

Searching for curvature pion radiation from protons in strongly magnetized pulsars

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Received: 14 July 2011 / Accepted: 20 August 2011 / Published online: 11 September 2011
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Abstract By using rather conservative estimates based on the simplest polar cap model, we search the ATNF Pulsar Catalogue for strongly magnetized stars that could accelerate relativistic protons up to the curvature pion production threshold. The best candidate turns out to be the 16 ms pulsar J0537-6910, but the corresponding characteristic parameter $\chi = a/m_p$ is yet too small to give origin to observable signals. We show that, for pulsars with period $P \approx 1$ ms, a surface polar magnetic field $B \approx 10^{12}$ G is required in order to induce detectable curvature pion radiation from accelerated protons in the magnetosphere. Some other emission processes are also considered.

Keywords Pulsars · Neutron stars · Magnetic fields · High energy protons

1 Introduction

Processes related to the emission of pions by accelerated protons like, for instance, $p^+ \xrightarrow{a} p^+ \pi^0$, have been considered in the literature since the sixties (Ginzburg and Zharkov 1965; Zharkov 1965; Ginzburg and Sirovatski 1965; Ritus 1985). The present available observational data on strongly magnetized astrophysical objects could provide

an exciting scenario to test theoretical predictions involving such kind of inertially forbidden processes. The relevant observer-independent parameter characterizing these phenomena is the dimensionless quantity $\chi = a/m_p$, where a and m_p stand, respectively, for the proton proper acceleration and rest mass. (Unless otherwise stated, natural unities are adopted through this work.) For $\chi \ll 1$, one can employ a semiclassical approach where the proton is described by a classical current while the pion is considered as a fully quantized field. This corresponds to the so called no-recoil approximation, for which many analytical formulas are available. (For some recent works on the subject, see, for instance, (Herpay and Patkos 2008; Herpay et al. 2008) and (Fregolente et al. 2006; Fregolente and Saa 2008) for the electromagnetic and gravitational cases, respectively.) In particular, we expect a strong suppression of the pion emission for $\chi \rightarrow 0$ since such a process is well known to be inertially forbidden. For $\chi \gg 1$, a full quantized treatment is mandatory (Ritus 1985; Berezhinsky et al. 1995). However, numerical evidences suggest that some appropriate limits of certain results obtained with the no-recoil approximation can still be considered as good estimates (Tokuhisa and Kajino 1999). For the case of the usual photon synchrotron radiation, for instance, quantum effects were carefully considered (Erber 1966) and the semiclassical approach was found to be accurate within a few percent in the limit $\chi \gg 1$. Notice that, in the cases where the proton acceleration is caused by strong magnetic fields, the parameter χ can be written in a similar way to the usual synchrotron radiation: $\chi = \gamma B/B_{\text{cr}}$, where γ is the Lorentz factor, γB is the magnetic field in the instantaneous reference frame of the proton, and $B_{\text{cr}} = m_p^2/e \approx 1.5 \times 10^{20}$ G is a critical magnetic field strength, denoting the limit of the validity of the no-recoil approximation.

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