

Y<sub>2022</sub>

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# The origin of MeV gamma-ray diffuse emission from the inner Galactic region

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# MeV gamma-ray science

## Astrophysics

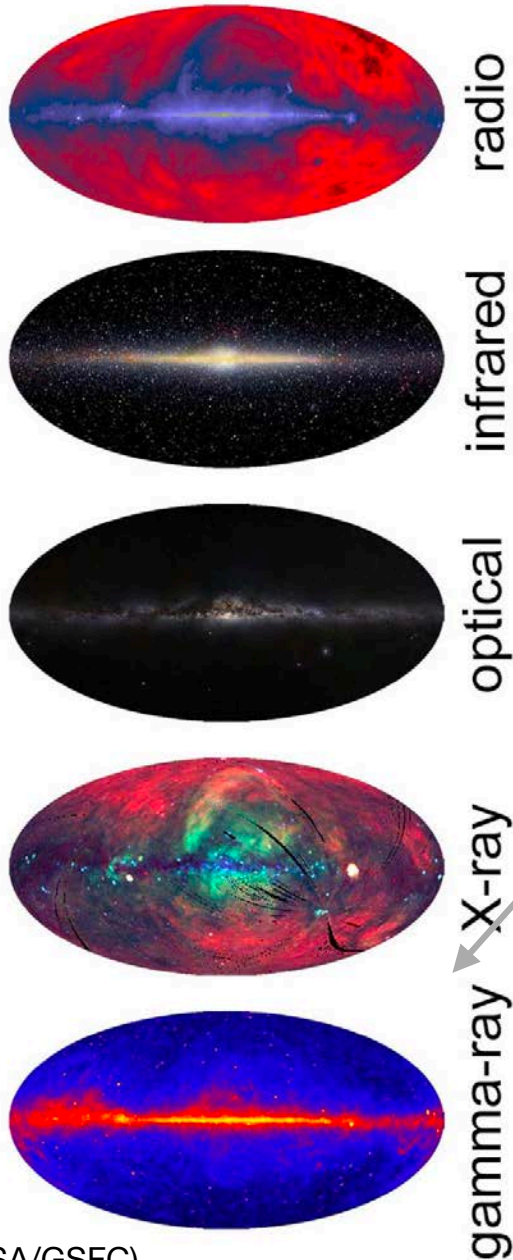
- Particle acceleration
- Relativistic jets
- Origin of matter
- Dark matter
- Cosmic history

## Sources

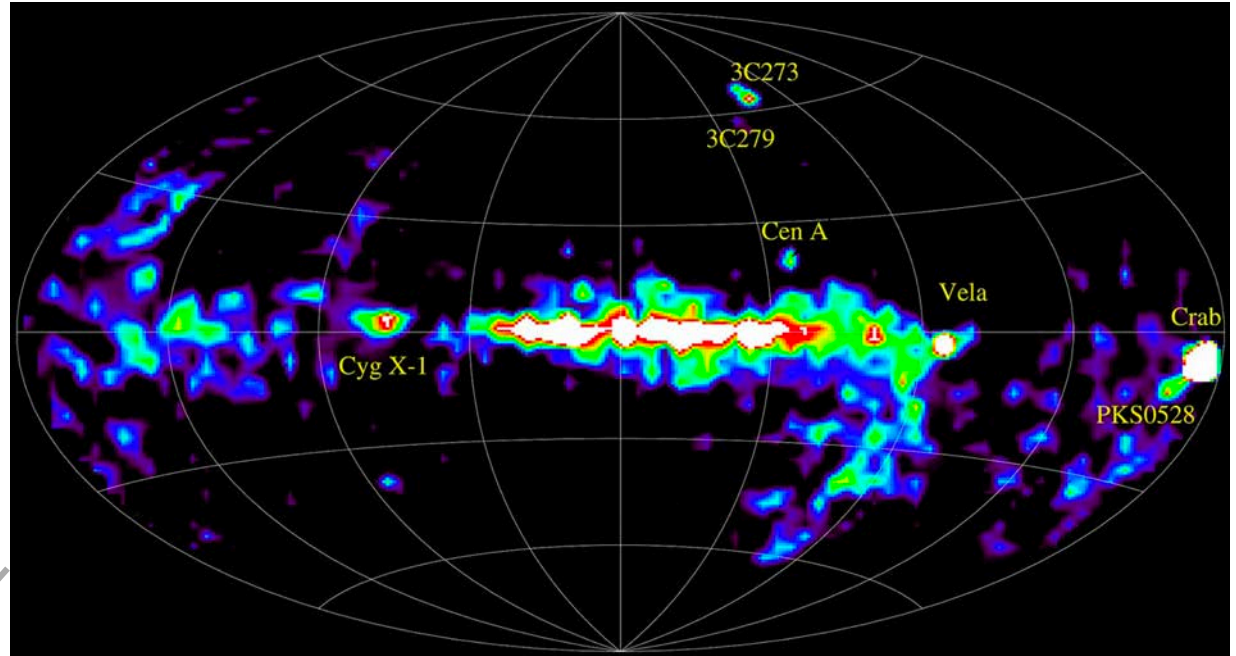


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# All-sky maps in multiwavelength



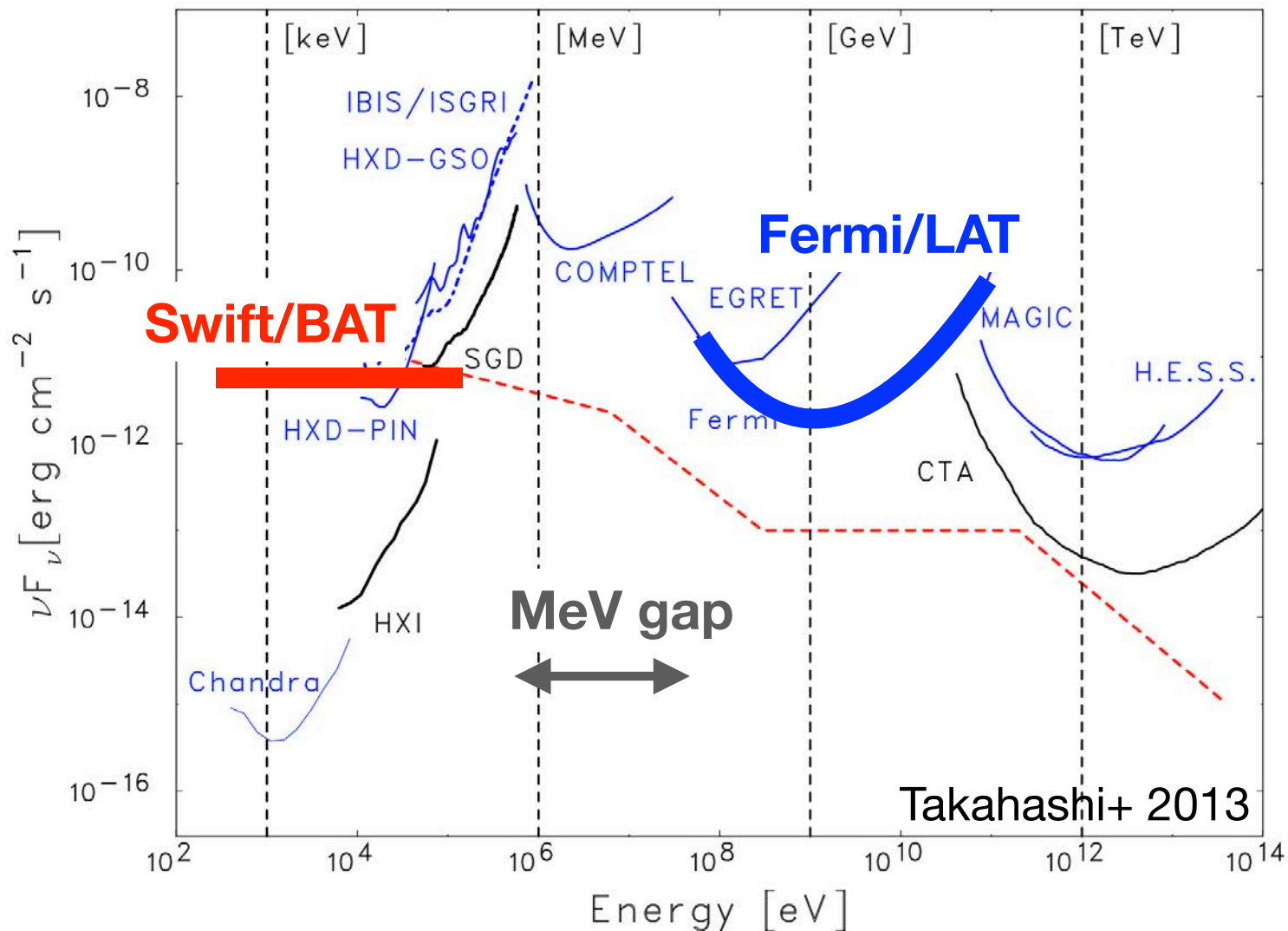
(NASA/GSFC)



## MeV gamma-ray all sky

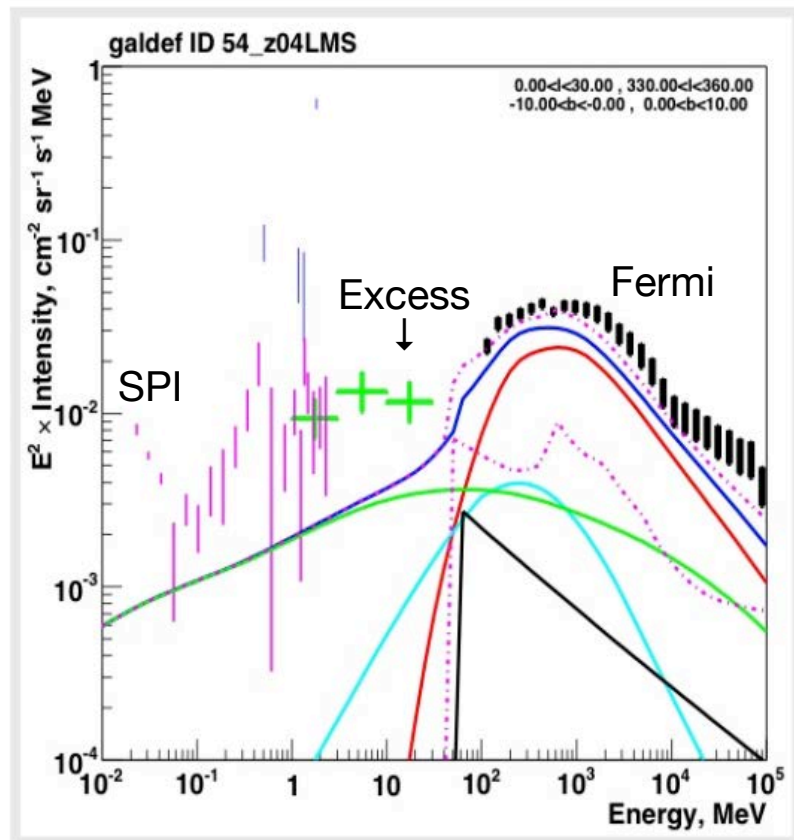
- Observed by COMPTEL (Strong et al. 1999)
- 32 steady sources and 31 GRBs
- Unexplored since then

# Sensitivity of X-ray and gamma-ray telescopes



- The gap (MeV gamma-ray sky) was covered by COMPTEL >20 years ago
- Hard X-ray and GeV gamma-ray windows are well studied (e.g., Swift and Fermi)

# COMPTEL excess



1–30 MeV diffuse emission from the inner Galactic region ( $|l| < 60^\circ$  and  $|b| < 10^\circ$ )

- CGRO/COMPTEL (Strong+ 1994; 1996; 2004)

Cannot be reproduced by standard GDE

→ "COMPTEL excess"

Also confirmed by

- INTEGRAL/SPI (Bouchet+ 2011; Siegert+ 2022)
- SMILE-2/ETCC (Takada+ 2022)

This work (Tsuji+ submitted)  
Investigation of COMPTEL excess by a combination of:

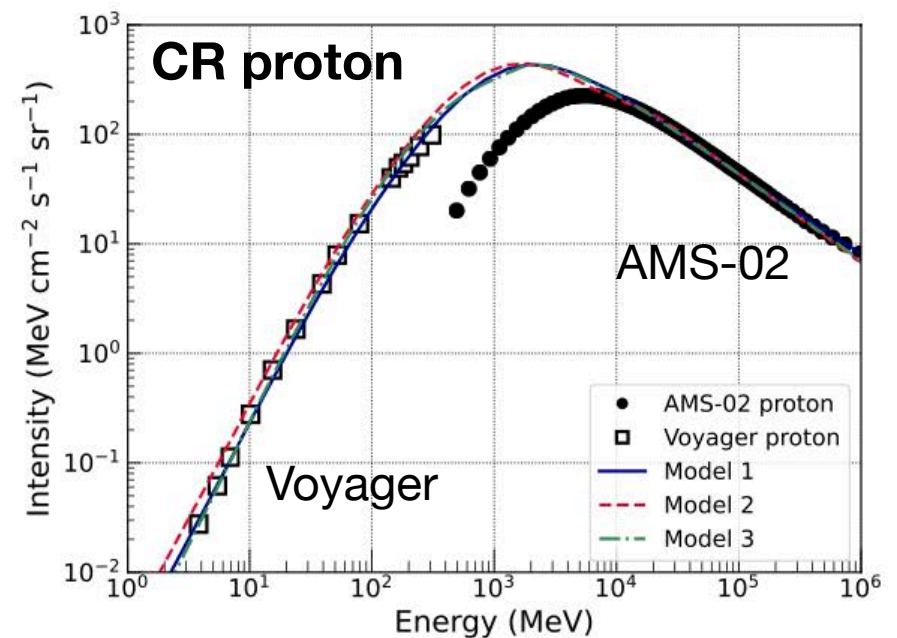
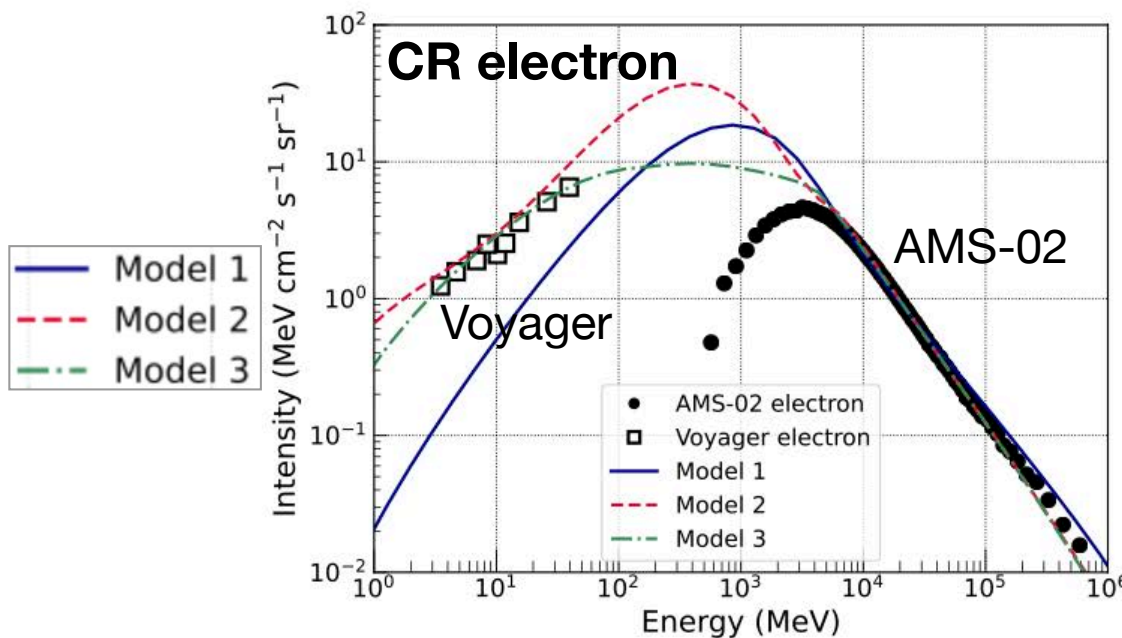
1. Galactic diffuse emission
2. MeV gamma-ray sources
- (3. Cosmic Gamma-ray background; CGB)



# 1. Galactic diffuse emission: CR spectra

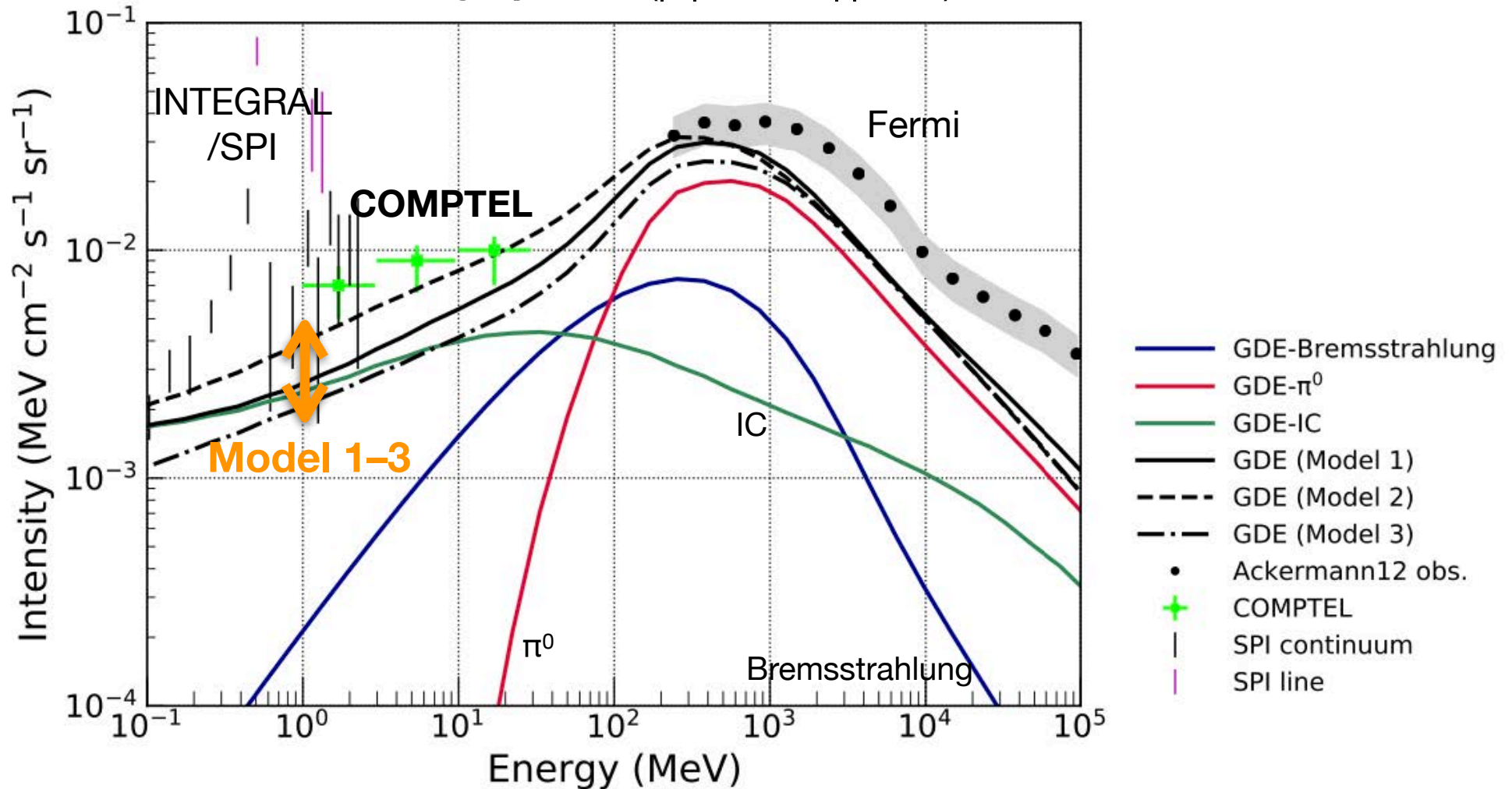
- CR propagation and gamma-ray radiation by GALPROP
- Three baseline models below

Model	Reference	CR electron	CR proton	Fermi $\gamma$ ray
1	Ackermann+ 2012	Not consistent w/ Voyager	OK	OK
2	Orlando 2018 (DRE)	OK	OK	OK
3	Orlando 2018 (DRELowV)	OK	OK	OK



# 1. Galactic diffuse emission

Gamma-ray spectra ( $|b| < 10^\circ$  &  $|l| < 60^\circ$ )



Model uncertainty in MeV gamma ray

→ ~a factor of 2–3, arising from CR electron in 100–1000 MeV

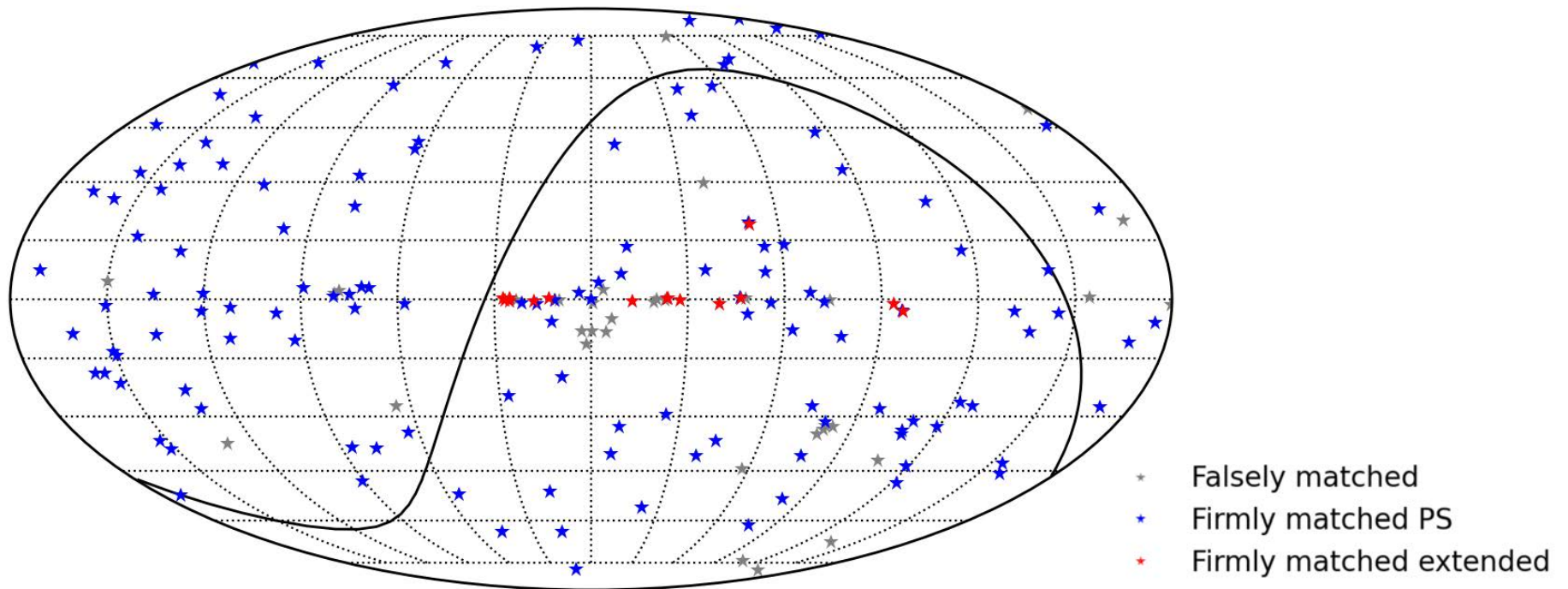
# Swift-BAT and Fermi-LAT catalog cross-match

Catalog cross-match (Tsuji+ 2021)

1. Swift-BAT 105 month catalog (1632 sources)
2. Fermi-LAT 10-yr catalog (5788 sources)

→ 187 cross-matched sources in total

- 156 point-like and 31 extended sources
- 145 firmly matched

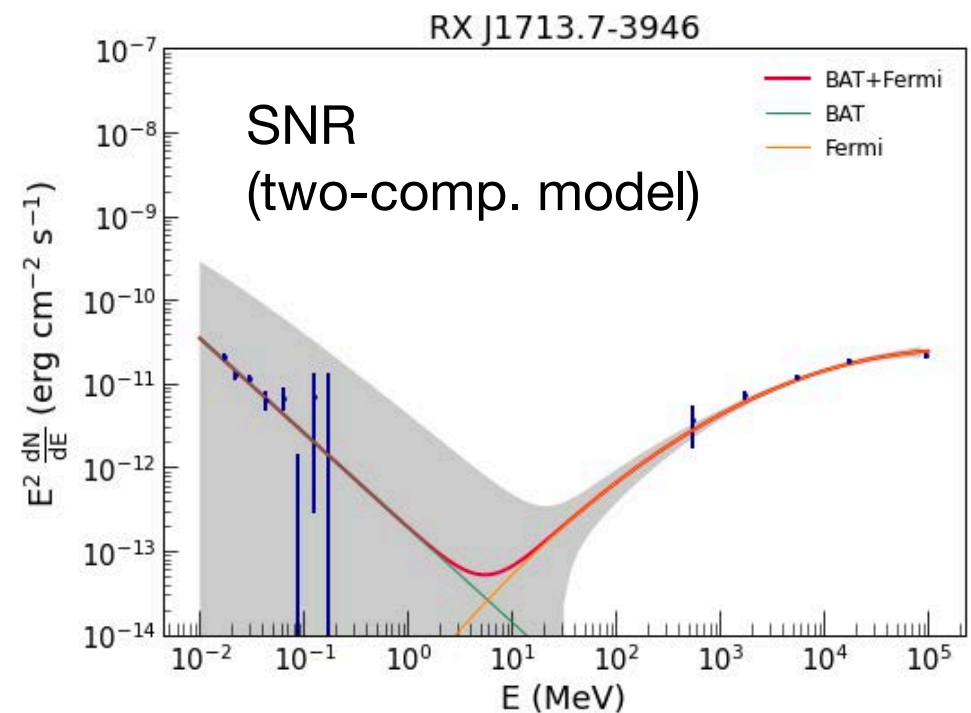
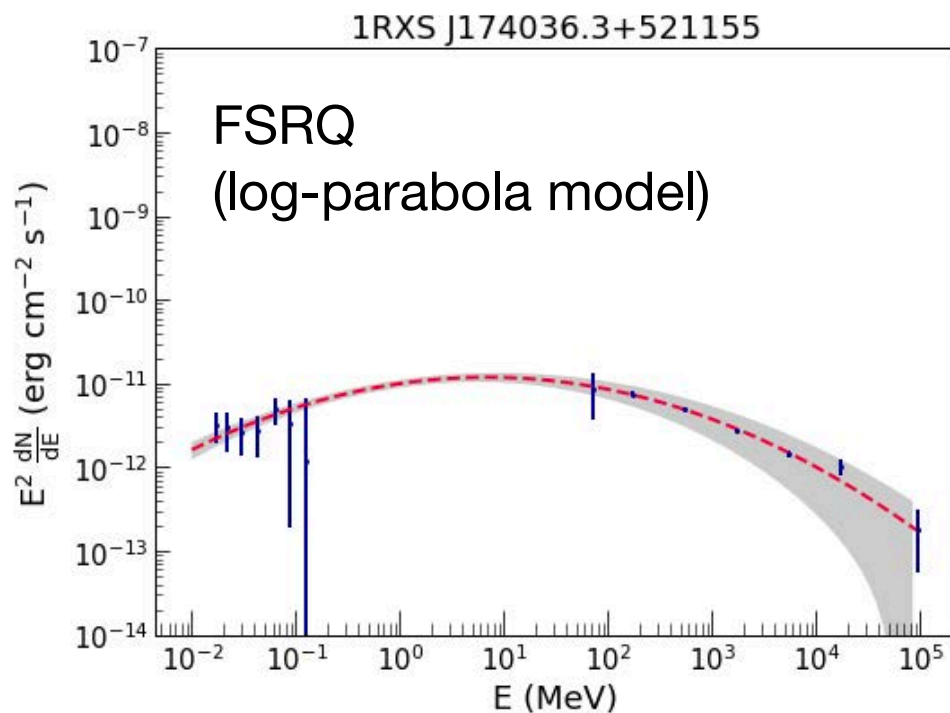


- Matched sources (i.e., hard X-ray and gamma-ray emitters)
- →“(0th) MeV source catalog”



## 2. Sources: SED joint fit

- Fitting SED of cross-matched sources
- Model
  - Log parabola (as default)
  - Two-component (Swift-BAT + Fermi-LAT models)



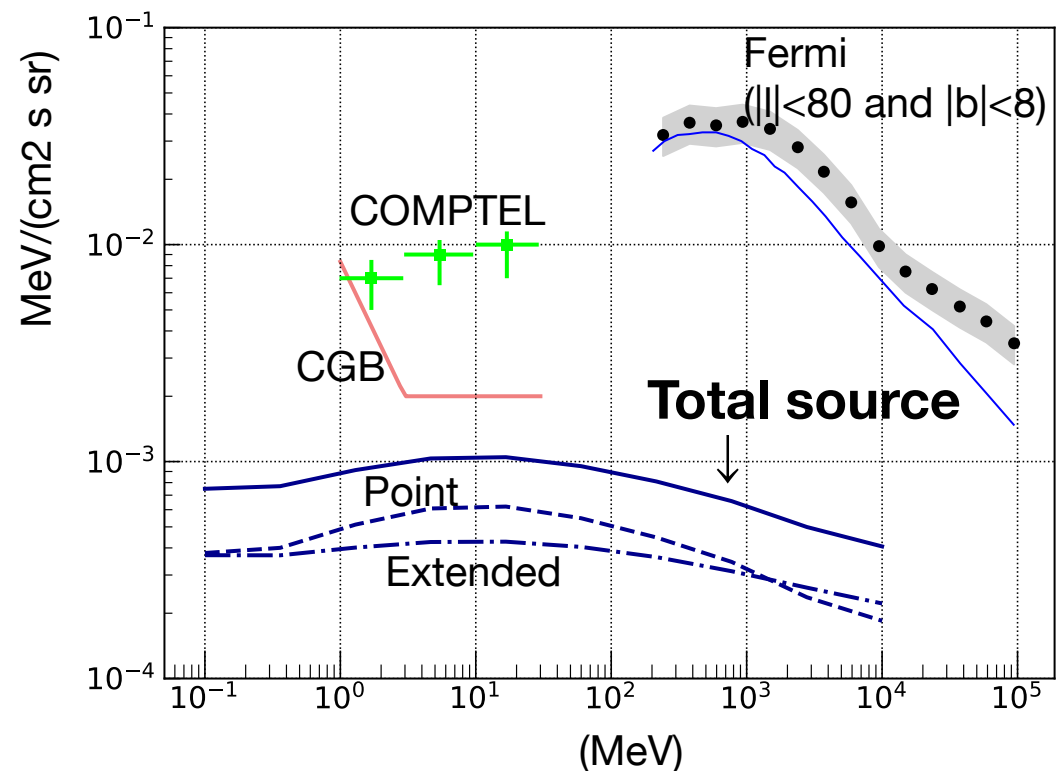
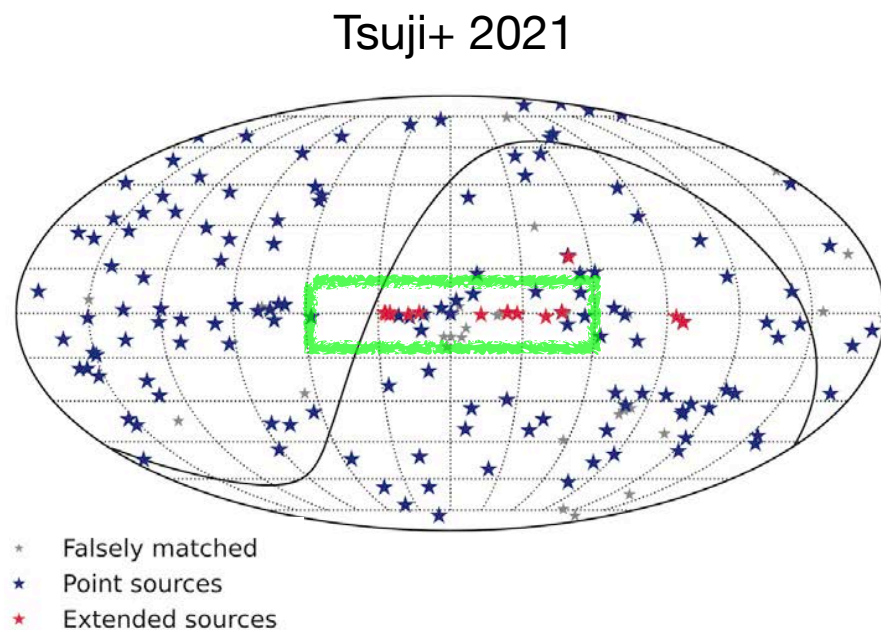
# 2. Sources

## (1) Point sources

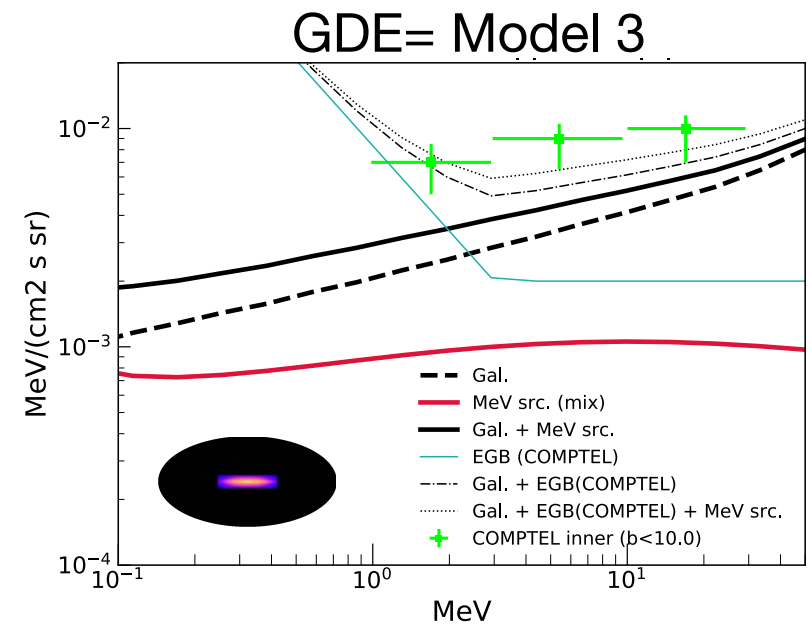
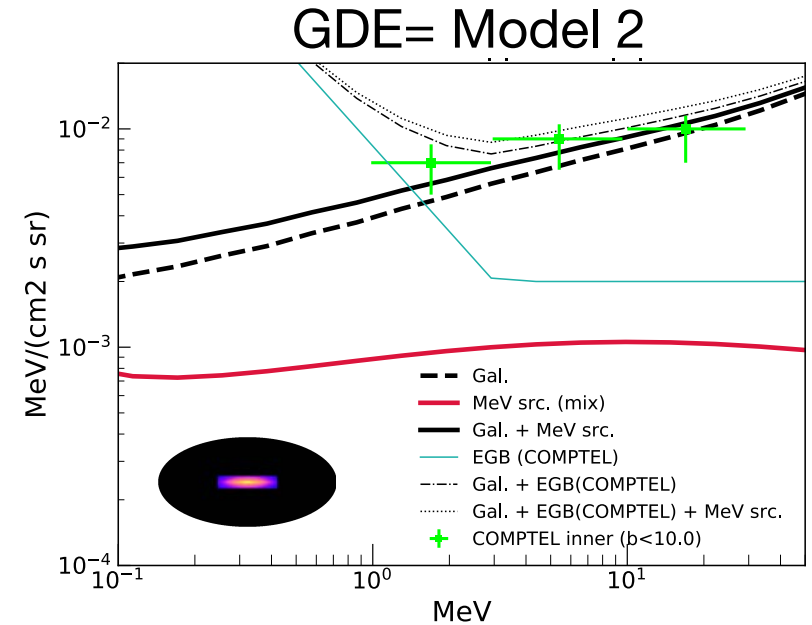
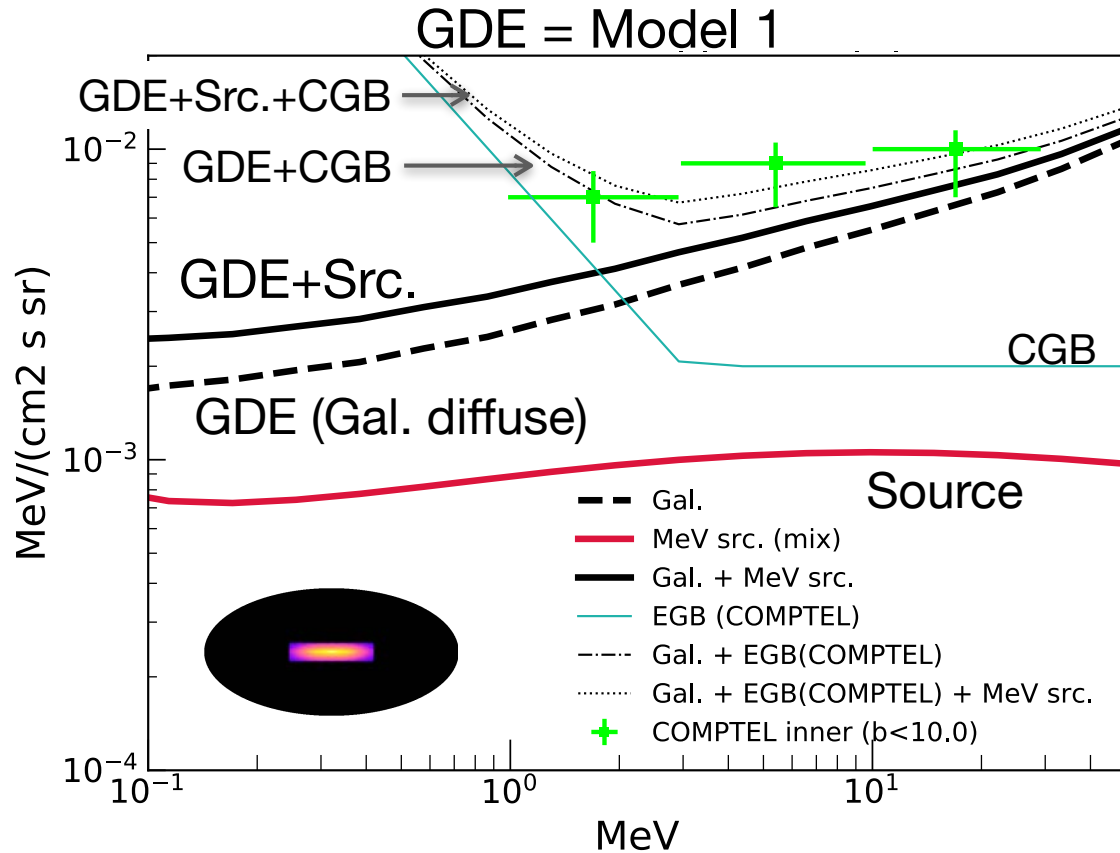
- 23 sources in the inner Galactic region ( $|\ell| < 60^\circ$  and  $|b| < 10^\circ$ )
- 5 Blazars, 1 Galactic center, 1 Seyfert, 1 SNR-PSR, 4 X-ray binaries, 3 PSRs, 1 Globular cluster, 3 False match, 4 Unk

## (2) Extended sources

- 17 sources in the inner Galactic region ( $|\ell| < 60^\circ$  and  $|b| < 10^\circ$ )
- 8 PWNe, 2 SNRs, 5 Spp, 2 Unk



# COMPTEL excess

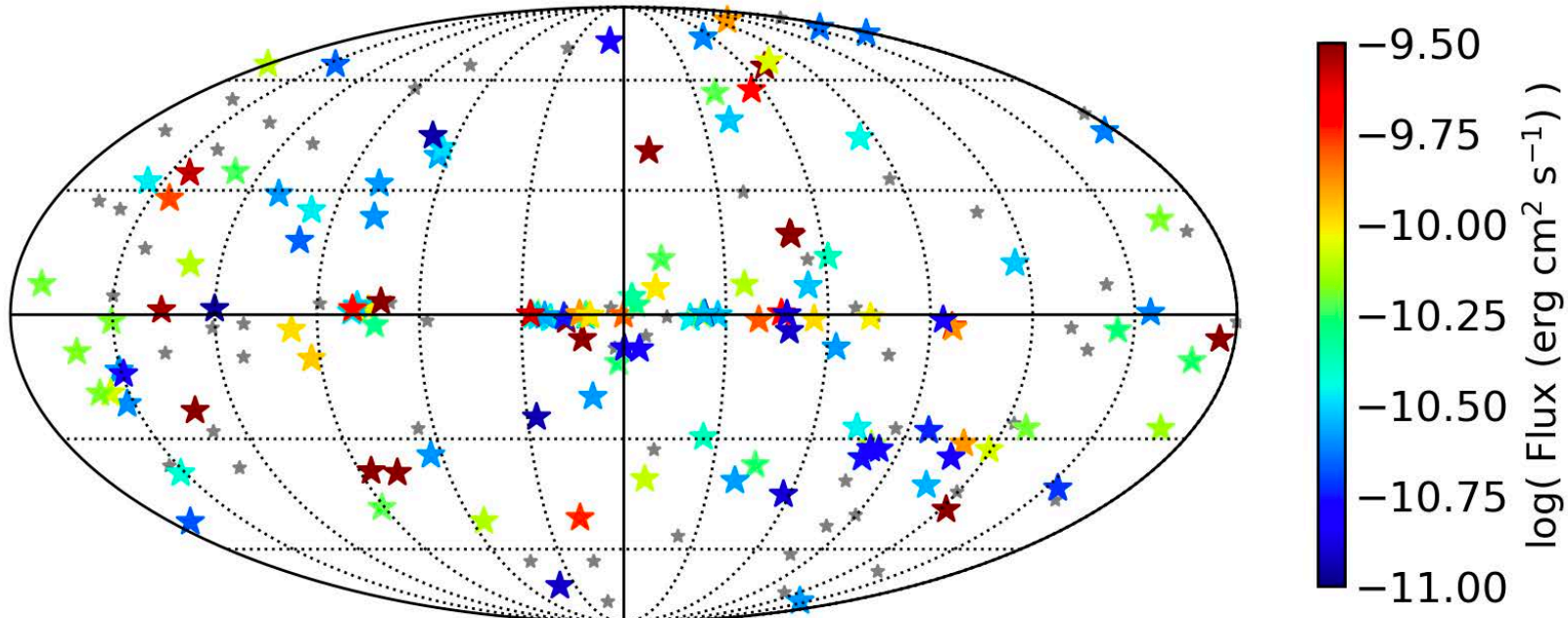


- COMPTEL excess = Galactic diffuse (GDE) + Source (+CGB)
- GDE is the most uncertain → constrained by future missions

Prospects for future missions  
&  
MeV Gamma-ray all sky



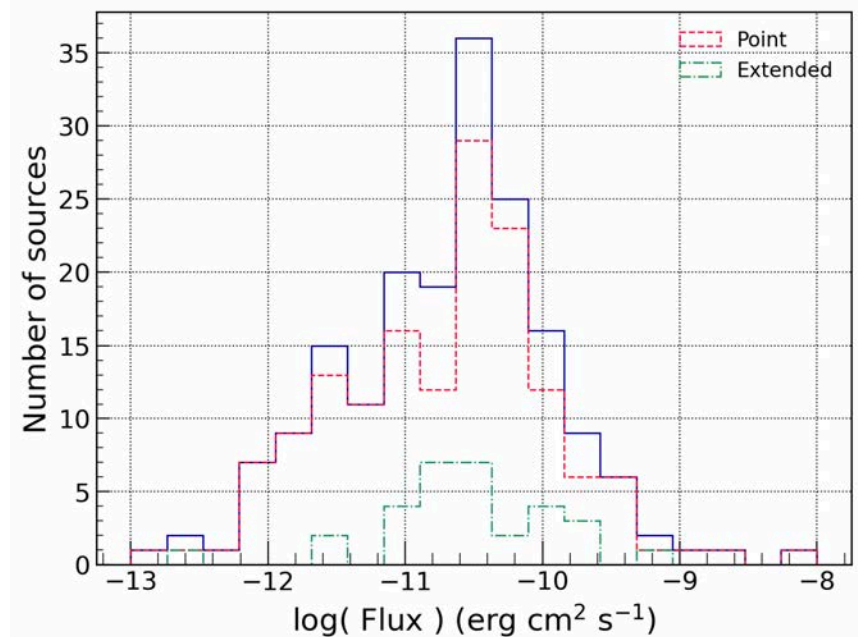
# MeV source map



Color points with  $F_{1-10 \text{ MeV}} > 10^{-11} \text{ erg/cm}^2/\text{s}$   
Gray points with  $F_{1-10 \text{ MeV}} < 10^{-11} \text{ erg/cm}^2/\text{s}$

✓ Flux in 1–10 MeV  $> 10^{-10} \text{ erg/cm}^2/\text{s}$   
→ **30 sources**  
(→ Consistent with COMPTEL)

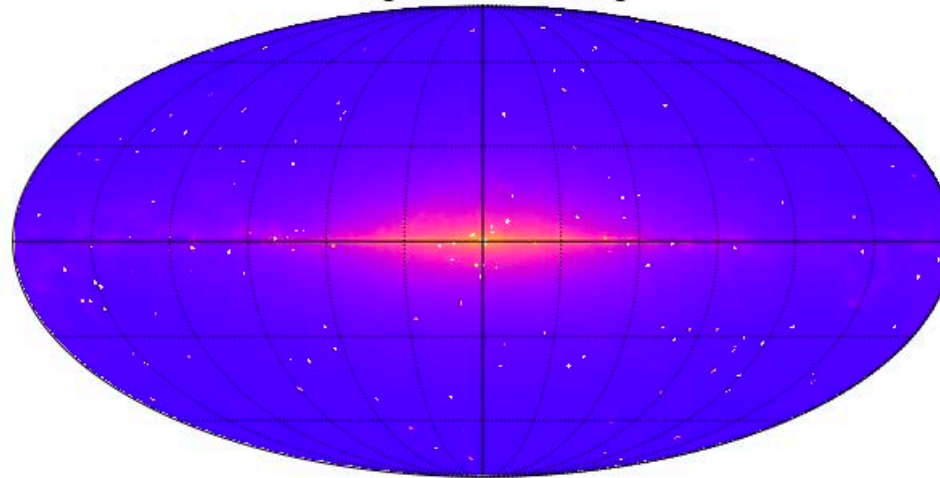
✓ Flux in 1–10 MeV  $> 10^{-11} \text{ erg/cm}^2/\text{s}$   
→ **125 sources**



# MeV gamma-ray all-sky map

All-sky map  
in 1–10 MeV  
(preliminary)

Source + galactic + extragalactic



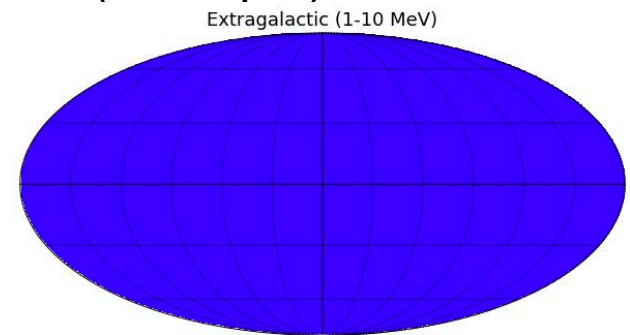
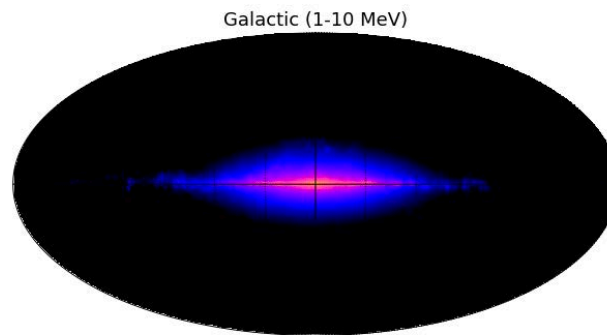
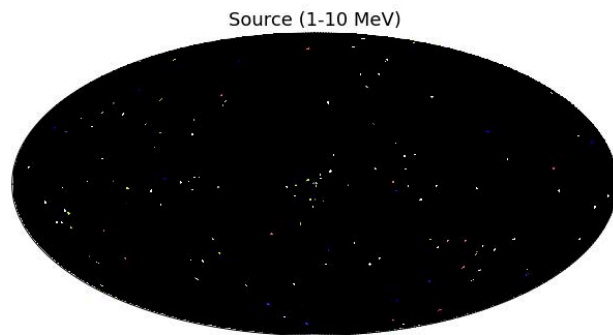
Sources



Galactic diffuse  
emission



Unresolved extragalactic  
(isotropic) emission



Cross-matched (only point)  
sources (Tsuji+ 2021)

Ackermann12 model

COMPTEL model

# MeV gamma-ray all-sky map

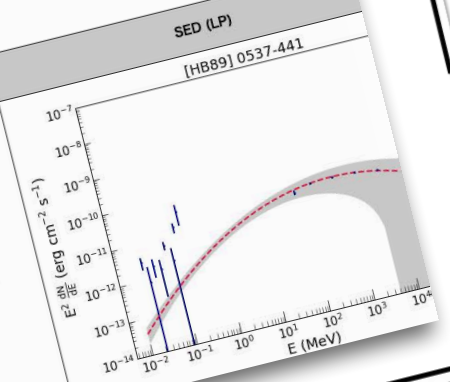
Source + galactic + extragalactic

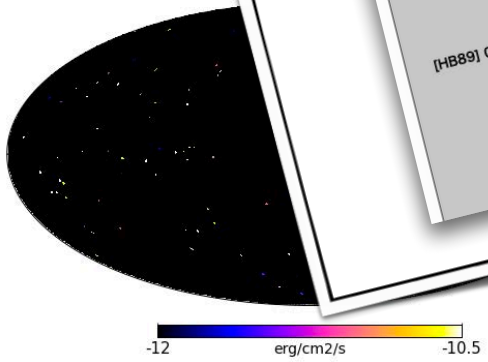
All-sky map  
in 1–10 MeV  
(preliminary)

Data release (very preliminary → [link](#))  
Source catalog + all-sky map (to be updated)

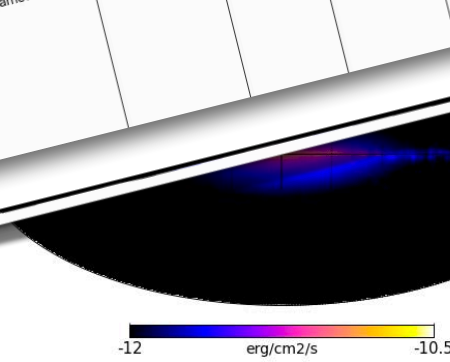
### Point sources

- "Galactic coordinate" column indicates the position of the Swift-BAT source, shown in units of degrees.
- When fitting SEDs with a broken power-law (BPL) model, the photon index below the ebergery break is set to be free.

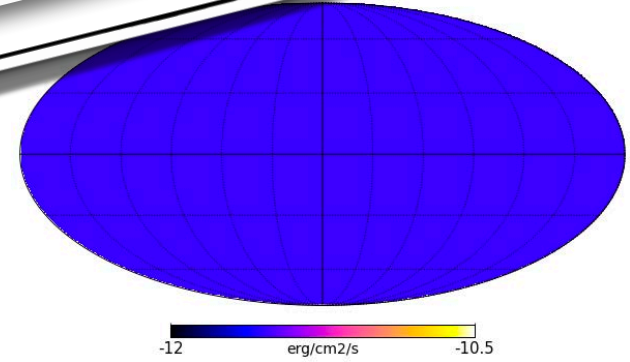
Swift-BAT name	No.	Flag	Swift-BAT category	Fermi name	Fermi name2	Fermi category	Galactic coordinate	Model	Inner Gal. region	SED (LP)
[HB89] 0537-441	1	M	Beamed AGN	PKS 0537-441	—	BLL	(250.1, -31.1)	BPL	False	



Cross-matched (only point) sources (Tsuji+ 2021)



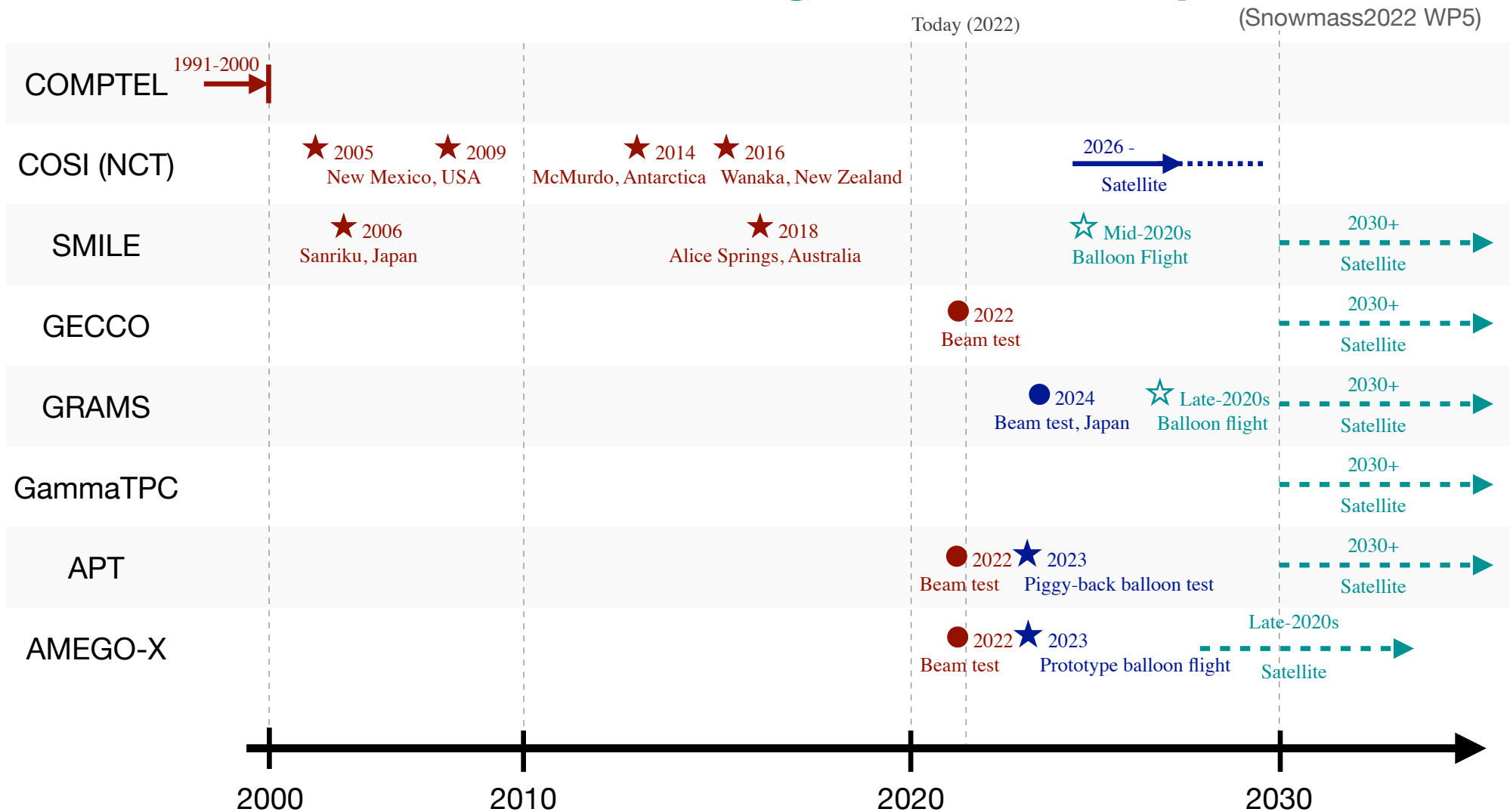
Ackermann12 model



COMPTEL model

# MeV gamma-ray missions

## Past, near-term, and long-term future plans



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# Summary

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- The origin of the inner Galactic diffuse emission (COMPTEL excess) is not known.
- We investigated COMPTEL excess by combining:
  1. Galactic diffuse emission  
By GALPROP and models in Ackermann+ 12; Orlando 18
  2. MeV gamma-ray sources  
Cross-match between Swift-BAT and Fermi-LAT catalogs (Tsuji+ 2021)
  3. Cosmic gamma-ray background
- Several future plans for MeV gamma rays
- Data release ([link](#))  
MeV gamma-ray source catalog + all-sky map