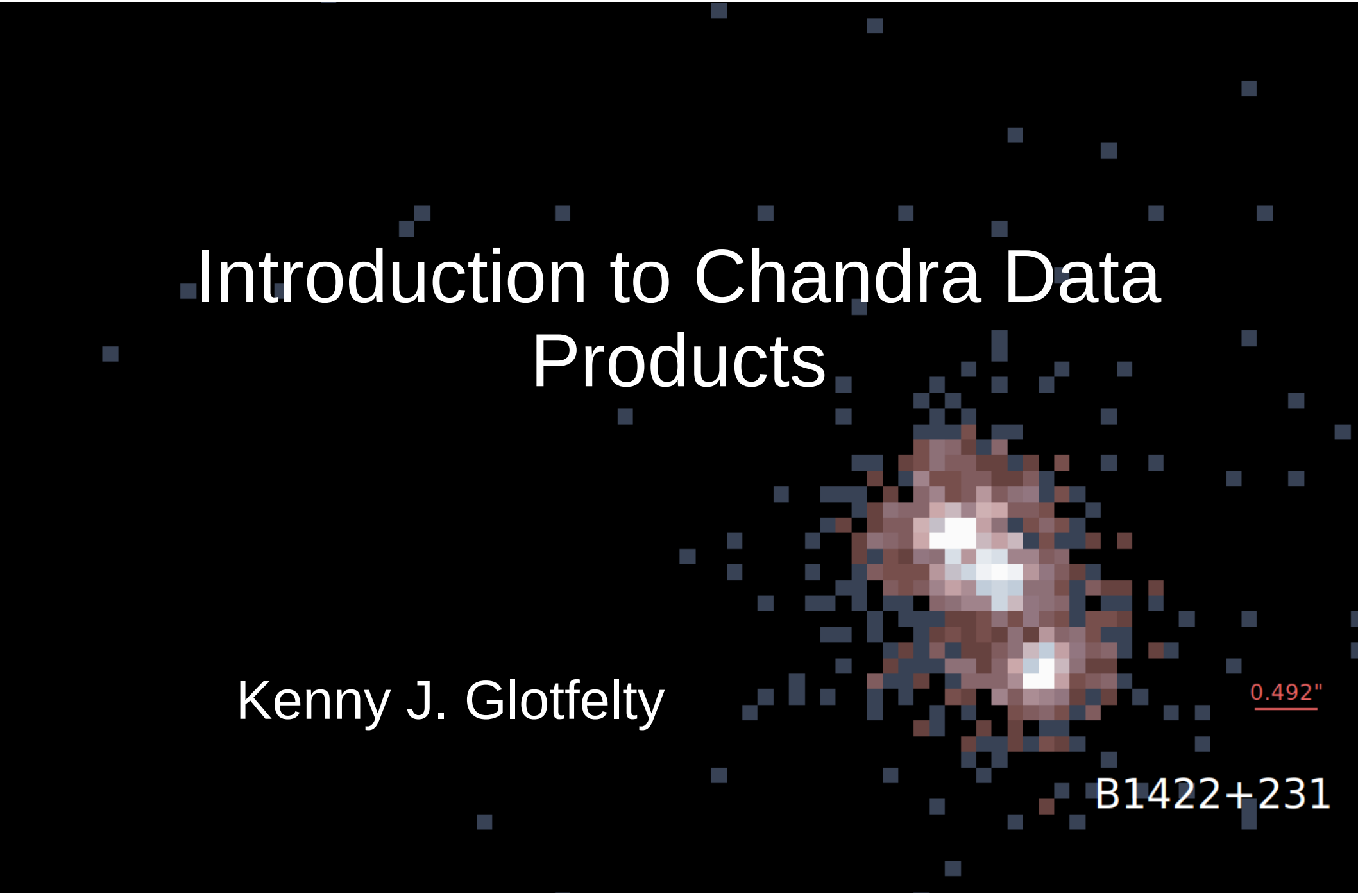
Introduction to Chandra Data Products

Kenny J. Glotfelty

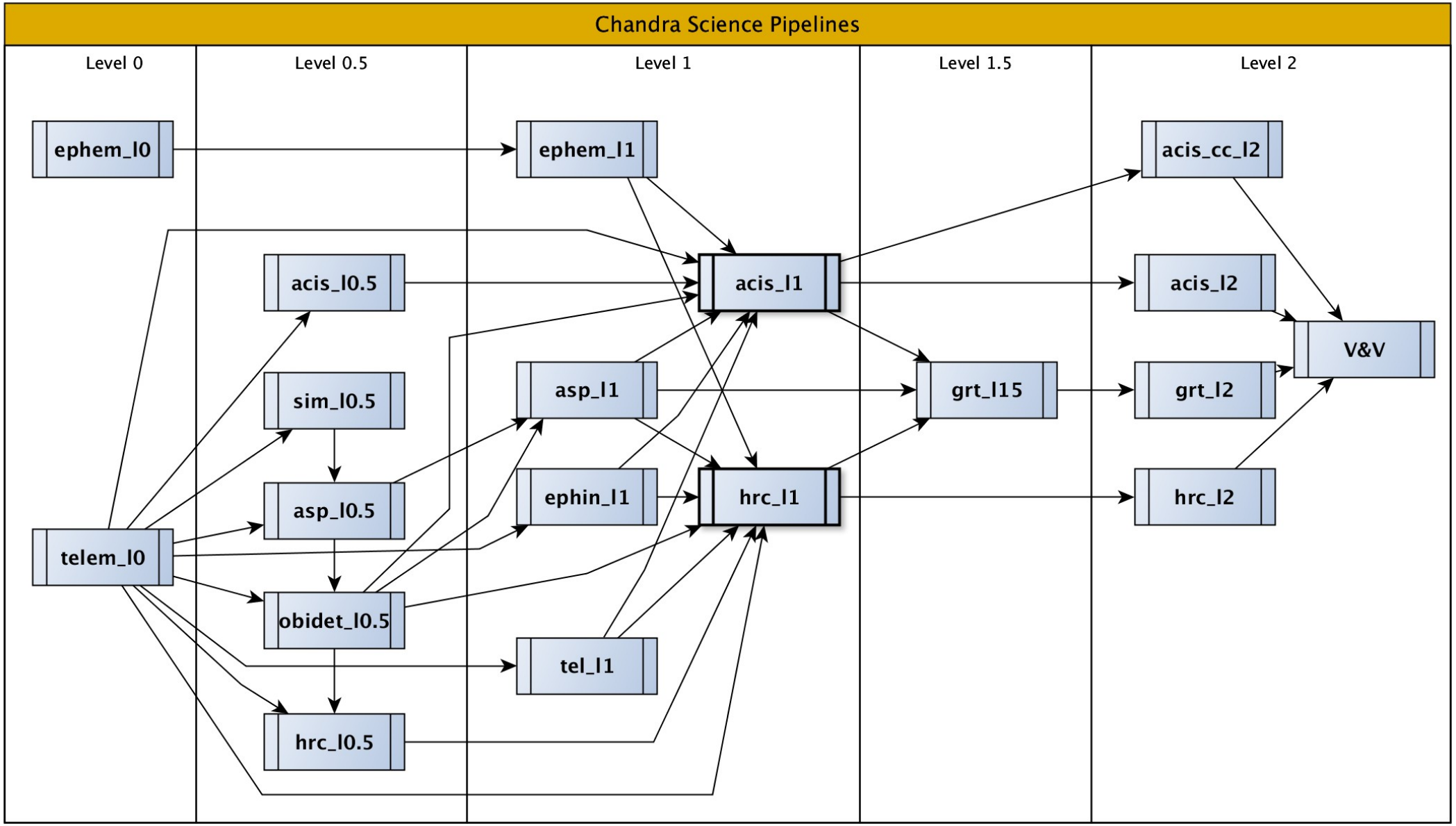


CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Outline

- Processing Levels
- Directory structure
  - File names
- Data Products
  - File content
  - Header keywords
- Reprocessing

Processing Levels



Note: Not all pipelines nor all dependencies are shown.

Jet Propulsion Laboratory | California Institute of Technology

DEEP SPACE NETWORK *NOW*

LAST UPDATED: OCT 4 6:00 PM (UTC)

DSN home

MADRID

OCT 4
8:10 PM

NHPC MMS2 ORX

63 65 54 55

GOLDSTONE

OCT 4
11:10 AM

DSS SOHO LRO ORX DSS

14 15 24 25 26

CANBERRA

OCT 5
5:10 AM

CHDR VGR2 GTL

43 34 35 36

TARGET

CHANDRA

VIEW ANTENNA | VIEW SPACECRAFT | VIEW WORLD MAP

CHDR

SPACECRAFT

NAME
Chandra

RANGE
78.16 thousand km

ROUND-TRIP LIGHT TIME
0.52 sec

ANTENNA

NAME
DSS 34

- less detail

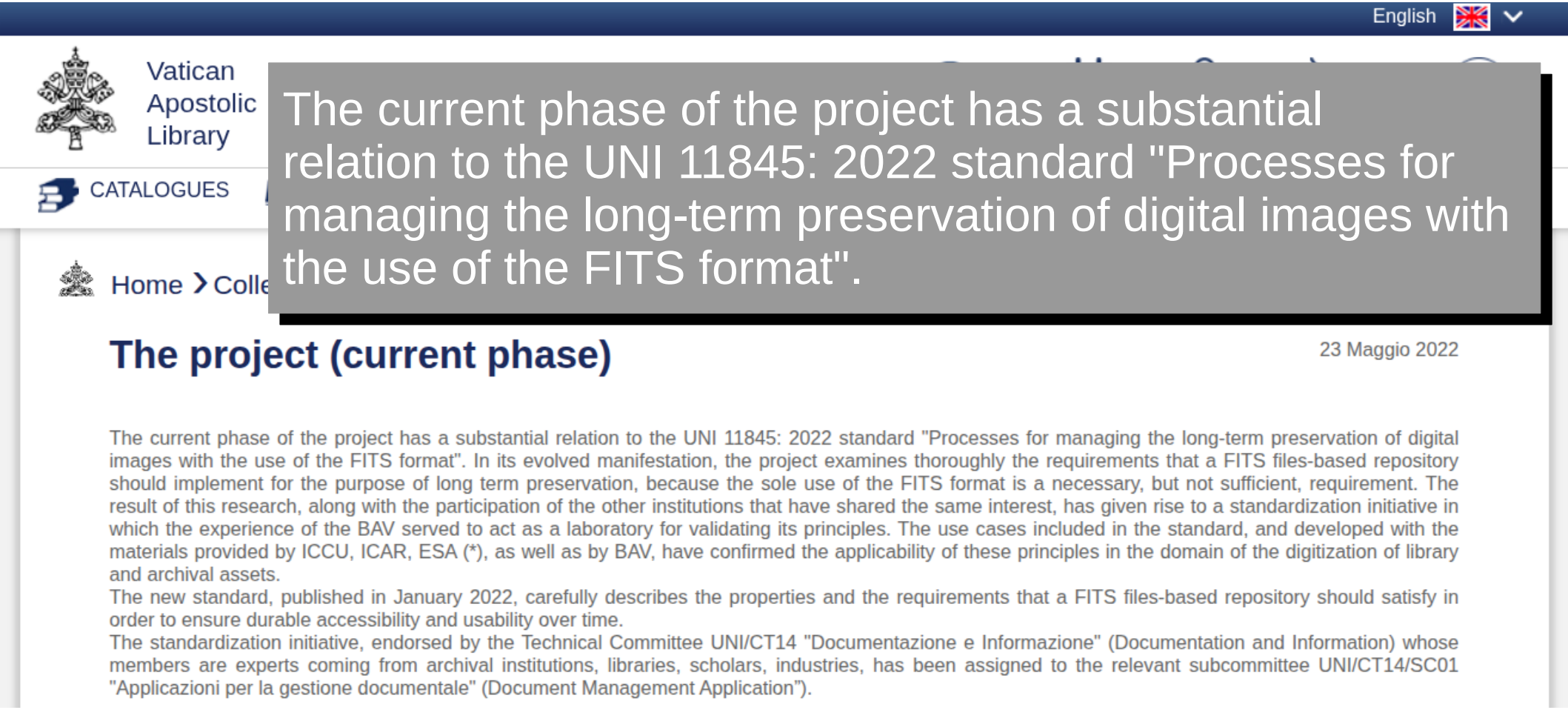
credits contact us

Level 0

- Convert raw telemetry into FITS files.
- **TIME** values are computed for all data products.
- Various engineering products are converted to physical units.

Who else uses FITS?

https://www.vaticanlibrary.va/en/in-digitalizzation/the-current-digital-project.html



Level 0.5

- Various intermediate steps needed to seed the science pipelines.
  - ASPECT : determines time intervals when in Kalman lock
  - OBI_DET : computes time boundaries between observations.
  - HRC : cuts data on proprietary time boundaries
  - ACIS : splits *interleaved mode* aka *alternating exposures* into separate files

Level 1

- Applies calibrations to science products (events and aspect)
  - celestial coordinates (WCS), GAIN, TGAIN, DEGAP, CTI, GRADE, boresite corrections, etc.
- Computes the GTI (Good Time Intervals)
- No filtering.
  - All L0 events fed into L1 are output by L1.

Level 1.5

- For grating observations only
- Determines 0^{th} order location
- Assigns gratings coordinates including order sorting.

Level 2

- ~~Combines multi-obi dataset (OBI_NUM)~~
- Applies standard filters based
  - ACIS: status=0, grade=0,2:4,6, GTIs
  - HRC: status, GTIs
- Gratings Only: extracts spectrum & creates responses
- All observations go through Verification and Validation (V&V)
  - Pipelines create various tables, plots, and images.
  - Pipes are manually reviewed by V&V operator.

Level 3: Chandra Source Catalog

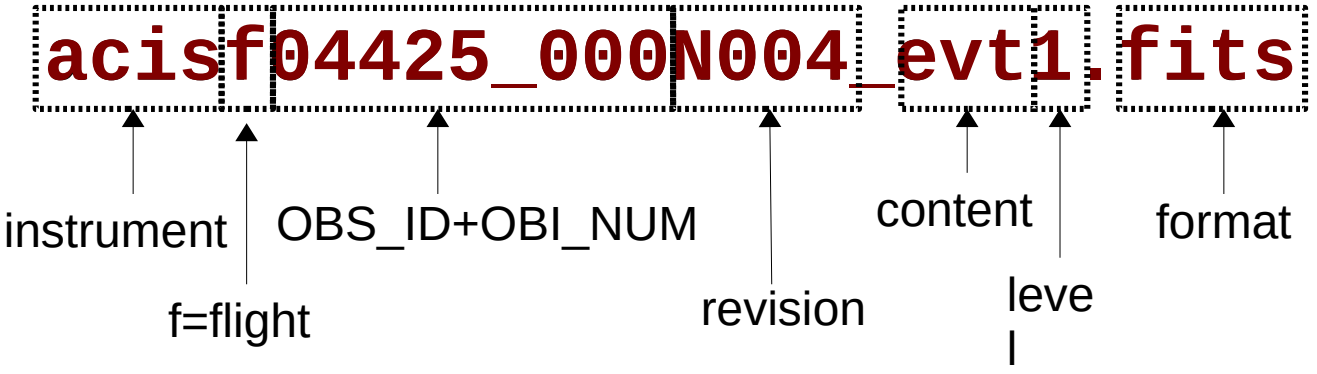
- Detects sources and computes source properties.
- Not currently run as part of SDP
  - Run separately on batches of data sets
- More info on CSC will be in later talks.

Pipeline Processing Notes

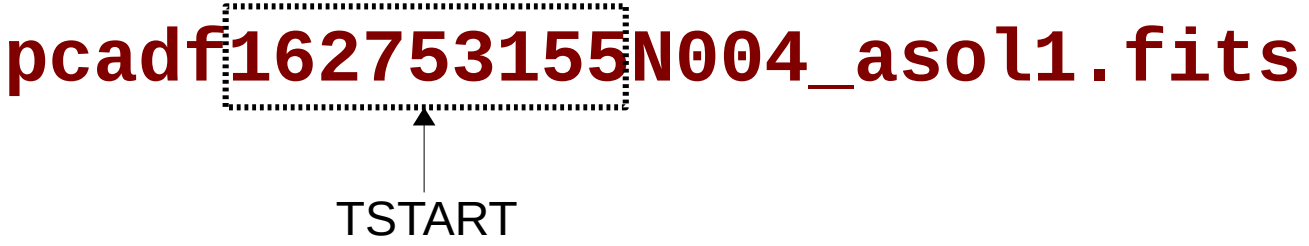
- Raw telemetry dumps are retrieved from the Deep Space Network via JPL approximately every 8 hours.
- Dumps go through quality checks and then are submitted to Standard Data Processing (SDP).
- Entire process is automated up to the manual V&V step.
- Time from end-of-observation to data delivery to PI varies, but generally less than 24 hours.

SDP file names

- Two common formats:
  - Based on OBS_ID



  - Based on TSTART



Notes on file names

- There may be an optional token between the revision and the content

  acisf09529_000N002_e2_evt1.fits

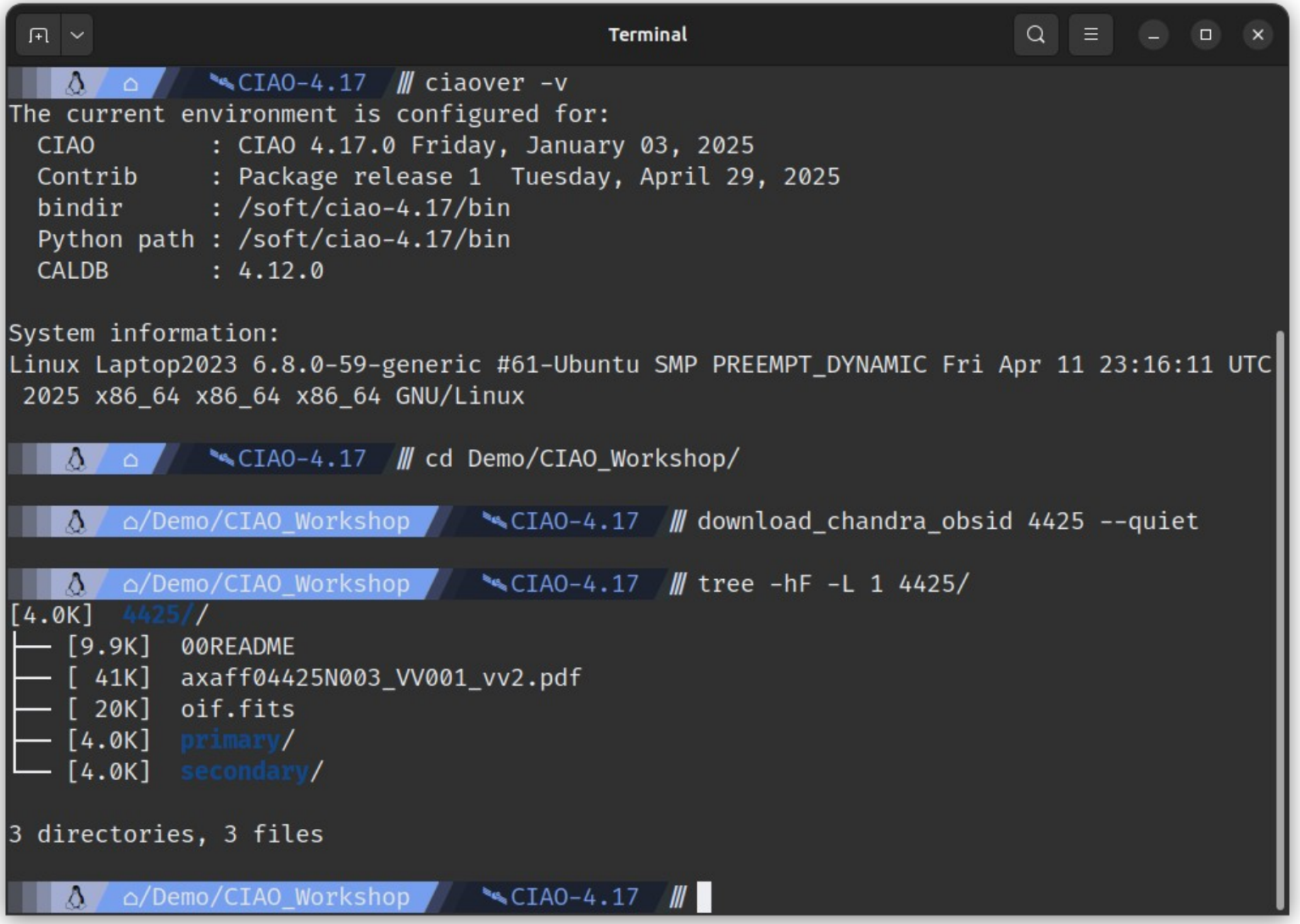
- OBI_NUM is removed at Level 2

  acisf09529N002_e2_evt2.fits

- The revision number is per pipeline. It is possible to have different revision numbers for the same observation

  acisf00306N004_evt2.fits
  pcadf062699826N003_asol1.fits

Directory Structure



Key Files

- vv2.pdf : Verification and Validation summary. Check comments for problems

/dsops/ap/VVCache/arc4gl_commands/pdf_04425N003_81253/vbh.3024.axaff04425N003_VV001_vv2.dvi — Okular

File View Edit Go Bookmarks Tools Settings Help

Browse | Text Selection | Yellow Highlighter | 1 of 2 | Zoom Out | 150% | Zoom In

Thumbnails

V&V Summary Report
L2 ASCDS Version : 10.9.4

Observation 4425 - L2 Version 5
Chandra X-Ray Center

L2 Processing Date : Apr 2 2021

See axaff04425N003_VV001_vvref2.pdf for the full report

V&V Scientist	Jen Lauer
V&V Date (YYYY-MM-DD)	2021.05.10
V&V Edition	1
V&V Disposition and Status	OK
V&V Charge Time	40.172

Comments

/dsops/ap/VVCache/arc4gl_commands/pdf_06647N003_68913/vbh.13267.axaff06647N003_VV001_vv2.dvi — Okular

File View Edit Go Bookmarks Tools Settings Help

Browse | Text Selection | Yellow Highlighter | 1 of 2 | Zoom Out | 150% | Zoom In

Thumbnails

V&V Summary Report
L2 ASCDS Version : 10.9.2

Observation 6647 - L2 Version 3
Chandra X-Ray Center

L2 Processing Date : Dec 17 2020

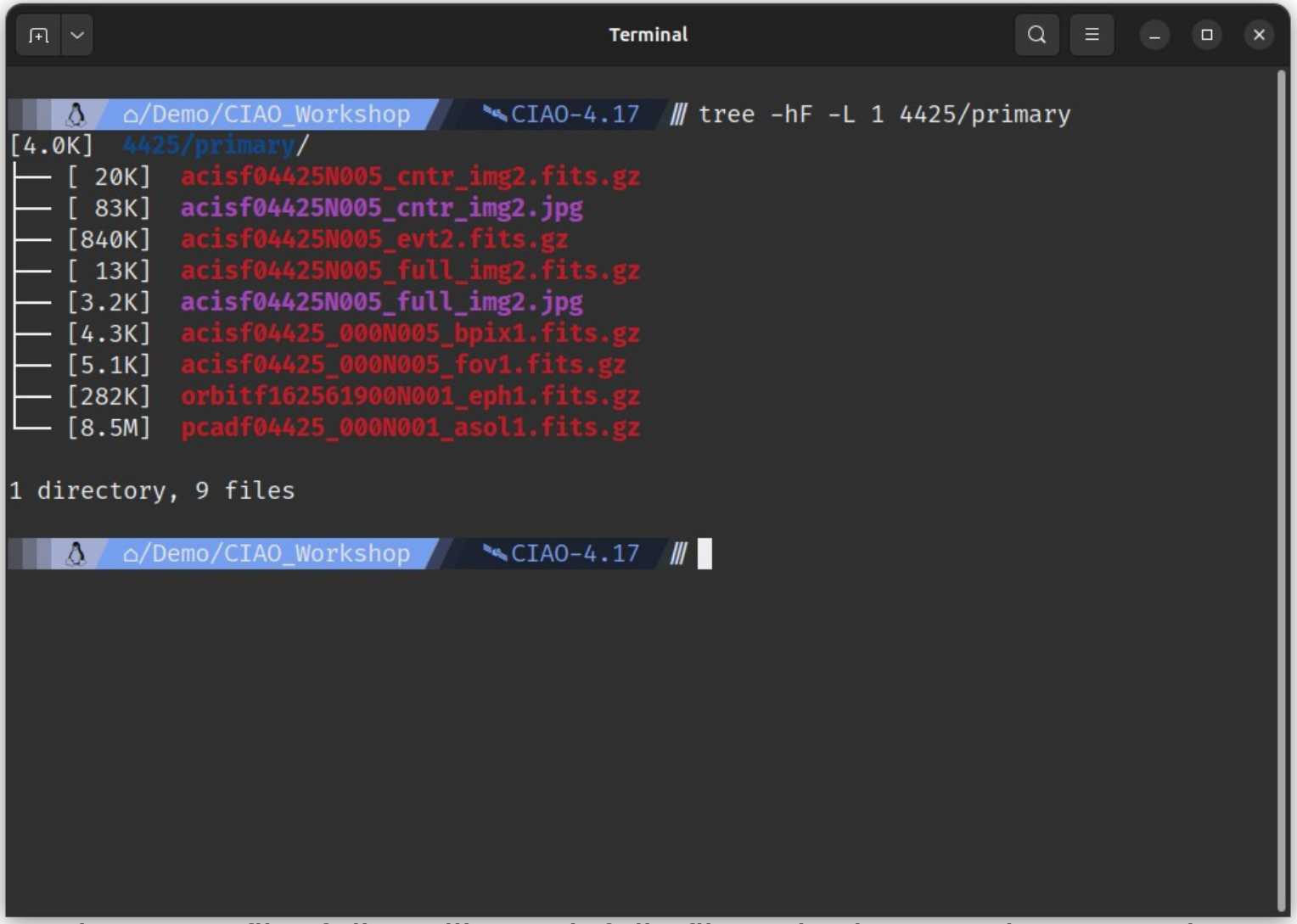
See axaff06647N003_VV001_vvref2.pdf for the full report

V&V Scientist	David Principe
V&V Date (YYYY-MM-DD)	2021.02.03
V&V Edition	1
V&V Disposition and Status	OK
V&V Charge Time	162.64076

Comments

WARNING: The target is not in the field of view. There is an error in the coordinates for RA, resulting in a 15 arcmin error in the pointing. Extracted spectral data included with this processing are based on the user-supplied position, which is incorrect. There is not source at this position.

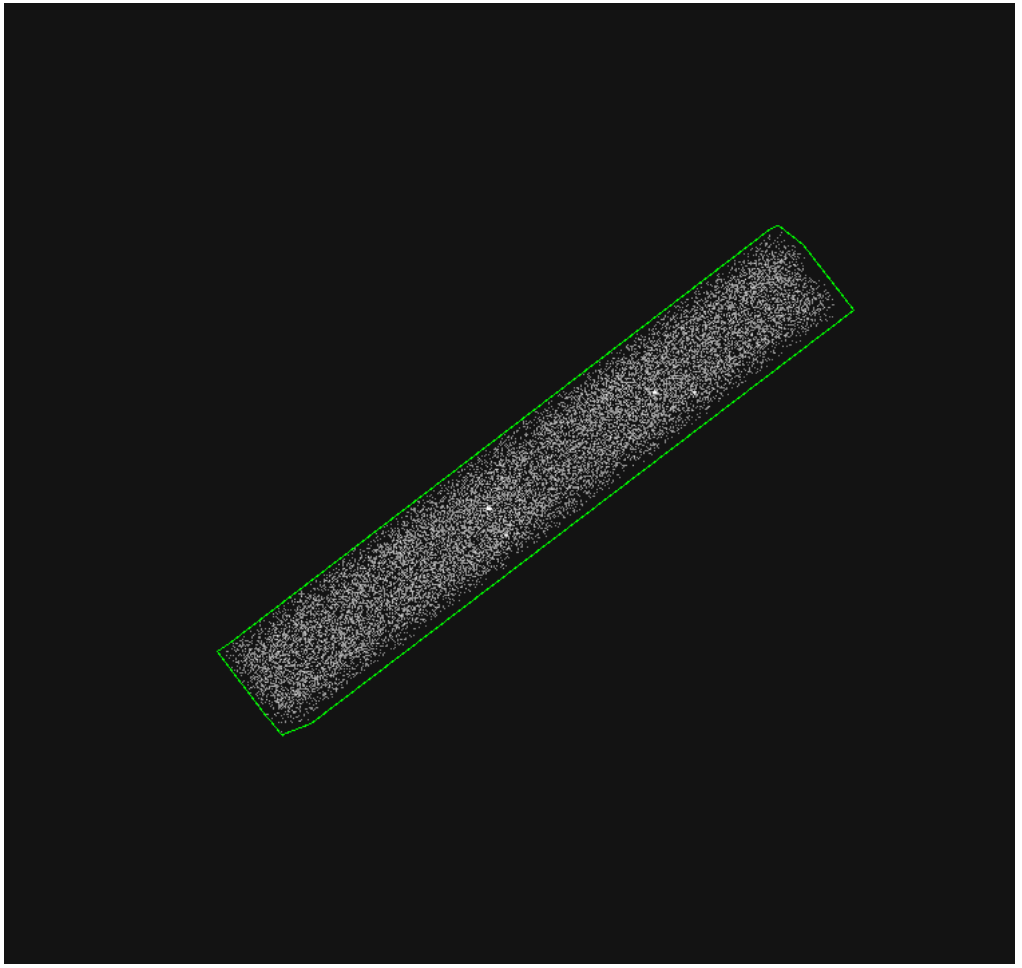
primary directory

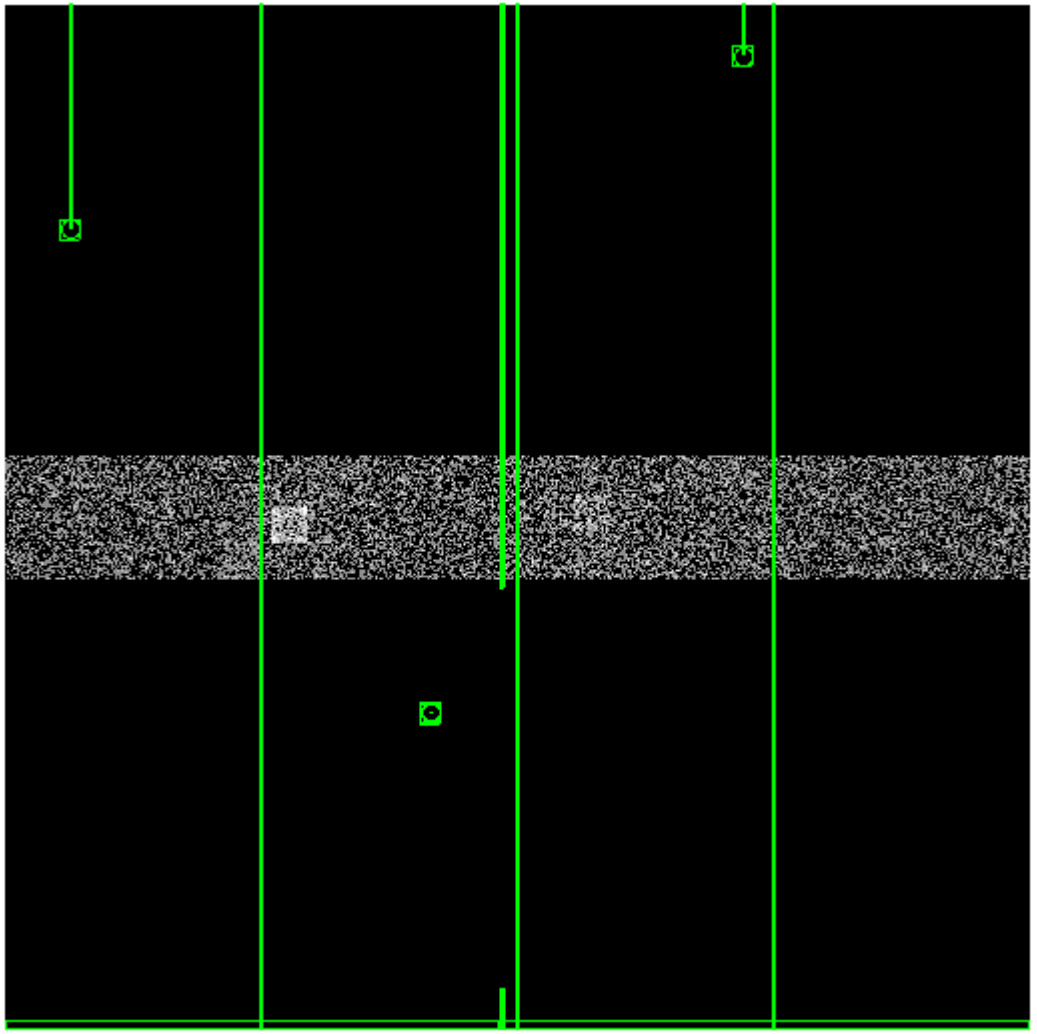


Key Files

- evt2.fits : Level 2 event file, fully calibrated, fully filtered primary science product.
- asol1.fits : Level 1 aspect solution file(s). Time resolved pointing information.
- bpix1.fits : Level 1 bad pixel file
- fov1.fits : Level 1 field-of-view file.

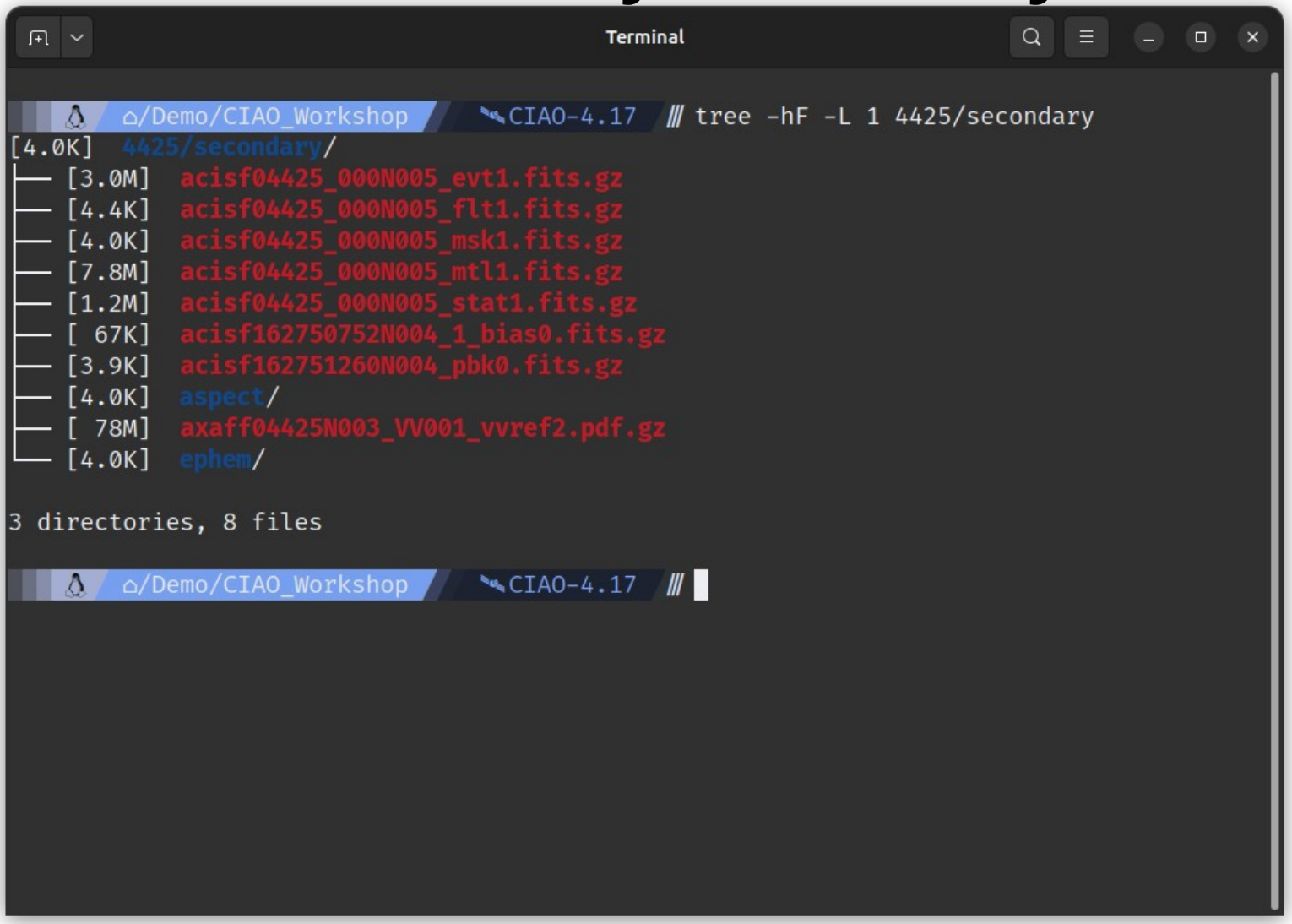
Field of View region shown in SKY coordinates





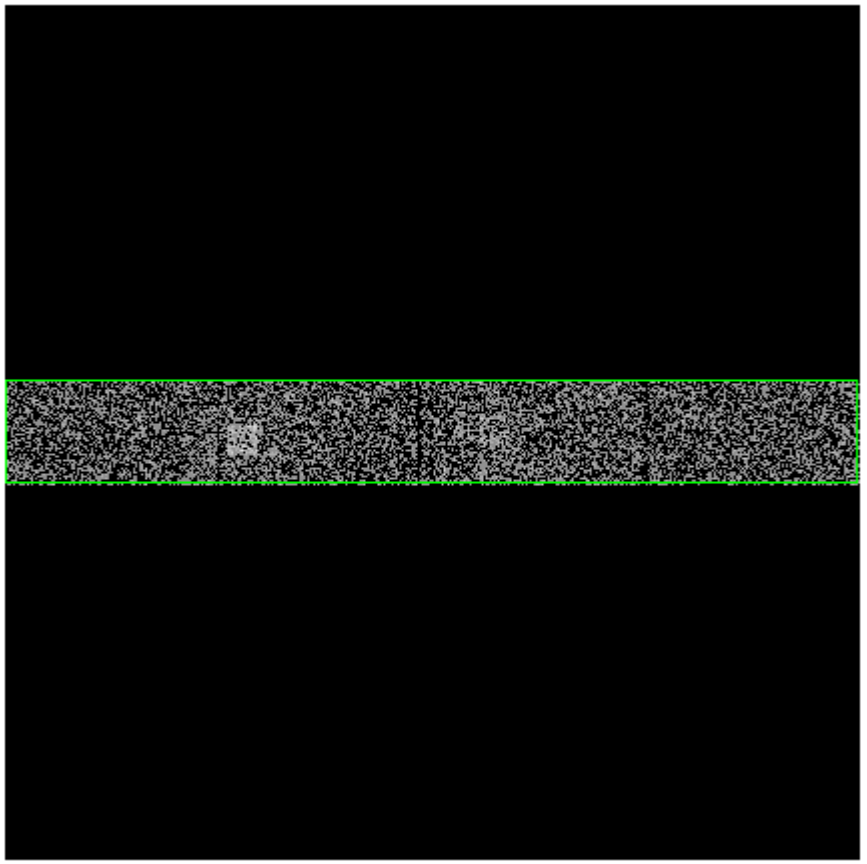
Bad pixel regions shown in CHIP coordinates

secondary directory

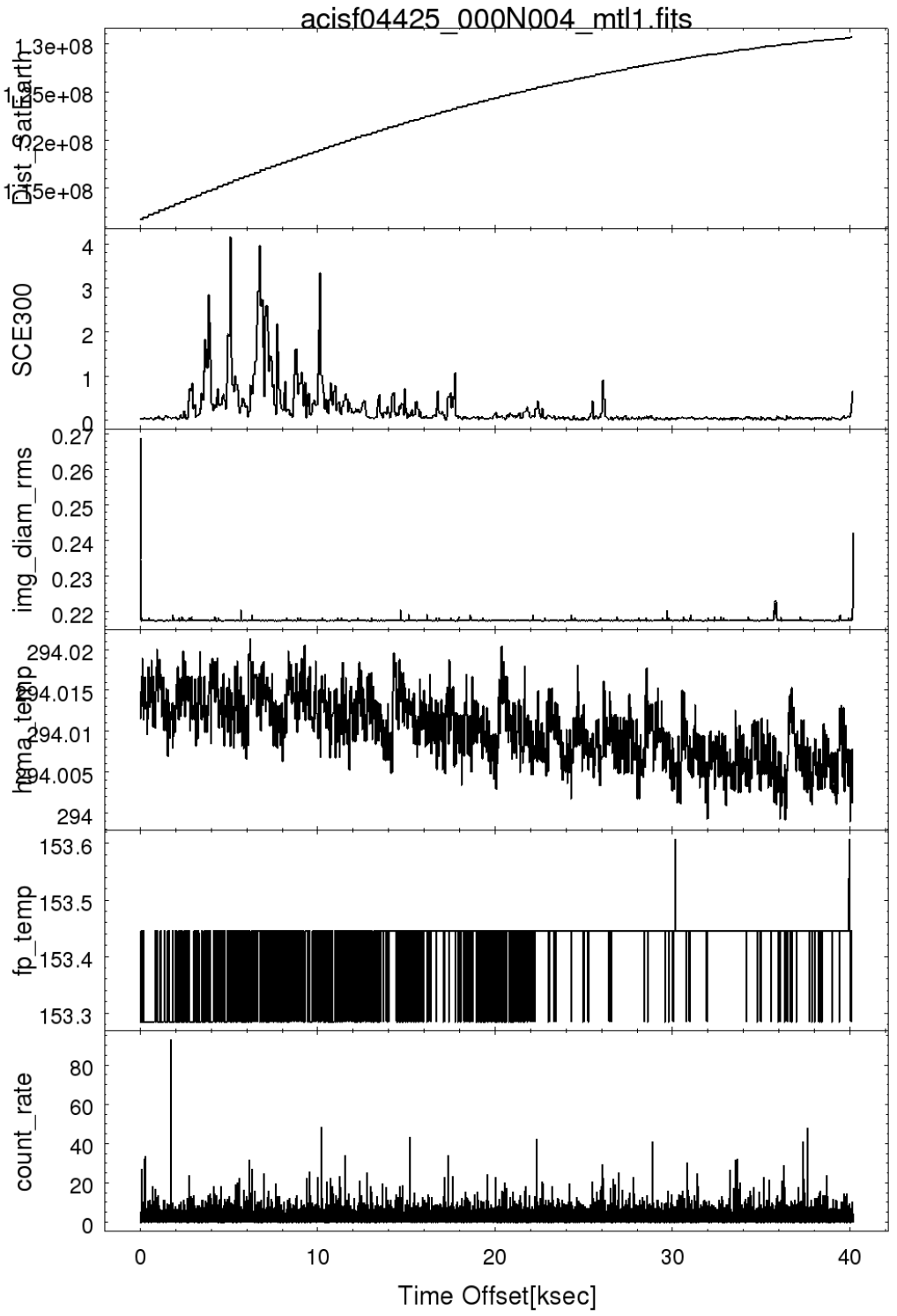


Key Files

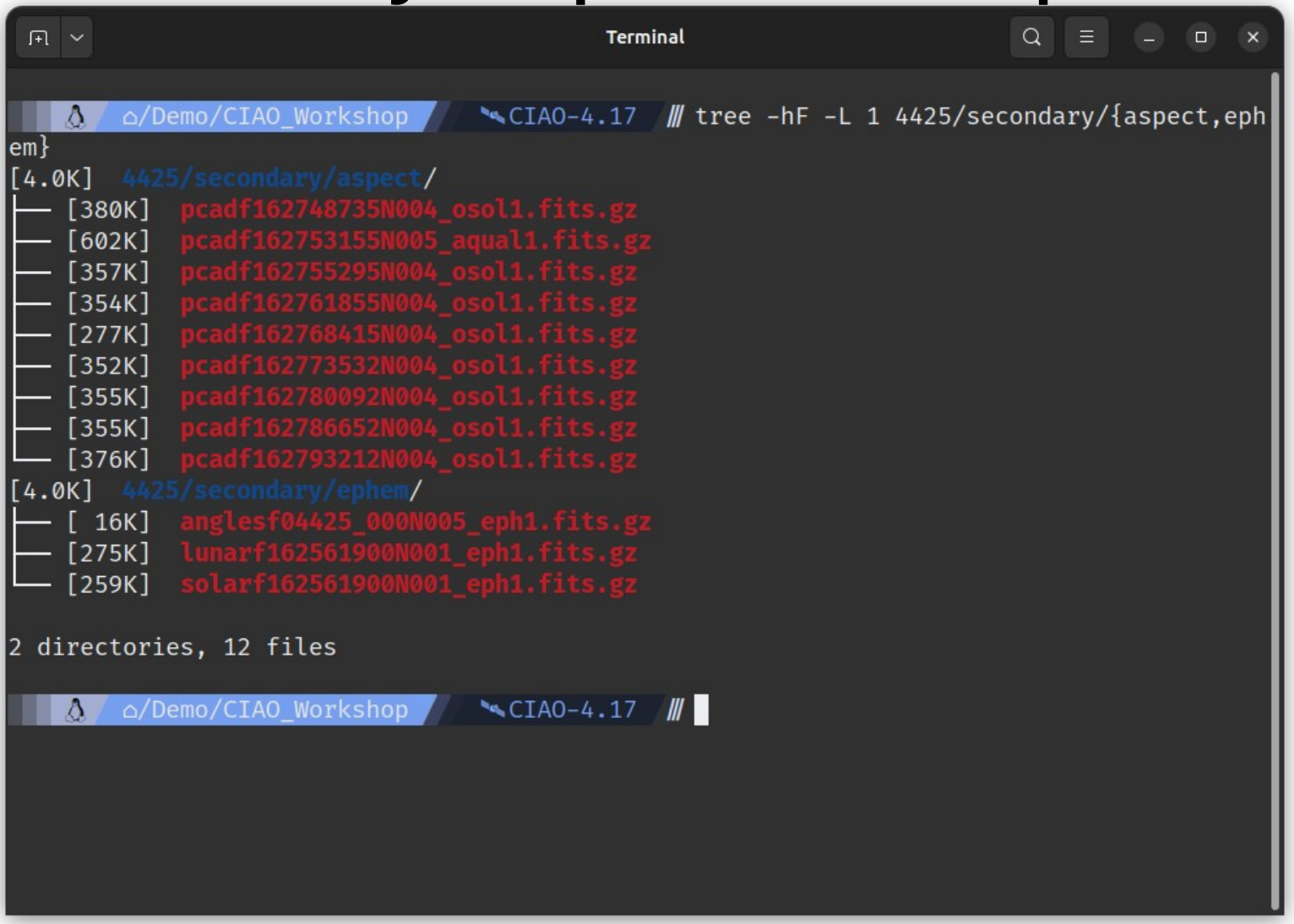
- evt1.fits : Event file, fully calibrated unfiltered event file. Used when reprocessing.
- msk1.fits : Mask file to identify active part of detector
- flt1.fits : Good time interval based on mission time line parameters
- mtl1.fits : Mission time line. Important science and engineering values vs time



Mask file shown in CHIP coordinates



secondary/aspect and ephem/



Key Files

- Generally these files are only useful by experts doing their own specialized analysis.

supporting directory

- Everything else.
  - Most level 0 files
  - Various engineering and housekeeping files
- Supporting products are only available via chaser or by special request.

Directory Structure Summary

- Always read the V&V report!
- Cite the Chandra Data Archive and CIAO in publications (see `00README`)
- Files from the archive are compressed, but the compression ratio is low.
  - Tools will run faster with files uncompressed
- Many scripts look for files in specific directories with their standard file names.
  - Rearranging and renaming files is not recommended.

Chandra Data Products

- Most products are FITS files.
  - Exceptions: README, JPEGs, PDFs
- Most FITS files are TABLEs only a few IMAGEs
  - L0 BIAS images, L2 low-res full-field and high-res center images.
- Most FITS files only contain 1 extension + NULL primary array
  - exceptions: badpixel files, mask file, grating evt2
- Self contained with generous meta-data

Sample ACIS Header Keywords

ASCSYS*	AIMPFILE	ASCDSVER	ASOLFILE	ASPTYPE	BIASFIL*	BPIXFILE
BTIMCORR	BTIMDRFT	BTIMNULL	BTIMRATE	CALDBVER	CCD_ID	CHECKSUM
CLOCKAPP	CONTENT	CORNERS	CREATOR	CTIFILE	CTI_APP	CTI_CORR
CYCLE	DATACLAS	DATAMODE	DATASUM	DATE	DATE-END	DATE-OBS
DEC_NOM	DEC_PNT	DEC_TARG	DEFOCUS	DETNAM	DS_IDENT	DTCOR
DTH_AVG	DTYCYCLE	DY_AVG	DZ_AVG	EXPOSUR*	EXPOSURE	EXPTIME
FEP_CCD	FEP_ID	FIRSTROW	FLSHTIMA	FLSHTIMB	FLSHTIME	FLTFILE
FOC_LEN	FP_TEMP	FSW_VERS	GAINFILE	GEOMFILE	GRADESYS	GRATING
GRD_FILE	HDUCLAS*	HDUCLASS	HDUDOC	HDUSPEC	HDUVERS	HISTNUM
INSTRUME	LIVETIME	LIVTIME*	MASKFILE	MISSION	MJDREF	MJD_OBS
MTLFILE	NROWS	OBI_NUM	OBJECT	OBSERVER	OBS_ID	OBS_MODE
OCLKPAIR	ONTIME	ONTIME*	ORC_MODE	ORIGIN	PBKFILE	PIX_ADJ
RADESYS	RAND_PI	RAND_SKY	RA_NOM	RA_PNT	RA_TARG	READMODE
REVISION	ROLL_NOM	ROLL_PNT	RUN_ID	SEQ_NUM	SHELLFIL	SIM_X
SIM_Y	SIM_Z	SKYFILE	STARTBEP	STARTMJF	STARTMNF	STARTOBT
STOPBEP	STOPMJF	STOPMNF	SUBPIXFL	SUM_2X2	TASSIGN	TDETFILE
TELESCOP	TGAINCOR	TGAINFIL	THRFILE	TIERABSO	TIERRELA	TIMEDEL
TIMEDELA	TIMEDELB	TIMEPIXR	TIMEREF	TIMESYS	TIMEUNIT	TIMEZERO
TIMVERSN	TITLE	TLMVER	TSTART	TSTOP		

Processing Configuration Control

ASCSYS*	AIMPFILE	**ASCDSVER**	ASOLFILE	ASPTYPE	BIASFIL*	BPIXFILE
BTIMCORR	BTIMDRFT	BTIMNULL	BTIMRATE	**CALDBVER**	CCD_ID	**CHECKSUM**
CLOCKAPP	CONTENT	CORNERS	**CREATOR**	CTIFILE	CTI_APP	CTI_CORR
CYCLE	DATACLAS	DATAMODE	**DATASUM**	DATE	DATE-END	DATE-OBS
DEC_NOM	DEC_PNT	DEC_TARG	DEFOCUS	DETNAM	DS_IDENT	DTCOR
DTH_AVG	DTYCYCLE	DY_AVG	DZ_AVG	EXPOSUR*	EXPOSURE	EXPTIME
FEP_CCD	FEP_ID	FIRSTROW	FLSHTIMA	FLSHTIMB	FLSHTIME	FLTFILE
FOC_LEN	FP_TEMP	FSW_VERS	GAINFILE	GEOMFILE	GRADESYS	GRATING
GRD_FILE	**HDUCLAS***	**HDUCLASS**	**HDUDOC**	**HDUSPEC**	**HDUVERS**	HISTNUM
INSTRUME	LIVETIME	LIVTIME*	MASKFILE	MISSION	MJDREF	MJD_OBS
MTLFILE	NROWS	OBI_NUM	OBJECT	OBSERVER	OBS_ID	OBS_MODE
OCLKPAIR	ONTIME	ONTIME*	ORC_MODE	**ORIGIN**	PBKFILE	PIX_ADJ
RADESYS	RAND_PI	RAND_SKY	RA_NOM	RA_PNT	RA_TARG	READMODE
REVISION	ROLL_NOM	ROLL_PNT	RUN_ID	SEQ_NUM	SHELLFIL	SIM_X
SIM_Y	SIM_Z	SKYFILE	STARTBEP	STARTMJF	STARTMNF	STARTOBT
STOPBEP	STOPMJF	STOPMNF	SUBPIXFL	SUM_2X2	TASSIGN	TDETFILE
TELESCOP	TGAINCOR	TGAINFIL	THRFILE	TIERABSO	TIERRELA	TIMEDEL
TIMEDELA	TIMEDELB	TIMEPIXR	TIMEREF	TIMESYS	TIMEUNIT	TIMEZERO
TIMVERSN	TITLE	**TLMVER**	TSTART	TSTOP		

Processing Configuration Control

Important keywords to know:

- ASCDSVER : Software version number

  Typical values look like '8.4.5'
  Very old files have numbers like 'R4CU3UPD2'
  Data after January 2000 have all been reprocessed

- CALDBVER : Calibration Database version number

  Set by pipeline for all files.

>>> CIAO tools do not change CALDBVER

Timing

ASCSYS*	AIMPFILE	ASCDSVER	ASOLFILE	ASPTYPE	BIASFIL*	BPIXFILE
BTIMCORR	**BTIMDRFT**	**BTIMNULL**	**BTIMRATE**	CALDBVER	CCD_ID	CHECKSUM
CLOCKAPP	CONTENT	CORNERS	CREATOR	CTIFILE	CTI_APP	CTI_CORR
CYCLE	DATACLAS	DATAMODE	DATASUM	**DATE**	**DATE-END**	**DATE-OBS**
DEC_NOM	DEC_PNT	DEC_TARG	DEFOCUS	DETNAM	DS_IDENT	DTCOR
DTH_AVG	DTYCYCLE	DY_AVG	DZ_AVG	EXPOSUR*	EXPOSURE	EXPTIME
FEP_CCD	FEP_ID	FIRSTROW	FLSHTIMA	FLSHTIMB	FLSHTIME	FLTFILE
FOC_LEN	FP_TEMP	FSW_VERS	GAINFILE	GEOMFILE	GRADESYS	GRATING
GRD_FILE	HDUCLAS*	HDUCLASS	HDUDOC	HDUSPEC	HDUVERS	HISTNUM
INSTRUME	LIVETIME	LIVTIME*	MASKFILE	MISSION	**MJDREF**	**MJD_OBS**
MTLFILE	NROWS	OBI_NUM	OBJECT	OBSERVER	OBS_ID	OBS_MODE
OCLKPAIR	ONTIME	ONTIME*	ORC_MODE	ORIGIN	PBKFILE	PIX_ADJ
RADESYS	RAND_PI	RAND_SKY	RA_NOM	RA_PNT	RA_TARG	READMODE
REVISION	ROLL_NOM	ROLL_PNT	RUN_ID	SEQ_NUM	SHELLFIL	SIM_X
SIM_Y	SIM_Z	SKYFILE	**STARTBEP**	**STARTMJF**	**STARTMNF**	**STARTOBT**
STOPBEP	**STOPMJF**	**STOPMNF**	SUBPIXFL	SUM_2X2	**TASSIGN**	TDETFILE
TELESCOP	TGAINCOR	TGAINFIL	THRFILE	**TIERABSO**	**TIERRELA**	**TIMEDEL**
TIMEDELA	TIMEDELB	**TIMEPIXR**	**TIMEREF**	**TIMESYS**	**TIMEUNIT**	**TIMEZERO**
TIMVERSN	TITLE	TLMVER	**TSTART**	**TSTOP**		

Timing

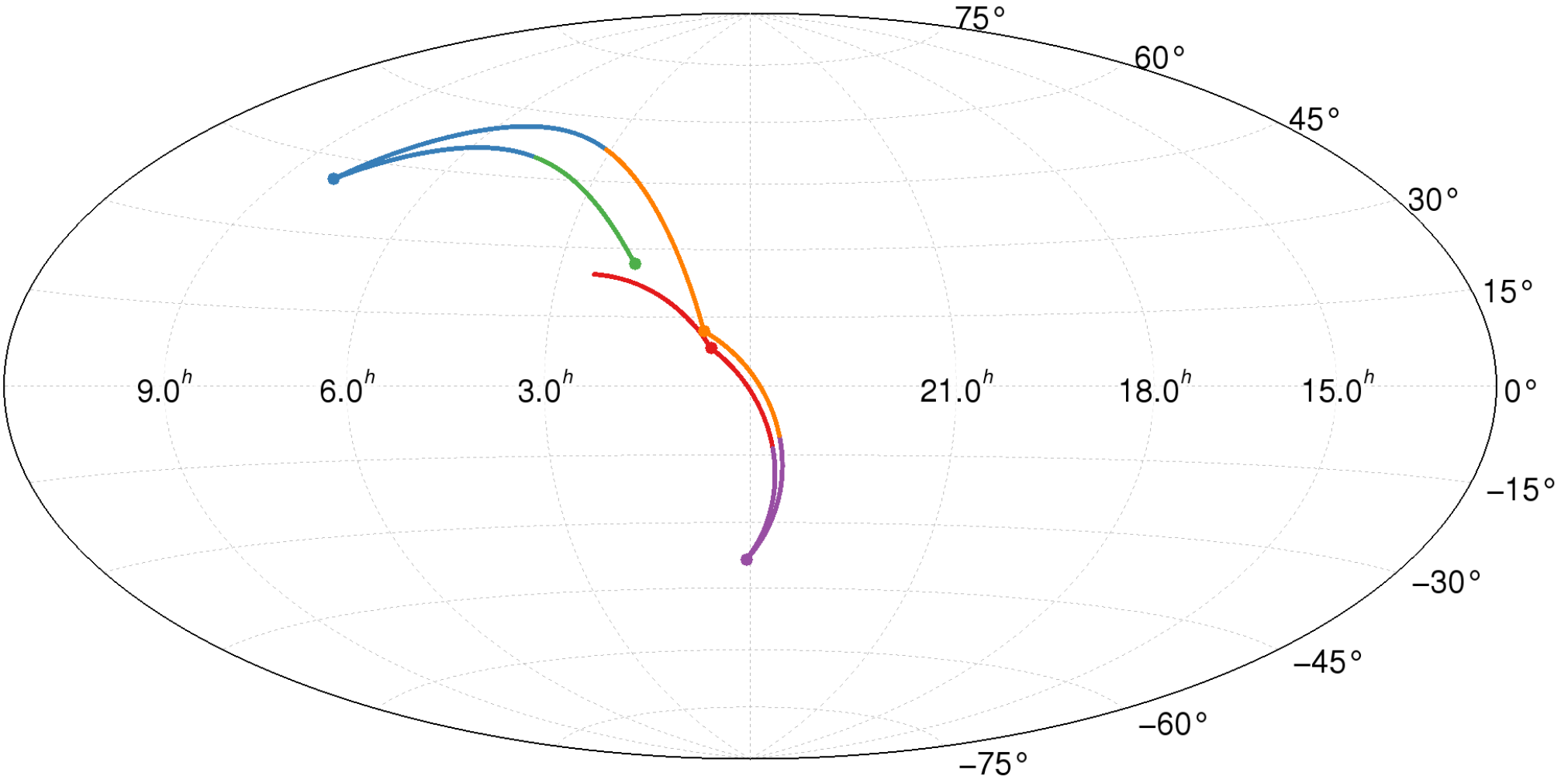
Important keywords to know

- DATE : Local time when files are created
- TIMEDEL : Time resolution
- DATE-OBS & DATE-END : Time of the Observation
- TSTART & TSTOP : Same as DATE-OBS & DATE-END in mission elapsed time (MET)

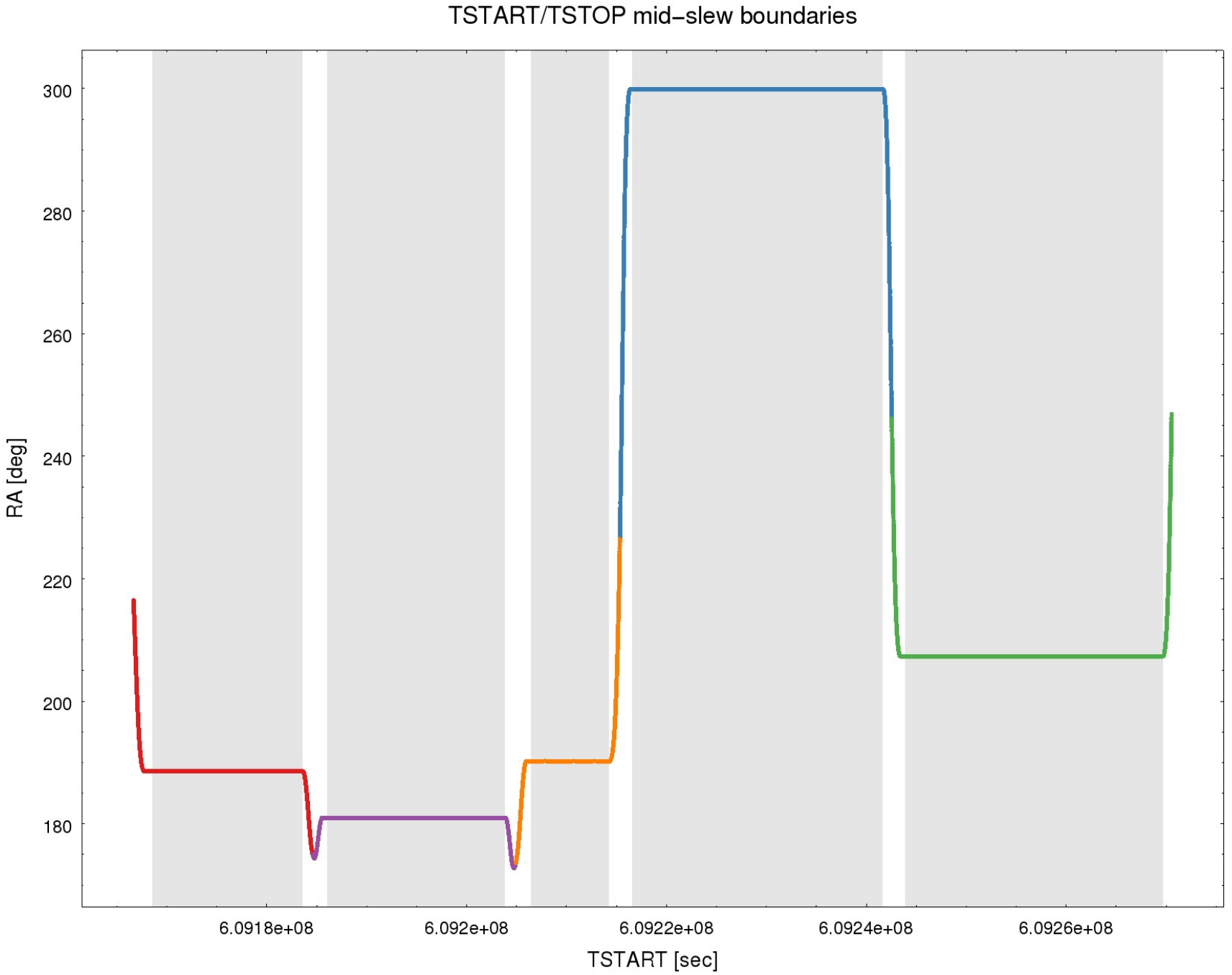
>>> Observation time boundaries are based on slew between target.

TSTART vs Event times

TSTART & TSTOP are defined to be mid-slew to mid-slew



Chandra pointings for approximately 30 hours covering 5 observation



Good time intervals for 5 observations are shaded in gray.

Observation Information

ASCSYS*	AIMPFILE	ASCDSVER	ASOLFILE	ASPTYPE	BIASFIL*	BPIXFILE
BTIMCORR	BTIMDRFT	BTIMNULL	BTIMRATE	CALDBVER	CCD_ID	CHECKSUM
CLOCKAPP	CONTENT	CORNERS	CREATOR	CTIFILE	CTI_APP	CTI_CORR
CYCLE	**DATACLAS**	**DATAMODE**	DATASUM	DATE	DATE-END	DATE-OBS
DEC_NOM	DEC_PNT	DEC_TARG	**DEFOCUS**	**DETNAM**	**DS_IDENT**	**DTCOR**
DTH_AVG	DTYCYCLE	**DY_AVG**	**DZ_AVG**	**EXPOSUR***	**EXPOSURE**	**EXPTIME**
FEP_CCD	FEP_ID	FIRSTROW	FLSHTIMA	FLSHTIMB	FLSHTIME	FLTFILE
FOC_LEN	FP_TEMP	FSW_VERS	GAINFILE	GEOMFILE	GRADESYS	**GRATING**
GRD_FILE	HDUCLAS*	HDUCLASS	HDUDOC	HDUSPEC	HDUVERS	HISTNUM
INSTRUME	**LIVETIME**	**LIVTIME***	MASKFILE	**MISSION**	MJDREF	MJD_OBS
MTLFILE	NROWS	**OBI_NUM**	**OBJECT**	**OBSERVER**	**OBS_ID**	**OBS_MODE**
OCLKPAIR	**ONTIME**	**ONTIME***	ORC_MODE	ORIGIN	PBKFILE	PIX_ADJ
RADESYS	RAND_PI	RAND_SKY	RA_NOM	RA_PNT	RA_TARG	**READMODE**
REVISION	ROLL_NOM	ROLL_PNT	RUN_ID	**SEQ_NUM**	SHELLFIL	**SIM_X**
SIM_Y	**SIM_Z**	SKYFILE	STARTBEP	STARTMJF	STARTMNF	STARTOBT
STOPBEP	STOPMJF	STOPMNF	SUBPIXFL	SUM_2X2	TASSIGN	TDETFILE
TELESCOP	TGAINCOR	TGAINFIL	THRFILE	TIERABSO	TIERRELA	TIMEDEL
TIMEDELA	TIMEDELB	TIMEPIXR	TIMEREF	TIMESYS	TIMEUNIT	TIMEZERO
TIMVERSN	**TITLE**	TLMVER	TSTART	TSTOP		

Observation Information

Important keywords to know:

- `OBS_ID, OBI_NUM, CYCLE` : keywords uniquely identify a dataset
  - `CYCYLE` is for ACIS interleaved mode
  - `OBI_NUM` is for multi-obi observations
- `INSTRUME`: ACIS or HRC
- `DETNAM`: detector name
  - HRC-I and HRC-S are separate detectors.
  - ACIS-I and ACIS-S are *aimpoint* locations not detectors.
- `GRATING`: HETG, LETG, or NONE
- `DATAMODE, REAMODE`: instrument modes
- `ONTIME, EXPOSURE, LIVETIME, DTCOR`: observation duration

ONTIME, EXPOSURE, & LIVETIME

- ONTIME is the sum of the Good Time Intervals (GTI).

$$\mathrm{ONTIME} = \sum_i \mathrm{STOP}_i - \mathrm{START}_i$$

- EXPOSURE is ONTIME corrected for dead time

$$\mathrm{EXPOSURE} = \mathrm{ONTIME} \bullet \mathrm{DTCOR}$$

- LIVETIME is EXPOSURE corrected for “all other” corrections

$$\mathrm{LIVETIME} = \mathrm{EXPOSURE}$$

- CIAO tools recompute these when a TIME filter is used.

ONTIME vs ONTIME*

- For ACIS, each CCD has a different GTI.
  - START and STOP times are slightly offset
  - Dropped exposures may occur on individual chips
- Individual ONTIME*, EXPOSUR* and LIVTIME* correspond to each GTI*
- The ONTIME, EXPOSURE, and LIVETIME keywords are for the **first** GTI in the file.
  - SDP forces the first GTI to be the CCD where the target position at RA_TARG, DEC_TARG is located.
- Be careful in CIAO when working with merged datasets.

Pointing Information

ASCSYS*	AIMPFILE	ASCDSVER	ASOLFILE	**ASPTYPE**	BIASFIL*	BPIXFILE
BTIMCORR	BTIMDRFT	BTIMNULL	BTIMRATE	CALDBVER	CCD_ID	CHECKSUM
CLOCKAPP	CONTENT	CORNERS	CREATOR	CTIFILE	CTI_APP	CTI_CORR
CYCLE	DATACLAS	DATAMODE	DATASUM	DATE	DATE-END	DATE-OBS
DEC_NOM	**DEC_PNT**	**DEC_TARG**	DEFOCUS	DETNAM	DS_IDENT	DTCOR
DTH_AVG	DTYCYCLE	DY_AVG	DZ_AVG	EXPOSUR*	EXPOSURE	EXPTIME
FEP_CCD	FEP_ID	FIRSTROW	FLSHTIMA	FLSHTIMB	FLSHTIME	FLTFILE
FOC_LEN	FP_TEMP	FSW_VERS	GAINFILE	GEOMFILE	GRADESYS	GRATING
GRD_FILE	HDUCLAS*	HDUCLASS	HDUDOC	HDUSPEC	HDUVERS	HISTNUM
INSTRUME	LIVETIME	LIVTIME*	MASKFILE	MISSION	MJDREF	MJD_OBS
MTLFILE	NROWS	OBI_NUM	**OBJECT**	OBSERVER	OBS_ID	OBS_MODE
OCLKPAIR	ONTIME	ONTIME*	ORC_MODE	ORIGIN	PBKFILE	PIX_ADJ
RADESYS	RAND_PI	RAND_SKY	**RA_NOM**	**RA_PNT**	**RA_TARG**	READMODE
REVISION	**ROLL_NOM**	**ROLL_PNT**	RUN_ID	SEQ_NUM	SHELLFIL	SIM_X
SIM_Y	SIM_Z	SKYFILE	STARTBEP	STARTMJF	STARTMNF	STARTOBT
STOPBEP	STOPMJF	STOPMNF	SUBPIXFL	SUM_2X2	TASSIGN	TDETFILE
TELESCOP	TGAINCOR	TGAINFIL	THRFILE	TIERABSO	TIERRELA	TIMEDEL
TIMEDELA	TIMEDELB	TIMEPIXR	TIMEREF	TIMESYS	TIMEUNIT	TIMEZERO
TIMVERSN	TITLE	TLMVER	TSTART	TSTOP		

Pointing Information

Important keywords to know

- `RA_TARG, DEC_TARG` : proposed target location
- `RA_NOM, DEC_NOM` : nominal pointing used for tangent plane projection
- `RA_PNT, DEC_PNT, ROLL_PNT`: mean pointing and spacecraft roll during the observation.

>>> For most observations *_NOM and *_PNT are the same until files are merged/corrected in CIAO.

TARG vs. NOM vs. PNT

- TARG values are input by the proposer. They are not used for data analysis.
- NOM values are the tangent point location. The values must be the same as the WCS keywords (ie CRVAL)
  - NOM values should be the same when merging observations.
  - NOM values are updated when using tools such as reproject_events, acis_process_events, hrc_process_events, reproject_image.
- PNT values represent the mean pointing during the observation. These values are adjusted to correct astrometric shifts between observations.
  - Changes to PNT keywords must also be reflected in aspect solution file.
  - PNT keywords are updated using wcs_update, reproject_aspect.

File Keywords

ASCSYS*	**AIMPFILE**	ASCDSVER	**ASOLFILE**	ASPTYPE	**BIASFIL***	**BPIXFILE**
BTIMCORR	BTIMDRFT	BTIMNULL	BTIMRATE	CALDBVER	CCD_ID	CHECKSUM
CLOCKAPP	CONTENT	CORNERS	CREATOR	**CTIFILE**	CTI_APP	CTI_CORR
CYCLE	DATACLAS	DATAMODE	DATASUM	DATE	DATE-END	DATE-OBS
DEC_NOM	DEC_PNT	DEC_TARG	DEFOCUS	DETNAM	DS_IDENT	DTCOR
DTH_AVG	DTYCYCLE	DY_AVG	DZ_AVG	EXPOSUR*	EXPOSURE	EXPTIME
FEP_CCD	FEP_ID	FIRSTROW	FLSHTIMA	FLSHTIMB	FLSHTIME	**FLTFILE**
FOC_LEN	FP_TEMP	FSW_VERS	**GAINFILE**	**GEOMFILE**	GRADESYS	GRATING
GRD_FILE	HDUCLAS*	HDUCLASS	HDUDOC	HDUSPEC	HDUVERS	HISTNUM
INSTRUME	LIVETIME	LIVTIME*	MASKFILE	MISSION	MJDREF	MJD_OBS
MTLFILE	NROWS	OBI_NUM	OBJECT	OBSERVER	OBS_ID	OBS_MODE
OCLKPAIR	ONTIME	ONTIME*	ORC_MODE	ORIGIN	**PBKFILE**	PIX_ADJ
RADESYS	RAND_PI	RAND_SKY	RA_NOM	RA_PNT	RA_TARG	READMODE
REVISION	ROLL_NOM	ROLL_PNT	RUN_ID	SEQ_NUM	**SHELLFIL**	SIM_X
SIM_Y	SIM_Z	SKYFILE	STARTBEP	STARTMJF	STARTMNF	STARTOBT
STOPBEP	STOPMJF	STOPMNF	SUBPIXFL	SUM_2X2	TASSIGN	**TDETFILE**
TELESCOP	TGAINCOR	**TGAINFIL**	**THRFILE**	TIERABSO	TIERRELA	TIMEDEL
TIMEDELA	TIMEDELB	TIMEPIXR	TIMEREF	TIMESYS	TIMEUNIT	TIMEZERO
TIMVERSN	TITLE	TLMVER	TSTART	TSTOP		

File Keywords

There are two types of FILE keywords:

Some keywords provide a reference to other related data products that are need when doing data analysis such as the badpixel file (BPIXFILE), aspect solution (ASOLFILE), etc.

The other keywords provide provenance for which calibrations files where used such as the detector gain (GAINFILE, TGAINFIL), the detector geometry (GEOMFILE), etc.

Instrument Specific Keywords

ASCSYS*	AIMPFILE	ASCDSVER	ASOLFILE	ASPTYPE	BIASFIL*	BPIXFILE
BTIMCORR	BTIMDRFT	BTIMNULL	BTIMRATE	CALDBVER	CCD_ID	CHECKSUM
CLOCKAPP	CONTENT	**CORNERS**	CREATOR	CTIFILE	**CTI_APP**	**CTI_CORR**
CYCLE	DATACLAS	DATAMODE	DATASUM	DATE	DATE-END	DATE-OBS
DEC_NOM	DEC_PNT	DEC_TARG	DEFOCUS	DETNAM	DS_IDENT	DTCOR
DTH_AVG	DTYCYCLE	DY_AVG	DZ_AVG	EXPOSUR*	EXPOSURE	EXPTIME
FEP_CCD	FEP_ID	**FIRSTROW**	**FLSHTIMA**	**FLSHTIMB**	**FLSHTIME**	FLTFILE
FOC_LEN	**FP_TEMP**	FSW_VERS	GAINFILE	GEOMFILE	**GRADESYS**	GRATING
GRD_FILE	HDUCLAS*	HDUCLASS	HDUDOC	HDUSPEC	HDUVERS	HISTNUM
INSTRUME	LIVETIME	LIVTIME*	MASKFILE	MISSION	MJDREF	MJD_OBS
MTLFILE	**NROWS**	OBI_NUM	OBJECT	OBSERVER	OBS_ID	OBS_MODE
OCLKPAIR	ONTIME	ONTIME*	ORC_MODE	ORIGIN	PBKFILE	**PIX_ADJ**
RADESYS	**RAND_PI**	**RAND_SKY**	RA_NOM	RA_PNT	RA_TARG	READMODE
REVISION	ROLL_NOM	ROLL_PNT	RUN_ID	SEQ_NUM	SHELLFIL	SIM_X
SIM_Y	SIM_Z	SKYFILE	STARTBEP	STARTMJF	STARTMNF	STARTOBT
STOPBEP	STOPMJF	STOPMNF	SUBPIXFL	**SUM_2X2**	TASSIGN	TDETFILE
TELESCOP	**TGAINCOR**	TGAINFIL	THRFILE	TIERABSO	TIERRELA	TIMEDEL
TIMEDELA	**TIMEDELB**	TIMEPIXR	TIMEREF	TIMESYS	TIMEUNIT	TIMEZERO
TIMVERSN	TITLE	TLMVER	TSTART	TSTOP		

Instrument Specific Keywords

Each tool and instrument then has their own set of unique keywords.

For an ACIS event file some of the important keywords to know are:

- `FP_TEMP` : mean focal plane temperature
- `PIX_ADJ` : if EDSER subpixel algorithm has been applied.
- `CTI_APP` : which CCDs have had CTI calibrations applied.

Why Know All This?

- Things like the CALDB use this information when determining which calibrations to apply.
- When working with merged datasets, differences in these keywords can lead to unexpected results.
- When something goes wrong, we go looking into the headers for clues!

History

- Chandra files contain a large number of structured HISTORY keywords containing processing parameters.
- Propagation
  - Output same as input? Copy all otherwise start over.
- Access
  - dmhistory

Terminal

```
~/Demo/CIAO_Workshop  CIAO-4.17 /// dmhistory infile=4425/repro/acisf04425_repro_evt2.fits tool=acis_process_events
 | sed "s,$HOME,~,g"
acis_process_events \
    infile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/output/acisf04425_000N005_tmp_evt1.fits" \
    outfile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/output/acisf04425_000N005_evt1.fits" \
    acaofffile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/input/pcadf04425_000N001_asol1.fits[time=162751763
.5763200:162794659.3156200]" \
    apply_cti="yes" \
    apply_tgain="yes" \
    obsfile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/output/axaff04425_000N001_obs1.par" \
    geompar="geom" \
    logfile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/output/acis_process_events.log" \
    gradefile="CALDB" \
    grade_image_file="CALDB" \
    gainfile="CALDB" \
    badpixfile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/output/acisf04425_000N005_bpix1.fits" \
    threshfile="CALDB" \
    ctifile="CALDB" \
    tgainfile="CALDB" \
    mtlfile="/dsops/repro5/sdp.1/opus/prs_run/tmp//ACIS_F_L1_733631319n579/output/acisf04425_000N005_fptemp_egti1.fits" \
    eventdef="{d:time,s:ccd_id,s:node_id,i:expno,s:chip,s:tdet,f:det,f:sky,s:phas,l:pha,l:pha_ro,f:energy,l:pi,s:fltgrade,s:grad
e,x:status}" \
    doevtgrade="yes" \
    check_vf_pha="no" \
    trail="0.027" \
    calculate_pi="yes" \
    pi_bin_width="14.6" \
    pi_num_bins="1024" \
    max_cti_iter="15" \
    cti_converge="0.1" \
    clobber="no" \
    verbose="0" \
    stop="sky" \
    rand_seed="1" \
    rand_pha="yes" \
    pix_adj="EDSER" \
    subpixfile="CALDB" \
    stdlev1="{d:time,l:expno,s:ccd_id,s:node_id,s:chip,s:tdet,f:det,f:sky,s:phas,l:pha,l:pha_ro,f:energy,l:pi,s:fltgrade,s:grade
,x:status}" \
    grdlev1="{d:time,l:expno,s:ccd_id,s:node_id,s:chip,s:tdet,f:det,f:sky,l:pha,l:pha_ro,s:corn_pha,f:energy,l:pi,s:fltgrade,s:g
rade,x:status}" \
    cclev1="{d:time,d:time_ro,l:expno,s:ccd_id,s:node_id,s:chip,s:tdet,f:det,f:sky,f:sky_1d,s:phas,l:pha,l:pha_ro,f:energy,l:pi,
s:fltgrade,s:grade,x:status}" \
    ccgrdlev1="{d:time,d:time_ro,l:expno,s:ccd_id,s:node_id,s:chip,s:tdet,f:det,f:sky,f:sky_1d,l:pha,l:pha_ro,s:corn_pha,f:energ
y,l:pi,s:fltgrade,s:grade,x:status}" \
    cclev1a="{d:time,d:time_ro,l:expno,s:ccd_id,s:node_id,s:chip,f:chipy_tg,f:chipy_zo,s:tdet,f:det,f:sky,f:sky_1d,s:phas,l:pha,
l:pha_ro,f:energy,l:pi,s:fltgrade,s:grade,f:rd,s:tg_m,f:tg_lam,f:tg_mlam,s:tg_srcid,s:tg_part,s:tg_smap,x:status}" \
    ccgrdlev1a="{d:time,d:time_ro,l:expno,s:ccd_id,s:node_id,s:chip,f:chipy_tg,f:chipy_zo,s:tdet,f:det,f:sky,f:sky_1d,l:pha,l:ph
a_ro,s:corn_pha,f:energy,l:pi,s:fltgrade,s:grade,f:rd,s:tg_m,f:tg_lam,f:tg_mlam,s:tg_srcid,s:tg_part,s:tg_smap,x:status}"
```

Header Review

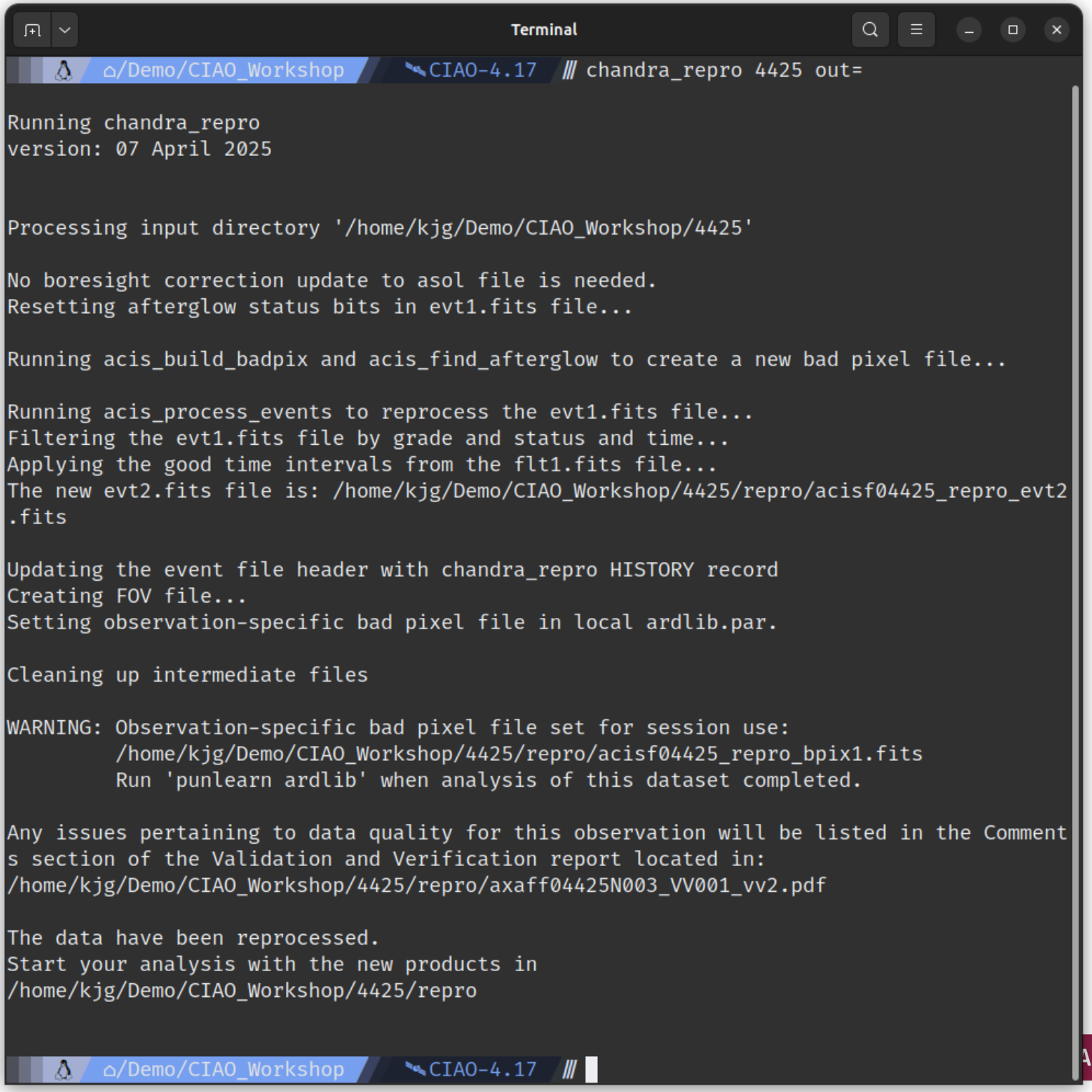
- The header information is used automatically by a large number of CIAO tools to
  - Identify calibration files
  - Parameter inputs into algorithms
  - Automatically locate associated data products
- In addition the headers provide the necessary provenance to identify
  - Exactly what the data are
  - How the data were processed.

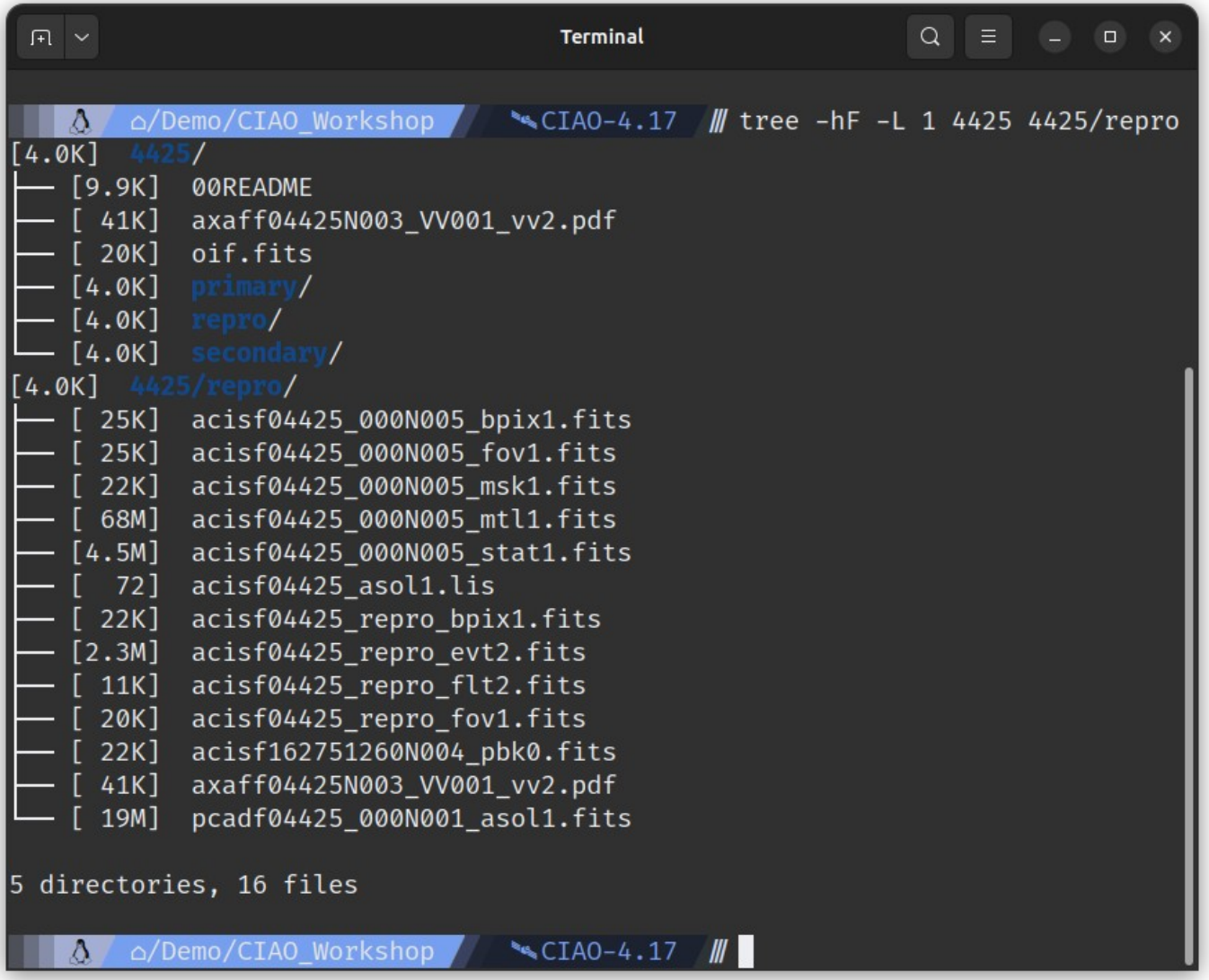
I know my data, now what?

- Reprocess your event file!

  Why?

  - Data from archive almost certainly used different CALDB version.
    - Users want to avoid calibration uncertainty by mixing very different version of calibration products.
  - Most archive data used predicted time-dependent gain calibration (TGAIN). Reprocessing will pickup the definitive (if available).


Terminal
⌂/Demo/CIAO_Workshop
CIAO-4.17
chandra_repro 4425 out=
Running chandra_repro
version: 07 April 2025
Processing input directory '/home/kjg/Demo/CIAO_Workshop/4425'
No boresight correction update to asol file is needed.
Resetting afterglow status bits in evt1.fits file...
Running acis_build_badpix and acis_find_afterglow to create a new bad pixel file...
Running acis_process_events to reprocess the evt1.fits file...
Filtering the evt1.fits file by grade and status and time...
Applying the good time intervals from the flt1.fits file...
The new evt2.fits file is: /home/kjg/Demo/CIAO_Workshop/4425/repro/acisf04425_repro_evt2
.fits
Updating the event file header with chandra_repro HISTORY record
Creating FOV file...
Setting observation-specific bad pixel file in local ardlib.par.
Cleaning up intermediate files
WARNING: Observation-specific bad pixel file set for session use:
/home/kjg/Demo/CIAO_Workshop/4425/repro/acisf04425_repro_bpix1.fits
Run 'punlearn ardlib' when analysis of this dataset completed.
Any issues pertaining to data quality for this observation will be listed in the Comment
s section of the Validation and Verification report located in:
/home/kjg/Demo/CIAO_Workshop/4425/repro/axaff04425N003_VV001_vv2.pdf
The data have been reprocessed.
Start your analysis with the new products in
/home/kjg/Demo/CIAO_Workshop/4425/repro
⌂/Demo/CIAO_Workshop
CIAO-4.17



Most analysis will use these files:

- repro_evt2.fits
- asol1.fits
- msk1.fits
- repro_bpix1.fits
- HRC + repro_dtf1.fits

chandra_repro

- What it does
  - Updates known badpixel information
  - Applies latest event calibrations
  - Applies standard status, grade, and GTI filters
- What it does not do
  - Compute an updated aspect solution
  - Determine new GTIs

Reprocessing summary

- Do it!

Questions?