technische universität
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SFB1491

Unfolding the Crab Nebula Flux with Gammapy*

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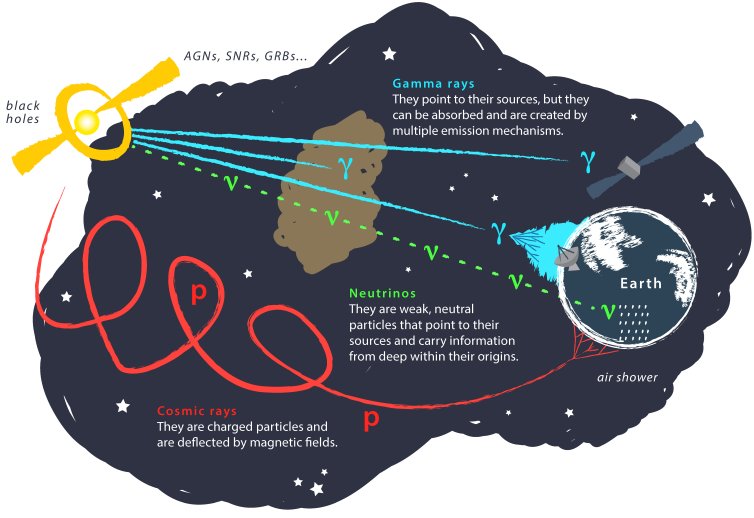
Outline

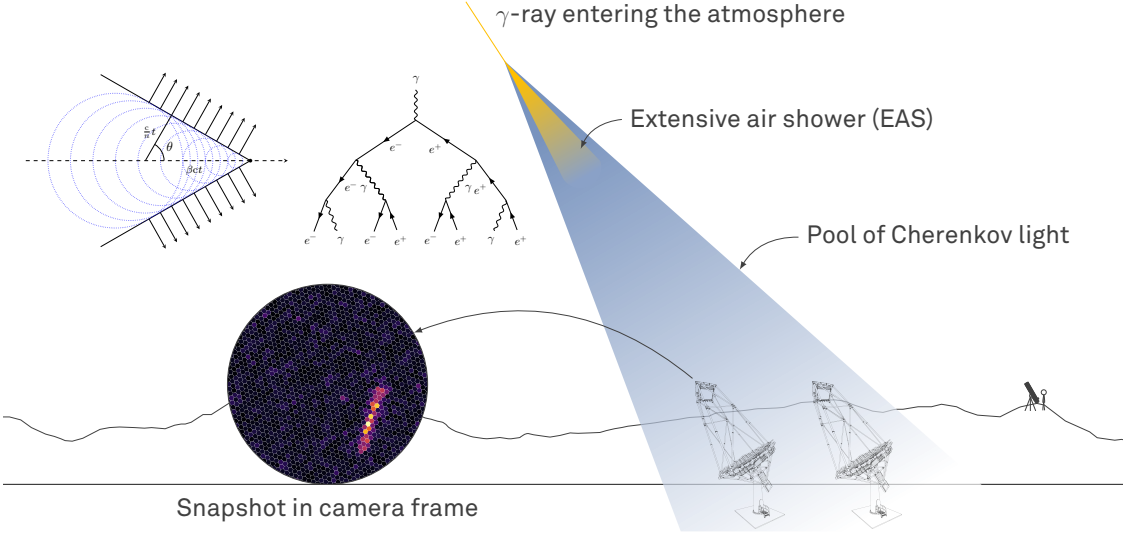
Cherenkov Astronomy

Gammapy & Joint Crab Analysis

Unfolding

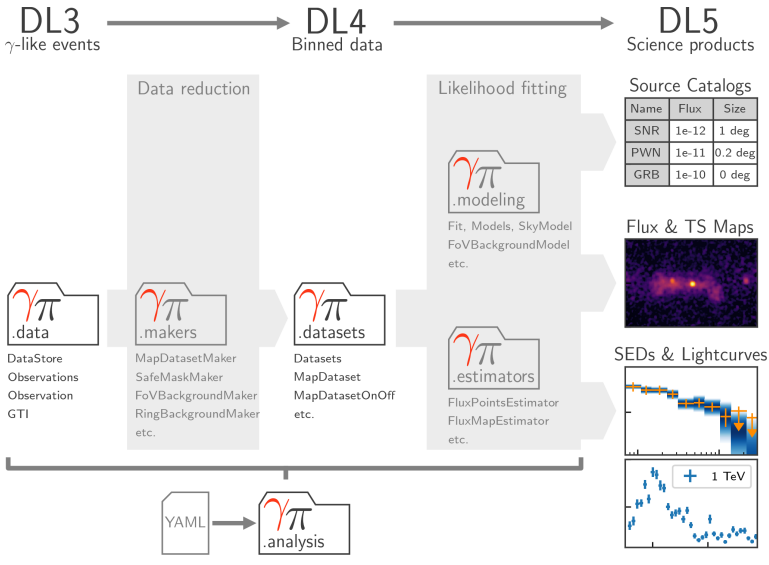
Results


AGNs, SNRs, GRBs...
black holes
Gamma rays
They point to their sources, but they can be absorbed and are created by multiple emission mechanisms.
γ
γ
γ
ν
ν
ν
ν
Earth
ν
p
Neutrinos
They are weak, neutral particles that point to their sources and carry information from deep within their origins.
air shower
Cosmic rays
They are charged particles and are deflected by magnetic fields.
p

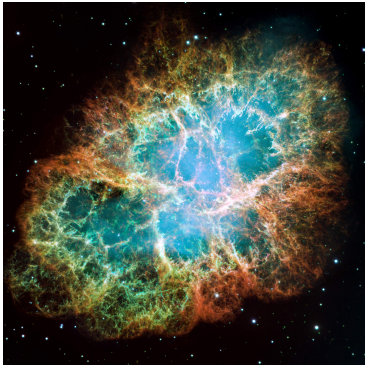

γ-ray entering the atmosphere
Extensive air shower (EAS)
Pool of Cherenkov light
Snapshot in camera frame

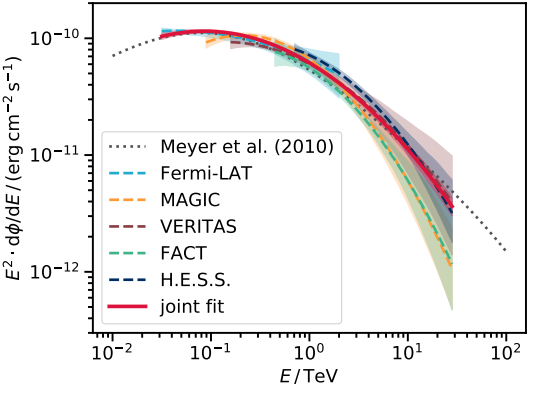
A **Python** package for **gamma-ray** astronomy

Gammapy is an open-source Python package aiming to analyze and model energy gamma-ray astronomy



https://github.com/open-gamma-ray-astro/joint-crab

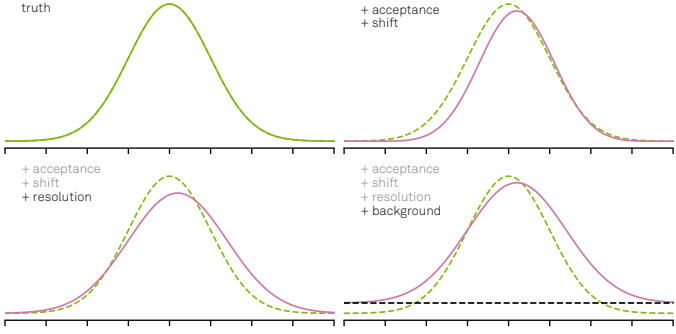




Unfolding

$$\underbrace{g(\hat{E},\hat{\alpha},\hat{\delta},\hat{t})}_{\text{Observed distribution}} = \iiint \overbrace{R(\hat{E},\hat{\alpha},\hat{\delta},\hat{t}\,|\,E,\alpha,\delta,t)}^{\text{Instrument Response}} \cdot \underbrace{f(E,\alpha,\delta,t)}_{\text{True } \gamma\text{-Signal}} \,\mathrm{d}E\,\mathrm{d}\Omega\,\mathrm{d}t + \overbrace{b(\hat{E},\hat{\alpha},\hat{\delta},\hat{t})}^{\text{Background}}$$

$$g_i = \sum_{j=1}^{n} A_{ij} f_j + b_i \quad \text{(discrete)}$$



Infer true distribution $f(\vec{x})$ from measured distribution $g(\vec{y})$: *inverse, stochastic, ill-conditioned problem*

Regularized Unfolding

$$g_i = \sum_{j=1}^{n} A_{ij} f_j + b_i$$

Model $\boldsymbol{g}$ with a Poisson-Likelihood → *Maximum Likelihood Approach for Unfolding*

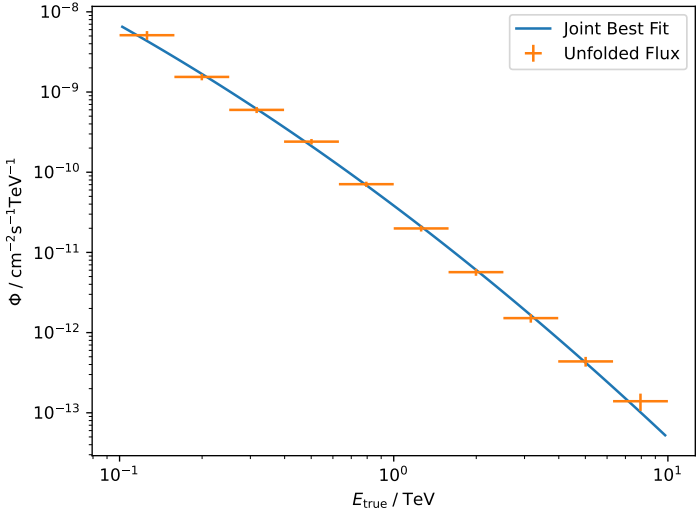
$$L = \prod_i f(x_i \mid \theta); \qquad l = -\log L = g \log\left(A\hat{f}\right) + A\hat{f}$$

Gammapy can do *this*, but regularization is needed

$$R = \frac{\tau}{2} \sum_{i=2}^{n-1} \left(f_{i-1} - 2f_i + f_{i+1}\right)^2$$

This work:[1] Define regularization as prior, attach to models

[1] PRs: **#4237**, **#4381**


Joint Best Fit
Unfolded Flux
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
Φ / cm^{-2}s^{-1}TeV^{-1}
10^{-1}
10^{0}
10^{1}
E_{true} / TeV