Audit Edouard

Servie d'Astrophysique
CEA
France

Turbulence and Fragmentation in the Interstellar Medium

Bate Matthew

School of Physics
University of Exeter
England

Radiation magnetohydrodynamical simulations of star and planet formation.

I will present results from recent hydrodynamical, radiation hydrodynamical, and radiation magnetohydrodynamical SPH simulations of the collapse and fragmentation of molecular clouds to form stellar groups and clusters.
I will discuss the processes by which stars and brown dwarfs form in the calculations and the predictions that are obtained for their statistical properties including the stellar initial mass function, multiplicity and binary properties.
I will end by discussing future directions for such simulations.

Bessolaz Nicolas

Service d'Astrophysique
CEA
France

On the influence of a magnetized disc on the stellar inner magnetosphere

Recent simulations of the star/disc interaction process (e.g. Romanova et al 2006, Bessolaz et al 2008) show that ejection events have almost ballistic properties occuring along the current sheet of the opening stellar magnetosphere whereas recent observational data are consistent with collimated jets from disc wind configurations (Ferreira et al. 2006).
We recently included in our simulations a disc magnetic field in addition to the stellar field. This disc field is chosen to be in the antiparallel configuration and in equipartition with the disc thermal pressure in order to study the possibility of collimation of the ejected plasmoids along the stellar rotation axis by the outer disc wind configuration. This simulation makes it also possible to test for the first time the launching of jets from Keplerian discs by taking into account specifically the inner boundary due to the central object. Results of such a mixed disk/star magnetic field configuration will be presented with special emphasize on the efficient feeding of the accretion funnel that yields steadier configurations, thus preventing oscillations at the disc inner edge like in classical magnetospheric simulations with a visco-resistive accretion disc.

Bhattacharjee Amitava

A. Bhattacharjee, K. Germaschewski, Y.-M. Huang, B. Rogers, and H. Yang 1

Space Science Center
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USA

Onset of Fast Magnetic Reconnection and its Nonlinear Stabilization in Laboratory and Space Plasmas

The onset of fast reconnection is widely studied in toroidal fusion plasmas, dedicated laboratory experiments, in situ satellite measurements in the Earth's magnetosphere, and solar flares. These observations place strong constraints on theory, which must explain not only a fast reconnection rate but also a sudden increase in the time-derivative of the reconnection rate. Using high-performance computing tools, based on Hall MHD (or two-fluid) equations, we will show that such dynamics can be accounted for in one unifying framework. The theory also elucidates the role of diamagnetic drifts that can quench nonlinearly the onset of fast reconnection. Thus, the theory explains not only when reconnection is near-explosive, but also when it is not. We will compare the predictions of theory with data from tokamaks, laboratory experiments, and magnetospheric and solar observations.

The problem takes on additional complexity when it is applied to large sytsems, which have been the subject of considerable interest recently. It is shown that the dynamics of thin current sheets in large sytsems is sensitive to the mechanism that breaks field lines, and that velocity shear along the thin current sheets plays an important role in controlling their geometry and stability. In the resistive MHD model, at high-Lundquist number, the long thin current sheet spanning Y-points becomes near-explosively unstable to secondary tearing, producing plasmoids copiously. Under these circumstances, contrary to accepted wisdom, one attains a new regime of fast reconnection in which the reconnection rate exceeds, by far, the predictions of Sweet-Parker theory. Particle-in-cell simulations point to a similar qualitative regime even though the mechanism that breaks field lines is different than that in the resistive MHD framework. We address the implications of these results for observations of reconnection in large-scale space and astrophysical plasmas.

Bushby Paul

Paul Bushby (Newcastle University)

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England

Small-scale dynamo action in compressible convection

Motivated by observations of magnetic fields at the surface of the Sun, we consider direct numerical simulations of dynamo action in highly-stratified, three-dimensional compressible convection. Whether or not a convective flow can drive a dynamo depends crucially upon the magnetic Reynolds number. If this parameter is large enough that the inductive effects of the fluid motions outweigh the dissipative effects of magnetic diffusion, then dynamo action can occur. Simulating convection with a (viscous) Reynolds number of approximately 150, we find that it is possible to excite a dynamo with computationally accessible values of the magnetic Reynolds number. In the kinematic regime, the growth rate of the dynamo appears to have a logarithmic dependence upon the magnetic Reynolds number. Following these dynamos into the non-linear regime, we find that partially-evacuated concentrations of magnetic flux form near the upper surface of the computational domain. From a computational perspective, this has a profound influence upon the efficiency of the (explicit) numerical scheme that is used in these calculations. These numerical results can be related (in a qualitative sense) to recent observations of magnetic fields in the quiet Sun

Commercon Benoit

Service d'Astrophysique
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France

Protostellar collapse: Radiation-Hydrodynamics calculations with the RAMSES code

We implement a Radiation HydroDynamics solver in the RAMSES code, using the Flux Limited Diffusion approximation. First, we compare FLD approximation with M1 model for dense core collapse calculations using a 1D spherical code. Then, I will present our solver and basics validation tests. I will discuss the impact of radiative transfer on outflow and fragmentation of magnetized dense core collapse calculations in low mass star framework. We compare our results with calculations made using an usual barotropic equation of state that traditionally reproduces isothermal and adiabatic phases of the collapse. We eventually discuss the impact of radiative feedback on small scales fragmentation.

De Zeeuw Darren

Darren De Zeeuw, Aaron Ridley, and Vladimir Bashkirov

Center for Space Environment Modeling
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USA

The Virtual Model Repository (VMR)

The Virtual Model Repository is a recently funded VxO (Virtual Observatory) which plans to integrate computational model results with observed data by facilitating visualization, data/model comparisons, and independent interpretation of model results. We will present an overview of several VxO projects and describe the VMR in detail and show progress and examples of its use. Using other VxO APIs, we will pull in relevant observed satellite data for the modeled time period and location and provide comparisons with CCMC run-on-request data. In addition, we will show how visualizations enhance the utility and understanding of existing datasets, including providing a global context to data.

Dubey Anshu

A. Dubey, D. Lee, K. Olson, K. Weide, K. Antypas

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USA

Exploiting the Extensibility of the FLASH Code
Architecture for Unsplit Time Integration

FLASH is a component-based massively parallel multiphysics simulation code with a wide user base. The time integration in FLASH was originally designed around Strang operator splitting for hydrodynamics. In version 3 of the FLASH release, we added an unsplit staggered MHD solver based on the constrained transport method of Lee and Deane. This method tested and exercised the modularity and extensibility of the FLASH code architecture. The integration of the method into the FLASH code, and its later adaptation into an unsplit hydrodynamic solver, also validated two major architectural features of the FLASH code. One of the two features relates to the successful mesh abstraction in FLASH, where uniform or adaptive discretization can be selected at configuration time. The second feature relates to the hierarchical organization of the Equation of State handling, which has been generalized while retaining the flexibility of user control. In this paper we present the relevant architectural details of the FLASH code that facilitated the incorporation of unsplit time integration into a primarily directionally split framework. Additionally, we discuss the challenges posed by adaptive mesh refinement to the staggered mesh solver and their solutions. Finally we present a comparative study of MHD simulations using the unsplit staggered mesh solver and the previously implemented split 8 wave solver by Powell et al., along with an analysis of their performance on the BG/P machine at Argonne National Laboratory.
This work is supported by the U.S. Department of Energy under Grant No. B523820 to the Center for Astrophysical Thermonuclear Flashes at the University of Chicago.

Falle S.A.E.G.

Sven van Loo and Sam Falle

Department of AppliedMathematics,
University of Leeds,Woodhouse Lane
United Kingdom

Magnetohydrodynamic Fragmentation

One of the outstanding problems in star formation is the nature of the mechanisms that are responsible for the observed clumpiness in star forming regions. Since the ratio of the thermal to magnetic pressure is observed to be small, it is natural to suppose that MHD waves play a crucial role. 3D simulations of turbulent gas motions do indeed show that dense cores with statistical properties similar to those observed can be formed in this way. However, these calculations generally contain so many ingredients that they obscure the fundamental mechanisms. By following the behaviour of a single MHD wave, analytic analyses and numerical simulations showed that clumps with a high-density contrast are generated by the excitation of slow-mode waves. This process works better in 2D than in 1D in the sense that the density contrasts are both larger and persist for longer. In these simulations the medium was treated as a single ideal plasma in which the gas is perfectly coupled with the magnetic field. However, the low ionisation fraction within molecular clouds implies that ambi-polar resistivity is important: In fact it seems that the dissipation length-scale sets the typical size of a dense core. Here, we will present the results of simulations following the evolution of a single MHD wave in 3D. We will discuss both the ideal and multifluid MHD results to show how the clump formation is modified by the dissipation.

Folini Doris

D. Folini and R. Walder

Dr. Doris Folini
CRAL ENS-Lyon
France

Supersonic turbulence in shock bound slabs

Colliding hypersonic flows and associated turbulence play a decisive role in many astrophysical objects. They contribute, for example, to molecular cloud structure and the initial mass function, the mixing of chemical elements in the galaxy, the X-ray emission of O-stars, differentiation of galactic sheets, appearance of wind-driven structures, or, possibly, to the prompt emission of gamma-ray bursts. By means of numerical simulations we study the turbulence within the collision zone of such flows and its back coupling with the confining shocks, an aspect not covered by the more widely spread 3D-periodic-box simulations of driven turbulence. The presented simulations cover isothermal as well as radiatively cooling interaction zones in 2D and 3D, resulting from the head on collision of two plane parallel flows. Corresponding results are presented and some related numerical issues like adaptive meshes and convergence are addressed. For symmetric upstream flow parameters and under isothermal conditions we find from simulations and on analytical grounds that the interaction zone is self-similar on average. Its characteristics depend only on the upstream Mach number M_u. In particular, we find the root-mean-square Mach-number within the interaction zone to scale as M_rms \approx 0.2 M_u. The mean density of the interaction zone is independent of M_u. The fraction f_eff of the upwind kinetic energy that survives shock passage scales as f_eff= 1 - M_rms^(-0.6). This dependence persists if the two head on colliding flows have different flow parameters, indicating that the turbulence within the interaction zone and its driving are mutually coupled. Larger upstream Mach-numbers lead to a faster expanding interaction zone, confining interfaces that are less inclined with respect to the upstream flow direction, more efficient driving, and finer interior structure with respect to the extension of the collision zone. The presence of well-resolved, extended cooling layers instead of isothermal shocks substantially damps the turbulence within the interaction zone.

Font Jose A.

Jose A. Font 1, Pablo Cerda-Duran 2, and Nikolaos Stergioulas 3

Departamento de Astronom\'ia y Astrof\'isica, Edificio de Investigaci\'on, Universidad de Valencia
Spain

Relativistic MHD simulations of Alfvén QPOs in magnetars.

We present results from recent two-dimensional simulations of Alfvén oscillations in magnetars, modeled as relativistic stars with a dipolar magnetic field. We use the anelastic approximation to general relativistic magnetohydrodynamics, which allows for an effective suppression of fluid modes and an accurate description of Alfvén waves. In addition, we compute Alfvén oscillation frequencies along individual magnetic field lines with a semi-analytic approach, employing a short-wavelength approximation. Our work confirms results of previous investigations based on perturbative approaches regarding the existence of two families of quasi-periodic oscillations (QPOs), with harmonics at integer multiples of the fundamental frequency. Empirical relations for the QPO frequencies are constructed and compared to observations of known Soft Gamma Repeaters. We find that, if the magnetic field of magnetars is characterized by a strong dipolar component, and QPOs are produced near the magnetic pole, then one can place an upper limit to the mean surface strength of the magnetic field of about $3-8\times10^{15}$G.

Ganse Urs

Astronomie
Universität Würzburg

KINETIC SIMULATION OF TYPE II RADIO BURSTS IN CME

The emission of solar radio bursts is closely related to coronal mass ejections. While the phenomenology of the bursts is rather well studied, the detailed mechanism of the emission is not yet fully understood [1]. Our approach to understand radio bursts - here the type II radio bursts - differs from previous approaches: Rather than trying to find the correct evolution of the CME using methods of fluid dynamics [2,3] or combined fluid/kinetic methods, we are using a fully kinetic approach to model the movement of electrons and protons in a shock environment, therefore neglecting the large scale evolution of the shock, while correctly modelling
the kinetic microphysics. The kinetic simulation itself is based on fully-relativistic Particle-in-Cell methods [4].
This technique allows for observation of plasma wave excitation in the shock region and gives a deep insight into the mechanisms of emission and transformation of different wave modes. We were using Fourier- and Laplace-transform based analysis to identify wave modes and electromagnetic emission, especially focused on their evolution in time.
In the setup of the simulation we were using a predefined shock environment in a computational box with periodic boundaries perpendicular to the shock direction and inflow boundaries along the shock direction. Our simulations were able to reproduce the phenomenological features of type II radio bursts and also additional information about fundamental processes taking place, with a focus on production of waves through three-wave interaction [5]. We present results of these simulations and compare them to previous models of radio burst modeling.

Glimm James

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Stony Brook University
USA

Turbulent Mixing, Transport and Subgrid Models

We combine two distinct themes for turbulent mixing modeling and add additional ideas. The results allow accurate simulation of macroscopic mixing as well as molecular level mixing, with feasible grid resolution, well short of full DNS resolution.

We combine the dynamic subgrid models proposed by Moin and coworkers with the high resolution methods favored by the capturing community, and to this we add our front tracking approach, which carries the high resolution futher. We improve the front tracking, to allow non zero mass diffusion across an interface, but only as given by the physical transport parameters, without numerical diffusion.

These ideas have been verified in an extensive 2D numerical study of a Richtmyer-Meshkov instability including reshock. For this problem, the macroscopic variables such as the mixing zone edges are shown to be insensitive to physical and numerical modeling of laminar and turbulent transport, but the molecular level mixing observables such as the joint pdf of temperature and concentration, or the chemical reaction rate of a temperature sensitive process, is very sensitive to these effects. For the problem considered, the chemical reaction rate is subject to statistical fluctuations even after a spatial average, a fact which complicates the mesh convergence study.

In a form without the subgrid models, these ideas have also been validated by the simulation of 3D Rayliegh-Taylor instabiities, in agreement with experiment. In this case both the micro and the macro observables (including the famous mixing rate parameter alpha) are sensitive to laminar and turbulent physical and numerical modeling issues.

Goldstein Melvyn

M. L. Goldstein, A. V. Usmanov, W. H. Matthaeus, and B. Breech

NASA Goddard Space Flight Center
USA

MHD MODELING OF THE SOLAR WIND WITH TURBULENCE TRANSPORT AND HEATING

We have developed a magnetohydrodynamic model that describes the global axisymmetric steady-state structure of the solar wind near solar minimum with account for transport of small-scale turbulence associated heating. The Reynolds-averaged mass, momentum, induction, and energy equations for the large-scale solar wind flow are solved simultaneously with the turbulence transport equations in the region from 0.3 to 100 AU. The large-scale equations include subgrid-scale terms due to turbulence and the turbulence (small-scale) equations describe the effects of transport and (phenomenologically) dissipation of the MHD turbulence based on a few statistical parameters (turbulence energy, normalized cross-helicity, and correlation scale). The coupled set of equations is integrated numerically for a source dipole field on the Sun by a time-relaxation method in the corotating frame of reference. We present results on the plasma, magnetic field, and turbulence distributions throughout the heliosphere and on the role of the turbulence in the large-scale structure and temperature distribution in the solar wind.

Gombosi Tamas I.

T.I. Gombosi, D.L. De Zeeuw, R.A. Frazin, W.B. Manchester, I.V. Sokolov, G.Tóth, B. van der Holst

Center for Space Environment Modeling
University of Michigan
USA

Modeling Solar Storms in the Heliosphere

Coronal mass ejections (CMEs) are the root cause of the most severe space weather events. Modeling the initiation and propagation of CMEs is one of the most challenging tasks in space weather modeling. The current generation 3D coronal models uses photospheric line-of-sight magnetograms to establish the lower boundary conditions at the Sun. Typically, the plasma temperature and density at the base is chosen in order to provide agreement with in-situ measurements of the solar wind speed at 1 AU. Due to the fact that coronal heating and momentum deposition remain poorly understood, the energetics of coronal plasma is treated with ad-hoc terms or simplified polytropic equations-of-state to energize the solar wind. New methods that use observations of the white-light corona are needed to improve the solution. Solar rotational tomography has emerged as a powerful technique for determining the 3D distribution of electron density from coronagraph images of the polarized brightness. The combination of solar rotational tomography with MHD modeling of the corona has the potential to vastly improve the accuracy of coronal modeling. This talk will present some of the initial work in this direction.

González Matthias

Matthias GONZÁLEZ[1], Edouard AUDIT[2]
1

Universidad Politécnica de Madrid
ETSII - Instituto de Fusión Nuclear
Spain

Underdense stellar jets propagating into the ISM :
radiation-hydrodynamics e ects

The stellar jets simulations often use a cooling approximation of the radiative transfer. However, in the case where the jet is still embedded in the optically thick molecular cloud, the photons may have a short mean free path needing a detailed radiative transfer treatment. We emphasize here the differences obtained in this latter case, carrying out radiation-hydrodynamics simulations performed with the 3D HERACLES code. We present simulations of the propagation of an underdense jet in an interstellar medium at rest. The results show that the jet is collimated due to purely radiative e ects and that a secundary jet can be created.

Hanawa Tomoyuki

Center for Frontier Science
Chiba University
Japan

A New Scheme to Solve Gas Disks around Stars.

I propose a new scheme to solve gas disks rotating around stars. Such gas disks are mainly supported by centrifugal force against gravity and the pressure force is relatively weak. In such case, high spatial resolution is required to integrated the hydrodynamical equations since the numerical cell should be smaller than the pressure scaleheight. In order to relax this condition, I decomposed the velocity into two components, given and unknown. The given velocity denotes the circular rotation while the unknown denotes the deviation. The former is set so that the inertia force cancels the gravity. Hence the apparent gravity vanishes in the hydrodymaical equations for the unknown velocity. The application of this scheme to accreting young binary is shown in the conference. This scheme captures spiral shock waves excited in the circumbinary and cicumstellar disks clearly.

Hennebelle Patrick

Laboratoire de radioastronomie – ENS

Collapse of magnetized prestellar cores

Understanding how dense prestellar dense cores collapse and possibly fragment is of great importance for our understanding of the star formation process. In the talk, I will present AMR MHD simulations, performed with the RAMSES code, of this phenomenon. In particular, I will discuss the problem of disc formation, launching of outflows as well as the impact of the magnetic field on the fragmentation of the core.

Heerikhuisen Jacob

Jacob Heerikhuisen

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USA

Kinetic Modeling of Interstellar Hydrogen in the Heliosphere

The heliospheric interface is created by the collision between the plasmas of the solar wind and local interstellar medium. The presence of Neutral Hydrogen significantly affects the resulting structures -- termination shock, bow shock and heliopause. Due to the large mean free paths, H-atoms must be modeled kinetically. We present results obtained from a model of the heliosphere that self-consistently couples the ion, modeled as MHD, and neutral, modeled kinetically, populations through charge-exchange collisions. The resulting neutral population is distinctly non-Maxwellian. We present predictions for NASA's IBEX mission which is currently detecting energetic neutral atoms from an eccentric Earth orbit. Details of the kinetic model, such a particle splitting, will be explained. Additionally we will describe procedures currently under development that will address time-dependence and ways to overcome difficulties in obtaining statistically accurate charge-exchange source terms for the MHD equations in places where the ion population changes rapidly

Hughes David

David W. Hughes

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University of Leeds
United Kingdom

Large- and small-scale turbulent dynamo action

One of the most important problems in astrophysical MHD is to explain the generation of large-scale magnetic fields (i.e. fileds with a strong component on scales much larger than typoical velocity scales). I shall discuss some of the difficulties in the standard mean field formualtion, illustrating these by reference to simulations of dynamo action driven by turbulent rotating convection.

Izmodenov Vladdislav

Izmodenov Vladislav V. (1,2,3), Alexashov Dmitry B. (2,3), Malama Yury G. (2,3)

Department of Aeromechanics and Gas Dynamics
Faculty of Mechanics and Gas Dynamics
Russia

Kinetic-gasdynamic modeling of the solar wind interaction with the partly-ionized local interstellar medium

This paper reviews modern kinetic-MHD models of the solar wind interaction with the local interstellar medium.These models take into account multi-component nature both the solar wind and interstellar medium. Local interstellar plasma including protons, electrons and ions of helium and neutral components, interstellar magnetic field are taking into account from interstellar side. The mean free path of the interstellar H atoms is comparable with the size of the SW/LIC interaction region and, therefore, the neutral component should be described kinetically. Penetrating inside the heliosphere the interstellar H atoms are charge exchanged with solar protons or photoionized. As a result of the charge exchange or photoionization new protons (called pickup protons) are created. The pickup protons constitutes new population of charged particles which does not assimilate into the solar wind and need to be described kinetically.
The paper reports kinetic-gasdynamic approach to model the SW/LIC interaction developed by our Moscow group since 1993. New results obtained in the frame of the recent 2D and 3D models are presented.

Janhunen Pekka

P. Janhunen

Finnish Meteorological Institute
Space Research
Finlande

Physics of thrust prediction of the solar wind electric sail propulsion system

The underlying elementary process of the solar wind electric sail propulsion system is the interaction of the solar wind plasma stream with a thin positively charged tether. The essential problem is to predict the thrust force per unit length that the plasma stream exerts on the tether when the tether is artificially kept in a 15-40 kV voltage. Since the force per unit length is approximately equal to the sheath width multiplied by the solar wind dynamic pressure, the problem is closely related to the prediction of the collisionless electron sheath width in flowing plasma conditions.
Our first attempts to predict the force used time-accurate particle-in-cell (PIC) simulations. By construction, these simulations included the extra shielding effect of trapped electron population which is always formed when the potential is ramped up. In case of a purely 2-D infinitely long tether, there appears to be no process that could deplete the trapped electron population in any reasonable timescale. However, natural trapped electron removal can nevertheless take place because one end of the tether is attached to the spacecraft where the potential pattern has a complex 3-D nature. This causes an effective randomisation of the electron angular momenta each time the particles visit the vicinity of the spacecraft. There is a finite probability that the electron collides with the tether wire because of this orbit randomisation. The end result is that the trapped electron population is removed in a few minute timescale.
To estimate the electric sail thrust analytically, we introduce the concept of an electrosphere and consider the force balance condition between the solar wind dynamic pressure and the electrostatic energy density at the electropause. These concepts are proposed as electrostatic analogues to the magnetosphere and the magnetic force balance condition which determines the subsolar distance of the magnetopause. Assuming no trapped electrons, the method predicts roughly five times higher thrust than the PIC simulation which included trapped electrons. For more accurate thrust predictions, new types of simulations would be needed. In the absence of trapped electrons, one could use e.g. the inside-out backward trajectory integration approach for solving the time-stationary Vlasov-Poisson system which has been used earlier for predicting the sheath width for electrodynamic tethers in low Earth orbit.
Augmented by the fivefold increased thrust estimates, the electric

sail appears to be an extremely promising alternative for solar system transport, with 100 kg systems producing continuous 1 N thrust being potentially feasible. If used as an asteroid material tug, for example, the lifetime delivered impulse per unit propulsion system mass of such an electric sail system would exceed a chemical rocket by factor 1000 and a contemporary ion engine by factor 100.

Jarvinen Riku

R. Jarvinen (1), E. Kallio(1,2), P. Janhunen (1), T. L. Zhang (3), S. Barabash (4), A. Fedorov (5), V. Pohjola (1), I. Sillanpää (6)

Finnish Meteorological Institute
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Hybrid modelling of the Venusian oxygen ion escape

We study the solar wind induced escape of oxygen ions from the Venusian atmosphere by a hybrid simulation (HYB-Venus). Oxygen abundance is an important factor in the evolution of terrestrial planets. In the Venus' upper atmosphere atomic oxygen (O^+) is the dominant ion species. Since Venus is a non-magnetized planet, the obstacle to the solar wind flow is the highly conduting ionosphere. As a result, an induced magnetosphere is formed around the planet, and the solar wind flows in close proximity to the upper atmosphere. This results in an interaction which erodes the planetary ions into the solar wind. O^+ is believed to escape from Venus approximately at the rate of 10^{25} s^{-1}.
In this study we have made simulation runs with emission rates of planetary thermal O^+ ranging from 10^{23} to 10^{27} s^{-1}. The used upstream conditions for the solar wind and IMF are close to the nominal Venusian values. The runs suggest that the rate of 10^{25} s^{-1} is close to a limit at which the planetary ions start to influence the configuration of the induced magnetosphere. Below this rate the O^+s behave like test particles in the global system. We also compare the simulation to particle and magnetic observations by Venus Express in an orbit case study.

Jenko Frank

K. Reuter, F. Jenko

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Germany

Waves, turbulence, and hysteresis effects in a spherical MHD dynamo model

We present direct numerical MHD simulations at low magnetic Prandtl numbers of a turbulent two-cell flow in a bounded, spherical geometry, driven by a localized, constant body force. The flow is of s2t2 type and similar to the flow used in the Madison Dynamo Experiment. Infinitesimal magnetic perturbations are amplified if the magnetic Reynolds number Rm is larger than a threshold value Rm_c(Re), resulting in a self-excited magnetic field dominated by a transverse dipole mode.
The stability curve Rm_c(Re) is mapped out numerically. With increasing Reynolds number Re, it first exhibits a steep increase and then transitions to a plateau for Re>1000. At low Reynolds numbers, a hydrodynamic instability causes internal waves with characteristic m=2 zonal wavenumber. This time-periodic flow acts as a dynamo although snapshots as well as the mean flow are not dynamos. The magnetic fields' growthrate shows resonance depending on the wave frequency. Furthermore, a cyclic self-killing and -recovering dynamo based on adjustment of magnetic field modes is presented. The phenomena are explained by mixing of non-orthogonal eigenstates of the induction equation, following recent work by Tilgner (PRL, 2008, 100, 128501).
Furthermore, finite amplitude perturbations to the magnetic field can trigger dynamo action below Rm_c in the turbulent regime: extending the study by Ponty on the Taylor-Green dynamo (PRL, 2007, 99, 224501) to the spherically bounded s2t2 dynamo, a hysteresis cycle is confirmed that can sustain dynamo action in an interval Rm_0<Rm<Rm_c. The instability is therefore governed by a subcritical bifurcation. This hysteretic behaviour is associated with changes in the turbulent velocity field caused by the finite amplitude magnetic field. It is then shown that the subcritical dynamo state can be accessed by transiently applying a transverse magnetic field from an external source, which implies the possibility that dynamo experiments which currently don't self-excite
(Rm<Rm_c) may nevertheless reach a state of self-sustained dynamo action.

Jouve Laurene

DAMTP/CMS, University of Cambridge
United Kingdom

Influence of convection and mean flows on rising magnetic fluxtubes
(L. Jouve & S. Brun)

We present the first 3D MHD study in spherical geometry of the non-linear dynamical evolution of magnetic flux tubes in a turbulent rotating convection zone. These numerical simulations use the anelastic spherical harmonic (ASH) code. We seek to understand the mechanism of emergence of strong toroidal fields through a turbulent layer from the base of the solar convection zone to the surface as active regions. We compare the dynamical behaviour of flux tubes in a fully convective shell with reference calculations done in an isentropic zone. Indeed, in our global simulations of rotating fully developed convection, mean flows such as differential rotation and meridional circulation are self-consistently generated and continuously maintained and they may influence the evolution of the tube-like structure.
We find that two parameters influence the tubes during their rise through the convection zone: the initial field strength and amount of twist, thus confirming previous findings in Cartesian geometry. Further, when the tube is sufficiently strong with respect to the equipartition field, it rises almost radially independently of the initial latitude (either low or high). By contrast, weaker field cases indicate that downflows and upflows control the rising velocity of particular regions of the rope and could in principle favour the emergence of flux through Ω-loop structures. For these latter cases, we focus on the orientation of bipolar regions and find that sufficiently arched structures are able to create bipolar regions with a predominantly East-West orientation. Meridional flow seems to determine the tra jectory of the magnetic rope when the field strength has been significantly reduced near the top of the domain. Local field emergence also feeds back on the horizontal flows thus perturbing the meridional circulation via Maxwell stresses. Finally differential rotation makes it more difficult for tubes introduced at low latitudes to emerge at the surface.

Kaehler Ralf

Konrad-Zuse-Zentrum f˙ur Informationstechnik Berlin (ZIB)
Division Scientific Computing
Department Visualization and Data Analysis
Germany

Visualization of Astrophysical Simulations on Programmable Graphics Hardware"

In numerical astrophysics and cosmology typically many length scales must be considered to accurately model the physical phenomena. For instance star formation, where the regions of proto-galaxies as well as the local environment of the stellar objects need to be resolved at the same time. A specific adaptive numerical technique that allows to cover a large range of spatial and temporal scales is called AMR (Adaptive Mesh Refinement). The basic idea is to recursively overlay regions of a coarse initial structured grid with patches of increasing resolution, making optimal use of the computational resources. Therefore this technique is often used in astrophysical simulations.
We will present our interactive visualization pipeline for rendering large, three-dimensional time-dependent astrophysical AMR data sets with interactive frame-rates on standard desktop computers. The approach exploits modern graphics hardware to process hundreds of screen pixels in parallel via programmable pixels shaders. It supports to integrate unstructured point datasets, like stars and/or galaxy splats into the rendering of gaseous interstellar, respectively intergalactic material. The approach further supports a combined color-mapping for several input data fields and allows for a very flexible adaption to the special requirements of different types of simulations. Its interactivity makes it an useful tool for data analysis as well as for fast generation of high-quality animations from astrophysical datasets.
We will show various resulting 3D HD-animations ranging from large scale structure formation in the early universe, to the evolution of the first stellar objects and the cosmological reionization era.

Kang Hyesung

Department of Earth Sciences
Pusan National University
Corée du sud

Self-Similar Evolution of Cosmic-Ray Modified Shocks

Hyesung Kang (Pusan National University, Pusan, Korea)

Diffusive shock acceleration (DSA) is widely accepted as the primary mechanism through which cosmic rays (CRs) are produced in a variety of astrophysical environments. We use kinetic simulations of DSA to study the time-dependent evolution of the energy spectrum of CRs accelerated by plane, quasi-parallel shocks. We find that the precursor and subshock transition approach the time-asymptotic state, and then evolve in an approximately self-similar fashion, depending only on the similarity variable, $x/(u_s t)$. During this self-similar stage, the CR spectrum at the subshock maintains a characteristic form as it evolves: the sum of two power-laws with the slopes determined by the subshock and total compression ratios with an exponential cutoff at the highest accelerated momentum. This analytic form may represent an approximate solution to the DSA problem for astrophysical shocks during the self-similar evolutionary stage.

Keppens Rony

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2 FOM-Institute for Plasma Physics Rijnhuizen, Nieuwegein, The Netherlands
3 Astronomical Institute, Utrecht University, The Netherlands

I will present grid-adaptive computational studies of both magnetized and unmagnetized jet flows, with significantly relativistic bulk speeds, as appropriate for AGN jets. Our relativistic jet studies shed light on the observationally established classification of Fanaroff-Riley galaxies, where the appearance in radio maps distinguishes two types of jet morphologies. We investigate how density changes in the external medium can induce one-sided jet decelerations, explaining the existence of hybrid morphology radio sources. Our simulations explore under which conditions highly energetic FR II jets may suddenly decelerate and continue with FR I characteristics.
In a related investigation, we explore the role of dynamically important, organized magnetic fields in the collimation of the relativistic jet flows. In that study, we concentrate on morphological features of the bow shock and the jet beam, for various jet Lorentz factors and magnetic field helicities. We show that the helicity of the magnetic field is effectively transported down the beam, with compression zones in between diagonal internal cross-shocks showing stronger toroidal field regions. For the high speed jets considered, significant jet deceleration only occurs beyond distances exceeding hundred jet radii, as the axial flow can reaccelerate downstream to internal cross-shocks. This reacceleration is magnetically aided, due to field compression across the internal shocks which pinch the flow.

Khachatryan Suren

Computer and Information Science Master degree Program,
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American University of Armenia

Numerical Integration of Propagation of 2D Nonlinear Density Waves in Gravitating Discs

Propagation of 2D nonlinear density waves in an infinitely thin gravitating gaseous disc is considered and an integration method is suggested. It constructs “equations of motion” of discretization mesh nodes and incorporates the evolution of the spatial domain into the physical problem. Such approach leads to reflection of irregularities in solutions in the mesh structure. Ways to regularize the latter are discussed.
The method is explored in hydrodynamic simulations of the global spiral structure in galactic discs. In addition, interpretation of the radially expanding local features in the central disc of the Galaxy in terms of the nonlinear density wave theory is evaluated.

Klahr Hubert

Max-Planck-Institut für Astronomie
Germany

The Role of Turbulence in the Formation of Planetary Systems

In recent years turbulence has shown to be of major importance for the formation of planets in disks around new born stars. This is true in may respects, from the diffusion of dusty material, heating of gas and dust, turbulence driven coagulation, gravoturbulent formation of planetesimals, migration of planets and the general evolution of disks. This presentation shall provide an concise overview on the current state of planet formation theory and the role numerical simulations of turbulence play within.

Klein Richard

University of California
Department of Astronomy
USA

Feedback Effects in the Formation of High Mass and Low Mass Star Formation"

The formation of massive stars remains one of the most significant unsolved problems in astrophysics, with implications for the formation of the elements and the structure and evolution of galaxies. It is these stars, with masses greater than 8-10 solar masses, that eventually explode as supernovae and produce most of the heavy elements in the universe, dominate the energy injection into the interstellar medium of galaxies and by injecting both heavy elements and energy into the surrounding medium, shape the evolution of galaxies. Despite the importance of massive star formation, relatively little is known about them theoretically as they pose a major theoretical challenge: How is it possible to sustain a sufficiently high mass accretion rate into a protostellar core despite the radiation pressure on the accreting envelope? I will discuss our work on the first 3D simulations of massive star formation. Using our high resolution 3D radiation-hydrodynamic adaptive mesh refinement code ORION with a v/c correct treatment of the radiation transport, we have investigated the formation of high mass stars from both smooth and turbulent initial conditions in the collapsing massive core. I discuss our work on identifying 2 new mechanisms that efficiently solve the problem of the Eddington barrier to high mass star formation; the presence of 3D Rayleigh Taylor instabilities in radiation driven bubbles present in the accreting envelope and the feedback due to protostellar outflows providing radiation an escape mechanism from the accreting envelope in addition to the feedback from protostellar radiation and its affect on stellar multiplicity. I will present predictions for upcoming EVLA and ALMA submillimeter observations. I also discuss the effects of radiative transfer on low mass star formation in a turbulent molecular cloud. I will compare the distribution of stellar masses, accretion rates, and temperatures in the cases with and without radiative transfer, and demonstrate that radiative feedback has profound effect on accretion, multiplicity, and mass by reducing the number of stars formed and the total rate at which gas turns into stars. Calculations that omit radiative feedback from protostars significantly underestimate the gas temperature and the strength of this effect.

Klingenberg Christian

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New numerical solvers for Hydro- and Magnetohydrodynamics applied to astrophysical flow simulations

We present a relaxation system for hydro and magnetohydrodynamics from which one can derive approximate Riemann solvers. The solvers satisfy discrete entropy inequalities, and preserve positivity of density and internal energy. Next we consider their practical implementation, and derive explicit wave speed estimates satisfying the stability conditions.
We put this into an astrophysical application by comparing our new positive and entropy stable approximate Riemann solver with state-of the-art algorithms for astrophysical fluid dynamics, the Prometheus code. We present shock tube tests, two-dimensional instability tests and driven turbulence simulations in three dimensions. The new Riemann solver increases the computational speed without loss of accuracy.
These 3-dimensional turbulence simulations are part of a plan to develop, implement, and apply our numerical scheme for modeling turbulent astrophysical flows. We shall present advances in this ongoing project

Kritsuk Alexei

Alexei G. Kritsuk, Sergey D. Ustyugov, Michael L. Norman, and Paolo Padoan

Department of Physics and Center for Astrophysics and Space Sciences
University of California at San Diego
USA

SUPERSONIC ISOTHERMAL TURBULENCE IN MAGNETIZED MOLECULAR CLOUDS

Magnetic fields are believed to play an important role in regulating star formation in turbulent molecular clouds. The nature of highly compressible magnetized turbulence in these clouds, however, remains poorly understood. In my talk I shall present results of large-scale simulations of MHD turbulence at a sonic Mach number of 10 carried out with the Piecewise Parabolic Method on a Local Stencil (PPML) at resolution up to 1024^3 mesh points. Our models explore universal trends in scaling properties of fully developed statistically isotropic turbulence as a function of the magnetic field strength. We show that the rigorous 4/3-law of incompressible MHD can be extended to supersonic turbulence if a proper density averaging of the Elsasser fields is included. This illustrates the importance of correlations between various fields involved in nonlinear interactions responsible for the direct energy cascade in compressible MHD. I will also discuss convergence of numerical solutions under mesh refinement, and effects of the driving force and numerical dissipation on the measured turbulence statistics.

Kucharek Harald

Harald Kucharek

University of New Hampshire
Space Science Center
USA

Hybrid modeling of plasma flows in geophysical and astrophysical settings

Hybrid simulations build the link between large-scale Magneto-Hydro-Dynamics (MHD), in which the plasma and its components are described as fluids, and fully kinetic simulations in which all the constituents are treated kinetically. In hybrid simulations ions are treated as charged particles for which the equations of motion are solved and electrons are considered to be a charge neutralizing fluid. Over the last 25 years these simulations have been very successfully applied to space plasmas, especially for describing physical processes in streaming plasmas, such as formation and evolution of instabilities, particle acceleration, and the turbulence at colllisionless shocks. Over the years and with increasing computing power these simulations became multi-dimensional containing several ion species, and their simulation size increased accordingly. Nowadays, these simulations are able to simulate even large-scale structures such as the Earth's bow shock. Processes at interplanetary traveling shocks and stationary planetary bow shock have been simulated and compared with spacecraft observations. Most recently Voyager spacecraft crossed the termination shock and entered the transition layer to the interstellar medium and provided very interesting data that need to be analyzed, interpreted, and modeled. The twin satellite mission STEREO provides simultaneous spatial observations and the Interstellar Boundary Explorer IBEX will soon provide a 3D map of the heliosheath.
In this presentation we will review the achievements, the capabilities, and the future path of these simulations in view of the demand from most recent observations to improve our current knowledge of plasma physical processes of the flowing solar wind plasma in the inner and outer heliosphere.

Lazarian Alexander

Department of Astronomy
University of Wisconsin-Madison

Fast 3D Reconnection of Weakly Stochastic Magnetic Field and Acceleration of Energetic Particles

With the progress of collisionless Hall-MHD reconnection models a really burning question arises. Is the reconnection rate fast in collisionless environments and slow when collisions are important? The positive answer to that question means that most of MHD simulations, including those of interstellar medium, do not represent astrophysical reality, as high numerical diffusivity makes reconnection in simulations fast.
I shall discuss the results new 3D MHD numerical simulations that support the scaling relations derived for the model of fast magnetic reconnection in Lazarian & Vishniac (1999). This model allows for fast reconnection in both collisional and collisionless plasma provided that magnetic field is weakly stochastic. As turbulence is ubiquitous in astrophysical environments, weak stochasticity of magnetic field lines is a default state for most of astrophysical magnetic fields. If initially magnetic field is too laminar, we show the reconnection itself may increase the level of turbulence resulting in reconnection instability or bursts of reconnection.
I shall demonstrate that numerical simulations provided in a generic 3D configuration with a substantial guide field provide reconnection rates which do not depend on the Ohmic resistivity, but is a functions of the turbulence injection strength and the turbulence injection scale. The observed dependences correspond to the theoretical predictions. The model is applicable to both collisionless and collisional environments and does not show dependences on anomalous resistivities that were introduced in some of the numerical runs to mimic plasma effects.
The predictions of the model include First Order Fermi acceleration of energetic particles within the extended reconnection layers predicted in the model. The power law of accelerated particles is steeper than the one predicted for the shock acceleration, but it gets flatter if the backreaction of the energetic particles is taken into account. The acceleration process is likely to be widely spread in Astrophysics. For instance, I propose that anomalous cosmic rays observed

Lapenta Giovanni

Giovanni Lapenta (KU Leuven), Stefano Markidis (University of Illinois Urbana Champaign, and Lawrence Berkeley National Laboratory)

Centrum voor Plasma-Astrofysica
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Parsek3D: a Massively Parallel Implicit Particle in Cell code for Kinetic Simulations

Astrophysical plasmas have a wide disparity of length and time scales. The kinetic description includes all physics levels, from the first page of a traditional plasma physics textbook(the Debye shielding and the plasma waves) to the last pages where large scale processes are described. However, to describe with great accuracy the large scale processes retaining fully all relevant kinetic physics does not typically require to resolve with great accuracy all kinetic scales down to the smallest and fastest. The explicit PIC method needs to resolve for stability always the finest scales in space and time resulting in needless waste of resources.

Here the implicit moment Particle=in-Cell method enters the scene: it provides a method that allows to retain only the scales of interest. It can resolve the Debye length and the plasma frequency, if needed, or it can operate at the MHD level, automatically averaging on the unresolved physics.

To take full advantage of the intrinsic adaptive properties of the implicit moment method one needs the following two capabilities. First, one needs to adapt the resolution in space and time locally, resolving where needed small scales and keeping in the rest of the system large scales. Explicit methods have started in this direction by resolving the local Debye length and taking advantage of the ability of using larger cells in lower density or colder regions. The implicit method can go much deeper allowing to select the local scale without any regards to the Debye length or plasma frequency. This has the proven ability to gain several orders of magnitude in grid spacing and time step. Second, one needs a massively parallel implementation to achieve the needed resolution and the required large system sizes.

We report our recent results with the Parsek3D code in both directions described above. We present our approach for the development of the AMR technique for the implicit PIC. Besides being the first attempt to integrate implicit PIC with the AMR methodology, we believe our innovative techniques will also be of interest for the wider PIC community, even for explicit methods. Furthermore we will present the massively parallel implementation of the implicit PIC method and demonstrate its scalability. Two applications will be shown: the interplay of current aligned and field aligned instabilities in 3D magnetic reconnection and the study of converging shocks and their interaction, a problem where the AMR capability will be deployed.

Lesaffre Pierre

L.R.A. Département de Physique ENS
France

Methods for analytical solutions of astrophysically

I will review some of the methods that have been used to get solutions to astrophysically relevant problems. I will in particular detail the method for self-similar solutions and provide an application to fast moving convective/radiative fronts in stars. I will then discuss possible applications to numerical algorithms for solving 1D partial differential equations.

Lesur Geoffroy

DAMTP/CMS, University of Cambridge
United Kingdom

relevant problems.

Spectral methods are known to be very efficient to study incompressible turbulence. In this talk, I will present a spectral method used to study sheared incompressible MHD turbulence, as found in accretion discs and stellar interiors. I will show how the MHD equations can be computed spectrally in a frame moving with the mean shear, and the advantages associated with this method. Parallelization technics will be discussed and compared with the efficiency of classical domain decomposition methods. Finally, I will present several results on MHD turbulence in accretion discs obtained using these technics.

Marek Andreas

Max-Planck-Institute of Astrophysics
Germany

Current status of modelling core collapse supernovae

For more than 40 years scientist investigate the explosion mechanism of core collapse supernovae. The high complexity of the events leading to the explosion of stars with stellar iron cores, and the non-linear interaction between different physical processes turn modelling of core collapse supernovae into a challenging task. Ideally, supernova modellers would have to include in their simulations multi-dimensional hydrodynamics with sufficient resolution to resolve the complex fluid flows and hydrodynamical instabilities,
together with adequate nuclear physics to treat the forming neutron star and the nuclear reaction networks, a sufficient accurate neutrino transport and neutrino-matter interaction rates, and last but not least general relativity. In this contribution, we will address the current status of modelling core collapse supernovae and the uncertainties and/or approximations that are in supernova models. Furthermore the complex interaction of hydrodynamical instabilities and neutrino interactions in the supernova core will be described, and our current understanding of the explosion mechanism of core collapse supernovae will be summarized.

Mathis Stéphane

S. Mathis et al.

Service d'Astrophysique
CEA/Saclay
France

Secular transport processes in stellar interiors modelling

Stars are dynamical rotating bodies. Then, their interiors are the seat of hydrodynamical processes that have dynamical but also secular time-scales. In this talk, we focus on the latters with making a short review of the different mechanisms that transport angular momentum and chemicals in stellar interiors. Then, we show how they are now modelled using spectral expansion of hydrodynamics equations on the low-degree spherical harmonics coupled with classical stellar evolution codes. The behaviour of the transports of angular momentum, heat and chemicals is then discussed for different types of stars and consequences for stellar evolution are presented.

Matsumoto Tomoaki

Faculty of Humanity and Environment
Hosei University
Japan

Starformation in a turbulent cloud core with Self-gravitational MHD Adaptive Mesh Refinement

Numerical simulations of collapse of turbulent molecular cloud core are performed by a self-gravitational MHD AMR code, SFUMATO. A cloud core with a strong magnetic field of ~20 □G undergoes collapse to form a single star when weak and moderate turbulence is assumed. Decay of turbulent flow allows the cloud core to collapse although the turbulence supports the cloud core against the gravity at the early stage. When a turbulent velocity is assumed to be a high Mach number larger than 5, the cloud core does not exhibit collapse in a few x 10 freefall times.

The envelope of cloud core with low density is highly disturbed by turbulent flow exhibiting a complex structure. In contrast the cloud center with high density exhibits approximately axisymmetric structure aligned with the local magnetic field. The central star, the first core, is surrounded by a disk envelope, and ejects outflows.

The simulation code, SFUMATO, solves self-gravitational MHD problems, based on the AMR technique. A block-structured grid is adopted as the grid of AMR hierarchy. Roe's scheme is adopted as the MHD solver, with hyperbolic cleaning of the divergence error of the magnetic field also implemented. The self-gravity is solved using a multigrid method based mainly on a full multigrid (FMG)-cycle on the AMR hierarchal grid.

In this talk, the scientific results on collapse of turbulent cloud cores and implementation of SFUMATO are presented.

Matsumoto Ryoji

Ryoji Matsumoto, Hiromitsu Nishikori,
Takayuki Ogawa, Hiroshi Oda (Chiba Univ.),
and Mami Machida (Nagoya Univ.)

Department of Physics
Faculty of Science
Japan

Global MHD Simulations of Galactic Gas Disks and Accretion Disks

We have developed a numerical simulator for rotating magnetized disks. It consists of the simulation engines solving the MHD equations and various modules setting up the simulation models. By applying this simulator, we carried out global three-dimensional MHD simulations of galactic gas disks and accretion disks. In the simulations for galactic gas disks, we adopted an axisymmetric gravitational potential which reproduces the rotation curve of the galaxy. The initial state is a torus rotating in this gravitational potential.
The initial magnetic field is assumed to be weak, and purely azimuthal. We found that the magnetic fields are amplified up to micro Gauss and that the direction of the mean azimuthal magnetic fields in the equatorial region changes quasi-periodically. Buoyantly escaping magnetic flux produces magnetic loops in the disk halo.
We also present the results of global 3D MHD simulations of the hard-to-soft state transitions in black hole accretion flows. When the disk density exceeds the threshold for the onset of the cooling instability, the contraction of the disk in the vertical direction enhances the mean azimuthal magnetic fields of the disk. Such disks supported by the magnetic pressure can explain the luminous hard state observed in black hole candidates.

Mayer Lucio

University of Zurich
Institute for Theoretical Physics
Suisse

Multi-scale cosmological simulations of galaxy formation; current progress and challenges

The formation of galaxies is a highly complex problem at the boundary between astrophysics and cosmology. We now have a fairly established theory of cosmological structure formation, the Lambda Cold Dark Matter model, which is supported by observations of the cosmic microwave background and the large scale structure of the Universe. Yet the formation of galaxies in such prevailing cosmology is still an unsolved problem due to the complex role played by the physics of the intergalactic and interstellar medium, as well as by star formation. The tool that is moving the field forward is, and will be even more in the future, multi-scale three-dimensional simulations of the coupled evolution of the collisionless cold dark matter and the dissipative baryonic component. Spatially and temporally adaptive gravitational and hydrodynamical simulation methods, such as Smoothed particle hydrodynamics (SPH) and Adaptive Mesh Refinement (AMR) techniques, are best suited to tackle the problem due to the huge range of spatial and temporal scales involved, ranging from their dark matter halos extended over hundreds of kiloparsecs to the main sites of star formation in galactic disks, Giant Molecular Clouds (GMCs), only tens of parsecs across.
I will show the tremendous progress achieved in the last few years owing to the increase of spatial and mass resolution in the simulations combined with more realistic phenomenological sub-grid models of unresolved processes such as star formation and energetic feedback from supernovae explosions.
I will show how cosmological simulations approaching tens of parsec scale resolutions are finally capable of producing galaxies with realistic properties across a wide range of mass scales, from galaxies much larger than our Milky Way to dwarf galaxies. These simulations can potentially solve a major problem of the current cosmological model, namely that rotation curves of low mass galaxies support the existence of constant density cores of dark matter at odds with the cuspy dark matter halo profiles predicted for two decades by simulations neglecting the baryonic component.

Meliani Zakaria

Multi-D high resolution simulations of relativistic two-component jets

We will present 2.5D and 3D high resolution numerical simulations done with the grid-adaptive relativistic AMRVAC code of two component relativistic jets.
Our aim is to investigate the stability of transverse magnetise astrophysical jets. We find evidence for the development of an extended shear flow layer between the two jet components, resulting from the growth of a body mode in the inner jet, Kelvin-Helmholtz surface modes at their original interface, and their nonlinear interaction.
However, we find that the presence of a heavy external jet allows the shear layer further development be slowed down, and the maintaince of a collimated flow.

Mignone Andrea

Dipartimento di Fisica Generale
Italy

"Implemention of High Order Finite Difference Schemes for multidimensional MHD"

Recent advances in computational fluid dynamics have demonstrated the benefits offered by numerical methods possessing higher than second order accuracy when solving hyperbolic systems of conservation laws.
In particular, I will focus on the extension of some finite difference schemes to the equation of compressible Magnetohydrodynamics (MHD) in more than one dimension.
The schemes of choice are based on the fifth and ninth-order WENO, the Monotonicity Preserving (MP) scheme of Suresh and Huynh (JCP 1997) and a finite difference version of the PPM scheme.
A cell-centered representation of the magnetic field is adopted whereby divergence errors are monitored and controlled using the mixed hyperbolic/parabolic divergence cleaning proposed by Dedner et al. (JCP, 2002).
The schemes have been successfully implemented in the PLUTO code for Astrophysics and will be available in futue releases.

Mueller Wolf-Christian

Max-Planck-Insitut für Plasmaphysik
Germany

Turbulence theory: combining numerical simulation, statistical closure theory
and physical intuition"

The complex nonlinear dynamics of plasma turbulence exhibits - even in the simplified magnetohydrodynamic (MHD) approximation - a large variety of statistical features that are observed in direct numerical simulations. These can, however, not be understood by the application of dimensional analysis
and similarity hypotheses alone. It is shown how quasi-normal statistical closure theory allows progress in the understanding
of numerical results regarding the interaction of kinetic and magnetic turbulent energy as well as the emergence of large-scale magnetic structures
in the course of an inverse cascade process in three-dimensional MHD turbulence. This "dynamical equilibrium" approach seems to be a promising
ansatz for making progress in the identification and understanding of
fundamental and probably universal properties of plasma turbulence.

Ng Chung-Sung

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L. Lin, and A. Bhattacharjee

Space Science Center
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Three Dimensional Simulations of the Parker's Model of Solar Coronal Heating: Lundquist Number Scaling due to Random Photospheric Footpoint Motion

Center for Integrated Computation and Analysis of Reconnection and Turbulence and Center for Magnetic Self-Organization, University of New Hampshire, Durham, New Hampshire 03824, USA
Parker's model [Parker, Astrophys. J., 174, 499 (1972)] is one of the mostly discussed mechanisms for coronal heating and has generated much debate. We have recently obtained new scaling results in two dimensions (2D) version of this problem suggesting that the heating rate becomes independent of resistivity in a statistical steady state [Ng and Bhattacharjee, Astrophys. J., 675, 899 (2008)]. Our numerical work has now been extended to 3D by means of large-scale numerical simulations. Random photospheric footpoint motion is applied for a time much longer than the correlation time of the motion to obtain converged average coronal heating rates. Simulations are done for different values of the Lundquist number to determine scaling. In the large Lundquist number limit, we recover the case in which the heating rate is independent of the Lundquist number, predicted by previous analysis as well as 2D simulations. In the same limit the average magnetic energy built up by the random footpoint motion saturates at a constant level, due to the formation of strong current layers and subsequent disruption when the equilibrium becomes unstable. In this talk, we will present latest numerical results from large-scale 3D simulations, and discuss challenges in future developments.
This research is supported by NSF grant AST-0434322, NASA grant NNX08BA71G, and DOE.

Nishikawa Ken-ichi

K.-I. Nishikawa, J. Niemiec, M. Medvedev, B. Zhang, P. Hardee, Y. Mizuno, A. Nordlund, J. Frederiksen, H. Sol, M. Pohl, M. Oka, D. H. Hartmann, J. F. Fishman

University of Alabama in Huntsville
CSPAR/NSSTC
USA

Simulation of relativistic shocks and associated radiation from turbulent magnetic fields

Recent PIC simulations of relativistic electron- positron (electron- ion) jets injected into a stationary medium show that particle acceleration occurs at shocked regions. Simulations show that the Weibel instability is responsible for generating and amplifying highly nonuniform, small-scale magnetic fields and particle acceleration. These magnetic fields contribute to the electron's transverse deflection behind the shock. The ``jitter'' radiation from deflected electrons in turbulent magnetic fields has different properties than synchrotron radiation, which is calculated in a uniform magnetic field. This jitter radiation may be important for understanding the complex time evolution and/or spectral structure in gamma-ray bursts, relativistic jets in general, and supernova remnants. New spectra based on small scale simulations will be presented.

Nominé Jean-Philippe

Dr. Jean-Philippe Nominé, CEA/DAM,DIF - Bruyères-le-Châtel, France

CEA/DIF
France

PRACE – Partnership for Advanced Computing in Europe
Preparation of a Petascale Supercomputing Infrastructure for European Scientists

PRACE project (http://www.prace-project.eu/, funded in part by the EU's 7th Framework Programme) has the objective to prepare the creation of a persistent pan-European HPC service, consisting of several tier-0, worl-class centres providing European researchers from all fields with access to capability computers and forming the top level of the European HPC ecosystem. This includes a wide range of administrative and technical work to be completed within the two years of the project.
We will present PRACE status at mid year of 2009, highlighting key achievements like applications and benchmarks preparation, prototypes assessment, training initiatives, and providing an outlook of the foreseeable starting of the European Research Infrastructure in 2010.

Nordlund Åke

Aake Nordlund 1), Paolo Padoan 2)

Niels Bohr Institute, Rockefeller Komplekset
Danemark

Understanding the Star Formation Rate

We have developed a theory that predicts the Star Formation Rate (SFR) in the interstellar medium as a function of key properties such as temperature, density, and turbulent Mach number. The theory has been arrived at by "looking the horse in the mouth"; i.e. by analyzing supercomputer simulations of supersonic MHD-turbulence in a self-gravitating gas representing the interstellar medium. The supersonic motions create localized strong compressions that become gravitationally unstable and collapse. The collapsing gas, and additional gas that subsequently accretes is collected onto sink particles, and the total rate of conversion of gas into stars is measured. By analyzing the balance of processes involved we have derived an analytical expression for the star formation rate that can be used in larger scale studies of star formation in the ISM, and in studies of galaxy formation.

O'Sullivan Stephen

Scholl of Mathematical Sciences
Dublin City University
Ireland

Stochastic particle acceleration in the lobes of giant radio galaxies

We investigate the acceleration of particles via the second-order Fermi process
in the lobes of giant radio galaxies. Such sites are candidates for the accelerators of ultra-high energy cosmic rays. We focus on the nearby FR I
radio galaxy Centaurus A. This is motivated by the coincidence of its position
with the arrival direction of several of the highest energy Auger events. The conditions necessary for consistency with the acceleration timescales predicted by quasi-linear theory are reviewed. Test particle calculations are performed in fields which guarantee electric fields with no component parallel to the \emph{local} magnetic field. The results of QLT are, to order
of magnitude, found to be accurate at low turbulence levels for non-relativistic
Alfven waves and at both low and high turbulence levels in the mildly relativistic
case.
We conclude that for pure stochastic acceleration to be plausible as the generator of ultra-high energy cosmic rays in Centaurus A, the baryon number density would need to be several orders of magnitude below currently held upper-limits.

Obergaulinger Martin

Max-Planck-Institute of Astrophysics
Germany

Simulations of the magneto-rotational instability in core-collapse supernovae

Core-collapse supernova explosions may be affected by strong magnetic fields, which can be expected only if the weak pre-collapse fields are amplified very efficiently after core bounce. Among the prime candidates for field amplification are instabilities such as convection and the magneto-rotational instability (MRI). The MRI can act in systems with differential rotation, a condition fulfilled in wide regions of the core. These regions are characterised by sub-Keplerian rotation and a strong thermal stratification with. I will report on the methods and results of our recent study of the MRI in such systems. We considered the dispersion relation of unstable modes and distinguished between different instability regimes covering both purely rotationally and purely thermally driven instabilities as well as mixed forms, and performed simulations of model systems belonging to the relevant regimes. The simulations confirm the growth rates of modes in different regimes obtained by linear analysis, and allow for the determination of correlations characterising the saturated state.

Olson Spencer E

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Gridless Direct Simulation Monte Carlo SPENCER E. OLSON, Air Force Research Laboratory, ANDREW J. CHRISTLIEB, Michigan State University — Physical systems are typically simulated in a manner where time and space are both discretized. This discretization has two major categories of side-effects: simulation fidelity and computational load. The fidelity of a simulation is affected in so far as the size of a spatial/temporal grid dictates the size/rate of physical processes that can be fully captured in a particular simulation, e.g. a spatial grid of size x cannot be used to simulate a physical process with features much smaller than x. The level of discretization also has strong implications on requirements for computational resources. For example, the memory footprint of a fine-resolution grid for a large system can be quite extreme. The work presented here involves the development of a gridless algorithm for modeling inter-particle interactions. By using a gridless algorithm, it is possible to mitigate the effects of a discretized simulation, such that computational requirements are lessened while at the same time a desired level of fidelity is reached throughout the entire simulation domain. Furthermore, a gridless algorithm can be used to simulate various physical systems without the need to perform time-consuming grid-mesh optimization. An octree algorithm provides the gridless character to a direct simulation Monte Carlo (DSMC) code by automatically sorting nearest-neighbor particles into local clusters. Automatic clustering allows abstraction of the DSMC algorithm from the physical system of the problem in question. This abstraction provides flexibility for domains with complex geometries as well as a decreased code development time for a given physical problem. An overview of the gridless algorithm and its implementation for DSMC will be presented. The results of timing experiments will also be presented. These results show that gridless DSMC can be competitive with other DSMC codes. Several test cases have been performed to validate gridless DSMC and demonstrate use-cases where gridless DSMC shows particular promise. The results of these tests cases will be presented. Finally, new developments and future direction for gridless algorithm development will be presented.

Pierrard Viviane

V. Pierrard[1,2]

Belgian Institute for Space Aeronomy
Belgium

A three-dimensional dynamic model of the plasmasphere based on the kinetic approach

The plasmasphere is the extension of the ionosphere at higher altitudes in the inner magnetosphere. A three dimensional physical dynamic model of the plasmasphere that is constrained by realistic data has been developed at BISA. The core of the plasmasphere is obtained from the kinetic exospheric approach assuming a kappa velocity distribution function for the particles. The relative abundance of trapped particles is constrained so that the density profiles correspond to ISEE satellite observations. The position of the plasmapause, the limit of the plasmasphere, is determined by the interchange instability mechanism. The electric field model is a combination of corotation and E5D convection empirical model, which depends on the level of geomagnetic activity. The deformation of the plasmasphere during quiet and disturbed geomagnetic periods is illustrated and compared with the results of other plasmaspheric models and observations of IMAGE and CLUSTER satellites. During quiet periods, the plasmasphere is extended to radial distances larger than 4 Re. During geomagnetic storms and substorms, the plasmasphere is eroded. Plumes are formed in the afternoon MLT sector and then rotate with the Earth.

Pogorelov Nikolai

N. V. Pogorelov, S. N. Borovikov, J. Heerikhuisen, I. A. Kryukov, G. P. Zank

CSPAR, UAH
USA

MODELING HELIOSPHERIC PHENOMENA WITH A MULTI-SCALE FLUID-KINETIC SIMULATION SUITE

Multi-scale Fluid-Kinetic Simulation Suite is designed to model flows of partially ionized plasma in which some components can be described by MHD and/or gas dynamic equations while the others should be treated kinetically, by solving the Boltzmann equation. We describe the application of the suite to modeling the interaction of the solar wind with the local interstellar medium. The aspects considered include the heliospheric asymmetries and the distribution of radio emission sources under strong interstellar magnetic field conditions and heliospheric response to such time-dependent phenomena as the Sun's rotation and solar cycle. The newest additions to MS-FLUKKS are discussed.

Price Daniel

School of Mathematical Sciences,
Monash University
Australie

Smoothed Particle (Magneto)Hydrodynamics -- a review and current status.

I will give an overview of the Smoothed Particle Hydrodynamics method, starting from the basics and covering the current state-of-the-art methods used for astrophysical problems. I will show how Lagrangian variational principles can be used to derive SPH algorithms from first principles even when quite complicated physics is simulated. Finally I will review the current status of Magnetohydrodynamics within the SPH method and discuss our recent applications of SPMHD algorithms to star formation problems over very wide ranges of length and time scale.

Proga Daniel

Physics Department
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USA

Simulations of Inflows Irradiated by a Quasar: Formation of Outflows

I present the results from multi-dimensional, time-dependent simulations of gas dynamics in active galactic nuclei (AGN). I will focus on outflows driven from a large-scale inflow by radiation emitted from a powerful quasar.
I discuss the relevance of these outflows to the so-called AGN feedback problem
However, the AGN feedback should not be considered separately from the AGN physics. Therefore, I also discuss the issue whether the properties of the same outflows are consistent with the gas properties in broad- and narrow-line regions.

Roepke Fritz

Max-Planck-Institut fuer Astrophysik
Garching, Germany

Max-Planck-Institute of Astrophysics
Germany

Modeling the diversity of Type Ia supernova explosions

Type Ia supernovae (SNe Ia) are one of the prime tools in observational cosmology. A relation between their peak luminosities and the shape of their light curves allows to infer their intrinsic luminosities and to use them as distance indicators. This relation has been established empirically. However, a theoretical understanding is necessary in order to get a handle on the systematics in SN Ia cosmology. A model reproducing the observed diversity of normal SNe Ia will be presented. The challenge in the numerical implementation arises from the vast range of scales involved in the physical mechanism. Simulating the supernova on scales of the exploding white dwarf requires specific models of the microphysics involved in the thermonuclear combustion process. Such models will be discussed and results of simulations will be presented.

Ryu Dongsu

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The Intergalactic Magnetic Field in the Large Scale Structure of the Universe

Turbulence is induced during the course of the the large scale structure formation of the universe. In this talk, we describe a scenario, in which the intergalactic magnetic field has been produced through the amplification of weak seed fields by the turbulence. Based on a turbulence dynamo model, we present the estimate of the strength and coherence length of the resulting intergalactic magnetic field.

Schmidt Wolfram

Department of Mathematics
Wuerzburg University, Am Hubland,
Germany

(Adaptively refined) large eddy simulation of supersonic turbulence

Large eddy simulations are of great utility to engineers and atmospheric scientists. While terrestrial turbulence is only weakly or moderately compressible, astrophysicists often deal with supersonic turbulence. A subgrid scale model that is applicable to this turbulent flow regime has been proposed by Woodward et al. I will attempt to answer the frequently asked question: Does it make a difference in turbulence simulations with grid-based codes? The basic issues are the bottleneck effect and its impact on scaling laws, the gas temperature, and the growth of instabilities. In addition, I will briefly introduce a new approach: Combine the technique of large eddy simulation with adaptive mesh refinement to accomplish both accuracy and versatility.

Shibata Masaru

Graduate School of Arts and Sciences
University of Tokyo
Japan

Fully general relativistic MHD simulation for the merger of
binary neutron stars

Merger of binary neutron stars is one of the promising sources of gravitational waves. It is also a possible candidate for the central engine of short-hard gamma-ray bursts. Many works have been performed for simulating the merger phenomena in the framework of numerical relativity
(i.e., in the framework of full general relativity).
However, so far, MHD effects have not been taken into account in detail in
numerical relativity, although neutron stars in general have strong magnetic fields.
In this talk I will present our latest results for of our fully general relativistic
MHD simulation, focusing in particular on the angular momentum transport in the
merged neutron stars.

Sim Stuart

Stuart Sim (MPA, Garching)

Max-Planck-Institute of Astrophysics
Germany

"Monte Carlo Radiative Transfer Simulations: Applications to Astrophysical Outflows and Explosions "

"The theory of radiative transfer provides the link between the physical conditions in an astrophysical object and the observable radiation which it emits. Thus, accurately modelling radiative transfer is often a necessary part of testing theoretical models by comparison with observations. I will describe a Monte Carlo method for the numerical simulation of radiation transport in astrophysical environments, focusing on applications involving expanding media. As an example application, I will discuss our work involving the use of this method for the calculation of light curves and spectra for multi-dimensional models of supernova explosions."

Slyz Adrianne

Oxford Astrophysics
Department of Physics
United Kingdom

A galaxy in the making

I will present results from high resolution resimulations of a high redshift galaxy and discuss the mechanisms at work in its formation.

Sokolov Igor V.

Igor V. Sokolov

Center for Space Environment Modeling
University of Michigan
USA

4D model for MHD wave turbulence in the solar corona and solar wind

The aim of the present paper is to unify the various transport equations for turbulent waves that are used in different areas of space physics. Here, we mostly focus on the magnetohydrodynamic (MHD) turbulence, in particular the Alfv\'enic turbulence. The applied methods, however, are general and can be extended to other forms of turbulence, for example the acoustic turbulence, or Langmuir plasma waves. With minor modifications, the derivations followed here can be extended for relativistic motions, thus making it possible to apply them to the wave transport in astrophysical objects with high plasma speeds (radio-jets), or strong gravity (black hole surroundings).

Surzhikov Sergey

Institute for Problems in Mechanics
Russian Academy of Sciences
Russia

Multi-Physics Magnetohydrodynamic and Radiation Gas Dynamic Numerical Simulation Models for Aerospace Applications

Three groups of numerical simulation models intended for multi-physics numerical simulation of magneto-hydrodynamic and radiation gas dynamic phenomena are considered. These are: computational models of ideal magnetohydrodynamics, drift-diffusion two-temperature and two-fluids models of gas discharges in hypersonic weekly ionized gas flows, and radiation gas dynamic models.

Numerical simulation methods developed for computational realization of the models are described and compared. Each of the methods is illustrated on example of concrete aerospace applications. The following problems are considered.

1) Three dimensional computational model and numerical simulation results for plasma plume of pulsed plasma thruster (PPT) interaction with ambient flow of magnetized plasma is described. Unsteady expansion of plasma plume generated by PPT during 100 microseconds is analyzed. Duration of the PPT plasma impulse is 6 microseconds. Parameters of the plasma plume in exit cross-section of the PPT simulate performance characteristics of real pulsed plasma thruster PPT-4, which is used as fuel solid Teflon. Presented magneto-hydrodynamic (MHD) model is based on ideal magnetohydrodynamics and allows predict dynamics of plasma plume after end of plasma impulse and its interaction with ambient ionized and magnetized media.

2) Subsonic and supersonic plasma flows through a localized heat release region in the presence of magnetic field are modeled by the system of single-fluid, viscous magneto-hydrodynamic equations. A numerical parametric investigation is carried out using a three-dimensional MHD code. Processes related to the formation of shocks and magnetosonic waves, propagations of perturbations in sub- and super-Alfvenic flows are investigated.

3) Review of results obtained at computational study of rarefied channel flows with direct current discharge and magnetic field is presented. Electrodynamic structure of direct current discharges (DCD) in rarefied hypersonic flows is analyzed in the frame of ambipolar and diffusion-drift model of a glow discharge. Consideration of statement and numerical simulation results for several configurations of glow discharges inside inlets are presented. These are:

- Surface gas discharges inside plane channel,
- Transversal gas discharges with magnetic field inside plane channel,
- Transversal gas discharges inside curvilinear channel with local bumps.

4) Radiation gas dynamic models are considered on the example of laser supported waves (LSW). A low temperature plasma inside LSW is maintained at temperatures about 12-20 kK by continuous or impulse laser radiation, usually generated by CO2 laser. A late stage of laser breakdown when the blast wave generated as a result of practically instantaneous energy emission moved to a significant distance from the energy emission area is considered. Gas is considered to be viscous, heat conductive, selectively radiating and absorbing radiation. Spectral optical properties are calculated with computer code ASTEROID, which provides

spectral absorption and emission coefficients for complex gas species compositions. Phenomena of strong coupling of gas dynamic and radiation transfer is considered

Teyssier Romain

Service d'Astrophysique
CEA
France

MHD simulations in cosmology: from large galaxy clusters to dwarf galaxies.

The evolution of the magnetic field in the universe is believed to proceed through a first phase of field generation through microscopic processes (Biermann Battery) at early time (cosmic reionization) followed by a second phase of a magnetic (alphaomega) dynamo in galactic disks. During the last 10 years, cosmological simulations of structure formation including the evolution of the magnetic field have been performed. The goal is to understand the evolution of the magnetic field within the hierarchical picture of galaxy formation. The first attempts have focused on the generation of magnetic fields at the Epoch of Reionization, on one hand, and on the amplification of magnetic fields by merger-driven turbulence in galaxy clusters on the other hand. The evolution of magnetic fields in galaxies has been only recently investigated by several groups. I will discuss some of the numerical aspects of cosmological MHD, and present recent results obtained in MHD simulations of clusters and galaxies within a cosmological context.

Toro E. F.

Eleuterio F. Toro

Laboratory of Applied Mathematics
Faculty of Engineering
University of Trento
Italy

Higher-order ADER schemes for hyperbolic equations. A review.

n this lecture I review the ADER fully-discrete approach for constructing numerical schemes of arbitrary order of accuracy in space and time for solving multi-dimensional hyperbolic balance laws on general meshes. Various ways of solving the associated high-order Riemann problem are reviewed. I also present some recent developments on low-order fluxes for general multi-dimensional hyperbolic systems in conservative form. These low-order monotone solvers constitute the building block for constructing the high-order ADER methods. I also address special issues, such as treatment of source terms (stiff and non-stiff) and nonconservative products.
The performance of the methods is illustrated via a number of aplications including the Euler equations, the MHD equations and the Baer-Nunziato multiphase flow equations in multiple space dimensions.

Tóth Gábor

Gabor Toth, Alex Glocer, Yingjuan Ma, Dalal Najib, Tamas Gombosi

Center for Space Environment Modeling, Dept. of AOSS
University of Michigan
USA

"Multi-ion magnetohydrodynamics"

We solve the full set of magnetohydrodynamic equations with multiple ion fluids. The numerical difficulties and the algorithmic solutions are discussed: a total ion fluid is used in combination with the individual ion fluids, the source terms are evaluated with a point-implicit scheme using an analytic Jacobian, the multi-ion equations may be solved in a restricted region, and an artificial friction term is applied to limit the relative velocities of the ion fluids. We show test results and a number of space physics applications.

Van der Holst Bart

B. van der Holst, W. Manchester IV, I.V. Sokolov, G. Toth, T.I. Gombosi,
D. DeZeeuw, O. Cohen

Center for Space Environment Modeling,
University of Michigan,
USA

BREAKOUT CORONAL MASS EJECTION OR STREAMER BLOWOUT: THE BUGLE EFFECT

We present three-dimensional numerical magnetohydrodynamic (MHD) simulations of coronal mass ejections (CMEs) initiated by the breakout mechanism. The initial steady state consists of a bipolar active region embedded in the solar wind. The field orientation of the active region is opposite to that of the overarching helmet streamer, so that this pre-eruptive region consists of three arcades with a magnetic null line on the leading edge of the central arcade. By applying footpoint motion near the polarity inversion line of the central arcade, the breakout reconnection is turned on. During the eruption, the plasma in front of the breakout arcade gets swept up. The latter effect causes a pre-event swelling of the streamer. The width of the helmet streamer increases in time and follows a `bugle' pattern. We will demonstrate that if this pre-event streamer swelling is insufficient, reconnection on the sides of the erupting breakout arcade/flux rope sets in. This will ultimately disconnect the helmet top, resulting in a streamer blowout CME. On the other hand, if this pre-event swelling is effective enough, the breakout reconnection will continue all the way to the top of the helmet streamer. The breakout mechanisms will then succeed in creating a breakout CME.

Vaytet Neil

Service d'Astrophysique
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France

A numerical model for multigroup radiation hydrodynamics

We present our latest development in numerical radiation hydrodynamics: a multigroup model for simulating radiative flows in environments where opacities vary with frequency, a situation omnipresent in astrophysics. This offers a much more realistic description of interstellar gas dynamics compared to previous grey models. The frequency domain is subdivided into a finite number of bins, in each of which we use the M1 closure to define the radiative pressure in terms of the radiative energy and flux. The radiation is fully coupled to the hydrodynamics in the comoving frame of the fluid. We adopt a finite volume method in the frequency domain to calculate the Doppler-shifting terms which allow energy transfers from one group to another. We illustrate the capabilities of our model with a series of tests.

Walder Rolf

D. Folini and R. Walder

CRAL
ENS-Lyon
France

Supersonic turbulence in shock bound slabs

Colliding hypersonic flows and associated turbulence play a decisive role in many astrophysical objects. They contribute, for example, to molecular cloud structure and the initial mass function, the mixing of chemical elements in the galaxy, the X-ray emission of O-stars, differentiation of galactic sheets, appearance of wind-driven structures, or, possibly, to the prompt emission of γ-ray bursts. By means of numerical simulations we study the turbulence within the collision zone of such flows and its back coupling with the confining shocks, an aspect not covered by the more widely spread 3D-periodic-box simulations of driven turbulence. The presented simulations cover isothermal as well as radiatively cooling interaction zones in 2D and 3D, resulting from the head on collision of two plane parallel flows. Corresponding results are presented and some related numerical issues like adaptive meshes and convergence are addressed. For symmetric upstream flow parameters and under isothermal conditions we find from simulations and on analytical grounds that the interaction zone is self-similar on average. Its characteristics depend only on the upstream Mach number M_{u}. In particular, we find the root-mean-square Mach-number within the interaction zone to scale as $M_{\mathrm{rms}} \approx 0.2 M_{\mathrm{u}}$. The mean density of the interaction zone is independent of M_{u}. The fraction f_{eff} of the upwind kinetic energy that survives shock passage scales as $f_{\mathrm{eff}}= 1 - M_{\mathrm{rms}}^{-0.6}$. This dependence persists if the two head on colliding flows have different flow parameters, indicating that the turbulence within the interaction zone and its driving are mutually coupled. Larger upstream Mach-numbers lead to a faster expanding interaction zone, confining interfaces that are less inclined with respect to the upstream flow direction, more efficient driving, and finer interior structure with respect to the extension of the collision zone. The presence of well-resolved, extended cooling layers instead of isothermal shocks substantially damps the turbulence within the interaction zone.

Weber Gunther H.

Gunther H. Weber, Lawrence Berkeley National Laboratory (LBNL)
Sean Ahern, Oak Ridge National Laboratory (ORNL)
E. Wes Bethel, LBNL
Sergey Borovikov, University of Alabama in Huntsville
Hank Childs, Lawrence Lawrence Livermore National Laboratory (LLNL)
E

Computational Research Division
Berkeley

Recent Advances in VisIt: Streamlines and Query-Driven Visualization

Adaptive Mesh Refinement (AMR) is a highly effective simulation method for spanning a large range of spatiotemporal scales such as those encountered in astrophysical simulations that must accommodate ranges from interstellar to sub-planetary. By combining research in novel AMR visualization algorithms and basic infrastructure work, the Department of Energy's (DOE's) Science Discovery through Advanced Computing (SciDAC) Visualization and Analytics Center for Enabling Technologies (VACET) has extended VisIt, an open source visualization tool that accommodates AMR as a first-class data type. This talk focuses mainly on two recent advances in the development of VisIt. First, we have developed streamline computation methods that properly handle an AMR hierarchy. In particular, our scheme detects streamline transitions from a coarse patch into a finer patch and improves interpolation at level boundaries. Second, we focus on visualization of large-scale particle data sets. By integrating the DOE Scientific Data Management (SDM) Center's FastBit indexing technology into VisIt, we are able to reduce particle counts effectively by thresholding and by loading only those particles from disk that satisfy the thresholding criteria. Furthermore, using FasBit it becomes possible to compute parallel coordinate views efficiently, thus facilitating interactive data exploration of massive particle data sets.
Gunther

Wu S. T.

S T. Wu1,2, Ai-Hua Wang1, and Jason Cassibry2

University of Alabama in Huntsville
CSPAR
USA

Characteristic Boundary Conditions for Numerical Magnetohydrodynamic (MHD) Simulation of Solar and Laboratory Plasma Dynamics

We discuss the self-consistent time-dependent numerical boundary conditions for the magnetohydrodynamic (MHD) simulation to study the solar and laboratory plasma dynamics. It is well known that these plasma flows cover from the sub-sonic and sub-Alfvénic to super-sonic and super-Alfvénic region. Hence the characteristic boundary conditions must be used because the information propagating according to these characteristics will affect the solutions. To illustrate the importance of this set of boundary conditions, two examples are presented; one for solar plasma which is to study the energy and magnetic flux transport from sub-photosphere to the corona, and the other one concerns laboratory plasma flow for the investigation of the sub-Alfvenic inlet boundary conditions for a MHD nozzle.

Zank Gary P.

G.P Zank, I. Krykov, N.V. Pogorelov, S. Borovikov

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The interaction of turbulence with shock waves

Zhang Ming

Ming Zhang

Florida Institute of Technology
USA

Calculation of diffusive particle acceleration by shock waves using asymmetric skew stochastic processes

Stochastic differential equation can replace the Fokker-Planck diffusion equation for calculation of diffusive particle acceleration by shock waves. Numerical solution to the stochastic differential equations is much easier to achieve than the Fokker-Planck equation, particularly when a problem requires calculation in high dimensions. However, the stochastic differential equation for shock acceleration contains a δ-function, because the particle momentum gain rate is proportional to the divergence of plasma velocity, which is infinite at the shock front. Straightforward calculation has to make a smooth transition of plasma velocity at the shock in order to avoid numerical infinity, which slows down the speed of numerical simulation. To overcome this difficulty, we have designed a skew stochastic process that has an asymmetric reflection probability. The skew stochastic process can be solves by scaling the spatial dimension differently for upstream and downstream regions. In this way, the shock can be treated as infinitely thin, and particle momentum gain is obtained by calculating the total local time, $\int \delta(x-x_{sh}) dt$, which is the time spent by the stochastic process right at the shock. In this talk, we are going to show a few examples of applying this method to diffusive shock acceleration models. Broad application of this method to other studies will also be demonstrated.

Ziegler Udo

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