CHANDRA SOURCE CATALOG

Progress Report

Ian Evans On behalf of the Chandra Source Catalog Project Team

> Chandra Users' Committee Meeting October 29, 2009



Summary

- Released version 1.0.1 of the Chandra Source Catalog on July 21, 2009
 - This patch release of the catalog includes a variability flag fix to release 1.0, but otherwise retains the same content as that release
- Released updates to the CSCview user interface to address novice user concerns
- Released IVOA compliant Simple Cone Search interface
- Released CSC Sky in Google Earth catalog image/FoV visualizer
- Completed primary statistical characterization of release 1.0
- Submitted catalog description paper for publication
 - Release 1 statistical characterization paper is currently in preparation
- Developed production system for release 1.1 (public HRC imaging and "catch-up" ACIS imaging observations)
 - Science evaluation of integration test underway
 - Characterization simulations underway
 - Expect to release version 1.1 in early 2010



Science Highlights Since Last CUC Meeting

- Updated catalog to release 1.0.1 to fix a variability flag error
- Updated public web site with latest user documentation and threads
 http://cxc.cfa.harvard.edu/csc/
- Documents and publications
 - 14 catalog-related posters presented at the Chandra 10 Years Symposium
 - Catalog description paper (Evans et al.) submitted to ApJS
 - Statistical characterization paper (Primini et al.) currently in advanced stage of preparation

Software Highlights Since Last CUC Meeting

- CAT 3.1 (Release system) build
 - Minor patches to maintain CSC operations

May 21	CSCview novice user/ CSC SCS
Jun 26	First release of CSC Sky in Google Earth
Aug 20	Updated CSC SCS
~Oct 26	Added all Chandra FoVs
	Jun 26 Aug 20

- CAT 3.2 (CSC 1.1 Release system) integration test build
 - Integration test run completed
 - Test results being reviewed by science team

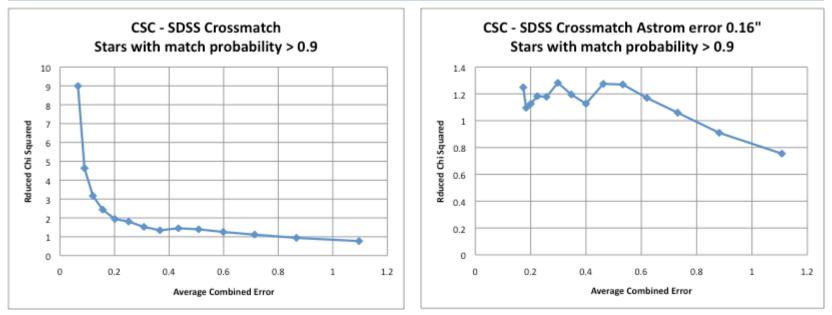


Catalog Statistical Characterization

- Statistical properties of Release 1 are available on the catalog web site
 http://cxc.cfa.harvard.edu/csc/char.html
- A paper describing the statistical properties is in preparation (Primini et al.)
- Characterization simulations for Release 1.1 are underway
 - Completed HRC blank sky simulations; currently running point source simulations



Release 1.0 Characterization

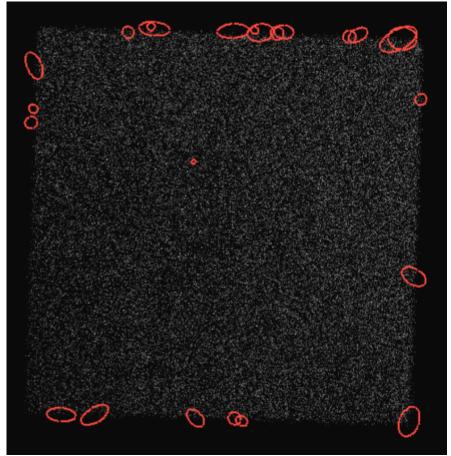


Absolute Astrometric Uncertainty

- The CSC-SDSS DR7 cross-match was used to calibrate the absolute astrometric uncertainty for catalog sources
 - The left hand plot shows the comparison of source separation vs. CSC-SDSS combined error as a function of average combined error, derived from SDSS matches for 6300 sources
 - The rapid increase above $\chi^2 \sim 1$ occurs because the intrinsic CSC position uncertainties underestimate the total error for small values of the average combined error (typically at small θ)
 - Drop below reduced $\chi^2 \sim 1$ is because CSC uncertainties are overestimated at large θ
 - The right hand plot is similar to the left hand side, with a radial absolute uncertainty of 0.16 arcsec (1σ) added in quadrature to the intrinsic CSC position errors
 - This compares favorably with a value of 90% within 0.6 arcsec derived in 2007 from 318 ACIS sources



Release 1.1 Characterization

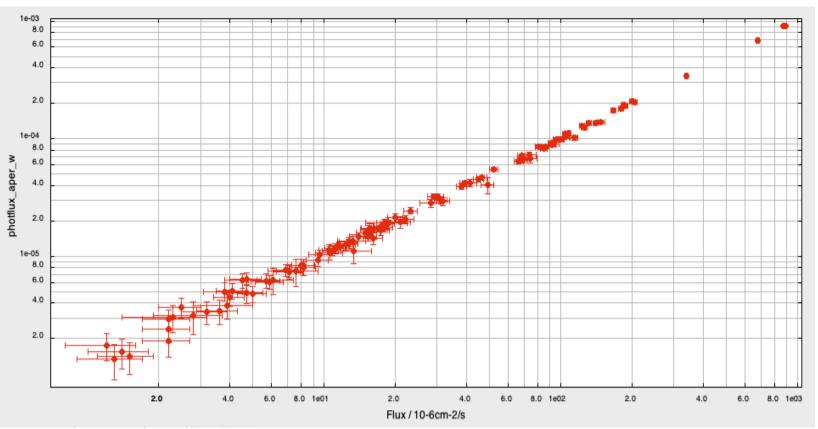


HRC Blank Sky Simulations

- HRC-I false source rate is comparable to ACIS false source rate
- Image shows all detections from 5 blank-sky simulations superimposed on a single simulated image
 - The seed ObsId is a 50 ks M31 imaging observation
 - None of the detections shown would pass the catalog quality assurance and catalog inclusion filters



Release 1.1 Characterization (cont.)



HRC Aperture Photometry

• Comparison of HRC wide band aperture photon fluxes computed using CAT 3.2 integration test build with published values (Kaaret 2002 ApJ 578, 114) for ObsId 1912 (M31)

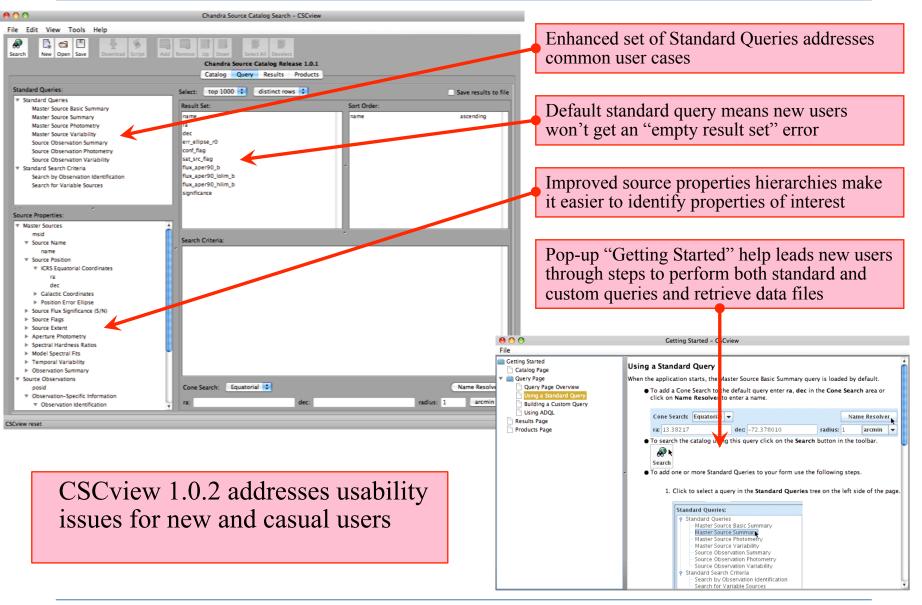


<u>CSCview</u>

- Enhancements since last CUC meeting
 - Added pop-up "Getting Started" help that guides first-time users through making queries, as well as providing examples of more sophisticated usage
 - Can be disabled by users familiar with the interface
 - Added several new queries that support most common requests to the set of standard queries
 - Standard queries are now directly accessible from the main form
 - Provided a new default standard query, so new users wont get the dreaded "empty result set" error
- Tested the new version in-house with a group of scientists who had never previously used CSCview, observing how they interacted with the GUI
 - Test users had a wide range of computer experience and computer skills
 - They were able to successfully query the catalog using the updated version of CSCview
 - The tests identified some areas of commonly requested functionality, and areas where further improvements could be made to the interface
- Joined a collaborative effort with a UK AstroGrid group to develop an IVOA-standards driven standard astronomical catalog data mining interface based on CSCview
 - Additional interest in CSCview has also been expressed by other parties also



CSCview GUI Enhancements



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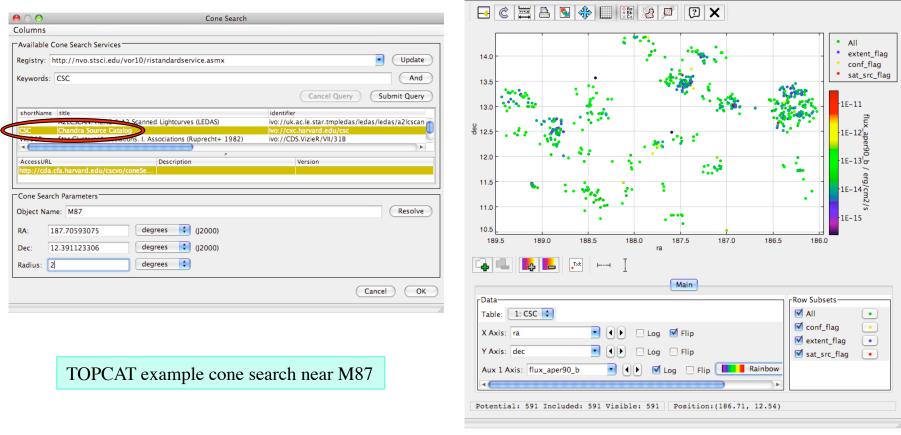
Catalog User Interfaces: Simple Cone Search

CSC Simple Cone Search

• IVOA-compliant SCS interface is directly accessible through VO portals such as DataScope, or via VO aware applications such as TOPCAT

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- Returns results as a VOTable
- Resource name is "CSC"



Scatter Plot



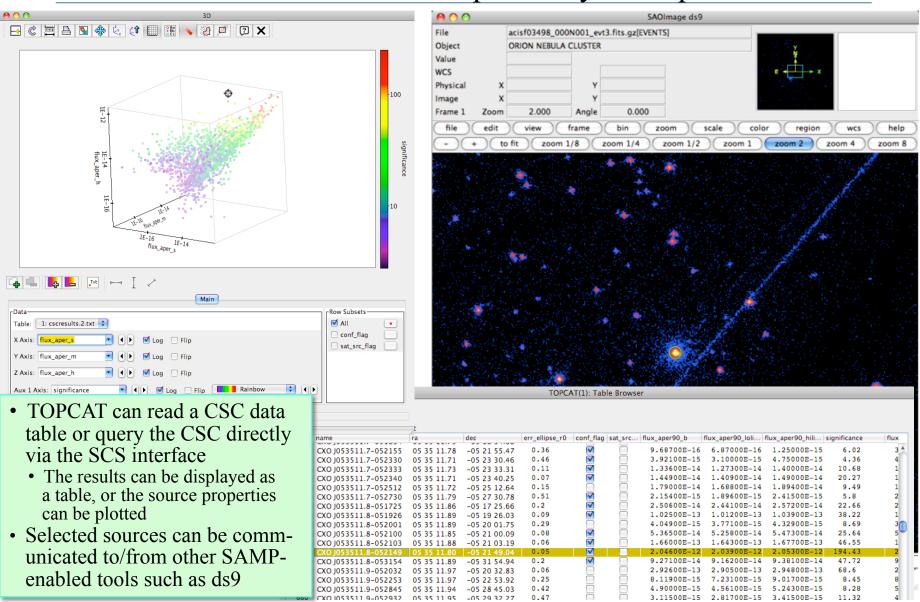
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Chandra Users' Committee Meeting



TOPCAT/ds9 Interoperability Example



Chandra Source Catalog

Chandra Users' Committee Meeting

October 29, 2009

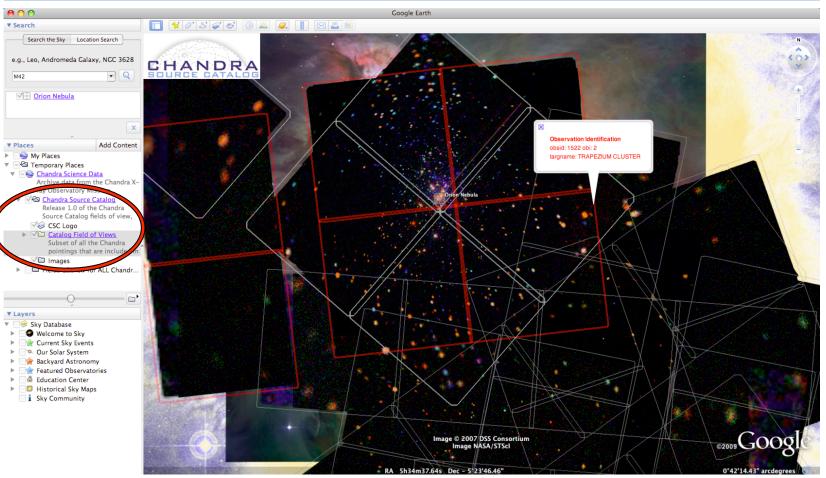
CXC Catalog User Interfaces: CSC Sky in Google Earth CXC

CSC Sky in Google Earth

- CSC Sky in Google Earth displays fields of view (FoVs) and images of all observations included in the CSC
 - Displays images in Google Earth 5.0 or later, which is available on a wide variety of user platforms
 - Beta release (July 28) provided 3-color images of all observations included in CSC release 1, together with FoV boundaries
 - Display can be zoomed out to show all FoVs over a wide sky area, or zoomed in to display images with ~arcsecond pixel scale
 - Display of images can be enabled/disabled at the single observation level
 - FoVs can be selected and basic information about observation is displayed
 - New release (week of October 26) can optionally display FoVs (but *not* images) for all completed Chandra observations
 - Next release will include pop-up balloons that display key data for each catalog master source
 - May eventually be able to retrieve data products via this interface also



CSC Sky in Google Earth



CSC Sky in Google Earth displays FoVs and images of all observations included in the CSC

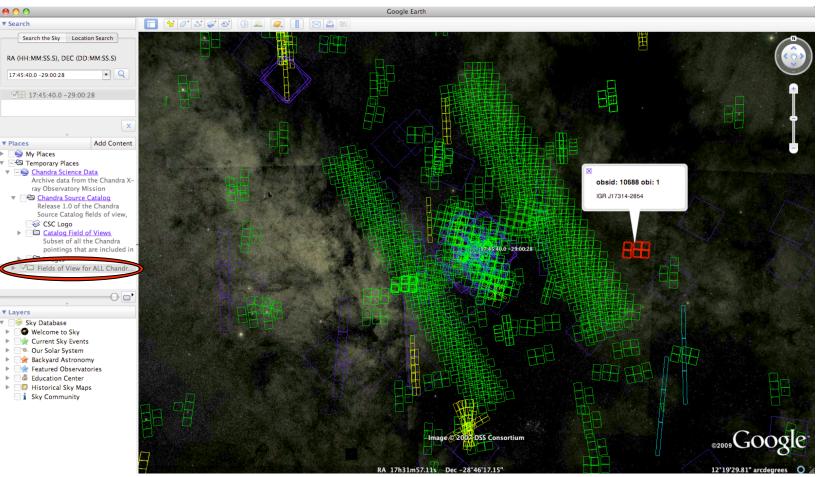
- Zoom out to show all FoVs over a wide sky area, or zoom in to arcsecond scale
- FoV can be selected and basic information about observation is displayed

Chandra Source Catalog



b-

CSC Sky in Google Earth



Latest release of CSC Sky in Google Earth optionally displays FoVs for all observations

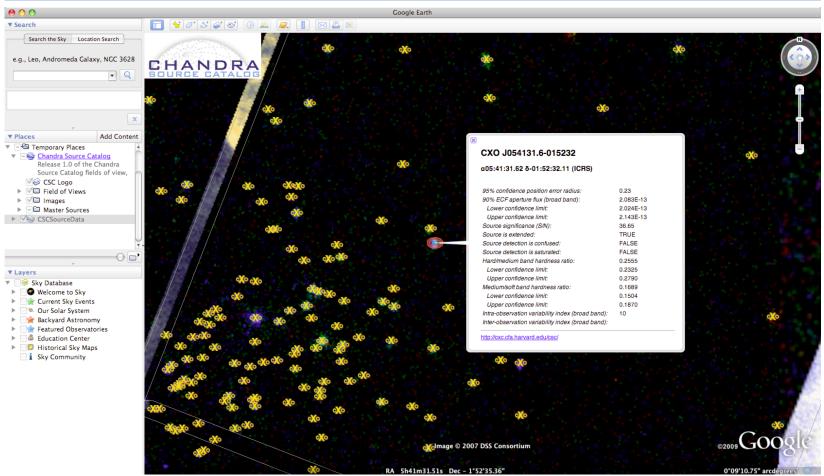
- FoVs are color-coded (ACIS imaging, ACIS spectroscopy, HRC imaging, HRC spectroscopy)
- CSC and "All" FoVs can be displayed independently

Chandra Source Catalog



CSC Sky in Google Earth





- The next release of CSC Sky for Google Earth will include pop-up balloons that display the primary source properties for each master source
 - These balloons could be enhanced to display spectra, light-curves etc., and eventually may provide direct links to allow FITS data products to be retrieved also



Additional Catalog Interfaces

CSC-SDSS Source Cross-Match

- Source position cross-match between CSC release 1.0 and SDSS DR 7
 - Collaborative effort with SDSS, who performed the source matching at JHU
 - Will be available from both CSC and SDSS web-sites
 - ~17,000 matches (~8,000 stars/9,000 galaxies, according to SDSS classification)
 - Should be available for use very soon

Limiting Sensitivity Service

- Allows users to determine whether a position (or set of positions) is included in any of the fields of view that comprise the catalog, and determine the minimum flux required for a point source to be included in the catalog at that position
 - Downloadable user script has been available on the CSC website for ~4 months
 - Provides limited capabilities, some caveats (only provides ACIS broad band sensitivity, blocked by ~30 arcsec pixels)
 - Prototype web-based user interface (based on the script) developed
 - Should be available for use soon; makes use of upcoming CDA footprint service

SIAP and SSAP

- IVOA Simple Image Access and Simple Spectral Access Protocols
 - SIAP will provide URL access to fluxed images from observations included in the catalog (similar to the existing CDA SIAP interface for observation images)
 - SSAP will provide URL access to PI spectra for individual catalog sources
 - SIAP will be available in the near term, followed by SSAP



CSC-SDSS Cross-Match Service

NAME	OBJID	SEPARATION	PROBABILIT	Y RA	DEC	FLUX_APER90_B	FLUX_APER90_LOLIM_E	FLUX_APER90_HILIM_B	RA_SDSS	DEC_SDSS	S R	ERR_R
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XO J001115.2+144601	587730773889974538	0.032566	0.999503	00 11 15.24	+14 46 01.84	2.341e-13	2.135e-13	2.549e-13	2.813485	14.767169	19.628693	0.016388
O J002025.2+154054	588290881639350397	0.119148	0.999255	00 20 25.22	+15 40 54.60	2.629e-13	2.53e-13	2.729e-13	5.105085	15.681865	17.429222	0.005358
J002042.5+153409	587730774964699322	0.4933	0.958833	00 20 42.58	+15 34 09.33	7.214e-14	6.536e-14	7.899e-14	5.177554	15.56929	20.418751	0.027714
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•	588015510347907565		0.997832	00 43 50.25	+00 57 50.94		OBJID (SDSS ld, int) SDSS_TYPE (3=Galaxy, 6=Star)				GAL_L (deg), GA	_B (deg)
-	587724198276104317		0.998165				SEPARATION between CSC and SDS BAYES_FAC (Bayes factor for match)				CONF_FLAG (Co EXTENT_FLAG (6	nfusion flag)
C J005104.8-010152	587731185135779968	0.146507	0.99893	00 51 04.86	-01 01 52.25	2.27e-13	PROBABILITY (Probability of correct			0	MAJOR_AKIS_B	Deconvolved sou
O J005905.5+000651	588015509275803698	0.132321	0.998595	00 59 05.51	+00 06 51.54	1.71e-12	SDSS parameters RA_SDSS (deg), DEC_SDSS (deg)				SAT_SRC_FLAG	
O J011431.0+002621	588015509814379094	0.136685	0.996324	01 14 31.01	+00 26 21.36	3.516e-14	RA_SDSS_ERR (arcsec), DEC_SDSS				HARD_HM (Hardr HARD_MS (Hardr	
O J011515.7+001248	587731513142673426	0.213709	0.997919	01 15 15.78	+00 12 48.71	4.044e-14	U (u magnitude), ERR_U (error in u n G (g magnitude), ERR_G (error in g n	nagnitude) magnitude)		0	HARD_HS (Hardn	ess ratio h-s ban
O J011522.1+001518	587731513142673682	0.349114	0.972347	01 15 22.17	+00 15 18.84	1.488e-13	R (r magnitude), ERR_R (error in r m [] I (i magnitude), ERR I (error in i magnitude).	agnitude)			VAR_INTRA_INDE	
•	587731513142673569		0.993439	01 15 37.71	+00 20 29.02	1.128e-13	Z (z magnitude), ERR_Z (error in z m					
•	587731513142739062		0.994877	-	+00 14 00.31							
-	587731511532388622		0.995604		-00 57 38.36				Enter Optiona	al Selection Crite	eria (default: all o	data)
5	587731511532454097		0.998959		-01 01 13.86		Specify service	ions on the values of the parameters above ()	e.g., SDSS_TYPE=	3 and SEPARA	TION<9.84 mar	be empty, meaning
•	587731511532453955		0.998587		-01 00 07.16				<, BETWEEN), log			
*	587731511532454195		0.998815	01 18 53.90	-01 02 54 14							
	587731511532454210 587731513680330851		0.998935	01 19 01.61	-00 59 41.57 +00 42 43.10			separat	tion < 0.5 and signific	cance > 10		
•	587731513680462055		0.991061		+00 42 43.10				Additional	l optional selection	n criterion: Cone S	earch
•	587731513680461866		0.989821	-	+00 49 29.08			RA		De	NC	Sea
•	588015507668140303		0.993594		-01 11 18.21			(decise of dec	meet	(decimal)	demaes)	20
-	587731513144705291		0.996551		+00 20 11.21			(decinal dej		(vectra)		
•	587731513144770582		0.999443		+00 15 36.60							
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The	CSC-SD	$SS(\Gamma$	)R7) s	ource	eros	S-				Output Fe	ormat	
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								ns may be browsed at: http://cas.sdss.org/ast			-	to identify at
								ews, one may want to look especially at Galax			and use the CBJID	to identify the so
							Additional interfa	ices to the Chandra Source Catalog are availa	able at: http://cxc.han	ward.edu/csc/		

Chandra Users' Committee Meeting



## Limiting Sensitivity Service

#### CSC Sensitivity Map Values (Broadband)

Enter RA and Dec. in degrees:		
R.A. Dec.		
Submit Data		
Choose a file to upload: /data/evans_i/radec.txt	Browse	Upload

Note: Large files (> ~10,000 sources) may need to be split into multiple, smaller files if an upload error occurs.

#### CSC Sensitivity Data for File: radec.txt

Healpix #	Input RA	Input Dec	Healpix RA	Healpix Dec	Sensitivity
21889	42.136322	89.401357	42.136329	89.401356	1.372809e-06
21890	42.967606	89.400383	42.967606	89.400383	4.980673e-06
22306	39.578599	89.394786	39.578599	89.394786	3.239705e-06
22307	40.404418	89.394201	40.404418	89.394201	6.428216e-06
22736	44.500478	89.389406	44.500478	89.389406	8.726818e-06
29587	46.652372	89.300946			

- Currently, a user can determine whether a position or list of positions is included in the catalog using a downloadable tool
  - Returns the ACIS broadband sensitivity in photons cm⁻² s⁻¹
  - HEALpix size is 30 arcsec, so sources near the edges of a field may not be correctly reported
- Prototype web interface (left) will allow specification of (RA, Dec) or upload of a file containing a list of (RA, Dec) pairs
  - Results returned as a file or displayed as a table
  - Interim plan is to use the Chandra Data Archive footprint service to identify for the user any positions that are in the uncertain area (the CDA footprint service is currently under development)
  - Longer term plan is to provide a limiting sensitivity service for all energy bands, based on a significantly smaller pixel size

Chandra Source Catalog



#### **Short Term Plans**

- Catalog Releases
  - Release 1.1 (early 2010) extends release 1 to include public HRC-I imaging observations, and newly public ACIS observations, but otherwise retains the same limitations as release 1
- Public Interfaces
  - CSCview GUI
    - Additional output file formats for query results (*e.g.*, VOTable)
    - JPEG quick image display, spectral and lightcurve plots
    - Support for cross-matching with user supplied catalogs
    - IVOA SAMP interface for communications with other applications
  - CSC Sky in Google Earth
    - Next release will include pop-up balloons that display key data for each catalog master source
  - Web Services
    - Catalog limiting sensitivity/footprint services preliminary; detail dependent on archive footprint
    - SIAP and SSAP
  - External Interfaces
    - Working with CDS Strasbourg to provide access to a subset of catalog master source properties through Vizier
      - » Expect to complete after version 1.1 is released
    - Inclusion of catalog sources in SIMBAD is evidently more complex
      - » Requires CDS to verify sources and cross-match with other SIMBAD catalogs
    - HEASARC Browse (?)



## **Future Directions**

#### **Longer Term Plans**

- Catalog releases
  - Catalog release 2
    - 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 are not fully established
  - Recently began a series of investigations and production experiments to evaluate methods for more robustly handling observation background, and reliably detecting sources from stacked data sets
    - Expect to report progress in these areas at the next CUC meeting