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Radio observations of a galactic high energy gamma-ray source(*)

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Summary. — PSR B1706-44 is one of the very few galactic pulsars that has been discovered at TeV energies. PSR B1706-44 has been also detected in the X-ray domain. It has been suggested that the high energy radiation could be due to inverse Compton radiation from a pulsar wind nebula (PWN). We report on VLA high-resolution observations of a region around the pulsar PSR B1706-44 at 1.4, 4.8 and 8.4 GHz. The pulsar appears embedded in a synchrotron nebula. We propose that this synchrotron nebula is the radio counterpart of the high energy emission powered by the spin-down energy of the pulsar.

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1. – Introduction

Cosmic rays with energies below 10^{15} eV are believed to be originated in the Galaxy. Together with supernova remnants, pulsars and their surrounding nebulae are considered good candidates for particle acceleration. It is generally accepted that most of the rotational energy loss of pulsars appears in the form of a relativistic wind of electron-positron pairs [1,2]. Under certain conditions, the interaction between this wind and its surroundings is observable in the form of a pulsar wind nebula (PWN). The Crab nebula is the most famous case of PWN and it is still the only one in which the quality and quantity of observational information at all wavelengths allow to make detailed theoretical models.

Pulsars are undisputed sources of relativistic electrons accelerated directly in the magnetosphere and /or by the pulsar wind termination shock [3]. Synchrotron radiation produced by these electrons moving through the nebular magnetic field explains the origin of the non-thermal spectrum of the PWN from radio to X-rays. The emission at

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TeV energies from these sources can be explained through inverse Compton scattering of the same relativistic electrons on the 2.7 K microwave background or other sources of low energy photons [4,5].

The existing sample of PWN containing a known pulsar is small. There are no more than seven confirmed cases at radio wavelengths, the number is higher for X-ray PWN, and only four cases have been detected as TeV sources with a significance of $10\,\sigma$ or greater. One of these latter sources is the pulsar PSR B1706-44.

PSR B1706-44 is a young pulsar (spin-down age 17400 years), with a period of 102 ms and a large spin-down luminosity of 3.4×10^{36} ergs^{-1}. There are several evidences that indicate the presence of a filled-center nebula surrounding the pulsar. Frail *et al.* [6] have noted in a low-resolution radio image at λ 20 cm that PSR B1706-44 appears embedded in a "halo" about $4'$ in size. The authors suggest that the emission could be originated in the power wind nebula around the pulsar. In the soft X-ray band, between 0.1–2.4 keV, unpulsed radiation was detected with a 2 σ upper limit on the pulsed fraction of 18 %. This unpulsed emission is thought to originate in a synchrotron compact nebula of about $1'$ in size around the pulsar [7,8]. More recent ASCA HRI [8] and RXTE [9] data confirm the lack of pulsation. Observations of PSR B1706-44 in the very high energy γ-rays by the CANGAROO imaging Čerenkov telescope have revealed unpulsed TeV radiation at a 10 σ confidence level [10]. It was suggested that the TeV emission could be due to inverse Compton radiation from a PWN [4,5].

We report multi-frequency polarimetric VLA([1]) observations toward PSR B1706-44 carried out in order to verify the existence of the radio PWN associated with the pulsar.

2. – Radio observations and results

As a part of a program searching for galactic PWN, Giacani *et al.* [11] have observed the radio emission around several pulsars.

The extended emission in the vicinity of PSR B1706-44 was imaged at 1425, 4860 and 8460 MHz in different observing runs using the CnB and DnC configurations of the VLA. Also, it was observed at 1425 MHz using the BnA array. Data were obtained in the Stokes parameters I Q U and V. The UV data from each array were combined to form a single dataset in order to obtain the shorter spatial frequencies. All data reduction and calibration was done following standard practice in use at the VLA. The beam size is $24'' \times 9''$ at 1425 MHz, $16'' \times 6''$ at 4860 MHz and $14'' \times 8''$ at 8460 MHz. The rms noise is near 4×10^{-5} Jy/beam in all frequencies.

The images obtained at 1425, 4860 and 8460 MHz reveal that PSR B1706-44 is surrounded by a synchrotron nebula about $4'$ (E-W direction) $\times 2'$ (N-S direction) in size. Significant linearly polarized intensity was detected at 4.8 and 8.4 GHz, with a mean fractional polarization of about 20 %.

From a least-squares fit in the $\log S$-$\log \nu$ plot, a radio spectral index $\alpha = 0.3$ (where S α $\nu^{-\alpha}$) between 330 MHz and 8.4 GHz was obtained, where the data at 330 MHz was taken from [6].

High degree of polarization ($> 5\%$) and flat radio spectral index ($0.1 \leq \alpha \leq 0.3$) are two unmistakable properties of the PWN in the radio band, thus we propose that this is the synchrotron nebula excited by the pulsar wind.

([1]) The NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. NRAO operates the VLA.

3. – Concluding remarks

We have presented high-resolution radio observations of the pulsar PSR B1706-44, revealing an extended surrounding nebula. We argue on the basis of its morphology, spectral index and polarization properties that this is the synchrotron nebula produced by the spin-down energy of the pulsar. These new data at low frequency allow to complete a very broadband spectrum of the nebular component of PSR B1706-44 from radio up to TeV energy band, a necessary tool to improve the theoretical models of pulsar nebulae.

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