STATUS OF A SEARCH FOR RADIO EMISSION FROM THE YOUNG 16-MS X-RAY PULSAR PSR J0537-6910

F. Crawford (1), M. McLaughlin (2), S. Johnston (3), R. Romani (4) and E. Sorrelgreen (1)

(1) Haverford College, (2) Jodrell Bank, (3) University of Sydney, (4) Stanford University

Abstract

Using the Parkes 64-m telescope, we have obtained a 12 hour observation of PSR J0537-6910 at 20 cm with high time and frequency resolution and searched for previously undetected radio pulsations (both giant and standard). The very large value of the pulsar's magnetic field at the light cylinder radius suggests that this pulsar may be emitting giant radio pulses like those seen in other pulsars with similar field strengths. We have not detected radio pulsations, and the upper limits for the radio luminosity of PSR J0537-6910 are likely to be the best available for the foreseeable future.

PSR J0537-6910

- PSR J0537-6910 discovered in X-rays by Marshall et al. (1998) with RXTE
- Inferred magnetic field strength at the light cylinder is higher than that of any known pulsar (good candidate for giant pulses)
- Fastest non-recycled pulsar known, (P = 16 ms)
- Located in SNR N157B in the LMC (see Figure 1)
- "Crab-like" pulsar:
  young (τ_c < 5 kyr)
  energetic (Edot = 5 x 10^{38} erg s^{-1})
  frequent glitcher
- No radio pulsations detected after X-ray discovery (Crawford et al. 1998)
- Previous 1400 MHz luminosity limit of 150 mJy kpc^2

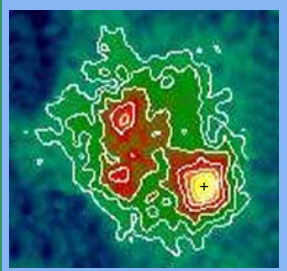

Figure 1: False color X-ray image of SNR N157B in the LMC. The location of PSR J0537-6910 is indicated by cross.

Motivation

Detection of a radio counterpart important for several reasons:

- Secondary timing method (ground-based observations)
- Possible determination of braking index *n* (e.g. Camilo et al. 2000) with long-term timing, test spin-down models (e.g., Melatos 1997)
- Investigation of pulsar glitch phenomenon (e.g. Alpar 1995), known to be common in young pulsars
- A measured dispersion measure (DM) would constrain LMC plasma distribution (e.g. Crawford et al. 2001).
- Determination of phase offset in X-ray/radio pulse profile, would aid understanding of magnetospheric physics of pulsars (Romani & Yadigaroglu 1995).
- Giant pulse detection would confirm connection with light-cylinder magnetic field strength

Observations and Analysis

Observations

- Used 64-m Parkes radio telescope
- Multibeam receiver (center beam only)
- Center frequency 1390 MHz, bandwidth 256 MHz
- 12 hr integration, sampling time 0.080 ms
- 512 channels used, 0.5 MHz per channel
- 32 GB raw data file produced
- Limiting flux sensitivity of about 0.02 mJy at 1400 MHz (see Figure 2)
- Corresponding 1400 luminosity limit of 50 mJy kpc^2 (factor of three improvement over previous limits)

Analysis

- Standard pulse search conducted with 20 computer Linux cluster at Haverford College
- 75 trial dedispersions from 50 to 200 pc cm^{-3}
- Both standard FFT search and folding trials at periods near nominal fold period
- Fold search spanned ± 1000 ns from the ephemeris period
- Period fold steps of 0.5 ns, ensures a maximum of 5% pulse smear

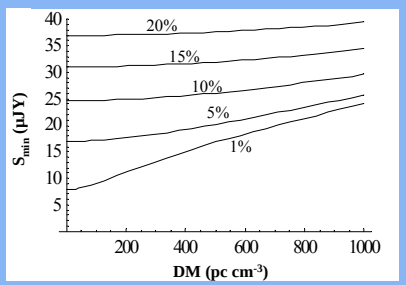

Figure 2. Plot of minimum detectable flux density , S_{min}, as a function of DM for PSR J0537-6910 for representative intrinsic duty cycles (ranging from 1-20%). Sensitivity calculated after Dewey et al. (1985).

Giant Pulse Search

- Good candidate for giant pulse search, light-cylinder magnetic field is largest known
- Light cylinder magnetic field is more than *twice as high* as next highest pulsar (see Table 1)

Table 1
Pulsars with the highest light-cylinder magnetic field strengths, B_{lc}

PSR	B_{lc} (x 10^5 Gauss)
J0537-6910	**20.6**
B1937+21	9.8
B0531+21 (Crab)	9.3
B1821-24	7.2
B0540-69	3.5

Giant Pulse Search

- Used 1000 trial DMs from 0 to 300 pc cm^{-3}
- Each dedispersed time series searched for pulses above 5σ threshold
- Times series smoothed multiple times to increase sensitivity to broadened pulses
- Incorporated procedures to remove pulses strongest at DM = 0 (likely RFI)

Giant Pulse Results

- No excess of single pulses at any particular DM and no single pulses with S/N greater than 7 detected.
- For comparison, for PSR B0540-69 expect to have detected 4-6 giant pulses above detection threshold
- Conclude that non-detection is probably a matter of sensitivity

Results

- No standard radio signal found through FFT search or folding search, no giant pulses found
- 1400 MHz luminosity upper limit (L_{1400}) is about 50 mJy kpc^2
- L_{1400} limit is comparable to or less than L_{1400} of several young pulsars with τ_c < 10 kyr (see Table 2)
- However, luminosity range for the young pulsar population spans two orders of magnitude (so no strict conclusions can be made)

Table 2
1400 MHz Luminosities of Young Rotation-powered Pulsars (with τ_c < 10 kyr)

PSR	τ_c (kyr)	P (sec)	L_{1400} (mJy kpc^2)
J1846-0258	0.72	0.051	< 50
B0531+21 (Crab)	1.24	0.033	56
B1509-58	1.55	0.150	27
J1119-6127	1.61	0.407	20
B0540-69	1.67	0.050	200
J1124-5916	2.87	0.135	2.3
J1930+1852	2.89	0.137	1.5
J0537-6910	**4.98**	**0.016**	**< 50**
J0205+6449	5.37	0.065	0.46
J1357-6429	7.30	0.166	2.7
J1614-5048	7.42	0.232	130
J1617-5055	8.13	0.069	20
J1734-3333	8.13	1.169	27

Full details of search status and results at http://cs.haverford.edu/pulsar

HAVERFORD

References

Alpar, M. A. 1995, in The Lives of the Neutron Stars, Kluwer: Dordrecht, 185

Camilo, F. et al. 2000, ApJ, 541, L367

Crawford, F. et al. 1998, Memorie della Societa Astronomia Italiana, 69, 951

Crawford, F. et al. 2001, ApJ, 541, 367

Dewey, R. J. et al. 1985, ApJ, 294, L25

Marshall, F. E et al. 1998, ApJL, 499, 179

Melatos, A. 1997, MNRAS, 288, 1049

Romani, R. W. & Yadigaroglu, I. A. 1995, ApJ, 438, 314