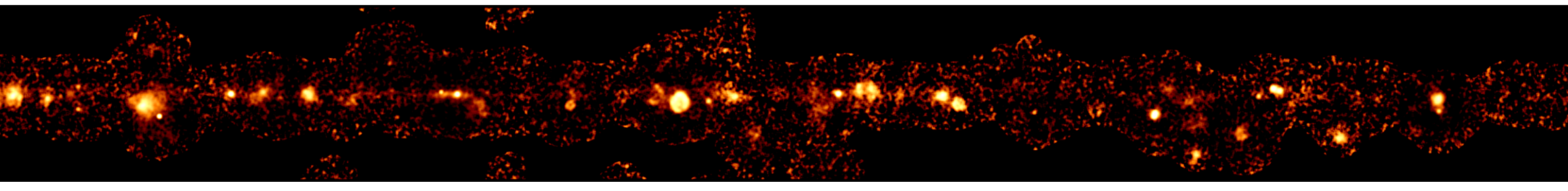
A **Python** package for
gamma-ray astronomy

Gammapy overview

Fabio(s), Atreyee, for the Gammapy Team

Based on presentations by **A. Donath, B. Khelifi, A. Sinha, R. Terrier et al.**



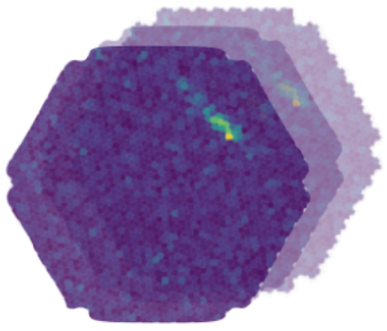
Where γπ starts

Separating instrument specific data treatment from common use cases and methods

Reconstruction pipeline (instrument specific)

Science Tools (general users)

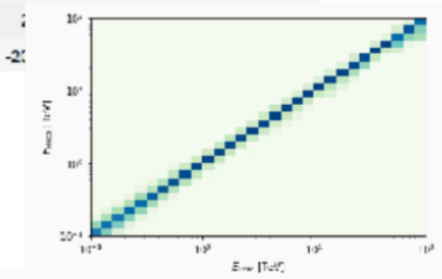
DL 0-1	DL 2	DL 3	DL 4	DL 5
raw - calibrated	*reconstructed*	*filtered γ-like events*	*science*	*high-level*

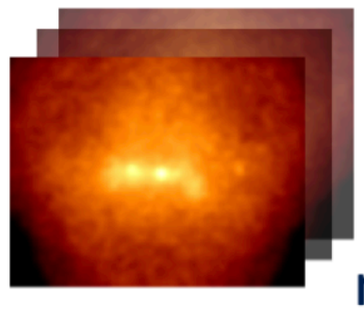


camera data

ENERGY	RA	DEC	L	B
MeV	deg	deg	deg	deg
float32	float32	float32	float32	float32
12186.642	260.45935	-33.553337	353.36273	1.7538676
25496.598	261.37506	-34.395004	353.09607	0.6520652
15421.498	259.56573	-33.409416	353.05673	2.4450684
12816.32	279.95583	-25.340391	6.45856	-4.0548879
185[illegible].387	260.[illegible]	-36.[illegible]	351.[illegible]	-0.10[illegible]
11610.93	266.[illegible]	-26.224436	2.1[illegible]	1.6[illegible]
13960.802	271.44742	29.615316	1.6267247	4.2431155
10477.372	266.3981	[illegible]	[illegible]	[illegible]
13030.88	271.70128	-2[illegible]	[illegible]	[illegible]

γ-like event lists
IRFs





maps,
spectra,
light curves

Main concept of Gammapy

Pointing γ-ray Observatories

cta

MAGIC

H.E.S.S.

VERITAS

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

Fermi
Gamma-ray
Space Telescope

All-sky γ-ray Observatories

GADF

Common
data format

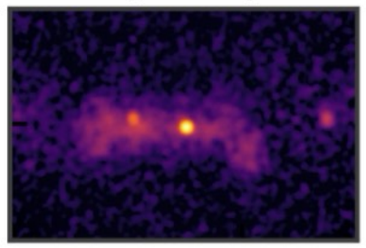
NumPy

SciPy

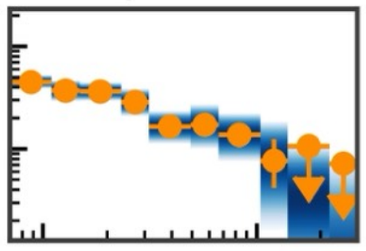
matplotlib

astropy

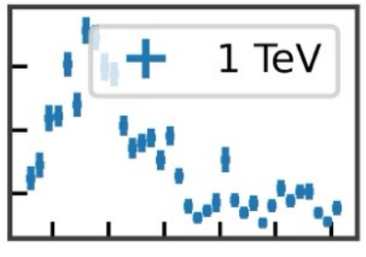
Sky maps



Spectra



Lightcurves



V1.2 released on Feb. 2024

Data workflow and package structure

DL3
γ-like events

DL4
Binned data

DL5/6
Science products

Data Reduction

.irf
PSF
EnergyDispersion
EffectiveArea

.data
DataStore
Observations
Observation
GTI

.makers
MapDatasetMaker
SafeMaskMaker
FoVBackgroundMaker
RingBackgroundMaker
etc.

.maps
WcsNDMap
HpxNDMap
etc.

.datasets
Datasets
MapDataset
MapDatasetOnOff
etc.

Modeling & Fitting

.modeling
Fit, Models, SkyModel
FoVBackgroundModel
etc.

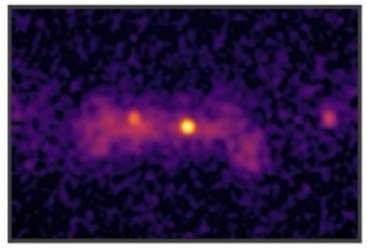
.estimators
FluxPointsEstimator
TSMapEstimator
etc.

YAML → .analysis

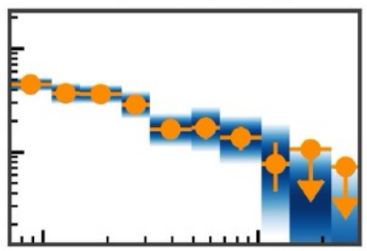
Source Catalogs

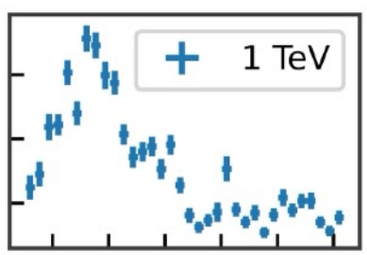
Name	Flux	Size
SNR	1e-12	1 deg
PWN	1e-11	0.2 deg
GRB	1e-10	0 deg

Sky Maps

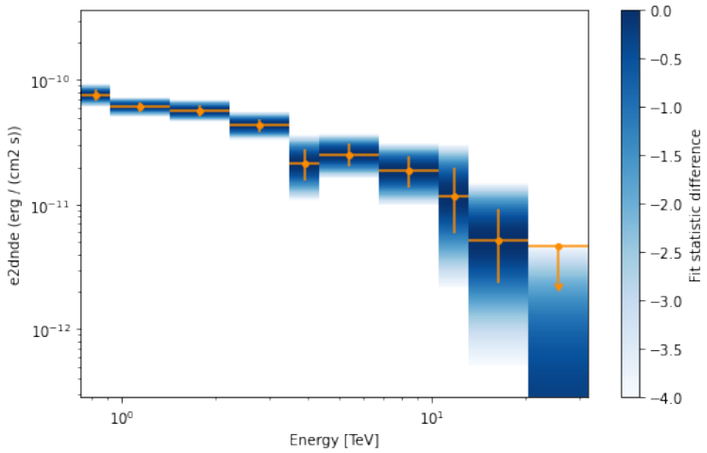


Flux Points

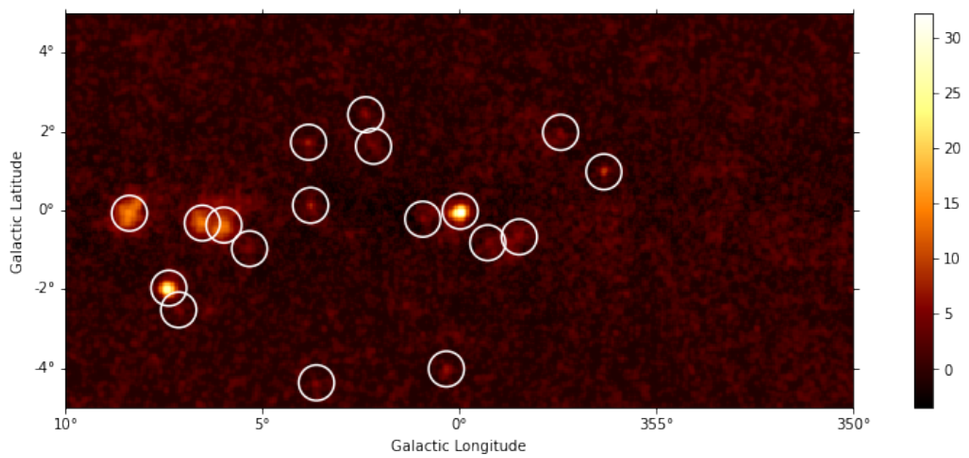




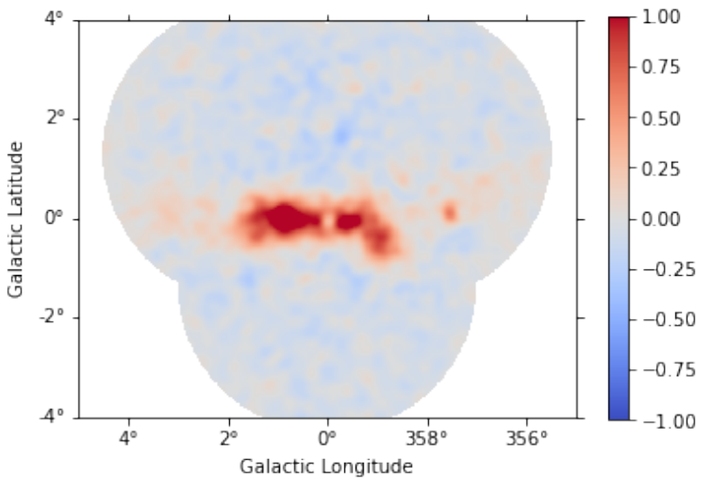
Typical analysis use cases



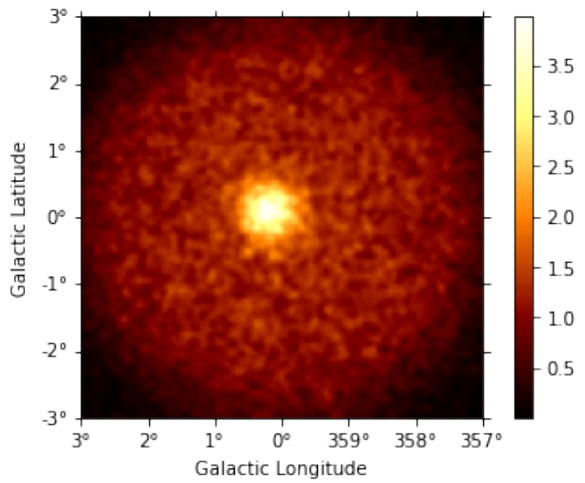
[1D spectral analysis]



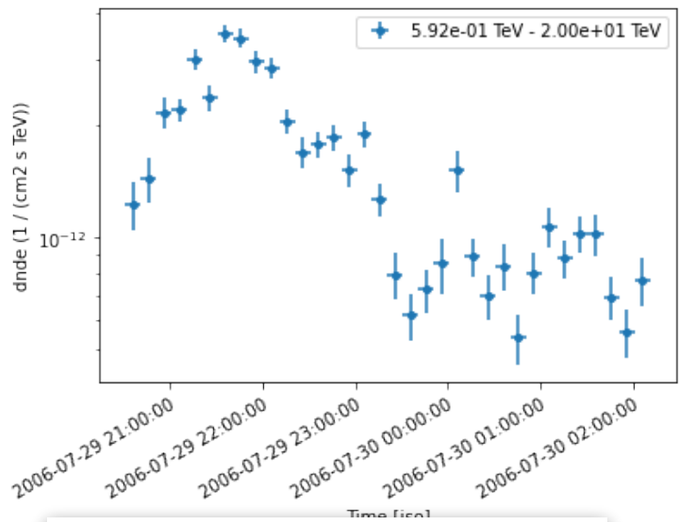
[Source detection]



[3D analysis]



[Observation simulation]



[Light-curve extraction]

All analysis types follow the same workflow and the same API

The basic analysis steps

DL3 to DL4

1. Select and retrieve observations
   - Datastore → list of Observation
2. Define the reduced dataset geometry
   - Is the analysis 1D or 3D?
   - Define target binning and projection
3. Initialize the data reduction methods (makers)
   - Data and IRF projection
   - Safe Mask determination
   - Background estimation
4. Loop over selected observations
   - Apply makers to produce reduced datasets
   - Combine them for stacked or joint analysis

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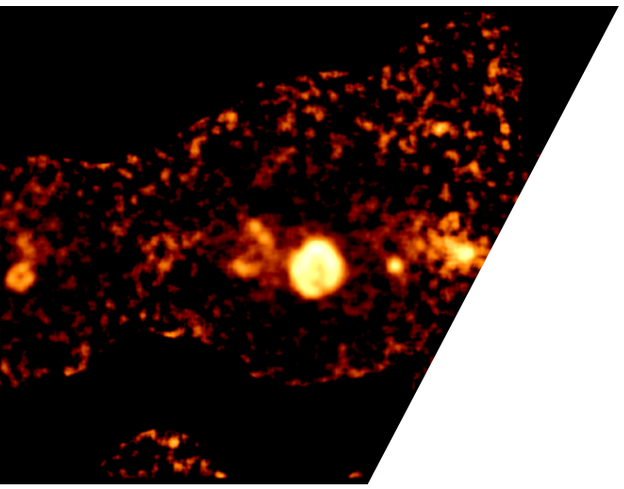
DL4 to DL5

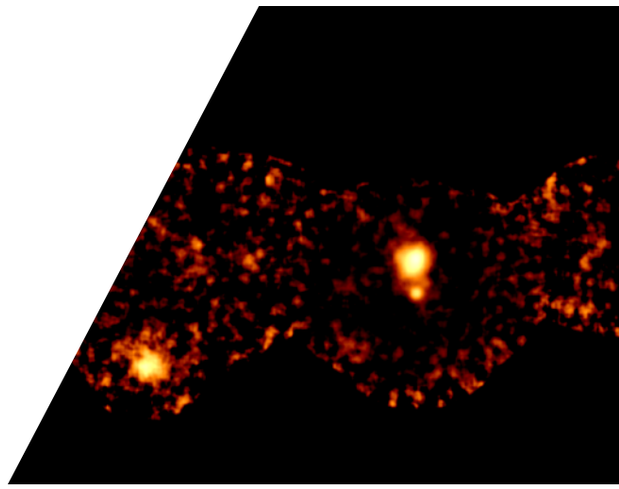
1. Modeling
   - Define your model(s)
   - Associate them/it to the correct datasets
2. Do the fit
   - Choose your minimization parameters
   - Make the control plots, compute significance
3. Run the DL5 estimators (estimators)
   - Initialization of the geometry
   - Creation of the estimator(s)
   - Run it/them on dataset(s)



Event list

Binned data

From DL3 to DL4



Data and IRF re-projection

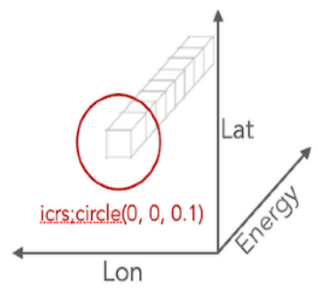
1D Counts

DL3
γ-like events

EVENT_ID	TIME	RA	DEC	ENERGY
	s	deg	deg	TeV
int64	float64	float32	float32	float32
5407363825684	123890826.66805482	84.97964	23.89347	10.352011
5407363825695	123890826.69749284	84.54751	21.004095	4.0246882
5407363825831	123890827.23673964	85.39696	19.41868	2.2048872
5407363825970	123890827.79615426	81.93147	20.79867	0.69548655
5407363826067	123890828.26131463	85.98302	21.053099	0.86911184
5407363826095	123890828.41393518	86.97305	21.837437	4.1240892
5407363826128	123890828.52555823	83.40073	19.771587	1.6680022
5407363826168	123890828.6829524	82.25036	19.22003	4.7649446
5407363826383	123890829.53362775	83.18322	22.008213	0.7920148
...	...	...	...	...

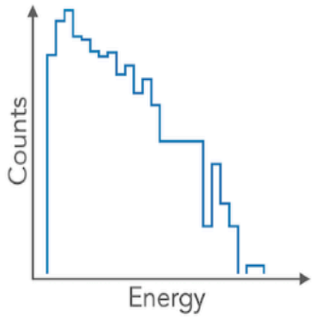
Observation and / or time selection

Data Reduction



Bin selection: Region & Energy

DL4
Binned data



Spectrum

SpectrumDatasetMaker

2D/3D Map

DL3
γ-like events

EVENT_ID	TIME	RA	DEC	ENERGY
	s	deg	deg	TeV
int64	float64	float32	float32	float32
5407363825684	123890826.66805482	84.97964	23.89347	10.352011
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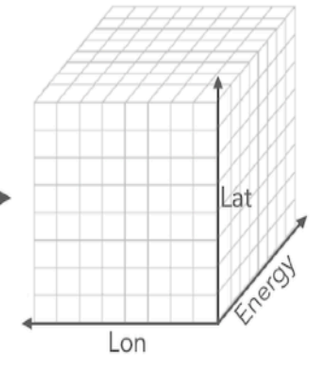
...	...	...	...	...

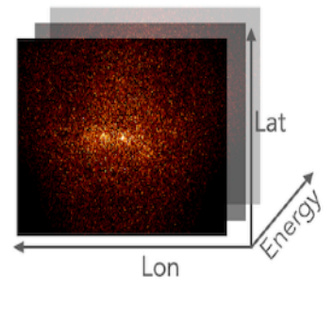
Observation and / or time selection

Data Reduction



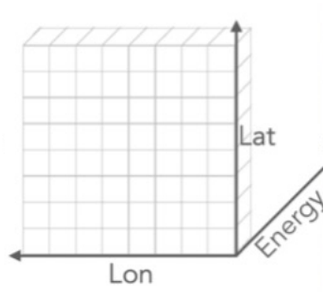
Bin selection: WCS & Energy

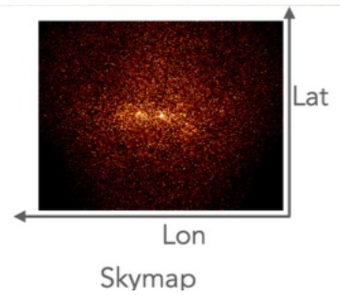
DL4
Binned data



Skymap / "Cube"

MapDatasetMaker





Skymap

3D with one bin

Binning data

1D Counts

DL3
γ-like events

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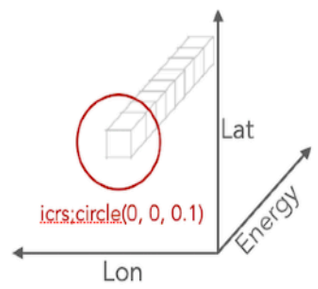
5407363826383	123890829.53362775	83.18322	22.008213	0.7920148
...	...	...	...	...

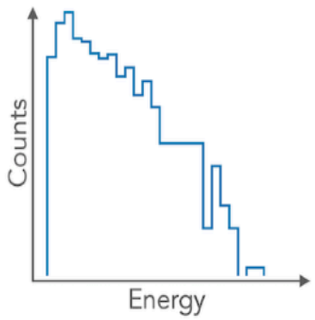
Observation and / or time selection

Data Reduction



Bin selection: Region & Energy

DL4
Binned data



Spectrum

SpectrumDatasetMaker

2D/3D Map

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γ-like events

EVENT_ID	TIME	RA	DEC	ENERGY
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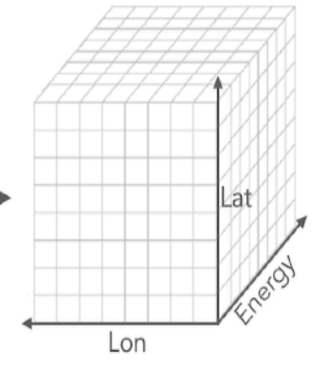
...	...	...	...	...

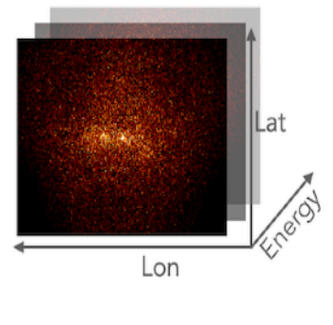
Observation and / or time selection

Data Reduction



Bin selection: WCS & Energy

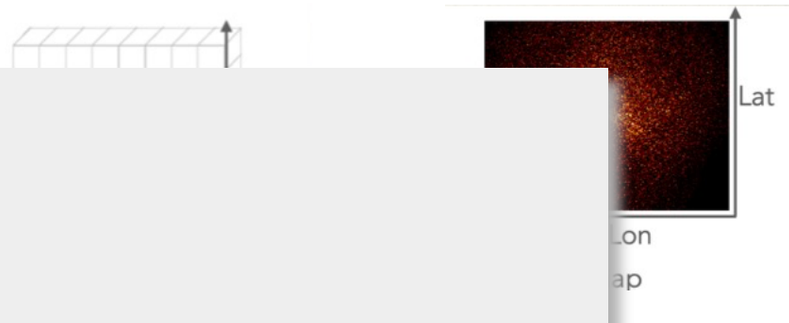
DL4
Binned data



Skymap / "Cube"

MapDatasetMaker

```
empty = MapDataset.create(
    geom,
    energy_axis_true=energy_true,
    name="my-dataset")
maker = MapDatasetMaker(selection=["exposure", "background", "psf", "edisp"])
dataset = maker.run(empty, observation)
```

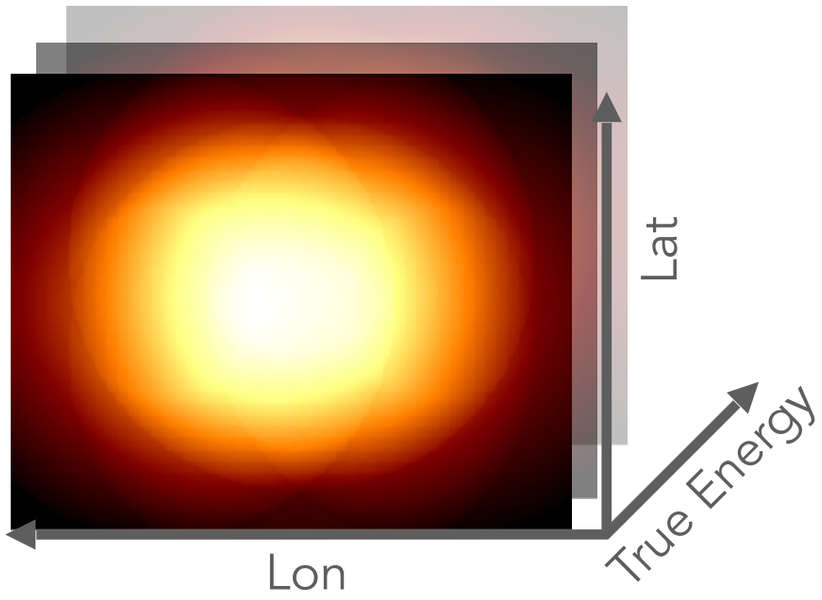


3D with one bin

Binning (reducing) IRFs

- DL3 IRFs are reprojected by the DatasetMaker on the target geometry

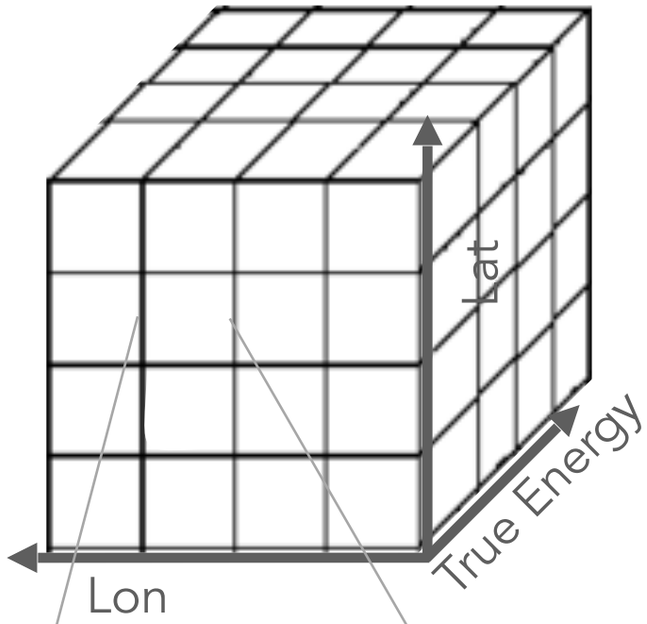
Exposure

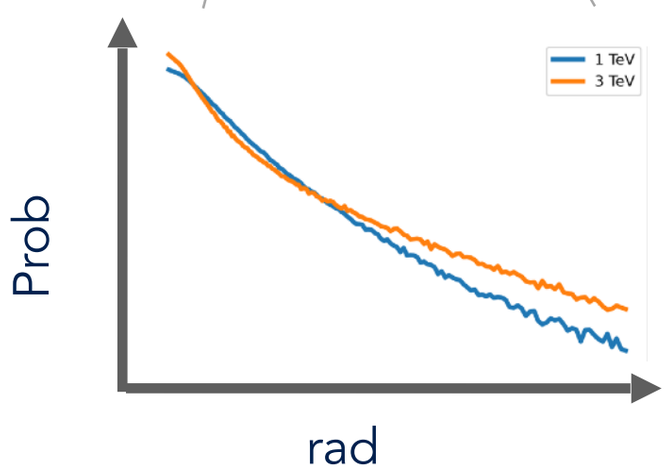


PSFMap / EDispKernelMap

PSF

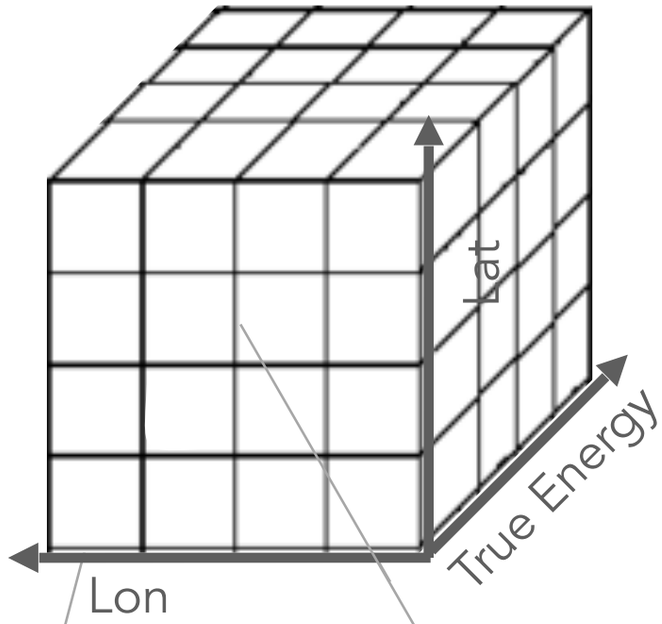
4th Dimension: rad

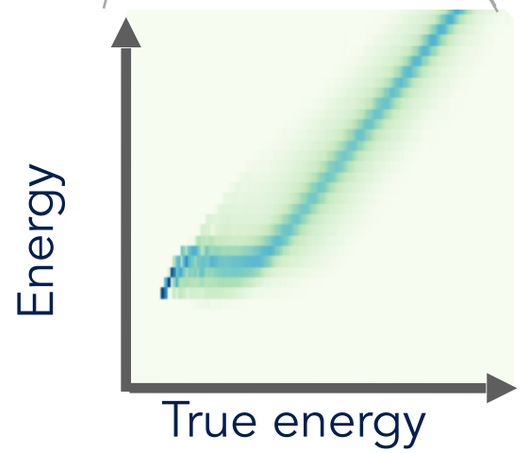




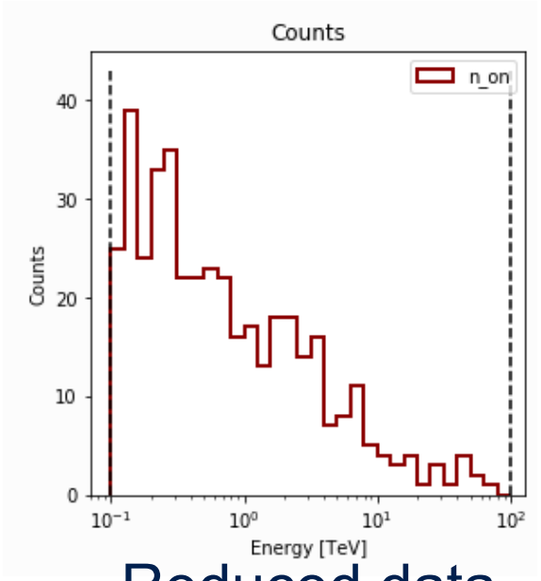
EDisp

4th Dimension: Energy

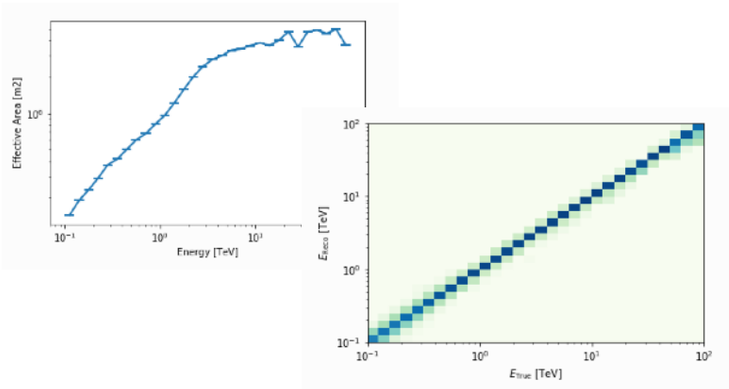




DL4 structures: Datasets



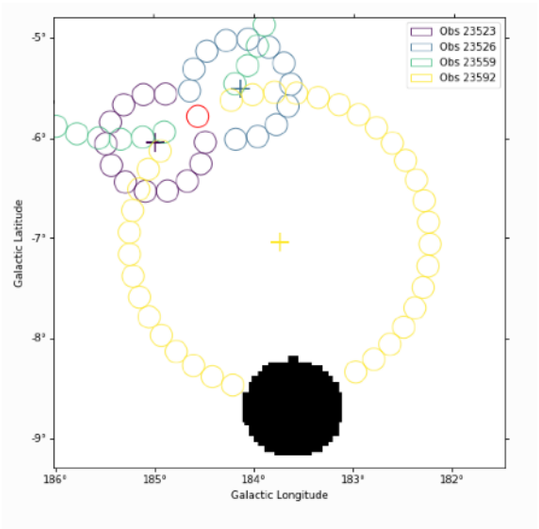
Reduced data



Reduced IRFs

I/O

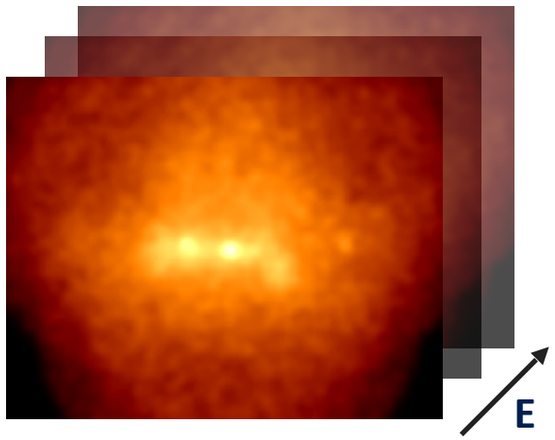
SpectrumDataset



Bkg data or model

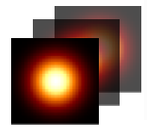
see: Dataset API tutorial

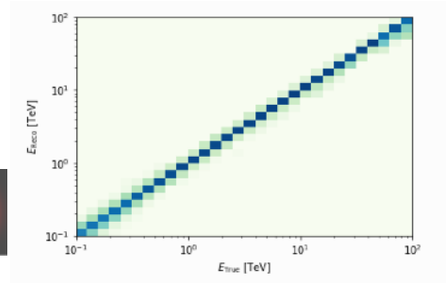
DL4 structures: Datasets



Reduced data

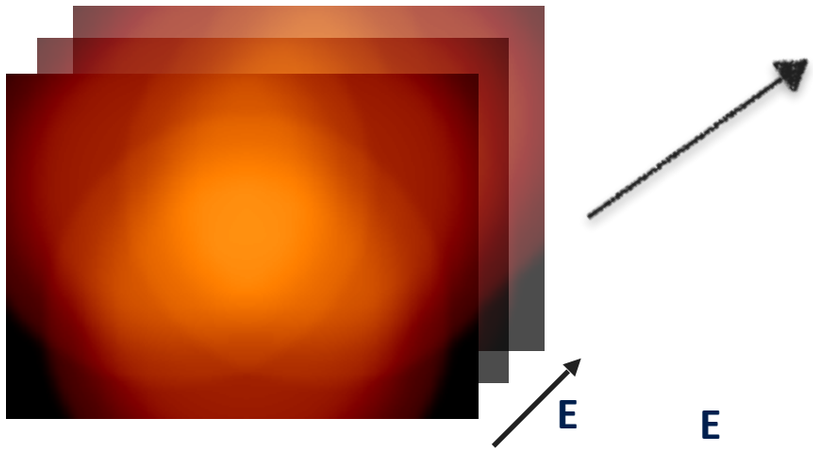
I/O





Reduced IRFs

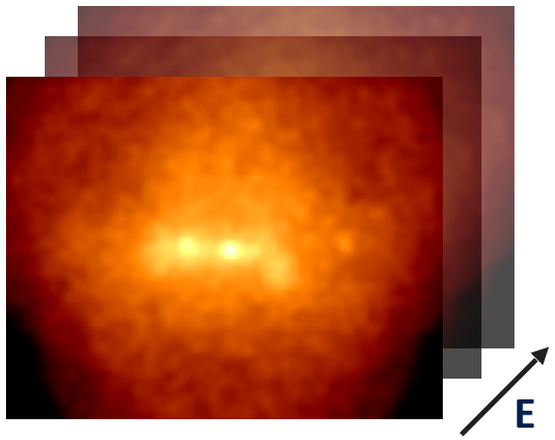
`MapDataset`



Bkg model

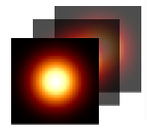
see: Dataset API tutorial

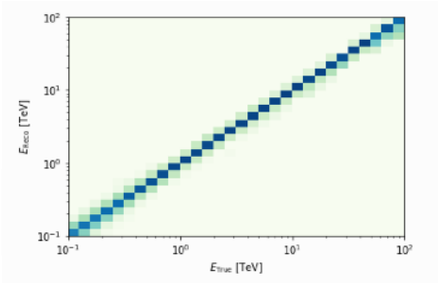
Datasets modeling and fitting



Reduced data

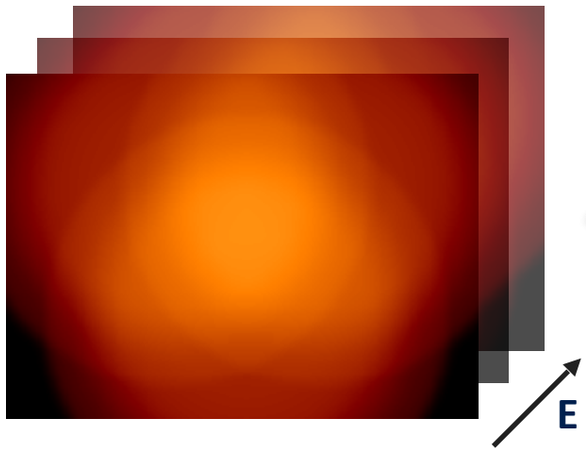
I/O





Reduced IRFs

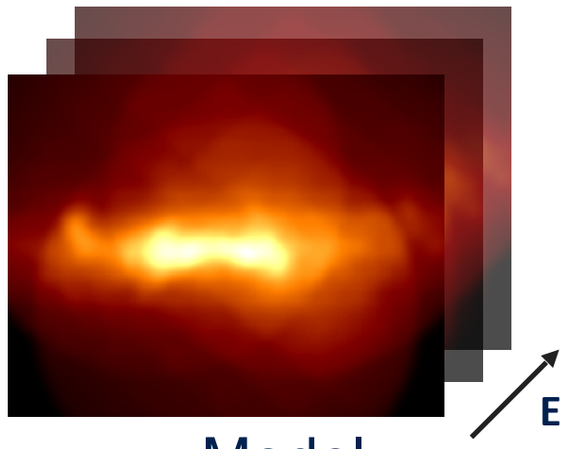
```
fit = Fit(optimize_opts={"print_level": 1})
result = fit.run(datasets=[dataset])
```



Bkg model

E

$L(x \mid \theta)$



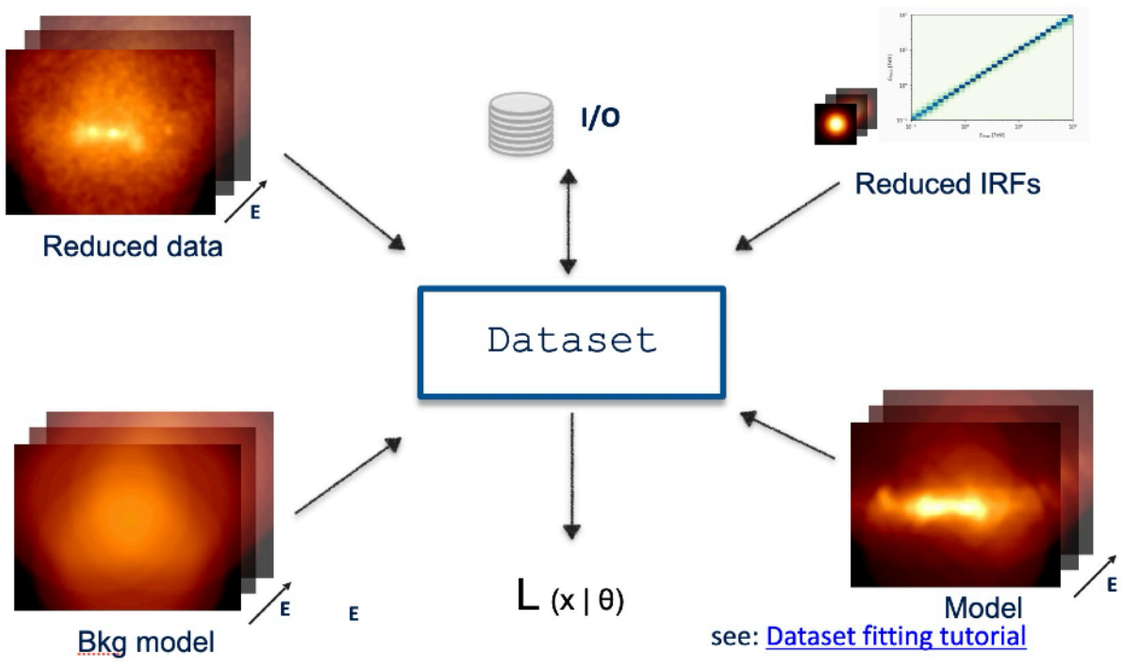
Model

see: [Dataset fitting tutorial]

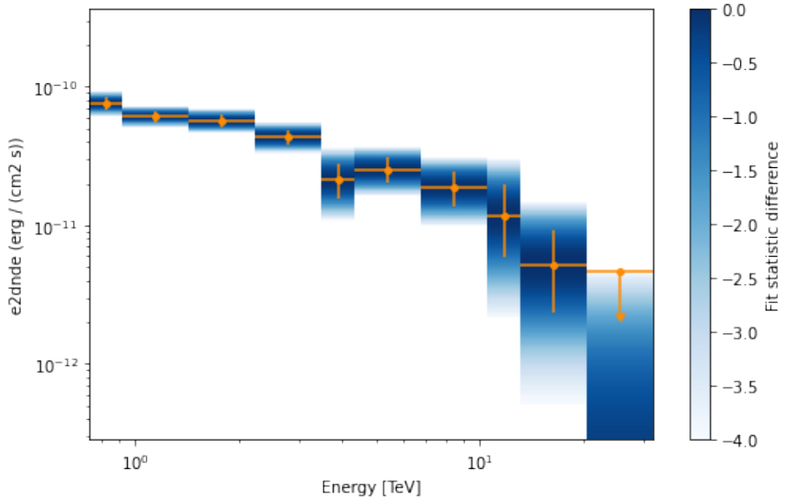
From DL4 to DL5

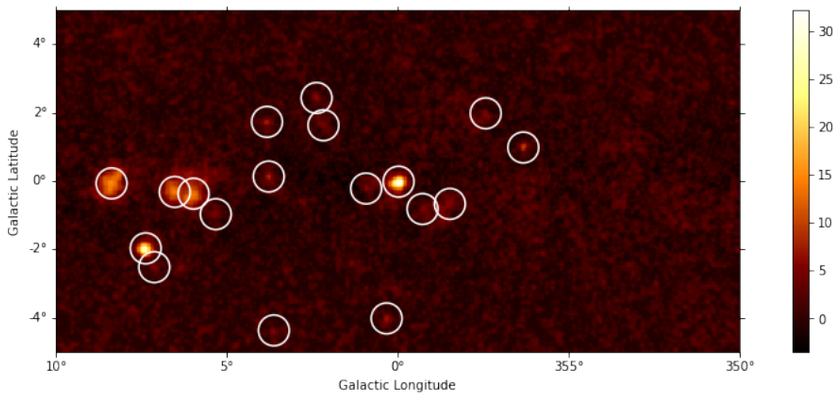
Estimators

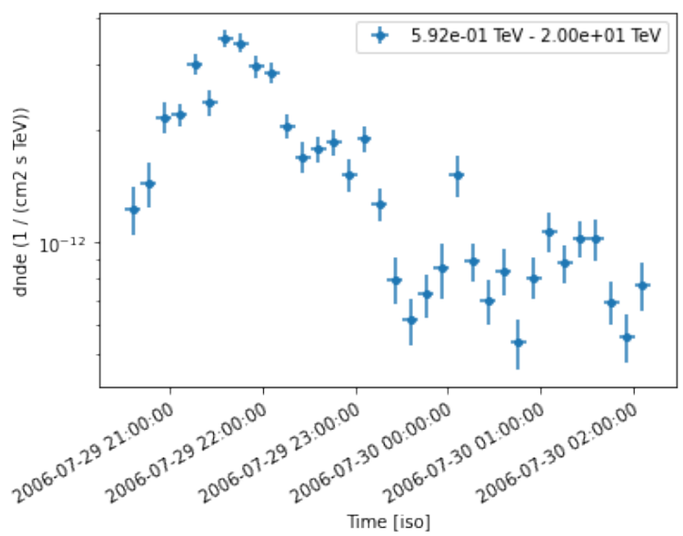
- FluxPointEstimator
- TSMapEstimator
- Etc



see: Dataset fitting tutorial

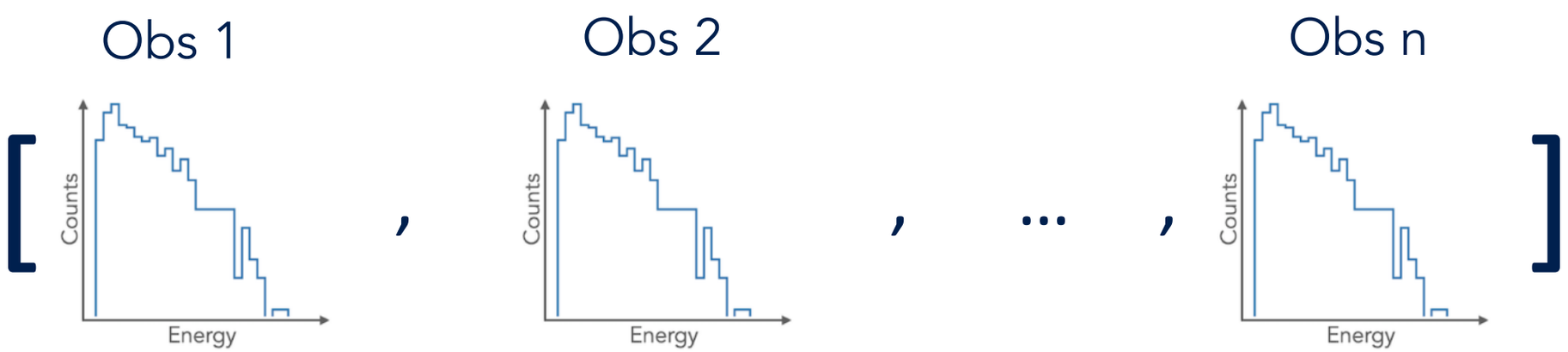




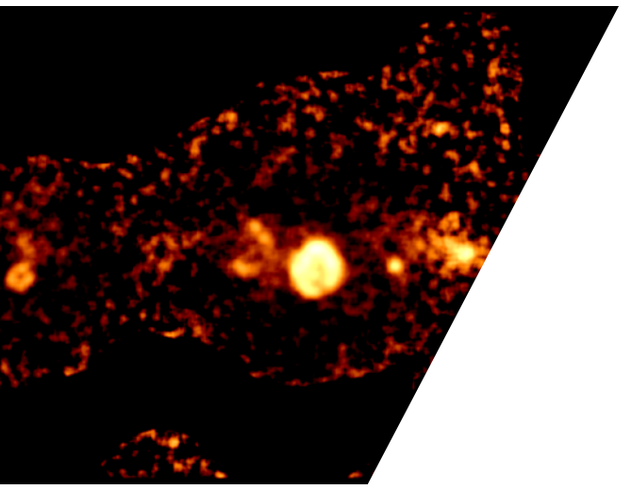


Dataset & Datasets

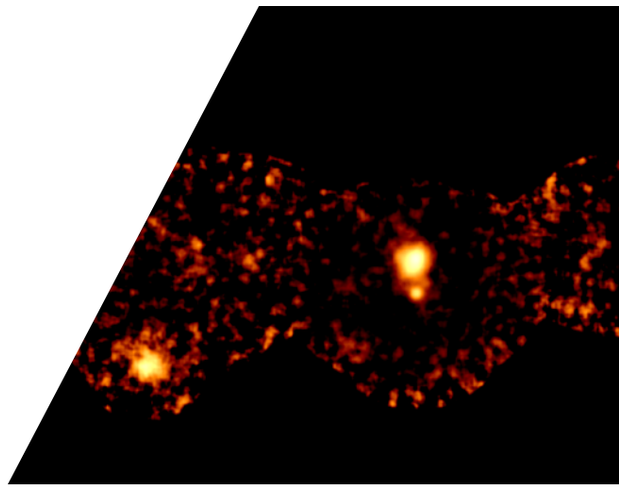
- Apply makers to produce reduced datasets
- Combine them for stacked or joint analysis



Will perform a joint fit with all Dataset. Could be different obs or even different Telescopes (e.g. Fermi + IACT)



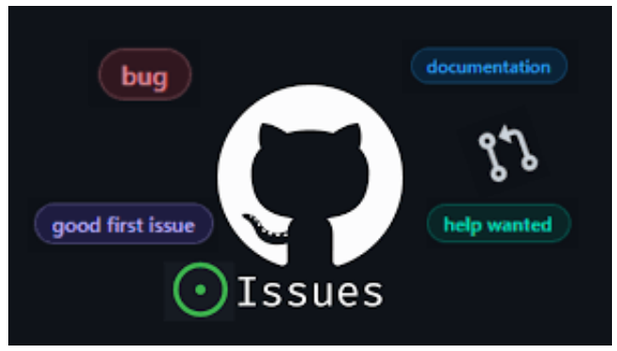
Where to start & get help ?



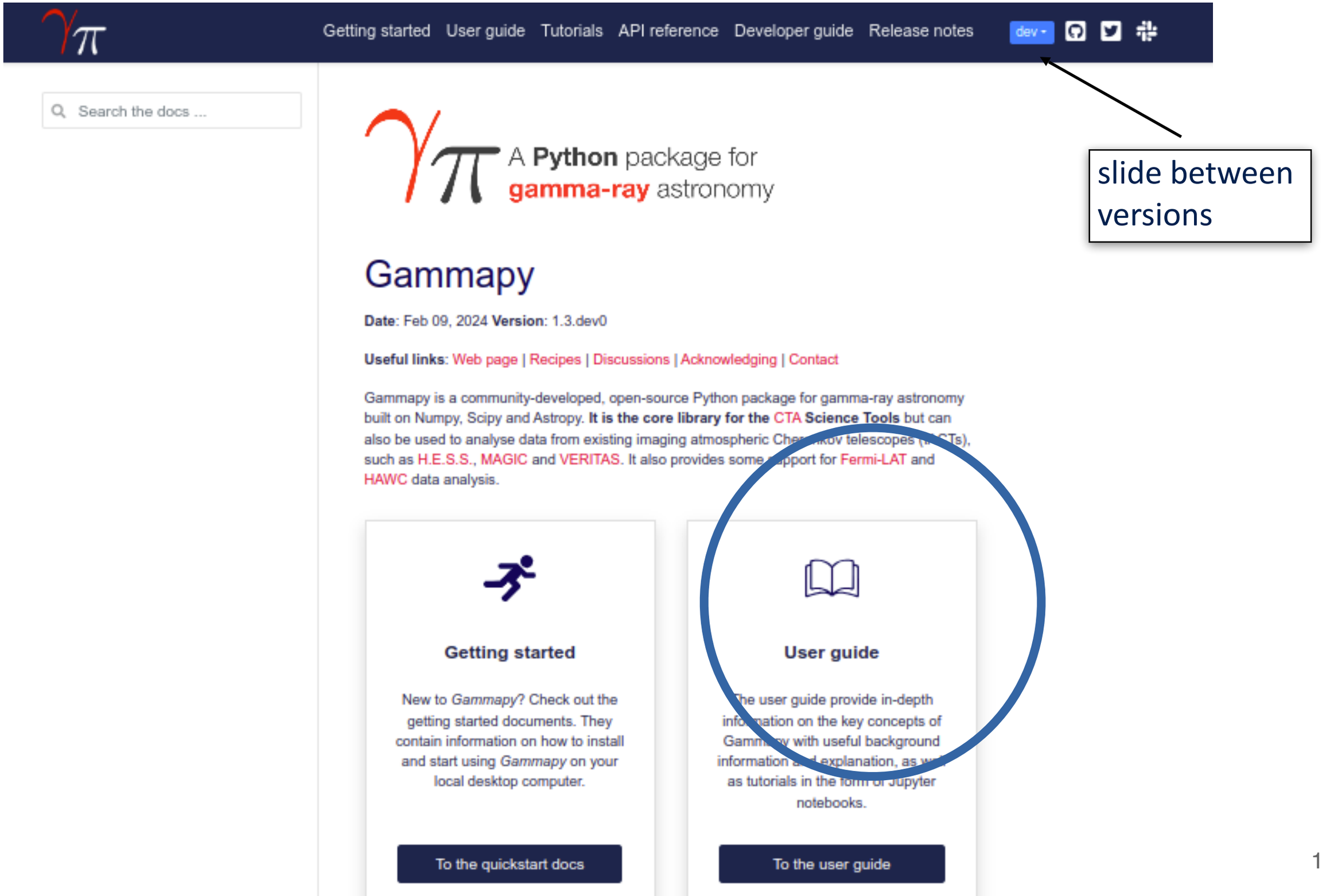
See docs.gammapy.org

Getting help

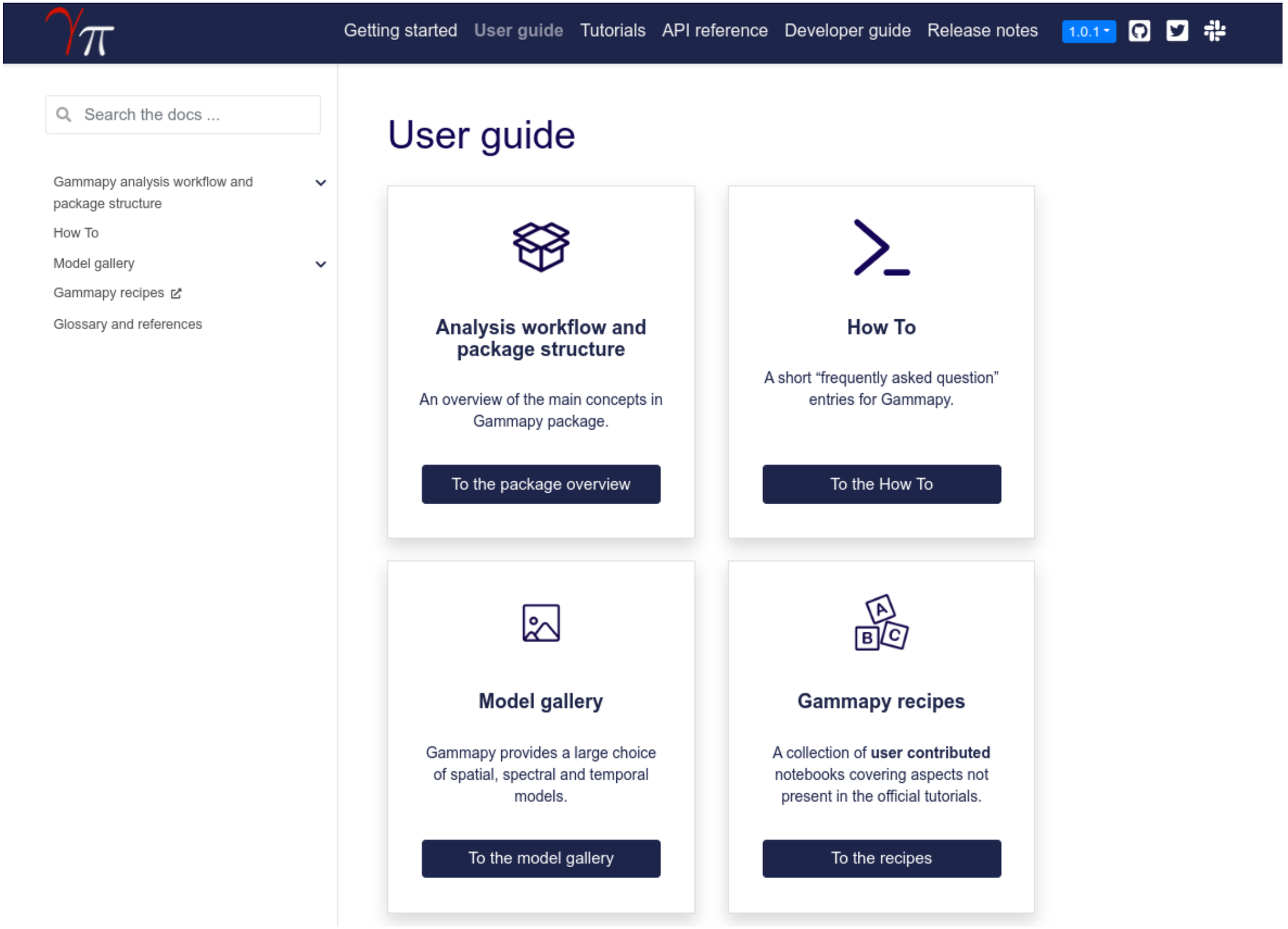
- Where/How to interact with dev team and experienced users, provide feedback, get help:
  - gammapy.slack
    - In particular: #help channel
  - GitHub discussions
    - help category
  - GitHub issues to report bugs or feature requests



Getting started: documentation

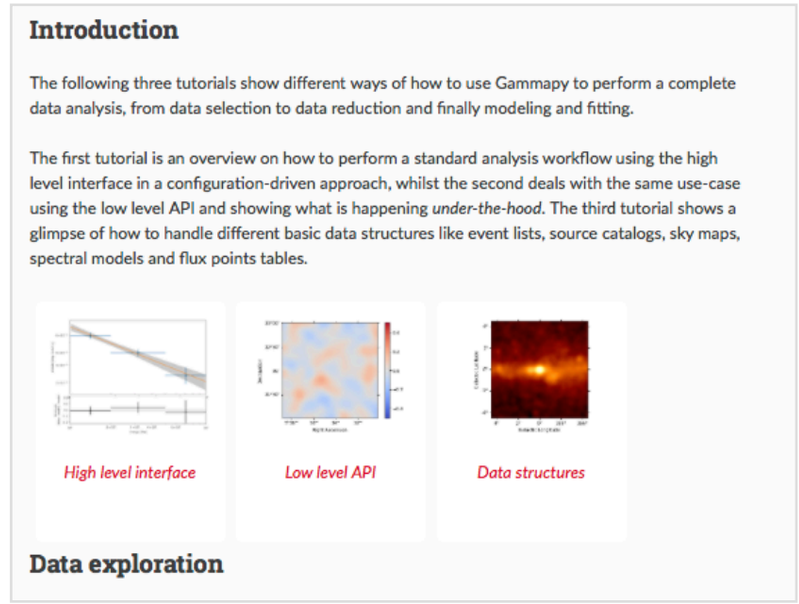


Getting started: documentation

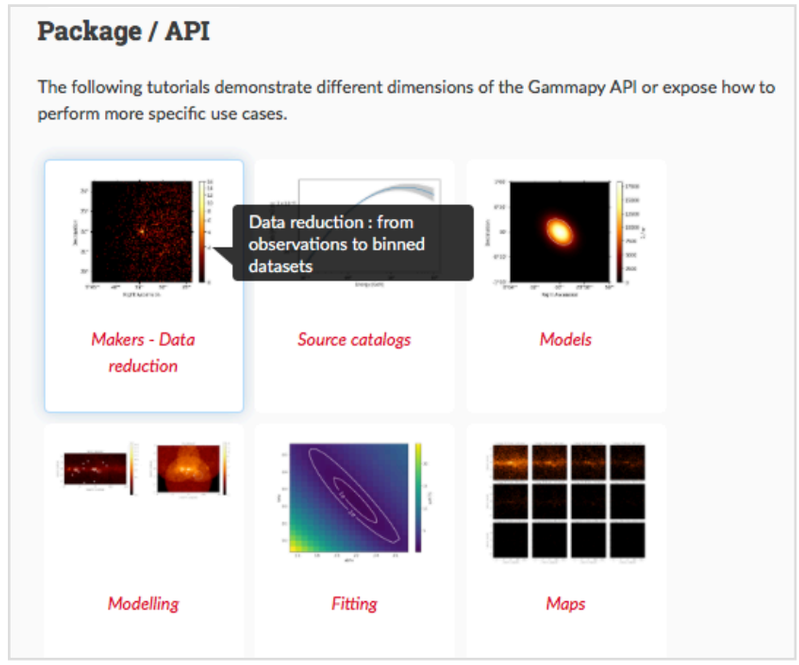


Getting started: documentation

- Learning with examples: the [Tutorials]



- More in depth: the [API description]



Recognition and valorization

PIG 24 - Authorship policy

- Authors: Bruno Khélifi, Thomas Vuillaume
- Created: May 25th, 2022
- Accepted: Oct. 20th, 2022
- Status: accepted
- Discussion: GH 3970

On this page

Abstract

Given that the Gammapy library is more widely used by the community, a proper citation of the project including a policy about the authorship is necessary. This PIG addresses this issue by setting an authorship policy for the Gammapy project for each type of products (releases, papers and conferences).

Gammapy Presentations

A collection of Gammapy presentations given a conferences, including posters ands slides for talks.

Conference	Topics and Material	Contributors
Scipy 2023	Gammapy - slides GH , talk	A. Donath et al.
ICRC 2023	Gammapy - poster	B. khélifi et al.
Gamma2022	Gammapy - talk	A. Sinha et al.
ICRC 2021	Gammapy - poster	A. Donath et al.

Gammapy hands-on sessions and schools

Disclaimer: list under construction! Please, do not hesitate to make a pull requestion in order to add your contribution..

Name	Material and links	Contributors
CTA Hands-on (Granada, 2023)	Hands-on	B. Khélifi, R. Terrier
ASTRI Hands-on (Palermo, 2022)	Hands-on	F. Pintore
ISAPP School (Orsay, 2022)	Hands-on	R. Terrier, F. Acero
CTA Hands-on (Bologna, 2022)	Hands-on	A. Sinha, L. Guinti
Hands-on (KU, 2022)	Hands-on	A. Sinha, R. Terrier
Thai-CTA workshop (Bangkok, 2021)	Hands-on	A. Sinha, B. Khélifi
Hands-on (Vaxjo, 2020)	Hands-on	B. Khélifi
CTA Hands-on (Lugano, 2019)	Hands-on (private)	A. Donath
CTA Hands-on (Berlin, 2018)	Hands-on (private)	A. Donath
CTA Hands-on (Orsay, 2018)	Hands-on (private)	C. Deil, R. Terrier, B. Khélifi
Hands-on (Meudon, 2017)	Hands-on	F. Acero, B. Khélifi
PyGamma15	Hands-on	C. Deil, A. Donath et al.

- Gammapy is a community effort
- Each Gammapy release is an official publication
  - The SWH/ZenodoDOI has an author list.
  - Any contributions makes you an author of the next release.
- Each presentation, hands-on session, school is promoted

Don't hesitate to join the Dev team (#dev in Slack)

How to cite $\gamma\pi$

Acknowledging or Citing gammapy

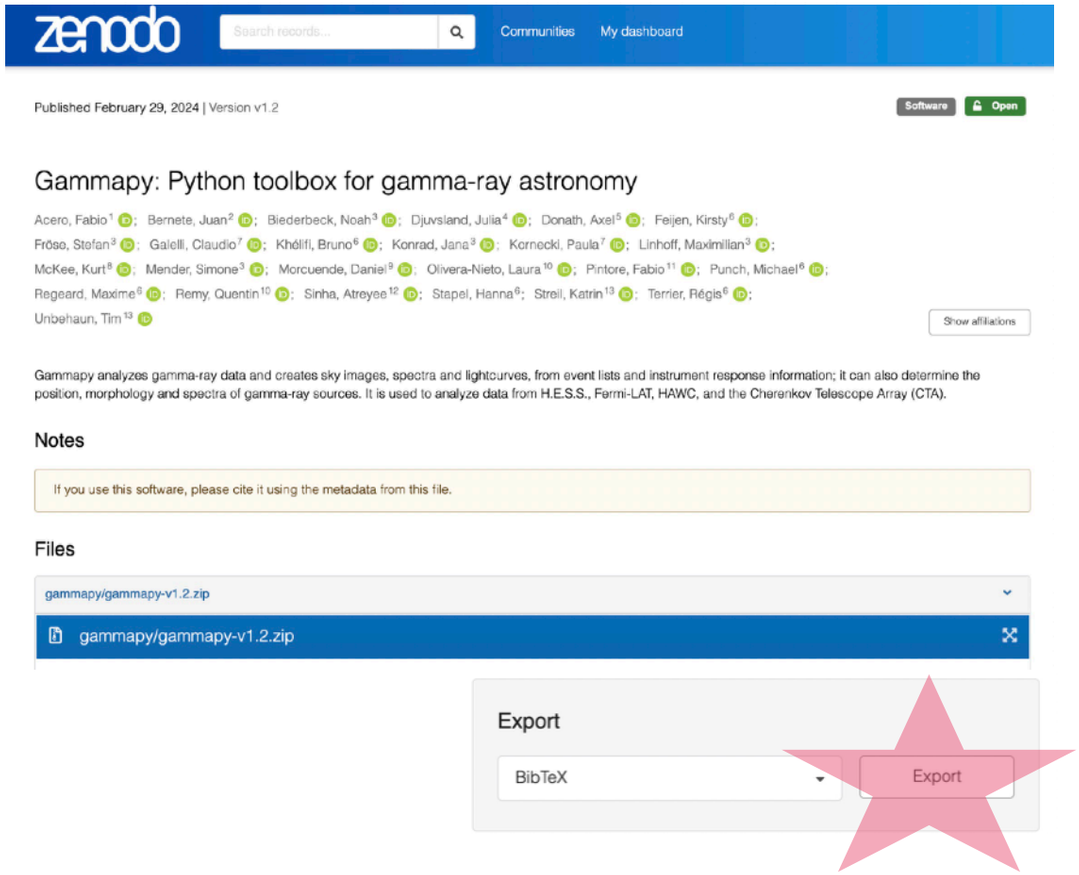
In publications | In presentations | In projects

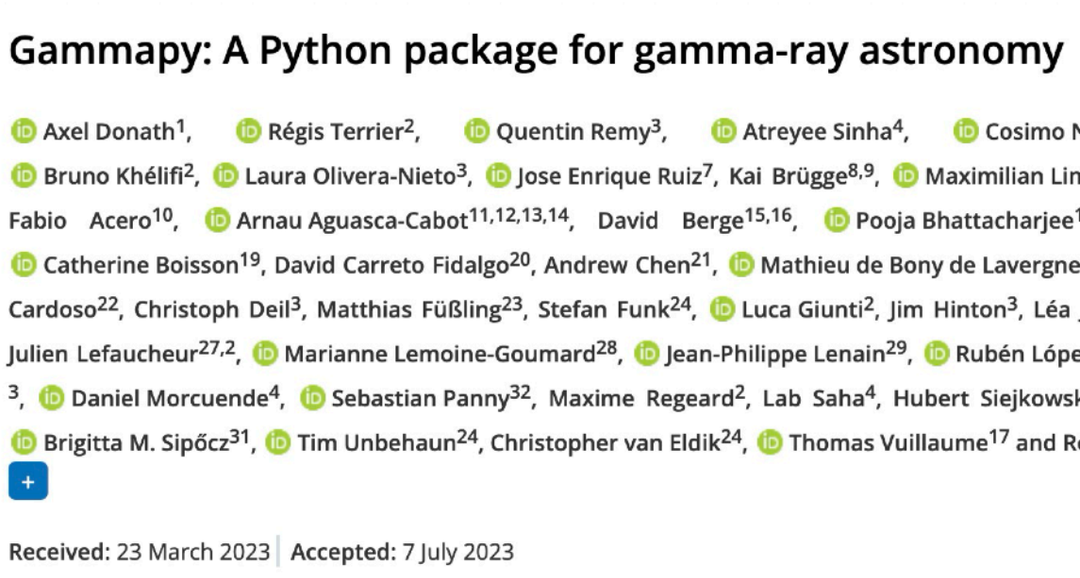
Cite: 1)the paper & 2) the version

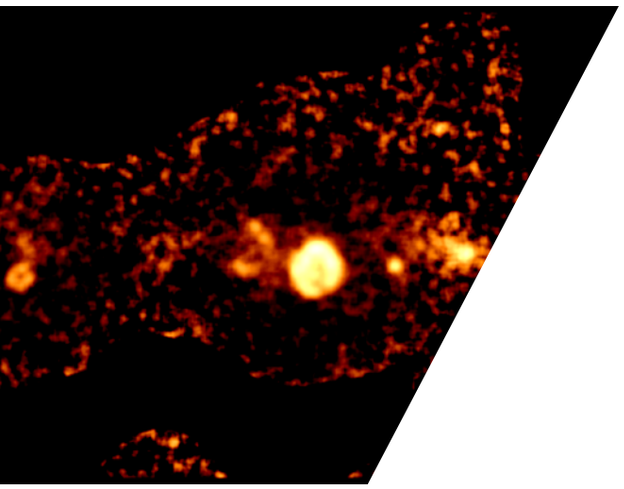
In publications

If you use Gammapy for work or research presented in a publication (whether directly, or as a dependency to another package), we ask you to add two citations to Gammapy:

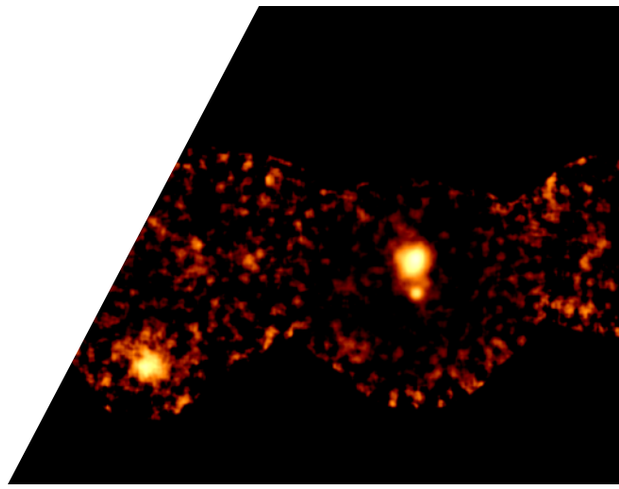
- Gammapy paper in A&A (as a general citation) Copy BibTeX to clipboard
- Gammapy on Zenodo (with the specific version used) - e.g. for the v1.2: Copy BibTeX to clipboard







Next sessions...



Today's agenda

Mix of presentation, analysis hands on, open problems:

I. Introduction to gammapy and concepts

II. Data handling & IRFs and 1D analysis

III. 3D analysis concepts & Minimization pitfalls

IV. 3D analysis

V. - - - LUNCH - - -

VI. Source simulation

VII. Open problems : Simulations, light curves, source catalog

VIII. Multi-instrument joint fit

Backup slides