Spotlight

On Alumna Christine Chalk

A Road Less Traveled - a Career in Science Policy

I was not a typical Physics Major back in the Fall of 1996. For one thing I already had a degree - in Economics, for another I already had a job and nearly 10 years on most of my fellow students. I was very pleasantly surprised to find several other "adults", also working, also in the UMD Physics program. In fact, I married one of them but that is another story.

This article is about my employer, the U.S. Department of Energy and what I do for a living. I have worked for Energy since 1991 and I have always worked in what is now called the Office of Science in a group called Planning and Analysis. But none of that means anything to anyone outside of my building. With an annual budget of over $3 billion, my organization supports the lion share of U.S. research in High Energy Physics, Nuclear Physics, Magnetic Fusion, Heavy Element Chemistry, Nuclear Medicine and Catalysis. We also make unique contributions to Scientific Computing, Climate Change Research, Nanoscience, Civilian Applied Math, Genomics and Biomedical applications of our research. We provide Fermilab, CEBAF, RHIC, the National Synchrotron Light Source, dozens of other large-scale scientific user facilities and five National Laboratories.

What I do is science policy and program evaluation. Mainly I draft documents, make vugraphs, give speeches and attend meetings. But it really is much more interesting than that sounds. I have the honor of working with brilliant and dedicated scientists, constantly learning about new ideas and new directions in fields as varied as microbial genomics, nanoscience, applied math, and astro-particle physics. I have met more than a dozen Nobel Laureates and chatted with the likes of Millie Dresselhaus, Freeman Dyson, and Craig Venter.

My job connects to another sphere as well. I frequently interact with policy makers in the Administration and on Capital Hill. I have briefed the Secretary of Energy, participated in White House meetings and conferences, contributed to international negotiations for scientific collaborations, written strategic plans, and worked with Congressman on an array of science issues. These are, of course, highlights of nearly 12 years of Government service. Throughout, both the good days and the bad, I have the benefit of believing that what I do helps to advance science.

So what do I do? Two of the biggest challenges to science are communicating with the public and demonstrating results without deterring scientific progress. Most of my time is spent in these two areas. First, communication is important because so much of

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Turbulence in Ionized Matter

By Professor William Dorland

The hydrogen atom is composed of a single proton and a single electron. One must supply about 2 x 10**-18 Joules of energy (13.6 eV) to pull the two apart or "ionize" the hydrogen. Those who have traveled in Europe and were inclined to read a candy bar label know that a typical candy bar provides the hungry snacker about a mega-Joule, or 10**6 Joules. Evidently, one could ionize a lot of hydrogen with a single Kit-Kat! On the other hand, one can see how hard it really is to ionize matter by considering the temperature to which one would have to heat hydrogen to ionize a significant fraction of it. One's first estimate might be that the gas has to be heated until there is approximately 13.6 eV of energy per atom -- that's about 150,000 degrees Kelvin. However, because the atoms in a gas have a distribution of energies (with a few high-energy members that are very effective at ionizing other atoms in collisions), and because the frequency of ionizing collisions depends on the density of the gas, it turns out that nearly complete ionization of a modest density hydrogen gas in thermodynamic equilibrium is obtained when the average energy per atom is only about 1 eV, corresponding to a temperature of about 10,000 K. This is still pretty hot for typical terrestrial conditions, of course.

Matter that has been ionized is called 'plasma'. Because we live on Earth, where matter is rarely heated to the point of ionization, plasma is less familiar to us than everyday condensed matter. It is, however, a very interesting state of matter to study, for fundamental reasons as well as for many applications. Because the constituent elements of a plasma carry net electric charge and can therefore interact over long distances via electromagnetic fields, plasma dynamics is a far richer area of study than ordinary fluid dynamics.
(In a fluid composed of non-ionized atoms, each atom is electrically neutral, so that interactions occur mainly only when atoms collide.) In fact, the complexity of plasma dynamics is so great that progress toward understanding and actually predicting the behavior and properties of flowing, turbulent plasma was limited until recently.

What has changed? Several decades of development of the fundamentals of plasma theory and steady experimental efforts to produce, measure and characterize plasma in the laboratory have recently been augmented by tremendous advances in supercomputer simulations. Algorithmic advances (including the development of simplified but rigorously correct nonlinear equations appropriate for specific situations) and advances in raw computational power have contributed roughly equally to advances in plasma simulation. As noted by a National Academy review in December, 2002, plasma physicists have achieved "notable advances in understanding and predicting plasma performance" in the last decade. The report continues, "Of particular note is the ongoing effort to develop a fundamental understanding of the complex turbulent processes that govern the confinement of hot plasmas in magnetic fields." Scientists at the University of Maryland have been at the forefront of this effort for many years. Recently hired Assistant Professor William Dorland is the leader of an international scientific team that is developing theory and simulations of hot, magnetized plasma turbulence, with a specific focus on collisionless dynamics.

Why might one be specifically interested in collisionless, magnetized plasma dynamics? These apparently exotic conditions arise in diverse situations. Fluctuations in the diffuse interstellar plasma which fills much of the space in our galaxy have been observed and are thought to be associated with collisionless, magnetized plasma turbulence. Dorland's research group has support from NASA and NSF to predict key signatures of these fluctuations, hopefully enabling more detailed characterizations of the interstellar matter and fields.

In a second astrophysical problem, there is a collisionless, magnetized plasma accreting onto a supermassive, compact object near the center of our galaxy (a situation that is likely typical of so-called 'bulge galaxies'). Characteristics of the turbulence in this plasma directly affect the X-ray luminosity of this accretion flow. New X-ray satellite telescopes (the USA's Chandra and its European counterpart) are collecting observational data from this region of space -- making now an excellent time to be in the business of predicting observable features. Key mysteries that are being addressed relate mainly to the dynamical basis of so-called 'two temperature' flows.

Dr. Dorland's group is attacking both astrophysical problems with simulation technology they developed to support the international controlled thermonuclear fusion program. Plasma turbulence is a central scientific problem in the quest for controlled thermonuclear fusion, because it is turbulence that limits the performance of existing experiments. To understand why, it is necessary to review the basics of thermonuclear fusion.

To achieve fusion, one must induce positively charged nuclei of light elements to get close enough together to allow the (attractive) strong force to take over from the (repulsive) electromagnetic force. Under such conditions, the nuclei will spontaneously fuse, releasing usable energy in the process. The fusion of almost any two nuclei that appear before iron in the periodic table will result in the release of energy -- the reaction is exothermic. (Elements beyond iron in the periodic table have exothermic _fission_ reactions.)

The electromagnetic repulsion felt by two nuclei is very strong, and is proportional to the product of the charges of the nuclei. It is easy to see, therefore, that hydrogen nuclei should be the easiest nuclei to fuse in the laboratory. In fact, it turns out that fusing 'heavy hydrogen' (specifically, the isotopes deuterium and tritium) is the easiest reaction to induce of all. In the magnetic confinement fusion program, plasma composed of heavy hydrogen is heated to approximately 250 million degrees, at which point typical collisions result in exothermic fusion reactions. This has been achieved in the laboratory -- but at a greater cost than expected. The problem is that turbulence in the super-heated plasma causes rapid cooling. More precisely, turbulence induces energy diffusion which gets stronger very rapidly as the plasma gets hotter. As a result, one must supply a lot of energy to get the fusion reactions going. The ultimate performance of a given experiment, measured by the ratio of self-heating to applied heating, is limited by and exquisitely sensitive to the details of the underlying turbulence.

Dr. Dorland and his group are working on the development of the theory and of first-principles simulations of this turbulence. Continuing progress requires maintaining the existing capability to perform and understand state-of-the-art simulations on the fastest parallel supercomputers available. Their calculations have profoundly affected the direction of the international magnetic confinement fusion program over the last decade. The present focus of their research is on conclusively identifying theoretically predicted signatures of the turbulence in experiments around the world, and on helping design new experimental configurations which should be much less affected by turbulence.

Dr. Dorland is an assistant professor in the University of Maryland Department of Physics working with plasma physics. If you have any questions for Dr. Dorland, you may contact him at bdorland@physics.umd.edu.

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fundamental science is supported with public funds. Though the public overwhelmingly support investment in science they all too often don't understand the process or the research and miss out on the excitement and the magnitude of scientific achievements. The members of the public elected to Congress are particularly critical to the scientific process in that they allocate funding and legislate limitations and accountability criteria that impact research.

The scientific community may believe that an imbalance has grown between funding for the life sciences and funding for the physical sciences, or a thousand other disparities, but can they effectively communicate the implications of disparities to the public? Can they prove that funding disparities adversely impacts research progress or, perhaps more importantly during a recession and budget deficit, economic growth or domestic security?

"Results" and "Performance" are increasingly linked with communication and increasingly required from Federal research programs. The Government Performance and results Act of 1993 requires all Government agencies to more rigorously and regularly assess performance and demonstrate results. The Bush Administration and the National Academies of Science have embraced Excellence and Relevance. Though we all support those criteria they are not quite enough for agencies that are required to have annual targets and quarterly progress reports. For example, nearly everyone agrees that peer review assures excellence in research projects but no one knows how to turn it into a quantitative or "trendable" measure for a research program or how you demonstrate improved "efficiency" in a system built on volunteers.

Albert Einstein said "Not everything that can be counted counts, and not everything that counts can be counted." Armed with an understanding of Economics and Physics including the ways in which research is conducted (thanks in no small part to my experiences at the University of Maryland), what I really do is to try to lighten the load on researchers by steering the Office of Science programs toward counting what counts and effectively communicating why it counts and to whom. There are days when I feel like a super hero and days when I feel like Sisyphus but I never doubt that the Science is worth the effort or that I am part of that effort.