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On the pulsar radiation mechanism

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Pulsars have typical magnetic field strengths between 10^8 and 10^{12} G. Therefore, even if the particles are produced with nonzero perpendicular component of velocity at the pole, they radiate out this component quickly due to synchrotron radiation. Therefore, the motion of a particle along a field line becomes one dimensional in regions where filed lines are straight. However, when they move along the curved magnetic field lines, they get accelerated due to the centrifugal force. They gain again the perpendicular energy at the expense of parallel energy, but can not gyrate in the curved field lines and hence do not experience any curvature or gradient drifts.

The effective electric field (Jackson 1993) acting on the particle moving along a curved magnetic field line is given by

$$\vec{E}_{eff} = \frac{\gamma m_o}{q}\frac{\vec{R}}{R}v_{\|}^2. \tag{1}$$

where q amd m_o are repectively the charge and rest mass, γ and $v_{\|}$ are relativistic Lorentz factor and parallel component of velocity of a particle, and $\vec{R}$ is the radius of curvature of a field line.

The perpendicular component of momentum of a particle is given by

$$\frac{d\vec{p}_{\perp}}{dt} = q\vec{E}_{eff}. \tag{2}$$

A powerful tool to deal with the charged particle motion parallel to the slowly varying magnetic field is the concept of adiabatic invariants. The action integral is given by

$$J = \oint \vec{p}_{\perp}.\vec{dl} = \gamma m_o \omega_B \pi a^2 = \frac{q}{c}(B\pi a^2), \tag{3}$$

where $\omega_B = qB/\gamma mc$, $\vec{B}$ the magnetic field, $\vec{dl}$ the line element along the direction of rotation, and $a = v_{\perp}/\omega_B$.

Consider the curved field line situation as shown in Fig. 1, where B acts mainly in the z–direction. In addition to the z–component of field, there is a small x–component due to the curvature of field line. Suppose that a particle is set into motion along a field line with $v_{\|o} \neq 0$ and $v_{\perp o} = 0$ at z=0, where the field strength is B_o. The speed of the particle at any point on the field line is $v_{\|}^2 + v_{\perp}^2 = v_o^2$, where $v_o^2 = v_{\|o}^2 + v_{\perp o}^2$. The particle radiates away its perpendicular component of energy due to the small component of magnetic field in the x–direction. It leads to an emission of orthogonal polarization modes, which are the basic components of pulsar radiation. They are produced due to the acceleration of electrons and positrons along the curved magnetic field lines in the pulsar magnetosphere. The forces acting on charged particles moving along a curved field line are the magnetic Lorentz force and the centrifugal force, latter is charge independent. Under the action of these forces, positively charged particles try to rotate in clockwise direction while negatively charged particles want to go counterclockwise. The discussion about the motion of a charged particle along a curved field line is given by Gangadhara (1996). It is shown in Fig. 2 that the

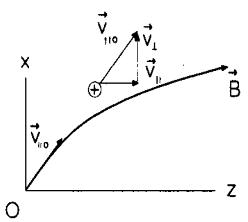

Fig. 1 Particle motion along field line OB.

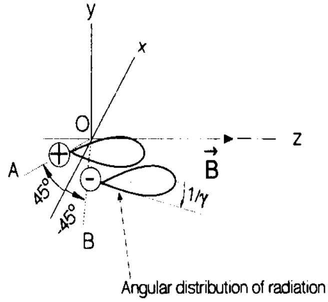

Fig. 2 Radiation emission from an electron and positron moving along field line OB.

positive particle will be at some point on OA perpendicular to $\vec{B}$. Similarly, the negatively charged particle will be on the line OB perpendicular to $\vec{B}$. We find for the electron and the positron, lines OA and OB are perpendicular to each other. Hence, if a sequence of electrons and positrons move towards the observer, the observer will see orthogonal position angle transitions: when radiation from a positron is received, the position angle will be at some value say 45^o with respect to the x-axis and will change by 90^o, when radiation from the electron is received. If both the species move simultaneously towards the observer, two orthogonal modes will be detected. Hence the electrons and the positrons can be considered as two emission components whose polarization is mutually orthogonal. Since the emitting sources (electrons and positrons) are the same at all frequencies, we expect an identical behavior in the polarization properties of these modes at different frequencies.

References

Jackson J.D. 1993, Classical Electrodynamics, Wiley Eastern Limited, Bangalore, p. 586

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