International Workshop

Multiscale Methods for Fluid and Plasma Turbulence :
Applications to Magnetically Confined Plasmas in Fusion Devices

April 21st to 25th 2008

Centre International de Rencontres Mathématiques, Marseille

Book of Abstracts

Organizers: Marie Farge, Ecole Normale Supérieure, Paris
Kai Schneider, Université de Provence, Marseille

Sponsors:

Agence Nationale de la Recherche	CNRS-Fédération sur la Fusion
CEA, Cadarache	Université Franco-Allemande
ONR Global	Université de Provence
ERCOFTAC	AFM
Région PACA	Conseil Général 13
Ville de Marseille	French Embassy in India

Aim of the meeting:

The aim of the meeting is to bring together applied mathematicians working in the field of numerical analysis and scientific computing, plasma phycicists working on magnetically confined plasmas and fluid mechanicians working on fluid turbulence. The state of the art in the field of numerical simulation of plasma and fluid turbulence will be reviewed and new promizing approaches based on multiscale decompositions will be presented. Numerical methods for Navier-Stokes and Maxwell equations shall be discussed as well as kinetic models based on Vlasov and Boltzmann equations using particle or hybrid particle methods.

The interdisciplinarity of the participants will yield synergetic effects and fruitful discussions between the different communities.

Short description of the meeting:

The optimization of many industrial processes requires improved prediction and control of fully developed turbulent flows. For their numerical simulation the developement of advanced numerical methods is essential. This aspect is particularly important in the case of magnetically confined plasmas encountered in tokamaks. The understanding of confinement properties necessitates a sound knowledge of turbulence and transport in plasmas, as the quality of the confinement determines the performance of the device.

Plasma turbulence shares numerous properties with fluid turbulence, especially they both involve a large number of spatial and temporal scales. Multiscale approaches are hence well suited to study turbulence in fluids and plasmas.
The workshop will focus on the presentation of new adaptive numerical methods based on multiscale representations (e.g. wavelets) for modeling and computing different turbulent flows encountered in fluid mechanics and plasma physics.

Plasma turbulence in fusion devices adds a level of specific complexity, like the toroidal geometry, the fast rotation of the plasma, the interaction of the plasma with the magnetic field and the resulting nonlinear collective effects, particularly in the scrape-off layer. The actual challenges in the field are the development and validation of efficient numerical methods to compute flows in tokamaks, in particular for ITER. It also requires the development of analysis tools applied to experimental data measured in the tokamaks.

The workshop fits into the framework of the arrival of ITER at Cadarache (France) and has the objective to present and discuss both well established and new numerical methods for data analysis and numerical simulation.

International workshop on

'Multiscale methods for fluid and plasma turbulence :

Applications to magnetically confined plasmas in fusion devices'

CIRM, Marseille, 21-25 April 2008

Program

Sponsored by

Monday April 21

8.50 *Welcome*

9.00 Pat Diamond (University of California, San Diego, USA):
'Theoretical Approaches to Model Reduction and Description of Multi-Scale Interaction in Tokamak Plasma Turbulence.'

10.00 Herman Clercx (TU Eindhoven, The Netherlands):
'Angular momentum generation in bounded 2D turbulent flows.'

10.30 Coffee break

11.00 J. Bryan Taylor (Wallingford, UK):
'Interacting vortices and spin-up in 2d turbulence.'

11.45 Chris Holland (University of California, San Diego, USA):
'Validation of Nonlinear Simulations of Core Tokamak Turbulence: Current Status and Future Directions.'

12.30Lunch

14.00 Yanick Sarazin (Association Euratom-CEA, Cadarache, France):
'Multiscale interactions in gyrokinetic simulations of turbulent transport in tokamak plasmas.'

14.30 Madalina Vlad (Association Euratom-MEC, Bucharest, Romania):
'Multiscale trajectory structures and turbulent transport in magnetically confined plasmas.'

15.00 – 15.30 Short talks (poster presentation)

15.00 Shinpei Futatani (Kyoto University, Japan):
'Multiscaling analysis of the spatio-temporal dynamics of impurity transport in magnetized plasmas.'

15.10 Magali Muraglia (Université de Provence, Marseille, France) :
'Nonlinear dynamics of magnetic islands imbedded in the edge Tokamak plasma microturbulence .'

15.20 Romain Nguyen van yen (ENS-Paris, France):
'Wavelets meet Burgulence: CVS filtered Burgers equation.'

15.30 Coffee break

16.00 Assad Oberai (Rensselaer Polytechnic Institute, USA):
' Progress in the Variational Multiscale Formulation of Large Eddy Simulation.'

16.30 Katsunori Yoshimatsu (Nagoya University, Japan):
'Coherent vortices in high resolution direct numerical simulation of homogeneous isotropic turbulence: a wavelet viewpoint.'

17.00 Wouter Bos (Ecole Centrale Lyon, France):
'The decay of magnetohydrodynamic turbulence in a confined domain.'

17.20 Silvia Perri (University of Calabria, Italy):
'*Superdiffusive transport in astrophysical plasmas.'*

17.40 Frederic Schwander (Association Euratom-CEA, Cadarache, France):
'Symmetry and evolution of radiative patterns in simulations of the tokamak edge plasma.'

18.00 Open discussion

18.30 End

19.30 **Dinner**

Tuesday April 22

9.00 Annick Pouquet (NCAR, Boulder, USA):
'MHD turbulence: interactions of eddies and waves.'

10.00 Grigory Vekstein (University of Manchester, UK):
'Two-fluid effects in magnetic reconnection.'

10.30 **Coffee break**

11.00 Volker Naulin (Euratom, Risoe, Denmark):
'Issues in plasma edge turbulence: simulating complex behaviour.'

12.00 Open discussion

12.30 **Lunch**

14.00 David Montgomery (Dartmouth College, USA):
'Boundary conditions for turbulent fluids and magnetofluids.'

15.00 – 15.30 **Short talks (poster presentation)**

15.00 Salah Neffaa (Université de Provence, Marseille, France)
'Magnetic spin-up in two-dimensional containers.'

15.10 Seiya Nishimura (Kyushu University, Japan):
'Rotation of magnetic islands with micro-scale fluctuations.'

15.20 Benjamin Kadoch (Université de Provence, Marseille, France):
'*Lagrangian acceleration in confined turbulent flow.'*

15.30 **Coffee break**

16.00 Eric Sonnendrucker (ULP Strasbourg, France):
‘Kinetic simulation of Tokamak plasmas.’

16.45 Caroline Nore (LIMSI, Orsay, France):
‘A finite element approach of nonlinear Magnetohydrodynamics (MHD) problems in bounded geometries.’

17.30 Piotr Boronski (University of Leeds, UK):
'Spectral method for matching interior elliptic problems with exterior harmonic solutions.'

17.50 Open discussion

18.30 End

19.30 **Dinner**

21.00 **Discussion on the ITER projet with Michel Chatelier,**
Director of the Institut de la Fusion Magnétique du CEA, Cadarache

22.00 **Fusion experiments: beer / champaign confinement**

Wednesday April 23

9.00 Rahul Pandit (Bangalore, India):
'MHD Turbulence: What can we learn from simple models?'

10.00 Edriss Titi (University of California, Irvine, USA):
'Alpha sub-grid scale models of turbulence and inviscid regularization.'

10.30 **Photo**

10.35 **Coffee break**

11.00 Uriel Frisch (Observatoire Nice, France)
'Hyperviscosity, Galerkin truncation and bottlenecks in turbulence.'

12.00 Claude Bardos (Université Paris VII, France):
'Mathematical analysis of singularity and regularity in fluid equations.'

12.30 **Lunch**

14.00 **Free afternoon**

Calanques, Marseille downtown, ITER Cadarache

19.30 **Dinner**

Thursday April 24

9.00 Rainer Grauer (Universität Bochum, Germany):
'Massively Parallel Simulations of Lagrangian Plasma Turbulence.'

10.00 Florin Spineanu (Association EURATOM-MEC, Bucharest, Romania):
'The scale length problem from Euler fluid to magnetized plasma.'

10.30 **Coffee break**

11.00 Taik Soo Hahm (Princeton University, USA):
'Gyrokinetic Description of Tokamak Core Turbulence;
Theory, Simulation,and Comparisons to Experiments.'

12.00 Open discussion

12.30 **Lunch**

14.00 Bob Krasny (University Michigan, USA):
'Lagrangian Particle Simulations of Plasmas and Fluids.'

14.45 Paolo Ricci (EPFL, Lausanne, Switzerland):
'The simulation effort for the TORPEX experiment and theory-simulation comparison.'

15.15 – 15.35 **Short talks (poster presentation)**

15.15 Thierry Lehner (Observatoire de Paris- Meudon, France):
'Weakly non linear analysis of a rotating and precessing inviscid fluid in a cylinder and generation of differential rotational mean flow.'

15.25 Livia Isoardi (M2P2, Université Paul-Cézanne, Marseille, France):
'Numerical modeling of transport within Tokamak edge plasma.'

15.35 **Coffee break**

16.00 Claude Cambon (Ecole Centrale Lyon, France):
'Review of three-dimensional wave-turbulence in fluids. Typical instances.'

16.30 Guido Ciraolo (Ecole Centrale Marseille, France):
'Spreading of SOL flow patterns into the edge plasma.'

17.00 Vivek Aggarwal (TIFR, Bangalore, India):
'Localized Relaxation and Non-standard Finite Difference Method for Hyperbolic Conservation Laws.'

17.20 Open discussion

17.40 End

18.00 **Concert: Lieder from Schumann and Wagner**

19.30 **Dinner: Bouillabaisse**

Friday April 25

9.00 Frank Jenko (IPP Garching, Germany)
'Multi-scale interactions in plasma microturbulence.'

10.00 Robert Rubinstein (NASA Langley, USA):
'Locality in HD and MHD turbulence.'

10.30 **Coffee break**

11.00 Yasuji Hamada (NIFS, Japan):
'Three-wave coupling of drift waves in tokamak core plasmas.'

11.30 Philippe Angot (Université de Provence, Marseille, France) :
'Vector and scalar penalty-projection methods for incompressible and variable density flows.'

12.00 Open discussion

12.30 **Lunch**

14.00 Mani Mehra (IIT, New Delhi, India):
'Adaptive wavelet collocation method for PDEs.'

14.30 Margarete Domingues (Brazilian Space Research Institute, Brazil):
'A space-time adaptive multiresolution scheme: applications to evolutionary PDEs.'

14.50 Fereidoun Sabetghadam (Azad University, Tehran, Iran):
'Fourier spectral embedded boundary solution of the incompressible two-dimensional Navier-Stokes equations.'

15.10 Debasis Chandra (Institute for Plasma Research, Gandhinagar, India):
'Nonlinear dynamics of multiple NTMs in tokamaks.'

15.30 **Coffee break**

16.00 Round table and final discussion
animated by Xavier Garbet (CEA, Cadarache, France)

17.00 *Good bye*

19.30 **Dinner**

International workshop on
'Multiscale methods for fluid and plasma turbulence :
Applications to magnetically confined plasmas in fusion devices'
CIRM, Marseille, 21-25 April 2008

Abstracts

Sponsored by

Localized Relaxation and Non-standard Finite Difference Method for Hyperbolic Conservation Laws

Vivek AGGARWAL

TIFR, Center for Applicable Mathematics, Bangalore, INDIA

Non-standard finite difference methods (NSFDM) introduced by Mickens are interesting alternatives to the traditional finite difference and finite volume methods. When applied to linear hyperbolic conservation laws, these methods reproduce exact solutions. NSFDM is first extended to hyperbolic systems of conservation laws, by a novel utilization of the decoupled equations using characteristic variables, and then the NSFDM is studied for its efficacy in application to non-linear scalar hyperbolic conservation laws. Some results for bench-mark problems have also been discussed.

Vector and scalar penalty-projection methods for incompressible and variable density flows.

Philippe Angot

LATP, Université de Provence, Marseille, France

Some forty years after the pioneering works of Chorin (1968) and Temam (1969) introducing the projection methods, we propose a new family of methods, the so-called two-parameter vector penalty-projection (VPPr;ε) methods [1, 2]. Here an original penalty-correction step for the velocity replaces the standard scalar pressure-correction one [4, 5] to calculate flows with divergence-free velocity. This allows us to impose the desired boundary condition to the end-of-step velocity-pressure variables without too much trouble. The counterpart to pay back is that these methods satisfy the constraint on the discrete divergence of velocity only approximately within a penalty-correction step and the penalty parameter $0 < \varepsilon \leq 1$ must be decreased until the resulting splitting error is made negligible compared to the time discretization error. Besides, the augmented Lagrangian prediction step with an augmentation parameter $r \geq 0$ plays the role of a preconditioning, as in [5, 6, 3]. However, the crucial issue is that the linear system associated with the vector projection step can be solved all the more easily as $\varepsilon\delta t$ is smaller whereas the L2-norm of the velocity divergence is shown to vary as $O(\varepsilon\delta t)$ and we can reach the machine precision of 10^{-15} for double precision floating point computations. Finally, the vector penalty-projection method (VPPr;ε) has several nice advantages: the Dirichlet or open boundary conditions are not spoiled through a scalar pressure-correction step. Moreover, this method can be generalized in a natural way for variable density or viscosity flows. Besides, the theoretical error analysis with the energy method exhibits nearly optimal error estimates for the velocity and pressure fields in the natural norms in the case of the Navier-Stokes problem with Dirichlet boundary conditions. They also proved to be in agreement with the numerical results.

References

[1] Ph. Angot, J.-P. Caltagirone and P. Fabrie (2008), Vector penalty-projection methods for the solution of unsteady incompressible flows, in 'Finite Volumes for Complex Applications V', Hermes Science (to appear).

[2] Ph. Angot, J.-P. Caltagirone and P. Fabrie (2008), On the family of vector penalty-projection methods for the unsteady Navier-Stokes problems, C. R. Math. Acad. Sci. Paris.

[3] Ph. Angot, M. Jobelin and J.-C. Latche (2006), Error analysis of the penalty-projection method for the time-dependent Stokes equations, SIAM J. Numer. Anal. (revised version 2008).

[4] J.-L. Guermond, P. Minev and J. Shen (2006), An overview of projection methods for incompressible flows, Comput. Methods Appl. Mech. Engrg. 195, p. 6011-6045.

[5] M. Jobelin, C. Lapuerta, J.-C. Latche, Ph. Angot and B. Piar (2006), A finite element penalty projection method for incompressible flows, J. Comput. Phys. 217(2), p. 502-518.

[6] M. Jobelin, B. Piar, Ph. Angot and J.-C. Latche (2007), Une methode de penalite-projection pour les ecoulements dilatables, European J. of Numerical Mechanics (to appear).

Mathematical analysis of singularity and regularity in fluid equations

Claude Bardos

Université Paris VII, France

Abstract:

In this talk I intend to give some examples of mathematical contribution to the understanding of singularities in some well known equations.
It is convenient to start with the Cauchy problem for the Dirichlet operator in the half space. Next to compare it with the singularities of the Birkhoff Rott equation and with the " entire analyticity " of the solution of the heat equation. This "entire analyticity" does not persist for Burger Hopf equation which exhibit complex singularities while it is recovered for an hyperviscous model proposed by Uriel Frisch according to a joint work with Edriss Titi.

Spectral method for matching interior elliptic problems with exterior harmonic solutions

Piotr Boronski

University of Leeds, UK

One of the fundamental problems in numerical magnetohydrodynamics is the formulation of boundary conditions. The governing equations describe the velocity and magnetic field in in a finite container of electrically conducting fluid. At the container boundaries, the velocity is specified, but the magnetic field is not. Instead, the magnetic field is required to satisfy continuity conditions with the exterior magnetic field in the domain surrounding the fluid. We present a spectral method for solving coupled elliptic problems on an interior and an exterior domain. The method is formulated and tested on the two-dimensional interior Poisson and exterior Laplace problems, whose solutions and their normal derivatives are required to be continuous across the interface. A complete basis of homogeneous solutions for the interior and exterior regions, corresponding to all possible Dirichlet boundary values at the interface, are calculated in a preprocessing step. This basis is used to construct the influence matrix which serves to transform the coupled boundary conditions into conditions on the interior problem. Chebyshev approximations are used to represent both the interior solutions and the boundary values. A standard Chebyshev spectral method is used to calculate the interior solutions. The exterior harmonic solutions are calculated as the convolution of the free-space Green's function with a surface density; this surface density is itself the solution to an integral equation which has an analytic solution when the boundary values are given as a Chebyshev expansion. Properties of Chebyshev approximations insure that the basis of exterior harmonic functions represents the external near-boundary solutions uniformly. The method is tested by calculating the electrostatic potential resulting from charge distributions in a rectangle. We discuss generalization of this approach to three-dimensional problems, in particular the magnetohydrodynamic equations in a finite axisymmetrical domain surrounded by a vacuum.

The decay of magnetohydrodynamic turbulence in a confined domain

Wouter J.T. Bos[1,2], Salah Neffaa[1], Kai Schneider[1]

[1] M2P2-CNRS and CMI, Université de Provence, Marseille, France
[2] LMFA, CNRS, Ecole Centrale de Lyon - UCBL - INSA, Lyon, France

The effect of non periodic boundary conditions on decaying two-dimensional magnetohydrodynamic turbulence is investigated. We consider a circular domain with no-slip boundary conditions for the velocity and where the normal component of the magnetic field vanishes at the wall. Different flow regimes are obtained by starting from random initial velocity and magnetic fields with varying integral quantities. These regimes, equivalent to the ones observed by Ting, Matthaeus and Montgomery [Phys. Fluids 29, 3261, (1986)] in periodic domains, are found to subsist in confined domains. We examine the effect of solid boundaries on the energy decay and alignment properties. The final states are characterized by functional relationships between velocity and magnetic field.

References:

S. Neffaa, W. J. T. Bos and K. Schneider.
The decay of magnetohydrodynamic turbulence in confined domains.
Preprint 12/2007, submitted.
http://arxiv.org/abs/0804.2810

Review of three-dimensional wave-turbulence in fluids. Typical instances

Claude Cambon

Ecole Centrale Lyon, France

Abstract: In wave-turbulence, the velocity field (with possibly other fields coupled with it) appears as a sea of weakly-interacting wave modes. Dramatic depletion of nonlinear interactions results from phase-mixing of dispersive waves, and allows us to derive rigorously the form of the `weak' energy transfer (using kinetic equations). This is not possible without additional heuristic assumptions in classical `strong' turbulence, in spite of formal analogies (using Lin equation).

Three cases are chosen for illustration of principles and salient features :

- 3D rotating turbulence, with effect of inertial waves phase-mixing on statistics, even at zero nonlinearity, and with salient features of the `weak' nonlinear theory (new cascade, anisotropy, intermittency)

- 3D turbulence in a stably-stratified medium, just mentioned for illustrating the emergence of `strong' turbulence if a non-propagating mode (toroidal here) coexists with wave (3D gravity waves here) modes.

- MHD turbulence: Illustration of Alfven waves altered by a possible anisotropic cut-off from Joule dissipation; brief reminder of recent results of pure `Alfvenic' wave-turbulence.

Finally, all the preceding examples deal with three-wave (triadic) interactions; discussion could be open for the case of four-waves interactions, which are often encountered in quasi-2D isotropic flows, as well as in plasmas.

Nonlinear dynamics of multiple NTMs in tokamaks

D. Chandra[1,2,4], O. Agullo[1,2], S. Benkadda[1,2], X. Garbet[3] and A. Sen[4]

[1]France-Japan Magnetic Fusion Laboratory, LIA 336 CNRS,
75794 Paris cedex 16, France

[2] Equipe Dynamique des Systemes Complexes, UMR 6633
CNRS-Universite de Provence, 13397 Marseille cedex 20, France

[3]Association Euratom-CEA, DRFC, CEA Cadarache,
13108 St-Paul-Lez-Durance, France

[4]Institute for Plasma Research, Bhat, Gandhinagar 382428, India

Abstract

Neoclassical tearing modes are one of the most serious concerns for operation of the next-step fusion devices such as ITER [1]. Recently ASDEX and JET experiments have shown that multiple NTMs can get coupled and the occurence of one NTM can limit the growth of the other NTM [2, 3]. Though there have been a few studies [4, 5] investigating the dynamics of multiple NTMs, the phenomenon is far from being well understood. We have carried out numerical simulations investigating the interaction of co-existent 2/1 and 3/1 NTMs using a 3D toroidal code [6] based on a set of generalized reduced MHD equations. The results show that the coupling between these NTMs leads to oscillations of energies. These GAM (geodesic accoustic mode)-like oscillations are observed in the presence of the neoclassical electron stress tensor term. Concommitantly the flow energy becomes higher than the magnetic energies of the modes. The perpendicular flows are found to spread out from the resonant surfaces and to get coupled between the different modes. There are also some large oscillations which appear in the Rutherford phase of time evolution in the presence of nonlinear V_k terms, but these get diminished at saturation.

References

[1] T.C. Hender, J.C. Wesley, J. Bialek et. al., Nucl. Fusion 47, (2007) S128.

[2] S. Gunter, M. Maraschek, M. de Baar et. al., Nucl. Fusion 44 (2004) 524.

[3] M.F.F. Nave, E. Lazzaro, R. Coelho et. al., Nucl. Fusion 43 (2003) 179.

[4] Q. Yu, S. Gunter, K. Lackner et. al., Nucl. Fusion 40 (2000) 2031.

[5] H. Lutjens and J-F Luciani, Phys. Plasmas 13 (2006) 112501.

[6] D. Chandra, A. Sen, P. Kaw et. al., Nucl. Fusion 45 (2005) 524.

Multiscale Full-f particle simulation of ITG turbulence in the core and edge of a real geometry tokamak plasma[a)]

C.S. Chang[1], S. Ku[1] and the CPES Team[2]

[1]Courant Institute of Mathematical Sciences, New York University, USA.
[2]SciDAC FSP Prototype Center for Plasma Edge Simulation, USA
E-mail: cschang@cims.nyu.edu

We report new core and edge multiscale physics of the ITG (ion temperature gradient) turbulence including the turbulence-driven mean and neoclassical background dynamics, using a full-f gyrokinetic particle code XGC1 in a real tokamak geometry with the magnetic X-point and the grounded material wall (input from a numerical g-eqdsk file). Full-f results will be compared with the conventional delta-f results in the core plasma. The edge ITG behavior in the L-mode pedestal across the magnetic separatrix is found to be quite different from the core ITG. Multiscale nature of the ITG turbulence will be discussed.

[a)]Work supported by US DOE

Spreading of SOL flow patterns into the edge plasma

G. Ciraolo[1], G. Chiavassa[1], P Haldenwang[1], E. Serre[1]

Ph. Ghendrih[2], Y. Sarazin[2], P. Tamain[2], X. Garbet[2]

[1] MSNM-GP, UMR 6181, La Jetée-Technopôle de Château Gombert, 38 rue Frédéric Joliot-Curie, F-13451 Marseille Cedex 20, France
[2] Association Euratom-CEA, CEA Cadarache, F-13108 St. Paul-lez-Durance, France

It is now recognised that plasma rotation is a key element to estimate the confinement performance of future devices such as ITER. Indeed, rotation will play a role on MHD activity as well as turbulent transport. For the latter, the transition region between closed and open magnetic flux surfaces plays a crucial role since an edge transport barrier can develop spontaneously in its vicinity. This leads to the so-called H-moderegime that is the reference scenario for ITER. Appropriate understanding of the edge region remains a major challenge owing to several open issues as momentum transport, turbulence overshoot or neutral penetration.
We consider a here a transport model system to investigate the propagation of parallel momentum from the SOL into the core plasma. The conservation equations of both density and momentum in the parallel direction are treated in two dimensions (2D), namely the parallel and the radial coordinates. The geometry of the problem includes the transition from the periodic region (closed magnetic flux surfaces) to the non periodic region (open magnetic flux surfaces) in the parallel direction. Appropriate boundary conditions for velocity and density, the so-called Bohm conditions, govern the properties of the interaction with the limiter. This leads to a complex boundary layer problem which requires appropriate numerical scheme to conjugate precision and stability in the transition region.
The control parameters of this system are the aspect ratios of the various scales, radial and parallel as well as limiter radial extent compared to the parallel scale. A third control parameter is the ratio of particle diffusion to momentum diffusion. The flow pattern is observed to vary in the radial direction with a sharp transition at the last closed magnetic surface. Spreading of these flow properties into the SOL, as well as into the core, are readily observed. The scaling properties of this flow pattern are under investigation. The structure of the density field reflects some of the properties of the flow pattern but also exhibits two radial scales in the density gradient. The analysis of the flow pattern indicates very sharp variation as well as spreading effects. Such features are important to understand the edge/SOL interplay and model 3D effects including Kelvin Helmholtz instabilities.

Angular momentum generation in bounded 2D turbulent flows

G.H. Keetels, H.J.H. Clercx, and G.J.F. van Heijst

TU Eindhoven, The Netherlands

Spontaneous spin-up, i.e. the significant increase of the total angular momentum of a flow that initially has no net angular momentum, is very characteristic for decaying 2D in square domains bounded by rigid no-slip walls [1]. We address this phenomenon first with numerical simulations where the integral-scale Reynolds number of the initial flow is increased by an order of magnitude with respect to previously reported results [2]. These high-Reynolds number simulations are achieved by means of a novel volume-penalization technique to model the no-slip boundary condition in a parallel Fourier spectral scheme [3]. It is observed that spontaneous spin-up is of crucial importance for the evolution of high-Reynolds number flow, as well. In addition, several properties of the time-series of the pressure fluctuations at the domain boundaries and the resulting torque that drives the spin-up process are considered.

In contrast, spontaneous spin-up is virtually absent for such flows in a circular domain with a no-slip boundary [4,5]. In order to acquire understanding of this strikingly different behavior observed on the square and the circle we consider a set of elliptic geometries with a gradual increase of the eccentricity. It is shown that a variation of the eccentricity can be used as a control parameter to tune the relative contribution of the pressure and viscous stresses in the angular momentum balance. Direct numerical simulations demonstrate that the magnitude of the torque can be related to the relative contribution of the pressure. As a consequence, the number of spin-up events in an ensemble of slightly different initial conditions strongly depends on the eccentricity.

For small eccentricities strong and rapid spin-up events are observed occasionally whereas the majority of the runs does not show significant spin-up. For sufficiently large eccentricities all the runs in the ensemble demonstrate strong and rapid spin-up, which is consistent with the flow development on the square. It is verified that the number of spin-up events for a given eccentricity does not depend on the Reynolds number of the flow. This observation is consistent with the conjecture that it is the pressure on the domain boundaries that drives the spin-up processes.

References:

[1] H.J.H. Clercx, S.R. Maassen, and G.J.F. van Heijst. Phys. Rev. Lett. 80, 5129 (1998).

[2] H.J.H. Clercx, A.H. Nielsen, D.J. Torres, and E.A. Coutsias. Eur. J. Mech. B/Fluids 20, 557 (2001).

[3] G.H. Keetels, U. d'Ortona, W. Kramer, H.J.H. Clercx, K. Schneider, and G.J.F. van Heijst. J. Comput. Phys. 227, 919 (2007).

[4] S. Li and D. Montgomery, Phys. Lett. A 218, 281 (1996).

[5] K. Schneider and M. Farge. Phys. Rev. Lett. 95, 244502 (2005).

Theoretical Approaches to Model Reduction and Description of Multi-Scale Interaction in Tokamak Plasma Turbulence

P.H. Diamond

Center for Astrophysics and Space Sciences, Department of Physics
University of California, San Diego, La Jolla, CA 92093-0424 USA

In this talk, I will discuss issues and critical uncertainties and shortcomings in current approaches to model reduction and description of multi-scale interaction in tokamak plasma turbulence. The applications discussed include zonal flow-drift wave interaction, transport barrier evolution and the interaction of drift wave turbulence with magnetic islands.

The most frequently utilized approaches to model reduction are:

a.) adiabatic theory and wave kinetics,
b.) Mori-Zwanzig type projection methods involving a memory function of variable width.

Adiabatic theory is based on the Liouvillian evolution of a conserved, phase-independent population density, which usually (but not always) corresponds to the wave action density. Of course, wave kinetics corresponds to the short-wavelength limit of reductive perturbation theory for phase and intensity evolution. Mori-Zwanzig theory seeks to project 'fast' variables onto the explicit 'slow' variables. It is assumed (hoped) that the fast variables 'equilibrate' on a time scale which is fast relative to slow variable evolution. Both approaches require some nominal separation of spatio-temporal scales, and so both are utilized primarily in applications to disparate scale interaction.

Here, we critically discuss the soft points of these approaches to modelling. The list includes, but is not limited to:

i.) What is the conserved population density? In systems with multiple quadratic inviscid invariants, wave action is not always the obvious choice.

ii.) What sets the oft-assumed, but rarely discussed, mean population - or equivalently, do fast variables really equilibrate? Is the time scale for equilibration sufficiently rapid?

iii.) Do the necessary moments of the mean population or equilibrium distribution of fast variables actually exist? Is some sort of fractional kinetics approach to adiabatic elimination needed, and even possible?

iv.) How do we handle strong anisotropy where scale separation applies in some directions but not in all?

v.) How well does the model reduction perform near the threshold of transport bifurcations?

vi.) If phase stochasticity (i.e. the random phase approximation) is utilized, what is the justification?

vii.) How do we treat the simultaneous incidence of local nonlinear transfer (especially inverse cascades) and disparate scale interaction?

viii.) Can any of these theoretical ideas be utilized in numerical simulations?

The theoretical issues enumerated above will be discussed in light of the specific applications we are concerned with. Some ideas and speculations on possible improvements are offered.

A space-time adaptive multiresolution scheme: applications to evolutionary PDEs

Margarete Oliveira Domingues
Laboratorio Associado de Computacao e Matematica Aplicada (LAC),
Centro de Tecnologias Especiais, Instituto Nacional de Pesquisas Espaciais (INPE),
Av. dos Astronautas, 1758, 12227-010 Sao Jose dos Campos, Brasil

Sônia M. Gomes
Universidade Estadual de Campinas, IMECC. Caixa Postal 6065. 13083-970
Campinas SP, Brasil. soniag@ime.unicamp.br

Olivier Roussel
Institut für Technische Chemie und Polymerchemie (TCP),
Universität Karlsruhe, Kaiserstr. 12, 76128 Karlsruhe, Germany

Kai Schneider
Laboratoire de Modélisation et Simulation Numérique en Mécanique et Génie
des Procédés (MSNM-GP),
CNRS and Universités d'Aix-Marseille, 38, rue F. Joliot-Curie,
13451 Marseille Cedex 20, France

Centre de Mathématiques et d'Informatique (CMI),
Université de Provence, 39 rue F. Joliot-Curie,
13453 Marseille Cedex 13, France

A multiresolution adaptative scheme for evolutionary PDEs based on a finite volume discretization with an explicit Runge-Kutta scale dependant time step for time discretization is presented. This multiscale strategy allows local grid refinement, while controlling the approximation error in space and it permits that the costly fluxes are evaluated only on this adaptive grid. A time step for the finest scale is choosen, due to the stability requirement of the explicit Runge-Kutta scheme used, and it is proportionally ajusted to the others coarser scales. This multiscale strategy implementation uses a dynamic tree data structure that allows memory compression and CPU time reduction. The combined space-time numerical scheme is validated and applied to a 3D space evolutionary problem for an efficiency verification. The gain in memory and CPU time without significant lost in accuracy demonstrates the efficiency of the method.

References:

M. Domingues, S. Gomes, O. Roussel and K. Schneider.
An adaptive multiresolution scheme with local time-stepping for evolutionary PDEs.
J. Comput. Phys., 227, 3758–3780, 2008.

M. Domingues, S. Gomes, O. Roussel and K. Schneider.
Space-Time adaptive multiresolution methods for hyperbolic conservation laws:
Applications to compressible Euler equations.
Appl. Num. Math., 2007, under revision.

Hyperviscosity, Galerkin truncation and bottlenecks in turbulence

Uriel Frisch

Observatoire Nice, France

Abstract: It is shown that the use of a high power α of the Laplacian in the dissipative term of hydrodynamical equations leads asymptotically to truncated inviscid conservative dynamics with a finite range of spatial Fourier modes. Those at large wavenumbers thermalize, whereas modes at small wavenumbers obey ordinary viscous dynamics [C. Cichowlas et al. Phys. Rev. Lett. 95, 264502 (2005)]. The energy bottleneck observed for finite α may be interpreted as incomplete thermalization. Artifacts arising from models with $\alpha > 1$ are discussed.

Authors: Uriel Frisch, Susan Kurien, Rahul Pandit, Walter Pauls,
Samriddhi Sankar Ray, Achim Wirth and Jian-Zhou Zhu

Submitted to Phys. Rev. Lett. Also available at
http://arxiv.org/abs/0803.4269

Multiscaling analysis of the spatio-temporal dynamics of impurity transport in magnetized plasmas

S. Futatani[1,2], S. Benkadda[1], D. del-Castillo-Negrete[3]

[1]France-Japan Magnetic Fusion Laboratory LIA 336 CNRS/ UMR 6633
CNRS-Université de Provence, Marseille, France

[2]Graduate School of Energy Science, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan

[3]Oak Ridge National Laboratory, Oak Ridge, TN 37831, United States

Impurities in fusion confinement devices can affect the confinement properties, they can in particular enhance the radiative energy losses and dilute the hydrogen fuel within the core plasma. It is thus important to understand impurity transport mechanisms in turbulent plasmas.

The present study focuses on the advection properties of impurities in the resistive drift wave turbulence modeled by the Hasagawa-Wkatani (HW) equations. Impurities are modeled as a passive scalar advected by the plasma turbulent flow. Three cases of HW system are studied: the adiabatic case, the quasi-adiabatic one and the hydrodynamic regime. A spatiotemporal analysis using Proper Orthogonal Decomposition (POD) technique will be used to characterize the dynamics of impurity in the turbulent plasma flow.

Massively Parallel Simulations of Lagrangian Plasma Turbulence

Rainer Grauer

Universität Bochum, Germany

Abstract:

We report on a comparison of high-resolution numerical simulations of Lagrangian particles advected by incompressible turbulent hydro- and magnetohydrodynamic (MHD) flows. Numerical simulations were performed with up to 1024^3 collocation points and 10 million particles in the Navier-Stokes case and 512^3 collocation points and 1 million particles in the MHD case. In the hydrodynamics case our findings compare with recent experiments from Mordant et al (2004) and Xu et al. (2005). Our simulations reveal that Lagrangian Navier-Stokes turbulence is more intermittent than MHD turbulence, whereas the situation is reversed in the Eulerian case. The crucial point is that the geometry of the dissipative structures have different implications for Lagrangian and Eulerian intermittency. This motivates a new definition of a Lagrangian structure function which allows to establish a connection to Eulerian transversal structure functions.

Gyrokinetic Description of Tokamak Core Turbulence; Theory, Simulation, and Comparisons to Experiments

T.S. Hahm

Princeton University, Plasma Physics Laboratory, Princeton, NJ 08543, USA

Abstract

In the past decade, considerable progress in understanding tokamak core turbulence and transport has been made thanks to advances in experimental measurements, nonlinear gyrokinetic simulations, and nonlinear theory. In this presentation, after a brief description of properties of tokamak core turbulence and physics behind the modern gyrokinetic theory, a few examples for which effective interactions among theorists and experimentalists led to significant achievements will be illustrated. Outstanding remaining problems will be discussed at the end.

Three-wave coupling of drift waves in tokamak core plasmas

Yasuji Hamada*,

NIFS, Japan

The three-wave interaction of drift waves in the hot core of tokamak plasmas is now measured for the first time by a heavy ion beam probe (HIBP) in JIPPT-IIU tokamak plasmas. These measurements of bicoherence of drift waves in the core plasma become feasible by Milligen's wavelet bicoherence method and also by the locality of HIBP measurements. General feature of measured bicoherence is not in contradiction with the requirement from by Hasegawa-Mima equation. The integration effect on the finite size of the sample volumes, however, severely limits the sensitivity of the short-wave measurement, we want to insist that the inverse cascading is stronger compared to cascading and the coupling of zonal flow with drift wave turbulence (in a sense, inverse cascading) is experimentally found to be strong. The three-wave coupling of drift-wave turbulence with zonal flows strongly support the present understanding that zonal flows are generated by drift wave turbulence.

* Also ERUSMUS MUNDUS visiting professor, to Complutense University de Madrid, Stuttgart University and Ghent University.

Validation of Nonlinear Simulations of Core Tokamak Turbulence: Current Status and Future Directions

C. Holland

University of California, San Diego

The process of verifying and validating transport and turbulence models is now recognized as an essential component for building and quantifying our confidence in these models. A particularly important part of the validation process for simulations of plasma turbulence is to compare code predictions against experimental measurements of fluctuations at multiple levels of the so-called primacy hierarchy, ranging from cross-phases and bicoherences to power spectra to heat and particle fluxes. In this talk, I will present an overview of the current status of research in this area, primarily using recent work [1] modeling a steady DIII-D L-mode discharge with the GYRO code as a case study. Highlighted topics will include assessing the success of fixed-gradient local and non-local simulations in reproducing experimental fluctuation measurements, the importance of using synthetic diagnostics in these comparisons, and the impact of statistical and systematic uncertainties in both the data input into the code (e.g. profiles and geometry) as well as in code output. I will then present some thoughts on future directions for improving the success of these models. In particular, I will discuss the need for (and limitations of) fixed-flux rather than fixed-gradient simulations. The issues of core-edge coupling and development of validation metrics will also be examined as necessary future topics of investigation. Finally, I will propose some experimental measurements which would significantly advance the validation of these codes.

[1] A. E. White et al., “Measurements of core electron temperature and density fluctuations in DIII-D and comparison to nonlinear gyrokinetic simulations,” submitted to Physics of Plasmas (2007)

Numerical modeling of transport within Tokamak edge plasma

Livia Isoardi, Guido Ciraolo

M2P2-CNRS, Marseille, France

The transition region between closed and open magnetic flux surfaces plays a crucial role since an edge transport barrier can develop spontaneously in its vicinity. This leads to an improved confinement regime that is the reference scenario for ITER. This is a rich variety of complex boundary layer problem and requires a powerful numerical treatment for the interface between the edge region and the core.
We consider a 2D fluid model based on the conservation of the ion density n_i and parallel particle flux $G_{//} = n_i v_{//}$ under the assumption of electroneutrality, with constant ion and electron temperatures Ti and Te and with dissipative *D* and viscosity n coefficients. Bohm conditions provide boundary conditions at the limiter for the velocity and the density.
The 2D solutions are obtained by using a second order Lax-Wendroff finite-difference scheme coupled with a flux limiter technique in order both to prevent oscillations caused by strong discontinuities and to guarantee a reasonable level of numerical dissipation.
The flow pattern has been investigated by varying the control parameters. The results show in particular a limit behavior at large Peclet number with the occurrence of a density barrier. Moreover, a non-zero parallel velocity at the boundary conditions with the core as well as an over density localized in space and time are used to simply model an effect of plasma and ice cube injection, respectively. The plasma rotation breaks the symmetry of the pattern whereas the over-density induces high perturbations in the plasma with the occurrence of a density front which propagates on field lines.

Multi-scale interactions in plasma microturbulence

Frank Jenko

MPI, Garching

Turbulence in magnetized plasmas can be driven by a number of different microinstabilities which can differ in space and time scales by up to a factor of about 100. Only recently have supercomputers become powerful enough to make nonlinear multi-scale simulations feasible. Interesting new effects discovered this way will be discussed, and the question of their theoretical description will be addressed.

Lagrangian acceleration in confined turbulent flow

Benjamin Kadoch[1], Wouter J.T. Bos[1,2], Kai Schneider[1]

[1] M2P2-CNRS and CMI, Université de Provence, Marseille, France
[2] LMFA, CNRS, Ecole Centrale de Lyon - UCBL - INSA, Lyon, France

A Lagrangian study of two-dimensional turbulence for two different geometries, a periodic and a confined circular geometry, is presented to investigate the influence of solid boundaries on the Lagrangian dynamics. It is found that the Lagrangian acceleration is even more intermittent in the confined domain than in the periodic domain. The flatness of the Lagrangian acceleration as a function of the radius shows that the influence of the wall on the Lagrangian dynamics becomes negligible in the center of the domain and it also reveals that the wall is responsible for the increased intermittency. The transition in the Lagrangian statistics between this region, not directly influenced by the walls, and a critical radius which defines a Lagrangian boundary layer, is shown to be very sharp with a sudden increase of the acceleration flatness from about 5 to about 20.

References:

[1] B. Kadoch, W. J. T. Bos and K. Schneider.
Extreme Lagrangian acceleration in confined turbulent flow.
Phys. Rev. Lett., 02/20087, accepted.
http://arxiv.org/abs/0802.3139

Lagrangian Particle Simulations of Plasmas and Fluids

Bob Krasny

University Michigan, USA

Abstract: This talk describes recent Lagrangian simulations of electrostatic collisionless plasmas and incompressible fluids. In both cases, the standard Eulerian formulation is replaced by a Lagrangian formulation in terms of the flow map. This leads naturally to a particle discretization. The particles carry electric charge in the case of a plasma and vorticity in the case of a fluid. The induced electric field and velocity are expressed as singular integrals. The numerical method uses kernel regularization for stability, adaptive particle insertion for accuracy, and a multipole treecode for efficiency. Examples to be presented include electron beams in 1D plasmas, and vortex sheets and vortex rings in 2D and 3D fluids. The Lagrangian approach gives direct access to dynamics, revealing the onset of chaos in these flows.

Weakly non linear analysis of a rotating and precessing inviscid fluid in a cylinder and generation of differential rotational mean flow

T. Lehner, J. Léorat, W.Mouhali

Luth,Cnrs,UMR8102,Observatory of Paris-Meudon, France

A. Mahalov

University of Arizona, Tempe, USA

Abstract : We undertake a weakly non linear analysis of a fluid submitted to both rotation and precession into a (finite or infinite) cylinder, by considering the modes coupling of two Kelvin (inertial) waves. The linear parametric instability known for this system is shown to saturate when one expands the Navier-Stokes equation to higher order in the assumed small precession parameter (ratio of precession to rotation frequencies) with the derivation of two coupled (Ginzburg) Landau equations to describe the dynamics of the modes. It is shown that an azimuthal mean flow with differential rotation is generated by this modes coupling. The time evolution of the associated dynamical system is studied. Its behavior can be compared with our own experiments together with relevant numerical simulations. Mechanisms for mean flow generation with differential rotation in the present case differ from other contribution due to viscosity effects.

Adaptive wavelet collocation method for PDEs

Mani MEHRA

IIT, Department of Computer Science and Engineering, New Delhi, INDIA

In this talk the focus is on dynamic adaptive wavelet collocation method for solving partial differential equations on sphere. The method is based on second-generation spherical wavelets based on spherical triangular grids. The accuracy and efficiency of the method is shown by several useful tests (application of spherical wavelets to geophysical turbulence, solid body rotation of cosine bell which is the most challenging problem of modern computational fluid dynamics). Thus, the strength of new method is that it can be easily extended to the whole class of manifolds other than sphere.

Boundary Conditions for Turbulent Fluids and Magnetofluids

David Montgomery

Physics and Astronomy Department
Dartmouth College, Hanover, New Hampshire 03755-3528, U.S.A.

Much if not most of the turbulent behavior in fluids and magnetofluids results from what is done to them at their boundaries. Yet turbulence theory has focused primarily on homogeneous (unbounded or periodic) cases, with perhaps a disproportionate emphasis on “universal” spectral and/or correlation behavior. Recent large numerical simulations suggest a “lack of universality,” a euphemistic way of saying that Kolmogorov-Obukhov theory has established itself as being satisfactory as far as it goes, but may be close to exhaustion as a source of new physical insights or more revealing accuracy. More attention might perhaps now be directed toward questions of bounded turbulence, and how particular boundaries and boundary conditions influence global properties of flows. The need seems particularly acute in magnetohydrodynamics (MHD). There, electrochemical processes at the boundary regions are so complicated as to seem to defy attempts to identify tractable boundary conditions for use in global magnetofluid codes when predictions for large-scale, nonlinear flows are the need (for example, in ITER). In neutral fluids, there is no shortage of “microfluidic” explorations of interfaces between material walls and fluids at the molecular level, but the results remain difficult to translate into fluid boundary conditions that would replace the common textbook ones (no-slip, stress-free, “free-slip,” etc.) in use. In MHD, diagnostics and theory for the “edge region” of confinement devices are difficult and contingent on a variety of conditions, and probably involve plasma physics in a regime in which fluid approximations themselves are difficult to believe in. Nevertheless, if theory is to have a global predictive role to play, there seems to be little choice but to undertake serious computations with non-ideal boundary conditions that are undoubtedly grossly oversimplified but may be the best ones presently available. This talk will survey several cases of wall-bounded turbulent computations, Navier-Stokes and MHD, some of which the author has been involved with and some that are taken from others’ literature. The goals are to stimulate additional computational attempts and to clarify what remain embarrassingly simple questions about mathematical conditions for interfaces between fluids and magnetofluids, and their material boundaries.

Nonlinear Dynamics of Magnetic Islands Imbedded in Edge Tokamak Plasma Microturbulence.

M. Muraglia[1], O. Agullo[1], S. Benkadda[1], P. Beyer[1], X. Garbet[2]

[1]France-Japan Magnetic Fusion Laboratory LIA 336 CNRS/ UMR 6633
CNRS-Université de Provence, Marseille, France
[2]Association EURATOM-CEA DRFC CEA-Cadarache, St. Paul Lez Durance, France

In tokamaks, macroscale MHD instabilities (magnetic islands) coexist with microscale turbulent fluctuations and zonal flows. Although many works were devoted to the study of macroscale and microscale instabilities separately, only few investigations explored the mutual interaction between these instabilities [1, 2]. We address here the multiscalenonlinear dynamics between macroscale tearing instabilities and gradient pressure driven microinstabilities (resistive interchange) by solving reduced MHD equations numerically.

The numerical study shows existence of regimes where the tearing instability in both, the linear and nonlinear phase, is controlled by pressure gradient properties. An interplay between the pressure and the magnetic flux controls the dynamics of the saturated state. A secondary instability can destabilize the magnetic island and produces an island poloidal rotation.

We show that interchange unstable modes are at the origin of the secondary instability. Convective cells growth and destabilize the macrotearingstructure. A zonal flow is generated and allows the magnetic island rotation. We also study the nature of these regimes according
to the viscosity values.

References

1] C. J. McDevitt, P. H. Diamond., *Phys. Plasmas* 13, 032302 (2006).

2] A. Ishizawa et al, *IAEA proceedings*, Chengdu 2006, TH/P221.

Issues in plasma edge turbulence: simulating complex behaviour

Volker Naulin

Risoe National Laboratory, Technical University of Denmark;
presently at JET

Extremely important for the success of magnetised plasma as a means of making nuclear fusion a viable energy source is good energy confinement. A most important part in achieving the so-called high confinement regime, or H-mode, is the transport barrier at the edge of the plasma, where the confining magnetic field lines open to end on material surfaces. Understanding, simulating and modelling the plasma edge, defined as the density gradient region together with the scrape off layer (SOL), are important steps in creating a predictive capability for present and future fusion devices. Transport into the SOL in the form of large events, like ELMs, is severely restricting the operating space of ITER, the new large fusion experiment presently constructed near Cadarache, France, and machines beyond.
Numerical simulations have in the last decade come to the point, where comparison with experiment begins to become realistic. Results from 3D flux simulations of electromagnetic turbulence using scale separation between background and fluctuations demonstrate the basic mechanisms of flow generation from turbulence. In realistic geometry, however, the flow energy never exceeds the energy content of the turbulence, demonstrating the lack of ingredients to form an edge transport barrier within such models. Further outward in the SOL scale separation is not at all applicable. A large part of the observed dynamics in the SOL is determined by the lack of scale separation, resulting in fluctuations locally and temporarily exceeding the average by orders of magnitude. Transport in these regions is carried by localised structures, leading to skewed PDFs and breaking the assumptions of diffusive, Fick type of transport law. Plasma in the edge shows a number of properties of complex, self organised, critical systems. Thus modelling the plasma edge from first principles needs to surpass the traditional paradigms of transport models to provide technically meaningful data.

Magnetic spin-up in two-dimensional containers

Salah Neffaa[1], Wouter J.T. Bos[1,2], Kai Schneider[1]

[1] M2P2-CNRS and CMI, Université de Provence, Marseille, France
[2] LMFA, CNRS, Ecole Centrale de Lyon - UCBL - INSA, Lyon, France

The spontaneous spin-up, observed in two-dimensional hydrodynamic turbulence in non-axisymmetric geometries (Clercx et al. Phys. Rev. Lett., 1998), is found to be replaced by generation of a magnetic moment in decaying MHD turbulence.

Wavelets meet Burgulence: CVS filtered Burgers equation

Romain Nguyen van yen[1], Marie Farge[1], Dmitry Kolomenskiy[2], Kai Schneider[2] and Nick Kingsbury[3]

[1]LMD–CNRS, Ecole Normale Supérieure, Paris, France
[2]M2P2–CNRS & CMI, Université de Provence, Marseille, France
[3]Deptartment of Engineering, University of Cambridge, UK

Numerical experiments of the one dimensional inviscid Burgers equation show that filtering the solution at each time step in a way similar to CVS (Coherent Vortex Simulation) gives the solution of the viscous Burgers equation. The CVS filter used here is based on a complex valued translation invariant wavelet representation of the velocity, from which one selects the wavelet coefficients having modulus larger than a threshold whose value is iteratively estimated. The flow evolution is computed from either deterministic or from random initial conditions.

References:

R. Nguyen van yen, M. Farge, D. Kolomenskiy, K. Schneider and N. Kingsbury.
Wavelets meet Burgulence: CVS-filtered Burgers equation.
Physica D, 2008, doi:10.1016/j.physd.2008.02.011, in press.

Rotation of Magnetic Islands with Micro-Scale Fluctuations

S. Nishimura[1,2,3], S. Benkadda[2,3], M. Yagi[2,4], S.-I. Itoh[2,4], K. Itoh[2,5]

[1] *Interdisciplinary Graduate School of Engineering Sciences, Kyushu University*
[2] *France-Japan Magnetic Fusion Laboratory, LIA 336 CNRS*
[3] *Equipe DSC, Laboratoire PIIM, UMR 6633 CNRS-Université de Provence*
[4] *Research Institute for Applied Mechanics, Kyushu University*
[5] *National Institute for Fusion Science*

The control of magnetic islands is one of important issues for the magnetically confined fusion plasmas. Magnetic islands rearrange ideal equilibrium profiles, and cause the upper limitation of the β value. In addition, the locking of the rotation of magnetic islands occasionally induces the so-called 'disruption'. Much works have been done for the stability of magnetic islands, and it has been pointed out that many factors should be considered (free energy sources, parallel transport, curvatures and external oscillations, etc). Especially, the rotation of magnetic islands is an important factor for the excitation of magnetic islands via the polarization current[1] and also the control of the disruption. More analytical and numerical investigations are necessary to understand the basic mechanism of the rotation of magnetic islands. Simultaneously, multi-scale interaction between magnetic islands and micro-fluctuations should be investigated, because fusion plasmas are strongly turbulent. We introduce a reduced set of two-fluid equations and perform numerical nonlinear simulations. Firstly, we examine the parameter dependence of the rotation of magnetic islands, where only the linear drift-tearing mode is unstable. It is found that the direction of the rotation is changed, according to values of ion viscosity and parallel resistivity. Basic mechanism of this phenomenon is related with self-generated $E\times B$ flow, where these transport coefficients change the balance between Reynolds stress and Maxwell stress[2]. Secondly, considering the effective gravitational force, we simulate the drift-tearing mode coexisting with the linearly unstable resistive interchange mode. We observe that, if the linear growthrate of the resistive interchange mode is larger than that of the drift-tearing mode, the growth and the rotation of magnetic islands are strongly affected by micro-fluctuations generated by the resistive interchange mode, in the condition where the energy of magnetic islands is smaller than that of micro-fluctuations.

References

[1] J. W. Connor, F. L. Waelbroeck, H. R. Wilson, Phys. Plasmas 8, 2835 (2001).
[2] S. Nishimuira, M. Yagi, S.-I. Itoh, K. Itoh, J. Phys. Soc. Jpn 77, 014501 (2008).

A finite element approach of nonlinear Magnetohydrodynamics (MHD) problems in bounded geometries

C. Nore[1], A. Ribeiro[1], K. Boronska[1], R. Laguerre[2], J.-L. Guermond[1,3] and J. Léorat[4]

[1]: LIMSI-CNRS, Bâtiment 508, BP 133, 91403 Orsay cedex
[2]: Université Libre de Bruxelles, CP231, boulevard du Triomphe, 1050 Bruxelles
[3]: Department of Mathematics, Texas A&M University, College Station, TX 77843
[4]: CNRS and Observatoire de Paris-Meudon, Place Janssen 02195-Meudon

Although the magnetic and the velocity fields verify similar evolution equations, the numerical implementation of the magnetic boundary conditions is a challenge in the common situation where the flow is embedded in a simply-connected insulating medium. As Maxwell equations apply in the whole numerical domain, continuity of the magnetic field with an exterior magnetic potential field must be ensured, which explains that most of the numerical studies of dynamo action involve restricted geometries: 3D periodic, spheres, slabs or infinite cylinders. In order to cope with realistic geometries of experimental or astrophysical interests, such as finite cylinders, disks, or ellipsoïds, we use a nonlinear FEM code, based on a new MHD algorithm (Guermond et al., JCP, **221**, 349-369, 2007). It allows treating MHD problems with axisymmetric interfaces between domains of uniform conductivity, of meridional sections of arbitrary shape. It has been validated on kinematic dynamo problems (Laguerre et al., CR Mécanique 334, 593-598, 2006) and is currently used to model various problems such as Alfvén waves in a cylinder or nonlinear dynamo action between finite Taylor-Couette cylinders. In the future, we plan to extend our code to Large Eddy Simulations MHD models in order to study turbulence.

Progress in the Variational Multiscale Formulation of Large Eddy Simulation

A. A. Oberai

Department of Mechanical Aerospace and Nuclear Engineering
Rensselaer Polytechnic Institute, USA

In the variational multiscale (VMS) formulation of large eddy simulation subgrid models are introduced in the variational (or weak) formulation of the Navier Stokes equations and a-priori scale separation is accomplished using projection operators to create coarse and fine scales. This separation leads to two sets of evolution equations: one for the coarse scales and another for the fine scales. The coarse scale equations are solved numerically while the fine scale equations are solved analytically to obtain an expression for the fine scales in terms of the coarse scales and hence achieve closure. Till date, the VMS formulation has lead to accurate results in the simulation of canonical turbulent flow problems. It has been implemented using spectral, finite element and finite volume methods.

In this talk, for the incompressible Navier Stokes equations, we will present some new ideas for modeling the fine scales within the context of the VMS formulation and discuss their impact on the coarse scale solution. We will present a simple residual-based approximation for the fine scales that accurately models the cross-stress term and demonstrate that when this term is append with an eddy viscosity model for the Reynolds stress, a new mixed-model is obtained. The application of these ideas will be illustrated through some simple numerical examples.

MHD Turbulence: What can we learn from simple models?

Rahul Pandit

Indian Institute of Science, Bangalore, India

Abstract - We give an introduction to a shell model for MHD and a Burgers-model analog for MHD. We show that the shell model for MHD turbulence can be studied at resolutions that are far in excess of those that can be achieved, at the moment, with the MHD equations in three dimensions. Early work on the multiscaling of structure functions is described briefly. We then show how to carry out a detailed study of dynamo action in the shell model for turbulence at both high Reynolds numbers and very low magnetic Prandtl numbers. We present the stability diagram of the turbulent dynamo in this MHD shell model in the magnetic Prandtl number and magnetic Reynolds number plane and show that a fractal-type boundary separates the dynamo and no dynamo regimes. Preliminary studies of the Burgers-model analog of the MHD equations are covered briefly.

Superdiffusive transport in astrophysical plasmas

S. Perri and G. Zimbardo

Dipartimento di Fisica, Universite della Calabria, Ponte P. Bucci, Cubo 31C,
I-87036 Arcavacata di Rende, Italy

Abstract:

Anomalous transport regimes, corresponding to either superdiffusion or subdiffusion, have been observed both in laboratory plasma experiments and in numerical simulations. The problem of particle transport in turbulent fluids and plasmas has a crucial role in understanding the influence of turbulence properties. Many works have highlighted that the dynamical properties of particles strongly depend on the turbulence level and on the turbulence anisotropy. In the case of superdiffusion, transport can be described by a Levy random walk and by the corresponding propagator, which exhibits power law tails.

In this work we study the propagation of energetic electrons in the presence of magnetic turbulence in the solar wind. These electrons are accelerated by corotating interaction region (CIR) shocks, forming by the interaction of fast and slow streams in the solar wind, and propagate upstream of the shock. By using the appropriate propagator, we show that in the case of superdiffusive transport, the time profile of particles accelerated at a traveling planar shock is a power law with slope γ, rather than an exponential decay as expected in the case of normal diffusion. By analyzing a dataset of CIR shocks in the solar wind, we find that the time profiles of energetic electrons, with energies between 65 and 290 keV, correspond to power laws, with slopes $\gamma \approx 0.30 - 0.98$, implying a mean square displacement $<\Delta x^2> \propto t^\alpha$, with $\alpha >1$, i.e., superdiffusion. These results indicate that, at least for electrons, the standard paradigm of diffusive shock acceleration has to be revised.

MHD turbulence: interactions of eddies and waves

Annick Pouquet

National Center for Atmospheric Research, Boulder (CO), pouquet@ucar.edu

Magnetohydrodynamic (MHD) turbulence is found, e.g. in the interstellar medium, in the solar wind and convection zone or in the magnetosphere of planets. In that context, a brief review of what are the known properties of MHD turbulence will be given, as well as what are the more numerous questions concerning its dynamics. Some of the illustrations will stem from two sets of recent direct numerical simulations of three-dimensional MHD at high Reynolds number on grids of 1536^3 points [1,2] or an equivalent grid of 2048^3 points implementing the symmetries of the Taylor-Green flow, as used in several laboratory experiments [3]. Such flows are incompressible and decaying in time, and the initial conditions are either a superposition of large scale ABC Beltrami flows for wavenumbers $k \leq 4$ and random noise at small scales, or a von Kàrmàn flow generalized to MHD; in both cases, there is negligible correlation between velocity and magnetic field and equal kinetic and magnetic energies; finally, no uniform magnetic field is imposed and the magnetic Prandtl number is unity.

At peak of dissipation, the total energy spectrum may be a combination of two components, each moderately resolved. Isotropy obtains in the large scales, with a spectrum compatible with the Iroshnikov-Kraichnan theory stemming from the weakening of nonlinear interactions due to Alfvén waves and leading to a $\sim k^{-3/2}$ law; scaling of structure functions confirms the non-Kolmogorovian nature of the flow in this range. At small scales, weak turbulence emerges with a $k^{-2}_{\perp}$ spectrum, the perpendicular direction referring to the local quasi-uniform magnetic field. Finally, local directional alignment of the velocity and magnetic field fluctuations occurs rapidly, both observed in direct numerical simulations and in solar wind data. This relaxation process leads to a local weakening of the nonlinear terms in the small scale vorticity and current structures where alignment takes place.

Whether such results are universal is not clear, and several parameters may play a role, such as the V-B correlation or the ratio of kinetic to magnetic energy, or the amount of magnetic helicity in the flow. Thus, large-scale experiments and detailed observations of turbulent MHD flows are needed and several are planned presently. Similarly, high-resolution parametric studies are in order – perhaps using adaptive mesh refinement or a combination with modeling techniques – so that one can understand the interactions of turbulent eddies and Alfvén waves and the dynamics of reconnection events.

[1] “Spectra stemming from interactions of Alfvén waves and turbulence,” PRL 99, 254502 (2007).

[2] “Rapid directional alignment of velocity and magnetic field in MHD,” PRL 100, 085003 (2008).

[3] “Turbulence and waves in the Taylor-Green flow generalized to MHD,” in preparation (2008).

The simulation effort for the TORPEX experiment and theory-simulation comparison

P. Ricci (1), S. Brunner (1), A. Diallo (1), A. Fasoli (1), I. Furno (1), D. Iraji (1), B. Labit (1), S. Müller (2), G. Plyushchev (1), M. Podestà (3), F. Poli (4), B. Rogers (5), C. Theiler (1)

(1) Centre de Recherche en Physique des Plasmas, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
(2) Center of Energy Research, University of California San Diego, La Jolla CA 92093
(3) UC Irvine, Irvine CA, USA
(4) Center for Fusion, Space and Astrophysics, University of Warwick, Coventry, United Kingdom
(5) Dartmouth College, Hanover NH, USA

The basic plasma experiment TORPEX is contributing to bridging the gap between plasma turbulence experiments and simulations. TORPEX is a toroidal plasma device (R=1m, a=0.2m), in which highly reproducible discharges of H, He, and Ar are generated. In addition to the main toroidal magnetic field of 0.1T, a small vertical field <5mT is superimposed. The typical plasma parameters (n~10^17m-3, Te~5eV) allow detailed plasma diagnostics, leading to a characterization of the plasma properties similar to the one available from typical plasma simulations. The diagnostics setup, with ~200 channels acquired simultaneously, include various probe arrays and optical diagnostics. Temporal and spatial resolutions, and the coverage of the plasma cross-section, go well beyond what can be usually reached in fusion devices. Reconstruction of the fluctuation spatial profiles, statistical and spectral properties, correlations, and dispersion relation are possible. Electrostatic instabilities that can be generally identified as drift and interchange waves are routinely observed. These instabilities give rise to turbulent structures, whose spatio-temporal evolution can be fully reconstructed.

We describe the simulation approach to the study of TORPEX plasma. A fluid model has been deduced to follow the TORPEX plasma dynamics, that takes into account the plasma sources, the parallel losses on the vessel, and the perpendicular transport due to the interchange turbulence. The simulations show the surprising presence of two turbulent regimes characterized by low and high confinement properties. We evaluate analytically the properties of the low confinement regime, obtaining expressions for the plasma gradients and for the density and heat fluxes that agree well with the simulation results. By increasing the plasma source strength or reducing the vertical magnetic field, a transition to a high confinement regime occurs, in which a strong velocity shear limits the perpendicular transport, the peak density and temperature increase and their gradients steepen up. The analytic estimate of the L-H transition condition agrees well with the simulation results. Finally, the comparison of simulation results with experimental data is discussed.

Locality in HD and MHD turbulence

Robert Rubinstein

Computational Aerosciences Branch
Mail Stop 128
NASA Langley Research Center
Hampton, VA 23681

Locality of energy transfer, a basic postulate of the Kolmogorov theory, is a cornerstone of our understanding of hydrodynamic turbulence. Locality in MHD turbulence is much less straightforward. We review results on locality in MHD turbulence that are suggested by closure theories, and draw some implications for modeling. Particular attention will be given to Alfvenization and equipartition in the solar wind, following recent work by Yoshizawa and Yokoi.

Fourier Spectral Embedded Boundary Solution of the Two-Dimensional Incompressible Navier-Stokes Equations

F. Sabetghadam, Sh.Sharafatmandjoor, S. Taheri

Engineering faculty, Science and Research Branch, Islamic Azad University (IAU), Tehran, Iran.
fsabet@sr.iau.ac.ir

In the present work, a Fourier spectral Embedded Boundary Method (EBM) is studied via using it in the numerical solution of the two-dimensional incompressible Navier-Stokes Equations (NSEs). The NSEs are considered in the vorticity-streamfunction formulation and the proposed EBM is applied to the elliptic part (i.e. the Poisson's equation for the streamfunction) [1]. Although there are some other Fourier spectral EBM which can be applied to the Poisson's equation with some kinds of boundary conditions (for example see [2]), they couldn't be used directly in the vorticity-streamfunction formulation of the NSEs, where its Dirichlet boundary conditions have a crucial role in capturing some essential features of the flow (especially presence of the solid walls) [3, 4].

In the present method, the vorticity and velocity boundary conditions (defined on the irregular domain and boundary) are extended smoothly and periodically to the regular domain D using some appropriate Heaviside functions. According to the desired boundary conditions, these Heaviside functions can act directly on the velocity field, or on the vorticity field which affects the other quantities in turn. The method, as a whole, is an attempt to extension of the conventional Fourier pseudospectarl method (with the well known advantage of simplicity of Biot-Savart kernel which needs O($N^2 \log(N)$) operations instead of O(N^3)), to the general irregular boundaries with non-periodic boundary conditions.

Time integration of the vorticity transport equation is done explicitly using the fourth-order Runge-Kutta method and the entire calculation are dealiased using the conventional (3/2N) rule. The numerical experiments have shown fairly good flexibility of the method in dealing with complex boundaries and discontinuities in the boundary conditions and the forcing function

References

[1] F. Sabetghadam, Sh. Sharafatmandjoor, and F.Norouzi, "Application of the Fourier Spectral Embedded Boundary Method in Solution of the Dirichlet Poisson's problem on Irregular Domains", under review, *J. computational Physics.*

[2] J.P. Boyd, 2005, "Fourier Embedded Domain Methods: Extending a Function Defined on an Irregular Region to a Rectangle so that the Extension is Spatially Periodic and $C^{¥}$ ", *Applied Mathematics and Computation,* 161, pp. 591-597.

[3] D. Russel and Z. J. Wang, 2003, "A Cartesian grid method for modeling multiple moving objects in 2D incompressible viscous flow", *J. Computational Physics*.

[4] H. Johansen and P. Collela, 1998, "A Cartesian grid embedded boundary method for Poisson's equation on irregular domains", *J. Computational Physics*.

Multiscale interactions in gyrokinetic simulations of turbulent transport in tokamak plasmas

Yanick SARAZIN

Association EURATOM-CEA
CEA/DSM/IRFM Cadarache, bat. 513
13108 Saint-Paul-Lez-Durance, France

Abstract:

The performances of magnetised fusion plasmas in terms of fusion energy gain factor Q are governed by the energy confinement time, which essentially results from the turbulent heat transport. 5D gyrokinetic codes are the most relevant first principle models to predict the level of turbulent transport in present and next step devices.
The present talk aims at emphasizing how small scale and medium frequency turbulence -- characterised by spatial scales of the order of a few ion Larmor radii ($\sim 10^{-3}$ m) and temporal scales governed by the ion diamagnetic frequency ($\sim 10^{5}$ s^{-1}) -- interacts with large scale structures such as mean or zonal poloidal flows, as well as much slower processes such as collisions. More specifically, sheared poloidal flows are found to efficiently reduce the level of turbulent transport, whereas collisions lead to potentially competing effects.

Symmetry and evolution of radiative patterns in simulations of the tokamak edge plasma

Frédéric Schwander

Euratom-CEA, Cadarache, France

Radiation in ITER is presently considered to be a controlled phenomenon that will allow one to operate the divertor in the steady state detachment while retaining the core H-mode confinement. When considering next step devices, steady state radiative layers at a level of 90% radiation or more will be required. The geometry of these layers is also most important since present results are based on poloidally symmetric shells, while MARFES, that appear to be predominantly poloidally localised in regions of largest magnetic expansion, will govern overheating of the main chamber wall. The issue of the stability of the radiative patterns to thermal bifurcations, which are likely to govern their non-linear changes, can be addressed by present simulations.

Thermal bifurcations can be shown in a 1-D parallel transport model where multiple steady state solutions are found in an S shaped bifurcation diagram, depending on a unique control parameter. This bifurcation scheme will be illustrated in two-dimensional numerical simulations of the heat problem including radiative losses, and the evolution of 2D and 3D patterns will be shown. Finally, the anisotropy of the problem resulting from the large thermal diffusivity in the direction of the magnetic field will allow a discussion of the efficiency of a field aligned spatial discretization.

The scale length problem from Euler fluid to magnetized plasma

Florin Spineanu

National Institute of Laser, Plasma and Radiation Physics
MG-36 Magurele, Bucharest 077125, Romania

The ideal incompressible (Euler) fluid can be described by an equivalent model of a discrete set of point-like vortices interacting in plane through a Coulombian potential. We will first show that the continuum limit of this model is a classical field theory with a Lagrangian for matter field (density of point-like vortices), gauge field (from the potential of mutual interaction) and with a nonlinear scalar term. The model identifies the asymptotic stationary states of the Euler fluid as states of self-duality and derives the sinh-Poisson equation. The absence of an intrinsic space scale is expressed as the conformal invariance of the theory.
The magnetized plasma is equivalent with a similar discrete model but the interaction between the point-like vortices is short range. We will construct the Lagrangian of a classical field theory for the continuum limit and show that the fast spatial decay of the interaction is the consequence of a classical Higgs mechanism. This introduces the Larmor radius as the fundamental length in the model and the gyration frequency as the basic time length. The loss of conformal invariance has many consequences. We argue that the system has no self-duality therefore there are no stationary asymptotic states consisting of stable coherent structures. This also rises questions on the possibility to find an equivalent of the sinh-Poisson equation. However, assuming quasi-stationarity we identify an equation which can describe the states of relaxation. This equation provides many interesting applications and we will present results for the tokamak plasma and for the planetary atmosphere.
A particular assumption on the reduction of the symmetry requirements (Abelian Dominance) for the preceding model leads us to a new equation for the stationary coherent states of the magnetized plasma and planetary atmosphere. Since the vorticity has a ring-type distribution, this model is adequate to describe several processes characteristic for the Tokamak plasma, atmosphere, etc. A particularly interesting aspect is revealed: the presence of topological content of the states, inducing a lower bound for the energy, or, equivalently, a threshold for attaining certain states.

Kinetic simulation of Tokamak plasmas

Eric Sonnendrucker

ULP Strasbourg, France

Abstract : The aim of this talk will be to describe specific issues linked to the development of numerical methods for the kinetic (Vlasov) description of Tokamak core plasmas, which are fundamental for the understanding of the development of turbulence. In addition to the general difficulty of solving the Vlasov equation which is defined in the 6D phase-space, magnetically confined plasmas are source for other problems like the anisotropy of particle motion along and accross magnetic field lines, the specific equilibrium geometry and the quasi-neutrality of the plasma. A review of these issues as well as our progress in the development of a quasi-neutral gyrokinetic semi-Lagrangian Vlasov solver will be presented.

Interacting Vortices and Spin-up in 2-D Turbulence

J B Taylor
Radwinter, Wallingford, OX10 9EJ, United Kingdom

Matthias Borchardt
Max Planck Insitute for Plasma Physics,
Wendelsteinstrasse 1, 17491, Greifswald, Germany

Two-dimensional turbulence, (which may to some extent be realised in magnetised plasmas, in rotating or stratied fluids and in thin films), has been extensively studied in numerical simulations. Recently Clercx et al.[1] discovered the intriguing phenomenon of "spin-up" in such simulations. (Spin-up is the *spontaneous* acquisition of angular momentum by a turbulent 2-D fluid in a rigid container.) A remakable feature of this phenomenon is that it is dependent on the shape of the container!

It has often been proposed that 2-D turbulence in near ideal fluids can be interpreted in terms of the statistical equilibria of interacting point vortices, or equivalently of interacting charged rods in a magnetic field. In this paper we re-examine this possibility and find that in bounded domains there are two classes of such equilibria. One class, described by the Sinh-Poisson Eq, has long been known [2]. The other is a new class, described by a more general Eq, that exists only in bounded domains. This result appears highly relevent to "spin-up" because the new equilibria *have non-zero angular momentum, even though the net circulation is zero*. Significantly, the relation between the two classes depends on the shape of the boundary and on the amplitude of the turbulence.

Of course, this discussion in terms of point vortices representing an ideal fluid, says nothing about *how* the spontaneous angular momentum is acquired. One can only suggest that a small viscosity may break the angular momentum constraint without signicantly affecting the calculated statistical equilibria - just as one can calculate thermal equilibria without introducing the weak collisions that lead to equilibrium.

[1] H J H Clercx, S R Massen and G F J van Heijst, Phys. Rev. Lett. 80, 5129 (1998)

[2] D L Book, S Fisher and B E McDonald, Phys. Rev. Lett. 34, 4 (1975)

Alpha Sub-grid Scale Models of Turbulence and Inviscid Regularization

Edriss S. Titi

Weizmann Institute of Science and
University of California – Irvine, USA

Abstract:

In recent years many analytical sub-grid scale models of turbulence were introduced based on the Navier-Stokes-alpha model (also known as a viscous Camassa--Holm equations or the Lagrangian Averaged Navier--Stokes-alpha (LANS-alpha)). Some of these are the Leray-alpha, the modified Leray-alpha, the simplified Bardina-alpha and the Clark-alpha models. In this talk we will show the global well-posedness of these models and provide estimates for the dimension of their global attractors, and relate these estimates to the relevant physical parameters. Furthermore, we will show that up to certain wave number in the inertial range the energy power spectra of these models obey the Kolmogorov -5/3 power law, however, for the rest the inertial range the energy spectra are much steeper.

In addition, we will show that by using these alpha models as closure models to the Reynolds averaged equations of the Navier-Stokes one gets very good agreement with empirical and numerical data of turbulent flows for a wide range of huge Reynolds numbers in infinite pipes and channels.

We also observe that, unlike the three-dimensional Euler equations and other inviscid alpha models, the inviscid simplified Bardina model has global regular solutions for all initial data. Inspired by this observation we introduce new inviscid regularizing schemes for the three-dimensional Euler, Navier-Stokes and MHD equations, which does not require, in the viscous case, any additional boundary conditions. This same kind of inviscid regularization is also used to regularize the Surface Quasi-Geostrophic model.

Finally, and based on the alpha regularization we will present new approximation of vortex sheets dynamics.

Two-Fluid Effects in Magnetic Reconnection

G. Vekstein

School of Physics and Astronomy, University of Manchester, UK

We consider how Hall effect modifies the pace of collisional (resistive) and collisionless (electron inertia) tearing instability in a sheared force-free magnetic field. An important novel element not included in previous studies is ion gyroviscosity. All possible instability regimes are revealed, each of which can be characterised by the three major parameters: Lundquist number, plasma beta, and normalised ion inertial skin depth. The case of forced reconnection in a tearing-stable magnetic configuration (Taylor problem) is also considered.

Multiscale trajectory structures and turbulent transport in magnetically confined plasmas

Madalina Vlad

Association Euratom-MEdC Romania on Fusion Research,
CNRS-Université de Provence, Marseille, France

A component of test particle motion in turbulent magnetized plasmas is the stochastic ExB drift. This drift determines a trapping effect or eddy motion in turbulence with slow time variation, which generates non-standard statistical behaviour of the trajectories: memory effects, non-Gaussian probability and high degree of coherence.
These statistical effects are quantitatively analysed using a semi-analytical approach, the nested subensemble method [1]. We show that quasi-coherent structures of trajectories appear. They are associated to the values of the potential in the starting point of trajectories and have all sizes in a static potential. Their formation time is an increasing function of the size. The probability of localization of particles in such structures saturates to a ring shape function. The probability of particle displacements is strongly influenced by these structures, which determine non-Gaussian distribution with a central, time-invariant peak.

The turbulent transport is studied taking into account, besides the ExB stochastic drift, the parallel motion, average flows and particle collisions. All these components of the motion destroy the trajectory structures when they are strong enough and produce Gaussian statistics of trajectories. Strong nonlinear effects appear when these perturbations are weak and trajectory structures are not completely destroyed. A rich class of anomalous diffusion regimes is shown to appear in the presence of trapping, with diffusion coefficients that have completely different dependence of the parameters compared to the Gaussian transport.

[1] M. Vlad, F. Spineanu, Physical Review E 70 (2004) 056304(14).

Coherent vortices in high resolution direct numerical simulation of homogeneous isotropic turbulence: A wavelet viewpoint

Katsunori Yoshimatsu and Naoya Okamoto
Department of Computational Science and Engineering, Nagoya University, Nagoya 464-8603, Japan

Kai Schneider
M2P2-CNRS and CMI, Université de Provence, 39 rue Frédéric Joliot-Curie, 13453 Marseille Cedex 13, France

Marie Farge
LMD-IPSL-CNRS, Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris Cedex 05, France

Yukio Kaneda
Department of Computational Science and Engineering, Nagoya University, Nagoya 464-8603, Japan

Coherent vortices are extracted from data obtained by direct numerical simulation DNS of three-dimensional homogeneous isotropic turbulence performed for different Taylor microscale Reynolds numbers, ranging from Re_λ =167 to 732, in order to study their role with respect to the flow intermittency. The wavelet-based extraction method assumes that coherent vortices are what remains after denoising, without requiring any template of their shape. Hypotheses are only made on the noise that, as the simplest guess, is considered to be additive, Gaussian, and white. The vorticity vector field is projected onto an orthogonal wavelet basis, and the coefficients whose moduli are larger than a given threshold are reconstructed in physical space, the threshold value depending on the enstrophy and the resolution of the field, which are both known *a priori*. The DNS dataset, computed with a dealiased pseudospectral method at resolutions N=256^3 , 512^3 , 1024^3, and 2048^3, is analyzed. It shows that, as the Reynolds number increases, the percentage of wavelet coefficients representing the coherent vortices decreases; i.e., flow intermittency increases. Although the number of degrees of freedom necessary to track the coherent vortices remains small e.g., 2.6% of N =2048^3 for Re_λ=732, it preserves the nonlinear dynamics of the flow. It is thus conjectured that using the wavelet representation the number of degrees of freedom to compute fully developed turbulent flows could be reduced in comparison to the standard estimation based on Kolmogorov's theory.

References:

N. Okamoto, K. Yoshimatsu, K. Schneider, M. Farge and Y. Kaneda.
Coherent vortices in high resolution direct numerical simulation of homogeneous isotropic turbulence : A wavelet viewpoint.
Phys. Fluids, 19, 115109 (13 pages), 2007.

International workshop on
'Multiscale methods for fluid and plasma turbulence :
Applications to magnetically confined plasmas in fusion devices'
CIRM, Marseille, 21-25 April 2008

List of participants

Sponsored by

Vivek AGGARWAL,
Tata Institute of Fundamental Research, TIFR Center for Applicable
Mathematics, P.O. Box No. 3, Sharadanagar, Chikkabommasandra,
560065 Bangalore, INDIA
vivek@math.tifrbng.res.in

Philippe ANGOT
Université d'Aix-Marseille, LATP - CMI 39 rue F. Joliot Curie
13453 Marseille, FRANCE
angot@cmi.univ-mrs.fr

Claude BARDOS
Laboratoire Jacques Louis Lions, 31 Avenue Trudaine
75009 Paris, FRANCE
claude.bardos@gmail.com

Peter BEYER
Univ. Provence Laboratoire PIIM Centre St. Jérôme, Case 321
13397 Marseille, FRANCE
peter.beyer@univ-provence.fr

Piotr BORONSKI
University of Leeds, 19 Woodside Avenue Meanwood
LS7 2UL Leeds, UNITED KINGDOM
boronski@gmail.com

Wouter BOS
LMFA, Ecole Centrale de Lyon 36, avenue Guy de Collongue ECULLY Cedex, France
69134 Ecully, FRANCE
wouter.bos@ec-lyon.fr

Claude CAMBON
LMFA, Ecole Centrale de Lyon , 36 avenue Guy de Collongue
69 134 Ecully Cedex, FRANCE
claude.cambon@ec-lyon.fr

Debasis CHANDRA
Lab PIIM, UMR 6633 CNRS-Univ de Provence, Case 321 Centre St Jerome, Av E Normandie Niemen
13397 Marseille, FRANCE
debasis@ipr.res.in

Guido CIRAOLO
Ecole Centrale Marseille & M2P2
IMT La Jetée - Technopôle de Château-Gombert 38, rue Frédéric Joliot Curie
13451 Marseille, FRANCE
guido.ciraolo@ec-marseille.fr

Herman CLERCX
Physics Department, CC 2.15 Eindhoven University of Technology PO Box 513
5600 MB Eindhoven, NETHERLANDS (THE)
h.j.h.clercx@tue.nl

Nicolas CROUSEILLES
INRIA Grand Est , 7 rue René Descartes
67084 Strasbourg, FRANCE
crouseil@math.u-strasbg.fr

Patrick DIAMOND
University of California San Diego, Center for Astrophysics and Space Sciences 0424, 9500 Gilman Drive
92093-0424 La Jolla, U.S.A.
pdiamond @ucsd.edu

Margarete DOMINGUES
Brazilian Space Research Institute, Av. dos Astronautas, 1758 Jd da Granja
12227-010 Sao Jose dos Campos, BRAZIL
margarete.oliveira.domingues@gmail.com

Dominique ESCANDE
CNRS-Université de Provence, Equipe Turbulence Plasma/UMR6633 Case 321 Av. Normandie Niemen
13397 Marseille Cedex 20, FRANCE
dominique.escande@univ-provence.fr

Marie FARGE
CNRS, Ecole Normale Superieure, 24 rue Lhomond,
75231 Paris Cedex 5, FRANCE
farge@lmd.ens.fr

Uriel FRISCH
Observatoire Cote d'Azur, OCA, BP 4229
06304 Nice Cedex 4, FRANCE
uriel@oca.eu

Guillaume FUHR
Laboratoire PIIM/CNRS UMR 6633 Université de Provence, Faculté de St Jerome case 321
13397 Marseille, FRANCE
guillaume.fuhr@univ-provence.fr

Shimpei FUTATANI
CNRS - University of Provence, Avenue Escadrille Normandie-Niémen, Case321
13397 Marseille, FRANCE
shimpei.futatani@gmail.com

Xavier GARBET
IRFM/SCCP, Bat 513, CEA Cadarache
13108 St Paul Lez Durance, FRANCE
xavier.garbet@cea.fr

Kazem GHAFFARY
Iranian Research and Development, Ferdousi square
578415475 Teheran, IRAN
amin_gh@gmail.com

Philippe GHENDRIH
Association Euratom-CEA, CEA/DSM/IRFM, Cadarache
13108 St Paul lez Durance, FRANCE
philippe.ghendrih@cea.fr

Fabien GODEFERD
École Centrale de Lyon, 36 av. Guy de Collongue
69134 Écully, FRANCE
fabien.godeferd@ec-lyon.fr

Tobias GOERLER
IPP, Garching, Max-Planck-Institut fuer Plasmaphysik Boltzmannstrasse 2
85748 Garching, GERMANY
tbg@ipp.mpg.de

Rainer GRAUER
Institute for Theoretical Physics I Ruhr-University Bochum Universitätsstrasse 150
44780 Bochum, GERMANY
grauer@tp1.ruhr-uni-bochum.de

Taik Soo HAHM
Princeton Univ. Plasma Physics, P.O. Box 451
08543 Princeton, NJ, U.S.A.
tshahm@pppl.gov

Yasuji HAMADA
NIFS, Japan, Oroshi-cho, Toki-ci, Gifu-ken Japan
623481 Toki-ci, JAPAN
hamada@toki-fs.jp

Christopher HOLLAND
University of California, San Diego, Department of Mechanical and Aerospace Engineering 460 Engineering Building
Unit II School of Engineering, UCSD 9500 Gilman Drive, Mail Code 0417
92093-0417 La Jolla, CA, U.S.A.
christopherholl@gmail.com

Livia ISOARDI
Laboratoire M2P2, UMR 6181 IMT La Jetée - Technopôle de Château-Gombert 38, rue Frédéric Joliot Curie
13451 Marseille Cedex 20, FRANCE
livia.isoardi@l3m.univ-mrs.fr

Frank JENKO
IPP Garching, Boltzmannstr. 2
85748 Garching, GERMANY
fsj@ipp.mpg.de

Benjamin KADOCH
M2P2, Université de Provence, 38 rue Frédéric Joliot-Curie
13451 Marseille, FRANCE
kadoch@l3m.univ-mrs.fr

Gerardus KEETELS
Department of Physics, Eindhoven University of Technology, PO Box 513
5600 MB Eindhoven, NETHERLANDS (THE)
g.h.keetels@gmail.com

Dmitry KOLOMENSKIY
M2P2, Université de Provence, 38 rue Frédéric Joliot-Curie
13451 Marseille, FRANCE
dkolom@gmail.com

Robert KRASNY
Department of Mathematics University of Michigan 525 Church Street
48109-1043 Ann Arbor, U.S.A.
krasny@umich.edu

Michael LECONTE
Univ. Provence, Centre St Jérome, UMR 6633 LPIIM Equipe DSC, case 321, Avenue Escadrille Normandie Niemen
13397 MARSEILLE, FRANCE
michael.leconte@univ-provence.fr

Thierry LEHNER
Observatoire de Paris, 5 Place Janssen
92195 Meudon, FRANCE
thierry.lehner@obspm.fr

Mani MEHRA,
G Street, # 12, IIT Campus
110016 New Delhi, INDIA
mmehra@maths.iitd.ac.in

David MONTGOMERY
Physics & Astronomy, Dartmouth, 203 Wilder Physical Laboratory Dartmouth College Hanover, NH 03755-3528, 03755 Hanover, U.S.A.
David.C.Montgomery@dartmouth.edu

Alexandre MOUTON
IRMA – Strasbourg, 7 rue René Descartes
67084 Strasbourg, FRANCE
mouton@math.u-strasbg.fr

Magali MURAGLIA
Laboratoire PIIM, CNRS/UMR 6633, Université de Provence, Centre St. jérôme, case 321, Av. Normandie Nièmen
13397 Marseille, FRANCE
magali.muraglia@univ-provence.fr

Volker NAULIN
Risoe DTU, OPL-129 Frederiksborgvej 399
DK-4000 Roskilde, DENMARK
volker.naulin@risoe.dk

Salah NEFFAA
M2P2, Ecole Centrale Marseille, 38 rue Frédéric Joliot-Curie
13451 Marseille, FRANCE
neffaa@l3m.univ-mrs.fr

Romain NGUYEN VAN YEN
ENS-Paris, 24 rue Lhomond
75005 Paris, FRANCE
rnguyen@lmd.ens.fr

Seiya NISHIMURA
CNRS-Univ. Provence, PIIM, Universite de Provence, Faculte St. Jerome, Case 321,
13397 Marseille, Cedex 20, FRANCE
nseiya@riam.kyushu-u.ac.jp

Caroline NORE
Univ. Paris Sud 11- LIMSI-CNRS batiment 508 BP 133
91403 Orsay cedex, FRANCE
nore@limsi.fr

Assad OBERAI
Rensselaer Polytechnic Institute, JEC 5048, RPI, 110 8th Street
12180 Troy, NY, U.S.A.
oberaa@rpi.edu

Rahul PANDIT
Physics IISc Bangalore, Dept. of Physics Indian Institute of Science
560012 Bangalore, INDIA
rahul@physics.iisc.ernet.in

Silvia PERRI
Università della Calabria, Ponte P. Bucci Cubo 31 C
I-87036 Rende, ITALIE
sperri@fis.unical.it

Annick POUQUET
NCAR, 2822 third street
80304 Boulder, U.S.A.
pouquet@ucar.edu

Samriddhi Sankar RAY
OCA/Nice et IISc/Bangalore, BP 4229,
06304 Nice Cedex 4, FRANCE
samriddhisankarray@gmail.com

Thomas RESPAUD
IRMA Strasbourg, ENS Cachan, 7 rue René Descartes
67084 Strasbourg, FRANCE
respaud@math.u-strasbg.fr

Paolo RICCI
EPFL-CRPP, Bât. PPB Station 13
1015 Lausanne, SWITZERLAND
celine.neyroud@epfl.ch

Robert RUBINSTEIN
NASA Langley Research Center , MS 128
Hampton VA 23681 U.S.A.
r.rubinstein@nasa.gov

Fereidoun SABETGHADAM
Science and Research Branch, A, Eng. Dept. Science and Research Branch,
Azad University, Ponack square, Tehran, Iran
14875412 Tehran, IRAN
fsabet@sr.iau.ac.ir

Yanick SARAZIN
Association EURATOM-CEA CEA/DSM/IRFM Cadarache
13108 Saint-Paul-Lez-Durance, FRANCE
yanick.sarazin@cea.fr

Kai SCHNEIDER
Univ. Provence, 39 rue Joliot-Curie
13453 Marseille cedex 13, FRANCE
kschneid@cmi.univ-mrs.fr

Frederic SCHWANDER
CEA, IRFM/SCCP, Bat 513 CEA Cadarache
13108 St Paul Lez Durance, FRANCE
frederic.schwander@cea.fr

Eric SERRE
Laboratoire M2P2, Technopole de Chateau-Gombert 38 rue Joliot-Curie
13451 Marseille, FRANCE
eric.serre@L3m.univ-mrs.fr

Eric SONNENDRUCKER
Univ. Louis Pasteur, 7, rue René Descartes
67084 Strasbourg, FRANCE
sonnen@math.u-strasbg.fr

Florin SPINEANU
INFLPR Romania , Atomistilor 409 MG-36 Magurele
077125 Bucarest, ROUMANIE
spineanu@nipne.ro

J Bryan TAYLOR
Radwinter Winterbrook Lane
OX10 9EJ Wallingford, UNITED KINGDOM (THE)
jbt@radwin.freeserve.co.uk

Edriss TITI
UC Irvine & Weizmann Institute
Dept. of Mathematics, The University of California Irvine, CA 92607-3875 USA
92697-3875 Irvine, U.S.A.
etiti@math.uci.edu

Nathalie TRONKO
Centre de Physique Théorique, CNRS case 907
13288 Marseille, FRANCE
nathalie.tronko@gmail.com

Grigory VEKSTEIN
University of Manchester, P.O.box 88
M13 9PL Manchester, ROYAUME-UNI
g.vekstein@manchester.ac.uk

Madalina VLAD
NILPRP, Romania, Atomistilor 409 POBox MG-36 Magurele
077125 Bucarest, ROUMANIE
madi@ifin.nipne.ro

Thibaut VOSLION
Université de Provence, 11 rue Nicolas Appert, Appartement 147 le Clos Campagne
13013 Marseille, FRANCE
thibaut.voslion@univ-provence.fr

Katsunori YOSHIMATSU
Department of Computational Science and Engineering, Nagoya University, Chikusa-ku, Nagoya, Aichi
464-8603 Nagoya, JAPAN
yosimatu@fluid.cse.nagoya-u.ac.jp