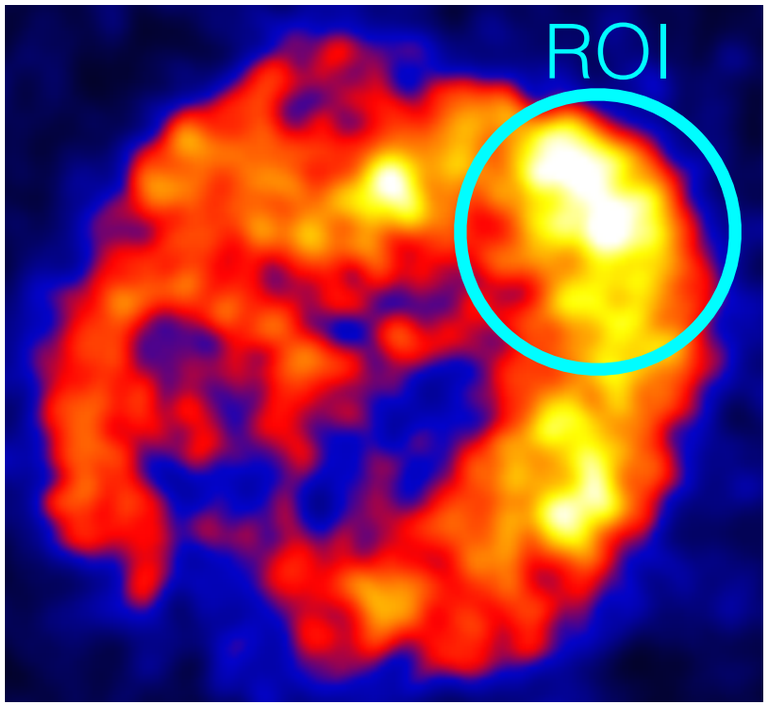
Cube-style analysis for Cherenkov telescope data

Peter Eger

PyGamma15 workshop
MPIK, Heidelberg,
November 16, 2015

Classical vs. cube-style analysis

Classical analysis



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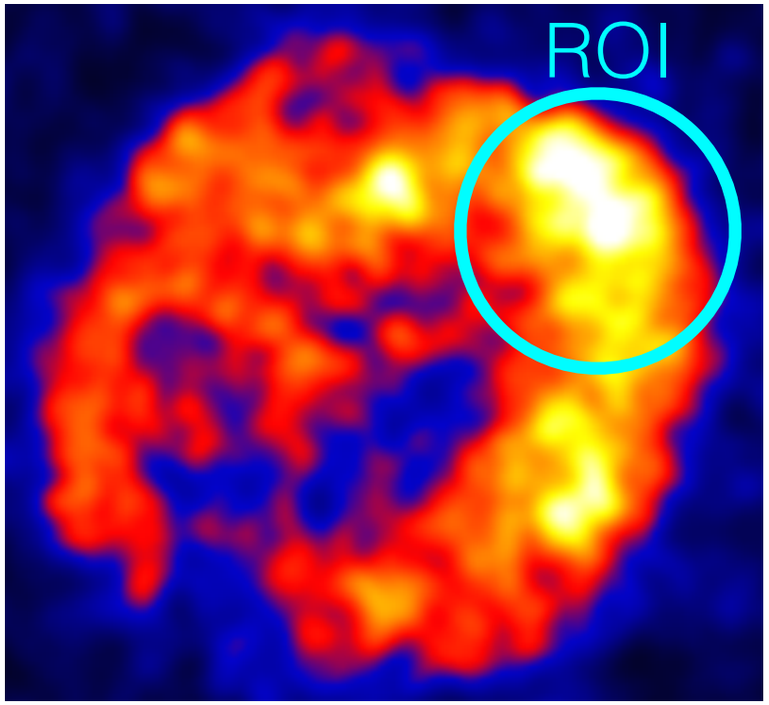
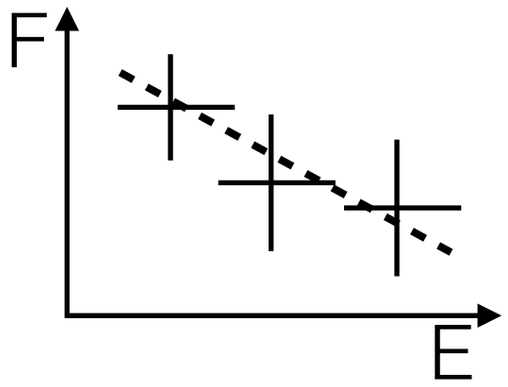


1D spectral analysis



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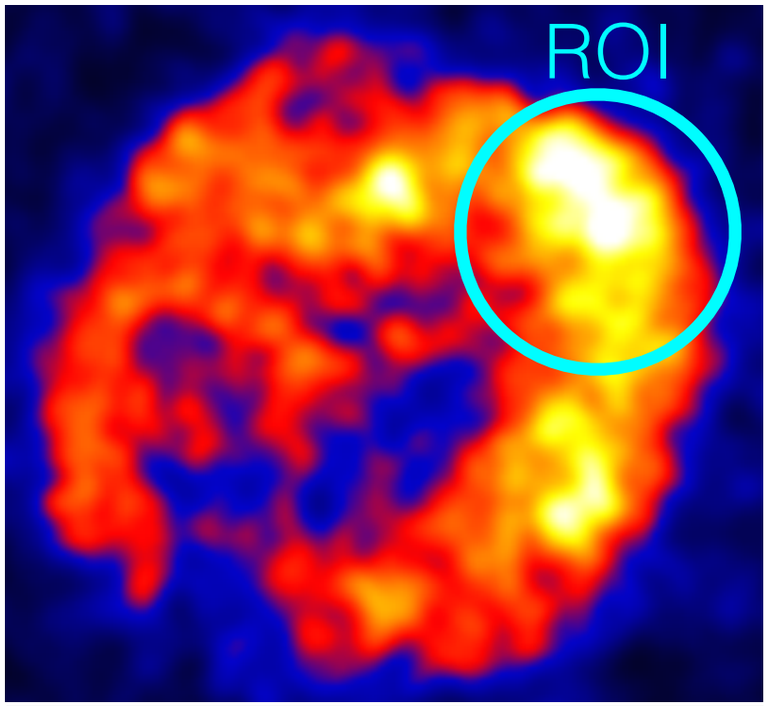

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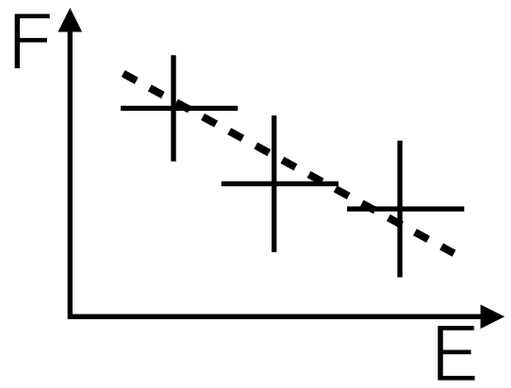

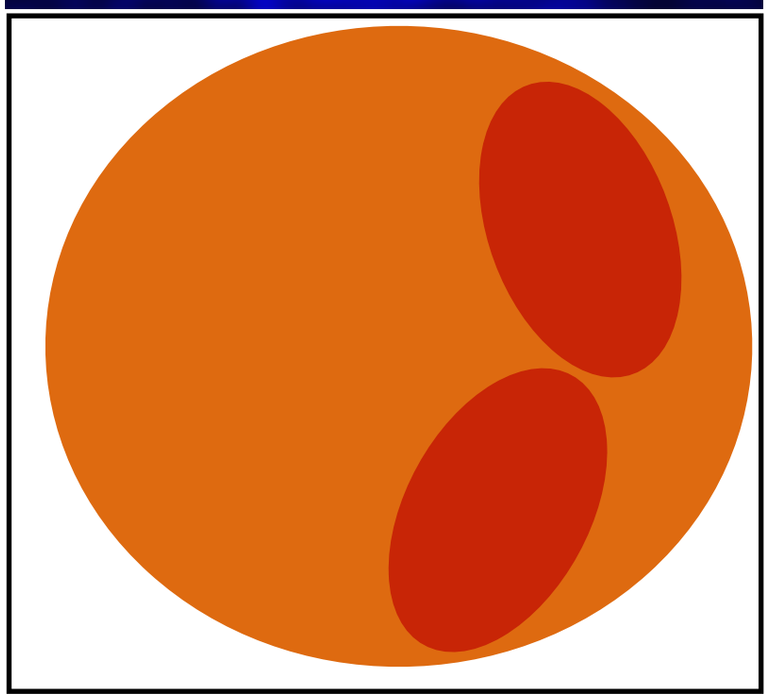

2D morphology fitting

Classical vs. cube-style analysis

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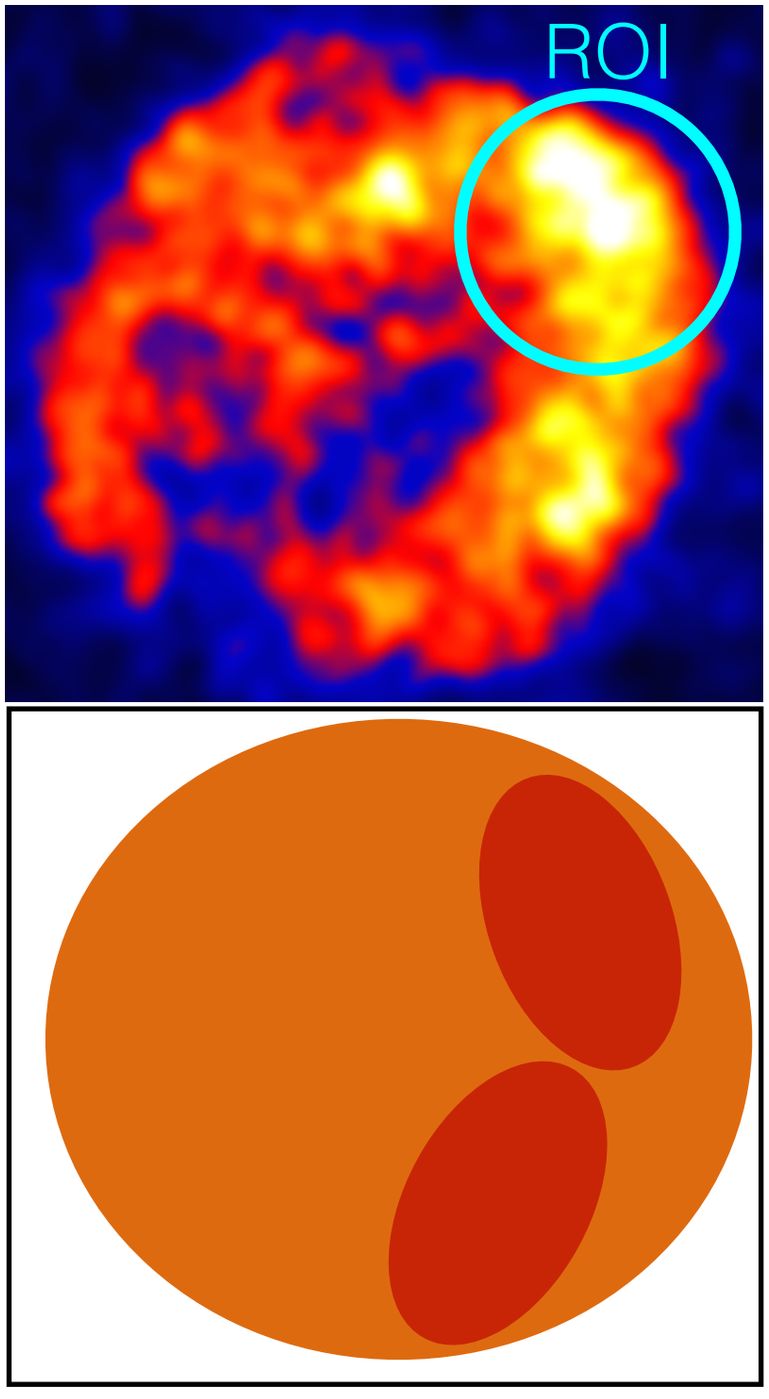

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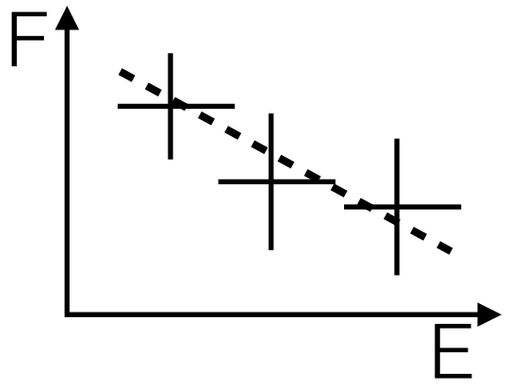
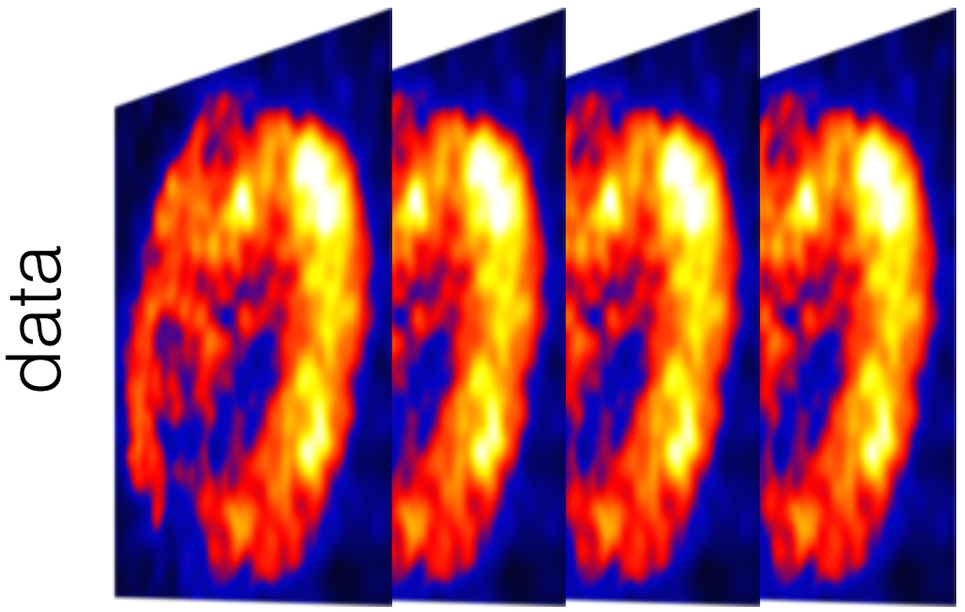


2D morphology fitting

cube-style analysis



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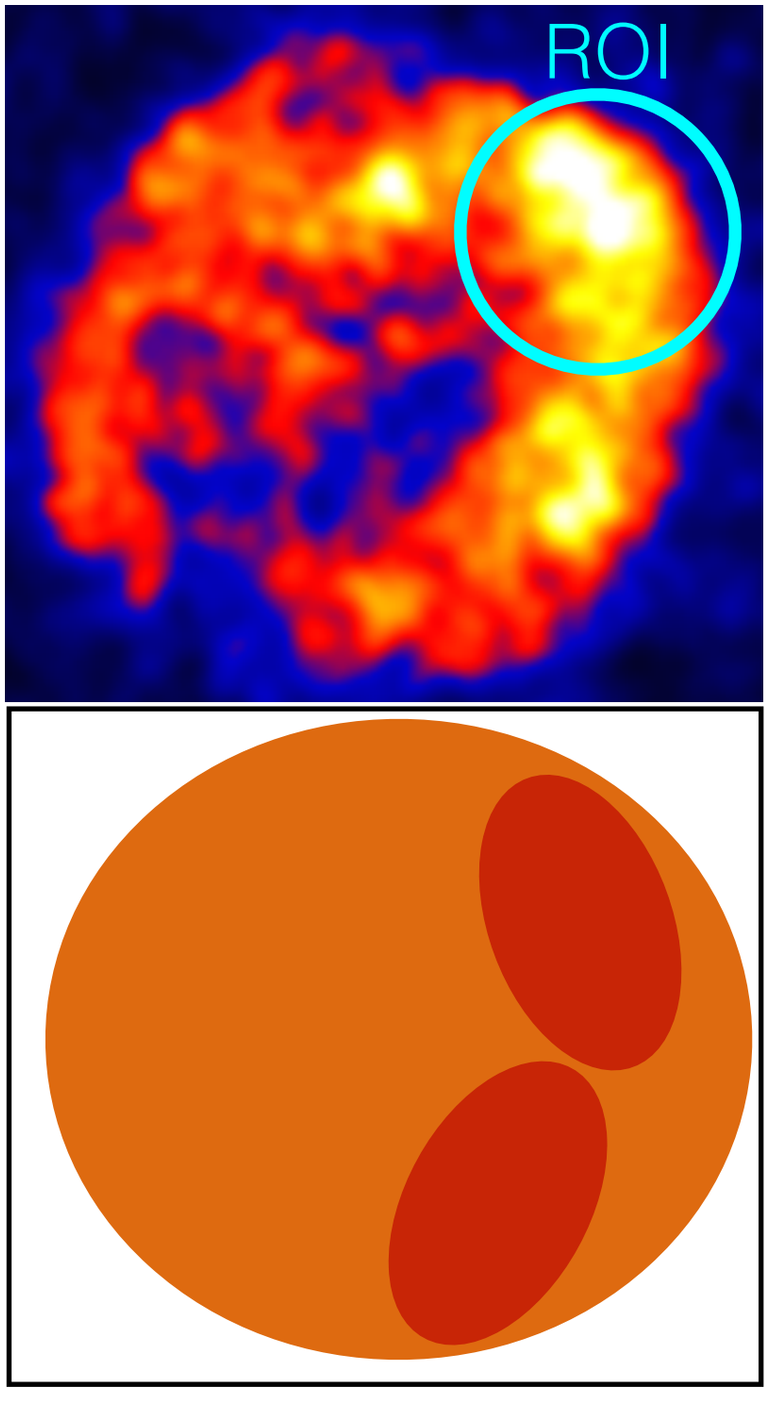
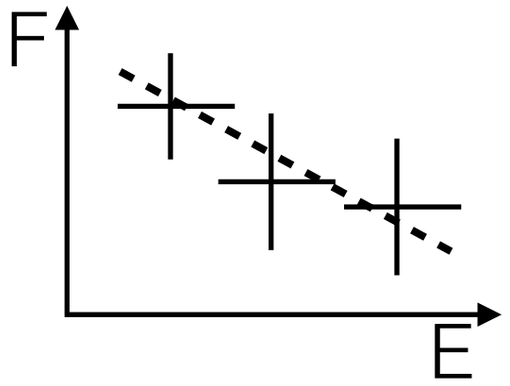


1D spectral analysis



2D morphology fitting

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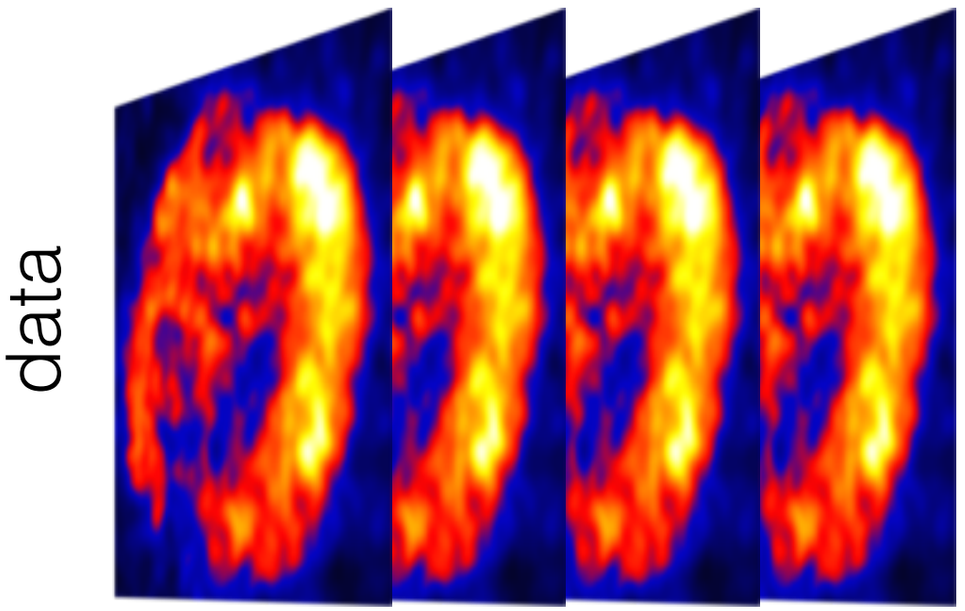
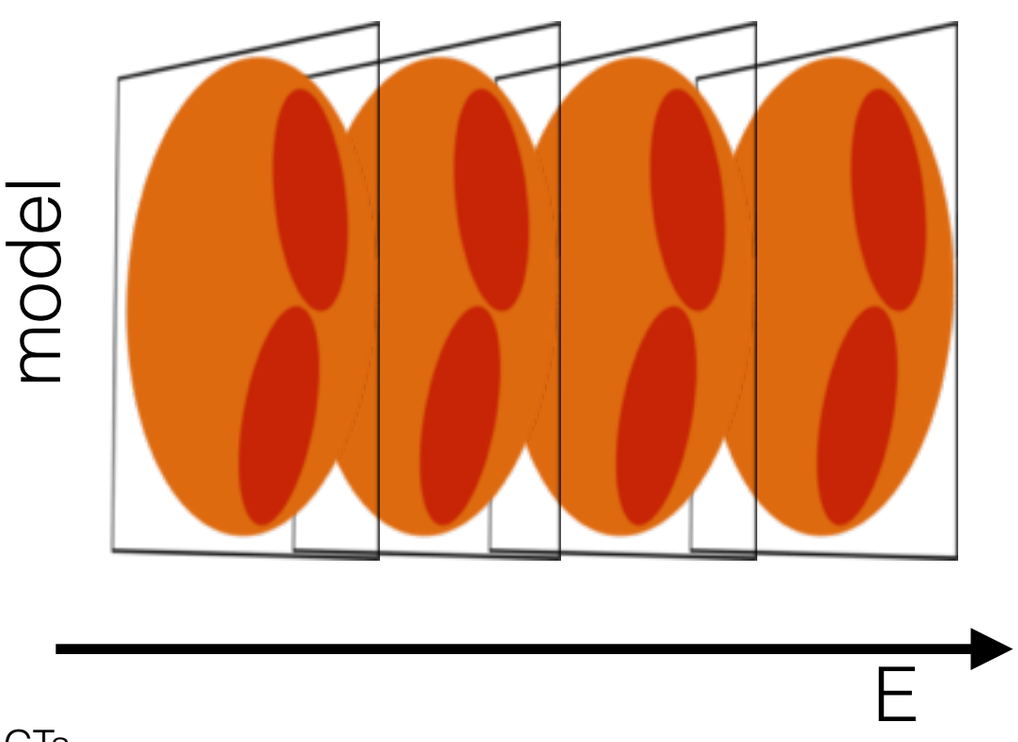
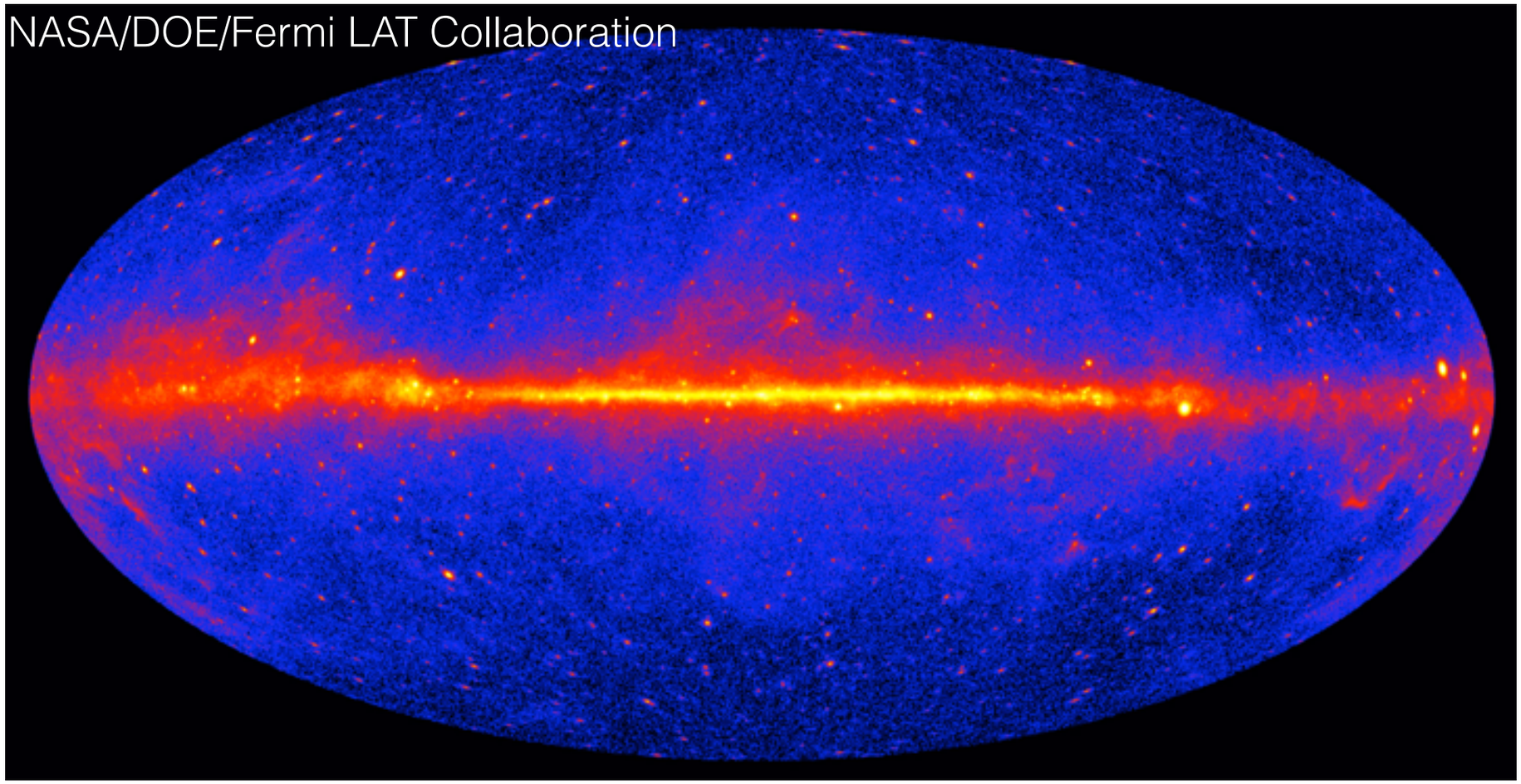




Advantages

- Morphology & spectrum modeled **at the same time**
- Full **multi-dimensional instrument response** (PSF, effective area, energy response) correctly taken into account for each energy band
- **Sensitivity gain** for point-like and extended sources
- **Separation of multiple source components** in crowded regions and/or on top of extended diffuse emission
- Analysis of **FoV-scale emission** through *background modeling* instead of *background subtraction*

Application: Fermi-LAT data



Model components:

- Isotropic diffuse flux
- Galactic diffuse (highly structured)
- Point sources
- Extended sources
- …

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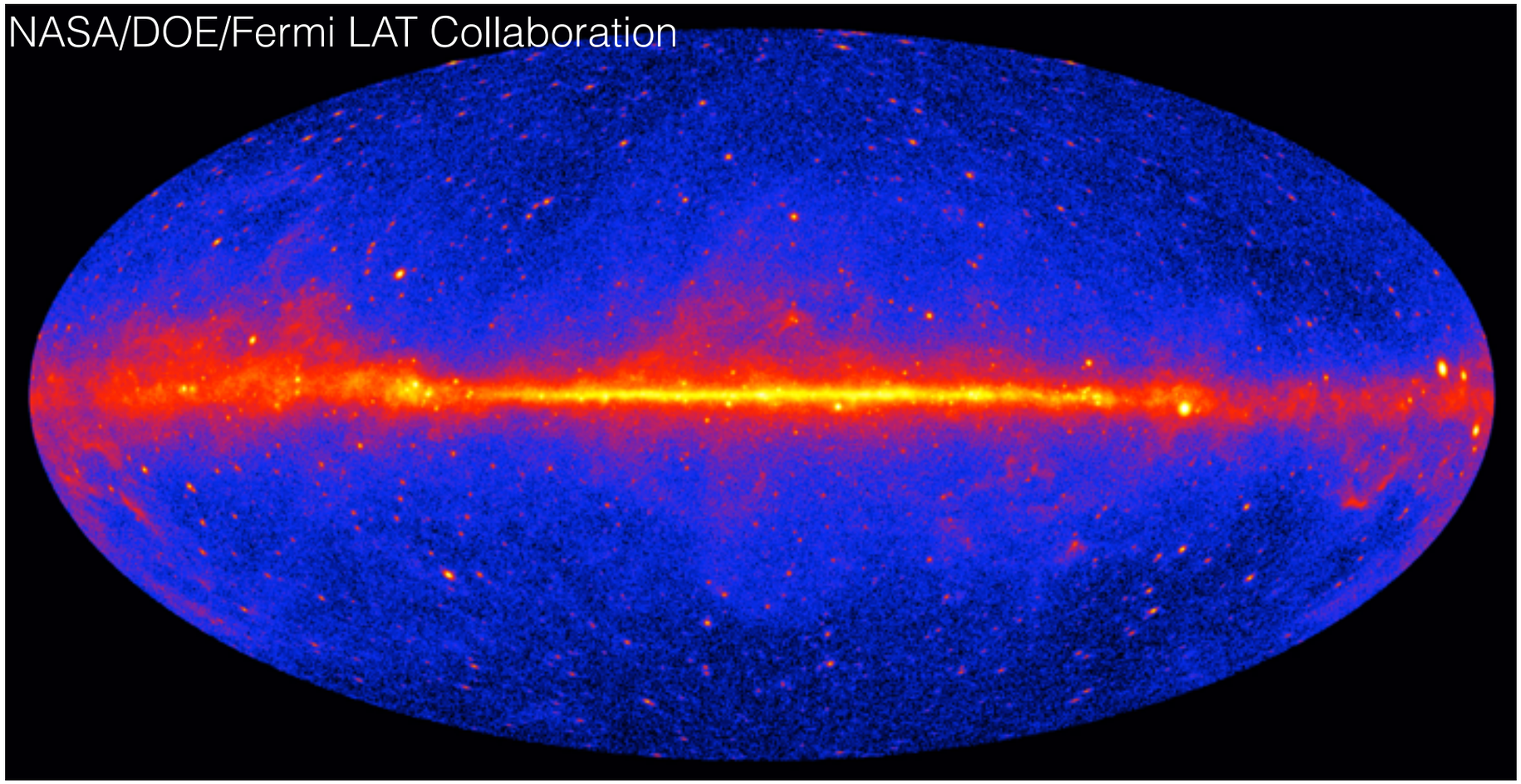

Model components:

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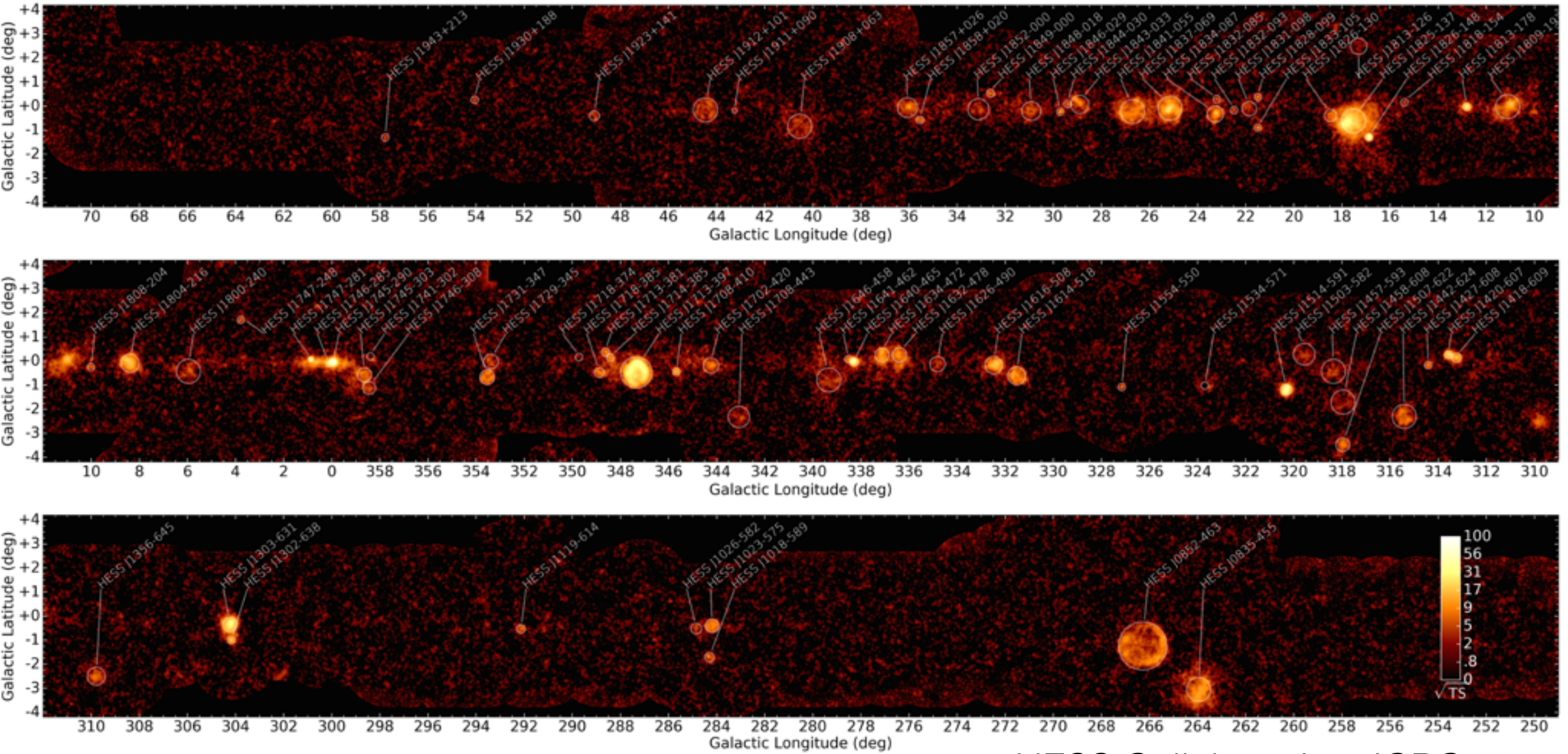
- Point sources
- Extended sources
- …

All models have different spectral characteristics

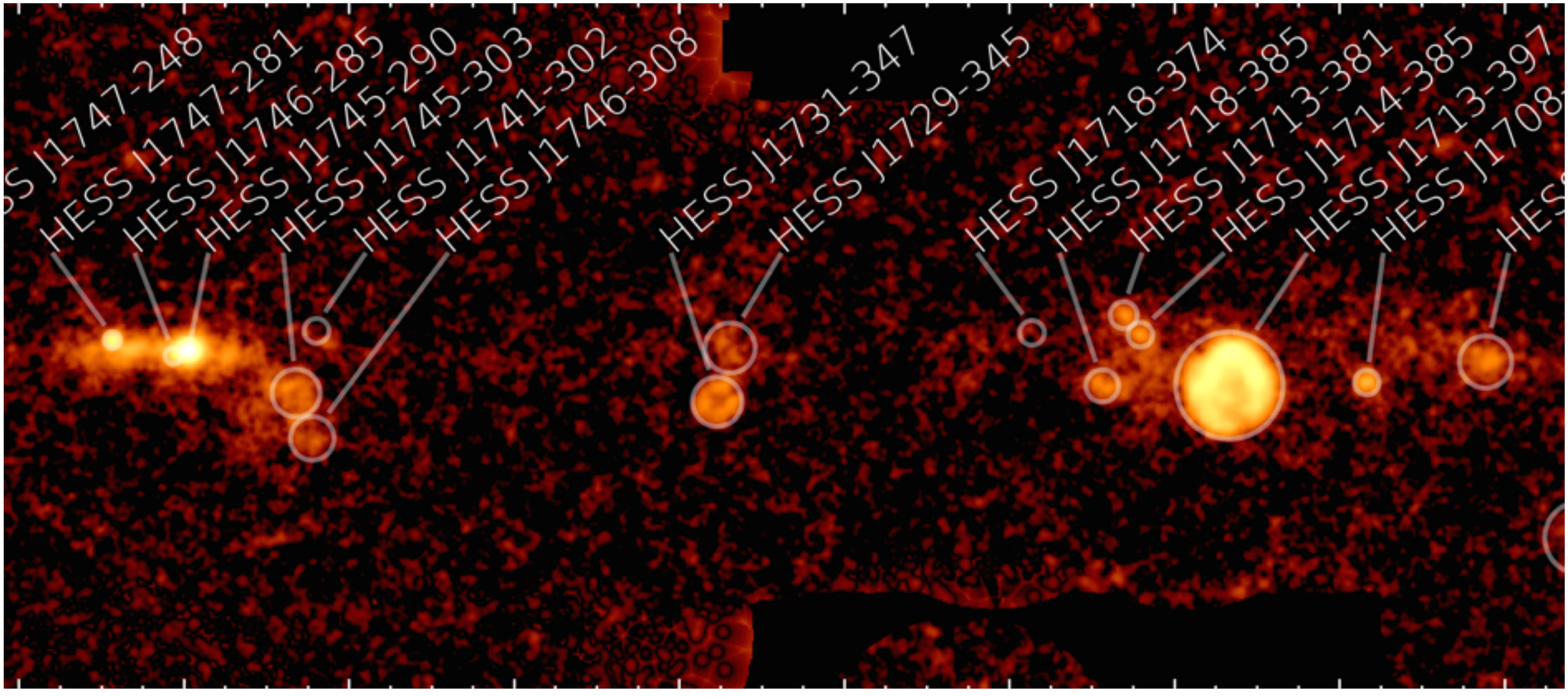
Application to H.E.S.S. data?



HESS Collaboration, ICRC 2015

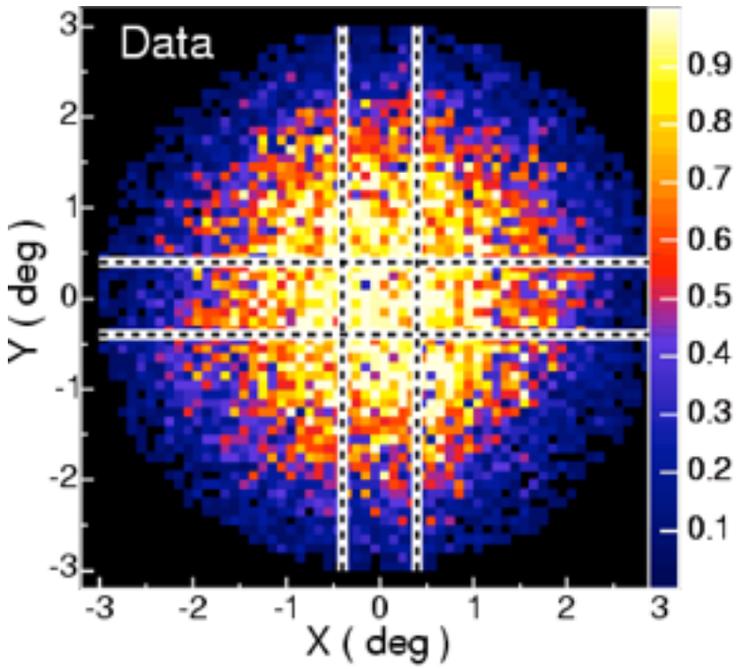
Application to H.E.S.S. data?

Zoom-in on some crowded & complicated regions in the HESS survey



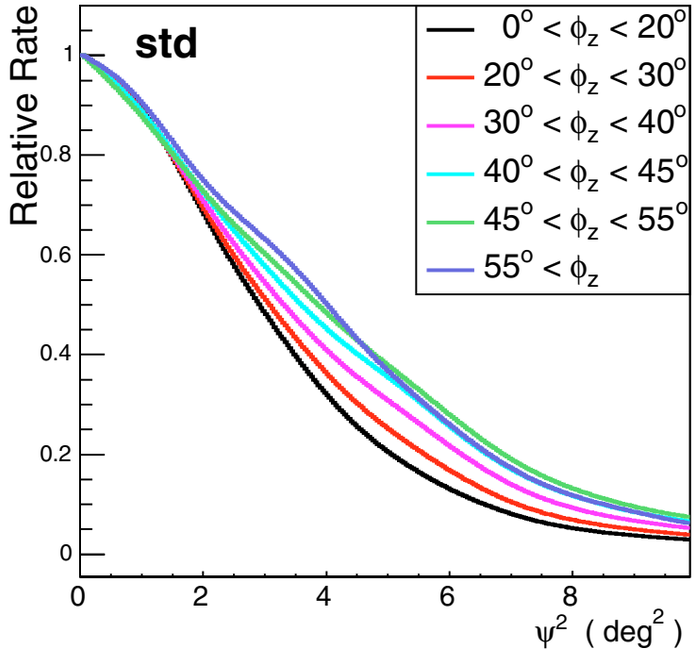
Challenges: Hadronic background

Background in the FoV



Berge et al. (2007)

zenith-angle dependence



- Morphology and intensity different for each run
- Spectral shape roughly consistent for all observations
- Modeled using a *"background library"* constructed from background-only data

Constructing cube background libraries in Cherenkov astronomy

- **Background** heavily dependent on **atmosphere**:
  zenith angle, season, dust, aerosols, clouds etc…

- **Estimated** from **data**: Coordinate transformations:
  Alt/Az (archival runs) —> Ra/Dec (new observation position)

- **Grouping** of archival runs into bins of **similar observation conditions**

- **Limited statistics** in background data (e.g. at high energies)
  —> Smoothing, oversampling, fitting,… of background data

- **Absolute normalisation** ob background needs to be **fit to data**
  For CTA: simultaneous Lidar measurements may fix BG norm

Challenges: eventlists & Instrument response functions (IRFs)

Input needed for cube-style analysis

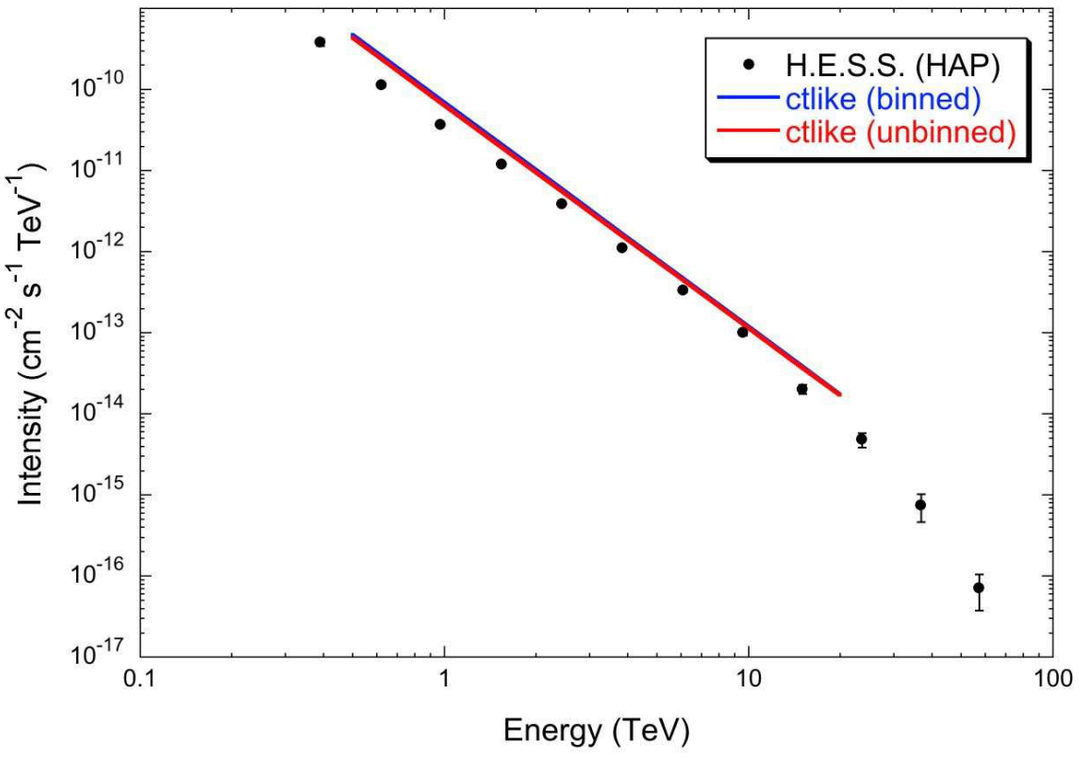
- Calibrated eventlists [reconstructed energy, direction, (class), (…)]
- Effective area vs. [energy, zenith, offset, (…)]
- True energy vs. [reconstructed energy, zenith, offset, (…)]
- Point-spread-function vs. [energy, zenith, offset, (…)]

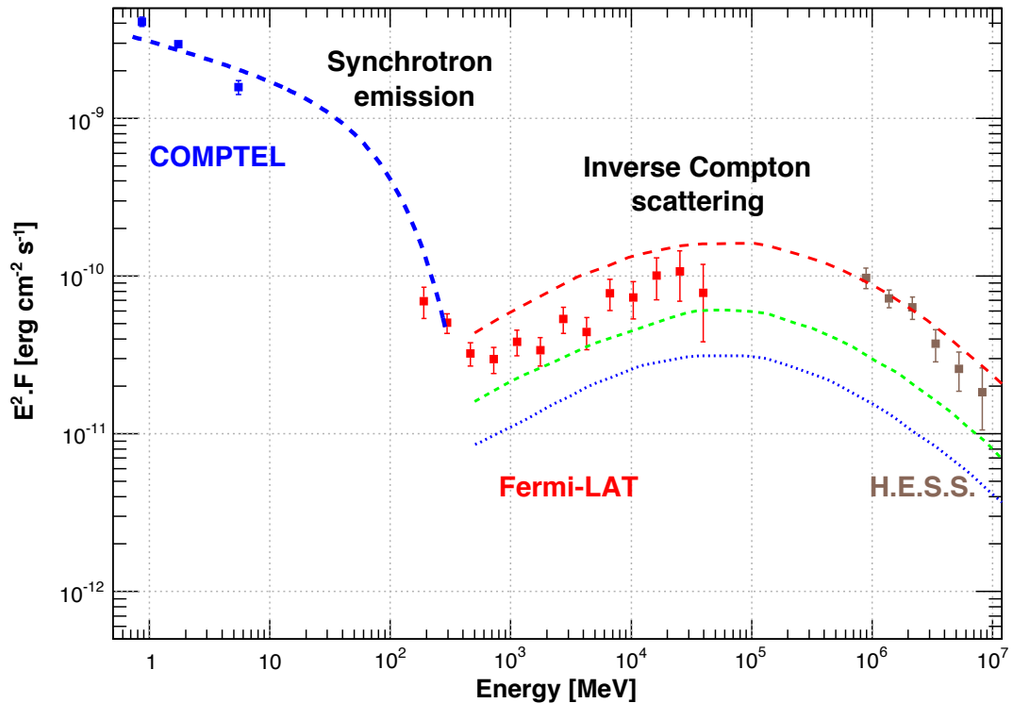
—> Accessible via standard analysis frameworks
—> Conversion into new data format needed by new analysis tools

Analysis pipelines: gammalib/CTOOLS

http://cta.irap.omp.eu/ctools/

First results & comparison to previously published results



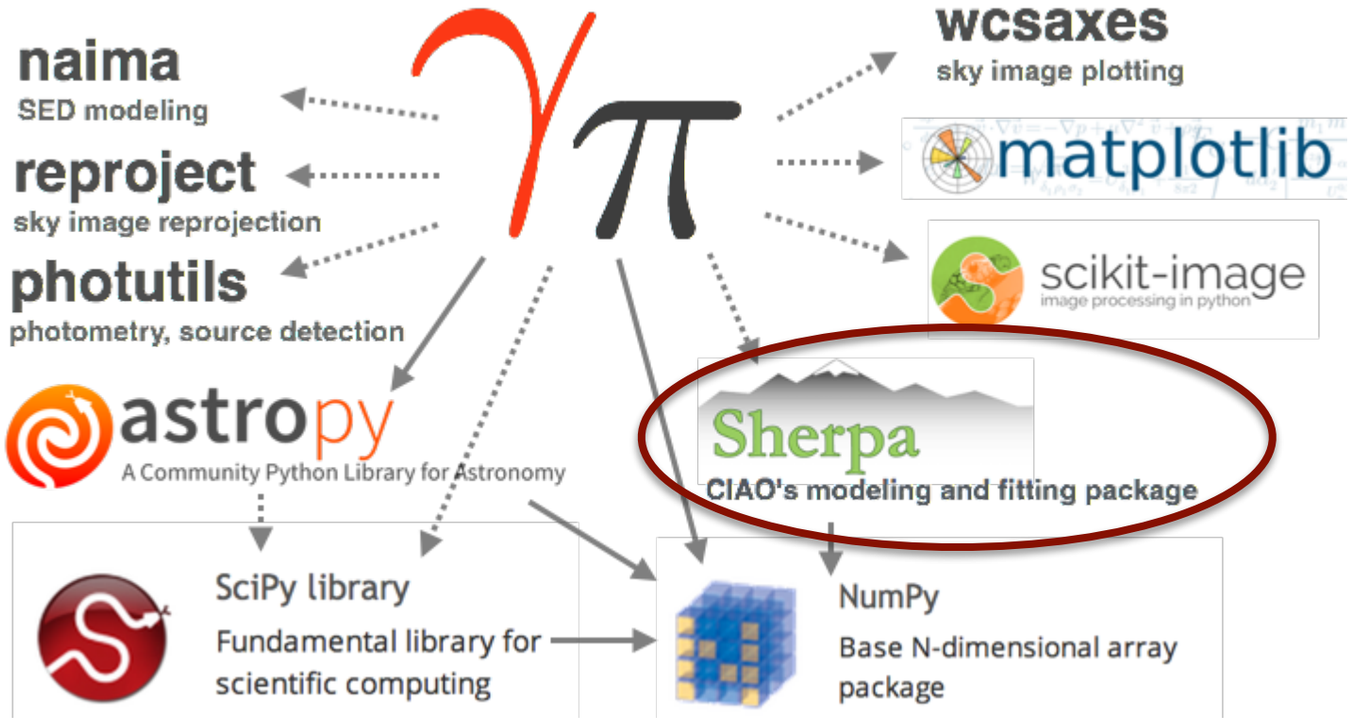


Knödlseder et al. (CTA Consortium), ICRC, 2013

- Analysis framework developed for CTA
- C++, minimal external library dependencies
- Binned & unbinned analysis
- scriptable with python

Analysis pipelines: gammapy

https://github.com/gammapy



see Axel's talk

- classical analysis implemented using Sherpa
- cube-style analysis not yet fully implemented
- plan to use Sherpa as the likelihood fitting tool

Summary & next steps

- cube-style analysis provides interesting new possibilities for TeV astronomy

- a few open-source projects started implementation of the analysis scheme

- Open source software —> accessible data formats and software, easy to combine data from several experiments for joint analysis

- Need to finalize, test & verify current software
—> work towards first science publication