Radio pulsars with expected gamma radiation and gamma-ray pulsars as pulsating radio emitters

Igor Fedorovich Malov and Maria Andreevna Timirkeeva

Pushchino Radio Astronomy Observatory, Astro Space Center, P. N. Lebedev Physical Institute, Pushchino 142290, Russia; malov@prao.ru

Received 2017 November 7; accepted 2017 December 14

Abstract Pulsars play a crucial astrophysical role as highly energetic compact radio, X-ray and gamma-ray sources. Our previous works show that radio pulsars identified as pulsing gamma-ray sources by the Large Area Telescope (LAT) on board the Fermi Gamma-Ray Space Telescope have high values of magnetic field near the light cylinder, two-three orders of magnitude stronger compared with the magnetic fields of radio pulsars: \( \log B_{lc} \) (G) are 3.60–3.95 and 1.75 correspondingly. Moreover, their losses of rotational energy are also three orders higher than the corresponding values for the main group of radio pulsars on average: \( \log \dot{E} \) (erg s\(^{-1}\)) = 35.37–35.53 and 32.64. The correlation between gamma-ray luminosities and radio luminosities is found. It allows us to select those objects from all sets of known radio pulsars that can be detected as gamma-ray pulsars with high probability. We provide a list of such radio pulsars and propose to search for gamma emission from these objects. On the other hand, the known catalog of gamma-ray pulsars contains some sources which are not currently identified as radio pulsars. Some of them have large values of gamma-ray luminosities and according to the obtained correlation, we can expect marked radio emission from these objects. We give the list of such pulsars and expected flux densities to search for radiation at frequencies 1400 and 111 MHz.

Key words: pulsars: individual — gamma-ray bursts: individual — stars: magnetic field

1 INTRODUCTION

The Fermi space telescope with the Large Area Telescope (LAT) has detected over 150 new gamma-ray pulsars, which are included in the Second Fermi LAT catalog (hereafter 2FGL catalog, Abdo et al. 2013), increasing their previous number (see, for example, Thompson, 1996) by a factor of several dozen. The analysis of their properties is very important for understanding the nature of pulsed emission. All data on gamma pulsars in our paper were taken from this 2FGL catalog. We have used parameters of known radio pulsars from the ATNF catalog (Manchester et al. 2005).

We have shown earlier (Malov & Timirkeeva 2014, Malov & Timirkeeva (2015)) that radio pulsars detected as pulsed gamma sources by Fermi/LAT are characterized by high magnetic fields at the light cylinder \( B_{lc} \), two-three orders of magnitude higher than in gamma quiet radio pulsars (Fig. 1). The mean values of \( \log B_{lc} \) (G) are 3.60–3.95 and 1.75, correspondingly. Gamma pulsars also have large values for losses of rotational energy \( \dot{E} \), three orders of magnitude higher than the main bulk of radio pulsars (Fig. 2) with mean values of \( \log \dot{E} \) (erg s\(^{-1}\)) = 35.37–35.53 and 32.64, correspondingly. However, some gamma quiet radio pulsars have values of \( B_{lc} \) and \( \dot{E} \) two-three orders of magnitude higher than the average over the whole sample. According to our results, we can expect marked gamma emission from such objects. On the other hand, there are gamma-ray pulsars in the 2FGL catalog, which have not been detected as radio pulsars up to now, although their parameters imply that their radio emission must have been registered. The main aim of our paper is to compile a list of gamma ray pulsars with expected radio emission.
2 SAMPLE OF PULSARS USED IN THIS STUDY

We have applied two criteria: magnetic fields at the light cylinder \( B_{lc} > 10^3 \text{G} \) and losses of rotational energy \( \dot{E} > 3 \times 10^{34} \text{erg s}^{-1} \). It is worth noting that both of these parameters are determined as functions of the pulsar period and its derivative

\[
\dot{E} = \frac{4\pi^2 I \dot{P}}{P^3},
\]

\[
B_{lc} = B_s \left( \frac{R_s}{r_{lc}} \right)^3 = \frac{8\pi^3 B_s R_s^3}{c^3 P^3}
= \frac{8\pi^3 A R_s^3 \dot{P}^{1/2}}{c^3 P^{5/2}}.
\]

The last expression has been derived by considering the dipole structure of magnetic fields through the whole pulsar magnetosphere. Moreover, it is suggested that the pulsar braking is caused by magneto-dipole radiation. Here \( I \sim 10^{45} \text{g cm}^2 \) is the moment of inertia, \( R_s \sim 10^6 \text{cm} \) is the radius of the neutron star and \( c \) is the speed of light,

\[
A = \left( \frac{3Ic^3}{2\pi^2 R_s^6} \right)^{1/2}.
\]

This means that there is an evident relation between \( \dot{E} \) and \( B_{lc} \). However, it is reasonable to take both of these parameters into account, since their physical meanings differ. The losses of rotational energy characterize the main source of pulsar energy for all processes in its magnetosphere, but the quantity \( B_{lc} \) determines the emission mechanism near the light cylinder.

We exclude pulsars in globular clusters and binary systems from the analysis, since their observed characteristics can be distorted by the influence of other nearby stars, and also J1836+5925, J2021+3651, J2021+4026 and J2030+3641 which have estimated efficiency for transforming rotational energy into gamma emission, \( \eta = L_{\gamma}/\dot{E} \), larger than 100%. Such high values of \( \eta \) can be caused by considering their radiation to be isotropic. However, the known models of gamma emission (see,
Fig. 2 Distributions of rotational energy losses for three samples of pulsars, as in Fig. 1.

Fig. 3 The relationship between radio and gamma-ray luminosities (see text).

for example, Pierbattista et al. 2012) indicate that such emission is restricted to a rather narrow beam and the real luminosity must be lower than what is given in Abdo et al. (2013). The analyzed sample is presented in Table 1. It contains values of pulsar periods $P$ (s), rotational energy losses $\dot{E}$ (erg s$^{-1}$), magnetic fields $B_{le}$ (G) at the light cylinders, radio luminosities $R_{lum1400}$ (mJy $\times$ kpc$^2$) and gamma-ray luminosities $L_{\gamma}$ (erg s$^{-1}$)$/10^{33}$. Comparing radio luminosities $R_{lum1400}$ from the ATNF Pulsar Catalogue and gamma-ray luminosities from the
Using Equation (4) for pulsars with $\dot{\mathcal{E}} > 3 \times 10^{34}$ erg s$^{-1}$ and $B_{\text{lc}} > 10^3$ G, we give estimates of the expected gamma-ray luminosities with uncertainties in the last column.

These 107 pulsars (see Table 2) can be detected in the gamma-ray range with rather high probability. Some assurance comes from recent detections of gamma emission from several studied objects in Table 2 after publication of the Second Fermi LAT pulsar catalog (with references denoted by superscripts $a$, $b$ and $c$ in Table 2). The estimates made by these authors are indicated in parentheses. Their real physical estimates are numerically close to our predicted values for most objects. These objects are not in 2FGL. However, some of them were discovered after publication of 2FGL, and we are sure that other sources from Table 2 can be registered in future observations.

4 GAMMA-RAY PULSARS WITH EXPECTED RADIO RADIATION

Table 1 contains some pulsars with certain gamma emission but without detected radio radiation. Using the same data as for Equation (4) we can rewrite it in the following form

$$\log R_{\text{Lum1400}} = (0.59 \pm 0.17) \log L_\gamma + 0.13 \pm 0.34 .$$

Such potential radio emitters are listed in Table 3. We excluded the pulsar J1057–5226 because its value of $\dot{\mathcal{E}}$ does not satisfy the criterion $\dot{\mathcal{E}} > 3 \times 10^{34}$ erg s$^{-1}$.

Table 3 contains values of pulsar periods, their gamma-ray luminosities and distances as listed in Abdo et al. (2013), expected radio luminosities calculated using Equation (6) and also expected flux densities at 1400 and 111 MHz. $S_{1400}$ has been calculated by dividing $R_{\text{Lum1400}}$ by $d^2$. We have calculated expected values of $S_{111}$ assuming the spectrum follows the power law

$$S_\nu = S_0 \nu^{-\alpha} .$$

Radio spectra of the pulsars from Table 3 are not known yet and we take the mean value of the spectral index $\alpha = \ldots$
| PSRJ        | $P$  | $R_{\text{lam},1400}$ | $E$   | $B_{\text{lc}}$ | $L_{\gamma}$ |
|------------|------|------------------------|-------|-----------------|-------------|
| J0007+7303 | 0.316| *                      | 4.5E+35 | 3.21E+03       | 94          |
| J0030+0451 | 0.005| 0.08                   | 3.5E+33 | 1.83E+04       | 0.58        |
| J0106+4855 | 0.083| 0.07                   | 2.9E+34 | 3.11E+03       | 21          |
| J0205+6449 | 0.066| 0.46                   | 2.7E+37 | 1.19E+05       | 24          |
| J0248+6021 | 0.217| 54.8                   | 2.1E+35 | 3.21E+03       | 25          |
| J0340+4130 | 0.003| 0.79                   | 7.8E+33 | 4.04E+04       | 7.3         |
| J0534+2200 | 0.033| 56                     | 4.5E+38 | 9.55E+05       | 619         |
| J0631+1036 | 0.288| 4.15                   | 1.7E+35 | 2.18E+03       | 5.6         |
| J0633+1746 | 0.237| *                      | 3.2E+34 | 1.15E+03       | 31.7        |
| J0659+1414 | 0.385| 0.31                   | 3.8E+34 | 7.66E+02       | 0.24        |
| J0742–2822 | 0.167| 60                     | 1.4E+35 | 3.43E+03       | 9           |
| J0835–4510 | 0.089| 86.24                  | 6.9E+36 | 4.45E+04       | 89.3        |
| J0908–4913 | 0.107| 10                     | 4.9E+35 | 9.92E+03       | 35          |
| J1016–5857 | 0.107| 4.59                   | 2.6E+36 | 2.26E+04       | 55          |
| J1024–0719 | 0.005| 2.23                   | 5.3E+33 | 2.13E+04       | 0.06        |
| J1028–5819 | 0.091| 0.73                   | 8.3E+35 | 1.51E+04       | 158         |
| J1048–5832 | 0.124| 54.66                  | 2E+36  | 1.73E+04       | 176         |
| J1057–5226 | 0.197| *                      | 3E+34  | 1.33E+03       | 4.3         |
| J1105–6107 | 0.063| 4.18                   | 2.5E+36 | 3.76E+04       | 150         |
| J1112–6103 | 0.065| 28.35                  | 4.5E+36 | 4.95E+04       | 360         |
| J1119–6127 | 0.408| 56.45                  | 2.3E+36 | 5.66E+03       | 600         |
| J1124–5916 | 0.135| 2                      | 1.2E+37 | 3.85E+04       | 170         |
| J1357–6429 | 0.166| 4.23                   | 3.1E+36 | 1.60E+04       | 25          |
| J1410–6132 | 0.050| 1095.12                | 1E+37  | 9.58E+04       | 800         |
| J1418–6058 | 0.111| *                      | 4.9E+36 | 3.04E+04       | 92          |
| J1420–6048 | 0.068| 28.43                  | 1E+37  | 7.13E+04       | 640         |
| J1509–5850 | 0.089| 1.68                   | 5.1E+35 | 1.22E+04       | 105         |
| J1513–5908 | 0.151| 18.2                   | 1.7E+37 | 4.17E+04       | 70          |
| J1531–5610 | 0.084| 4.87                   | 9.1E+35 | 1.71E+04       | 1           |
| J1648–4611 | 0.165| 11.59                  | 2.1E+35 | 4.18E+03       | 160         |
| J1658–5324 | 0.002| 0.54                   | 3E+34  | 1.08E+05       | 3           |
| J1702–4128 | 0.182| 17.34                  | 3.4E+35 | 4.85E+03       | 80          |
| J1709–4429 | 0.102| 49.35                  | 3.4E+36 | 2.72E+04       | 853         |
| J1718–3825 | 0.075| 15.83                  | 1.3E+36 | 2.26E+04       | 138         |
| J1730–3350 | 0.139| 38.75                  | 1.2E+36 | 1.20E+04       | 36          |
| J1732–3131 | 0.197| *                      | 1.5E+35 | 2.93E+03       | 8.6         |
| J1741–2054 | 0.414| 0.01                   | 9.5E+33 | 3.55E+02       | 2.1         |
| J1744–1134 | 0.004| 0.48                   | 5.2E+33 | 2.68E+04       | 0.68        |
| J1747–2958 | 0.099| 1.59                   | 2.5E+36 | 2.42E+04       | 570         |
| J1747–4036 | 0.002| 46.01                  | 1.2E+35 | 3.13E+05       | 40          |
| J1801–2451 | 0.125| 12.21                  | 2.6E+36 | 1.95E+04       | 14          |
| J1809–2332 | 0.147| *                      | 4.3E+35 | 6.74E+03       | 164         |
| J1833–1034 | 0.062| 1.19                   | 3.4E+37 | 1.42E+05       | 160         |
| J1835–1106 | 0.166| 21.97                  | 1.8E+35 | 3.84E+03       | 6           |
| J1907+0602 | 0.107| 0.02                   | 2.8E+36 | 2.38E+04       | 314         |
| J1939+2134 | 0.002| 161.7                  | 1.1E+36 | 1.02E+06       | 14          |
| J1952+3252 | 0.040| 9                      | 3.7E+36 | 7.38E+04       | 66          |
| J2043+2740 | 0.096| *                      | 5.6E+34 | 3.73E+03       | 3.8         |
| J2124–3358 | 0.005| 0.61                   | 6.8E+33 | 2.52E+04       | 0.4         |
| J2229+6114 | 0.052| 2.25                   | 2.2E+37 | 1.39E+05       | 19.4        |
| J2240+5832 | 0.140| 142.7                  | 2.2E+35 | 5.08E+03       | 80          |
| PSRJ       | $P$   | $R_{\text{lim}1400}$ | $L_\gamma$ |
|------------|-------|-----------------------|------------|
| J0117+5914 | 0.101 | 0.94                  | 15.07 ± 7.11 |
| J0358+5413 | 0.156 | 23                    | 58.39 ± 45.54 |
| J0535-6935 | 0.201 | 123.5                 | 119.00 ± 132.49 |
| J0538+2817 | 0.143 | 3.21                  | 25.35 ± 13.22 |
| J0540-6919 | 0.051 | 59.28                 | 87.20 ± 83.42 |
| J0543+2329 | 0.246 | 21.9                  | 57.19 ± 44.13 |
| J0614+2229 | 0.335 | 6.66                  | 34.54 ± 20.61 |
| J0729-1448 | 0.252 | 5.07                  | 30.77 ± 17.39 |
| J0820-3826 | 0.125 | 20.91                 | 56.08 ± 42.84 |
| J0834-4159 | 0.121 | 5.77                  | 32.50 ± 18.84 |
| J0855-4644 | 0.065 | 6.52                  | 34.23 ± 20.34 |
| J0940-5428 | 0.088 | 0.1                   | 5.83 ± 3.80 |
| J1015-5719 | 0.140 | 6.71                  | 34.65 ± 20.71 |
| J1016-5819 | 0.088 | 2.08                  | 21.10 ± 10.37 |
| J1019-5749 | 0.162 | 95.05                 | 106.50 ± 112.42 |
| J1020-6026 | 0.140 | 1.5                   | 18.37 ± 8.77 |
| J1052-5954 | 0.181 | 1.48                  | 18.27 ± 8.72 |
| J1055-6028 | 0.100 | 11.44                 | 43.44 ± 29.07 (280) |
| J1138-6207 | 0.118 | 25.33                 | 60.82 ± 48.46 |
| J1151-6108 | 0.102 | 0.3                   | 9.29 ± 4.88 |
| J1156-5707 | 0.288 | 1.54                  | 18.58 ± 8.89 |
| J1248-6344 | 0.198 | 13.74                 | 46.94 ± 32.70 |
| J1301-6305 | 0.185 | 52.86                 | 83.06 ± 77.56 |
| J1327-6400 | 0.281 | 61.12                 | 88.33 ± 85.06 |
| J1341-6220 | 0.193 | 301.17                | 173.59 ± 230.42 |
| J1359-6038 | 0.128 | 190                   | 142.82 ± 173.31 |
| J1400-6325 | 0.031 | 12.25                 | 44.71 ± 30.37 |
| J1406-6121 | 0.213 | 19.34                 | 54.26 ± 40.74 |
| J1412-6145 | 0.315 | 23.83                 | 59.27 ± 46.59 |
| J1413-6141 | 0.286 | 44.59                 | 77.29 ± 69.60 |
| J1437-5959 | 0.062 | 5.48                  | 31.80 ± 18.25 |
| J1512-5759 | 0.129 | 280.71                | 168.49 ± 220.64 |
| J1514-5925 | 0.149 | 4.15                  | 28.27 ± 15.40 |
| J1524-5625 | 0.078 | 9.48                  | 40.11 ± 25.78 |
| J1538-5551 | 0.105 | 8.94                  | 39.13 ± 24.83 |
| J1541-5535 | 0.296 | 5.88                  | 32.76 ± 19.07 |
| J1548-5607 | 0.171 | 32.6                  | 67.69 ± 56.97 |
| J1601-5335 | 0.288 | 2.8                   | 23.93 ± 12.22 |
| J1611-5209 | 0.182 | 10.44                 | 41.79 ± 27.42 |
| J1614-5048 | 0.232 | 63.65                 | 89.86 ± 87.27 |
| J1632-4757 | 0.229 | 7.06                  | 35.40 ± 21.38 |
| J1636-4440 | 0.207 | 59                    | 87.02 ± 83.17 |
| J1637-4553 | 0.119 | 13.02                 | 45.88 ± 31.59 |
| J1637-4642 | 0.154 | 15.1                  | 48.86 ± 34.74 |
| J1638-4417 | 0.118 | 30.34                 | 65.66 ± 54.41 |
| J1638-4608 | 0.278 | 6.89                  | 35.04 ± 21.06 |
| J1643-4505 | 0.237 | 6.34                  | 33.83 ± 19.99 |
| J1646-4346 | 0.232 | 38.28                 | 72.45 ± 63.14 |
| J1702-4306 | 0.216 | 6.83                  | 34.91 ± 20.94 |
| J1702-4310 | 0.241 | 13.44                 | 46.50 ± 32.24 |
| J1705-3950 | 0.319 | 17.65                 | 52.19 ± 38.41 |
| J1715-3903 | 0.278 | 6.4                   | 33.96 ± 20.10 |
| J1721-3532 | 0.280 | 232.76                | 155.64 ± 196.54 |
| J1722-3712 | 0.236 | 19.68                 | 54.66 ± 41.20 |
| PSRJ     | $P$ (s) | $R_{\text{1400}}$ (mJy $\times$ kpc$^2$) | $L_\gamma$ $10^{33}$ (erg s$^{-1}$) |
|----------|---------|----------------------------------------|-------------------------------------|
| J1723–3659 | 0.203   | 18.38                                  | 53.10 ± 39.43                       |
| J1739–3023 | 0.114   | 9.42                                   | 40.00 ± 25.67 (16.2)                |
| J1740–1000 | 0.154   | 13.92                                  | 47.20 ± 32.97                       |
| J1743–3153 | 0.193   | 39.25                                  | 73.22 ± 64.16                       |
| J1755–2421 | 0.234   | 3.29                                   | 25.62 ± 13.41                       |
| J1757–2421 | 0.234   | 37.96                                  | 72.19 ± 62.80                       |
| J1803–2137 | 0.134   | 269.1                                  | 165.51 ± 214.97                     |
| J1809–1917 | 0.083   | 26.73                                  | 62.23 ± 50.16                       |
| J1815–1738 | 0.198   | 5.98                                   | 33.00 ± 19.27                       |
| J1825–1446 | 0.279   | 51.95                                  | 82.46 ± 76.71                       |
| J1826–1334 | 0.101   | 27.37                                  | 62.85 ± 50.93                       |
| J1828–1057 | 0.246   | 3.03                                   | 24.74 ± 12.79                       |
| J1828–1101 | 0.072   | 65.98                                  | 91.24 ± 89.28 (140)                 |
| J1831–0952 | 0.067   | 4.47                                   | 29.17 ± 16.10                       |
| J1833–0827 | 0.085   | 72.9                                   | 95.18 ± 95.10                       |
| J1835–0643 | 0.306   | 33.28                                  | 68.28 ± 57.73                       |
| J1835–0944 | 0.145   | 7.3                                    | 35.91 ± 21.84                       |
| J1837–0604 | 0.096   | 15.99                                  | 50.06 ± 36.05 (370)                 |
| J1838–0453 | 0.381   | 14.73                                  | 48.34 ± 34.19                       |
| J1838–0549 | 0.235   | 4.76                                   | 29.96 ± 16.73                       |
| J1839–0321 | 0.239   | 16.43                                  | 50.63 ± 36.68                       |
| J1841–0425 | 0.204   | 20                                    | 55.03 ± 41.63                       |
| J1841–0524 | 0.186   | 50.34                                  | 81.36 ± 75.19                       |
| J1843–1113 | 0.002   | 0.16                                   | 7.12 ± 4.20 (5.4)                   |
| J1845–0316 | 0.208   | 9                                      | 39.24 ± 24.94                       |
| J1850–0026 | 0.167   | 79.69                                  | 98.84 ± 100.60                      |
| J1853–0004 | 0.101   | 24.81                                  | 60.29 ± 47.82                       |
| J1853+0056 | 0.276   | 3.1                                    | 24.98 ± 12.96                       |
| J1856+0113 | 0.267   | 2.07                                   | 21.05 ± 10.35                       |
| J1856+0245 | 0.081   | 23.17                                  | 58.57 ± 45.76                       |
| J1857+0143 | 0.140   | 15.45                                  | 49.33 ± 35.26                       |
| J1904+0800 | 0.263   | 43.16                                  | 76.23 ± 68.17                       |
| J1907+0631 | 0.324   | 2.89                                   | 24.25 ± 12.44                       |
| J1907+0918 | 0.226   | 19.59                                  | 54.55 ± 41.08                       |
| J1909+0749 | 0.237   | 15.53                                  | 49.44 ± 35.38                       |
| J1909+0912 | 0.223   | 20.27                                  | 55.35 ± 41.99                       |
| J1913+0832 | 0.134   | 40.34                                  | 74.08 ± 65.29                       |
| J1913+0904 | 0.163   | 2.02                                   | 20.84 ± 10.21 (34)                  |
| J1913+1011 | 0.036   | 10.63                                  | 42.11 ± 27.74                       |
| J1916+1225 | 0.227   | 3.96                                   | 27.71 ± 14.97                       |
| J1917+1353 | 0.195   | 47.5                                   | 79.39 ± 72.46                       |
| J1922+1733 | 0.236   | 33.24                                  | 68.25 ± 57.69                       |
| J1925+1720 | 0.076   | 1.79                                   | 19.80 ± 9.59                        |
| J1928+1746 | 0.069   | 5.26                                   | 31.25 ± 17.79                       |
| J1930+1852 | 0.137   | 2.94                                   | 24.43 ± 12.57                       |
| J1932+2220 | 0.144   | 142.57                                 | 126.46 ± 144.93                     |
| J1934+2352 | 0.178   | 9.23                                   | 39.66 ± 25.34                       |
| J1935+2025 | 0.080   | 11.15                                  | 42.97 ± 28.60                       |
| J1938+2213 | 0.166   | 6.9                                    | 35.06 ± 21.08                       |
| J1948+2551 | 0.197   | 47.08                                  | 79.09 ± 72.05                       |
| J2004+3429 | 0.241   | 12.78                                  | 45.52 ± 31.21                       |
| J2006+3102 | 0.164   | 9.82                                   | 40.72 ± 26.37                       |

References: $^a$ Hou X., Smith D.A., Guillemot L. et al., Hou et al. (2014); $^b$ Smith D.A., Guillemot L., Kerr M., Ng C., Barr E., Smith et al. (2017); $^c$ Laffon H., Smith D. A., Guillemot L., Laffon et al. (2015).
Table 3 Gamma-ray Pulsars with Expected Radio Emission

| PSR  | $P$ (s) | $R_{1400}$ (mJy $\times$ kpc$^2$) | $L_{\gamma}$ (mJy) | $d$ (kpc) | $S_{1400}$ (mJy) | $S_{111}$ (mJy) |
|------|--------|-------------------------------|-------------------|---------|-----------------|-----------------|
| 1 J0007+7303 | 0.316 | 8.90 | 94 | 1.4 | 4.5 | 203.4 |
| 2 J0633+1746 | 0.237 | 5.35 | 31.7 | 0.25 | 85.6 | 3835.7 |
| 3 J1418–6058 | 0.111 | 8.81 | 92 | 1.6 | 3.4 | 154.2 |
| 4 J1732–3131 | 0.197 | 2.91 | 8.6 | 0.64 | 7.1 | 317.9 |
| 5 J1809–2332 | 0.147 | 11.55 | 164 | 1.7 | 4.0 | 179.0 |
| 6 J2043+2740 | 0.096 | 1.98 | 3.8 | 1.25 | 1.3 | 56.9 |

1.5 (Malov & Malofeev 2010) for all considered objects. In the frame of these suggestions we have

$$S_{111} = 44.8 \times S_{1400}. \quad (8)$$

These estimates show that pulsars from Table 3 can be registered in the radio range with high probability. The most promising candidates for gamma-ray pulsars in the Northern Hemisphere are J0007+7303 and J0633+1746.

5 CONCLUSIONS

The sample of pulsars detected as radio and/or gamma-ray emitters is presented. It is restricted to objects with losses of rotational energy $\dot{E} > 3 \times 10^{34}$ erg s$^{-1}$ and magnetic fields at the light cylinder $B_{lc} > 10^3$ G.

Pulsars listed in the 2FGL catalog show a correlation between luminosities in the radio and gamma ranges. This correlation gives an opportunity to choose radio pulsars which can be detected as gamma-ray sources by Fermi/LAT. Using the same correlation, we propose to search for radio emission from several gamma-ray pulsars believed to be radio quiet up to now. It is worth noting that J0633+1746 has already been detected as a radio pulsar (see Malofeev & Malov 2002). This detection demonstrates that the proposed program of searching for new radio pulsars is quite reasonable.

We propose a program of observations using the Large Phased Antenna (LPA) at the Pushchino Radio Astronomy Observatory to search for radio emission from the objects in Table 3 at 111 MHz. The results of these observations will be published separately. This paper has been written on the basis of results presented to the All-Russian Astronomical Conference VAK-2017 (see the Preface Samus & Li (2018) in this issue).

Acknowledgements This work has been carried out with financial support of Basic Research Program of the Presidium of the Russian Academy of Sciences “Transitional and Explosive Processes in Astrophysics (P-41)” and Russian Foundation for Basic Research (grant 16–02–00954).

References

Abdo, A. A., Ajello, M., Allafort, A., et al. 2013, ApJS, 208, 17
Hou, X., Smith, D. A., Guillemot, L., et al. 2014, A&A, 570, A44
Laffon, H., Smith, D. A., Guillemot, L., & for the Fermi-LAT Collaboration. 2015, arXiv:1502.03251
Loginov, A. A., & Malov, I. F. 2014, Astronomy Reports, 58, 733
Malofeev, V. M., & Malov, O. I. 2002, in IAU Symposium, 199, The Universe at Low Radio Frequencies, ed. A. Pramesh Rao, G. Swarup, & Gopal-Krishna, 393
Malov, I. F., & Timirkeeva, M. A. 2014, Astronomy Reports, 58, 611
Malov, I. F., & Timirkeeva, M. A. 2015, Astronomy Reports, 59, 865
Malov, O. I., & Malofeev, V. M. 2010, Astronomy Reports, 54, 210
Manchester, R. N., Hobbs, G. B., Teoh, A., & Hobbs, M. 2005, AJ, 129, 1993
Pierbattista, M., Grenier, I. A., Harding, A. K., & Gonthier, P. L. 2012, A&A, 545, A42
Samus, N. N., & Li, Y. RAA (Research in Astronomy and Astrophysics), 2018, 18, 88
Smith, D. A., Guillemot, L., Kerr, M., Ng, C., & Barr, E. 2017, arXiv:1706.03592
Thompson D. J. 1996, ASP Conference Series, 105, 307