On the path of an analytical solution for QED showers in strongly magnetized environments

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In extreme astrophysical environments such as neutron stars, pulsars and magnetars, magnetic fields can reach strengths as high as 10^{15} Gauss. Due to the fast rotation of the star, a very large electric field is associated with these strong magnetic fields which accelerates charged particles to energies from GeV to TeV and provides an excellent environment for so-called QED shower [1-2]. Subject to an intense electromagnetic field, an electron can emit high-energy photons (non-linear Compton scattering) that can decay into an electron-positron pair (non-linear Breit-Wheeler process) which can further contribute to the shower. It will develop until the emitted photon does have not enough energy to decay and the remaining photons will escape thus providing the main source of radiation from the magnetized environments.

An analytical model of the shower characteristics has been proposed in [3] but shown to be inadequate for quantitative predictions [4]. In this work, the number of produced pairs as a function of the interaction time, the initial particle energy and the magnetic field intensity is identified using a different approach. Two scaling laws respectively valid at short times (before the electron distribution has significantly cooled down) and at long times (when the majority of the incident particle energy is exhausted) are investigated.

A systematic study using the particle-in-cell code SMILEI [5] and an in-house Monte Carlo code shows excellent agreement with our model predictions for the photon energy spectrum and evolution of the number of pairs. It has practical applications for laser-driven showers in the laboratory and for astrophysical observations of pulsar radiation.

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