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MEDIA CONTACTS
Saralyn Stewart
(512) 694-2320
stewart@physics.utexas.edu

Caught in the Act: Speedy Plasmoids Breaking Their Chains

Speedy plasmoids, caught on camera, help untangle the mysteries of magnetic reconnection.

MILWAUKEE, Wis.—Some of the most extreme events in the universe occur when gases of hot ionized particles, known as "plasma," break free from the magnetic fields which bind them together. This process is known as "magnetic reconnection," and the energy from the magnetic field heats and accelerates plasma particles as they free themselves. Spectacular examples of reconnection are solar flares, huge arcs of plasma on the sun's surface, which explode outwards into the solar system. The storm of high energy particles they produce is responsible for the aurora, the stunning light show over the Earth's poles.

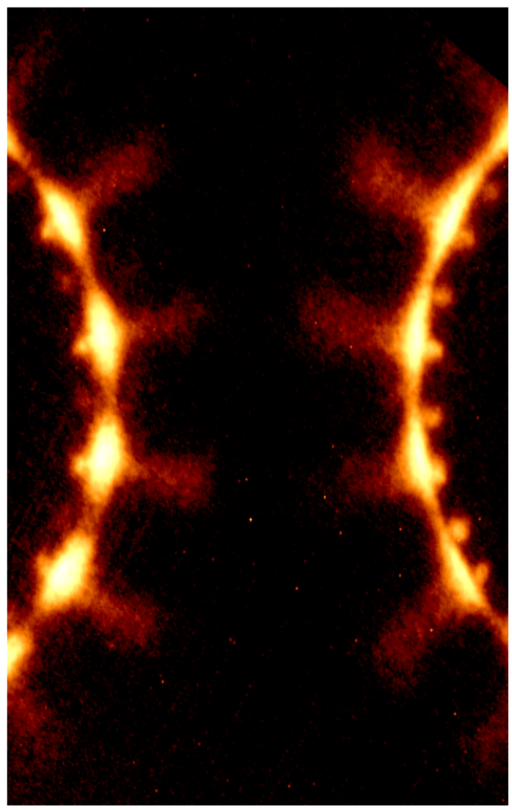

Figure 1: Animation of visible light images from the reconnection experiment at Imperial College London shows plasma-jet collision, followed by plasmoid expulsion.

In the last decade, scientists have realized that magnetic reconnection can be an inherently unstable process, in which blobs of plasma, known as "plasmoids," are ejected in an erratic fashion, accompanied by bursts of high energy electrons. Tantalizing evidence for the presence of plasmoids has been found in space using telescopes and satellites, but to make detailed observations requires producing these plasmoids in the laboratory.

Recently, researchers at Imperial College London have designed a new experiment to recreate the conditions for magnetic reconnection in the laboratory. Their experiment uses a powerful burst of electrical current (over 1 million amperes) delivered in a short space of time (less than 1 millionth of a second) to heat thin metal wires to the point where they become a plasma. The intense electric current creates large magnetic fields which sculpt the plasma into the shape necessary for magnetic reconnection to occur.

In these experiments, plasmoids were imaged using an ultra-high speed camera, capable of taking a picture every 10 billionths of a second. Scientist Jack Hare of Imperial College states, "The plasma is so hot that it glows like a red-hot poker, and that light can be captured by the high speed camera." The resulting movie shows jets of plasma coming in from the left and the right, and the jets collide at the center, forming a layer in which reconnection occurs (Figure 1). Over time, this layer breaks up to form a chain of fast moving plasmoids which exit the image at high speed.

The team also looked for evidence of high-energy particles, accelerated by magnetic reconnection. They surrounded the experiment with metal foils, which emit X-rays when they are struck by ultra-fast electron beams. The energy of these electrons was determined by careful measurements of the X-rays they produced, and these measurements also show that the X-rays were produced in short, intense bursts.

The team found that changing the material of the thin wires made a big impact on the reconnection process. Hare adds, "When the plasma was made using aluminum wires, the burst of electrons was more intense, but plasmoids weren't seen by the camera. When we used carbon wires, the reconnection process became very unstable, with copious plasmoids ejected at high speeds, along with a smaller X-ray burst."

Understanding the conditions in which plasmoids and electron bursts occur is vital for studying magnetic reconnection in space, and an improved understanding will help with forecasting extreme space weather events, which can damage satellites and power lines.

Contacts:
Dr. Jack Hare, Imperial College London, jdhare@imperial.ac.uk
Prof. Sergey Lebedev, Imperial College London, s.lebedev@imperial.ac.uk

Abstracts

NI2:00001	Anomalous heating and plasmoid formation in pulsed power driven magnetic reconnection experiments
Session	NI2: Reconnection: Experiments and Observations 9:30 AM–12:30 PM, Wednesday, October 25, 2017 Room: 102ABC
BO6.00004	Electron acceleration in pulsed-power driven magnetic-reconnection experiments
Session	BO6: Reconnection 9:30 AM–12:18 PM, Monday, October 23, 2017 Room: 202C
YO6.00002	Anomalous heating and plasmoid formation in pulsed power driven magnetic reconnection experiments
Session	YO6: Magnetized HEDP and HED Measurement/Diagnostic Techniques

9:30 AM–11:42 AM, Friday, October 27, 2017
Room: 202C