PPPL U.S. DEPARTMENT OF ENERGY

PRINCETON PLASMA PHYSICS LABORATORY WEEKLY

MONDAY, APRIL 30, 2012

At PPPL THIS WEEK

WEDNESDAY, MAY 2

PPPL Colloquium
4:15 p.m. ◆ M.B. Gottlieb Auditorium

A Slightly Longer History of $E=mc^2$, or How I Came to Hate 4/3

Tony Rothman (Princeton University)

CLICK HERE FOR ABSTRACT

THURSDAY, MAY 3

Physics Colloquium
4:30 p.m. - 6 p.m. ◆ Main Campus Jadwin A10

Whistles and Thumps: Listening to the Transient Gravitational Wave Universe

Bernard Schutz
(Max Planck Institute for Gravitational Physics)

CLICK HERE FOR ABSTRACT

FRIDAY, MAY 4

DIII-D Science Meeting
1 p.m. ◆ B-233

SATURDAY, MAY 5

INCIDENT UPDATE

Safety Comes First at PPPL

By **Stewart Prager** — Director, Princeton Plasma Physics Laboratory

Dear PPPL'ers,

We do amazing, world leading, much needed research at PPPL. It is imperative that this work be performed in a way that keeps all of our staff safe. Indeed, we cannot continue to do that work if we don't do it safely. At PPPL, we follow and fully embrace the Integrated Safety Management concept: We all must recognize the importance of safety and its deep relevance to everything we do here.

Let me be clear and blunt – I do not want any experiment or any supporting activity to be performed unless it can be executed safely. We are a team and we must all ensure that this philosophy is implemented. If anybody sees an activity that is not being conducted safely (or planned correctly), I expect you to stop that work or notify someone who can assure it is not continued until it can be done safely – notifying me if necessary. This is clearly stated in our PPPL policies, in which we note that the "health and safety of the public, PPPL personnel and on-site subcontractors" receive the highest consideration in all our work. More importantly, it follows from a very simple idea: Great science has to be founded on safe science.

Research in fusion energy and plasma physics is challenging, not only scientifically, but because of the inherent hazards and complex facilities involved. And those facilities are supported by a host of other instruments and related infrastructure that are equally complicated and potentially as hazardous. Collectively, we must understand and address the risks inherent in this research and at this Lab every day.

As I wrote to you in the PPPL Weekly last Monday, we are working diligently to understand the cause of an accident that occurred March 8 in which an employee was seriously injured while operating an apparatus, a John Deere "Skid Steer," to dig holes on the PPPL campus. The injured staff member is recovering. We are in the process of determining what happened, why it happened, and what we need to do at the Lab to prevent recurrence. The first step — investigating the accident and documenting the causes in a root cause analysis report — is finished. Other assessments are looking at auxiliary issues, the extent to which the causes of this incident exist elsewhere across the Lab, and what management, safety culture and other "human factors" contributed to this accident or in other ways hinder our ability to conduct safe work at PPPL. I assure you that I want to understand fully how deep problems may go, including management and leadership issues. I'll also note that Princeton University will be organizing and conducting a broad review of our safety culture and program at the Lab in June, so we will benefit from outside eyes looking at our processes.

The first report, titled "Skid Steer Operator Injury Incident," was compiled by an investigative team of mostly PPPL staffers headed by Larry Dudek, the committee chair and Head of the Fabrications & Operations Division. Other members included: Tracy Estes,

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PPPL Scientists Propose Solution to a Critical Barrier to Producing Fusion

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DOE-PSO Safety Engineer; Judy Malsbury, Head, Quality Assurance; Marissa Mills-Clark, Safety Division industrial hygienist; and Mike Viola, Head, Technical Shops. This is an excellent report, the first investigation of what happened. It will be followed by other investigations, including one that assesses the human factors that contributed to the incident. We must and will fix this.

In February, PPPL technicians began digging holes on the site for the installation of concrete light pole footings to provide the foundation for new solar-powered lights. On March 8, two technicians had to redrill one hole to remove mud that had accumulated from weekend rains. They collected the Skid Steer and brought it to a storage trailer. There they planned to attach to it a drilling device known as an auger. During this connection process, the technician who was operating the vehicle was accidentally pinned by the vehicle's hydraulically controlled arm. Severely injured, he was taken to the hospital.

On the same day, Mike Williams, the Associate Laboratory Director for Engineering and Infrastructure, issued a Stop Work order for all mobile hydraulic equipment on site and appointed a team to conduct an investigation per Laboratory procedures. The team began its investigation the following day. The investigation committee found that, in operating this piece, certain unfortunate steps occurred involving actions on the machine while it was still powered up. This led to the severe injury of the technician. The committee also identified several contributing causes, which include concerns about inadequate maintenance, lack of a process to insure that built-in safety devices on a machine are operable, and less than adequate training and oversight by those responsible for insuring the safe operation of equipment.

This accident, like most, was preventable. Recognizing hazards, following our safety procedures, and helping one another to assure compliance will make this a safer Laboratory. I expect each of you to fully implement our safety program. As you can imagine, the breadth of the causes and the issues to address will lead to very comprehensive, significant actions. We are in the process of finishing the initial Corrective Action Plan, and as implied above, the Action Plan will be amended as additional information is learned from the other assessment activities. I will continue to keep you informed via updates in the Weekly and through direct discussions with you.

Please mark all your calendars for Wednesday, May 16. We will be conducting a Laboratory-wide standdown, dedicating our entire Safety Forum to a discussion focused solely on this accident. This will be held at PPPL in the MBG Auditorium. We will discuss the results of the several investigations that have been carried out to learn why the accident happened, what auxiliary issues exist as a result of those conclusions and what human factors played a role. We will communicate lessons learned and how we can learn and how we will do better. I will also be asking you to complete a safety culture survey, which will help us improve our safety lab-wide.

Stet C. Pray

PPPL Scientists Propose Solution to a Critical Barrier to Producing Fusion

By John Greenwald

Physicists from the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) have discovered a possible solution to a mystery that has long baffled researchers working to harness fusion. If confirmed by experiment, the finding could help scientists eliminate a major impediment to the development of fusion as a clean and abundant source of energy for producing electric power.

An in-depth analysis by PPPL scientists zeroed in on tiny, bubble-like islands that appear in the hot, charged gases — or plasmas — during experiments. These minute islands collect impurities that cool the plasma. And these islands, the scientists report in the April 20 issue of the journal Physical Review Letters, are at the root of a longstanding problem known as the "density limit" that can prevent fusion reactors from operating at maximum efficiency.

Fusion occurs when plasmas become hot and dense enough for the atomic nuclei contained within the hot gas to combine and release energy. But when the plasmas in experimental reactors called tokamaks reach the mysterious density limit, they can spiral apart into a flash of light.

"The big mystery is why adding more heating power to the plasma doesn't get you to higher density," said David Gates, a principal research physicist at PPPL and co-author of the proposed solution with Luis Delgado-Aparicio, a postdoctoral

From left: physicists Luis Delgado-Aparicio and David Gates.

fellow at PPPL and a visiting scientist at the Massachusetts Institute of Technology's Plasma Science Fusion Center. "This is critical because density is the key parameter in reaching fusion and people have been puzzling about this for 30 or 40 years."

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Fusion Solution

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The scientists hit upon their theory in what Gates called "a 10-minute 'Aha!' moment." Working out equations on a whiteboard in Gates' office, the physicists focused on the islands and the impurities that drive away energy. The impurities stem from particles that the plasma kicks up from the tokamak wall. "When you hit this magical density limit, the islands grow and coalesce and the plasma ends up in a disruption," said Delgado-Aparicio.

These islands actually inflict double damage, the scientists said. Besides cooling the plasma, the islands act as shields that block out added power. The balance tips when more power escapes from the islands than researchers can pump into the plasma through a process called ohmic heating — the same process that heats a toaster when electricity passes through it. When the islands grow large enough, the electric current that helps to heat and confine the plasma collapses, allowing the plasma to fly apart.

Gates and Delgado-Aparicio now hope to test their theory with experiments on a tokamak called Alcator C-Mod at MIT, and on the DIII-D tokamak at General Atomics in San Diego. Among other things, they intend to see if injecting power directly into the islands will lead to higher density. If so, that could help future tokamaks reach the extreme density and 100-million-degree temperatures that fusion requires.

The scientists' theory represents a fresh approach to the density limit, which also is known as the "Greenwald limit" after MIT physicist Martin Greenwald, who has derived an equation that describes it. Greenwald has another potential explanation for the source of the limit. He thinks it may occur when turbulence creates fluctuations that cool the edge of the plasma and squeeze too much current into too little space in the core of the plasma, causing the current to become unstable and crash. "There is a fair amount of evidence for this," Greenwald said. However, he added, "We don't have a nice story with a beginning and end and we should always be open to new ideas."

Clues

Gates and Delgado-Aparicio pieced together their model from a variety of clues that have developed in recent decades. Gates first heard of the density limit while working as a postdoctoral fellow at the Culham Centre for Fusion Energy in Abingdon, England, in 1993. The limit had previously been named for Culham scientist Jan Hugill, who described it to Gates in detail.

Separately, papers on plasma islands were beginning to surface in scientific circles. French physicist Paul-Henri Rebut described radiation-driven islands in a mid-1980s conference paper, but not in a periodical. German physicist Wolfgang Suttrop speculated a decade later that the islands were associated with the density limit. "The paper he wrote was actually the trigger for our idea, but he didn't relate the islands directly to the Greenwald limit," said Gates, who had worked with Suttrop on a tokamak experiment at the Max Planck Institute for Plasma Physics in Garching, Germany, in 1996 before joining PPPL the following year.

In early 2011, the topic of plasma islands had mostly receded from Gates' mind. But a talk by Delgado-Aparicio about the possibility of such islands erupting in the plasmas contained within the Alcator C-Mod tokamak reignited his interest. Delgado-Aparicio spoke of corkscrew-shaped phenomena called snakes that had first been observed by PPPL scientists in the 1980s and initially reported by German physicist Arthur Weller.

Intrigued by the talk, Gates urged Delgado-Aparicio to read the papers on islands by Rebut and Suttrop. An email from Delgado-Aparicio landed in Gates' inbox some eight months later. In it was a paper that described the behavior of snakes in a way that fit nicely with the C-Mod data. "I said, 'Wow! He's made a lot of progress,'" Gates remembered. "I said, 'You should come down and talk about this.'"

Growth of Islands

What most excited Gates was an equation for the growth of islands that hinted at the density limit by modifying a formula that British physicist Paul Harding Rutherford had derived back in the 1980s. "I thought, 'If Wolfgang (Suttrop) was right about the islands, this equation should be telling us the Greenwald limit," Gates said. "So when Luis arrived I pulled him into my office."

Then a curious thing happened. "It turns out that we didn't even need the entire equation," Gates said. "It was much simpler than that." By focusing solely on the density of the electrons in a plasma and the heat radiating from the islands, the researchers devised a formula for when the heat loss would surpass the electron density. That in turn pinpointed a possible mechanism behind the Greenwald limit.

Delgado-Aparicio became so absorbed in the scientists' new ideas that he missed several turnoffs while driving back to Cambridge, Mass., that night. "It's intriguing to try to explain Mother Nature," he said. "When you understand a theory you can try to find a way to beat it. By that I mean find a way to work at densities higher than the limit."

Conquering the limit could provide essential improvements for future tokamaks that will need to produce self-sustaining fusion reactions, or "burning plasmas," to generate electric power. Such machines include proposed successors to ITER, a $20 billion experimental reactor that is being built in Cadarache, France, by the European Union, the United States and five other countries.

Why hadn't researchers pieced together a similar theory of the density-limit puzzle before? The answer, said Gates, lies in how ideas percolate through the scientific community. "The radiation-driven islands idea never got a lot of press," he said. "People thought of them as curiosities. The way we disseminate information is through publications, and this idea had a weak initial push."

PPPL Celebrates Earth Day

PPPL celebrated Earth Day on April 24, with presentations in the Auditorium, environmental exhibits in the Lobby, and the distribution of Green Machine Awards. In photo below (center) are some of the Green Machine award recipients, who were honored for their efforts to build a greener PPPL.

Photo by Cassandra Pugh

From the PPPL Site Protection Division

PPPL PARKING AND TRAFFIC REGULATIONS

The PPPL Parking and Traffic Regulations have been updated and posted to the Employee Services (internal) Home Page (www-local.pppl.gov/pdf/PARKING_TRAFFIC.pdf). The regulations were strengthened to improve safety for bicyclists. The privilege of operating a motor vehicle or bicycle on the PPPL site and parking privileges are granted by PPPL upon the condition that all staff comply with the PPPL Parking and Traffic Regulations.

ACCESS CONTROL REQUEST FORM

The Access Control Request Form has been updated and posted to the Employee Services (internal) Home Page in the Forms & Manuals Section (www-local.pppl.gov/AccessControlRequestFormPdf.pdf). Complete this form to request unescorted access to specified restricted areas within the Laboratory. These areas are accessible by card reader only. The NBPC 1st Floor Machine Shop was added to the form.

FOREIGN NATIONAL REGISTRATION FORM

The Foreign Visits and Assignments Office (FV&A) has updated the Foreign National Registration Form. Modifications to the form include (1) determinations regarding export controlled subjects and (2) assignment of an Alternate Host for each visitor. In addition, the FV&A Office worked with IT to update the electronic registration form and to create a new web-link to the form provided here: http://fnvisit.pppl.gov/fnregister.aspx. The Foreign National Registration Form is required for visits to PPPL by a Foreign National. This form is posted on the Employee Services Homes Page in the PPPL Forms and Manuals Section.

Questions may be directed to Dolores Stevenson at ext. 3208. Thank you for your cooperation.

COLLOQUIUM

A Slightly Longer History of E=mc², or How I Came to Hate 4/3

TONY ROTHMAN
Princeton University

Wednesday, May 2

4:15 p.m. (Coffee/Tea at 4 p.m.)
M.B.G. Auditorium, Lyman Spitzer Building

University Medical Center of Princeton at Plainsboro
OPEN HOUSE Saturday, May 12 • Noon to 6 p.m.
1 Plainsboro Road, Plainsboro

Brock PPPL Café Menu

BREAKFAST ..... 7 a.m. • 10 a.m.
CONTINENTAL BREAKFAST..... 10 a.m. • 11:30 a.m.
LUNCH ..... 11:30 p.m. • 1:30 p.m.
SNACK SERVICE ..... until 2:30 p.m.

	MONDAY APRIL 30	TUESDAY MAY 1	WEDNESDAY MAY 2	THURSDAY MAY 3	FRIDAY MAY 4
COMMAND PERFORMANCE CHEF'S FEATURE	 PARMESAN CHICKEN BREAST WITH PASTA	 BAKED SALMON WITH CITRUS BUTTER W/RICE	 CREATE YOUR OWN MAC AND CHEESE BAR	 ROASTED VEGETABLE PASTA	 PULLED PORK BBQ WITH COLE SLAW AND FRIES
EARLY RISER	Grilled Cheese with Pork Roll	Steak, Egg and Cheese Quesadilla	The XL Spinach, Tomato, Onion Omelet w/Potatoes	Gina's Breakfast Casserole	Turkey Sausage, Eggwhites, Swiss Cheese Wheat Wrap
COUNTRY KETTLE	Chicken and Rice	Cream of Mushroom	Texas Chili	Hearty Onion	Corn, Jalapeno and Cheese Soup
GRILLE SPECIAL	Double Turkey Burger with Turkey Bacon with Fries	Chicken Finger Parmesan Hoagie with Onion Rings	Fresh Made Nut and Bean Burger with Fries	Black Bean and Corn Veggie Burger	Tex Mex Cheese Steak with Curly Fries
DELI SPECIAL	Classic Ham and Cheese Hoagie	Louisiana Seafood Salad on a Multi Grain Roll	Walnut, Grape and Honey Chicken Salad	Greek Chicken with Spinach	Turkey BLT on a Multi Grain Roll
PANINI	The Seasider	Salami and 3 Cheese	Crispy Buffalo Chicken	Turkey Pastrami, Sauer-kraut, Swiss,Russian Dress.	Ham, Pepper Jack, Bacon, Tomato and Chipotle Mayo

MENU SUBJECT TO CHANGE WITHOUT NOTICE

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WEEKLY

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Send to: pwieser@pppl.gov ◆ Comments: commteam@pppl.gov ◆ **PPPL WEEKLY** is archived on the web at: http://www.pppl.gov/ppplweekly.cfm