Kinetic model of Neutron stars charge starved vacuum gaps

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The magnetospheres of rotating astrophysical compact objects such as neutron stars or black holes can become charge starved, giving rise to the formation of vacuum gaps in which pair plasma is produced. More precisely, in these gaps, permeated by strong rotationally induced electric fields, leptons are accelerated to ultra-relativistic energies, emitting gamma-ray that can decay in electron-positron pairs via quantum electrodynamics processes. The cascade process is interrupted when the electrostatic field associated to the new created pair plasma is able to screen the accelerating electric field. The production of strong QED cascades in vacuum gaps has long been proposed to be connected to coherent emission mechanisms from these objects.

There has been a great endeavour in the past years to model from first-principles (with QED effects) the full dynamics of these gaps with 1D electrostatic PIC codes [1] and more recently with 2D electromagnetic PIC codes [2]. The main conclusions of these numerical works indicate that the gap is periodically screened with QED cascades, accompanied by the emission of plasma waves. However, a full kinetic model that could predict the growth rate of the cascade, the screening time, and the subsequent emissions is still lacking. We show in this work how the kinetic equations can be used to provide such predictions two setups [3]: a uniform electric field and a more realistic vacuum-gap space-time dependent electric field. We show also that the full QED differential probability rates can be approximated by heuristic rate for photon emission and pair creation. The analytical results ate compared with the particle-in-cell code OSIRIS-QED.

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References

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