Introduction to the

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Introduction

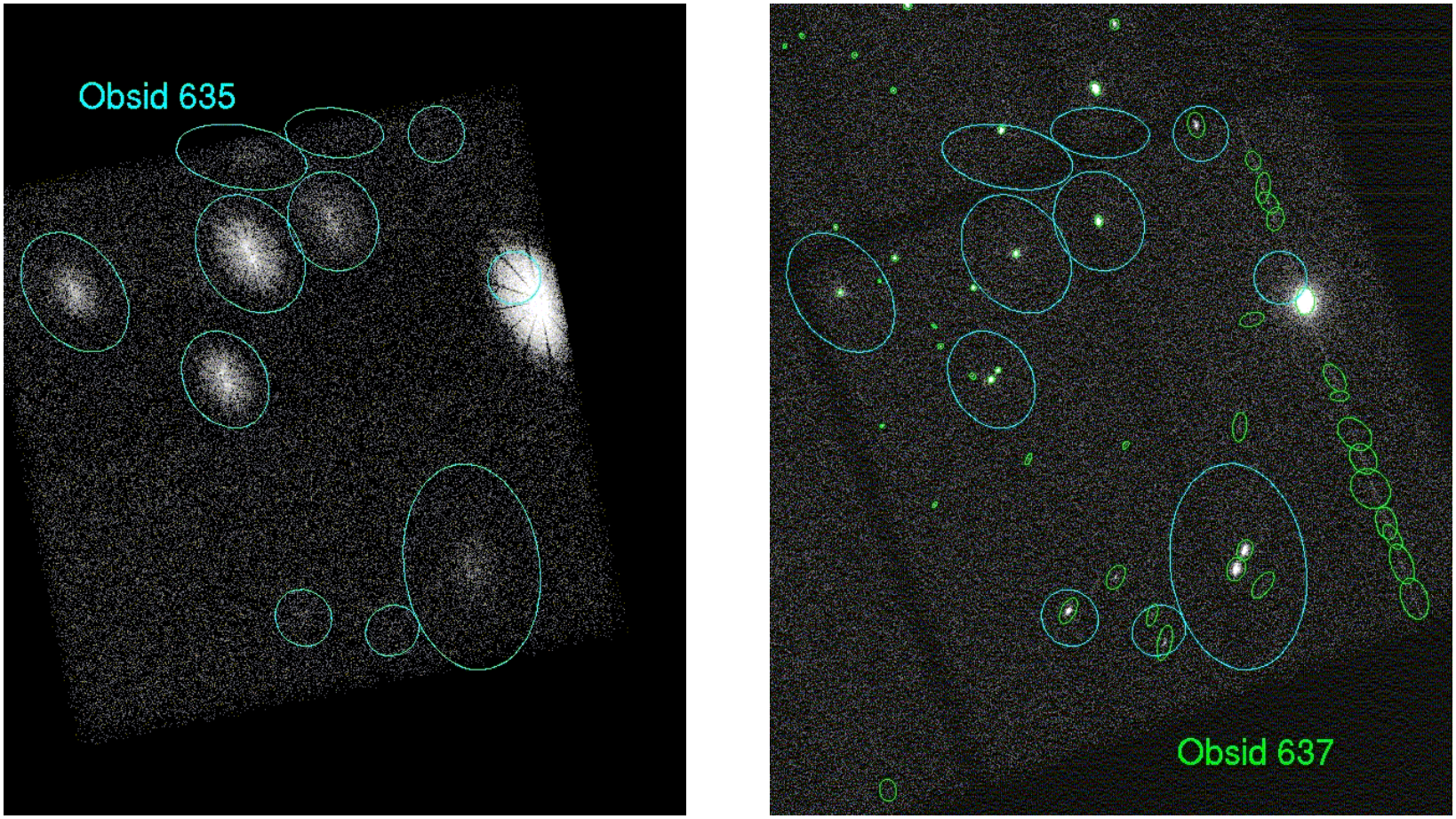
- The Chandra Source Catalog (CSC) will ultimately be the definitive catalog of X-ray sources detected by the Chandra X-ray
  - The catalog is constructed from pointed observations obtained using Chandra; it is not an all-sky catalog, and does not include sources detected to a uniform depth
  - The catalog is being deployed using a phased approach
  - Each new release will add new capabilities and functionality
  - New catalog releases will take place roughly every 18−24 months
  - Production run for Release 1 is now in progress
- Catalog Release 1
  - Restricted to point and compact sources with observed spatial extents < ~ 30 arcsec detected in a subset of public imaging observations
  - Source detections are performed on individual observations (no stacking)
  - Some observations of fields containing extended sources are excluded from the catalog, or in some cases only a part of the field is included
  - Official release 1 (Jan 2009) will include characterization of statistical properties
  - Public access to the *catalog database* is available while the catalog is being constructed
    - The contents of the database are subject to revision and a small fraction of detected sources may not meet all of the catalog quality assurance requirements
- User web site includes detailed documentation and provides access to the CSCview catalog GUI
  - **http://cxc.cfa.harvard.edu/csc/**

Catalog Concepts

Catalog Organization

- The catalog includes two tables of source properties, and a set of file-based data products that can be manipulated using CIAO
  - Table of Master Sources
    - Contains an entry for each distinct detected X-ray source on the sky, with "best" estimates of the source properties derived from observations in which the source is detected
  - Table of Individual Source Observations
    - Contains an entry for each source detection from each individual observation, with the source properties derived from that single observation
- Distinguishing detections from sky sources addresses the "spatially-variable PSF" problem
  - Not an issue for catalogs constructed in most other wavebands
- Also allows retrieval of distinct observation data for variable sources
- Entries in the table of master sources and entries in the table of individual source observations are associated via *unique* or *ambiguous* links
  - Allows queries to be performed on properties determined from each observation (*e.g.*, "identify all potential master sources associated with this off-axis source detection that was observed to flare")

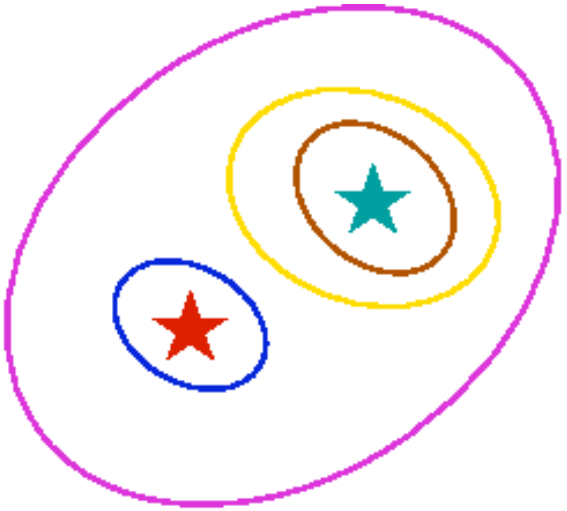
Spatially Variable PSF

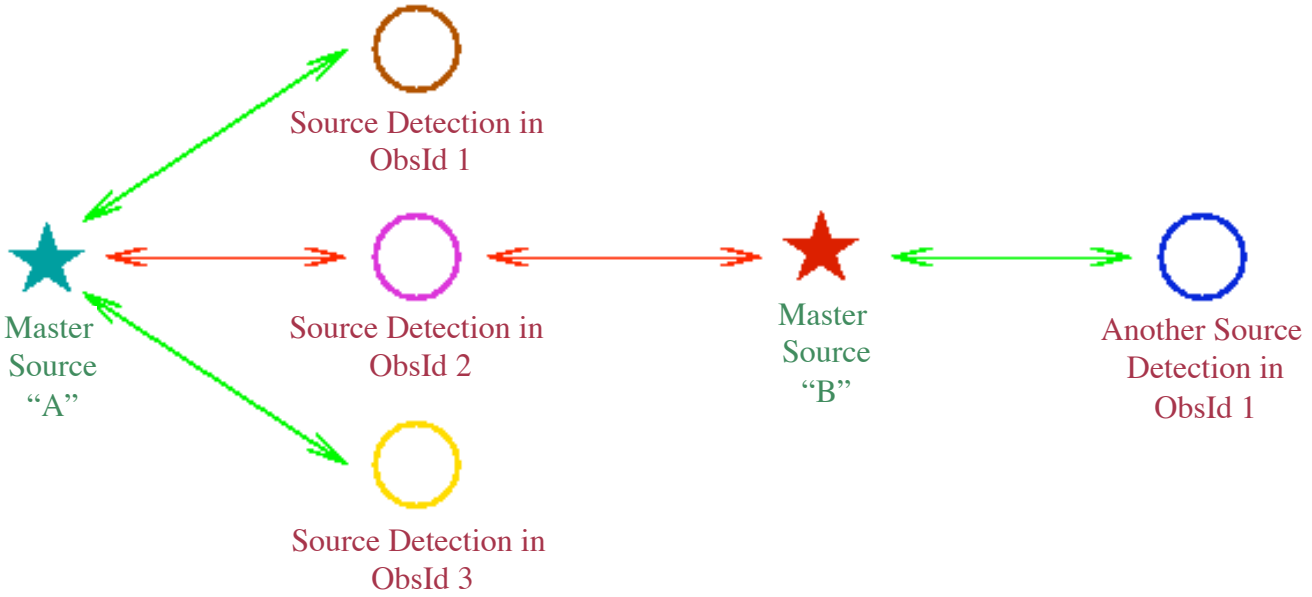


- Comparison of a region of the sky from Obsid 635 (left) compared with the same region from Obsid 637 (right)
  - The off-axis PSF in Obsid 635 confuses multiple sources that are clearly resolved in Obsid 637 where the same region is observed on-axis

Unique and Ambiguous Links

- Source detections are recorded in the table of individual source observations
- Master sources are recorded in the master source table
- *Unique* links between individual source observation entries and single master source table entries are shown in green
- *Ambiguous* links to multiple master source table entries are shown in red





Catalog Concepts

Catalog Databases

- The tabular contents of the catalog are recorded in a set of SQL databases
  - Currently, these databases are being populated as catalog production processes existing public observations
  - Since Chandra is an on-going mission, the databases will continue to be populated in the future as observations become public
- The need to allow the catalog databases to be continually updated while providing the user with stable, well-characterized datasets (*i.e.*, official catalog releases) is achieved by allowing the user to select specific views of the catalog (starting with formal release 1 in January 2009)

Catalog Concepts

Catalog Views

- There are two types of views: catalog release views and database views
  - Prior to official release 1, only the current database view is available
- A catalog release view allows the user to see the contents of a specific released version of the catalog
  - Catalog release views are frozen and will never change
  - Catalog release view entries are guaranteed to meet all of the catalog quality assurance requirements
  - The statistical properties of the contents of catalog release views will be well characterized
- A database view allows the user to see the contents of the database at a user-specified date and time (with the current date and time being the defaults)
  - Source information (including source names, if the source has not been included in a catalog release) may change
  - Database view entries typically (99.9+%) will meet all catalog quality assurance requirements, but this is not guaranteed
  - The statistical properties of the contents of database views may not be well characterized
- We anticipate that users who want well-characterized, stable datasets will prefer to use the catalog release view, while users who need access to the latest processed data will use a database view

Catalog Contents

Table of Individual Source Observations

- Observation information
  - Identifies the observation in which the source was detected
    - Includes the observation identification, spacecraft pointing, observation timing, instrument configuration, and data processing software and calibration database versions
- Source information
  - Provides the extracted data for each source
    - Includes the source identification, source position, source and background regions and PSF 90% ECF aperture, observed source extent and local PSF extent, estimated deconvolved source extent, aperture photometry fluxes (discussed later), significance (S/N), hardness ratios, power-law and black-body spectral fits (for 150+ net source counts only), variability probabilities and statistics, and a set of flags and codes that indicate circumstances that may be relevant to the user
    - In general, measured and derived properties have associated confidence limits or other defined errors
    - Note that a source *name* is not defined at this stage

Catalog Contents

Energy Bands

- Most properties are determined in several energy bands
  - Broad (**b**) ACIS band covers the energy range 0.5−7.0 keV
  - Hard (**h**) ACIS band covers the energy range 2.0−7.0 keV
  - Medium (**m**) ACIS band covers the energy range 1.2−2.0 keV
  - Soft (**s**) ACIS band covers the energy range 0.5−1.2 keV
  - Ultrasoft (**u**) ACIS band covers the energy range 0.2−0.5 keV
  - Wide (**w**) HRC band covers roughly the energy range 0.1−10.0 keV

Aperture Photometry Fluxes

- Reported for each energy band, both within the source region and within the PSF 90% ECF aperture
  - Total aperture (and background aperture) counts, PSF aperture fraction corrected source counts and source count rate, source photon flux, and source energy flux
  - Source energy flux is calculated in two different ways
    - Summing the incident photon energies scaled by the local ARF (the background is corrected using the mean background photon energy)
    - Inferring the energy flux needed to fit the measured source count rate from a scaled spectral model folded through calibrated response
      - » Both a canonical $E^{-1.7}$ power law [+ N_H(Gal)] model and a kT = 1.0 keV black body [+ $N_H = 3\times10^{20}$ cm^{-2}] model are used

Catalog Contents

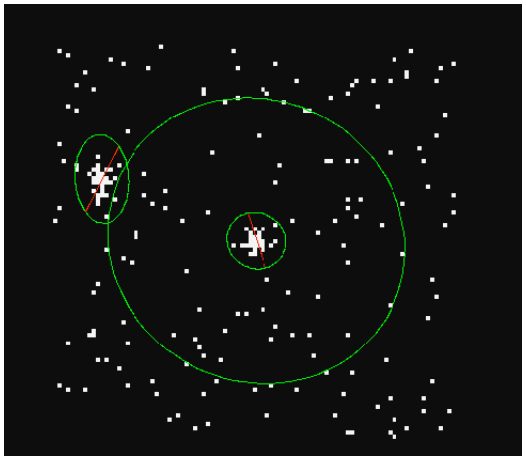
Table of Master Sources

- Source information
  - Provides estimates of properties for each distinct source on the sky
    - Includes the source name, source position, estimated deconvolved source extent, aperture photometry fluxes, source significance (S/N), hardness ratios, power-law and black-body spectral fits, intra- and inter-observation variability probabilities and statistics, and flags
    - Source *name* is CXO J*hhmmss.s±ddmmss*, where coordinates are ICRS
  - Master source properties
    - Computed by combining properties from individual source observations (*e.g.*, merged source positions and position errors; hardness ratios; inter-observation variability)
    - Use "best" estimate based on individual observation with highest S/N (*e.g.*, spectral fit properties)
    - Merged source properties are computed from individual source observations that have unique links to the master source only (individual source observations that have ambiguous links to multiple master sources are not considered)
      - » However, individual ACIS source observations that are heavily piled-up are not considered when computing merged source properties unless all such observations are piled-up

Catalog Contents

Data Products

- Each individual source observation has an associated set of data products
  - These include full field data products for the observation including the source, and source-specific data products
    - FITS format, with "quick look" JPEG equivalents for the images
  - Full field data products include the "Level 3" event file, fluxed images (several bands and blocking factors), background images, exposure map, limiting sensitivity map, aspect histogram, bad pixel, and field of view files
    - The limiting sensitivity map records the limiting sensitivity needed for a point source to satisfy the minimum flux significance criterion for inclusion in the catalog
  - Source-specific data products include the source region event file, fluxed images, PSF images, exposure map, low resolution PI spectrum, ARF, RMF, adaptively binned light curve, and region definitions



The source region event file contains events within a rectangular bounding box on the tangent plane that encloses the background region; to extract only the events included in the source region the source region filter must be applied

Catalog User Website

Website Contents

- The catalog user website provides:
  - Links to launch the catalog GUI (CSCview), and associated documentation
  - Catalog processing status
  - A high level description of the catalog, how the catalog is organized, and the views into the catalog that are available to users
  - Catalog caveats and limitations
  - How the catalog was created, including observation selection and catalog processing
  - Descriptions of the contents of the catalog tables and the catalog data products
  - Detailed explanations for certain topics
  - Links to useful documents
- Aimed at catalog end users, including users from other wavebands who may be unfamiliar with X-ray astronomy and Chandra data
- Subject to constant revision as processing continues and additional capabilities become available
  - For example, as statistical characterization proceeds, the results will be posted

CHANDRA SOURCE CATALOG

CSC Data Access (CSCview)

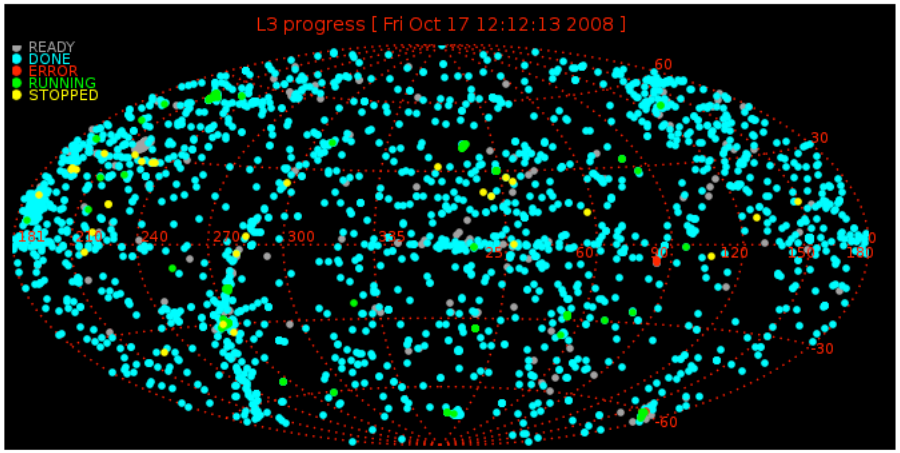
CSCview Software Requirements

CSCview Help

Catalog Processing Status

The Chandra Source Catalog

Data access is currently provided only to the catalog production database. The contents of the database are subject to revision and a small fraction of detected sources may not meet all of the catalog quality assurance requirements. Users should review the catalog Caveats and Limitations for further information. The first official release of the Chandra Source Catalog is scheduled for January 2009.



The Chandra Source Catalog (CSC) is the definitive catalog of all X-ray sources detected by the Chandra X-Ray Observatory. The CSC contains positions and multi-band count rates for the sources, as well as derived spatial, spectral and temporal calibrated source properties that may be compared with data obtained by other telescopes. The CSC also includes associated data products for each source, including images, photon event lists, light curves, and spectra.

The first release of the CSC (January 2009) will include information about sources detected in public ACIS imaging observations from roughly the first eight years of the Chandra mission. Only point sources, and compact sources with extents < ~30 arcsec, will be included. Highly extended sources, and sources located in selected fields containing bright, highly extended sources, will be excluded.

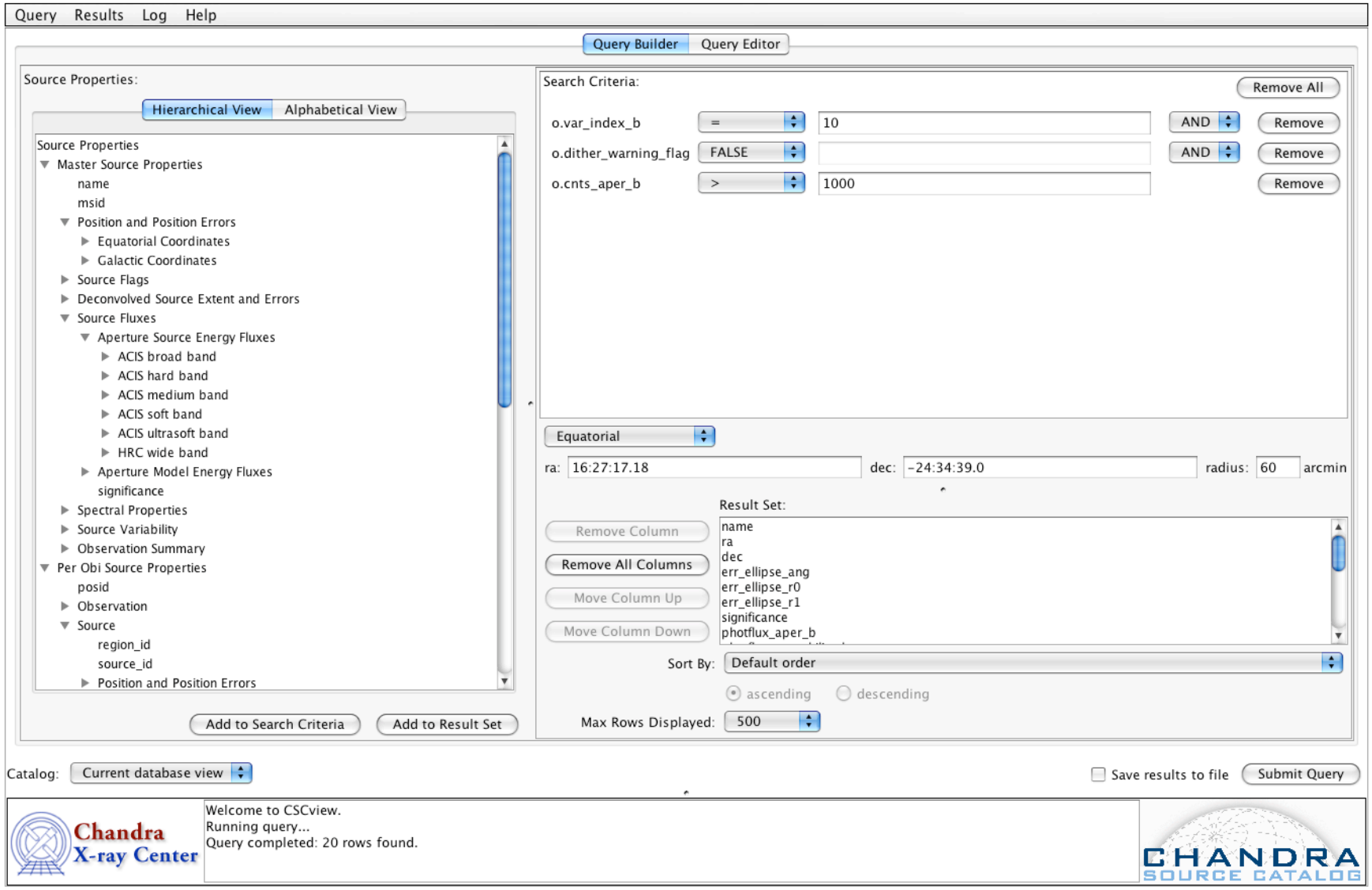
Each distinct source on the sky (i.e., object at a specific RA and Dec) is recorded in a single "master source" table entry and one or more "individual source" table entries. The individual source entries contain the properties of a single detection from a single observation. The master source entry is the best estimate of all the properties of a source, based on the data extracted from the individual source entries. The Catalog Organization page contains further details.

CSCview Catalog User Interface

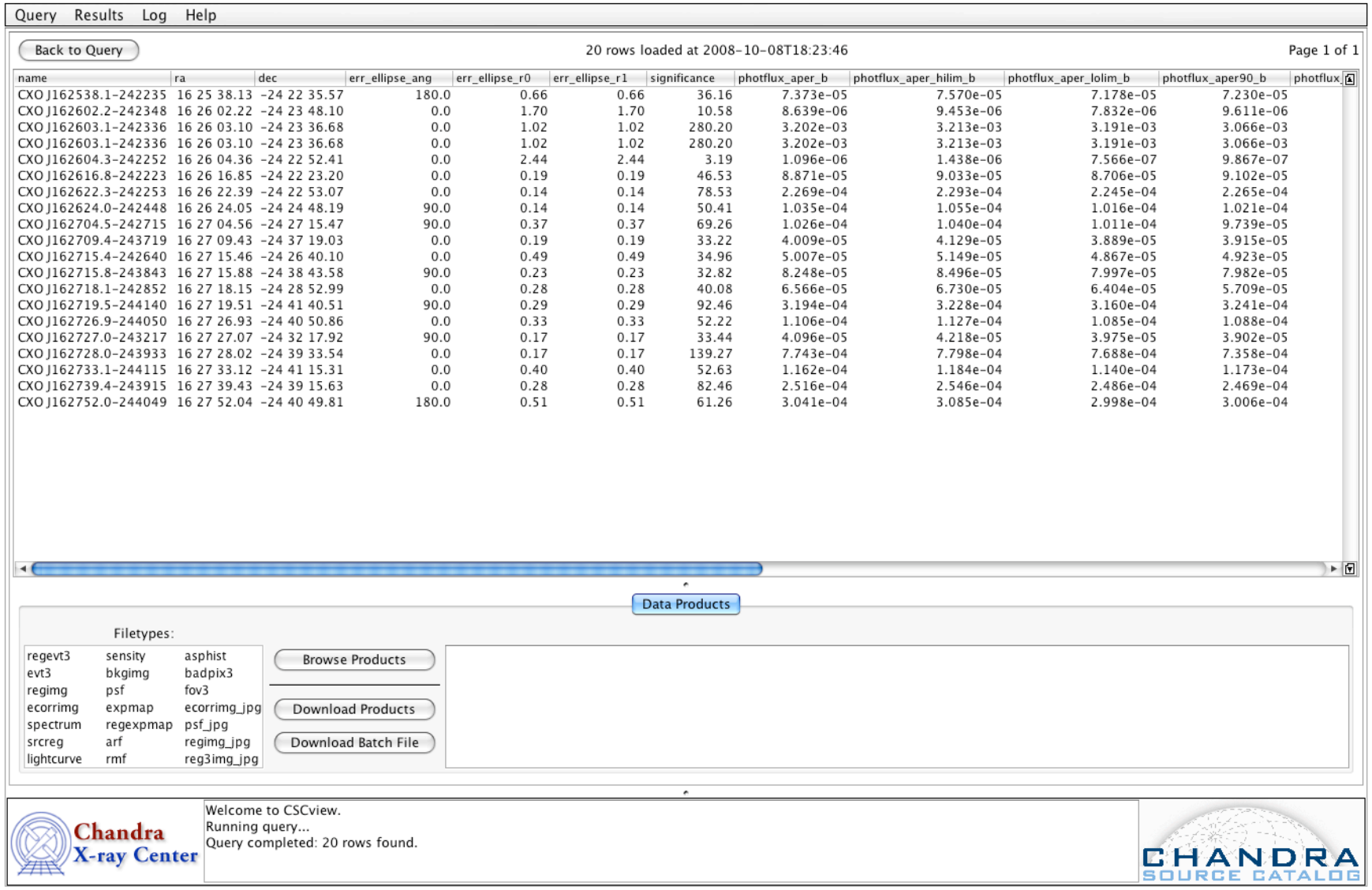
CSCview

- The primary user interface to the catalog (CSCview) is available on through the catalog user website
  - The interface runs in the user's web browser, and is written in Java (requires Java version 1.5 [aka J2SE 5.0] or later)
- CSCview allows the user to construct queries of any source properties, and return a table with selected source properties for matching sources
  - Users can perform a cone search around specified coordinates, with or without additional query constraints
  - Users can view the results of the query on the screen or save the results to a file
  - Users can download observation- or source-specific data products for selected sources matching their query
- The current version of CSCview should be considered to be a beta release
  - Some important functionality is still missing
    - Pre-canned "simple" queries, "simple" data subset display, "property" or "band" priority source property hierarchies, display of JPEG images, …
    - Support for VO standards such as ADQL, VOTable output, …
  - The layout of the user interface will change to accommodate the missing functionality

CSCview Query Form



CSCview Results Form



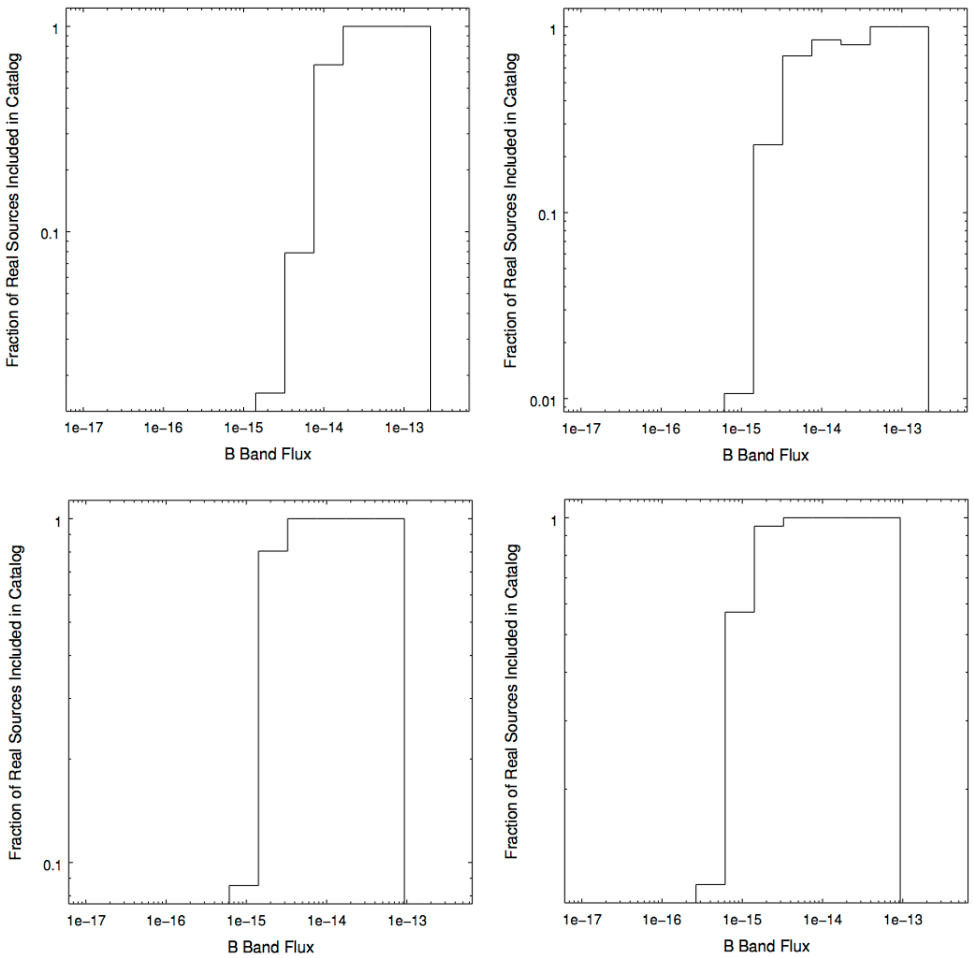
name	ra	dec	err_ellipse_ang	err_ellipse_r0	err_ellipse_r1	significance	photflux_aper_b	photflux_aper_hilim_b	photflux_aper_lolim_b	photflux_aper90_b	photflux
CXO J162538.1-242235	16 25 38.13	-24 22 35.57	180.0	0.66	0.66	36.16	7.373e-05	7.570e-05	7.178e-05	7.230e-05	
CXO J162602.2-242348	16 26 02.22	-24 23 48.10	0.0	1.70	1.70	10.58	8.639e-06	9.453e-06	7.832e-06	9.611e-06	
CXO J162603.1-242336	16 26 03.10	-24 23 36.68	0.0	1.02	1.02	280.20	3.202e-03	3.213e-03	3.191e-03	3.066e-03	
CXO J162603.1-242336	16 26 03.10	-24 23 36.68	0.0	1.02	1.02	280.20	3.202e-03	3.213e-03	3.191e-03	3.066e-03	
CXO J162604.3-242252	16 26 04.36	-24 22 52.41	0.0	2.44	2.44	3.19	1.096e-06	1.438e-06	7.566e-07	9.867e-07	
CXO J162616.8-242223	16 26 16.85	-24 22 23.20	0.0	0.19	0.19	46.53	8.871e-05	9.033e-05	8.706e-05	9.102e-05	
CXO J162622.3-242253	16 26 22.39	-24 22 53.07	0.0	0.14	0.14	78.53	2.269e-04	2.293e-04	2.245e-04	2.265e-04	
CXO J162624.0-242448	16 26 24.05	-24 24 48.19	90.0	0.14	0.14	50.41	1.035e-04	1.055e-04	1.016e-04	1.021e-04	
CXO J162704.5-242715	16 27 04.56	-24 27 15.47	90.0	0.37	0.37	69.26	1.026e-04	1.040e-04	1.011e-04	9.739e-05	
CXO J162709.4-243719	16 27 09.43	-24 37 19.03	0.0	0.19	0.19	33.22	4.009e-05	4.129e-05	3.889e-05	3.915e-05	
CXO J162715.4-242640	16 27 15.46	-24 26 40.10	0.0	0.49	0.49	34.96	5.007e-05	5.149e-05	4.867e-05	4.923e-05	
CXO J162715.8-243843	16 27 15.88	-24 38 43.58	90.0	0.23	0.23	32.82	8.248e-05	8.496e-05	7.997e-05	7.982e-05	
CXO J162718.1-242852	16 27 18.15	-24 28 52.99	0.0	0.28	0.28	40.08	6.566e-05	6.730e-05	6.404e-05	5.709e-05	
CXO J162719.5-244140	16 27 19.51	-24 41 40.51	90.0	0.29	0.29	92.46	3.194e-04	3.228e-04	3.160e-04	3.241e-04	
CXO J162726.9-244050	16 27 26.93	-24 40 50.86	0.0	0.33	0.33	52.22	1.106e-04	1.127e-04	1.085e-04	1.088e-04	
CXO J162727.0-243217	16 27 27.07	-24 32 17.92	90.0	0.17	0.17	33.44	4.096e-05	4.218e-05	3.975e-05	3.902e-05	
CXO J162728.0-243933	16 27 28.02	-24 39 33.54	0.0	0.17	0.17	139.27	7.743e-04	7.798e-04	7.688e-04	7.358e-04	
CXO J162733.1-244115	16 27 33.12	-24 41 15.31	0.0	0.40	0.40	52.63	1.162e-04	1.184e-04	1.140e-04	1.173e-04	
CXO J162739.4-243915	16 27 39.43	-24 39 15.63	0.0	0.28	0.28	82.46	2.516e-04	2.546e-04	2.486e-04	2.469e-04	
CXO J162752.0-244049	16 27 52.04	-24 40 49.81	180.0	0.51	0.51	61.26	3.041e-04	3.085e-04	2.998e-04	3.006e-04	

regevt3	sensity	asphist
evt3	bkgimg	badpix3
regimg	psf	fov3
ecorrimg	expmap	ecorrimg_jpg
spectrum	regexpmap	psf_jpg
srcreg	arf	regimg_jpg
lightcurve	rmf	reg3img_jpg

Preliminary Characterization

Completeness Function

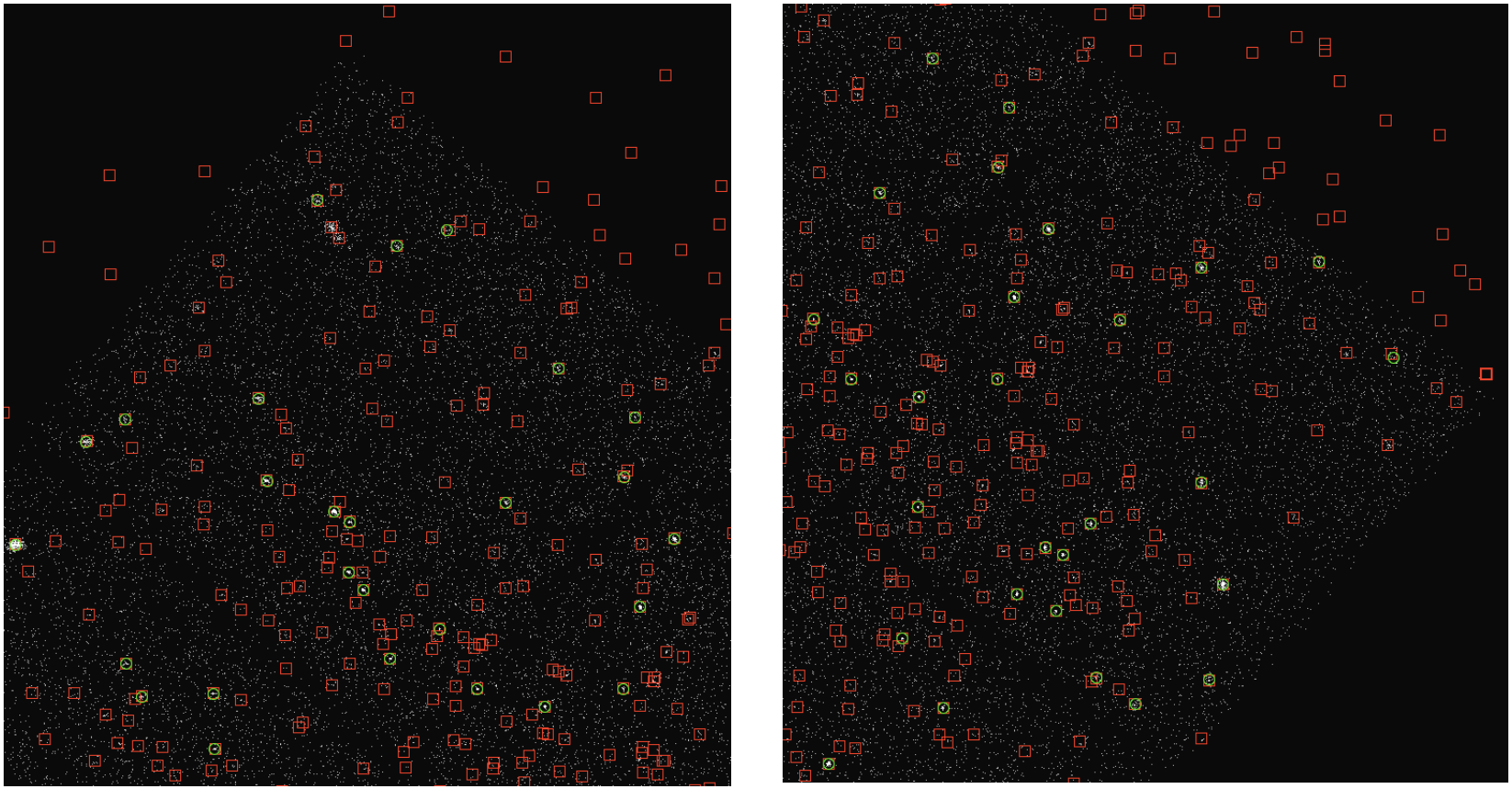
- Preliminary CSC completeness function derived from the ratio of the number of CSC sources detected to number of external catalog sources vs. flux
  - Top left and right: ObsIds 2386 (10 ks) and 3388 (50 ks) vs. CDF-N survey (2 Ms)
  - Bottom left and right: ObsIds 1708 (61 ks) and 927 (125 ks) vs. Spices-II survey (185 ks; Stern et al. 2002)
  - Published catalogs are assumed to be complete at the level of the individual ObsIds
  - Band fluxes are approximate, since energy bands do not match exactly
  - Histograms show differential source count fraction in each flux bin (not cumulative count fraction)



Preliminary Characterization

Field False Source Rate

- Field false source rate is < 1 false source per 50 ks observation
  - False source rate in areas of enhanced background (e.g., readout streaks) will be characterized as part of detailed false source rate study

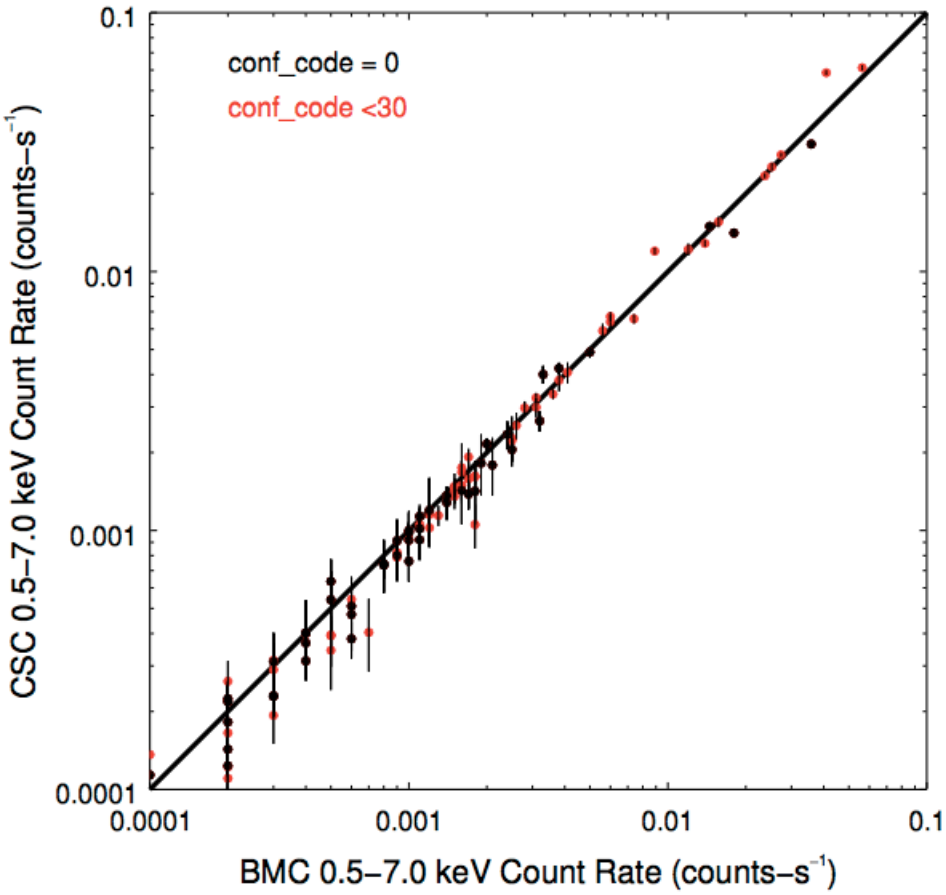


Comparison of CSC source detections (green circles) for ObsId 3388 (50 ks) with 2 Ms HDF-N composite catalog (red squares; Alexander et al. 2003) indicates that all CSC source detections are associated with deep HDF-N detections.

Preliminary Characterization

Aperture Photometry

- CSC ACIS **b** band count rate vs. the Brera Catalog (Romano et al. 2008) for sources observed in the same ObsId (this removes the uncertainty due to variable sources)
  - `conf_code < 30` implies source regions do not overlap any other source regions
  - `conf_code = 0` implies source and background regions do not overlap any other source or background regions



Catalog Future Directions

Short Term Plans

- CSCview GUI
  - Predefined common queries and results display
  - Addition of name resolver support (e.g., for cone searches)
  - Support for cross-matching with user supplied catalogs
  - Additional output file formats for query results
- CIAO tools
  - A number of the catalog-related tools will be made available to users over the next ~year
    - Examples include: aprates, BEHR, dmellipse, eff2evt, glvary, lim_sens, MHO/iss
- Web Services
  - Catalog limiting sensitivity service, VO standard cone search and footprint services

Longer Term Plans

- Catalog Release 2
  - Combining observations that were split due to thermal constraints, prior to source detection; the exact limitations on what can be combined are not clear, but likely include "similar" instrument configurations and pointings
  - Improved background modeling, particularly in areas of extended emission
- Catalog Release 3+
  - Support for extended sources
  - "Simultaneous" multi-observation detection