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Magnetic Reconnection: A Powerful Cosmic Particle Accelerator

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Astrophysical magnetic reconnection sites have long been expected to be sources of high-energy particles. Recent observations of high-energy gamma-ray flares from the Crab nebula and hard X-ray emission from solar flares have motivated us to better understand magnetic reconnection and its associated particle acceleration in plasma conditions where the magnetic energy is dominant. We will present fully kinetic particle-in-cell simulations of anti-parallel magnetic reconnection in the highly magnetized regime (the magnetization parameter sigma $>>1$ or plasma beta $<<1$). The magnetic energy is converted efficiently into kinetic energy of nonthermal relativistic particles in a power-law spectrum. For a sufficiently large system and strong magnetic field, the power-law index approaches "-1". The dominant acceleration mechanism is a first-order Fermi process accomplished through the curvature drift motion of particles in magnetic flux tubes along the electric field induced by fast plasma flows. We will show simulations in three dimensions and with open boundary conditions. We will present an analytical model for the formation of power-law distribution and show the nonthermal distribution may be a common feature of magnetically dominated reconnection. Collaborators: Hui Li, William Daughton, Yi-Hsin Liu, Xiaocan Li References: Fan Guo, Hui Li, William Daughton, Yi-Hsin Liu (2014) Formation of Hard Power-laws in the Energetic Particle Spectra Resulting from Relativistic Magnetic Reconnection, Physical Review Letters, 113, 155005 Yi-Hsin Liu, Fan Guo, William Daughton, Hui Li, Michael Hesse (2015) Scaling of Magnetic Reconnection in Relativistic Collisionless Plasmas, Physical Review Letters, 114, 095002 Fan Guo, Yi-Hsin Liu, William Daughton, Hui Li (2015) Particle Acceleration and Plasma Dynamics during Magnetic Reconnection in the Magnetically-dominated Regime, Astrophysical Journal 806, 167 Xiaocan Li, Fan Guo, Hui Li, Gang Li (2015) Nonthermally Dominated Electron Acceleration during Magnetic Reconnection in a Low-beta Plasma, ArXiv: 1505.02166