The Impact of Radiation Reaction on the Topology of the Momentum Space

P J Bilbao[1] and L O Silva[1]

[1] *GoLP/IPFN, Instituto Superior Tecnico, Universidade de Lisboa, 1049-001, Lisbon, Portugal*
Contact Email: pablojbilbao@tecnico.ulisboa.pt

In the presence of ultra-high laser intensities and the extreme electromagnetic fields present in compact objects, the particle trajectories are strongly affected by radiation reaction. In this work, we show that radiation reaction can lead to topological changes in the plasma distribution functions, which in turn can impact the plasma dynamics *e.g.* triggering kinetic instabilities. To explore these processes, we develop an analytical model based on the extension of the Vlasov equation to include the Landau-Lifshitz radiation reaction force [1-3]. We demonstrate that initially stable momentum distributions, *i.e.* distributions in thermal equilibrium, evolve, due to the radiation reaction force, into ring momentum distributions that are kinetically unstable. We attribute this to the differential radiation cooling the plasma particles experience in the presence of intense fields, e.g. under strong magnetic fields with synchrotron cooling [4]. We also show that these unstable distributions can prompt coherent radiation emission mechanisms, such as the electron cyclotron maser instability [5]. Our analytical results are compared with particle-in-cell simulations using OSIRIS [6,7], which corroborate our theoretical predictions on the formation and evolution of the rings in momentum space over a wide range of initial conditions. This work describes a previously unexplored process through which kinetically unstable distributions can be produced via radiation reaction and their relevance in the laboratory and astrophysical scenarios.

Acknowledgements: Work partially supported by FCT (Portugal) (Grant UI/BD/151559/2021), European Research Council (ERC) -2015-AdG Grant 695088 – InPairs and EuroHPC-JU project (EHPC-REG-2021R0038).

References

[1] L D Landau and E M Lifshitz, The Classical Theory of Fields, vol. 2, Pergamon Press, Oxford, 1975

[2] L S Kuz'menkov, Sov. Phys. Dokl. **23**, 469 (1978)

[3] A Gonoskov, T G Blackburn, M Marklund and S S Bulanov, arXiv:2107.02161 (2021)

[4] P J Bilbao and L O Silva, to be submitted to Phys. Rev. Lett.

[5] R A Cairns, I Vorgul and R Bingham, Phys. Rev. Lett. **101**, 215003 (2008)

[6] R A Fonseca, L O Silva, F S Tsung *et al.*, in: G Goos, J Hartmanis and J van Leeuwen (eds.), Lecture Notes in Computer Science, vol. 2331, Springer-Verlag Berlin Heidelberg New York, 2002, p. 342

[7] J Derouillat, A Beck, F Pérez *et al.*, Comput. Phys. Commun. **204**, 141 (2016)