CHANDRA SOURCE CATALOG

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

MIT KAVLI INSTITUTE

The Chandra Source Catalog 2.0

F. Civano (CfA/CXC)

On behalf of the *Chandra* Source Catalog team

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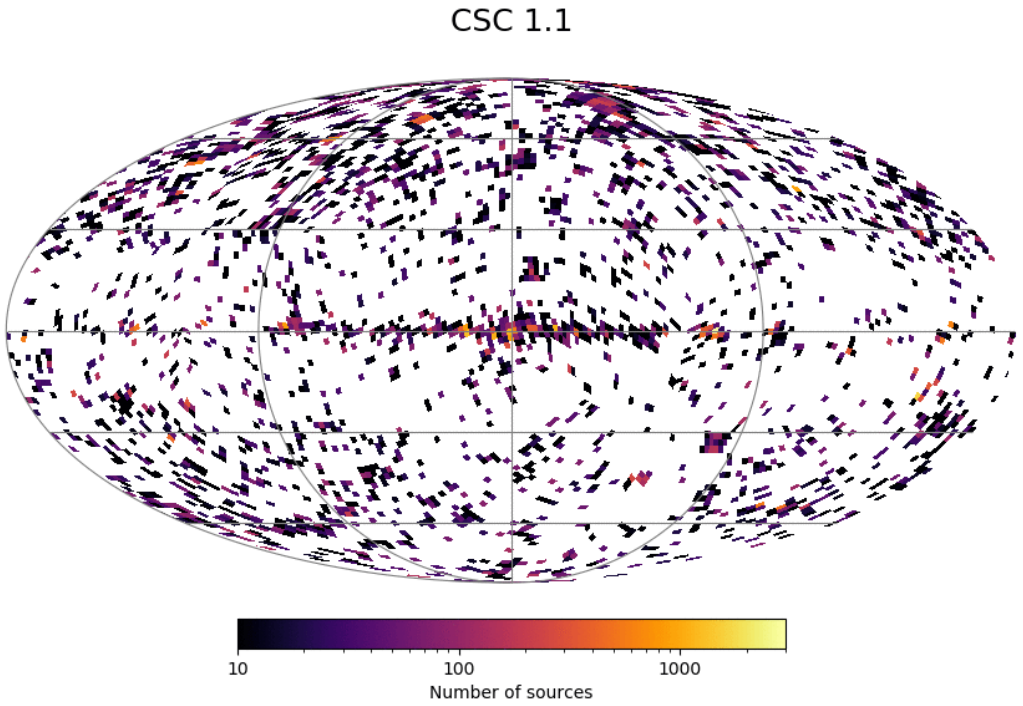
[4]*MIT Kavli Institute for Astrophysics and Space Research*

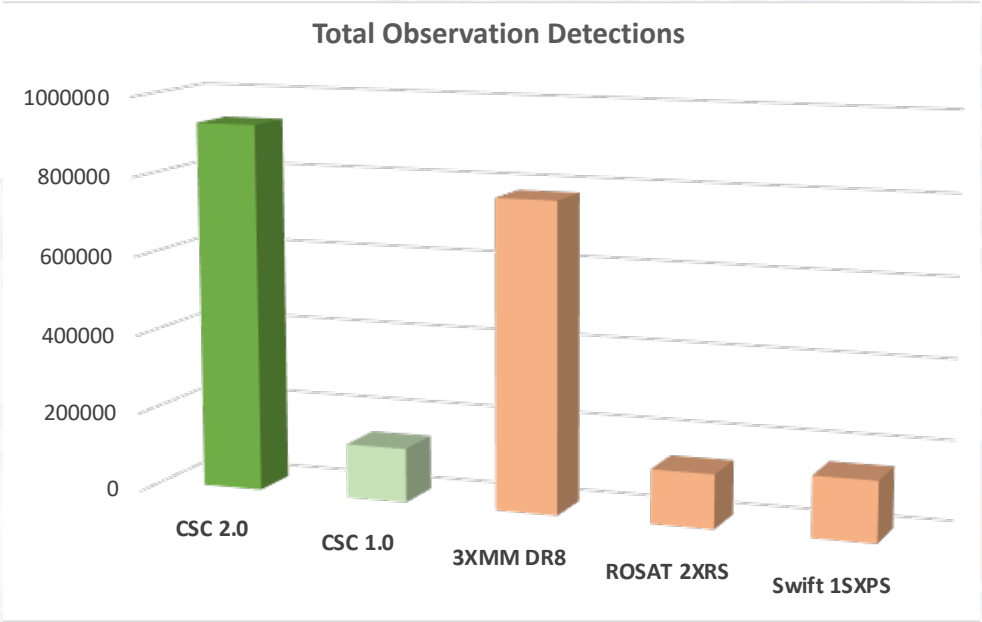
CSC 2.0 and CSC 1.0

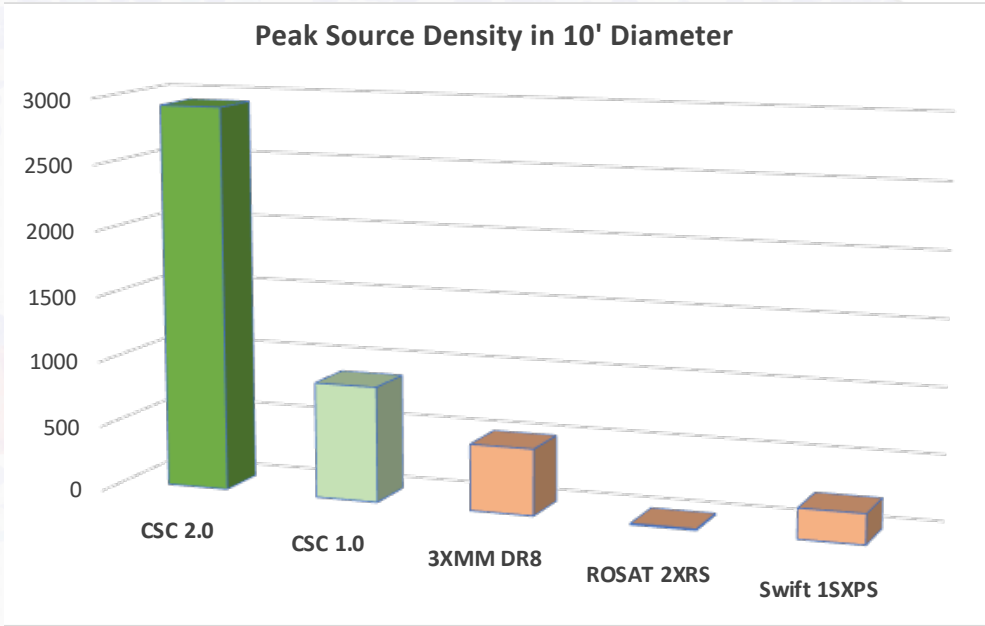
	CSC 1	CSC 2
Individual obsids	5110	10,382
Obsid years	1999-2009	1999-2014
Total exposure		245.8 Ms
longest exposure	190 ks	5.8 Ms
Counts on-axis	~10	~4-5
Number of sources	106,586	**317,167**
Number of detections	158,071	**928,280**

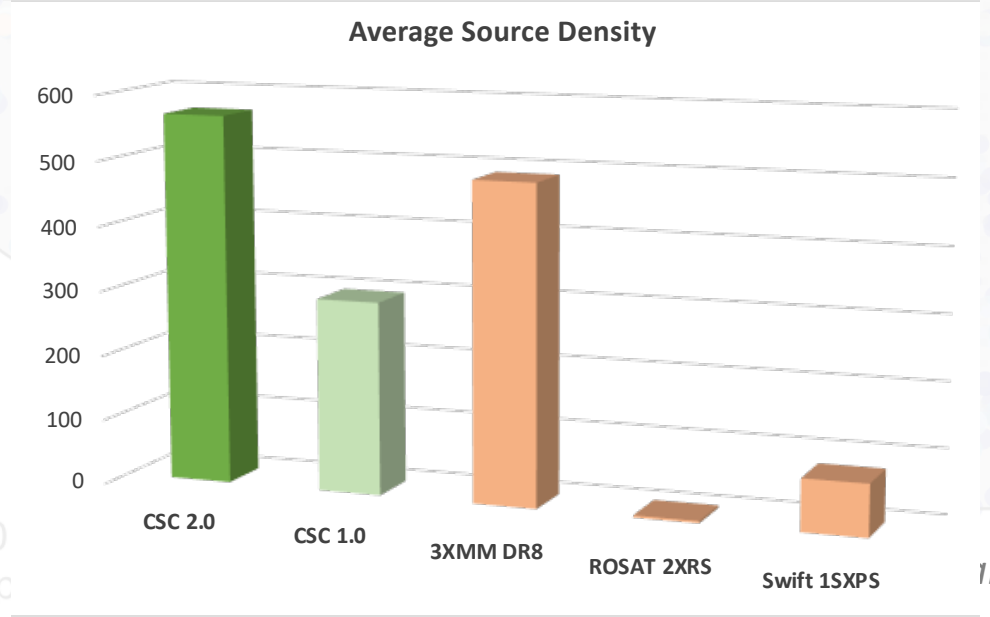


~550 deg^2
Area covered
~1.3% of sky

Comparison with other catalogs

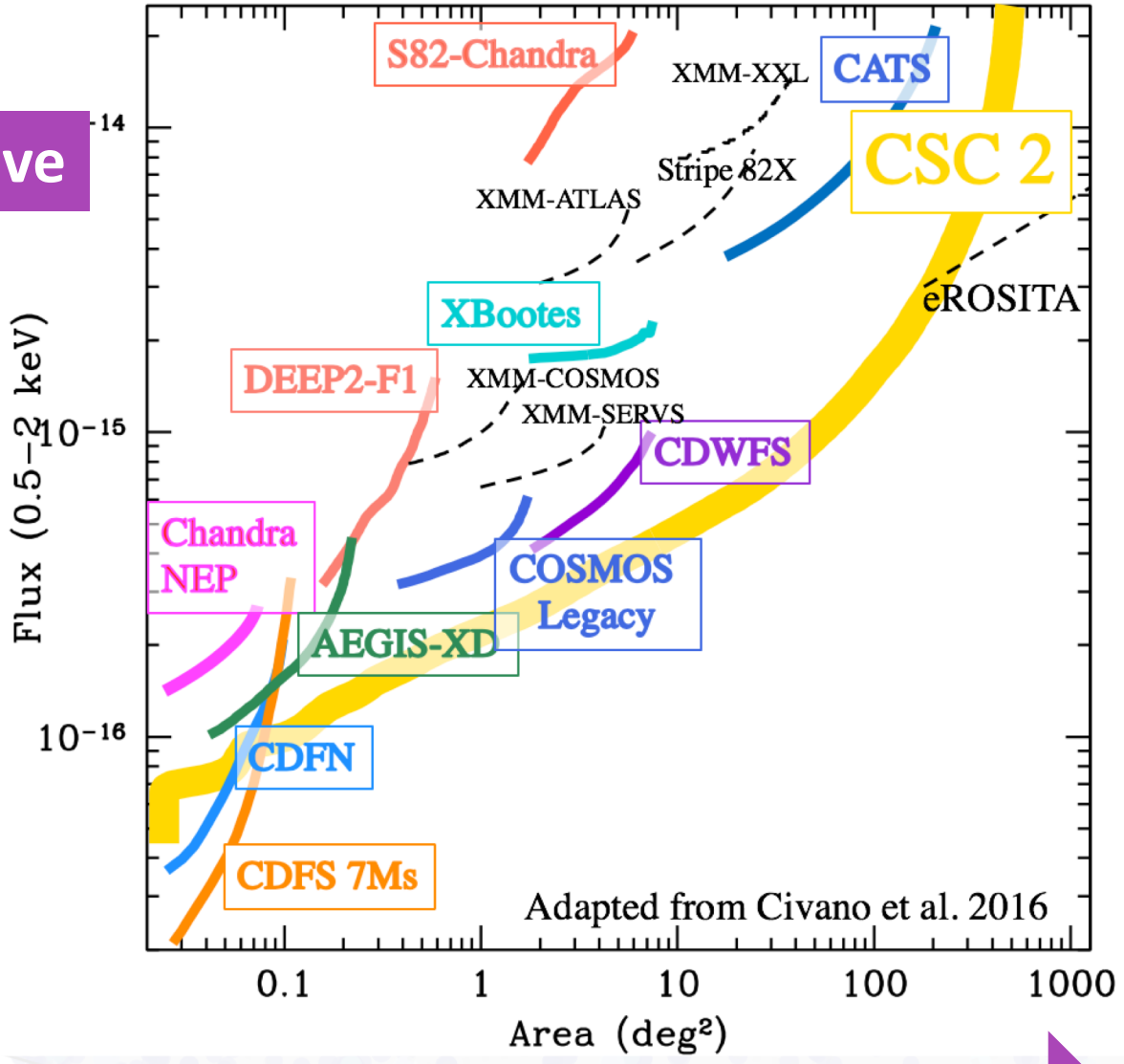






CSC 2.0 as a survey

More sensitive



~550 deg² Area covered

LARGER AREA

F. Civano – virtual Caltech - 2021

CSC 2.0 features

- **Source detection on stacked observations**

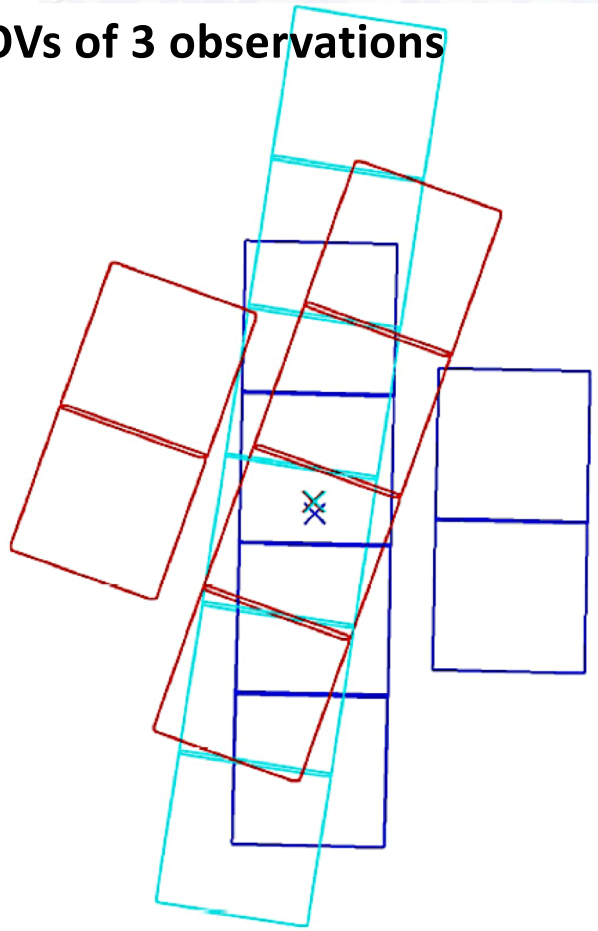
New source detection approach

- Wavelet detection with "permissive" parameters *plus* entirely new Voronoi tessellation algorithm for both background determination *and* source detection
- Maximum likelihood estimator grades candidate detection and improves on-axis detection limit to 5 net counts for exposures < 15 ks
- MCMC draws provide relative astrometry position error *ellipses*
- Aperture photometry PDFs computed using Bayesian algorithms
- Multiple observations grouped by multi-band Bayesian Blocks algorithm to improve S/N even for variable sources (properties archived for each block)
- Integrated multi-band limiting sensitivity computed on 4" x 4" pixels

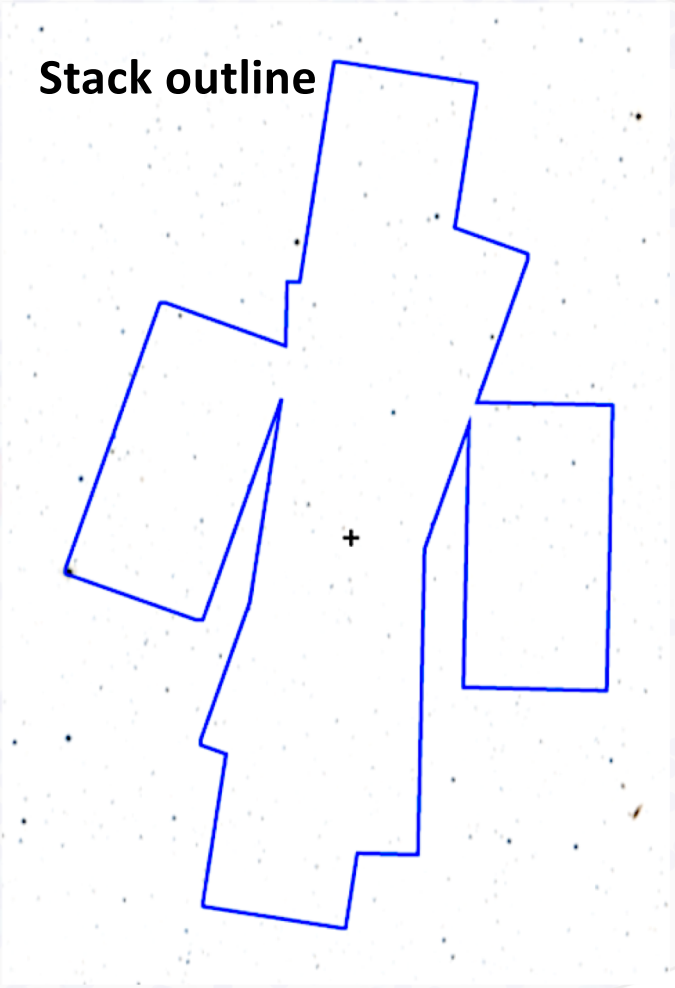
Stacked observations

STACKS: sum of observations with pointings within 1’ to increase sensitivity

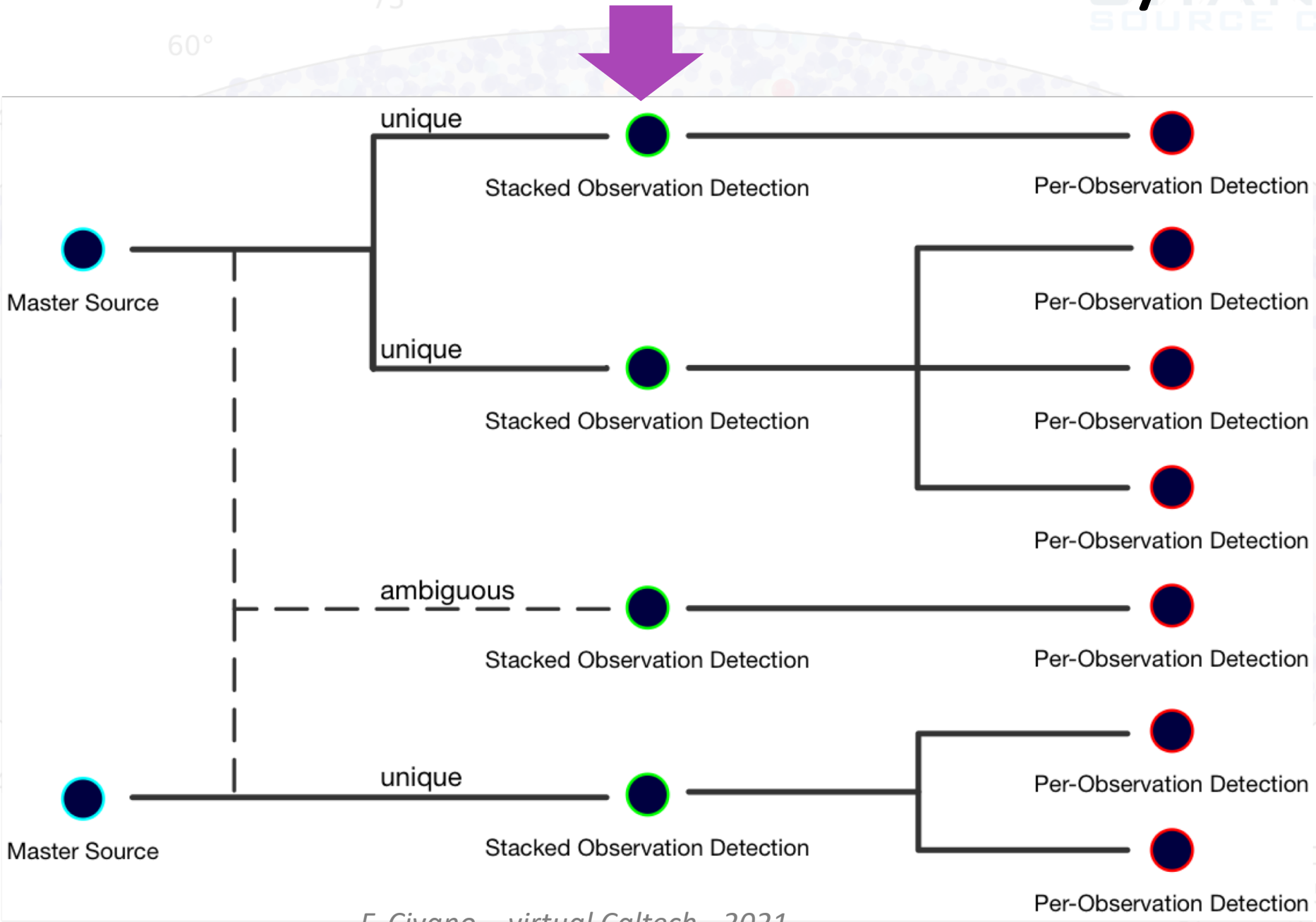
FOVs of 3 observations



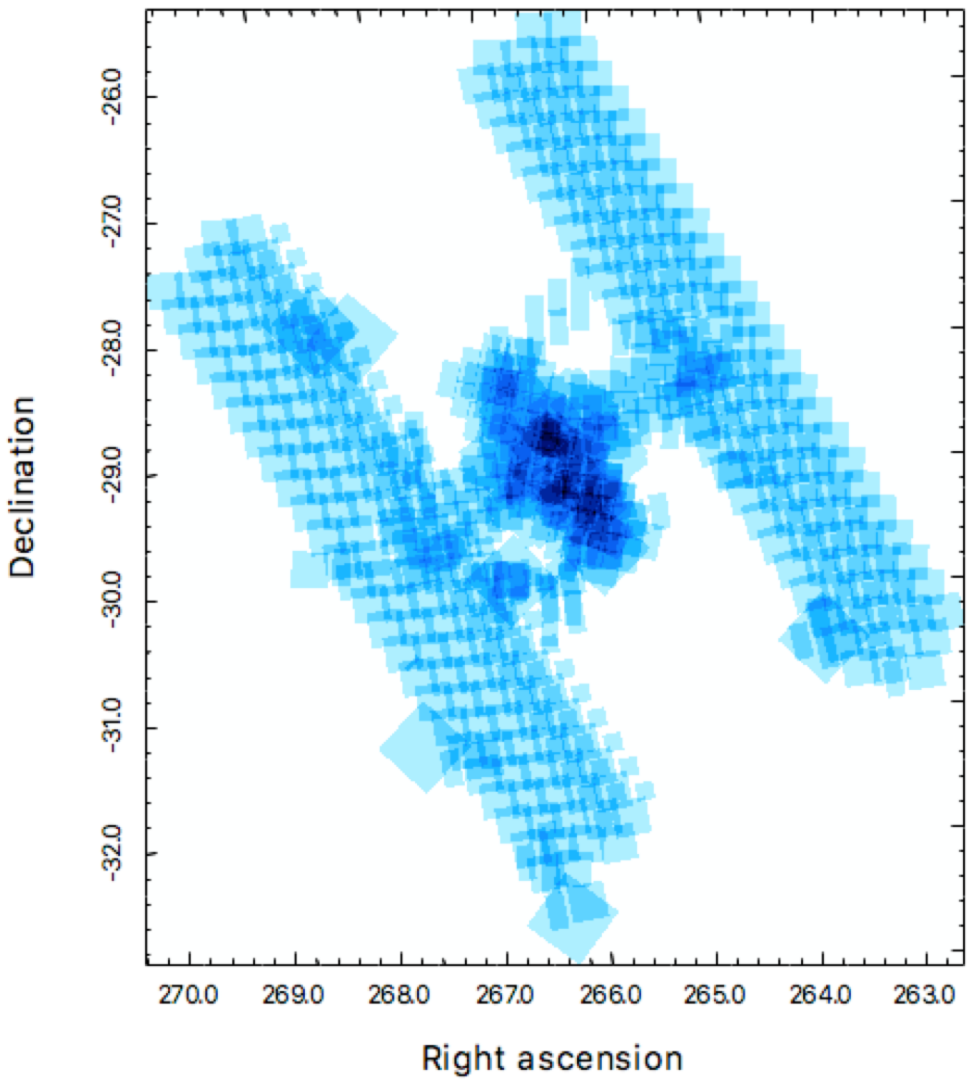
Stack outline



Source detection hierarchy



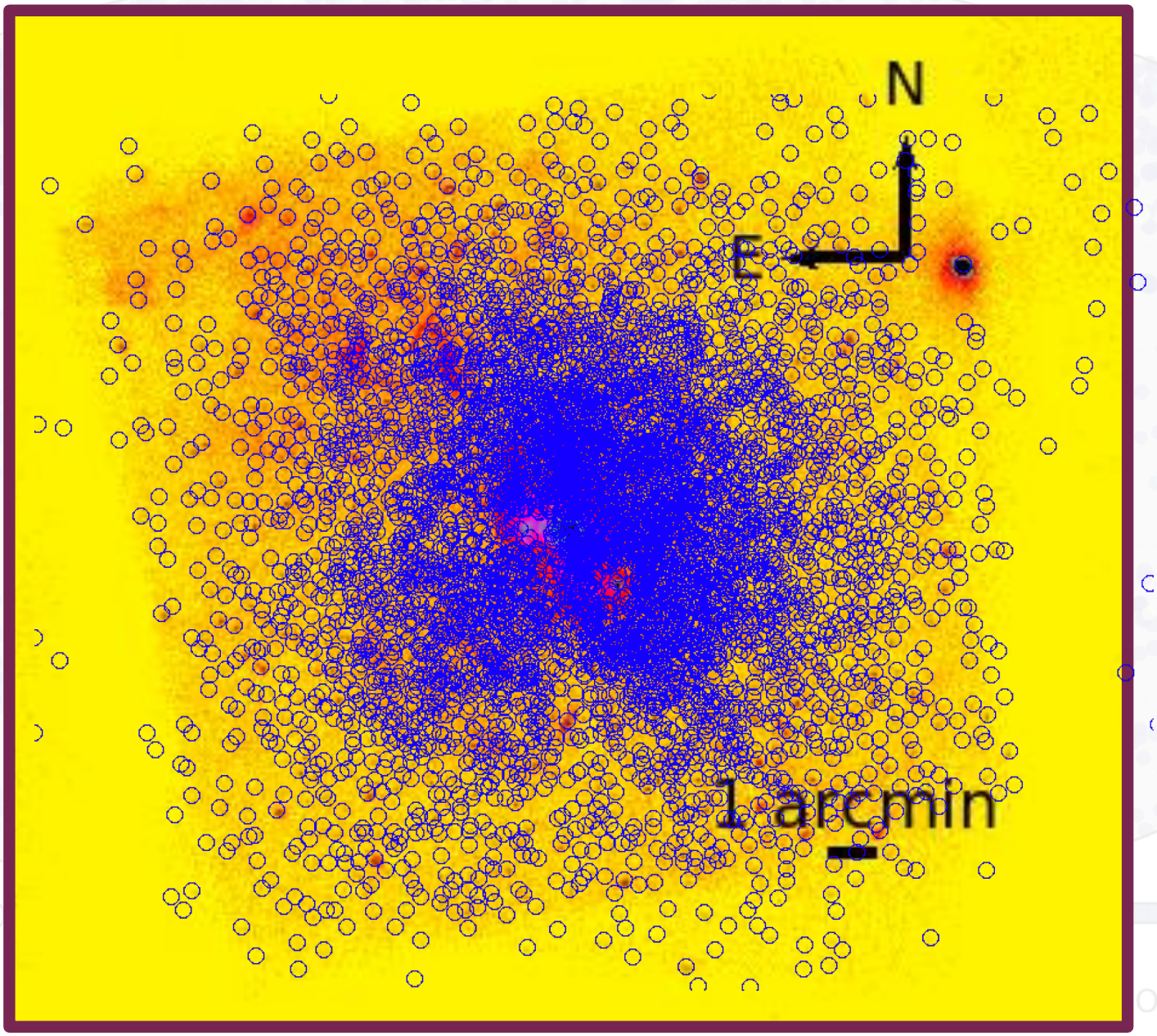
Example: Galactic Center Area



- 534 single *Chandra* observations
- 379 stacks (36 HRC and 343 ACIS)
- Total area covered ~ 19 deg^2
- Total exposure time ~ 9 Ms

Example: Galactic Center Area

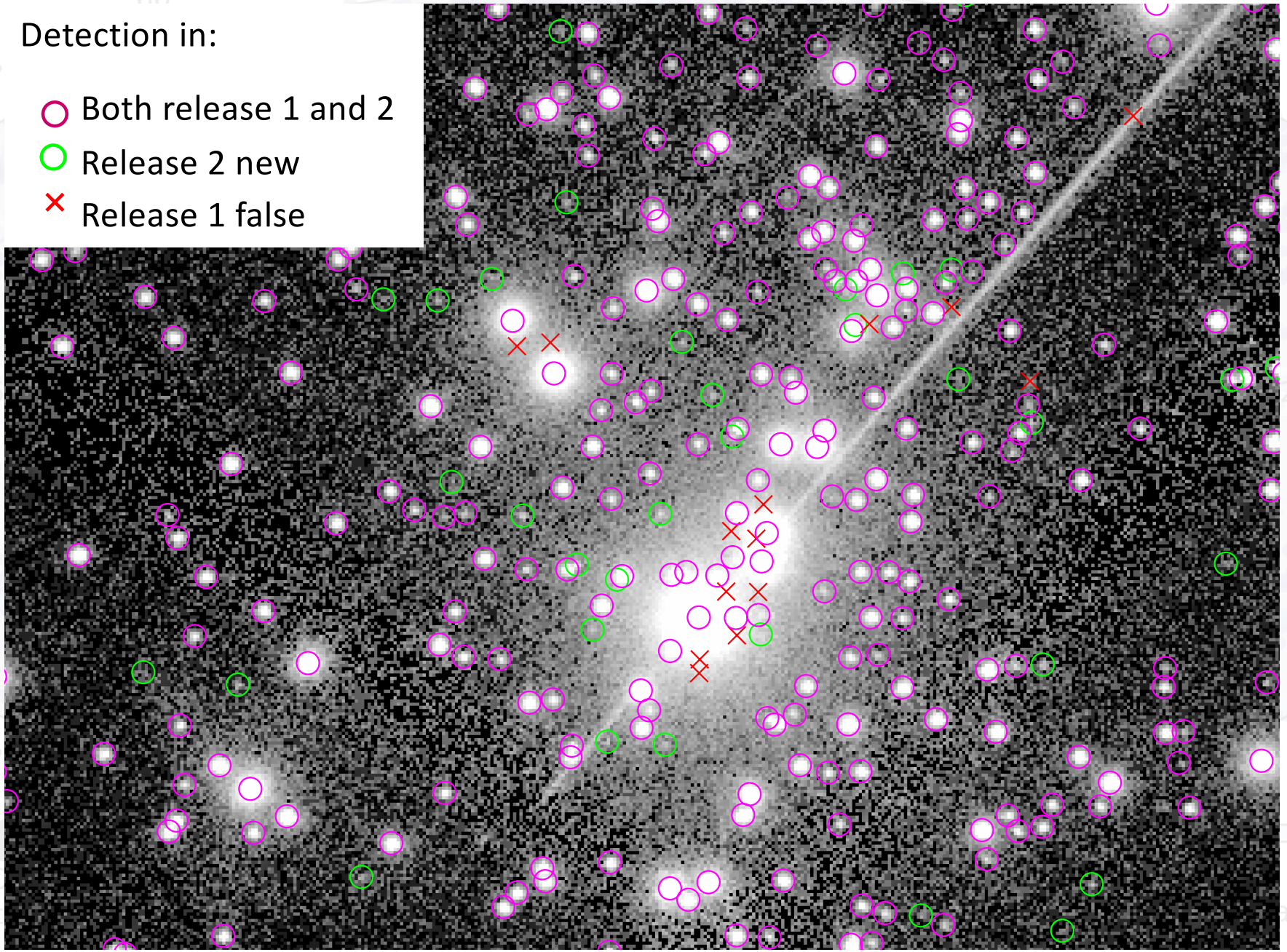
central stack: 71 observations, ~6000 sources



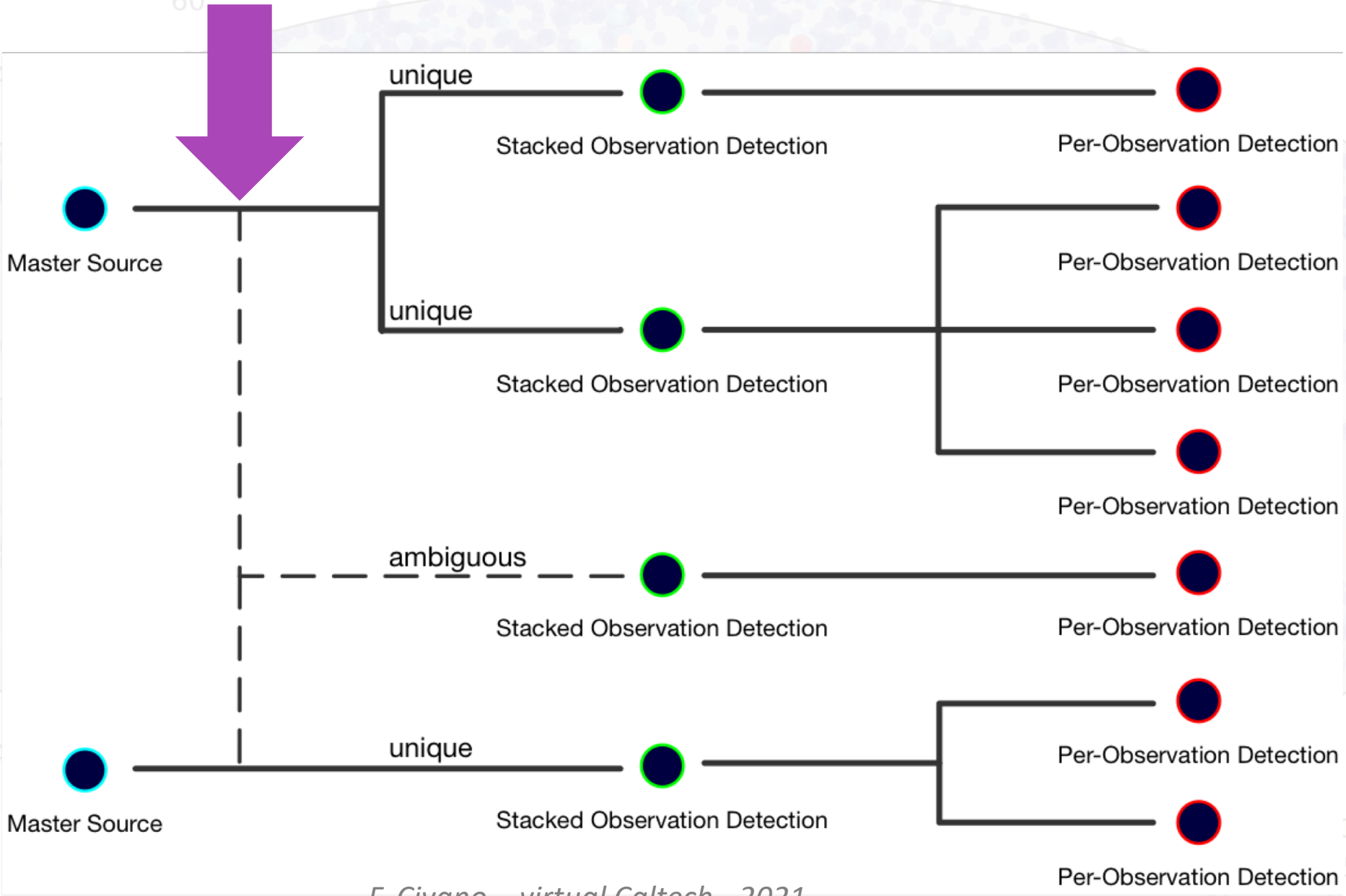
CSC 2.0 features

- Source detection on stacked observations
- **New source detection approach**
  - **Wavelet detection *plus* Voronoi tessellation algorithm**
  - **Maximum likelihood estimator to improve on-axis detection (~5 net counts for exposures < 15 ks)**

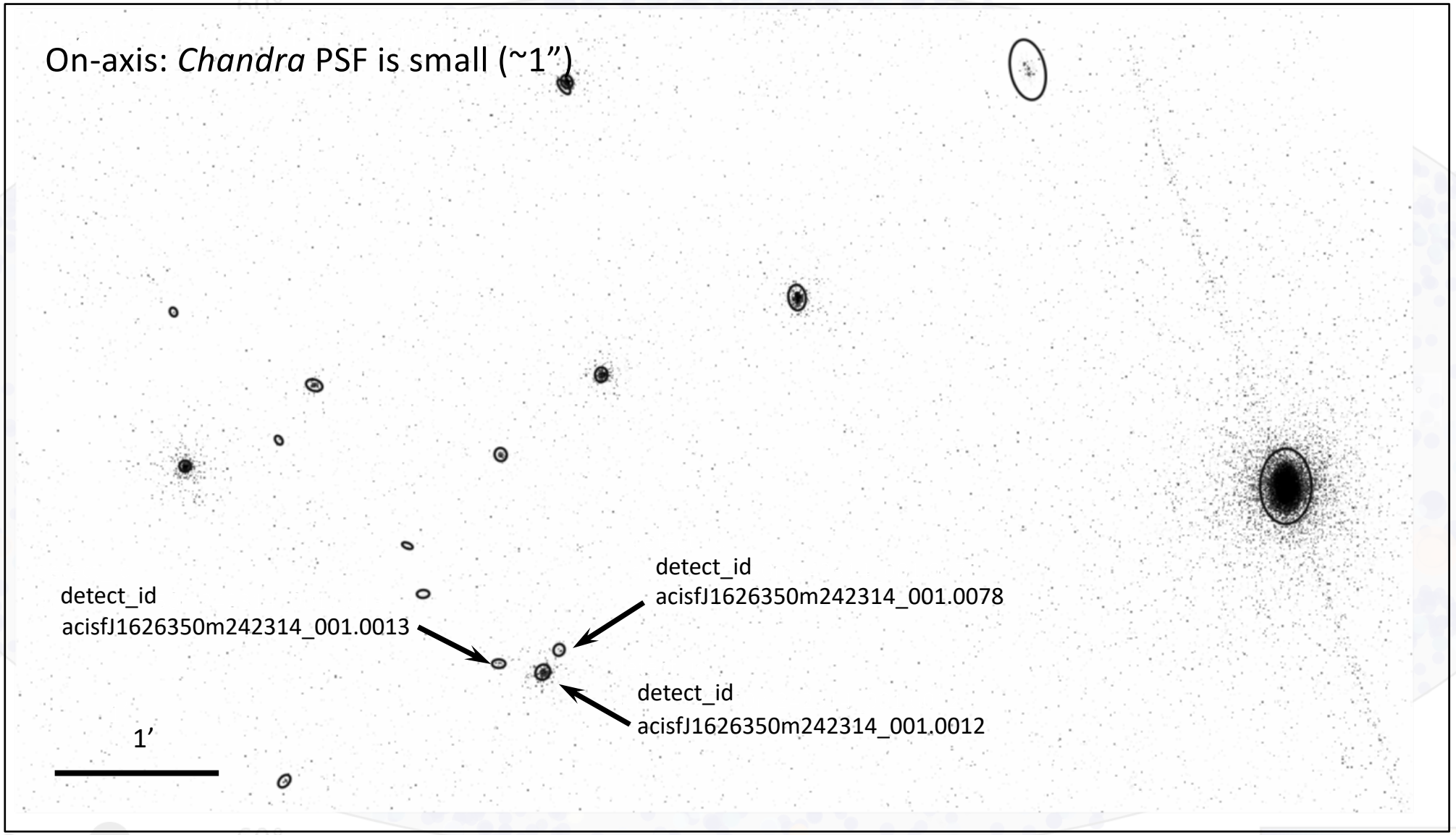
Detection: reaching the faintest sources



Master matching process



Detections and sources



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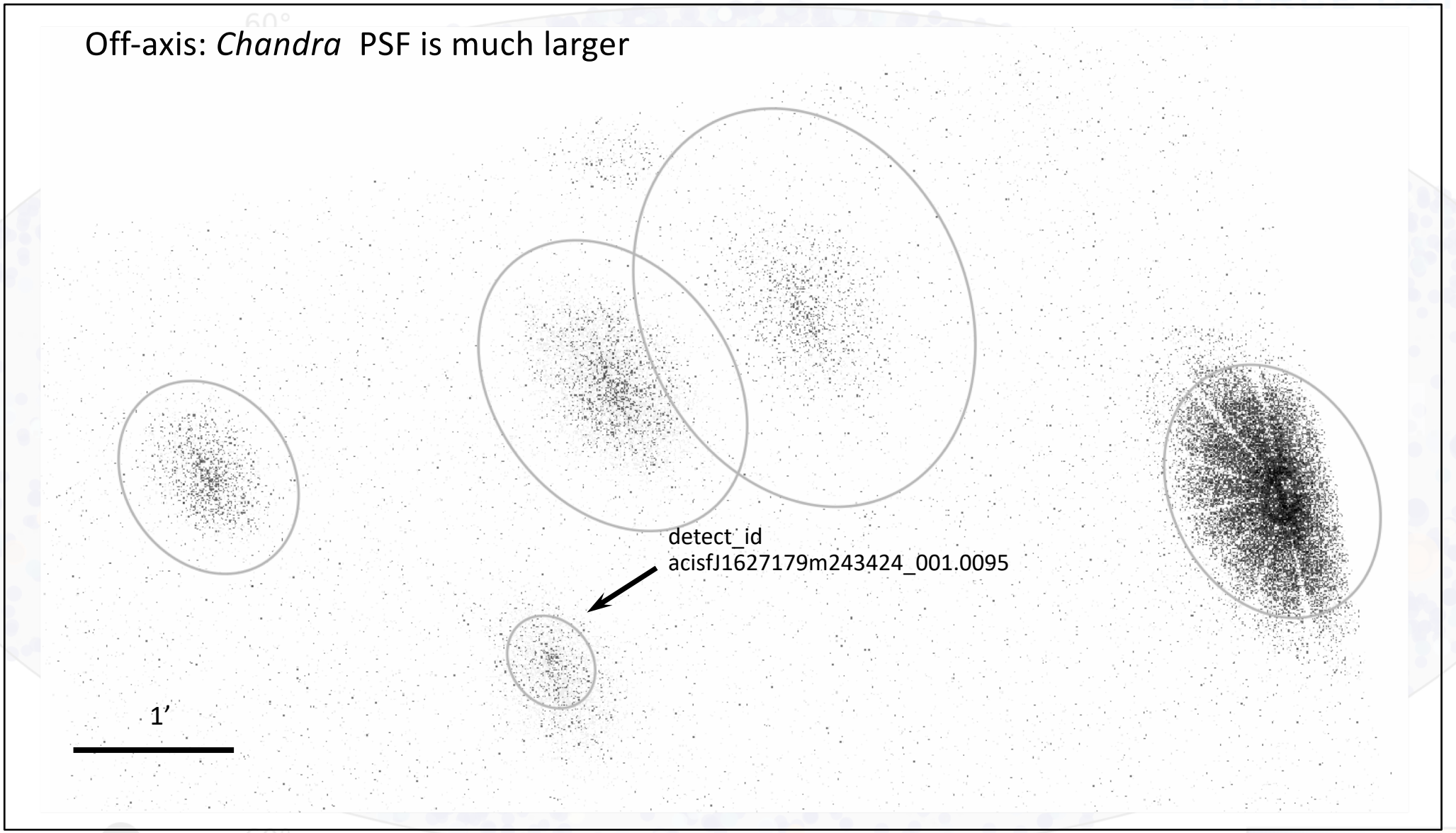
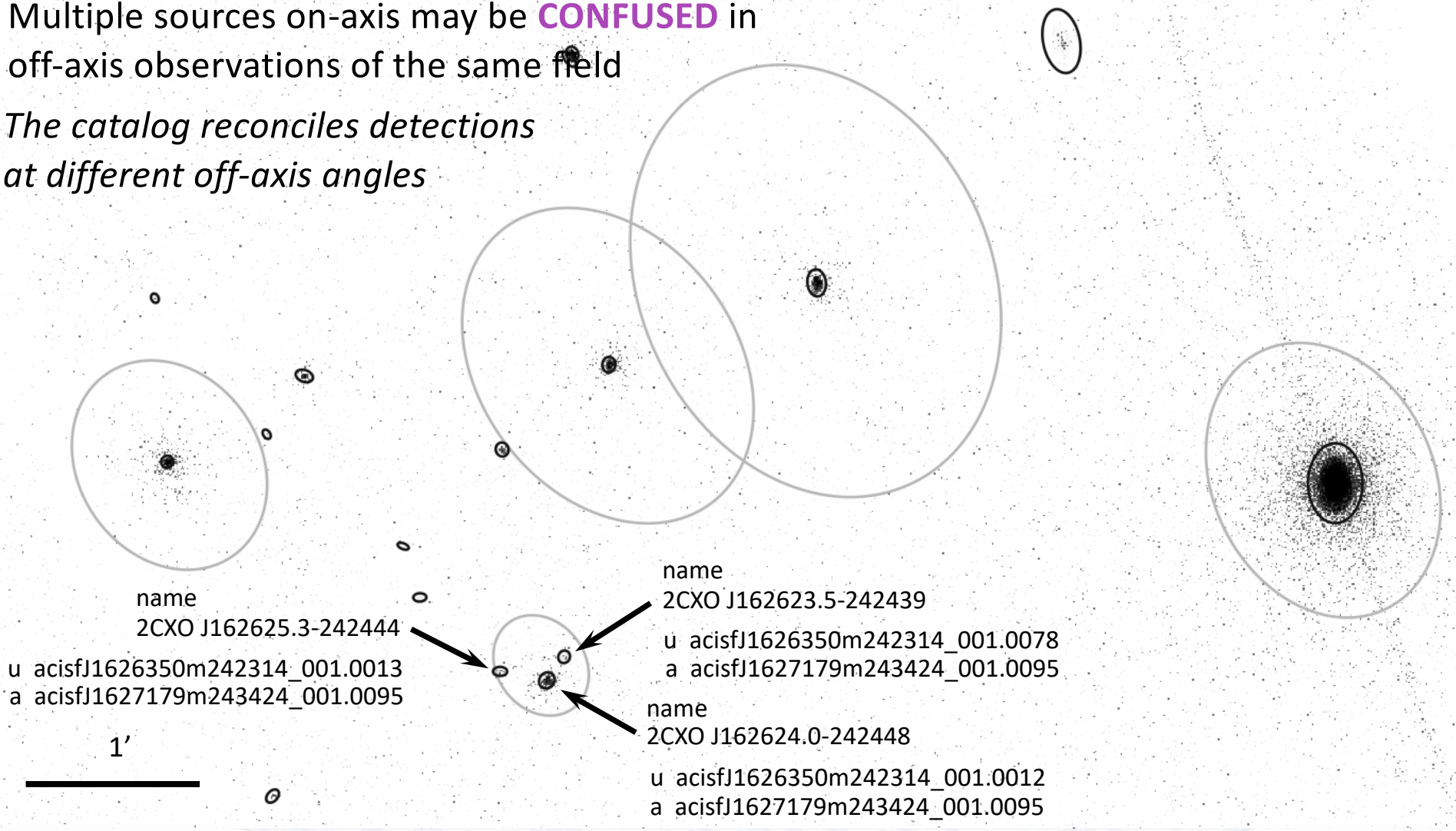


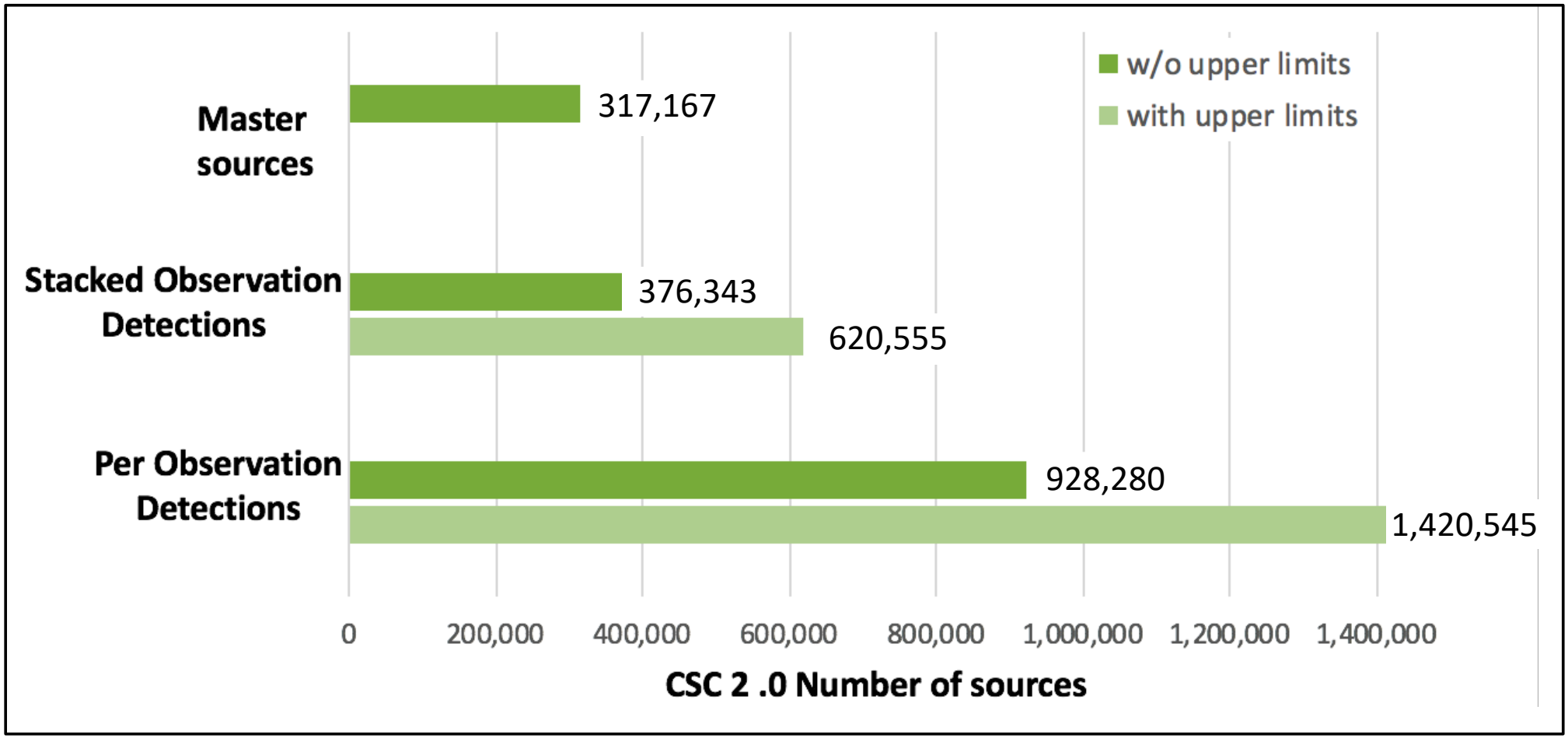
Detections and sources

Multiple sources on-axis may be **CONFUSED** in off-axis observations of the same field

The catalog reconciles detections at different off-axis angles



Master sources and detections



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- Source detection on stacked observations
- New source detection approach
  - Wavelet detection *plus* Voronoi tessellation algorithm
  - Maximum likelihood estimator to improve on-axis detection (~5 net counts for exposures < 15 ks)
- **MCMC draws provide relative astrometry position error *ellipses***
- Aperture photometry PDFs computed using Bayesian algorithms
- Multiple observations grouped by multi-band Bayesian Blocks algorithm to improve S/N even for variable sources (properties archived for each block)
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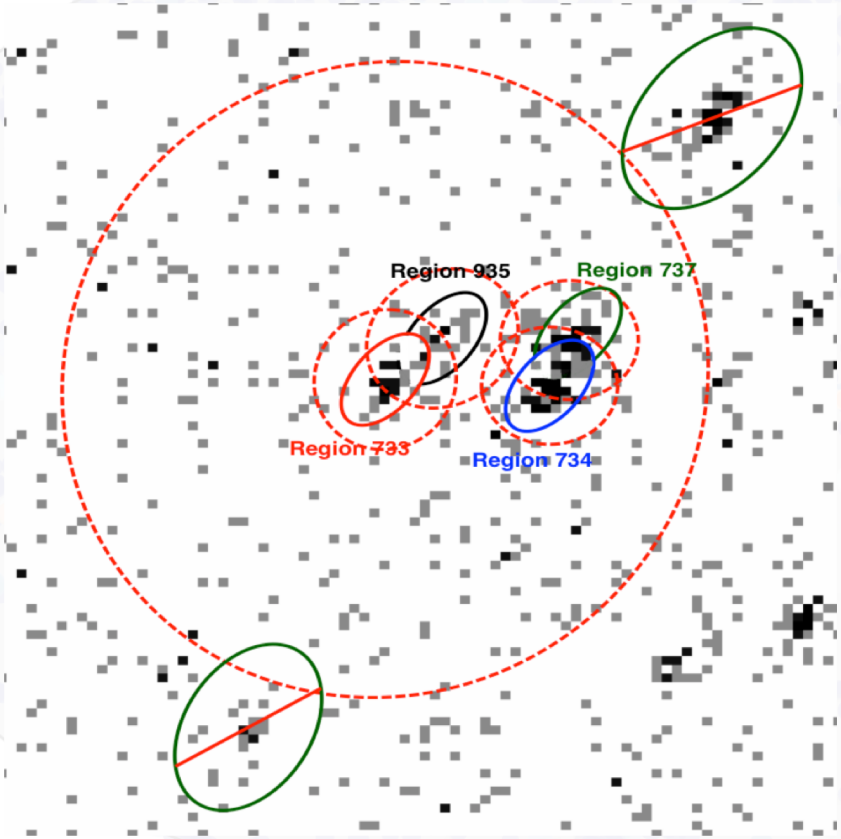
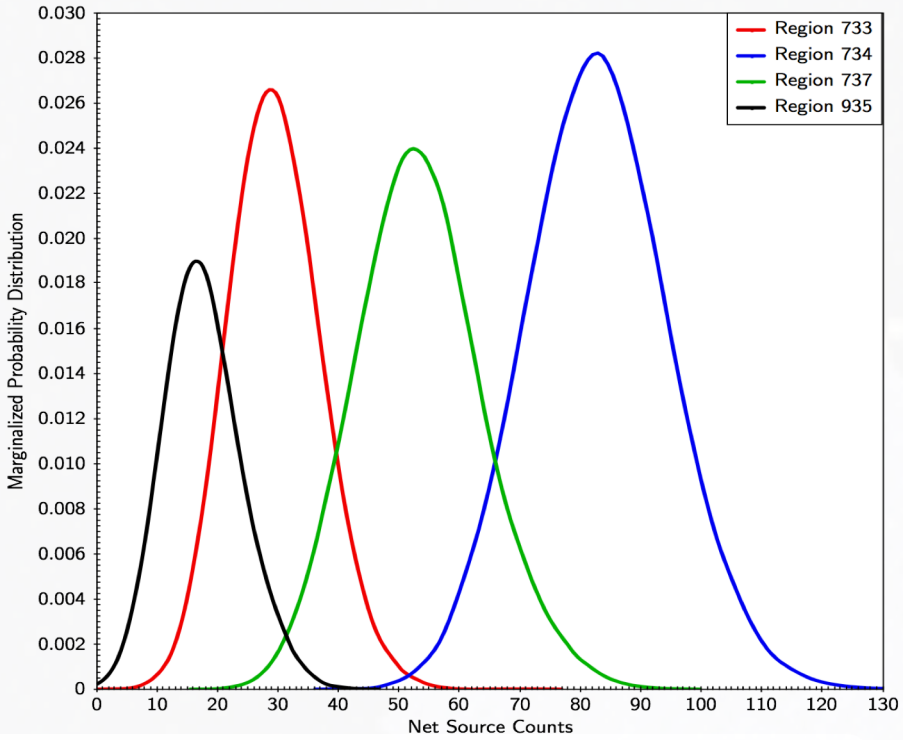
- **Aperture photometry; multi-band Bayesian Blocks algorithm**

Source Properties: Aperture Photometry

Fluxes are measured in each observation: Bayesian approach for simultaneous aperture photometry estimation in crowded fields *(Primini, F. A. & Kashyap, V. L. 2014)*





Photometric PDFs are estimated simultaneously for the overlapping detections

Source Properties: Aperture Photometry

Bayesian Model

Analyze sources with overlapping apertures, near-by sources, and background simultaneously.
Joint posterior for source fluxes and background flux (for single observation):

$$P(s_1 \ldots s_n, b | C_1 \ldots C_n, B) = K \times P(b) P_{Pois}(B \,|\, \phi) \prod P(s_i) P_{Pois}(C_i \,|\, \theta_i)$$

$$\theta_i = E_i \times \left[\sum_{j=1}^{n} f_{ij} s_j \; + \; \Omega_i b \right] ; \; \phi = E_b \times \left[\sum_{i=1}^{n} g_i s_i \; + \; \Omega_b b \right]$$

Counts in overlpaping regions assigned to brightest source

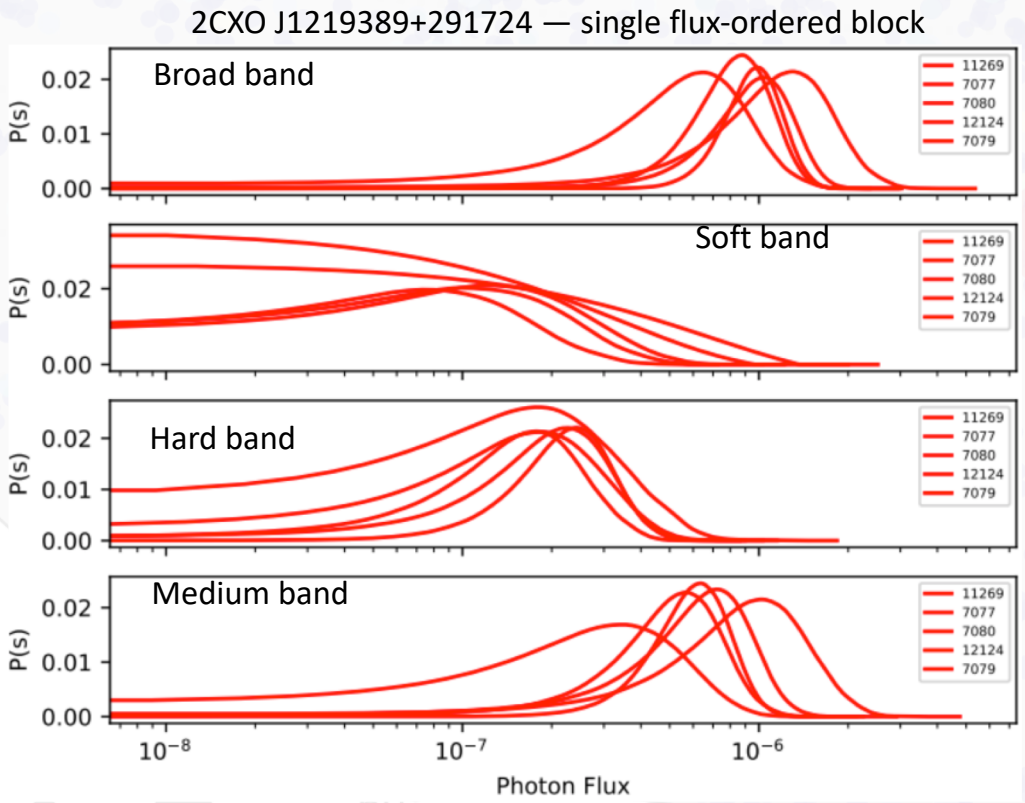
Master source flux for source s_k in an n-source bundle is determined from the Bayesian block for that source with the largest exposure. In this case:

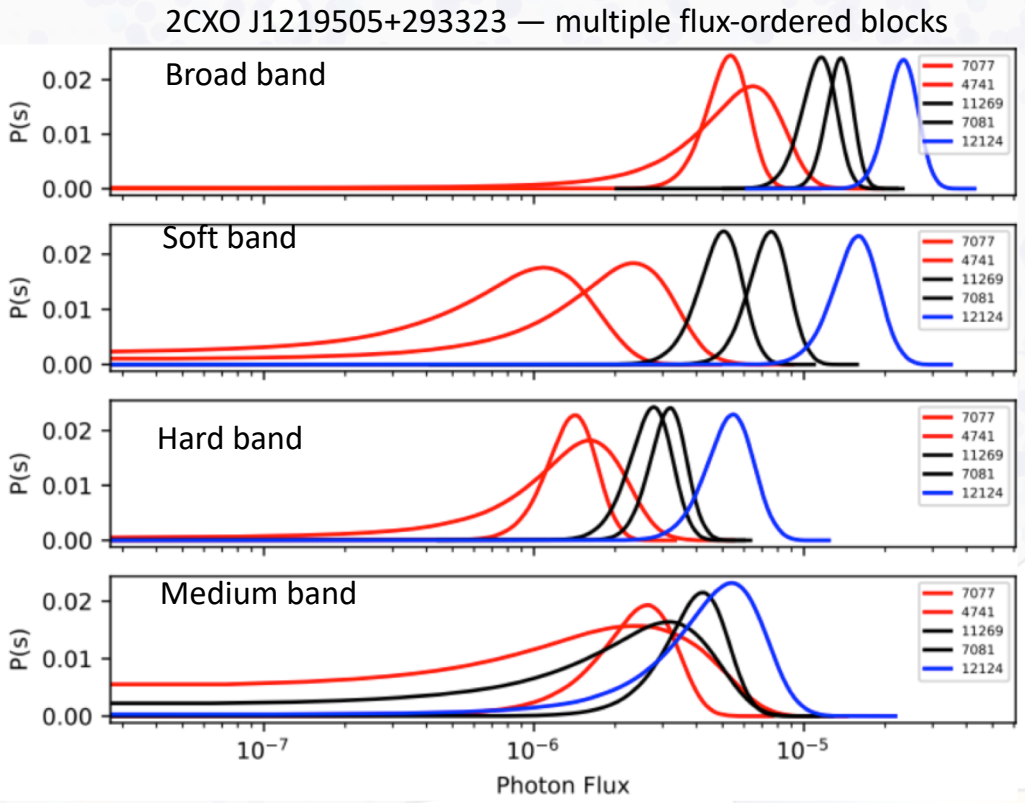
$$P(s_k | \{C_i^j\}, \{B^j\}) \cong P(s_k) \prod_{j=1}^{m} \left[P_{Pois}(B^j \,|\, \hat{\phi}^j) \times \; P_{Pois}(C_k^j | \hat{\theta}_k^j) \prod_{i=1, i \neq k}^{n} P_{Pois}(C_i^j \,|\, \hat{\theta}_i^j) \right]$$

In all cases, a marginalized posterior is obtained for each source are obtained by integration over all other sources and background.
Posteriors optimized and sampled using MCMC in Sherpa.

Grouping Observations to Improve S/N

- Multi-band Bayesian Blocks analysis *(Scargle+2013)* on detection fluxes to identify observations that can be analyzed/grouped together
- The combined properties for the longest exposure Bayesian Block are databased, but the properties for *all* blocks are recorded in a FITS data product





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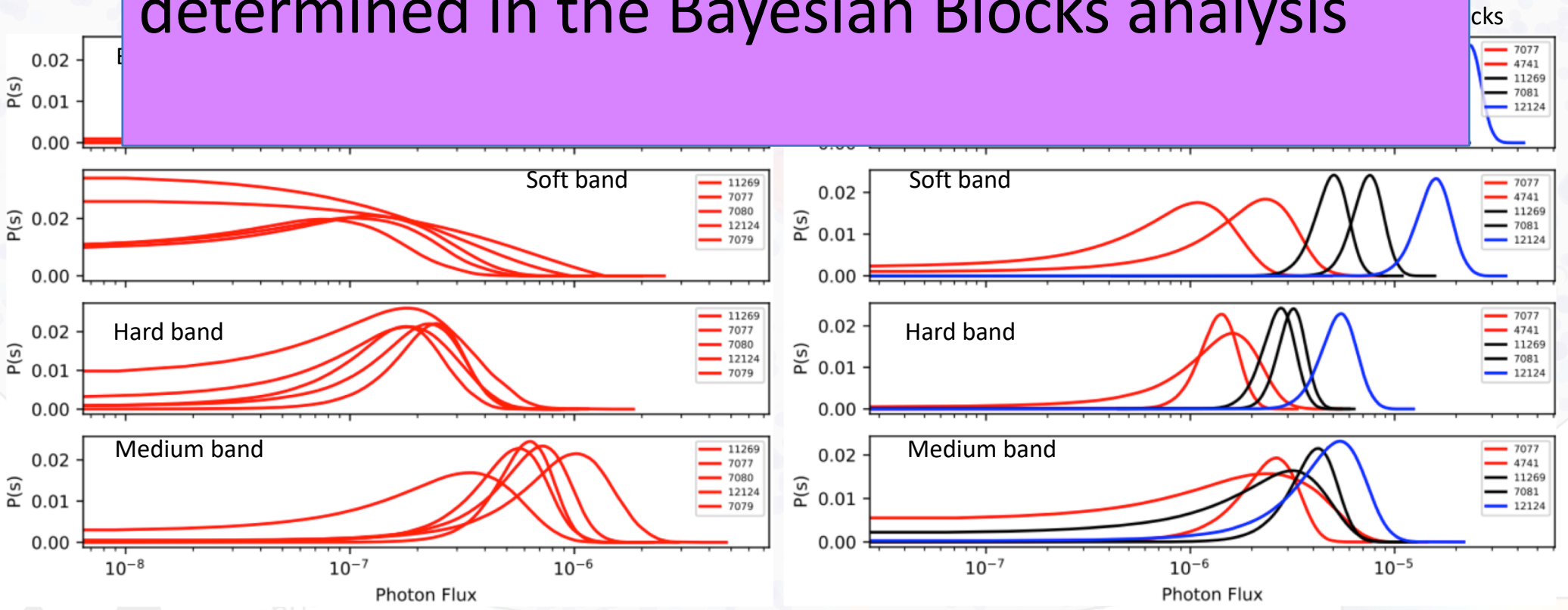
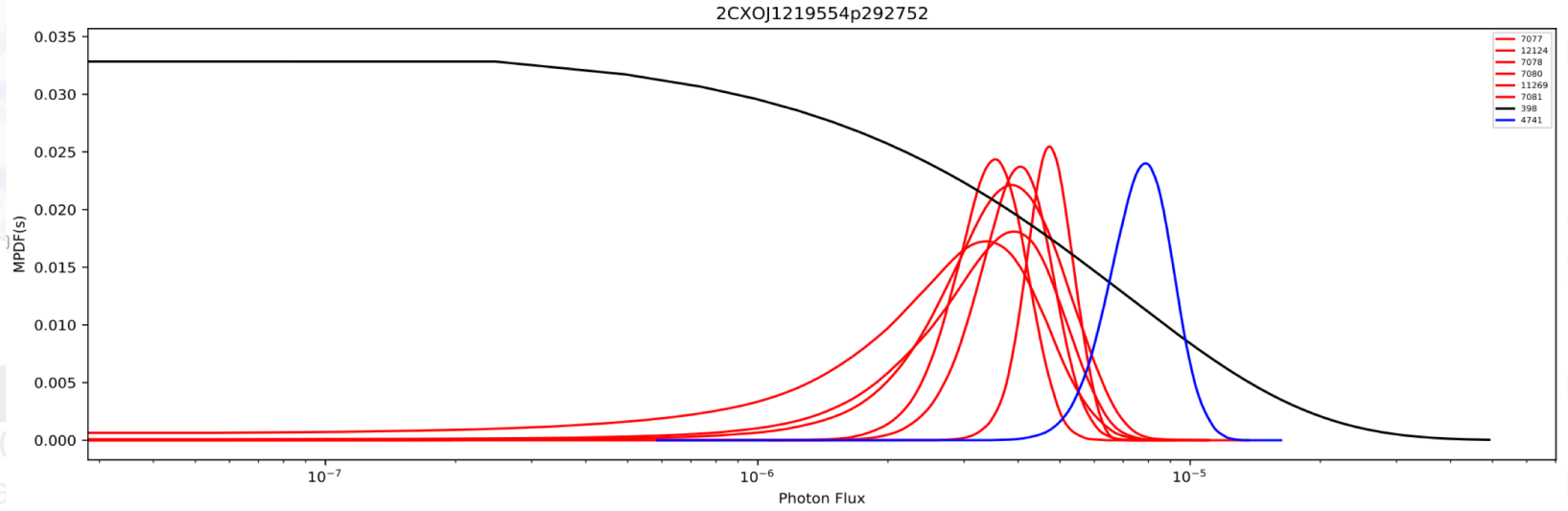
master level fluxes --> the best flux block determined in the Bayesian Blocks analysis



Variability Analysis

- **Single observation:** Gregory-Loredo Test: Hypothesis rejection test (i.e., odds ratio of assuming variability vs not assuming it). The probability that events detected are not arriving at a uniform rate. Used to estimate intra-obs variability (pick max prob among stack obsids).
- **Multiple observations:** Inter-observation variability. Variability test is based on a likelihood ratio between the null hypothesis of no variability, and the assumption of variability, when several observations are considered.



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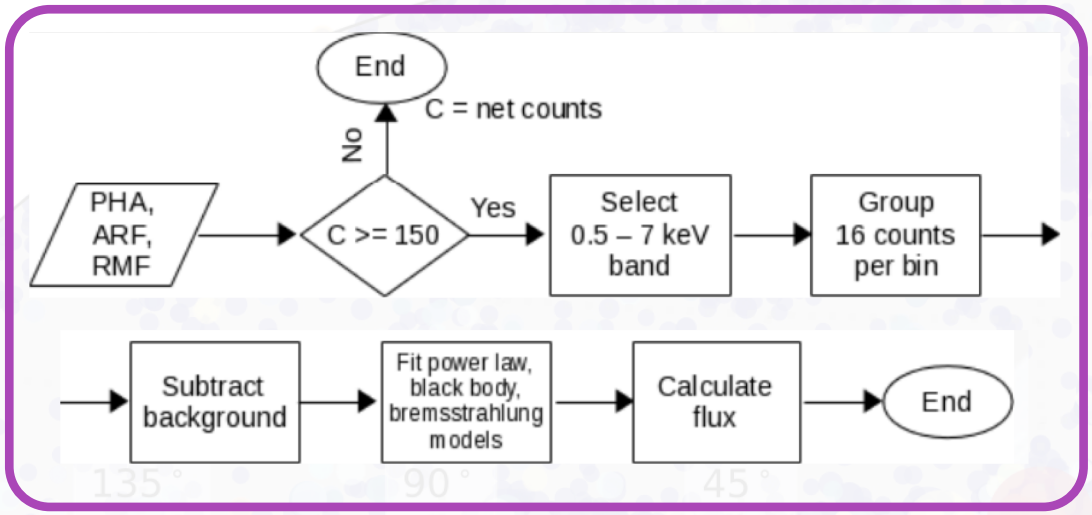
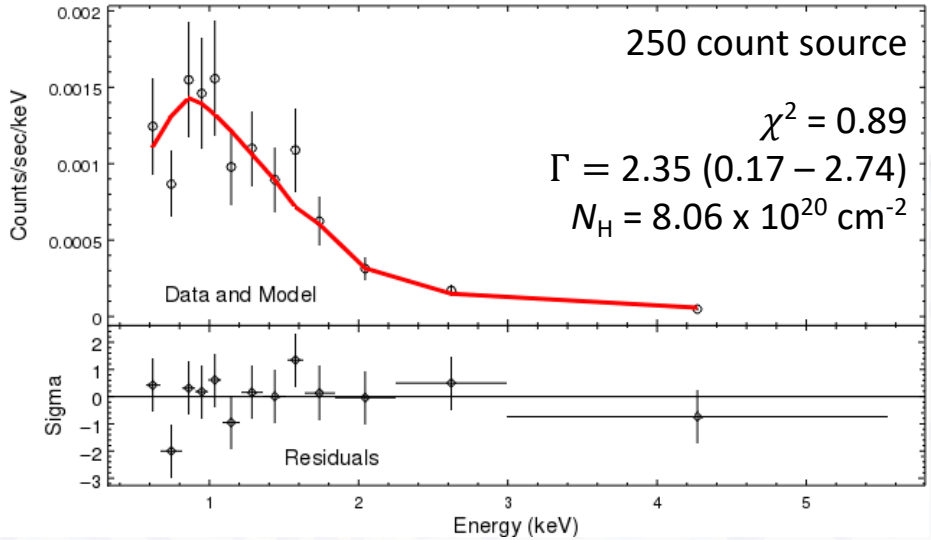
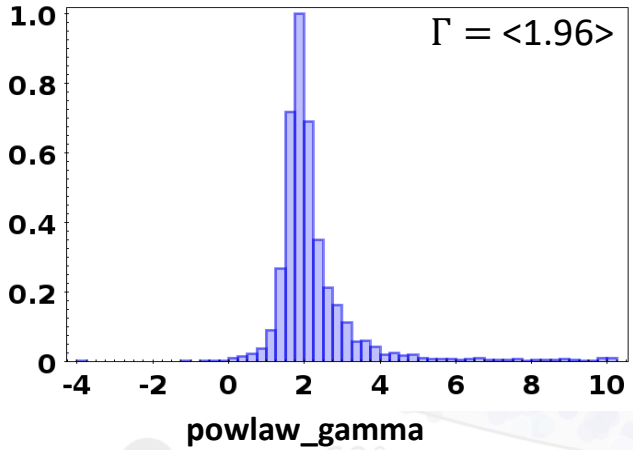
- **Spectra extraction of ALL DETECTIONS and spectral analysis**

Spectral Analysis

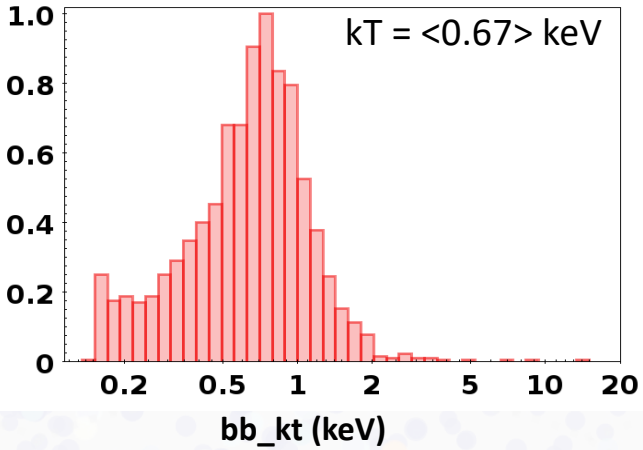




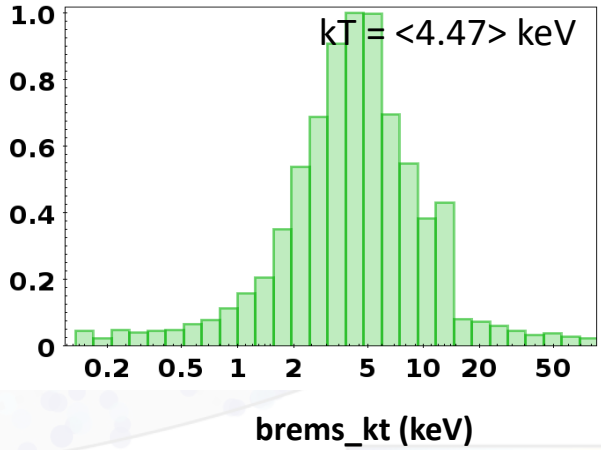
Abs. power law



Abs. black body

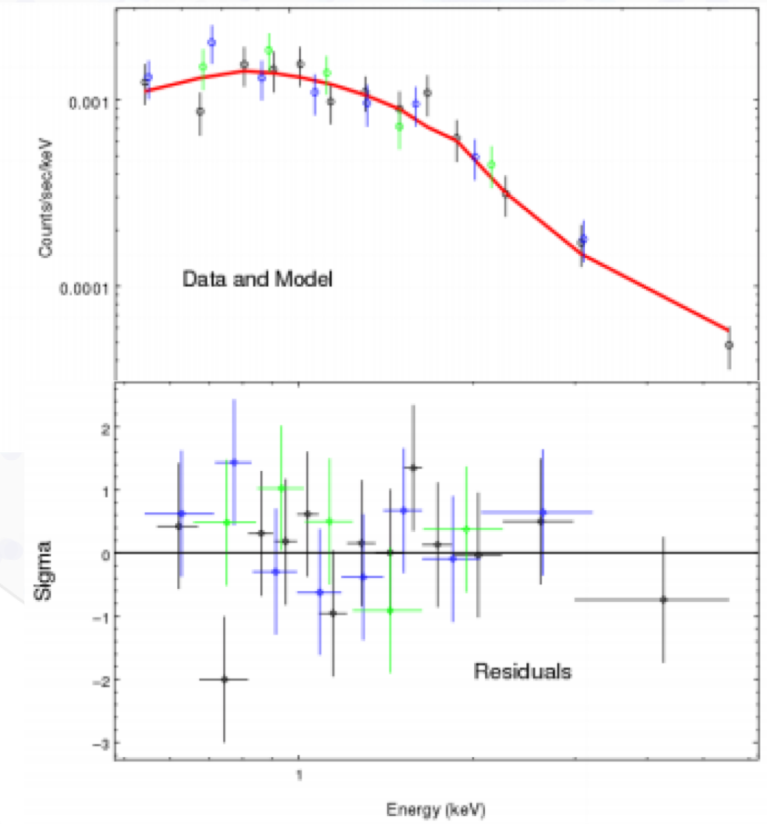


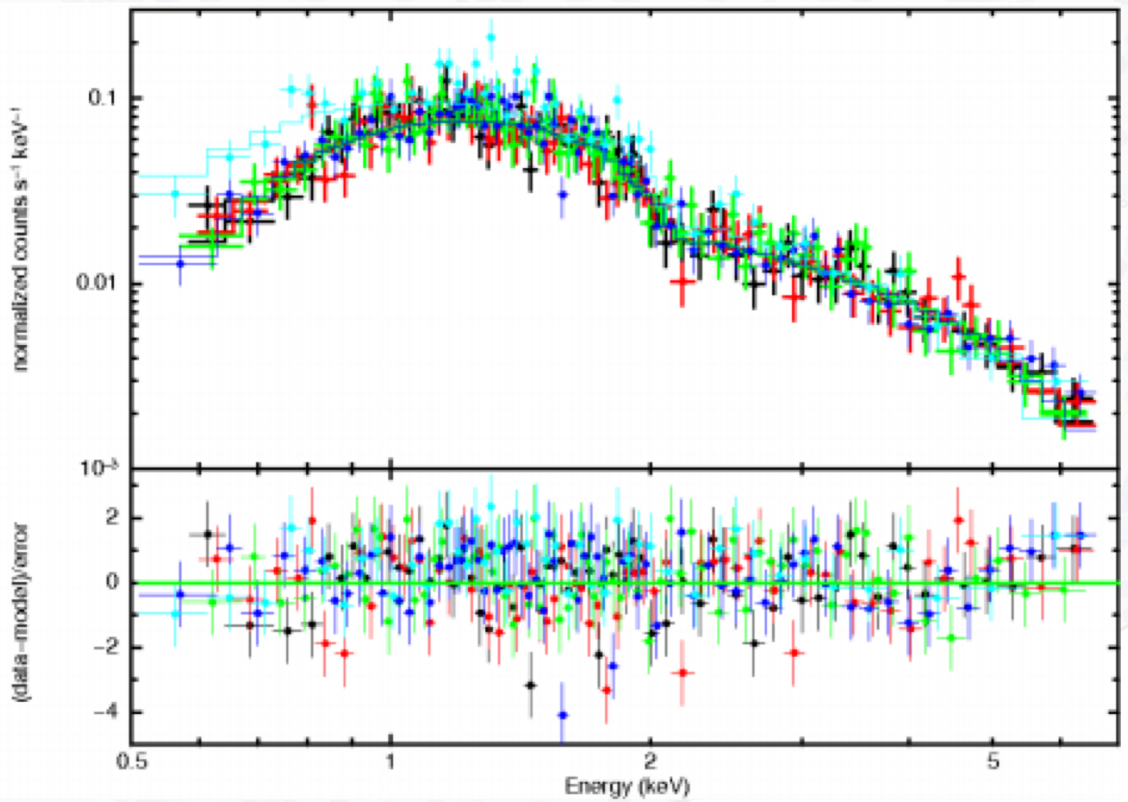
Abs. bremsstrahlung



Joint Spectral Fits

- Sources that are observed multiple times are grouped by the Bayesian blocks analysis
- All spectra in the block are simultaneously fit





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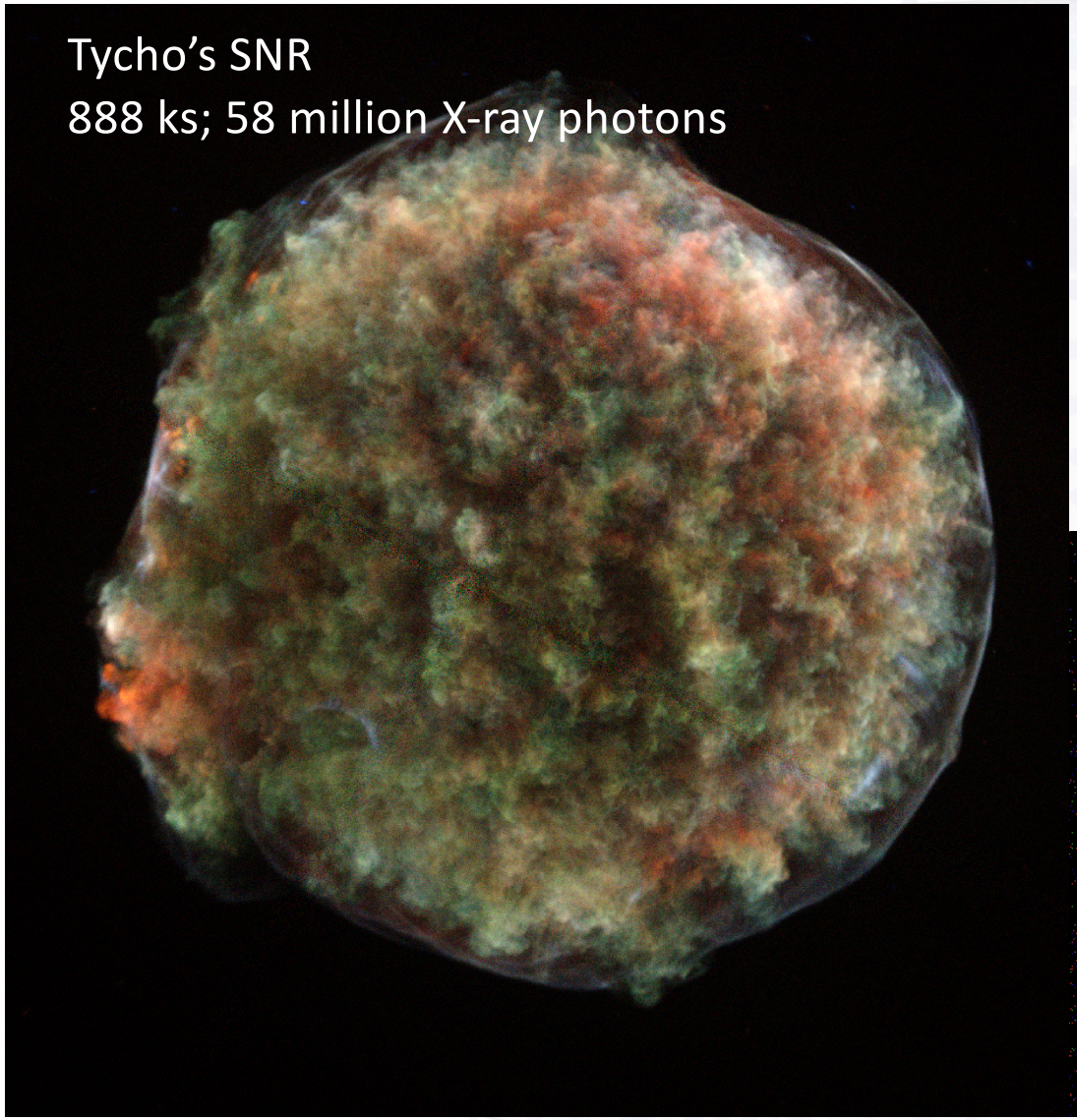
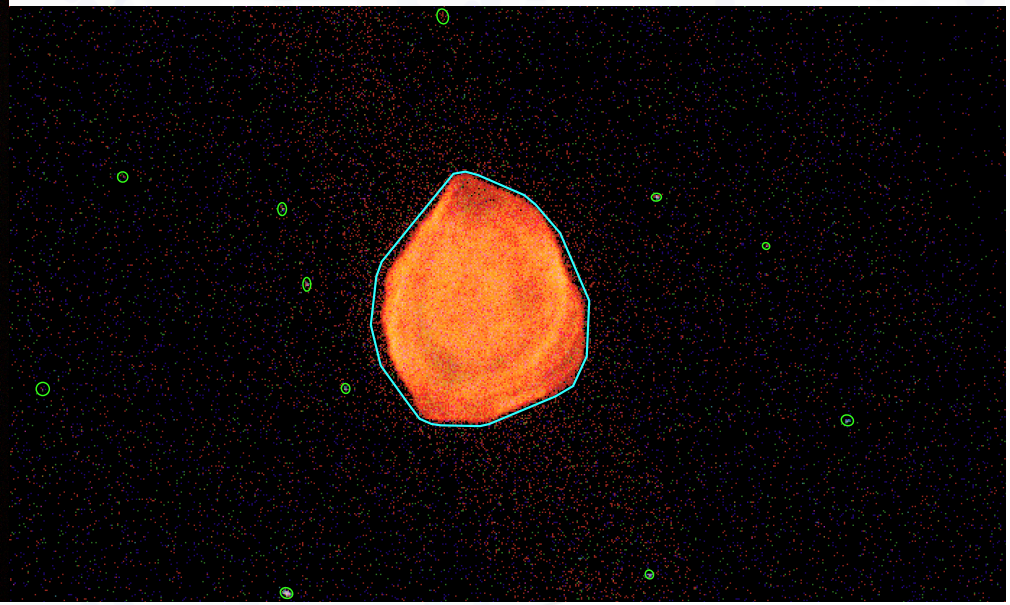
- Spectra extraction and spectral analysis
- **Extended emission properties**

Extended sources (>30”)



- 1,299 highly extended sources
- SNRs, cluster of galaxies, extended galaxies, jets, etc.
- Photometric properties are integrated over a convex hull bounding region
- Fluxes and regions are provided



Databased properties

Master Source Properties

- Source name, position and position errors, significance, source flags, multi-band deconvolved extent, multi-band aperture photometry (photon and energy fluxes, spectral model fluxes [multiple spectral models]), hardness ratios, spectral model fits [multiple spectral models], multi-band intra- and inter-observation temporal variability

Stacked-Observation Detection Properties

- Position and position errors, multi-band significance, detection flags and codes, multi-band deconvolved extent, multi-band aperture photometry (net counts and count rates, photon and energy fluxes), aperture parameters, hardness ratios, multi-band intra- and inter-observation temporal variability

Per-Observation Detection Properties

- Detector position, multi-band significance, detection flags and codes, multi-band raw, PSF, and deconvolved extent, multi-band aperture photometry (total counts, net counts and count rates, photon and energy fluxes, spectral model fluxes [multiple spectral models]), masked aperture parameters, spectral model fits [multiple spectral models], multi-band intra-observation temporal variability

Science-Ready FITS Data Products

~25 million files, ~32 TB

Observation Data Products

- Observation event list, aspect solution and histogram, bad pixel map, FoV, pixel mask
- Multi-band images, background images, exposure maps

Stacked-Observation Data Products

- Stack event list, FoV, merged detection list
- Multi-band images, background images, exposure maps, limiting sensitivity

Detection Region Data Products

- Detection region stack and observation region definitions, event lists
- Multi-band per-stack and per-observation images, exposure maps, position error MCMC draws, aperture photometry PDFs
- Multi-band per-observation PSFs, light curves
- Per-observation PHA spectrum, RMF, ARF

Source Level Data Products

- Aperture photometry PDFs, per-Bayesian block properties (aperture photometry fluxes, model energy fluxes, spectral fits, hardness ratios)

Catalog Access

http://cxc.cfa.harvard.edu/csc/

Not Secure | cxc.cfa.harvard.edu/csc/

Apps | Google Maps | Bank of America | Belmont Savings | Astro | OPS | webTA: | SAO/NASA ADS C... | Other Bookmarks

CHANDRA X-RAY OBSERVATORY

CXC HOME | PROPOSER | ARCHIVE | DATA ANALYSIS | INSTRUMENTS & CALIBRATION | FOR THE PUBLIC

Last modified: 24 October 2019

Search http://cxc.harvard.edu/csc2/

Google Custom Search

Contact the CXC HelpDesk

CHANDRA SOURCE CATALOG

CSC 2 CSC 1

CSC Data Access

- **CSCview** (help)
- Quick Search NEW
- View in WWT
- CIAO scripts
- Virtual Observatory

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Catalog Release Views and Database Access Views
Catalog Statistical Characterization
Caveats and Limitations
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Catalog Processing
Data Products
Chandra Data Archive
Using the Catalog➤
Threads
CSCview GUI
CSC CLI
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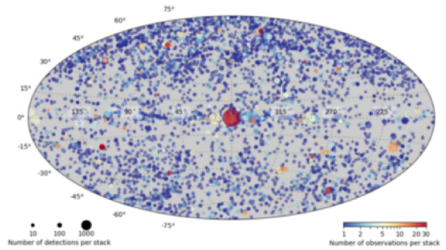
alphabetical | by context
Stacked Observation Detections Table:
alphabetical | by context
Per-Observation Detections Table:
alphabetical | by context
Column Descriptions➤
Position and Position Errors
Source Flags
Source Extent and Errors
Energy Bands
Source Fluxes
Source Significance

Chandra Source Catalog Release 2.0 (CSC 2.0)

What's New? | Watch Out

The Chandra Source Catalog (CSC) is the definitive catalog of X-ray sources detected by the *Chandra* X-ray Observatory. Version 2.0 (CSC2) is the second major release of the catalog, and represents a significant improvement with respect to version 1.1 in terms of sky coverage, sensitivity and capabilities. CSC2 includes measured properties for **317,167 unique compact and extended X-ray sources** in the sky, allowing statistical analysis of large samples, as well as individual source studies. Extracted properties are provided for **928,280 individual observation detections** identified in 10,382 *Chandra* ACIS and HRC-I imaging observations released publicly through the end of 2014. CSC 2.0 also includes—as an "alpha" release—photometric properties for 1,299 highly extended (≈30″) sources, together with surface brightness polygons for several contour levels. There are approximately 1,700 columns of tabular data with pertinent information about each source across 5 bands (broad, hard, medium, soft, and ultra-soft) for ACIS and 1 band (wide) for HRC (see the energy-bands page for the definition of these bands), and 40 data products per source. The total size of the archive is close to 36 TB.



[Version: full-size]

The locations, in Galactic coordinates, of the CSC 2.0 detections. The size of each symbol is proportional to the logarithm of the number of sources detected in the stack, while the color encodes the number of closely-located observations.

What is CSC 2.0?

Explore CSC 2.0 using the World Wide Telescope

How do I access or download CSC 2.0?

Are there any caveats for CSC 2.0?

What properties are available in CSC 2.0?

Is my favorite source in CSC 2.0?

How do I find the flux of a source?

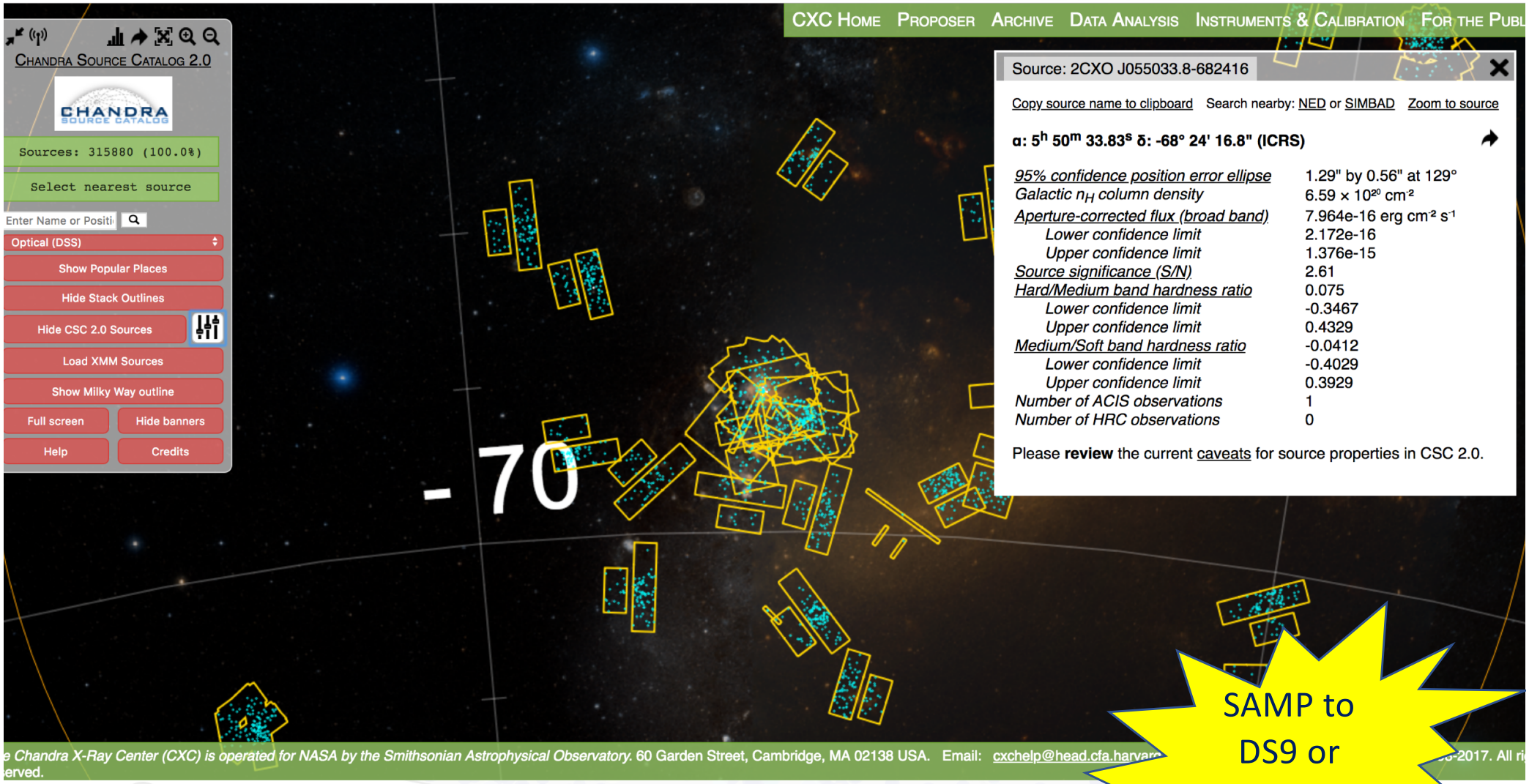
How do I cite CSC 2.0?

Data Access

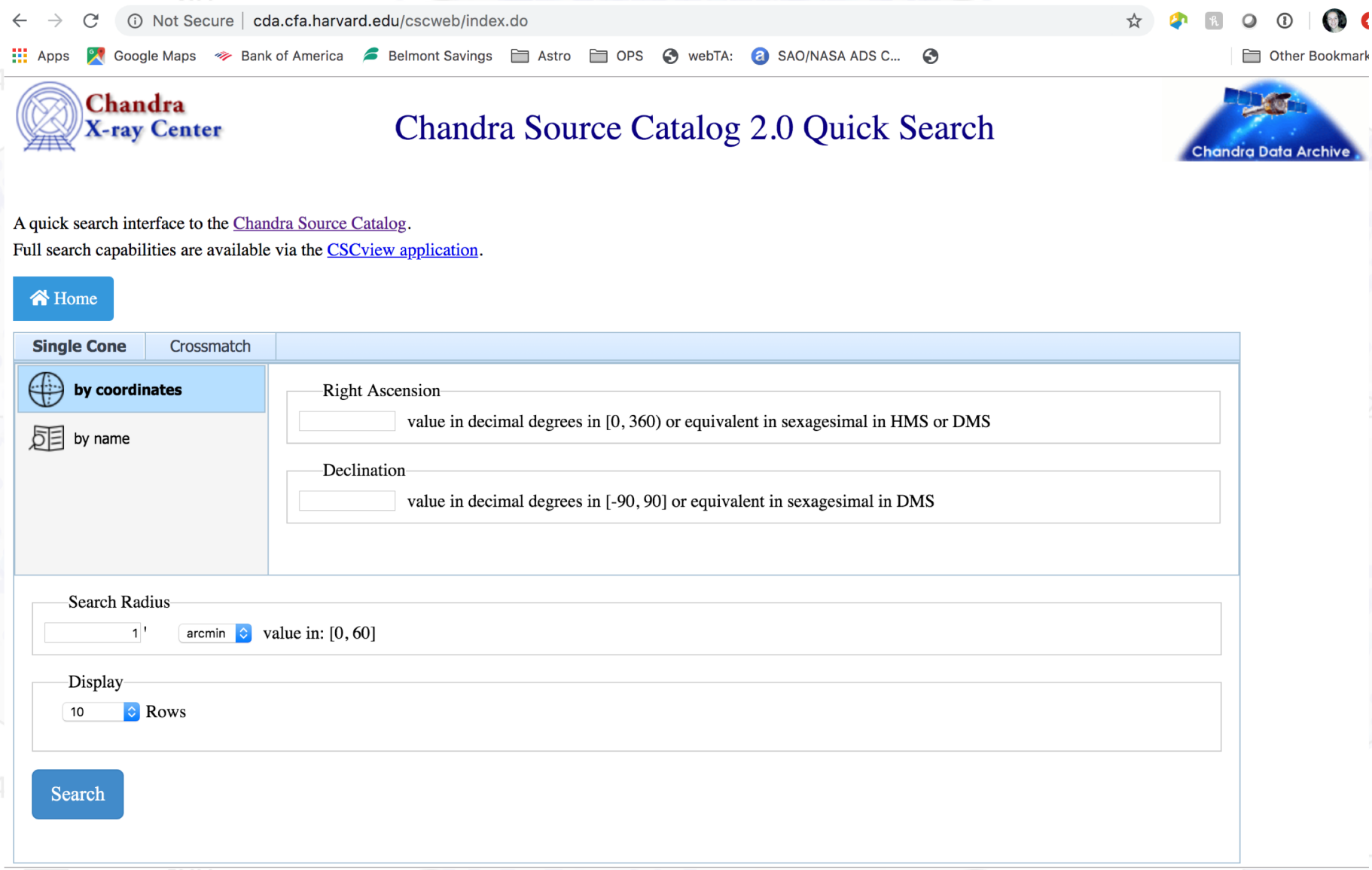
http://cxc.cfa.harvard.edu/csc/

- The CSCview application
- Quick Search: the CSC web interface NEW
- View in the World Wide Telescope
- CIAO scripts
  - search_csc
  - obsid_search_csc
- Using Virtual-Observatory interfaces
  - Astronomical Data Query Language
  - Cone search
  - Table Access Protocol
  - Simple Image Access Protocol

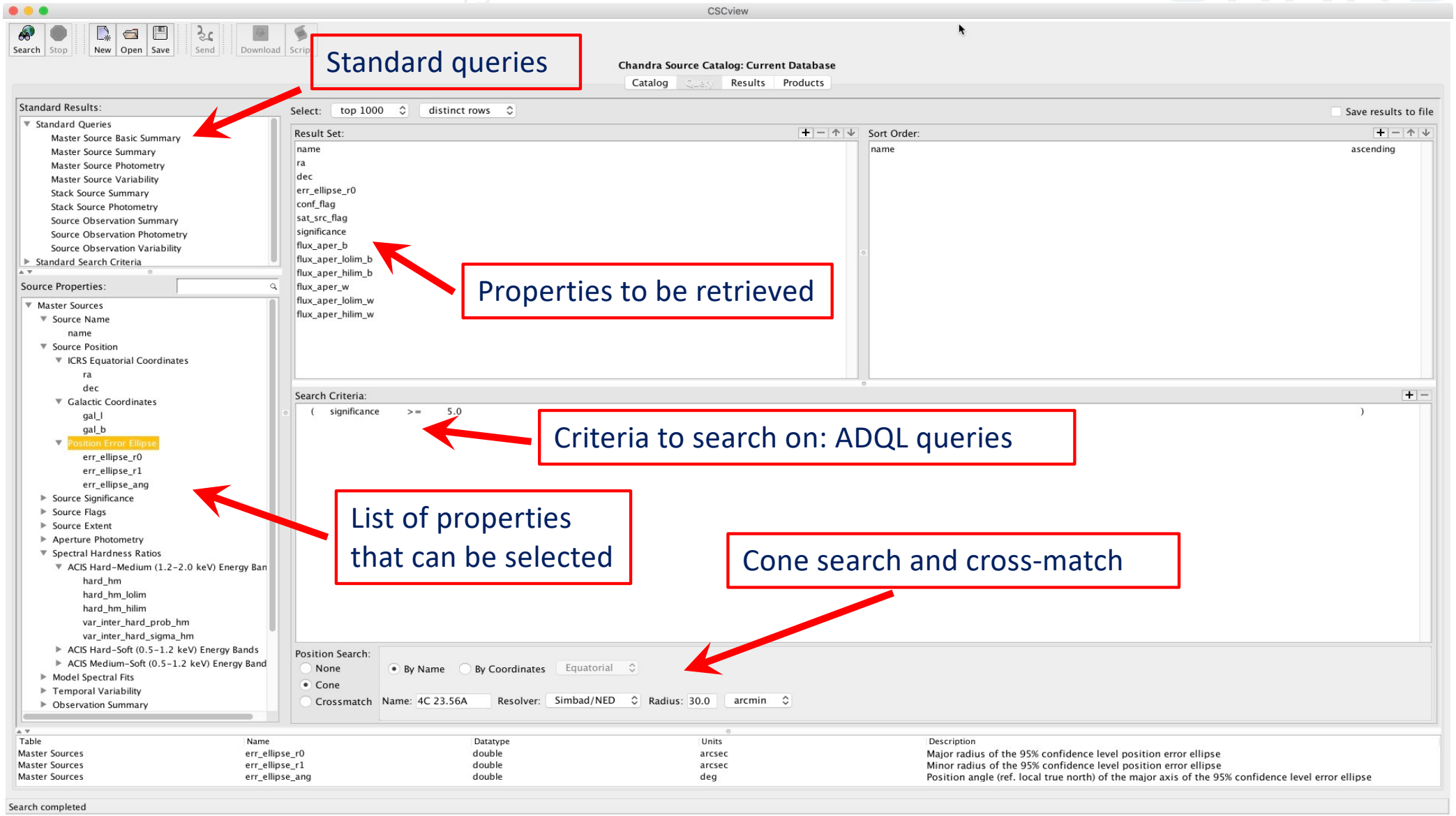
For a quick view: WWT



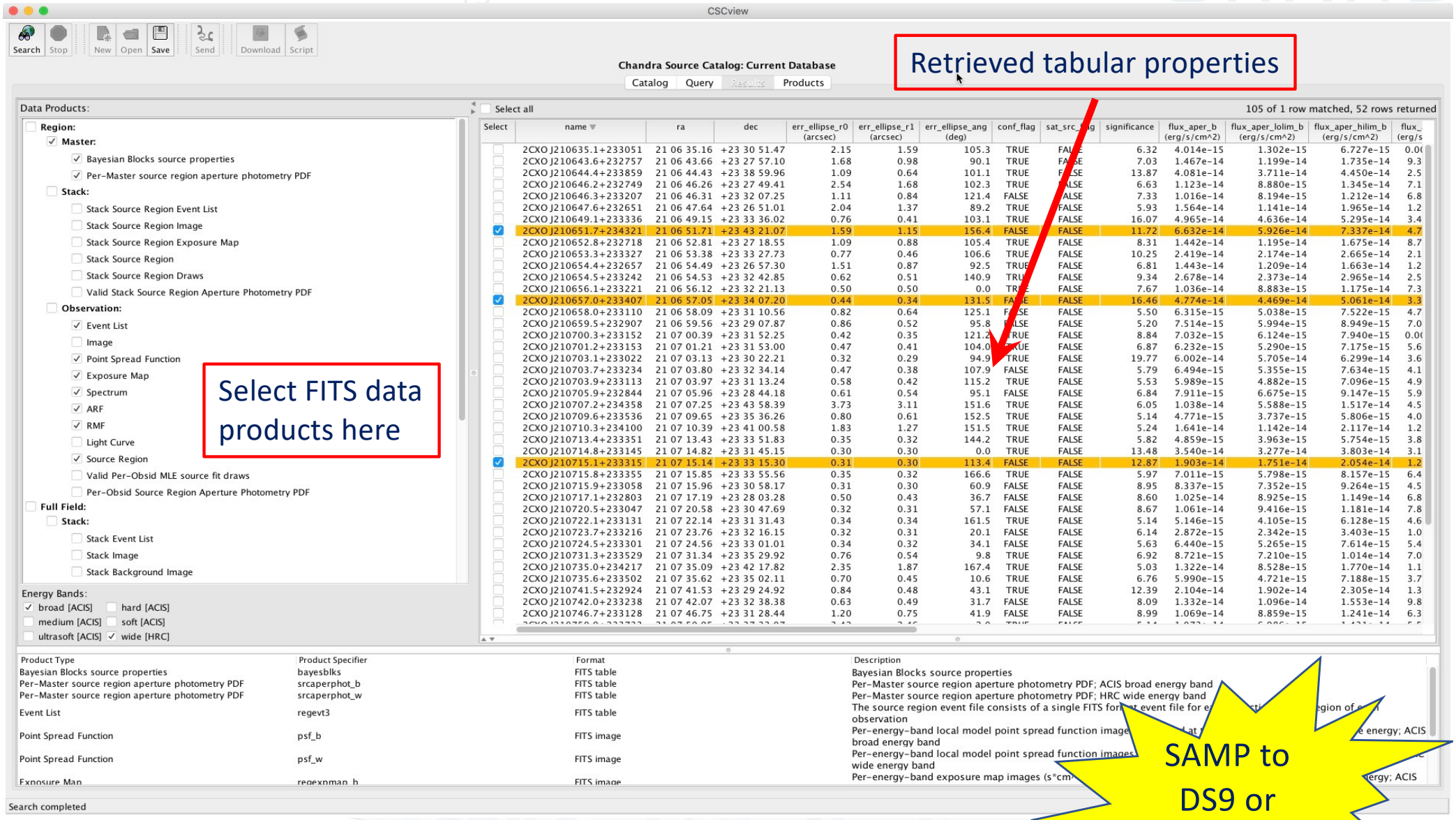
For a quick search: web search

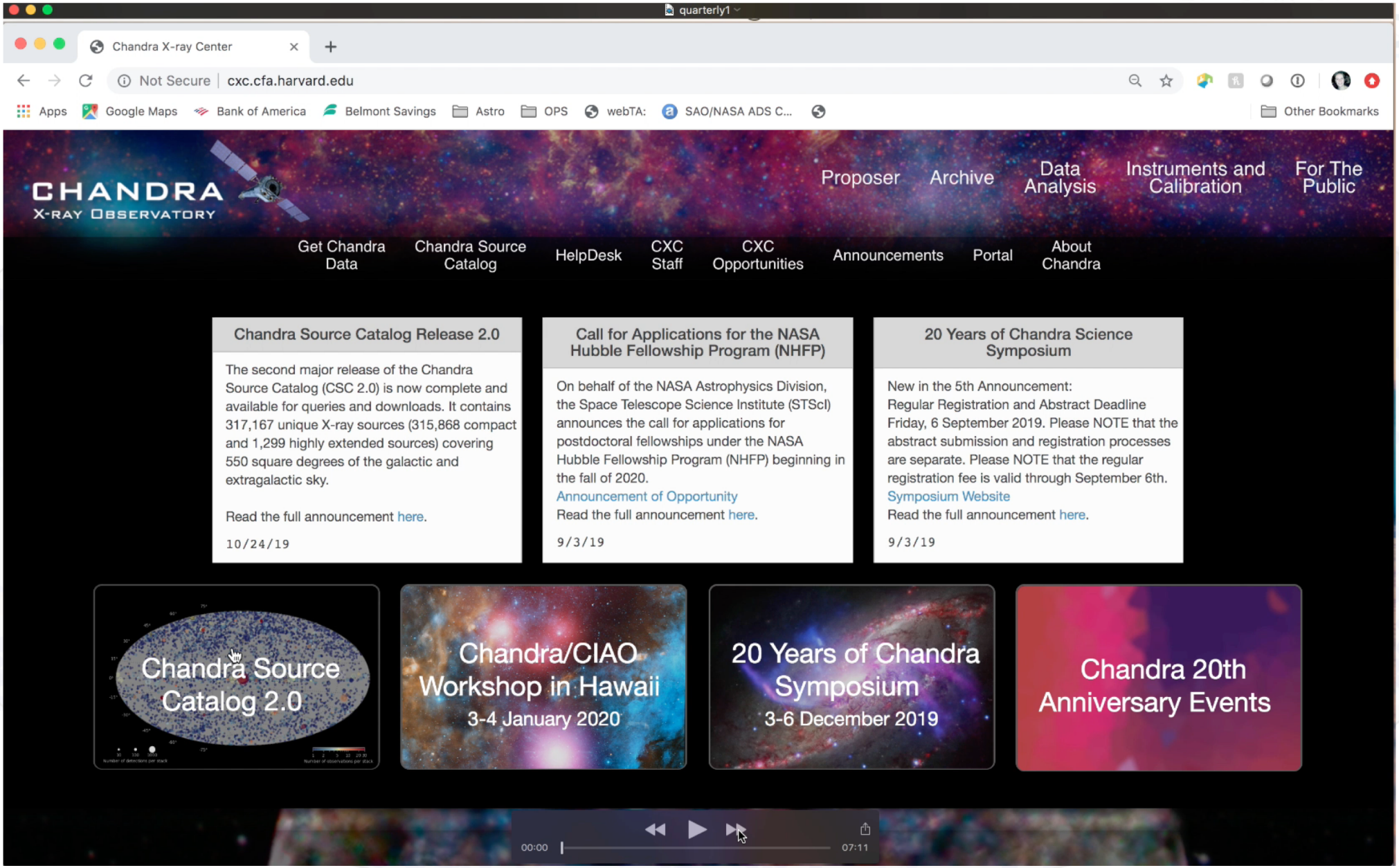


Data Retrieval: CSCView



Data Retrieval: CSCView




quarterly1
Chandra X-ray Center
Not Secure | cxc.cfa.harvard.edu
Apps
Google Maps
Bank of America
Belmont Savings
Astro
OPS
webTA:
SAO/NASA ADS C...
Other Bookmarks
CHANDRA
X-RAY OBSERVATORY
Proposer
Archive
Data Analysis
Instruments and Calibration
For The Public
Get Chandra Data
Chandra Source Catalog
HelpDesk
CXC Staff
CXC Opportunities
Announcements
Portal
About Chandra
Chandra Source Catalog Release 2.0
The second major release of the Chandra Source Catalog (CSC 2.0) is now complete and available for queries and downloads. It contains 317,167 unique X-ray sources (315,868 compact and 1,299 highly extended sources) covering 550 square degrees of the galactic and extragalactic sky.
Read the full announcement here.
10/24/19
Call for Applications for the NASA Hubble Fellowship Program (NHFP)
On behalf of the NASA Astrophysics Division, the Space Telescope Science Institute (STScI) announces the call for applications for postdoctoral fellowships under the NASA Hubble Fellowship Program (NHFP) beginning in the fall of 2020.
Announcement of Opportunity
Read the full announcement here.
9/3/19
20 Years of Chandra Science Symposium
New in the 5th Announcement:
Regular Registration and Abstract Deadline Friday, 6 September 2019. Please NOTE that the abstract submission and registration processes are separate. Please NOTE that the regular registration fee is valid through September 6th.
Symposium Website
Read the full announcement here.
9/3/19
Chandra Source Catalog 2.0
Chandra/CIAO Workshop in Hawaii
3-4 January 2020
20 Years of Chandra Symposium
3-6 December 2019
Chandra 20th Anniversary Events
00:00
07:11

NEW

Multiwavelength Associations (1)

- Systematic cross-match with SDSS, Gaia, ALLWISE, and Pan-STARRS catalogs
- Two similar Bayesian algorithms: Xmatch (A. Rots), NWAY (J. Buchner)
- Cross-match tables will be made available via CXC website and CDS

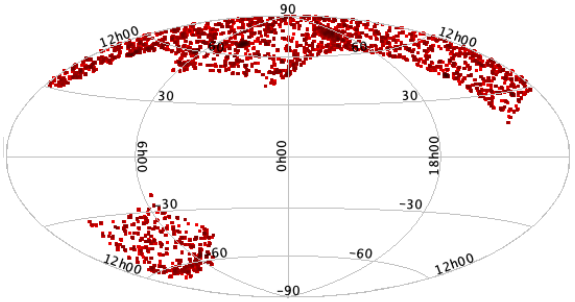
NEW

Multiwavelength Associations (2)

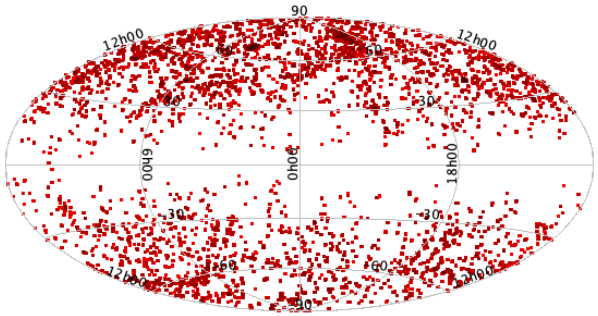
Number of matches at <10" separation:

35k matches	SDSS
92k matches	GAIA
105k matches	PanSTARRS
71k matches	2MASS
124k matches	WISE
32k matches	GALEX

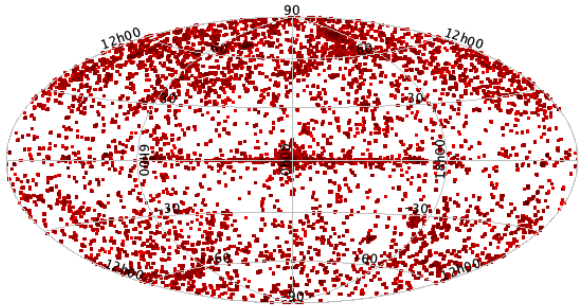
SDSS



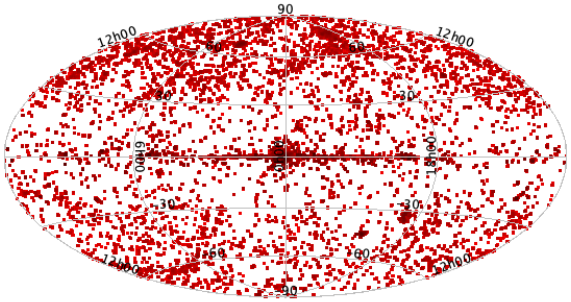
GALEX



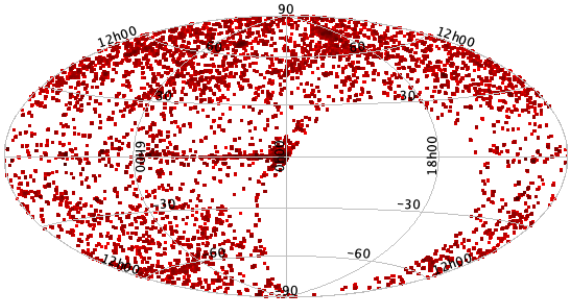
WISE



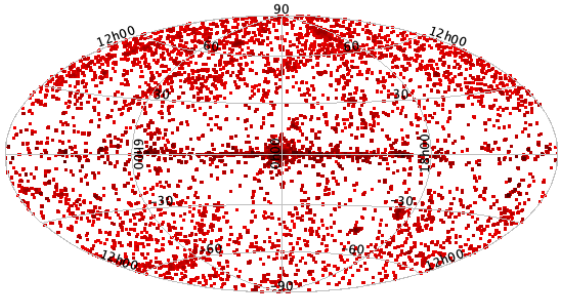
GAIA



PanSTARRS



2MASS

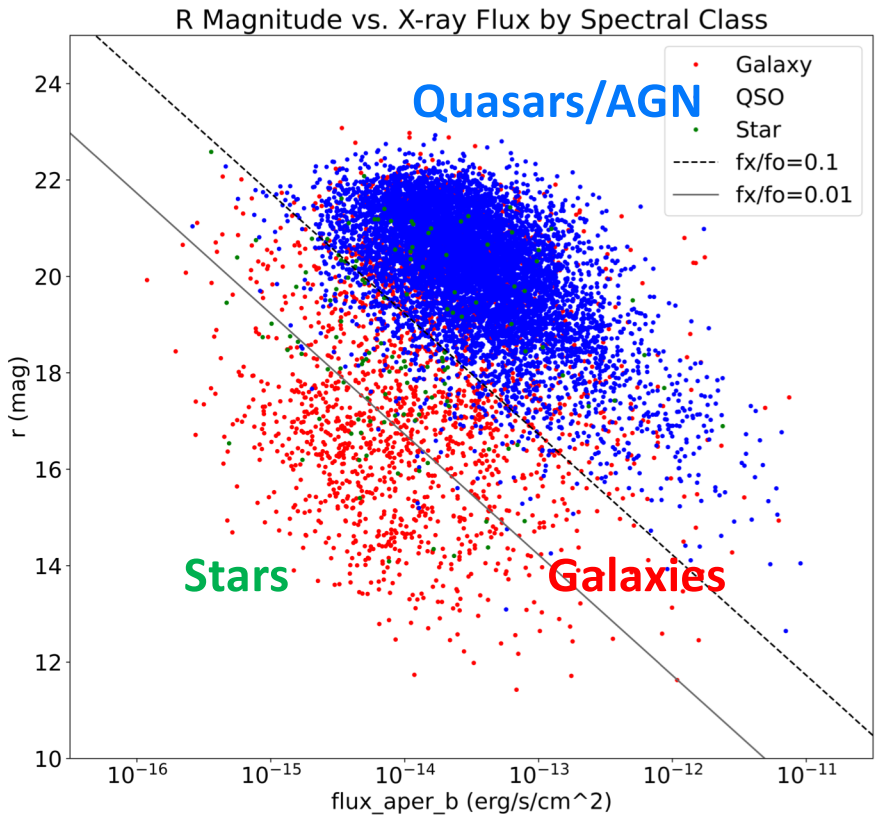


Credit to D-W. Kim, A. Cassity

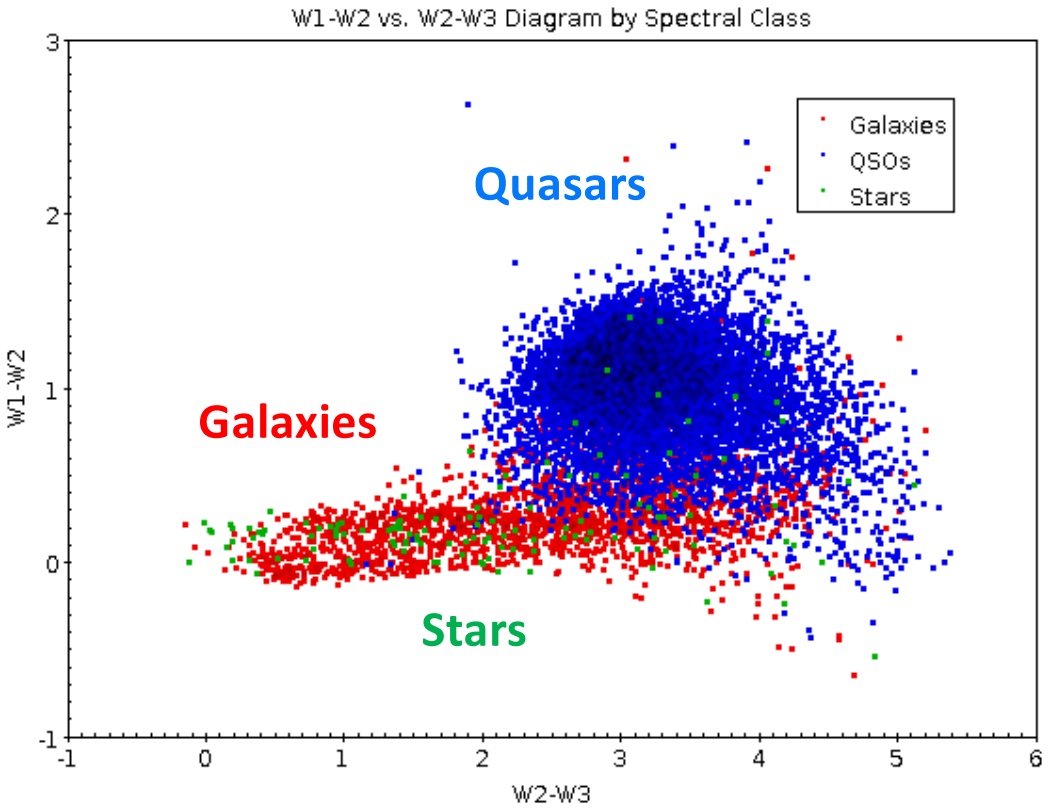
NEW

Multiwavelength Properties

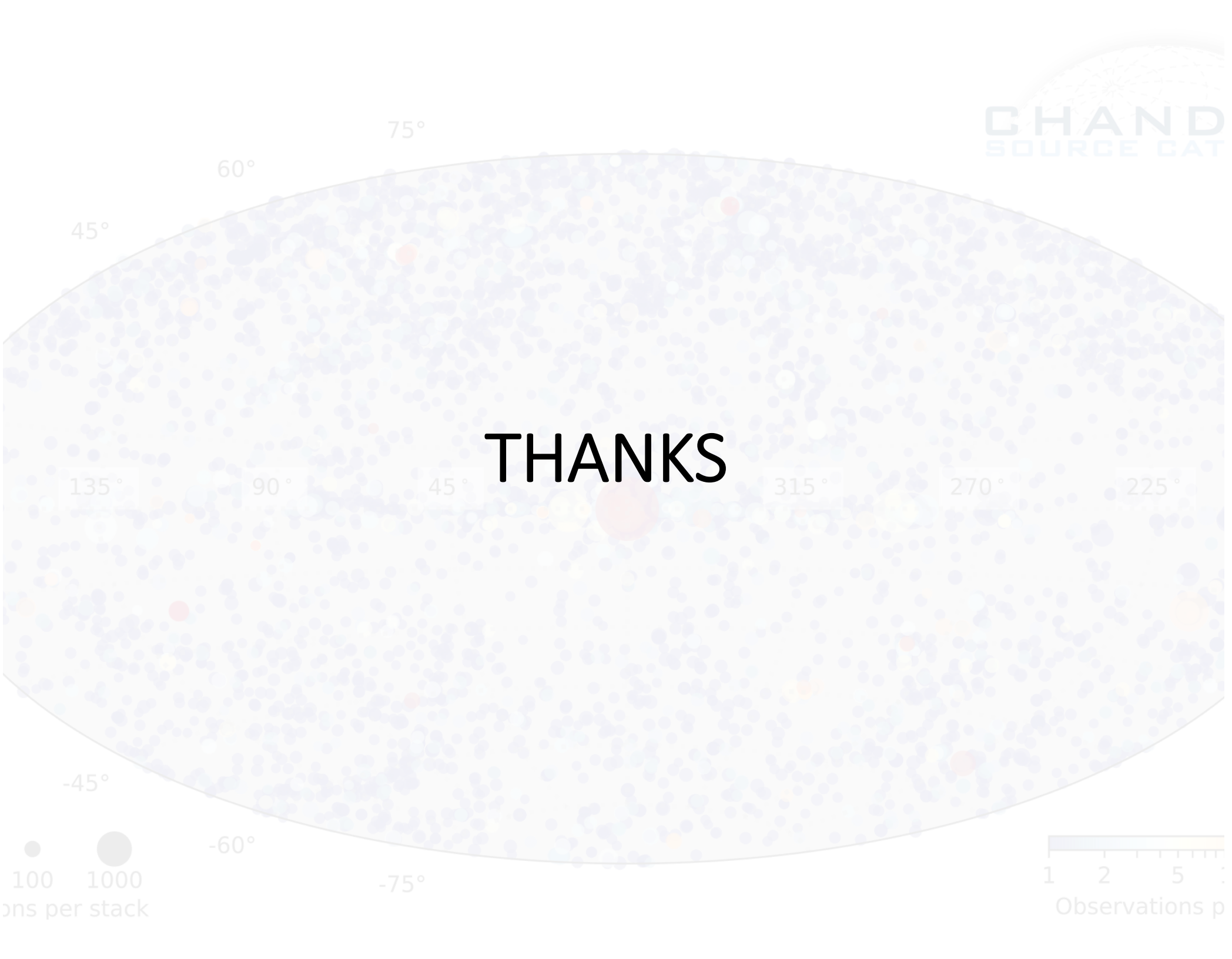
X-ray to optical flux with SDSS classification



WISE colors with SDSS classification



Credit to D-W. Kim, A. Cassity


75°
60°
45°
135°
90°
45°
315°
270°
225°
-45°
-60°
-75°
100
1000
ons per stack
1
2
5
Observations p

THANKS