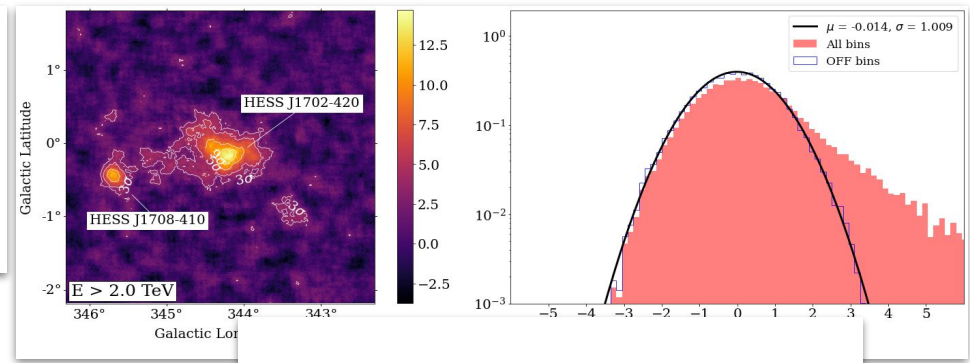
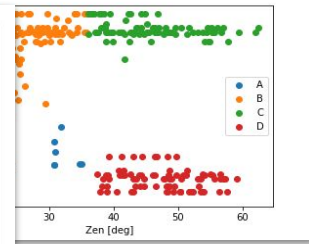
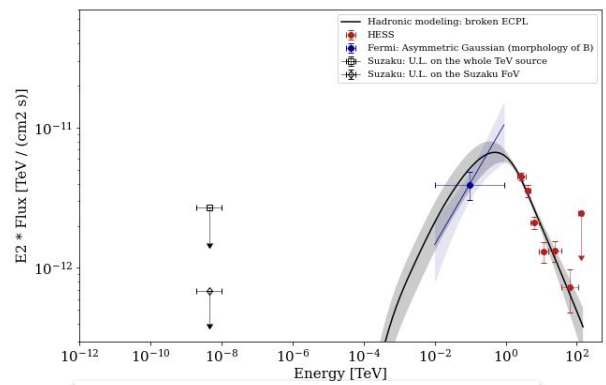


HESS J1702-420 analysis: implications for gamma

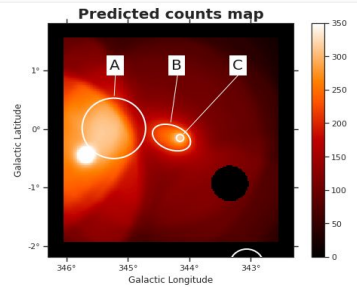
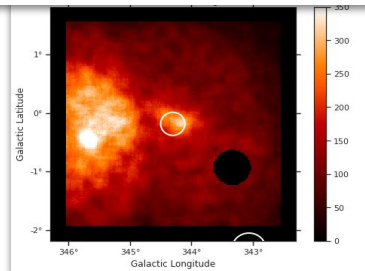
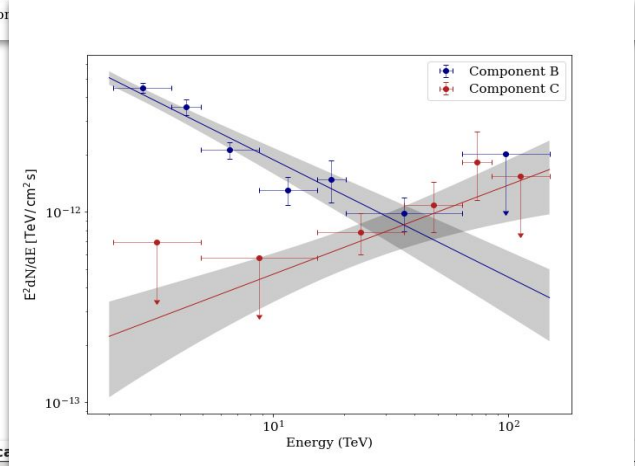
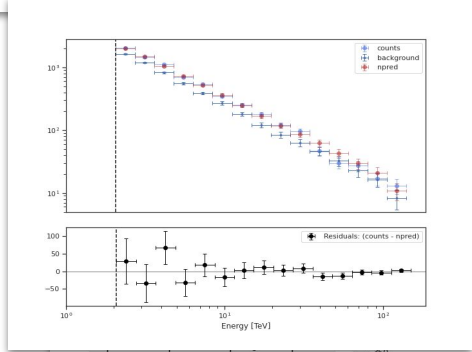
lgianti@apc.in2p3.fr

6/07/2020

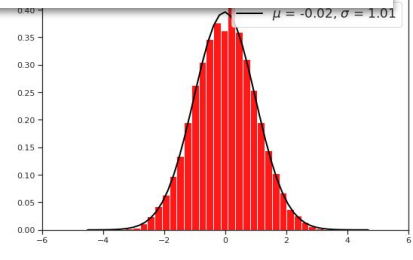
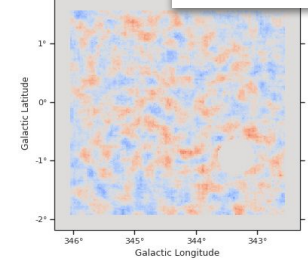




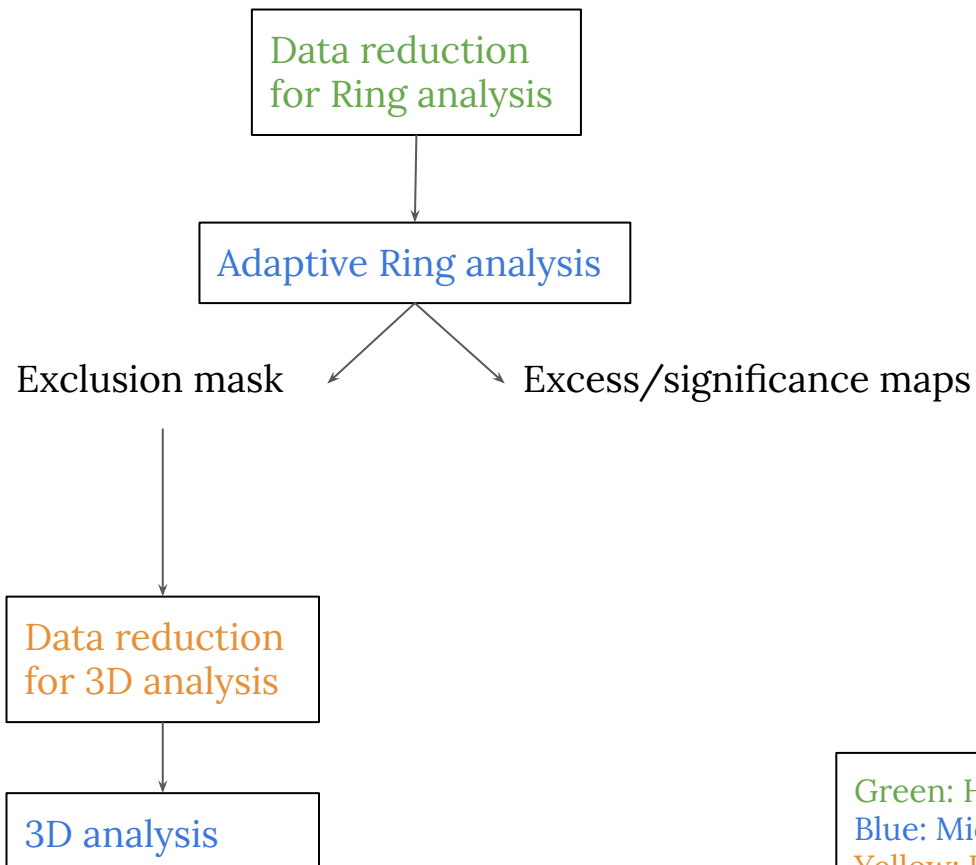
It works!



Residuals significance



Workflow

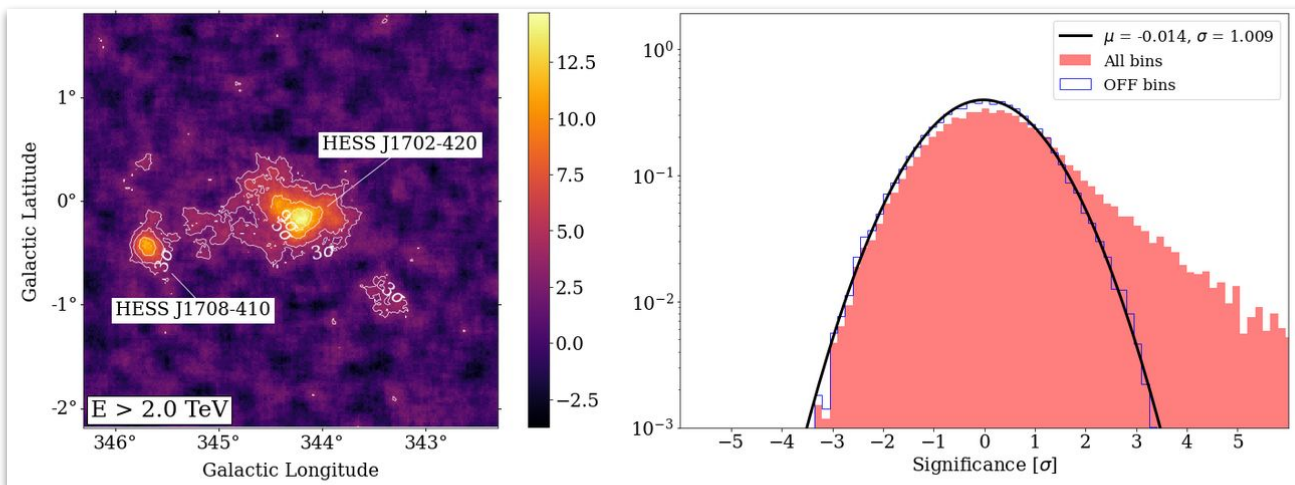
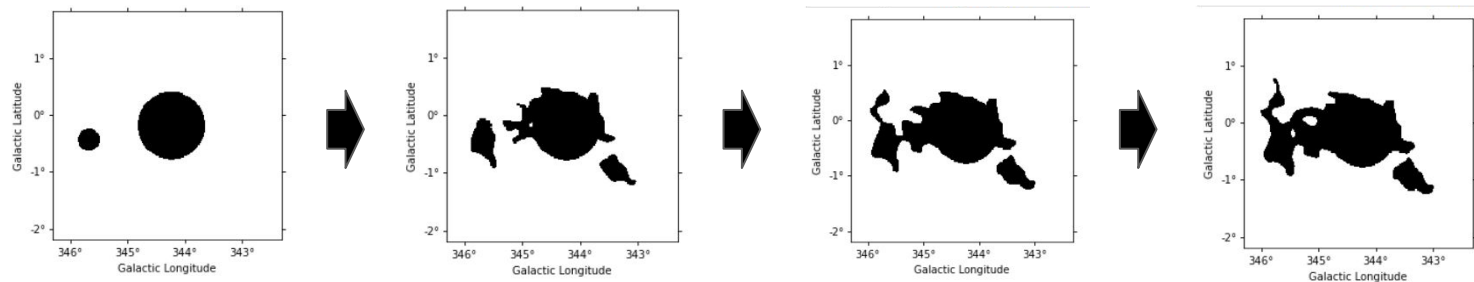


Green: HLI
Blue: Middle-level API
Yellow: Both

Gammapy version: 0.17

Ring analysis

Exclusion mask production: Iterative procedure (`skimage.filters.apply_hysteresis_threshold`)



3D analysis: Data reduction

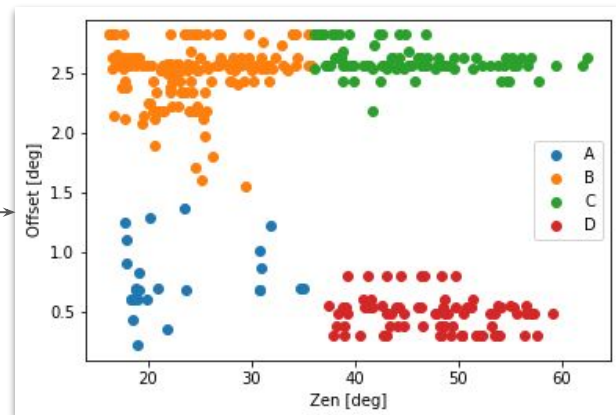
HLI

Use config to select observations (360) and display Offset-Zenith distribution.

Based on the Offset-Zenith distribution, define “bins” of runs with similar conditions

For each “bin”, create a config and run data reduction (`get_datasets()`):

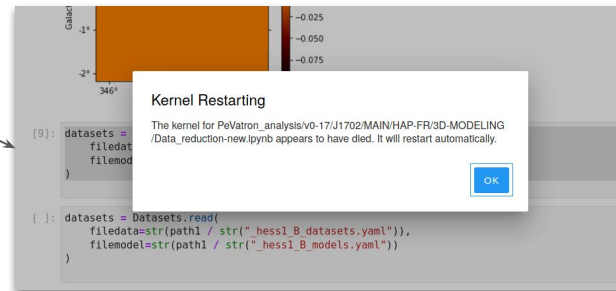
- No `FoVBackgroundMaker`, because energy range cannot be configured
- No stacking yet: **18.3 Gb of data**



Middle-level
API

Step out of the HLI:

- Run `FoVBackgroundMaker` using:
 - exclusion mask from Ring analysis
 - $E_{\min} = 2 \text{ TeV}$
- Stack within each bin, to end up with only 4 datasets. Create a `Datasets` and store: **150 Mb of data**



3D analysis

Workflow:

- Load the reduced datasets: `datasets = Datasets.read(...)`
- Iteratively add source components and fit. At the Nth iteration step:
 - Create a copy of the (Nth-1) Datasets: `datasets_N = datasets_N-1.copy()`
 - Append an additional model component
 - Fit ($E_{\min}=2$ TeV)
 - Check fit results:
 - Fitted parameters
 - TS
 - Spatial residuals
 - Spectral residuals
 - Store Datasets

Check fitted parameters

```
dataset_joint.models.parameters.to_table().show_in_browser()
```



name	value	unit	min	max	frozen	error
norm	9.955e-01		0.000e+00	nan	False	1.579e-02
tilt	0.000e+00		nan	nan	True	0.000e+00
reference	1.000e+00	TeV	nan	nan	True	0.000e+00
index	3.158e+00		2.158e+00	4.158e+00	False	2.181e-01
amplitude	1.026e-13	cm-2 s-1 TeV-1	1.027e-14	1.027e-12	False	1.389e-14
reference	2.523e+00	TeV	nan	nan	True	0.000e+00
lon_0	3.457e+02	deg	3.456e+02	3.458e+02	False	1.157e-02
lat_0	-4.486e-01	deg	-5.688e-01	-3.688e-01	False	1.175e-02
sigma	6.058e-02	deg	0.000e+00	nan	False	1.095e-02
e	0.000e+00		0.000e+00	1.000e+00	True	0.000e+00
phi	0.000e+00	deg	nan	nan	True	0.000e+00
index	2.170e+00		nan	nan	True	0.000e+00
amplitude	1.230e-12	cm-2 s-1 TeV-1	0.000e+00	nan	True	0.000e+00
reference	1.700e+00	TeV	nan	nan	True	0.000e+00
lon_0	3.431e+02	deg	nan	nan	True	0.000e+00
lat_0	-2.330e+00	deg	-9.000e+01	9.000e+01	True	0.000e+00
sigma	2.790e-01	deg	0.000e+00	nan	True	0.000e+00
e	0.000e+00		0.000e+00	1.000e+00	True	0.000e+00
phi	0.000e+00	deg	nan	nan	True	0.000e+00
index	2.370e+00		1.372e+00	3.372e+00	False	7.422e-02
amplitude	8.133e-14	cm-2 s-1 TeV-1	8.160e-15	8.160e-13	False	9.890e-15
reference	6.514e+00	TeV	nan	nan	True	0.000e+00
lon_0	3.452e+02	deg	3.448e+02	3.458e+02	False	6.345e-02
lat_0	1.318e-02	deg	-4.000e-01	2.000e-01	False	3.982e-02
sigma	5.161e-01	deg	0.000e+00	nan	False	3.466e-02
e	0.000e+00		0.000e+00	1.000e+00	True	0.000e+00
phi	0.000e+00	deg	nan	nan	True	0.000e+00
index	2.616e+00		1.617e+00	3.617e+00	False	9.896e-02
amplitude	5.933e-13	cm-2 s-1 TeV-1	5.938e-14	5.938e-12	False	4.558e-14
reference	2.672e+00	TeV	nan	nan	True	0.000e+00
lon_0	3.443e+02	deg	3.438e+02	3.451e+02	False	2.501e-02
lat_0	-1.451e-01	deg	-6.837e-01	3.163e-01	False	1.431e-02
sigma	3.245e-01	deg	0.000e+00	nan	False	2.128e-02
e	7.740e-01		0.000e+00	1.000e+00	False	4.803e-02
phi	6.697e+01	deg	0.000e+00	1.800e+02	False	5.379e+00
index	1.533e+00		5.359e-01	2.536e+00	False	1.877e-01
amplitude	1.189e-15	cm-2 s-1 TeV-1	1.189e-16	1.189e-14	False	2.810e-16
reference	2.453e+01	TeV	nan	nan	True	0.000e+00
lon_0	3.441e+02	deg	3.441e+02	3.442e+02	False	1.748e-02
lat_0	-1.515e-01	deg	-2.137e-01	-9.372e-02	False	1.474e-02
sigma	5.931e-02	deg	0.000e+00	nan	False	1.493e-02
e	0.000e+00		0.000e+00	1.000e+00	True	0.000e+00
phi	0.000e+00	deg	nan	nan	True	0.000e+00
norm	9.803e-01		0.000e+00	nan	False	1.172e-02
tilt	0.000e+00		nan	nan	True	0.000e+00
reference	1.000e+00	TeV	nan	nan	True	0.000e+00
norm	9.641e-01		0.000e+00	nan	False	8.876e-03
tilt	0.000e+00		nan	nan	True	0.000e+00
reference	1.000e+00	TeV	nan	nan	True	0.000e+00

Model components

#####

HESS J1708-410

index: (2.9710364662503066 +- 0.15841023187392522) [FREE]
amplitude: (1.8619797723119263e-12 +- 3.536176208244538e-13) 1 / (cm2 s TeV) [FREE]
reference: (1.05 +- 0.0) TeV [FROZEN]
lon_0: (345.67213992172185 +- 0.013078544709577172) deg [FREE]
lat_0: (-0.43528115067396095 +- 0.013364220996865671) deg [FREE]
sigma: (0.08390139461491938 +- 0.013901509522478674) deg [FREE]
e: (0.0 +- 0.0) [FROZEN]
phi: (0.0 +- 0.0) deg [FROZEN]

HESS J1708-443

index: (2.17 +- 0.0) [FROZEN]
amplitude: (1.23e-12 +- 0.0) 1 / (cm2 s TeV) [FROZEN]
reference: (1.7 +- 0.0) TeV [FROZEN]
lon_0: (343.06466288076007 +- 0.0) deg [FROZEN]
lat_0: (-2.3295422521942575 +- 0.0) deg [FROZEN]
sigma: (0.279 +- 0.0) deg [FROZEN]
e: (0.0 +- 0.0) [FROZEN]
phi: (0.0 +- 0.0) deg [FROZEN]

Background models

#####

OnFPk0m2-bkg

norm: (1.0484225008019181 +- 0.015396200082216534) [FREE]
tilt: (0.0 +- 0.0) [FROZEN]
reference: (1.0 +- 0.0) TeV [FROZEN]

t5xknDK_-bkg

norm: (1.0461435036403692 +- 0.010829622060735981) [FREE]
tilt: (0.0 +- 0.0) [FROZEN]
reference: (1.0 +- 0.0) TeV [FROZEN]

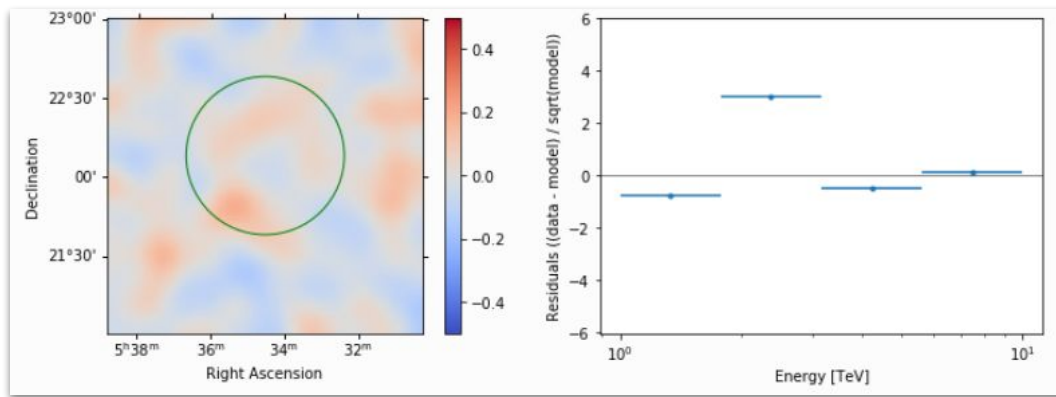
l9_0s7JF-bkg

norm: (1.0629258808313176 +- 0.011399710530649934) [FREE]
tilt: (0.0 +- 0.0) [FROZEN]
reference: (1.0 +- 0.0) TeV [FROZEN]

hQj3mDPd-bkg

norm: (1.0517246730107814 +- 0.007050733340433526) [FREE]
tilt: (0.0 +- 0.0) [FROZEN]
reference: (1.0 +- 0.0) TeV [FROZEN]

MapDataset.plot_residuals()



Limitations:

- `MapDataset.mask_fit` not taken into account. Bad, because I use it to define the fit energy range
- Cannot compute proper residuals significance (cash)
- Don't show position/size of model components, which is crucial to understand what is going on
- Cannot choose an energy range for the residuals computation
- Lack vertical error bars in the spectral residuals plot
- Doesn't work for a joint Datasets. Need to stack beforehand (maybe this is OK, because a Datasets could contain also spectral datasets of flux points...)

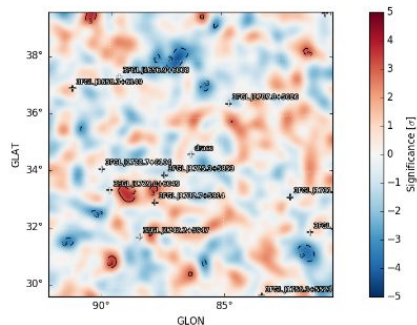
Spatial residuals

What fermipy has? `gta.residmap('res', model=model, make_plots=True)`

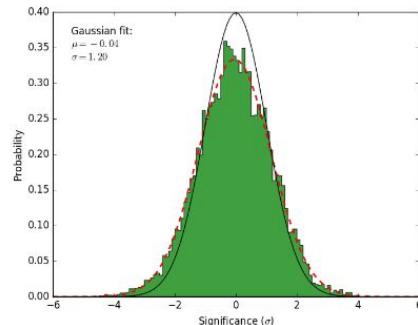
This will generate the following plots:

- `residmap_excess` : Smoothed excess map (data-model).
- `residmap_data` : Smoothed data map.
- `residmap_model` : Smoothed model map.
- `residmap_sigma` : Map of residual significance. The color map is truncated at -5 and 5 sigma with labeled isocontours at 2 sigma intervals indicating values outside of this range.
- `residmap_sigma_hist` : Histogram of significance values for all points in the map. Overplotted are distributions for the best-fit Gaussian and a unit Gaussian.

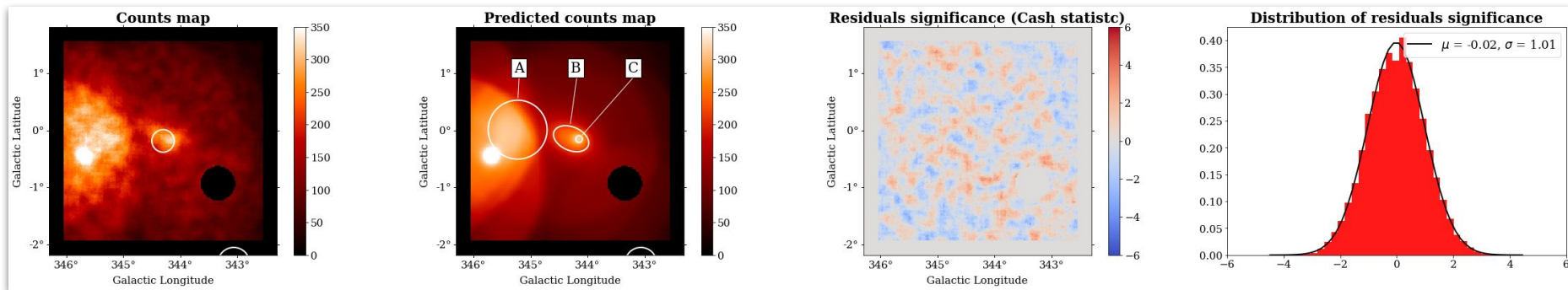
Residual Significance Map



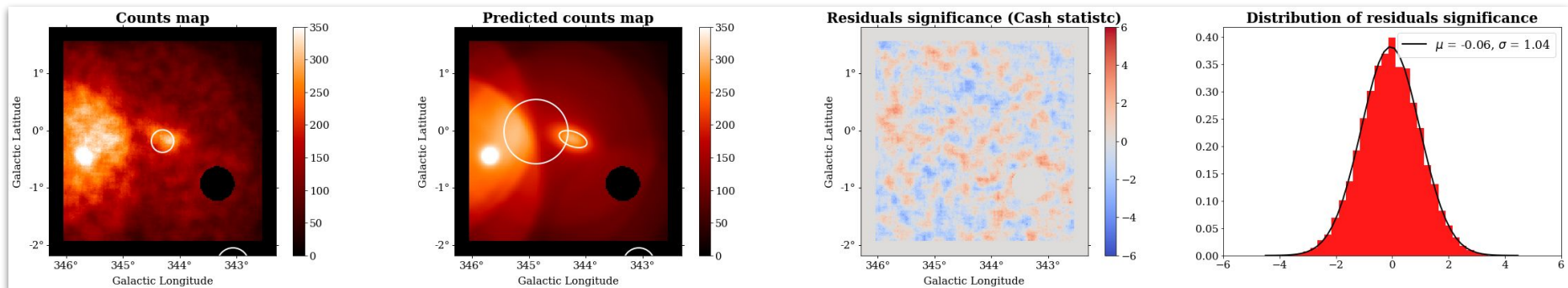
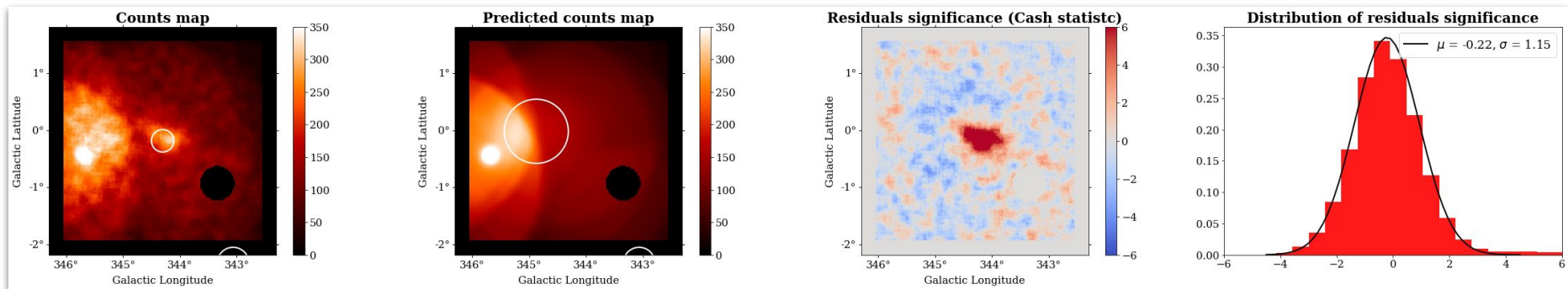
Significance Histogram



Spatial residuals

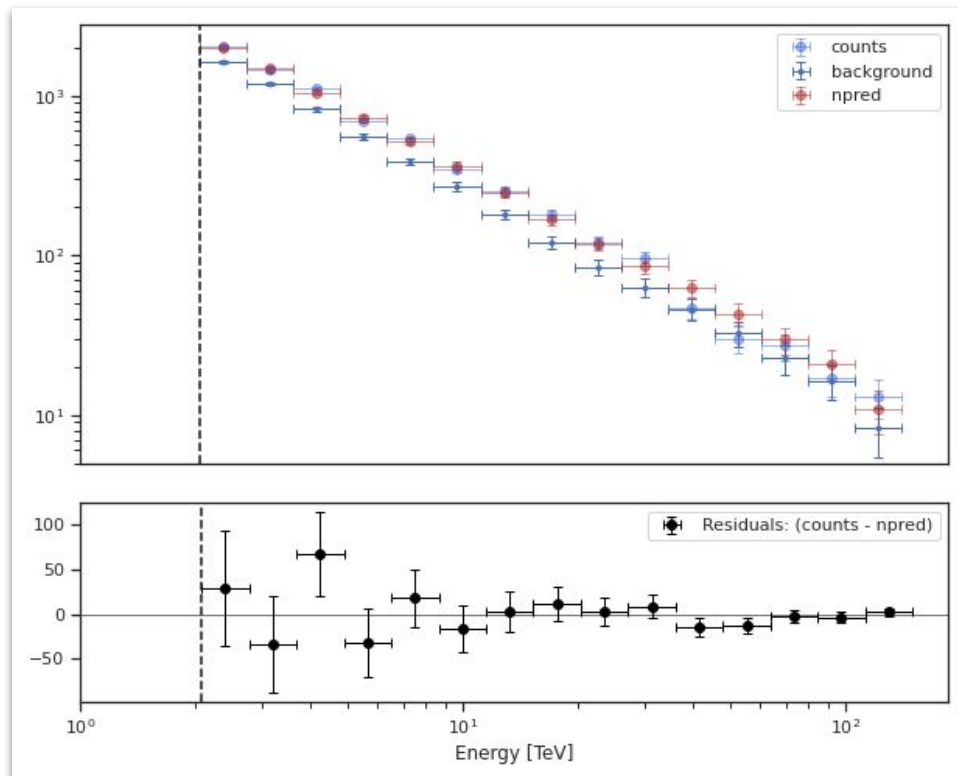


```
plot_spatial_residuals(  
    datasets,  
    vmax=350,  
    vmin=0,  
    vsig=6,  
    emin=2 * u.TeV,  
    emax=20 * u.TeV,  
    corr_radius=0.1 * u.deg  
)
```



Check spectral residuals

```
plot_spectral_residuals(  
    datasets,  
    region=region,  
    method='diff',  
)
```



More logging needed

It would be **very useful** to add a verbose mode for:

- `Fit.stat_profile(...)` → Fitted values of the nuisance parameters?
- `FluxPointsEstimator.run(...)` → Fitted values of the nuisance parameters (typically, bkg norm) in each bin?
- `FoVBackgroundMaker.run(...)` → Fitted norm/tilt values? How many OFF counts were used for the fit?

Why?

- Sometimes the output of these function is useless, without knowledge of the nuisance parameters values
- It is information that is computed in any case, so it wouldn't really cost anything

Summary

- I performed the full analysis from A to Z for the source HESS J1702-420
- I used a mixture of HLI and middle-level API
- In general, this **works really well!**
- I encountered some weaknesses in the workflow at the stage of fit quality assessment

Proposed contributions

- Implement in `gammapy.visualization`:
 - `plot_spatial_residuals(datasets)`
 - `plot_spectral_residuals(datasets)` → Can work also for `SpectrumDataset`
- Add a “verbose”/”debug” option for:
 - `Fit.stat_profile(...)`
 - `FluxPointsEstimator.run(...)`
 - `FoVBackgroundMaker.run(...)`

(Question: The additional info should be logged on screen or stored in arrays?)