

Memorandum of Understanding between
The FAST Collaboration
and
The *Fermi* Large Area Telescope (LAT) Collaboration
for
Pulsar Studies using the FAST Radio Telescope and
the *Fermi* Large Area Telescope

PARTICIPANTS

Name, role or affiliation
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The *Fermi Gamma-ray Space Telescope* has been in orbit since 2008 June 11. Its primary instrument, the Large Area Telescope (LAT)¹, has been surveying the sky since 2008 August 4. Data (reconstructed photon lists and spacecraft position information as well as analysis tools) are available on public servers². The LAT has detected well over 200 gamma-ray pulsars³, the first 117 of which are characterized in detail in *The Second Fermi Large Area Telescope Catalog of Gamma-Ray Pulsars*⁴.

Ultimately, all gamma-ray pulsars are seen by calculating the rotational phase of photons from the direction of the pulsar using a timing ephemeris, to then study the resulting phase histogram (“*phase folding*”). Timing ephemerides originate in three ways. The first is from repeated observations of radio or X-ray pulsars discovered independently of *Fermi*, for example in radio surveys. This first approach was the focus of *Pulsar Timing for the Fermi Large Area Telescope*⁵ and has resulted in the discovery of roughly half of the LAT pulsars. Pulsars with lower gamma-ray fluxes than for the two other discovery channels can be seen. The other two methods are blind searches of the gamma-ray data⁶ and targeted deep radio searches⁷. “*Blind*” means that there is no a priori information about the spin characteristics, the exact position or, for radio searches, the value of the dispersion measure. Both methods start from lists of candidate positions provided by the LAT, typically non-varying well-localized sources not associated with known active galaxies, perhaps with pulsar-like spectral characteristics. Roughly one third of all known millisecond pulsars outside of globular clusters have been discovered in radio blind searches of LAT sources. Roughly one quarter of all gamma-ray pulsars have been discovered in gamma-ray blind searches.

While LAT data and analysis tools are public, LAT team members have special expertise making them valuable collaborators for astronomers using other instruments in many cases. A specific example is the preparation of the LAT catalogs. The 3rd (“*3FGL*”) was published in 2015⁸ and the 4th (“*4FGL*”) should appear in 2018. In the intervening years, the LAT teams generate and work with preliminary source lists benefitting from myriad analysis improvements, and with lower minimum significance than the published catalogs.

The **Five-hundred-meter Aperture Spherical radio Telescope** (FAST) is the world’s largest single dish antenna with a 300 m effective diameter, parabolic, active primary surface, located in Guizhou Province, southwestern China. Commissioning is ongoing in 2017. Significant progress in August 2017⁹ allowed FAST to discover its first new pulsars. FAST’s large collecting surface

¹ <http://adsabs.harvard.edu/abs/2009ApJ...697.1071A>

² <https://fermi.gsfc.nasa.gov/ssc/data/>

³ <https://confluence.slac.stanford.edu/display/GLAMCOG/Public+List+of+LAT-Detected+Gamma-Ray+Pulsars>

⁴ <http://adsabs.harvard.edu/abs/2013ApJS..208...17A>

⁵ <http://adsabs.harvard.edu/abs/2008A&A...492..923S>

⁶ For example, <http://adsabs.harvard.edu/abs/2017ApJ...834..106C> and references therein.

⁷ For example, see <http://adsabs.harvard.edu/abs/2017ApJ...846L..19P> and references therein.

⁸ <http://adsabs.harvard.edu/abs/2015ApJS..218...23A>

⁹ Dr. Di Li at IAUS 337, Jodrell Bank, September 2017.

and state-of-the-art electronics and computing will make it one of the most sensitive radio telescopes in the world.

This Memorandum of Understanding (MoU) describes an agreement, between radio astronomers using FAST and the LAT collaboration of gamma-ray astronomers, to share expertise and resources with the goal of new pulsar discoveries. This document specifies the mutual understanding between FAST and Fermi LAT pertaining to issues such as the authorship of papers and the sharing of unpublished data or analysis.

This agreement complements previous agreements with radio and X-ray pulsar observers, two of which are called the Pulsar Timing Consortium (PTC) and the Pulsar Search Consortium (PSC)¹⁰.

ARTICLE I *Blind radio searches of unidentified gamma-ray sources*

LAT will provide FAST with the coordinates of possible gamma-ray counterparts to currently unknown pulsars, to allow FAST to search them for radio pulsations. The LAT sources may be unpublished.

FAST will inform LAT of the results of their searches, including both detections and upper limits. FAST will make a best effort to provide LAT with rotation ephemerides for the newly discovered pulsars when these become available.

ARTICLE II *Deep radio searches of new gamma-ray pulsars*

LAT may provide FAST with rotation ephemerides of newly discovered gamma-ray pulsars, to allow deep searches for radio counterparts.

FAST will inform LAT of the results of their searches, including both detections and upper limits.

ARTICLE III *Gamma-ray searches of new radio pulsars*

FAST may provide LAT with rotation ephemerides of newly discovered radio pulsars to allow LAT team members to search for corresponding gamma-ray pulsations.

LAT will inform FAST of the results of their searches, including both detections and upper limits.

ARTICLE IV *Joint Observing Campaigns*

¹⁰<https://confluence.slac.stanford.edu/display/GLAMCOG/Fermi+LAT+Multiwavelength+Coordinating+Group>

LAT team and FAST team will organize simultaneous campaign of ToOs and other targets of potential high impact, when opportunities arise.

ARTICLE V Publication authorship

When FAST publishes discoveries, or upper limits, on sources provided by LAT, the LAT team members listed in this document, as well as others not listed who have made identifiable contributions to the work, will be invited to sign the papers.

When LAT publishes results that include FAST pulsar searches or measurements, the FAST team members listed in this document, as well as others not listed who have made identifiable contributions to the work, will be invited to sign the papers.

ARTICLE VI Duration

The agreement is valid for two years after the date of signature but applies to articles-in-preparation for which a significant draft exists at the end of the time period of validity of this agreement.

ARTICLE VII Privacy and non-exclusivity

All data and analysis shared under this agreement are private: information provided to LAT (FAST) by FAST (LAT) will not be given to persons outside those two teams. Group members will be cautioned not to share these results outside the collaborations in any form, including publications, Web sites, e-mail, ATEs, or seminars.

All exchanges prescribed by this Memorandum are non-exclusive. FAST and LAT scientists can share their own information with other scientists.

Appendix I: *Fermi* LAT Collaboration 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 “Publications Board” and science working group leaders assign papers to categories. Details of the LAT publication policy are found at

https://www-glast.stanford.edu/pub_policy.html

Category I papers report “major” results. They may be signed by any team member who so desires (over 200 people), as well as by scientists from outside the team contributing to that work. Generally authors will be in alphabetical order but the possibility exists that the first authors be the study leaders.

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 Publication Board.

There is no automatic authorship on any LAT papers. 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 to 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.

Appendix II: *FAST* publication policy

The *FAST* publication policy is still to be formally approved and announced by the Chinese Academy of Sciences. The National Astronomical Observatory of China (NAOC) does not expect any substantive change relevant to this MoU. The *FAST* team also promise best efforts to discuss any changes with potential impact on this MoU with the *Fermi*-LAT team.

Any publication based on unpublished *FAST* data can be of three categories. Category I (CI) includes the very first publication based on *FAST* data, the first *FAST* source catalogue, and the first publication on a high-impact journal. CI papers will be lead by an author specified by the *FAST* board and with *FAST* core team members as co-authors. External co-authors need to be approved by the *FAST* board. Category II (CII) refers to papers mainly based on *FAST* data, but not fall in CI. CII papers are expected to be lead by the actual science lead, subject to approval before publication by the *FAST* board, which has the right to add relevant *FAST* team members as co-authors. Category III (CIII) refers to papers only partially based on unpublished *FAST* data. The lead authors of CIII papers should notify the *FAST* board before publication. The *FAST* board reserve the right to suggest individual *FAST* members as co-authors, although it is not prerequisite for publication.

Signatures:

For the *FAST* collaboration: Dr. Jun Yan, *FAST* Manager.

Jun Yan Dec. 19, 2017

For the *Fermi* LAT collaboration: Professor Peter F Michelson, Principal Investigator

Peter F Michelson Dec 14, 2017