Theoretical and Analytical Aspects of Kinetic equations in Plasmas

Aspects théoriques et analytiques des équations cinétiques dans les plasmas

25 – 29 March 2024

Centre International de Rencontres Mathématiques, Marseille

As part of the Chaire Jean Morlet: Aggregation-Diffusion and Kinetic Equations, Collective Behavior Models and Applications

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Schedule

Monday, 25 March 2024

09:00 – 09:10			OPENING REMARKS
09:10 – 09:55	Maria GUALDANI	Global smooth solutions of the Landau-Coulomb equation in $L^{3/2}$
09:55 – 10:40	Nicolas CROUSEILLES	TBA
10:40 – 11:10		BREAK
11:10 – 11:55	Yijia TANG	Random batch particle method for the homogeneous Landau equation
12:30 – 14:30		LUNCH
14:30 – 15:00	Dominik BELL	Vlasov-Maxwell Models with delta-f Methods and their Hamiltonian Formulations
15:00 – 15:30	Tino LAIDIN	Discrete hypocoercivity for a nonlinear kinetic reaction model
15:30 – 16:00		BREAK
16:00 – 16:30	Annamaria MASSIMINI	Finite volumes for a generalized Poisson-Nernst-Planck system with cross-diffusion and size exclusion
19:30 – 21:30		DINNER

Tuesday, 26 March 2024

09:00 – 09:45	Giacomo DIMARCO	Control and uncertainty quantification through deep neural networks for plasma simulation
09:45 – 10:30	James BUCHANAN	Gaussian Process Emulation of Kinetic Instabilities in Spherical Tokamaks
10:30 – 11:00		BREAK
11:00 – 11:45	Stéphane BRULL	Discrete BGK scheme for the bitemperature Euler system and application to MHD
12:30 – 14:30		LUNCH
14:30 – 15:15	Maxime HERDA	Vlasov-Fokker-Planck model of relativistic charged particle beams
15:15 – 16:00	Thomas REY	Projective integration methods for multiscale kinetic equations
16:00 – 16:30		BREAK
16:30 – 17:15	Frédéric HÉRAU	Low temperature analysis and metastability for kinetic models with several conservation laws
19:30 – 21:30		DINNER

Wednesday, 27 March 2024

09:00 – 09:45	Mehdi BADSI	Plasma sheath solutions for a bi-species Vlasov-Poisson-BGK model
09:45 – 10:30	Alexandre REGE	Uniqueness and stability for magnetized Vlasov equations
10:30 – 11:00		BREAK
11:00 – 11:30	Andrea MEDAGLIA	Particle stochastic-Galerkin methods for the Landau equation with random inputs
11:30 – 12:00	Damien PREL	Deterministic particles method for Fokker-Planck equation
12:30 – 14:30		LUNCH
14:30 – 19:30		FREE DISCUSSION
19:30 – 21:30		DINNER

Thursday, 28 March 2024

09:00 – 09:45	Laurent Desvillettes	About the Landau collision kernel of plasma theory
09:45 – 10:30	Maxence Thévenet	Particle-in-cell simulations for plasma acceleration: combining advanced numerical methods and GPU computing.
10:30 – 11:00		Break
11:00 – 11:45	Michel Mehrenberger	The semi-Lagrangian method with polar type coordinates for guiding center simulations
12:30 – 14:30		Lunch
14:30 – 15:15	Thierry Goudon	A two-dimensional pseudo-gravity model: a model for magneto-optical traps
15:15 – 16:00	Bruno Despres	Gyrokinetic equations discretized with Hermite based moment methods
16:00 – 16:30		Break
16:30 – 17:15	Yingda Cheng	A micro-macro decomposed reduced basis method for the time-dependent radiative transfer equation
19:30 – 21:30		Dinner

Friday, 29 March 2024

09:00 – 09:45	Francis Filbet	A structure and asymptotic preserving scheme for the Vlasov-Poisson-Fokker-Planck model
09:45 – 10:30	Nuno Alves	Zero-electron-mass and quasi-neutral limits for bipolar Euler-Poisson systems
10:30 – 11:00		Break
11:00 – 11:45	Emily Bourne	Distributing Calculations with Splines
11:45 – 12:30	Lukas Einkemmer	Theory and numerics of asymptotic preserving low-rank schemes
12:30 – 12:40		Closing remarks

Abstracts

Nuno Alves

University of Vienna, Austria

Zero-electron-mass and quasi-neutral limits for bipolar Euler-Poisson systems

We consider a bipolar Euler-Poisson system and present two asymptotic limiting processes. The first is the zero-electron-mass limit, which formally results in a nonlinear adiabatic electron system. Secondly, we consider the combined zero-electron-mass and quasi-neutral limits, which together lead to a compressible Euler system. Using the relative energy method, these limiting processes are rigorously justified for dissipative weak solutions of the bipolar Euler–Poisson as well as for strong solutions of the limit systems that are bounded away from vacuum. This justification is valid in the regime of initial data for which strong solutions exist. To deal with the electric potential, in the first case we use elliptic theory, whereas in the second case we employ the theory of Riesz potentials and properties of the Neumann function. This is a joint work with Athanasios Tzavaras.

Mehdi Badsi

Université de Nantes, France

Plasma sheath solutions for a bi-species Vlasov-Poisson-BGK model

The Debye sheath is a positively charged boundary layer that forms when a plasma is in contact with a metallic wall. It has been shown that it is possible to construct sheath type solutions for the Vlasov-Poisson equations (in a bounded domain) provided the ions distribution function verifies the so called Bohm condition of plasma physics.

When particles experience collision or friction, the role played by the Bohm condition is unclear. We will show that for a simple Vlasov-Poisson-BGK model it is possible to construct solutions for which the density is non negative and the electric potential is strictly monotone. Our method of proof shows that there is a competition between the Debye length and the collision frequency. We will discuss numerically whether one can enlarge the range of the physical parameters.

Dominik Bell

Technical University of Munich, Germany

Vlasov-Maxwell Models with delta-f Methods and their Hamiltonian Formulations

We study the linearized Vlasov-Maxwell model with a Maxwellian background using a delta-f method. We explore its Hamiltonian structure and discuss a structure-preserving discretization consisting of a particle-in-cell (PIC) method for the perturbation to the distribution function and the Finite Element Exterior Calculus (FEEC) for the field variables. The whole model is formulated in curvilinear coordinates. Finally, we perform a Poisson splitting yielding 5 substeps and show how they can be numerically integrated in time. In the second part, we discuss a Hamiltonian framework for the full Vlasov-Maxwell with a delta-f method. Using the same discretization as before we obtain similar equations of motion as for the linearized system, however, with one additional substep which needs to be solved.

Emily Bourne

EPFL, Switzerland

Distributing Calculations with Splines

Splines are a useful tool for building a smooth, continuous representation of a function from discrete data. This is necessary in the semi-Lagrangian method which underpins the GYSELA code. This code carries out massively parallel gyrokinetic simulations of tokamak plasmas. However the global nature of splines imposes serious restrictions on the parallelism that is possible in these simulations. In this presentation we will explore different attempts to alleviate these constraints.

We will discuss the advantages and disadvantages of different methods in the context of plasma simulations. The methods will include an existing method originally described by Crouseilles et al. [1] and a new method which we will present. The new method avoids the reconstruction of derivatives by advecting derivatives thus increasing the locality of the problem. The stability of this method will be proven in 1D and some first numerical results will be given.

References [1] Nicolas Crouseilles, Guillaume Latu, and Eric Sonnendr"ucker. A parallel Vlasov solver based on local cubic spline interpolation on patches. Journal of Computational Physics, 228(5):1429–1446, 2009

Stéphane Brull

Université de Bordeaux, France

Discrete BGK scheme for the bitemperature Euler system and application to MHD

This talk is devoted to the approximation of the bitemperature Euler system.

This system is a non conservative hyperbolic system describing a plasma. This plasma is quasi-neutral

and is situated a out of equilibrium thermal regime. The nonconservativity comes on the one hand from the presence of products between pressure gradients and velocities and on the other hand from source terms. In this case, we have derived an entropy compatible BGK model.

In this talk, we will present a numerical scheme of order 2 that is based on a finite volume discretisation.

In a last part, we will explain how to integrate magnetic fields in the models and in the schemes.

James Buchanan

Atomic Energy Authority, UK

Gaussian Process Emulation of Kinetic Instabilities in Spherical Tokamaks

Turbulent core transport is a critical design driver for a tokamak power plant effectively setting the energy confinement time of the reactor, one of the key performance metrics. Simulation of turbulent processes and the calculation of the resulting heat, particle and momentum fluxes is computationally expensive, requiring solution of the gyrokinetic equation. Such simulations typically cost hundreds of thousands of CPU hours per non-linear simulation for a single flux surface. This is in tension with the need to perform time evolving integrated modelling to optimise the steady state configuration, ramp-up trajectory and control of plasma scenarios, which requires many such simulations at each radial location at each time step. Machine learning offers a possible route to mitigate the extreme cost of such simulations. Instead of directly using gyrokinetic simulations in integrated models, one can attempt to train ML models on pre-generated datasets of simulations to build cheap surrogate models which can be exploited in place of the original expensive simulations for iterative design. Recent work at UKAEA has explored the use of both neural networks and Gaussian Process regression to build models of the linear and quasi-linear properties of both electrostatic and electromagnetic turbulent instabilities expected to be present in both the current generation of experimental reactors and future spherical tokamak powerplants. In both cases it was found that incorporating aspects of the physics in the models provides significant benefit in terms of required dataset size. Notably the development of a classifier to learn the stability manifold of the modes was found to be extremely beneficial. Further efficiency gains can be achieved via active learning, whereby the sampling of the dataset used for training is guided iteratively by the model's uncertainty. This talk will introduce the UK fusion program, notably the STEP project (Spherical Tokamak for Energy Production) which aims to develop a UK based spherical tokamak by 2040, discuss the critical importance of understanding of the properties of core gyrokinetic turbulence, and present the recent work described above towards the eventual goal of developing cheap, accurate, actionable surrogate models of turbulent transport for reactor design.

Yingda Cheng

Virginia Tech, USA

A micro-macro decomposed reduced basis method for the time-dependent radiative transfer equation

Kinetic transport equations are notoriously difficult to simulate because of their complex multiscale behaviors and the need to numerically resolve a high dimensional probability density function. Past literature has focused on building reduced order models (ROM) by analytical methods. In recent years, there is a surge of interest in developing ROM using data-driven or computational tools that offer more applicability and flexibility. We leverage the low-rank structure of the solution manifold induced by the angular variable and further advance the methodology to the time-dependent model. Particularly, we take the celebrated reduced basis method (RBM) approach and propose a novel micro-macro decomposed reduced basis method (MMD-RBM). The MMD-RBM is constructed by exploiting, in a greedy fashion, the low-rank structures of both the micro- and macro-solution manifolds with respect to the angular and temporal variables. Our reduced order surrogate consists of: reduced bases for reduced order subspaces and a reduced quadrature rule in the angular space. The proposed MMD-RBM features several structure-preserving components: 1) an equilibrium-respecting strategy to construct reduced order subspaces which better utilize the structure of the decomposed system, and 2) a recipe for preserving positivity of the quadrature weights thus to maintain the stability of the underlying reduced solver. The resulting ROM can be used to achieve a fast online solve for the angular flux in angular directions outside the training set and for arbitrary order moment of the angular flux, and be used in outer loop calculations.

Nicolas Crouseilles

Centre Inria de l'Université de Rennes, France

TBA

TBA

Bruno Despres

Sorbonne Université, France

Gyrokinetic equations discretized with Hermite based moment methods

Gyrokinetic equations are used to model the displacement of charged particles in a strongly magnetized environment. I will consider a popular method for the numerical discretization, which is based on the asymmetric Hermite basis.

Unfortunately this method leads to a fundamental numerical stability problem. It was explained in Shumer-Holloway 98' and received recent attention in Funaro/Manzini 21' and Bessemoulin-Chatard/Filbet 22'. A purely numerical original solution will be proposed based on seemingly new formulas for the scalar product of two asymmetric functions. This is based on joint works with F. Charles, S. Hirstoaga and R. Dai.

Laurent Desvillettes

Université Paris Diderot, France

About the Landau collision kernel of plasma theory

We propose a discussion of several results related to the Landau collision kernel with Coulomb interaction, and its entropy structure, together with its variants, like Landau-Fermi-Dirac collision kernel.

Giacomo Dimarco

University of Ferrara, Italy

Control and uncertainty quantification through deep neural networks for plasma simulation

We will consider the development of numerical methods for simulating plasmas in magnetic confinement nuclear fusion reactors. In particular, we focus on the Vlasov-Maxwell equations describing out of equilibrium plasmas influenced by an external magnetic field and we approximate this model through the use of particle methods. We will additionally set an optimal control problem aiming at minimizing the temperature at the boundaries of the fusion device or alternatively the number of particles hitting the boundary. Our goal consists then in confining the plasma in the center of the physical domain. In this framework, we consider the construction of multifidelity methods based on neural network architectures for estimating the uncertainties due to the lack of knowledge of all the physical aspects arising in the modeling of plasma.

Lukas Einkemmer

University of Innsbruck, Austria

Theory and numerics of asymptotic preserving low-rank schemes

Solving kinetic equations, owing to the up to 6-dimensional phase space, is extremely expensive from a computational point of view. Recently, using dynamical low-rank approximation has emerged as an attractive complexity reduction technique that, in many cases, succeeds in drastically reducing the time required to run such simulations.

Such kinetic problems are often posed in a context where either a fluid or diffusive limit is obtained for large collisionality. In many problems of practical interest, both the fully kinetic and limit regime can be present (in different parts of the spatial domain). Therefore, it is important to derive numerical schemes that can capture these limits. In this talk, we will report on recent advances of such asymptotic preserving dynamical low-rank algorithms both from a practical and theoretical point of view. We will consider under which conditions the corresponding limit is low-rank, prove convergence of dynamical low-rank schemes to this limit (using energy estimates), and explore proper numerical discretizations (implicit-explicit methods, transition of the CFL condition from the kinetic regime to the diffusive regime, and nodal vs modal discretizations).

Francis Filbet

Université Toulouse III - Paul Sabatier, France

A structure and asymptotic preserving scheme for the Vlasov-Poisson-Fokker-Planck model

We propose a numerical method for the Vlasov-Poisson-Fokker-Planck model written as an hyperbolic system thanks to a spectral decomposition in the basis of Hermite functions with respect to the velocity variable and a structure preserving finite volume scheme for the space variable. On the one hand, we show that this scheme naturally preserves both stationary solutions and linearized free-energy estimate. On the other hand, we adapt previous arguments based on hypocoercivity methods to get quantitative estimates ensuring the exponential relaxation to equilibrium of the discrete solution for the linearized Vlasov-Poisson-Fokker-Planck system, uniformly with respect to both scaling and discretization parameters. Finally, we perform substantial numerical simulations for the nonlinear system to illustrate the efficiency of this approach for a large variety of collisional regimes (plasma echos for weakly collisional regimes and trend to equilibrium for collisional plasmas) and to highlight its robustness (unconditional stability, asymptotic preserving properties).

Work in collaboration with Alain Blaustein (Penn State University).

Thierry Goudon

INRIA Sophia Antipolis, France

A two-dimensional pseudo-gravity model: a model for magneto-optical traps

We will present a 2D PDE model describing the evolution of a cloud of particles confined in a magneto-optical trap. The equation has the flavour of usual models for self-attracting particles.

However in contrast to the standard gravitational forces, here the force field does not derive from a potential and the coupling does not involve a convolution with respect to all the space variables.

These features induce specific difficulties. We will discuss the existence of solutions and the derivation of the equation in a mean-field regime.

Maria Gualdani

University of Texas at Austin, USA

Global smooth solutions of the Landau-Coulomb equation in $L^{3/2}$

The Landau equation, introduced by Lev Landau in 1936, is a modification of the Boltzmann equation to specific applications in plasma physics, and describes the interactions and collisions among charged particles in a plasma. The mathematical investigation of the Landau equation has been active for several decades, with researchers exploring various aspects of its behavior and properties and has culminated in the recent global well-posedness result by Guillen and Silvestre for smooth initial data. In this talk I will present the first global well-posedness theory for the Landau-Coulomb with rough initial data and show that, even for non-smooth configurations, the equation has a very strong regularization effect thanks to the diffusion dominating the reaction at any time.

Frédéric Hérau

Nantes Université, France

Low temperature analysis and metastability for kinetic models with several conservation laws

In this talk, we will present the analysis at low temperature of an inelastic linear BGK type kinetic model conserving mass and momentum, in the case when there is unique potentiel well ensuring confinment of the sytem of particles descibed by the equation. We take profit of recent hypocoercive results on multi-conservation laws Boltzmann type models. The tools are close to the ones used in the semiclassical PDE community, involving small parameters. We exhibit controlled out of equilibrium steady or periodic states minimizing entropy and study quantitatively, with respect to the temperature, the convergence in time to these states. This is a common work with Thomas Normand and Dorian Le Peutrec (Nantes University).

Maxime Herda

Université de Lille, France

Vlasov-Fokker-Planck model of relativistic charged particle beams

In this talk, I will present a kinetic model describing the longitudinal dynamics of an electron bunch in the storage ring of a synchrotron particle accelerator. In this model, unlike electrostatic plasmas, charged particles interact in a non-symmetric way which results in interesting and complex dynamical behaviors. I will present preliminary results on the derivation and well-posedness of the model, as well as long time behavior in weakly nonlinear regimes, using hypocoercivity techniques. This is a work in collaboration with Ludovic Cesbron (CY Cergy Paris Université).

Tino Laidin

Université de Lille, France

Discrete hypocoercivity for a nonlinear kinetic reaction model

I will present a work in collaboration with M. Bessemoulin-Chatard and T. Rey, in which we consider a non-linear kinetic model describing a two-species generation-recombination reaction that can be considered as a simplified version of models describing the generation and recombination of electron-hole pairs in semiconductors. I will introduce a finite volume discretization of this model for which we can prove an exponential decay towards the steady state using discrete hypocoercivity methods. After presenting the ideas of the proof in the continuous framework, I will highlight the main difficulties induced by the discretization process. The properties of the method will then be illustrated by several numerical examples.

Annamaria Massimini

Vienna University of Technology, Austria

Finite volumes for a generalized Poisson-Nernst-Planck system with cross-diffusion and size exclusion

In this talk I will present two finite volume approaches to modelling the diffusion of charged particles, in particular ions, in constrained geometries, using a degenerate Poisson-Nernst-Planck system with cross-diffusion and volume filling. Both methods use a two-point flow approximation and fall within the framework of exponential fitting schemes. The only difference between the two is the choice of a Stolarsky mean for the drift term that results from a self-consistent electric potential. The first version of the scheme, called (SQRA), uses a geometric mean and is an extension of the square root approximation scheme. The second scheme, (SG), uses an inverse logarithmic mean to create a generalised version of the Scharfetter-Gummel scheme. Both approaches guarantee the decay of a certain discrete free energy. Classical numerical analysis results, as well as some numerical simulations, will be discussed. The latter show that both schemes are effective for moderately small Debye lengths, with scheme (SG) demonstrating greater robustness in the regime of small Debye lengths.

Andrea Medaglia

University of Pavia, Italy

Particle stochastic-Galerkin methods for the Landau equation with random inputs

Plasma models are studied at the kinetic level by the Landau equation and have gained a lot of interest due to the important applications related to fusion reactors and ongoing projects such as ITER, JET, and SPARC. Moreover, the importance of considering uncertainties into the PDEs is growing, partly due to the increased presence of real-world data

The construction of numerical methods for such equation with random inputs is a challenging problem, thanks to the high dimensional structure of the equation, involving both phase space variables and stochastic parameters, and the formation of multiscale structures that must be captured by the numerical schemes. Furthermore, a numerical solver must be able to preserve the structural physical properties such as the non-negativity of the distribution function, the main conservations of invariant quantities, the entropy dissipation, and the equilibrium states. Besides, the regularity of the solution with respect to the random parameter is crucial to derive efficient numerical methods, and must be investigated.

Recently, a new class of numerical methods that combine a particle-based approximation of the distribution function in the phase space together with a stochastic Galerkin expansion of the particles in the random space has been proposed. These methods are spectrally accurate in the space of the random parameters, thanks to the sG formulation, and conserve the structural properties of the equation, because of the particle nature.

The schemes have been presented for the homogeneous Landau equation in [1, 3] and for the Vlasov-Poisson-BGK system with random inputs in [2]. Current ongoing works are focussing on the space inhomogeneous Landau equation.

References [1] R. Bailo, J.A. Carrillo, A. Medaglia, and M. Zanella, Uncertainty Quantification for the Homogeneous Landau-Fokker-Planck Equation via Deterministic Particle Galerkin methods, arxiv:2312.07218, (2023), 1-23.

[2] A. Medaglia, L. Pareschi, M. Zanella, Stochastic Galerkin particle methods for kinetic equations of plasmas with uncertainties, J. Comput. Phys., 479 (2023), pp. 112011.

[3] A. Medaglia, L. Pareschi, M. Zanella, Particle simulation methods for the Landau- Fokker-Planck equation with uncertain data, J. Comput. Phys., 503 (2024), pp. 112845.

Michel Mehrenberger

Aix-Marseille Université, France

The semi-Lagrangian method with polar type coordinates for guiding center simulations

We propose a semi-Lagrangian method for solving the guiding center model (which is a 2D prototype for further gyro-kinetic simulations [1]) on some disk like geometries, using Lagrange interpolation for the advection and finite differences for the Poisson equation, following [2]. For simplicity, we focus on geometries where the inverse mapping between cartesian and polar type coordinates is known, and first deal with the case of the polar geometry (see some first numerical results on Figure 1). With respect to a preliminary work [3], the algorithm is described here for the full guiding center model ; we use no more a shifted mesh, neither change the discretization of each concentric curve, but we are still able to handle the polar singularity. It is a variant of [4], where a solution has been proposed using a finite element solver with C1 smooth polar splines for the Poisson equation and spline interpolation with the introduction of pseudo-cartesian coordinates (which could also be useful in our setting, for dealing with the case where the inverse mapping is not easy to compute) for the advection. Note that, in this context, different Poisson solvers have been discussed recently [5].

References [1] Grandgirard, Virginie, et al. A 5D gyrokinetic full-f global semi-Lagrangian code for flux-driven ion turbulence simulations. Computer physics communications 207 (2016) : 35-68.

[2] Strikwerda, John C., and Y. M. Nagel. Finite difference methods for polar coordinate systems. University of Wisconsin-Madison. Mathematics Research Center, 1986.

[3] Bouzat, N., Bressan, C., Grandgirard, V., Latu, G., and Mehrenberger, M. (2018). Targeting realistic geometry in Tokamak code Gysela. ESAIM : Proceedings and Surveys, 63, 179-207.

[4] Zoni, Edoardo, and Güçlü, Yaman. Solving hyperbolic-elliptic problems on singular mapped disk- like domains with the method of characteristics and spline finite elements. Journal of Computa- tional Physics 398 (2019) : 108889.

[5] Bourne, Emily, et al. Solver comparison for Poisson-like equations on tokamak geometries. Journal of Computational Physics (2023) : 112249.

Damien Prel

Laboratoire de Mathématiques Jean Leray, France

Deterministic particles method for Fokker-Planck equation

In some cases, collisions have to be considered when we deal with plasmas. It can be modelised with the Fokker-Planck collision operator. In this talk, I present a deterministic particle method for Fokker-Planck equation based on the regularization of relative entropy. This method conserve mass, momentum and energy, up to a correction, and the relative entropy is dissipated. At the end, I show some numerical results.

Alexandre Rege

ETH Zurich, Switzerland

Uniqueness and stability for magnetized Vlasov equations

We present recent advances regarding uniqueness and stability for Vlasov equations with an external magnetic field. First we show how the seminal contribution by Loeper (Uniqueness of the solution to the Vlasov–Poisson system with bounded density, J. Math. Pures Appl. 86 (2006), 68–79) can be extended to the magnetized framework. In particular, we observe that if the external magnetic is non-uniform, than this creates anisotropy in the stability of the system because one has to impose more decay in velocity on only one of the solutions. Second, we extend the recent improved Dobrushin estimate by Iacobelli (M. Iacobelli. A new perspective on Wasserstein distances for kinetic problems, Arch. Ration. Mech. Anal. 244 (2022), pp. 27–50.) to the Vlasov equation with a uniform external magnetic field, generalizing the idea that one has to renormalize by the linear dynamics to obtain a precise estimate in the small interaction and small time regime.

Thomas Rey

Université Côte d'Azur, France

Projective integration methods for multiscale kinetic equations

Projective integration has recently been proposed as a viable alternative to fully implicit and micro-macro methods to provide lightweight, non-intrusive and "almost AP" integrators for numerically solving multi-scale kinetic equations. These methods use a sequence of small time steps of the Explicit Euler scheme, interspersed with large extrapolation time steps. The telescopic approach iterates these extrapolations by recurrence for models with a large number of different time scales. These approaches allow the computational complexity of the method to be essentially independent of the stiffness of the problem, making it possible to efficiently solve the equations considered in rarefied or fluid regimes.

We will present the basics of the method, some basic kinetic theory, and a series of numerical a series of numerical simulations to validate these schemes on different models from physics and biology.

This is a joint work with Rafael Bailo and Giovanni Samaey.

Yijia Tang

Karlsruhe Institute of Technology, Germany

Random batch particle method for the homogeneous Landau equation

We consider random batch particle methods for efficiently solving the homogeneous Landau equation in plasma physics. The methods are stochastic variations of the particle methods proposed by Carrillo et al. [J. Comput. Phys.: X 7: 100066, 2020] using the random batch strategy. The collisions only take place inside the small but randomly selected batches so that the computational cost is reduced to $O(N)$ per time step. Meanwhile, our methods can preserve the conservation of mass, momentum, energy and the decay of entropy. Several numerical examples are performed to validate our methods.

Maxence Thévenet

Deutsches Elektronen-Synchrotron (DESY), Germany

Particle-in-cell simulations for plasma acceleration: combining advanced numerical methods and GPU computing.

Plasma accelerators are a promising alternative to build particle accelerators orders of magnitude more compact than conventional technologies, and could be a considerable driver for basic physics, material science, and biology. Numerical simulations with the particle-in-cell method have been decisive to the understanding and progress of plasma accelerators, but the prohibitive cost of full-physics 3D simulations led to a number of improvements of the standard particle-in-cell method to address the particularities of this problem. In this presentation, we will review some of the milestones that permit affordable and accurate simulations, combining advanced numerical schemes with modern high-performance computing on Graphics Processing Units (GPUs), and discuss their generality for other problems.