Theory and numerical modeling of radiation from sub-Larmor-scale magnetic turbulence

Mikhail V. Medvedev[1], J.T. Frederiksen[2], T. Haugboelle[2], and A. Nordlund[2]

[1]University of Kansas
[2]Niels Bohr Institute, Copenhagen

March 22, 2012

Abstract

Spontaneous rapid growth of strong magnetic fields is ubiquitous in high-energy density environments ranging from astrophysical sources and relativistic shocks, to reconnection, to laser-plasma interaction laboratory experiments, where they are produced by kinetic streaming instabilities of the Weibel type. Relativistic electrons propagating through these sub-Larmor-scale magnetic fields radiate in the jitter regime, in which the anisotropy of the magnetic fields and the particle distribution have a strong effect on the produced radiation. We present the general theory of jitter radiation, which includes (i) anisotropic magnetic fields and electron velocity distributions, (ii) the effects of trapped electrons and (iii) extends the description to large deflection angles of radiating particles thus establishing a cross-over between the classical jitter and synchrotron regimes. Our results are in remarkable agreement with dedicated particle-in-cell simulations of the classical Weibel instability. Particularly interesting is the onset of the field growth, when the transient hard synchrotron-violating spectra are common, which can serve as a distinct observational signature of the violent field growth in astro sources and lab experiments. It is also interesting that a system with small-scale magnetic turbulence fields tends to evolve toward the small-angle jitter regime.