Limits on the compression of magnetic islands, a source of synchrotron radiation bursts in PIC simulations of strong-field 3D relativistic 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 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 Therefore, standard plasma models for magnetic reconnection are no longer valid in these scenarios.

A study employing 2D and 3D particle-in-cell simulations taking advantage of the radiative quantum electrodynamic (QED) module [1] of the OSIRIS framework investigates relativistic magnetic reconnection of a pair plasma with strong fields. These conditions are expected in magnetospheres around compact objects such as neutron stars. Our previous 2D study [2] has shown that reconnection produces concentrated regions at the centers of magnetic islands with higher temperatures and compressed density and magnetic fields, leading to enhanced synchrotron emission. For sufficiently strong fields, this emission can reach the gamma-ray range. In the present work, our simulations show this also to be true in 3D, and we provide a theoretical model for the limits of the compression of the magnetic field and plasma density. These limits can be clearly visualized using a novel 2D histogram diagnostic of the density and magnetic fields measured at each point in space of our simulations. The magnetic field compression is theorized to be limited by dissipation manifested as an effective radiative resistivity, and the density compression to be limited by 3D kinking instabilities. This process of compression and enhancement of radiation may help explain the gamma-ray flares observed near pulsar and magnetar magnetospheres, where strong-field reconnection regimes are expected.

References

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