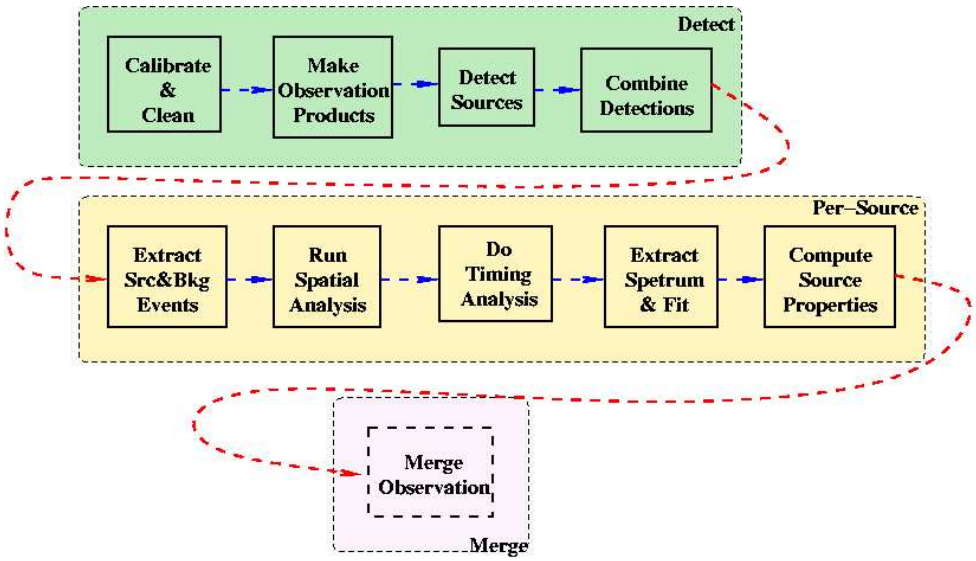
Level 3 Pipelines

- Currently consists of 2 separate pipelines
  - Source Detect
  - Per Observation histograms, responses, and properties
- Run per-observation
- Running on 14 node Linux Beowulf Cluster
- 10,000 observation @ 50 sources each @ 28 CPUs
  - 6 hrs per 'detect' => 100 days
  - To process entire catalog in 1 year, ~30min per source

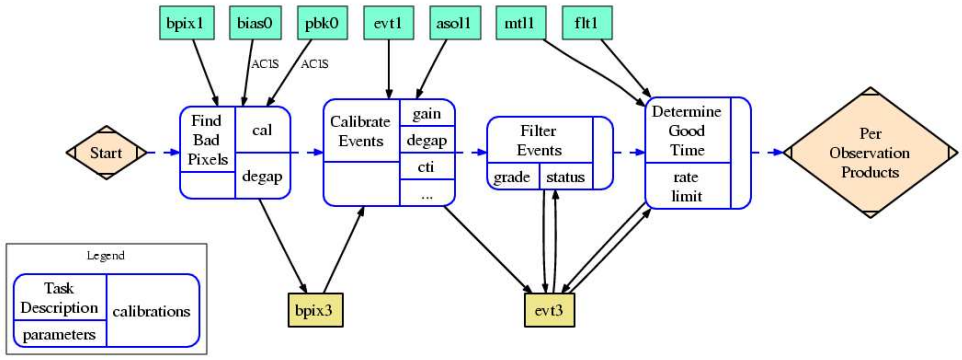
Overview Diagram



Detect Pipeline

- Calibrate and clean the data
  - Applies the latest calibrations and ensures consistent calibrations for down-stream products
  - More conservative than SDP filtering
- Creates per-observation products
  - aspect histograms, instrument maps, field-of-view
  - (TBR) background, sensitivity maps, etc
- Detects sources
  - Multiple runs of wavdetect at multiple blocking factors and energy bands (ACIS: 4 bands, 3 blocking = 12 runs)
- Merges detections and creates spatial regions

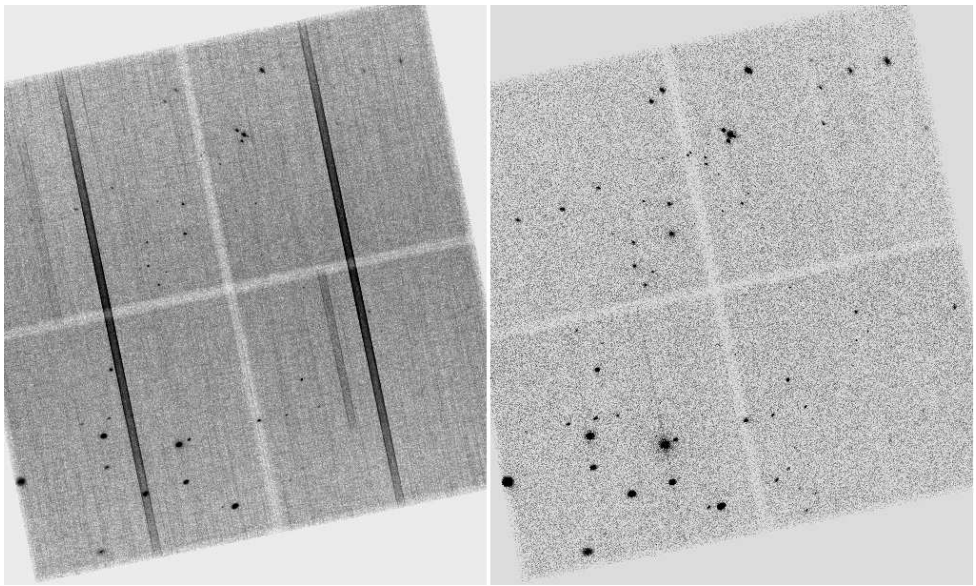
Calibrate and Clean Diagram



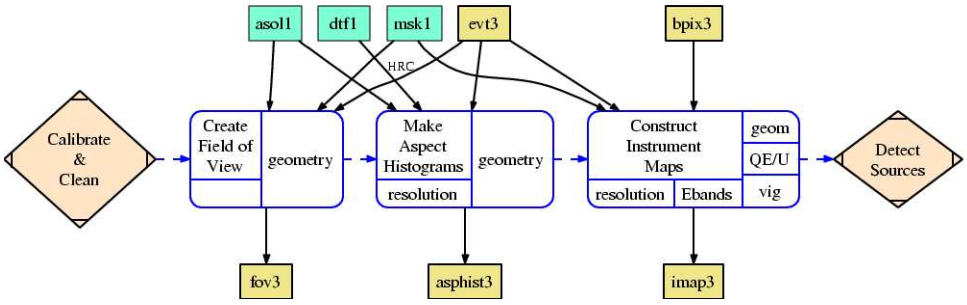
Calibrate and Clean

- SDP / CIAO event processing tools
- ACIS calibrations
  - gain, CTI, TGAIN, grade/morphology, bad pixels, geometry, etc
- HRC calibrations
  - degap, tap ringing, bad pixels, AMPSF, flatness, quality, etc
- Re-filter data similar to L2
  - Standard grades & status (ACIS)
  - Standard status (HRC-I and -S)
- Identify & filter background flares
- Other
  - destreak (ACIS)

Example of before & after cleaning



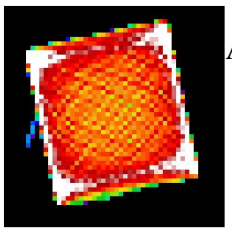
Make-Observation Products Diagram



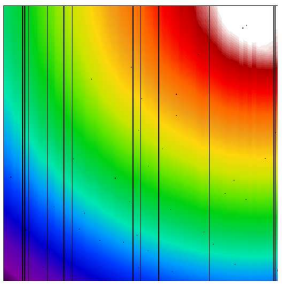
Make-Observation products

- Aspect histogram
  - sparse 3D histogram of pointing vs. duration
- Instrument maps
  - Per chip/plate
  - For each energy band (selected mono-chromatic energies)
- Field of View
  - detector boundaries
- TBD
  - Background maps
  - Sensitivity maps
  - Mosaics
  - Etc.

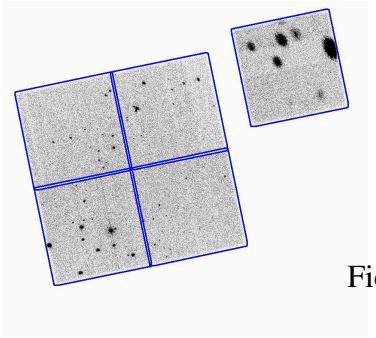
Example of Observation products



Aspect Histogram

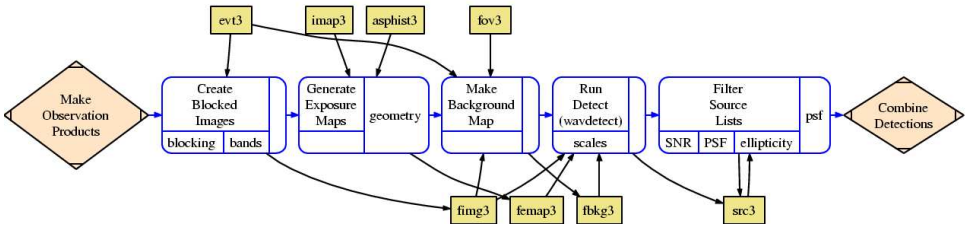


Instrument Map



Field of View

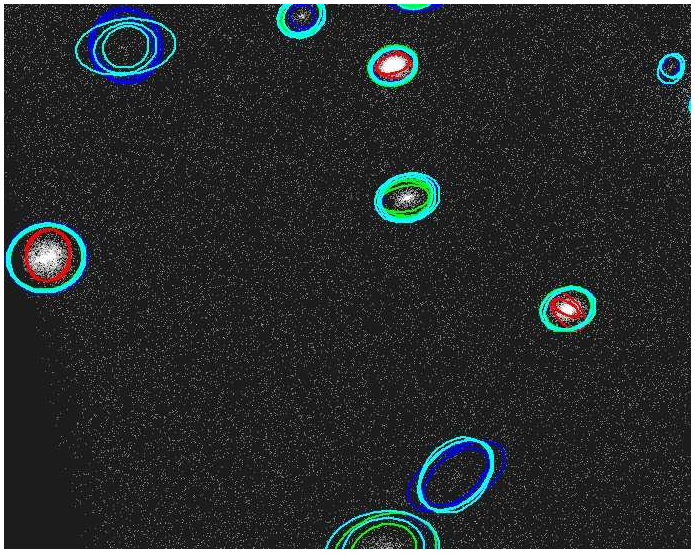
Detect Sources Diagram



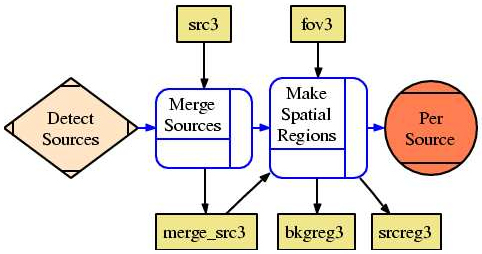
Detect Sources

- Running wavdetect (See Freeman et al. [astro-ph/0108429])
  - 2k x 2k images; multiple blocking factors covers FOV
    - ACIS: 8k x 8k full resolution
    - HRC-I: 32k x 32k full resolution
    - HRC-S: 64k x 64k full resolution
  - Using exposure maps
  - Running for each pre-defined energy band
    - Broad: 0.2 - 7.5 keV w/ 2.3 keV mono. energy for imap
    - Soft: 0.2 - 0.5 keV w/ 0.4 keV mono. energy for imap
    - Medium: 0.5 - 2.0 keV w/ 1.25 keV mono. energy for imap
    - Hard: 2.0 - 7.5 keV w/ 3.8 keV mono. energy for imap
- Remove bad detections
  - Size compared to PSF too small
  - SNR threshold
  - Detection artifacts (size=0)

Example of multiple detections



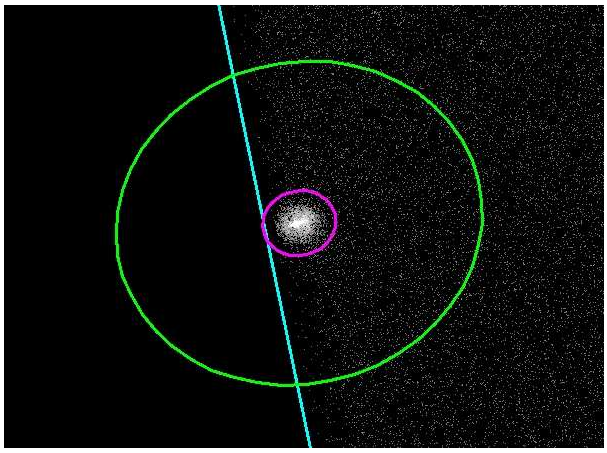
Combine Detections diagram



Combine Detections

- Combine detect runs from multiple bands and multiple blocking factors
- Pick the 'best' detect for initial position, size, and other source properties
- Construct source and co-located background regions that exclude nearby sources.
  - Include FOV edge boundary

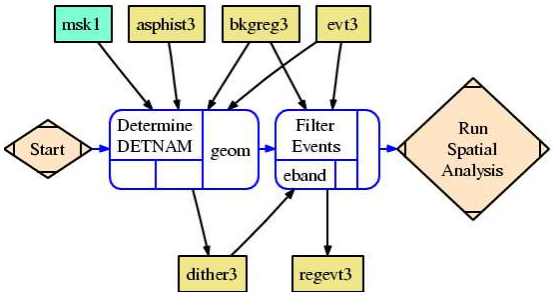
Example of Regions



Per-Source Pipeline

- Run for each detected source
- Creates histograms and responses for each axis
  - Spatial: images, PSF, exposure maps
  - Temporal: light-curve, exposure, dither fraction
  - Spectral (ACIS): spectrum, RMF, ARF
- Extract per-observation source properties

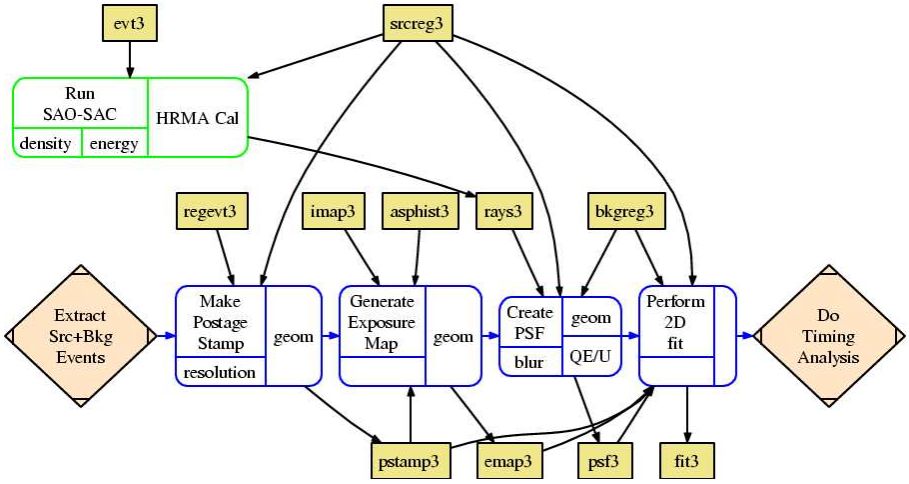
Extract Src+Bkg Events Diagram



Extract Src+Bkg Events

- Filter full evt3 file to select events in regions that bounds the background
- Includes all source and background events for the source being examined
- Also includes events from nearby sources that fall within the bounding box around the background annulus
  - Allows for relatively small-scale extended source analysis
- Updates the meta-data for files (DETNAM) so that downstream analysis is only done over 'interesting' chips

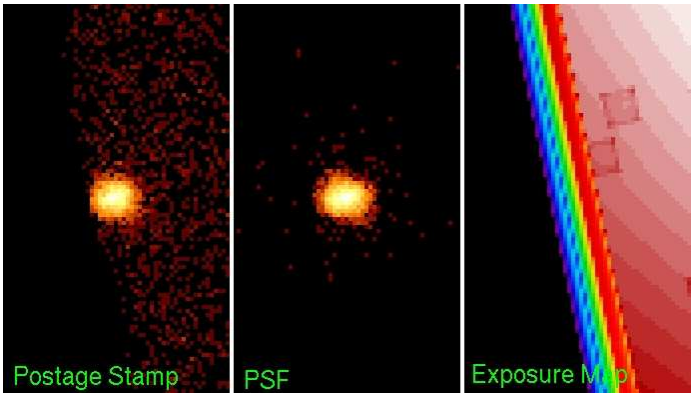
Run Spatial Analysis Diagram



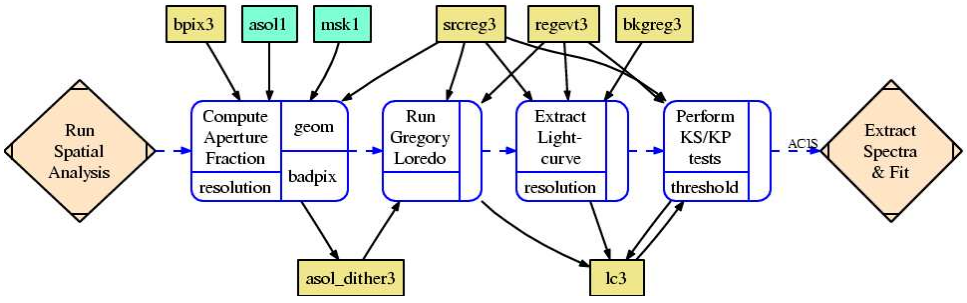
Run Spatial Analysis

- Bin the region events into a 2D image (postage stamp)
  - Different blocking factors are used at different off-axis angles
- Simulate the PSF
  - SAO-SAC is run as a pre-process step in the pipeline
  - rays are projected onto detector planes (no chip edges)
- Exposure maps are made to match resolution of postage stamps
- Image, PSF, Exposure Map are fed into a 2D fitting routine
  - Looks for 1 point source, 2 point sources, or extended source
  - 'Best' position
  - 'Best' flux

Example of Spatial Products



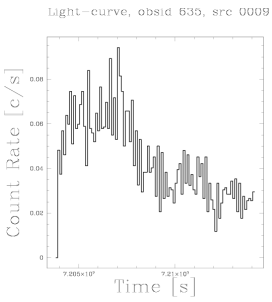
Do Timing Analysis Diagram



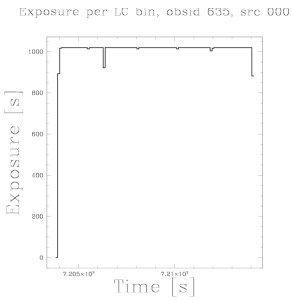
Do Timing Analysis

- Compute fraction of aperture 'on-chip' as a function of time
- Run Gregory Loredo (GL) to
  - test for variability
  - establish 'optimal' binning for light-curve
- Bin events into light-curve
  - (TBR) Use GL info to set binning size
  - Extracts source and background light-curves
  - (TBR) Use PSF-fraction to adjust exposure per bin
- Perform a Kolmogorov-Smirnov (KS) test and Kuiper (KP) test to check for intra-observation variability

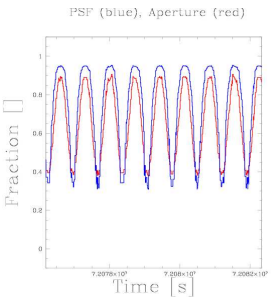
Example of Timing Products



Light-curve

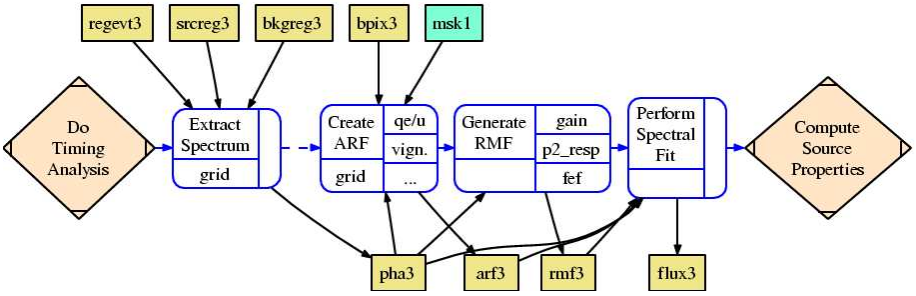


Exposure



Aperture/PSF

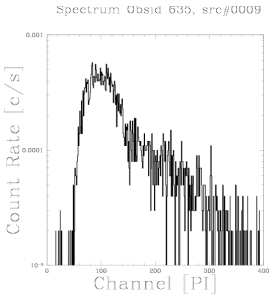
Extract Spectra & Fit Diagram



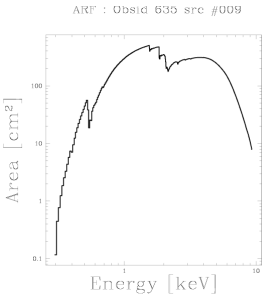
Extract Spectra & Fit (ACIS only)

- Extract spectrum in PI space
  - Source and background spectrum
  - Also compute 'wmap' for weighted response products
- Compute the ARF
  - Weighted with 'wmap'
  - (TBR) Applies adjustment to ARF based on PSF-Fraction vs. Energy
- Computes the RMF
  - Different calibration epochs require different tools
- Lookup the N_h value
  - Using NRAO
- Perform spectral fits
  - based on # counts; different models/parameters are used/free'ed

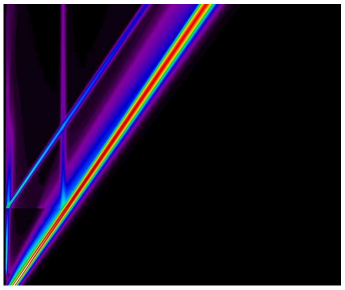
Example of Spectral Products



Spectrum

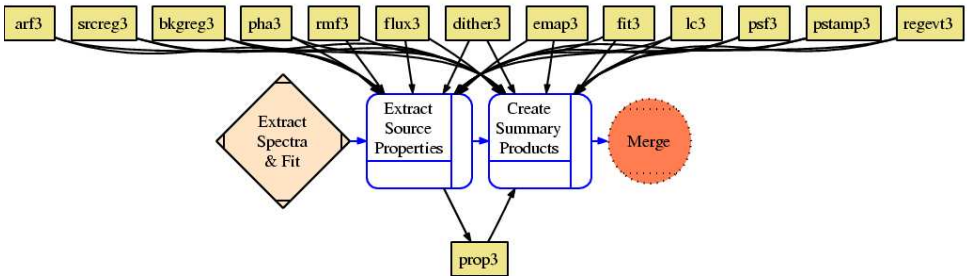


ARF



RMF

Compute Source Properties Diagram



Compute Source Properties

- Compiles and computes data from different bands
- Prepares "prop3.par" parameter file with scalar values to be included in static database
- Creates summary-style products
  - HTML pages with tabular data
  - JPEG images of products for easy web viewing

Example of Observation Source Properties

- [See hand out]

Appendix A - Data Dictionary

- Input Files
  - **evt1**: Photon event list: contains spatial, spectral, timing and quality information.
    - Also includes sets of Good Time Intervals (GTIs)
  - **asol1** : Aspect solution: spacecraft pointing vs time and 'optical'-bench alignment
  - **bpix1:** Bad pixel files (vs. time)
  - **dtf1** (HRC only): Dead time factors: instrumental recovery times
  - **msk1:** Mask: spatial mask of active detector regions
  - **flt1:** Filter: sets of Good Time Intervals (ACIS: per chip)
  - **mtl1:** Mission time line: various instrumental & housekeeping values vs. time
  - **bias0** (ACIS only): Bias images
  - **pbk0** (ACIS only): Parameter block: various instrument configuration

Appendix A - continued

- Output Files
  - Per observation
    - **evt3:** Photon event list re-calibrated and more filtering w/ GTIs
    - **bpix3:** re-calibrated and updated bad pixel file
    - **asphist3:** aspect histogram: 3D 'sparse' histogram duration vs. pointing; ACIS: one per chip
    - **imap3:** instrument map: combo of detector efficiency, uniformity and telescope vignetting. One per chip/plate (ACIS & HRC). ACIS: per energy band
    - **merge_src3:** Combined source list
    - **srcreg3 / bkgreg3:** Source and Background spatial region filter. One pair per source.
  - Per Source (/Band)
    - **regevt3** - photon event list filtered for spatial region bounding background.
    - Spatial
      - **pstamp3** - 2D image of src & background
      - **emap3** - localized exposure map
      - **psf3 -** point spread function
      - **fit3** - 2D fit parameters
    - Spectral
      - **pha3** - spectrum
      - **arf3** - auxiliary response file
      - **rmf3** - redistribution matrix
      - **flux3** - spectral fit parameters
    - Timing
      - **lc3**- light curve
      - **dither3** (TBR) - aperture area vs time

Appendix B - File Multiplicity

	Per-Obs	Per-chip	Per-source	Per-band
evt3	x			
bpix3	x			
asphist3	x	x		
imap3	x	x		x
merge_src3	x			
srcreg3	x		x	
bkgreg3	x		x	
regevt3	x		x	x
pstamp3	x		x	x
emap3	x		x	x
psf3	x		x	x
fit3	x		x	x
pha3	x		x	
arf3	x		x	
rmf3	x		x	
flux3	x		x	
lc3	x		x	x
dither3	x		x	x