Léo Le Moigne

June 6th 2024

***Gammapy* meeting**

- Time dependent Li&Ma -

Time dependent Li&Ma

→ Methods

→ Create new IRFs

→ Simulate DL3 with new IRFs

→ Perform Li&Ma time dependent and compare with classic Li&Ma method

Methods

Li&Ma (likelihood ratio method)

$$L = P\left(N_{ON} \middle| \langle N_{ON} \rangle\right) P\left(N_{OFF} \middle| \langle N_{OFF} \rangle\right) = \frac{e^{-(\bar{s}+\bar{b})T_{ON}}\left((\bar{s}+\bar{b})T_{ON}\right)^{N_{ON}}}{N_{ON}!} \frac{e^{-\bar{b}T_{OFF}}\left(\bar{b}T_{OFF}\right)^{N_{OFF}}}{N_{OFF}!}$$

$$L_0 = P\left(N_{ON} \middle| \langle N_{ON} \rangle\right) P\left(N_{OFF} \middle| \langle N_{OFF} \rangle\right) = \frac{e^{-\bar{b}_0 T_{ON}}\left(\bar{b}_0 T_{ON}\right)^{N_{ON}}}{N_{ON}!} \frac{e^{-\bar{b}_0 T_{OFF}}\left(\bar{b}_0 T_{OFF}\right)^{N_{OFF}}}{N_{OFF}!}$$

Likelihood functions maximized for : $\bar{b}_0 = \frac{N_{ON}+N_{OFF}}{T_{ON}+T_{OFF}} \quad \bar{b} = \frac{N_{OFF}}{T_{OFF}} \quad \bar{s} = \frac{N_{ON}}{T_{ON}} - \frac{N_{OFF}}{T_{OFF}}$

Significance : $\sqrt{TS} = \sqrt{-2\log\left(\frac{L_0}{L}\right)}$

Ori M. Weiner, T.B. Humensky, Reshmi Mukherjee, Marcos Santander, Estimating significance in observations of variable and transient gamma-ray sources, Astroparticle Physics, Volume 93, 2017, Pages 1-7, ISSN 0927-6505

Methods

Li&Ma time dependent

→ divide the ON source time observation T_{ON} into time N bins of equal length Δt

→ arrival time of ON source counts : $\{t_{ON}\}$

→ likelihood : $$L=\left(\prod_{t_i=(\Delta t,\dots,N\Delta t)} \frac{\left(\Delta t\left(b+s\left(t_i\right)\right)\right)^{\{0,1\}}}{\{0,1\}!} e^{-\Delta t\left(b+s\left(t_i\right)\right)}\right)\left(\frac{\left(b\,T_{OFF}\right)^{N_{OFF}}}{N_{OFF}!} e^{-b\,T_{OFF}}\right)$$

product of the probability mass function for each T_{ON} bin (0 or 1 event, for a large N)

probability mass function for OFF observations

Ori M. Weiner, T.B. Humensky, Reshmi Mukherjee, Marcos Santander, Estimating significance in observations of variable and transient gamma-ray sources, Astroparticle Physics, Volume 93, 2017, Pages 1-7, ISSN 0927-6505

Methods

Li&Ma time dependent

→ for the null hypothesis : s(t) = 0 and b = b_0

- likelihood function : $L_0 = \Delta t^{N_{ON}} b_0^{N_{ON}} \frac{\left(b T_{OFF}\right)^{N_{OFF}}}{N_{OFF}!} e^{-\left(N_{ON}+N_{OFF}\right)}$

- background rate maximized by : $b_0 = \frac{N_{ON}+N_{OFF}}{T_{ON}+T_{OFF}}$

Ori M. Weiner, T.B. Humensky, Reshmi Mukherjee, Marcos Santander, Estimating significance in observations of variable and transient gamma-ray sources, Astroparticle Physics, Volume 93, 2017, Pages 1-7, ISSN 0927-6505

Methods

Li&Ma time dependent

→ signal time profile (1 free parameter) : $s(t)=\theta f(t)$

→ assumption for the type profile of the burst f(t) ~ 1/t

- likelihood function : $L=\Delta t^{N_{ON}}\left(\prod_{t_i\in t_{ON}}\left(b+s(t_i)\right)\right)\frac{\left(b\,T_{OFF}\right)^{N_{OFF}}}{N_{OFF}!}e^{-b(T_{ON}+T_{OFF})-\int_{t_{ON}(0)}^{T_{ON}}dt\,s(t)}$

- background rate maximized by : $b=\frac{N_{ON}+N_{OFF}-\int_0^{T_{ON}}dt\,s(t)}{T_{ON}+T_{OFF}}$

Ori M. Weiner, T.B. Humensky, Reshmi Mukherjee, Marcos Santander, Estimating significance in observations of variable and transient gamma-ray sources, Astroparticle Physics, Volume 93, 2017, Pages 1-7, ISSN 0927-6505

Method

Li&Ma time dependent

→ maximize θ with Brent method

→ ratio likelihood test $TS = -2 \log\left(\frac{L_0}{L}\right)$

→ Li&Ma time dependent significance $\sigma = \sqrt{TS}$

Ori M. Weiner, T.B. Humensky, Reshmi Mukherjee, Marcos Santander, Estimating significance in observations of variable and transient gamma-ray sources, Astroparticle Physics, Volume 93, 2017, Pages 1-7, ISSN 0927-6505

Create new IRFs

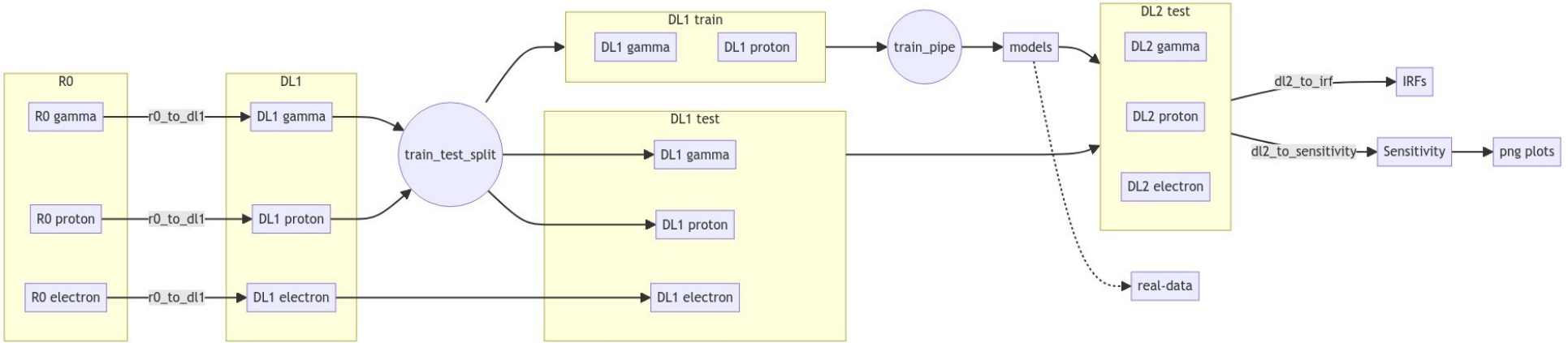
Production : 20200629_prod5_trans80 (old MC !)

→ gamma diffuse

→ background with protons and electrons

} Full enclosure

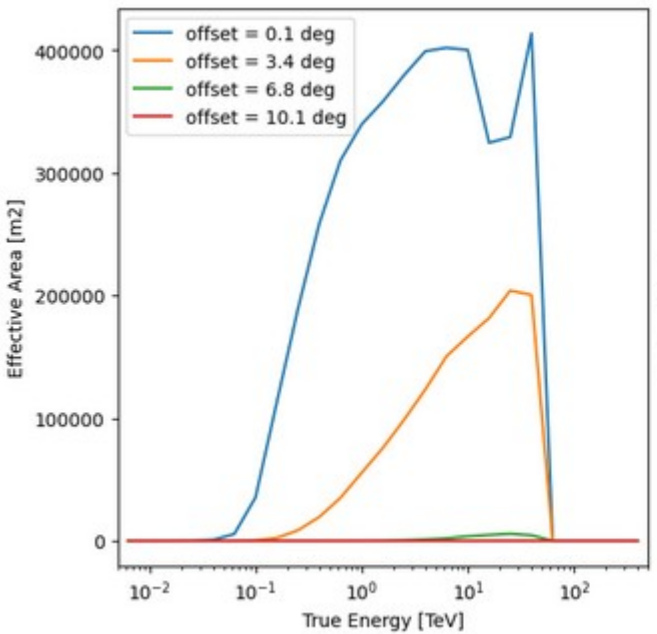
No existing IRFs with lstchain v0.10.5

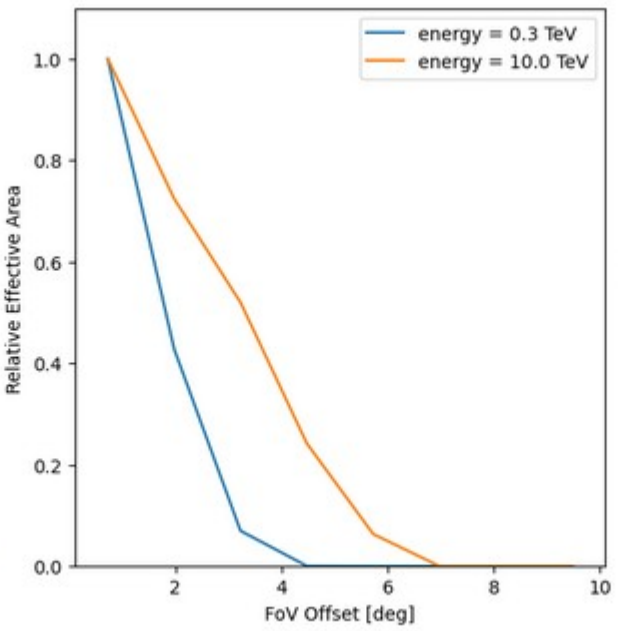


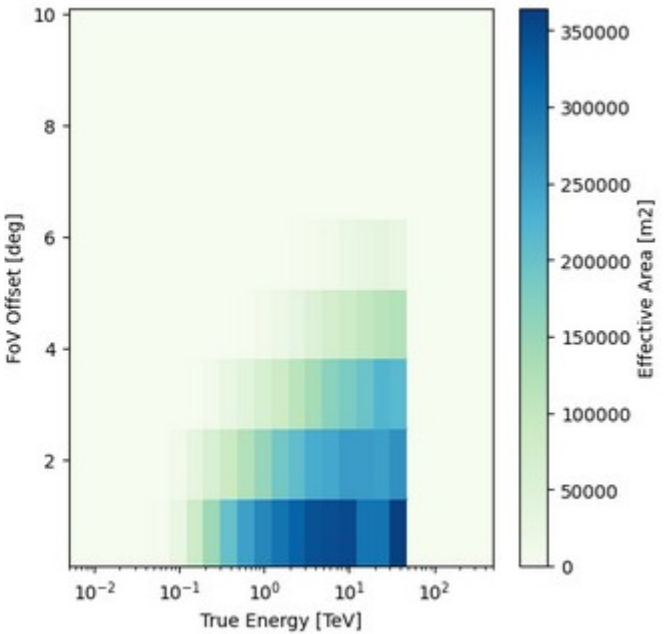
https://cta-observatory.github.io/lstmcpipe/pipeline.html#prod3-prod5-pipelines

Create new IRFs

Effective area

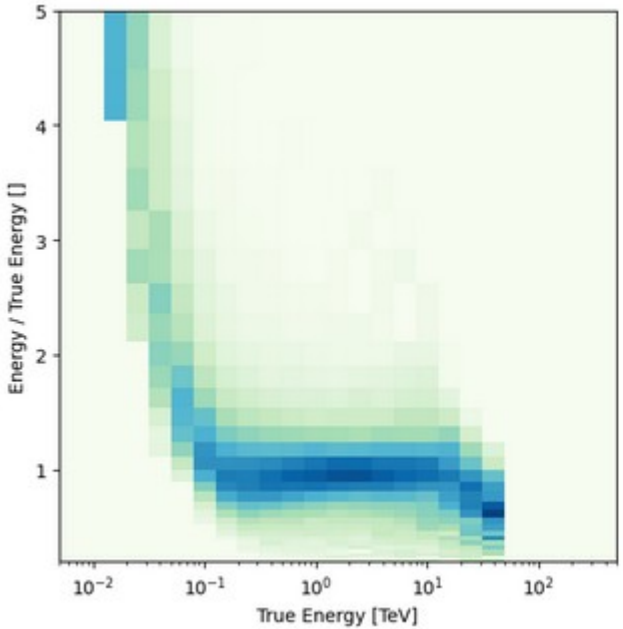


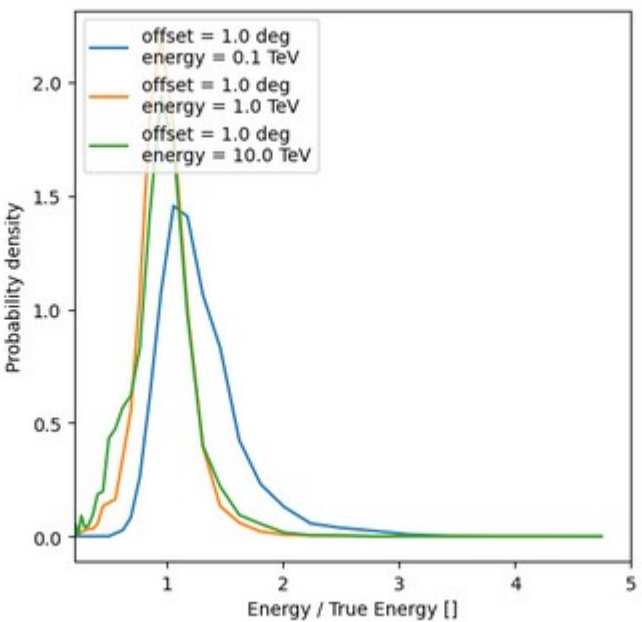


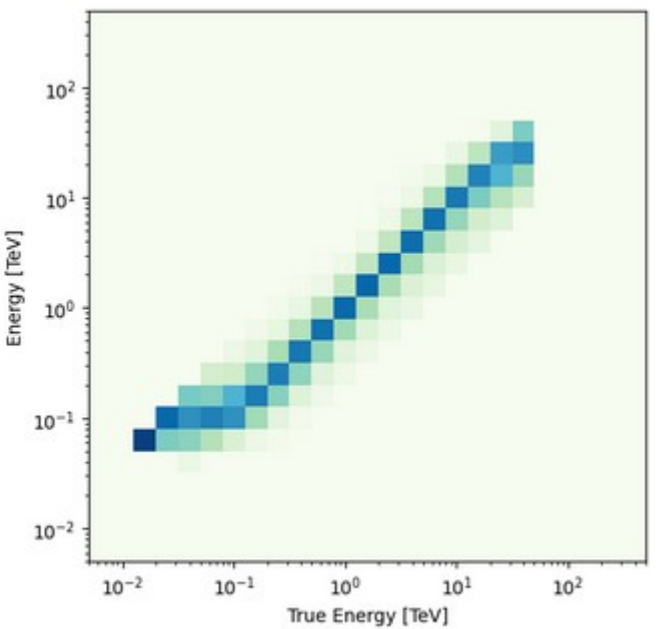


Create new IRFs

Energy dispersion

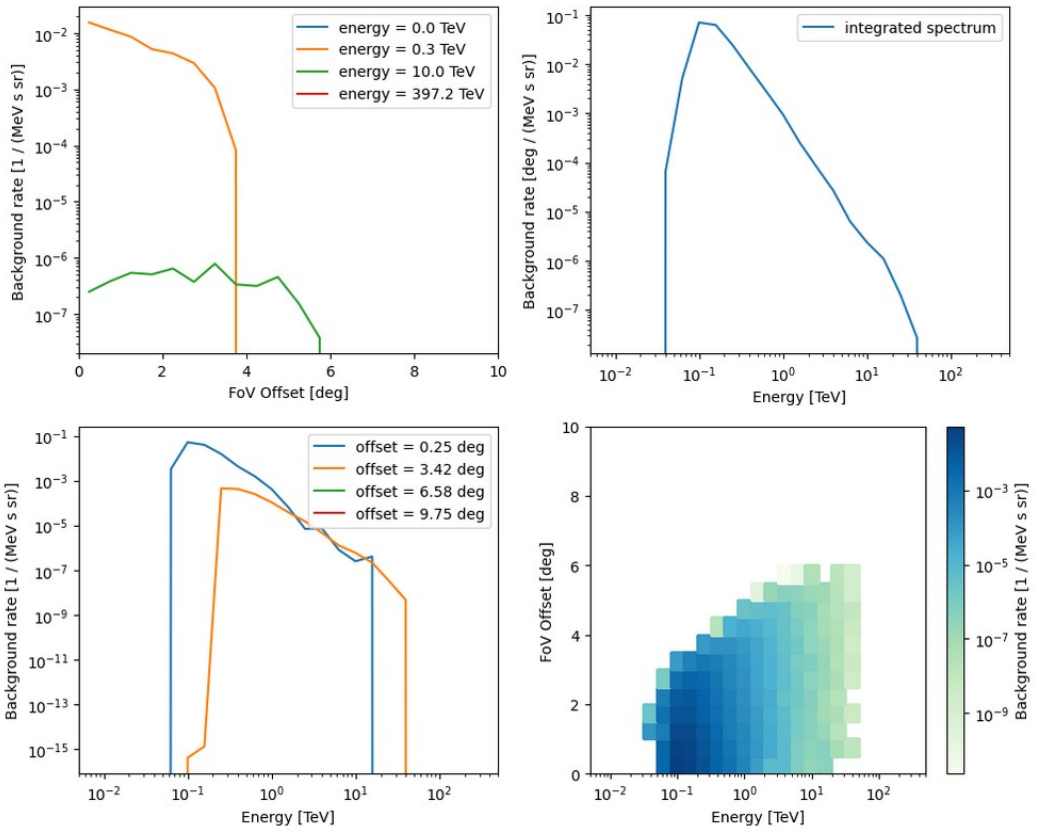






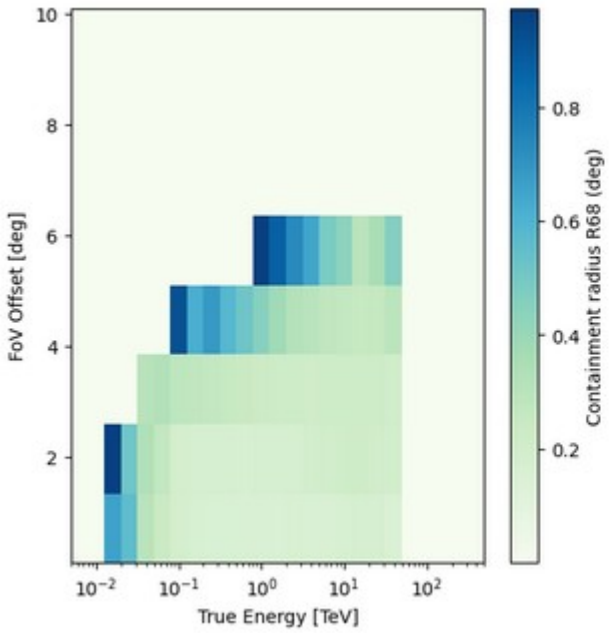
Create new IRFs

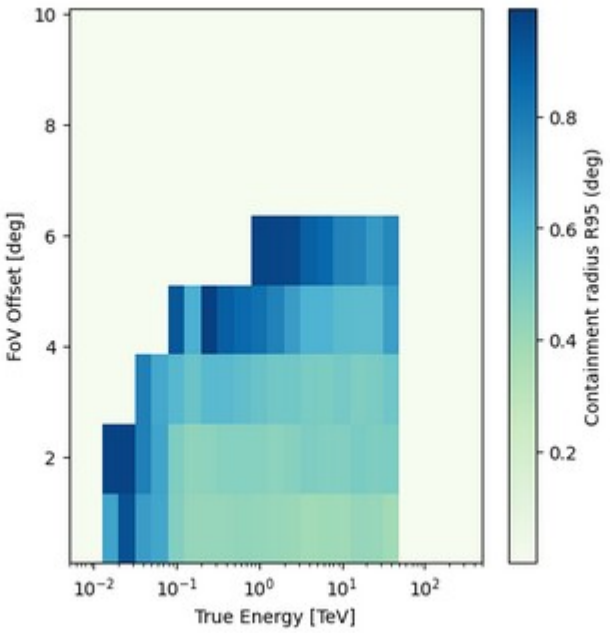
Background

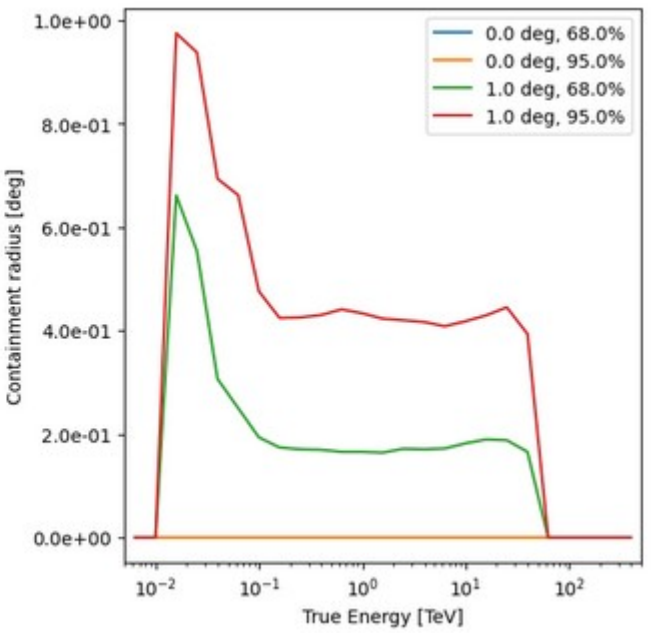


Create new IRFs

Point spread function







Simulate DL3

Generate observation table

id	time_reference	livetime	delay	temporal_index	time_scale	normalization	spectral_index	energy_reference	redshift
0	2000-01-01	4800.0	364.481709	-2.72453	30.0	2.105078e-07	4.41179	30.0	NaN

Generate run table

id	id_obs	file_obs	file_model	livetime	delay	offset	offset_direction
0	0	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	1200.0	364.481709	0.4	0.0
1	0	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	1200.0	1564.481709	0.4	90.0
2	0	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	1200.0	2764.481709	0.4	180.0
3	0	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	/home/lemoigne/gammapy/gammapy-notebooks/Simul...	1200.0	3964.481709	0.4	270.0

https://gitlab.cta-observatory.org/mdebony/japan_lapp_transient/-/tree/edna_fix?ref_type=heads

Simulate DL3

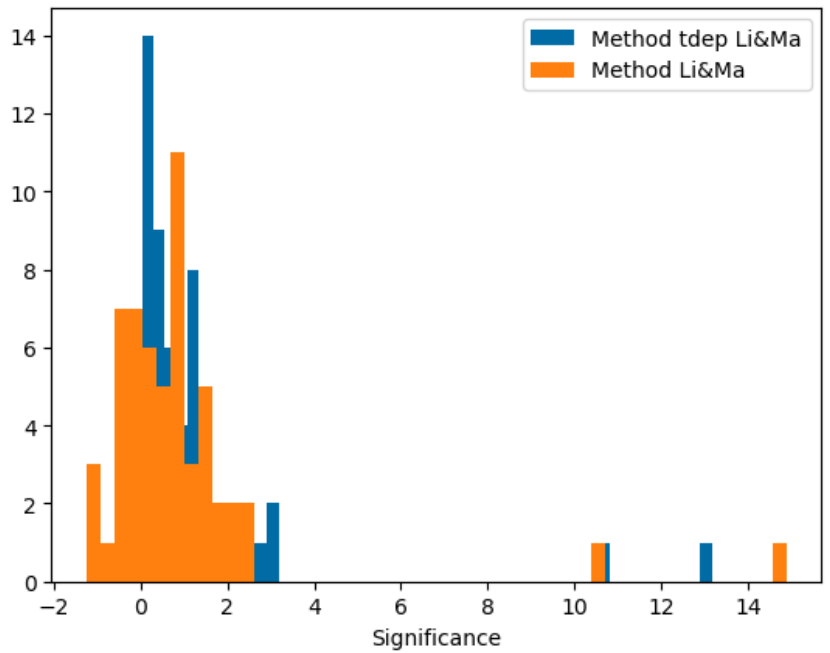
Make simulations

id	id_obs	integration_time	significance	optimized_amplitude	tdep_significance	excess	background	livetime	mc_source_counts	mc_source_counts_on_region	mc_background_counts_on_region	run_time
0	0	10.0	0.943202	7227.574428	0.857085	15.0	162.0	600.0	0	0	177	0.695145
1	0	20.0	-0.692925	4838.441060	0.650122	-15.5	340.5	1200.0	0	0	325	0.799172
2	0	40.0	-1.130287	4919.087312	0.712939	-35.5	673.5	2400.0	0	0	638	1.164876
3	0	60.0	-0.491923	3777.910962	0.562439	-19.0	1003.0	3600.0	0	0	984	1.650263
4	0	80.0	-0.470224	3375.279296	0.510201	-21.0	1339.0	4800.0	0	0	1318	2.212151

https://gitlab.cta-observatory.org/mdebony/japan_lapp_transient/-/tree/edna_fix?ref_type=heads

Perform Li&Ma methods

for 100 source simulations,



Distribution of the significance for the 100 simulated events

tdep significance always positive => take the sign of the excess ?

Perform more simulations with Must

for 10 000 simulations, submit a submit file

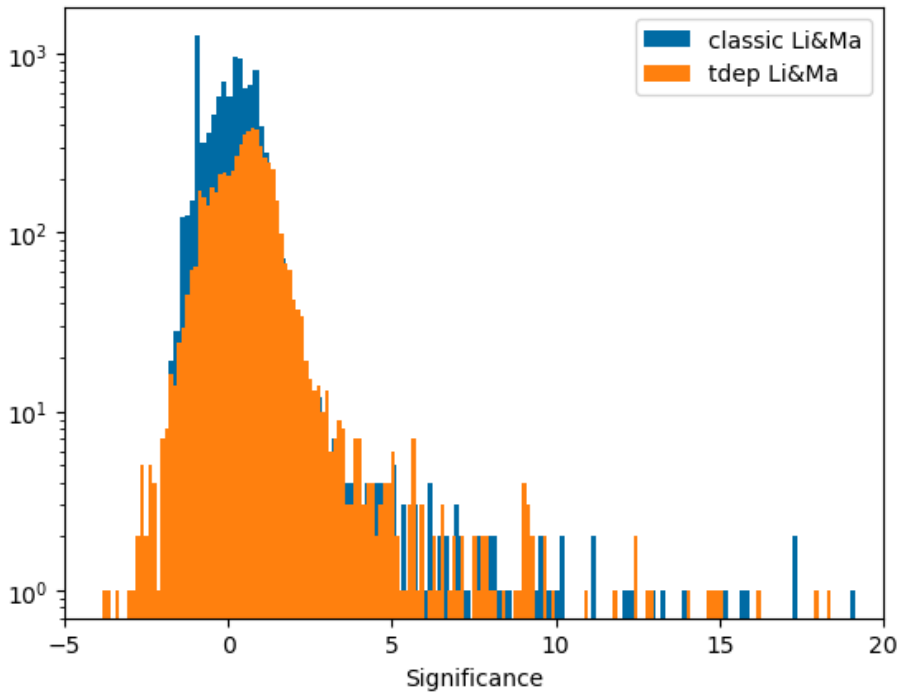
```
executable = /mustfs/LAPP-DATA/cta/lemoigne/miniconda3/envs/japan/bin/japan-run-simulations
arguments = "-c /mustfs/LAPP-DATA/cta/lemoigne/japan_lapp_transient/config/config_simulation_lappui.json -i $(input_file)
-o /mustfs/LAPP-DATA/cta/lemoigne/japan_files/out_redshift/out_04/out_$Fn(input_file).pkl"

universe = vanilla

output = OUT/OUTPUT_FILE.out
error = ERROR/LOG_FILE.error
log = LOG/LOG_FILE.log

should_transfer_files = yes
when_to_transfer_output = ON_EXIT

getenv = True
```

→ 1000 input files (format pickle) with :

- observation table path
- run table path
- list of 10 observations from the tables to perform

Perform more simulations with Must

for 10 000 simulations,

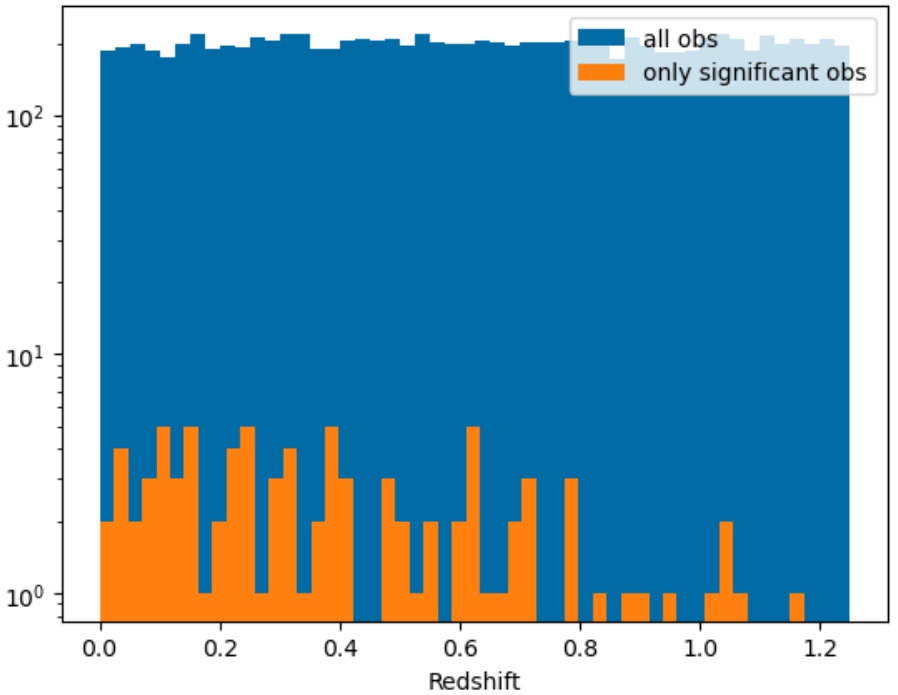


Distribution of the significance for the 10000 simulated events

In 4185 cases, no results for tdep Li&Ma → failing optimization for the amplitude of the signal (only for unsignificant sources)

Perform more simulations with Must

for 10 000 simulations,

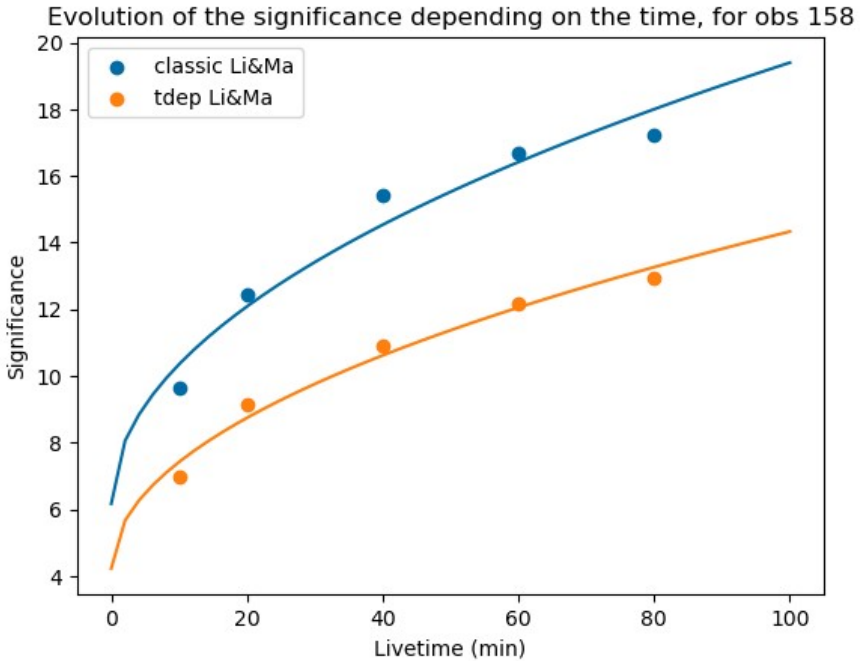


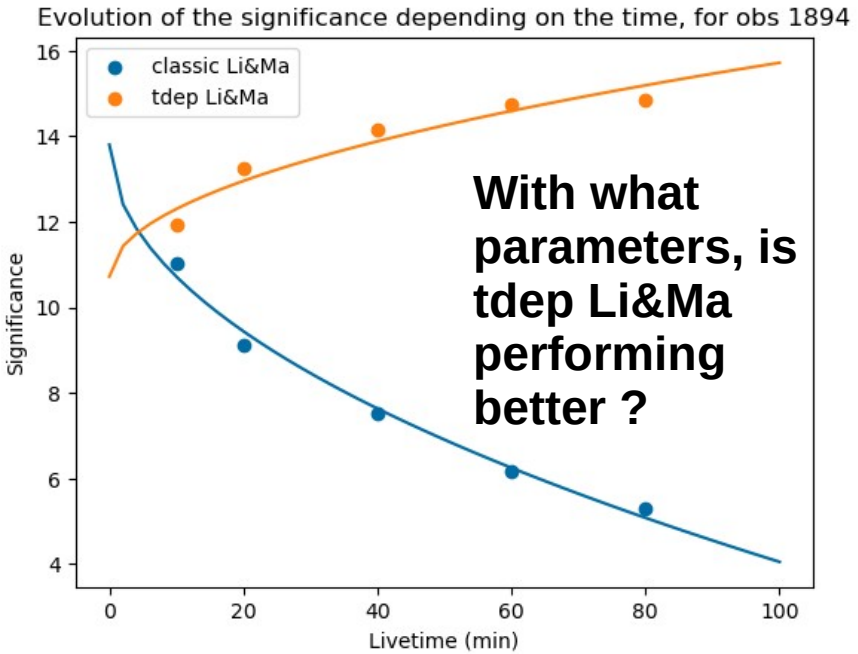
Distribution of the redshift for the 10000 simulated events

Space of parameters : z from 0 to 1.25

Perform more simulations with Must

for 10 000 simulations,

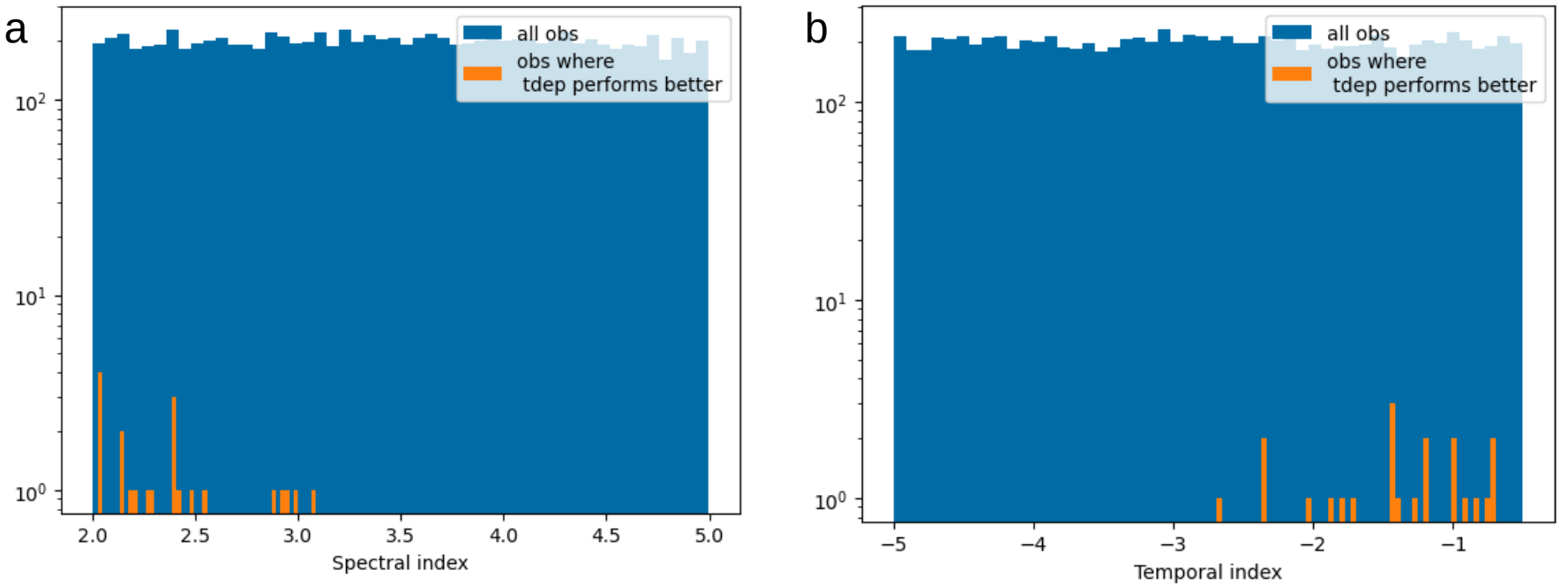




Perform more simulations with Must

for 10 000 simulations,

Parameter spaces too large ?
=> a lot of unsignificant sources

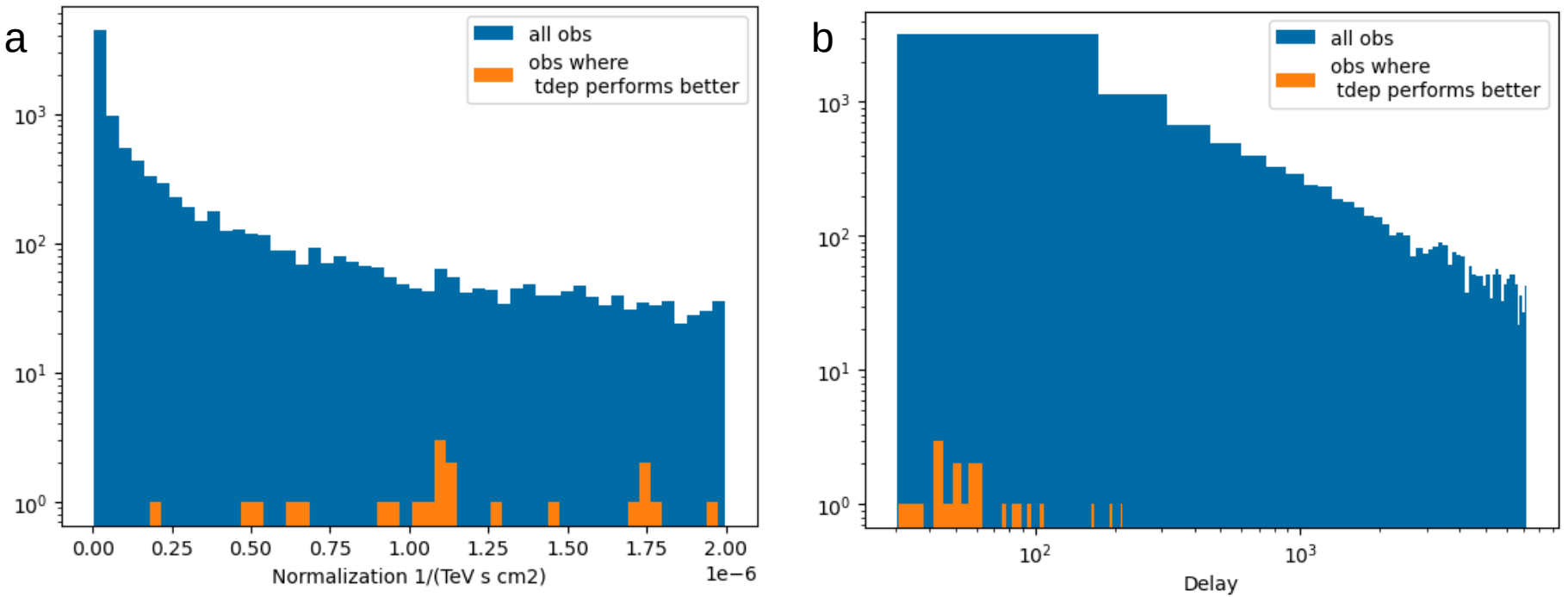


Distribution of the spectral index (a) and temporal index (b) for the 10000 simulated sources

Perform more simulations with Must

for 10 000 simulations,

Parameter spaces too large ?
=> a lot of unsignificant sources



Distribution of the normalization (a) and delay (b) for the 10000 simulated sources