Space Plasmas and Astrophysics International workshop

in honor of

André Mangeney

WORKSHOP'S PROGRAM

Program

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Sept 11 p.m.: Opening talk

TUE 14:30-15:00

Opening talk

Pierre Couturier

Observatoire de Paris

Sept 11 p.m.: Solar wind

TUE 15:00-15:30

Kinetic Aspects of the Solar Wind

Milan Maksimovic

LESIA, Observatoire de Paris, Paris, France

Non-thermal electron and ion velocity distribution functions are permanently observed in the solar wind. The exact origins of such departures from equilibrium Maxwell-Boltzmann distributions remain unclear. It is however believed that the rarity of Coulomb collisions in most of the extended corona and solar wind plays a crucial role in the mechanisms which produce and/or maintain such distributions. In this presentation, I will focuss more on the electron distribution functions. I will summarize their various observations and discuss about their possible coronal origin and role in the Solar Wind acceleration processes.

TUE 15:30-16:00

Alfvén waves, MHD turbulence and Models of Coronal Heating and Solar Wind Acceleration.

Marco Velli

Dipartimento di Astronomia, Università di Firenze

When I moved to Paris in 1989, I knew little of Alfvén waves and MHD turbulence and even less about the problems of coronal heating and solar wind acceleration. Much of what I have learned has come from the collaborations and discussions I have had with André and his students and colleagues Roland Grappin, Pier Luigi Veltri, Giorgio Einaudi and many others. In this presentation I would like to review what we have understood on the origin, propagation, and evolution of Alfvénic fluctuations, together with some recent progress in models of coronal heating and solar wind acceleration where MHD turbulence plays a fundamental role. These include the so-called Parker problem of field line tangling for the heating of coronal loops in the magnetically confined solar atmosphere and the question of propagation, reflection, dissipation of Alfvén waves on open magnetic field lines from the photosphere out to the solar wind.

TUE 16:30-17:00

Solar wind parameters over the solar cycle from in situ radio observations

Karine Issautier

LESIA, Observatoire de Paris

The method of quasi-thermal noise spectroscopy is a powerful technique, which is successfully used in various space media. In particular, it yields in routine accurate solar wind measurements of the electron density and core temperature. Ulysses spacecraft gives a unique opportunity to study the fast solar wind out of the ecliptic plane and its large-scale variations during a whole solar cycle. I will review these observations and compared them to the in-ecliptic observations obtained from Wind spacecraft. In particular, I will focus on the electron density fluctuation spectrum obtained using the large sample of data near the 1996 solar minimum in the steady-state fast solar wind.

TUE 17:00-17:30

The evolution of the solar wind proton temperature anisotropy from 0.3 to 2.5 AU

Lorenzo Matteini

Università di Firenze, Italia

We report an analysis of the proton temperature anisotropy evolution from 0.3 to 2.5 AU based on the Helios and Ulysses observations. With increasing distance, the fast wind data show a path in the parameter space ($\beta_\parallel$,$T_\perp/T_\parallel$), and the first part of the trajectory is well described by an anticorrelation between the temperature anisotropy $T_\perp/T_\parallel$ and the proton parallel beta, while after 1 AU the evolution with distance in the parameter space changes and the data result in agreement with the constraints derived by a fire hose instability. The slow wind data show a more irregular behavior, and in general it is not possible to recover a single evolution path. However, on small temporal scale we find that different slow streams populate different regions of the parameter space, and this suggests that when considering single streams also the slow wind follows some possible evolution path.

TUE 17:30-18:00

A Vlasov model for the generation of suprathermal electron tails in solar wind conditions.

Francesco Califano

Dipartimento di Fisica, Universita' di Pisa, Italy

Space and laboratory collisionless plasmas are most often out of local thermodynamic equilibrium. In particular, their charged particle velocity distributions usually differ from simple Maxwellian distributions and exhibit a great variety of anisotropies and components such as suprathermal beams and tails. Here we propose a new model responsible for a "local" origin of electron suprathermal tails. The model is based on adding a high and a low frequency external forcing to the Vlasov - Poisson system of equations. The first one represents the electric field generated by charge separation effects and the second one, limited to the Vlasov ion equation, the energy injection on the small scales coming from the energy cascade generated by the large scale fluid (MHD) turbulence. This work is a collaboration with A. Mangeney.

Sept 12 a.m.: Turbulence I

WED 09:30-10:00

A belated thank you and more recent work on turbulence

Paul J. Kellogg

University of Minnesota, Minneapolis, MN, USA

I wish to thank Andre for something he did for me nearly 50 years ago. Then: Turbulence is not only magnetic. Electric fields and density fluctuations are important aspects of solar wind turbulence. In the ion cyclotron frequency range, electric fields exert larger (resonant) forces on protons than magnetic fluctuations do.

WED 10:00-10:30

Small scale electrostatic structures in space plasmas.

André Mangeney

LESIA, Observatoire de Paris

Small scale (of the order of the Debye length) electrostatic structures are observed in many space plasmas (solar wind, magnetosperic tail, auroral zones, etc...). They are usually explained as being local deviations from charge neutrality associated to charged particle trapping in unstable waves. The instability itself is thought to be due to non equilibrium features in the particle distribution functions (beams for example).
I will show that such non equilibrium features result naturally from the evolution of inhomogeneities in density, temperature, etc... If this evolution occurs on a sufficiently slow time scale, low frequency instabilities develop and lead to the formation of phase space "vortices" associated to the observed electrostatic structures.
These ideas will be illustrated with numerical simulations based on a 1D Vlasov code and compared with observations in the magnetosheath.
This work is made in collaboration with M. Goldman.

WED 10:30-11:00

Space plasma turbulence and Alfven vortices

Olga Alexandrova

LESIA, Observatoire de Paris, France

I will discuss some results obtained in two natural laboratories of turbulent plasmas, the Earth magnetosheath and the solar wind. Turbulent spectra observed in the solar wind and in the magnetosheath consist in two well defined power laws separated by a spectral break, which is observed in the vicinity of the proton cyclotron frequency f_{cp}. It is generally believed that at this frequency the nonlinear cascade is stopped and a kind of "dissipation" range takes place. Magnetic field fluctuations in a range more than one decade above f_{ci} are investigated by using the CLUSTER mission data. The increase of intermittency with frequency observed in this range and well defined power law indicate that turbulence cannot be characterized by a "dissipative range". Rather we conjecture that above the break there is another nonlinear cascade. To describe these small scale inertial range observed in the solar wind and in the Earth magnetosheath, a simple phenomenological model based on compressible Hall MHD is proposed.
The two natural laboratories of the turbulent plasma are however very different: solar wind is an example of a freely developed turbulence, the Earth magnetosheath on the contrary is a domain bounded by the bow-shock and the magnetopause. In the magnetosheath, downstream of quasi-perpendicular bow-shock and for plasma β smaller than 3, the incompressible Alfvén vortices have been observed [Alexandrova et al., 2006]. They appear in the turbulent spectrum as a local maximum at the break frequency. The generation mechanism of incompressible Alfvén vortices in a compressible magnetosheath plasma, their stability and role in the collisionless plasma turbulence are still open questions.

WED 11:30-12:00

Hall-MHD turbulence in the solar wind

Sébastien Galtier

Institut d'Astrophysique Spatiale

Waves and turbulence are ubiquitous in the solar wind. Whereas Alfvén waves and Kolmogorov-type energy spectra are found at low frequencies, whistler waves and significant steeper magnetic fluctuation power law spectra are detected at frequencies higher than a fraction of hertz at one astronomical units. This multi-scale turbulence behavior may be investigated in the framework of 3D Hall MHD. We show that both wave turbulence analysis and high Reynolds number simulations of strong turbulent flows converge towards a steepening of magnetic spectra which may be attributed to dispersive nonlinear processes rather than pure dissipation as often stated.

WED 12:00-12:30

Solar wind MHD Turbulence: Anomalous scaling and Intermittency effects

Chadi Salem

Space Sciences Laboratory, University of California, Berkeley, USA

In the Alfvénic regime, i.e. for frequencies below the local proton cyclotron frequency, solar wind MHD turbulence exhibits what appears like an inertial domain, with power-law spectra and scale-invariance, suggesting as in fluid turbulence, a nonlinear energy cascade from the large "energy containing" scales towards much smaller scales, where dissipation via kinetic effects is presumed to act. Although considerable progress has been made in the understanding of MHD turbulence over the past few decades through the analysis of in-situ Solar Wind data, two of the primary problems of solar wind MHD turbulence that still remain a puzzle are the nature of the nonlinear energy cascade, and the strong intermittent character of solar wind fluctuations in the inertial range. Indeed, the intermittent character of the solar wind fluctuations in the inertial range is much more important than in ordinary fluids. The fluctuations seem to consist of a mixture of random fluctuations and small-scale "singular" or coherent structures. This intermittency modifies significantly the scaling exponents of actual power-law spectra, which are directly related to the physical nature of the energy cascade taking place in the solar wind. The identification of the most intermittent structures and their relation to dissipation represents then a crucial problem in the framework of turbulence. We present here recent results on scaling laws and intermittency based on the use of Wavelet transforms on simultaneous WIND 3s resolution particle and magnetic field data from the 3DP and the MFi experiments respectively. More specifically, the Haar Wavelet transform is used to compute spectra, structure functions and probability distribution functions (PDFs). We show that this powerful technique allows: (1) for a systematic study of intermittency effects on these spectra, structure functions and PDFs, thus for a clear determination of the actual scaling properties in the inertial range, and (2) for a direct and systematic identification of the most active, singular structures responsible for the intermittency in the solar wind. The analysis of structure functions and PDFs, as well as new results on the nature of the intermittent coherent structures will be discussed. [Chadi Salem (Space Sciences Laboratory, University of California, Berkeley, USA), Andre Mangeney (LESIA, Observatoire de Paris-Meudon, Meudon, France)]

Sept 12 p.m.: Physical processes in plasmas I

WED 14:30-15:00

Shocks: Real and Simulated

David Burgess

Astronomy Unit, Queen Mary, London

Almost all of the major advances in the recent study of collisionless shocks has been through the use of numerical simulations. On the other hand, almost all of the breakthroughs have been stimulated by observational data. The tension and symbiosis between observation and simulation will be discussed using historical examples such as the perpendicular and quasi-parallel supercritical shocks. Multipoint data, such as from Cluster, offer a new view of the structure of collisionless shocks, one which challenges the sometimes simplistic interpretations of the simulationist. Some of the problems of interpretation of multipoint data of shock structure, inspired by recent work on the quasi-perpendicular shock, will be discussed, and how simulations can, hopefully, provide some of the answers.

WED 15:00-15:30

On the heat flux in a dilute plasma

Filippo Pantellini

Observatoire de Paris, France

I will discuss results from numerical simulations of weakly collisional plasmas which may be pertinent to the plasma in and above the solar transition region.

WED 15:30-16:00

On the heating mechanisms of the solar corona

Gaetano Zimbardo

Universita' della Calabria, Arcavacata di Rende, Italy

Two possible mechanisms for coronal heating will be discussed. One is based on the dissipation of magnetic fluctuations in coronal loops. Considering a transport model known as Rechester and Rosenbluth diffusion, and by a numerical evaluation of the Kolmogorov entropy of magnetic field lines in the non linear regime, a substantial level of magnetic fluctuations is deduced to be present in coronal loops, also on the basis of TRACE observations. A second mechanisms is based on coronal shock waves: this seems a promising possibility for explaining some puzzling observations.

WED 16:30-17:00

Global kinetic simulations of the interaction between plasma flows and miscellaneous objects of our solar system

Pavel Travnicek

Friend of Andre Mangeney/Institute of Atmospheric Physics/Astronomical Institute, ASCR

We study kinetic processes in a global kinetic numerical models of the interaction between solar wind (or a plasma flow) and a miscellaneous objects of our solar system. Global numerical simulations have been for last decades performed using MHD codes which treat collisionless plasma as a magnetohydrodynamic fluid. The kinetic nature of collisionless plasmas, however, is significantly compromised in magnetohydrodynamic (MHD) models and/or hybrid models with insufficiant spatial resolution, while many important processes in space plasmas involve wave-particle interactions. Space plasmas are oftenly subject of slow flow induced plasma expansion, compression, and stretching which causes the temperature anisotropy to grow. Consequently, we observe the plasma oftenly in a marginally stable state - a balance between processes driving anisotropy of the particle velocity distribution functions and waves generated due to mirror, Alfven cyclotron and fire-hose instabilities causing the distribution functions to isotropize. Other example of a process caused by the wave-particle nature of space plasmas is the scattering of particles on a bow shock responsible for the formation of foreshock regions populated by heated magnetosheath plasma. We focus our study on different processes caused by the kinetic nature of space plasmas.

WED 17:00-17:30

Benchmarks in computational plasma physiscs

Pasquale Londrillo

INAF-Osservatorio di Bologna

A new 3D fully electromagnetic PIC code, characterized by high-order space-time integration schemes (AlaDyne, C.Benedetti et.al., 2007), has been constructed. Using this computational framework, a set of applications, ranging from high frequency regimes (relativistic Laser-Plasma interaction, two-streams instability, kinetic magnetic reconnection) to lower frequency phenomena (fire-hose instability), is presented and discussed. [P. Londrillo (INAF- Osservatorio di Bologna) and S. Landi (Dip. di Astron. e Scienze dello Spazio, Università di Firenze)]

WED 17:30-18:00

Is the chromospheric transition region stable?

Roland Grappin

Observatoire de Paris, Paris, France

The chromospheric transition region plays the role of a (partially) reflecting boundary. In fact, it has its own dynamics, which is essential to understand coronal sismology, and more generally coronal heating and wind. Published numerical simulations on the coronal dynamics including the transition region belong to two classes: either the transition region is given (or computed), but its oscillations are limited (relaxation models); or, in the rare self-consistent simulations in which the corona is heated by either viscous or ohmic heating (Gudiksen and Nordlund 2005; Suzuki and Inutsuka 2005), the transition region is free, and in the latter case, it is observed to be unstationary. The present work studies the stability issue in the 1D, hydrodynamic case, including chromosphere, corona and solar wind; we demonstrate that using relaxation models for the transition region leads to artificial stability, and that when this constraint is relaxed, the transition region may show an unstable behaviour, by trapping the energy of oscillations propagating upwards from the photospheric basis.

Sept 13 a.m.: Turbulence II

THU 09:30-10:00

Turbulence in the heliosphere

Vincenzo Carbone

Dipartimento di Fisica, Università della Calabria

After a brief introduction on the phenomenon of turbulence in usual fluid flows, I will review some of the main results of solar wind turbulence as measured by in situ space missions.

THU 10:00-10:30

Kinetic effects on Hall-magnetohydrodynamics slab turbulence in solar wind plasmas

Francesco Valentini

Università della Calabria

We numerically investigate the role of kinetic effects on 1D slab turbulence in solar wind plasmas in the range of wavenumbers around $k_i = 1/\lambda_i$ (λ_i being the ion skin depth), by using a newly developed hybrid-Vlasov code [1] that solves the Vlasov-Maxwell set of equations for a non-relativistic plasma, in the hybrid approximation, where the Vlasov equation is solved for the ion distribution function and the electrons are treated as a fluid. The low frequency approximation is used by neglecting the time derivative of the electric field, i.e. the displacement current in the Ampere equation. Nonlinear three-wave coupling process at large wavelengths produces a Magnetohydrodynamics turbulent cascade that transfers energy to scales of the order of the ion skin depth. In this range of wavenumbers, proton cyclotron resonance with left-handed cyclotron waves [2] self-consistently generates temperature anisotropy $T_\perp > T_\parallel$ in the ion distribution function that is a possible source of free energy for many instabilities. For cold electrons ($T_e = 0$), anisotropy production saturates at a certain level of the ratio $T_\perp/T_\parallel$; ion-acoustic waves propagating parallel to the ambient magnetic field are excited as the result of the temperature anisotropy of the ion distribution function.

[1] F. Valentini, P. Trávníček, F. Califano, P. Hellinger, and A. Mangeney, J. of Comput. Phys., in press (2007).

[2] J. V. Holloweg and P. A. Isenberg, Geophys. Res., 107, 1147 (2002).

THU 10:30-11:00

Decay and cascades of kinetic Alfven waves within a FLR Landau-fluid model.

Thierry Passot

Observatoire de la Côte d'Azur, Nice, France

The Alfvén wave cascade preferentially develops small scales in the transverse direction. Assuming that turbulence remains anisotropic at these scales with frequencies much smaller than the ion gyrofrequency, it has recently been proposed to use the gyrokinetic equations to study the properties of the so-called dissipation range, that develops at scales smaller than the ion gyroradius, with a power-law spectrum steeper than that of the Alfvén wave cascade. To address the physics of the tail of the Alfven wave cascade we here propose another approach, computationnally less costly, that consists in enriching usual MHD by the adjonction of the most relevant kinetic effects (Landau damping and finite Larmor radius corrections), estimated from the linearized Vlasov equation using the gyrokinetic scaling. This model, which does not exclude fast waves and allows for anisotropic temperatures, contains the correct dispersion and dissipation for the slow and kinetic Alfvén waves, and also for the mirror modes, up to scales that are much smaller than the ion gyroradius. After presenting a few tests to validate the model, we discuss, as a first step, one-dimensional simulations of the decay instability of kinetic Alfvén waves and of the associated cascades.

THU 11:30-12:00

Fully developed MHD turbulence: anisotropy, slopes

Roland Grappin

Observatoire de Paris, Paris, France

One reports the result of incompressible MHD simulations with resolution 1024^3. Well-defined slopes show up for the total energy (magnetic + kinetic energy) and residual energy (magnetic - kinetic energy). Two regimes are identified, depending on whether a strong mean field is present or not. Spectral anisotropy is considered: one discusses two simple theoretical possibilities, first, same inertial slopes in the parallel and perp directions, with all energy imbalance located at the largest scales; or the Goldreich-Sridhar conjecture. The two hypothesis are compared to simulations.

THU 12:00-12:30

Kinetic turbulence in space plasmas

Alexander Schekochihin

Imperial College London

I will first discuss the use and applicability of the gyrokinetic theory to the solar wind: what is it? why is it valid? why is it useful? I will then explain how the familiar "fluid" turbulence ideas such as the energy cascade are generalised for a kinetic turbulence in a weakly collisional plasma and what new features arise. I will focus on the dissipation range of the solar wind and argue that the turbulence there is a superposition of the familiar fluid-like component (kinetic Alfven waves) and a purely kinetic part, which involves a cascade of entropy in in phase space. In this talk, I will NOT assume that the audience has any previous familiarity with gyrokinetics and will attempt to present the ideas outlined above in a qualitative way suitable both for theoreticians and observers.

Sept 13 p.m.: Planets and stars

THU 14:30-15:00

Clustering of Polarity Reversals of the Geomagnetic Field

Pierluigi Veltri

Dipartimento di Fisica, Università della Calabria, 87036-Arcavacata di Rende (CS), Italy

Often in nature the temporal distribution of inh o m o g e n e o u s stochastic point processes can be modeled as a realization of renewal Poisson processes with a variable rate. We have investigated one of these classical examples, namely the temporal distribution of polarity reversal of the geomagnetic field. In spite of the commonly used underlying hypothesis, we show that this process strongly departs from a Poisson statistics, the origin of tis failure stemming from the presence of temporal clustering. We find that a Levy statistics is able to reproduce paleomagnetic data, thus suggesting the presence of long range correlations in the underlying dynamo process. A new model to describe dynamo processes based on the use of a shell model to describe MHD turbulence is set up in order to reproduce the observed behavior.

THU 15:00-15:30

Convection dans les coquilles sphériques et circulation des planètes géantes

Pierre Drossart

LESIA, Observatoire de Paris, CNRS, UPMC, Université Denis Diderot

La question de l'origine de la circulation générale en bandes des planètes géantes reste encore aujourd'hui non résolue. Dans le courant des années 80, une approche hydrodynamique directe de la question de l'influence de l'instabilité convective sur la circulation générale a été entreprise dans une collaboration entre A. Mangeney, O. Talagrand et P. Drossart. Un code hydrodynamique a été construit ab initio pour d'abord étudier l'instabilité convective dans l'approximation de Boussinesq près du seuil de convection, puis tester l'influence d'un chauffage solaire sur l'instabilité convective. Ce travail a permis de clarifier certains aspects importants dans la circulation générale des planètes sur ce sujet complexe et fort discuté encore aujourd'hui.

THU 15:30-16:00

Wave chaos in rapidly rotating stars

François Lignières

Observatoire Midi-Pyrenees

Stellar oscillations are our main source of information on the interior of stars. Dedicated space missions (MOST and COROT) have been launched recently to detect oscillation frequencies in a large variety of stars. While the frequency spectrum of acoustic modes is well understood in slowly rotating stars like the sun, the way rapid rotation affects these oscillations remains largely unknown. This problem actually prevents a reliable interpretation of the frequencies observed in most massive and hot stars. Here we show that acoustic ray dynamics combined with methods of quantum chaos reveal the structure of the high frequency spectrum of rapidly rotating polytropic stars. Three main subsets of axisymmetric modes with distinct frequency distributions can be defined. Two classes display regular frequency patterns analogous albeit different from those found in the non-rotating case. The third one displays clear signatures of waves chaos such as statistical level repulsion. We anticipate that this understanding of the mixed structure of the frequency spectrum will be key to solve the long-standing problem of interpreting the observed spectra of rapidly rotating stars. It also constitutes a new and potentially observable manifestation of quantum chaos phenomenology in a large scale natural system.

THU 16:30-17:00

The birth of space asteroseismology in France

Claude Catala

Observatoire de Paris, Paris, France

On December 27, 2006, the CoRoT satellite for asteroseismology and search for planetary transits was successfully launched from Baikonur, and has been accumulating wonderful ultra-high precision photometric data since then. This is the accomplishment of a long adventure, which started in the early 1980's, and in which André Mangeney has played a pioneering role. I will briefly recall this genesis of space asteroseismology.

THU 17:00-17:30

Everything You Always Wanted to Know About André (But Were Afraid to Ask)

Suzy Collin

LUTH, Observatoire de Paris

Sept 14 a.m.: Physical processes in plasmas II

FRI 09:30-10:00

Fluid vs kinetic models: the dilemma

Gerard Belmont

CETP, Velizy, France

Most of the cross scale phenomena, in the collisionless space plasmas, imply complex interactions between the large scales, often well described by MHD, and the small ones, which demand modeling various phenomena such as Hall effect or electron inertia. Shocks and reconnection are two famous examples of this dilemma: some characteristics are fully determined by the remote boundary conditions, (eg Rankine Hugoniot conditions) and some do depend on the local microphysics (eg reconnection rate, particle acceleration). Furthermore, the resonant effects, such as Landau damping, are scale independent, and can also noticeably influence on the global "fluid" behavior. We will discuss the limits of MHD with respect to both the Ohm's law, and the question of a closure equation.

FRI 10:00-10:30

Mirror instability near the threshold

Petr Hellinger

Institute of Atmospheric Physics, Prague, Czech Republic

Nonlinear behaviour of the mirror instability is investigated using 1-D hybrid simulations. The simulation results are compared with predictions of linear, quasi-linear and some nonlinear theories.

FRI 10:30-11:00

Particular initial perturbations that kill Landau damping.

Fabrice Mottez

Observatoire de Paris, Meudon, France

The particle signatures of linear Landau damping are investigated using numerical simulations with very low noise. The results put strong limits to the basic notion of ”resonant particles” usually associated to this phenomenon, and can change the intuitive view that one can have about the role of these particles in all similar ”resonant” effects. The theory is re-derived in order to show why the observed features, even when counter intuitive, are in full agreement with it. The notion of one damped mode among an infinity of possible kinetic solutions is emphasized, and, as an illustration, it is shown that damping different from Landau's one can easily be obtained by choosing adequate initial conditions.

FRI 11:30-12:00

Vlasov equilibria with density and temperature inhomogeneities

Francesco Pegoraro

Dipartimento di Fisica Università di Pisa

Stationary selfconsistent solutions of the Vlasov Maxwell system in a magnetized inhomogeneous plasma (so called Vlasov equilibria) provide the natural starting point for the investigation of plasma stability and of the nonlinear development of plasma instabilities in collisionless or weakly collisional regimes. In view of the different mechanisms that drive these instabilities, we discuss Vlasov equilibria with both density and temperature gradients.

FRI 12:00-12:30

High-Mach Number Collisionless Shocks: theory and experimental evidence of shock front reformation

Vladimir Krasnoselskikh

LPCE / CNRS-University of Orleans

The problem of shock front variability for high Mach number quasiperpendicular collisionless shocks is formulated many years ago at the beginning of shock studies. This question was addressed in many theoretical works and in computer simulation studies. Cluster multi-point measurements allowed for the first time to examine shock front structure making use in situ measurements. We present a set of experimental data is presented for a high-Mach-number ($M_{\mathrm{f}} = 5$) quasiperpendicular ($\theta_{\mathrm{Bn}} = 81°$) bow shock layer crossed by Cluster spacecraft on 24 January 2001 at $07:05-07:09$ UT. The measurements of magnetic field, spectra of electric field fluctuations, and ion distributions reveal that the shock is highly nonstationary. In particular, the magnetic field profiles measured aboard different spacecraft differ considerably from each other. The mean frequency of downshifted waves observed upstream of the shock ramp oscillates with a characteristic time comparable with the proton gyroperiod. In addition, the reflection of ions from the shock is bursty and a characteristic time for this process is also comparable with the ion gyroperiod. All of these features in conjunction are the first convincing experimental evidence in favor of the shock front reformation.

FRI 12:30-12:50

Concluding remarks on the workshop

André Mangeney

LESIA, Observatoire de Paris

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