Laboratory investigation of particle energization through magnetized shocks and associated instabilities

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Aims: The origin of the high-energy particles flying through the Universe is still an open question. One identified source is collisionless shock waves. By interacting with the ambient medium, these shocks, with their associated instabilities, can transfer energy to particles.

Methodology: Here we show that super-critical quasi-perpendicular magnetized collisionless shocks [1-3], as well as the magnetic Rayleigh-Taylor instability [4], can be produced and characterized in the laboratory using high-power lasers, coupled with strong magnetic fields.

Results: We observe the energization of protons from the ambient gas. Particle-in-cell simulations identified shock surfing as the acceleration mechanism; the collision between two such shocks can bring additional acceleration; and magneto-hydrodynamic simulations with test-particles pinpoint stochastic Fermi acceleration as the dominated mechanism.

Conclusion: Our measurements provide the first direct evidence of early stage ion energization by collisionless shocks and associated instabilities. The platform opens the door to future laboratory experiments investigating the possible transition to other mechanisms, e.g. shock drift acceleration and diffusive shock acceleration.

REFERENCES

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