2005–2006 APS/DPP Distinguished Lecturers Program

The Division of Plasma Physics of the American Physical Society is pleased to announce the Distinguished Lecturers in Plasma Physics for 2005–2006. This Program is intended to share with the larger scientific community exciting recent advances in plasma physics.

Under the Plasma Physics Travel Grant Program funded by the U.S. Department of Energy, the Lecturers are available for talks at U.S. colleges and universities for the academic year 2005–2006. Their travel expenses will be supported by the grant.

The Lecturers may be invited by contacting them directly.

Additional information about the Plasma Travel Grant Program can be obtained from the Chair of the DPP Education and Outreach Committee:

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The following Distinguished Lecturers have been chosen by the DPP:

Michael Brown
Lecturer's Title: Self-Organization in Magnetized Plasmas
Dept. of Physics and Astronomy
Swarthmore College
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Gail Glendinning
Lecturer's Title: Experiments on the National Ignition Facility
Lawrence Livermore National Laboratory
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Chuck Greenfield
Lecturer's Title: Advances and New Developments in Fusion Energy Research Using the Tokamak
General Atomics
email: Chuck.Greenfield@gat.com

David Newman
Lecturer's Title: Plasmas as a Prototypical Complex System: Self-Organized Criticality as a Paradigm for Plasma Transport
Univ. of Alaska – Fairbanks
email: ffden@uaf.edu

Edmund Synakowski
Lecturer's Title: Fusion energy, plasma turbulence, and a shifting scientific landscape
Princeton Plasma Physics Laboratory
Princeton, New Jersey
email: synakowski@pppl.gov

Christopher Watts
Lecturer's Title: Heating the Solar Corona: A hot topic in plasma astrophysics
University of New Mexico
email: cwatts@ece.unm.edu

Lecture Descriptions are on the back...

Self-Organization in Magnetized Plasmas

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It is a common process in the universe for plasma and magnetic fields to evolve together in a turbulent way but then rapidly relax to simple, self-organized structures. Solar flares erupt from the photosphere tangled and chaotic, but via a process called magnetic reconnection, they relax and straighten. This process releases energy in the form of superheated plasma and rapidly flowing jets. On a much larger scale (millions of light years), galactic disks collapse, rapidly shedding angular momentum and in the process generate extended, magnetized jets along their axes. On human scales, laboratory experiments are underway seeking self-organized magnetic structures that would be suitable "bottles" for a fusion reactor. We present recent experimental results from the merger of two rings of hot, magnetized plasma in the Swarthmore Spheromak Experiment (SSX). During the merging process, the plasma self-organizes to generate a single, large scale (ρ = 0.2 m, L = 0.6 m), three-dimensional magnetic structure called a field-reversed configuration (FRC). The rate at which the merging proceeds is governed locally by magnetic reconnection in which magnetic fields associated with each ring become shared. The magnetic reconnection rate is fast and fully three-dimensional. Magnetic reconnection converts magnetic energy to heat (up to Te $\approx 10^6$ K), energetic particles (Ei > 100 eV), and flow (up to 100 km/s). See http://plasma.physics.swarthmore .edu/selforg/index.html for more information.

Experiments at Extreme States - X-Games Physics on the National Ignition Facility

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The National Ignition Facility (NIF) is a 1.8 Megajoule laser currently under construction at the Lawrence Livermore National Laboratory. When complete, it will be used to research fundamental questions about matter in extreme states. In 2003, the National Research Council of the National Academy of Sciences (NAS) published a report titled "Frontiers in High Energy Density Physics: The X-Games of Contemporary Science". Their conclusion was that experimental facilities such as the NIF, Sandia National Laboratory's Z machine, and the Stanford Linear Accelerator Center (SLAC) (among others) are now capable of reaching regimes of high energy density allowing unprecedented insight into the behavior of matter under extreme conditions. We describe in this presentation experiments planned for the NIF addressing some of the questions posed in this report:

- How does matter behave under conditions of extreme temperature, pressure, density and electromagnetic fields?
- Can the transition to turbulence, and the turbulent state, in high energy density systems be understood experimentally and theoretically?
- Will measurements of the equation of state and opacity of materials at high temperatures and pressures change models of stellar and planetary structure? Experiments are beginning on the NIF, using the first four of its eventual 192 beams. We will describe results from an experiment beginning to address the question understanding the transition to turbulence in a high energy density system.

Advances and New Developments in Fusion Energy Research Using the Tokamak

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Fusion energy science promises a virtually limitless supply of clean energy for mankind's growing needs. To reach fusion conditions, the gaseous fuel needs to be heated to temperatures of hundreds of millions of degrees and this mixture needs to be confined for a long enough time for fusion reactions to occur. One approach is to develop a magnetic "bottle," in which the ionized gaseous fuel (called a plasma) is held in place by magnetic fields. The tokamak is the most successful such device thus far, with its doughnut shaped toroidal chamber. In this device, the plasma is confined by magnetic fields produced both by external axisymmetric coils and by current flowing in the plasma itself. The plasma current is usually driven by a transformer, necessitating the periodic shutdown and restart of the device. Current research is underway to develop techniques allowing continuous operation of the tokamak at high plasma pressure and improved efficiency. Progress in tokamak research is reviewed, including a discussion of the most recent advances in understanding the physical processes governing the plasma's behavior. Large and small scale instabilities can affect plasma performance in many ways. Much of the research on tokamaks has focused on the prediction, measurement and control of these instabilities. Sophisticated numerical models have advanced rapidly in recent years and are now capable of reproducing, and even predicting, much of the behavior of the tokamak plasma. This progress has brought us to the point where we are preparing for the construction of the International Thermonuclear Experimental Reactor (ITER), which is expected to produce hundreds of megawatts of fusion power using the deuterium-tritium fusion reaction.

Plasmas as a Prototypical Complex System: Self-Organized Criticality as a Paradigm for Plasma Transport

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In nature there are many systems which exhibit some form of self-organization. Among these are forest fires, earthquakes, sandpiles, maybe sunspots and even life itself. Investigations into the similarity of the dynamics of such systems have been undertaken by using simple cellular automata models. These models have produced some important insight into the dynamics of such systems. Recently a Self-Organized Criticality (SOC) model for turbulent transport in magnetically confined plasmas has been proposed in order to explain some of the observed features of the transport dynamics in these plasmas. This model is based on the dynamics of a sandpile and has among others, the remarkable feature that a sheared wind across the sandpile (or a flow across the plasma) can fundamentally change the transport. The dynamics of the model show some remarkably similar characteristics to the observed data and suggest explanations for some puzzling aspects of the observations. Adding new, physically realistic, dynamical transport mechanisms such as classical diffusion to the SOC system have been found to lead to a new set of dynamical regimes with evidence of critical transitions between them. These regimes can then be explored in the plasma experiments. In addition to the intrinsic novelty of the basic physics involved, these observations can have interesting ramifications for the control of many real systems. Some of these features of the SOC systems, from forest fires to earthquakes, and the extension to the sandpile model for turbulent transport will be discussed.

Fusion energy, Plasma Turbulence, and a Shifting Scientific Landscape

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An enormous development and important shift in perspective regarding magnetic fusion and plasma turbulence understanding took place in the 80's and 90's. Indeed, what was thought of as acceptable, necessary, or even possible regarding the understanding of heat and particle transport across a confining magnetic field changed dramatically during this period. This talk travels along a particular slice of the history of plasma turbulence research performed by universities and larger labs alike. Twenty years ago, elements of an important framework regarding turbulence, confinement efficiency, and flows were established. This framework was forged from dedicated measurements, a union with a theory community that was fundamentally motivated by direct coupling with observations, and surprising observations that toroidally confined plasmas could exhibit a remarkable class of dynamics. These dynamics, which we now know to be grounded in the nonlinear physics of turbulence, flows, and flow shear, are compelling from a physics standpoint as well as being of great practical importance to the attractiveness of magnetic fusion. Some success in developing this framework promoted a transformation in how fusion research is approached, and generated important changes in the set of expectations of what can be known of and manipulated within a fusion-grade plasma. At the start, comparisons of predicted fluxes to experiment underscored the daunting nature of the task of understanding and predicting turbulent transport. At some point during the ensuing years, however, a profound shift occurred. It became apparent that transport was knowable, and that theory could guide experiment in key respects, rather than only following it with qualitative descriptions. The talk takes its final turn with two points. First, the shift described above points to strategies for influencing how a magnetic fusion reactor can be optimized through manipulation of plasma turbulence. Finally, the prospects are good for using present experiments as test beds for theory tools that can be applied to certain astrophysical problems pertaining to turbulence.

Heating the Solar Corona: A hot topic in plasma astrophysics

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The surface or photosphere of the sun is a blackbody with a temperature of about 7500 °C, and the basic mechanism that heats the sun, nuclear fusion, is well understood. However, there is a disconcerting paradox: The temperature of the solar atmosphere or corona starts to rise away from the surface to about 1,000,000 °C. It's like walking away from a fire and you suddenly feel hotter. The energy that heats the corona is almost certainly stored in the magnetic field of the sun. There are two main competing models for how this energy is released: 1) Magnetic waves and 2) Tearing and reconnection of the magnetic field. Both models are probably valid in different regimes. In this talk, I will present an overview of the coronal heating paradox and the two heating models. Then I'll talk about current research by plasma physicists, using both remote observations and laboratory simulations, focused on substantiating these models.