Energetic particles in astrophysics and the laboratory

Tony Bell[1,2]

[1] *University of Oxford, UK*

[2] *Rutherford Appleton Laboratory, UK*

Particle acceleration is prevalent on all scales in the Universe, from the solar system to clusters of galaxies. Energetic particles arrive at the Earth as cosmic rays (CR) with energies ranging from GeV to EeV. Observations show that acceleration to 100s of TeV takes place at the outer shocks of supernova remnants (SNR). Diffusive shock acceleration (DSA) robustly produces cosmic rays at the observed energies, with the observed energy spectrum, and with the required high efficiency. Cosmic ray streaming excites plasma instabilities that drive MHD turbulence, scatter the CR, confine the CR near the shock and mediate the acceleration process. The instabilities also amplify the magnetic fields as observed in SNR.

The origin of ultra-high energy cosmic rays (UHECR) at energies up to 100 EeV is much less certain, although DSA on kpc scales in outflows from active galaxies is a likely explanation.

Energetic particles are also a feature of laser-produced plasmas. Although the scales differ by very many orders of magnitude, the underlying concepts are surprisingly similar. Dedicated laboratory experiments have the potential to validate and further clarify the plasma physics of astrophysical particle acceleration.