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Limits on the compression of magnetic islands in strongly radiative magnetic reconnection

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Magnetic reconnection has been suggested to play an important role in the production of gamma-ray flares, which are observed near the magnetospheres around compact objects such as pulsars and magnetars. Reconnection leads to the generation of magnetic islands and the acceleration of non-thermal particles. In such scenarios, the field strength can be close to the critical (Schwinger) field, resulting in quantum electrodynamic (QED) effects including discrete gamma-ray emission and pair creation. Therefore, standard plasma models for magnetic reconnection are no longer valid in these scenarios.

The evolution of magnetic islands generated in a reconnecting relativistic pair plasma is investigated using 2D and 3D particle-in-cell simulations in strong magnetic fields. For sufficiently strong fields (and a weak guide field), radiation cooling leads to compression of the magnetic islands, which amplifies fields and plasma density [1]. The QED module [2] of the OSIRIS framework allows us to model the radiation as either classical radiation reaction or the QED emission of discrete photons according to non-linear Compton scattering, as well as single-photon decay into pairs (non-linear Breit-Wheeler). We show that the measured increases in density n and magnetic fields B due to compression are limited by power laws in n-B space. In 3D, the magnetic flux ropes become kink-unstable, which effectively limits the compression of density, while radiation can limit the compression of the magnetic fields. Based on trends in parameter space, scaling to large systems with high upstream plasma magnetization should result in enough magnetic field compression to result in significant pair production and gamma-ray emission.

References

[1] K. Schoeffler et al., Astrophysical Journal 870, 1 (2019)

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