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Document Title **Memo of Understanding for Pulsar Timing at the Urumqi Observatory**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Memo of Understanding for

Pulsar Timing

at the Urumqi Observatory

DOCUMENT APPROVAL

Date	Approved by	Name, role or affiliation
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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
00	7 May 2008	Initial draft
01	15 May 2008	Appendix of 38 pulsar added by N. Wang. Send for signatures.
02		

1. Purpose

The GLAST Large Area Telescope (LAT) is a long-awaited opportunity to increase the understanding of pulsars significantly. Gamma-ray pulsar studies are enhanced by the availability of contemporaneous timing ephemerides from other wavelengths. Up to hundreds of known pulsars are viable candidates for gamma emission, justifying a large, coordinated timing campaign over several years. LAT data analysis is complex and members of the instrument team provide high quality gamma ray measurements. LAT photon data are available only to team members during Cycle 1.

[The Cycle 1 mission epoch is the approximately one-year period beginning at the end of the 60 day satellite and instrument commissioning period ("L&EO", for Launch & Early Operations). The end of Cycle 1 is when NASA makes the first year photon data public. Cycle 2 is the period following Cycle 1.]

We believe that combining our efforts will bring a scientific return whose sum is richer than if we worked apart. This document describes an agreement between radio astronomers using the Nanshan 25 meter antenna at Urumqi Observatory in China and the LAT collaboration of gamma astronomers to share expertise and resources, specifically pertaining to issues such as the authorship of articles and the sharing of unpublished data.

This agreement complements a similar agreement with other radio and X-ray timing observers. That agreement is described in LAT-MD-09047, Memo of Understanding for a Pulsar Timing Consortium.

2. Overview of the pulsar timing campaign

The pulsar timing campaign for the GLAST LAT is described in an article to be submitted to A&A in Spring 2008. It contains a list of 230 pulsars with spindown energy $dE/dt > 1 \times 10^{34}$. Those with $dE/dt < 3 \times 10^{34}$ erg/s are considered to be "worthwhile" candidates for GLAST. Those with $dE/dt > 3 \times 10^{34}$ erg/s are called "must-do". Alternate schemes to select gamma candidates mostly overlap this list – the candidate selection details are beyond the scope of this document.

Amongst the justifications for such a long list of gamma candidates is the LAT field-of-view of ~20% of the sky. During Cycle 1 data will be acquired mainly in "survey mode", where the entire sky will be surveyed every two orbits (3 hours). LAT's sensitivity is such that the Vela pulsar is detected well enough in 6 hours to consistently determine the pulsar peak position to better than 800 microseconds. For weaker pulsars, however, LAT data will have to be accumulated for an extended time interval – years in some cases – before a gamma-ray signal will emerge.

As of May 2008, Urumqi Observatory is timing a total of roughly 270 pulsars with $\delta > -35°$, three times per month. 38 of these are in the list of 230 high dE/dt pulsars. They have data spans exceeding 6 years for most of these pulsars. The observing system is a cryogenic dual-channel receiver with an analogue filterbank of 320 MHz bandwidth centered at 1540 MHz. Consequently TOA precisions are quite acceptable for young pulsars with S1400 greater than about 0.5 mJy. During Summer 2008 they will take delivery of a Digital Filterbank system, constructed at ATNF and the same as used at Parkes.

The frequent observations (3 times per month) are particularly valuable for gamma-ray pulsation searches on pulsars with large timing noise. Urumqi Observatory may be able to increase the number of noisy pulsars from the GLAST LAT list being monitored. They may also study nearby, noisy pulsars just below the 10^{34} erg/s cut-off in order to provide the rotation parameters to the LAT collaboration.

It is trivial to add additional timing solutions for any pulsar beyond those on the target list. Because the gamma-ray data are being accumulated continuously, the key requirement on any timing solution is that it be phase-locked over a long enough time interval to make a gamma-ray analysis worthwhile.

3. Pulsar Ephemerides on the Bordeaux and NASA GSFC Data Servers

Timing ephemerides are the product of significant expertise applied to difficult-to-obtain data, and are essential for the study of gamma ray pulsations in most cases. To maximize the scientific return from the GLAST mission, a balance must be found between the need to sustain repeated timing over several years, and the need to open the data to the broadest scrutiny possible.

Timing solutions provided to the LAT team (".par files" and ancillary files such as templates, when provided) will be stored at the CENBG (Centre d'Etudes Nucléaires de Bordeaux-Gradignan, France). A web-interface will allow LAT and their radio astronomer colleagues to create "D4.fits" files, the file format used by the LAT "Science Tools". The timing solutions remain the intellectual property of the radio astronomers at this step, to be shared outside the LAT collaboration only with their consent. David Smith is the point-of-contact for the LAT. Data portal users will be invited to contact the radio astronomers to obtain ephemerides not available on the public servers. Later in the mission, the intent is for the CENBG archive and/or the web functionality to migrate to the GSSC (GLAST Science Support Center) at the Goddard Space Flight Center in Greenbelt, Maryland.

At the end of the Cycle 1 all-sky survey, LAT photon data will be posted on the public data portals at the GSSC. New data will be made public as processed (typically less than a few days after detection). It is the intention of the LAT team to work with the radio astronomers to publish primary pulsar results during Cycle 1, so that a public release of timing information will serve primarily to allow other scientists to confirm the gamma-ray pulsar results.

ARTICLE I

The radio astronomers agree to make a best effort to:

- *publish most of the 38 timing solutions by the end of Cycle 1;*
- *put Cycle 1 timing solutions into the GLAST public database for those pulsars for which LAT detects pulsed emission, with submission to occur when the paper is accepted; and*
- *put the Cycle 1 timing solutions for all 38 pulsars into the public database 6 months after the end of Cycle 1.*

The public database documentation will encourage users to cite the timing parameter authors for published results or to work with the timing scientists directly. Users interested in timing solutions not in the database will be directed to the astronomers monitoring those objects.

A large number of high dE/dt pulsar rotation ephemerides will be updated regularly in the years following. The radio astronomers are not obligated to make such information public, although the benefits to the science may provide a strong incentive to do so.

4. LAT publication policy

LAT guidelines for multi-wavelength work are at
https://confluence.slac.stanford.edu/display/GLAMCOG/

The LAT collaboration has defined two publication categories called I and II. The LAT "publication board" assigns papers to categories. Presently, the publication board is Peter Michelson, Steve Ritz, Neil Gehrels, Pat Nolan, and Julie McEnery.

Category I papers are intended to be "major" results. They may be signed by any team member who so desires (over 100 people), as well as by scientists from outside the team contributing to that work. Generally they will be in alphabetical order but the possibility exists that the first authors be the study leaders. During Cycle 1 most papers are likely to be Category I.

Category II papers are signed only by those having contributed directly to that work. The order of authorship is determined by the authors and approved by the publications board.

It should be emphasized that there is no automatic authorship on any LAT paper in either category. This rule applies to LAT team members as well as outside contributors. For each paper, the eligible scientists are invited to participate in the paper preparation and sign the paper, but each individual must actively inform the lead author that he/she wishes to be an author. Radio astronomers will be informed at an early stage of any planned paper and will be encouraged to contribute to the results and the text of the paper. All authors are expected to be able to defend the paper or major portions of it.

The timing campaign resembles other large multi-wavelength efforts for the GLAST mission, such as radio and optical blazer flare monitoring. It is however unique in its duration over the 5 to 10 year mission lifetime.

ARTICLE II

The radio pulsar timers signing this agreement are eligible to participate in the preparation of and to sign any LAT paper using any *timing data on the 38 pulsars cited above, whether or not they contributed ephemerides used in that paper.*

In return, the LAT collaboration asks that they share all timing data on the 38 pulsars of interest to the LAT with the LAT team in a timely manner.

The LAT collaboration holds that privileged access to LAT pulsar results and instrument team expertise has high value, justifying a two-year commitment, but accepts one year.. At that time we will discuss renewal or combining this cooperative effort with the larger pulsar consortium. The LAT collaboration hopes they will find it in their interest to continue to share timing solutions with LAT team members even after the initial commitment ends and LAT data have become public.

ARTICLE III

The agreement is valid until LAT photon data are made public at the end of Cycle 1, but applies to articles-in-preparation for which a significant draft exists at that time.

If the radio astronomers choose to share timing solutions for pulsars beyond the 38 in this MoU with the LAT team, to allow gamma pulsation searches in close coordination with LAT team members, the resulting publications would be co-authored with the LAT team.

All agreements in this Memorandum are non-exclusive. Timing scientists can share the timing solutions with other observers. LAT scientists can publish results that do not depend on these timing solutions.

Appendix:
List of the 38 pulsars.

#	PSRJ	P0 (s)	P1	S1400 (mJy)	AGE (Yr)	EDOT (ergs/s)
1	J0534+2200	0.033085	4.23e-13	14.00	1.24e+03	4.61e+38
2	J1952+3252	0.039531	5.84e-15	1.00	1.07e+05	3.74e+36
3	J1826-1334	0.101466	7.51e-14	2.10	2.14e+04	2.84e+36
4	J1801-2451	0.124924	1.28e-13	0.85	1.55e+04	2.59e+36
5	J1803-2137	0.133617	1.34e-13	7.60	1.58e+04	2.22e+36
6	J1730-3350	0.139460	8.48e-14	3.20	2.60e+04	1.23e+36
7	J1932+2220	0.144470	5.76e-14	1.20	3.98e+04	7.54e+35
8	J1833-0827	0.085284	9.17e-15	3.60	1.47e+05	5.84e+35
9	J0729-1448	0.251659	1.13e-13	0.70	3.52e+04	2.81e+35
10	J1841-0345	0.204068	5.79e-14	1.40	5.59e+04	2.69e+35
11	J1835-1106	0.165907	2.06e-14	2.20	1.28e+05	1.78e+35
12	J0631+1036	0.287773	1.05e-13	0.80	4.36e+04	1.73e+35
13	J0742-2822	0.166762	1.68e-14	15.00	1.57e+05	1.43e+35
14	J1740-3015	0.606784	4.66e-13	6.40	2.06e+04	8.24e+34
15	J0614+2229	0.334960	5.94e-14	2.20	8.93e+04	6.24e+34
16	J2337+6151	0.495300	1.92e-13	1.40	4.09e+04	6.23e+34
17	J1801-2304	0.415796	1.13e-13	2.20	5.84e+04	6.20e+34
18	J0358+5413	0.156382	4.40e-15	23.00	5.64e+05	4.54e+34
19	J1721-3532	0.280424	2.52e-14	11.00	1.76e+05	4.51e+34
20	J1825-1446	0.279187	2.27e-14	2.60	1.95e+05	4.11e+34
21	J0543+2329	0.245975	1.54e-14	9.00	2.53e+05	4.09e+34
22	J1757-2421	0.234101	1.29e-14	3.90	2.87e+05	3.98e+34
23	J1841-0425	0.186147	6.39e-15	2.60	4.61e+05	3.91e+34
24	J1917+1353	0.194631	7.20e-15	1.90	4.28e+05	3.85e+34
25	J0659+1414	0.384891	5.50e-14	3.70	1.11e+05	3.81e+34
26	J1723-3659	0.202722	8.01e-15	1.50	4.01e+05	3.79e+34
27	J1830-1059	0.405043	6.00e-14	1.40	1.07e+05	3.57e+34
28	J1722-3712	0.236173	1.09e-14	3.20	3.45e+05	3.25e+34
29	J1824-1945	0.189335	5.23e-15	4.90	5.73e+05	3.04e+34
30	J2013+3845	0.230194	8.85e-15	6.40	4.12e+05	2.86e+34
31	J1844-0538	0.255699	9.71e-15	2.20	4.17e+05	2.29e+34
32	J1857+0212	0.415823	4.03e-14	1.60	1.64e+05	2.21e+34
33	J0139+5814	0.272451	1.07e-14	4.60	4.03e+05	2.09e+34

34	J1733-3716	0.337586	1.50e-14	3.40	3.55e+05	1.54e+34
35	J1845-0743	0.104695	3.67e-16	2.70	4.52e+06	1.26e+34
36	J2002+3217	0.696761	1.05e-13	1.20	1.05e+05	1.23e+34
37	J1853+0545	0.126400	6.11e-16	1.60	3.28e+06	1.19e+34
38	J2150+5247	0.332206	1.01e-14	2.00	5.21e+05	1.09e+34