Progress Report

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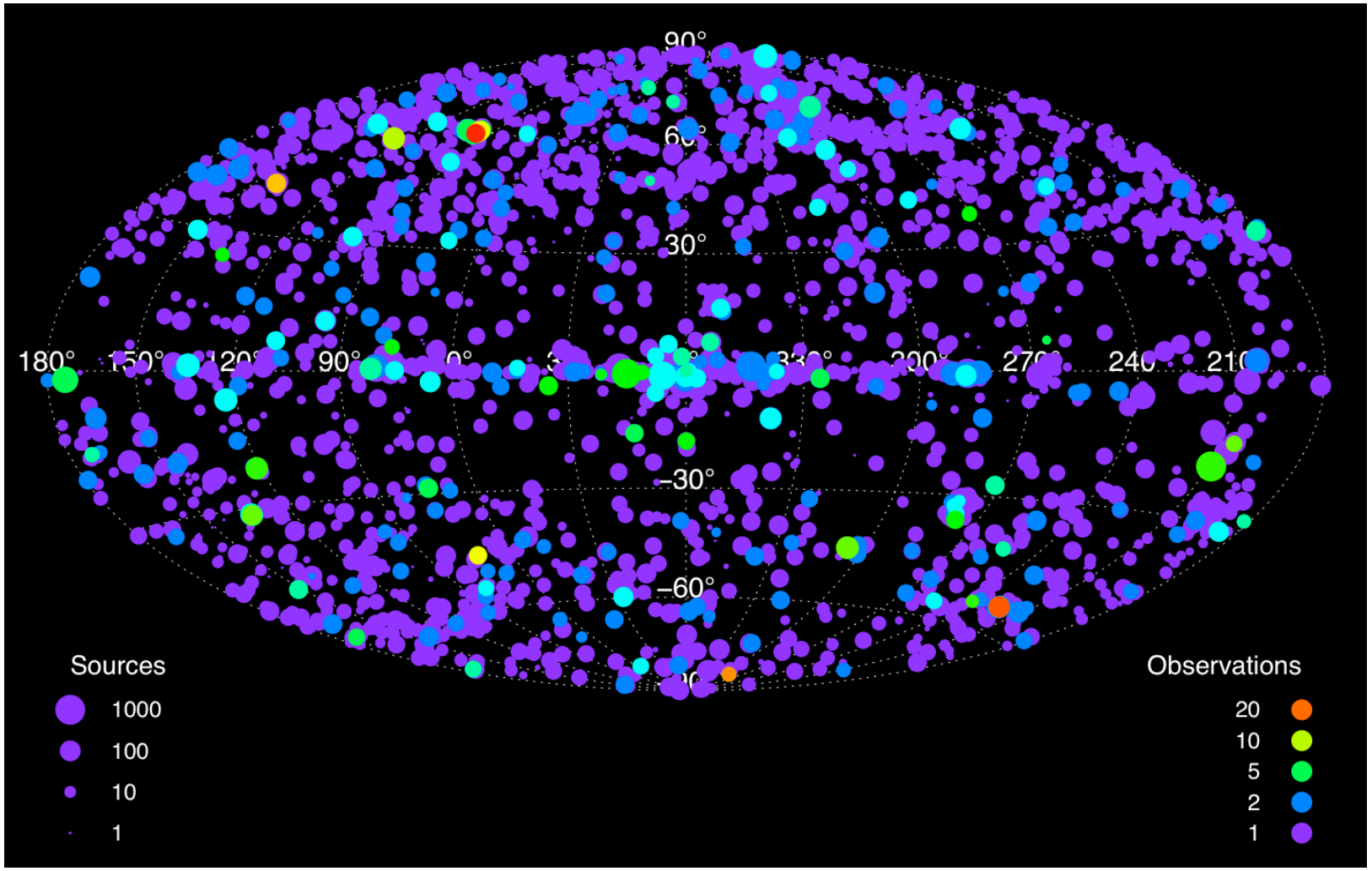
On behalf of the Chandra Source Catalog Project Team

Chandra Users' Committee Meeting
April 6, 2009

Summary

- ***Released version 1 of the Chandra Source Catalog on March 4, 2009***
  - This release of the catalog includes
    94,676 master Chandra sources (unique sources on the sky)
    135,914 individual source observations (detected-source regions)
    3,921 observation intervals
- Release includes point and compact sources detected in a subset of ACIS imaging observations released publicly prior to 2009
  - Only sources with observed spatial extents <~30 arcseconds are included
  - Observations with highly extended sources are either excluded, or a subset of the active CCDs are included if the extended source is restricted to a single chip
  - Multiple observations of the same field are not co-added prior to source detection
  - Future catalog releases will relax these restrictions
- The release includes an extensive statistical characterization of the derived source properties included in the catalog

Chandra Source Catalog Observations



- 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

Science Highlights Since Last CUC Meeting

- Completed catalog production and release 1, including statistical characterization release 1 liens
- Updated public web site with latest user documentation and threads
  - **http://cxc.cfa.harvard.edu/csc/**
- Documents and publications delivered
  - "Chandra Source Catalog Requirements version 1.0"
  - "Statistical Characterization of the Chandra Source Catalog, Release 1"
  - Posters presented at the January AAS
    - "The Chandra Source Catalog" — I. N. Evans et al.
    - "The Chandra Source Catalog: User Interface" — N. R. Bonaventura et al.
    - "The Chandra Source Catalog: Source Properties and Data Products" — A. H. Rots et al.
    - "The Chandra Source Catalog: Spectral Properties" — S. M. Doe et al.
    - "The Chandra Source Catalog: Statistical Characterization" — F. A. Primini et al.
    - "The Chandra Source Catalog: Algorithms" — J. C. McDowell et al.
    - "The Chandra Source Catalog: Processing and Infrastructure" — J. D. Evans et al.
    - "The Chandra Source Catalog: Automated Source Correlation" — R. Hain et al.
    - "The Chandra Source Catalog: X-ray Aperture Photometry" — V. L. Kashyap et al.
    - "The Chandra Source Catalog: Background Determination and Source Detection" — M. L. McCollough et al.
    - "The Chandra Source Catalog: Source Variability" — M. Nowak et al.
  - Catalog paper (Evans et al.) and statistical characterization paper (Primini et al.) currently in advanced stages of preparation

Software Highlights Since Last CUC Meeting

- CAT 3.0 (Production system) build
  - Minor patches to maintain CSC operations

CAT 3.0.3	Nov 17	ACIS 1-chip filtering / QA update / few bug-fixes
CAT 3.0.4	Dec 04	Master pipeline bug-fix (no science changes)
CAT 3.0.5	Dec 16	Archive server upgrade; added 2008 leap second
CAT 3.0.6	Dec 22	Master pipeline/Repro bug-fix
CAT 3.0.7	Jan 26	Merge Review GUI bug-fix
CAT 3.0.8	Feb 09	Master Pipeline Repro support through Merge Review GUI
CAT 3.0.9	Feb 19	Aper_90 per obi source bug-fix
CAT 3.0.10	Feb 25	Release 1 migration tasks

- CAT 3.1 (Release system) build
  - CSCview bug-fixes and enhancements
- Software team ran catalog pipeline processing operations for release 1 production and statistical characterization simulation runs

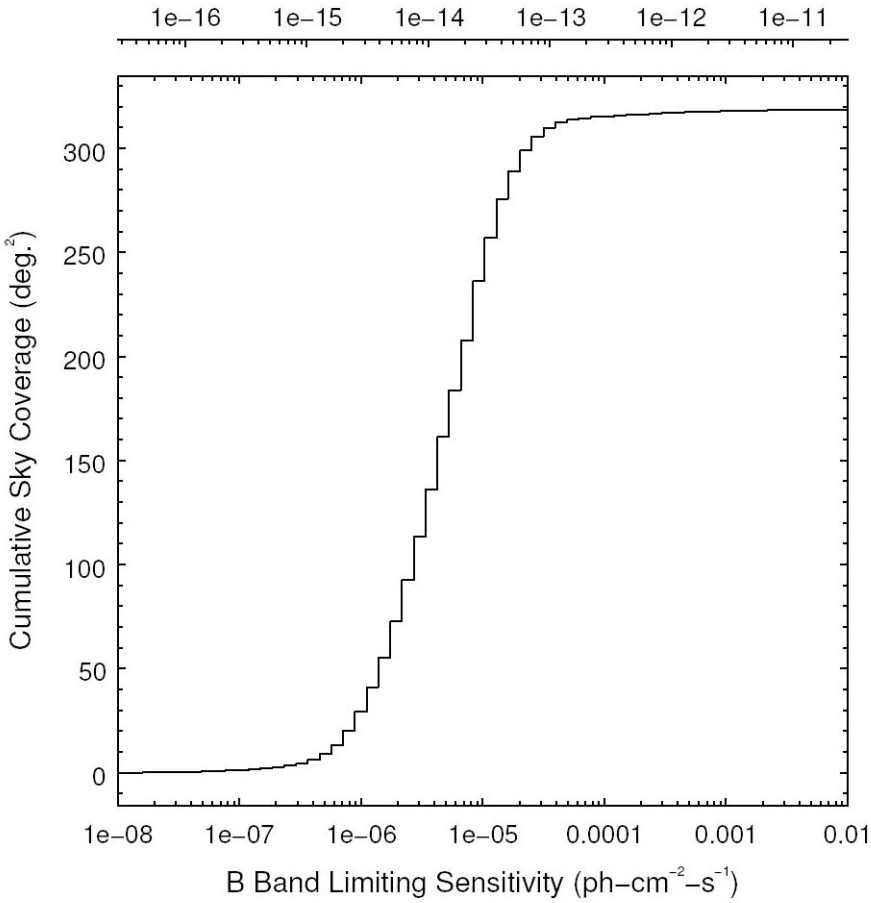
Catalog Statistical Characterization

- Statistical characterization is a scientifically essential component of the CSC
  - Characterization determines statistically how well the science algorithms used in catalog construction actually performed
  - Statistical characterization provides the user with the information to judge whether a particular line of enquiry is feasible using the catalog release data
- Statistical characterization of catalog source properties is accomplished primarily by processing simulated datasets through the catalog pipelines
- Characterization is an ongoing, evolving process
  - The results provided with the catalog release give a good overview of the general catalog properties
  - Some specific questions identified during production or with existing characterization runs have still to be addressed
    - E.g.: source detection efficiency in the vicinity of the bright, crowded cores of galaxies
  - Feedback from users will identify areas where existing characterization should be refined
- Statistical characterization results are published on the catalog web site
  - **http://cxc.cfa.harvard.edu/csc/char.html**

Catalog Properties: Sky Coverage

Sky Coverage

- The sky coverage represents the total area in the CSC sensitive to point sources greater than a given flux, as a function of flux
  - We estimate sky coverage by assigning all non-zero limiting sensitivity map values to all-sky pixels, keeping only the most sensitive value in each all-sky pixel
- Approximate sky coverage
  - ~300 deg^2 at 2×10^{-5} photons cm^{-2} s^{-1} (~ 5×10^{-14} ergs cm^{-2} s^{-1})
  - ~70 deg^2 at 2×10^{-6} photons cm^{-2} s^{-1} (~ 5×10^{-15} ergs cm^{-2} s^{-1})
  - ~6 deg^2 at 4×10^{-7} photons cm^{-2} s^{-1} (~ 1×10^{-15} ergs cm^{-2} s^{-1})

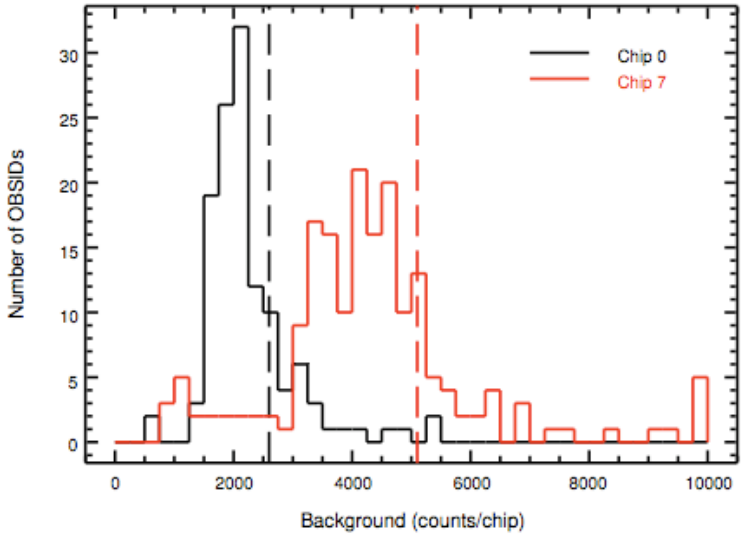


Total ACIS "b" band sky coverage is ~320 deg^2

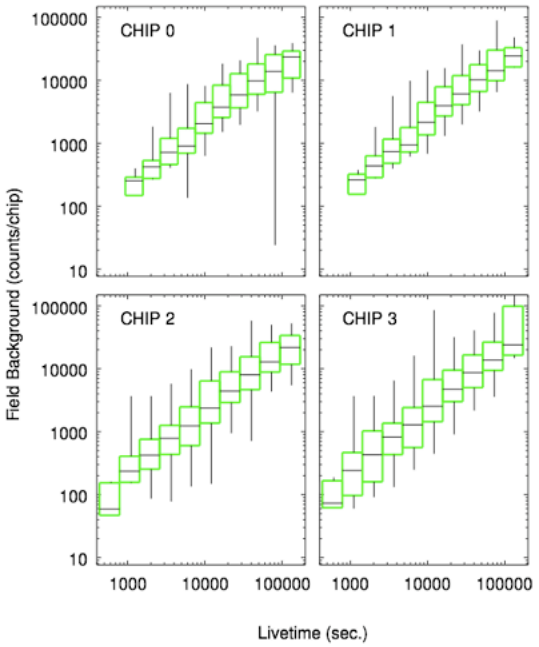
Catalog Properties: Field Background

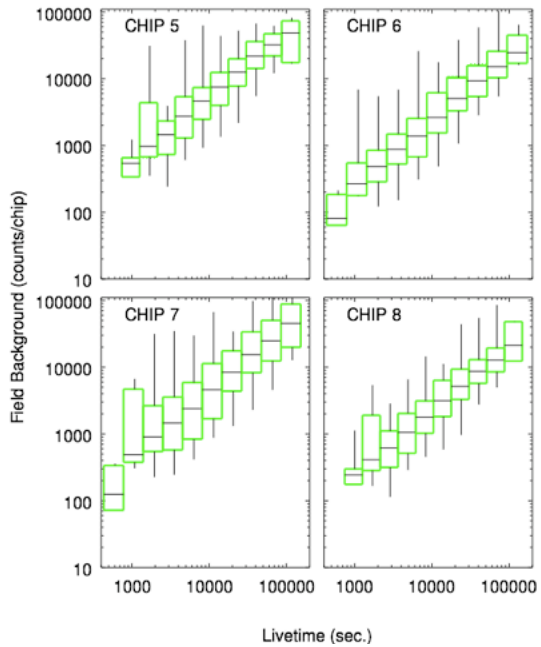
Field Background

- Top panel: distribution of chip 0 and chip 7 ACIS "b" band background estimated from CSC 10 ks event lists with sources removed
  - Dashed vertical lines indicate the values cited in version 11 of the POG
  - Event screening performed in the CSC pipeline processing is more aggressive than that done in standard data processing, so the non-X-ray background is typically reduced



- Bottom panel: field background per chip *vs.* livetime
  - Median background counts per bin are indicated by horizontal lines
  - Boxes include 95% of the measurements in each bin, and vertical lines indicate extreme values

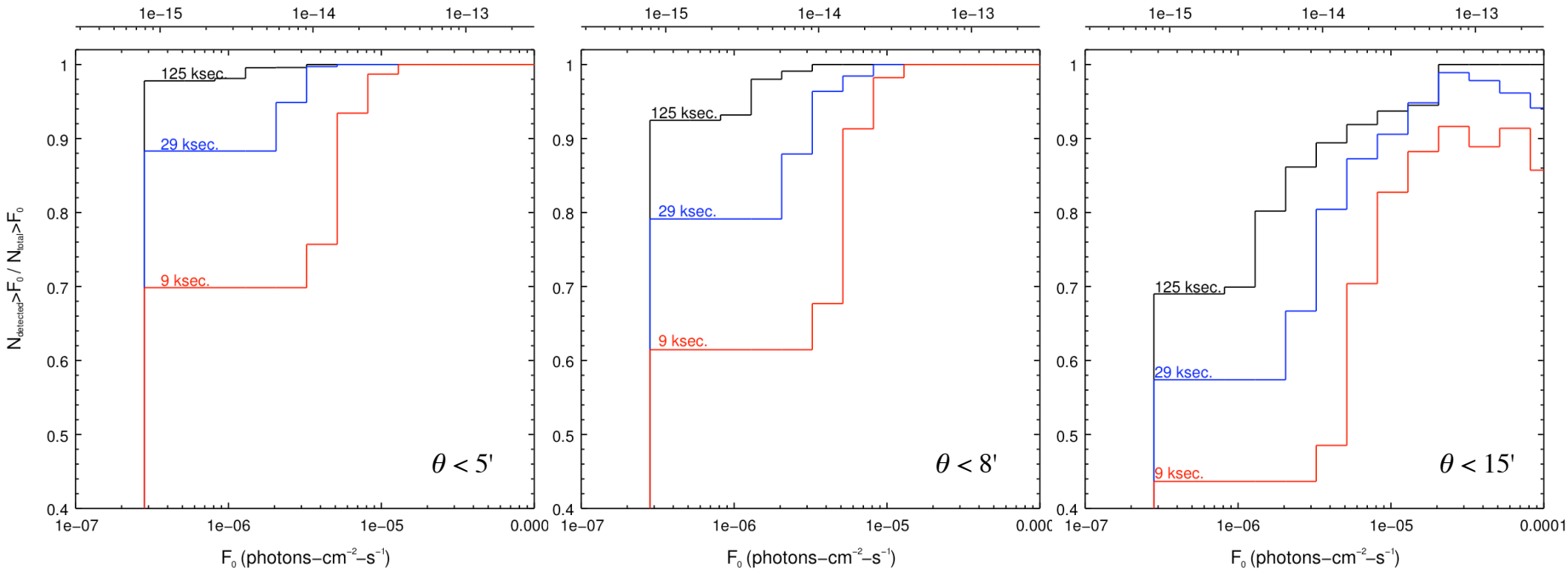




Catalog Properties: Source Detection Efficiency

Source Detection Efficiency

- Estimated from fraction of simulated sources of a given flux actually detected
  - Simulated absorbed ($N_H = 3\times10^{20}$ cm^{-2}) power-law ($E^{-1.7}$) and blackbody ($kT = 1.0$ keV) spectra, with a power-law $N > S$ distribution with index 1.5

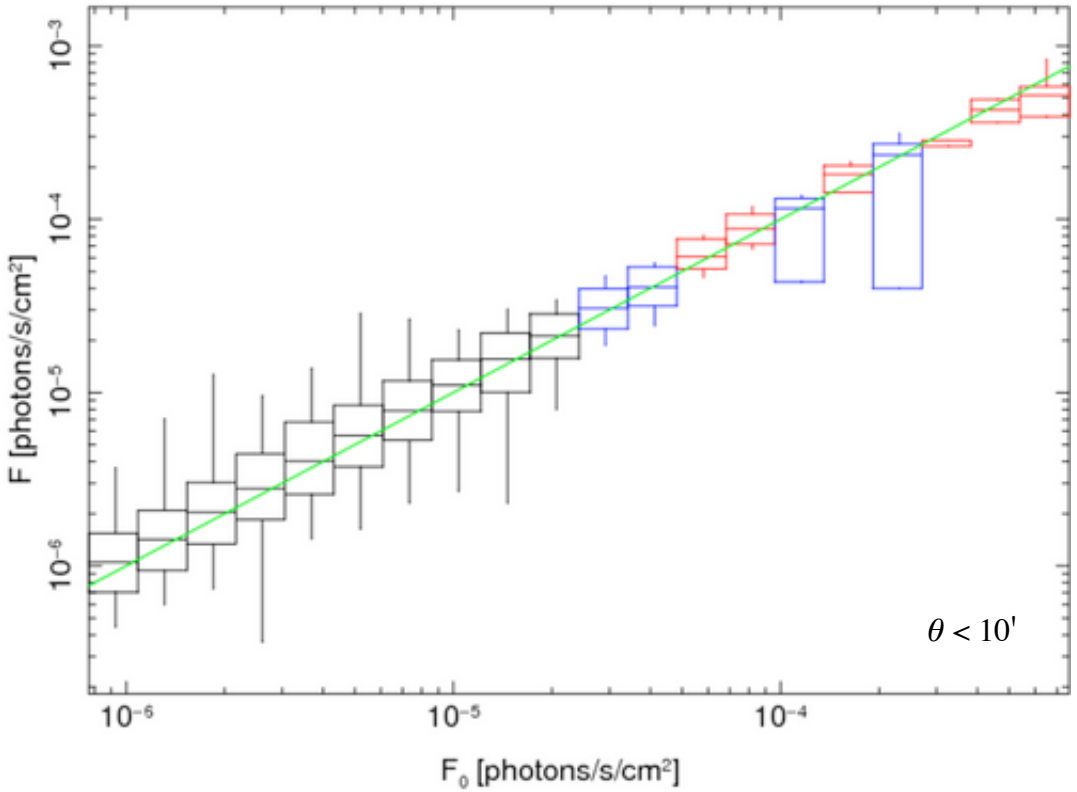


- High flux end suffers from low number statistics
- Reduced efficiencies for the $\theta < 15'$ curves are real and indicate reduced sensitivity at large values of θ because of the increased aperture background

Catalog Properties: Flux Accuracy

Flux Accuracy

- Estimated from comparison of the input and measured fluxes of the simulated source
- Results indicate good agreement for sources within 10' of the aim point
  - For sources beyond 10', there appears to systematic overestimate of a factor of ~2 for sources fainter than ~3 x 10^{-6} photons cm^{-2} s^{-1}

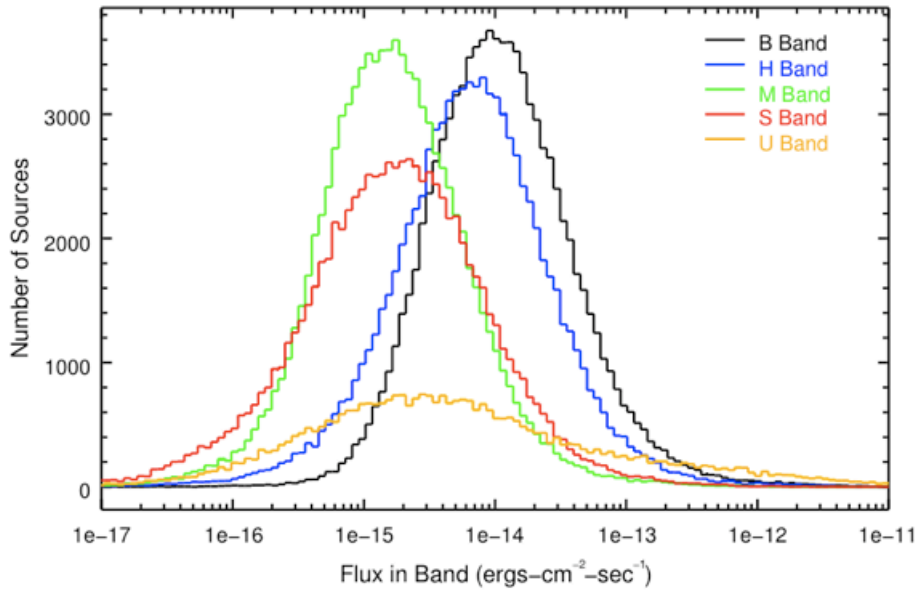


- Comparison of input and measured ACIS 'b' band fluxes for sources with power-law spectra
  - Bins in **red** contain fewer than 100 measurements; bins in **blue** contain 100–400 measurements; bins in **black** contain more than 400 measurements

Catalog Properties: Flux Distribution

Flux Distribution

- Although CSC fluxes range from below ~10^{-18} erg cm^{-2} sec^{-1} (for the deepest exposures) to ~10^{-10} erg cm^{-2} sec^{-1}, most CSC sources have fluxes of ~10^{-15}–10^{-13} erg cm^{-2} sec^{-1} (ACIS "b" band, or 0.5–7.0 keV)



- Distribution of CSC fluxes in the broad (black), hard (blue), medium (green), soft (red), and ultra-soft (orange) bands, obtained from the catalog master source table flux_aper column

Catalog User Interface Updates

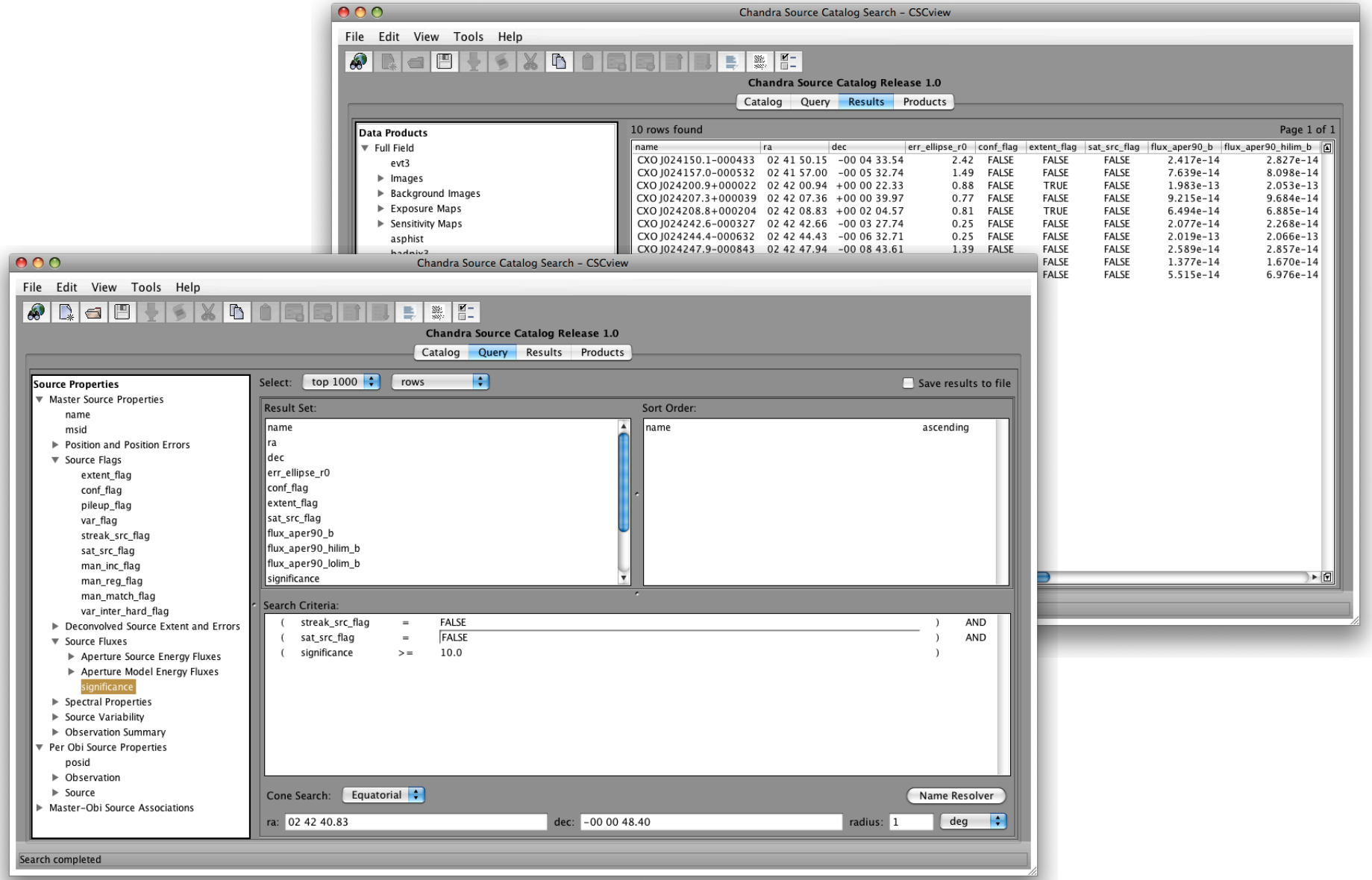
CSCview

- CSCview is the primary user interface to the catalog
  - Available on the web via the catalog user website
  - Java applet runs in the user's web browser (requires Java version 1.5 or later)
- Numerous enhancements since last CUC meeting
  - Improved human interface looks more like a typical application
    - Standardized layout of menus, buttons, forms; standardized icons etc.
  - Supports ADQL VO query language in addition to the form interface
  - Provides access to several "pre-canned" result sets
    - These will be made more visible in a future release
  - Much improved interface for accessing and retrieving file-based data products
  - Improved boolean expression functionality for query form search criteria
  - Improved cone search functionality, including name resolution
  - Provides better extensibility "under the hood"

cURL/wget Interface

- Updated to accept ADQL queries

CSCview GUI


Chandra Source Catalog Search – CSCview
File Edit View Tools Help
Chandra Source Catalog Release 1.0
Catalog Query Results Products
Data Products
Full Field
evt3
Images
Background Images
Exposure Maps
Sensitivity Maps
asphist
10 rows found
Page 1 of 1
name ra dec err_ellipse_r0 conf_flag extent_flag sat_src_flag flux_aper90_b flux_aper90_hilim_b
CXO J024150.1-000433 02 41 50.15 -00 04 33.54 2.42 FALSE FALSE FALSE 2.417e-14 2.827e-14
CXO J024157.0-000532 02 41 57.00 -00 05 32.74 1.49 FALSE FALSE FALSE 7.639e-14 8.098e-14
CXO J024200.9+000022 02 42 00.94 +00 00 22.33 0.88 FALSE TRUE FALSE 1.983e-13 2.053e-13
CXO J024207.3+000039 02 42 07.36 +00 00 39.97 0.77 FALSE FALSE FALSE 9.215e-14 9.684e-14
CXO J024208.8+000204 02 42 08.83 +00 02 04.57 0.81 FALSE TRUE FALSE 6.494e-14 6.885e-14
CXO J024242.6-000327 02 42 42.66 -00 03 27.74 0.25 FALSE FALSE FALSE 2.077e-14 2.268e-14
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FALSE FALSE 1.377e-14 1.670e-14
FALSE FALSE 5.515e-14 6.976e-14
Chandra Source Catalog Search – CSCview
File Edit View Tools Help
Chandra Source Catalog Release 1.0
Catalog Query Results Products
Source Properties
Master Source Properties
name
msid
Position and Position Errors
Source Flags
extent_flag
conf_flag
pileup_flag
var_flag
streak_src_flag
sat_src_flag
man_inc_flag
man_reg_flag
man_match_flag
var_inter_hard_flag
Deconvolved Source Extent and Errors
Source Fluxes
Aperture Source Energy Fluxes
Aperture Model Energy Fluxes
significance
Spectral Properties
Source Variability
Observation Summary
Per Obi Source Properties
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Observation
Source
Master-Obi Source Associations
Select: top 1000 rows
Save results to file
Result Set:
name
ra
dec
err_ellipse_r0
conf_flag
extent_flag
sat_src_flag
flux_aper90_b
flux_aper90_hilim_b
flux_aper90_lolim_b
significance
Sort Order:
name ascending
Search Criteria:
(streak_src_flag = FALSE) AND
(sat_src_flag = FALSE) AND
(significance >= 10.0)
Cone Search: Equatorial
Name Resolver
ra: 02 42 40.83
dec: -00 00 48.40
radius: 1
deg
Search completed

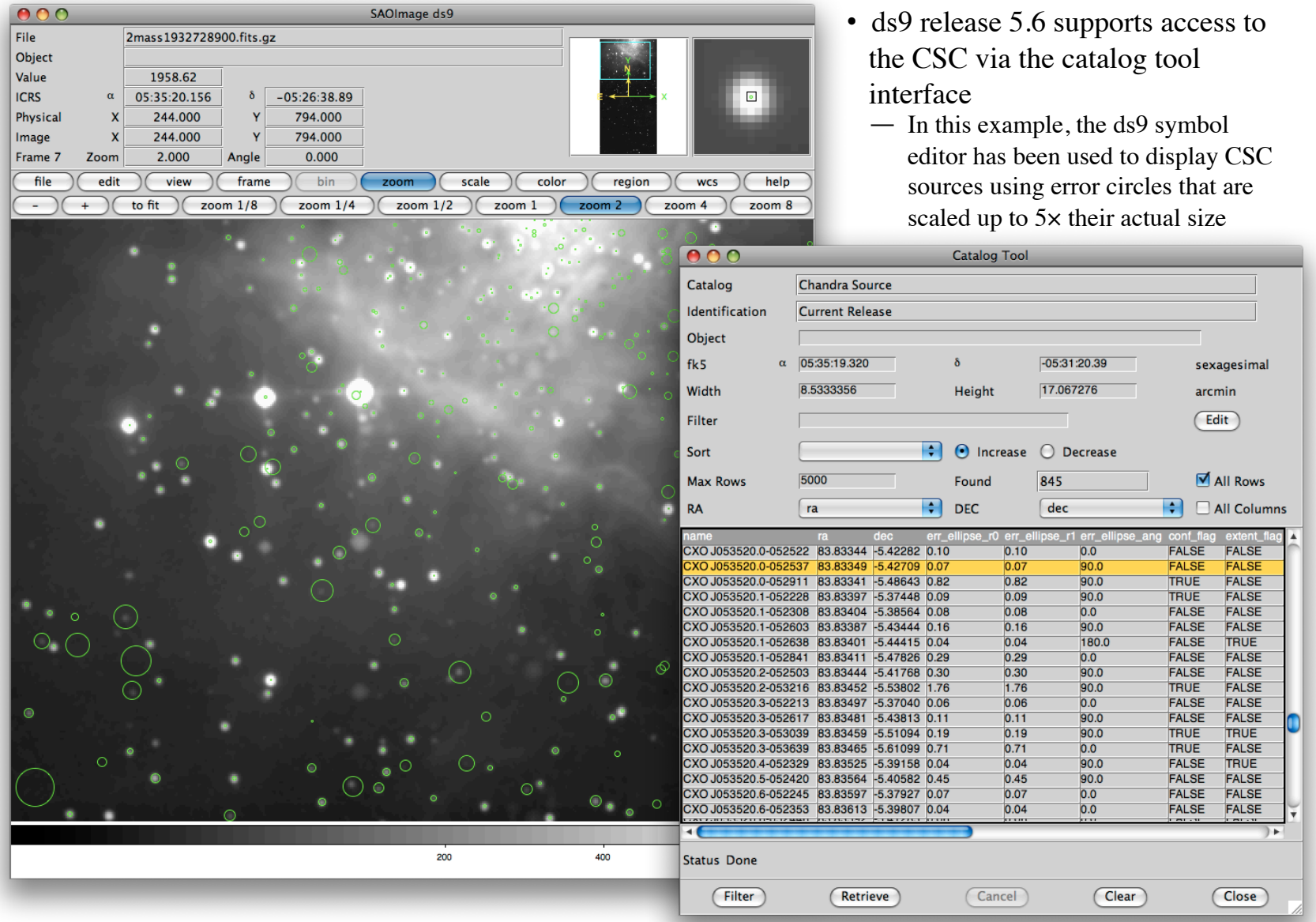
Short Term Plans

- Catalog Releases
  - 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 Rel. 1
- Public Interfaces
  - CSCview GUI
    - Additional output file formats for query results (VOTable, Vizier TSV)
    - Support for cross-matching with user supplied catalogs
    - SAMP interface
  - Web Services
    - VO cone search service
    - Catalog limiting sensitivity and footprint services
    - CSC — SDSS (DR7) cross-match
  - Additional Interfaces
    - Display catalog sources directly in **`ds9`** version 5.6
    - Google Sky Interface
      - » Catalog visualization for both scientific and education/public outreach users
    - External Interfaces
      - » CSC file dumps currently works with **`TOPCAT`** ("TST" format)
      - » In discussions with Vizier to host catalog tables
- CIAO tools
  - A number of the catalog-related tools will be made available to users in CIAO 4.1.2/4.2
    - Details discussed in SDS CIAO presentation

Longer Term Plans

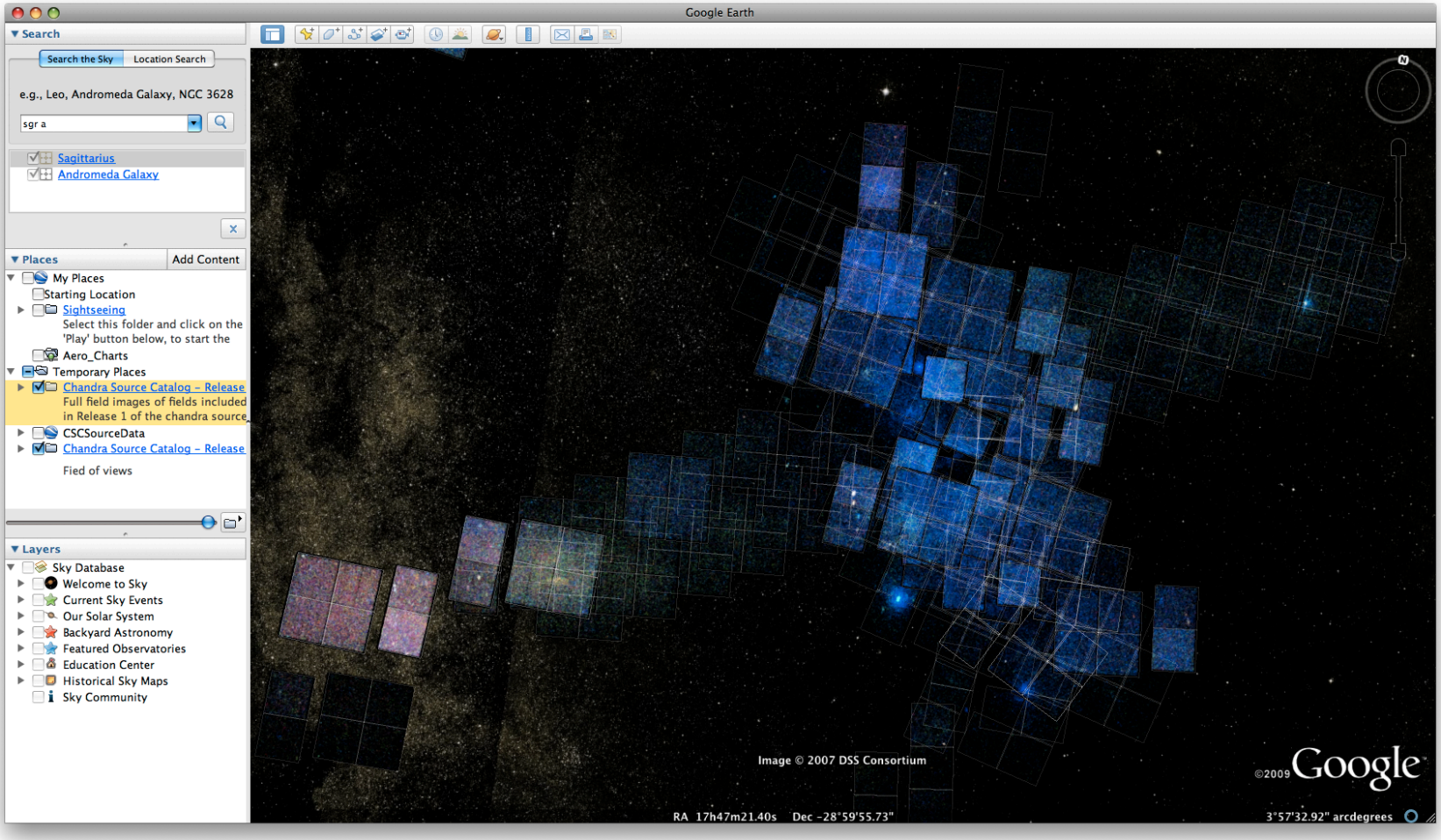
- Catalog releases
  - Catalog Release 2 (late 2010)
    - Co-add multiple observations of the same field that use the same instrument prior to source detection to achieve fainter limiting sensitivities
    - Improve background modeling, particularly in areas of extended emission
    - Improve aperture photometry in crowded fields
    - Improve extended source handling
  - Future Releases
    - Simultaneous source detection across overlapping observations with different detectors and pointings (and thus very different local PSFs)
    - Detection and classification of very extended sources
- Detailed plans for Release 2 and later are not fully established
  - Items identified above for Release 2 will have significant impact on the depth and quality of the catalog
  - Plan is to seek community feedback for guiding further development
    - Want input from a broad audience that includes the general multi-wavelength community and well as experienced Chandra users
    - Catalog needs several month soak period in the community for useful feedback from a wider audience
    - Consider establishing community working groups with focus on specific areas of complexity (such as robust extended source detection) if there is sufficient interest

ds9 Release 5.6 Interface



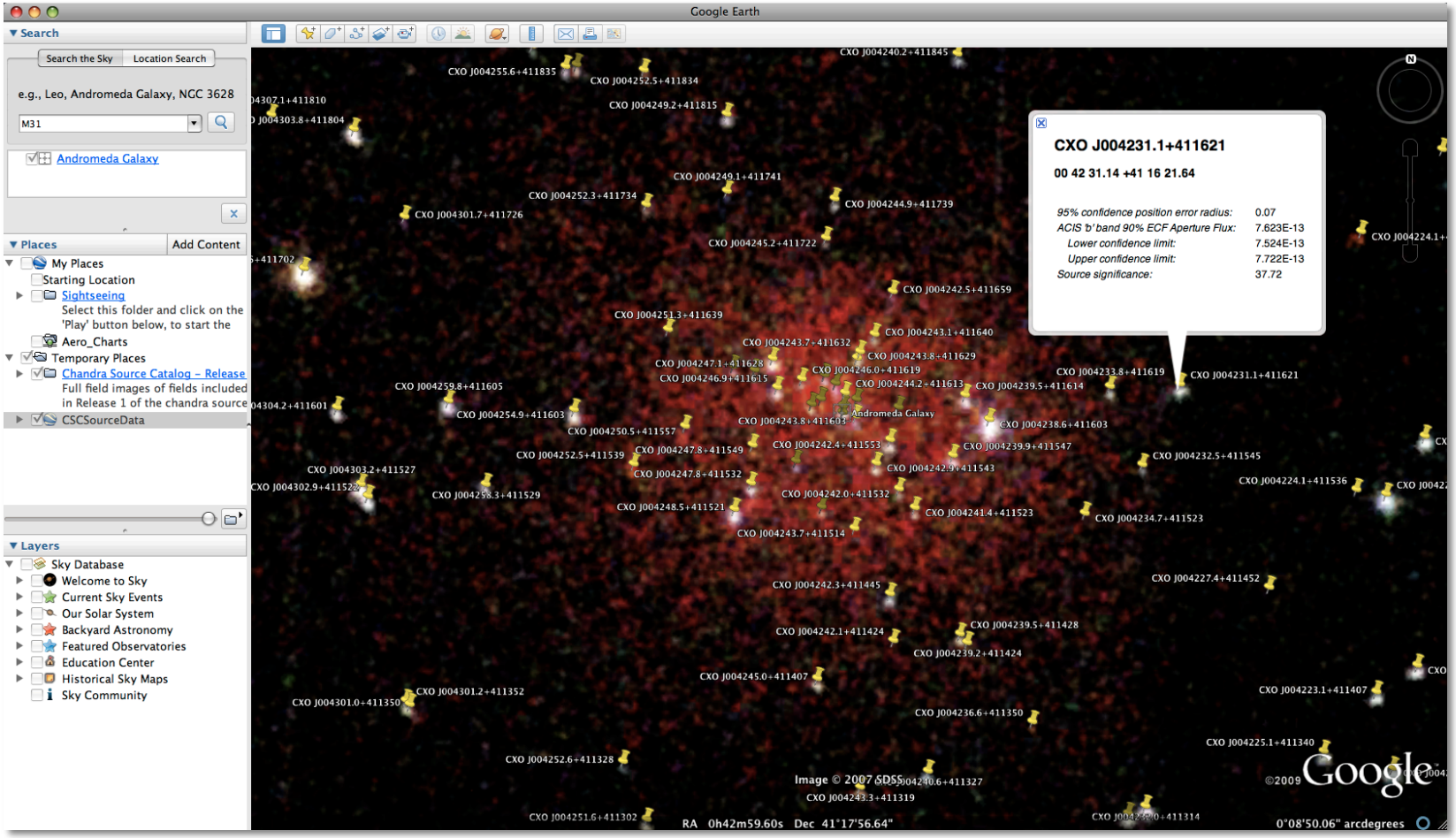
- ds9 release 5.6 supports access to the CSC via the catalog tool interface
  - In this example, the ds9 symbol editor has been used to display CSC sources using error circles that are scaled up to 5× their actual size

Google Sky Interface



- Currently testing an experimental Google Sky interface for visualizing the CSC contents
  - Platform independent interface provides quick visualization of catalog contents for scientists
  - Simple to build and easily extensible; could be readily adapted for education and public outreach uses
  - Panel displays the catalog coverage in the vicinity of the Galactic Center, with observation FoVs displayed (optional)
    - Fields are blue because the observations were obtained using ACIS with an E > 1.0 keV energy filter

Google Sky Interface (cont.)



- Summary source data can be added to the displayed catalog observation images
  - In this case, push pins locate and name CSC master sources in the core of M31, with associated simple source summary pop-ups, but graphical source regions and more sophisticated associated data can easily be added