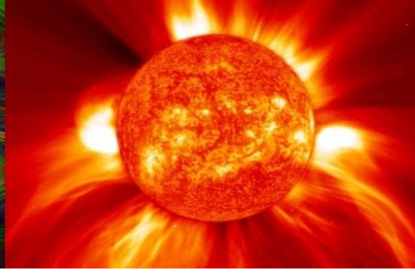
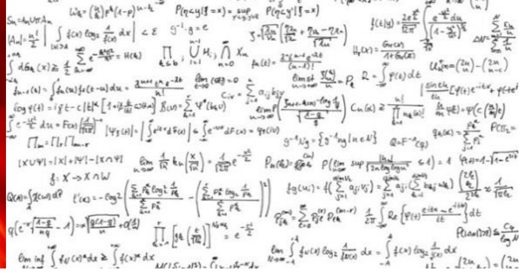




VLASOVIA 2019

Sixth International Workshop on the Theory and Applications of the Vlasov Equation

Strasbourg, July 22-25, 2019

École européenne de chimie, polymères et matériaux de Strasbourg (ECPM)

Amphithéatre Forestier




GENERAL INFORMATION

Objectives

The Vlasov equation is used for the modelling of a wide range of phenomena occurring in natural and man-made plasmas, as well as in other many-particle systems that display a collective behaviour. This workshop aims to provide an up-to-date programme for all scientists working in the field of Vlasov theory and related applications. Cross-disciplinary contributions are especially encouraged.

Topics

Basic colllisionless plasma physics
Space and astrophysical plasmas
Magnetic and inertial confinement fusion plasmas
Computational and mathematical approaches
Gravitational systems
Plasmonics and solid-state plasmas

Website: https://vlasovia2019.sciencesconf.org/

Contact e-mail: vlasovia2019@ipcms.unistra.fr

Scientific committee

F. Califano (Università di Pisa), G. Manfredi (CNRS, Strasbourg), F. Valentini (Università della Calabria).

Local organizing committee

G. Manfredi (IPCMS, Strasbourg), J. Pétri (Observatoire de Strasbourg), B. Famaey (Observatoire de Strasbourg), E. Gravier (IJL, Nancy).

Venue

Ecole européenne de chimie, polymères et matériaux de Strasbourg (ECPM), Strasbourg, France.

Special issue publication

Original papers based on the oral/poster presentations will be considered for publication as refereed articles in a special issue of *Journal of Plasma Physics* (Cambridge University Press).

INVITED SPEAKERS

Silvio S. Cerri (Princeton University)

Francesco Pucci (Katholieke Universiteit Leuven)

Matthew Kunz (Princeton University)

Alessandro Biancalani (Max-Planck-Institute, Garching)

Oreste Pezzi (Gran Sasso Science Institute)

Nicolas Besse (Université de Nice)

Fabrice Deluzet (Université de Toulouse)

Alberto Bottino (Max-Planck-Institute, Garching)

Daniel Told (Max-Planck-Institute, Garching)

Jörg Büchner (Max-Planck-Institute, Göttingen)

Urs Ganse (University of Helsinki)

Paul Cassak (West Virginia University)

Giacomo Monari (Leibniz-Institut für Astrophysik, Potsdam)

Laurent Garrigues (Université de Toulouse)

Dan Dubin (University of California, San Diego)

Jason TenBarge (Princeton University)

Jean-Baptiste Fouvry (Institute for Advanced Studies, Princeton)

Denise Perrone (Imperial College London)

Jérémy Dargent (Università di Pisa)

CONFERENCE VENUE

École européenne de chimie, polymères et matériaux de Strasbourg (ECPM)
25 Rue Becquerel
67087 Strasbourg

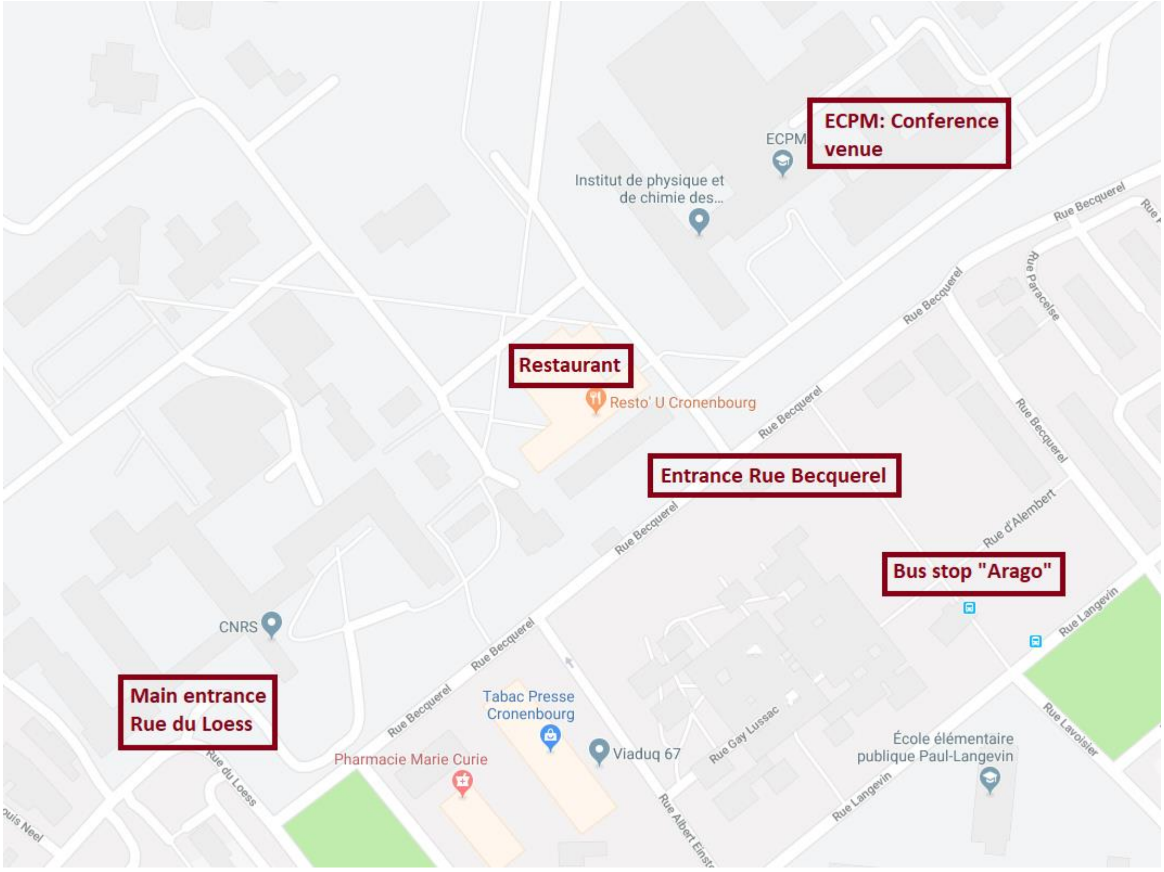
The conference will take place in the **Amphithéatre Forestier**, located on the second floor.

The EPCM is located within the CNRS Campus de Cronenbourg, on the northern outskirts of Strasbourg. The Campus entrance closest to the EPCM is situated in Rue Becquerel.

ACCESS BY PUBLIC TRANSPORT

From the central railway station, take the bus line "G" (outside the main entrance, slightly on the left) direction Espace Européen de l'Entreprise, and get off at the stop "Arago". The campus entrance rue Becquerel is situated just in front. The ride from the station to the Campus takes less than 10 min.
See annotated map below.

Important info: The entrance of Rue Becquerel is only open between 7:30-9:30 and 17:00-19:00. Outside these times, you can access the campus from the main entrance located in the Rue du Loess (follow the rue Becquerel with the campus on your right-hand side, then turn right after the Place de Haldenbourg).



CONFERENCE DINNER

The conference dinner will take place on **Wednesday, July 24th, at 8pm**, at the restaurant "**Maison Kammerzell**", situated on the **Place de la Cathédrale**.

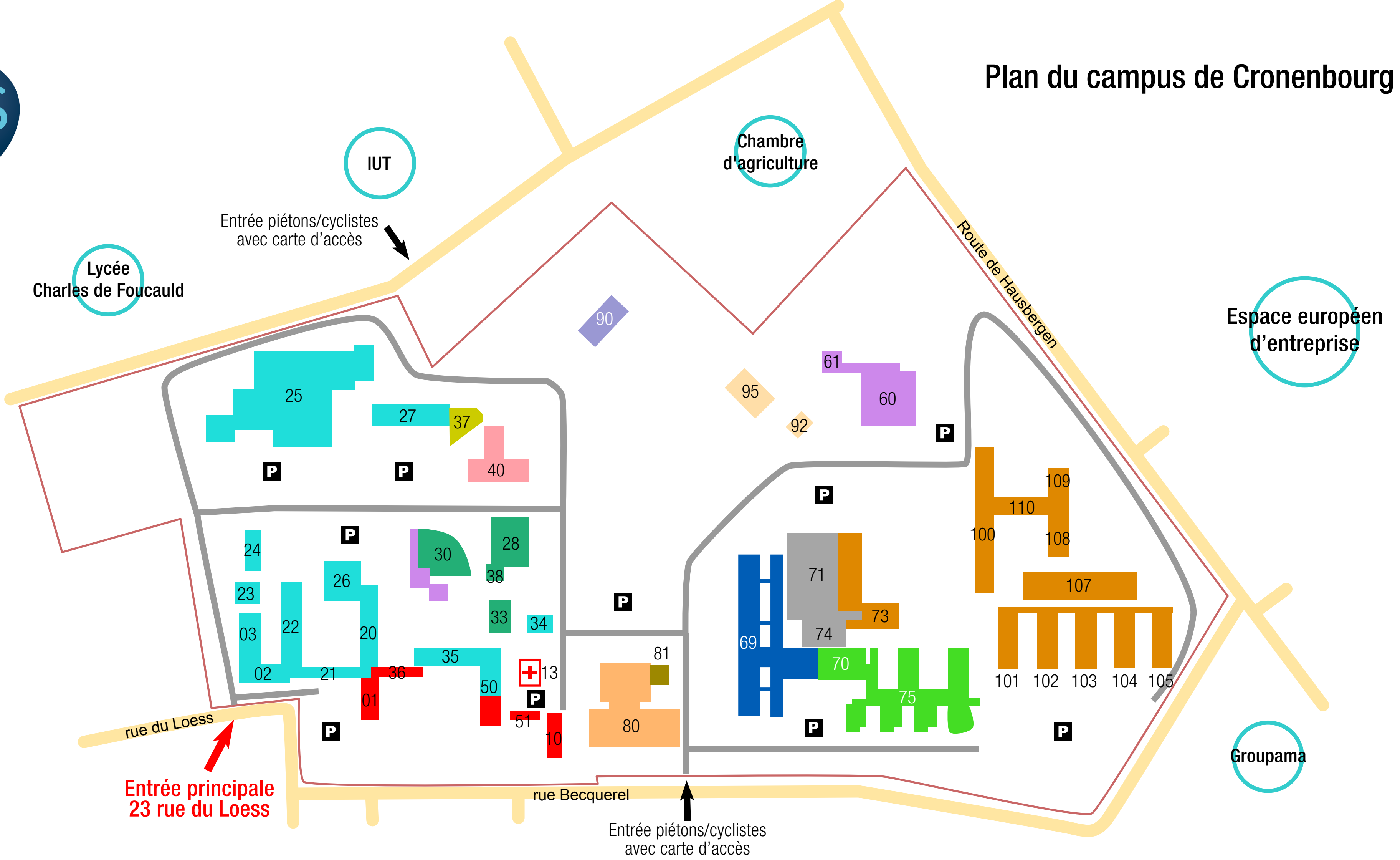
The building hosting the "Maison Kammerzell, dating from the 15th cntury, is one of the most famous building of Strasbourg and one of the most ornate and well preserved medieval civil housing buildings in late Gothic architecture in the areas formerly belonging to the Holy Roman Empire.

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY	
9:00-9:30	**Registration and opening**		**INV: Dubin**		**INV: Kunz**		**INV: Büchner**	
9:30-10:00			**Morel**	**Allanson**	**Petri**	**Juno**	**Després**	**Tronko**
10:00-10:30	**INV: Cassak**		**INV: Pezzi**		**INV: TenBarge**		**INV: Garrigues**	
10:30-11:00	Coffee break		Coffee break		Coffee break		Coffee break	
11:00-11:30	**INV: Cerri**		**INV: Bottino**		**INV: Fouvry**		**INV: Perrone**	
11:30-12:00	**Friedland**	**Trivedi**	**Furman**	**Woods**	**Wurtele**	**Minenna**	**Bienaymé**	**Del Sarto**
12:00-12:30	**INV: Monari**		**INV: Biancalani**		**Malara**	**Gravier**	**INV: Dargent**	
12:30-14:30	**Lunch**		**Lunch**		**Lunch**		**Lunch**	
14:30-15:00	**INV: Told**		**INV: Pucci**		**INV: Besse**		**Closing**	
15:00-15:30	**Schneider**	**Neukirch**	**Kessler**	**Settino**	**Mandal**	**Lacroix**		
15:30-16:00	Coffee break		Coffee break		Coffee break			
16:00-16:30	**INV: Deluzet**		**POSTER SESSION**		**INV: Ganse**			
16:30-17:00	**DiTroia**	**Deoliveira**			**Hamilton**			
20:00					**Conference dinner**			

INV: 30 min including questions

ORALS: 15 min including questions

Plan du campus de Cronenbourg



- CNRS Délégation Alsace
- IPHC (Institut pluridisciplinaire Hubert Curien)
  - Département recherches subatomiques (DRS)
  - Département sciences analytiques (DSA)
- IPHC : département Ecologie, physiologie et éthologie (DEPE)
- Institut de physique et de chimie des matériaux de Strasbourg (IPCMS)
- Institut Charles Sadron (ICS)
- Ecole européenne chimie, polymères et matériaux (ECPM), Institut de chimie et procédés pour l'énergie, l'environnement et la santé (ICPEES)
- Laboratoire des sciences de l'ingénieur, de l'informatique et de l'imagerie (ICube)
- Centre d'investigations neurocognitives et neurophysiologiques (CI2N)
- Restaurant CROUS
- Salles de formation, de réunion
- Institut franco-allemand de recherche sur l'environnement
- Comité d'action et d'entraide sociale (CAES)
- Centre de loisirs éducatifs (CLE)
- Bibliothèque
- Service médical

CNRS Alsace - 23 rue du Loess BP20 - 67037 Strasbourg cedex 2 - Tél : 03 88 10 63 01

INVITED TALKS

Regularity and entropy dissipation in a Vlasovian plasma

Nicolas Besse*[1], Claude Bardos[2], and Toan T Nguyen[3]

[1]Observatoire de la Côte dÁzur – Observatoire de la Cote d'Azur – France
[2]PolytechṔaris-UPMC – Sorbonne Universite – France
[3]Penn State University – United States

Abstract

In this talk we uncover the link between the regularity and entropy dissipation of solutions of a Vlasovian plasma. More precisely we present an Onsager type conjecture on conservation of energy and entropies of weak solutions to the relativistic Vlasov–Maxwell equations. As concerns the regularity of weak solutions, say in Sobolev spaces, we determine Onsager type exponents that guarantee the conservation of all entropies and the validity of the renormalization property. In particular, we obtain Onsager type exponents that are smaller than the famous Onsager exponent 1/3 established for anomalous dissipative solutions of the incompressible Euler equations.

*Speaker

Interaction of geodesic acoustic modes and energetic particles in tokamaks

Alessandro Biancalani*[1], Alberto Bottino[1], Daniele Del Sarto[2], Alessandro Di Siena[1], Ozgur Gurcan[3], Maxime Lesur[2], Pierre Morel[3], and Ivan Novikau[1]

[1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching – Germany

[2]Institut Jean Lamour, 54506 Vandoeuvre-le-Nancy – Université de Lorraine, Centre National de la Recherche Scientifique : UMR7198 – France

[3]Laboratoire de Physique des Plasmas, 91128 Palaiseau – Centre National de la Recherche Scientifique - CNRS – France

Abstract

Tokamak plasmas are low-collisional plasmas heated with the goal of reaching fusion temperatures. In a reactor, energetic particles (EP) are expected to be present due to external heating, and as a product of fusion reactions. Axisymmetric low-frequency modes like geodesic acoustic modes (GAMs) [1], with the characteristic sound frequency, are important to study because they interact with turbulence modifying the radial transport. For this study, a kinetic theory is necessary, due to the strong effect of resonances with thermal ions and electrons, but also with the EP, exciting the so-called EGAMs [2].

In this work, the nonlinear dynamics of EGAMs is investigated with the gyrokinetic particle-in- cell code ORB5 [3, 4] and the results are compared with analytical theory. In particular, the EGAM saturation due to wave-particle and wave-wave nonlinearity is studied. The saturation level and the EP redistribution in phase space are described. Moreover, the nonlinear modification of the frequency and radial structure is discussed. As a particular example, the comparison with the beam-plasma instability, namely a Langmuir wave driven unstable by an electron beam in a 1D system, is also discussed [5, 6]. Comparisons with results obtained with the gyrokinetic Eulerian code GENE [7] are also shown.

(1) N. Winsor et al., Phys. Fluids 11, 2448, (1968)

(2) G. Fu, et al., Phys. Rev. Lett. 101 185002 (2008)
(3) S. Jolliet, et al. Comput. Phys 177, 409 (2007)
(4) A. Bottino, et al. Plasma Phys. Control. Fusion 53, 124027 (2011)
(5) A. Biancalani, et al., J. Plasma Phys. 83, 725830602 (2017)
(6) A. Biancalani, et al., J. Plasma Phys. 84, 725840602 (2018)
(7) T. Goerler, et al., J. Comput. Phys. 230, 7053 (2011)

*Speaker

Electromagnetic gyrokinetic Particle-In-Cell simulations of Alfvén modes and turbulence in tokamak geometry

Alberto Bottino*[1], Alessandro Biancalani , Stephan Brunner , Roman Hatzky , Thomas Hayward-Schneider , Emmanuel Lanti , Zhixin Lu , Ben Mcmillan , Alexey Mishchenko , Ivan Novikau , Noe Ohana , Natalia Tronko , Francesco Vannini , and Laurent Villard

[1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching – Germany

Abstract

The particle-in-cell (PIC) algorithm is one of the most popular methods for the simulation of the general 6-D Vlasov-Maxwell problem and it is widely used also for the simulation of the 5D gyrokinetic equations. The global gyrokinetic PIC code ORB5 [S. Jolliet et al., Comp. Phys. Comm., 177, 409 (2007)] can simultaneously include electromagnetic perturbations, shaped MHD axisymmetric equilibria, zonal-flow preserving sources, collisions, and the ability to solve the full tokamak core plasma including the magnetic axis. Multiple ion species are described by gyrokinetic equations, derived from a gyrokinetic Lagrangian, while a drift-kinetic model is generally used for the electrons. Recently, the algorithm of the electromagnetic solver has been rewritten, based on the so-called mixed-variable formulation of the gyrokinetic theory [A. Mishchenko et al., Computer Physics Communications 239 (2019)]. The resulting code allows for significantly larger time steps even for experimentally relevant conditions. It has been applied to various Alfvénic physics problems and verified against other existing codes. In this work, we will give an overview of the gyrokinetic model [N. Tronko et al., Physics of Plasmas 23, 082505 (2016)] and the new algorithms used in the code. Moreover, numerical simulations of MHD modes (e.g. Toroidal Alfvén Eigenmodes, internal kink modes...) and electromagnetic micro-turbulence will be presented and discussed.

*Speaker

Current sheets and reconnection in strong guide-field, small beta vs. turbulent finite-beta plasmas

Joerg Buechner*[1,2], Neeraj Jain[1], and Patricio Munoz[1]

[1]Center for Astronomy and Astrophysics, Berlin Institute of Technology, Hardenbergstr. 36 10623 Berlin – Germany

[2]Max Planck Institute for Solar System Research – Germany

Abstract

We report on observations and numerical simulation of the stability of current sheets (CS) and of reconnection (a) in strong guide-field-, small beta and (b) in turbulent finite-beta plasmas. Typical applications are solar / stellar atmospheres (coronae) and the Earth's magnetosheath as well as the interstellar medium (ISM), respectively. We discuss the typical CS instabilities in cases (a) and (b) from simple electron-shear flow driven ones to compressional and Alfvenic-type turbulence in collisionless force-free current sheets. For simulations we will discuss PIC-, hybrid- and gyrokinetic results.

*Speaker

Kinetic Entropy as a Diagnostic in Particle-in-Cell Simulations of the Vlasov Equation

Haoming Liang[1], Paul Cassak*[1], Sergio Servidio[2], Michael Shay[3], James Drake[4], Marc Swisdak[4], Matt Argall[5], John Dorelli[6], Earl Scime[1], William Matthaeus[3], Vadim Roytershteyn[7], and Gian Luca Delzanno[8]

[1]West Virginia University – United States
[2]Università della Calabria – Italy
[3]University of Delaware – United States
[4]University of Maryland, College Park – United States
[5]University of New Hampshire – United States
[6]NASA Goddard Space Flight Center – United States
[7]Space Science Institute – United States
[8]Los Alamos National Laboratory – United States

Abstract

Dissipation in nearly collisionless plasmas is a key feature of numerous heliospheric, astrophysical, and planetary phenomena, including magnetic reconnection, turbulence, shocks, and their many applications. Entropy is the natural metric of irreversible dissipation since it is conserved in ideal closed systems and increases when there is dissipation. Entropy has been used in fluid and gyrokinetic models, but has been vastly underutilized in fully kinetic systems. Here, we develop the kinetic entropy diagnostic in particle-in-cell (PIC) simulations of the Vlasov equation. We calculate the "continuous" kinetic entropy related to f ln f, where f is the particle velocity distribution function and the "combinatoric" kinetic entropy related to the number of microstates for a given macrostate, and discuss the advantages of each. Using collisionless PIC simulations that are two-dimensional in position space and three-dimensional in velocity space, we verify the implementation of the diagnostics and discuss how to optimize parameters to ensure accuracy. We show total kinetic entropy is conserved to _~3% in an optimized simulation of anti-parallel magnetic reconnection, and use the departure from perfect conservation to quantify the effective numerical dissipation of the PIC simulation. Kinetic entropy can be decomposed into a sum of a position space entropy and a velocity space entropy, and we use this to investigate the nature of kinetic entropy transport during collisionless reconnection. We find velocity space entropy increases in time due to heating, while position space entropy decreases due to compression. This project uses collisionless simulations, so it cannot address physical dissipation mechanisms; nonetheless, the infrastructure should be useful for collisional systems. Finally, we use kinetic entropy to identify regions with non-Maxwellian distributions and compare it to other measures including J dot E', agyrotropy, and Pi-D, and compare the kinetic entropy to data from Magnetospheric Multiscale (MMS).

*Speaker

Reconnection and ion heating in low-β plasma turbulence

Silvio Sergio Cerri*[1]

[1]Department of Astrophysical Sciences [Princeton] – United States

Abstract

Turbulence and kinetic processes in collisionless, magnetized plasmas have been extensively investigated over the past decades via theoretical models, in-situ spacecraft measurements in the heliosphere, and numerical simulations. Alongside the debate about the nature of ion- and electron-scale fluctuations in solar-wind turbulence, one of the fundamental open questions concerns how turbulent energy is partitioned between ions and electrons due to that vague process usually called "turbulent heating". In space and astrophysical plasmas, this heating process may involve a wide variety of collisionless plasma mechanisms, depending on the regime that is being considered.

In this talk, we present preliminary results from 3D hybrid particle-in-cell (PIC) simulations of continuously driven, critically balanced plasma turbulence at low β. The interplay between magnetic reconnection and different ion-heating mechanisms – and how to possibly diagnose and/or disentangle them – will be discussed. Contextually, predictions on the possible ion-to-electron heating in turbulent low-β plasmas will be provided.

*Speaker

Competition between Kelvin-Helmholtz and Lower-Hybrid Drift instabilities along a Mercury-like magnetopause: fully Particle-In-Cell simulations

Jérémy Dargent*[1]

[1]Dipartimento di Fisica ”E. Fermi” – Italy

Abstract

Boundary layers in space plasmas are always the locations of many phenomena allowing the mixing of plasma. But for a given boundary, different mechanisms can coexist and compete one with each others. In our work, we look with fully Particle-In-Cell simulations at velocity shear boundary layers with a gradient of density and/or magnetic field. We observe that in presence of a density gradient, a lower hybrid drift instability (LHDI) develops along the layer much quicker than the Kelvin-Helmholtz instability (KHI). Although the two instabilities develops at different scales (both spatial and temporal), we observe that during the nonlinear phase, the LHDI is cascading from small scales to higher scales and can compete (and even suppress) the KHI, depending on the density gradient in the layer. Such a result can make us reconsider the main mixing mechanisms in plasma layers with strong density gradient, such as the magnetopause of Mercury.

*Speaker

Asymptotic Preserving Methods for plasma physics.

Fabrice Deluzet*[1]

[1]Institut de Mathématiques de Toulouse – Université Paul Sabatier-Toulouse III - UPS – France

Abstract

The multiscale nature of plasma physics is the source of severe difficulties for the derivation of efficient numerical methods. One specific issue is related to the large variations of parameters that may introduce stiffness into the model and eventually the degeracy of the equations. Some example can be named, with the quasi-neutral limit of plasma models or the fluid limit of collisional kinetic equations.
To cope with these difficulties, Asymptotic-Preserving methods have been developped in the last decades. The purpose of these methods is to derive numerical methods bridging different plasma modelling: quasi-neutral and non quasi-neutral plasma modelling, fluid and kinetic plasma description, ...
This talk will be devoted to an overview on the concept of Asymptotic-Preserving methods in the context of plasma physics.

*Speaker

Parametric Instability Driven by Weakly Trapped Particles in Nonlinear Plasma Waves

Dan Dubin*[1]

[1]Department of Physics, University of California San Diego – United States

Abstract

This talk discusses a new parametric instability mechanism caused by particles that are "weakly trapped" in the potential wells of a nonlinear wave[1]. The mechanism applies to low-collisionality "Vlasov" plasmas supporting waves with near-acoustic dispersion relations such as ion sound waves, magnetized Langmuir waves, or Alfven waves. The theory is compared to particle in cell [PIC] simulations of Trivelpiece-Gould [TG] waves, as well as to experiments[2] on pure ion plasmas that observe parametric instability in TG standing waves. For TG waves, the standard parametric instability mechanism induced by wave-wave coupling is suppressed. The new mechanism predicts instability only if weakly trapped particles are present, at rates found to be in agreement with the simulations, and consistent with the experiments.

In the parametric instability studied here, a nonlinear "pump" wave is unstable to the growth of daughter waves with twice the wavelength and nearly the same phase velocity as the pump. This induces adjacent potential peaks in the wave to slowly approach one-another, receding from other pairs of peaks. Particles that are weakly trapped between approaching peaks, with kinetic energies just below the potential maxima, are heated by compression and escape the well, and then become retrapped on the other side of the approaching peaks, where they amplify the compression by pushing the peaks together. Distributions with weakly trapped particle populations (appearing as phase space "holes" or "rings" in the trapped particle distribution) often occur in nonlinear plasma waves and BGK states, and such distributions can be unstable to this new trapped particle mechanism.

(1) D. Dubin, Phys. Rev. Lett. **121,** 015001 (2018)

(2) F. Anderegg, M. Affolter, A. Ashourvan, D. Dubin, F. Valentini and C. F. Driscoll, Phys. Rev. Lett. **121,** 235004 (2018).

Supported by DOE grant DE-SC0018236 , NSF grant PHY-1805764, and AFSOR grant FA9550-19-1-0099

*Speaker

Resonant Relaxation of Stars around a Supermassive Black Hole

Jean-Baptiste Fouvry*[1]

[1]Institute for Advanced Study [Princeton] – United States

Abstract

In the vicinity of a supermassive black hole, stars move on nearly Keplerian orbits.
Yet, because of the enclosed stellar mass and general relativity, the potential slightly deviates from the Keplerian one, which causes the stellar orbits to precess.
Similarly, as a result of the finite number of stars, the mutual gravitational torques between pairs of stars also drive a rapid reorientation of the stars' orbital orientation, much faster than the standard two-body relaxation driven by local scatterings.
Overall, the combination of these two effects leads to a stochastic evolution of stellar orbital angular momentum vectors, through a process named "resonant relaxation".
Owing to recent developments in the diffusion theory of long-range interacting systems, I will show how one can fully describe such dynamics, in particular scalar resonant relaxation (relaxation of the norm of the angular momentum) and vector resonant relaxation (relaxation of the direction of the angular momentum vector).
I will also try to highlight some first applications of these formalisms as well as connections with other fields of physics.

*Speaker

Vlasiator: Simulating Earth's Magnetosphere in Hybrid-Vlasov

Urs Ganse*[1], Minna Palmroth[1,2], Yann Pfau-Kempf[1], Thiago Brito[1], Lucile Turc[1], Maxime Grandin[1], Sebastian Von Alfthan[3], Markus Battarbee[1], and Tuomas Koskela[1,4]

[1]Department of Physics, University of Helsinki – Finland
[2]Finnish Meteorological Institute – Finland
[3]CSC - Centre for Scientific Computing Ltd – Finland
[4]University of Turku, Department of Physics and Astronomy – Finland

Abstract

Dynamic plasma phenomena in Earth's magnetosphere span a large number of scales, and have for the longest time been inaccessible to global-scale kinetic modelling. While hybrid particle-in-cell simulation are nowadays able to capture some of the structures and effects happening around Earth, the fundamental shot-noise limitation of the PIC approach makes the study of nonlinear phenomena difficult.
Enter Vlasiator, the first attempt to model the entire magnetosphere selfconsistently using a direct eulerian Vlasov simulation approach. Using a hybrid formulation of collisionless plasma physics, a number of aggressive systematic and numerical optimizations and a large amount of supercomputer resources, it has been successfuly employed to model global kinetic phenomena, and eludicate some plasma phenomena hitherto unexplained.
This presentation will give an overview of the architecture of Vlasiator, recent simulation and science results.

*Speaker

Electron Drift Instability in a Hall Thruster: Inside Particle-In-Cell Simulations

Laurent Garrigues*[1]

[1]Laplace – Université Paul Sabatier [UPS] - Toulouse III, Centre National de la Recherche Scientifique - CNRS, ENSEEIHT – France

Abstract

A Hall Thruster is an ExB low temperature discharge where the cylindrical geometry of the system leads to magnetized electrons to drift in the azimuthal direction while unmagnetized ions are mainly flowing in the direction of the electric field (normal to B and ExB planes). The large difference between electron and ion velocities induces a kinetic instability in the azimuthal (ExB) direction representing a coupling between electron Bernstein modes and ion acoustic waves. The resulting electron drift instability (EDI) induces an axial transport of the electrons responsible for non-collisional transport.
To study the EDI, we have developed a two-dimensional Explicit Parallel-Particle-In-Cell (EP-PIC) model in a slab geometry considering axial and azimuthal directions. The simulation is not purely self-consistent, the profile of ionization source term being given. The integral of the ionization source term fixes the plasma current and density strengths. All collisions are also ignored. The magnetic field perpendicular to the simulation plane whose profile is imposed is not modified by the plasma. The electric forces acting on charged particles are calculated through the resolution of the Poisson's equation. In the axial direction, Dirichlet boundary conditions are applied with 0 V at the cathode and a fixed voltage at the anode. Particles are lost at the anode and cathode planes. To close the anode-cathode system, electrons are continuously injected at the cathode plane depending of the charge balance at the anode. In the azimuthal direction, periodic boundary conditions are applied. The studied system illustrates a Vlasov-Poisson model case in the context of a Hall thruster.

The properties of the EDI will be shown as a function of plasma density and compared with previously derived dispersion relations.
Acknowledgments: This work was granted access to the HPC resources of CALMIP supercomputing center under the allocation 2013-P1125.

*Speaker

Fluctuation dynamo in collisionless and weakly collisional plasmas

Matthew Kunz*[1]

[1]Princeton University – United States

Abstract

The Universe is magnetized. While magnetic-field strengths of just _˜10ˆ{-18} G are required to achieve this both in our Galaxy and in clusters of galaxies, observations of Faraday rotation, Zeeman splitting, and synchrotron emission all make the case of ubiquitous _˜μG fields. That these systems are not content with hosting weaker fields is surprising, at least until one realizes that the energy density of a _˜μG field is comparable to that of the observed turbulent motions. It is then natural to attribute the amplification and sustenance of (at least the random component of) the interstellar and intracluster magnetic fields to the fluctuation (or "turbulent") dynamo. I will present recent advances in the theory and numerical simulation of the turbulent dynamo in a weakly collisional plasma, the latter made possible through both hybrid-kinetic and Braginskii-MHD approaches. These demonstrate the various ways in which plasma microphysics makes magnetic-field amplification in such plasmas by macroscale turbulent motions possible, with field-biased pressure anisotropy and magnetic self-organization playing key roles. A scenario for explosive growth of magnetic fields in the intracluster medium of galaxy clusters will be proposed.

*Speaker

Using the Vlasov Equation to model the Milky Way

Giacomo Monari*[1]

[1]Leibniz-Institut für Astrophysik Potsdam (AIP) – Germany

Abstract

I summarise the use of the Vlasov Equation in the context of the dynamics of disc galaxies, and in particular in the case of our own Galaxy, the Milky Way. This is particular relevant, because we can now dispose of high quality information on the position and velocity of more than a billion of stars in the Milky Way, thanks to ESA's satellite Gaia. I will focus in particular on the inclusion in the models of the effect of the non-axisymmetric components of the Galaxy, i.e. the bar, the spiral arms, the satellite galaxies, etc., which can be done linearising the Vlasov equation far from the resonances, and using the perturbation theory in the vicinity of the resonances.

*Speaker

Velocity-space cascade in space plasmas: Vlasov simulations and observations

Denise Perrone*[1], Sergio Servidio[2], Oreste Pezzi[3], Francesco Valentini[2], Alexandros Chasapis[4], W. H. Matthaeus[5], Antonella Greco[2], Luca Sorriso-Valvo[6,7], and Pierluigi Veltri[2]

[1]Agenzia Spaziale Italiana – Italy
[2]Dipartimento di Fisica, Università della Calabria, 87036 Rende – Italy
[3]Gran Sasso Science Institute, L'Aquila – Italy
[4]Bartol Research Institute, Department of Physics and Astronomy, University of Delaware – United States
[5]Bartol Research Institute, Department of Physics and Astronomy, University of Delaware – Newark, DE, United States
[6]Nanotec/CNR, U.O.S. di Cosenza, 87036 Rende – Italy
[7]Departamento de Física, Escuela Politecnica Nacional, 170517 Quito – Ecuador

Abstract

A puzzling aspect of solar-wind dynamics consists in the empirical evidence that it is hotterthan expected for an adiabatic expanding gas. Understanding the mechanisms of energydissipation into heat from the Sun in such a collision-free system represents a key challengenot only in space plasma physics but also for thermodynamics in general.
Spacecraft measurements generally reveal that electromagnetic fluctuations are in a state offully-developed turbulence. Plasma turbulence is a challenging problem, involving a varietyof complex phenomena: the energy transferred towards smaller scales by turbulenceproduces localized regions (coherent structures) where dissipation increases, and particledistribution functions are strongly distorted. The absence of an equilibrium attractor leavesthe plasma state free to explore the dual spatial-velocity phase space.
Here, a novel theory of space plasma turbulence is described to investigate the possibility ofa velocity-space cascade, by means of a three-dimensional Hermite decomposition applied toboth numerical and 'in situ' measurements. In particular, high resolved hybrid Vlasov-Maxwell simulations in a simplified 2.5D-3V geometry have been used to investigate thedetails of the strong deformation of the ion distribution function. Moreover, thanks to therecent NASA Magnetospheric Multiscale mission (MMS), the ion distribution function hasbeen described in the low-collisionality space plasma with unprecedented temporal andvelocity-scale resolution. A broad-band, power-law Hermite spectrum for the velocity spacefluctuations of the ion velocity distribution is recovered in both numerical and 'in situ'experiments. A Kolmogorov approach leads directly to a range of predictions for this phase-spacecascade, with different predictions depending on the plasma regime. The phase-spacecascade might be of general relevance for the nonlinear dynamics of a weakly-collisionalplasma in a wide variety of conditions.

*Speaker

The role of proton-proton collisions in the turbulent solar wind by means of hybrid Boltzmann-Maxwell simulations

Oreste Pezzi*[1,2], Denise Perrone[3], Sergio Servidio[4], Francesco Valentini[4], Luca Sorriso-Valvo[5,6], and Pierluigi Veltri[4]

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Abstract

High temperature and low density plasmas are ubiquitous in the Universe. These systems often exhibit a turbulent dynamics, characterized by the cross-scale coupling of fluid and kinetic scales and by the inhomogeneous development of coherent spatial and temporal structures. At smaller scales the energy of fluctuations is dissipated and plasma is eventually heated. Despite collisions are usually ruled out from the description of these systems, it has been recently shown that plasma collisionality may be locally enhanced by the presence of fine structures in velocity space. Here, in order to explore the possible role of inter-particle collisions, for the first time, collisional and collisionless simulations of plasma turbulence have been compared using Eulerian Hybrid Boltzmann-Maxwell simulations, that explicitly model the proton-proton collisions through the nonlinear Dougherty operator. Although collisions do not significantly influence the statistical characteristics of the turbulence, they strongly suppress the production of non-thermal features in the proton distribution function. The latter consists in a suppression of the enstrophy/entropy cascade in the velocity space, damping the spectral transfer towards large Hermite modes. Moreover, we observe that dissipation is located within regions of strong current activity, confirming that the heating process in turbulent plasmas is spatially inhomogeneous.

*Speaker

Generation of Turbulence in Colliding Reconnection Jets

Francesco Pucci*[1], William H. Matthaeus , Alexandros Chasapis , Sergio Servidio , Luca Sorriso-Valvo , Vyacheslav Olshevskyi , David L. Newman , Martin V. Goldman , and Giovanni Lapenta

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Abstract

The collision of magnetic reconnection jets is studied by means of a three-dimensional numerical simulation at the kinetic scale, in the presence of a strong guide field. We show that turbulence develops due to the collision of jets, producing several current sheets in reconnection outflows, aligned with the guide field direction. The turbulence is mainly two-dimensional, with stronger gradients in the plane perpendicular to the guide field and low wave-like activity in the parallel direction. First, we provide a numerical method to isolate the central turbulent region. Second, we analyze the spatial second-order structure function and prove that turbulence is confined in this region. Finally, we compute local magnetic and electric frequency spectra, finding a trend in the subion range that differs from typical cases for which the Taylor hypothesis is valid, as well as wave activity in the range between ion and electron cyclotron frequencies. Our results are relevant to understand observed collisions of reconnection jets in space plasmas.

*Speaker

Diagnosing Energy Dissipation in Continuum Vlasov-Maxwell Plasmas

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[4]University of Iowa [Iowa City] – United States
[5]University of Arizona – United States

Abstract

We present a novel algorithm for the direct discretization of the Vlasov-Maxwell system using the Gkeyll simulation framework that employs high order discontinuous Galerkin finite elements on an up to 3D-3V phase space grid, including the implementation of a Dougherty collision operator. We leverage the pristine phase space representation made possible by direct discretization to examine energy dissipation in a variety of systems relevant to space and astrophysical plasmas. Specifically, we employ the field-particle correlation technique in phase space to directly diagnose the exchange of energy between fields and particles. We present results from a variety of simple systems, including magnetic pumping and resonant wave damping, and we also apply the field-particle correlation technique to 2D-3V Vlasov-Maxwell simulations of reconnection and turbulence.

*Speaker

High-realism gyrokinetic simulations of space plasma turbulence

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Abstract

The nature of the turbulent dissipation of energy at small phase-space scales is one of the most important unsolved problems of space plasma physics [1]. Understanding the physics governing these processes also impacts directly on our interpretation of astrophysical phenomena exhibiting plasma turbulence.
Here, we will give an overview of how gyrokinetic theory and simulations [2-4] can contribute to answering these questions. We present new simulations using the gyrokinetic turbulence code GENE [5] that analyze the effect of different mass ratios on the species distribution of turbulent dissipation. In addition, we study how more realistic driving scenarios (using, e.g., aligned or imbalanced energy injection) affect the turbulence properties and the resultant dissipation of free energy.

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*Speaker

CONTRIBUTED TALKS

Self-consistent whistler-mode wave-particle interactions in a cold plasma

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Abstract

Most diffusion models of the Earth's Outer Radiation Belt use a particular variety of quasilinear theory of wave-particle interactions. Whistler-mode waves are included in these models, and contribute to local acceleration and loss of electrons. However, the physical characteristics of whistler-mode waves are unlikely to always satisfy the assumptions used to derive the quasilinear theory that is used. Through the use of self-consistent particle-in-cell numerical experiments, we model the interaction between driven, incoherent, and broadband whistler-mode waves waves and an ambient background cold plasma. This particle-in-cell experiment is intended to complement test-particle experiments run by X. Tao et al 2011 (GRL), and we constrain our experiment in order to resemble theirs as far as possible. We do so in order to benchmark the procedure of obtaining diffusion characteristics using the particle-in-cell technique. We investigate the nature of the plasma response in energy and pitch angle space, for both resonant and non-resonant particles. For the timescales considered, we observe that the diffusive response is a function of both phase-space and time, with different regions of phase-space exhibiting behaviour that seems compatible with either 'normal diffusion', or 'anomalous diffusion.'

*Speaker

Collisionless Boltzmann equation approach for the study of stellar discs

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Abstract

The kinematics of stellar disc populations within the solar neighbourhood of our Galaxy show imprints of the Galactic bar. We carried out an analysis by applying a numerical resolution of the 2D2V collisionless Boltzmann equation and we can model the stellar motions within the plane of the Galaxy.

*Speaker

On the role of domain discretization in phase-mixing Hamiltonian systems

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Abstract

We consider the differences between the continuum and the discretized modelling of the free advection problem for a set of particles uniformely distributed in a connected region of the phase-space. Two points are in particular addressed: 1) We analyze the implications of coarse-graining for the notion of topological connection and for Poincare recurrence, which differently occur in an Eulerian and in a Lagrangian domain, where they are differently related to mechanisms of loss of information. 2) We characterize a generic Hamiltonian phase-mixing process in terms of two competing mechanisms which respectively determine a kinetic cooling or heating of a distribution of force-free particles moving in a bounded domain in the physical space. We then discuss some implications for the interpretation of numerical simulations of continuum Hamiltonian models via PIC and Eulerian schemes, by presenting some preliminary applications to electrostatic Vlasov plasmas.

*Speaker

Hybrid formulation of fully- and gyrokinetic Hamiltonian field theory for astrophysical plasmas

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[2]Astronomisches Institut der Ruhr-Universität Bochum – Germany

Abstract

Recent works[1-3] have shown that the electron dynamics plays an important role in the behavior of solar wind. In order to throughly understand the nature of turbulence in space plasma, the study of electron kinetic dynamics is of vital importance.

Higher-order Lie-transform perturbative methods applied to Hamiltonian formulation of guiding-center motion are widely used to describe the dynamics of particles in plasma physics [4-6]. Thereunder, the elegant and compact Lagrangian formulation allows for the derivation of the equations of motion from the Lagrangian two-form, or sympletic two-form[7], w_L =-dxˆidpˆi ∈ ˆ2T*M. Here, T*M represents a space T tangent to a manifold M.

In the present work, we develop a hybrid model where the dynamics of protons is described within a fully kinetic framework and the one of electrons using a gyrokinetic description. From the Lagrangian 2-form, one performs[8] a serie of gauge transformations in order to eliminate the theta dependence up to the chosen ordering. A lie transformation ensures theta independence in the Hamiltonian part of the Lagrangian. By making use of the variational principle in the total action, which also includes the electromagnetic fields, one can consistently derive the equations of motion for electrons and protons, and field equations under the same theoretical framework. With this work, we wish to develop a cost-effective computational framework to investigate in detail the kinetic effects present in space plasma turbulence [1][2].

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*Speaker

Scattering structures of linear Vlasov equations

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Abstract

It has recently been observed [2] that the the linear Vlasov-Poisson equation can be rewritten within the abstract scattering theory [6]: it provides an alternative to the Hamiltonian theory used for collisionless plasmas [5]. I will report an recent improvements of the approach with abstract scattering theory.
Indeed one can show that an original reformulation satisfies the trace class property. It yields the existence of the wave operators by means of the Kato- Birmann theory. One technical crux of proving the trace class property is the Diperna-Lions Theorem [3] of compactness by integration which provides the required small gain of regularity. A first application of this method is linear Landau damping around a non homogeneous in space Boltzmanian state [1], in the context of plasmas for an electron hole [4]. Another recent application is the full spectral decomposition of the linear Vlasov operator with constant magnetic field (joint work with A. Rege PHD and F. Charles at LJLL-SU, and with R. Weder UNAM-Mexico).

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*Speaker

Vlasov equation from Kaluza-Klein model and from the guiding center description of motion

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Abstract

In this work it is shown by a simple Lagrangian density over the phase-space, with an Hilbert-Einstein term and without the electromagnetic density lagrangian term, how it is possible to derive Gravitation and Electromagnetism by varying the metric tensor on the phase-space extended to the time, in the same way as it is derived Einstein's equation. The non-perturbative guiding center transformation, that will be briefly described, will be used for showing in a more evident way such consistent geometrical derivation of forces and fields (unified theory of forces). The gyro-phase will be associated both with the gauge function to implement the guiding-center transformation, and with the fifth dimension in the Kaluza-Klein model.
From the same Lagrangian density, the Lorentz force will be obtained by varying the coordinates of the phase-space and it will be shown, thanks to the gauge invariance of electromagnetism, that it is no longer possible to discern the particle motion from the guiding center motion (misleading symmetry).

Moreover, the Boltzmann equation is obtained from the variation with respect to the principal Hamilton function and its time derivative, which is the single particle Lagrangian.

In this formulation, the distribution function of masses appears as the conjugated to the principal Hamilton function variable in hamiltonian mechanics. From the Boltzmann equation it will be shown in which limit the Vlasov equation takes place and how to prevent the problem of the BBGKY hierarchy. Thus it is possible to show that the fluid description of the plasma is no longer constrained by statistical approximations for truncating or for asymptotically expanding the multi-moments description of the kinetic approach, in such a way that the Eulerian picture describing plasmas can be applyed well outside the ranges up to now considered.
Di Troia, C. (2018) Journal of Modern Physics, 9, 701

*Speaker

Giant standing ion acoustic waves

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[3]UC Berkeley – United States

Abstract

We study formation of large amplitude standing ion acoustic waves (SIAW) by nonlinear phase-locking (autoresonance) with a weak, chirped frequency standing ponderomotive drive. These waves comprise a nonlinear two-phase solution each phase locked to one of the two traveling waves comprising the drive. The autoresonance in the system is guaranteed provided the driving amplitude exceeds a threshold. The phenomenon is illustrated via water bag simulations within a nonlinear warm ion fluid model and analysed using Whitham's averaged variational principle. The local ion and electron densities in the autoresonant SIAW may significantly exceed the initial unperturbed plasma density and are only limited by the kinetic wave-breaking.

Supported by the NSF-BSF grant #1803874 (BSF #6079), and performed under the auspices of the U.S. DOE by LLNL under Contract No. DE-AC52-07NA27344, with support from the LLNL-LDRD Program under Project tracking #18-ERD-046.

*Speaker

Multiscale asymptotic paraxial models for approximating Vlasov-Maxwell equations

Yevgeni Furman*[1] and Franck Assous[1]

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Abstract

This work introduces a new paraxial asymptotic model for approximating the Vlasov-Maxwell equations, governing the behavior of charged particle beams moving along an optical axis. Such models have been already proposed for ultra-relativistic beams, and have the advantage of being simpler and easier to solve than the complete Vlasov-Maxwell one. The innovation introduced here is the expansion of the model to much slower beams, even in cases when the axial velocity of the beam frame is comparable to the tangential ones. Like in other paraxial approximations, the model follows the beam frame, but allows its velocity to be a fraction of the light velocity. Nevertheless, when the velocity tends to the light velocity, this model coincides with the ultra-relativistic one. To derive the model, new non-dimensional coordinates have been introduced and used to scale the system of equations according to the physical assumptions. This results in a new, non-dimensional system of equations which are dependent on a small parameter representing the ratio between the axial velocity in the beam frame and the light velocity. Next, using asymptotic expansion, the system is decomposed into powers of this small parameter. With this approach, one is able to give a n-th order accurate model, for a given integer n, thus allowing for greater flexibility and accuracy. This work lays the foundation for a numerical method that can give a simple and efficient scheme to solve the problem with a wide range of velocities.

*Speaker

Transport driven by trapped particle turbulence in magnetized plasmas

Etienne Gravier*[1], Maxime Lesur[1], Thierry Reveille[1], Thomas Drouot[1], Malik Idouakass[1], Julien Medina[1], Kyungtak Lim[1], Xavier Garbet[2], and Yanick Sarazin[2]

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[2]Institut de Recherche sur la Fusion par confinement Magnétique – Commissariat à l'énergie atomique et aux énergies alternatives : DSM/IRFM – France

Abstract

The results described here are based on an electrostatic reduced bounce averaged gyrokinetic model. This bounce-averaged gyrokinetic model is an interesting tool for investigating fundamental physical processes at low computational cost, making efficient use of parallel computing. It can be used as a complementary approach to more comprehensive models. The model is relevant for relatively low frequency modes, such as Trapped-Ion Modes (TIM) and Trapped-Electron Modes (TEM). These assumptions lead to a reduction of dimensionality, from 5D gyro kinetics, to 4D gyrobounce-gyrokinetics.

First a hysteresis in the relationship between zonal flows and electron heating is observed numerically. The confinement of the plasma and the heat flux are thus found to be sensitive to the history of the magnetized plasma. These transitions are associated with large exchanges of energy between the modes corresponding to instabilities (m$>$ 0) and zonal flows (m = 0). Second the diffusive impurity transport is analysed. The impurity species are treated self-consistently. It is found that the diffusive impurity transport does not depend on the mass number, but notably depends on the charge number. This transport also depends on the nature of the instability that drives turbulence. The impurity flux due to TEM turbulence increases with the charge number Z. In contrast, it is found to decrease with Z in the TIM mode dominated. In order to explain these observations, the quasilinear flux is derived and is compared with results obtained from the nonlinear simulations. Quasi-linear theory qualitatively reproduces the numerical observations.

*Speaker

Secular evolution of globular clusters

Chris Hamilton*[1]

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Abstract

The classical (Spitzer-Chandrasekhar) theory of cluster relaxation is unsatisfactory because it involves the Coulomb logarithm and completely neglects the cluster's self-gravity. A modern alternative is the Balescu-Lenard (BL) equation, which has no such ill-defined parameter and includes self-gravity. The BL equation was originally derived in plasma physics but has recently been applied to self-gravitating systems, and has helped to explain the secular evolution of collisionless stellar discs. In this talk I will review the classical theory of cluster relaxation and demonstrate its pitfalls, showing at each stage why the BL equation does a better job. I will then present the first application of the BL formalism to spherical systems. I will show how the BL flux through action space differs from the corresponding classical flux, and discuss what a complete theory of cluster relaxation might entail.

*Speaker

A quadrature- and matrix-free discretization of the multi-species, non-relativistic, Vlasov-Maxwell system of equations

James Juno*[1], Ammar Hakim[2], Jason Tenbarge[3], Valentin Skoutnev[2], William Dorland[1], and Marc Swisdak[1]

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[3]Department of Astrophysical Sciences [Princeton] – United States

Abstract

We present a novel algorithm for the numerical solution of the multi-species, non-relativistic, Vlasov-Maxwell system of equations which uses high order discontinuous Galerkin finite elements to discretize the system on a phase space grid. The resulting numerical method is robust and retains a number of important properties of the continuous system, such as conservation of mass and energy. In addition, we will discuss a number of discoveries concerning the computational implementation of the algorithm which bring the cost of directly discretizing the Vlasov-Maxwell system down tremendously. We demonstrate a favorable computational complexity, and, likewise, an acceptable performance on modern supercomputing architectures up to scale. Thanks to the discontinuous Galerkin algorithm's locality of data, and a novel use of a large spectrum of MPI-3's functionality, including shared memory and neighborhood collectives, we are able to show good scaling on many-core architectures and we compare the sustained performance of the code to common performance benchmarks such as LinPak. Most importantly, we devote a portion of the presentation to the central motivation of developing a continuum discretization of the Vlasov-Maxwell system: a clean, noise-free representation of the distribution function and electromagnetic fields. We discuss a set of recent results (Skoutnev et al. ApJ Letters 2019) which disagree with particle-in-cell simulations with the same parameters and initial conditions, and demonstrate the role particle noise plays in the disagreement. We thus argue for the utility of the continuum approach, which despite its challenges and expense compared to the particle-in-cell method, nonetheless provides a complementary tool for addressing kinetic problems in plasma physics.

*Speaker

Grid-free boundary integral formulation for the Vlasov-Poisson system

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Abstract

In this talk, we present a grid-free method for the numerical treatment of the three-dimensional Vlasov-Poisson system. After the discretisation of the density function with a standard particle method, the solution of the Poisson equation is split into two parts: a particle-particle part and a solution of a Laplace problem. Solving the later with the Boundary Element Method (BEM) leads to a (volume) grid-free method.

The BEM makes use of an equivalent boundary integral formulation of the Laplace problem, which is descretised on a boundary mesh. This reduces the three-dimensional volume problem to a two-dimensional problem on the boundary. Consequently, the number of degrees of freedom of the BEM is typically much smaller than the number of particles.

The electric field is approximated by hierarchical matrices which are computed on the fly. The computational complexity for their evaluation is linear in the number of particles and nearly linear in the number of degrees of freedom of the BEM. The numerical experiments confirm the theoretical complexity estimates.

*Speaker

On the applicability and predictivity of Eddington-like inversion methods in the context of dark matter searches

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Abstract

In the context of dark matter (DM) searches, it is crucial to quantify and reduce theoretical uncertainties affecting predictions of observables that depend on the DM velocity distribution. The well-known Eddington inversion formalism, for the self-consistent reconstruction of the solution of the Vlasov-Poisson system from a galactic mass model, provides versatile tools to go beyond the very simplistic Maxwell-Boltzmann approximation or direct extrapolations from cosmological numerical simulations, with limited technicalities. However, this method and its anisotropic extensions can be ill-defined depending on the DM and baryonic content of the galaxy of interest. In this presentation, I will first discuss the validity range of the Eddington inversion methods from a theoretical perspective, as well as issues relevant to DM searches. Then, even in their theoretical validity range, these methods must be tested against hydrodynamical cosmological simulations to assess their relevance for complex gravitational systems such as Milky-Way-like galaxies. I will therefore discuss the predictivity of these methods based on zoom simulations. As an application, I will also present novel constraints on velocity-suppressed DM annihilation, and the associated theoretical uncertainties.

*Speaker

Exact hybrid Vlasov equilibria for sheared plasmas with uniform magnetic field

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Abstract

The hybrid Vlasov-Maxwell system of equations is suitable to describe a magnetized plasma at scales on the order of or larger than proton kinetic scales. Within this approach, an exact stationary solution is presented with a uniform-density shear flow, directed parallel, perpendicular or oblique with respect to a uniform magnetic field. A quantitative characterization of the equilibrium distribution function is provided by studying both analytically and numerically the temperature anisotropy and gyrotropy and the heat flux. In both cases, in the shear region, the velocity distribution significantly departs from local thermodynamical equilibrium. A comparison between the time behavior of the usual "fluidlike" equilibrium shifted Maxwellian and the exact stationary solutions is carried out by means of numerical simulations of the hybrid Vlasov-Maxwell equations. These hybrid equilibria can be employed as unperturbed states for various problems which involve sheared flows, such as the wave propagation in an inhomogeneous background and the onset of the Kelvin-Helmholtz instability.

*Speaker

Collective Plasma Structures with kinetic nonlinearity: their stability criterion and interactions

Debraj Mandal*[1,2] and Devendra Sharma[1]

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Abstract

A large part of the universe that exists in the plasma state satisfies the collisionless conditions and evolves by means of strong kinetic nonlinear activity. The elegant collisional linear description and its nonlinear counterparts lose their applicability in this regime and plasmas begin to show a strong departure from these conventional results. Finding a general nonlinear kinetic description of collective structures defines the central idea of the modern plasma theory of collective waves and instability. These coherent structures are observed in a variety of plasmas from hot fusion plasmas to space plasmas. The high resolution, multispecies, fully kinetic Vlasov simulations of nonlinear, collective kinetic plasma response to phase-space perturbations are done, describing their underlying stability mechanism and the mutual interaction of coherent phase space structures in the present study.

In the first part, the validity of linear stability criterion of the current driven ion acoustic instability in the subcritical regime is explored by evolving an initial seed like (x-v) space perturbation in this stable regime (linear). It becomes unstable and finally forms a stable coherent structure at higher velocity[1]. The results of multiscale simulations and the acceleration mechanism are analyzed following the kinetic prescription of phase-space vortex solutions that account for a stronger nonlinearity originating from the electron trapping, and we define new stability criterion based on the Nonlinear Dispersion Relation[2] of electron hole. In the next part, the nonlinear interactions between multiple solitary electron phase-space holes are studied. Evolution of the analytic trapped particle solitary solutions prescribed by H. Schamel[2] is examined, observing them propagate stably, preserve their identity across strong mutual interactions in adiabatic processes and display close correspondence with observable processes in nature[1].

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*Speaker

Practical applications of the self-consistent hamiltonian N-body approach for wave-particle interactions

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Abstract

To investigate the nonlinear wave-particle interaction, the classical vlasovian description can be derived from its "finite version", the many-body (finite-N) dynamics, when the coupling is smooth enough. A benefit of the vlasovian approach is to enable the use of classical functions obeying (hopefully smooth) partial differential equations, whereas the N-body picture has long been deemed impossible due to its excessive number of degrees of freedom. However, the N-body approach is already used to easily introduce basic microscopic plasma phenomena such as Landau damping, or Debye shielding from prescribed initial conditions. In this contribution, we are going further than just using this description for intuitive interpretations: we use it to simulate real experimental devices as a viable alternative to vlasovian models. To tame the number of degrees of freedom, we developed a reduction model validated for periodical structures, such as traveling-wave tubes, gyrotrons, free-electron lasers, of particle accelerators. This approach is combined with a self-consistent hamiltonian in one space dimension to model the momentum exchange between fields and particles. From it, we build a symplectic integrator in time domain that is able to reproduce turbulences from the nonlinear dynamics of particles. The drastic reduction of degrees of freedom and the hamiltonian conservation properties allow fast simulations: 5min for industrial traveling-wave tubes versus 12h for identical tubes with particle-in-cell codes based on kinetic equations, for the same accuracy. Simulations of Landau damping and hamiltonian chaos are ongoing using our model along with experiments on the Aix-Marseille University-CNRS traveling-wave tube.

*Speaker

Study of trapped particles turbulence in magnetic fusion plasmas

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Abstract

In magnetized plasmas, the inhomogeneity of magnetic field traps the particles in the low field area. In addition to their rapid cyclotron motion, these particles are bouncing along the poloidal angle, and it is therefore possible to reduce their dynamics to two dimensions and two invariants, thanks to bounce and cyclotron averages.
Despite this reduction, the system obtained retains the original form of the Vlasov-Poisson system and the associated kinetic properties[1,2]. On the other hand, the Poisson bracket displays a 2D structure, allowing the use of reduced models of turbulence primarily developped for hydrodynamics. A hierarchy of such models is used here: from shell models[3,4,5], to Logarithmically Discretized Model[6,7] and spiral chain models[8].

Independently of the model describing the nonlinear interactions, the resulting systems have all certain common features, such as, for example the fact that the turbulence is driven by the background ion and electron profiles of, leading respectively to the Trapped Ion Modes (TIM) or Trapped Electron Modes (TEM) instabilities. The temperature ratio allows to transit from TIM to TEM turbulence.

Several models are compared, with a focus on the spectral characteristics of the free energy balance. The effect of varying the magnetic field strength, affecting the Larmor radius and the banana width, will also be presented.

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Particle-In-Cell Simulation of Hot-Electron Transport in Normal Metal-Ferromagnet Heterostructures

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Abstract

Ultrashort optical pulses applied to ferromagnets excite spin polarized electronic distributions far from equilibrium (which are often referred to as "hot electrons"). Such an ultrashort-pulse excitation can lead to demagnetization [1], but also to a loss of electronic spin polarization due to hot-electron transport in and out of ferromagnetic layers [2]. We present a theoretical analysis of optically excited hot-carrier transport in multilayers consisting of normal metals and ferromagnets [3], which we model by the Boltzmann Transport Equation. The numerical solution is achieved using a Particle-In-Cell approach to treat both transport and scattering effects in a numerically efficient way that is based on ab-initio input and can be easily adapted to different structures. In materials with spin Hall effect, induced spin-currents can be efficiently converted into charge currents that are the source for Tera-Hertz emission [4,5]. By combining the particle-in-cell method for spin-polarized hot-electron transport with a calculation of optical fields for laser absorption and broadband THz emission[3], we analyze optically excited electron spin transport in Fe-Au bilayers, Fe-Au-Fe spin-valve structures and THz emission from Fe/Pt-layers.

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*Speaker

From the Harris sheet to the force-free Harris sheet - a family of self-consistent Vlasov-Maxwell equilibrium distribution functions

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Abstract

We discuss a family of Vlasov-Maxwell equilibrium distribution functions for current sheet equilibira that are intermediate cases between the Harris sheet and the force-free (or modified) Harris sheet. These equilibria have potential applications to space and astrophysical plasmas. The existence of equilibrium distribution functions for these intermediate cases has been briefly discussed in the literature (Harrison and Neukirch, 2009), but it turns out that there are mathematical problems with a singular limit as the guide field goes to zero. We discuss this problem and then present an alternative approach that allows us to avoid the singularity by considering an intermediate magnetic field profile (and the associated distribution function) that is slightly differentfrom the one considered by Harrison and Neukirch (2009), but that also describes a transition between the Harris and force-free Harris cases.

*Speaker

A relativistic particle pusher for ultrastrong electromagnetic fields

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Abstract

Kinetic plasma simulations are nowadays commonly used to study a wealth of non-linear behaviour and properties in laboratories and in space plasmas. In particular, in high-energy physics and astrophysics, the plasma usually evolves in ultra-strong electromagnetic fields produced by intense lasers for the former or by compact objects such as neutron stars and black holes for the latter. In ultra-strong magnetic fields, the gyro-period is several orders of magnitude smaller than the timescale on which we desire to investigate the plasma evolution. Some approximations are required like for instance artificially decreasing the magnetic field strength which is certainly not satisfactory. The main flaw of this downscaling is that it cannot reproduce single particle acceleration to ultra-relativistic speeds with Lorentz factor above 1e3. In this paper, we design a new algorithm able to catch particle motion and acceleration to Lorentz factor up to 1e10 or even 1e15 by using a Lorentz boost to a special frame where electric and magnetic field are parallel. Assuming that this field is locally uniform, we solve analytically the equation of motion in a tiny region smaller than the length scale of the gradient of the field. This alleviates any constrain on the time step, allowing us to use very large time step, avoiding to resolved the ultra high frequency gyromotion. We performed simulations in ultra-strong spatially and time dependent electromagnetic fields, showing that our particle pusher is able to follow accurately the exact analytical solution. This property is crucial to properly simulate lepton electrodynamics in electromagnetic waves produced by rotating neutron stars.

*Speaker

Hybrid Vlasov-Maxwell simulations of Kelvin-Helmholtz instability

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Abstract

Kelvin-Helmholtz instability (KHI) can develop in sheared flows when the jump of the bulk velocity is larger than a certain threshold (generally the parallel component of the Alfvén speed). Such a configuration can be found in many natural environments, as, for instance, the Earth's magnetosphere.
Three different phases can be distinguished during the development of the KHI: an initial linear stage, in which the growth of the unstable modes occurs, a non-linear phase leading to the formation of vortices along the shear and, finally, the interaction between vortices, which gives rise to a turbulent scenario.

We studied KHI by solving numerically the Vlasov-Maxwell system of equations in hybrid approximation, where the protons kinetic dynamics is retained, while electrons are treated as a massless fluid.

We solved this system of equations through the so-called Hybrid Vlasov-Maxwell (HVM) code in a multi-dimensional phase-space, 2.5D-3V (2.5 dimensions in space and 3 in velocity space), in physical conditions close to those of the magnetospheric plasma.

From a numerical point of view, we initialized our simulations by setting up an exact hybrid equilibrium configuration with a shear flow, recently derived in Ref.[1]. At variance with the commonly used initial setup with a shifted-Maxwellian proton distribution function, our exact equilibrium allows to study the onset and the consequent evolution of the KHI getting rid of the spurious oscillations, triggered by the shifted-Maxwellian initial setup.

In this work, we provide the analysis of the KHI based on a point-to-point comparison between the two different initial conditions, discussing analogies and differences in the evolution of the instability, in linear, nonlinear and fully turbulent regime.
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*Speaker

Kinetic Simulation of Electrostatic Ion Phase Space Vortices In A 1D Driven-Dissipative Vlasov System

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Abstract

In collisionless plasmas, it is well known that wave-particle interactions lead to coherent phase space vortices (PSVs). This is a subject of intense efforts world-wide because the fundamental ideas are applicable to both space plasmas as well as laboratory plasmas. In reality, in most situations, the plasmas are not completely collision-less, but are weakly collisional. From the point of view of kinetics, depending on the parameters, physics of low collisionality can be different from that of null or zero collisionality. Thus nearly collisionless regimes are important to a number of physical processes, including runaway electrons in magnetically confined fusion plasmas, magnetic reconnection in weakly collisional regime, low density edge in a tokamak plasma, solar plasma near sunspots, and non-neutral plasmas etc. In such cases, the evolution of the plasma is a result of complex combination of kinetic processes and collisionality. In the present work, an Eulerian time-splitting algorithm for the study of the driven electrostatic ion phase space vortices (PSV) in an unbounded weakly collisional plasmas is presented. Collisions are modeled through one-dimensional operators of the Krook and Fokker-Planck type. Particular attention is devoted to the study of collisional effects on the formation and dynamics of driven ion PSVs [1, 2]. In the present work, using a numerical Vlasov-Poisson solver, we bring out several interesting features of ion phase space structures in a driven-dissipative
system, the details of which will be presented [3]. References

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*Speaker

Self-consistent reduced kinetic modelling of fusion plasma.

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Abstract

Since more than three decades, numerical simulations of fusion plasmas have undergone significant development. Nowadays, access to the High-Performance Computing facilities allows one to model realistic plasma scenarios. The questions perhaps remain open about verification and validity of the results obtained from the numerical simulations.
It has been proved that the gyrokinetic models accurately predict violent, turbulent transport in the core region of a tokamak [1]. However, understanding of the processes in the edge of fusion devices, e.g. transition towards the high confinement mode with drastically increased plasma confinement, still be lacking.

Several groups undertake the gyrokinetic simulations of the edge region across the world [2,3,4]. However, the codes models suitable for the core of the tokamak are unsuitable for simulations of the edge region. Indeed, the models for the edge should include electromagnetic effects and be fully non-linear. There exist no gyrokinetic code nowadays, possessing a self-consistent, energy conserving electromagnetic full-f model.

In this talk, the two-fold theoretical framework [5] for gyrokinetic models verification suitable for the large spectrum of gyrokinetic codes will be presented for the edge modelling. It will be shown how the use of Hamiltonian and Lagrangian tools helps to prevent all the bottlenecks related to the models implemented in gyrokinetic simulations. Examples of test cases and simulations allowing to identify limits of currently implemented gyrokinetic models applications will be given for ORB5 code.

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*Speaker

Analytical solutions for nonlinear plasma waves with time-varying complex frequency

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Abstract

Bernstein-Green-Kruskal modes are ubiquitous in plasma physics, where particles lie on conservative orbits in phase-space. Here, we instead investigate solutions to the Vlasov equation where the particles take non-conservative orbits, allowing for a wider range of nonlinear solutions.

First, we analytically examine the time evolution of plasma waves with time-varying complex frequency γ–iω in the linear and nonlinear phases. Using a Laplace-like decomposition of the electric potential, we give allowed solutions for the time-varying complex frequencies. Then, we give closed form solutions that allow for finite growth rate and finite frequency sweeping rate via a series of functionals, allowing for the shear of phase-space islands.

*Speaker

Excitation and Control of BGK Modes with Chirped Drives

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Abstract

The excitation of Bernstein-Green-Kruskal (BGK) waves using a drive field with slow amplitude and phase variation is investigated theoretically and numerically. The model assumes that throughout the excitation the plasma remains in a weakly nonlinear BGK equilibrium described by slowly varying parameters. The Vlasov-Poisson system is reduced to three differential equations that describe the BGK equilibrium as a function of the drive parameters and the plasma density and temperature. A parameter regime is found where, depending on parameters, the BGK mode can either be locked to the drive, as is typically assumed, or, for other parameter choices, the mode becomes π out of phase with the drive perturbation. The role of plasma temperature in the dynamics is discussed and comparisons between theory and simulation are presented. *This work was supported by NSF grant No. 1803874.

*Speaker

POSTERS

Self-consistent Models for the Description of Magnetized Charged Particle Beams

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Abstract

The behavior of magnetized charged particle beam is of a great interest for numerous applications such as conventional and advanced concept accelerators, electron and ion guns, novel sources of the radiation and other electronic devices. The states of the charged particle beams may be described with the help of the Vlasov theory. The model solutions of the Vlasov equation which represent the kinetic functions dependent on the combinations of the integrals of the beam particle motion allow easily to find the time evolution of the beam characteristics. The solution of the Vlasov equation dependent on the kinetic function as a function of the beam particle coordinates and their derivatives leads to the self-consistent equations for the particle oscillations. The states of charged-dominated and emittance-dominated beams may be described. The time evolution of the beam envelope as well as beam phase volume may be found in both cases. For the common situation when the beam may be approximated by the continuous one with elliptical cross-section the beam dynamics is analyzed. The beam behavior dependence on the initial angular momentum in external magnetic field is shown. The analytical results as well as the results of the simulation are presented in the report.

*Speaker

Kinetic ladder climbing of electron plasma waves

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Abstract

When the background density in a bounded plasma is modulated in time, discrete modes become coupled. Interestingly, for appropriately chosen modulations, the average plasmon energy might be made to grow in a ladder-like manner, achieving upconversion or downconversion of the plasmon energy. This reversible process is identified as a classical analog of the effect known as quantum ladder climbing (LC) so that the efficiency and the rate of this process can be written immediately by analogy to a quantum particle in a box. In the limit of a densely spaced spectrum, ladder climbing transforms into continuous autoresonance; plasmons may then be manipulated by chirped background modulations much like electrons are autoresonantly manipulated by chirped fields. LC of electron plasma waves is investigated using fully nonlinear Vlasov-Poisson simulations of collisionless bounded plasma. In agreement with linear theory, kinetic simulations show that plasmons survive substantial transformations of the spectrum and are destroyed only when their wave numbers become large enough to trigger Landau damping. In the nonlinear regime, simulations show that since the damping rate decreases, LC becomes even more efficient when practiced on structures like quasiperiodic Bernstein-Greene-Kruskal (BGK) waves rather than on Langmuir waves.

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*Speaker

Turbulence in an electron Vlasov plasma: comparison with the EMHD fluid regime

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Abstract

We study the problem of 2D turbulence decay in a magnetised electron Vlasov plasma in which ions form a neutralising background at rest. The fluid counterpart of this model, in the non-relativistic limit, is the so-called incompressible Electron Magnetohydrodynamics regime [1]. We present results of numerical studies performed by using a PIC Vlasov code (SMILEI [2]) in a parameter regime which approaches the hydrodynamic limit. This allows a comparison, in principle, with results of EMHD turbulence [3,4]. Numerical simulations of the latter have been run with a 2D EMHD pseudo-spectral code [5]. The results we present are preparatory to a characterisation of kinetic turbulence in the warm and possibly relativistic electron Vlasov plasma regime, which will be afforded with both the relativistic Vlasov PIC code SMILEI [2] and the semi-lagrangian relativistic Vlasov code VLEM [6].

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Study of Langmuir waves in a weak electron-beam plasma interaction

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Abstract

Numerical solutions of the Vlasov-Poisson system for a one-dimensional unmagnetized plasma are used for analize the Langmuir waves exicited due to a beam-plasma interaction. The presence of an electron beam breaks the symmetry of a Maxwellian plasma and consequently also the symmetry property of Langmuir waves.
Through a systematic study it has been investigated the possibility to observe small-amplitude backward or forward Lagmauir waves, or both excited simultaneosly when an electron beam is weakly interacting with a plasma.
By changing the macroscopic parameters, such as density, drift velocities and thermal speed, the conditions under which the backward Langmuir waves are less damped than their forward couterpart and vice-versa have been investigated. Analogously, the parameters for which both Langmuir waves exhibit similar damping have been identified.
In particular, we have revisited the one-side, bump-on-tail case first studied by Demeio and Zweifel [1], who iterpreted the results of their simulation in terms of beating between the unstable and the least-stable mode in the system, the beam mode and a weakly damped backward-propagationg mode. However, according to our stability analysis and our simulations, their case corresponds just to the situation where both Langmuir waves are present.

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*Speaker

Generation of Pressure Anisotropy in the Solar Wind

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Abstract

It is clear that transport of energy in the solar wind (a turbulent and collisionless plasma) is a multi-scale process, making an odysseus-like journey before irreversible thermal heating occurs. We study a model for one of the mechanisms: the dynamical equations of Chew, Goldberger, and Low for the pressure anisotropy equipped with the linear kinetic theory of proton anistropy instabilities. The general processes is envisaged to occur as dilations in the magnetic field, heat fluxes, velocity field compressions etc. generate ion temperature anisotropy making the distribution function susceptible to the instability thresholds, where the energy is converted into the electric/magnetic fields. We apply statistical studies to WIND and THEMIS spacecraft measurements of the pressure tensor to better understand the inital phase of the outlined mechanism in the context of turbulence theory. In general we seek to answer: how the energy cascade is altered by the presence of pressure anisotropy energy transport, what types of coherent structure are generated and what is the spectral content of the pressure anisotropy?

*Speaker

Theory and observations in near-Earth plasmas: energy conversion rates in proximity of magnetic reconnection sites

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Abstract

One of the fundamental aspects of plasma dynamics is how internal energy, bulk energy and electromagnetic energy are exchanged. Here, by means of hybrid Vlasov-Maxwell simulations we investigate how energy conversions take place in proximity of reconnection sites forming in a turbulent plasma environment. The theoretical investigation is carried on in the framework of a (multi)-fluid approach, on one hand by focusing on each species separately and on the other by considering the whole medium as a single fluid. Comparisons are made with MMS (Magnetospheric Multiscale) data revealing turbulence in Earth's magnetosphere and magnetotail. Interestingly, some energy exchange terms are found to be negligible everywhere but close to reconnection sites. We propose here to use these terms as proxies for reconnection.

*Speaker

Electron dynamic in magnetic reconnection: a hybrid model with Landau fluid closure

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Abstract

One of the main challenges in (space) plasma physics is to provide a clear analysis of the electron dynamics and of the electromagnetic fields in the reconnection layer, in particular in the so-called electron diffusion. Here we present new results using a hybrid model with kinetic ions and fluid electrons. The electron model adopts the 3+1 moments Landau Fluid closure, a nonadiabatic closure recently developed (Sulem and Passot 2015) aimed at reproducing the Landau damping effect and gyrotropic anisotropy. The model is integrated numerically using an Eulerian Vlasov code. An isothermal closure for the electrons has been also adopted for comparison. Both simulations start from an Harris-like equilibrium together with small amplitude magnetic fluctuations which spontaneously develop magnetic reconnection manifesting into a chain of X-points. The one with Landau Fluid closure develops electron pressure anisotropy and, near the X points, current layers and electron outflow jets showing the typical asymmetric and elongated geometry found in fully kinetic simulations. The pressure anisotropy appears to be bounded by both firehose and mirror marginal stability thresholds. By comparison with the isothermal model, we can argue that Landau damping do play an important role in speed-up the reconnection dynamics starting from the linear phase, as we found that the reconnection rate and the growth rate of the most unstable modes result significantly boosted.

*Speaker

Generation of Superthermal Electrons by Beam-Plasma Interaction via Particle Simulation

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Abstract

The existence of superthermal particles in solar wind has been continually confirmed in different regions of the heliosphere. The presence of these superthermal particles is characterized by high energy tails in the particle velocity distribution. Phenomenological descriptions of superthermal tails have made use of the so called kappa distribution functions, which feature a power law decay in the high energy range. Although observed distributions are well described by kappa functions, the physical processes responsible for the energization of particles is a matter of debate. In this research we study the physical processes related to the acceleration of suprathermal electrons due to the beam-plasma instabilities, using PIC simulation method (paticle-in-cell). Comparing the results of the simulations with the theoretical description for this kind of system, we verified that the appearance of suprathermal particles in the distribution function occurs after the system reaches the turbulent phase (nonlinear wave-particle interaction), and analyzing the space-time evolution of the velocity distribution function of the beam and the background presented separately, we identify that the population of particles that makes up the suprathermal tail at the end of the simulation process is basically composed by the beam particles. Moreover, our results show that the velocity distribution function assumes a shape that is better adjusted by a kappa-like distribution function.

*Speaker

Non-linear optics analogue of ”fuzzy” dark matter: experiment proposal

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Abstract

The understanding of self-gravitating collapse and subsequent galaxy or globular cluster formation, via the so-called violent relaxation process, is still not well understood. Moreover, astrophysical time-scales are so large that it is not possible to observe the dynamics. For this reason, it is very useful to perform analogue experiments where it is possible to test theory. In this proposal we describe an experiment in a non-linear optical device which is analogue to ”fuzzy” dark matter, which is a theoretically currently popular model in cosmology. It is a self-gravitating system, in with quantum effects arises up to macroscopic galactic scales. In the proposal, we describe how to control experimentally h/m (i.e. how to create systems which are analogues to the classical or quantum version of the original systems) and how it would be possible to observe the formation of an analogue galaxy through the process of violent relaxation. In addition, it would be possible to observe characteristic phenomena as virialization, filamentation of phase space and compare quantitatively theory and experiment.

*Speaker

Wigner-Maxwell and Vlasov-Maxwell equations for particles with spin

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Abstract

Using the phase-space formulation of quantum mechanics, we derive a four-component Wigner equation for a system composed of spin-1/2 fermions (typically electrons) including the Zeeman effect and the spin-orbit coupling. This Wigner equation is coupled to the appropriate Maxwell equations to form a self-consistent mean-field model. A set of semiclassical Vlasov equations with spin effects is obtained by expanding the full quantum model to first order in the Planck constant. The corresponding hydrodynamic equations are derived by taking velocity moments of the phase-space distribution function and using a simple closure relation. These results are illustrated by an application to nanoplamonics, namely the generation of spin currents in thin nickel films by means of ultrafast laser pulses.

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*Speaker

Test particles dynamics in low-frequency tokamak turbulence

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Abstract

We study the evolution of one million test particles in a turbulent plasma simulation, using the gyrokinetic code TERESA, as a method to get insights on the type of transport governing the plasma. TERESA (Trapped Element REduction in Semi lagrangian Approach) is a collisionless global 4D code which treats the trapped particles kinetically while the passing particles are considered adiabatic. The Vlasov-Poisson system of equations is averaged over the cyclotron and the trapped particle's bounce motion, thus the model focuses on slow phenomena of the order of the toroidal precession motion of the trapped particles "bananas". We initialize the test particles, which are de facto "test banana-centers", at a time of the simulation when the plasma is turbulent. We impose an initial temperature and density gradients and only Trapped Ion Mode (TIM) instability can develop in this system.
We then calculate the variance of the radial displacement of the test particles as a function of time in order to obtain a random walk diffusion coefficient. We observe that the radial diffusion of the test particles depends on their toroidal precession kinetic energy, in such a way that transport of particles and heat is dominated by a strong, relatively narrow peak at the resonant energies. A radial particle diffusion flux is then calculated and compared to the total radial particle flux accounting for all the diffusive and convective processes which is obtained directly from the code. We can thus separate the diffusive and convective contributions to the particles flux. The results are then compared to quasi-linear theory fluxes.

*Speaker

Study of wave particle interaction using Eulerian simulations in spatially non-uniform 1D Vlasov-Poisson system.

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Abstract

Wave particle interaction in an uniform, non-magnetized, collision-less plasma was first studied theoretically by Landau in 1946 wherein kinetic damping of a collective mode in the absence of collisions was first reported[1]. Since then Landau damping has been studied extensively for Vlasov-Poisson systems using experiments [2] and computer simulations [3] for spatially homogenous plasma systems. Several attempts have been made to generalize Landau damping to non-uniform, 1D collisionless, spatially periodic [4] and bounded Maxwellian plasmas [5] with various approximations. In the following, we address the question of wave particle interaction i.e Landau damping in linear and weakly non-linear limits of perturbation amplitude, for an nonuniform, two species 1D Vlasov plasma system with periodic boundaries without any approximations on inhomegenity scale length. In our study, using a 1D, Vlasov - Poisson solver VPPM-2.0 [6,7], we obtain numerical results of the physics of Landau damping of Langmuir waves both in the linear and weakly nonlinear limits for stationary cold ions and kinetic electrons. The details of this work will be presented.

*Speaker

ViDA: a Vlasov-DArwin solver for plasma physics at electron scales

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Abstract

Here, a novel Vlasov-DArwin numerical code (ViDA) is presented. The algorithm that has been specifically designed in order to address multi-scale plasma physics problems, where small-scale high accuracy and low noise level is requested even during the non linear regime to guarantee a clean description of the plasma dynamics at fine spatial wavelengths scales. The algorithm provides a low-noise description of proton and electron kinetic dynamics, by splitting in time the multi-advection Vlasov equation in phase space. Maxwell equations for the electric and magnetic fields are reorganized according to Darwin approximation to remove light waves. Several numerical tests show that ViDA properly reproduces the propagation of linear and nonlinear waves and captures the physics of magnetic reconnection. We also discuss preliminary tests of the parallelization algorithm efficiency, performed at CINECA on the Marconi-KNL cluster.

ViDA will allow to run Eulerian simulations of a non-relativistic fully-kinetic collisionless plasma and it is expected to provide relevant insights on important problems of plasma astrophysics such as, for instance, the development of the turbulent cascade at electron scales and the onset of magnetic reconnection.

*Speaker

Numerical results for the 1d-2v Vlasov-Poisson system in a uniform magnetic field

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Abstract

The goal of this research is to use a Semi-Lagrangian method with splitting [2] on a 1d-2v Vlasov-Poisson equation to obtain numerical illustrations of the Landau-Bernstein paradox [1, 4]. Indeed, the Semi-Lagrangian method is one of the classical tools [3] for the numerical resolution of Vlasov equations. The Landau-Berstein paradox is, in essence, that in unmagnetized plasmas the electric field exhibits Landau damping, whereas in magnetized plasmas Bernstein modes perpendicular to the magnetic field are undamped, independently of the magnetic field. Thus, I will present our last results regarding the study of this physical phenomenon.

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*Speaker

Turbulence-driven ion beams in space plasmas

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Abstract

The description of the local turbulent energy transfer and the high-resolution ion distributions measured by the Magnetospheric Multiscale mission together provide a formidable tool to explore the cross-scale connection between the fluid-scale energy cascade and plasma processes at subion scales. When the small-scale energy transfer is dominated by Alfvénic, correlated velocity, and magnetic field fluctuations, beams of accelerated particles are more likely observed. Both space observations and numerical simulations suggest the nonlinear wave-particle interaction as one possible mechanism for the energy dissipation in space plasmas.

*Speaker

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