Abstract Book

Bringing Space Down to Earth:

Exploring the Physics of Space Plasmas in the Laboratory

Basic Plasma Science Facility
UCLA
10-12 April 2017

Monday, April 10, 2017

8:00	8:30	Breakfast: Bagels and Coffee	BAPSF
8:30	8:45	Welcome: Aims of this Workshop	Howes
8:45	9:00	Welcome to the Basic Plasma Science Facility (BAPSF)	Carter
9:00	9:30	*What's on the Horizon for Space Physics in the Laboratory?*	Howes
9:30	10:00	*Particle Heating in Space and Laboratory Plasmas*	Scime
10:00	10:20	*Generating dynamic magnetic turbulence in a laboratory device using plasma guns and evolving spheromaks*	Schaffner
10:20	10:40	Discussion	
10:40	11:00	Coffee Break and Informal Discussions	
11:00	11:30	*Alfven wave interactions and temperature-anisotropy-driven instabilities: review of LAPD experiments and future prospects*	Carter
11:30	11:50	*Exploring waves through their effects on particle velocity distributions for electrons and ions*	Skiff
11:50	12:00	Discussion	
12:00	1:20	Lunch Break	Westwood
1:20	1:50	*Understanding Space Plasmas Through Laboratory Experiments*	Ganguli
1:50	2:10	*Plasma, Planetary Surfaces, and Cosmic Dust Experiments at the University of Colorado*	Munsat
2:10	2:30	*Magnetized collisionless shocks in the LAPD*	Niemann
2:30	2:50	Discussion	
2:50	3:10	Coffee Break and Informal Discussions	
3:10	3:30	*New Capabilities in Space and Laboratory Measurements*	Keesee
3:30	3:50	*Nonlinear MHD waves in weakly collisional high-beta plasmas*	Squire
3:50	4:10	*The Solar Probe Plus Mission and our Understanding of the Solar Wind and Heliosphere*	Velli
4:10	4:30	Discussion	
4:30	4:50	Daily Wrap Up	
6:00		No Host Group Dinner	Rocco's, Westwood

What's on the Horizon for Space Physics in the Laboratory?

Gregory G. Howes, University of Iowa

Laboratory experiments can be a valuable avenue to explore the fundamental physics at play in space plasmas without the restrictions inherent to spacecraft measurements. I will first briefly review some recent successful experimental campaigns to explore the fundamentals of plasma turbulence and auroral electron acceleration performed on the Large Plasma Device (LAPD) at UCLA. Although the need to confine the plasma in an experiment often limits investigations to systems with low plasma beta (ratio of thermal to magnetic pressure), new experimental capabilities are opening the door to explore space physics in other regimes, such as unity or higher plasma beta. Beyond new experimental facilities, advancements in both diagnostic instrumentation and innovative analysis methods are enabling a wide range of potential new investigations. In particular, the recently developed field-particle correlation technique enables measurements of the velocity distribution functions along with electromagnetic field measurements to probe directly the transfer of energy between fields and particles, a fundamental process underlying many compelling problems at the frontier of space physics. Improved diagnostic capabilities to measure both ion and electron velocity distributions coupled with this new analysis technique has the potential to open up velocity space as an important new frontier for discovery science in space physics. Lastly, cutting-edge kinetic numerical simulations provide an important bridge to connect idealized theoretical concepts to the often messy reality of laboratory experiments and spacecraft observations.

Particle Heating in Space and Laboratory Plasmas

Earl Scime, West Virginia University

I will review recent laboratory and space measurements of particle velocity and energy distribution functions and the implications of these measurements for the definition of the temperature of a plasma.

Generating dynamic magnetic turbulence in a laboratory device using plasma guns and evolving spheromaks

David Schaffner, Bryn Mawr College

Most plasma turbulence currently studied in the laboratory consists of fluctuating flows and densities within a strong background magnetic field, as is found on the edges of tokamaks or the LAPD. That is, the magnetic field is not a significant dynamic element of these systems. In space plasmas, such as the solar wind, magnetic fields are evolving as dynamically and turbulently as the flows given the essentially unbound nature of these plasma. Given the need for confinement in terrestrial plasmas, it can be difficult to simulate this type of magnetic turbulence in the laboratory. One approach is to utilize self-consistent magnetic structures such as the spheromak as an environment for studying this type of turbulence. A spheromak can be generated inside a flux conserving chamber without a background magnetic field; though the spheromak is itself confined within the chamber, the magnetic fields of the structure are free to fluctuate within the structure. Experiments in the Swarthmore Spheromak Experiment (SSX) launch spheromaks into long narrow flux conserving tubes, forcing the structures to reconfigure their fields in order to minimize energy while conserving helicity. Initial results demonstrate that this transformation process is likely a turbulent one as broadband magnetic spectra have been observed. A new experimental device at Bryn Mawr College is in development to build upon this technique and is designed to produce longer plasma discharges with much higher spatial density diagnostic access. Some approaches for comparing this laboratory plasma to space plasma include using similar analysis techniques, such as spectra, correlation, and PDF of increments. New experimental approaches planned with the Bryn Mawr experiment include comparison of spatial versus temporal spectra for evaluation of the Taylor Hypothesis as well as tetrahedral arrangement of probes for comparison to similar setups in multi-satellite missions such as Cluster or MMS.

Alfven wave interactions and temperature-anisotropy-driven instabilities: review of LAPD experiments and future prospects

Troy Carter, UCLA

I will review work using LAPD to study nonlinear interactions between Alfven waves, motivated by MHD turbulence. New capabilities associated with the BaPSF, in particular LaB6 plasma sources, enable exploration of the physics of Alfven waves and other processes in higher beta plasmas. I will discuss prospects for these potential future studies, including a discussion of the possibility of observing mirror and firehose instabilities in a laboratory plasma.

Exploring waves through their effects on particle velocity distributions for electrons and ions

Fred Skiff, University of Iowa

Recent progress in determining collective-mode power spectra in plasmas through cross-correlated fluctuations of particle distributions will be presented. Ion distributions fluctuations using laser-induced fluorescence and supra-thermal electron distributions using whistler mode wave absorption will be considered.

Understanding Space Plasmas Through Laboratory Experiments*

Guru Ganguli, Plasma Physics Division, Naval Research Laboratory

In the space plasma environment it is hard to pinpoint the causality of events and isolate a specific phenomenon for precise and repeated measurements necessary for definitive conclusion. Complementary laboratory experiments scaled to the appropriate space conditions can help in understanding the physics. Coordinated analyses using both laboratory and space data have been shown to clarify subtleties of space plasma processes. Specific examples will be discussed to highlight the synergy derived from laboratory experiments in understanding natural plasma phenomena. These include cause and effect of turbulence in space, coherent and incoherent processes associated with triggered/chorus emissions frequently observed in the radiation belts, and structure and dynamics of boundary layers such as dipolarization fronts, etc.

* Work supported by NRL Base Funds

Plasma, Planetary Surfaces, and Cosmic Dust Experiments at the University of Colorado

Tobin Munsat, University of Colorado

We present an overview of three experiments related to space plasma and cosmic dust at the Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT) at the University of Colorado (impact.colorado.edu). The first is the Colorado Solar Wind Experiment (CSWE), a large ion source for studies of the interaction of solar wind plasma with planetary surfaces and cosmic dust, and for the investigation of plasma wake physics. With a plasma beam diameter of 12 cm at the source, ion energies of up to 1 keV, and ion flows of up to 1 mA/cm2, a large cross-section Kaufman Ion Source is used to create steady state plasma flow to model the solar wind in an experimental vacuum chamber. The second experiment addresses dust charging and transport on the surface of airless bodies, based on UV and plasma exposure. Recent experimental observations show that the emission and re-absorption of photoelectrons and/or secondary electrons at the walls of microcavities formed between neighboring dust particles below the surface are responsible for generating unexpectedly large negative charges and intense particle-particle repulsive forces to mobilize and lift off dust particles. Finally, we describe the Colorado Dust Accelerator, a 3 MV linear electrostatic accelerator used to launch micron-sized dust particles to speeds exceeding 100 km/s, for studies of cosmic dust impacts and surface weathering, as well as for the development of satellite-borne dust instruments.

Magnetized collisionless shocks in the LAPD

Christoph Niemann, UCLA

We will discuss the potential of scaled laboratory experiments for the exploration of both perpendicular and quasi-parallel magnetized collisionless shocks of cosmic relevance. Our particular focus will be on experiments based on laser-driven pistons, such as the ones performed on the LAPD. In these experiments a rapidly exploding, and super-Alfvenic (M_A>2) plasma plume is created by irradiating a solid target within the LAPD plasma with an energetic laser pulse (200 J in 20 ns). The dynamics of the laser-plasma piston and response of the ambient plasma is measured with probes over large spatial scales. We will show measurements and numerical simulations of collisionless coupling and magnetosonic shock formation in experiments with quasi-perpendicular geometry, as well as the first data on electromagnetic ion-ion instabilities relevant to Alfvenic shock formation from experiments in quasi-parallel geometry. We will discuss how this particular experiment can benefit from scaled experiments elsewhere.

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New Capabilities in Space and Laboratory Measurements

Amy Keesee, West Virginia University

Our research team is developing a new instrument for satellite-based measurements and a new laboratory experiment. The ultra-compact plasma spectrometer (UCPS) is designed to measure ions and electrons in the ~5-20 keV energy range, be manufactured like a computer chip, and be the size of a sugar cube. In addition, the instrument has no high or sweeping voltage, and the geometric factor scales linearly rather than as a function of volume. This instrument will enable cubesat and constellation missions, including the Geospace Dynamics Constellation and Magnetospheric Constellation mission described in the Heliophysics Roadmap. The Diagnosis of Acceleration, Reconnection, Turbulence, and Heating (DARTH) laboratory experiment is being constructed from the Reconnection Scaling Experiment (RSX) obtained from Los Alamos National Laboratory. The new design will include a diagnostics chamber for unprecedented access to obtaining detailed measurements of the 3D reconnection volume. Details of the UCPS and DARTH will be presented, along with science questions that we plan to address with these new capabilities. We are interested in soliciting ideas from workshop participants for additional ways to utilize the UCPS and DARTH.

Nonlinear MHD waves in weakly collisional high-beta plasmas

Jonathan Squire, California Institute of Technology

Microinstabilities, in particular the firehose and mirror instabilities, are expected to be fundamental to the dynamics of weakly collisional space and astrophysical plasmas at high beta. They occur because changes in the magnetic field in high-beta plasmas readily create pressure anisotropies that exceed the magnetic pressure. Moreover, by limiting further growth of anisotropy and scattering particles, the nonlinear saturation of microinstabilities has a strong influence on large-scale plasma dynamics. I will explore some of the unexpected physics that occurs when microinstabilities are excited by large-amplitude MHD waves. Shear-Alfvén waves present a particularly interesting case: because the wave's restoring force arises due to magnetic tension, if a wave's amplitude is large enough to excite firehose fluctuations, it will be "interrupted" and unable to oscillate. I will discuss measurements of wave interruption in the solar wind and the possibility of probing such effects (or perhaps using them as a tool for more general study of microinstabilities) in the lab.

The Solar Probe Plus Mission and our Understanding of the Solar Wind and Heliosphere

Marco Velli, UCLA

Solar Probe Plus (SPP), one of the most challenging missions to understand the origins of the Heliosphere, will carry a payload consisting of plasma and energetic particle detectors, electromagnetic field antennas and magnetometers, and a white light imager, to the unexplored regions extending from 70 to less than 9 solar radii (0.3 to 0.05 AU) from the photosphere of the Sun. Solar Probe Plus's goals are to understand the extended heating of the solar corona and acceleration of the solar wind,the origins of solar wind structures including high and low speed streams, and the origins of energetic particle acceleration in Coronal Mass Ejections and CMEs. This presentation will provide a broad context for the mission objectives and measurements and illustrate the likely progress SPP will bring to the understanding of the Heliosphere, stellar winds, and the fundamental physics of particle acceleration, reconnection, and turbulence in space and astrophysical plasmas.

Coauthor: A. Tenerani, UCLA

Tuesday, April 11, 2017

8:30	9:00	Breakfast: Bagels and Coffee	BAPSF
9:00	9:30	*Potential new opportunities utilizing laboratory facilities for elucidating the fundamental plasma physics mechanisms at play in space plasma*	Koepke
9:30	9:50	*Radiation Belt Wave Observations on the Van Allen Probes and Opportunities for Lab Experiments*	Kletzing
9:50	10:10	*Bayesian Techniques For Plasma Theory To Bridge the Gap Between Space and Lab Plasmas*	Crabtree
10:10	10:30	Discussion	
10:30	10:50	Coffee Break and Informal Discussions	
10:50	11:20	*Particle Energization and the Tearing-Driven Turbulent Cascade*	Sarff
11:20	11:40	*Validation in Modeling Laboratory Plasma Phenomena of Relevance to Astrophysics*	Terry
11:40	12:00	Discussion	
12:00	1:20	Lunch Break	Westwood
1:20	1:50	*To Be Determined*	Kasper
1:50	2:10	*Application of Field-Particle Correlations to Space and Laboratory Plasmas*	Klein
2:10	2:30	*Disks, winds, atmospheres, and dynamos: An astro-plasma theorist's laboratory wish list*	Kunz
2:30	2:50	Discussion	
2:50	3:10	Coffee Break and Informal Discussions	
3:10	3:30	*Laboratory plasma experiments using merging supersonic plasma jets*	Hsu
3:30	4:00	Discussion and Daily Wrap Up	
4:00	6:00	Wine and Cheese in the STRB	STRB

Potential new opportunities utilizing laboratory facilities for elucidating the fundamental plasma physics mechanisms at play in space plasma

Mark Koepke, West Virginia University

Suggestions for space plasma physics campaigns to be carried out on current and forthcoming experimental facilities were solicited from space scientists passionate about the interrelationship between plasma experiments in the laboratory and in space. The submitted ideas will be outlined in terms of realizable configurations: A systematic study of the transition from weak to strong turbulence of low frequency fluctuations in magnetized plasmas [H. Pecseli]; an investigation of the localized electrostatic turbulence inside several neighboring striations and or the electromagnetic coupling between these different striations and the turbulence inside them [T. Leyser]; and re-creating the conditions of a electrostatic, i.e., inverted V, aurora to verify the theory for auroral acceleration [H. Gunell].

Radiation Belt Wave Observations on the Van Allen Probes and Opportunities for Lab Experiments

Craig A. Kletzing, University of Iowa

The physics of the creation, loss, and transport of radiation belt particles is intimately connected to the electric and magnetic fields which mediate these processes. A large range of field and particle interactions are involved in this physics from large-scale ring current ion and magnetic field dynamics to microscopic kinetic interactions of whistler-mode chorus waves with energetic electrons. To measure these kinds of radiation belt interactions, NASA implemented the two-satellite Van Allen Probes mission. As part of the mission, the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation is an integrated set of instruments consisting of a tri-axial fluxgate magnetometer (MAG) and a Waves instrument which includes a tri-axial search coil magnetometer (MSC). These wave measurements include AC electric and magnetic fields from 10Hz to 400 kHz. We show a variety of waves thought to be important for wave particle interactions in the radiation belts: low frequency ULF pulsations, EMIC waves, and whistler mode waves including upper and lower band chorus. Several of these wave modes could benefit from laboratory studies to further refine our understanding of the detailed physics of the wave-particle interactions which lead to energization, pitch angle scattering, and cross-field transport. We illustrate some of the processes and compare the wave data with particle measurements to show relationships between wave activity and particle process observed in the inner magnetosphere.

Bayesian Techniques For Plasma Theory To Bridge the Gap Between Space and Lab Plasmas

Chris Crabtree, Plasma Physics Division, Naval Research Laboratory

In this talk, we will show how Bayesian techniques provide a general data analysis methodology that is better suited to investigating nonlinear theories than traditional tools. We will provide short examples of how Bayesian techniques have been successfully used in the radiation belts and the laboratory and how these techniques can be applied to future physical problems in space and laboratory plasmas. We will demonstrate how Bayesian techniques allow for the direct competition of different physical theories with data acting as the necessary arbitrator. We will also discuss why Bayesian techniques are appropriate for a theorist to use, and how these techniques can be used to overcome some of the limitations of traditional analytical theoretical methods.

Particle Energization and the Tearing-Driven Turbulent Cascade

John Sarff, University of Wisconsin, Madison

Understanding particle energization associated with magnetic reconnection and turbulence is a grand challenge. The processes involved span global to kinetic scales, which increases demands on both modeling and measurements. Two aspects of the challenge provide opportunity for near-term investigation. First, measurement capabilities must be developed that isolate and distinguish energization mechanisms. Second, multi-scale modeling can begin to bridge the gap of large-scale dynamics that govern stability and small-scale dynamics where heating mechanisms are anticipated to thrive. Self organizing feedback can influence both the large scale structure and the detailed turbulence dynamics, which emphasizes the importance of multi-scale modeling capability. The tearing-driven cascade in reversed field pinch plasmas produces one of the most powerful examples of particle energization (both heating and acceleration) in the laboratory. The instantaneous ion heating rate can reach 100 MW, and energetic tail formation occurs for both ions and electrons. Self-organization is mediated by nonlinear interactions operating primarily on the large scale, and this launches the turbulent cascade. These dynamics will be used to exemplify the breadth of processes and importance of multi-scale interactions.

Validation in Modeling Laboratory Plasma Phenomena of Relevance to Astrophysics

Paul W. Terry, University of Wisconsin, Madison

A vexing problem in understanding dynamical processes of astrophysical plasmas through measurements made in a terrestrial laboratory arises from disparities in astrophysical and laboratory plasmas for one or a number of critical parameters. The statement that computer simulations can bridge the gap sounds promising but ultimately is glib unless it addresses how such an exercise can be made convincing, including even to the one performing it. This talk considers the methodology of model validation as a way of addressing this issue. Several practices and approaches in validation will be examined in light of the present-day status of laboratory experiments and modeling efforts for astrophysical phenomena, indicating adaptations that may be required. Three examples of modeling efforts will be given, illustrating challenges, adaptations, and ultimately, given the ideals of validation, the large gap that remains in convincingly validating numerical models.

Title: To Be Determined

Justin Kasper, University of Michigan

Abstract: To Be Determined

Application of Field-Particle Correlations to Space and Laboratory Plasmas

Kristopher G. Klein, University of Michigan

Identifying the mechanisms through which energy is transferred between electromagnetic fields and charged particles in a turbulent, magnetized plasma system is an enduring question in the study of plasma and space physics. A number of classes of mechanisms have been proposed that mediate the field-particle energy transfer, including resonant (e.g. Landau and cyclotron damping), stochastic, and spatially intermittent (e.g. energization associated with current sheets and reconnection sites) mechanisms. Characterizing this damping, and the associated dissipation, will help to complete our description of the energy transport in a multitude of complex environments including solar winds, magnetospheres, accretion disks, as well as terrestrial laboratory plasmas. The field-particle energy transfer fundamentally depends on the nonlinear field-particle interaction term in the Vlasov equation, and the structure of this interaction as a function of coordinate and velocity phase space can be used to characterize the mechanism responsible for the transfer. We provide a brief overview of a metric designed to capture the structure of this energy transfer, a field-particle correlation based upon the Lorentz acceleration term. A derivation of the form of the correlation is outlined, followed by discussion of its application to numerical simulations and spacecraft observations, focusing on how velocity-space structure can be used to identify the underlying energy transfer mechanism. We then review the application of field-particle correlations to laboratory measurements of plasma distributions, with the aim of determining potential overlap in the application of this analysis technique to both space and laboratory plasmas.

Disks, winds, atmospheres, and dynamos: An astro-plasma theorist's laboratory wish list

Matthew Kunz, Princeton University

In this talk, I'll present recent efforts by our group to understand turbulence, transport, instability, and magnetic-field amplification and self-organization in astrophysical accretion disks, thermally stratified atmospheres, fluctuation dynamos, and the solar wind. The focus will be on dilute, magnetized plasmas, which exhibit a large scale separation between the kinetic microscales, the turbulent mesoscales, and the global macroscales. Wild dreams and implausible desires will be chased in the pursuit of laboratory support for a theorist's whimsies.

Laboratory plasma experiments using merging supersonic plasma jets

Scott Hsu, P-24 Plasma Physics Group, Los Alamos National Laboratory

Since 2012, we have used merging supersonic plasma jets as a means to study the physics of plasma shocks from collisional toward collisionless regimes. The plasma jets are formed and launched by pulsed-power-driven plasma guns, developed and fabricated by collaborator HyperV Technologies Corp., with an unprecedented combination of mass, density, and velocity using any species or mixture available from a compressed-gas bottle. Our latest plasma guns, developed under ARPA-E support for as a novel magneto-inertial-fusion driver, have several improvements over our prior railguns such that we expect to reach fully collisionless shock regimes with respect to the counter-streaming ion-ion mean free path between merging jets. Furthermore, we are proposing to add to our facility a free-boundary mirror-plasma "target," in which impinging plasma jets and/or beams could drive flow-dominated processes involving, e.g., dynamo, reconnection, shock particle acceleration, and/or turbulence. This short talk will describe our existing and proposed experimental platform, achievable plasma parameters, and a few examples of our recent research results.

Wednesday, April 12, 2017

8:30	9:00	Breakfast: Bagels and Coffee	BAPSF
9:00	9:30	*The Laboratory Magnetosphere: Studying space physics in plasmas confined by a levitated dipole magnet*	Garnier
9:30	9:50	*Solving the Coronal Heating Problem*	Hahn
9:50	10:10	*Scaled Experiments in NRL SPSC for Satellite Observations*	Tejero
10:10	10:30	Discussion	
10:30	10:50	Coffee Break and Informal Discussions	
10:50	11:10	*The Importance of Being Opportunistic*	Bellan
11:10	12:00	Identify Specific Viable Projects on Horizon	
12:00	1:20	Lunch Break	Westwood
1:20	1:50	Wrap-Up: The Future of Space Physics in the Laboratory	
1:50	3:30	Follow-up Splinter Groups for new Projects/Collaborations	
3:30		Workshop Adjourn	

The Laboratory Magnetosphere: Studying space physics in plasmas confined by a levitated dipole magnet

Darren Garner, Columbia University

Investigations of space plasma physics in the laboratory go back to the first experiments by Birkeland and his magnetic "terrella", a plasma confined by a supported dipole coil. During the past decade, two experiments built with levitated superconducting dipole magnets demonstrated a new and reliable method to create and study high-temperature plasma in the magnetospheric configuration. The LDX device, previously located at MIT, and the RT-1 at the University of Tokyo both sustained a magnetized plasma torus in near steady-state conditions, with high plasma temperature and high local plasma beta, $\beta \sim 1$, using only low-power heating. These experiments, inspired by observations of space plasma, demonstrated turbulent drift-like entropy modes and an inverse cascade to larger scale causing self-organization through the turbulent pinch.

A new laboratory magnetospheric device, the Magnetospheric Plasma Turbulence Facility (MPTF) will be discussed. The MPTF will explore a larger range of plasma parameters than prior devices, having input higher power and utilizing next generation superconducting technology. A full range of magnetized plasma turbulence, including both drift-like entropy mode at low beta and electromagnetic turbulence at high beta, can be studied in a single, steady-state plasma torus simply by applying significantly higher power heating of various types. Because charged particles have classical orbits within the axisymmetric magnetospheric configuration, both thermal and energetic particles may be present. By controlling the fraction of energetic particles, turbulence can be excited by faster energetic particle modes (that can couple to Alfvén waves and damp by ion cyclotron resonance.)

The proposed Magnetospheric Plasma Turbulence Facility is intended as a national user facility. The basic parameter ranges for the device, and examples of possible user experiments will be discussed.

Solving the Coronal Heating Problem

Michael Hahn, Columbia University

The coronal heating problem is to explain the sharp jump in temperature from the photosphere to the corona of the Sun. Most research focuses on two possible coronal heating mechanisms, either magnetic reconnection in the form of numerous unresolved events known as nanoflares or the dissipation of plasma waves. Within each category there are numerous questions about the details. Focusing on the wave perspective, one would like to know the important wave modes in the corona, where and how they are generated, how they propagate through the transition region, and how they are dissipated. Laboratory experiments can help to address these challenges by providing a detailed understanding of basic physical processes under conditions that are as similar as practically possible to those of the Sun. Understanding the influence of these processes on coronal heating is complicated by the ambiguity inherent in spectroscopic and imaging observations and by the need for models to span a large range of length and time scales.

Laboratory experiments also permit the testing of detailed simulations on a well-diagnosed system, so that those simulations can be reliably compared to solar observations.

Scaled Experiments in NRL SPSC for Satellite Observations

Erik Tejero, Naval Research Laboratory

An overview of the Space Physics Simulation Chamber (SPSC) facility at the Naval Research Laboratory will be presented. We will discuss recent results in the context of the benefits that laboratory experiments can bring to bear on the underlying physics important to space phenomena, such as the effect of plasma compression in depolarization fronts and nonlinear effects associated with plasma turbulence. We will present our new effort of investigating the generation mechanism of waves near depolarization fronts as a case study for developing these collaborations between laboratory, space observations, theory, and simulation to spur discussion on how to make this process more efficient.

The Importance of Being Opportunistic

Paul Bellan, Caltech

Experience has revealed that there are several types of experiments. I list these below with some well-known examples from astronomy:

1. Experiments designed to validate, observe, or verify a theoretical postulate (gravity wave observation).
2. Experiments designed to exploit some new observational capability (new telescopes, adaptive optics).
3. Experiments that scan parameter space and look for something interesting (sky surveys).

My personal experience is that outsiders and funding agencies when discussing lab plasmas always think of the first type of experiment, stating "Why don't you look for such and such a phenomenon that so and so predicted?" but are rarely supportive of the second two types. While I feel the first type is important, it often leads to excessive investment of time and resources when the same time and resources would have provided more interesting results from the second, more unpredictable and more risky types.

I believe that one should start with a goal but be prepared to change paths when something interesting shows up and then one should follow one's nose to find out what is really happening rather than stick to some rigid plan. I also feel that because so many different regimes and phenomena exist in space plasmas, it is often counter-productive to try to make a lab plasma mimic some specific space plasma situation because this can be very difficult, expensive, and maybe impossible. Instead, it is often best to take the lab experiment as it is, try to understand what is going in as much detail as possible, and then search for a space plasma situation where similar phenomena are occurring. In other words, find a good answer and then look for the question. I do not claim that this approach should always be used, but rather state that it can be extremely profitable and that it has not been used enough. Once one is on the trail of something interesting, one can develop new diagnostics as required.

The history of the Caltech jet experiment provides an example. This experiment was originally intended to explore how Taylor relaxation works with no ideas about jets. First jets were discovered, then the kinking of the jets became evident, then it was determined that the effective gravity of the jets caused a Rayleigh-Taylor instability, then that the RT instability instigated a localized magnetic reconnection, then that whistler waves were excited by this reconnection, then that localized heating was occurring, and most recently that a very brief burst of hard X-rays was generated. The important lessons were (i) paying attention to this sequence of phenomena rather than sticking to the Taylor relaxation hypothesis and (ii) developing new diagnostics on the fly to pursue the succession of opportunities that were presented. Another example is the ice dusty plasma experiment at Caltech for which there were no theoretical predictions and possible relevance to Saturn's rings, comet ice, and accretion disk. The idea was to make an interesting experiment and see what happens. I think that it is important to have contingency funds that allow following opportunities that appear. As for new hardware and diagnostics, I think that we are now in an age where time-dependent imaging of many parameters is an achievable goal. I also think that using pulsed power technology opens up new regimes at low expense. I feel lab experiments should identify new mechanisms and show the microscopic details of what is happening and should not attempt to be exact replicas of space. Lab experiments should not necessarily be considered failures if they do not reproduce a theoretical prediction because the theory could be wrong. Finally, the lab experiments should be clean and reproducible so that the results are clear and straightforward to analyze.

There is always new technology being developed outside of plasma physics and the lab experiments should always be trying to exploit whatever new technology is becoming available. This requires an awareness of what is going on outside of plasma physics.