

Fermi LAT status

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LAT Principal Investigator & LAT
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Stanford University

Fermi User Group Meeting
November 29, 2023

National Aeronautics and Space Administration



Fermi

Gamma-ray Space Telescope

www.nasa.gov/fermi

Summary

- Fermi LAT Collaboration is very busy and very productive more than 15 years after launch
- LAT Instrument operations remain stable; science performance is very stable
 - Maintaining coverage in all areas due to multitasking, including ***supporting infrastructure transition of LAT data processing pipelines at SLAC National Accelerator Laboratory.***
- LAT science operations support high science productivity
 - maintaining and upgrading various science analysis pipelines and analysis tools (with FSSC, e.g., Fermipy, LCR)
 - supporting science analysis results, including recently updated source catalogs (e.g., 4FGL-DR4, 3PC)

Fermi LAT Overview

International and interagency collaboration:

- NASA and DOE in the US
- CEA and CNRS (IN2P3) in France
- ASI and INFN in Italy
- MEXT, KEK and JAXA in Japan
- K. A. Wallenberg Foundation, SRC and SNSB in Sweden
- Additional science support: INAF (Italy) and CNES (France)

LAT Science operations rely on integrated effort from:

- Instrument:
 - LAT: Stanford/SLAC/NRL/GSFC/international participants
- Fermi Science Support Center (FSSC):
 - GSFC
- Fermi Flight Operations Team (FOT):
 - GSFC

LAT Instrument team responsibilities (1)

- **operation of the LAT instrument**, including identification and evaluation of anomalies;
 - **sustaining engineering including anomaly resolution**;
 - **LAT flight software maintenance**; both on-board science algorithms and anomaly resolution;
 - **maintenance of instrument calibration**;
- **continuous data quality monitoring**;
- **highly efficient operation of LAT data-processing pipelines**;
includes flaring source analysis, algorithm improvements and adaptation for anomalies and detector aging effects;
- **occasional reprocessing of LAT data**;
- **analysis software maintenance and upgrades**; LAT team uses the same tools as community, and shares improvements with community through FSSC;

LAT Instrument team responsibilities (2)

- **generate source catalogs and update diffuse background models to support analyses;**
- **operate quick, automated science processing analysis for GRBs and other transients or flaring sources and provide rapid delivery of results to the community through the FSSC;**
 - LAT scientists examine output from ASP pipeline and perform follow-up analyses, produce ATels, and propose ToOs
- **maintain pulsar timing database**

Activities are fully supported by scientists from across the LAT collaboration; the LAT is not a black box

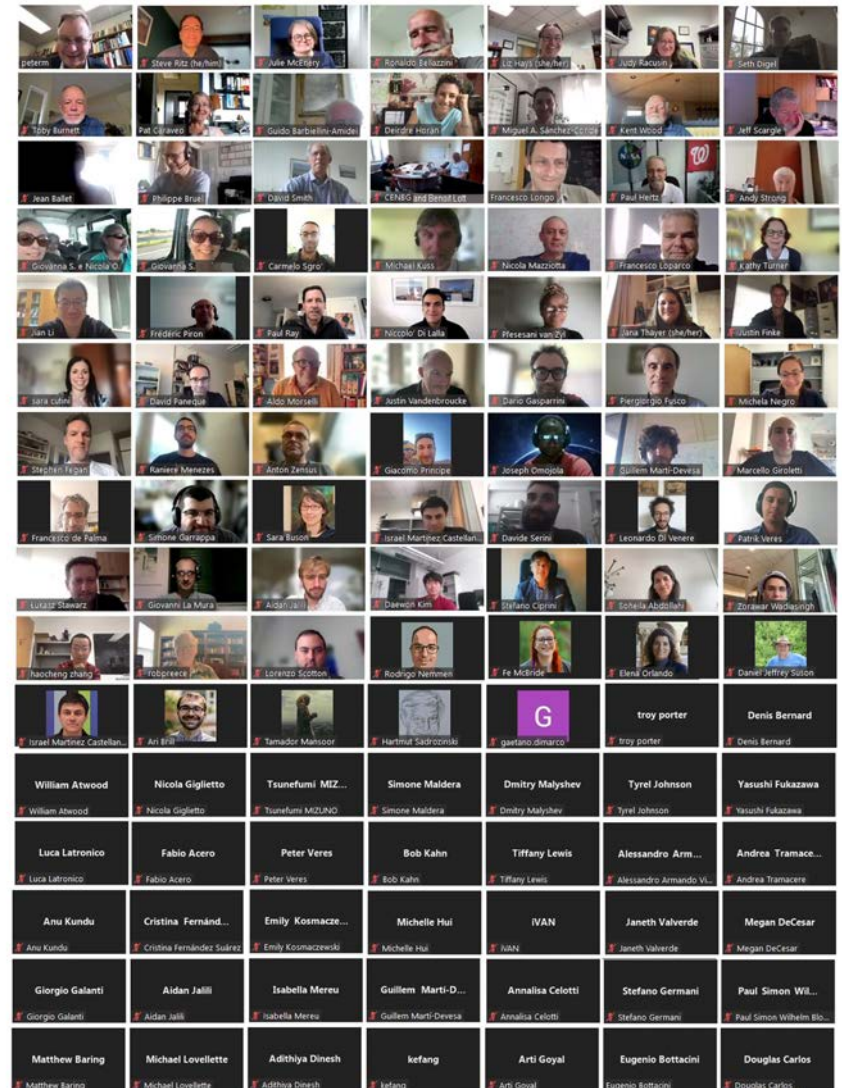
Fermi @ 15

LAT Collaboration celebrated on June 11, 2023 – more than 100 participants (via Zoom)

Some Fermi@15 LAT metrics:

- 84,444 orbits since launch
- 98.8% uptime
- 913 billion triggers
- 1.67 billion source photons available at the FSSC

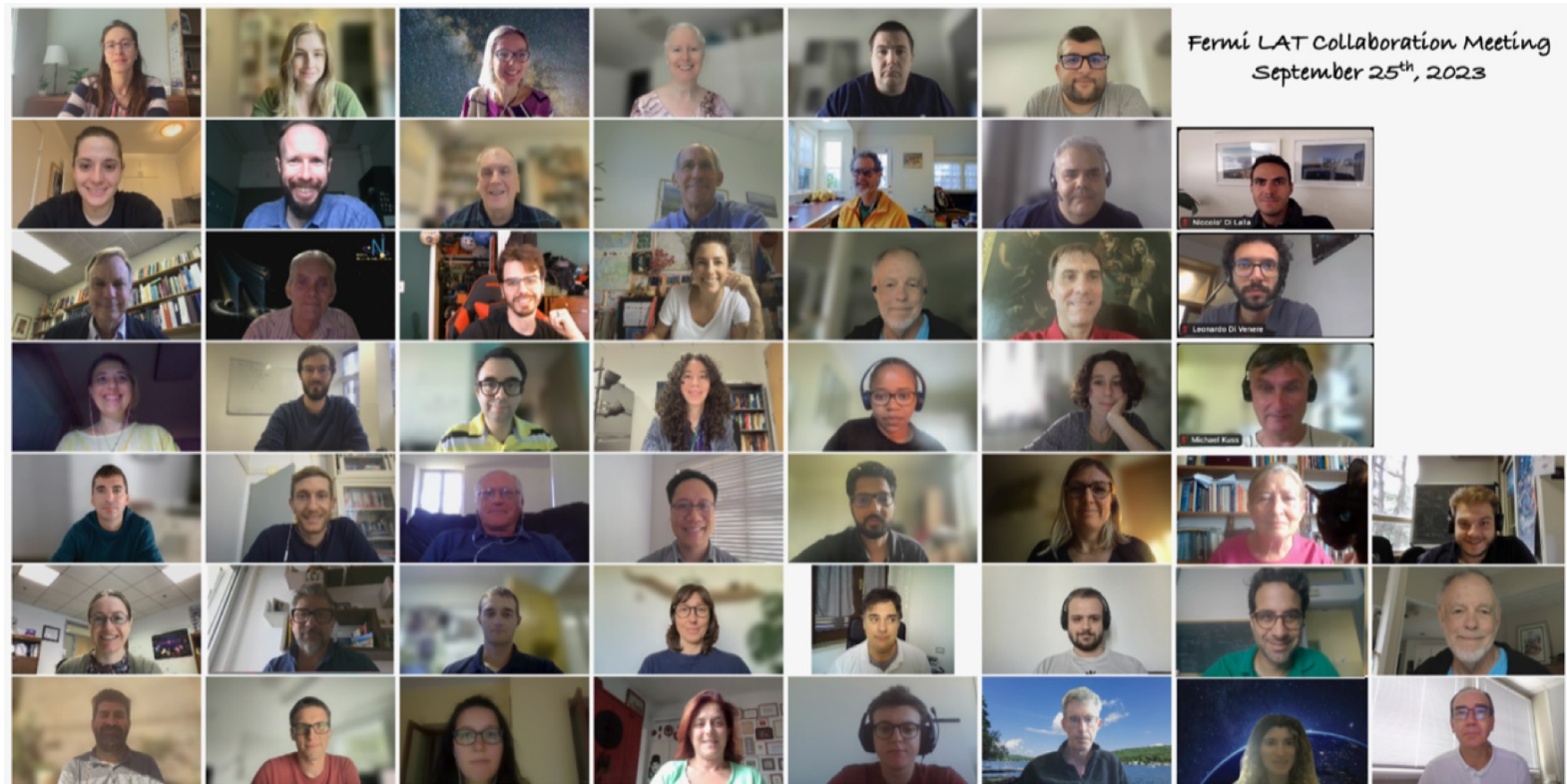
Gradual degradation in LAT components compensated by ongoing calibration



Fermi @ 15

- *Fermi* LAT is a very **active** collaboration!

- Science group meetings almost every weekday
- Switched from 2 in-person meetings/ year -> 1 hybrid & 1 virtual
- Fall 2023 Collaboration Meeting took place last month: ~113 attendees*

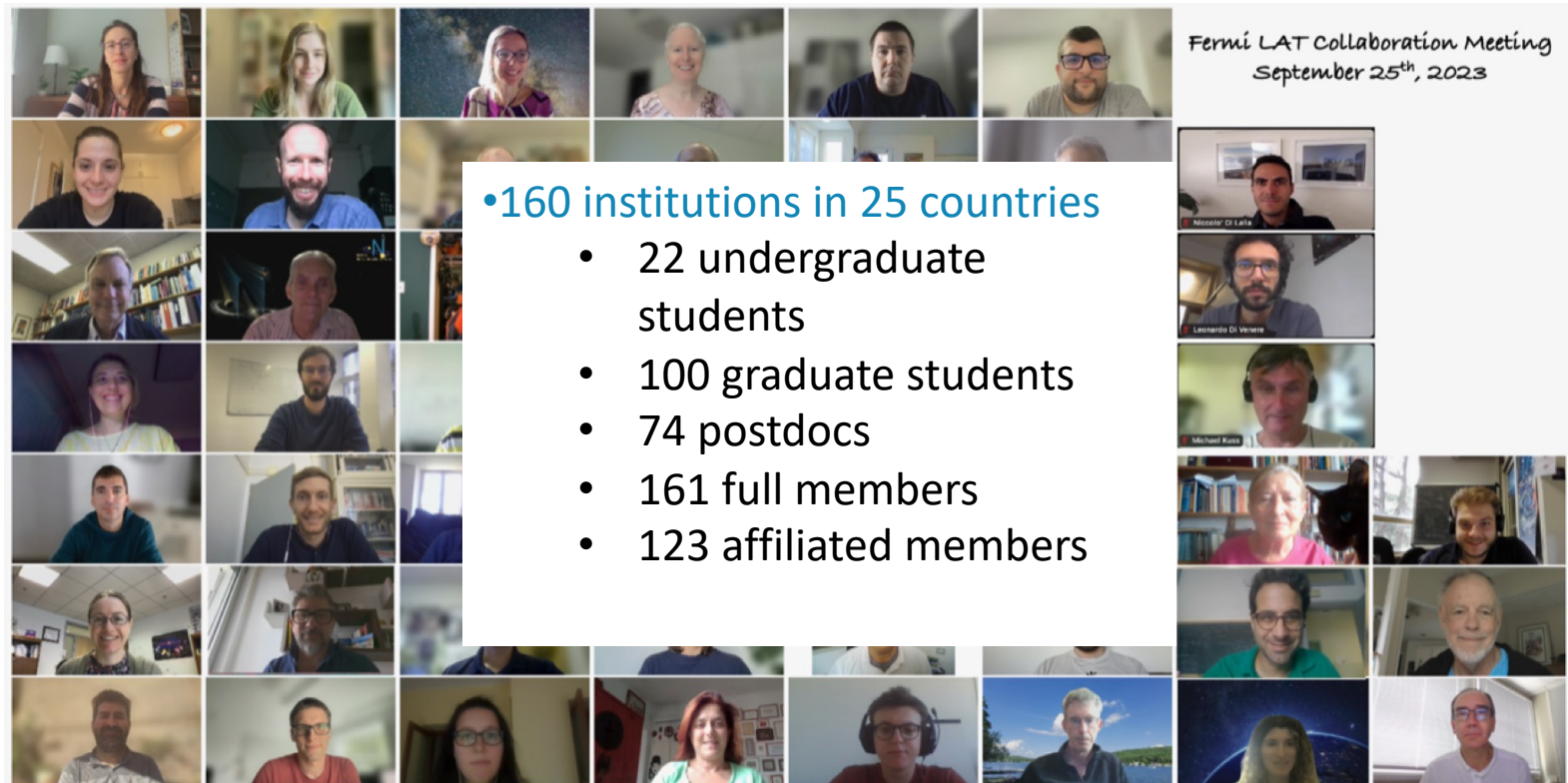


*not all in the photograph

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Fermi Mentoring Program (MP)



Started in spring 2021. Each cycle now lasts 1 year. We have now successfully launched the 5th cycle

Fermi MP components

Mentees:

Graduate students within the LAT and GBM collaborations.

Mentors:

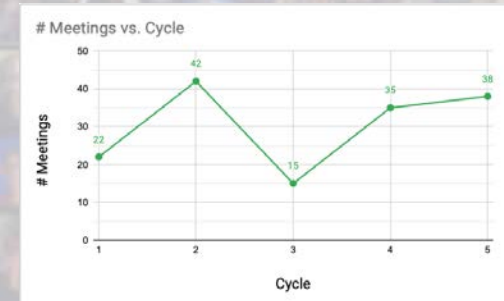
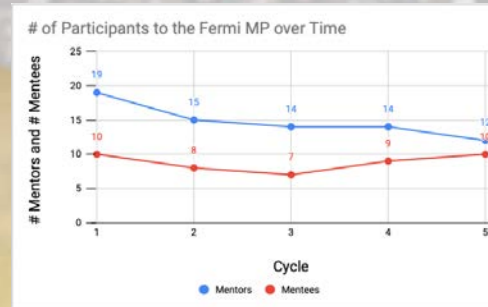
LAT/GBM PhD-holders. They do not supersede or interfere with the role of the research advisor, but rather serve as an additional resource.

MP Committee:

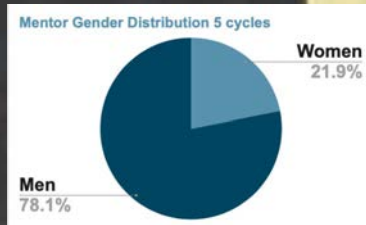
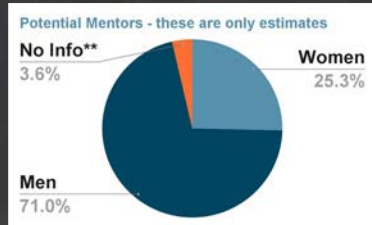
Volunteer-based group responsible for overseeing the MP. In charge of mentor-mentee **matching** and **training**. Mediates in case of misunderstandings.

Statistics

In the first 5 cycles (note the 5th is on going) of the *Fermi* MP, **88** people, between mentors and mentees, have met for a total of **152** hours of mentoring sessions that can be seen as **304** “people hours” of mentoring time.



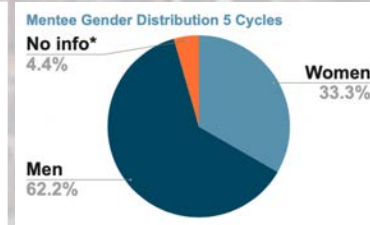
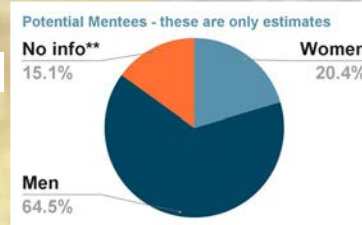
Mentors



Gender distribution of mentors/mentees

reflects the distribution in our collaborations

Mentees



**We don't know

*Not shared/Non-binary/Transgender/Other

**We don't know

Fermi LAT Collaboration's DEIA Panels

The Fermi LAT Collaboration's DEI Org presents a panel on **Bias & Applicant Evaluation**

Featuring:

Dr. Grace Wong Sneddon
former Director of Academic Leadership Initiatives &
Advisor to the Provost on Equity and Diversity at the
University of Victoria

Dr. Dessie Clark
Director of Curriculum Development & Implementation
at the University of Wisconsin - Madison

Prof. Isabelle Grenier
Université Paris Cité, Faculty of Sciences, Vice Dean,
International Relations

Prof. Matthew Baring
Co-Chair for Graduate Admissions and Recruiting, Dept
of Physics & Astronomy, Rice University

Join us for a special DEIA-themed WAM

Friday 23 June, 11am EDT

This panel will discuss how evaluators
and hiring committees can spot bias in
applications and interviews.

The usual Zoom links and Confluence page still apply.

If you have ideas about future DEIA themes or want to get involved with Fermi's DEI Org, please let us know.
Points of Contact: Tiffany Lewis (tiffanylewisphd@gmail.com); Giovanna Senatore (giovanna@stanford.edu)

The Fermi LAT Collaboration's DEI Org presents a panel on **DEI Work in Science Positions**

Featuring:

Dr. Milena Crnogorčević
Postdoctoral Fellow at the Oskar Klein Centre,
Stockholm University

Dr. Chandra Turpen
Assistant Research Professor, Department of Physics,
University of Maryland

Dr. William Ratcliff
Physicist, National Institute of Standards and
Technology

Join us for a special DEIA-themed WAM

Friday 15 Sept, 11am EDT

This panel will discuss DEIA work in the
context of roles primarily focused on
science. Folks of all genders, ethnicities,
and career stages are invited to attend and
engage in this important conversation.

The usual Zoom links and Confluence page still apply.

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The Fermi LAT Collaboration's DEI Org presents a panel on **Curriculum Vitae**

Featuring:

Dr. Marco Ajello
Associate Professor, Department of Physics &
Astronomy, Clemson University

Dr. Midhat Farooq
Senior Careers Program Manager, American
Physical Society

Dr. Stefan Funk
Professor of Physics, Erlangen Centre for
Astroparticle Physics,
Friedrich-Alexander-Universität
Erlangen-Nürnberg

Join us for a special
Early Career-themed WAM

Friday 13 Oct, 11am EDT

This panel will discuss what people
who receive CVs wish applicants knew
about drafting them, and answer
anonymous audience questions.

The usual Zoom links and Confluence page still apply.

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The Fermi LAT Collaboration's DEI Org presents a panel on **Hidden Curriculum**

Featuring:

Dr. Rachel Gable
Author of "The Hidden Curriculum: First Generation Students at Legacy
Universities", rgable0529@gmail.com

Dr. Neil Speirs
Widening Participation Manager at The University of Edinburgh

Mr. Marvin Q. Jones, Jr.
Astrophysics Ph.D. Candidate, Department of Physics, Indiana
University Bloomington

Dr. Kelli Warble
Teacher in Residence, Department of Physics, Arizona State University

Join us for a special DEIA-themed WAM

Friday 17 Nov, 11am EDT

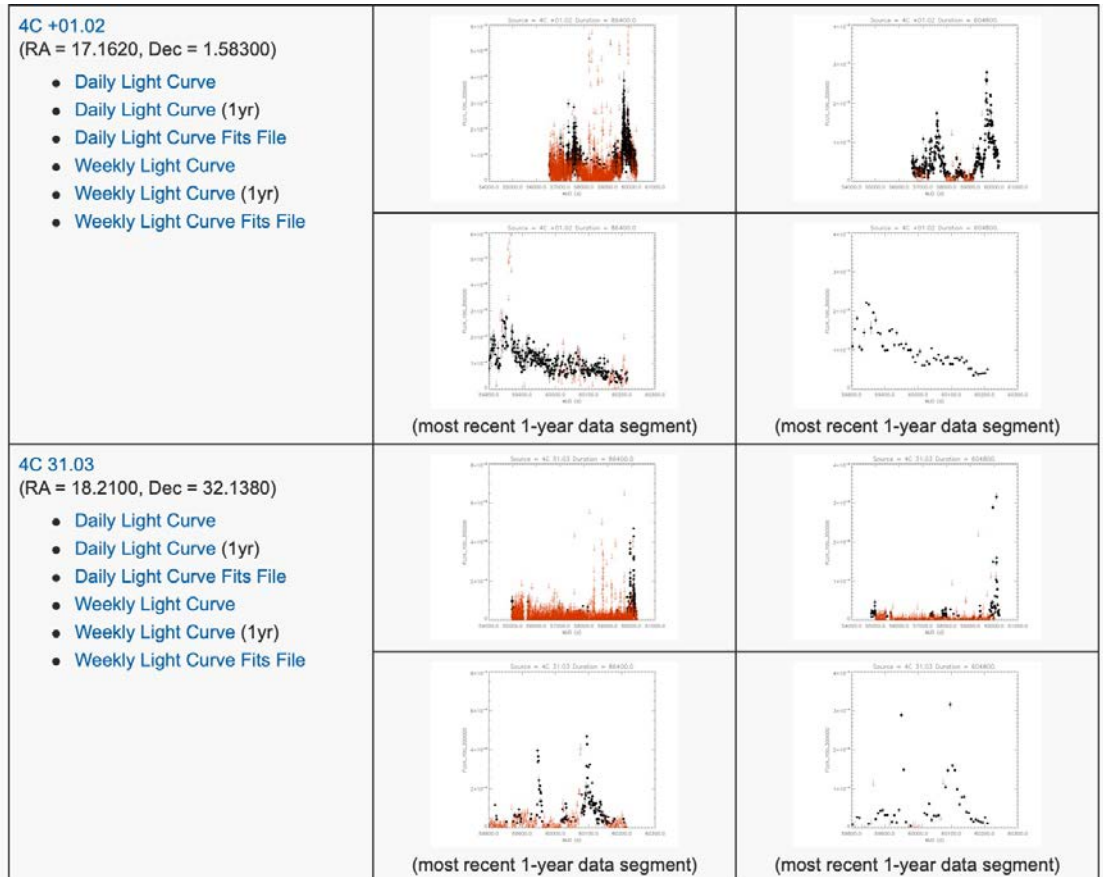
This panel will discuss the
expectations for success not
covered in formal instruction. Folks
of all genders, ethnicities, and
career stages are invited to attend
and engage in this important
conversation.

The usual Zoom links and Confluence page still apply.

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Monitored sources

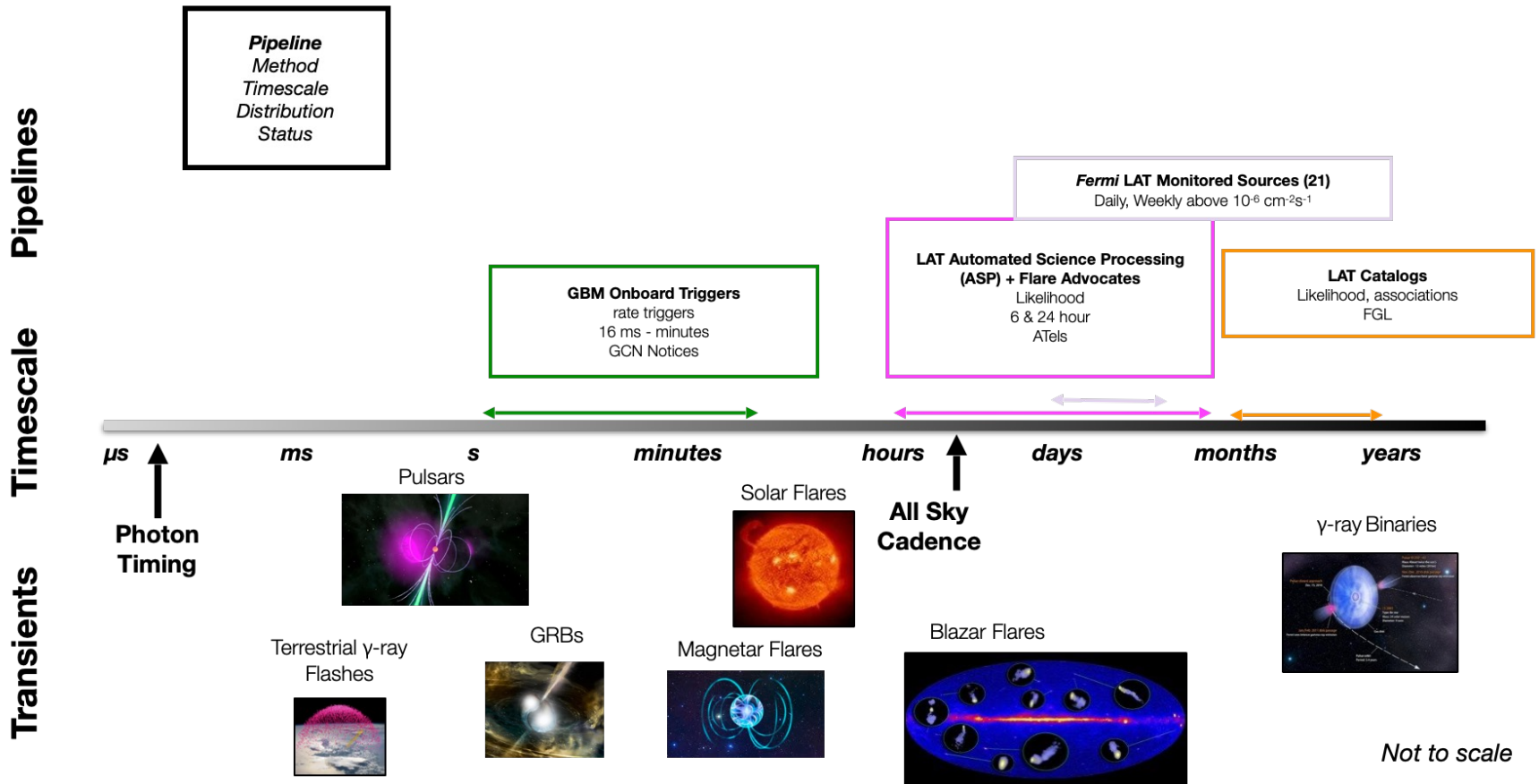
- The *Fermi* LAT table of monitored sources provides daily and weekly fluxes for sources of interest available at https://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/
- List is updated with new sources on a regular basis
- 4 added in last 6 months
- Started as a list of **25** - now, there are **201**



Fermi @ 15

The era of time-domain astrophysics

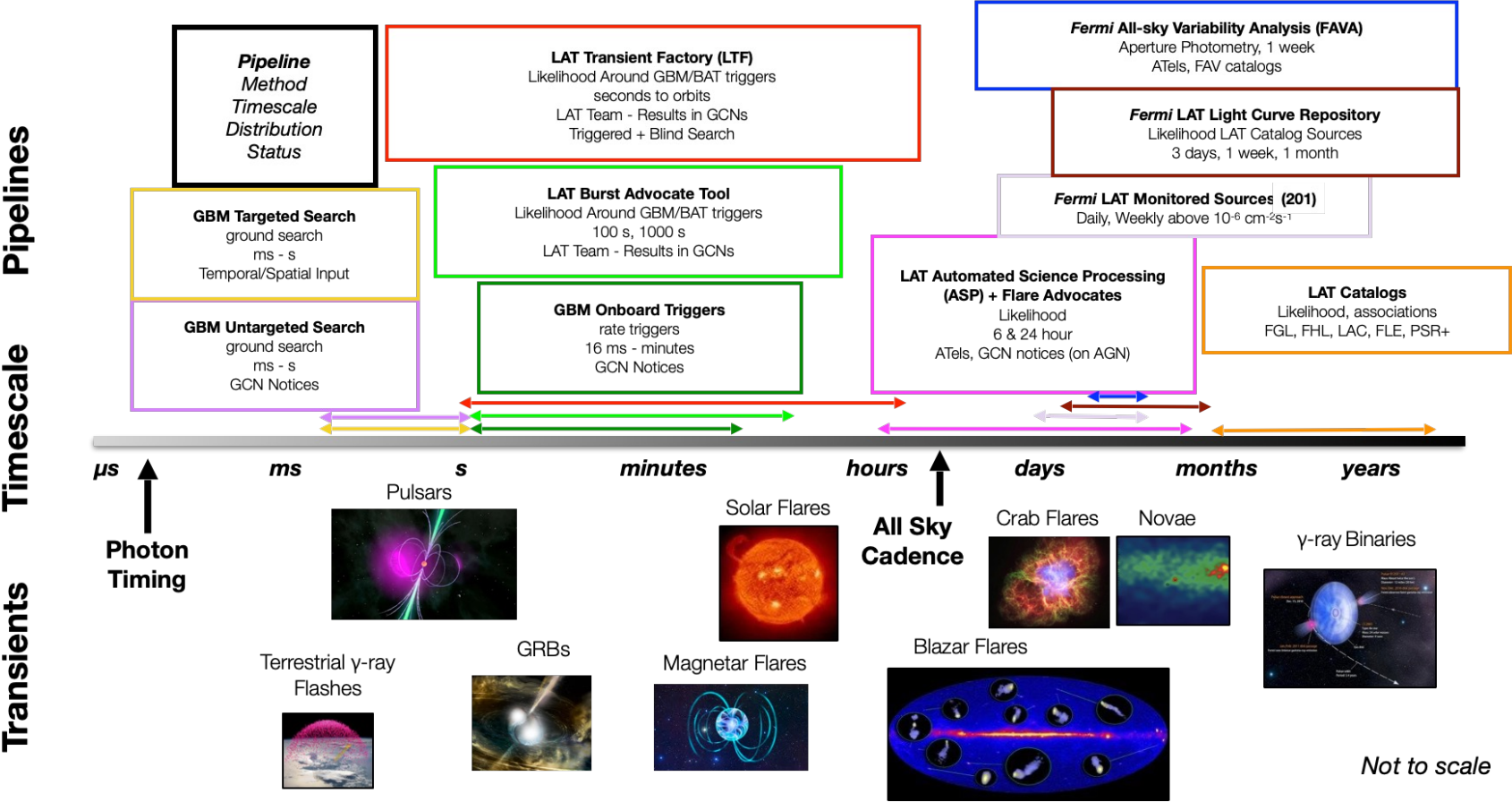
Fermi Transient Searches 2008-2009



Fermi @ 15

The era of time-domain astrophysics

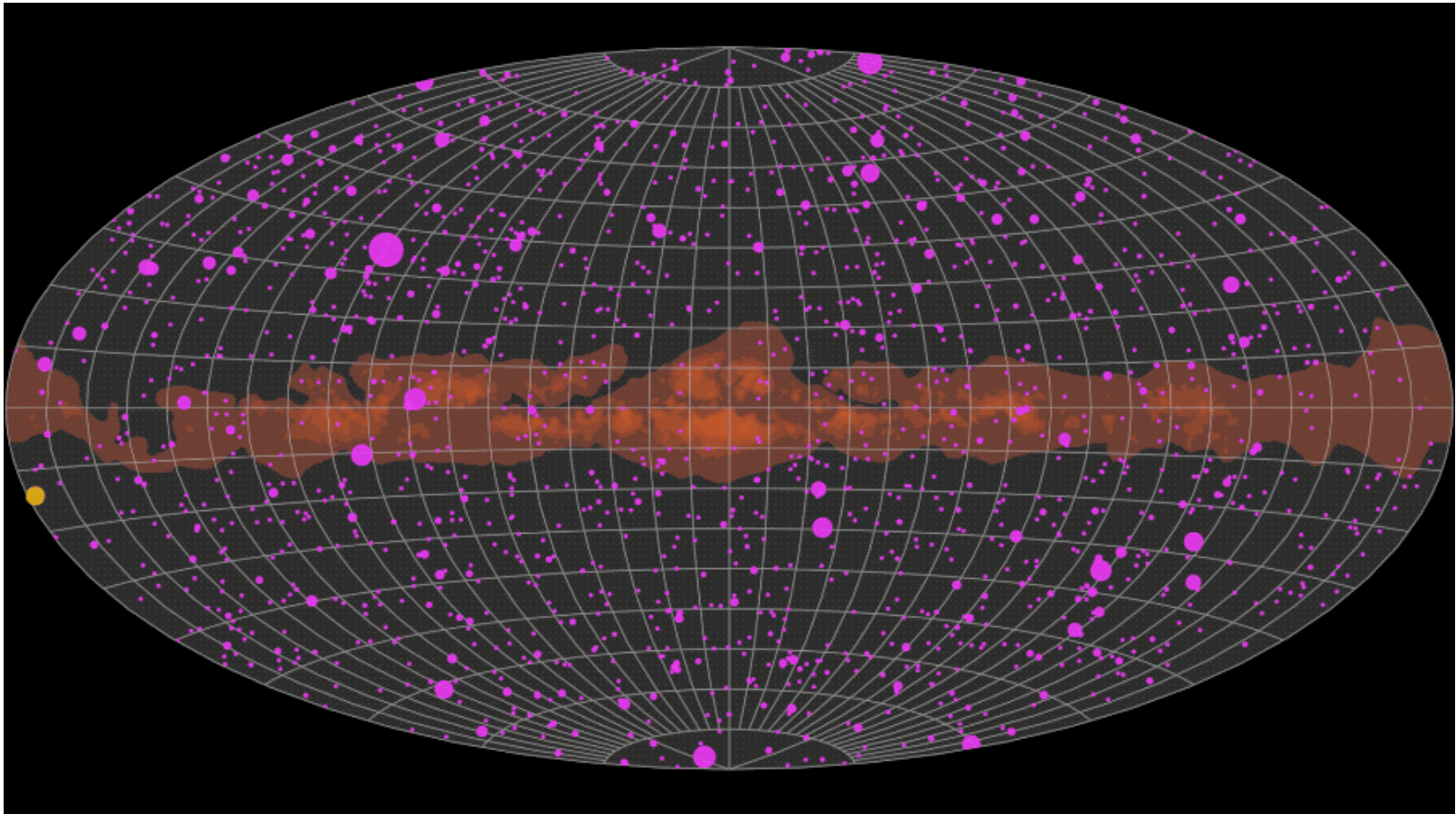
Fermi Transient Searches



Fermi-LAT Light Curve Repository

<https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/>

ref: Abdollahi, et al, ApJ Suppl 265, 31 (2023)

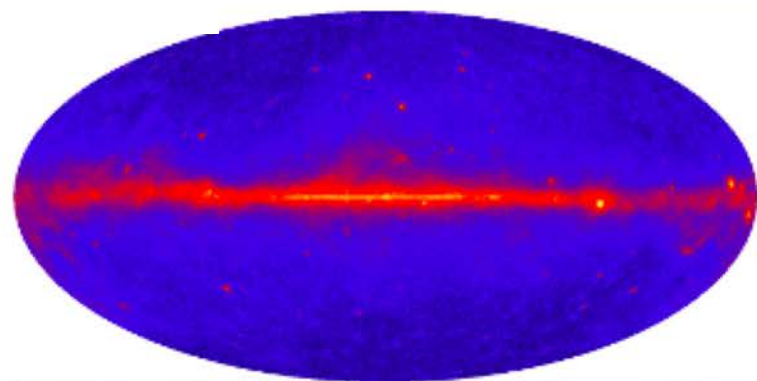


Animation shows subset of LAT gamma-ray records now available for more than 1,500 objects, deemed time-variable, in a continually updated repository. Over 90% of these sources are blazars.

D. Kovevski, J. Valverde, M. Negro, A. Brill, S. Grappa

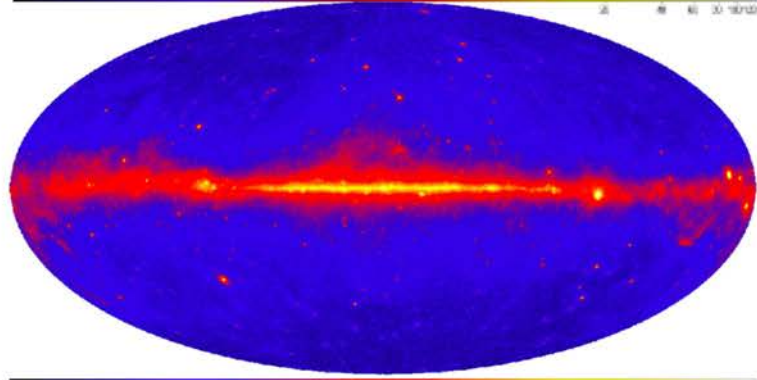
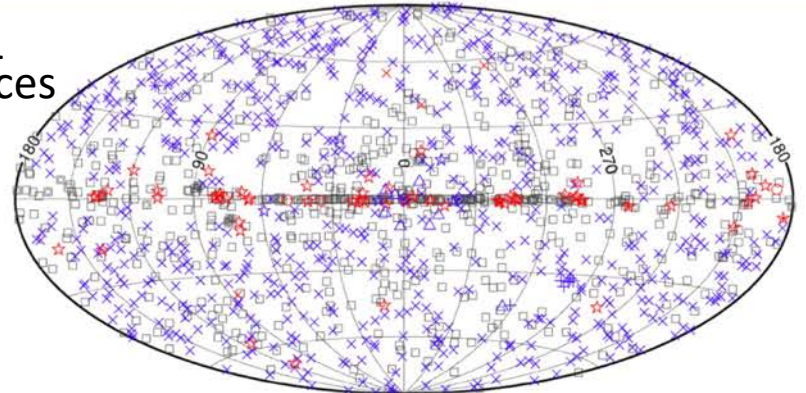
Fermi LAT Source Catalog

3FGL: LAT Collaboration, ApJS 218:23 (June 2015)



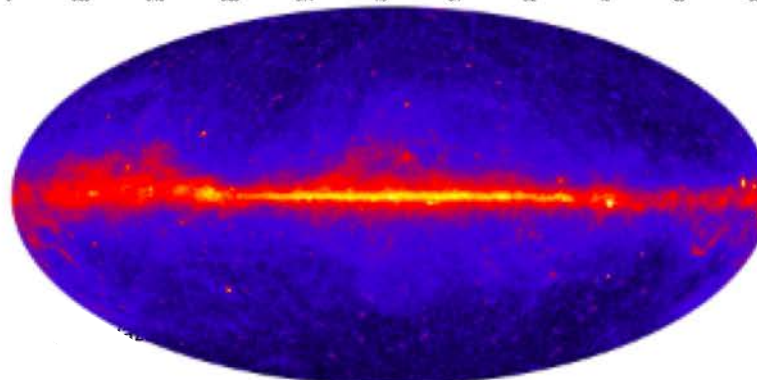
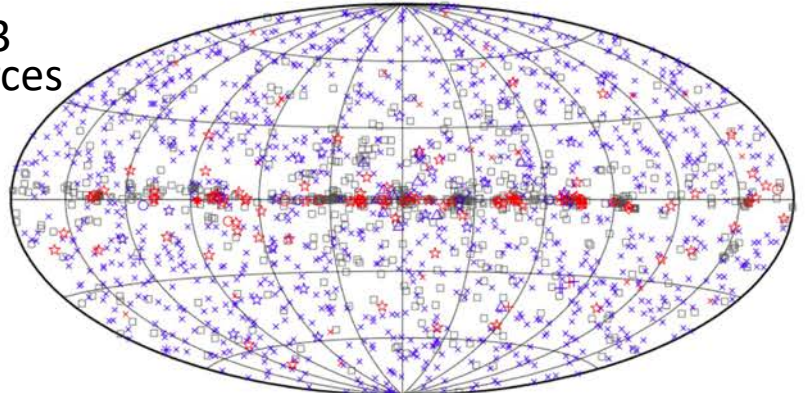
1FGL
11 m

1451
sources



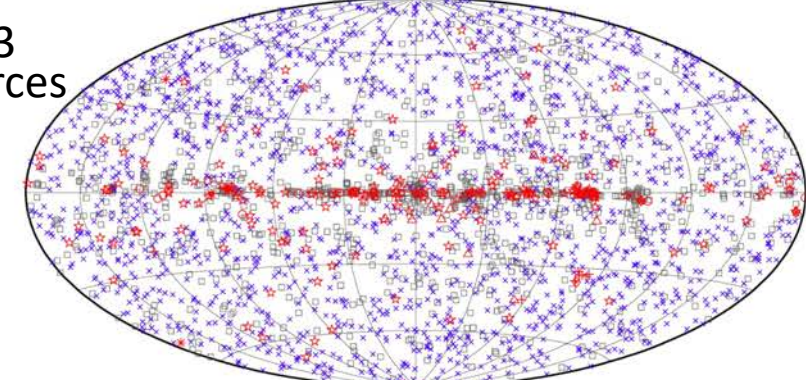
2FGL
2 y

1873
sources



3FGL
4 y

3033
sources



4FGL-DR4: 4th Fermi LAT Source Catalog update

<https://heasarc.gsfc.nasa.gov/w3browse/fermi/fermilpsc.html>

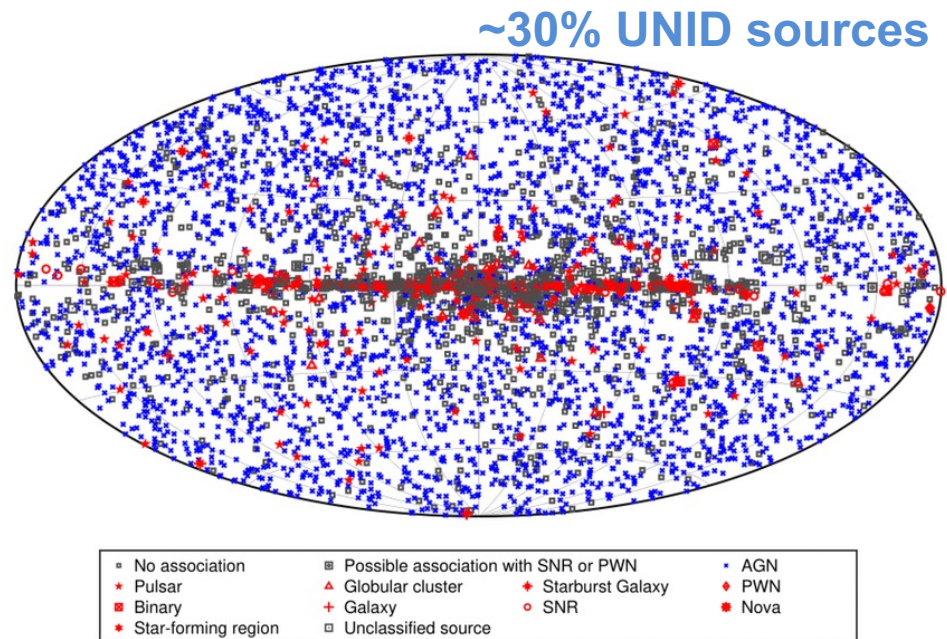
Since first 4FGL catalog release [ApJ Suppl 247, 33 (2020)], reporting 5,064 sources from 8 years of data, data have been stable, no new Galactic interstellar emission model, and analysis method has not evolved.

Catalog updates released every 2 years:

- 4FGL-DR2, 10 years, 5,788 sources
- 4FGL-DR3, 12 years, 6,658 sources ApJ Suppl, 260, 53 (2022)
- 4FGL-DR4, 14 years, 7,194 sources

currently available as a FITS file at FSSC; can be used for data analysis within the FermiTools: https://fermi.gsfc.nasa.gov/ssc/data/access/lat/14yr_catalog/

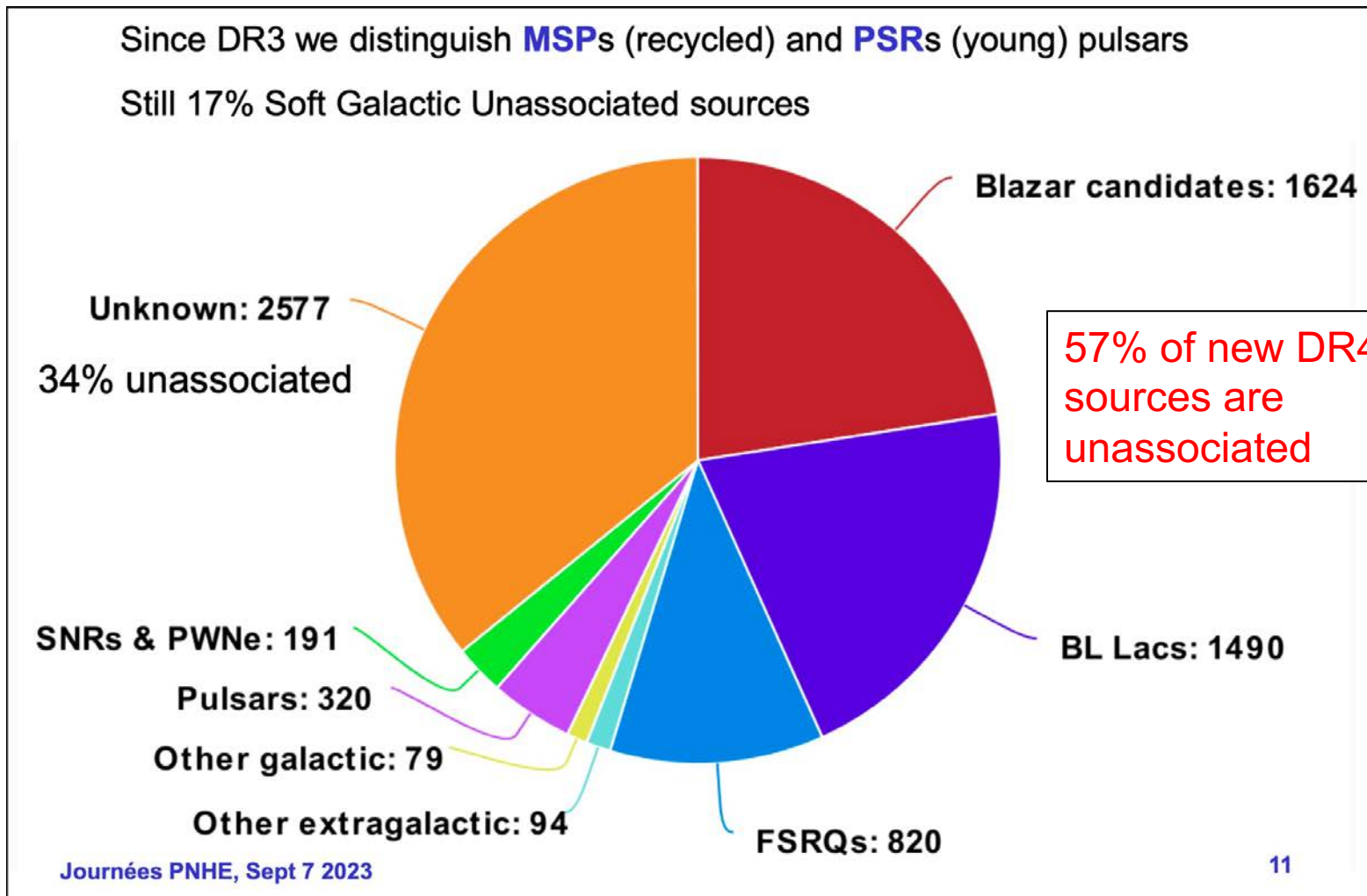
Description	Identified		Associated	
	Designator	Number	Designator	Number
Galactic center	GC	1	...	...
Young pulsars, identified by pulsations	PSR	135	...	...
Young pulsars, no pulsations seen in LAT yet	...	...	psr	2
Millisecond pulsars, identified by pulsations	MSP	120	...	...
Millisecond pulsars, no pulsations seen in LAT yet	...	...	msp	35
Pulsar wind nebula	PWN	11	pwn	8
Supernova remnant	SNR	24	snr	19
Supernova remnant / Pulsar wind nebula	SPP	0	spp	114
Globular cluster	GLC	0	glc	35
Star-forming region	SFR	3	sfr	2
High-mass binary	HMB	8	hmb	3
Low-mass binary	LMB	2	lmb	6
Binary	BIN	1	bin	6
Nova	NOV	4	nov	0
BL Lac type of blazar	BLL	22	bll	1435
FSRQ type of blazar	FSRQ	44	fsrq	750
Radio galaxy	RDG	6	rdg	39
Nonblazar active galaxy	AGN	1	agn	8
Steep spectrum radio quasar	SSRQ	0	ssrq	2
Compact steep spectrum radio source	CSS	0	css	5
Blazar candidate of uncertain type	BCU	1	bcu	1491
Narrow-line Seyfert 1	NLSY1	4	nlsy1	4
Seyfert galaxy	SEY	0	sey	2
Starburst galaxy	SBG	0	sbg	8
Normal galaxy (or part)	GAL	2	gal	4
Unknown	UNK	0	unk	134
Total	...	389	...	4112
Unassociated	...	...	...	2157



4FGL-DR4: 4th Fermi LAT Source Catalog update

<https://heasarc.gsfc.nasa.gov/w3browse/fermi/fermilpsc.html>

- Ballet et al. (2023), arXiv 2307.12546



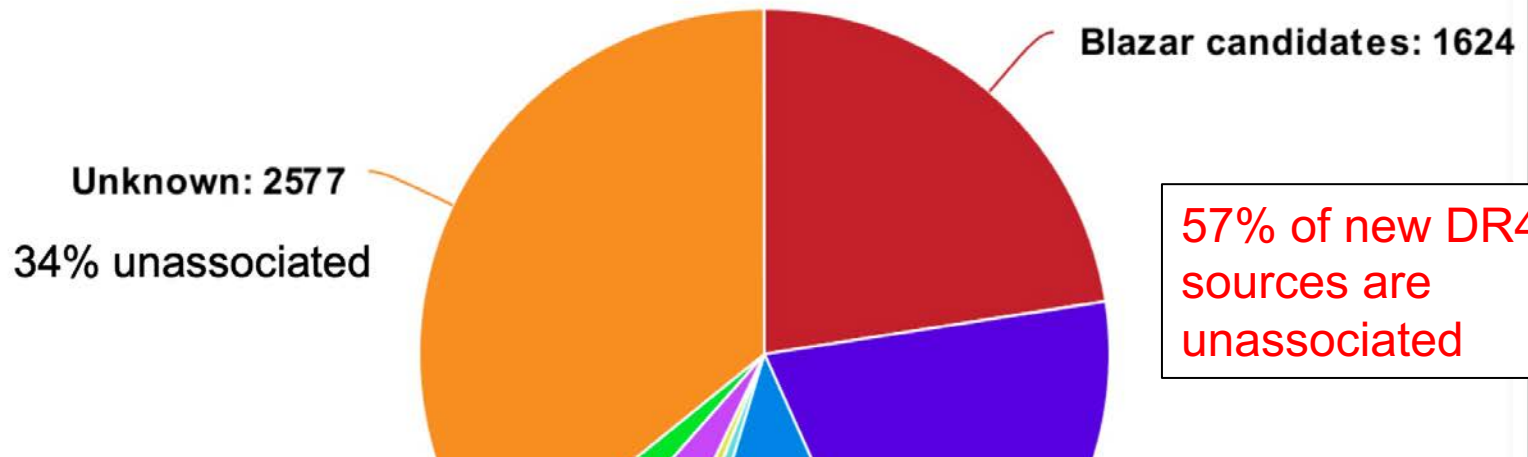
4FGL-DR4: 4th Fermi LAT Source Catalog update

<https://heasarc.gsfc.nasa.gov/w3browse/fermi/fermilpsc.html>

- Ballet et al. (2023), arXiv 2307.12546

Since DR3 we distinguish **MSPs** (recycled) and **PSRs** (young) pulsars

Still 17% Soft Galactic Unassociated sources



105 of the 199 DR4 sources at TS > 25 above 100 GeV are **not known TeV sources yet**

84 are BL Lacs.

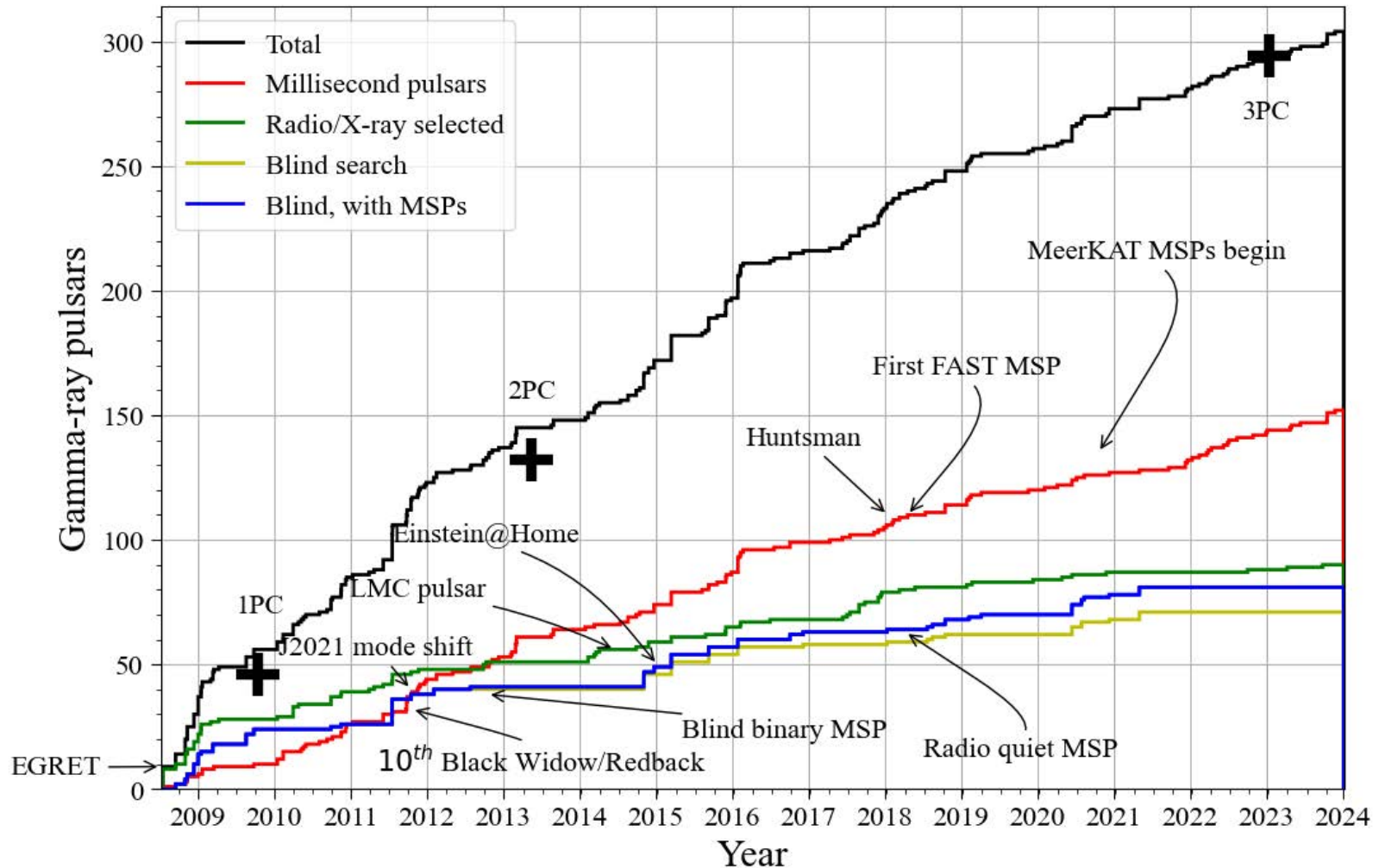
TS > 25	4FGL	DR3	DR4
Above 30 GeV	618	907	1028
Above 100 GeV		172	199

FSRQs: 820

3PC: 3rd Pulsar Catalog

Smith, et al. (Fermi LAT Collaboration), accepted ApJ Suppl. (2023)

"This catalog thus reports roughly 340 gamma-ray pulsars *and candidates*, 10% of all known pulsars, compared to ≤ 11 known before Fermi."



3PC: 3rd Pulsar Catalog

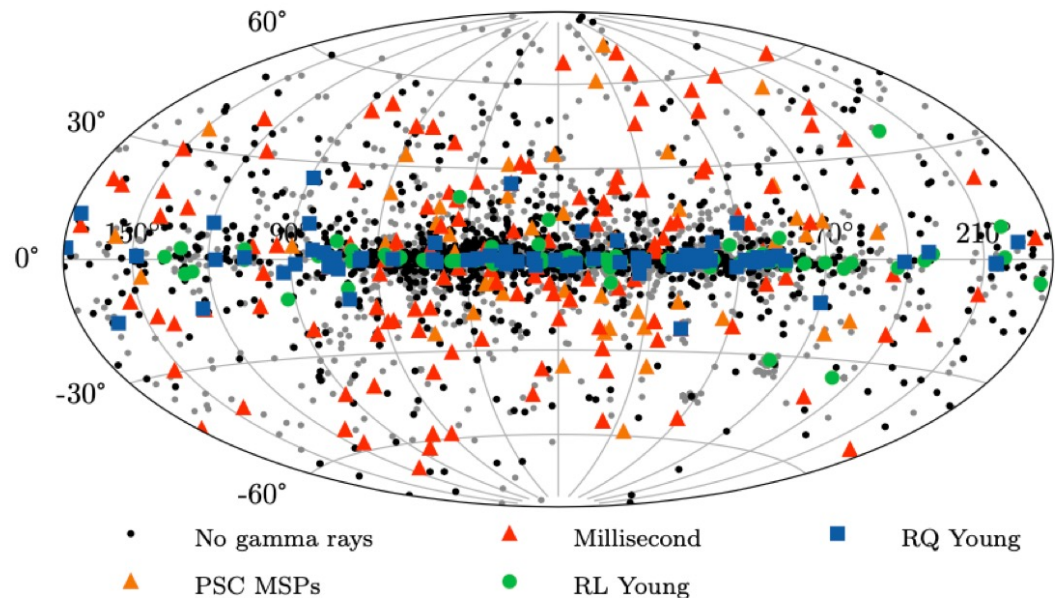
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"This catalog thus reports roughly 340 gamma-ray pulsars *and candidates*, 10% of all known pulsars, compared to ≤ 11 known before Fermi."

number of γ -ray pulsar detections surpassed all but the most optimistic predictions

Contributing to this population are

- "garden variety" young energetic pulsars,
- radio-quiet pulsars discovered with blind searches,
- heavily-obscured short period binary millisecond pulsars; i.e. "spiders",
- very gamma-faint radio pulsars
- very stably spinning MSPs



- 3PC catalog provides gamma-ray pulsar ephemerides and various properties; for more, go to the FSSC website at

https://fermi.gsfc.nasa.gov/ssc/data/access/lat/3rd_PSR_catalog/

3PC: 3rd Pulsar Catalog

The 3PC is also available as an overlap option at the Fermi LAT Light Curve Repository

<https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/>

Data Overlays	
LAT Point Source Catalog (4FGL) Abdollahi et al. 2020 - 5523 Sources	<input checked="" type="checkbox"/>
2nd LAT GRB Catalog (2FLGC) Ajello et al. 2019/GCN - 186 Detections	<input type="checkbox"/>
IceCube Neutrino Alerts GCN/AMON Notices	<input type="checkbox"/>
FAVA Flare Catalog (2FAV) Abdollahi et al. 2017 - 4309 Flares	<input type="checkbox"/>
3rd LAT Pulsar Catalog (3PC) Smith et al. 2023 - 294 Pulsars	<input type="checkbox"/>



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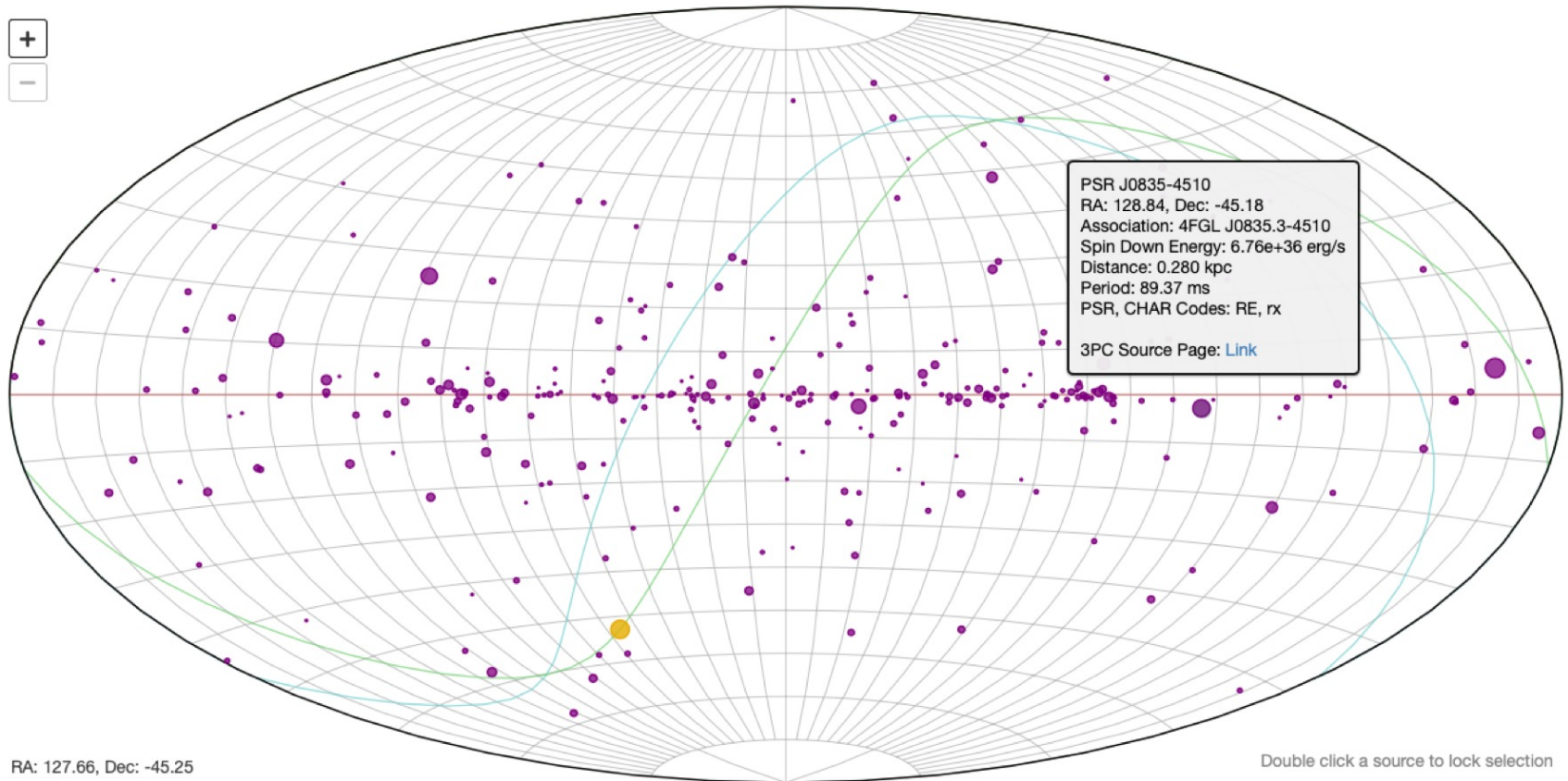
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3PC: 3rd Pulsar Catalog

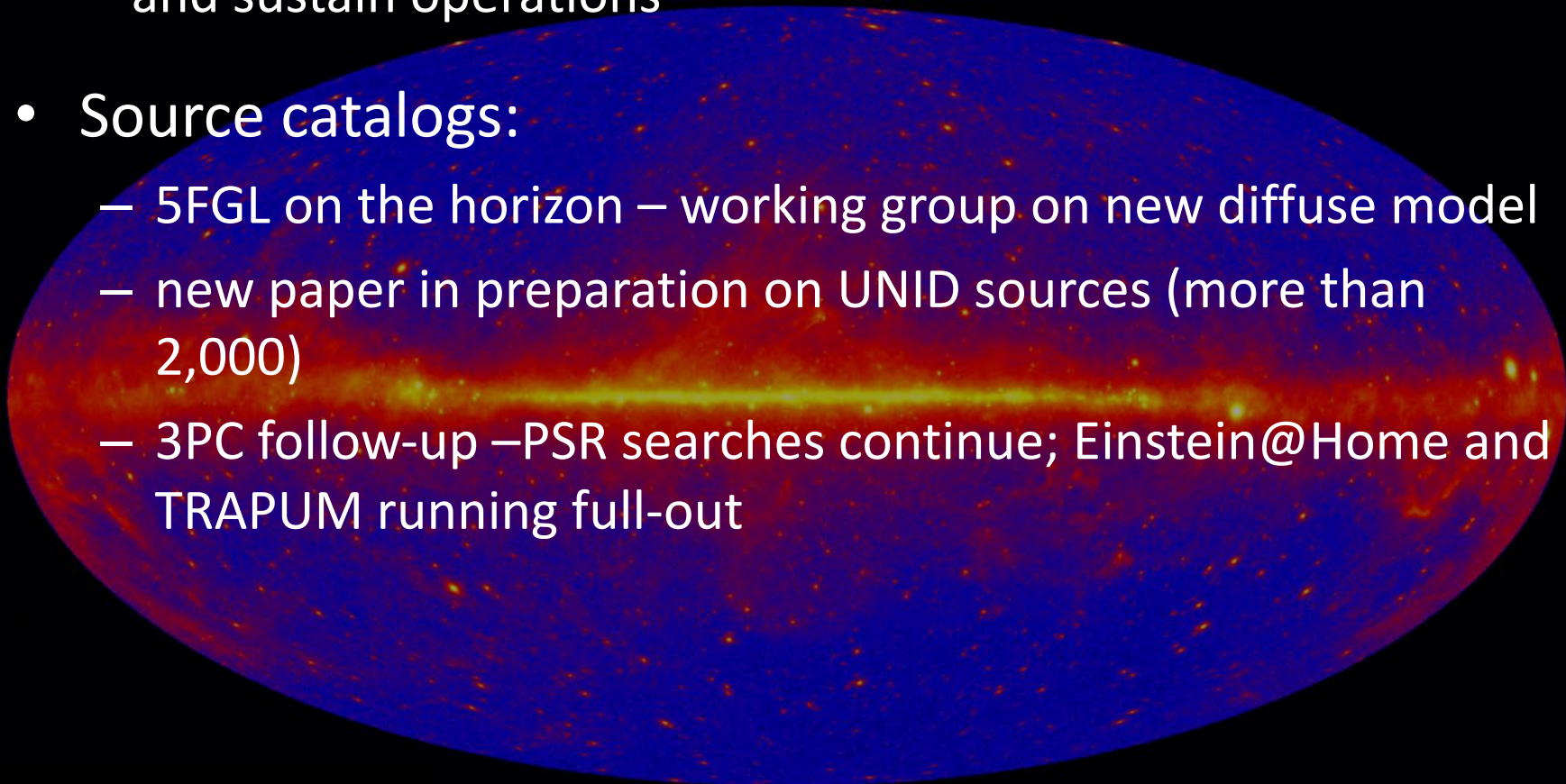
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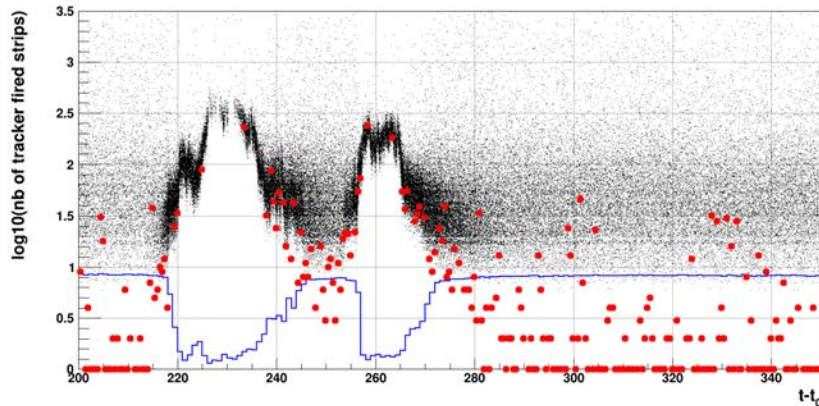
Fermi LAT: What's ahead?

- complete transition of data pipeline processing and computing infrastructure at SLAC by Spring 2024
 - and sustain operations
- Source catalogs:
 - 5FGL on the horizon – working group on new diffuse model
 - new paper in preparation on UNID sources (more than 2,000)
 - 3PC follow-up – PSR searches continue; Einstein@Home and TRAPUM running full-out



Status of the B.O.A.T.

- GRB221009A is the brightest GRB ever detected. It exhibited intense X-ray and soft gamma-ray flux during its main episode, rendering data from this period unusable for standard LAT analysis due to induced noise in all subsystems.



Black: number of tracker hits. Hard X-rays and soft gamma rays increased the number of hits in the tracker: extra noise.

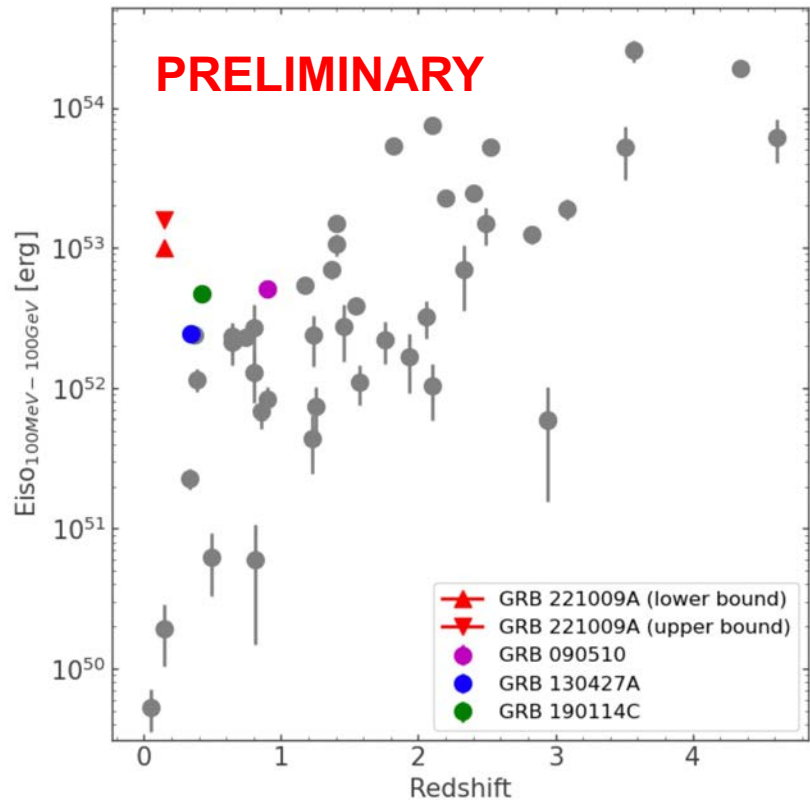
Blue: livetime. It approaches to zero during the brightest pulses (with larger noise)

Red: Periodic (2 Hz) trigger: follows the number of fired strips (which is unrelated from the actual >100 MeV gamma-ray flux)

- An effort from members of the Fermi LAT collaboration (Bruehl, Omodei) is ongoing with the goal of obtaining reliable flux and spectral index estimations during the affected interval.
 - Measuring TKR hit noise using the GBM spectrum as a proxy for hard X-ray/soft gamma ray flux
 - Using the Earth limb to calibrate the efficiency of the LAT

Status of the B.O.A.T.

- Analysis is still ongoing: but we can recover the flux and spectral indexes during the main episode:
 - Very important to constrain total energetics, and constraining models



GRB 221009A is a rare event
(comparable to $z=1.5$ GRBs)