ASTROPEILER STOCKERT e.V.
Historische Radiosternwarte

Pulsar Observations

Results achieved with the Stockert 25m telescope

Status as of May 2015

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1 Observational Setup and Methods

1.1 Telescope and Frontend

Pulsars were observed using the 25m dish of the Stockert Radio Telescope[1] at 21cm.
The receiver frontend is mounted in prime focus configuration and is receiving both orientations of linear polarizations. The received signal is down converted to an IF frequency in the 100 - 200 MHz range before it is brought down from the prime focus to the backends.

The bandwidth used is mostly 55 MHz. Very recent measurements since May 2015 have been done with 100 MHz bandwidth. This became possible after a modification of the IF filter configuration.

1.2 Backend

The backend is a Pulsar Fast Fourier Transform Spectrometer (PFFTS) with a frequency resolution of 0.58 MHz and a maximum time resolution of 54 µs. This time resolution, however, was only used for the observation of millisecond pulsars. "Normal" pulsars were observed with a time resolution of 218 µs.
This spectrometer is a development by the digital group of the Max Planck Institute for Radio Astronomy and is a modified version of the Fast Fourier Transform Spectrometer used for spectroscopic work[2]. This modification consists of additional network interfaces and loading a specific core into the FPGA of the device.

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[1] www.astropeiler.de

[2] B. Klein, S. Hochgürtel, I. Krämer, A. Bell, K. Meyer, and R. Güsten. High-resolution wide-band fast Fourier transform spectrometers. *Astronomy and Astrophysics*, 542:L3, 2012

1.3 Post-processing

Post-processing was performed using the SICPROC package developed by D. Lorimer[3].

The post-processing consisted of the following steps:

- Conversion of the PFFTS specific format to the filterbank format
- De-dispersion of the data using published values for the dispersion measure
- Folding the data with the topocentric pulsar period as calculated by the predictive mode of the TEMPO package[4]. Pulsar ephemerides for TEMPO were obtained from the ATNF pulsar data base[5]. For binary pulsars, TEMPO2[6] was used.

In most cases folding was done into 256 bins. The main exception is the millisecond pulsar where the time resolution of 54 µs limits the number of available bins.

In a final step the folded profiles were adjusted in phase and offset by a program developed at the Astropeiler in order to produce the plotted profiles presented in this paper.

1.4 Integration times

Integration times varied by the expected flux of the pulsar to be observed, the time ranged from 1 minute to 100 minutes.

1.5 RFI Mitigation

No RFI mitigation measures were applied to the data sets. If data was found to be affected by RFI, the measurement was discarded.

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[3] http://sigproc.sourceforge.net/

[4] http://tempo.sourceforge.net/

[5] http://www.atnf.csiro.au/people/pulsar/psrcat/

[6] http://www.atnf.csiro.au/research/pulsar/tempo2/

Due to the exposed location of the Stockert Telescope this was not an infrequent event.

1.6 Verification of Results

Care must be taken that an observed signal is actually coming from a pulsar and is not RFI mimicking an actual result. Various methods have been used to verify results and to exclude false data (usually a combination of several of these methods):

1. Successfully repeating measurements
2. Comparing measurement with off target reference measurements
3. Verifying, that the observed pulse period exactly matches the calculated rotation period. Folding with a slightly different period must broaden the signal or make it disappear. This method is especially sensitive for long observation times
4. Subintegration: Folding the signal with twice the pulsar period should produce a plot with two pulses
5. Dispersion: Setting the dispersion measure to 0 when de-dispersing should broaden the signal or make it disappear. This only applies if the DM is large enough.
6. Subband-folding: Folding seperate subbands should produce a signal in each subband. This method is only applicable if SNR is good enough
7. Comparing the profile[7] with published profiles should verify that the observed profile matches within measurement uncertainty

At least the methods 1, 3, 5 and 7 have been successfully passed for the reported observations.

[7] Profiles are published at the EPN data base
http://www.jb.man.ac.uk/pulsar/Resources/epn/

2 Observed Pulsars

Until May 2015, a total of 75 pulsars have been observed:

NAME	P0 (s)	DM (cm^-3 pc)	S1400 (mJy)
B0031-07	0.943	11.38	11.0
B0136+57	0.272	73.75	4.6
B0138+59	1.222	34.80	4.5
J0248+6021	0.217	370.00	13.7
B0329+54	0.715	26.83	203.0
B0355+54	0.156	57.03	22.9
B0450+55	0.341	14.60	12.9
B0450-18	0.549	39.93	5.3
B0525+21	3.746	50.94	9.0
B0531+21	0.034	56.79	14.4
B0540+23	0.246	77.70	8.9
B0609+37	0.298	27.14	4.0
B0626+24	0.477	84.20	3.2
B0628-28	1.244	34.36	23.4
B0656+14	0.384	14.00	3.7
B0740-28	0.167	73.77	23.0
B0809+74	1.292	6.12	10.0
B0818-13	1.238	40.94	7.0
B0823+26	0.531	19.46	10.0
B0834+06	1.273	12.85	4.0
B0906-17	0.402	15.89	3.2
B0919+06	0.431	27.31	4.2
B0950+08	0.253	2.96	84.0
B1039-19	1.386	33.78	4.0
B1112+50	1.656	9.20	3.0
B1133+16	1.188	4.85	32.0
B1237+25	1.382	9.30	10.0
B1508+55	0.740	19.61	8.0
J1518+4904	0.041	11.61	4.0
B1604-00	0.422	10.68	5.0
B1642-03	0.388	35.73	21.0
B1700-32	1.212	110.31	7.6
B1737+13	0.803	32.70	3.9
B1737-30	0.606	153.00	6.4
J1740+1000	0.154	23.85	9,2
B1742-30	0.367	88.80	14.1
B1749-28	0.563	50.37	18.0
B1804-08	0.164	112.38	15.0

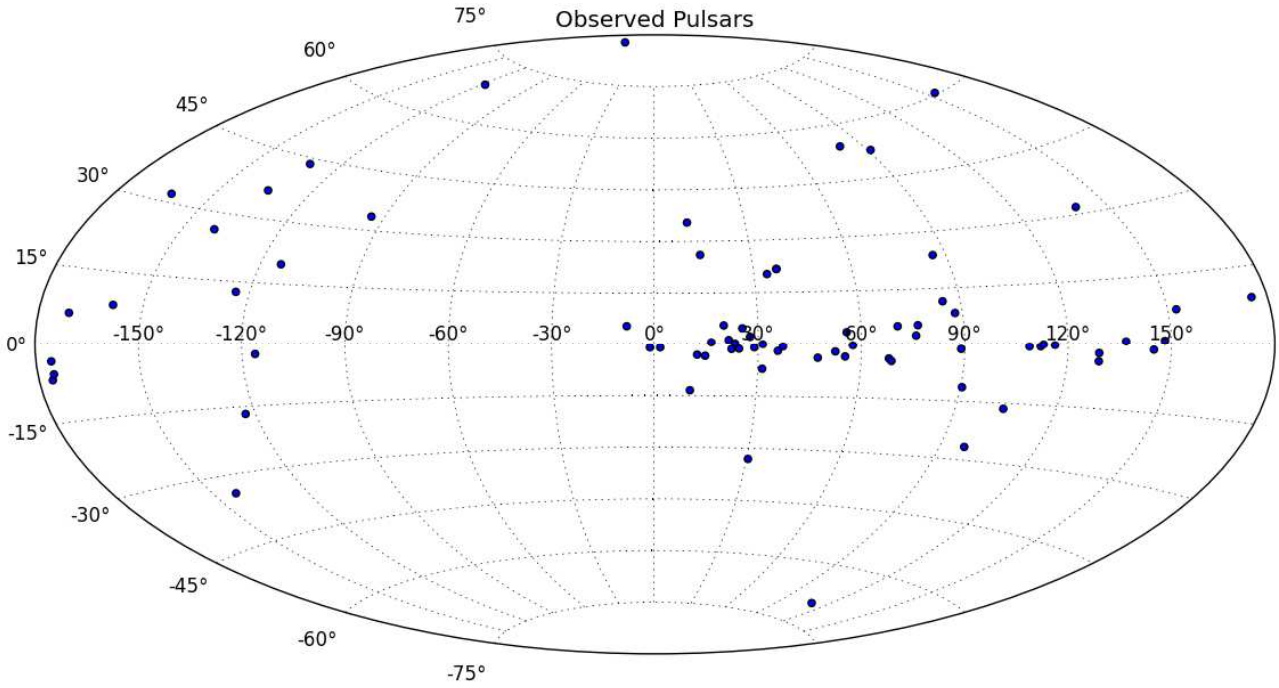
Table 1: List of observed Pulsars (Part 1)

NAME	P0 (s)	DM (cm^-3 pc)	S1400 (mJy)
B1815-14	0.291	622.00	7.1
B1818-04	0.598	84.38	8.0
B1821-19	0.189	224.65	4,9
B1822-09	0.769	19.46	10.8
B1826-17	0.307	217.11	7.7
B1829-08	0.647	300.87	2.1
B1831-03	0.687	234.54	2.8
B1834-10	0.563	316.98	3.7
B1839+56	1.653	26.70	4.0
J1840-0809	0.956	349.80	2.3
B1844+00	0.461	345.54	8.6
B1845-01	0.659	159.53	8.6
B1857-26	0.612	37.99	13.0
B1859+03	0.655	402.08	4.2
B1900+01	0.729	245.17	5.5
B1911-04	0.826	89.39	4.4
B1919+21	1.337	12.46	6.0
B1929+10	0.227	3.18	36.0
B1933+16	0.359	158.52	42.0
B1937+21	0.002	71.04	13.8
B1944+17	0.441	16.30	10.0
B1946+35	0.717	129.07	8.3
B1953+50	0.519	31.97	4.0
B2000+40	0.905	131.33	4.9
B2011+38	0.230	238.22	6.4
B2016+28	0.558	14.17	30.0
B2020+28	0.343	24.64	38.0
B2021+51	0.529	22.65	27.0
B2045-16	1.962	11.46	13.0
B2111+46	1.015	141.26	19.0
B2154+40	1.525	70.86	17.0
B2255+58	0.368	151.08	9.2
B2303+30	1.576	49.54	2.2
B2310+42	0.349	17.30	14.6
B2319+60	2.256	94.59	12.0
B2324+60	0.234	122.61	4.4
B2351+61	0.945	94.66	5.0

Table 1: (continued): List of observed Pulsars (Part 2)[8]

[8] P0: Pulse period , DM: Dispersion measure, S1400: Average flux @ 1400 MHz
Data from ATNF data base http://www.atnf.csiro.au/people/pulsar/psrcat/

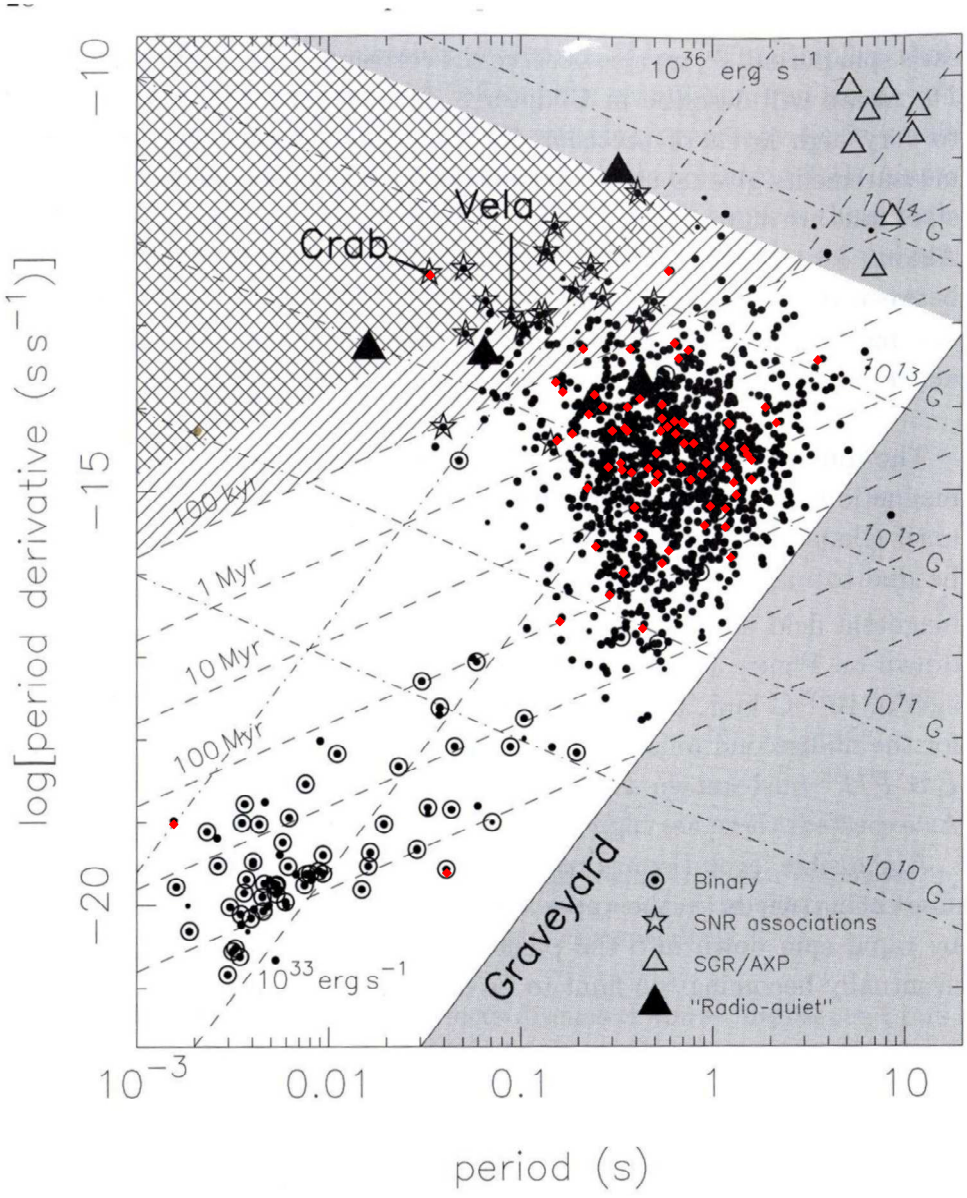
The distribution of these pulsars over the galaxy is depicted below (in galactic coordinates):



3 P/Pdot Diagram

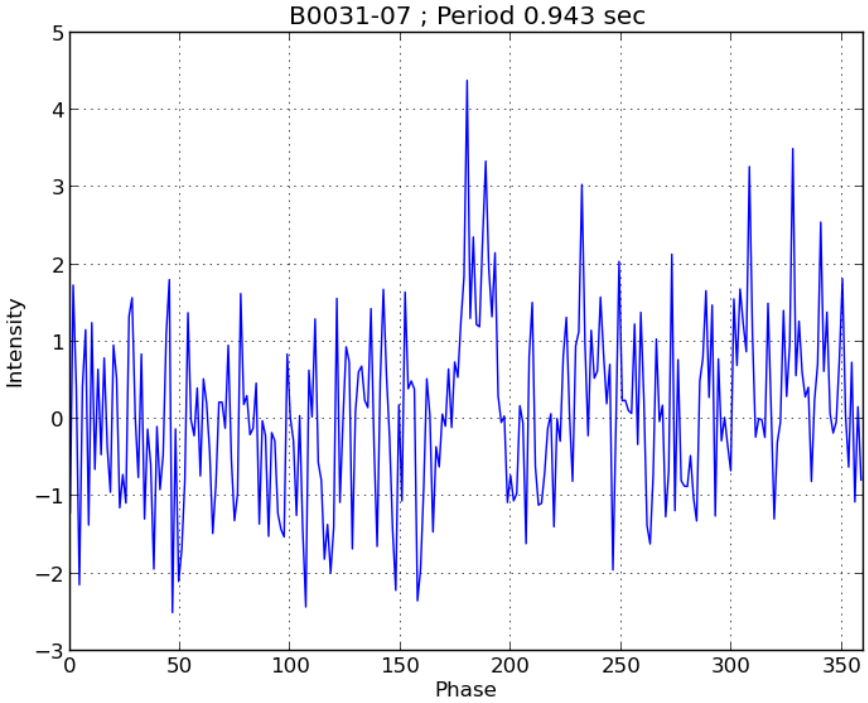
This plot[9] depicts the spindown rate vs. pulsar period.

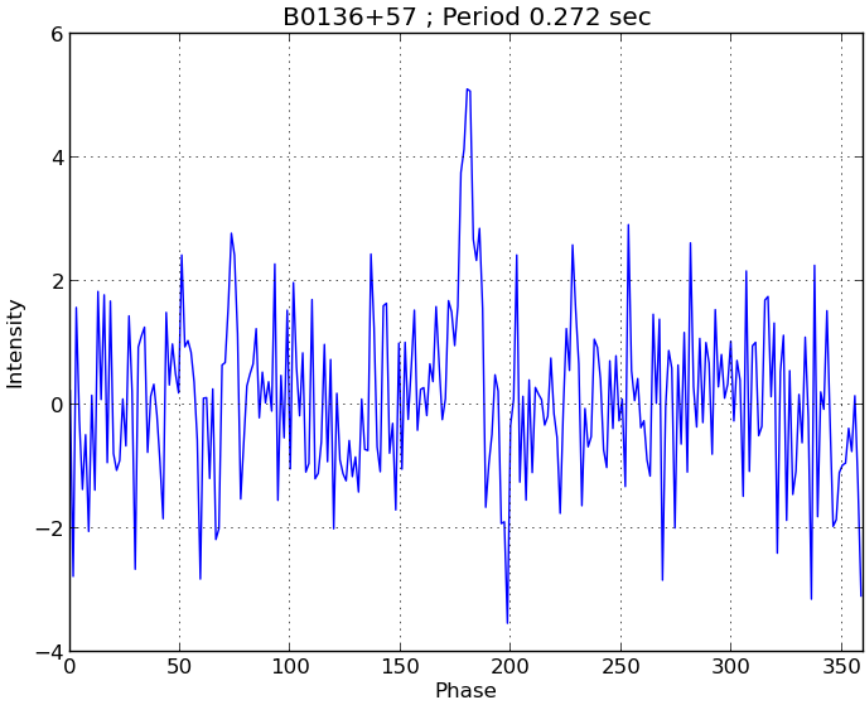
Black dots are the known pulsars, red dots depict the pulsars observed.

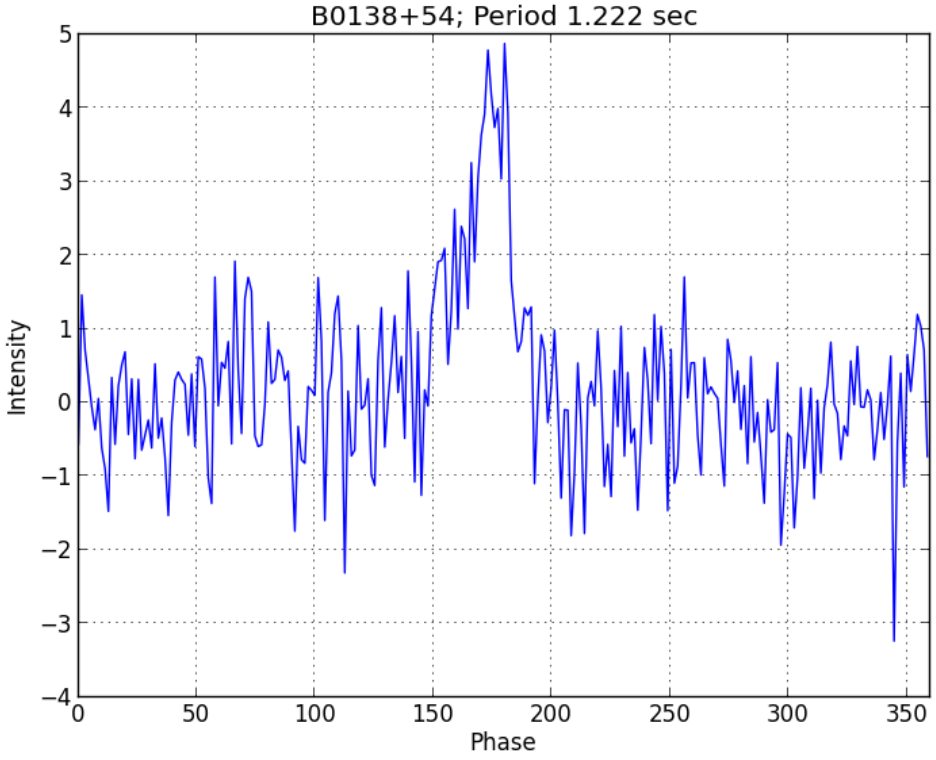


[9] Background graph from Duncan Lorimer, Michael Kramer, Handbook of Pulsar Astronomy, Cambridge University Press 2005
P and Pdot for observed pulsars were taken from the ATNF data base http://www.atnf.csiro.au/people/pulsar/psrcat/

4 Plots of Individual Observations






B0138+54; Period 1.222 sec
Intensity
Phase
5
4
3
2
1
0
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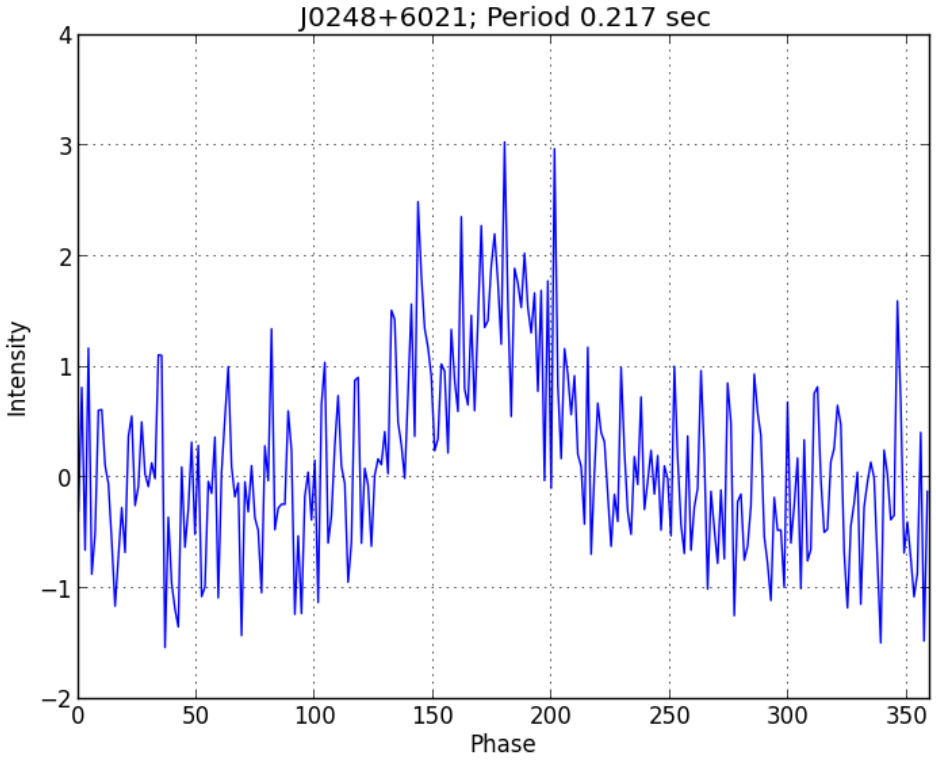
−2
−3
−4
0
50
100
150
200
250
300
350


J0248+6021; Period 0.217 sec
Intensity
Phase
4
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2
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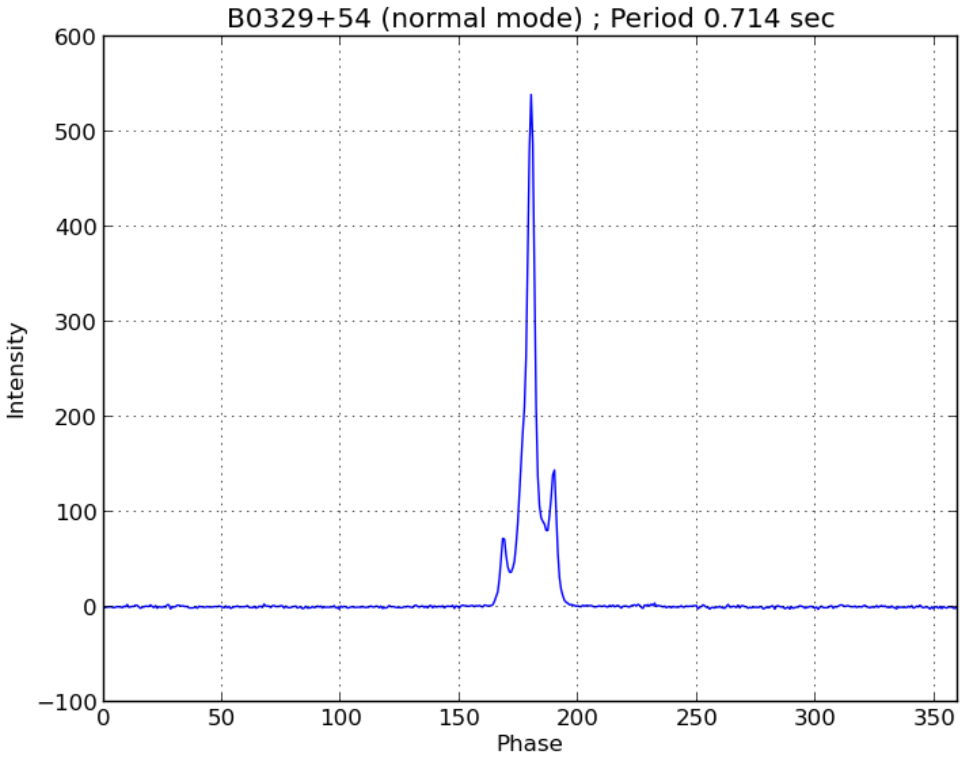
−1
−2
0
50
100
150
200
250
300
350


B0329+54 (normal mode) ; Period 0.714 sec
Intensity
Phase
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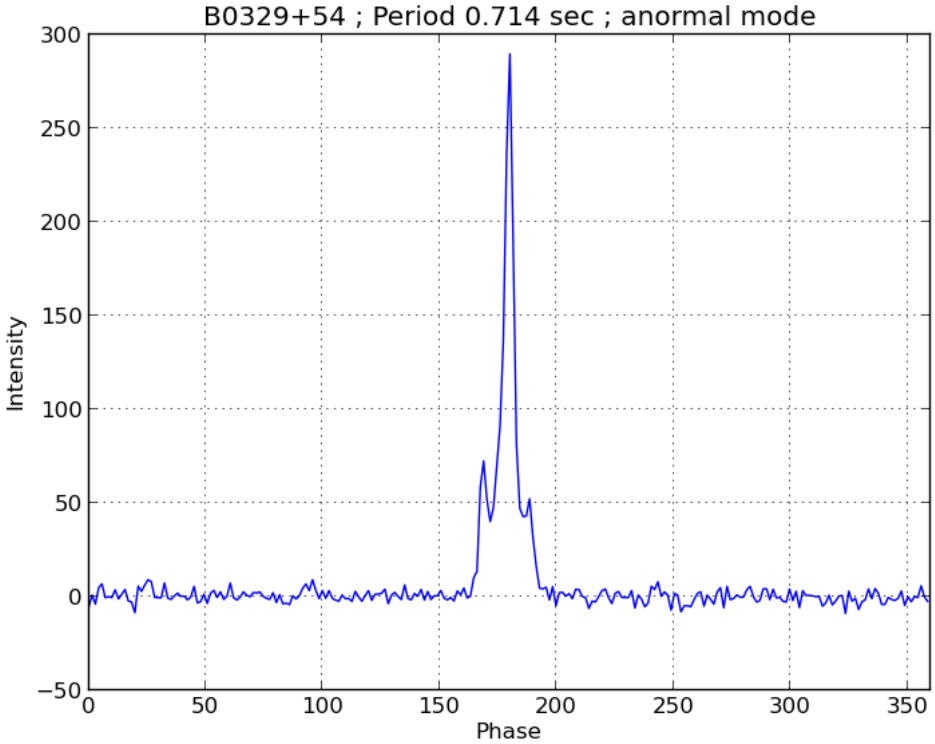
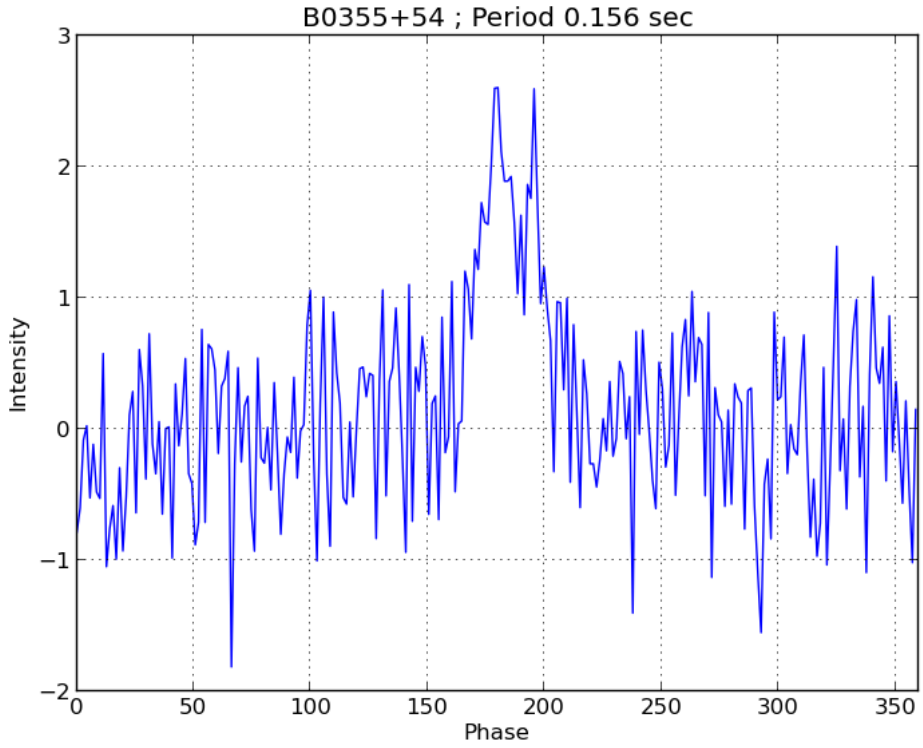
400
300
200
100
0
−100
0
50
100
150
200
250
300
350


B0329+54 ; Period 0.714 sec ; anormal mode
Intensity
Phase
300
250
200
150
100
50
0
−50
0
50
100
150
200
250
300
350


B0355+54 ; Period 0.156 sec
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Phase
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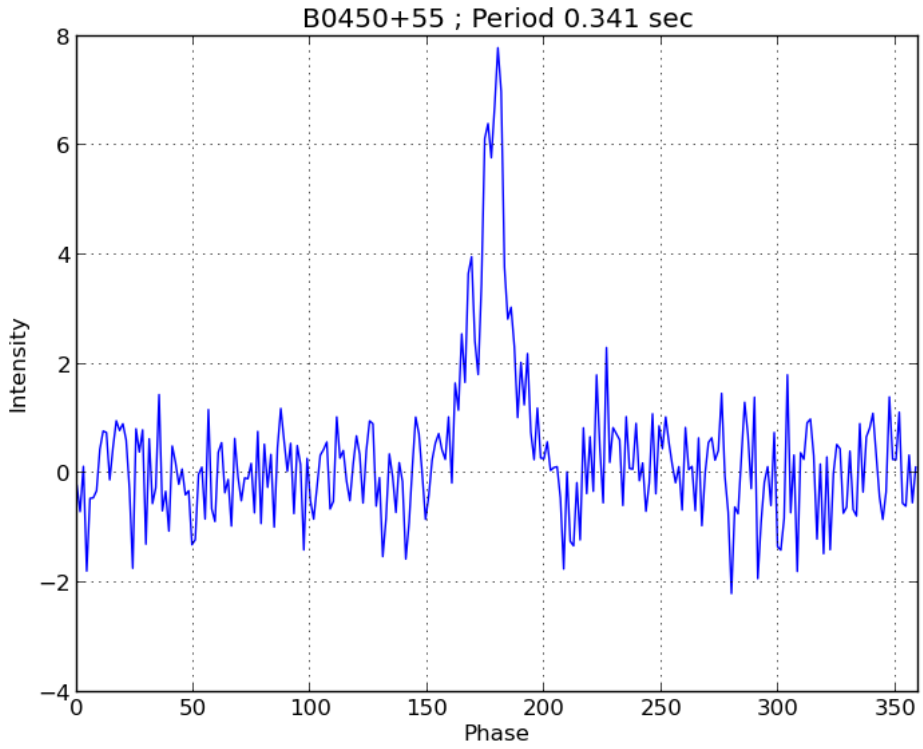
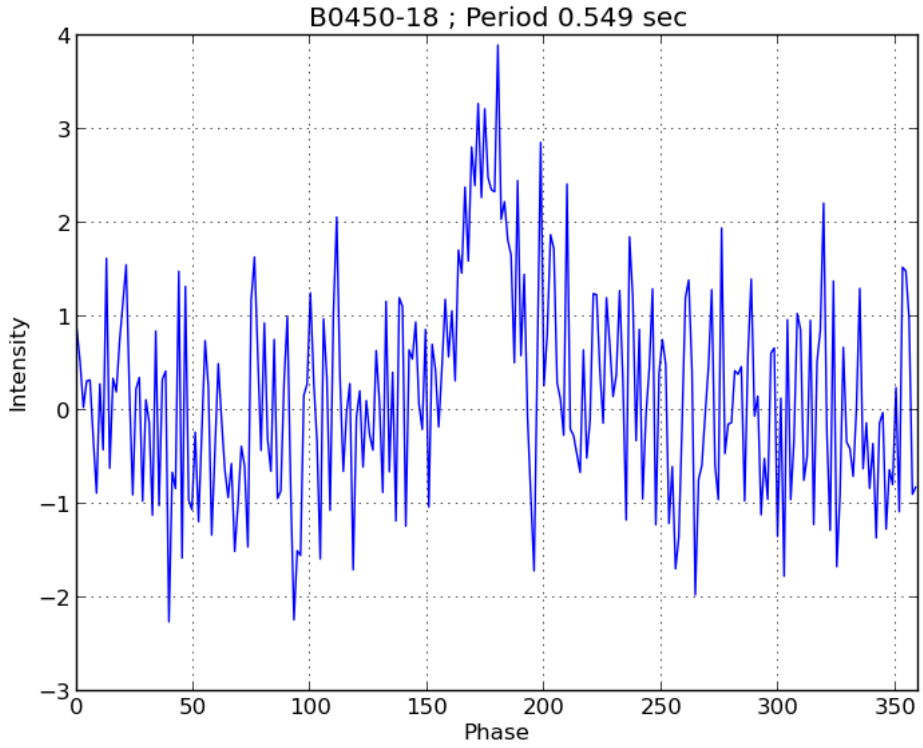
0
−1
−2
0
50
100
150
200
250
300
350


B0450+55 ; Period 0.341 sec
Intensity
Phase
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350


B0450-18 ; Period 0.549 sec
Intensity
Phase
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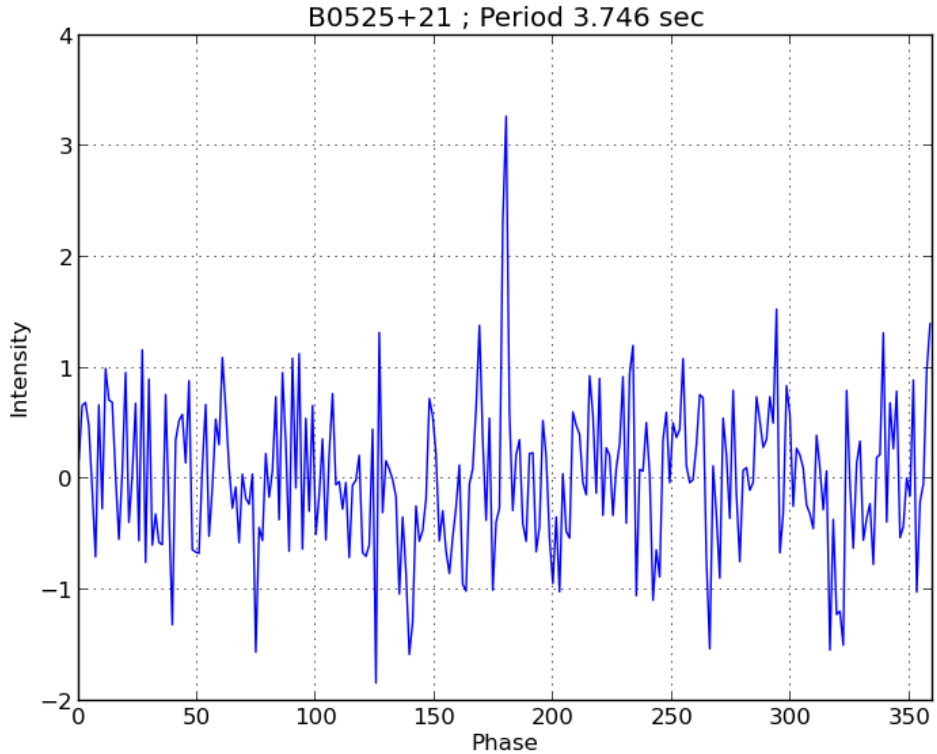
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350


B0525+21 ; Period 3.746 sec
Intensity
Phase
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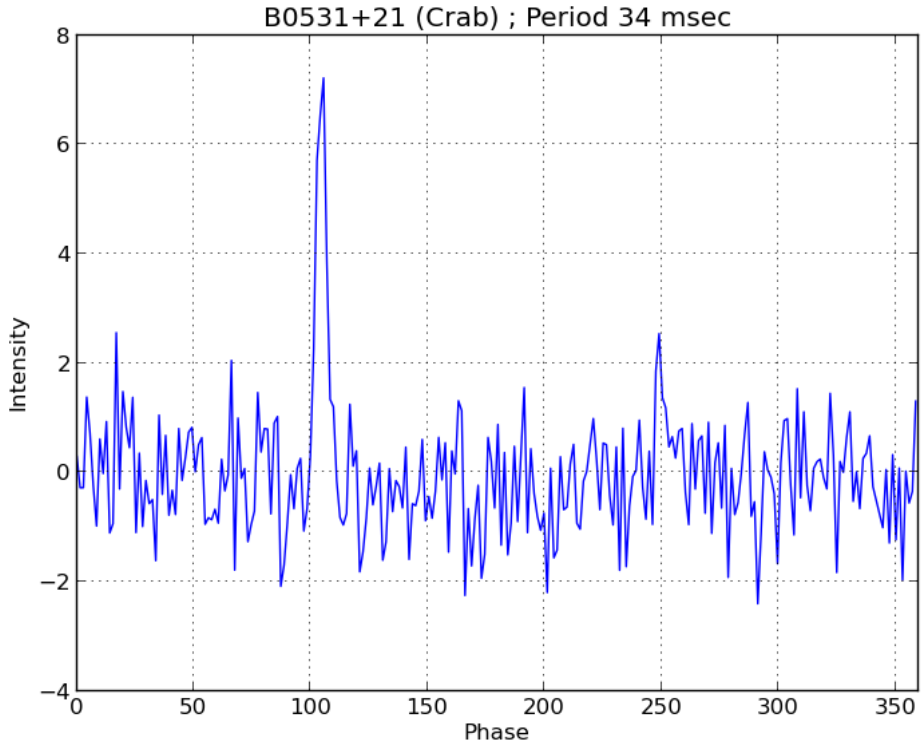
2
1
0
−1
−2
0
50
100
150
200
250
300
350


B0531+21 (Crab) ; Period 34 msec
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Phase
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6
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−2
−4
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100
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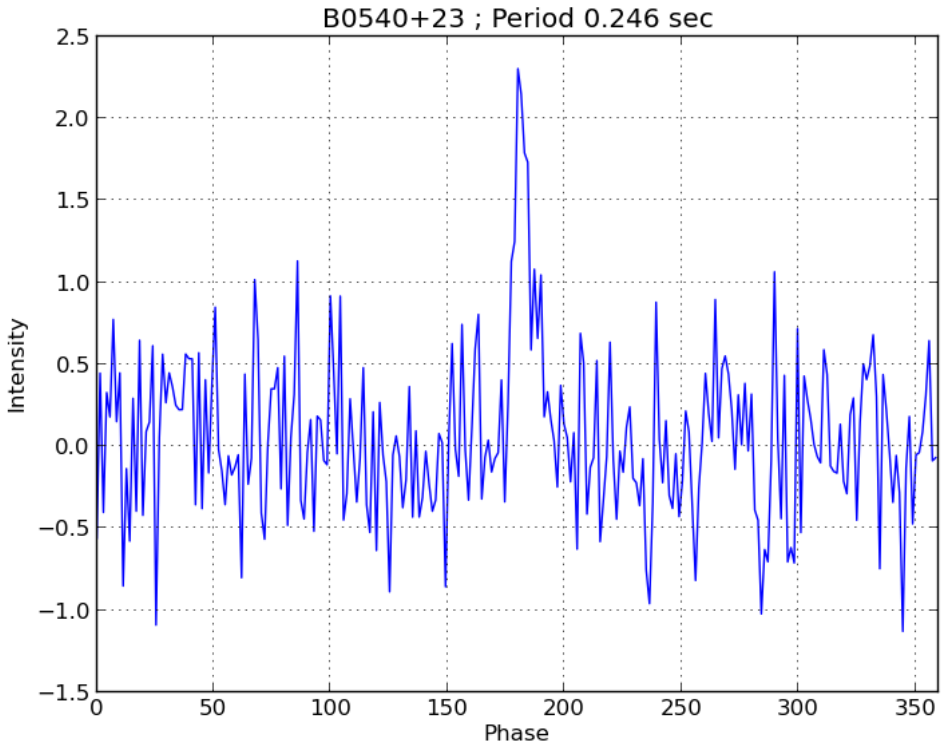
200
250
300
350


B0540+23 ; Period 0.246 sec
Intensity
Phase
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2.0
1.5
1.0
0.5
0.0
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−1.5
0
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150
200
250
300
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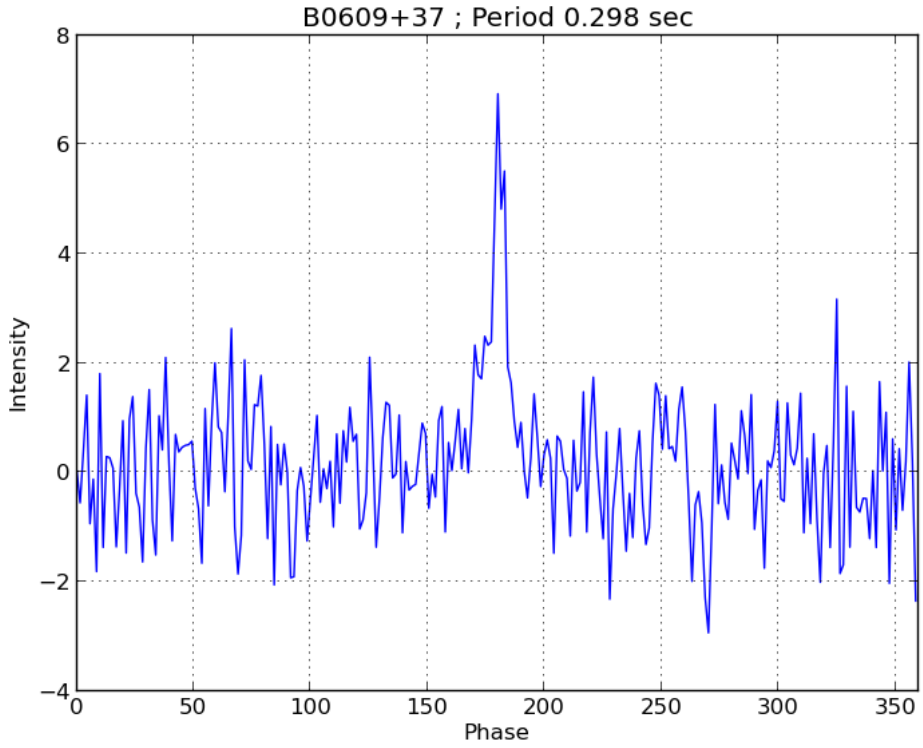
B0609+37 ; Period 0.298 sec
Intensity
Phase
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6
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2
0
−2
−4
0
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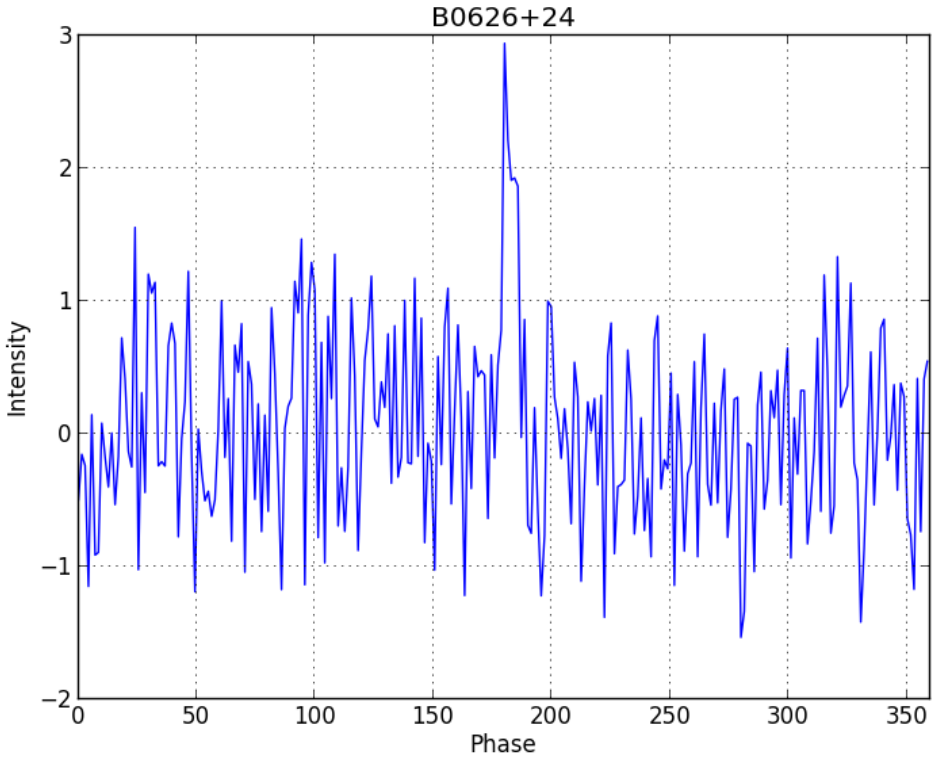
100
150
200
250
300
350


B0626+24
Intensity
Phase
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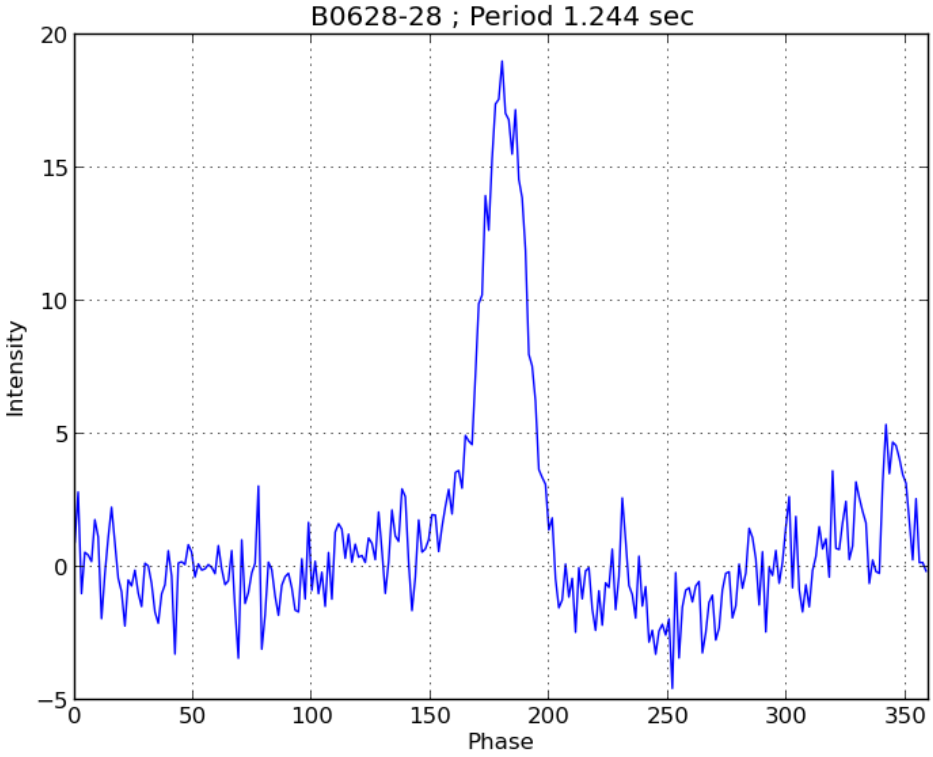
−1
−2
0
50
100
150
200
250
300
350


B0628-28 ; Period 1.244 sec
Intensity
Phase
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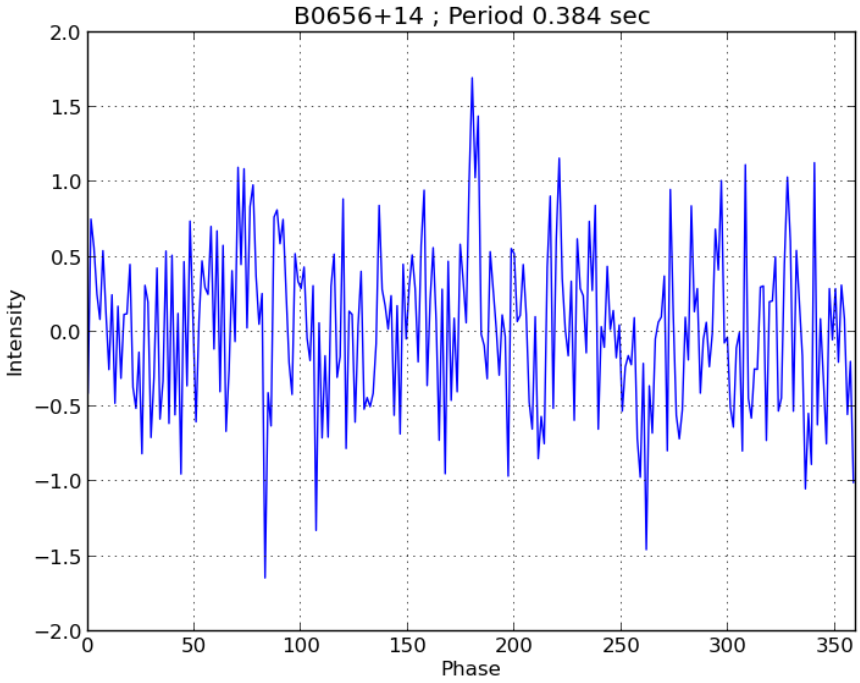
15
10
5
0
−5
0
50
100
150
200
250
300
350


B0656+14 ; Period 0.384 sec
Intensity
Phase
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1.5
1.0
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−1.0
−1.5
−2.0
0
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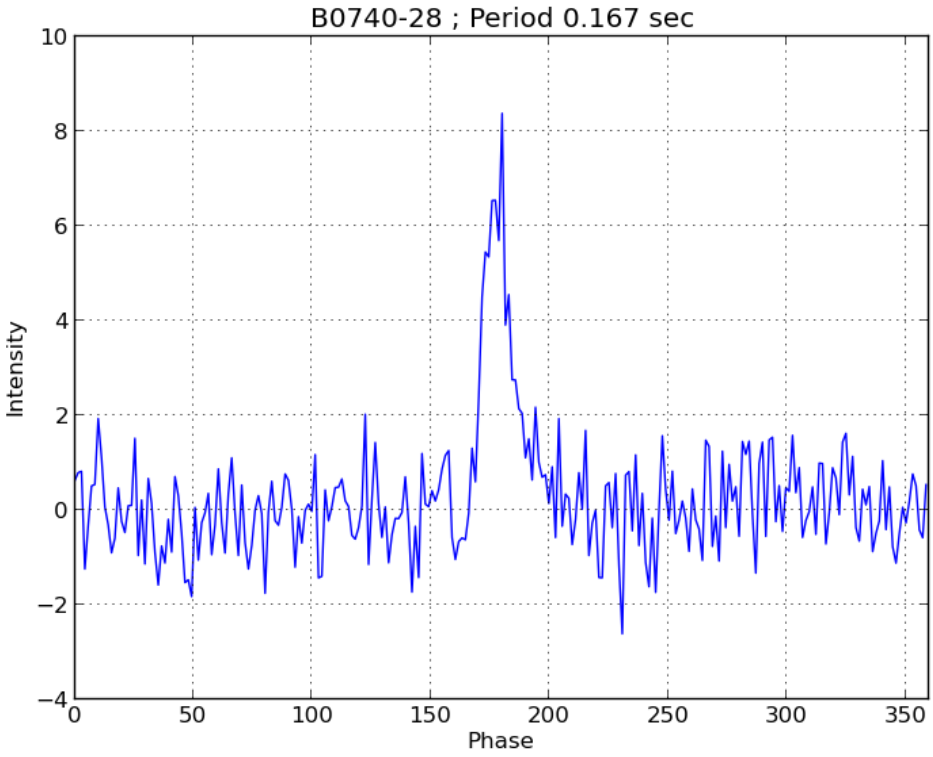
100
150
200
250
300
350


B0740-28 ; Period 0.167 sec
Intensity
Phase
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8
6
4
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0
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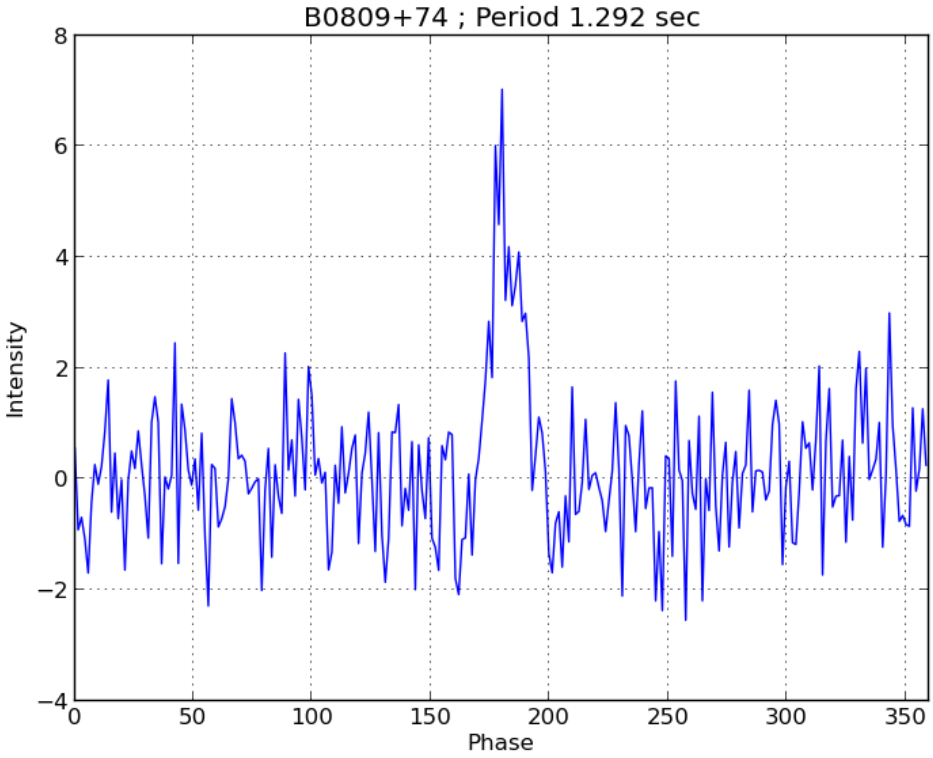
−4
0
50
100
150
200
250
300
350


B0809+74 ; Period 1.292 sec
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Phase
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−4
0
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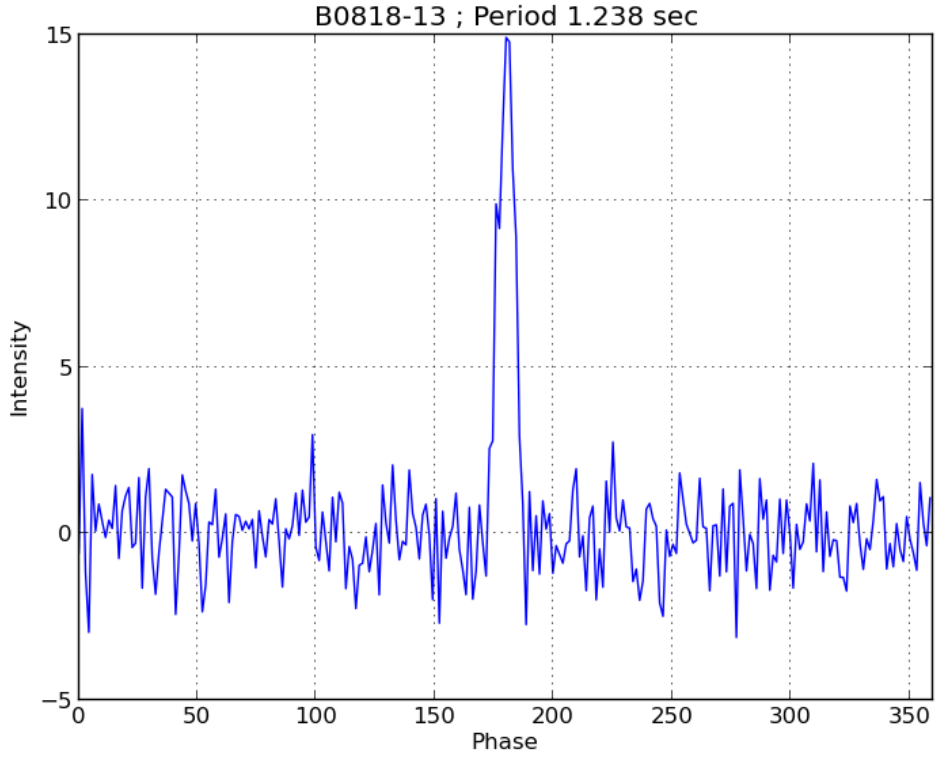
150
200
250
300
350


B0818-13 ; Period 1.238 sec
Intensity
Phase
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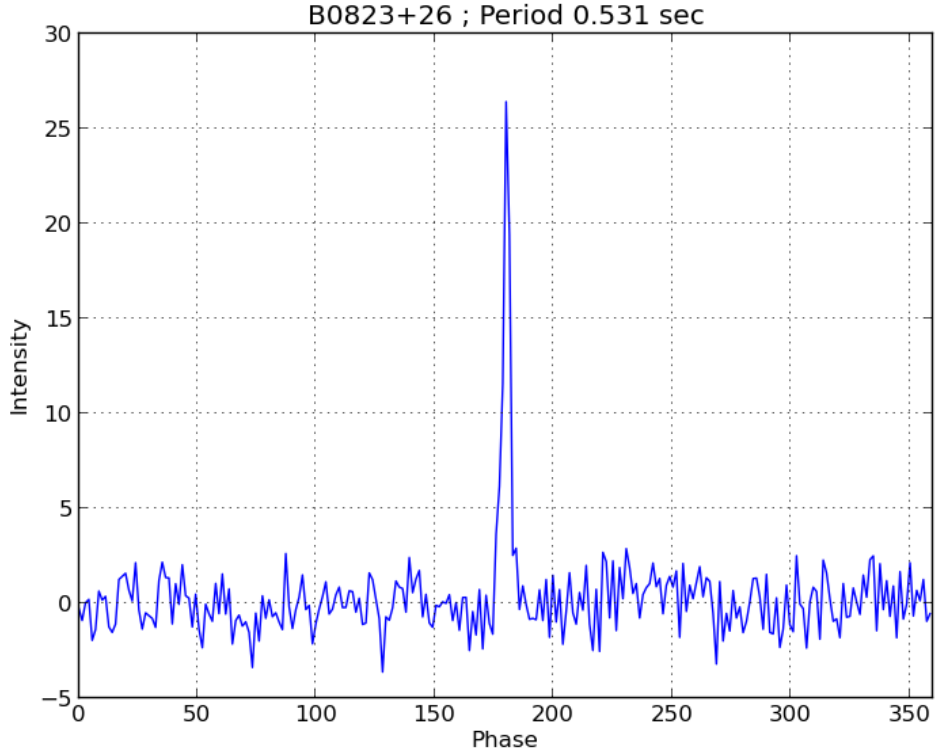
10
5
0
−5
0
50
100
150
200
250
300
350


B0823+26 ; Period 0.531 sec
Intensity
Phase
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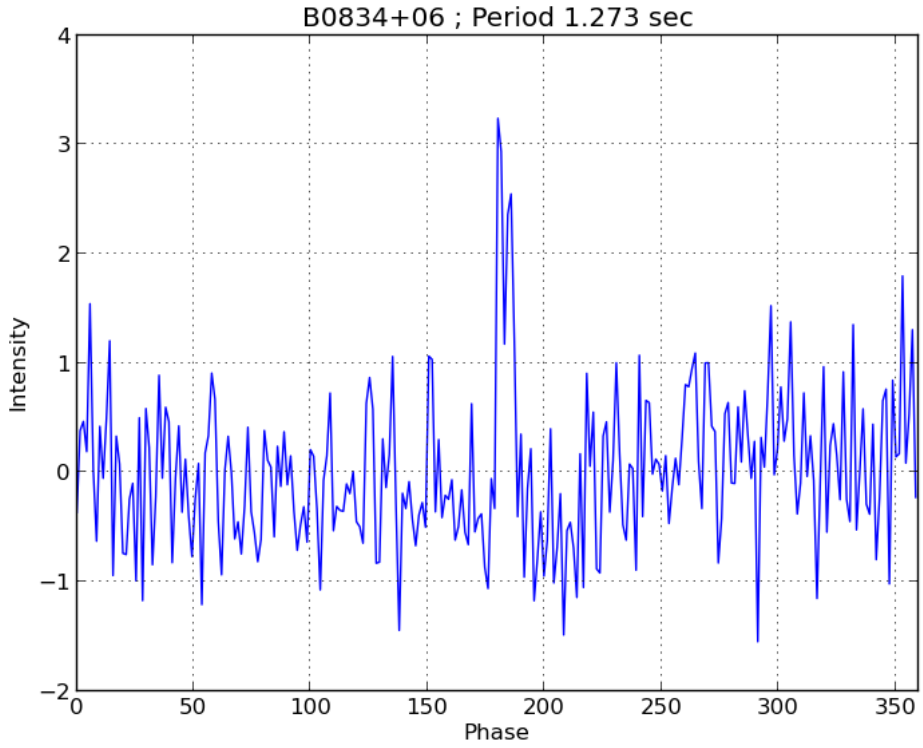
25
20
15
10
5
0
−5
0
50
100
150
200
250
300
350


B0834+06 ; Period 1.273 sec
Intensity
Phase
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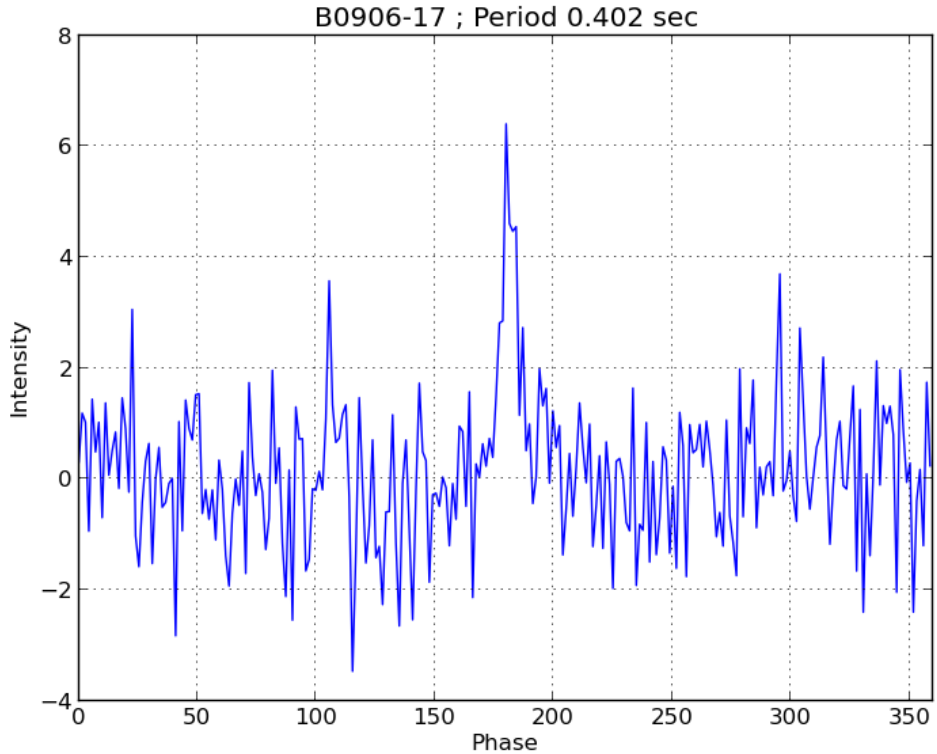
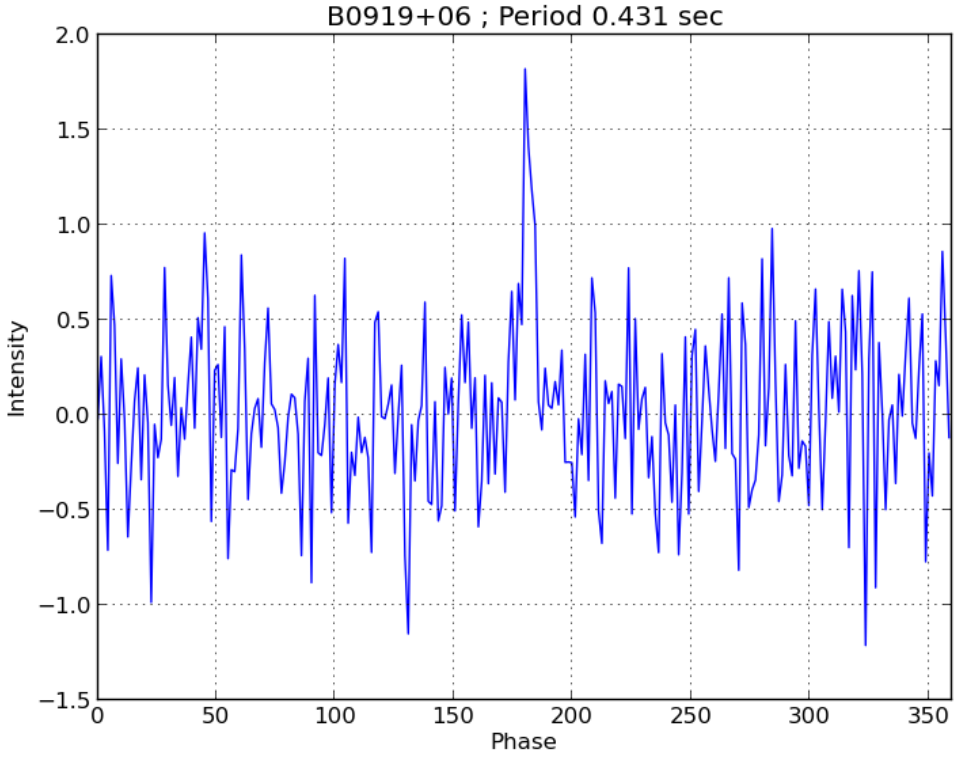
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350


B0906-17 ; Period 0.402 sec
Intensity
Phase
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350


B0919+06 ; Period 0.431 sec
Intensity
Phase
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1.5
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0
50
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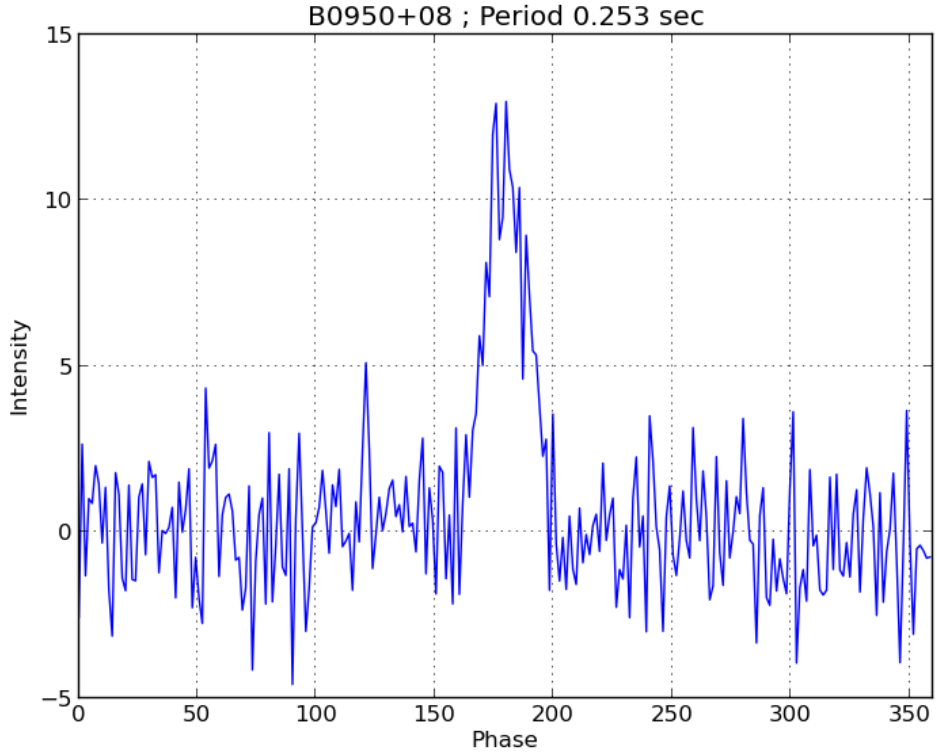
150
200
250
300
350


B0950+08 ; Period 0.253 sec
Intensity
Phase
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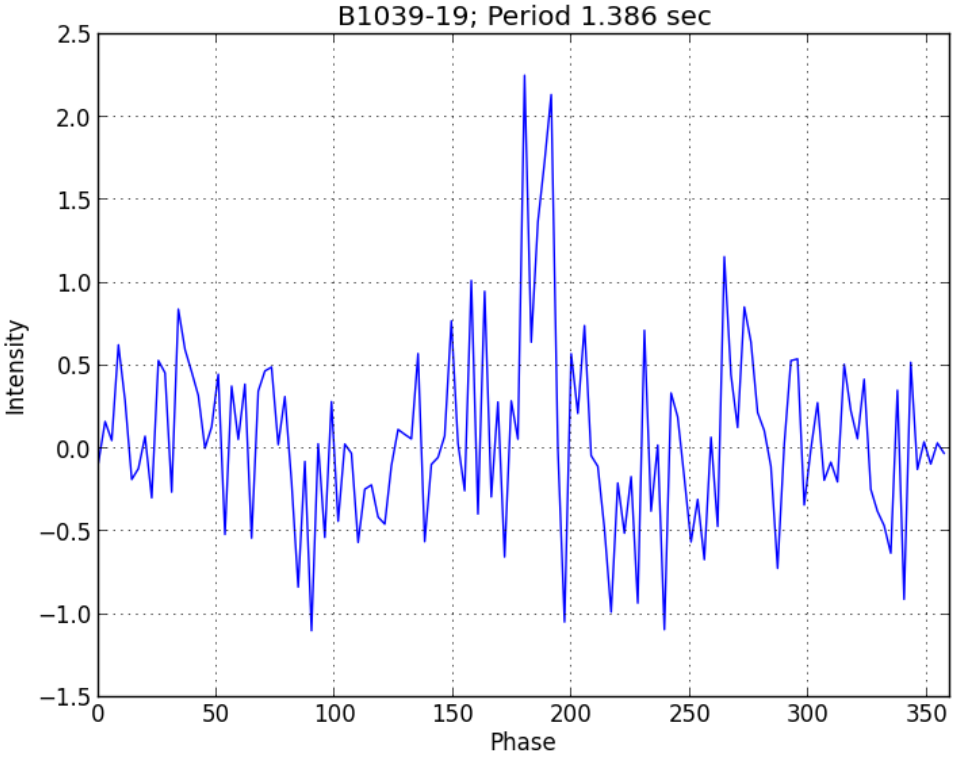
10
5
0
−5
0
50
100
150
200
250
300
350


B1039-19; Period 1.386 sec
Intensity
Phase
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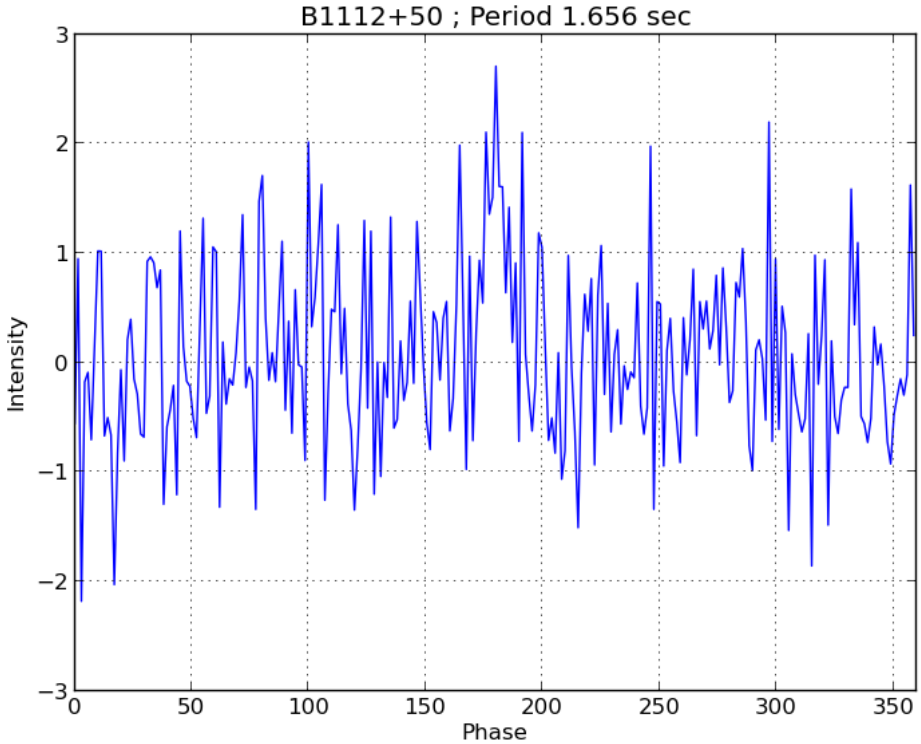
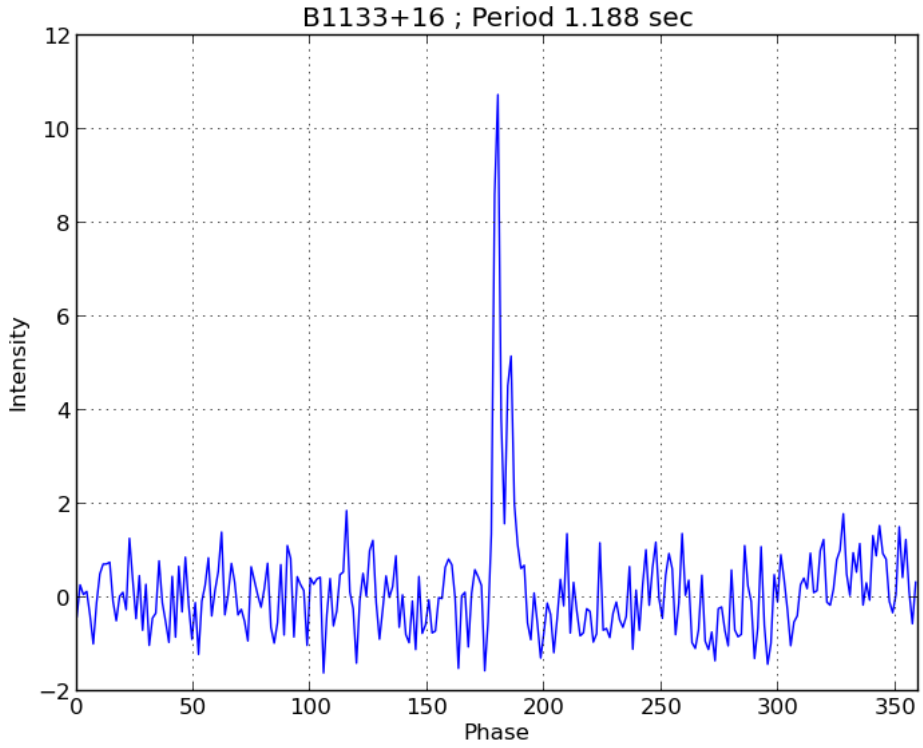
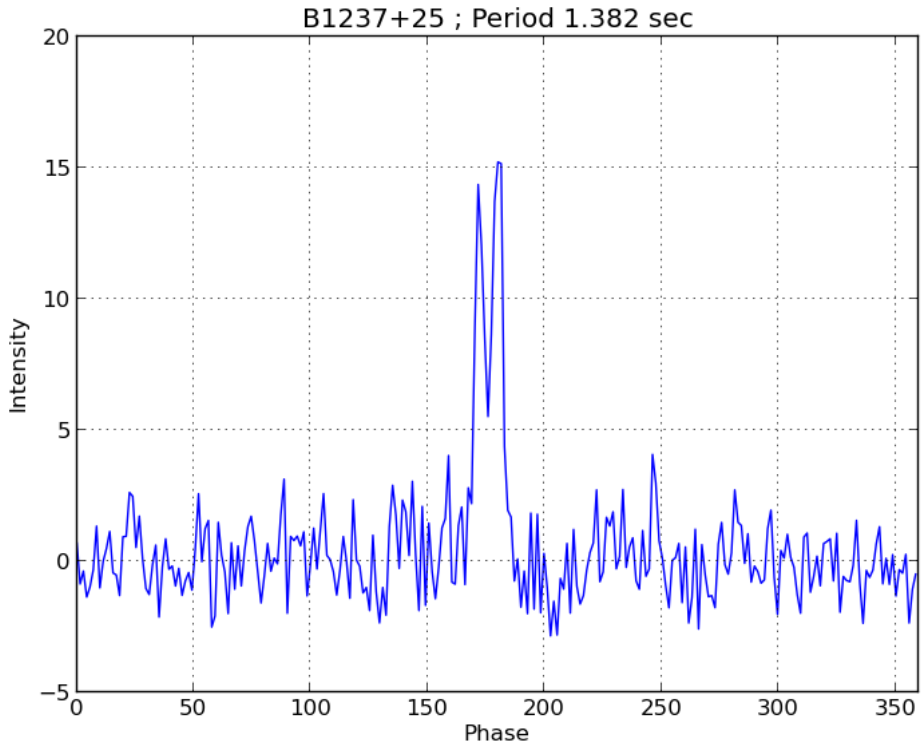
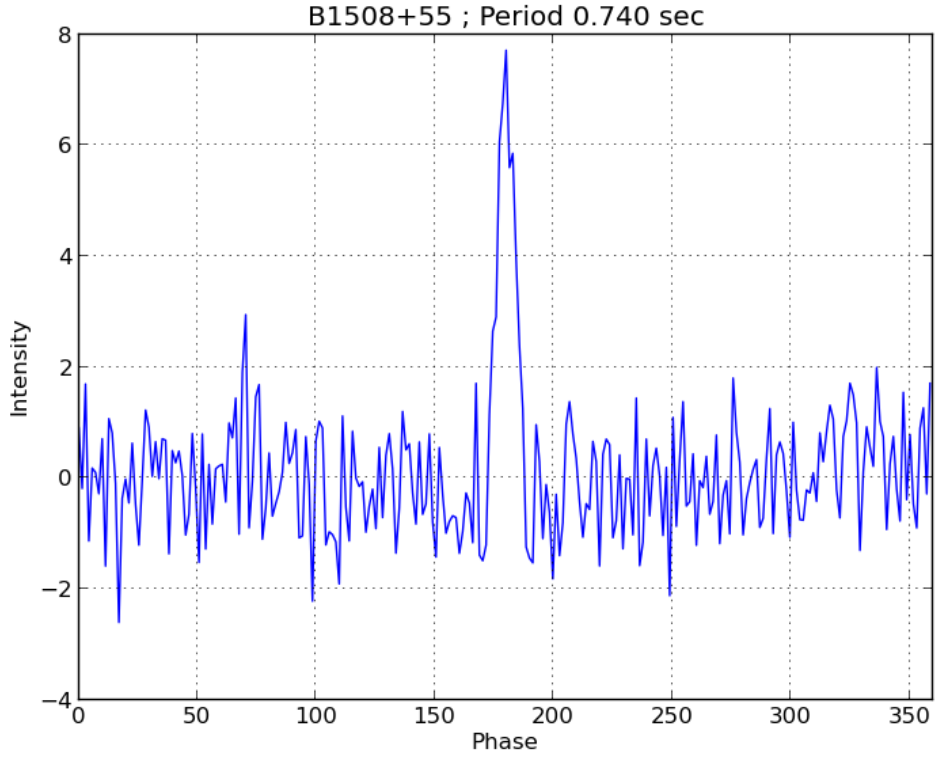
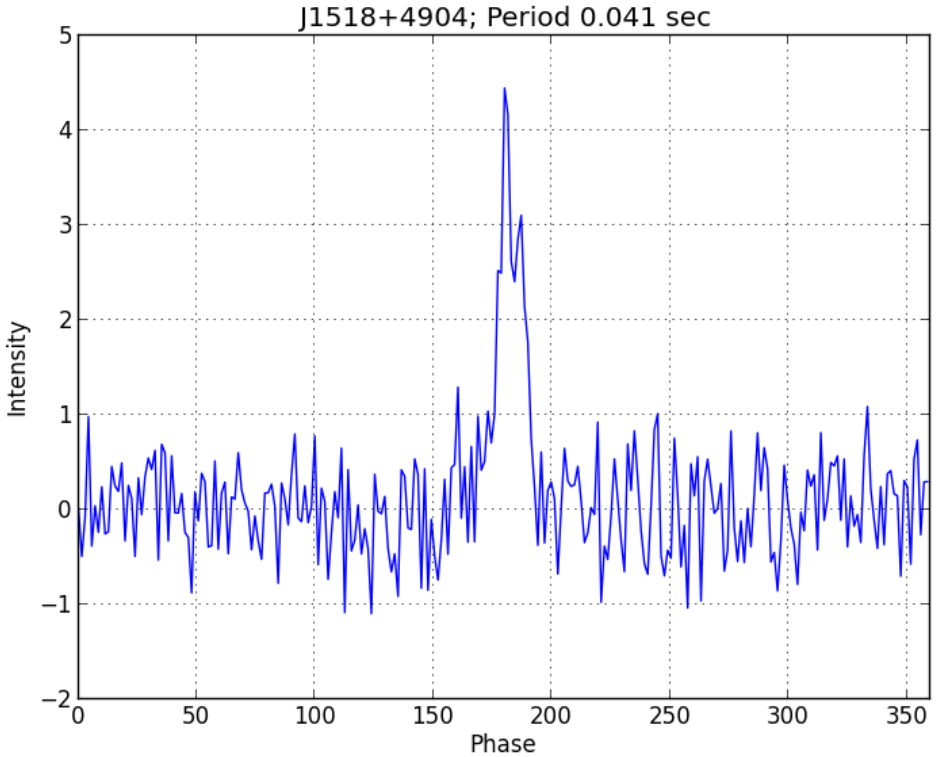
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
50
100
150
200
250
300
350

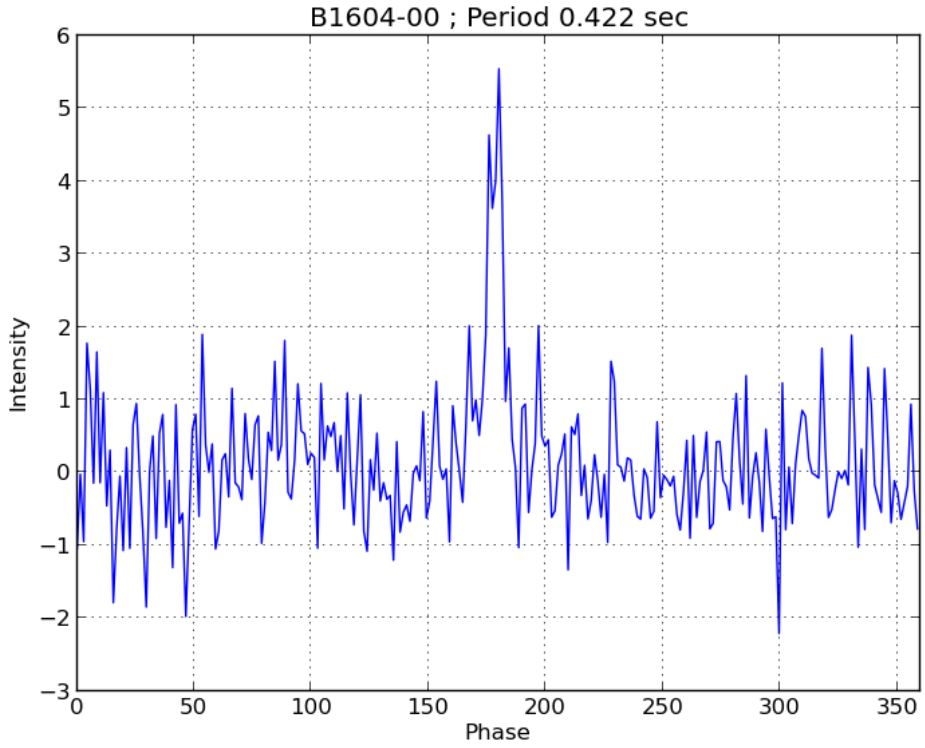

B1112+50 ; Period 1.656 sec
Intensity
Phase
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

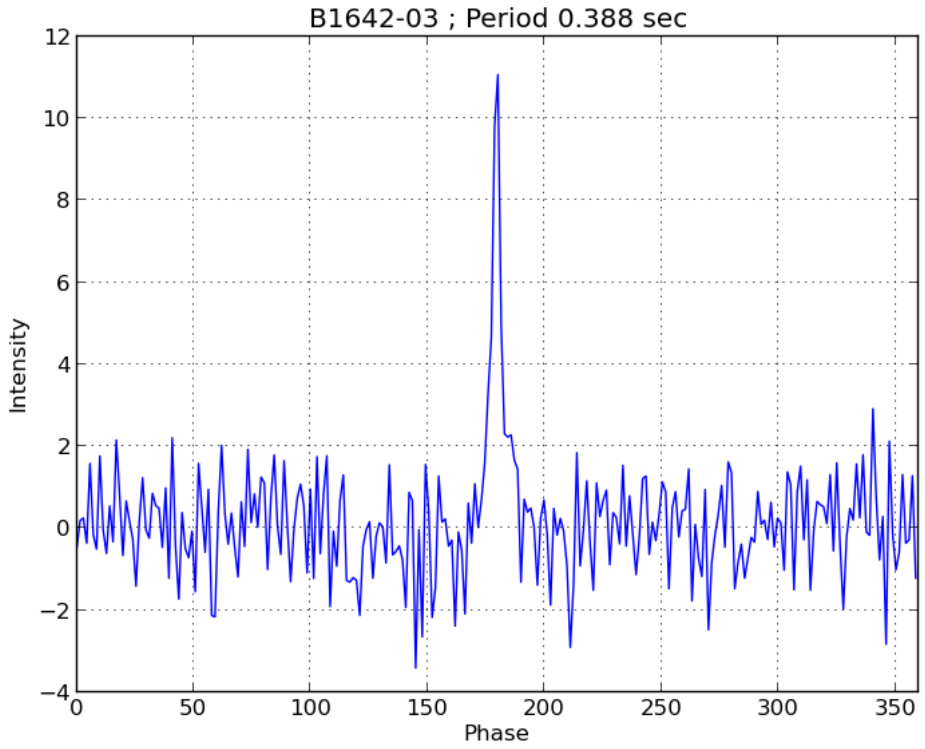

B1133+16 ; Period 1.188 sec
Intensity
Phase
12
10
8
6
4
2
0
−2
0
50
100
150
200
250
300
350

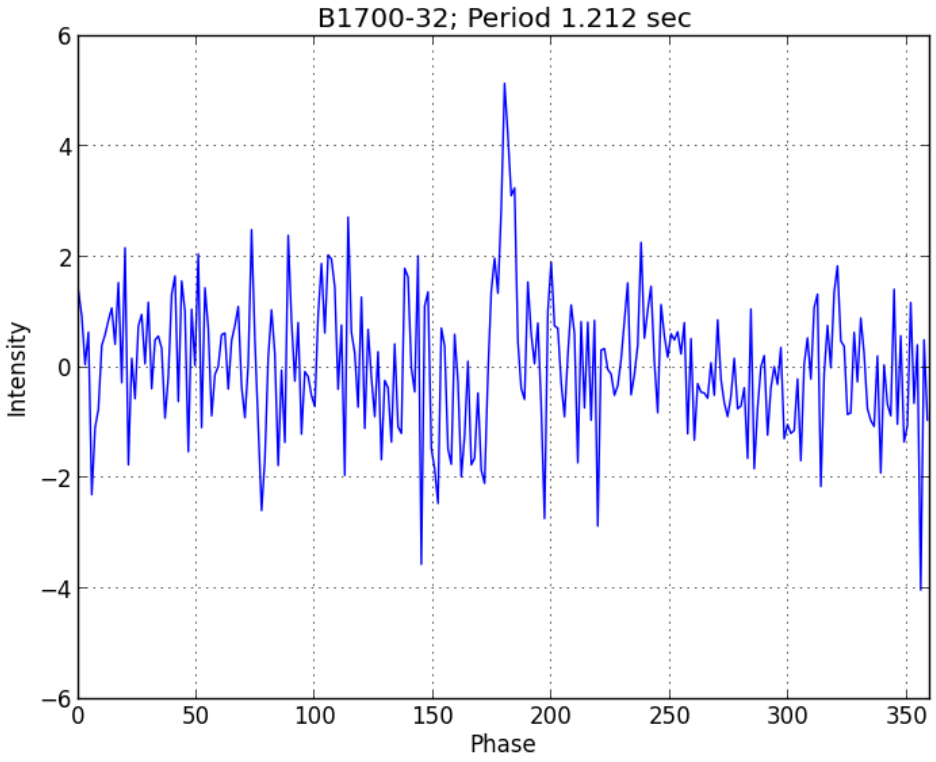

B1237+25 ; Period 1.382 sec
Intensity
Phase
20
15
10
5
0
−5
0
50
100
150
200
250
300
350

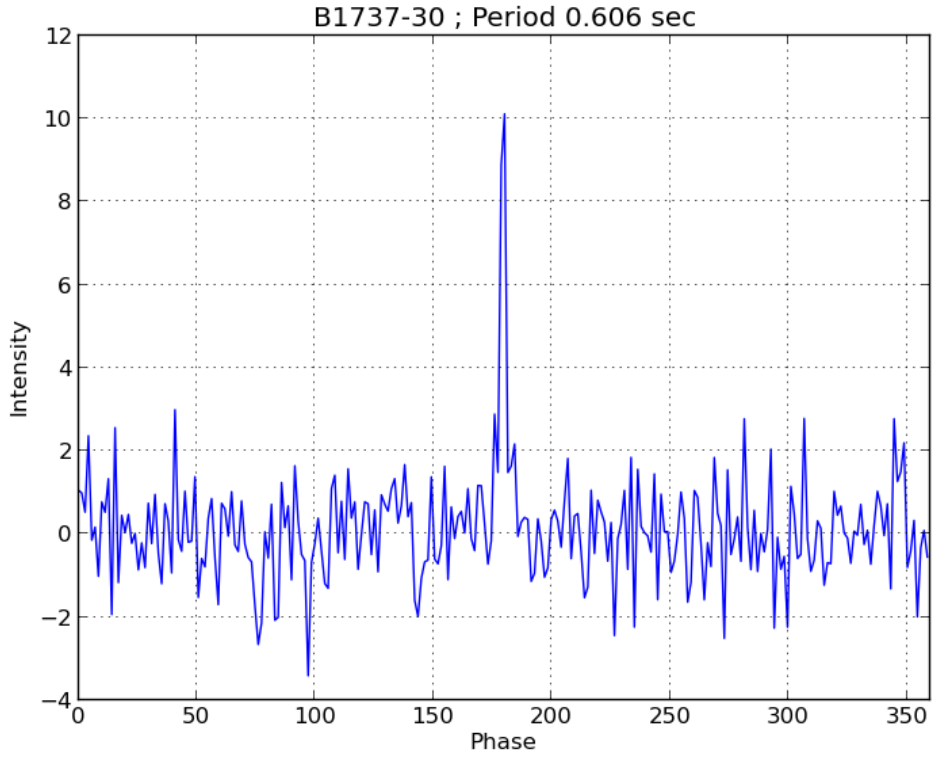

B1508+55 ; Period 0.740 sec
Intensity
Phase
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

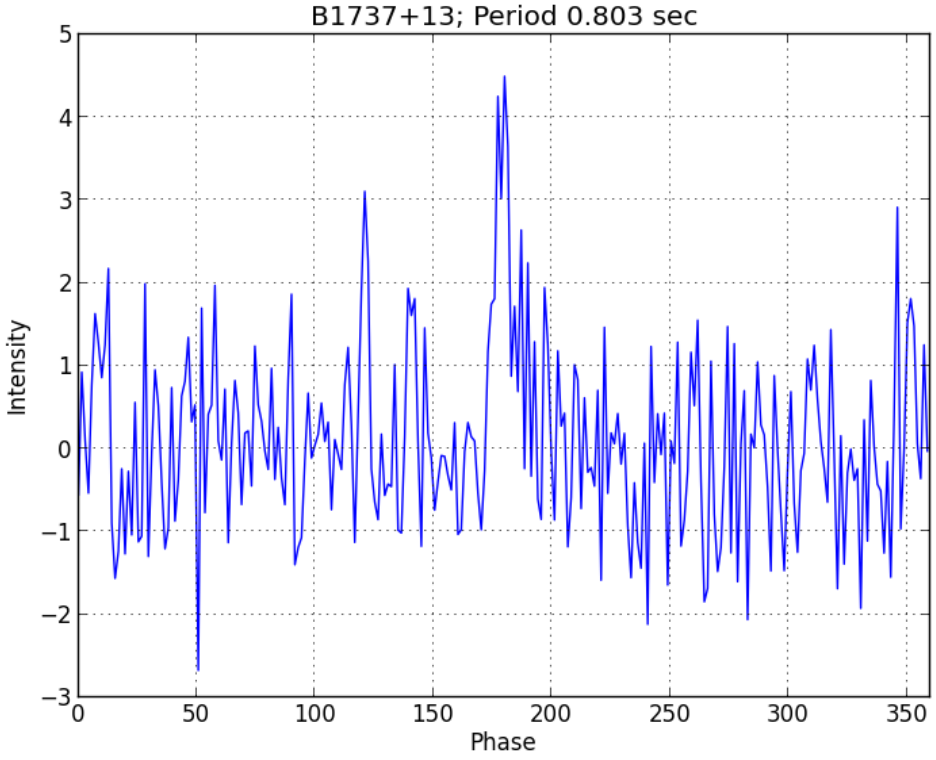

J1518+4904; Period 0.041 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

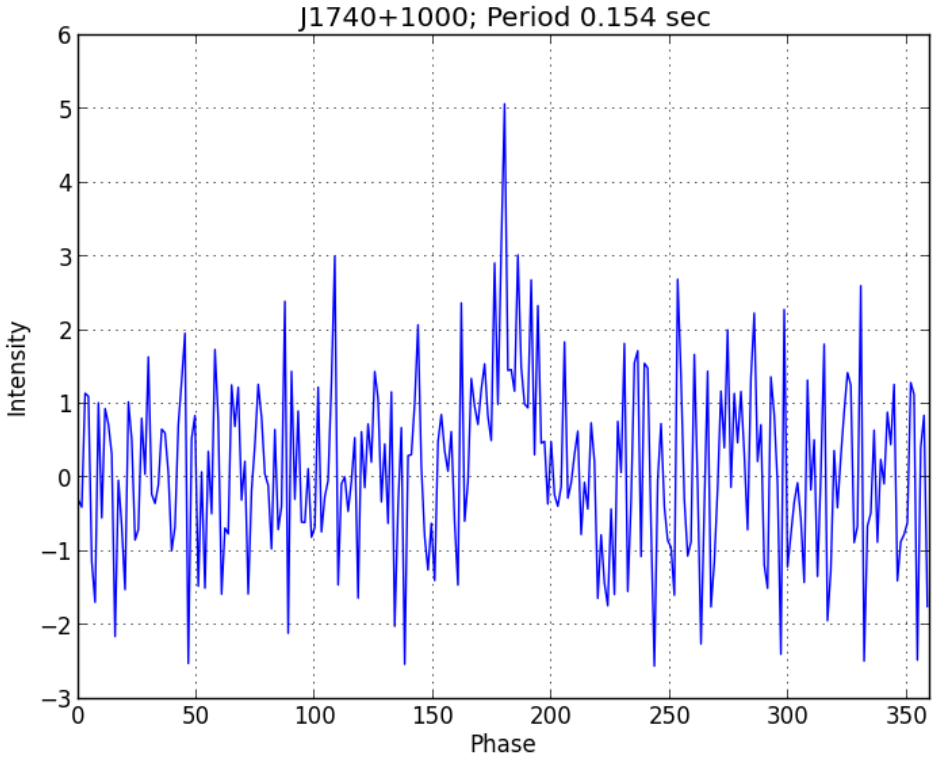

B1604-00 ; Period 0.422 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

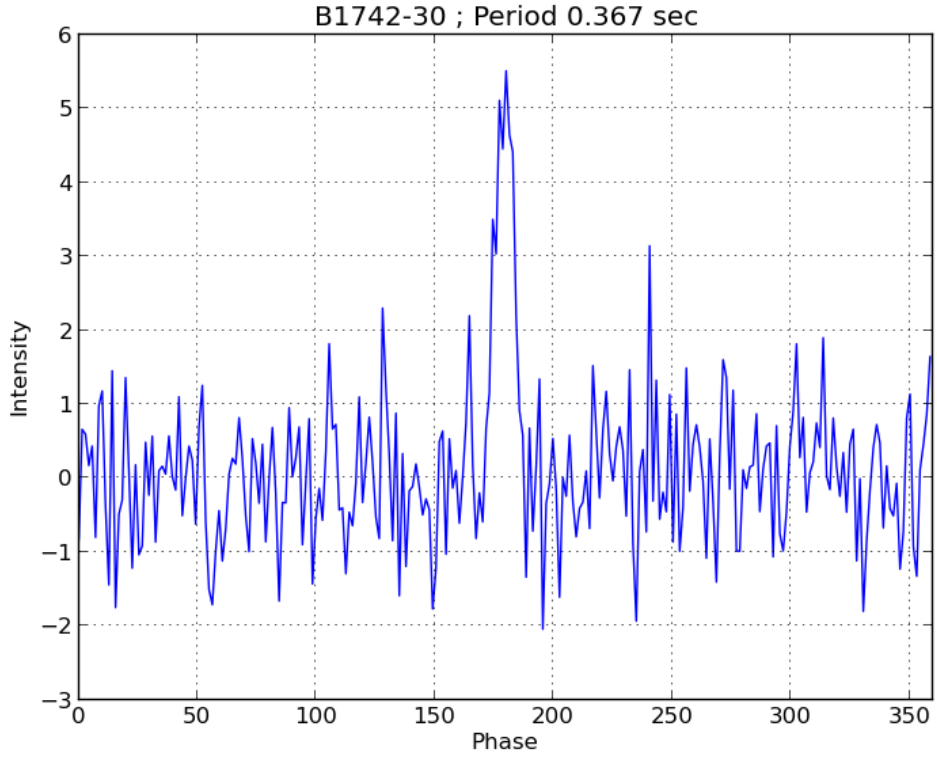

B1642-03 ; Period 0.388 sec
Intensity
Phase
12
10
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

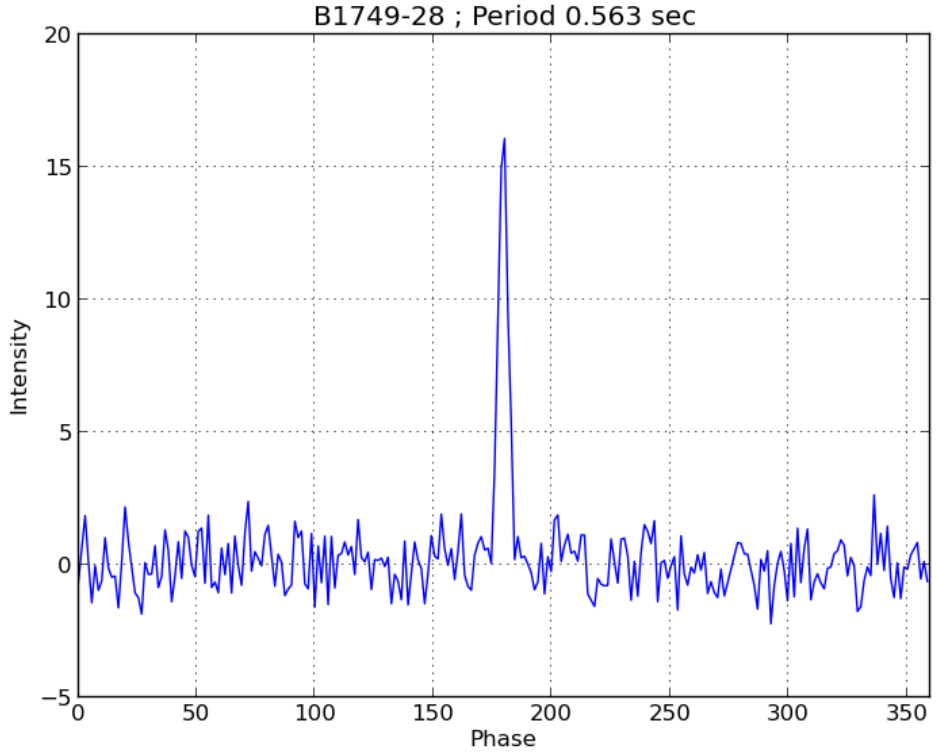

B1700-32; Period 1.212 sec
Intensity
Phase
6
4
2
0
−2
−4
−6
0
50
100
150
200
250
300
350

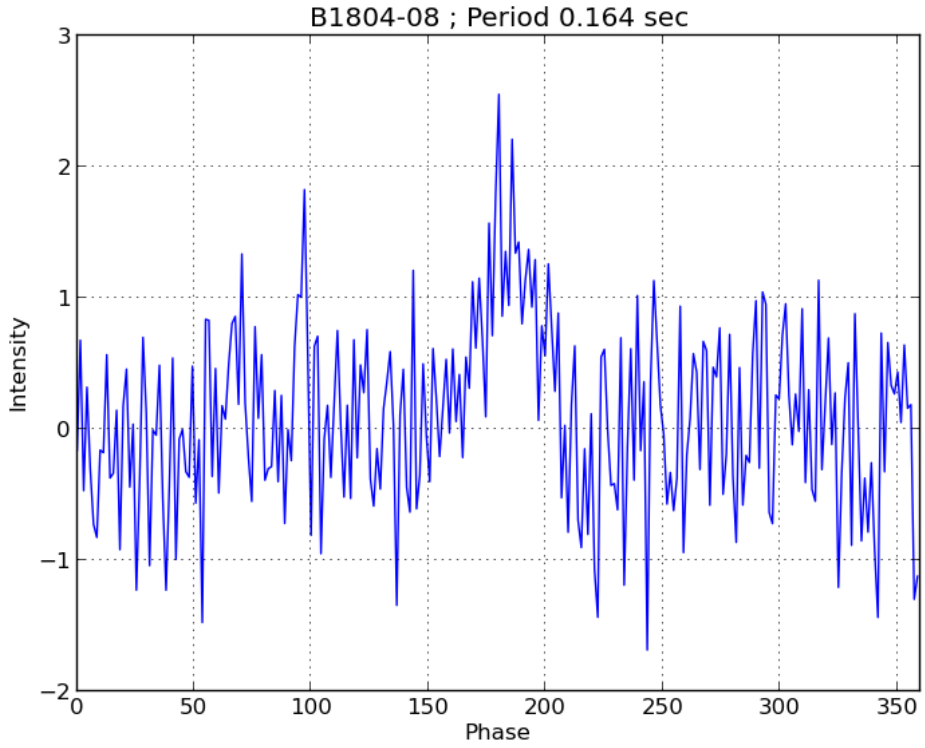

B1737-30 ; Period 0.606 sec
Intensity
Phase
12
10
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

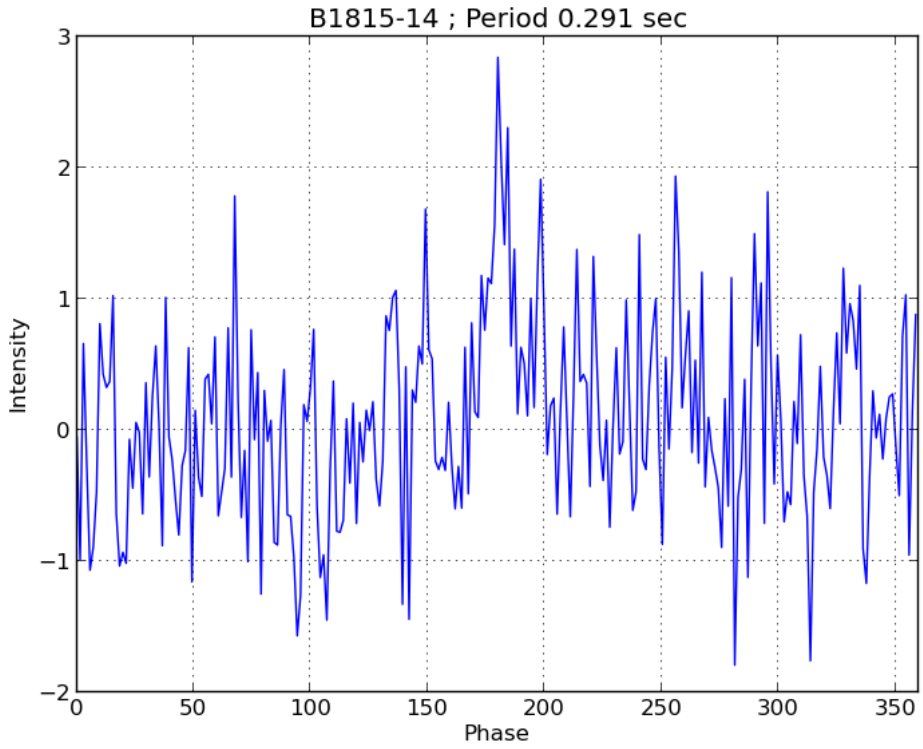

B1737+13; Period 0.803 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

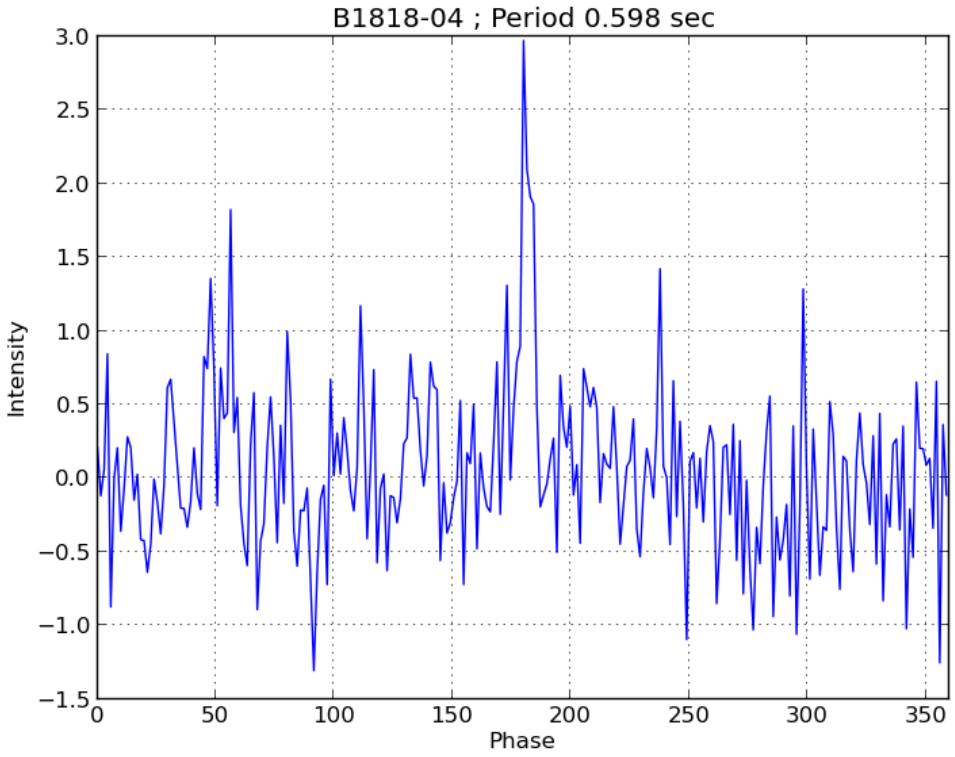

J1740+1000; Period 0.154 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

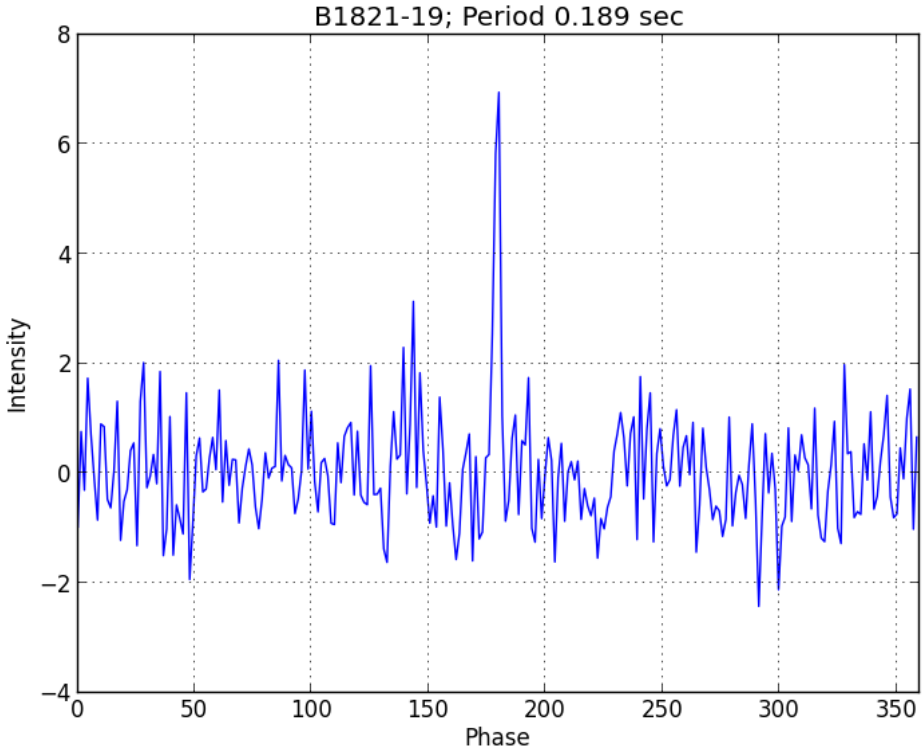

B1742-30 ; Period 0.367 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

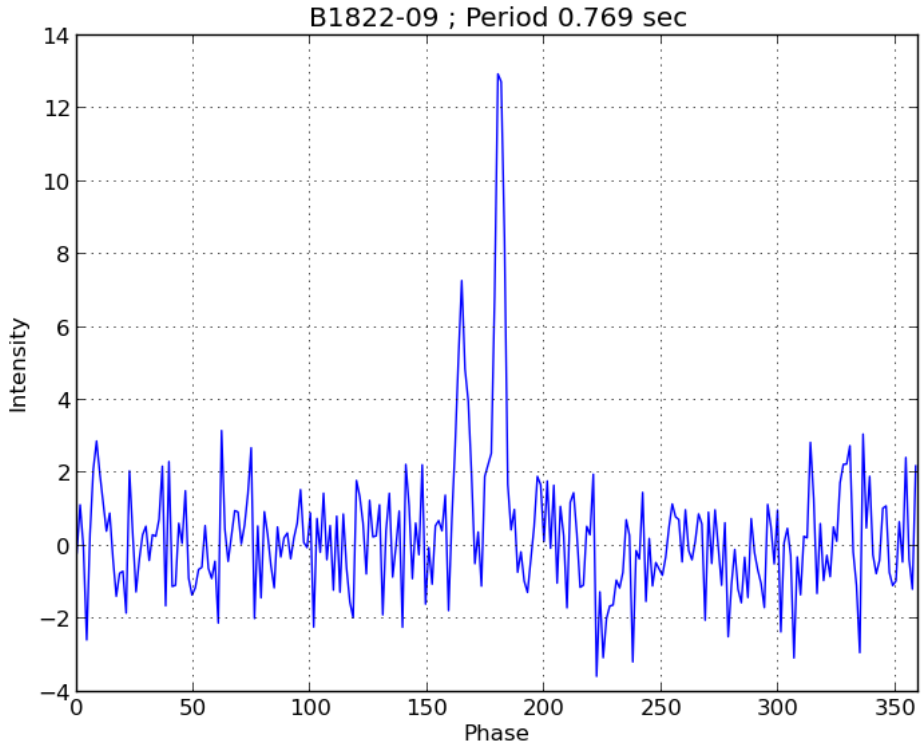

B1749-28 ; Period 0.563 sec
Intensity
Phase
20
15
10
5
0
−5
0
50
100
150
200
250
300
350

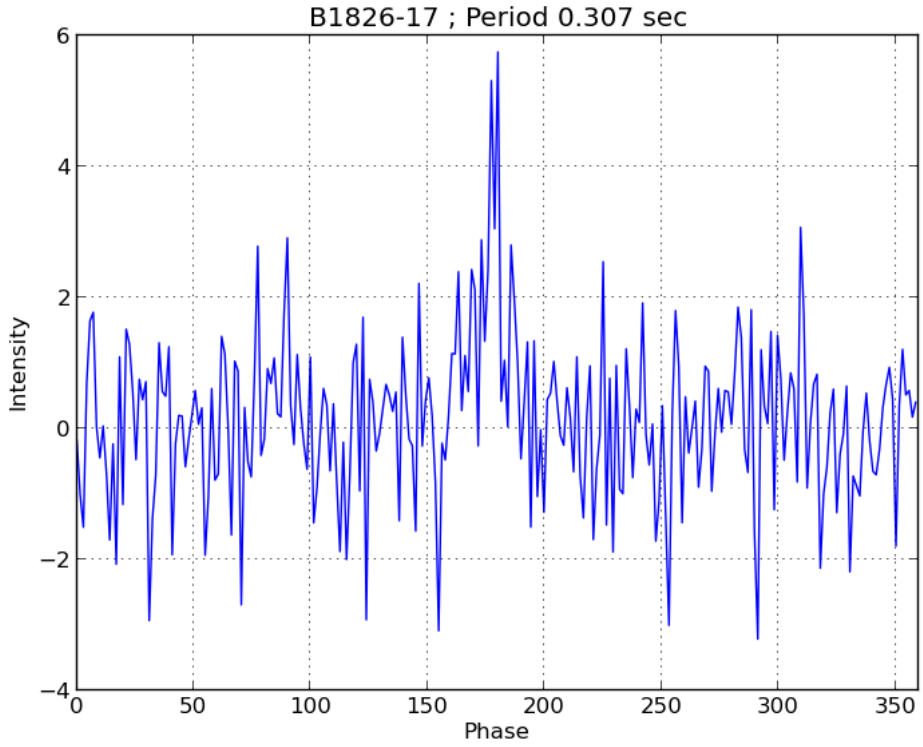

B1804-08 ; Period 0.164 sec
Intensity
Phase
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

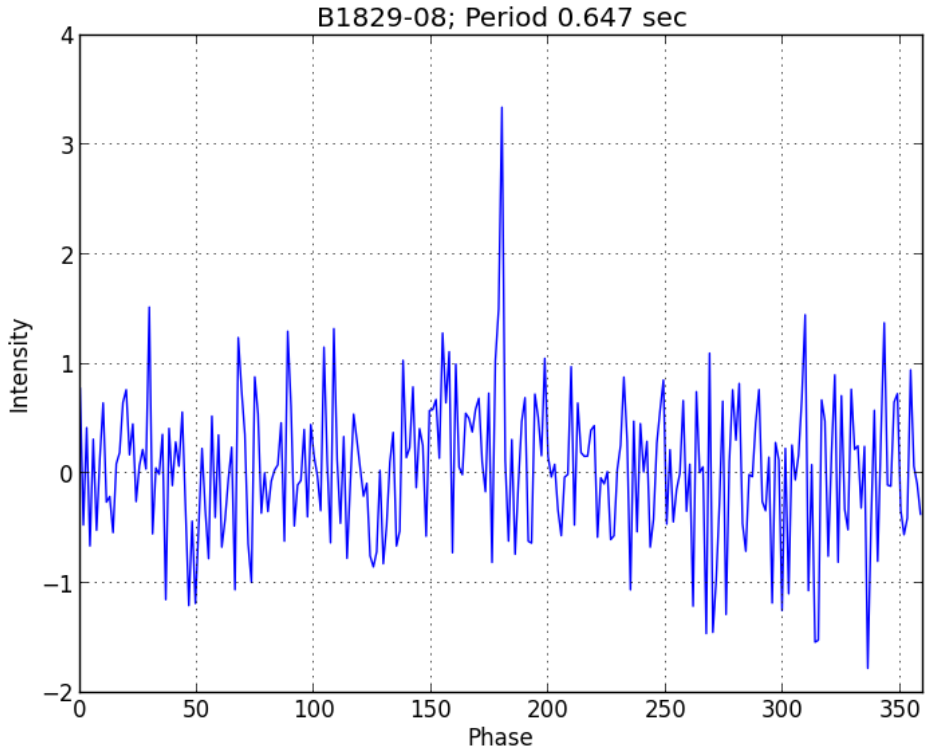

B1815-14 ; Period 0.291 sec
Intensity
Phase
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

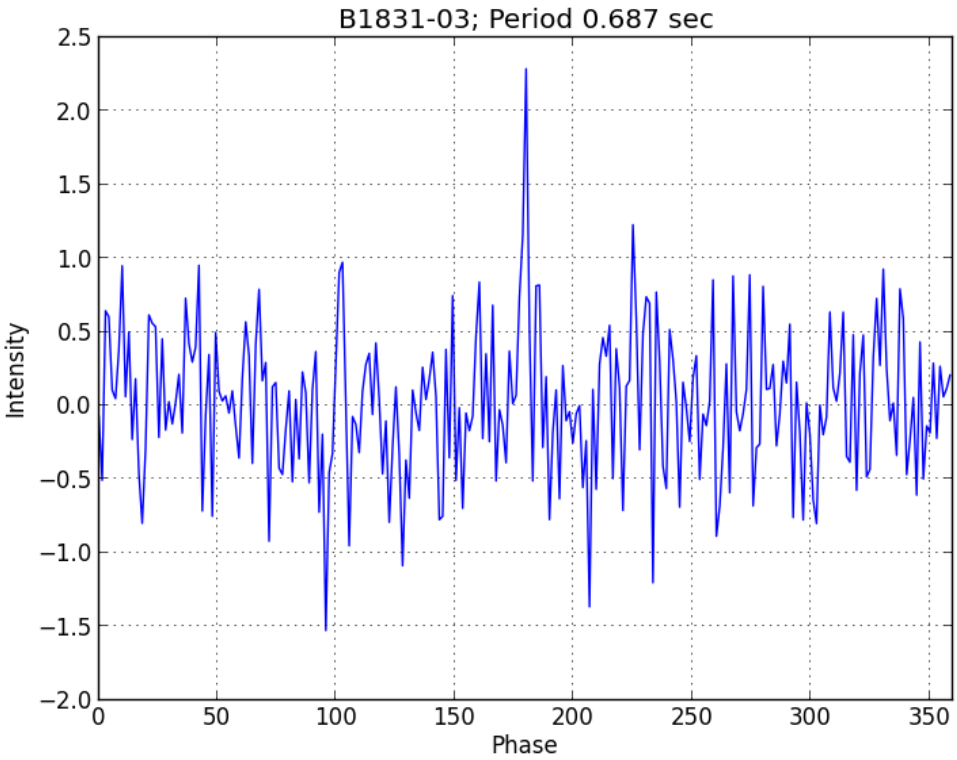

B1818-04 ; Period 0.598 sec
Intensity
Phase
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
50
100
150
200
250
300
350

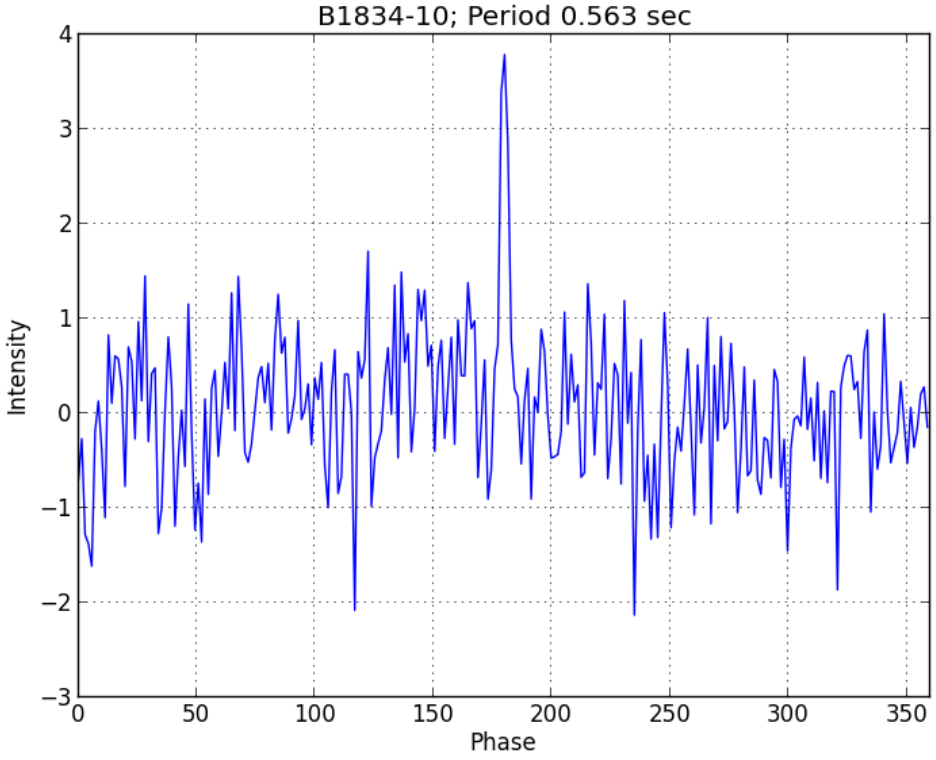

B1821-19; Period 0.189 sec
Intensity
Phase
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

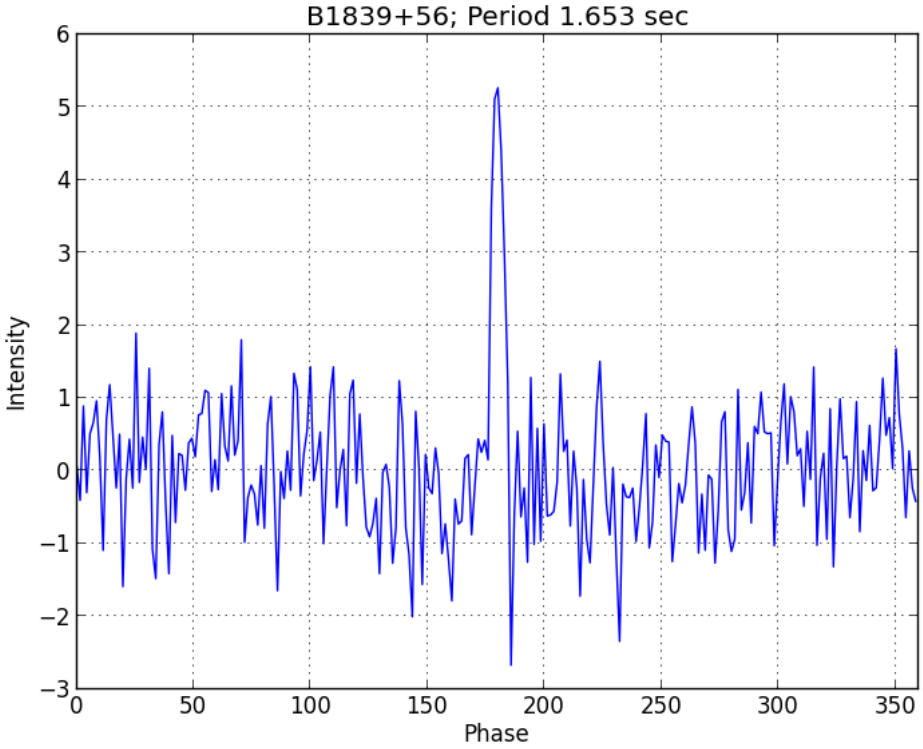

B1822-09 ; Period 0.769 sec
Intensity
Phase
14
12
10
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

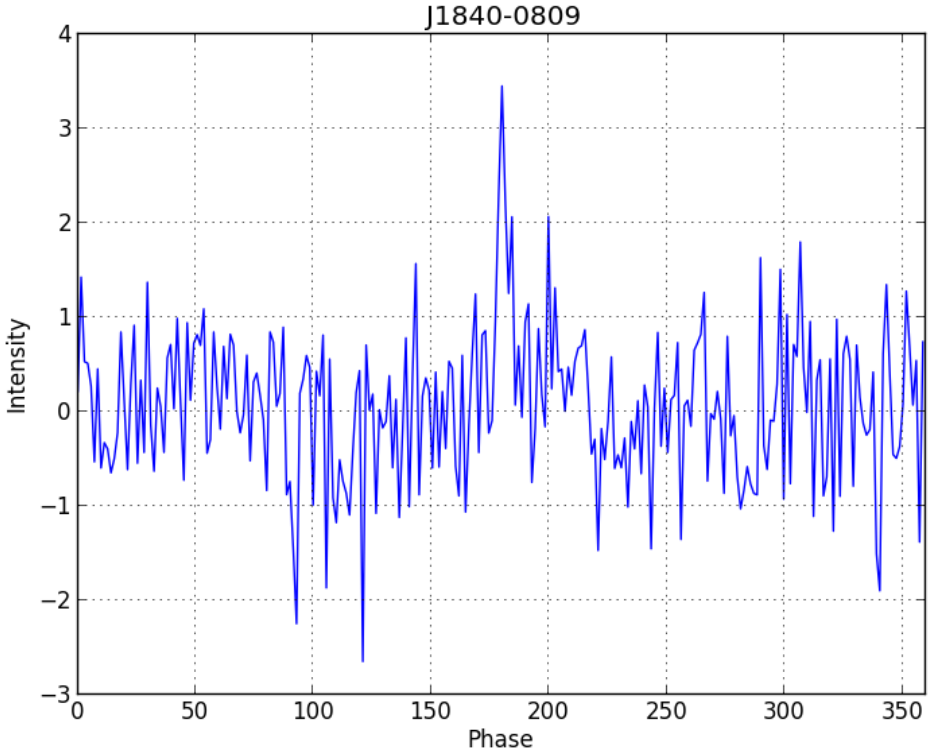

B1826-17 ; Period 0.307 sec
Intensity
Phase
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

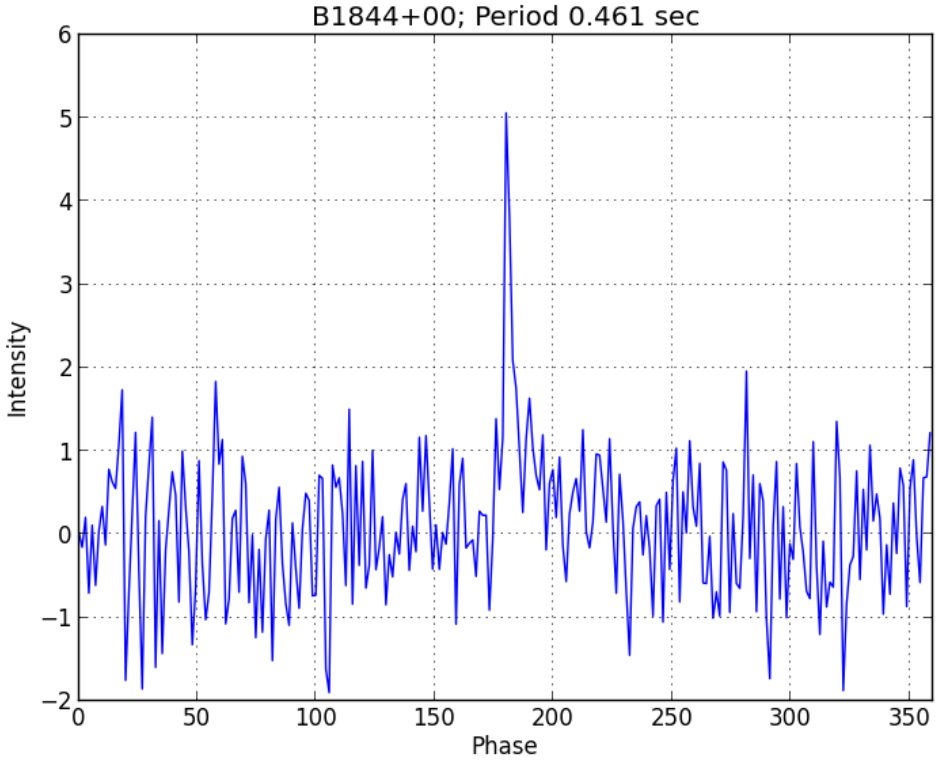

B1829-08; Period 0.647 sec
Intensity
Phase
4
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

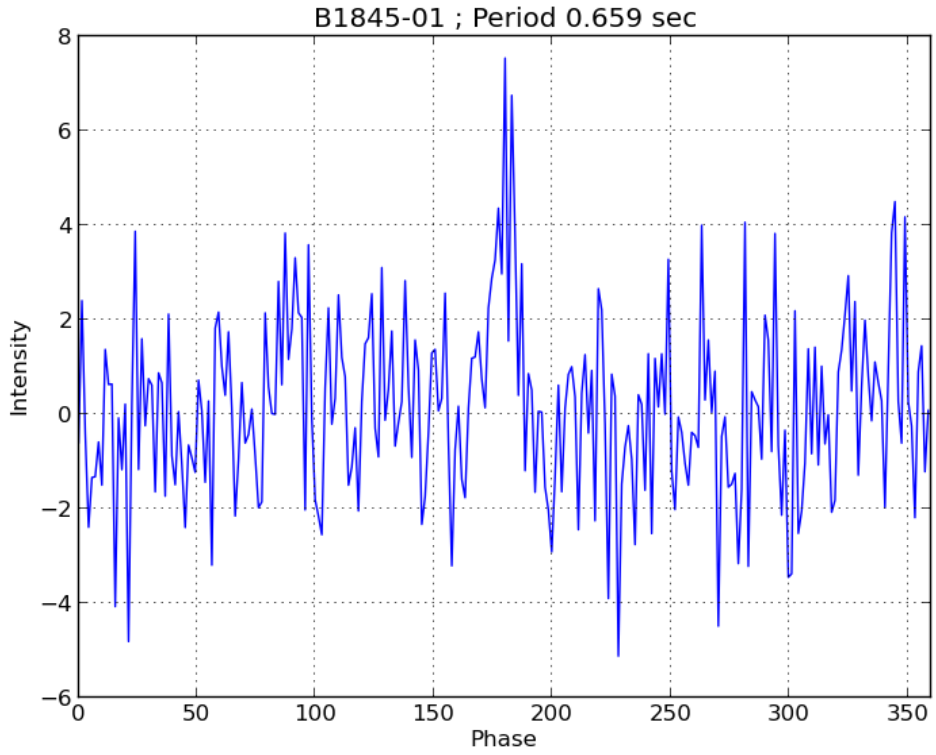

B1831-03; Period 0.687 sec
Intensity
Phase
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
50
100
150
200
250
300
350

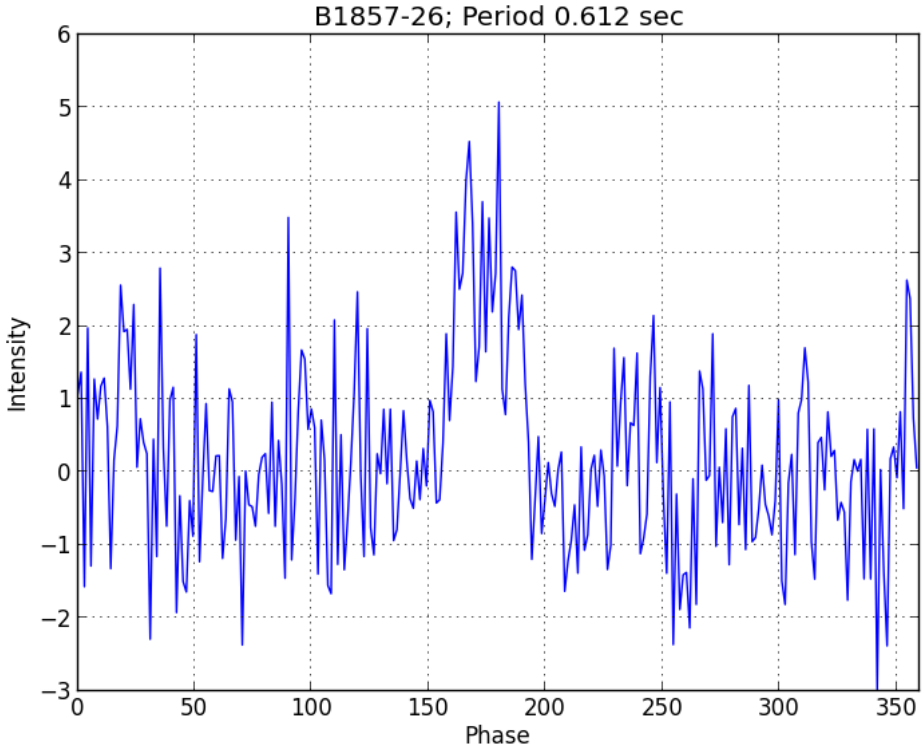

B1834-10; Period 0.563 sec
Intensity
Phase
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

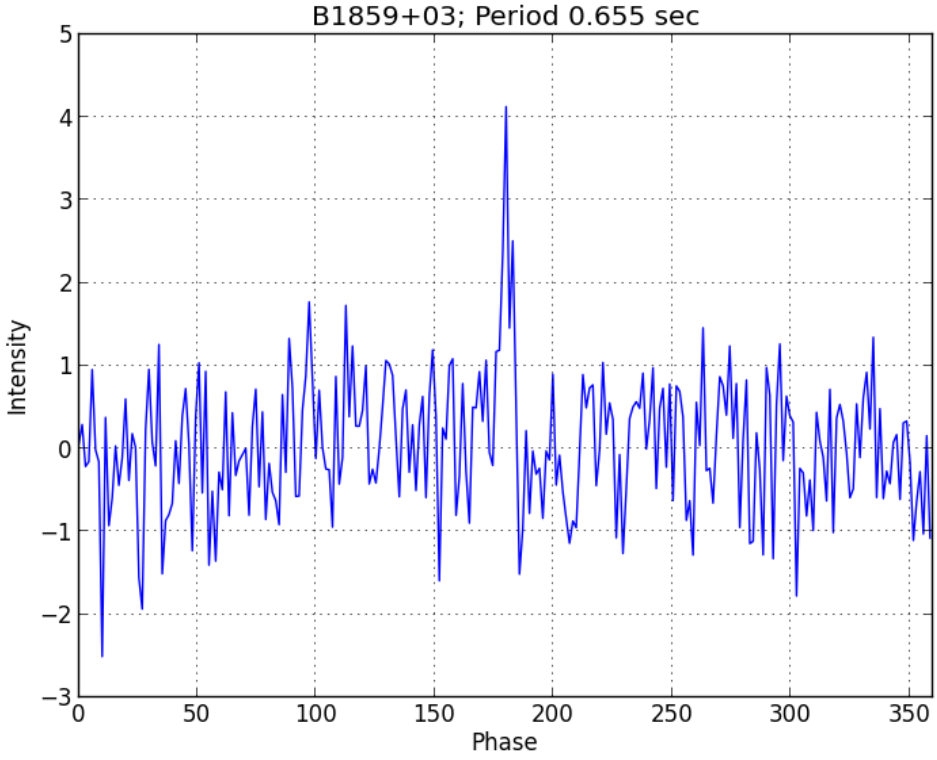

B1839+56; Period 1.653 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

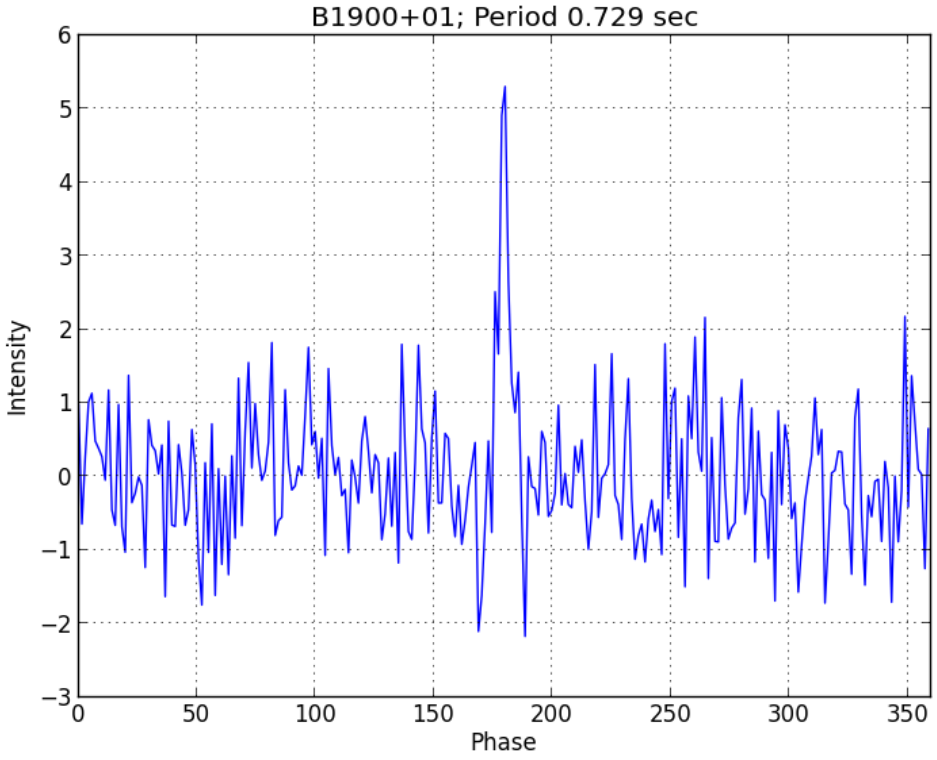

J1840-0809
Intensity
Phase
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

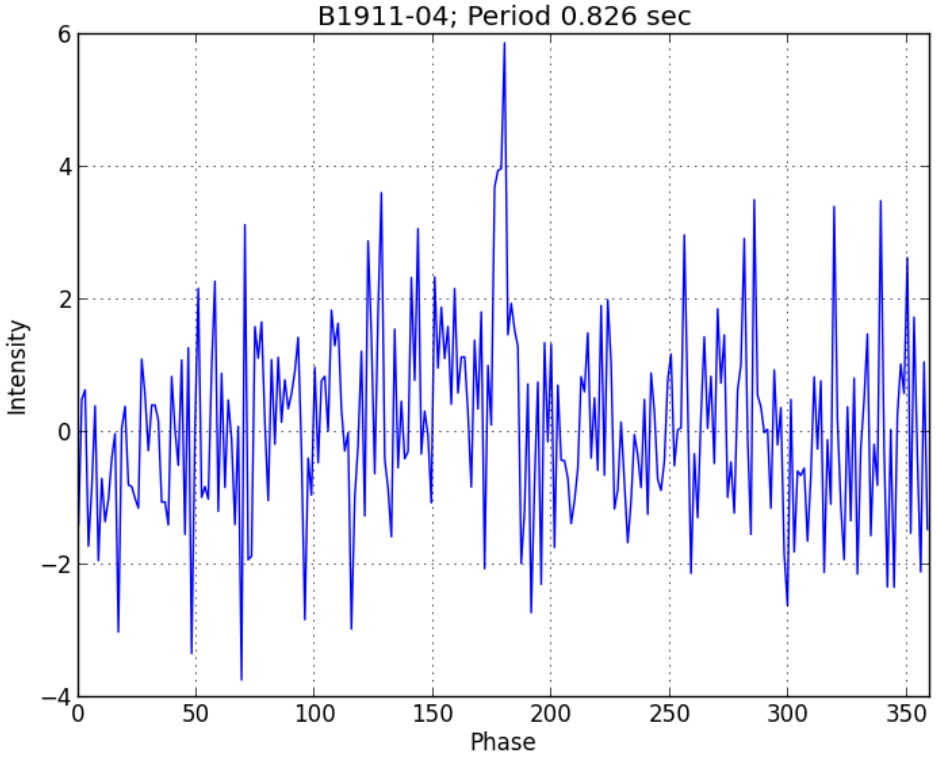

B1844+00; Period 0.461 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

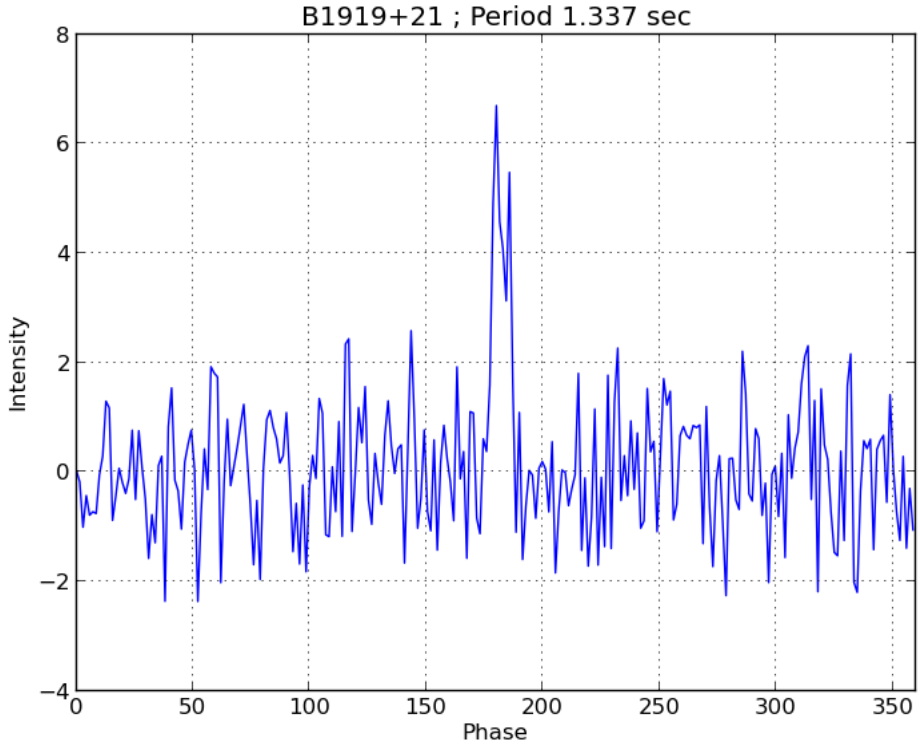

B1845-01 ; Period 0.659 sec
Intensity
Phase
8
6
4
2
0
−2
−4
−6
0
50
100
150
200
250
300
350

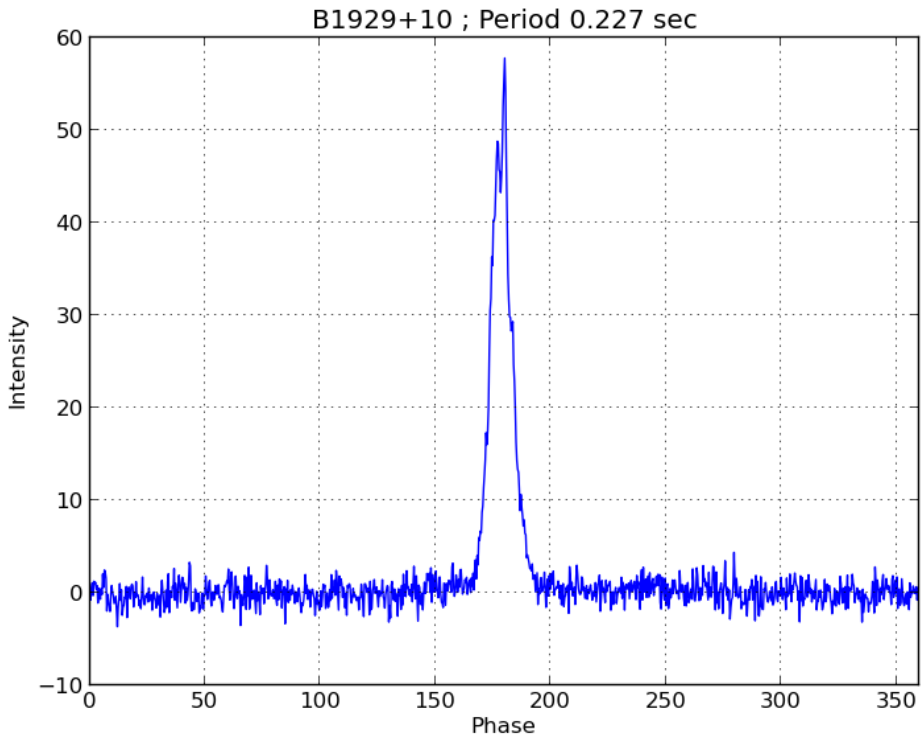

B1857-26; Period 0.612 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

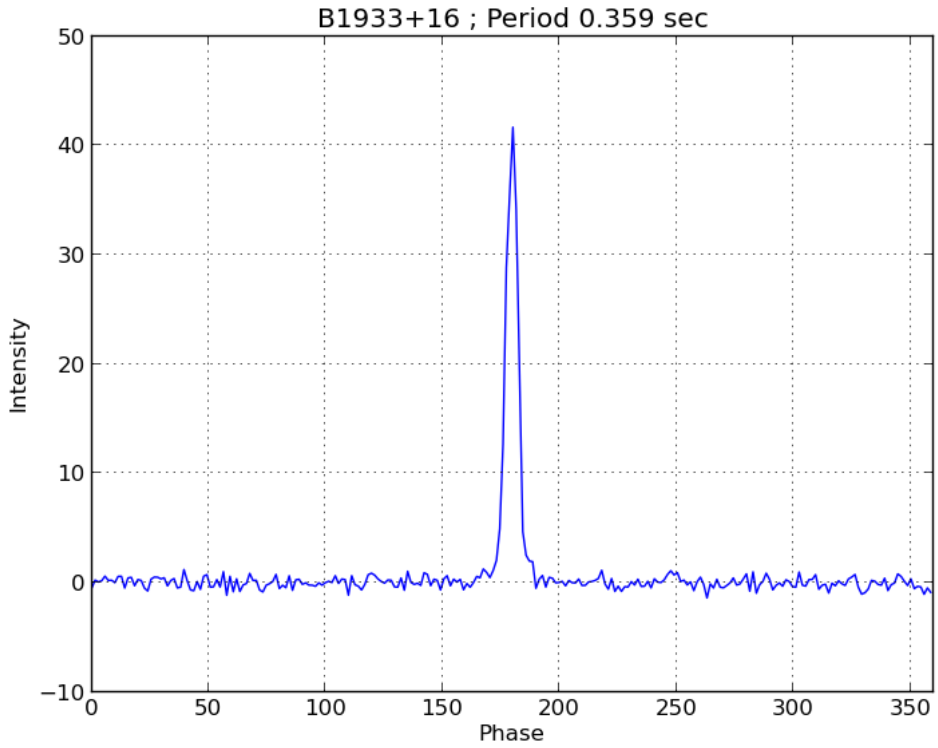

B1859+03; Period 0.655 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

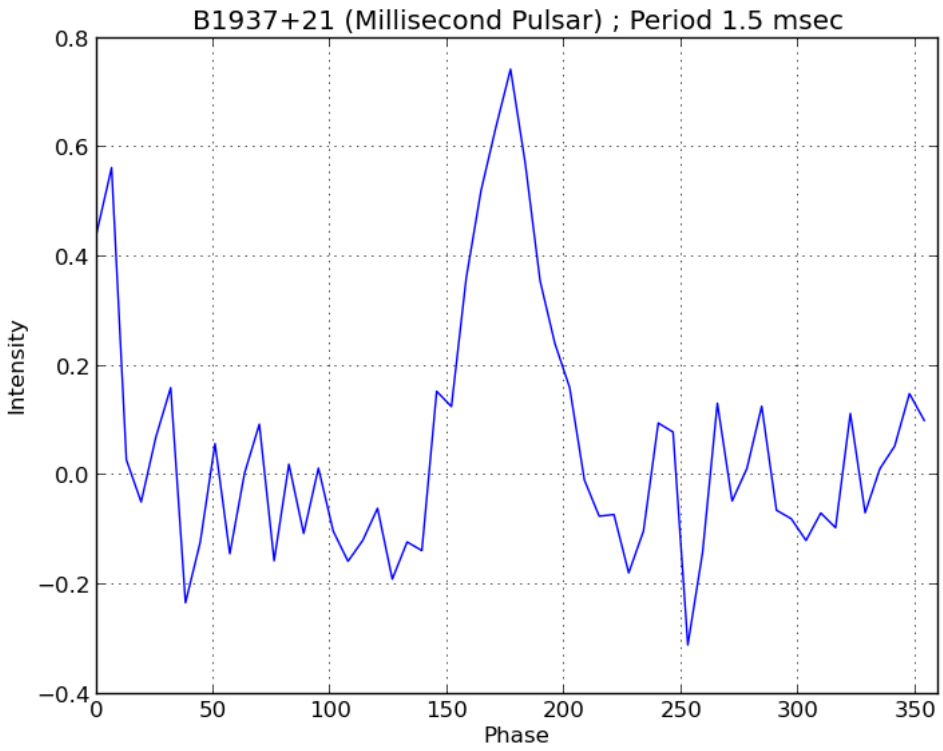

B1900+01; Period 0.729 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

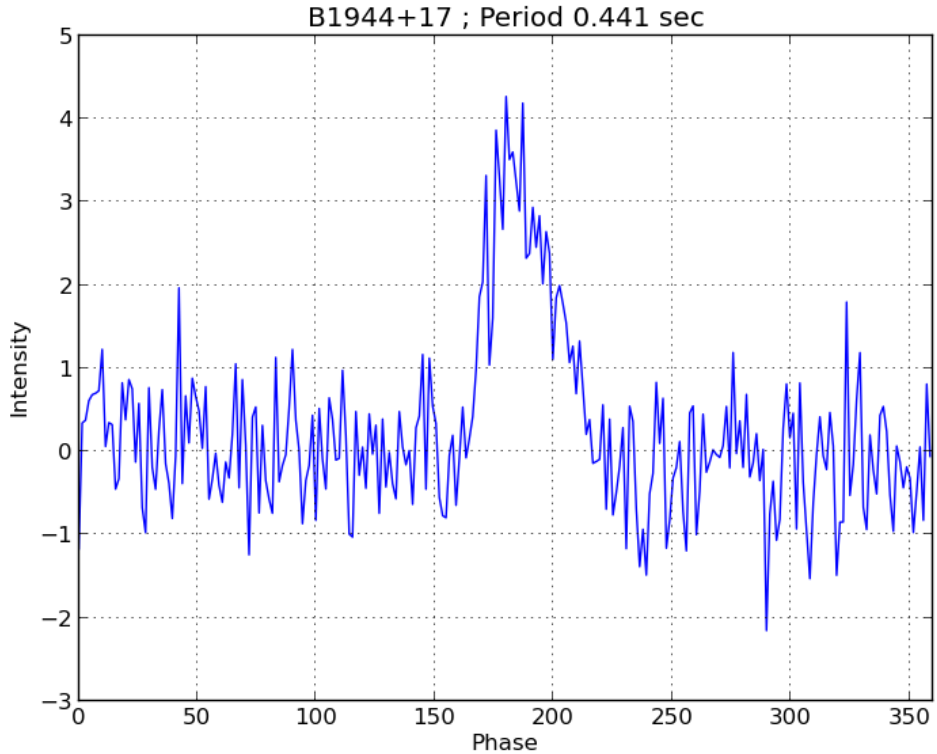

B1911-04; Period 0.826 sec
Intensity
Phase
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

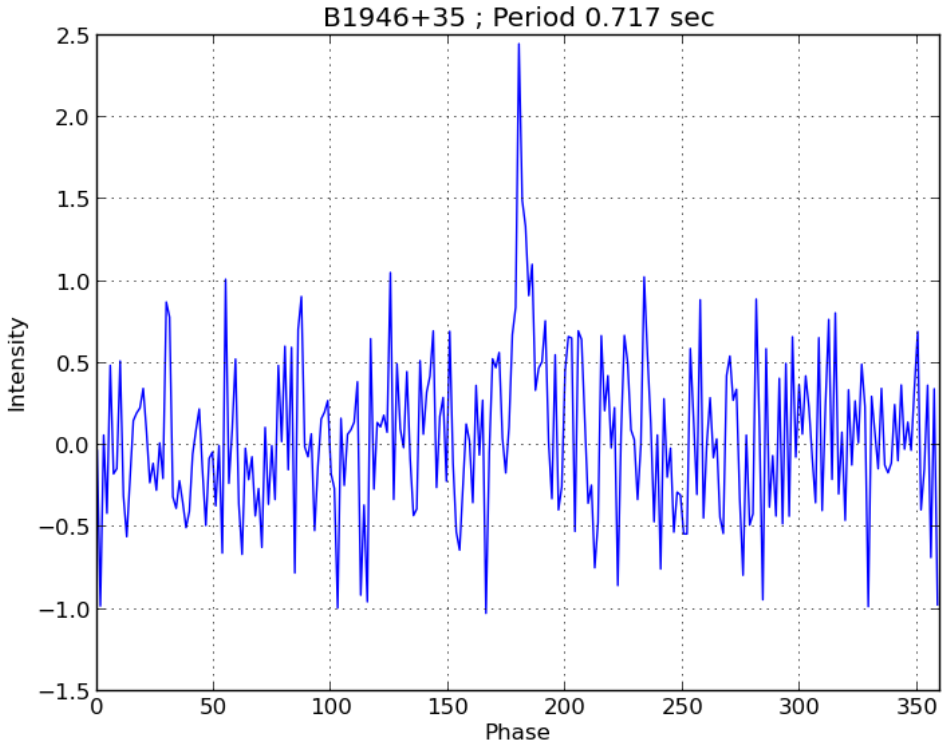

B1919+21 ; Period 1.337 sec
Intensity
Phase
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

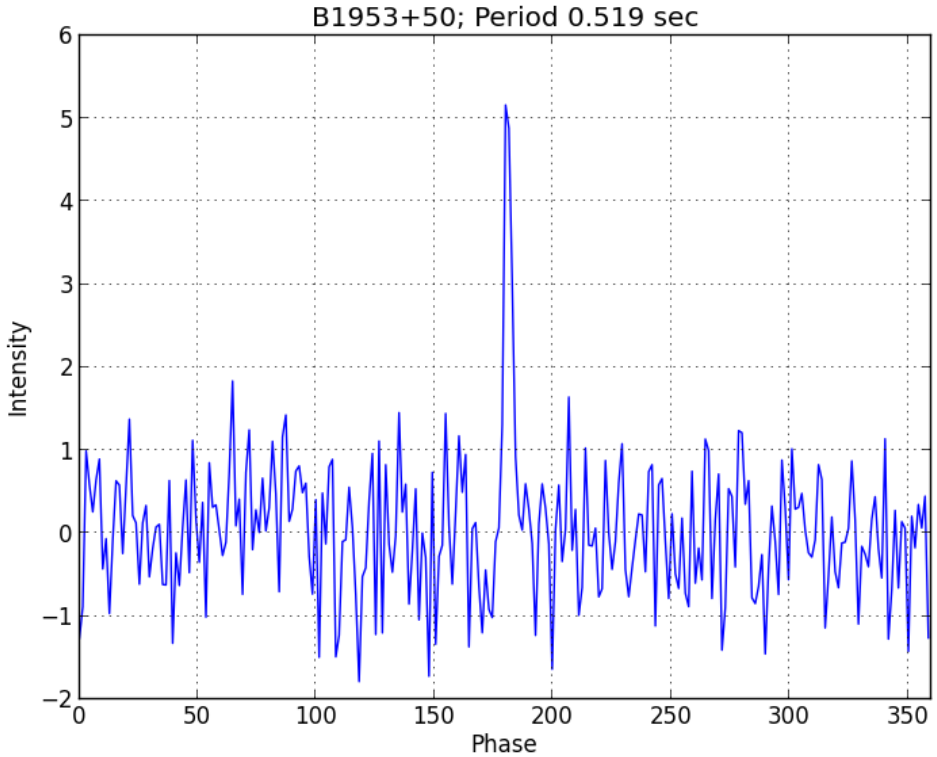

B1929+10 ; Period 0.227 sec
Intensity
Phase
60
50
40
30
20
10
0
−10
0
50
100
150
200
250
300
350

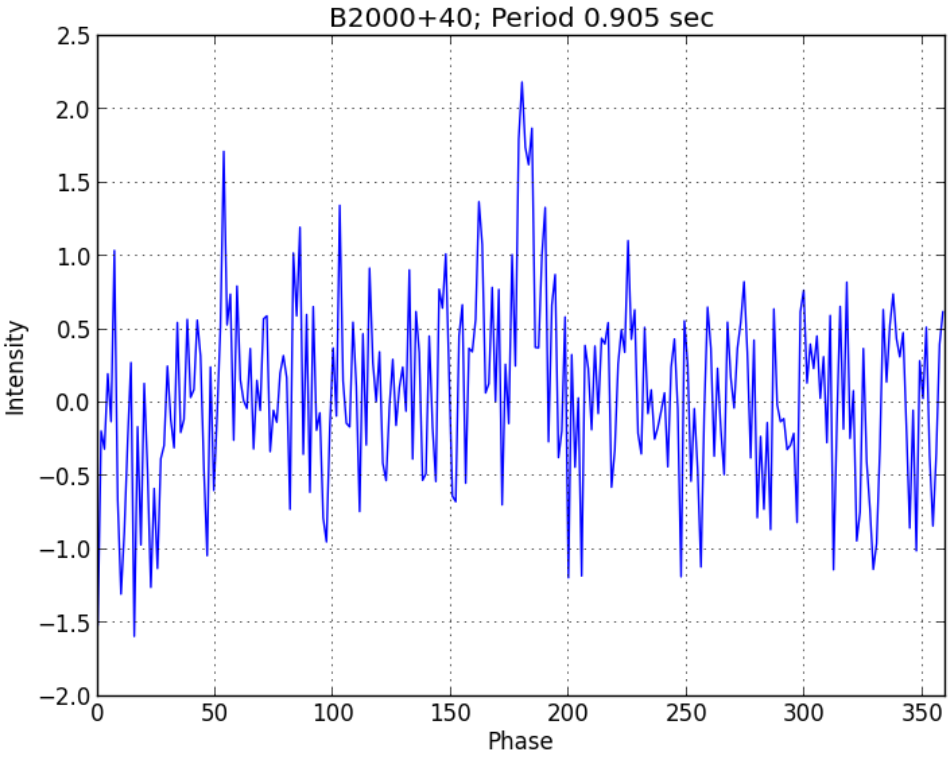

B1933+16 ; Period 0.359 sec
Intensity
Phase
50
40
30
20
10
0
−10
0
50
100
150
200
250
300
350

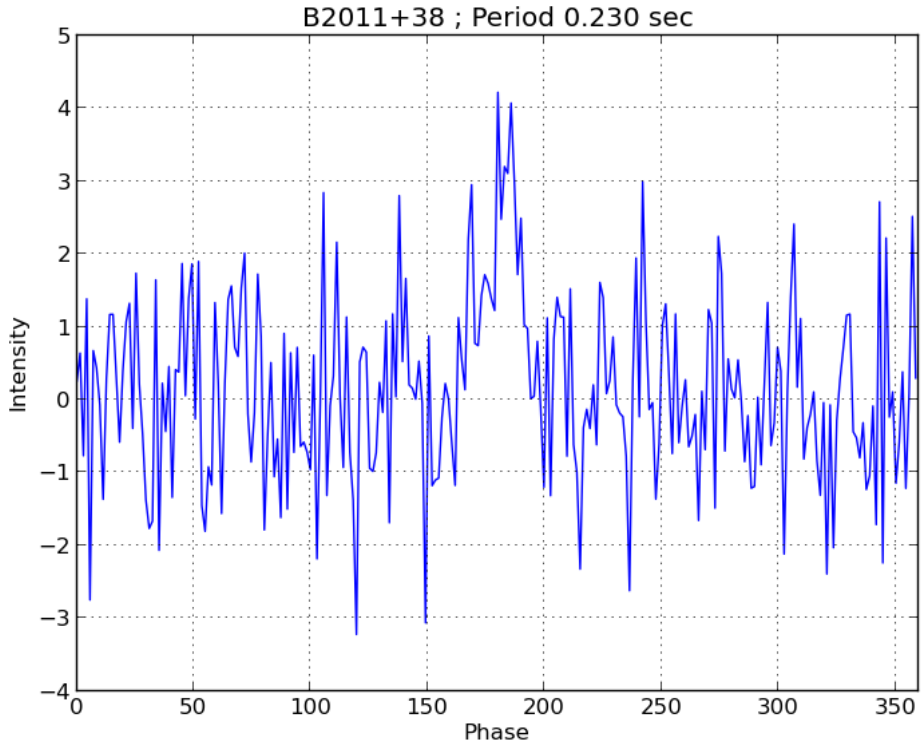

B1937+21 (Millisecond Pulsar) ; Period 1.5 msec
Intensity
Phase
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
0
50
100
150
200
250
300
350

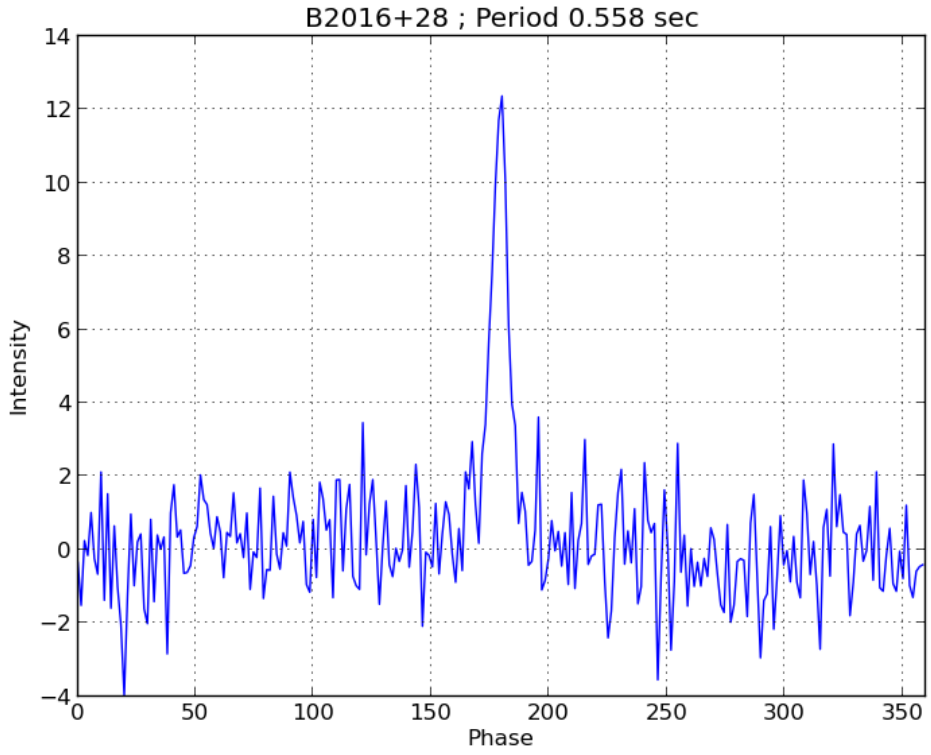

B1944+17 ; Period 0.441 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

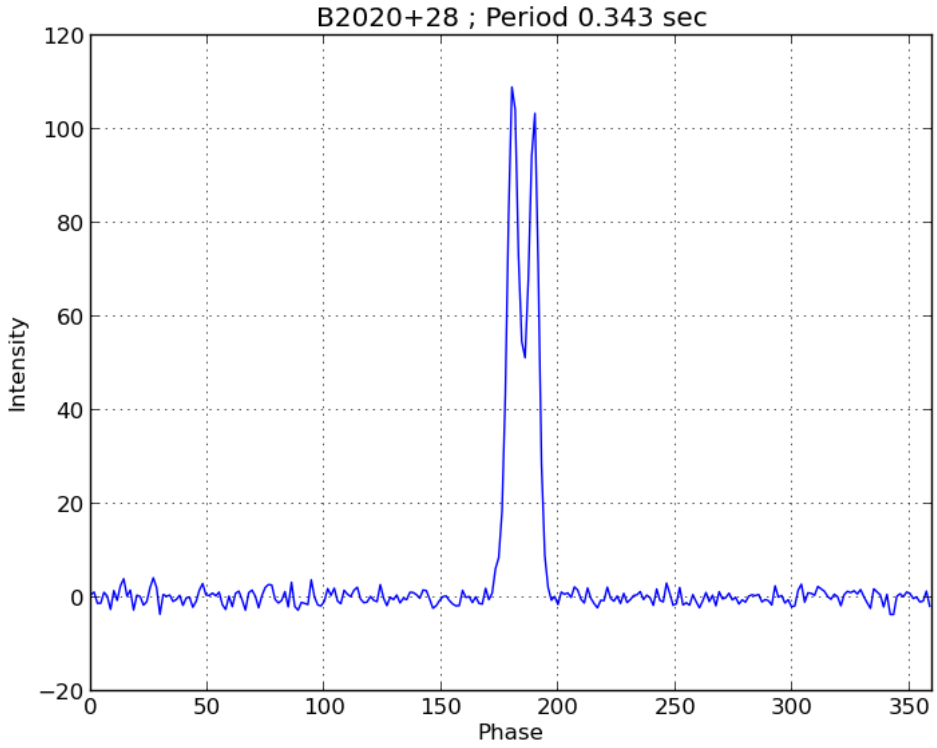

B1946+35 ; Period 0.717 sec
Intensity
Phase
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
50
100
150
200
250
300
350

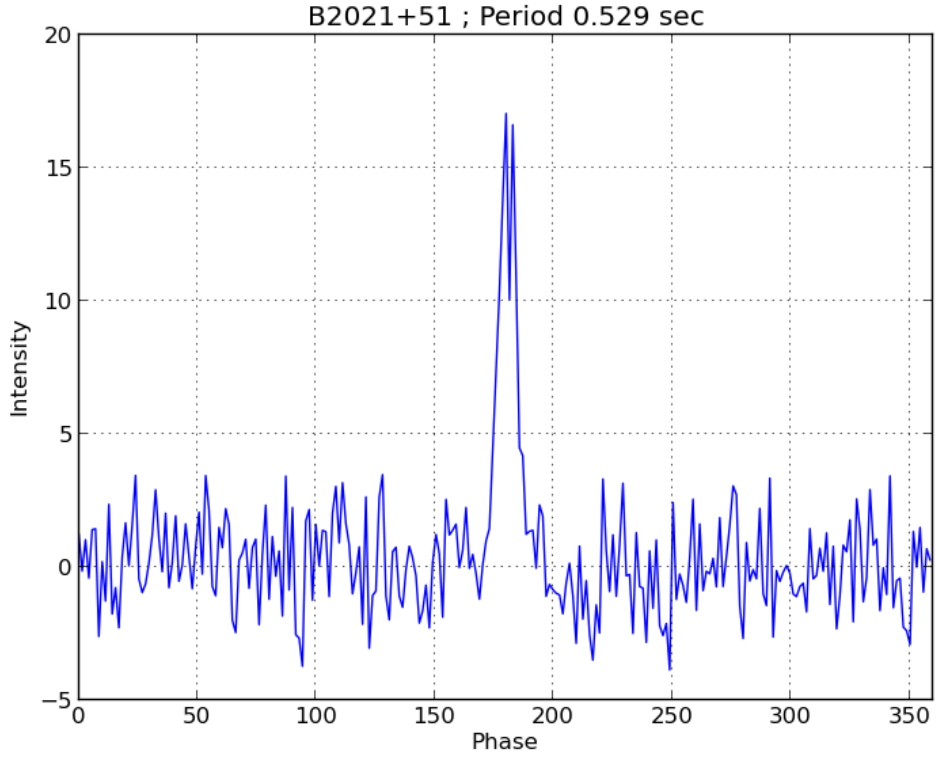

B1953+50; Period 0.519 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

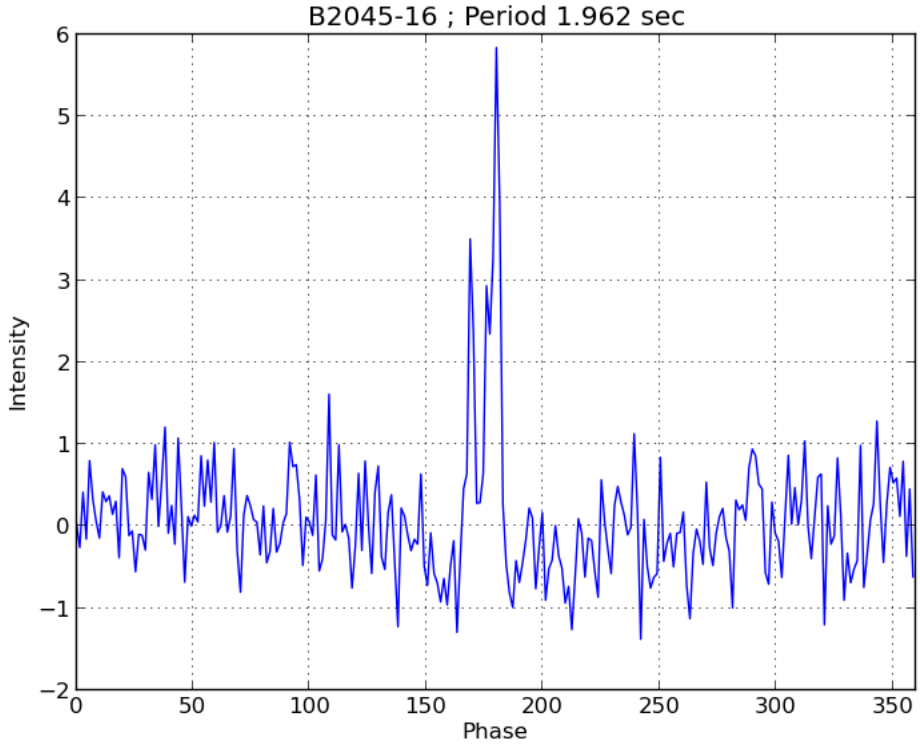

B2000+40; Period 0.905 sec
Intensity
Phase
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
50
100
150
200
250
300
350

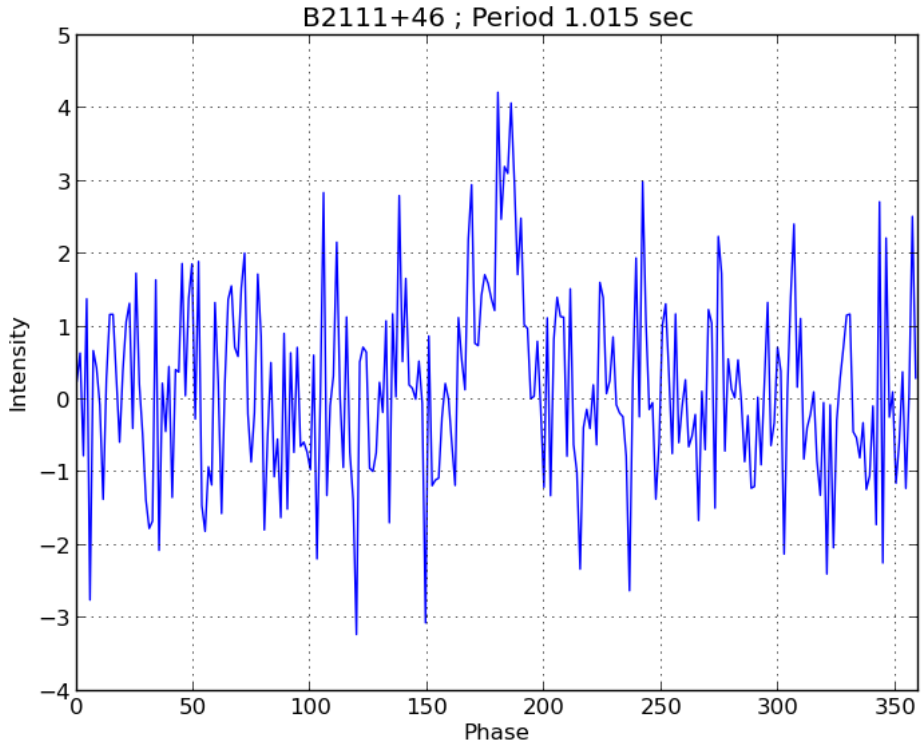

B2011+38 ; Period 0.230 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
−3
−4
0
50
100
150
200
250
300
350

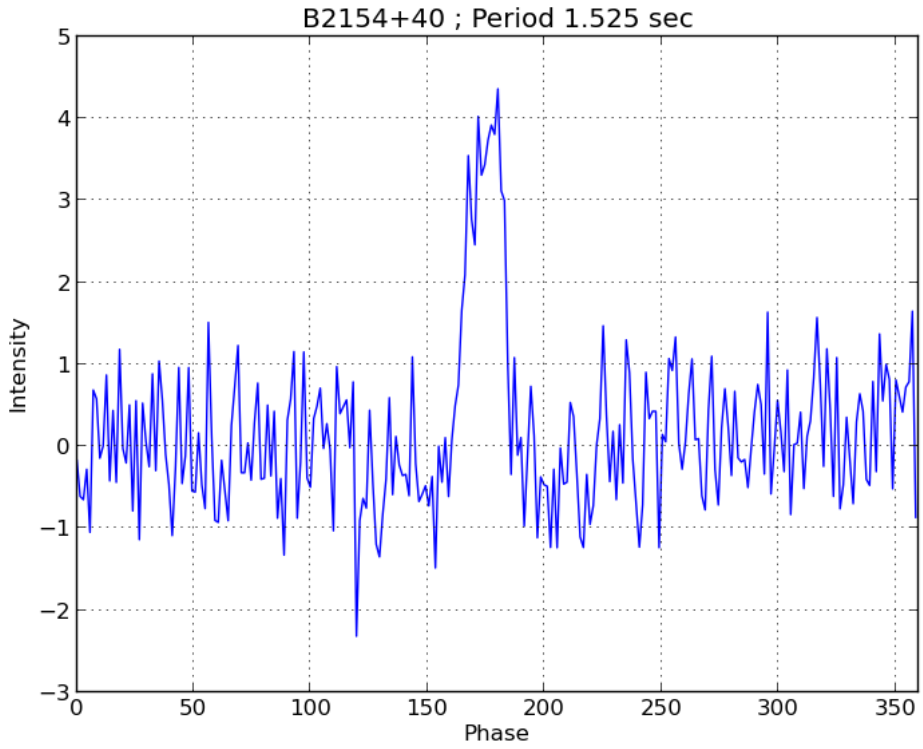

B2016+28 ; Period 0.558 sec
Intensity
Phase
14
12
10
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350

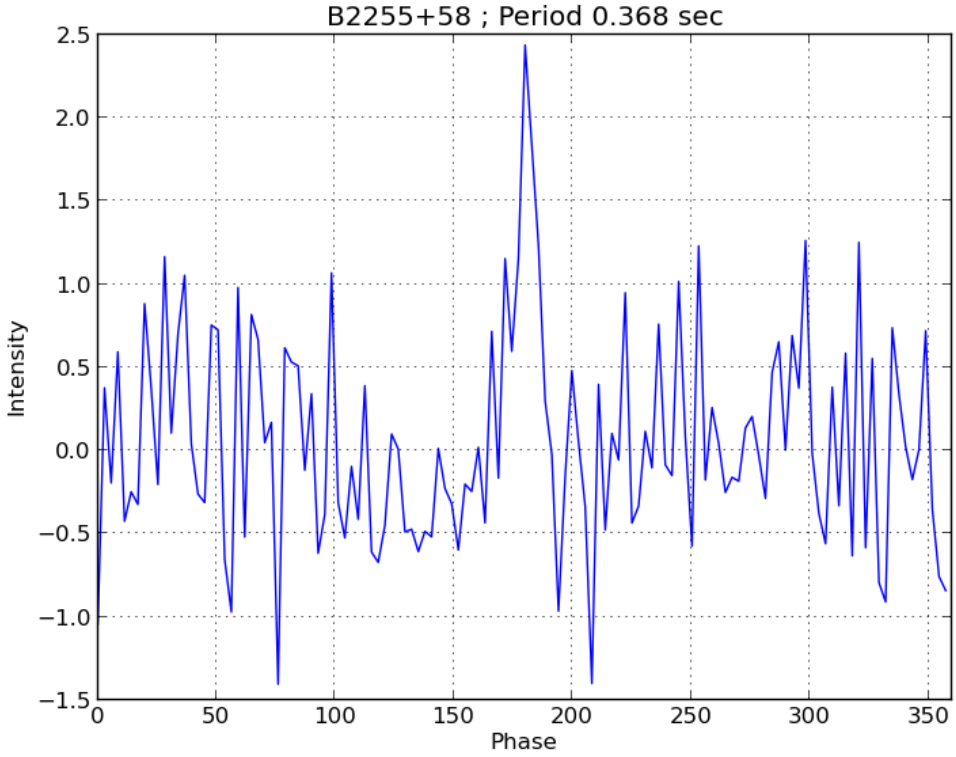

B2020+28 ; Period 0.343 sec
Intensity
Phase
120
100
80
60
40
20
0
−20
0
50
100
150
200
250
300
350

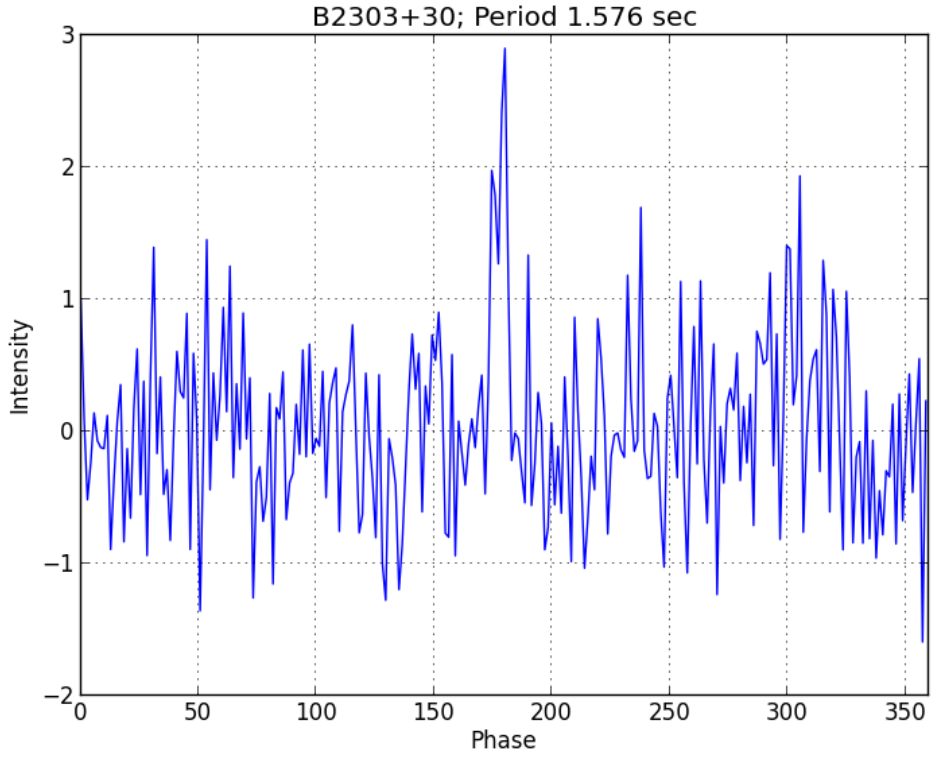

B2021+51 ; Period 0.529 sec
Intensity
Phase
20
15
10
5
0
−5
0
50
100
150
200
250
300
350

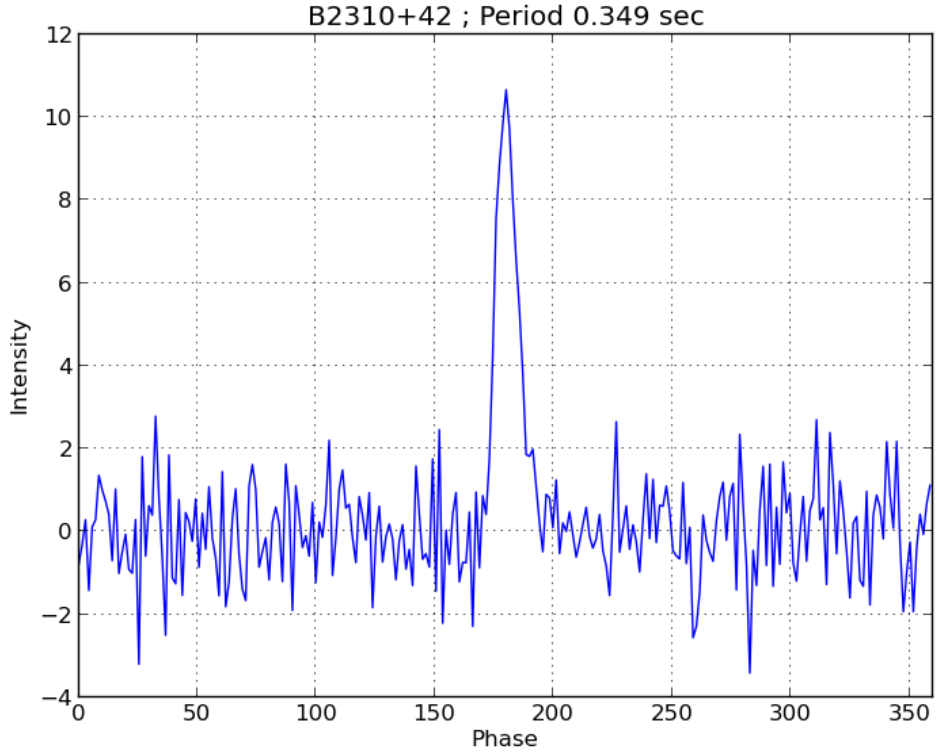

B2045-16 ; Period 1.962 sec
Intensity
Phase
6
5
4
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350

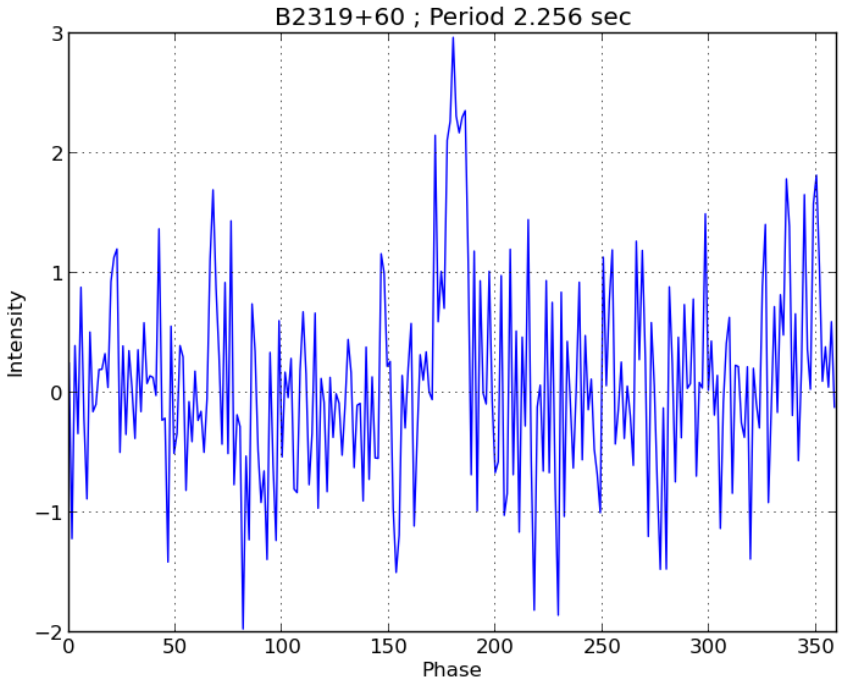

B2111+46 ; Period 1.015 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
−3
−4
0
50
100
150
200
250
300
350

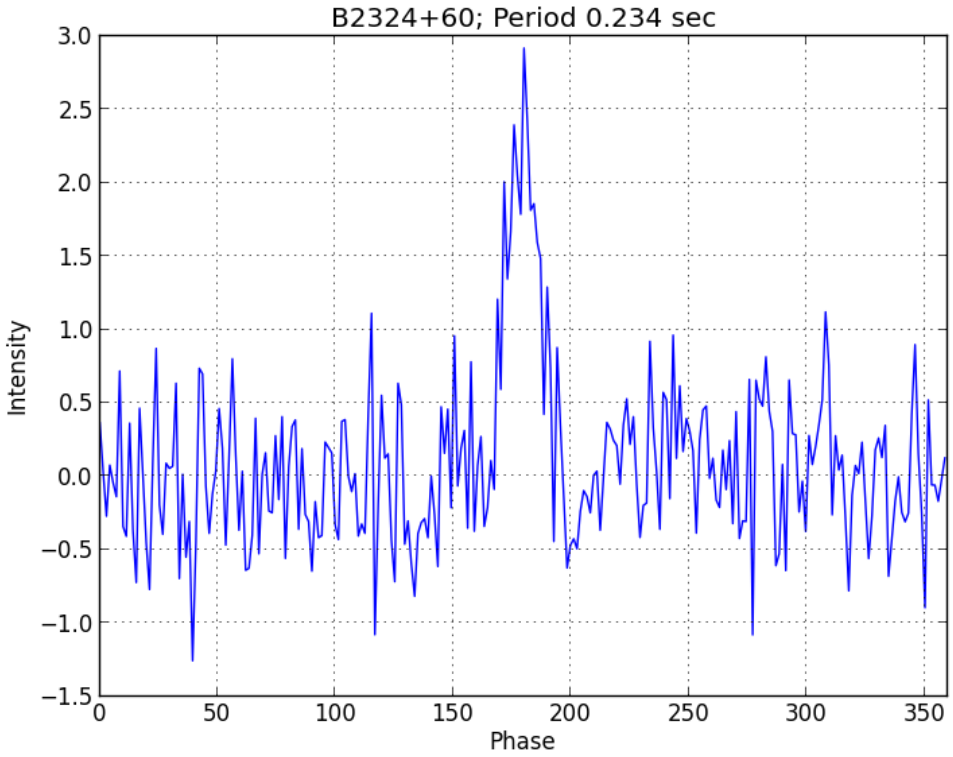

B2154+40 ; Period 1.525 sec
Intensity
Phase
5
4
3
2
1
0
−1
−2
−3
0
50
100
150
200
250
300
350

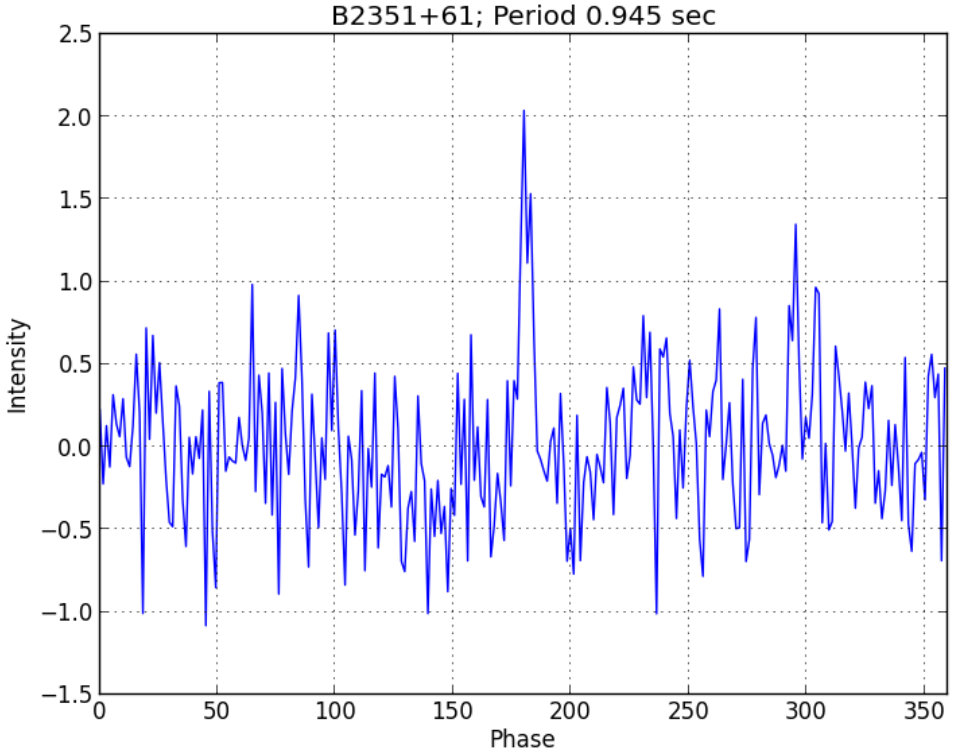

B2255+58 ; Period 0.368 sec
Intensity
Phase
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
50
100
150
200
250
300
350


B2303+30; Period 1.576 sec
Intensity
Phase
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350


B2310+42 ; Period 0.349 sec
Intensity
Phase
12
10
8
6
4
2
0
−2
−4
0
50
100
150
200
250
300
350


B2319+60 ; Period 2.256 sec
Intensity
Phase
3
2
1
0
−1
−2
0
50
100
150
200
250
300
350


B2324+60; Period 0.234 sec
Intensity
Phase
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
50
100
150
200
250
300
350


B2351+61; Period 0.945 sec
Intensity
Phase
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
50
100
150
200
250
300
350