

Next incremental release of the *Fermi* LAT source catalog

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Abstract :The latest Fermi-LAT source catalog (4FGL DR3: 6658 sources above 50 MeV) was based on twelve years (2008 - 2020) of data. Since neither the event reconstruction (Pass 8) nor the interstellar emission model (gll_iem_v07) has evolved since 2019, we provide incremental 4FGL releases at regular intervals of two years, until one of those two key ingredients changes. The next incremental catalog, 4FGL DR4 covering fourteen years of LAT data, will be released in 2023.

I describe how we plan to improve the catalog for DR4 with respect to DR3, besides adding two years. Adding priors on the spectral curvature parameters (1) helps to stabilize the source model at low energy. Smoothly modulating the diffuse model (3) spatially avoids jumps between regions of interest. We will update extended sources (5). Entering strongly variable sources that have average fluxes below detectability over the full time range (7) ensures that their flare is not attributed to a neighbor. Other improvements (2, 4, 6) are considered but not validated yet.

1. Adding priors to spectral curvature

Problem: The curvature (β of the LogParabola model) is low (around 0.1) in bright (high TS) AGN. It is larger in bright pulsars, but never reaches 1.

The accumulation of large β values (very peaked spectra) in faint sources is not realistic and the hard cut at 1 disrupts the covariance matrix.

Solution: Enter **priors on curvature parameters** (rather than a hard cut) to stabilize the model.

Difficulty: SNRs and pulsars are more curved than AGN and binaries.

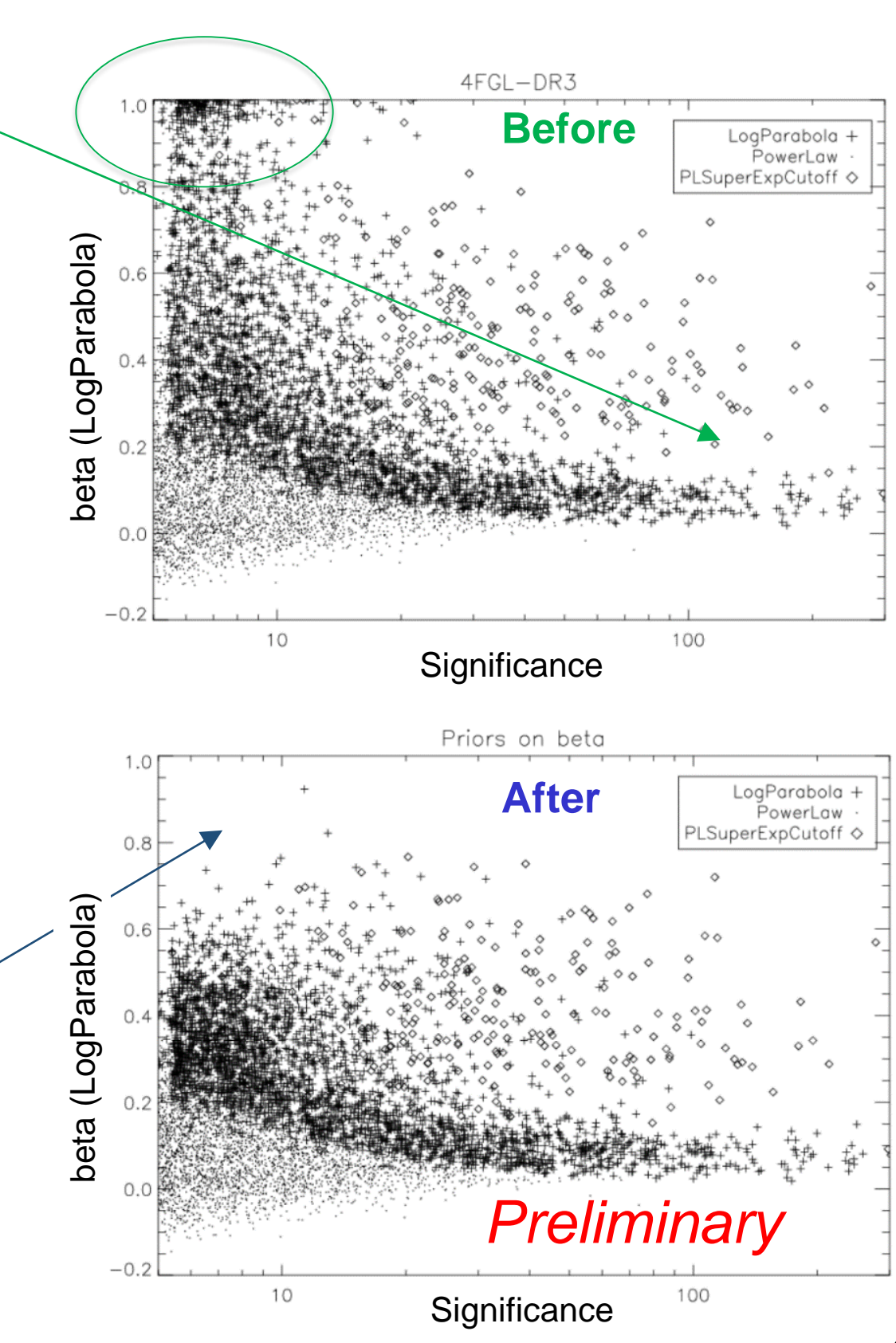
Soft priors to accommodate all:

- on LogParabola β : mean = 0.1, stdev = 0.3
- on PLEC4 ExpfactorS ($\sim 2\beta$): mean=0.6, stdev=0.6

As expected, gets rid of the tail at large β .

No impact on β error (smaller than 0.3 at TS > 25)

Baselined for DR4



2. Leaving index free for light curves

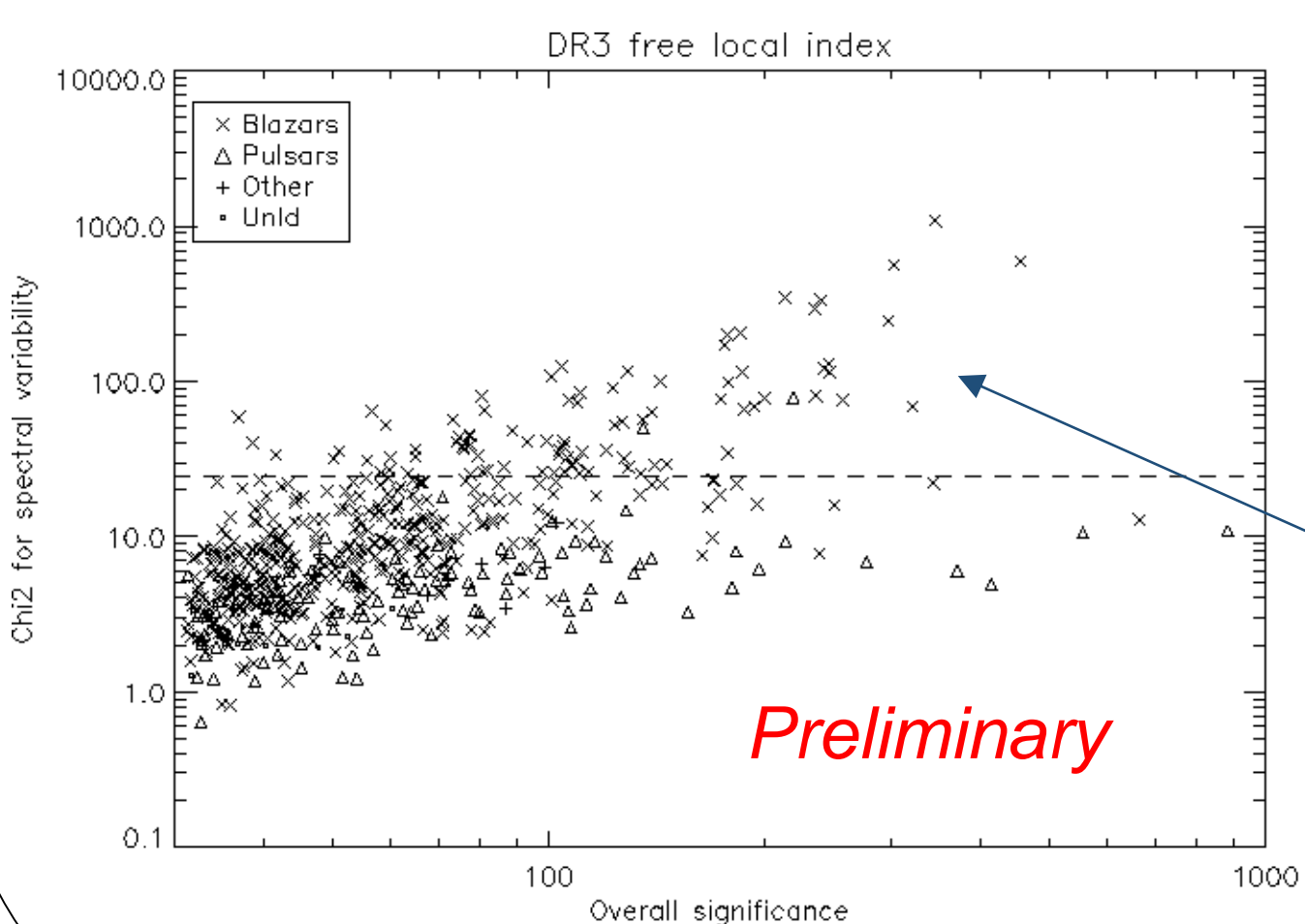
Problem: Standard catalog processing fits only source normalization in each light curve bin (year). Spectral variability of very bright AGN can result in false variability of their neighbors.

Solution: Leave spectral index (not curvature) free for bright sources.

Difficulties: Don't know in advance which sources are variable, define TS threshold

Priors around spectral index to avoid non significant fluctuations; mean = global best fit, tried **stdev = 0.1** (not too large)

Leave index free in all bins when **global TS > 1000** (except extended sources and bins in which TS < 1) and in fainter sources when **local TS > 100**.



The number of degrees of freedom in the light curve is **not constant** any more. Replace Variability_Index with **Signif_Variability** (in sigma units)

In general, only very bright sources at TS > 10,000 show **spectral variability**

Fractional variability harder to measure because of correlation between flux and index (larger errors).

In consideration for 5FGL

3. Modulating the diffuse background

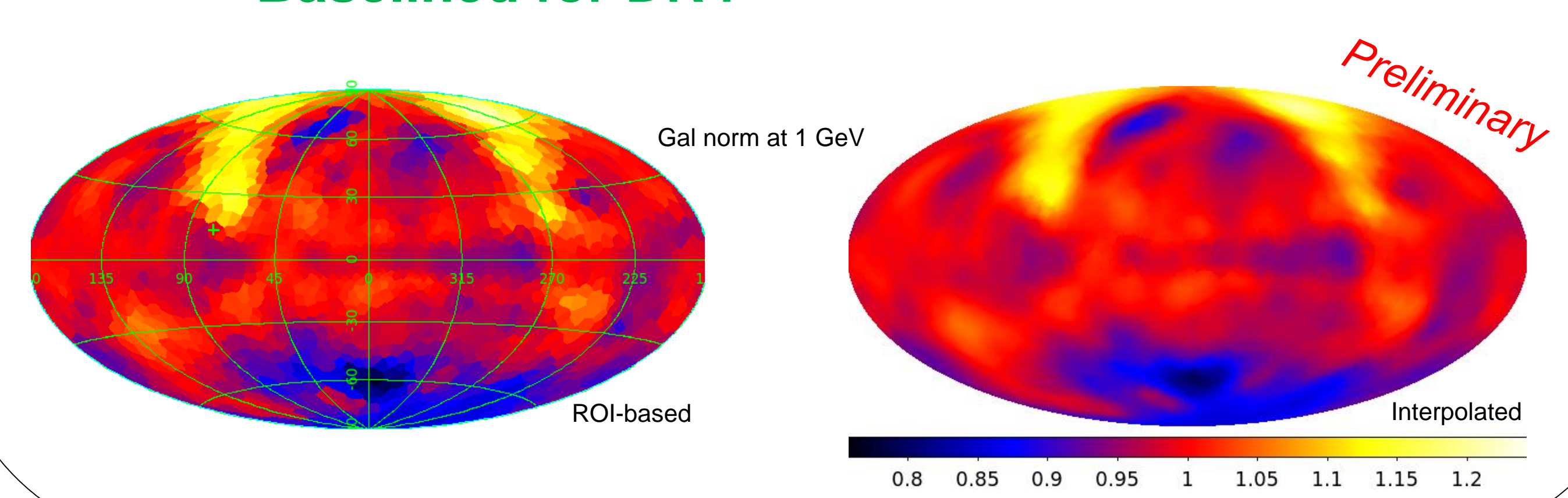
Problem: Diffuse parameters are fit independently in each Region of Interest (RoI), resulting in small but **sharp changes at RoI boundaries**.

Solution: Interpolate spatially over diffuse parameter values to make them vary smoothly over the sky. Rather than modulate the isotropic, fix it and add one parameter to the Galactic diffuse (LP modulation).

Interpolation: Weighted average of up to 15 ROIs $w_i = (\max(D_i, R_i, 2)\sigma_i)^{-2}$
 D_i : distance to RoI center; R_i : RoI radius; σ_i : uncertainty on parameter
LogLikelihood improves.

Difficulty: Still requires first run with independent parameters. Small but significant fluctuations remain from RoI to RoI.

Baselined for DR4



4. Adding priors to spectral index

Problem: Very hard ($\Gamma < 1.5$) or very soft ($\Gamma > 3$) faint sources, not seen among brighter ones.

Solution: Entering **priors** to the spectral index.

Difficulty: Broad range of observed spectral indices (2.28 +/- 0.30)

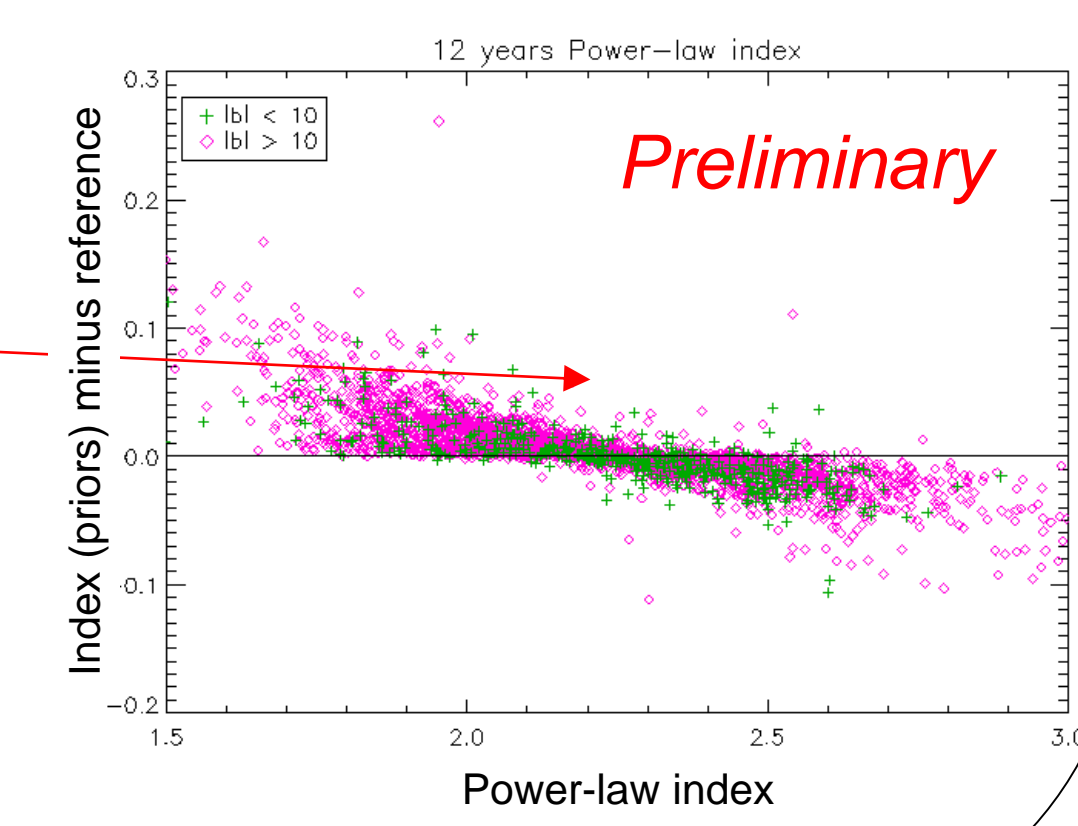
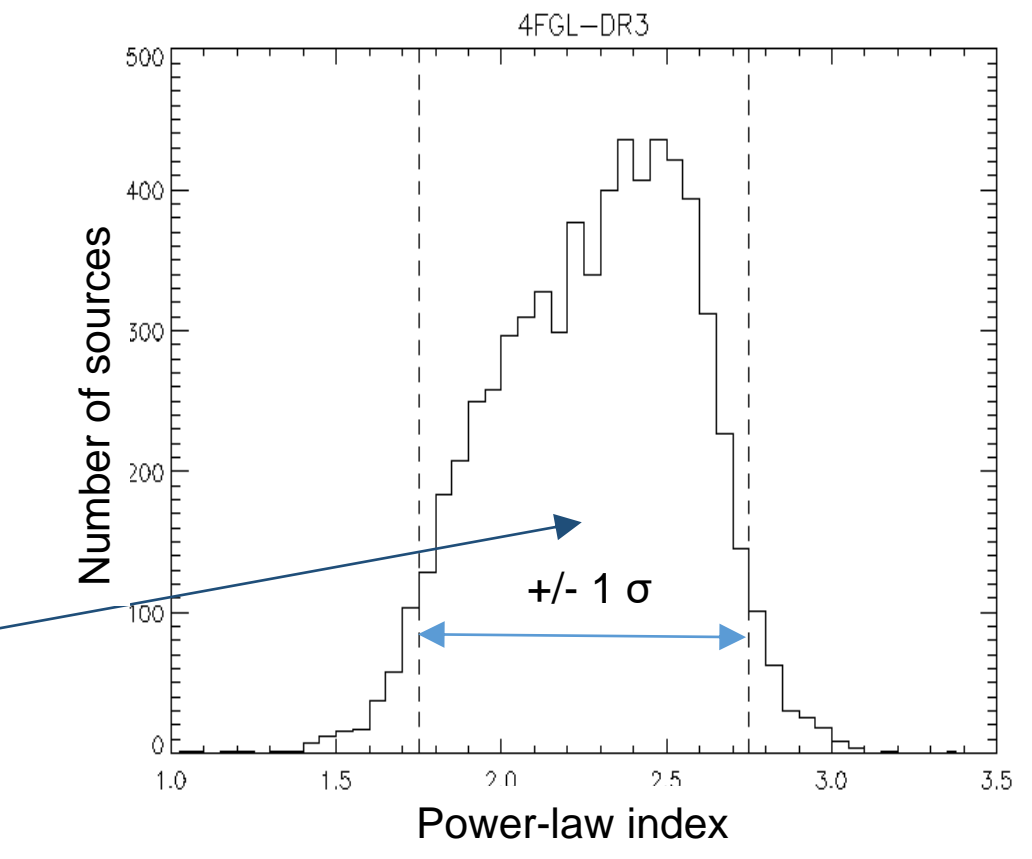
Apply priors at **2.25 +/- 0.50** (broader than observed)

• No effect on energy flux

• Fewer sources at $\Gamma < 1.5$ or $\Gamma > 3$ (with TS > 16, during iterations) as expected

• **Side effect:** Obviously, the priors pull the sources toward the mean, the more so when far from the mean. However, that effect decreases fast with TS (not noticeable at TS > 100).

In consideration for 5FGL



5. Updating extended sources

New extended sources

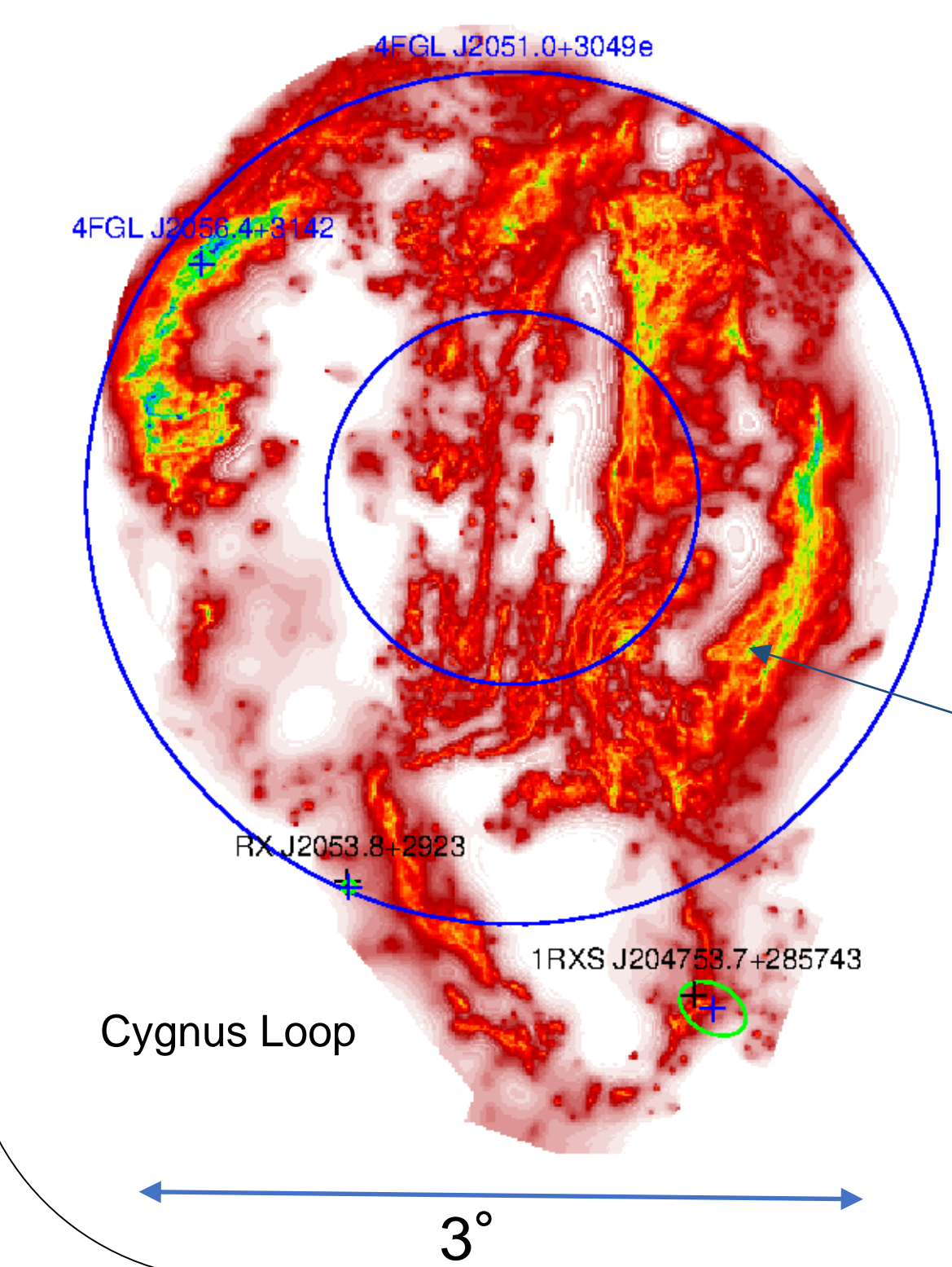
- CTB 80 (Araya & Herrera 2021)
- G51.26+0.11 (Araya 2021)
- 3C 58 (Li+ 2018) affects PSR J0205

Modified extended sources

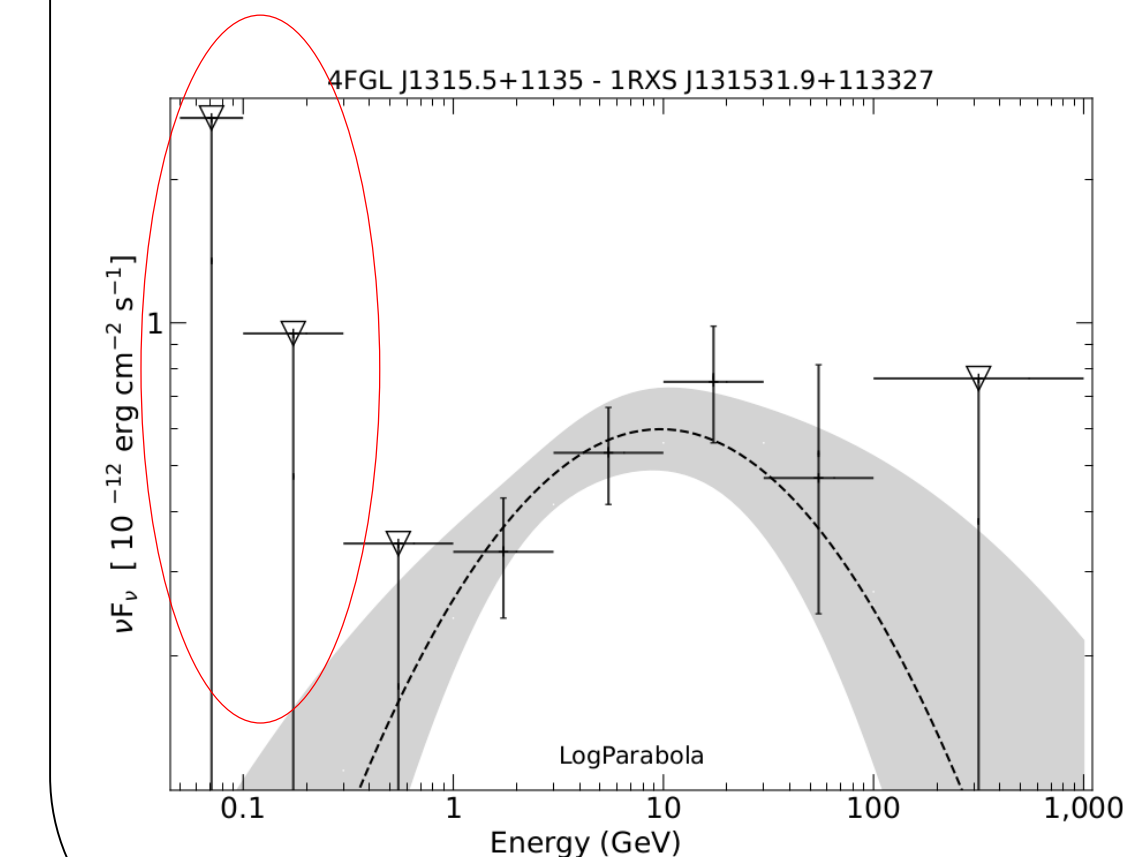
- Puppis A (Xin+ 2017, Mayer+ 2021)
- Cygnus Loop (Tutone+ 2021)

Baselined for DR4

More coming for 5FGL



6. Priors in SED calculation?



Problem: Large errors in the low-energy bands (50-100 and 100-300 MeV) and convergence errors because of too large correlation between sources.

Solution: Enter **priors from global fit** into SED calculation to stabilize the model

Difficulty: need to select prior carefully

In consideration for 5FGL

7. Source contents

Problem: Several flaring sources (novae, very variable AGN) are not in the main catalog because they do not reach TS > 25 over the full interval.

Solution: Force all known variable sources into the catalog, to avoid detecting false variability in their neighbors.

It can apply to all **clear-cut** detections of variable sources:

• Transients like PSR B1259-63, novae, ...

• Results of automatic searches over monthly time scale (1FLT, ...)

Difficulty: precise criterion for **clear-cut**, define best localization

Baselined for DR4