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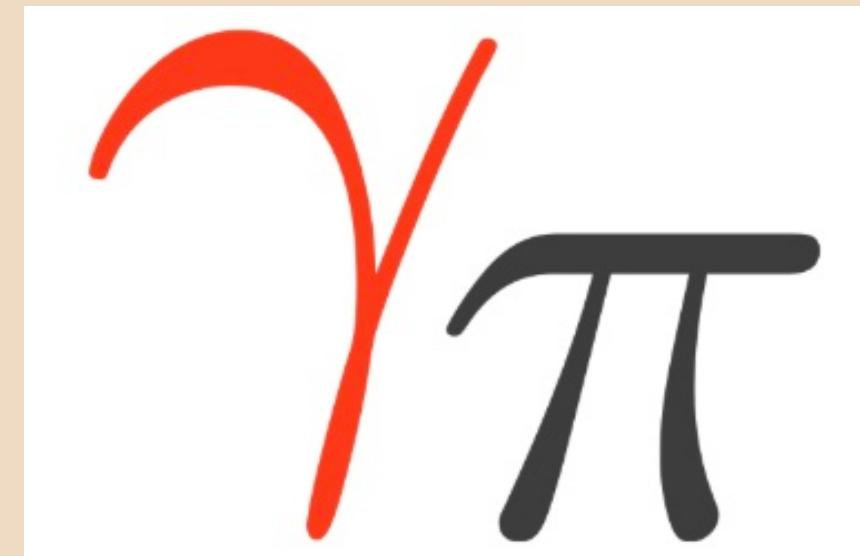
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Gammipy

A Python package for
gamma-ray astronomy



2nd VHEGAM meeting, Bari
May 26-28, 2025

Fabio Pintore (INAF/IASF Palermo), on behalf of the Gammipy team
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Gammappy

Gammappy was born with the idea to develop an open-source software for the very high energy (VHE) data analysis;

This was intended to overpass the proprietary software philosophy and provide an observatory-independent data-analysis tool;

Since 2013 (with a 1st release - v0.1 - on Aug. 2014), a team is working on an independent open library to analyse VHE data formattted following a community-accepted format ([GADF](#));

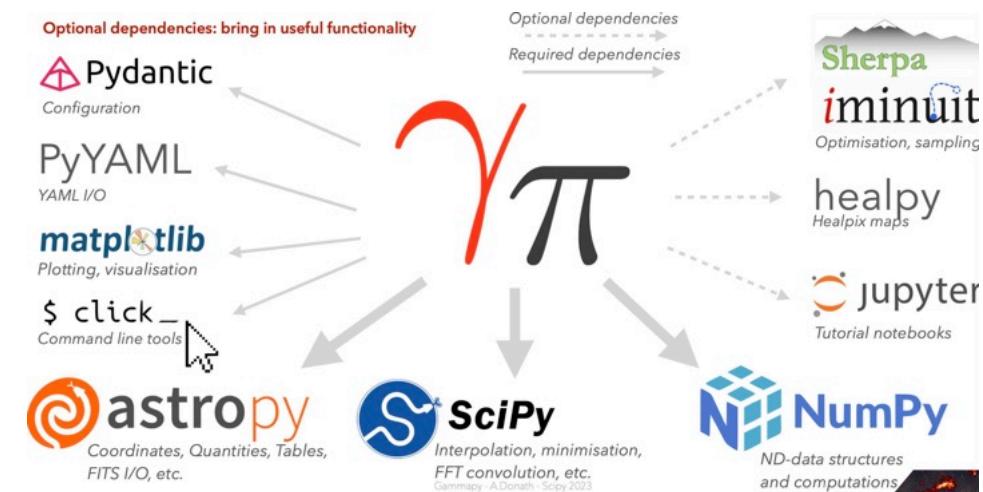
Gammapy

On 2021, Gammapy was selected as the official data-analysis tool of CTAO

However, it is currently adopted by a wider community and several facilities
(HESS, MAGIC, HAWC, ASTRI...)

Gammapy is a Python based package, which lives
in a Python ecosystem comprising *Numpy*,
Astropy, *Scipy*...

<https://gammapy.org/>



Gammappy organization

The gammappy organization is well structured (<https://gammappy.org/team.html>):



Gammapy organization

The gammapy organization is well structured (<https://gammapy.org/team.html>):





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Gammapy helpdesk

Gammapy offers several media to contact developers, ask questions, pose doubts or request new features!

- Gammapy *help* channel, on [slack](#)

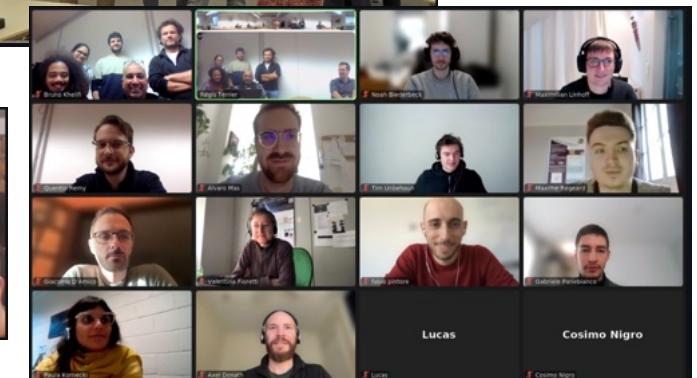
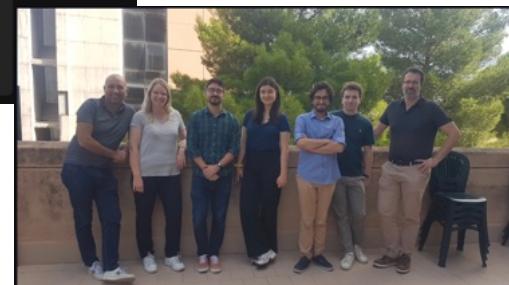


- A dedicated git repository:
<https://github.com/gammapy/gammapy/discussions/categories/help>

- The developer calls, every Friday at 2pm

Coding sprints

Coding sprints are meetings which aim at working together for a full week on the development of Gammipy. They are usually organised about one or twice per years



La Laguna- 2025
Heidelberg -2024
Palermo - 2023
Madrid - 2023
Paris - 2022



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Gammapy version release

The first Long Stable release (v1.0) was made public on November 2022;

Intermediate, stable versions are released about every six months;

The current Gammapy version is v1.3, released on November 26th, 2024;

A development version is always available!



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Gammapy installation

Installation can be done through *Anaconda/Miniconda*, *Mamba*, *pip*, *sudo apt-get*;

<https://docs.gammapy.org/1.3/getting-started/index.html>

A repository of data is also available: it can be used for tests, data-analysis and Gammapy developments



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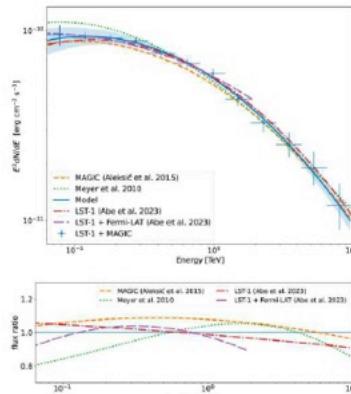


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$\gamma\pi$ A Python package for
gamma-ray astronomy

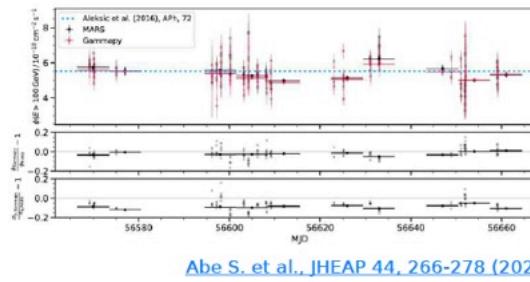
Gammapy validation

LST-1 and MAGIC with the Crab Nebula



Abe H. et al., A&A 680 A66 (2023)

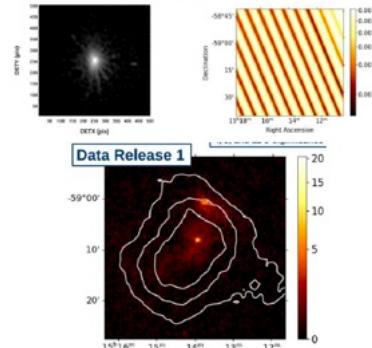
Gammapy vs MARS (MAGIC) on the Crab



Abe S. et al., JHEAP 44, 266-278 (2024)

H.E.S.S. and eROSITA on MSH15-52

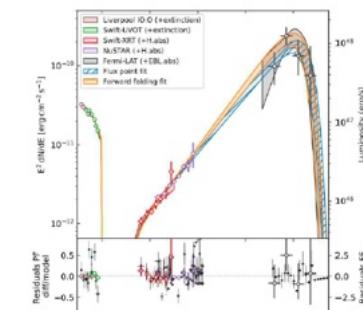
K. Egg et A. Mitchell (Gamma 2024)



Data Release 1

OP 313 detected by LST-1: Joint forward fitting fit (eV → 10¹⁰ eV)

M. Nieves Rosillo et al. (arXiv:2409.20487)



Missione 4 Istruzione e Ricerca
Componente 2 Dalla ricerca all'impresa
Linea di investimento 3.1



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Multi-instrument analysis

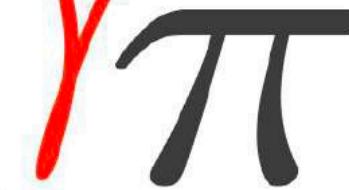
Gammipy is designed to handle data from different observatories

Pointing γ -ray Observatories



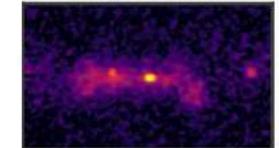
All-sky γ -ray Observatories

GADF
Common data format

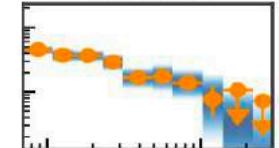


$\gamma\pi$ A Python package for
gamma-ray astronomy

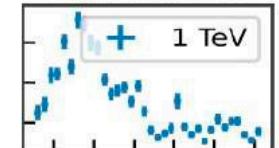
Sky maps



Spectra



Lightcurves





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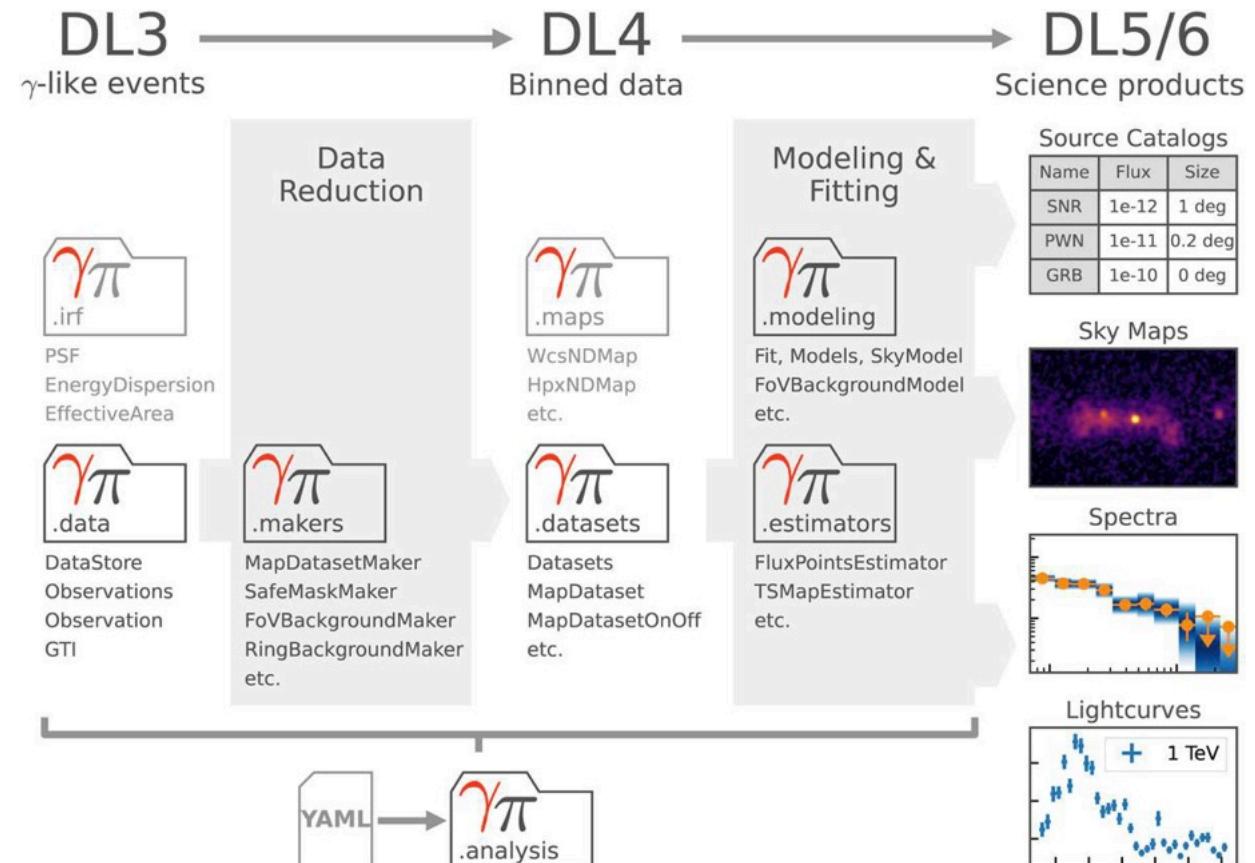


Gammapy workflow

The main Gammapy workflow aims at a data-reduction from a data level (DL)3 to a binned DL4.

The latter are then analysed to extract science products (DL5).

A number of classes and different data-reduction/analysis approaches are available.





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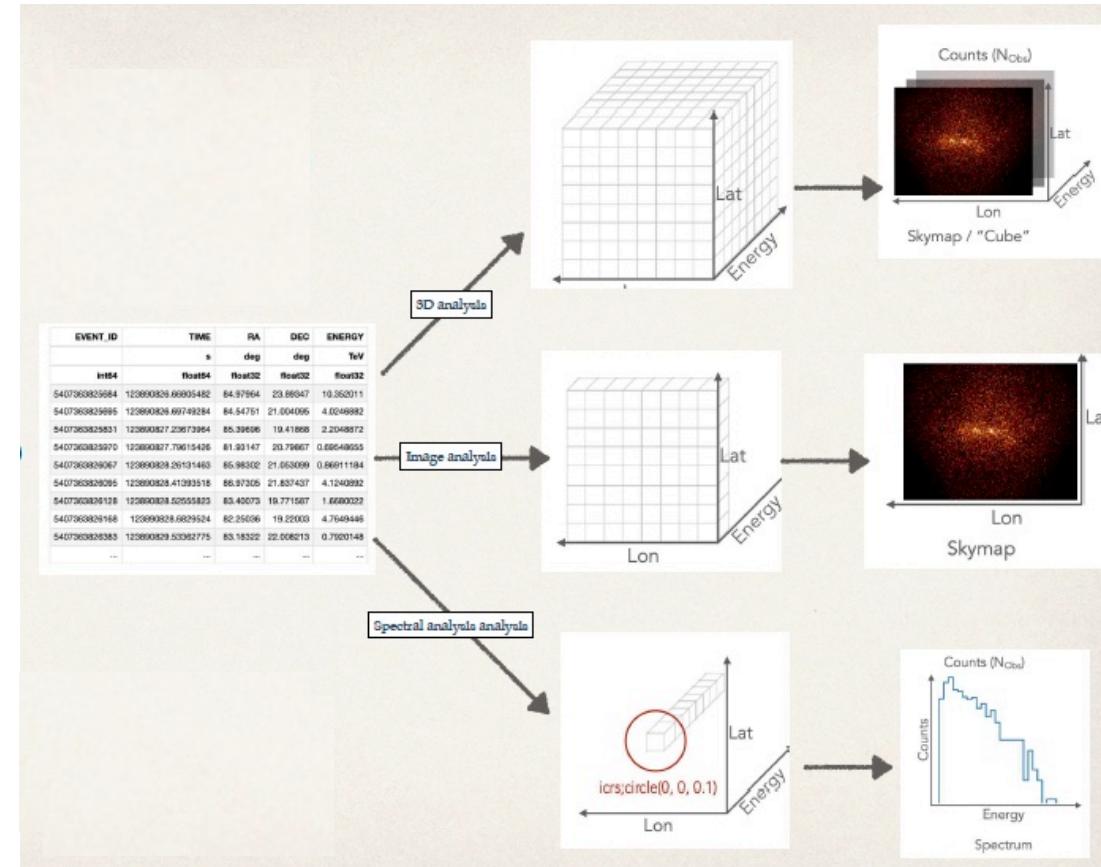
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Gammapy workflow

Gammapy adopts a binned approach (energetic and spatial axes) for both data and IRFs;

Events can be selected from coordinates, energies and time;





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Functionalities

Gammapy offers a wide range of different tools and kinds of data-analysis. Just a few examples:

- Data-handling from different facilities and multiple observations
- IRF access and manipulation
- Multi-instrument joint analysis
- Imaging (sky, counts, flux, exposure, excess... maps)
- Spectral analysis (1D/3D) of point-like and extended sources
- Source detection
- Temporal analysis
- Model fitting
- Background estimation (reflected regions, ring, FoV background)
- High-level interface
- Catalogues



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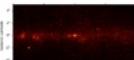
$\gamma\pi$ A Python package for
gamma-ray astronomy

A number of tutorials is available!

Introduction

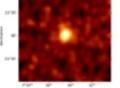
The following three tutorials show how to perform data exploration with Gammapy, providing an overview from data selection to data re-

The first tutorial is an overview of the configuration-driven approach showing what is happening in the code and the resulting data structures like event lists, source catalogs, sky maps, spectral models and flux points tables.



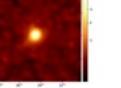
Data structures

H.E.S.S.
with
Gammapy



High level interface

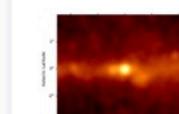
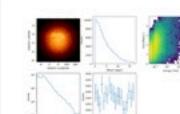
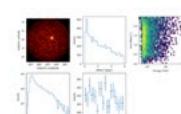
CTAO with
Gammapy



Low level API

Data exploration

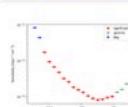
These tutorials show how to perform data exploration with Gammapy, providing an overview from data selection to data re-



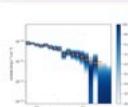
Data analysis

The following set of tutorials are devoted to data analysis, and grouped according to the specific covered use cases in spectral analysis and flux fitting, image and cube analysis modelling and fitting, as well as time-dependent analysis with light-curves.

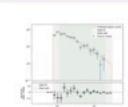
1D Spectral



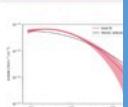
Point source sensitivity



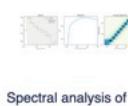
Spectral analysis



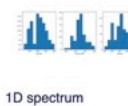
Spectral analysis with the HLI



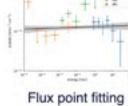
Spectral analysis with energy-dependent directional cuts



Spectral analysis of extended sources



1D spectrum simulation

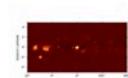


Flux point fitting

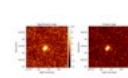


Account for spectral absorption due to the EBL

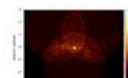
2D Image



Source detection and significance maps



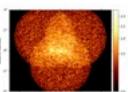
Ring background map



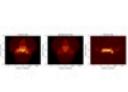
2D map fitting

[Back to top](#)

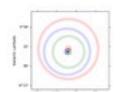
3D Cube



3D detailed analysis



Basic image exploration and fitting



Morphological energy dependence estimation



Multi instrument joint 3D and 1D analysis

Time



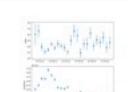
Light curves



Light curves for flares



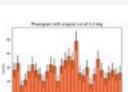
Estimation of time variability in a lightcurve



Time resolved spectroscopy estimator



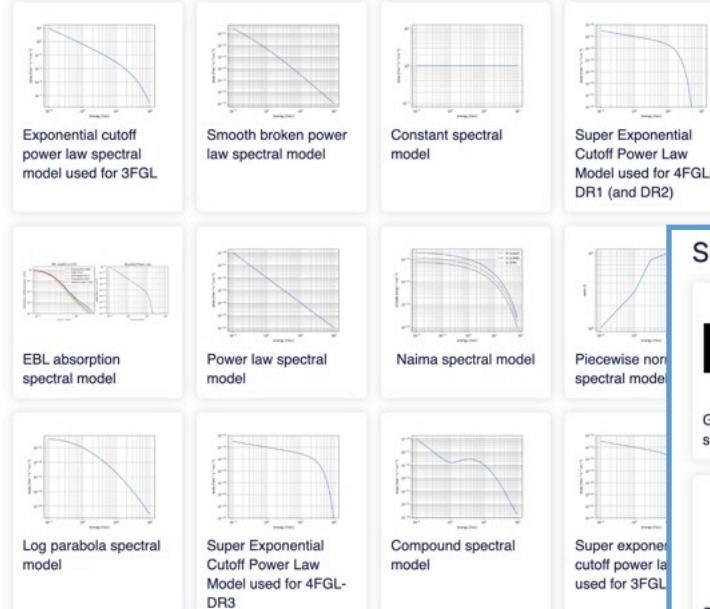
Simulating and fitting a time varying source



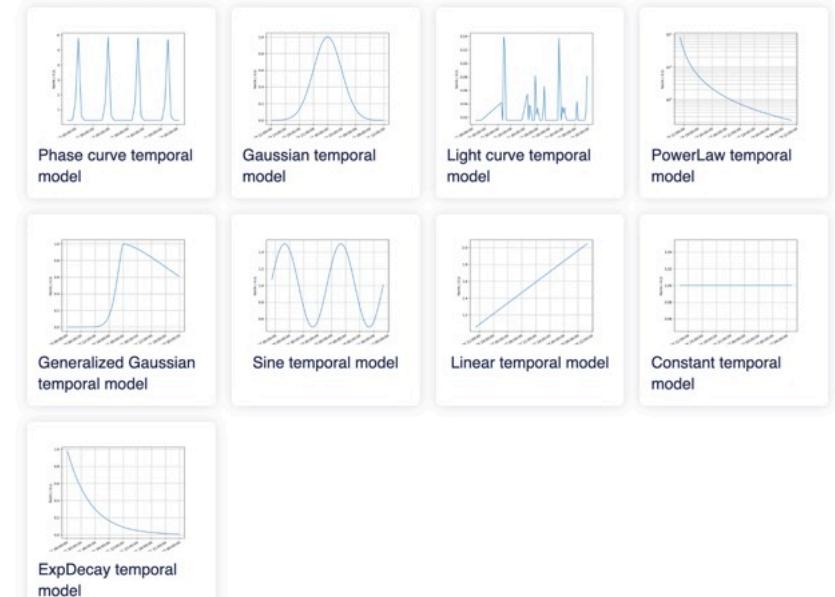
Pulsar analysis

Gammapy model gallery (spectral, spatial and temporal)

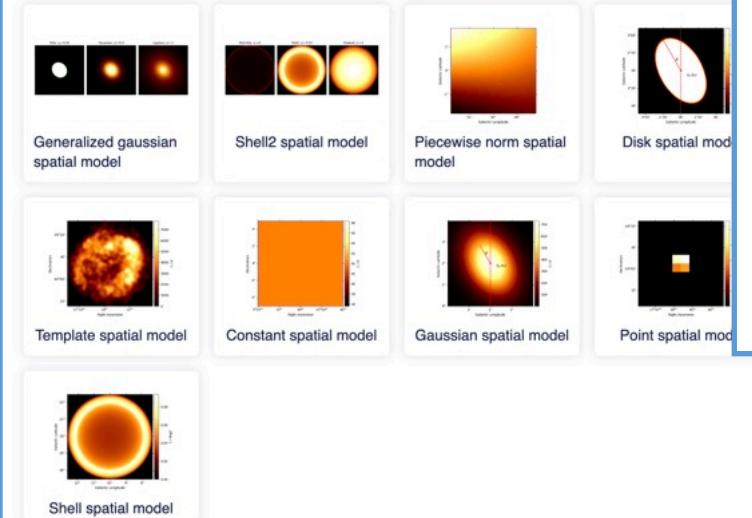
Spectral models



Temporal models



Spatial models





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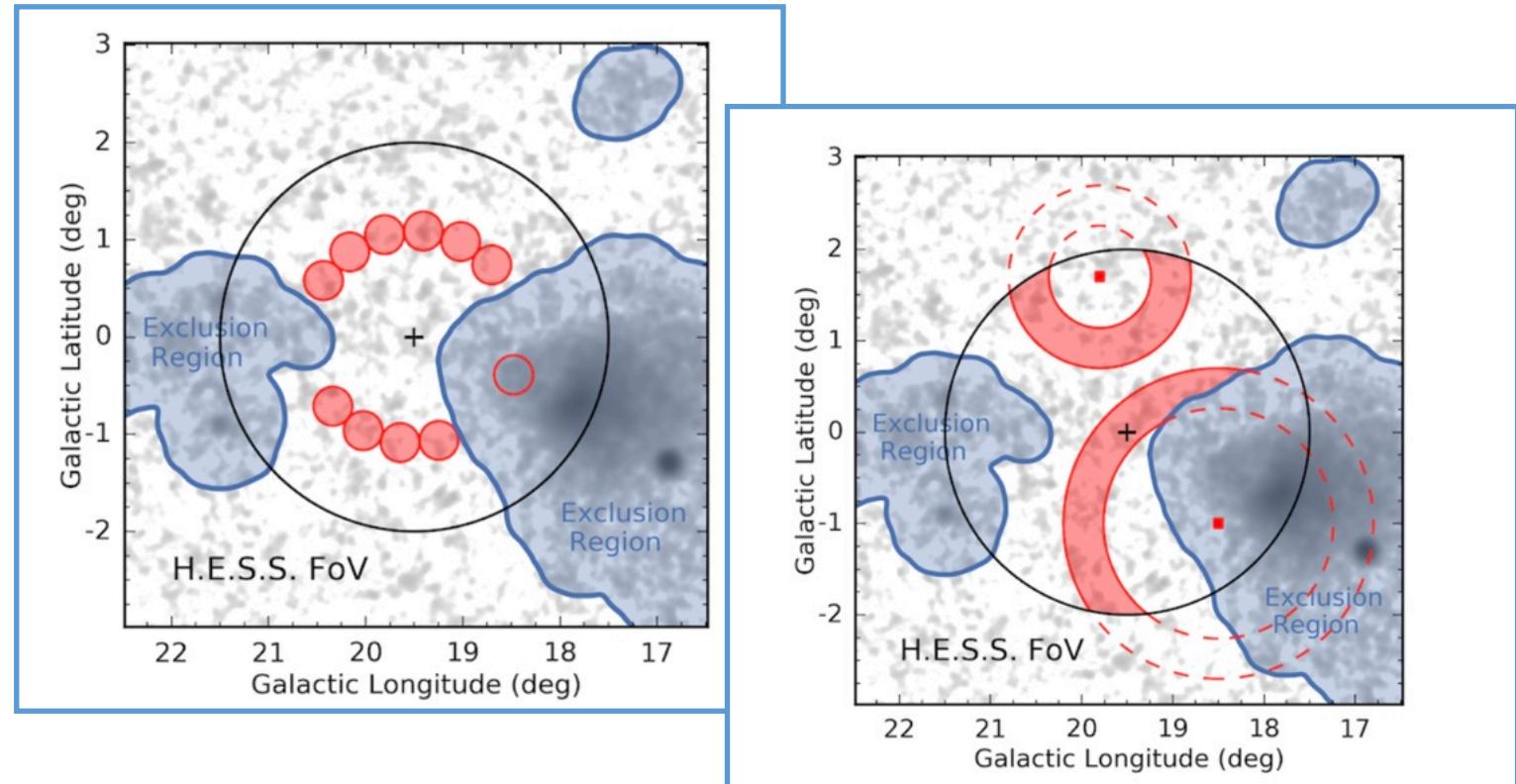
The application programming interface (API) is well organised and detailed:

<https://docs.gammipy.org/1.3/api-reference/index.html>

Background estimation

Background can be estimated following different methods:

- Reflected regions
- Ring background

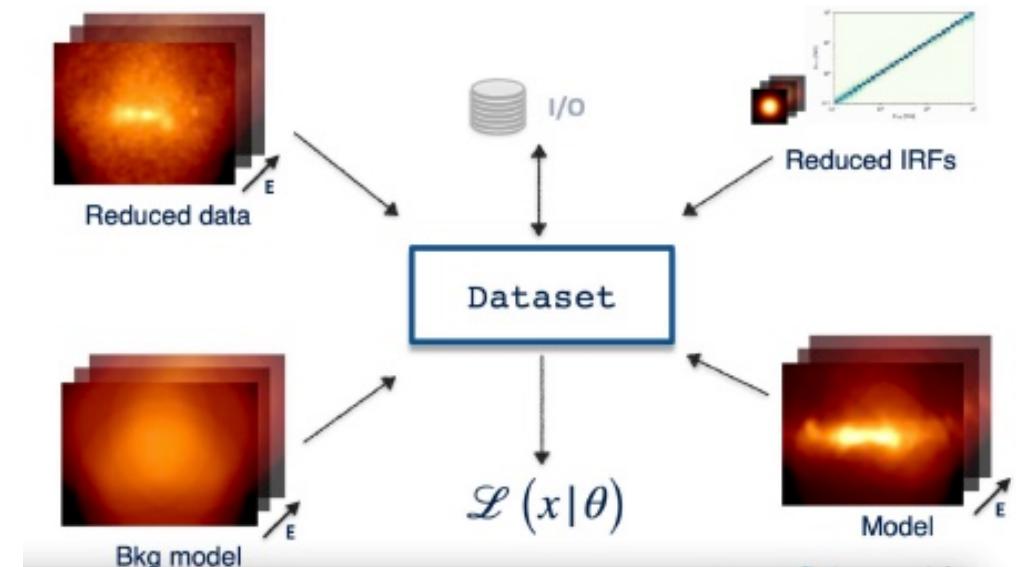


Fitting approaches are based on a forward folding with maximum likelihood estimation.
 The predicted events are a convolution of source and background events.

- Cash statistics

The background model is known:

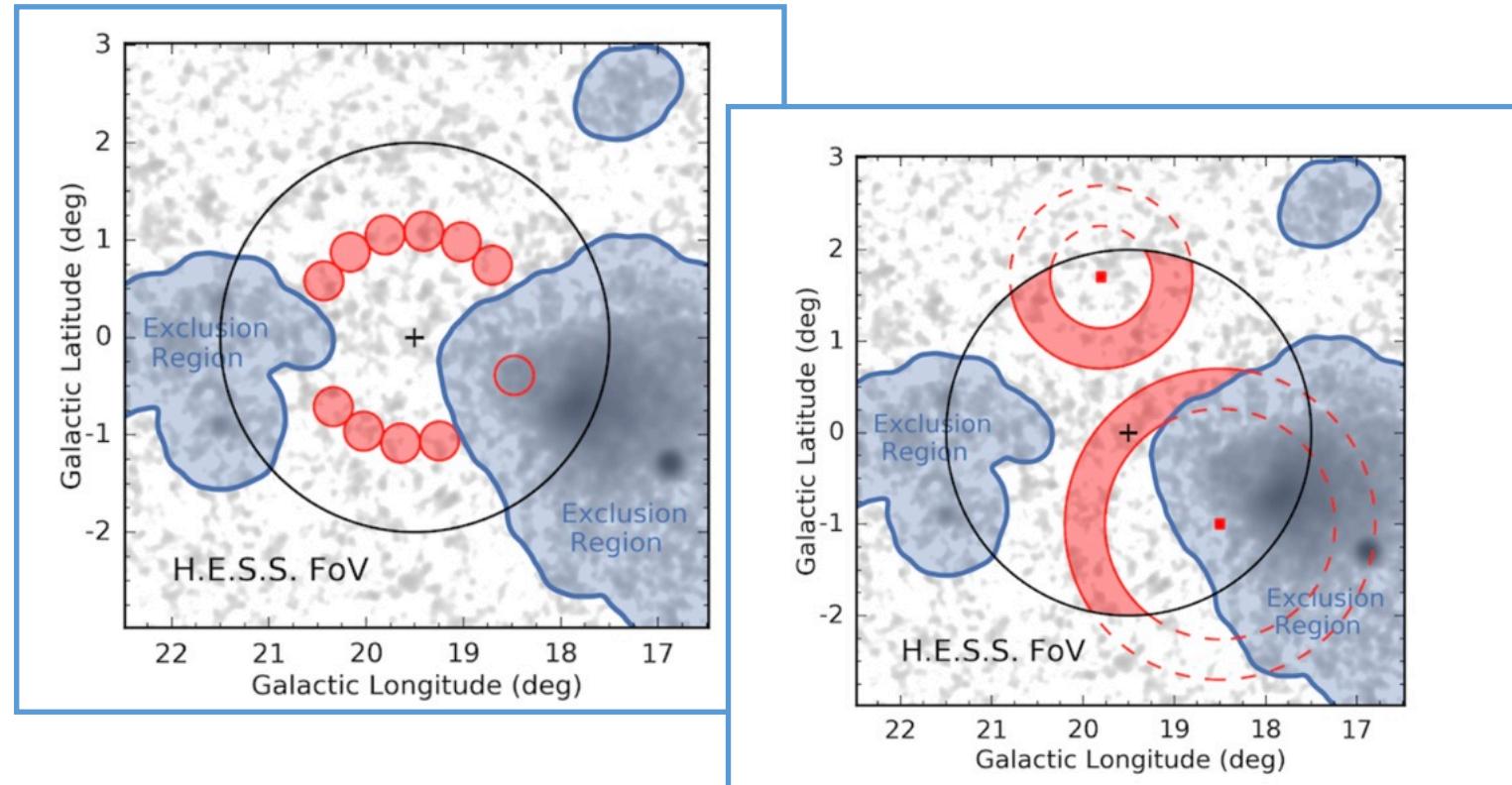
$$TS = -2 \log L = 2 \sum (N \times \log N_{pred} - N_{pred})$$



Background estimation

Background can be estimated following different methods:

- Reflected regions
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- FoV background



Fitting approaches are based on a forward folding with maximum likelihood estimation.
The predicted events are a convolution of source and background events.

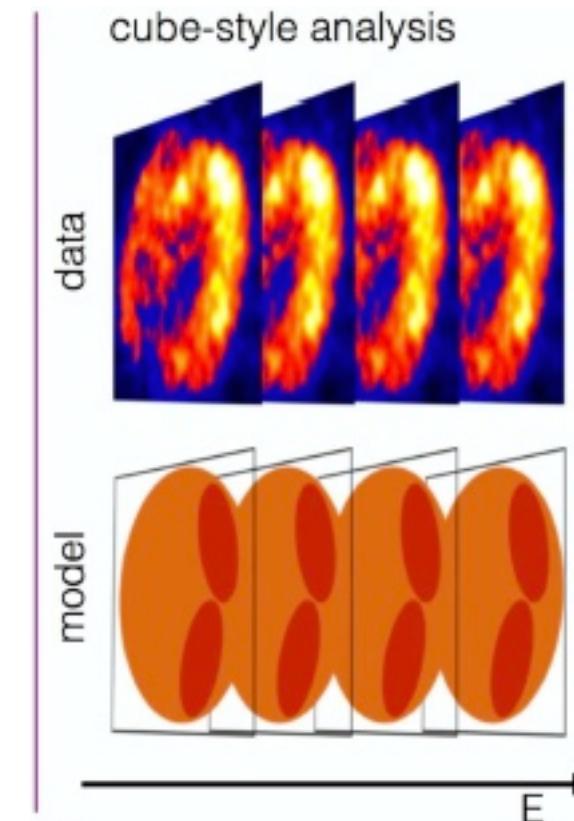
- Cash statistics

The background model is known:

$$TS = -2 \log L = 2 \sum (N \times \log N_{pred} - N_{pred})$$

- Wstat statistics

The background is estimated from the data





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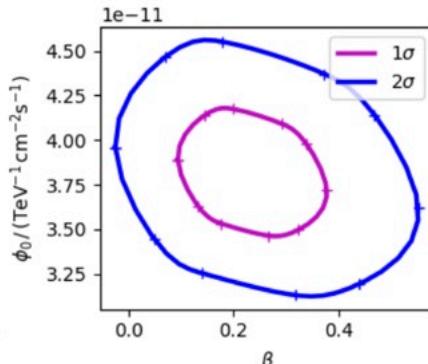
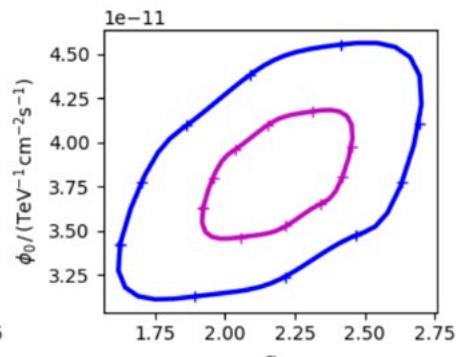
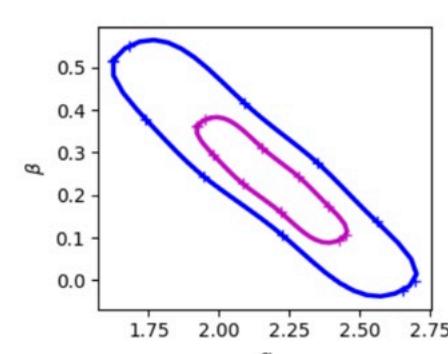
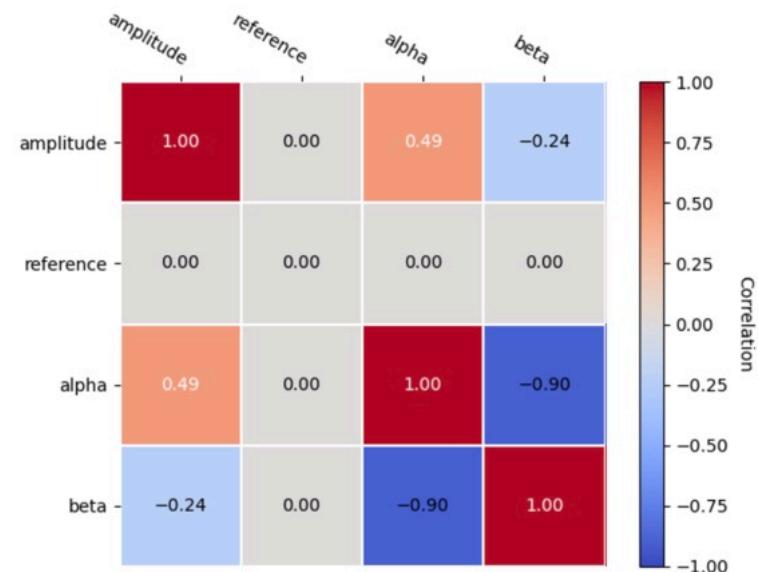
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Fitting

Fitting can access different backend (*sherpa*, *iminuit*...) and optimisation algorithms (*Levenberg-Marquardt*, *Simplex*, *Monte Carlo*...).

Possibility to choose optimisation parameters and fitting strategy;





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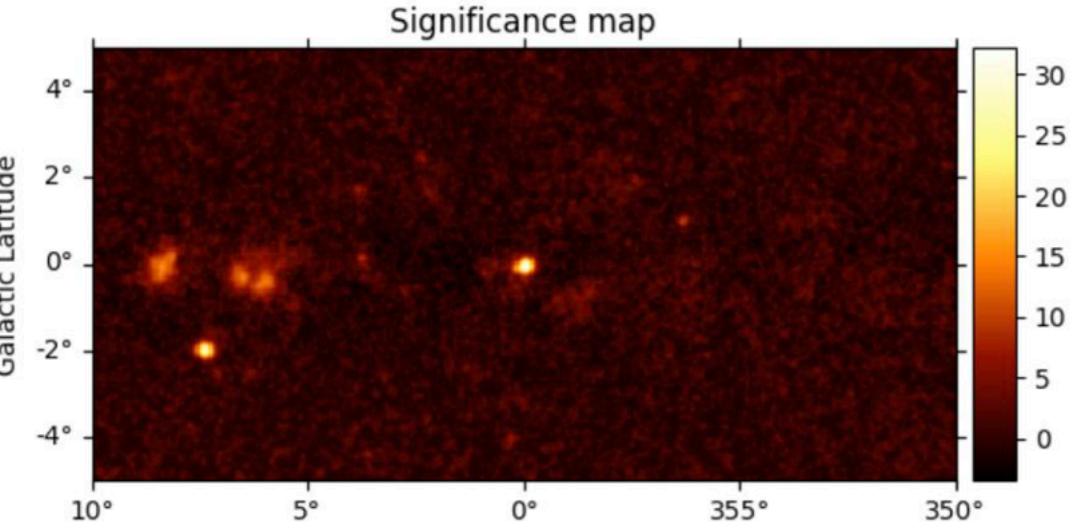
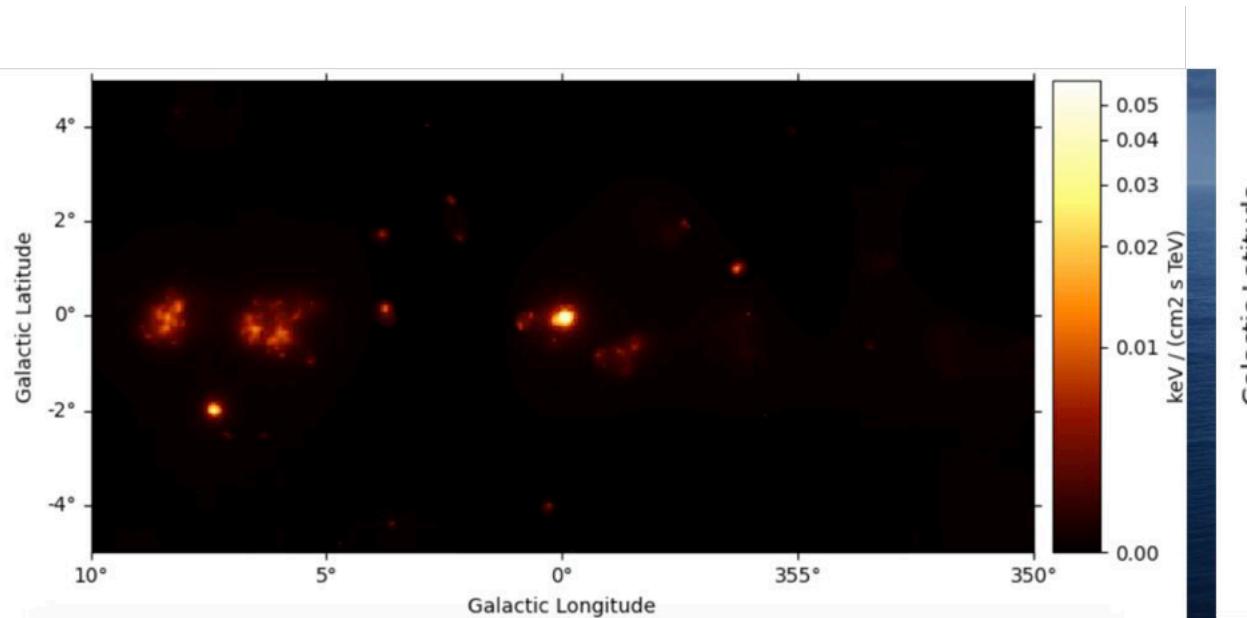
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Gammapy.maps



Maps can be created over arbitrary energies or spatial geometries;

Possibility of reshape, downsample or upsample the geometries;



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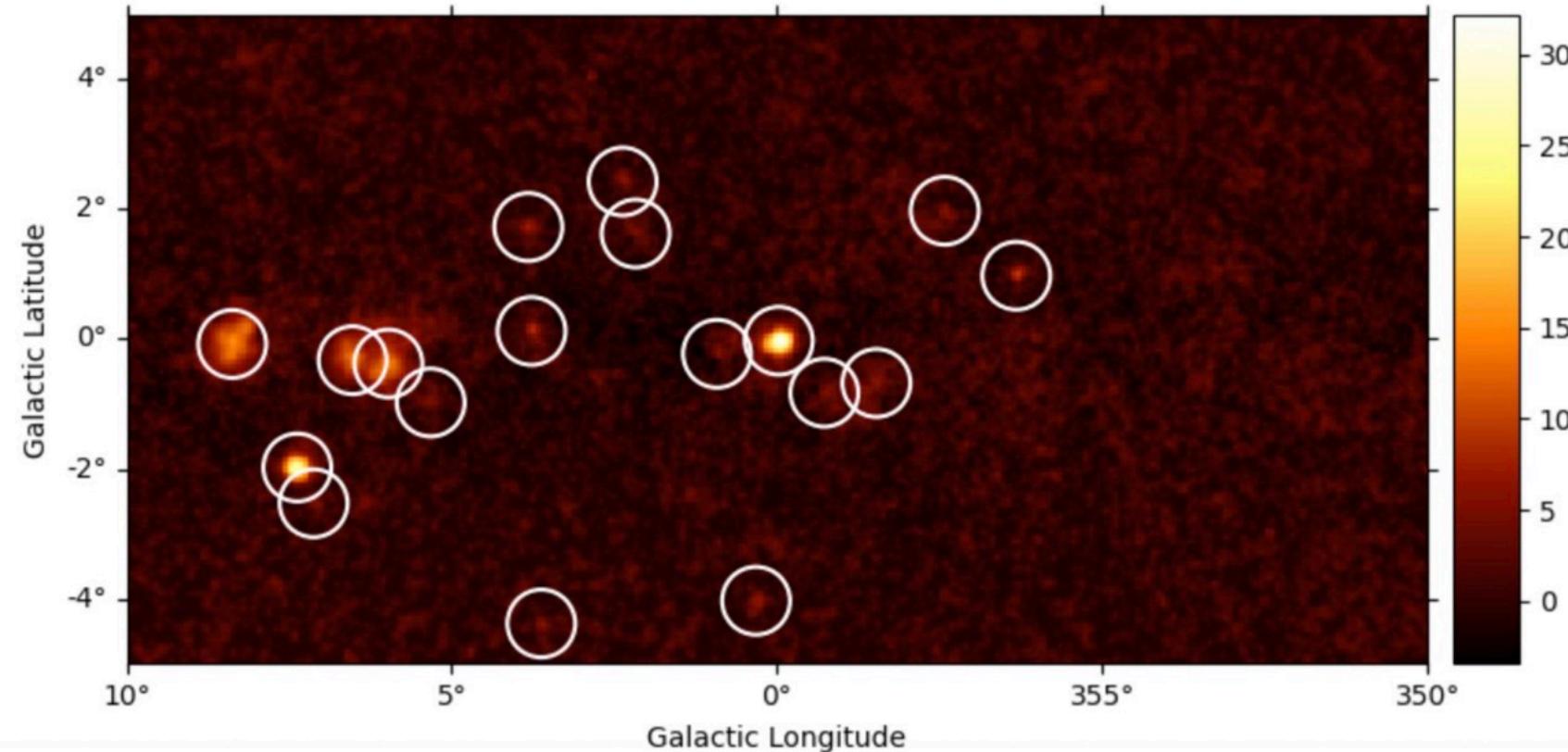
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Gammapy.maps + source detection



SOURCE DETECTION



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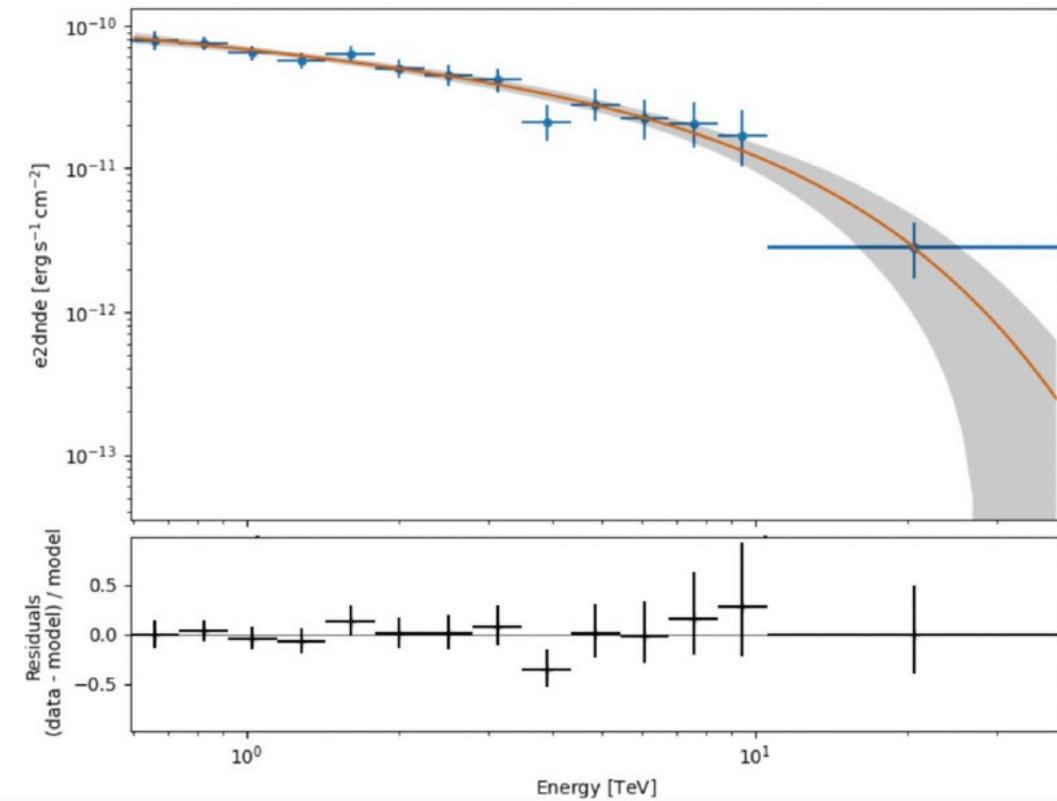
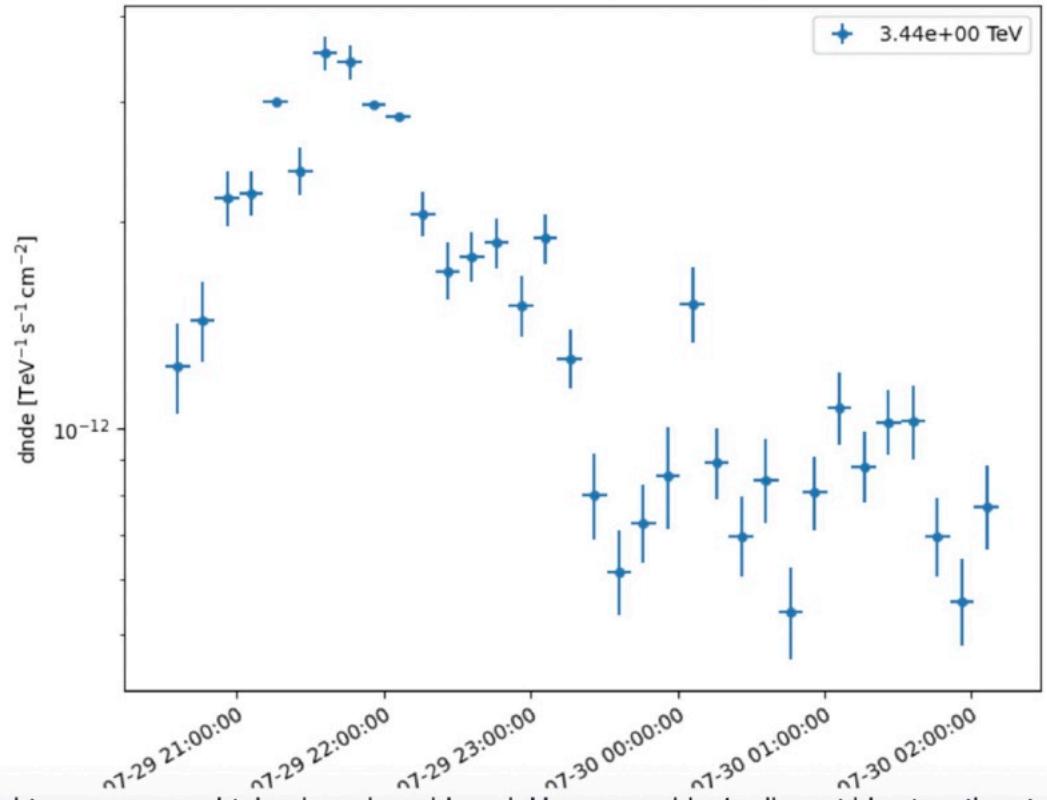
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Lightcurves and spectra





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How to: simulate an observation event list with Gammapy



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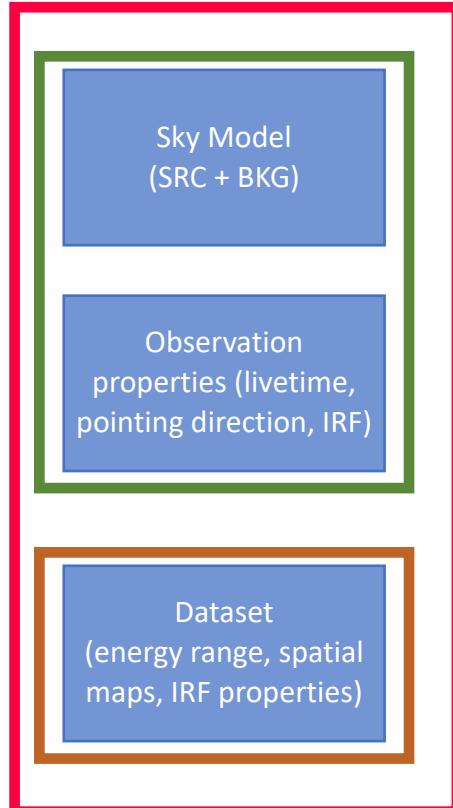


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Gammapy event sampling

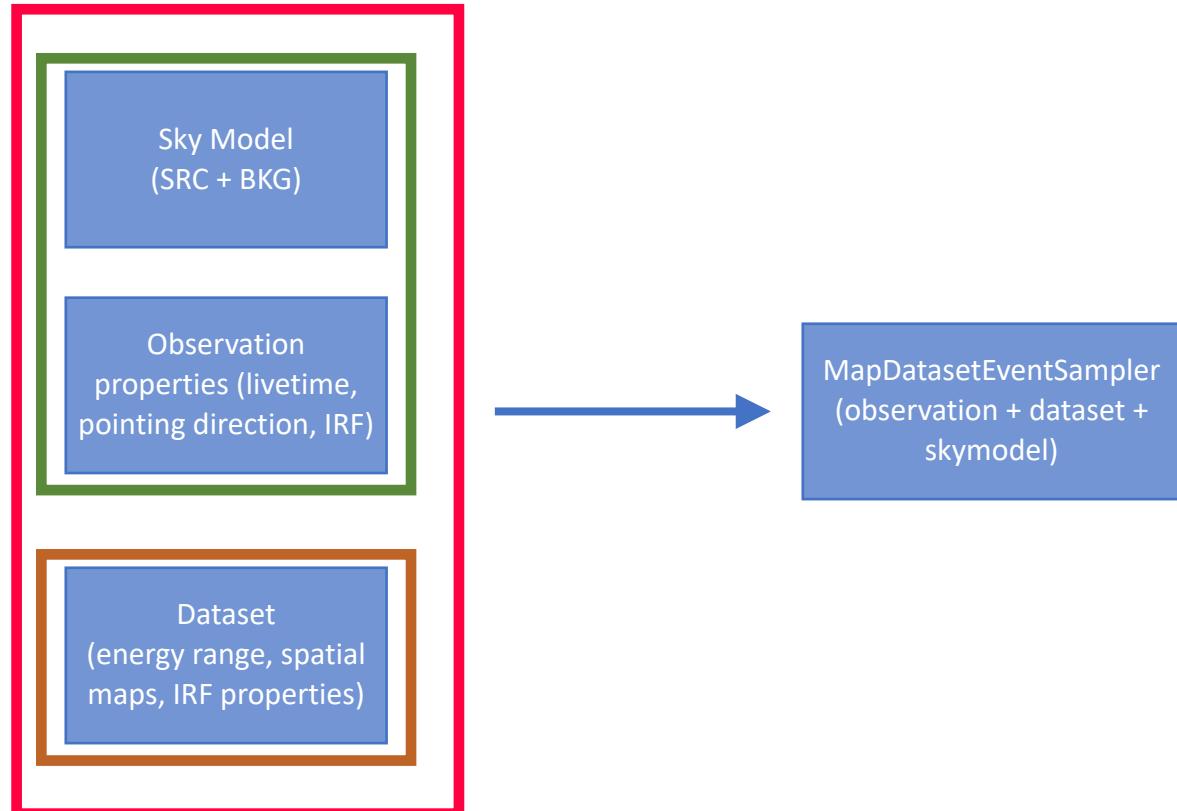
MapDatasetMaker



MapDatasetMaker applies a binning of the spatial and energy axes, and projects the IRF properties in the sky-direction!

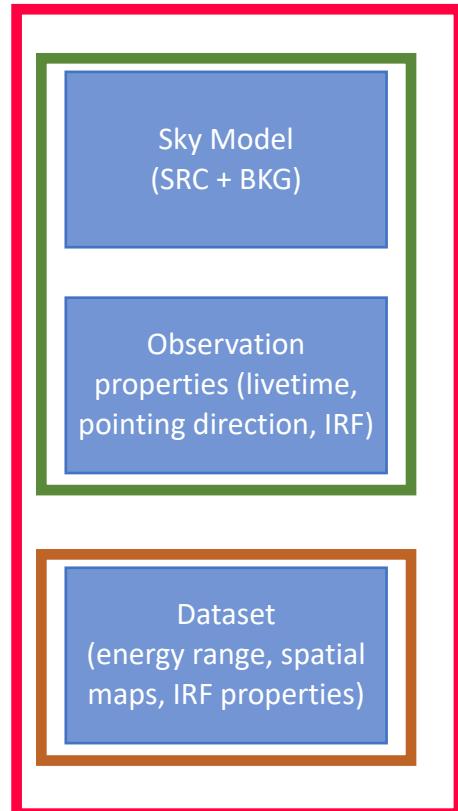
Gammapy event sampling

MapDatasetMaker



Gammapy event sampling

MapDatasetMaker





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How to: source detection



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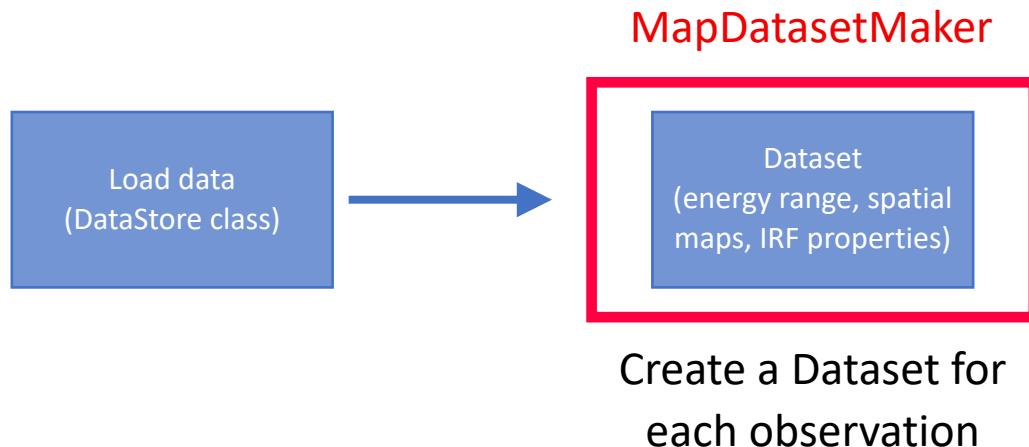
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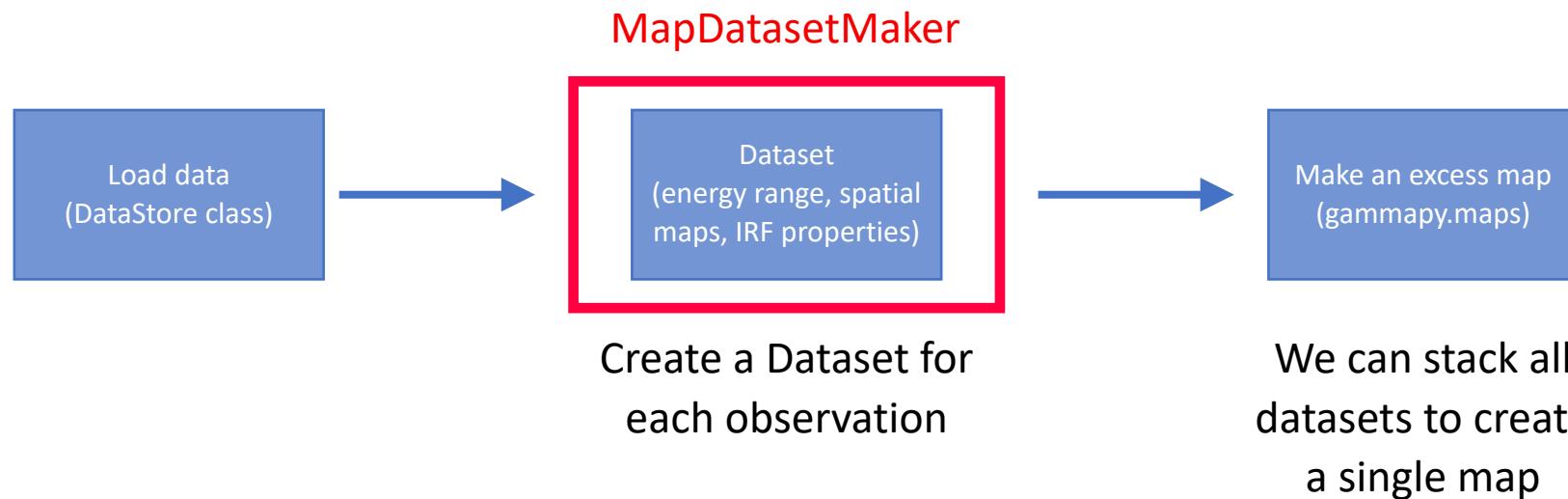
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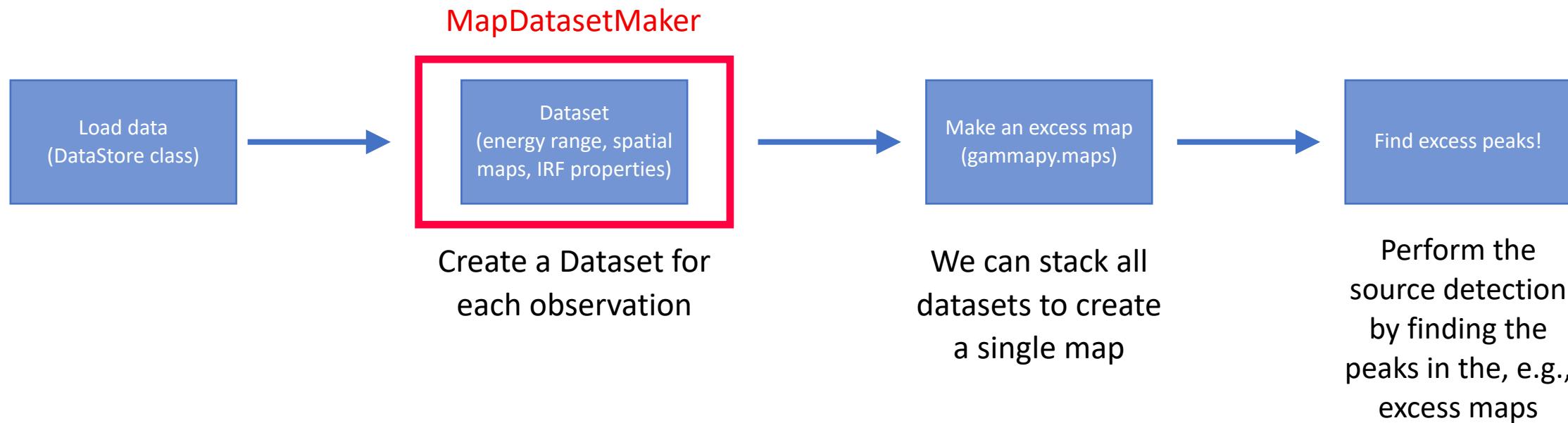
Gammapy source detection



Gammapy source detection



Gammmapy source detection





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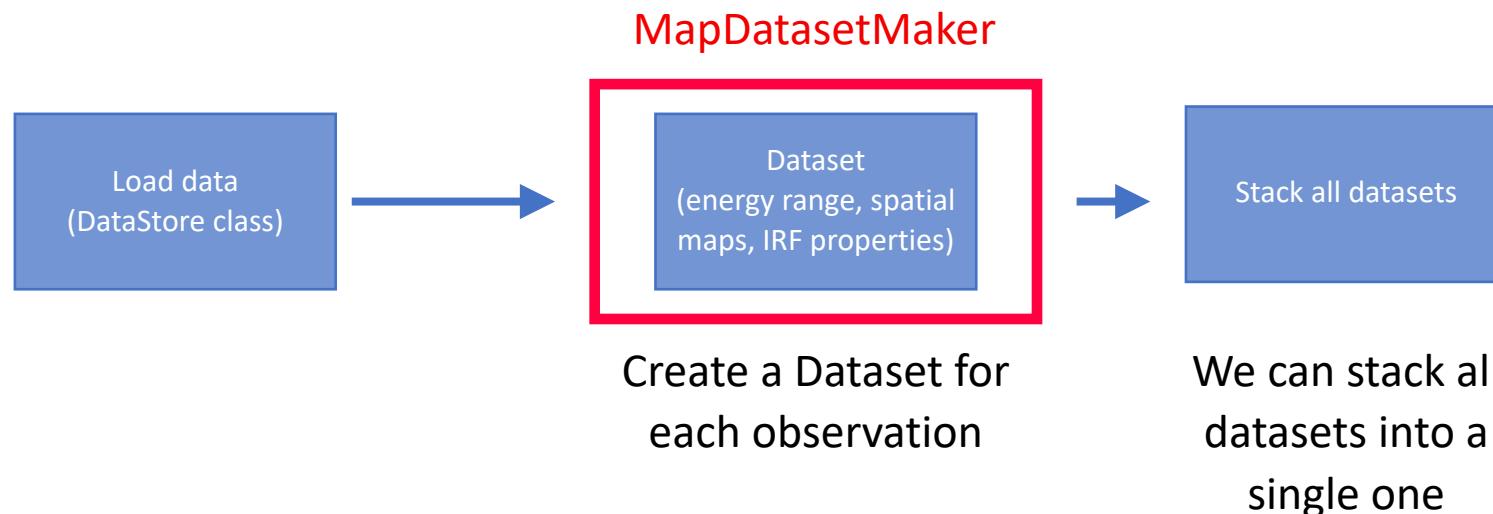


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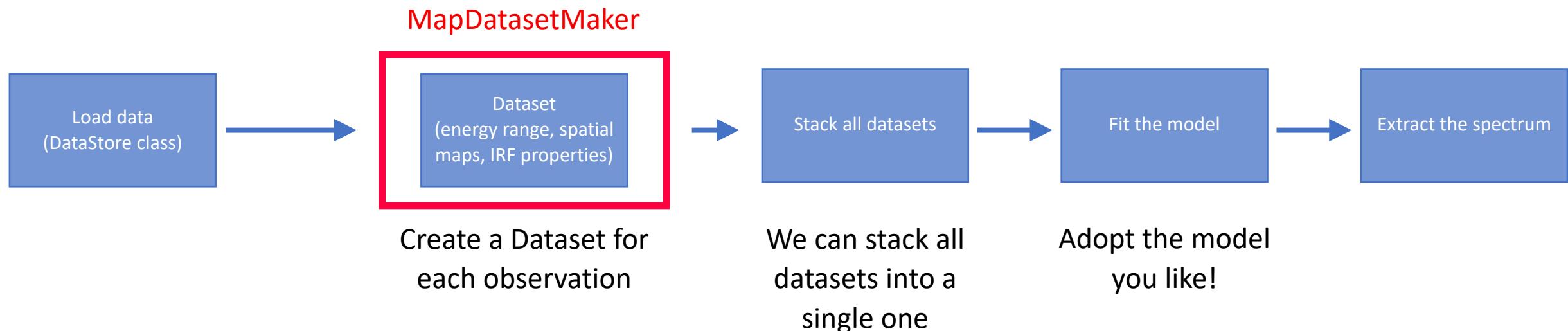


How to: 1D stacked spectral analysis

Gammapy stacked spectral analysis: 1D



Gammapy stacked spectral analysis: 1D





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How to: extract a long-term lightcurve



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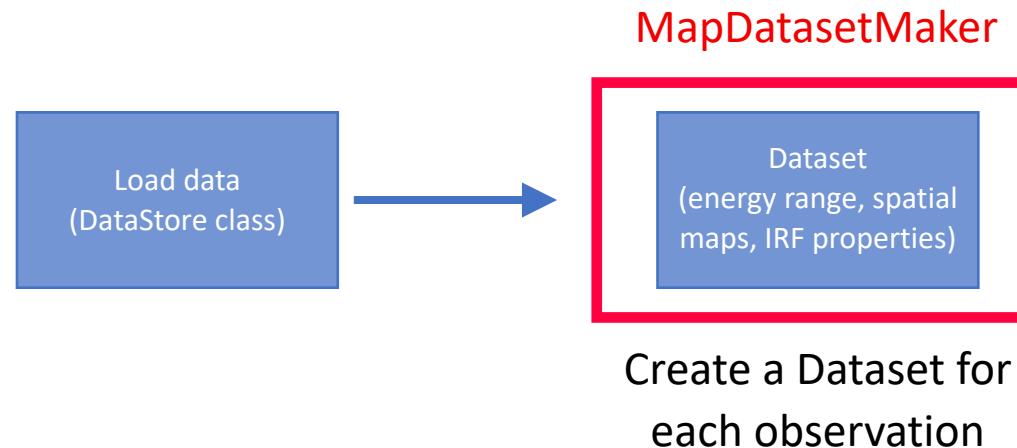
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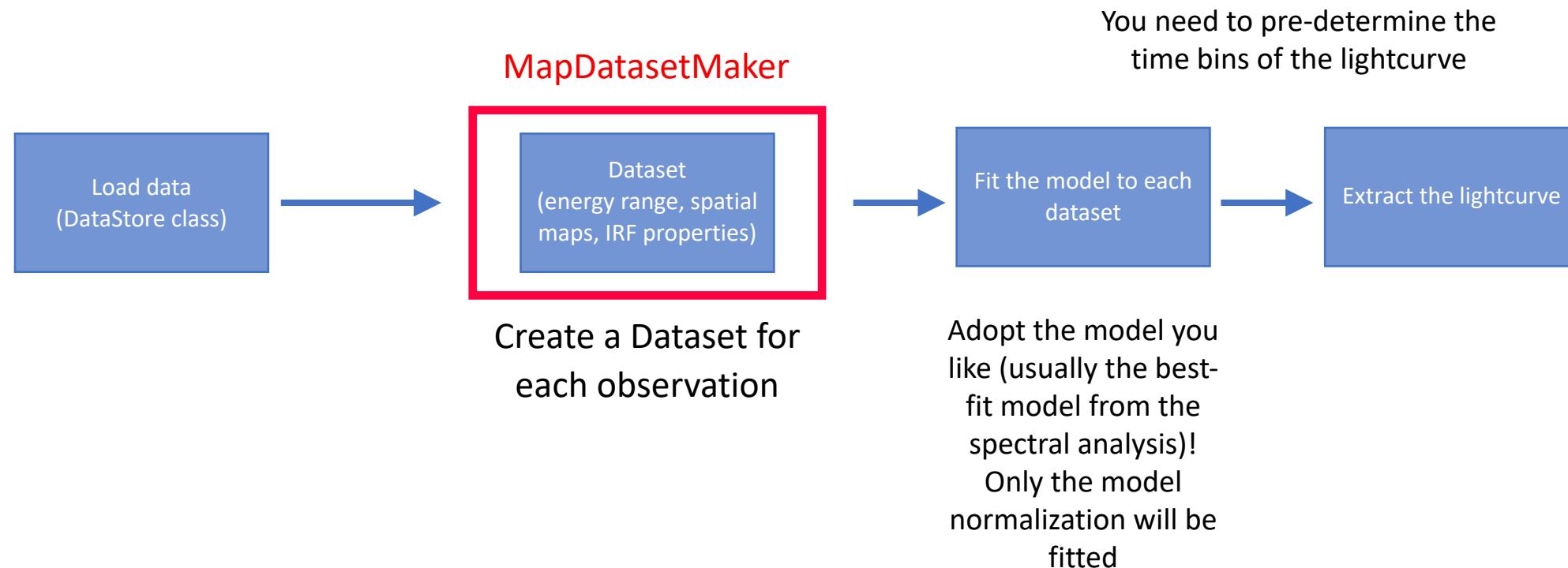
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Long-term lightcurve



Long-term lightcurve





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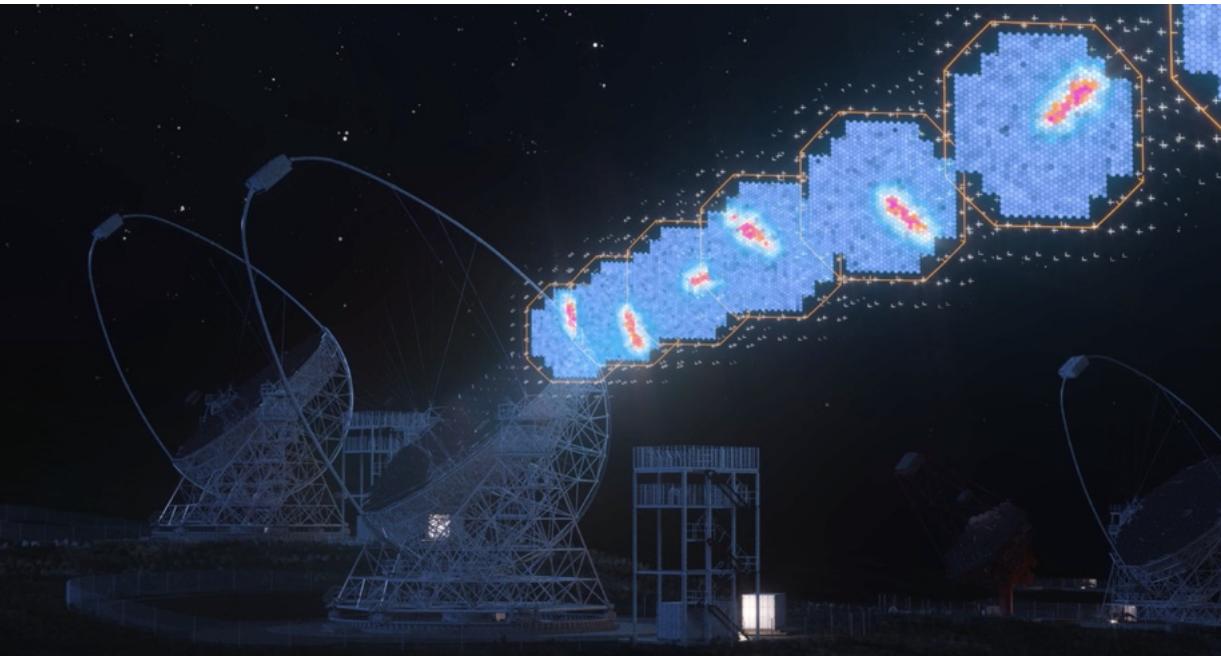


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Thanks for the attention!