Radiative Relativistic Magnetic Reconnection in Extreme Astrophysical Plasmas

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Magnetic reconnection – a fundamental collective plasma process of violent reorganization of magnetic field topology leading to a rapid magnetic energy release – is ubiquitous in space and astrophysical environments, powering bright high-energy flares. While our physical understanding of reconnection in laboratory devices (including tokamaks and dedicated reconnection experiments) and in various heliospheric scenarios (e.g., solar flares and geomagnetic storms) is now mature and well developed, our ideas about how, whether, and where reconnection occurs in the exotic astrophysical environments of neutron stars and black holes are not as firmly established. The physical plasma conditions around these relativistic compact objects are so extreme that reconnection takes place in a qualitatively different, new relativistic radiative regime, which in the last few years has flourished in a very active, rapidly developing area of research. This regime is characterized by efficient acceleration of large numbers of particles to relativistic energies, powering intense synchrotron and/or inverse-Compton emission. In turn, the resulting radiative losses affect the reconnection process, altering its dynamics and energetics and suppressing nonthermal particle acceleration. In the more extreme cases, QED processes like pair creation come into play and lead to a nontrivial self-regulating regime where the reconnection layer creates its own plasma. In this talk I will review the recent advances in our exploration of this fascinating radiative-reconnection frontier of modern plasma astrophysics enabled by the advent of first-principles radiative-QED particle-in-cell simulations in combination with analytical theory. I will also discuss their astrophysical implications and will outline the most promising directions of future research.