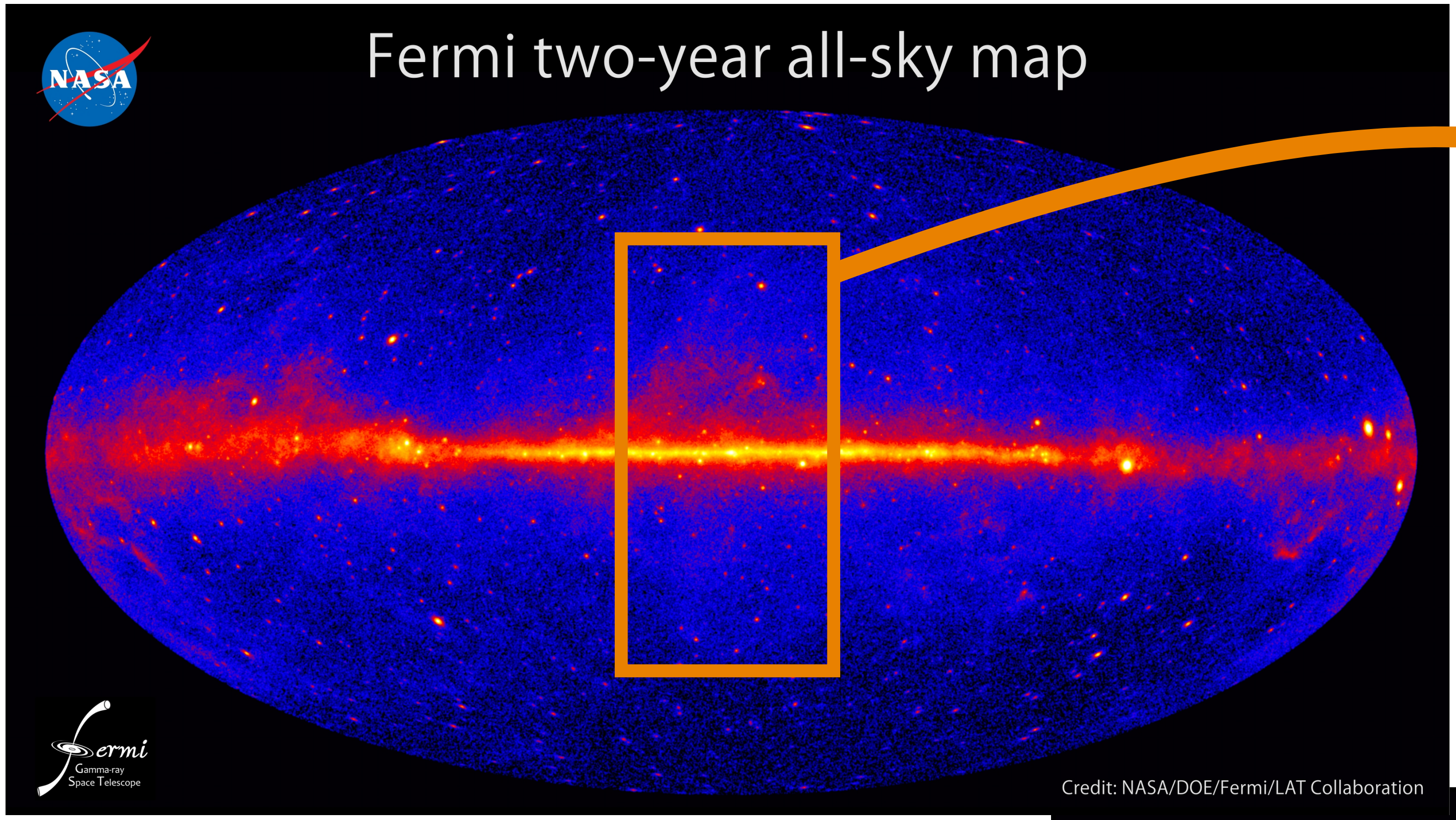
Is there evidence for gamma-ray emission from the Sagittarius dwarf galaxy?

Christopher Eckner (eckner@lapth.cnrs.fr)
LAPP Annecy, CNRS, France
14th of September 2023

summarising work in progress in collaboration with Francesca Calore and Silvia Manconi
TeV Particle Astrophysics 2023; 11th — 15th of September 2023, Napoli

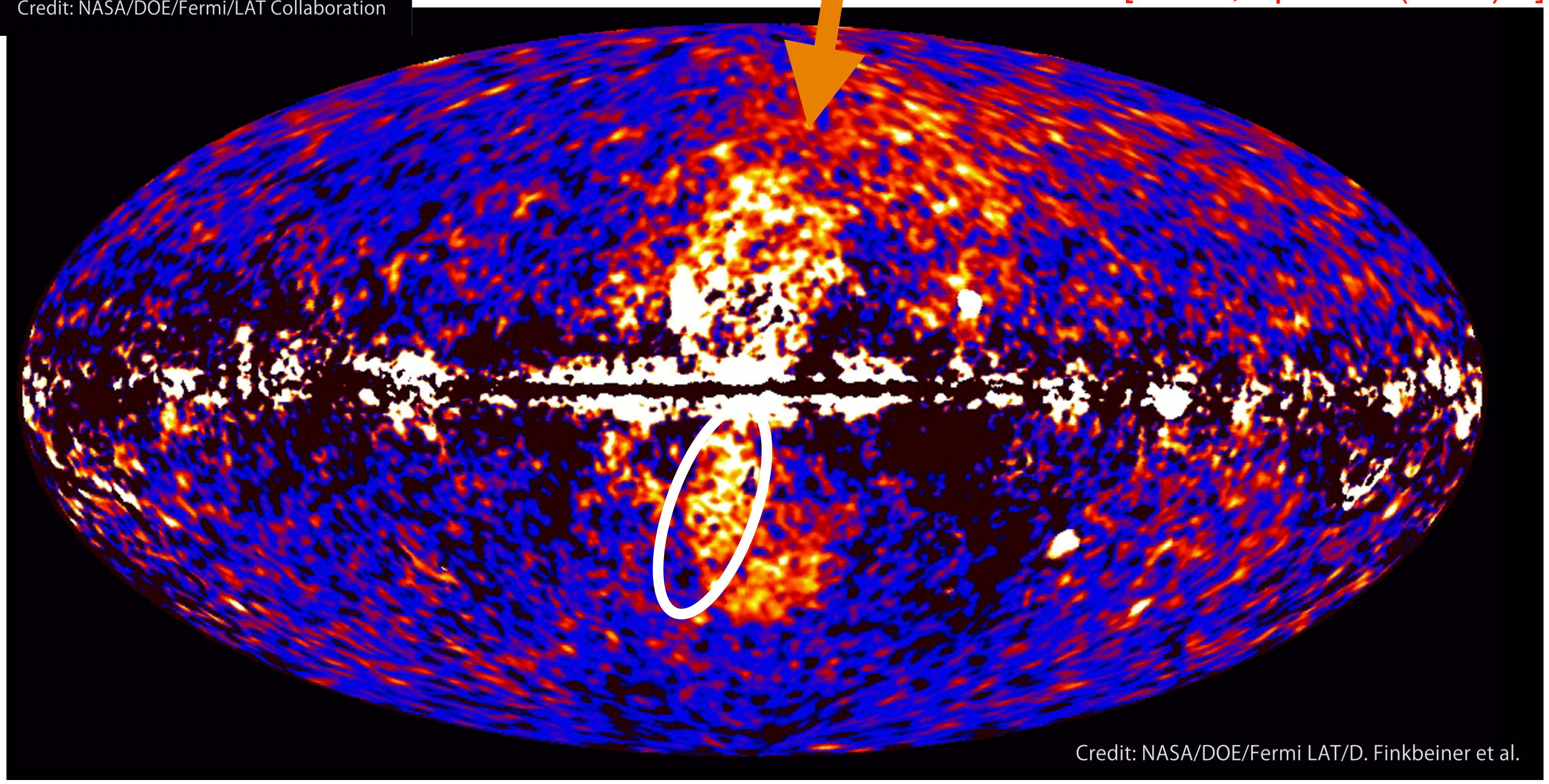
Discovery and properties of the Fermi Bubbles

The Fermi Bubbles were uncovered as residual emission above expected gamma-ray emission components.



after subtracting known foregrounds

[M. Su, ApJ 724 (2010) 2]



Properties:

- bilobular shape, symmetric about the plane
- extension: 50° in longitude, up to ±50° in latitude
- spectrum: rather hard $\sim E^{-1.9}$
- sharp edges
- almost uniform emission, **except for "cocoon region"**

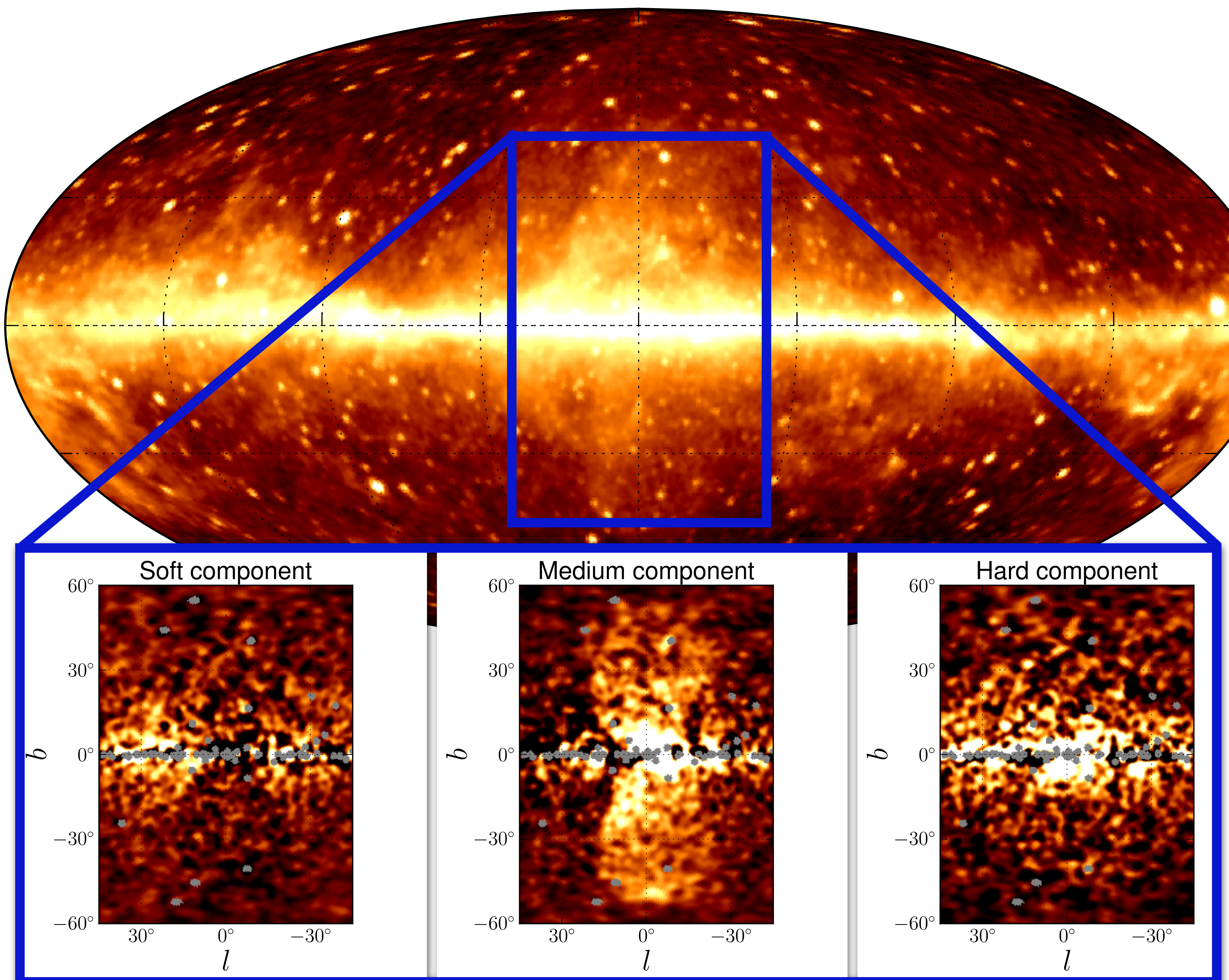
Discovery and properties of the Fermi Bubbles

A closer look at the spectral properties of the residuals in the Fermi Bubbles region in the range from 1 to 10 GeV.

—> Very surprising: The hard spectrum extends even to the highest latitudes!

soft:

$\sim E^{-2.3}$



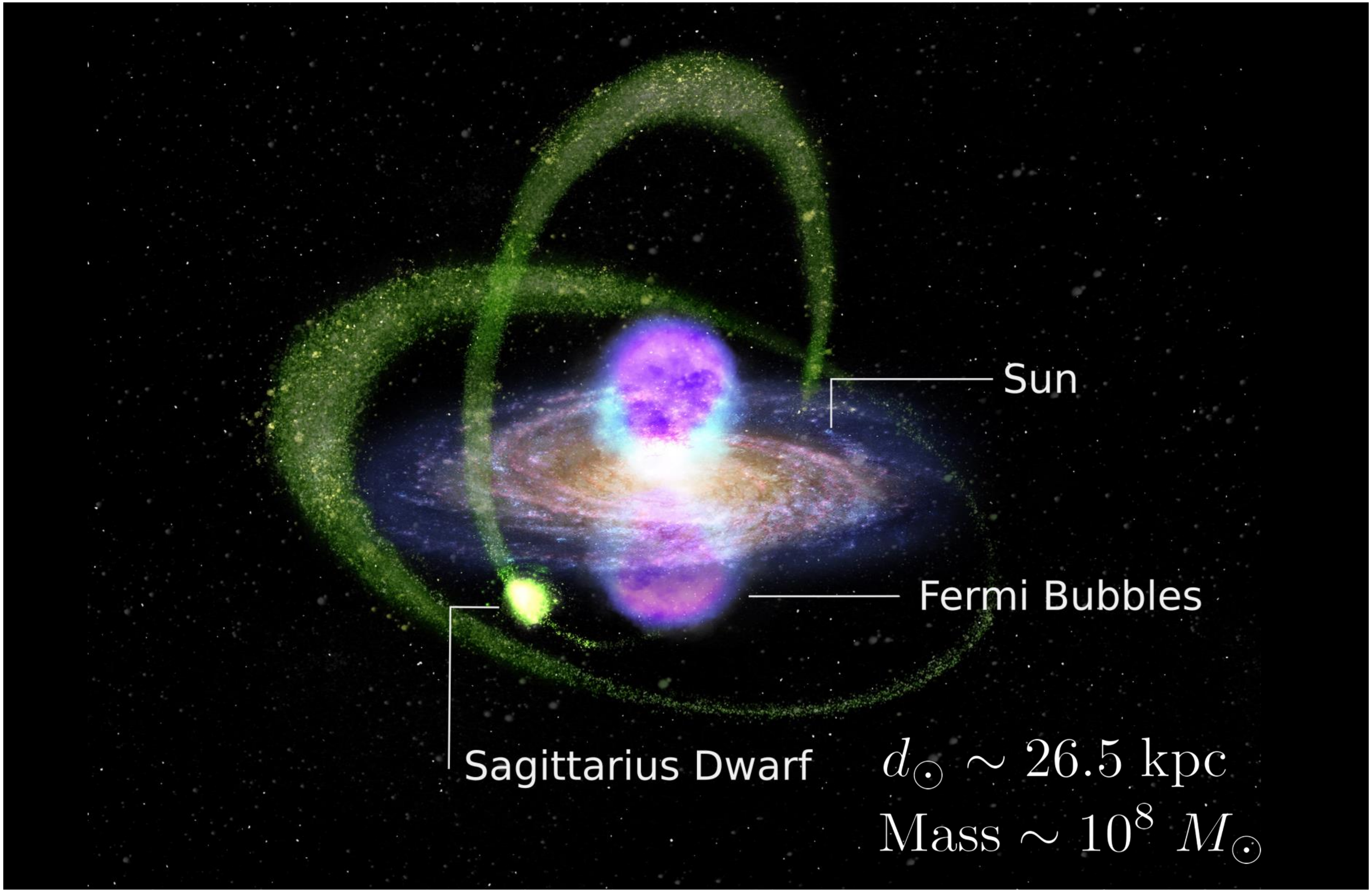
millisecond-pulsar-like:

$\sim E^{-1.6} \times e^{(-E/4\,\mathrm{GeV})}$

hard: $\sim E^{-1.9}$

[Fermi-LAT collab., ApJ 840 (2017) 1]

Is the cocoon emission fuelled by a satellite galaxy?



[slide credit: Oscar Macias, image credit: Aya Tsuboi (Kavli IPMU)]

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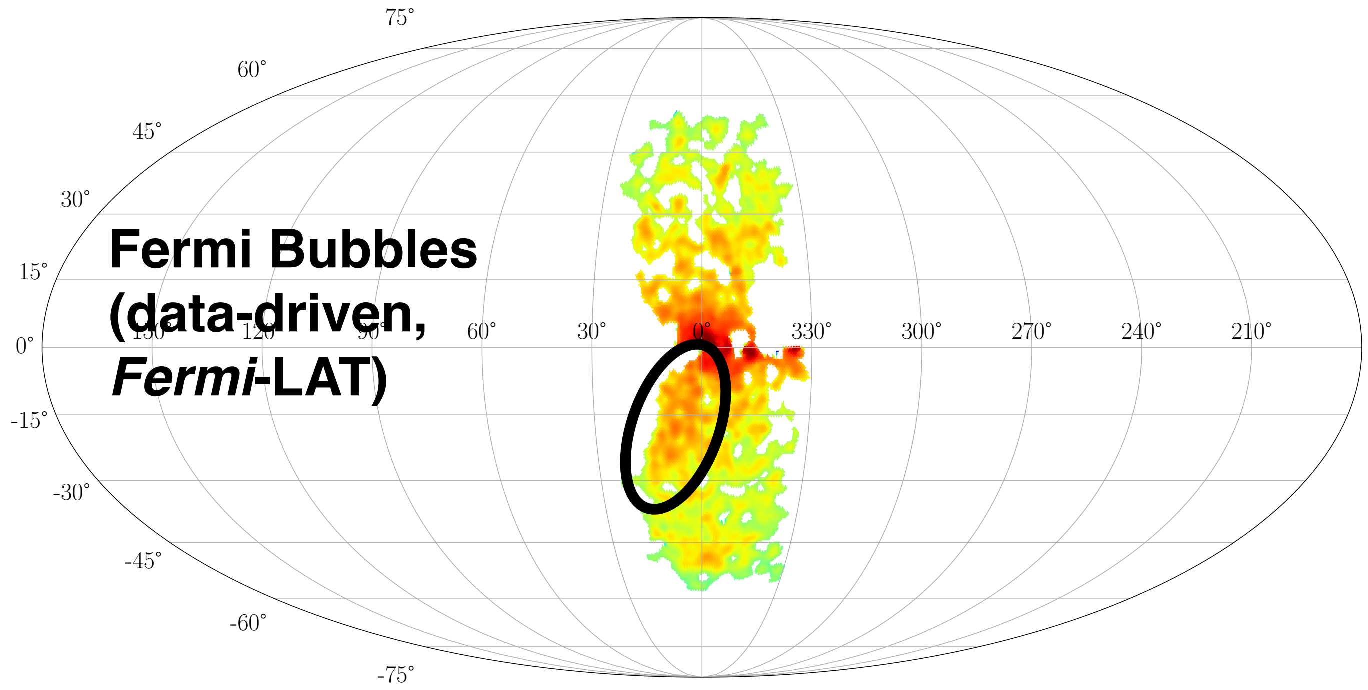
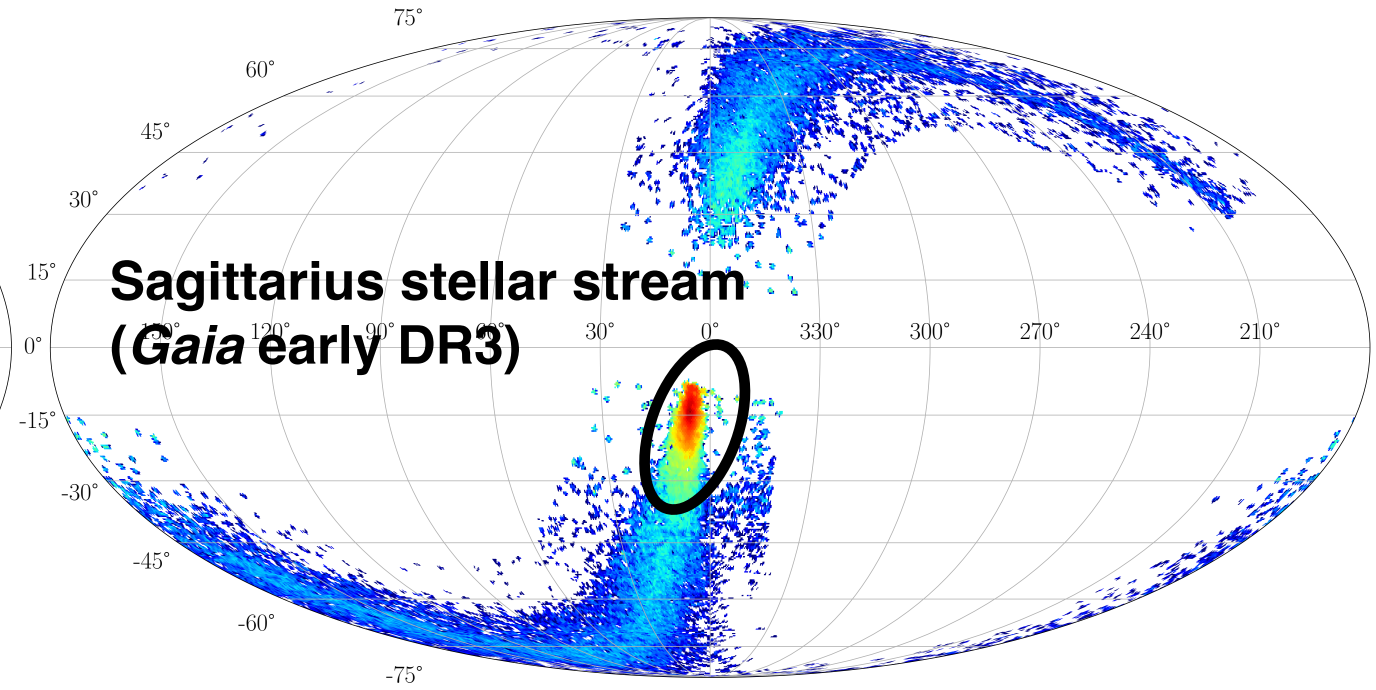
Crocker et al. [R. Crocker et al., Nature Astron. 6 (2022) 11] **proposed to explain the cocoon's gamma-ray emission by emission from the Sagittarius dwarf galaxy.**



[O. Macias et al., JCAP 09 (2019) 042]



[P. Ramos et al., A&A 666, A64 (2022)]

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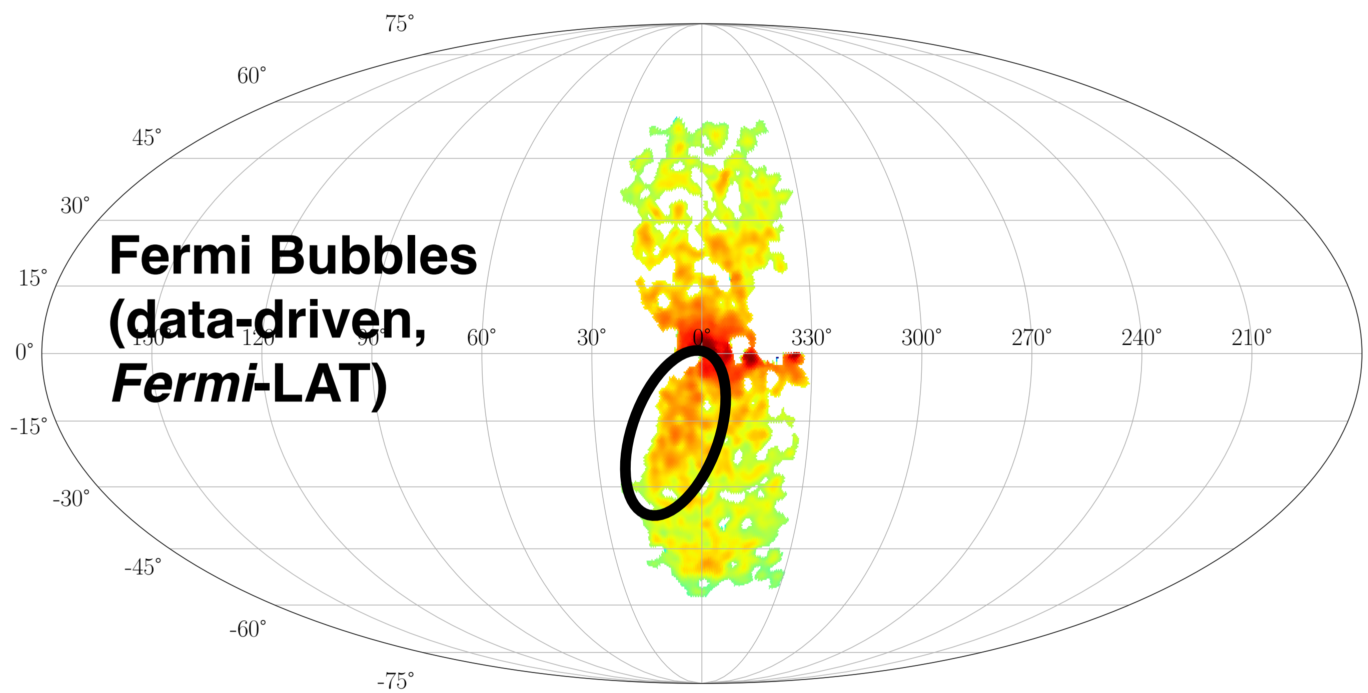

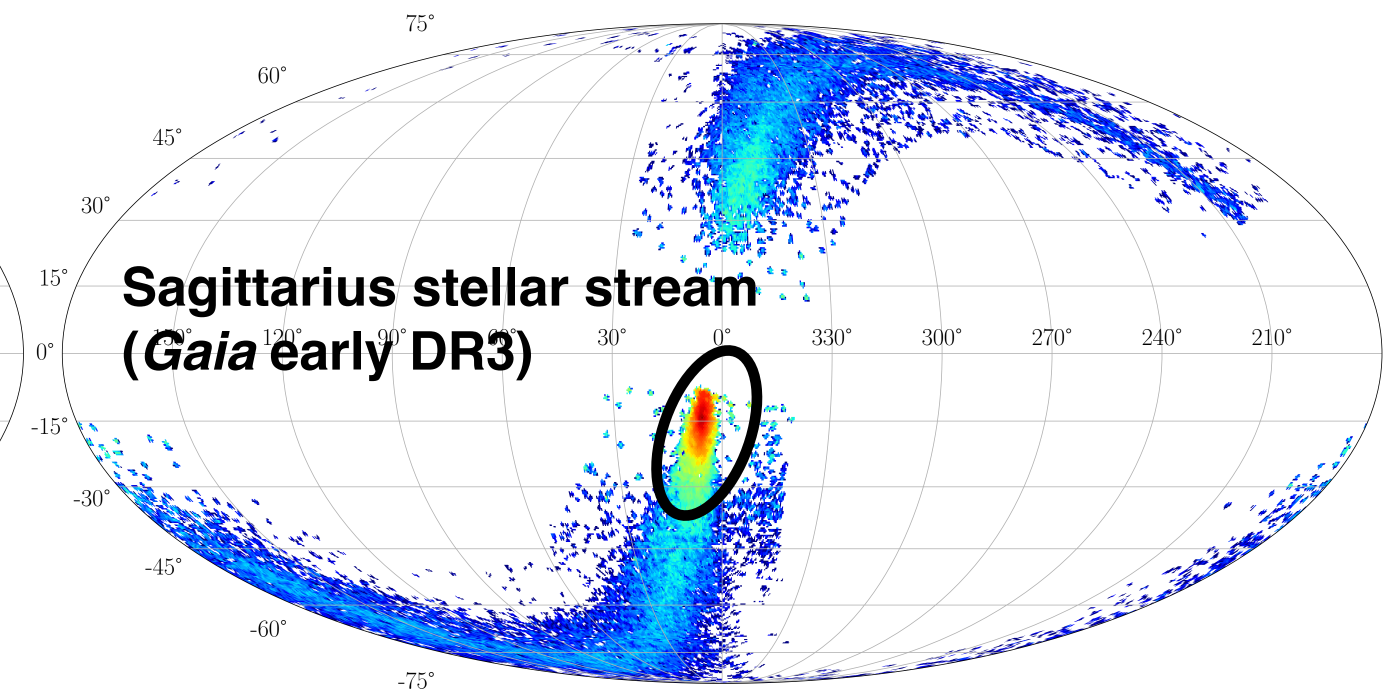

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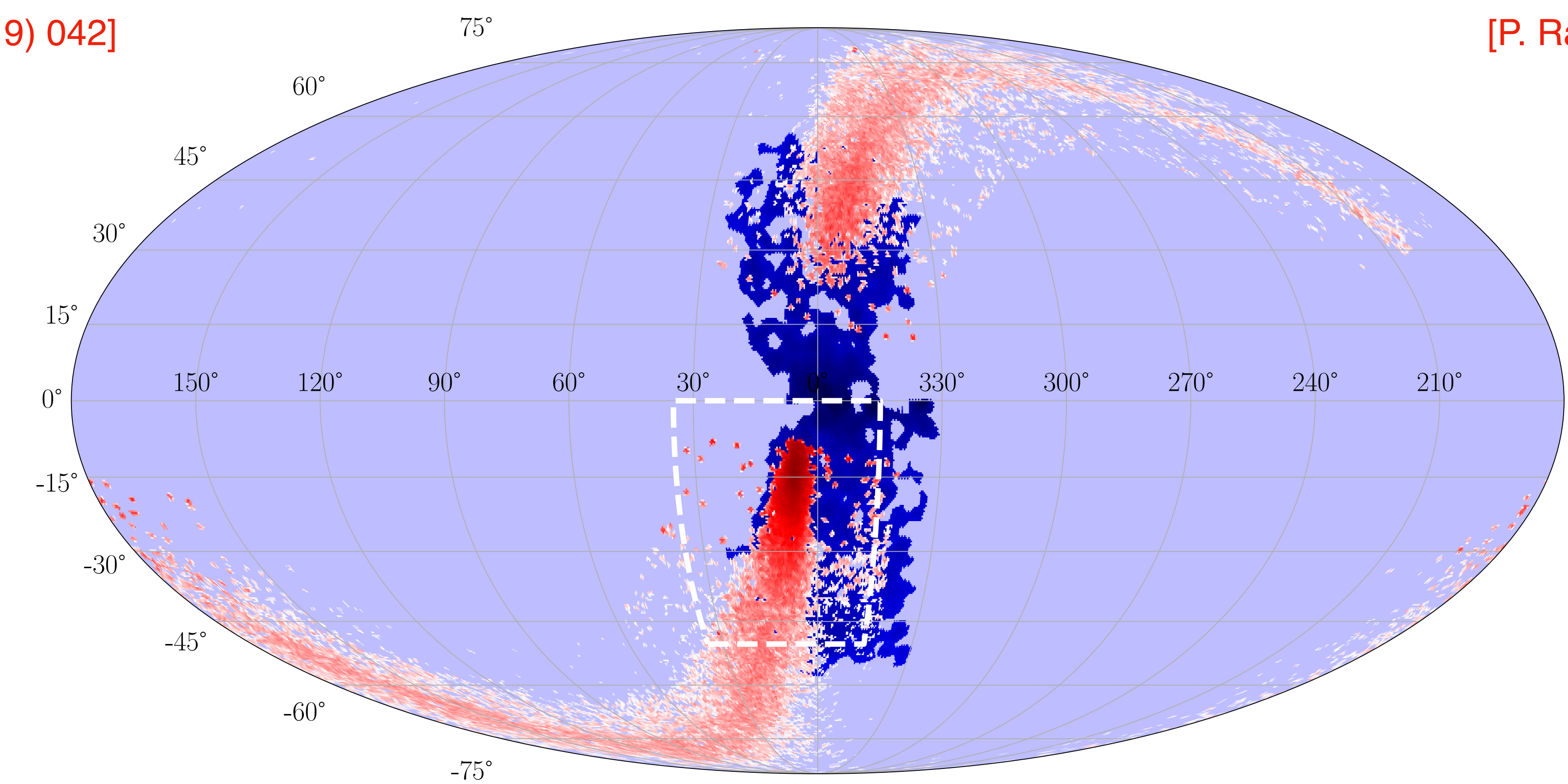
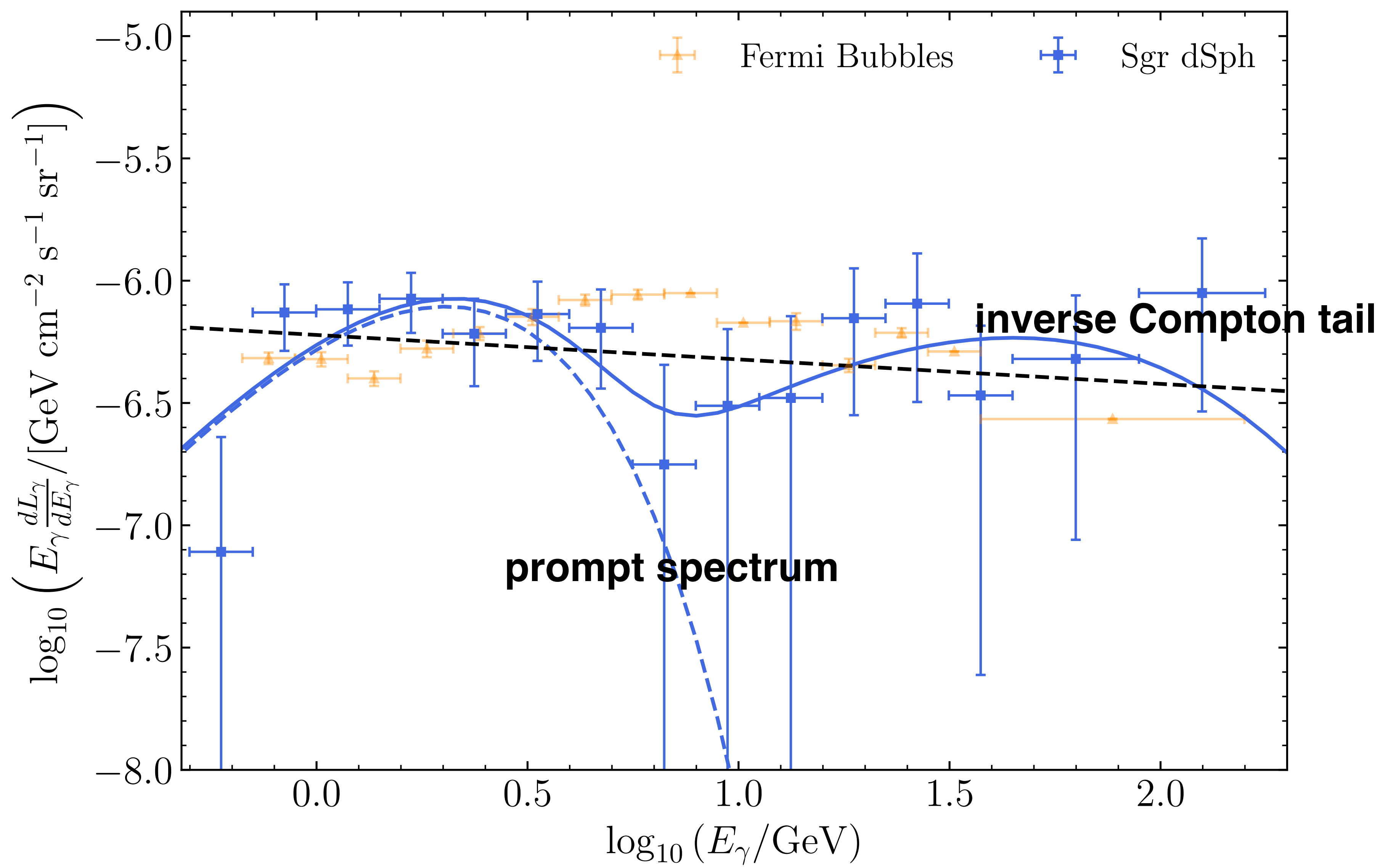


A striking spatial coincidence!

A snapshot of the results of Crocker et al.

Two important findings:

1. **Sagittarius' emission is significant ($> 5\sigma$) for almost all employed sky models.**
2. **The reconstructed spectrum is well explained by a population of millisecond pulsars (MSPs) in Sagittarius.**



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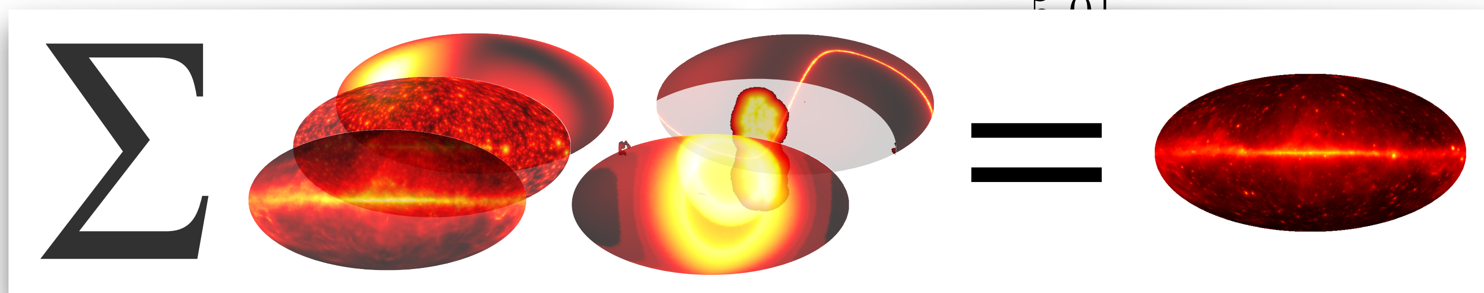
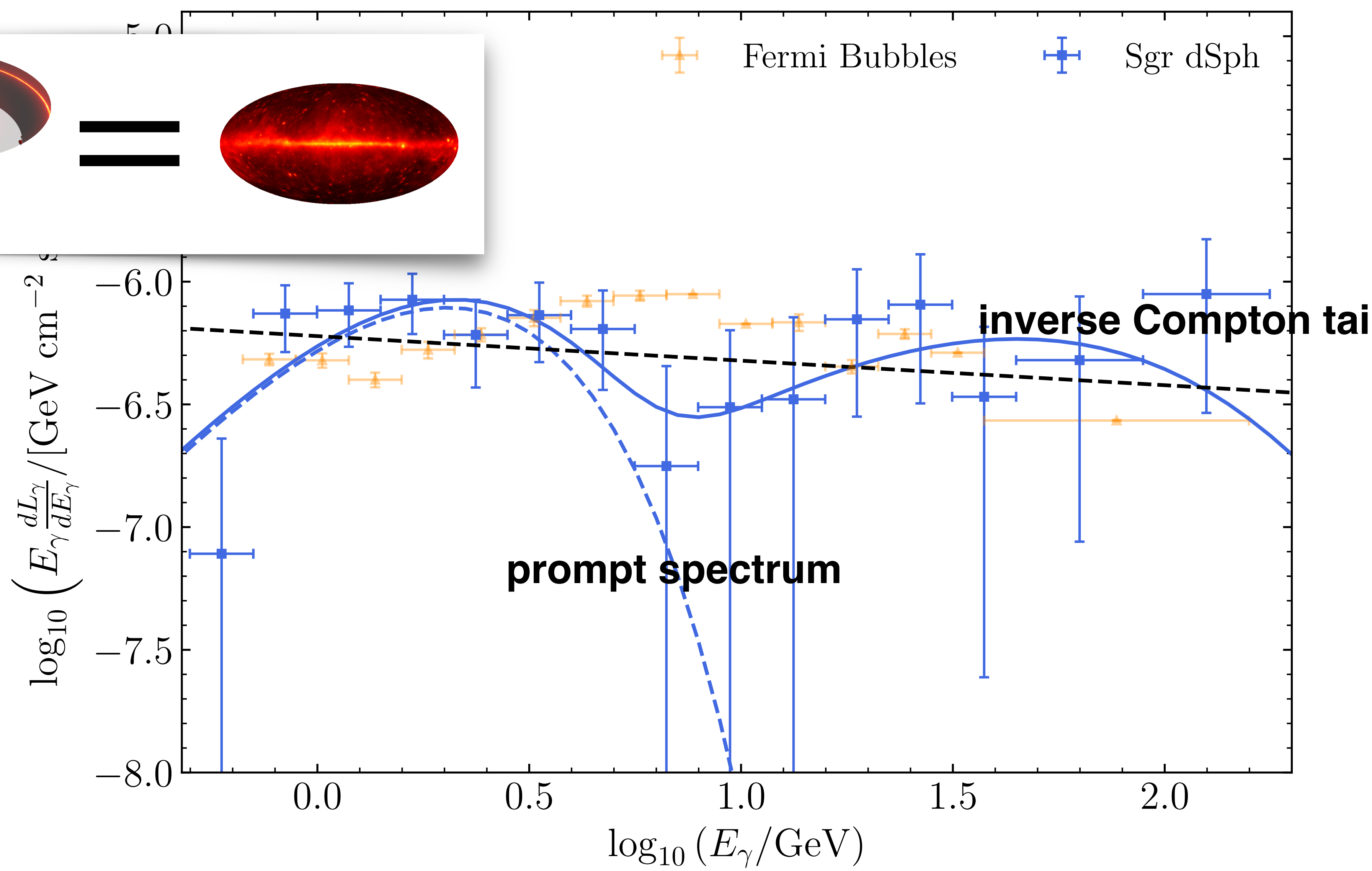


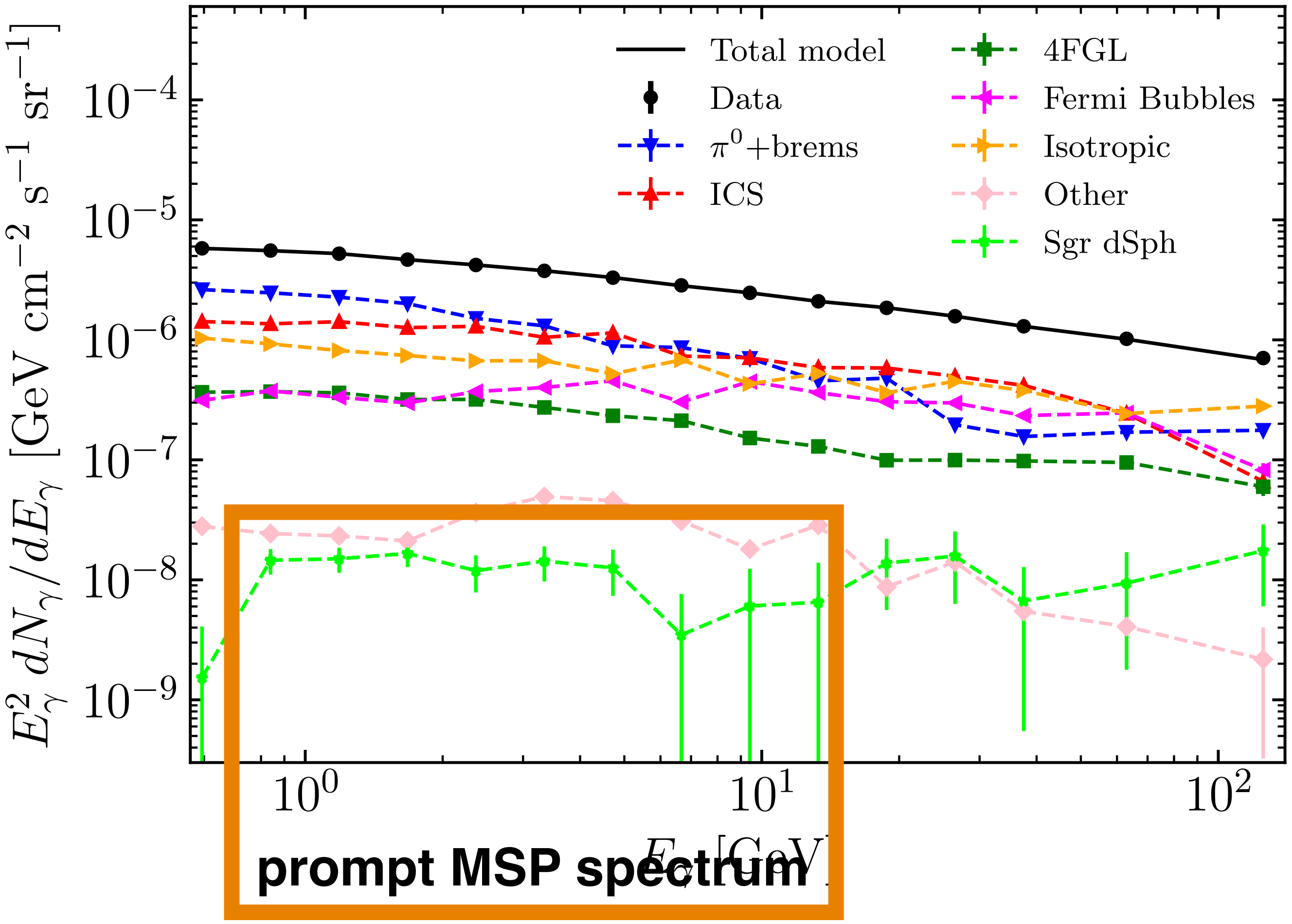


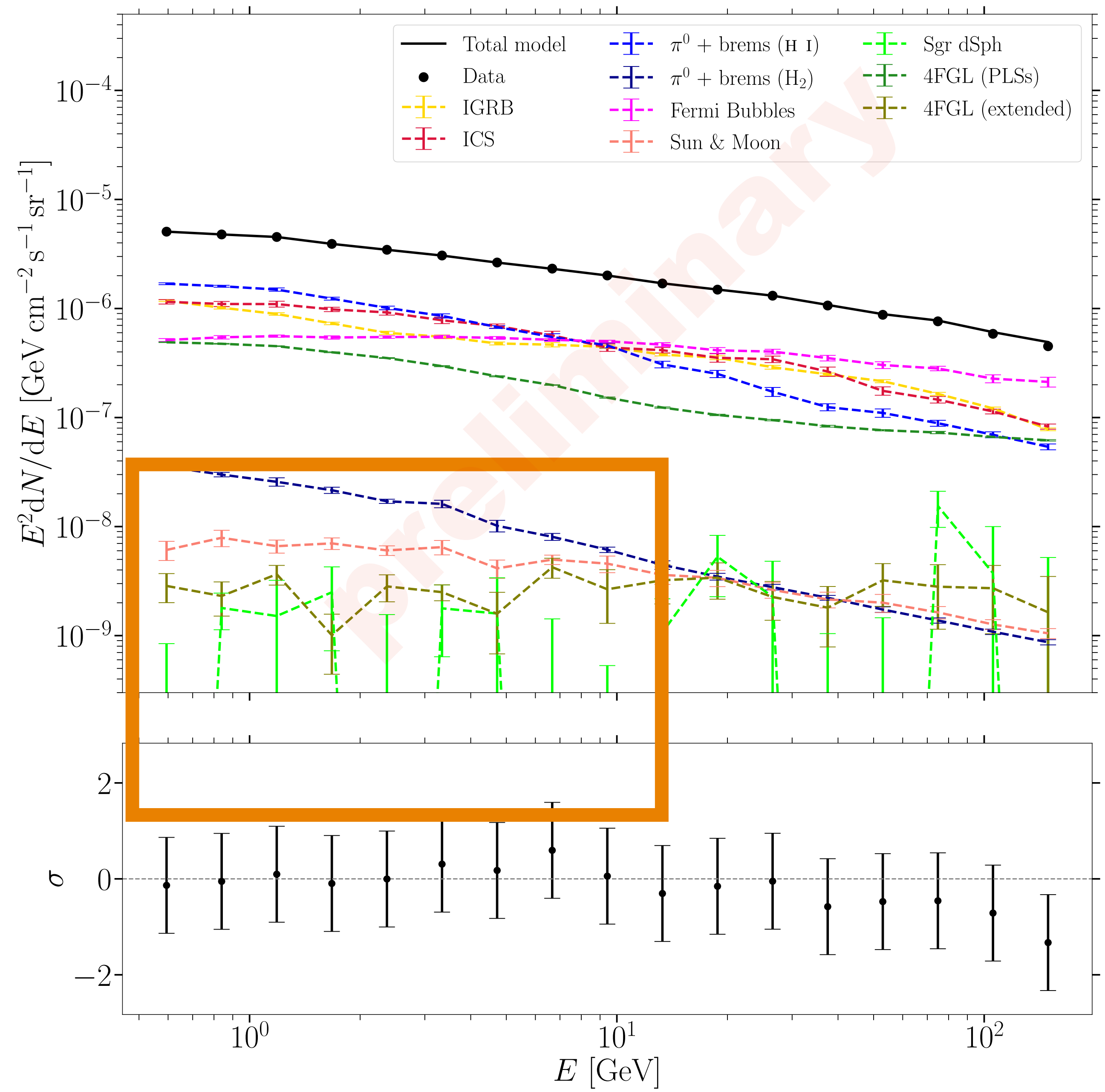
template-based analysis:
— rigid spatial morphology
— foreground mis-modelling hard to mitigate

Does the significance of Sagittarius persist when we account for foreground mis-modelling?

SkyFACT analysis vs. Crocker et al. — Results

Let us get to the point: Our final result employing background re-modulation to all components in comparison to the original work [R. Crocker et al., Nature Astron. 6 (2022) 11]**:**





1. **Diffuse spectra broadly consistent between both works.**
2. **We do not find evidence for the need of a prompt MSP-like spectrum between 1 to 10 GeV in the cocoon region.**

Adaptive template-fitting with skyFACT

We go beyond standard template-fitting by adding regularised image reconstruction as implemented in the software skyFACT.

k : component
p : spatial pixel
b : energy bin

$$\text{Model} \sim \sum_k T_p^{(k)} \tau_p^{(k)} \otimes S_b^{(k)} \sigma_b^{(k)} \cdot \nu^{(k)}$$

Spatial + spectral templates

Modulation parameters:
- **spatial,**
- **spectral,**
- **overall**

[E. Storm et al., JCAP 08 (2017) 022]
[R. Bartels et al., Nature Astron. 2 (2018) 10]
[F. Calore & S. Manconi, PRL 127 (2021) 16]
[C. Armand & F. Calore, PRD 103 (2021) 8]

Constraints on the modulation parameters by penalising likelihood function contribution on top of the Poisson likelihood: $\ln \mathscr{L} = \ln \mathscr{L}_P + \ln \mathscr{L}_R$.

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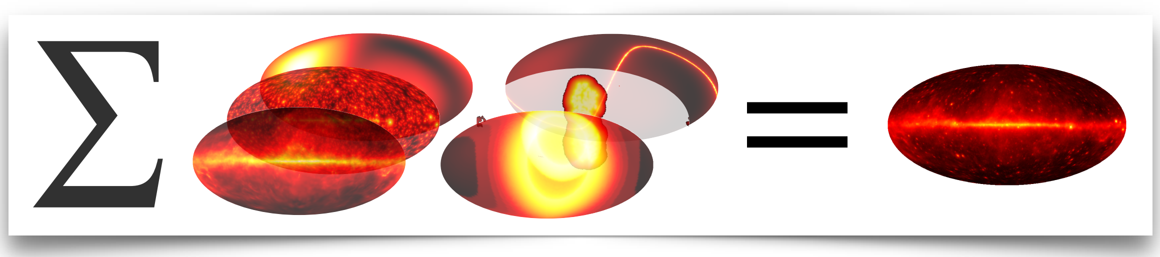
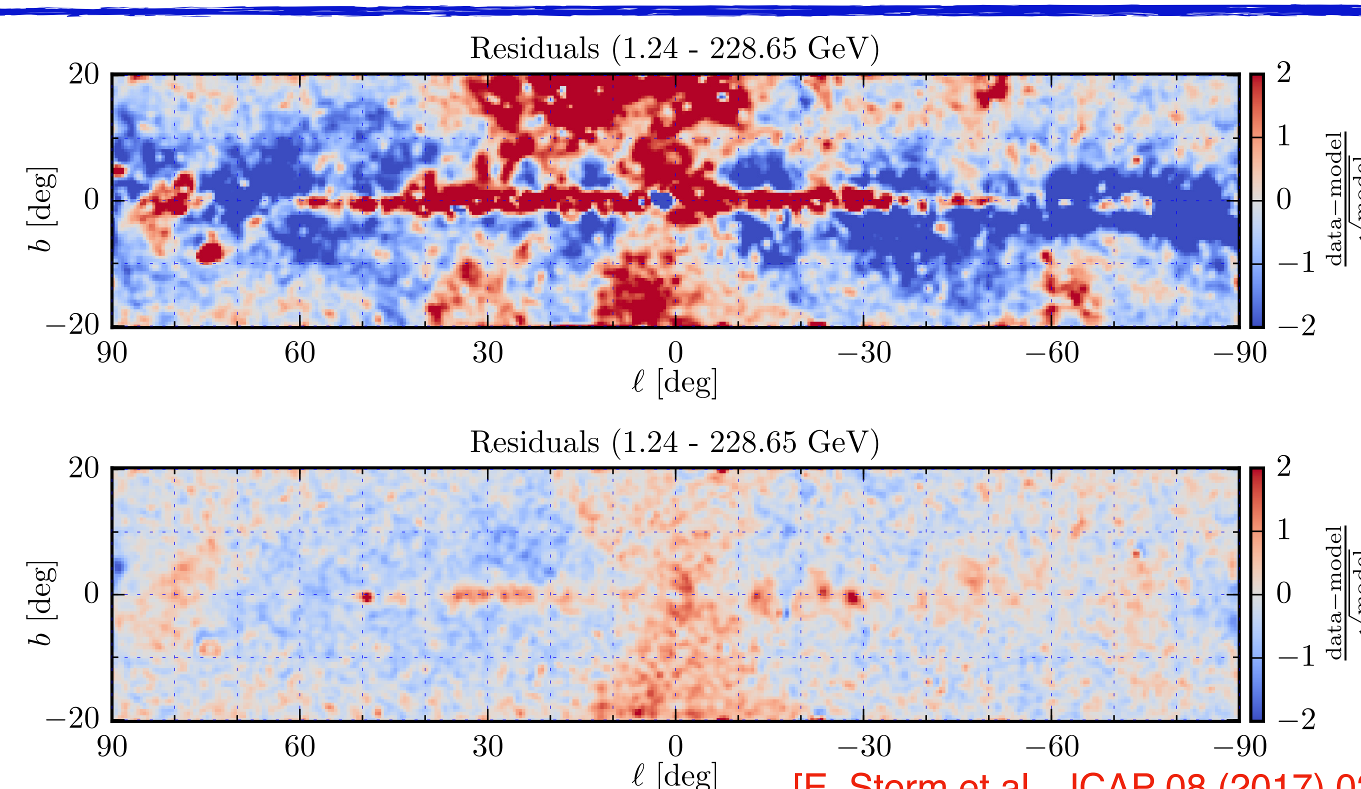


skyFACT



*model does not contain all known components

[E. Storm et al., JCAP 08 (2017) 022]

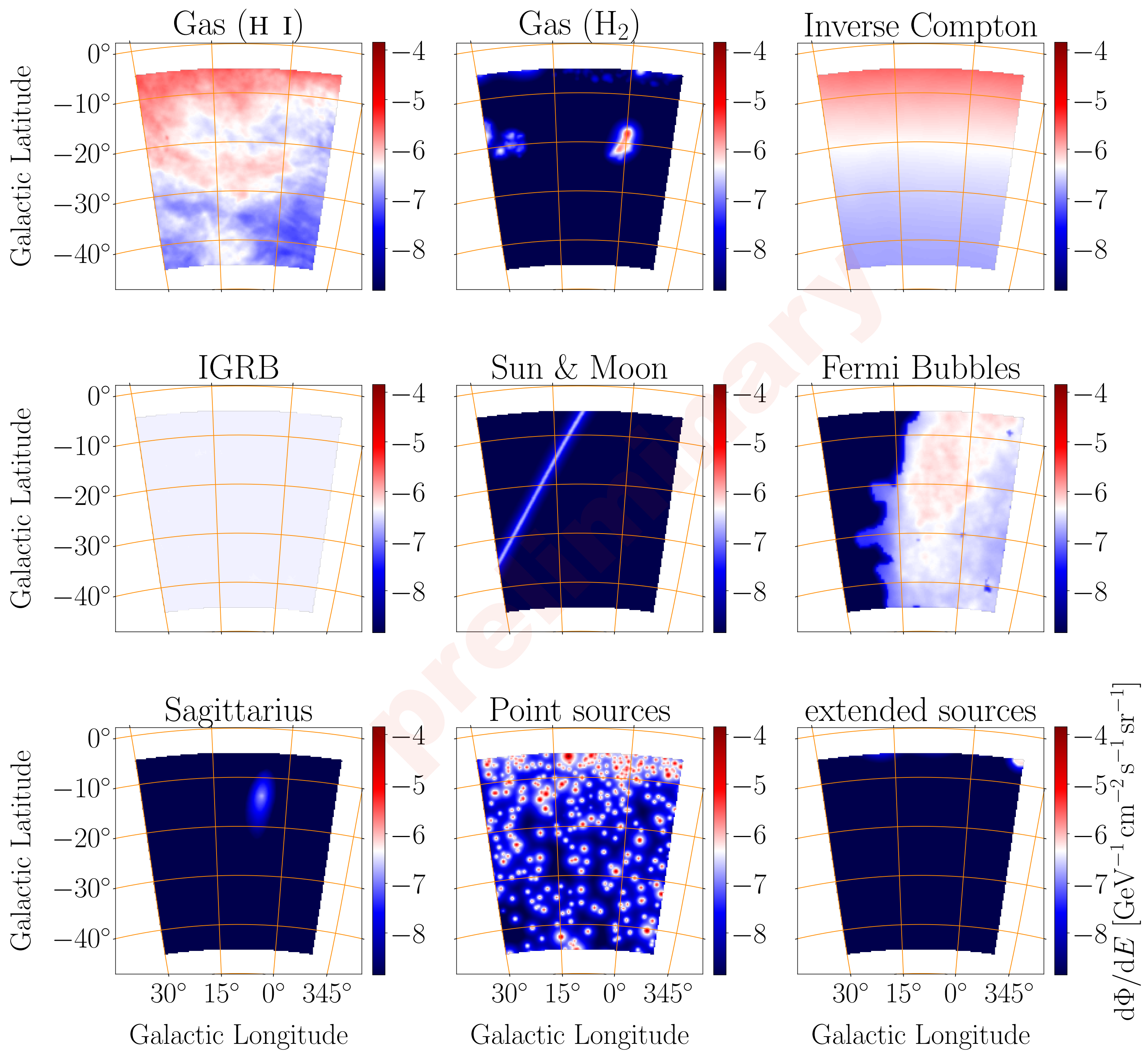
Analysis rationale and setup

We aim to directly investigate the findings of Crocker et al. by **adopting most of their data selection and model composition**; largest difference: 8 years —> 12 years of data.

Rationale:

1. Sequential fit to gamma-ray data based on templates on the right.
2. Enable iteratively spatial and spectral modulation of the initial template input.
3. Run skyFACT initialisation twice: with and w/o Sagittarius template to assess significance.

Baseline gamma-ray emission components*:



*Templates show the optimised components of Run 8.

Definition and results of our systematic scan

Now some details: **The systematic fits are initialised with priors on the spectral and spatial morphology of the components as well as skyFACT hyper-parameters.**

Components	Run 0	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8
	skyFACT hyper-parameters: $\begin{bmatrix} \lambda & \lambda' & \lambda'' \\ \eta & \eta' & \cdot \end{bmatrix}$								
4FGL (PLS)	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$
4FGL (ext)	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$
π^0 (H I)	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 44 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$
π^0 (H_2)	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 44 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$
IC	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$
IGRB	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & \frac{1}{25} \\ 0 & 0 & \cdot \end{bmatrix}$
Sun&Moon	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$
FBs (flat)	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	–	$\begin{bmatrix} 0 & 10^4 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 400 & \frac{1}{25} \\ 6 & 0 & \cdot \end{bmatrix}$
FBs (structured)	–	–	–	–	–	–	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	–	–
Sgr	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$
$-2\ln\mathcal{L}_{\mathrm{base}}$	309106	309227	309210	297427	297469	297419	297014	295710	296010
$-2\ln\mathcal{L}_{\mathrm{base+Sgr}}$	308879	309013	309002	297350	297389	297357	296987	295690	295996
$\mathcal{Z}_{\mathrm{Sgr}}$ [σ]	13.6	13.1	12.9	6.9	7.0	6.0	3.0	2.2	1.5

Fermi Bubbles are by default treated as uniform emission (restricted to their position) to avoid bias by common data-driven models that include the cocoon region. Only once exchanged for a structured template ([O. Macias et al., JCAP 09 (2019) 042]).

Definition and results of our systematic scan

Now some details: **The systematic fits are initialised with priors on the spectral and spatial morphology of the components as well as skyFACT hyper-parameters.**

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$\mathcal{Z}_{\mathrm{Sgr}}$ $[\sigma]$	13.6	13.1	12.9	6.9	7.0	6.0	3.0	2.2	1.5

Run 0: Standard template fit (+ spectral re-fitting of all point-like sources)
—> highest significance of Sagittarius; comparable to Crocker et al. results
Run 5: Re-modulation of diffuse components **except for Fermi Bubbles**
—> significance of Sagittarius more than halved!

Definition and results of our systematic scan

Now some details: The systematic fits are initialised with priors on the spectral and spatial morphology of the components as well as skyFACT hyper-parameters.

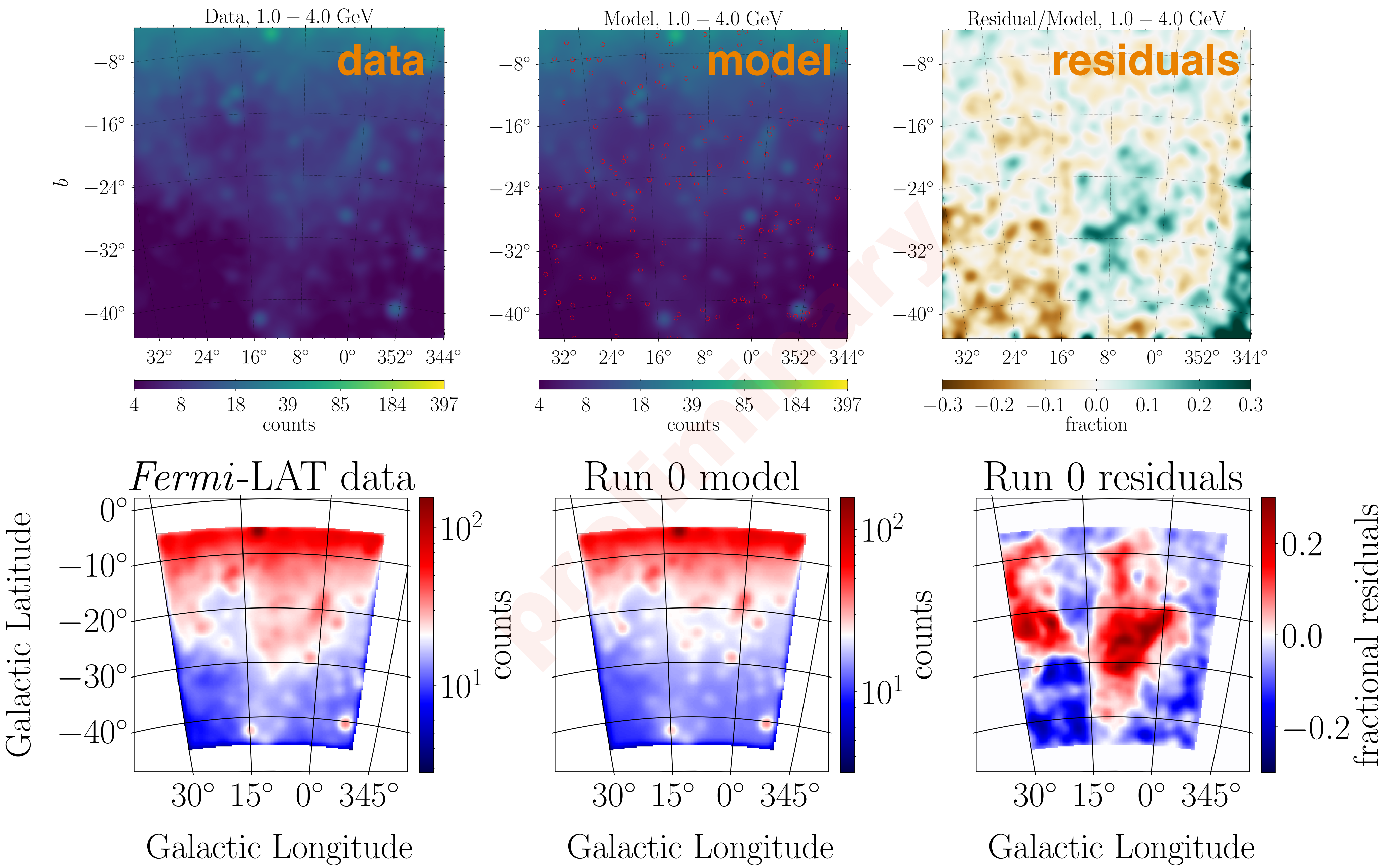
Components	Run 0	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8
	skyFACT hyper-parameters: $\begin{bmatrix} \lambda & \lambda' & \lambda'' \\ \eta & \eta' & \cdot \end{bmatrix}$								
4FGL (PLS)	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \cdot & 25 & 10 \\ \cdot & 0 & \cdot \end{bmatrix}$
4FGL (ext)	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$
π^0 (H I)	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 44 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$
π^0 (H_2)	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 400 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \frac{1}{25} & 44 & 0 \\ 40 & 0 & \cdot \end{bmatrix}$
IC	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 1 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$
IGRB	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 400 & \frac{1}{25} \\ 0 & 0 & \cdot \end{bmatrix}$
Sun&Moon	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 10 & 16 & 0 \\ 150 & 0 & \cdot \end{bmatrix}$
FBs (flat)	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	—	$\begin{bmatrix} 0 & 10^4 & \infty \\ 6 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} 0 & 400 & \frac{1}{25} \\ 6 & 0 & \cdot \end{bmatrix}$
FBs (structured)	—	—	—	—	—	—	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	—	—
Sgr	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$	$\begin{bmatrix} \infty & 0 & 0 \\ 0 & 0 & \cdot \end{bmatrix}$
$-2\ln\mathcal{L}_{\mathrm{base}}$	309106	309227	309210	297427	297469	297419	297014	295710	296010
$-2\ln\mathcal{L}_{\mathrm{base+Sgr}}$	308879	309013	309002	297350	297389	297357	296987	295690	295996
$\mathcal{Z}_{\mathrm{Sgr}}$ $[\sigma]$	13.6	13.1	12.9	6.9	7.0	6.0	3.0	2.2	1.5

Run 6 — 8: Introducing structure & spatial modulation of Fermi Bubbles + strict prior on their spectrum (derived hard-spectrum of [Fermi-LAT collab., ApJ 793 (2014) 64])

—> Sagittarius ceases to be significant

Comparison Run 0 with Crocker et al. — Residuals

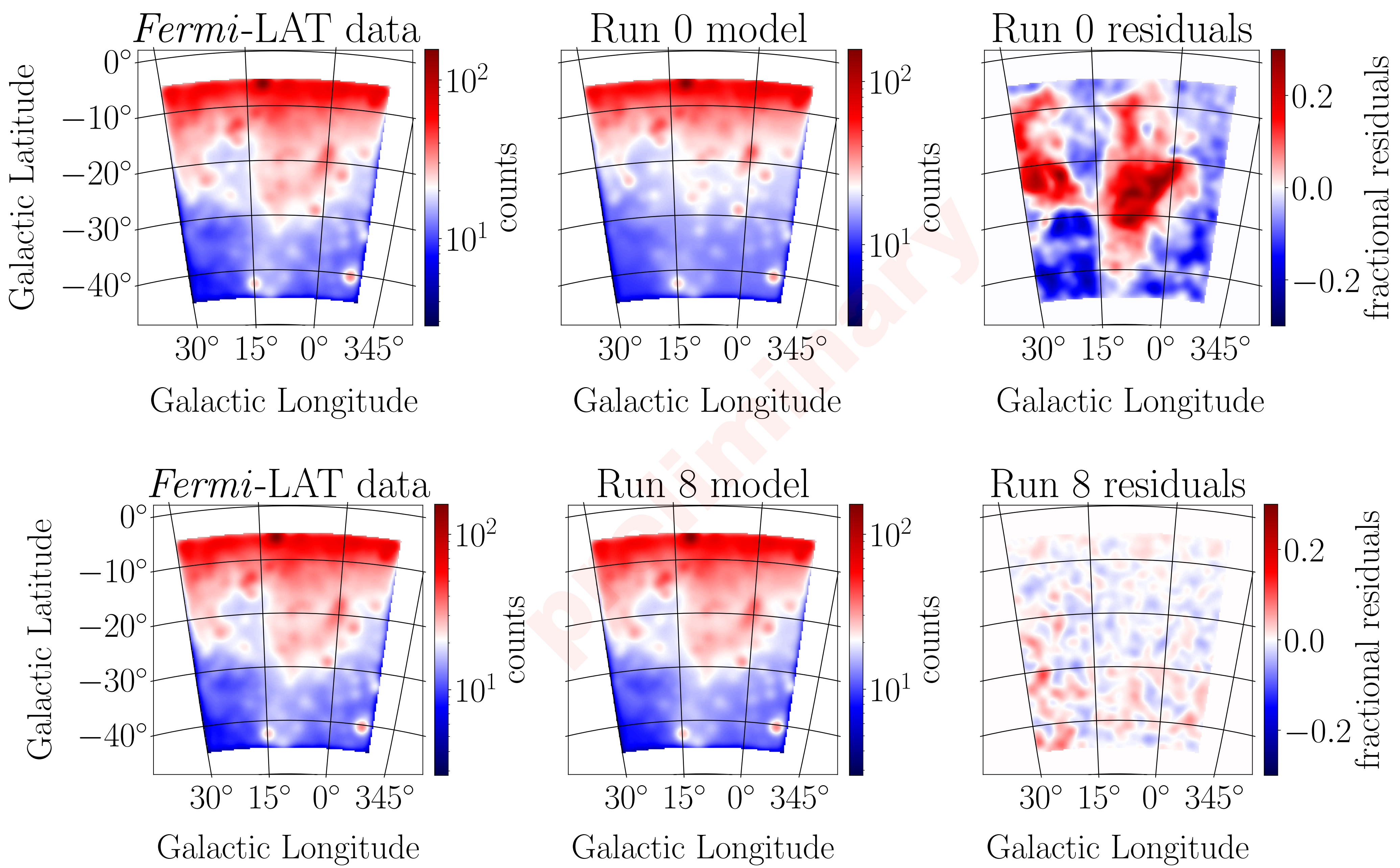
How do we compare/reproduce the original work [R. Crocker et al., Nature Astron. 6 (2022) 11] **in Run 0; the standard template fit.**



Residuals show a very similar structure in spatial morphology and overall magnitude. Likewise, comparable significance of emission from Sagittarius.

Comparison skyFACT Run 0 & 8

Run 0: Standard template fit.
Run 8: Spatial and spectral re-modulation of all diffuse components; varying level of constraints.



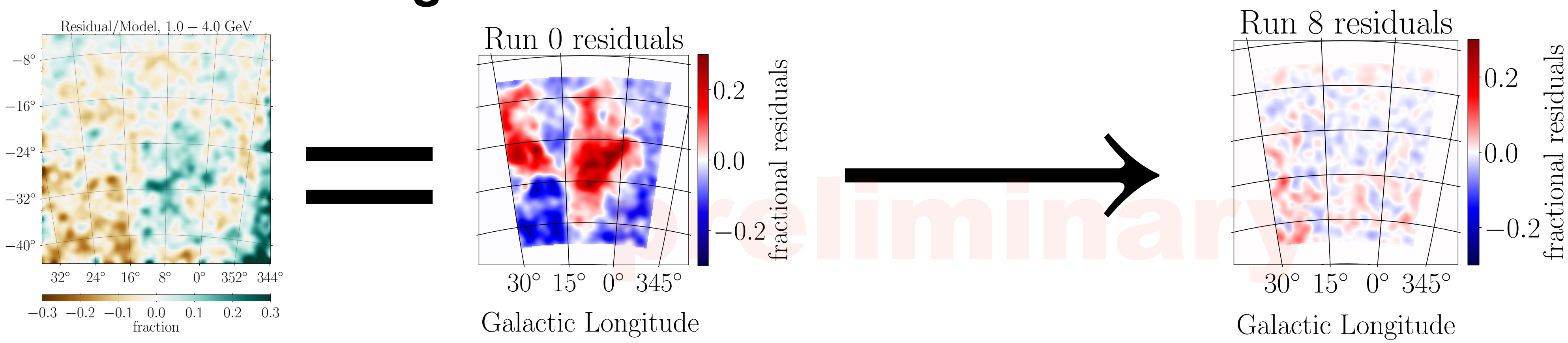
As expected and intended, skyFACT reduces the residuals to a minimum erasing most of their structure —> gamma-ray emission attributed to model components.
Optimising the diffuse background marginalises Sagittarius' significance!

Summary and outlook

- **Crocker et al.** [R. Crocker et al., Nature Astron. 6 (2022) 11] **proposed** to connect the gamma-ray emission of the **cocoon region within the Fermi Bubbles** with the **emission of millisecond pulsars in the Sagittarius dwarf galaxy** due to intriguing spatial overlap.

- **We probe this hypothesis via skyFACT**; thereby improving on the commonly employed technique of template fitting to **account for background mis-modelling**.

- While we are able to reproduce the result of Crocker et al. in our model and a template fit, **the evidence for Sagittarius' emission vanishes when fully accounting for background mis-modelling.**



Ongoing studies:
We examine the MSP hypothesis specifically via skyFACT simulations and fits of such a population in the Sagittarius dwarf and **pixel-count statistics as implemented in the 1pPDF method**. **Preliminary results of the latter study do not point towards significant evidence for such a scenario**.