with deterministic curves in different classes; the amount of correlation depends in a subtle fashion from the values of the thresholds considered and the symmetry properties of the deterministic curves. In particular, we prove the existence of *resonant pairs* of threshold values where the asymptotic correlation is full, that is, at such values one functional can be perfectly predicted from the other in the high energy limit. We focus mainly on $d = 2$ with some extensions to $d = 3$.

We will also briefly discuss a related problem of independent interest in geometry, concerning the characterisation of certain special classes of curves and surfaces that naturally come into play.

Keywords: Random Field · Correlation · Moments.

Contributed Session
CS103: Moments, Cumulants and dependence: Classical and Modern Perspectives organized by Elvira Di Nardo

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⋆ Presenter

Critical density of the Stochastic Sandpile Model

Concetta Campailla

Sapienza Università di Roma
mariaconcetta.campailla@uniroma1.it

The Stochastic Sandpile Model is an interacting particle system introduced in the physics literature in the '90s to study the concept of self-organized criticality, which describes physical systems that spontaneously evolve toward a critical state without the need to fine-tune their parameters. In this talk, I will present the model and discuss some questions related to its behaviour, such as the critical density at which the phase transition occurs, how to exactly sample from the stationary distribution on finite graphs, and the stationary particle density on the complete graph.

Keywords: Stochastic Sandpile Model · Self-organized criticality · Interacting particle systems.

Contributed Session
CS167: Dynamics and phase transitions on discrete structures organized by Vanessa Jacquier and Giacomo Passuello

Intrinsic stochasticity in the Landau–Lifshitz–Navier–Stokes equations on logarithmic lattices

Ciro Campolina

Scuola Normale Superiore, Pisa, Italy
ciro.campolina@sns.it

Motivated by the intrinsic unpredictability of turbulent flows, it has long been conjectured that solutions of the stochastic Navier–Stokes equations remain random in the double limit of vanishing noise amplitude and vanishing viscosity. Although this fundamental mathematical question remains open, direct numerical verification in the full system is currently out of reach due to the extreme computational cost. In this talk, we investigate this conjecture within a reduced yet dynamically faithful framework. We consider the three-dimensional incompressible Landau–Lifshitz–Navier–Stokes equations on logarithmic Fourier lattices with small-scale additive noise. This setting allows for high-resolution simulations in regimes of decreasing viscosity and vanishing noise amplitude. By analyzing the statistics of individual large-scale Fourier modes, we provide numerical evidence of intrinsic stochasticity in two distinct scenarios: evolution from rough initial data and continuation beyond finite-time blow-up of a strong solution. In both cases, the convergence of probability density functions across different parameter sequences indicates the emergence of a limiting universal stochastic process. All results presented in this talk are reported in a recent paper [1] in collaboration with Erika Ortiz and Alexei Mailybaev.

This work received funding from the French National Research Agency (ANR Project TILT, ANR-20-CE30-0035) and from the European Union's ERC program (NoisyFluid, Grant No. 101053472).

Keywords: Intrinsic stochasticity· vanishing noise · inviscid limit · logarithmic lattice

Contributed Session
CS171: "Methods in stochastic fluid dynamics: a young researchers perspective" organized by Lorenzo Marino and Theresa Lange

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Stationary Mean-Field singular control of an Ornstein-Uhlenbeck process

Federico Cannerozzi*

Center for Mathematical Economics (IMW), Bielefeld University, Germany,
federico.cannerozzi@uni-bielefeld.de

Motivated by continuous-time optimal inventory management, we study a class of stationary mean-field control problems with singular controls. The dynamics are modeled by a mean-reverting Ornstein-Uhlenbeck process, and the performance criterion is given by a quadratic long-time average expected cost functional. The mean-field dependence is through the stationary mean of the controlled process itself, which enters the ergodic cost functional. We characterize the solution to the stationary mean-field control problem in terms of the equilibria of an associated stationary mean-field game, showing that solutions of the control problem are in bijection with the equilibria of this mean-field game. Finally, we solve the stationary mean-field game, thereby providing a solution to the original stationary mean-field control problem.

Keywords: singular stochastic control · mean-field control problems · mean-field games.

Contributed Session
CS125: Cooperative and competitive mean-field models - Part I organized by Federico Cannerozzi and Giorgio Ferrari

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* Presenter

Fractional Cointegration of Geometric Functionals

Alessia Caponera[1], Domenico Marinucci[2], and Anna Vidotto[3*]

[1] Department of AI, Data and Decision Sciences, LUISS Guido Carli, Italy
acaponera@luiss.it
[2] Department of Mathematics, University of Rome Tor Vergata, Italy
marinucc@mat.uniroma2.it
[3] Department of Basic and Applied Sciences for Engineering, Sapienza University of Rome, Italy
anna.vidotto@uniroma1.it

In this talk, we show that geometric functionals (e.g., excursion area, boundary length) evaluated on excursion sets of sphere-cross-time long memory random fields can exhibit fractional cointegration, meaning that some of their linear combinations have shorter memory than the original vector. These results prove the existence of long-run equilibrium relationships between functionals evaluated at different threshold values; as a statistical application, we discuss a frequency-domain estimator for the Adler-Taylor metric factor, i.e., the variance of the field's gradient. Our results are illustrated also by Monte Carlo simulations.

Keywords: Sphere-cross-time Random Fields · Geometric Functionals · Long Memory · Fractional Cointegration.

Contributed Session
CS123: Asymptotic properties of Gaussian fields organized by Leonardo Maini

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* Presenter

Optimizing Fuzzy Partitions for Visual Sensors

Andrea Capotorti* and Marco Baioletti

Department of Mathematics and Computer Science, University of Perugia, Italy,
{andre.capotorti,marco.baioletti}@unipg.it

This paper presents a novel optimization framework for the design of fuzzy partitions specifically tailored to data acquired from visual sensors operating in complex environments. Visual sensor streams are typically high-dimensional and affected by uncertainty and vagueness arising from illumination changes, occlusions, and sensor noise, which makes their processing within a Fuzzy Logic System (FLS) particularly appealing. In such systems, the overall performance, robustness, and interpretability crucially depend on the choice of the membership functions that define the fuzzy partition of the input space.

We address this design problem by introducing an automatic tuning scheme for the parameters of parametric membership functions, focusing on triangular and Gaussian shapes, whose centers and widths are optimized over a prescribed spectral range. The proposed method formulates the search for an adequate partition as a continuous optimization problem, where the objective function combines a global sensitivity index with a penalty term controlling the extent of under-threshold zones, i.e., regions in which all memberships fall below a given minimum sensitivity level. In particular, we define a total sensitivity functional Δ, based on the integrated squared differences between membership profiles, and an under-threshold multi-interval E, obtained as the intersection of the individual under-threshold sets associated with each fuzzy membership. The resulting objective $\Psi = \Delta - w_\varepsilon E$, with w_ε a weight, enforces a trade-off between maximizing discrimination among fuzzy sets and minimizing poorly covered regions of the domain.

Conceptually, our approach is inspired by the view of biological sensory systems as collections of specialized fuzzifiers[1], where stimuli are encoded through families of overlapping receptive fields and processed via fuzzy-granular representations. In particular, the human visual system exemplifies how a limited number of receptor types can support fine discrimination by means of suitably arranged fuzzy membership functions over the sensory domain. Preliminary analytical evaluations of the proposed objective show that, for both triangular and Gaussian memberships, the sensitivity term admits closed-form expressions, which allow an efficient numerical implementation of the optimization procedure. Moreover, the explicit characterization of under-threshold zones through a Marzullo-like algorithm provides a controllable mechanism to tune coverage according to application-dependent sensitivity requirements. These first results support Gentili's thesis that perception-oriented fuzzy structures can serve as a conceptual blueprint for artificial sensory systems, and they indicate that optimized fuzzy partitions can enhance both discrimination capability and semantic transparency in visual-sensor FLS models.

Keywords: Fuzzy Logic System · Visual sensors · Membership functions · Partition optimization · Specialized fuzzifiers

Contributed Session

CS181: Approaches to Uncertainty and Information Measures organized by Andrea Capotorti and Silvia Lorenzini

* Presenter

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Stability of Reaction Networks with Randomly Switching Parameters - part 2

Aidan Howells

Dipartimento di Scienze Matematiche, Politecnico di Torino,
aidan.howells@polito.it

Since the dawn of stochastic chemical reaction network theory over 50 years ago, there have been many general results about (positive) recurrence, especially in the case of mass-action kinetics. One less-explored area is that of mass-action models whose rate constants, rather than being static, are themselves stochastic. Such models have relevance in applications, since biomolecular systems rarely exist in isolation and their rates often depend on time-changing quantities. In this series of two talks, we will study the stability of such models under some linearity assumptions.

Specifically, this second talk will present matrix conditions for positive recurrence and transience in the special case where there are finitely many possible choices of rate constants. These conditions will depend on the specific choice of parameters for the model, which makes it possible to uncover phase transitions where the stability behavior of the model varies. We will see that the speed at which the rate constants are changing plays an important role, with the model behaving as one with averaged rate constants when this speed is high and behaving as though the rate constants were unaveraged when this speed is low. This talk is based on joint work with Daniele Cappelletti and Chuang Xu.

Keywords: Reactions Networks · Continuous-Time Markov Chains

Contributed Session

CS163: Stochastic chemical reaction network dynamics organized by Daniele Cappelletti and Lucie Laurence

Stochastic ordering tools for reaction network models

Daniele Cappelletti, Giulio Cuniberti*, and Paola Siri

Department of Mathematical Sciences, Politecnico di Torino, Turin, Italy
{daniele.cappelletti,giulio.cuniberti,paola.siri}@polito.it

Stochastic reaction networks are mathematical models with a wide range of applications in biochemistry, ecology, and epidemiology, and are often complex to analyze. Except for some special cases, it is generally difficult to predict how the abundances of all considered species evolve over time. A possible approach to address this issue is to develop tools to compare the model under study with a similar one whose behavior is better understood. The main contribution of our work is to provide direct and computable conditions that can be used to ensure the existence of an ordered coupling between two stochastic reaction networks and to identify which parameter changes in a given model lead to an increase or decrease in the count of certain species. We also make an algorithm available that implements our theory and we illustrate it with several applications.

Keywords: continuous-time Markov chain · reaction network · stochastic ordering

Contributed Session
CS163: Stochastic chemical reaction network dynamics organized by Daniele Cappelletti and Lucie Laurence

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* Presenter

Stability of Reaction Networks with Randomly Switching Parameters - part 1

Daniele Cappelletti[1]*, Abhishek Pal Majumder[2], and Carsten Wiuf[2]

[1] Department of Mathematical Sciences, Politecnico di Torino, Turin, Italy,
daniele.cappelletti@polito.it
[2] Department of Mathematical Statistics, University of Reading, Reading, UK
[3] Department of Mathematical Sciences, University of Copenhagen, Copenhagen, Denmark

In this talk I will present the work published in [1]. This work is related to the more recent work [2], also presented in this session.

Since the dawn of stochastic chemical reaction network theory over 50 years ago, there have been many general results about (positive) recurrence, especially in the case of mass-action kinetics. One less-explored area is that of mass-action models whose rate constants, rather than being static, are themselves stochastic. Such models have relevance in applications, since biomolecular systems rarely exist in isolation and their rates often depend on time-changing quantities. In this series of two talks, we will study the stability of such models under some linearity assumptions. In this first talk, I will present structural conditions implying positive recurrence, regardless of the specific choice of parameters of the model. I will further present an algebraic characterization of the stationary distribution in terms of a stochastic recurrence equation, which can be exploited to numerically calculate the conditional stationary distribution and its moments.

Keywords: Stochastic Reaction Networks · Positive Recurrence · Stationary Distribution.

Contributed Session
CS163: Stochastic chemical reaction network dynamics organized by Lucie Laurence and Daniele Cappelletti

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* Presenter

Parameter estimation in a fractional neuronal model

Pauliina Ilmonen[1], Milla Laurikkala[1], Enrica Pirozzi[2], Luigia Caputo[3⋆], and Lauri Viitasaari[4]

[1] Aalto University School of Science, Department of Mathematics and Systems Analysis, PO Box 11100, 00076 Aalto, Finland, {pauliina.ilmonen,milla.laurikkala}@aalto.fi
[2] Department of Mathematics and Physics, University of Campania Luigi Vanvitelli, Caserta, 81100, Italy, enrica.pirozzi@unicampania.it
[3] Department of Mathematics and Applications, University of Naples Federico II, Naples, 80126, Italy, luigia.caputo@unina.it
[4] Aalto University School of Business, Department of Information and Service Management, PO Box 11110, 00076 Aalto, Finland, lauri.viitasaari@aalto.fi

In the framework of stochastic modelling of some biological dynamics, the fractional calculus is one of the valid tool to insert memory effects in widely applied Markov models (see, for instance, [1], [2]). Here, we focus on a class of fractional stochastic neuronal models among them those investigated in [3], [4] and [5].

In particular, we apply techniques of parameter estimation for a generalized neuronal model driven by a fractional dynamic and stochastic input. Specifically, the membrane potential $V = \{V_t\}_{t\geq 0}$ is modeled through the Caputo fractional differential equation

$$D^\alpha V_t = AV_t + b + \eta(t), \qquad \alpha \in (0,1),$$

where D^α denotes the Caputo derivative of order α, $A, b \in \mathbb{R}$, and the latent input process η satisfies the Ornstein–Uhlenbeck-type dynamics

$$d\eta(t) = -\Theta\eta(t)\,dt + \sigma\,dG_t,$$

with $\Theta, \sigma > 0$ and a driving process G with stationary increments. The framework is intrinsically multidimensional, although the estimation methodology is first developed in the univariate case.

The mild solution of the fractional equation is expressed in terms of the Mittag–Leffler functions as follows:

$$V_t = E_\alpha(t^\alpha A)V_0 + \int_0^t s^{\alpha-1}E_{\alpha,\alpha}(s^\alpha A)\big(b + \eta(t-s)\big)\,ds,$$

which provides short- and long-time asymptotics. These asymptotic expansions constitute the basis of a constructive estimation strategy. First, in the case of $b = 0$, exploiting the behavior of V_t as $t \downarrow 0$ we derive estimators for the fractional order α. Alternative difference-based estimators are proposed to mitigate the slow convergence of bias terms involving $\log t$. Once $\widehat{\alpha}$ is obtained, the same asymptotics and large-time expansions of E_α yield consistent estimators of A.

After recovering $(\widehat{\alpha}, \widehat{A})$, the latent noise is reconstructed via

$$\widehat{\eta}(t) = D^{\widehat{\alpha}}V_t - \widehat{A}V_t,$$

and classical methods for Vasicek-type processes are applied to estimate (Θ, σ). The propagation of estimation error from the fractional stage to the second-step inference is analyzed numerically.

⋆ Presenter

A discretization scheme for the Caputo derivative of order α is implemented, leading to an iterative algorithm of computational complexity $O(n^2)$. Simulation studies demonstrate that accurate estimation of α requires observations on a sufficiently fine grid near zero, while reliable inference for (Θ, σ) necessitates long time series. The results confirm the feasibility of the proposed two-step procedure and highlight the interplay between fractional memory effects and stochastic input estimation in generalized neuronal models.

Keywords: Fractional derivative · Simulation · Statistical estimates.

This study was partially funded by the project PRIN-PNRR P2022XSF5H of European Union – NextGenerationEU– (MUR) Project Title "Stochastic Models in Biomathematics and Applications"; and by the project PRIN2022-MUR 2022XZSAFN.

Contributed Session
CS191: Selected Topics in Probability and Statistics organized by Andrea Simonetti

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Noise sensitivity and directed polymers

Francesco Caravenna[1] and Anna Donadini[1⋆]

Department of Mathematics, University of Milano-Bicocca, Italy,
francesco.caravenna@unimib.it, a.donadini@campus.unimib.it

Noise sensitivity for functionals of independent random variables, introduced by Benjamini, Kalai and Schramm in 1999 in the context of Boolean functions, describes the phenomenon where a small perturbation of the underlying randomness leads to an asymptotically independent outcome.

In this talk, we extend classical noise sensitivity criteria beyond the Boolean setting and derive quantitative estimates with optimal rates. We then consider the model of directed polymers in random environments, and apply our results to the regime in which the partition function converges to a universal limit known as the Stochastic Heat Flow, which we show to be independent of the white noise arising from the scaling limit of disorder.

Keywords: Noise sensitivity · Directed polymers · Stochastic Heat Flow.

Contributed Session
CS131: Directed Polymers and Stochastic Heat Flow organized by Francesca Cottini

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⋆ Presenter

On the Lyapunov exponent of discrete and continuum generalized Ising-models

Tommaso Carazzato

Department of Mathematics, University of Padova, Italy,
tommaso.carazzato@studenti.unipd.it

The Ising model is a Random Field built on a lattice where, for each site, it is assigned a ± 1 value called spin. This model is used to represent the ferromagnetic phenomena in physics and the spins are organized in such a way that neighbouring spins tend to be aligned. We are interested in the model when it interacts with random external fields: in particular, we analyze the partition function and the free energy density as they encode the observable information of the model. In dimension one the model has been completely solved and it has been proven that the partition function can be expressed as the trace of the product of 2 by 2 random matrices, called transfer matrices. Furthermore, the free energy density can be expressed through the transfer matrices: it is their Lyapunov exponent. The Lyapunov exponent of a sequence of random matrices is the value which describes how fast the logarithm of the norm of their product diverges: it can be considered as the equivalent of a Law of Large Numbers in higher dimension. In this talk we will deal with a generalization of the Ising model proposed in the physical literature and we will explain what role plays the Lyapunov exponent in the analysis of this statistical mechanics model. The main focus will be on the comparison between the discrete model and a continuum one, obtained via a scaling limit: our target is to understand whether the discrete Lyapunov exponent converges to the one in the continuum case. This is based on a joint work with A. Chiarini and G. Giacomin.

Keywords: Random Fields · Lyapunov exponent · Generalized Ising Model.

Contributed Session

CS170: Advances in the Geometry of Random fields organized by Francesca Pistolato

Berry-Heisenberg Random Waves

Marco Carfagnini[1⋆] and Anna Paola Todino[2]

[1] School of Mathematics and Statistics, University of Melbourne, Parkville VIC 3010, Australia,
marco.carfagnini@unimelb.edu.au
[2] Dipartimento di Scienze e Innovazione Tecnologica Università del Piemonte Orientale
annapaola.todino@uniupo.it

In the 70s, Berry argued that in the high-energy limit wave functions locally look like random superpositions of independent plane waves, having all the same wavenumber. He introduced a Gaussian random field whose sample paths are generalized Laplace eigenfunctions. The aim of this talk is to present a similar model for the sub-Laplacian on the Heisenberg group, which is the analogue of the Euclidean space in sub-Riemannian geometry. It combines ideas from PDE, representation theory, and stationary random fields.

Keywords: Random waves · stationary fields on lie groups · Heisenberg group.

Contributed Session
CS 123 : Asymptotic properties of Gaussian fields organized by Leonardo Maini

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⋆ Presenter

Accurate Bayesian inference for tail risk extrapolation in time series

David L. Carl[1], Simone A. Padoan[1*], and Stefano Rizzelli[2]

[1] Department of Decision Sciences, Bocconi University, Milan, Italy,
david.carl@phd.unibocconi.it, simone.padoan@unibocconi.it
[2] Department of Statistical Science, University of Padova, Padova, Italy
stefano.rizzelli@unipd.it

Accurately quantifying tail risks—rare but high-impact events such as financial crashes or extreme weather—is a central challenge in risk management, with serially dependent data. We develop a Bayesian framework based on the Generalized Pareto (GP) distribution for modeling threshold exceedances, providing posterior distributions for the GP parameters and tail quantiles in time series. Two cases are considered: extrapolation of tail quantiles for the stationary marginal distribution under β-mixing dependence, and dynamic, past-conditional tail quantiles in heteroscedastic regression models. The proposal yields asymptotically honest credible regions, whose coverage probabilities converge to their nominal levels. We establish the asymptotic theory for the Bayesian procedure, deriving conditions on the prior distributions under which the posterior satisfies key asymptotic properties. To achieve this, we first develop a likelihood theory under serial dependence, providing local and global bounds for the empirical log-likelihood process of the misspecified GP model and deriving corresponding asymptotic properties of the Maximum Likelihood Estimator (MLE). Simulations demonstrate that our Bayesian credible regions outperform naïve Bayesian and MLE-based confidence regions across several standard time-series models, including ARMA, GARCH, and Markovian copula models. Two real-data applications—to U.S. interest rates and Swiss electricity demand—highlight the relevance of the proposed methodology.

Keywords: Bayesian inference · Empirical Bayes · Generalised Pareto · Tail risk · Threshold Exceedances · Mixing · Weak dependence

Contributed Session
CS149: Modeling the Unseen: Theory and Methods for Extreme Events organized by Stefano Rizelli

* Presenter

Asymptotic theory for the likelihood-based block maxima method in time series

David L. Carl[1*], Simone A. Padoan[2], and Stefano Rizzelli[3]

[1] Department of Decision Sciences, Bocconi University, Milan, Italy,
david.carl@phd.unibocconi.it
[2] Department of Decision Sciences, Bocconi University, Milan, Italy,
simone.padoan@unibocconi.it
[3] Department of Statistical Sciences, University of Padova, Padova, Italy
stefano.rizzelli@unipd.it

In this work, we investigate the block maxima method in the context of stationary time series. We begin by extending aspects of likelihood asymptotic theory for the estimation of the marginal parameters of the Generalized Extreme Value (GEV) distribution from the case of independence to scenarios involving serial dependence. Once the likelihood framework is established at a suitable level of generality, we shift our focus to its Bayesian counterpart, studying the corresponding asymptotic properties. Frequentist and Bayesian inference is then employed to estimate marginal parameters of the GEV, the extremal index, return levels and extreme quantiles of the underlying stationary distribution.

Keywords: Asymptotic Theory · Bayesian Inference · Block Maxima · Extreme Value Theory · Time Series.

Contributed Session
CS149: Modeling the Unseen: Theory and Methods for Extreme Events organized by Stefano Rizzelli

* David Carl

Multi-Criteria Decision-Making, Conditional Probabilities, and Fuzzy Sets

Lydia Castronovo

Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli Studi di Messina, Messina, Italy
lydia.castronovo@studenti.unime.it

In the framework of (fuzzy) multi-criteria decision making [1,2], we propose a method that allows the decision maker to subjectively approach the problem by suitably modifying the decision matrix. Starting from [4] and following the recent approach proposed in [3], we use the conditional probability interpretation of membership functions and the operations among conditionals in the framework of conditional random quantities [5] to model logical and probabilistic operations among the columns of the decision matrix seen as particular fuzzy sets. We consider a decision problem related to a random quantity X with set of values $\mathcal{X} = \{x_1, x_2, \dots, x_n\}$. Let $\mathcal{E}$ be a meta-expert who chooses the relevant properties $\{C_1, C_2, \dots, C_m\}$ of X, with C_i logically independent. In this setting, the properties C_j are the criteria of the decision problem and the alternatives are represented by the events $A_i = (X = x_i)$ for $i = 1, \dots, n$. To build the decision matrix, the decision maker has to set the criteria's weights w_j and the scores a_{ij}. The criteria's weights w_j, for $j = 1, \dots, m$, are seen as the probabilities of the events "C_j is relevant with respect to the decision problem". Moreover, given a criterion C_j and alternative A_i, the corresponding score is interpreted as $a_{ij} = P(E_{C_j}|A_i)$, that is, the conditional probability assigned to the conditional event $E_{C_j}|A_i$="$\mathcal{E}$ claims that X satisfies property C_j, knowing that $(X = x_i)$". Then, in this setting we allow logical operations among criteria, by exploiting the conditional probability interpretation. More precisely, when considering the complement, conjunction and disjunction of criteria, we build the complement, intersection and union of the corresponding fuzzy sets. The conditional probability interpretation of the scores helps us find the new scores of the modified decision matrix, which retains all the original criteria, as well as the new columns given by the logical operations considered by the decision maker.

This talk is based on a joint work [2] with G. Filippone, G. La Rosa, G. Sanfilippo and M. E. Tabacchi from Università degli Studi di Palermo, Italy.

Keywords: Compound Conditionals · Conditional Random Quantities · Fréchet-Hoeffding Bounds · Fuzzy Sets · Multi-Criteria Decision-Making.

Contributed Session

CS181: Approaches to Uncertainty and Information Measures organized by Andrea Capotorti and Silvia Lorenzini

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Hierarchical Random Measures without Tables

Marta Catalano[1⋆] and Claudio Del Sole[2]

[1] Department of AI, Data and Decision Sciences, Luiss University, Italy,
mcatalano@luiss.it
[2] Department of Economics, Management and Statistics, University of Milano-Bicocca, Milan, Italy
claudio.delsole@unimib.it

Bayesian multilevel models provide an effective framework to borrow information between different data sources through the sharing of common features. In a nonparametric setting, a classic example is the hierarchical Dirichlet process, whose generative model can be described through a set of latent variables, commonly referred to as tables in the popular restaurant franchise metaphor. The latent tables greatly simplify the expression of the posterior and allow for the implementation of a Gibbs sampling algorithm to approximately draw samples from it. However, managing their assignments can become computationally expensive, especially as the size of the dataset and of the number of levels increase. In this talk, we identify a prior for the concentration parameter of the hierarchical Dirichlet process that (i) induces a quasi-conjugate posterior distribution, and (ii) removes the need of tables, bringing to more interpretable expressions for the posterior, with both a scalable and an exact algorithm to sample from it. This construction extends beyond the Dirichlet process, leading to a new framework for defining normalized hierarchical random measures and a new class of algorithms to sample from their posteriors.

Keywords: Bayesian nonparametrics · Completely random measure · Dirichlet process · Multilevel model · Partial exchangeability.

Contributed Session
CS108: "Discrete random structures for Bayesian learning" organized by Giovanni Rebaudo

⋆ Presenter

Measuring partial exchangeability with reproducing kernel Hilbert spaces

Marta Catalano[1], Hugo Lavenant[2⋆], and Francesco Mascari[2]

[1] Department of AI, Data and Decision Sciences, Luiss University, Italy,
mcatalano@luiss.it
[2] Department of Decision Sciences, Bocconi University, Milan, Italy
{hugo.lavenant,francesco.mascari}@unibocconi.it

In Bayesian multilevel models, the data are structured in interconnected groups, and their posteriors borrow information from one another due to prior dependence between latent parameters. In this work, we develop a general framework for measuring the amount of dependence for parametric and nonparametric models, both a priori and a posteriori. We define an index measuring partial exchangeability that detects exchangeability for common models, is invariant by reparametrization, can be estimated through samples, and, crucially, is well-suited for posteriors. We achieve these properties through the use of Reproducing Kernel Hilbert Spaces, which map any random probability to a random object on a Hilbert space. This leads to many convenient properties and tractable expressions, especially a priori and under mixing. This presentation is based on the work [1].

Keywords: Bayesian Nonparametrics · Correlation · Random Probability Measure.

Contributed Session
CS147: Kernel methods in Bayesian statistics organized by Marta Catalano and Hugo Lavenant

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⋆ Presenter

Convergence for linear quadratic potential mean field games

Alekos Cecchin[1] and Jodi Dianetti[2⋆]

[1] Department of Mathematics "Tullio Levi-Civita", University of Padova, Padova, Italy
alekos.cecchin@unipd.it
[2] Department of Economics and Finance, University of Rome Tor Vergata, Rome, Italy
jodi.dianetti@uniroma2.it

Our work studies the limits of empirical means of open-loop Nash equilibria of linear-quadratic stochastic differential games as the number of players goes to infinity, when the corresponding mean field game is of potential type and may have multiple equilibria. Via weak compactness arguments, the limit points are characterized as optimal trajectories of the related deterministic control problem, thus ruling out some of the mean field equilibria. Our result is obtained by first connecting the finite player game to a suitable control problem, whose optimal trajectories are the empirical means of Nash equilibria of the game, and in which the number of players N becomes a parameter. True convergence to the unique minimizer of the limit control problem then holds for almost every initial mean. In cases of multiple optimizers, we focus on examples to show that some symmetry of the data ensures that the sequence admits a random limit which is distributes uniformly among the minimizers of the potential. Multidimensional examples of the convergence result appear here for the first time, which show the flexibility of our method. We also establish a similar convergence results for the corresponding linear-quadratic potential mean field games with common noise, as the noise vanishes.

The presenter will be Jodi Dianetti.

Keywords: Mean field games · convergence problem · mean field control.

Contributed Session

CS126: Cooperative and competitive mean-field models - Part II organized by Federico Cannerozzi and Giorgio Ferrari

⋆ Presenter

Edgeworth Expansions and Non-Gaussian Corrections in Finite-Width Wide Neural Networks

Lucia Celli*

Department of Mathematics, University of Luxembourg, Luxembourg,
lucia.celli@uni.lu

Finite-width fully connected neural networks with Gaussian initialization deviate from their infinite-width Gaussian limit through non-vanishing higher-order cumulants. In this talk, I present multidimensional Edgeworth expansions of arbitrary order for neural network outputs evaluated on a finite collection of inputs, providing a systematic way to approximate these non-Gaussian effects. Under the assumption that the limiting Gaussian covariance matrix is invertible and that the activation function is polynomially bounded, we obtain upper bounds of order n^{-m} in total variation distance between the true network law and its Edgeworth approximation of order $4m-2$, together with matching lower bounds. Beyond neural networks, the results apply to general sequences of conditionally Gaussian vectors converging to a non-degenerate Gaussian limit. As an application, I discuss quantitative bounds for Bayesian neural networks, measuring the error introduced when replacing the prior distribution with its Edgeworth approximation.

Keywords: Edgeworth expansion · Neural networks · Limit theorems · Conditionally Gaussian Random variables · Gaussian initialization · Total variation distance · Bayesian supervised learning.

Contributed Session

CS116: "Neural Networks and Gaussian Processes: Perspectives from Young Researchers" organized by Claudio Macci

* Presenter

Robust quasi-convex and cash-subadditive risk measures: theory, duality, and applications

Asmerilda Hitaj[1⋆], Francesca Centrone[2], Elisa Mastrogiacomo[1], and Emanuela Rosazza Gianin[3]

[1] Dipartimento di Economia, Università degli Studi dell'Insubria, Varese, Italy,
asmerilda.hitaj@uninsubria.it, elisa.mastrogiacomo@uninsubria.it

[2] Department of Economics and Business Studies, University of Eastern Piedmont, Italy
francesca.centrone@uniupo.it

[3] Department of Statistics and Quantitative Methods, University of Milano-Bicocca
emanuela.rosazza1@unimib.it

In recent years, robust risk measures have emerged as a key tool to incorporate model uncertainty into financial decision-making. A standard approach extends convex, cash-additive risk measures to robust settings. In particular, [5] defines $\tilde{\rho}(X) \triangleq \sup_{Z \in \mathcal{U}_X} \rho(Z)$, where ρ is monotone, cash-additive, and convex, and $\mathcal{U}_X$ is the uncertainty set of X. This framework has also been studied in risk sharing and dynamic settings [6,4]. However, convexity and cash-additivity may be too restrictive in the presence of frictions, illiquidity, or nonlinear pricing. This motivates cash-subadditive and quasi-convex risk measures, introduced respectively in [3] and [1]. Despite these developments, a general construction of robust quasi-convex, possibly cash-subadditive, risk measures is still missing. We address this gap by proposing a unified framework. We first identify sufficient conditions on uncertainty sets ensuring quasi-convexity of $\tilde{\rho}$, including the classical convexity condition $\mathcal{U}_{\lambda X+(1-\lambda)Y} \subseteq \lambda \mathcal{U}_X + (1-\lambda)\mathcal{U}_Y$, and the weaker condition $\mathcal{U}_{\lambda X+(1-\lambda)Y} \subseteq \mathcal{U}_X \cup \mathcal{U}_Y$, see [7], and we also introduce a cone-based construction. We then characterize the largest class of uncertainty sets generating a given robust risk measure and study when robustification preserves monotonicity, (quasi)convexity, law invariance, and continuity from above. Next, we derive dual representations for robust quasi-convex risk measures, recovering the classical convex cash-additive case as a special instance. Finally, using the acceptance-family framework of [2], we relate the acceptance families of ρ and $\tilde{\rho}$, and extend the analysis to capital allocation, with examples based on Wasserstein and p-norm uncertainty sets.

Keywords: Robust risk measures · Quasi-convexity · Cash-subadditivity · Model uncertainty · Dual representation · Acceptance families.

Contributed Session

CS110: Risk measures: static and dynamic aspects organized by Emanuela Rosazza Gianin and Elisa Mastrogiacomo

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⋆ Presenter

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Large field problem in coercive singular PDEs

Ilya Chevyrev[1⋆] and Massimiliano Gubinelli[2]

[1] Mathematics Area, SISSA, Italy,
ichevyrev@gmail.com
[2] Mathematical Institute, University of Oxford, United Kingdom
gubinelli@maths.ox.ac.uk

We derive a priori estimates for singular differential equations of the form

$$\mathcal{L}\phi = P(\phi, \nabla\phi) + f(\phi, \nabla\phi)\xi$$

where P is a polynomial, f is a sufficiently well-behaved function, and ξ is an irregular distribution such that the equation is subcritical. The differential operator $\mathcal{L}$ is either a derivative in time, in which case we interpret the equation using rough path theory, or a heat operator, in which case we interpret the equation using regularity structures. Our only assumption on P is that solutions with $\xi = 0$ exhibit coercivity. Our estimates are local in space and time, independent of boundary conditions, and generalise the results of [5,2,4,3,6].

Our method is based on rescaling the equation, which differs from the aforementioned works and which makes the role of subcriticality especially transparent. One of our main results is an abstract estimate that allows one to pass from a local coercivity property to a global one using scaling, for a large class of equations. This allows us to reduce the problem of deriving a priori estimates to the case when ξ is small.

This talk is based on the work [1].

Keywords: A priori estimates · regularity structures · rough path theory.

Contributed Session

CS162: Singular stochastic analysis and stochastic quantization organized by Alberto Bonicelli · Francesco De Vecchi

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⋆ Presenter

A semiconcavity approach to stability of entropic plans and exponential convergence of Sinkhorn's algorithm - Part 1

Alberto Chiarini[1], Giovanni Conforti[1], Giacomo Greco[2], and Luca Tamanini[3⋆]

[1] Dipartimento di Matematica "Tullio Levi-Civita", Università degli Studi di Padova,
{chiarini,gconfort}@math.unipd.it
[2] RoMaDS - Dipartimento di Matematica, Università degli Studi di Roma Tor Vergata,
greco@mat.uniroma2.it
[3] Dipartimento di Matematica e Fisica "Niccolò Tartaglia", Università Cattolica del Sacro Cuore
luca.tamanini@unicatt.it

We study stability of optimizers and convergence of Sinkhorn's algorithm for the entropic optimal transport problem. In the special case of the quadratic cost, our stability bounds imply that if one of the two entropic potentials is semiconcave, then the relative entropy between optimal plans is controlled by the squared Wasserstein distance between their marginals. When employed in the analysis of Sinkhorn's algorithm, this result gives a natural sufficient condition for its exponential convergence, which does not require the ground cost to be bounded. By controlling from above the Hessians of Sinkhorn potentials in examples of interest, we obtain new exponential convergence results. For instance, for the first time we obtain exponential convergence for log-concave marginals and quadratic costs for all values of the regularization parameter, based on semiconcavity propagation results. These optimal rates are also established in situations where one of the two marginals does not have subgaussian tails. Other interesting will be presented in this joint-talk.

Keywords: Entropic Optimal Transport · Sinkhorn's algorithm · Entropic stability · Semiconcavity propagation.

Contributed Session
CS121: Advances in entropic optimal transport organized by Giovanni Conforti

⋆ Presenter

A semiconcavity approach to stability of entropic plans and exponential convergence of Sinkhorn's algorithm - Part 2

Alberto Chiarini[1], Giovanni Conforti[1], Giacomo Greco[2⋆], and Luca Tamanini[3]

[1] Dipartimento di Matematica "Tullio Levi-Civita", Università degli Studi di Padova,
{chiarini,gconfort}@math.unipd.it

[2] RoMaDS - Dipartimento di Matematica, Università degli Studi di Roma Tor Vergata,
greco@mat.uniroma2.it

[3] Dipartimento di Matematica e Fisica "Niccolò Tartaglia", Università Cattolica del Sacro Cuore
luca.tamanini@unicatt.it

We study stability of optimizers and convergence of Sinkhorn's algorithm for the entropic optimal transport problem. In the special case of the quadratic cost, our stability bounds imply that if one of the two entropic potentials is semiconcave, then the relative entropy between optimal plans is controlled by the squared Wasserstein distance between their marginals. When employed in the analysis of Sinkhorn's algorithm, this result gives a natural sufficient condition for its exponential convergence, which does not require the ground cost to be bounded. By controlling from above the Hessians of Sinkhorn potentials in examples of interest, we obtain new exponential convergence results. For instance, for the first time we obtain exponential convergence for log-concave marginals and quadratic costs for all values of the regularization parameter, based on semiconcavity propagation results. These optimal rates are also established in situations where one of the two marginals does not have subgaussian tails. Other interesting will be presented in this joint-talk.

Keywords: Entropic Optimal Transport · Sinkhorn's algorithm · Entropic stability · Semiconcavity propagation.

Contributed Session
CS121: Advances in entropic optimal transport organized by Giovanni Conforti

⋆ Presenter

Fluctuations of the Simple Exclusion Process on Point Processes

Alberto Chiarini[1*] and Alessandra Faggionato[2]

[1] Department of Mathematics, Università degli Studi di Padova, Italy,
chiarini@math.unipd.it
[2] Department of Mathematics, Università di Roma La Sapienza, Italy
afaggiona@mat.uniroma1.it

The simple exclusion process is one of the most prominent models of interacting particle systems. In this seminar, we consider a resistor network whose nodes are sampled according to a simple point process on $\mathbb{R}^d$ and are connected by certain random conductances. On top of this resistor network, particles move according to random walks with the rule that there is at most one particle per site. Under soft assumptions on the point process measure and conductances, which include ergodicity, stationarity and certain moment conditions, it is known that the empirical density of particles converges for almost all realisation of the environment to the solution of an heat equation with a certain homogenised diffusivity. In this talk, we examine its equilibrium fluctuations. For $d \geq 3$, under the same assumptions that ensure the hydrodynamical limit, we show that the empirical density fluctuation field converges for almost all realisation of the environment, in the sense of finite-dimensional distributions, to a generalised Ornstein-Uhlenbeck process. For $d = 2$, if we require some additional regularity on the environment to have Hölder regularity estimates for solutions to parabolic problems, we can show that the same conclusion holds. T jo

Keywords: Stochastic Homogenization · Interacting Particle Systems · Random environment.

Contributed Session
CS178: Disordered systems in statistical mechanics organized by Alberto Chiarini

* Presenter

Solidification estimates for random walks on supercritical percolation clusters

Alberto Chiarini[1], Zhizhou Liu[2⋆], and Maximilian Nitzschner[2]

[1] Department of Mathematics "Tullio Levi-Civita", Università degli Studi di Padova, Italy
chiarini@math.unipd.it
[2] Department of Mathematics, The Hong Kong University of Science and Technology, Hong Kong
zliugm@connect.ust.hk, mnitzschner@ust.hk

We consider the simple random walk on the infinite cluster of a general class of percolation models on $\mathbb{Z}^d$, $d \geq 3$, including Bernoulli percolation as well as models with strong, algebraically decaying correlations. For almost every realization of the percolation configuration, we obtain uniform controls on the absorption probability of a random walk by certain "porous interfaces" surrounding the discrete blow-up of a compact set A. These controls substantially generalize previous results obtained in [1] for Brownian motion in $\mathbb{R}^d$ and in [2] for random walks on $\mathbb{Z}^d$ equipped with uniformly elliptic edge weights to a manifestly non-elliptic framework. This talk is based on the recent work [3] and an ongoing project.

Keywords: Solidification estimates · random walk · percolation · capacity.

Contributed Session
CS178: Disordered systems in statistical mechanics organized by Alberto Chiarini

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⋆ Presenter

Adaptive denoising diffusion modelling via random time reversal

Sören Christensen[1], Jan Kallsen[1], Claudia Strauch[2], and Lukas Trottner[3*]

[1] Department of Mathematics, Kiel University, Kiel, Germany
{christensen,kallsen}@math.uni-kiel.de
[2] Institute of Mathematics, Heidelberg University, Heidelberg, Germany
strauch@math.uni-heidelberg.de
[3] Department of Mathematics, University of Stuttgart, Stuttgart, Germany
lukas.trottner@isa.uni-stuttgart.de

We introduce a new class of generative diusion models that, unlike conventional denoising diusion models, achieve a time-homogeneous structure for both the noising and denoising processes, allowing the number of steps to adaptively adjust based on the noise level. This is accomplished by conditioning the forward process using Doob's h-transform, which terminates the process at a suitable sampling distribution at a random time. The model is particularly well suited for generating data with lower intrinsic dimensions, as the termination criterion simplifies to a first hitting rule. A key feature of the model is its adaptability to the target data, enabling a variety of downstream tasks using a pre-trained unconditional generative model. We highlight this point by demonstrating how our generative model may be used as an unsupervised learning algorithm: in high dimensions the model outputs with high probability the metric projection of a noisy observation y of some latent data point x onto the lower-dimensional support of the data—which we don't assume to be analytically accessible but to be only represented by the unlabeled training data set of the generative model.

Keywords: denoising diffusion models · manifold learning · score matching

Contributed Session
CS142: Diffusion Processes in Machine Learning organized by Francesco Iafrate and Alessandro de Gregorio

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* Presenter

Reinsurance games through quantile-constrained Choquet-Wasserstein approximations

Andrea Cinfrignini[1], Silvia Lorenzini[2]⋆, Davide Petturiti[3], and Barbara Vantaggi[3]

[1] Dept. Economics and Statistics, University of Siena, Siena, Italy
andrea.cinfrignini@unisi.it
[2] Dept. Economics, University of Perugia, Perugia, Italy
silvia.lorenzini@dottorandi.unipg.it
[3] Dept. MEMOTEF, Sapienza University of Rome, Rome, Italy
{davide.petturiti,barbara.vantaggi}@uniroma1.it

The Dempster-Shafer theory [3,6] is a well-known mathematical framework for modeling situations involving incomplete or partially specified information, that generalizes classical probability theory through completely monotone normalized capacities, the latter known as belief functions. The theory of probability boxes (or p-boxes for short) [5,8] is a distinguished part of this theory, since natural extensions of p-boxes reveal to be special belief functions, whose properties are given by the positional structure of jumps in the related p-boxes.

Following [2], we consider the problem of approximating an arbitrary belief function with a "closest" p-box natural extension under some constraints. The resulting approximation seeks to preserve the same information of the p-box induced by the initial belief function and to satisfy given upper bounds on the corresponding lower and upper Value-at-Risk (VaR) risk measures, defined as generalized inverse functions [4]. The quoted approximation problem can be faced through a generalization of the classical optimal transport problem and the related Wasserstein distance [7]. Then, the computation of the approximating p-box can be carried out efficiently through a generalization of the Dykstra's algorithm by relying on a proper entropic formulation.

We apply the described approximation on an ambiguous stop-loss reinsurance problem modeled as a Stackelberg game between a reinsurer, who acts as leader, and an insurer, who acts as follower. More precisely, the reinsurer's aim is to choose the safety loading to determine the reinsurance premium, while the insurer's aim, inspired by [1], is to choose the retention level that minimizes the lower VaR of his total loss, given by the sum between the retained loss and the optimistic reinsurance premium. In this formulation, we assume that the leader faces two different kinds of ambiguity: a strategic ambiguity on how the follower will respond and an epistemic ambiguity on how the final reward will be evaluated. While the first one reflects a typical Stackelberg-like ambiguity on agent interaction, the second one captures an uncertain external state. This double notion of ambiguity results in four distinct bilevel optimization problems, corresponding to all combinations of optimism or pessimism on both dimensions.

Keywords: Belief functions · Stop-loss reinsurance · Stackelberg game.

Contributed Session

CS181: Approaches to Uncertainty and Information Measures organized by Andrea Capotorti and Silvia Lorenzini

⋆ Presenter

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Multidimensional random motions with a natural number of velocities

Fabrizio Cinque

Department of Statistical Sciences, Sapienza University of Rome, Italy,
cinque.fabrizio@gmail.com

We discuss about random motions moving in higher spaces with a natural number of velocities (also known as telegraph processes, continuous time random walks or run-and-tumble processes). In the case of the so-called minimal random dynamics, under some broad assumptions, we establish an affine relationship between motions moving with different directions and we derive the joint distribution of the position of the motion (for both the inner part and the boundary of the support) and the number of displacements performed with each velocity. Explicit results for cyclic and complete motions are presented as particular cases.
We also study some useful relationships between motions moving in different spaces, and we obtain the form of the distribution of the movements in arbitrary dimension.
Finally,we present further results concerning the distribution over the singularities of the support of motions governed by non-homogeneous Poisson processes.

Keywords: Motions in higher space · telegraph process

Contributed Session
CS151: Stochastic Models and Random Perturbations organized by Verdiana Mustaro

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Maintaining k-MinHash Signatures over Fully-Dynamic Data Streams with Recovery

Andrea Clementi[1], Luciano Gualà[1], Luca Pepè Sciarria[1⋆], and Alessandro Straziota[1]

Department of Enterprise Engineering, University of Rome "Tor Vergata", Italy,
clementi@axp.mat.uniroma2.it gualà@mat.uniroma2.it, luca.pepesciarria@gmail.com
alessandro.straziota@uniroma2.it

We consider the task of performing Jaccard similarity queries over a large collection of items that are dynamically updated according to a streaming input model. An item here is a subset of a large universe U of elements. A well-studied approach to address this important problem in data mining is to design *fast-similarity data sketches*. In this paper, we focus on *global solutions* for this problem, i.e., a single data structure which is able to answer both *Similarity Estimation* and *All-Candidate Pairs* queries, while also dynamically managing an arbitrary, online sequence of element insertions and deletions received in input.

In this talk we introduce and provide an in-depth analysis of a dynamic, buffered version of the well-known k-min hash sketch. This buffered version better manages critical update operations thus significantly reducing the number of times the sketch needs to be rebuilt from scratch using expensive recovery queries. We prove that the *buffered* k-min hash uses $O(k \log |U|)$ memory words per subset and that its *amortized* update time per insertion/deletion is $O(k \log |U|)$ *with high probability*. Moreover, our data structure can return the k-min hash signature of any subset in $O(k)$ time, and this signature is exactly the same signature that would be computed from scratch (and thus the quality of the signature is the same as the one guaranteed by the static k-min hash).

Analytical and experimental comparisons with the other, state-of-the-art global solutions for this problem given in [Bury et al.,WSDM'18] show that the *buffered* k-min hash turns out to be competitive in a wide and relevant range of the online input parameters.

Keywords: Data Sketches · Dynamic Algorithms · Streaming Algorithms · MinHashing · Probabilistic Analysis of Algorithms · Probabilistic Data Structure and Algorithms

Contributed Session
CS173: Probability for Graph Algorithms organized by Alessandro Straziota and Luca Pepè Sciarria

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⋆ Presenter

Deep Hilbert Galerkin methods for PDEs on Hilbert spaces via derivative-informed operator learning with applications to stochastic optimal control of infinite-dimensional systems

Samuel N. Cohen[1], Filippo de Feo[2], Jackson Hebner[1⋆], and Justin Sirignano[1]

[1] Mathematical Institute, University of Oxford, UK,
cohens,hebner,justin.sirignano@maths.ox.ac.uk
[2] Institut für Mathematik, Technische Universität Berlin, Germany
defeo@math.tu-berlin.de

Our previous research (joint with S. Cohen, F. de Feo, J. Sirignano) shows that Hilbert Neural Operators are able to approximate classical solutions of fully nonlinear second-order partial differential equations on Hilbert spaces, such as Hamilton-Jacobi-Bellman and backwards Kolmogorov equations. Based on this result, we propose two actor-critic algorithms for solving Hilbert-valued HJB equations and two algorithms for solving Hilbert-valued backwards Kolmogorov equations. We then apply these algorithms to the control of the stochastic heat equation, a stochastic delay equation, the stochastic Burgers equation, and a mean-field control problem. To the best of our knowledge, these algorithms are the first methods for solving PDEs directly on their whole Hilbert space domain.

Keywords: Operator learning · stochastic control · Deep Galerkin method.

Contributed Session
CS145: Frontiers in Infinite-Dimensional Stochastic Control: Theory and Applications organized by Filippo de Feo

⋆ Presenter

Universal Approximation of Nonlinear Operators and Their Derivatives

Samuel N. Cohen[1], Filippo de Feo[2⋆], Jackson Hebner[1], and Justin Sirignano[1]

[1] Mathematical Institute, University of Oxford, UK,
[2] Institut für Mathematik, Technische Universität Berlin, Germany

Derivative-Informed Operator Learning (DIOL), i.e. learning a (nonlinear) operator and its derivatives, is an open research frontier at the foundations of the influential field of Operator Learning (OL). In particular, Universal Approximation Theorems (UATs) of nonlinear operators and their derivatives are foundational open questions and delicate problems in nonlinear functional analysis. We prove the first UATs of non-linear k-times differentiable operators between Banach spaces and their derivatives, uniformly on compact sets and in novel weighted Sobolev spaces for general finite input measures, via OL architectures. Our results are the first complete generalizations of the corresponding influential classical results in [Hornik, 1991] to infinite-dimensional spaces and OL. Our weighted Sobolev spaces are a generalization of classical Gaussian Sobolev spaces in [Bogachev, Gaussian Measures].

We discuss several open areas where DIOL and our UATs find applications: high-order accuracy in OL; fast constrained optimization in Banach spaces (e.g. optimal control of PDEs, inverse problems) via Learn-Then-Optimize; numerical methods for infinite-dimensional PDEs (e.g. HJB PDEs from infinite-dimensional optimal control, such as optimal control of PDEs, SPDEs, path-dependent systems, partially observed systems, mean-field control).

We parameterize nonlinear operators via Encoder-Decoder Architectures, classical architecture in OL, which include famous examples such as DeepONets, Deep-H-ONets, PCA-Nets.

Based on
[de Feo arXiv:2605.15285]; [Cohen, de Feo, Hebner, Sirignano, arXiv:2603.19463]

Keywords: Operator learning · stochastic control · Deep Galerkin method.

Contributed Session
CS145: Frontiers in Infinite-Dimensional Stochastic Control: Theory and Applications organized by Filippo de Feo

⋆ Presenter

Strategic Focus or Technological Neutrality? On the Optimal Mix of Green Investment and Carbon Capture and Storage Research in a Budget-Constraint World

Katia Colaneri[1⋆], Alessio D'Amato[2], and Rüdiger Frey[3]

[1] Department of Economics and Finance, University of Rome Tor Vergata, Rome, Italy, katia.colaneri@uniroma2.it
[2] Department of Economic and Legal Studies, University of Naples Parthenope, Naples, Italy, alessio.damato@uniparthenope.it
[3] Institute for Statistics and Mathematics, Vienna University of Economics and Business, Vienna, Italy rfrey@wu.ac.at

Major pathways for carbon abatement include a large-scale deployment of renewable en- ergy sources (RES) and investment in carbon capture and storage (CCS) technologies. While RES such as solar and wind power offer clean, sustainable energy, significantly expanding their share in the energy mix necessitates heavy infrastructure investment. This is primarily due to issues of intermit- tency and the need to upgrade or redesign existing electricity grids to ensure stability and reliability. On the other hand, CCS technologies offer a potential solution to decarbonize existing fossil fuel-based infrastructure. However, CCS remains technologically immature and economically un-viable at large scale. Significant research and development (R&D) efforts are required to reach a breakthrough that would make CCS a competitive option. Given limited fiscal capacity, it may be infeasible for societies to simultaneously invest heavily in RES infrastructure and fund foundational CCS research.
We explores this trade-off by modeling the problem as a stochastic optimization problem. We analyze the optimal allocation of a constrained research and investment budget over time, under uncertainty about technological breakthroughs and deployment costs. We study the problem using theoretical and numerical methods.

Keywords: Abatement technologies, Stochastic optimization, Constraints.

Contributed Session
CS153: Optimal Stopping, Stochastic Control and Stochastic Games II organized by Andrea Bovo and Alessandro Milazzo

⋆ Katia Colaneri

Generalizations of Elastic Brownian Motion

Fausto Colantoni[1]*

Department of Basic and Applied Sciences for Engineering, Sapienza University of Rome, Italy
fausto.colantoni@uniroma1.it

Abstract. In this talk, we present several generalizations of elastic Brownian motion, analyzing three distinct scenarios that extend the process's classical dynamics. First, we consider a model in which the killing rate is governed by an independent continuous-time Markov chain (CTMC), thereby introducing a switching mechanism for the process's extinction. Next, we introduce non-exponential delays at the boundary; this extension leads to the appearance of non-local operators in time (for instance, fractional derivatives and convolution-type operators). Finally, we study the case in which the process, instead of being killed, restarts inside the domain via jumps (stochastic restart). The latter dynamics are described by non-local spatial operators, as boundary conditions, related to the jump distribution. For each case, we discuss the associated PDEs and the connection with non-local operators, describing the stochastic dynamics and potential physical applications.

Keywords: Elastic Brownian Motion · Non-local operators · Continuous Time Markov Chains · Stochastic Restart · Fractional Calculus.

Contributed Session
CS146: Fractional Processes and Non-local Operators (Part 1) organized by Luisa Beghin

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* Presenter

Learning with Neural Networks on Structured Inputs

Elisabetta Cornacchia[1]*

Department of Computing Sciences, Bocconi University, Italy,
elisabetta.cornacchia@unibocconi.it

The success of deep learning in high-dimensional settings is often attributed to low-dimensional structure in real-world data. Many theoretical models assume this structure lies in the target function—mapping otherwise unstructured inputs through a low-dimensional subspace. However, data such as images or text also exhibit strong correlations in the input space itself (e.g., spatial locality). In this talk, we propose a tractable model to study how such spatial correlations affect the sample complexity of learning with gradient descent in shallow neural networks. We further analyze how temporal correlations, relative to the standard i.i.d. training-sample setting, can influence the learnability of certain target functions.

Keywords: Neural networks · Gradient descent · Complexity

Contributed Session
CS180: Mathematics of Neural Networks organized by Stefano Vigogna

* Presenter

Simultaneous global and local clustering in multiplex networks with covariate information

Joshua Corneck[1], Edward A. K. Cohen[1], James S. Martin[1], Lekha Patel[2], Kurtis W. Shuler[2], and Francesco Sanna Passino[1⋆]

[1] Department of Mathematics, Imperial College London, London (United Kingdom)
f.sannapassino@imperial.ac.uk
[2] Sandia National Laboratories, Albuquerque (New Mexico, United States)

Understanding both global and layer-specific group structures is useful for uncovering complex patterns in networks with multiple interaction types. In this work, we introduce a new model, the hierarchical multiplex stochastic blockmodel (HMPSBM), that simultaneously detects communities within individual layers of a multiplex network while inferring a global node clustering across the layers. A stochastic blockmodel is assumed in each layer, with probabilities of layer-level group memberships determined by a node's global group assignment. Our model uses a Bayesian framework, employing a probit stick-breaking process to construct node-specific mixing proportions over a set of shared Griffiths-Engen-McCloskey (GEM) distributions. These proportions determine layer-level community assignment, allowing for an unknown and varying number of groups across layers, while incorporating nodal covariate information to inform the global clustering. We propose a scalable variational inference procedure with parallelisable updates for application to large networks. Extensive simulation studies demonstrate our model's ability to accurately recover both global and layer-level clusters in complicated settings, and applications to real data showcase the model's effectiveness in uncovering interesting latent network structure.

Keywords: community detection · multilayer networks · stochastic blockmodel · variational Bayesian inference.

Contributed Session
CS118: Bayesian nonparametrics for network data organized by Francesco Gaffi

⋆ Presenter

Directed polymer in spatially correlated environment

Francesca Cottini[1]*, Clément Cosco[2], and Anna Donadini[2]

[1] LPSM, Sorbonne Université, France
francesca.cottini@sorbonne-universite.fr
[2] Université Paris Dauphine, France; Università degli Studi di Milano-Bicocca, Italy
cosco@ceremade.dauphine.fr - a.donadini@campus.unimib.it

Directed polymers in random environments describe a perturbation of the simple random walk given by a random disorder (environment). The partition functions of this model have been thoroughly investigated in recent years, also motivated by their link with the solution of the Stochastic Heat Equation. While classical results focus on space-time independent disorder, we consider a Gaussian environment with (critical) spatial correlations decaying as $|x|^{-2}$ times a slowly varying function. We show that a phase transition, analogous to that in the space-time independent case, still occurs: in the high temperature regime the log-partition function satisfies a central limit theorem, while it vanishes in law in the low temperature regime. Remarkably, the inverse temperature needs to be tuned differently from the independent case, where the scaling constant $\hat{\beta}$ emerges from a nontrivial multi-scale dependence in the second moment computation — the core technical challenge of the work.
Based on a joint work with Clément Cosco (Paris Dauphine) and Anna Donadini (Milano-Bicocca).

Keywords: Directed Polymer in Random Environment · Critical space-correlation · Bessel functions · Central Limit Theorem · Disordered Systems.

Contributed Session
CS131: Directed Polymers and Stochastic Heat Flow organized by Francesca Cottini

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* Presenter

A probabilistic approach for optimal stopping mean-field games

Andrea Cosso[1⋆], Laura D'Andolfi[2], and Roxana Dumitrescu[2]

[1] Department of Mathematics, University of Milan, Italy
[2] CREST, ENSAE, Institut Polytechnique de Paris, Palaiseau, France

We propose a probabilistic formulation of optimal-stopping mean field games by introducing a new class of BSDEs, termed McKean-Vlasov reflected backward stochastic differential equations. An equilibrium is characterized by a quadruple (Y, Z, A, L), where L is a $[0, 1]$-valued, non-increasing càdlàg process, representing a randomized stopping strategy. Two additional Skorokhod-type conditions involving the process L enforce the optimality of the stopping rule at equilibrium. We prove the existence of equilibria (Y, Z, A, L) by applying the Kakutani–Fan–Glicksberg fixed-point theorem to a set-valued best-response map; and, under alternative assumptions, we also obtain existence via Tarski's fixed-point theorem. Furthermore, we establish uniqueness under specifc conditions. We also show that the mean field equilibrium induces an approximate Nash equilibrium for the associated N-player stopping game. Finally, we connect our probabilistic formulation to the analytical approach, which is characterized by a system of constrained partial differential equations.

Contributed Session

CS148: "Mean field control and games" organized by Alekos Cecchin and Jodi Dianetti

⋆ Presenter

Stochastic Evolution Inclusions with Nonlocal Initial Conditions

Alessandra Cretarola

Department of Economic Studies
University "G. D'Annunzio" of Chieti-Pescara, Pescara, Italy,
alessandra.cretarola@unich.it

We provide sufficient conditions for the existence of mild solutions to stochastic differential inclusions in infinite-dimensional Hilbert spaces driven by a cylindrical Wiener process. The initial condition is described by a prescribed map depending on the behavior of the solution over the whole time interval. The model includes multivalued terms both in the drift and in the diffusion part. This structure allows us to cover a broad range of applications: multivalued terms can represent uncertainty or measurement errors in the data, as well as constraints arising, for instance, in optimal control problems. Under our assumptions, classical initial conditions, such as periodic and multipoint ones, can be treated within a unified framework by means of a single map. This provides a comprehensive setting capable of encompassing a wide class of problems.

Assuming suitable growth and upper semicontinuity conditions, we prove the existence of at least one mild solution. The analysis is developed within two complementary frameworks, depending on whether the semigroup generated by the linear part is compact or not. When the underlying semigroup is compact, existence follows from the compactness of the associated solution operator. In the non-compact case, relying on preliminary results contained in [1], we adopt a weak-topology approach: compactness is replaced by weak sequential compactness in appropriate Bochner spaces, together with weak closedness of the solution multivalued map. In both frameworks, the argument is completed by applying an appropriate multivalued fixed point theorem.

We also extend our results to the half-line and prove the existence of periodic mild solutions.

The compactness-based approach is well established in the literature (see, e.g., [3]), whereas the weak-topology framework has been less extensively investigated (see, e.g., [7]). Moreover, stochastic differential inclusions have been mainly studied in finite-dimensional settings; we refer to the seminal book [6].

Applications include transport-type stochastic models generated by noncompact shift semigroups, which naturally fit the framework considered here (see e.g. [4] and references therein). This occurs, for example, in models for forward curve dynamics in financial mathematics. The abstract setting also applies to climate change modeling, where nondeterministic differential equations are required to describe rapidly varying phenomena such as cyclones (see, e.g., [5]). In both contexts, periodicity is crucial to capture seasonal effects and recurrent temporal patterns.

The talk is based on [2], a joint work with Irene Benedetti, Lorenzo Guida and Teresa Marino.

Keywords: Stochastic evolution inclusions · Mild solutions · Periodic solutions.

Contributed Session
CS166: SPDEs in Finance organized by Claudio Fontana

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Urn models: interaction, synchronization and generalized reinforcement

Irene Crimaldi[3], Pierre-Yves Louis[1,2*], Ida G. Minelli[4], and Meghdad Mirebrahimi[5]

[1] Université Bourgogne Europe, Institut Agro, INRAE, UMR PAM, F-21000 Dijon, France
pierre-yves.louis@math.cnrs.fr
[2] Université Bourgogne Europe, CNRS, Institut Agro, IMB UMR 5584, 21000 Dijon, France
pierre-yves.louis@institut-agro.fr
[3] IMT School for Advanced Studies Lucca, Piazza San Ponziano 6, 55100 Lucca, Italy
irene.crimaldi@imtlucca.it
[4] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, Via Vetoio, 67100 L'Aquila, Italy
ida.minelli@univaq.it
[5] Department of Mathematics, Faculty of Mathematical Sciences, University of Mazandaran, Babolsar, Iran
meghdad3520@gmail.com

Urn models have found several applications, from adaptive design in medical treatments to random networks and opinion dynamics. Their dynamical evolution is based on reinforced stochastic processes, where the probability of future states depends on the history of the system. In this talk, we review some of the most popular urn models, in particular Pólya's and Friedman's urns, from the perspective of associated stochastic processes and present some recent results about interaction and synchronization.

Using the framework of Stochastic Approximation, we first analyze systems of interacting urns where agents are coupled via mean-field or network-based interactions. We survey conditions under which the interplay between reinforcement and interaction leads to almost sure synchronization of the urn proportions and characterize the fluctuations around the limit.

We then extend this review to more general reinforcement mechanisms. First, we discuss recent results on urn models with random multiple drawing and random addition, where the reinforcement matrix is time-dependent and non-balanced. This framework allows for modeling complex sampled populations or clinical trials. Second, we address the phenomenon of "non-synchronization". We investigate how non-linear reinforcement functions or competing reinforcement rates (individual versus collective reinforcement) can induce phase transitions, leading to the fragmentation of the system into distinct equilibria.

This talk is based on joint works with I. Crimaldi, P. Dai Pra, I. G. Minelli and M. Mirebrahimi.

Keywords: Interacting urns, Reinforced processes, Stochastic approximation, Synchronization, Multidrawing.

Contributed Session
CS177: Stochastic Algorithms and Interacting Reinforced Processes organized by Michele Aleandri and Ida Germana Minelli

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* Presenter

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Zero-noise selection and Large Deviations in $L^\infty_t L^p_x$ for the stochastic transport equation beyond DiPerna-Lions

Gianluca Crippa[1], Eliseo Luongo[2], and Umberto Pappalettera[1] *

[1] Departement Mathematik und Informatik, Universität Basel, Spiegelgasse 1, CH-4051 Basel, Switzerland
{gianluca.crippa,umberto.papplaettera}@unibas.ch
[2] Fakultät für Mathematik, Universität Bielefeld, 33501 Bielefeld, Germany
eluongo@math.uni-bielefeld.de

We consider $L^\infty_t L^p_x$ solutions of the stochastic transport equation with drift in $L^\infty_t W^{1,q}_x$. We show strong existence and pathwise uniqueness of solutions in a regime of parameters p, q for which non-unique weak solutions of the deterministic transport equation exist. When the intensity of the noise goes to zero, we prove that the solutions of the stochastic transport equation converge to the unique renormalized solution of the transport equation in the sense of DiPerna-Lions. Furthermore, we show that the convergence is governed by a Large Deviations Principle in the space $L^\infty_t L^p_x$. Since the space $L^\infty_t L^p_x$ is not separable, the weak convergence approach to Large Deviations by Budhiraja, Dupuis, and Maroulas is not directly applicable.

Keywords: Large Deviations Principle · Stochastic transport equation · Zero-noise selection

Contributed Session
CS137: Stochastic Models in Fluid Dynamics organized by Federico Butori and Yassine Tahraoui

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* Presenter

Fractional Calculus and Gaussian Processes: extensions and alternatives to fractional Brownian motion

Lorenzo Cristofaro

Department of Mathematics, University of Luxembourg,
lorenzo,cristofaro@uni.lu

We introduce new classes of Gaussian processes exhibiting distinct memory characteristics, namely Bernstein processes and Hadamard fractional Brownian motion. By applying fractional operators within a white noise framework, we model a variety of memory behaviors. On the one hand, these constructions yield Gaussian processes with explicit Wiener integral representations; on the other hand, the choice of fractional operators determines specific forms of the integrand functions.

Keywords: Generalized fractional operators · Bernstein functions · Lévy measures · Fractional Brownian motion · Sonine pair · White noise space

Contributed Session
CS 146: Fractional Processes and Non-local Operators (Part 1) organized by Luisa Beghin

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Modeling with neural SPDEs: data-driven Heath-Jarrow-Morton models

Christa Cuchiero[1⋆], Claudio Fontana[2], and Alessandro Gnoatto[3]

[1] Department of Statistics and Operations Research, University of Vienna, Austria
christa.cuchiero@univie.ac.at
[2] Department of Mathematics "Tullio Levi-Civita", University of Padova, Italy
claudio.fontana@unipd.it
[3] Department of Economics, University of Verona, Italy
alessandro.gnoatto@univr.it

Motivated by recent advances in AI inspired generative modeling, we investigate the mathematical foundations and universal approximation properties of neural stochastic partial differential equations (SPDEs) of Heath–Jarrow–Morton (HJM) type, whose coefficients are parameterized by function-valued neural networks.

Building on this framework, we then propose a fully data-driven HJM model for the forward interest rate dynamics. Specifically, we consider dynamics driven by linear functionals of the yield curve, such as a finite collection of representative forward rates, possibly augmented by observable macroeconomic factors whose characteristics can be directly estimated from market data. The volatility structure is parameterized via artificial neural networks, naturally leading to a neural SPDE formulation. The neural network parameters are learned from historical yield curve data, yielding an arbitrage-free and data-driven framework for the generation and prediction of yield curves. We demonstrate the proposed deep learning methodology by reconstructing and forecasting the Euro area yield curves.

Keywords: Neural SPDEs · Heath-Jarrow-Morton models · Generative interest rate modeling

Contributed Session
CS166: SPDEs in Finance organized by Claudio Fontana

⋆ Presenter

A jewel and two dials in the ideal Poisson–Voronoi tessellation

Matteo D'Achille[1⋆]

Institut Élie Cartan de Lorraine, CNRS, Université de Lorraine, F-57070, Metz, France
matteo.d-achille@univ-lorraine.fr

I will discuss limits in low intensity of Poisson–Voronoi tessellations, which we called ideal Poisson–Voronoi tessellations (IPVTs).

In real hyperbolic space of dimension $d \geq 2$, a simple Poissonian description of the cell containing the origin ("jewel") allows us to study the fine properties of all cells of the IPVT, each of which is unbounded with an infinite number of bounded faces and a single point at the ideal boundary.

The Poissonian description of the IPVT remains simple in other cases, such as the Cartesian product of hyperbolic planes equipped with the L^1 metric, where the properties of the cells are different but can be glimpsed thanks to a two-dial type argument.

Keywords: Low intensity · Gromov boundary · ends · deposition model

Contributed Session
CS156: Point processes in the continuum organized by Lorenzo Dello Schiavo and Alexander Zass

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⋆ Presenter

Functional marked self-exciting point process models

Nicoletta D'Angelo[1*], Marco Tarantino[1], Giada Adelfio[1], and Marcello Chiodi[1]

Department of Economics, Business and Statistics, University of Palermo, Italy,
{nicoletta.dangelo,marco.tarantino01,giada.adelfio,marcello.chiodi}@unipa.it

Point processes are stochastic models for discrete events occurring in continuous space, time, or space–time domains. When each event carries an additional attribute, such as earthquake magnitude or burned area, the process is called a marked point process.

Self-exciting point processes represent a natural framework for modeling memory effects in non-Markov stochastic processes, since the occurrence of an event increases the probability of future events through the dependence encoded in the conditional intensity function [4]. In such models, the intensity is typically decomposed into a background component and a triggering component, the latter capturing the temporal persistence and excitation mechanism.

Traditional approaches mainly focus on the spatio-temporal configuration of events, without incorporating additional information. Only recently have models including explanatory variables been developed for the analysis of epidemic phenomena [8], seismicity [2], and crimes [10,5].

At the same time, interest in point processes with functional marks has increased. [7] formalized functional marked point processes (FMPPs), where marks are random elements in a (Polish) function space, such as temporal signals or spatial trajectories. In seismology, for example, each earthquake may be associated with a ground-motion waveform or its spectral representation, both naturally treated as functional covariates.

Motivated by the will of jointly analysing earthquake locations and their waveform characteristics, [6] introduced local inhomogeneous mark-weighted summary statistics to detect spatial dependence in functional marks and proposed a test to identify regions where the random labelling assumption fails. However, this approach implicitly calls for fully specified FMPP models, which remain underdeveloped.

To address this gap, we extend the Epidemic Type Aftershock Sequence (ETAS) model [9] by incorporating functional marks derived from waveform data into the triggering component, thereby enriching the representation of memory effects driving seismic activity. Following [1], waveforms are summarized through Functional Principal Component Analysis (FPCA) scores, which are included as covariates in the triggering term. Estimation is performed via the Forward Predictive Likelihood (FLP) approach [3].

The goal is to assess the presence of local spatial dependence in the functional marks and to evaluate how the inclusion of waveform-based covariates in the triggering part improves the fit to earthquake sequences.

Keywords: stochastic processes · point processes · functional data analysis.

Contributed Session
CS187: Memory effects in Markov and non-Markov stochastic processes organized by Salvatore Micciché

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Mean field games with option to buy information

Bernardo D'Auria[2] and Markus Fischer[1]*

[1] Departimento di Matematica "Tullio Levi-Civita", Università degli Studi di Padova, Italia,
fischer@math.unipd.it

[2] Departimento di Matematica "Tullio Levi-Civita", Università degli Studi di Padova, Italia,
bernardo.dauria@unipd.it

We introduce a class of continuous time finite horizon mean field games where the objective function of the representative player depends on a hidden state, in addition to position, control, and the population distribution. While acting on the position dynamics, the agent has the option to pay for seeing the hidden state. We connect the original formulation of our model with a mean field model of optimal control with discretionary stopping and discuss questions of existence and characterization of solutions. For a class of N-player games with compatible information structure, we show that approximate Nash equilibria can be constructed starting from a solution to the limit model.

Keywords: mean field games · incomplete information · discretionary stopping.

Contributed Session
CS148: Mean Field Control and Games organized by Alekos Cecchin and Jodi Dianetti

* Presenter

Random walks with stochastic resetting in complex networks

G. D'Onofrio[1], T.M. Michelitsch[2], F. Polito[3⋆], and A.P. Riascos[4]

[1] Department of Mathematical Sciences, Politecnico di Torino, 10129 Torino, Italy,
giuseppe.donofrio@polito.it
[2] Sorbonne Université, Institut Jean le Rond d'Alembert, CNRS UMR 7190
michel@lmm.jussieu.fr
[3] Department of Mathematics "G. Peano", University of Torino, 10123 Torino, Italy
federico.polito@unito.it
[4] Departamento de Física, Universidad Nacional de Colombia, Bogotá, Colombia
alperezri@unal.edu.co

We consider a discrete-time Markovian random walk with resets on a connected undirected network. The resets, in which the walker is relocated to randomly chosen nodes, are governed by an independent discrete-time renewal process. Some nodes of the network are target nodes, and we focus on the statistics of first hitting of these nodes. In the non-Markov case of the renewal process, we consider both light- and fat-tailed inter-reset distributions. We derive the propagator matrix in terms of discrete backward recurrence time pdfs and in the light-tailed case we show the existence of a non-equilibrium steady state. In order to tackle the non-Markov scenario, we derive a defective propagator matrix which describes an auxiliary walk characterized by killing the walker as soon as it hits target nodes. This propagator provides the information on the mean first passage statistics to the target nodes. We establish sufficient conditions for ergodicity of the walk under resetting. Furthermore, we discuss a generic resetting mechanism for which the walk is non-ergodic. Finally, we analyze inter-reset time distributions with infinite mean where we focus on the Sibuya case. We apply these results to study the mean first passage times for Markovian and non-Markovian (Sibuya) renewal resetting protocols in realizations of Watts-Strogatz and Barabási–Albert random graphs. We show non trivial behavior of the dependence of the mean first passage time on the proportions of the relocation nodes, target nodes and of the resetting rates. It turns out that, in the large-world case of the Watts-Strogatz graph, the efficiency of a random searcher particularly benefits from the presence of resets.

Keywords: Stochastic resetting · Heavy tails · Sibuya random variable · Hitting time on networks.

Contributed Session
CS146: Fractional Processes and Non-local Operators (Part 1) organized by Luisa Beghin

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⋆ Presenter

Two-factor models via subordination of multiparameter Markov processes

Giuseppe D'Onofrio[1]*, Alessandro Mutti[1], and Patrizia Semeraro[1]

[1] Dipartimento di Scienze Matematiche, Politecnico di Torino, Torino, Italy,
{giuseppe.donofrio, alessandro.mutti, patrizia.semeraro}@polito.it

In this talk, we introduce a class of two-factor models whose construction is based on subordination of multiparameter Markov processes (see [1]). This approach provides a flexible and mathematically tractable framework for generating dependent factors, where both the dependence structure and jump behavior are driven by a common subordinator.

We investigate structural properties of the resulting subordinated processes that are particularly relevant for pricing applications, including their polynomial structure, characteristic function, and integral process representation.

Multi-factor models play a central role in financial mathematics, particularly in applications such as electricity price modeling and short-rate dynamics. In many practical settings, two factors are sufficient to capture the key features of observed market behavior; however, the construction extends straightforwardly to higher dimensions.

The presented results are relevant in financial mathematics, particularly for asset pricing applications; however, their generality also makes them of independent mathematical interest.

Keywords: Multiparameter Markov processes · Time-changed processes · Levy-type processes.

Contributed Session
CS132: Subordinated Markov processes and applications organized by Giovanni Amici

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* Presenter

Additive subordination of multiparameter Markov processes

Giuseppe D'Onofrio[1], Alessandro Mutti[1⋆], and Patrizia Semeraro[1]

Department of Mathematical Sciences, Politecnico di Torino, Italy,
alessandro.mutti@polito.it

Time-inhomogeneous Markov processes are widely used in finance to model asset returns. We propose a construction of time-inhomogeneous Markov processes based on multiparameter stochastic time change ([1]). The approach consists in subordinating a multiparameter Markov process with an independent multivariate additive subordinator. Since additive subordinators generalize Lévy subordinators by allowing non-stationary increments, this model introduces time inhomogeneity while preserving analytical tractability.

We generalize the results in [2] and [3]. By extending Phillips theorem to the multiparameter and time-inhomogeneous setting, we show that the resulting process is a Feller evolution and we characterize its generator. We derive its pseudo-differential representation and show that the associated symbol admits a Lévy–Khintchine representation.

We then focus on a family of analytically tractable multivariate additive subordinators: multivariate Sato subordinators ([4]) with exponential tempered distributions. We characterize multivariate Sato subordinators by characterizing their Lévy measures, and we focus on a specific dependence structure widely used in finance to include correlations in multivariate models. Then, we build a multivariate time-inhomogeneous Markov process using multivariate Sato-subordination. The construction is designed to obtain a multivariate process with the same dependence structure as the factor-based $\rho\alpha$-model in [5]. Our aim is to keep the flexibility of their dependence structure, to have one-dimensional unit time distributions in given classes, and to include time-inhomogeneous increments. Finally, we consider the case of a multiparameter Ornstein–Uhlenbeck process to incorporate mean reversion, which is an important feature in applications such as energy markets.

Keywords: Inhomogeneous subordination · Lévy-type processes · Markov processes · Multiparameter stochastic processes.

Contributed Session
CS132: Subordinated Markov processes and applications organized by Giovanni Amici

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⋆ Presenter

Non-local dynamic boundary conditions for sticky Brownian motions on smooth domains

Mirko D'Ovidio[1*]

Department of Statistics, Sapienza, Italy
mirko.dovidio@uniroma1.it

Sticky diffusion processes on bounded domains can spend finite time (and finite mean time) on the lower-dimensional space given by the boundary. Once the process hits the boundary, then it starts again after a random amount of time. While on the boundary it can stay or move according to dynamics that are different from those in the interior. Such processes may be characterized by a time-derivative appearing in the boundary condition for the governing problem. We use suitable time changes in order to describe fractional sticky conditions and the associated boundary behaviours. We obtain that fractional boundary value problems (involving fractional dynamic boundary conditions) lead to sticky diffusions, strong Markov on the interior, spending an infinite mean time (and finite time) on the boundary. Such a behaviour can be associated with a trap effect from the macroscopic point of view. We provide an example on fractals.

Keywords: Dynamic boundary conditions · Time changes · Brownian motions · Trap domains.

Contributed Session
CS154: Interplay between statistical physics and probabilistic methods: the case of anomalous diffusion organized by Gianni Pagnini and Costantino Ricciuti

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* Presenter

Sticky vertices with energy accumulation

Mirko D'Ovidio[1]*

Department of Statistics, Sapienza, Italy
mirko.dovidio@uniroma1.it

We provide a general model for Brownian motions on metric graphs with interactions. In a general setting, for (sticky) Brownian propagations on edges, our model provides a characterization of lifetimes and holding times on vertices in terms of (jumping) Brownian accumulation of energy associated with that vertices. Propagation and accumulation are given by drifted Brownian motions subjected to non-local (also dynamic) boundary conditions. As the continuous (sticky) process approaches a vertex, then the right-continuous process has a restart (resetting), it jumps randomly away from the zero-level of energy. According with this new energy, the continuous process can start (or not) as a new process in a randomly chosen edge. The model well extends to a higher order of interactions, here we provide a simple case and focus on the analysis of earthquakes.

Keywords: Dynamic boundary value problems · Non-local operators · Metric graphs.

Contributed Session
CS158: Stochastic Processes, PDEs and Networks organized by Fausto Colantoni

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* Presenter

Multi-type logistic branching processes with selection: frequency process and genealogy for large carrying capacities

Marta Dai Pra

Department of Mathematics, Humboldt University Berlin and
Faculty of Technology, University of Bielefeld, Germany,
daimarta@hu-berlin.de

We present a model for growth in a multi-species population. We consider two types evolving as a logistic branching process with mutation, where one of the types has a selective advantage. We first study the frequency of the disadvantageous type and show that, once the population approaches the carrying capacity, its evolution converges to a Gillespie-Wright-Fisher diffusion process. We then study the dynamics backward in time: we fix a time horizon at which the population is at carrying capacity and we study the ancestral relations of a sample of individuals. We prove that, provided that the advantageous and disadvantageous branching measures are ordered, this ancestral line process converges to the moment dual of the limiting diffusion. This talk is based on joint work with Julian Kern.

Keywords: logistic branching process · Wright–Fisher diffusion · scaling limits of interacting populations.

Contributed Session
CS189: Stochastic population dynamics organized by Dario Spanó and Martina Favero

Mean-Field Control Approach to Deep Learning

Samuel Daudin[1]

Université Paris Cité, Laboratoire Jacques-Louis Lions,
samuel.daudin@u-paris.fr

In this talk I will explain how the training phase of certain deep neural networks can modeled, in some asymptotic regimes, as a mean-field optimal control problem. I will then explain how this view point allows to address uniqueness and stability properties of the optimal distribution of parameters and what can be said regarding the associated gradient descent. This is based on joint works with F. Delarue.

Keywords: Mean-Field Control · Deep Learning · Gradient Descent.

Contributed Session
CS148: Mean Field Control and Games organized by Alekos Cecchin and Jodi Dianetti

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Diameter in preferential attachment models with random initial degrees

Carlo De Ambroggio[1⋆], Federico Polito[1], Laura Sacerdote[1], and Tamas Makai[2]

[1] Department of Mathematics Giuseppe Peano, University of Turin, Italy,
{carlo.deambroggio, federico.polito, laura.sacerdote}@unito.it
[2] Department of Mathematics, Ludwig Maximilians University, Munich, Germany
makai@math.lmu.it

Let $\{X_t\}_{t\geq 1}$ an i.i.d. sequence of random variables having a power law distribution with parameter $\alpha \in (2,3)$, and consider the random graph process $\{G(t)\}_{t\geq 1}$ built as follow: at each time step a new vertex is added to the graph with initial degree X_t, and then is attached to the older vertices of the graph following a preferential attachment rule. In this context we show that depending on the support of the random out-degree (whether is 1 or ≥ 2) the resulting graph is a small-world or an ultra-small world, namely it has diameter which is of the order of $C \log t$ or $C \log \log t$ for C some constant. This extends the results for the classical preferential attachment model to the one with random initial degrees (the so-called PARID).

Keywords: Random graphs · Preferential attachment · Random structures

Contributed Session
CS175: Global and local topological properties of random graphs organized by Carlo De Ambroggio

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⋆ Presenter

Mean-field control of heterogeneous systems

Anna De Crescenzo[1⋆], Filippo de Feo[2], Marco Fuhrman[3], Idris Kharroubi[4], and Huyên Pham[5]

[1] ETH Zürich
anna.decrescenzo@math.ethz.ch
[2] TU Berlin
defeo@math.tu-berlin.de
[3] University of Milan
marco.fuhrman@unimi.it
[4] LPSM, Sorbonne University
idris.kharroubi@upmc.fr
[5] École Polytechnique
huyen.pham@polytechnique.edu

We study the optimal control of mean-field systems with heterogeneous and asymmetric interactions. This leads to considering a family of controlled Brownian diffusion processes with dynamics depending on the whole collection of marginal probability laws. We prove the well-posedness of such systems and define the control problem together with its related value function. Leveraging tools tailored for this framework, such as derivatives along flows of measures and associated Itô calculus, we establish that the value function for this control problem satisfies a Bellman dynamic programming equation in a L^2-set of Wasserstein space-valued functions. To illustrate the applicability of our approach, we present a linear-quadratic graphon model with analytical solutions, and apply it to a systemic risk example involving heterogeneous banks.

Keywords: Heterogeneous interaction · Mean-field control · LQ mean-field control.

Contributed Session
CS135: Stochastic Systems, Mean-Field Models, and Control organized by Fulvia Confortola and Giuseppina Guatteri

⋆ Presenter

Second Quantization and Evolution Operators in infinite dimension

Paolo De Fazio* and Davide Addona[1]

Dipartimento di Scienze Matematiche Fisiche e Informatiche, Università degli Studi di Parma, Italy,
davide.addona@unipr.it

In an infinite dimensional separable Hilbert space X, we study compactness properties and the hypercontractivity of the Ornstein-Uhlenbeck evolution operators $P_{s,t}$ in the spaces $L^p(X, \gamma_t)$, $\{\gamma_t\}_{t \in R}$ being a suitable evolution system of measures for $P_{s,t}$. Moreover, we study the asymptotic behavior of $P_{s,t}$. Our results are produced thanks to a representation formula for $P_{s,t}$ through the second quantization operator. Among the examples, we consider the transition evolution operator associated to a non-autonomous stochastic parabolic PDE.

Keywords: Evolution Operators · Second Quantization · Infinite Dimensional Analysis · Hypercontractivity Property · Asymptotic Behavior.

Contributed Session
CS124: Infinite Dimensional Analysis and Malliavin Calculus organized by Davide Addona

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* Presenter

Stochastic solutions to abstract telegraph-type equations involving fractional dynamics

Alessandro De Gregorio

Department of Statistical Sciences, Sapienza University of Rome, Italy,
alessandro.degregorio@uniroma1.it

In this talk we investigate abstract integro-differential hyperbolic equations, focusing on the probabilistic representation of their solutions. Our analysis is based on fractional derivatives and non-local operators, which are powerful tools for modeling anomalous behavior and non-Markovian dynamics observed in various phenomena.

We first analyze a time-fractional version of the abstract telegraph equation (involving the Caputo derivative), restricting our analysis to positive self-adjoint operators to leverage spectral theory, which includes key operators in applications, such as the fractional Laplace operator. We derive analytical representations for the solution and provide a stochastic solution to the telegraph-diffusion equation for a specific range of the fractional parameter α, thereby generalizing existing results.

Furthermore, we consider the abstract Euler-Poisson-Darboux (EPD) equation, characterized by a singular time coefficient. We demonstrate that the stochastic solution to this EPD equation can be represented in terms of the solution to the abstract wave equation. Crucially, we prove that the solution to the EPD equation admits a representation by means of the Erdelyi-Kober fractional integral.

Finally, this work provides a comprehensive analysis of both time-fractional and singular-coefficient abstract telegraph-type equations, offering new analytical and stochastic representation formulas.

Keywords: Fractional derivative · Euler-Poisson-Darboux equation · Random time change

Contributed Session
CS141: Fractional Processes and Non-local Operators (Part 2) organized by Federico Polito

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The infimal convolution structure of the Hellinger–Kantorovich distance

Nicolò De Ponti[1], Giacomo Enrico Sodini[2], and Luca Tamanini[3⋆]

[1] Dipartimento di Matematica, Politecnico di Milano, Italy,
nicolo.deponti@polimi.it
[2] Institute of Analysis and Scientific Computing, TU Wien, Austria,
giacomo.sodini@tuwien.ac.at
[3] Dipartimento di Matematica e Fisica "Niccolò Tartaglia", Università Cattolica del Sacro Cuore, Italy
luca.tamanini@unicatt.it

It has been conjectured by Liero, Mielke, and Savaré that the Hellinger–Kantorovich distance can be expressed as the metric infimal convolution of the Hellinger and the Wasserstein distances. This statement is quite clear, at least intuitively, if one compares the dynamical representations of the three distances. However, no rigorous proof had yet been provided. We first discuss the infimal convolution between two generic distances, highlighting the difficulties that may arise: in particular, finiteness and triangle inequality may fail. We then sketch the proof of the main result. To prove it, we study with the tools of Unbalanced Optimal Transport the so-called Marginal Entropy-Transport problem that arises as a single minimization step in the definition of infimal convolution. This is a joint work with Nicolò De Ponti and Giacomo Enrico Sodini.

Keywords: Unbalanced Optimal Transport · Hellinger–Kantorovich distance · infimal convolution.

Contributed Session
CS128: (Stochastic) Analysis on Spaces of Probability Measures and Applications organized by Mattia Martini and Giacomo Enrico Sodini

⋆ Presenter

The forward-backward approach to interacting fermionic states on the lattice

Francesco De Vecchi[1], Luca Fresta[2⋆], and Massimiliano Gubinelli[3]

[1] Department of Mathematics and Physics, University of Roma Tre, Rome, Italy,
luca.fresta@uniroma3.it
[2] Department of Mathematics, University of Pavia, Pavia, Italy
francescocarlo.devecchi@unipv.it
[3] Mathematical Institute, University of Oxford, Oxford, UK
gubinelli@maths.ox.ac.uk

I will review the forward-backward stochastic differential equation (FBSDE) approach to the stochastic quantisation of Grassmann measures. This framework allows for the construction of families of weakly coupled super-renormalisable Euclidean fermionic field theories and the study of their correlations. Building on these ideas, I will also consider the extension to many-body interacting states on the lattice, where similar stochastic methods can be applied to construct the corresponding Grassmann measures and study relevant observables. Our preliminary results indicate that the FBSDE formulation provides a flexible and alternative tool for the analysis of interacting fermionic states.

Keywords: Euclidean field theory · Stochastic quantisation · Non-commutative probability

Contributed Session

CS162: Singular stochastic analysis and stochastic quantization organized by Francesco Carlo De Vecchi and Alberto Bonicelli

⋆ Presenter

On the uniqueness of reversible invariant measures for SPDEs on the full space

Francesco Carlo De Vecchi[1⋆], Davide Augusto Bignamini[2], and Carlo Orrieri[3]

[1] Dipartimento di Matematica, Università degli studi di Pavia, Pavia, Italy,
francescocarlo.devecchi@unipv.it
[2] Dipartimento di Scienza e alta Tecnologia, Università degli studi dell'Insubria, Como, Italy
da.bignamini@uninsubria.it
[3] Dipartimento di Matematica, Università degli studi di Pavia, Pavia, Italy, carlo.orrieri@unipv.it

In this talk, we address the existence and uniqueness of invariant and reversible measures for a class of stochastic partial differential equations (SPDEs) posed on the full space $\mathbb{R}$, and more generally on $\mathbb{R}^n$. In this setting, the standard approach to proving uniqueness and ergodicity of invariant measures, which is based on establishing the strong Feller or asymptotic strong Feller property of the associated Markov semigroup, typically fails.
To overcome this difficulty, we propose a different strategy. We show that any reversible measure for a (sufficiently regular) SPDE on $\mathbb{R}$ must be a Gibbs measure satisfying suitable Dobrushin–Lanford–Ruelle (DLR) equations. Whenever these equations admit a unique solution, it follows that the SPDE admits a unique reversible invariant measure, which is ergodic.

Keywords: Stochastic partial differential equations · Invariant and ergodic measures · Gibbs measures on infinite dimensional spaces

Contributed Session

CS115: Stochastic partial differential equations and invariant measures organized by Davide Augusto Bignamini

⋆ Presenter

Approximation of first passage times and hitting times for stochastic differential equations

Madalina Deaconu[1⋆], Samuel Herrmann[2], and Cristina Zucca[3]

[1] Université de Lorraine, CNRS, Inria, IECL, F-54000 Nancy, France,
madalina.deaconu@inria.fr
[2] Université Bourgogne Europe, CNRS, IMB UMR 5584, 21000 Dijon, France
Samuel.Herrmann@ube.fr
[3] Department of Mathematics, University of Turin, Via Carlo Alberto, 10, Torino, 10123, Italy
cristina.zucca@unito.it

The study and approximation of first-passage and hitting times for stochastic processes play a central role in numerous applied fields, as for example in geophysics and finance. We will introduce some techniques allowing to approximate these hitting times without using a time-splitting procedure like the Euler scheme. The idea is to construct non-linear boundaries for which we are able to obtain the explicit form of the distribution of the hitting time. Combining this with the connexion between the Bessel process and the Brownian motion will permit to construct a generic algorithm for both the hitting time (or first passage time) and the corresponding position of the process. These results apply well in some particular cases as we can obtain a path approximation for Bessel processes and some classes of stochastic differential equations. This procedure constructs jointly the sequences of exit times and corresponding exit positions of some well chosen domains.

The talk will develop also some new results on the inverse first passage time problem which seeks to determine the boundary corresponding to a given stochastic process and a fixed first passage time distribution. We consider the case of Bessel process and also more general diffusions. Bessel processes are particularly valuable in our study due to the availability of explicit solutions to the direct hitting time problem [3]. These known solutions provide a reliable benchmark for validating numerical methods developed for the inverse problem.

Furthermore, we obtain convergence results and present numerical simulations that permit to illustrate the efficiency and accuracy of these methods.

Keywords: Hitting times · First passage time · Inverse problem.

Contributed Session
CS138: First Passage Times: theory and simulations organized by Serena Spina and Cristina Zucca

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⋆ Presenter

Symmetries of SDEs: from invariance properties to integration by parts formulas

Susanna Dehò[1*], Francesco C. de Vecchi[2], Paola Morando[3], and Stefania Ugolini[4]

[1] Department of Mathematics, University of Milan, Italy,
susanna.deho@unimi.it
[2] Department of Mathematics, University of Pavia, Italy
francescocarlo.devecchi@unipv.it
[3] Department of Agricultural and Environmental Sciences, University of Milan, Italy
paola.morando@unimi.it
[4] Department of Mathematics, University of Milan, Italy
stefania.ugolini@unimi.it

The study of symmetries in differential equations, pioneered by Sophus Lie, constitutes a fundamental geometric approach to understand the invariance properties governing a dynamical system. By identifying the groups of transformations that preserve the equation's structure, this framework provides systematic tools for order reduction, the construction of exact solutions, and the simplification of complex problems. Although symmetry analysis stands as a classical pillar for deterministic differential equations (ODEs and PDEs), supported by extensive literature, its extension to Stochastic Differential Equations (SDEs) represents a relatively recent field of research.

Recent literature has also highlighted significant connections with the symmetries of the associated Fokker-Planck or Kolmogorov equations. Furthermore, the application of Lie symmetry theory to SDEs enables the derivation of integration by parts formulas inspired by Bismut's variational approach to Malliavin calculus, with notable applications to the analysis of the law and regularity of the processes, as well as to the development of a stochastic calculus of variations.

In this talk, we will discuss various notions of symmetry for SDEs, highlighting their connections to established invariance properties of well-known stochastic models. We will analyze how a geometric approach, inspired by Lie's deterministic framework, enables the development of powerful computational tools for symmetry calculation. Subsequently, we will demonstrate how applying this geometric theory allows for the constructive derivation of an integration by parts formula for SDEs. Finally, we will show how this integration by parts formula acts as a generating identity for well-known probability formulas, and discuss its connections to Stein's identities.

This contribution is based on a joint work with F.C. De Vecchi, P. Morando and S. Ugolini.

Keywords: Lie symmetry analysis of SDEs · Invariance properties · Integration by parts formula and Stein identities.

Contributed Session
CS191: Selected Topics in Probability and Statistics organized by Andrea Simonetti

* Presenter

On the Ryll-Nardzewski Theorem for Quantum Stochastic Processes

Simone Del Vecchio[1]

Dipartimento di Matematica, Università di Bari Aldo Moro, Italia,
simone.delvecchio@uniba.it

In Classical Probability, a sequence of random variables is said to be exchangeable if its joint distributions are invariant under all finite permutations. Ryll-Nardzeski's Theorem establishes that exchangeability is the same as spreadability, the a priori weaker symmetry where all subsequences of the given sequence have the same joint distributions.

In the non-commutative setting, it is known that the two symmetries no longer coincide for general quantum stochastic processes. We show that under very natural hypothesis there is an extension of the Ryll-Nardzewski Theorem in the noncommutative setting which covers a wide variety of models. Furthermore we obtain an extended De Finetti's Theorem for various models including processes based on the CAR algebra, processes based on the infinite noncommutative torus and on parafermion algebras.

This talk is based on joint work with Valeriano Aiello and Stefano Rossi.

Contributed Session
CS159: "Probabilistic approach to quantum mechanics" organized by Federico Girotti and Anderson Melchor Hernandez

Massive particle systems, Wasserstein Brownian motions, and the Dean–Kawasaki equation

Lorenzo Dello Schiavo[1]*

Department of Mathematics, Università degli Studi di Roma "Tor Vergata",
delloschiavo@mat.uniroma2.it

Let W be a conservative, ergodic Markov diffusion on some arbitrary state space M, converging exponentially fast to equilibrium. We consider:

(1) Systems of up to countably many massive particles in M, with finite total mass. Each particle is subject to an independent instance of the noise W, with volatility the inverse mass carried by the particle. We prove that the corresponding infinite system of SDEs has a unique solution, for every starting configuration and every distribution of the masses in the infinite simplex.
(2) Solutions to the Dean–Kawasaki SPDE with singular drift, driven by the generator L of W. We prove that the equation may be given rigorous meaning on M, and that it has a unique 'distributional' solution. This extends Konarovskyi–Lehmann–von Renesse's 'ill-posedness vs. triviality' [2,3] to the case of infinitely many massive particles.
(3) Diffusions with values in the space $\mathscr{P}$ of all probability measures on M, driven by the geometry induced by L.
(4) In the case when M is a manifold, differential-geometric and metric-measure Brownian motions on $\mathscr{P}$ induced by the geometry of optimal transportation and reversible for a normalized completely random measure. We show that all these objects coincide.

Based on [1,4].

Keywords: interacting particle system · Wasserstein space · Dean–Kawasaki equation

Contributed Session
CS121: Advances in entropic optimal transport organized by Giovanni Conforti

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Spectral and Geometric Phase Transitions in Deep Neural Networks

Simmaco Di Lillo

Department of Mathematics, University of Rome Tor Vergata, Italy,
dilillo@mat.uniroma2.it

In the infinite-width limit, deep neural networks induce isotropic Gaussian fields whose covariance structure encodes fundamental information about the network architecture and the choice of activation function.

In this talk, I present a unified theoretical framework, based on three recent works, which reveals a robust three-regime classification that consistently emerges across spectral and geometric descriptors of random networks.

In the first work [3], we introduce the notion of spectral complexity and classify activation functions into three distinct regimes, namely sparse, low-disorder, and high-disorder, according to the asymptotic behavior of the angular power spectrum of the limiting field. This classification reveals deep structural differences in network expressivity, with sparsity emerging prominently in deep ReLU architectures.

In the second work [2], we study the geometry of level set boundaries. For non-smooth activations (e.g., Heaviside), the boundaries exhibit fractal behavior, with Hausdorff dimension increasing with depth. For smoother activations, the boundary volume follows one of three distinct trends, namely contraction, stability, or exponential growth, precisely mirroring the regimes identified at the spectral level.

In the third work [1], we analyze the distribution of critical points of the limiting fields. Under suitable regularity assumptions, we derive asymptotic formulas for the expected number of critical points (at fixed index or above a given threshold), revealing once more the same universal trichotomy: convergence, polynomial growth, or exponential proliferation, depending on the local behavior of the covariance kernel.

We show that this trichotomy is universal and governed by the local behavior of the covariance kernel near its fixed points.

Keywords: Gaussian random fields · spectral asymptotics · random geometry · deep neural networks

Contributed Session

CS116: Neural Networks and Gaussian Processes: Perspectives from Young Researchers organized by Claudio Macci

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Efficient computation and estimation of generalized cumulants via complementary set partitions

Elvira Di Nardo

Department of Mathematics, University of Turin, Italy,
elvira.dinardo@unito.it

Generalized cumulants provide a powerful framework for the analysis of non-linear statistical quantities, playing a central role in problems involving ratios of quadratic forms, saddlepoint approximations, likelihood expansions, and bootstrap procedures. They naturally arise as intermediate objects between joint moments and joint cumulants, allowing one to express the cumulants of polynomial functions of random variables in a systematic way [2]. Despite their theoretical relevance and wide range of applications, generalized cumulants remain underused in practice. The main obstacle is the severe computational burden associated with their evaluation, which relies on the enumeration of a specific class of set partitions known as complementary set partitions [3].

In practice, the lack of efficient computational tools has led to a widespread reliance on precomputed tables of complementary set partitions, most notably those reported in McCullagh's monograph [4]. While these tables remain a fundamental reference, they are necessarily incomplete and become impractical to extend as the order increases. Existing computational approaches are mostly graph-theoretic or algebraic in nature and are typically confined to symbolic software, severely limiting their accessibility in widely used numerical environments such as `R`.

This work addresses these limitations by introducing a novel combinatorial and algorithmic approach for the efficient computation of complementary set partitions. The proposed method is based on two-block partitions and avoids the traditional use of connected graphs, Laplacian matrices, or symbolic algebra. By exploiting simple combinatorial constructions, the algorithm identifies all non-complementary partitions and recovers the complementary ones by set difference. This strategy leads to a procedure that is both conceptually simple and computationally scalable. A new implementation in `R` is developed, filling a gap in the available software landscape. Since alternative methods are not currently implemented in `R`, computational comparisons are carried out in Maple, where the proposed algorithm consistently outperforms existing techniques in terms of execution time.

From a theoretical perspective, we extend the classical definition of generalized cumulants to include more complex dependence structures. This extension is formulated using multiset subdivisions and multi-index partitions, which provide a natural framework for handling powers of random variables. Within this setting, generalized multivariate cumulants are defined as intermediate quantities between multivariate moments and multivariate cumulants, and explicit closed-form expressions are derived in terms of products of multivariate cumulants.

Finally, we propose a novel approach to the unbiased estimation of generalized cumulants. Building on the theory of k-statistics and multivariate polykays [1], the proposed estimators exploit dummy variables, labeling rules, and tailored transformations between multi-index partitions and set partitions. This strategy substantially reduces computational complexity compared to traditional plug-in or symbolic methods, making the practical use of generalized cumulants feasible in high-dimensional statistical applications.

Keywords: Generalized cumulants · k-statistics · complementary set partitions.

Elvira Di Nardo

Contributed Session

CS103: Moments, Cumulants and dependence: Classical and Modern Perspectives organized by Elvira Di Nardo

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Stochastic diffuse interface models driven by conservative noise

Andrea Di Primio[1⋆], Maurizio Grasselli[2], and Luca Scarpa[2]

[1] Classe di Scienze, Scuola Normale Superiore, Pisa, Italy,
andrea.diprimio@sns.it
[2] Dipartimento di Matematica, Politecnico di Milano, Milano, Italy
{maurizio.grasselli, luca.scarpa}@polimi.it

In this talk, we deal with a class of stochastic diffuse interface models driven by conservative noise. More precisely, we introduce the Cahn–Hilliard and the conserved Allen–Cahn equations with logarithmic type potential and conservative noise in a periodic domain. These features ensure on one hand that the order parameter takes its values in the physical range and, on the other, albeit the stochastic nature of the problems, that the total mass is conserved almost surely in time. Existence and uniqueness of probabilistically-strong solutions is discussed, highlighting the key technical points arising from the structure of the noise. Further directions of research will also be presented.

Keywords: Cahn–Hilliard equations · Allen–Cahn equations · Flory–Huggins potential · stochastic flows · conservative noise.
Contributed Session
CS104: SPDEs for physical models organized by Margherita Zanella and Benedetta Ferrario

⋆ Presenter

Existence, uniqueness and asymptotic stability of invariant measures for the stochastic Allen–Cahn–Navier–Stokes system with singular potential.

Margherita Zanella[1⋆], Andrea di Primio[2], and Luca Scarpa[2]

[1] Department of Mathematics, Milano, Politecnico di Milano, Italy,
`margherita.zanella@polimi.it`
[2] Department of Mathematics, Scuola Normale Superiore, Pisa, Italy
`andrea.diprimio@sns.it`
[3] Department of Mathematics, Milano, Politecnico di Milano, Italy,
`luca.scarpa@polimi.it`

In this talk we present the study of the long-time behaviour of a stochastic Allen-Cahn-Navier-Stokes system. The model features two stochastic forcings, one on the velocity in the Navier-Stokes equation and one on the phase variable in the Allen-Cahn equation, and includes the thermodynamically-relevant Flory-Huggins logarithmic potential. We first show existence of ergodic invariant measures. Secondly, we prove that if the noise acting in the Navier-Stokes equation is non-degenerate along a sufficiently large number of low modes, and the Allen-Cahn equation is highly dissipative, then the stochastic flow admits a unique invariant measure which is asymptotically stable with respect to a suitable Wasserstein metric. The talk is based on a joint work with A. Di Primio and L. Scarpa.

Keywords: Stochastic Allen-Cahn-Navier-Stokes system · singular potential · invariant measures · ergodicity · asymptotic stability · Foias-Prodi estimates.

Contributed Session
CS115: Stochastic partial differential equations and invariant measures organized by Davide Bignamini

⋆ Presenter

Hydrodynamic limits of exploration processes on large random graphs

Pascal Moyal[1⋆], Mohamed Habib Diallo Aoudi[2], and Vincent Robin[2]

[1] IECL, Université de Lorraine,
pascal.moyal@univ-lorraine.fr
[2] LMAC, Université de Technologie de Compiègne
{mohamed.habib.diallo,vincent.robin}@utc.fr

In this talk, we propose an analysis of a class of exploration processes on large random graphs having a fixed degree distribution, using the “constructing while exploring” approach: The graph is constructed by uniform pairing of half-edges (thus leading to a realization of the configuration model - see e.g. [2,8]), while simultaneously exploring it.

This procedure has been applied in various forms and various contexts, e.g., to study a SIR process in [3], to address the greedy independent set problem in [1], to online matching on bipartite graphs in [7,4], or to a Depth-First Search algorithm in [6].

Under general assumptions, we show how this approach allows to estimate key characteristics of the exploration process, to the large graph limit, by solving a system of ordinary differential equations in a space of measures, obtained as the hydrodynamic limits of a (properly scaled) sequence of point measure-valued continuous-time Markov chains. This procedure thus extends Wormald’s *differential equation method* [9,10], to a space of infinite dimension.

We will focus on a particular example to illustrate this methodology: the greedy matching problem on general graphs, using a local matching criterion, developing the recent results obtained in [5].

Keywords: Random graphs · Hydrodynamic limits · Greedy matching · Greedy Independent set.

Contributed Session
CS168: Scaling limits for stochastic processes organized by Pascal Moyal

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Exponential Random Edge–Colored Graphs via Probability Graphons: Free Energies and Extremal Colorings

Pierfrancesco Dionigi[1]*

Alfréd Rényi Institute of Mathematics, Budapest, Hungary
probablypier@outlook.com

In joint work with B. Bhattacharya, A. Ganguly and G. Zucal, we study dense *edge–colored* exponential random graph models (ERGMs) through the language of *probability graphons*, building on the large deviation principle developed with Zucal in [1]. For a finite set of k colors, a probability graphon is a symmetric measurable map $W : [0,1]^2 \to \Delta_k$ (the k probability simplex), extending the usual graphon formalism [2] to colored graphs (and, more generally, to random weighted graphs with a prescribed edge-color law).

Within this framework, the asymptotic log-partition function admits a variational characterization that balances the chosen Hamiltonian with an explicit relative-entropy functional, extending the dense-graph ERGM theory [3,4] to the colored setting. The same formulation yields compactness of maximizers and natural optimality conditions (Euler–Lagrange type) for typical interaction terms built from chromatic subgraph densities. We also discuss qualitative consequences for the typical structure of the model depending on its parameters, including regimes of uniqueness/replica-symmetric behavior and the onset of symmetry breaking as parameters vary.

Finally, a low-temperature (large-parameter) scaling links the probabilistic variational problem to *extremal combinatorics*: the model concentrates around near-extremizers of the underlying density functional, providing an entropic/probabilistic-method perspective on stability phenomena. We illustrate this connection on rainbow-triangle-type objectives and related extremal colorings [5,6].

Keywords: Graph limits · Probability graphons · Large deviations · Random weighted graphs · Extremal combinatorics · Exponential random graphs.

Contributed Session
CS127: Asymptotics of random graphs organized by Elena Magnanini and Pierfrancesco Dionigi

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* Presenter

Does cooperation improve individual performance?

Marco Maggis

Department of Mathematics, University of Milan, Italy,
marco.maggis@unimi.it

Classical asset–pricing theory is built around a representative agent operating in frictionless markets, where no–arbitrage and pricing are characterized by individual martingale measures. However, modern financial markets increasingly exhibit features such as heterogeneity, segmentation, frictions, and opportunities for cooperation and risk sharing, which challenge the individualistic foundations of traditional theory. This paper contributes to the emerging theory of Collective Finance by studying how coordinated exchanges among multiple agents reshape notions of arbitrage, efficiency, and replicability.

Biagini et al. (*Collective arbitrage and the value of cooperation*, F&S, 2025) introduced the concept of Collective Arbitrage (CA), defined as a zero–sum risk exchange among agents that yields nonnegative terminal payoffs for all participants and strictly positive gains for at least one agent. The absence of such opportunities, namely No Collective Arbitrage (NCA), generalizes classical no–arbitrage in settings with heterogeneous trading opportunities or information and admissible risk exchanges. Under mild conditions NCA is equivalent to the existence of collective martingale measures: vectors of agent–specific pricing measures that price individual assets consistently while assigning zero aggregate value to admissible exchanges.

A central contribution of the paper is the analysis of the interplay between collective market efficiency and individual rationality, in a very general semimartingale market model. We formalize the notion of beneficial exchanges as risk transfers that strictly improve all agents' indirect utilities given their preferences and beliefs. We show that a collective free lunch always implies the existence of beneficial exchanges with potentially unbounded utility gains. In collective markets satisfying an opportune No Free Lunch condition, however, the existence of beneficial exchanges depends on a precise compatibility condition between agents' preferences and market structure. Specifically, a beneficial exchange exists if and only if the vector of minimax martingale measures induced by agents' preferences does not belong to the set of collective martingale measures.

Keywords: Collective arbitrage theory · beneficial exchanges · min-max martingale measures.

Contributed Session

CS106: Collective Phenomena in Financial Markets: Arbitrage, Replication, and Risk organized by Marco Frittelli

Collective completeness and pricing hedging duality

Alessandro Doldi[1⋆], Marco Frittelli[1], and Marco Maggis[1]

Department of Mathematics, Università degli Studi di Milano, Italy,
{alessandro.doldi,marco.frittelli,marco.maggis}@unimi.it

This paper develops a comprehensive theory of collective arbitrage, pricing–hedging duality, and market completeness in a discrete-time multi-agent framework with segmented markets and cooperative risk exchange. Building on the notion of Collective Arbitrage introduced by [1], we investigate financial markets in which agents trade in distinct submarkets while being allowed to reallocate risk through structured exchange mechanisms. Within this setting, the absence of arbitrage must be reformulated as No Collective Arbitrage (NCA), reflecting the possibility that cooperation itself may generate or eliminate arbitrage opportunities. Wespecifically work with sets of exchanges modelled by finite dimensional vector spaces of zero-sum rando vectors. Our first contribution is a strengthened version of the First Fundamental Theorem of Asset Pricing (CFTAP I), establishing the equivalence between NCA and the existence of equivalent collective martingale measures under minimal integrability requirements. The proof introduces new techniques and relaxes certain assumptions present in earlier work, allowing for heterogeneous filtrations and greater flexibility in the choice of probability measures. Second, we prove a collective pricing–hedging duality: the collective superhedging price of a vector of contingent claims equals the supremum of the aggregated expectations under suitable collective martingale measures. As the exchange space is finite dimensional, we establish closure properties of the relevant attainable sets, obtain dual representations without restrictive integrability conditions, and prove attainment of optimal hedging strategies. Third, we introduce the notion of collective replication and characterize collectively complete markets. We show that a segmented multi-agent market is collectively complete if and only if the set of equivalent collective martingale measures is a singleton (CFTAP II), thereby extending the classical Second Fundamental Theorem of Asset Pricing to cooperative environments.

Keywords: Cooperation · Completeness · Collective FTAP.

Contributed Session

CS106 : Collective Phenomena in Financial Markets: Arbitrage, Replication, and Risk organized by Marco Frittelli

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⋆ Presenter

A new approach to Bayesian consistency rates via Wasserstein dynamics

Emanuele Dolera[1⋆], Stefano Favaro[2], and Edoardo Mainini[3]

[1] Dipartimento di Matematica, Università di Pavia, Pavia, Italy
emanuele.dolera@unipv.it
[2] Dipartimento di Economia e Statistica, Università di Torino e Collegio Carlo Alberto, Torino, Italy
[3] Dipartimento di Ingegneria meccanica, energetica, gestionale e dei trasporti, Università degli studi di Genova, Genova, Italy
stefano.favaro@unito.it, edoardo.mainini@unige.it

We present a new mathematical approach to posterior contraction rates (PCRs) in *Bayesian consistency*, based on Wasserstein calculus. A PCR represents the speed at which the posterior distribution π_n concentrates on sequentially small neighborhoods of the true parameter, as the sample size goes to infinity. See [4, Ch. 6–10]. Our analysis focuses on dominated statistical models $\{f_\theta\}_{\theta\in\Theta}$, presentable as an infinite-dimensional exponential family with the parameter space Θ included in some separable Banach space.

Current literature (both Bayesian and freqentist) has developed two main approaches to study rates of consistence. On the one hand, one considers neighborhoods of the true density f_{θ_0} in the space of densities (see [5]). On the other hand, one studies neighborhoods of the true parameter θ_0 in Θ, endowed with its natural norm-topology (see [6]). We follow the latter approach by transferring the analysis onto the space $\mathcal{P}_2(\Theta)$ of all probability measures (p.m.'s) on Θ with finite second moment, exploiting the geodesic interpretation of the 2-Wasserstein $\mathcal{W}_2$. See [2]. In our approach, we start from the existence of a Bayesian sufficient statistic T_n in the form $T_n = \frac{1}{n}\sum_{i=1}^n \varphi(x_i)$, where φ takes values in some Banach space $\mathbb{B}$. Thus, the posterior π_n satisfies $\pi_n(\cdot|x_1,\ldots,x_n) = \pi_n^*(\cdot|T_n)$ for some probability kernel $\pi_n^* : \mathcal{B}(\Theta)\times\mathbb{B}\to[0,1]$. Considering i.i.d. data $\xi_1,\ldots,\xi_n$ distributed according to f_{θ_0}, suitable infinite-dimensional versions of the SLLN for T_n entail that $T_n \to T_0$, for some $T_0\in\mathbb{B}$. Our work derives PCRs from the following, more tractable rates:

A) the speed of $\pi_n^*(\cdot|T_0)\to\delta_{\theta_0}$ in $(\mathcal{P}_2(\Theta),\mathcal{W}_2)$;
B) the speed of $T_n(\xi_1,\ldots,\xi_n)\to T_0$ in $L^1(\Omega;\mathbb{B})$.

To quantify rates in A)-B), we develop some new mathematical tools of independent interest. Concerning A), we investigate the *Laplace method* for approximating Laplace integrals in infinite-dimensional spaces. This topic is connected with the asymptotics of *Small Balls* through interpolation inequalities *à la* Gagliardo-Niremberg. On the other hand, to take advantage of the knowledge of the rates in B), we need a (local) Lipschitz-continuity of the map $\mathbb{B}\ni b\mapsto\pi_n^*(\cdot|b)\in\mathcal{P}_2(\Theta)$, previously investigated in [3]. Critical to this analysis is the behaviour of *weighted Poincaré-Wirtinger constants* in infinite-dimensional setting.

The presentation of our theory is illustrated on some infinite-dimensional statistical models of interest: logistic-Gaussian model (see [2, Section 4.5]); White Noise with Besov-Laplace priors (see [1]); Poisson-mixture models for Empirical Bayes (work in progress).

Keywords: Bayesian Consistency · Wasserstein distance · Laplace integral · Poincaré-Wirtinger inequality.

⋆ Presenter

Contributed Session

CS143: Optimal Transport Methods for Statistics organized by Marta Catalano and Hugo Lavenant

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Testing for Multivariate Regular Variation

Holger Drees

Department of Mathematics, University of Hamburg, Germany
holger.drees@uni-hamburg.de

Many statistical methods for analyzing the extreme value behavior of a sample of d-dimensional random vectors rely on the assumption that the observed vectors are multivariate regularly varying (perhaps after a marginal transformation). Despite its importance, surprisingly few statistical tests for this hypothesis have been proposed and thoroughly analyzed. Taking up an idea from [1], we discuss a general approach to tackle this problem. The proposed test statistics are based on empirical processes, which give further insight about the type of deviation from regular variation if the test rejects the null hypothesis.

Keywords: Multivariate regular variation · Hypothesis test · Empirical process.

Contributed Session
CS149: Modeling the Unseen: Theory and Methods for Extreme Events organized by Stefano Rizzelli

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Fast-slow mean-field games with common noise

Roxana Dumitrescu[1*], Julian Gutierrez Pineda[2], and Peter Tankov[1]

[1] CREST-ENSAE, Institut Polytechnique de Paris, France
roxana.dumitrescu@ensae.fr, peter.tankov@ensae.fr
[2] New York University Abu Dhabi
julian.gutierrezpin@gmail.com

We propose a framework for approximating Nash equilibria in mean-field games (MFGs) with common noise based on a two-time-scale structure. In our model, the common noise is modeled by a fast variable evolving under ergodic dynamics. The framework applies to several classes of MFGs, including games with regular control and with optimal stopping. The main idea is to avoid solving the full MFG with common noise by approximating it with an "effective" MFG without common noise, whose coefficients are obtained by averaging with respect to the stationary measure of the fast-scale process.

Starting from an equilibrium of the effective MFG, we construct an explicit ε-MFG equilibrium for the original game by introducing randomized control and stopping. To this end, we establish new existence results for MFG equilibria with randomized stopping. Our approach relies on convergence results for two-scale diffusions under various structural assumptions on the MFG, and we show that the time-scale separation parameter controls the error in the Nash equilibrium condition.

Keywords: Multi-scale · Mean-field games · common noise · optimal stopping · optimal control.

Contributed Session

CS125: Cooperative and competitive mean-field models – Part I organized by Federico Cannerozzi · Giorgio Ferrari

* Presenter

Algorithm- and Data-Dependent Generalization Bounds for Diffusion Models

Benjamin Dupuis[1⋆], Dario Shariatian[1], Maxime Haddouche[1], Alain Durmus[2], and Umut Şimşekli[1]

[1] Inria, CNRS, École Normale Supérieure, PSL Research University, France,
name.surname@inria.fr
[2] CMAP, École Polytechnique, Institut Polytechnique de Paris, France
name.surname@polytechnique.edu

Score-based generative models (SGMs), including diffusion models, have become a leading paradigm for high-dimensional generation. Existing statistical analyses typically adopt an approximation-theoretic viewpoint: they bound the discrepancy between the data distribution and the generated distribution via (i) initialization error, (ii) discretization error, and (iii) a score-approximation term, and then control the latter by worst-case function class arguments. While valuable, these approaches are often pessimistic and, crucially, do not explain the concrete impact of the training algorithm and its hyperparameters on generalization.

We address this gap by providing the first algorithm- and data-dependent generalization analysis for diffusion models. We begin with simple experiments showing that optimizer choices (e.g.,ADAM), learning rates, and batch sizes substantially affect generation quality. We then derive a decomposition of the score approximation error at any network parameter into three components: an explicit score matching loss optimized during training, a data-dependent diffusion gap capturing the interaction between the dataset and the forward process, and a score generalization gap relating population and empirical risks. We bound the data-dependent diffusion gap at high probability, highlighting its $\mathcal{O}(n^{-1/2})$ scaling (up to constants), and show that the remaining score generalization gap can be controlled using modern algorithm-dependent tools from learning theory. In particular, we instantiate our framework with bounds based on (i) gradient norms along stochastic optimization dynamics and (ii) topological complexity measures of optimization trajectories, leading to KL generalization bounds that explicitly reflect optimization behavior. Our theoretical predictions are supported by empirical results across low- and high-dimensional datasets.

Keywords: diffusion models · score-based generative models · generalization bounds · optimization dynamics · learning theory.

Contributed Session
CS120: Probabilistic Perspectives on Generative Modeling organized by Antonio Ocello

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⋆ Presenter

Spectral Bayesian Regression on the Sphere

Claudio Durastanti*

Department SBAI, University of Rome "La Sapienza", Italy
claudio.durastanti@uniroma1.it

We develop a spectral approach to Bayesian nonparametric regression on the sphere. The methodology is based on isotropic Gaussian random field priors defined through the eigensystem of the Laplace–Beltrami operator and the associated spherical harmonic decomposition. This representation provides a natural frequency-domain description of both the signal and the prior, and transforms the regression problem into a diagonal Gaussian sequence model. As a consequence, posterior inference admits an explicit characterization and can be interpreted as frequency-wise Bayesian shrinkage. The angular power spectrum plays a central role in determining the regularity properties of the prior and the resulting asymptotic behaviour of the posterior distribution. Connections with Gaussian random fields, harmonic analysis on the sphere and spectral regularization methods will also be discussed.

Keywords: Bayesian nonparametric regression· Sphere· Laplace–Beltrami operator .

Contributed Session
CS129: New Horizons for Random Fields in Probability and Statistics organized by Claudio Durastanti

* Presenter

Properties of diffusion transport maps via creation of log-semiconcavity along heat flows

Katharina Eichinger[1⋆], Louis-Pierre Chaintron[2], and Giovanni Conforti[3]

[1] ParMA, Inria Saclay and LMO, Université Paris Saclay, France
katharina.eichinger@inria.fr
[2] École Polytechnique Fédérale de Lausanne, Switzerland
[3] University of Padova, Italy

Finding regular transport maps between measures is an important task in generative modelling and a useful tool to transfer functional inequalities. The most well-known result in this field is Caffarelli's contraction theorem, which shows that the optimal transport map from a Gaussian to a uniformly log-concave measure is globally Lipschitz. Note that for our purposes optimality of the transport map does not play a role. This is why several works investigate other transport maps, such as those derived from diffusion processes, as introduced by Kim and Milman. Here, we establish a lower bound on the log-semiconcavity along the heat flow for a class of what we call asymptotically log-concave measures. We will see that this implies Lipschitz bounds for the heat flow map introduced by Kim and Milman. I will also comment on its implication for stability of these maps.

Based on a joint work with Louis-Pierre Chaintron and Giovanni Conforti.

Keywords: Heat flow · Transport map · Weak log-concavity.

Contributed Session
CS121: Advances in entropic optimal transport organized by Conforti Giovanni

⋆ presenter

Play longer when it matters: optimal match length in knock-out tournaments

Erik Ekström[1] and Yuqiong Wang[2⋆]

[1] Department of Mathematics, Uppsala University, Uppsala, Sweden
Erik.Ekstrom@math.uu.se
[2] Department of Mathematics, University of Michigan, Ann Arbor, United States,
yuqw@umich.edu

Later-stage matches in sports tournaments, especially semifinals and finals, are often treated as more important and therefore played longer. We ask whether this intuition can be justified from a sequential testing viewpoint. We study a knock-out tournament with 2^n players in which each match is modeled by a Brownian motion with an unobservable drift, representing the players' relative abilities. The tournament designer chooses how long each match should be played so that the strongest player wins the tournament with a prescribed probability.

We analyze two design regimes: (i) deterministic designs, where all match lengths are fixed in advance, and (ii) sequential designs, where match duration can adapt to the observed paths. Our main structural result shows that in both regimes, the optimal schedule makes the late-round matches longer than early-round matches, providing a formal statistical justification for common tournament practice.

We then quantify the efficiency gain from allowing sequential decisions, comparing the expected total observation time under optimal sequential designs to that of optimal deterministic schedules achieving the same success probability. We derive explicit bounds on the average reduction in sample size: sequential testing saves at least 36% and at most 75% on average. Moreover, the relative advantage of sequential methods grows as one requires higher precision.

Keywords: Knock-out tournaments · sequential testing · optimal match-length.

Contributed Session
CS152: Optimal stopping, stochastic control and stochastic games I organized by Alessandro Milazzo, Andrea Bovo and Tiziano De Angelis

⋆ Presenter

Random Flights and Anomalous Diffusion: A non-Markovian Take on Lorentz Processes

Lorenzo Facciaroni[1]*, Costantino Ricciuti[1], Enrico Scalas[1], and Bruno Toaldo[2]

[1] Department of Statistical Sciences, Sapienza University of Rome, Italy,
lorenzo.facciaroni@uniroma1.it,costantino.ricciuti@uniroma1.it,enrico.scalas@uniroma1.it
[2] Department of Mathematics Giuseppe Peano, Torino, Italy
bruno.toaldo@unito.it

A Lorentz process is a model for the motion of a particle among randomly located scatterers, also known as obstacles. It was originally used to describe the transport of electrons through a conductor.

In the classical setting, when the scatterers are distributed according to a Poisson point process, the deterministic dynamics of elastic collisions can be approximated, under the Boltzmann-Grad scaling limit, by a Markovian random flight. The density of this limiting process is governed by the Boltzmann equation. Passing further to the hydrodynamic limit, one recovers Brownian motion as the macroscopic description of the particle's position.

In this work, we introduce a new class of point processes that generalizes the Poisson process and we investigate the motion of a particle which collides elastically with obstacles distributed according to this distribution. Unlike the classical case, the corresponding limiting random flight process is no longer Markovian. Instead, it exhibits memory effects that lead to superdiffusive behavior. At the macroscopic level, the particle's position converges to a continuous superdiffusive process.

Within this framework, we derive a non-local analogue of the Boltzmann equation governing the non-Markovian random flight. Moreover, we show that the density of the superdiffusive scaling limit satisfies a fractional heat equation, reflecting the anomalous transport induced by the underlying correlations.

Keywords: Lorentz process · Boltzmann-Grad limit · Feller semigroups.

Contributed Session

CS154: Interplay between statistical physics and probabilistic methods: the case of anomalous diffusion organized by Gianni Pagnini and Costantino Ricciuti

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* Presenter

An Application of Fuzzy Set Theory and Interval-Based Distances for Expert Judgment Aggregation

Giuseppe Failla

Department of Mathematics and Computer Sciences, Palermo, Italy,
giuseppe.failla02@unipa.it

We present a recent joint work with G. La Rosa, M. E. Tabacchi [1], where a judgment aggregation argument is pointed out. In particular, we adopt the perspective of a meta-expert who forms its final judgement after consulting a group of experts, giving greater weight to opinions closer to its own.
Expert assessments are modelled using trapezoidal fuzzy numbers for both criteria weights and ratings, while the aggregation process relies on t-norms and t-conorms to combine fuzzy information coherently.
The influence of each expert is determined through a recently introduced distance measure, see [2], for trapezoidal fuzzy numbers, suitably rescaled to quantify the divergence between the meta-experts confidence index and those of the others. A deeper discussion on this distance is provided (existence, nonexistence and characterization). Moreover, the use of this interval distance allows us to consider a neutral, meta-expert that evaluate and aggregate the judgements of other experts and decides to assign lower weights to opinions that are farther from their own and higher weights to those that are closer. Nevertheless, this does not imply ignoring the opinions that are too far away. On the other hand, the trapezoidal fuzzy numbers permits to capture both the inherent epistemic uncertainties in expert judgements and the vagueness associated with linguistic evaluations.
Finally, a benchmark on the seminal engineering problem of Sequoyah nuclear power plant (the aim is the evaluation of the pressure rise inside the containment building of the Sequoyah Nuclear Power Plant) is analysed.

Keywords: Expert judgments · Fuzzy set theory · Interval distance · Fuzzy distance.

Contributed Session

CS172: Uncertainty, Vagueness, and Decision Support: Logical and AI Approaches organized by Arianna Pavone and Gianmarco La Rosa

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Large-sample asymptotics of coalescent importance sampling algorithms

Martina Favero[1] and Jere Koskela[2⋆]

[1] Department of Mathematics, Stockholm University, Sweden,
martina.favero@math.su.se
[2] School of Mathematics, Statistics and Physics, Newcastle University, UK
jere.koskela@newcastle.ac.uk

The coalescent is a foundational model of latent genealogical trees under neutral evolution, but suffers from intractable sampling probabilities. Methods for approximating these sampling probabilities either introduce bias or fail to scale to large sample sizes. We identify a class of functionals of the coalescent which describe the variance of estimators from classical importance sampling algorithms, and which have tractable infinite-sample limits. These functionals provide the first mathematical descriptions of the performance of some seminal coalescent inference methods, and reveal that coalescent importance sampling differs markedly from the behaviour of (sequential) importance samplers in more standard settings, with or without resampling.

Keywords: coalescent process · importance sampling · large-sample asymptotics · resampling.

Contributed Session
CS189: Stochastic population dynamics organized by Dario Spanò

⋆ Presenter

Stability and renormalization of Jackson networks with non-idling mobile servers

Fayolle, Guy[1] and Fricker, Christine*[1]

INRIA de Paris, Paris, France
guy.fayolle@inria.fr
christine.fricker@inria.fr

A tandem of two queues sharing a pool of servers, where users need time to switch to the second queue, is used to model a typical pathway through an emergency department (ED), where patients undergo two consultations separated by diagnostic tests. In this paper [1], explicit conditions for ergodicity, transience and null-recurrence are given and proven via Foster's criterion, using a linear Lyapunov function. This result is extended to a Jackson network, with the key feature that the nodes share a pool of servers, with a non-idling one-limited service policy and Markovian routing for the servers. Furthermore, delay times for customers to move from one node to another are also taken into account. This covers some of the main features of models for emergency departments, namely priorities (triage) between patients.

In the case of the tandem queue, after scaling the arrival rate and the number of servers by N, and dividing the process by N, we obtain a renormalized process converging to the solution of an ordinary differential equation (ODE) subject to boundary conditions. We gives some insights of the solution of this ODE in case of ergodicity, mainly we discuss the long time behavior, more precisely convergence to the equilibrium point.

Keywords: Markov Process, Jackson Queueing Networks, Lyapunov Function, Fluid Limit, ODE with discontinuities.

Contributed Session
CS168: Scaling limits for stochastic processes organized by Moyal Pascal

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* Fricker, Christine

Mean Field Games in Hilbert Spaces

Salvatore Federico[1] *, Daria Ghilli[2], Fausto Gozzi[3], and Andrzej Swiech[4]

[1] Dipartimento di Matematica, Università di Bologna, Italy
s.federico@unibo.it
[2] Dipartimento di Economia, Università di Pavia, Italy
daria.ghilli@unipv.it
[3] LUISS, Rome, Italy
fgozzi@luiss.it
[4] School of Mathematics, Georgia Tech, Atlanta, US
swiech@math.gatech.edu

We study Mean Field Games (MFG) systems in real separable infinite-dimensional Hilbert spaces, addressing both general nonlinear formulations and the specific linear-quadratic (LQ) case. In the general setting [1], the MFG system consists of a second-order parabolic Hamilton-Jacobi-Bellman (HJB) equation coupled with a nonlinear Fokker-Planck (FP) equation, both involving Kolmogorov operators. Solutions are interpreted respectively in the mild and weak senses, and we establish well-posedness via Tikhonov's fixed point theorem, with uniqueness ensured under separability and Lasry-Lions-type monotonicity conditions. In the LQ framework [2], we focus on the case where the mean field interaction enters only through the objective functional via the mean of the distribution. This structure allows the reduction of the MFG system to a Riccati equation and a forward-backward system of abstract evolution equations—an approach that is novel in infinite dimensions. Existence and uniqueness are obtained through a refined approximation method, and the theory is applied to a production output planning problem with delayed control.

Keywords: Mean Field Games · Hilbert Spaces · Hamilton-Jacobi-Bellman and Fokker-Planck coupled systems.

Contributed Session

CS125: Cooperative and competitive mean-field models – Part I organized by Federico Cannerozzi and Giorgio Ferrari

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* Presenter

The grass-bushes-trees process on a scale-free network

John Fernley[*] and Daniel Valesin

Department of Statistics, University of Warwick, United Kingdom
{john.fernley,daniel.valesin}@warwick.ac.uk

The grass-bushes-trees process is a two-type contact process in which one type (the trees), of infection parameter λ_1, can invade the other type (the bushes) of infection parameter λ_2. We look to show which graph parameters lead to the possibility of coexistence versus the necessity of competitive displacement, i.e. metastability of both types or fast extinction of the bushes.

Keywords: Multitype contact process · Metastability · Competitive displacement

Contributed Session
CS160: Non-homogeneous random graphs organized by Luca Avena

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[*] Presenter

Singular Mean-field Control via Singular Mean-field Games

Giorgio Ferrari[1]*, Andrea Amato[2], and Federico Cannerozzi[3]

[1] Center for Mathematical Economics (IMW), Bielefeld University, Germany
giorgio.ferrari@uni-bielefeld.de
[2] Department of Mathematics, University of Bologna, Italy
andrea.amato6@studio.unibo.it
[3] Center for Mathematical Economics (IMW), Bielefeld University, Germany
federico.cannerozzi@uni-bielefeld.de

We study a mean-field control (MFC) problem with singular controls over a finite horizon, allowing for general dependence on the measure argument. To analyze the search for an optimal MFC strategy, we associate to it a mean-field game (MFG), which we refer to as a potential MFG of singular controls. We show that, under suitable convexity assumptions, any solution to this potential MFG yields a solution to the original MFC problem. We apply our results to a mean-field control version of the classical Monotone Follower problem of I. Karatzas and S. E. Shreve [1]. The scalar mean-field interaction term is modulated by an interaction-strength parameter, leading to either strategic complementarity or strategic substitutability. The associated potential MFG with singular controls is solved by relying on its connection with optimal stopping problems for the optimization step, and on two distinct fixed-point theorems to handle the two strategic regimes.

Keywords: mean-field control · singular stochastic control · mean-field games

Contributed Session
CS126: Cooperative and competitive mean-field models - Part II organized by Federico Cannerozzi and Giorgio Ferrari

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* Presenter

Hypercontractivity type property for generalized Mehler semigroups

Simone Ferrari

Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, Italy,
simone.ferrari@unisalento.it

A natural framework for studying semigroups associated with elliptic operators with unbounded coefficients is given by L^p spaces related to invariant measures. This is the case, for instance, of the classical Ornstein–Uhlenbeck semigroup $(P(t))_{t\geq 0}$, which enjoys many nice properties in $L^p(\gamma)$, where γ denotes the standard Gaussian measure that turns out to be the unique associated invariant measure. One of the most relevant properties of the Ornstein–Uhlenbeck semigroup, proved by Nelson in [6], concerns hypercontractivity; that is, for any $1 < p < q < \infty$ there exists $\overline{t}(p,q) > 0$ such that

$$\|P(t)f\|_{L^q(\gamma)} \leq \|f\|_{L^p(\gamma)}, \tag{1}$$

for all $f \in L^p(\gamma)$ and $t \geq \overline{t}(p,q)$.

The hypercontractivity of $P(t)$ is strictly connected to the validity of the classical logarithmic Sobolev inequality, which establishes the embedding of $W^{1,p}(\gamma)$ into $L^1(\gamma)\ln L^1(\gamma)$. Moreover, estimate (1) allows one to deduce the asymptotic behavior of $P(t)$ as $t \to \infty$.

The Ornstein–Uhlenbeck semigroup can be interpreted as a particular case of a generalized Mehler semigroup and, as is well known, in the general case hypercontractivity fails to hold for such semigroups.

In this talk we consider generalized Mehler semigroups on L^p spaces related to invariant measures and investigate their summability-improving properties. We identify natural subspaces of L^p where hypercontractivity-type estimates are satisfied, providing both examples and counterexamples. The results we prove extend and, in some cases, improve the existing theory. This is joint work with Luciana Angiuli (Università del Salento).

Keywords: Generalized Mehler semigroups · Hypercontractivity · Logarithmic Sobolev inequality.

Contributed Session

CS124: Infinite Dimensional Analysis and Malliavin Calculus organized by Davide Addona

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The nonlinear Schrödinger equation with multiplicative noise and arbitrary power of the nonlinearity

Z. Brzeźniak[1], B. Ferrario[2⋆], M. Maurelli[3], and M. Zanella[4]

[1] Department of Mathematics, University of York, UK
zdzislaw.brzezniak@york.ac.uk
[2] Dipartimento di Scienze Economiche e Aziendali, Università di Pavia, Italy
benedetta.ferrario@unipv.it
[3] Dipartimento di Matematica, Università di Pisa, Italy
mario.maurelli@unipi.it
[4] Dipartimento di Matematica, Politecnico di Milano, Italy
margherita.zanella@polimi.it

We consider the stochastic nonlinear Schrödinger equation on a d-dimensional domain with the polynomial nonlinearity

$$\mathrm{d}u(t,x) + \left[\mathrm{i}\Delta u(t,x) + \mathrm{i}\alpha |u(t,x)|^{2\sigma} u(t,x)\right] \, \mathrm{d}t = \phi(u(t,x))\, \mathrm{d}W(t)$$

Classical results of global existence are obtained for power σ not too large, depending on the spatial dimension d and the parameter α ($\alpha > 0$ is the focusing case and $\alpha < 0$ is the defocusing case). This is known for the deterministic equation ($\phi = 0$) and the stochastic one with an additive or linear multiplicative noise. Higher values of σ can give rise to blow-up in finite time.

In our paper [2] we prove that working on the d-dimensional torus $\mathbb{T}^d$, for any power $\sigma \in \mathbb{N}$ there exists a class of noises such that there exists a unique global solution for *any* initial data in $H^s(\mathbb{T}^d)$ when $s > \frac{d}{2}$. The effect of the noise is to prevent blow-up in finite time, differently from the deterministic setting (see [1]). Moreover, we prove the existence of an invariant measure and its uniqueness under more restrictive assumptions on the noise term.

As an example, one can consider a one dimensional real Wiener process W and diffusion $\phi(u) = [a(1+\|u\|_{L^\infty})^\sigma + \mathrm{i}b(1+\|u\|_{L^\infty})^\sigma]u$ for real values a, b with a large enough. The choice $s > \frac{d}{2}$ provides the helpful estimate $\|u\|_{L^\infty(\mathbb{T}^d)} \leq C\|u\|_{H^s(\mathbb{T}^d)}$, because of the continuous embedding $H^s(\mathbb{T}^d) \subset L^\infty(\mathbb{T}^d)$. Therefore the local existence result is a trivial fact. Our proof of global existence relies on a tightness method based on the choice of a suitable Lyapunov function. In particular, the global existence holds in both focusing and defocusing cases.

Keywords: Stochastic nonlinear Schrödinger equation · Multiplicative noise · Regularization by noise

Contributed Session

CS115: Stochastic partial differential equations and invariant measures organized by Davide Augusto Bignamini

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⋆ Presenter

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Artificial Experts in Multi-Criteria Group Decision-Making

Giuseppe Filippone[2][0000−0001−7315−1852]⋆

Dipartimento di Matematica e Informatica
Via Archirafi 34, 90123, Palermo
Università degli Studi di Palermo
giuseppe.filippone01@unipa.it

Multi-Criteria Decision-Making (MCDM) is a framework for decision-making in which an expert selects the optimal alternative from a range of feasible options. In instances where multiple experts are involved, the framework is designated *Multi-Criteria Group Decision-Making* (MCGDM) [1,7,8,11]. In this latter framework, a weighted aggregation of the alternatives selected by the experts is employed. Selecting the appropriate weight for each human expert may raise a considerable challenge. For instance, people generally dislike being assigned a weight. Moreover, it is challenging to assign weights to experts in a given field.

In our approach, human experts are replaced by artificial ones (e.g., algorithms), the weight of which can be computed using more deterministic methods. In particular, based on the decision problem, the most suitable algorithms related to the problem are selected as experts. We determine the weight of each algorithm (expert) by modelling a *Fuzzy Rule-Based System* (FRBS) [4,5,9,10,12]. FRBSs express their knowledge base using IF-THEN rules whose antecedents and consequents are fuzzy statements. More precisely, in our settings, the fuzzy sets in the antecedents are the criteria (e.g., *Robustness*, *Precision*, *MemoryUse*, and so on) selected to compare the experts, and the weight is the fuzzy set in the consequent. Subsequently, the outputs are subjected to defuzzification and normalisation within the interval $[0, 1]$ to derive the crisp value used for the weighting of the experts.

It is acknowledged that there are multiple FRBSs, such as Mamdani, Larsen, and Takagi-Sugeno-Kang, which differ in the way they compute or compose the consequent. For example, Mamdani and Larsen FRBSs use fuzzy sets in the consequents, whereas Takagi-Sugeno-Kang FRBSs use a mathematical function (typically linear) of the input variables.

In this particular context, the Larsen system was employed, which clips the fuzzy set in the consequent prior to the defuzzification process.

This framework provides a structured approach for defining a straightforward, deterministic method for weighting a pool of experts in a given field. This approach has the potential to be utilised in a variety of applications involving a group of experts, such as the aforementioned MCGDM. In future, we plan to use the proposed framework to weigh experts involved in the fuzzyification of an ontology using a MCGDM framework [6,3,2].

Keywords: Multi-Criteria Group Decision-Making · Fuzzy Ontology · Fuzzy Method · Fuzzy Multi-Expert Decision-Making · Artificial Experts

Contributed Session

CS172: Uncertainty, Vagueness, and Decision Support: Logical and AI Approaches organized by Arianna Pavone and Gianmarco La Rosa

⋆ Presenter

Giuseppe Filippone

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LEARNING THEORY OF SHALLOW NEURAL NETWORKS THROUGH THE LENS OF RKBS

Lorenzo Fiorito[1⋆], Shuo Huang[2], Emanuele Naldi[1], Ernesto De Vito[1], and Lorenzo Rosasco[2,3]

[1] MaLGa- DIMA- Università di Genova, Genoa, Italy
{lorenzo.fiorito, emanuele.naldi} @edu.unige.it, ernesto.devito@unige.it
[2] Istituto Italiano di Tecnologia, Genoa, Italy
shuo.huang@iit.it
[3] MaLGa- DIBRIS- Università di Genova, Genoa, Italy
lrosasco@mit.edu

We develop a functional framework for shallow neural networks based on reproducing kernel Banach spaces. This approach enables a nonparametric treatment of neural networks, in direct analogy with kernel methods. A representer theorem shows that finite networks suffice for empirical risk minimization. Estimation and approximation error bounds can then be derived in linear function spaces. As a byproduct, we obtain universality results and approximation bounds showing that neural networks can adapt to latent structure in the problem. Further, we derive complexity estimates based on the Rademacher complexities of RKBS balls, independent of network size.

Keywords: Statistical learning · Neural networks · Reproducing kernel Banach spaces

Contributed Session
CS191: Selected Topics in Probability and Mathematical Statistics organized by Andrea Simonetti

References

⋆ Presenter

Real-world models for multiple term structures: a unifying HJM semimartingale framework

Claudio Fontana[1]*, Eckhard Platen[2], and Stefan Tappe[2]

[1] Department of Mathematics "Tullio Levi-Civita", University of Padova, Italy,
fontana@math.unipd.it
[2] School of Mathematical Sciences, University of Technology Sydney, Australia
Eckhard.Platen@uts.edu.au
[3] Department of Mathematical Stochastics, University of Freiburg, Germany
stefan.tappe@math.uni-freiburg.de

We develop a unified framework for modeling multiple term structures arising in financial, insurance, and energy markets, adopting an extended Heath-Jarrow-Morton (HJM) approach under the real-world probability measure. We study market viability and characterize the set of local martingale deflators. We conduct an analysis of the associated stochastic partial differential equation (SPDE), addressing existence and uniqueness of solutions, invariance properties and existence of affine realizations.

Keywords: Heath-Jarrow-Morton framework · large financial market · stochastic partial differential equation.

Contributed Session
CS166: SPDEs in Finance organized by Claudio Fontana and

* Presenter

A Conformal Prediction Approach to Predict Populations of Graphs

Matteo Fontana[1⋆], Anna Calissano[2], Gianluca Zeni[3], and Simone Vantini[3]

[1] Royal Holloway, University of London
matteo.fontana@rhul.ac.uk
[2] University College, London
anna.calissano@ucl.ac.uk
[3] MOX-Department of Mathematics, Politecnico di Milano
simone.vantini@polimi.it

This presentation introduces a conformal prediction methodology for quantifying uncertainty in populations of graph data [12,5]. While existing literature offers numerous methods for graph prediction [11,7], techniques for assessing the uncertainty of these predictions remain scarce [6,10]. The proposed framework addresses this gap by generating prediction regions for both labelled graphs, which possess a clear correspondence between nodes across observations, and unlabelled graphs, which lack such correspondence.

For unlabelled graphs, the methodology constructs prediction regions embedded within a discrete quotient metric space, referred to as graph space [8]. The approach is model-free and does not rely on distributional assumptions. It achieves finite-sample validity and produces component-wise interpretable prediction regions configured as parallelotopes [4]. Furthermore, the framework incorporates a length modulation mechanism to account for the local variability of specific edge or node attributes [9].

The theoretical properties and empirical performance of this forecasting technique are evaluated through two simulation studies covering both labelled and unlabelled graph scenarios. Additionally, the practical utility of the method is demonstrated using a real-world dataset of player passing networks from the FIFA 2018 World Cup. This application illustrates the framework's capacity to analyze network topology and quantify prediction uncertainty for football teams categorized by varying performance levels [3,2,1].

Keywords: Conformal Prediction · Uncertainty Quantification · Unlabelled Graphs.

Contributed Session
CS139: Conformal prediction: theory and methods organized by Stefano Favaro and Simone Vantini

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Predictive Bernstein–von Mises Theorems

Sandra Fortini[1⋆] and Sonia Petrone[1]

Department of Decision Sciences, Bocconi University, Milano,
sandra.fortini@unibocconi.it,sonia.petrone@unibocconi.it

Abstract. Predictive inference takes the sequence of one–step–ahead predictive distributions as the primitive object for learning and inference, rather than an explicit model–prior specification [1,2]. This approach naturally encompasses Bayesian procedures, but also applies to prediction–based learning rules that are only asymptotically exchangeable or arise from computationally motivated approximations [3,4].
We study asymptotic inference induced by predictive learning rules that are not necessarily exchangeable but converge almost surely to a random limiting distribution. Our main contribution is a functional Doob–type Bernstein–von Mises theorem for predictive inference. We show that, under suitable regularity conditions, the conditional distribution of the limiting predictive process, centered at the current predictive distribution and suitably rescaled, converges almost surely to a Gaussian law in an appropriate functional space. The associated covariance structure is explicitly characterized in terms of predictive updates, yielding an analytic approximation of the implicit posterior distribution and providing a direct tool for uncertainty quantification and predictive efficiency assessment.
Under i.i.d. observations, we obtain a Bernstein–von Mises theorem for the predictive distribution, showing asymptotic normality of the implicit posterior centered at the predictive mean, with variance determined by the learning dynamics of the predictive rule.
Finally, we discuss extensions of the framework to supervised settings with regressors, where predictive distributions depend on covariates. In this context, functional central limit theorems for predictive distributions with fixed covariate values provide Gaussian approximations for conditional laws, with applications to regression and modern prediction–based learning methods.

Keywords: Predictive inference · Functional central limit theorems· Bernstein–von Mises theorem.

Contributed Session
CS155: Asymptotic results for predictive distributions organized by Lorenzo Cappello

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⋆ Presenter

Uniqueness for Finite-State Mean Field Games with Non-Separable Hamiltonians

Nicola Fraccarolo[1⋆], Alekos Cecchin[1], and Luca Di Persio[2]

[1] Department of Mathematics, University of Padova, Italy,
{nicola.fraccarolo,alekos.cecchin}@unipd.it
[2] Department of Computer Science, University of Verona, Verona, Italy
luca.dipersio@univr.it

Mean field games (MFGs), introduced independently by Lasry and Lions and by Huang, Malhamé and Caines, describe strategic interactions among a large population of agents through the coupled evolution of a value function and of the distribution of a representative player. A fundamental issue in this theory is the uniqueness of equilibria, which is essential both for modelling purposes and for the stability of numerical approximations. In the classical framework, uniqueness is usually obtained under the Lasry-Lions monotonicity condition, which relies on a separable structure of the Hamiltonian with respect to the state and the population distribution.

In this work we study finite-state continuous-time mean field games with distribution-dependent jump intensities, leading to Hamiltonians that are genuinely non-separable. The state of a representative player evolves in a finite set $\Sigma = \{1, \dots, d\}$ and, when the player is in state x, the transition rate towards a different state y is of the form

$$\alpha_y(t,x) + b(x, \mu(t)),$$

where α is the control and b is a nonnegative interaction term depending on the population distribution $\mu(t)$. This structure naturally arises in models with congestion, network effects or endogenous transition mechanisms.

For a fixed flow of measures, the associated Hamilton-Jacobi-Bellman equation involves the Hamiltonian

$$H(x,\mu,p) = \sum_{y \neq x} \left(\frac{1}{2}(p_y)_-^2 - b(x,\mu)p_y \right),$$

which couples the population variable and the finite differences of the value function in a non-separable way. The mean field equilibrium is characterised by a forward-backward system consisting of this Hamilton-Jacobi-Bellman equation and a Kolmogorov equation with distribution-dependent transition rates.

We provide a uniqueness result for this class of non-separable finite-state mean field games, valid on arbitrary finite time horizons.

Uniqueness is established under a combination of a strong monotonicity condition on the running cost, a standard monotonicity condition on the terminal cost, and Lipschitz continuity of the interaction term b with respect to the population distribution. In contrast with the classical Lasry-Lions theory, the monotonicity of the costs alone is not sufficient: the dependence of the dynamics on the distribution generates additional coupling terms which must be controlled by explicit quantitative conditions. Our results highlight the precise balance between cost monotonicity and the strength of the distribution-dependent transition rates required to recover uniqueness in non-separable mean field game models.

Keywords: Mean Field Games · Non-separable Hamiltonians · Uniqueness of Equilibria

⋆ Presenter

Contributed Session

CS148: Mean field control and games organized by Alekos Cecchin and Jodi Dianetti

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Dynamic network clustering via connectivity pattern persistence and node-level dependence

Beatrice Franzolini[1⋆] and Francesco Gaffi[2]

[1] Department of Economics, Management and Statistics, University of Milano-Bicocca, Italy, beatrice.franzolini@unimib.it
[2] Department of Economics, University of Bergamo, Italy francesco.gaffi@unibg.it

We consider the problem of node clustering in dynamic networks through an invariance-based probabilistic framework grounded on conditional partial exchangeability. Specifically, we extend stochastic block models by allowing community memberships to evolve according to a temporal hierarchy of dependent species-sampling mechanisms. The resulting construction induces a dynamic partition structure that preserves probabilistic coherence with the network data. A spike-and-slab base measure introduces a persistence mechanism that favors the retention of community memberships and connectivity patterns across time. This yields a flexible non-Markovian network-valued process with both node-level and global temporal dependence, acting on both the partition structure and the connectivity patterns. We derive marginal representations of the model and develop efficient sampling algorithms for posterior inference. The generality of the framework and the relaxation of Markovian assumptions allow the model to be studied not only in terms of clustering performance but also for temporal network prediction. Numerical experiments illustrate the inferential and predictive performance of the proposed methodology.

Keywords: Conditional partial exchangeability, Multiple partition models, Bayesian nonparametrics, Stochastic block models.

Contributed Session
CS118: Bayesian nonparametrics for network data organized by Francesco Gaffi

⋆ Presenter

Optimal control of McKean-Vlasov systems under partial observation and hidden Markov switching

Marco Fuhrman[1⋆], Huyên Pham[2], and Silvia Rudà[1]

[1] Dipartmento di Matematica, Università degli Studi di Milano
{marco.fuhrman,silvia.ruda}@unimi.it
[2] CMAP, École Polytechnique, Paris
huyen.pham@polytechnique.edu

We study optimal control problems for a class of dynamical system of McKean–Vlasov type exhibiting mean-field effects, namely where the coefficients also depend on the joint distribution of the state and control. The controlled system is subject to regime switching driven by a hidden Markov chain, so that the problems under consideration are partially observed. The main contribution of this paper is to show how the distribution dependence can be handled within a change-of-probability framework, leading to a well-posed separated control problem. We derive a controlled Zakai equation with a specific structure for the unnormalized filter, and show that the corresponding value function satisfies a dynamic programming principle. This yields a Bellman equation posed on a convex subset of a Wasserstein space, characterizing the optimal control problem under partial observation. The paper is available as arXiv:2601.09311v1.

Keywords: McKean-Vlasov optimal control · partial observation · dynamic programming equation in Wasserstein space.

Contributed Session
CS126: Cooperative and competitive mean-field models - Part II organized by Federico Cannerozzi and Giorgio Ferrari

⋆ Presenter

An optimal transport foundation for a class of dynamically consistent risk measures

Sven Fuhrmann[1], Michael Kupper[1], and Max Nendel[2⋆]

[1] Department of Mathematics and Statistics, University of Konstanz, Germany,
sven.fuhrmann@uni-konstanz.de, kupper@uni-konstanz.de
[2] Department of Statistics and Actuarial Science, University of Waterloo, Canada
mnendel@uwaterloo.ca

In this talk, we study a class of dynamically consistent risk measures that robustify a time-homogeneous Markovian reference model by allowing for distributional uncertainty in its transition laws. We start from one-step convex risk evaluations in which ambiguity is captured by penalized worst-case expectations over alternative transition laws. Imposing time consistency then yields a convex monotone semigroup on bounded continuous payoff functions, and this semigroup represents the associated dynamic risk measure. The semigroup is uniquely characterized by its risk generator. Under a lower bound on the family of penalties in terms of suitable optimal transport costs relative to the reference laws, we identify the generator on smooth test functions. For optimal transport bounds with linear small-time scaling, this produces a first-order, drift-type correction given by a convex Hamiltonian acting on the gradient. Under martingale-transport constraints and a different scaling, however, the leading correction is genuinely of second order and is described by a convex monotone functional acting on the Hessian. We illustrate both regimes for Wasserstein and martingale Wasserstein penalizations and derive explicit formulas via convex conjugates of the underlying transport costs.

Keywords: dynamic risk measure, time consistency, convex monotone semigroup, risk generator, optimal transport

Contributed Session

CS152: Optimal stopping, stochastic control and stochastic games I organized by Alessandro Milazzo, Andrea Bovo, and Tiziano De Angelis

⋆ Presenter

Exchangeable random permutations with an application to Bayesian graph matching

Francesco Gaffi[1⋆], Nathaniel Josephs[2], and Lizhen Lin[3]

[1] Department of Economics, University of Bergamo, Italy
francesco.gaffi@unibg.it
[2] Department of Statistics, North Carolina State University, Raleigh, USA
nathaniel.josephs@ncsu.edu
[3] Department of Mathematics, University of Maryland, College Park, USA
lizhen01@umd.edu

We introduce a general Bayesian framework for graph matching grounded in a new theory of *exchangeable random permutations*. Leveraging the cycle representation of permutations and the literature on exchangeable random partitions, we define, characterize, and study the structural and predictive properties of these probabilistic objects. A novel sequential metaphor, the *position-aware generalized Chinese restaurant process*, provides a constructive foundation for this theory and supports practical algorithmic design. Exchangeable random permutations offer flexible priors for a wide range of inferential problems centered on permutations. As an application, we develop a Bayesian model for graph matching that integrates a correlated stochastic block model with our novel class of priors. The cycle structure of the matching is linked to latent node partitions that explain connectivity patterns, an assumption consistent with the homogeneity requirement underlying the graph matching task itself. Posterior inference is performed through a node-wise blocked Gibbs sampler directly enabled by the proposed sequential construction. To summarize posterior uncertainty, we introduce *perSALSO*, an adaptation of SALSO to the permutation domain that provides principled point estimation and interpretable posterior summaries. Together, these contributions establish a unified probabilistic framework for modeling, inference, and uncertainty quantification over permutations.

Keywords: Bayesian nonparametrics · position-aware generalized Chinese restaurant process · exchangeable permutation probability function · correlated stochastic blockmodel

Contributed Session
CS108: Discrete random structures for Bayesian learning organized by Giovanni Rebaudo

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⋆ Presenter

Anomalous phenomena in the Kraichnan model of turbulence

Lucio Galeati[1⋆], Francesco Grotto[2], Mario Maurelli[3], Theodore D. Drivas[4], and Umberto Pappalettera[5]

[1] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, L'Aquila, Italy
lucio.galeati@univaq.it
[2] Dipartimento di Matematica, Università degli Studi di Pisa, Pisa, Italy
francesco.grotto@unipi.it
[3] Dipartimento di Matematica,, Università degli Studi di Pisa, Pisa, Italy
mario.maurelli@unipi.it
[4] Department of Mathematics, Stony Brook University, Stony Brook, NY, United States
tdrivas@math.stonybrook.edu
[5] Departement Mathematik und Informatik, Universität Basel, Basel, Switzerland
umberto.pappalettera@unibas.ch

In the 60's, Kraichnan proposed a synthetic model for passive scalar turbulence, consisting of a scalar advected by a random Gaussian velocity field, white in time and α-Hölder continuous in space. Despite its simplicity, this SPDE displays anomalous dissipation of energy, spontaneous stochasticity and intermittency, which are also expected for more realistic turbulent fluids. At the same time, solutions to the inviscid SPDE are unique and can be recovered by vanishing viscosity and mollification schemes. In this talk I will present some recent further understandings on this model: i) solutions to the transport equation with L^2 initial data display anomalous regularisation and almost gain Sobolev regularity $H^{1-\alpha}$, but not better (see [1,2]); ii) solutions to the continuity equation starting from Dirac deltas instantaneously gain Lebesgue integrability, due to the diffusive behaviour of Lagrangian particle splitting, and their variance at small times grows like $t^{1/(1-\alpha)}$ (see [2]).

Keywords: Kraichnan model · Anomalous dissipation · Anomalous regularization · Richardson's law

Contributed Session
CS105: Regularisation by noise for SPDEs organized by Carlo Orrieri and Luca Scarpa

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⋆ Presenter

Anomalous Regularization and Dissipation for 2D Euler Equations with Rough Kraichnan Noise

Eliseo Luongo[1*], Lucio Galeati[2], and Umberto Pappalettera[3]

[1] Fakultät für Mathematik, Universität Bielefeld, Bielefeld, Germany
eluongo@math.uni-bielefeld.de
[2] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, L'Aquila, Italy
lucio.galeati@univaq.it
[3] Departement Mathematik und Informatik, Universität Basel, Basel, Switzerland
umberto.pappalettera@unibas.ch

In the 1960s, Robert Kraichnan [1] proposed a synthetic model for passive scalar turbulence, consisting of a scalar advected by a random Gaussian velocity field that is white in time and Hölder continuous in space. Despite its simplicity, this linear SPDE exhibits key features of realistic turbulent flows, such as anomalous dissipation. Renewed interest in this model followed [2], where it was proved that the same transport-type noise restores well-posedness in regimes where the deterministic 2D Euler equations admit non-unique weak solutions.

In this talk, we further develop this line of research by investigating additional properties of the solutions constructed in [2]. In particular, we present new results on anomalous fractional Sobolev regularity and anomalous dissipation of the mean enstrophy for solutions to the 2D Euler equations with rough Kraichnan noise. Time permitting, we will also discuss implications for the well-posedness theory of more singular nonlinear advection models, such as the Surface Quasi-Geostrophic and Incompressible Porous Media equations.

This talk is based on ongoing joint work with L. Galeati and U. Pappalettera.

Keywords: Euler Equations · Anomalous Dissipation · Anomalous Regularization.

Contributed Session
CS104: SPDEs for physical models organized by Benedetta Ferrario and Margherita Zanella

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* Presenter

Non-selection of Lagrangian trajectories in the zero-noise limit

Lucio Galeati[2], Filippo Giovagnini[1⋆], and Massimo Sorella[1]

[1] Department of Mathematics, Imperial College London, UK
{f.giovagnini23, m.sorella}@imperial.ac.uk
[2] Department of Information Engineering, Computer Science and Mathematics, University of L'Aquila, Italy
lucio.galeati@univaq.it

We investigate the vanishing-noise limit for stochastic regularizations of Lagrangian trajectories associated with incompressible velocity fields on the two-dimensional torus. Given a divergence-free drift $u \in C^{\alpha}([0,1] \times \mathbb{T}^2)$ with $\alpha \in (0,1)$, we prove that if X^{κ} is the solution to

$$X_t^{\kappa} = x + \int_0^t u(r, X_r^{\kappa})\, dr + \kappa W_t,$$

where W is either a Brownian Motion, a fractional Brownian motion (fBm) or a Lévy process then X^{κ} does not have a limit when $\kappa \downarrow 0$. As a consequence, we also obtain non-selection phenomena for vanishing (fractional) viscosity limits of the associated transport–diffusion equations, providing explicit examples where stochastic or viscous regularization does not single out a unique inviscid limit.

Keywords: zero-noise limit · regularization by noise · anomalous dissipation · fractional Brownian motion · Lévy processes

Contributed Session

CS171: Methods in stochastic fluid dynamics: a young researchers' perspective organized by Theresa Lange and Lorenzo Marino

⋆ Presenter

Functional PCA for Risk-Neutral densities in Bayes space

Anna Maria Gambaro[1*], Giovanni Amici[2], and Gianluca Fusai[3]

[1] DISEI, University of Piemonte Orientale, Italy,
annamaria.gambaro@uniupo.it
[2] Department of Industrial and Systems Engineering, North Carolina State University
gamici@ncsu.edu
[3] Faculty of Finance, Bayes Business School City St George's, University of London
gianluca.fusai.1@city.ac.uk

Implied volatility (IV) surfaces are well known to exhibit pronounced smiles, skews, and complex term structures that deviate significantly from the assumptions of the Black–Scholes model. Moreover, IV surfaces evolve dynamically over time as market conditions change. Accurately capturing both the cross-sectional features and the temporal dynamics of IV surfaces remains a challenging task. A key requirement for any model is the absence of static arbitrage, which imposes structural constraints on admissible surfaces [1,2]. These constraints further complicate the modeling problem, particularly when only sparse option data across strikes and maturities are available.

Traditional approaches to IV surface construction include spline-based interpolation methods [3], parametric models such as SVI [1] and SABR [4], and nonparametric regression techniques. While effective in certain settings, these methods often rely on restrictive functional assumptions and may introduce arbitrage when calibrated to market data. More recently, machine learning approaches have been proposed to enhance flexibility, either by penalizing arbitrage violations [5] or by embedding no-arbitrage constraints directly into model architectures.

In parallel, functional data analysis (FDA) has emerged as a powerful framework for modeling complex objects such as curves and surfaces [6]. In the context of option markets, [7] model the dynamics of IV surfaces using a functional approach, while [8] apply functional principal component analysis (FPCA) to forecast IV smiles. At the same time, a related strand of literature focuses on the nonparametric estimation of risk-neutral densities (RNDs) from option prices, exploiting the fact that the second derivative of option prices with respect to strike yields the underlying density [9]. Subsequent contributions incorporate shape constraints such as monotonicity and convexity to ensure no-arbitrage conditions [10].

Orthogonal polynomial expansions provide a flexible and theoretically grounded method for approximating density functions [11]. However, classical Gram–Charlier expansions may fail to preserve non-negativity when truncated [12]. Exponential (C-type) expansions overcome this limitation by ensuring positivity and allowing for skewness and heavy tails [13]. Furthermore, recent advances link these expansions to the theory of Bayes Hilbert spaces via the centered log-ratio transformation (CLRT), which maps densities to the space of square-integrable functions [14,15].

In this paper, we propose a novel, fully nonparametric methodology for modeling and forecasting risk-neutral densities and the associated IV smiles. Our approach is characterized by three key features: (i) it avoids parametric assumptions on both densities and volatility surfaces; (ii) it enforces static no-arbitrage conditions by construction; and (iii) it is computationally efficient and suitable for practical implementation. The central idea is to model the dynamics of the risk-neutral density directly, from which IV smiles can be consistently derived.

[*] Presenter

We first reconstruct risk-neutral densities from observed option prices using exponential expansions of orthogonal polynomials, ensuring positivity and flexibility in capturing empirical distributional features. We then apply FPCA methods specifically designed for density-valued data [16,17]. Since densities belong to a constrained space, we employ the centered log-ratio transformation to map them into a Hilbert space, where FPCA can be performed. The resulting components are mapped back via the inverse transformation to obtain valid densities, thereby preserving the no-arbitrage property.

This transformation-based FPCA framework provides a parsimonious representation of the dynamics of risk-neutral densities. The leading functional principal components capture key features such as dispersion, asymmetry, and tail behavior. The temporal evolution of the associated scores can then be modeled using standard time series techniques, enabling the forecasting of arbitrage-free IV smiles.

Empirical results based on historical option data demonstrate the accuracy, robustness, and practical feasibility of the proposed methodology, highlighting its potential for applications in option pricing and risk management.

Keywords: Functional principal component analysis · Risk neutral density· Bayes Hilbert space.

Contributed Session
CS164: Stochastic Processes for Finance organized by Alessandro Mutti and Giuseppe D'Onofrio

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Optimal autonomous trading strategies in models based on Ornstein-Uhlenbeck processes with mean-reverting levels

Pavel V. Gapeev

London School of Economics, Department of Mathematics, Houghton Street, London WC2A 2AE, United Kingdom
p.v.gapeev@lse.ac.uk

We present closed-form solutions to the autonomous trading problems in the model in which the logarithm of dynamics of the asset price is described by the observation process from the extended Kalman-Bucy filtering model with generalised Ornstein-Uhlenbeck processes having mean-reverting levels. One can consider the cases in which the mean-reverting levels are either observable (full information) or unobservable (partial information). The optimal trading times are shown to be the first hitting times of the risky asset price process to either upper or lower either stochastic boundaries depending on the running filtering values (full information) or time-dependent boundaries (partial information). The method of proof consists of embedding the initial problems into optimal double-stopping problems for either two-dimensional time-homogeneous (full information) or one-dimensional time-inhomogeneous (partial information) continuous Markov diffusion processes. The latter are solved as either the equivalent elliptic-type free-boundary problems (full information) or the equivalend parabolic-type free-boundary problems (partial information). We show that the resulting optimal trading boundaries provide unique solutions to the associated systems of nonlinear Fredholm-type integral equations.

Keywords: Optimal autonomous trading strategies · Optimal double-stopping problem · Extended Kalman-Bucy filtering model · Full and partial information · First passage time · Elliptic-type free-boundary problem · Parabolic-type free-boundary problem · A change-of-variable formula with local time on surfaces.

Contributed Session

CS133: Optimal Stopping and Applications organized by Bruno Buonaguidi

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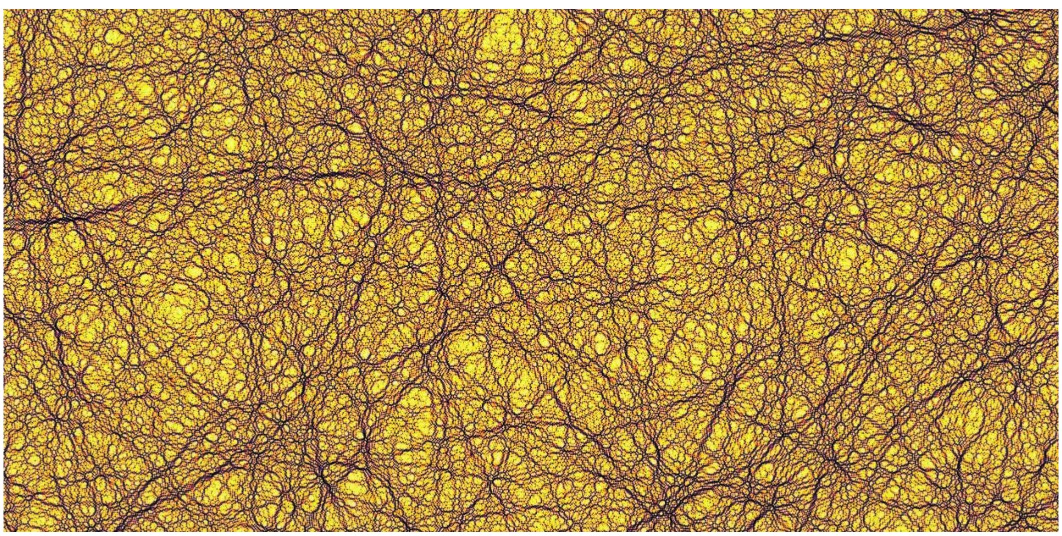
Random scars : overview and recent advances

Louis Gass[1*]; joint work with Giovanni Peccati[2] and Michele Stecconi[2]

[1] University of Luxembourg, Luxembourg,
louis.gass@uni.lu
[2] University of Luxembourg, Luxembourg
giovanni.peccati@uni.lu, michele.stecconi@uni.lu

What happens when multiple randomly translated and rotated copies of a periodic function are superposed? This question was explored visually by American artist Sol LeWitt in a series of works during the second half of the 20th century. Interestingly, the resulting patterns often display "scars": long strands of large-amplitude oscillations. These patterns diverge from the white-noise structure usually displayed by random fields at large scale. Remarkably, similar scar-like structures have been observed in the completely different setting of quantum dynamics, in high-energy eigenfunctions of the Laplace operator on a manifold.

In this talk, I will provide an overview of the phenomenon of (random) scars, highlighting the connection between these seemingly unrelated models, and discuss recent advances that provide statistical evidence for the scar phenomenon, via the analysis of high critical points of the Berry random wave model.



Realization of the Berry random wave model. High values of the field are displayed in dark.

Keywords: Gaussian field · Quantum dynamics · point processes.

Contributed Session
CS170: Advances in the Geometry of Random fields organized by Francesca Pistolato

* Presenter

Exponential Convergence Guarantees for Iterative Markovian Fitting

Marta Gentiloni Silveri

Centre de Mathématiques Appliquées, École Polytechnique, France,
marta.gentiloni-silveri@polytechnique.edu

The Schrödinger Bridge (SB) problem has become a fundamental tool in computational optimal transport and generative modeling. To address this problem, ideal methods such as Iterative Proportional Fitting and Iterative Markovian Fitting (IMF) have been proposed—alongside practical approximations like Diffusion Schrödinger Bridge and its Matching (DSBM) variant. While previous work have established asymptotic convergence guarantees for IMF, a quantitative, nonasymptotic understanding remains unknown. In this talk, I will present the first non-asymptotic exponential convergence guarantees for IMF under mild structural assumptions on the reference measure and marginal distributions, assuming a sufficiently large time horizon. These results encompass two key regimes: one where the marginals are log-concave, and another where they are weakly log-concave. The analysis relies on new contraction results for the Markovian projection operator and paves the way to theoretical guarantees for DSBM. The talk is based on a joint work with Giovanni Conforti and Alain Durmus [1].

Keywords: Generative Models · Convergence Guarantees · Schrödinger Bridge · Markovian Projection.

Contributed Session
CS120: Probabilistic Perspectives on Generative Modeling organized by Antonio Ocello

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Nonparametric Inference for Multivariate and Complex Data Structures

Massimiliano Giacalone[1*], Stefano Cervellera[2], and Carlo Cusatelli[2]

[1] Department of Economics, University of Campania "Luigi Vanvitelli", Italy
massimiliano.giacalone@unicampania.it
[2] Ionian Department, University of Bari "Aldo Moro", Italy
{stefano.cervellera, carlo.cusatelli}@uniba.it

The increasing availability of high-dimensional, heterogeneous, and non-Gaussian data has reinforced the importance of nonparametric inference in modern statistical analysis. In many applied contexts, classical parametric assumptions such as normality, linearity, and homoscedasticity are often violated, potentially leading to biased or misleading conclusions [1]. As a result, rank-based and distribution-free methods have gained renewed attention in the analysis of complex data structures.

This contribution focuses on nonparametric methods for multivariate analysis, with particular emphasis on Spearman's rank correlation coefficient. Using rank differences, the classical expression is

$$\rho_S = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n\,(n^2-1)}, \tag{1}$$

where d_i is the difference between the ranks of two variables for the i-th pair of data, and n is the number of pairs of observations, a robust measure of dependence originally introduced by Spearman [2]. ρ_S captures monotonic relationships by operating on ranked data, making it especially suitable for ordinal variables, skewed distributions, nonlinear associations, and datasets affected by outliers [3]. These features are increasingly common in real-world applications, where strict parametric assumptions are rarely satisfied.

Within multivariate frameworks, ρ_S plays a dual role. First, it provides an interpretable measure of pairwise association that remains stable under deviations from normality. Second, it is an effective diagnostic tool for detecting multicollinearity and near-redundancy among variables, a critical issue in multivariate modeling and variable selection procedures [4]. High rank correlations can be used as thresholds to identify redundant information, improving model parsimony and robustness.

The methodological relevance of ρ_S is illustrated through its application to the analysis of the Italian pension system, a socio-economic system characterized by strong interdependencies between demographic and economic variables. Using official institutional data and a nonparametric correlation-based approach, associations among pension costs, revenue inflows, GDP, employment rates, and retirement indicators are explored without imposing restrictive distributional assumptions. The results reveal extremely strong rank correlations among key economic aggregates, confirming structural dependencies previously highlighted in the literature on pension system sustainability [5,6]. Moreover, the analysis uncovers significant regional heterogeneity across macro-areas, emphasizing the complexity of territorial dynamics.

Beyond descriptive analysis, ρ_S serves as a foundational step for subsequent inferential and forecasting procedures. In particular, it supports informed variable selection prior to the application of time-series models on non-stationary data, enhancing both interpretability and statistical stability.

* Presenter

Massimiliano Giacalone, Stefano Cervellera, and Carlo Cusatelli

Keywords: Ranked data · Skewed distributions · Nonlinear associations.

Contributed Session

CS190: Methodological Issues in Multidimensional and Composite Data Analysis organized by Massimiliano Giacalone and Gianfranco Piscopo

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The Minority Dynamics

George Giakkoupis[1], Dimitrios Los[2], Thomas Sauerwald[3], and Isabella Ziccardi[⋆4]

[1] INRIA Rennes, Rennes, France
george.giakkoupis@inria.fr
[2] Google, London, United Kingdom
mail@dimitrioslos.com
[3] Cambridge University, Cambridge, United Kingdom
thomas.sauerwald@cl.cam.ac.uk
[4] CNRS, IRIF, Paris, France
isabella.ziccardi@irif.fr

Consider n agents labeled $\{1, \ldots, n\}$, each holding an arbitrary initial binary opinion $x_i \in \{0, 1\}$. We study the *minority dynamics*, in which, at each round, each agent i samples k opinions uniformly at random from $\{x_1, \ldots, x_n\}$, and then replaces x_i with the *least common* value among the sampled opinions. The minority dynamics is of interest in computer science and distributed algorithms due to its connection with the *bit-dissemination problem*, which models information spread in biological systems.

This process was previously analyzed in [1], where it was shown that if $k = \Omega(\sqrt{n \log n})$ and $k \leq n/2$, the system converges to a unanimous state (all 0's or all 1's) within $O(\log^2 n)$ rounds with high probability.

In this work, we analyze the minority dynamics for *polylogarithmic sample sizes*, i.e., $k = \Omega(\text{polylog}(n))$, and show that consensus is still reached rapidly, in $O(\text{polylog}(n))$ rounds with high probability. The chaotic and non-monotone nature of the minority dynamics makes its analysis depart significantly from that of previously studied consensus dynamics in similar settings, as it precludes the identification of a natural potential function to measure progress toward consensus.

Keywords: Distributed Algorithms · Randomized Algorithms · Consensus Dynamics

Contributed Session
CS173: Probability for Graph Algorithms organized by Alessandro Straziota and Luca Sciarria

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⋆ Presenter

Cognitive data analysis with Bayesian Drift Diffusion Model

Alice Giampino[1⋆], Sonia Migliorati[1], Joachim Vandekerckhove[2], and Michele Guindani[3]

[1] Department of Economics, Management and Statistics, University of Milano-Bicocca, Italy
{alice.giampino, sonia.migliorati}@unimib.it
[2] Department of Cognitive Science, University of California, Irvine, U.S. joachim@uci.edu
[3] Department of Biostatistics, University of California, Los Angeles, U.S. mguindani@ucla.edu

Understanding latent cognitive processes underlying decision-making and their neural correlates is a central goal in cognitive psychology and neuroscience. Serial reaction time (SRT) tasks provide a valuable framework for studying these processes, as variations in response times and accuracy reflect differences in underlying cognitive and neural mechanisms, ranging from controlled, deliberative processing to more automatic responses. Drift-diffusion models (DDMs) offer a principled computational framework for analyzing such data by modeling decision-making as a process of evidence accumulation toward a response threshold [4,5,2,10]. Key parameters of the DDM, including drift rate, decision threshold, starting point, and non-decision time, provide interpretable measures of cognitive efficiency, response caution, and processing delays. Recent advances have sought to integrate behavioral and neural data, such as electroencephalography (EEG), into DDM frameworks to better characterize brain–behavior relationships [9,8,7]. However, existing approaches typically focus on linking neural features to model parameters without explicitly capturing structured heterogeneity across trials, time, brain regions, or individuals. Moreover, they often neglect the full functional dynamics of neural signals and the role of brain connectivity networks in shaping cognitive processes.

Our work is motivated by the need for flexible and tailored statistical models to analyze neuro-behavioral datasets, such as the publicly available SRT task data examined in [6], which combines behavioral reaction times with simultaneously recorded EEG signals. Recent contributions have advanced Bayesian approaches for drift-diffusion modeling in related contexts. In particular, [3] proposed a semiparametric Bayesian framework for studying tone learning in adults, enabling inference on key decision parameters such as drift rates and decision boundaries. Building on this framework, [1] addressed the problem of recovering latent category structure in the absence of additional labeling information, highlighting the potential of Bayesian methods to uncover hidden cognitive states from behavioral data alone.

We propose hierarchical integrative neuro-behavioral models to study brain–behavior relationships in cognitive processes across multiple dimensions, including trials, time, spatial locations (i.e., ERP-measured brain regions), and participant subgroups. By clustering observations across trials and time, the framework captures the dynamic evolution of cognitive processes, such as learning and attentional changes. Identifying participant subgroups further enables the investigation of variability in cognitive and neural function. To our knowledge, fully Bayesian drift-diffusion models integrating these dimensions within a unified framework have not been previously proposed.

Keywords: Drift-diffusion models · Bayesian hierarchical modeling · Neuro-behavioral data integration

Contributed Session
CS109: Recent Advances in Bayesian Nonparametrics, organized by Beatrice Franzolini

⋆ Alice Giampino

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Bayesian nonparametric inference for covariate-driven point processes

Matteo Giordano[1*] and Patric Dolmeta[1]

ESOMAS Department, University of Turin, Italy,
matteo.giordano@unito.it

A central task in the statistical analysis of spatial point patterns is to infer the relationship between the point distribution and a collection of covariates of interest. This talk will present recent theoretical and methodological advances for covariate-based nonparametric Bayesian intensity estimation. We devise a "multi-bandwidth" Gaussian process method, and prove that it achieves optimal and adaptive posterior contraction rates in observation schemes with replicated observations of the point pattern and the covariates. Our result cover the case of "anisotropic" intensity functions, which is common in applications where the covariates have different physical nature. We further show how posterior inference can be implemented in practice via a suitable Metropolis-within-Gibbs sampling algorithm. Lastly, we will illustrate the performance of the method via numerical simulations, and present an application to a Canadian wildfire dataset. Joint work Patric Dolmeta.

Keywords: Cox process · Gaussian prior · Markov chain Monte Carlo · Inhomogeneous Poisson process · Posterior contraction rates

Contributed Session
CS 101: Statistical methods for complex spatial data analysis organized by Nicoletta D'Angelo and Matteo Giordano

[*] Presenter

On the Markov modulated Poisson process and its application in shock models

Nicola Giordano[1⋆], Barbara Martinucci[2], and Paola Paraggio[2]

Department of Mathematics, University of Salerno, Italy,
{ngiordano,bmartinucci,pparaggio}@unisa.it

The Markov modulated Poisson process (MMPP) extends the classical Poisson process by allowing the arrival intensity to evolve according to an underlying continuous–time Markov chain, thus capturing regime-switching behavior and temporal dependence [2]. We study a 2-state Markov modulated Poisson process N_t and provide explicit expressions for the probability distribution by making use of probability generating function techniques. The analysis relies on representations involving special functions [1]. The limiting and asymptotic behavior of the state probabilities are also analyzed, providing insight into the role of switching intensities and transition rates. In particular, limiting regimes are examined, revealing connections with the standard Poisson process and highlighting structural transitions in the distributional behavior. We address stationary and interval-stationary versions of the process, and introduce time-changed versions of N_t obtained through different subordinators, including Poisson, Gamma, α-stable, and inverse α-stable. For each resulting process, explicit expressions for the moment generating function, mean, and variance are obtained, highlighting how the choice of subordinator affects memory properties and variability. These extensions are consistent with broader Markov-modulated Poisson modeling frameworks [3].

Shock models driven by a MMP process provide a natural and effective framework for applications in which systems accumulate damage or experience failures at rates influenced by an unobservable or fluctuating environmental regime. We investigate both extreme and cumulative shock models driven by N_t, in line with recent developments on shock processes governed by mixed Poisson dynamics [4]. In particular, in the cumulative shock model, system failure is assumed to occur when the total damage produced by successive shocks exceeds a threshold, which is assumed to be either deterministic or exponentially distributed. We provide analytical formulas for the failure rate function, whose monotonic decreasing behavior is discussed, as well as closed-form expressions of the mean and variance of the lifetime distribution.

Keywords: 2-state Markov modulated Poisson process · Cumulative shock model · Extreme shock model · Survival analysis.

Contributed Session
CS151: Stochastic Models and Random Perturbations organized by Verdiana Mustaro

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⋆ Speaker

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Well-posedness results and asymptotic estimates for fractional partial differential equations

Giovanni Girardi[1⋆]

Department of Engineering and Sciences, Mercatorum University, Italy,
giovanni.girardi@unimercatorum.it

In this talk we investigate the asymptotic behavior (as $t \to \infty$) of solutions to some multi-term fractional evolution equations with constant coefficients, employing techniques from Fourier analysis. Furthermore, we provide some insights into the use of pseudo-differential calculus for studying the well-posedness, regularity, and spatial decay ($|x| \to \infty$) of sub-diffusive models featuring variable coefficients.
The presentation is based on results obtained in [1], [2] and [3].

Keywords: Fractional Evolution Equations · Well-posedness · Asymptotic estimates.

Contributed Session
CS141: Fractional Processes and Non-local Operators (Part 2) organized by Federico Polito

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⋆ Presenter

Purification of quantum trajectories in infinite dimensions

Federico Girotti[1⋆] and Alessandro Vitale[1]

Department of Mathematics, Polytechnic University of Milan, Italy,
federico.girotti@polimi.it

Quantum trajectories are Markov processes describing the evolution of quantum systems undergoing repeated indirect measurements. They were first introduced in the study of continuously monitored quantum systems and as useful computational tools in the theory of open quantum systems. When the measurement is perfect, namely when no information flows into the system and all the information leaking from the system is observed, the set of pure states is invariant under the dynamics. A natural question is under which conditions the set of pure states is also attractive, in the sense that the state of the system almost surely tends to "purify" at large times, regardless of the initial state. Besides its intrinsic mathematical interest, there are several motivations for studying purification, which will be briefly discussed in this talk.

In the case of systems with finitely many degrees of freedom, purification is well understood and an insightful characterization was obtained in [1,2,3]: purification occurs unless the dynamics encounters a family of "dark" subspaces, namely subspaces from which no information leaks out. In this talk, we will present the first steps towards understanding purification in infinite-dimensional systems. In particular, we will exhibit a class of models for which purification fails even in the absence of dark subspaces, showing that the finite dimensional characterization no longer holds in full generality in infinite dimensions. We will discuss the mechanism underlying this class of examples and explain that it is representative of all infinite dimensional situations in which purification fails. If time permits, we will conclude by discussing some classes of systems for which the characterization of purification in terms of dark subspaces remains valid even in infinite dimensions.

The presentation is based on [4].

Keywords: Quantum trajectories · Purification · Markov processes · Quantum filtering · Limit theorems.

Contributed Session

CS159: Probabilistic approach to quantum mechanics organized by Federico Girotti and Anderson Melchor Hernandez

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⋆ Presenter

Stochastic McKean-Vlasov dynamics with singular Lennard-Jones drift: a mesoscale regularization

Ernesto M. Greco[1*] and Daniela Morale[1]

Department of Mathematics, University of Milano, Italy,
{ernesto.greco,daniela.morale}@unimi.it

We discuss analytical results at both the micro and macroscale for diffusions in $\mathbb{R}^d$ subject to advection driven by a drift which is strongly singular at the origin, such as the Lennard-Jones force. The Lennard-Jones kernel, characterized by the parameters $(a, b) \in \mathbb{R}^2_+$, with $a > b > 0$, and, $\epsilon, R_0 \in \mathbb{R}_+$ is given by:

$$K(x) = \epsilon \left(\frac{R_0^a}{|x|^{a+1}} - \frac{R_0^b}{|x|^{b+1}} \right) \frac{x}{|x|},$$

This type of force is frequently used in applications to model pairwise interaction of molecules and particles; however, analytical results are not available in the literature.

We briefly examine the local integrability properties of the force by establishing clear relations between the integrability spaces and the free parameters a and b. Then, a more probabilistic argument follows. At the microscale we address the existence of a pathwise unique strong solution to the McKean-Vlasov SDE

$$dX_t = (K * u)(t, X_t)dt + \sqrt{2}dW_t, \quad 0 < t \leq T,$$

where $\mathcal{L}(X_t) \sim u(t, \cdot)dx$. At the macroscale the marginal density of X_t is identified as the mild solution to a corresponding Fokker-Planck PDE. Thus, at the microscale we consider the dynamics of a typical Brownian particle interacting with a mean field that evolves at the macroscale, governed by the associated diffusion-advection PDE. At the microscale we further consider a system of a finite number $N \in \mathbb{N}$ of Brownian particles that pairwise interact at a mesoscale. The link between these different scales is proved by showing the convergence in probability of the empirical particle density associated with the particle system to the unique mild solution of the Fokker–Planck equation. This is achieved via a mesoscale regularization approach of prescribed order $\alpha \in (0, 1)$, under the assumption that particles interact moderately. A law of large numbers is established by restricting the range of the mesoscale in a appropriate way. We discuss the relationship between the mesoscale regularization parameters and the rate of convergence of the law. In particular, we identify suitable functional spaces associated with the order of singularity of the Lennard-Jones force.

Keywords: Interacting particles · Lennard-Jones potential · SDE · mesoscale · singular kernels · mean-field approximation

Contributed Session
CS130: McKean-Vlasov SDEs and associated nonlinear PDEs organized by Daniela Morale and Stefania Ugolini

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* Presenter

Robust Ergodic Singular Control of Compound–Poisson Jump Diffusions under Drift and Intensity Ambiguity

Abel Azze[1], Bernardo D'Auria[2⋆], and Giorgio Ferrari[3]

[1] Department of Quantitative Methods, CUNEF University of Madrid, Spain,
abel.guada@cunef.edu

[2] Department of Mathematics "Tullio Levi Civita", University of Padova, Italy
bernardo.dauria@unipd.it

[3] Center for Mathematical Economics (IMW) Bielefeld University, Germany
giorgio.ferrari@uni-bielefeld.de

We study an ergodic singular stochastic control problem for a one-dimensional compound–Poisson jump diffusion under model ambiguity. Ambiguity affects both the drift and the jump intensity and is modeled via a (κ, λ)-ignorance framework, leading to a robust control problem formulated as a min–max optimization over admissible controls strategies.

We show that the associated robust Hamilton–Jacobi–Bellman equation admits a reduction to a non-ambiguous formulation in which the worst-case drift and jump intensity are of bang-bang type. Under an infinite-horizon average-cost criterion, optimality is characterized by a free-boundary problem with gradient constraints for which we establish a verification theorem.

Focusing on negative and exponentially distributed jump sizes, we obtain a more explicit expression for the bang-bang regions for the drift and the jump intensity. We derive an integro-differential free-boundary problem that can be reduced to piecewise system of ordinary differential equations whose solutions have to satisfy local and global regularity constraints

We propose a two-stage numerical scheme combining closed-form expressions with a root-finding procedure to compute the solution. Numerical experiments illustrate the qualitative effects of ambiguity on the optimal policy and confirm the analytical findings.

The associate paper is still in preparation, it will be soon available on arXiv.

Keywords: Ergodic singular control · Jump–diffusion processes · Robust control · Ambiguity.

Contributed Session
CS153: Optimal stopping, stochastic control and stochastic games II organized by Andrea Bovo and Alessandro Milazzo

⋆ Presenter

The Volterra signature

Christa Cuchiero[1], Paul P. Hager[1], Fabian N. Harang[2], Luca Pelizzari[1*], and Samy Tindel[3]

[1] University of Vienna, Vienna, Austria
luca.pelizzari@univie.ac.at
[2] BI Norwegian Business School, Oslo, Norway
[3] Purdue University, West Lafayette, USA

In this talk, we introduce the Volterra signature – an extension of Chen's path signature [1] that incorporates memory kernels in a principled way. Formally, it is defined as the collection of iterated integrals arising from Picard expansions of linear controlled/stochastic Volterra equations, and thus plays the role of the resolvent associated with such equations. The additional flexibility provided by the kernel yields a powerful, memory-aware feature map for machine-learning applications to path and time-series data. In the first part of the talk, we leverage analytic and algebraic properties to prove learning-theoretic results, including universal approximation theorems for continuous functionals on path spaces and PDE-based kernel tricks for the associated reproducing kernel Hilbert space (RKHS). Moreover, to exploit these learning guarantees, we develop practical algorithms to compute Volterra signatures for time series across a broad class of kernels, relying on the fundamental Volterra–Chen relation. Finally, we present first applications on synthetic and real data, showing promising performance in learning tasks with complex memory dependence. This first part is based on the two papers [2,3]. In the second part, if time permits, we discuss ongoing research on stochastic Volterra signatures, including explicit expected signature formulas, stochastic Taylor expansions, and Wong–Zakai type of approximations.

Keywords: Signatures · stochastic Volterra equations · machine learning · rough paths

Contributed Session
CS157: Recent Advances in Stochastic Volterra Equations organized by Sergio Pulido.

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* Presenter

Approximation of Diffusion Exit Times from Bounded Domains via a Rejection-Based Random Walk

Madalina Deaconu[1] and Samuel Herrmann[2*]

[1] Université de Lorraine, CNRS, Inria, IECL, F-54000 Nancy, France,
Madalina.Deaconu@inria.fr
[2] Université Bourgogne Europe, CNRS, IMB UMR 5584, 21000 Dijon, France
Samuel.Herrmann@ube.fr

First exit times of stochastic processes are fundamental in many applications. In mathematical finance, they are used to quantify default risk in path-dependent derivatives; in neuroscience, they describe interspike interval distributions. Diffusion processes, as solutions of stochastic differential equations, form a central class of models, making the accurate approximation of their exit times a problem of broad interest.

We consider the multidimensional setting and study the numerical approximation of the first exit time $\tau_{\mathcal{D}}$ of a d-dimensional diffusion process $(X_t)_{t\geq 0}$ from a bounded, regular domain $\mathcal{D}$. The process satisfies

$$dX_t = \nabla\mathcal{U}(X_t, t), dt + dB_t, \qquad X_0 \in \mathcal{D},$$

where (B_t) is a d-dimensional Brownian motion and the drift term may depend on both space and time. Our objective is to design an efficient alternative to the classical Euler scheme, which requires small time steps to ensure accuracy near the boundary.

In the Brownian case, the Random Walk on Spheres (WOS) algorithm exploits isotropy to perform large spatial jumps, leading to a mean number of steps proportional to $|\log(\varepsilon)|$, where ε is the boundary layer parameter. Extensions based on spheroids allow the joint approximation of exit position and exit time.

We generalize this approach to multidimensional diffusion processes with drift. The proposed method relies on an acceptance–rejection procedure applied to random walk trajectories and introduces truncated spheroids to account for nonzero drift. This construction preserves the efficiency of large spatial displacements while incorporating the effect of the drift term. The performance of the algorithm is supported by theoretical results and illustrated through numerical experiments.

Keywords: Exit problem · Diffusion process · Rejection sampling

Contributed Session
CS138: First Passage Times: theory and simulations organized by Serena Spina and Cristina Zucca

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[*] Presenter

Modified logarithmic Sobolev inequalities for point processes

Ronan Herry

Université de Rennes
ronan.herry@univ-rennes.fr

Modified logarithmic Sobolev inequalities characterise exponential speed of convergence to equilibrium for Markov processes. In this talk, I will show how to derive such inequalities for point processes, beyond the Poisson case. Our approach relies on (non-optimal) transport maps from Poisson to the target process, and yields sufficient condition in the spirit of the celebrated Bakry–Émery criterion on manifolds.

Joint work with Baptiste Huguet and Pablo López Rivera.

Contributed Session

CS156: Point processes in the continuum organized by Lorenzo Dello Schiavo and Alexander Zass

Learning Interaction Networks for High-Dimensional Diffusion Processes

Francesco Iafrate[1⋆]

Department of Mathematics, University of Hamburg, Germany,
francesco.iafrate@uni-hamburg.de

We consider the setting where the state dynamics at each node in a network depend on interactions with its neighbors. We model this using the general framework of Network Stochastic Differential Equations (N-SDEs). The evolution at each node arises from three components: intrinsic dynamics (a momentum term), feedback from adjacent nodes (a network term), and a stochastic volatility component driven by Brownian motion. Our goals are twofold: parameter estimation for N-SDE systems and recovery of the underlying graph. The main motivation is to handle very high-dimensional time series by exploiting sparsity in the network structure. We study two settings. i) Known network structure: the graph is given, and we provide identifiability conditions for the parameters, accounting for the fact that the parameter dimension grows with the number of edges. ii) Unknown network structure: the graph must be learned from data; for this case, we propose an iterative procedure based on adaptive Lasso, developed for a particular class of N-SDE models. We focus on oriented graphs, which supports applications to causal inference by allowing the investigation of directed cause–effect relationships in dynamical systems. Using simulations and real data, we illustrate the performance of the proposed estimators across several graph topologies in high-dimensional regimes. We establish non-asymptotic bounds for parametric estimation when the system dimension is large, in two observation schemes: (1) high-frequency data from an ergodic diffusion, and (2) continuous observation in a small-diffusion, not necessarily ergodic, setting. Based on joint works with S.M. Iacus and N. Yoshida.

Keywords: graph recovery · identifiability conditions · adaptive Lasso regularization.

Contributed Session
CS117: Statistical inference for high-dimensional diffusions organized by Chiara Amorino

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⋆ Presenter

The moment problem beyond finite dimensions

Maria Infusino[1]*, Salma Kuhlmann[2], Tobias Kuna[3], and Patrick Michalski[2]

[1] Department of Mathematics and Computer Science, University of Cagliari, Cagliari, Italy
maria.infusino@unica.it

[2] Department of Mathematics and Statistics, University of Konstanz, Germany
salma.kuhlmann@uni-konstanz.de, patrick.michalski@uni-konstanz.de

[3] Department of Information Engineering, Computer Science and Mathematics, University of L'Aquila, Italy tobias.kuna@univaq.it

In this talk we present a new approach to the following general instance of infinite dimensional moment problem: when can a linear functional on an infinitely generated algebra A be represented as an integral with respect to a Radon measure on the space $X(A)$ of all characters of A?

Our approach is based on projective limit techniques, which allow us to exploit the results for the classical finite dimensional moment problem in the infinite dimensional case. In fact, we prove that under the so-called Prokhorov condition, the infinite dimensional moment problem on A is solvable if and only if for any finitely generated subalgebra S of A the corresponding finite dimensional moment problem is solvable.

Among other applications, we present a new characterization of all linear functionals L on A representable as an integral w.r.t. a compactly supported Radon measure solely in terms of a growth condition on L, that permits to exactly identify the compact support. This is particularly surprising as the other characterizations available in the literature only show that the support of the representing Radon measure is contained in a compact set and so do not provide exact support descriptions.

Keywords: moment problem · projective limit · Prokhorov's condition · compact support.

Contributed Session

CS103: Moments, Cumulants and dependence: Classical and Modern Perspectives organized by Elvira Di Nardo

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* Presenter

Minimal shapes on the hyperbolic lattices and the emergence of metastability

Vanessa Jacquier[1]

Department of Mathematics, University of Padova, Italy,
vanessa.jacquier@unipd.it

We investigate geometric and dynamical aspects of hyperbolic lattices arising from regular tilings with 1/p+1/q<1/2. We first characterize finite shapes with minimal perimeter and show that the ratio of perimeter to volume converges to the isoperimetric constant. We also construct a family of regular layered balls that achieve this constant for any fixed volume. We then study the Ising model on finite subgraphs with minus boundary conditions and a positive external field h. For a suitable range of h, we prove the presence of metastable behavior, identify the metastable state, and characterize the exit time. Finally, we describe the energy landscape and analyze the nucleation mechanism for all positive values of h, including beyond the metastable regime.

Keywords: Ising model · hyperbolic lattice · metastability · Glauber dynamics · Cheeger constant · large deviations.

Contributed Session
CS 167: Dynamics and phase transitions on discrete structures organized by Vanessa Jacquier and Giacomo Passuello

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Exponential integrability of the solution and the invariant measure to the stochastic Burgers equation

Josef Janák

Department of Mathematics, University of Pavia, Italy,
josefjanak@seznam.cz

We consider the one-dimensional stochastic Burgers equation driven by a "rougher" space-time white noise

$$\begin{cases} dX(t) &= \Delta X(t)\,dt + \frac{1}{2}\partial_\xi \left(X^2(t)\right)\,dt + (-\Delta)^\gamma\,dW(t), \\ X(0) &= x, \\ X(t)|_{\partial\Lambda} &= 0, \quad 0 < t \le T, \end{cases} \tag{1}$$

on the finite time interval $[0,T]$. The driving process W is a cylindrical Brownian motion with values in $L^2(\Lambda)$, where $\Lambda = (0,1)$. The operator Δ is the Laplacian operator on Λ with Dirichlet boundary conditions. We consider a deterministic initial condition $x \in L^2(\Lambda)$ and $\gamma \in [0,1/4)$.

The stochastic Burgers equation stands an important role in fluid dynamics and has been studied by several authors. We mainly refer to the works [3], [4], [5] and [1], where the existence and uniqueness of the global solution as well as the existence and uniqueness of the invariant measure have been established in the "classical" case $\gamma = 0$. The polynomial moment estimates of the solution have been proven in the case $\gamma = 0$ in [2].

In our work we generalize the results of [2] for $\gamma \in [0,1/4)$ and we improve the polynomial moment estimates to the exponential moment estimates.

In the second part of our talk we establish the existence and uniqueness of the invariant measure to our system (1) and we also show its exponential integrability.

Keywords: Stochastic Burgers equation · Exponential integrability · Invariant measure.

Contributed Session

CS115: Stochastic partial differential equations and invariant measures organized by Davide Augusto Bignamini

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The bead model and the macroscopic behaviour of Gelfand-Tsetlin patterns

Samuel G. G. Johnston[1*] and Joscha Prochno[2]

[1] Department of Mathematics, King's College London, United Kingdom
samuel.g.johnston@kcl.ac.uk
[2] Department of Mathematics, University of Passau, Germany
joscha.prochno@uni-passau.de

Consider the semi-discrete torus $T_n = [0,1) \times \{0,1,\ldots,n-1\}$, representing unit-length strings running in parallel. A bead configuration on T_n is a point process on T_n with the property that between every two consecutive points on the same string, there lies a point on each of the neighbouring strings. In [2], we develop a continuous version of Kasteleyn theory to show that partition functions for bead configurations on T_n may be expressed in terms of Fredholm determinants of certain operators on T_n. We obtain an explicit formula for the volumes of bead configurations on T_n, and show that the asymptotic correlations match those obtained by Boutillier [1].

The asymptotics of the volume formula confirm a recent prediction due to Shlyakhtenko and Tao [4] in the free probability literature. We use these asymptotics to prove a large deviation principle for the macroscopic shape of Gelfand–Tsetlin patterns [3].

Keywords: Bead model · Kasteleyn theory · Gelfand-Tsetlin pattern · Surface tension · Free probability · Exclusion process

Contributed Session

CS107: Combinatorial Structures in Probability and Mathematical Physics organized by Fabio Deelan Cunden

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* Presenter

Nested stochastic block model for simultaneously clustering networks and nodes

Nathaniel Josephs[1*], Arash A. Amini[2], Marina Paez[3], and Lizhen Lin[4]

[1] Department of Statistics, North Carolina State University
nathaniel.josephs@ncsu.edu
[2] Department of Statistics, UCLA
aaamini@ucla.edu
[3] Department of Statistical Methods, Federal University of Rio de Janeiro
marina@im.ufrj.br
[4] Department of Mathematics, University of Maryland
lizhen01@umd.edu

We introduce the nested stochastic block model (NSBM) to cluster a collection of networks while simultaneously detecting communities within each network. NSBM has several appealing features including the ability to work on unlabeled networks with potentially different node sets, the flexibility to model heterogeneous communities, and the means to automatically select the number of classes for the networks and the number of communities within each network. This is accomplished via a Bayesian model, with a novel application of the nested Dirichlet process (NDP) as a prior to jointly model the between-network and within-network clusters. The dependency introduced by the network data creates nontrivial challenges for the NDP, especially in the development of efficient samplers. For posterior inference, we propose several Markov chain Monte Carlo algorithms including a standard Gibbs sampler, a collapsed Gibbs sampler, and two blocked Gibbs samplers that ultimately return two levels of clustering labels from both within and across the networks. Extensive simulation studies are carried out which demonstrate that the model provides very accurate estimates of both levels of the clustering structure. We also apply our model to two social network datasets that cannot be analyzed using any previous method in the literature due to the anonymity of the nodes and the varying number of nodes in each network.

Keywords: Bayesian nonparametrics · position-aware generalized Chinese restaurant process · exchangeable permutation probability function · correlated stochastic blockmodel

Contributed Session
CS118: Bayesian nonparametrics for network data organized by Francesco Gaffi

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* Presenter

Two-sample test for laws of random probabilities via optimal transport

George Kanchaveli[1]*, Marta Catalano[2], and Hugo Lavenant[1]

[1] Department of Decision Sciences, Bocconi University, Italy,
george.kanchaveli@phd.unibocconi.it
hugo.lavenant@unibocconi.it

[2] Department of AI, Data and Decision Science, Luiss University, Italy
mcatalano@luiss.it

Two-sample testing assesses whether two populations differ by comparing their probability distributions, with the Kolmogorov–Smirnov test as a classic example. While numerous extensions address multivariate data, modern applications increasingly involve complex objects such as probability distributions themselves. This leads to the problem of testing the equality of laws of random probability measures. We propose a distance-based two-sample test for distinguishing laws of random probability measures using optimal transport theory, and leverage tools from empirical process theory to establish nonparametric theoretical guarantees. Empirically, we benchmark our method against existing approaches on simulated datasets and apply it to a mortality dataset.

Keywords: Two-sample test · Hierarchical sample · Integral Probability Metrics · Optimal transport · Donsker classes.

Contributed Session

CS143: Optimal Transport Methods for Statistics organized by Marta Catalano and Hugo Lavenant

* Presenter

Generalized Fractional Derivative Operators and Fractional Diffusion Equations Connected to Semistable Lévy Processes

Peter Kern[1*], Svenja Lage[1], and Mark M. Meerschaert[2]

[1] Mathematical Institute, Heinrich Heine University Düsseldorf, Germany,
kern@hhu.de, Svenja.Lage@uni-duesseldorf.de
[2] Department of Statistics and Probability, Michigan State University, East Lansing, USA
mcubed@stt.msu.edu

We focus on semistable Lévy processes that appear as limits of normalized sums of iid random variables when the sample size grows geometrically instead of linearly. This generalizes the class of stable Lévy processes in having a weaker scaling property such that the power law behavior of the tail of the Lévy measure can additionally be disturbed by a log-periodic function. The probability density functions of semistable Lévy processes solve a space-fractional diffusion equation, where the fractional derivative of Marchaud-Weyl form can be represented by a Grünwald-Letnikov type formula by using a Fourier series approach for the periodic perturbations [3]. A solution to the corresponding time-fractional differential equation can be given by the densities of an inverse semistable subordinator and is connected to the space-fractional equation by Zolotarev duality [1]. The time-fractional operator of Caputo type is intimately connected to self-similar Bernstein functions [2] and can be seen as a generalized fractional derivative in the sense of Kochubei [4]. These space-fractional and time-fractional processes and also their composition as a space-time-fractional solution serve as models for anomalous diffusion with log-periodic perturbations and appear as limits of certain continuous-time random walks.

Keywords: Semistable Lévy processes · Semi-fractional derivatives and diffusion equations · log-periodic perturbation · Zolotarev duality · Self-similar Bernstein functions.

Contributed Session
CS141: Fractional Processes and Non-local Operators (Part 2) organized by Federico Polito

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* Presenter

When investors force the green transition: a two-dimensional singular stochastic control problem

Omar Khattab[1]⋆, Peter Tankov[1], and Tiziano De Angelis[2]

[1] CREST, ENSAE, France,
omar.khattab@ensae.fr peter.tankov@ensae.fr
[2] School of Management and Economics, University of Turin, Italy
tiziano.deangelis@unito.it

Traditional corporate compensation schemes inherently discourage sustainable operations, as managerial incentives remain strictly aligned with financial returns rather than environmental outcomes. However, when a firm is backed by a fully informed "green" investor, this misalignment can be overcome. Building on the framework introduced in [1], we investigate the first-best benchmark of this principal-agent interaction. In our setting, the investor can perfectly deduce the manager's actions and threatens heavy penalties for any deviation from the socially optimal policy. Under this threat, the investor effectively acts as a social planner, directly implementing the optimal greening and investment strategies. We formulate this benchmark as a two-dimensional singular optimal control problem. The firm's state is primarily characterized by its production capacity, X, alongside the accumulated abatement effort, R. The investor controls the firm's dynamics through two forces: injecting external capital (ν) when production capacity is deemed too low, and enforcing abatement (η). Crucially, abatement operates through a pure substitution effect—the cost of greening is fully internalized as a direct reduction in the production capacity X.
In this talk, we formalize the principal's optimization criterion as a two-dimensional singular stochastic control problem and analyze the properties of the value function via its associated Hamilton-Jacobi-Bellman variational inequality. The core mathematical challenge arises from the interplay between a degenerate diffusion and an oblique reflection driven by the substitution effect. By exploiting the optimal policies derived under a deterministic setting, we explore the geometry of the free boundaries that partition the state space into continuation and action regions. Our preliminary results reveal that the optimal intervention takes the form of a Skorokhod-type reflection along moving boundaries, which are monotonically increasing with respect to the firm's accumulated abatement effort.

Keywords: Singular control · HJB equations · Reversible investment.

Contributed Session
CS153: Optimal Stopping, Stochastic Control and Stochastic Games II organized by Andrea Bovo and Alessandro Milazzo

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⋆ Presenter

Sampling error bounds for the denoising diffusion probabilistic model via the Föllmer process

Yuta Koike[1]⋆

Graduate School of Mathematical Sciences, University of Tokyo, Japan
kyuta@ms.u-tokyo.ac.jp

The Föllmer process is a Brownian motion conditioned to have a pre-specified law at time 1. This process can be interpreted as an "augmented" time-compression of the reverse stochastic differential equation (SDE) corresponding to the denoising diffusion probabilistic model (DDPM). While this fact has been indirectly used to analyze DDPM sampling errors via discretization of the reverse SDE, implications of directly discretizing the Föllmer process have not yet been fully explored. This talk aims to clarify these implications while surveying relevant results from existing work.

Keywords: Discretization · Score-based generative modeling · Stochastic localization.

Contributed Session
CS142: Diffusion Processes in Machine Learning organized by Francesco Iafrate and Alessandro Degregorio

⋆ Presenter

Anomalous regularization for the non-smooth Kraichnan and Kazantsev-Kraichnan models on the torus

Sotirios Kotitsas[1⋆], Lucio Galeati[2], and Mario Maurelli[3]

[1] Department of Mathematics, EPFL, Lausanne, Switzerland,
sotirios.kotitsas@epfl.ch
[2] Department of Engineering, Information Technology and Mathematics, University of L'Aquila, L'Aquila, Italy
lucio.galeati@univaq.it
[3] Department of Mathematics, University of Pisa, Pisa, Italy,
mario.maurelli@unipi.it

We examine Kraichnan's passive scalar model on the d-dimensional torus. On $\mathbb{R}^d$, this model exhibits anomalous dissipation and anomalous regularization. We establish that the model on the torus enjoys a similar anomalous regularization property. The added difficulty in this setting is the absence of translation invariance, and to get around this, we use a scheme relying on an expansion of the correlation function of the driving noise. We establish a similar result for the Kazantsev-Kraichnan model on the torus. Based on joint work with Lucio Galeati and Mario Maurelli.

Keywords: stochastic transport equation · anomalous regularization · anomalous dissipation · regularization by noise.

Contributed Session
CS137: Stochastic Models in Fluid Dynamics organized by Federico Butori and Yassine Tahraoui

⋆ Presenter

Theoretical guarantees for diffusion models — beyond log-concavity

Gitte Kremling*, Francesco Iafrate, Mahsa Taheri, and Johannes Lederer

Department of Mathematics, University of Hamburg, Germany,
{gitte.kremling,francesco.iafrate,mahsa.taheri,johannes.lederer}@uni-hamburg.de

Score-based generative modeling, implemented through probability flow ODEs, has shown impressive results in numerous practical settings. However, most convergence guarantees rely on restrictive regularity assumptions on the target distribution—such as strong log-concavity or bounded support. This work establishes non-asymptotic convergence bounds in the 2-Wasserstein distance for a general class of probability flow ODEs under considerably weaker assumptions: weak log-concavity and Lipschitz continuity of the score function. Our framework accommodates non-log-concave distributions, such as Gaussian mixtures, and explicitly accounts for initialization errors, score approximation errors, and effects of discretization via an exponential integrator scheme.

Bridging a key theoretical challenge in diffusion-based generative modeling, our results extend convergence theory to more realistic data distributions and practical ODE solvers. We provide concrete guarantees for the efficiency and correctness of the sampling algorithm, complementing the empirical success of diffusion models with rigorous theory. Moreover, from a practical perspective, our explicit rates might be helpful in choosing hyperparameters, such as the step size in the discretization.

Keywords: Score-based generative modeling · Diffusion models · Convergence analysis · Wasserstein distance.

Contributed Session
CS142: Diffusion Processes in Machine Learning organized by Francesco Iafrate and Alessandro De Gregorio

* Presenter

Measuring Financial Resilience Using Backward Stochastic Differential Equations

Roger J. A. Laeven[1], Matteo Ferrari[2⋆], Emanuela Rosazza Gianin[3], and Marco Zullino[4]

[1] Dept. of Quantitative Economics, University of Amsterdam, CentER and EURANDOM, The Netherlands,
R.J.A.Laeven@uva.nl
[2] Dept. of Quantitative Economics, University of Amsterdam, The Netherlands,
M.Ferrari@uva.nl
[3] Dept. of Statistics and Quantitative Methods, University of Milano-Bicocca, Italy,
emanuela.rosazza1@unimib.it
[4] Dept. of Mathematics and Applications, University of Milano-Bicocca, Italy,
M.Zullino@campus.unimib.it

We introduce the *resilience rate* as a measure of financial resilience. It captures the expected rate at which a dynamic risk measure recovers, i.e., bounces back, when the risk-acceptance set is breached. We develop the corresponding stochastic calculus by establishing representation theorems for expected time-derivatives of solutions to backward stochastic differential equations (BSDEs) with jumps, evaluated at stopping times. These results reveal that the resilience rate can be represented as a suitable expectation of the generator of a BSDE. We analyze the main properties of the resilience rate and the formal connection of these properties to the BSDE generator. We also introduce resilience-acceptance sets and study their properties in relation to both the resilience rate and the dynamic risk measure. We illustrate our results in several canonical financial examples and highlight their implications via the notion of resilience neutrality.

Keywords: Financial resilience · Bouncing drift· Backward Stochastic Differential Equations· Generator· Stopping time· Dynamic risk measures· Acceptance sets.

Contributed Session
CS110: "Risk measures: static and dynamic aspects" organized by Elisa Mastrogiacomo and Emanuela Rosazza Gianin.

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⋆ Presenter

Transport noise in natural convection

Theresa Lange[1*], Franco Flandoli[1], and Camilla Nobili[2]

[1] Scuola Normale Superiore di Pisa, Piazza dei Cavalieri 7, 56126 Pisa, Italy
{theresa.lange,franco-flandoli}@sns.it
[2] School of Mathematics and Physics, University of Surrey, Guildford, Surrey GU2 7HX, UK
c.nobili@surrey.ac.uk

Noise of transport type enjoys high popularity in stochastic fluid dynamics for its modelling abilities and regularising properties. In this talk, we will explore it in the context of natural convection: a fluid confined between two horizontally aligned plates will be heated from below and cooled from above. At a high temperature difference at the boundaries, the fluid will be turbulent and it is a longstanding challenge in physics and engineering to characterise the average heat flux (the Nusselt number Nu) in terms of said temperature difference. In the mathematical literature various results in this direction have been obtained in the form of upper bounds on Nu confirming physicists' predictions. In this talk, I will present a novel viewpoint on a treatment of this problem via stochastic parametrisation: informed by the evolution equations of convection, the stochastic velocity field acts as a transport noise on the temperature and provides a physically relevant upper bound for Nu.

Keywords: Transport noise · Stochastic fluid dynamics · Nusselt number

Contributed Session
CS105: Regularisation by noise for SPDEs
organized by Carlo Orrieri and Luca Scarpa

* Presenter

Noise induced stabilization in stochastic chemical reaction network

Lucie Laurence[1*] and Andrea Agazzi[1]

[1] IMSV, University of Bern, Switzerland,
lucie.laurence@unibe.ch
[2] andrea.agazzi@unibe.ch

Chemical reaction networks (CRNs) are commonly analyzed through deterministic or stochastic models that track molecular populations over time. In regimes with large molecule counts, stochastic dynamics are typically approximated by deterministic mass-action kinetics. We present a CRN that defies this expectation: while the deterministic system is unstable, exhibiting finite-time blow-up of trajectories within the interior of the state space, its stochastic counterpart is positive recurrent.

Keywords: Continuous time Markov chains · Chemical reaction networks · Lyapunov criterion.

Contributed Session
CS163: Stochastic chemical reaction network dynamics organized by Daniele Cappelletti and Lucie Laurence

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* Presenter

Approximate Bayesian computation with kernel Wasserstein distance

Sirio Legramanti[1*] and Marta Catalano[2]

[1] Department of Economics, University of Bergamo, Bergamo, Italy,
sirio.legramanti@unibg.it
[2] Department of AI, Data and Decision Sciences, Luiss University, Rome, Italy
mcatalano@luiss.it

Approximate Bayesian Computation (ABC) is a family of methods that allow sampling from an approximate posterior even when the likelihood is intractable, provided one can simulate from the model and quantify the discrepancy between simulated and observed data. While this discrepancy has traditionally been defined through summary statistics, recent developments in ABC leverage distances between empirical distributions, with the Wasserstein distance emerging as an interpretable and principled choice. However, it has been shown that Wasserstein ABC can be highly sensitive to outlier contamination. We identify that this sensitivity arises from the choice of the cost function rather than from the Wasserstein distance itself. We then propose to replace the usual Euclidean cost with a kernel-based cost, leading to a kernel Wasserstein distance that substantially enhances robustness while preserving ABC posterior concentration under broad conditions. This provides a flexible and theoretically grounded alternative to classical Wasserstein ABC.

Keywords: Approximate Bayesian Computation, Kernel Methods, Wasserstein distance

Contributed Session
CS147: Kernel methods in Bayesian statistics organized by Marta Catalano and Hugo Lavenant

* Presenter

Pinning polymer model in correlated random environment

Alexandre Legrand

Dipartimento di Matimatica Tullio Levi-Civita, Università di Padova, Italy,
legrand@math.unipd.it

We are interested in the *random pinning model*, which depicts a physical system made of a polymer chain interacting attractively with a defect line. The model undergoes a *phase transition* as the strength of the interaction increases, from a *delocalized* regime where the polymer touches the defect line finitely many times, to a *localized* regime where the number of contact points is proportional to the length of the chain. This phase transition has been extensively studied in the case where the interactions between the sequence of monomers and the line are homogeneous, or when they are given by a random i.i.d. sequence called the disorder or the *environment*. In this work we are interested in the case where the environment is not independent, but on the contrary displays long-range correlations. In this talk we focus on the localized regime and discuss several quantities such as the length of the longest loop between successive contact points, or the asymptotics of the total number of contacts.

Keywords: Polymer model · Phase transition · Correlated environment.

Contributed Session
CS178: Disordered systems in statistical mechanics organized by Alberto Chiarini

Asymptotic and empirical properties of some classes of predictive distribution

Fabrizio Leisen[1⋆], Samuele Garelli[2], Luca Pratelli[3], and Pietro Rigo[4]

[1] Department of Mathematics, King's College, Strand WC2R 2LS, London, United Kingdom,
fabrizio.leisen@kcl.ac.uk
[2] Dipartimento di Scienze Statistiche "P. Fortunati", Universit'a di Bologna, via delle Belle Arti 41, 40126 Bologna, Italy,
samuele.garelli2@unibo.it
[3] Accademia Navale di Livorno, viale Italia 72, 57100 Livorno, Italy
luca.pratelli@icloud.com
[4] Dipartimento di Scienze Statistiche "P. Fortunati", Universit'a di Bologna, via delle Belle Arti 41, 40126 Bologna, Italy,
pietro.rigo@unibo.it

This talk will focus on introducing new classes of predictive distributions which make use of sample quantities. Theoretical properties of these models will be discussed and compared with a recent proposal based on copulas. We will show some illustrations of their use in the context of predictive resampling.

Keywords: Bayesian predictive inference · Conditional identity in distribution · Convergence of probability measures · Predictive distribution, Predictive resampling · Total variation distance

Contributed Session
CS155: Asymptotic results for predictive distributions organized by Lorenzo Cappello

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⋆ Presenter

Intermediate Interactions in Particle Systems: Applications to Fluid Dynamics and Biological Modeling

Marta Leocata[1⋆]

Luiss Guido Carli University,
mleocata@luiss.it

This talk will provide an overview of intermediate interactions in particle systems and their applications to fluid dynamics and biological modeling. The discussion will begin with an introduction to scaling limits, highlighting the distinctions between Mean Field, local, and intermediate interaction cases, which serve as bridges between microscopic particle dynamics and macroscopic PDE formulations. Next, I will explore two applications of this type of interaction: a microscopic approach to the Vlasov-Fokker-Planck-Navier-Stokes equations, which model particle-fluid interactions, and a PDE model for cell-cell adhesion, with a focus on biological aggregation phenomena. The main results will illustrate the convergence properties of empirical measures, achieved through energy estimates and tightness conditions, while addressing challenges in particle-fluid coupling and stochastic modeling. Finally, I will conclude with a discussion of open questions, particularly those related to the problem of fluctuations.

Keywords: Interacting particle systems · Mean-Field, · Intermediate Interaction · Vlasov-Navier-Stokes

Contributed Session
CS130: McKean-Vlasov SDEs and associated nonlinear PDEs organized by Daniela Morale and Stefania Ugolini

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⋆ Presenter

Understanding the Quality of the Environment: Act local, Think Global?

Marta Leocata[1*]

Luiss Guido Carli University,
mleocata@luiss.it

This talk will provide an overview of intermediate interactions in particle systems and their applications to fluid dynamics and biological modeling. The discussion will begin with an introduction to scaling limits, highlighting the distinctions between Mean Field, local, and intermediate interaction cases, which serve as bridges between microscopic particle dynamics and macroscopic PDE formulations. Next, I will explore two applications of this type of interaction: a microscopic approach to the Vlasov-Fokker-Planck-Navier-Stokes equations, which model particle-fluid interactions, and a PDE model for cell-cell adhesion, with a focus on biological aggregation phenomena. The main results will illustrate the convergence properties of empirical measures, achieved through energy estimates and tightness conditions, while addressing challenges in particle-fluid coupling and stochastic modeling. Finally, I will conclude with a discussion of open questions, particularly those related to the problem of fluctuations.

Keywords: Environmental asset · Optimal control · N-players game, Social Planner· Pigouvian tax· Mean field game

Contributed Session
CS135: Stochastic Systems, Mean-Field Models, and Control organized by Confortola Fulvia and Guatteri Giuseppina

References

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[*] Presenter

Entropic Regularization of Rearranged Stochastic Heat Equation

Rhoss Likibi Pellat[1*] and Francois Delarue[1]

Laboratoire J.A.Dieudonné, Université Côte d'Azur, Nice, France
rhoss.likibi-pellat@univ-cotedazur.fr
francoisdelarue@univ-cotedazur.fr

We extend a previously introduced one-dimensional diffusion model on probability measures, defined via the rearranged stochastic heat equation, by penalizing the dynamics with an additional entropy-driven gradient-descent term. By means of a splitting argument, we prove that despite the opposite effects of rearrangement and entropy minimization, the resulting penalized stochastic heat equation is well defined. We study several properties of the associated dynamics and show, in particular, that solutions admit a density satisfying a corrected version of the Dean–Kawasaki equation. Moreover, smoothing properties established for the stochastic heat equation are shown to persist, which, together with the existence of a density, leads to regularization results for mean-field models depending on the pointwise value of the density.

Keywords: Rearranged stochastic heat equation · Wasserstein diffusion with idiosyncratic noise· Weak convergence · corrected Dean-Kawasaki equation.

Contributed Session

CS128: Stochastic Analysis on Spaces of Probability Measures and Applications organized by Giacomo Sodini and Mattia Martini

* Presenter

Moment structure of the critical stochastic heat flow and independence of collision times of random walks

Ziyang Liu[1]*

Department of Mathematics, University of Warwick, United Kingdom,
ziyang.liu.1@warwick.ac.uk

The Critical Stochastic Heat Flow (SHF) is a measure valued stochastic process that defines a non-trivial solution to the two-dimensional stochastic heat equation with multiplicative space-time noise. Its one-time marginals are a.s. singular with respect to the Lebesgue measure, meaning that the mass they assign to shrinking balls decays to zero faster than their Lebesgue volume. In this talk, we explore the intermittency properties of the Critical 2d SHF by studying the asymptotics of the h-th moment of the mass that it assigns to shrinking balls of radius ϵ. Using a similar method, we also study collision local times of random walks, and identify $\sqrt{\log N}$ as the critical scale for independence of pairwise collision local times of random walks, with lower and upper bound results up to double-logarithmic corrections. Such critical scale was introduced in [1], and this is a refinement of their result.

Keywords: critical stochastic heat flow · directed polymer in random environments · Erdos-Taylor theorem.

Contributed Session
CS131: Directed Polymers and Stochastic Heat Flow organized by Francesca Cottini

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* Presenter

Strong regularisation-by-noise for degenerate SDEs of kinetic type: results and open problems

Giacomo Lucertini[1⋆], Stéphane Menozzi[2], and Stefano Pagliarani[3]

[1] Institut für Mathematik, Universität Augsburg, Germany,
giacomo.lucertini@uni-a.de
[2] Laboratoire de Modélisation Mathématiques d'Evry (LAMME), Université d'Evry Val d'Essonne-Paris Saclay, France,
stephane.menozzi@univ-evry.fr
[3] Dipartimento di Matematica, Università di Bologna, Italy,
stefano.pagliarani9@unibo.it

In this talk, we present recent results on strong well-posedness for kinetic SDEs. In particular, we focus on a model with autonomous diffusion driven by a symmetric α-stable process under Hölder regularity conditions for the drift term. We partially recover the thresholds for the Hölder regularity that are optimal for weak uniqueness. In general dimension, we only consider $\alpha = 2$ and need an additional integrability assumption for the gradient of the drift: this condition is satisfied by Peano-type functions. In the one-dimensional case, we do not need any additional assumption. The results presented are based on the joint work with Stéphane Menozzi and Stefano Pagliarani [1].

Keywords: Stochastic differential equations · Kinetic dynamics · strong uniqueness.

Contributed Session
CS161: "Singular SDEs: Well Posedness and Numerics" organized by Luca Bondi and Matteo Cagnotti

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⋆ Presenter

A partial likelihood approach to tree-based density modeling and its application in Bayesian inference

Li Ma[1] and Benedetta Bruni[1⋆]

Department of Statistics, University of Chicago, IL,
benedettabruni@uchicago.edu

Tree-based priors for probability distributions are usually specified using a predetermined, data-independent collection of candidate recursive partitions of the sample space. To characterize an unknown target density in detail over the entire sample space, candidate partitions must have the capacity to expand deeply into all areas of the sample space with potential non-zero sampling probability. Such an expansive system of partitions often incurs prohibitive computational costs and makes inference prone to overfitting, especially in regions with little probability mass. Thus, existing models typically make a compromise and rely on relatively shallow trees. This hampers one of the most desirable features of trees, their ability to characterize local features, and results in reduced statistical efficiency. Traditional wisdom suggests that this compromise is inevitable to ensure coherent likelihood-based reasoning in Bayesian inference, as a data-dependent partition system that allows deeper expansion only in regions with more observations would induce double dipping of the data. We propose a simple strategy to restore coherency while allowing the candidate partitions to be data-dependent, using Cox's partial likelihood. Our partial likelihood approach is broadly applicable to existing likelihood-based methods and, in particular, to Bayesian inference on tree-based models. We give examples in density estimation in which the partial likelihood is endowed with existing priors on tree-based models and compare with the standard, full-likelihood approach. The results show substantial gains in estimation accuracy and computational efficiency from adopting the partial likelihood.

Keywords: Bayesian Nonparametrics · Generative Models · Trees · Density Estimation

Contributed Session
CS109: Recent Advances in Bayesian Nonparametrics organized by Beatrice Franzolini

⋆ Presenter

Distribution-Free Outlier Detection and Enumeration

Chiara Gaia Magnani[1] and Matteo Sesia[2] and Aldo Solari[3*]

[1] Bocconi Institute for Data Science and Analytics, Milan, Italy
chiara.magnani@unibocconi.it
[2] Department of Data Sciences and Operations, University of Southern California, Los Angeles, California, USA
sesia@marshall.usc.edu
[3] Department of Economics, Ca' Foscari University of Venice, Venice, Italy
aldo.solari@unive.it

A flexible, distribution-free framework for collective outlier detection and enumeration is introduced, targeting situations in which the presence of outliers can be detected powerfully even though their precise identification may be challenging due to the sparsity, weakness, or elusiveness of their signals. The methodology builds on recent advances in conformal inference and integrates classical ideas from multiple testing, locally most powerful and adaptive rank tests, and nonparametric large-sample asymptotics.

Keywords: Conformal Inference · Multiple Comparisons · Rank Tests.

Contributed Session
CS139: Conformal prediction: theory and methods organized by Stefano Favaro and Simone Vantini

References

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* Presenter

Non-universal fluctuations for functionals of random neural networks

Leonardo Maini

Department of Mathematics, Università di Roma Tor Vergata, Italy.

We establish central and non-central limit theorems for sequences of geometric functionals of the limiting Gaussian output of random neural networks on the sphere. We show that, as the depth increases, the asymptotic behaviour is determined by the fixed points of the covariance kernel and leads to three possible regimes: convergence to the same functional evaluated at a limiting Gaussian field; convergence to a Gaussian distribution; or convergence to a spherical Rosenblatt/Hermite-type distribution.

More generally, we prove that the transition between these behaviours is governed by the uniform order of integrability (up to controlled errors) of the renormalized covariance function. This mechanism is closely related to what occurs for Gaussian fields with regularly varying covariances at infinity in the Euclidean setting, and reveals an analogous structure on the sphere. Based on a joint work with S. Di Lillo and D. Marinucci.

Keywords: Gaussian fields · Neural networks · Central and non central limit theorems.

Contributed Session

CS170: "Advances in the Geometry of Random fields" organized by Francesca Pistolato .

Sharp thresholds for higher powers of Hamilton cycles in random graphs

Tamás Makai[1⋆], Matija Pasch[2], Kalina Petrova[3], and Leon Schiller[4]

[1] Department of Mathematics, LMU Munich
makai@math.lmu.de
[2] Independent Researcher
matija.pasch@gmail.com
[3] Institute of Science and Technology Austria (ISTA)
kalina.petrova@ist.ac.at
[4] Hasso Plattner Institute
leon.schiller@hpi.de

For $k \geq 4$, we establish that $p = (e/n)^{1/k}$ is a sharp threshold for the existence of the k-th power H of a Hamilton cycle in the binomial random graph model. Our proof builds upon an approach by Riordan based on the second moment method, which previously established a weak threshold for H. This method expresses the second moment bound through contributions of subgraphs of H, with two key quantities: the number of copies of each subgraph in H and the subgraphs' densities. We control these two quantities more precisely by carefully restructuring Riordan's proof and treating sparse and dense subgraphs of H separately. This allows us to determine the exact constant in the threshold.

Keywords: Random Graph · Powers of a Hamilton cycle · Sharp threshold.

Contributed Session
CS175: Global and local topological properties of random graphs organized by Carlo De Ambroggio

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⋆ Presenter

Do random initial degrees suppress concentration in preferential attachment graphs?

T. Makai[1], F. Polito[2⋆], and L. Sacerdote[2]

[1] Mathematisches Institut, Ludwig- Maximilians-Universitaät München, Germany
makai@math.lmu.de
[2] Dipartimento di Matematica "G. Peano", Università degli Studi di Torino, Italy
{federico.polito,laura.sacerdote}@unito.it

We consider the open problem concerning the possible lack of concentration of the degree distribution in preferential attachment graphs with random initial degree, when its distribution is characterized by extremely heavy tails of power-law type. We show that the addition of such a large number of edges causes a significant upset of the degree distribution, leading to its non-concentration. Furthermore, we show that the smallest value of the exponent for which the degree distribution exhibits concentration is 2.

Keywords: Dynamic random graphs · Preferential attachment with random initial degree · Heavy tails · Concentration of the degree sequence.

Contributed Session
CS175: Global and local topological properties of random graphs organized by Carlo De Ambroggio

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⋆ Presenter

Optimal reinsurance with unobservable claim arrival intensity: a Stackelberg differential game

Katia Colaneri[2], Edoardo Lombardo[2], and Daniele Mancinelli[1⋆]

[1] Department of Mathematics, Politecnico di Milano, Italy,
daniele.mancinelli@polimi.it
[2] Department of Economics and Finance, University of Rome Tor Vergata, Italy
{katia.colaneri, edoardo.lombardo}@uniroma2.it

We study Stackelberg differential games between an insurer and a reinsurer in an unobservable Markov-modulated Poisson compound risk model, where the intensity is not known but has to be inferred from the observations of claims arrivals. We consider two different games in which the reinsurance is proportional and the reinsurer adopts an intensity-adjusted variance premium principle. In the first games, both insurer and reinsurer aim to maximize the expected exponential utility of their terminal surplus. In the second game, both insurer and reinsurer seeks to maximize the expected terminal surplus penalized by a quadratic term that discourages extreme values of the protection level – either too small, resulting in excessive risk retention, or too large, leading to over-reliance on reinsurance. We characterize the equilibrium of the game and the corresponding value functions under partial information and full information for comparison reasons. Moreover, we numerically investigate the effect of the unobservable stochastic factor that modulates the claim arrival process on the game equilibria.

Keywords: Stackelberg differential game · Reinsurance · Stochastic control · Partial information.

Contributed Session
CS169: Applications of probability to economics, finance, and insurance organized by Elena Bandini and Alessandro Calvia

⋆ Presenter

Wasserstein Least Squares: statistics, geometry, and algorithms

Uriel Martínez León[1*] and Jonathan Niles-Weed[1]

Courant Institute School of Mathematics, Computing, and Data Science, New York University, NY, USA
uriel.leon@nyu.edu

We present Wasserstein Least Squares Regression (WLSR), a model that canonically extends least squares regression in the presence of vector-valued covariates and distribution-valued responses. Unlike competing proposals, which focus on the linear structure (or lack of it) in the space of probability measures, ours works directly with the functional form of linear regression. In this talk, we will delve into the geometry of WLSR and draw methodological connections with regression models in Eucledian space.

Keywords: Regression · Wasserstein Space · Barycenters

Contributed Session
CS119: Statistical Learning through Kernels and Transport organized by Leonardo Santoro and Alessia Caponera.

[*] Presenter

On the notion of Wasserstein BSDE and its application to Mean Field Control

Mao Fabrice Djete[1] and Mattia Martini[1*]

1. École polytechnique, CMAP, France.
mattia.martini@polytechnique.edu

Classical BSDE theory provides an elegant probabilistic representation of stochastic control problems and their associated PDEs. However, this correspondence breaks down in the mean field (McKean–Vlasov) setting, where the law of the state process enters the dynamics intrinsically, rendering the standard framework inadequate. Following [1], we discuss a class of "BSDEs" on the Wasserstein space of probability measures, whose solutions are intrinsically measure-dependent. A key feature of this definition is its correspondence with mean field control problems and with PDEs on the Wasserstein space, providing a fully probabilistic counterpart to analytic approaches based on the master equation. Despite these promising applications, well-posedness results for such BSDEs have been proven in [1] only in a few particular cases, such as for generators with linear or quadratic growth in the z-variable.

Our main contribution is an existence and uniqueness result for this class of BSDEs, which goes beyond previously studied settings. Our key argument is based on an alternative representation of the solution, which is of independent interest, especially for numerical applications. This talk is based on ongoing joint work with Mao Fabrice Djete.

Keywords: BSDEs · Mean field control · HJB equations on the space of probability measures

Contributed Session
CS135: Stochastic Systems, Mean-Field Models, and Control organized by Fulvia Confortola and Giuseppina Guatteri

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* Presenter

Likelihood-based priors: a kernel mixture approach

Luca Martino[1]

Dip. Economia e Impresa (DEI), University of Catania, Catania, Italy
luca.martino@unict.it

Kernel methods has been used in Bayesian inference for construction adaptive quadrature schemes [6], and/or adaptive proposal densities [5] and/or as possible emulators of noisy and costly posteriors [8].
Furthermore, in Bayesian inference, the choice of prior distributions plays a central role, and a large body of literature has investigated constructions in which priors are linked, either directly or indirectly, to the likelihood function or to the observed data [4,7]. These approaches are often motivated by the desire to reduce subjectivity in prior specification while retaining coherence with the underlying statistical model. These "non-informative" specifications are determined by the model structure rather than by expert knowledge. Some well examples are given by (a) the empirical Bayes approach for prior parameter tuning, (b) Jeffreys priors (which are derived from the Fisher information) and (c) reference priors, to name a few. More generally, reference priors were developed as a formal framework to maximize the expected information gain from data, providing a principled way to construct priors [1].
In this work, we aim to extend the methodologies developed for the so-called partial, intrinsic, and fractional Bayes factors [2,9], along with related approaches [3,10]. We also show the relationship with the use some improper priors and the application of the proposed approach for model selection purposes.

Keywords: Prior choice · model selection · marginal likelihood · Bayes factors.

Contributed Session
CS147: Kernel methods in Bayesian statistics organized by Marta Catalano and Hugo Lavenant

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Modeling Monkeypox transmission through stochastic dynamics with self-excitation

Giulia Di Nunno[1], Nicola Giordano[2], Barbara Martinucci[2*], and Olena Tymoshenko[3]

[1] Department of Mathematics, University of Oslo, Norway,
[2] Department of Mathematics, University of Salerno, Italy,
[3] Department of Mathematical Analysis and Probability Theory, NTUU Igor Sikorsky Kyiv Polytechnic Institute, Ukraine

giulian@math.uio.no, ngiordano@unisa.it, bmartinucci@unisa.it, otymoshenkokpi@gmail.com

The transmission of Mpox, a zoonotic Orthopoxvirus with rodents as primary reservoirs, exhibits marked clustering during mass gatherings and superspreader events, a feature overlooked by existing models [1]. We introduce a stochastic compartmental model incorporating Hawkes processes [2] to capture these self-exciting dynamics in human populations, complemented by Brownian noise for environmental fluctuations in both human and rodent compartments [3].

We prove global existence, uniqueness, and positivity of solutions. Furthermore, we derive the basic reproduction number and establish explicit persistence-in-the-mean conditions for both infected rodents and humans. Numerical simulations are provided to illustrate the impact of self-exciting jumps on epidemic trajectories, highlighting how Hawkes dynamics significantly enhance the predictive capacity of Mpox modeling compared to classical stochastic approaches. Our results suggest that incorporating temporal dependence in jump processes is essential for evaluating the effectiveness of public health interventions, such as quarantine and public awareness campaigns, in the face of clustered transmission patterns.

Keywords: Monkeypox virus · Hawkes process · stochastic epidemic model.

Contributed Session

CS176: Continuous-time random walks and diffusion processes: resetting and transformation for biological modeling organized by Luigia Caputo and Enrica Pirozzi

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* Presenter

Hilbert-Based Correlation Indices for Distributional Data

Francesco Mascari[1*], Hugo Lavenant[1], and Marta Catalano[1]

[1] Department of Decision Sciences, Bocconi University, Milan, Italy,
francesco.mascari@phd.unibocconi.it,hugo.lavenant@unibocconi.it
[2] Department of AI, Data and Decision Sciences, Luiss Univeristy, Rome, Italy
mcatalano@luiss.it

We propose a unified mathematical framework for defining indices of dependence for random probability measures by embedding them into a Hilbert space and applying correlation indices to the resulting Hilbert-valued random variables. This approach overcomes the lack of a linear structure in the space of probability measures and relies on two sources of variability: the choice of the correlation index and the choice of the embedding. We consider Canonical Correlation, Centered Alignment, and Trace Correlation, combined with a Wasserstein-based embedding and two kernel-based embeddings, allowing us to reinterpret existing dependence measures and extend Kernelized Canonical Correlation and Centered Kernel Alignment to distribution-valued data. We characterize the extremal behavior of the proposed indices under independence, almost sure equality, and equality up to linear push-forward transformations, providing theoretical guarantees and interpretability. Numerical experiments on synthetic data and an application to hierarchical clustering of cortical regions in functional brain imaging illustrate the practical relevance of the framework.

Keywords: Dependence Measure · Random Probability Measures · Reproducing Kernel Hilbert Spaces · Wasserstein Spaces.

Contributed Session

CS119: Statistical Learning Through Kernels and Transport organized by Leonardo Santoro and Alessia Caponera

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1. Mascari, F., Lavenant, H., Catalano, M.: Hilbert-Based Correlation Indices for Distributional Data. *Working Paper*

* Presenter

Finite vs Infinite-Mean Heavy-Tailed Fitness: Geometry and Connectivity in Inhomogeneous Random Graphs

Elena Matteini[1*], Luisa Andreis[2], Luca Avena[1], and Rajat Hazra[3]

[1] Department of Mathematics and Computer Science, University of Florence, Florence, Italy
elena.matteini@unifi.it luca.avena@unifi.it
[2] Department of Mathematics "Giuseppe Peano", University of Turin, Turin, Italy
luisa.andreis@unito.it
[3] Mathematical Institute, Leiden University, Leiden, The Netherlands
r.s.hazra@math.leidenuniv.nl

We consider a class of inhomogeneous random graphs $G_n(\alpha, \varepsilon)$ where n vertices carry i.i.d. Pareto weights $(W_i)_{i\in[n]}$ with tail index $\alpha > 0$. Conditionally on the weights, edges are drawn independently with probability $p_{ij} = \min(\varepsilon W_i W_j, 1)$, where $\varepsilon = \varepsilon_n$ controls sparsity.
The behaviour of the model is driven by the tail index α, with a sharp structural change at the boundary $\alpha = 1$. The infinite-mean and finite-mean regimes lead to fundamentally different emerging landscapes.
Building on recent work of L. Avena, D. Garlaschelli, R.S. Hazra and M. Lalli (Journal of Applied Probability 2025), we analyze the degree asymptotics across the full range $\alpha > 0$ and identify the relevant scalings of ε_n in each regime for the convergence in distribution of the typical degree.
We then characterize the connectivity threshold. In the infinite-mean case $\alpha \leq 1$, connectivity is hub-driven and forces a collapse of the diameter to at most two. In the finite-mean regime $\alpha > 1$, connectivity emerges through a collective mechanism at a density scale distinct from that of ultra-small-world behaviour.
This is joint ongoing work with Luisa Andreis, Luca Avena and Rajat Hazra.

Keywords: Inhomogeneous random graphs · Heavy-tailed fitness · Connectivity threshold

Contributed Session
CS160: Non-Homogeneous Random Graphs organized by Luca Avena

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* Presenter

Singular SDEs through interfaces: the threshold Cox-Ingersoll-Ross model

Sara Mazzonetto[1*]

University of Lorraine, France
sara.mazzonetto@univ-lorraine.fr

Diffusions whose dynamics are perturbed at an interface point (through coefficient discontinuities or boundary effects such as reflection, skewness, or stickiness) arise naturally in short-rate and volatility modeling. In this talk we focus on one-dimensional singular SDEs with interfaces and singular diffusion coefficient.

We discuss pathwise (strong) existence and uniqueness under assumptions that allow generalized drift components, including local time terms at the interface, and non-uniformly elliptic diffusion coefficient. As a motivating example, we consider a threshold Cox-Ingersoll-Ross model, where the drift and the diffusion coefficients change across a prescribed level.

We also comment on parameter estimation and simulation of the resulting dynamics, highlighting how first-passage times enter both in the well-posedness analysis and in the simulation and estimation questions.

This talk is mainly based on the recent preprint in collaboration with Benoît Nieto. The estimation aspects are based on joint works with Benoît Nieto, and Paolo Pigato. The simulation aspects are object of the PhD thesis of Julia Budzinski.

Keywords: Cox-Ingersoll-Ross model · Existence and uniqueness · Threshold diffusions.

Contributed Session
CS138: First Passage Times: theory and simulations organized by Serena Spina and Cristina Zucca

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[*] Presenter

Quantitative Convergence of Trained Quantum Neural Networks to a Gaussian Process

Anderson Melchor Hernandez[1⋆], Filippo Girardi[2,3], Davide Pastorello[1], and Giacomo De Palma[1]

[1] Department of Mathematics, University of Bologna, Bologna, Italy
{anderson.melchor, davide.pastorello3, giacomo.depalma}@unibo.it
[2] Scuola Normale Superiore, Pisa, Italy
filippo.girardi@sns.it
[3] Korteweg-de Vries Institute for Mathematics, University of Amsterdam, Amsterdam, Netherlands

Quantum neural networks (QNNs) constitute the quantum version of deep neural models, where the generated functions are defined by the expectation values of quantum observables measured on the output of parametric circuits. A fundamental breakthrough in the theory of classical deep learning has been the proof that, in the limit of infinite width, the probability distribution of the function generated by a neural network converges to a Gaussian process.

In this presentation, I will explore the extension of these properties to the quantum domain. While recent advancements have established this convergence qualitatively, we provide a rigorous quantitative proof. Using Stein's method for normal approximation, we establish explicit upper bounds on the Wasserstein distance of order 1 between the distribution of a finite-width QNN and the limiting Gaussian process. Furthermore, I will analyze the training dynamics under gradient flow, proving that these quantitative bounds remain valid throughout the optimization process and are uniform in time. This analysis confirms that large-width QNNs preserve their Gaussian characteristics even for infinite training time, providing a solid theoretical foundation for understanding the behavior and stability of overparameterized quantum machine learning models.
This talk is based on joint works with F. Girardi, D. Pastorello, and G. De Palma.

Keywords: Quantum Neural Networks · Gaussian Processes · Stein's Method · Wasserstein Distance · Lazy Training.

Contributed Session
CS116: Neural Networks and Gaussian Processes: Perspectives from Young Researchers organized by Claudio Macci

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⋆ Presenter

Association in Spatial Queueing-Filtering Networks

Emanuele Mengoli[1,2⋆] and Nahuel Soprano-Loto[2]

[1] Télécom Paris, France
[2] Centre Inria de Paris, France
{emanuele.mengoli, nahuel.soprano-loto}@inria.fr

We study a class of spatially structured stochastic networks that couple queueing-type communication dynamics with sensing-type state estimation. Network nodes are distributed according to a stationary homogeneous Poisson point process $\Phi \subset \mathbb{R}^2$. Around each node, secondary agents evolve according to localised random motions, yielding a dynamic marked point process. Interactions are induced through shot-noise interference generated by full spectrum reuse, so that both communication and sensing performances depend on the same underlying random field. Communication dynamics are modelled as spatially indexed queues whose service rates are monotone functionals of the instantaneous signal-to-interference-plus-noise ratio (SINR). Sensing dynamics are described by a partially observed stochastic process whose observation noise covariance is itself a functional of the same interference field, leading to a state-dependent filtering problem. This construction induces a non-trivial coupling between a queueing network in random environment and a family of stochastic estimators driven by spatial shot noise. We define system-level performance metrics under the Palm distribution of Φ. Our main result establishes the association property between communication and sensing functionals at the typical node. Under general shot-noise interference model, we prove that the queue workload process and the filtering error process are associated, in the sense of increasing functionals. The proof relies on coupling constructions, stochastic monotonicity, and comparison arguments for interacting particle systems in random environment. The results suggest that operating regimes that improve communication performance also improve sensing accuracy. More broadly, this framework provides a probabilistic foundation for the analysis of spatial networks with coupled service and estimation mechanisms. It illustrates how tools from stochastic geometry, interacting particle systems, and queueing theory can be combined to analyse large-scale systems where geometry and flow dynamics are intrinsically intertwined.

Keywords: Stochastic geometry · Palm calculus · Association · Queueing theory.

Contributed Session
CS144: Probabilistic Analysis of Complex Engineering Networks organized by Emanuele Mengoli

⋆ Presenter

Nonlocal α-size biasing: Stein characterization and one-sided concentration bound

Alessandra Meoli* and Antonio Di Crescenzo

Department of Mathematics, University of Salerno, Italy,
ameoli@unisa.it
adicrescenzo@unisa.it

We introduce a nonlocal α-size–biased transform for nonnegative random variables, which recovers the classical size bias in the limit $\alpha \to 1$. The transform admits a clear sampling interpretation: it corresponds to an infinite-horizon renewal inspection scheme in which the observation mechanism is α-dependently power-biased toward longer waiting-time gaps. This biasing viewpoint provides a direct link to renewal-based CTRW models of anomalous diffusion, where different observation protocols induce biased waiting-time statistics. We characterize the transform via a Stein identity based on the Riemann–Liouville integral and derive a one-sided concentration inequality as an application. Joint work with Antonio Di Crescenzo.

Keywords: Nonlocal size bias of order α · Stein identity · Concentration bound

Contributed Session

CS154: Interplay between statistical physics and probabilistic methods: the case of anomalous diffusion organized by Costantino Ricciuti and Gianni Pagnini

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* Presenter

Collective Arbitrage and Superreplication

T. Meyer-Brandis[1⋆], F. Biagini[1], A. Doldi[2], J.P. Fouque[3], and M. Frittelli[2]

[1] Department of Mathematics, University of Munich, Germany,
{meyerbra, biagini}@math.lmu.de
[2] Department of Mathematics, Universita degli Studi di Milano, Italy
{alessandro.doldi, marco.frittelli}@unimi.it
[3] Department of Statistics, University of Santa Barbara, USA
fouque@pstat.ucsb.edu@unimi.it

We extend the classical Arbitrage Pricing Theory to a setting where N agents are investing in their respective security markets and additionally are allowed to cooperate through a zero-sum risk exchange mechanism, where no money is injected or taken out of the overall system. Cooperation and the multi-dimensional aspect are the new key features of our setting. In the case of only one agent, the collective theory reduces to the classical Arbitrage Pricing Theory. Within this framework, we introduce the novel notion of Collective Arbitrage. We study the connection between collective and classical arbitrage in our market, and provide various collective versions of the First Fundamental Theorem of Asset Pricing.

Secondly, we extend the classical notion of super-replication to the notion of Collective Super-Replication. Collective Super-replication for a given vector of contingent claims, one for each agent in the system, allows for cooperation through risk exchanges among the agents which reduces the overall cost compared to classical individual super-replication. We describe the main properties of the Collective Super-replication functional and its dual representation and discuss the fairness of the cost allocation associated with the Collective Super-replication procedure.

Keywords: Collective Arbitrage · Collective Superreplication· Multiple Agents.

Contributed Session
CS106: Collective Phenomena in Financial Markets: Arbitrage, Replication, and Risk organized by Marco Frittelli

⋆ Presenter

Target hitting counting process in networks and applications to evanescent random walks

Thomas Michelitsch

Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, F-75005 Paris, France,
thomas.michelitsch@sorbonne-universite.fr

An efficient foraging strategy is vital for all living beings [1]. Often such search problems can be described by evanescent random walkers (searchers) aiming to hit targets containing the resources which they need for their survival [2].

In the first part, we consider the target hitting counting process (THCP) of an immortal Markov walker navigating in an ergodic network [3]. We analyze the THCP of an arbitrary stationary set $\mathcal{B}$ of target nodes. We associate the THCP with an integer counting variable $\mathcal{N}_i(t;\mathcal{B}) = \{0,1,2,\ldots\}$ (with $\mathcal{N}_i(0;\mathcal{B}) = 0$ where i is the departure node). This non-decreasing counting variable is increased by a unit when a target node $j \in \mathcal{B}$ is hit by the walker. In general, the THCP is not a renewal counting process apart of the distinguished cases, in which (a) target $\mathcal{B}$ consists of a single target node coinciding with the departure node; and (b) for stationary Markov chains, where the THCP boils down to a Bernoulli counting process. We highlight connections with the literature [4].

Then we connect the THCP with the survival statistics of a mortal walker performing Markov steps in an ergodic network [5]. The survival of the walker requires a positive "budget". Each step reduces the budget by one unit. The budget is reset at target hitting times to an IID copy of its initial value, highlighting the connection with stochastic resetting [6,7]. The walker dies when the budget reaches null for the first time. We obtain analytically the evanescent propagator matrix, the survival probability of the walker, the mean residence time on a set of nodes during the walker's lifetime, and the expected lifetime. The results also include the number of target hits (budget renewals) in a walker's lifetime. We identify analytically and numerically three pertinent scenarios: (i) the forager scenario, in which frequent encounters with target nodes extend the walker's lifetime, (ii) a detrimental scenario, where frequent encounters instead reduce it, and a neutral scenario (iii) where the frequency of target node hits has no effect on the lifetime. We corroborate our analytical results with random walk simulations on Barabási–Albert graphs. The model has cross-disciplinary applications in finance, gambling, population dynamics, epidemic spreading, chemical reactions, and others [8,9]. Extensions of our model include mortal walkers subjected to stochastic resetting, which sensitively modifies the dynamics [10].

Keywords: Target hitting counting process · mortal random walker · budget renewals · survival statistics

Contributed Session

CS141: Fractional Processes and Non-local Operators (Part 2) organized by Federico Polito

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Self-normalization of sums of dependent random variables

Thomas Mikosch[1]*, Muneya Matsui[2], and Olivier Wintenberger[2]

[1] Department of Mathematics, University of Copenhagen, Denmark,
mikosch@math.ku.dk
[2] University of Osaka, Japan, and Sorbonne, Paris, France

Self-normalized sums are often considered to be "more robust" as regards the influence of large obervations. They are very much present in log-return data of stock prices and indices, foreign exchange rates, interest rates, etc.

In this context a stunning result was proved by Logan et al. [1]. Assuming an iid centered sequence (X_t) with a regularly varying tail, i.e., $P(\pm X_t > x) \sim p_\pm x^{-\alpha}$ as $x \to \infty$, the studentized sum $S_n = X_1 + \cdots + X_n$ has asymptotically a Gaussian tail even if $\alpha \in (1,2)$, i.e., when $\mathrm{var}(X_1) = \infty$. This result is in agreement with the fact that S_n and the sample standard deviation are of the same asymptotic order. Moreover, if $\alpha \in (1,2)$, (S_n/a_n) converges in distribution to an α-stable law with a (commonly unknown) normalizing sequence (a_n). Self-normalization avoids knowledge of (a_n). Similar results remain valid for S_n under self-normalization with the maximum of $|X_1|, \ldots, |X_n|$.

If (X_t) is (strictly) stationary and regularly varying (in a sense to be defined) with index $\alpha \in (0,2)$ similar asymptotic theory is valid for self-normalized sums. These include financial time series models such as stochastic volatility models, GARCH processes, autoregressive conditional durations models. A particularly nice case is a regularly varying linear process with infinite variance: limit results for the self-normalized sample mean are the same as in the iid case modulo some scaling constants; see Davis and Resnick [2]. Unfortunately, this is (almost) the only nice case. In presence of extremal clusters in the sequence limit theory for self-normalized sums becomes complicated and depends on the model at hand. In particular, the limit laws may lack moments, in contrast to the iid case, and graphical tools based on self-normalized quantities may fool one; see Matsui et al. [3] and Mikosch and Wintenberger [4].

Keywords: Self-normalized sums · Regularly varying time series· Financial time series.

Contributed Session
CS149: Modeling the Unseen: Theory and Methods for Extreme Events organized by Steffano Rizzelli

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* Presenter

Learning from Surrogate Data: Weak-to-Strong Generalization through the Lens of High-Dimensional Regression

Marco Mondelli

Institute of Science and Technology Austria (ISTA)
marco.mondelli@ist.ac.at

It is increasingly common in machine learning to use learned models to label data and then employ such data to train more capable models. The phenomenon of *weak-to-strong generalization* exemplifies the advantage of this two-stage procedure: a strong student is trained on imperfect labels obtained from a weak teacher, and yet the strong student outperforms the weak teacher. In the talk, I will start by considering ridgeless, high-dimensional regression, and I will provide a sharp characterization of the risk of the target model when the surrogate model is either arbitrary or obtained via empirical risk minimization [1]. This shows that weak-to-strong training, with the surrogate as the weak model, provably outperforms training with strong labels under the same data budget, but it is unable to improve the scaling law. Next, I will show that the scaling law can improve when both the student and the teacher are trained via random feature ridge regression [2]. I will derive a dimension-free deterministic equivalent for the risk of the student trained on teacher labels and then, via this deterministic equivalent, I will identify regimes in which the scaling law of the student improves upon that of the teacher. This shows that the improvement can be achieved both in bias-dominated and variance-dominated settings. Strikingly, the student may attain the minimax optimal rate regardless of the scaling law of the teacher—in fact, when the risk of the teacher does not even decay with the sample size.

Keywords: High-dimensional regression · Random feature ridge regression · Knowledge distillation · Weak-to-strong generalization · Deterministic equivalent.

Contributed Session
CS180: Mathematics of Neural Networks organized by Stefano Vigogna

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Branching random walks with ageing

Elena Montanaro[1]*, Daniela Bertacchi[2], and Fabio Zucca[2]

[1] Department of Statistics, Sapienza University of Rome, Rome, Italy,
elena.montanaro@uniroma1.it
[2] Department of Mathematics, University of Milano–Bicocca, Milano, Italy
daniela.bertacchi@unimib.it
[3] Department of Mathematics, Politecnico of Milan, Milano, Italy
fabio.zucca@polimi.it

Branching processes are models used to describe populations that reproduce and die over time. In the classical setting, an individual's reproductive capacity remains constant throughout its lifetime. However, in real-world situations, reproductive capacity typically undergoes ageing - that is, after reaching a peak, it decreases over time. In this work, we study the influence of ageing on the behaviour of the process and how modifying its parameters, along with reproduction rates, affects the destiny of the process. More precisely, we introduce an ageing mechanism through a time-dependent birth rate, focusing on the case of exponential decay governed by a parameter α. This modification allows us to capture realistic biological and epidemiological scenarios in which reproduction or transmissibility is strongest at early stages and progressively weakens over time. We analyse how the interplay between the reproduction intensity λ, the ageing parameter α, and the spatial structure of the model determines survival and extinction.

Keywords: branching random walk · branching process · ageing · critical parameters.

Contributed Session
CS151: Stochastic Models and Random Perturbations organized by Verdiana Mustaro

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* Presenter

Quantitative Master Theorems for Tensor Programs via the Wasserstein distance

Eloy Mosig García[1⋆], Dario Trevisan[1], and Andrea Agazzi[2]

[1] Department of Mathematics, University of Pisa, Italy,
{eloy.mosig@phd.,dario.trevisan@}unipi.it
[2] Institute of Mathematical Statistics and Actuarial Science, University of Bern, Switzerland
andrea.agazzi.unibe.ch

Tensor programs [1] provide a unified formalism for describing wide neural network architectures and analyzing their infinite-width limits, under appropriate scaling. Classical master theorems establish convergence in distribution of finite-width networks to their infinite-width counterparts, but typically do not provide explicit finite-width error bounds beyond specific settings.

In this work, we prove quantitative master theorems for general tensor programs. Generalizing the main result of [2], we establish non-asymptotic bounds in Wasserstein distance between the joint law of the feature variables generated by the finite-width execution and those of the corresponding infinite-width execution. Our results apply under mild assumptions on the activation function and yield explicit convergence rates in terms of the layer widths. As a consequence, we obtain quantitative kernel convergence estimates with matching rates. The proof proceeds by induction over program lines and relies on a detailed analysis of conditional Gaussian updates for matrix multiplication operations, combined with stability estimates the rest of steps in the program.

These results provide a general quantitative refinement of the master theorem in [1] and yield explicit finite-width control for a broad class of neural network architectures.

Keywords: Neural networks · Wide limit · Tensor progams.

Contributed Session
CS116: Neural Networks and Gaussian Processes: Perspectives from Young Researchers organized by Claudio Macci

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⋆ Presenter

On some drift-based transformations of multidimensional diffusion processes and their applications

Antonio Di Crescenzo[1], Verdiana Mustaro[1⋆], and Serena Spina[1]

Department of Mathematics, University of Salerno, Italy,
vmustaro,adicrescenzo,sspina@unisa.it

We investigate a class of drift-based transformations for multidimensional diffusion processes. The approach is finalized to construct a transformed diffusion whose transition probability density function (p.d.f.) admits a product-form representation with respect to the p.d.f. of the original process. In particular, the ratio between the transformed and original transition densities reduces to a simple expression involving a weight function w. The framework is formulated in terms of stochastic differential equations, from which the weight function w is obtained. Moreover, we establish general conditions under which the transformed p.d.f. remains analytically tractable in the multidimensional setting. Specific choices of the weight function yield mixture representations of the transformed density, revealing structural properties such as bimodality and modified stochastic ordering. The analysis also shows how the product-form relation persists under Poissonian resetting mechanisms, leading in certain cases to explicit stationary distributions and offering insight into diffusions evolving in potential fields.

Two fundamental case studies are examined in detail, based on transformations of the Wiener and Ornstein–Uhlenbeck processes. For these models, explicit expressions of the weight function, potential structure, and transition densities are derived. Special attention is devoted to the two-dimensional setting, for which the conditions and behaviors of the transformed processes are analyzed in depth.

Beyond its theoretical relevance, the representation suggests practical applications in simulation. In particular, it naturally supports rejection sampling schemes, where the original transition density serves as a proposal distribution. Under suitable boundedness conditions, the acceptance probability can be expressed directly in terms of the weight function, resulting in an efficient and implementable algorithm.

The results highlight the flexibility of drift-based transformations as a tool for constructing analytically tractable diffusions. While the present work focuses on prototypical Gaussian models, the methodology suggests several possible extensions, including more general diffusion classes, alternative resetting mechanisms, and further analytical and computational developments.

This contribution is based on [1].

Keywords: Symmetric diffusion processes · drift-based transformations · Wiener process · Orstein-Uhlenbeck process

Contributed Session

CS176: Continuous-time random walks and diffusion processes: resetting and transformation for biological modeling organized by Luigia Caputo and Enrica Pirozzi

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Capturing Growth and Shock Dynamics through Lognormal Diffusions with Binomial Catastrophes

Sabina Musto[1]*, Antonio Di Crescenzo[1], Paola Paraggio[2], and Francisco de Asís Torres Ruiz[2]

[1] Department of Mathematics, University of Salerno, Italy,
smusto@unisa.it
[2] Departamento de Estadística e I.O., University of Granada, Spain
{adicrescenzo,pparaggio}@unisa.it fdeasis@ugr.es

Stochastic growth models and sigmoidal processes are crucial due to their ability to describe phenomena commonly observed in nature. These models are particularly relevant in fields such as medicine and biology, where they are used to represent the spread of diseases, immune responses, and the growth of cellular populations. However, they also have significant applications in finance and physics (see, for example, [2]). This work (cf. [1]) focuses on the lognormal diffusion process subject to random catastrophes, random events which cause jumps and reset the process to a possibly different random state (cf. [3]). The primary contribution of this research is the assumption that the post-catastrophe recovery level follows a binomial distribution. Unlike traditional models where a system might revert to a fixed initial size, our approach allows the population to restart at a random level which reflects a certain survival probability for each element of the population.
To demonstrate the usefulness of this framework, we apply it to the population dynamics of wolves subjected to external disturbances. Furthermore, the model effectively captures real-world economic scenarios, such as the trajectories of GDP (Gross Domestic Product) in five European countries impacted by the crises of 2009 and 2020. The findings show that the model can realistically reproduce complex trajectories, displaying periods of gradual growth interspersed with sudden declines triggered by unpredictable external shocks.

Keywords: Lognormal diffusion processes · Binomial catastrophes · Maximum likelihood estimation · Biological application · Financial crisis.

Contributed Session
CS151: Stochastic Models and Random Perturbations organized by Verdiana Mustaro

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* Presenter

The critical percolation window in growing random graphs

Peter Mörters

Department of Mathematics, University of Cologne, Germany
p.moerters@uni-koeln.de

We describe the critical window for percolation on sparse growing random graphs. In our models, vertices arrive sequentially and connect independently to each earlier vertex v with probability proportional to a nonpositive power of the arrival time of v, continuing until the graph has n vertices. These models include uniformly grown random graphs and inhomogeneous random graphs of preferential-attachment type. Whenever the critical percolation threshold is positive, we show that the critical window has width of order $(\log n)^{-2}$ and a secondary phase transition at its finite upper boundary. Inside this window the largest component has size of order $\sqrt{n}/\log n$, and the susceptibility remains finite and independent of the position in the window. The proofs couple component explorations to branching random walks killed outside an interval of length $\log n$, allowing sharp control of the barely subcritical and critical regimes. The talk is based on joint work with Joost Jorritsma and Pascal Maillard.

Keywords: Phase transition · growing graph · dynamic network · percolation.

Contributed Session
CS165: Processes on dynamic random graphs organized by Michele Salvi

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Dimension-free statistical guarantees for guidance scale adaptation of conditional diffusion models via PAC-Bayes bounds

Shogo Nakakita[1⋆], Pierre Alquier[2], and Masaaki Imaizumi[3]

[1] The University of Osaka, Japan
nakakita.shogo.es@osaka-u.ac.jp
[2] ESSEC Business School, Singapore
alquier@essec.edu
[3] The University of Tokyo, Japan
RIKEN AIP, Japan
Kyoto University, Japan
imaizumi@g.ecc.u-tokyo.ac.jp

Classifier-free guidance is a well-known sampling strategy applied at inference time to manage the trade-off between quality and diversity in diffusion models. Recent work has explored adapting the guidance scale dynamically over time, yielding improved sampling results. However, the theoretical understanding of this approach remains limited. In particular, there is a scarcity of datasets for learning such dynamic guidance schedules, raising concerns about how well these methods generalize.

In this paper, we provide statistical guarantees for learning time-dependent guidance scales in conditional diffusion models using classifier-free guidance. We establish concentration bounds for generalization error that do not depend on (i) the dimensionality of the state or prompt spaces, (ii) the specific architectures used for conditional or unconditional score functions, or (iii) hidden constant factors. Furthermore, although the number of timesteps defines the parameter space dimension, we can make the bound independent of it by constraining the sum of the maximal values of the scales weighted by noise schedules.

To obtain these results, we develop novel coupling-based PAC-Bayes bounds alongside a coupling framework for diffusion models. A key conceptual contribution is a shift in perspective: we treat fixed diffusion models as prior distributions and guided models as corresponding posteriors within the PAC-Bayes framework.

Keywords: Conditional diffusion models · generalization errors · quasi-Bayes · stochastic control · test-time adaptation.

Contributed Session

CS142: Diffusion Processes in Machine Learning organized by Francesco Iafrate and Alessandro De Gregorio

⋆ Presenter

Adaptive Bayesian inference using low-rank Variational Gaussian processes

Dennis Nieman[1⋆] and Botond Szabó[2]

[1] Institut für Mathematik, Humboldt University Berlin
dennisnieman@pm.me
[2] Department of Decision Sciences, Università Bocconi, Milano

Accurate tuning of hyperparameters is crucial to ensure that models can generalise effectively across different settings. In this talk, we present theoretical guarantees for hyperparameter selection using variational Bayes in the nonparametric regression model. We construct a variational approximation to a hierarchical Bayes procedure, and derive upper bounds for the contraction rate of the variational posterior in an abstract setting. The theory is applied to various Gaussian process priors and variational classes, resulting in minimax optimal rates. Our theoretical results are accompanied with numerical analysis both on synthetic and real world data sets.

Keywords: variational inference · Bayesian model selection · Gaussian processes · uncertainty quantification · contraction rates

Contributed Session
CS147: Kernel methods in Bayesian statistics organized by Marta Catalano and Hugo Lavenant

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⋆ Presenter

An Analogue Fréchet-Shohat Moments Convergence Theorem for Indeterminate Moment Problems

Pier luigi Novi Inverardi[1*] and Aldo Tagliani[2]

Department of Economics and Management, University of Trento, Italy,
pierluigi.noviinverardi@unitn.it
aldo.tagliani@unitn.it

Originally established in 1931, the Fréchet-Shohat Theorem (FST) is a fundamental result in the method of moments. It provides sufficient conditions under which the convergence of a sequence of moments $\{m_{k,n}\}_{n=1}^{\infty}$ to a limit sequence $\{m_k\}$ ensures the weak convergence of the associated distribution functions $\{G_n\}$ to a limit G. A critical requirement of the classical theorem is the determinacy of the underlying moment problem; that is, G must be the unique distribution characterized by $\{m_k\}$.

This study extends the foundational Fréchet-Shohat framework to the setting of indeterminate Hamburger and Stieltjes moment problems, where the classical FST traditionally fails due to the non-uniqueness of the limiting distribution. We demonstrate that by imposing an entropic constraint on the sequence $\{G_n\}$ - specifically, convergence in Shannon entropy - one can recover a unique limit entropy-distinguishable distribution, G_{hmax}, from the indeterminate class having the given moments. This result facilitates a unified treatment of FST across both determinate and indeterminate frameworks.

The role of Entropy and MaxEnt principle

Given an indeterminate moment sequence $\{m_k\}$ of the Hamburger or Stieltjes type, the associated class $\mathcal{C}_\infty$ of satisfying densities contains a unique maximizer of the Shannon differential entropy,

$$H[g] = -\int_{\Omega} g(x) \ln g(x)\, dx \tag{1}$$

where $\Omega = \mathbb{R}$ for Hamburger or $\Omega = \mathbb{R}^+$ for Stieltjes problems, denoted by g_{hmax}, in virtue of the convexity of $\mathcal{C}_\infty$ and strict concavity of the Shannon entropy functional H. The density g_{hmax} serves as the unique entropy-distinguishable representative within $\mathcal{C}_\infty$. We exploit this uniqueness to bridge the gap between moment-sequence convergence and distributional convergence within M-indeterminate settings.

Main results

It is well-established that the MaxEnt approximant f_M, constrained by the first M moments of $\{m_k\}$, converges in entropy to g_{hmax} as $M \to \infty$. Building upon this foundation, the primary contribution of the present work is the formulation of a generalized Fréchet-Shohat convergence theorem, applicable to both determinate and indeterminate frameworks. We demonstrate that for a sequence $\{f_M\}$ consistent with the prescribed moment constraints, the supplementary condition

$$\lim_{M\to\infty} H[f_M] = H[g_{hmax}] \tag{2}$$

where $H[g_{hmax}]$ is finite, is sufficient to guarantee that the sequence of distribution $\{G_M\}$ converges uniformly to G_{hmax}. The proof relies on the relationship between entropy and the

[*] Presenter

Kullback-Leibler (KL) divergence. Specifically, as M increases, $H[f_M]$ approaches $H[g_{hmax}]$ from above and this implies that KL-divergence $D(f_M \| g_M) = H[f_M] - H[g_M]$ tends to zero. Then, through Pinsker inequality,

$$V(f_M, g_{hmax}) \leq \sqrt{2D(f_M \| g_{hmax})} \tag{3}$$

so that also the total variation distance V is forced to zero. It follows that also the distance in $\mathcal{L}^1$ norm between f_M and g_{hmax} goes to zero, which in turn implies uniform, and then pointwise, convergence of $\{F_M\}$ to G_{hmax}.

g_{hmax} and Stieltjes classes

The density g_{hmax}, consistent with the informational content in $\{m_k\}$, can be also calculated through complex integration techniques via analytic continuation and Mellin transform inversion, circumventing the numerical instabilities and ill-conditioning inherent in traditional constrained optimization problems, particularly as the number of moments increases. This allow us to explore Stieltjes classes, defined by perturbations of a base density $g_{hmax}(x)$, using a function $h(x)$ such that $g_\epsilon(x) = g_{hmax}(x)[1+\varepsilon\, h(x)]$, $|\varepsilon| \leq 1$, where $h(x)$ is orthogonal to all powers of x. We demonstrate that in such classes, the moments remain invariant, but the entropy varies. Without the entropy convergence condition, a sequence can oscillate between different values of ε, leading to multiple cluster points in the sense of weak convergence.

Conclusions

By incorporating an entropic convergence criterion, the proposed methodology provides a unified analytical formalism applicable to both determinate and indeterminate regimes. In the M-det case, the approach recovers the unique density consistent with the moment sequence $\{m_k\}$, whereas in the$M$-indet case, it isolates the MaxEnt density g_{hmax} as the natural representative. These results facilitate a generalized Fréchet–Shohat framework, providing a rigorous probabilistic foundation for the integration of MaxEnt-based methods into statistical inference.

Keywords: Indeterminate Moment Problem · Maximum Entropy · Shannon Entropy · Fréchet-Shohat Theorem · Stieltjes Class · Kullback-Leibler Divergence.

Contributed Session
CS103: Moments, Cumulants and dependence: Classical and Modern Perspectives organized by Elvira Di Nardo

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Large deviations for stochastic approximation: A weak convergence approach

Henrik Hult[2], Adam Lindhe[2], Pierre Nyquist[1,2*], and Guo-Jhen Wu[2]

[1] Department of Mathematical Sciences, Chalmers University of Technology and University of Gothenburg, Sweden,
pnyquist@chalmers.se

[2] Department of Mathematics and Computer Science, University of Palermo, Palermo, Italy
{pierren, hult, adlindhe, gjwu}@kth.se

In this talk I will discuss new large deviation results for general stochastic approximation algorithms with state-dependent Markovian noise and decreasing step size.

The theory of stochastic approximations form the theoretical foundation for studying convergence properties of many popular recursive learning algorithms in statistics, machine learning and statistical physics. Large deviation results for stochastic approximations therefore provide asymptotic estimates of the probability that the learning algorithm deviates from its expected path, given by a limit ODE, and the large deviation rate function gives insights to the most likely way that such deviations occur.

The focus of the talk is a new large deviation principle for general stochastic approximations with state-dependent Markovian noise and decreasing step size, obtained using the weak convergence approach. Using this approach, we are able to generalize previous results for stochastic approximations and identify the appropriate scaling sequence for the large deviation principle. We also give a new representation for the rate function, in which the rate function is expressed as an action functional involving the family of Markov transition kernels. Examples of learning algorithms that are covered by the large deviation principle include stochastic gradient descent, persistent contrastive divergence and the Wang-Landau algorithm. Time permitted I will also highlight some connections to weak KAM theory and viscosity solutions to Hamilton-Jacobi equations. In particular regarding the projected Aubry set associated with a stochastic approximation algorithm.

Keywords: Large deviations · stochastic approximation · recursive algorithms · state-dependent noise · stochatic gradient descent.

Contributed Session

CS177: Stochastic Algorithms and Interacting Reinforced Processes organized by Michele Aleandri and Ida Minelli

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* Presenter

On Forgetting and Stability of Score-based Generative models

Stanislas Strasman[1], Gabriel Victorino-Cardoso[2], Sylvain Le Corff[1], Vincent Lemaire[1], Antonio Ocello[3⋆]

[1] Sorbonne Université and Université Paris Cité, CNRS, LPSM, F-75005 Paris, France
[2] Geostatistics team, Centre for geosciences and geoengineering, Mines Paris, PSL University, Fontaineableau, France
[3] Centre de Recherche en Économie et de Statistiques (CREST), Groupe ENSAE-ENSAI, ENSAE Paris, Institut Polytechnique de Paris, Palaiseau, France
antonio.ocello@ensae.fr

Understanding the stability and long-time behavior of generative models is a fundamental problem in modern machine learning. This paper provides quantitative bounds on the sampling error of score-based generative models by leveraging stability and forgetting properties of the Markov chain associated with the reverse-time dynamics. Under weak assumptions, we provide the two structural properties to ensure the propagation of initialization and discretization errors of the backward process: a Lyapunov drift condition and a Doeblin-type minorization condition. A practical consequence is quantitative stability of the sampling procedure, as the reverse diffusion dynamics induces a contraction mechanism along the sampling trajectory. Our results clarify the role of stochastic dynamics in score-based models and provide a principled framework for analyzing propagation of errors in such approaches.

Keywords: Generative models · Score-based generative models · Stability analysis · Lyapunov functions

Contributed Session
CS120: Probabilistic Perspectives on Generative Modeling organized by Antonio Ocello

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⋆ Presenter

Master Equations for Continuous-Time Random Walks with Stochastic Resetting

Gianni Pagnini[1]* and Fausto Colantoni[2]

[1] BCAM – Basque Center for Applied Mathematics & Ikerbasque, Bilbao, Basque Country – Spain,
gpagnini@bcamath.org
[2] Department of Basic and Applied Sciences for Engineering, Sapienza University of Rome, Rome, Italy
fausto.colantoni@uniroma1.it

We study a general continuous-time random walk (CTRW), by including non-Markovian cases and Lévy flights, under complete stochastic resetting to the initial position with an arbitrary law, which can be power-lawed as well as Poissonian. We provide three linked results. First, we show that the random walk under stochastic resetting is a CTRW with the same jump-size distribution of the non-reset original CTRW but different counting process. Later, we derive the condition for a CTRW with stochastic resetting to be a meaningful displacement process at large elapsed times, i.e., the probability to jump to any site is higher than the probability to be reset to the initial position, and we call this condition the zero-law for stochastic resetting. This law joins with the other two laws for reset random walks concerning the existence and the non-existence of a non-equilibrium stationary state. Finally, we derive master equations for CTRWs when the resetting law is a completely monotone function. The talk is based on the recent paper [1].

Keywords: Stochastic resetting · Continuous-time random walks · Master equations.

Contributed Session
CS176: Continuous-time random walks and diffusion processes: resetting and transformation for biological modeling organized by Luigia Caputo and Enrica Pirozzi

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* Presenter

Existence of Strong Randomized Equilibria in Mean-Field Games of Optimal Stopping with Common Noise

Anna Pajola[1⋆] and Giorgio Ferrari[2]

[1] Center for Mathematical Economics, Bielefeld University, Germany,
anna.pajola@uni-bielefeld.de
[2] Center for Mathematical Economics, Bielefeld University, Germany,
giorgio.ferrari@uni-bielefeld.de

We investigate a mean-field game of optimal stopping with common noise, in which a representative agent seeks the optimal stopping time to maximize a reward functional. Both the running and terminal reward functions depend on the mean-field interaction term, which, in equilibrium, corresponds to the conditional law of the optimal stopping time given the common noise. The setting we consider is non-Markovian, as the reward functions are general random functions, and the analysis is performed through a purely probabilistic approach. We seek strong mean-field equilibria in the sense of strong solutions to stochastic differential equations: we fix the probability space and the σ-algebra representing the common noise and look for adapted solutions. In mean-field games without common noise, strong solutions are usually obtained using fixed point theorems, such as Schauder's or Kakutani's theorems.

Our main contribution is an existence result for strong randomized mean-field equilibria in a setting with continuity assumptions of the reward functions with respect to the interaction terms. We define a strong randomized mean-field equilibrium as a pair, in which the mean-field interaction term is adapted to the common noise, while the stopping time is randomized, following the framework introduced in [1]. In this sense, we allow additional randomization in the stopping times, while maintaining adapted mean-field interaction terms. In order to be able to identify compact subsets within the space of mean-field interactions through tightness arguments, we assume that the common noise is generated by a countable partition of the probability space.

In addition, we study the mean-field game of optimal stopping in a setting with an order structure and monotonicity properties of the reward functions with respect to the mean-field interaction terms. In this framework, the common noise is represented by a general σ-algebra. We establish the existence of strong mean-field equilibria (with strict optimal stopping times, not randomized) by applying Tarski's fixed point theorem, a result which appears in earlier works (e.g., [2], [3] and [4]). Our contribution lies in a comparative statics analysis of the set of strong mean-field equilibria.

Keywords: Mean-field Games · Optimal Stopping · Common noise

Contributed Session
CS125: Cooperative and competitive mean-field models - Part I organized by Federico Cannerozzi and Giorgio Ferrari

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Beyond NNGP: Large Deviations and Feature Learning in Bayesian Neural Networks

Katerina Papagiannouli[1⋆] and Dario Trevisan[1]

Department of Mathematics, University of Pisa, Italy,
aikaterini.papagiannouli, dario.trevisan @unipi.it

Bayesian neural networks, in the overparameterized and infinite-width regime, are now well understood. Under mild assumptions, their prior converges to a Gaussian process (NNGP), and both Bayesian inference and training dynamics can be described by kernel methods. Although, these infinite-width limits provide tractable models and sharp theoretical insights, they also exhibit a fundamental rigidity: the induced feature representation becomes fixed and independent of data. As a result, feature learning disappears in the infinite-width limit, and Bayesian inference reduces to kernel regression with a predetermined kernel.

In this talk, we present a complementary large-deviation perspective on wide Bayesian neural networks. Rather than studying typical Gaussian fluctuations, we analyse exponentially rare, but statistically dominant, configurations that govern posterior concentration as width grows. At this scale, Bayesian inference becomes variational: posterior mass concentrates near minimizers of an explicit functional rate function defined directly on predictors. Our main result shows that, in contrast to the Gaussian-process limit, the posterior large-deviation rate function involves a joint optimization over predictors and internal covariance kernels. This nested variational structure leads to data-dependent kernel selection and provides a mechanism for feature learning that persists even in the infinite-width regime. In particular, we prove that the posterior-optimal kernel generically differs from the NNGP kernel.

Keywords: Large Deviations · Bayesian Learning · Wide Neural Networks· Gaussian Processes.

Contributed Session
CS180: Mathematics of Neural Networks organized by Stefano Vigogna

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⋆ Presenter

Non-local operators for Pearson diffusions

Ivan Papić[1⋆], Luisa Beghin[2], Nikolai N. Leonenko[3], and Jayme Vaz[4]

[1] School of Applied Mathematics and Informatics, University of Osijek,
ipapic@mathos.hr
[2] Department of Statistical Sciences, Sapienza University, Rome, Italy,
luisa.beghin@uniroma1.it
[3] School of Mathematics, Cardiff University, Cardiff, United Kingdom,
LeonenkoN@cardiff.ac.uk
[4] Departamento de Matemática Aplicada, Universidade Estadual de Campinas, Campinas, Brazil
vaz@unicamp.br

Pearson diffusions form a fundamental class of one-dimensional Markov processes with linear drift and quadratic diffusion coefficients, encompassing the Ornstein–Uhlenbeck, Cox–Ingersoll–Ross, and Jacobi processes. Their generators admit complete spectral decompositions in orthogonal polynomial bases, ensuring analytic tractability and explicit invariant measures, which make them central in stochastic analysis and operator theory.

We develop a non-local framework for Pearson diffusions by replacing the classical first-order time derivative in the Kolmogorov equations with a generalized Caputo-type operator. This extension captures memory effects and yields non-Markovian dynamics, which is obtained via time-change by inverse subordinators. Going beyond standard Caputo fractional derivatives, we introduce a stretched two-parameter non-local operator generating a broader class of memory kernels.

Using the spectral structure of Pearson generators, we establish existence and uniqueness of strong solutions to the associated non-local Cauchy problems. Solutions admit explicit spectral representations in which the classical exponential decay is replaced by Kilbas-Saigo functions, which are generalized Mittag–Leffler–type functions, exhibiting power-law decay. The resulting processes preserve invariant distributions while displaying stretched temporal behavior. These results generalize fractional Pearson diffusions and provide new operator-theoretic insights into anomalous diffusion and long-memory stochastic systems.

Keywords: Pearson diffusion · Time-change · Caputo fractional derivative · Kilbas-Saigo function · Spectral representation.

Contributed Session
CS146: Fractional Processes and Non-local Operators organized by Luisa Beghin

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⋆ Presenter

Hard wall repulsion for the discrete Gaussian free field in random environment in supercritical dimension

Emanuele Pasqui[1⋆], Alberto Chiarini[2], and Alessandra Cipriani[3]

[1] Department of Mathematics "Tullio Levi Civita", University of Padua, Italy,
pasqui@math.unipd.it
[2] Department of Mathematics "Tullio Levi Civita", University of Padua, Italy,
chiarini@math.unipd.it
[3] Department of Statistical Sciences, University College London, UK
a.cipriani@ucl.ac.uk

We consider the discrete Gaussian free field in random environment, where disorder is introduced through random edge conductances on the underlying graph. Such a model describes microscopic fluctuations of a crystal at positive temperature in the presence of inhomogeneities.

We focus on the integer lattice $\mathbb{Z}^d$ for $d \geq 3$, and analyse the maximal fluctuation of the field and its behaviour in the presence of a macroscopic hard wall constraint.

First, we derive sharp quenched large deviation asymptotics for the hard wall event. The rate is governed by two key quantities: the homogenized capacity of the associated random conductance model, and the essential supremum of the on-site (random) variances of the field. Secondly, we investigate the law of the field conditioned on the hard wall. We prove that the conditioned field exhibits an entropic push away from the zero height, and identify its expected asymptotic profile. Lastly, we characterize the pathwise behaviour of the conditioned field. This is based on [1], a joint work with Alberto Chiarini.

We conclude by discussing ongoing work with Alberto Chiarini and Alessandra Cipriani, where, still in the supercritical dimension, we replace the lattice $\mathbb{Z}^d$ with different underlying graphs, and study how their structure influences both the decay for the hard wall probability and the asymptotic profile for the expectation of the conditioned field.

Keywords: Gaussian free field · random environment · hard wall.

Contributed Session
CS178: Disordered systems in statistical mechanics organized by Alberto Chiarini

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⋆ Presenter

Spectral properties of directed inhomogeneous graphs

Giacomo Passuello[1⋆] and Rajat Subhra Hazra[2]

[1] Delft University of Technology, Delft Institute of Applied Mathematics (DIAM), Mekelweg 4, 2628CD Delft, Netherlands
g.passuello@tudelft.nl
[2] Mathematical Institute, Leiden University, Gorlaeus Gebouw, BW-vleugel, Einsteinweg 55, 2333 CC Leiden, The Netherlands
r.s.hazra@math.leidenuniv.nl

We consider the spectrum of the adjacency matrix of directed inhomogeneous graphs with independent edges.

Our framework includes, directed stochastic block models and the directed Chung–Lu model. We assume that the expected adjacency matrix has k non-zero eigenvalues of multiplicity 1 and we scale connection probabilities, so that average degrees diverge at least poly-logarithmically in the number of vertices.

In the rank one case, under suitable conditions, we provide a characterization of the asymptotic empirical spectral distribution, in terms of non-dilute Gaussian arrays. This is done extending to the inhomogeneous case previous results on the least singular values of complex diagonal shifts for the rescaled matrix. Using tools from free probability, we provide a more precise analysis and an explicit expression of the asymptotic singular value distribution.

Moreover, we establish the existence, with high probability, of k real outliers of the spectrum, whose scale is the square of the bulk's one. We further show that, centering and properly rescaling, the joint law of the k outliers converges in distribution to Gaussian multivariate law with an explicit covariance matrix.

Our analysis complements previous works in the symmetric setting.

Based on an ongoing work with Rajat Hazra.

Keywords: random graphs · random matrices · spectra

Contributed Session
CS127: Asymptotics of random graphs organized by Elena Magnanini and Pierfrancesco Dionigi

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⋆ Presenter

A Quantum-Probabilistic Framework for Decision-Making under Vagueness

Arianna Pavone

Department of Mathematics and Computer Science, University of Palermo, Italy,
ariannamaria.pavone@unipa.it

Modeling decision processes under semantic vagueness and contextual uncertainty remains a fundamental challenge in logic and artificial intelligence. Classical probabilistic and symbolic frameworks typically assume that cognitive states are well-defined prior to evaluation and that uncertainty can be fully captured within a Kolmogorovian probability space. However, empirical findings in cognitive science reveal systematic violations of classical probability theory in situations involving ambiguity, order effects, and context dependence [2,5]. In this talk, we propose a quantum-inspired formal framework in which cognitive states are represented as vectors in a Hilbert-like conceptual space, allowing vagueness to be modeled as the structured coexistence of multiple latent and potentially incompatible interpretations [1]. Within this setting, context is formalized as an observable acting on the conceptual state, and decision-making is modeled as a probabilistic collapse governed by the Born rule. This approach naturally accommodates contextuality, non-commutativity, and interference effects, offering a non-Kolmogorovian perspective on uncertainty consistent with broader quantum-like probabilistic frameworks [4]. We complement the theoretical formulation with a computational simulation in which conceptual states evolve via unitary transformations before collapsing under context-defined observables, thereby modeling the transition from indeterminate cognitive potentialities to determinate outcomes. Although illustrated through scenarios of creative cognition [3], the proposed model provides a more general paradigm for reasoning and context-dependent decision dynamics under vagueness. The framework suggests a unified formal perspective for studying uncertainty, semantic ambiguity, and probabilistic contextual selection in AI systems.

Keywords: Quantum Cognition · Contextual Uncertainty · Semantic Vagueness · Non-Kolmogorovian Probability · Context-Dependent Decision-Making

Contributed Session

CS172: Uncertainty, Vagueness, and Decision Support: Logical and AI Approaches organized by Arianna Pavone and Gianmarco La Rosa

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Mean field optimal stopping and related N-player cooperative games

Laura Perelli[1⋆] and François Delarue[2]

[1] Department of Mathematics, University of Milan, Milan, Italy
laura.perelli@unimi.it
[2] Department of Mathematics, Université Côte d'Azur, Nice, France
francois.delarue@univ-cotedazur.fr

We study finite-horizon mean field optimal stopping problems in which the state process is unaffected by the stopping time and is therefore uncontrolled. Such problems arise, for instance, in the pricing of American options when the underlying asset follows McKean–Vlasov dynamics. Due to the intrinsic time inconsistency, we introduce a suitable reformulation on an enlarged state space, referred to as the *extended problem*, which restores time consistency and admits a dynamic programming principle. In particular, this reformulation allows us to characterize both the value function and the optimal stopping time of the original problem in terms of the extended value function.
Building on this theoretical framework, the main focus of the presentation is on recent and ongoing developments concerning the N-player cooperative optimal stopping games associated with our mean field problem. Exploiting the strong connection between the original and extended formulations, we analyze the games corresponding to both settings. In particular, to reflect the cooperative nature of the games, we consider only exchangeable stopping strategies. We first investigate the N-player game linked to the extended problem and rigorously prove the convergence of its value function to that of the reformulated mean field limit as $N \to \infty$. Using this result, together with the established relationship between the extended and original limit value functions, we then derive the analogous convergence result for the original problem. Moreover, studying the extended game yields a key characterization of the optimal stopping strategies: for the original (non-extended) game, restricting our analysis to exchangeable strategies implies that the optimal policy consists of N coinciding stopping times, so that all players stop at the same instant.
Finally, relying on the characterization of the limiting optimal stopping time and on the convergence of the value functions, we analyze the asymptotic behavior of the N-player optimal stopping time. To obtain explicit probabilistic bounds on its distance from the limit optimal stopping time, our approach crucially exploits the analytic properties of the mean field free boundary, working in a one-dimensional, time-homogeneous Markovian framework under the assumption of a time-decreasing running gain.

Keywords: Mean field optimal stopping · N-player cooperative games · McKean-Vlasov dynamics · Free boundary

Contributed Session
CS126: Cooperative and competitive mean-field models - Part II organized by Federico Cannerozzi and Giorgio Ferrari

⋆ Presenter

Invariant measures for one-dimensional stochastic compressible fluid equations

Pescatore Lorenzo

Department of Information Engineering, Computer Science and Mathematics, University of L'Aquila, Italy,
lorenzo.pescatore@univaq.it

We investigate the long-time behavior of one-dimensional models of compressible viscous fluids subject to stochastic forcing. In particular, we focus on the Navier–Stokes–Korteweg equations (NSK), which describe the dynamics of a compressible viscous fluid in regimes where capillarity effects cannot be neglected. In this framework, we establish the existence of invariant measures by adapting the Krylov–Bogoliubov method to the case of a non-Feller Markov semigroup. The analysis of invariant measures and, more generally, of ergodic properties for compressible fluid systems presents several structural obstacles, including the lack of compactness, the possible formation of vacuum regions, and the absence of classical regularity frameworks typically used in incompressible settings. This talk provides an overview of these challenges and discusses recent strategies to overcome them. The proof of the existence of invariant measures for the NSK equations relies on the derivation of suitable a priori estimates providing an appropriate time-growth rate of solutions, despite the presence of high-order nonlinear terms due to capillarity. Building on these estimates, we perform a stochastic compactness argument and introduce a class of functions that is invariant under the Markov semigroup while remaining compatible with the available convergence result. Overall, the present result highlights specific properties of Korteweg fluids that remain unknown in models where capillarity effects are neglected.

Keywords: Invariant measures · Stochastic compressible fluids.

Contributed Session
CS171: Methods in stochastic fluid dynamics: a young researchers' perspective organized by Theresa Lange and Lorenzo Marino

The Dubins Constants for Walsh's Spider Process

Goran Peskir

Department of Mathematics, The University of Manchester, United Kingdom,
goran@maths.man.ac.uk

A long-standing open problem of L. E. Dubins seeks to determine the maximal expected range of Walsh's spider process on n edges per root of the expected stopping time. The solution is known for $n = 1$ (1988) and $n = 2$ (2009). In this talk I will present the solution for $n \geq 3$.

Keywords: Dubins constants · Walsh spider process · Brownian motion.

Contributed Session
CS133: Optimal Stopping and Applications organized by Bruno Buonaguidi

Non-Asymptotic Convergence of Discrete Diffusion Models: Masked and Random Walk dynamics

Le-Tuyet-Nhi Pham[1⋆], Giovanni Conforti[2], Alain Durmus[1], and Gaël Raoul[1]

[1] École Polytechnique, CMAP, IP Paris, Palaiseau, France
{le-tuyet-nhi.pham, alain.durmus, gael.raoul}@polytechnique.edu
[2] Department of Mathematics, University of Padova, Padova, Italy
giovanni.conforti@math.unipd.it

Diffusion models for continuous state spaces based on Gaussian noising processes are now relatively well understood from both practical and theoretical perspectives. In contrast, results for diffusion models on discrete state spaces remain far less explored and pose significant challenges, particularly due to their combinatorial structure and their more recent introduction in generative modelling. In this work, we establish new and sharp convergence guarantees for three popular discrete diffusion models (DDMs). Two of these models are designed for finite state spaces and are based respectively on the random walk and the masking process. The third DDM we consider is defined on the countably infinite space $\mathbb{N}^d$ and uses a drifted random walk as its forward process. For each of these models, the backward process can be characterized by a discrete score function that can, in principle, be estimated. However, even with perfect access to these scores, simulating the exact backward process is infeasible, and one must rely on time discretization. In this work, we study Euler-type approximations and establish convergence bounds in both Kullback–Leibler divergence and total variation distance for the resulting models, under minimal assumptions on the data distribution. To the best of our knowledge, this study provides the *optimal non-asymptotic* convergence guarantees for these noising processes that do not rely on boundedness assumptions on the estimated score. In particular, the computational complexity of each method scales only *linearly in the dimension, up to logarithmic factors.*

Keywords: Discrete diffusion models, · Non-asymptotic convergence · Masked diffusion · Random walk · Generative models for discrete data · Infinitely countable data · Score monotonicity.

Contributed Session
CS120: Probabilistic Perspectives on Generative Modeling organized by Antonio Ocello

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⋆ Presenter

A stochastic volatility approximation for a tick-by-tick price model with mean-field interaction

Paolo Pigato

Department of Economics and Finance, University of Rome Tor Vergata, Italy.
paolo.pigato@uniroma2.it

We consider a tick-by-tick model of price formation, in which buy and sell orders are modeled as self-exciting point processes (Hawkes process), similar to the one in [1,2]. We adopt an agent based approach by studying the aggregation of a large number of these point processes, mutually interacting in a mean-field sense.

The financial interpretation is that of an asset on which several labeled agents place buy and sell orders following these point processes, influencing the price. The mean-field interaction introduces positive correlations between order volumes coming from different agents that reflect features of real markets such as herd behavior and contagion. When the large scale limit of the aggregated asset price is computed, if parameters are set to a critical value, a singular phenomenon occurs: the aggregated model converges to a stochastic volatility model with leverage effect and faster-than-linear mean reversion of the volatility process.

The faster-than-linear mean reversion of the volatility process is supported by econometric evidence, and we have linked it in [3] to the observed multifractal behavior of assets prices and market indices. This seems connected to the Statistical Physics perspective that expects anomalous scaling properties to arise in the critical regime.

The presentation is based on [4], joint work with Paolo Dai Pra.

Keywords: Stochastic Volatility · Hawkes processes · multifractality · mean-field · nonlinearity · criticality.

Contributed Session

CS169: Applications of probability to economics, finance, and insurance organized by Elena Bandini and Alessandro Calvia

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Nonparametric Estimation of the Diffusive Interaction Function in Particle Systems

Francisco Pina[1], Chiara Amorino[2], and Mark Podolskij[1]

[1] Department of Mathematics, University of Luxembourg, Luxembourg,
francisco.pina@uni.lu mark.podolskij@uni.lu
[2] Department of Economics and Business, Universitat Pompeu Fabra, Spain
chiara.amorino@upf.edu

In this talk, we present a nonparametric estimator for the diffusive interaction function in particle systems, constructed from Nn discrete observations of the trajectories. We comment its statistical performance and provide theoretical guarantees on the estimation error within suitable function classes and norms. We also discuss the main challenges arising in this setting and comment on optimality properties of the estimator.

Keywords: Interacting particle systems · Nonparametric statistics · High-dimensional statistics.

Contributed Session
CS117: Statistical inference for high-dimensional diffusions organized by Chiara Amorino

References

The Wasserstein geometry of random measures

Alessandro Pinzi[1⋆] and Giuseppe Savaré[1]

Department of Decision Sciences, Bocconi University, Milano, Italy,
alessandro.pinzi@phd.unibocconi.it
giuseppe.savare@unibocconi.it

We study the geometric structure of the space of random measures $\mathcal{P}_p(\mathcal{P}_p(X))$, endowed with the Wasserstein-on-Wasserstein metric, where (X, d) is a complete separable metric space. In this setting, we prove a metric superposition principle, that will allow us to recover important geometric features of the space.

When X is $\mathbb{R}^d$, we study the differential structure of $\mathcal{P}_p(\mathcal{P}_p(\mathbb{R}^d))$ in analogy with the simpler Wasserstein space $\mathcal{P}_p(\mathbb{R}^d)$. We show that continuity equations for laws of random measures involving the abstract concept of derivation acting on cylinder functions can be more conveniently described by suitable non-local vector fields $b : [0,T]\times\mathbb{R}^d\times\mathcal{P}_p(\mathbb{R}^d) \to \mathbb{R}^d$. In this way, we can: characterize the absolutely continuous curves on the Wasserstein-on-Wasserstein space; define and characterize its tangent bundle; prove a Benamou-Brenier-like formula; prove a superposition principle for the solutions to the standard non-local continuity equation in terms of solutions of interacting particle systems.

Keywords: Wasserstein geometry · Random measures · Superposition principle.

Contributed Session
CS128: (Stochastic) Analysis on Spaces of Probability Measures and Applications organized by Mattia Martini and Giacomo Enrico Sodini

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⋆ Presenter

Analysis of Systems through the Regression Importance Signature

Giulia Pisano[1*], Antonio Di Crescenzo[1], and Alfonso Suárez-Llorens[2]

[1] Department of Mathematics, University of Salerno, Salerno, Italy,
{gpisano,adicrescenzo}@unisa.it
[2] Department of Statistics and Operational Research, University of Cádiz, Cádiz, Spain
alfonso.suarez@uca.es

The regression importance index of a coherent system evaluates a component's importance based on the system's conditional mean lifetime when the component's failure time is known (see Arriaza et al. [1]). We aim to introduce the "regression importance signature", a tool designed to identify, for a given number of components, the subgroup that should be prioritized in reliability analysis and failure localization. To achieve this, the concept of importance index is generalized for subgroups of components, taking into account the occurrence of failures within the subgroup. General results for systems with dependent components are provided, with a particular focus on system modules, as well as sufficient conditions for comparing the importance of individual components and subgroups. This analysis highlights how a component's relevance depends not only on its reliability but also on its structural role within the system. As an application, we consider the ship control system already discussed in [1], extending the original analysis to the computation of the full signature. This allows us to identify the most influential subgroups of components and to explore how the dependence modeled by the FGM copula and the variation of its parameters affect the importance of different subsets of components.

Keywords: Coherent systems · Importance measures · Stochastic orders.

Contributed Session
CS181: Approaches to Uncertainty and Information Measures organized by Andrea Capotorti and Silvia Lorenzini

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* Presenter

Permutation Tests and NPC Methodology. Theory and Application in Education, in Clinical Research and in Social Security

Gianfranco Piscopo[1⋆] and Maria Longobardi[1]

Department of Mathematics and Applications "R. Caccioppoli", University of Naples Federico II, Naples, Italy
gianfranco.piscopo@unina.it
maria.longobardi@unina.it

Real-world data frequently violate the assumptions underlying classical parametric inference, including normality, homoscedasticity, and balanced experimental designs. These challenges are particularly relevant in applied contexts characterized by heterogeneous samples, mixed outcome types, and small data sizes. This work investigates permutation tests and the Nonparametric Combination (NPC) methodology as a unified framework for robust statistical inference under minimal assumptions.

Permutation tests reconstruct the null distribution of test statistics through resampling based on exchangeability, yielding exact or Monte Carlo–exact inference without distributional constraints. The NPC methodology extends this approach to multivariate settings by combining partial permutation tests using suitable combining functions, such as Fisher statistics, enabling global inference while preserving dependence structures through synchronized permutations and controlling the family-wise error rate. From an applied perspective, this framework naturally accommodates mixed measurement scales, correlated endpoints, and unbalanced designs.

The empirical contribution is illustrated through three interdisciplinary applications. In education, the methodology evaluates teaching effectiveness using a randomized classroom experiment with heterogeneous outcomes, including continuous improvement measures and ordinal satisfaction indicators, providing strong global evidence of learning gains. In clinical research, the NPC framework is applied to a dataset of patients affected by necrotizing fasciitis, combining continuous biomarkers and binary survival outcomes within a small heterogeneous sample. The analysis identifies key predictors and demonstrates the stability of permutation-based inference in noisy medical data. Finally, in the social security domain, permutation tests and NPC methodology are employed to assess regional pension disparities in Italy using administrative microdata, revealing statistically significant territorial inequality and highlighting the ability of the framework to integrate correlated socio-economic indicators into a single coherent inferential measure.

Overall, permutation-based NPC methods emerge as robust, interpretable, and distribution-free tools for interdisciplinary statistical analysis, offering a practically relevant alternative to classical parametric approaches.

Keywords: Permutation tests · Nonparametric Combination · Multivariate inference · Mixed outcomes · Small sample inference

Contributed Session
CS190: Methodological Issues in Multidimensional and Composite Data Analysis organized by Massimiliano Giacalone and Gianfranco Piscopo

⋆ Presenter

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Limit theorems for space-time Gaussian fields on $\mathbb{R}^d$

Francesca Pistolato[1]

Department of Mathematics, University of Luxembourg, Luxembourg
francesca.pistolato@uni.lu

We study non-linear additive functionals of Gaussian fields over anisotropically growing domains on $\mathbb{R}^d$ — for instance, spatiotemporal ones — and show that Gaussian or Rosenblatt-type limits arise under non-separable covariance structures, depending on precise long-range dependence conditions, thereby extending existing spatiotemporal limit theorems beyond the separable and short-memory frameworks. In particular, we prove that 2-domain Rosenblatt distributions emerge as limits for Gaussian fields with Gneiting-type covariance functions, widely used in spatiotemporal applications. The talk is based on a joint work with N. Leonenko, I. Nourdin, and L. Maini.

Keywords: Long-range dependence · Rosenblatt distribution · Anisotropic Gaussian fields

Contributed Session
CS129: New Horizons for Random Fields in Probability and Statistics organized by Claudio Durastanti

Some structural results for Gaussian Quantum Markov Semigroups

Damiano Poletti[1⋆], Franco Fagnola[2], Federico Girotti[2], Emanuela Sasso[1], and Veronica Umanità[1]

[1] Department of Mathematics, University of Genova, Italy
{damiano.poletti, emanuela.sasso, veronica.umanita}@unige.it
[2] Department of Mathematics, Politecnico di Milano, Italy
{franco.fagnola, federico.girotti}@polimi.it

Quantum Markov Semigroups (QMSs) have been used in the literature to model the reduced evolution of a quantum system coupled to the environment. Gaussian QMSs are a specific type of such semigroups, acting on bounded operators on the Boson Fock space, characterized by the fact that their predual map gaussian states into other gaussian states. They are not only relevant in the applications but also from a mathematical standpoint, since they constitute an amenable class of not uniformly continuous semigroups, where many computations can still be performed, and are closely related to the classical Ornstein-Uhlenbeck semigroups.

In this talk I will present a summary of results from [1,2,3] from a double perspective. On the one hand, they provide algebraic conditions on the parameters that define the semigroup to characterize relevant properties of the semigroup itself, such as the spectral gap, the decoherence-free subalgebra, the existence of an invariant state and the symmetry of the semigroup with respect to it. On the other hand, these properties shape the semigroup, forcing it to have a specific, simpler structure.

Keywords: Quantum Markov Semigroups · Gaussian states · Symmetry.

Contributed Session
CS159: Probabilistic approach to quantum mechanics organized by Federico Girotti and Anderson Hernandez

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⋆ Presenter

Ordering and measuring the complexity of lotteries

Giulio Principi

Department of Economics, New York University, USA
gp2187@nyu.edu

We model complexity by introducing a *complexity order* that ranks lotteries by their Wasserstein distances from degenerate lotteries, which carry no risk. The resulting relation is a continuous incomplete preorder whose properties reflect the geometry of the outcome space. We relate it to the convex order, showing that they coincide for univariate monetary lotteries, while this equivalence fails in higher dimensions.
To address incompleteness, we introduce a *complexity measure* defined by how well a lottery can be approximated by a degenerate one. This measure provides a natural completion of the complexity order and inherits many of its properties. It enables comparative statics for mixtures of lotteries and yields explicit maximally complex lotteries in several cases.
Finally, we apply these notions to choice under risk. Combining the complexity order with first-order stochastic dominance yields a choice criterion that, for monetary lotteries, is equivalent to second-order stochastic dominance. Using our complexity measure, we define *Complexity-Sensitive Expected Utility* (CSEU) preferences. For this class of preferences, we analyze how complexity aversion interacts with risk aversion and, in particular, prove that complexity aversion is a component of risk aversion.

Keywords: Complexity · Lotteries · Risk.

Contributed Session
CS174: Probability, Risk and Decision Theory organized by Fabio Bellini

Chapter 2: Transport Equation and Kolmogorov equations

Enrico Priola

Department of Mathematics, University of Pavia, Italy,
enrico.priola@unipv.it

I will begin by introducing the paper [7] regarding a singular stochastic transport equation. This appears to have been the first paper concerning a PDE of interest in fluid dynamics that becomes well-posed under the influence of a (multiplicative) Wiener noise.

Next, I will discuss several developments and research directions stemming from this work. The first direction involves papers on regularization by transport noise of Wiener type (such as [8], [6], [1] and [9]). This field has grown significantly, leading to several important ramifications. I will primarily focus on works published up to 2015.

A second direction concerns singular stochastic evolution equations in infinite dimensions. In this regard, the paper [7] and the theory of Kolmogorov equations in infinite dimensions (see [4], [5] and the references therein) inspired the seminal paper [3] on strong uniqueness for SPDEs with Hölder continuous and bounded coefficients. I will also mention some recent developments in this area.

Finally, I will explore regularization by Lévy noise. It appears that the first paper on this topic was [11] which showed that a singular one-dimensional deterministic differential equation can become well-posed under the influence of a stable noise. I will briefly discuss some contributions to this field (including [10]) and a recent work [2] regarding a singular stochastic transport equation driven by pure-jump Lévy noise.

Keywords: Stochastic transport equations · Kolmogorov equations · Stochastic evolution equations

Contributed Session

CS102: "Tales of Randomness: A Historical Perspective on SPDEs" organized by Eliseo Luongo and Umberto Pappalettera

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Explosions of stochastic Volterra equations

Sergio Pulido[1*] and Alessandro Bondi[2]

[1] ENSIIE-LaMME, Evry, France
sergio.pulidonino@ensiie.fr
[2] Department of AI, Data and Decision Sciences, Luiss University, Rome, Italy
abondi@luiss.it

We present a Feller-type test for explosions of one-dimensional continuous stochastic Volterra processes of convolution type. We focus on dynamics driven by nonsingular kernels, which preserve the semimartingale property of the processes while incorporating memory effects through a path-dependent drift. For the Volterra square-root diffusion, also known as the Volterra CIR process, we provide a detailed discussion of the approximation of the singular fractional kernel by a sum of exponentials, a technique commonly used in the mathematical finance literature.

Keywords: Feller test for explosions · Stochastic Volterra Equations · Volterra square-root diffusion.

CS 157:
Contributed Session
CS157: Recent Advances in Stochastic Volterra Equationse organized by Sergio Pulido

* Presenter

Metastability of Glauber dynamics with inhomogeneous coupling disorder

Elena Pulvirenti[1*]

Delft Institute of Applied Mathematics, Delft University of Technology, Netherlands,
e.pulvirenti@tudelft.nl

I will first introduce a general class of mean-field-like spin systems with random couplings that comprises both the Ising model on inhomogeneous dense random graphs and the randomly diluted Hopfield model. I will then present quantitative estimates of metastability in large volumes at fixed temperatures when these systems evolve according to a Glauber dynamics, i.e. where spins flip with Metropolis rates at inverse temperature β. The main result identifies conditions ensuring that with high probability the system behaves like the corresponding system where the random couplings are replaced by their averages. More precisely, we prove that the metastability of the former system is implied with high probability by the metastability of the latter. Moreover, we consider relevant metastable hitting times of the two systems and find the asymptotic tail behaviour and the moments of their ratio. Based on a joint work in collaboration with Anton Bovier, Frank den Hollander, Saeda Marello and Martin Slowik.

Keywords: Metastability · Glauber dynamics · disorder.

Contributed Session
CS160: Non-homogeneous random graphs organized by Luca Avena

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* Elena Pulvirenti

ZOBA: An Efficient Single-loop Zeroth-order Bilevel Optimization Algorithm

Marco Rando[1⋆] and Samuel Vaiter[2]

[1] Université Côte d'Azur, Inria, CNRS, LJAD, Nice, France,
marco.rando@inria.fr
[2] CNRS & Université Côte d'Azur, LJAD, Nice, France,
Samuel.VAITER@univ-cotedazur.fr

Bilevel optimization problems consist of minimizing a value function whose evaluation depends on the solution of an inner optimization problem. These problems are typically tackled using first-order methods that require computing the gradient of the value function (*the hypergradient*). However, in several practical settings, first-order information is unavailable (*zeroth-order setting*), rendering these methods inapplicable. Finite-difference methods provide an alternative by approximating hypergradients using function evaluations along a set of directions. Nevertheless, such surrogates are notoriously expensive, and existing finite-difference bilevel methods rely on two-loop algorithms that are poorly parallelizable [1,2,3]. To tackle these limitations, we propose ZOBA, the first finite-difference single-loop algorithm for bilevel optimization. Our method leverages finite-difference hypergradient approximations based on delayed information to eliminate the need for nested loops. We analyze the proposed algorithm and establish convergence rates in the non-convex setting, achieving a complexity of $\mathcal{O}(p(d+p)^2\varepsilon^{-2})$, where p and d denote the dimension of inner and outer spaces respectively and $\varepsilon \in (0,1)$ an accuracy parameter, which is better than prior approaches based on Hessian approximation. We further introduce and analyze HF-ZOBA, a Hessian-free variant that yields additional complexity improvements. Finally, we corroborate our findings with numerical experiments on synthetic functions and a real-world black-box task in adversarial machine learning. Our results show that our methods achieve accuracy comparable to state-of-the-art techniques while requiring less computation time.

Keywords: Zeroth-order Optimization · Black-box Optimization · Bilevel Optimization · Stochastic Optimization.

Contributed Session
CS179: Interacting Particles and Optimization in Machine Learning organized by Andrea Agazzi and Elena Issoglio

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⋆ Presenter

Separate Exchangeability as Modeling Principle in Bayesian Nonparametrics

Giovanni Rebaudo

ESOMAS Department, University of Torino and Collegio Carlo Alberto, Italy,
giovanni.rebaudo@unito.it

We argue for the use of separate exchangeability as a modeling principle in Bayesian nonparametric (BNP) inference. Separate exchangeability is *de facto* widely applied in the Bayesian parametric case, e.g., it naturally arises in simple mixed models. However, while in some areas, such as random graphs, separate and (closely related) joint exchangeable models are widely used, they are curiously underused for several other applications in BNP. We briefly review the definition of separate exchangeability, focusing on the implications of such a definition in Bayesian modeling. We then discuss two tractable classes of models that implement separate exchangeability, which are the natural counterparts of familiar partially exchangeable BNP models.

The first is nested random partitions for a data matrix, defining a partition of columns and nested partitions of rows, nested within column clusters. Many recent models for nested partitions implement partially exchangeable models related to variations of the well-known nested Dirichlet process. We argue that inference under such models in some cases ignores important features of the experimental setup. We obtain the separately exchangeable counterpart of such partially exchangeable partition structures.

The second class is about setting up separately exchangeable priors for a nonparametric regression model when multiple sets of experimental units are involved. We highlight how a Dirichlet process mixture of linear models, known as ANOVA DDP, can naturally implement separate exchangeability in such regression problems. Finally, we illustrate how to perform inference under such models in two real data examples.

This presentation is based on [4], a joint work with Qiaohui Lin and Peter Müller.

Keywords: Separate Exchangeability · Bayesian Nonparametrics · Modeling Principles · Partial Exchangeability · Random Partition Model.

Contributed Session
CS109: Recent Advances in Bayesian Nonparametrics organized by Beatrice Franzolini.

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Relative Performance Concerns in Financial Markets under Recursive Intertemporal Preferences

Frank Riedel[1⋆], Jodi Dianetti[2], and Lorenzo Stanca[3]

[1] Center for Mathematical Economics, Bielefeld University, Germany
frank.riedel@uni-bielefeld.de
[2] University of Rome Tor Vergata, Italy
jodi.dianetti@uniroma2.it
[3] Collegio Carlo Alberto and University of Turin, Italy
lorenzomaria.stanca@unito.it

This paper studies the strategic behavior of traders who care about their performance relative to others in financial markets, a phenomenon well documented both empirically and anecdotally. In many institutional settings, such as the asset management industry, fund managers are evaluated against benchmark indices or peer performance, creating strong incentives to match or outperform competitors. These relative performance concerns generate strategic interactions among traders and shape both portfolio and consumption decisions.

We analyze this interaction in a continuous-time financial market framework where agents have recursive (Epstein–Zin) preferences, extending earlier models that relied on time-additive utility. Epstein–Zin preferences are particularly important because they allow risk aversion and the intertemporal elasticity of substitution (IES) to be disentangled – two concepts that are confounded in standard discounted expected utility models. This distinction is both conceptually and empirically relevant, as it permits more realistic modeling of asset prices, aggregate risk premia, and consumption dynamics, and aligns better with observed investor behavior.

Within this framework, the paper formulates a non-cooperative game among traders with relative performance concerns and recursive intertemporal preferences. Despite the complexity arising from continuous-time markets, strategic interaction, and stochastic differential utility, we are able to derive a closed-form Nash equilibrium. We further extend the analysis to a mean-field game setting with a continuum of agents, representing the first example in the literature of a mean-field game involving stochastic differential utility.

Allowing for recursive preferences leads to important and nontrivial implications for equilibrium outcomes. In contrast to time-additive utility models, Epstein–Zin preferences incorporate a preference for the early resolution of uncertainty, which significantly affects consumption behavior. The paper shows that equilibrium intertemporal consumption patterns depend critically on how an individual's preference for early resolution of uncertainty compares to the population average. As a result, standard time-additive models may miss key aspects of consumption dynamics and generate misleading predictions. The analysis also delivers a clear separation between the determinants of portfolio choice and consumption. Portfolio allocation is driven solely by the parameter of risk aversion, while the intertemporal elasticity of substitution primarily governs consumption dynamics. This result is consistent with the Epstein–Zin literature for single-agent models, but is here shown to persist in a strategic, multi-agent environment with relative performance concerns. Overall, the paper provides a tractable and analytically rich framework that integrates relative performance motives, recursive preferences, and strategic interaction, yielding new insights into equilibrium portfolio and consumption behavior in financial markets.

⋆ Presenter

Frank Riedel, Jodi Dianetti, and Lorenzo Stanca

Keywords: mean-field games · portfolio choice · recursive utility · stochastic differential utility · BSDEs

Contributed Session

CS106: Collective Phenomena in Financial Markets: Arbitrage, Replication, and Risk organized by Marco Fritelli

Large-Scale Analysis of Multi-Scale Queuing Networks: Applications to Car-Sharing Systems

Alessia Rigonat[1⋆], Christine Fricker[1], and Hanene Mohamed[2]

[1] INRIA Paris, DI ENS, France,
{alessia.rigonat,christine.fricker}@inria.fr
[2] MODAL'X, Nanterre Univeristy, France
hmohamed@parisnanterre.fr

We develop a probabilistic model for free-floating car-sharing systems. In these systems, shared vehicles occupy the same parking spaces as private cars. The availability of parking spaces across different zones of a city depends on private cars, which are far more numerous than free-floating vehicles (see [1]). The system dynamics are described by a closed network of queues in which private and free-floating cars move among the same nodes, representing city zones. Nodes have finite capacity, and saturation is handled through a blocking and rerouting policy. We show that these dynamics preserve the product-form structure of the invariant distribution, extending the result in [2]. The model accounts for spatial heterogeneity in both user demand and availability of parking spaces. We identify, in this setting, phase transitions between an overloaded regime where all nodes are saturated and underloaded regimes with saturated and non-saturated nodes. Scaling limits and stochastic averaging methods are used to analyze the behavior of the system when the capacity of the nodes is large. The analysis is performed when the average number of private cars per zone increases linearly with capacity, while the number of free-floating cars remains of smaller order. Our goal is to characterize the macroscopic behavior of the system and provide insights for optimizing vehicle distribution.

Keywords: queuing networks · scaling limits · car-sharing.

Contributed Session
CS144: Probabilistic Analysis of Complex Engineering Networks organized by Emanuele Mengoli

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⋆ Presenter

Flow equation approach to stochastic quantisation

Paolo Rinaldi[1⋆], Massimiliano Gubinelli[2], and Pawel Duch[3]

[1] Dipartimento di Fisica, Università di Pavia, Italy,
paolo.rinaldi@unipv.it
[2] Mathematical Institute, University of Oxford, United Kingdom
gubinelli@maths.ox.ac.uk
[3] EPFL, Lausanne, Switzerland
pawel.duch@epfl.ch

We present a construction of the measure of the fractional Φ^4 Euclidean quantum field theory on $\mathbf{R}^3$ in the full subcritical regime via parabolic stochastic quantisation. Our approach is based on the use of a truncated flow equation for the effective description of the model at sufficiently small scales and on coercive estimates for the nonlinear stochastic partial differential equation describing the interacting field. The constructed measure is invariant under translations, reflection positive and has quartic exponential tails.

Keywords: stochastic quantisation · renormalisation group · fractional Laplacian.

Contributed Session

CS162: Singular stochastic analysis and stochastic quantization organized by Alberto Bonicelli and Francesco De Vecchi

⋆ Presenter

Homophily within and across groups: a maximum-entropy framework for analyzing different social scales

Abbas K. Rizi[1,2,3], Riccardo Michielan[4,5⋆], Clara Stegehuis[4], and Mikko Kivelä[3]

[1] DTU Compute, Technical University of Denmark, Kongens Lyngby, Denmark
akari@dtu.dk
[2] Department of Computer Science, School of Science, Aalto University, Espoo, Finland
mikko.kivela@aalto.fi
[3] Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, Netherlands
clara.stegehuis@utwente.nl
[4] Gran Sasso Science Institute, L'Aquila, Italy
riccardo.michielan@gssi.it

Homophily is the tendency of people to interact more with others who are similar to them (for instance by age, gender, or opinion). It is often summarized by a single assortativity number for the entire network, but this can hide important structural features. From a probabilistic viewpoint, this is a loss of information: two networks may share the same global homophily yet have very different local organization and large-scale behavior.

A key observation is that social interactions naturally occur at different "scales". Some interactions are one-to-one, while others occur within small groups (for example, a work team, a classroom, or a recurring social circle). These scales need not display the same mixing pattern: a society may have many cross-group acquaintances but mostly same-group close circles, or vice versa. Standard network statistics typically blend these effects.

In this talk, we present a modeling framework that makes this multi-scale structure explicit while remaining analytically tractable. The idea is to represent a sparse network as the superposition of group interactions of different sizes. For each size we control, we estimate how strongly interactions tend to occur within versus across groups. The model is built using a maximum-entropy principle: among all random networks consistent with basic constraints (such as the overall group proportions and the observed amount of same-group interaction at each scale), we select the least biased distribution.

Empirically, fitting the model to social networks reveals that homophily can be strongly scale-dependent. Networks that appear similar when judged by a single assortativity score can differ markedly once we separate direct contacts from small-group structure. This yields an informative "homophily profile" across scales and helps explain which parts of the network architecture are responsible for perceived segregation or integration.

We also discuss why these distinctions matter for probabilistic questions about connectivity and spreading. In many applications, transmission (of information, behaviors, or infections) occurs through a combination of reinforcement inside groups and occasional bridges between groups. Changing where homophily sits, mostly in direct links versus mostly inside groups, can change the onset and size of large connected components and alter the effectiveness of interventions. Overall, the framework offers a principled way to connect interpretable social mechanisms to the behavior of random graph models at scale.

Keywords: homophily · social networks · community structure · cliques.

Contributed Session

CS140: Community structure of Complex Networks organized by Riccardo Michielan and Lars Schroeder

⋆ Presenter

Chapter 1: Ergodicity and Markov Selections

Marco Romito[1]

Dipartimento di Matematica, Università di Pisa, Italia,
marco.romito@unipi.it

Once upon a time, the problem started with a question: can the addition of (some kind of) noise improve structural properties of infinite-dimensional systems, such as existence, uniqueness, regularity, stability, etc.? First, we will discuss some finite-dimensional examples in which the answer is positive, as well as some infinite dimensional examples, to convince our readers that this question is worth asking. We will then tell about some of the early attempts, made by a few groups, to obtain additional properties of solutions (mainly Markovianity, relaxation to equilibrium) by means of the underlying probabilistic structure.

Keywords: stochastic PDEs · Markov selections · unique ergodicity.

Contributed Session
CS102: Tales of Randomness: A Historical Perspective on SPDEs organized by Eliseo Luongo and Umberto Pappalettera

Interacting vertex reinforced random walks on complete subgraphs with simultaneous and independent transitions

Fernando P. A. Prado and Rafael A. Rosales

Departamento de Computação e Matemática Universidade de São Paulo, SP 14040-901, Brazil
rrosales@usp.br, feprado@usp.br

We will describe a model for interacting vertex-reinforced random walks, each taking values on a complete subgraph of a locally finite undirected graph. The transition probability of a walk to a given vertex depends on the cumulative proportion of visits by all walks that have access to that vertex. Proportions are modified by multiplication by a real valued interaction parameter and the addition of a parameter representing the intrinsic preference of the walk for the vertex. This model covers a wide range of interactions, including the cooperation or competition of several walks at single vertices. Under mild regularity conditions, the proportion of visits to each vertex by all walks converges almost surely towards the set of fixed points of the transition probabilities. Convergence to a single fixed point is in fact the generic behaviour as this is shown to hold for almost all parameters. Far beyond convergence, the model allows for a detailed description of the asymptotic behaviour depending on the interaction parameters and subgraph geometries. This will be illustrated by few examples including competing walks on complete graphs and complete subgraphs of stars and cycles.

We will also consider the case where each walk i makes transitions at independent random times $t_1^i, t_2^i, t_3^i, \ldots$ with geometrically distributed inter-transition times with parameter $p^i \in (0, 1]$. Independently of the value of p^i, we prove that the vertex occupation measure converges almost surely to the same set of fixed points as the synchronous version of the process–remarkably, these accumulation points do not depend on the parameters p^i. However, an interesting open question remains: although the accumulation points are invariant to p^i, the probability distribution over these limit points may be substantially affected by these parameters. In competitive dynamics, walks with larger p^i transition more frequently and may occupy more attractive vertices with higher probability, potentially excluding slower opponents more effectively.

If time allows, we will mention few open problems and discuss possible directions for future research. The results to be presented are based in part on those described in [1].

Keywords: Reinforced random walk · Stochastic approximation · Strong laws

Contributed Session
CS177: Stochastic Algorithms and Interacting Reinforced Processes organized by Michele Aleandri and Ida Germana Minelli

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Learning ergodic dynamical systems from finite trajectories

Oleksii Kachaiev[1], Silvia Villa[1], and Lorenzo Rosasco[2⋆]

[1] MaLGa, DIMA, University of Genova, Italy
{oleksii.kachaiev,silvia.villa}@unige.it
[2] MaLGa, DIBRIS, University of Genova & Istituto Italiano di Tecnologia, Italy
lorenzo.rosasco@unige.it

We consider the problem of learning ergodic dynamical systems from a finite trajectory. We derive learning guarantees for a basic least squares estimator and contrast them with classical supervised learning results for independent and identically distributed data. We further provide extensions to higher-order systems, systems with finite state spaces, and learning Koopman operators. Our analysis integrates tools from statistical learning theory and Markov processes, together with suitable concentration results for non-i.i.d. Hilbert space–valued random variables.

Keywords: Statistical learning theory · Dynamical systems · Koopman operators · Markov processes

Contributed Session
CS119: Statistical Learning through Kernels and Transport organized by Leonardo Santoro and Alessia Caponera

⋆ Presenter

Invariant measures for the open KPZ equation

Alex Dunlap, Yu Gu, Tommaso Rosati

Department of Mathematics, University of Warwick, UK,
t.rosati@warwick.ac.uk

We provide an analytic proof for celebrated relative density formulas of the open KPZ equation with respect to white noise. The proof relies on a Girsanov transform, a time reversal and a subtle use of the theory of regularity structures to reconstruct the force of the solution to the KPZ equation at the boundary of the domain.

Contributed Session

CS111: Dynamical Aspects of Stochastic PDEs organized by Antonio Agresti and Max Sauerbrey

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Markov chain based algorithm for long-range correlated stochastic process

Dario Roscioli[1], Rosario Nunzio Mantegna[2,3] ⋆, and Salvatore Miccichè[2]

[1] Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania, Catania, Italy
dario.roscioli@phd.unict.it
[2] Dipartimento di Fisica e Chimica - Emilio Segrè, Università degli Studi di Palermo, Palermo, Italy
{rosario.mantegna,salvatore.micciche}@unipa.it
[3] Complexity Science Hub, Vienna, Austria

We propose a new algorithm generating discrete stochastic processes with tailored long-range auto-correlation. The algorithm is based on a Markov chain characterized by equispaced real eigenvalues ranging from zero (excluded) to one (included). The stochastic matrix of the Markov chain can be efficiently and accurately obtained by using Soules matrices. Once the $N \times N$ Markov chain is produced, by setting a specific projection of the visited states of the chain we generate a stochastic process with a tailored autocorrelation function associated with the selected projection. In this talk, we consider stochastic processes with power-law or logarithmic autocorrelation functions. Among these stochastic processes, we are able to generate an approximate $1/f$ noise with spectral density power covering in frequency a few orders of magnitude.

Keywords: Algorithms· Long-range auto-correlation · Markov Chains.

Contributed Session
CS187:: Memory effects in Markov and non-Markov stochastic processes organized by Salvatore Miccichè

⋆ Presenter

Limit theorems for functionals of stationary Gaussian fields

Maurizia Rossi[1*]

Dipartimento di Matematica e Applicazioni, Università di Milano-Bicocca, Italy
maurizia.rossi@unimib.it

In this talk, we explore central and non-central limit theorems for functionals of stationary Gaussian random fields, together with their regularity properties, through the lens of their decomposition into Wiener chaoses. We will emphasize three main settings: the case in which the functional is "concentrated on a single chaos"; the Breuer–Major setting, where all chaotic components contribute equally to the limit; and the challenging scenario in which the dominant contribution to the variance arises from the tail of the chaotic expansion. Throughout the presentation, we will illustrate these phenomena with key examples and discuss some open questions.

This talk is mainly based on joint works with L. Maini, N. Turchi and G. Zheng.

Keywords: Limit theorems · Wiener chaos · Malliavin regularity

Contributed Session
CS123: Asymptotic properties of Gaussian fields organized by Leonardo Maini

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De Finetti theorem for quantum stochastic processes based on twisted products: conditional independence

Stefano Rossi

Department of Mathematics, University of Bari, Italy,
stefano.rossi@uniba.it

After recalling the role played by the tail algebra of a sequence of random variables in Classical Probability, I will discuss the equivalence of two natural definitions of what the tail algebra ought to be in the framework of quantum processes based on twisted tensor products. I will then move on to explain why a canonical conditional expectation onto the tail algebra always exists in this setting as well. This will put me in a position to provide a statement of de Finetti's theorem for spreadable quantum processes on twisted tensor products in terms of (orderly/full) conditional independence with respect to the tail algebra: spreadability is the same as orderly/full independece w.r.t. the tail algebra.
Time permitting, I would also like to highlight a striking difference of the quantum case as opposed the classical case: the bilateral tail algebra of a spreadable bilateral sequence may well fail to coincide with the unilateral tail algebra.

Keywords: Tail algebra · Conditional independence

Contributed Session
CS159: Probabilistic approach to quantum mechanics organized by Federico Girotti and Anderson Melchor Hernandez

A Double Jump Stochastic Volatility model based on a Compound CARMA(p,q)-Hawkes

Edit Rroji[1]*, Lorenzo Mercuri[2], and Andrea Perchiazzo[3]

[1] Department of Mathematics, University of Milano-Bicocca, Italy,
edit.rroji@unimib.it
[2] Department of Economics and Quantitative Methods, University of Milan, Italy
lorenzo.mercuri@unimi.it
[3] Department of Economics and Business Studies, Eastern Piedmont University, Italy
andrea.perchiazzo@uniupo.it

In this paper we introduce a stochastic volatility model with correlated jumps, incorporating a self-exciting effect in the intensity dynamics. First we derive a pricing formula based on the compound CARMA(p, q)-Hawkes framework, where the stochastic volatility is influenced by the quadratic variation of the counting process in the log-price dynamics. Additionally, we construct a simulation algorithm for the jump term founded on the thinning algorithm. This algorithm is rooted in the existence of a Hawkes intensity with exponential kernel, which serves as an upper bound for the CARMA(p, q)-Hawkes intensity. Finally, we present numerical and empirical analyses.

Keywords: Jumps · Stochastic Volatility· Self-Exciting.

Contributed Session
CSa64: Stochastic Processes for Finance organized by Alessandro Mutti and Giuseppe D'Onofrio

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* Presenter

Well-posedness of stochastic reacting particle system with non-local and Lennard–Jones interactions

Giulia Rui[1⋆], Daniela Morale[1], and Stefania Ugolini[1]

Department of Mathematics, University of Milano, Italy,
{giulia.rui,daniela.morale,stefania.ugolini}@unimi.it

We prove the existence and pathwise uniqueness of a strong solution for a system of N interacting stochastic particles driven by independent Brownian motions. Particles are subject to two types of interactions: a pairwise force generated by a strongly singular drift and a nonlocal interaction with an underlying field c. Each particle evolves up to a random reaction time. The coupled process (X, H, c), describing respectively the particles positions, their activity state and the underlying field, satisfies the following system for $t \in (0, T]$ and $i \in N^* = \{1, ..., N\}$:

$$dX_t^i = \left[-\frac{1}{N} \sum_{j \neq i}^{N} \nabla V(X_t^i - X_t^j) + F(c(t, \cdot))(X_t^i) \right] dt + \sigma \; dW_t^i, \qquad t < \tau_i;$$

$$H_t^i = H_0^i + \int_{(0,t] \times N^* \times \mathbb{R}_+} \mathbb{1}_{\{i\}}(j) \, \mathbb{1}_{\{0\}}(H_{s^-}^i) \; \mathbb{1}_{\{z \leq \lambda \, c(s, X_s^i)\}} \, M(ds, dj, dz), \qquad t > 0;$$

$$\partial_t c(t, x) = -\lambda \, c(t, x) \, \frac{1}{N} \sum_{j=1}^{N} K(x - X_t^j), \qquad (t, x) \in (0, T] \times \mathbb{R}^d.$$

The pairwise interaction is governed by means of the strongly singular Lennard-Jones potential

$$V(x) := \frac{A}{|x|^\alpha} - \frac{B}{|x|^\beta}, \qquad A, B > 0, \quad \alpha > \beta > 0,$$

which induces a repulsive-attractive force with singular behavior at the origin. The underlying field c influences the particle dynamics from two different perspectives: on the one hand, it biases the motion of active particles through the non-local drift $F(c(t, \cdot))$; on the other hand, it affects the switching rate of particles from active ($H_i(t) = 0$) to inactive ($H_i(t) = 1$) through reaction random times τ_i driven by a Poisson random measure M on $(0, T] \times N^* \times \mathbb{R}_+$ with intensity modulated by c. In turn, the field c is random itself: it evolves according to the instantaneous particle configuration, yielding a fully coupled stochastic system.

The proof of well-posedness proceeds in two steps. We first establish existence and pathwise uniqueness for the system without reactions. We then treat the full coupled dynamics using an interlacing argument to incorporate the jump mechanism.

The model is motivated by microscopic stochastic descriptions of sulphation processes in cultural-heritage materials, where interacting diffusive particles and chemically reactive fields coexist at small scales.

Keywords: Interacting particle systems · Singular drift · Lennard–Jones potential · Strong solutions · Interlacing · State-dependent killing.

⋆ Presenter

Giulia Rui, Daniela Morale, and Stefania Ugolini

Contributed Session

CS130: McKean-Vlasov SDEs and associated nonlinear PDEs organized by Daniela Morale and Stefania Ugolini

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Boltzmann processes

Barbara Rüdiger[1]⋆ and Padmanabhan Sundar[2]

[1] Department of Mathematics and Informatics, University of Wuppertal Germany,
ruediger@uni-wuppertal.de
[2] Department of Mathematics , Louisiana State University, Baton Rouge, USA
psundar@lsu.edu

The Boltzmann equation describes the dynamics of a density in position and velocity of a rarified gas expanding in vacuum. Ludwig Eduard Boltzmann (1844 -1906) derived the Boltzmann equation, by assuming any gas molecule of a rarified gas to travel straight in vacuum until an elastic collision occurs with another molecule of the same gas. In the Boltzmann equation, only binary centered collisions are considered. In this talk we present the "Boltzmann process" [1], i.e the process whose density evolves according to the Boltzmann equation. Using the Ito formula, we prove that this is a solution of a stochastic differential equation of McKean Vlasov type, for which we prove the existence [2].

Keywords: Boltzmann equation · SDE of Mc Kean Vlasov type · associated Kolmogorov equation.

Contributed Session
CS113: Stochastics in Classical and Quantum Physics organized by Mazzucchi Sonia and Ugolini Stefania

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⋆ Presenter

The spectrum of dense kernel-based random graphs

Michele Salvi[1⋆], Alessandra Cipriani[2], Rajat Hazra[3], and Nandan Malhotra[3]

[1] Department of Mathematics, University of Rome Tor Vergata,
salvi@mat.uniroma2.it
[2] Department of Statistical Science, University College London
[3] Mathematical Institute, University of Leiden

We study a broad class of inhomogeneous spatial random graphs, including long-range and scale-free percolation and preferential attachment-like models. Vertices are placed on the discrete d-dimensional torus and are equipped with heavy tailed random weights. The probability of linking any pair of vertices decays in their distance but increases as a function of the weights. We focus on the adjacency matrix of such graphs in the dense regime and prove that, as the size of the torus goes to infinity, the empirical spectral distribution converges. The corresponding limiting measure is given by an operator-valued semicircle law that we show to be absolutely continuous and to have finite second moment, even when the weights have infinite variance. We also characterize its Stieltjes transform by a fixed point equation in an appropriate Banach space.

Keywords: Inhomogeneous spatial random graphs · Random matrices.

Contributed Session
CS160: Non-homogeneous Random Graphs organized by Luca Avena

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⋆ Presenter

Gamma duality and a tractable transition density for the Wright–Fisher diffusion with selection

Jaromir Sant[1*], Paul A. Jenkins[2], and Matteo Ruggiero[3]

[1] Department of Statistics, Universidad Carlos III de Madrid, Spain,
jsant@est-econ.uc3m.es
[2] Department of Statistics, University of Warwick, United Kingdom
Department of Computer Science, University of Warwick, United Kingdom
p.jenkins@warwick.ac.uk
[3] Stern School of Business, NYU Abu Dhabi, UAE
mr7690@nyu.edu

The transition function of the Wright–Fisher diffusion with selection is central to understanding non-neutral evolution but, unlike in the neutral case, is not available in a form that is straightforward to evaluate: duality-based approaches typically lead to dual processes with intractable rates, while spectral methods rely on truncation whose computational burden grows rapidly with the strength of selection and model complexity.

We develop a *gamma duality* framework for a multi-allelic Wright–Fisher diffusion with parent-independent mutation and genic selection, based on an exponential augmentation of polynomial duality. We show that the resulting birth-and-death dual process has tractable infinitesimal rates, identify its stationary distribution, and describe its small-time behavior. This dual yields an explicit representation of the transition function as a mixture of standard Dirichlet components, with mixing weights characterized by the dual started from an entrance boundary.

The representation supports computation for arbitrary numbers of alleles and selection coefficients, including regimes where existing approaches are unavailable or impractical. We illustrate that our algorithms deliver substantially improved runtimes over specialized methods, when these do apply.

Keywords: Wright–Fisher diffusion · selection · duality · transition function · simulation.

Contributed Session
CS189: Stochastic population dynamics organized by Dario Spanò

* Presenter

New Distributed Beacon-Based Approaches for Multi-Parameter Monitoring: Sentinel-GRID

Vito Santarcangelo[1*], Angelo Romano[1], Alessandro D'Alcantara[1], Sergio Vitullo[1], Gioele Gargano[1], Emilio Massa[1], Davide Scintu[1], Teresa Maltese[3], Michele Di Lecce[1], Giuseppe Oddo[1], Mario Azzone[2], Rocco Chiechi[2], and Giovanni Azzone[2]

[1] iInformatica Srl, Matera, Italy
vito@iinformatica.it
[2] Al.trafo Srl, Matera, Italy
amministrazione@altrafo.com
[3] Studio Risorse Srl

The increasing complexity of low-voltage distribution assets calls for scalable, non-intrusive monitoring solutions with low energy consumption and minimal maintenance. We present Sentinel-GRID, a distributed, beacon-based approach for multi-parameter monitoring of secondary substations and distribution transformers, built around ultra-low-power IoT sensor nodes operating in an event-driven "fit-and-forget" paradigm. Heterogeneous sensing (e.g., electromagnetic signatures, temperature, vibration and acoustic indicators) is combined with deep-sleep operation, where nodes wake only upon relevant conditions, enabling multi-year autonomy and compatibility with micro energy-harvesting. Data acquisition leverages a hybrid architecture: BLE beaconing [2] enables opportunistic collection by mobile gateways (e.g., smartphones used by field crews), supported by a progressive web app and Data over Audio links for harsh environments [1]. For periodic reporting and resilient backhaul, long-range channels such as LoRaWAN can be used, while critical events trigger priority alerts over high-availability paths. In addition, a low-power computer-vision node supports visual inspection: by tracking retroreflective markers positioned near tightening points, the system estimates micro-displacements and movements of transformer bolts, providing an early indicator of loosening and supporting multimodal diagnostics [3]. On the backend, a cloud platform integrates Digital Twin services and ML/AI analytics tailored to sparse and asynchronous streams, offering anomaly detection and explainable diagnostics. Overall, Sentinel-GRID aims to reduce OPEX, improve safety, and accelerate predictive maintenance adoption in distribution networks.

Keywords: SENTINEL-GRID · Data over Audio · Beacon-based monitoring.

Contributed Session
CS190: Methodological Issues in Multidimensional and Composite Data Analysis organized by Giacalone and Piscopo

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* Presenter

Exchangeable measure-valued Pólya sequences

Hristo Sariev[1,2]

[1] Faculty of Mathematics and Informatics, Sofia University "St. Kliment Ohridski", Bulgaria
[2] Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, Bulgaria
h.sariev@math.bas.bg

Measure-valued Pólya sequences (MVPS) are stochastic processes whose dynamics are governed by generalized Pólya urn schemes with infinitely many colors. Assuming a general reinforcement rule, MVPSs can be viewed as extensions of Blackwell and MacQueen's Pólya sequence, which characterizes an exchangeable sequence with a Dirichlet process (DP) prior distribution. In this talk, we give a complete account of the class of exchangeable MVPSs. We show that under exchangeability, an MVPS is necessarily balanced and its reinforcement kernel is, after normalization, a proper regular conditional distribution. As a result, its prior distribution is that of a DP mixture with respect to a latent parameter, which is associated with the conditioning σ-algebra. Furthermore, we examine the effects of relaxing exchangeability to conditional identity in distribution (c.i.d.) and find that the two are equivalent for balanced MVPSs. In the unbalanced case, it is still possible to have c.i.d. MVPSs that are not exchangeable, but this necessitates a particular form of the reinforcement kernel.

This is joint work with Yoana R. Chorbadzhiyska and Mladen Savov.

Keywords: Pólya urns · Predictive distributions · Exchangeability · Proper conditional distributions · Conditional identity in distribution.

Contributed Session
CS155: Asymptotic Results for Predictive Distributions organized by Lorenzo Cappello

The incompressible Navier–Stokes–Fourier system with thermal noise

Max Sauerbrey

Max Planck Institute for Mathematics in the Sciences, 04103 Leipzig, Germany,
maxsauerbrey97@gmail.com

We establish a solution theory (global weak existence, local strong existence and weak-strong uniqueness) for the incompressible Navier–Stokes–Fourier system with thermal noise, posed on the three-dimensional torus. While in the incompressible deterministic setting the equation for the velocity can be solved independently of the temperature, the inclusion of the effects of thermal fluctuations by means of the GENERIC framework leads to a nonlinear gradient noise term, which couples the dynamics of both variables. Therefore, the analysis of the stochastic system poses new challenges, which are absent in deterministic Navier–Sokes–Fourier equations. This talk is based on the joint work [1] with Benjamin Gess and Zhengyan Wu.

Keywords: Stochastic partial differential equations · Navier-Stokes equations · Thermal noise.

Contributed Session
CS111: Dynamical Aspects of Stochastic PDEs organized by Antonio Agresti and Max Sauerbrey

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Global Optimization via Softmin Energy Minimization

Samuele Saviozzi[1⋆], Andrea Agazzi[2], Vittorio Carlei[3], and Marco Romito[1]

[1] Department of Mathematics, University of Pisa, Italy,
samuele.saviozzi@phd.unipi.it, marco.romito@unipi.it
[2] Institute of Mathematical Statistics and Actuarial Science, University of Bern, Bern, Switzerland
andrea.agazzi@unibe.ch {second.author,third.author}@unipalermo.it
[3] Department of Buisness Economics, University Gabreiele D'annunzio, Chieti, Italy
carlei@unich.it

We introduce a gradient-based swarm optimization method built on a Softmin Energy interaction function $J_\beta(\mathbf{x})$, which provides a smooth approximation of the minimum value among particles. By defining a stochastic gradient flow with Brownian exploration and an annealing-like control parameter β, our approach retains gradient efficiency while promoting global exploration. The main theoretical result shows that our dynamics reduce effective potential barriers compared to Simulated Annealing, leading to faster transitions between local minima and improved exploration of the energy landscape. Analytical estimates of hitting times and experiments on benchmark functions, such as double-well and Ackley landscapes, confirm accelerated convergence and better global search performance.

Keywords: Particle Swarm · Non-convex Optimization · Stochastic Particles Methods· Boltzmann Energy.

Contributed Session
CS179: Interacting Particles and Optimization in Machine Learning organized by Andrea Agazzi and Elena Issoglio

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⋆ Presenter

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Normalizing Flows as Approximations of the Optimal Transport Map

Alessandro Scagliotti[1,2⋆] and Sara Farinelli[3]

[1] CIT School, Technical University of Munich, Germany
scag@ma.tum.de
[2] Munich Center for Machine Learning (MCML), Germany
[3] DIMA (MalGa), Università degli Studi di Genova, Italy
sara.farinelli@edu.unige.it

Normalizing flows provide a flexible class of invertible transformations for learning probability distributions and can be interpreted as flows on spaces of measures. In this talk, we present a theoretical framework in which normalizing flows are viewed as approximations of optimal transport maps, constructed via neural ordinary differential equations with linear control structure. Within this setting, we establish approximation results showing that suitably constrained neural ODEs can approximate optimal transport maps between absolutely continuous measures. In order to formulate a tractable finite-dimensional optimization problem, the transport is approximated using discrete empirical measures; consistency as the number of atoms tends to infinity is guaranteed by a Γ-convergence result [1]. The optimal transport plans associated to the discrete approximating measures naturally encode information only in an L^2-type topology. This creates a mismatch with the underlying approximation results for diffeomorphisms, which are stated in a stronger topology, namely uniform convergence on compact sets, and prevents a direct exploitation of these results. We discuss ongoing work aimed at bridging this gap by incorporating risk measures into the optimization problem, thereby providing a principled way to interpolate between L^2 and C^0 topologies. Finally, we outline future directions toward quantitative estimates, with the goal of expressing the approximation error of the optimal transport map in terms of the Wasserstein distance between discrete empirical measures and their continuous counterparts.

Keywords: Optimal transport · Ensemble optimal control · Normalizing Flows · Machine Learning.

Contributed Session
CS128: (Stochastic) Analysis on Spaces of Probability Measures and Applications organized by Mattia Martini and Giacomo Sodini

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⋆ Presenter

A fractional Hawkes process

Enrico Scalas[1*]

Department of Statistical Sciences, Sapienza University of Rome, Italy,
enrico.scalas@uniroma1.it

I summarise results of three papers [1,2,3] on a fractional Hawkes process with kernel proportional to the probability density function of Mittag-Leffler random variables. This is joint work with Jane A. Aduda, Maggie Chen, the late Alan G. Hawkes, Cassien Habyarimana, and Federico Polito. The code used to generate simulations and figures is freely available from `https://github.com/habyarimanacassien/Fractional-Hawkes`.

Keywords: Point processes · Hawkes processes · Complex systems.

Contributed Session
CS187: Memory effects in Markov and non-Markov stochastic processes organized by Salvatore Miccichè

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* Presenter

Strong Feller property and irreducibility for stochastic PDEs with degenerate multiplicative noise

Luca Scarpa[1]* and Margherita Zanella[2]

[1] Department of Mathematics, Politecnico di Milano, Italy,
luca.scarpa@polimi.it
[2] Department of Mathematics, Politecnico di Milano, Italy
margherita.zanella@polimi.it

We establish strong Feller property and irreducibility for the transition semigroup associated to a class of nonlinear stochastic partial differential equations with multiplicative degenerate noise. As a by-product, we prove uniqueness of the invariant measure under very mild assumptions. The drift of the equation diverges exactly where the noise coefficient vanishes, resulting in a competition between the dissipative effects and the degeneracy of the noise. The main idea is to introduce a mathematical method to measure the accumulation of the solution towards the potential barriers, allowing to give rigorous meaning to the inverse of the noise operator even in the degenerate case. If the singularity of the drift and the degeneracy of the noise are suitably balanced, the dynamics are shown to stabilise for large times. From the mathematical point of view, the results provide a first generalisation of the classical work by Peszat & Zabczyk [1] to the case of degenerate multiplicative diffusions. From the application perspective, the models cover interesting scenarios in physics, in the context of evolution of relative concentrations of mixtures, under the influence of thermodynamically-relevant potentials of Flory-Huggins type.

Keywords: Degenerate noise · Strong Feller property · Irreducibility.

Contributed Session
CS104: SPDEs for physical models, organized by Benedetta Ferrario and Margherita Zanella

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* Presenter

Multivariate tempered stable additive subordination for financial models

Patrizia Semeraro

Department of Mathematics, Politecnico di Torino, Italy,
patrizia.semeraro@polito.it

We build a class of additive inhomogeneous processes by subordination of a multiparameter Brownian motion. The subordinator is chosen to be a Sato process (see e.g. [2]) and it is constructed to incorporate both a time transform common to all assets and an idiosyncratic one. The resulting process is a generalization of multivariate Lévy processes with good fit properties on financial data, see [3]. We specify the model to have unit time normal inverse Gaussian distribution, introduced in [1] to model asset returns, and we discuss the ability of the model to fit time inhomogeneous correlations on real data.

Keywords: Sato processes · Multivariate additive subordination · Multivariate asset modeling.

Contributed Session
CS132: Subordinated Markov processes and applications organized by Giovanni Amici

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Competing growth on the configuration model via first-passage percolation and long-range jumps

Matteo Sfragara ⋆ and Bernardo D'Auria

Department of Mathematics, University of Padova, Italy,
matteo.sfragara@unipd.it, bernardo.dauria@unipd.it

We study two-type competing first-passage percolation on random graphs generated by the configuration model with a power-law degree distribution with exponent $\tau \in (1, 2)$, corresponding to the infinite-mean regime. In the classical nearest-neighbor setting [1], the competition is dominated by giant-degree hubs: the type that first reaches a hub rapidly infects the entire network, leading to a "winner takes it all but one" phenomenon. We extend this model by introducing long-range infections: each infected vertex infects a uniformly chosen vertex at rate $\gamma > 0$, independently of the edge-based dynamics. This global transmission mechanism competes with the local spread and fundamentally changes the phase diagram.

In cybersecurity terms, this models malware or information campaigns that spread both through local network connections and via global mechanisms, such as phishing, mass email, or broadcast exploits, which can reach arbitrary devices. This provides a natural framework for studying attacks on heterogeneous networks, many of which have heavy-tailed degree distributions with $\tau \in (1, 2)$ or $\tau \in (2, 3)$.

We identify a sharp threshold for coexistence as a function of γ. In the subcritical regime, the "winner takes it all" phenomenon arises, with the losing type infecting either finitely many vertices or even infinitely many but a vanishing proportion of the graph. In the supercritical regime, long-range transmission enables macroscopic coexistence, including an extreme case in which the final proportions of the two types converge to a random limit characterized by a Pólya urn.

Keywords: Random graphs · Configuration model · Competing growth

Contributed Session

CS167: Dynamics and phase transitions on discrete structures organized by Vanessa Jacquier and Giacomo Passuello

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⋆ Matteo Sfragara

Random Quadratic Form on a Sphere: Synchronization by Common Noise

Anna Shalova[1⋆] and Maximilian Engel[1,2]

[1] Korteweg-de Vries Institute for Mathematics, University of Amsterdam, the Netherlands,
{a.shalova, m.r.engel}@uva.nl
[2] Department of Mathematics and Computer Science, FU Berlin, Germany

We introduce the Random Quadratic Form (RQF): a stochastic differential equation which formally corresponds to the gradient flow of a random quadratic functional on a sphere. While the one-point motion of the system is a Wiener process and thus has no preferred direction, the two-point motion exhibits nontrivial synchronizing behaviour. In this work we study synchronization of the RQF, namely we give both distributional and path-wise characterizations of the solutions by studying invariant measures and random attractors of the system.

The RQF model is motivated by the study of the role of linear layers in transformers and illustrates the *synchronization by common noise* phenomena arising in the simplified models of transformers. In particular, we provide an alternative (independent of self-attention) explanation of the clustering behaviour in deep transformers and show that tokens cluster even in the absence of the self-attention mechanism.

Keywords: synchronization · random dynamics · transformers.

Contributed Session
CS179: Interacting Particles and Optimization in Machine Learning organized by Andrea Agazzi and Elena Issoglio

⋆ Presenter

Scaling limits of the one-dimensional facilitated exclusion process

Marielle Simon

Institut de Mathématiques de Marseille, Université Aix-Marseille, France
marielle.simon@univ-amu.fr

I will present some recent results obtained for the facilitated exclusion process in one dimension. This stochastic lattice gas model is subject to strong kinetic constraints that create a continuous phase transition to an absorbing state at a critical particle density value. If the microscopic dynamics is symmetric, its macroscopic behavior (with periodic boundary conditions and in the diffusive time scale) is governed by a nonlinear PDE belonging to free boundary problems (or Stefan problems). One of the major ingredients is to show that the system reaches the "ergodic" component in a subdiffusive time. When the particle system is put in contact with reservoirs (which can either destroy or inject particles at both boundaries), it leads to a Dirichlet boundary-value problem. Starting from a suitable initial condition, the weakly asymmetric case gives rise to a new KPZ-type equation on the half line. All these results rely, to various extent, on mapping arguments (towards auxiliary processes), which completely fail in dimension higher than 1. I will finally discuss some open problems and questions, especially in dimension 2. Based on several joint works with G. Barraquand, O. Blondel, H. Da Cunha, C. Erignoux, M. Sasada and L. Zhao.

Keywords: Hydrodynamic limit · Exclusion processes · Kinetic constraints · Free boundary problem

Contributed Session
CS168: Scaling limits for stochastic processes organized by Pascal Moyal

Recent Developments on Singular SPDEs in Heterogeneous Media and Curved Spaces

Harprit Singh

SISSA, Italy,
harprit.singh@sissa.it

The theory of stochastic partial differential equations has seen rapid progress over the past decade, spurred by the introduction of the theories of regularity structures [7] and paracontrolled calculus [6]. Despite the close connections of singular SPDEs to physical phenomena— for instance through statistical mechanics where heterogeneous environments arise naturally (for instance defects in Φ^4, a toy model for ferromagnets) or through quantum field theory, where models are naturally geometric (for example, Yang–Mills theory, canonically formulated on principal bundles)—the theory of singular SPDEs was until recently focused mainly on homogeneous settings.

In this overview talk, I will motivate and present recent developments that make it possible to treat singular SPDEs in genuinely inhomogeneous environments, including parabolic equations with heterogeneous operators [2,9,4] and bundle-valued equations on Riemannian manifolds [1,5,3,8].

Keywords: Rough Analysis · SPDEs .

Contributed Session
CS150: Rough analysis organized by Carlo Bellingeri

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The geometry of the stability region of randomly modulated queuing systems

Nahuel Soprano-Loto[1⋆], Urtzi Ayesta[2], and Ina Maria Verloop[2]

[1] Inria Paris, France
nahuel.soprano-loto@inria.fr
[2] IRIT-CNRS, France
urtzi.ayesta@irit.fr, ina-maria.verloop@cnrs.fr

We investigate a fundamental object in operations research: the stability region of a randomly modulated scheduling problem. Specifically, we consider a queueing system comprising multiple queues and a single server, where the scheduling decisions are influenced by stationary random modulations of the queue capacities, evolving autonomously over a finite state space (which is essentially the model studied in [1]). In this setting, we identify the stability problem with two structures arising, respectively, in combinatorial optimisation and convex geometry: a generalised network flow – or network flow with gains – and a cephoid – the Minkowski sum of deGua simplices. These novel identifications yield: strongly polynomial algorithms for feasibility; new characterisations of the stability region – explicit in some cases; and algorithms for computing its minimal descriptions. In the particular ON/OFF case (initially studied in [2]), where the first identification reduces to a classical network flow, we present a unified framework tied together by the max-flow/min-cut theorem.

Keywords: queuing systems · scheduling · random modulations · stability · generalised network flows · max-flow/min-cut theorem · Minkowski sum · deGua simplices · cephoids.

Contributed Session
CS144: Probabilistic Analysis of Complex Engineering Networks organized by Emanuele Mengoli

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⋆ Presenter

A Novel Approach to Peng's Maximum Principle for McKean-Vlasov Stochastic Differential Equations

Johan Benedikt Spille[1⋆] and Wilhelm Stannat[2]

[1] Department of Mathematics, Technische Universität Berlin, Germany
spille@math.tu-berlin.de
[2] Department of Mathematics, Technische Universität Berlin, Germany
stannat@math.tu-berlin.de

We consider the control of a McKean-Vlasov stochastic differential equation (SDE) and present a novel approach to the proof of Peng's maximum principle [1]. The main step is the introduction of a third adjoint equation, a conditional McKean-Vlasov backward SDE: Peng's maximum principle is derived from a second-order Taylor expansion of the cost functional, which in the McKean-Vlasov case, due to the structure of the Lions derivative, introduces quadratic terms that contain independent copies of the variational processes. To accommodate the dualization of these terms, we introduce this third adjoint equation. We only treat SDEs in $\mathbb{R}^d$ but the dependence on the distribution already makes these equations inherently infinite dimensional. Our approach will also be useful in further extensions to the common noise setting in mean-field control and the control of Hilbert space valued McKean-Vlasov SDEs.

Keywords: Maximum principle · McKean-Vlasov equation · Mean-field equation · Adjoint calculus

Contributed Session
CS145: "Frontiers in Infinite-Dimensional Stochastic Control: Theory and Applications" organized by Filippo de Feo.

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⋆ Presenter

First-passage times through closed curves for bivariate diffusion processes, simulations and comparisons based on stochastic orderings

Serena Spina* and Antonio Di Crescenzo

Department of Mathematics, University of Salerno, Italy,
sspina@unisa.it, adicrescenzo@unisa.it

Stochastic processes provide a fundamental framework for describing systems that evolve randomly over time. A key aspect in the analysis of stochastic dynamics is the study of the first-passage time (FPT), defined as the time required for a trajectory to reach a prescribed region for the first time. FPT problems are essential for characterizing threshold phenomena, rare events, and barrier-crossing mechanisms, and they offer deep insights into the statistical structure of the underlying processes.

FPT problems for diffusion processes in discs, spheres, and general closed domains are often investigated with the aim of deriving closed-form solutions. However, the inherent mathematical complexity of these problems typically limits such analysis, leading researchers to focus on approximate results or on low-order moments, such as the mean or variance, rather than on the distribution of the FPT. For regular elliptic domains, the problem has been addressed in [2] for the Wiener and Ornstein–Uhlenbeck two-dimensional processes, considering both interior and exterior initial states. In this setting, the Laplace transform of the FPT density and the corresponding moments are derived and analyzed, and numerical inversion techniques are employed to obtain approximate probability density functions. Particular attention is devoted to the asymptotic behavior of FET moments, highlighting the differences between the dynamics of the two processes.

The FPT problem through closed boundaries has been considered also for perturbated closed curves. For example, in [5], the authors estimate the mean FPT for irregular domains obtained by perturbing the boundary of a disk or an ellipse, with applications to geographical settings where islands are modeled as perturbed elliptic shapes. Further investigations on mean FPT in elongated planar domains, including elliptic geometries, are reported in [3].

The present contribution aims to investigate FPT problems for two-dimensional diffusion processes through perturbed elliptic boundaries. In particular, we focus on two-dimensional Wiener and Ornstein–Uhlenbeck processes, which play a central role in probability theory and have applications ranging from physics and biology to economics and information theory. The analysis combines analytical, probabilistic, and computational approaches, with the goal of providing a comprehensive characterization of FPT distributions in geometrically nontrivial settings.

Since explicit analytical solutions are not available for perturbed elliptic domains, in addition to a simulation analysis, a comparison-based approach is adopted. In particular, we focus on the perturbed region enclosed between two regular ellipses, allowing the corresponding FPT distributions to be suitably bounded. We resort to stochastic ordering theory, with special reference to the usual stochastic order (see [4]) and the Laplace transform ratio order (as in [1]). Both such orders lead to robust inequalities for the FPT distribution and rigorous estimates of first-passage statistics for complex geometries.

* Presenter

Serena Spina and Antonio Di Crescenzo

Keywords: First-passage-time problems · Diffusion processes · Stochastic orderings.

Contributed Session

CS138: First Passage Times: theory and simulations organized by Serena Spina and Cristina Zucca

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Event Valence and Subjective Probability

Adam Brandenburger[2], Paolo Ghirardato[1], Daniele Pennesi[1], and Lorenzo Stanca[1]*

[1] ESOMAS Department and Collegio Carlo Alberto, Università di Torino, Turin, Italy
{paolo.ghirardato,daniele.pennesi,lorenzomaria.stanca}@unito.it
[2] NYU Stern School of Business, New York University, New York, USA
adam.brandenburger@stern.nyu.edu

We introduce a decision-theoretic model in which an individual's willingness-to-bet (WTB) on an event reflects not only its subjective likelihood but also its *valence*, a primitive capturing the event's intrinsic attractiveness or aversiveness. In contrast to standard subjective expected utility (SEU), WTB can be negative (the agent pays to avoid exposure) or exceed one (the agent pays more than the stake to gain exposure). Formally, the model—signed subjective expected utility (SSEU)—extends SEU by weakening monotonicity while preserving the core mixture/independence structure on acts.

Our main representation result identifies, from revealed preferences over simple bets, (i) a von Neumann–Morgenstern utility index u and (ii) a finitely additive *signed* measure ν governing WTB. We then characterize the set of decompositions of ν into a probability component and a valence distortion that are compatible with dynamic consistency and consequentialism. This set corresponds to exponential tilts of a canonical prior p^*, yielding a sharp link between valence and probabilistic distortions. An additional calibration condition (expressible directly in terms of WTB ratios) selects a unique, canonical decomposition and hence uniquely pins down p^*.

Beyond foundations, SSEU provides a unified account of several empirical regularities typically viewed as violations of probabilistic reasoning or dominance, including hedging aversion, the conjunction fallacy, coexistence of insurance and gambling, choice of dominated actions in strategy-proof mechanisms, and the home equity bias puzzle. We also discuss an extension allowing stake-dependent (and potentially non-additive) WTB, accommodating joint violations of monotonicity and independence documented in recent experiments.

Keywords: Subjective probability · Signed measures · Willingness to bet · Decision theory · Behavioral anomalies.

Contributed Session
CS000: Probability and Statistics (Contributed Session) organized by To be announced

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* Presenter

New Chaos Decomposition of Gaussian Nodal Volumes

Michele Stecconi[1] and Anna Paola Todino[2⋆]

[1] Department of Mathematics, University of Luxembourg, Esch-sur-Alzette, Luxembourg
michele.stecconi@unilu.it
[2] Dipartimento di Scienze e Innovazione Tecnologica, Università del Piemonte Orientale, Alessandria, Italia.
annapaola.todino@uniupo.it

We investigate the random variable defined by the volume of the zero set of a smooth Gaussian field, on a general Riemannian manifold possibly with boundary. We prove a new explicit formula for its Wiener-Itô chaos decomposition that is notably simpler than existing alternatives and which holds in greater generality, without requiring the field to be compatible with the geometry of the manifold. A key advantage of our formulation is a significant reduction of the complexity of the computations of the variance of the nodal volume. Unlike the standard Hermite expansion, which requires evaluating the expectation of products of $2+2n$ Hermite polynomials, our approach reduces this task - in any dimension n - to computing the expectation of a product of just four Hermite polynomials. As a consequence, we establish a new exact formula for the variance.

Keywords: Nodal volume · Wiener-Itô chaos decomposition · Random fields.

Contributed Session
CS129: New Horizons for Random Fields in Probability and Statistics organized by Claudio Durastanti

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⋆ Presenter

Scars in random waves: concentration and oscillation

Louis Gass, Giovanni Peccati, and Michele Stecconi[1*]

Department of Mathematics, University of Luxembourg, Luxembourg
michele.stecconi@uni.lu

Berry's random wave is obtained by superimposing plane waves whose directions are chosen uniformly at random on the unit sphere. It serves as a canonical uninversal local model for high-energy Laplace eigenfunctions on chaotic manifolds. Simulations on large domains reveal persistent filamentary patterns, often called scars, that are absent from other natural Gaussian fields. We provide the first rigorous description of this phenomenon, showing that the fluctuations of Berry's field become asymptotically indistinguishable from those of a Poisson line process, and converge to a fractional Gaussian field of index 1/2. Complementary to such concentration along lines is the question of oscillation along them. We prove that, along each scar, the field oscillates according to a universal frequency profile that depends on the dimension. In dimension two only, it reduces to a single frequency: the field oscillates like a pure sinusoid along every scar line.

Keywords: Gaussian fields · quantum chaos · High-frequency eigenfunctions.

Contributed Session
CS123: Asymptotic properties of Gaussian fields organized by Leonardo Maini

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[*] Presenter

Economic growth models on networks with regime-switching dynamics

Alessandro Calvia[1] and Ilaria Stefani[2⋆]

[1] Dipartimento di Matematica, Politecnico di Milano, via Bonardi 9, 20133, Milano, Italy.
alessandro.calvia@polimi.it
[2] Dipartimento di Scienze Economiche e Aziendali, Università di Parma, via J. F. Kennedy 6, 43125, Parma, Italy.
ilaria.stefani@unipr.it

We develop a finite-network growth model in which capital accumulates at each location and productivity follows a continuous-time regime-switching process. A social planner chooses location-specific consumption to maximize discounted utility, under linear AK dynamics with mobility across nodes and state constraints. After introducing the model and the associated control problem, we prove existence and uniqueness of an optimal control and establish regularity properties of the value function that support a feedback characterization of the optimal policy. The resulting Hamilton–Jacobi–Bellman system is solved numerically delivering computed optimal paths for capital and consumption. We illustrate the framework with a numerical application for a two-location economy with symmetric links, specialized to a three-regime specification, and show how risk aversion and the intensity of regime switches shape the value function and the resulting trajectories.

Keywords: Stochastic economic growth model · networks · regime-switching

Contributed Session
CS169: Applications of probability to economics, finance, and insurance organized by Elena Bandini and Alessandro Calvia

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⋆ Presenter

Approximate 2-hop Neighborhoods on Incremental Graphs: An Efficient Lazy Approach

Alessandro Straziota[1⋆], Luca Becchetti[2], Andrea Clementi[1], Luciano Gualà[1], Luca Pepè Sciarria[1], and Matteo Stromieri[1]

[1] *Tor Vergata* University of Rome, Rome, Italy
alessandro.straziota@uniroma2.it, {clementi,guala}@mat.uniroma2.it
luca.pepesciarria@gmail.com, matteo.stromieri@students.uniroma2.eu,
[2] *Sapienza* Univeristy of Rome, Rome, Italy
becchetti@diag.uniroma1.it

In this work, we propose, analyze and empirically validate a lazy-update approach to maintain accurate approximations of the 2-hop neighborhoods of dynamic graphs resulting from sequences of edge insertions.

We first show that under random input sequences, our algorithm exhibits an optimal trade-off between accuracy and insertion cost: it only performs $O(\frac{1}{\varepsilon})$ (amortized) updates per edge insertion, while the estimated size of any vertex's 2-hop neighborhood is at most a factor ε away from its true value in most cases, *regardless* of the underlying graph topology and for any $\varepsilon > 0$.

As a further theoretical contribution, we explore adversarial scenarios that can force our approach into a worst-case behavior at any given time t of interest. We show that while worst-case input sequences do exist, a necessary condition for them to occur is that the *girth* of the graph released up to time t be at most 4.

Finally, we conduct extensive experiments on a collection of real, incremental social networks of different sizes, which typically have low girth. Empirical results are consistent with and typically better than our theoretical analysis anticipates. This further supports the robustness of our theoretical findings: forcing our algorithm into a worst-case behavior not only requires topologies characterized by a low girth, but also carefully crafted input sequences that are unlikely to occur in practice.

Combined with standard sketching techniques, our lazy approach proves an effective and efficient tool to support key neighborhood queries on large, incremental graphs, including neighborhood size, Jaccard similarity between neighborhoods and, in general, functions of the union and/or intersection of 2-hop neighborhoods.

Keywords: Graph Mining · Algorithms for Dynamic Networks · Data Sketches.

Contributed Session
CS173: Probability for Graph Algorithms organized by Alessandro Straziota and Luca Pepè Sciarria

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⋆ Presenter

Bayesian nonparametric estimation of spatio-temporal Hawkes processes

Déborah Sulem[1⋆], Wenqing Liu[1], and Xenia Miscouridou[2]

[1] Faculty of Informatic, Universitá della Svizzera italiana, Switzerland
deborah.sulem@usi.ch
[2] Department of Mathematics and Statistics, University of Cyprus,Cyprus

In [1] we develop a Bayesian nonparametric framework for inference in multivariate spatio-temporal Hawkes processes, extending existing theoretical results beyond the purely temporal setting. Our framework encompasses modelling both the background and triggering components of the Hawkes process through Gaussian process priors. Under appropriate smoothness and regularity assumptions on the true parameter and the nonparametric prior family, we derive posterior contraction rates for the intensity function and the parameter, in the asymptotic regime of repeatedly observed sequences. These results provide, to our knowledge, the first theoretical guarantees for Bayesian nonparametric methods in spatio-temporal point data. We also show that we can numerically approximate the posterior via variational inference and demonstrate the benefit of nonparametric modelling in the context of spatio-temporal events.

Keywords: Posterior concentration · Gaussian processes · Variational inference.

Contributed Session
CS101: Statistical methods for complex spatial data analysis organized by Matteo Giordano and Nicoletta D'Angelo

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⋆ Presenter

Mean-Field Games in Hilbert Spaces: A Viscosity Approach

Andrzej Święch[1] and Lukas Wessels[2*]

[1] School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, USA,
swiech@math.gatech.edu

[2] Laboratoire J.A. Dieudonné, Université Côte d'Azur, 06108 Nice, France,
lukas.wessels@univ-cotedazur.fr

We investigate a Mean-Field Game (MFG) posed in an infinite-dimensional Hilbert space and driven by degenerate noise. The associated MFG system consists of a Hamilton–Jacobi–Bellman (HJB) equation coupled with a nonlinear Fokker–Planck (FP) equation, both governed by a degenerate Kolmogorov operator.

The degeneracy of the noise introduces significant analytical challenges. In particular, the HJB equation is treated in the viscosity sense, while the FP equation is interpreted in a suitable weak formulation. A major difficulty stems from the degeneracy of the Kolmogorov operator, which makes the uniqueness of solutions to the FP equation particularly delicate.

Under appropriate structural assumptions, we establish well-posedness of the MFG system. As an application, we consider Mean-Field Games arising from stochastic delay differential equations, highlighting how delay effects naturally lead to infinite-dimensional and degenerate dynamics.

This talk is based on joint work with Andrzej Święch.

Keywords: Mean-Field Games · PDEs in Infinite Dimensional Spaces · Fokker–Planck Equation · Hamilton–Jacobi–Bellman Equation · Viscosity Solutions · Wasserstein Space.

Contributed Session

CS135: Stochastic Systems, Mean-Field Models, and Control organized by Fulvia Confortola and Giuseppina Guatteri

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* Presenter

Hookean dumbbell model for polymers, stretching noise and turbulence

Yassine Tahraoui[1]*

Scuola Normale Superiore, Pisa, Italy
yassine.tahraoui@sns.it

It is recognized that the addition of polymers is very efficient in reducing the friction drag in turbulent regimes. My talk is about the effects of small-scale turbulence on polymers distribution by using a stochastic scaling and singular limits. Many works have been done in recent years using the scaling limit in both scalar and vector cases. The second one is characterized by the presence of stretching, which adds complications over the scalar case. This talk is based on [1] and [2].

In [1], we investigate the stretching mechanism of stochastic models of turbulence acting on a simple model of polymer. Namely, we investigate a scaling limit problem, under suitable intensity assumption. The polymer density equation, initially an SPDE converges (in the first step) weakly to a limit deterministic equation with a new degenerate term with some singular parameter. Recently, in [2] we investigate the singular limit in the spirit of the hydrodynamic limit techniques. One consequence is that the limiting density shows a power-law decay in the polymer length, which is consistent with physical predictions.

The activities mentioned herein were performed in the framework of the project: EU-HORIZON EUROPE ERC-2021-ADG "Noise in Fluids" (NoisyFluid), no. 101053472.

Keywords: SPDE · Transport-stretching noise · Scaling limit · Polymers.

Contributed Session

CS137: Stochastic Models in Fluid Dynamics organized by Federico Butori and Yassine Tahraoui

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* Presenter

Statistical inference for SDEs using Signatures

Nikolas Tapia[1,2⋆], Ilya Chevyrev[3], Emilio Ferrucci[3], Darrick Lee[4], Terry Lyons[5,6], Harald Oberhauser[5], Markus Reiß[2], and Christian Bayer[1]

[1] Weierstrass Institute, Berlin, Germany,
{tapia,bayerc}@wias-berlin.de
[2] Institut für Mathematik, Humboldt-Universität zu Berlin, Berlin, Germany,
markus.reiss@math.hu-berlin.de
[3] SISSA, Trieste, Italy,
{ilya.chevyrev,emilio.ferrucci}@sissa.it
[4] School of Mathematica, University of Edinburgh, UK,
darrick.lee@ed.ac.uk
[5] Mathematical Institute, University of Oxford, Oxford, UK,
{terry.lyons,oberhauser@maths.ox.ac.uk
[6] Department of Mathematica, Imperial College London, London, UK.

We introduce a framework for constructing orthogonal polynomials on path space. Beginning with an introduction to signatures which play the role of polynomials, and we orthogonalise these features to obtain L^2-convergent series for square-integrable path functionals. Under an infinite radius of convergence assumption, we prove linear functionals on the signature are dense in L^p.

Identifying the shuffle algebra with polynomials over the free Lie algebra, we generalise orthogonal polynomial theory: establishing recurrence relations, a Favard-type theorem, and connections to spectral measures. For Brownian motion, a natural (dimension-independent) orthogonal basis exists only with time-augmentation, yielding explicit Itô-orthogonal polynomials.

In ongoing work with Markus Reiß and Christian Bayer, we apply these methods to classify Ornstein-Uhlenbeck processes, obtaining closed-form expected signatures and optimal discriminative features for hypothesis testing

Keywords: Statistical methods for SDEs· orthogonal polynomials · signature method

Contributed Session
CS150: Rough analysis organized by Carlo Bellingeri

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⋆ Presenter

Invariant cones for jump-diffusions in infinite dimensions

Stefan Tappe[1⋆]

Department of Mathematical Stochastics, Albert Ludwig University of Freiburg, Germany,
stefan.tappe@math.uni-freiburg.de

In this presentation we deal with mild solutions to semilinear stochastic partial differential equations (SPDEs) of jump-diffusion type

$$dr_t = (Ar_t + \alpha(r_t))dt + \sigma(r_t)dW_t + \int_E \gamma(r_{t-}, x)(N(dt, dx) - F(dx)dt), \quad r_0 = h_0$$

driven by a trace class Wiener process W and a Poisson random measure N on some mark space E with compensator $dt \otimes F(dx)$. The state space of the SPDE is a separable Hilbert space H, and the operator A is the generator of a strongly continuous semigroup $(S_t)_{t\geq 0}$ on H. Let $K \subset H$ be a closed convex cone in H. We say that the cone K is *invariant* for the SPDE if for each starting point $h_0 \in K$ the corresponding solution process r stays in the cone K.

The goal of this talk is to characterize stochastic invariance of the closed convex cone K by means of the coefficients α, σ, γ of the SPDE. Moreover, we will present applications of our findings to SPDEs arising in mathematical finance.

This presentation is based on the paper [1], where further details can be found.

Keywords: Stochastic partial differential equation · closed convex cone · stochastic invariance · mathematical finance.

Contributed Session
CS166: SPDEs in Finance organized by Claudio Fontana

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⋆ Presenter

Guidelines for Cubature-based Likelihood approximation of 3D Poisson Point Processes

Marco Tarantino*, Nicoletta D'Angelo, and Giada Adelfio

Department of Economics, Business and Statistics, University of Palermo, Palermo, Italy
marco.tarantino01@unipa.it

Presenter: Marco Tarantino

Poisson point processes are the simplest, yet fundamental, models for the analysis of spatial and spatio–temporal point patterns. They can be used to describe the locations of events or objects of interest and to estimate the intensity of these point patterns within a defined region. Beyond Poisson models, many widely used spatial and spatio–temporal point process models are built on a Poisson–type intensity. For instance, log–Gaussian Cox processes [1] and self–exciting or Hawkes–type processes [2] typically relies on a well–specified first–order intensity, and on a Poisson (or Poisson–like) likelihood to estimate it. Consequently, obtaining consistent, low–bias first–order intensity estimates is critical not only for Poisson models but also for the robustness of more complex models built upon them.

Likelihood-based inference for three-dimensional Poisson point process models requires approximating the integral term in the log-likelihood over a 3D observation window. In practice this is done via a quadrature scheme [3], which replaces the integral with a weighted sum over observed points and a set of dummy points. Despite its widespread use, the accuracy of the approximation strongly depends on a few tuning parameters: whether dummy points are placed on a regular grid or randomly, the dummy-to-data multiplier q, so that $n_d = q\,n$ dummy points are generated (where n represents the number of observed points in the pattern), and the window partition resolution n_c, providing n_c^3 voxels and cubature weights. Clear guidance on how to select these parameters to obtain reliable inference is missing, especially in three dimensions, while concerns about quadrature accuracy have long been noted [4].

We formalise the cubature scheme and its replicated version for multi-type/categorical marks, and develop data-driven guidelines through an extensive simulation study. We simulate three-dimensional inhomogeneous Poisson processes across different scenarios in which the intensity depends on coordinates, external covariates and categorical marks, with multiple sample sizes, fitting models over a wide grid of (q, n_c) values under both dummy-point layouts. Performance is assessed via the mean squared error of parameter estimates and by second-order diagnostics such inhomogeneous K-function weighted by the fitted intensity. Across scenarios, we identify well-delimited regions of (q, n_c) that provides stable likelihood approximations and accurate intensity recovery. A validation study confirms the robustness of these recommendations. Finally, an application to 2008 Greece background seismicity shows that baseline cubature choices can fail diagnostics, whereas guideline-based settings provide coherent parameter estimates and pass global envelope tests.

Keywords: Cubature scheme · Likelihood approximation · Three-dimensional Poisson point processes.

Contributed Session

CS101: Statistical methods for complex spatial data analysis organized by Nicoletta D'Angelo and Matteo Giordano

* Corresponding author

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McKean–Vlasov dynamics with killing and memory: probabilistic representations of a McKean-type PDE

Leonardo Tarquini[1]*, Daniela Morale[2], and Stefania Ugolini[2]

[1] Dept. of Mathematics, University of Oslo, Norway,
leonardt@math.uio.no
[2] Dept. of Mathematics, University of Milano, Italy,
{daniela.morale,stefania.ugolini}@unimi.it

Keywords: McKean-Vlasov-type nonlinear SDEs · Nonlinear reaction-diffusion PDEs · Interacting particle systems.

We address two probabilistic approaches for associating a specific stochastic dynamics with a McKean-type partial differential equation featuring a reaction term and path-dependent coefficients.

The non-conservative nature of the macroscopic dynamics leads to two possible interpretations of both the sub-probability measure and the associated SDE equation at the microscale: on the one hand, as a measure-valued solution of a Feynman–Kac-type equation [1]; on the other hand, as the sub-probability associated with an SDE with memory defined up to a survival time with a reaction-dependent rate [2]. These different interpretations give rise to two different microscopic stochastic models and therefore to two different techniques of probabilistic analysis[3]. Then, by considering the interacting particle systems associated with each of the microscopic models, we discuss how their empirical densities provide two different kernel estimators for the PDE solution.

Finally, we discuss how the convergence to a standard advection-diffusion-reaction McKean-type PDE is achieved [4] by rescaling the interaction kernel at an intermediate scale and using a semigroup approach.

The PDE model under consideration arises in applications in materials science: it describes the sulphation phenomenon, a degradation process affecting marble surfaces exposed to atmospheric pollutants.

Contributed Session

CS130: McKean-Vlasov SDEs and associated nonlinear PDEs organized by Daniela Morale and Stefania Ugolini

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* Presenter

Integrated expectile-based measures of inequality

Marco Tarsia[1⋆] and Ignacio Cascos[2]

[1] Department of Economics, University of Insubria, Varese, Italy
marco.tarsia@uninsubria.it
[2] Departamento de Estadística, Universidad Carlos III de Madrid, Leganés, Spain
ignacio.cascos@uc3m.es

Expectiles provide a smooth and naturally tail-sensitive alternative to quantiles, and have recently emerged as powerful tools for describing dispersion and asymmetry. In this talk, we develop a framework in which expectiles serve as the basis for measuring inequality, leading to a new class of expectile-based inequality indices that offer a natural geometric counterpart to classical Lorenz-Gini methodology.

The key observation is that comparisons in convex stochastic order can be expressed in terms of inclusions between suitably defined expectile regions. This allows distributional spread to be described geometrically through a nested family of regions capturing tail behavior. Building on this idea, we introduce law-invariant functionals obtained by integrating expectiles or inter-expectile ranges across asymmetry levels. These constructions give rise not only to generalized deviation and inequality measures, but also to expectile-based risk measures, while remaining fully consistent with convex-order comparisons and preserving a clear probabilistic interpretation.

A central aspect of the approach is a geometric representation of expectiles via a star-shaped set in the plane, whose boundary is traced by scaled expectiles. The area of this set naturally defines an inequality index, playing a role analogous to that of the Gini index, but arising from expectile geometry rather than from quantile-based Lorenz curves.

We also extend the construction to multivariate settings by defining expectile regions through directional projections, thereby obtaining inequality measures capable of capturing genuinely multidimensional heterogeneity. Finally, we discuss empirical implementation and computational aspects, showing that the proposed functionals can be evaluated efficiently in practice.

Keywords: Expectiles · Risk and deviation measures · Inequality indices.

Contributed Session
CS110: Risk measures: static and dynamic aspects organized by Elisa Mastrogiacomo and Emanuela Rosazza Gianin

⋆ Presenter

On some stochastic models of Anomalous Diffusion

Bruno Toaldo[1*]

Department of Mathematics, University of Turin, Italy,
bruno.toaldo@unito.it

In this talk we will briefly introduce several stochastic models of anomalous diffusion. In particular, we will focus on random processes subject to trapping effects, diffusion processes subject to reflecting barriers and kinetic processes subject to random obstacles. For these different models, we will discuss the anomalous diffusive behavior, the (non-) Markov property, the (non-local) PDE connections and, in particular and simulation methods. Particular attention will be dedicated to their connection with scaling limits of Continuous Time Random Walks / Lévy walks.

Keywords: Anomalous Diffusion · Semi-Markov processes · non-local dynamics.

Contributed Session
CS154: Interplay between statistical physics and probabilistic methods: the case of anomalous diffusion organized by Gianni Pagnini and Costantino Ricciuti

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Thorin processes: subordination and applications

Lorenzo Torricelli

Department of Statistical Sciences "P. Fortunati" University of Bologna

A Thorin process is a stochastic process with independent and stationary increments whose laws are weak limits of finite convolutions of gamma distributions. Many popular Lévy processes fall under this class. The Thorin class can be characterized by a representing triplet that conveys more information on the process compared to the Lévy triplet. We provide a full account of the theory of multivariate Thorin processes, starting from the Thorin–Bondesson representation for the characteristic exponent, and highlight the roles of the Thorin measure in the analysis of density functions, moments, path variation and subordination. Various old and new examples are discussed. It is illustrated how univariate Brownian subordination with respect to Thorin subordinators produces Thorin processes whose representing measure is given by a pushforward with respect to a hyperbolic function, leading to easier formulae compared to the Bochner integral for the Lévy measure. We further detail a treatment of subordination of gamma processes with respect to negative binomial subordinators which is made possible by the Thorin–Bondesson representation, and show some examples of applications in finance (from a joint work with D. Madan).

Keywords: Thorin processes · Lévy processes · generalized gamma convolutions · subordination · convolution equivalence · generalized negative binomial convolutions.

Contributed Session
CS132: Subordinated Markov processes and applications organized by Giovanni Amici

Averaging Dynamics and Wong-Zakai approximations for a Fast-Slow Navier-Stokes System Driven by fractional Brownian Motion

Francesco Triggiano[1⋆] and Eliseo Luongo[2]

[1] Scuola Normale Superiore, Piazza dei Cavalieri, 7, 56126 Pisa, Italia
francesco.triggiano@sns.it
[2] Fakultät für Mathematik, Universität Bielefeld, 33501 Bielefeld, Germany
eluongo@math.uni-bielefeld.de

We study a slow-fast system of coupled two- and three-dimensional Navier-Stokes equations in which the fast component is perturbed by an additive fractional Brownian noise with Hurst parameter $\mathcal{H} > \frac{1}{3}$:

$$\begin{cases} du^\epsilon = \nu \Delta u^\epsilon dt - (u^\epsilon + v^\epsilon) \cdot \nabla u^\epsilon dt + \nabla p^\epsilon \, dt, \\ dv^\epsilon = \left(\nu \Delta v^\epsilon + \epsilon^{-1} C v^\epsilon - (u^\epsilon + v^\epsilon) \cdot \nabla v^\epsilon + \nabla q^\epsilon\right) \, dt + \epsilon^{-\alpha} dW_t^{\mathcal{H}}, \\ \nabla \cdot u^\epsilon = 0, \quad \nabla \cdot v^\epsilon = 0. \end{cases} \tag{1}$$

The system is analyzed using rough path theory, and the limiting behaviour strongly depends on the value of $\mathcal{H}$. We prove convergence in law of the slow component to a Navier–Stokes system with an additional Itô-Stokes drift when $\mathcal{H} < \frac{1}{2}$ and $\alpha = \frac{1}{2} + \mathcal{H}$:

$$\begin{cases} \partial_t u = \nu \Delta u - \overline{r} \cdot \nabla u - u \cdot \nabla u + \nabla p, \\ \nabla \cdot u = 0. \end{cases} \tag{2}$$

In contrast, for $\mathcal{H} \in (\frac{1}{2}, 1)$ and $\alpha = 1$, the limit equation features only a transport noise driven by a rough path, namely

$$\begin{cases} du = (\nu \Delta u - u \cdot \nabla u) \, dt + d\nabla p - d(-C)^{-1} W^{\mathcal{H}} \cdot \nabla u, \\ \nabla \cdot u = 0. \end{cases} \tag{3}$$

It can be seen that the two regimes, $\alpha = \frac{1}{2} + \mathcal{H}$ and $\alpha = 1$, coincides for the Brownian motion case. Indeed, in that case, both the effects, the Itô-Stokes drift and the transport noise, appear in the limiting equation (see [1], [2]).

Keywords: Navier-Stokes Equations · Transport Noise· Itô–Stokes Drift · Gaussian Rough Paths· Fractional Brownian Motion.

Contributed Session
CS137: Stochastic Models in Fluid Dynamics organized by Federico Butori and Yassine Tahraoui

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⋆ Presenter

Node immunization via random forests

Luca Avena[1], Alexandre Gaudillière[2], Irina Gurewitsch[3], Adoré Randriamandroso[4], and Alessio Troiani[5]*

[1] University of Florence, Florence, Italy
[2] CNRS, Marseille, France
[3] Merck Sharp & Dohme, Haarlem, The Netherlands
[4] University of Fianarantsoa, Fianarantsoa, Madagascar
[5] University of Perugia, Perugia, Italy,
alessio.troiani@unipg.it

Consider a viral agent spreading through a network with prescribed infection and healing rates. The multiple-node optimization problem requires identifying a set of k nodes to immunize to minimize the spread of the infection. This problem is computationally hard, and various heuristic methods have been considered to address it. We propose an algorithm that chooses the nodes to immunize as the complement of the set of roots of a suitably sampled random forest. We provide a theoretical description of the algorithm's features and offer numerical evidence that it improves the results of the reference deterministic heuristic while maintaining the same asymptotic computational cost [1].

Keywords: Node Immunization · Random Forests · Wilson's Algorithm.

Contributed Session
CS167: Dynamics and phase transitions on discrete structures organized by Vanessa Jacquier and Giacomo Passuello

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* Presenter

The Reverse Hypergeometric distribution for attribute concentration in small groups

Michele Tumminello[1], Andrea Simonetti[⋆1], Giuseppe Sanfilippo[2], and Tiziana Di Matteo[3]

[1] Department of Economics, Business and Statistics, University of Palermo, Palermo, Italy
{michele.tumminello,andrea.simonetti01}@unipa.it
[2] Department of Mathematics and Computer Science, University of Palermo, Palermo, Italy
giuseppe.sanfilippo@unipa.it
[3] Department of Mathematics, King's College London, London, UK
tiziana.di_matteo@kcl.ac.uk

In the framework of urn models, we introduce a probability distribution designed to quantify the concentration of attributes among members of small groups [1]. This new distribution addresses a specific occupancy problem, focusing on how particular marbles are allocated to urns [2]. We fully characterize this distribution, referred to as the Reverse Hypergeometric distribution, and propose a statistical test based on it. The model enables testing for excess intra-group similarity against a null hypothesis of random co-occurrence of marbles with the same attribute in the urns. We compare it with established models, including the Multinomial and the Multivariate Hypergeometric distributions. We also provide an asymptotic approximation of the Reverse Hypergeometric distribution by gauging a Multinomial distribution and demonstrate how the model results from urn exchangeability [3]. We illustrate its use through three real-world applications in the domains of network science, social science, and text analysis: investigating the presence of homophily in relationship networks, assessing the excess of same-sex children within households, and analyzing the concentration of sentiment-polarized sentences in the abstracts of scientific papers. Finally, we present a generalization of the model that accommodates groups of varying sizes, enhancing its versatility for different domains and data structures.

Keywords: Discrete Probability Distribution · Categorical Data Analysis · Combinatorics · Urn Models · Exchangeability · Hypothesis Testing

Contributed Session
CS191: Selected Topics in Probability and Statistics organized by Andrea Simonetti

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⋆ Presenter

Contact process on interchange process

Daniel Valesin[1*], Marcelo Hilário[2], Daniel Ungaretti[3], and Maria Eulalia Vares[3]

[1] University of Warwick, United Kingdom
daniel.valesin@warwick.ac.uk
[2] Universidade Federal de Minas Gerais, Brazil
mhilario@mat.ufmg.br
[3] Universidade Federal do Rio de Janeiro, Brazil
{eulalia,daniel}@im.ufrj.br

We introduce a model of epidemics among moving particles on any locally finite graph. At any time, each vertex either is empty, occupied by a healthy particle, or occupied by an infected particle. Infected particles recover at rate 1 and transmit the infection to healthy particles at neighboring vertices at rate λ. In addition, particles perform an interchange process with rate v, that is, the states of adjacent vertices are swapped independently at rate v, allowing the infection to spread also through the movement of infected particles. On the d-dimensional Euclidean lattice, we start with a single infected particle at the origin and with all the other vertices independently occupied by a healthy particle with probability p or empty with probability $1 - p$. We define $\lambda_c(\mathsf{v}, p)$ as the threshold value for λ above which the infection persists with positive probability and analyze its asymptotic behavior as $\mathsf{v} \to \infty$ for fixed p.

Keywords: Contact process, interacting particle systems

Contributed Session
CS165: Processes on dynamic random graphs organized by Michele Salvi

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* Presenter

de Finetti Theorems for Constrained Exchangeable Graphs

Vince Velkey[1]* and Peter Orbanz[1]

Gatsby CNU, University College London, United Kingdom,
{vince.velkey.23, p.orbanz}@ucl.ac.uk

The analogue of de Finetti's theorem for random graphs is the Aldous–Hoover theorem, which provides a representation of exchangeable random graphs as a mixture of graphon models.

We study exchangeable random graphs subject to structural constraints, such as bipartiteness, transitivity, or the presence or absence of specific subgraphs. A notable example is the transitive case, where exchangeable random graphs reduce to exchangeable partitions.

We prove de Finetti–style representation theorems for constrained exchangeable graphs, showing that they correspond to mixtures over restricted classes of graphons satisfying explicit algebraic or functional constraints. This perspective unifies, in a single framework, several previously studied objects, including exchangeable partitions and exchangeable posets. We also establish finite exchangeability results for these constrained graph models.

Our results provide a principled foundation for Bayesian modeling of networks with structural constraints.

Keywords: de Finetti priors · Graphons · Ergodic decomposition· Aldous-Hoover theorem· Graph parameters.

Contributed Session
CS118: Bayesian nonparametrics for network data organized by Francesco Gaffi

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* Presenter

A Risk Minimization Approach to PCA with Irregular Data

Dr. Kartik G. Waghmare[1⋆], Dr. Almond Stoecker[2], and Prof. Victor M. Panaretos[2]

[1] Seminar for Statistics, ETH Zürich
kartik.waghmare@stat.math.ethz.ch
[2] Department of Mathematics, EPFL
{almond.stoecker, victor.panaretos}@epfl.ch

Functional principal component analysis (FPCA) is a fundamental tool for exploring variation in samples of random curves or surfaces. We propose a new approach to FPCA for functional data observed irregularly and sparsely over their domains, based on smoothing directly at the level of the eigenfunctions. Our formulation leads to an efficient optimization-based procedure whose computational and storage costs are comparable to those of standard multivariate PCA for regularly observed data. The method is flexible with respect to domain geometry and model class, accommodates structural constraints and penalties, and facilitates uncertainty quantification via resampling and asymptotic theory.

Keywords: Principal Components Analysis · Irregular Data · Empirical Risk Minimization.

Contributed Session

CS129: New Horizons for Random Fields in Probability and Statistics organized by Prof. Claudio Durastanti

⋆ Presenter

Stationary half-space random growth, via combinatorics

Mattia Cafasso[1], Alessandra Occelli[1], Daniel Ofner[1], and Harriet Walsh[3⋆]

[1] Université d'Angers, Angers, France,
[2] KTH Royal Institute of Technology, Stockholm, Sweden
[3] University College Dublin, Dublin, Ireland
harriet.walsh@ucd.ie

I will talk about a model of two dimensional random growth (namely, polynuclear growth) where we can find nice exact expressions for the distributions of key statistics, via the RSK correspondence. By analysing this model in half-space with external sources, we can show the appearance of a universal interface fluctuations associated with stationary random growth, previously studied by Beta, Ferrari and Occelli[1], and then Barraquand, Le Doussal and Krajenbrink[2]. We also find a distribution which interpolates between the half-space stationary one and different Tracy—Widom distributions (in other words, a half-space analogue of a distribution of Baik and Rains[3]). Our approach uses connections between enumeration of Young tableaux, symmetric functions, matrix integrals, and Hankel determinants, plus a Riemann—Hilbert problem. I'll discuss how we can extend this approach to an inhomogeneous version of TASEP.

Keywords: Integrable probability · stationary random growth · polynuclear growth · longest increasing subsequence problem · last passage percolation · RSK correspondence · Riemann–Hilbert problems.

Contributed Session
CS107: Combinatorial structures in probability and mathematical physics organized by Fabio Cunden

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⋆ Presenter

Optimal Control of Infinite-Dimensional Differential Systems with Randomness and Path-Dependence and Stochastic Path-Dependent Hamilton–Jacobi Equations

Yang Yang[1⋆] and Jinniao Qiu[2]

[1] Faculty of Mathematics and Natural Sciences, Humboldt-Universität zu Berlin, Germany,
yang.yang.1@hu-berlin.de
[2] Department of Mathematics and Statistics, University of Calgary, Canada
{Jinniao Qiu}jinniao.qiu@ucalgary.ca

This talk is devoted to the stochastic optimal control problem of infinite-dimensional differential systems allowing for both path-dependence and measurable randomness. As opposed to the deterministic path-dependent cases studied by Bayraktar and Keller [J. Funct. Anal. 275 (2018) 2096-2161], the value function turns out to be a random field on the path space and it is characterized by a stochastic path-dependent Hamilton-Jacobi (SPHJ) equation. A notion of viscosity solution is proposed and the value function is proved to be the unique viscosity solution to the associated SPHJ equation.

Keywords: stochastic path-dependent Hamilton-Jacobi equation · stochastic optimal control · viscosity solution.

Contributed Session
CS145: Frontiers in Infinite-Dimensional Stochastic Control: Theory and Applications organized by Filippo de Feo

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⋆ Presenter

Low-Dose Tomography of Random Fields and the Problem of Continuous Heterogeneity

Ho Yun[1], Alessia Caponera[2⋆], and Victor M. Panaretos[1]

[1] Department of AI, Data and Decision Sciences, Luiss Guido Carli, Italy,
acaponera@luiss.it
[2] Institute of Mathematics, Ecole Polytechnique Fédérale de Lausanne, Switzerland
ho.yun@epfl.ch, victor.panaretos@epfl.ch

We consider the problem of nonparametric estimation of the conformational variability in a population of related structures, based on low-dose tomography of a random sample of representative individuals. In this context, each individual represents a random perturbation of a common template and is imaged noisily and discretely at but a few projection angles. Such problems arise in the cryo Electron Microscopy of structurally heterogeneous biological macromolecules. We model the population as a random field, whose mean captures the typical structure, and whose covariance reflects the heterogeneity. We show that consistent estimation is achievable with as few as two projections per individual, and derive uniform convergence rates reflecting how the various parameters of the problem affect statistical efficiency, and their trade-offs. Our analysis formulates the domain of the forward operator to be a reproducing kernel Hilbert space, where we establish representer and Mercer theorems tailored to question at hand. This allows us to exploit pooling estimation strategies central to functional data analysis, illustrating their versatility in a novel context. We provide an efficient computational implementation using tensorized Krylov methods and demonstrate the performance of our methodology by way of simulation.

Keywords: Inverse Problems · RKHS · Radon Transform · cryo-EM · Krylov.

Contributed Session
CS101: Statistical methods for complex spatial data analysis organized by Nicoletta D'Angelo and Matteo Giordano

⋆ Presenter

Linearization of McKean SDEs with application to parameter estimation

Andrea Zanoni[1]* and Grigorios A. Pavliotis[2]

[1] Centro di Ricerca Matematica Ennio De Giorgi, Scuola Normale Superiore, Pisa, Italy,
andrea.zanoni@sns.it
[2] Department of Mathematics, Imperial College London, London SW7 2AZ, UK
g.pavliotis@imperial.ac.uk

We consider ergodic McKean stochastic differential equations with a unique stationary state and study the linearized (in the sense of McKean) diffusion process obtained by replacing the law of the nonlinear process with its unique invariant measure. We prove that the law of the nonlinear McKean process and its linearized counterpart are exponentially close in time, both in relative entropy and in Wasserstein distance. The analysis, based on entropy estimates and logarithmic Sobolev inequalities, is carried out on both the whole space and the torus. We then show how the resulting linearized diffusion can be used to replace the original nonlinear process for tasks depending on the long-time behavior of the dynamics, with a particular focus on parameter estimation from a single observed long trajectory. This talk is based on our recent work [1].

Keywords: Inference · Invariant measure · McKean–Vlasov.

Contributed Session
CS117: Statistical inference for high-dimensional diffusions organized by Chiara Amorino

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* Presenter

Long-time behaviour for birth-and-death dynamics in the continuum

Alexander Zass *

Weierstrass Institute, Berlin, Germany,
zass@wias-berlin.it

Gibbs measures are often thought of as the equilibrium measures of thermodynamical systems, but this statement is not universally proven. Indeed, while many detailed results on the dynamics of lattice systems exist, very little is known about the dynamical aspects of Gibbs point processes, in particular regarding out-of-equilibrium dynamics and convergence. In this talk, I will present a model for a continuous-time birth-and-death dynamics in d-dimensional Euclidean space. For such a model, thanks to a de Bruijn-type identity relating the time evolution of the specific relative entropy along trajectories to the Fisher information, we were able to confirm the intuition that the Gibbs measures are the long-time (weak) limit points of the dynamics.

This talk is based on joint works with B. Jahnel, J. Köppl, and Y. Steenbeck, available at arXiv:2508.21196 and arXiv:2602.13474.

Keywords: Gibbs measures · Point processes · Spatial birth and death · Relative entropy · Entropy dissipation · Attractor properties

Contributed Session
CS156: Point processes in the continuum organized by Lorenzo Dello Schiavo and Alexander Zass

* Presenter

Gaussian Optimal Transport Beyond Brenier's Theorem

Ho Yun[1] and Yoav Zemel[1*]

Institut de Mathématique, École polytechnique fédérale de Lausanne, Switzerland,
{ho.yun,yoav.zemel}@epfl.ch

We explore the geometry of the Bures-Wasserstein space for potentially degenerate Gaussian measures on a separable Hilbert space. In this general setting, the optimal transport map is formally the subgradient of a convex function that is infinite almost everywhere, rendering conventional duality-based variational methods ineffective. We overcome this analytical barrier by exploiting a constructive operator-theoretic approach. Our central result proves that the Kantorovich problem for any pair of Gaussian measures reduces to a Monge problem; that is, an optimal transport map exists in at least one direction between two measures. This reduction allows for a complete characterization with explicit formulas for all optimal (potentially unbounded) Monge transport map and Kantorovich couplings, as well as establishing their uniqueness. Furthermore, we provide a full description of the convex set of geodesics between degenerate measures, revealing a rich geometric structure where the classical McCann interpolants arise as the extreme points. We apply these findings to construct transport maps for Gaussian processes and introduce a novel framework for Wasserstein barycenters based on random Green's operators.

Keywords: Covariance Operator · Degenerate Gaussian Measures · Geodesics · Optimal Transport

Contributed Session
CS143: Optimal Transport Methods for Statistics organized by Marta Catalano and Hugo Lavenant

References

1. Yun, H., Zemel, Y.: Gaussian Optimal Transport Beyond Brenier's Theorem. arXiv:2512.21464 (2025)

* Presenter

Analysing sideward contact tracing through a branching process with sibling dependencies

Dongni Zhang[1] and Martina Favero[2] *

[1] Department of Health, Medicine and Caring Sciences, Linköping University, Sweden,
dongni.zhang@liu.se
[2] Department of Mathematics,Stockholm University, Sweden
martina.favero@math.su.se

We consider a stochastic epidemic model with dynamics driven by mixing events (gatherings of two or more individuals), and the corresponding early-phase branching process approximation. We introduce into the model a special type of contact tracing, *sideward contact tracing*, which aims at tracing individuals who were infected at the same event as a diagnosed individual. In order to deal with the dependencies caused by the tracing, we define a new branching process where sibling groups of the original branching process correspond to multi-type macro-individuals on an enriched state space, free of dependencies. This then allows us to analyse the impact of sideward contact tracing on the epidemic dynamics.

Keywords: stochastic epidemic models · branching processes · sibling dependencies

Contributed Session
CS189: Stochastic population dynamics organized by Dario Spanò

* Presenter

Exploring the space of graphs with fixed discrete curvatures

Giulio Zucal[1,2,3*]

[1] Max Planck Institute of Cell Biology and Genetics, Dresden, Germany
[2] Center for Systems Biology Dresden, Germany
[3] Max Planck Institute for Physics of Complex Systems, Dresden, Germany
zucal@mpi-cbg.de

Discrete curvatures are quantities associated to the nodes and edges of a graph that reflect the local geometry around them. These curvatures have a rich mathematical theory and they have recently found success as a tool to analyze networks across a wide range of domains. We consider the problem of constructing graphs with a prescribed set of discrete edge curvatures, and explore the space of such graphs. In particular, we solve the exact reconstruction problem for the specific case of Forman–Ricci curvature. By leveraging the algebraic theory of Markov bases, we obtain a finite set of rewiring moves that connects the space of all graphs with a fixed discrete curvature. These moves allow us to define a Markov chain to sample from the space of graphs with a given curvature, providing a foundation for generating curvature-constrained null models. Based on joint work with Michelle Roost, Karel Devriendt and Jürgen Jost and ongoing work with Jane Ivy Coons.

Keywords: Discrete curvature · Forman-Ricci curvature · Markov bases · Markov chain Monte Carlo algorithms.

Contributed Session
CS175: Global and local topological properties of random graphs organized by Carlo De Ambroggio

References

1. Roost, Michelle, Devriendt, Karel, Zucal, Giulio and Jost, Jürgen. "Exploring the space of graphs with fixed discrete curvatures." Journal of Physics: Complexity 5.3 (2024): 035011.
2. Coons, Jane and Zucal, Giulio.: Markov and lattice bases for sampling graphs with given degree and Forman-Ricci curvature sequences (in preparation).

* zucal@mpi-cbg.de

Probability graphons and large deviations for random weighted graphs

Giulio Zucal[1,2,3⋆]

[1] Max Planck Institute of Cell Biology and Genetics, Dresden, Germany
[2] Center for Systems Biology Dresden, Germany
[3] Max Planck Institute for Physics of Complex Systems, Dresden, Germany
zucal@mpi-cbg.de

Graph limit theory studies the convergence of sequences of graphs as the number of vertices grows, providing an effective framework for representing large networks. In this talk, I will give a brief introduction to graph limits and report on recent extensions to weighted graphs, colored graphs and multiplex networks (probability graphons and P-variables). As an application of this theory I will present a large deviation principle (LDP) for random weighted graphs that generalizes the LDP for Erdős-Rényi random graphs by Chatterjee and Varadhan (2011), based on joint work with Pierfrancesco Dionigi.

Keywords: Graph limits · Probability graphons · Large deviations · Random weighted graphs.

Contributed Session
CS127: Asymptotics of random graphs organized by Pierfrancesco Dionigi and Elena Magnanini

References

1. Dionigi, Pierfrancesco, and Zucal, Giulio: Large deviations for probability graphons. *arXiv preprint arXiv:2509.14204* (2025).
2. Zucal, Giulio: Probability graphons: the right convergence point of view. *arXiv preprint arXiv:2407.05998* (2024).
3. Zucal, Giulio: Probability graphons and P-variables: two equivalent viewpoints for dense weighted graph limits. *arXiv preprint arXiv:2408.07572* (2024).

⋆ Presenter

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