A statistical study of pulsar timing irregularities using observations from Jodrell Bank Observatory

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ABSTRACT

We provide an analysis of structures observed in the timing residuals of 374 pulsars. Observations obtained using the 76-m Lovell radio telescope over the last 20 years have allowed us to carry-out the first large-scale analysis of pulsar timing noise containing long-data spans, numerous observations at multiple frequencies for a large number of pulsars. We plot the timing residuals for each of these pulsars and carry out statistical analyses in order to determine relationships between pulsar parameters and the amplitude and timescale of timing noise. We show that the timing noise characteristics are consistent with young pulsars being dominated by the recovery from glitches, whereas the older pulsars are affected by pseudo-sinusoidal structures that could be due to free-precession of the neutron star.

Key words:

1 INTRODUCTION

The Jodrell Bank data archive of pulsar observations contains over 6000 years of pulsar rotational history. The basic observational parameters for the pulsars with data spanning more than six years were provided in Hobbs et al. (2004); hereafter Paper I. These timing ephemerides included the pulsar positions, rotational frequencies and their first two derivatives, dispersion measures and their derivatives and proper motions. The proper motions were updated with more recent observations and analysed in Hobbs et al. (2005). In this paper, we describe and quantify the structures observed in the timing residuals.

Structures previously observed in the timing residuals have been explained by unmodelled planetary companions (e.g. Cordes 1993), free-precession (e.g. Stairs, Lyne & Shemar 2000 who reported on free-precession in PSR B1828-11), glitches (Lyne, Shemar & Graham-Smith 2000) or timing noise (e.g. Lyne 1999). Glitches are thought to represent sudden increases in the pulsar's rotation rate. Timing noise describes a continuous, noise-like fluctuation in rotation rate.

The relationship between glitches and timing noise is not understood. Glitches are discrete events which occur more commonly in young pulsars (although for two pulsars with similar rotational parameters, one may glitch frequently while the other has never been observed to glitch) and seem to be divided into two sizes: most are large with fractional frequency increases of $\sim 10^{-6}$ while the smaller events are in the range 10^{-7} to 10^{-9} . No model currently predicts the time between glitches or the size of the event although pulsars with large glitches tend to show larger intervals between glitches (Lyne et al. 2000).

Much of the basic theoretical work carried out on timing noise was described in Boynton et al. (1972) who analysed the arrival times for the Crab pulsar over a two-year period. In this paper, an attempt was made to describe the timing noise as either phase (ϕ) , frequency (ν) or slowing-down $(\dot{\nu})$ noise corresponding to random walks in these parameters. Later, Cordes & Helfand (1980) concluded that out of a sample of 11 pulsars, seven showed timing noise consistent with frequency noise, two from slowing-down noise and two from phase-noise. Cordes & Helfand (1980) concluded that 1) timing noise is widespread in pulsars, 2) it is correlated with period derivative and weakly with period, 3) is not correlated with height above the Galactic plane, luminosity nor pulse shape changes. However, Cordes & Downs (1985) showed that the idealized, large-rate random walk process was too simple. They developed a more detailed model where discrete 'micro-jumps' in one or more of the timing parameters are superimposed on the random walk process. D'Alessandro et al. (1995) analysed the timing residuals for 45 pulsars with data spanning up to seven years. 19 of their pulsars show very weak timing noise, for seven the activity is attributed to random walk processes comprising a large number of events in one of the rotation variables, a further seven are explained as resolved jumps in ν and $\dot{\nu}$ superimposed on a random walk process, seven

more as resolved jumps on a low-level activity background and for the remaining five the timing noise cannot be due to a pure random walk process or resolved jumps.

The majority of analyses undertaken to understand pulsar timing noise have used relatively short data spans of <10 yr. However, a few recent papers have studied much longer data spans for a few pulsars. Scott, Finger & Wilson (2003) reported on the timing noise of the Crab pulsar over a 7 year interval, the study of PSR B1642–03 over a 30 year data span (Shabanova, Lyne & Urama 2001), a 16 year data span for PSR B0329+54 (Shabanova 1995), a 13 year data span for PSR B1828–11 (Stairs, Lyne & Shemar 2000), four pulsars for 14 years (Baykal et al. 1999), 12 years for PSR J1713+0747 (Splaver et al 2004) and 21 years of timing for PSR B1509–58 (Livingstone et al. 2005). discuss the recent science paper and its implications for timing noise

In this paper, we first show and describe the structures observed in the timing residuals for 370 pulsars with the shortest data span being 10 years and the longest over 35 years. This allows us to catagorize the forms seen in the timing residuals. We tabulate and analyse the amplitude and timescale of the timing noise and their relation with other pulsar parameters. We calculate and compare various stability parameters used to provide a measure of the amount of timing noise in any particular pulsar data set. We conclude the paper with a periodogram analysis of the timing residuals which allows us to study the spectrum of timing noise and to search for periodicities in the data.

An understanding of pulsar timing noise will lead to many important results. For instance, pulsar timing array projects are being developed around the world with the aim of detecting gravitational waves by looking for irregularities in the timing of millisecond pulsars (Hobbs 2005 and references therein). The gravitational wave signature from a stochastic background of coalescing binary black hole systems is expected to produce signatures in the timing residuals with amplitudes of approximately 100 ns. If the intrinsic timing noise for millisecond pulsars are at a higher level, then it will become extremely difficult to extract the gravitational wave signal from the observations. Explaining the cause of timing noise and glitches in the young pulsars may allow us to relate these phenomena and provide an insight into the interior structure of a neutron star.

2 RESULTS

The timing solutions for the pulsars in our sample have been updated using recent data available from the Jodrell Bank Observatory data archive. The timing solutions were obtained in an identical manner to that described in Paper I. In brief, the majority of the observations were obtained from the 76-m Lovell radio telescope at Jodrell Bank Observatory. The earliest times-of-arrival (TOAs) for 18 pulsars were obtained from observations using the NASA Deep Space Network (Downs & Reichley 1983). Observations using the Lovell telescope were carried at predominately at frequencies close to 408, 610, 910, 1410 and 1630 MHz with a few early observations at 235 and 325 MHz. The signals were combined to produce, for every observation, a total intensity profile. TOAs were subsequently determined by convolving,



Figure 2. $P-\dot{P}$ diagram for the pulsars in our sample.

in the time domain, the profile with a template corresponding to the observing frequency. The pulsar timing residuals were obtained by fitting a timing model to the TOAs using the TEMPO2 pulsar timing software (Hobbs, Edwards, Manchester 2006).

In Figure 1 we plot the timing residuals for all the pulsars in our sample. The horizontal scale of each panel represents 35 years of observations and the vertical is scaled for each seperate panel. The upper value gives the range from the minimum to the maximum residual in milliseconds. The lower values give the same range, but in units of the pulsars' rotational periods.

In Table 1 we present the basic parameters for these pulsars. In column order, we first provide the pulsar's J2000 and B1950 names, spin-frequency, ν , frequency derivative, $\dot{\nu}$, and frequency second derivative, $\ddot{\nu}$. The next two columns give the logarithm of the pulsar's characteristic age, $\tau_c =$ $-\nu/(2\dot{\nu})$ in years and the surface magnetic flux density $B_s = 3.2 \times 10^{19} \sqrt{\dot{\nu}/\nu^3}$. The following three columns gives the epoch of the centre of the data span, the number of observations and the time span of the observations. The final columns give σ_1 the unweighted rms of the residuals after fitting for a quadratic term, σ_2 the unweighted rms of the residuals after removal of a cubic term and σ_3 the whitened rms residuals. For the recycled pulsars¹ the unweighted rms of the residuals after subtracting a cubic term range from ${\sim}10\mu s$ for PSRs J1713+0747 and J1744–1134 to $850\mu s$ for the globular cluster pulsar PSR B1820-30A and $430\mu s$ for PSR B1953+29. For the ordinary pulsars the rms ranges to 948 ms for PSR B1706-16 which is a pulsar with a 653 msspin-period. A period-period derivative diagram for the pulsars in our sample is shown in Figure 2.

¹ Our sample includes 31 recycled pulsars defined as pulsars with spin-periods, P < 0.1 s and spin-down rates, $\dot{P} < 10^{-17}$.

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Figure 1. Timing residuals after subtraction of the pulsar's spin frequency and its first derivative. Vertical lines indicate epochs at which glitch events have been reported. The three labels on the left provide the pulsar name, the range from the minimum to maximum residual (ms) and the same range scaled with the pulsar's rotational period.

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Table 1. Basic parameters for the pulsars in our sample. σ_1 is the rms residual after removing a quadratic term, σ_2 , the rms value after removing a cubic term and σ_3 the value after whitening the data.

PSR J	PSR B	$_{(s^{-1})}^{\nu}$	$\dot{\nu}_{(10^{-15}s^{-2})}$	$\ddot{\nu}_{(10^{-24}s^{-3})}$	$\log_{10}(\tau_c)$	$\log_{10} B_s$ (G)	Epoch (MJD)	Ν	T_{span} (yr)	σ_1 (ms)	σ_2 (ms)	σ_3 (ms)
$\begin{array}{c} J0014{+}4746\\ J0034{-}0534\\ J0034{-}0721\\ J0040{+}5716\\ J0048{+}3412 \end{array}$	$\begin{array}{c} B0011{+}47\\\\ B0031{-}07\\ B0037{+}56\\ B0045{+}33\end{array}$	0.806 532.713 1.061 0.894 0.822	-0.367 -1.409 -0.459 -2.302 -1.589	$\begin{array}{c} +0.00035(20) \\ -0.045(10) \\ +0.00033(3) \\ -0.00005(6) \\ -0.0003(3) \end{array}$	7.54 9.78 7.56 6.79 6.91	$ 11.93 \\ 7.99 \\ 11.80 \\ 12.26 \\ 12.23 $	49285.0 51096.0 47051.0 50091.0 50083.0	365 402 772 425 200	22.8 12.8 35.0 18.5 18.4	$\begin{array}{c} 4.25 \\ 0.06 \\ 3.77 \\ 0.62 \\ 2.18 \end{array}$	$\begin{array}{c} 4.23 \\ 0.06 \\ 3.47 \\ 0.62 \\ 2.16 \end{array}$	$\begin{array}{c} 4.19 \\ 0.05 \\ 3.37 \\ 0.61 \\ 2.11 \end{array}$
J0055+5117 J0056+4756 J0102+6537 J0108+6608 J0108+6905	$\begin{array}{c} B0052{+}51\\ B0053{+}47\\ B0059{+}65\\ B0105{+}65\\ B0105{+}68\end{array}$	0.473 2.118 0.596 0.779 0.934	-2.132 -14.938 -2.113 -7.918 -0.042	$\begin{array}{c} +0.00092(5) \\ -0.0083(18) \\ -0.02862(17) \\ +0.107(16) \\ -0.0002(3) \end{array}$		$12.66 \\ 12.10 \\ 12.51 \\ 12.62 \\ 11.36$	50092.0 50103.0 50091.0 50482.0 50091.0	$416 \\ 251 \\ 338 \\ 426 \\ 335$	$18.5 \\ 17.2 \\ 18.5 \\ 16.1 \\ 18.5$	1.48 5.78 24.49 156.51 2.63	$1.08 \\ 5.73 \\ 2.53 \\ 148.47 \\ 2.62$	1.00 2.28 1.29 12.21 2.59
J0108-1431 J0117+5914 J0134-2937 J0139+5814 J0141+6009	 B0114+58 B0136+57 B0138+59	1.238 9.858 7.301 3.670 0.818	-0.118 -568.596 -4.178 -144.309 -0.261	$\begin{array}{c} -0.0030(18) \\ -2.91(3) \\ -0.0004(5) \\ -0.065(10) \\ +0.00029(6) \end{array}$	8.22 5.44 7.44 5.61 7.70	11.40 11.89 11.02 12.24 11.84	51251.0 50083.0 51251.0 49706.0 49495.0	332 313 298 683 450	$12.1 \\ 18.2 \\ 12.1 \\ 20.6 \\ 19.4$	$\begin{array}{c} 4.49 \\ 160.88 \\ 0.19 \\ 54.30 \\ 1.09 \end{array}$	4.47 25.74 0.19 52.30 1.06	$\begin{array}{c} 4.38 \\ 0.70 \\ 0.18 \\ 2.05 \\ 1.04 \end{array}$
J0147+5922 J0152-1637 J0156+3949 J0157+6212 J0215+6218	B0144+59 B0149-16 B0153+39 B0154+61 	5.094 1.201 0.552 0.425 1.822	-6.661 -1.874 -0.046 -34.159 -2.198	$\begin{array}{c} +0.0255(7) \\ -0.00425(5) \\ -0.0001(12) \\ -0.0093(8) \\ -0.0022(12) \end{array}$	7.08 7.01 8.27 5.29 7.12	$11.36 \\ 12.02 \\ 11.73 \\ 13.33 \\ 11.79$	50080.0 48651.0 50104.0 50126.0 51788.0	$429 \\ 454 \\ 80 \\ 462 \\ 294$	17.3 25.5 16.5 18.1 9.4	2.60 5.63 10.00 22.84 0.92	$1.16 \\ 1.39 \\ 10.00 \\ 20.14 \\ 0.92$	$0.17 \\ 0.59 \\ 9.00 \\ 2.43 \\ 0.43$
J0218+4232 J0231+7026 J0304+1932 J0323+3944 J0332+5434	 B0226+70 B0301+19 B0320+39 B0329+54	$\begin{array}{c} 430.461 \\ 0.682 \\ 0.721 \\ 0.330 \\ 1.400 \end{array}$	-14.340 -1.445 -0.673 -0.069 -4.012	$\begin{array}{c} -0.007(8) \\ +0.00026(13) \\ -0.00274(7) \\ +0.00004(4) \\ +0.00092(7) \end{array}$	8.68 6.87 7.23 7.88 6.74	8.63 12.33 12.13 12.15 12.09	51268.0 50088.0 49141.0 49229.0 46775.0	$387 \\ 304 \\ 498 \\ 519 \\ 1169$	11.9 18.5 23.7 23.2 36.5	0.05 1.83 3.90 2.25 7.38	0.05 1.82 1.76 2.24 6.76	$0.05 \\ 1.75 \\ 0.95 \\ 2.20 \\ 0.50$
$J0335+4555 \\ J0343+5312 \\ J0357+5236 \\ J0406+6138 \\ J0415+6954$	$B0331+45 \\ B0339+53 \\ B0353+52 \\ B0402+61 \\ B0410+69$	3.715 0.517 5.075 1.682 2.559	-0.101 -3.587 -12.277 -15.773 -0.502	$\begin{array}{c} +0.00014(12) \\ -0.00131(15) \\ +0.0078(4) \\ +0.0476(19) \\ +0.00142(11) \end{array}$	8.76 6.36 6.82 6.23 7.91	$10.65 \\ 12.71 \\ 11.49 \\ 12.27 \\ 11.24$	50081.0 49557.0 50081.0 50428.0 50092.0	$482 \\ 325 \\ 411 \\ 406 \\ 374$	18.2 22.9 18.2 16.7 18.5	0.33 4.64 0.95 13.75 0.47	$0.33 \\ 4.14 \\ 0.63 \\ 8.44 \\ 0.40$	0.32 3.97 0.21 0.57 0.36
J0421-0345 J0448-2749 J0450-1248 J0452-1759 J0454+5543	$\begin{array}{c}\\\\\\\\\\\\\\\\\\$	0.463 2.220 2.283 1.822 2.935	-0.249 -0.731 -0.535 -19.092 -20.441	$\begin{array}{c} +0.0019(5) \\ -0.0029(9) \\ -0.0010(3) \\ +0.0137(5) \\ -0.184(4) \end{array}$	7.47 7.68 7.83 6.18 6.36	$12.21 \\ 11.42 \\ 11.33 \\ 12.25 \\ 11.96$	50847.0 51427.0 49751.0 49295.0 50336.0	$140 \\ 331 \\ 526 \\ 576 \\ 334$	9.7 11.2 19.7 22.9 17.2	$1.28 \\ 0.88 \\ 1.68 \\ 8.20 \\ 27.68$	$1.21 \\ 0.86 \\ 1.65 \\ 5.15 \\ 10.00$	$1.17 \\ 0.85 \\ 1.63 \\ 0.30 \\ 0.38$
J0459-0210 J0502+4654 J0520-2553 J0525+1115 J0528+2200	B0458+46 B0523+11 B0525+21	0.883 1.566 4.138 2.821 0.267	-1.089 -13.690 -0.515 -0.586 -2.854	$\begin{array}{c} -0.0004(5) \\ +0.01057(16) \\ +0.0026(12) \\ -0.000239(20) \\ +0.00082(4) \end{array}$	7.11 6.26 8.10 7.88 6.17	$12.11 \\ 12.28 \\ 10.94 \\ 11.21 \\ 13.09$	51269.0 49129.0 51657.0 48663.0 46909.0	238 497 181 642 954	12.0 23.6 10.2 26.3 35.8	$1.34 \\ 7.24 \\ 0.42 \\ 0.32 \\ 20.18$	$1.34 \\ 2.20 \\ 0.41 \\ 0.28 \\ 15.26$	$1.32 \\ 0.55 \\ 0.40 \\ 0.27 \\ 1.44$
$\begin{array}{c} J0538{+}2817\\ J0543{+}2329\\ J0612{+}3721\\ J0613{-}0200\\ J0614{+}2229 \end{array}$	 B0540+23 B0609+37 B0611+22		-179.088 -254.893 -0.670 -1.019 -529.523	$\begin{array}{c} -0.6718(18) \\ +0.1707(20) \\ -0.0125(3) \\ +0.009(4) \\ +8.35(8) \end{array}$	5.79 5.40 7.90 9.71 4.95	$11.87 \\ 12.29 \\ 11.13 \\ 8.24 \\ 12.65$	51821.0 49294.0 50092.0 51240.0 50164.0	$313 \\ 691 \\ 455 \\ 655 \\ 970$	9.0 22.9 18.5 12.1 18.1	$\begin{array}{c} 6.55 \\ 37.82 \\ 2.00 \\ 0.04 \\ 1502.68 \end{array}$	$\begin{array}{c} 0.29 \\ 14.53 \\ 0.80 \\ 0.04 \\ 404.91 \end{array}$	$0.18 \\ 0.19 \\ 0.36 \\ 0.04 \\ 40.85$
J0621+1002 J0624-0424 J0629+2415 J0630-2834 J0653+8051	$\begin{array}{c}$	34.657 0.962 2.098 0.804 0.823	-0.057 -0.769 -8.785 -4.601 -2.576	$\begin{array}{c} +0.0011(5) \\ +0.00001(10) \\ +0.0049(8) \\ -0.0175(7) \\ +0.00069(4) \end{array}$	9.997.306.586.446.70	9.07 11.97 11.99 12.48 12.34	51145.0 50302.0 49846.0 47013.0 49141.0	$634 \\ 458 \\ 541 \\ 806 \\ 283$	9.6 17.3 19.7 35.1 23.7	0.02 0.87 5.75 131.71 1.23	$\begin{array}{c} 0.02 \\ 0.87 \\ 5.53 \\ 91.58 \\ 0.83 \end{array}$	$0.02 \\ 0.84 \\ 0.58 \\ 1.54 \\ 0.71$
J0659+1414 J0700+6418 J0725-1635 J0729-1836 J0742-2822	$\begin{array}{c} B0656{+}14\\ B0655{+}64\\\\ B0727{-}18\\ B0740{-}28 \end{array}$	2.598 5.111 2.357 1.960 5.997	-371.288 -0.018 -0.515 -72.832 -604.876	$\begin{array}{c} +0.7636(19) \\ +0.00019(13) \\ +0.0015(10) \\ +0.245(7) \\ -0.61(5) \end{array}$	5.04 9.66 7.86 5.63 5.20	$12.67 \\10.07 \\11.30 \\12.50 \\12.23$	$\begin{array}{c} 49721.0\\ 49138.0\\ 50884.0\\ 50126.0\\ 49696.0\end{array}$	$771 \\ 402 \\ 176 \\ 634 \\ 1009$	$16.1 \\ 23.7 \\ 9.9 \\ 18.3 \\ 20.6$	$106.66 \\ 0.64 \\ 0.60 \\ 73.73 \\ 160.98$	7.22 0.64 0.60 39.66 140.42	$1.59 \\ 0.60 \\ 0.57 \\ 3.42 \\ 5.35$
J0751+1807 J0754+3231 J0814+7429 J0820-1350 J0823+0159	$\begin{array}{c} - \\ B0751+32 \\ B0809+74 \\ B0818-13 \\ B0820+02 \end{array}$	287.458 0.693 0.774 0.808 1.156	-0.643 -0.519 -0.101 -1.373 -0.140	$\begin{array}{c} -0.002(4) \\ -0.00081(6) \\ +0.00014(5) \\ +0.000028(19) \\ -0.00074(5) \end{array}$	9.85 7.33 8.09 6.97 8.12	8.22 12.10 11.67 12.21 11.48	51389.0 49763.0 49369.0 49299.0 49144.0	530 491 473 631 573	11.3 19.8 22.1 22.7 23.7	$0.04 \\ 1.54 \\ 1.07 \\ 0.55 \\ 1.10$	$0.04 \\ 1.28 \\ 1.06 \\ 0.55 \\ 0.88$	$0.04 \\ 1.22 \\ 1.03 \\ 0.27 \\ 0.84$
$\begin{array}{c} J0826{+}2637\\ J0828{-}3417\\ J0837{+}0610\\ J0846{-}3533\\ J0849{+}8028 \end{array}$	B0823+26 B0826-34 B0834+06 B0844-35 B0841+80	$1.884 \\ 0.541 \\ 0.785 \\ 0.896 \\ 0.624$	-6.069 -0.292 -4.191 -1.285 -0.174	$\begin{array}{c} +0.0240(12) \\ -0.0035(4) \\ +0.000102(11) \\ +0.00107(13) \\ +0.00005(74) \end{array}$	6.69 7.47 6.47 7.04 7.76	$11.98 \\ 12.14 \\ 12.47 \\ 12.13 \\ 11.93$	46857.0 48508.0 49138.0 49145.0 50419.0	$978 \\ 145 \\ 536 \\ 119 \\ 90$	$36.1 \\ 25.9 \\ 23.7 \\ 23.7 \\ 16.6$	110.69 19.28 0.36 1.96 4.82	90.20 15.84 0.34 1.53 4.82	$0.50 \\ 12.98 \\ 0.32 \\ 1.41 \\ 4.44$
$\begin{array}{c} J0855-3331\\ J0908-1739\\ J0921+6254\\ J0922+0638\\ J0943+1631\end{array}$	B0853-33 B0906-17 B0917+63 B0919+06 B0940+16	0.789 2.490 0.638 2.322 0.920	-3.934 -4.151 -1.468 -73.982 -0.077	$\begin{array}{c} +0.00059(15) \\ +0.00165(5) \\ +0.00018(12) \\ +0.1385(12) \\ +0.00008(16) \end{array}$	6.50 6.98 6.84 5.70 8.28	$12.46 \\ 11.72 \\ 12.38 \\ 12.39 \\ 11.50$	$\begin{array}{c} 49735.5\\ 49140.0\\ 49687.0\\ 48518.0\\ 49143.0\end{array}$	$434 \\ 639 \\ 156 \\ 765 \\ 443$	17.2 23.7 16.3 27.0 23.7	$1.63 \\ 0.73 \\ 0.86 \\ 97.96 \\ 4.05$	$1.60 \\ 0.43 \\ 0.85 \\ 22.19 \\ 4.04$	$1.57 \\ 0.29 \\ 0.78 \\ 2.53 \\ 3.96$
J0944-1354 J0946+0951 J0953+0755 J1012+5307 J1012-2337	B0942-13 B0943+10 B0950+08 B1010-23	$1.754 \\ 0.911 \\ 3.952 \\ 190.268 \\ 0.397$	-0.139 -2.902 -3.588 -0.620 -0.139	$\begin{array}{c} -0.00027(5) \\ -0.0377(8) \\ -0.0048(3) \\ +0.0030(12) \\ +0.00012(12) \end{array}$	8.30 6.70 7.24 9.69 7.66	$11.21 \\ 12.30 \\ 11.39 \\ 8.48 \\ 12.18$	$\begin{array}{c} 49764.0\\ 49352.0\\ 46777.0\\ 51331.0\\ 49127.0\end{array}$	$532 \\ 117 \\ 953 \\ 521 \\ 137$	$19.8 \\ 22.3 \\ 36.5 \\ 11.6 \\ 23.6$	$\begin{array}{c} 0.41 \\ 47.99 \\ 11.19 \\ 0.02 \\ 4.59 \end{array}$	$0.40 \\ 10.33 \\ 9.54 \\ 0.02 \\ 4.57$	$0.39 \\ 9.51 \\ 0.40 \\ 0.02 \\ 4.26$
$\begin{array}{c} J1018-1642\\ J1022+1001\\ J1024-0719\\ J1034-3224\\ J1041-1942 \end{array}$	B1016-16 — — B1039-19	$0.554 \\ 60.779 \\ 193.716 \\ 0.869 \\ 0.721$	-0.535 -0.160 -0.695 -0.174 -0.492	$\begin{array}{c} +0.00006(18) \\ -0.0004(8) \\ +0.007(6) \\ -0.0005(6) \\ -0.000009(500) \end{array}$	7.22 9.78 9.64 7.90 7.37	$12.25 \\ 8.93 \\ 8.50 \\ 11.72 \\ 12.06$	50093.0 51638.0 51422.0 51123.0 49143.0	$243 \\ 630 \\ 365 \\ 224 \\ 477$	$18.5 \\ 9.9 \\ 10.9 \\ 12.9 \\ 23.7$	$2.79 \\ 0.03 \\ 0.06 \\ 1.83 \\ 1.31$	$2.79 \\ 0.03 \\ 0.06 \\ 1.83 \\ 1.31$	$2.70 \\ 0.03 \\ 0.06 \\ 1.75 \\ 1.29$
$\begin{array}{c} J1047\!-\!3032\\ J1115\!+\!5030\\ J1136\!+\!1551\\ J1141\!-\!3107\\ J1141\!-\!3322 \end{array}$	B1112+50 B1133+16 	3.027 0.604 0.842 1.857 6.862	-0.559 -0.909 -2.646 -6.880 -10.921	$\begin{array}{c} -0.004(3) \\ -0.00006(5) \\ +0.00047(5) \\ -0.61(3) \\ -0.291(14) \end{array}$	7.93 7.02 6.70 6.63 7.00	$11.16 \\ 12.31 \\ 12.33 \\ 12.02 \\ 11.27$	51445.0 49753.0 46407.0 51271.0 51446.0	263 490 900 178 327	$11.1 \\ 19.7 \\ 36.4 \\ 12.0 \\ 11.1$	$ 1.85 \\ 1.29 \\ 9.11 \\ 70.21 \\ 6.56 $	$1.84 \\ 1.28 \\ 8.66 \\ 37.88 \\ 4.23$	$1.82 \\ 1.26 \\ 0.25 \\ 3.11 \\ 0.63$
$\substack{J \ 1238+21\\J1239+2453\\J1257-1027\\J1300+1240\\J1311-1228}$	$\substack{ B1238+21 \\ B1237+25 \\ B1254-10 \\ B1257+12 \\ B1309-12 }$	$0.894 \\ 0.723 \\ 1.620 \\ 160.810 \\ 2.235$	-1.155 -0.502 -0.952 -2.957 -0.753	$\begin{array}{c} -0.003(3) \\ -0.000350(7) \\ -0.00009(16) \\ +0.002(4) \\ -0.00141(12) \end{array}$	7.09 7.36 7.43 8.94 7.67	$12.11 \\ 12.07 \\ 11.68 \\ 8.93 \\ 11.42$	51822.0 46942.0 49348.2 50788.0 50094.0	72 1026 475 360 433 C	8.9 35.6 18.4 14.5 18.5 0000 RA	1.86 2.70 1.12 0.08 0.65 S, MNRA	1.85 1.41 1.12 0.08 0.56 AS 000 ,	${}^{1.77}_{0.59}_{1.08}_{0.08}_{0.50}_{000-000}$

PSR J	PSR B	$_{(s^{-1})}^{\nu}$	${}^{\dot{\nu}}_{(10^{-15}s^{-2})}$	$\ddot{\nu}_{(10^{-24}s^{-3})}$	$\log_{10}(\tau_c)$	$\log_{10} B_s$ (G)	Epoch (MJD)	Ν	T_{span} (yr)	σ_1 (ms)	σ_2 (ms)	σ_3 (ms)
$\begin{array}{c} J1321{+}8323\\ J1332{-}3032\\ J1455{-}3330\\ J1509{+}5531\\ J1518{+}4904 \end{array}$	B1322+83 — — B1508+55 —	$1.492 \\1.537 \\125.200 \\1.352 \\24.429$	-1.262 -1.322 -0.381 -9.144 -0.016	$\begin{array}{c} -0.0056(3) \\ +0.017(9) \\ -0.008(4) \\ +0.0819(15) \\ +0.0002(5) \end{array}$	7.27 7.27 9.72 6.37 10.38	$ \begin{array}{r} 11.79 \\ 11.79 \\ 8.65 \\ 12.29 \\ 9.03 \\ \end{array} $	$\begin{array}{c} 49282.0\\ 51447.0\\ 51190.0\\ 49294.0\\ 51619.0\end{array}$	289 191 269 470 308	22.8 11.0 12.4 22.7 9.9	3.97 9.66 0.07 59.55 0.03	$2.31 \\ 9.57 \\ 0.07 \\ 22.06 \\ 0.03$	2.17 9.04 0.07 0.55 0.03
$\begin{array}{c} J1532 + 2745\\ J1537 + 1155\\ J1543 + 0929\\ J1543 - 0620\\ J1555 - 2341 \end{array}$	$\substack{ B1530+27\\ B1534+12\\ B1541+09\\ B1540-06\\ B1552-23 }$	0.889 26.382 1.336 1.410 1.878	-0.616 -1.686 -0.772 -1.749 -2.447	$\begin{array}{c} -0.0024(3) \\ +0.00004(26) \\ -0.0093(4) \\ +0.0130(3) \\ -0.0280(4) \end{array}$	7.36 8.39 7.44 7.11 7.08	$ 11.98 \\ 9.99 \\ 11.76 \\ 11.90 \\ 11.79 $	50096.0 50300.0 49141.0 49839.0 50301.0	$414 \\ 399 \\ 451 \\ 502 \\ 346$	$18.5 \\13.8 \\23.7 \\19.7 \\17.3$	$3.37 \\ 0.04 \\ 10.40 \\ 6.98 \\ 6.42$	$3.04 \\ 0.04 \\ 6.46 \\ 3.03 \\ 1.40$	$1.66 \\ 0.04 \\ 3.27 \\ 0.44 \\ 0.89$
$\begin{array}{c} J1555-3134\\ J1603-2531\\ J1603-2712\\ J1607-0032\\ J1610-1322 \end{array}$	B1552-31 — B1600-27 B1604-00 B1607-13	$ 1.930 \\ 3.533 \\ 1.285 \\ 2.371 \\ 0.982 $	-0.232 -19.875 -4.968 -1.720 -0.222	$\begin{array}{c} -0.00018(19) \\ -0.068(12) \\ -0.0025(3) \\ -0.002015(10) \\ -0.0003(6) \end{array}$	8.12 6.45 6.61 7.34 7.85	$11.26 \\ 11.83 \\ 12.19 \\ 11.56 \\ 11.69$	50299.0 51121.0 50302.0 47386.0 50094.0	289 191 199 728 213	17.3 12.0 17.3 33.2 18.5	0.70 9.09 1.61 3.54 4.76	$0.69 \\ 8.19 \\ 1.37 \\ 0.47 \\ 4.76$	$0.67 \\ 0.43 \\ 0.67 \\ 0.44 \\ 4.65$
$\begin{array}{c} J1614{+}0737\\ J1615{-}2940\\ J1623{-}0908\\ J1623{-}2631\\ J1635{+}2418\\ \end{array}$	$\substack{ B1612+07 \\ B1612-29 \\ B1620-09 \\ B1620-26 \\ B1633+24 }$	$\begin{array}{c} 0.829 \\ 0.404 \\ 0.783 \\ 90.287 \\ 2.039 \end{array}$	-1.620 -0.258 -1.584 -2.953 -0.496	$\begin{array}{c} -0.0007(3) \\ +0.00012(17) \\ +0.00027(3) \\ +18.346(11) \\ +0.00070(20) \end{array}$		$12.23 \\ 12.30 \\ 12.26 \\ 9.31 \\ 11.39$	$\begin{array}{c} 49897.0\\ 49026.0\\ 49142.0\\ 50292.0\\ 49130.0\end{array}$	160 98 393 767 148	$15.1 \\ 23.1 \\ 23.7 \\ 17.5 \\ 16.6$	1.15 4.88 0.84 103.67 1.19	$1.12 \\ 4.87 \\ 0.76 \\ 3.06 \\ 1.19$	1.07 4.62 0.71 0.15 1.16
$\begin{array}{c} J1643-1224\\ J1645-0317\\ J1648-3256\\ J1650-1654\\ J1651-1709 \end{array}$	 B1642-03 B1648-17	216.373 2.579 1.390 0.572 1.027	-0.865 -11.846 -6.815 -1.046 -3.205	$\begin{array}{c} -0.0044(19) \\ +0.0053(5) \\ +0.004(3) \\ -0.0027(8) \\ +0.0007(4) \end{array}$	9.60 6.54 6.51 6.94 6.71	$8.47 \\11.92 \\12.21 \\12.38 \\12.24$	51251.0 46930.0 51276.0 51272.0 50430.0	$432 \\ 956 \\ 148 \\ 171 \\ 167$	12.0 35.6 12.0 12.0 16.3	$\begin{array}{c} 0.03\\ 21.70\\ 4.54\\ 3.06\\ 1.56 \end{array}$	$\begin{array}{c} 0.03 \\ 20.05 \\ 4.51 \\ 2.93 \\ 1.54 \end{array}$	$0.02 \\ 1.21 \\ 0.83 \\ 2.77 \\ 1.36$
$\begin{array}{c} J1652-2404\\ J1654-2713\\ J1659-1305\\ J1700-3312\\ J1703-1846 \end{array}$	B1649-23 — B1657-13 — B1700-18	0.587 1.263 1.560 0.736 1.243	-1.088 -0.268 -1.503 -2.555 -2.676	$\begin{array}{c} -0.00155(5) \\ +0.002(3) \\ +0.0309(7) \\ -0.0163(6) \\ +0.00003(12) \end{array}$	6.93 7.87 7.22 6.66 6.87	$12.37 \\11.57 \\11.80 \\12.41 \\12.08$	$\begin{array}{c} 49132.0\\ 51414.0\\ 50094.0\\ 51276.0\\ 50314.0\end{array}$	$347 \\ 154 \\ 145 \\ 249 \\ 209$	23.6 11.1 18.5 12.0 17.3	3.17 2.40 10.87 3.93 0.56	$1.70 \\ 2.39 \\ 2.68 \\ 1.88 \\ 0.56$	1.60 2.36 2.37 1.46 0.52
$\begin{array}{c} J1703-3241\\ J1705-1906\\ J1705-3423\\ J1708-3426\\ J1709-1640\\ \end{array}$	B1700-32 B1702-19 — B1706-16	0.825 3.345 3.915 1.445 1.531	-0.449 -46.284 -16.484 -8.775 -14.780	$\begin{array}{c} +0.00122(9) \\ -0.0009(6) \\ +0.085(6) \\ -0.0101(14) \\ +0.3397(11) \end{array}$	7.46 6.06 6.58 6.42 6.22	$11.96 \\ 12.05 \\ 11.72 \\ 12.24 \\ 12.31$	50427.0 50497.0 51256.0 51276.0 47389.0	$158 \\ 410 \\ 151 \\ 123 \\ 484$	16.3 16.3 11.9 12.0 33.2	$\begin{array}{c} 0.77 \\ 1.25 \\ 4.63 \\ 2.43 \\ 837.06 \end{array}$	$\begin{array}{c} 0.51 \\ 1.24 \\ 2.86 \\ 2.07 \\ 156.71 \end{array}$	$\begin{array}{c} 0.48 \\ 0.36 \\ 1.11 \\ 1.98 \\ 0.93 \end{array}$
$\begin{array}{c} J1711-1509\\ J1713+0747\\ J1717-3425\\ J1720-0212\\ J1720-1633 \end{array}$	B1709-15 	$1.151 \\ 218.812 \\ 1.524 \\ 2.093 \\ 0.639$	-1.461 -0.409 -22.761 -0.363 -2.366	$\begin{array}{c} +0.0067(3) \\ +0.0020(13) \\ +0.022(8) \\ -0.0001(6) \\ -0.00002(72) \end{array}$	7.10 9.93 6.03 7.96 6.63	12.00 8.30 12.41 11.30 12.48	50094.0 51318.0 50673.0 49853.0 50084.0	197 344 138 319 207	18.5 11.5 15.2 19.8 18.4	$3.77 \\ 0.01 \\ 17.92 \\ 3.45 \\ 9.09$	$1.72 \\ 0.01 \\ 17.45 \\ 3.45 \\ 9.09$	$0.68 \\ 0.01 \\ 1.38 \\ 3.39 \\ 1.43$
J1720-2933 J1721-1936 J1721-3532 J1722-3207 J1728-0007	$\begin{array}{c} B1717-29\\ B1718-19\\ B1718-35\\ B1718-32\\ B1726-00\\ \end{array}$	1.612 0.996 3.566 2.096 2.591	-1.938 -1.609 -320.260 -2.838 -7.535	$\begin{array}{c} -0.0142(3) \\ +0.153(13) \\ -0.07(6) \\ -0.0010(7) \\ -0.0167(7) \end{array}$	7.12 6.99 5.25 7.07 6.74	$11.84 \\ 12.11 \\ 12.43 \\ 11.75 \\ 11.82$	50290.0 50840.0 51505.0 50495.0 50513.0	164 288 138 180 151	$17.2 \\ 14.4 \\ 10.2 \\ 16.3 \\ 16.1$	$3.89 \\ 67.67 \\ 14.95 \\ 1.72 \\ 2.89$	$0.87 \\ 54.78 \\ 15.94 \\ 1.71 \\ 1.29$	$\begin{array}{c} 0.70 \\ 5.31 \\ 3.33 \\ 0.22 \\ 0.95 \end{array}$
$\begin{array}{c} J1730-2304\\ J1730-3350\\ J1732-1930\\ J1733-2228\\ J1734-0212 \end{array}$	B1727-33 B1730-22 B1732-02	$123.110 \\ 7.170 \\ 2.067 \\ 1.147 \\ 1.191$	-0.306 -4361.164 -0.776 -0.056 -0.597	$\begin{array}{c} -0.0060(13)\\ -51.5(20)\\ -0.004(3)\\ -0.00006(8)\\ +0.0026(8)\end{array}$	9.80 4.42 7.63 8.51 7.50	8.61 12.54 11.48 11.29 11.78	51240.0 51419.0 51644.0 49140.0 50117.0	443 351 99 394 127	$12.0 \\ 11.2 \\ 10.1 \\ 23.7 \\ 18.3$	$\begin{array}{c} 0.03 \\ 1204.52 \\ 1.41 \\ 1.41 \\ 3.52 \end{array}$	$0.03 \\ 491.30 \\ 1.40 \\ 1.40 \\ 3.37$	0.03 197.19 1.36 1.39 3.22
$\begin{array}{c} J1735 {-}0724\\ J1738 {-}3211\\ J1739 {-}2903\\ J1739 {-}3131\\ J1740 {+}1311 \end{array}$	B1732-07 B1735-32 B1736-29 B1736-31 B1737+13	2.385 1.301 3.097 1.889 1.245	-6.908 -1.346 -75.578 -66.269 -2.250	+0.0019(4) +0.00043(14) +0.127(4) +0.78(4) +0.01946(14)	6.74 7.19 5.81 5.65 6.94	$11.86 \\ 11.90 \\ 12.21 \\ 12.50 \\ 12.04$	50312.0 50018.0 49872.0 49884.0 48669.0	$342 \\ 360 \\ 392 \\ 243 \\ 442$	17.3 18.9 18.9 18.1 26.3	$1.22 \\ 1.33 \\ 28.56 \\ 279.24 \\ 24.90$	$1.18 \\ 1.31 \\ 10.50 \\ 175.12 \\ 3.58$	$0.26 \\ 1.28 \\ 1.45 \\ 6.54 \\ 0.57$
J1741+2758 J1741-0840 J1743-0339 J1743-1351 J1743-3150	$\begin{array}{c}$	$0.735 \\ 0.489 \\ 2.249 \\ 2.467 \\ 0.414$	-0.994 -0.545 -7.873 -2.910 -20.716	+0.001(6) -0.00007(10) +0.41(4) -0.080(3) -0.0184(7)	7.07 7.15 6.66 7.13 5.50	12.20 12.34 11.93 11.65 13.24	51750.0 50306.0 50199.0 50095.0 50674.0	71 295 135 184 280	9.4 17.2 16.6 18.5 15.3	$\begin{array}{c} 4.72 \\ 1.34 \\ 109.68 \\ 19.33 \\ 16.67 \end{array}$	4.72 1.34 77.53 8.55 8.66	$\begin{array}{c} 4.64 \\ 1.33 \\ 8.37 \\ 1.14 \\ 2.74 \end{array}$
$\begin{array}{c} J1744-1134\\ J1745-3040\\ J1748-1300\\ J1748-2021\\ J1748-2444 \end{array}$	B1742-30 B1745-12 B1745-20	245.426 2.722 2.537 3.465 2.258	-0.539 -79.021 -7.808 -4.803 -0.568	$\begin{array}{c} -0.0075(12) \\ -0.0629(18) \\ -0.0347(7) \\ +0.059(8) \\ -0.0024(12) \end{array}$	9.86 5.74 6.71 7.06 7.80	8.29 12.30 11.84 11.54 11.35	51490.0 50311.0 50315.0 50677.0 50917.0	281 393 289 362 189	10.7 17.3 17.3 15.3 14.2	$0.01 \\ 10.44 \\ 5.89 \\ 14.86 \\ 1.82$	$0.01 \\ 4.97 \\ 1.86 \\ 13.69 \\ 1.80$	$0.01 \\ 0.19 \\ 0.28 \\ 13.31 \\ 1.77$
$\begin{array}{c} J1749 - 3002 \\ J1750 - 3157 \\ J1750 - 3503 \\ J1752 - 2806 \\ J1753 - 2501 \end{array}$	B1746-30 B1747-31 B1749-28 B1750-24	1.640 1.098 1.462 1.778 1.893	-21.163 -0.237 -0.079 -25.687 -50.565	$\begin{array}{c} -0.0525(20) \\ +0.0003(4) \\ +0.031(16) \\ +0.0087(10) \\ -0.014(5) \end{array}$	6.09 7.87 8.47 6.04 5.77	$12.35 \\ 11.63 \\ 11.21 \\ 12.34 \\ 12.44$	50653.0 50674.0 51426.0 46889.0 49883.0	$192 \\ 212 \\ 131 \\ 654 \\ 215$	$15.2 \\ 15.3 \\ 11.2 \\ 35.8 \\ 18.9$	$11.50 \\ 1.33 \\ 15.94 \\ 66.82 \\ 21.48$	$5.34 \\ 1.33 \\ 15.71 \\ 63.08 \\ 21.33$	2.04 1.27 14.94 1.11 3.95
$\begin{array}{c} J1754{+}5201\\ J1756{-}2435\\ J1757{-}2421\\ J1759{-}2205\\ J1759{-}2922\end{array}$	B1753+52 B1753-24 B1754-24 B1756-22 	$\begin{array}{c} 0.418 \\ 1.491 \\ 4.272 \\ 2.169 \\ 1.741 \end{array}$	-0.274 -0.633 -235.739 -51.171 -14.028	$\begin{array}{c} -0.0003(3)\\ -0.00005(12)\\ +0.140(4)\\ -0.213(3)\\ +0.0017(9) \end{array}$	7.38 7.57 5.46 5.83 6.29	$12.29 \\ 11.65 \\ 12.25 \\ 12.36 \\ 12.22$	50095.0 49848.0 49121.0 50126.0 51256.0	289 231 396 388 132	18.5 18.8 22.8 18.3 11.9	5.01 0.75 37.47 49.84 0.96	$5.00 \\ 0.75 \\ 17.55 \\ 11.51 \\ 0.95$	$\begin{array}{c} 4.87 \\ 0.70 \\ 1.54 \\ 0.54 \\ 0.84 \end{array}$
$\begin{array}{c} J1801-0357\\ J1801-2920\\ J1803-2137\\ J1803-2712\\ J1804-0735 \end{array}$	B1758-03 B1758-29 B1800-21 B1800-27 B1802-07	$1.085 \\ 0.924 \\ 7.484 \\ 2.990 \\ 43.288$	-3.897 -2.814 -7511.505 -0.153 -0.875	$\begin{array}{c} -0.032(3) \\ -0.0041(8) \\ +220.36(3) \\ +0.0012(7) \\ +0.0036(14) \end{array}$	6.64 6.72 4.20 8.49 8.89	$12.25 \\ 12.28 \\ 12.63 \\ 10.88 \\ 9.52$	50084.0 51417.0 49527.0 50661.0 50709.0	$201 \\ 228 \\ 356 \\ 151 \\ 432$	$18.4 \\ 11.0 \\ 6.9 \\ 15.1 \\ 15.0$	22.60 1.58 954.70 1.17 0.28	16.77 1.50 47.85 1.18 0.28	$1.20 \\ 0.61 \\ 3.18 \\ 1.10 \\ 0.28$
J1804-2717 J1805+0306 J1806-1154 J1807-0847 J1807-2715	B1802+03 B1804-12 B1804-08 B1804-27	$107.032 \\ 4.572 \\ 1.913 \\ 6.108 \\ 1.208$	-0.468 -20.892 -5.157 -1.074 -17.768	$\begin{array}{c} -0.010(3) \\ +0.04414(19) \\ +0.0299(6) \\ -0.003045(9) \\ -0.08609(14) \end{array}$	9.56 6.54 6.77 7.95 6.03	8.80 11.67 11.94 10.84 12.51	51440.0 50331.0 51096.0 48671.0 50291.0	$260 \\ 196 \\ 179 \\ 456 \\ 233$	$10.9 \\ 16.5 \\ 12.7 \\ 26.3 \\ 17.2$	0.07 3.81 2.68 1.04 27.46	0.07 1.74 1.07 0.55 3.32	0.07 0.26 0.77 0.09 0.79
$\begin{array}{c} J1808-0813\\ J1808-2057\\ J1809-2109\\ J1812+0226\\ J1812-1718 \end{array}$	 B1805-20 B1806-21 B1810+02 	1.141 1.089 1.424 1.260 0.830	-1.616 -20.243 -7.747 -5.711 -13.128	+0.0028(4) +0.07844(13) -0.00934(7) +0.0007(3) +0.08279(7)	7.05 5.93 6.46 6.54 6.00	12.02 12.60 12.22 12.23 12.69	51271.0 49937.0 49995.0 50336.0 49887.0	$153 \\ 187 \\ 226 \\ 244 \\ 233$	12.0 18.8 18.8 17.1 18.9	$0.99 \\ 44.89 \\ 4.88 \\ 1.32 \\ 80.84$	$0.91 \\ 4.63 \\ 3.12 \\ 1.28 \\ 48.68$	$0.84 \\ 1.59 \\ 0.36 \\ 1.17 \\ 3.29$

A statistical study of pulsar timing irregularities using observations from Jodrell Bank Observatory 7

PSR J	PSR B	$_{(s^{-1})}^{\nu}$	$\dot{\nu}_{(10^{-15}s^{-2})}$	$\ddot{\nu}$ (10 ⁻²⁴ s ⁻³)	$\log_{10}(\tau_c)$	$\log_{10} B_s$ (G)	Epoch (MJD)	Ν	T_{span} (yr)	σ_1 (ms)	σ_2 (ms)	σ_3 (ms)
$\begin{array}{c} J1812-1733\\ J1813+4013\\ J1816-1729\\ J1816-2650\\ J1818-1422 \end{array}$	$\begin{array}{c}\\ B1811+40\\ B1813-17\\ B1813-26\\ B1815-14 \end{array}$	$1.858 \\ 1.074 \\ 1.278 \\ 1.687 \\ 3.431$	-3.390 -2.939 -11.873 -0.189 -23.995	$\begin{array}{c} -0.0134(8) \\ +0.01290(12) \\ -0.20505(10) \\ -0.00109(10) \\ -0.01865(10) \end{array}$	6.94 6.76 6.23 8.15 6.36	11.87 12.19 12.38 11.30 11.89	50688.0 50300.0 49887.0 49573.9 49993.0	191 266 237 260 217	$15.2 \\ 17.2 \\ 18.8 \\ 23.6 \\ 18.6$	3.81 5.02 99.19 2.04 8.77	3.01 1.16 16.47 1.88 8.34	2.81 0.88 1.10 1.84 0.96
$\begin{array}{c} J1820-0427\\ J1820-1346\\ J1820-1818\\ J\ 1821+17\\ J1822+0705 \end{array}$	B1818-04 B1817-13 B1817-18 B1821+17 —	$1.672 \\ 1.085 \\ 3.227 \\ 0.732 \\ 0.734$	-17.700 -5.294 -0.975 -0.466 -0.941	$\begin{array}{c} +0.0269096(15) \\ +0.01260(12) \\ +0.0039(5) \\ +0.0003(19) \\ +0.0011(13) \end{array}$	6.18 6.51 7.72 7.40 7.09	12.29 12.31 11.24 12.04 12.19	47020.0 50018.0 50663.0 51819.0 51748.0	690 217 170 91 78	$35.1 \\ 18.9 \\ 15.1 \\ 9.0 \\ 9.4$	91.86 7.77 0.71 2.52 1.12	46.26 2.01 0.58 2.53 1.13	0.75 1.26 0.55 2.52 1.12
$\begin{array}{c} J1822-1400\\ J1822-2256\\ J1823+0550\\ J1823-0154\\ J1823-1115 \end{array}$	B1820-14 B1819-22 B1821+05 — B1820-11	$\begin{array}{c} 4.656 \\ 0.534 \\ 1.328 \\ 1.316 \\ 3.574 \end{array}$	-19.665 -0.385 -0.400 -1.960 -17.611	$\begin{array}{c} -0.1110(3) \\ +0.00013(10) \\ -0.00149(5) \\ -0.0088(4) \\ -0.1563(5) \end{array}$	6.57 7.34 7.72 7.03 6.51	11.65 12.21 11.62 11.97 11.80	50042.0 49120.0 49844.0 51276.0 49993.0	$207 \\ 164 \\ 354 \\ 155 \\ 448$	18.6 16.0 19.4 12.0 18.6	16.75 1.11 1.01 1.35 25.98	9.97 1.11 0.58 0.71 11.65	1.00 1.07 0.36 0.57 2.98
$\begin{array}{c} J1823-3021\\ J1823-3021\\ J1823-3106\\ J1824-1118\\ J1824-1945 \end{array}$	 B1820-31 B1821-11 B1821-19	$183.823 \\ 2.641 \\ 3.520 \\ 2.295 \\ 5.282$	-114.337 -0.225 -36.278 -18.716 -145.939	$\begin{array}{c} +0.528(3) \\ +0.0032(4) \\ -0.12980(5) \\ +0.05739(12) \\ -0.17194(4) \end{array}$	7.41 8.27 6.19 6.29 5.76	9.64 11.05 11.97 12.10 12.00	50719.0 50700.0 50315.0 49874.0 50101.0	301 302 237 232 351	15.0 14.9 17.3 18.7 18.2	$0.84 \\ 0.78 \\ 17.69 \\ 25.95 \\ 36.93$	$0.09 \\ 0.72 \\ 8.32 \\ 20.53 \\ 34.03$	$0.09 \\ 0.64 \\ 0.35 \\ 1.74 \\ 0.53$
$\begin{array}{c} J1824-2452\\ J1825+0004\\ J1825-0935\\ J1825-1446\\ J1826-1131 \end{array}$	$\begin{array}{c} B1821-24\\ B1822+00\\ B1822-09\\ B1822-14\\ B1823-11 \end{array}$	327.406 1.284 1.300 3.582 0.478	-173.519 -1.445 -88.369 -290.948 -1.121	$\begin{array}{c} +0.049(5) \\ -0.00788(14) \\ +1.54726(3) \\ +0.18805(10) \\ +0.00419(7) \end{array}$	7.48 7.15 5.37 5.29 6.83	$9.35 \\11.92 \\12.81 \\12.41 \\12.51$	50238.0 50336.0 49831.0 49862.0 49867.0	162 238 503 233 339	17.4 17.1 19.7 19.1 19.7	$\begin{array}{c} 0.13 \\ 3.30 \\ 759.34 \\ 33.63 \\ 6.76 \end{array}$	0.11 2.22 173.46 8.70 3.20	$0.09 \\ 0.63 \\ 16.36 \\ 1.51 \\ 2.41$
$\begin{array}{c} J1826-1334\\ J1827-0958\\ J1829-1751\\ J1830-1059\\ J1832-0827 \end{array}$	$\begin{array}{c} B1823-13\\ B1824-10\\ B1826-17\\ B1828-11\\ B1829-08 \end{array}$	9.856 4.069 3.256 2.469 1.545	-7294.596 -16.597 -58.853 -365.841 -152.462	$\begin{array}{c} +147.730(5) \\ -0.0398(4) \\ +0.05928(5) \\ +0.841539(17) \\ -0.02462(4) \end{array}$	$\begin{array}{c} 4.33 \\ 6.59 \\ 5.94 \\ 5.03 \\ 5.21 \end{array}$	$12.45 \\ 11.70 \\ 12.12 \\ 12.70 \\ 12.81$	50639.9 49883.0 50101.0 50031.0 49868.0	237 252 363 754 358	7.8 18.8 18.2 18.7 18.8	705.55 6.86 10.50 187.26 28.04	30.29 3.64 7.69 18.07 27.42	
$\begin{array}{c} J1832-1021\\ J1833-0338\\ J1833-0827\\ J1834-0010\\ J1834-0426 \end{array}$	B1829-10 B1831-03 B1830-08 B1831-00 B1831-04	3.027 1.456 11.725 1.920 3.447	-38.493 -88.139 -1260.890 -0.039 -0.854	$\begin{array}{c} +0.25131(9)\\ +0.09744(4)\\ -1.3659(4)\\ -0.0030(18)\\ +0.02158(18)\end{array}$	6.10 5.42 5.17 8.89 7.81	$12.08 \\ 12.73 \\ 11.95 \\ 10.88 \\ 11.16$	$\begin{array}{c} 49883.0\\ 50123.0\\ 50740.0\\ 49123.0\\ 50165.0\end{array}$	$371 \\ 499 \\ 350 \\ 148 \\ 250$	18.8 18.3 14.7 12.8 18.1	50.10 44.27 31.25 5.42 3.21	9.82 31.26 3.54 5.48 1.25	0.70 2.87 0.34 5.20 0.49
$\begin{array}{c} J1835\!-\!0643\\ J1835\!-\!1106\\ J1836\!-\!0436\\ J1836\!-\!1008\\ J1837\!-\!0045 \end{array}$	B1832-06 	3.270 6.027 2.823 1.777 1.621	-432.507 -748.767 -13.239 -37.278 -4.424	$\begin{array}{c} +0.7941(5) \\ +9.0989(4) \\ -0.06576(8) \\ -0.01277(4) \\ -0.0031(16) \end{array}$	5.08 5.11 6.53 5.88 6.76	12.55 12.27 11.89 12.42 12.01	$\begin{array}{c} 49993.0\\ 51289.0\\ 49957.0\\ 50123.0\\ 51400.0\end{array}$	254 242 246 278 193	$18.8 \\ 12.1 \\ 19.2 \\ 17.3 \\ 11.0$	$148.66 \\ 319.72 \\ 16.92 \\ 35.35 \\ 1.40$	27.75 180.82 7.55 35.99 1.38	2.17 43.26 0.51 1.31 1.38
$\begin{array}{c} J1837{-}0653\\ J1840{+}5640\\ J1841{+}0912\\ J1841{-}0425\\ J1842{-}0359 \end{array}$	B1834-06 B1839+56 B1839+09 B1838-04 B1839-04	$0.525 \\ 0.605 \\ 2.622 \\ 5.372 \\ 0.543$	-0.213 -0.547 -7.496 -184.441 -0.150	$\begin{array}{c} -0.00003(13)\\ -0.000906(16)\\ +0.045286(19)\\ +0.04131(7)\\ +0.00038(10)\end{array}$	7.59 7.24 6.74 5.66 7.76	12.09 12.20 11.81 12.04 11.99	50014.0 49129.0 48854.0 49849.0 49848.0	240 368 374 319 302	18.5 23.6 25.3 18.6 19.6	3.11 2.01 28.07 21.77 2.73	3.11 1.09 13.47 22.29 2.69	3.02 1.05 1.17 0.39 2.63
$\begin{array}{c} J1844{+}1454\\ J1844{-}0244\\ J1844{-}0433\\ J1844{-}0538\\ J1845{-}0434 \end{array}$	B1842+14 B1842-02 B1841-04 B1841-05 B1842-04	2.663 1.970 1.009 3.911 6.163	-13.281 -64.936 -3.986 -148.444 -143.409	$\begin{array}{c} +0.04488(4) \\ +0.0765(3) \\ -0.00112(7) \\ -0.06503(8) \\ +0.2989(3) \end{array}$		11.93 12.47 12.30 12.20 11.90	$\begin{array}{c} 49766.0\\ 49884.0\\ 50032.0\\ 49867.0\\ 49610.0\end{array}$	386 243 348 295 210	20.3 19.2 18.8 19.2 16.5	$\begin{array}{c} 42.19\\ 35.87\\ 1.41\\ 20.12\\ 37.68\end{array}$	40.60 26.13 1.22 17.51 31.84	0.90 2.29 0.71 0.55 2.30
$\begin{array}{c} J1847-0402\\ J1848-0123\\ J1848-1414\\ J1848-1952\\ J1849-0636\\ \end{array}$	B1844-04 B1845-01 B1845-19 B1846-06	1.673 1.516 3.358 0.232 0.689	-144.702 -12.075 -0.158 -1.254 -21.953	$\begin{array}{c} +0.08200(3) \\ +0.05418(5) \\ +0.0009(12) \\ -0.00041(12) \\ -0.00971(3) \end{array}$	5.26 6.30 8.53 6.47 5.70	$12.75 \\12.27 \\10.82 \\13.01 \\12.92$	$\begin{array}{c} 49142.0\\ 50407.0\\ 51269.0\\ 50515.0\\ 49142.0\end{array}$	421 288 141 177 343	22.9 16.2 12.0 16.2 21.7	50.58 19.92 1.12 4.11 9.55	2.89 17.61 1.12 4.06 4.69	$0.44 \\ 0.45 \\ 1.10 \\ 3.89 \\ 0.53$
$\begin{array}{c} J1850{+}1335\\ J1851{+}0418\\ J1851{+}1259\\ J1852{+}0031\\ J1852{-}2610 \end{array}$	B1848+13 B1848+04 B1849+00 	2.894 3.513 0.830 0.459 2.973	-12.497 -13.431 -7.924 -20.398 -0.775	$\begin{array}{c} -0.01154(11) \\ +0.2039(6) \\ +0.20318(11) \\ -0.0095(5) \\ +0.0153(5) \end{array}$	6.56 6.62 6.22 5.55 7.78	11.86 11.75 12.58 13.17 11.24	50128.0 50113.0 50106.0 49995.0 51249.0	214 254 193 231 124	18.3 18.2 18.4 18.8 11.9	$1.98 \\ 29.26 \\ 134.53 \\ 32.45 \\ 0.88$	$0.39 \\ 4.39 \\ 41.85 \\ 29.14 \\ 0.30$	0.27 1.42 1.09 21.70 0.27
$\begin{array}{c} J1854{+}1050\\ J1854{-}1421\\ J1856{+}0113\\ J1857{+}0057\\ J1857{+}0212 \end{array}$	$\substack{ B1852+10 \\ B1851-14 \\ B1853+01 \\ B1854+00 \\ B1855+02 }$	$1.745 \\ 0.872 \\ 3.739 \\ 2.802 \\ 2.405$	-1.938 -3.166 -2911.541 -0.429 -232.901	$\begin{array}{c} +0.011(4) \\ -0.02349(10) \\ +25.6829(3) \\ -0.0040(8) \\ +0.24472(8) \end{array}$	7.15 6.64 4.31 8.02 5.21	$11.79 \\ 12.34 \\ 12.88 \\ 11.15 \\ 12.62$	50869.0 50313.0 50523.0 50097.0 49945.0	266 193 344 136 279	$14.2 \\ 17.3 \\ 16.3 \\ 18.5 \\ 18.8$	$11.45 \\ 11.52 \\ 3043.03 \\ 2.56 \\ 65.35$	$11.32 \\ 4.55 \\ 140.80 \\ 2.45 \\ 8.69$	$10.93 \\ 0.71 \\ 18.41 \\ 2.34 \\ 0.31$
$\begin{array}{c} J1857{+}0943\\ J1900{-}2600\\ J1901{+}0156\\ J1901{+}0331\\ J1901{+}0716\\ \end{array}$	$\substack{ B1855+09 \\ B1857-26 \\ B1859+01 \\ B1859+03 \\ B1859+07 \\ }$	186.494 1.633 3.470 1.526 1.553	-0.620 -0.546 -28.379 -17.358 -5.498	$\begin{array}{c} -0.0016(5) \\ -0.00382(5) \\ -0.0225(7) \\ +0.07654(7) \\ +0.0571(3) \end{array}$	9.68 7.68 6.29 6.14 6.65	8.50 11.55 11.92 12.35 12.09	50027.0 50105.0 49345.0 50312.0 50016.0	447 228 131 252 364	18.7 18.2 11.6 17.3 18.9	$0.04 \\ 1.13 \\ 1.03 \\ 54.54 \\ 133.31$	$0.04 \\ 0.31 \\ 0.86 \\ 51.24 \\ 130.51$	$0.04 \\ 0.22 \\ 0.31 \\ 1.33 \\ 9.78$
$\begin{array}{c} J1901-0906\\ J1902+0556\\ J1902+0615\\ J1903+0135\\ J1903-0632 \end{array}$	$\begin{array}{c}\\ B1900+05\\ B1900+06\\ B1900+01\\ B1900-06\end{array}$	$1.122 \\ 1.339 \\ 1.485 \\ 1.371 \\ 2.315$	-1.032 -23.098 -16.990 -7.582 -18.224	$\begin{array}{c} +0.0013(3) \\ +0.04707(8) \\ -0.03224(8) \\ -0.00650(4) \\ +0.23973(11) \end{array}$	7.24 5.96 6.14 6.46 6.30	$11.94 \\ 12.50 \\ 12.36 \\ 12.24 \\ 12.09$	51277.0 50112.0 50300.0 50430.0 50430.0	$140 \\ 354 \\ 401 \\ 242 \\ 215$	12.0 18.2 17.2 16.3 16.3	0.41 18.75 9.12 2.96 61.75	$\begin{array}{c} 0.36 \\ 2.26 \\ 3.42 \\ 2.20 \\ 40.77 \end{array}$	$\begin{array}{c} 0.34 \\ 0.61 \\ 0.60 \\ 0.37 \\ 0.58 \end{array}$
$\begin{array}{c} J1904\!+\!0004\\ J1904\!-\!1224\\ J1905\!+\!0709\\ J1905\!-\!0056\\ J1906\!+\!0641 \end{array}$	 B1903+07 B1902-01 B1904+06	7.167 1.332 1.543 1.555 3.741	-6.065 -1.317 -11.750 -7.378 -29.895	$\begin{array}{c} +0.0410(8) \\ -0.0035(8) \\ +0.5539(3) \\ -0.01931(8) \\ -0.00358(10) \end{array}$	7.27 7.20 6.32 6.52 6.30	$11.11 \\ 11.88 \\ 12.26 \\ 12.15 \\ 11.88$	51269.0 51037.0 49856.0 50127.0 50016.0	$147 \\ 95 \\ 355 \\ 220 \\ 246$	12.0 8.9 19.6 18.3 18.9	$1.80 \\ 0.52 \\ 266.65 \\ 5.93 \\ 0.98$	$1.44 \\ 0.50 \\ 81.60 \\ 1.19 \\ 0.78$	$0.45 \\ 0.47 \\ 8.82 \\ 0.26 \\ 0.31$
$\begin{array}{c} J1907{+}4002\\ J1909{+}0007\\ J1909{+}0254\\ J1909{+}1102\\ J1910{+}0358 \end{array}$	B1905+39 B1907+00 B1907+02 B1907+10 B1907+03	$0.809 \\ 0.983 \\ 1.010 \\ 3.526 \\ 0.429$	-0.354 -5.336 -5.634 -32.811 -0.822	$\begin{array}{c} -0.00010(6) \\ +0.00586(3) \\ +0.07290(12) \\ -0.01965(5) \\ +0.0283(4) \end{array}$	7.56 6.47 6.45 6.23 6.92	11.92 12.38 12.37 11.94 12.51	$\begin{array}{c} 49144.0\\ 49121.0\\ 50496.0\\ 50316.0\\ 50428.0\end{array}$	$364 \\ 328 \\ 264 \\ 379 \\ 193$	23.7 22.8 16.3 17.3 16.1	2.28 21.37 27.55 13.65 31.57	2.29 19.16 2.09 13.66 15.22	$2.20 \\ 0.73 \\ 0.74 \\ 0.33 \\ 4.44$
$\begin{array}{c} J1910{+}1231\\ J1910{-}0309\\ J1911{-}1114\\ J1912{+}2104\\ J1913{+}1400\\ \end{array}$		$0.694 \\ 1.982 \\ 275.805 \\ 0.448 \\ 1.918$	-3.959 -8.593 -1.065 -2.042 -2.955	$\begin{array}{c} +0.0006(3) \\ -0.08667(14) \\ +0.005(6) \\ -0.00149(16) \\ -0.01266(9) \end{array}$	$6.44 \\ 6.56 \\ 9.61 \\ 6.54 \\ 7.01$	$12.54 \\ 12.03 \\ 8.36 \\ 12.68 \\ 11.82$	49275.0 50430.0 51513.0 50299.0 50314.0	$173 \\ 186 \\ 253 \\ 253 \\ 255$	22.8 16.3 10.4 17.2 17.3	2.50 21.56 0.05 2.18 3.15	2.31 12.27 0.05 1.73 1.22	2.18 1.99 0.05 1.69 0.25

PSR J	PSR B	$_{(s^{-1})}^{\nu}$	$\dot{\nu}_{(10^{-15}s^{-2})}$	$\ddot{\nu}_{(10^{-24}s^{-3})}$	$\log_{10}(\tau_c)$	$\log_{10} B_s$ (G)	Epoch (MJD)	Ν	T_{span} (yr)	σ_1 (ms)	σ_2 (ms)	σ_3 (ms)
$\begin{array}{c} J1913-0440\\ J1915+1009\\ J1915+1606\\ J1915+1647\\ J1916+0951 \end{array}$	$\begin{array}{c} B1911-04\\ B1913+10\\ B1913+16\\\\ B1914+09 \end{array}$	$\begin{array}{c} 1.211 \\ 2.472 \\ 16.941 \\ 0.619 \\ 3.700 \end{array}$	-5.963 -93.191 -2.476 -0.155 -34.482	$\begin{array}{c} +0.014721(3) \\ +0.03947(6) \\ +0.0036(7) \\ +0.00050(9) \\ -0.02010(12) \end{array}$	6.51 5.62 8.04 7.80 6.23	$12.27 \\ 12.40 \\ 10.36 \\ 11.91 \\ 11.92$	$\begin{array}{r} 47036.0\\ 50389.0\\ 46444.0\\ 49290.0\\ 50312.0\end{array}$	$543 \\ 454 \\ 346 \\ 256 \\ 291$	35.0 16.8 18.3 22.8 17.3	53.91 7.78 0.47 2.70 2.64	$13.14 \\ 4.05 \\ 0.46 \\ 2.64 \\ 1.44$	$0.79 \\ 0.32 \\ 0.38 \\ 2.53 \\ 0.25$
$\begin{array}{c} J1916{+}1312\\ J1917{+}1353\\ J1917{+}2224\\ J1918{+}1444\\ J1919{+}0021 \end{array}$	$\substack{ B1914+13\\ B1915+13\\ B1915+22\\ B1916+14\\ B1917+00 }$	3.548 5.138 2.348 0.847 0.786	-46.027 -189.997 -15.798 -152.252 -4.739	$\begin{array}{c} -1.36038(10) \\ +0.33352(3) \\ +0.006(4) \\ -0.08907(6) \\ +0.00497(5) \end{array}$	6.09 5.63 6.37 4.95 6.42	$12.01 \\ 12.08 \\ 12.05 \\ 13.20 \\ 12.50$	50312.0 50161.0 51813.0 50088.0 49832.0	$310 \\ 517 \\ 164 \\ 475 \\ 367$	17.3 18.1 9.1 18.3 19.7	172.41 33.63 2.49 126.51 13.41	64.62 10.90 2.49 110.21 12.92	$5.03 \\ 0.48 \\ 2.33 \\ 2.90 \\ 1.26$
J1920+2650 J1921+1419 J1921+1948 J1921+2153 J1922+2018	B1918+26 B1919+14 B1918+19 B1919+21 B1920+20	$1.273 \\ 1.618 \\ 1.218 \\ 0.748 \\ 0.853$	-0.056 -14.657 -1.329 -0.754 -0.472	$\begin{array}{c} +0.00017(19) \\ +0.02964(11) \\ +0.00153(13) \\ -0.000077(19) \\ -0.0012(4) \end{array}$	8.56 6.24 7.16 7.20 7.46	$11.22 \\ 12.27 \\ 11.94 \\ 12.13 \\ 11.95$	50095.0 48698.0 48395.9 48469.7 50085.0	123 304 173 302 194	17.1 26.0 22.9 22.1 18.3	$1.53 \\ 30.57 \\ 3.65 \\ 0.49 \\ 3.26$	$1.55 \\ 13.61 \\ 3.28 \\ 0.48 \\ 3.33$	$1.53 \\ 2.10 \\ 3.14 \\ 0.47 \\ 3.22$
J1922+2110 J1926+0431 J1926+1434 J1926+1648 J1932+1059	B1920+21 B1923+04 B1924+14 B1924+16 B1929+10	0.928 0.931 0.755 1.725 4.415	-7.038 -2.130 -0.125 -53.526 -22.561	$\begin{array}{c} +0.03863(11)\\ +0.01533(11)\\ +0.00017(9)\\ +0.01525(9)\\ -0.0225058(18)\end{array}$	6.32 6.84 7.98 5.71 6.49	$12.48 \\ 12.22 \\ 11.74 \\ 12.51 \\ 11.71$	50305.0 50300.0 49142.0 50122.0 46926.0	$344 \\ 206 \\ 136 \\ 436 \\ 768$	17.3 17.0 18.3 18.3 35.7	$26.56 \\ 6.65 \\ 2.15 \\ 31.84 \\ 49.34$	$19.12 \\ 1.42 \\ 2.17 \\ 31.63 \\ 44.61$	$1.17 \\ 0.69 \\ 1.98 \\ 1.00 \\ 0.43$
J1932+2020 J1932+2220 J1933+2421 J1935+1616 J1937+2544	B1929+20 B1930+22 B1931+24 B1933+16 B1935+25	3.728 6.922 1.229 2.788 4.976	-58.625 -2756.790 -12.213 -46.642 -15.917	$\begin{array}{c} -0.18479(11) \\ +40.6659(8) \\ +0.63194(15) \\ +0.0150133(11) \\ -0.00337(10) \end{array}$	$ \begin{array}{r} 6.00 \\ 4.60 \\ 6.20 \\ 5.98 \\ 6.69 \\ \end{array} $	$12.03 \\ 12.47 \\ 12.41 \\ 12.17 \\ 11.56$	50302.0 51867.0 51014.0 46827.0 50126.0	224 410 579 936 370	17.2 8.9 13.5 36.2 18.3	$21.29 \\ 418.59 \\ 101.44 \\ 28.89 \\ 0.51$	5.44 31.23 43.31 4.97 0.46	$0.74 \\ 16.53 \\ 4.29 \\ 0.27 \\ 0.20$
J1939+2134 J1939+2449 J1941-2602 J1943-1237 J1944-1750	B1937+21 B1937+24 B1937-26 B1940-12 B1941-17	641.928 1.550 2.482 1.028 1.189	-43.314 -43.904 -5.892 -1.751 -1.394	$\begin{array}{c} +0.0179(8) \\ +0.8292(6) \\ -0.00806(7) \\ +0.00034(3) \\ +0.0097(3) \end{array}$	8.37 5.75 6.82 6.97 7.13	8.61 12.54 11.80 12.11 11.96	$\begin{array}{c} 49389.0\\ 50351.0\\ 50498.0\\ 49145.0\\ 50314.0\end{array}$	517 128 193 138 139	$22.2 \\ 12.4 \\ 16.3 \\ 23.7 \\ 17.3$	$0.04 \\ 123.97 \\ 1.31 \\ 1.23 \\ 4.87$	$0.03 \\ 100.22 \\ 0.18 \\ 1.14 \\ 3.12$	$\begin{array}{c} 0.03 \\ 6.20 \\ 0.11 \\ 0.49 \\ 2.06 \end{array}$
$\begin{array}{c} J1945-0040\\ J1946+1805\\ J1946-2913\\ J1948+3540\\ J1949-2524 \end{array}$	$\begin{array}{c} B1942-00\\ B1944+17\\ B1943-29\\ B1946+35\\ B1946-25\end{array}$	$\begin{array}{c} 0.956 \\ 2.270 \\ 1.042 \\ 1.394 \\ 1.044 \end{array}$	-0.489 -0.124 -1.617 -13.723 -3.566	$\begin{array}{c} -0.00004(8) \\ +0.00035(6) \\ -0.00139(6) \\ +0.004243(14) \\ -0.00057(6) \end{array}$	7.49 8.46 7.01 6.21 6.67	$11.88 \\ 11.02 \\ 12.08 \\ 12.36 \\ 12.25$	48532.0 49291.0 49123.0 49852.0 48533.0	$141 \\ 240 \\ 117 \\ 458 \\ 128$	27.0 22.8 22.8 19.8 22.9	$1.91 \\ 0.98 \\ 1.79 \\ 3.82 \\ 1.42$	$1.92 \\ 0.97 \\ 0.84 \\ 3.01 \\ 1.18$	$1.87 \\ 0.95 \\ 0.75 \\ 0.22 \\ 0.54$
$\begin{array}{c} J1952{+}1410\\ J1952{+}3252\\ J1954{+}2923\\ J1955{+}2908\\ J1955{+}5059 \end{array}$	B1949+14 B1951+32 B1952+29 B1953+29 B1953+50	$3.636 \\ 25.296 \\ 2.344 \\ 163.048 \\ 1.927$	-1.694 -3739.491 -0.009 -0.789 -5.096	$\begin{array}{c} +0.0009(13) \\ +17.1322(4) \\ +0.00011(14) \\ -0.0014(14) \\ -0.009170(12) \end{array}$	7.53 5.03 9.59 9.51 6.78	$11.28 \\ 11.69 \\ 10.44 \\ 8.64 \\ 11.93$	50096.0 50249.0 49137.0 49456.0 49145.0	$141 \\ 656 \\ 203 \\ 313 \\ 405$	16.0 17.6 16.2 21.8 22.2	$1.72 \\ 355.49 \\ 0.20 \\ 0.43 \\ 3.89$	$1.71 \\ 54.32 \\ 0.20 \\ 0.43 \\ 0.51$	$1.59 \\ 8.64 \\ 0.19 \\ 0.41 \\ 0.13$
$\begin{array}{c} J1957+2831\\ J2002+3217\\ J2002+4050\\ J2004+3137\\ J2005-0020\\ \end{array}$	$\begin{array}{c}$	3.250 1.435 1.105 0.474 0.877	-32.849 -216.622 -2.123 -16.723 -9.876	$\begin{array}{c} +0.0209(12) \\ -0.87458(5) \\ -0.00202(4) \\ -0.011606(18) \\ -0.0025(17) \end{array}$		$12.00 \\ 12.94 \\ 12.10 \\ 13.10 \\ 12.59$	51873.0 50015.0 50094.0 49142.0 51404.0	$247 \\ 496 \\ 387 \\ 424 \\ 140$	8.9 18.9 18.3 22.7 11.0	$1.14 \\ 459.77 \\ 1.01 \\ 19.68 \\ 3.55$	1.07 233.08 0.56 17.56 3.57	$0.56 \\ 5.64 \\ 0.40 \\ 0.56 \\ 3.47$
$\begin{array}{c} J2006-0807\\ J2013+3845\\ J2018+2839\\ J2019+2425\\ J2022+5154 \end{array}$	$\begin{array}{c} B2003-08\\ B2011+38\\ B2016+28\\\\ B2021+51\end{array}$	$\begin{array}{c} 1.722 \\ 4.344 \\ 1.792 \\ 254.160 \\ 1.890 \end{array}$	-0.136 -167.035 -0.476 -0.454 -10.939	$\begin{array}{c} -0.0031(4) \\ +0.01260(11) \\ +0.004641(3) \\ -0.028(8) \\ -0.0182612(16) \end{array}$	8.30 5.61 7.78 9.95 6.44	$11.22 \\ 12.16 \\ 11.46 \\ 8.23 \\ 12.11$	50190.0 50094.0 46774.0 51351.0 47028.0	$302 \\ 457 \\ 617 \\ 169 \\ 781$	17.7 18.3 36.5 11.0 35.1	2.90 2.88 12.57 0.09 64.51	2.79 2.45 1.59 0.09 45.79	$2.73 \\ 0.60 \\ 0.32 \\ 0.09 \\ 0.33$
J2023+5037 J2029+3744 J2030+2228 J2037+3621 J2038+5319	$\substack{ B2022+50 \\ B2027+37 \\ B2028+22 \\ B2035+36 \\ B2036+53 \\ }$	2.684 0.822 1.586 1.616 0.702	-18.091 -8.323 -2.225 -11.772 -0.465	$\begin{array}{c} +0.04043(6) \\ -0.06458(8) \\ +0.0132(5) \\ -0.48722(15) \\ +0.0012(4) \end{array}$	6.37 6.19 7.05 6.34 7.38	$11.99 \\ 12.59 \\ 11.88 \\ 12.23 \\ 12.07$	50313.0 50094.0 51088.0 50093.0 50122.0	365 230 161 162 93	17.3 18.5 13.1 17.3 13.9	7.19 39.77 1.80 180.22 1.95	3.03 3.42 0.93 97.45 1.91	$0.24 \\ 0.98 \\ 0.56 \\ 8.31 \\ 1.85$
$\begin{array}{c} J2046{+}1540\\ J2046{+}5708\\ J2046{-}0421\\ J2048{-}1616\\ J2051{-}0827\\ \end{array}$	B2044+15 B2045+56 B2043-04 B2045-16	0.879 2.098 0.646 0.510 221.796	-0.141 -48.934 -0.615 -2.848 -0.626	$\begin{array}{c} +0.00004(5) \\ +0.0105(3) \\ +0.00016(3) \\ -0.0009500(16) \\ +0.007(4) \end{array}$	8.00 5.83 7.22 6.45 9.75	$11.66 \\ 12.37 \\ 12.18 \\ 12.67 \\ 8.38$	$\begin{array}{c} 49850.0\\ 50155.0\\ 49763.0\\ 46827.0\\ 51481.0\end{array}$	341 299 353 594 302	$19.8 \\ 18.0 \\ 20.3 \\ 36.1 \\ 10.7$	$0.73 \\ 5.40 \\ 0.89 \\ 12.82 \\ 0.08$	0.73 4.81 0.87 7.58 0.08	$\begin{array}{c} 0.73 \\ 1.89 \\ 0.83 \\ 0.52 \\ 0.08 \end{array}$
$J2055+2209 \\ J2055+3630 \\ J2108+4441 \\ J2113+2754 \\ J2113+4644$	$\begin{array}{c} B2053{+}21\\ B2053{+}36\\ B2106{+}44\\ B2110{+}27\\ B2111{+}46\end{array}$	$\begin{array}{c} 1.227 \\ 4.515 \\ 2.410 \\ 0.831 \\ 0.986 \end{array}$	-2.017 -7.524 -0.501 -1.813 -0.694	$\begin{array}{c} -0.00025(6) \\ -0.01150(3) \\ +0.00107(10) \\ +0.000256(18) \\ +0.017725(4) \end{array}$	6.98 6.98 7.88 6.86 7.35	$12.02 \\ 11.46 \\ 11.28 \\ 12.25 \\ 11.94$	50095.0 49753.0 50315.0 49133.0 47007.0	253 472 292 383 601	$18.3 \\ 20.2 \\ 17.3 \\ 23.6 \\ 35.2$	$0.54 \\ 1.85 \\ 0.64 \\ 0.88 \\ 80.60$	$0.52 \\ 0.69 \\ 0.61 \\ 0.79 \\ 8.21$	$\begin{array}{c} 0.51 \\ 0.13 \\ 0.60 \\ 0.73 \\ 2.51 \end{array}$
$\begin{array}{c} J2116{+}1414\\ J2124{+}1407\\ J2124{-}3358\\ J2145{-}0750\\ J2149{+}6329 \end{array}$	B2113+14 B2122+13 — — B2148+63	$\begin{array}{c} 2.272 \\ 1.441 \\ 202.794 \\ 62.296 \\ 2.631 \end{array}$	-1.494 -1.594 -0.846 -0.115 -1.177	$\begin{array}{c} -0.00395(6) \\ +0.0042(4) \\ +0.011(5) \\ -0.0006(3) \\ -0.00136(4) \end{array}$	7.38 7.16 9.58 9.93 7.55	11.56 11.87 8.51 8.84 11.41	$\begin{array}{c} 49855.0\\ 50276.0\\ 51284.0\\ 51173.0\\ 49852.0 \end{array}$	372 79 226 469 388	19.8 17.2 11.7 12.3 19.8	2.15 1.55 0.08 0.02 0.67	$1.86 \\ 0.74 \\ 0.08 \\ 0.02 \\ 0.56$	$0.44 \\ 0.73 \\ 0.08 \\ 0.02 \\ 0.26$
$\begin{array}{c} J2150+5247\\ J2155-3118\\ J2157+4017\\ J2212+2933\\ J2219+4754 \end{array}$	$\begin{array}{c} \text{B2148+52} \\ \text{B2152-31} \\ \text{B2154+40} \\ \text{B2210+29} \\ \text{B2217+47} \end{array}$	$3.010 \\ 0.971 \\ 0.656 \\ 0.995 \\ 1.857$	-91.574 -1.169 -1.477 -0.491 -9.537	$\begin{array}{c} -0.02643(5) \\ +0.0023(3) \\ -0.03803(3) \\ -0.00270(15) \\ -0.002956(3) \end{array}$	5.72 7.12 6.85 7.51 6.49	$12.27 \\ 12.06 \\ 12.36 \\ 11.85 \\ 12.09$	50094.0 50429.0 49686.0 50093.0 46471.0	400 124 473 303 509	18.3 16.3 20.5 18.3 35.2	$5.74 \\ 2.05 \\ 45.25 \\ 1.65 \\ 7.50$	$3.42 \\ 1.82 \\ 8.30 \\ 1.19 \\ 2.61$	$\begin{array}{c} 0.31 \\ 1.77 \\ 1.01 \\ 1.13 \\ 0.65 \end{array}$
$\begin{array}{c} J2222+2923\\ J2225+6535\\ J2229+2643\\ J2229+6205\\ J2242+6950 \end{array}$	B2224+65 M B2227+61 B2241+69	$3.554 \\ 1.465 \\ 335.816 \\ 2.257 \\ 0.601$	-0.078 -20.734 -0.171 -11.489 -1.741	$\begin{array}{c} +0.0018(16) \\ +0.01545(7) \\ -0.005(7) \\ -0.01031(16) \\ -0.0003(3) \end{array}$	8.86 6.05 10.49 6.49 6.74	$10.62 \\ 12.41 \\ 7.83 \\ 12.00 \\ 12.46$	51671.0 49142.0 51625.0 50081.0 50092.0	$231 \\ 516 \\ 249 \\ 214 \\ 114$	9.9 23.7 9.8 17.5 18.5	$0.96 \\ 18.41 \\ 0.03 \\ 3.05 \\ 3.30$	$0.95 \\ 16.35 \\ 0.03 \\ 2.38 \\ 3.28$	$0.95 \\ 0.84 \\ 0.03 \\ 0.47 \\ 3.08$
$\begin{array}{c} J2248 {-}0101\\ J2257 {+}5909\\ J2305 {+}3100\\ J2305 {+}4707\\ J2308 {+}5547 \end{array}$	$\begin{array}{c}\\ B2255+58\\ B2303+30\\ B2303+46\\ B2306+55\end{array}$	2.095 2.716 0.635 0.938 2.105	-2.894 -42.428 -1.164 -0.500 -0.884	$\begin{array}{c} +0.0351(4) \\ -0.10513(4) \\ -0.00143(6) \\ -0.0008(4) \\ -0.00535(7) \end{array}$	7.06 6.01 6.94 7.47 7.58	$ \begin{array}{r} 11.75 \\ 12.17 \\ 12.33 \\ 11.90 \\ 11.49 \end{array} $	51270.0 50502.0 50302.0 50088.0 49841.0	171 236 277 185 394	12.0 16.1 17.3 17.3 19.7	3.15 16.40 1.42 4.50 2.01	0.81 5.92 1.04 4.47 0.87	$0.52 \\ 0.57 \\ 0.74 \\ 4.35 \\ 0.52$
$\begin{array}{c} J2313{+}4253\\ J2317{+}1439\\ J2317{+}2149\\ J2321{+}6024\\ J2322{+}2057\\ \end{array}$	B2310+42 	2.862 290.255 0.692 0.443 207.968	-0.920 -0.204 -0.502 -1.382 -0.418	$\begin{array}{c} +0.006386(7) \\ -0.001(8) \\ -0.0009(4) \\ -0.00122(3) \\ +0.004(9) \end{array}$	$7.69 \\ 10.35 \\ 7.34 \\ 6.71 \\ 9.90$	$ \begin{array}{r} 11.30 \\ 7.97 \\ 12.10 \\ 12.61 \\ 8.34 \\ \end{array} $	$\begin{array}{c} 48202.7\\ 51656.0\\ 49142.0\\ 49332.0\\ 51335.0 \end{array}$	498 202 300 347 150	25.6 9.8 20.2 22.6 11.4	$3.59 \\ 0.04 \\ 0.55 \\ 2.89 \\ 0.08$	$0.87 \\ 0.04 \\ 0.54 \\ 1.39 \\ 0.08$	$0.13 \\ 0.04 \\ 0.54 \\ 1.12 \\ 0.07$

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Figure 1. ... continued

PSR J	PSR B	$_{(s^{-1})}^{\nu}$	$\dot{\nu}_{(10^{-15}s^{-2})}$	$\ddot{\nu}_{(10^{-24}s^{-3})}$	$\log_{10}(\tau_c)$	$\begin{array}{c} \log_{10} B_s \\ (\mathrm{G}) \end{array}$	Epoch (MJD)	Ν	T_{span} (yr)	σ_1 (ms)	σ_2 (ms)	σ_3 (ms)
$\begin{array}{c} J2325{+}6316\\ J2326{+}6113\\ J2330{-}2005\\ J2337{+}6151\\ J2346{-}0609 \end{array}$	B2323+63 B2324+60 B2327-20 B2334+61 —	$0.696 \\ 4.280 \\ 0.608 \\ 2.019 \\ 0.846$	-1.370 -6.458 -1.714 -781.495 -0.977	$\begin{array}{c} +0.00053(7) \\ +0.00222(4) \\ -0.00003(7) \\ +3.12568(14) \\ -0.0014(4) \end{array}$	$ \begin{array}{r} 6.91 \\ 7.02 \\ 6.75 \\ 4.61 \\ 7.14 \\ \end{array} $	$12.31 \\ 11.46 \\ 12.45 \\ 12.99 \\ 12.11$	$\begin{array}{c} 48714.0\\ 50069.0\\ 50304.0\\ 50094.0\\ 51426.0\end{array}$	381 394 231 464 236	26.1 18.3 16.2 18.3 11.2	$4.57 \\ 0.51 \\ 1.11 \\ 862.99 \\ 0.63$	$\begin{array}{c} 4.44 \\ 0.46 \\ 1.11 \\ 4.44 \\ 0.60 \end{array}$	$4.38 \\ 0.28 \\ 1.08 \\ 1.20 \\ 0.59$
$J_{2354+6155}$	B2351 + 61	1.058	-18.219	+0.023876(17)	5.96	12.60	49276.0	375	22.8	23.27	6.72	0.52

3 DISCUSSION

The large-scale structures seen in the timing residuals of these pulsars are not due to the observing systems or offline processing. Some of these pulsars are also observed as part of long-term timing programs at other observatories; in all cases we see the same large-scale features in the timing residuals. The structures are also not being produced by the off-line processing. We have obtained timing residuals from site-arrival-times using three pulsar timing packages, PSR-TIME, TEMPO and TEMPO2 for many of our pulsars. Again, we see the same features in all cases. Finally, the choice of clock corrections applied to the data and the exact choice of solar system ephemeris can be shown not to be causing the observed timing noise.

3.1 Dispersion measure variations

It has been postulated that the effects of interstellar or interplanetary dispersion measure (DM) variations may lead to timing noise. The large-scale structures seen in our data are observed at all observing frequencies and so are not due to DM variations. For instance, we show in Figure ??, the timing residuals for PSR B1815-14 at 20 cm overlaid with other frequencies. It is likely that smaller scale variations will be due to DM effects. The interplanetary DM variations are mainly due to the solar wind. This is modelled to sufficient precision within TEMPO2. The millisecond pulsar PSR J1022+1001 has the smallest ecliptic latitude in our sample of -0.06° . However, this pulsar is not observed when the line-of-sight to the pulsar is close the Sun and so the extra DM delay expected is insignificant. Only for J1730-2304 do we see a significant variation (Figure 3). However, the variation is small, restricted in time to a few days per year and is well modelled in TEMPO2.

3.2 Categorising the timing noise

It is instructive to categorise the pulsars by the structures seen in their timing residuals. As the TOAs for some pulsars are measured much more precisely than others any such scheme can only be approximate. For instance, in Figure 4 we plot the detailed structure observed for PSR B1900+01 overlaid on the residuals for PSR B1745-20 that are seemingly flat. It is also unfortunate that for the frequently glitch-

1730-2304 (rms = 25.436 us) post-fit



Figure 3. Timing residuals for PSR J1730-2304 without fitting for the solar wind. The vertical dotted line represents the closest approach of the line-of-sight to the Sun.

ing pulsars it often impossible to obtain a timing solution over a long observation span. The short spans that are available do not clearly show the variety of structures present in their timing residuals.

However, very broadly the pulsars can be classified into A) flat residuals, B) cubics corresponding to $\ddot{\nu} > 0$, C) cubics where $\ddot{\nu} < 0$ and D) curves that are more complicated than cubics. Examples of each classification are given in Figure 5. 37% of our sample are characterised as type A pulsars, 24% as type B, 22% as type C and 17% as type D. However, it is important to emphasise that the classification of any particular pulsar is likely to change as more data are obtained. For instance, in Figure 6 we plot the timing residuals that would have been obtained for PSR B0950+08 if we had access only to a) one, b) five, c) six, d) eleven and e) 35-years of observations. With these data it is likely that the pulsar would have been classified as type A, C, B and E respectively.

3.3 The cubics

For those pulsars whose residuals are dominated by a cubic term (and hence are denoted as type 'B' or 'C') we plot, in Figure 7, the timing residuals after the cubic term has been removed. The recycled pulsars PSR B1620-26 and



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Figure 6. The timing residuals for PSR B0950+08 obtained from different sections of the entire data span available. In each section the pulsar's spin-frequency and its first derivative have been fitted. The data spans are approximately a) 1 year, b) 5 years, c) 6 years, d) 11 years and e) the full 35 years.

B1820–30A are unusual in that they are the only millisecond pulsars that are not characterised by an 'A' indicating flat residuals. The timing residuals for both of these pulsars are dominated by a cubic term of type 'B'. They both lie within globular clusters (M4 and NGC6624 respectively) and the cubic terms are therefore explained as being due to the acceleration of the pulsar in the cluster's gravitational field.

A pulsar's measured braking index can be calculated from

$$n = \frac{\nu \dot{\nu}}{\dot{\nu}^2} \tag{1}$$

where a value of n = 3 is predicted for a pulsar slowing down due to pure magnetic dipole radiation. However, the measured braking indices for the non-recycled pulsars range from -287986 to +36246 with a mean of -1713 and median of 22. For the pulsars with data spanning more than 30 years we obtain braking indices ranging from -1701 to +36246 with a mean of +3750 and median +29.

Clearly for n = 3 the $\ddot{\nu}$ value will be positive as

$$\ddot{\nu}_{dipole} = 3\dot{\nu}^2/\nu \tag{2}$$

Out of our sample of 126 pulsars, 68 (54%) have a postive measure $\ddot{\nu}$ value and 46% with negative $\ddot{\nu}$. As concluded, in Paper I, the $\ddot{\nu}$ values are clealy not due to magnetic dipole radiation.

Six of our pulsars have reported glitch events. For these, three have positive $\ddot{\nu}$ and three have negative $\ddot{\nu}$.

For the 19 pulsars in our sample where we have more than 30 years of timing data we show, in Figure 8 measured $\ddot{\nu}$ values obtained using different data spans and over different sections of the data. For these 19 pulsars, only six have negative $\ddot{\nu}$ when measured over the entire data span. Those pulsars with positive $\ddot{\nu}$ have corresponding braking indices

0052+51 8.71 0.00		0059+65 22.89 0.01	a Frankes geingele die geschaft aus and an die geschaft aus	0114+58 168.96 1.67	\sim	0149-16 7.19 0.01	
0301+19 17.94 0.01		0402+61 53.76 0.09	$\langle \ \ \ \ \ \ \ \ \ \ \ \ \ $	0421-0345 8.33 0.00		0450-18 47.01 0.09	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
0450+55 78.29 0.23		0458+46 19.95 0.03	"It is a support of the state of the second	0538+2817 1.61 0.01		0540+23 39.45 0.16	
0609+37 5.73 0.02		0611+22 2124.48 6.34	$\sim \sim$	0656+14 43.11 0.11	And A Constant of the Constant	0820+02 12.86 0.01	1. I wanter the state of the st
0844-35 8.67 0.01		0906-17 4.54 0.01		0919+06 180.27 0.42	/~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	0943+10 55.26 0.05	n in the second of the second
1141-3107 140.51 0.26		1322+83 16.16 0.02		1541+09 34.13 0.05	1 - 1- HIY Law Weldy PT	1552-23 10.20 0.02	Jay Marky, and Aller a war
1604–00 4.18 0.01	No contraction and and the	1620-26 7.85 0.71		1649-23 12.91 0.01		1657-13 16.90 0.03	
1700-3312 11.75 0.01		1700-32 2.86 0.00		1706-16 381.01 0.58		1709-15 9.25 0.01	
1717-29 4.52 0.01		1726-00 7.21 0.02		1737+13 26.73 0.03	A management	1754-24 85.51 0.37	
1756-22 58.37 0.13		1804–12 10.58 0.02		1804-27 16.55 0.02	" " " " " " " " " " " " " " " " " " "	1805-20 30.80 0.03	put the series and share the
1811+40 6.98 0.01		1813–17 166.89 0.21		1817-13 11.07 0.01	Mr. Wash Million An and	1823-0154 3.84 0.01	
1820-30A 0.52 0.10		1820-30B 5.00 0.01		1822-09 1284.40 1.67		1822-14 66.93 0.24	
1828-11 77.44 0.19	W. MWWWW	1829–10 98.22 0.30		1831-04 8.85 0.03		1832-06 112.04 0.37	
1839+56 8.36 0.01		1844-04 12.11 0.02	a mark	1848+13 2.59 0.01	HALANA MARTIN AND	1848+04 29.20 0.10	Maria Maria I
1851+1259 274.74 0.23	\sim	1852-2610 1.51 0.00		1853+01 953.20 3.56	\sim	1855+02 42.08 0.10	$\langle \ \rangle $
1857–26 3.08 0.01	1	1900+05 15.67 0.02		1900+06 24.68 0.04	Salar 1	1902-01 7.76 0.01	
1907+02 9.86 0.01	New Million I MI	1911+13 6.86 0.01	Jone Harris	1911–04 64.65 0.08		1923+04 9.88 0.01	1994 May 1984 1.
1929+20 29.81 0.11		1933+16 20.49 0.86		1937-26 1.01 0.00	Miller Miller	1941-17 16.98 0.02	
1943-29 4.63 0.00		1951+32 271.00 6.86	~~``.	1953+50 7.89 0.02	and the second	2000+32 1117.89 1.60	\sim
2016+28 10.91 0.02	We assessed and the second sec	2027+37 23.90 0.02	ياجها الأ ¹¹ المحسب المجار	2028+22 5.38 0.01	1	2035+36 599.65 0.97	······································
2111+46 44.5 0.04	· · · · · · · /	2122+13 3.73 0.01		2154+40 46.97 0.03		2210+29 8.29 0.01	
2248-0101 3.87 0.01	//w/i/////	2306+55 5.42 0.01		2319+60 9.63 0.00		2334+61 19.29 0.04	
2351+61 25.33 0.03							

Figure 7. Pulsar timing residuals after the removal of a cubic term

of 70, 24, 1126, 35, 94, 2592, 30, 144, 510, 19, 36448 and 36878. what are errors in these numbers?

Glitch events prior to the first observation will produce cubics where $\ddot{\nu} > 0$ (ie. pulsars of type B). In Figure 9 we plot $|\ddot{\nu}|$ versus the pulsars' characteristic ages τ_c . Pulsars with $\ddot{\nu} > 0$ are indicated with 'plus' symbols and those with $\ddot{\nu} < 0$ with circles. For the youngest pulsars, with $\tau_c < 10^5$ all except one pulsar has $\ddot{\nu} > 0$ which is explainable by the timing noise for young pulsars being dominated by the recovery from glitch events. Almost equal numbers of the older pulsars exist with the different signs of $\ddot{\nu}$.

can we show that the youngest pulsars are all dominated by the recovery from glitches whereas

all older pulsars are dominated by pseudo-sinusoidal timing residuals?

We note that long-term timing noise is not dominated by cubic terms - ie. the total number of pulsars characterised as type B or C for 10 yr dataspans is 40%,for 15 yr dataspans 50%, for 20 yr dataspans 53% and for 25 yr spans 57%. **something wrong here**.

3.4 Stability

For each pulsar we calculate various stability parameters which are listed in Table XXX. We include the Δ_8 value introduced by Arzoumanian et al. (1994):





Figure 8. Frequency second derivative values obtained using different dataspans of 1, 2, 4, 8, 16 and 32 years.



$$\Delta_8 = \log_{10} \left(\frac{1}{6\nu} |\ddot{\nu}| t^3 \right) \tag{3}$$

where the spin-frequency, ν and its second derivative, $\ddot{\nu}$, are measured over a $t = 10^8 \sec (\sim 3.16 \,\mathrm{yr})$ interval. As our pulsar data-sets contain at least 10 yr of data, we list the average Δ_8 value and its variance obtained by fitting for ν and $\ddot{\nu}$ in unique 3 yr segments.

The Δ_8 parameter provides information at only one specified time-scale. More recently, Matsakis, Taylor & Eubanks (1997) showed how the σ_z parameter can be applied to pulsar timing residuals where

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$$\sigma_z(\tau) = \frac{\tau^2}{2\sqrt{5}} \langle c^2 \rangle^{1/2} \tag{4}$$



Figure 4. The timing residuals for PSR B1900+01 (thick, line) overlaid on the timing residuals for PSR B1745-20.



Figure 5. A classification scheme for structures seen in the timing residuals. The pulsars shown are a) PSR B0031-07, b) B1706-16, c) B2154+40 and d) B1133+16.

where the magnitude, c, of cubic terms fitted to short sections of the dataspan, τ are averaged to give. In Figure 10 we plot the $\sigma_z(\tau)$ parameter for pulsars within given characteristic age ranges. For comparison we include the σ_z curve for the publically available Arecibo observatory observations of PSR B1855+09 (Kaspi et al. 1994), a comparison between the two time-scales NIST and PTB (Edwards, private communication) and the expected stability limit due to a gravitational wave background. To produce a statistic for comparison with other pulsar parameters we record, in Table 3, the σ_z parameter measured at $\tau = 3$ yr and also at $\tau = 10$ yr.

In Figure XXX we compare the following stability measures: $\ddot{\nu}$, Δ_8 , $\sigma_z(3yr)$, $\sigma_z(10yr)$. In Figure XXX we plot $\sigma_z(10yr)$ versus the pulsars' spin-frequency, frequency-derivative, characteristic age, surface magnetic field, energy loss rate and magnetic field at the light cylinder.

3.5 Power spectra

For each of our pulsars we obtain a Lomb-Scargle periodogram after whitening the timing residuals using multiple frequency-derivative terms. We also obtain a powerspectrum obtained from the amplitude of fitted Gram-Schmidt polynomials to the non-whitened data-sets.

We list, in Table 2, any significant periodicities found in the Lomb-Scargle periodograms.

We represent each Gram-Schmidt spectrum as P(f) =



Figure 10. σ_z parameter versus timescale, τ for the recycled pulsars.

Table 2. Periodicities found in the recycled pulsar residuals

PSR	Period (d)	Period (yr)	Prob.
J0621+1002 B1620-26 B1937+21	582.62 187.81 51.43 68.08	$1.60 \\ 0.51 \\ 0.14 \\ 0.19$	$\begin{array}{c} 1.93 \times 10^{-15} \\ 3.90 \times 10^{-4} \\ 3.54 \times 10^{-4} \\ \sim 3 \times 10^{-4} \end{array}$

Note: B1620-26 requires significant whitening. The periodicity observed may be part of the "red"-noise. The periodicity is also close to the known orbital period of 191 d.

 Af^{α} and record the amplitude and power-law index α in Table 3.

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 Table 3. Table of offsets and gradients in the power spectra

PSR	$\sigma_z(3yr)$	$\sigma_z(10 \mathrm{yr})$	offset	gradient
0034-0534			-0.21 ± 0.13	0.01 ± 0.07
0218 + 4232			-0.14 ± 0.14	0.09 ± 0.08
0613-0200			-3.35 ± 0.55	-1.47 ± 0.22
0621 + 1002			-0.63 ± 0.30	-0.39 ± 0.15
0751 + 1807			-0.60 ± 0.13	-0.26 ± 0.07
1012 + 5307			-0.24 ± 0.20	-0.08 ± 0.10
1022 + 1001			-1.49 ± 0.30	-0.74 ± 0.15
1024-0719			-0.27 ± 0.19	-0.03 ± 0.10
1300 + 1240			0.33 ± 0.25	0.26 ± 0.12
1455 - 3330			-0.80 ± 0.41	-0.26 ± 0.17
1518 + 4904			-0.24 ± 0.18	-0.01 ± 0.09
1537 + 1155			-0.28 ± 0.16	-0.14 ± 0.08
1623 - 2631			-6.21 ± 1.06	-2.34 ± 0.36
1643 - 1224			-2.10 ± 0.48	-0.89 ± 0.20
1713 + 0747			-1.00 ± 0.44	-0.43 ± 0.18
1730-2304			-2.11 ± 0.46	-0.91 ± 0.17
1744-1134			-0.85 ± 0.55	-0.38 ± 0.21
1804-0735			-1.23 ± 0.25	-0.42 ± 0.11
1804-2717			-0.88 ± 0.48	-0.35 ± 0.19
1823-3021A			-6.14 ± 1.06	-2.26 ± 0.36
1824-2452			-3.63 ± 0.77	-1.33 ± 0.28
1857 ± 0.02			-1.66 ± 0.30	-0.70 ± 0.12
1911-1114			-0.09 ± 0.20	-0.01 ± 0.10
1915 + 1606			-1.87 ± 0.30	-0.70 ± 0.11
1939 + 2134			-1.52 ± 0.30	-0.80 ± 0.12
1955 + 2908			0.43 ± 0.42	0.22 ± 0.16
2019 + 2425			1.04 ± 0.51	0.58 ± 0.21
2051 - 0827			-0.17 ± 0.14	-0.04 ± 0.07
2124 - 3358			-0.28 ± 0.19	-0.06 ± 0.09
2145-0750			-1.11 ± 0.34	-0.47 ± 0.15
2220 + 22.42				0.10 0.10
2229 + 2643			-0.57 ± 0.25	-0.12 ± 0.12
2317 + 1439			1.34 ± 0.55	0.65 ± 0.23
2322 + 2057			-0.77 ± 0.44	-0.12 ± 0.18