2001.01.29
D. Huenemoerder

Chandra X-Ray Data Analysis Overview

$$S_D(\sigma, h, t) = T(\sigma, t) \int d\lambda \int dp \, R(\sigma, h, \lambda, \Omega(t) \cdot \hat{p}, t) \, S(\lambda, \hat{p})$$

- $S_D(\sigma, h, t)$: counts
- $T(\sigma, t)$: Good-Time, Dead-Time
- $R(\ldots)$: Response:
  - Mirror area
  - Mirror PSF
  - Grating effic
  - Grating LSF
  - Detector effic
  - Detector redistribution
  - Aspect
  - Coordinate systems
- $S(\lambda, \hat{p})$: Truth

$\sigma \equiv$ detected position
$h \equiv$ detected "wavelength"
$t \equiv$ time
$\lambda \equiv$ incident wavelength
$\hat{p} \equiv$ incident angle

$\therefore$ The 3 most important things are:

1. CALIBRATION

2. CALIBRATION

3. CALIBRATION

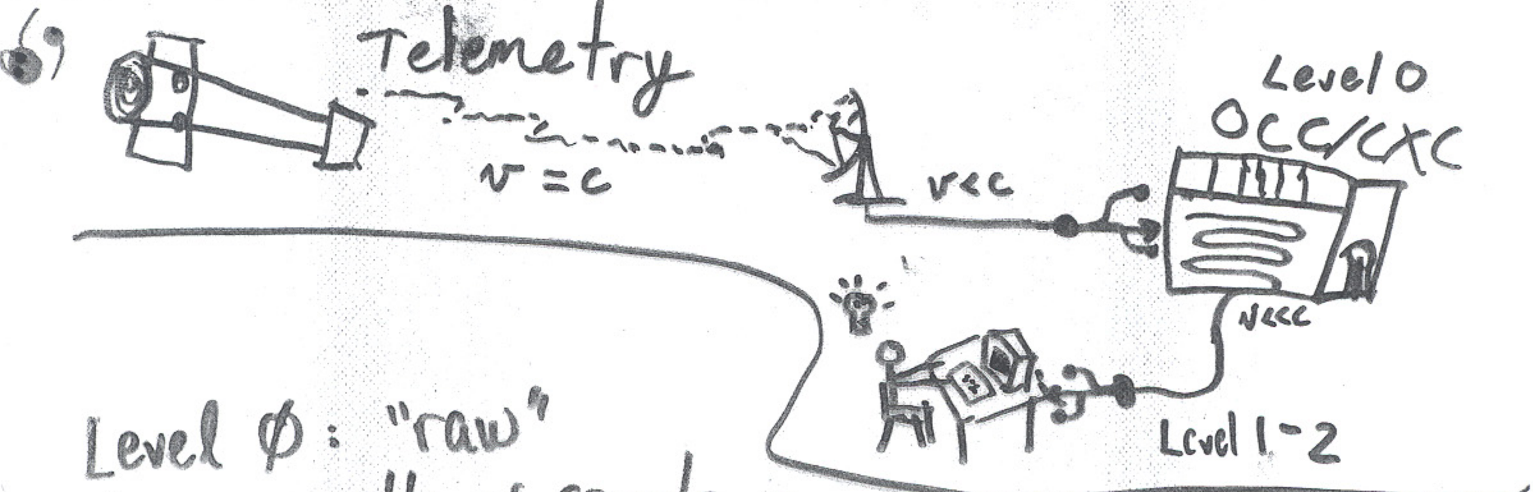
The rest is

- software
- organization

⇘

ANALYSIS

Data Products



Level φ : "raw"
voltagas, counts, frames

Level 1 : scaled, calibrated, aspect-corrected
ENERGY : f(chip, gain)

Level 1.5 (a.k.a. 1a) : source dependent coords.
(grating) detect, src
diffraction coo

Level 2 – filtered, concatenated, binned
good grades
good pixels
good aspect...

User Level 2 : binning, modeling
images
spectra
light-curves
responses
src models
fits

2001.01.29 dph

ANALYSIS - Preparation

Where to start?

Know your data! "OIF" = Observation Index File

evt2.fits - filtered event list (+ GTI)

pha2 - (if grating) binned counts spectr[um] (+ REGION)

Check your data:

VV.obsid

Display, e.g. sky x,y vs order, r[...]

det x,y

pha vs time

counts vs channel

vs wavelength

Check cal files -

ASCDSVER

CALDBVER

vs info on web or chandra-us[...]

Reprocess?

evt1 acis_process_events tgdetect

evt1a hrc_ " " tg_create_mask

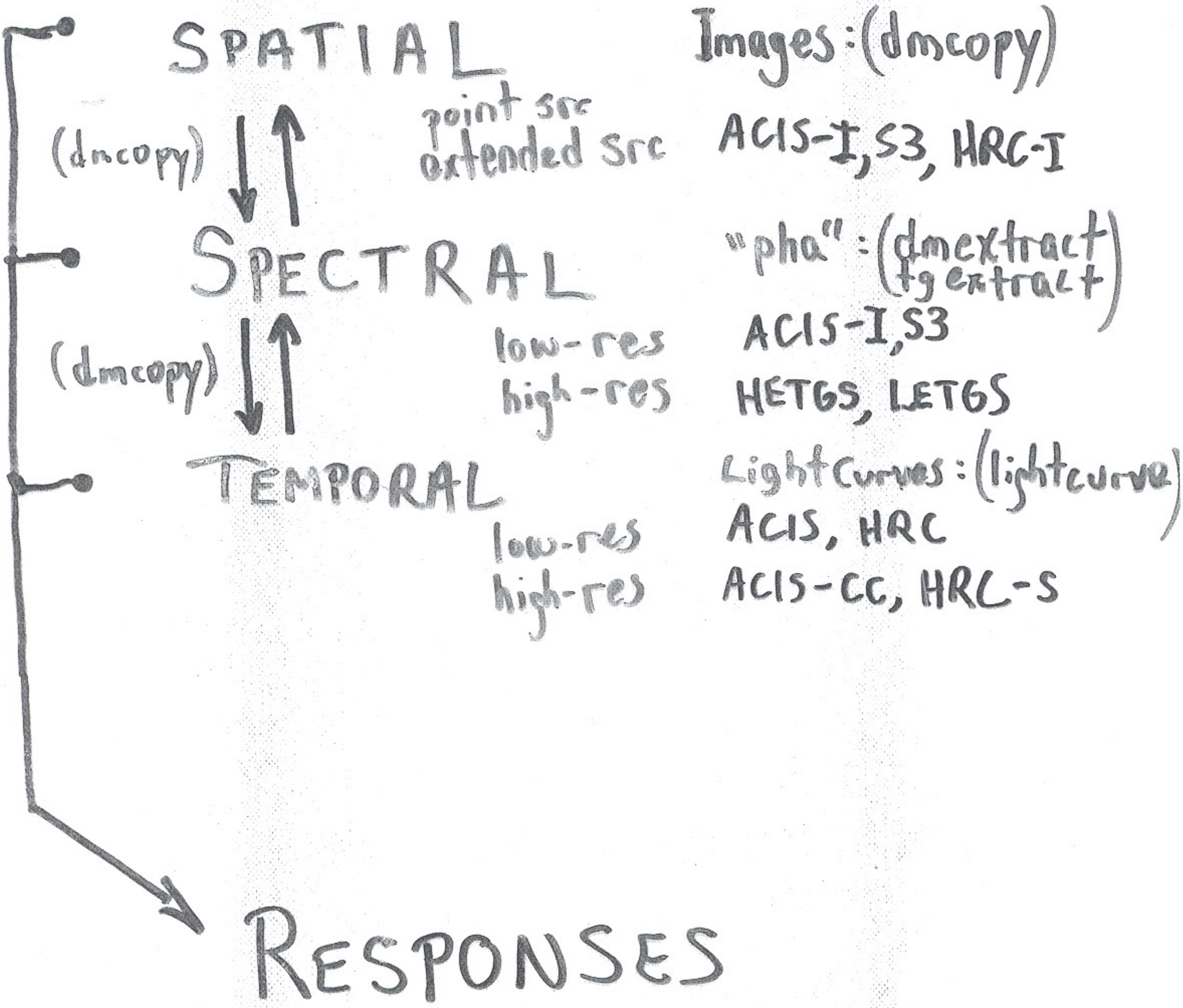
asol dmcopy tg_resolve_events

aoff tgextract

bpix

2001.01.24 DPH

Analysis -- Planning



2001.01.29 DPH.

RESPONSES

Spatial: Exposure* Map

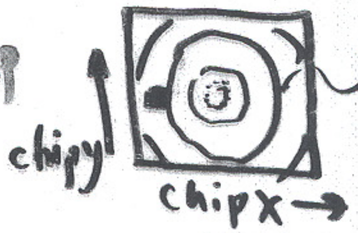
*[area × time]

- keeps spatial information at the expense of spectral

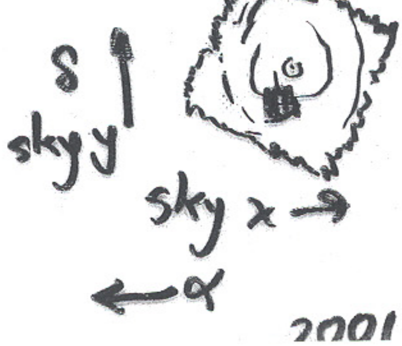
$$\int_{\lambda\in\Delta\lambda} d\lambda\, S_{\mathcal{F}}(\lambda,\hat{p}) \approx \frac{C(\Delta h,\hat{p})}{E(\Delta h,\lambda,\hat{p})}$$

Instrument map → all calibration info band-integrated

mkinstmap



Exposure map → • applies aspect (via aspect histogram)
• applies coordinate xform



Responses

Spectral - Low Resolution

- keeps spectral information at the expense of spatial

$$C_\Omega(h) = \tau_{eff} \int d\lambda \, D_R(h,\lambda) A_\Omega(\lambda,\hat{q})^* S(\lambda)$$

* point source, at location $\hat{q}$, in region Ω.

$D_R(h,\lambda)^{**}$ ≡ Redistribution Matrix Function [File]
"RMF"

$A_\Omega(\lambda,\hat{q})$ = Auxiliary Response Function [File]
"ARF"

≡ "effective*" effective area

* mkarf: applies inverse aspect to map sky to detector vs time

** mkrmf: computes/looks up vs chip + position

2001.01.29 DPH

Responses –

Spectral – High Resolution

- spatial + spectral tightly coupled
- imaging spectral ("PHA") + spatial strongly coupled

$$C_{\Omega}^{(m)}(h)^{*} = \tau_{eff} \int d\lambda \, G_{\Omega}^{(m)}(\lambda, \hat{q}) A_m(h,\lambda) \, s(\lambda)$$

order sort $\Rightarrow A_m(\lambda) = \sum_{h=h_0(\lambda)}^{h_1(\lambda)} A_m(h,\lambda)$

$A_m(\lambda) \equiv$ grating ARF, order m.

mkgarf: applies source position
calibration
inverse aspect
To map λ to detector vs time

$G_{\Omega}^{(m)}(\lambda, \hat{q}) \equiv$ grating RMF, order m

Describes the redistribution from λ to channel (diffraction angle)
a.k.a. Line Spread Function (LSF)

*Note: LETGS has only $\sum_{m,h} C_{\Omega}^{(m)}(h)$

Responses –

Temporal – $C(\Delta h, \Delta t) = \int dt \int dh\, C(h,t) = \ldots$

- exposure time per bin
- ARF or map, as appropriate [per bin ?]*

lightcurve: produces exposure time/bin
counts/bin
rate

* Time resolved ARF or map probably rarely needed – dither smooths

Mixed-modes :

e.g. dmcopy to make λ, t image
h, t image
$h, \hat{p}$ image

Responses ~independent
[some operational inconveniences]

CAVEAT THESE RESPONSES ARE DEFINED FOR POINT SOURCES

+ for PSF & QE non-uniformities

2001.01.29 DPH

Some Practical Matters:

Compatibility: FITS
OGIP

Largely back-compatible w/ XSPEC

Architecture:

CALDB - all calibration data vs time
version

ARDLIB - mission independent
interface to CALDB

e.g.: QE(E) is a function
ACIS-S3 QE(x,y,chip) is
Chandra specific, + built
from several CALDB files

Response tools use common
interface of ARDLIB to CALDB.

More Practical Matters

- S/N ⇒ accuracy required
  - e.g. expmap bin sizes
  - Is expmap dithering required?
- Soureeproperties:
  - which is more appropriate?
    - Spatial mode: $\frac{\text{counts}}{\text{expmap}}$
      (flux obtained depends on source spectrum + bandpasses)
    - Spectral mode: $\int \text{ARF} \cdot \text{RMF} \cdot s(E)\, dE$
      (may not be enough counts to fit)
- High-res spectra
  - Fit jointly, or add?
    adding compromises resolution, knowledge of cal. systematics
  - RMF or not?
    If only want flux, can use counts/ARF
    If LSF matters, use RMF
-

New w/ Chandra

Dither – makes responses more observation-specific

e.g. chip gaps in grating spectra

– BUT: smooths small-scale features & makes response computation more tractable

Calibration quality –

– harder to hide systematics (a good thing)

Small PSF

Many chips, many modes

– each like a separate telescope, ⇒ more work to make responses

Diffraction gratings –

– introduced most new features to data-structures, analysis

Problems, difficulties, thing which can go wrong...

- Check V & V report
- Check "caveats" www-page

- L1 : CCD gain - energy wrong, check CAL
  bias - no good grades

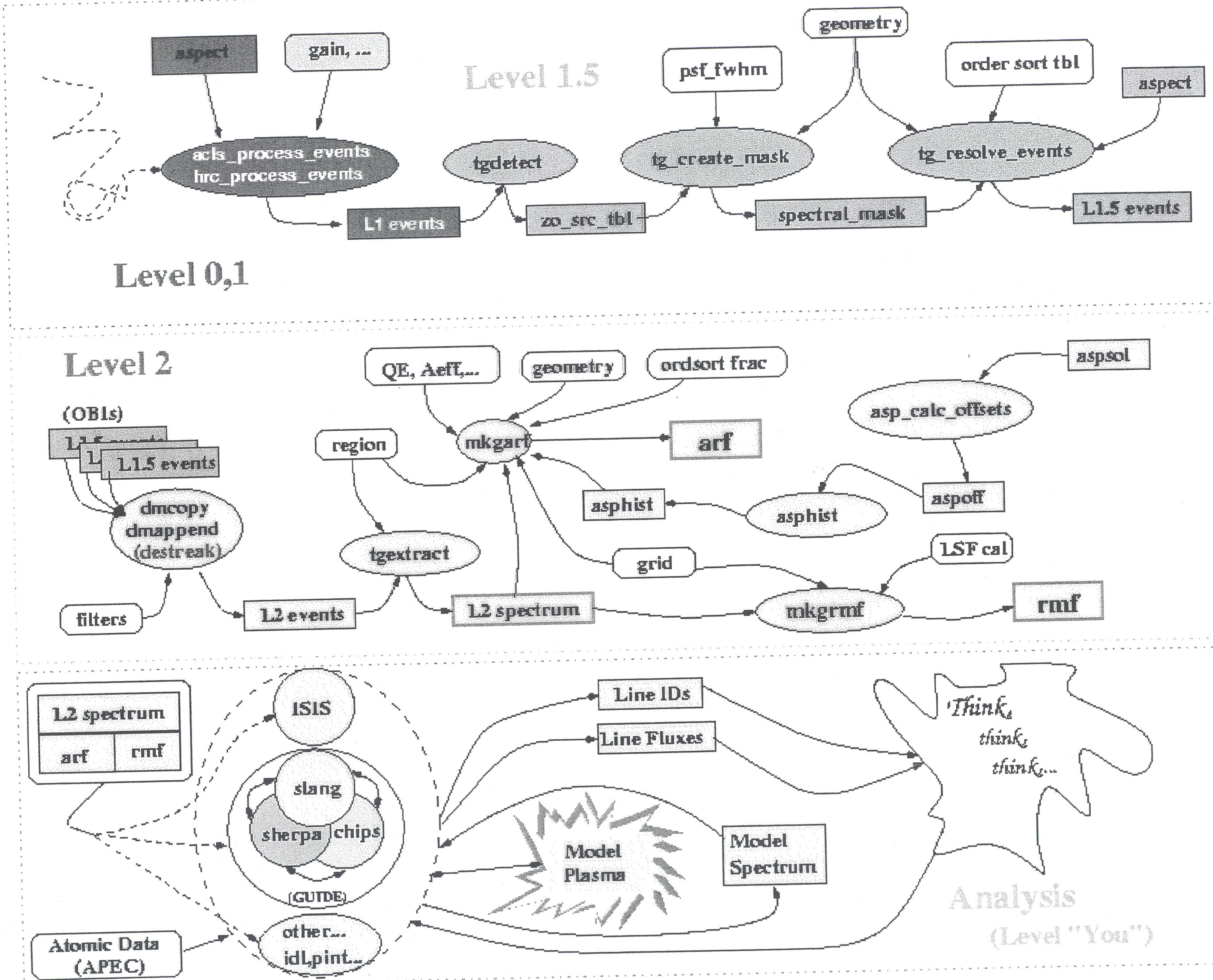
  Aspect

- L1.5 zero-order pos. poor? (± λ's differ)
  LETGS λ's off (CAL problem)

- Responses: gARF gaps, EXPMAP edges off
  → aspect; zero-order

- Poorly supported modes:
  ACIS CC
  Zero-order blocked
  ⇒ CALL for help!

- PILEUP - a non-linear problem.
  ISIS module will fit w/ non-linear response



(Ellipses are processes, rectangles are products, and rounded-rectangles are reference data.)

2001.01.25 DPH 14