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ORIGINAL ARTICLE

High-frequency cutoff and change of radio emission mechanism in pulsars

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Abstract Pulsars are fast rotating neutron stars with a strong magnetic field, that emit over a wide frequency range. In spite of all efforts during the 40 years after the discovery of pulsars, the mechanism of their radio emission so far remains unknown. We propose a new approach to solving this problem for a subset of pulsars with a high-frequency cutoff of the spectrum from the Pushchino catalogue (the "Pushchino" sample). We provide a theoretical explanation of the observed dependence of the high-frequency cutoff on the pulsar period, and we predict the dependence of the cutoff position from the magnetic field. This explanation is based on a new mechanism for electron radio emission in pulsars. Namely, radiation occurs in the inner (polar) gap, when electrons are accelerated in the electric field that is increasing from zero level at the star surface. In this case the acceleration of electrons passes through a maximum and goes to zero when the electron velocity approaches the speed of light. All the radiated power is located within the radio frequency band. The averaging of radiation intensity over the polar cap, with some natural assumptions of the coherence of the radiation, leads to the observed spectra. It also leads to an acceptable estimate of the power of radio emission.

Keywords Pulsars: Radio emission · Spectra

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1 Introduction

Pulsars are magnetized neutron stars that have a magnetosphere filled with an electron-positron plasma of about the GJ density (Smith 1977; Manchester and Taylor 1977; Beskin et al. 1993). New discoveries of a double pulsar system (Lane et al. 2004) and intermittent pulsars (Kramer et al. 2006; Lorimer et al. 2012; Camilo et al. 2012) give direct observational support to that idea. It is thought that this plasma in the region of open magnetic field lines over the magnetic polar cap is generated by particles (through gamma quanta production) accelerating in a gap under the magnetosphere (Sturrock 1971; Ruderman and Sutherland 1975; Arons 1981; Beskin 2010). The acceleration of electrons occurs in a gap in the electric field that is longitudinal with respect to the magnetic field and induced by the rotation of the magnetized star. The most popular explanation is that directed coherent electromagnetic radiation of relativistic particles from the region of open lines creates a beacon effect, resulting in the observed pulses.

To explain the radio emission of pulsars (see the reviews of Malov 2004; Manchester 2009 and additional references in Malov and Machabeli 2004; Kontorovich 2009; Beskin and Philippov 2012) plasma flow instabilities, beam instabilities, and similar effects in the magnetospheric plasma[1] have been discussed. Apparently, various mechanisms of radio emission are realized and may in certain circumstances succeed each other.

[1]Besides plasma beam instabilities (see, e.g., Usov 1987; Kazbegi et al. 1992), note also cyclotron, drift, and modulation instabilities, Zakharov's wave collapse and magnetic reconnection for giant pulses (GPs), low-frequency "tails" of the synchrotron radiation, and Cherenkov, Doppler, and curvature radiation in the relativistic electron-positron plasma.