Experimental demonstration of proton diffusion in a turbulent magnetised plasma

A. Bott¹, A. Rigby¹, P. Tzeferacos¹,², A. R. Bell¹, R. Bingham³,⁴, E.M. Churazov⁵,⁶, F. Fiuza⁷, C. Forest⁸, J. Foster⁹, J. Katz¹⁰, M. Koenig¹¹, C.-K. Li¹², F. Séguin¹², J. Meinecke¹, H-S. Park¹³, S. Ross¹³, T.G. White¹, B. Reville¹⁴, F. Miniati¹⁵, D.H. Froula¹⁰, A.A. Schekochihin¹, D.Q. Lamb², G. Gregori¹,²

¹ University of Oxford, Oxford, UK
² University of Chicago, Chicago, USA
³ Rutherford Appleton Laboratory, Didcot, UK
⁴ University of Strathclyde, Glasgow, UK
⁵ Max Planck Institute for Astrophysics, Garching, Germany
⁶ Space Research Institute (IKI), Moscow, Russia
⁷ SLAC National Accelerator Laboratory, Menlo Park, USA
⁸ University of Wisconsin-Madison, Madison, USA
⁹ AWE, Aldermaston, UK
¹⁰ University of Rochester, NY, USA
¹¹ Université Paris VI Ecole Polytechnique, Paris, France
¹² Massachusetts Institute of Technology, Cambridge, USA
¹³ Lawrence Livermore National Laboratory, Livermore, USA
¹⁴ Queens University Belfast, Belfast, UK
¹⁵ ETH Zürich, Zürich, Switzerland

The phenomenon of diffusive scattering of a beam of protons by stochastic magnetic fields has been investigated in an experiment carried out on the OMEGA laser facility at the University of Rochester (NY). The proton beams are generated by the laser implosion of a D³He capsule, resulting in the creation of two species of fusion protons whose energy spectrum and source size are well known. The spatial extent of the beam is truncated using a pinhole, and the beam then passed through a previously studied turbulent magnetised plasma produced by the collision of two de-stabilised jets driven by intense laser irradiation. The resulting images of pinhole beams show dispersion when strongest magnetic fields are present, which is supportive of the hypothesis that stochastic magnetic fields can lead to diffusion of charged particle beams, and further allows for the measurement of the beam’s perpendicular momentum diffusion coefficient.

The conclusions presented here are of significance in realising a physical process thought to be crucial for the proper understanding of cosmic ray dynamics in astrophysical environments, and also provide an inferred experimental estimate of the magnitude of second-order Fermi acceleration achievable in similar laboratory set-ups.