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A Sensitive Targeted Search Campaign at Parkes to Find Young Radio Pulsars at 20 cm

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Abstract. We describe a sensitive targeted search campaign at Parkes to find faint young radio pulsars using the center beam of the 20-cm multibeam receiver. The high frequency of the receiver mitigates scattering effects which can dominate profiles of distant pulsars at low frequencies and prevent detection. The targets included several composite supernova remnants (SNRs), two fast X-ray pulsars, long-period anomalous X-ray pulsars, and a soft gamma repeater. The sensitivity limits in this search are significantly better than those previously reported for these objects. We have discovered three new radio pulsars, two of which are not associated with the target objects. The third pulsar, PSR J1713−3949, is possibly associated with SNR G347.3−0.5; the estimated ages and distances of the two objects are consistent, but a more significant positional coincidence must be established with the central X-ray source in the SNR through pulsar timing to confirm or refute the association.

1. Introduction

The highly successful Parkes Multibeam Pulsar Survey (PM Survey) and other recent surveys have used the 20-cm multibeam receiver on the Parkes telescope for pulsar searches (e.g., Manchester et al. 2001; Crawford et al. 2001). Apart from the advantages of the multiple beams and good raw sensitivity of this receiver, deleterious pulse scattering and dispersion smearing effects are greatly reduced at the high observing frequency. This instrument is therefore good for finding fast, distant pulsars which may have been missed in previous low-frequency surveys.

2. Search Observations

We have used the multibeam receiver and the Parkes telescope to search young objects for radio pulsars. The list of objects is shown in Table 1 and includes supernova remnants (SNRs), anomalous X-ray pulsars (AXPs), fast X-ray pulsars, and a soft gamma repeater (SGR). In the search, we used the center beam of the multibeam receiver at a center frequency of 1374 MHz. Integration times of 16800 s were typically used with 0.25 ms sampling and 288 MHz of bandwidth split into 96 channels. During processing, data were dedispersed at trial dispersion measures (DMs) ranging from 0 to 3000 pc cm^{-3}, frequency channels were summed, and each resulting time series was filtered then Fourier transformed to get an amplitude spectrum for each DM trial. Candidate periods were identified in the spectra, and the original data were dedispersed and folded at these periods. The flux sensitivity limits of the searches in all cases are $S_{\rm min} \lesssim 0.3$ mJy at 1374 MHz (see Table 1). These limits were estimated using the survey sensitivity modeling described in Crawford (2000) and Manchester et al. (2001), and they took into account estimates of DM, scattering, and sky temperature, as well as instrumental effects. For those objects for which no *a priori* period was known, $P = 50$ ms was assumed in the sensitivity calculations. The flux sensitivity limits in all cases are better than those previously reported for these objects. However, they depend on assumptions about pulsed duty cycle, period, DM, and scattering effects.

3. Search Results

We obtained upper limits at 1374 MHz for most objects (Table 1), and discovered three new radio pulsars in the search. These discoveries are presented in Table 2 and are described below.

Table 1. Target Objects Searched

Target Object	Period (s)	Distance (kpc)	DM (pc cm^{-3})	$S_{\rm min}^{1374}$ (mJy)	Result/PSR
SNR G0.9+0.1	?	10 ± 3	~ 775	0.18	J1747−2802
SNR G21.5−0.9	?	5.5 ± 0.5	~ 360	0.16	–
SNR G266.2−1.2	?	$\lesssim 1$	$\lesssim 85$	0.11	–
SNR G327.1−1.1	?	6.5 ± 1	~ 330	0.07	–
SNR G347.3−0.5	?	6 ± 1	~ 450	0.06	J1713−3949
A0538−66	0.069	~ 50	~ 100	0.04	–
AX J0043−737	0.087	~ 57	~ 100	0.04	–
1E 1048−5937	6.456	~ 10?	~ 500?	0.13	–
AX J1845−0258	6.971	~ 10?	~ 960?	0.13	J1844−0256
1E 1841−045	11.774	~ 7	~ 560	0.25	–
RXS J1708[a]	11	~ 10?	~ 800?	0.22	–
SGR 0526−66	8	~ 50	~ 100	0.14	–

[a]RXS J170849−400910

Table 2. Newly Discovered Pulsars.

PSR	J1713−3949	J1747−2802	J1844−0256
P (ms)	392	2780	273
$\tau_c \equiv P/2\dot{P}$	$\sim$ 100 kyr	$\sim$ 20 Myr	$\sim$ 300 kyr
DM (pc cm^{-3})	337 ± 3	795 ± 10	820 ± 3
Distance (kpc)	5.0 ± 0.2	11.4 ± 0.1	8.8 ± 0.5
S/N$_{\rm detection}$	33.4	10.7	22.9
Target Object	SNR G347.3−0.5	SNR G0.9+0.1	AX J1845−0258
Association?	possible	no	no

3.1. PSR J1713−3949

PSR J1713−3949 has a period P = 392 ms and was discovered while searching the X-ray point source 1WGAJ1713.4−3949 at the center of SNR G347.3−0.5 (see Figure 1). This central source is believed to be a neutron star associated with the SNR (Slane et al. 1999). The pulsar's DM of 337 pc cm^{-3} indicates a distance of $\sim$ 5 kpc using the Taylor & Cordes (1993) DM-distance model. This is consistent with the estimated SNR distance of 6 ± 1 kpc (Slane et al. 1999). A measured period derivative obtained from observations of the pulsar taken a year apart indicates a characteristic age of $\tau_c \equiv P/2\dot{P} \sim 100$ kyr. This value is larger than the SNR age of $\tau_{\rm SNR} \lesssim 40$ kyr suggested by Slane et al. (1999). However, these ages could still be consistent given the uncertainties in both of the age estimates and the possibility that τ_c might not reflect the true pulsar age.

The positional coincidence of PSR J1713−3949 with 1WGAJ1713.4−3949 also suggests an association with the SNR, but the uncertainty in the pulsar's position is large ($\sim 7'$, the discovery beam radius). A timing solution for the pulsar will provide arcsecond positional accuracy for the pulsar as well as a more accurate age estimate. This will enable us to establish a more significant positional coincidence with 1WGAJ1713.4−3949 which can directly confirm or refute an association between PSR J1713−3949 and SNR G347.3−0.5.

3.2. PSR J1747−2802 and PSR J1844−0256

PSR J1747−2802 is coincident with SNR G0.9+0.1 and has a period P = 2780 ms and DM = 795 pc cm^{-3} with a large scattering tail ($\tau_{\rm scat} \sim 100$ ms). This pulsar was also discovered in the PM Survey, and timing results are reported in detail by Morris et al. (2002). The pulsar is old ($\tau_c \sim 20$ Myr) and is clearly not associated with SNR G0.9+0.1 ($\tau_{\rm SNR} \sim$ 1–7 kyr).

PSR J1844−0256 was discovered in a search of AXP AX J1845−0258. Its P = 273 ms and DM = 820 pc cm^{-3} with a large scattering tail ($\tau_{\rm scat} \sim 40$ ms). The period derivative obtained from observations taken a year apart indicates that the pulsar is much older ($\tau_c \sim 300$ kyr) than the target AXP ($\tau_{\rm AXP} \lesssim 10$ kyr), which is associated with SNR G29.6+0.1 (Gaensler, Gotthelf, & Vasisht 1999). The pulsar's age and observed period indicate that there is no association with AX J1845−0258.

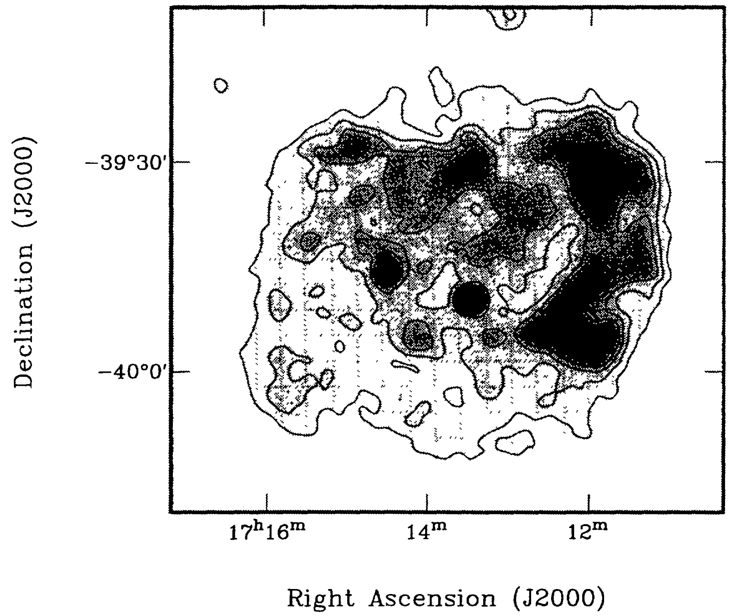

Figure 1. X-ray image of SNR G347.3−0.5 (Figure 1 of Slane et al. 1999). The discovery beam of PSR J1713−3949 was centered on the X-ray point source 1WGAJ1713.4−3949 (dark circular knot) at the center of the SNR, which is believed to be a neutron star.

4. Conclusions

We have used the 20-cm multibeam receiver at Parkes to conduct targeted pulsar searches of young objects. Our upper limits on radio pulsations from these objects are the best yet obtained, but they depend on assumptions about pulsed duty cycle, scattering effects, and DM. Three new pulsars were discovered in the search; two of the pulsars (PSRs J1747−2802 and J1844−0256) are not associated with the target objects, while PSR J1713−3949 might be associated with SNR G347.3−0.5. The agreement in age and distance suggests a possible association. However, a more significant positional coincidence must be established between PSR J1713−3949 and the central X-ray source 1WGAJ1713.4−3949 in SNR G347.3−0.3 to confirm or refute this conclusion.

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