UNIWERSYTET
MIKOŁAJA KOPERNIKA
W TORUNIU
Wydział Fizyki, Astronomii
i Informatyki Stosowanej

Toruń, 6.11.2022

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Review of the doctoral PhD Thesis of Mr. Jose Ortuño-Macías, entitled "Kinetic numerical simulations of particle acceleration mechanisms in relativistically magnetized jets.".

The PhD Thesis by Mr. Jose Ortuño-Macías deals with particle acceleration processes modelled using particle-in-cell (PIC) kinetic numerical simulations of relativistic plasmas. The presented research focuses on two physical situations. The first refers to modelling particle acceleration relativistic magnetic reconnection in electron-positron plasma with radiative losses incorporated into the model. The second setup relates to modelling particle acceleration in dynamically unstable, magnetized relativistic jets. The Thesis includes two refereed papers:
1. Ortuño-Macías, J., Nalewajko, K.,
Ra*diative kinetic simulations of steady-state relativistic plasmoid magnetic reconnection*, MNRAS, 497, 1365-1381 (2020)
2. José Ortuño-Macías, J., Nalewajko, K., Dmitri A. Uzdensky, D.A., Mitchell C. Begelman, M.C., Werner, G.R., Chen, A.Y., Mishra, B.,
Kin*etic Simulations of Instabilities and Particle Acceleration in Cylindrical Magnetized Relativistic Jets*

The PhD Thesis consists of three major chapters. In the introduction (Chapter 1) the author presents general astrophysical aspects of the subject: an overview of astrophysical jets and blazars, an introduction to particle acceleration processes, magnetic reconnection, and the instabilities of astrophysical jets. The author subsequently describes the physical bases and technical details of particle-in-cell simulations and then presents the Zeltron PIC simulation code, which has been used in numerical simulations carried out within the PhD project. Finally, the author overviews the results of his research project and presents prospects for the further development of the research field.

In the first paper, the author studies, through 2D PIC simulations, the formation of plasmoids in the process of steady-state magnetic reconnection ongoing in positron-electron plasma. The goal of the work is to explain rapid flares of blazars.

The author observed chains of plasmoids formed in the reconnection process, moving with speeds depending on their size. The small ones achieve bulk relativistic speeds, while large ones reach mildly relativistic speeds and absorb the small plasmoids in tail-on collisions. Large plasmoids emit synchrotron radiation with several orders of magnitude higher emissivity than the small plasmoids. Rapid and bright emission flares originating from the tail-on collisions contribute to a substantial variability of the synchrotron emitting system. One of the original findings of the paper states that synchrotron emissivity is strongly concentrated in central parts of the plasmoids and that plasmoids undergo significant time evolution with a systematic increase of plasmoid peak density and peak magnetic field strength. The author suggests that the cores of large plasmoids and small plasmoids are important for understanding the production of rapid radiation flares. He also concludes that tail-on collisions of unequal plasmoids can be responsible for most of the sharpest features observed in the resulting light curves.

In the second paper, the author investigates the development of current and pressure-driven MHD instabilities in magnetized relativistic jets through 3D kinetic simulations of cylindrical configurations of toroidal magnetic fields with electron-positron pair plasma. He analyses a series of initial structures in which forces due to the toroidal magnetic field are balanced by a combination of forces due to the axial magnetic field and gas pressure. The author finds that in all investigated cases, a kink mode arises in the central core region with a growth timescale consistent with the predictions of linearized MHD models. In the case of a gas-pressure-balanced (Z-pinch) profile, he identifies a weak local pinch mode well outside the jet core.

The development of the instabilities is carefully analyzed together with the evolution of electric fields and particle spectra. The simulations clearly show that the dissipation of the toroidal magnetic field associated with the instability development results in the growth of the electric field and, consequently, efficient particle acceleration. Moreover, the presented results clearly show that an electric field perpendicular to the local magnetic fields dominates particle acceleration.

The results reported in the two papers represent the top-level research on the particle acceleration resulting from the dissipation of magnetic fields in relativistically magnetized jets. The results undoubtedly contribute to a better understanding of particle acceleration mechanisms in relativistic environments. However, in my opinion, the Thesis lacks a comparative discussion of both considered mechanisms of particle acceleration and a more detailed reference of the obtained results to observations of real sources. Nevertheless, despite the shortcomings mentioned, my overall impression of the PhD Thesis by MSC. Ortuño-Macías is very good.

Conclusion

The results of the original research by Mr. Jose Ortuño-Macías, presented in the PhD Thesis, represent an original solution to a scientific problem studying Kinetic numerical simulations of particle acceleration mechanisms in relativistically magnetized jets. The doctoral PhD Thesis demonstrates the candidate's general theoretical knowledge and ability to conduct independent research in the discipline of astronomy.

The Doctoral PhD Thesis of Mr. Jose Ortuño-Macías meets the requirements of Article 187 of the Law on Higher Education and Science of 20th July 2018.

Therefore I request that this PhD Thesis be admitted to the public defence.

Michal Hanasz