Analytical Theory of Neutral Current Sheets with a Sheared Magnetic Field in Collisionless Relativistic Plasma

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Quasistationary neutral current sheets are important elements of various structures in collisionless plasma, including the relativistic plasma of neutron stars' magnetosphere and wind. Most analytical studies of these structures are limited by a plain configuration of the field lines and ignore the effect of shear. At the same time the latter appears naturally in the system "rotating magnetosphere – outgoing wind".

We derive and describe analytically a new wide class of magnetostatic structures with sheared field lines using a superposition of current sheets with orthogonal magnetic fields and arbitrary energy distribution of particles [1]. We consider particle distributions as functions of generalized particle momenta and restrict ourselves to the sum of two cylindrically symmetric particle distribution functions with orthogonal axes. In this simple but yet poorly explored situation, the equations of magnetostatics break down into two independent nonlinear Grad–Shafranov equations. We develop a way to find analytically their solutions and present a complete classification of possible current and magnetic field profiles.

In the talk, we analyze various superpositions of two current sheets taken so, that the magnetic field of one solution is directed along the cylindrical symmetry axis of the distribution function of the other. These superpositions satisfy the general equation of pressure balance and allow us to construct configurations with an arbitrarily sheared magnetic field. It turns out that periodic helical structures and localized current sheets exist with either constant direction of magnetic field rotation, or with a single switch in the shear direction. The presence of an external magnetic field is allowed in each "combinable" solution. We provide analytical examples for all these structures and describe possible relations between their spatial scales, magnitudes of currents and magnetic field, the degree of anisotropy of particle distributions, and the magnetic-to-particle energy ratio.

We show that the major part of previously known current sheets with sheared field lines are particular cases of this novel wide class of current sheets. Finally, we discuss possible applications of the outlined class of sheared magnetic field configurations to the physics of wind and magnetosphere of neutron stars.

References

[1] V. V. Kocharovsky, Vl. V. Kocharovsky, V. Yu. Martyanov, S. V. Tarasov, *Phys. Uspekhi* 59, 1165 (2016)

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