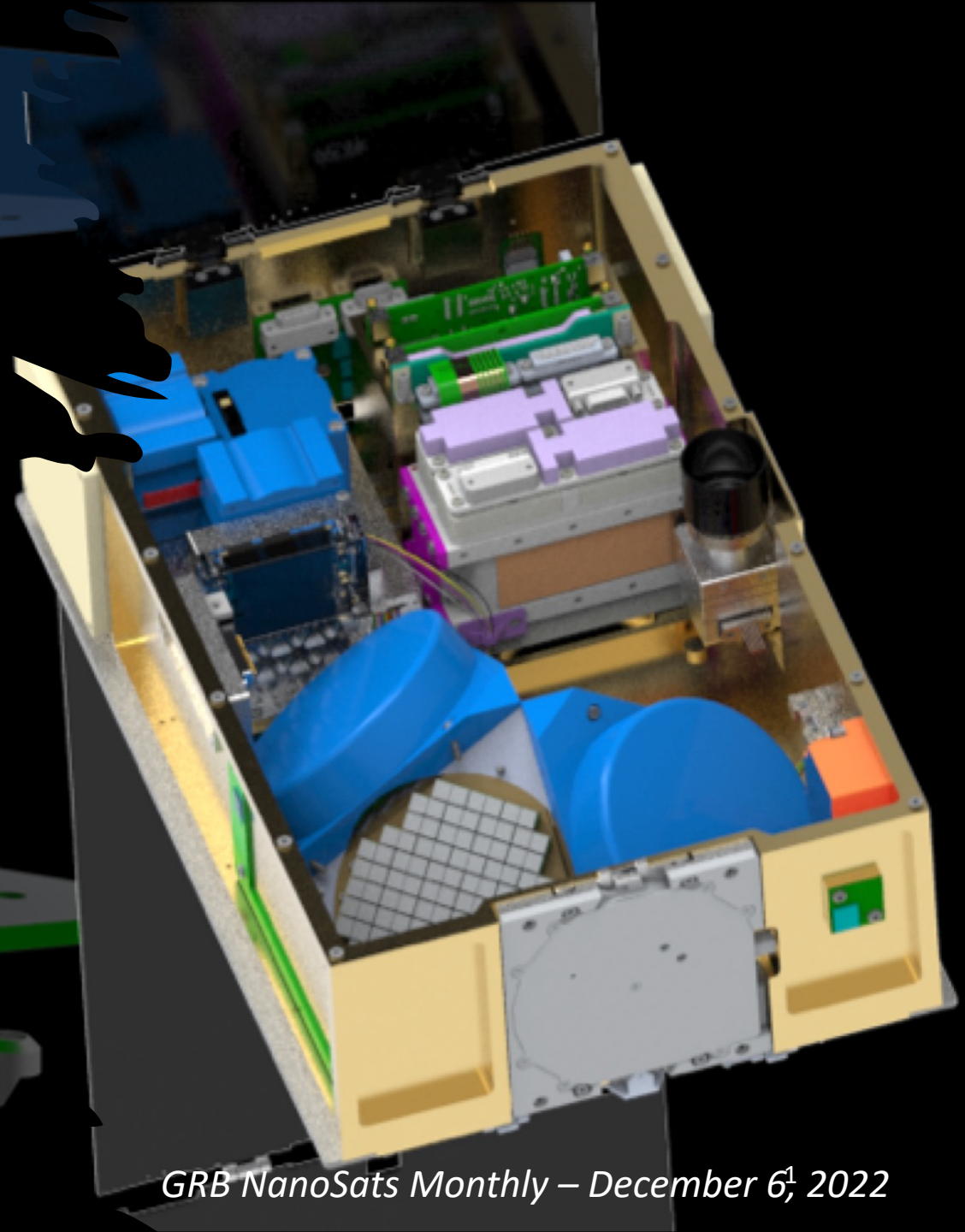


Data Formats and Archive

(BurstCube as an example for wide-field gamma-ray GRB NanoSats, and still in development)

Judy Racusin (NASA/GSFC)
on behalf of the
BurstCube Team





BurstCube Team

PI: Jeremy Perkins (NASA/GSFC)

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Adam Goldstein
Oliver Roberts

Wisconsin

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Marshall Space
Flight Center





Why do we care about BurstCube-specific formats and archive?

- Maybe this will prevent your team from reinventing the wheel
- Uniformity in file formats will make it easier to reuse software and pipelines
- It'll be easier to combine datasets from different instruments for science analyses and joint localizations or sub-threshold searches



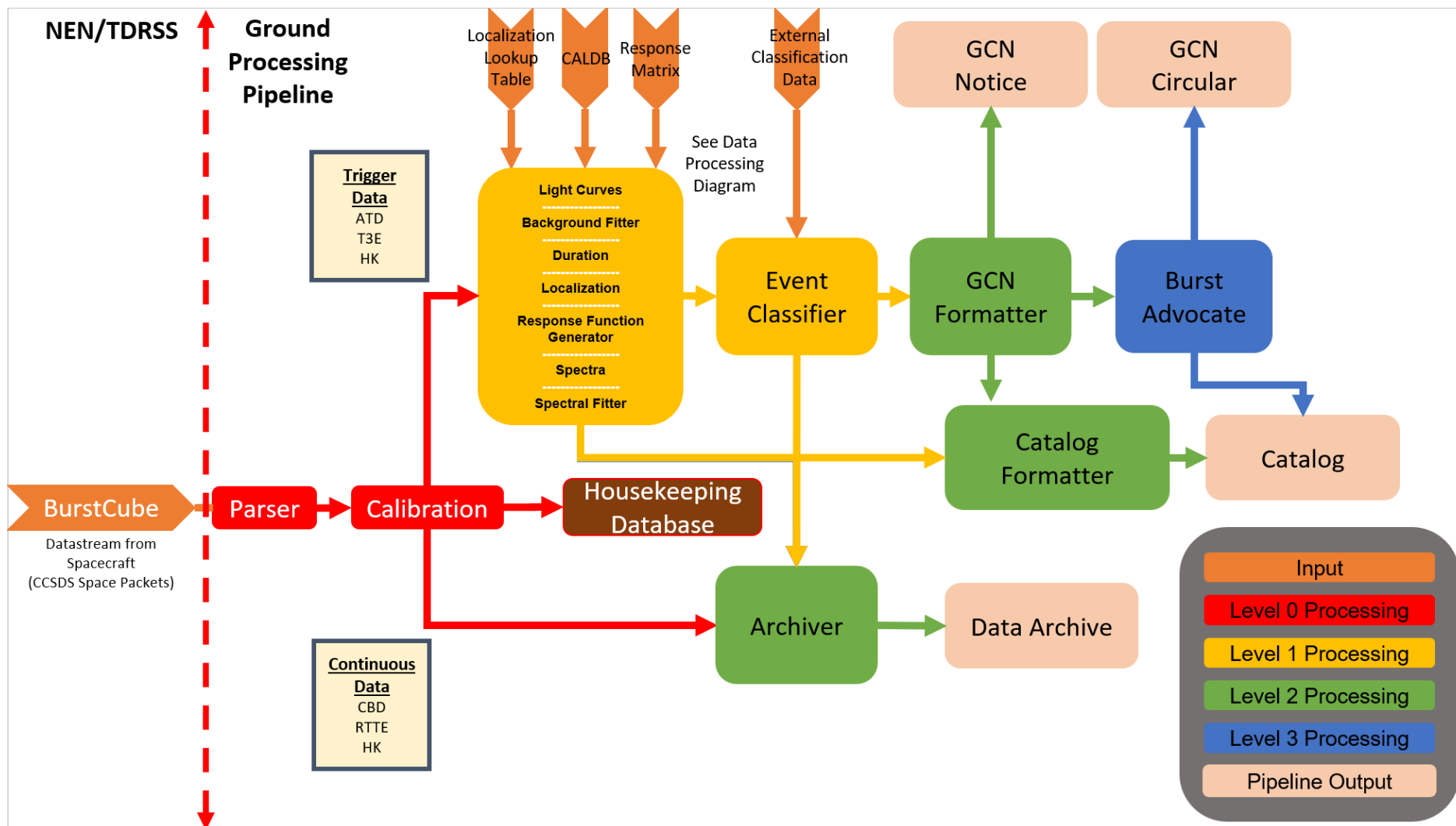


Limitations/Restrictions

- HEASARC compliance (designed for pointed X-ray instruments)
 - FITS standards
 - CALDB
 - FTOOLS compatibility
 - https://heasarc.gsfc.nasa.gov/docs/heasarc/heasarc_req.html
- All data public immediately upon processing (except for most spacecraft housekeeping)
- Fast processing for generating GCN Notices
- Bandwidth
 - Direct to Earth (DTE): s-band, once daily pass, 2 Mbit/s
 - TDRSS (space network): s-band, as needed, 1 kbit/s



BurstCube Pipeline





BurstCube Data Products

Inputs

Files from spacecraft:
CCSDS space packets

L1 Data Products, CALDB,
Localization Lookup Table, Response
Matrix, External Classification
Information (optional)

L2 Data Products

L3 Data Products

Level 0

Space Packet File Parser

Level 1

Localizer, Light Curve Generator, Response Matrix Generator,
Background fitter, Spectra Generator, Spectral Fitter, Event
Classifier

Level 2

GCN Formatter/Updater, Archive Updater,
Catalog Updater, GSPEC

Level 3

Burst Advocate (Science Team), GSPEC

Outputs

Level 1 Data Products:
Parsed L0 data files: ATD, CBD,
RTTE, T3E, Parsed Housekeeping
(Instrument & Spacecraft),
Pipeline output metadata

Level 2 Data Products:
Localization, Light Curves,
Durations, Spectra & Spectral
Fits, Event Classification

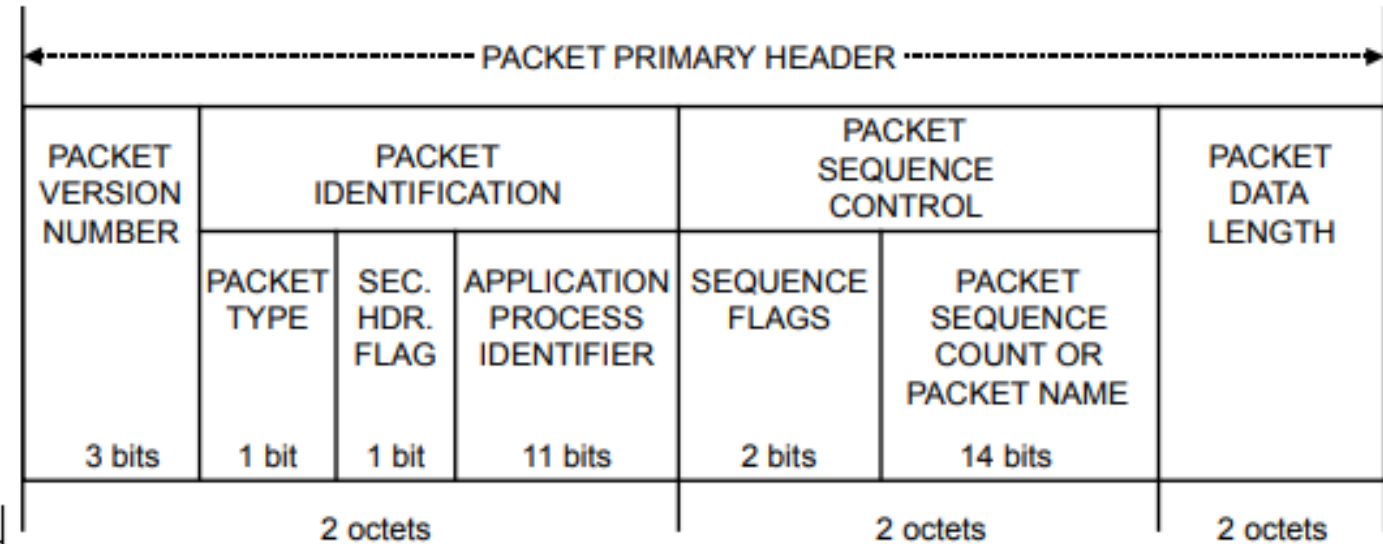
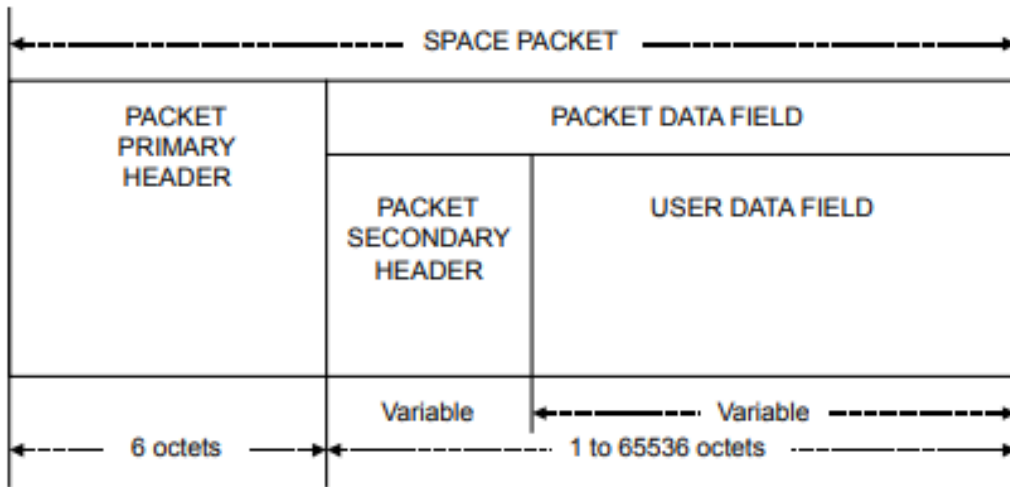
Level 3 Data Products:
Updated Archive, Catalog,
GCN Notices

Level 4 Data Products:
GCN Circular, Updated Catalog



BurstCube Data Products (Level 0)

- Raw Space packets -> FITS
- Packet handling
 - packet sorting
 - gaps



<https://public.ccsds.org/Pubs/133x0b2e1.pdf>



BurstCube Data Products (Level 1)

Datatype	Latency	Type	Energy Channels	Time Resolution	Time Coverage
Alert Trigger Data (ATD)	$\lesssim 15$ min	Trigger	16	50 ms to 2 s	-60 to +60 s
Triggered Time Tagged Event (T ³ E)	$\lesssim 1$ day	Trigger	1024	10 μ s	-30 to 100 s
Requested TTE (RTTE)	$\lesssim 1$ day	Requested	1024	10 μ s	requested
Continuous Binned Data (CBD)	$\lesssim 1$ day	Continuous (excluding SAA)	16	256 ms	Continuous (excluding SAA)
Instrument Housekeeping (IHK)	$\lesssim 1$ day	housekeeping	N/A	1 s, 60 s	continuous
Orbit/Attitude Spacecraft Files	$\lesssim 1$ day	housekeeping	N/A	60 s	continuous



Requested Time Tagged Event Data (RTTE)

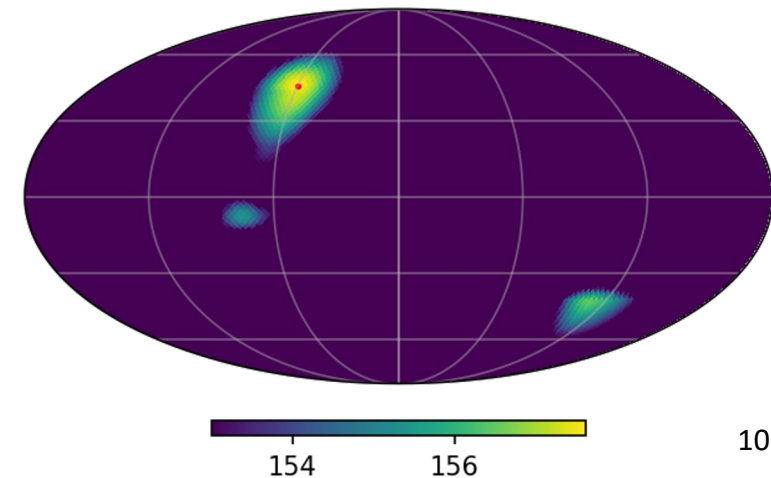
- Onboard buffer holds ~48 hours of TTE data
 - Passes insufficient to downlink all
 - Can downlink <1 hour/day
- Onboard file system setup such that we can downlink upon request
 - community request via a webform
 - requests generated via GCN Notices on detections by other instruments
- Prioritization based upon likelihood of subthreshold counterparts and astrophysical interestingness
- Window of data around time of interest will be downlinked at daily pass on a best effort basis
- Same format at T³E



BurstCube Data Products (Level 2)

- Triggers Only
- Light Curves (FITS and images)
 - 1 file per detector
 - 50-100, 100-300, 300-1000 keV at 64 ms (TTE) and 1 s resolution (ATD + TTE)
 - 1 file with summed detectors
 - 50-100, 100-300, 300-1000 keV at 64 ms (TTE) and 1 s resolution (ATD + TTE)
- Spectra
 - source PHA2 files
 - response functions
 - background spectra
- Duration
 - Includes automated background estimation

- Spectral Modeling
 - PL, CPL, Band, SBPL fits
- Localization
 - 2D image with WCS coordinates
 - Healpix probability map
 - image of localization map
- Trigger Classification
 - GCN Notice
 - Catalog





BurstCube Data Products (Level 3)

- GCN Notices
 - Standard parameters
 - trigger details (time, trig algorithm, timescale, etc.)
 - localization (RA/Dec circular approximation radius, HEALPIX map)
 - classification (GRB, solar flare, TGF, particles, galactic transient)
 - Automated analysis parameters
 - fluxes, fluences
 - spectral fits
- Trigger Catalog
 - summary of details in notices and more characterization (spectral fits, duration, etc.)
 - based upon Fermi-GBM catalogs



BurstCube Data Products (Level 4)

- GCN Circulars
 - descriptions of triggers based upon data in notices
- Updated Catalog
 - From science team improved background and spectral fits

TITLE: GCN CIRCULAR
NUMBER: 40234
SUBJECT: GRB 231206A: BurstCube Detection
DATE: Judith Racusin at NASA/GSFC (judith.racusin@nasa.gov)

J. L. Racusin (NASA/GSFC) reports on behalf of the BurstCube Team:

At 22:09:04.72 UT on 6 December 2023, BurstCube triggered and located GRB 231206A (trigger 193492323/20231206923).

The on-ground calculated location, using the BurstCube trigger data is:

RA/Dec = 234.3, -47.3 (J2000)
with a circular equivalent statistical error of 10.4 deg (radius, 90% confidence).

The skymap and HEALPix FITS file can be found here:

https://heasarc.gsfc.nasa.gov/FTP/burstcube/data/transient/2023/bn231206923/quicklook/bc231206923csa_atdloc.fits

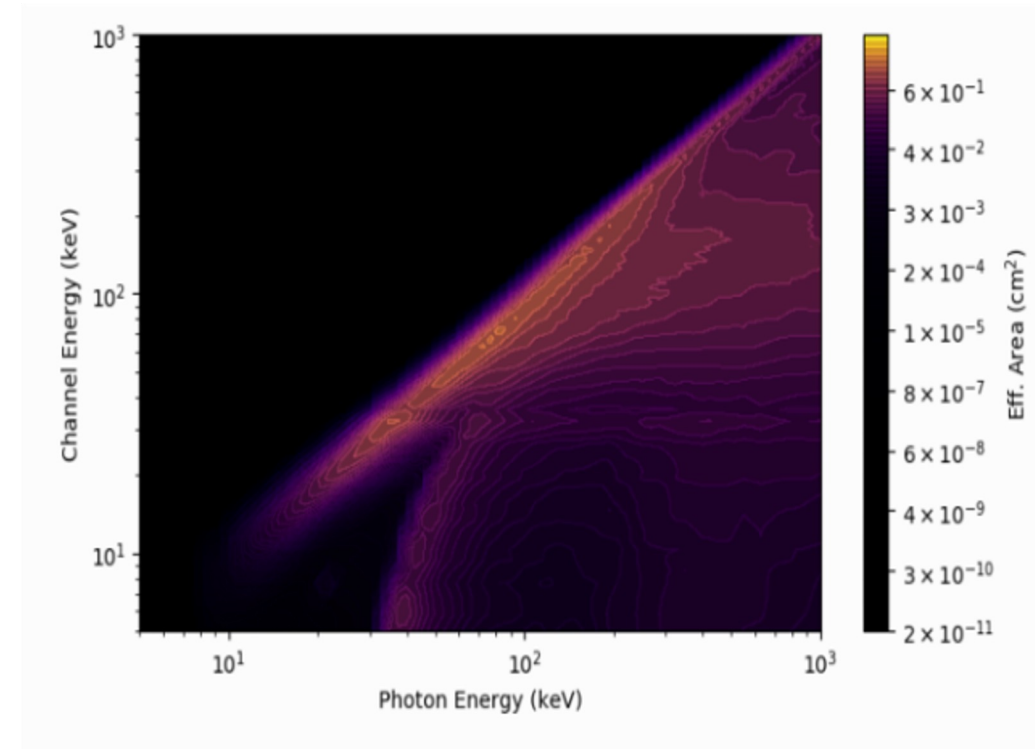
The light curve can be found here:

https://heasarc.gsfc.nasa.gov/FTP/burstcube/data/transient/2023/bn231206923/quicklook/bc231206923csa_atdlc.fits



Calibration Database (CALDB)

- Alignment file
 - describes detector orientations and relative coordinate systems
- SAA polygon definition
- Energy bounds
 - 16 energy channels (ATD, CBD)
 - 1024 energy channels (TTE)
- Response functions
 - 3072 per detector (NSIDE=16)



See also talk by Israel Martinez

[/burstcube](#)
[/csa](#)
[/bcf](#) [/cpf](#) [/index](#)
[/...](#) [/...](#) [file1](#) [file2](#)



BurstCube Archive Structure

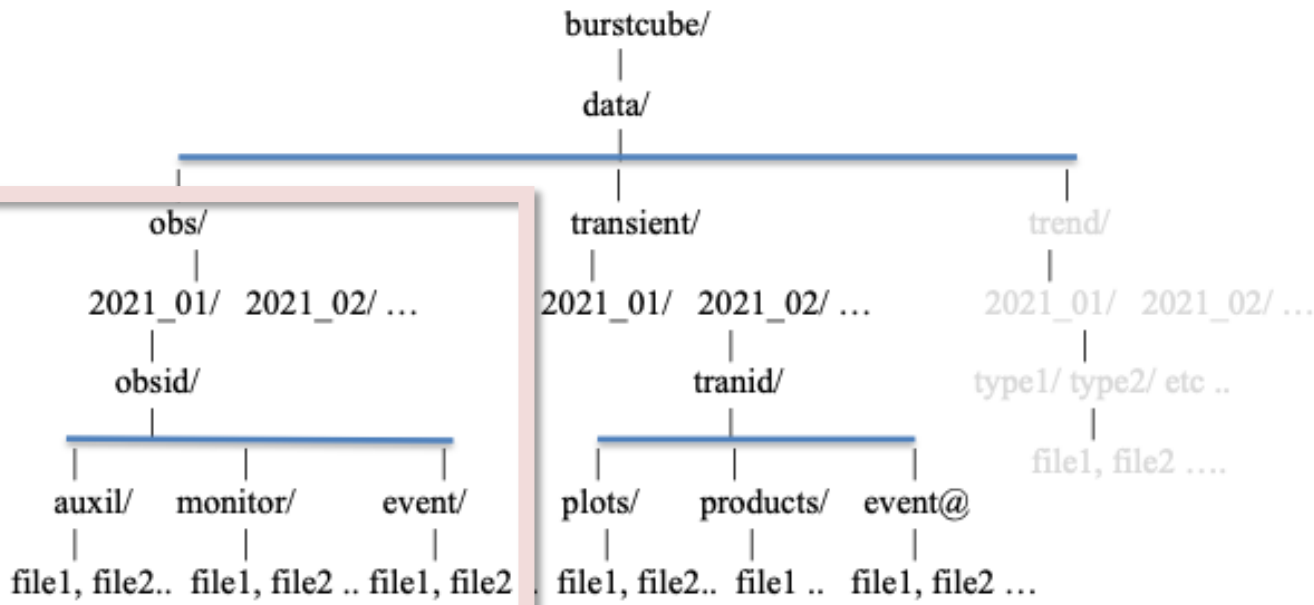


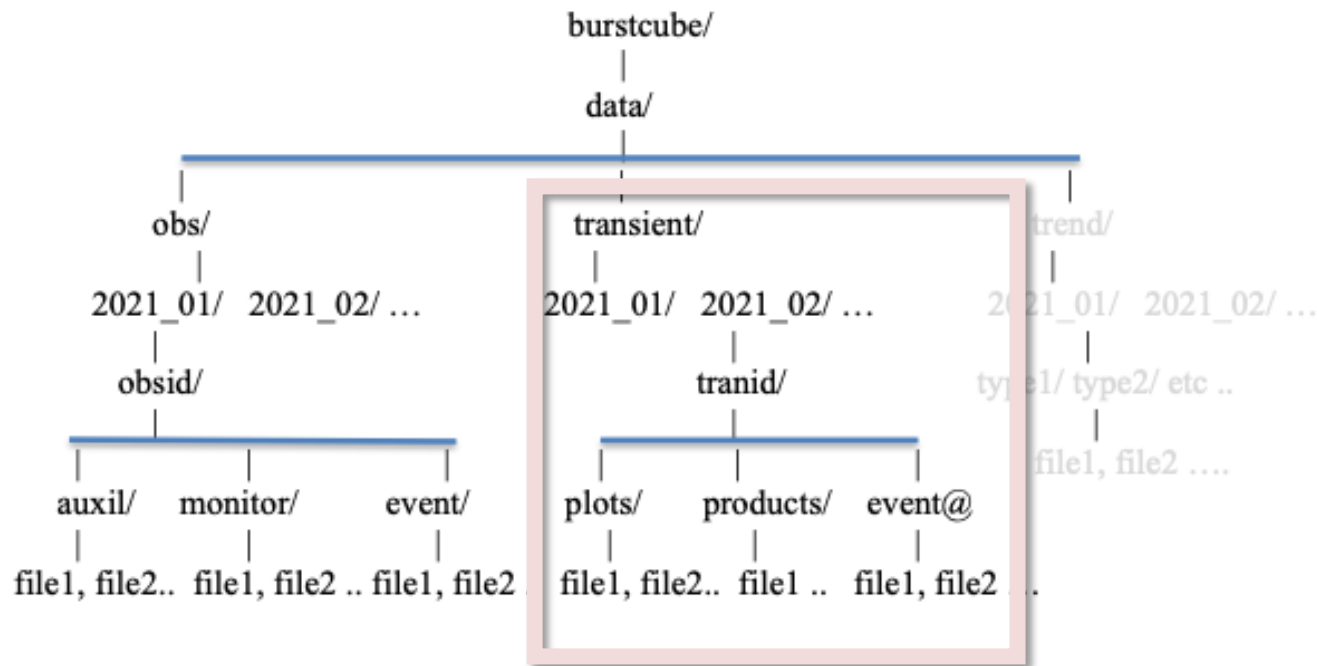
Table 3.4

a) 1st data set : daily observation data

obs/	
Auxiliary filename	Description
auxil/	
bcYYMMDDcsa.hk	HK for the parameters of the detectors
bcYYMMDD.hk	HK for spacecraft including attitude and orbit
bcYYMMDD.cat	Catalog file
bcYYMMDD_joblog.html	Log file of the processing
Science Data	Description
monitor/	
bcYYMMDDcs0_Xcbd.fits	Binned 16 chan spectra NNN s detector CS0
bcYYMMDDcs1_Xcbd.fits	Binned 16 chan spectra NNN s detector CS1
bcYYMMDDcs2_Xcbd.fits	Binned 16 chan spectra NNN s detector CS2
bcYYMMDDcs3_Xcbd.fits	Binned 16 chan spectra NNN s detector CS3
*NNN is one of the selectable integration time	
events/	
bcYYMMDDcs0_atdYYMMDDXXX.fits	Alert trigger cs0 YYMMDDXXX
bcYYMMDDcs1_atdYYMMDDXXX.fits	Alert trigger cs1 YYMMDDXXX
bcYYMMDDcs2_atdYYMMDDXXX.fits	Alert trigger cs2 YYMMDDXXX
bcYYMMDDcs3_atdYYMMDDXXX.fits	Alert trigger cs3 tYYMMDDXXX
bcYYMMDDcs0_tteYYMMDDXXX_uf.evt	T3E/RTTE det cs0 trig YYMMDDXXX
bcYYMMDDcs1_tteYYMMDDXXX_uf.evt	T3E/RTTE det cs1 trig YYMMDDXXX
bcYYMMDDcs2_tteYYMMDDXXX_uf.evt	T3E/RTTE det cs2 trig YYMMDDXXX
bcYYMMDDcs3_tteYYMMDDXXX_uf.evt	T3E/RTTE det cs3 trig YYMMDDXXX



BurstCube Archive Structure



b)2nd data set : transient data

transient/ Science Data	Description
products/	
bcYYMMDDXXXcs0 ttelc	Lighcurves several extensions per cs0
bcYYMMDDXXXcs1 tte.lc	Lighcurves several extensions per cs1
bcYYMMDDXXXcs2 tte.lc	Lighcurves several extensions per cs2
bcYYMMDDXXXcs3 tte.lc	Lighcurves several extensions per cs3
bcYYMMDDXXXcsa tte.lc	Lighcurves several extensions per all csa
bcYYMMDDXXXcs0 tte.pha	PHA2 Spectra per cs0
bcYYMMDDXXXcs1 tte.pha	PHA2 Spectra per cs1
bcYYMMDDXXXcs2 tte.pha	PHA2 Spectra per cs2
bcYYMMDDXXXcs3 tte.pha	PHA2 spectra per cs3
bcYYMMDDXXXcs0 bg.pha	Background spectrum for cs0
bcYYMMDDXXXcs1 bg.pha	Background spectrum for cs1
bcYYMMDDXXXcs2 bg.pha	Background spectrum for cs2
bcYYMMDDXXXcs3 bg.pha	Background spectrum for cs3
bcYYMMDDXXXcs0.rsp	Response per cs0
bcYYMMDDXXXcs1.rsp	Response per cs1
bcYYMMDDXXXcs2.rsp	Response per cs2
bcYYMMDDXXXcs3.rsp	Response per cs3
bcYYMMDDXXXcsa.fits	Localization for the trigger YYMMDDXXX: 2d image primary plus keywords for trigger information, healpix representation in 1 st extension
bcYYMMDDXXX.cat	Catalog file
bcYYMMDDXXX_joblog.html	Log file of the processing
plots/	
bcYYMMDDXXXcs0_atdlc.gif [png]	Plot lightcurve cs0
bcYYMMDDXXXcs1_atdlc.gif [png]	Plot lightcurve cs1
bcYYMMDDXXXcs2_atdlc.gif [png]	Plot lightcurve cs2
bcYYMMDDXXXcs3_atdlc.gif [png]	Plot lightcurve cs3
bcYYMMDDXXXcs0_atdpha.gif [png]	Plot spectra cs0
bcYYMMDDXXXcs1_atdpha.gif [png]	Plot spectra cs1
bcYYMMDDXXXcs2_atdpha.gif [png]	Plot spectra cs2
bcYYMMDDXXXcs3_atdpha.gif [png]	Plot spectra cs3
bcYYMMDDXXXcs0_ttelc.gif [png]	Plot lightcurve cs0
bcYYMMDDXXXcs1_ttelc.gif [png]	Plot lightcurve cs1
bcYYMMDDXXXcs2_ttelc.gif [png]	Plot lightcurve cs2
bcYYMMDDXXXcs3_ttelc.gif [png]	Plot lightcurve cs3
bcYYMMDDXXXcs0_ttepha.gif [png]	Plot spectra cs0
bcYYMMDDXXXcs1_ttepha.gif [png]	Plot spectra cs1
bcYYMMDDXXXcs2_ttepha.gif [png]	Plot spectra cs2
bcYYMMDDXXXcs3_ttepha.gif [png]	Plot spectra cs3
bcYYMMDDXXXcsa.gif [png]	Plot image of the localization



Data Analysis Tools

- GBM Data Tools
 - Fermi-GBM python analysis package
 - https://fermi.gsfc.nasa.gov/ssc/data/analysis/gbm/gbm_data_tools/gdt-docs/index.html
- bc-tools
 - BurstCube specific tools built upon GBM Data Tools
 - <https://gitlab.com/burstcube/bc-tools/>
 - Towards an effort to make detector-agnostic programming interface for count-based gamma-ray instruments



GCN Modernization on behalf of GCN Team:

- General Coordinates Network (<https://gcn.nasa.gov>)
- Phasing out legacy GCN system (GCN Classic) over next couple of years

Why switch to the new GCN?

	GCN Classic	GCN Classic over Kafka
Self-service	NO. Users need to contact administrator in order to make account and subscription changes	YES. Manage your own account and subscription settings through the web site
Open standards	NO. Notices are sent using three custom protocols	YES. Notices are sent using one standard protocol, Apache Kafka
Open source	NO. Custom software needed to receive notices	YES. Receive notices using open-source software
Highly available	NO. Notices are broadcast by a single server	YES. Notices are broadcast by a cluster of highly-available Kafka brokers in the cloud
Secure	NO. Notices are sent as plaintext	YES. Notices are protected with SSL/TLS

The screenshot shows a browser window at localhost:3333 displaying the General Coordinates Network (GCN) website. The page features a navigation bar with links for Missions, Notices, Circulars, Documentation, and Sign in / Sign up. The main content area has a header titled "The new GCN: Multimessenger astronomy alerts delivered over Kafka" with a "Start streaming GCN Notices" button. Below this is a diagram showing various observatories (Ulysses, Integral, Swift, XTE, IHEHE) connected to a central GCN hub, which then distributes alerts to ground-based sites (radio and optical). A text block explains that GCN is a public collaboration platform for sharing alerts and rapid communications. Below this, three columns compare the systems: "For legacy applications GCN Classic" (using VOEvent Transport Protocol and Email), "Recommended GCN Classic over Kafka" (using VOEvent and Kafka), and "Coming soon GCN Kafka" (using JSON and Kafka). The latter two columns emphasize "One format, one protocol."

New GCN web portal



GCN Notices

- Producer Instruments
 - All new notice types will go thru the new GCN not legacy system (GCN Classic)
 - Unifying schema between instruments (as much as possible) - available soon
- Consumers – Switch now!
 - Self-managed GCN Notice subscriptions via email
 - Self-managed GCN Notices over Kafka (replaces socket & VOEvent transport protocol)
 - Still available in all 3 legacy formats (text, 160-byte binary, VOEvent)
- More Details
 - <https://nasa-gcn.github.io/gcn-presentation/>



GCN Circulars (Coming Soon)

- Modernization of GCN Circulars
 - Self-service subscription management
 - Self-service submitter registration using peer endorsement system
 - automatic onboarding of existing subscribers and submitters
 - Webform submission with Astro-flavored Markdown (email submission still accepted)
 - Correct handling of Unicode
 - Contextual parsing of links
- Migrate archive
- Smooth transition of subscribers
- Future enhancements
 - Automatically minted DOIs and BiBTeX entries
 - Link ORCID to GCN Circulars
 - Filtering by source type
 - Erratum