FOR IMMEDIATE RELEASE
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Laser experiments mimic cosmic explosions and planetary cores

Scientists bring plasma tsunamis and crushing pressures into the lab.

NEW ORLEANS—Researchers are finding ways to understand some of the mysteries of space without leaving earth. Using high-intensity lasers at the University of Rochester's OMEGA EP Facility focused on targets smaller than a pencil's eraser, they conducted experiments to create colliding jets of plasma knotted by plasma filaments and self-generated magnetic fields, reaching pressures a billion times higher than seen on earth.

In two related experiments, researchers used powerful lasers to recreate a tiny laboratory version of what happens at the beginning of solar flares and stellar explosions, creating something like a gigantic plasma tsunami in space. Much of what happens in those situations is related to magnetic reconnection, which can accelerate particles to high energy and is the force driving solar flares towards earth.

Figure 1: Hubble Telescope photo of an exploding star (NGC 5189), ejecting a large fraction of its mass into space in tangled filaments of dust and plasma. The processes at work in shaping such explosions are gradually coming to light through computer simulations, space telescope data, and laboratory experiments.

In a separate experiment, high-power lasers were focused on a small sphere to create intense shock waves, producing some of the highest pressures ever measured—nearly a billion atmospheres. The results provide information on how matter behaves at very high density, such as in the metallic cores of gas-giant planets and in imploding capsules for inertial fusion energy development.

Laboratory experiment aims to identify how tsunamis of plasma called "shock waves" form in space

William Fox, a researcher at the U.S. Department of Energy's Princeton Plasma Physics Laboratory, and his colleague Gennady Fiksel, of the University of Rochester, got an unexpected result when they used lasers in the Laboratory to recreate a tiny version of a gigantic plasma tsunami in space.

These tsunamis, called "shock waves," are thin areas found at the boundary between a collapsed supernova, a ball of super-hot, electrically charged gas called plasma, and the colder material around it. At that boundary is a steep, tsunami-like wall of plasma that has a turbulent magnetic field that sweeps up plasma to create the tsunami. Cosmic rays, extremely high-energy space particles, play a role in the tsunamis as they interact over and over again with the tsunami's turbulent magnetic field.

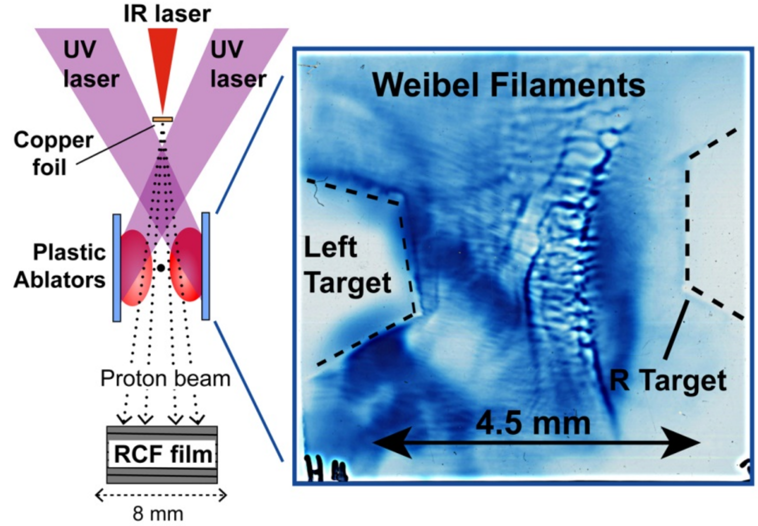

Figure 1: Converging UV laser beams illuminate flat plastic targets to produce expanding plasma shockwaves. The waves interact to produce a new instability, seen for the first time in the laboratory, using a beam of protons at the OMEGA laser facility at the University of Rochester Laboratory for Laser Energetics.

The researchers used two very powerful lasers to zap two pieces of plastic in a vacuum chamber to 10 million degrees and create two colliding plumes of extremely hot plasma.

Researchers were able to analyze what happened when the plasmas collided by using a third laser to send a beam of protons through the colliding plasma. The protons struck layers of film on the other side. The layers of film separated the various energies of protons in the beam.

Fox and Fiksel found that when the two plasmas merged they broke into clumps of long thin filaments called a "Weibel instability." It was the first time this instability was identified in a laboratory and was not predicted by the researchers themselves.

The researchers believe the Weibel instability is what causes the turbulent magnetic fields that form the tsunamis, or shock waves, in space. This magnetic field is also what pushes on and accelerates cosmic rays.

Their research could help answer questions about the origin of primordial magnetic fields that formed when galaxies were created and could help researchers understand how cosmic rays work and how plasmas are produced.

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Abstracts:

BI2.00003	Astrophysical Weibel instability in counter-streaming laser-produced plasmas 10:30 AM–11:00 AM, Monday, October 27, 2014
Session	BI2: Space, Astro, and Lab Astro 9:30 AM–12:30 PM, Monday, October 27, 2014 Room: Bissonet

Magnetic reconnection in the laboratory

The solar corona already contains a strong magnetic field, so colliding plasmas there behave somewhat differently. In their next phase of research, Fiksel and Fox added a magnetic field by pulsing current through very small wires next to the experiment. They then created the two colliding plumes of plasma as they did in the earlier experiment. When the two plasmas collided it compressed and stretched the magnetic field and a tremendous amount of energy accumulated in the field like a stretched rubber band. As the magnetic field lines are pushed close together, the long lines break apart and reform like a single stretched rubber band, forming a slingshot that propels the plasma and releases the energy into the plasma, accelerating the plasma and heating it.

The experiment found that the reconnection process happens faster than theorists had previously predicted. This could help shed light on solar flares and coronal mass ejections, which also happen extremely quickly. Coronal mass ejections can trigger geomagnetic storms that can interfere with satellites and wreak havoc with cellphone service.

The laser technique the scientists are using is new in the area of high energy density plasma and allows scientists to control the magnetic field to manipulate it in various ways.

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Abstracts:

TO7.00002 Strongly Driven Magnetic Reconnection in a Magnetized High-Energy-Density Plasma

9:42 AM–9:54 AM, Thursday, October 30, 2014

Session TO7: Magnetic Reconnection

9:30 AM–12:18 PM, Thursday, October 30, 2014

Room: Galerie 6

A fusion energy laser technique may also be useful for understanding planetary interiors

In another experiment at the OMEGA EP facility, researchers used a new laser technique to study shock ignition, a technique used in inertial confinement fusion research, which aims to create fusion energy by heating and compressing a fuel pellet.

Wolfgang Theobald, of the University of Rochester, and other researchers used lasers to zap a solid spherical target with laser beams. This blows off the outer layer of the target, forcing the inner core to implode. By using a laser beam that creates a powerful spike of energy, researchers created a shockwave that travels quickly to the core of the fuel pellet and creates intense pressures and super-hot temperatures that “ignite” the plasma, potentially creating fusion energy.

When the shock reaches the center of the target, it creates an X-ray flash, which is used to measure the exact time the shock reaches the center.

This technique not only has applications to inertial fusion, but could also lead to new high-energy-density-physics experiments that might shed light on other high-pressure conditions that exist in the universe. For example, researchers could use this experiment to study the extreme heat and high-pressure conditions at the core of planets.

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Abstracts:

CI1.00002 Spherical Strong-Shock Generation for Shock-Ignition Inertial Fusion

2:30 PM–3:00 PM, Monday, October 27, 2014

Session	CI1: Direct Drive, Shock and Fast Ignition, Magneto-inertial Fusion 2:00 PM–5:00 PM, Monday, October 27, 2014 Room: Acadia
GO6.00005	Spherical Strong-Shock Inferences on OMEGA 2:30 PM–3:00 PM, Monday, October 27, 2014
Session	Shock and Fast Ignition 9:30 AM–12:18 PM, Tuesday, October 28, 2014 Room: Galerie 3
PO4.00011	Multibeam Laser--Plasma Interactions Lead to Localized Interaction Regions 2:30 PM–3:00 PM, Monday, October 27, 2014
Session	PO4: Laser Plasma Interactions 2:00 PM–5:00 PM, Wednesday, October 29, 2014 Room: Salon E