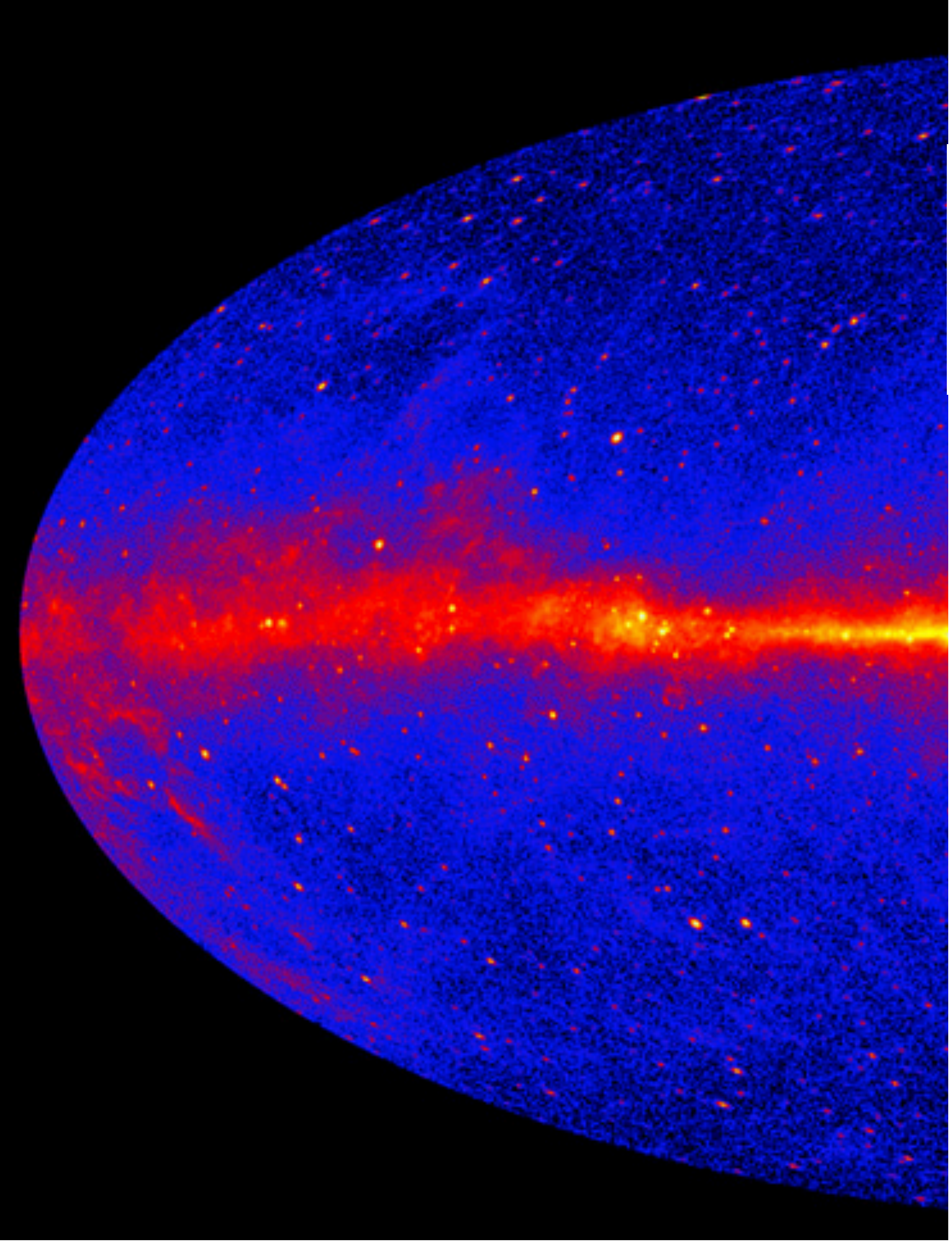


Observation of the sky with gamma-ray from space:

16 years of discoveries with Fermi Large Area Telescope and Italian AGILE Satellite

Sara Cutini

INFN Perugia, Italy

On behalf of the *Fermi* LAT Collaboration and with courtesy of *Carlotta Pittori (AGILE collaboration)*

Road map of gamma-ray astronomy

The first gamma-ray telescope in **Explorer 11**,picked up fewer than 100 gamma-ray photons coming isotropically from the sky

OSO-3
It detected 621 events attributable to cosmic gamma rays.

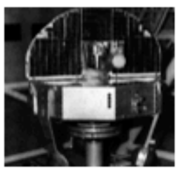
SAS-2 and the **Cos-B** provided for the first time and entire view of gamma rays sky, detected the first gamma-ray sources.

EGRET onboard **CGRO**
it was able to create a detailed map of the "entire high-energy gamma-ray sky. The T 3EG Catalog consists of 271 sources

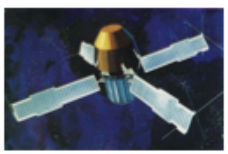
AGILE
Premio Bruno Rossi 2012 for the detection of the flaring Crab

1961

1967

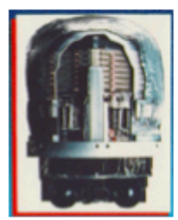


1972

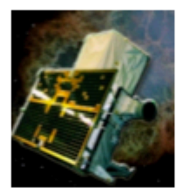


1975

1991



2007



2008 FERMI

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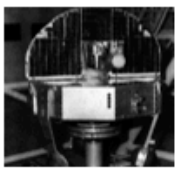

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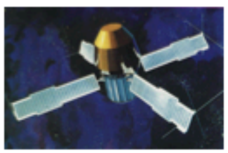
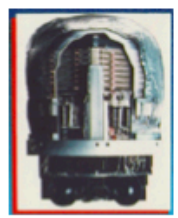
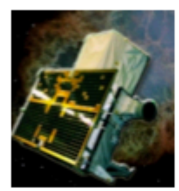


1975

1991



2007



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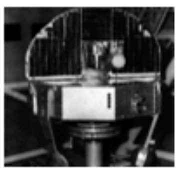

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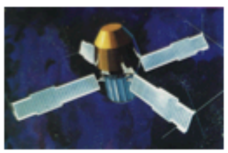

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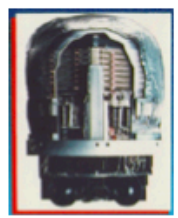
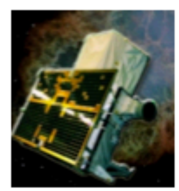


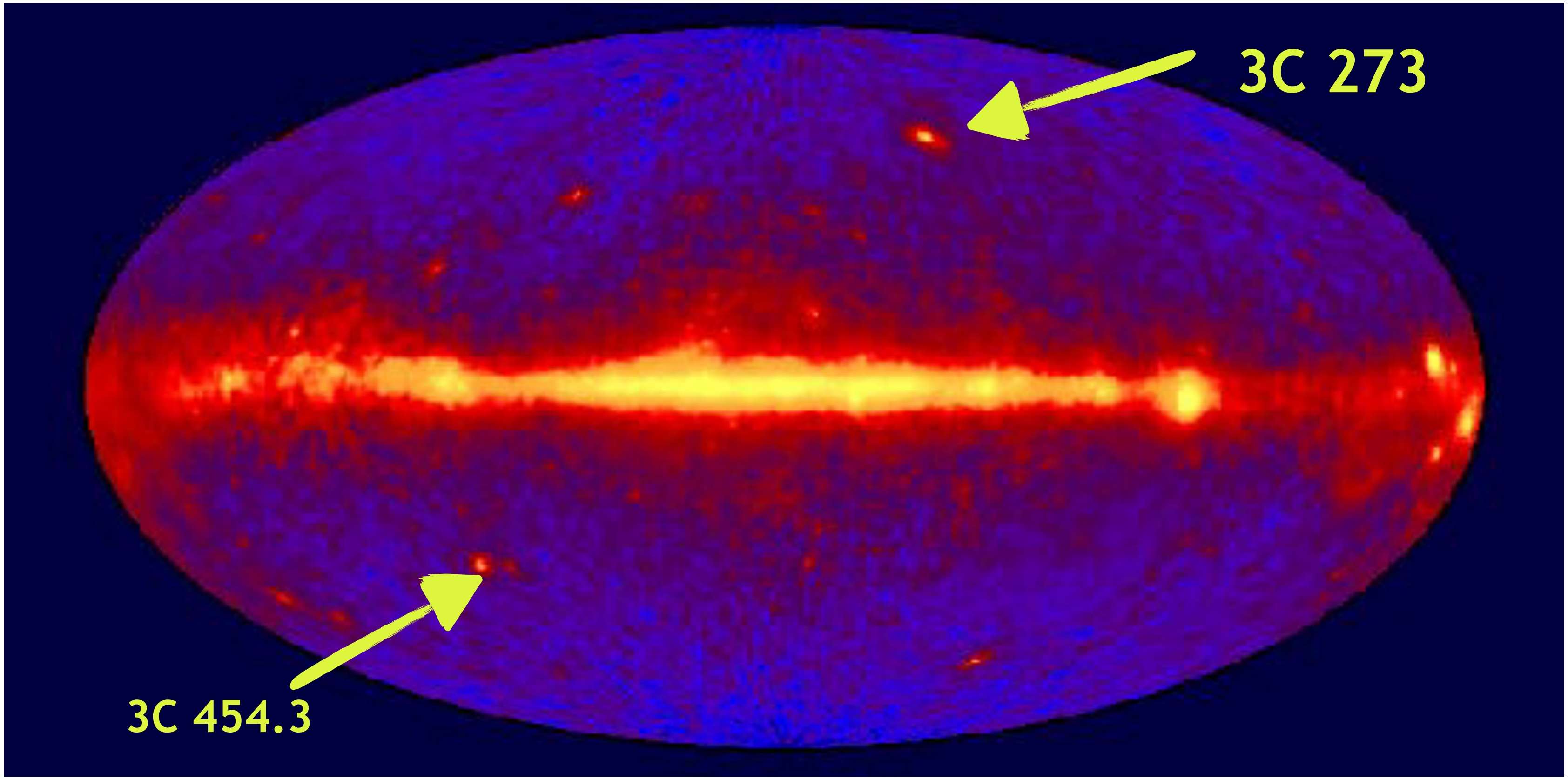
2007



2008 FERMI

First image of gamma-ray sky with EGRET

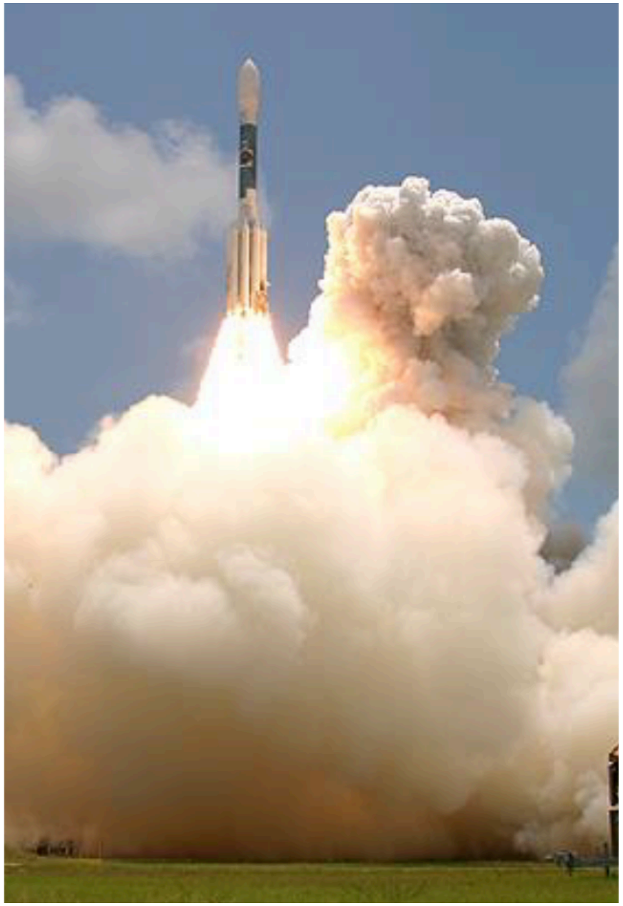
Third EGRET Catalogue ~200 gamma-ray sources —> 27 possible AGN/blazar identifications



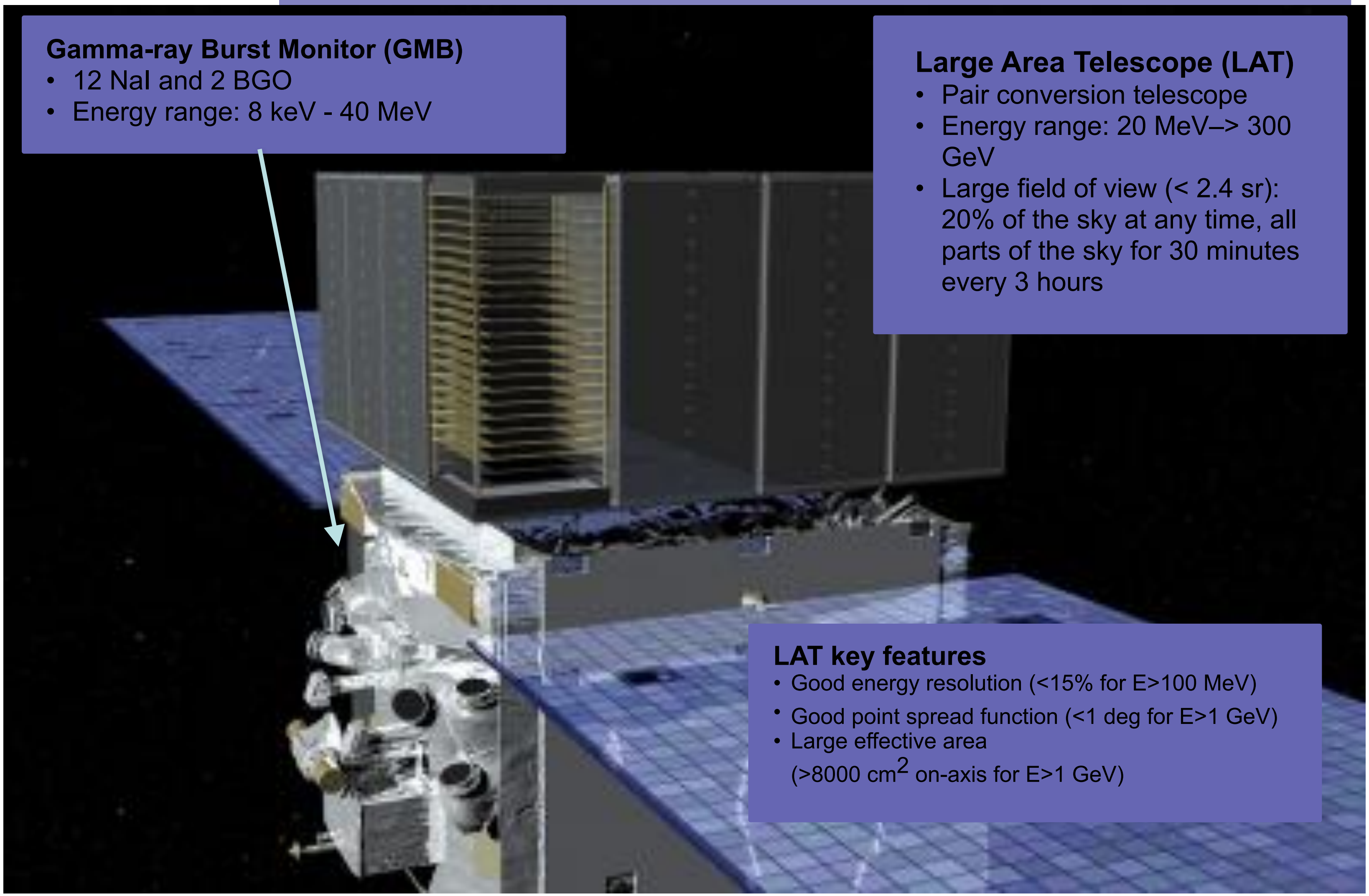
Fermi Gamma-ray Space Telescope

Launched by NASA on 2008 June 11, from Cape Canaveral, Florida. Science mission started on August 2008.

International collaboration between NASA and DOE in the US and agencies in France, Germany, Italy, Japan and Sweden



Fermi Gamma-ray Space Telescope



Gamma-ray Burst Monitor (GMB)
- 12 NaI and 2 BGO
- Energy range: 8 keV - 40 MeV

Large Area Telescope (LAT)
- Pair conversion telescope
- Energy range: 20 MeV–> 300 GeV
- Large field of view (< 2.4 sr): 20% of the sky at any time, all parts of the sky for 30 minutes every 3 hours

LAT key features
- Good energy resolution (<15% for E>100 MeV)
- Good point spread function (<1 deg for E>1 GeV)
- Large effective area (>8000 cm^2 on-axis for E>1 GeV)

Atwood, W. B 2009ApJ...697.1071A

Fermi in numbers

Fermi-LAT in data

- 99792 orbits since launch
- 6237 days of science mission (2008 Aug. 4)
- LAT has 99.8% runtime

Event counts

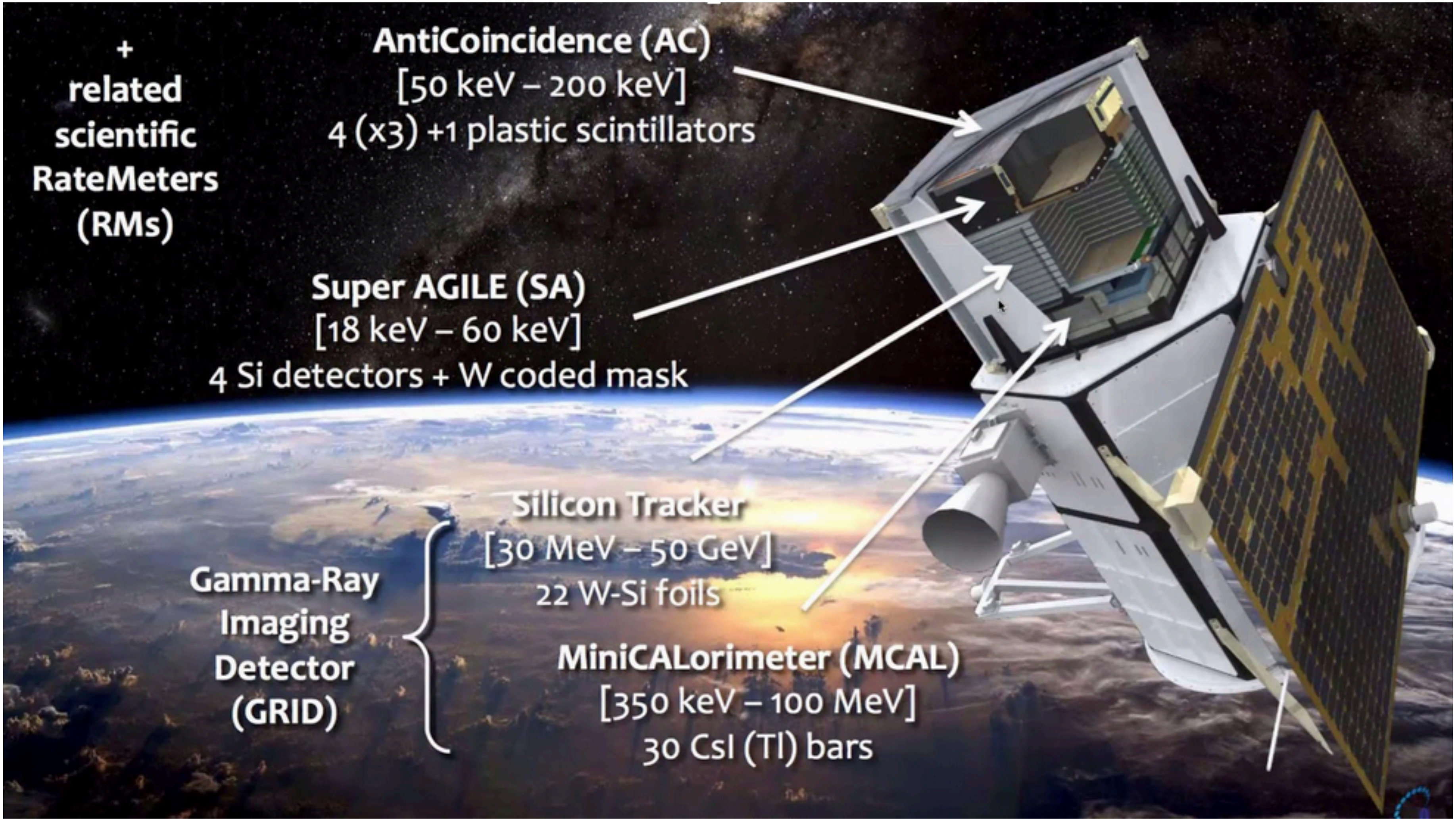
- ~ 8.5 billion triggers on the LAT
- ~ 200 billion events downlinked
- ~ 5 billion LAT events available at the FSSC

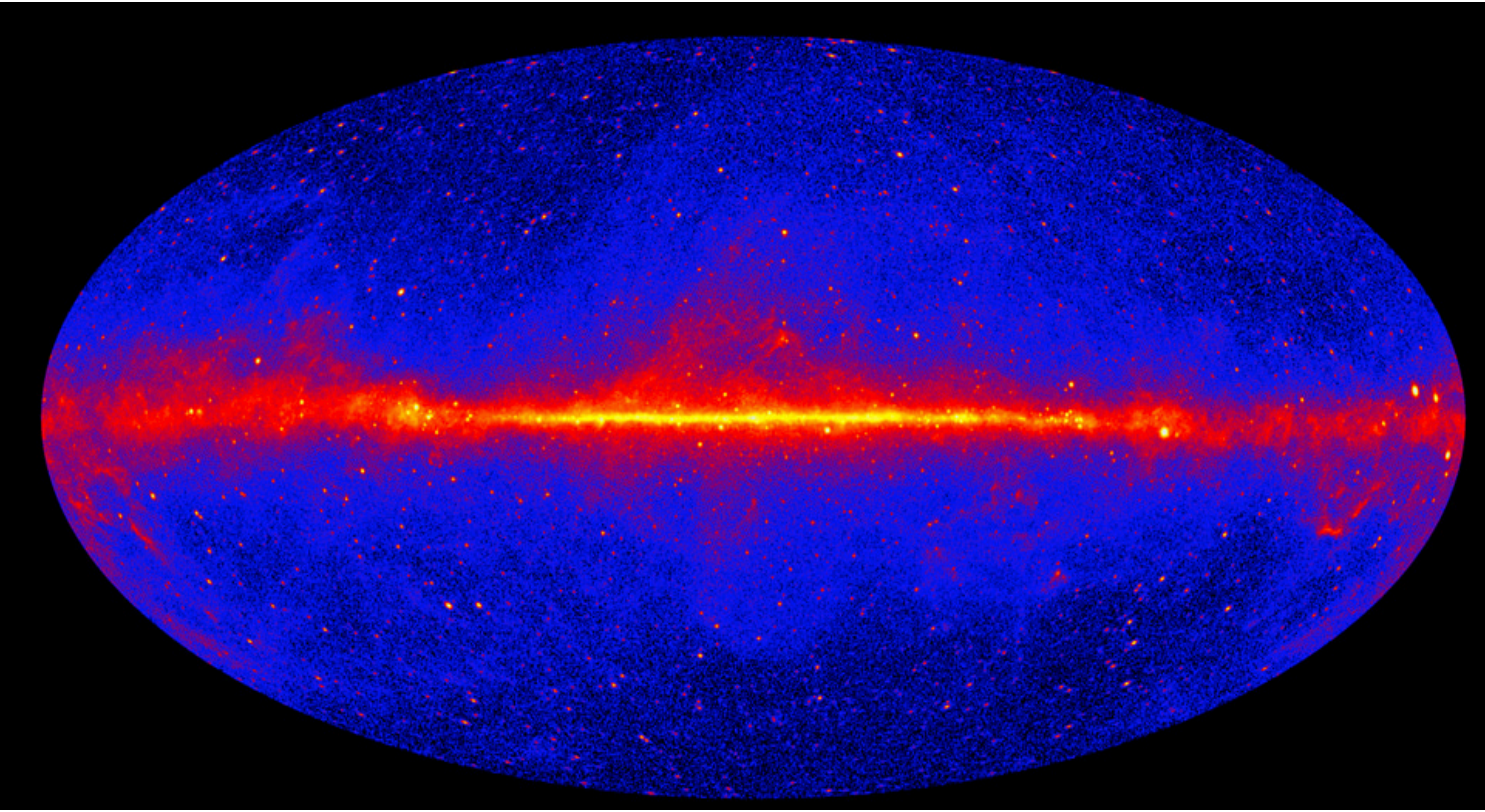
Short notice publications (LAT):

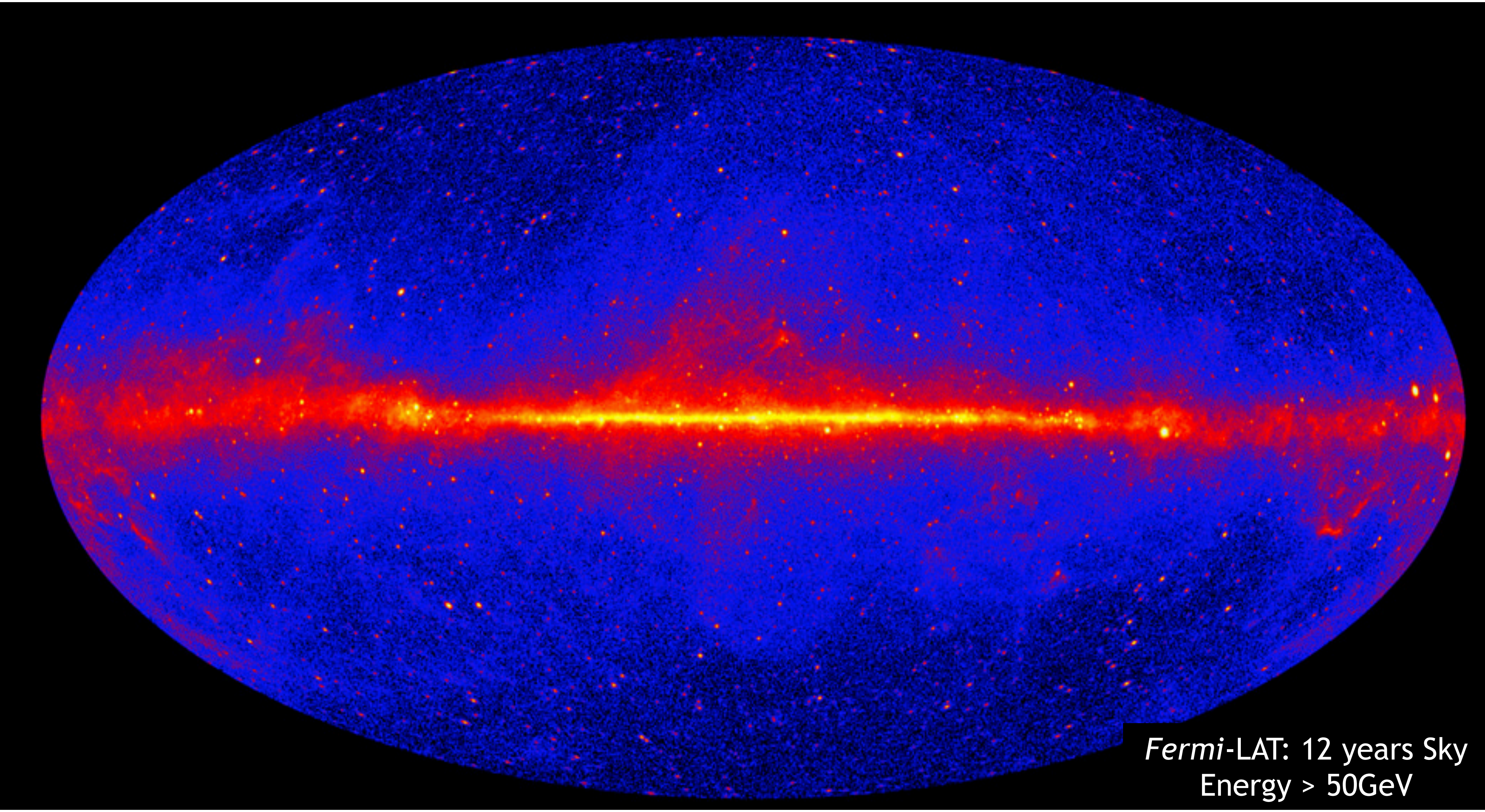
788 ATels of flaring source activity

488 GCN circular on GRB and others of LAT detections

AGILE

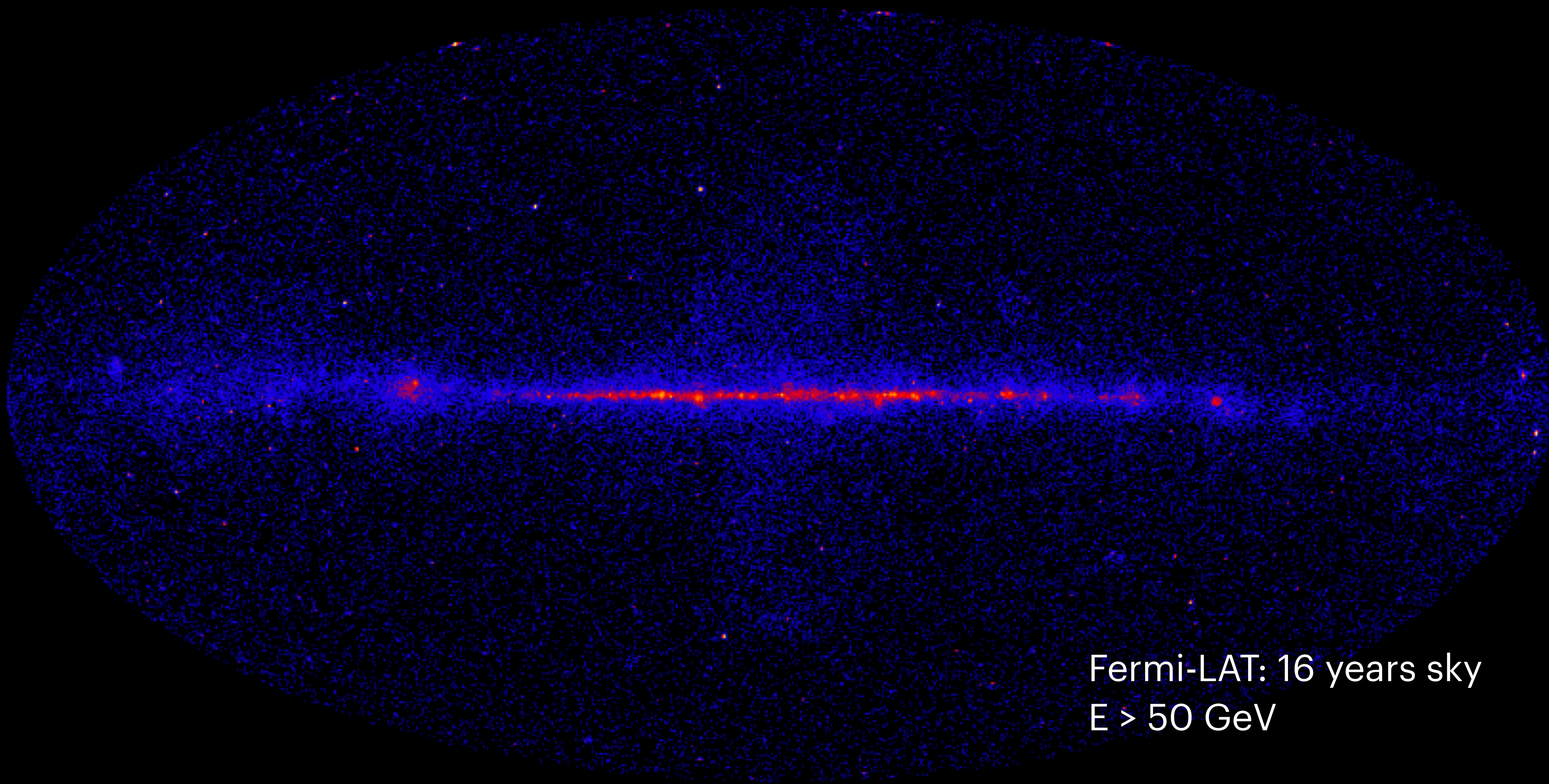

+ related scientific RateMeters (RMs)
AntiCoincidence (AC)
[50 keV – 200 keV]
4 (x3) +1 plastic scintillators
Super AGILE (SA)
[18 keV – 60 keV]
4 Si detectors + W coded mask
Gamma-Ray Imaging Detector (GRID)
Silicon Tracker
[30 MeV – 50 GeV]
22 W-Si foils
MiniCALorimeter (MCAL)
[350 keV – 100 MeV]
30 CsI (Tl) bars




Fermi-LAT: 12 years Sky
Energy > 50GeV

γ-ray Sky

Preliminary



γ-ray Sky

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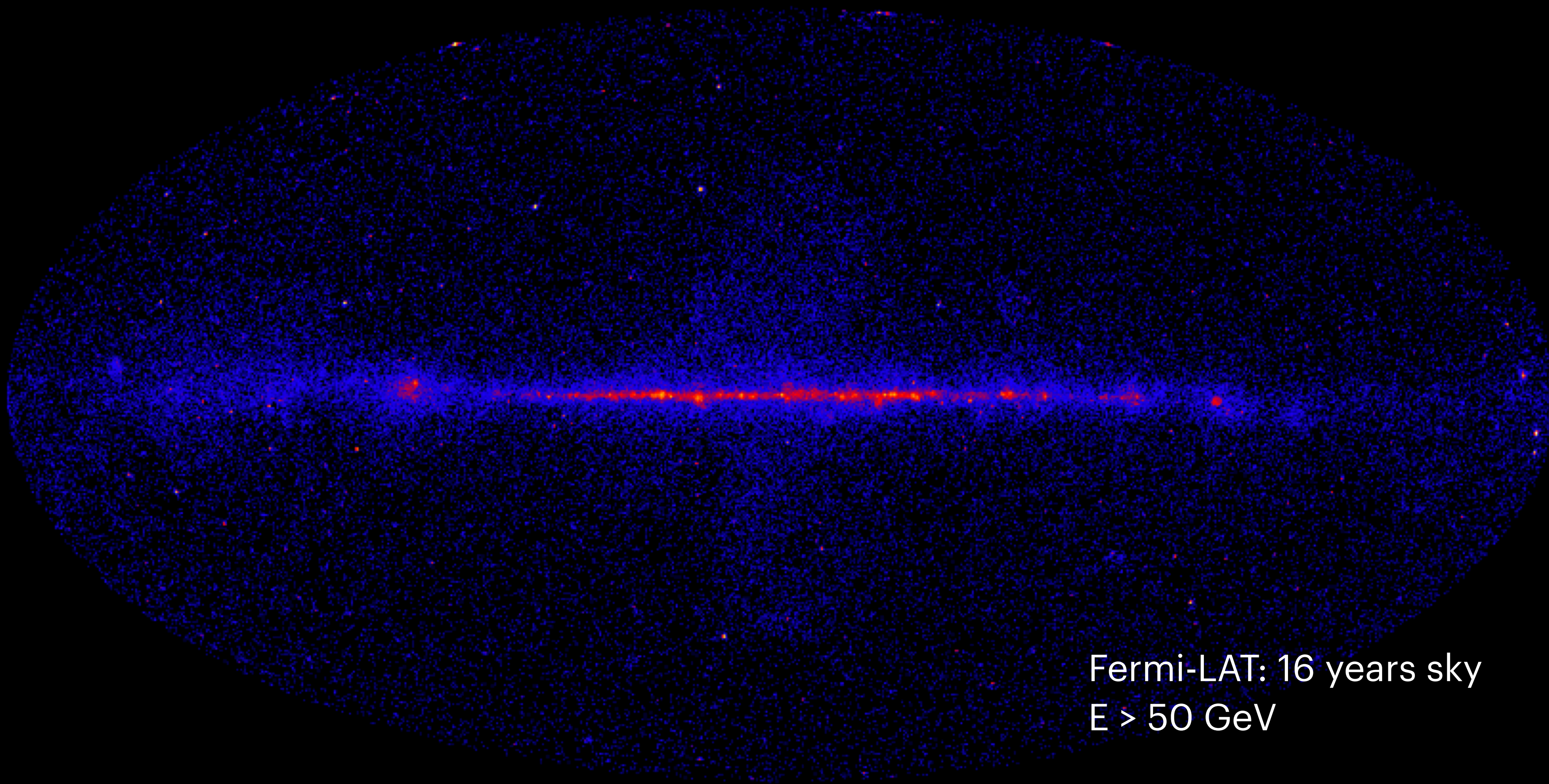
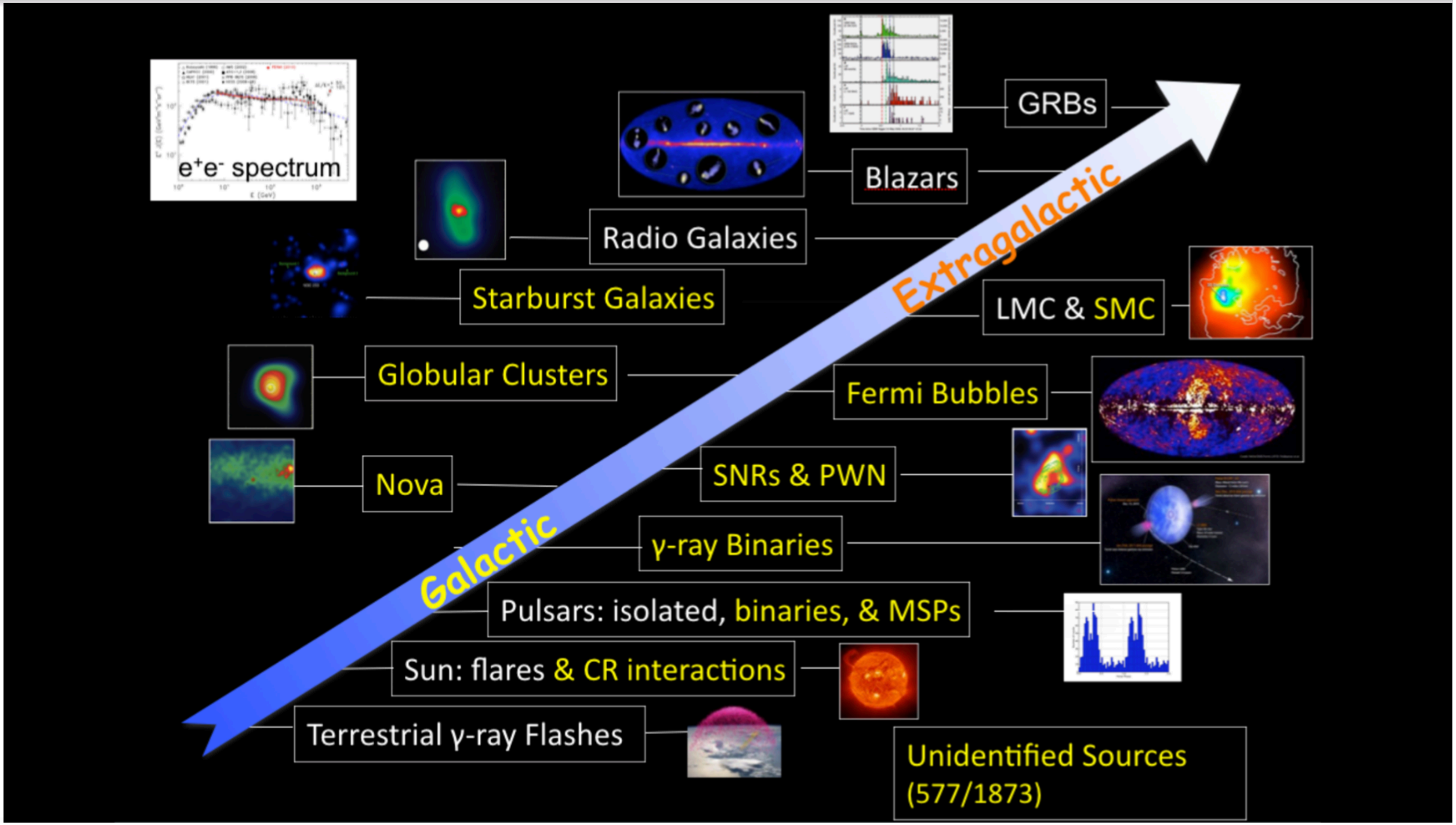
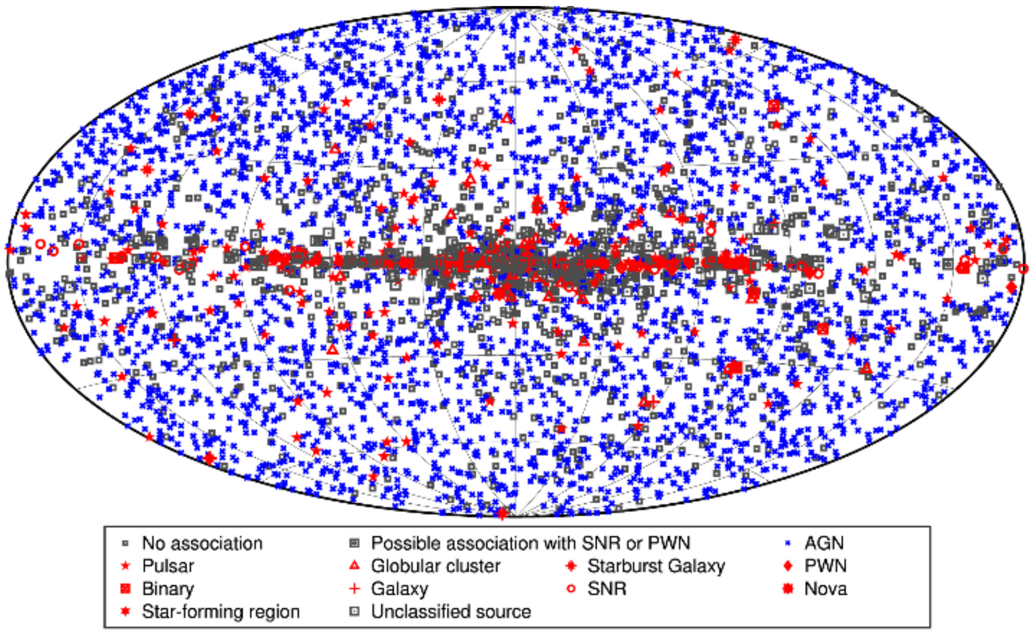


Gamma-ray science menù



4th Fermi-LAT Source Catalog



4FGL-DR4 catalog contains 7195 gamma-ray sources [1]
14 years of Fermi LAT data
50 MeV < E < 1 TeV

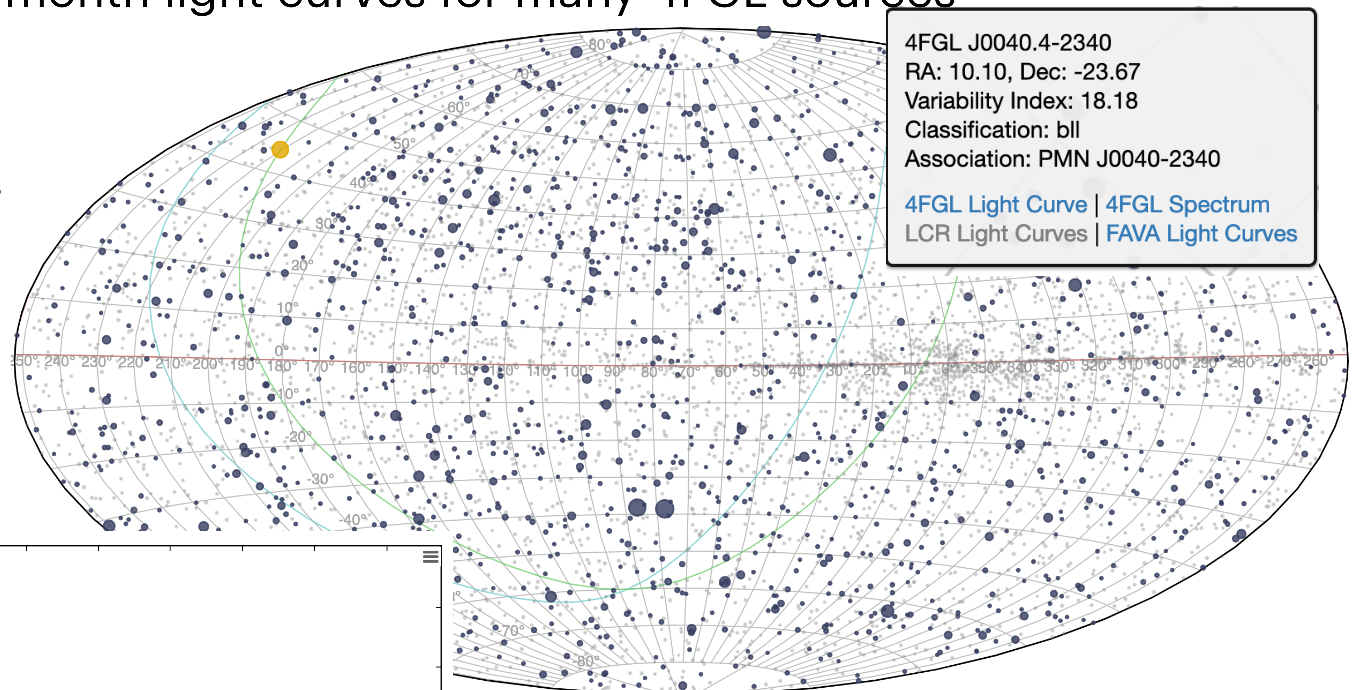
Ballet et al. 2023 , 10.48550/arXiv.2307.12546

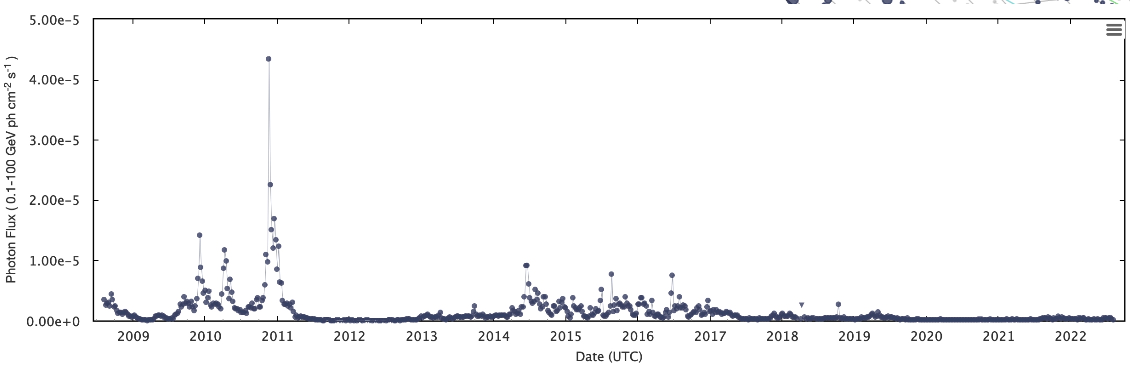
Fermi-LAT catalog included source not seen before in gamma-ray:
non-AGN galaxies, globular clusters, high-mass binaries, novae and star forming regions
Some source classes are more populated than expected:
milliseconds pulsars, radio quite pulsars and high redshift AGNs
~30% of sources are still unassociated:
new type of gamma-ray emitters?

Fermi light curve repository online

https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/about.html

- Provides 3 day, 1 week and 1 month light curves for many 4FGL sources
- Energy flux and photon flux
- Light curves derived from Maximum likelihood analysis

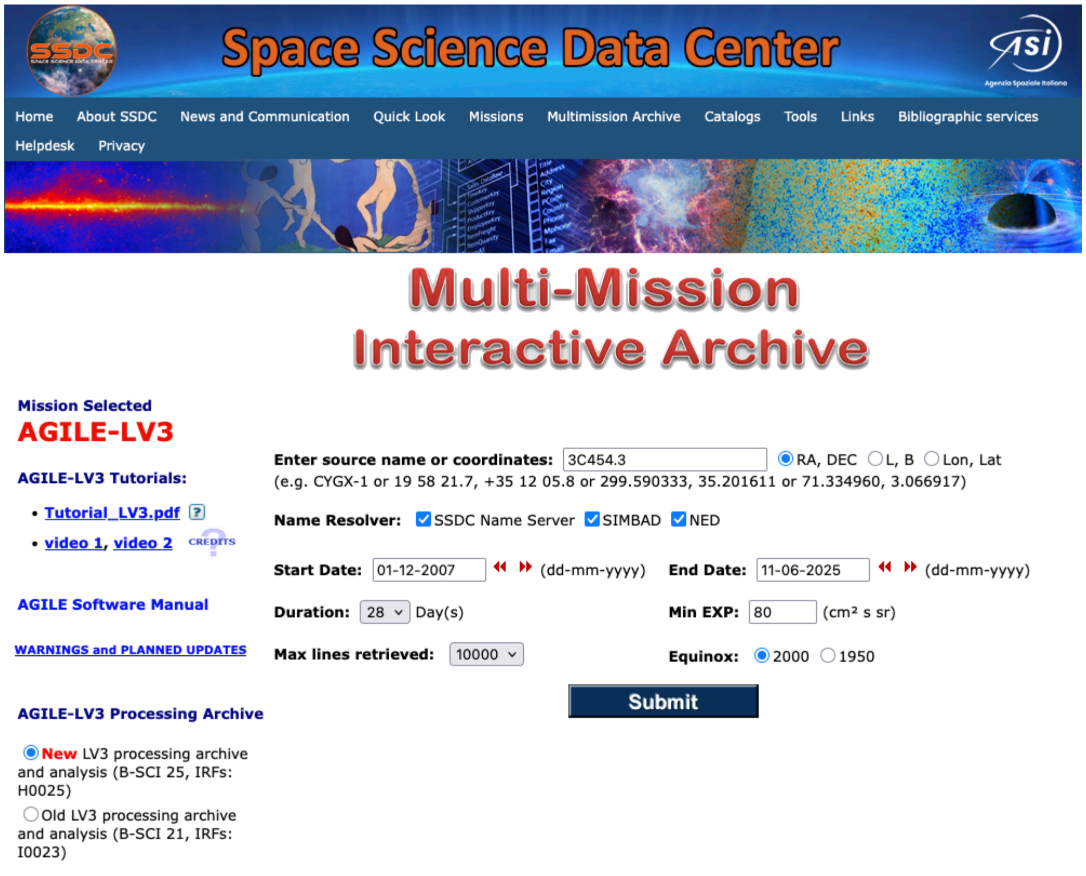


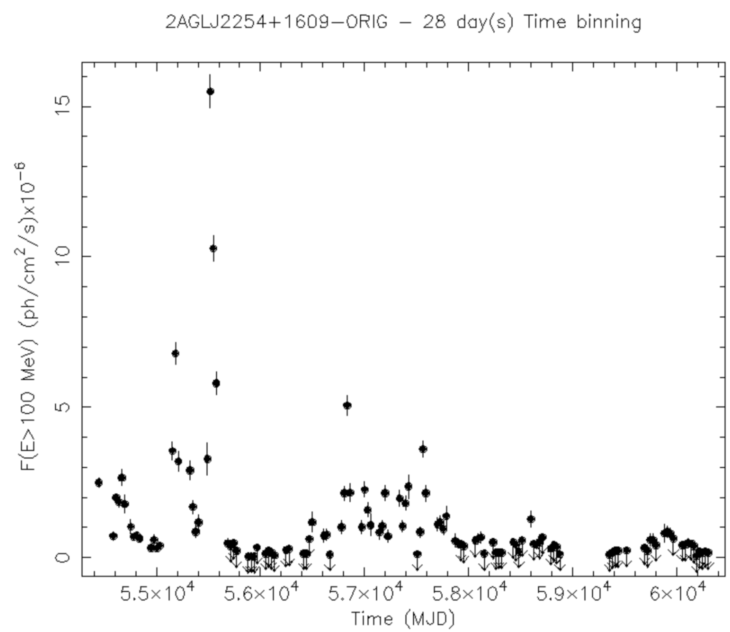


Abdollahi et al. 2023, 10.3847/1538-4365/acbb6a

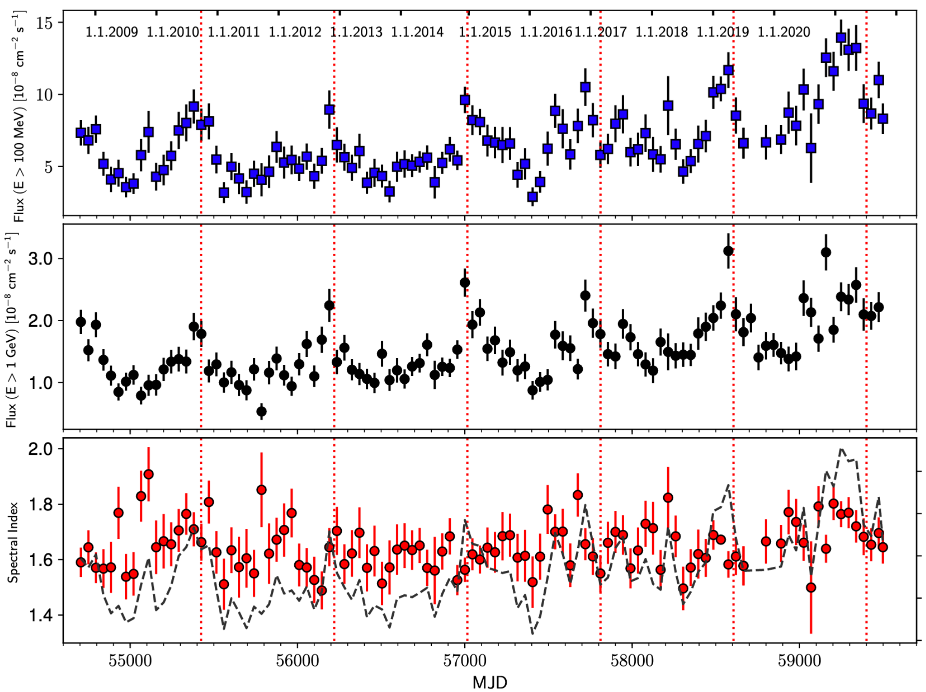
AGILE Light Curve interactive analysis

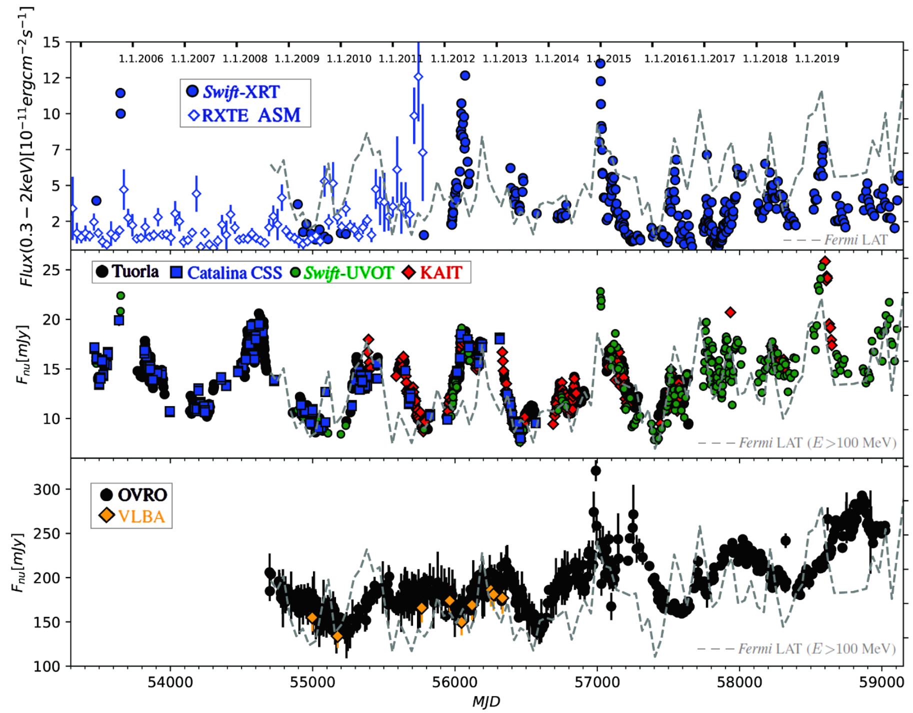
https://www.ssdc.asi.it/mmia/index.php?mission=agilelv3mmia





PG 1553+113 periodicity studies





- Confirmed the predicted maxima up to now
- Optical and radio LC shows a similar periodicity then gamma-ray one
    - Primary hypothesis —> super massive binary BH system

Abdollahi et al. 2023, 10.3847/1538-4357/ad64c5

Fermi-LAT catalogs of periodic sources

Preliminary

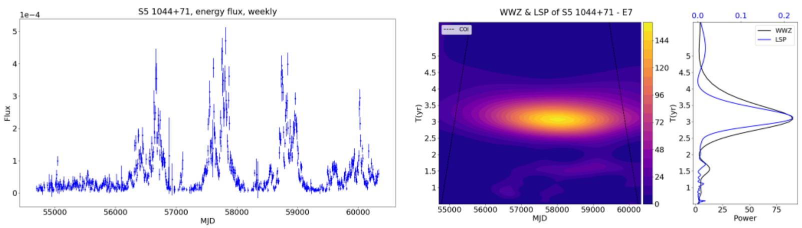
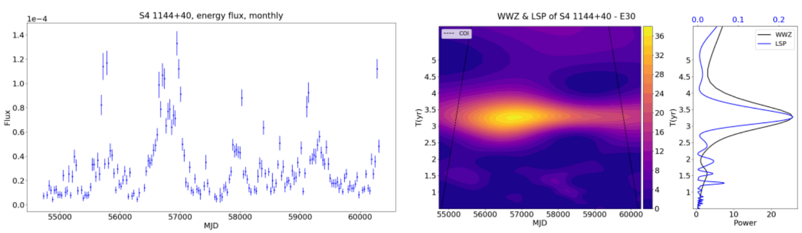
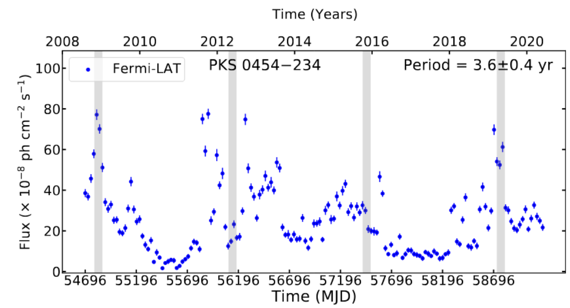


Figure 6.13: On the left, the light curve of S5 1044+71, in energy flux with monthly binning. On the right the local WWZ and on its side the global wavelet, black line, and the LSP, blue line. It exhibits a period of 3.1 *yr* with a significance $> 4.7\sigma$ from E13 simulations.



Source Name	Period (yr)	Nσ
PKS 0215+015	3.4	3.5σ
4C +28.07	3.4	3.3σ
PKS 0405-385	2.6	3σ
PKS 0426-380	3.7	3.4σ
PKS 0454-234	3.4	3.5σ
TXS 0518+211	3	$> 4.7\sigma$
OJ 014	4.2	$> 4.7\sigma$
S4 0814+42	2.2	$> 4.7\sigma$
S5 1044+71	3.1	$> 4.7\sigma$
S4 1144+40	3.3	$> 4.7\sigma$
B2 1215+30	2.8	3.5σ
PKS 1502+106	2.3	3.7σ
PG 1553+113	2.2	$> 4.7\sigma$
PKS 2155-304	1.6	3.7σ

Table 6.1: Sources with E13 significance $> 3\sigma$. We can highlight a golden sample of 6 sources with $> 4.7\sigma$, no higher peaks in 1 million simulations for each source.



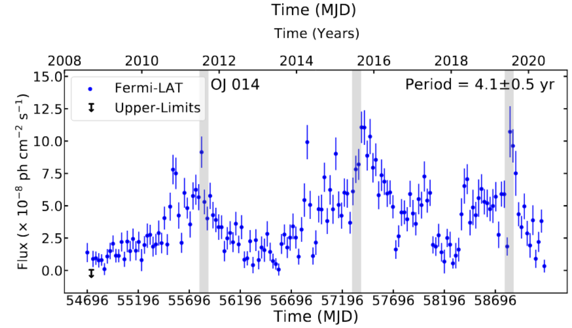
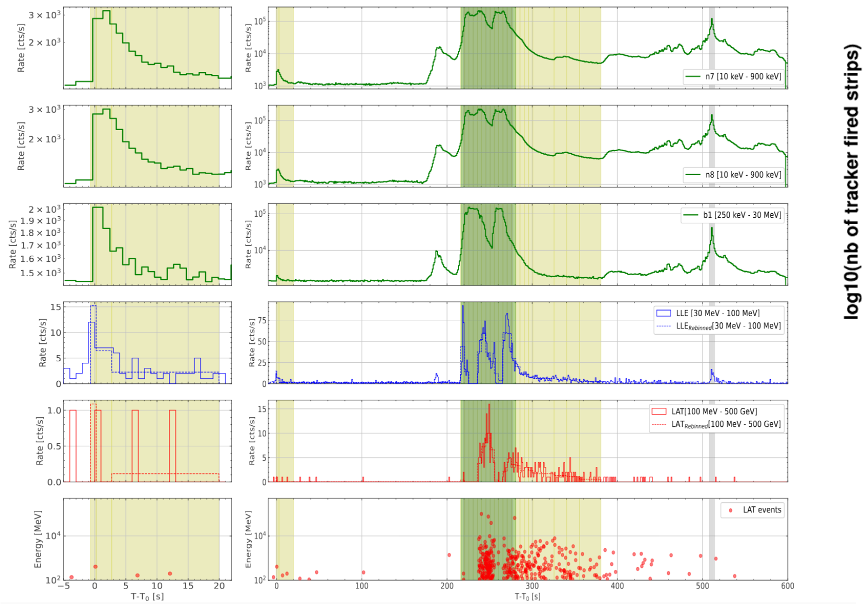


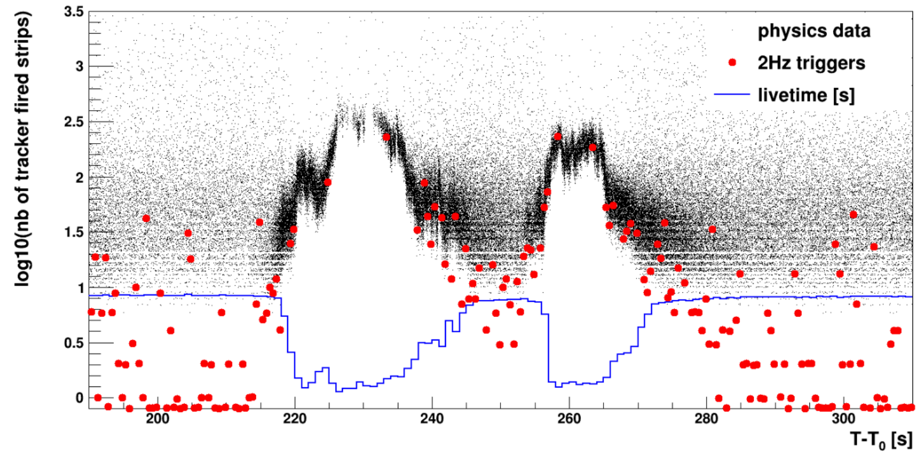
Table 1. *Top:* list of the 11 periodic-emission candidates, with their *Fermi*-LAT name, coordinates, AGN type, redshift, association name and period (in years) obtained with the periodicity-search pipeline. *Bottom:* list of 13 AGN with low significance period detection.

3FGL Source Name	RAJ2000	DecJ2000	Type	Redshift	Association Name	Period
J0043.8+3425	10.96782	34.42687	fsrq	0.966	GB6 J0043+3426	1.8
J0210.7−5101	32.68952	−51.01695	fsrq	1.003	PKS 0208−512	2.6
J0211.2+1051	32.81532	10.85811	bll	0.2	MG1 J021114+1051	1.7
J0521.7+2113	80.44379	21.21369	bll	0.108	TXS 0518+211	2.8
J0811.3+0146	122.86418	1.77344	bll	1.148	OJ 014	4.3
J1146.8+3958	176.73987	39.96861	fsrq	1.089	S4 1144+40	3.3
J1248.2+5820	192.07728	58.34622	bll	–	PG 1246+586	2.2
J1454.5+5124	238.93169	11.18768	bll	–	TXS 1452+516	2.1
J1555.7+1111	238.93169	11.18768	bll	0.36	PG 1553+113	2.2
J2158.8−3013	329.71409	−30.22556	bll	0.116	PKS 2155−304	1.7
J2258.0−2759	344.50485	−27.97588	fsrq	0.926	PKS 2255−282	1.3

Cristarella Orestano et al. In preparation
Penil et al 2020 10.3847/1538-4357/ab910d,
Penil et al 2023, 10.1093/mnras/stae594

GRB 221009A: The BOAT

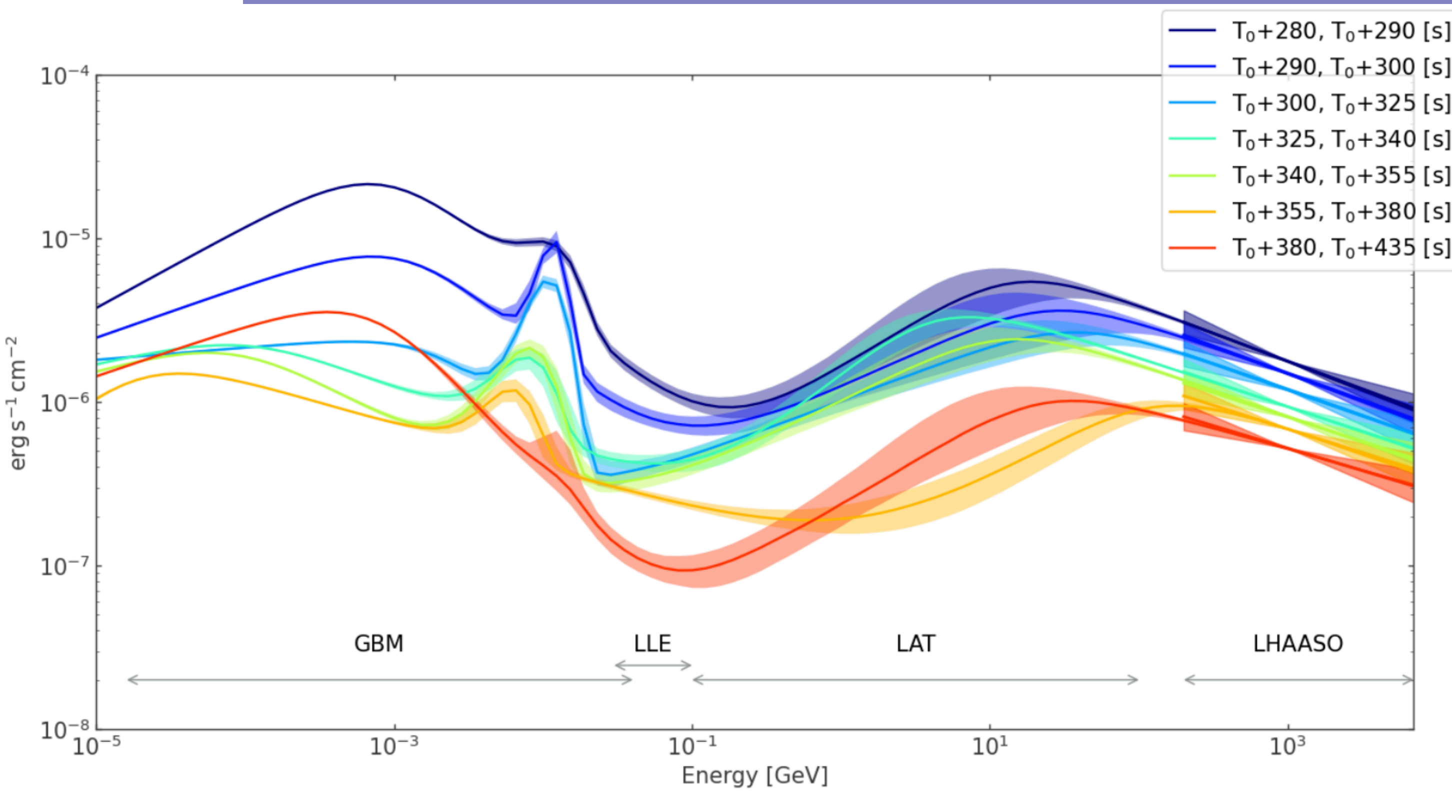




Axelsson et al 2024 10.3847/1538-4365/ada272
S. Lesage et al. 2023, 10.3847/2041-8213/ace5b4

The prompt phase of GRB 221009A lasted a few hundred seconds. It was so bright that we identify a bad time interval of 64 s caused by the extremely high flux of hard X-rays and soft gamma rays

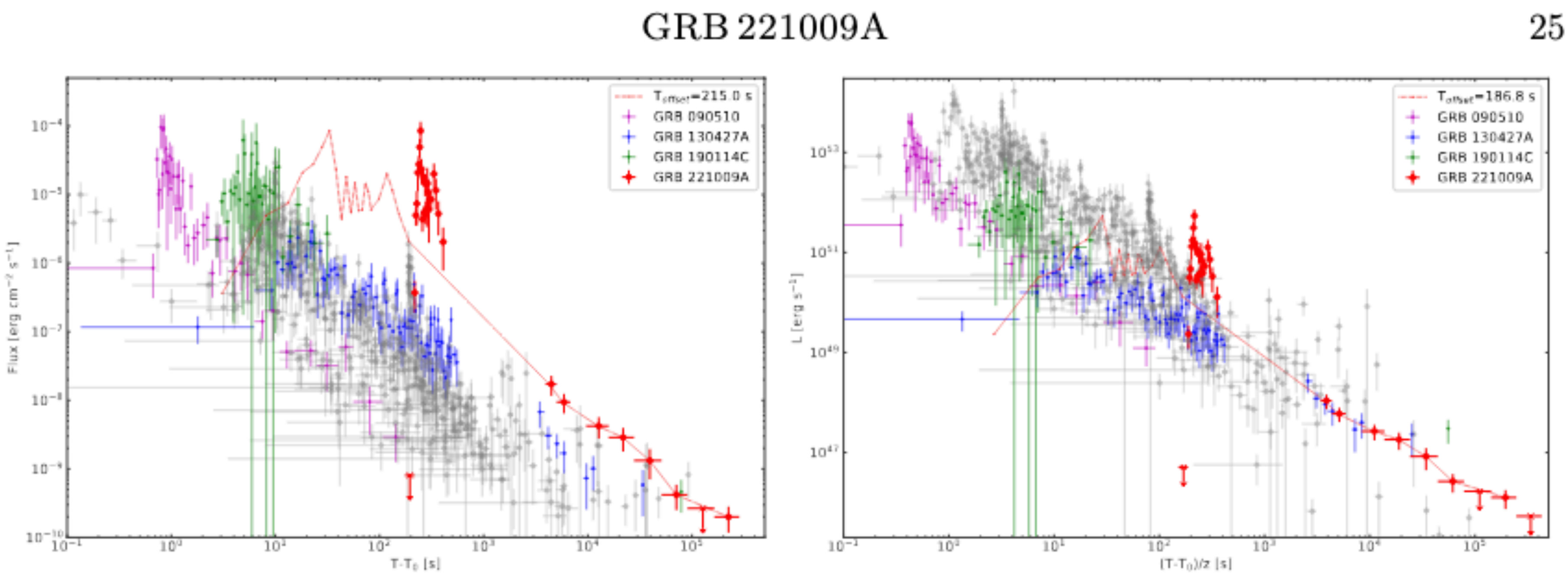
GRB 221009A: The BOAT



Axelsson et al 2024 10.3847/1538-4365/ada272
S. Lesage et al. 2023, 10.3847/2041-8213/ace5b4

The overall spectrum exhibits a characteristic two-bump structure typical of synchrotron and SSC, In addition, a Gaussian line is statistically significant in the first five intervals, and only marginally significant (or not significant) in the last two.

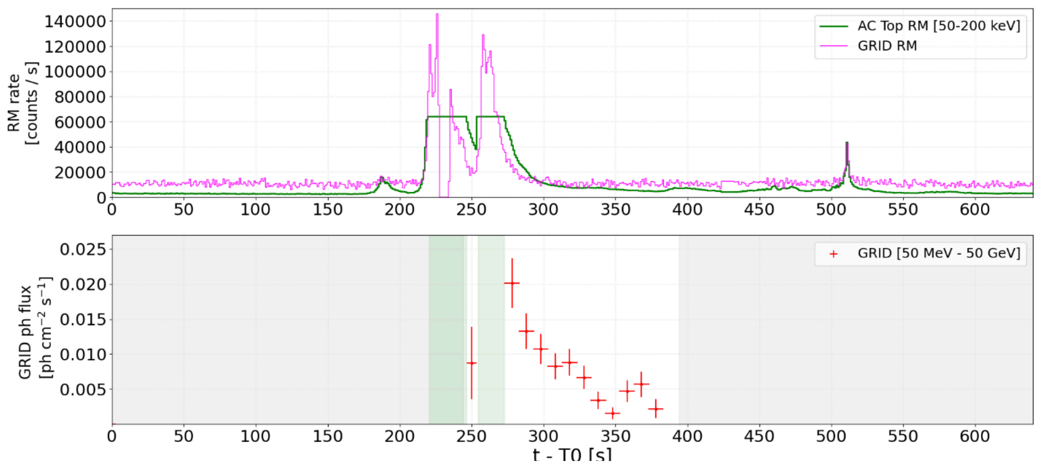
GRB 221009A: The BOAT

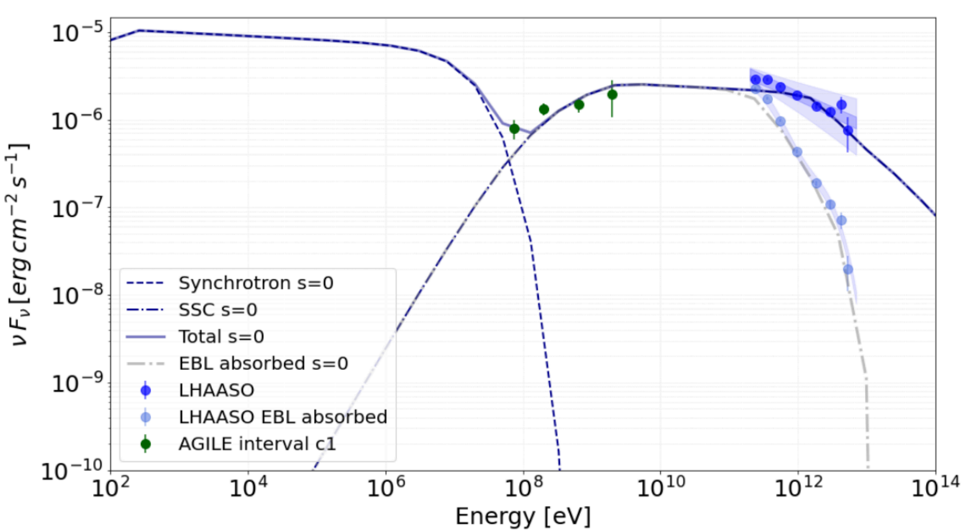


Roberts et al. 2021 2021Natur.589..207R
Svinkin et al. 2021, 2021Nature.589..211S

Flux light curves (left panel) and rest-frame luminosity light curves (right panel) in the 100 MeV-100 GeV rest frame energy range for GRB 221009A (red) and for other LAT-detected GRBs with redshifts included in the 2FLGC. Three previous record-holder GRBs are highlighted in different marker colors. . GRB 221009A is particularly bright thanks to its proximity.

GRB 221009A: The BOAT





Very intense GeV gamma-ray emission is detected by AGILE in the prompt and early afterglow phase up to 10,000 seconds. During the prompt phase, the event shows spectrally different MeV and GeV emissions that are most likely generated by physical mechanisms occurring in different locations.

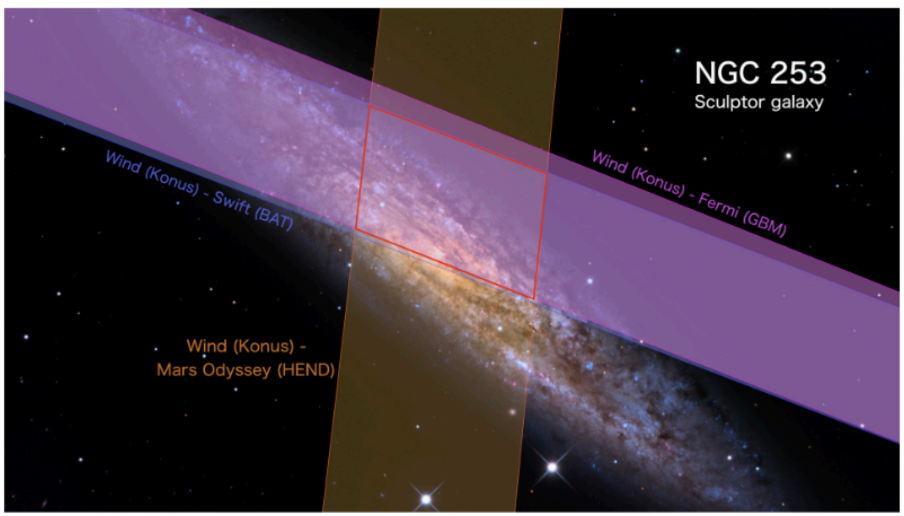
Tavani et al. 2023, 10.3847/2041-8213/acfaff

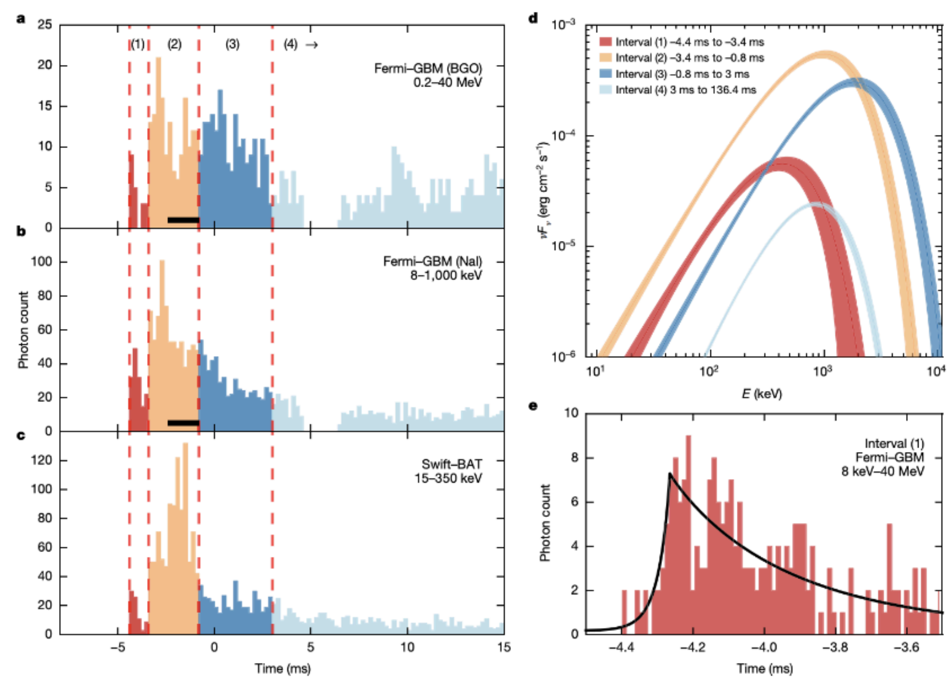
Magnetar Giant Flares

GRB 200415A

Transient on April 15th 2020

- GBM triggered at 08:48:05.56 UTC
- Localized with 20 square arcmin precision through interplanetary Network of gamma-ray detectors
- Burst most likely originated in star forming Sculptor Galaxy, DL~ 3.5 Mpc





Roberts et al. 2021 2021Natur.589..207R

Svinkin et al. 2021, 2021Nature.589..211S

Magnetar Giant Flares

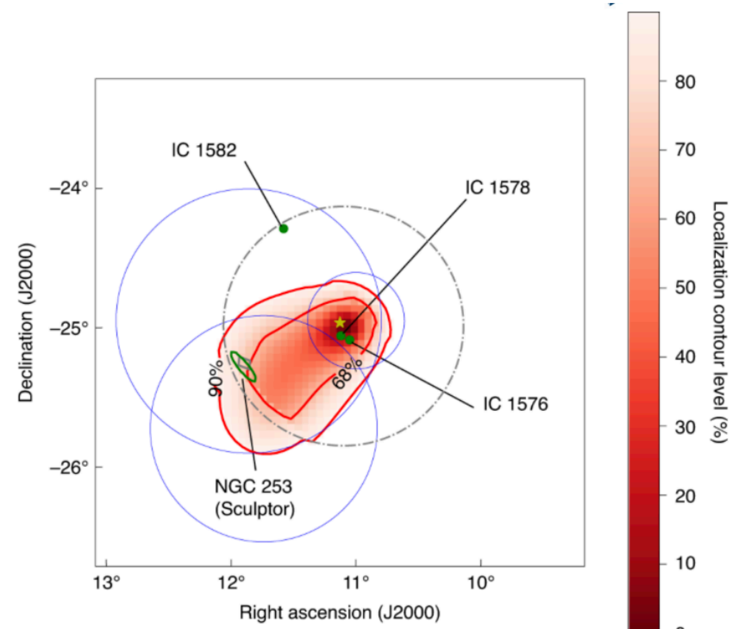
GRB 200415A

LAT detected 3 photons

Maximum test statistic TS=29

- NGC 253 (Sculptur gal.) at 72% localization CL
- Probability of chance coincidence: < 2.9 x 10-3
- Long delay of first photon to T0 atypical for sGRB

Time since T_0 (s)	Energy (MeV)	Distance to NGC 253 (°)	Assoc. Prob.
19.18	480	0.3	0.990
180.22	1300	0.5	0.988
284.05	1700	0.9	0.999

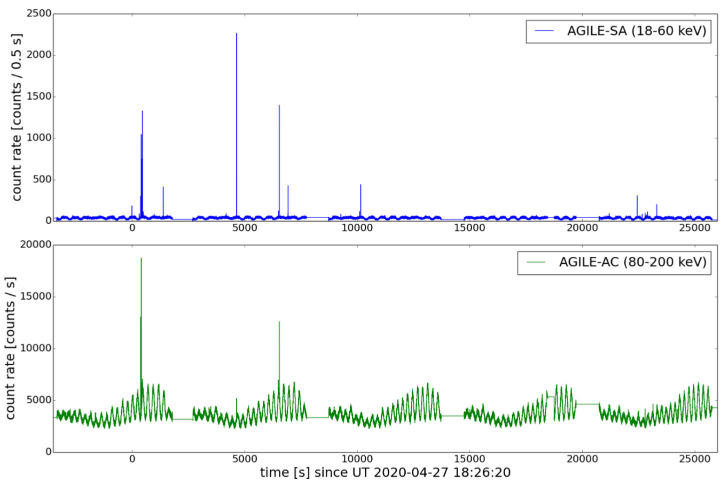


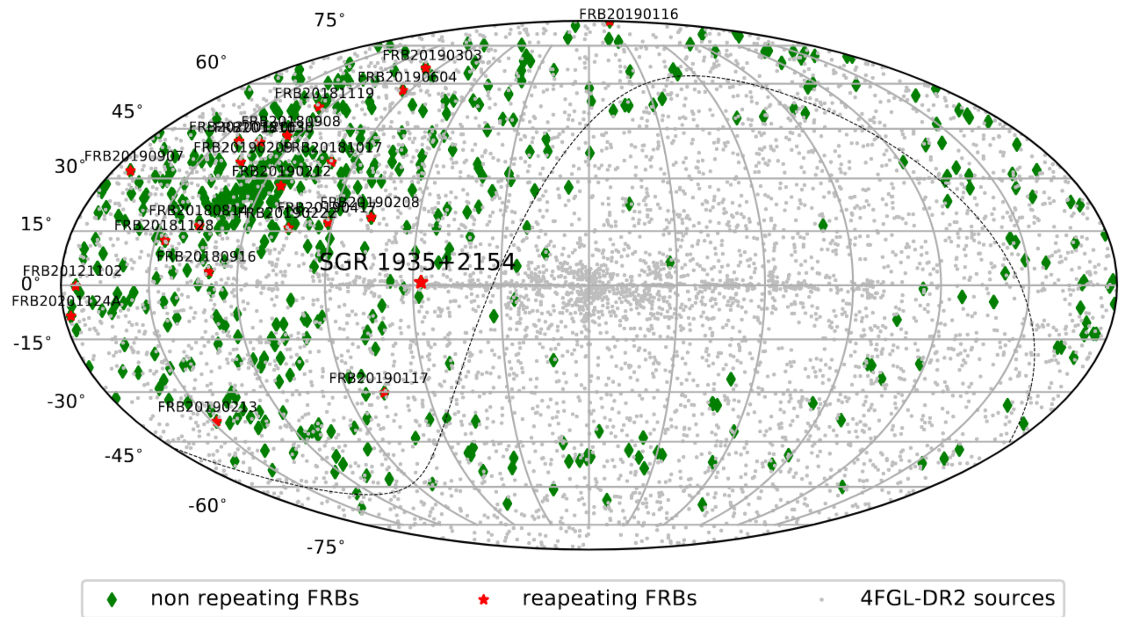
Ajello et al. 2021 2021NatAst...5585F

Magnetars and FRB connection?

The recent LAT detection of GeV emission from a magnetar flare in the sculptor galaxy motivated the search for gamma-rays from FRBs
AGILE detection of X-ray burst in coincidence with the very bright radio burst from the Galactic magnetar SGR 1935+2154
—>The largest and deepest systematic search for gamma-ray emission was performed from all the reported repeating and not-repeating FRB with 12 years of Fermi-LAT data

AGILE detection of the "forest" of X-ray bursts from SGR 1935+2154. Ratemeter lightcurves of SA data in the 18-60 keV band (top panel) and AC data (80-200 keV)





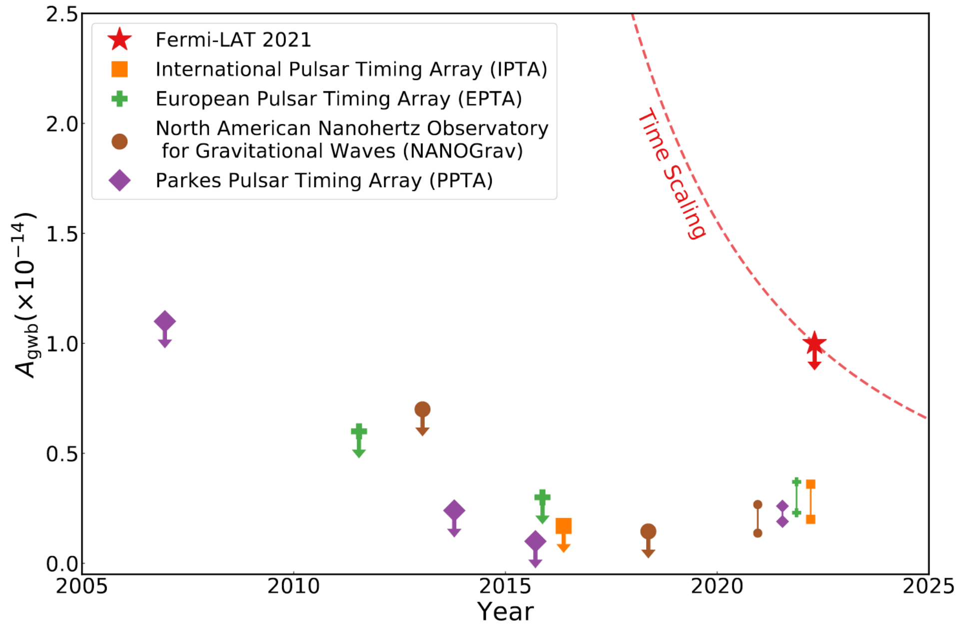
Principe et al. 2023, 10.1051/0004-6361/202346492
Tavani et al 2021, 10.1038/s41550-020-01276-x

Gamma-ray pulsar timing array (PTA)

Coalescing supermassive black holes in the centers of merging galaxies fill the universe with low-frequency gravitational waves (@nanohertz)

Searches for this background utilize pulsar timing arrays.
—>We use 12.5 years and 35 brightest MSP of Fermi Large Area Telescope data form a gamma-ray pulsar timing array.

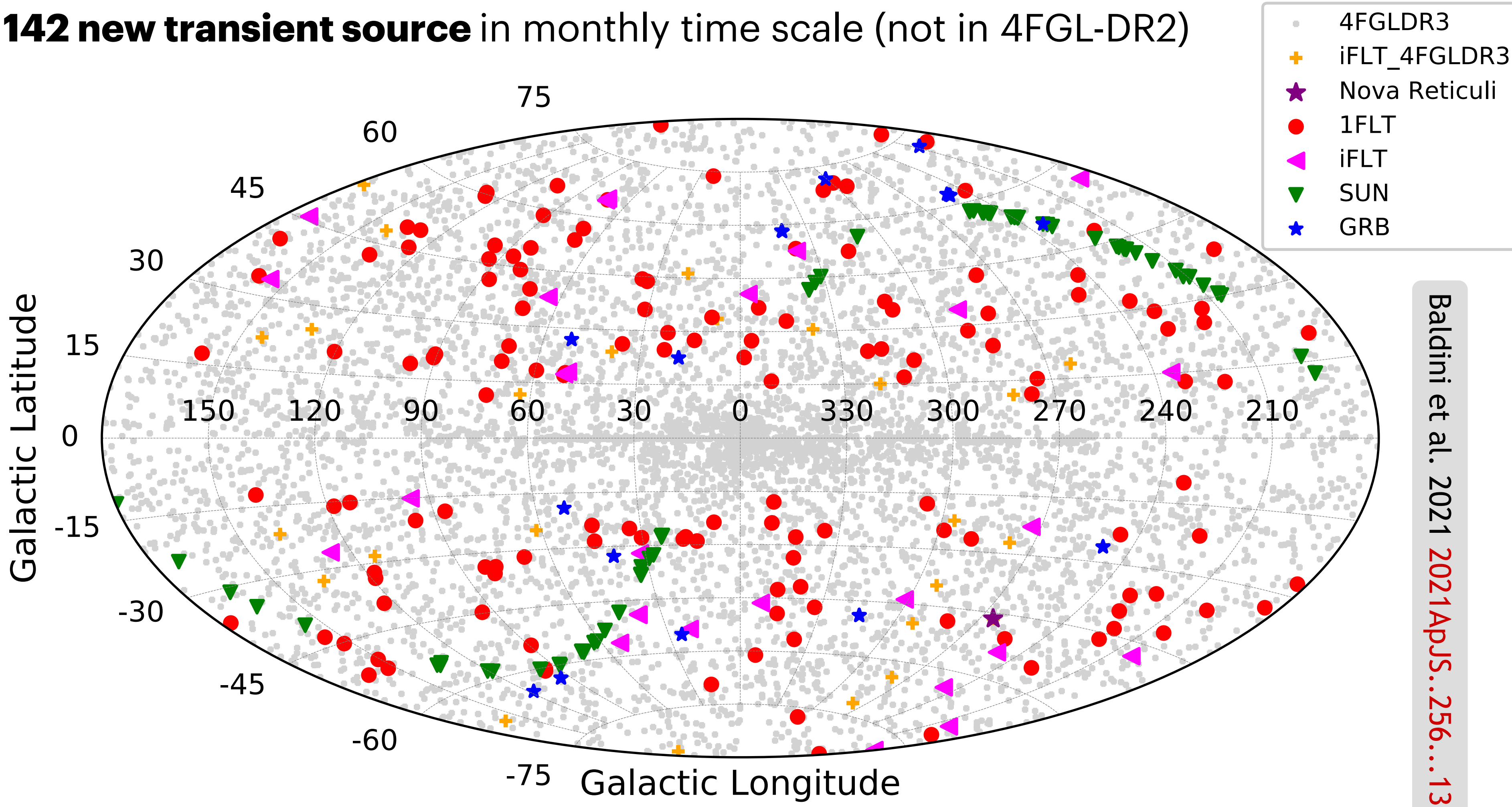
This provides an independent method to search for signals detected by radio PTAs; unlike the radio PTAs, it is free from the effects of the ionized interstellar medium.



Ajello et al. 2019; 2022Sci...376..521F

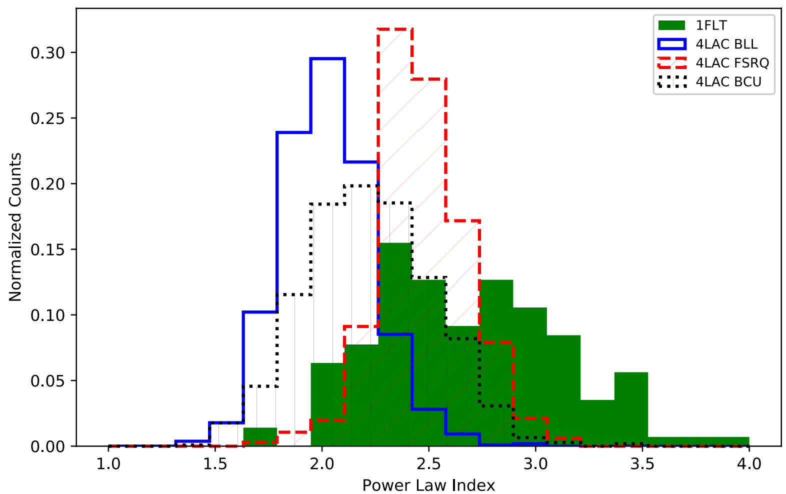
1FLT Catalog of Long-Term Transient Sources

142 new transient source in monthly time scale (not in 4FGL-DR2)

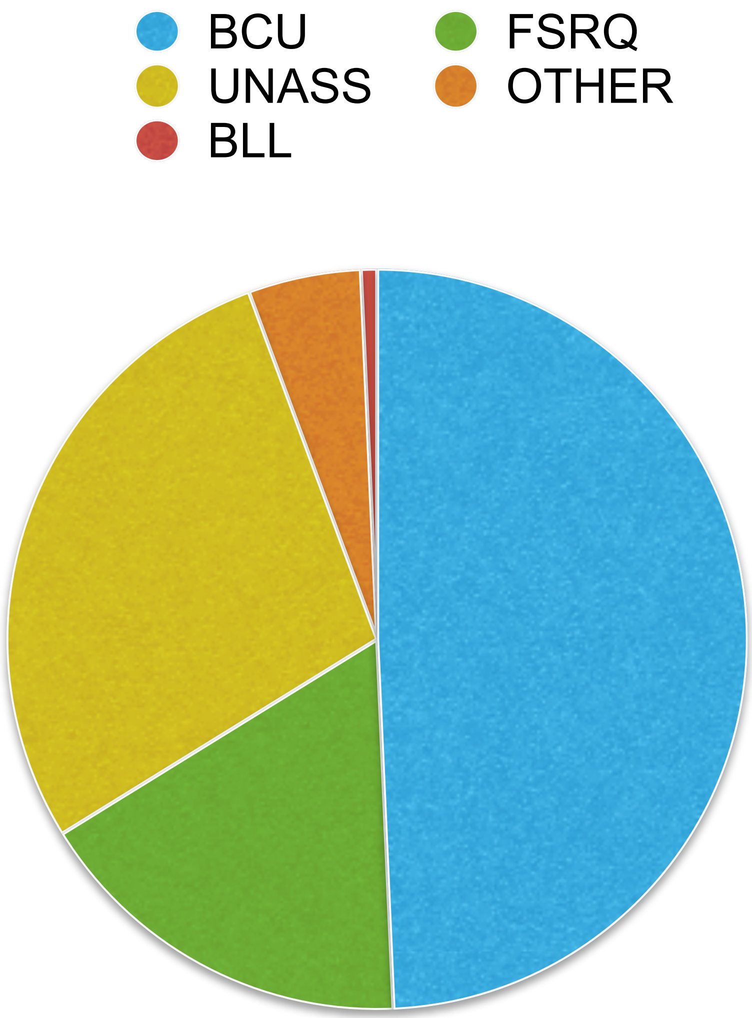


Baldini et al. 2021 2021ApJS..256...13B

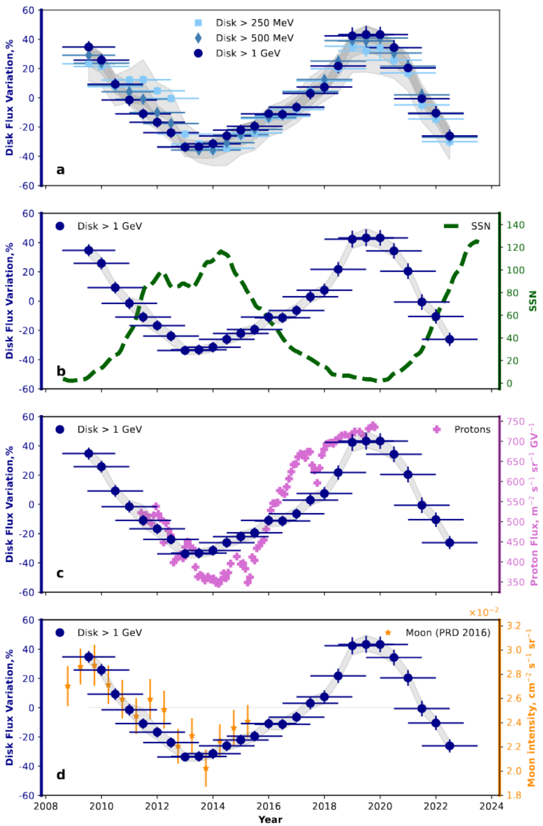
1FLT Catalog of Long-Term Transient Sources

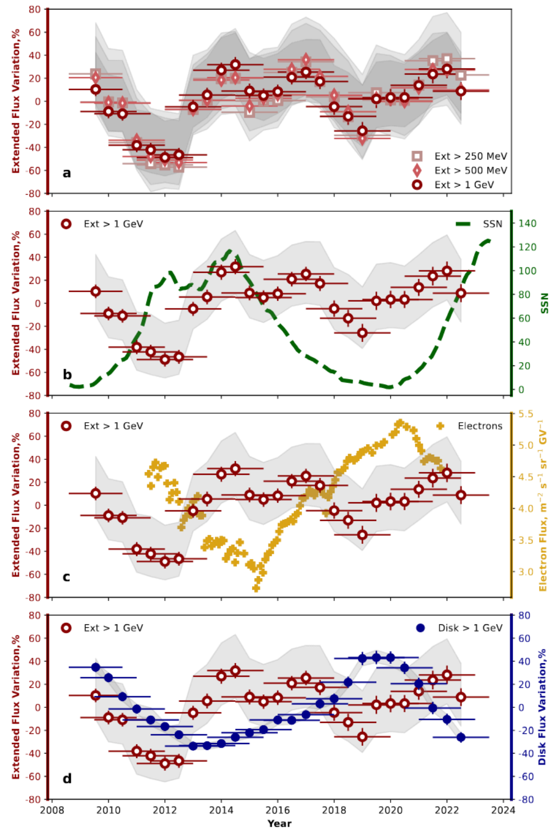


The 1FLT distribution extends to softer Γ values compared to 4LAC, with a median value of 2.7 compared to 2.2 of 4LAC (2.5 if we consider only 4LAC FSRQs.)



Variation of Gamma Rays from the Sun over the Solar Cycle





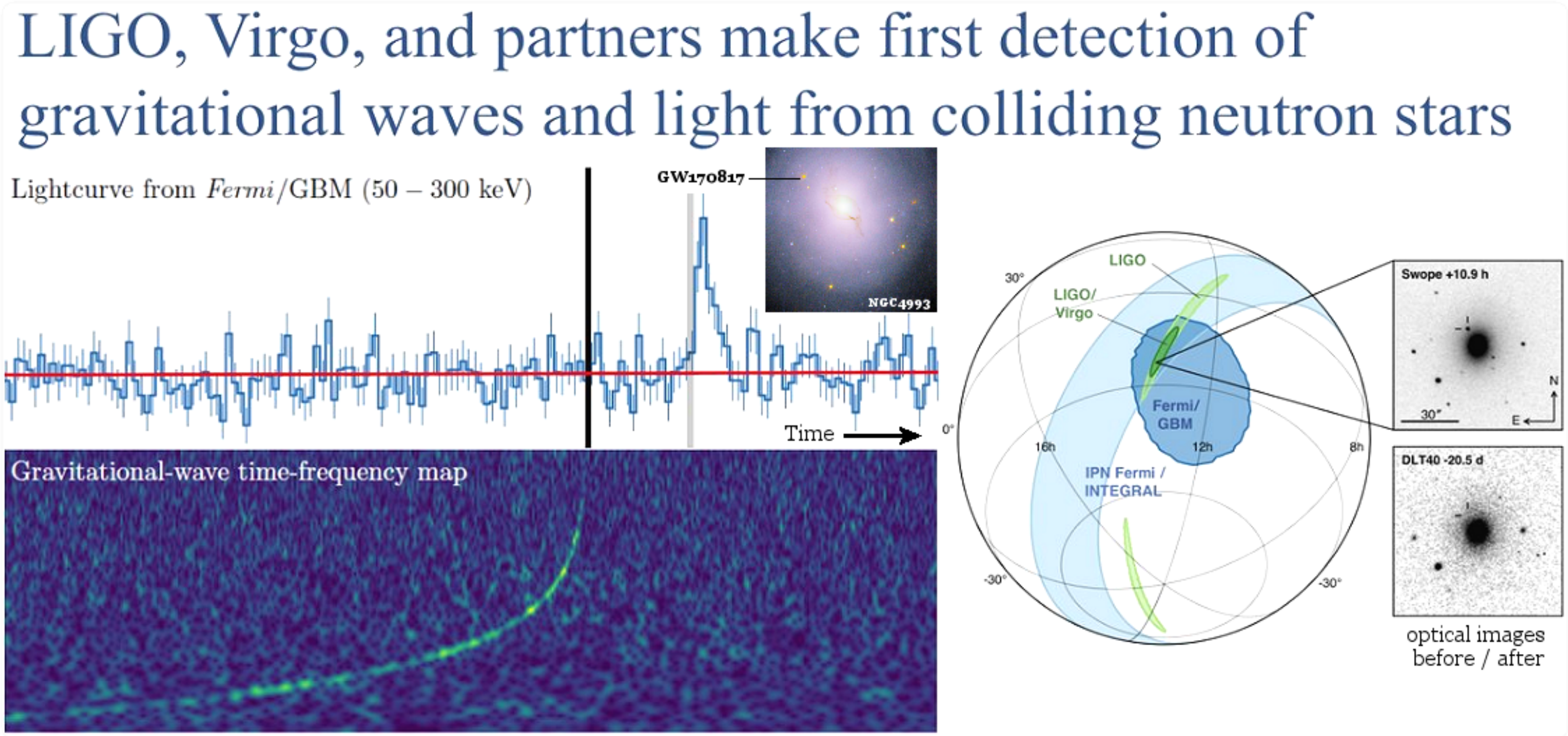
We find that the flux variation of the disk anticorrelates with solar activity and correlates with cosmic-ray protons.

The flux variation of the extended component anticorrelates with solar activity only until mid ~2012.

After that, we no longer observe any correlation or anticorrelation, even with the CR electron flux. This most likely suggests that cosmic-ray transport and modulation in the inner heliosphere are unexpectedly complex and different for electrons and protons or, alternatively, the presence of an additional, unknown component of gamma rays or cosmic rays.

Acharya et al. 2025, 10.48550/arXiv.2505.06348

Gravitational wave follow-up



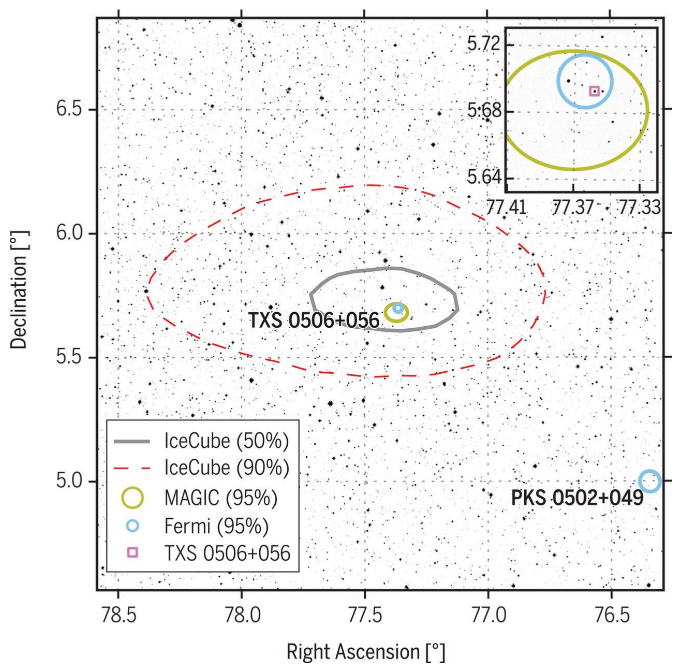
Fermi and AGILE play a fundamental rule in the follow-up of GW
—> huge FoV and good localization
—>Exploring also Fermi ACD data

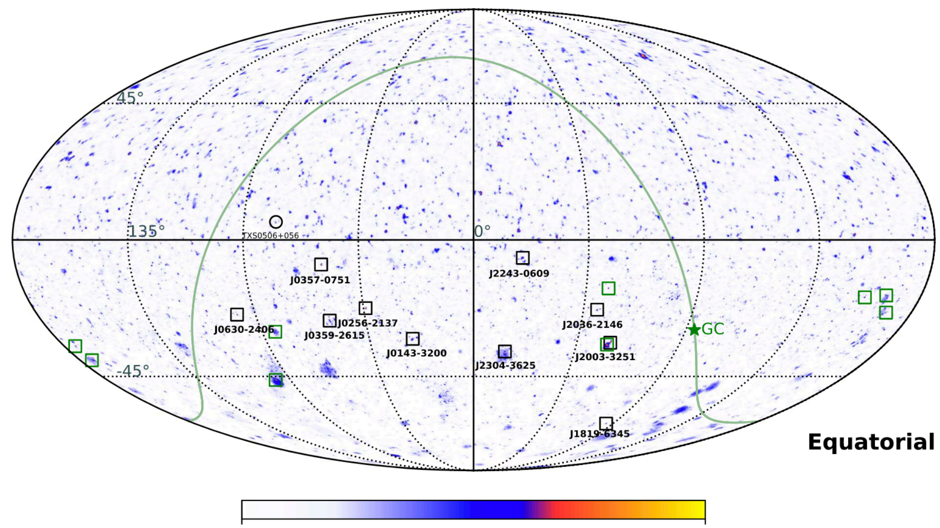
Abbott et al. 2017; 2017ApJ...848L..12A
Abbott et al. 2017; 2017ApJ...848L..13A

Neutrino - gamma ray connection

Association of neutrino with flaring blazar TXS 0506+056 sparked interest to identify further counterparts

- So far, no other counterpart has been unambiguously identified—> however 10 IceCube neutrino's hotspots located in the southern sky are likely originated from blazars





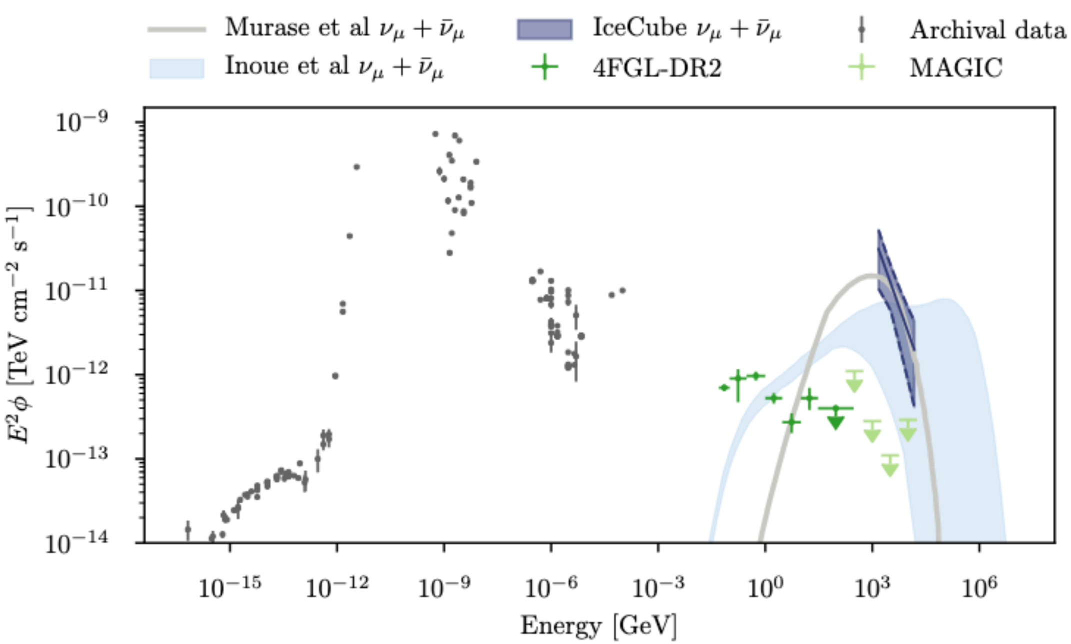
List of PeVatron blazars/Neutrino Hotspot Associations Found by This Work

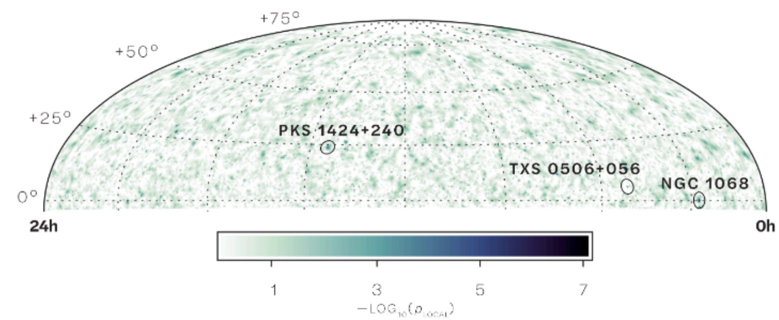
IceCube Hotspots				Blazar Associations		
	α_{hs}[°]	δ_{hs}[°]	L	5BZCat	z	Separation[°]
IC J2243−0540	340.75	−5.68	4.012	5BZB J2243−0609	0.30[c]	0.47
IC J0359−0746	59.85	−7.78	5.565	5BZQ J0357−0751	1.05	0.42
IC J0256−2146	44.12	−21.78	4.873	5BZQ J0256−2137	1.47	0.17
IC J2037−2216	309.38	−22.27	4.664	,5BZQ J2036−2146	2.299	0.51
IC J0630−2353	97.56	−23.89	4.420	5BZB J0630−2406[a],[b]	>1.238[d]	0.28
IC J0359−2551	59.94	−25.86	4.356	55BZB J0359−2615[a]	1.47[e]	0.40
IC J0145−3154	26.28	−31.91	4.937	55BZU J0143−3200[a]	0.375	0.42
IC J2001−3314	300.41	−33.24	4.905	5BZQ J2003−3251	3.773	0.53
IC J2304−3614	346.03	−36.24	4.025	5BZQ J2304−3625	0.962	0.24
IC J1818−6315	274.50	−63.26	4.030	5BZU J1819−6345	0.063	0.53

IceCube Coll. et al. 2018, 2018Sci...361.1378I; Garrappa et al. 2019, 2022icrc.confE.956G ; Buson et al 2022; 2022ApJ...933L..43B

Neutrino - NGC 1068

IceCube collaboration had found an excess of 79^{+22}_{-20} neutrinos associated with the nearby active galaxy NGC 1068 at a significance of 4.2 σ.
NGC 1068 is one of the closest Seyfert II galaxies, it hosts Compton-thick AGN.





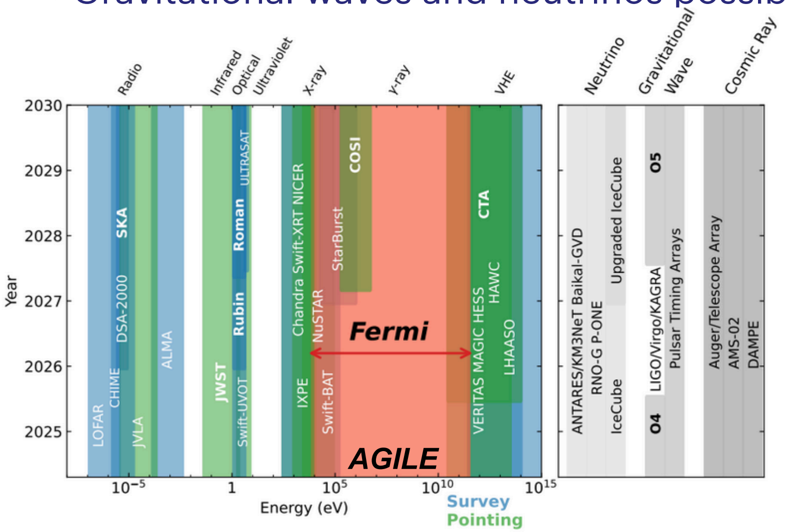
IceCube Coll. et al. 2024,
10.1038/s41550-024-02339-z

Summary and Conclusions

- Fermi and AGILE first 16 years have produced numerous scientific discoveries that have revolutionized our understanding of the gamma-ray universe

- Fermi-LAT and GBM are working without major problems:
  —>Fermi had his first hardware failure on March 16, 2018, however the observatory has so much flexibility that this glitch has only minor impact on science operations
- After 17 years of operations, the AGILE satellite re-entered the atmosphere on 14 February 2024

- Fermi observations remain indispensable for multi-messenger counterpart searches
  —>Gravitational waves and neutrinos possibile counterparts



Without Fermi and AGILE the astrophysics is not the same!

Back-up slides

Gravitational wave follow-up

The new GW observing run is approaching; O4 will start at the end of the year

Promising previsions for Fermi in O4

Patricelli et al. 2022; 2022MNRAS.513.4159P

GW+ GRBs conservative approach

Model	$\mathcal{R}(0)$	GW	GW+EM (prompt)							
			Swift/BAT		Fermi/GBM		INTEGRAL/IBIS		SVOM/ECLAIRs	
			uniform	structured	uniform	structured	uniform	structured	uniform	structured
	$\mathrm{Gpc^{-3}yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$
A1	31	1	0.0006 (0.0023)	0.014-0.020	0.003 (0.013)	0.070-0.11	0.0001 (0.0004)	0.0024-0.0035	0.0005 (0.0019)	0.013-0.017
A3	258	5	0.003 (0.01)	0.07-0.10	0.017 (0.068)	0.35-0.54	0.0005 (0.002)	0.01-0.02	0.002 (0.01)	0.06-0.08
A7	765	13	0.008 (0.031)	0.18-0.26	0.045 (0.18)	0.91-1.42	0.001 (0.005)	0.031-0.046	0.006 (0.025)	0.17-0.22

GW+ GRBs more optimistic approach

Model	$\mathcal{R}(0)$	GW	GW+EM (prompt)							
			Swift/BAT		Fermi/GBM		INTEGRAL/IBIS		SVOM/ECLAIRs	
			uniform	structured	uniform	structured	uniform	structured	uniform	structured
	$\mathrm{Gpc^{-3}yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$	$\mathrm{yr^{-1}}$
A1	31	5	0.002 (0.01)	0.05-0.08	0.014 (0.06)	0.27-0.46	0.0005 (0.002)	0.009-0.014	0.002 (0.008)	0.05-0.07
A3	258	22	0.01 (0.04)	0.24-0.37	0.06 (0.26)	1.17-2.00	0.002 (0.008)	0.04-0.06	0.009 (0.04)	0.22-0.32
A7	765	61	0.03 (0.12)	0.67-1.05	0.18 (0.74)	3.28-5.65	0.006 (0.02)	0.11-0.18	0.02 (0.10)	0.63-0.90

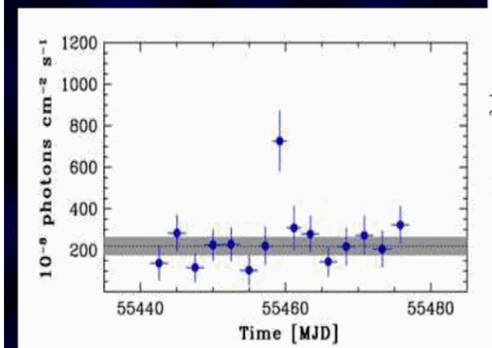
AGILE: three most important results

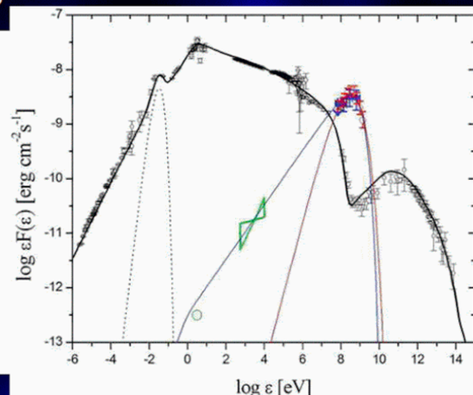
Slide from M. Cardillo, SAIT 2025

AGILE: three of the most important results – 1
Flaring Crab

Bruno Rossi Prize 2012
Marco Tavani and the AGILE team

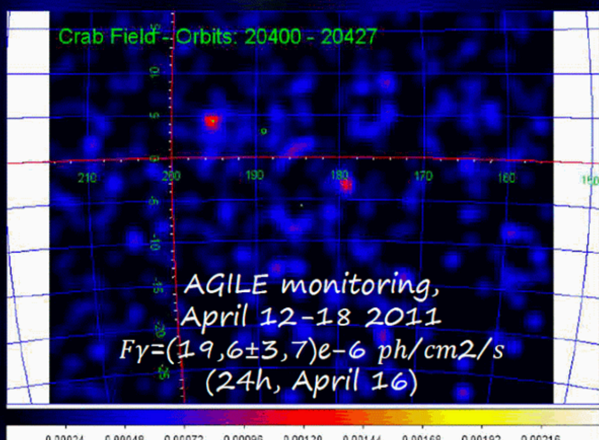
AGILE, September 20-22, 2010





Tavani et al. 2011

- The Crab nebula has an average constant multi-wavelength flux → calibration source
- September 2010: AGILE detected and announced a flare (ATEL 2855) w F=(7.2±1.4)e-6 ph/cm2/s confirmed by Fermi-LAT
- October 2007: AGILE already detected a flare in its first Science Verification period → no communication
- Several other flares, the greatest one in 2011
- Flares not related to pulsar and not seen in other frequencies → only in the γ-ray band → unknown acceleration phenomena

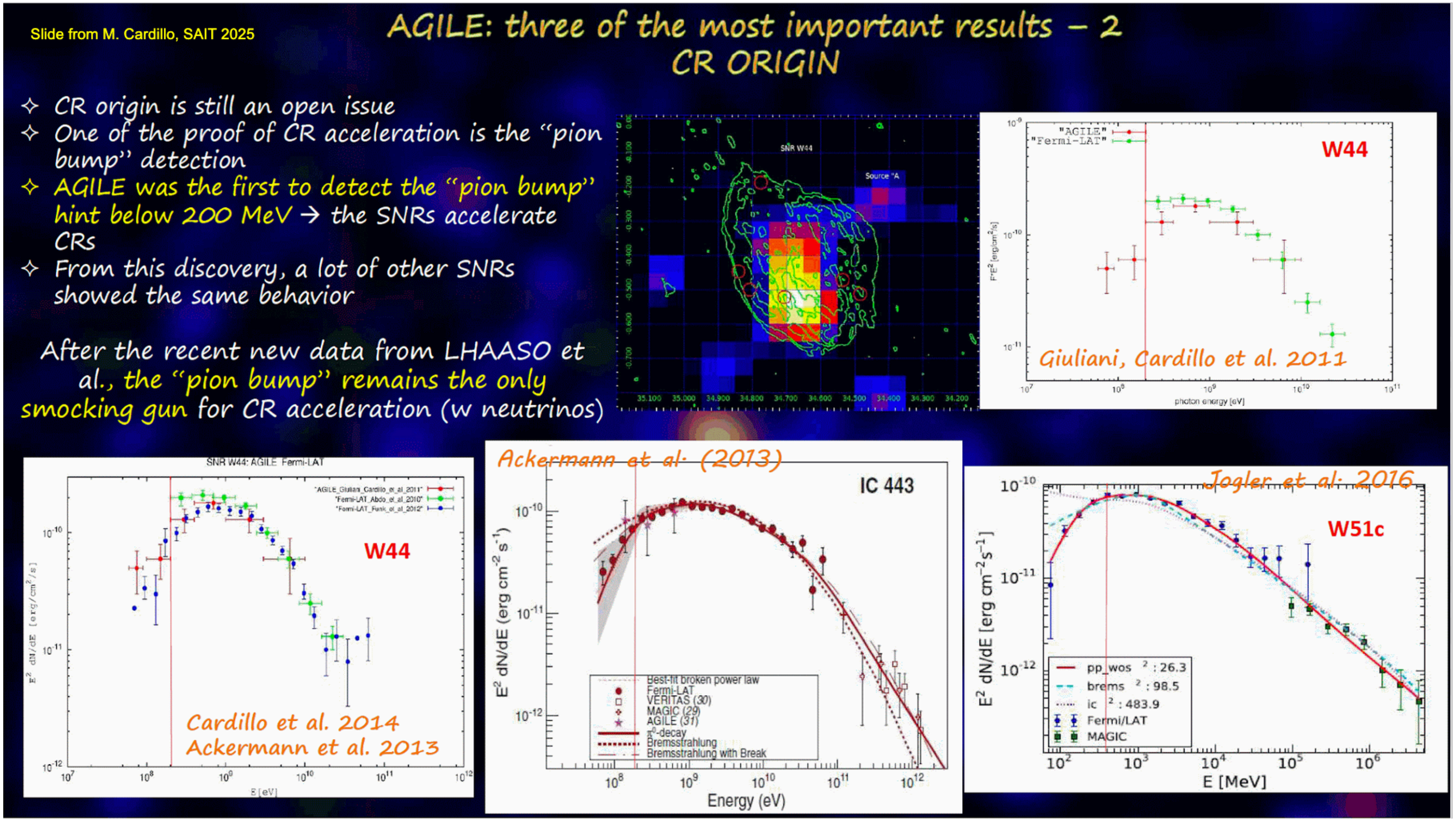


And now the Crab is showing new surprising features: it is a PeVatron!!!

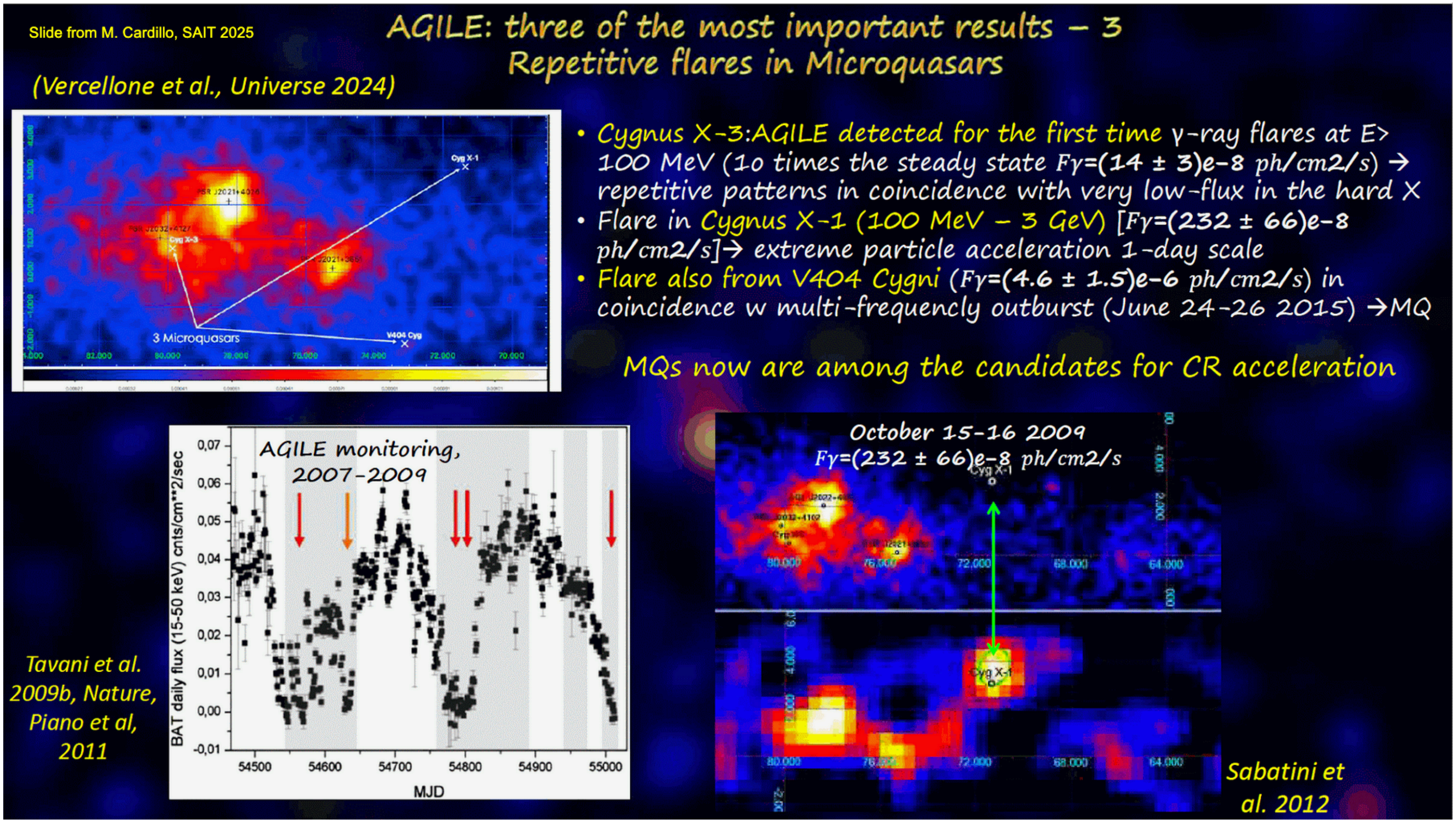
Flare Date	Duration (Days)	Peak γ-ray Flux $\times 10^{-6}$ Photons cm^{-2} s^{-1}	Instrument
2007 October	≈15	≈6	AGILE
2009 February	≈15	≈4	*Fermi*
2010 September	≈4	≈5	AGILE, *Fermi*
2011 April	≈2	≈0	*Fermi*, AGILE
2012 July	≈3	≈5	*Fermi*
2013 March	≈4	≈11	AGILE
2013 October	≈3	≈10	*Fermi*, AGILE
2014 August	≈4	≈7	*Fermi*
2016 October	≈13	≈7	AGILE, *Fermi*
2018 March	≈3	≈5	*Fermi*, AGILE
2018 October	≈10	≈11	*Fermi*, AGILE
2019 May	≈6	≈5	*Fermi*

(Vercellone et al., Universe 2024)

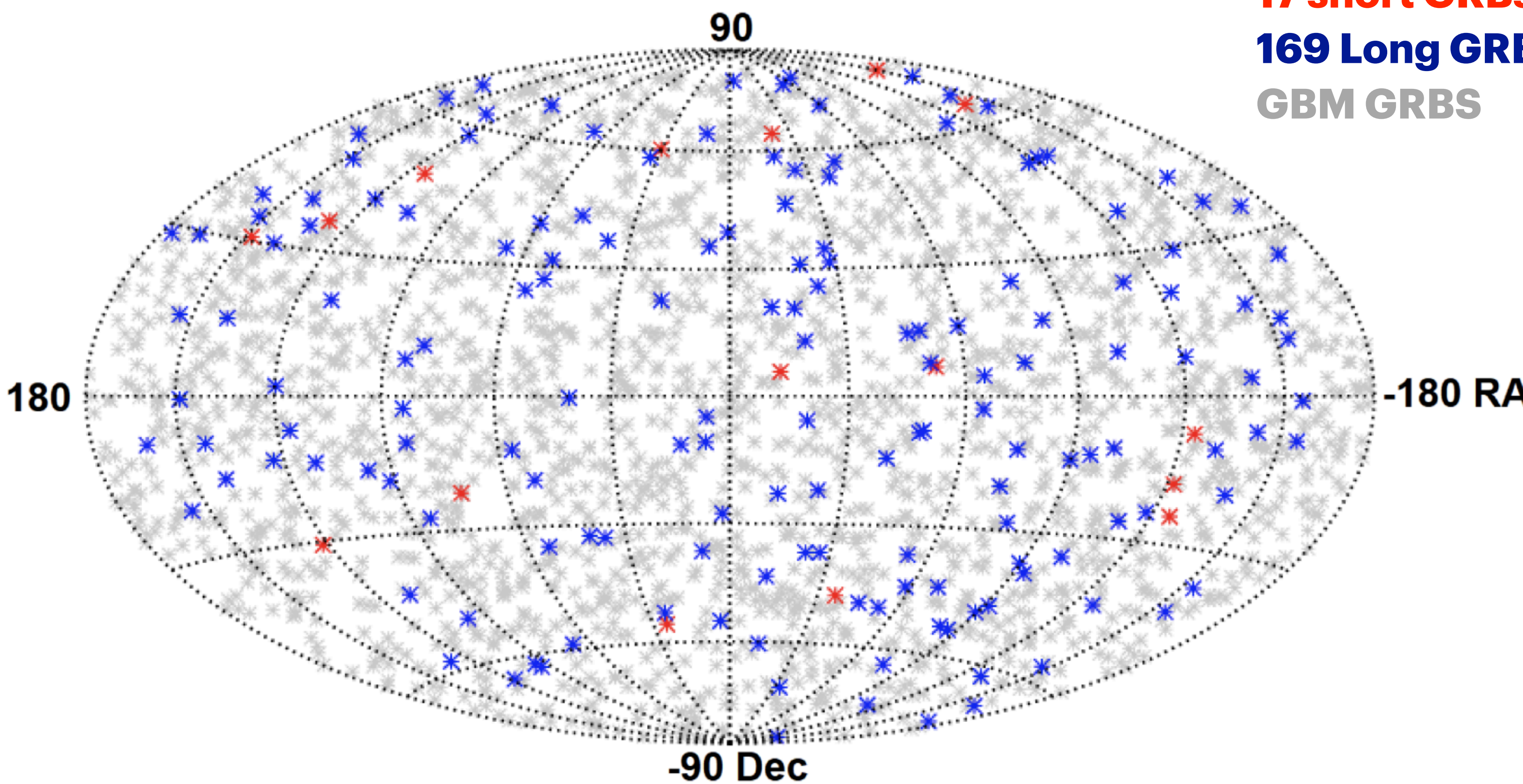
AGILE: three most important results



AGILE: three most important results



Second Gamma Ray Burst Catalog

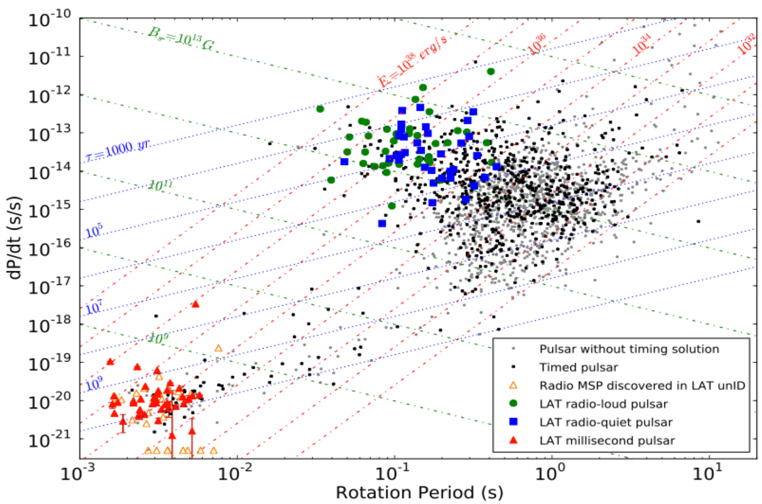


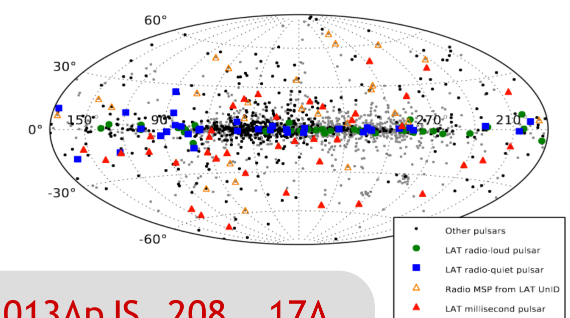
10 years of data
17 short GRBs
169 Long GRBs
GBM GRBS

Ajello et al. 2019 2019ApJ...878...52A

Pulsars population

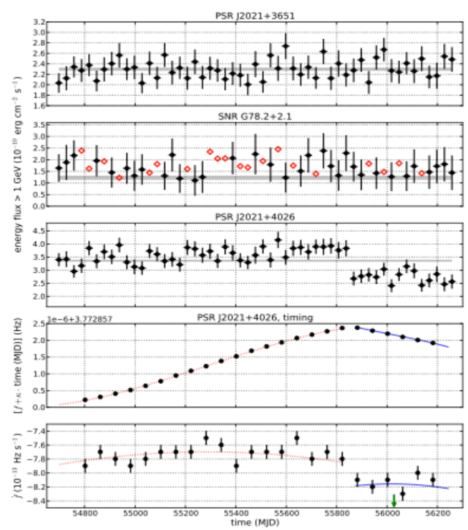
Family portrait



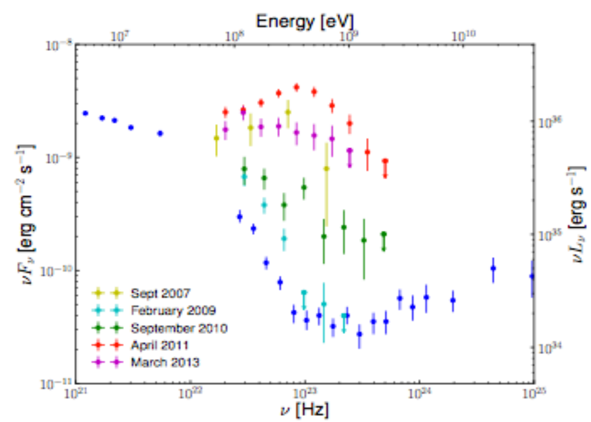


Before Fermi only 7 pulsars, now 147 with 2nd pulsars catalog [1]
Emission region location: outer-gap model preferred respect to the polar-gap[2]
Pulsars, considered the must stable sources were discovered to be variable![3,4]

PSR J2021+4026 in the Gamma Cygni region:
the first variable gamma-ray pulsar[3]



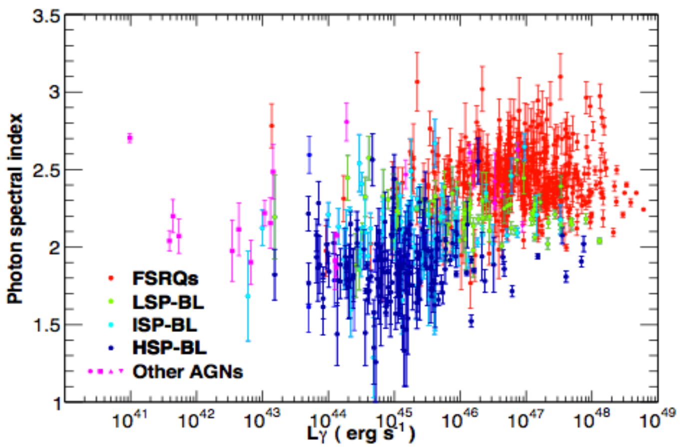
Crab flare related to the nebulae[4]

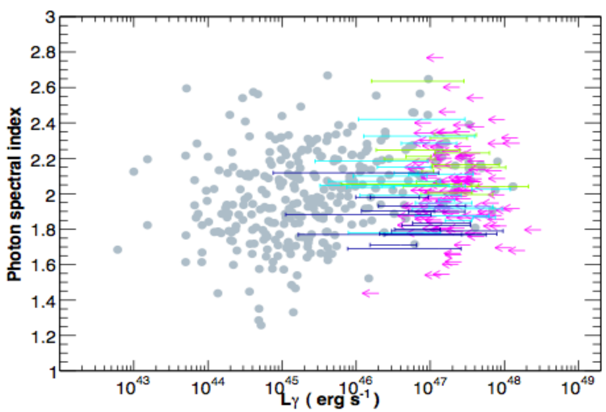


[1] Abdo A. A, 2013ApJS..208…17A
[2] Abdo A.A 2009ApJ...696.1084A
[3] Allafort, A. 2013ApJ...777L...2A
[4] Abdo A. A. 2011Sci...331..739A

Active Galaxy Nucleus population and evolution

The 75% of the gamma-ray sources are aligned AGN: blazars (BL Lacs + FSRQ)[1]
MW follow-ups provide z for many Fermi blazars introducing the LL a population of high redshift BL Lacs were found[1,2]

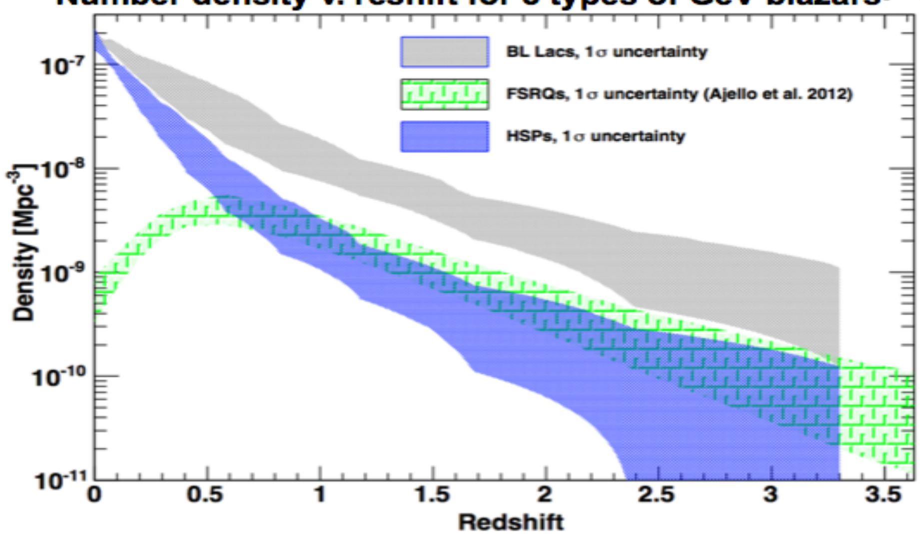




Many gamma-ray blazars in the early universe, but still unclear how to form so many supermassive BH so early

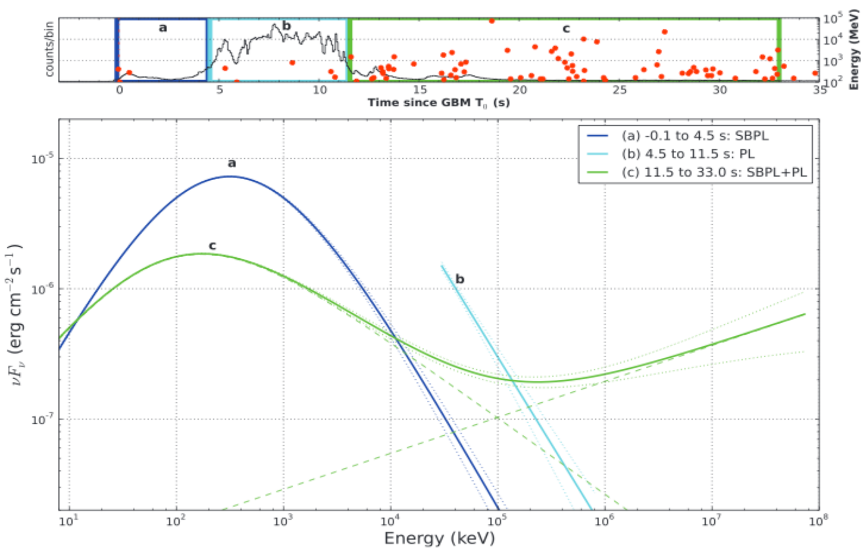
Population studies show that the high syn peaked BL Lacs could be the evolution of FSRQ that cleans up the surrunding[3]

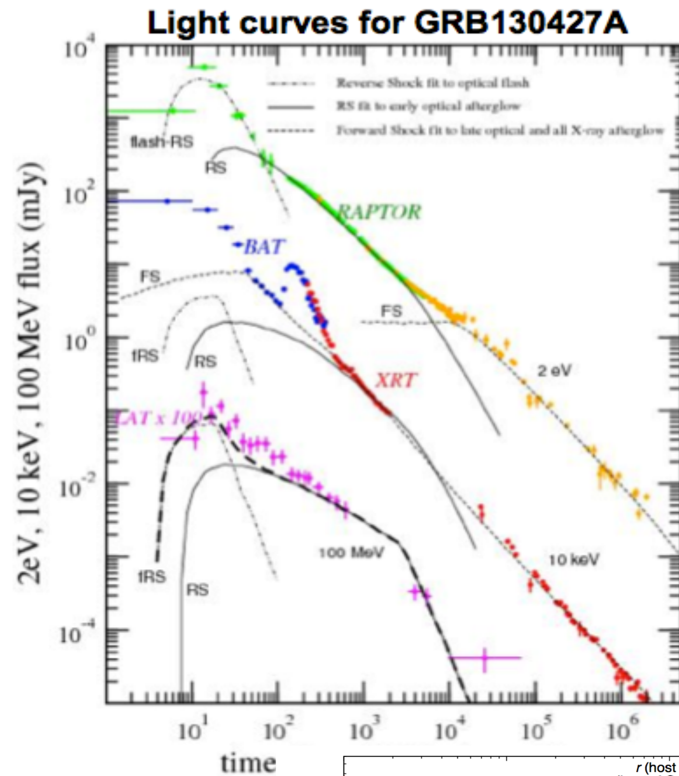
Number density v. reshift for 3 types of GeV blazars[1,2]

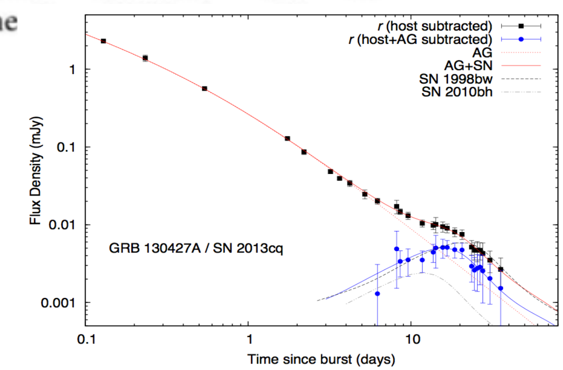


[1]Ackermann M. 2015arXiv150106054A
[2] Shaw M. 2013ApJ...764..135S
[3] Ajello, M. 2014ApJ...780...73A

GRB 130427A: a nearby monster







Record breaking:

Highest γ-ray fluence (prompt) > 10^{-3}erg/cm^2[1]

Highest γ-ray photons detected 95GeV[1]

Longest live γ-ray emission (prompt+afterglow)[1]

First Fermi-LAT γ-ray GRB with super novae detection:

GRB 130427A/SN 2013cq connection[2]

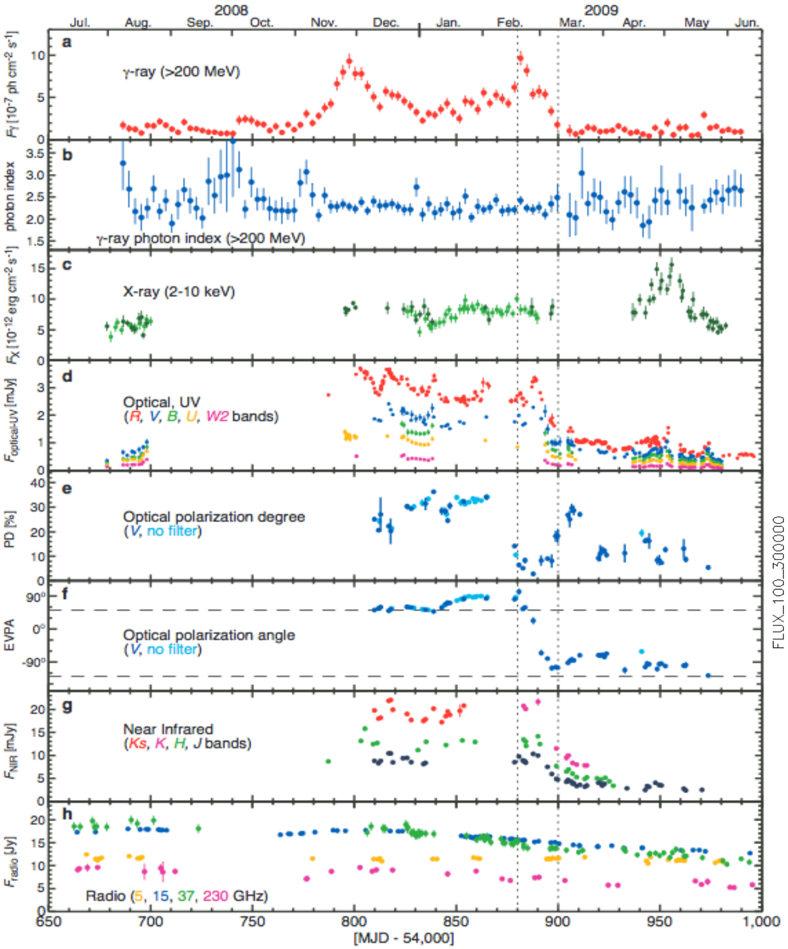
2th brightest optical flash ever observed[3]

Prompt emission described as Self Synchrotron Compton[1]

[1] Ackermann, M. 2014Sci...343...42A
[2] D. Xu 2013ApJ...776...98X
[3] Maselli, A. 2014Sci...343...48M

3C 279: one of the most famous

History of flux in various band and optical polarization during the 2009 flare



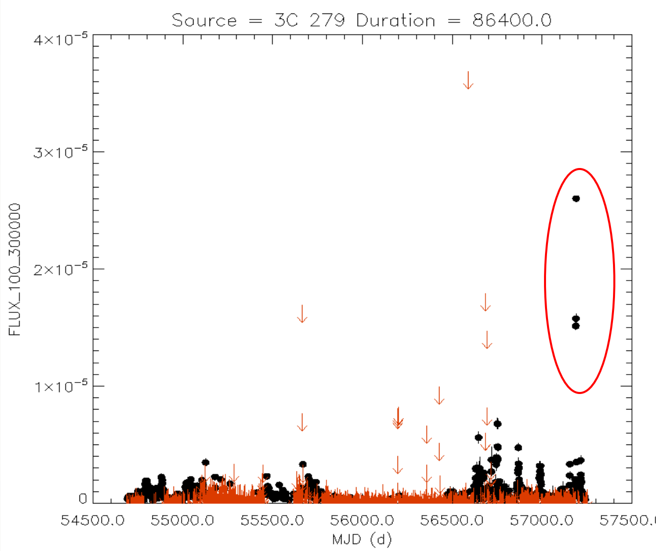
Strong gamma-ray flare in Feb. 2009 with associated a drammatic change of the polarization angle:

➔co-spatiality of the optical and gamma-ray emission zone

➔highly ordered jet magnetic field

➔emission region distant from the BH

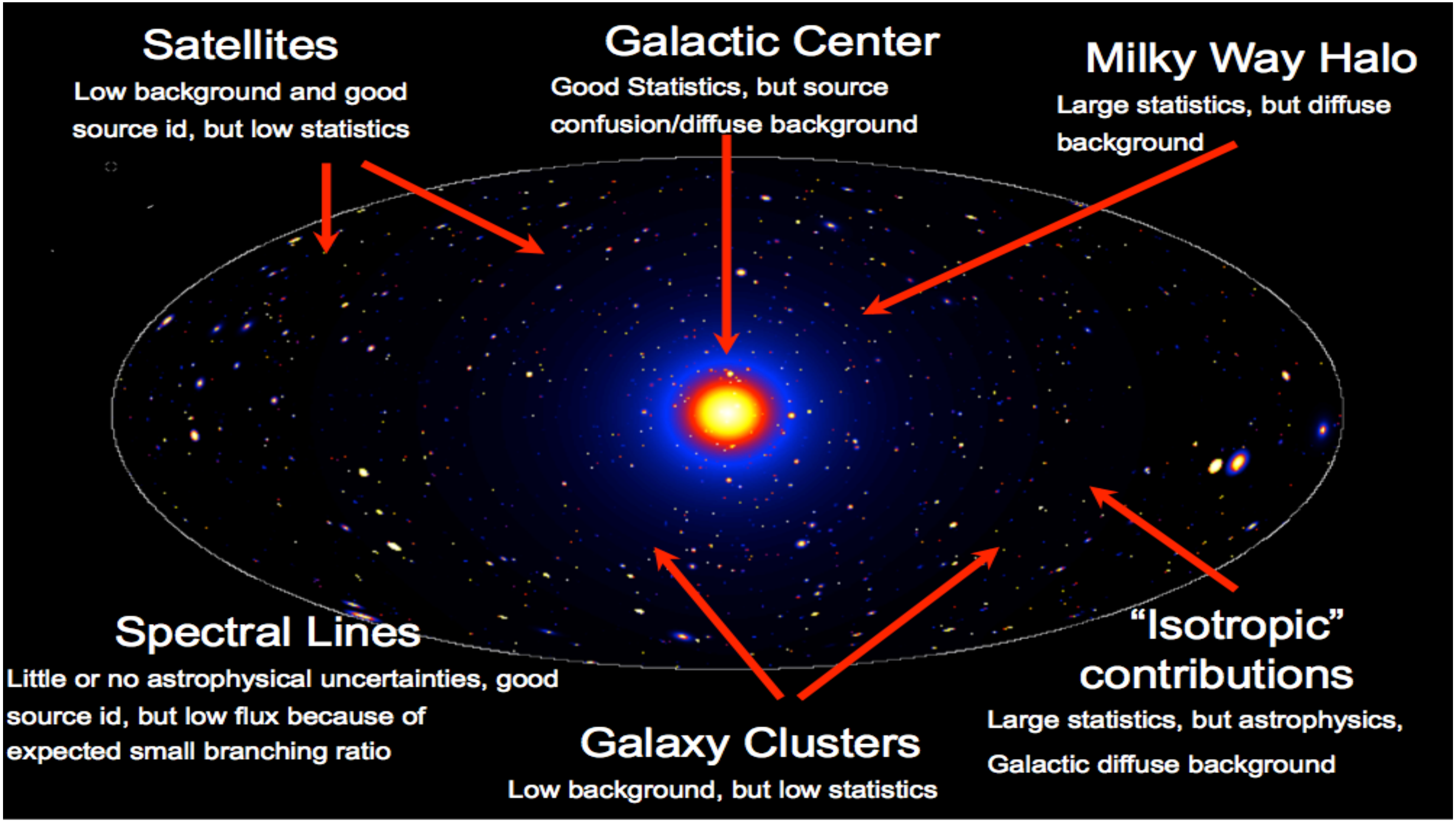
➔Possibility of a bend jet scenario



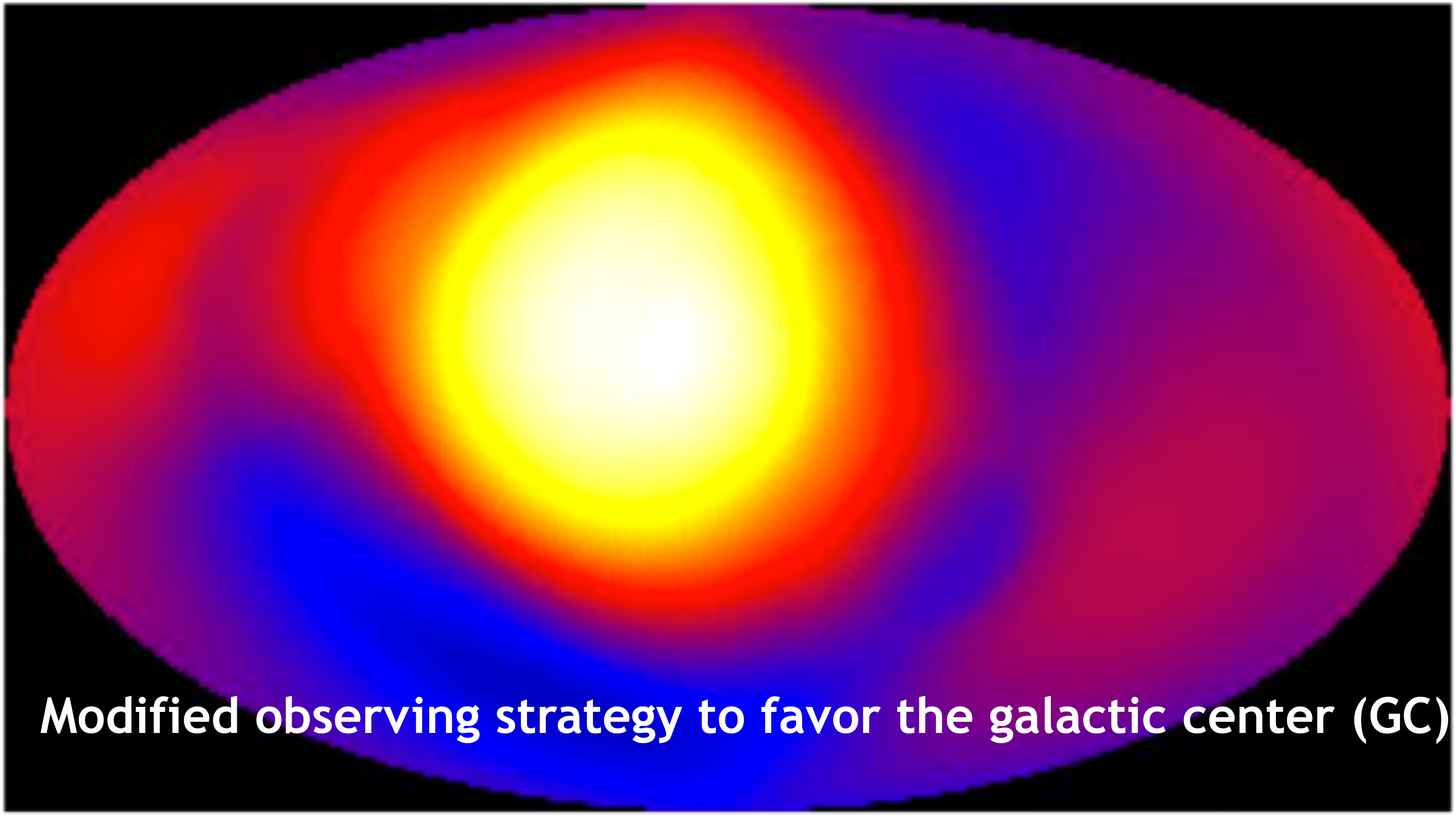
NEWS: Record flux in 14 June 2015 since 1991 The brighter object in the sky for few hours[2]

[1] Abdo, A.,A.2010Natur.463.919A
[2] Cutini, S. 2015ATel.7633....1C

LAT target of DM search



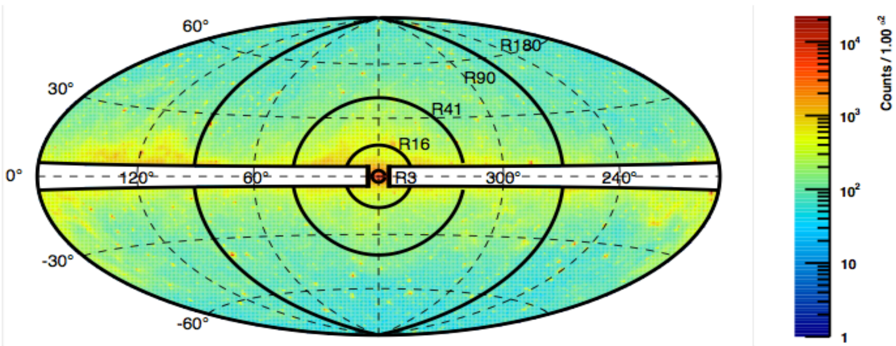
LAT target of DM search

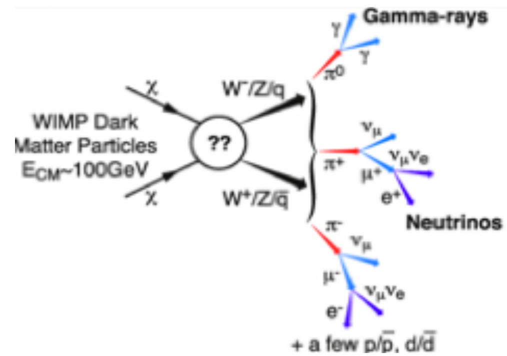


Search for spectral line: 133 GeV case

Weakly Iteracting Massive Particles (WIMP) are a promising dark matter candidate
Indirect DM search: WIMP annihilation

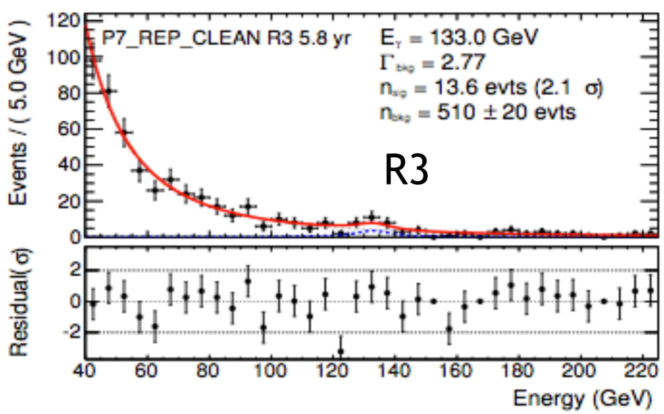
Definition of the ROI centered in the GC

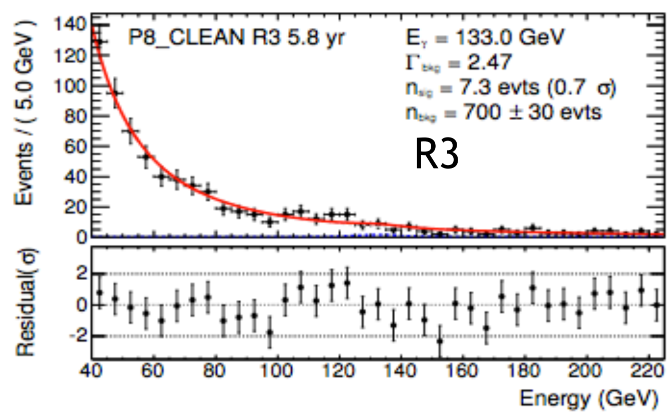




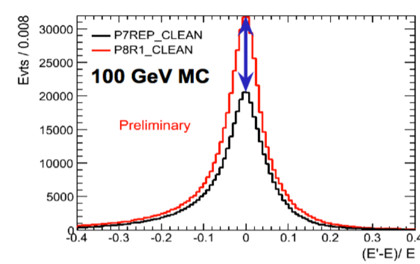
[1] Ackermann, M. 2013PhRvD..88h2002A
[2] Ackermann, M. 2015PhRvD..91l2002A
[3] Weniger C. 2012JCAP...08..007W

No globally spectral lines is detected with P7rep $\sigma<2$[1], even smaller significance with P8[2]
Too narrow feature in 133 GeV is seen with P7rep (previously reported in [3])



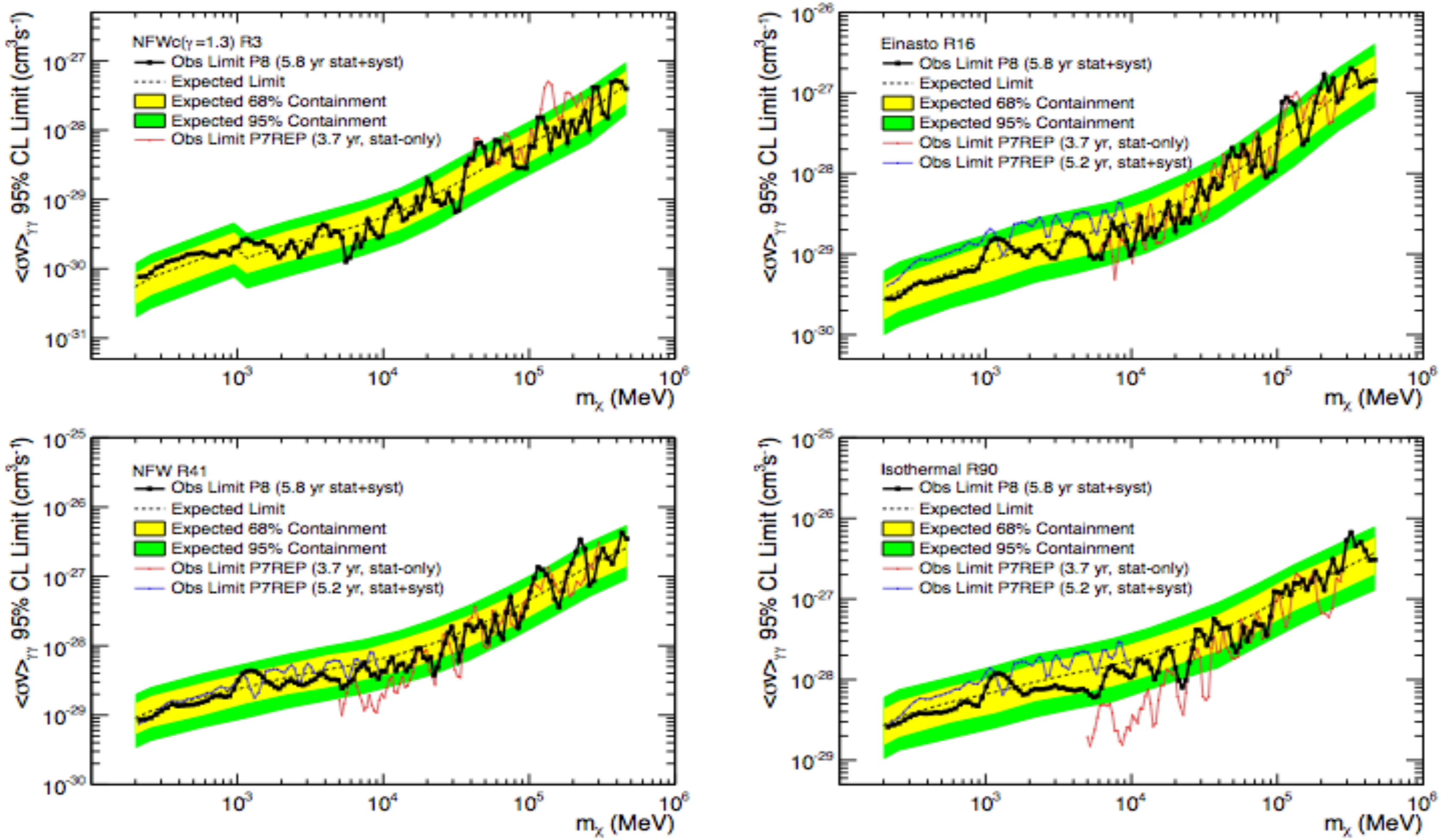


Strongly increasing the acceptance with pass8



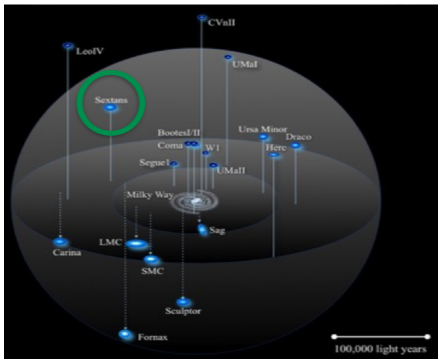
Search for spectral line

No globally significant lines found in each ROI



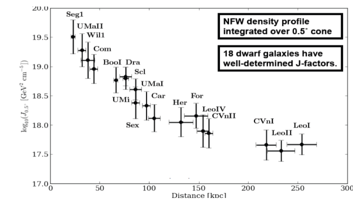
Dark matter annihilation the Milky Way: dwarf Spheriodal Galaxies

The stellar kinematic data indicate that the dwarf spheriodal satellite galaxies (dSphs) of the Milky way contain a substantial DM component - 25 dSphs close to us to 25-250 Kpc



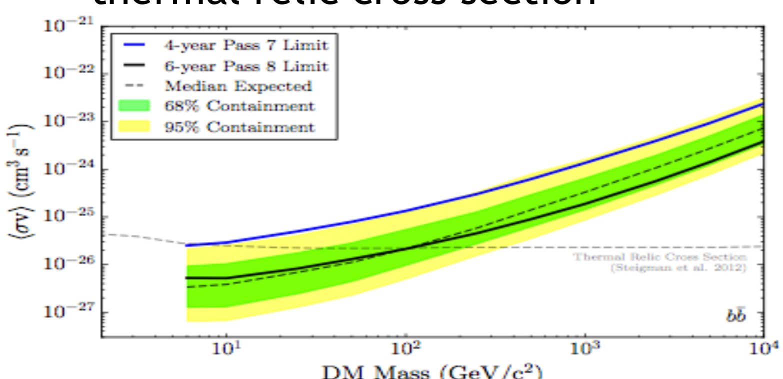
gamma-ray signals = particles properties x astrophysical properties

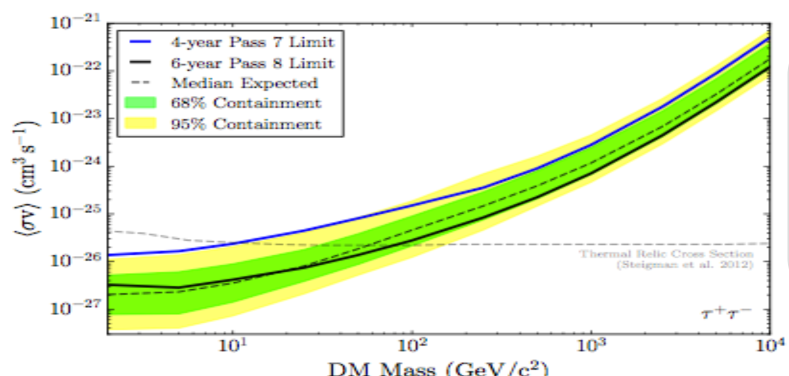
$$\phi_\gamma(E,\psi) = \frac{1}{4\pi}\frac{\langle\sigma_\chi v\rangle}{2m_\chi^2}N_\gamma(E)\times J(\psi)$$



Dwarf J-factors are determined **spectroscopically** from the stellar velocity dispesions ➔using the los velocity dispersion and assuming DM density profile (NFW) we can estimate the J-factor

Joint likelihood analysis in 15 dSphs : we constrain the dark matter annhilation cross section through the quark and τ-lepton channel for WIMP with m_χ < 100 GeV➔lies below the canonical thermal relic cross section

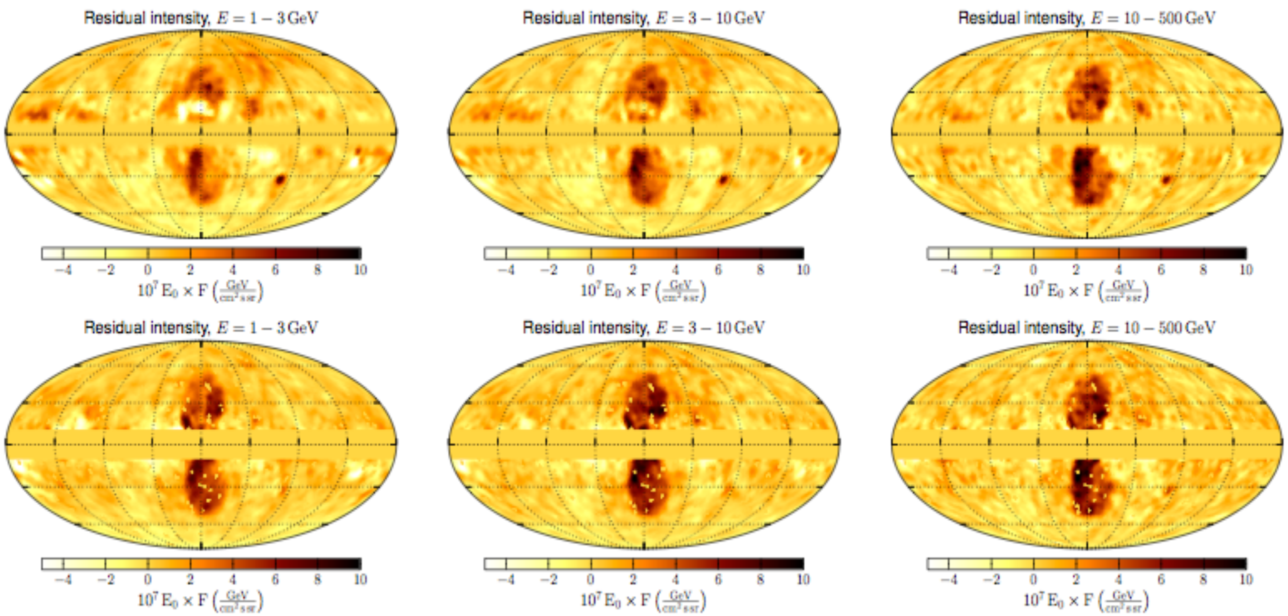


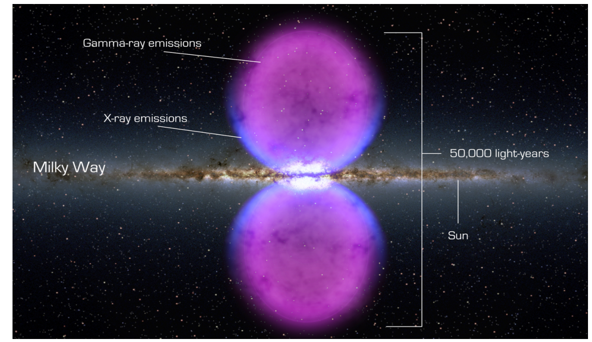


[1] Ackermann, M. 2014PhRvD..89d2001A
[2] Ackermann, M. 2011PhRvL.107x1302A
[3] Drlica-Wagner, A 2015ApJ...809L...4D

Fermi Bubbles

We detected an excess in the diffuse emission beween 1 GeV up to 50GeV [1*





Bubbles extend above and below the galactic plane of about 55^{o}[2]

Fermi bubbles have the same morphology of the WMAP microwave haze ➔ **common origin**
The Fermi bubble structures were likely created by some large episode of energy injection in the GC, such as a past accretion event onto the central MBH, or a nuclear starburst in the last~10 Myr.

Evidence of substructures but no an evidence of a jet

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[2] Ackermann, M. 2014ApJ...793...64A

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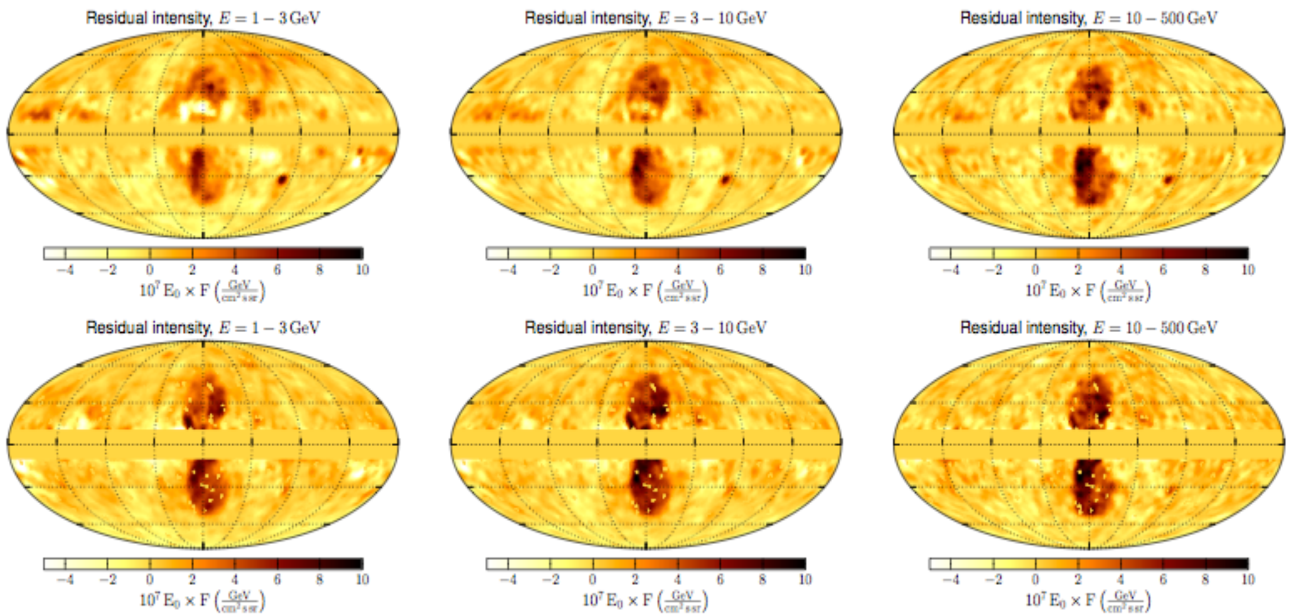

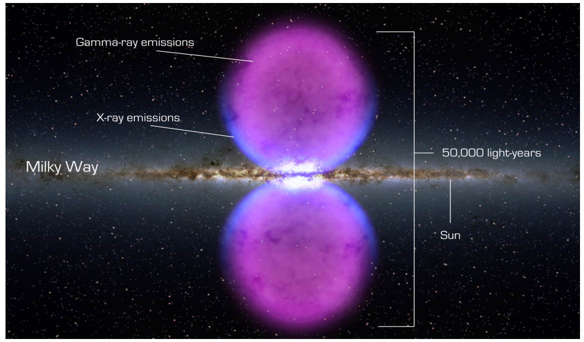

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