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## Abstract

The *Chandra* Source Catalog (CSC) is ultimately intended to be the definitive catalog of X-ray sources detected by the *Chandra* X-ray Observatory (CXO). When compared to all previous and current X-ray missions, *Chandra* breaks the resolution barrier with an arcsecond scale on-axis point spread function. The combination of excellent spatial resolution, a reasonable field of view, and low instrumental background translate into a high detectable-source density, with low confusion and good astrometry. The wealth of information that can be extracted from identified serendipitous sources is a powerful and valuable resource for astronomy.

The aim of the CSC is to disseminate this wealth of information by characterizing the X-ray sky as seen by *Chandra*. The CSC provides simple access to *Chandra* data for individual sources or sets of sources matching user-specified search criteria. The catalog is intended to satisfy the needs of a broad-based group of scientists, including those who may be less familiar with astronomical data analysis in the X-ray regime. For each detected X-ray source, the catalog lists the source position and a detailed set of source properties, including multi-band aperture fluxes, X-ray colors and hardness ratios, spectra, temporal variability information, and source extent estimates. In addition to these traditional elements, the catalog includes file-based data products that can be manipulated interactively, including images, photon event lists, light curves, and spectra for each source individually from each observation in which a source is detected.

The first release of the CSC includes information for ~100,000 X-ray sources detected in a subset of public imaging observations from the first eight years of the *Chandra* mission. Only point sources, and compact sources with extents <~30 arcsec, are included. Highly extended sources, and sources located in selected fields containing bright, highly extended sources, are excluded from this release.

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## Catalog Contents

The first release of the CSC includes sources detected with a minimum 3 $\sigma$  significance level above the background (typically corresponding to about 10 net source counts on-axis and roughly 20–30 net source counts off-axis).

For each detected source and observation, the catalog includes the following properties:

- Source position and errors,
- Aperture photometry fluxes and errors in several energy bands,
- Spectral hardness ratios,
- Power-law and thermal black-body spectral fits for bright sources,
- Source variability measures,
- Estimates of the source extent compared to the local PSF.

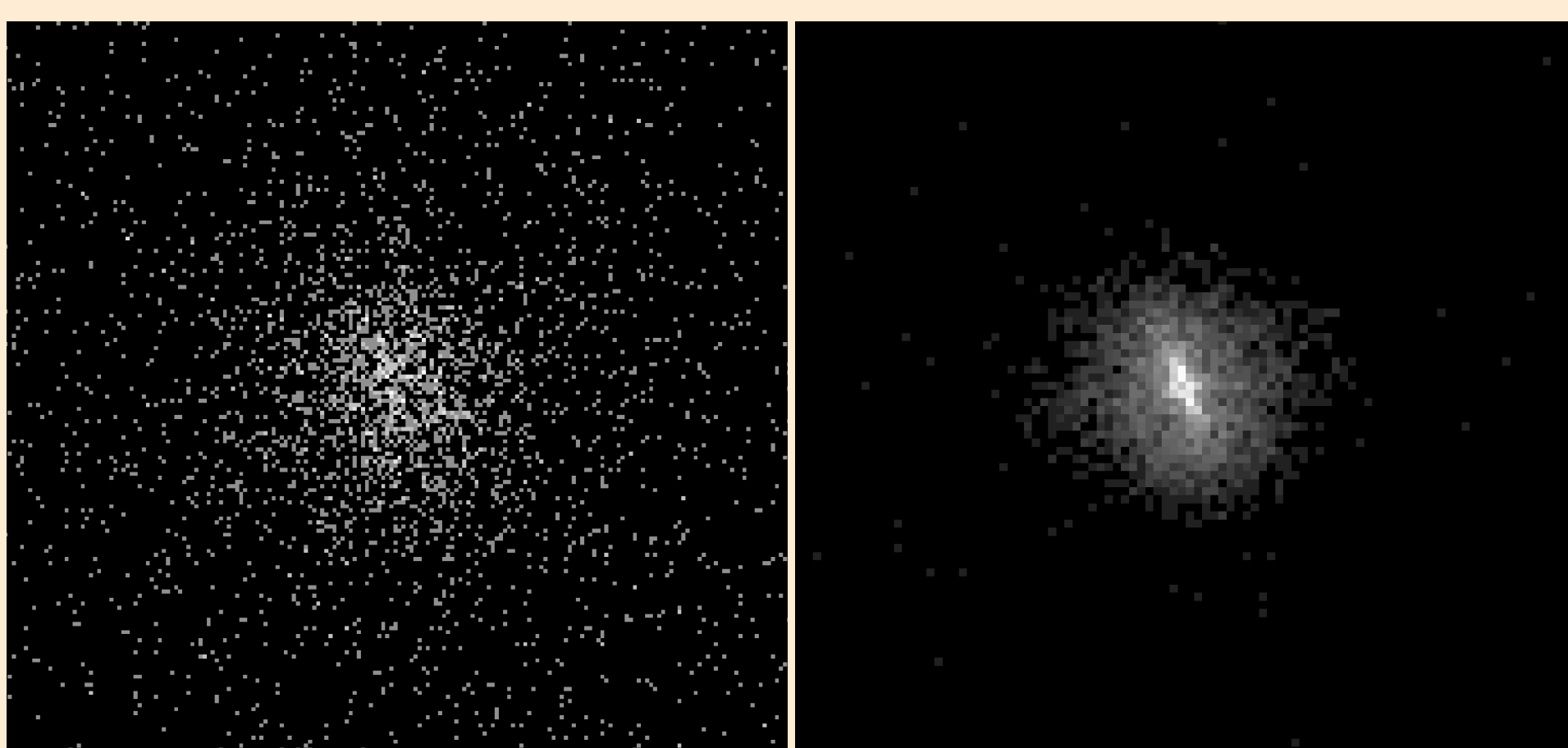
In addition, a number of file-based data products are produced for each observation and source individually, suitable for analysis in the CIAO data analysis environment. They include full field images, exposure map, and limiting sensitivity map; together with source region and PSF images, source region exposure map, source light-curve, source region photon event list, and (for ACIS) source PI spectrum, ARF, and RMF.

Each release of the CSC will include a complete characterization of the statistical properties of the catalog, determined using a combination of simulations and real data sets reported in other published *Chandra* catalogs.

Since *Chandra* is an on-going mission, new observations are continually becoming public and being added to the CSC database. Users may choose to interact with the catalog via a *Catalog Release View* or a *Database Access View*. A *Catalog Release View* provides access to a carefully reviewed, static release of the CSC, and is appropriate for the user who requires a homogeneous dataset with a detailed statistical characterization. A *Database Access View* provides direct access to the active CSC database. This view includes recently processed datasets which have not yet been included in a catalog release, and may be appropriate for users who wish to search the latest data, for example to identify sources with specific signatures for followup studies.

## Source Position and Extent

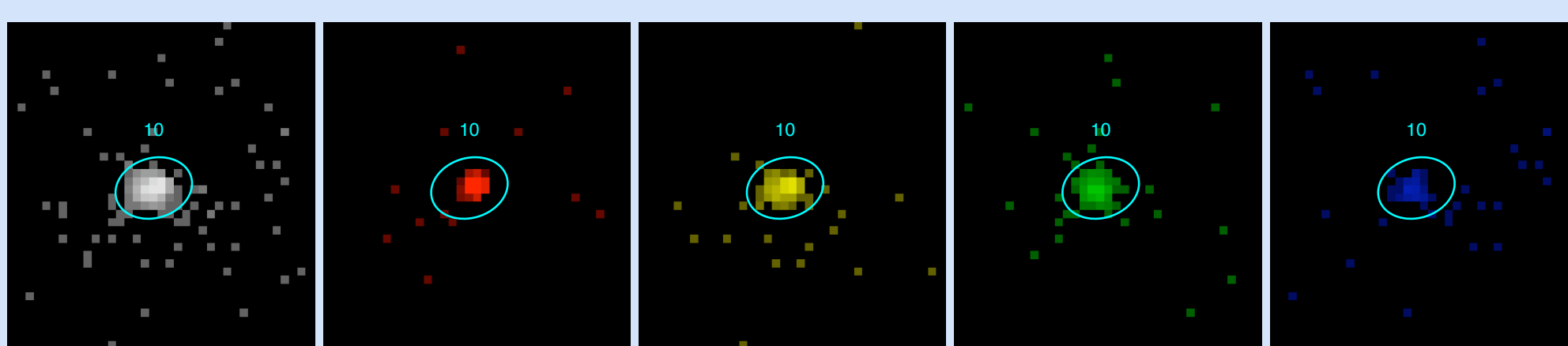
The CSC includes the best estimate of the source position measured from each observation, as well as raw (measured) source and PSF extents, and the deconvolved source extent in each energy band.



This figure shows the broad band image of the mildly extended (~1.2" deconvolved size) source CXO J140037.1+622132, observed at an off-axis angle  $\theta \sim 9.2'$ , on the left, with the associated model PSF on the right.

## Aperture Photometry

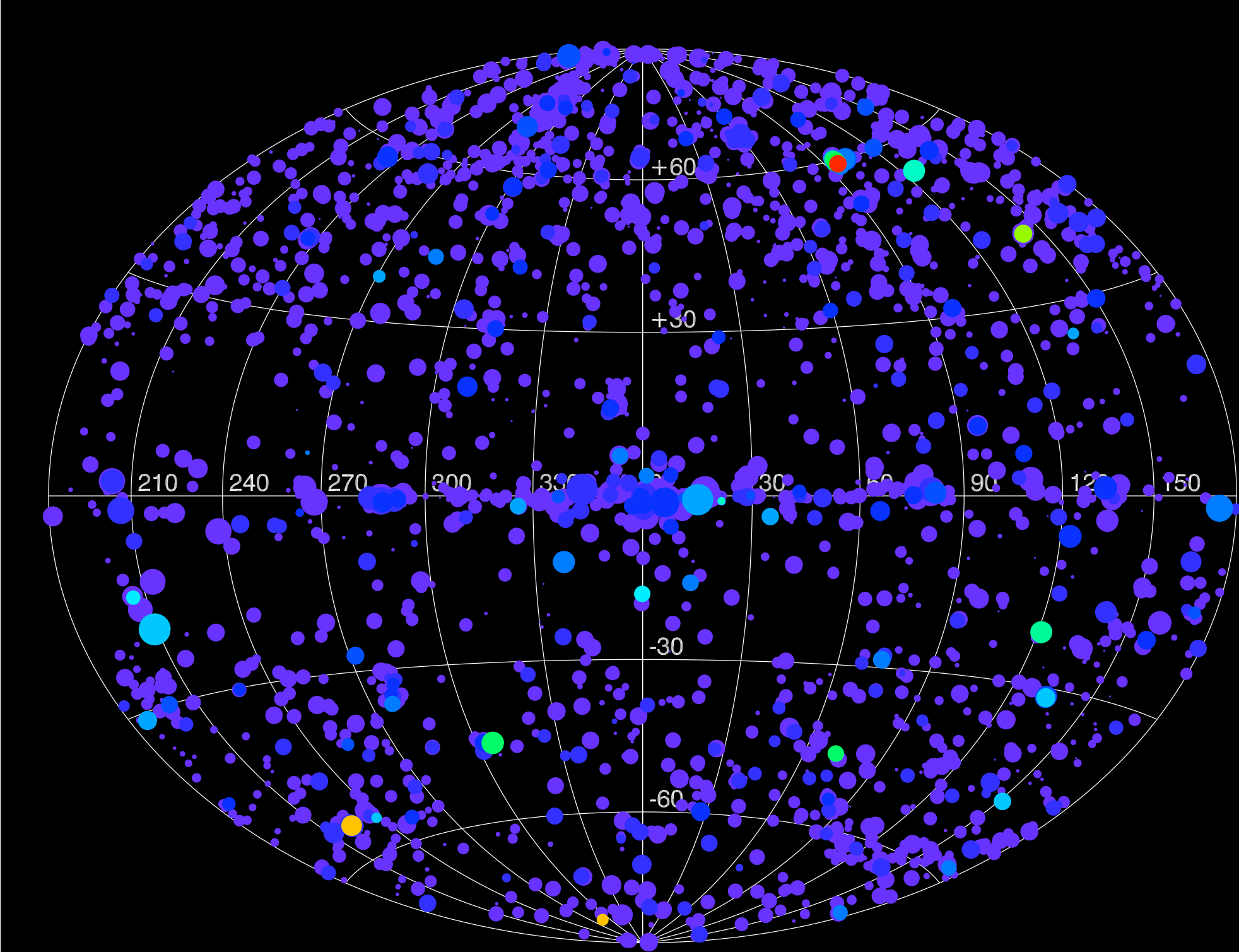
The CSC computes source aperture photometry from ACIS observations in 5 energy bands — broad (0.5–7.0 keV), ultra-soft (0.2–0.5 keV), soft (0.5–1.2 keV), medium (1.2–2.0 keV), and hard (2.0–7.0 keV) — using multiple methods. Band images and exposure maps are provided for each source, together with a full-field limiting sensitivity map.



This figure shows the broad, ultra-soft, soft, medium, and hard band event images of the source CXO J021920.8-025840. The source region aperture is superimposed in cyan.

## Catalog Sources

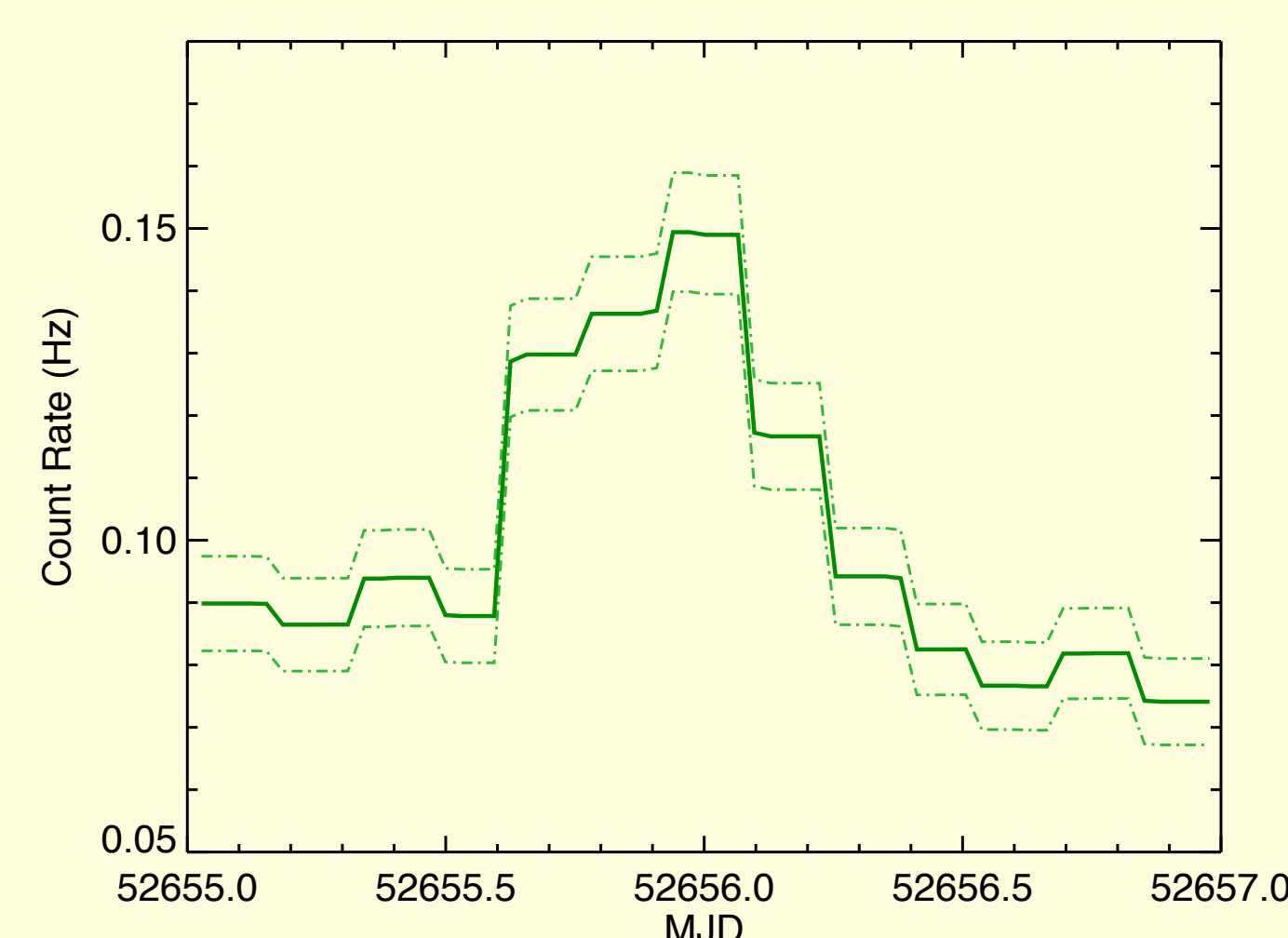
The first release of the CSC includes sources detected in public ACIS imaging observations from roughly the first 8 years of the *Chandra* mission.



This figure shows the locations of observations included in the CSC (in Galactic 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.

## Variability Measures

The CSC includes several source variability measures, both within a single observation of a source and between multiple observations that include the same source. Intra-observation measures include K-S and Kuiper test probabilities, and a Gregory-Loredo odds ratio. An optimally binned light curve is produced for each source.



This figure shows the optimally binned light curve for CXO J053515.2-052256.

## Catalog Releases

**Release 1** (January 2009) includes information about sources detected in public ACIS imaging observations. *Only point and compact sources, with observed spatial extents < ~30 arcsec, are included.* Observations of fields containing extended sources have been excluded from the catalog, or in some cases only a part of the field has been included. *Multiple observations of the same field are not co-added prior to performing source detection;* source detection is performed on each observation individually.

**Release 1.1** (Fall 2009) extends Release 1 to include public HRC-I imaging observations, and newly public ACIS observations, but otherwise retains the same limitations as Release 1.

**Release 2** (2010) co-adds multiple observations of the same field that use the same instrument prior to source detection, to achieve fainter limiting sensitivities, as well as providing improvements in extended source handling.

**Future Releases** will see improvements in simultaneous source detection across overlapping observations with different detectors and pointings (and thus very different local PSFs), and detection and classification of extremely extended sources.

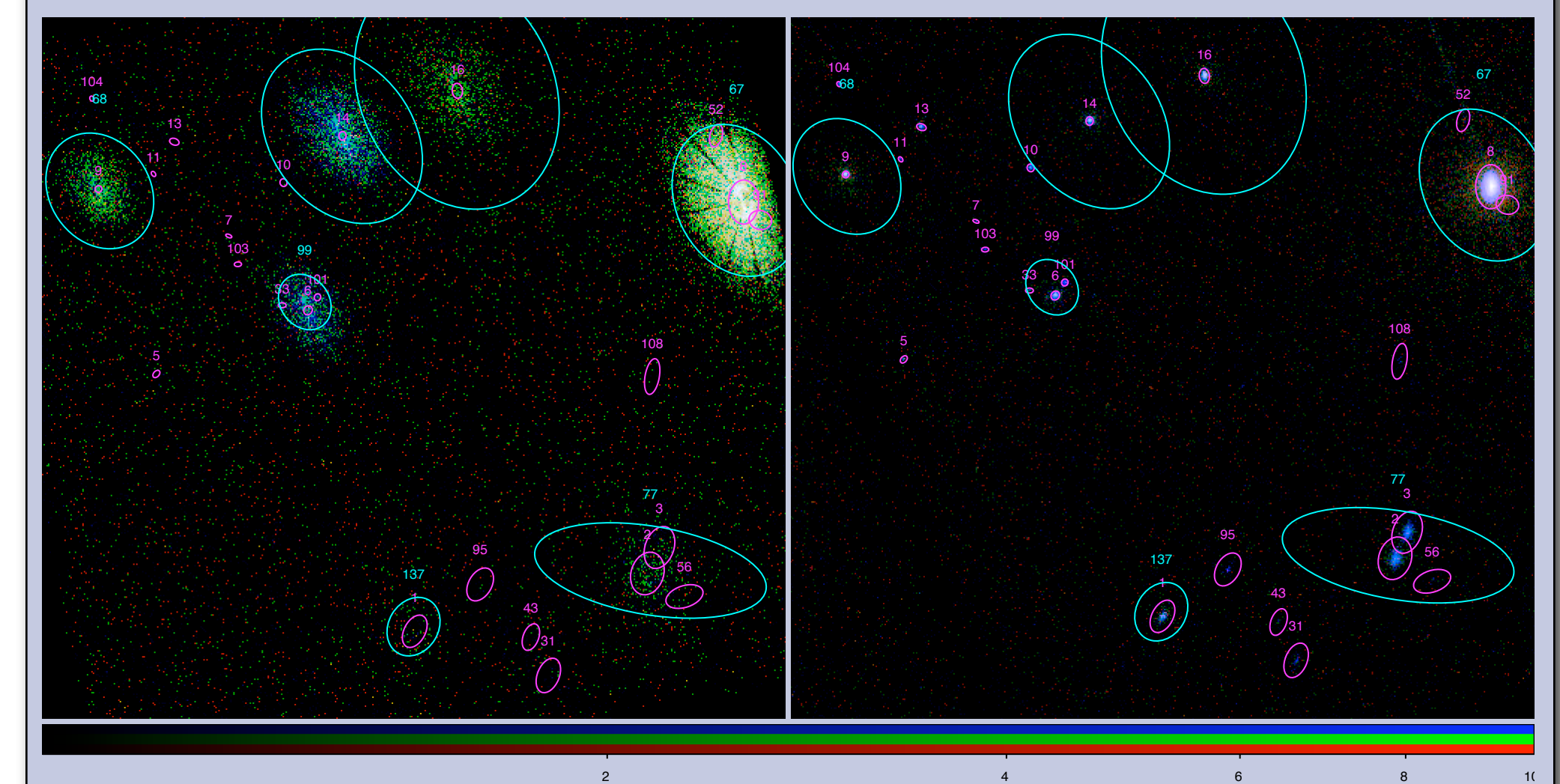
## Catalog Organization

Each distinct X-ray source on the sky identified in the CSC is represented by a single *Master Chandra Source Table* entry and one or more entries in the *Table of Individual Source Observations* (one entry for each observation in which the source was detected).

The Table of Individual Source Observations contains source properties derived independently from each *Chandra* observation in which the source is detected. This table also includes observation-specific properties, such as pointing and instrument information, as well as links to full-field and per-source file-based data products.

The *Master Chandra Source Table* includes a single entry for each distinct identified X-ray source on the sky. If a source is detected in multiple observations that overlap the same region of sky, then that entry is produced by merging the corresponding entries from the table of individual source observations. The resulting properties are the "best estimates" of the actual source properties derived from the set of individual source observations contributing to the master source.

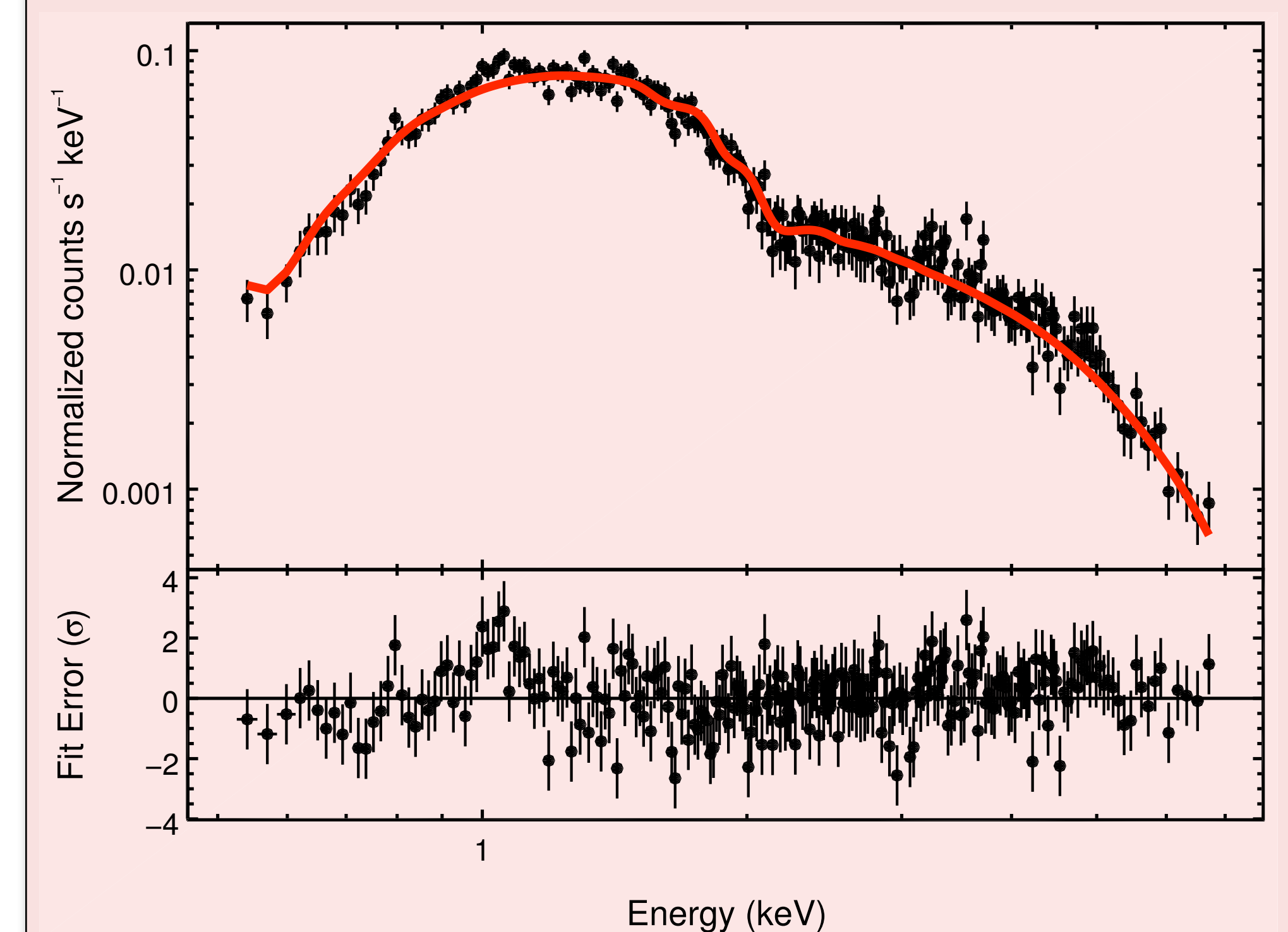
Bidirectional links within the catalog database connect each *Master Chandra Source Table* entry with its associated entries in the Table of Individual Source Observations. These links enable the user to uniquely associate multiple observations of the same source, as well as identify any confused off-axis sources that may be associated with multiple master sources.



This figure shows source detections from two observations that include the same region of the field of  $\rho$  Oph. Source regions detected in the off-axis observation at left are shown in cyan, while source regions detected in the on-axis observation at right are shown in magenta. Properties of detected sources in each observation are recorded in the Table of Individual Source Observations, while the *Master Chandra Source Table* will include a single entry for each unique source on the sky.

## Spectral Properties

The CSC includes three-band spectral hardness ratios for all detected sources, and absorbed power-law and black-body spectral fits for sources with at least 150 net counts. Source pulse-invariant spectra and spectral response matrices are produced for sources detected in ACIS observations.



This figure shows a power-law spectral fit to the X-ray spectrum of CXO J053455.6-052937.

For more information about the *Chandra* Source Catalog, please refer to the public catalog web pages at the following URL: <http://cxc.cfa.harvard.edu/csc/>