CHANDRA
SOURCE CATALOG

Jonathan McDowell
After 18 years Chandra has observed about 1% of sky

CSC1.1 (2010) 106,586 sources
   Wavelet detect on single observations, no co-adding
   Public data to end of 2009
   Fields with large extended sources omitted
Published as Evans et al 2010 ApJS 189, 37
   Primini et al 2011 ApJS 194,37

CSC2.0 (2017/18) 315,887 sources (TBR)
   Wavelet + Max Likelihood detect on co-added observations
   Public data to end of 2014
   Fields whose aimpoint is within 1’ are combined into ‘stacks’
   Overlapping stacks are processed together
Usage Statistics

Current Release

- Catalog version: 1.1; Released: 2010 Aug 10
  - 106,586 master sources
  - 158,071 source detections
  - 5,110 observations with at least one detected source
- Subset of master source properties are available via HEASARC Browse, NED, and Vizier services
  - Usage statistics reported below do not include accesses via these services

Usage Statistics

<table>
<thead>
<tr>
<th></th>
<th>Release 1.1</th>
<th>Reporting Period 2015 Sep 01 – 2016 Mar 31</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>% Non-CfA</td>
</tr>
<tr>
<td>CSCview catalog browser initializations</td>
<td>112 /month</td>
<td>92%</td>
</tr>
<tr>
<td>CSCview catalog browser properties searches</td>
<td>229 /month</td>
<td>93%</td>
</tr>
<tr>
<td>Command-line (CLI) searches</td>
<td>1865 /month*</td>
<td>65%</td>
</tr>
<tr>
<td>VO cone searches</td>
<td>6501 /month</td>
<td>~100%</td>
</tr>
<tr>
<td>CSC Sky in Google Earth</td>
<td>582 visits/month</td>
<td></td>
</tr>
</tbody>
</table>

* Excludes 20K searches (~ all non-CfA) from 2016 March
CSC:

5 bands

u  0.2–0.5 keV
s  0.5-1.2 keV
m  1.2-2.0 keV
h  2.0-7.0 keV
b  0.5-7.0 keV

2 apertures:

- detection aperture determined by wavelet detect
- aperture containing 90% of flux

3 flux methods:

- spectral fits  (if > 150 net counts)
- power law fit with normalization free
- model-independent flux using ARF but ignoring RMF
Chandra Deep Field South (81 ObsId – 5.8 Ms)

~1000 Preliminary detections
Multiple sources on-axis may be confused in the same field off-axis

Catalog reconciles detections at different off-axis angles
CSC1 comparison with SDSS: better than 1” (within 8” off axis)

CSC2 internal position errors are smaller than the ChaMP errors used in CSC1 for sources with \( \geq 50 \) net counts and \( \theta \lesssim 5 \) arcmin

This plot does not include the absolute catalog astrometric position uncertainty (\( \sim 0.16 \) arcsec for CSC1)
ACIS Likelihood Threshold Calibration

Short Exposure

No sources injected

With ~7 count sources injected

Long Exposure

Detections from multiple simulations overlayed on PSF map

True
Marginal
False
Position error ellipses with position confidence MCMC draws

Multi-band X-ray aperture photometry with Bayesian probability density functions

Source extent and local PSF models for every source and energy band

Source properties — all have associated upper and lower confidence bounds

Spectral model fits and fluxes determined using multiple models (>150 cts)

Hardness ratios

Intra- and inter-observation variability measures and light curves
Example of Aperture Photometry Extraction

- Simultaneous photometry estimation in crowded field
- Algorithm checked against simulations
- Pipeline results verified against published algorithm
Fluxes from Probability Density Estimation

cohort: acisfj0859206m473014_001, bundle 154, band b

Photon Flux
Limiting Sensitivity Map

- For an observed portion of the sky, we provide our best estimate of the *lowest value of the flux that would have been detectable* as a source in our catalog.

(Preliminary Map for CSC v2; F. Primini, priv. comm.)
Sgr A* Region
Source Density

- Sgr A* stacks detections included in pd2
- Map shows detection density (number of detections per pixel)
How to get the data (1):
CSC2 preliminary detections FITS table, available now at cxc.cfa.harvard.edu/csc2/preliminary

Chandra Source Catalog Release 2.0 Preliminary Detections List

Contents
- Data Access
- Column definitions
- Caveats

Data Access
The March 2017 release of the data is available at:
- `preliminary_delist.fits.gz` (53.4 Mb compressed and 124.4 Mb uncompressed)

It contains the results of Maximum Likelihood Estimator (MLE) fits to the candidate source detections. The column definitions and Caveats for this file can be found below. The file contains 362182 detections, with 279549 labelled as `SRC_QUALITY = TRUE` and 82633 (23%) with `SRC_QUALITY = MARGINAL`. When split by `EXTRACT_CLASS`, there are 3583882 detections with a value of `near`: 3183 (0.9%), with `source`, and 617 (0.2%) with `marginal`. The breakdown by energy—-the energy band corresponding to the measured values—-are 271607 broad band (`b`), 305 ultra soft (`u`), 26995 soft (`s`), 26524 medium (`m`), 31297 hard (`h`), and 5284 wide (HIC) band (`w`) rows; the band definitions are the same as in release 3. There are 354 detections with `SPEAK_FLAGS = True`.

Column Definitions

<table>
<thead>
<tr>
<th>Column name</th>
<th>Units</th>
<th>Comment</th>
<th>Example</th>
<th>Data type</th>
<th>FITS format</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DETECT_ID</td>
<td></td>
<td></td>
<td><code>acisf08123456p012345_001</code></td>
<td>string</td>
<td>2BA</td>
<td>Highest source likelihood</td>
</tr>
<tr>
<td>Likelhood</td>
<td></td>
<td>Highest source log likelihood</td>
<td>108.6</td>
<td>double</td>
<td></td>
<td>Highest source likelihood</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Values are <code>TRUE</code> or <code>MARGINAL</code></td>
</tr>
</tbody>
</table>
How to get the data (2):
CSC1 site  cxc.cfa.harvard.edu/csc/

The Chandra Source Catalog

Click here for information about CSC Release 2

Release 1.1: Point and compact source catalog

What's New? | Watch On

The locations of observations included in the CSC, in Galactic coordinates (click the image for equatorial coordinates). The size of each symbol is proportional to the logarithm of the number of sources detected in the field, while the color encodes the number of closely-located observations.

The Chandra source catalog (CSC) is ultimately intended to be the definitive catalog of X-ray sources detected by the Chandra X-ray Observatory. To achieve that goal, the catalog will be released to the user community in a series of increments with increasing capability. The first official release of the CSC includes information about sources detected in public ACIS and HRG imaging observations from roughly the first eight years of the Chandra mission. Only point sources, and compact sources, with observed spatial extents $< 5$ arcseconds, are included. Highly extended sources, and sources located in selected fields containing bright, highly extended sources, are excluded from the first release.

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.

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 "source observation" 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.

The current version of the catalog is release 1.1. This version includes the information contained in release 1.0.3, plus point and compact source data extracted from HRC imaging observations, and catch-up ACIS observations released publicly prior to the end of 2009. A new version of CSCView is also available with this release.

The CSC-SDSS cross-match Catalog, the CSC Sensitivity Map Service, and the CSC interface to Sky in Google Earth have been updated as of 24 November 2010 to access release 1.1.
How to get the data (3): CSCView application

CSCView java application:
java -jar cscview.jar
Release 2.0 Catalog Data Products

FITS Catalog Data Products
- Per-Observation Full Field Data Products
  • Event list, exposure corrected image*, background image*, exposure map*, adaptively smoothed exposure map*, aspect solution (incl. fine astrometry updates), aspect histogram, bad pixel map, field of view, pixel mask, extended source region polygons* (multiple contour levels)
- Stack Full Field Data Products
  • Event list, exposure corrected image*, background image*, exposure map*, field of view, limiting sensitivity*, merged source detection list
- Per-Observation Source Region Data Products
  • Region definitions, region event list, region image*, local PSF* (~50K counts), region exposure map*, PHA spectrum, ARF, RMF, light curve*, position error MCMC draws*, aperture photometry PDF*
- Stack Source Region Data Products
  • Region definitions, region event list, region image*, region exposure map*, position error MCMC draws*
- Master Source Data Products
  • Bayesian block aperture photometry PDFs*, Bayesian block spectral fits, Bayesian block model fluxes*, Bayesian block hardness ratios, Bayesian block temporal properties*, master light curve*

* Multiple energy bands
Other Source Catalogs

- Chandra Orion Ultra-deep Point Source Catalog (COUP)
  - [http://heasarc.gsfc.nasa.gov/w3browse/chandra/coup.html](http://heasarc.gsfc.nasa.gov/w3browse/chandra/coup.html)

- Chandra Multi-wavelength Project (CHAMP)
  - [http://heasarc.gsfc.nasa.gov/w3browse/chandra/champpsc.html](http://heasarc.gsfc.nasa.gov/w3browse/chandra/champpsc.html)

- Bootes Field X-ray Point Source Catalog (XBOOTES)
  - [http://heasarc.gsfc.nasa.gov/w3browse/all/xbootes.html](http://heasarc.gsfc.nasa.gov/w3browse/all/xbootes.html)

- Catalog of AGN in the XMM-Newton Archive (CAIXA):
  - [https://heasarc.gsfc.nasa.gov/W3Browse/all/caixa.html](https://heasarc.gsfc.nasa.gov/W3Browse/all/caixa.html)

- And many more! Typically, these are *specialty* catalogs, can tailor their methods to their science. CSC & 3XMM must work *everywhere*.