

Bridging the Gap -The first sensitive 20-200 MeV catalog

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On behalf of: Chris Karwin, Marco Ajello, Scott Joffre
and the *Fermi*-LAT collaboration

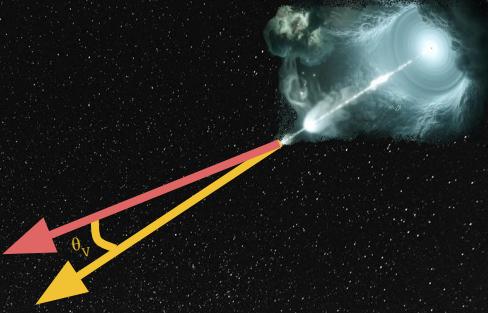
10th International Fermi Symposium
Oct. 11 2022



The MeV sky

High Mass binaries
(HMB)

$\theta_V \leq 5^\circ - 10^\circ$

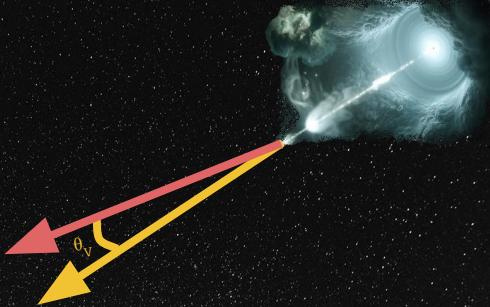


Blazars

The MeV sky

High Mass binaries
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$\theta_V \leq 5^\circ - 10^\circ$



Blazars

Pulsars

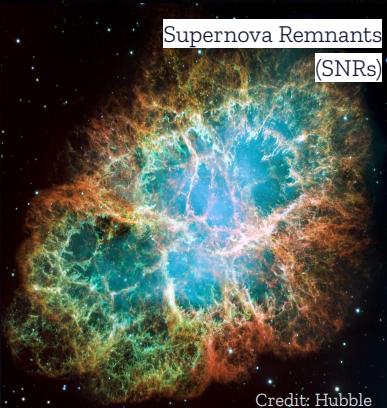


Credit: Hubble

The MeV sky

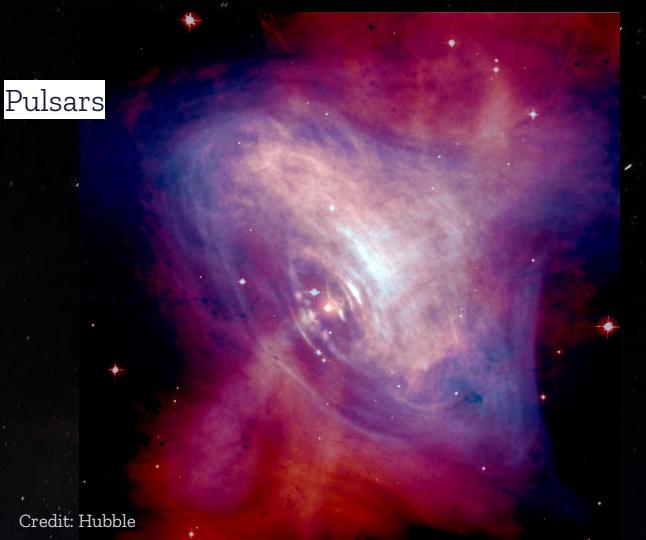
High Mass binaries
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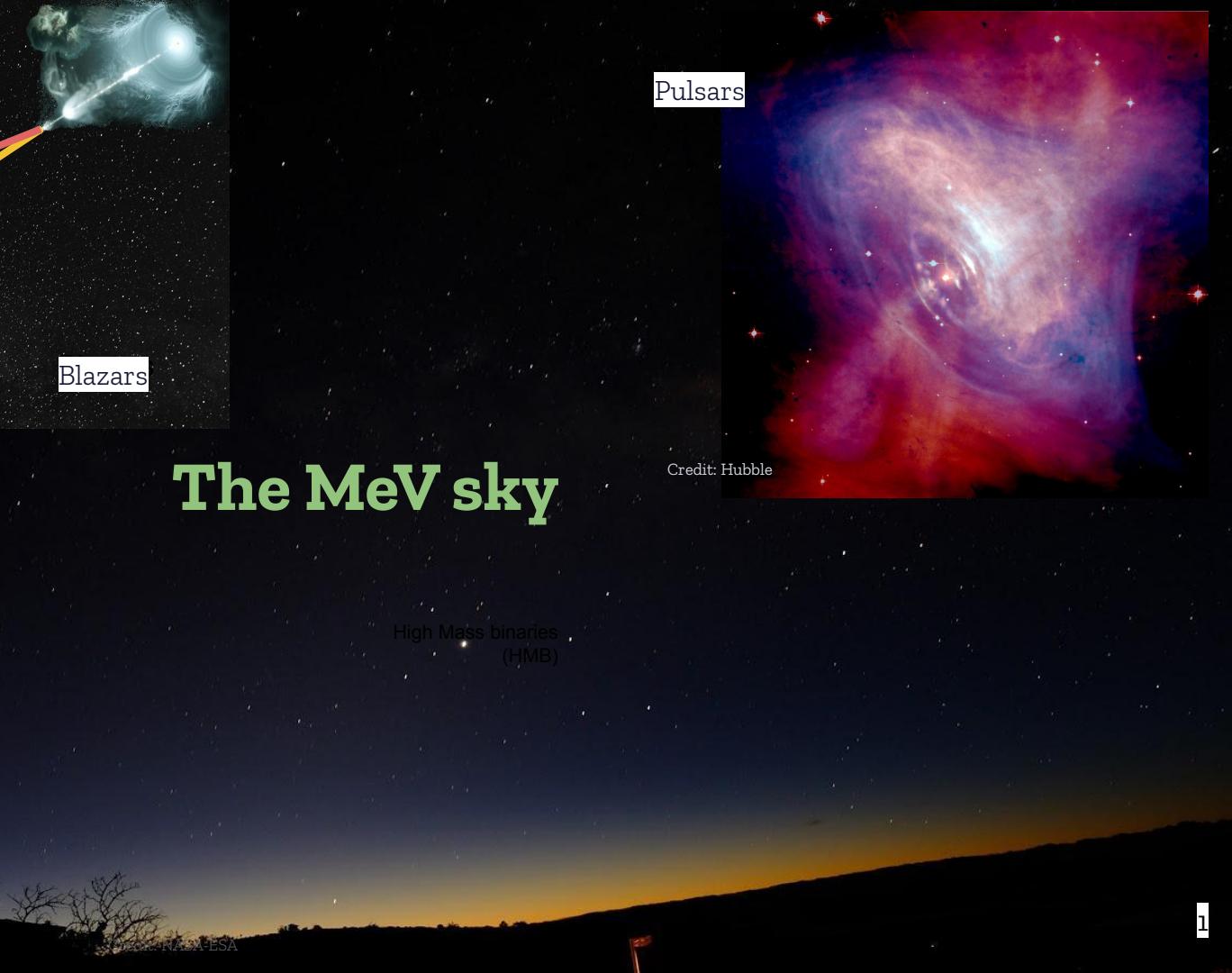
Blazars

Pulsars

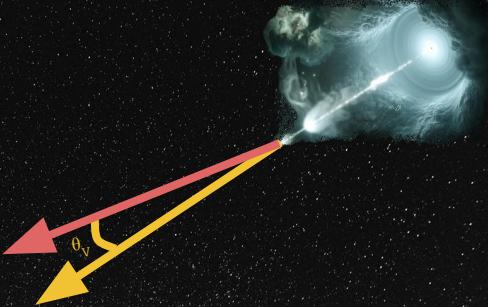


The MeV sky

High Mass binaries (HMB)



$\theta_V \leq 5^\circ - 10^\circ$



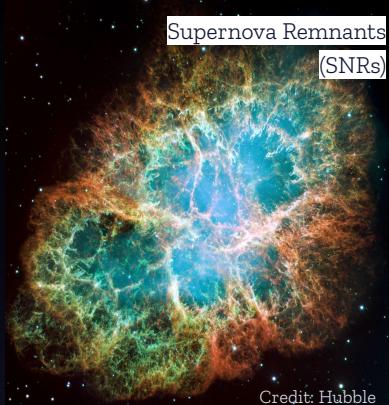
Blazars

Pulsars



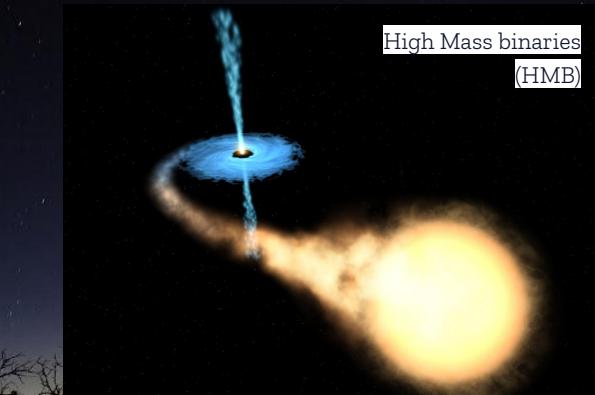
Credit: Hubble

The MeV sky



Supernova Remnants
(SNRs)

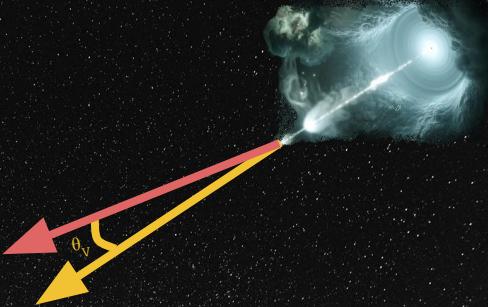
1



High Mass binaries
(HMB)

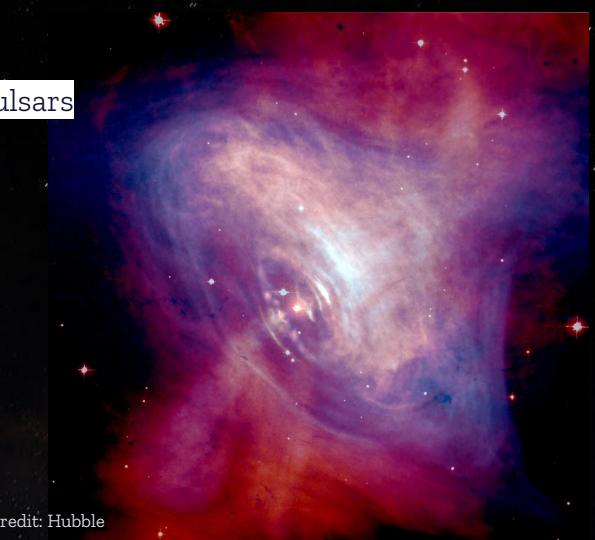
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$\theta_V \leq 5^\circ - 10^\circ$

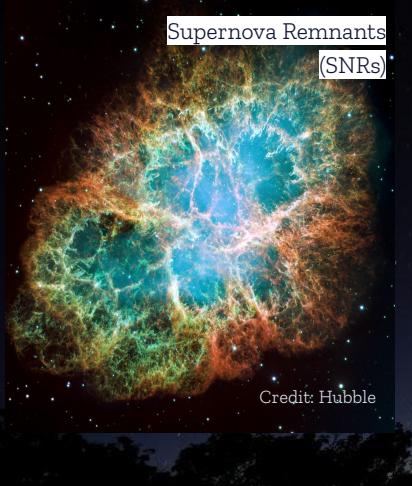


Blazars

Pulsars



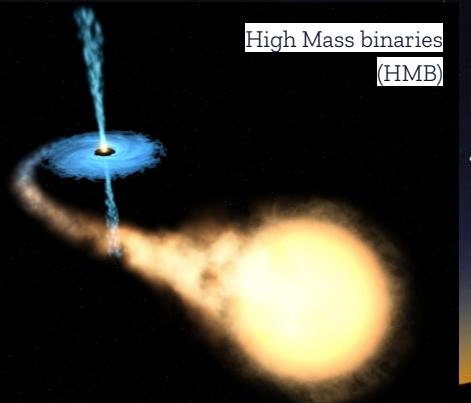
Credit: Hubble



Supernova Remnants
(SNRs)

Credit: Hubble

The MeV sky

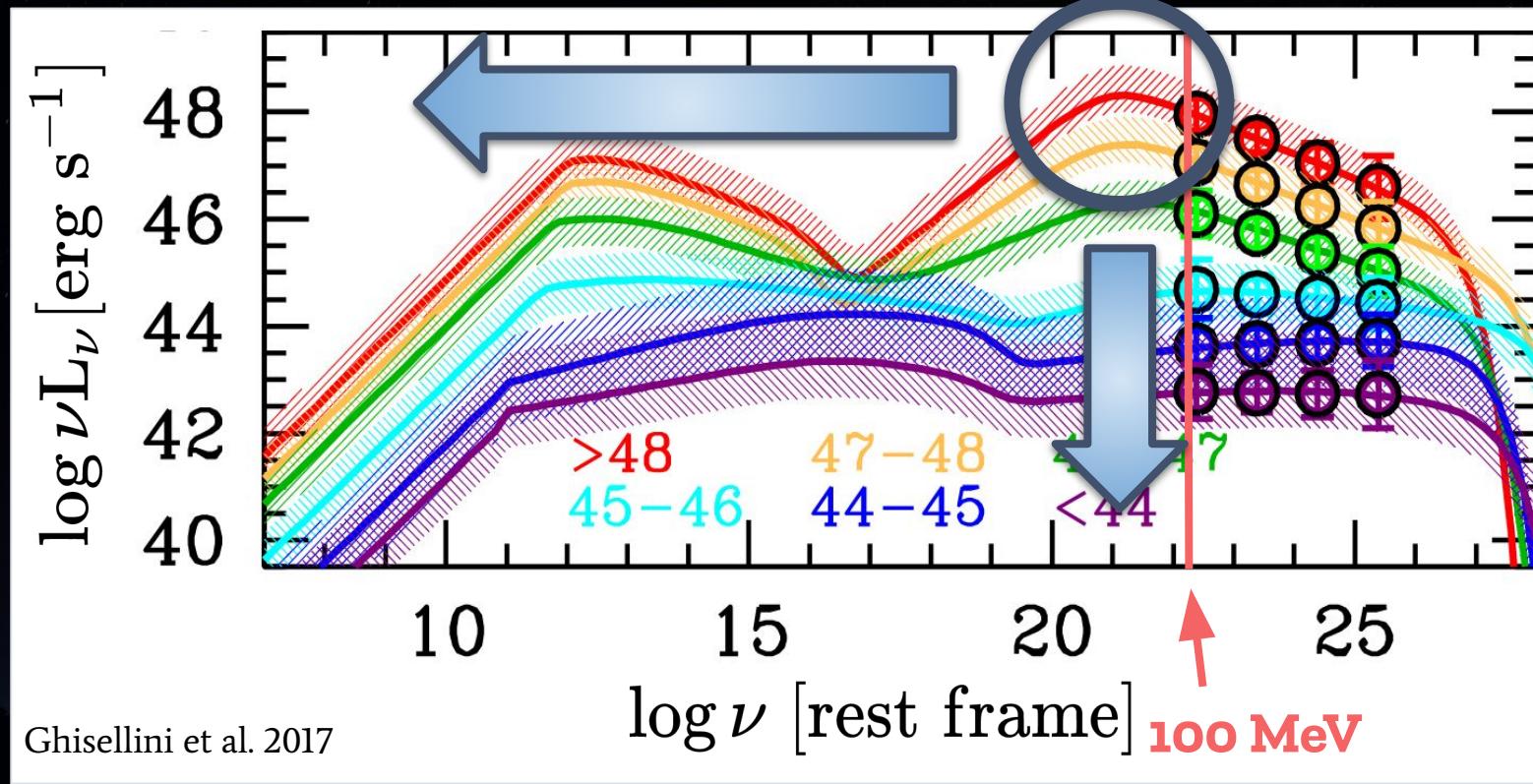


High Mass binaries
(HMB)

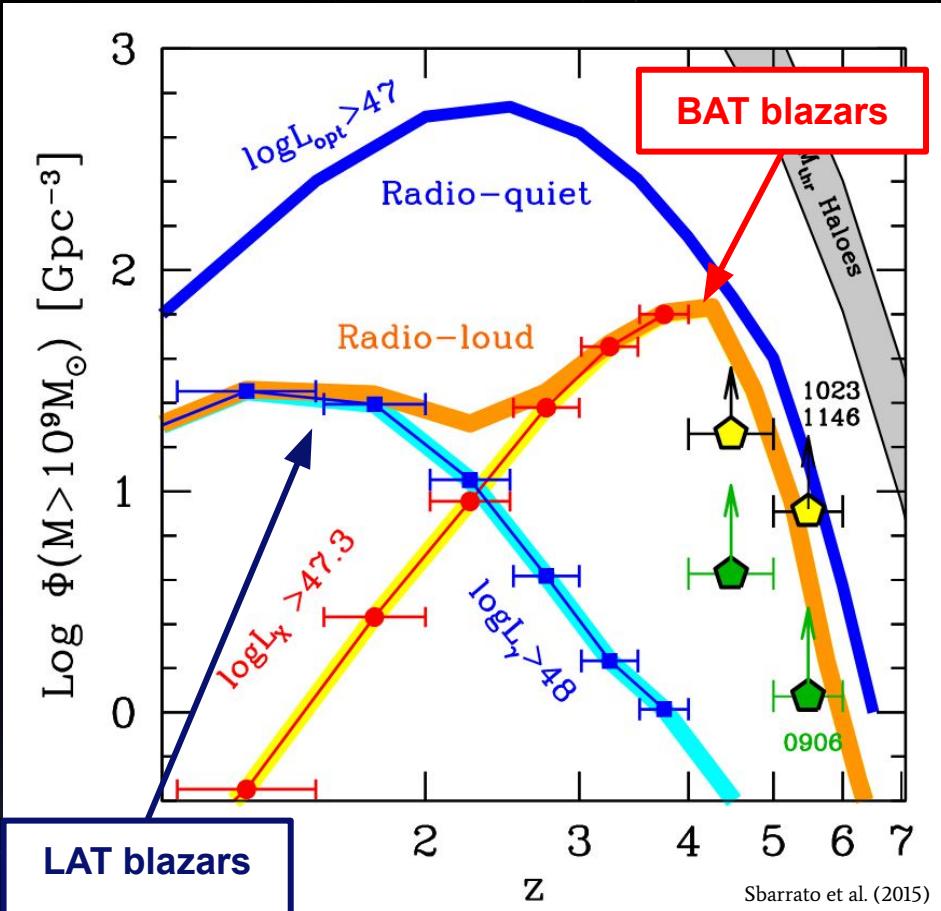


Blazar population

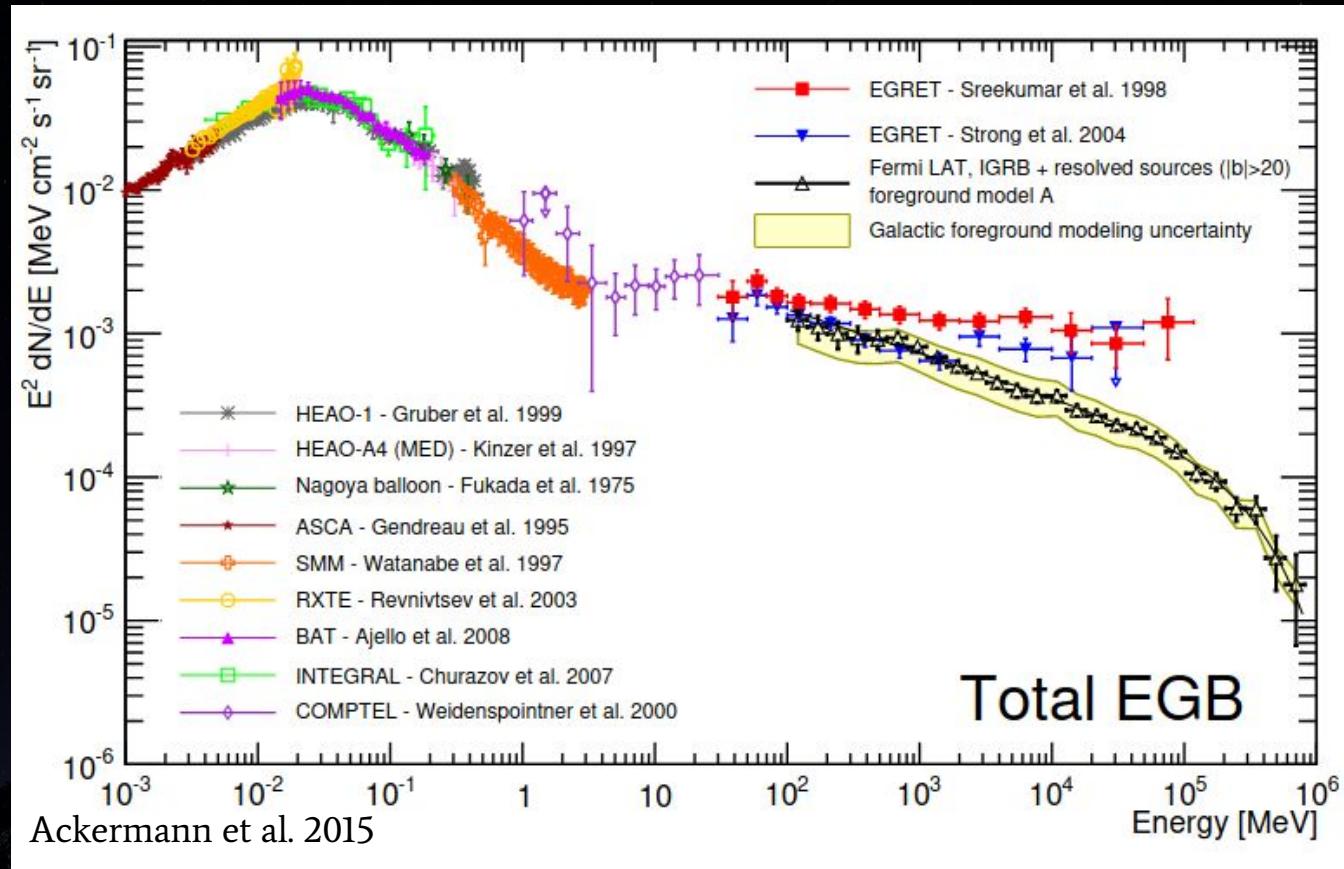
- The more luminous blazars have the high-energy peak at <100 MeV
- We refer to this class as "MeV blazars"

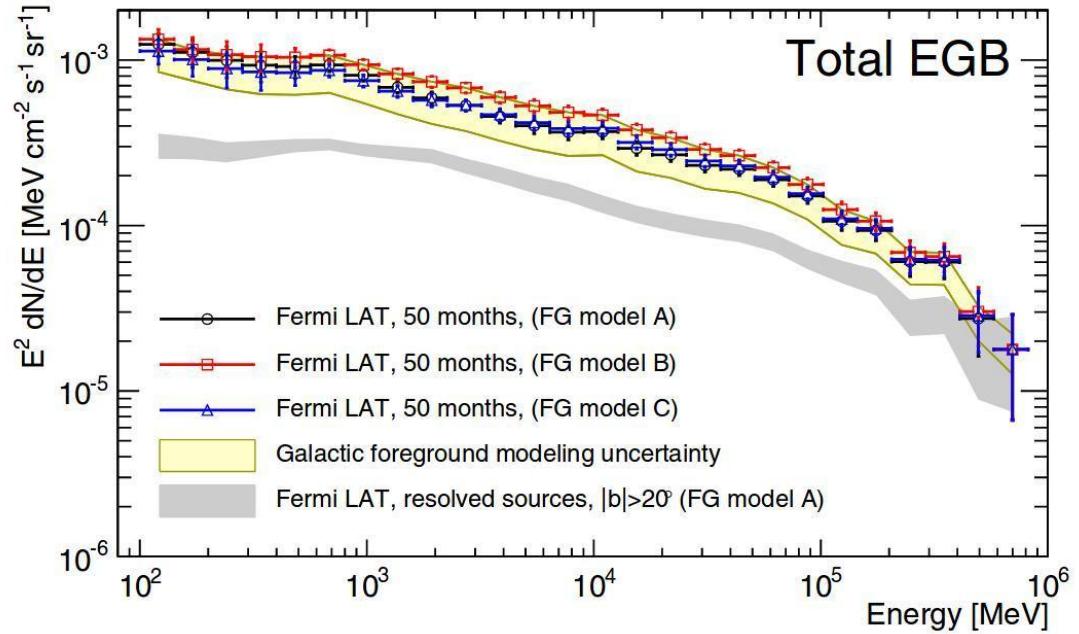


Blazars and SMBH Evolution



The Cosmic High-Energy Background





e.g. Ackermann et al. 2015; Ajello et al. 2015; Di Mauro et al. 2018; Marcotulli et al. 2020

Ackermann et al. 2015



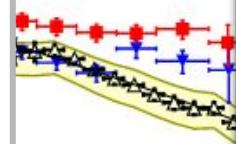
round

EGRET - Sreekumar et al. 1998

EGRET - Strong et al.

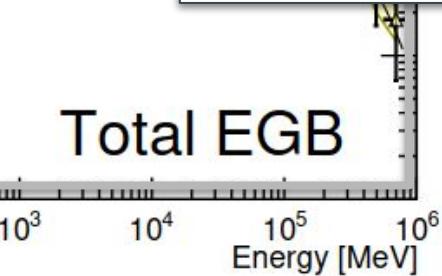
Fermi LAT, IGRB + res foreground model A

Galactic foreground m



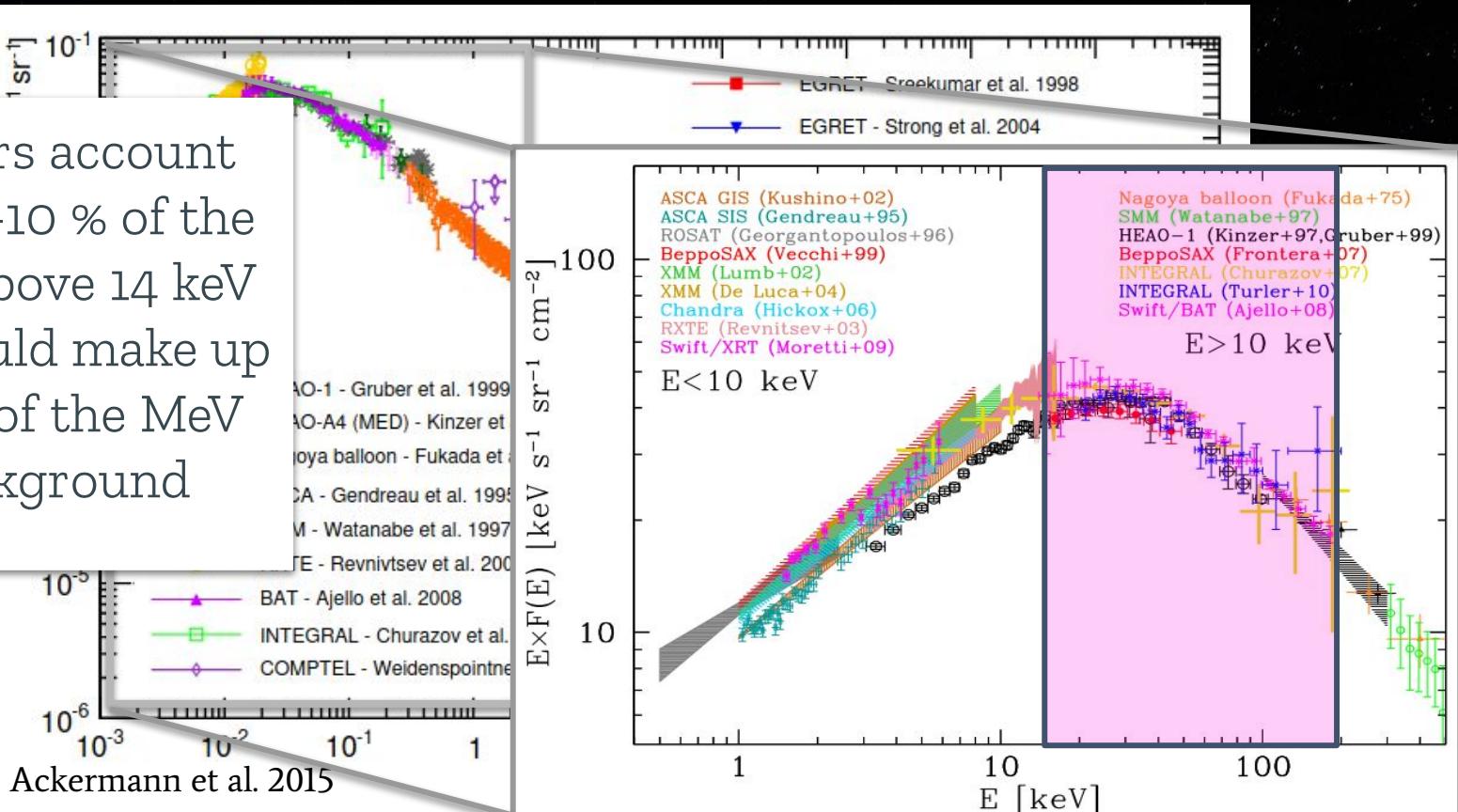
Blazars account for $\sim 30\%$ of the EGB below 100 GeV and for more than 50% above 100 GeV

Total EGB



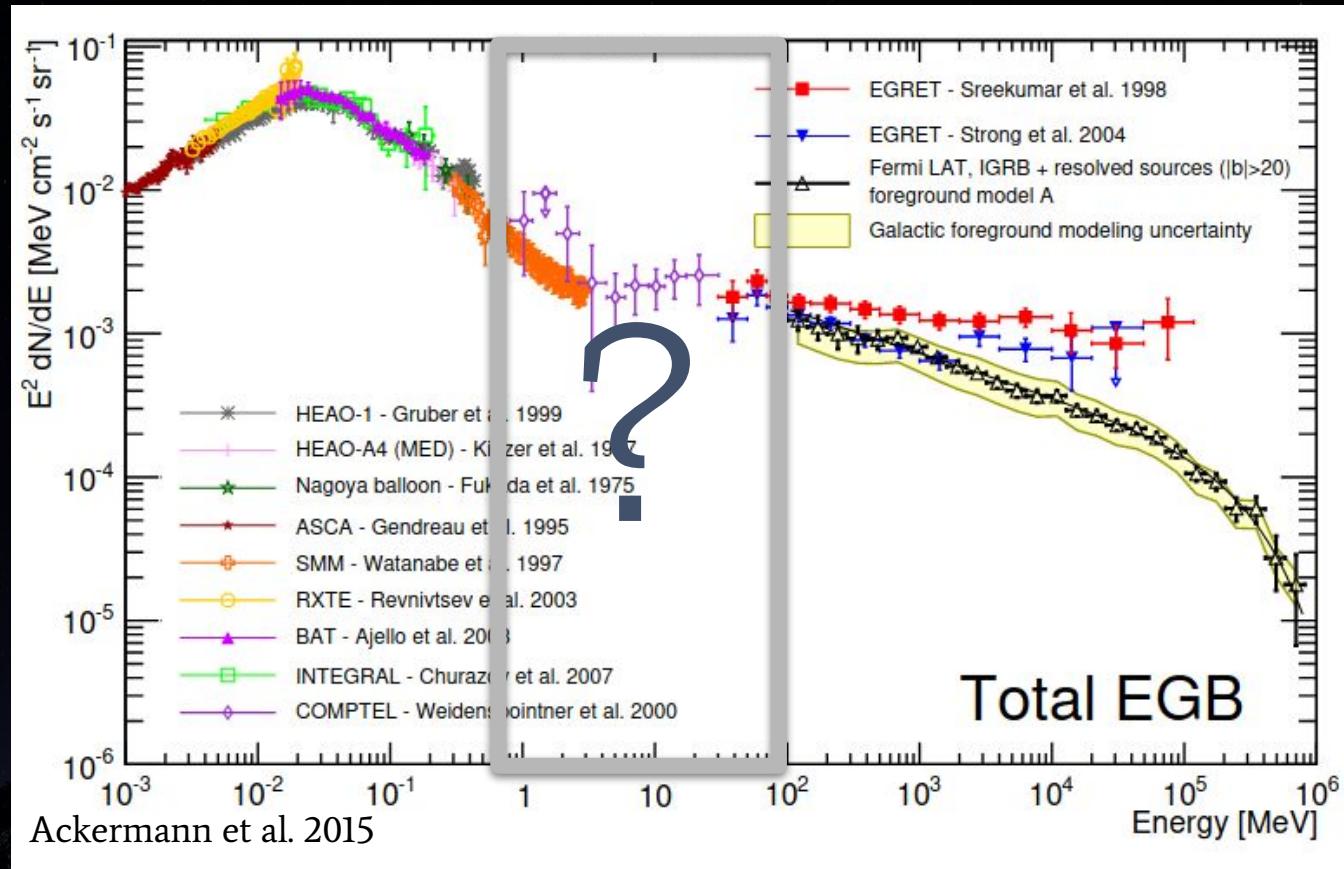
The Cosmic High-Energy Background

Blazars account for $\sim 5\text{-}10\%$ of the CXB above 14 keV and could make up 100% of the MeV background

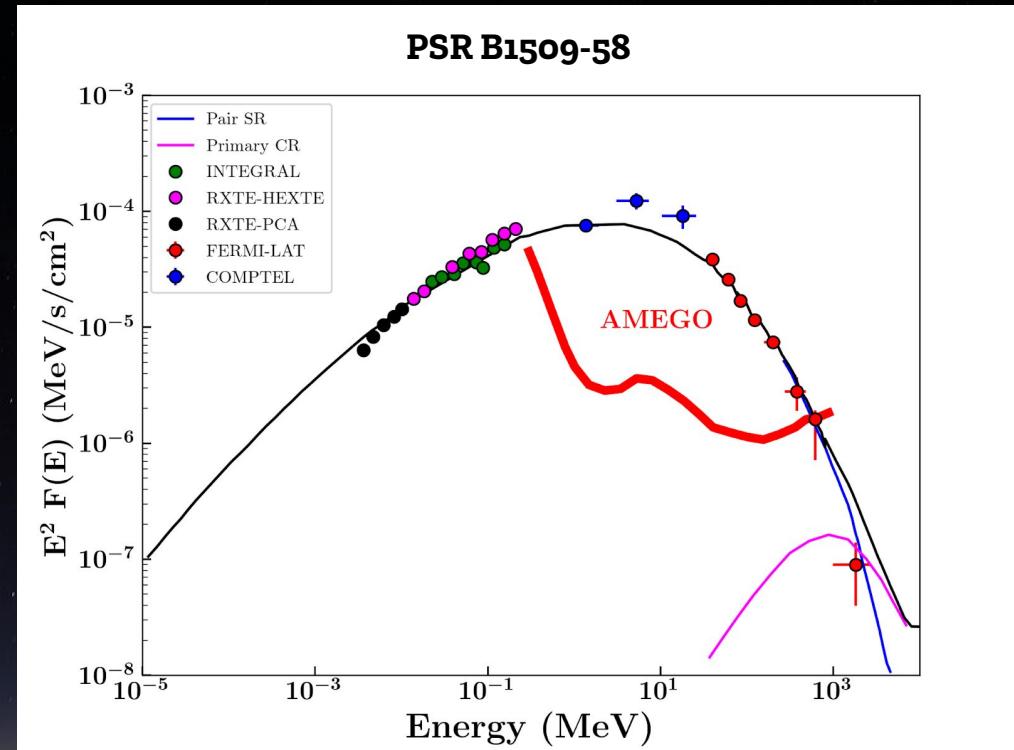


e.g. Ajello et al. 2009;
Ueda et al. 2014;
Aird et al. 2015; Ananna
et al. 2020; Marcotulli
et al. 2022 (ApJ
accepted)

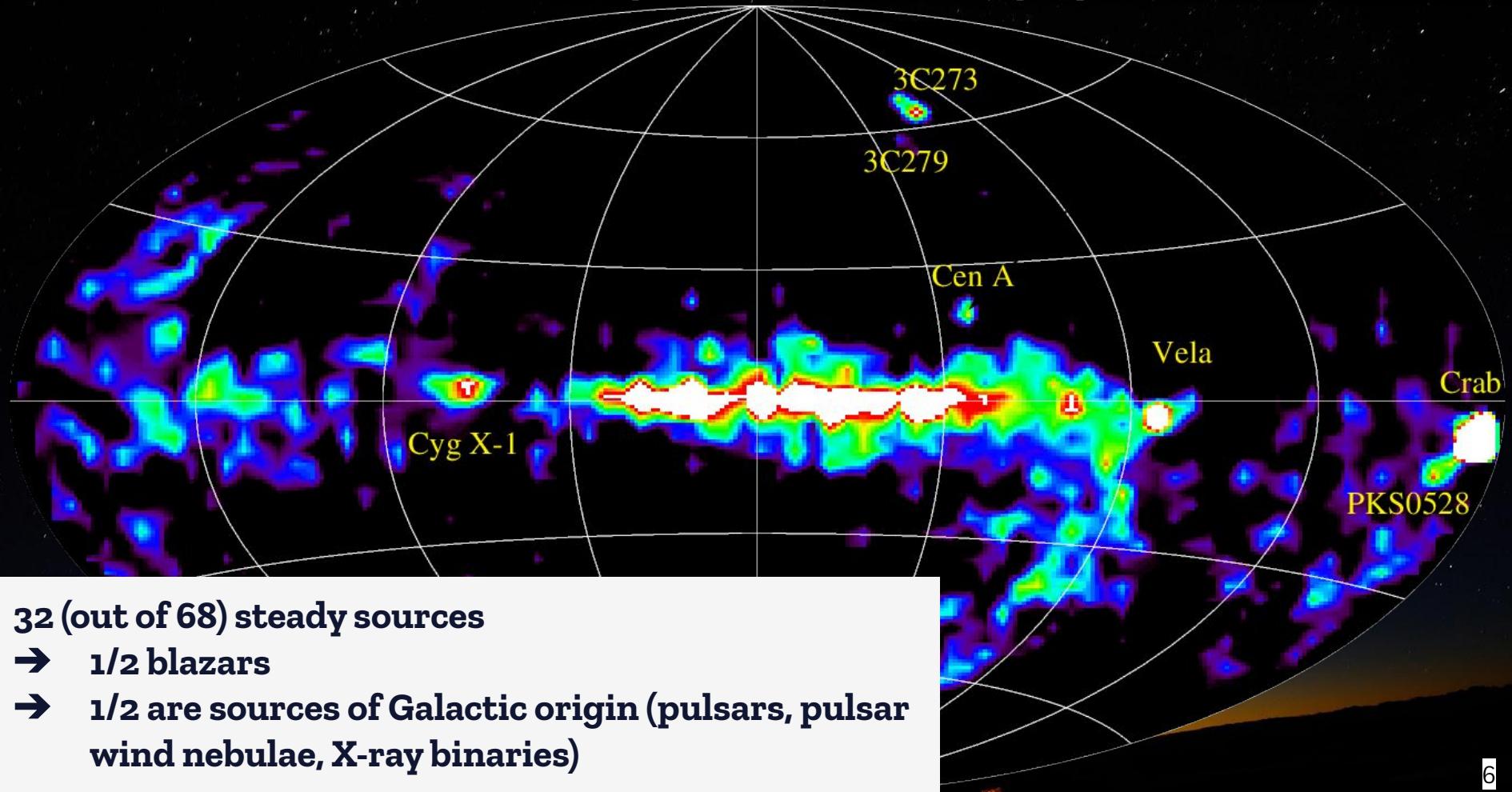
The Cosmic High-Energy Background



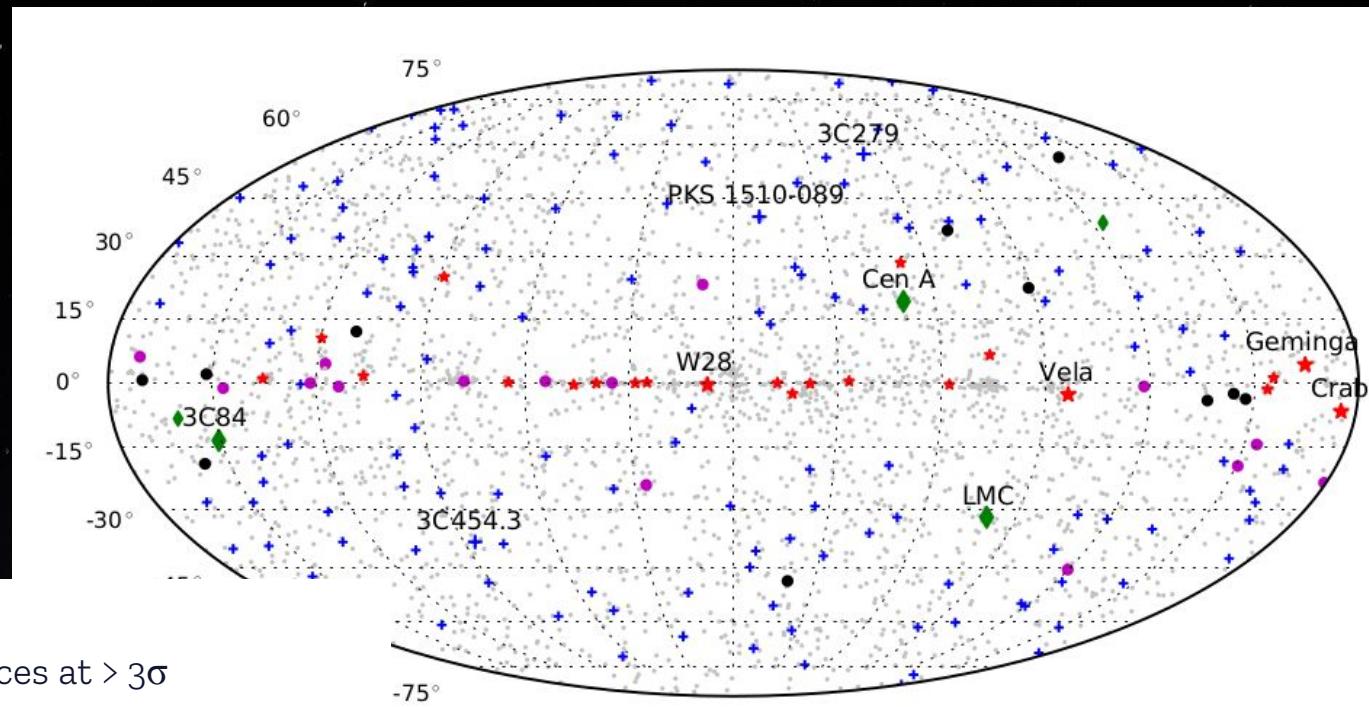
Pulsars



Adapted from Harding et al. 2017



- ★ Pulsar, PWN, SNR, HMB
- + Blazars
- ◆ Other Extragalactic
- Unclassified
- Unassociated
- 3FGL sources



1FLE* (Principe et al. 2018)

E = [30, 100] MeV - 198 sources at $> 3\sigma$

- 72% blazars
- 11% sources of Galactic origin (e.g. pulsars, pulsar wind nebulae, high mass binaries)
- 3% other AGN type
- 9% unclassified
- 5% unassociated with the 3FGL

*no diffuse emission model used

1FLE all-sky map, Principe et al. 2018

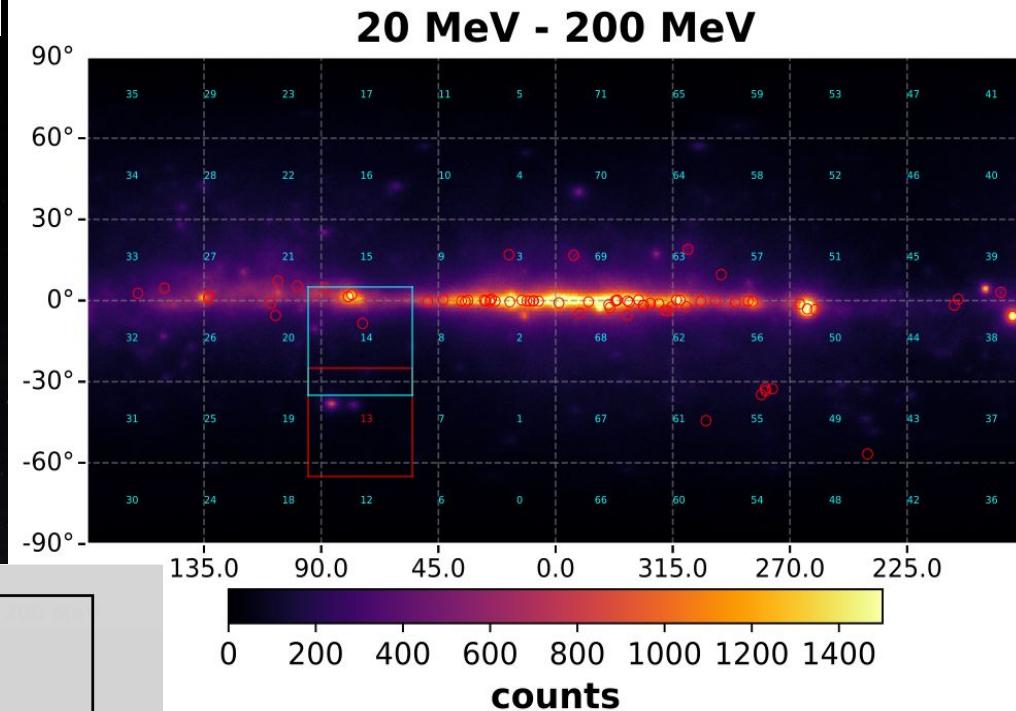
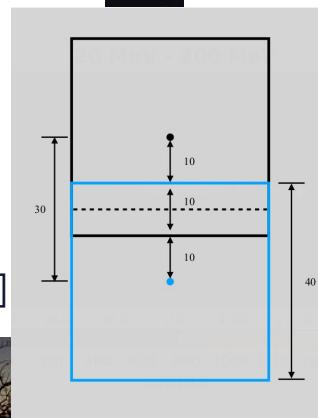


New low-energy catalog

Analysis details

- $E = [20,200]$ MeV
- Dataset - P8R3 (p305)
- Event type = PSF3 (32)
- Event Class = P8R3 Source (128)
- Time coverage - 13 years
- **Galactic diffuse model - gll_iem_v07**
- Isotropic emission -
iso_P8R3_SOURCE_v2_PSF3_v1
- 4FGL extended sources
- Starting catalog = NONE
- ROI width = 40°
- $z_{\text{max}} = 90^\circ$
- **3D likelihood**

[Using Fermipy v0.19 and FermiTools 1.2.23]

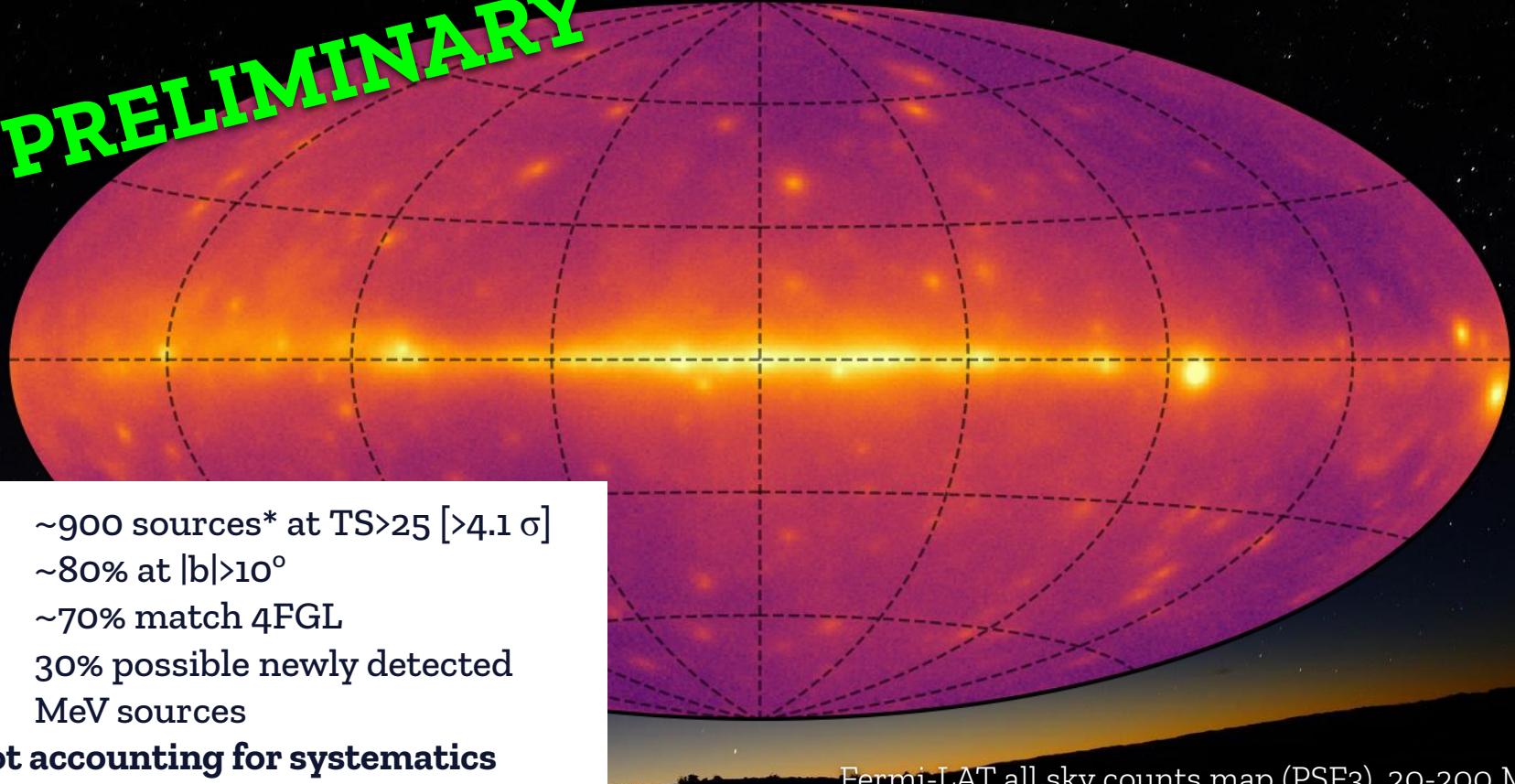


Preliminary low-energy catalog

PRELIMINARY

- ~900 sources* at $\text{TS} > 25$ [$> 4.1 \sigma$]
- ~80% at $|b| > 10^\circ$
- ~70% match 4FGL
- 30% possible newly detected MeV sources

*not accounting for systematics

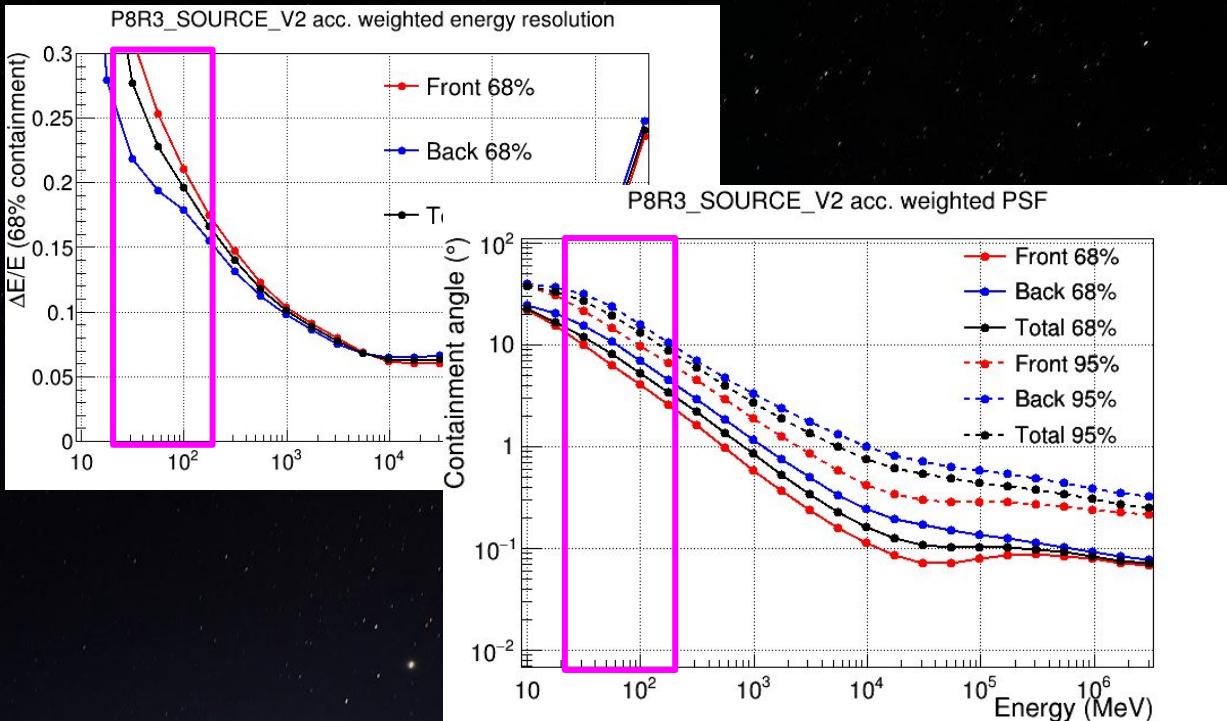


Fermi-LAT all sky counts map (PSF3), 20-200 MeV

Main Challenges

LAT performance at low-energy:

1. Large PSF ($\text{few}^\circ \rightarrow 10^\circ$)
2. Worse energy resolution

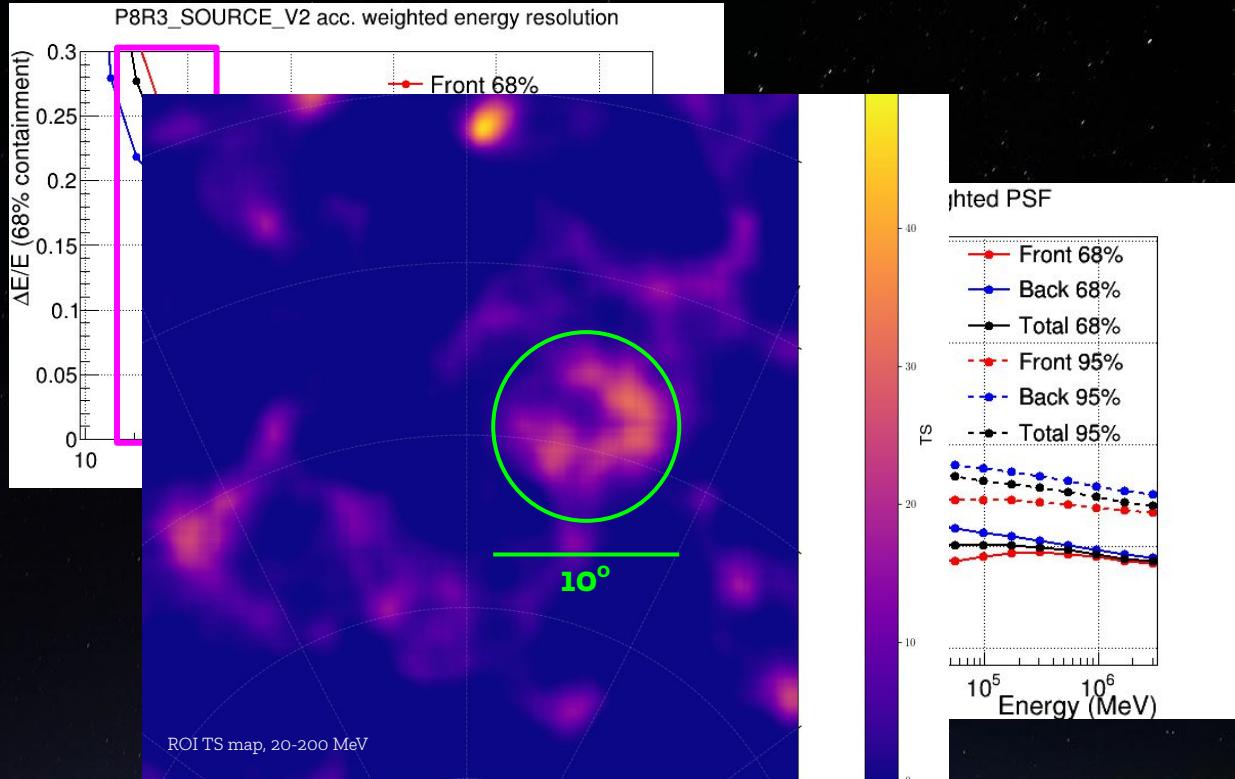


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SOURCE CONFUSION



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SOURCE CONFUSION

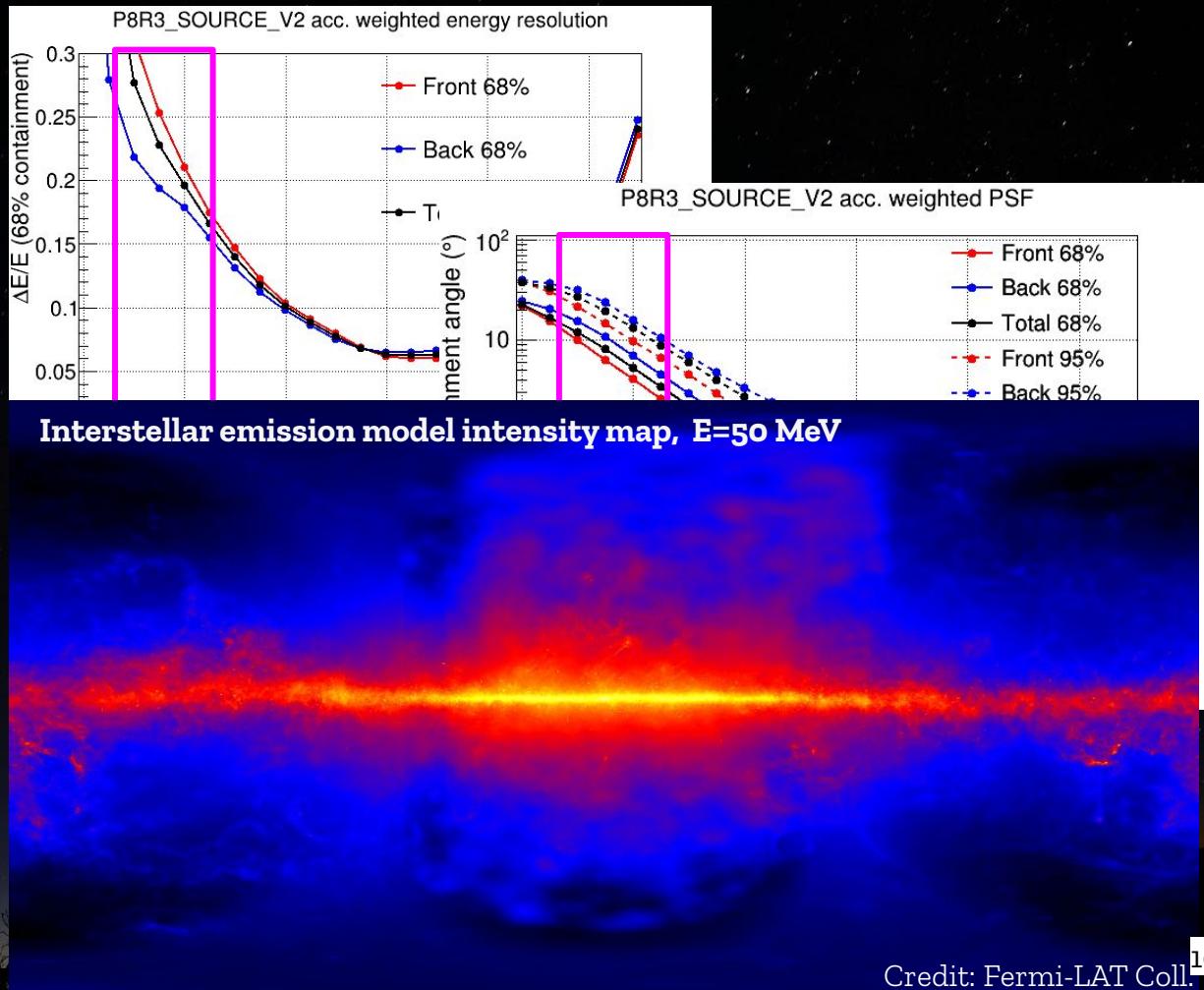
Imperfect interstellar emission model

+

Earth Limb emission

+

Extrapolation of the isotropic spectrum



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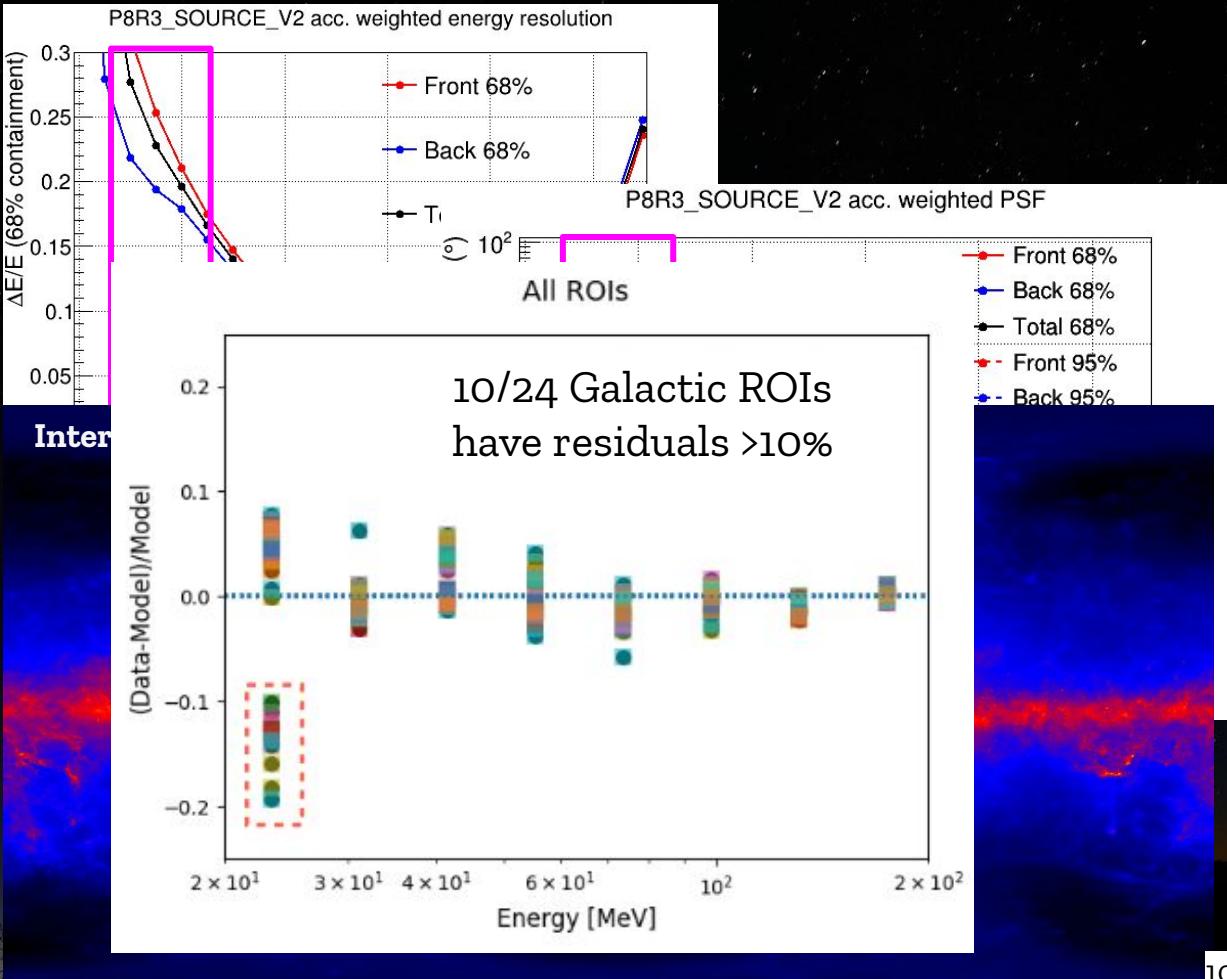
Earth Limb emission

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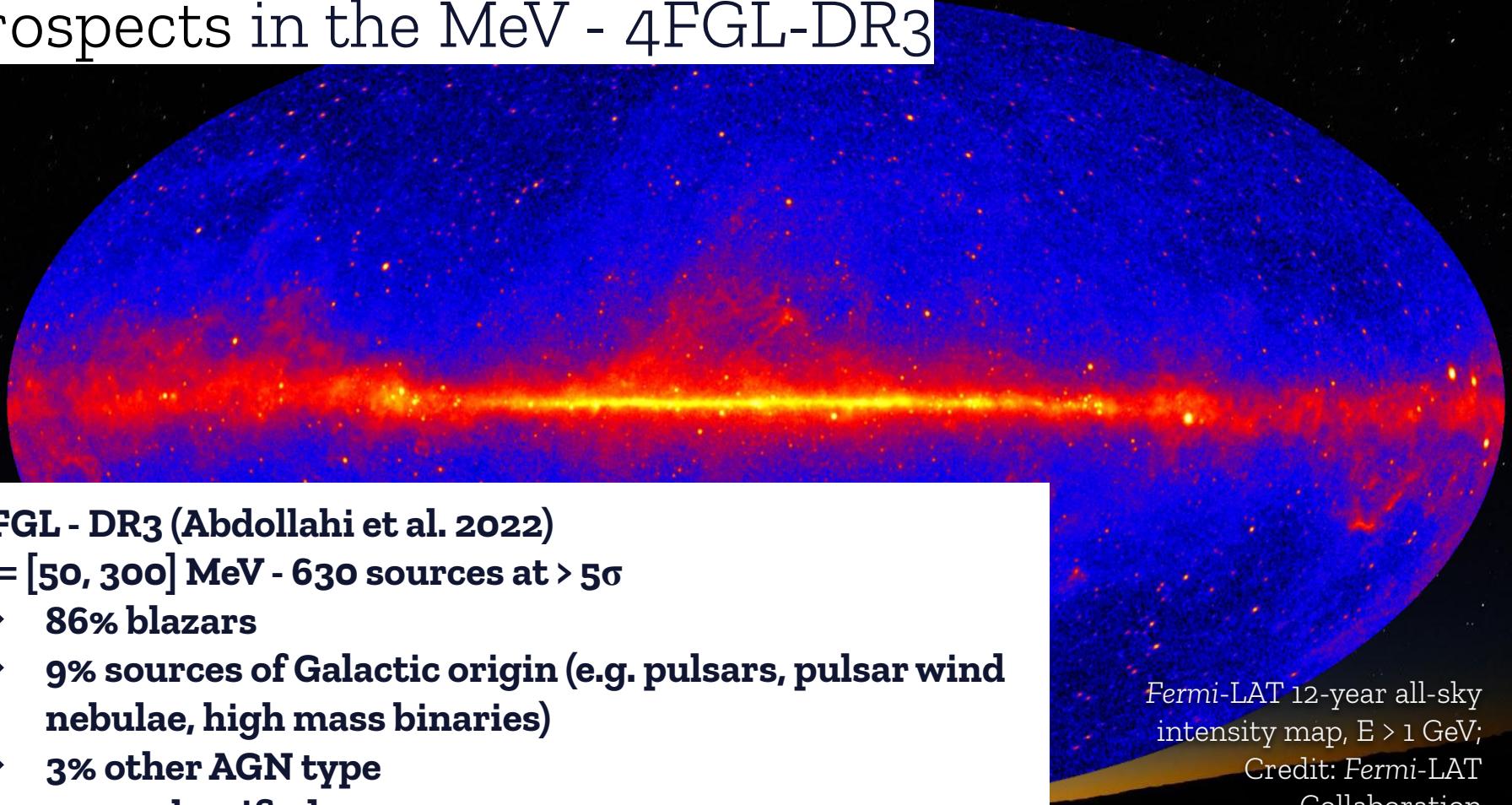
Extrapolation of the isotropic spectrum



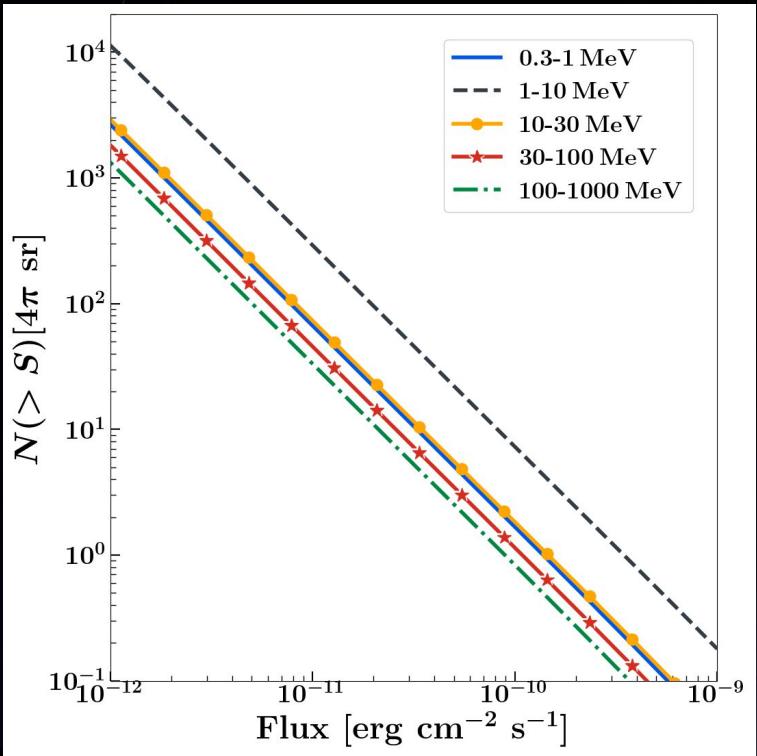
SYSTEMATICS



Prospects in the MeV - 4FGL-DR3



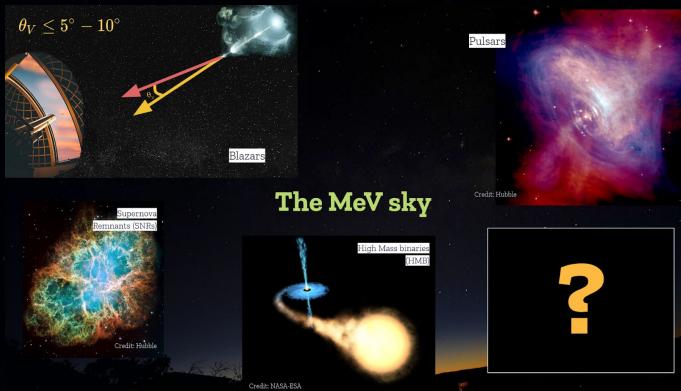
Prospects in the MeV - blazar counts



MISSION	Sensitivity	$N(>S)[4\pi \text{ sr}]$	Timeline
Fermi - LAT	$>2 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ (20-200 MeV in 10 years)	~1000	Operational since 2008
COSI	$>4 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ (0.2-5 MeV in 2 years)	~40	Launch expected in 2026
AMEGO-X	$>1.6 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$ (1-10 MeV in 3 years)	~130	Future NASA MIDEX calls (launch ~2030)
ASTROGAM	$>5 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ (1-10 MeV in 1 year)	~832	ESA M7 mission call (launch ~2037)



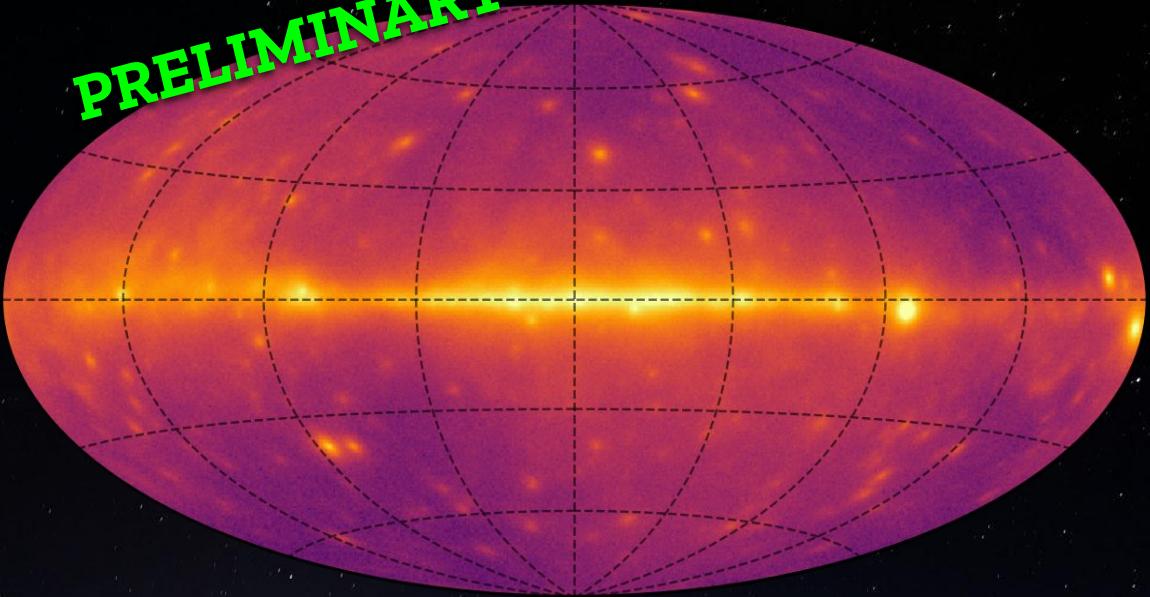
Future missions session
Friday @2PM



Conclusions

- ★ New analysis to detect $E = [20-200]$ MeV sources
- ★ Expect more than 1000 sources (MeV blazars, PSRs, etc.)
- ★ Possibility of discovery space of new source types in the MeV band
- ★ Catalog will be used as map for upcoming MeV missions

PRELIMINARY



EXTRA SLIDES

Detection Procedure

Using Fermipy v0.19 and FermiTools 1.2.23

1. Fit diffuse

- gal [PL shape]
- iso [BPL shape]

2. Find sources

- gta.find_sources()
- Index = 2.0
- Min sep = [$3^{\circ}, 2^{\circ}, 1^{\circ}$]
- 3 iterations \rightarrow TS = [64, 36, 16]

3. Fit diffuse

- gal & iso free
- all sources frozen

4. Optimize Localization

- gta.localize()
- Rank in descending order of TS
- Iterate through each source

5. Final cuts

- Remove sources with TS < 16
- Remove sources within 5° from the edge of the ROI

Iterate through each source

- gal & iso free
- Fit source
- Remove source if it does not converge (status=0, quality=3)

Fit normalization of all sources in the iteration

- gal & iso free
- Confirm convergence

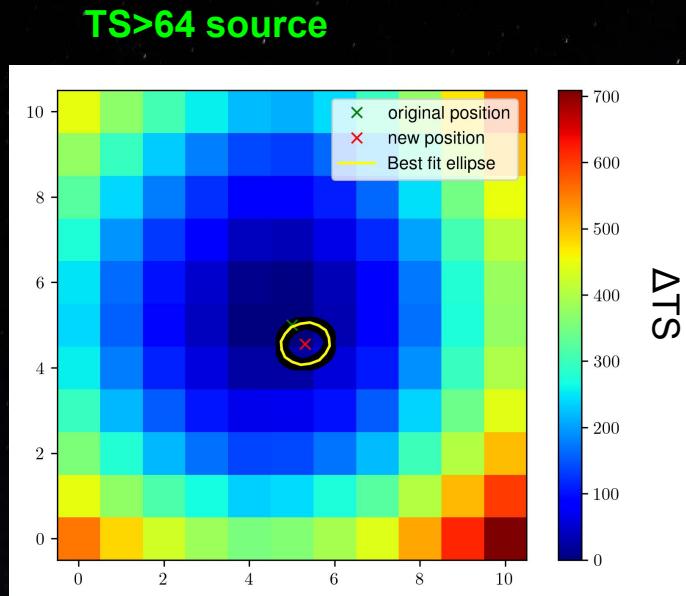
Iteration 1

- All other sources fixed

Iteration 2

- Free sources within 10°

Our methodology



TS>36 source

