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RELATIVISTIC ELECTRON-POSITRON PLASMA QUASI-LINEAR RELAXATION AT THE PRESENCE OF MAGNETIC BREMSSTRAHLUNG


Recently a significant attention is paid to instabilities and non-linear phenomena, connected with them. In adopted models they may take place in pulsar magnetospheres. Such plasma specific features are determined by its ultrarelativity and very strong magnetic field ($B \sim 10^{12}$ gauss).

An ultrarelativistic particle in a strong magnetic field loses its transverse momentum due to magnetic bremsstrahlung and as a result particle distribution relaxes to a one-dimensional. By the existing notion, pulsar magnetosphere is filled up with electron-positron plasma, moving along magnetic field force line with a typical Lorentz-factor $\gamma \sim 10^2-10^3$ and with electron-positron beam with Lorentz-factor $\gamma \sim 10^2-10^7$. A beam instability $\gamma_1$ is excited at the Cherenkov resonance of beam particles with Langmuir oscillation is generated in such plasma. Particle distribution due to quasi-linear particle interaction with the excitations, relaxes to a one-dimensional with an elongated tail. In analogy with nonrelativistic case $\gamma_2$ one may expect that such distribution must be unstable with respect to perturbations excited at the cyclotron resonance ($\omega - \omega_b \approx 0$ $(\omega_c^2 \beta^2)$ with beam particles, and for the real and imaginary parts of frequency

$$\omega = \omega_c (1 - \frac{\omega_b^2}{\omega_c^2}) \gamma, \quad \gamma = \frac{\beta}{\gamma_c}$$

Here $\omega_b = \frac{4e^2 \gamma^2}{mc}$, $\gamma_c^2 = \frac{mc}{e}$ - density of beam.

Perturbations, characterized by frequency and growth rate (1) at the quasi-linear diffusion of particles lead to a transverse momentum rise. Such relaxation must complete with a magnetic bremsstrahlung, leading to a transverse momentum decrease. A competition of these two processes will determine a final form of distribution function.

The initial kinetic equation has a form

$$\frac{d\mathbf{F}_1}{dt} + \frac{1}{2} \frac{\partial}{\partial t} \mathbf{F}_1 + \frac{1}{2} \frac{\partial}{\partial \mathbf{F}_2} (\mathbf{F}_1 \mathbf{F}_1^T) + \frac{\partial}{\partial \mathbf{F}_2} (\mathbf{F}_2^T) = \mathcal{S}_{QL} (2)$$

Here $\mathbf{F}_2, \mathbf{F}_1$ - are transverse and longitudinal components of bremsstrahlung force,

$$\mathbf{F}_2 = -\frac{d}{dt} \left( \frac{\mathbf{P}_1}{\mathbf{F}_1^2} \right), \mathbf{F}_1 = -\frac{\partial}{\partial \mathbf{F}_2} (\mathbf{F}_2^T) \quad \mathcal{S}_{QL}$$

is operator of quasilinear diffusion.

$$\mathcal{S}_{QL} = \frac{1}{2} \frac{\partial}{\partial \mathbf{P}_1} \left( \frac{\mathbf{P}_1}{\mathbf{F}_1^2} \frac{\partial}{\partial \mathbf{P}_1} \right) \frac{1}{2} \mathbf{E}^2 \mathbf{F}_1^2 \gamma_c^2 \left| E(\mathbf{r}) \right|^2$$

Considering derivatives of $\frac{\partial}{\partial \mathbf{P}_1}$ to be greater in comparison with $\frac{\partial}{\partial \mathbf{F}_1}$, $\frac{\partial}{\partial \mathbf{F}_2}$, we find out from (2) in a first approximation by a small parameter.
We have considered cyclotron instability and connected with it quasilinear relaxation of ultrarelativistic particle beam in relativistic plasma in a strong magnetic field, taking into account magnetic bremsstrahlung. Supposing that such radiation is a strong one, we have got a system of one-dimensional quasilinear equations and have found an asymptotic solution of the system for large time. It has been shown, that as a consequence of a quasilinear relaxation in a condition of strong magnetic bremsstrahlung a beam deceleration appears and beam energy transforms into the energy of radiation.

The process considered in this paper is important for pulsar magnetosphere physics.

REFERENCES