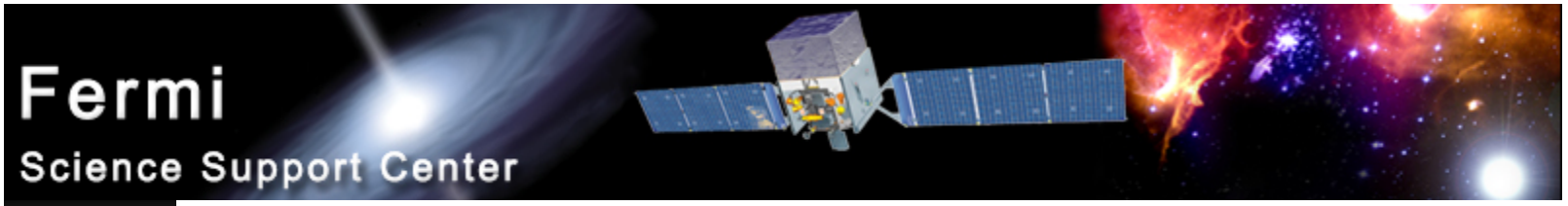
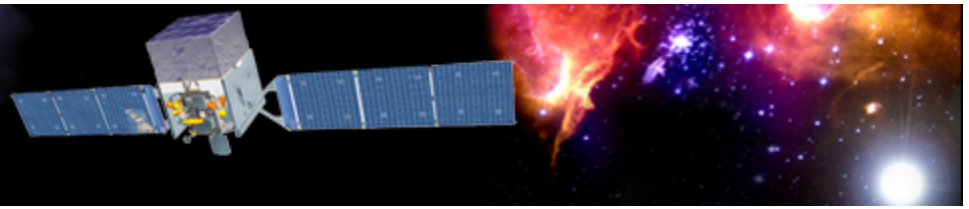


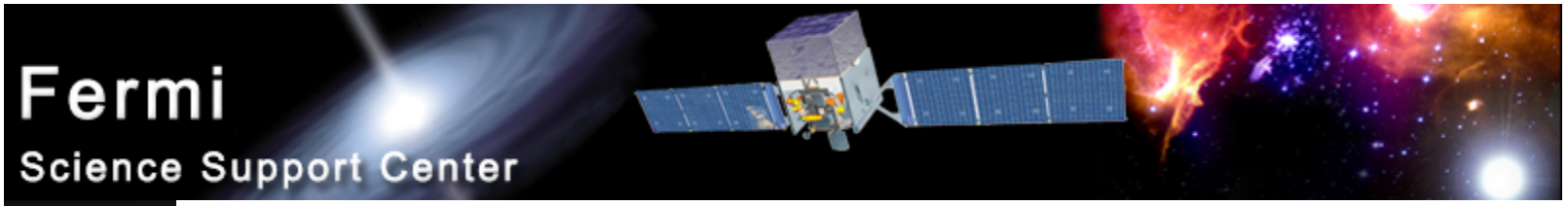
FSSC Science Tools

Data Selection and Exploration



Science Analysis Tools

- *Overview of capabilities*
  - *Pulsars—period analysis, blind searches*
    - *Database of ephemerides available at the FSSC*
    - *.par files available for TEMPO2 use*
  - *GRBs—temporal cuts, spectral analysis: Maximum likelihood tool, XSPEC*
  - *Maximum likelihood tool—spatial-spectral analysis of region (source detection, flux)*
    - *Includes background models*
- *Tools and documentation are released through FSSC website (http://fermi.gsfc.nasa.gov/ssc/)*



Available at FSSC site

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- Data Analysis
  - + System Overview
  - + Software Download
  - + Documentation
  - + Analysis Threads
  - + User Contributions
- Caveats
- Newsletter
- FAQ

Installing the Femi Science Tools

You can install the Fermi Science Tools using either a source distribution or using a precompiled binary. The preferred method is to use the **binary** distribution. If you are unsure which distribution to select contact your system administrator. On a unix command line you can find your machine type with the command

uname -m

and you should see something like i686, x86_64, or powerpc.

To determine the version of libc you can try

ls /lib/libc-*

and you should see something like

/lib/libc-2.5.so

where the 2.5 is the libc version.

Please read the release notes.

Current software version v9r23p1, released May 25, 2011.

We have binary distributions for:

- Scientific Linux 5 32 bit libc 2.5
- Scientific Linux 5 32 bit libc 2.5 (without root)
- Scientific Linux 5 64 bit libc 2.5
- Scientific Linux 5 64 bit libc 2.5 (without root)
- MAC OS X 10.5 powerpc
- MAC OS X 10.5 powerpc (without root)
- MAC OS X 10.5 intel
- MAC OS X 10.5 intel (without root)
- MAC OS X 10.6
- MAC OS X 10.6 (without root)

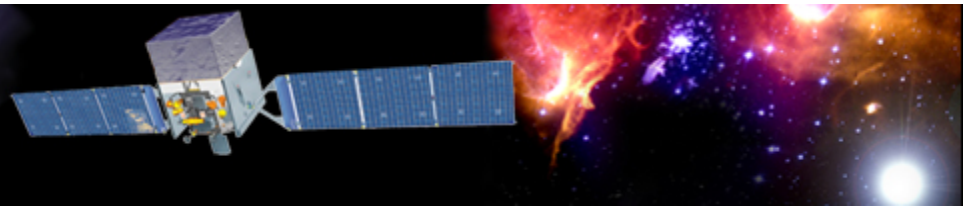
Instructions for installing the tools from the binary tarfile are here

The package with the source distribution is here.

Supported platforms

If your system is not supported, try the closest binary distribution first

If that doesn't work, you can try building from source

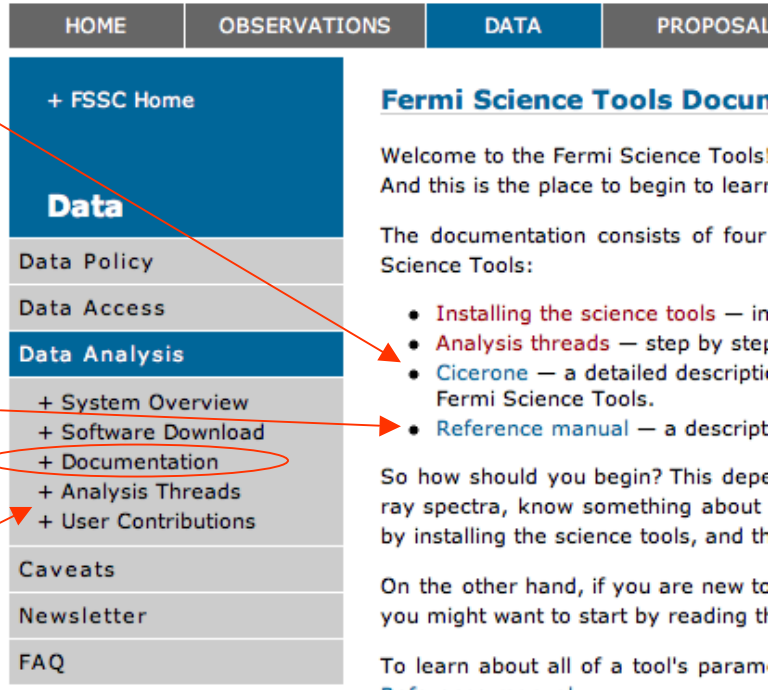


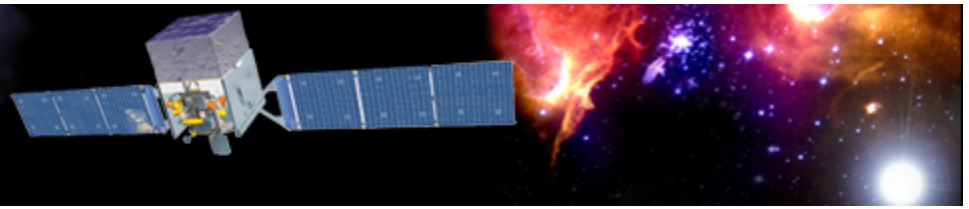
Science Tools: Structure

- *"Atomic" executables*
  - *Allows for divergent analysis without task repetition*
  - *Scriptable into more complex analysis chains*
- *Standard file types*
  - *FITS data i/o*
  - *IRAF style param files*
  - *XML source models*
  - *Text-based supporting files*
- *Standard toolsets for astronomy*
  - *FV, DS9, XSPEC*

Science Tools: Documentation

- *Multiple levels of Documentation*
  - *Detailed analysis description ('Cicerone')*
    - *Describes instrumentation and data acquisition*
    - *Explains analysis methods*
    - *Provides current recommendations from instrument teams*
  - *Individual tool descriptions (like fhelp)*
    - *Explains individual parameters in detail*
  - *Analysis threads (cook book examples)*
    - *Follow the analysis chain step-by-step*





Parameter Files

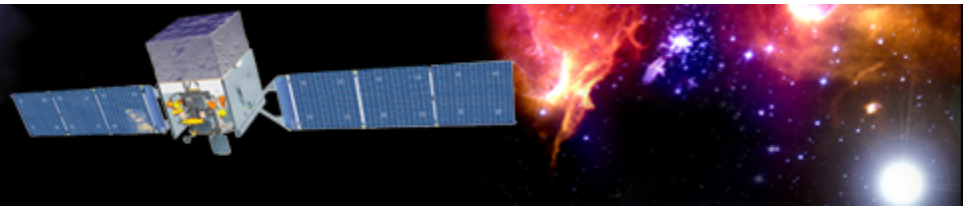
- *Contain parameter defaults or previous values*

```
#
# $Header: /nfs/slac/g/glast/ground/cvs/dataSubselector/pfiles/gtselect.par,v 1.19 2010/02/08
21:22:50 jchiang Exp $
#
infile,f,a,"",,,"Input FT1 file"
outfile,f,a,"",,,"Output FT1 file"
ra,r,a,INDEF,0,360,RA for new search center (degrees)
dec,r,a,INDEF,-90,90,Dec for new search center (degrees)
rad,r,a,INDEF,0,180,radius of new search region (degrees)
tmin,r,a,INDEF,0,,start time (MET in s)
tmax,r,a,INDEF,0,,end time (MET in s)
emin,r,a,30,0,,lower energy limit (MeV)
emax,r,a,300000,0,,upper energy limit (MeV)
zmax,r,a,180,0,180,maximum zenith angle value (degrees)
evclsmin,i,h,3,0,1000,"Minimum event class ID"
evclsmax,i,h,4,0,1000,"Maximum event class ID"
convtype,i,h,-1,-1,1,"Conversion type (-1=both, 0=Front, 1=Back)"
phasemin,r,h,0,0,1,minimum pulse phase
phasemax,r,h,1,0,1,maximum pulse phase

evtable,s,h,"EVENTS",,,"Event data extension"

chatter,i,h,2,0,4,Output verbosity
clobber,        b, h, yes, , , "Overwrite existing output files"
debug,          b, h, no, , , "Activate debugging mode"
gui,            b, h, no, , , "GUI mode activated"
mode,           s, h, "ql", , , "Mode of automatic parameters"
```

Parameters can be:
a = prompted
h = hidden

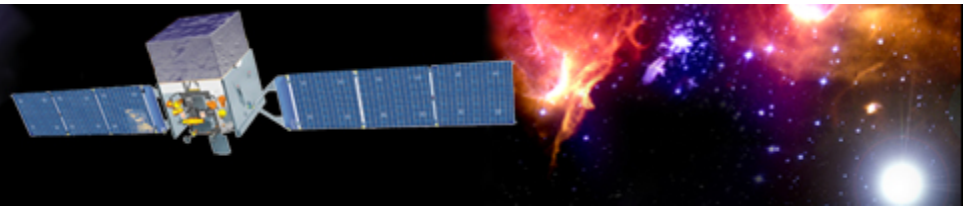
Hidden parameters must be given on command line.

To keep from overwriting files, set clobber=no



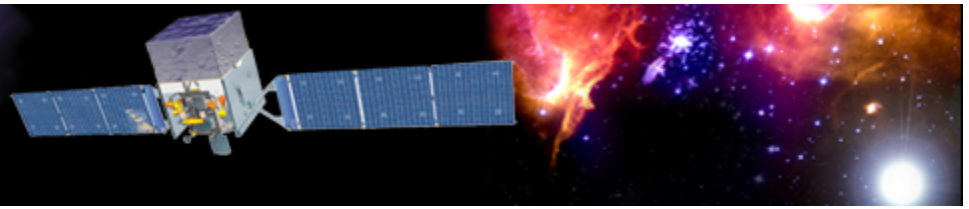
Science Tools: Execution

- *Parameters can be input in three ways*
  - *Command line entry - useful for scripting*
    - *Allows modification of "hidden" parameters (likely not needed for standard analyses)*
  - *Last value stored in param file for next use*
  - *Interactive prompted entry*
    - *No access to hidden parameters*
- *Parameter input can be mixed*
  - *%gtselect*
  - *%gtselect clobber=no*
  - *%gtselect clobber=no, infile=events.fits, outfile=events_cut.fits, etc...*



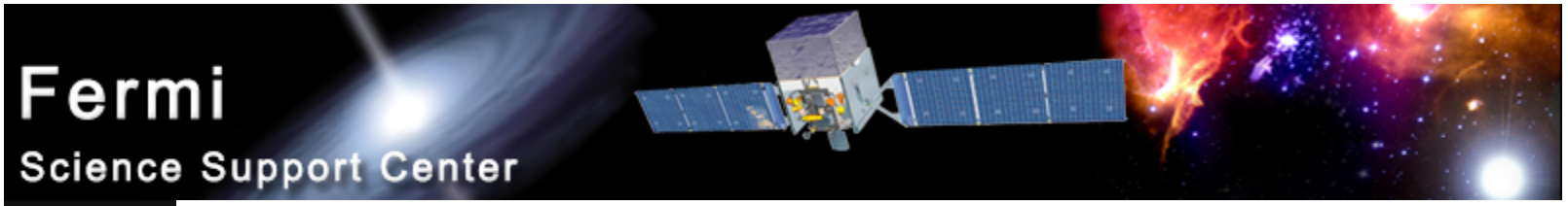
Data Access: Downloads

- *Download data from:*
  - *http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/extract_latdata.html*
    - *Allows retrieval of data for a specified region*
    - *Default values correspond to suggested data selections for most analysis types*
  - *http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/WeeklyFiles.cgi*
    - *Weekly files contain all event classes*
    - *Weekly spacecraft files are also available*
  - *FTP: Can be retrieved automatically using wget*
    - *Spacecraft: ftp://legacy.gsfc.nasa.gov/fermi/data/lat/weekly/spacecraft/*
    - *Photon: ftp://legacy.gsfc.nasa.gov/fermi/data/lat/weekly/photon/*

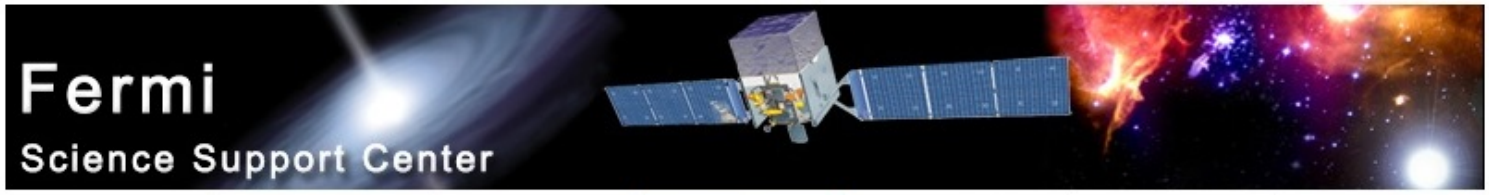


Data Access: File types

- *Events File (2 types)*
  - ***Photon** files contain all needed information for science analysis*
  - ***Extended** files contain additional information about each event that is used for specialized analysis*
    - *not needed by any science analysis tool*
  - *All event classes are available in both file types*
    1) *Transient - Loose quality definition, significant background contamination*
    2) *Source - Moderate quality, not recommended for specific analyses*
    3) ***Diffuse - High quality, lowest background contamination, Use this for most analyses***
    4) *Dataclean - Highest quality, recommended for diffuse studies*
- *Spacecraft File*
  - *Spacecraft Orientation and orbit position information*
    - *where Fermi is and where Fermi is pointed*
  - *One entry every 30 seconds*



Data Access: Data Server - 1



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Accessible from Data Access menu

LAT Photon, Extended, and Spacecraft Data Query

The Photon database currently holds 224948768 photons collected between 2008-08-04T15:43:37 and 2009-12-15T11:46:39 (239557417 and 282570399 seconds Mission Elapsed Time (MET)).

NOTE: For queries encompassing the whole sky (or close to it), please use the pre-generated Weekly Allsky Files.

For all-sky data, faster to download these

Start Search | Reset

NOTE: additional selections must be applied to data downloaded from the data server prior to use in a data analysis. See **recommended data selections** and **LAT caveats** for more details.

1. Do you want to search around a position ... ?

Object Name Or Coordinates:

(e.g. '**8 34 12, -45 45 00**' or '**128.55, -45.75**' or '**Vela**')

Coordinate System: J2000

Selection Radius: 15 degrees

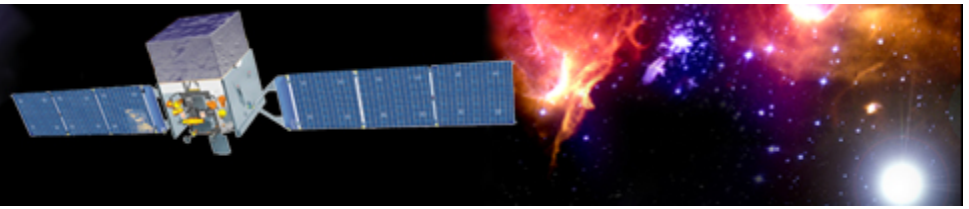
Will write DSS position keywords

... and/or search by date?

Observations Dates: Gregorian

Can use "START" and "END"

If you do not enter anything, it will return results from the past 6 months.



Data Access: Data Server - 2

... and/or search by energy? Default energies: 100MeV - 300 GeV

Energy Range: MeV

Enter the minimum and (optional) maximum energy, separated by a comma.
(By default, only data between 100 MeV and 300 GeV is returned.)

2. What missions and catalogs do you want to search?

FERMI Data

☑ Photon Data ☐ Extended Data ☑ Spacecraft Data Select type(s) of data files

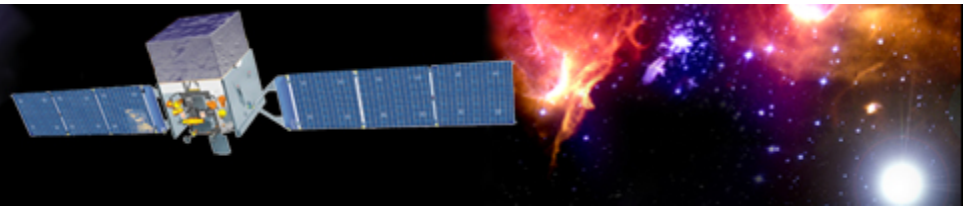
NOTE: additional selections must be applied to data downloaded from the data server prior to use in a data analysis. See **recommended data selections** and **LAT caveats** for more details.

Start Search Reset

For questions, contact the Helpdesk →

+ Privacy Policy and Important Notices
+ Get Plugins (Acrobat, etc.)
+ Contact NASA
+ Learn More About Fermi
+ FSSC Helpdesk

Curator: J.D. Myers
Responsible NASA Official: Phil Newman
NASA Science Official: Neil Gehrels



Data Access: Data Server - Results

LAT Data Query Results

Welcome to the LAT Data Query Results page. This page provides access to the LAT data requested from the FSSC's data servers.

The submitted query parameters for query ID=L100110230031E0D2F37E95 were:

Search was for 3C 454.3

Search Center (RA,Dec)=(343.491,16.1482)
Radius =15 degrees
Start Time (MET) =269298220 seconds (2009-07-14T21:03:40)
Stop Time (MET) =284850220 seconds (2010-01-10T21:03:40)
Minimum Energy =100 MeV
Maximum Energy =300000 MeV

Save this information for future reference

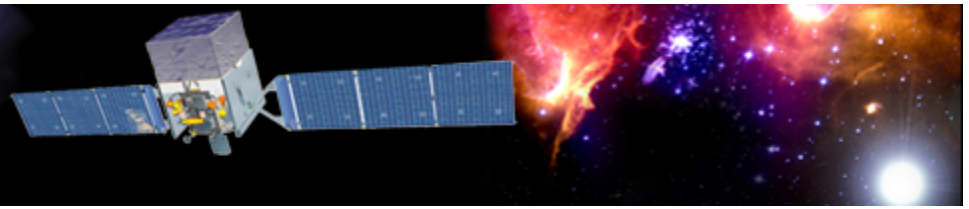
Server	Position in Queue	Estimated Time Remaining
Photon Server	Query Completed	N/A

The filenames of the result files consist of the Query ID string with an identifier appended to indicate which database the file came from. The identifiers are of the form: _DDNN where DD indicates the database and NN is the file number. The file number will generally be '00' unless the query resulted in a very large data return. In that case the data is broken up into multiple files. The values of the database field are:

- PH - Photon Database
- SC - Spacecraft Pointing, Livetime, and History Database
- EV - Extended Database

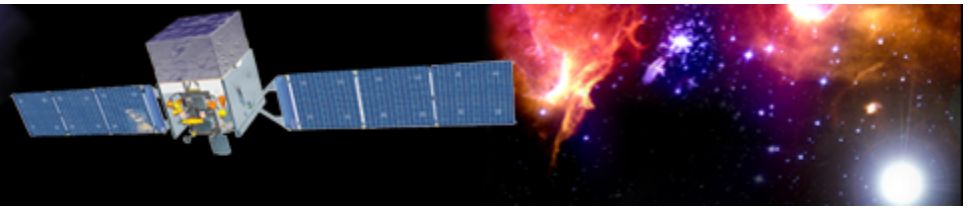
Notice the multiple photon files

Filename	Number of Entries	Size (MB)	Status
L100110230031E0D2F37E95_PH00.fits	418607	36.77	Available
L100110230031E0D2F37E95_PH01.fits	457801	40.21	Available
L100110230031E0D2F37E95_SC00.fits		0.00	Processing



Preparing your data

- *Prior to beginning an analysis you must:*
  - *Select the event class (for Pass 6 data, use Diffuse in almost all cases)*
  - *Decide how you intend to exclude time intervals where the bright Earth limb comes close to the edge of your region of interest*
- *Combine photon files if necessary*
  - *For large time ranges you will likely have multiple photon files*
  - *Combine using @filelist.txt syntax where filelist.txt is a listing of all photon files to be included, one per line*
- *Combine spacecraft files if necessary*
  - *Easiest method is to request the full time range from the data server*
  - *Can use **ftmerge** to concatenate the files together (not recommended)*
    - *Be aware of updates to the header keywords*



Data Selection - 1

- *Event-specific cuts can be made with **gtselect***
  - *Time range, energy range, position, ROI radius, zenith angle*

Hidden parameters defined on the command line

```
[wcne-128-154-203-60:Workshops/Datasets/3c454] eferrara% gtselect evclsmin=3
Input FT1 file[] L090923112502E0D2F37E71_PH00.fits
Output FT1 file[] 3c454_ecut.fits
RA for new search center (degrees) (0:360) [INDEF] 343.490616
Dec for new search center (degrees) (-90:90) [INDEF] 16.148211
radius of new search region (degrees) (0:180) [INDEF] 15
start time (MET in s) (0:) [INDEF] 266976000
end time (MET in s) (0:) [INDEF] 275369897
lower energy limit (MeV) (0:) [30] 100
upper energy limit (MeV) (0:) [300000] 300000
maximum zenith angle value (degrees) (0:180) [180] 105
Done.
```

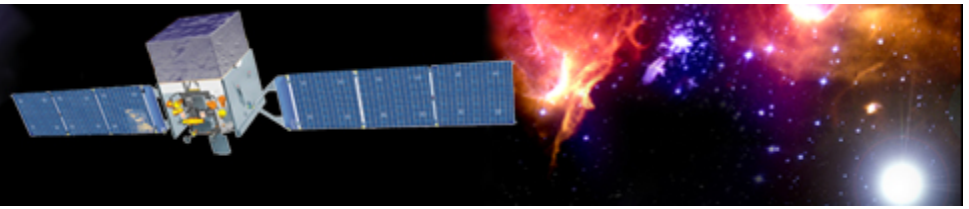
Or @filelist.txt

Parameter values can be read from the header keywords by inputting INDEF

- *Temporal cuts using spacecraft file keywords are made with **gtmktime***
  - *This MUST be applied if a zenith cut was used with gtselect*

```
[wcne-128-154-203-60:Workshops/Datasets/3c454] eferrara% gtmktime
Spacecraft data file[] L090923112502E0D2F37E71_SC00.fits
Filter expression[DATA_QUAL==1 && LAT_CONFIG==1 && ABS(ROCK_ANGLE)<52]
Apply ROI-based zenith angle cut[yes]
Event data file[] 3c454_ecut.fits
Output event file name[] 3c454_ecut_gti.fits
```

Applies zenith angle cut from gtselect



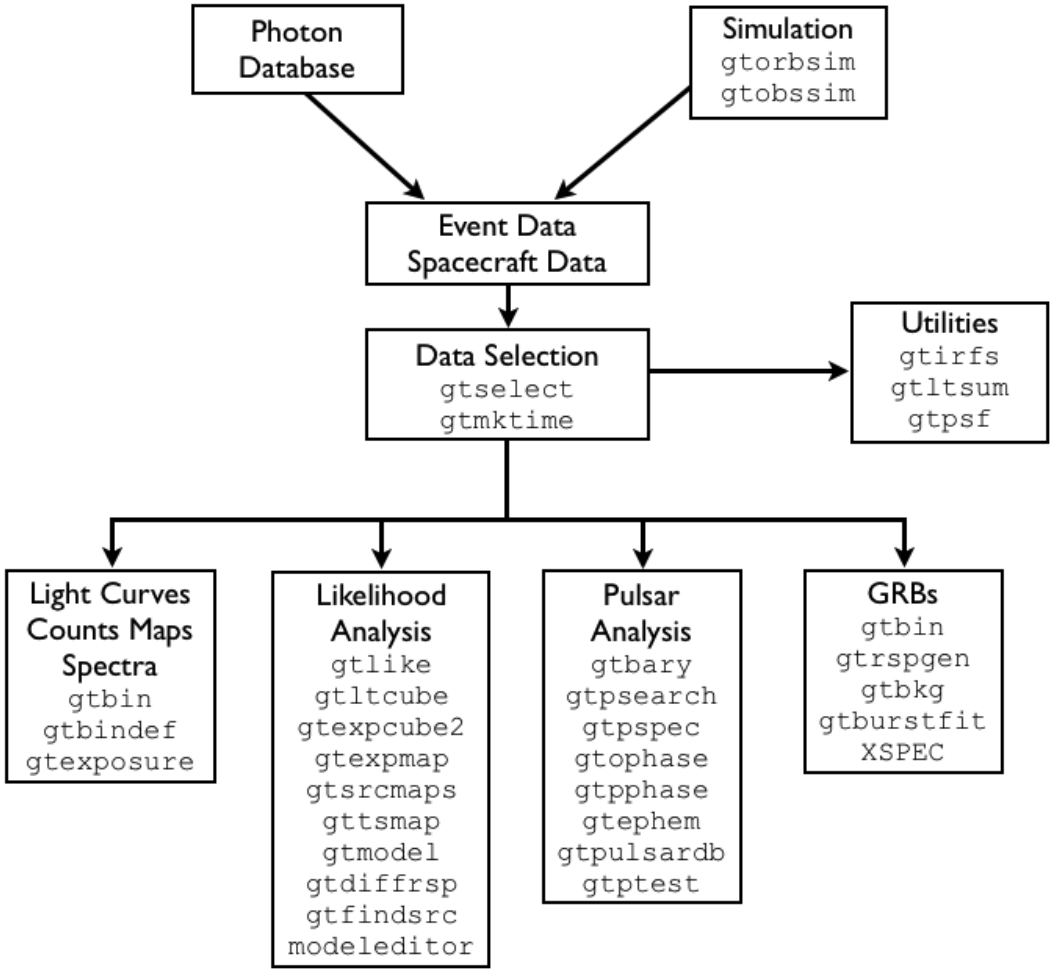
Data Selection - 2

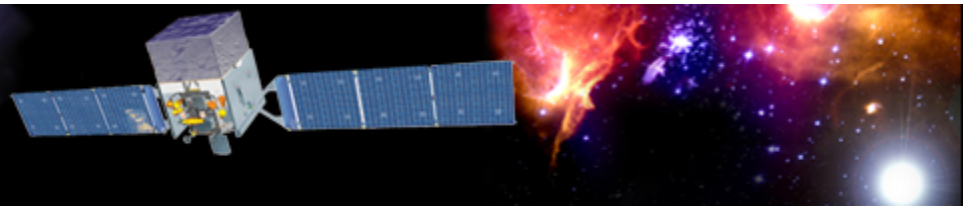
- *Different cuts should be used for different types of data analysis*
  - *Point Source analysis*
    - *For hard spectrum sources, localization analysis may benefit from a higher minimum energy cut due to energy-dependent PSF*
  - *Pulsar Timing analysis*
    - *Requires that spacecraft file span a greater time range than event file*
    - *Data server automatically pads the spacecraft file, unless you use START or END time keys*
  - *GRB analysis (~ few hundred seconds)*
    - *Typically uses "Transient" class photons (evclsmin=1)*
- *The current set of cuts can be reviewed using **gtvcut***

- *Recommended cuts are documented at:*

http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Data_Exploration/Data_preparation.html

Science Tools - Relationships

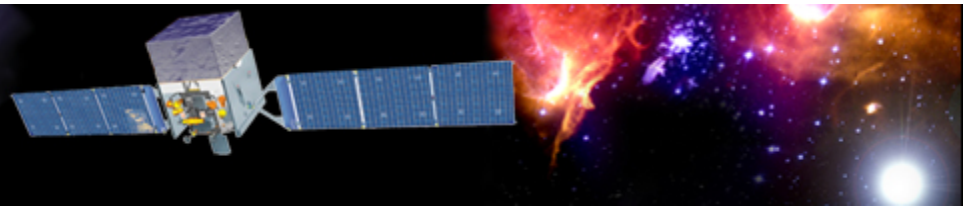




Binning for Visualization - 1

- ***gtbin*** *can be used to create several useful visualization products*
  - *Raw counts map*
  - *Quick-look light curve*
  - *PHA1 file*
- *Results are in format used by other science tools like* ***XSPEC***
  - *Includes WSC keywords for ease of viewing*
- *Useful to get a rough idea of the data, but do not include:*
  - *Exposure correction*
  - *Instrument responses*

Require Likelihood analysis for valid results



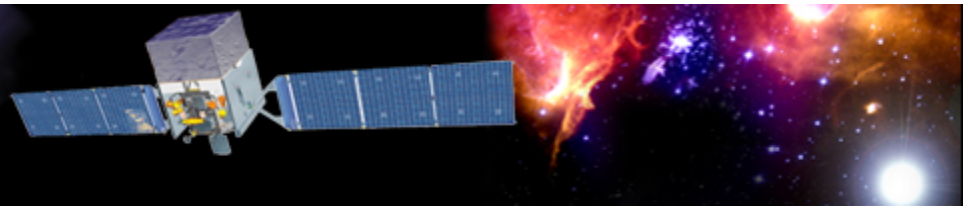
Binning for Visualization - 2

- *Making a counts map*

```
[wcne-128-154-203-60:Workshops/Datasets/3c454] eferrara% gtbin
This is gtbin version ScienceTools-v9r17p0-fssc-20100906
Type of output file (CCUBE|CMAP|LC|PHA1|PHA2) [PHA2] CMAP
Event data file name[] 3c454_ecut_gti.fits
Output file name[] 3c454_ecut_gti_cmap.fits
Spacecraft data file name[NONE] L090923112502E0D2F37E71_SC00.fits
Size of the X axis in pixels[] 300
Size of the Y axis in pixels[] 300
Image scale (in degrees/pixel)[] .1
Coordinate system (CEL - celestial, GAL -galactic) (CEL|GAL) [CEL] CEL
First coordinate of image center in degrees (RA or galactic l)[] 343.490616
Second coordinate of image center in degrees (DEC or galactic b)[] 16.148211
Rotation angle of image axis, in degrees[0.] 0
Projection method e.g. AIT|ARC|CAR|GLS|MER|NCP|SIN|STG|TAN:[AIT] AIT
[wcne-128-154-203-60:Workshops/Datasets/3c454] eferrara%
```

Here, ROI diameter × image scale = size of each axis

To view the entire region, match these values to the header values



Binning for Visualization - 3

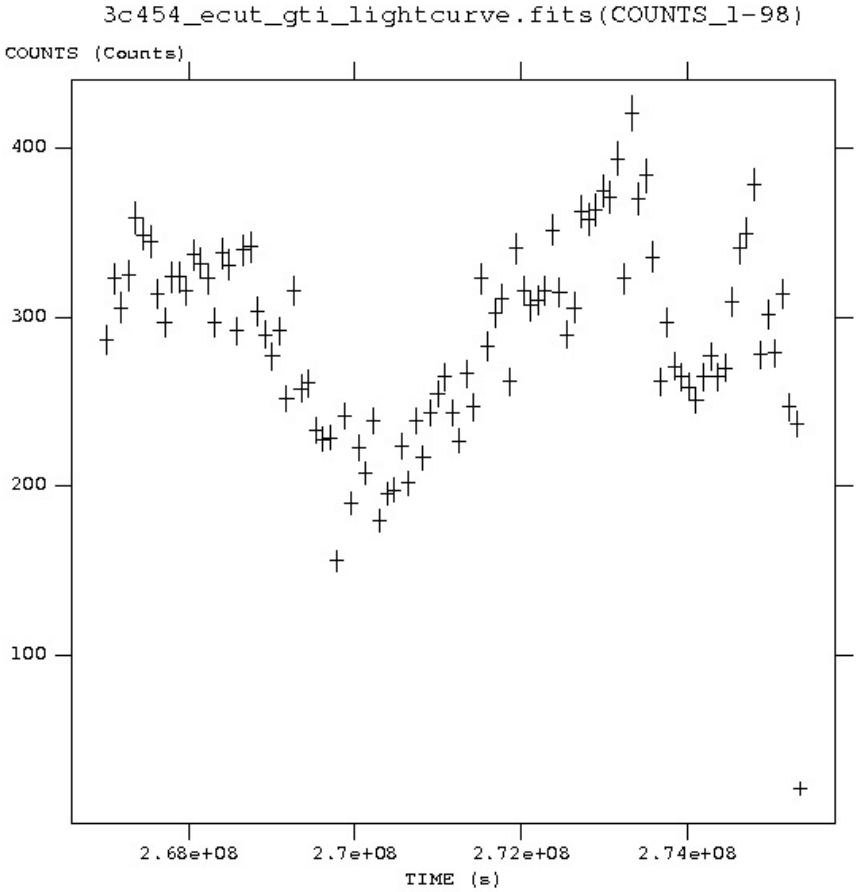
- *Making a quick-look lightcurve*

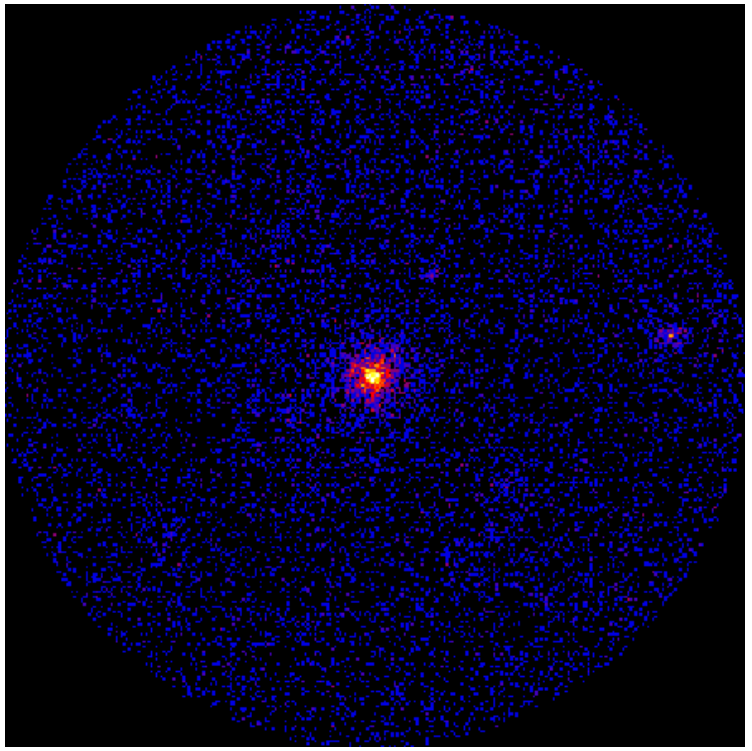
```
[wcne-128-154-203-60:Workshops/Datasets/3c454] eferrara% gtbin
This is gtbin version ScienceTools-v9r17p0-fssc-20100906
Type of output file (CCUBE|CMAP|LC|PHA1|PHA2) [CMAP] LC
Event data file name[3c454_ecut_gti.fits]
Output file name[3c454_ecut_gti_cmap.fits] 3c454_ecut_gti_lightcurve.fits
Spacecraft data file name[L090923112502E0D2F37E71_SC00.fits] L090923112502E0D2F37E71_SC00.fits
Algorithm for defining time bins (FILE|LIN|SNR) [LIN] LIN
Start value for first time bin in MET[0] 266976000
Stop value for last time bin in MET[0] 275369897
Width of linearly uniform time bins in seconds[0] 86400
[wcne-128-154-203-60:Workshops/Datasets/3c454] eferrara%
```

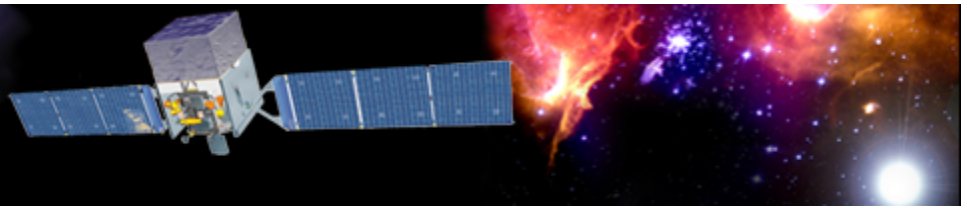
Times do not have to align to full data series

Binning for Visualization - 4

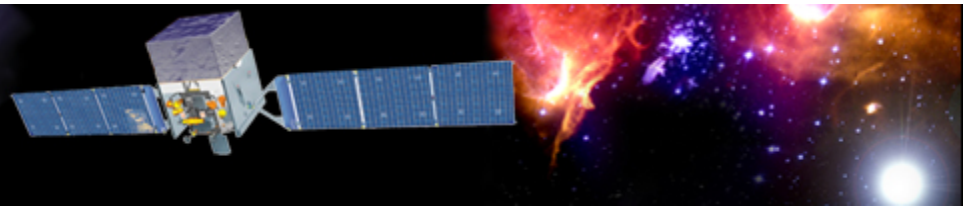
- *Gtbin products are easily viewable in fv or ds9*







End - Data Exploration



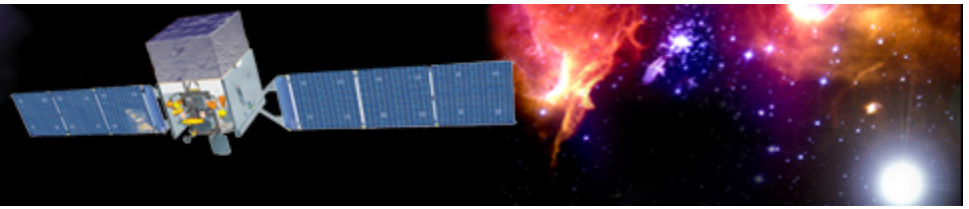
Aperture Photometry - 1

- *The results from gtbin must be exposure corrected using gtexposure*
  - *Adds an exposure column to the lightcurve file*

```
[wcne-128-154-203-21:Workshops/Oct2009_workshop/3c454_workshop] eferrara% gtexposure
Light curve file[] 3c454_ecut_gti_lightcurve.fits
Spacecraft file[] L090923112502E0D2F37E71_SC00.fits
Response functions[P6_V3_DIFFUSE]
Source model XML file[none]
Photon index for spectral weighting[-2.1]
```

A more complicated region will require a source model

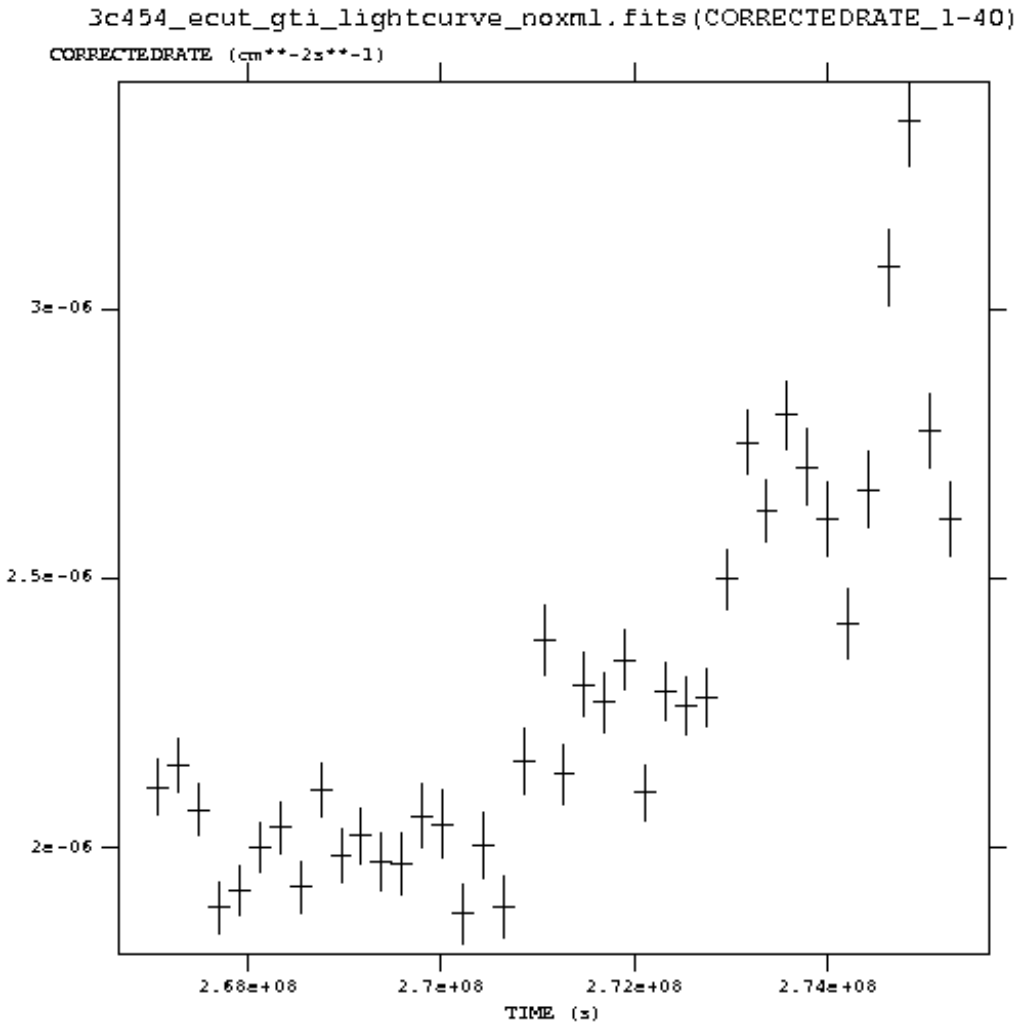
This is a good "default" spectral index for LAT sources

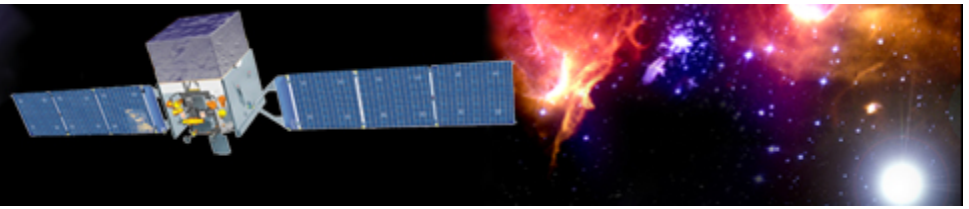


Aperture Photometry - 2

- *Final FITS file contains:*
  - *Time in MET*
  - *Bin Width in seconds*
  - *Number of counts per bin*
  - *Error*
  - *Exposure*
- *To convert to rates, use fv or other tool to divide counts and errors by exposure*
- *Error bars in output are sqrt(counts)*
  - *In some instances (e.g. too few counts) this may be incorrect*
  - *Correcting this may be more complicated*

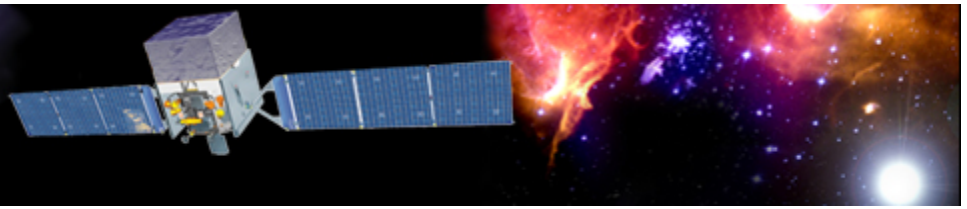
Exposure Corrected Light Curve



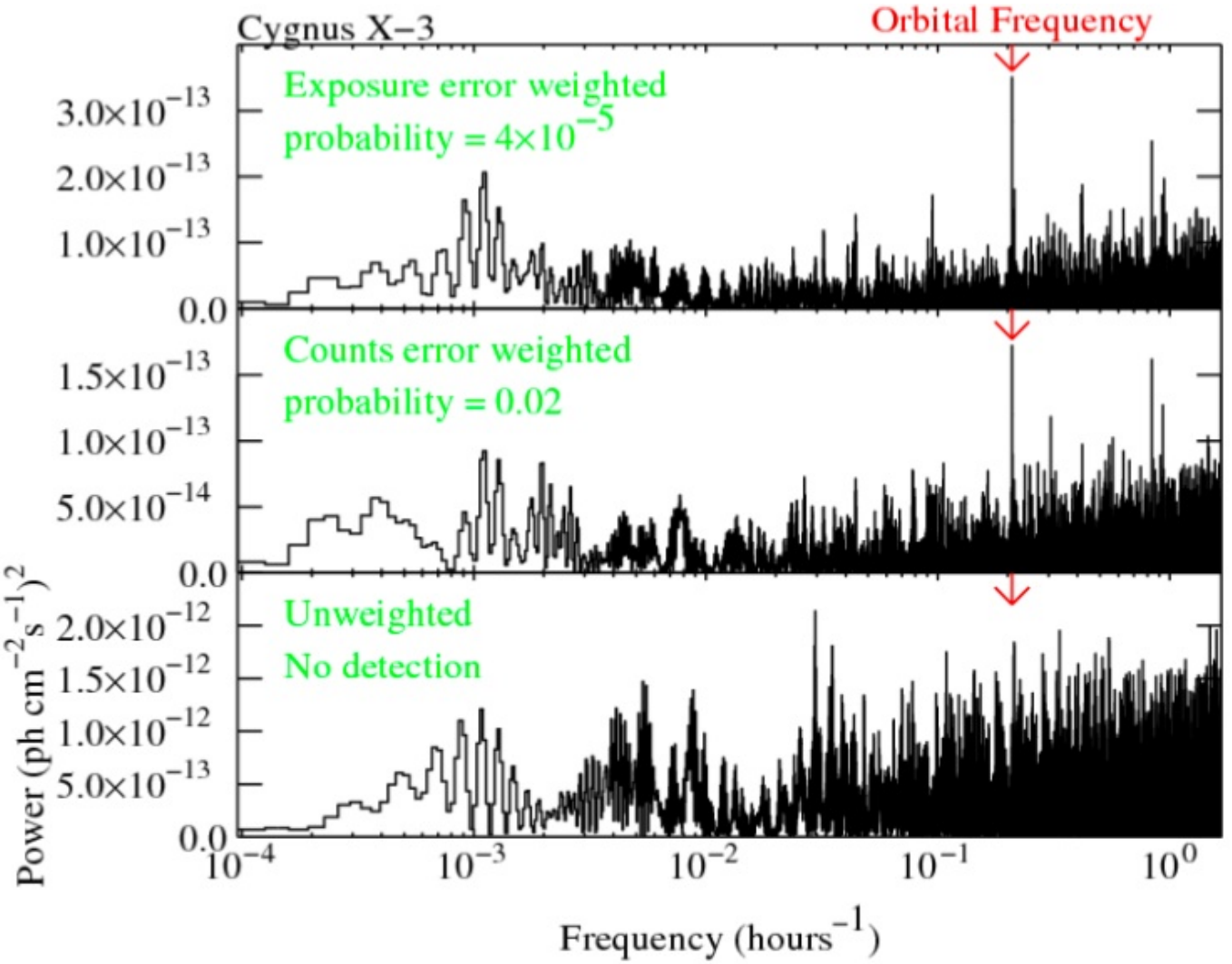


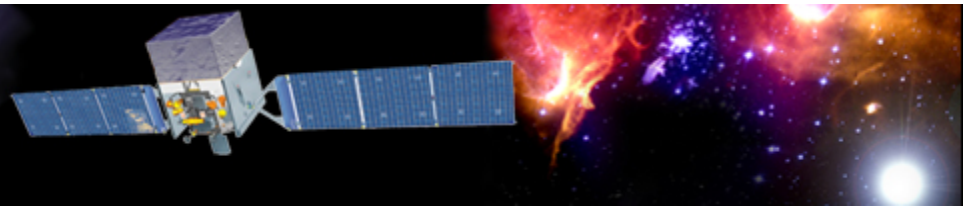
Using Exposure Errors

- *For some purposes, errors based on observed counts may not be correct*
- *Alternative is to use errors based on the exposure*
  - *Calculate the mean count rate*
  - *For each time bin, calculate the expected number of counts based on the exposure for that time bin*
  - *Take the square root of that predicted number of counts*
  - *Divide by the exposure to get the rate*
  - *The resulting error value is based only on the "quality" of each time bin*
- *References for error bars treatment:*
  - *Gehrels, 1986, ApJ, 303, 336*
  - *Kraft, Burrows, & Nousek, 1991, ApJ, 374, 344*



Comparing Error types





Barycentering

- *If your source is sensitive to the motion of the Earth, you may wish to barycenter the events file to remove that effect*
- *gtbary is usually used to barycenter the events file for pulsar timing. But it can also be used for light curves*
  - *gtbary must be the last step of the analysis (after exposure calculation)*
  - *Spacecraft file must be longer than the events file (remember this when doing the gtselect step)*
  - *gtbary overwrites the time column with the barycentered (corrected) photon arrival times. It's wise to make a copy of your data file before running gtbary.*