Relativistic plasmas in high-energy astrophysics

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Plasmas are the fundamental state of matter in space, they represent 99% of the known content of matter in the universe. More specifically, in high-energy astrophysics, the electromagnetic activity of neutron stars and black holes is mostly attributed to relativistic electron/positron pairs evolving in magnetically dominated flows and forming the magnetosphere. The plasma within this magnetosphere is well described by a collisionless relativistic plasma made of electrons, positrons and sometimes with a small fraction of protons/ions. These particles are subject not only to the diktat of gravitation but also to intense radiation fields produced by synchrotron and inverse Compton emission. Moreover instabilities and reconnection phenomena play are crucial role for the long term variability of these sources. Strongly magnetized relativistic outflows emanating from neutron star or black hole magnetospheres are ubiquitous. They impact on their surrounding by forming for instance strong shocks and thin current sheets [1].

It is the purpose of this talk to present an overview of current research in the field of relativistic plasma astrophysics using analytical and numerical tools based on the Vlasov-Maxwell equations. We first give an example of shocked wind leading to magnetic annihilation, using 1D relativistic PIC simulations [2]. Then the linear dispersion relation for the tearing mode obtained by linearization of the Vlasov-Mawell equations is presented for a relativistic Harris current sheet [3]. Another important but less known topic concerns non-neutral plasma physics [4]. Indeed, in the magnetosphere, some charge separated plasma builts up, leading to well confined regions with sharp plasma/vacuum interfaces, called electrosphere [5]. We study the stability properties of such configuration by means of a linear stability analysis followed by 2D numerical electrostatic PIC simulations in a cylindrical coordinate system [6]. These simulations confirm the presence of the diocotron instability (pure electrostatic mode) which could be generalized to the magnetron case i.e. including the perturbation in the magnetic field.

References

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