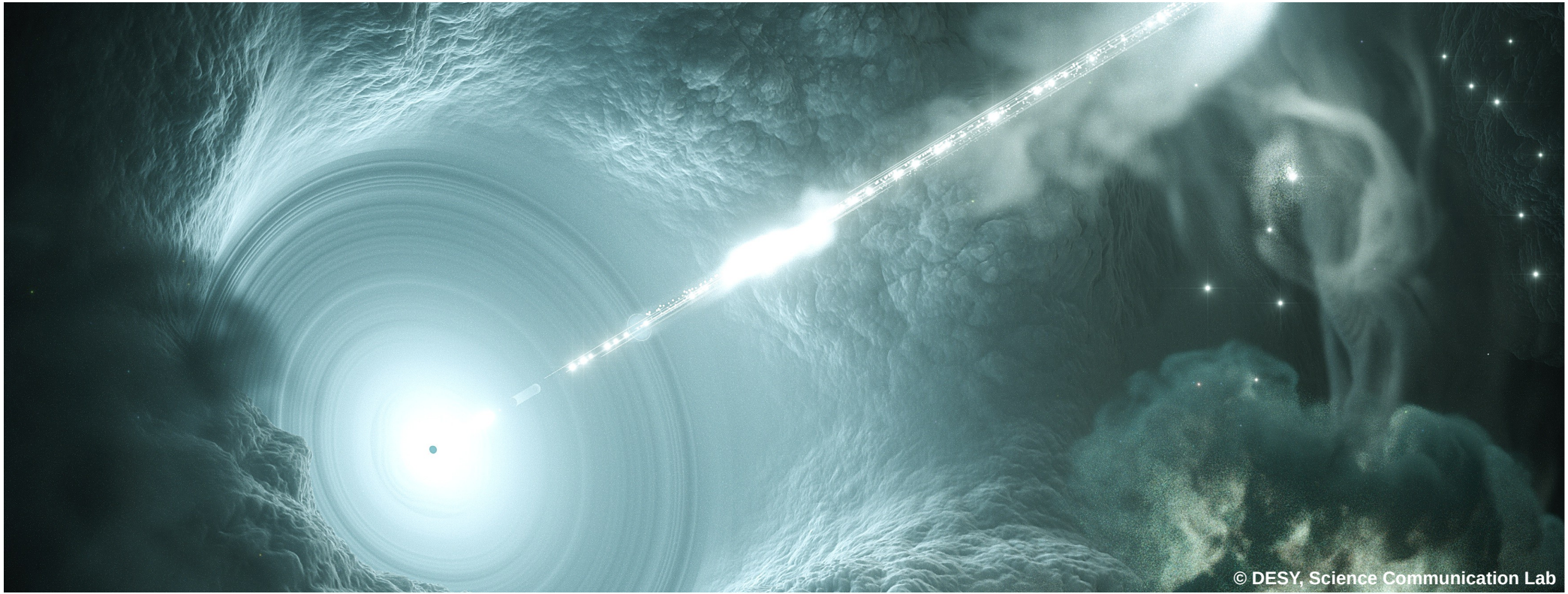
# Facilitating multi-messenger modelling using Gammapy

**Lea Heckmann, Matteo Cerruti, Bruno Khélifi, Justin Albinet**



# Active galactic nuclei (AGNs) & blazars

- Most luminous persistent sources in the Universe
- Supermassive black holes hosted at the centers of galaxies

Credit: http://www.astro.princeton.edu/~lilew/

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- Most luminous persistent sources in the Universe
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- But there are many open questions:
  - What is radiating?
  - How are particles accelerated?
  - In which environment is this taking place?

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# Current AGN modelling

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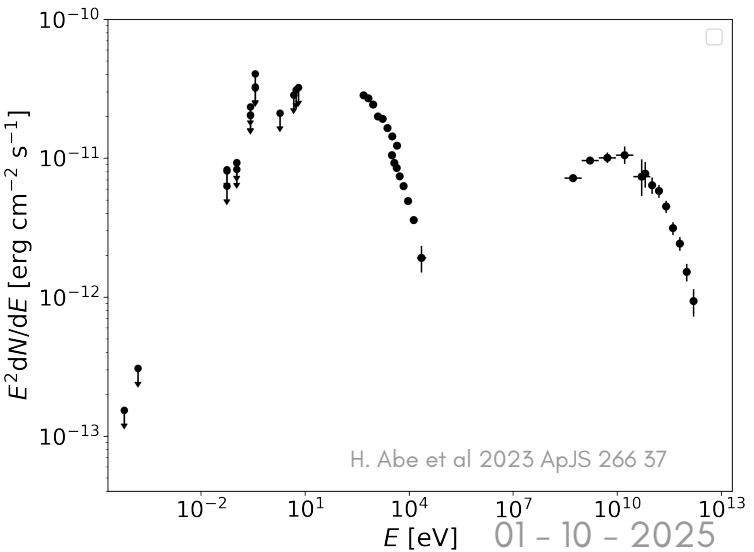
- Combining MWL data on flux point level:



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- Combining MWL data on flux point level:
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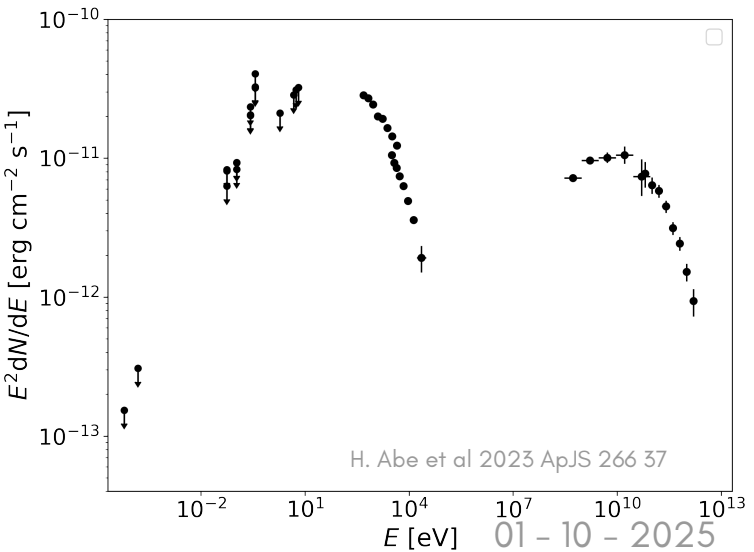
    - using different frameworks for different instruments
    - assuming simplistic models (e.g. power-law) – single instruments cannot constrain physical models (e.g. SSC)



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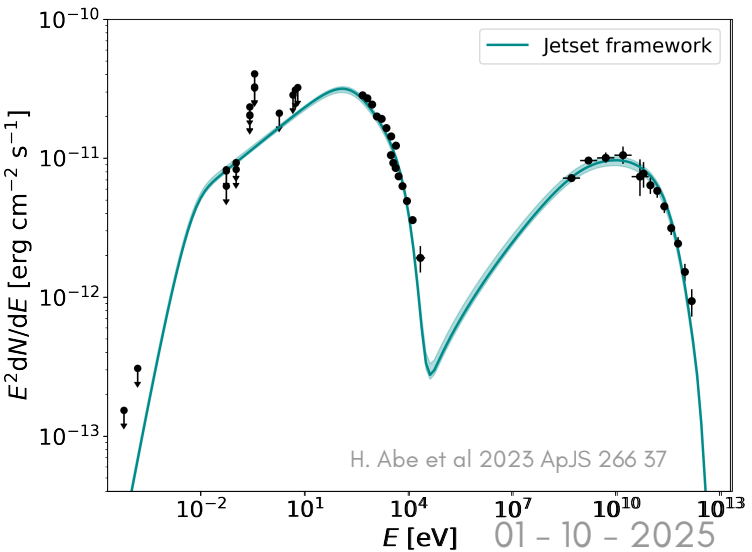

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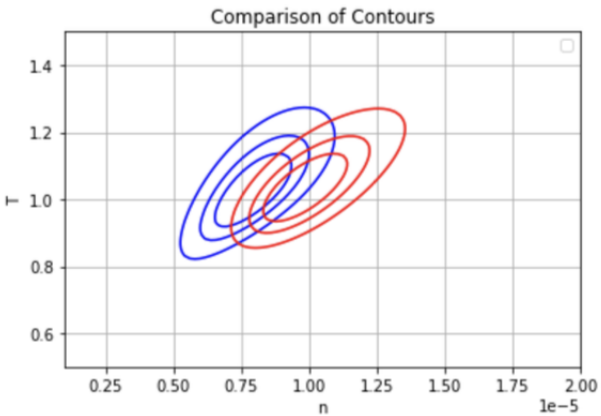

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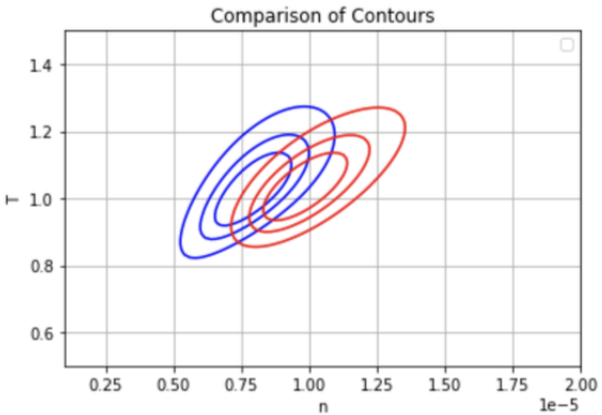


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- **Long-term goal: Enable event-based multi-messenger fits in Gammapy**
  - We start with blazars and JetSet as an example here

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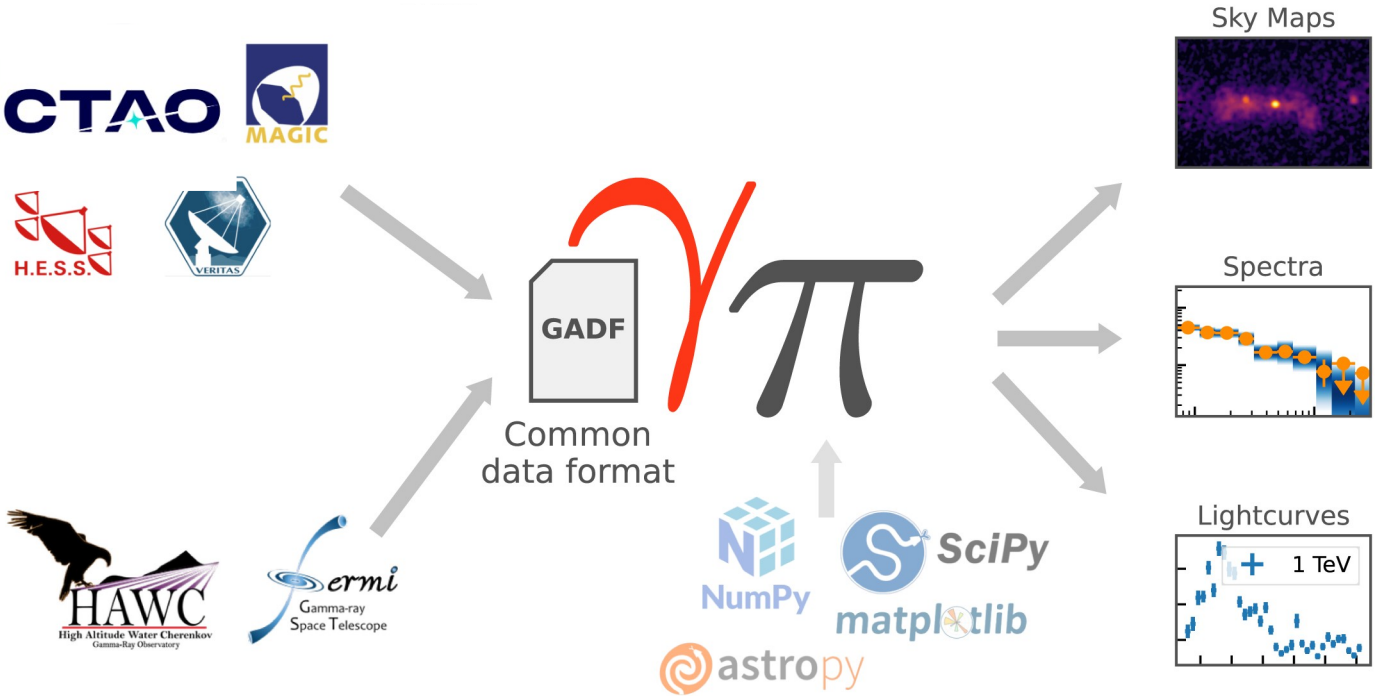
  - Python package for gamma-ray astronomy

A **Python** package for **gamma-ray** astronomy




Adapted from:
A. Donath et al. 2023, A&A, 678, A157

# Gammapy & MWL data

- Works nicely for gamma-ray data and joint instrument fits:

C. Nigro et al. 2019, A&A 625, A10

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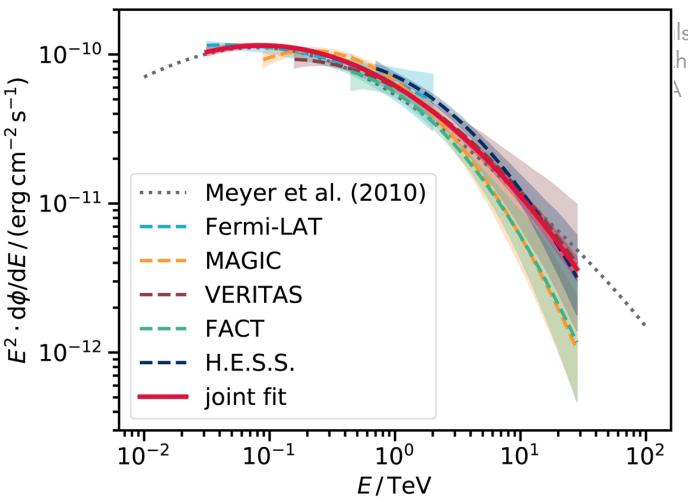

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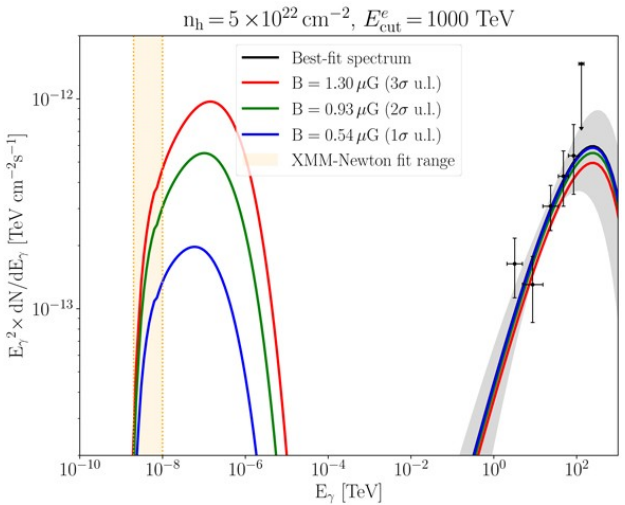


L. Giunti et al. 2022, A&A 667, A130

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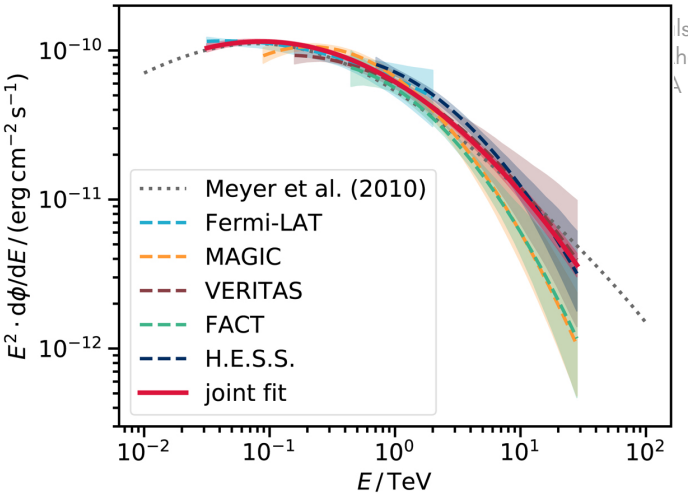


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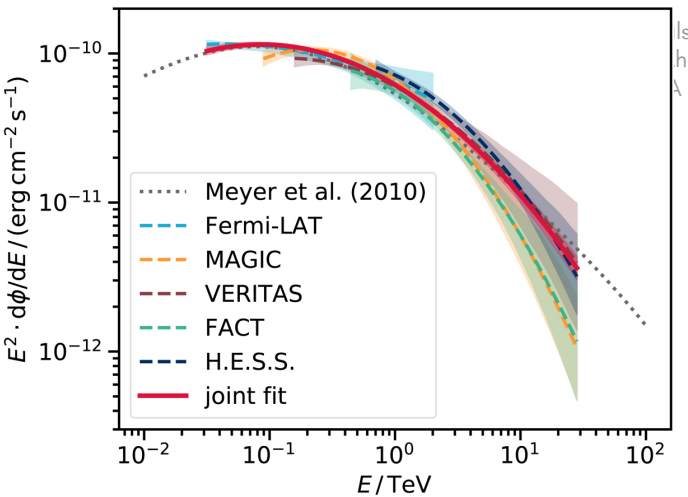


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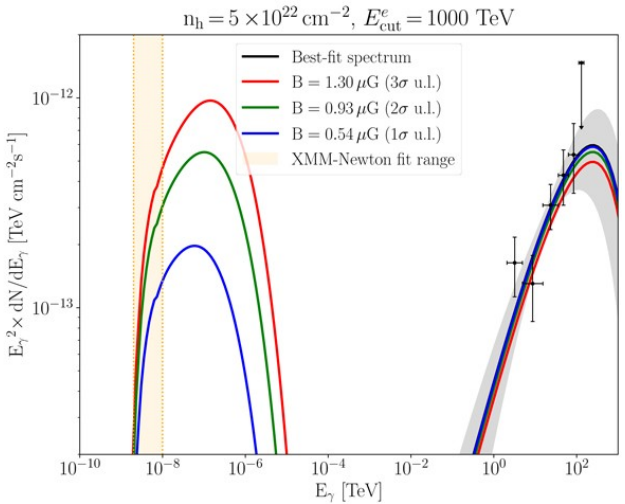


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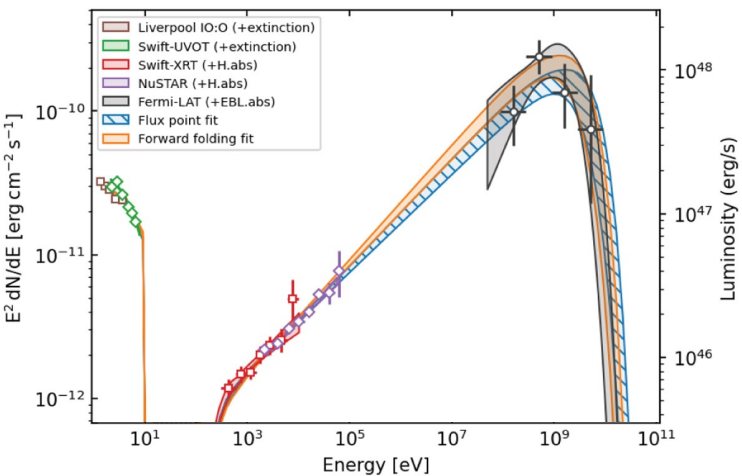
- Extension to UV/ optical:
  https://github.com/mireianievas/gammapy_mwl_workflow




M. Nievas Rosillo et al. 2025, A&A, 693, A287

# New AGN modelling approach with Gammapy

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- IRFs from UV to gamma-rays within Gammapy
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- Simulation of MWL data based on these IRFs using Gammapy:
  - Physical model:
    - Leptonic Self-Synchrotron (SSC) model with EBL absorption
      - JetSeT (2020ascl.soft09001T) with its Gammapy plugin

  + Systematics for different bands

  + Absorption processes via the sherpa (10.5281/zenodo.593753.) module for xspec models

# Gammapy & SSC

- We produce 2 MWL Gammapy datasets:
  1) Event data (DL3) set with event lists and IRFs
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     - Produced for each waveband
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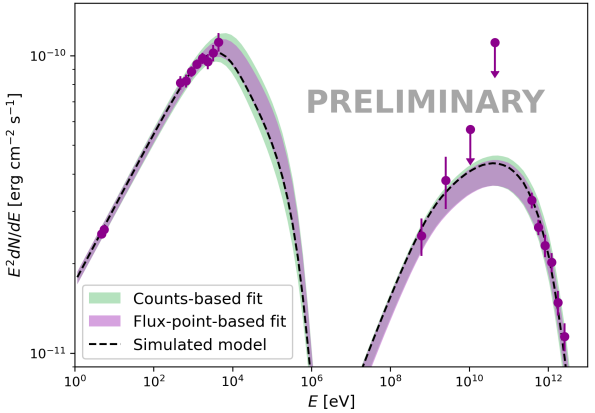
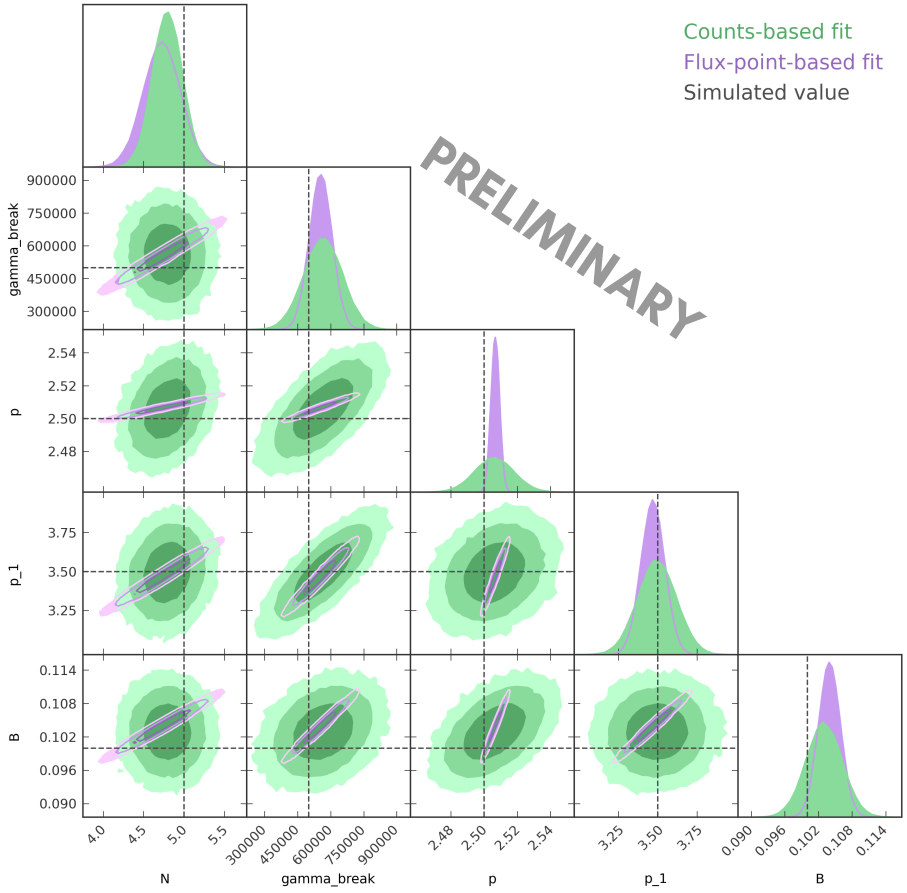
- We fit both datasets with a SSC model using JetSeT



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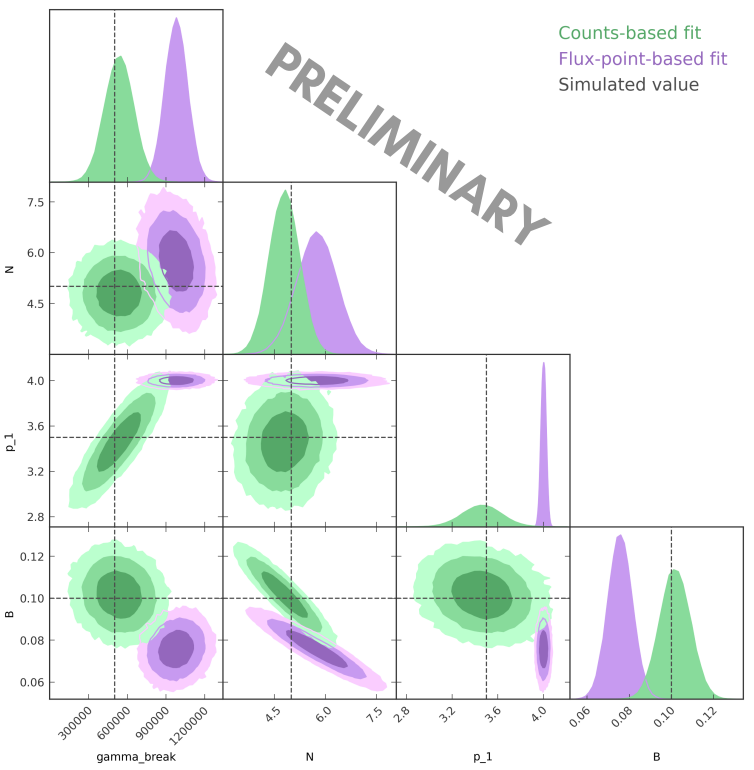


- Using grid models and interpolation
  - Grid for E and parameters
  - SciPy RegularGridInterpolator

→ Works well from a physical point, but limited by computation time and memory usage

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- For **slow models (e.g. hadronic ones) – multimessenger fitting**
  - We are currently investigating **grid models + interpolation** methods
  - **Neural networks** and other machine learning methods might be a promising alternative

**Thank you**
**for your attention!**

**Get in touch!**
**We’re open to different use-cases**