

Joint Spatial–spectral Gaussian Process Modeling of the Galactic Center Excess

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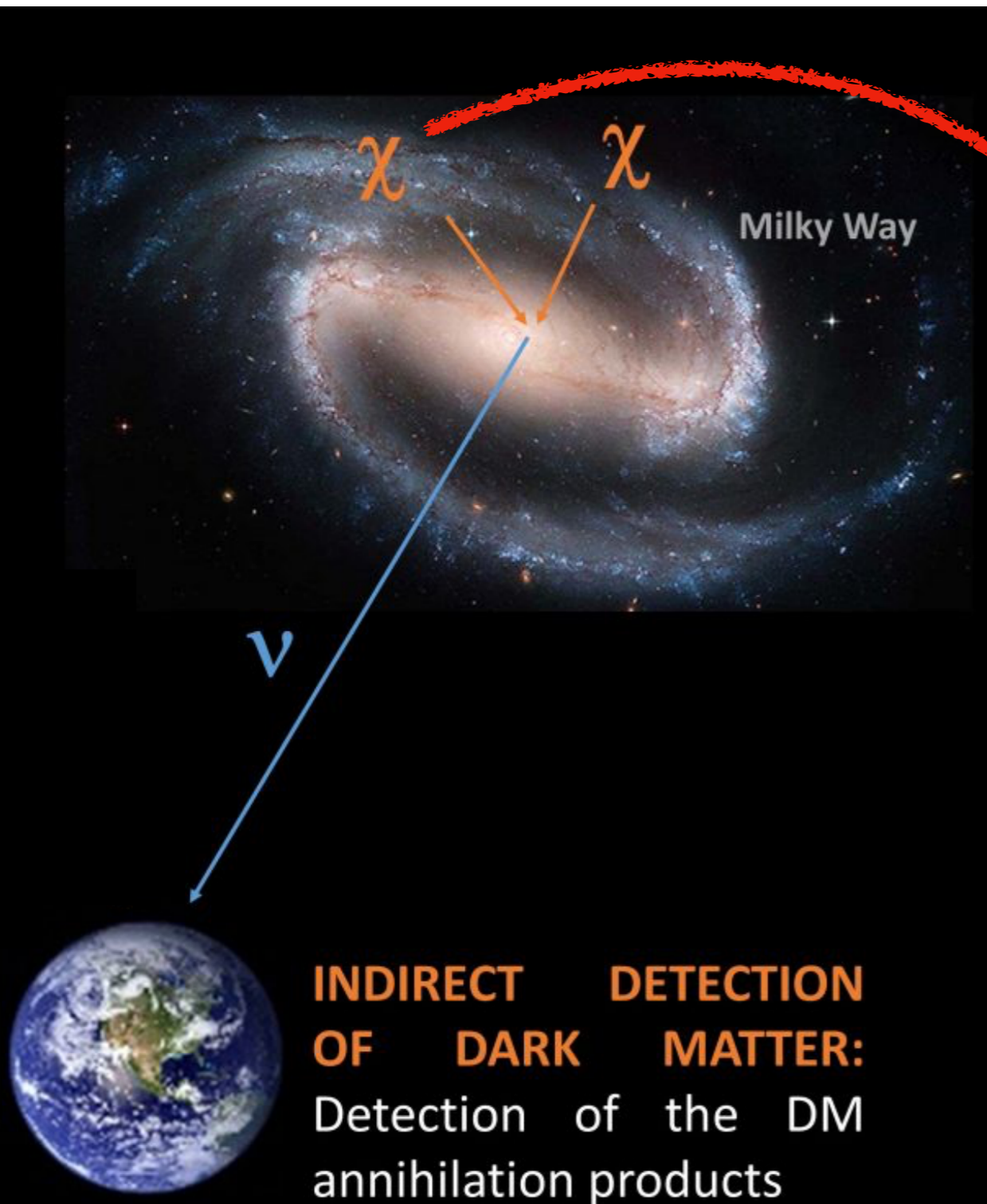
Tracy Slatyer

Yitian Sun



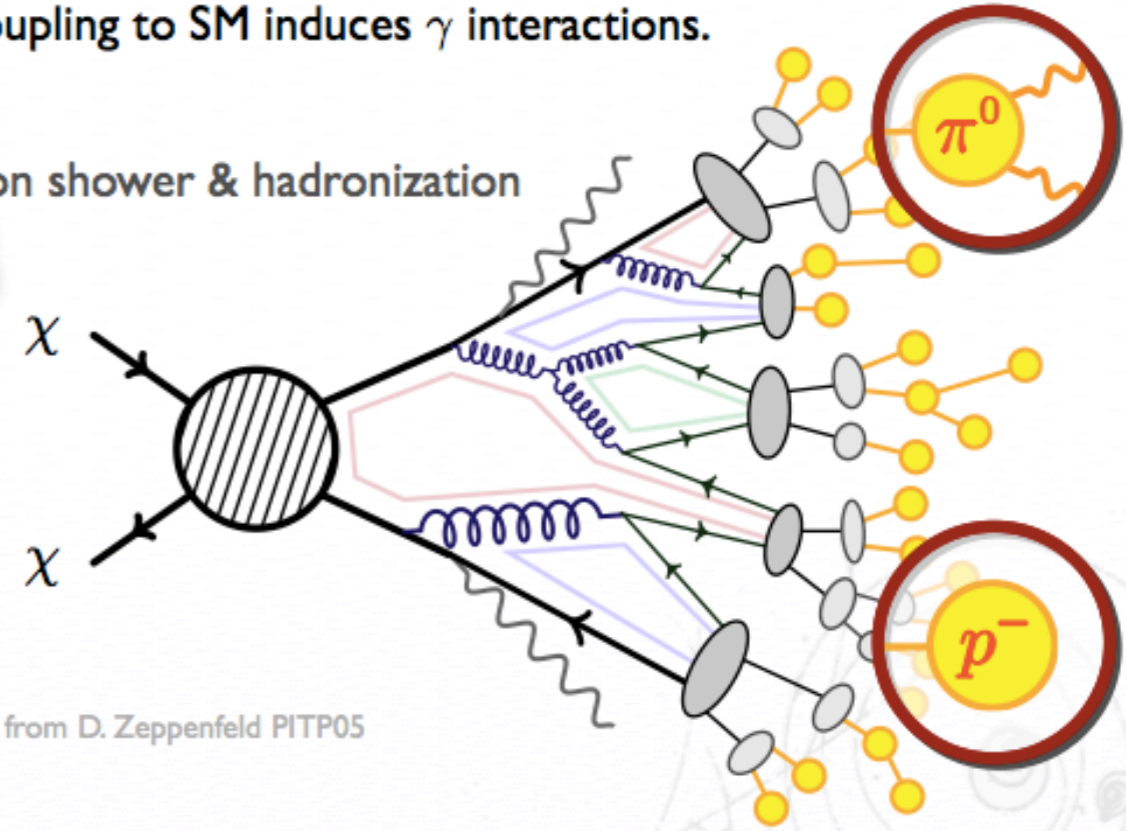
Pheno 2026, Pittsburgh

Galaxy as DM Detection Laboratory



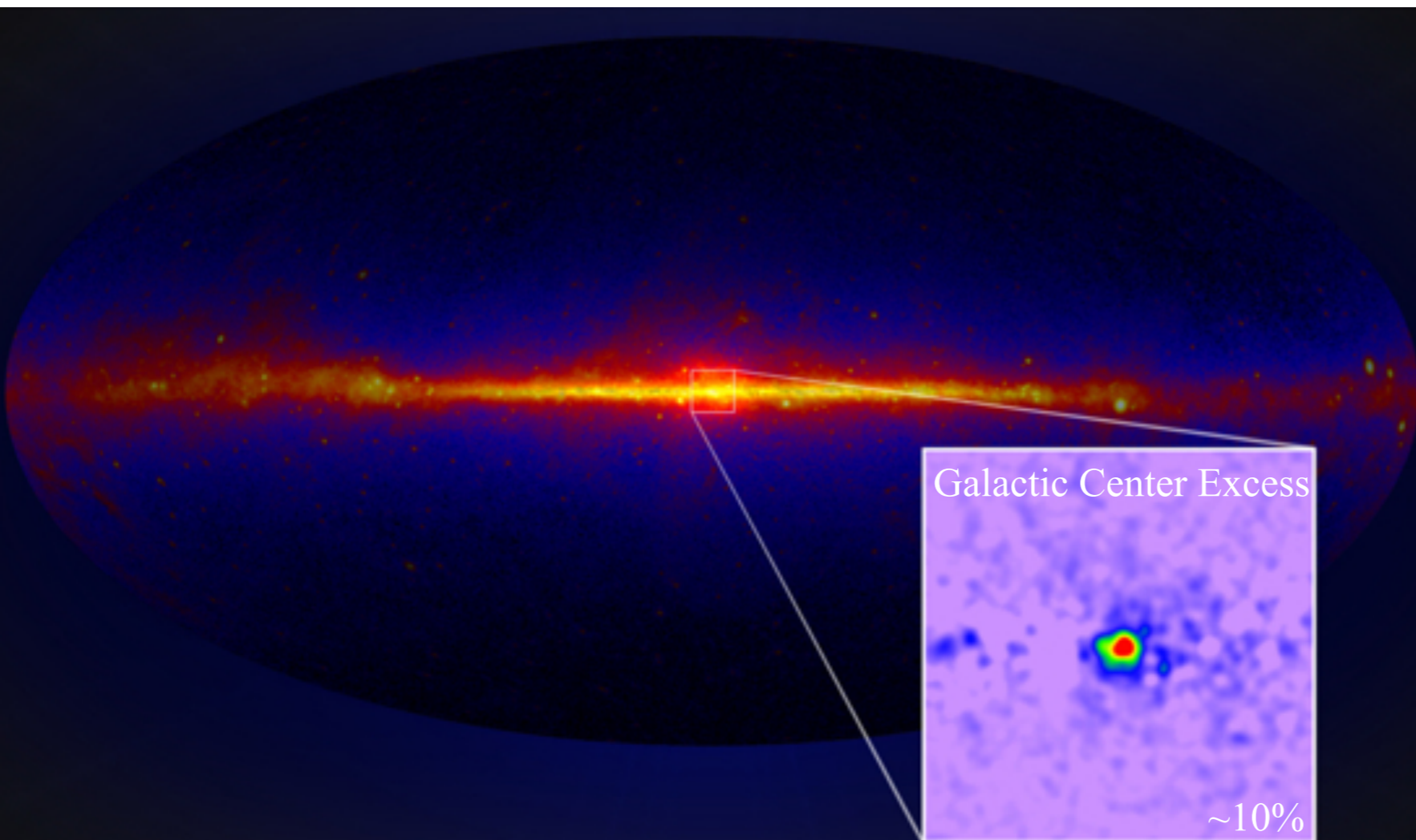
DM coupling to SM induces γ interactions.

Parton shower & hadronization



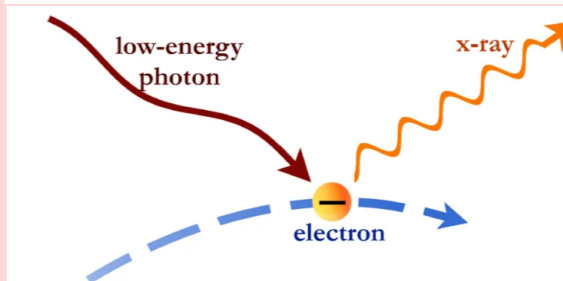
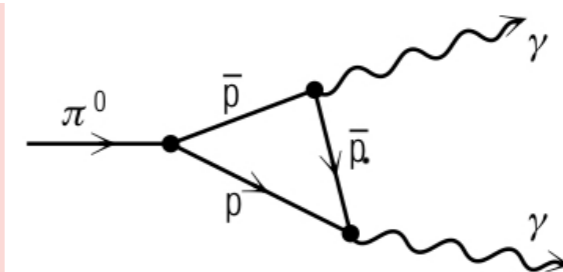
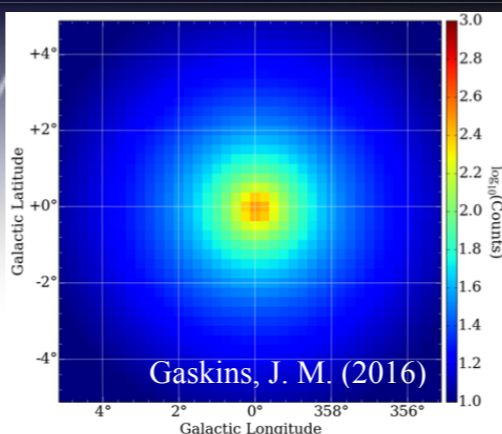
Adapted from D. Zeppenfeld PITP05

Galactic Center Excess



NASA/T. Linden, U.Chicago

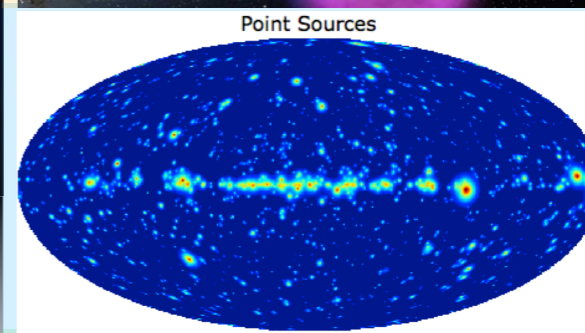
DM annihilation signal
 $\langle \sigma v \rangle \sim 10^{-26} \text{ cm}^3/\text{s}$



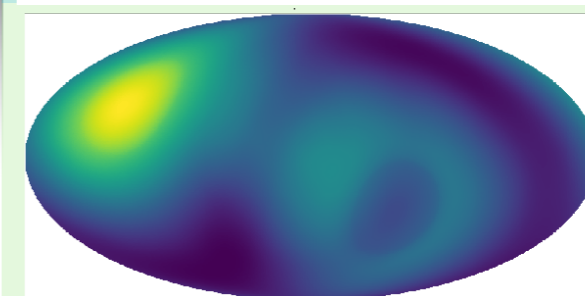
Diffuse
Models



Fermi
Bubbles

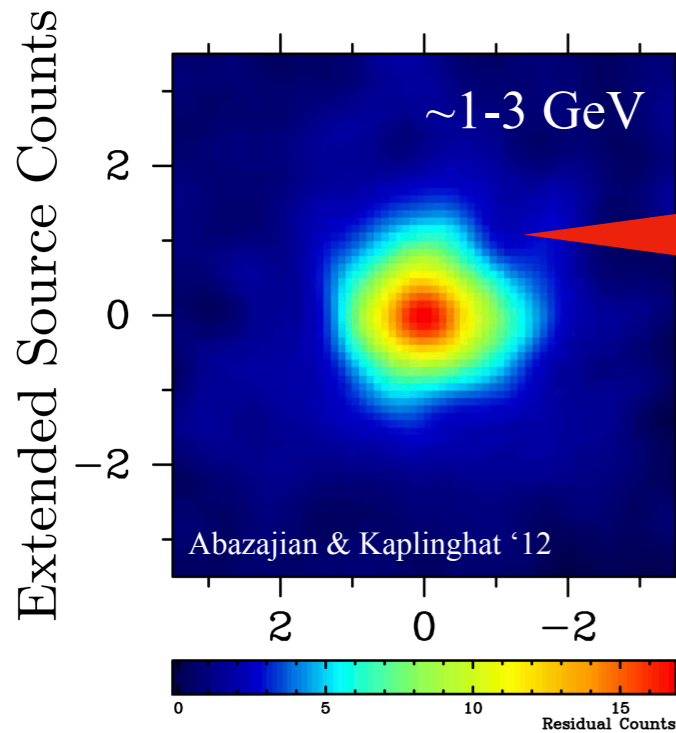


Point
Sources

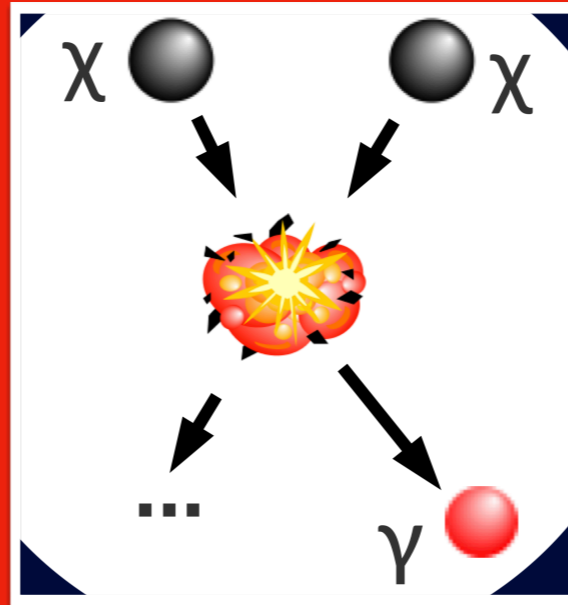


Isotropic

Potential Sources of GCE



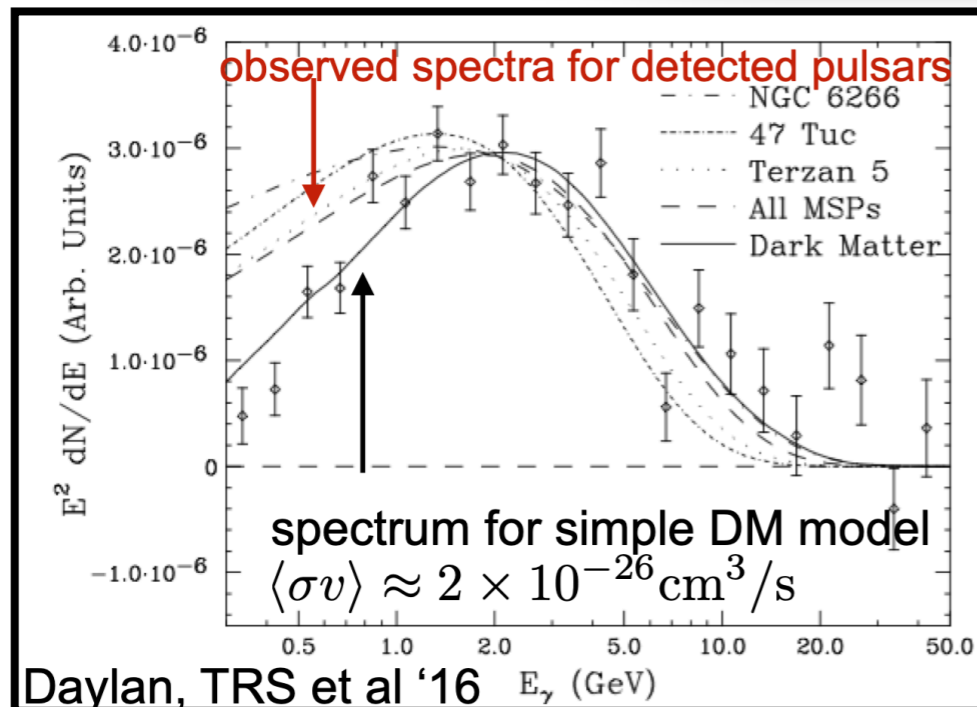
Residual: where do they come from?



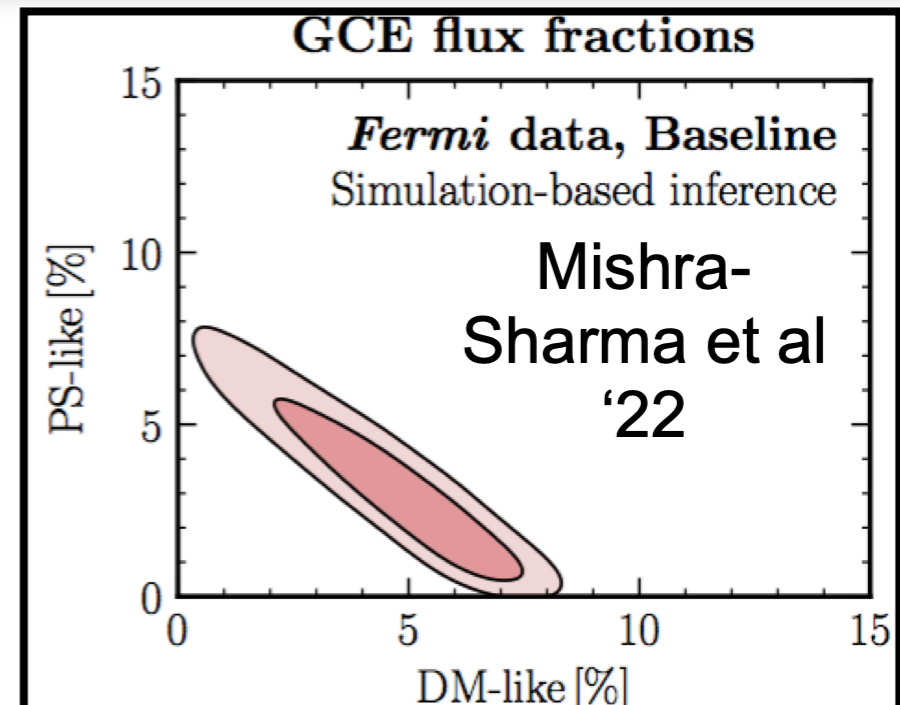
Florian List's talk (2023)



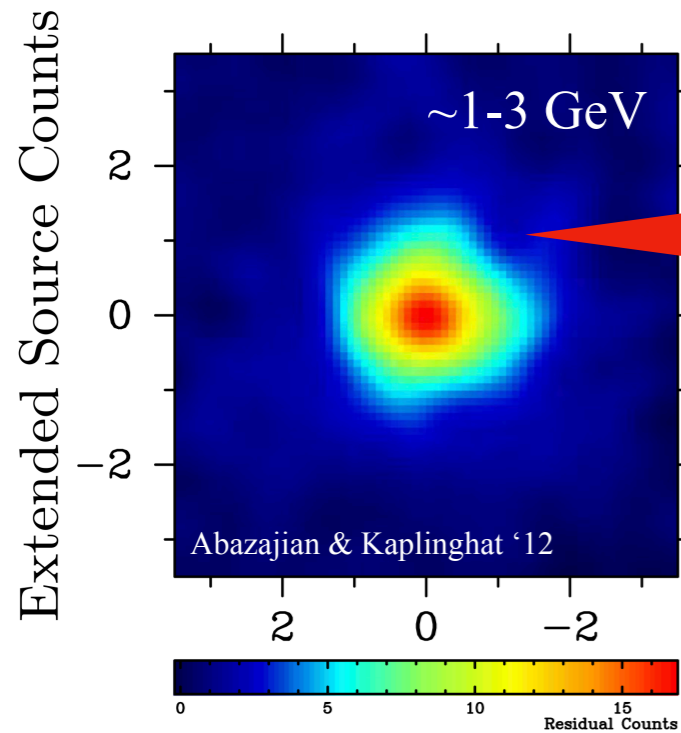
NASA



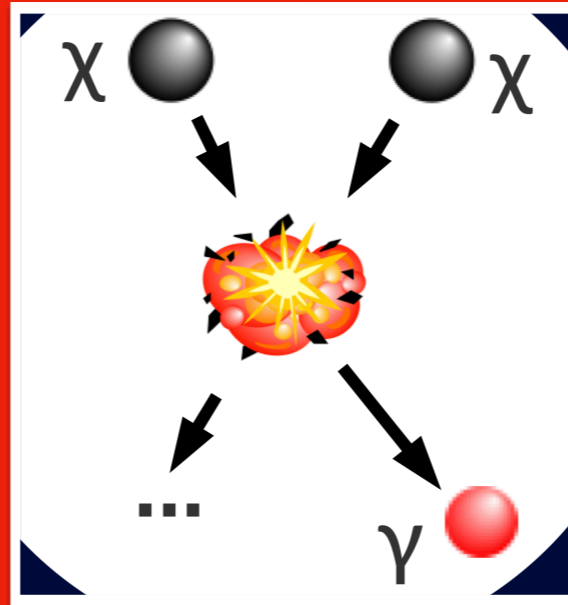
Daylan, TRS et al '16



Potential Sources of GCE



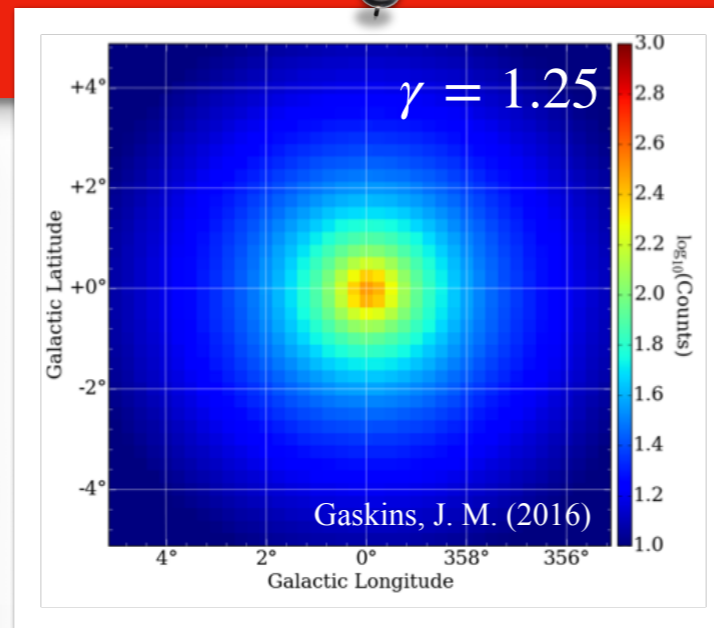
Residual: what is the morphology?



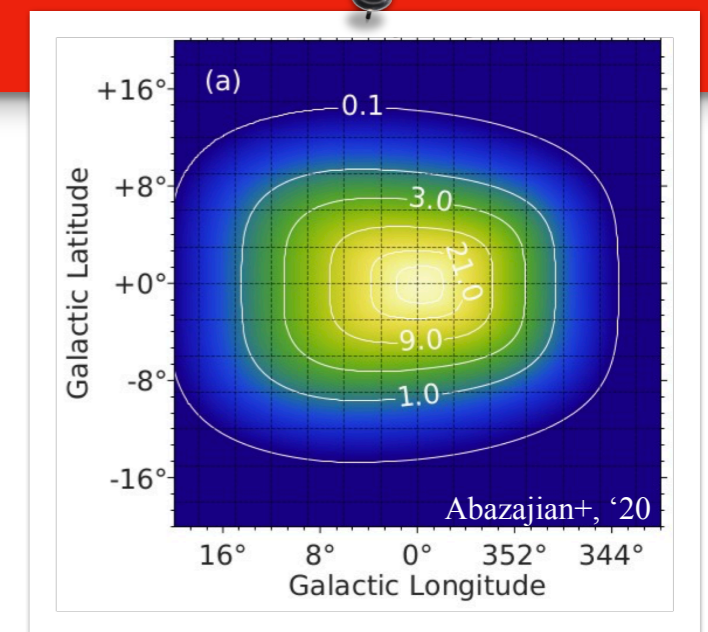
Florian List's talk (2023)



NASA



nfw

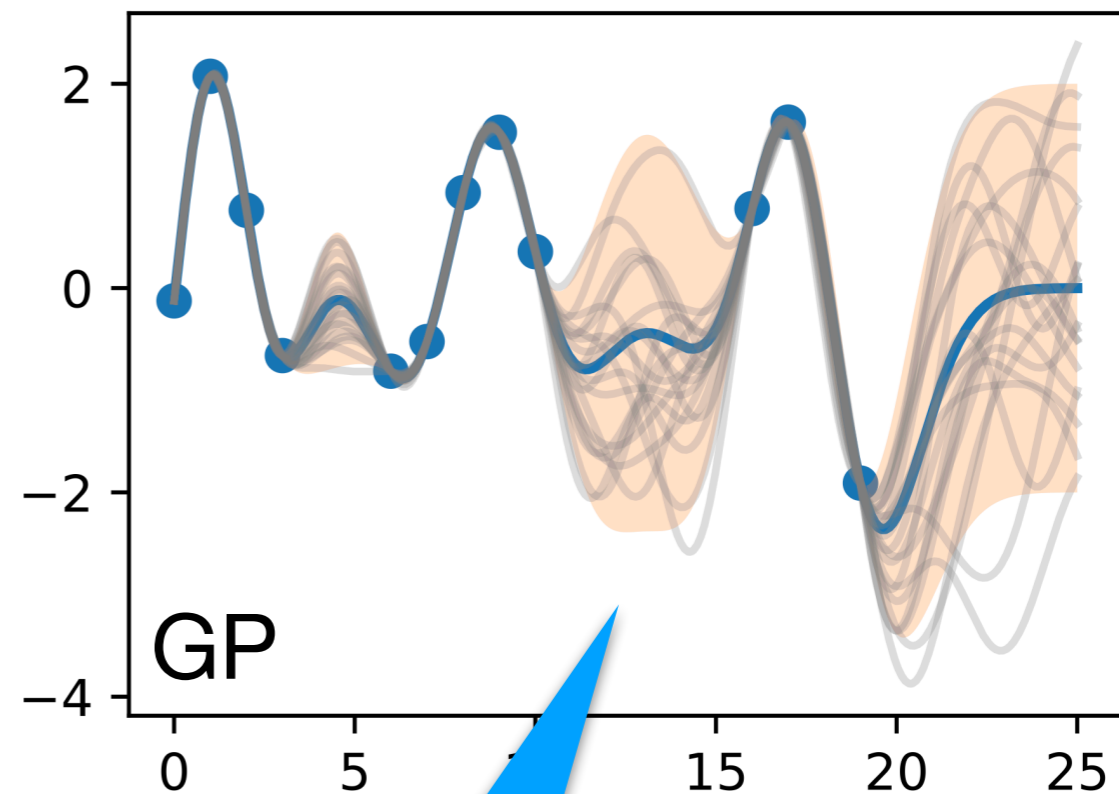
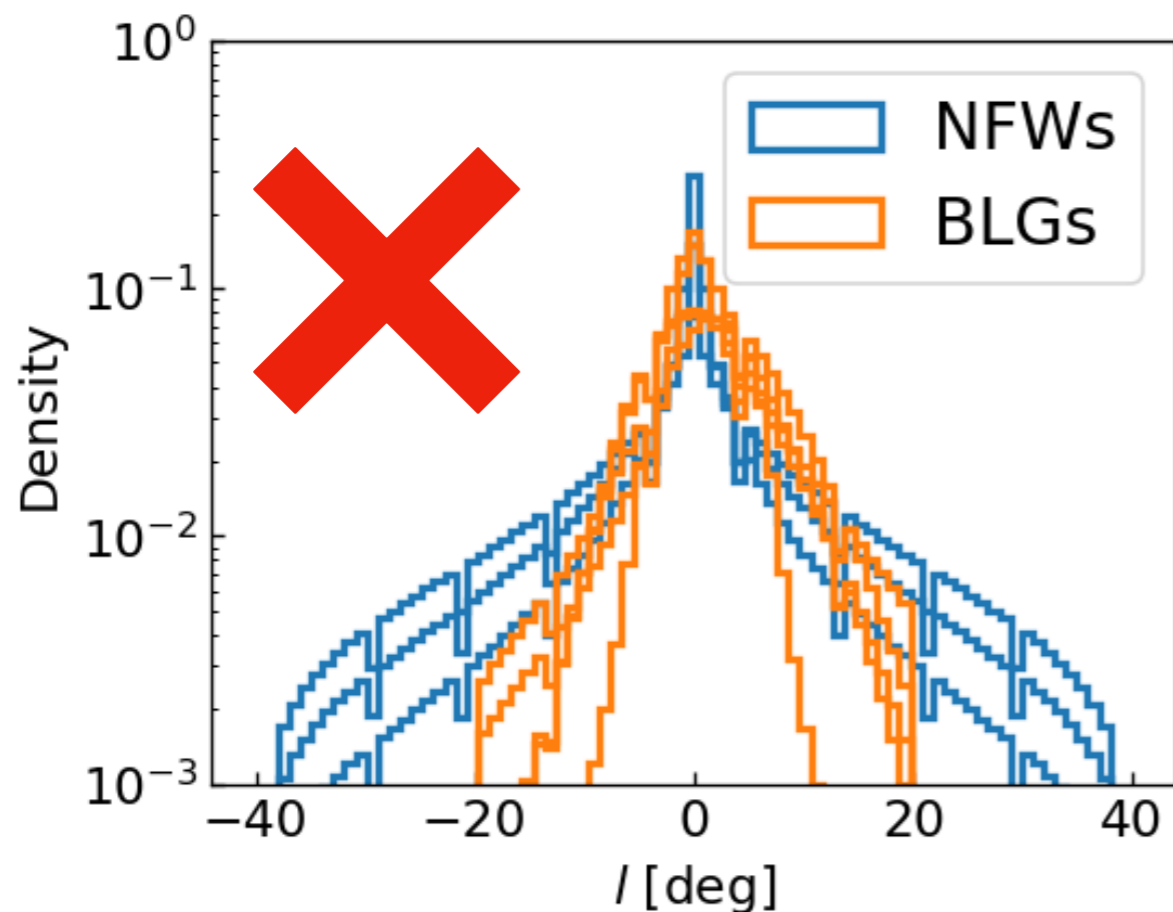


blg

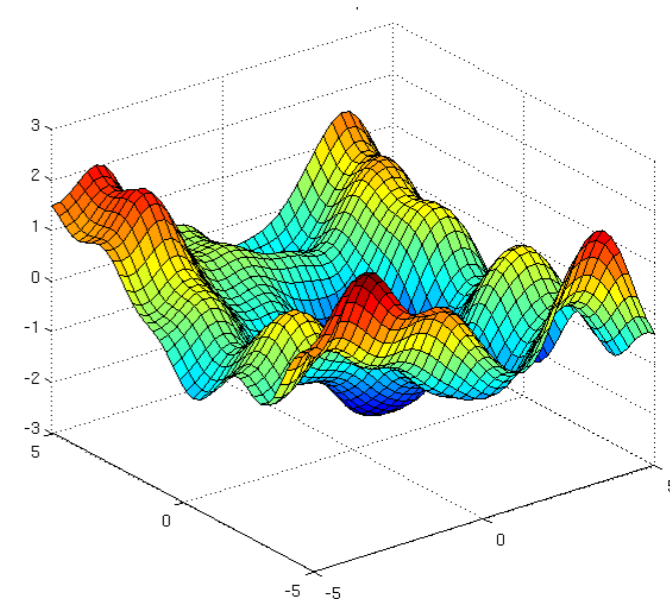
Checkpoint

A. Flexible morphology for excess signal

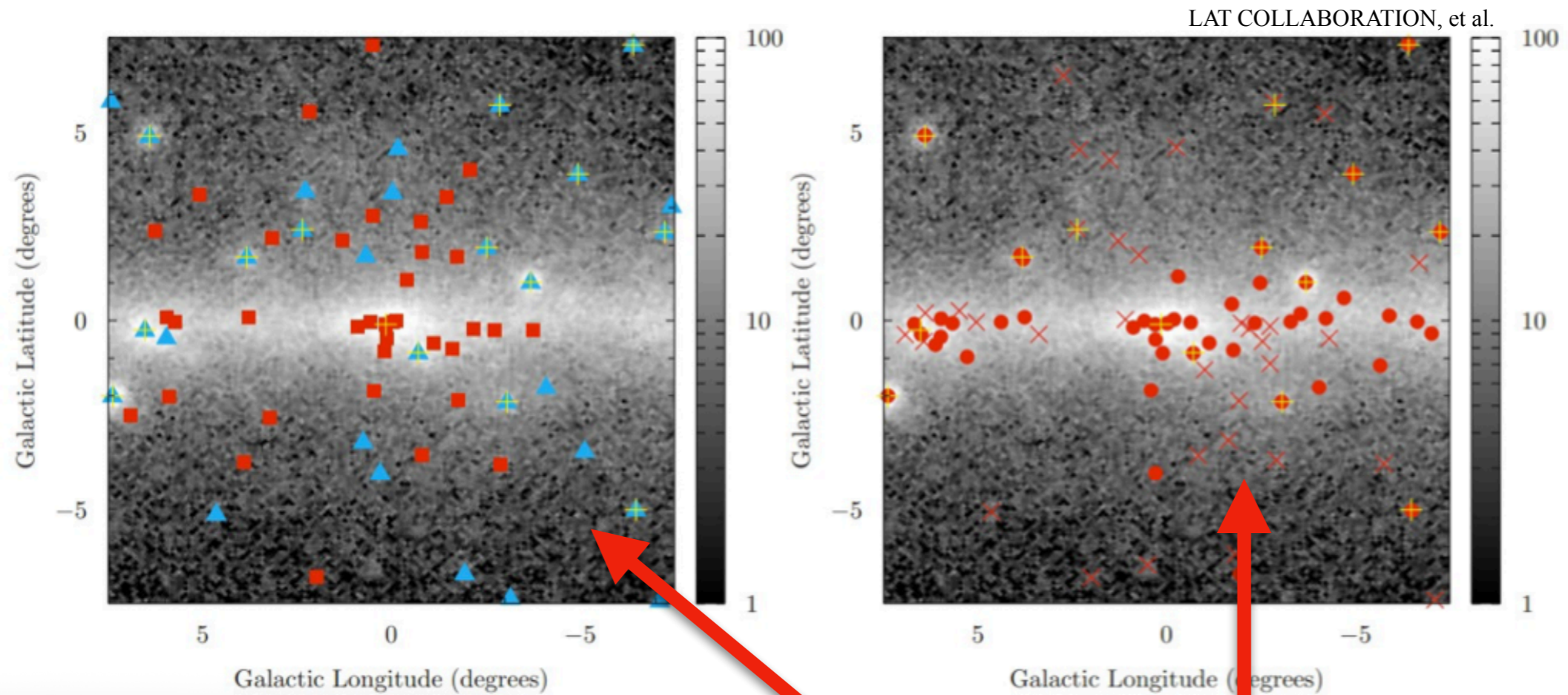
Gaussian Process



- Functional of two point correlation among pixels
- Flexible prior over functions
- Provides credible intervals by sampling functions (uncertainty estimates)



Background Modeling

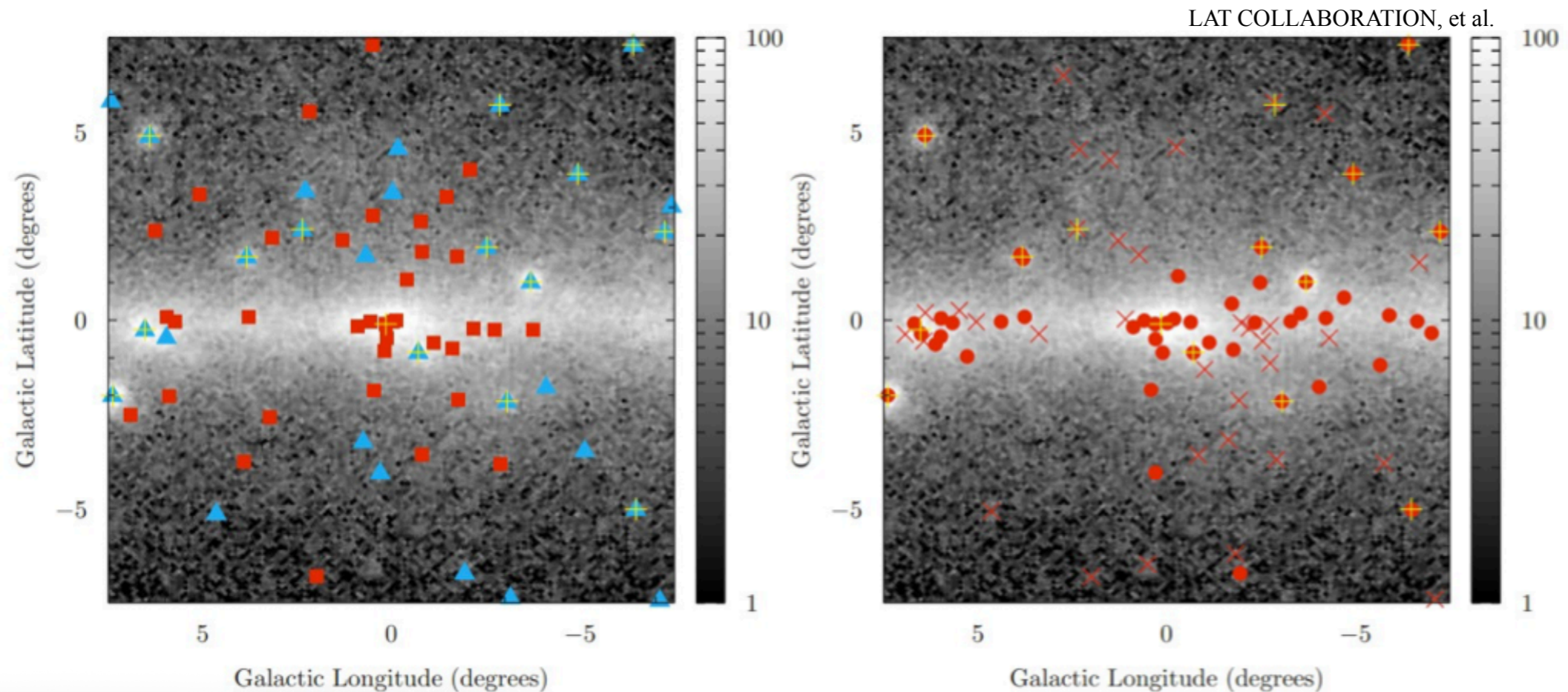


Checkpoint

- A. Flexible morphology for excess signal
- B. Cross modeling check

Fitting different diffuse models results in different excess

Background Modeling

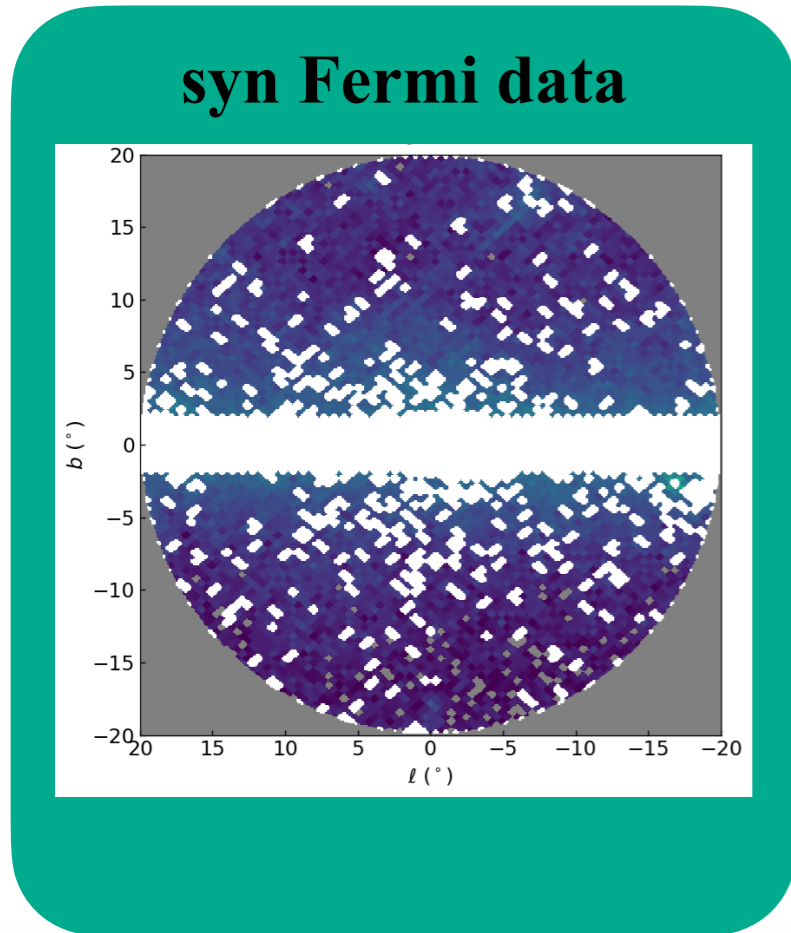


Checkpoint

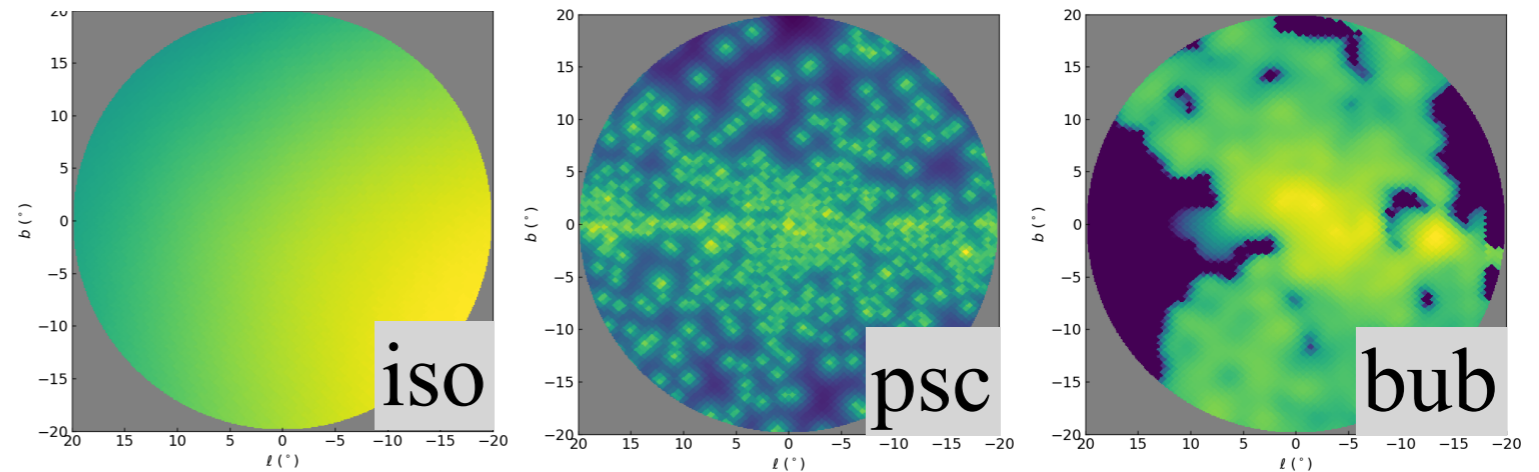
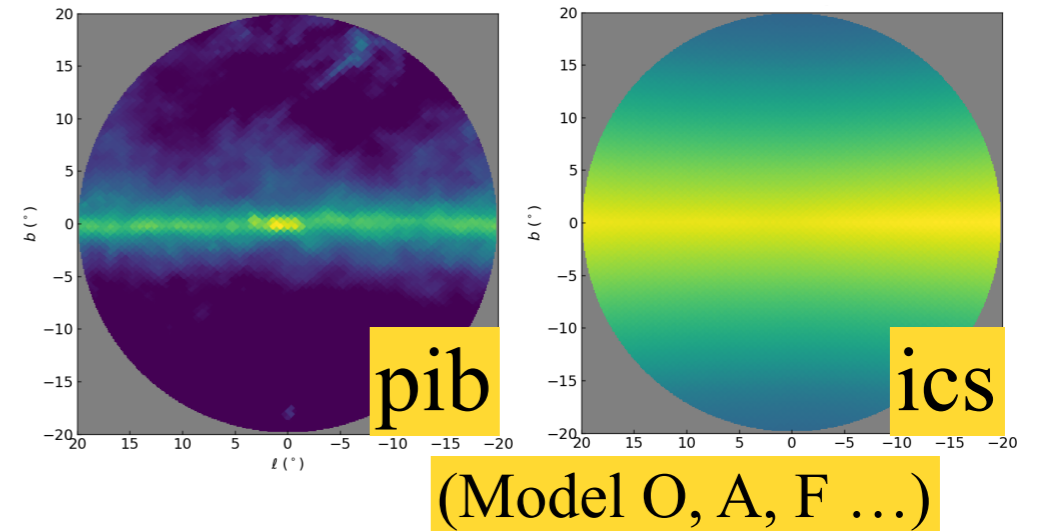
- A. Flexible morphology for excess signal
- B. Cross modeling check

**Cross modeling checks:
what if the model in reality is
different from our model?**

Fitting Pipeline



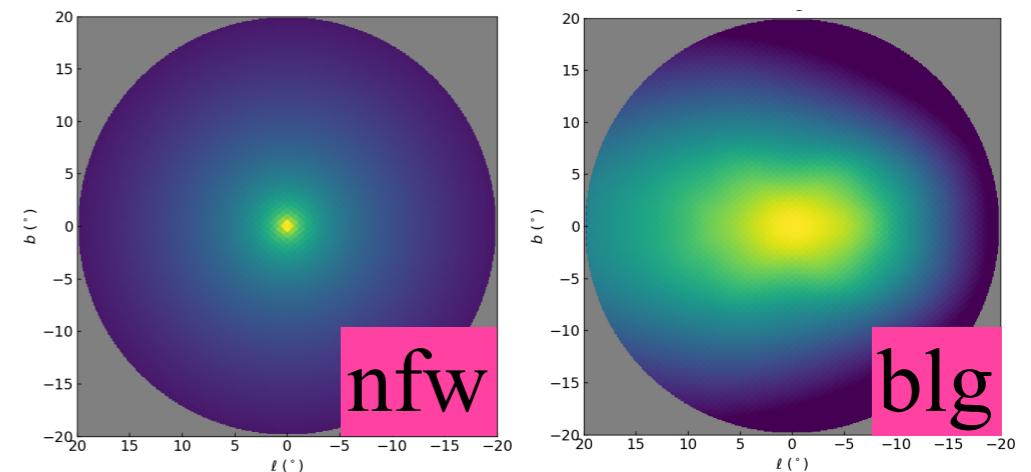
bkg



Checkpoint

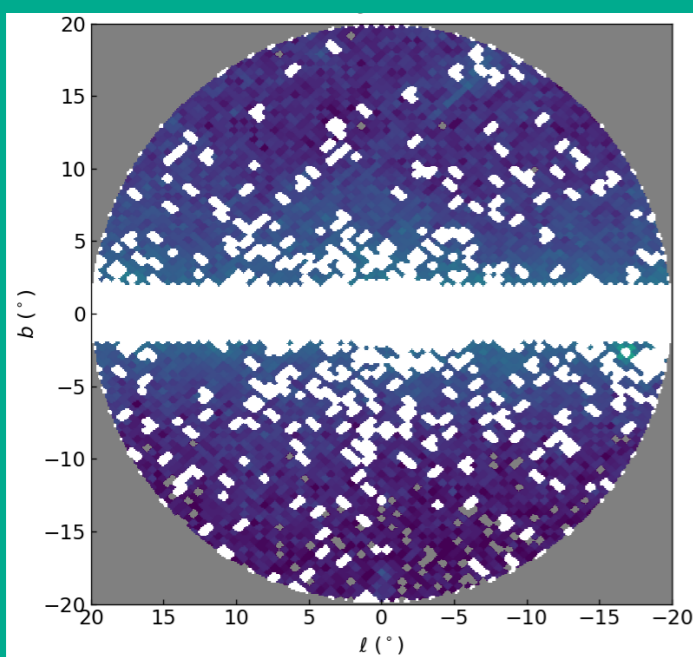
- A. Flexible morphology for excess signal
- B. Cross modeling check

signal

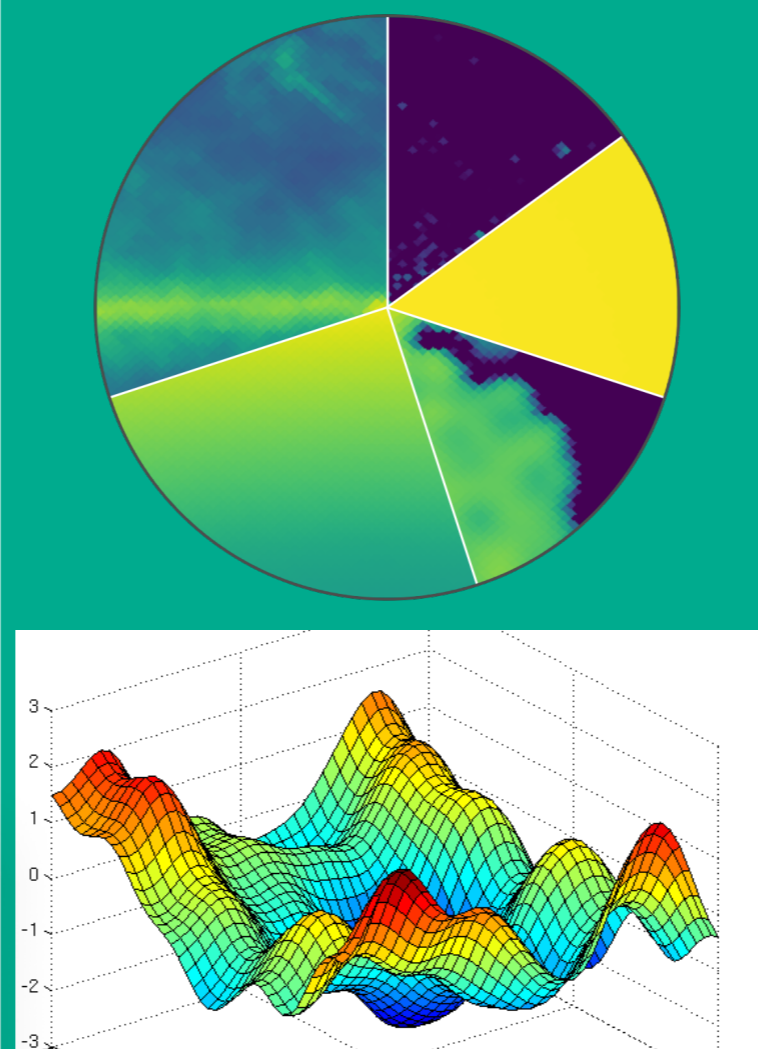


Fitting Pipeline

syn Fermi data

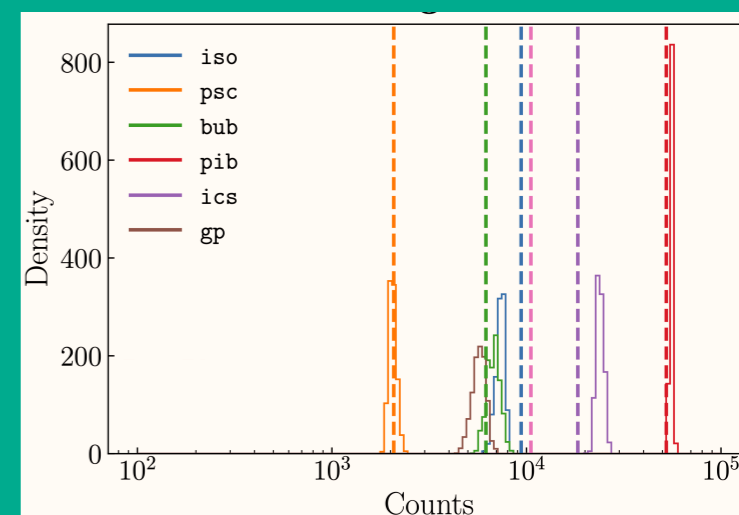
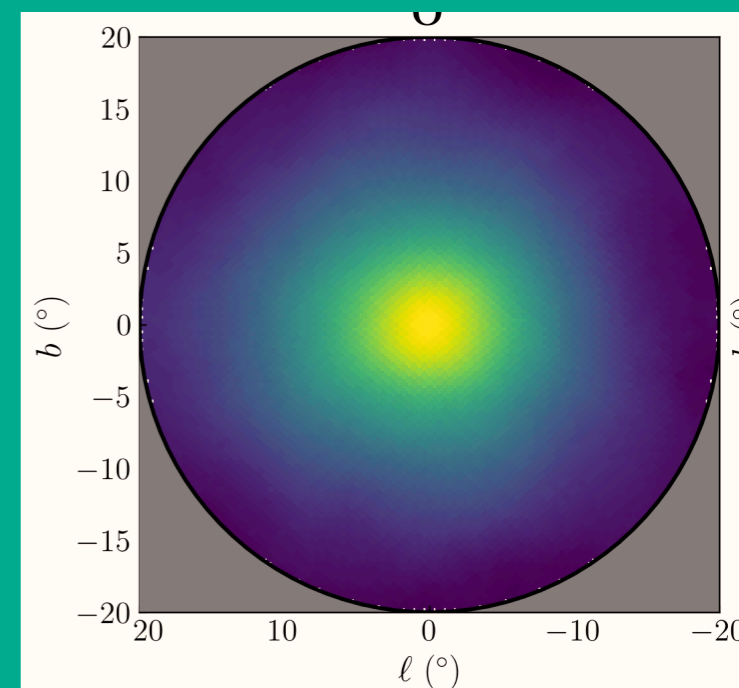


SVI Fitting



Gaussian Process

Output



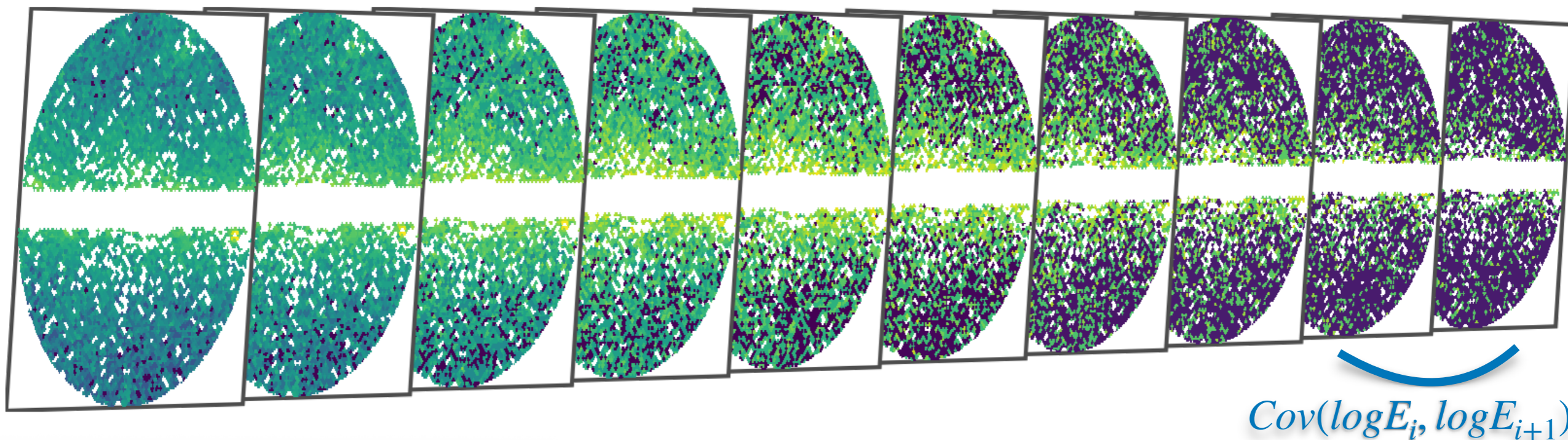
Checkpoint

- Flexible morphology for excess signal
- Cross modeling check

NEW: Spatial-spectral Correlation

2 GeV

20 GeV

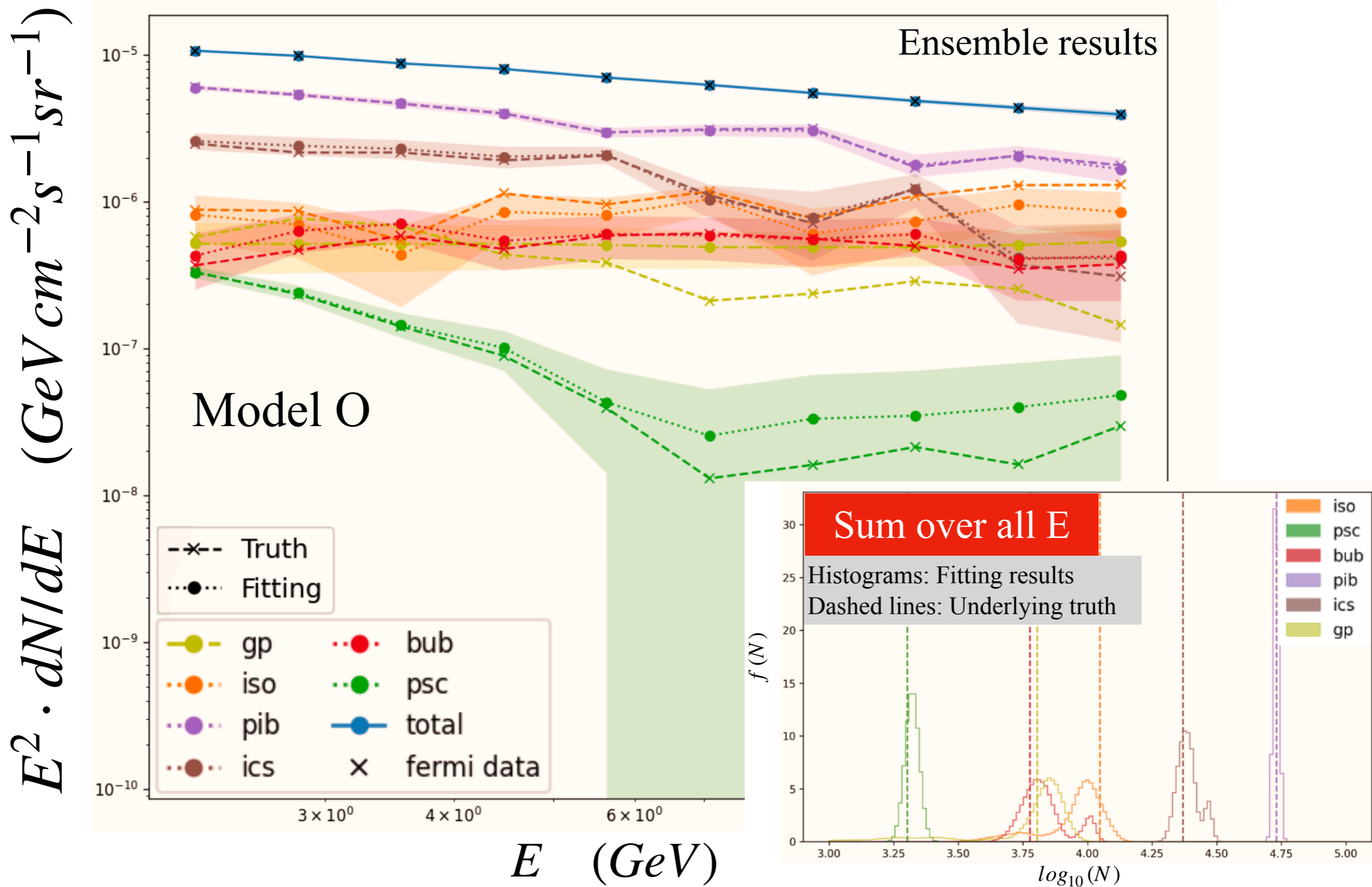


Checkpoint

- A. Flexible morphology for excess signal
- B. Cross modeling check
- C. Add spectral correlation

Extend a single coarse energy bin to 10 as real Fermi data is!

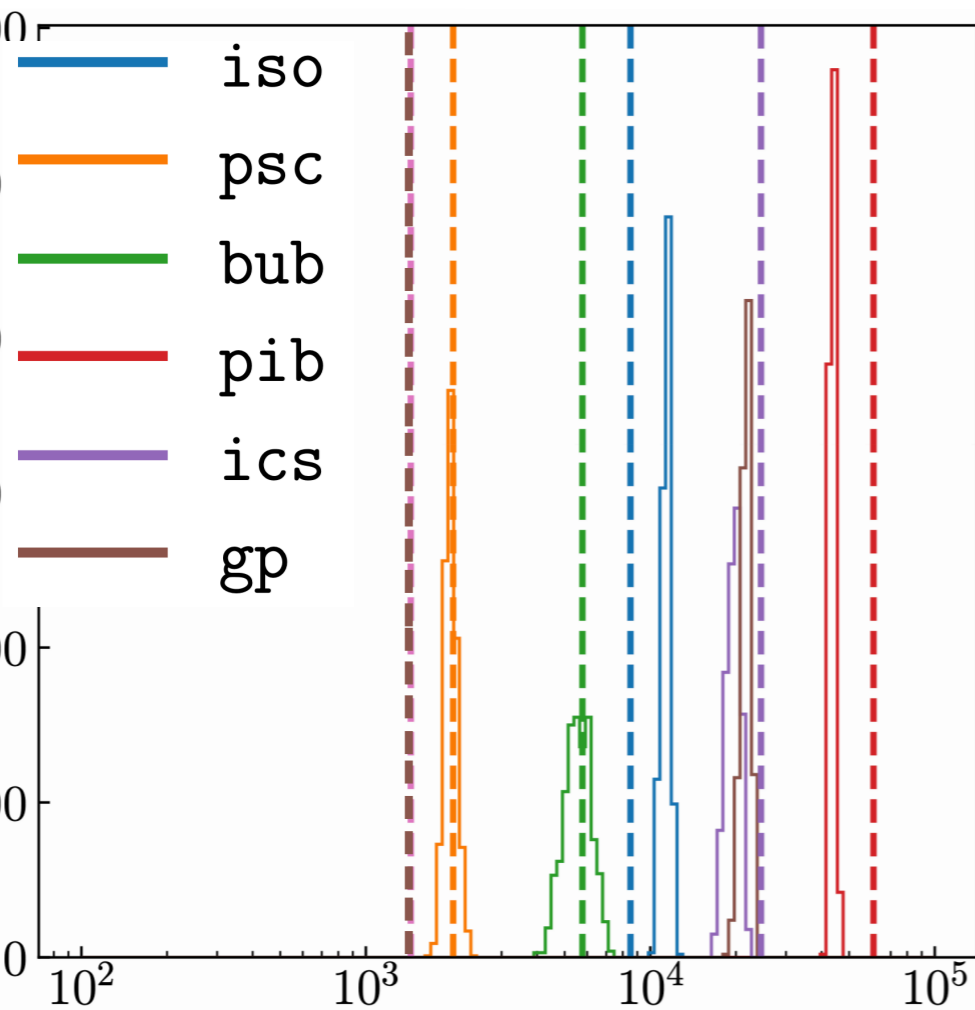
Results – Spectrum



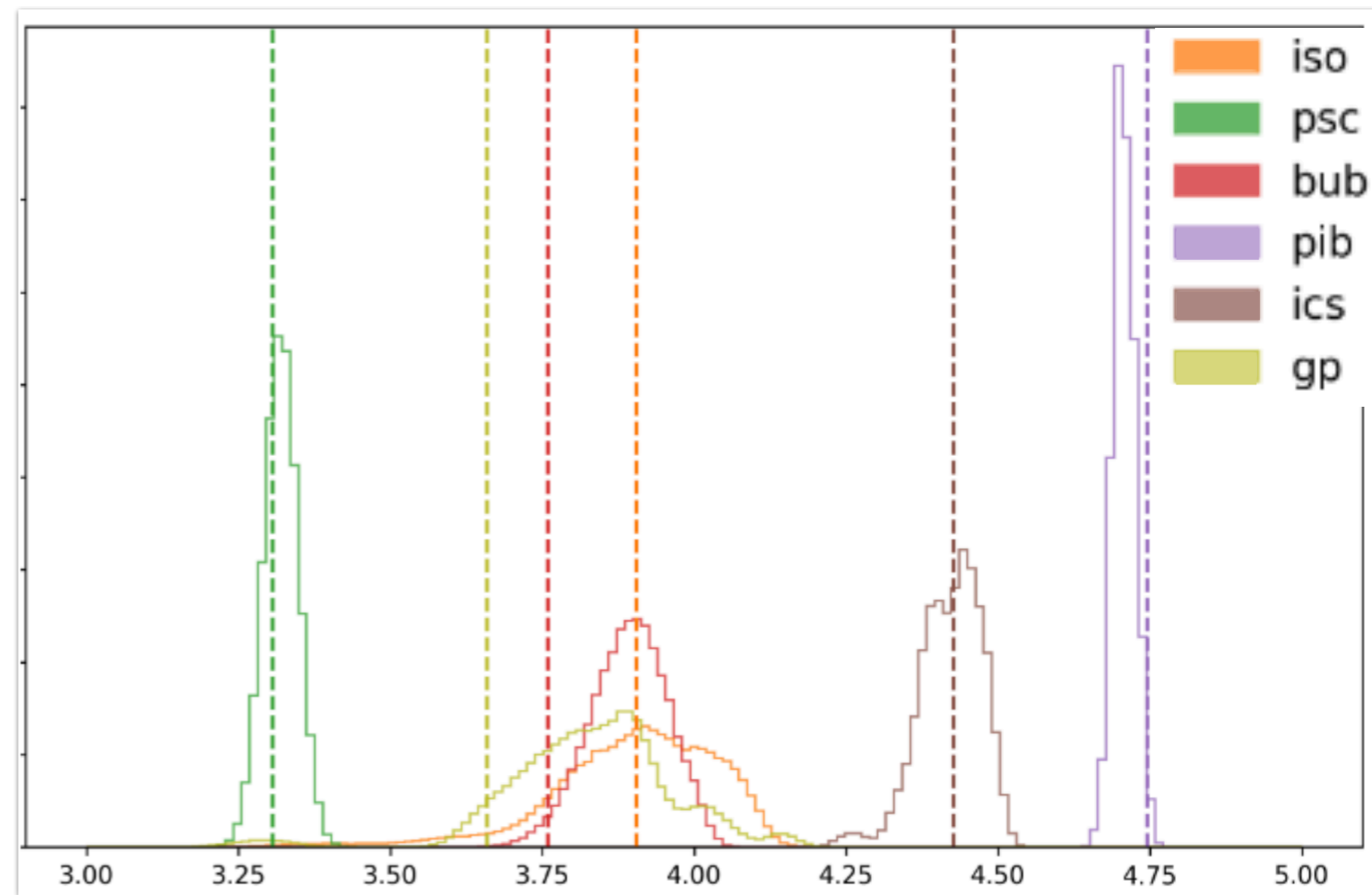
Cross modeling – Intensity

Model O fit to model F synthetic data

RAMIREZ, E. D., et al.

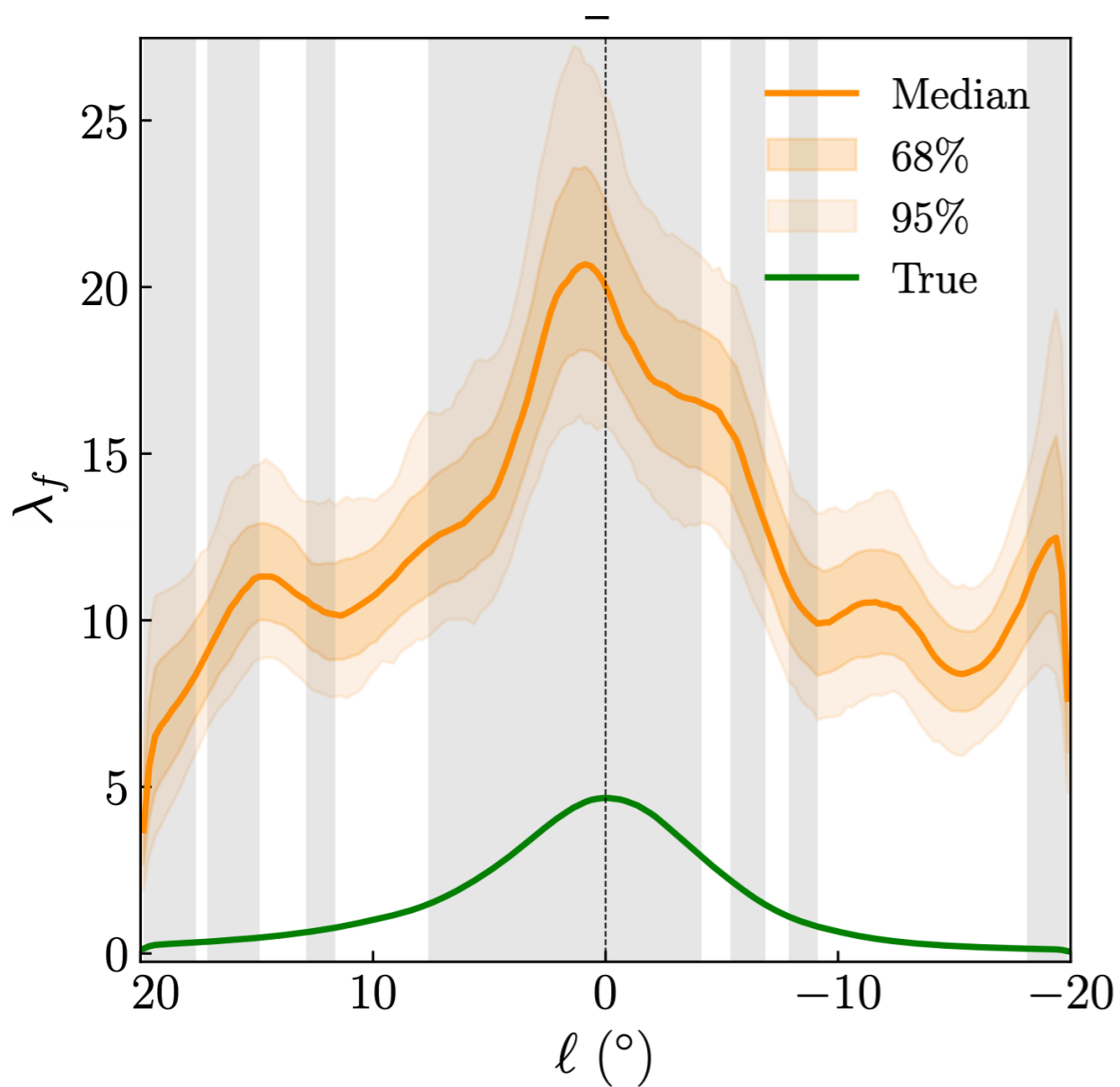


Ours work

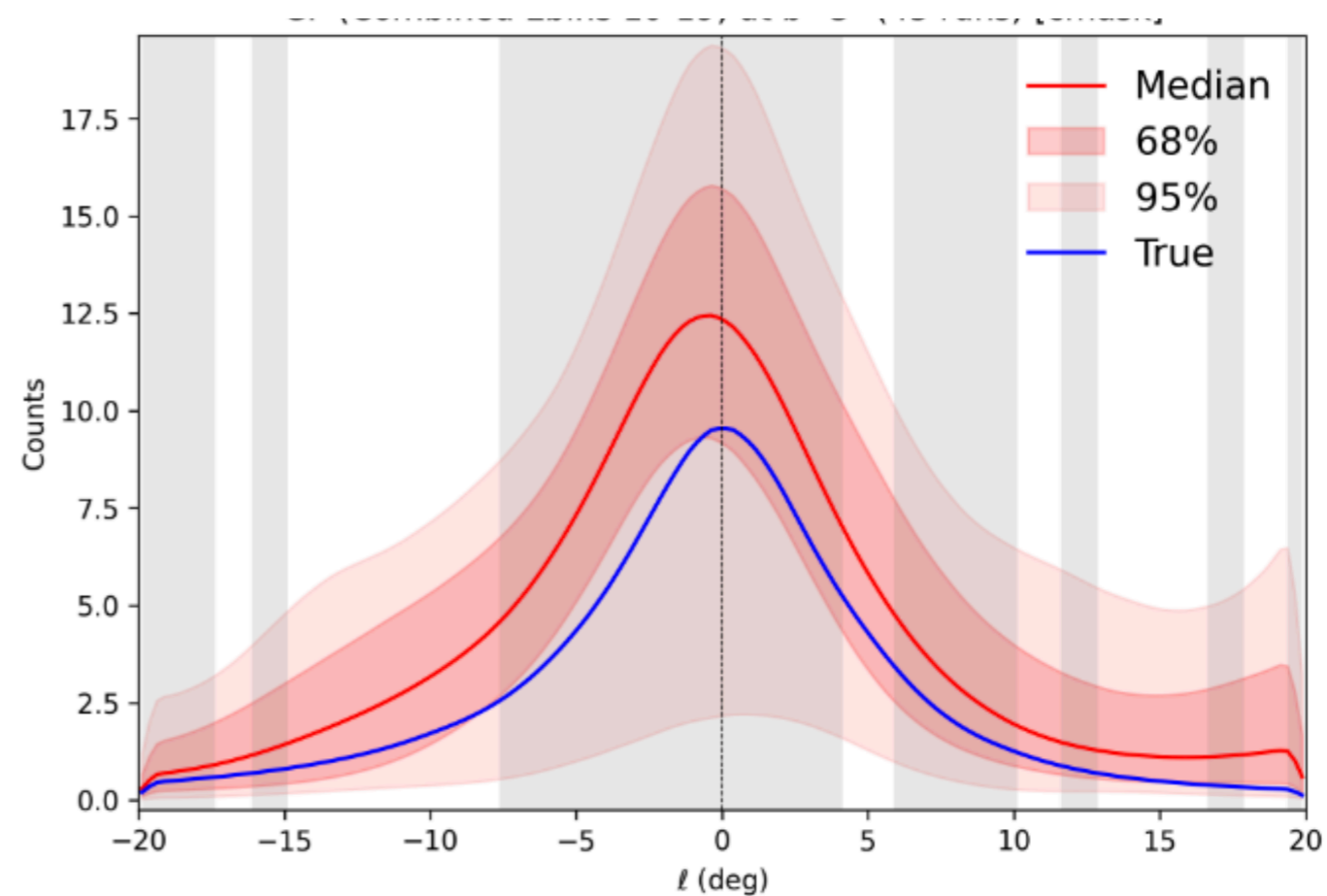


Cross modeling – Morphology

Model O fit to model F synthetic data



at $b \sim 3^\circ$

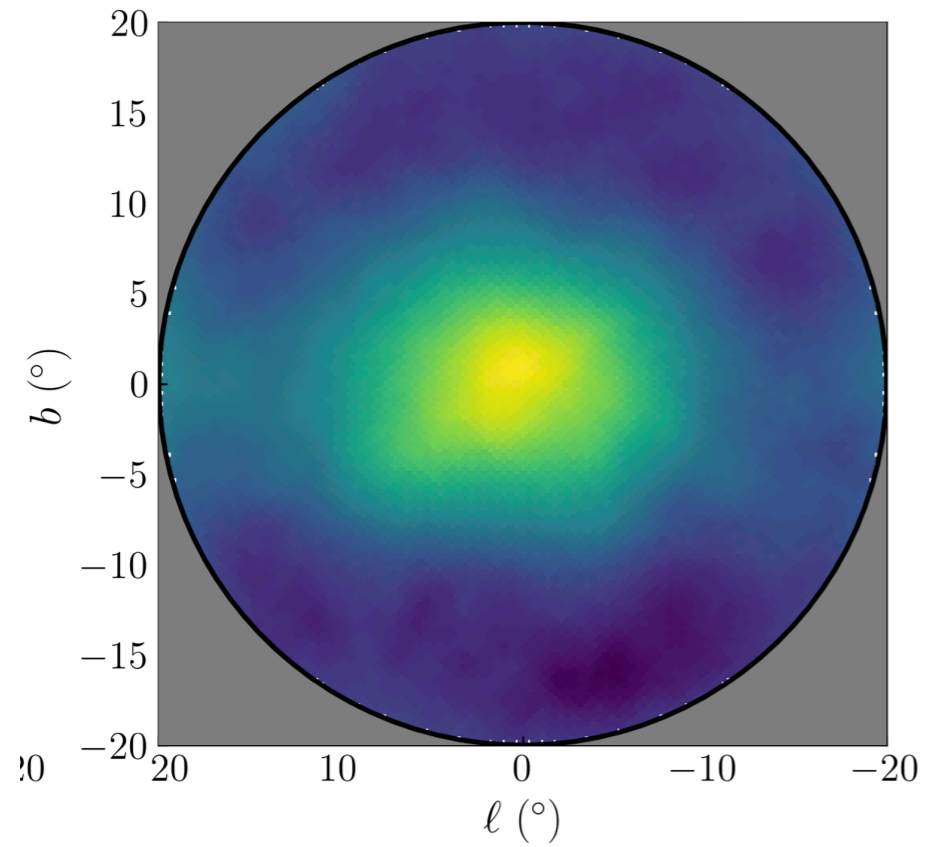


RAMIREZ, E. D., et al.(2024)

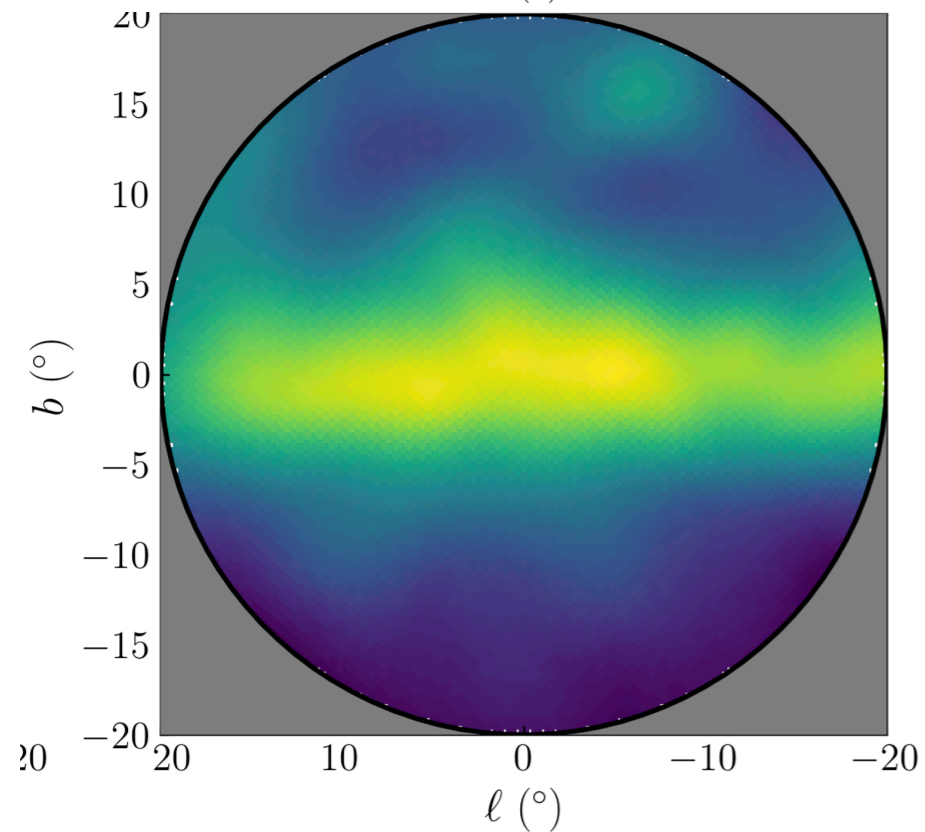
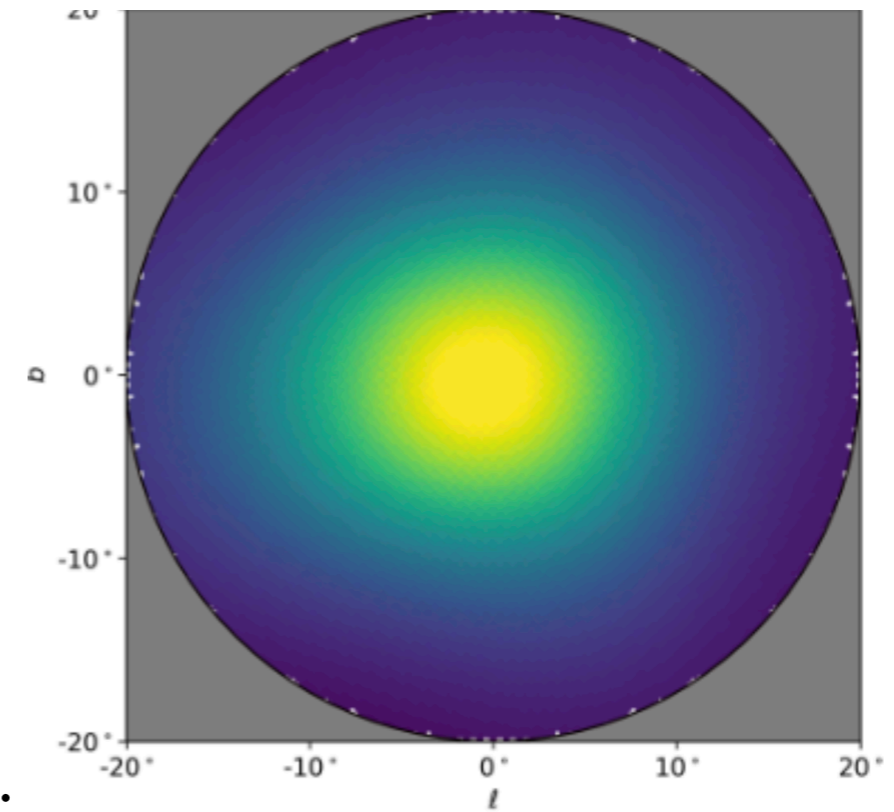
Ours work

RAMIREZ, E. D., et al.(2024)

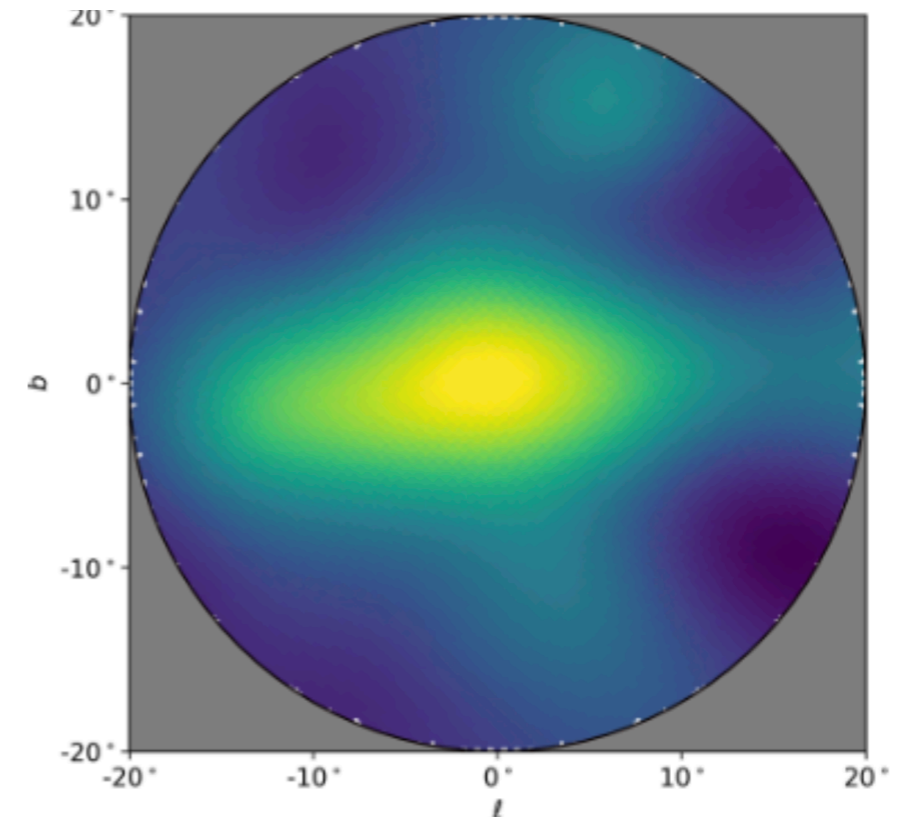
Ours work



F-F



O-F



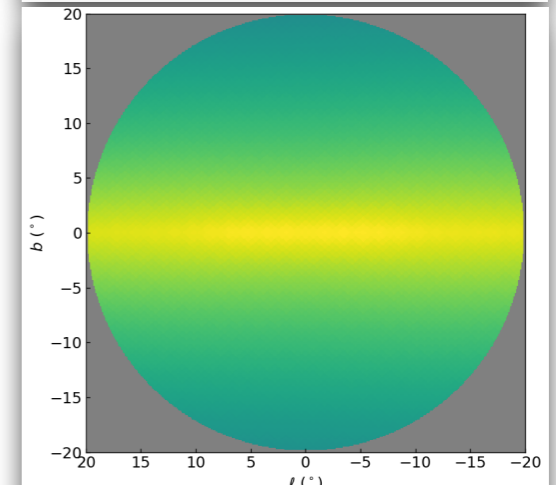
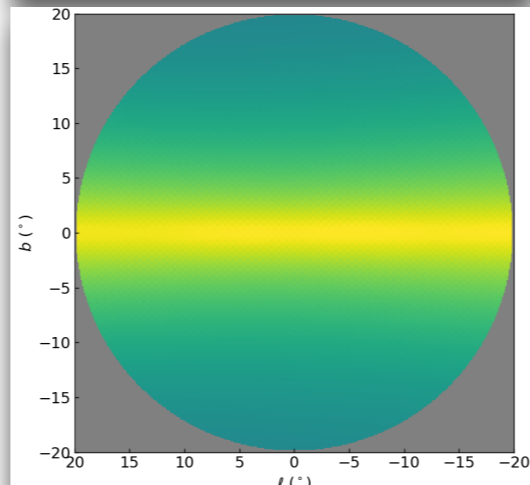
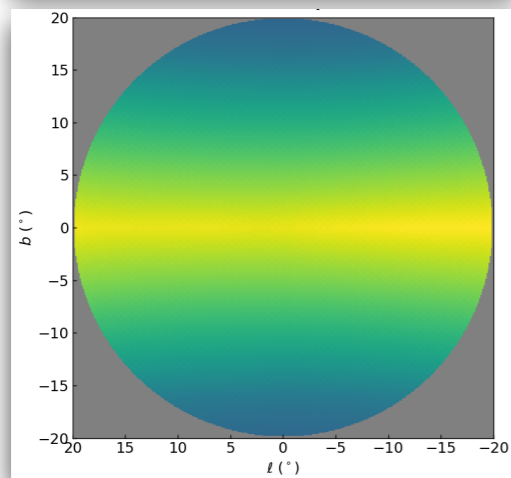
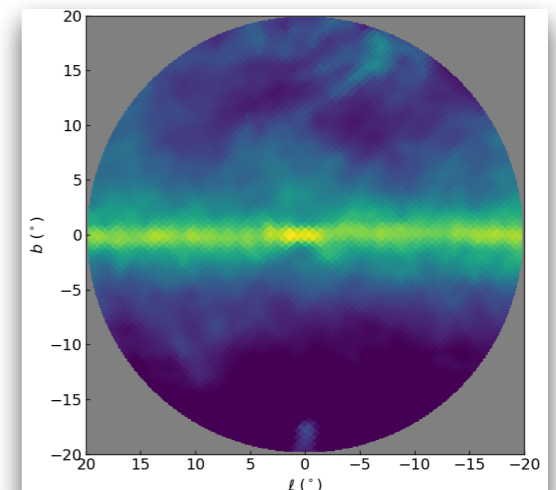
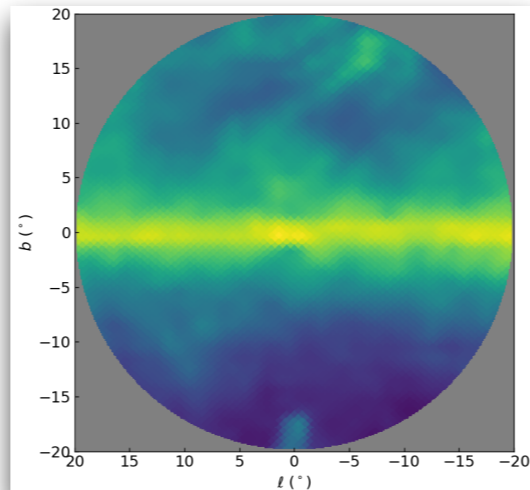
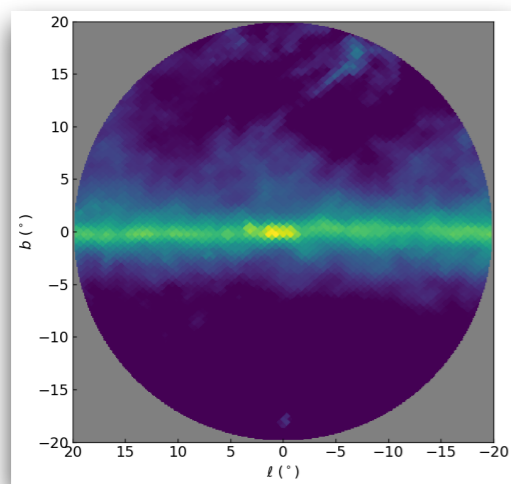
Takeaways & What's Next

- Joint spatial–spectral GP modeling recovers the GCE more consistently across diffuse models — both in morphology and intensity.
- Extend cross-modeling to a broader set of diffuse templates (beyond Models O, A, F).
- Apply the pipeline to real Fermi-LAT data to pin down the GCE morphology.

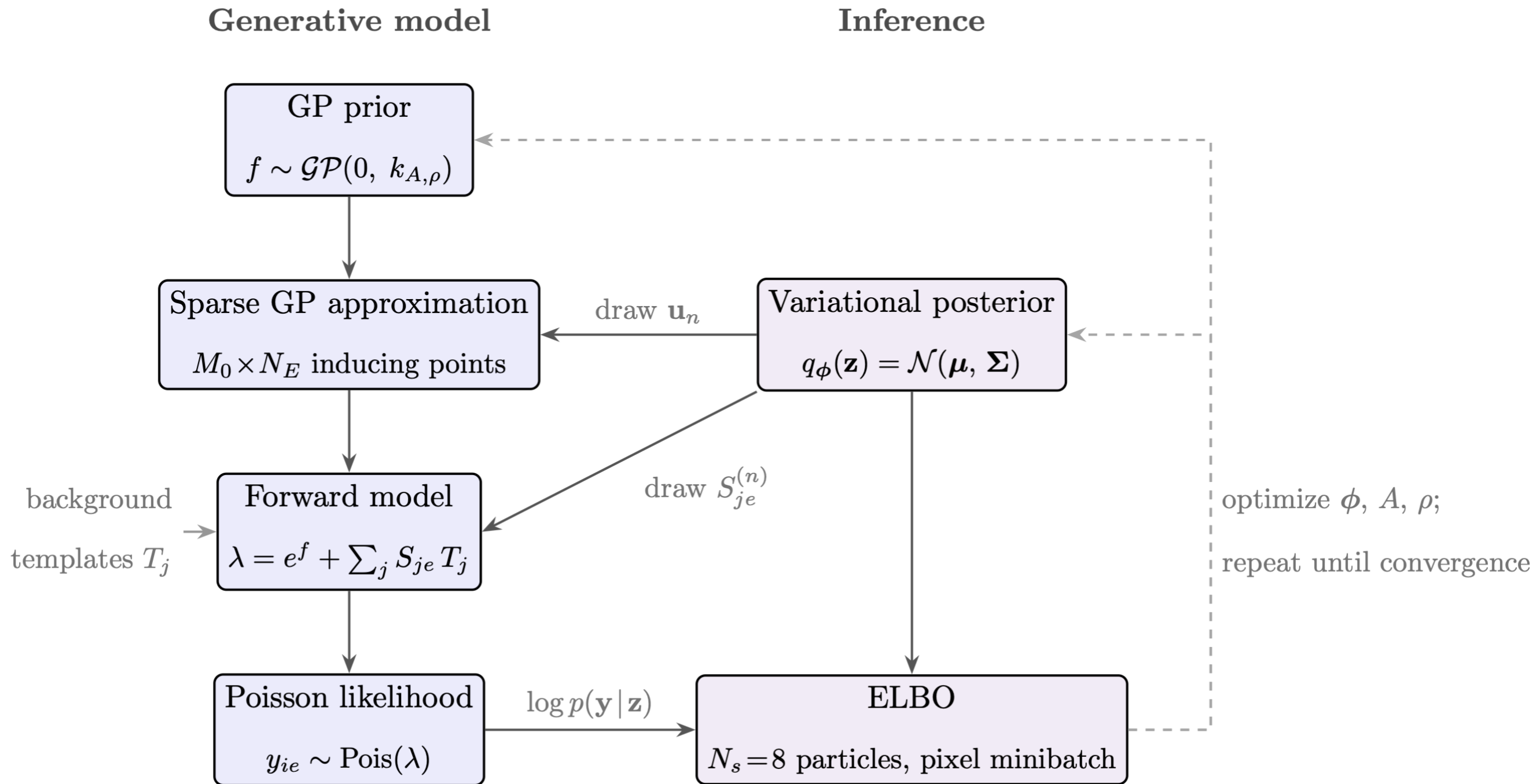
Backup

Diffuse model comparison

Model	O	A	F
pib	ISM simulated	Galprop	Galprop
ics	Galprop	Galprop	Galprop
Approach	Ring-based	Galprop (predicted)	Galprop (predicted)
Role / source	Buschmann+ 2020	Calore+ 2014 reference	Calore+ 2014 best-fit



Fitting Procedure



Outer ROI used in RAMIREZ, E. D., et al. [2410.21367]

Outer ROI break degeneracy, but may spoiled the fitting results due to large pixels counts!

And the energy correlation get rid of this degeneracy!

