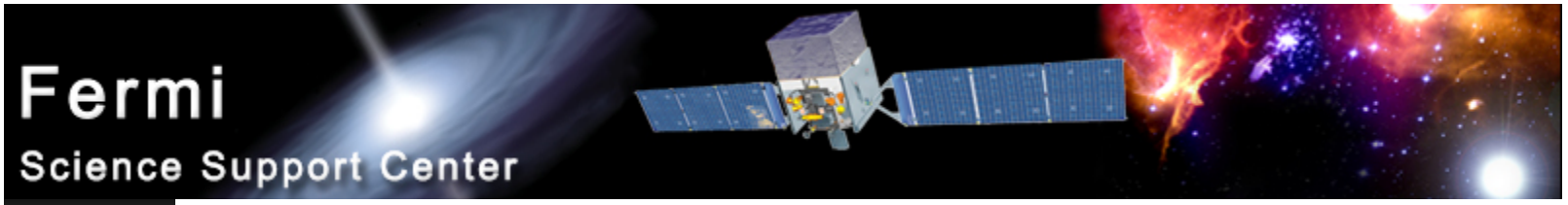
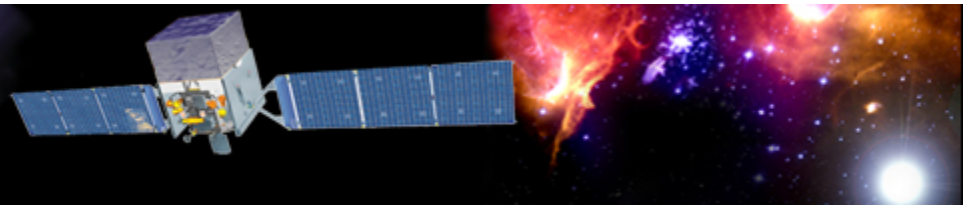


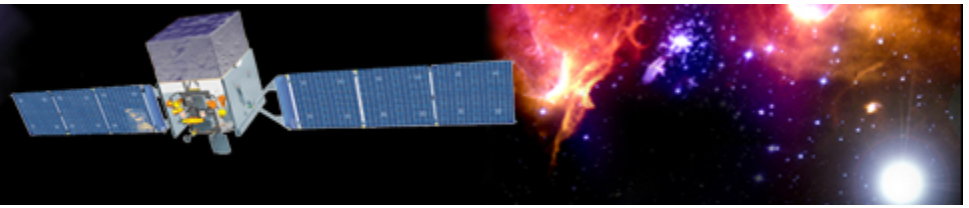
FSSC Science Tools

Pulsar Analysis



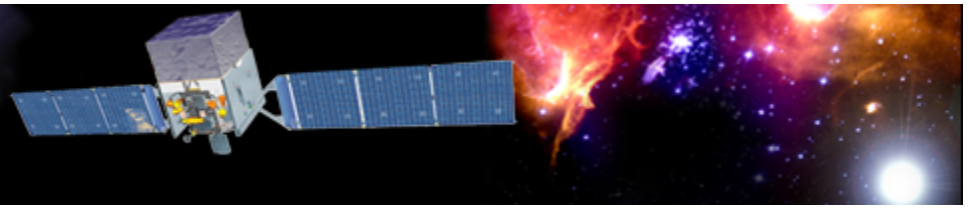
Typical Pulsar Analysis

- *Download data and screen events*
  - *Event file*
  - *Spacecraft file*
  - *Pulsar database file (Fermi_PulsarDB_v001.fits)*
- *Analyze time series data*
  - *Search for pulsations*
  - *Determine or refine pulsar ephemeris*
  - *Confirm periodicity published in the literature*
- *Assign pulse phase or orbital phase to each photon*
  - *Folded light curve (pulse shape or pulse profile)*
  - *Phase-resolved spectrum*
  - *Phase-resolved image*



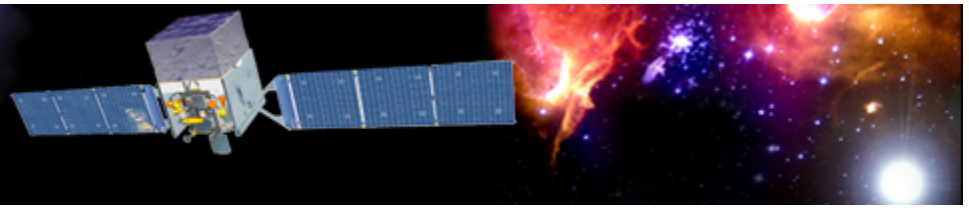
Tips for Data Screening

- *For time series analysis*
  - *For maximum sensitivity on pulse detection and frequency determination, screen data to maximize pulsed component and minimize constant ("background") component.*
    - *Tight spacial selection (typically size of a couple of PSFs)*
    - *Wider energy range*
    - *Broader choice of event types*
- *For analysis using pulse/orbital phase*
  - *Use standard event selection for spectral or image analysis.*



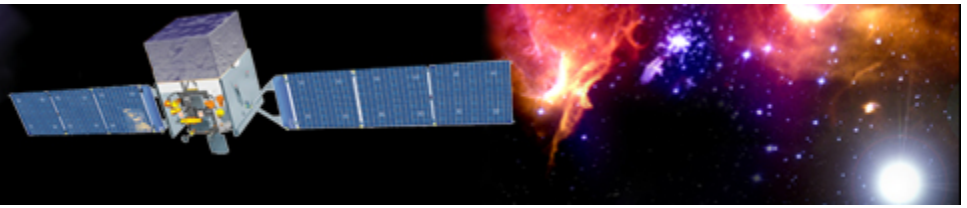
Time Series Analysis

- *Periodicity test*
  - *Chi-squared test (Leahy et al. 1983, ApJ 266, 160; Vaughan et al. 1994, ApJ 435, 362)*
  - *Z_n^2 test (Buccheri et al. 1983, A&A 128, 245)*
  - *Rayleigh test (equivalent to Z_n^2 test for n = 1)*
  - *H test (De Jager et al. 1989, A&A 221, 180)*
    - *Science Tools: gtpsearch, gtptest*
    - *Other tools: efsearch (XRONOS)*
- *Period search*
  - *Discrete Fourier transforms (Ransom 2002, AJ 124, 1788)*
    - *Science Tools: gtpspec*
    - *Other tools: powspec (XRONOS)*



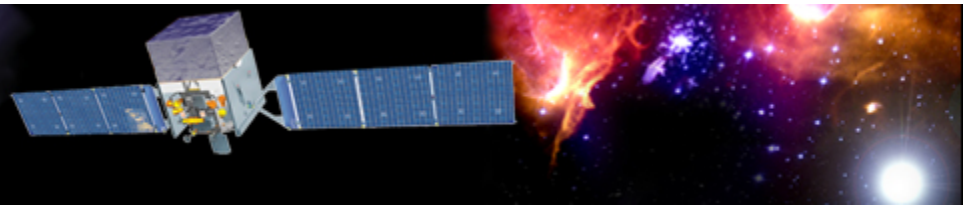
Pulse / Orbital Phase Assignment

- *Pulse Phase*
  - *Computes a pulse phase for each photon.*
  - *Appends the phase value to the event entry for later use.*
    - *Science Tools: gtpphase*
    - *Other tools: TEMPO2 with Fermi plugin*
- *Orbital Phase*
  - *Computes an orbital phase for each photon.*
  - *Appends the phase value to the event entry for later use.*
    - *Science Tools: gtophase*



Utility Tools

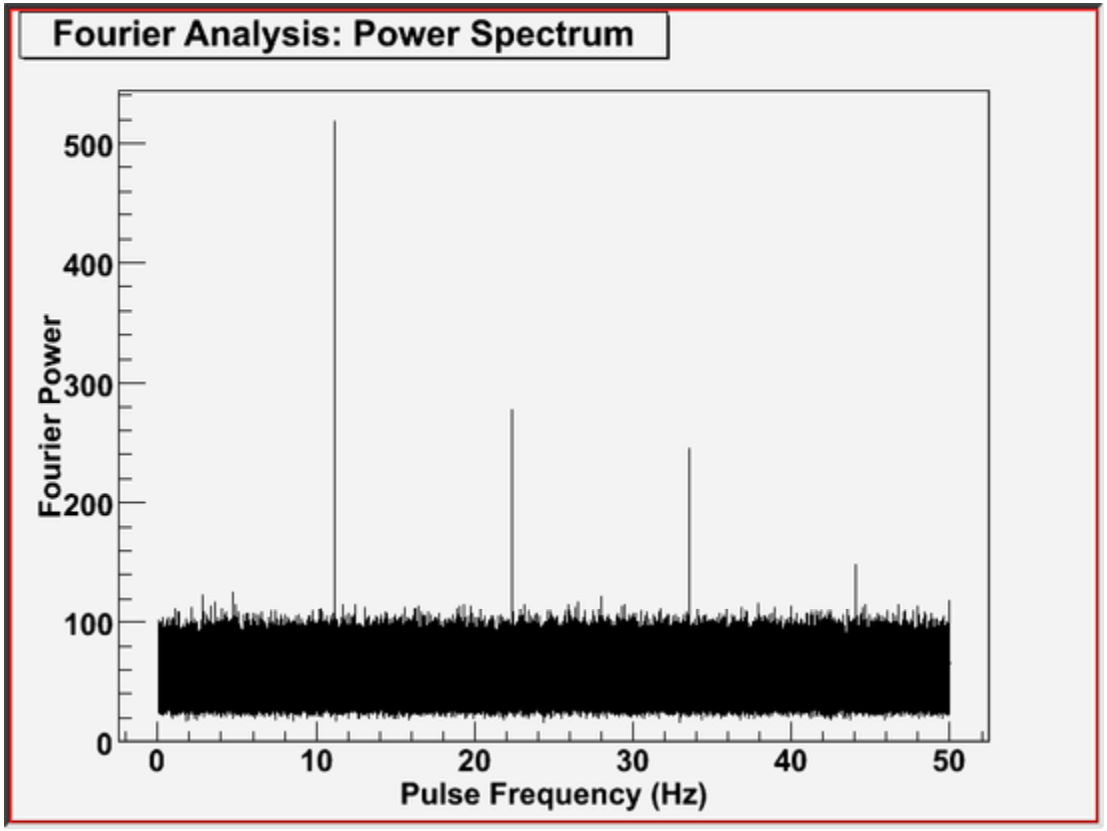
- *Ephemeris computer **gtephem***
  - *Reads pulsar ephemerides database and computes pulsar's spin ephemeris (such as pulse frequency) at a given moment in time.*
  - *Also serves as a sanity checker for first-time users of our pulsar ephemerides database.*
- *Pulsar ephemerides manipulation tool **gtpulsardb***
  - *Sub-selects pulsar ephemerides from a master database.*
  - *Also used to create, modify, merge pulsar ephemerides database.*
- *Photon arrival time correction **gtbary***
  - *Computes barycentric or geocentric time for each event and modifies event time in event file, for use with non-Fermi analysis tools such as XRONOS tools.*
  - ***CAUTION:** event files processed by gtbary must not be used in any analysis with Science Tools.*

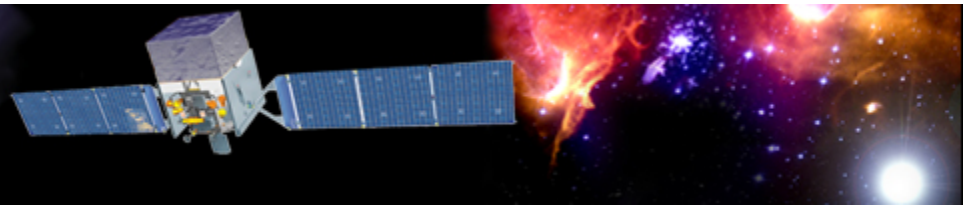


Analyzing Vela data

```
prompt> gtpspec
This is gtpspec version ScienceTools-v9r15p2-fssc-20090701
Event data file name[] Vela_100_300000_evt02.fits
Spacecraft data file name[] L090923110451E0D2F37E17_SC00.fits
Name of input pulsar ephemerides database file (for binary demodulation only)[]  Fermi_PulsarDB_v001.fits
Pulsar name (for binary demodulation only)[ANY] PSR J0835-4510
Output FITS file name (NONE for no FITS output)[] gtpspec_out.fits
Width of time bins, in seconds (0.:) [1.e-2] 0.01
Number of time bins to be transformed at once[1000000] 10000000
How will the time origin of the periodicity test be specified? (START|STOP|MIDDLE|USER) [MIDDLE] MIDDLE
Right Ascension to be used for barycenter corrections (degrees)[0.] 128.836048
Declination to be used for barycenter corrections (degrees)[0.] -45.176425
How will spin ephemeris be specified? (FREQ|PER) [FREQ] FREQ
Ratio of frequency first time derivative to frequency at the time origin (Hz)[0.] 0.0
Ratio of frequency second time derivative to frequency at the time origin (Hz/s)[0.] 0.0
Search Type: Fourier Analysis
Fourier Resolution: 1e-05 Hz
Sampling Frequency: 1e-05 Hz
Data Binning: 27 segments with 10000000 time bins in each segment
Probability Distribution: Chi Squared with 54 degrees of freedom
Search Range (Hz): [0.01, 50]
Number of Trial Frequencies: 4999000
Number of Independent Trials: 4999000
Maximum Statistic: 518.813411319925 at 11.19001 Hz
Chance Probability Range: (1.75188080614015e-70, 1.75205599227056e-70)
Warning in <TClass::TClass>: no dictionary for class st_graph::IFrame is available
prompt>
```

Analyzing Vela data (cont.)

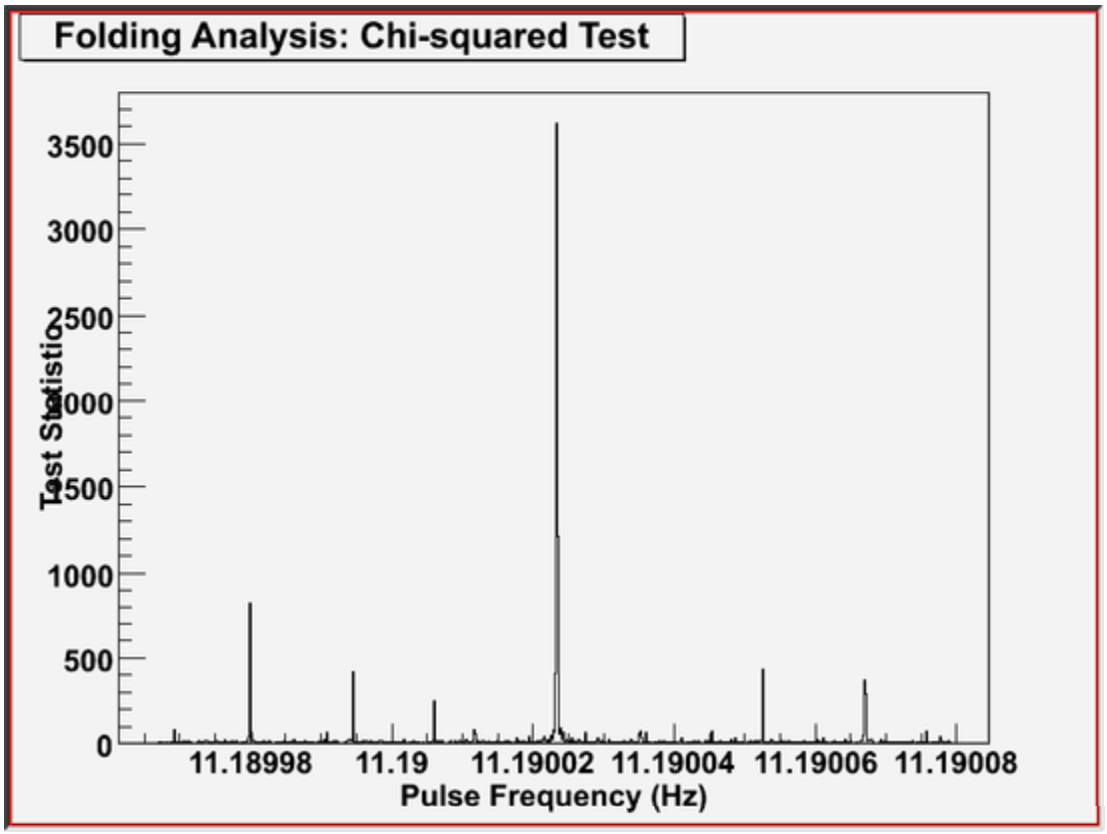


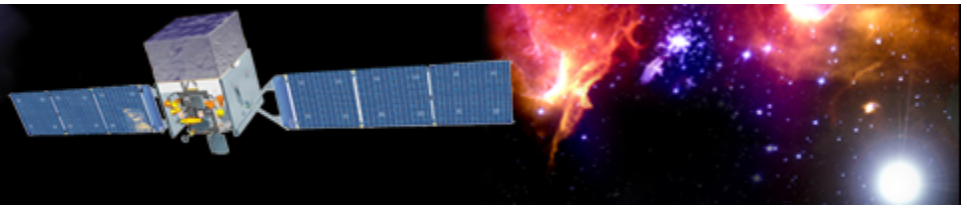


Analyzing Vela data (cont.)

```
prompt> gtpsearch
This is gtpsearch version ScienceTools-v9r15p2-fssc-20090701
Event data file name[] Vela_100_300000_evt02.fits
Spacecraft data file name[] L090923110451E0D2F37E17_SC00.fits
Pulsar ephemerides database file name[] Fermi_PulsarDB_v001.fits
Pulsar name[ANY] PSR J0835-4510
Output FITS file name (NONE for no FITS output)[] gtpsearch_out.fits
Type of statistical test to perform (CHI2 - Chi squared, RAYLEIGH - Rayleigh test, Z2N - Z2n test, H - H test) (CHI2|RAYLEIGH|Z2N|H) [CHI2] Chi2
Number of phase bins for Chi2 test[10] 10
Size of steps for trials, in units of the Fourier resolution (0.:) [0.5] 0.5
Number of trials[100] 600
How will the time origin of the periodicity test be specified? (START|STOP|MIDDLE|USER) [MIDDLE] USER
Time origin of the periodicity test[0.] 55028.5
Time format for the user-supplied time origin (FILE|MJD|ISO|FERMI|GLAST) [FILE] MJD
Time system for the user-supplied time origin (FILE|TAI|TDB|TT|UTC) [FILE] TDB
How will spin ephemeris be specified? (DB|FREQ|PER) [DB] FREQ
Epoch for the spin ephemeris[0.] 54663.0
Time format for spin ephemeris epoch (FILE|MJD|ISO|FERMI|GLAST) [FILE] MJD
Time system for spin ephemeris epoch (FILE|TAI|TDB|TT|UTC) [FILE] TDB
Right Ascension to be used for barycenter corrections (degrees)[0.] 128.836048
Declination to be used for barycenter corrections (degrees)[0.] -45.176425
Pulse frequency at the epoch of the spin ephemeris (Hz) (0.:) [1.] 11.19051540397055
First time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s)[0.] -1.559072535133380e-11
Second time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s/s)[0.] 0.0
Search Type: Folding Analysis
Fourier Resolution: 3.73754e-07 Hz
Sampling Frequency: 1.86877e-07 Hz
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
Search Range (Hz): [11.1899669982264, 11.1900789375696]
Number of Trial Frequencies: 600
Number of Independent Trials: 300
Maximum Statistic: 3617.22319536 at 11.1900234350906 Hz
Chance Probability Range: (0, 6.11271140709163e-97)
Warning in <TClass::TClass>: no dictionary for class st_graph::IFrame is available
prompt>
```

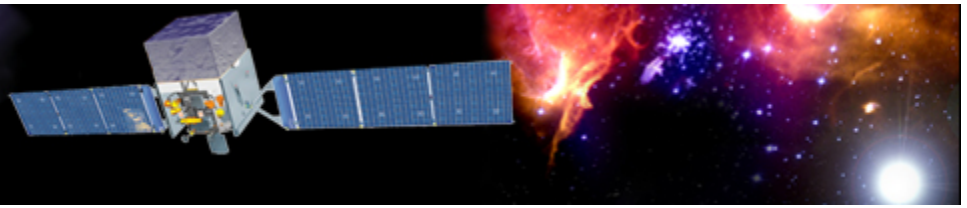
Analyzing Vela data (cont.)





Analyzing Vela data (cont.)

```
prompt> gtpphase
This is gtpphase version ScienceTools-v9r15p2-fssc-20090701
Event data file name[] Vela_100_300000_evt02.fits
Spacecraft data file name[] L090923110451E0D2F37E17_SC00.fits
Pulsar ephemerides database file name[] Fermi_PulsarDB_v001.fits
Pulsar name[ANY] PSR J0835-4510
How will spin ephemeris be specified? (DB|FREQ|PER) [DB] FREQ
Epoch for the spin ephemeris[0.] 55028.5
Time format for spin ephemeris epoch (FILE|MJD|ISO|FERMI|GLAST) [FILE] MJD
Time system for spin ephemeris epoch (FILE|TAI|TDB|TT|UTC) [FILE] TDB
Right Ascension to be used for barycenter corrections (degrees)[0.] 128.836048
Declination to be used for barycenter corrections (degrees)[0.] -45.176425
Base value of phase at this epoch[0.] 0.5
Pulse frequency at the epoch of the spin ephemeris (Hz) (0.:) [1.] 11.1900234350 906
First time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s)[0.] -1.559072535133380e-11
Second time derivative of the pulse frequency at the epoch of the spin ephemeris (Hz/s/s)[0.] 0.0
prompt>
```

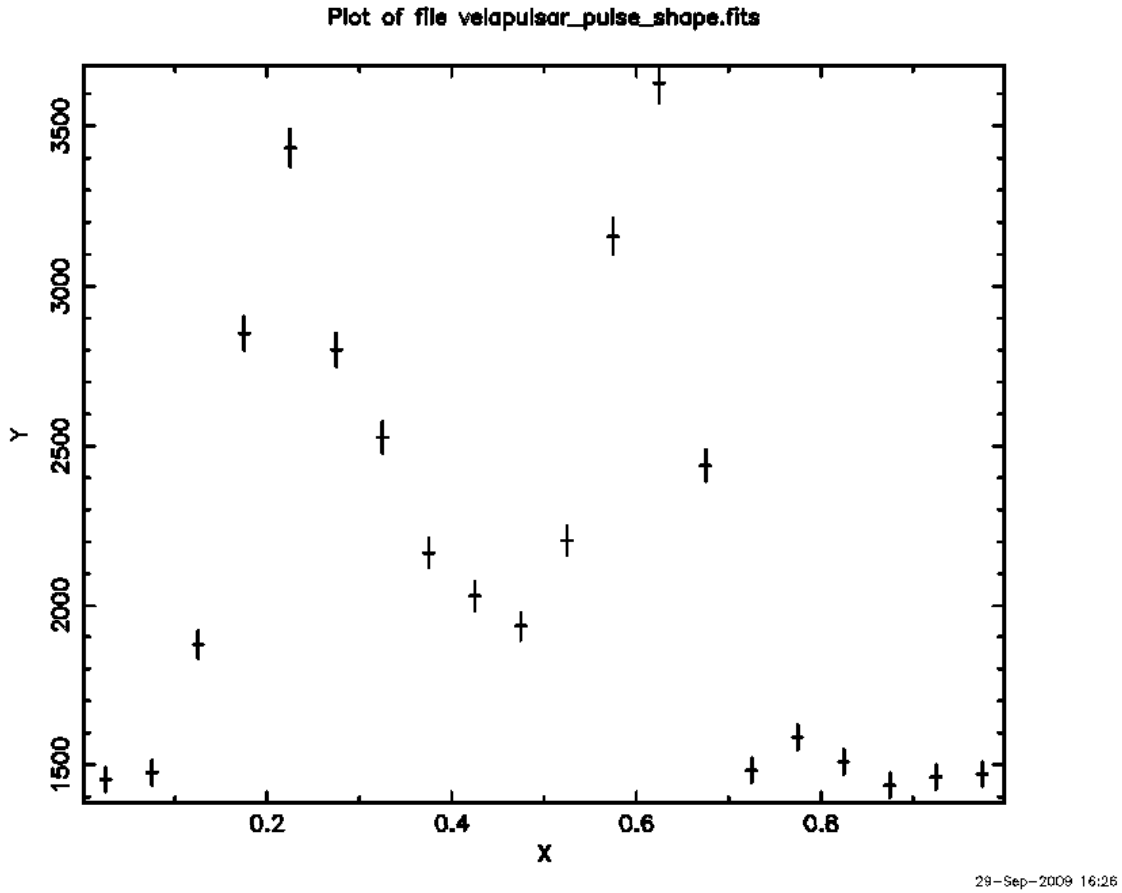


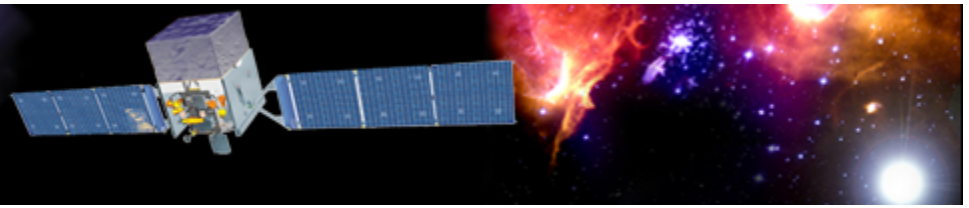
Analyzing Vela data (cont.)

```
prompt> fhisto lowval=0.0 highval=1.0
Name of FITS file and [ext#][] Vela_100_300000_evt02.fits
Name of output FITS file[] velapulsar_pulse_shape.fits
Name of column to generate histogram[] PULSE_PHASE
Size of bins[INDEF] 0.05
input file (no binspec): file://Vela_100_300000_evt02.fits[1]
input file: file://Vela_100_300000_evt02.fits[1][bin  PULSE_PHASE=0:1:0.05]
The histogram extension: 1dhisto
prompt>
```

```
prompt> fplot
Name of FITS file and [ext#][] velapulsar_pulse_shape.fits
Name of X Axis Parameter[error][] X
Name of Y Axis Parameter[error] up to 8 allowed[] Y[Error]
Lists of rows[-] -
Device: /XWindow, /XTerm, /TK, /PS, etc[/XW] /xserv
Any legal PLT command[] marker on
PLT> exit
prompt>
```

Analyzing Vela data (cont.)





Analyzing Vela data (cont.)

```
prompt> gtptest
This is gtptest version ScienceTools-v9r15p2-fssc-20090701
Event data file name[] Vela_100_300000_evt02.fits
Output FITS file name (NONE for no FITS output)[] gtptest_out.fits
Number of phase bins for Chi2 test[10] 10
Number of harmonics for Z2n test[10] 10
Maximum number of harmonics for H test[10] 10
Type of test: Chi-squared Test, 10 phase bins
Probability distribution: Chi-squared, 9 degrees of freedom
Test Statistic: 3617.22319536
Chance Probability Range: (0, 2.03757046903054e-99)
Type of test: Rayleigh Test
Probability distribution: Chi-squared, 2 degrees of freedom
Test Statistic: 1700.6017260263
Chance Probability Range: (0, 2.00883927982452e-99)
Type of test: Z2n Test, 10 harmonics
Probability distribution: Chi-squared, 20 degrees of freedom
Test Statistic: 4797.77337691268
Chance Probability Range: (0, 2.07853386442652e-99)
Type of test: H Test, 10 maximum harmonics
Probability distribution: H Test-specific
Test Statistic: 4762.16995611264
Chance Probability Range: (0, 4e-08)
Warning in <TClass::TClass>: no dictionary for class st_graph::IFrame is available
prompt>
```

Analyzing Vela data (cont.)