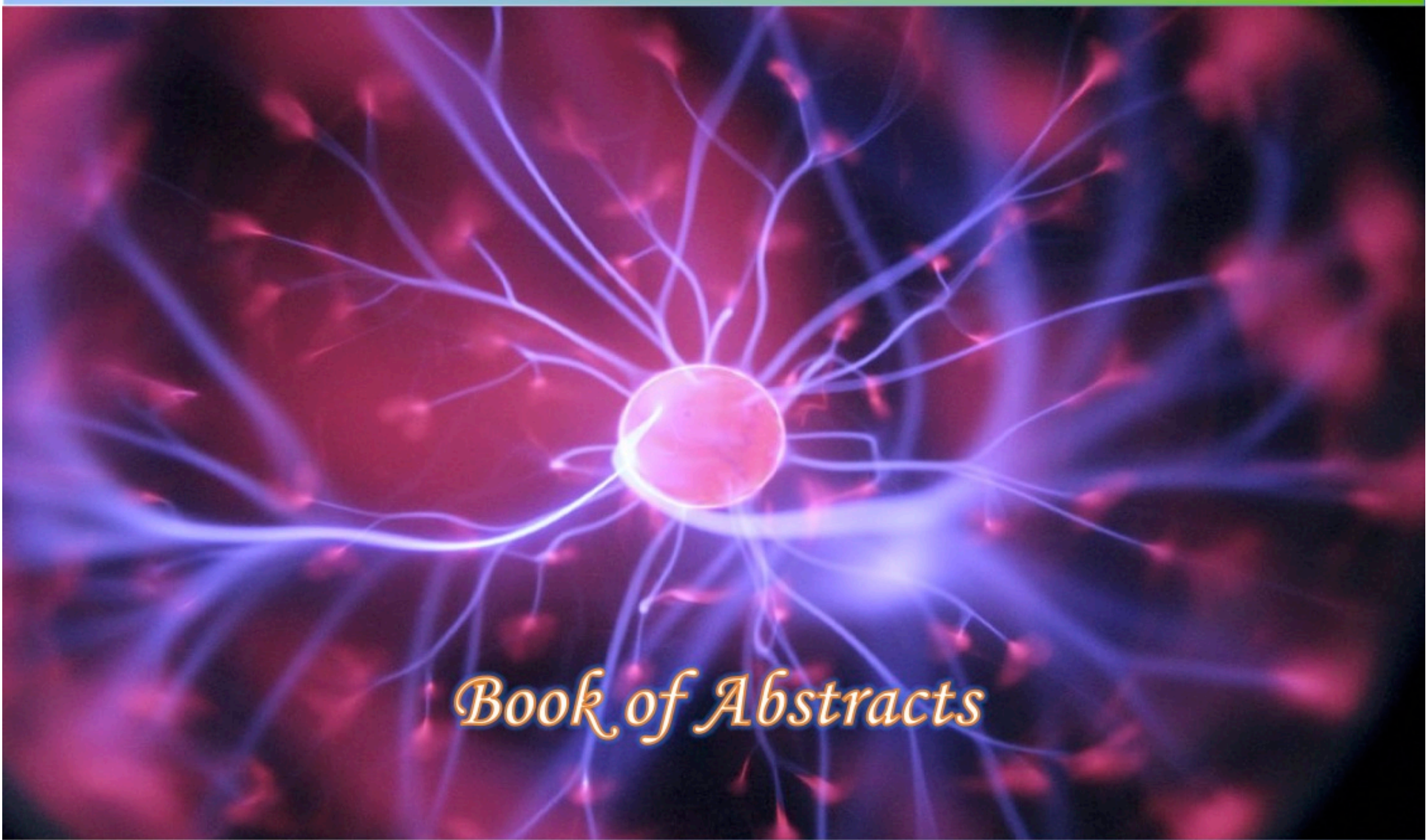
Conference on Plasma Simulation-2020

23-24 January 2020



Dr. Sarveshwar Sharma
(Convener)

Organized By
Institute For Plasma Research
Bhat, Gandhinagar-382428, India

CPS -2020

Conference on Plasma Simulation

23-24 January 2020

Book of Abstracts

Dr. Shashank Chaturvedi

(Patron)

Dr. Sarveshwar Sharma

(Convener)

Compiled & Edited by

Mr. Avadhesh Maurya

<u>**Organized by**</u>

Institute For Plasma Research

Bhat, Gandhinagar-382428 India

National Advisory Committee:

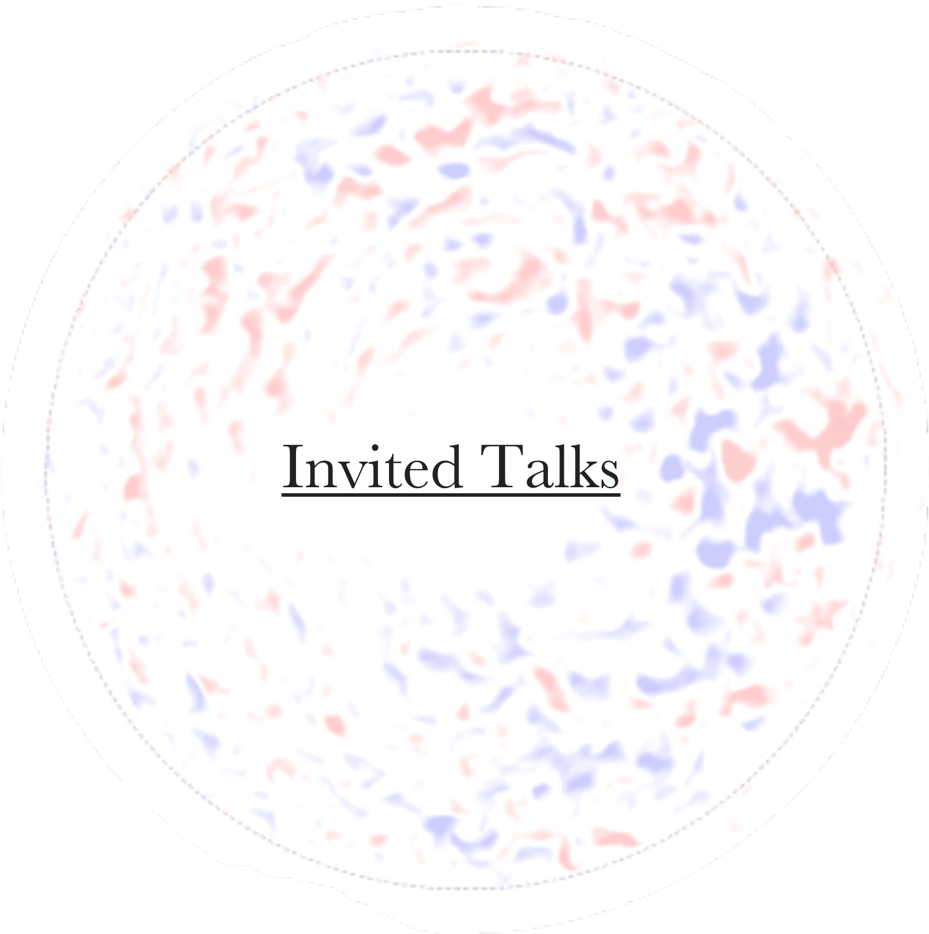
Dr. Shashank Chaturvedi	IPR, Gandhinagar
Prof. Abhijit Sen	IPR, Gandhinagar
Prof. Shishir Deshpande	IPR, Gandhinagar
Prof. Arnab Roy Chaudhary	IISc, Bangalore
Prof. Mahendra Verma	IIT, Kanpur
Prof. Rahul Pandit	IISc, Bangalore
Prof. Kandaswamy Subramanian	IUCAA, Pune
Prof. M. S. Janaki	SINP, Kolkata
Prof. Hari Ramachandaran	IITM, Madras
Prof. Ramachandaran	Bhartiyar University

Scientific Programme Committee:

Prof. S.P. Deshpande	Chairman
Dr. Sarveshwar Sharma	Member Secretary
Prof. R. Ganesh	Member
Prof. Sudip Sengupta	Member
Dr. S. K. Nema	Member
Mr. K.K. Gotewal	Member

Local Organizing Committee:

Dr. Mritunjay Kundu	Chairman
Mr. K. K. Gotewal	Member
Mr. Mangesh Vartak	Member
Dr. Kishore Mishra	Member
Mr. Avadhesh Maurya	Member
Mr. Govind Lokhande	Member
Mr. Hardik Mistry	Member
Mr. Harshad Chamunde	Member



Invited Talks

From Magnetohydrodynamic (MHD) to Hall MHD Turbulence: An overview of statistical properties

Rahul Pandit
Department of Physics, Indian Institute of Science, Bangalore 560012.

Abstract:
After a brief comparison of the equations of three-dimensional (3D) MHD and Hall MHD (3D HMHD), I will present an overview of the properties of statistically homogeneous and isotropic turbulence in these systems, based on our studies of shell models and the full 3D MHD and 3D HMHD equations. In particular, I will cover the scaling of energy spectra, the multiscaling of structure functions, and various probability distribution functions (PDFs) that characterise, e.g., the alignment of velocity and magnetic fields.

Non-equilibrium Thermodynamic & Transport Properties in Industrial Plasma Modeling

S. Ghorui[1,2]

[1]*Thermal Plasma Technologies Section, Laser & Plasma Technology Division*
Bhabha Atomic Research Centre, Trombay, Mumbai-400085
[2]*Homi Bhabha National Institute, Anushaktinagar, Mumbai-400094*

Abstract

Highly concentrated directed heat flux, extremely high temperature, ability to convert multistep conventional process into a single step one, operability in inert as well as reactive process environment, tremendous enthalpy content, extremely sharp thermal and species gradient, high concentration of nascent free radicals, atomic and ionic species leading to extraordinarily fast reactions, redundant vacuum system, drastically reduced effluent generation, high throughput, environment friendly nature, and cost effectiveness are some of the crucial features that establish plasma technology as one of the most promising field in the advanced technology areas. Presence of thermal and chemical non-equilibrium make design and development of the plasma generating devices through simulation a challenging task due to complex and highly nonlinear interaction among thermal, fluid dynamic and electromagnetic fields. It is the thermodynamic and transport properties of a plasma that critically determines the ultimate behaviour of a plasma system in terms of its extent in physical space as well as its velocity, temperature, heat content and response to instability and non-equilibrium.

Under the frame work of two-temperature non-equilibrium model, behavior of thermo-physical properties of different plasmas are explored computationally over electron temperature ranging from of 300 to 50000K, pressure ranging from 0.1 to 5 atm and thermal non-equilibrium (ratio of electron temperature and heavy species temperature) ranging from 1 to 10. The computed properties are benchmarked against data available in literature and reasonable agreement is observed in most of the cases. Deviations observed are explained. It has been shown through comparison with experimental results and data available in literature that the computed properties offer a better match with experimental data compared to others especially in the regime of higher temperature and higher thermal non-equilibrium. Interesting features of different transport properties and their possible impact on the produced plasma are discussed. A possible scheme for including chemical non-equilibrium is introduced and associated results are discussed.

Particle-in-Cell Simulations of Non-neutral Plasmas

Rajaraman Ganesh
Institute for Plasma Research, Bhat, Gandhinagar 382 428

Abstract:
Unlike neutral plasmas wherein total charge content is close to zero, non-neutral plasmas span a muchwider range of parameter space - from purely single species plasmas to nearly neutral plasmas. Non-neutral plasmas are ubiquitous in astrophysical conditions. In laboratories worldwide, pure electron or pure ion plasmas have been extensively studied from low temperature (i.e, a few eVs) to ultra-cold limit (i.e., 1e-7 eV or less). In particular, pure electron plasmas confined in a straight cylinder with a help of an axial magnetic field have been exploited for their similarity to 2D incompressible Hydrodynamics.

Institute for Plasma Research is a world leader in studies in pure electron plasmas confined by toroidal magnetic field at very tight aspect ratio. Work at IPR has lead to several pioneering experiments, theory and computational efforts. In this presentation, recent development in electrostatic 2D3V [1] and 3D3V PIC [2]suite of codes namely PEC2PIC/PEC3PIC will be presented along with their applications to study pure electron plasma experimental device at very tight aspect ratio. A comparison of simulations with experiments will also be presented.

References:

[1] Meghraj Sengupta, HBNI PhD Thesis IPR (2017)

[2] S Khamaru et al Phys Plasmas (2019)

Stochastic solutions of Plasma Fluid Equations: 3D boundary value problem of Scrape-off Layer (SOL) transport equilibria

Devendra Sharma

[1]*Institute for Plasma Research, HBNI, Bhat, Gandhinagar, India, 382428*

Email: devendra@ipr.res.in

Abstract:
Numerically simulating the steady-state transport equilibria of energetic fusion plasmas flowing to physical targets involves multi-dimensional solutions of plasma-neutral transport equations in magnetized plasma boundary layers, essentially in the field aligned coordinates. The solutions of a typical 2D boundary value problem of the toroidally symmetric tokamak SOL region becomes numerically even more challenging in the 3D SOL of a stellarator, or that of a tokamak having strongly structured targets, like in ITER (International Thermonuclear Experimental Reactor). Efforts over last few decades have resulted in numerically efficient and scalable stochastic techniques to solve the set of hydrodynamic plasma transport equations in 3D domains having highly structured boundaries. A Monte-Carlo simulation scheme is implemented by the 3D code EMC3-EIRENE, originally developed for stellarator class of devices, and is applied in IPR to simulate plasma-neutral transport in strongly structured SOL of the Aditya tokamak as well as of the ITER. The plasma-neutral transport equilibria simulated for various configurations of Aditya SOL (original and Upgrade), and a recent application to ITER SOL, will be discussed.

Spatio-temporal evolution of space charge waves in a warm inhomogeneous plasma

Sudip Sengupta
Institute for Plasma Research, Bhat, Gandhinagar 382 428, India

Abstract
Spatio-temporal evolution of space charge waves in a warm inhomogeneous plasma is studied using an in-house developed one-dimensional particle-in-cell (PIC) code. In contrast to the conventional wisdom, it is found that for an inhomogeneous plasma, there exists a critical value of electron temperature beyond which the wave does not break. This novel result, which is of relevance to present day laser plasma experiments, has been explained on the basis of interplay between electron thermal pressure and background inhomogeneity.

Computation of Engineering Plasmas

Kowsik Bodi
Indian Institute of Technology Bombay, India

Abstract:
We are interested in a few engineering applications of plasmas, e.g., multiphase MHD flows, electric arcs, and plasma thrusters. Modelling of electric arcs is of interest for simulating atmospheric re-entry conditions on ground-based test facilities. Multiphase MHD flows are of interest in the context of accident scenarios of the Tritium Breeding Modules (TBMs) of ITER. We use the open-source CFD package, OpenFOAM, for these studies. We have recently started working on the modelling of plasma propulsion devices. In this regard, we will present the our efforts towards the development of a PIC solver for the computational study of plasma thrusters.

Understanding the stellar magnetic cycles using dynamo modellings

Bidya Binay Karak
Department of Physics
Indian Institute of Technology (BHU), Varanasi

Abstract:
The Sun and many other low-main sequence stars have active magnetic fields. The magnetic field of Sun is observed to reverse its polarity in about 11 years. The magnetic cycles of other stars are also detected. The strength and period of these cycles mainly depend on the stellar rotation rates. The rotating convection in the stratified stellar convection drives large-scale flows such as differential rotation and meridional circulation. These flows along with the helical convection produce nonlinear dynamo, which is the cause of the stellar magnetic cycles. In this presentation, I shall discuss how the magnetohydrodynamic simulation allows us to model this dynamo action in the stellar convection zones. I shall present how the properties of magnetic cycles in different stars change with the rotation rate of the stars. Finally, I will highlight, how the rotating convection in the slowly rotating stellar convection zones shapes the azimuthal motion and produces the so-called anti-solar differential rotation and what effect this can have on the stellar dynamo.

Spontaneous generation of three-dimensional magnetic nulls

Ramit Bhattacharyya
Udaipur Solar Observatory, Physical Research Laboratory

Abstract:
Three dimensional magnetic nulls are points where the magnetic field vanishes, and relates to the magnetic topology. Being preferred sites for magnetic reconnection, the nulls can trigger various solar coronal transients---in the likes of flares, coronal mass ejections (CMEs) and coronal jets. Although abundant in nature, the generation and evolution of the nulls are not straightforward and requires an in-depth research. Toward this objective, results of magnetohydrodynamic simulations are presented, indicating the nulls to be dissipative self-organized structures which make them ubiquitous in naturally occurring plasmas.

Precursor magneto-sonic solitons in a plasma from a moving charged object

Atul Kumar and Abhijit Sen
Institute for Plasma Research, Bhat, Gandhinagar - 382428, India

E-mail: atul.j1211@gmail.com

Abstract:
The nature of fore-wake excitations created by a charged object moving in a magnetized plasma is investigated using particle-in-cell simulations. Our studies establish for the first time the existence of precursor magneto-sonic solitons traveling ahead of a moving charged object. The nature of these excitations and the conditions governing their existence are delineated. We also confirm earlier fluid simulation [1] and molecular dynamic [2] results related to electrostatic precursor solitons obtained in the absence of a magnetic field. The electromagnetic precursors could have interesting practical applications such as in the interpretation of observed nonlinear structures during the interaction of the solar wind with the earth and the moon and may also serve as useful tracking signatures of charged space debris traveling in the ionosphere.

Reference:

[1] Sanat Kumar Tiwari and Abhijit Sen, Phys. Plasmas **23** (2016) 022301

[2] Sanat Kumar Tiwari and Abhijit Sen, Phys. Plasmas **23** (2016) 100705

PIC simulation for Helicon Thruster

Gursharn Singh
Bhabha Atomic Research Center

gursharn@.gov.in

Abstract:
A 2-D and 3-D Electromagnetic Relativistic Particle-in-Cell (PIC) software program for plasma simulations has been developed. This software has been validated against a wide range of problems available from literature as well as local experimental and simple theoretical problems. So far the developed software was used for the simulations of High Power Microwave Softwares (HPM) like vircator and klystron. The software was also used for plasma sheath simulations. Recently the software (three dimensional Particle in Cell) is adapted to model the operation of a plasma thruster. The geometrical parameters are provided by IPR from a real experiment and during simulation the geometry is defined as near as possible to the experimental apparatus. The ion and electron velocities are initialized using a Maxewellian distribution corresponding to room temperature. The static magnetic field is provided externally (no computation done) and the ionization is computed using Monte Carlo collisions from a cross section database. The gas source is simulated with a generic model. To achieve the optimized operating conditions parameters like gas flow within a range has been simulated. The results along with theoretical approach for the simulation will be presented.

Simulation of laser Plasma Interaction in a Novel Regime

Amita Das
Indian Institute of Technology Delhi, Delhi, India

Abstract:
In the conventional regime of laser plasma interaction the high frequency oscillating electromagnetic field of the laser interacts mainly with the lighter electron species of the plasma target. The heavier ions in this case play a subsidiary role and their participation subsequently in dynamics relies on collisional and plasma based collective processes. A novel regime of laser plasma interaction is being proposed where ions can play an active role and electron dynamics becomes subsidiary. This is achieved by an application of an external magnetic field of an appropriate strength which magnetizes the electrons but ensures that the ions remain un-magnetized. The talk will cover details about the Particle – In – Cell simulations which have been carried out in this regime. Observations (i) excitation of Magnetosonic solitons and Lower Hybrid waves (ii) illustrating novel laser energy absorption mechanism, will be presented in the talk.

How relativistic jets from supermassive black holes affect galaxy evolution

Dipanjan Mukherjee
University of Torino
Email: dipanjan.mukherjee@unito.it

Abstract:
Relativistic jets from supermassive blackholes are an important driver of galaxy evolution. They impact the nearby environment over different physical scales during their lifetime, with varying effects. They first interact with the host galaxy's interstellar medium before breaking out to larger scales, significantly affecting the galaxy's morphology and evolution. I shall present the results of our recent 3D relativistic (magneto) hydrodynamic simulations, performed on scales of a few kilo parsecs to several tens of kilo parsecs, of AGN jets interacting with the ambient interstellar medium and the circum galactic medium. I will discuss the implications of such jet feedback on the morphology and kinematics of the galaxy and its long term evolution. I shall discuss the effect of different MHD instabilities (kink modes and Kelvin-Helmholtz) on the jet dynamics and their implications for the non-thermal emission observable from such jets.

Kinetic Simulation of Plasma Sheaths formed in Magnetic Fusion Devices

Raju Khanal
Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu 44613, Nepal

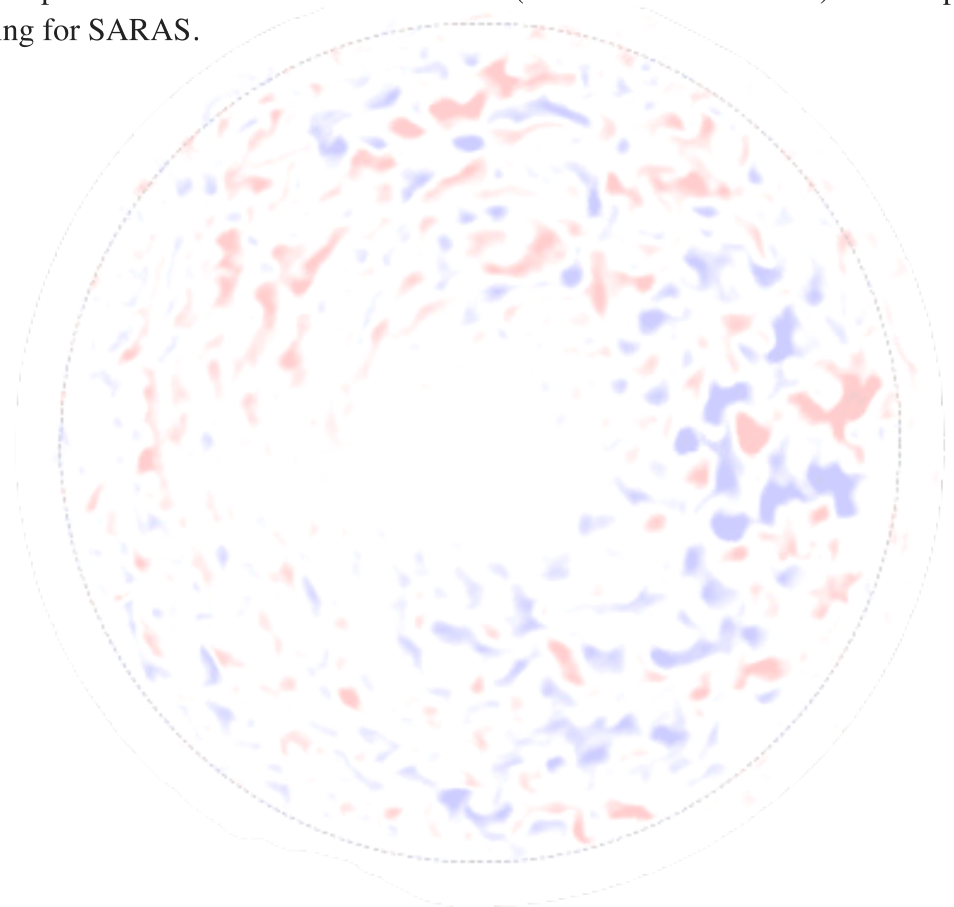
E-mail: plasmanepal@hotmail.com

Abstract
A kinetic trajectory simulation (KTS) model has been developed to simulate any bounded plasma which has been used to study magnetized plasma sheath relevant to magnetic fusion devices. In our model, the exact ion trajectories are followed for given distribution functions at the injection whereas the electron densities are obtained analytically considering Boltzmann distribution and cut-off by the negative wall. For given presheath parameters, which are considered to be consistent with sheaths formed in magnetic fusion devices, the potential profile is iterated towards the final time-independent self-consistent state. A presheath-sheath coupling scheme has also been developed which can yield kinetic parameters at the sheath side for given fluid parameters at the presheath side of the interface. Recently, the KTS model is extended to study the plasma sheath formed for various situation of interest like: electronegative plasma with cut-off distribution and modification in Bohm criterion, multi-component magnetized plasma sheath, response of carbon and tungsten surfaces, etc. The development of the KTS model and some recent results will be presented and discussed.

Extreme simulations using spectral and finite difference codes TARANG and SARAS

Mahendra K. Verma
Dept. of Physics , I. I. T. Kanpur, Kanpur 208016

Abstract:
I will highlight the main features of our spectral code TARANG and finite-difference code SARAS. Due to their flexible design, these codes can solve hydrodynamics, buoyant flows, magnetohydrodynamics, rotating flows, etc. for different boundary condition. TARANG has been scaled up to 196608 cores of CRAY XC40 (Shaheen II of KAUST). We expect even better scaling for SARAS.



Magnetosheath Turbulence Driven by Kinetic Alfvèn Waves

N. K. Dwivedi*[1], P. Kovacs[2], S. Kumar[3,4], E. Yordanova[5], M. Echim[6], M. L. Khodachenko[1,7,8], R. P. Sharma[9]

[1]*Space Research Institute, Austrian Academy of Sciences, Schmiedlstraß 6, 8042 Graz, Austria*
[2]*Geological and Geophysical Institute of Hungary, Budapest, Hungary*
[3]*School of Space Research, Kyung Hee University, Yongin, Gyeonggi-Do, 446-701, Korea*
[4]*Shandong Provincial Key Laboratory of Optical Astronomy and Solar-terrestrial Environment, Institute of Space Science, Shandong University, Weihai, China*
[5]*Swedish Institute of Space Physics, Uppsala, Sweden*
[6] *Institut Royale d'Aeronomie Spatiale de Belgique, 1180 Brussels, Belgium*
[7]*Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia*
[8] *Institute of Astronomy, Russian Academy of Science, Moscow 119017, Russian Federation*
[9]*Centre for Energy Studies, Indian Institute of Technology Delhi, India*

Abstract
In the present paper, we investigate the power-law behaviour of the magnetic field spectra in the Earth's magnetosheath region using Cluster spacecraft data under solar minimum condition. The power spectral density of the magnetic field data and spectral slopes at various frequencies are analysed. Propagation angle, θ_{kB}, and compressibility, R_1, are used to test the nature of turbulent fluctuations. The magnetic field spectra have the spectral slopes, α, between -1.5 to 0 down to spatial scales of 20 λi (where λi is ion inertial length), and show clear evidence of transition to steeper spectrum for smaller scales with a second power-law, having α between -3 to -1.6. At low frequencies, fsc < fci (where fci is ion gyro-frequency), θ_{kB}90 to the mean magnetic field, B_0 , and R_1shows a broad distribution, $0.1 \leq R_1 \leq 0.9$. On the other hand at fsc > fci, θ_{kB} exhibits a broad range, $30 \leq \theta_{kB} \leq 90$, while R_1 has a small variation: $0.2 \leq R_1 \leq 0.5$. We conjecture that at high frequencies, the perpendicularly propagating Alfvén waves could partly explain the statistical analysis of spectra. To support our prediction of kinetic Alfvèn wave dominated spectral slope behaviour at high frequency, we also present a theoretical model and simulate the magnetic field turbulence spectra due to nonlinear evolution of kinetic Alfvèn waves. The present study also shows the analogy between the observational and simulated spectra.

Keywords: Turbulence, magnetic field spectra, spectral slope, kinetic Alfvèn wave, nonlinearity
*Corresponding author: N. K. Dwivedi
*Email: navin.dwivedi@gmail.com

Non-conventional collisional absorption of laser light in under-dense plasma

Mrityunjay Kundu[1,2]
[1]*Institute for Plasma Research, Bhat, Gandhinagar - 382 428, Gujarat, India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai - 400 094, India*

mkundu@ipr.res.in

Abstract:
Collisional absorption of laser light in under-dense plasma is studied by particle-in-cell (PIC) simulation with Monte-Carlo binary coulomb collisions between charge particles. For a given plasma thickness of a few times the wavelength of 800 nm laser, fractional absorption of laser light due to Coulomb collisions (mainly between electrons and ions) is calculated at different electron temperature by incorporating a total velocity dependent Coulomb logarithm whereandare thermal and ponderomotive velocity of an electron. It is found that, in the low temperature regimeeV, fractional absorption of light increases with increasing laser intensity up to a maximum corresponding to an intensity and then it drops obeying the conventional scaling of when The non-conventional variation of fractional absorption in the low intensity regime was demonstrated earlier in experiments [1,2] and recently explained by classical and quantum models [3,4]. Here, we report such non-conventional variation of collisional laser absorption by detailed PIC simulation [5]; thus bridging the gap between models, simulations, and experimental findings.

Reference:
[1] D. Riley, L. A. Gizzi, A. J. Mackinnon, S. M. Viana, and O. Willi, Phys. Rev. E 48, 4855 (1993).

[2] S. Eliezer, The Interaction of High-Power Lasers with Plasmas, (IOP Publishing, Bristol, 2002).

[3] M. Kundu, Phys. Plasmas 21, 013302 (2014).

[4] M. Kundu, Phys. Rev. E 91, 043102 (2015).

[5] M. Kundu, Pramana-J. Phys (2019) 92:50.

Simulation of electric field structures in the Earth's magnetosphere

Amar Kakad, Bharati Kakad, and Ajay Lotekar
Indian Institute of Geomagnetism, New Panvel (West), Navi Mumbai

Abstract:
Over the past three decades, many spacecrafts (e.g., Polar, GEOTAIL, FAST, Cluster, THEMIS, MMS, Van Allen) have observed variety of electric field structures in various regions of the Earth’s magnetosphere These structures possess isolated impulsive electric fields in the monopolar, bipolar and tripolar forms, with a significant component parallel to the ambient magnetic field. These structures are abundantly observed in the Earth’s radiation belts. Recently it has been suggested that they play an important role in the macroscopic dynamics of the radiation belts, providing the mechanism of acceleration of low-energy electrons up to keV energies after which they further accelerated by whistler waves to MeV energies in the radiation belts. We perform computer simulations to investigate the generation mechanism of different types of electric field structures in the Earth’s magnetospheric plasma. We found that the density and velocity perturbations that are commonly available as free energy sources in the magnetosphere drive these localized electric field structures. Various physical aspects involved in the formation process of these structures will be discussed in this talk.

Modeling the Solar Spicule Forest

Sahel Dey[1], Piyali Chatterjee[1], Robert Erdelyi[2]
[1]*IIA, India*
[2]*University of Sheffield*

Abstract:
Solar spicules are thin elongated structures comprising of cold and dense chromospheric plasma making incursions –all the time– into the much hotter solar transition region and coronal plasma. Spicules are believed to be conduits for mass and energy from the solar chromospheres into the corona through magnetic waveguides and are conjectured to play an important part in the heating of the upper solar atmosphere. In this talk, we will present a series of two and three-dimensional magnetohydrodynamic (MHD) simulations varying both the magnetic field orientation and strength, which forms the solar spicule forest, self consistently. We demonstrate that the thousands of spicules generated in each of our simulation, whose properties like length, lifetime, modes of oscillations are in remarkable agreement with the observations and, are primarily associated with two distinct phenomena– 1) MHD shock or 2) lower atmospheric magnetic reconnection. There is evidence for both scenarios, therefore our simulations further contribute to unveiling the subtleties of spicule formation. We also anticipate the presence of Kelvin-Helmholtz instability and its effect on the multi-stranded structure of spicules. Finally, we analyze different oscillation modes of the synthetic spicules using time-distance diagrams and estimate the energy corresponding to each mode.

Decaying turbulence and magnetic fields in galaxy clusters

Sharanya.sur
IIAP, India

sharanya.sur@iiap.res.in

Abstract:
Free decay of magnetohydrodynamic (MHD) turbulence has been an active area of research in a variety of contexts. Starting from the generation of large-scale primordial magnetic fields in the early Universe, decaying MHD turbulence has also been studied in connection with the recent detection of strong optical polarization in gamma-ray burst (GRB) afterglows and to measure the decay rates of sub- and super-Alfvenic supersonic turbulence in the interstellar medium. A common feature in these works is that they all start from a magnetically dominated regime with the field initialized by a power spectrum peaked at around a large wavenumber. In galaxies and clusters the magnetic Reynolds numbers (Rm) are large enough to excite a Fluctuation/small-scale dynamo. The resulting field exhibits an intermittent structure with the magnetic energy spectrum peaked at resistive scales at early times which then gradually shifts to larger scales as the dynamo approaches saturation. Here, we explore the decay of turbulence and such dynamo generated fields in the context of galaxy clusters where such a decaying phase can occur in the aftermath of a major merger event. Irrespective of the compressibility of the flow, we find that both rms velocity and magnetic field decay as a power-law in time. In the subsonic case we find that the exponent of the power-law is consistent with the -3/5 scaling reported in previous studies. However, in the transonic regime both the rms velocity and the magnetic field initially undergo rapid decay with an $\approx t^{-11}$ scaling with time. This is followed by a phase of slow decay where the rms velocity exhibits an scaling in time while the rms magnetic field scales as $\approx -5/7$ Furthermore, analysis of the Faraday rotation measure reveals that the Faraday RM decays also decays as a power law in time $\approx t^{-5/7}$; steeper than the$\approx t^{-2/7}$scaling obtained in previous simulations of magnetic field decay in subsonic turbulence. We conclude by discussing potential implications of our work to the study of magnetic fields in elliptical galaxies.

Reference : MNRAS, Vol. 488, Issue 3, 2019.

"Dissecting AGN jets through simulations in the era of multi-messenger Astronomy”

Bhargav Vaidya
Indian institute of Technology Indore, India

Abstract:
Jets from Active Galactic nuclei (AGNs) are important from the point of view of feedback they provide to their surrounding. Further, emission from such jets cover a multi-wavelength band from radio to energetic gamma rays. Understanding the spectral distribution will enable us to get a comprehensive picture of physical processes in these jets and provide clues of their launching mechanism and their collimated nature . Recently, a breakthrough in the discovery of neutrinos from a blazar source using the IceCube experiments (IceCube Collaboration et al., 2018) has ushered the research of AGNs into a new era of multi-messenger astronomy. Such a discovery has far reaching implications in our understanding of the jet composition. By gathering information from multiple messengers, one could develop a more coherent physical picture of these sources. Thus, from the perspective of multi-messenger astronomy, jets from AGNs form an ideal laboratory.

An appropriate bridge between models and observations is imperative to connect the pieces of information and gather physical insights from multiple messengers associated with these jets. The biggest challenge in the numerical simulation of AGN jets is its multi-scalar nature and it requires computational approach for a deeper understanding of complex interplay between various micro-physical processes that contribute in these astrophysical systems at various scales. In this talk, I will our describe our recent results on simulating AGN jets at various lengths scales with a focus on bridging the small scale plasma processes to macro-physical scales relevant for astrophysical systems. The talk will also focus on different processes that play a crucial role in accelerating particles in these systems viz. diffusive shock acceleration. stochastic acceleration and magnetic re-connection. Further, I will demonstrate the applicability of a hybrid framework to explain non-thermal emission and polarisation signatures from relativistic jets typically observed from AGNs.

Understanding Galactic Dynamo

Abhijit Bendre
The Inter-University Centre for Astronomy and Astrophysics, Pune, India

Abstract:
Ordered magnetic fields in typical spiral galaxies observed via radio synchrotron emission are thought to be generated by a mean-field dynamo operating in the turbulent interstellar medium (ISM). However, the behaviour of dynamo model near equipartitio strength of magnetic field does not satisfactorily explain the observed large pitch angles. We present direct magnetohydrodynamic simulations of a local patch of diffuse multiphase ISM with turbulence driven via supernova (SN) explosions. This then leads to a fast initial growth (for approximately a Gyr) and eventual saturation of large-scale fields. Emergent fast outflow velocities could explain this saturation while maintaining the pitch angles. By analyzing our results in the context of a mean-field dynamo, we are able to demonstrate that our outcomes can be effectively understood in terms of a simple alpha-omega dynamo model including wind.

Modelling of SPT-100 Stationary Plasma Thruster (Hall Thruster)

Chandrasekhar Shukla, Anand Karpatne, and Laxminarayan Raja
Samspra Aerospace Pvt. Ltd., Bangalore-56008, India

chandrashekar.shukla@samspraaerospace.com, anand.karpatne@samspraaerospace.com , lraja@samspraaerospace.com

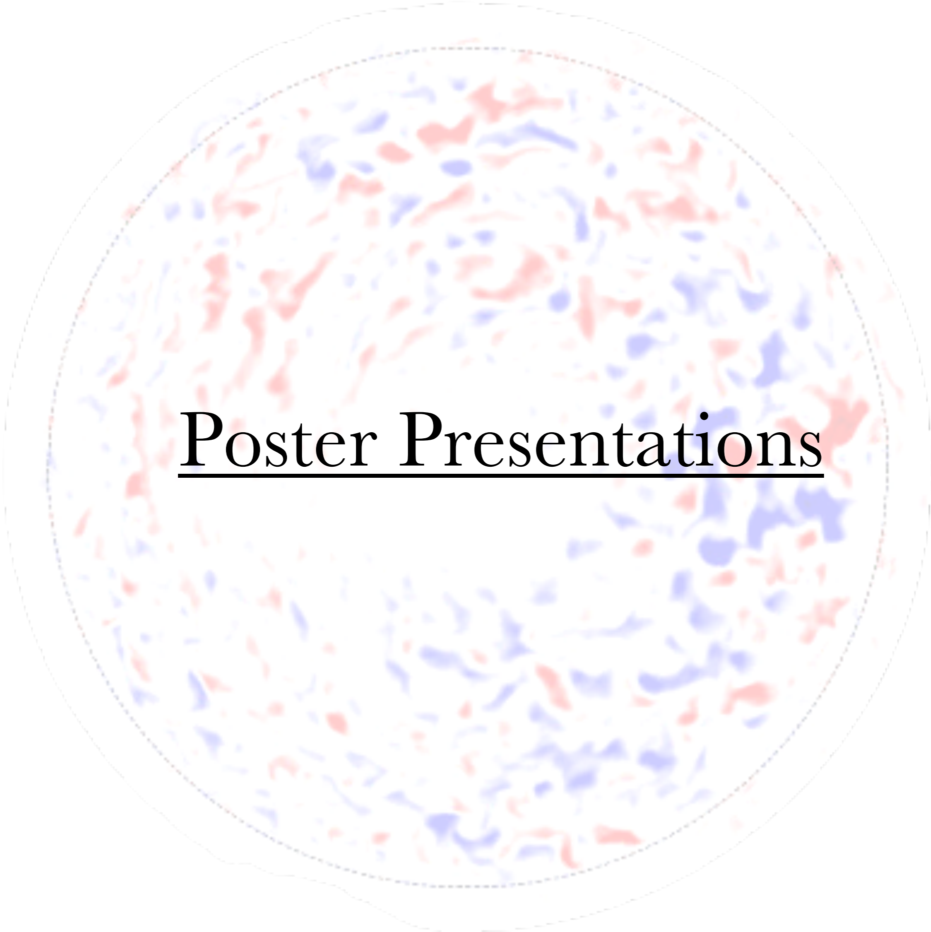
Abstract:
Stationary plasma thrusters (SPT) [A. I. Morozov et. al. 2000, Goebel et. al. 2008] also known as Hall effect thrusters are among the most mature electric propulsion devices used in various space applications including satellite orbit correction and station keeping. Hall thruster uses large local electric field in plasma by using a transverse magnetic field to reduce electron conductivity. This electric field can extract positive ion from plasma and can accelerate them to high velocity in comparison with conventional chemical thrusters providing thrust.

In spite of decades of research and development, due to involvement of nonlinear complex underlying physics, SPT is not fully understood. In recent time, due to rapid development of computational capability, the numerical simulations are providing useful insight in such problems. To predict the performance matrix of SPT as well to get more insight of SPT physics, a fast, robust, and accurate predictive simulation tool for Hall thruster plasma phenomena has been developed on the *VizGlow*® plasma modelling tool framework. The approach is based on Hybrid Plasma Modeling with coupled Particle and Fluid models for different aspects of the physical phenomena. The details of modeling of SPT-100 and benchmark for experimental results of SPT-100 will be presented.

References:

[1] A. I. Morozov and V. V. Savelyev, in Reviews of Plasma Physics, edited by B. B. Kadomstev and V. D. Shafranov (Kluwer Academic/Plenum Publishers, New York, 2000), Vol. 21.

[2] D. M. Goebel and I. Katz, "Fundamentals of Electric Propulsion: Ion and Hall Thrusters" (Wiley, 2008).



Poster Presentations

Analytical and simulation study of terahertz radiation generation by the interaction of circularly polarized laser pulse with magnetized plasma

Pooja Sharma and Pallavi Jha*
Department of Physics, University of Lucknow, India
*retired
E-mail: shubhpooja.77@gmail.com

Abstract

Interaction of intense laser radiation with plasma produces various nonlinear phenomena such as wakefield generation [1], harmonic generation [2] and terahertz (THz) radiation [3] generation. The generation of terahertz radiation has been an active area of research over past few decades due to its widespread use in ultrafast spectroscopy [4], THz imaging [5], chemical and biological sensing [6] and explosive detection [7]. THz radiation can be generated by the interaction of high power laser pulses with electro-optic crystals [8] and semiconducting materials [9] but low conversion efficiency and material breakdown are the major problems. However, laser driven plasma based schemes are impervious to such problems and have the potential of generating high power THz radiation. Recent analytical [10] and simulation [11] studies of THz radiation generation by propagation of linearly polarized laser pulses in magnetized plasma have motivated the present study.

Analytical and simulation studies of terahertz radiation generation by propagation of circularly polarized laser pulses in magnetized plasma, in the mildly relativistic regime, has been presented in this paper. The uniform magnetic field is applied along the direction of propagation of the laser pulse. The electric and magnetic wakefields within and behind the laser pulse are obtained using a perturbative technique. The transverse electric and magnetic wakefields lead to the generation of terahertz radiation. It is shown that two off-axis linearly polarized terahertz electromagnetic fields are generated. Using XOOPIC code, a simulation study of terahertz radiation generation for the same configuration, validates the analytical results.

References:

[1] T. Tajima and J. M. Dawson, Phys. Rev. Lett. **43**, 267 (1979).
[2] S. Y. Chen, A. Maksimchuk, E. Esarey, and D. Umstadter, Phys. Rev. Lett. **84**, 5528 (2000).
[3] H. Hamster, A. Sullivan, S. Gordon, W. White, and R. W. Falcone, Phys. Rev. Lett. **71**, 2725 (1993).
[4]C. J. Strachan, P. F. Taday, D. A. Newnham, K. C. Gordon, J. A. Zeitler, M. Pepper and T. Rades, J. Pharm. Sci. **94**, 837-846 (2005)
[5]W. L. Chan, M. L. Moravec, R. G. Baraniuk and D. mittleman, Opt. Lett. **33**, 974-976 (2008)
[6]M. Tonouchi, Nat. Photonics **1**, 97 (2007)
[7]H. B. Liu, Y. Chen, G. J. Bastiaans and X. C. Zhang, Opt. Express 14, 415-423 (2006)
[8]S. Matsuura, M. Tani and K. Sakai, Appl. Phys. Lett. **70**, 559-561 (1997)
[9]Y. C. Shen, P. C. Upadhyay, H. E. Beere and E. H. Linfield, Appl. Phys. Lett. **84**, 164-166 (2004)
[10]P. Jha, A. Saroch, and R. K. Mishra, Europhys. Lett. **94**, 15001 (2011)
[11]P. Jha, N. K. Verma, Phys. Plasmas **21**, 063106 (2014)

Wakefield generation in plasma via propagation of chirped laser pulses

Saumya Singh and Bhupesh Kumar
Department of Physics, University of Lucknow, India

saumyasingh.phy@gmail.com

Abstract

Wakefields can be generated via propagation of intense laser pulses in plasma. The generated wakefields which can accelerate charged particles upto GeV/m gradients, have the potential of replacing the conventional R.F. linacs [1,2]. Higher intensities and hence higher wakefields can be achieved with the help of chirped laser pulses [3]. Self-chirping is also introduced as laser pulses propagate in plasma [4].

The present study deals with wakefield generation by pulses having different profiles, via simulation using Particle in Cell (PIC) codes. It is observed that, positive (negative) chirping of laser pulses tends to increase (decrease) the peak wakefield amplitude.

References:

[1] T. Tajima and J.M. Dawson, Phys. Rev. Lett. 43(4) 267 (1979)

[2] P. Jha, A. Saroch, and R. K. Mishra, Europhys. Lett. 94, 15001 (2011)

[3] D. Strickland and G. Mourou, Opt. Comm. 55(6) 447(1985)

[4] P. Jha, Hemlata, R. K. Mishra, Physics of Plasmas 21, 123106 (2014)

Wave Instability Of Ion Acoustic Plasma Embedded Super Thermal Electrons

Mythili Kailas [1], K.Raghavi [1], Amrutha[1], Dr.L.Kavitha[1 2]

[1] *Department of physics,school of basic and applied sciences,central university of Tamilnadu,Thiruvarur 610 101 ,India*

[2] *The Abdus Salam International Centre For Theoretical Physics,Trieste,Italy*

Abstract:

Plasma is manifestly a non-linear medium and the non-linear consequences tend to restrict the growth of instabilities. Molecular instability of Ion Acoustic waves in nonlinear plasma has been the question of both theoretical and experimental inspections. In order to numerically analyse the modulational instability of Ion-Acoustic waves in a multicomponent plasma consisting of cold ions and super thermal hot electrons, we invoke the One Dimensional (1D) Particle In Cell (PIC) technique and predict the instability regime. We also modulate the carrier wave propagating along the multicomponent plasma and we derive the dynamical equation as Non Linear Schrodinger Equation(NLSE) and we examine the instability of the same.

Kyewords: One Dimensional Particle In Cell-Non Linear Schrodinger Equation-Ion Acoustic waves

References:

1) L.Kavitha,C.Lavanya,V.Senthil Kumar,D.Gopi and A.Pasqua, "Perturbed soliton excitations of Rao-dust Alfven waves in magnetized dusty plasma ",Physics of Plasmas.
2) Yi-Rong Ma et al 2019 chinese phys.B 28025201

Multi Solitonic Profile Of Dusty Plasma With Five Components

K. Raghavi,[1] Mythili Kailas,[1] Amrutha,[1] Dr.L.Kavitha[1,2]

[1]*Department of Physics, School of basic and applied sciences, Central University of Tamilnadu, Thiruvarur 610101, India*
[2]*The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.*

Abstract:
Globe is spanned by multicomponent dusty plasma and the dust is charged by photoionization when nearing the stars and planets. Starting from a short time ago, the attentiveness towards dusty plasma has increased and it is often difficult to pin down their range of application from laboratory plasma to space plasma. The work represents a huge effort to investigate the structure of solitary wave in five component dusty plasma whose constituents are positively and negatively charged dust, photoelectrons, hot electrons and ions. In this framework, a couple of equations of motion is derived by invoking reductive perturbation method and the resultant Korteweg-de Vries (kd-V) equation is solved by employing Jacobian-Elliptical Function Method and Non Linear Schrodinger Equation(NLSE) solved by Hirota-Bilinearization method. The solutions representing solitonic profile is analysed for potential applications of dusty plasma.

Keyword: Multicomponent - Reductive perturbation - Kd-V - NLSE - Hirota-Bilinearzation - Solitonic profile.

References:

1) L.Kavitha , C. Lavanya, V. Senthil Kumar, D. Gopi and A.Pasqua, "Perturbed soliton excitations of Rao-dust Alfven waves in magnetized dusty plasma", Physics of Plasmas.

2) Sijo Sebastin et al, International Journal of Science and research, 2319-7064.

Magnetized Wind Mediated Sun-Earth-Moon Interactions

Ranadeep Ghosh Dastidar[1 2], Arnab Basak[1 2], D. Nandy[1 2]
[1]*Indian Institute of Science Education and Research (IISER), Kolkata*
[2]*Center of Excellence in Space Sciences India (CESSI), IISER Kolkata*

Abstract:
Outflowing magnetized winds from host stars shape planetary and exo-planetary magnetospheres. Planets with and without intrinsic magnetospheres are affected differently by stellar wind. While the intrinsic magnetospheres get modified leading to formation of bow shock and magnetotail, in the absence of intrinsic magnetic field an imposed magnetosphere is observed. If two such planetary objects are present near each other (planet-moon systems) the dynamics may further vary due to relative location and impact of an additional wakefield (like planetary magnetotail). We study such binary systems for far-out planets and their natural satellites, with a special focus on the Earth-Moon system. We perform 3D compressible magnetohydrodynamic simulations of such interactions with a star planet interaction module created at CESSI, based on the PLUTO code. We expect to observe the modifications in imposed lunar magnetosphere due to the presence of modified geo-magnetosphere and vice versa, identify the reconnection regions and plasma exchange between the Earth-Moon and stellar wind leading to dynamical steady state. Such simulations are important for understanding the impact of space weather in Planet-Moon system and for interpretation of data from lunar and interplanetary space missions.

Magnetohydrodynamic Simulations of the Solar Forcing of Planetary Magnetospheres.

Souvik Roy[1] and **Dibyendu Nandy** [1,2]

[1]Center of Excellence in Space Sciences India, Indian Institute of Science Education and Research Kolkata, Mohanpur 741246, India;

[2]Department of Physical Sciences, Indian Institute of Science Education and Research Kolkata, Mohanpur 741246, India.

Abstract:

Magnetized wind outflow from a star gets modified as the star becomes old. This magnetized plasma flow from a host star interacts with the planets and give rise to various interesting magnetohydrodynamic processes like bow-shock, magnetopause, magnetotail, planet-bound current sheets, magnetic reconnections, atmospheric mass loss as well as particle injection into the planetary atmosphere, etc. We use 3D compressible magnetohydrodynamic simulation of a star-planet system and study the age-dependency of these interaction phenomena. We vary the properties of the stellar wind and planet's intrinsic magnetosphere and we expect to observe a change in magnetopause distances, magnetotail length, atmospheric mass loss and other dynamical steady-state properties of the planet with the age of the star. This study is important for exploring the consequences of earth's and exoplanet's atmospheric dynamics, intrinsic magnetic field's variation and habitability due to the ageing of the host star.

Modulational instability of ion-acoustic wave in plasmas with presence of positron and two-electron temperature

J. K. Chawla
Govt. Girls College Banswara, Rajasthan, India-327001
E-mail: jitendra123chawla@yahoo.co.in

Abstract:
Study the effects of positron density and temperature on modulational instability of ion-acoustic wave in electron-positron-ion plasmas with two-electron temperature distributions (Chawla, Mishra, and Tiwari 2014). Using the Krylov-Bogoliubov-Mitropolosky (KBM) perturbation technique a nonlinear Schrödinger equation governing the slow modulation of the wave amplitude is derived for the system. The dispersive and nonlinear coefficients are obtained which depend on the temperature and concentration of the hot and cold electron species as well as the positron density and temperature. The results obtained in this study may be useful to explain the stable and unstable modulational of ion acoustic wave in the astrophysical environments where electrons, positrons and ions are present.

Fluid Simulation Of Asymmetric Electron Acoustic Double Layers Observed In The Earth's Inner Magnetosphere.

Ajay Lotekar, Amar Kakad, and Bharati Kakad
Indian Institute of Geomagnetism, New Panvel (West), Navi Mumbai-410218
E-mail: ablotekar@gmail.com

Abstract:
The Van Allen Probes have recorded an interesting observation of symmetric and asymmetric bipolar electric field structures on November 13, 2012 in the Earth's inner magnetosphere. Conventionally, the symmetric bipolar pulses are interpreted as electron phase-space holes and its associated dynamics is well understood. These asymmetric structures are interpreted as electron acoustic double layers (EADLs). Even though they are interpreted as EADLs, their generation mechanism and physical properties are not well understood yet. We have simulated the EADLs observed on November 13, 2012, by Van Allen Probe-B. In order to understand their formation and evolution, we have performed the fluid simulation. We have found that the localized depletion and enhancement in the electron populations in the Earth's magnetosphere act as a perturbation to excite the symmetric bipolar electron acoustic solitary waves, which later evolve into the EADLs. The ponderomotive force is found to be the main driver behind transformation of the solitary wave to EADLs via formation of the electron-acoustic shocks.

A Simulation Study of Charged Particles Trapped in Earth's Dipolar Field

Pankaj Kumar Soni* , Bharati Kakad, and Amar Kakad
Indian Institute of Geomagnetism, Navi Mumbai, 410-218.

Abstract:
Ions and electrons trapped in Earth's magnetic field effect our space technology. Highly energetic plasma particles can damage satellites and pose serious health hazards for astronauts. Spectacles like the aurora are created by these particles that enter the Earth's atmosphere in the polar region. This article aims to understand the dynamics of charged particles trapped in Earth's dipolar magnetic field. The emphasis is on numerical simulation to characterize the trajectories of the charged particles of solar origin that enter the Earth's magnetosphere and get trapped. These particles perform three different periodic motions namely: gyration around magnetic field line, bounce over magnetic mirror point, and azimuthal drift around the Earth. We developed a test particle simulation model in which the relativistic equation of motion is solved numerically using Runge-Kutta sixth-order method. For proton, fourth-order Runge-Kutta method is sufficient whereas for electron three order smaller gyro-period demands higher accuracy in numerical scheme. Also, for lower energetic particles, the drift period increases for both proton and electron. When we perform simulations for a longer time, numerical errors in the estimates of velocity and position of particles may get integrated and subsequently enhance. Thus, one requires higher accuracy numerical schemes. The stability of the simulation model is verified by checking the adiabatic invariants linked with each type of motion. We found that bounce and drift periods of particles obtained from simulations are in good agreement with their theoretical estimates when adiabatic invariants are conserved. However, the energy ranges for which adiabatic invariants are violated, the theoretical estimates of the bounce/drift periods are not valid. This situation is successfully demonstrated through the present simulation, which arises due to larger gyro-radius (few Earth radii) of particles, over which the ambient magnetic field is not constant. In addition, we have examined the pitch angle distributions of the trapped particles. It is noted that the pitch angle distribution tends to follow 90o-peaked distribution when adiabatic invariants are not conserved. This information is useful to understand charged particle pitch angle distributions observed from some recent spacecraft in the Earth's magnetosphere.

Phase transition in strongly coupled dusty plasma

Hirakjyoti Sarma, Nilakshi Das
Department of Physics, Tezpur University-784028, Assam

Email :hirakj@tezu.ernet.in

Abstract
Dusty plasma provides a model system to study the phase transition of a system interacting via any potential. In this work ,we have performed Brownian Dynamics simulation of a three dimensional dusty plasma system in presence of ion flow and an external magnetic field. Radial distribution function and structure factor are obtained to understand the phase state of the system .It is found that ions streaming through the charged dust grains significantly affect the structure of the system and the conditions for transition from solid crystalline state to the liquid state. Here an effort has been made to find the melting parameter for dusty plasma as a function of ion flow velocity and magnetic field.

References
[1] S. Hamaguchi and R.T Farouki , The Journal of Chemical Physics 101, 9876 (1994)

[2] R.T Farouki and S. Hamaguchi,The Journal of Chemical Physics 101, 9885 (1994)

[3] Bezbaruah, P. & Das, N. Eur. Phys. J. D (2017) 71: 114

Modulational interactions in polar semiconductor plasmas: Effect of carrier concentration

Ratna Agrawal[1, a], Ravi Vanshpal[2] and Swati Dubey[1]
[1]*School of Studies in Physics, Vikram University, Ujjain-456010 (M.P.) India*
[2]*Department of Physics, Shri Vaishnav Institute of Physics, Shri Vaishnav Vidhyapeeth Vishwavidyalaya, Indore, India*

E-mail: ratnagarwal@gmail.com

Abstract:
In this paper, an analytical investigation has been made for modulational interactions of polaron mode in polar semiconductors. In the frame work of hydrodynamic model and coupled mode theory, under the assumption that the origin of modulational interactions lies in the third order optical susceptibility x^3arising from the nonlinear induced current density, analytical expressions for threshold pump amplitude and growth rate of polaron mode are derived. The numerical estimates are made for n-InSb crystal at 77 K duly shined by pulsed $10.6^{\mu m}CO_2$ laser. The effect of carrier concentration on the threshold field required for the onset of modulational amplification of polaron mode and its growth rate has been critically examined.

Keywords: Electron-LO phonon, Modulational interaction

Experimental Analysis of Nanogenerator using spin coating technique for energy harvesting applications

V. Vijayalakshmi[1], **Dr. K. S. Geetha**[2], **Dr. Shanmukha Nagaraj**[3],

[1]*Research Scholar, ECE Department, RV College of Engineering, Bangalore*

[2]*Professor & Head, ECE Department, RV College of Engineering, Bangalore*

[3]*Professor & Dean Academics, RV College of Engineering, Bangalore and affliated to Visvesvaraya Technological University, Belagavi, Karnataka, India*

Abstract

Overall increasing in human population and decreasing in conventional energy sources made the human resources to think towards Alternate source of energy. Moreover, potential applications of tiny portable electronic devices have been increasing in our daily life and their energy requirements also very less in terms of few mW/µW. This act as a key point for many researchers to turn their eyes towards energy harvesting techniques from human physiological body movements like walking, breathing, jogging, squatting etc., This research work focuses on fabrication of nanogenerator using organic polymer materials like PDMS Poly (dimethylsiloxane) by low cost spin coating technique and subsequent annealing.

Keywords: energy harvesters, portable tiny electronics, polymer materials, mW/µW, PDMS, nanogenerator, spin coating technique.

Parametric Decay of high power laser, to generate Whistler Waves and Kinetic Alfvén Wave in Laser-Plasma interaction.

Himani Dewan, Neha Pathak, R.Uma and R.P. Sharma,
Centre for Energy Studies, Indian Institute of Technology Delhi, New Delhi 110016, India.

Email: him20010@gmail.com.

Abstract:
In this paper, a wave–wave interaction model is investigated, pertaining to the parametric decay instability of the elliptically-polarized laser beam ω_0 .The laser plasma interaction induces the decay of high-intensity ellipticallypolarized Laser (ω_0) into Whistler Wave $\omega_1$and Kinetic Alfvén Wave (KAW, ω_2) . The importance of Whistler Wavesω_1 and Kinetic Alfvén Wave (KAW, ω_2)) similar to solar wind spectra34 has been pointed out, as a means to understand the turbulent magnetic field amplification; implicating electron and ion dynamics34- 39 . In the nonlinear stage, the decay instability is expected to attain the turbulent state, via a cascade process or filamentation/modulation instability (Oscillating Two Stream Instability,(OTSI)).Therefore, in the present paper, we have considered the first part of this research, namely,the beating mechanism $\omega_2 = \omega_0 - \omega_1$;induced due to the nonlinear interaction of elliptically-polarized Laser velocity and Whistler Wave density perturbation.The nonlinear saturation will be conferred in future investigations. Besides turbulence, the relevance of the present work to terahertz radiation generation[21-24, 38] and Fast Ignition laser fusion40 by ion heating has been emphasized. The coefficients for the nonlinear coupling pertaining to this parametric decay process and the growth rate of the decay instability are investigated.

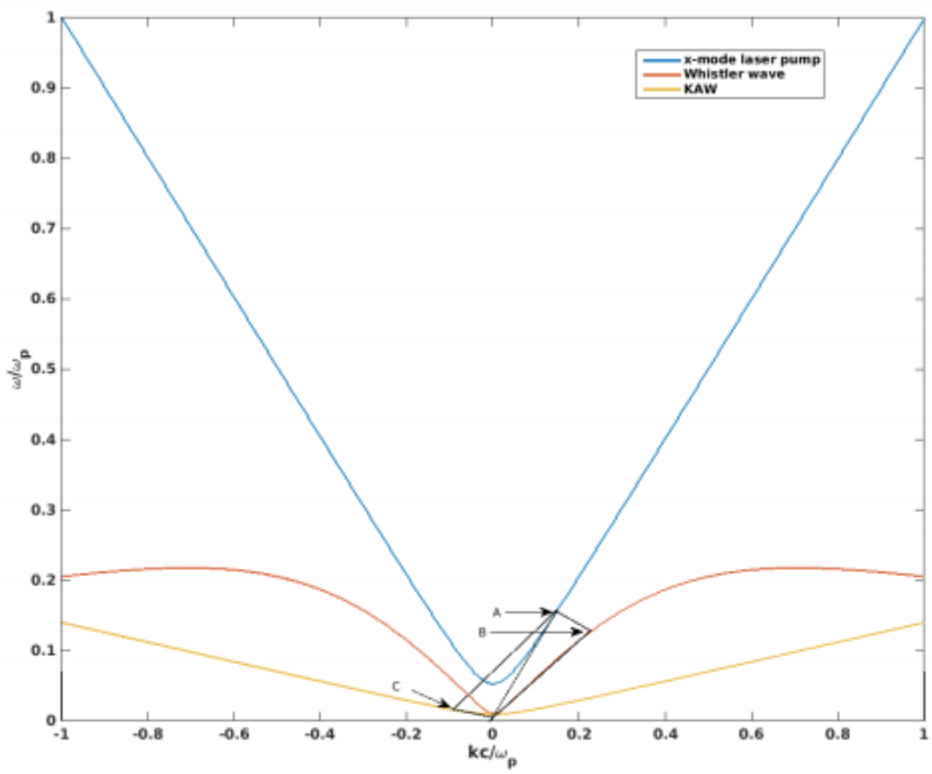


FIG.1. Illustration of parametric decay instability, when high power laser beams (ω_0, k_0) (blue) interact with highly magnetized plasma, it excites two plasma modes i.e. Whistler wave (ω_1, k_1) (orange) and KAW (ω_2, k_2)(yellow). The selection rules for this decay process are based on the simultaneous conservation of energy and momentum. 'A' corresponds to the decay point for pump wave, B and C to the two resultant waves (Whistler wave & KAW).

References

1. Yao Zhao, Suming Weng, Zhengming Sheng, Jianqiang Zhu,Phys. Plasmas,arXiv:1906.03910.

2. F. S. McDermott, G. Bekefi, K. E. Hackett, J. S. Levine, and M. Porkolab, The Physics of Fluids 25, 1488 (1982).

3. D. B. Schaeffer, D. Winske, D. J. Larson , M. M. Cowee , C. G. Constantin, A. S. Bondarenko, S. E. Clark, and C. Niemann, Phys. Plasmas 24, 041405 (2017).

4. W. Fox , J. Park, W. Deng , G. Fiksel, A. Spitkovsky, and A. Bhattacharjee, Phys. Plasmas 25, 022303 (2018).

5. Kyunghwan Dokgo , Kyoung-Wook Min, Cheong-Rim Choi , Minho Woo, Peter H. Yoon , and KyoungJoo Hwang, Phys. Plasmas 25, 062904 (2018).

6. S. Saito , Y. Nariyuki, and T. Umeda,Phys. Plasmas 25, 122301 (2018).

7. Miroslav Horký, Yoshiharu Omura , and Ondřej Santolík, Phys. Plasmas 25, 042905 (2018).

8. Q.-G. Zong, A. S. Leonovich , and D. A. Kozlov, Plasmas 25, 122904 (2018).

9. S.K. Hansen,S.K. Nielsen, J. Stober, J. Rasmussen, M. Stejner, and the ASDEX Upgrade Team, EPJ Web of Conferences 203, 02007 (2019).

10. Konrad Sauer, Klaus Baumgärtel, Richard Sydora, and Daniel Winterhalter,Journal of Geophysical Research: Space Physics, 124, 68–89.

11. I.N. Tsymbalov, D.A. Gorlova, V.Yu. Bychenkov, A.B. Savel'ev, Quantum Electronics 49 (4) 386 – 390 (2019).

12. Askar A. Ilyasov, Alexander A. Chernyshov, Mikhail M. Mogilevsky, Irina V. Golovchanskaya, and Boris V.Kozelov, Physics of Plasmas 22, 032906 (2015).

13. Dastgeer Shaikh, Mon. Not. R. Astron. Soc. 405, 2521–2528 (2010).

14. Yosuke Mizuno, Martin Pohl, Jacek Niemiec, Bing Zhang, Ken-Ichi Nishikawa, and Philip E. Hardee, The Astrophysical Journal, 726:62 (11pp), (2011).

15. P. K. Kaw, A. T. Lin, and J. M. Dawson,Phys. Fluids 16, 1967 (1973).

16. S. Perri, M. L. Goldstein, J. C. Dorelli, and F. Sahraoui, PRL 109, 191101 (2012).

17. B. Ferguson and X.-C. Zhang, Nature Materials, Vol. 1, 26-33, (2002).

18. Debayle, A., Gonzalez De Alaiza Martinez, P., Gremillet, L. & Berge, L, Phys. Rev. A 91, 041801 (2015).

19. Daniel M. Mittleman, Journal of Applied Physics 122, 230901 (2017).

20. Perenzoni, Matteo, Paul, Douglas, Springer Series In Optical Sciences, (2014).

21. Monika Singh, Ram Kishor Singh and R. P. Sharma,Euro Phys. Lett. 104, 35002 (2013).

22. Himani Dewan, M. Singh, R. Uma, and R. P. Sharma, Physics of Plasmas 25, 103105 (2018)40

Numerical Implementation of Stochastic Acceleration in Turbulent Astrophysical Plasma

Sayan Kundu, Bhargav Vaidya
Discipline of Astronomy, Astrophysics and Space Engineering
Indian Institute of Technology Indore, Indore

Abstract:
Various astrophysical sites are found to possess a huge amount of non-thermal particles, which isevident from their power-law type energy distribution, as opposed to the thermal Maxwellian distribution. Several mechanisms have been associated with the generation of these non-thermal particles. The well-known mechanisms that can produce non-thermal particles are Diffusive shock acceleration, stochastic turbulent acceleration, and magnetic reconnection. In this work, we will focus on stochastic turbulent acceleration or Fermi *IInd* order mechanism and its effect on the spectral index for different astrophysical sources which in turn can tell us about the spectral ages of these sources. This acceleration process is found to be well modeled with the Fokker-Planck equation with a momentum diffusion term. Due to the difficulty in solving this Fokker-Planck equation for general functional-coefficient analytically, we have solved it numerically using two numerical schemes; semi-implicit Chang-Cooper algorithm and Ito's stochastic differential equation. A comparative study between them will be shown and the possibility of a semi-Lagrangian scheme to overcome the numerical limitations of the above two methods will also be examined. The possible applications of this mechanism concerning spectral index mapping of radio lobes and galaxy cluster will also be discussed.

X-shaped Radio Galaxies: Theories and their validation

Gourab Giri and Dr. Bhargav Vaidya
Disciple of Astronomy, Astrophysics and Space Engineering
Indian Institute of Technology Indore, Khandwa Road, Simrol, Indore 453552, India

Abstract:
The recent discovery by Event Horizon Telescope has shown evidence of the existence of Super Massive Black-hole (SMBH) at the centre of radio galaxies. These galaxies typically show the presence of radio jets that are well collimated plasma flows ranging up to Mpc scales. In some cases, we see significant distortion occurring in these large-scaled radio jets and resulting in X-shaped morphologies. They can be identified from the presence of two double-lobed jet structure aligned at an angle to each other (wing and active lobe). Till date, there exists no single model which can explain all the properties of X-shaped radio galaxies. Though, Back-flow model and Merger model have gathered some attention in describing these galaxies. Back-flow model is based on the back-flowing of plasma and its evolution in a tri-axial ambient medium whereas the merger model based on the accretion and/or merging of galaxies leading to spin-flip of SMBH. Through our work, we want to verify whether there exists any universal model for these galaxies or not. In this presentation, I will describe three major properties of Back-flow model using state-of-the-art numerical simulation. We were able to check the wing formation mechanism, effect of magnetic field in its formation and the long-term particle/plasma evolution through high-resolution 2D- axisymmetric RMHD runs using PLUTO code. Additionally, results from parametric studies of the Back-flow model will also be discussed.

Particle-in-Cell (PIC) Simulations of Far-out Planetary Systems and Space Weather:

Arghya Mukherjee, Arnab Basak and Dibyendu Nandy
Center of Excellence in Space Sciences India (CESSI)
Indian Institute of Science Education and Research (IISER Kolkata)
West Bengal, 741246, India

Abstract: The high energetic magnetized wind from a host star plays a crucial role in determining the magnetic configuration of the planets it harbours. The dynamics of such systems are essentially governed by the nonlinear Magnetohydrodynamics (MHD) equations[1]. But MHD essentially neglects the single particle aspects and treats the wind & the ambient medium as conducting fluids characterized by macroscopic parameters viz. density, velocity, magnetic field and temperature. The interactions of high energetic charged particles, present in the wind, with the magnetic field of the planet exhibit fascinating events under certain conditions and often control the space weather. By using Particle-in-Cell (PIC)simulations method [2, 3] an empirical model for a Far-out Planetary system [4] has been developed in-house to reveal the microscopic dynamics of such systems. This model has been benchmarked by comparing the outcomes with existing theoretical results. We present the major findings obtained from our model and also discuss the essential physics.

References:

[1] Strugarek A. (2017) Models of Star-Planet Magnetic Interaction. In: Deeg H., Belmonte J. (eds) Handbook of Exoplanets. Springer, Cham
[2] Mignone et. al., The Astrophysical Journal, 859:13 (2018)
[3] Markidis et. al., Mathematics and Computers in Simulation, 80(7), 1509-1519
[4] Das et. al., The Astrophysical Journal, 877:80 (2019)

Solar wind interaction with planetary off-centered mini magnetosphere: A case study for Mars

Sajal Gupta, Arnab Basak, Dibyendu Nandy
Dept. Of Physical Sciences
IISER Kolkata, India

Abstract
The configuration of a planet's intrinsic magnetic field plays a vital role in interactions with the magnetized stellar wind from its host star. Magnetohydrodynamic simulations of star-planet interactions provide the theoretical basis to understand the impact of host star activity on planetary magnetospheres, including mini-magnetospheres. We carry out 3D compressible magnetohydrodynamic simulations for a far-out star-planet system with a Star-Planet Interaction Module created at CESSI, based on the PLUTO code. An off-centered, weak dipolar magnetic field is incorporated on the planetary surface to identify local magnetic reconnections and their effects on the atmospheric loss. We also explore changes in the structures of localized bow shock and magnetopause.. This study is expected to provide insight into the crustal magnetic field reconnections of Mars and its consequences on atmospheric loss and planetary habitability within the localized mini-magnetosphere.

Second Harmonic Generation of Quadruple Gaussian Laser Beams Interacting Nonlinearly with Underdense Plasma Targets

Naveen Gupta and Sandeep Kumar
Lovely Professional University, Phagwara

Corresponding author: naveens222@rediffmail.com

Abstract:
A scheme to produce second harmonics of intense laser beams interacting nonlinearly withunderdense plasma targets has been presented. In order to get efficient generation of the second harmonics, quadruple Gaussian (Q.G) laser beam as optical pump beam has been taken. Variational theory has been used to find semi analytic solution to the wave equation for the pump beam. When laser beam with frequency ω_0 propagates through plasma it makes the plasma electrons to oscillate at pump frequency ω_0. These oscillations of the plasma electrons in the presence of thermal velocity generate an electron plasma wave (EPW) at frequency ω_0. The generated EPW beats with the pump beam to produce its second harmonics. By using hydrodynamic fluid model of plasma, nonlinear current density for the SHG has been obtained. Emphasis are put on investigation of the effect of various laser and plasma parameters on propagation dynamics of pump beam and conversion efficiency of second harmonics. Effect of ponderomotive self-focusing of the laser beam on the process of second harmonic generation (S.H.G) has also been incorporated.

Self-Focusing of *q*-Gaussian Laser Beams in Preformed Parabolic Plasma Channels

Naveen Gupta and Rajender Singh
Lovely Professional University, Phagwara

Corresponding author: naveens222@rediffmail.com

Abstract:
Theoretical investigation on self-focusing of intense laser beams propagating through preformed parabolic plasma channels has been presented. The effect of deviations of the intensity profile of the laser beam from ideal Gaussian profile its self focusing has been incorporated through *q*-Gaussian distribution function for the irradiance over the cross section of the beam. Due to transverse intensity gradient over the cross section of the beam, the d.c component of ponderomotive force becomes finite. This results in the migration of the carriers from the axis of the channel towards its edges. This in turn enhances the transverse gradient of the index of refraction. Following variational theory the differential equation for the evolution of the beam width of the laser beam with distance has been obtained. Numerical simulations have been carried out to see the effect of laser and plasma parameters on evolution of the beam width of the laser beam.

Effect of presheath electron temperature on magnetized plasma-wall transition and wall sputtering by plasma having two species of positive ions

S. Basnet, A. Sarma[a] and R. Khanal

Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu 44613, Nepal

[a]School of Advanced Sciences (SAS), VIT Chennai Campus, Chennai, Tamil Nadu, India

E-mail: sbplasma1986@gmail.com

Abstract:

In this work, the kinetic simulation method has been employed to study the effect of presheath electron temperature on plasma-wall interaction mechanism and its consequence on wall sputtering. Multi-component plasma interacts with tungsten (W) surface through non-neutral plasma sheath formed near the Plasma Facing Material (PFM). It is assumed that two ion species have different temperatures with same degree of ionization. We have examined the ion velocity distributions in front of material wall. The thermal mobility of electron at the presheath-sheath interface determines the dimension of magnetic presheath and Debye sheath and hence energy flows towards the wall. The obtained results of the present work conclude that the angle of incidence at the wall and its sputtering rate is highly affected by electron temperature at the presheath-sheath boundary.

References:

[1] K. Chung, J. Appl. Phys.**71**, 1177 (1992).

[2] H. Pedit and S. Kuhn, Phys. Plasmas**1**, 13 (1994).

[3] C. Garcia-Rosales, W. Eckstein and J. Roth, J. Nucl. Mater.**218**, 8 (1995).

[4] W. Eckstein and R. Preuss, J. Nucl. Mater. 320, 209 (2003).

[5] J. I. F. Palop, J. Ballesteros, R. M. Crespo and M. A. Hernandez, Appl. Phys. Lett**. 88**, 261502 (2006).

[6] W. Eckstein, Sputtering Yields. In Sputtering by Particle Bombardment (Berlin: Springer) pp 33-187 (2007).

Role of ion-neutral collision on structure formation in dusty plasma: A Brownian dynamics study

Biswajit Dutta and Nilakshi Das
Tezpur University, Tezpur, Assam, 784028

E-mail: biswa1995@tezu.ernet.in

Abstract
Interaction potential in complex plasma with streaming ions is derived analytically in presence of ion neutral collision. The linear dielectric response function obtained describes the behavior of charged micron sized dust particles in strong collisional limit. A new type of repulsive potential is found to be operative among the dust grains apart from the normal Debye–Huckel potential. Langevin Dynamics Simulation is performed for 700 dust particles immersed in a plasma. Here, the effects have been incorporated via the relevant interaction potential operative among dust grains. Velocity Varlet Algorithm is implemented to solve Newton's equation of motion which in turn yields positions of particles at every time step. The temperature fluctuations in the system are regulated through velocity rescaling with the use of Berendsen thermostat. The Periodic Boundary Condition (PBC) is imposed along the three axes so that the particle number and linear momentum in the system remains unchanged. The interaction among particles and images is in accordance with minimum image convention adopted in our simulation.

References :

[1] A note on the binary interaction potential in complex (dusty) plasmas, Phys. Plasmas 15, 084502 (2008).

[2] Collisional effects on interaction potential in complex plasma in presence of magnetic field, Phys. Plasmas 23(4), 043701 (2016).

[3] Interaction mechanisms between dust grains in the presence of asymmetric ion flow and an external magnetic field in complex plasma, Eur. Phys. J. D 68, 184 (2014).

Waldmeier effect in stellar cycles: Hint for a common underlying plasma mechanism for the generation of solar and stellar cycles.

Suyog Garg[1] , Bidya Binay Karak[2] , Ricky Egeland[3] , Willie Soon[4] , and Sallie Baluinas[5]

[1]Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram, Chennai 600127, India

[2]Department of Physics, Indian Institute of Technology (Banaras Hindu University), Varanasi 221005, India

[3]High Altitude Observatory, National Center for Atmospheric Research, 3080 Center Green CO 80301, USA

[4]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA AND SALLIE,

[5]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

Abstract:

One of the most robust features of the solar magnetic cycle is that the stronger cycles rise faster than the weaker ones. This is popularly known as the Waldmeier Effect, which has been known for more than 100 yr. This fundamental feature of the solar cycle has not only practical implications, e.g., in predicting the solar cycle, but also implications in understanding the solar dynamo. In this paper we ask whether the Waldmeier Effect exists in other Sun-like stars. To answer this question, we analyze the Ca II H and K S-index from Mount Wilson Observatory for 21 Sun-like G–K stars. We specifically check two aspects of the Waldmeier Effect, namely, (1) WE1: the anticorrelation between the rise times and the peaks and (2) WE2: the positive correlation between rise rates and amplitudes. We show that, except for four stars which have peculiar cycles all other stars considered in the analysis show WE2, while WE1 is found to be present only in some of the stars studied. Furthermore, the WE1 correlation is weaker than the WE2. Both WE1 and WE2 exist in the solar S-index as well. Similar to the solar cycles, the magnetic cycles of many stars are asymmetric about their maxima. The existence of the Waldmeier Effect and asymmetric cycles in Sun-like stars hints towards a common plasma transport mechanism for the generation of magnetic cycles in both Sun and these stars. This suggests that the dynamo mechanism operating in the Sun should also be operating in other Stars.

Analytical and simulation studies ofwakefield generation by intense laser pulses propagating in plasma

Dinkar Mishra and Bhupesh Kumar
Department of Physics, University of Lucknow

mishra.edu@gmail.com

Abstract:
An intense laser pulse propagating through plasma generates longitudinal wakefields which can be used for accelerating charged particles like electron and protons [1-3]. Such generated wakefields can lead to energy gradientsup to the order of TeV/m, which can be very useful for building cost effective and small size accelerators as compared to large sized future circular colliders (FCC) [4].The present study deals with the comparison and verification of analytical and simulation results of wakefield generation via laser-plasma interaction. Particle in cell (PIC) simulation has been carried out by propagating linearly polarized laser pulses having different profiles through preformed homogenous plasma and the simulation results are compared with analytical formulation based on Maxwell's equations, Lorentz force, continuity, and Poisson's equations.

References:

[1] T. Tajima and J.M. Dawson, Phys. Rev. Lett. 43(4) 267 (1979)

[2] P. Chen et al., Phys. Rev. Lett. 54(7) 693 (1985).

[3] T. Katsouleas et al., Part. Accel. 22, 81 (1987)

[4] Rohit Kumar Mishra, Akanksha Saroch and Pallavi Jha Physics of Plasmas, 20, 094502 (2013)

Optical phase conjugation reflectivity in semiconductor quantum plasmas

R. Vanshpal[1], Ratna Agrawal[2]
[1]Shri Vaishnav Institute of Science, SVVV, Indore, India
[2]School of Studies in Physics, Vikram University, Ujjain, India
Email - ravivanshpal@gmail.com

Abstract
Present study deals with the behaviour of threshold pump intensity for the onset of optical phase conjugated stimulated Brillouin scattering (OPC-SBS). Using quantum hydrodynamic model (QHD) an analytical investigation is made for the determination of phase conjugate reflectivity of an electromagnetic wave via stimulated Brillouin scattering in a centrosymmetric, doped semiconductor medium . Effect of Bohm potential on the phase conjugate reflectivity is studied through the quantum corrections in classical hydrodynamic equations. The numerical estimations are made for n-type InSb crystal at 77K duly shined by pulsed 10.6$^{\mu m}$$CO_2$ laser. Phase conjugate reflectivity with quantum effect is found to increase with the pump intensity. Above the threshold pump field maximum phase conjugate reflectivity equal to 80% is obtained at pump intensities below optical damage threshold of the crystals. The main utility of the analysis is in establishing the potential of quantum correction through Fermi temperature and Bohm Potential terms for the reduction in the threshold pump intensity of the said process has been realized.

Keywords: Phase conjugation, Stimulated Brillouin Scattering

Enhanced second harmonic generation of dark hollow Gaussian laser beam in a collisionless magneto-plasma

Trivesh Kant, Jyoti Wadhwa and Arvinder Singh
Department of Physics, National Institute of Technology Jalandhar, India

Abstract

This paper presents an analysis and subsequent discussion of self-focusing and second harmonic generation (SHG) of a dark hollow Gaussian (dhG) laser beam in a a magneto-plasma, considering ponder-motive non-linearity. As a result of collisionless non-linearity, non-uniform distribution of plasma electrons take place due to non-uniform irradiance of intensity along the wavefront of the laser beam which leads to the self-focusing of laser beam and production of density gradient in the transverse direction. As a result of density gradient, an electron plasma wave is excited at pump frequency that interacts with the pump beam to produce its second harmonics of frequency twice that of latter. To envision the spot size and dynamics of propagation of dhG laser beam, moment theory in Webtzel-Kramers-Brillouin (W.K.B) approximation has been involved. The nature of self-focusing and second harmonic yield (SHY) is highlighted through critical curves as a plot of dimensionless beam width parameter and power of second harmonic radiation versus the distance of propagation. The effect of magnetic field on self-focusing and SHY of various orders of dhG laser beam has also been explored.

References:

[1] M.S.Sodha, R.K.Khanna, V.K.Tripath, Self-focusing of a Laser Beam in a Strongly Ionized Plasma, Opto-electronics 5.6 (1973) 533-538.

[2] P.Gibbion, High Order Harmonic Generation in Plasmas, IEEE J. Quantum Electron 33 (1997) 1915.

[3] N.Singh, N.Gupta, A.Singh, Second Harmonic Generation of Cosh-Gaussian laser beam in collisional plasma with non-linear absorption, Optics Communications 381 (2016) 180-188.

Study of the oxygen transport using a semi–implicit formulation of the radial impurity transport equation in the Aditya tokamak

Amrita Bhattacharya[1], †, Joydeep Ghosh[2], M. B. Chowdhuri[2], Prabhat Munshi[1]

[1]*Indian Institute of Technology Kanpur, Kalyanpur, Kanpur-208016, Uttar Pradesh, India*
[2]*Institute for Plasma Research, Gandhinagar, Bhat-382428, Gujarat, India*

amritab@iitk.ac.in

Abstract:
Impurity elements are the non–fuel species in tokamak plasma that are mainly generated towards the plasma boundary, near the wall and limiters/divertors of the system, which gradually enter into the main plasma. Impurity atoms/ions, depending upon the radial profile of plasma temperature, can lead to radiation losses or plasma dilution disrupting the steady operations in tokamaks. The present study is a step towards understanding the transport properties of intrinsic impurity species that are of relevance to the Aditya tokamak (r_o = 0.25 m, R = 0.75 m, $B_{t,o}$ = 0.75T) at the Institute for Plasma Research (IPR) Gandhinagar. 'Intrinsic' impurity here means the impurity species that remain inherent and are not purposefully injected into the plasma. The impurity element considered for the study is oxygen (Z = 8). Impurity distributions in tokamak are numerically determined by solving the radial impurity transport equation (RITE). The RITE for tokamak plasma is a form of non–linear, coupled, parabolic, diffusion–convection–reaction equation. The RITE for an impurity ionization state Z is coupled to the previous ionization state (Z-1) and next ionization state (Z+1) by means of its reaction term. The set of coupled equations is thus solved simultaneously for all charge states of a given impurity species. A novel approach towards solving the radial impurity transport equation has been attempted with a semi–implicit method in the present study. The present study briefly highlights the advantages of the newly applied method over other existing methods [1] and brushes upon the stability analysis of the implemented scheme conducted using the von Neumann stability analysis [2]. The number densities of the oxygen ions from the semi–implicit RITE are further used in determining the radial emissivity profiles of their characteristic 'excitation' transitions. The radial profiles of the transport coefficients of oxygen ions are obtained by iteratively constraining the simulated radial emissivity profile to the experimentally measured emissivity data of the 650.024 nm transition characteristic of the Be–like O^{4+} ion [3, 4]. The results obtained from the developed semi– implicit RITE simulation code are further used in determining the neo-classical transport coefficients [5] for the various charge states of the oxygen ion.

Keywords: Radial impurity transport equation, semi–implicit numerical method, stabilityanalysis, neoclassical transport, Aditya tokamak

References:
[1] R. Dux, 'Impurity Transport in tokamak plasma', STRAHL, IPP 10/27 Garching (2005)
[2] A. Bhattacharya et. al, Journal of Fusion Energy, 37 (5), 211–237 (2018)
[3] M. B. Chowdhuri et. al, Nuclear Fusion, 53, 023006 (2013)
[4] A. Bhattacharya et. al, Plasma and Fusion Research, 14, 1403155 (2019)
[5] S. P. Hirshman and D. J. Sigmar, Nuclear Fusion, 21(9), 1079–1201 (1981)

Role of localized structures and turbulence generation at magnetopause reconnection region

Neha Pathak[1], R. Uma[1] and R.P.Sharma[1]
[1]*Centre for Energy Studies, Indian Institute of Technology Delhi, New Delhi,* India

Email: npsneha90@gmail.com

Paper category: Space and Astrophysical Plasma

Abstract:
Kinetic Alfvén wave and whistler wave play a key role in the framework of turbulence and reconnection. There are lot of observations of these wave in the magnetopause region. The present work deals with the nonlinear evolution of KAW and a weak whistler wave through the pre-existing magnetic reconnection site. For this study the dynamical evolution equations are derived by taking into account the ponderomotive force driven density modification and magnetic field fluctuations due to shear field modelled by the Harris sheet. Furthermore, these equations have been solved numerically as well as semi-analytically. For numerical integrations we have used the pseudospectral method and finite difference method and for semi-analytically Runge Kutta method. Simulated results have shown the evolution of coherent structures or current sheets, which are capable to energy transfer efficiently. These structures give the signature of turbulence generation. Therefore, the magnetic power spectrum with scaling is also presented and their relevance with the observed spectrum (Chaston et al., 2008) is also pointed out.

Reference:

1. Chaston, C. C., J. Bonnell, J. P. McFadden, C. W. Carlson, C. Cully, O. Le Contel, A. Roux, Auster, H. U., K. H. Glassmeier, V. Angelopoulos, and C. T. Russell (2008),

2. Turbulent heating and cross-field transport near the magnetopause from THEMIS, Geophys. Res. Lett. 35, L17S08, doi:10.1029/2008GL033601 .

Development of finite element Poisson solver on field-aligned mesh in global toroidal geometry

Tajinder Singh[*,1] , Animesh Kuley[1] , Sarveshwar Sharma[2] , Zhihong Lin[3]

[1] *Department of Physics, Indian Institute of Science, Bangalore, India*

[2] *Institute of Plasma Research, Bhat, Gandhinagar, India*

[3] *University of California, Irvine, United States*

∗Corresponding author: stajinder@iisc.ac.in

Abstract:
A new Poisson solver based on the finite element (FE) method has been developed and incorporated in the global toroidal code using X-point (GTC-X) by making use of the field-aligned mesh created on the realistic geometry of DIII-D tokamak to extend the simulation domain to the X-point and beyond, where the conventional finite difference (FD) method will lose its capabilities. This new finite element Poisson solver is tested on the circular equilibrium and is in good agreement with that of the analytical solution. A new zonal flow solver with the realistic equilibrium profile of DIII-D tokamak is developed and benchmarked in the core region. The above incorporated capabilities are used to further verify the ion temperature gradient (ITG) driven microturbulences in the core region.

Keywords: Finite element method; Poisson equation; Global toroidal code.

Statistical Properties in three-dimensional (3D) Hall Magnetohydrodynamics (HMHD) Turbulence

Sharad K Yadav ∗ , Nadia B Padhan and Rahul Pandit †

Centre for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bangalore 560012, India

Abstract:

Turbulence in the solar wind is often studied using the three-dimensional (3D) Hall magnetohydrodynamics (HMHD) equations[1, 2]. Some earlier studies have investigated the statistical properties of 3D HMHD turbulence by using simple shell models [2] or pseudospectral direct numerical simulations of the 3D HMHD equations; the latter have been restricted to modest spatial resolutions and have covered a limited parameter range. To explore the dependence of 3D HMHD turbulence on the Reynolds number (Re), the magnetic Prandtl number (Pr_M), and the ion-inertial scale (d_I), we have developed a pseudospectra code for DNSs of the 3D HMHD equations. This code is also benchmarked by comparing our results with those that exist in the literature [3]. We present detail of the statistical properties of 3D HMHD turbulence obtained in the simulation.

References:

[1] K. H. Kiyani, S. C. Chapman, Y. V. Khotyaintsev, M. W. Dunlop, and F. Sahraoui, Phys. Rev. Lett., 103, 075006 (2009).

[2] D. Banerjee, S. S. Ray, G. Sahoo, and R. Pandit, Phys. Rev. Lett., 111, 174501 (2013).

[3] S. Galtier and E. Buchlin, The Astrophysical Journal, 656, 560-566, 2007.56

Path-planning microswimmers can swim efficiently in turbulent flows

[1]Jaya Kumar Alageshan, [1]Akhilesh Verma, [2]Jeremie Bec, [1]Rahul Pandit
[1]Department of Physics, Indian Institute of Science, Bangalore 560012
[3]CNRS, MINES ParisTech

Abstract:
We develop an adversarial-reinforcement learning scheme for microswimmers in statistically homogeneous and isotropic turbulent fluid flows, in both two (2D) and three dimensions (3D). We show that this scheme allows microswimmers to find non-trivial paths, which enable them to reach a target on average in less time than a nave microswimmer, which tries, at any instant of time and at a given position in space, to swim in the direction of the target. We use pseudospectral direct numerical simulations (DNSs) of the 2D and 3D (incompressible) Navier-Stokes equations to obtain the turbulent flows. We then introduce passive micro- swimmers that try to swim along a given direction in these flows; the microswimmers do not affect the flow, but they are advected by it. Two, non-dimensional, control parameters play important roles in our learning scheme: (a) the ratio $\tilde{V}_s$ of the microswimmer's bareVelocity $\tilde{V}_s$ and the root-mean-square (rms) velocity u_{rms} of the turbulentfluid; and (b) the product $\tilde{B}$ of the microswimmer-response time B and the ω_{rms} vorticityof the fluid. We show that, in a substantial part of the V_sB plane, the average time required for the microswimmers to reach the target, by using our adversarial-learning scheme, eventually reduces below the average time taken by microswimmers that follow the nave strategy.

Effect of impurity injection on runaway electrons separatrix and energy loss due to collisional dissipation

Ansh Patel[1], Santosh P. Pandya[2]
[1]School of Liberal Studies, Pandit Deendayal Petroleum University, Gandhinagar -382 007, India
[2]Institute for Plasma Research, Bhat, Gandhinagar – 382 428, India.
E-mail: psantosh@ipr.res.in

Abstract

Runaway electrons (REs) generated during the plasma disruption phase can lead to serious damage to the confining structure in the tokamak if they collide with the plasma-facing components. This is particularly severe in the large size tokamaks like ITER where a large fraction of the plasma current can be converted into RE-current during the disruption phase. This makes it very important to develop a fast but controlled RE mitigation method. A highly preferred mitigation method [1-4] is to inject high Z inert gas impurities in the form of shattered pellet~~s~~ injection (SPI) and/or massive gas injection~~s~~ (MGI) which leads to an increase in the plasma density (. This causes the collisional drag and Bremsstrahlung radiation loss [4-5] to increase in the plasma due to a rise in the number of field electrons and ions. As a consequence, REs lose their energy and RE-generation rate is also suppressed. In this paper, we use a test particle model (TPM) [5-7] to study these effects. The TPM can simulate the effects of a toroidal electric field, plasma collisional drag force, deceleration due to synchrotron radiation loss and Bremsstrahlung emission loss. The effect of an SPI/MGI is considered by increasing and that causes the runaway generation separatrix to shift towards higher momenta and hence decrease of RE generation. Simultaneously, an increase in the density leads to collision-induced pitch angle scattering hereby causing the synchrotron radiation to increase, further decreasing the energy of REs. The present modeling work can aid the assessment of the effectiveness of aforementioned RE mitigation methods. Further, the simulations can also help in developing plasma scenarios for avoidance and suppression of REs. The dynamics of REs are studied and reported herein for parametric variation of typical tokamak parameters.

References:

1. J.R. Martín-Solís, et al, Phy. of Plasmas 22 082503 (2015)
2. J.R. Martín-Solís, et al, Phy. of Plasmas 22 092512 (2015)
3. E. M. Hollmann, et al, Phy. of Plasmas 24 062505 (2017)
4. J.R. Martín-Solís, et al, Nucl. Fusion 57 066025(2017)
5. M. Bakhtiari, et al, Phy. of Plasmas 12, 102503(2005)
6. J. R. Martín-Solís, et al, Phy. of Plasmas 6 (1999)
7. J. R. Martín-Solís, et al,Phy. of Plasmas, 9 (2002)

Current gradient driven instabilities in electron current layers: Particle in cell simulations

[1]Nishka Sheth, [2]Bhavesh Patel and [1]Gurudatt Gaur
[1]Institute of Advanced Research, Gandhinagar – 382426, India
[2]Institute for Plasma Research, Gandhinagar – 382428, India

Abstract
Electron current configurations are formed in a variety of physical phenomena like, collisionless magnetic reconnections, fast ignition variant of laser fusion, fast z-pinches, interplanetary current-carrying plasmas etc. These current configurations are susceptible to various instabilities, which lead to the evolution of current configurations, sometimes to the point of complete destruction.

Earlier work shows that the perturbations parallel to one dimensional equilibrium magnetic fields, driven by the current gradient, lead to two different modes – tearing and non-tearing. The tearing mode evolves to form the magnetic island due to reconnection of field lines while, the non-tearing mode evolves to form the channel-like structures. In this work, we perform two-dimensional PIC (particle-in-cell) simulations of tearing and non-tearing instabilities. We will present the simulation results for various cases when one or both the modes are present in the system.

Pseudo-spectral time domain solution of Maxwell's equations for wave propagation in one dimension

Lalita Devi[1] and Mrityunjay Kundu[1,2]
[1]*Institute for Plasma Research, Bhat, Gandhinagar - 382 428, Gujarat, India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai - 400 094, India*
Email: lalita.garg@ipr.res.in, mkundu@ipr.res.in

Abstract:
A dispersion-free numerical algorithm is often required to study interaction of electromagnetic waves (e.g., microwaves and lasers) with plasmas and to understand the wave absorption phenomena in plasmas. To this aim, a pseudo-spectral time domain (PSTD) code [1] is developed first to study electromagnetic wave propagation in free space by solving Maxwell's equations in one dimension. In the PSTD method, Fast Fourier Transforms (FFTs) are used to represent spatial derivatives of Maxwell's equations instead of finite differences as used in the traditional finite difference time domain (FDTD) methods [2]. Perfectly matched layer [3,4] absorbing boundary conditions are implemented in the PSTD code to avoid the spurious reflections from the boundaries of the problem space to mimic wave propagation in infinite domain. The dispersion relation obtained from the PSTD algorithm is compared with the FDTD algorithm which shows PSTD is much more dispersion-free than FDTD method. The effect of grid density with the relative dispersion error from the exact dispersion relation for both the PSTD and FDTD is also analyzed.

References:

[1] Q. H. Liu, Microwave Opt. Technol. Lett. 15, 158 (1997).

[2] R. Lehe, A. Lifschitz, C. Thaury, V. Malka, and X. Davoine, Phys. Rev. Spec. Top. Accel. Beams 16, 021301 (2013).

[3] D.M.Sullivan, Electromagnetic simulation using the FDTD method, IEEE Press (2000).

[4] J. Berenger, J. Comp. Phys. 114, 185 (1994).

Laser cluster interaction in strong external magnetic field including effect of electron cyclotron resonance

Kalyani Swain[1,2] and Mrityunjay Kundu[1,2]

[1]Institute for Plasma Research, Bhat, Gandhinagar - 382 428, Gujarat, India

[2]Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai - 400 094, India

Email: kalyani.swain@ipr.res.in, mkundu@ipr.res.in

Abstract:

Laser interaction with atomic nano-clusters leads to the production of energetic electrons, ions and x-rays which are useful for charge particle and photon accelerators. However, the effect of laser magnetic field is often neglected in the theory and simulation of laser-cluster interaction since laser magnetic field is very weak by a factor of inverse light speed as compared to the laser electric field. By a simple non-linear oscillator model of cluster, it is found that, even in the non-relativistic regime of laser intensities ($\leq 7.5 \times 10^{17}$ W/cm^2) the peak magnetic field strength (~ 3.33 kilo Tesla) is substantial to alter the electron dynamics and energy absorption by electrons in the short-pulse regime of laser cluster interaction. In addition to the transverse laser magnetic field we apply an external magnetic field in different orientations w.r.t. to the former and study the dynamics of cluster electrons and consequent laser energy absorption. Further we look for the possibility of electron cyclotron resonance by matching the cyclotron frequency either to plasma frequency or to the laser frequency and its effect on laser-cluster interaction.

References:

[1] M. Kundu and D. Bauer, Phys. Rev. Lett. 96, 123401 (2006).

[2] S.S. Mahalik, M Kundu, Phys. Rev. A 97, 063406 (2018).

Sheet Simulation of Relativistic Upper-hybrid waves in a cold magnetized plasma

Nidhi Rathee[1,2], Arghya Mukherjee[3] and Sudip Sengupta[1,2]

[1)]Institute for Plasma Research, Gandhinagar, 382428, India
[2)] Homi Bhabha National Institute, Training School Complex, Mumbai, 400094, India
[3)]Center for Excellence in Space Sciences India, Indian Institute of Science Education and Research Kolkata, Mohanpur, 741246, India

E-mail :nidhi.rathee@ipr.res.in

Abstract:

The space-time evolution of relativistic upper-hybrid oscillations [1] and waves [2], in a cold homogeneous magnetized plasma, has been studied analytically and by performing simulations. A complete solution of the fluid-Maxwell equations has been provided, using Dawson Sheet Model [3]. It is found that in the case of stationary oscillations, the oscillation frequency becomes a function of space which results in phase mixing [1, 3, 4, 5, 6], whereas the traveling wave solution [2] does not exhibit phase mixing; it is like an Akhiezer-Polovin mode in an unmagnetized cold plasma [4]. Further, a numerical 1-1/2 D code, based on Dawson Sheet Model [3], has been developed to simulate the evolution of the relativistic upper-hybrid mode. The sensitivity of the traveling waves, towards a small amplitude longitudinal perturbation, has been studied and it is observed that waves break via the process of phase mixing when subjected to a small amplitude perturbation. An analytical expression for this breaking time has been derived and verified via simulations, for an entire range of input parameters.

References :

[1] Chandan Maity, Anwesa Sarkar, Padma Kant Shukla and Nikhil Chakrabarti, Phys. Rev. Lett. 110, p 215002 (2013)

[2] Mithun Karmakar, Chandan Maity and Nikhil Chakrabarti, Physics of Plasmas 23, p 064503 (2016) [3] J. M. Dawson, Phys. Rev. 113, p 383–387 (1959).

[4] J. F. Drake, Y. C. Lee, K. Nishikawa and N. L. Tsintsadze, Phys. Rev. Lett. 36, p 196 (1976)

[5]Sudip Sengupta, Vikrant Saxena, Predhiman K. Kaw, Abhijit Sen, and Amita Das, Phys. Rev. E 79 , p 026404 (2009)

[6] Prabal Singh Verma, Sudip Sengupta, and Predhiman Kaw, Phys. Rev Lett. 108, 125005 (2012)

[7] A. I. Akhiezer and R. V. Polovin, Sov. Phys. JETP., 3, p 696 (1956)

Multiple potential structures in an expanding magnetised plasma with variable source dimensions

Sneha Gupta, Devendra Sharma
Institute for Plasma Research, Gandhinagar 382 428

sneha.gupta@ipr.res.in

Abstract
A steady-state plasma flow exiting through a source region along an expanding magnetic field, develop potential structures, identified as current free double layer, which have applications in plasma thrusters. The outflowing ions in the set up are accelerated via a gridless mechanism, suitable for deep space propulsions. The study is done by the means of an electrostatic Particle in Cell (PIC) numerical simulations using a 2D PIC code XOOPIC. To start with, a plasma source model is considered involving plasma parameters, such as temperature and source strength, which are estimated and used in the simulations corresponding to prescribed combinations of input power and neutral gas flow values. In many experiments, the plasma generated is often localized and may not uniformly cover the entire physical volume of the bounded source chamber. Considering this factor, the effects of change in plasma source region dimension, axially localized in the source chamber having uniform-magnetic-field, is explored, with respect to a fixed location of the entry to the expansion region. Simulated axial potential profiles at various radial locations show development of a step-wise axial potential drop, producing plasma (ion) acceleration in the corresponding regions. For narrow source region, with long pre-expansion flow region, ion phase-space scatters show trapped region and signatures of chaotic ion trajectories indicating a possible pre-expansion ion heating. Considering the relevance of the studied flow equilibria to the thrust generation schemes for space propulsion, a formal estimate of thrust values associated with plasma outflow is also done which is recovered to be 0.07-0.04 × 10^{-6} N for the cases simulated.

Study of structure evolution in Vlasov-Poisson system using conservative simulation methods

A. K. Paul and D. Sharma
Institute for Plasma Research Gandhinagar -382428 Gujarat,India, HBNI

anjan.paul@ipr.res.in

Abstract:
The numerical flux balance (FB) method was applied to solve kinetic equation. In a Vlasov (collisionless) plasma the numerical integration of electrostatic Vlasov-Poisson system produces an evolution which shows coherent structures of various categories depending on the parameter regime covered by the simulation setup. In order to quantify the effects of underlying approximations in the riginal FB algorithm and to overcome them a modified FB method was developed. The central modification of the scheme is done by introducing an improved and systematic phase space transport model in the original FB scheme. The modified method is characterized with respect to transport coefficients in oder to generate comparision with the first version of the scheme. The associate numerical analysis of the results will be presented.

3D fluid monte-carlo modeling in ITER first wall panel using EMC3-EIRENE

B. P. Sahoo[1], D. Sharma[1], R. Pitts[2], W. Zhang[3]
[1]*Institute for Plasma Research, HBNI, Bhat, Gandhinagar, India, 382428*
[2]*ITER organization, Route de Vinon-sur-Verdon, CS 90 046, F-13067 St-Paul-lez-Durance, France*
[3]*Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, Greifswald, D-17491, Germany*

Email: bibhuprasad@ipr.res.in

Abstract:
The main chamber recycling is one of the major concerns in diverted configurations of magnetic confinement based fusion machines, including in the tokamak ITER. The plasma-neutral transport simulations in a tokamak scarpe-off layer (SOL) needs 3D treatment to obtain the recycling patterns formed on a structured, 3D first wall panel. The 3D model EMC3-EIRENE which is based on fluid plasma and kinetic neutral monte-carlo method and is MPI parallelized, has the capability to capture the recycling of neutrals from the main chamber along with different plasma profiles will help to design spectroscopic camera to obtain the proper line of sight for measuring H-alpha signals as done previously for W7-X for start-up limiter configurations [1, 2]. The transport study is based on generating Monte-carlo particles on separatrix for particle, momentum and energy and transport them along the flux tube in scrape-off layer (SOL) region and map the pattern in 3D wall and divertor region for many such iterations to have a better convergence of the solutions. The first sets of simulations with small and large number of Monte-Carlo particles in ITER shows neutral density strong and intense on mid of inboard wall region and top of vessel but very less intense on outboard regions, also the interaction with vessel wall is captured in toroidal and poloidal plane using EMC3 field line mapping to the 3D vessel wall.

References:

[1] H. Frerichs, et al., Nucl. Fusion. 57, (2017), 126022

[2] R. A. Pitts, et al., J. Nucl. Matter. 415, (2011), S957–S964

Plasma Parametric Dependence Of Core Ion Temperature As Studied For Various Discharges In Aditya Using Electrostatic Parallel Plate Neutral Particle Analyzer [Epp-Npa] Measurements And Simulation

Kumar Ajay*, Snehlata Aggarwal, Santosh P. Pandya
Institute for Plasma Research, Bhat Village, Gandhinagar-382428 (INDIA)

*E-mail: ajaykuma@ipr.res.in

Abstract

Charge exchange fast neutral spectrum has been obtained, studied and have been analyzed for numerous plasma discharges in Aditya using Electrostatic Parallel Plate Neutral Particle Analyzer [EPP-NPA] measurements of Core Ion temperature [1]. An attempt to correlate the dependence of measured core Ion temperature on various operational plasma parameters of Aditya discharges like, average plasma density $<N_e>$, flat top plasma current [I_p], magnetic field [B_t] etc. has been carried out. The passive mode of charge exchange diagnostics installed on radial port 10 of Aditya (with gas cell configuration of ionization chamber) consistently showed the measured core temperature to be from 100 eV to 300 eV [2]. These temperature values [$T_i(0)$] have been found to be following a definite pattern of dependence on the plasma‘s other operational parameters. This study, being reported in this paper, is based on a few simulations carried out for estimating the charge exchange flux and the core ion temperature as well as EPPA-experimental data obtained during Aditya operations.

References

2. T. A. Santosh Kumar, L. M. Awasthi, C. Chhaya, H. D. Pujara, B. N. Buch, H. R. Prabhakara and S. K. Mattoo, A technical report: Aditya Charge Exchange Diagnostics, IPR/TR-56/96, February 1996.

2. Santosh P. Pandya, Kumar Ajay, Priyanka Mishra, Rajani D. Dhingra and J. Govindarajan, "Core-Ion Temperature Measurement using Passive Charge Exchange Neutral Particle Energy Analyzer for the ADITYA tokamak", Review of Scientific Instrument, Vol. 84, Issue 2, p023503, (2013).

Recurrent and Nonlinear Oscillations : A comparative study between GMHD3D code and PLUTO code

Shishir Biswas[1], Rupak Mukherjee[2] , R Ganesh[1]

[1] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, HBNI, India.*

[2] *Princeton Plasma Physics Laboratory, Princeton University, New Jersey, USA, 08540*

shishir.biswas@ipr.res.in

Abstract:

At the Institute for Plasma Research (IPR), an OpenACC code GMHD3D solves compressible 3D resistive MHD equations in conservative form [1]. Using this code, in a recent series of publications, novel MHD phenomena such as recurrence of an initial MHD state [2], nonlinear oscillations with linear Alfven dispersion [3] were investigated [1]. In this present work, we have used PLUTO [4] code to investigate the above said phenomena and have made a quantitative comparison of the results with those of GMHD3D code. The details of this comparative study will be presented along with some new results from PLUTO code.

References:

[1] Thesis Title "TURBULENCE, FLOWS AND MAGNETIC FIELD GENERATION IN PLASMAS USING A MAGNETOHYDRODYNAMIC MODEL", by Rupak Mukherjee, 2019, IPR, India.

[2] Mukherjee, R., Ganesh, R. and Sen, A., 2019. Recurrence in three dimensional magnetohydrodynamic plasma. Physics of Plasmas, 26(2), p.022101.

[3] Mukherjee, R., Ganesh, R., & Sen, A. (2019). Coherent nonlinear oscillations in magnetohydrodynamic plasma.Physics of Plasmas, 26(4), 042121.

[4] Mignone, A., Bodo, G., Massaglia, S., Matsakos, T., Tesileanu, O., Zanni, C. and Ferrari, A., 2007. PLUTO: A numerical code for computational astrophysics. The Astrophysical Journal Supplement Series, 170(1), p.228.

Eigenfunction approach to computing bounded dusty plasma vortex equilibria with multiple scale drive.

Prince Kumar and Devendra Sharma
Institute for Plasma Research, HBNI, Bhat, Gandhinagar - 382 428, Gujarat, India

Abstract

The computation of dust vortex equilibria in a dusty plasma is done where dust con nement is achieved by conservative elds but a non-conservative drive by plasma background produces strong inhomogeniety in the the 2D hydrodynamic mathematical model. The dust vortex ow in bounded con guration is treated numerically to obtain the equilibrium solutions in a slab-like 2D geometry. In order to compute stream-function solutions, the linear boundary value problem is treating as an eigenvalue problem in which driven dust ow eld and driver eld are represented in term of linear combinations of eigenfunctions that satisfy the desire boundary conditions for dust. Eigenvalue equation then converted into a set of algebraic equations at discrete spatial location to form a matrix equation for the dust stream-function coe cients. For prescribed value of driver coe cients, the dust stream-function coe cients is then computed by matrix inversion. The problem is solved using a combination of driver eigenmodes of multiple scales. A comparison with vortex solutions driven by individual modes and a characterization of the numerical procedure for multiple scale driver case are done.

Keywords: dust vortex equilibria, inhomogeniety, eigenvalue, boundary value problem

References

[1] M. Laishram, D. Sharma, and P. K. Kaw, Phys. Rev. E 91, 063110 (2015).

2D hydrodynamic simulations of obliquely propagation of nonlinear waves in plasma

Gayatri Barsagade[1,2] and Devendra Sharma[1,2]
[1]*Institute for Plasma Research, Bhat Village, Gandhinagar -382428, Gujarat, India*
[2]*Homi Bhabha National Institute, Anushaktinagar, Mumbai-400094, Maharashtra, India*

E-mail:gayatri.barsagade@ipr.res.in

Abstract
In our numerical simulations, we analyze propagation of electrostatic and electromagnetic Magneto Hydrodynamic (MHD) waves in a plasma in 2-dimensional plasma set up. The simulations are also attempted with oblique propagation of electrostatic waves, with respect to the dimensions of the double periodic rectangular simulation zone, using a recently implemented flux corrected numerical algorithm. The technique is further applied to low frequency single fluid, incompressible MHD waves, including shear Alfven waves. The characterization of the technique is done in both electrostatic and electromagnetic cases by validating the simulation results against the analytic results and recovering dispersion relations of the corresponding modes for various plasma parameters.

References:

[1] Oblique nonlinear whistler wave,J.Geophys. Res.Space Physics, 119, 1851–1862,doi:10.1002/2013JA018993.

[2] LCPFCT-Fluid Corrected Transport Algorithm for solving Generalized Continuity Equations by Jay P.Boris, Alendra M.Landsberg Elaine.Oran and John H.Gardner.

Computations of field spectra and Poynting flux in magnetized plasma for fusion application

Akshaya Kumar Shaw and Devendra Sharma
Institute for Plasma Research, Bhat, Gandhinagar-382428, India

Abstract
Computations have been carried out of optimal coupling RF power by magneto-sonic waves excited using external antenna in a magnetized tokamak plasma. The transverse propagation of electromagnetic waves in the plasma is considered to numerically calculate the field spectra and poynting flux generated by a 2D ICRH antenna. The electric (E) and magnetic (B) field components associated with waves have been calculated for a range of wave vectors and. Which are determined based on the plasma parameters, corresponding plasma profiles and the antenna dimensions. The single pass absorption scenario is implemented involving a point of resonance, determined by magnetosonic dispersion, where maximum power is dumped assuming its location within the radial extension of the plasma profile. The implemented scheme uses poynting theorem and the WKB approximation for computing the power delivered localized a short range about the resonant location, thereby integrating the poynting flux conservation theorem from to. The numerical scheme provided by the BRussels Antenna Coupling (BRAC) code is used with some important modifications in the integration technique of the magnetosonic wave model, mainly in order to archive a standalone execution of the scheme without dependencies on external solution procedures. The applied scheme is therefore results into a computational tool which is much more simplified than the original numerical scheme.

Development of a geometrical model and anti-spectral algorithm to understand diamagnetic cavity in laser-produced plasma

Narayan Behera* and R. K. Singh
Institute for Plasma Research, Gandhinagar - 382428, India
*E-mail: nbehera@ipr.res.in

Abstract

A geometrical model is developed to explain the origin of the elliptical cylinder-like diamagnetic cavity over the theoretically predicted spherical shape in laser-produced plasma plume. The proposed model is compared with experimentally observed diamagnetism of expanding aluminium plasma across the transverse magnetic field. The magnetic field is produced by special designed Helmholtz coils and three-dimensional images of expanding plasma plume are captured by two-directional fast imaging technique. An Nd:YAG laser (λ =1064 nm, 8 ns pulse width) having power density ~ 10^9 W/cm^2 is used to generate aluminum plasma plume. Moreover, a new algorithm known as anti-spectral algorithm is also developed to understand flow of diamagnetic current on surface of expanding plasma plume. Details of developed models and associated physics will be discussed.

References

1. N. Behera, R. K. Singh, V. Chaudhari and A. Kumar, *Phys. Plasmas* 24, 033511 (2017).
2. D. Winske, *Phys. Fluids B* 1, 1900 (1989).

Collisionless absorption of laser pulses in deuterium cluster: redshift of resonance absorption peak with laser intensity and pulse duration for linear and circular polarization

Sagar Sekhar Mahalik* and Mrityunjay Kundu
Institute for Plasma Research, HBNI, Gandhinagar, Gujarat, India - 382428

*E-mail :sagar.sekhar@ipr.res.in

Abstract
Energy absorption for a laser-irradiated cluster is expected to be maximum at linear resonance absorption (LR) when laser frequency matches Mie-resonance frequency i.e., $\omega=\omega_M$ [1, 2]. However, previous simulation work [3] and in subsequent studies [4] of laser heated clusters, argued that there is no role of LR due to the absence of any absorption maximum while passing through the LR [3, 4]. To resolve the controversy, we study the interaction of laser pulses of various intensity, polarization and pulse duration with a deuterium cluster using molecular dynamics (MD) simulation [5]. For given laser energy and pulse duration, it is found that maximum laser absorption does not happen at the expected $\lambda_M \approx 263$ nm irrespective of linear polarization (LP) and circular polarization (CP) state of the laser. With increasing intensity, the absorption peak is gradually red-shifted in the band of $\lambda \approx (1-1.5)\lambda_M$ from the λ_M owing to gradual outer ionization and cluster expansion; and above an intensity, the absorption peak disappears (sometimes followed by even a growth of absorption) when outer ionization saturates at 100% for both LP and CP. A similar conclusion can be drawn for fixed pulse energy and increasing pulse duration for both LP and CP.

References:

[1] T. Ditmire et al., Phys. Rev. A 53, 3379 (1996)

[2] T. Döppner et al., Phys. Rev. A 73, 031202(R) (2006)

[3] G. M. Petrov et al., Phys. Rev. E 71, 036411 (2005)

[4] G. M. Petrov and J. Davis, Phys. Plasmas 13, 033106 (2006)

[5] S. S. Mahalik and M. Kundu, Phys. Rev. A, 97, 063406 (2018).

Properties Of Plasmoid Instability In Double Tearing Mode: A Reduced Mhd Approach

Jagannath Mahapatra [1,2], R Ganesh[1,2]
[1]*Institute for Plasma research, HBNI, Bhat, Gadhinagar, Gujarat, India 382428*
[2]*Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai - 400 094, India*

E-mail: jaga.physics94@gmail.com/jagannath.mahapatra@ipr.res.in

Abstract
MagnetoHydrodynamics model can be used to study low frequency and long wavelength phenomena in magnetized plasma. For high beta value plasmas for which sonic Mach number is very small, one can apply incompressible approximation to regular MHD equations. Using this incompressible model, resistive MHD instabilities like single tearing mode (STM)[1], double tearing mode (DTM)[2] have been reported in past. With this idea, a 2D incompressible MHD solver is developed which solves Reduced MHD (RMHD) equations[3]. The code was tested with results of current island coalescence problem[4]. However, contribution of numerical viscosity for more fine grid size is to be investigated properly. Using a recently introduced technique of energy calculation[5], a numerical dissipation model is implemented in an in-house developed 2D, semi-bounded domain reduced MHD code called RMHD_2DSolver. Detail of this work will be presented.

References:

[1] E. Tolman et. al., J. Plasma Phys. 84, (2018).

[2] M. Janvier, Phys. Res. Lett.107, 195001 (2011).

[3] H. R. Strauss, Phys. Fluids 19, 134(1976).

[4] P. L. Pritchett et. al., Phys. Fluids 22, 2140 (1979).

[5] S. Kumar et. al., Phys. Plasmas 21, 052904 (2014).

Development of OpenACC version of Multi Potential Molecular Dynamics Code

Soumen De Karmakar[1] , Rajaraman Ganesh[2]
[1, 2]Institute for Plasma Research, HBNI, Bhat, Gandhinagar, Gujarat – 382428, India

E.mail : soumendekarmakar@gmail.com , soumen.dekarmakar@ipr.res.in

Abstract:
One of the effective way of understanding macroscopic physical system, including plasma, is to understand it form the smallest possible length scales, i.e., at the length scale associated with the constituent particles of the system. For system like atmospheric plasma or dusty plasma, where quantum effects are negligible, we can safely consider the constituent particles as classical particles and solve the N-body equations numerically to get detail insight of the behavior of such system. Fundamentally, there is no problem at all, only constraint is the present day computational power, which restrict us to only few hundreds of particles and for very short time period. Fortunately, due to the availability of new computing resources like multi node clusters with integrated powerful GPU computing nodes, we can push beyond our limits and increase the particle number to few millions for sufficiently large time periods. In this view, we have upgraded our in-house code, Multi Potential Molecular Dynamics[1, 2], to run on modern GPUs (similar to the GPUs in ANTYA cluster at IPR) nodes. We have achieved a very good speedup in comparison to OpenMP and MPI versions of the same code. We will demonstrate our results in this conference and will search for any potential collaboration for further development of our code.

References:

[1] A. J. and R. Ganesh, Phys. Rev. Lett. 104, 215003 (2010)

[2] H. Charan, HBNI, PhD Thesis, Institute for Plasma Research (2017)

Development and Applications of an OpenMp Vlasov-Poisson suite for collision-less plasmas

Sanjeev Kr. Pandey[1], Pallavi Trivedi[2], R. Ganesh[1]
[1]*Institute for Plasma Research, HBNI, Bhat, Gandhinagar 382428, India*
[2] *Princeton plasma physics laboratory (PPPL), Princeton 08540, New Jersey, USA*
E-mail: sanjeev.pandey@ipr.res.in

Abstract
Gridded Vlasov methods which solve directly the coupled Vlasov-Poisson equation on a grid of phase space has proven to be an efficient method to study non-linear wave-particle interaction phenomenon associated with several laboratory and astrophysical plasmas [1,2,3]. For example energetic particles produced in fusion experiments, solar wind and magneto spheric plasmas etc. Already, the formation and dynamics of 1D electrostatic phase space vortices has been studied, at electron as well as ion scale and in collision-less plasmas as well as in the collisional environment, using in-house developed 1D-1V Vlasov - Poisson solver (VPPM 2.0)[4]. VPPM 2.0 is a Eulerian solver based on Piecewise Parabolic Method (PPM) [5] and Cheng - Knorr[6] time spilling scheme with periodic boundary conditions. Now in order to address more realistic problems related to laboratory and space plasmas, VPPM 2.0 demands an upgrade to higher dimension i.e 1D-2V / 2D-2V.

In the following we will address benchmarking and speedup performance of OpenMp (1D-2V / 2D-2V) VPPM 2.0 and the problem of kinetic linear and non-linear electrostatic wave particle interaction phenomenon using (1D-2V / 2D-2V) VPPM 2.0 with various perturbative methods. The details of the work will be presented.

References:
[1] F. Filbet a, E. Sonnendrücker, Computer Phy Communications 150 (2003) 247–266

[2] V. Saini, S. K. Pandey, P. Trivedi, and R. Ganesh, Phys. Plasmas 25, 092107 (2018).

[3] M. M. Shoucri and R. R. J. Gagne, J. Comput. Phys. 23,242-262, (1977).

[4] P. Trivedi, PhD Thesis, HBNI, Institute for Plasma Research (2019).

[5] P. Colella and P. R. Woodward, J. Comput. Phys. 54, 174 (1984).

[6] C. Z. Cheng and G. Knorr, J. Comput. Phys. 22, 330 (1976).

Study of plane parallel shear flows in a strongly correlated 2D Yukawa fluid using molecular dynamics

Suruj Jyoti Kalita, R Ganesh
Institute for Plamsa Research ,HBNI, Bhat, Gandhinagar-382428
E-mail: suruj.kalita@ipr.res.in

Abstract
In regular 2D incompressible Hydrodynamics, a plane shear flow between two plane parallel walls with flow profile varying as a linear function of the perpendicular distance between the walls is known to be stable [1].

Using Molecular Dynamics Simulation code MPMD-2D [2], a large no of particles interacting via Yukawa interaction potential is simulated. Such an interaction is found in Complex plasmas and is often called as a Yukawa fluid.In a strongly correlated limit when the potential energy per particle is greater than the kinetic energy per particle, using MPMD-2D [2], a variety of shear flows in a planar geometry are investigated, the details of which will be presented.

References:
[1]K M Case, Phys. Fluids 3, 143(1960).

[2] Harish Charan PhD Thesis (2017), HBNI, IPR

OpenACC Parallelization of PEC2PIC Particle-in-Cell Code to Investigate Low Temperature Plasma Devices

Swapnali Khamaru[1], Meghraj Sengupta[2], R. Ganesh[1]
[1]Institute for Plasma Research, HBNI, Bhat, Gandhinagar 382428, India
[2] Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Canada
E-mail: swapnali.khamaru@ipr.res.in

Abstract

Pure electron plasma confined in cylindrical Penning Malmberg trap[1] with an axial external magnetic field, is an excellent example of a magnetised low-temperature device. This non-neutral plasma species is studied theoretically/computationally and experimentally, to explore the fundamental ideas (as for example: isomorphism between 2D inviscid Euler fluids[2], ion resonance instability[3]).

With the help of PEC2PIC suite of codes, Particle-in-Cell (PIC) simulation study of the collisionless, cold, pure electron plasma, has been performed in cylindrical[5] and toroidal[6] experimental devices supporting the theoretical predictions[4] as well as several new findings[7]. In order to investigate realistic, large degrees of freedom low temperature plasma devices, it is imperative that a form of parallelization is necessary. The existing OpenMP PEC2PIC code is upgraded to OpenACC GPU version. In this work, the details of the conversion and the corresponding to physics benchmark will be presented.

References:

[1] J. H. Malmberg and J. S. deGrassie, Phys. Rev. Lett. 35, 577–580 (1975)

[2] K. S. Fine et al. Phys. Rev. Lett. 75, 3277–3280 (1995)

[3] P. Zaveri et al, Phys. Rev. Lett. 68, 3295–3298 (1992)

[4] R. C. Davidson, An Introduction to the Physics of Nonneutral Plasmas (IEEE, 1990)

[5] M. Sengupta and R. Ganesh, Phys. Plasmas 22, 072112 (2015)

[6] S. Khamaru, M. Sengupta and R. Ganesh, Phys. of Plasmas, 26, 112106 (2019)

[7] M. Sengupta and R. Ganesh, Phys. Plasmas 24, 032105 (2017)

Effect of multiple mass species on the formation of Rayleigh-Benard Convection Cells in Yukawa Liquid

Pawandeep Kaur[1,2,] and R.Ganesh[1,2]

[1] *Institute for Plasma Research, Bhat, Gandhinagar, India, 382428*

[2]*HBNI, Training School Complex, Anushakti Nagar, Mumbai, India, 400085*

pawandeep.kaur@ipr.res.in

Abstract:

It has been shown, using two-dimensional Molecular Dynamics simulations, that when a system is subjected to external gravity, g and external temperature difference, ΔT/T between the top and bottom plates, it leads to the formation of Rayleigh-Benard convection cells beyond some critical value of external temperature difference, (ΔT/T)c[1]. Further recently, it has also been reported that such a far-from-equilibrium system satisfies ECM fluctuation theorem[2]. The above described work has been performed in a single charge and single mass Yukawa system. In this work, using 2D Molecular Dynamics simulation, we study the effect of multiple mass species on the formation of RBCC in Yukawa liquid, in particular its effect on the onset of Rayleigh Benard convection. Details of this work will be presented.

References:

[1] Harish Charan, PhD Thesis(March 2017)- Yukawa liquids under external forcing: A molecular dynamics study.

[2] Pawandeep Kaur, Rajaraman Ganesh, Phys. Rev. E. 100, 053201 (2019)

Laser Excited EMHD Dipoles In Overdense plasma

Devshree Mandal[1], Ayushi Vashistha[1] and Amita Das[2]
[1]Institute For Plasma Research, Bhat,HBNI, Gandhinagar, 382428, India
[2]Indian Institute of Technology, Delhi, 110 016, India

E-mail : devshreemandal@gmail.com

Abstract

We demonstrate the excitation of EMHD dipoles in overdense plasma by laser pulse using PIC simulation in OSIRIS4.0 framework. In this study, laser beam of finite transverse focal spot is incident on an overdense plasma target where the finite extent of laser pulse has been found to be important. The spatial and temporal profile of the REB(Relativistic Electron Beam) that gets generated at the critical surface has been characterized in detail. Furthermore, the spatio-temporal behavior of the forward and return current is also monitored[1,2]. Detail study of EMHD dipole and their propagation in overdense plasma will be presented.

References :

[1] A. Das, Plasma Phys Controlled Fusion 41, A531 (1999)

[2] Anomalous Resistivity Resulting from MeV-Electron Transport in Overdense Plasma, Y Sentoku et. al. Phys. Rev. Lett. 90, 155001, (2003)

Excitation of lower hybrid mode in laser plasma interaction

Ayushi Vashistha[1,2], Devshree Mandal[1,2] , Amita Das[3]

[1]*Institute For Plasma Research, Bhat, Gandhinagar, 382428*

[2]*Homi Bhabha National Institute, Mumbai, 400094,*

[3]*Indian Institute OF Technology, Delhi, 110016.*

E-mail: ayushivashistha@gmail.com

Abstract

The interaction of laser with plasma is known to be highly nonlinear and give rise to several drifts and instabilities. In our 2-D Particle - In - Cell (PIC) simulation study using OSIRIS4.0, we have mainly concentrated on role of EXB drift in coupling laser energy into plasma and into ion species in particular. We show that non-relativistic pulsed CO2 laser (λ = 10μm) in the presence of ambient magnetic field have been able to couple its energy into over-dense plasma which is otherwise not possible according to the presently known absorption mechanisms. EXB drift creates a charge separation in the system which leads to coupling of laser energy into plasma via generation of some modes in the system. We show through several arguments that the mode generated is electrostatic in nature and show signatures of lower hybrid oscillations.

References:

[1] Kruer et.al, Phys. Fluids 28:430(1985).

[2] Atul Kumar et.al, Plasma Phys. Control. Fusion, vol. 61, 2019

[3] Ayushi Vashistha et.al, arXiv:1907.02105v2 [physics.plasmph]

Numerical Modeling for the Estimation of Low Pressure Mixed Plasma Reactor Species and Temperature

H. L. Swami*, and R. Srinivasan
Institute for Plasma Research, Gandhinagar, Gujarat, India
**Email: hswami@ipr.res.in*

Abstract
Low pressure plasma etching process plays a very important role in the processing of integrated circuits to remove specific entity from surfaces of the materials. This process performance depends on various plasma parameters like deposited power, gas flow rate, pressure, etc. The numerical modeling of the plasma etching process can provide the support to better optimization of the etching reactors. A numerical model has been developed to simulate the low pressure plasma etching process. The model is based on the homogenized plasma reactor. The mechanism of chemistry includes positive and negative ions, electron and neutral species. The plasma species reactions such as electron-impact ionization, dissociative attachment, dissociations, and excitation are included in the model. The surface reactions of the plasma particularly adsorption and abstraction of atoms are also incorporated. The estimation of gas temperature and the electron temperature has been done using energy conservation laws. All losses and sources of energy during the plasma process are accounted for the modeling. The model has been presently applied for low pressure Cl_2 plasma. The Cl_2 plasma species have estimated along with the gas temperature and electron temperature. A glimpse of the model will be presented in the paper along with the performance study of plasma reactor using Cl_2 gas.

Effect of weak transverse magnetic field on electric field transients in very high frequency capacitive discharges

Sanket Patil [1] , Omstavan Samant[1] , Sarveshwar Sharma[1] , Sudip Sengupta[1]
[1]*Institute for Plasma Research, Gandhinagar*

Abstract:
The formation of electric field transients in capacitively coupled plasmas (CCP) at high frequencies is reported in literature [1, 2]. In a recent publication, it has been observed that the transients split and form filament-like structures in the spatiotemporal profile when applied voltage is varied from 10V to 150V[3] .

In the present work, the effects of a transverse magnetic field on the electric field transients has been investigated using the EDIPIC code in symmetric and collisionless capacitively coupled plasmas (CCP). At a driving frequency of 60 MHz, discharge voltage of 10 V and argon gas pressure of 5 mTorr, the external magnetic field is varied from 0 G to 100 G. We observe that the electric field transients which are present in unmagnetized cases split and form filament-like structures in the spatiotemporal profile. The presence of higher harmonics of the applied RF frequency in the electric field, and higher plasma densities are observed with increasing magnetic field. The magnetization of charged species results in the formation of higher harmonics which causes the penetration of transients inside bulk, leading to deposition of higher power in the discharge via electron heating.

References:

[1] Sharma, S., et al. "Effect of driving frequency on the electron energy distribution function and electron-sheath interaction in a low pressure capacitively coupled plasma." Physics of Plasmas 23.11 (2016): 110701.

[2] Sharma, Sarveshwar, et al. "Plasma density and ion energy control via driving frequency and applied voltage in a collisionless capacitively coupled plasma discharge." Physics of Plasmas 25.8 (2018): 080705.

[3] Sharma, Sarveshwar, et al. "Electric field filamentation and higher harmonic generation in very high frequency capacitive discharges." Journal of Physics D: Applied Physics (2019).

Particle based computational study of micro instability and associated transport in Hall Thruster

Debraj Mandal and Devendra Sharma
Institute for Plasma Research Gandhinagar India

Abstract

One fundamental plasma physics subject of special interest for the Hall thrusters industrial development is the study of microturbulence, that is likely to result into the electron anomalous transport observed after the channel exit. In that domain, the neutral atom density is so low that the electron collisions cannot explain the high electron flux along the axial direction, observed experimentally. Indeed, the electron transport coefficients are two orders of magnitude higher than those given by the collision transport model. We intend to explore theoretically and numerically the possibility for microturbulence to explain this discrepancy. Microturbulence has been observed by collective scattering experiments. This micro instability was found to follow a simple dispersion relation, close to that of ion-acoustic waves. Multiple approaches are possible for studying the micro instability and the associated particle transport. A recently applied approach is to consider the dispersion relation and study the transport mechanism by the electrostatic modes which follow the dispersion relation and then calculate the diffusion coefficient using the test particle model. We solve the equation of motion numerically in the presence of electrostatic waves and constant magnetic field using the Bori's integration scheme. Then to analyse the transport property we consider a large number of electrons and apply statistic on their dynamics and a close agreement with experimental diffusive current density was recovered. These results are also compared with the neoclassical transport theory.

CFD Modelling of Plasma Pyrolysis Reactor

Hardik Mistry*, A.N. Mistry, Deepak Sharma, P.V. Murugan, A. Sanghariyat, V. Jain, C. Patil, B.K. Patel, S. Patnaik, P. Chaudhuri, S. K. Nema & Shashank Chaturvedi

Institute for Plasma Research, Bhat, Gandhinagar - 382428, India

**Corresponding author: hardik.mistry@ipr.res.in*

Abstarct:
Plasma pyrolysis is a promising non-burn technology for safe disposal of hazardous waste. The very high temperature ($>5000^{0}C$ in plasma plume) generated by plasma torches and oxygen starved environment helps in destroying pathogens and simultaneously prevents the formation of toxic compounds such as dioxins, furans, Poly Aromatic Hydrocarbons etc. Uniform temperature distribution inside the primary chamber and heat losses through the chamber walls are critical parameters in designing the primary chamber. CFD simulation can be helpful in optimizing the design of the primary chamber. CFD simulations were benchmarked with the current 50 kg/hour pyrolysis system working at FCIPT. Temperatures inside and outside the chamber were also measured with the help of thermocouples. The simulation results are in good agreement with the experimental data. The similar simulations were done for optimizing the design of 200 kg/hour pyrolysis system which is currently under development. Positions of plasma arcs in the chamber and material selection for primary chamber were optimized using simulation results. The present paper describes the simulation procedure and comparison of the simulation results with the experimental data.

Computer Simulations of Interaction of α-Particles and Neutrons with Tungsten First-Wall in Spherical Tokamak based Component Test Facilities

P. N. Maya and S. P. Deshpande

Institute for Plasma Research, Bhat, Gandhinagar-382428

Abstract:
Spherical Tokamaks (ST) have been proposed as Component Test Facilities (CTF) where, the plasma-facing components of the machine will be exposed to high heat loads, plasma as well as neutron flux [1,2]. In an ST-CTF, it is possible that the poloidal banana width of the alpha-particles are comparable to that of the machine minor radius, which can lead to a large fraction of unconfined alpha particles of 3.5 MeV energy. This, along with the 14.1 MeV neutrons and the heat interact with the first wall and divertor of the device makes it possible to simulate high wall loads which makes it suitable for CTF.

In this work, we present the radiation damage of tungsten first wall due to 3.5 MeV alpha particles and 14 MeV neutrons. The primary energy transfer between the incident particles and tungsten is simulated using binary collision Monte Carlo methods. The primary-knock-on atom (PKA) spectra generated by neutrons and alpha are in the similar range in tungsten, that is less than 300 keV. This is a fast time scale process which takes place within a few 10s of femto-seconds. The attenuation of the PKA in the lattice is simulated using molecular dynamics simulations. The PKA continue to dissipate its energy in the lattice what is called a collision cascade which results in the formation of defect structures such as vacancy clusters, dislocation loops etc. At low PKA energies, the cascade volume increases linearly with the energy and consequently the defect structures. At PKA energies above 160 keV, the cascade tends to fragment into smaller ones limiting the size of the individual defects. The details of collision cascade, defect structure formation and its consequences in the plasma and material will be discussed.

References:

[1] Gi et al., Nucl. Fusion 55 063036 (2015)

[2] A. Sykes et al., Nucl. Fusion 58 016039 (2018) and references therein

See you soon in

CPS 2022…