Discovery of a Young, Energetic Pulsar Near the Supernova Remnant G290.1−0.8 and the γ-ray Source 2EG J1103−6106

V. M. Kaspi[1]

IPAC/Caltech/Jet Propulsion Laboratory, Pasadena CA 91127

M. Bailes

University of Melbourne, School of Physics, Parkville, Victoria 3052, Australia

R. N. Manchester

Australia Telescope National Facility, CSIRO, PO Box 76, Epping NSW 2121, Australia

B. W. Stappers

Mount Stromlo and Siding Spring Observatories, ANU, Private Bag, Weston Creek, ACT 2611, Australia

J. Sandhu

California Institute of Technology, MS 105-24, Pasadena, CA 91125

J. Navarro

Orrestien 2511, 4022 Stavanger, Norway

N. D'Amico

Osservatorio Astronomico, via Zamboni 33, 40126 Bologna and Istituto di Radioastronomia, Via P. Gobetti 101, 40129 Bologna, Italy

Received _____, accepted _____

[1]Hubble Fellow

ABSTRACT

We report on the discovery and follow-up timing observations of a 63-ms radio pulsar, PSR J1105-6107. We show that the pulsar is young, having a characteristic age of only 63 kyr. We consider its possible association with the nearby supernova remnant G290.1-0.8 (MSH 11-61*A*) but uncertainties in the distances and ages preclude a firm conclusion. Proof of an association would be provided if the pulsar's velocity is measured to be ~650 km s^{-1} directed away from the remnant center, for a distance of 7 kpc and assuming the pulsar's characteristic age is the true age. The pulsar's spin-down luminosity, 2.5×10^{36} erg s^{-1}, is among the highest 1% of all known pulsars, and together with its estimated distance of 7 kpc, makes it a likely observable high energy source. Indeed, it is coincident with the known CGRO/EGRET source 2EG J1103-6106; we consider the possible association and conclude that it is likely.

Subject headings: stars: II(wtl'oil, pulsars: individual:(PSR J]105-6107'), supernova remnants, gamma rays: observa tions

1. Introduction

We have discovered a 63 ms radio pulsar during a recent search for pulsars using the 64 m radio telescope at Parkes, NSW, Australia. Most pulsars with similar rotation periods fall into one of two categories: those that are young and energetic, the short spin period a result of its relatively recent birth at a spin period comparable to that of the Crab pulsar, or those that have been mildly recycled by a binary companion, like original binary pulsar, PSR B1913+16, which has spin period 59 ms. Thus, a 63 ms radio pulsar is an important find, worthy of careful follow-up investigation.

Here we report on the discovery and follow-up timing observa ions of this new pulsar, PSR J1105- 6107. We show that the pulsar is in fact a member of he first category above, namely young and energetic. Pulsars are hypothesized to have been born in supernova explosions; the existence of a young pulsar requires the consideration of whether there is an associated remnant of its birth supernova explosion. In the case of PSR J1105- 6107, the known remnant G290.1- 0.8 (MSH 11- 61*A*) lies nearby, and we consider here the possible association. In addition, the existence of an energetic pulsar requires consideration of whether there should be associated high energy emission, since magnetospheric X-ray and γ-ray emission, generally representing a significant fraction of the pulsar's spin-down luminosity, very likely holds clues to the yet-elusive pulsar emission mechanism. We show that PSR J1105- 6107 should be detectable at high energies, and consider whether the known γ-ray source 2EG J1103- 6106 is associated with the pulsar.

2. Observations and Results

PSR J1105- 6107 was discovered at Parkes in July 1994 in a search at a central radio frequency of 1420 MHz. The search targetted OB runaway stars in the hope of detecting

new pulsar/OB star binaries. PSR J1105−6107 was discovered while pointing the Parkes telescope at the B4V star HD96264, however the follow up observations described below rule out any association. The details of the search will be described elsewhere (Kaspi, Manchester & D'Amico 1996).

Subsequent timing observations of PSR J1105−6107 were done at Parkes. A total of 96 timing observations of PSR J1105−6107 were obtained between 1993 July 8 and 1996 July 4. Of these, 91 were obtained at center radio frequencies ranging from 1390 to 2050 MHz. The remaining 5 observations were obtained at 660 MHz in July 1995. All data taken prior to 1995 were obtained using filter-bank timing systems ($2 \times 64 \times 5$ MHz at 1520 MHz and $2 \times 256 \times 0.125$ MHz at 660 MHz) that have been described in detail elsewhere (e.g. Bailes et al. 1991). Most data from after 1995 were obtained using the Caltech correlator-based pulsar timing machine (Navarro 1994), which has 2×128 lags across 128 MHz in each of two separate frequency bands. Typically, correlator observations were made at center frequencies of 1420 and 1650 MHz simultaneously. Its narrower frequency resolution as compared to the filter-bank system resulted in less channel dispersion smearing and hence finer time resolution. Filter-bank data were recorded on tape and folded offline, while correlator data were folded online. Average profiles were convolved with high signal-to-noise ratio templates to yield pulse arrival times. The average profile at 1650 MHz shown in Figure 1 was obtained by aligning and summing numerous individual correlator profiles. The profile at 1420 MHz is similar. The two components obvious in Figure 1 cannot be resolved in the 660 MHz data because of dispersion smearing. Resulting arrival times were analyzed using the standard TEMPO pulsar timing software package (Taylor & Weisberg 1989) together with the JPL DE200 ephemeris (Standish 1982). Typical arrival time uncertainties were $\sim$250 μs, for $\sim$10 min integrations having signal-to-noise ratio $\sim$20 at frequencies above 1390 MHz. Arrival times at 660 MHz had uncertainties approximately twice as large.

In the timing analysis, the pulsar dispersion measure (DM) was first determined using 15 arrival times measured in July 1995, including all 5 measured at 660 MHz. This was to ensure good frequency coverage, and no contamination from long term timing noise so common to young pulsars. The measured DM is (271.01 ± 0.01) pc cm^{-3} and during the subsequent timing analysis, it was held fixed at this value. To minimize contamination of the timing position from long-term timing noise, we "pre-whitened" the data, fitting out sufficiently many frequency derivatives (four) to render the residuals approximately Gaussian distributed, determined by eye. The timing position, determined while fitting out these derivatives, is given in Table 1 and was subsequently held fixed. Finally, we measured the best period and period derivative, also given in Table 1. The uncertainties in all parameters are the nominal TEMPO-reported 1σ statistical uncertainties, obtained assuming equal weighting for all arrival times. They include no contribution for possible contamination from timing noise. The pulsar's surface magnetic field $B = 3.2 \times 10^{19}\,(P\dot{P})^{1/2} = 1 \times 10^{12}$ G, and its spin down luminosity $\dot{E} = 4719\pi^2 I\dot{P}/P^3 = 2.5 \times 10^{36}$ erg s^{-1}, where the neutron star moment of inertia I is taken to be 10^{45} g cm^2. The pulsar's characteristic age $\tau_c \equiv P/2\dot{P} = 63$ kyr.

Post-fit residuals, after removal of the timing model given in the Table, are shown in Figure 2. In the plot, uncertainties are typically much smaller than the size of the symbol and the timing noise, interpreted as irregularities in the neutron star's rotation, is obvious. We can quantify the amount of timing noise, as prescribed by Arzoumanian et al. (1994), by measuring $\Delta_8 \equiv \log(|\ddot{\nu}|t^3/6\nu)$, where $\nu = 1/P$ and for $t = 10^8$ s. 1"011'S1{ ,11105- 6107 we find $\Delta_8 = 0.8$, which is consistent within the scatter with Δ_8 parameters for other young pulsars. The small τ_c, as well as the large amount of timing noise, suggest that PSR J1105- 6107 is an excellent candidate for glitches. Indeed we cannot rule out some contamination of the timing parameters by a slowly-relaxing glitch that occurred prior to July 1993 ((cf. Manchester *et al.* 1991, Lyne *et al.* 1996a). Timing noise and glitches will most likely preclude a measurement of the pulsar's proper motion via timing.

That the timing observations for PSR J1105- 6107 reported here extend back a full year prior to the pulsar's discovery requires some explanation. In general, raw, dispersed, and unfolded filter-bank timing data are recorded and archived on tape. By chance, PSR J1105- 6107 lies within half a Parkes 1420 MHz primary beam-width of the pulsar PSR J1103- 6101, which was discovered in July 1992, as part of a major search for pulsars near supernova remnants (Kaspi *et al.* 1996). The DM toward PSR J1103- 6101 is only 75 pc cm^{-3}, indicating it is a much closer object. Once the discovery of PSR J1105- 6107 was made and its proximity to PSR J1103- 6101 realized, the archived raw data for the latter could be retrieved, dedispersed, and folded at the former's parameters. PSR J1105- 6107 was not detected as part of the Kaspi et al. (1996) search because it was outside the Parkes search beam. Only after a year of timing was the correct timing position for PSR J1103- 6101 determined. Observations made after that date had the telescope pointing at its refined position, which then included that of PSR J1105- 6107. Thus, data for PSR J1105- 6107 extend back to July 1993, the epoch when the correct timing position for PSR J1103- 6103 was determined.

3. Discussion

3.1. Possible Association with G290.1- 0.8

PSR J1105- 6107 is located near the Galactic supernova remnant G290.1- 0.8, also known as MSH11-61A (Shaw & Goss 1970). The proximity of a young pulsar to a supernova remnant suggests they may have been formed in the same explosion. Alternately they may be coincidentally superposed on the sky; indeed the Galactic plane is replete with pulsars and supernova remnants and the possibility of chance alignment is non-negligible. Here we consider whether there is a genuine association between PSR J1105- 6107 and G290.1- 0.8.

The Taylor & Cordes (1993) DM-distance model places PSR J1105- 6107 at a distance of 7 kpc, given its DM and location in the Galaxy. The uncertainty on this distance is estimated 10 be ~25%. Thus, the range consistent with the DM -distance model is 5 9 kpc. Regions of enhanced free electrondensity(like II 11 regions) along the line-of-sight can result in an overest imate of the pulsar's distance from its DM e.g. see Kaspi, Manchester & D'Amico 1996).

The distance to G290.1- 0.8 has been estimated in the literature in two ways. First, H I absorption measurements made by Dickel (1973) suggest the remnant is probably at 3.4 4 kpc. The Σ - D relation, which is known to be very uncertain, suggests a distance of 5.8 kpc (Clark & Caswell 1976). Other authors have suggested the remnant is considerably more distant than either of these estimates, on the basis of its optical morphology and Hα to [S II] ratio, which are more typical of older (hence larger) remnants like the Monoceros Ring (Elliott & Malin 1979, Kirshner & Winkler 1979).

Age estimates for G290.1- 0.8 depend strongly on the assumed distance. Milne et al. (1989) estimated the remnant is only 2200 yr old, assuming the smallest distance estimate. By contrast, the resemblance of the optical emission to that of the Monoceros Ring, whose age is ~ 50 kyr (Leahy, Naranan, & Singh 1986), suggests a much larger age for G290.1- 0.8.

The age τ of a radio pulsar is given by

$$\tau = \frac{P}{(n-1)\dot{P}} \left[1 - \left(\frac{P_0}{P}\right)^{n-1} \right], \tag{1}$$

where P is its current spin period, P_0 is its spin period at birth, and n is its braking index. The characteristic age is usually defined as $\tau_c = P/2\dot{P}$, which assumes that $n = 3$ and $P_0 << P$. For PSR J1105-6107, $\tau_c = 63$ kyr. However, the short current spin period for PSR J1105- 6107 compared with other, younger pulsars (e.g. PSR B1509- 58, $\tau_c = 1.5$ kyr, $P = 150$ ms) suggests $P_0 << P$ does not necessarily hold in this case, and the true age may be smaller. Alternatively, if the braking index $n < 3$, as has been measured for all pulsars

for which it is measurable, then τ is an underestimate. Notable is the recent measurement by Lyne et al. (1996) of $n = 1.6 \pm 0.4$ for the Vela pulsar. Figure 3 shows how the true age of PSR J1105-6107 depends on P_0 for four values of n. For small P_0, the pulsar's age may be anywhere between 63 kyr and 250 kyr. For $P_0 \simeq P$, the pulsar's age must be smaller than 63 kyr, independent of n. If we assume the pulsar was born with spin period ~ 20 ms, as for the Crab pulsar, then $63 < \tau < 110$ kyr. Thus, for an association to be real, the pulsar age most likely requires the remnant age to be significantly older than the Milne et al. (1989) estimate, in line with the hypothesis that it is old and distant.

Figure 4 shows the location of the pulsar with respect to the remnant. It lies just over two remnant radii from the approximate remnant geometric center. Its location well outside the remnant boundaries argues against an association (Gaensler & Johnston 1995). However, for a distance of 7 kpc, and assuming the age of the system to be 63 kyr, the transverse velocity of the pulsar must be ~ 650 km s^{-1}, larger than the mean pulsar transverse velocity (Lyne & Lorimer 1994), but much less than has been implied for pulsars in other proposed associations (e.g. Frail & Kulkarni 1991, Manchester *et al.* 1991, Caraveo 1993), and certainly well within the range of measured pulsar velocities (Lyne & Lorimer 1994). Thus, that the pulsar lies well outside the remnant does not necessarily rule out an association; it would require the pulsar transverse velocity to exceed the mean remnant expansion velocity by over a factor of two, not unreasonable if the remnant is expanding into a dense environment, as is suggested by its axisymmetric morphology. Radio maps of the region closer to the pulsar show no evidence for any other supernova remnant (Whiteoak & Green 1996). Intriguingly, the pulsar's inferred trajectory appears to bisect the remnant along its line of symmetry.

Seward (1990) published an X-ray image of G290.1-0.8 that shows that the emission is centrally peaked. This is in contrast to the radio morphology which is shell-like. This suggests G290.1-0.8 is like the supernova remnant W44 (Rho *et al.* 1994), which, like W28

and 3C400.2 (Long *et al.* 1991), has centrally peaked X-ray emission but shell-like radio morphology. The central X-ray emission in these remnants is thermal. It is interpreted as being due to the evaporation of dense cloudlets that survived the initial blast wave, rather than a central 11('(1(1"011 Still', as is the case for remnants with centrally-peaked non-thermal X-ray emission and centrally peaked radio emission like the Crab. Since its morphology suggests this is true of G290.1-0.8 as well, there is no evidence for a central point source that would argue against an association" with PSR J1105-6107. We note also that W44, W28, and 3C400.2 are relatively old remnants, all having estimated ages greater than 10 kyr. Future X-ray studies of G290.1-0.8 may shed light on its association with PSR J1105-6107, by demonstrating that the X-ray emission is thermal, as well as by measuring the neutral hydrogen absorption toward the source, which may help constrain the distance.

A measurement of the proper motion for PSR J1105-610% is highly desirable for determining whether it is associated with G290.1-0. S. Sadly, a timing proper motion will not be forthcoming, given the large amount 0[timing noise exhibited by the pulsar (Figure 2). Also, its low flux density (see Table 1) will make interferometric observations using currently available telescopes difficult,. A measurement of the pulsar's scintillation speed through observations of its radio dynamic spectrum may provide some evidence against an association)" if a small speed is found, although this will be difficult again because of the pulsar's low flux density. This technique was recently used by Nicastro, Johnston & Koribalski (1996) to argue against an association between the radio pulsar PSR B1706-44 and the supernova remnant G343.1-2.3. If the association is real, the pulsar proper motion should be 22 (63 kyr/τ) mas yr^{-1}, independent of the distance.

3.2. Possible association with γ-ray source 2EG J1103-6106

At a distance of 7 kpc, given its large spin-down luminosity (Table 1), PSR J1105-6107 ranks twentieth in a list of rotation-powered pulsars ordered by $\dot{E}/d^2$. The top six spots are held by known γ-ray pulsars, while most of the top thirty are known X-ray sources. In this list, a large value for this parameter suggests that a pulsar is likely to be observable at high energies. In this list, PSR J1105-6107 is higher than the thirtieth-ranked known X-ray and γ-ray pulsar PSR B1055-52 (Cheng & Helfand 1983, Fierro *et al.* 1993). Thus, PSR J1105-6107 is a good candidate for detection of high energy magnetospheric emission.

In fact, the radio timing position of PSR J1105-6107 (Table 1) lies well inside the 95% confidence $49' \times 32'$ error ellipse of the second EGRET catalog source 2EG J1103-6106 (Thompson *et al.* 1995). This γ-ray source was referred to in the first EGRET catalog as GRO J1110-60 (Fichtel *et al.* 1994), and is near, but outside the error box of the Second COS B catalog source 2CG 288-00 (Swanenburg *et al.* 1981). Reported $E > 100$ MeV fluxes of 2EG J1103-6106 show no evidence of significant variability, consistent with its interpretation as a rotation-powered pulsar (Thompson *et al.* 1995, Ramanamurthy *et al.* 1995). If the sources are associated, the estimated mean flux of 2EG J1103-6106 suggests PSR J1105-6107 converts approximately 3% of its spin-down luminosity to high-energy γ-rays for a beaming angle of 1.0 sr, comparable with the efficiencies of the Vela pulsar and PSR B1706-44 (Thompson *et al.* 1992, Grenier, Hermsen, & Clear 1988).

Although only the detection of γ-ray pulsations at the radio period can provide unambiguous proof of the association of PSR J1105-6107 with 2EG J1103-6106 (an analysis which is in progress), the evidence for the association, based only on the positional coincidence and large pulsar $\dot{E}/d^2$, is strong. There are 17 radio pulsars within 10° of the Galactic plane that have higher $\dot{E}/d^2$ than PSR B1055-52 for which pulsations have not yet been detected by EGRET. Four of these, including PSR J1105-6107, lie within the 99% confidence

contours of unidentified EGRET sources. By contrast, of 26 8 known radio pulsars within 10° of the Galactic plane whose energetics should be below the EGRET threshold for detection, only two lie within the 99% confidence contours of unidentified EGRET sources (Fierro 1995). Assuming this control group is spatially distributed like the young pulsars, and even accepting the large uncertainties in DM-distance determinations, this strongly suggests that the young pulsar coincidences, including that for PSR J1105 6107 and 2EG J1103- 6106, are real.

The γ-ray source 2EG J1103-6106, as well as GRO J1110- 60 and 2CG288- 00, have been argued by several authors as being associated with the Carina complex, which includes the peculiar star η Car, open clusters Tr 16, Tr 14, and several OB associations, with the γ rays being produced by cosmic ray nuclei interacting in the interstellar gas, or by η Car itself (Morfill, Forman, & Bignami 1984, Borgwald & Friedlander 1993, Manchanda *et al.* 1996). The identification of 2EG J1103 6106 with PSR J1105 6107 does not necessarily preclude these interpretations, since 2EG J1103-6106 may be a composite of several sources. Indeed there is marginal evidence that its emission is extended (Swanenburg *et al.* 1981, Thompson *et al.* 1995). Nevertheless, the discovery of a luminous young pulsar near the γ-ray source casts some doubts on alternative interpretations. Sturner & Dermer (1995) suggested GRO J1110- 60 is associated with the supernova remnant MSH 11- 62, with the emission a result of cosmic ray interactions with the remnant. With the revisions made in the second EGRET catalog, the source is now closer to the position of PSR J1105- 6107 and G290 1- 0.8; this and the discovery of PSR J1105- 6107 suggest their proposed model is not relevant to this particular γ-ray source.

Kaaret & Cottam (1996) suggested that 2EG J1103-6106 is a young pulsar associated with the OB association Car 2. The measured distance to the association is 2.16 kpc (Mel'nik & Efremov 1995), which is inconsistent with the DM-derived distance of 7 kpc for

PSR J1105-6107 suggesting the [illegible]iation lies in the foreground. If the pulsar actually is in the cluster, its association with G290.1-0.8 is doubtful because the remnant dimensions would su[illegible] it is much younger than the pulsar and it would be hard to understand the pulsar's position so far outside the remnant since the latter would have had less time to decelerate. In this case, the pulsar should be a bright X-ray source, having X-ray luminosity $\sim 2 \times 10^{[illegible]}$ erg s^{-1} cm^{-2} (Seward & Wang 1988) and should be easily detected by the ASCA X-ray satellite. An analysis of a deep ASCA observation of the source is in progress.

4 Conclusions

We have reported on timing observations of PSR J1105-6107, and shown it to be young and energetic. We have considered its proximity to the supernova remnant G290.1-0.8 and show that an association between the two is possible, but we can come to no firm conclusion given that there are large uncertainties on the distances and ages of both objects. We have also considered a possible association of PSR J1105-6107 with the EGRET source 2EG J1103-6106 and concluded it is likely. X-ray observations of the remnant and pulsar will be useful for constraining the distances to both sources, and should provide evidence for or against the associations.

It is remarkable that this interesting pulsar was found serendipitously in a search unrelated to either EGRET sources or supernova remnants, while recent targeted searches of both have been done but have met very limited success. (e.g. Kaspi *et al.* 1996, Gorham *et al.* 1996, Nice & Sayer 1996). That PSR J1105-6107 was missed by a survey of G290.1-0.8 is not surprising given the pulsar's low flux and large angular displacement from the remnant. Nevertheless the question naturally arises as to whether, in searching for pulsars in supernova remnants, one should take care to search a large area around the remnant, not just inside. Statistical studies arguing that in most true associations, the pulsar is found within the rem-

nant boundaries, suggest other w ise (Gaensler & Johnston 1995). If the association l)('tW'('('l] PSR .11105 - 6107 and G290.1-0.8 is one day proven, the impact on strategies for future pulsar searches will be large. Either way, the discovery of PSR J1105- 6107 suggests deeper sea rc hes of the error boxes of unidentified EGRET sources for radio pulsars are war ranted.

We thank Joseph Fierro for helpful discussions regarding EGRET source coincidences with radio pulsars, and Brya n Gaensler and Anne Green for help with the remnant n n-age. The filter-l)allk systems used in the observations were constructed at the University of Ma nc hester, Jodrell Ba nk . Part of this resea rch was carried out at the Jet Propulsion Laboratory, California Instit ute of Technology, u nder contract with the National Aeronautics and Space Administration. VMK received support from NRAO, and from Hubble Fellowship grant numb er HF-1061.01-94A from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, II I('., under NASA('01111'?1((NAS5 26555.

REFERENCES

Arzoumanian, z., Nice, D. J., Taylor, J. 11., & Thorsett, S. E. 1994, ApJ, 422, 67]

Bailes, M. *et al.* 1994, ApJ, 4'25, 1,41

Borgwald, J . M . & Friedlander, M. W. 1993, ApJ , 408, 230

Caraveo, P. A. 1993, ApJ, 415, L1 11

Cheng, A. l{'. & Helfand, D. J. 1983, ApJ, 271, 271

Clark, D. 11. & Caswell, J. 1,. 1976, MNRAS, 174, 267

Dickel, J. R. 1973, Astrophys. Lett., 15, 61

Elliott, K. 11. & Malin, D. F. 1979, MNRAS, 186, 45P

Fichtel, C. E. *et al.* 1994, ApJ S, 94, 551

Fierro, J. M. 1995. PhD thesis, Stanford University

Fierro, J. M. *et al.* 1993, ApJ, 413, L27

Frail, D. A. & Kulkarni, S. R. 1991, Nature, 352, 785

Gaensler, B. M. & Johnston, S. 1995, MNRAS, 277, 1243

Gorham, P. W., Ray, P. s., Anderson, S. B., Kulkarni, S. R., & Prince, '1'. A. 1996, ApJ, 458, 257

Grenier, 1. A., Hermsen, W., & Clear, J. 1988, A&A, 204, 117

Kaaret, 1'. & Cottam, J. 1996, ApJ, 462, L35

Kaspi, V. M., Manchester, R. N., Johnston, S., Lyne, A. G., & D'Amico, N. 1996, Astron. J., 111, 2028

Kirshner, R. P. & Winkler, P. F. 1979, ApJ, 227, 853

Leahy, 1). A., Naranan, S., & Singh, K. l). 1986, Ap&SS, 119, 249L

Long, K. S., Blair, W. l)., Matsui, Y ., & White, R. L. 1991 , ApJ, 373, 567

Lyne, A. G., Kaspi, \'. M., Bailes, M., Manchester, R.N., Taylor, 11., & Arzoumanian, Z. 1996a, MNRAS, 281, L14

Lyne, A. G. & Lorimer, D. R. 1994, Nature, 369, 127

Lyne, A. G., Pritchard, R. S., Graham-Smith, F., & Camilo, F. 1996b, Nature, 381, 497

Manchanda, R. K. *et al.* 1996, A&A, 305, 457

Manchester, R. N., Kaspi, V. M., Johnston, , S, Lyne, A. G., & D'Amico, N. 1991, MNRAS, 253, 7P

Mel'nik, A. M. & Efremov, Y. N. 1995, Sov. Astron. Lett., 21, 10

Milne, D. K., Caswell, J. 1,., Kesteven, M. J., Haynes, R.F., & Roger, R. S. 1 989, Pub. Astr. S(K. Aust., 8, 187

Morfill, G. E., Forman, M., & Bignami, G. 1984, ApJ, 284, 856

Navarro, J. 1994. PhD thesis, California Institute of Technology

Nicastro, 1,., Johnston, S., & Koribalski, B. 1996, A&A, 306, 49

Nice, 1). J. & Sayer, R. W. 1996, ApJ. In press

Ramanamurthy, P. V. *et al.* 1995, ApJ, 450, 791

Rho, J., Petre, R., Schlegel, E., & Hester, J. 1994, ApJ, 430, 757

Seward, II'. D. 1990, ApJS, 73, 781

Seward, F. D. & Wang, Z.-U. 1988, ApJ, 332, 199

Shaver, P. A. & Goss, W. M. 1970, Aust. J. Phys. Astr. Supp., 14, 77

Standish, E. M. 1982, A&A, 114, 297

Sturner, S. J. & Dermer, C. D. 1995, A&A, 293, L17

Swanenburg, B. N. *et al.* 1981, ApJ, 243, L69

Taylor, J. H. & Cordes, J. M. 1993, ApJ, 411, 674

Taylor, J. H. & Weisberg, J. M. 1989, ApJ, 345, 434

Thompson, D. J. *et al.* 1992, Nature, 359, 615

Thompson, D. J. *et al.* 1995, ApJS, 101, 259

Whiteoak, J. B. Z. & Green, A. J. 1996, A&AS, 118, 329

This manuscript was prepared with the AAS LaTeX macros v4.0.

Table 1. Astrometric, Spin, and Radio Parameters for PSR J1105-6107

Parameter	Value
Right Ascension, α (.12000)	$11^h05^m26^s.07(7)$
Declination, δ (J2000)	$61°07'52''.1(4)$
Period, 1)	0.0631912527 92(3) s
Period Derivative, $\dot{P}$	15.80465(12) x lo" 15
Dispersion Measure, DM	271.01(2) pccm^{-3}
Epoch ofl'cried	MJD 49545.0000
R.M.S. timing residual	6.2 111s
Surface Magnetic Field Strength, B	1.0×10^{12} G
Characteristic Age, τ_c	63,350 yr
Spin-Down Luminosity, $\dot{E}$	2.5×10^{36} erg s^{-1}
Flux Density at 660 MHz[1]	4.1(7) mJy
Flux Density at 1420 MHz[2]	1.84(14) mJy
Flux Density at 1650 MHz[3]	1.58(6) mJy
Spectral Ill(l('x	-1.36(1)

Note. — Timing parameter uncertainties are nominal 1σ statistical uncertainties as reported by TEMPO and include no contribution for possible contamination by timing noise.

(1) reported flux is the mean of those measured at 3 epochs

(2) reported flux is the mean of that measured at 24 epochs

(3) reported flux is the mean of that measured at 16 epochs

Is

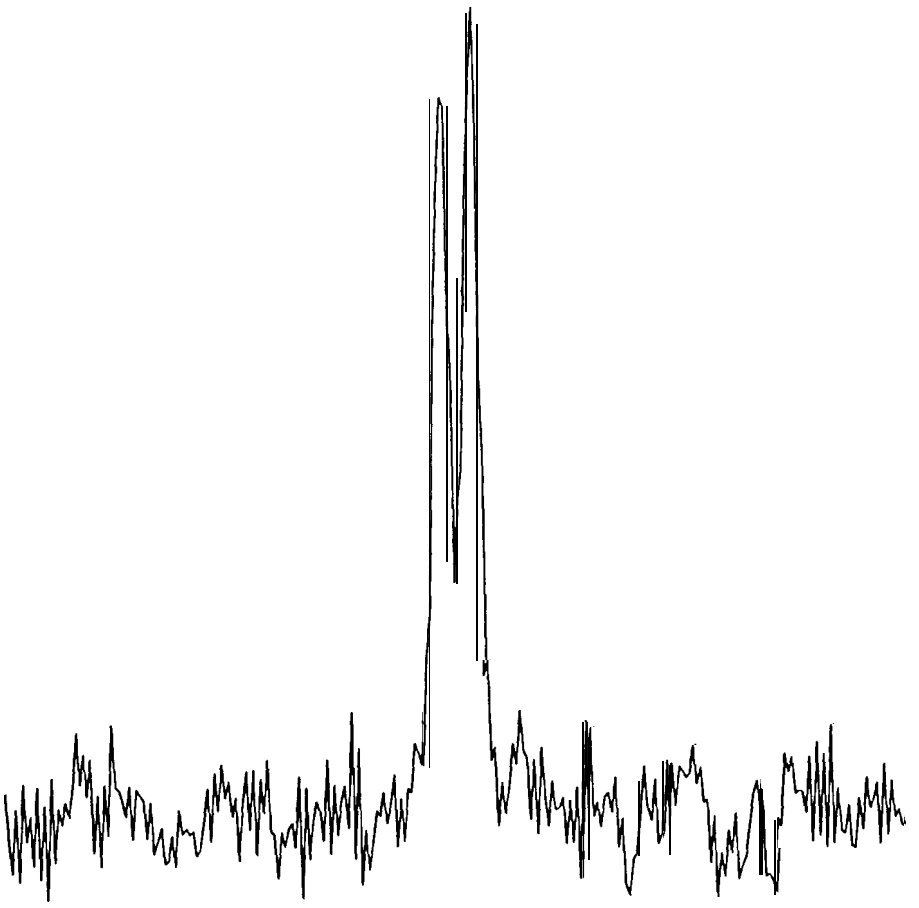

Fig. I. Pulse profile for PSR .11105 - 6107 at 1650 MHz. The profile is similar at 1420 MHz. The apparent off-pulse structure is a result of interference.

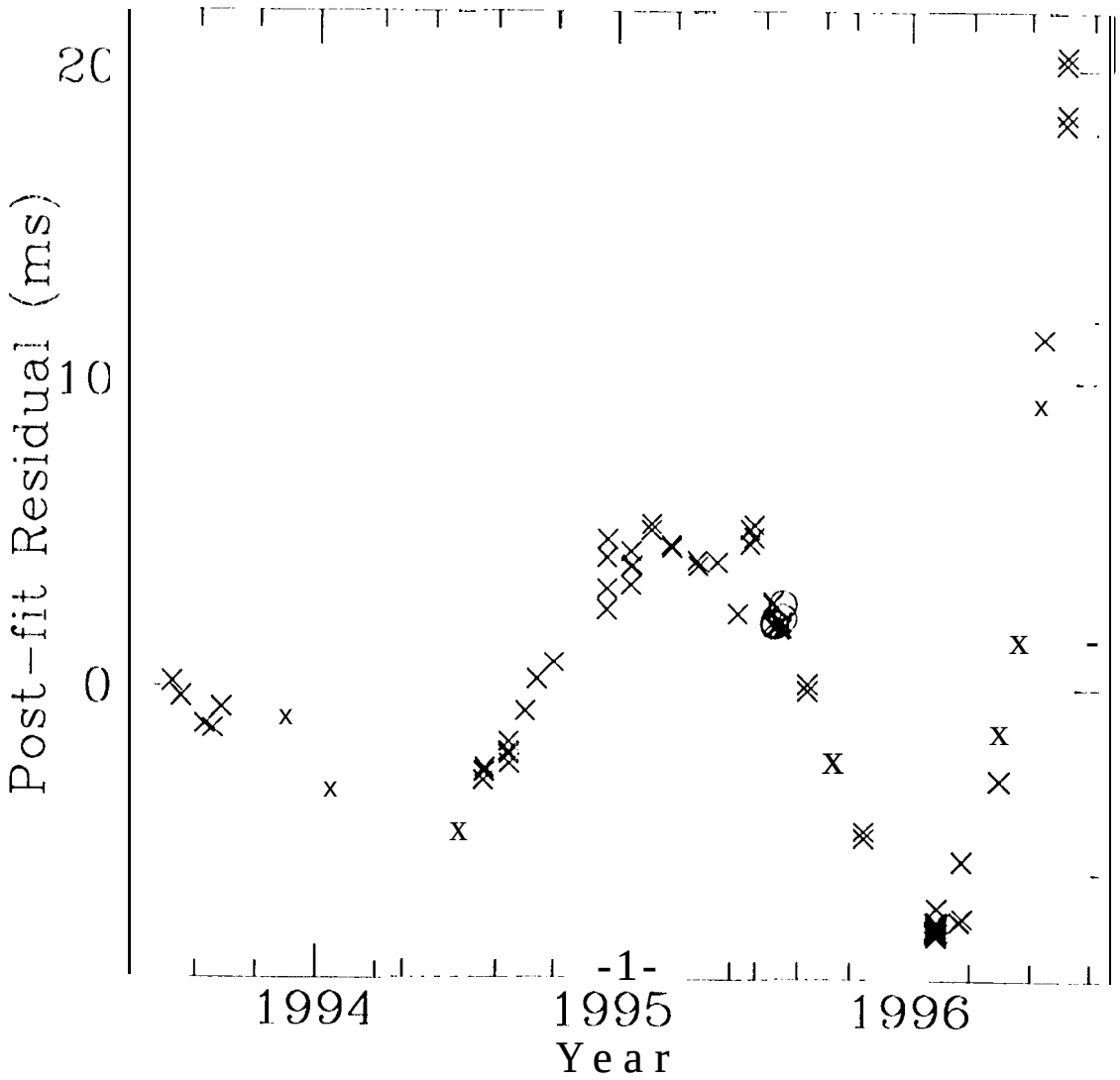

Fig. 2. Post-fit residuals for PSR J1105-6107 after fitting out the model given in Table 1. Residuals at 660 MHz are shown as open circles. Uncertainties on arrival times are typically smaller than the size of the points.

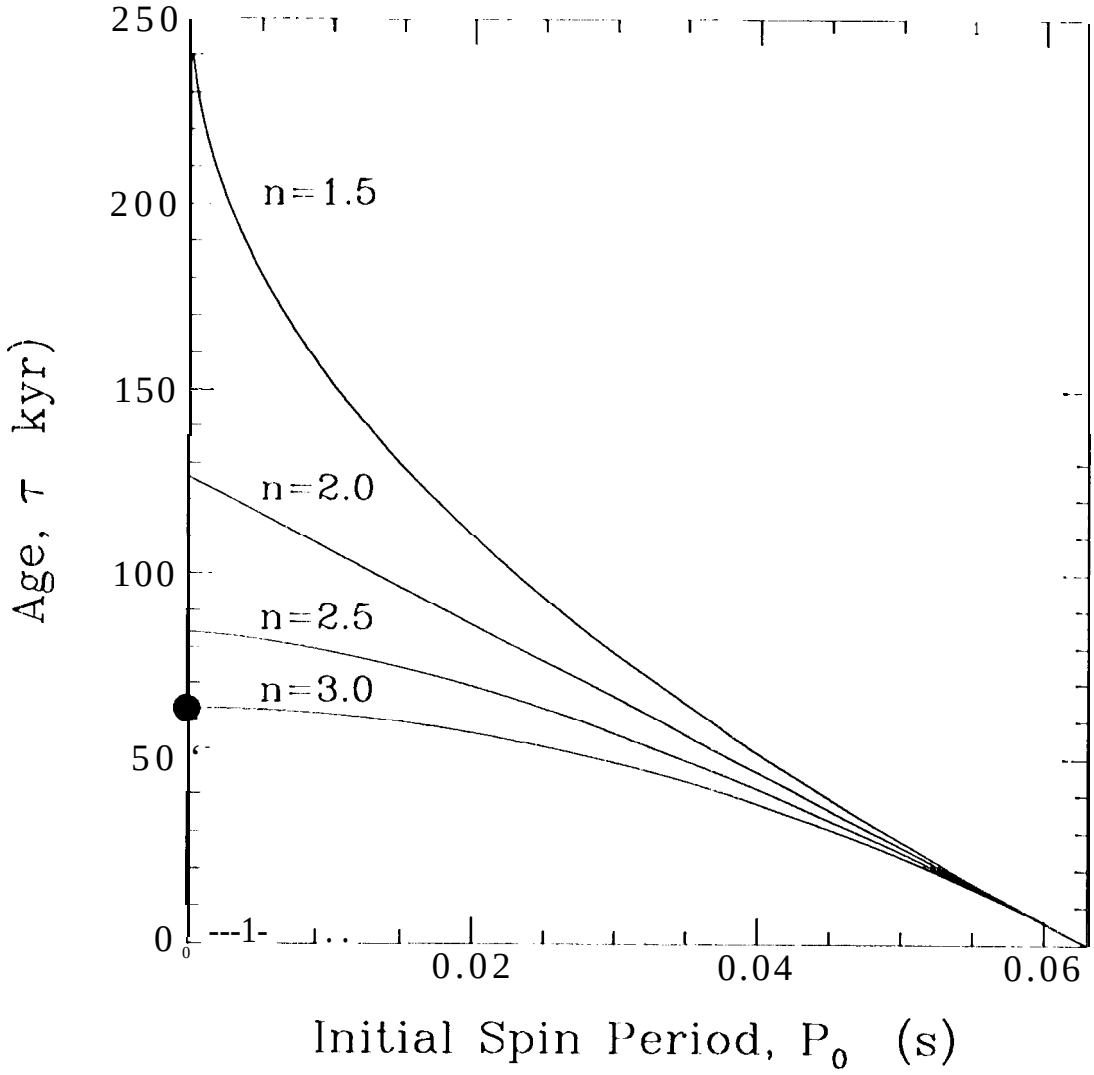

Fig. 3.- The age τ of PSR J1105- 6107 as a function of initial spin period P_0 for four values of the braking index n. The filled circle represents the characteristic age $\tau_c \equiv P/2\dot{P}$, typically assumed for a pulsar's age.

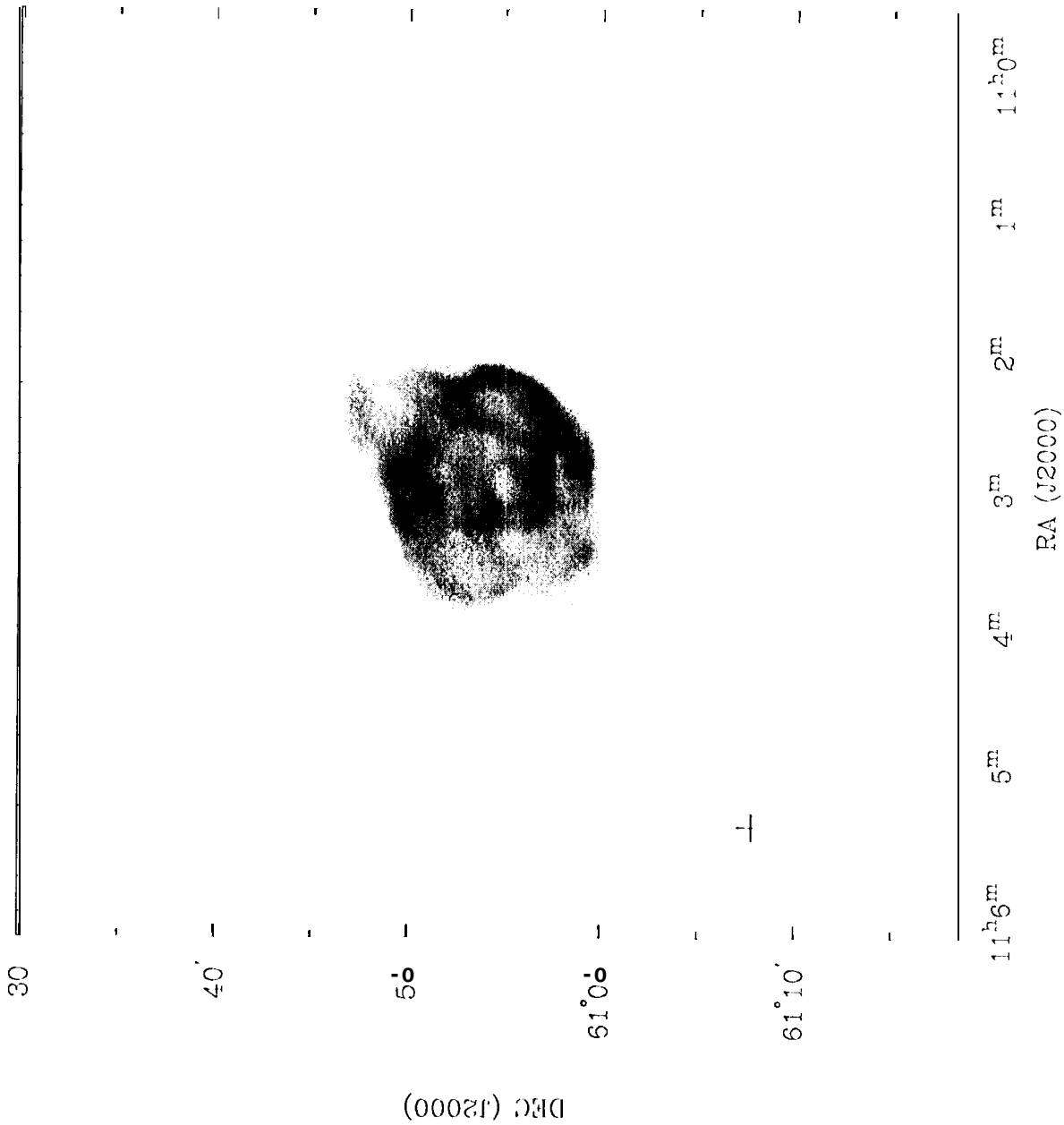

Fig. 4.– MOST radio image of G290.1−0.8 at 843 MHz (after Whiteoak & Green 1996). The position of the pulsar is indicated by a cross. [ANNE GREEN WILL GET US A BETTER IMAGE]