Titles & Abstracts
Interacting Particles, Fluctuating Systems, and SPDEs

8-10 June, 2023

Mathematical Institute, University of Oxford

8 June, Lecture Hall 3, Mathematical Institute

Time	Speaker
9:30-10:00	Registration
10:00-11:00	Avi Mayorcas
11:00-11:30	Coffee, Common Room
11:30-12:30	Alexandra Neamtu
12:30-2:30	Lunch
2:30-3:30	Claudia Raithel
3:30-4:00	Coffee, Common Room
4:00-5:00	Ilya Chevyrev
7:00	Dinner, Pierre Victoire

9 June, Lecture Hall 4, Mathematical Institute

Time	Speaker
9:00-10:00	Daniel Heydecker
10:00-11:00	Ana Djurdjevac
11:00-11:30	Coffee, Common Room
11:30-12:30	Federico Cornalba
12:30-2:30	Lunch
2:30-3:30	Giuseppe Cannizzaro
3:30-4:00	Coffee, Common Room
4:00-5:00	Bálint Tóth

10 June, Lecture Hall 4, Mathematical Institute

Time	Speaker
9:00-10:00	Peter Morfe
10:00-11:00	Simon Gabriel
11:00-11:30	Coffee, Common Room
11:30-12:30	Ajay Chandra

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10:00-11:00	**An Additive Noise Approximation to the Keller–Segel–Dean–Kawasaki Equation**
Avi Mayorcas	The Dean-Kawasaki (DK) equation is a proposed singular SPDE model for the random fluctuations of stochastic interacting particle systems around their mean field limits. However, it is by now well understood that the fully singular DK equation is ill-posed outside of a specific parameter set and that in this case the only solutions are empirical measures. This makes the continuum DK equation a challenge to study. In this talk I will present joint work with A. Martini (Oxford) in which we study an additive noise approximation to the DK equation for a stochastic particle model of chemotaxis. Applying the theory of paracontrolled distributions we obtain well-posedness of the approximate equation along with a generalised LLN, CLT and LDP.
11:30-12:30	**A semigroup approach to quasilinear rough PDEs**
Alexandra Neamtu	We investigate quasilinear parabolic evolution equations driven by a γ-Hölder rough path, where $\gamma \in (1/3, 1/2]$. We explore the mild formulation that combines functional analysis techniques and the controlled rough path approach which entail the local well-posedness of such equations. We apply our results to the stochastic Landau–Lifshitz–Gilbert and Shigesada–Kawasaki–Teramoto equation. In this framework we obtain a random dynamical system associated to the Landau–Lifshitz–Gilbert equation. This talk is based on a joint work with Antoine Hocquet.
2:30-3:30	**Density fluctuations in weakly interacting particle systems via the Dean–Kawasaki equation**
Claudia Raithel	It has been proposed that the density fluctuations of a system of weakly interacting particles in the regime of large but finite particle number are captured by the Dean-Kawasaki equation. A rigorous justification of the Dean-Kawasaki equation has been hindered by it being a highly singular SPDE. Motivated by the recent treatment of the non-interacting case by Cornalba and Fischer, in this talk we give a justification for the Dean-Kawasaki equation in the setting of weakly interacting particles. In particular, we show that, using a suitable weak distance, the law of the fluctuations as predicted by a spatially discretized Dean-Kawasaki equation coincides with the law of the fluctuations of the particle system up to arbitrary order in the inverse particle number and a discretization error. This talk is based on a joint work with Federico Cornalba, Julian Fischer, and Jonas Ingmanns.
4:00-5:00	**Invariant measure and universality of the 2D Yang-Mills Langevin dynamic**
Ilya Chevyrev	Yang-Mills (YM) theories form the basis for mathematical models of forces in quantum field theory. Despite the attention that they have received, making rigorous sense of quantum YM theories has proved to be challenging even in low dimensions. A great success story is the complete classification of 2D YM theories, which are exactly solvable. In work with Chandra-Hairer-Shen, we gave meaning to the 2D and 3D YM Langevin dynamic (stochastic quantisation equation), but proving a link between the 2D YM measure and its Langevin dynamic remained an open problem. In this talk, we will present a solution to this problem that establishes the YM measure on the 2D torus as the unique invariant measure of its Langevin dynamic. We will discuss some elements of the proof as well as some corollaries, including a universality result for the YM measure. Based on arXiv:2302.12160, which is joint work with Hao Shen.

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9:00-10:00	**The Porous Medium Equation: Rescaled Zero-Range Process, Large Deviations and Gradient Flow**
Daniel Heydecker	We study a rescaling of the zero-range process with homogenous jump rates $g(k) = k^{\alpha}$ with arbitrary $\alpha \geq 1$. With a simultaneous rescaling of space, time and particle size, we identify the dynamical large deviations from the porous medium equation, using pathwise discretised regularity estimates to prove a version of the superexponential estimate in the spirit of the Aubin–Lions–Simons lemma. Finally, we use the large deviation principle to give an expression of the porous medium equation as the gradient flow of the Boltzmann entropy with respect to a tailor-made Wasserstein-type distance.
10:00-11:00	**Nonlinear SPDE approximation of the Dean–Kawasaki equation**
Ana Djurdjevac	Interacting particle systems provide flexible and powerful models that are useful in many application areas such as sociology (agents), molecular dynamics (proteins) etc. However, particle systems with large numbers of particles are very complex and difficult to handle, both analytically and computationally. Therefore, a common strategy is to derive effective equations that describe the time evolution of the empirical particle density. Our aim is to derive and study continuum models for the mesoscopic behaviour of particle systems. In particular, we are interested in finite size effects. We will introduce nonlinear and non-Gaussian models that provide a more faithful representation of the evolution of the empirical density of a given independent particle system, than the usual linear Gaussian perturbations around the hydrodynamic limit models. We want to study the well-posedness of these nonlinear SPDE models and to control the weak error of the SPDE approximation. A prototypical example that we will consider is the formal identification of a finite system of diffusions with the singular Dean-Kawasaki SPDE. This is the joint work with H. Kremp and N. Perkowski. Furthermore, we will discuss the application of these types of equations in the feedback-loop opinion dynamics. This is a joint work with N. Dj. Conrad and Jonas Köppl.
11:30-12:30	**Reducing variance in discretised overdamped Dean–Kawasaki models**
Federico Cornalba	The theory of Fluctuating Hydrodynamics uses suitable stochastic PDEs (SPDEs) to provide a mesoscopic description of underlying finite-size particle systems subject to random fluctuations. The SPDE models in this ever-growing theory are nowadays being looked at under several different angles (modeling, analysis, simulation, quantitative fluctuation analysis, etc...) After giving some brief context for Fluctuating Hydrodynamics, I will focus on variance reduction methods (in the form of Multilevel Monte Carlo schemes, MLMC for short) for suitable discretisations of the overdamped Dean–Kawasaki model, which describes the motion of N independent Brownian particles. As main result, I will show that the proposed MLMC scheme gains efficiency over the standard MC scheme in the same scaling regime in which the Dean–Kawasaki model gains efficiency over direct particle simulation. This talk is based on joint work in progress with J. Fischer (ISTA) and Q. Winters (TU Munich).

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2:30-3:30	**Weak coupling scaling of critical SPDEs**
Giuseppe Cannizzaro	The study of stochastic PDEs has known tremendous advances in recent years and, thanks to Hairer's theory of regularity structures and Gubinelli and Perkowski's paracontrolled approach, (local) existence and uniqueness of solutions of *subcritical* SPDEs is by now well-understood. The goal of this talk is to move beyond the aforementioned theories and present novel tools to derive the scaling limit (in the so-called weak coupling scaling) for some stationary SPDEs at the *critical* dimension. Our techniques are inspired by the resolvent method developed by Landim, Olla, Yau, Varadhan, and many others, in the context of particle systems in the *supercritical* dimension and might be well-suited to study a much wider class of statistical mechanics models at criticality.
4:00-5:00	**Random walks in divergence-free random environments**
Bálint Tóth	We will discuss some recent progress on the homogenization of potentially degenerate random environments with divergence-free drift.

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9:00-10:00	**Anomalous Diffusion in the Curl of the Gaussian Free Field**
Peter Morfe	I will describe recent work on anomalous diffusion asymptotics for diffusions advected by turbulent velocity fields. Precisely, the model of interest involves a passive tracer subjected to Brownian diffusion and advection by the curl of the Gaussian free field (or divergence-free white noise). Recent work of Cannizzaro, Haunschmidt-Sibitz, and Toninelli (2022) established that the mean-square displacement grows like $t\sqrt{\ln(t)}$, confirming earlier predictions of the physics literature and a conjecture of Toth and Valko (2011). In joint work with Chatzigeorgiou, Otto, and Wang, we give an alternative proof built around ideas from stochastic homogenization, with a slightly stronger conclusion.
10:00-11:00	**The Allen-Cahn equation with random critical initial datum**
Simon Gabriel	We consider the Allen-Cahn equation with white noise initial datum in a weak coupling regime. The usual approach of performing a Picard iteration of the solution yields an infinite series of stochastic iterated integrals. In contrast to considering initial datum under sub-critical rescaling, each term in the infinite expansion/series has a positive contribution to the solution. In this talk, we present an approach that keeps track of each summand's contribution, using the notion of rooted trees, and determine their non-trivial Gaussian fluctuations exactly. Furthermore, by exploiting the structure of the equation, we approximate the infinite series while controlling the imposed error, and determine its limiting law. The talk is based on joint work with Tommaso Rosati and Nikos Zygouras.
11:30-12:30	**Stochastic quantization for a non-local field theory**
Ajay Chandra	I will introduce quartic melonic tensor field theories, a class of field theories built using a non-local quartic interaction term. These resemble the more well-known Φ^4_d models but behave differently with regards to power-counting and the structure of their divergences. In particular, these models are conjectured to be non-trivial in their critical dimension, in contrast with Φ^4_4. I will then report on recent joint work with Léonard Ferdinand where we use stochastic analysis methods to construct the Φ^4_2 and Φ^4_3 analogs of these models.