ESCAPE

European Science Cluster of Astronomy &
Particle physics ESFRI research Infrastructures

Gammapy: a Python Package for Gamma-Ray Astronomy

CTA
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E-OSSR Onboarding Presentation
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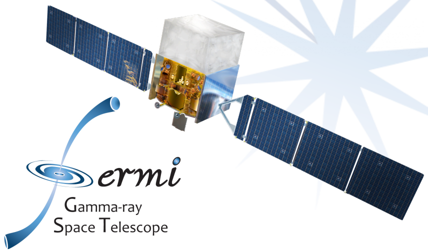
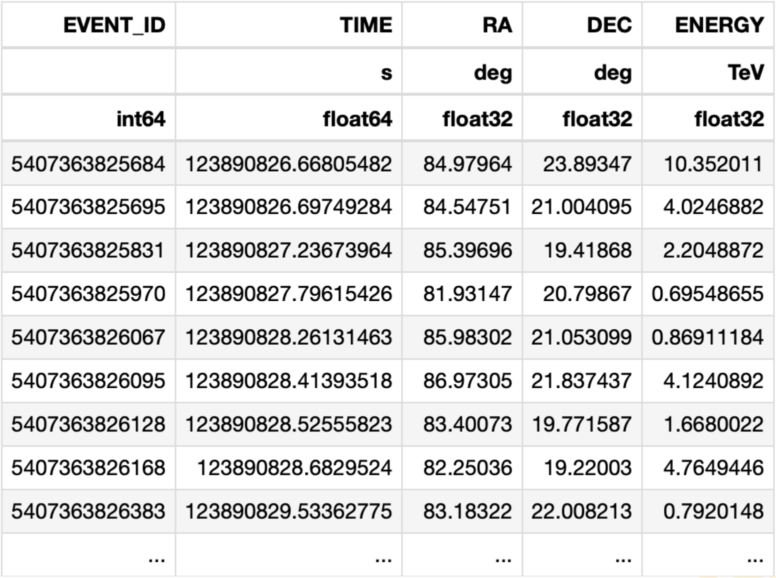
Introduction

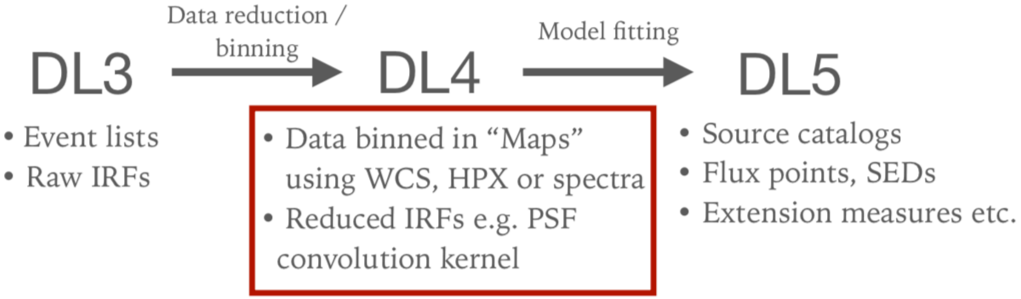
…oversimplified…





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
...	...	...	...	...

- **Scientific goal:** combine data of different instruments to cover wider energy ranges and better restrict (spectral) measurements.
- **General goals:** share common approaches, avoid duplicated efforts and bring the community of gamma-ray astronomers together.



DL3 → Data reduction / binning → DL4 → Model fitting → DL5

DL3
- Event lists
- Raw IRFs

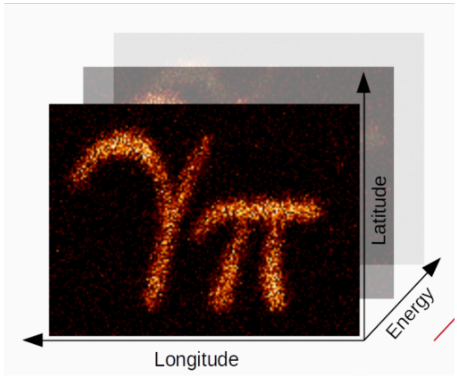
DL4
- Data binned in “Maps” using WCS, HPX or spectra
- Reduced IRFs e.g. PSF convolution kernel

DL5
- Source catalogs
- Flux points, SEDs
- Extension measures etc.

After reconstruction of the primary events and background rejection (gamma-hadron separation) the structure of the data of all Gamma- Ray counting experiments / observatories is the essentially the same

Introduction: DL3 data formats

- Basically an adaption / extension of the existing Fermi-LAT formats for Imaging Atmospheric Cherenkov Telescopes
- An effort to define common DL3 data-formats for gamma-ray astronomy based on FITS
- Includes formats for event lists, effective area, energy resolution and point spread function as well as instrumental background
- A prototype data format for CTA
- Also partly includes DL4 format definitions (e.g. binned sky maps in WCS and HPX)
- https://gamma-astro-data-formats.readthedocs.io
- https://github.com/open-gamma-ray-astro/gamma-astro-data-formats



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Introduction: Gammapy

- Gammapy is a **Python Package for Gamma-Ray astronomy** build on Numpy, Scipy and Astropy
- It builds on unified **DL3 data input formats** derived from Fermi-LAT and extended for Imaging Atmospheric Cherenkov Telescope (IACT) analysis
- Also a **prototype for the CTA science tools**, but developed to be useful for a broader community
- Provides data reduction and visualisation, **model fitting, flux point computation, TS map computation, joint-likelihood analyses**, etc.
- https://github.com/gammapy/gammapy
- https://docs.gammapy.org/0.18.2/
- http://gammapy.slack.com/

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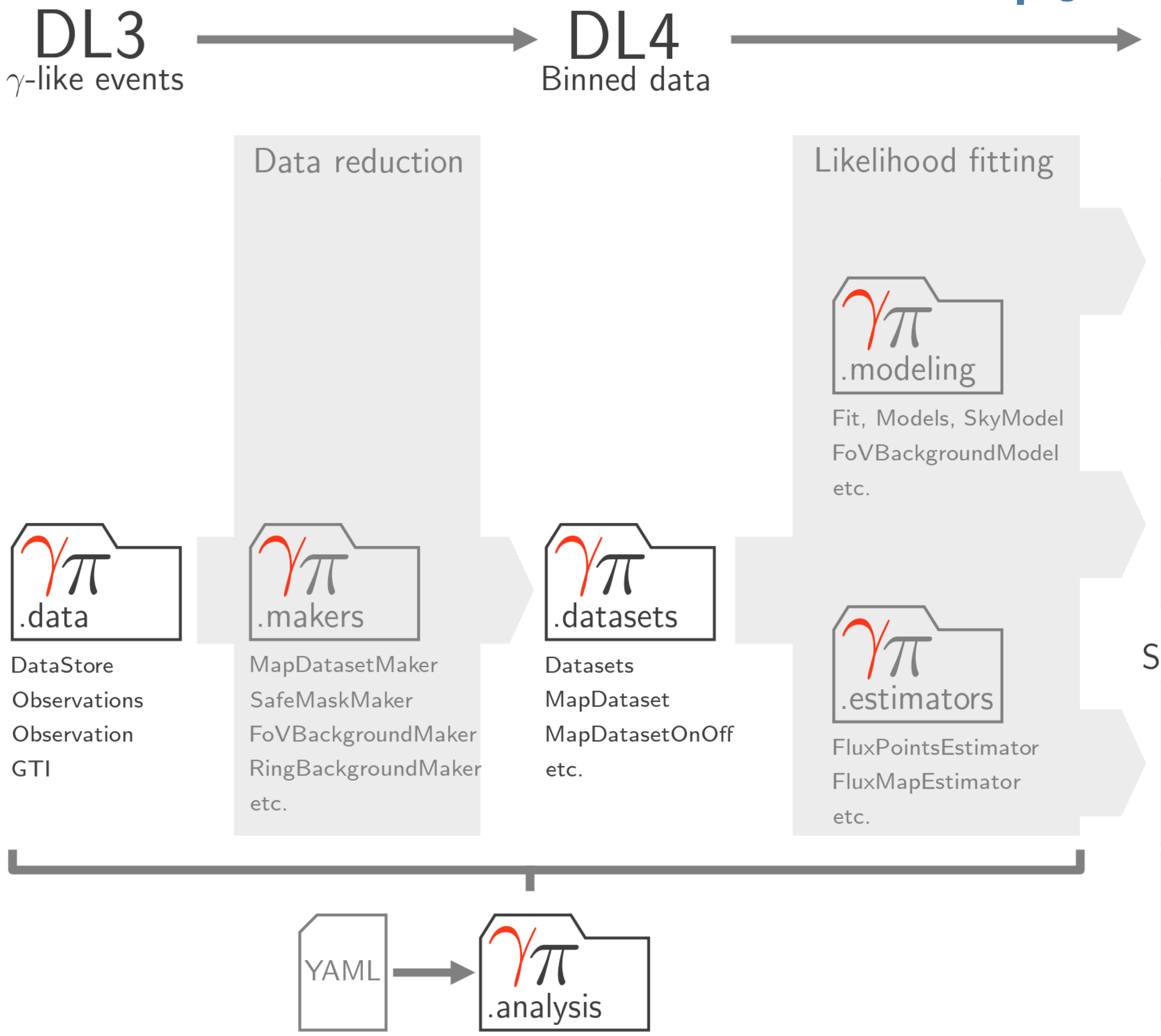
Introduction: Gammapy Overview



DL3
γ-like events

DL4
Binned data

Data reduction

Likelihood fitting

.data
DataStore
Observations
Observation
GTI

.makers
MapDatasetMaker
SafeMaskMaker
FoVBackgroundMaker
RingBackgroundMaker
etc.

.datasets
Datasets
MapDataset
MapDatasetOnOff
etc.

.modeling
Fit, Models, SkyModel
FoVBackgroundModel
etc.

.estimators
FluxPointsEstimator
FluxMapEstimator
etc.

YAML

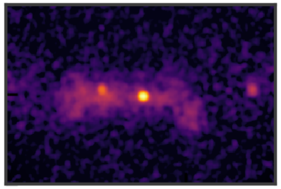
.analysis

DL5
Science products

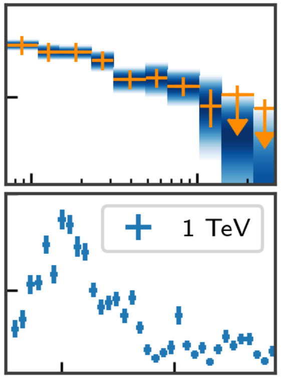
Source Catalogs

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

Flux & TS Maps



SEDs & Lightcurves



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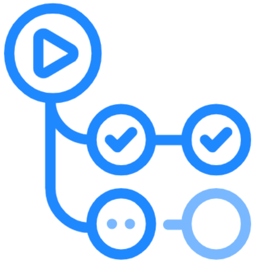
Gammapy Development

- Openly developed on GitHub: https://github.com/gammapy/gammapy, using standard **"multi branch GitHub" workflow**: new features are developed on the side in branches and merged via pull request (PR) into the master branch
- Each **PR is reviewed** by a more experience developer
- **Continuous integration** via GitHub actions: testing of each PR
- Automatic **build and deployment of docs** in https://github.com/gammapy/gammapy-docs
- **Validation and benchmarks** run daily: https://github.com/gammapy/gammapy-benchmarks
- Licensed under **BSD3**



GitHub Actions

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Gammapy Development

- Uses **pytest for testing** and **sphinx for documentation**
- "black" as an automatic code formatting tool
- "Proposal for Improving Gammapy" (PIG) system just like PEP for larger development projects
- Gammapy developer meeting and **co-working day** every Fridays, **co working weeks and coding sprints**
- Regular release cycle of ~2 months, currently a bit less…
- Currently only minor versions, started to do bug fix releases as "training", **working towards a LST v1.0** version

Gammapy Requirements

- Operating System, compilation environment
  - Linux, MacOS, Windows (with slightly limited optional functionality), Python 3, pip package, conda package
- Hardware requirements
  - **No particular hardware** requirements, customer type laptop / desktop pc, cluster, currently no support for parallelisation / GPU (but to be expected…)
- Containerisation and portability requirements
  - Available as conda package, possibly docker containers
- Workflow / interface requirements to other software/services
  - Standardised **FITS based input DL3 data formats**, Python interface to the scientific Python ecosystem

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OSSR Integration

- What is available?
  - Source code, pip package, conda package, tutorials, test data
- What will be on-boarded (source code, container, test workflow incl. data)?
  - Source code, pip package, conda package?, tutorials, test data?, possibly container
- Are there open points and requirements?
  - Would need to check how the test data is licensed and limited in re-use…certainly data associated with ESFRIs should work…

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OSSR Integration

- What is the user story?
  - Any counts based data, that can be brought into the "DL3" data model can be analysed, this typically includes gamma-ray data, but has already been done with x-ray or neutrino data as well
  - In addition any kind of SED data can be included, e.g. radio flux points and combined on a likelihood level
  - It natively allows to combine data form different instruments using a "joint likelihood" approach, so e.g. joint data analysis of multiple gamma-ray instruments but neutrino data as well
  - Analysis requires physical models, such as provided by agnpy
  - Compute Gamma-ray flux points with "exported" likelihoods ("likelihood profiles"), that can again be combined with e.g. Radio data in SED likelihood fits…

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Time for a short demo (~10 min)

- Notebooks / tutorials available on Binder, e.g.:
  - CTA data exploration with Gammapy
  - CTA data analysis with Gammapy
- Start screen share…

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Open Points and Discussion Time

- In the Gammapy community there were some concerns on “diluting” citations, if there were both a Paper and Zenodo DOIs. Comments?

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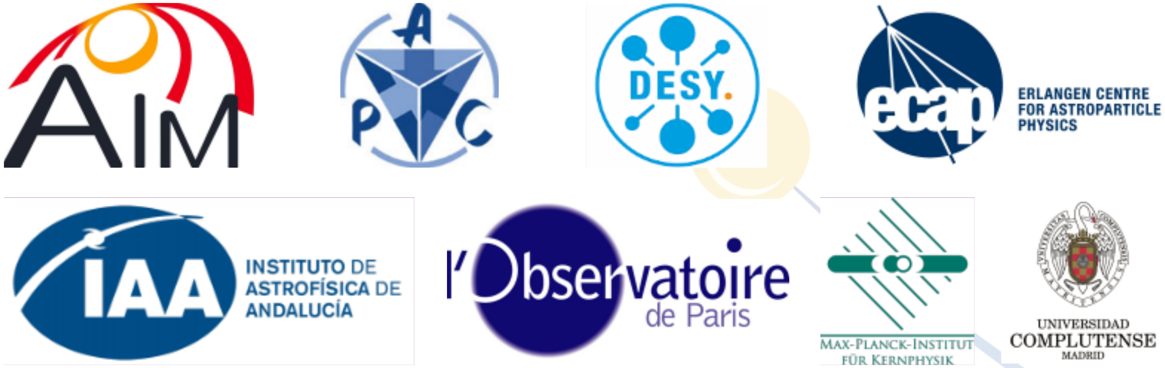
Institutes involved in Gammapy…


AIM
APC
DESY.
ecap
ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS
IAA
INSTITUTO DE ASTROFÍSICA DE ANDALUCÍA
l'Observatoire de Paris
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