Workshop on

"Vlasov-Poisson in cosmology and plasma physics: monokinetic and multi-beam/stream solutions"

WPI, Vienna, 18. – 22. December 2017

Monday, 18th December

14:00 **Cornelius Rampf (U. Heidelberg):**
"Shell-crossing in quasi-one-dimensional flow"

14:45 Coffee break

15:30 **Stephane Colombi (I.Astrophysique Paris):**
"Phase-space structure of dark matter proto-halos:
pre- and -post-collapse regimes"

16:15 Coffee break

Tuesday, 19th December

09:30 **Toan Nguyen (U. Pennsylvania):**
"Long-time estimates for Vlasov-Maxwell in the non-relativistic limit"

10:15 Coffee break

14:30 **Maxime Lesur (U. Lorraine):**
"Plasma turbulence and transport dominated by nonlinear kinetic effects"

15:15 Coffee break

Wednesday, 20th December

09:30 **Yann Brenier (CNRS X Palaiseau):**
"On the MAK reconstruction method for the early universe"

10:15 Coffee break

14:30 **Özgür Gürcan (U. PMC Paris):**
"Dynamics of a shell model of bounced averaged gyrokinetic Vlasov Equation"

15:15 Coffee break

Thursday, 21th December

09:30 **Patrick Diamond (UC San Diego):**
"Quasi-Geostrophic Fluids and Vlasov Plasmas: Parallels and Intersections"

10:15 Coffee break

15:00 **Cora Uhlemann (U. Cambridge):**
"Finding closure - what Schrödinger-Poisson can teach us about cumulant hierarchies"

15:45 Coffee break

Friday, 22 th December

10:00 **Pierre Germain (NYU Courant):**
"Recent mathematical progress on weak turbulence"

10:45 Coffee break

Abstracts

Cornelius Rampf (U. Heidelberg)

Title: Shell-crossing in quasi-one-dimensional flow

Abstract: Blow-up of solutions for the cosmological fluid equations, often dubbed shell-crossing or orbit crossing, denotes the breakdown of the single-stream regime of the cold-dark-matter fluid. At this instant, the velocity becomes multi-valued and the density singular. Shell-crossing is well understood in one dimension (1D), but not in higher dimensions. This talk is about quasi-one-dimensional (Q1D) flow that depends on all three coordinates but differs only slightly from a strictly 1D flow, thereby allowing a perturbative treatment of shell-crossing using the Euler-Poisson equations written in Lagrangian coordinates. The signature of shell-crossing is then just the vanishing of the Jacobian of the Lagrangian map, a regular perturbation problem. In essence the problem of the first shell-crossing, which is highly singular in Eulerian coordinates, has been desingularized by switching to Lagrangian coordinates, and can then be handled by perturbation theory. All-order recursion relations are obtained for the time-Taylor coefficients of the displacement field, and it is shown that the Taylor series has an infinite radius of convergence. This allows the determination of the time and location of the first shell-crossing, which is generically shown to be taking place earlier than for the unperturbed 1D flow. The time variable used for these statements is not the cosmic time t but the linear growth time $\tau sim t^{2/3}$. For simplicity, calculations are restricted to an Einstein-de Sitter universe in the Newtonian approximation, and tailored initial data are used. However it is straightforward to relax these limitations, if needed.

Stephane Colombi (I.Astrophysique Paris)

Title: Phase-space structure of dark matter proto-halos: pre- and -post-collapse regimes

Abstract: During this talk I'll discuss the formation of primordial dark matter halos from smooth initial conditions. To simplify furthermore the context, we shall consider structures seeded by 3 sine waves of various amplitudes. Phase-space evolution of these objects will be studied from the computational point of view, by using a state of the art Vlasov solver, and the theoretical point of view, by comparing the numerical results to predictions of Lagrangian perturbation theory. While these latter are in principle only calculable prior to collapse, extension to multi-streaming regime will be discussed, with actual implementation in the 1D cosmological case of "post-collapse" Lagrangian perturbation theory.

Toan Nguyen (U. Pennsylvania)

Title: Long-time estimates for Vlasov-Maxwell in the non-relativistic limit

Abstract: I will present a joint work with D. Han-Kwan and F. Rousset on establishing long time estimates for Vlasov-Maxwell systems near stable homogeneous equilibria, which are valid for times of an arbitrarily large polynomial order of the speed of light in the non-relativistic limit.

Maxime Lesur (U. Lorraine)

Title: Plasma turbulence and transport dominated by nonlinear kinetic effects

Abstract: In hot plasmas, collisions are so rare that microscopic vortex-like structures develop in the phase-space of the particle distribution: coupling both real space and velocity (or energy) space. In this work, we focus on magnetic confinement fusion plasmas (in toroidal geometry). We base our approach on a reduced kinetic model [1, 2], akin to the Vlasov-Poisson model. Our numerical simulations indicate the nonlinear self-organisation, within the turbulence, of fine-scale velocity-space (or energy-space) structures, which can drive most of the macroscopic radial transport in some regimes.

Yann Brenier (CNRS X Palaiseau):

Title: On the MAK reconstruction method for the early universe

Abstract: I will report on some very recent progress made on the MAK method for the numerical reconstruction of the early universe (in particular by Bruno Lévy and Jean-David Benamou), based either on the geometric algorithm of Mérigot for the Monge-Ampère equation or on the entropic regularization method (going back to Schrödinger in the 30s) for the optimal mass transport problem with quadratic cost.

Özgür Gürcan (U. PMC Paris)

Title: Dynamics of a shell model of bounced averaged gyrokinetic Vlasov Equation

Abstract: Development of a shell model for a bounced averaged gyrokinetic Vlasov equation is presented. First, the linear dynamics is compared with a linear solver based on solving the linear dispersion relation numerically. Then the nonlinear dynamics is studied by analyzing the wave-number spectrum of quadratic conserved quantities. The resulting spectra seems to show a cascade spectrum at high k and predator-prey like oscillations in low k. Future perspectives including a logarithmically discretized three dimensional version of the model, which is 2D in space and 1D in energy, is discussed.

Patrick Diamond (UC San Diego)

Title: Quasi-Geostrophic Fluids and Vlasov Plasmas: Parallels and Intersections

Abstract: This talk explores connections and contrasts between the nonlinear dynamics of two prototypical systems in plasmas and fluids. The first is the quasi-geostrophic fluid, which evolves by conservative advection of potential vorticity. The QG system is the minimal model for large-scale atmospheric waves and the jet stream (zonal flow). The second is the Vlasov–Poisson system, in which the Vlasov equation describes the conservative advection of a phase space density. Many interesting connections between these two systems already have been noted. This talk will expand the list and suggest directions for future cross-fertilization .

Cora Uhlemann (U. Cambridge)

Title: Finding closure - what Schrödinger-Poisson can teach us about cumulant hierarchies

Abstract: Since dark matter almost exclusively interacts gravitationally, the dynamics of its phase space distribution is described by Vlasov-Poisson. One key property of Vlasov-Poisson is that it corresponds to an infinite tower of coupled equations for its cumulants. Hence, determining the time-evolution of dark matter density and velocity demands solving the full cumulant hierarchy. While the perfect pressureless fluid model is the only consistent truncation, it cannot describe the dynamics in the multi-streaming regime. Given this inadequacy of truncations for the cumulant hierarchy, I suggest to take a closer look at closure schemes that rely on recurrence. To this end, I will introduce Schrödinger-Poisson as theoretically motivated and phenomenologically viable approximation to Vlasov-Poisson. I will show how Schrödinger-Poisson generates cumulants at all orders consistently and hence can serve as inspirational example for finding closure schemes.

Pierre Germain (NYU Courant)

Title: Recent mathematical progress on weak turbulence

Abtract: I will present two recent rigorous results on weak turbulence: the first one is on the local well-posedness of the kinetic wave equation (with A. Ionescu and M.-B. Tran). And the second one on the derivation of the kinetic wave equation from the nonlinear Schrodinger equation (work in progress, with T. Buckmaster, Z. Hani, and J. Shatah).