1992ApJ...399L.155K

The Astrophysical Journal, 399:L155–L157, 1992 November 10

PSR J1341−6220: A YOUNG PULSAR IN A SUPERNOVA REMNANT

Victoria M. Kaspi
Joseph Henry Laboratories and Physics Department, Princeton University, Princeton, NJ 08544

R. N. Manchester and Simon Johnston
Australia Telescope National Facility, CSIRO, P.O. Box 76, Epping, NSW 2121, Australia

A. G. Lyne
University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank, Macclesfield, SK11 9DL, UK

and

N. D'Amico
Istituto di Fisica dell'Università di Palermo and Istituto di Radioastronomia del CNR, Bologna, 40126, Italy
Received 1992 June 22; accepted 1992 August 17

ABSTRACT

Timing observations of PSR J1341−6220 (PSR B1338−62) made over a 27 month period using the 64 m Parkes radio telescope show that this pulsar is young and located within the supernova remnant G308.8−0.1. The pulsar characteristic age of 12,000 years and its estimated distance are comparable to the corresponding estimates for the remnant, confirming the association. The location of the pulsar suggests that it plays a significant role in determining the morphology of the remnant. Two large glitches and one smaller glitch have been observed in the pulsar period since the beginning of our observations, making it the most actively glitching pulsar known.

Subject headings: pulsar: individual (PSR J1341−6220) — supernova remnants

1. INTRODUCTION

Of the over 550 pulsars now known, in only eight cases is there convincing evidence for an association with a supernova remnant. The paucity of such associations may be attributable to many factors, such as relatively short supernova remnant fading times, small pulsar beaming angles, and asymmetric supernova explosions that eject the pulsar from the remnant. When considering the statistics of pulsar-supernova remnant associations, these factors must be taken carefully into account. Another significant reason for so few associations that has recently emerged is the incomplete mapping of some supernova remnants. For example, G5.4−1.2 is a remnant that was considered to have an unusual morphology, and perhaps to exemplify a "new class of radio source" (Becker & Helfand 1985), until Caswell et al. (1987) showed that there is an arc of emission outside the original map. Once the extension was observed, the remnant showed the familiar bilateral symmetry, and the association of the pulsar PSR B1758−24 (also known as PSR B1757−24) with the remnant was readily made (Frail & Kulkarni 1991; Manchester et al. 1991).

In a companion paper, Caswell et al. (1992) report on the detection of a low-level arclike feature to the south of G308.7+0.0, which they argue is an extension of G308.7+0.0. The combined source, designated G308.8−0.1, has a total extent of 25′ and encompasses PSR J1341−6220 (PSR B1338−62). This pulsar, like PSR B1758−24, was discovered in a search for pulsars associated with supernova remnants by Manchester, D'Amico, & Tuohy (1985). Its location south of G308.7+0.0 suggested that it was not associated with the remnant which appeared centrally condensed in the image of Caswell, Milne, & Wellington (1981). This situation has now changed with the discovery of the southern feature by Caswell et al. (1992). The location of the pulsar near the center of the remnant now strongly suggests that the two objects are associated.

In this paper we report on timing observations of PSR J1341−6220, made using the 64 m Parkes radio telescope over nearly 2.5 years. Analysis of these results shows that the pulsar has the fourth-largest known period derivative and hence is very young. Not only is the pulsar located centrally within the supernova remnant, but it lies near the tip of a feature extending from the brighter northern portion. These facts establish beyond any doubt the association of the pulsar with the supernova remnant. The pulsar has suffered two large and one small period glitches in less than 2.5 years. The large glitches are comparable in size to those observed in the Vela pulsar.

2. OBSERVATIONS AND RESULTS

Using the 64 m Parkes radio telescope, we have made timing observations of PSR J1341−6220 at a central observing frequency of 1520 MHz. A total of 67 observations in 28 separate sessions were made from 1990 January through 1992 May using a cryogenically cooled, dual-channel system which received orthogonal linear polarizations. The signals were down-converted to an intermediate frequency, filtered in a 2 × 64 × 5 MHz multichannel filterbank spectrometer, detected and low-pass filtered. After summing the two polarizations, the signals were sampled at 1.2 ms intervals by a multichannel one-bit digitizing system and recorded on magnetic tape. One observation of PSR J1341−6220 typically lasted 500 s. Mean pulse profiles were formed off-line by folding the data for each observation at the apparent pulsar period. Pulse arrival times were then obtained by cross-correlating the mean profiles with a standard template. Period parameters were obtained using the program TEMPO with the JPL ephemeris DE200. Relative pulse arrival times across

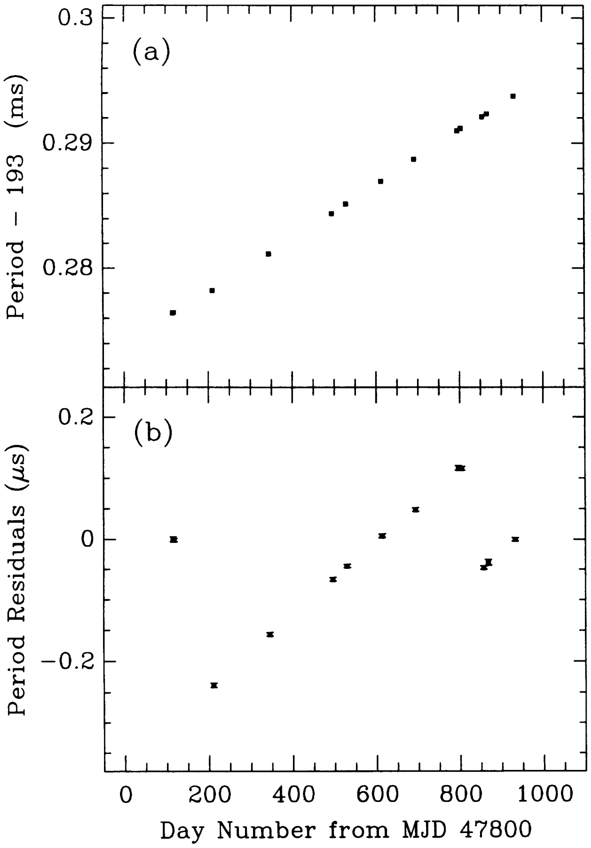

FIG. 1.—Barycentric period of PSR J1341−6220 vs. time (*a*) before and (*b*) after subtracting the mean period derivative of 246.08×10^{-15}. Periods were determined by fitting to groups of three or four arrival times separated by a few days. In (*a*) the periods have errors smaller than the plotted points.

the 320 MHz bandwidth of the receiver were used to estimate the dispersion measure.

It was soon clear from the arrival-time analysis that PSR J1341−6220 has a very large period derivative and is subject to large period irregularities. Figure 1*a* illustrates the rapid spin-down rate, and Figure 1*b* shows the period variations remaining after subtracting the mean period derivative. It is clear that the pulsar suffered two large glitches during the 28 month span of our observations. A more detailed analysis shows that a third, much smaller, glitch occurred between the two large glitches. Table 1 gives period parameters for four intervals, separated by the three glitches. Data from the second and longest interval were used to determine the pulsar position. Only the period and period derivative were fitted in the other three intervals. Quoted errors are twice the formal standard deviation, and, for the periods, the error is in units of the last quoted digit.

There is no evidence for any relaxation of the period toward the preglitch value after the glitches. However, rapid decays could have been easily missed because of the large gaps between observing sessions, and decays with longer time scales could have been at least partly absorbed into the fitted period and its derivative. Table 2 lists the glitch epochs and the corresponding values of $\Delta P/P$. The $\Delta P/P$ values were calculated for the center of the interval by extrapolation of the adjacent fits; quoted errors include a contribution resulting from the uncertainty in glitch epoch.

TABLE 1

PARAMETERS FOR PSR J1341−6220

Parameter	Value
Right ascension (J2000)	$13^{\rm h}41^{\rm m}42\overset{\rm s}{.}5 \pm 0\overset{\rm s}{.}2$
Declination (J2000)	$-62^\circ 20' 25'' \pm 2''$
Right ascension (B1950)	$13^{\rm h}38^{\rm m}15\overset{\rm s}{.}1$
Declination (B1950)	$-62^\circ 05' 16''$
Dispersion measure	730 ± 10 pc cm^{-3}
Mean flux density at 1520 MHz	1.9 ± 0.5 mJy
Characteristic age	12,000 yr
Surface magnetic field strength	7.1×10^{12} G
MJD range/No. of observations	47915–47968/9
Period	0.1932764286 ± 8 s
Period derivative	$252.8 \pm 0.4 \times 10^{-15}$
Period epoch (MJD)	47916.9800
RMS residual	616 μs
MJD range/No. of observations	48011–48441/28
Period	0.19328698190 ± 3 s
Period derivative	$253.083 \pm 0.002 \times 10^{-15}$
Period epoch (MJD)	48413.0000
RMS residual	1460 μs
MJD range/No. of observations	48465–48635/17
Period	0.19328778654 ± 9 s
Period derivative	$252.98 \pm 0.01 \times 10^{-15}$
Period epoch (Modified Julian Day)	48450.0000
RMS residual	792 μs
MJD range/No. of observations	48656–48745/13
Period	0.1932921194 ± 2 s
Period derivative	$253.23 \pm 0.04 \times 10^{-15}$
Period epoch (Modified Julian Day)	48657.0000
RMS residual	617 μs

3. DISCUSSION

The evidence for the association of PSR J1341−6220 with G308.8−0.1 is compelling. Figure 2 shows that the pulsar is located near the center of the remnant. The pulsar is young, and its characteristic age, $P/(2\dot{P})$, of 12,000 years is not inconsistent with the estimated age of the remnant. Caswell et al. (1992) quote 32,500 years for the remnant age, calculated on the assumption that it expanded into a homogeneous interstellar medium. They point out that the age could be much smaller if the remnant expanded into a preexisting cavity. The distance to the pulsar, obtained from the dispersion measure using a revised Galactic electron density model (J. H. Taylor 1992, private communication) and a solar Galactocentric radius of 8.5 kpc, is 15 kpc. Caswell et al. (1992) state that G308.8−0.1 is located beyond 4 kpc and estimate a distance, based on the observed radio surface brightness of the remnant, of 6.9 kpc. Given the considerable uncertainties in the distance estimates to both the pulsar and the remnant, and the strong likelihood of intervening H II regions along the line of sight to the pulsar, these values are compatible. We therefore conclude that PSR J1341−6220 and G308.8−0.1 were born in the same supernova explosion.

TABLE 2

THE GLITCHES OF PSR J1341−6220

Glitch Epoch (MJD)	$\Delta P/P$ (10^{-8})
47989 ± 22	150.4 ± 0.3
48453 ± 12	2.30 ± 0.06
48645 ± 11	99.3 ± 0.1

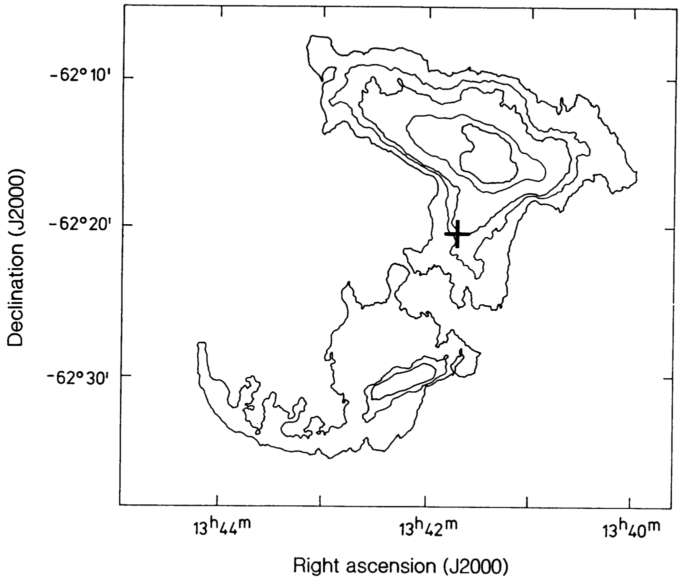

FIG. 2.—Radio continuum image of G308.8−0.1 at 843 MHz (after Caswell et al. 1992) with the position of PSR J1341−6220 marked by a cross.

The morphology of the G308.8−0.1–PSR J1341−6220 association is similar to that of G320.4−1.2 and PSR B1509−58 (Caswell et al. 1981; Manchester 1987; Caswell et al. 1992). In both cases, the remnant has a bright region (which happens to be slightly west of north from the pulsar in both cases) with a more extended shell-like structure on the other side of the pulsar. Figure 2 also shows that the bright region has an extension from its southern side toward the pulsar and that the pulsar is located near the tip of this extension. A very similar extension of the bright region toward the pulsar is observed in G320.4−1.2 (Manchester & Durdin 1983). The emission from the bright region may be due to a stronger interaction with the interstellar medium. If this is the case, the brighter side of the remnant is moving slower and has therefore traveled a shorter distance from the explosion center, marked by the location of the pulsar. This assumes, however, that the pulsar is located at its birthplace, whereas many pulsars are known to have large space velocities owing to the asymmetric supernova explosions that created them. Alternatively, these results may suggest that injection of relativistic particles from the pulsar is responsible for the enhanced emission. A similar injection was suggested by Frail & Kulkarni (1991) to account for the fact that the arc of G5.4−1.2 nearest to PSR B1758−24 is brighter than the opposing arc. If this is the case, then these brighter regions are "plerions" in the sense that they are driven by the pulsar despite their not being centered on the pulsar. The possible implications concerning anisotropic propagation of relativistic particles over large distances are interesting and require investigation.

A similar situation may exist in the Vela supernova remnant. It has long been proposed that the brighter Vela X portion of the remnant is a plerion (e.g., Weiler & Panagia 1980), driven by the pulsar. Milne & Manchester (1986) and Manchester (1987) argued that Vela X was a brighter section of the shell emission and not directly driven by the pulsar, and the proper motion measurements of Bailes et al. (1989) showed that the pulsar was not born within Vela X. Most recently, Dwarakanath (1991) has verified that the spectrum of Vela X is flatter than that of the remainder of the shell. All these observations could be reconciled if Vela X is near the boundary of the supernova remnant, but still powered by the pulsar.

With three glitches in 2.5 years, PSR J1341−6220 is the second most frequently glitching pulsar known, after PSR B1737−30 (McKenna & Lyne 1990). The two larger of the PSR J1341−6220 glitches are comparable in size to those which occur in the Vela pulsar (Cordes, Downs, & Krause-Polstorff 1988). McKenna & Lyne defined a "glitch activity parameter" to be the mean fraction change in period per year due to glitches. For PSR J1341−6220, the activity parameter is $\sim 10^{-6}$ yr^{-1}, about 20% more than that for the Vela pulsar, making it the most actively glitching pulsar known. This result is in accord with the trend, noted by McKenna & Lyne (1990), that pulsars with ages between 2000 and 20,000 years have the highest glitch activity. We also note that such pulsars are good candidates for pulsed gamma-ray emission.

This is the ninth reasonably well established pulsar–supernova remnant association (cf. Manchester et al. 1991). The number of associations, while still small compared to the number of known supernova remnants, continues to grow. We emphasize the importance of obtaining high surface brightness sensitivity images of supernova remnants in order to define their full angular extent. For G5.4−1.2 (Caswell et al. 1987) and G308.8−0.1 (Caswell et al. 1992), such images played an important role in establishing the association.

V. M. K. thanks the Natural Sciences and Engineering Research Council of Canada and the National Science Foundation for support.

REFERENCES

Bailes, M., Manchester, R. N., Kesteven, M. J., Norris, R. P., & Reynolds, J. E. 1989, ApJ, 343, L53
Becker, R. H., & Helfand, D. J. 1985, Nature, 313, 115
Caswell, J. L., Kesteven, M. J., Komesaroff, M. M., Haynes, R. F., Milne, D. K., Stewart, R. T., & Wilson, S. G. 1987, MNRAS, 225, 329
Caswell, J. L., Kesteven, M. J., Stewart, R. T., Milne, D. K., & Haynes, R. F. 1992, ApJ, 399, L151
Caswell, J. L., Milne, D. K., & Wellington, K. J. 1981, MNRAS, 195, 89
Cordes, J. M., Downs, G. S., & Krause-Polstorff, J. 1988, ApJ, 330, 847
Dwarakanath, K. S. 1991, A&A, 12, 199
Frail, D. A., & Kulkarni, S. R. 1991, Nature, 352, 785
Manchester, R. N. 1987, A&A, 171, 205
Manchester, R. N., D'Amico, N., & Tuohy, I. R. 1985, MNRAS, 212, 975
Manchester, R. N., & Durdin, J. M. 1983, in IAU Symp. 101, Supernova Remnants and Their X-Ray Emission, ed. J. Danziger & P. Gorenstein (Dordrecht: Reidel), 421
Manchester, R. N., Kaspi, V. M., Johnston, S., Lyne, A. G., & D'Amico, N. 1991, MNRAS, 253, 7P
McKenna, J., & Lyne, A. G. 1990, Nature, 343, 349
Milne, D. K., & Manchester, R. N. 1986, A&A, 167, 117
Weiler, K. W., & Panagia, N. 1980, A&A, 90, 269