Plasma experiment shows how astrophysical jets are formed

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Applied physicists at the California Institute of Technology have devised a plasma experiment that shows how huge long, thin jets of material shoot out from exotic astrophysical objects such as young stars, black holes, and galactic nuclei.

Reporting in an upcoming issue of the journal *Physical Review Letters*, applied physics professor Paul Bellan, his graduate student Gunsu Yun, and postdoctoral scholar Setthivoine You describe how they create jets of plasma at will in an experimental device known as a "planar spheromak gun." The researchers form the jets by sending an intense electric current through a gas to form a plasma, after applying a background magnetic field to the whole system. The magnetized plasma then naturally tends to shoot out of the gun in the form of a long collimated filament.

According to Bellan, his research group is the first to achieve an experimental result showing how astrophysical jets are formed. Theorists have done mathematical modeling and computer simulations to show how known magnetohydrodynamic effects could explain the jet phenomenon, but the Bellan experiment actually creates similar jets in a lab device.

"We're not claiming to make scale models, but I think we've captured the essence of astrophysical jets," says Bellan, who has been working on this and related projects at Caltech since the late 1990s.

Although there are differences between astrophysical jets and the ones created in the spheromak gun, Bellan says there are also important similarities that link the 13-inch-long plasma jets created in the lab to the enormous jets in outer space. The similarity is primarily in the way that the magnetic flux tubes are straightened through a sort of squeezing effect that points to a common collimation process.

Astrophysical jets are accelerated by magnetic forces, but also carry along magnetic fields, the researchers explain. These magnetic fields are frozen into the plasma that makes up the jet and wrapped around the jet like rubber bands around a paper tube. The flowing plasma piles up, much like fast traffic coming up on slower traffic on a freeway, and this pile-up increases the plasma density just like the density of cars increases in a traffic jam.

The frozen-in bandlike magnetic field lines also become squeezed together in this "traffic jam," and so, just like rubber bands piling up on a paper tube, pinch down the diameter of the plasma jet, making it thin and even more dense.

Why do the researchers think this is an accurate portrayal of astrophysical jets? Because this is precisely how they make similar but smaller jets in their experiment.

"Very dense, fast, thin plasma jets observed in our laboratory experiments have been shown to be in good agreement with this picture," explains You.

Bellan says that the research stems from work he and his group have done for years in the formidable and longstanding effort to make fusion power an eventual reality. The current results have implications for the goal of containing the extremely hot plasma required for fusion, as well as for explaining certain exotic events in the cosmos.

Source: California Institute of Technology