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Radiation from accelerated particles in shocks

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Abstract. Recent PIC simulations of relativistic electron-positron (electron-ion) jets injected into a stationary medium show that particle acceleration occurs in the shocked regions. Simulations show that the Weibel instability is responsible for generating and amplifying highly nonuniform, small-scale magnetic fields and for particle acceleration. These magnetic fields contribute to the electron’s transverse deflection behind the shock. The “jitter” radiation from deflected electrons in turbulent magnetic fields has properties different from synchrotron radiation calculated in a uniform magnetic field. This jitter radiation may be important for understanding the complex time evolution and/or spectral structure of gamma-ray bursts, relativistic jets in general, and supernova remnants. In order to calculate radiation from first principles and go beyond the standard synchrotron model, we have used PIC simulations. We present synthetic spectra to compare with the spectra obtained from Fermi observations.

Keywords. Relativistic jets, Weibel instability, magnetic field generation, particle acceleration, radiation.

We have calculated the radiation spectra directly from our simulations by integrating the expression for the retarded power, derived from the Liénard-Wiechert potentials for a large number of representative particles in the PIC representation of the plasma (Nishikawa *et al.* 2009, 2011). In order to obtain the spectrum of the synchrotron/jitter emission, we consider an ensemble of electrons selected in the region where the Weibel instability has fully grown and where the electrons are accelerated in the self-consistently generated magnetic fields.

Figure 1 shows how our synthetic spectrum matches with spectra obtained from Fermi observations. Figure 1a shows the observed spectra in νF_ν as modeled by Abdo *et al.* (2009) at five different time intervals.

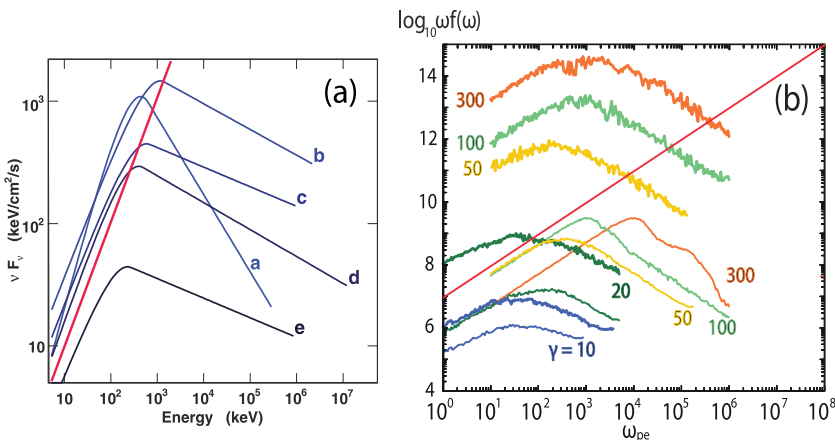


Figure 1. Comparison of a synthetic spectrum with spectra obtained from Fermi observations. Figure 1a shows the modeled Fermi spectra in νF_ν units for five time intervals. A flat spectrum would indicate equal energy per decade in photon energy. The changing shapes show the evolution of the spectrum over time. Figure 1b shows the spectra for the cases of $\gamma = 10, 20, 50, 100,$ and 300 with cold (thin lines) and warm (thick lines) electron jets. The low frequency slope is approximately 1.

The red line in Fig. 1a indicates a slope of one, and except for the spectrum at time “a” the low frequency slopes are all approximately one. This is similar to a Bremsstrahlung-like spectrum at least for the low frequency side. As shown in Fig. 1b the slope at low frequency is very similar to the observed spectra. The peaks and slopes at high frequencies change over time.

Emission computed using the method described above is obtained self-consistently, and automatically accounts for magnetic field structures on the small scales responsible for jitter emission. By performing such calculations for simulations using different parameters, we can investigate and compare the different regimes of jitter- and synchrotron-type emission (Medvedev 2006). Thus, we should be able to address the low frequency GRB spectral index violation of the synchrotron spectrum line of death (Medvedev 2006).

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