UPPER LIMITS ON RADIO EMISSION FROM THE YOUNG X-RAY PULSARS IN THE SUPERNOVA REMNANTS G11.2−0.3 AND N157B

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ABSTRACT. Using the Parkes radio telescope, we have searched for pulsed radio emission from the recently discovered X-ray pulsars AX J1811.5−1926 and PSR J0537−6910 in the supernova remnants G11.2−0.3 and N157B, respectively. We detected no significant pulsed radio emission from these pulsars and have set an upper limit of 0.07 mJy on the 1374 MHz flux from AX J1811.5−1926 and upper limits of 0.18 mJy and 0.06 mJy for the flux from PSR J0537−6910 at 660 MHz and 1374 MHz, respectively. Assuming a power law radio spectral index of 2, these flux limits correspond to luminosity limits at 400 MHz of 20 mJy kpc^2 for AX J1811.5−1926 and 1100 mJy kpc^2 for PSR J0537−6910. Our luminosity limit for AX J1811.5−1926 is lower than the observed luminosities of other young radio pulsars. The upper limit on the luminosity for PSR J0537−6910 in N157B is not significantly constraining due to the large distance to the pulsar. We have also searched for giant radio pulses from both pulsars and have found no convincing candidates.

1. Introduction

Recently, two rotation-powered X-ray pulsars were discovered in the young supernova remnants G11.2−0.3 and N157B. The pulsar AX J1811.5−1926 in the Galactic remnant G11.2−0.3, discovered in archival *ASCA* data, has a 65 ms period (Torii et al. 1997). PSR J0537−6910, discovered in N157B in the Large Magellanic Cloud (LMC), was found in *XTE* data and has a period of 16 ms, making it the fastest known pulsar associated with a remnant (Marshall et al. 1998). The discovery of these two pulsars brings the total number of known young Crab-like pulsars in plerionic nebulae to five and doubles the number of such systems known in the LMC.

The discovery of pulsed radio emission from these systems would be important for several reasons. A determination of the dispersion measure (DM) for these pulsars would constrain the electron distribution toward the LMC as well as the Taylor & Cordes (1993) Galactic DM-distance model. In addition, determining the radio luminosity distribution for young pulsars is important for population synthesis models. Furthermore, ground-based radio telescope facilities are often more practical for long-term timing of pulsars

than are X-ray instruments. For young pulsars with high spin-down rates, long-term timing can determine accurate braking indexes. In the several cases where young pulsars show infrequent but sudden spin-ups known as glitches, radio timing can also give information on the interior physics of the neutron star (e.g. Shemar & Lyne 1996). In addition, measuring a time-of-arrival phase offset between the radio and X-ray pulses helps constrain the pulsar magnetic field geometry and radiation emission mechanism (e.g. Romani & Yadigaroglu 1995).

2. Observations and Analysis

We have undertaken a search for pulsed radio emission from these two pulsars using the 64-m radio telescope in Parkes, NSW, Australia. We conducted the search at two center frequencies, 660 MHz and 1374 MHz. For the 1374 MHz observations, we used the center beam of the newly installed 20-cm multibeam receiver with a filter-bank back end designed and built at Jodrell Bank. The search setup used was similar to that of the current Parkes multibeam pulsar survey, described elsewhere (Camilo et al. 1997). AX J1811.5−1926 was observed for a single 4.5 hr integration at 1374 MHz while PSR J0537−6910 was observed twice at 660 MHz in separate 4 hr integrations and once at 1374 MHz for 6 hr. Data were recorded on magnetic tape for processing offline. As part of this same project, we searched for and found the pulsar PSR J1617−5055 at 1374 MHz near the supernova remnant RCW 103 (Kaspi et al. 1998) which was also first discovered as an X-ray pulsar from archival *ASCA* data (Torii et al. 1998).

Since the predicted topocentric period for AX J1811.5−1926 was uncertain due to the unknown period derivative of the pulsar, we performed a standard spectral analysis, after first dedispersing the data at a variety of DMs from 0 to 1477 pc cm^{-3}. After each dedispersion, the frequency channels were summed and a power spectrum computed from the resulting time series. This power spectrum was then searched for significant spikes. Each candidate frequency was then further investigated by dedispersing and folding the original data at the candidate DM and period. A search was then performed for a small range in DM and period around the nominal DM and period and the highest resulting signal-to-noise profile was computed.

Since the ephemeris for PSR J0537−6910 has a well-constrained period derivative (Marshall et al. 1998), we folded the data at the predicted topocentric period at a variety of DMs spanning 0 to 300 pc cm^{-3}, which includes the expected DM range of 50 to 200 pc cm^{-3} for LMC pulsars, based on previous pulsar discoveries (McConnell et al. 1991, Manchester et al. 1993). In each DM trial, the data were searched in a period range spanning the nominal folding period. For the 660 MHz data, this period range was ±150 ns, and for the 1374 MHz data the range was ±95 ns, corresponding to ±36σ and ±23σ from the expected period, respectively.

We have also searched the dedispersed time series for Crab-like giant radio pulses at the expected range of DMs. In this search, each dedispersed time series was rebinned at a variety of widths and searched for samples greatly exceeding the noise. Potential giant pulse candidates were investigated by examining the non-dispersed time series for a strong signal in the same part of the time series in order to rule out signals from terrestrial interference. For pulsar AX J1811.5−1926, we searched a DM range from 40

to 670 pc cm^{-3} and found no convincing giant pulse candidates. For PSR J0537$-$6910, we searched the two 660 MHz data sets and the 1374 MHz data set over the expected LMC DM range of 50 to 200 pc cm^{-3}. We found no convincing giant pulse candidates in any of the three N157B data sets.

3. Results and Discussion

We did not detect radio pulsations from either of the two X-ray pulsars. By assuming distances to the remnants and using the Taylor & Cordes (1993) DM-distance model to estimate temporal smearing of pulses from dispersion, we set upper limits for pulsed emission of 0.07 mJy and 0.06 mJy at 1374 MHz for AX J1811.5$-$1926 and PSR J0537$-$6910, respectively. We have also set an upper limit of 0.18 mJy for the 660 MHz flux for PSR J0537$-$6910. By assuming a radio power law index of $\alpha = 2$ and distances of $d = 5$ kpc for G11.2$-$0.3 (Green et al. 1988) and $d = 47$ kpc for N157B (Gould 1995), we obtain 400 MHz luminosity (L_{400}) upper limits for the two pulsars, for comparison with other sources. For AX J1811.5$-$1926, $L_{400} < 20$ mJy kpc^2. For PSR J0537$-$6910, the luminosity upper limit is $L_{400} < 1100$ mJy kpc^2 using the more constraining 660 MHz flux limit. These results are outlined in Table 1.

Table 1 - Summary of Radio Observations

Remnant Name	G11.2$-$0.3	N157B
Pulsar Name	AX J1811.5$-$1926	PSR J0537$-$6910
Period	65 ms	16 ms
S_{660} upper limit	$-$	0.18 mJy
S_{1374} upper limit	0.07 mJy	0.06 mJy
Assumed distance	5 kpc	47 kpc
L_{400} limit (for $\alpha = 2$)	20 mJy kpc^2	1100 mJy kpc^2

Of the five known radio pulsars having characteristic age $\tau_c \equiv P/2\dot{P} < 10$ kyr (the Crab pulsar, PSR B1509$-$58, PSR B0540$-$69, PSR B1610$-$50, and PSR J1617$-$5055), PSR B1509$-$58 has the lowest pulsed radio luminosity, $L_{400} \simeq 50$ mJy kpc^2. The largest luminosities belong to the Crab pulsar and PSR B0540$-$69, which have $L_{400} = 2600$ mJy kpc^2 and 1800 mJy kpc^2 respectively. Of course, all luminosity estimates are distance-dependent, hence subject to some uncertainty.

Our upper limit of $L_{400} < 20$ mJy kpc^2 for AX J1811.5$-$1926 is significantly lower than the luminosities of the Crab pulsar and PSR B0540$-$69 and is below the value for PSR B1509$-$58. This suggests that AX J1811.5$-$1926 should have detectable radio emission. From the Taylor & Cordes (1993) DM-distance model, we estimate that the expected DM for AX J1811.5$-$1926 is $\sim$350 pc cm^{-3}, corresponding to about 3 ms dispersion smearing in each frequency channel, and that the multipath scattering from plasma inhomogeneities should be less than 1 ms. Thus, neither of these effects should significantly affect the detectability of the 65 ms periodicity. Therefore, the non-detection means that either the radio beam does not intersect our line of sight or that the radio

luminosities of very young pulsars can be lower than what has been generally thought (e.g. Narayan & Ostriker 1990). If the latter is true, then deeper radio searches with higher sensitivity may reveal a previously undiscovered population of young faint pulsars.

Our luminosity limit is not as stringent for PSR J0537−6910 due to its large distance. Also, the poorly known interstellar/intergalactic medium in this direction could significantly scatter radio pulses beyond detectability, particularly at 660 MHz.

4. Conclusions

We conclude from our search that the X-ray pulsar AX J1811.5−1926 in G11.2−0.3 has pulsed radio emission that is certainly of significantly lower flux than all other known pulsars of comparable age, and is probably either underluminous relative to these sources or is not beaming toward Earth. Our much less stringent limits on the radio luminosity for PSR J0537−6910 in N157B are unconstraining. Next generation telescopes such as the square kilometer array would be ideal instruments to carry out deeper searches toward these sources.

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