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Dual-angle proton radiography quantifies magnetic field in shock fronts

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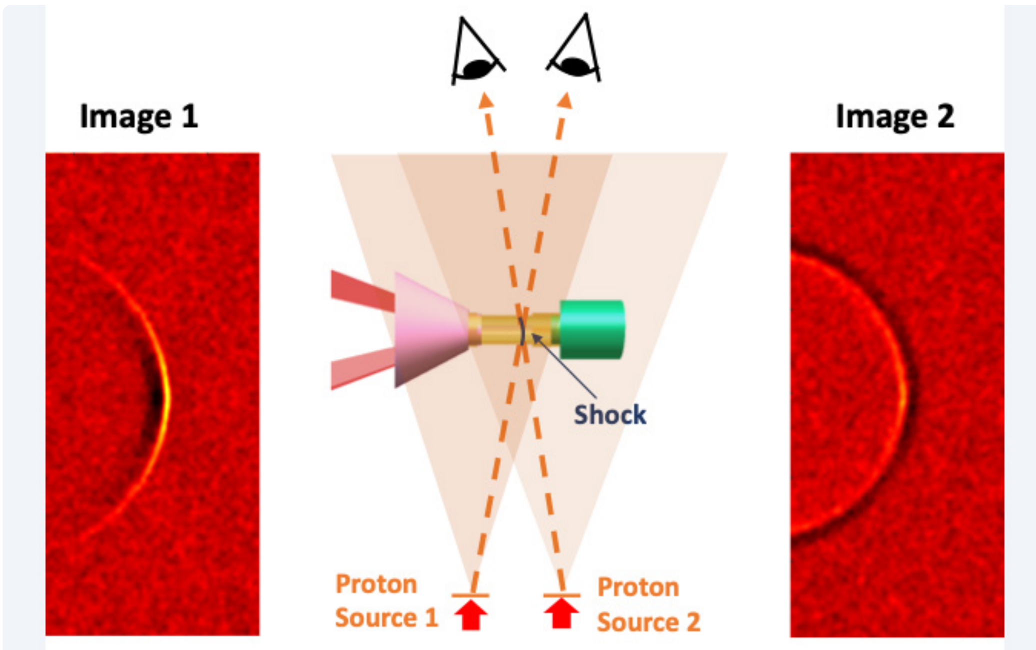

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The experimental setup is illustrated in the center panel, showing the proton sources at two angles. The images at the left and right side are simulated proton radiographs at the two angles: the flipped polarity of the bright and dark regions confirms the magnetic field.

Shocks are abundant both in astrophysics and inertial confinement fusion. While the electric fields generated at shock fronts have recently attracted great attention, the self-generated magnetic field is rarely studied.

It is quite common to measure these fields by proton radiography, a method similar to X-ray radiography but using protons that are positively charged that will change their trajectories in fields. However, in many cases, electric fields and magnetic fields create similar features in radiographs, making the analysis ambiguous.

A Lawrence Livermore National Laboratory team, along with collaborators from the

University of California San Diego and the University of California, Los Angeles, have observed and quantified the magnetic field at shock fronts using proton radiography at two different viewing angles.

"This dual-angle proton radiography breaks down the ambiguity, providing a unique answer in quantifying whether it is electric field or magnetic field." Said Rui Hua, the lead author of a paper appearing in *Physical Review Letters* (https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.123.215001). She carried out the experiments under the supervision of Yuan Ping, a staff scientist at LLNL, and Farhat Beg at UCSD.

The experiments were performed using the OMEGA EP laser facility at the Laboratory for Laser Energetics (LLE) at the University of Rochester. The proton beam with mega-electron-volt energies was generated by metal foils irradiated by short laser pulses at relativistic intensities.

"Our results show that magnetic fields can be self-induced in a non-spherical shock front in low-density gases, which could be one of the mechanisms for the origin of cosmic magnetic field," said Ping.

"The next key question is how the magnetic field generation scales with the size of the system, which could be answered by a similar but larger-scale experiment on NIF," Beg added.

In intertial confinement fusion capsules, if the initial shock in the fuel gas has any non-spherical shape due to instabilities or asymmetries, the magnetic field can be self-generated and consequently affect the evolution of the implosion. This effect has not been taken into account in current simulations, according to Ping.

Other LLNL researchers include Mark Sherlock and Scott Wilks. The work is supported by the DOE Office of Science Early Career program, the Laboratory Directed Research and Development program and the University of California Office of the President Lab Fee Grant.

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