Swift XRT Data Analysis

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Overview

- The *XRTDAS* package

- XRT instrument and science modes

- Data reduction: main steps

- Extraction of products

- Archives and data retrieval

- Example of data processing and analysis (interactive demo)

XRT Data Analysis Software (*XRTDAS*)

- Set of FTOOLS specifically developed for the XRT instrument

- Generates high-level scientific data products from the FITS-formatted telemetry data

- Uses the HEASARC calibration database (CALDB)

- Runs on most popular Unix platforms

- Written using C, Fortran and Perl languages

- Developed at the ISAC/ASDC (ASI Science Data Center, Italy) by a team of 3 scientists (ASI and INAF) and 2 software analysts (Dataspazio) in collaboration with HEASARC at NASA/GSFC

- Included in the pipeline processing at NASA/GSFC to generate the XRT archive

XRTDAS (2)

- XRTDAS is part of the HEAsoft Package distributed by NASA's HEASARC

- Current version of HEAsoft (6.0.4) contains XRTDAS v.1.7.1 (Nov. 2005)

- Latest XRT CALDB version is 20060104

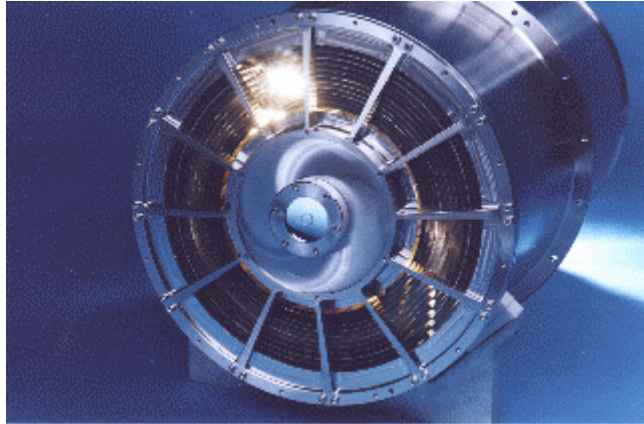- Download of the HEAsoft package (source code or pre-compiled) and Swift CALDB at:

    http://swift.gscf.nasa.gov/software/lheasoft/

    http://heasarc.gscf.nasa.gov/docs/heasarc/caldb/swift/

- Software documentation (BAT, XRT, UVOT data reduction guides) available as pdf files at:

    http://swift.gscf.nasa.gov/docs/swift/analysis/

XRT Instrument

Telescope	Wolter I (grazing incidence)
Focal Length	3.5 m
Effective Area	110 cm² @ 1.5 keV
PSF	~18 arcsec HPD @ 1.5 keV
Position accuracy	~5 arcsec
Detector	600x600 pxls / 2.36 arcsec/pxl
Energy Range	0.2 – 10 keV
Spectral resolution	~ 140 eV @ 6 keV
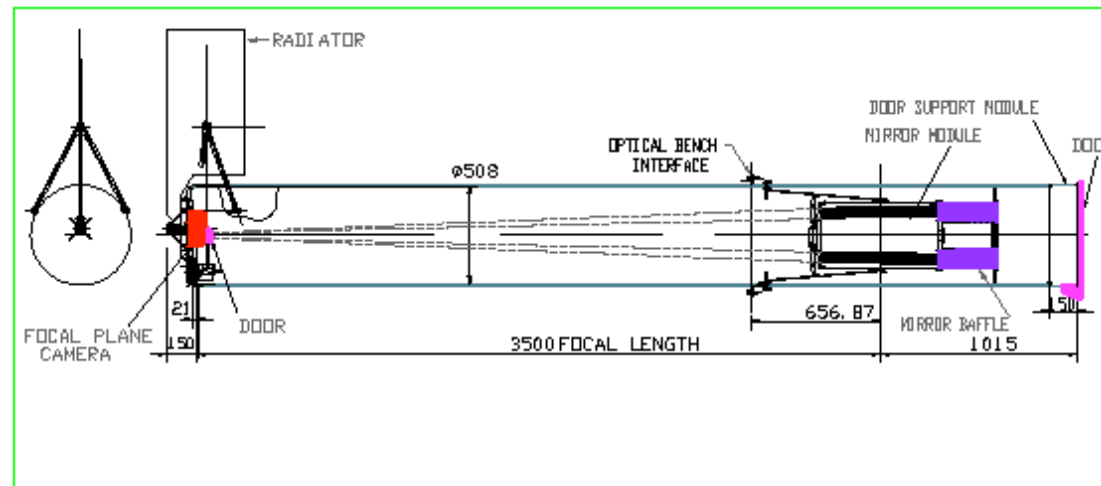
XRT Readout Modes
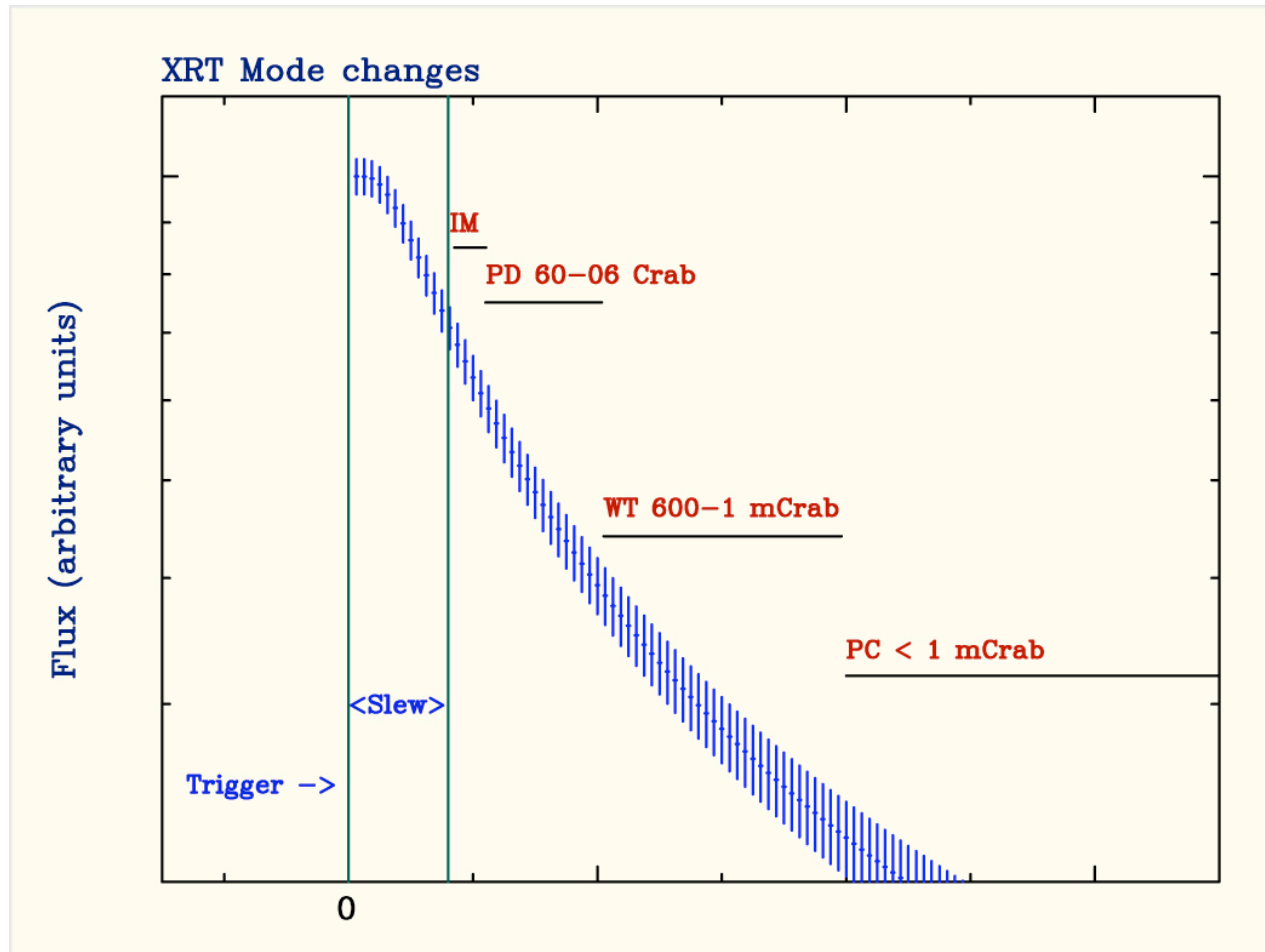
XRT can automatically select the CCD readout mode according to the instantaneous count rate (to avoid pile-up):

Photodiode (PD)
Windowed Timing (WT)
Photon Counting (PC)

For centroid determination:

Imaging mode (IM)

Photon Counting mode (PC)

- Default window: 500x500 pixels (20x20 arcmin) (1 pixel=2.36 arcsec)

- Each pixel contains the total charge collected on that pixel

- Bias map subtracted on-board

- On-board event recognition
  (3x3 pixels array telemetered)

- Time resolution: 2.5 s

- Flux Limit (to avoid pile-up):
     ~1 mCrab (~ 0.5 cts/s)
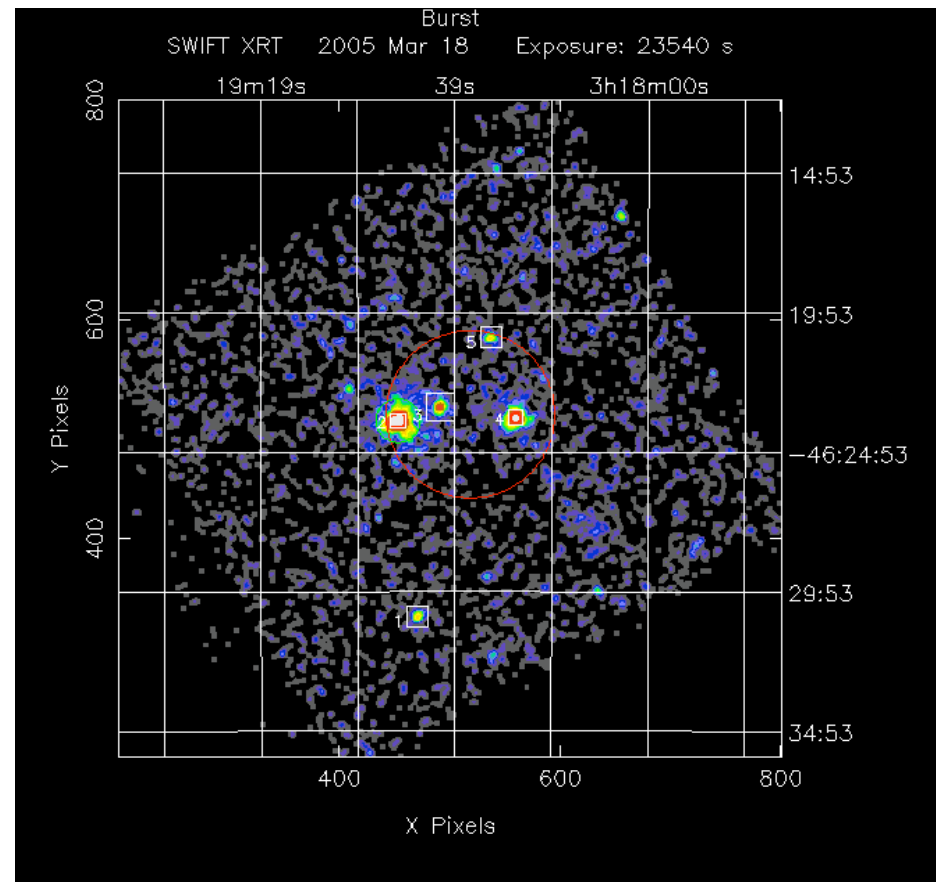
Windowed Timing mode (WT)

- One readout every 10 parallel clock shifts: each row contains the sum of 10 CCD rows

- 1-D spatial information (default window of 200 pixels, ~8 arcmin)

- Bias row subtracted on-board

- No on-board event recognition

- Time resolution: ~1.8 ms

- Flux Limit: ~0.6 Crab (~200 cts/s)
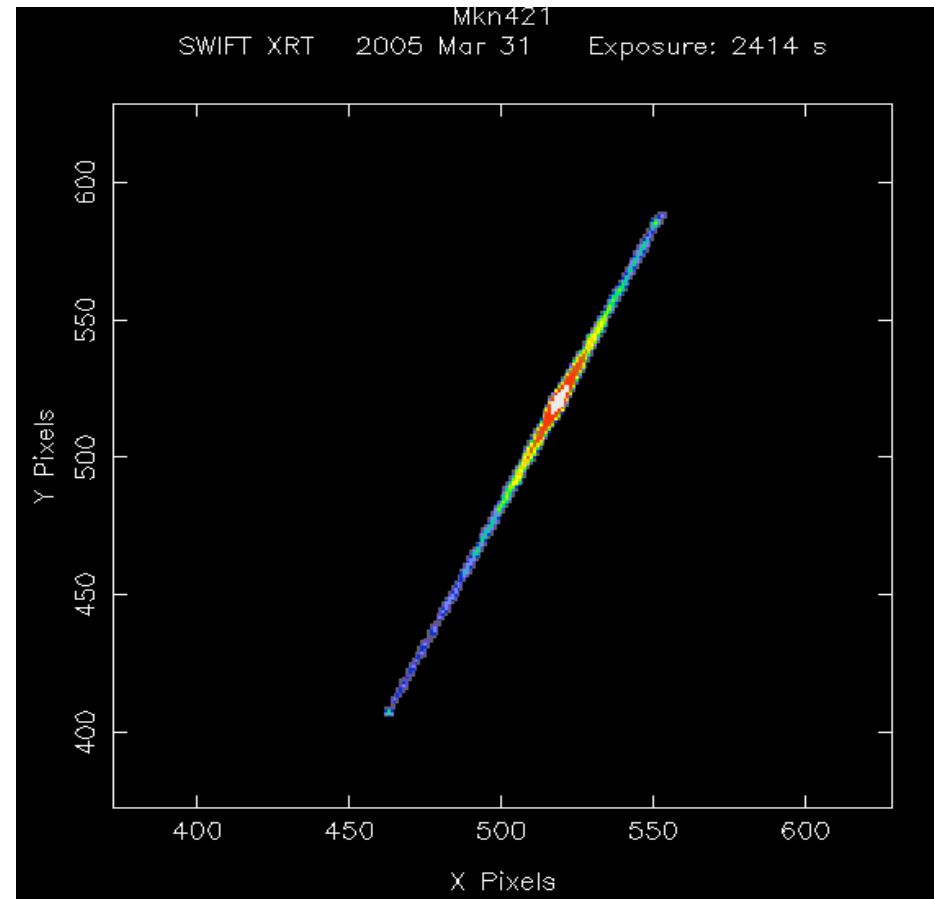
Photodiode mode (PD)

This mode is designed for very bright sources:

- 1 serial and 1 parallel clock shifts are alternate --> very rapid clocking of each pixel across the CCD
- no spatial information: every pixel contains the charge integrated over the entire field of view (image dominated by a bright source)
- Pixels with calibration sources contribute as well
- No on-board event recognition

- Time resolution: ~0.14 ms
- Flux Limit: ~60 Crab

- Two sub-modes (according to telemetry format):

  - Piled-up (PU): all pixels are sent down
  - Low rate (LR): only pixels between LLD and ULD sent down

Imaging mode (IM)

Used by the XRT to obtain a rapid position of a new GRB:

- 2-D spatial information
- No X-ray event recognition
- Each pixel contains the total charge collected in that pixel

Two possible integration times:

0.1 s (short image)
2.5 s (long image)

Flux limits: ~45 Crab - 25 mCrab
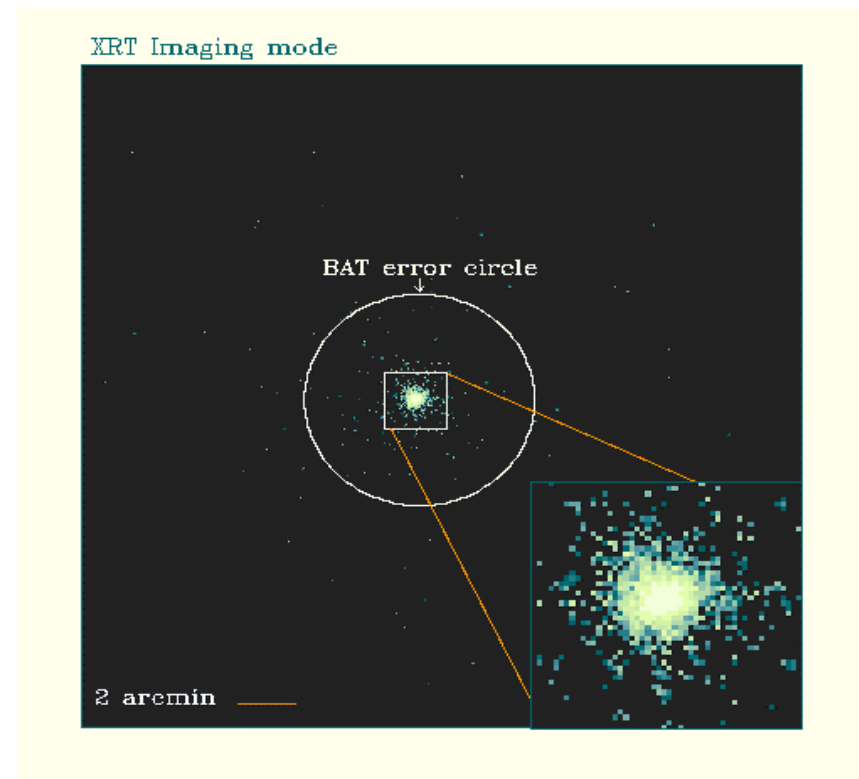
Data reduction: basic scheme

Input: telemetry data converted into FITS files
(generated at the Swift Data Center at GSFC)

XRT data processing consists of three main stages:

- Stage 1: the data are *calibrated* using information from CALDB files, attitude and instrument housekeepings.

  Output: Level 1 calibrated event files

- Stage 2: the calibrated data are *screened* by applying conditions on specified parameters (e.g. CCD Temperature, Sun Angle).

  Output: Level 2 cleaned event files

- Stage 3: standard high-level scientific products (spectra, light curves, images) are extracted from the Level 2 event files.

Stage 1: data calibration

The calibration stage is mode dependent and consists of several steps:

- – sky coordinates calculation
- – bias subtraction
- – bad pixels (columns) flagging
- – hot pixels identification
- – reconstruction of photon arrival times ('time tagging') for timing modes (Photodiode and Windowed Timing)
- – event reconstruction
- – photon energy calibration (conversion from PHA to PI)
- – GRADE assignment

Classification of events: GRADE library

PC mode

Valid PC

WT & PD modes

Valid PD

Valid WT
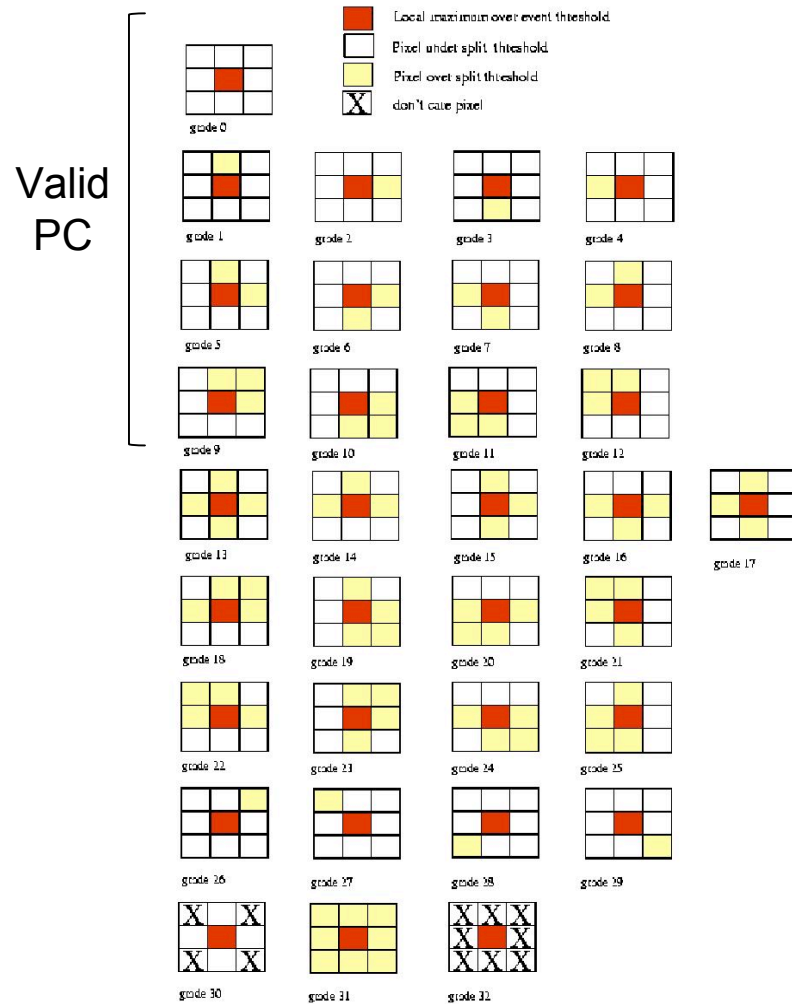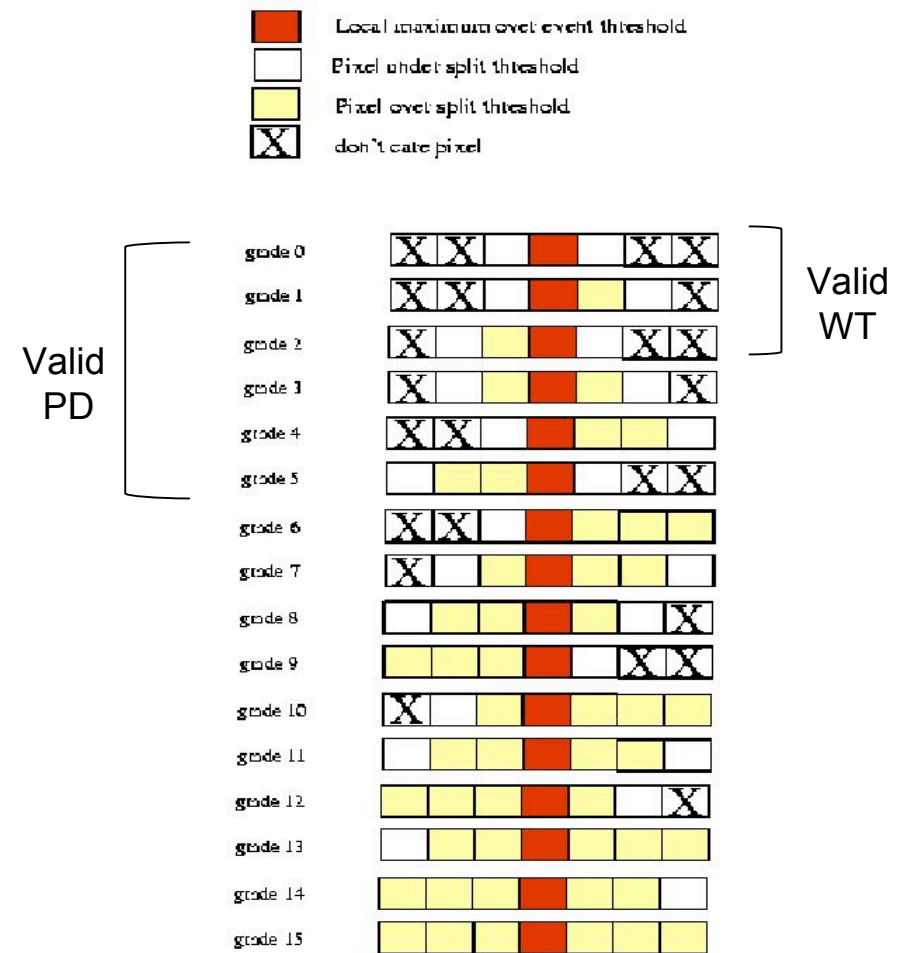
Stage 2: data screening

Produces *cleaned* event files appropriate for scientific analysis.

Screening criteria can be grouped in three categories:

- attitude parameters
- instrument HK parameters
- event properties (STATUS and GRADE columns)

Two steps:

1. Good Time Intervals (GTIs) are calculated based on boolean expressions
2. Data are filtered using the GTIs and event files columns

Attitude and instrument parameters included in the filter file (.mkf)

Default screening criteria

Instrument parameters:

CCDTemp>=-102&&CCDTemp<=-47	CCD temperature
Vod1>=29.8&&Vod1<=30.25	Output Drain Voltage for Amp 1
Vod2>=29.30&&Vod2<=29.80	Output Drain Voltage for Amp 2
Vrd1>=16.40&&Vrd1<=16.80	Reference Voltage for Amp 1
Vrd2>=16.45&&Vrd2<=16.90	Reference Voltage for Amp 2
Vsub>=-0.1&&Vsub<=0.1	Substrate Bias Voltage
Vbackjun>=-0.1&&Vbackjun<=0.1	Back Junction Bias Voltage
BaseLin1>=0.1&&BaseLin1<=0.4	Baseline Voltage for Signal Chan A
BaseLin2>=-0.1&&BaseLin2<=0.1	Baseline Voltage for Signal Chan B

Attitude related parameters:

ELV>=30	Elevation Angle
BR_EARTH>=120	Bright Earth Angle
SUN_ANGLE>=45	Sun Angle
MOON_ANGLE>=14	Moon Angle
ANG_DIST<=0.08	Angular Distance

GRADE selection: **0 - 2**   (WT), **0 - 5**   (PD), **0 - 12** (PC)

STATUS selection ("good" events):   **STATUS==b0**

Stage 3: Products extraction (all event modes)

Extraction of *high-level* scientific products from the Level 2 cleaned event files.

xrtproducts:

- Generate high level products: images, spectra and light curves. If a spectrum is produced also generates the correspondig ARF file using *xrtmkarf*
    - the products extraction is performed through the XSELECT program
    - spatial (WT, PC) and temporal (all modes) filtering can be applied
  Output: Level 3 scientific products (images, spectra, light curves)

xrtmkarf (developed in collaboration with INAF/OAB):

- Calculate an Ancillary Response File (ARF) file for the PD, WT and PC modes for a given input spectrum and response matrix. Vignetting and PSF corrections are applied.

 Note: XSELECT can be used to extract products for different selections (e.g. intensity or grade)

Stage 3: exposure map generation (PC mode)

exposure map accounting for CCD bad columns and pixels, hot pixels, attitude variations and, if required, telescope vignetting
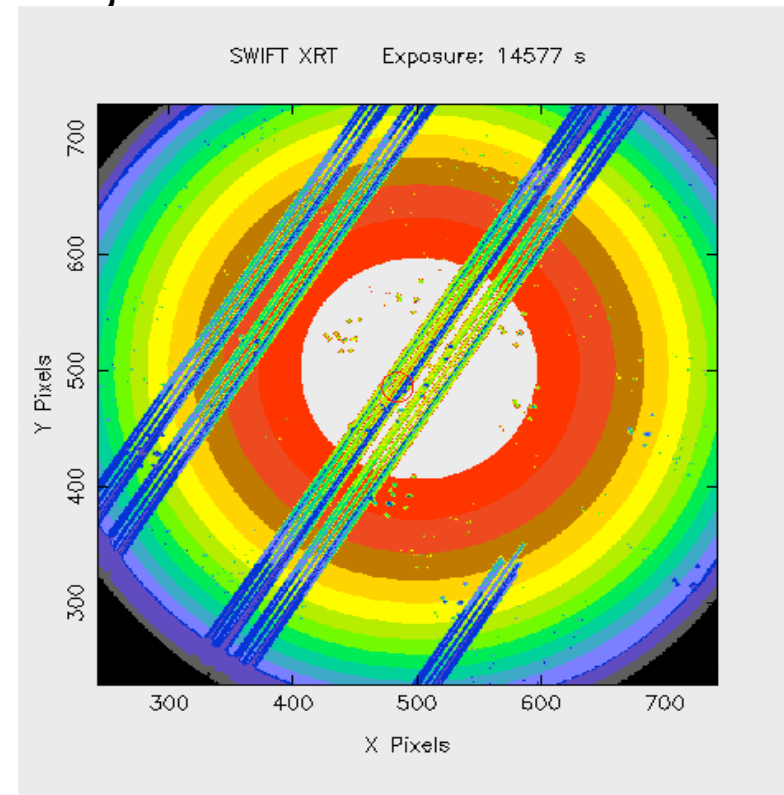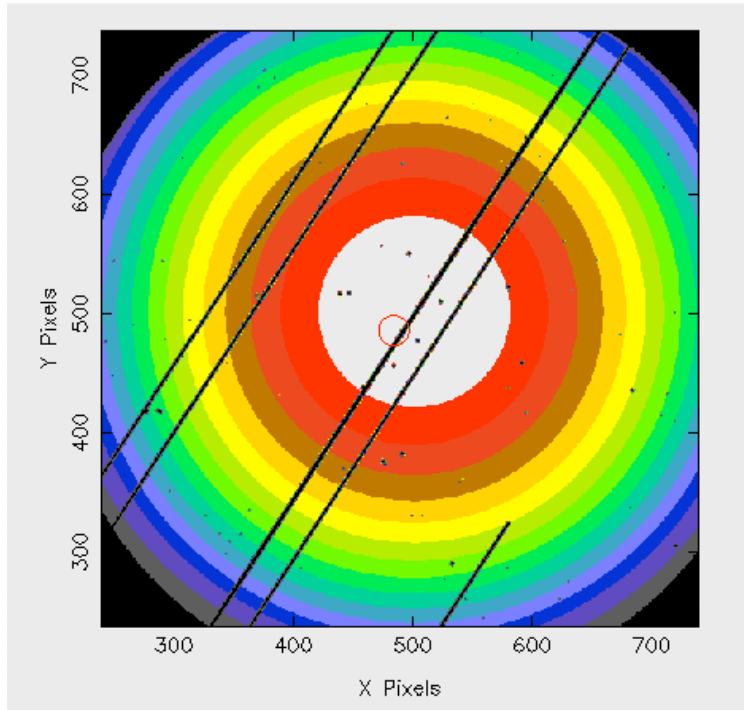
xrtmkarf corrects for the exposure effects using an input exposure map : the net exposure of each sky pixel in the extraction region is taken into account when the ARF is computed.

How everything is tight together: *xrtpipeline*

Calibration, screening and products extraction are coded in the script
xrtpipeline:

Timing Modes (PD & WT):

xrthkproc
xrtfilter
xrtflagpix (WT only)
xrtpdcorr (PD only)   Stage 1
xrttimetag
xrtevtrec
xrtcalcpi

xrtscreen   Stage 2
xrtproducts   Stage 3

Photon Counting Mode:

xrtfilter
coordinator
xrtflagpix   Stage 1
xrtpcgrade
xrtcalcpi
xrthotpix

xrtscreen   Stage 2
xrtproducts   Stage 3
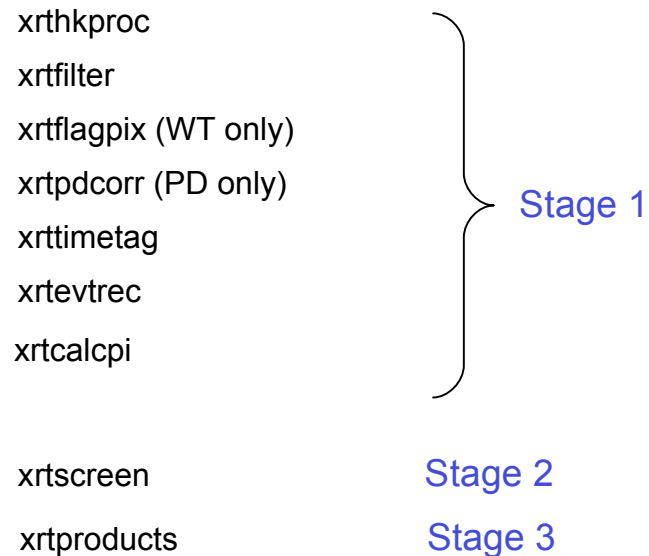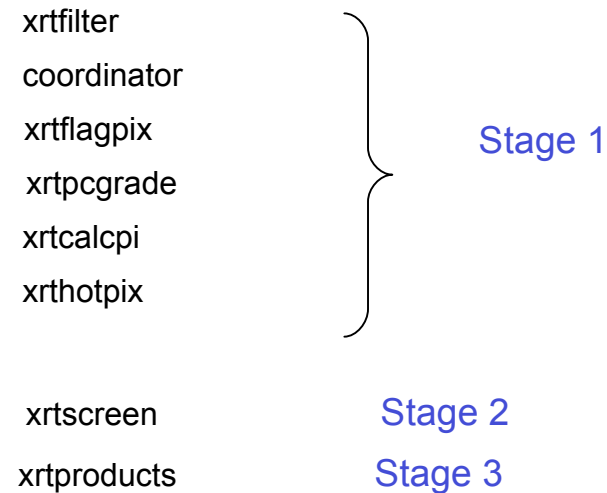
Imaging mode:

xrtimage
swiftxform

xtpipeline usage examples

1. Basic command with required input parameters (all other parameters set to default values):

xrtpipeline indir=/data/00111529000 outdir=./ steminputs=sw00111529000 srcra="03 18 51.1" srcdec="-46 23 44.7"

2. Processing of WT data only with non standard grade selection:

xrtpipeline indir=/data/00111529000 outdir=./ steminputs=sw00111529000 srcra="03 18 51.1" srcdec="-46 23 44.7" datamode=WT exprwtgrade=0

3. Processing of PC data only with a user defined GTIs expression:

xrtpipeline indir=/data/00111529000 outdir=./ steminputs=sw00111529000 srcra="03 18 51.1" srcdec="-46 23 44.7" datamode=PC gtiexpr="CCDTemp>=-102&&CCDTemp<=-55"

Swift Data

- Swift Telemetry transmitted through the ASI Malindi ground-station (Kenia)

- Converted to standard OGIP FITS formats by the Swift Data Center (SDC) at NASA/GSFC

- Data Analysis Software (*XRTDAS* for XRT) performs data processing and analysis (at SDC)

- Data products available on SDC Quick-Look site within 2 hours of ground pass and transmitted immediately to the mirrors in Italy and UK

ARCHIVE DIRECTORY STRUCTURE:

- **/auxil** - containing attitude and orbit information, the filter file (mkf), and overview information about the sequence;
- **/bat** - containing any BAT data for the sequence;
- **/log** - containing instrument data processing reports and summaries;
- **/uvot** - containing any UVOT data for the sequence;
- **/xrt** - containing any XRT data for the sequence;
- **/tdrss** - containing any TDRSS data for the sequence;

Swift Quick Look Site

- **The Quick Look site contains the more recent data.**
- **After one week data are archived at HEASARC, ISAC-ASDC and UKDC.**

Swift QL site: useful info

In the SDC Quicklook staging area. The data is organized into a table with columns:

Sequence	Version	Object	Observed	Processed	Comment
00154406000	004	Burst	2005-09-10T04:52:04	2005-09-10	new data: moc2005-09-10T10:35

The sequence number (Observation ID) is used to uniquely identify the data, for example:

00154436000

- **the first eight digits (target ID) identify the target**

- **the last three digits (segment number) distinguish different observations of the same target (e.g. 000 segment is the data from the autonomous slew; 001 segment is the data from the first ground-commanded follow-up observation.**

  [991 and 992 segments: 1st day XRT-only and UVOT-only data in QL site. This is done to quickly process XRT and UVOT data in parallel as soon as new science data are received. To be used in the very early analysis]

The version number records the number of times data from this sequence has been processed by the pipeline.

Swift XRT File Naming convention

File name format for the Swift XRT science event files:

sw[obs_id]x[mm][ww][pp]_[lev].evt

[obs_id]: 11 digits number (target sequence)

[mm]: XRT science mode (two character string, e.g. pc, wt)

[ww]: window setting (e.g. w2 for 500x500 pixels PC window)

[pp]: satellite status (slew, settling or pointing phase)

[lev]: file level (e.g. uf and cl for level 1 and 2)

Examples:

sw00111529000xpcw2po_uf.evt

sw00111529000xwtw2po_cl.evt

Swift Archive - HEASARC

Swift archive interface at HEASARC:

http://heasarc.gsfc.nasa.gov/cgi-bin/W3Browse/swift.pl

Swift Archive - ISAC-ASDC

Swift archive interface at ASDC-ISAC:

http://www.asdc.asi.it/mmia/index.php?mission=swiftmastr

XRT data analysis session...