Limiting polarization of the pulsar radio emission

A. N. Andrianov[1,2*], V. S. Beskin[1†]

[1]P. N. Lebedev Physical Institute, Moscow

[2]Moscow Institute of Physics and Technology, Dolgoprudny

In spite of forty years of extensive studies, there is no common point of view on the nature of coherent radio emission of radio pulsars [1]. Moreover, propagation effects in a pulsar magnetosphere were not analyzed carefully enough. For instance, the effect of limiting polarization was considered only in [2], where the magnetic field was assumed to be infinite. This approach does not allow one to determine correctly circular polarization of outgoing waves and, hence, restricts essentially the quantitative analysis within the hollow-cone paradigm.

We used the method of wave propagation in inhomogeneous media described in [3]. This approach allows us to include into consideration not only the transition from geometrical optics to vacuum propagation but swings of the magnetic field as well. As is well-known, the polarization of outgoing waves forms in the region, where

$$\left[\frac{1}{(1+q^2)}\,\frac{\mathrm{d}q}{\mathrm{d}r}\right]^2 \sim \left|\frac{\omega^2}{c^2}\,(\Delta n)^2 + 2i\frac{\omega}{c}\,\frac{\mathrm{d}\Delta n}{\mathrm{d}r}\right|. \tag{1}$$

Here, $\Delta n = n_1 - n_2$, and the parameter q is determined as $K = iE_x/E_y = q \pm \sqrt{1+q^2}$ (see [4] for details; our approach results in the same condition). Using the hydrodynamical expression of the dielectric tensor, one can find that the polarization parameter q_∞ at infinity can be evaluated as $q_\infty \approx q(r_{\rm esc}) \approx 1/\theta(r_{\rm esc})$, where θ is the angle between the wave vector $\mathbf{k}$ and magnetic field $\mathbf{B}$. For ordinary pulsars (period $P \sim 1$ s, magnetic field $B_0 \sim 10^{12}$ G, multiplicity parameter $\lambda \sim 10^4$), polarization is formed inside the light cylinder at the distance $r_{\rm esc} \sim (100 - 1000)R$ from the neutron star, where

$$q_{\rm esc} \sim 10 - 100. \tag{2}$$

This value corresponds to 1–10% circular polarization of the observable radio pulses. Numerical simulation allows us to determine polarization characteristics for arbitrary parameters of radio pulsars.

References

[1] V. S. Beskin. Physics Uspekhi, 42, 1071 (1999)

[2] S. A. Petrova, Yu. E. Lyubarskii. A&A, 355, 1168 (2000)

[3] Yu. A. Kravtsov, Yu. I. Orlov. *Geometrical Optics of Inhomogeneous Media* (Berlin: Springer, 1990)

[4] V. V. Zheleznyakov. *Radiation in Astrophysical Plasmas* (Boston: Kluwer, 1996)

*E-mail: andrianov_andrey@mail.ru

†E-mail: beskin@lpi.ru