Working with FITS data

Outline

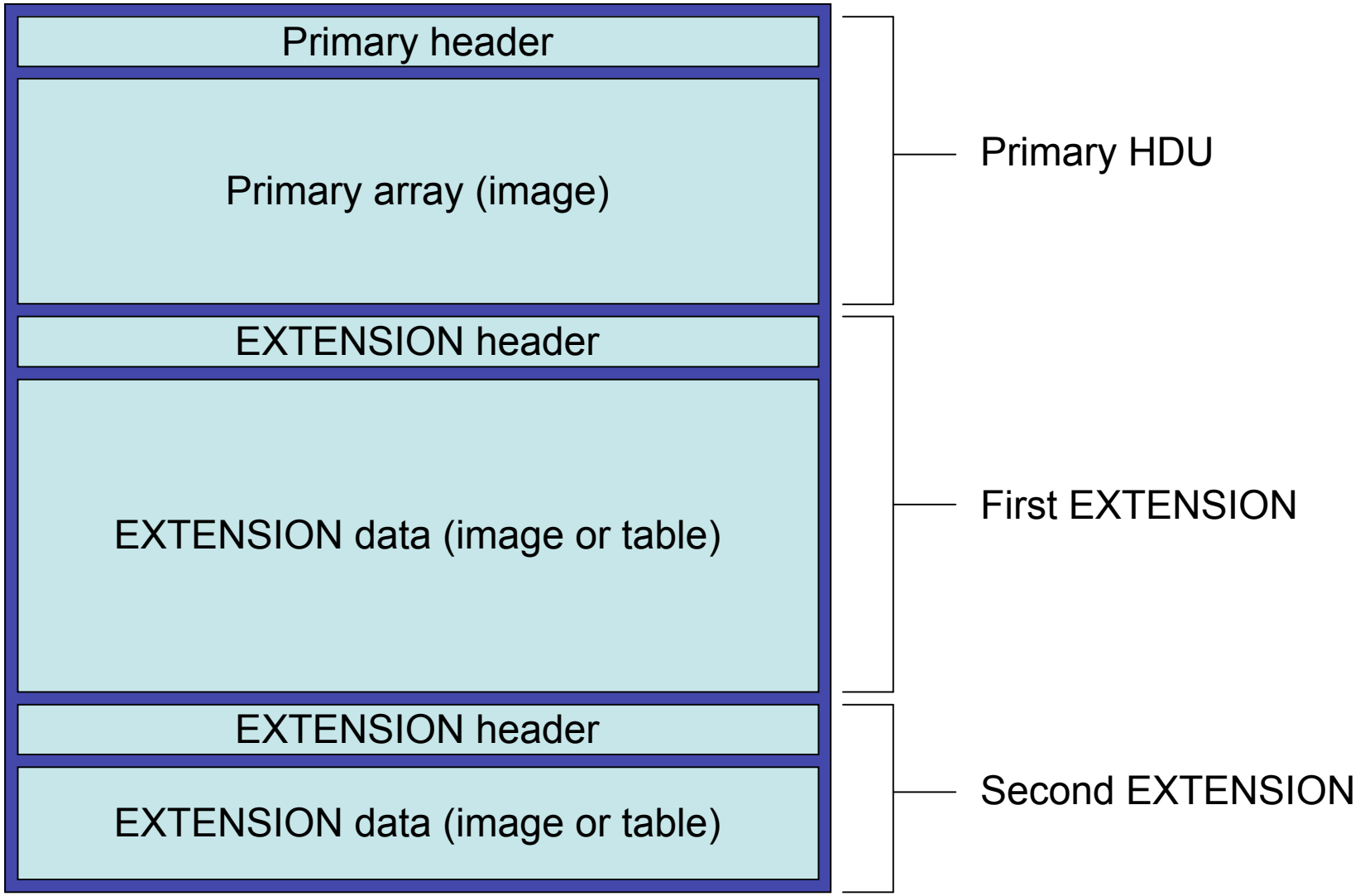
- What is a FITS file?
- Contents of a FITS file
  - headers
  - images
  - tables
- Software for manipulating FITS files
  - FTOOLS
  - FV, ds9, GAIA
- FITS for programmers
- Tricks & tips

FITS and FTOOLS

- FITS = Flexible Image Transport System
  - It's a file format standard used extensively in high energy astronomy
  - It goes far beyond just images
  - Default format used by
    - XSPEC – spectral analysis
    - XIMAGE – image analysis
    - XRONOS – timing analysis
  - Used for ASCA, Einstein, CGRO, Rosat, XTE, and now INTEGRAL data

FITS info at http://heasarc.gsfc.nasa.gov/docs/heasarc/fits.html

Anatomy of a FITS file



Headers

- Conform to `KEYNAME = value / comment string`
- Example primary header:

```
SIMPLE  = T                / file does conform to FITS standard
BITPIX  = 16               / number of bits per data pixel
NAXIS   = 2                / number of data axes
NAXIS1  = 440              / length of data axis 1
NAXIS2  = 300              / length of data axis 2
```

440x300 pixel image

- Example EXTENSION header:

```
XTENSION= 'BINTABLE'   / binary table extension
EXTNAME = 'MYDATA'     / data name
BITPIX  = 16           / number of bits per data pixel
NAXIS   = 2            / number of data axes
NAXIS1  = 440          / width of table in bytes
NAXIS2  = 300          / rows in table
.
.
```

Extensions

- Extensions are the main data storage area – the primary array is usually not used now.
- Images can contain IMAGES or TABLES
- Tables can be ASCII or binary
  - ASCII are faster to display
  - Binary are more compact
- Table columns can be vectors
  - n-dimensional structure
- Extensions are a good way to store several related but separate data structures in a single file, even if the data are of different types

FTOOLS

- Provided/distributed by HEASARC
- Is a set of programs to display, edit, manipulate data in FITS files
- Standard interface (command-line driven)
- Also mission-specific tools (so are expecting data in a certain format) for use with ASCA, CGRO, ROSAT etc data

http://heasarc.gsfc.nasa.gov/docs/software/ftools/ftools_menu.html

First FTOOLS commands

- Starting FTOOLS
  - lhea-init shell script (may already be started)
- Getting help
  - fhelp <ftool> … help pages for each FTOOL
  - fapropos <subject> … search for FTOOLS which could help on a subject
  - flaunch … a GUI launcher for all the FTOOLS and analysis packages (with built-in help)

Using FTOOLS commands

- Each FTOOL has a set of parameters, which can be either mandatory or hidden
- See the parameters for an FTOOL with either fhelp or plist
- Specify parameters and values on the command line or, if you don't…
  - Mandatory parameters will be requested
  - Hidden parameters will use defaults
- Specify hidden parameters on the command line to override the defaults. In fhelp, hidden parameters are shown as (parameter)

Specifying FITS filenames

- The filename can be used to specify file and/or extension in a variety of ways:

• myfile.fits	the file itself (depends on s/w how this is used)
• myfile.fits[1]	1st extension in myfile.fits
• myfile.fits+1	as above, but old-style notation
• myfile.fits[EVENTS]	1st binary table with EXTNAME=EVENTS

- Prefix a filename with ! to let it be overwritten, or use the clobber parameter

- Use quotes or \ if you use [ ] or ! on a command line

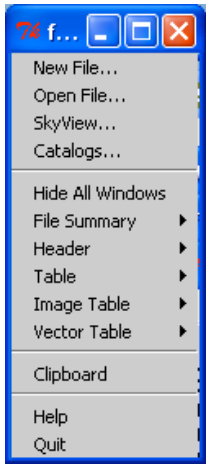
  - fimgstat myfile.fits[4] doesn't work
  - fimgstat myfile.fits¥[4] does

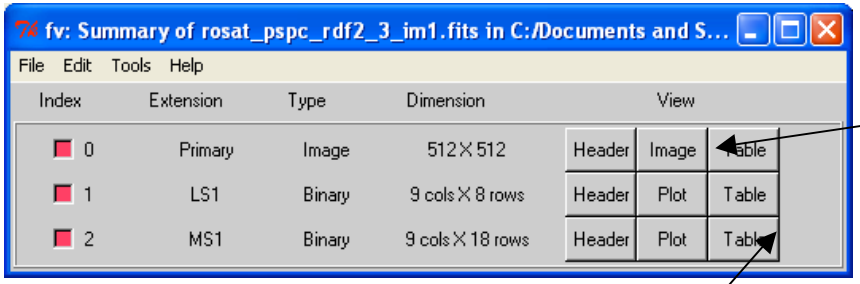
- See later for rowfilter, colfilter and histogram options

Top 10 FTOOLS

- FV
- fselect – filtering of event data in tables
- fhisto/f2dhisto/fimghisto – histogramming
- fstatistic/fimgstat – quick stats
- farith – arithmetic on 2 images
- fsort – sort a *small* table
- fdiff – difference between 2 FITS files
- fstruct – get structure of file
- fdump – ASCII view of contents
- fcreate – make a FITS file from scratch

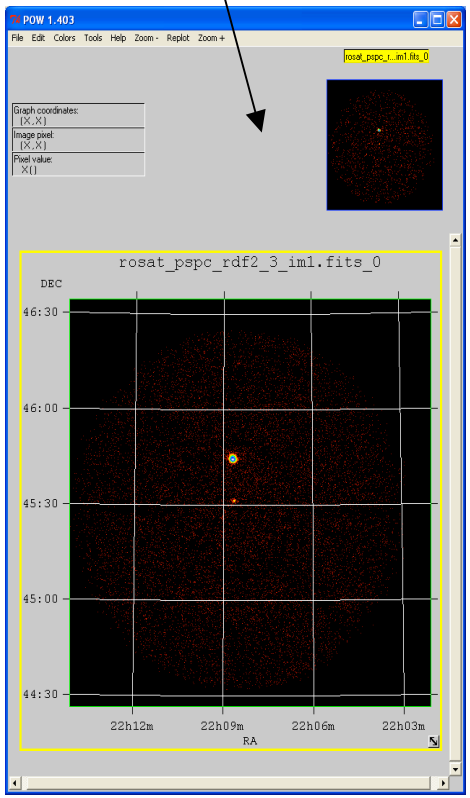
FV – the #1 FTOOL

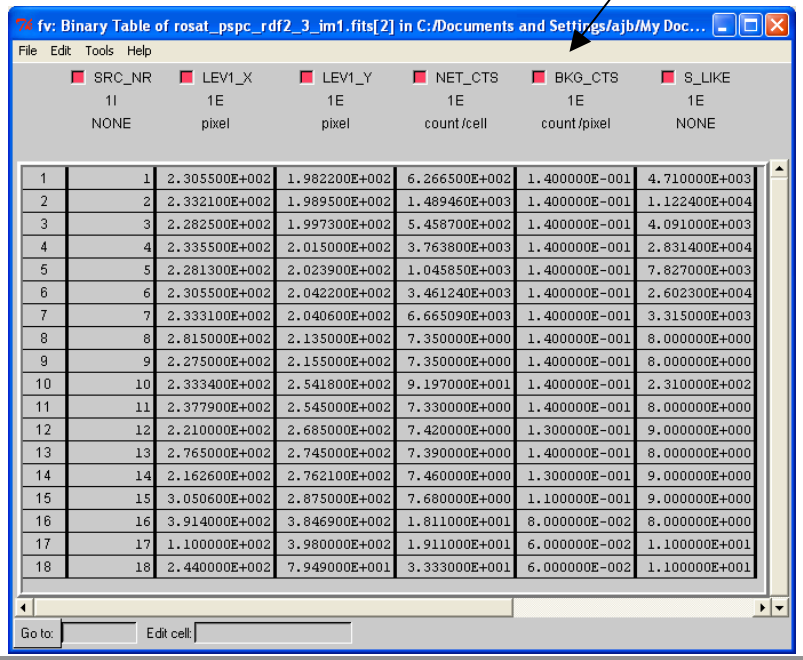




Click here for image display

Inspect table data





Alternatives to FTOOLS

- Other visualisation tools exist
  - SAOimage
  - DS9
  - Gaia
  - XIMAGE

- The DIY approach (programming)

FITS programming

- For when the standard TOOLS don't do what you want…

Language	For FITS
FORTRAN	fitsio
C	cfitsio, DAL
C++	cfitsio, CCfitsio
Perl	Perl/cfitsio
IDL	astrolib

- Watch out for 'historical' FORTRAN-style array ordering !

http://heasarc.gsfc.nasa.gov/docs/software/fitsio/fitsio.html

Advanced FITSing (1)

- Assuming we have an events list in first extension of myfile.fits…
- Row filtering on the command line
  - myfile.fits[1][QUALITY>5]
    - select only the rows in which the QUALITY column has a value > 5
  - myfile.fits[1] [#row >= 125 && #row <= 175]
    - select rows 125-175
- Histogramming on the command line
  - myfile.fits[1] [bini detx, dety]
    - Creates a temporary 2D histogram of integer values in detx and dety columns. Use default limits and bin size
  - myfile.fits[1][bin time=TSTART:TSTOP:0.1]
    - creates a histogram of values in time column, limits are taken from the TSTART and TSTOP keywords in header, bin size is 0.1

Advanced FITSing (2)

- GROUPING and hierarchical data
  - Grouping uses special tables with EXTNAME = GROUPING which contain links to data structures, or other GROUPING structures.
  - A large data structure can be split over several physical files.
  - Software (cfitsio or DAL) can then search the data tree for a specific structure without the user needing to know where it is.