Coherent electron cyclotron maser emission triggered by radiation reaction

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We demonstrate the efficient generation of highly coherent cyclotron maser radiation in strongly magnetized relativistic plasmas [1]. This results from the evolution of the momentum distribution into a ring momentum distribution in synchrotron-cooled plasmas [2]. We show that the resulting emission properties are relevant to understanding astronomical observations of coherent radiation sources, such as FRBs [3]. With the help of kinetic theory and particle-in-cell simulations, we have characterized the properties and timescales of the emission mechanism and have demonstrated that the linearly polarised X-mode is efficiently amplified via the electron cyclotron maser instability in electron-positron pair-beam plasmas. Notably, the emission occurs in several small frequency bands at the harmonics of the cyclotron frequency. Furthermore, we have studied the nonlinear regime of the instability and have shown that it enters a marginally stable state capable of continuous emission or burst-like repeating behavior. Finally, we estimate that for relativistic pair-beam plasmas in magnetic fields of comparable strength to those found around magnetars and pulsars [4] the expected emitted frequency is in the radio spectrum, and a high luminosity is expected due to Lorentz focusing. Consequently, the proposed mechanism is of timely relevance to understanding currently unexplained astronomical coherent radiation sources [3].
The onset of the electron cyclotron maser instability is confirmed with simulations performed with the Particle-in-cell OSIRIS code [5,6].
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[1] P. J. Bilbao, et al. in prep (2024)

[2] P. J. Bilbao & L. O. Silva, Phys. Rev. Lett. 130, 165101 (2023)

[3] E. Waxman, APJ 842.1, 34 (2017)

[4] M. Lyutikov, APJ 922.2, 166 (2021)

[5] R. A. Fonseca , et. al. Lect. Notes. Comput. Sc. 2331 342–51 (2002)

[6] Vranic M., et. al. Comput. Phys. Commun. 204 141-151 (2016)