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Radio Emission by Particles Accelerated in Pulsar Magnetosphere

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Abstract. We present a relativistic model of pulsar radio emission by plasma accelerated along the rotating magnetic field lines projected on to a 2D plane perpendicular to the rotation axis. We have derived the expression for the trajectory of a particle, and estimated the spectrum of radio emission by the plasma bunches. We used the parameters given in the paper by Peyman and Gangadhara (2002). Further the analytical expressions for the Stokes parameters are derived, and compared them with the observed profiles. The one sense of circular polarization, observed in many pulsars, can be explained in the light of our model.

Keywords : Pulsar – Emission mechanism

1. Introduction

It is important to understand the charged particle dynamics in the pulsar magnetosphere to unravel the radiation mechanism of pulsars. The particles are constrained to move strictly along the field lines, owing to the superstrong magnetic field that the gyration of the particles are almost suppressed. The equation of motion for a charged particle moving along the rotating field line is given by Gangadhara (1996). Here we extend this work to obtain an analytical expression for particle trajectory and Stokes parameters. The pulsar rotation effects such as aberration and retardation can create asymmetric pulsar profiles.

2. Dynamics of a Charged Particle

The equation of motion for a relativistic electron moving along a rotating magnetic field line is given by (Gangadhara 1996)

$$\frac{d}{dt}\left(m\frac{dr}{dt}\right) = m\Omega^{*2}r, \tag{1}$$

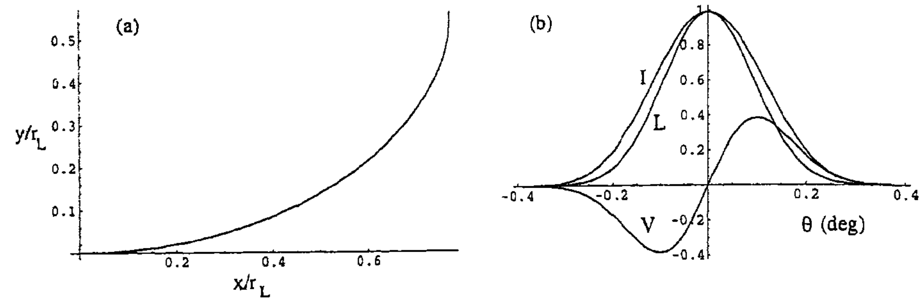

Figure 1. (a) Particle trajectory in x-y plane, (b) Stokes parameters of the emitted radiation.

where $m = m_0\gamma$ is the relativistic electron mass, γ is the Lorentz factor. Ω and Ω^* are the pulsar and electron angular velocities, respectively. r is the radial position of the particle. We solved Eq. (1) and obtained the analytical solution: $r = (c\sqrt{1+D^2}/\Omega)\mathrm{cn}(\lambda - \Omega t)$, where $\mathrm{cn}(\lambda - \Omega t)$ is the Jacobian Elliptical cosine function (Abramowitz & Stegun 1972),

$$D = \frac{\Omega d_0 \cos\theta_0}{c}, \quad \lambda = \int_0^{\phi_0} \frac{d\zeta}{\sqrt{1-k^2 \sin\zeta^2}}, \quad \phi_0 = \arccos\left(\frac{r_0\Omega}{c}\right),$$

r_0 the initial particle injection point, d_0 the distance between magnetic pole and rotation axis in projected 2D plane, θ_0 initial injection angle with respect meridianal plane, k is an integration constant and ζ is a dummy variable. For a pulsar with period of 1 s, we have plotted the particle trajectory in Fig. 1a where 'x' and 'y' are the coordinates of particle. We estimated the components of the electric field of radiation and hence the Stokes parameters. In Fig. 1b, we have plotted the intensity I, linear polarization L and circular polarization V with respect to θ, the angle between line of sight and 2D plane. It shows when the line of sight is parallel to 2D plane, radiation is linearly polarized, but when the line of sight is at some angle it will be elliptically polarized.

References

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