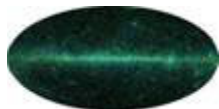


Living with FITS

Brief overview of FITS files, contents of the principal FITS files for DC1, some specific tips and tools for dealing with FITS

Seth Digel, HEPL/Stanford Univ.



Introduction

- **Essentially universally used in ground-based astronomy and adopted by NASA astronomy missions at least 20 years ago.**

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FITS : A FLEXIBLE IMAGE TRANSPORT SYSTEM

D. C. WELLS (1), E. W. GREISEN (*) (2) and R. H. HARTEN (**)

Kitt Peak National Observatory Tucson, Arizona, U.S.A.

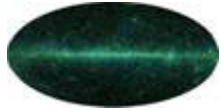
(*) National Radio Astronomy Observatory Charlottesville, Virginia, U.S.A.

(**) The Netherlands Foundation for Radio Astronomy, Postbus 2, 7990 AA Dwingeloo, the Netherlands

Received March 31, accepted September 4, 1980

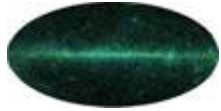
Summary.- A format for the interchange of astronomical images and other digital arrays on magnetic tape is described. This format provides a simple but powerful mechanism for the unambiguous transmission of n -dimensional, regularly spaced data arrays. It also provides a method for the transmission of a virtually unlimited number of auxiliary parameters that may be associated with the image. The parameters are written in a form which is easily interpreted by both humans and computers. The FITS format has been adopted for the transmission of astronomical image data by several large observatories including the Very Large Array, the Westerbork synthesis telescope, the Kitt Peak Observatory and the Anglo-Australian Observatory.

Key words : data analysis



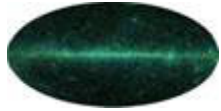
Introduction (2)

- **'Flexible' is true, as the original image (multi-dimensional array) standard has been extended to include tables (ASCII and binary) and more exotic data structures, including variable-length records**
- **The best thing about a standard is generally that it is a standard**
- **FITS is a formal standard and has an oversight committee that in a very deliberate way keeps it current**
- **[NASA FITS Support Office](#) [a virtual office] is a good reference**



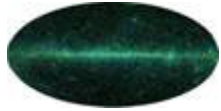
Structure of a FITS File

- FITS files consist of one or more ‘Header-Data Units’
- The header part of an HDU is ASCII (i.e., **human readable without special software**) and describes in a defined way the contents of the HDU.
 - For historical reasons the header is always a multiple of 2880 bytes long, i.e., padded to that length
 - As tables are an extension to the original definition, FITS files with tables require a runt main header with no associated data array, to identify them as files that might have tables in succeeding HDUs
- Headers can be quite descriptive, e.g., in a table defining the units of a quantity and the allowed range
- Owing to the adherence to the standard, general FITS readers for images and tables exist. Good and free.



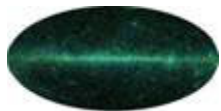
LAT FITS

- **LAT FITS Format Definition Working Group, led by Masa Hirayama (SSC), members Sandhia Bansal (SSC), Jerry Bonnell (GSFC), Guillaume Dubus (IN2P3/LLR), and Yasushi Ikebe (SSC)**
- http://glast.gsfc.nasa.gov/ssc/dev/fits_def/
- **The LFFDWG coordinates rationalization of what we want to do with existing standards/conventions**
- **HEASARC has some oversight of keyword definition for high-energy astrophysics data, and the LFFDWG has consulted this group**
 - **Guess what, it is called the HEASARC FITS Working Group**
- **Issues can be subtle – like the definition of time, especially at the level needed for pulsar timing**



Event summaries (FT1)

- **Event summary information, specifically for gamma rays**
 - **Basics: Event ID, time, energy, direction, event class, inclination, azimuth, zenith angle, Recon & classification versions, calibration versions**
- **The definition of the contents will be refined post-DC1, but the basics won't change**
 - **In particular, we were not sure until recently how the event classification would be passed through to the FT1 files, so we more or less threw in the kitchen sink**
 - **The intent is to include everything that might be useful for someone's idea of high-level analysis**
- **It is essentially a binary table**
 - **With the addition of a 'Good Time Interval' extension, it is now recognizable to standard timing software used in high-energy astrophysics**



FT1 Contents

- **Official reference:**

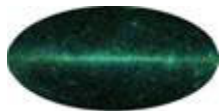
http://glast.gsfc.nasa.gov/ssc/dev/fits_def/definitionFT1.html

- **Primary header**

```

SIMPLE      =                               T / file does conform to FITS standard
BITPIX     =                               8 / number of bits per data pixel
NAXIS      =                               0 / number of data axes
EXTEND     =                               T / FITS dataset may contain extensions
COMMENT    FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT    and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
TELESCOP= 'GLAST      ' / name of telescope generating data
INSTRUME= 'LAT        ' / name of instrument generating data
EQUINOX   =                               2000. / equinox for ra and dec
RADECSYS= 'FK5        ' / world coord. system for this file (FK5 or FK4)
DATE       = '2003-12-07T06:38:46' / file creation date (YYYY-MM-DDThh:mm:ss UT)
DATE-OBS= '2005-07-18T00:00:00.0000' / Start Date and Time of the observation (U
DATE-END= '2005-07-19T00:00:00.0000' / End Date and Time of the observation (UTC
FILENAME= 'DC1AllSky-FT1.fits' / name of this file
ORIGIN    = 'GSSC      ' / name of organization making file
AUTHOR    =                               / name of person responsible for file generation
CREATOR   = 'GOODI     ' / software and version creating file
VERSION   =                               / integer? string? (TBD) release version of the
SOFTWARE=                               / version of the processing software
CHECKSUM= 'jCFak999jCEAj997' / HDU checksum updated 2003-12-07T06:38:46
DATASUM  = '              0' / data unit checksum updated 2003-12-07T06:38:46
END

```



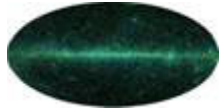
More FT1 Contents

- **Event extension header**
- **Files also have a 2nd extension for the Good Time Intervals**
 - **This is for windowing by time, background filtering more relevant for X-ray astronomy**
 - **Current list just one time interval, the whole range of the file**

```

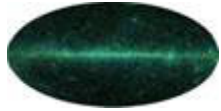
XTENSION= 'BINTABLE'           / binary table extension
BITPIX   =                      8 / 8-bit bytes
NAXIS    =                      2 / 2-dimensional binary table
NAXIS1   =                    172 / width of table in bytes
NAXIS2   =                   737627 / number of rows in table
PCOUNT   =                      0 / size of special data area
GCOUNT   =                      1 / one data group (required keyword)
TFIELDS  =                      27 / number of fields in each row
TTYPE1   = 'ENERGY'           / label for field
TFORM1   = 'E'                / format of field
TTYPE2   = 'RA'               / label for field
TFORM2   = 'E'                / format of field
...
EXTNAME  = 'EVENTS'           / name of this binary table extension
HDUCLASS= 'OGIP'              / format conforms to OGIP standard
HDUCLAS1= 'EVENTS'           / extension contains events
HDUCLAS2= 'ALL'               / extension contains all events detected
TSTART   =                    0. / mission time of the start of the observation
TSTOP    =                    0. / mission time of the end of the observation
MJDREF   =                   58300. / MJD corresponding to SC clock start
TIMEUNIT= 's'                 / units for the time related keywords
TIMESYS  = 'TT'               / type of time system that is used
TIMEREFS= 'LOCAL'             / reference frame used for times
TASSIGN  = 'SATELLITE'        / location where time assignment performed
CLOCKAPP= T                    / whether a clock drift correction has been appli
GPS_OUT  = T                    / whether GPS time was unavailable at any time du
...
TUNIT1   = 'MeV'              / physical unit of field
TLMIN1   =                    0. / minimum value
TLMAX1   =                   10000000. / maximum value
TUNIT2   = 'deg'              / physical unit of field
TLMIN2   =                    0. / minimum value
TLMAX2   =                    360. / maximum value
...
EXTVER   =                    1 / auto assigned by template parser
FILENAME= 'DC1AllSky-FT1.fits'
CHECKSUM= '3idXAidV3idVAidV' / HDU checksum updated 2003-12-07T06:38:46
DATASUM  = '1837843024'       / data unit checksum updated 2003-12-07T06:38:46
END

```

Pointing/Livetime History (FT2)

- **Pointing, livetime, mode history, for calculating exposures**
- **Also a FITS binary table**
- **The contents will evolve here, too.**
 - **Presently one entry per minute. In real life, we may get entries at 5 Hz, the rate at which the LAT will receive updated position and orientation information from the spacecraft.**
 - **In real life, the mode history will include times that the LAT is off for SAA passages. It can also record different modes of operation, e.g., for solar flares**
 - **It includes livetime, too, although not presently used**



FT2 Contents

- **Official reference:**

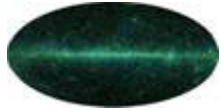
http://glast.gsfc.nasa.gov/ssc/dev/fits_def/definitionFT2.html

- **Excerpt of contents**

```

TTYPE1 = 'START ' / label for field
TFORM1 = 'D ' / format of field
TTYPE2 = 'STOP ' / label for field
TFORM2 = 'D ' / format of field
TTYPE3 = 'SC_POSITION' / label for field
TFORM3 = '3E ' / format of field
TTYPE4 = 'LAT_GEO ' / label for field
TFORM4 = 'E ' / format of field
TTYPE5 = 'LON_GEO ' / label for field
TFORM5 = 'E ' / format of field
TTYPE6 = 'RAD_GEO ' / label for field
TFORM6 = 'E ' / format of field
TTYPE7 = 'RA_ZENITH' / label for field
TFORM7 = 'E ' / format of field
TTYPE8 = 'DEC_ZENITH' / label for field
TFORM8 = 'E ' / format of field
TTYPE9 = 'B_MCILWAIN' / label for field
TFORM9 = 'E ' / format of field
TTYPE10 = 'L_MCILWAIN' / label for field
TFORM10 = 'E ' / format of field
TTYPE11 = 'RA_SCZ ' / label for field
TFORM11 = 'E ' / format of field
TTYPE12 = 'DEC_SCZ ' / label for field
TFORM12 = 'E ' / format of field
TTYPE13 = 'RA_SCX ' / label for field
TFORM13 = 'E ' / format of field
TTYPE14 = 'DEC_SCX ' / label for field
TFORM14 = 'E ' / format of field
TTYPE15 = 'LAT_MODE' / label for field
TFORM15 = 'J ' / format of field
TTYPE16 = 'LIVETIME' / label for field
TFORM16 = 'D ' / format of field
TTYPE17 = 'DEADTIME' / label for field
TFORM17 = 'D ' / format of field

```



Some useful software

- **fv** – <http://ftools.gsfc.nasa.gov/lheasoft/ftools/fv> - interactive editor for FITS files. Also shows images, makes histograms. Many platforms supported, including Windows at least marginally
- **FTOOLS** futils in general – see <http://ftools.gsfc.nasa.gov/lheasoft/ftools> - general purpose utilities for manipulating contents and headers of FITS files. For Windows, Cygwin is needed
- **Image display: DS9** – see <http://hea-www.harvard.edu/RD/ds9/> - astronomical image display tool, very flexible. A completely functional (as far as I can tell) Windows binary distribution is available
- **I/O libraries** exist for high-level languages and for IDL, Matlab, Python, etc – see http://heasarc.gsfc.nasa.gov/docs/heasarc/fits/fits_libraries.html