COMPTEL DETECTION OF PULSED EMISSION FROM PSR B1509-58 UP TO AT LEAST 10 MEV

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ABSTRACT We report the COMPTEL detection of pulsed $\gamma$-emission from PSR B1509-58 up to at least 10 MeV using data collected over more than 6 years. The 0.75-10 MeV lightcurve is broad and reaches its maximum near radio-phase 0.38, slightly beyond the maximum found at hard X-rays/soft $\gamma$-rays. In the 10-30 MeV energy range a strong source is present in the skymap positionally consistent with the pulsar, but we do not detect significant pulsed emission. However, the lightcurve is consistent with the pulse shape changing from a single broad pulse into a double-peak morphology. Our results significantly constrain pulsar modelling.

KEYWORDS: gamma-rays; pulsars; PSR B1509-58; COMPTEL.

1. INTRODUCTION

PSR B1509-58 was discovered in the late seventies as a 150 ms X-ray pulsar in Einstein data of the Supernova Remnant MSH 15-52 (Seward et al. 1982). Its inferred characteristic age and polar surface magnetic field strength are 1570 year and $3.1 \times 10^{13}$ Gauß. The latter estimate is among the highest of the radio-pulsar population. Ginga (2-60 keV) detected pulsed emission at hard X-rays (Kawai et al. 1991), the profile being broad and asymmetric, and its maximum trails the radio-pulse $0.25 \pm 0.02$ in phase. After the launch of the Compton Gamma-Ray Observatory (CGRO) pulsed emission in the soft $\gamma$-ray band was seen by BATSE (Wilson et al. 1993) and OSSE (Ulmer et al. 1993; Matz et al. 1995). At medium energy $\gamma$-rays indications were found near $\sim 1$ MeV in COMPTEL data (Hermsen et al. 1994; Carramiñana et al. 1995). The non-detection by EGRET (e.g. Brazier et al. 1994) indicates that the pulsed spectrum must break before the high-energy (HE) $\gamma$-rays. Here we report the results from a COMPTEL (0.75-30 MeV) study of PSR B1509-58 using data collected over more than 6 years, applying improved event selections. More detailed information will be given in Kuiper et al. (1999).
2. COMPTEL TIMING ANALYSIS RESULTS

The arrival times of the selected events at the spacecraft, each recorded with a 0.125 ms accuracy, have been converted to Solar System Barycentric arrival times and subsequently phase folded with a proper radio-pulsar ephemeris. The resulting 0.75-30 MeV lightcurve shows a 5.4σ modulation significance ($Z^2_2$-test) with a single pulse roughly aligned with the pulse detected at lower energies. The maximum of the pulse is at phase 0.38 slightly above 0.27 found at hard X-rays and coincides with the “shoulder” in the RXTE 2-16 keV lightcurve (Fig. 1a). For the differential energy windows 0.75-3 MeV, 3-10 MeV and 10-30 MeV we show the lightcurves in Fig. 1; the modulation significances are 3.7σ, 4.0σ and 2.1σ, respectively. This proves that we detected pulsed emission from this source at least up to 10 MeV. The 10-30 MeV lightcurve (Fig. 1b) shows an indication for the broad pulse and a high bin near phase 0.85, which seems to be responsible for the low modulation significance. Based on the RXTE lightcurve (Fig. 1a) we defined an “unpulsed” phase interval: 0.65-1.15. The excess counts in the “pulsed” interval, 0.15-0.65, have been converted to flux estimates for the 3 COMPTEL energy windows taking into account the efficiency factors due to our event selection criteria. These “pulsed” fluxes are: $(3.69 \pm 0.73) \times 10^{-5}$, $(4.52 \pm 0.77) \times 10^{-6}$ and $(1.21 \pm 0.85) \times 10^{-7}$ in units $ph/cm^2 \cdot s \cdot MeV$ for the energy windows 0.75-3 MeV, 3-10 MeV and 10-30 MeV, respectively.

3. COMPTEL IMAGING ANALYSIS RESULTS

We performed imaging analyses selecting also on pulse phase (“Total”, phase range 0-1; “Pulsed” and “Unpulsed” intervals). Below 10 MeV the signal from PSR B1509-58 is consistent with being 100% pulsed (Kuiper et al. 1999). In the 10-30 MeV range, where the timing analysis did not reveal significant modulation, we surprisingly detect in the “Total” map a $\sim 6\sigma$ source atop the instrumental and galactic diffuse background positionally consistent with the pulsar (see Collmar et al., these proceedings). In view of the absence of any measurable pulsar/nebula DC emission or nearby unrelated source below 10 MeV, where COMPTEL is more sensitive, we consider it most likely that the pulsar is also detected above 10 MeV, possibly changing its pulse morphology. In order to find support for the latter interpretation we also analysed contemporaneous EGRET 30-100 MeV data.

4. EGRET 30-100 MeV AND COMPTEL 10-30 MeV RESULTS

In the spatial analysis in the EGRET 30-100 MeV energy window we detected a 6.7σ excess positionally consistent with PSR B1509-58, which is probably composed of contributions from both the unidentified EGRET source 2EG J1443-6040 and PSR B1509-58. In the timing analysis, applying the same event selections as in the spatial analysis in combination with a “standard” energy dependent cone selection (Thompson et al. 1996), we found only a 1.1σ deviation from a flat distribution (Fig. 1d). Summing the independent COMPTEL 10-30 MeV and EGRET 30-100
5. COMPARISON WITH THEORY

For explaining pulsed HE-radiation two categories of models exist, polar cap and outer gap, with as main difference the production site of the HE-radiation. Recently, in a polar cap scenario Harding et al. (1997) (see also Baring & Harding these proceedings) tried to explain the earlier HE-spectrum of PSR B1509-58 by including the exotic photon splitting process, only effective for magnetic field strengths near $\sim 4.41 \times 10^{13}$ Gauß, to attenuate the primary HE-$\gamma$-rays in their cascade calculations. Our new 0.75-30 MeV data constrain the magnetic co-latitude of the emission rim,
one of their model parameters, to be about 2°, close to the “classical” polar cap half-angle. In the outer gap scenario (Romani 1996) several distinct HE-radiation components can be identified. If the synchrotron component, most important at medium energy γ-rays, is dominant, then also this model might qualitatively explain the HE-spectrum of PSR B1509-58. Another high B-field young pulsar resembling PSR B1509-58, although ∼20 times weaker in spin-down flux, is PSR B1610-50. This pulsar will also be a promising target for future INTEGRAL observations.

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