Effective particle acceleration in the parabolic magnetic field

V. S. Beskin[1] *, E. E. Nokhrina[2] †

[1]Lebedev Physical Institute, Russian Academy of Sciences

[2]Moscow Institute of Physics and Technology

The problem of the efficiency of the transformation from the electromagnetic (Poynting) energy flux to particle flux is considered within the Grad-Shafranov approach, i.e., for a stationary axisymmetric MHD flow. Assuming that the magnetic field structure is similar to the exact parabolic force-free solution [1], it is possible to find the disturbance of the magnetic surfaces as well as the position of fast magnetosonic surface and the Lorentz-factor of plasma resulting from the finite particle mass. It is shown that the greatest Lorentz-factor on the fast surface turns out to be $\sigma^{1/3}$ (where σ is the Michel magnetization parameter) as for the radial outflow [2]. On the other hand, it is shown that for the parabolic geometry of the magnetic field the centrifugal force resulting from the curvature of magnetic surfaces plays no role in the force balance. Together with the fact, that the fast surface of the considered problem and the fast surface of a cylindrical flow with the same transverse scale coincide, it allows us to regard the problem as one-dimensional. As a result, we found that at the distance of $r \sim \sigma\gamma_{\rm in} R_{\rm L}$ along the axis ($\gamma_{\rm in}$ corresponds the value in the source) the Lorentz-factor of the outflowing particles is equal to $(\sigma\gamma_{in})^{1/2}$, and at the distance $r \sim \sigma^2 R_{\rm L}$ the Lorentz-factor reaches σ corresponding to the almost total energy conversion of electromagnetic energy flux to particle energy flux.

References

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*E-mail: beskin@lpi.ru

†E-mail: cverg@pochta.ru