Fermi LAT Data Extraction and Preparation

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Overview

- We will learn how to extract Fermi LAT data and prepare for analysis with the Science Tools
- Data Access:
  - File types
  - Event classes
  - Obtaining the data
  - Preparing the data for analysis
- Science Tools:
  - What are Science Tools?
  - Documentation
  - Execution modes

Data Access

File Types:

- Event file
  - Photon files: contain all information needed to perform science analysis
  - Extended fils: contain additional information about each photon. Not necessary for most science analysis
- Spacecraft pointing and livetime history file:
  - Contains info about the spacecraft (the LAT to be more specific) position and orientation in 30 seconds intervals
  - Used to make time cuts on events based on Good Time Intervals (GTIs)

Event Classes

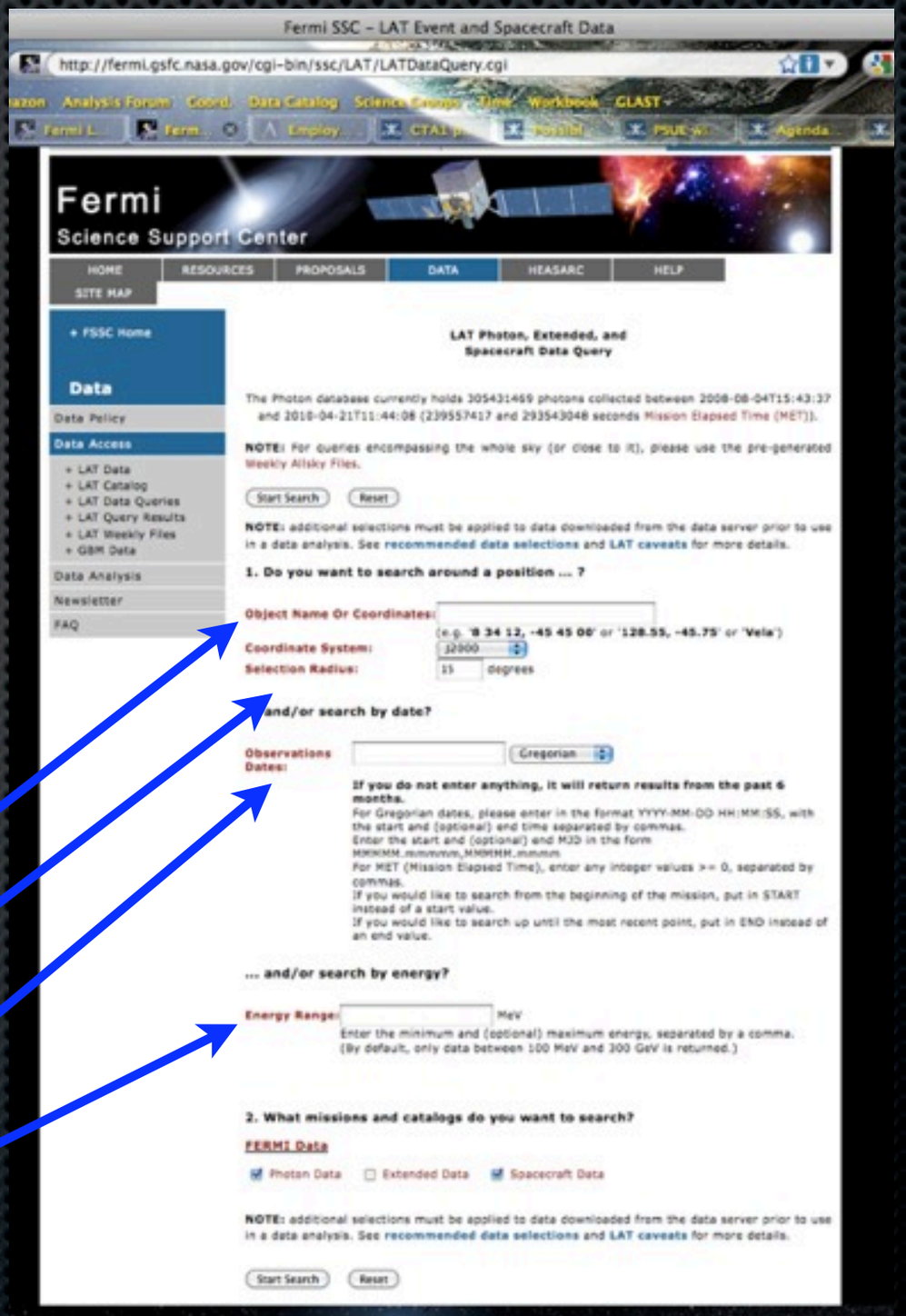
- There are three classes available in both types of event files:
  - **Transient:** Loose quality definition. Likely some background contamination
  - **Source:** Tighter quality cuts. Typically included in transient analyses
  - **Diffuse:** Tightest background rejection cuts. Highest probability of being a photon. Used for most analyses.

Data Access

- All *Fermi* LAT data products are available on the Fermi Science Support Center (FSSC) page:

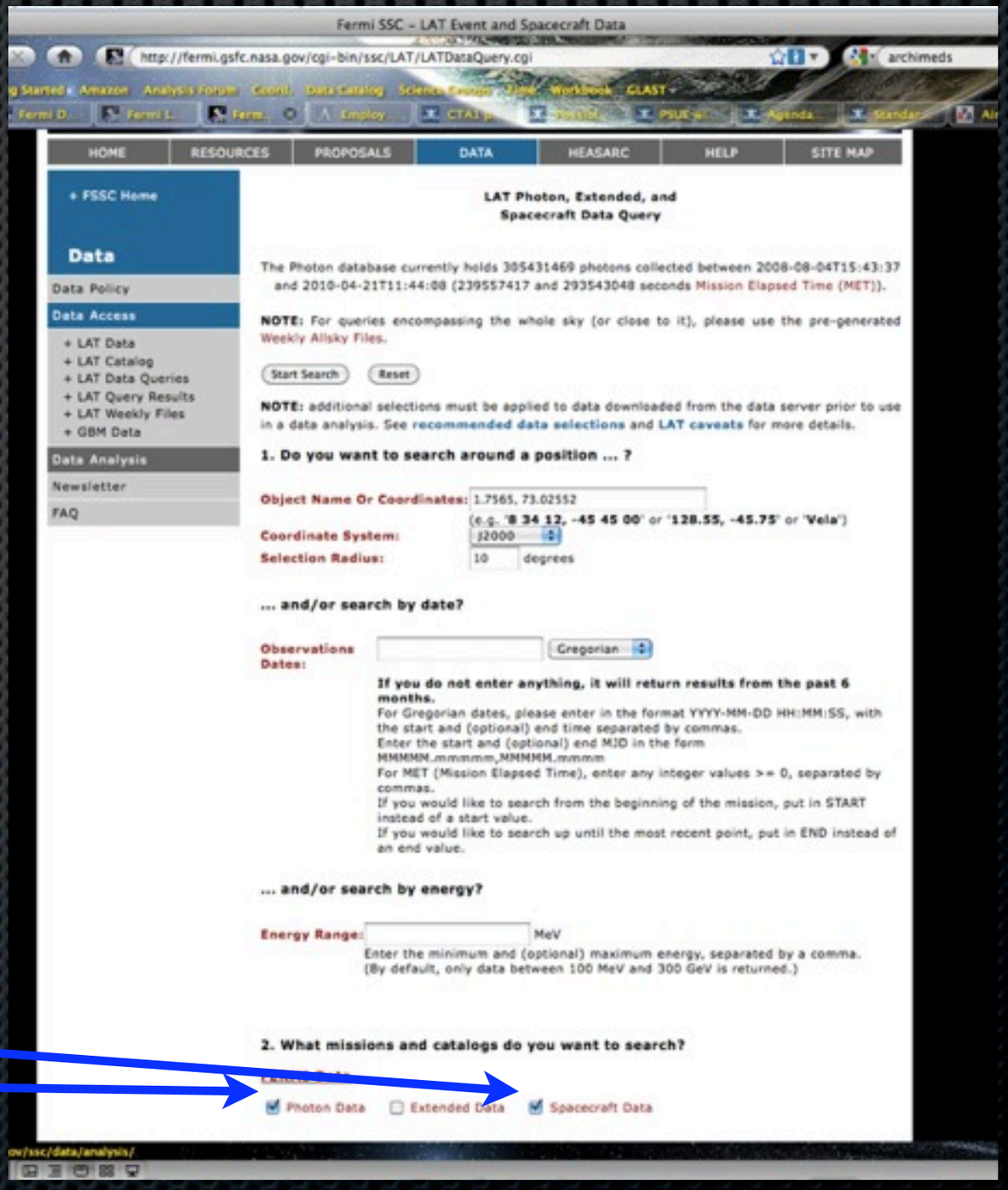
  <http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi>

- On this page user can select a region of the sky around a given object.
  - User can specify either the name of the object or its coordinates.
  - Select on the radius of the region of interest (ROI)
  - Specify start and stop times for the observation dates
  - Specify an energy range



Data Selection

- We will extract data in a 10 degree radius around the CTA1 pulsar (RA = 1.7656, DEC = 73.02552).
- Leaving the date and energy range fields empty will retrieve all data available in the 100 MeV - 300 GeV range
- We are interested in the photon data and spacecraft data files.

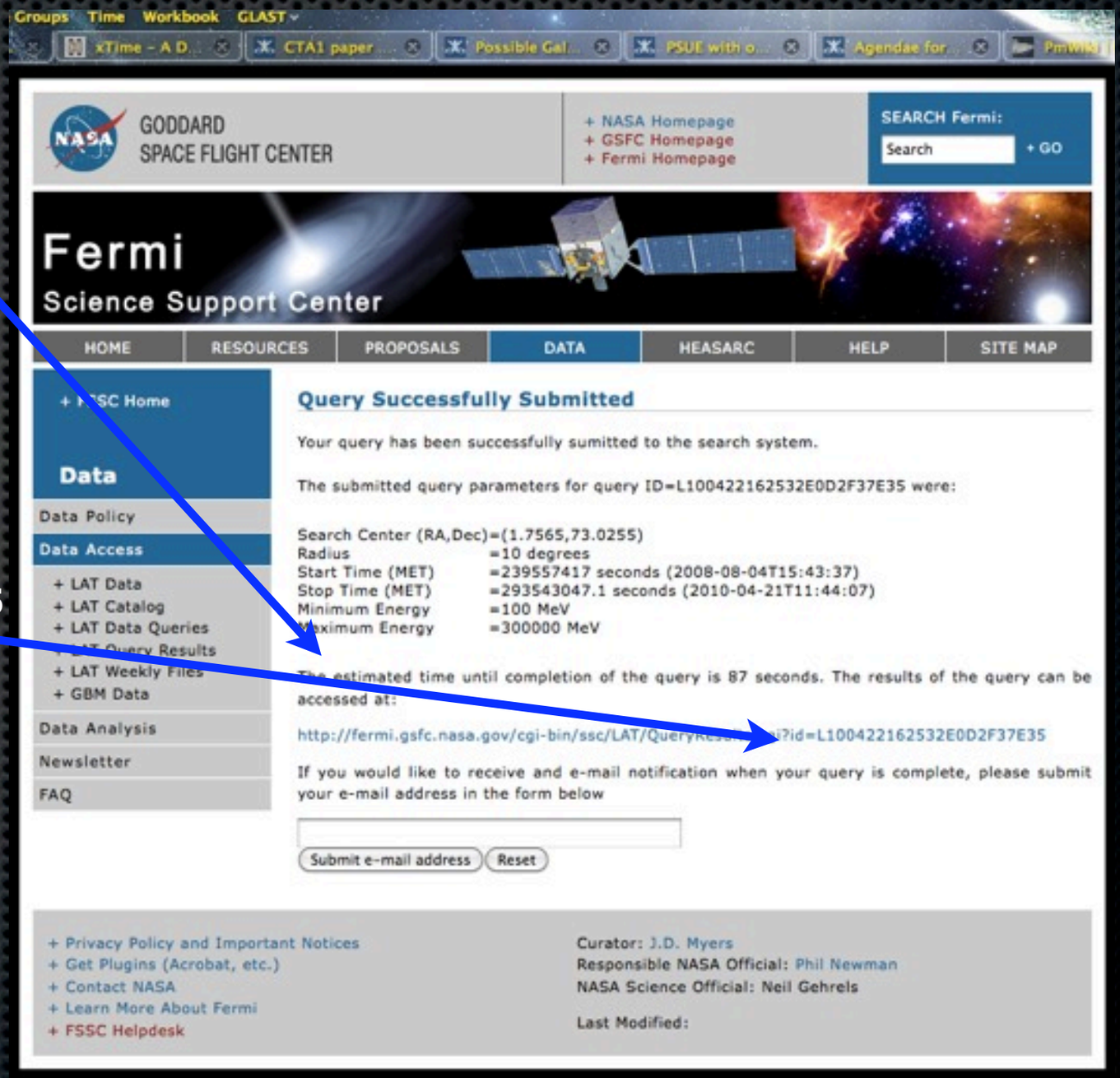


Data Selection

- You will get a page like this which summarizes your query and gives an estimated time for your data to be ready to download
- You can retrieve this same data in the future using the unique query number assigned to this one query. **L100422162532E0D2F37E35** in this case
- To access this query in the future just go to: <http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/QueryResults.cgi>

  ≥

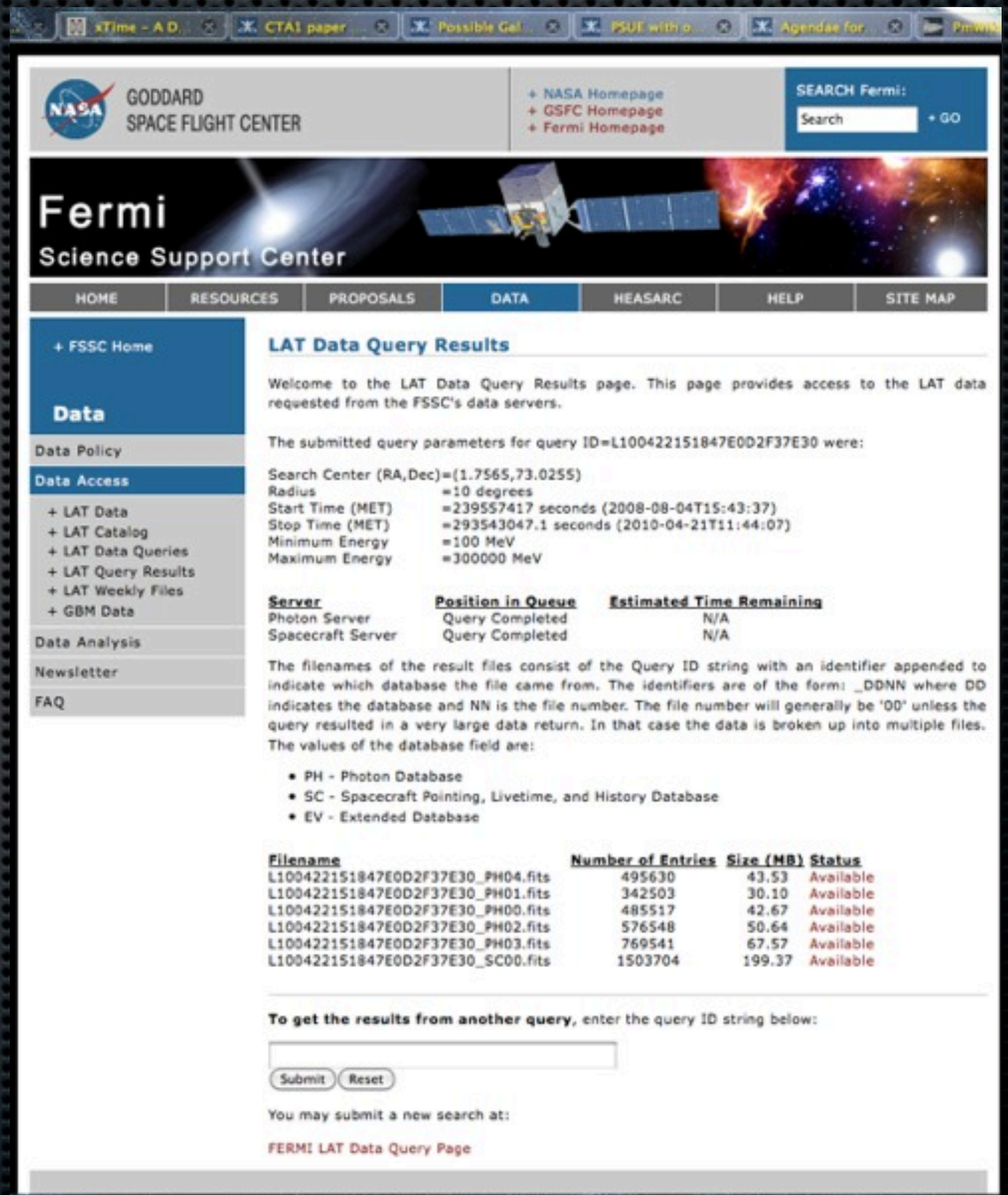
  and use the query #



Data Selection

- If you click on the link in the query summary page you will get the requested files.
  - Files tagged with the PH## string are the photon events files
  - Space craft file is tagged with the SC string
- Download the files

```
[abdo@heselin tutorial]$ ls -1 L100422151847E0D2F37E30_*
L100422151847E0D2F37E30_PH00.fits
L100422151847E0D2F37E30_PH01.fits
L100422151847E0D2F37E30_PH02.fits
L100422151847E0D2F37E30_PH03.fits
L100422151847E0D2F37E30_PH04.fits
L100422151847E0D2F37E30_SC00.fits
[abdo@heselin tutorial]$
```



Weekly Files

- Often one is interested in multiple regions of the sky and would like to keep an all sky data files handy on the cluster.
- The easy way to do this is to download the weekly files already merged from the FSSC.
  - <http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/WeeklyFiles.cgi>
- The weekly files contain only the "Diffuse" class photon events
- Weekly spacecraft files are also available
- An easy way to get these files is using wget:

```
$wget -m -P . -nH --cut-dirs=4 -np http://fermi.gsfc.nasa.gov/FTP/
fermi/data/lat/weekly/
```

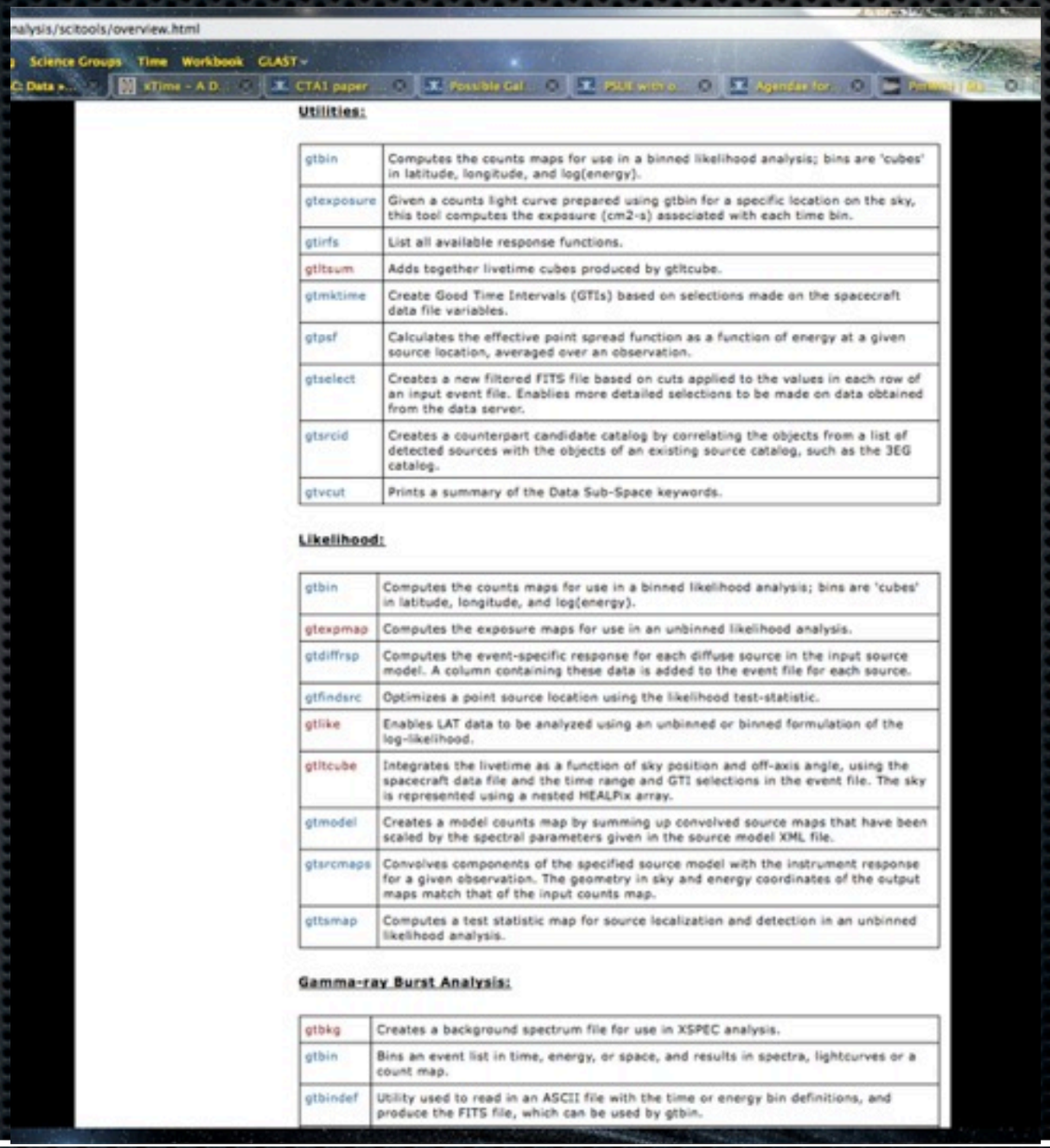
- This will download all weekly files (spacecraft, photon, and skymap images)

Science Tools

- Developed by the Fermi LAT team and is available on the FSSC website:
  - < http://fermi.gsfc.nasa.gov/ssc/data/analysis/ >
- Documentation at< http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/ >:
  - **Cicerone** <http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/>: Describes the full Fermi Science Tools. It is a detailed description of the analysis environment and its methodology.
  - **Reference manual** < http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/references.html> : Detailed description of each tool
  - **Analysis threads** < http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/ >: Cookbook examples of some common analyses
- User contributed S/W:
  - < http://fermi.gsfc.nasa.gov/ssc/data/analysis/user/ >
  - Any body can contribute! FSSC is in no way responsible for this S/W

Science Tools

- A list of all available Science Tools:
  < http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/overview.html >



Science Tools

- Execution:
  - Interactive:
    - User will be asked for parameter entries on the command line
    - Allows for access of some parameters of the tool. No access for hidden parameters

```
$ gtselect
Input FT1 file[@events.txt]
Output FT1 file[FT1.fits]
RA for new search center (degrees) (0:360) [0] 1.7565
Dec for new search center (degrees) (-90:90) [0] 73.02552
radius of new search region (degrees) (0:180) [180] 10
start time (MET in s) (0:) [0] 239557417
end time (MET in s) (0:) [0] 293543047
lower energy limit (MeV) (0:) [100]
upper energy limit (MeV) (0:) [300000]
maximum zenith angle value (degrees) (0:180) [180] 105
```

  - Command line style:
    - Allows access for all parameters of a given tool.
    - Useful for scripting

```
$gtselect infile=@events.txt outfile=FT1.fits ra=1.7565 dec=73.02552 rad=10.0 tmin=239557417 tmax=293543047 emin=100
emax=300000 evclsmin=3 evclsmax=3 zmax=105
```

FITS Format Data Files

- Standard file format for astronomical data
- FITS stands for Flexible Image Transport System
- Designed to store scientific data sets consisting of multi-dimensional arrays such as:
  - 1-D spectra
  - 2-D images
  - 3-D data cubes
  - Tables containing rows and columns of data
- In addition to data stored FITS files contain “metadata” which is a list of information about the data set

FITS Data Files

- One can look at what is inside a FITS file with fv:

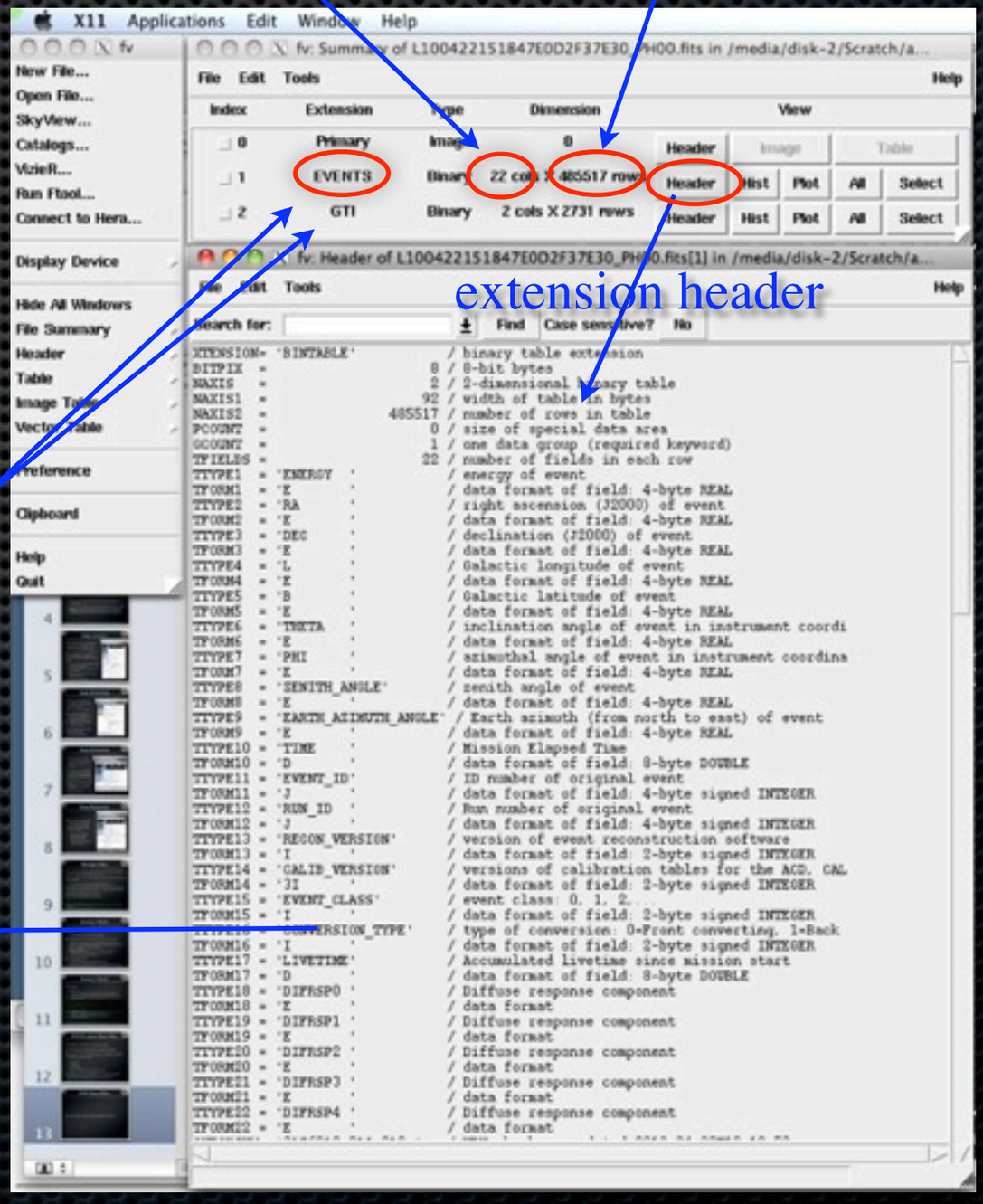
```
$fv L100422151847E0D2F37E30_PH00.fits
```

Contains helpful information about the data such as the energy cuts, start and stop times, and info about the ROI

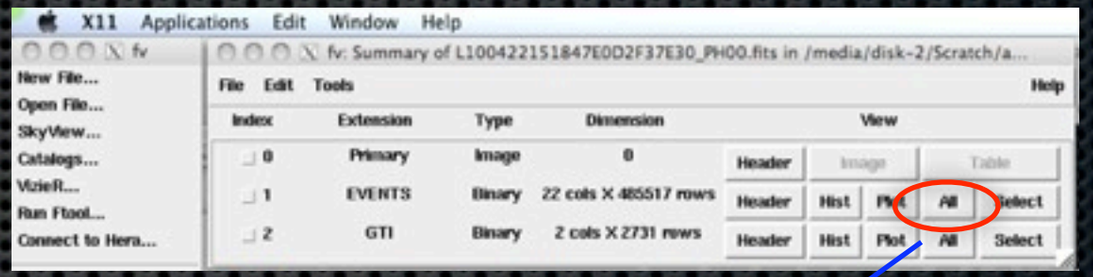
```
EXTVER  =                    1 / auto assigned by template parser
HISTORY Input merit file: /scratch/glastmp/P105-FT1/0/r0239557414-000000_merit.r
HISTORY oot
HISTORY Filter string: (FswGamState==0||FswGamState==3) && (CTBCORE>0) && (CTBBe
HISTORY stEnergyProb>0) && (CTBBestEnergy>10) && (CTBBestEnergyRatio<5) && (CTBC
HISTORY lassLevel>0) && (EvtElapsedTime >= 239557417)  && (EvtElapsedTime <= 239
HISTORY 558070)
DSTYP1  = 'TIME     '
DSUNI1  = 's        '
DSVAL1  = 'TABLE    '
DSREF1  = ':GTI     '
NDSKEYS =                    4 / Number of data subspace keywords in header
HISTORY CFITSIO used the following filtering expression to create this table:
HISTORY /scratch/glastmp/P105-FT1/0/foo.fit[EVENTS][gtifilter("/scratch/glastmp/
HISTORY P105-FT1/0/gll_ph_r0239557414_v105.fit_tempgti")]
DSTYP2  = 'POS(RA,DEC)'
DSUNI2  = 'deg      '
DSVAL2  = 'circle(1.756500,73.025520,10.000000)'
DSTYP3  = 'TIME     '
DSUNI3  = 's        '
DSVAL3  = '239557417.000000:293543047.085000'
DSTYP4  = 'ENERGY   '
DSUNI4  = 'MeV      '
DSVAL4  = '100.000000:300000.000000'
END
```

Extensions

24 Event parameters 485517 Events



FITS Files



Data table

fv: Binary Table of L100422151847E0D2F37E30_PH00.fits[1] in /media/disk-2/Scratch/abdo/tutorial/

File Edit Tools

Select All Invert	ENERGY E MeV Modify	RA E deg Modify	DEC E deg Modify	L E deg Modify	B E deg Modify	THETA E deg Modify	PHI E deg Modify	ZENITH_ANGLE E deg Modify	EARTH_AZIMUTH_ANGLE E deg Modify	TIME D s Modify	EVENT_ID J Modify	RUN_ID J Modify	RECON_VERSION I Modify	CALIB_VERSION 3I Modify
1	1.422766E+02	3.594714E+02	7.979739E+01	1.204719E+02	1.710243E+01	6.910254E+01	3.022012E+02	9.885333E+01	9.534511E+00	2.395605354906E+08	3266873	239559565	0	Plot
2	6.630074E+02	3.552198E+02	8.041496E+01	1.198917E+02	1.796245E+01	5.995349E+01	3.209974E+02	8.909497E+01	6.957580E+00	2.395608211238E+08	3807054	239559565	0	Plot
3	9.023116E+02	3.574374E+02	8.135407E+01	1.205124E+02	1.877364E+01	4.585815E+01	3.542967E+02	7.540024E+01	3.445021E+00	2.395612811929E+08	4555559	239559565	0	Plot
4	1.771124E+02	3.543519E+02	8.143912E+01	1.200680E+02	1.898205E+01	3.139957E+01	2.777657E+01	6.379387E+01	3.587201E+02	2.395674775070E+08	3939947	239565645	0	Plot
5	2.098734E+02	3.475662E+02	8.066676E+01	1.187390E+02	1.862966E+01	2.459715E+01	8.939301E+01	5.936841E+01	3.514109E+02	2.395680481979E+08	4955984	239565645	0	Plot
6	3.502753E+02	3.499189E+02	8.138141E+01	1.193874E+02	1.914824E+01	2.860217E+01	1.145971E+02	6.194921E+01	3.508727E+02	2.395683214002E+08	5526752	239565645	0	Plot
7	1.781785E+02	3.578154E+02	8.157468E+01	1.206275E+02	1.897354E+01	3.936227E+01	1.460957E+02	6.969838E+01	3.510123E+02	2.395687529421E+08	6488198	239565645	0	Plot
8	2.574498E+02	3.589905E+02	7.956792E+01	1.203313E+02	1.697745E+01	5.110657E+01	1.724866E+02	7.959357E+01	3.499977E+02	2.395690757812E+08	7189960	239565645	0	Plot
9	1.656817E+02	3.504794E+02	8.159678E+01	1.195520E+02	1.931879E+01	5.690671E+01	1.920872E+02	8.629076E+01	3.535395E+02	2.395692771012E+08	7609752	239565645	0	Plot
10	1.609002E+02	3.436289E+02	8.210265E+01	1.188331E+02	2.017861E+01	2.954037E+01	3.892424E+01	6.304522E+01	3.563375E+02	2.395790453021E+08	2732559	239577663	0	Plot
11	2.314772E+02	3.510547E+02	8.081142E+01	1.193452E+02	1.855312E+01	2.657988E+01	1.074564E+02	6.039319E+01	3.507241E+02	2.395796981481E+08	3861692	239577663	0	Plot
12	6.706958E+02	3.404523E+02	8.179659E+01	1.182607E+02	2.012719E+01	2.884743E+01	3.961025E+01	6.256845E+01	3.557742E+02	2.396019843679E+08	1443949	239601276	0	Plot
13	1.048911E+03	3.473953E+02	8.144180E+01	1.190439E+02	1.934956E+01	2.734716E+01	4.231366E+01	6.118829E+01	3.561180E+02	2.396020330678E+08	1538493	239601276	0	Plot
14	1.007900E+02	3.565889E+02	7.966393E+01	1.199163E+02	1.717535E+01	2.240885E+01	8.667103E+01	5.720770E+01	3.519543E+02	2.396024279398E+08	2324489	239601276	0	Plot
15	1.419089E+02	3.432040E+02	8.167627E+01	1.185654E+02	1.982917E+01	3.856222E+01	1.364588E+02	6.954747E+01	3.511872E+02	2.396030548513E+08	3547407	239601276	0	Plot
16	1.377816E+02	3.593776E+02	8.295177E+01	1.211848E+02	2.026375E+01	6.878880E+01	2.521326E+02	9.926472E+01	3.559296E+02	2.396041253564E+08	5300410	239601276	0	Plot
17	7.190220E+02	3.557790E+02	8.199392E+01	1.204457E+02	1.945409E+01	2.384986E+01	7.394768E+01	5.882036E+01	3.544506E+02	2.396138221867E+08	3166617	239612600	0	Plot
18	3.713688E+02	3.460890E+02	8.087586E+01	1.186022E+02	1.891786E+01	3.805448E+01	1.361325E+02	6.877351E+01	3.502170E+02	2.396144999728E+08	4595556	239612600	0	Plot
19	4.937043E+02	3.576205E+02	8.193576E+01	1.206928E+02	1.933039E+01	5.253804E+01	1.722994E+02	8.161399E+01	3.525101E+02	2.396150111359E+08	5521101	239612600	0	Plot
20	1.544778E+02	3.561945E+02	7.945380E+01	1.197861E+02	1.699154E+01	7.462011E+01	6.216640E+01	5.929400E+01	3.579223E+02	2.396306386893E+08	1706290	239629788	0	Plot
21	5.892498E+03	3.595913E+02	8.284727E+01	1.211878E+02	2.015600E+01	6.792636E+01	4.949624E+01	5.907465E+01	3.554954E+02	2.396310314699E+08	2966742	239629788	0	Plot

Go to: Edit cell:

Preparing The Data

- After you have downloaded the data from the FSSC server there are some necessary steps to prepare your data for the analysis:

1. Select the event class suitable for your type of analysis. In most cases you want to select the "Diffuse" class event. This is done with `gtselect`
2. Exclude "bad" time intervals with `gtmktime`.
3. If you got more than one event file, like in our case, you could either merge all these files on one event file to use in your analysis or you could use a list of these files.
4. Files from the FSSC are not time ordered. It is a good practice to time order these files especially before performing pulsar analysis. This will make some of the Science Tools run much faster. This is done with ftsort or fsort

1. Selecting Event Class

- So now we have four event files that we just downloaded from the FSSC. We will select only “Diffuse”
- We will first make a list of these files and store it in a text file:

```
$ls
L100422151847E0D2F37E30_PH00.fits
L100422151847E0D2F37E30_PH01.fits
L100422151847E0D2F37E30_PH02.fits
L100422151847E0D2F37E30_PH03.fits
L100422151847E0D2F37E30_PH04.fits
L100422151847E0D2F37E30_SC00.fits

$ls -1 L100422151847E0D2F37E30_PH0* > events.txt
```

1. Selecting Event Class Cont'd

- By default, gtselect prompts for cuts on:
  - Time
  - Energy
  - Position (RA,Dec,radius)
  - Maximum Zenith Angle
- However, by using hidden parameters (or the 'Show Advanced Parameters' check box in GUI mode), you can also make cuts on:
  - Minimum event class ID
  - Maximum event class ID
  - Minimum pulse phase
  - Maximum pulse phase

```
Search Center (RA,Dec)=(1.7565,73.0255)
Radius                =10 degrees
Start Time (MET)      =239557417 seconds (2008-08-04T15:43:37)
Stop Time (MET)       =293543047.1 seconds (2010-04-21T11:44:07)
Minimum Energy        =100 MeV
Maximum Energy        =300000 MeV
```

```
$gtselect infile=@events.txt outfile=FT1.fits ra=1.7565
dec=73.02552 rad=10.0 tmin=239557417 tmax=293543047
emin=100 emax=300000 evclsmin=3 evclsmax=3 zmax=105
```

- Selection on event class is done through the evclsmin and evclsmax hidden parameters

2. Good Time Intervals

- A GTI is a time range in which the data collected is considered to be valid.
- Why would that happen:
  - Dead time
  - Additional cuts, especially on the zenith angle, might mean that the source will not be in FOV
  - Space craft problems(SIUs).
- gtmktime will update the GTI extension in the events file
- GTIs are used by Science Tools to calculate the exposure for a given observation

2. Good Time Intervals Cont'd

- Parameters to use with gtmktime:
  - DATA_QUAL: Data quality flag in spacecraft files (use `DATA_QUAL == 1`)
  - IN_SAA: Was FERMI in the Southern Atlantic Anomaly region, if yes then discard events from this time period (use `IN_SAA!=T`)
  - LAT_CONFIG: Configuration of the spacecraft. (use `LAT_CONFIG == 1` for science intended data)
  - ROCK_ANGLE: Angle range at which the spacecraft "rocks" in its survey mode. (use `ABS(ROCK_ANGLE)<52`)
- Overall expression will be:
  - `DATA_QUAL==1 && LAT_CONFIG==1 && ABS(ROCK_ANGLE)<52 && IN_SAA!=T`

2. Good Time Intervals Cont'd

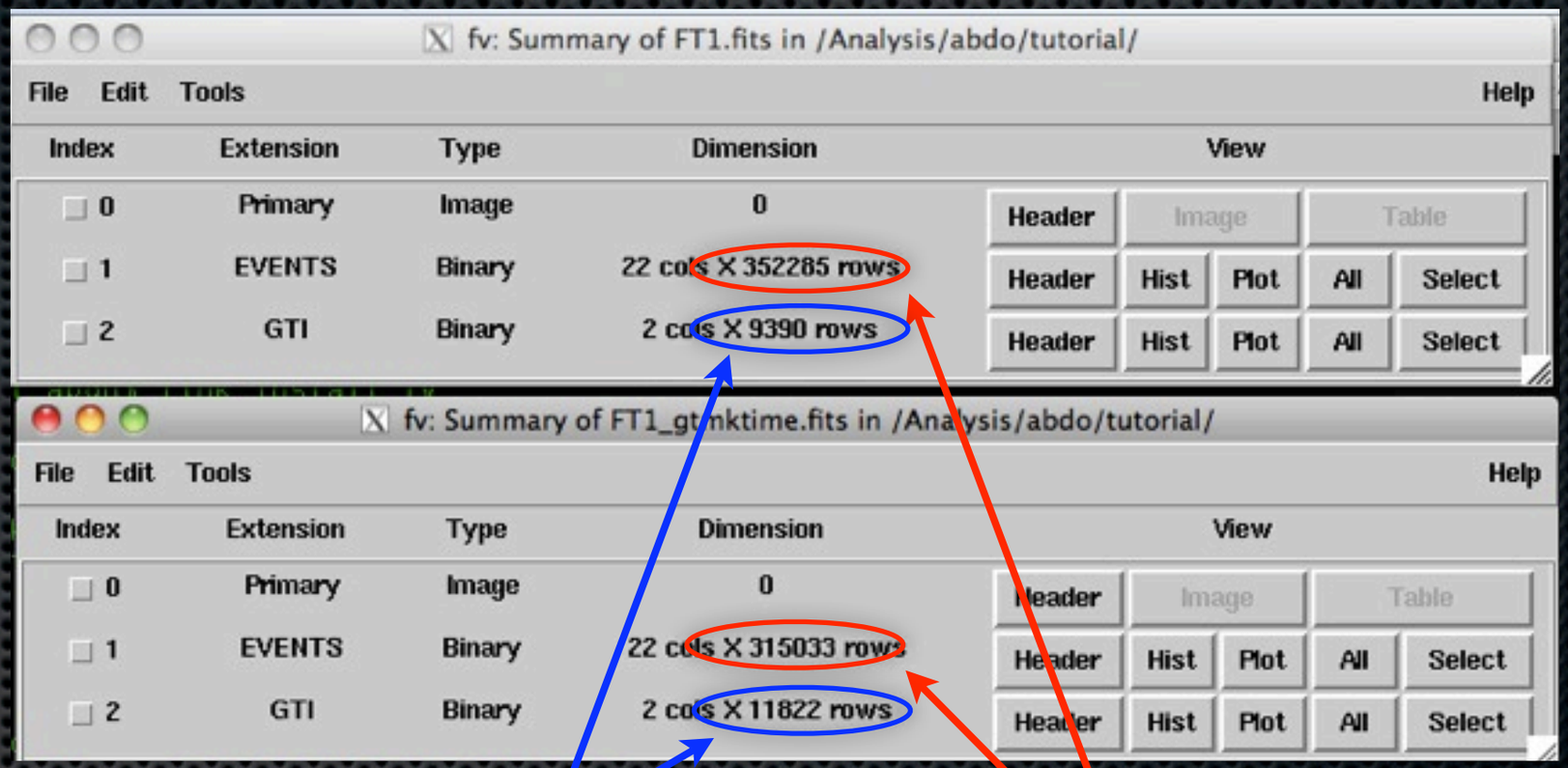
```
$ gtmktime
Spacecraft data file[]L1004221518 47E0D2F37E30_SC00.fits
Filter expression[] DATA_QUAL==1 && LAT_CONFIG==1 &&
ABS(ROCK_ANGLE)<52 && IN_SAA!=T
Apply ROI-based zenith angle cut[yes]
Event data file[]FT1.fits
Output event file name[]FT1_gtmktime.fits
```

Applies zenith angle based on the value from gtselect (105 deg. in this case)

2. Good Time Intervals Cont'd

Original file

gtmktime file



Number of GTIs increased

Number of events decreased

- The increase in the numbers of GTIs is due to the fact that after applying the cuts the original GTIs were split into smaller intervals.

3. Time Ordering

- To time order events in a given event file we will use the ftsort tool:

```
$ ftsort FT1_gtmktime.fits FT1_gtmktime_sorted.fits TIME
clobber=yes
```

- The time ordering is done over the TIME parameter in the events file
- The file (`FT1_gtmktime_sorted.fits`) is the new file we will be using