



Estimating the Cherenkov Telescope Array Observatory sensitivity to detect the Fermi Bubbles

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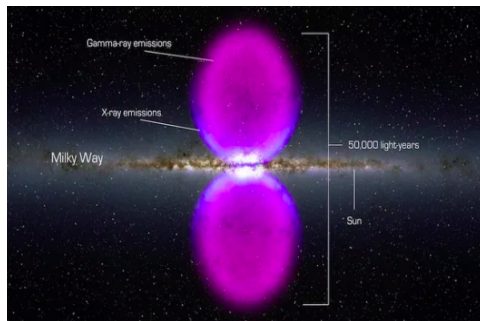
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What are the Fermi Bubbles?

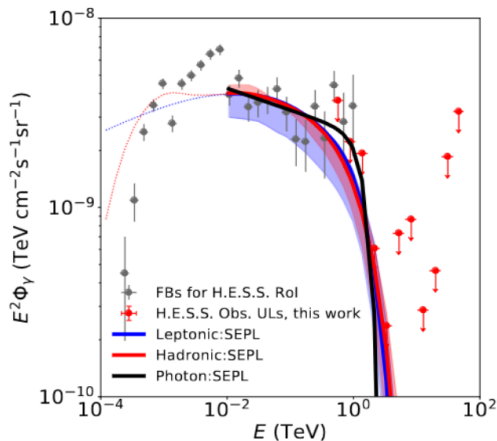
- Giant gamma-ray emitting structures extending up to 55° above and below the Galactic Centre (GC)
- Discovered by the Fermi Gamma-ray Space Telescope in 2010
- Origin remains unknown
- Theorized to be produced either in hadronic interactions or in leptonic inverse Compton scattering



<https://www.space.com/fermi-bubbles-milky-way-radiation-mystery.html>

Fermi Bubbles spectrum

- Existing data between ~ 0.1 GeV and ~ 1 TeV
- Spectrum consistent with an Exponential Cutoff Power Law or a (Super) Exponential Cutoff Power Law
- Softening at 100 GeV
- Lack of detection above 1 TeV, best energy for sensitivity of CTA



Moulin et al., 2021, 2108.10028

This project

Goals:

- Study the sensitivity of CTA to detect the Fermi Bubbles in a realistic manner
- Find the optimal observational strategies for the Fermi Bubbles

How to do it:

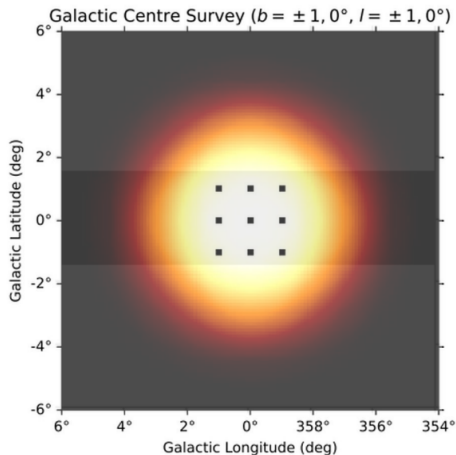
- Simulate the observation:
 - Galactic Centre Survey [The CTA Consortium, 2021, 2007.16129] - 525 hours, $12^\circ \times 12^\circ$ FoV
 - Extended Galactic Survey [The CTA Consortium, 2021, 2007.16129] - 825 hours, $20^\circ \times 22^\circ$ FoV
 - (Maybe) Extragalactic Survey [The CTA Consortium, 2018, 1709.07997]
- Template Fitting with Standard Likelihood approach
 - To create the simulations and for fitting we use the official CTA science tool: **Gammapy** [Donath et al., 2023, 2308.13584]
 - We will consider systematics following: [The CTA Consortium, 2021, 2007.16129]

Working group:

- Gabrijela Zaharijaš
- Judit Pérez-Romero
- Christopher Eckner
- Dima Malyshev
- Francesco Xotta
- Nina Bavdaž

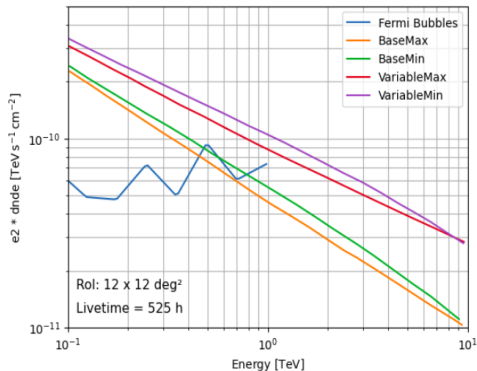
Galactic Centre Survey for Fermi Bubbles

- We consider two set-ups:
 1. **Galactic Centre Survey**, no mask (test study)
 2. **Galactic Centre Survey**, mask on Galactic Plane
- Galactic Centre Survey [The CTA Consortium, 2018, 1709.07997]
- GP Mask: $|b| < 1.5^\circ$
- Observation time: 525 h, split in 9 points as in figure (~ 58 h each)



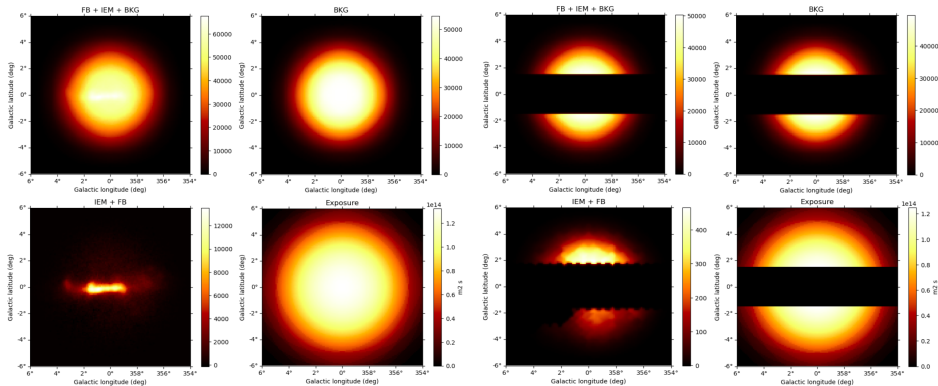
Emission models

- FB model from [*The Fermi-LAT Collaboration*, 2017, 1704.03910]
- Different Interstellar Emission (IE) models are used both for simulations and fitting
- IE Models from [De la Torre, 2022, 2203.15759]
- Max and Min depend on the CR spectral indexes
- Variable and Base depend on the CR Diffusion coefficient
- Instrument CR Background



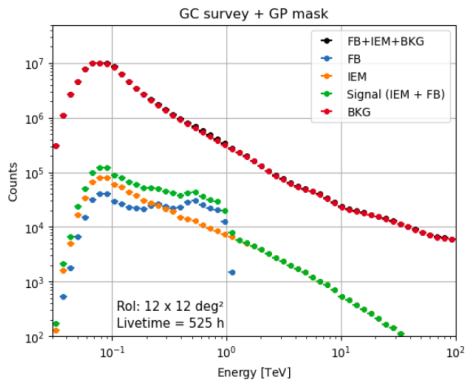
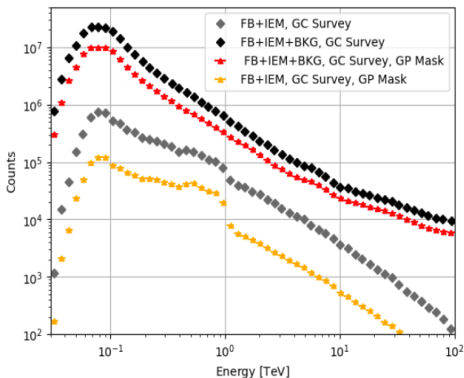
Characterization of the Simulation

- Simulations with BaseMax benchmark model for IE



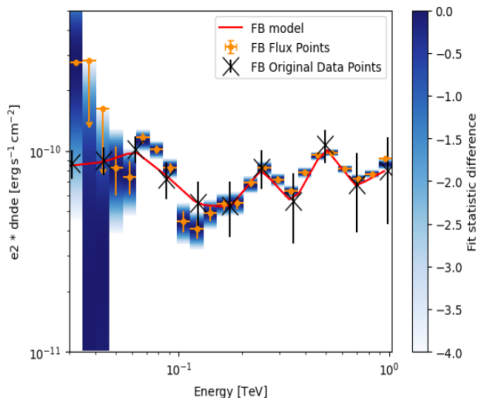
Characterization of the Simulation

- Comparison between the two different set-ups
- GP mask increases signal to noise ratio



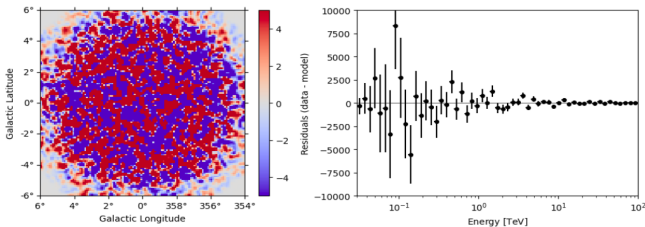
Fit Results

- Fitting parameters: FB Normalization, FB Tilt, CR Background Normalization, CR Background Tilt, IE Normalization and IE Tilt
- IEM Model is BaseMax for Simulation and Fitting
- FB Original Data Points from [The Fermi-LAT Collaboration,2017, 1704.03910]

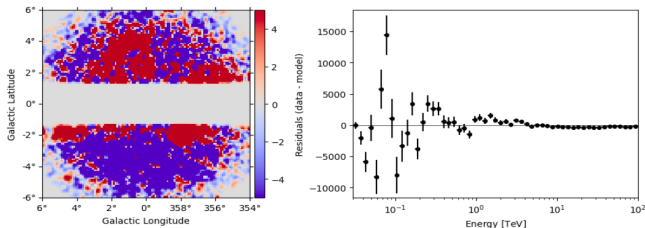


Residuals of Galactic Center Survey

- Galactic center Survey

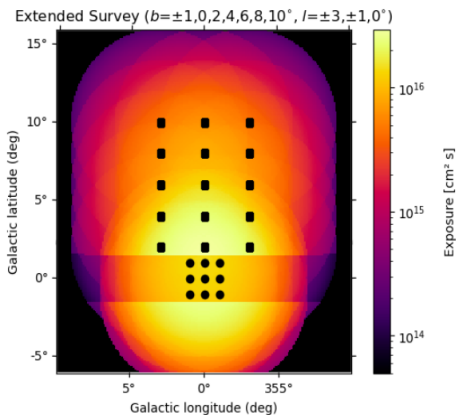


- Galactic center Survey + GP Mask



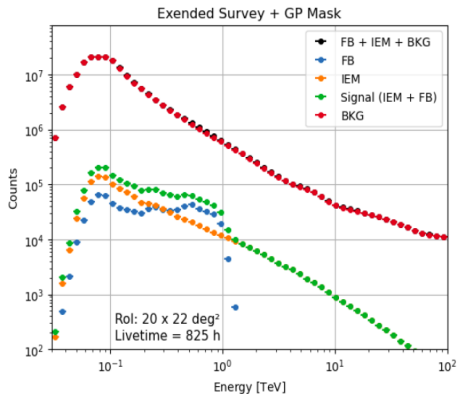
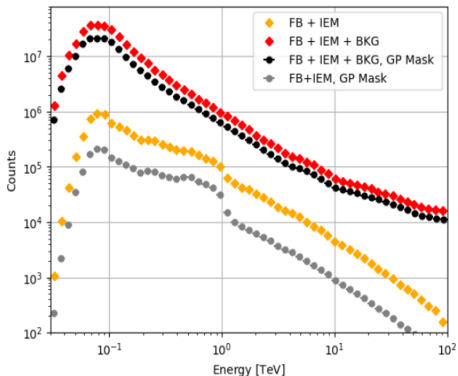
Extended Galactic Survey for Fermi Bubbles

- Extended Galactic Survey:
 1. **Galactic Centre Survey** - 9 pointings
 2. **Extended Survey** - 15 pointings
- Extended Survey [The CTA Consortium, 2018, 1709.07997]
- GP Mask: $|b| < 1.5^\circ$
- Observation time: 825 h - split between 9 points (~ 58 h each) and 15 points (30 h each)



Characterization of the Simulation

- Comparison between the Extended Survey with mask and without mask



Summary and Future Prospects

Summary:

- Fermi Bubbles are giant structures that emit gamma rays
- CTA is expected to detect the emission of Fermi Bubbles
- To create simulations and for fitting we use Gammapy

Future Work:

- Use the Extended Galactic Survey [The CTA Consortium, 2021, 2007.16129]:
 - To check high latitude properties of GC
 - To study the transition between high latitude and low latitude
- (Maybe) Use Extragalactic Survey [The CTA Consortium, 2018, 1709.07997]
- Include systematic uncertainties in the fit:
 - See [The CTA Consortium, 2021, 2007.16129]
- Explore how sensitive CTA will be to the cut-off of the FB

Thank you for your attention!