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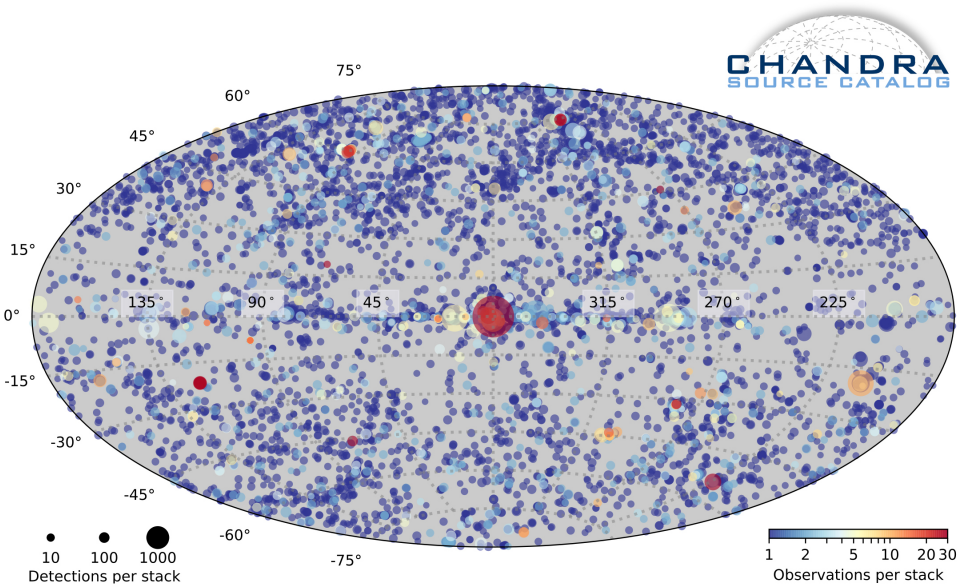
[4]*MIT Kavli Institute for Astrophysics and Space Research*

CSC 2.0 in numbers

	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	~5
Number of sources	106,586	315,875
Number of detections	158,071	374,349



~550 deg²
Area covered
~1.3% of sky

CSC 2.0 features

- **Source detection on stacked observations**

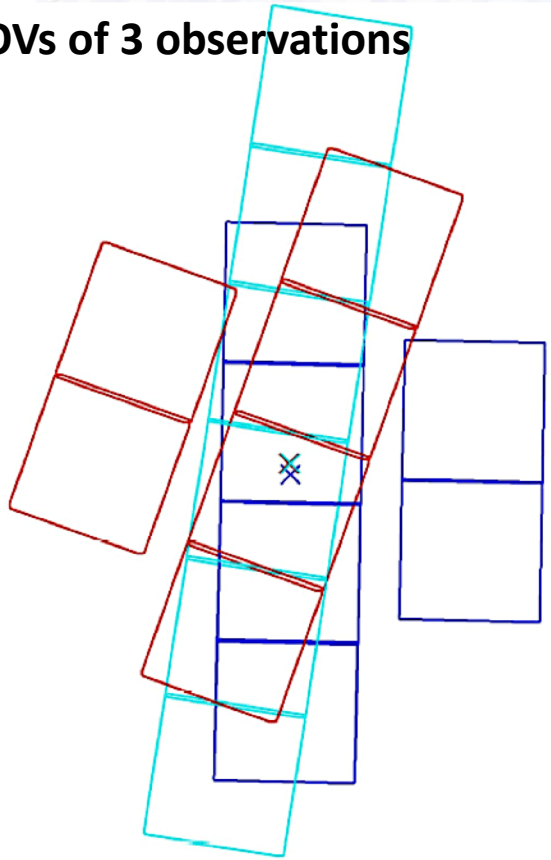
New source detection approach

- 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: ~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

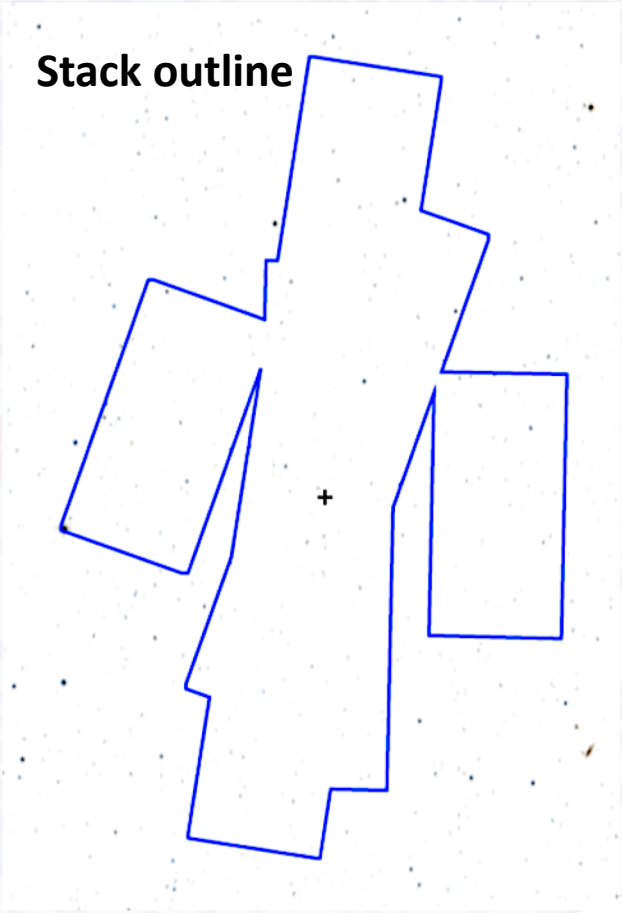
Stacked observations

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

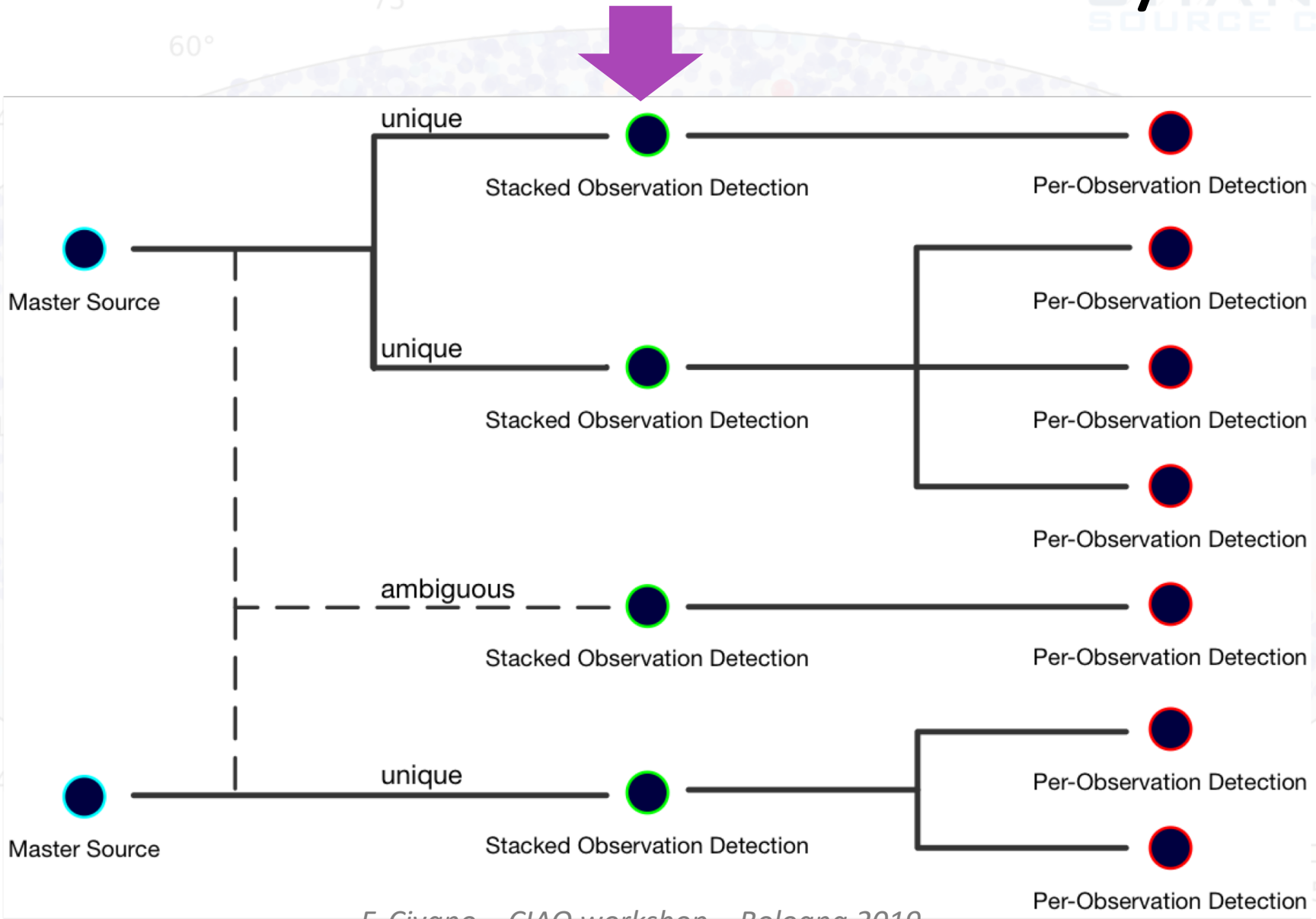
FOVs of 3 observations



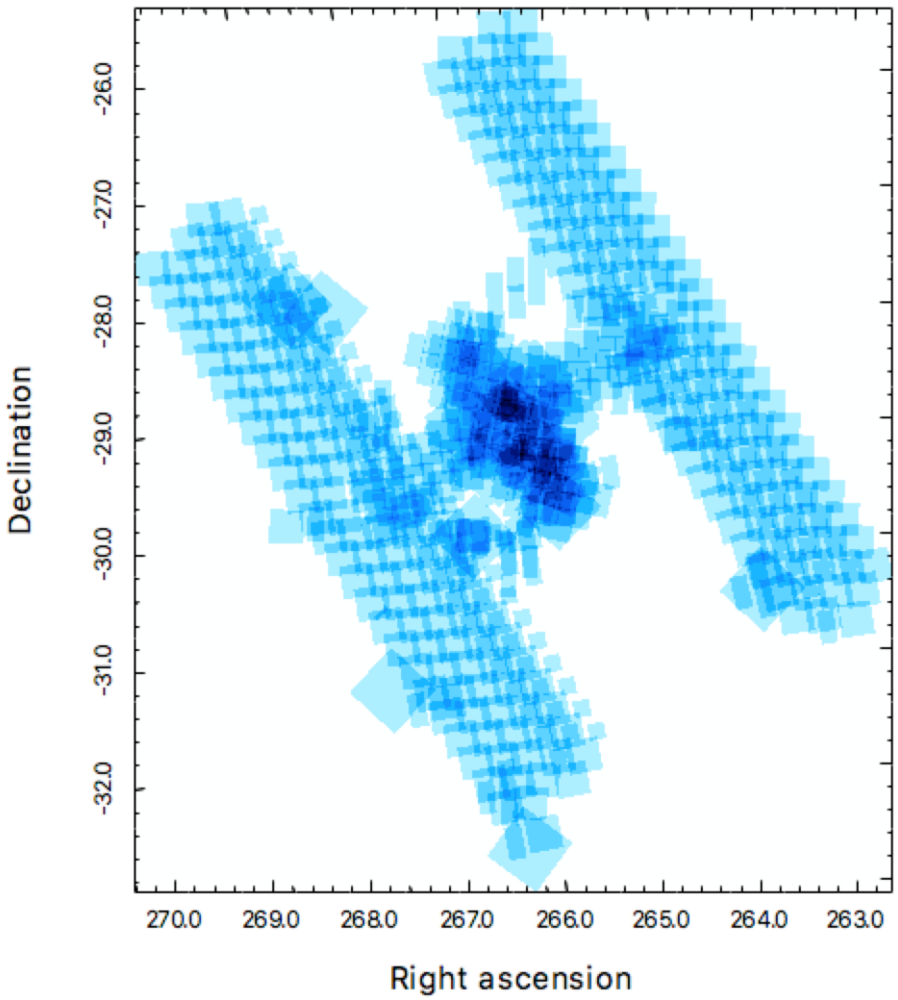
Stack outline



Source detection hierarchy



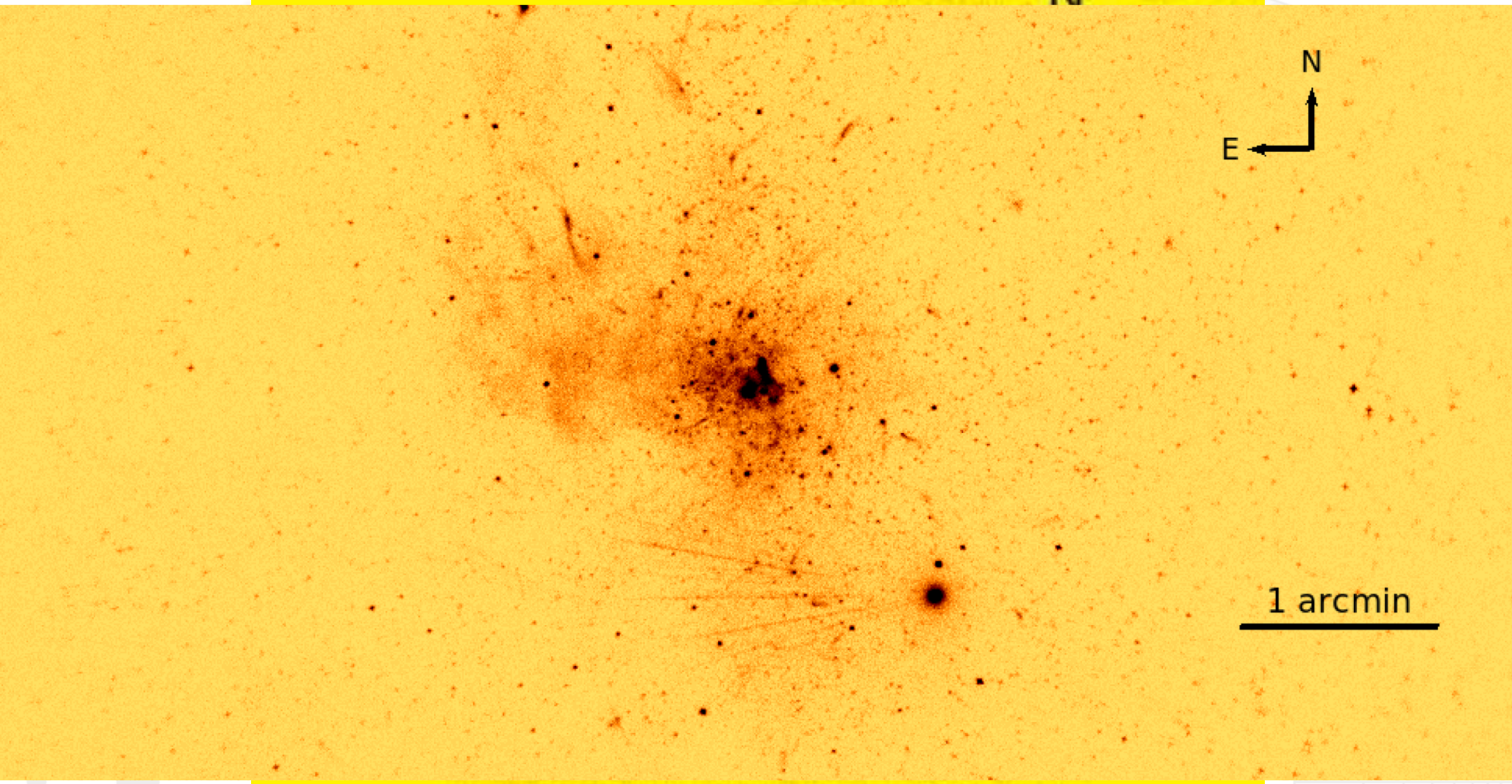
Example: Galactic Center Area



- 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

Sgr A* - central stack of 71 observations



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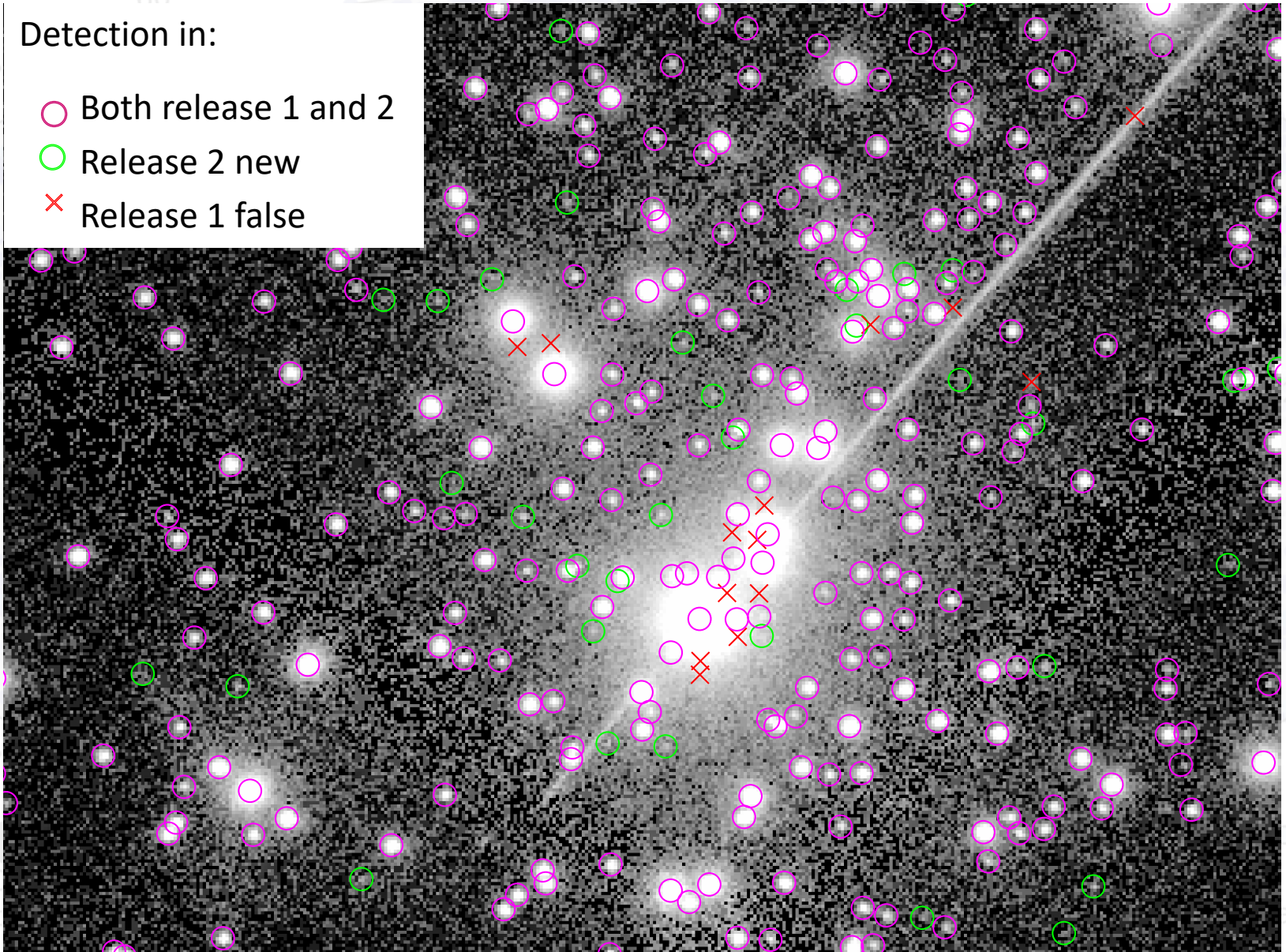
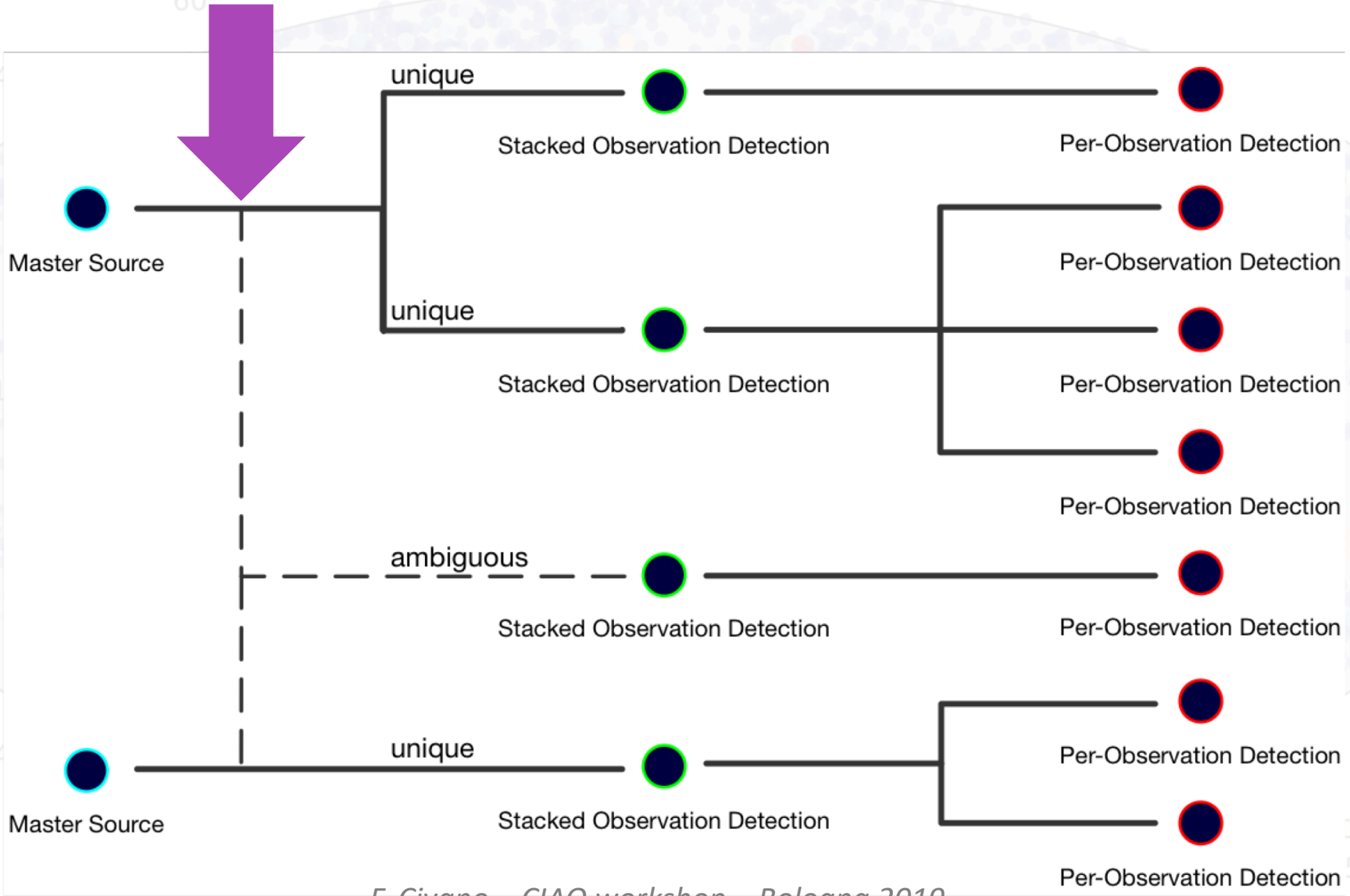
  - **Wavelet detection *plus* Voronoi tessellation algorithm**
  - **Maximum likelihood estimator to improve on-axis detection (~5 net counts for exposures < 15 ks)**

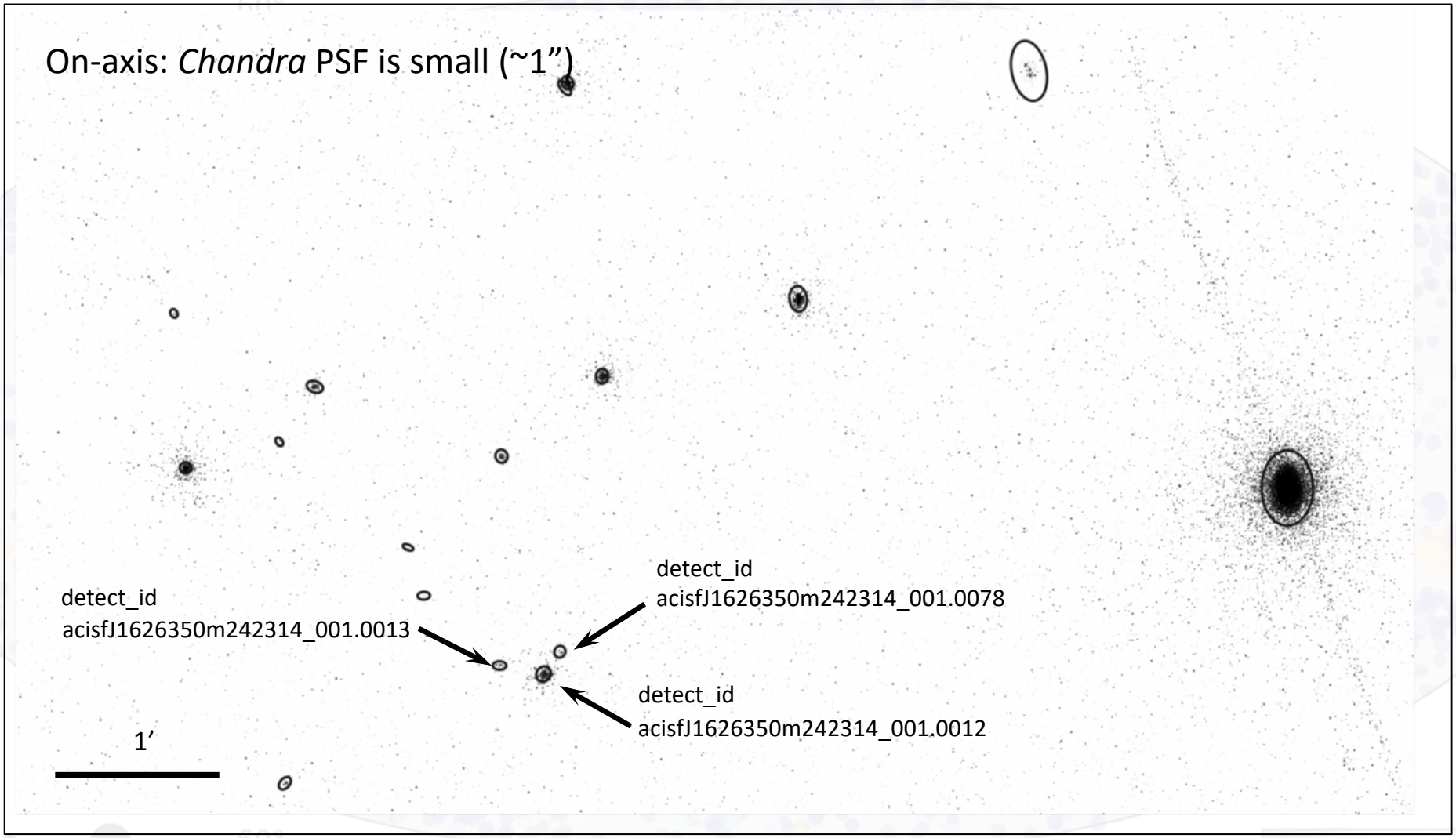
Detection: reaching the faintest sources



Master matching process



Detections and sources



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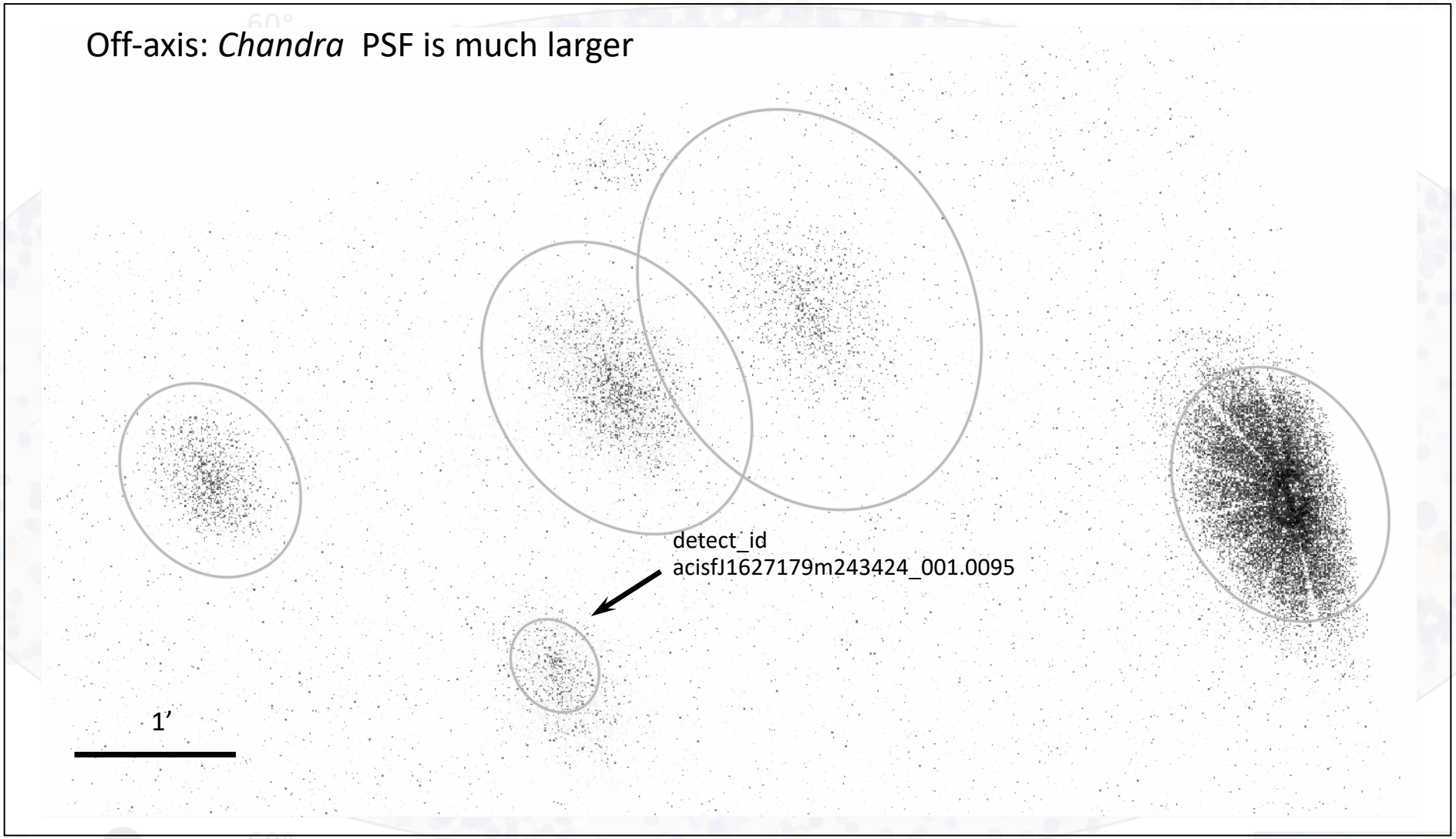
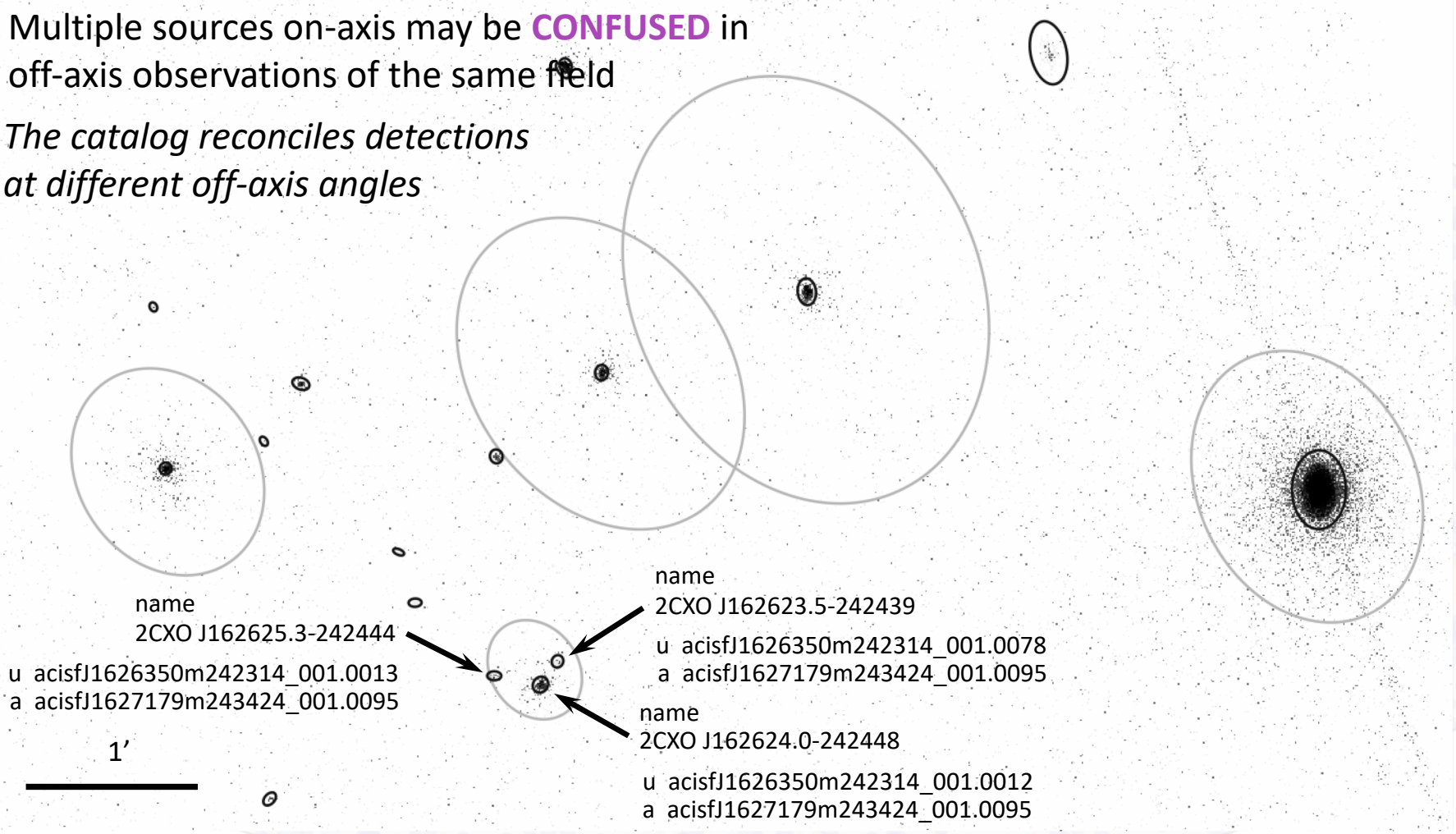


Detections and sources

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

The catalog reconciles detections at different off-axis angles



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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

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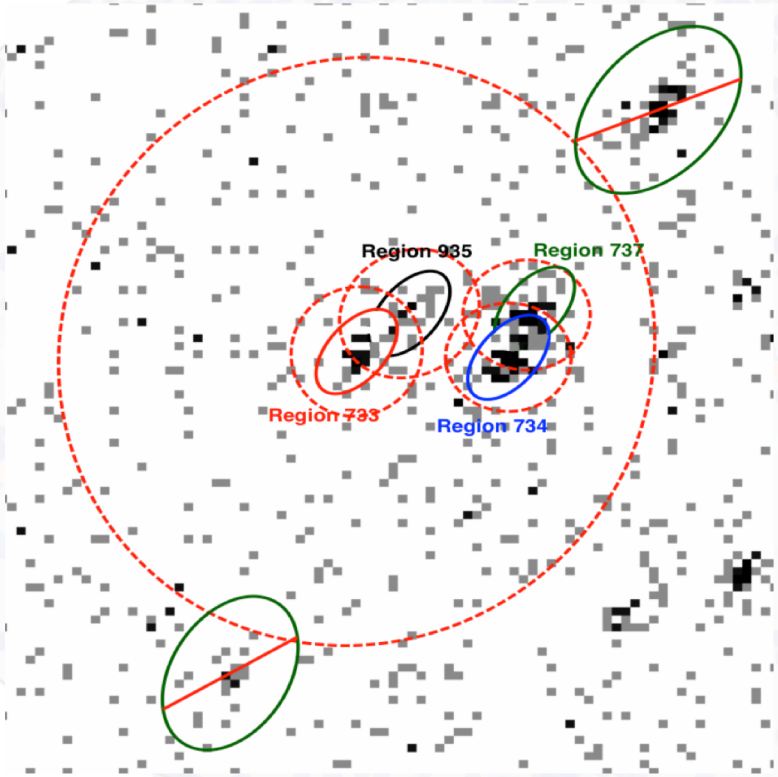
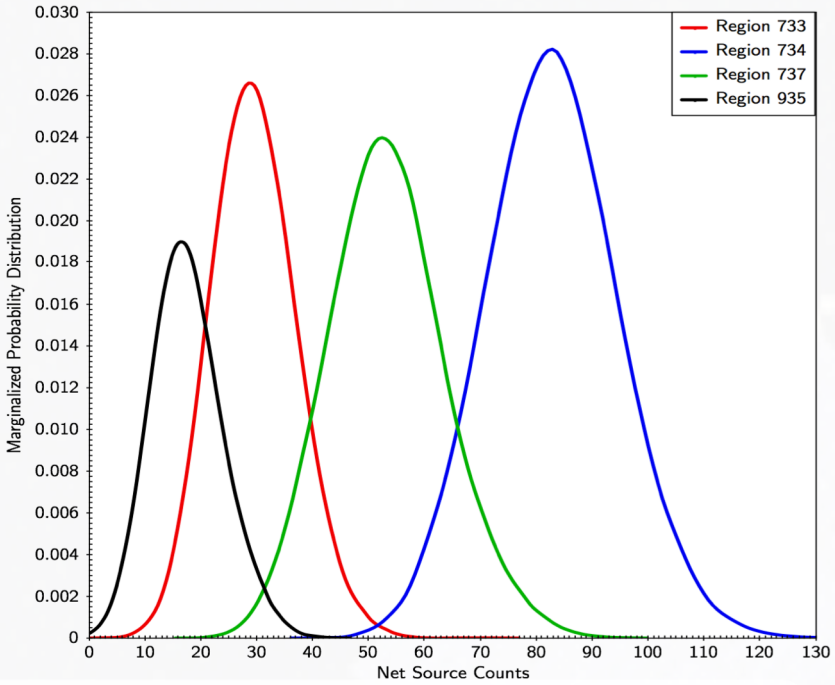
- **Aperture photometry; multi-band Bayesian Blocks algorithm**

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

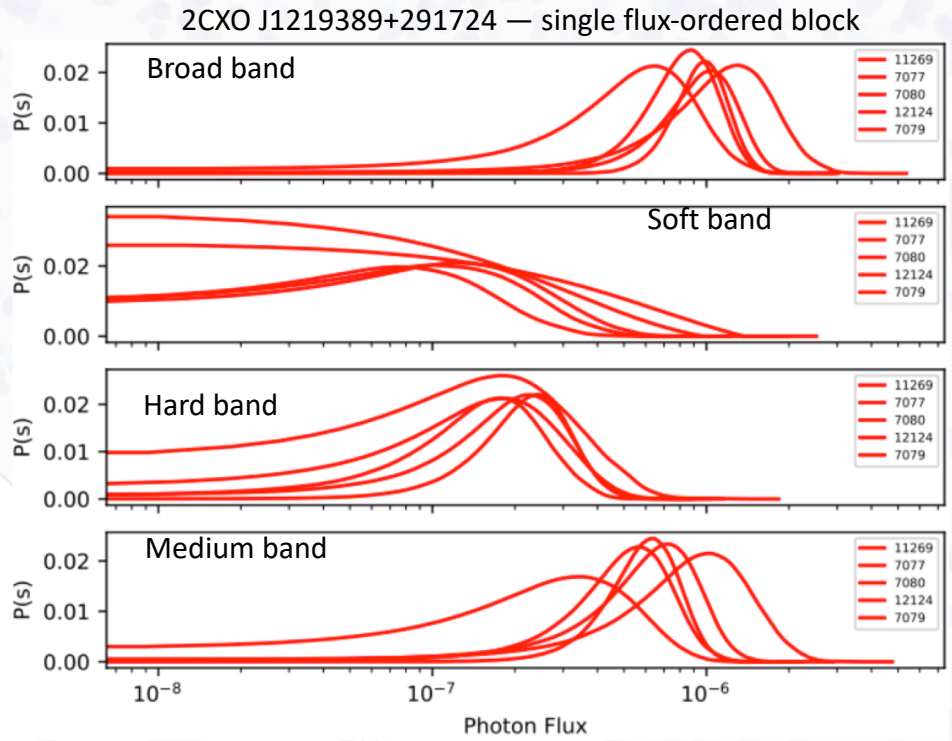
Master source flux for source s_k in an n-source bundle is determined from the Bayesian block for that source with the largest exposure. In this case:

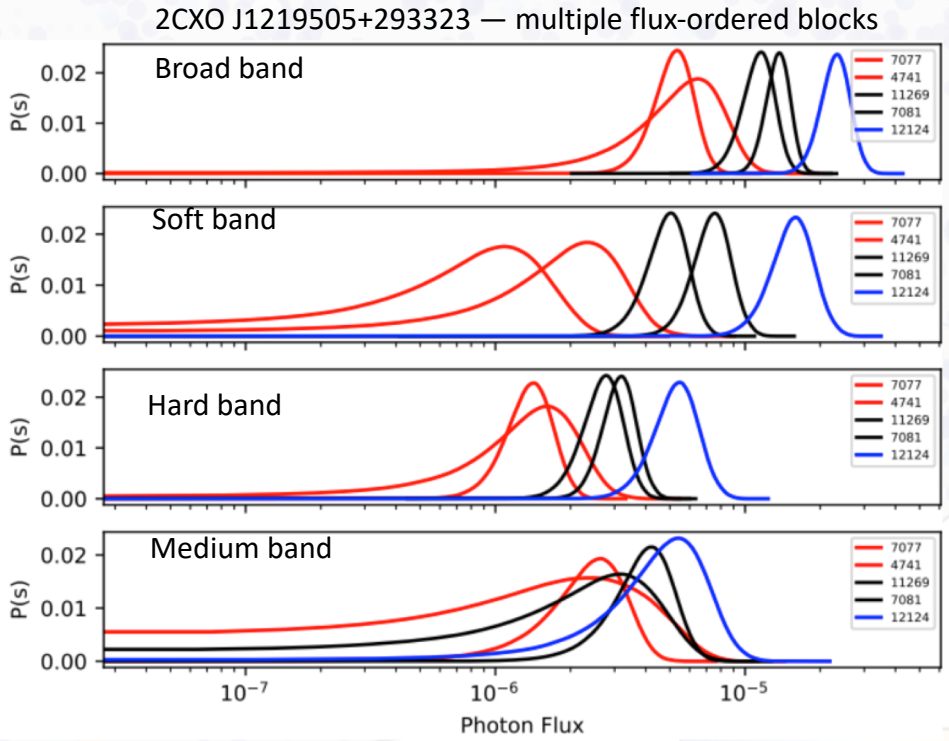
$$P(s_k | \{C_i^j\}, \{B^j\}) \cong P(s_k) \prod_{j=1}^{m} \left[P_{Pois}(B^j \,|\, \hat{\phi}^j) \times P_{Pois}(C_k^j | \hat{\theta}_k^j) \prod_{i=1, i \neq k}^{n} P_{Pois}(C_i^j \,|\, \hat{\theta}_i^j) \right]$$

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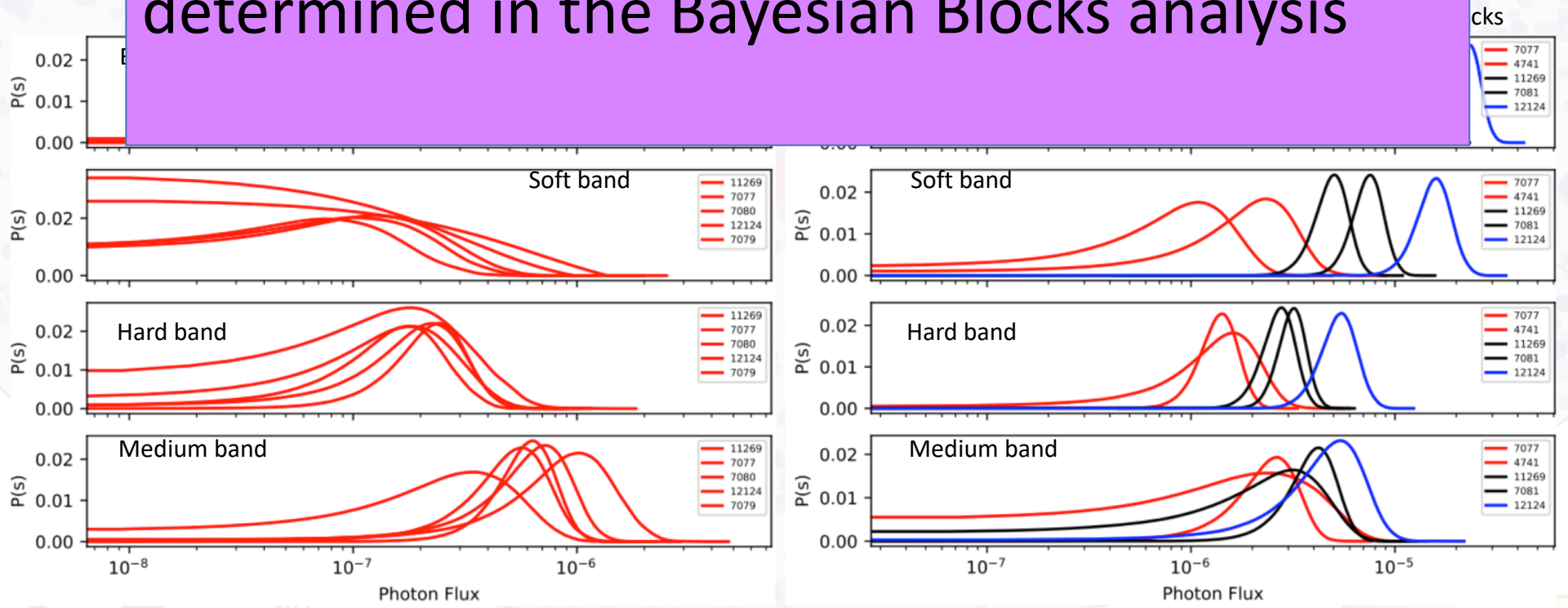
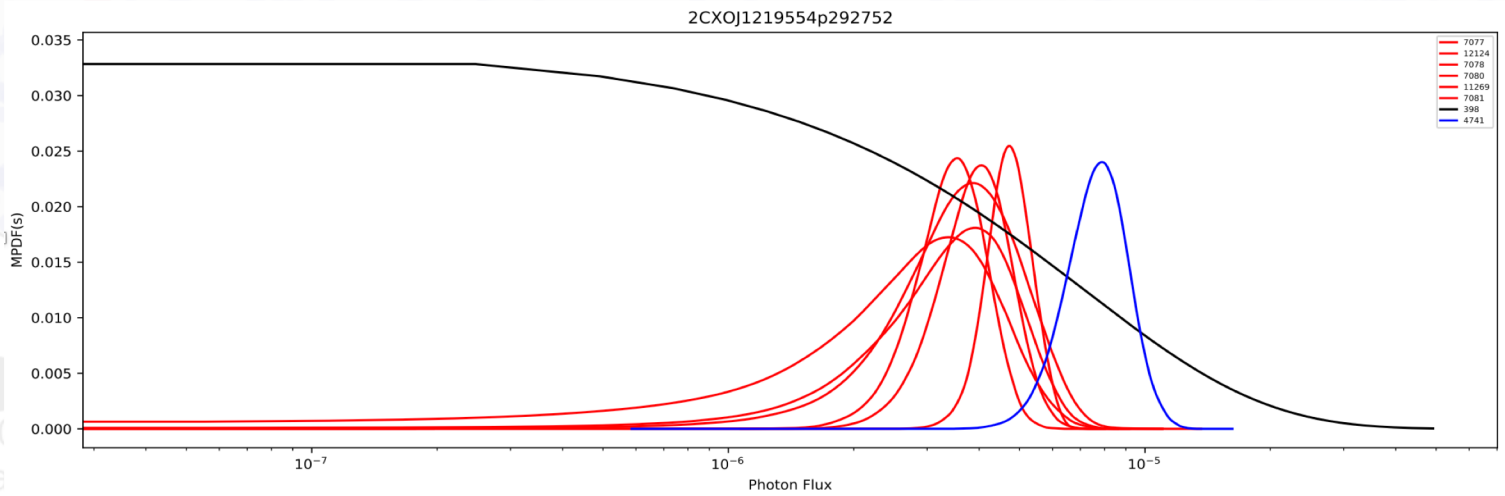
master level fluxes --> the best flux block determined in the Bayesian Blocks analysis



Temporal Variability

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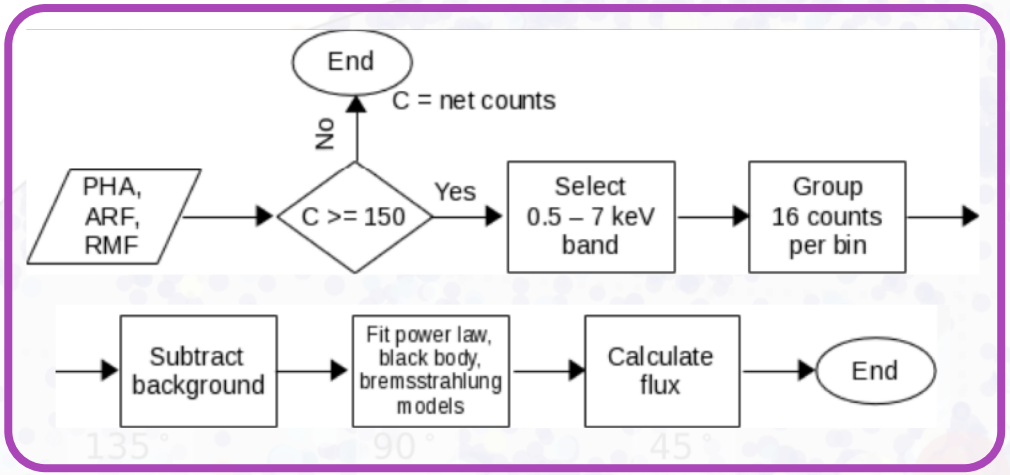
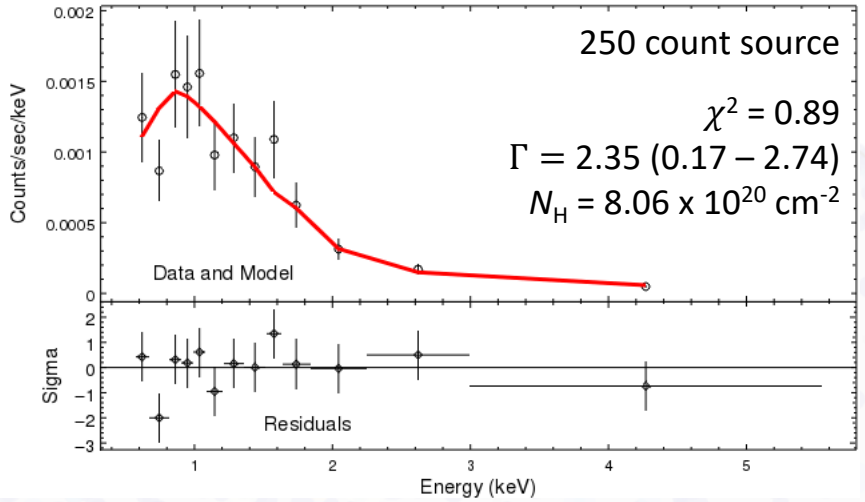
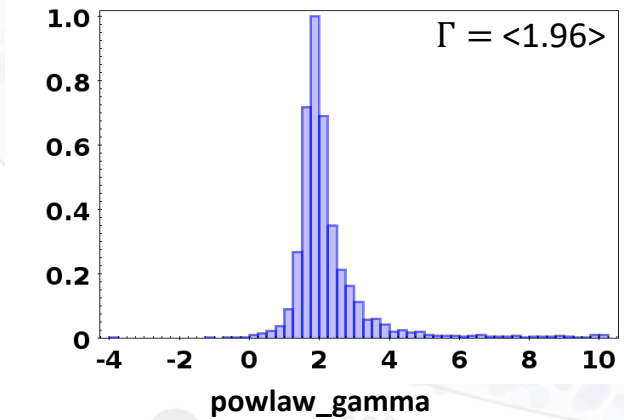
- **Spectra extraction of ALL DETECTIONS and spectral analysis**

Spectral Analysis

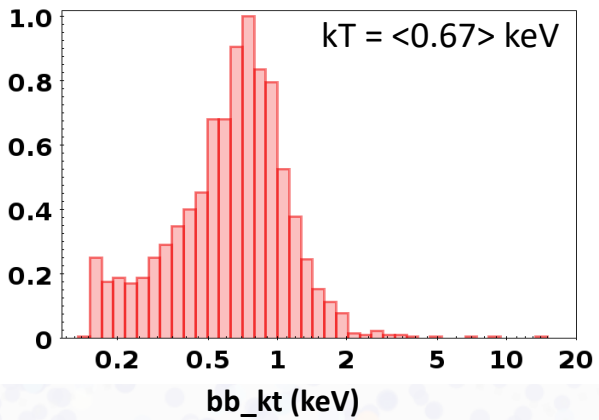




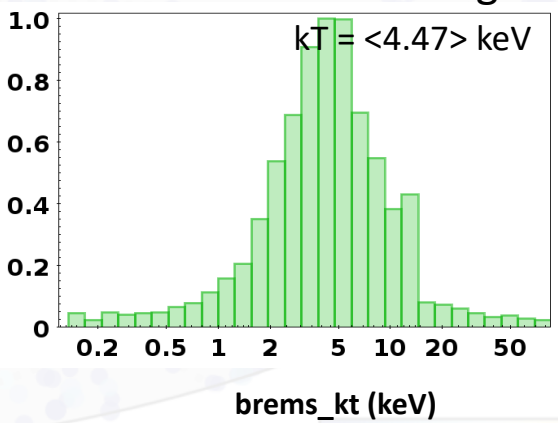
Abs. power law



Abs. black body

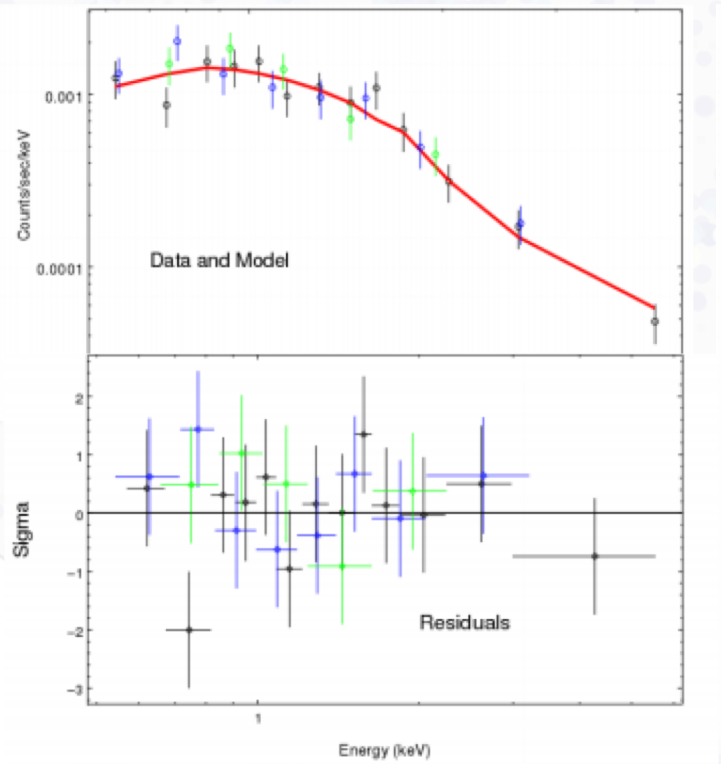


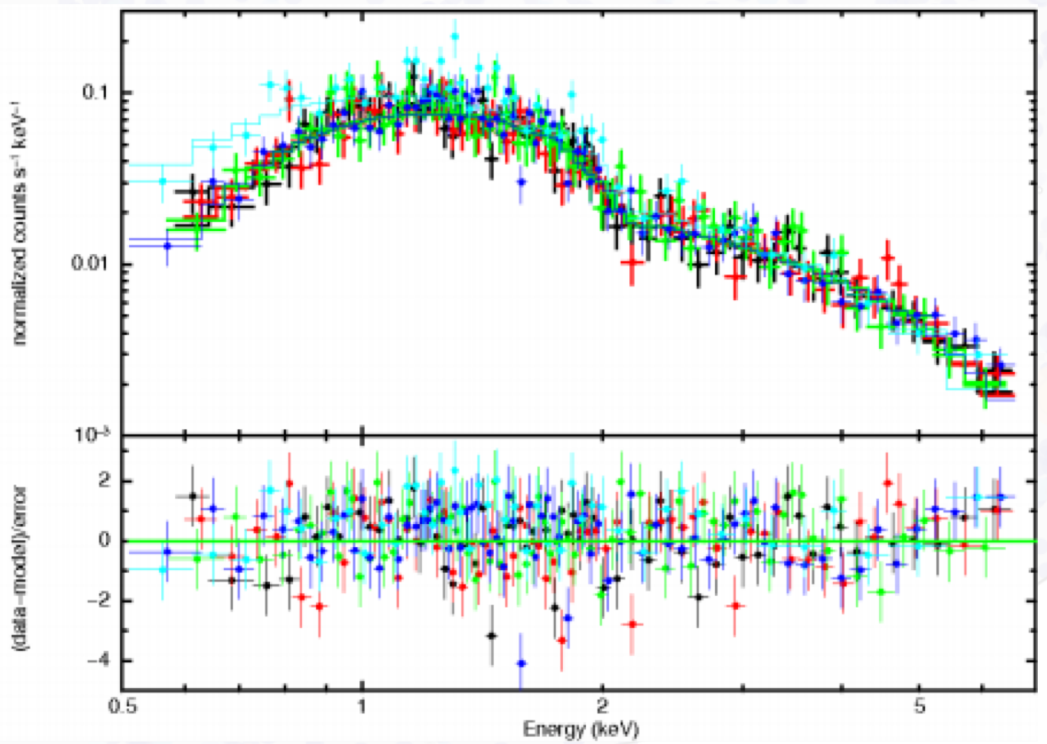
Abs. bremsstrahlung



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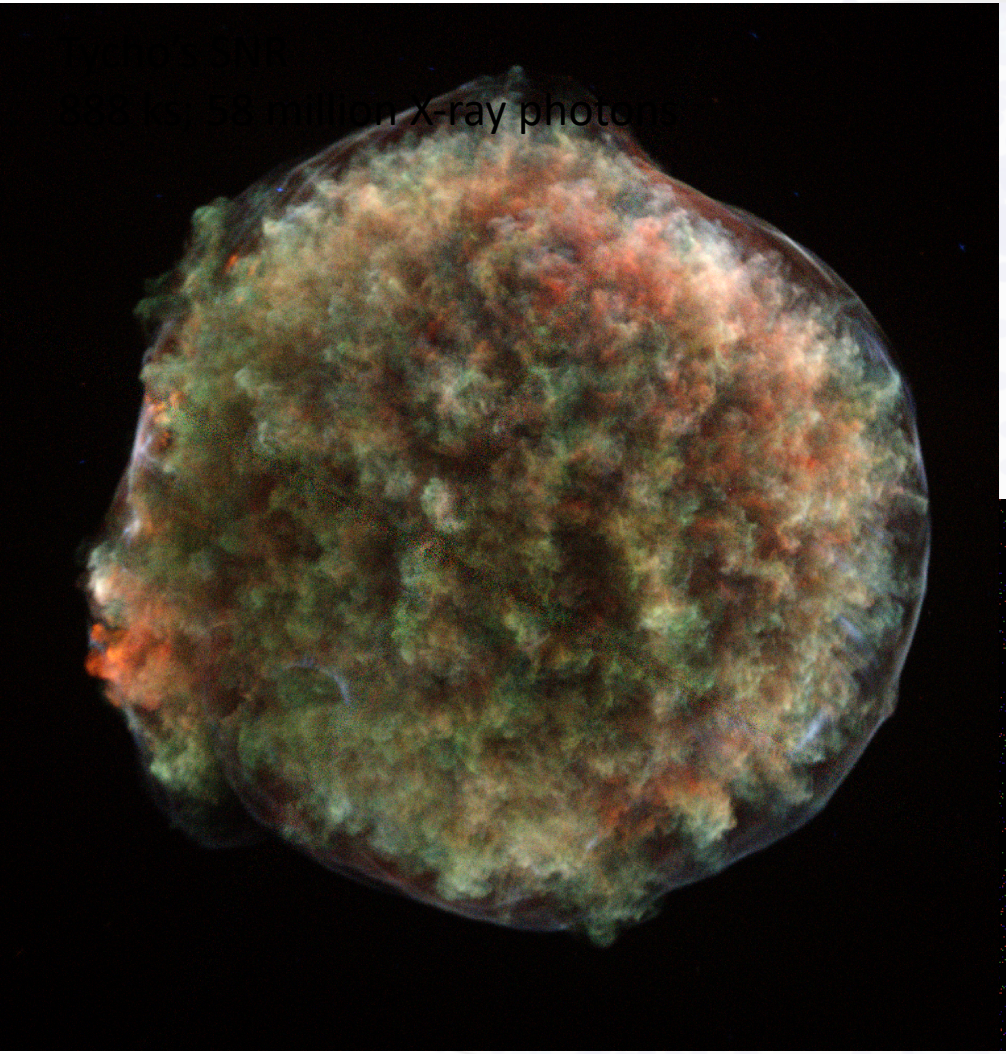
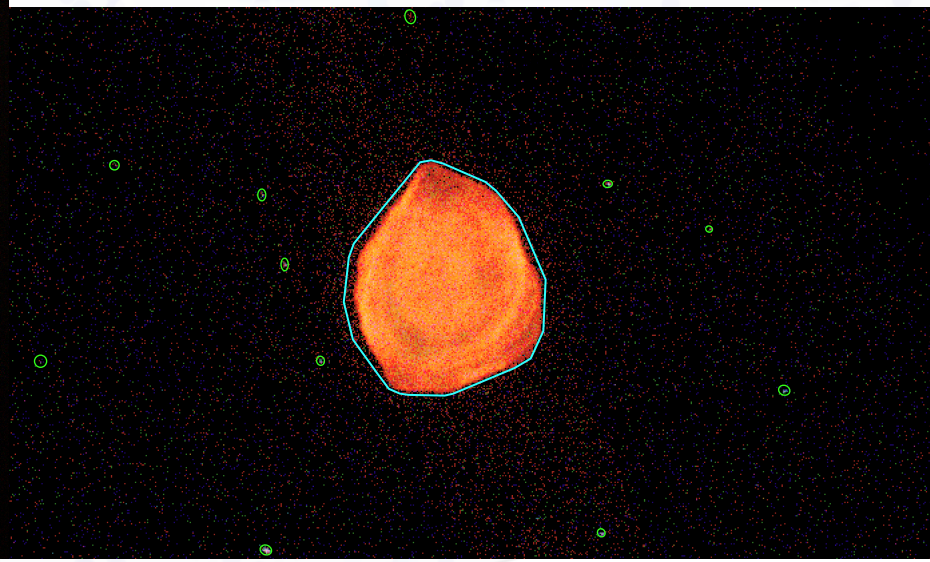
- Spectra extraction and spectral analysis
- **Extended emission properties**

Extended emissions



- SNRs, cluster of galaxies, extended galaxies, jets, etc.
- Photometric properties are integrated over a convex hull bounding region aperture (cyan below).

- Fluxes and regions are going to be 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)

Data Access

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

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CSC 2 CSC 1

CSC Data Access:

CSCview
CSCview Help

Command-line Interface

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- Version History

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- Catalog Processing
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- Chandra Data Archive

Using the Catalog➤
- Threads
- Level-3 Files
- CSCview GUI

Catalog Columns➤
- Master Sources Table: alphabetical | by context
- Stacked Observation Detections Table: alphabetical | by context
- Per-Observation Detections Table: alphabetical | by context

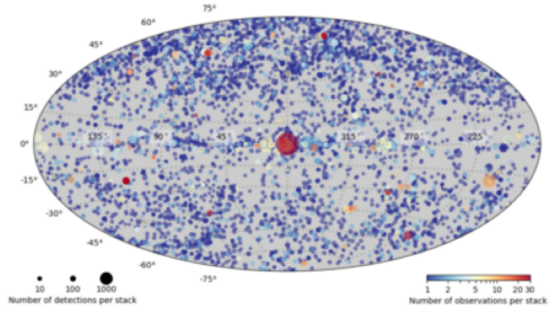
Column Descriptions➤
- Position and Position Errors

Chandra Source Catalog Release 2.0 (CSC 2.0)

Current Database

What's New? | Watch Out

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 second major release of the CSC (release 2.0) includes data for roughly 315,000 X-ray sources on the sky extracted from 10,382 Chandra ACIS and HRC-I imaging observations released publicly through the end of 2014.



[Version: full-size]

The locations, in Galactic coordinates, of the 362,182 detections in the CSC 2.0 pre1 release. 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.

What is CSC 2.0?

How do I access or download CSC 2.0?

Is my favorite source in CSC 2.0?

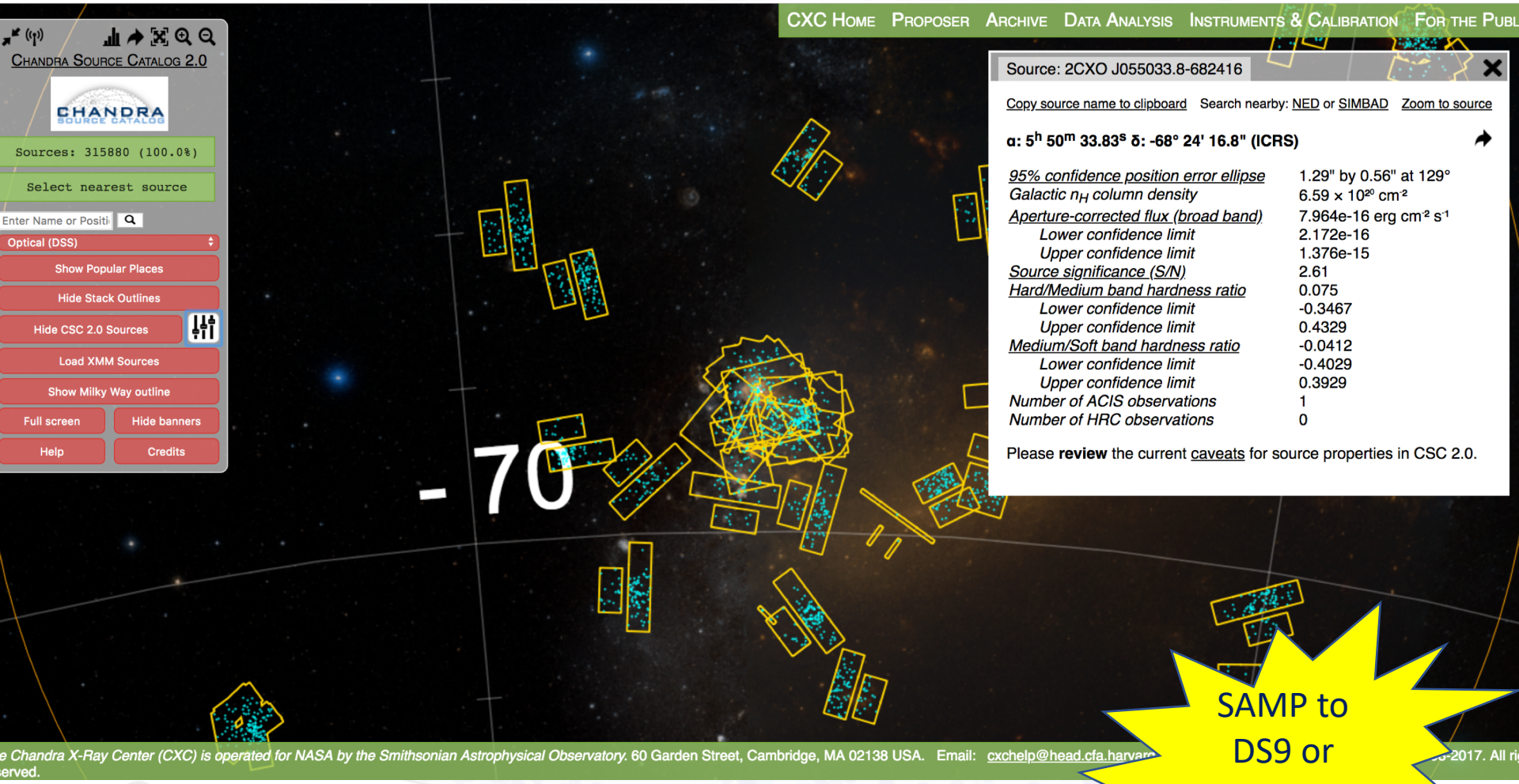
How do I find the flux of a source?

What is the processing status of CSC 2.0?

Use the WWT to view the processing status of CSC 2.0

How do I cite CSC 2.0?

For a quick view: WWT



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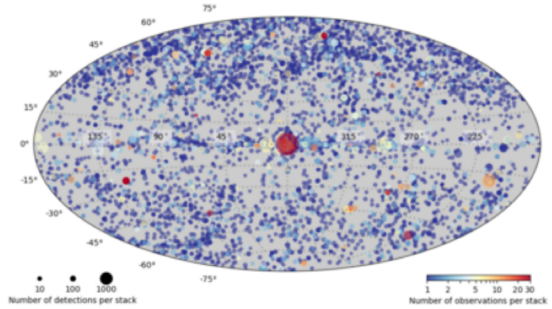

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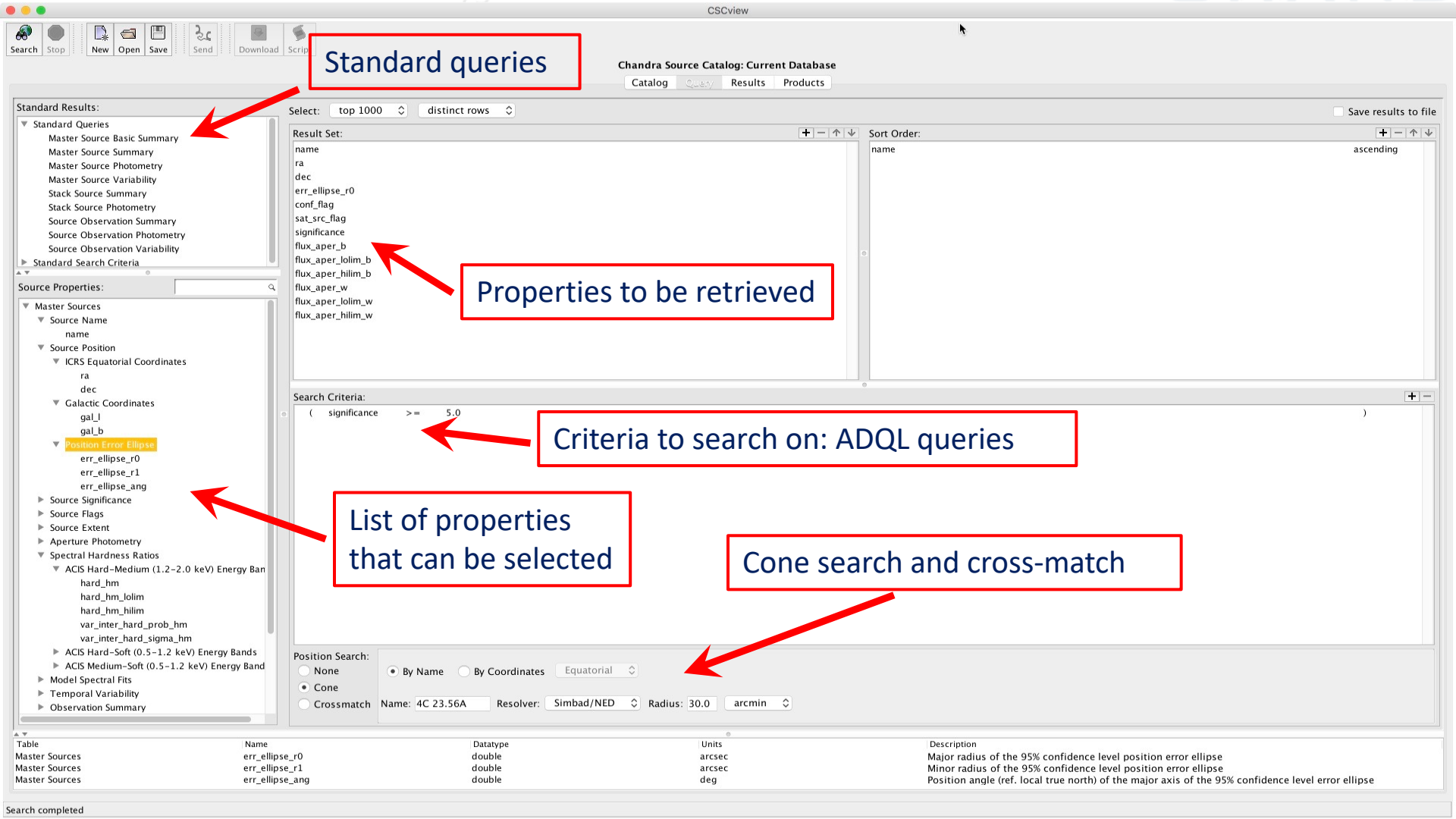

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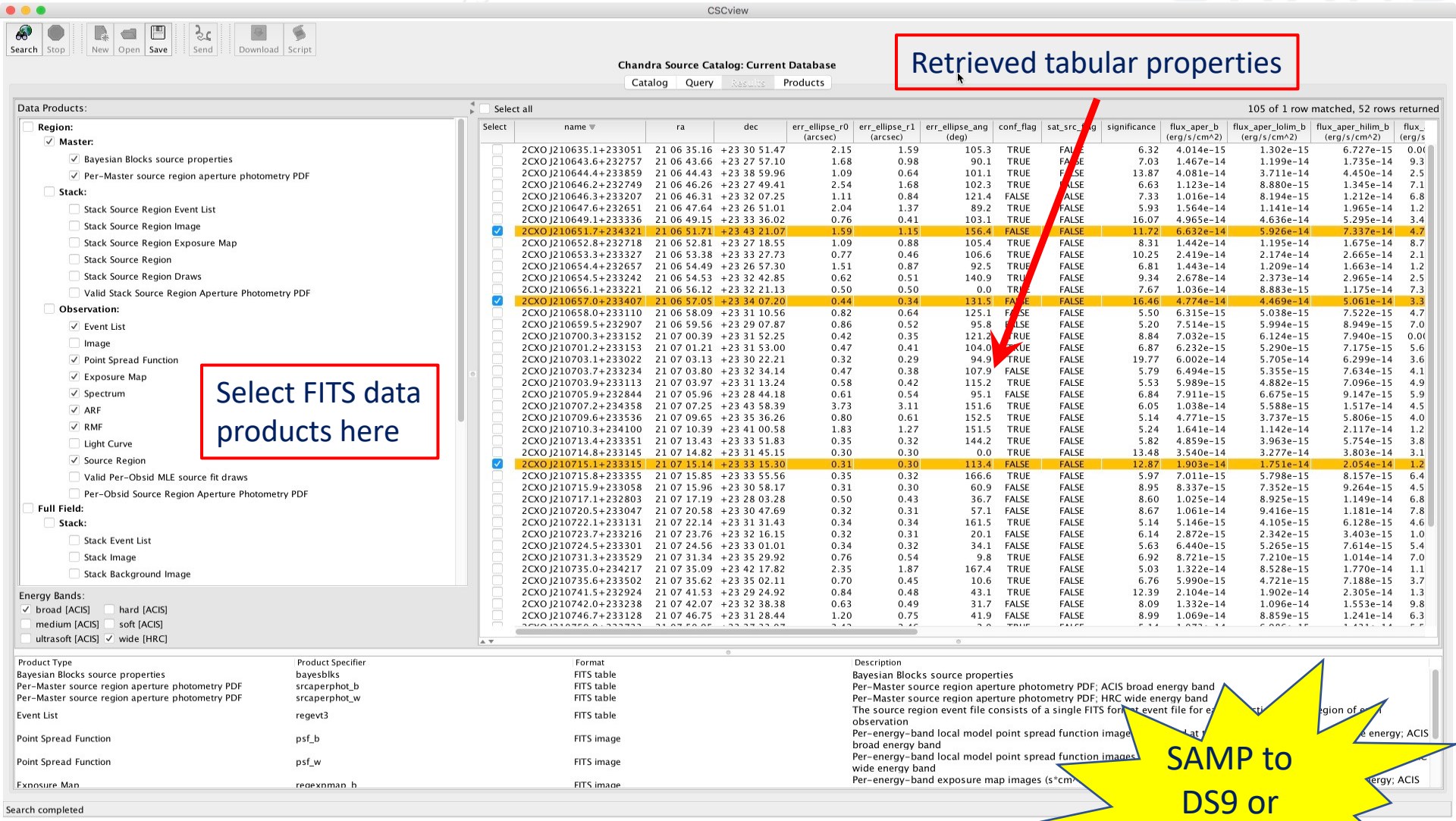
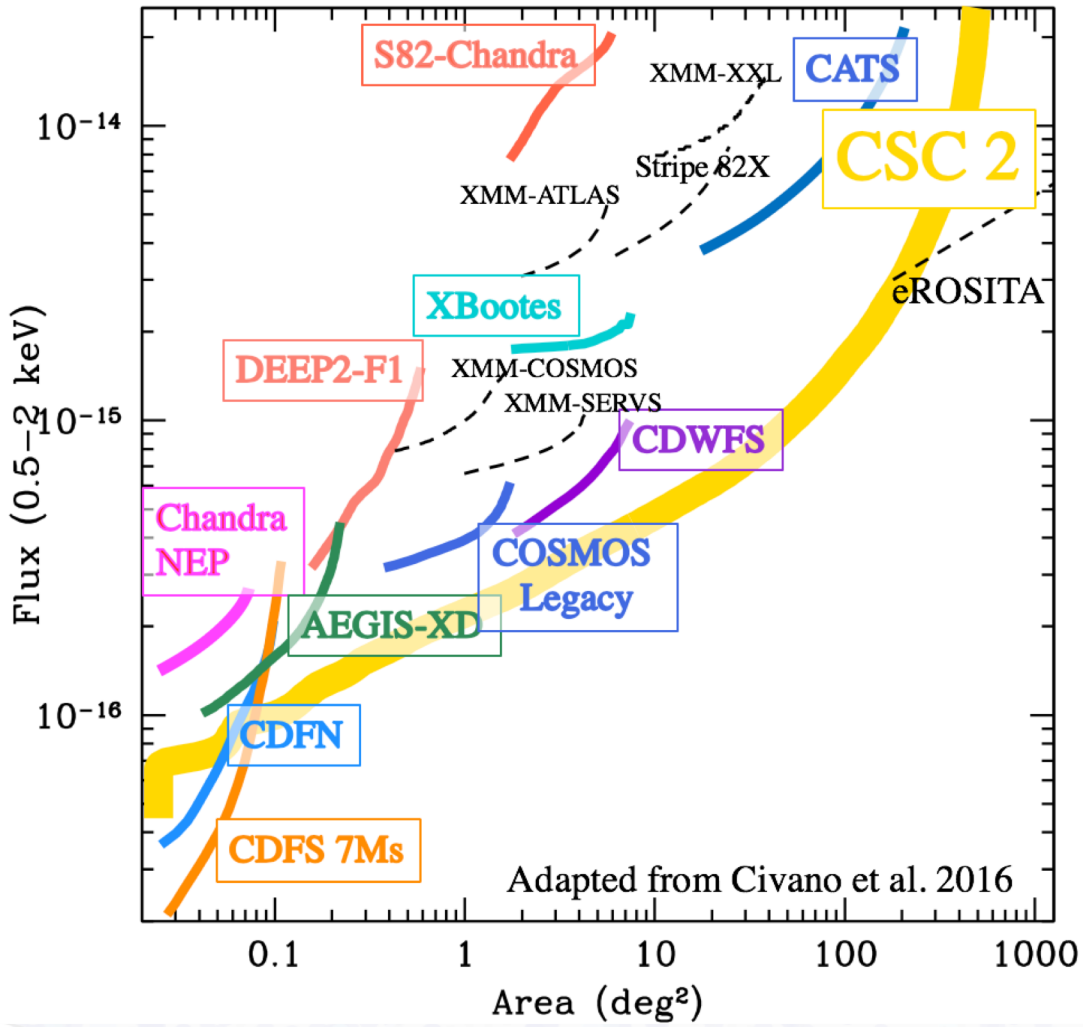



75°
60°
45°
135°
90°
45°
315°
270°
225°
-45°
-60°
-75°
100
1000
ons per stack
1
2
5
Observations p

THANKS

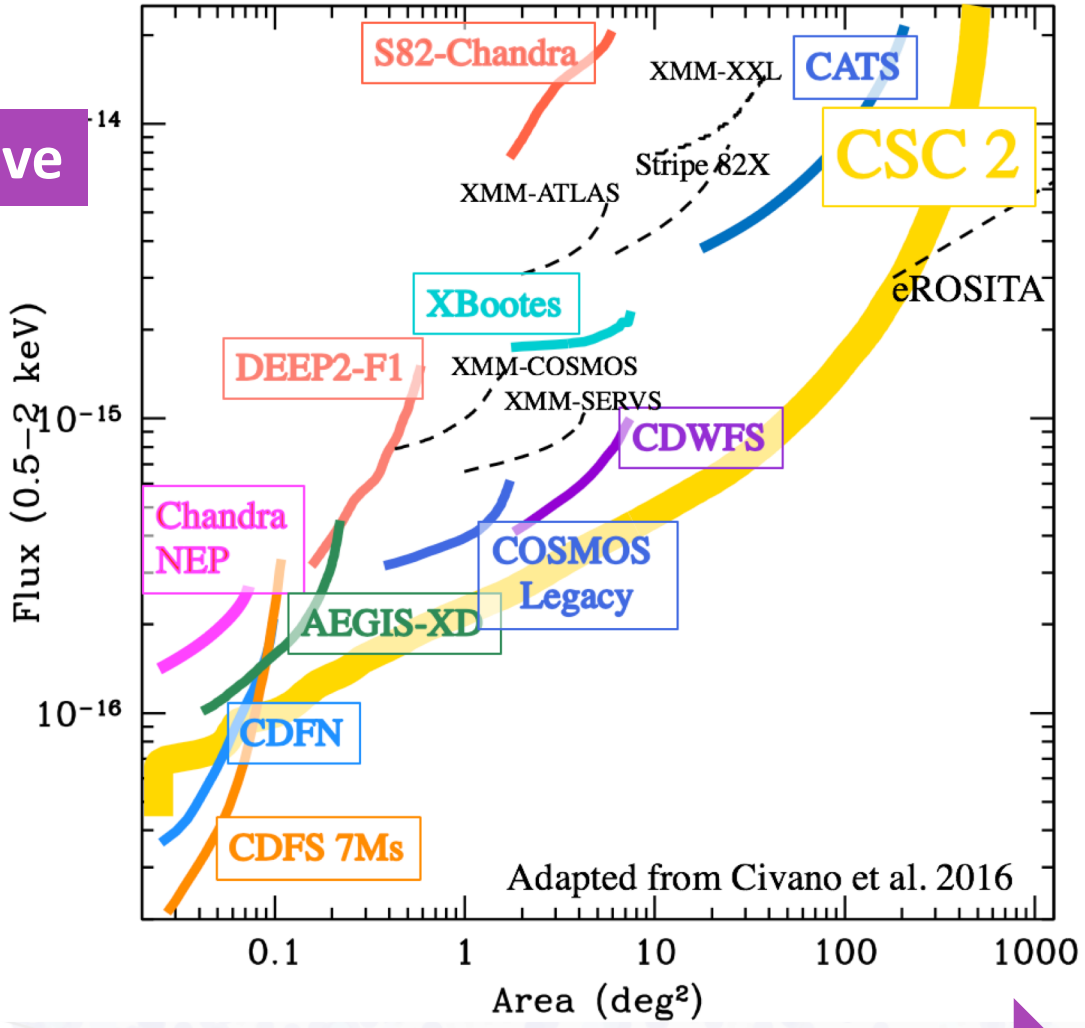
CSC 2.0 as a survey



~550 deg²
Area covered

CSC 2.0 as a survey

More sensitive



~550 deg² Area covered

LARGER AREA