Reconnection and shocks in magnetically-dominated plasmas

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Magnetic fields can be the dominant component of astrophysical plasmas, so that the magnetic energy density might exceed even the rest-mass energy density of matter. This plasma regime, applicable to a variety of astrophysical sources — magnetars, pulsars and pulsar wind nebulae (PWNe), jets of Active Galactic Nuclei (AGNs) and Gamma-Ray Bursts (GRBs) — is dramatically different from laboratory plasmas, the magnetospheres of planets, and the interplanetary plasma. With first-principles particle-in-cell (PIC) fully-kinetic simulations, we show that reconnection in magnetically-dominated AGN jets satisfies all the basic conditions for the emission: extended non-thermal distributions of accelerated particles (with power-law slope between -2 and -1), efficient dissipation and rough equipartition between particles and magnetic field in the emitting region. In addition, we demonstrate that ultra-relativistic magnetic islands generated by reconnection in the jet can power the ultra-fast bright flares observed from a number of TeV blazars. Unlike reconnection, perpendicular shocks in magnetically-dominated plasmas are not efficient particle accelerators. While thermalizing, the incoming particles gyrate in the shock-compressed fields and radiate a strong quasi-coherent precursor wave into the upstream medium. We study with multi-dimensional PIC simulations the amplitude and spectrum of the precursor wave in magnetically-dominated shocks, as a potential mechanism for producing the bursts of millisecond duration recently discovered in the GHz band (i.e., the fast radio bursts).