Gamma Ray Pulsar Candidates for GLAST

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> > Abstract

The GLAST satellite (Gamma-ray Large Area Space Telescope) will be launched less than a year from now, and its Large Area Telescope (LAT) is expected to discover scores to hundreds of gamma ray pulsars. This poster discusses which of the nearly 1700 known pulsars, mostly visible only at radio frequencies, are likely to emit > 100 MeV gamma rays with intensities detectable by the LAT. The main figures of merit used to select gamma ray pulsar candidates are É and 🗏 /d², where É is the energy loss due to rotational spindown, and d is the distance to the pulsar. A few individual objects are cited to illustrate the issues. Since large E pulsars also tend to have large timing noise, their ephemerides can become inaccurate in weeks to months, and the GLAST LAT will need timing measurements contemporaneous to the continuous gamma ray observations. The poster will describe efforts to coordinate pulsar radio timing of the candidate gamma ray pulsars.



Which pulsars might emit gamma rays over 100 MeV ? 1627 pulsars are currently listed in the ANTF Pulsar Catalog. The Vela pulsar and six additional pulsars were seen at high energies by EGRET or COMPTEL with high-confidence and at least three more objects like the millisecond pulsar J0218+4232 were seen by EGRET with lower-confidence. The GLAST LAT (Large Area Telescope), with its unprecedented sensitivity, is expected to increase the number of known gamma ray emitting pulsars substantially, see Figures 1 and 3 (between 30 and 100 for Thompson, 2003, about 600 for Gonthier et al., 2004, and up to 750 for McLaughlin and Cordes 2000). timing measurements With a large effective area (10000 cm² at 1 GeV), a narrow point spread function, and a large field of view (24 sr), GLAST will record enough photons for gamma-ray pulsation searches far more sensitive (for 1 year, 4x10³ ph/cm²/s (E>100 MeV)) than EGRET's and should detect scores to hundreds of large E radio pulsars. Figure 4 illustrates GLAST's superior source localisation. However, timing noise also scales with Pdot and timing ephemerides become inaccurate within weeks to months for many of the best gamma pulsar candidates (Arzoumanian et al 1994). BLAFLAT Stelefiste 1 ¥., OLART LAT ٦. and Cordes, 2000). However, to succeed in discovering gamma ray emission from known pulsars, it will be essential to have high-precision ephemerides : that is, for a typical pulsar, an uncertainty on its period *De* 2 % of *P*. Hence, it is important to determine which of the 1627 pulsars may be potential gamma ray sources. Spin-down energy as seen at a function of period for the The GLAST LAT sensitivity on the diffuse namma 12¹⁰ an el Study of model predictions and the EGRET sample suggest various parameters that could be well correlated with gamma ray intensity. We have chosen a quantity illustrated in Figure 2: 1000 10.00 Good ephemerides will dramatically enhance the number of detectable pulsars, as well as phase-resolved and multiwavelength studies. GLAST needs timing measurements contemporaneous to the continuous gamma ray observations. $\frac{\sqrt{\dot{E}}}{d^2} = \frac{\dot{E}}{d^2} \times \frac{1}{\sqrt{\dot{E}}} = \frac{1}{d^2} \sqrt{4\pi^2 I \frac{\dot{P}}{P^3}} \propto \frac{V}{d^2}$ 1 In this expression, É denotes the energy loss due to the pulsar spindown, d the distance to the pulsar, I the moment of inertia of the neutron star, and V the open field line voltage. The factor \dot{E}/d^2 is the available energy of the pulsar and $1/\sqrt{E}$ is the gamma ray radiation efficiency according to Arons, 1966. Pulsars are expected to stop being gamma ray emitters when É falls to a < death-line » which is below 3 10⁴⁴ erg/s, so that the following cut-off has been chosen : 1000 19" $\dot{E} \approx 10^{34} \text{ erg/s}$ This choice leads to a list of 215 gamma ray emitting candidates, which are then sorted by \sqrt{E} /d². A few examples are cited on the poster. 0.2 al significance of a pr 49: J0218+4232, first of many gamma MSP's ? #1: Vela, first instrument test 7: J2229+6114, noisy pulsars need fresh ephemerides Gamma ray candidates Same? 100

Coordinated pulsar timing campaigns for GLAST

Figure 12: X-ray image of PSR J2223+6114 and its sasciated PVIN, taken with Chandra ACIS-1 (Halpern et al., recen

As for EGRET (Fierro 1994), we have an a priori list of radio pulsars most likely to be detectable with the GLAST LAT (https://confluence.slac.stanford.edu/display/GLAMCOG/GLAST+LAT+Multiwavelength+Coordinating+Group). Also as before (see e.g. Arzoumanian et al 1994), timing campaigns have begun. However, GLAST's timing needs are substantially greater than EGRET's were: The number of known radio pulsars has more than tripled since the CGRO launch.

• GLAST will scan the whole sky continuously during the first year, and generally thereafter: All pulsars will be observed all the time

Three observatories will routinely time most of the gamma ray candidates: Parkes for the southern sky (contacts: <u>Simon_Johnston@atnf.csiro.au</u> and <u>dick.manchester@ciro.au</u>), and Jodrell (contact: <u>mkramer@ib.man.ac.uk</u>) and Nançay (contact: <u>icognard@cnrs-orleans.fr</u>) in the north. The most sensitive but less available instruments, Green Bank Telescope and Arecibo, will be used for pulsars particularly interesting in gamma rays but difficult to detect in radio, and to perform deep searches for radio counterparts to gamma ray sources that the LAT will detect, pulsed or unpulsed.

We need help from other radio telescopes: the a priori list reflects current theoretical prejudices, heavily influenced by the very small number of currently known gamma ray pulsars, yet the LAT will observe all radio pulsars so we want valid ephemerides for as many as possible. Some radio-bright, glitch-prone pulsars merit more frequent observations. The monitoring must be sustained for 5 to 10 years, a tratic for explorements. strain for any observatory

A database (http://glast.gs/c.nasa.gov/ssc/dev/psr_tools/) readable by the Science Tools package (http://glast. ground.slac.stanford.edu/workbook/solTools Home.htm) will allow analysis of data as it becomes available on the servers (http://glast.gs/c.nasa.gov/cgi-bin/ssc/LAT/DC2DataQuery.cgi) For pulsars more easily detectable in X-rays than in radio, we welcome any help in providing the GLAST LAT with accurate ephemerides

Those who provide ephemerides used to obtain gamma ray results will co-author publications. While true that GLAST data becomes public after the first year, GLAST data analysis is complex, especially for weaker sources not seen during the first year: radio, Xray and gamma ray astronomers are likely to all benefit from cooperation.

If you can contribute to LAT pulsar timing, please contact the GLAST pulsar IDS (InterDisciplinary Scientist), Stephen Thorsett (thorsett@ucclick.org) and/or the "Pulsar, Supernova, and Pulsar Wind Nebula Science Working Group" leaders, David Thompson (<u>dit@egret.gsfc.nasa.gov</u>) and Roger Romani (<u>wr@astro.stanford.edu</u>).

GLAST needs contemporaneous

The hi Edot radio pulsar J2229+6114 discovered at the end of the CGRO mission is a concrete example. A search in EGRET data archives using different methods failed to find significant evidence of pulsation (Figure 5) since the EGRET photons are too few, and too old compared to the ephemerides (Thompson et al., 2002).



Rank	Name	Normalized Flux
1	B0833-45	1
2	J0633+1746	0.2237
3	J0437-4715	0.179
4	B0531+21	0.1717
5	B0656+14	0.07422
6	B0743-53	0.05373
7	J0034-0534	0.01902
8	J0205+6449	0.01625
9	J1747-2958	0.01253
10	B1706-44	0.01116
11	B1055-52	0.0107
12	J1833-1034	0.0101
13	J1740 + 1000	0.009987
14	B1951+32	0.009855
15	J1357-6429	0.009241
16	B1257+12	0.007444
17	J1524-5625	0.007306
18	B1509-58*	0.007017
19	J1531-5610	0.006993
20	B1046-58	0.006076
1	I.	1
37	J2229+6114	0.002857
:	1	1
49	J0218+4232	0.0022

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