Leftovers
Odds and Ends
Bits and Bobs
Cleaning out the Fridge

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Time Conversion

- Timekeeping is complicated. **Time formats** are independent of **time scales**!
- E.g. TT = terrestrial time does not have leap seconds, UTC does.
- MET overview: https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Data/Time_in_ScienceTools.html
- Online conversion tool: https://heasarc.gsfc.nasa.gov/cgi-bin/Tools/xTime/xTime.pl
- DIY: **`MJDREFI=51910; MJDREFF=7.428703703703703e-4`** (86400 seconds/day)
- Use astropy.time to convert between scales, e.g. TT to calendar time (UTC).

- **MET**: Mission elapsed time (s)
- **MJD**: Modified Julian date (d)
- **TT**: Terrestrial time
- **UTC**: Coordinated Universal Time

```
from astropy.time import Time

myTT = 675702050 / 86400 + (51910+7.428703703703703e-4)
t = Time(myTT, format='mjd', scale='tt')

print("TT: ", t, " = ", t.isot)
print("UTC:", t.utc, " = ", t.utc.isot)

TT:  59730.62632157407  =  2022-05-31T15:01:54.184
UTC: 59730.62552083333  =  2022-05-31T15:00:45.000
```

PLEC4

PLSuperExpCutoff4:

Example: XML Model Definition

For modeling pulsars.

$$\frac{dN}{dE} = \begin{cases} N_0 \left(\frac{E}{E_0}\right)^{\gamma_0 - \frac{d}{2}\ln\frac{E}{E_0} - \frac{db}{6}\ln^2\frac{E}{E_0} - \frac{db^2}{24}\ln^3\frac{E}{E_0}}, & \text{if } |b\ln\frac{E}{E_0}| < 1e^{-2} \\ N_0 \left(\frac{E}{E_0}\right)^{\gamma_0 + d/b} exp\left(\frac{d}{b^2}(1 - (\frac{E}{E_0})^b)\right) & \text{otherwise} \end{cases}$$

where

- Prefactor = N_0
- IndexS = γ_0
- Scale = E_0
- ExpfactorS = d
- Index2 = b

Note:

- N_0 is the normalization (flux density) at E_0.
- γ_0 is the local spectral index at E_0.
- d is the local curvature at E_0

The $b = 0$ case corresponds to a LogParabola with $\alpha = \gamma_0$ and $\beta = d/2$.

To provide more information on curved spectra, we now report systematically in the catalog the peak energy in νF_ν and its uncertainty for all sources (including those not significantly curved) and both models as `(Unc_)LP_EPeak` and `(Unc_)PLEC_EPeak`:

$$E_{\rm peak}({\rm LP}) = E_0 \ \exp\left(\frac{2-\alpha}{2\,\beta}\right) \qquad (4)$$

$$E_{\rm peak}({\rm PLEC}) = E_0 \ \left(1 + \frac{b}{d}(2 - \Gamma_S)\right)^{1/b} \qquad (5)$$

https://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source_models.html#PLSuperExpCutoff4

PLEC4

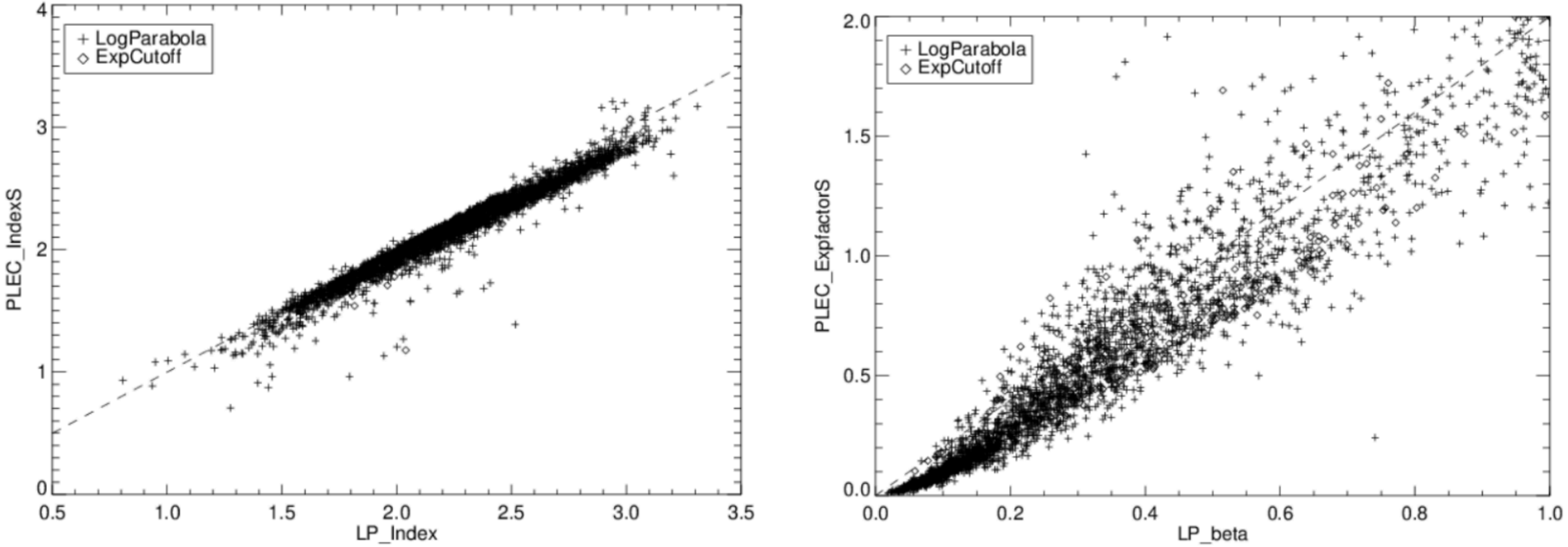

Figure 4. Left: comparison of α of the LP model and Γ_S of the PLEC model (`LP_Index` and `PLEC_IndexS` in the FITS file), showing that these parameters are largely similar. Right: comparison of LP β and PLEC d (`LP_beta` and `PLEC_ExpfactorS` in the FITS file), showing that d is well correlated to 2β. The dashed lines show a one-to-one correlation. The outliers have large errors on both plots (none is farther off than 2 σ).

https://arxiv.org/pdf/2201.11184.pdf (4FGL-DR3 paper)

Spectral models in 4FGL-DR3

The new PLEC parameterization allows a 4-parameter fit (with **free b**) in fainter sources. We have applied it to **all pulsars with TS > 10,000** (28, up from 6 in DR1 and DR2). At TS < 10,000 Δb becomes larger than 0.15, which is the natural scatter on b in the brightest pulsars, so freeing b is no longer beneficial. For all other significantly curved pulsars, **b is fixed to 2/3 as in 4FGL**. For comparison, the median b over the 28 pulsars with free b is 0.51, its weighted (with 1/σ2) average is 0.55, and its intrinsic dispersion is 0.16.

The **Small Magellanic Cloud has b = 1**, as before (Abdo et al. 2010). Besides 3C 454.3, the five other **AGN with TS > 80,000** were modeled with PLEC and free b as well: CTA 102, Mkn 421, S5 0716+71, 3C 279 and PKS 1424–41.

The new parameterization **contains the LP model** (for b=0) so there is no risk of a worse fit, but non-convergence can occur when the model is not constrained well enough. The TS threshold for free b is higher in AGN than pulsars, because the curvature is much less in AGN, so Δb is larger. The main objective of fitting PLEC with free b remains to **improve the modeling of the surroundings of very bright sources at low energy**.

In the DR1 and DR2 catalogs, the sources were represented with a curved spectral model (LP or PLEC) rather than a power law (PL) when TScurv = 2 (log L(curved spectrum)– log L(PL)) was larger than 9 (3 σ). **For DR3 we have lowered that threshold to 4 (2 σ)** [...].

https://arxiv.org/pdf/2201.11184.pdf (4FGL-DR3 paper)

Parameter bounds in fermipy

```
def set_parameter(self, name, par, value, true_value=True, scale=None, bounds=None,
error=None, update_source=True):
    """
    Update the value of a parameter.  Parameter bounds will automatically be adjusted to
encompass the new parameter value.

    Parameters
    ----------
    name : str - Source name.
    par : str - Parameter name.
    value : float - Parameter value. By default this argument should be the unscaled
(True) parameter value.
    scale : float - Parameter scale (optional). Value argument is interpreted with
respect to the scale parameter if it is provided.
    error : float - Parameter error (optional). By default this argument should be the
unscaled (True) parameter value.
    update_source : bool - Update the source dictionary for the object.
    """
```

Examples

```
gta.roi["4FGL J0425.6+5522e"].spectral_pars["norm"]

{'name': 'norm',
 'value': 1.236583491,
 'error': 0.06524381672,
 'min': 1e-05,
 'max': 1000.0,
 'free': True,
 'scale': 1e-13}
```

```
gta.set_parameter("4FGL J0425.6+5522e", "norm",
1.236583491, bounds=[0.01, 100], scale=1e-13,
true_value=False)

gta.roi["4FGL
J0425.6+5522e"].spectral_pars["norm"]

{'name': 'norm',
 'value': 1.236583491,
 'error': 0.06524381672,
 'min': 0.01,
 'max': 100.0,
 'free': True,
 'scale': 1e-13}
```

```
gta.set_parameter("4FGL J0425.6+5522e",
"norm", 1.236583491e-13, bounds=[0.01, 100],
scale=1e-13, true_value=True)

gta.roi["4FGL
J0425.6+5522e"].spectral_pars["norm"]

{'name': 'norm',
 'value': 1.236583491,
 'error': 0.06524381672,
 'min': 0.01,
 'max': 100.0,
 'free': True,
 'scale': 1e-13}
```

https://fermipy.readthedocs.io/en/latest/config.html#roiopt

Fermipy configuration

- Configuration options for `config.yaml` are described in the documentation
- Can be overwritten at run time when you call the relevant functions.

roiopt

The options in *roiopt* control the default behavior of the `optimize` method. For more information about using this method see the ROI Optimization and Fitting page.

roiopt Options

Option	Default	Description
`max_free_sources`	5	Maximum number of sources that will be fit simultaneously in the first optimization step.
`npred_frac`	0.95	
`npred_threshold`	1.0	
`shape_ts_threshold`	25.0	Threshold on source TS used for determining the sources that will be fit in the third optimization step.
`skip`	None	List of str source names to skip while optimizing.

https://fermipy.readthedocs.io/en/latest/config.html#sed

SED configuration

Option	Default	Description
`bin_index`	2.0	Spectral index that will be use when fitting the energy distribution within an energy bin.
`cov_scale`	3.0	Scale factor that sets the strength of the prior on nuisance parameters that are free. Setting this to None disables the prior.
`free_background`	False	Leave background parameters free when performing the fit. If True then any parameters that are currently free in the model will be fit simultaneously with the source of interest.
`free_pars`	None	Set the parameters of the source of interest that will be freed when performing the global fit. By default all parameters will be freed.
`free_radius`	None	Free normalizations of background sources within this angular distance in degrees from the source of interest. If None then no sources will be freed.
`make_plots`	False	Generate diagnostic plots.
`ul_confidence`	0.95	Confidence level for flux upper limit.
`use_local_index`	False	Use a power-law approximation to the shape of the global spectrum in each bin. If this is false then a constant index set to `bin_index` will be used.
`write_fits`	True	Write the output to a FITS file.
`write_npy`	True	Write the output dictionary to a numpy file.

Fermipy Lightcurves: Under the Hood

Lightcurve fitting routine:

1. Start by freeing target and provided list of sources, fix all else -
   1a. If fit fails, **fix all pars except norm** and try again

2. If that fails to converge then try **fixing low TS (<4) sources** and then refit

3. If that fails to converge then try **fixing low-moderate TS (<9) sources** and then refit

4. If that fails then **fix sources out to 1dg away from center of ROI.**
   NB: This comment can be misleading - sources with offset>1 deg are fixed.

5. If that fails **set values to 0 in output** and print warning message.

lightcurve Options

Option	Default	Description
binsz	86400.0	Set the lightcurve bin size in seconds.
free_background	False	Leave background parameters free when performing the fit. If True then any parameters that are currently free in the model will be fit simultaneously with the source of interest.
free_params	None	Set the parameters of the source of interest that will be re-fit in each time bin. If this list is empty then all parameters will be freed.
free_radius	None	Free normalizations of background sources within this angular distance in degrees from the source of interest. If None then no sources will be freed.
free_sources	None	List of sources to be freed. These sources will be added to the list of sources satisfying the free_radius selection.
make_plots	False	Generate diagnostic plots.
max_free_sources	5	Maximum number of sources that will be fit simultaneously with the source of interest.
multithread	False	Split the calculation across number of processes set by nthread option.
nbins	None	Set the number of lightcurve bins. The total time range will be evenly split into this number of time bins.
nthread	None	Number of processes to create when multithread is True. If None then one process will be created for each available core.
outdir	None	Store all data in this directory (e.g. "30days"). If None then use current directory.
save_bin_data	True	Save analysis directories for individual time bins. If False then only the analysis results table will be saved.
shape_ts_threshold	16.0	Set the TS threshold at which shape parameters of sources will be freed. If a source is detected with TS less than this value then its shape parameters will be fixed to values derived from the analysis of the full time range.
systematic	0.02	Systematic correction factor for TS:subscript: `var` . See Sect. 3.6 in 2FGL for details.
time_bins	None	Set the lightcurve bin edge sequence in MET. This option takes precedence over binsz and nbins.
use_local_ltcube	True	Generate a fast LT cube.
use_scaled_srcmap	False	Generate approximate source maps for each time bin by scaling the current source maps by the exposure ratio with respect to that time bin.
write_fits	True	Write the output to a FITS file.
write_npy	True	Write the output dictionary to a numpy file.

Fermipy as a community contributed tool

- Who's the community?

Fermipy as a community contributed tool

- Who is the community?
- We all are!
- Many of the original developers have left and/or have little time to implement new features. None are funded to work on fermipy full-time.
- Please let us know if you find a bug, want a new feature, or documentation is lacking.
- https://github.com/fermiPy/fermipy/issues/
  (fermipy only - contact FSSC for fermitools or general analysis questions)
- Contribute!
  - Bug reports & feature requests
  - Code (pull request)
  - Documentation updates 🙏
- Please reach out know if you need help to get started.

Backup