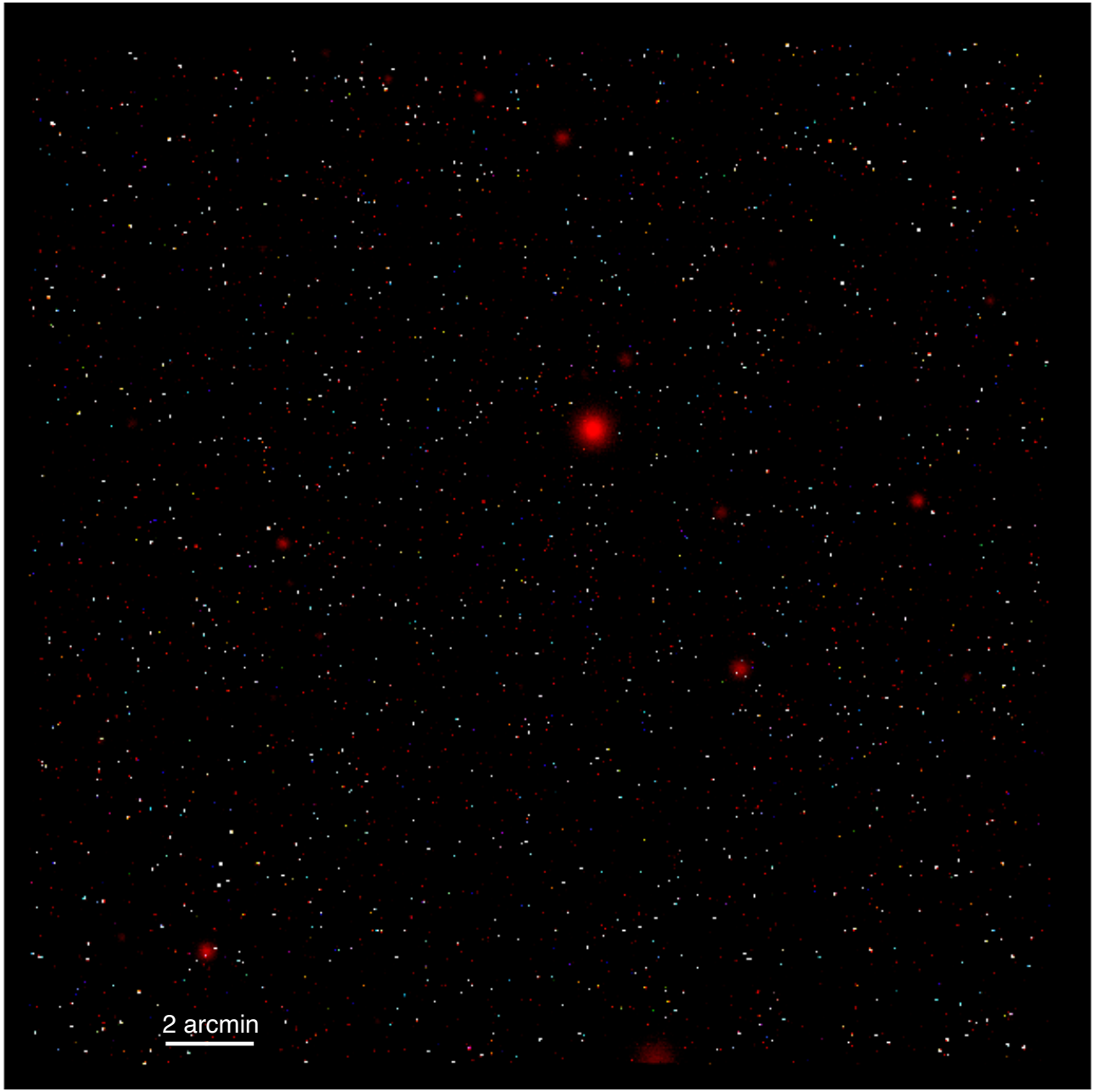
Understanding the AGN population: X-ray surveys



X-rays as a strategic tool in AGN analysis

X-ray emission contributes only to <10% to AGN bolometric luminosity. However, X-ray emission offers an unique point of view in the AGN analysis. In fact, X-ray offer the…

Donley et al. (2008, 2012); Ballantyne et al. (2011) Comastri et al. (2011); Georgantopoulos et al. (2013); Lanzuisi et al. (2015); Buchner et al. (2015)

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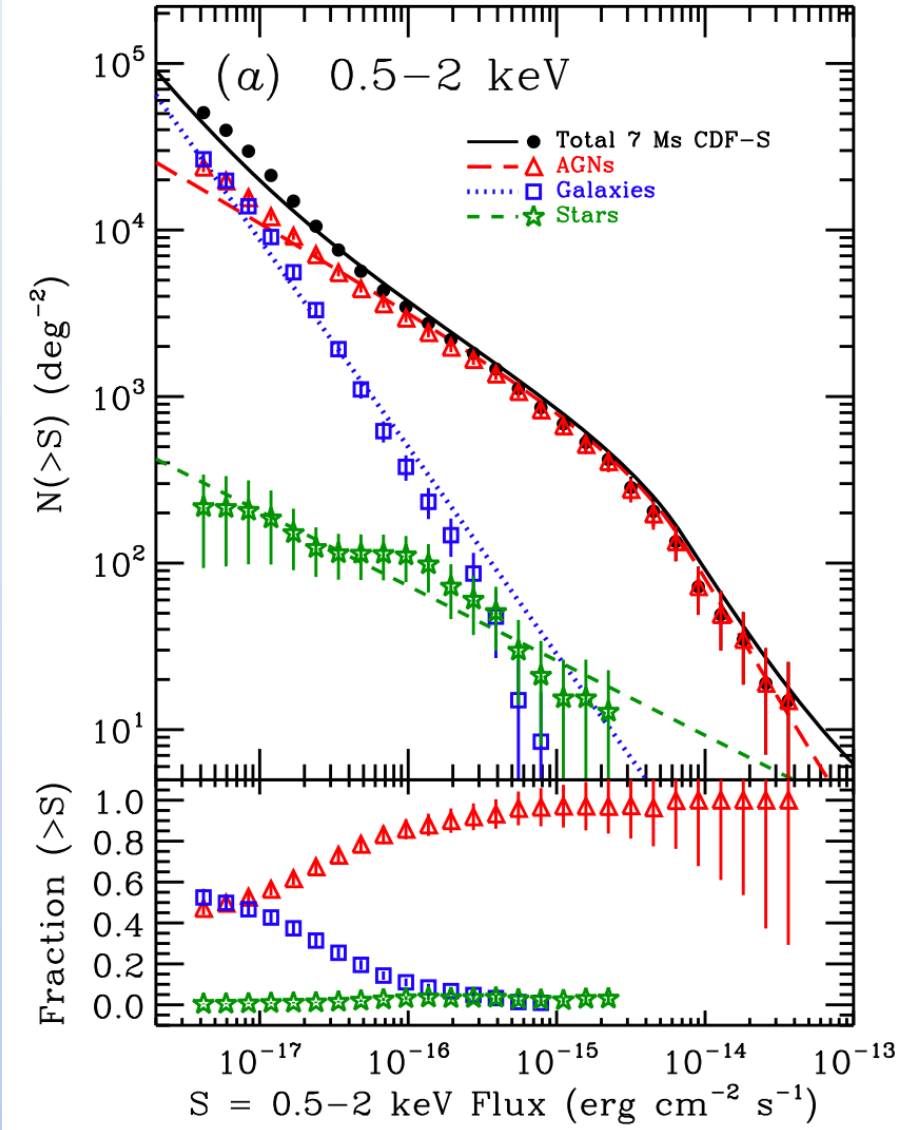

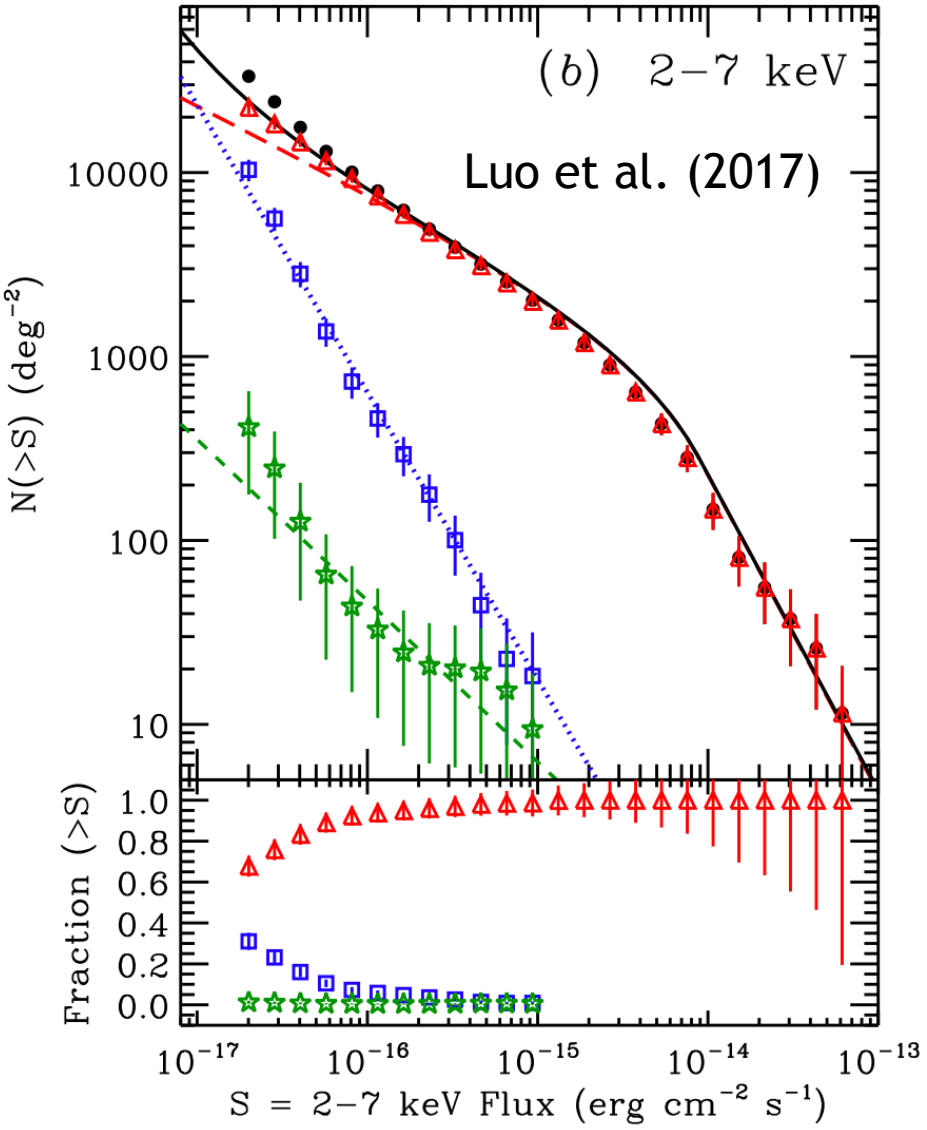

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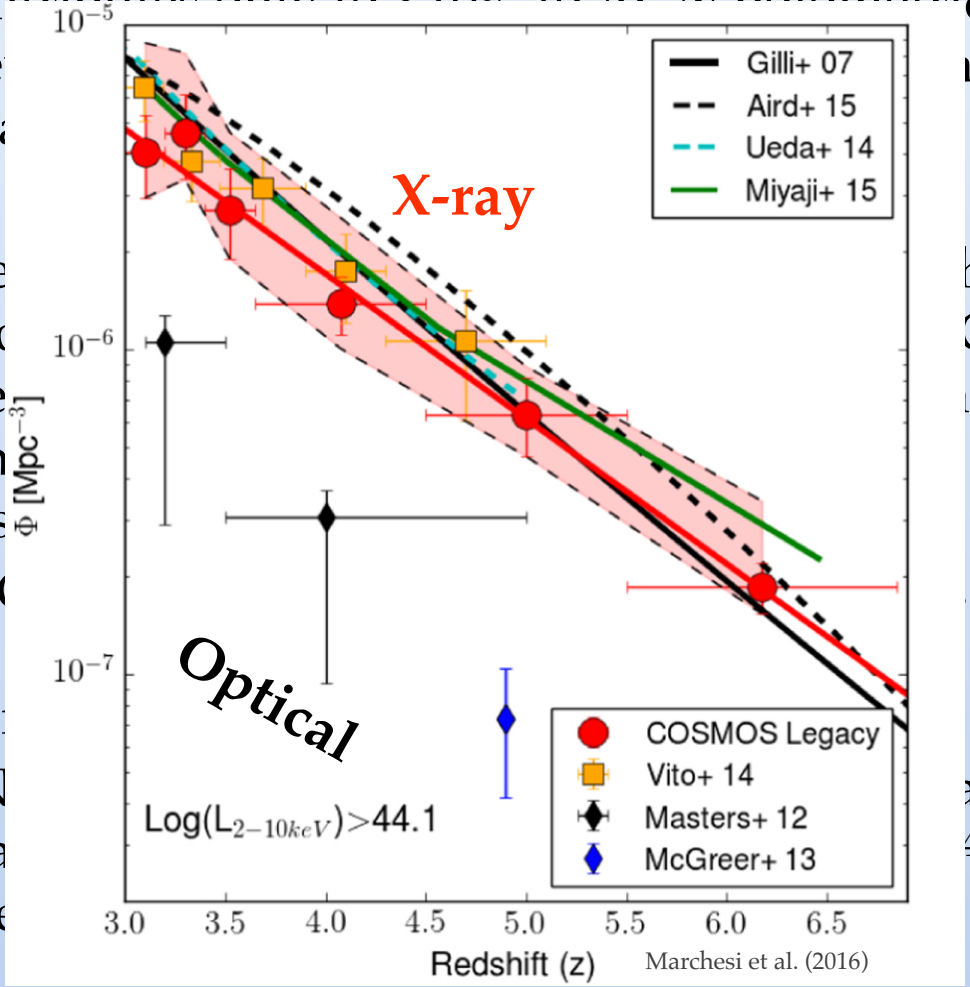

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The X-ray surveys wedding-cake strategy

Depth

X-ray Flux Limit

10^{-14}

10^{-15}

10^{-16}

10^{-17}

J1030 Field 0.1 deg²
Nanni et al. 2020

CDFN-CDFS 0.1deg²
Alexander+ 2003; Luo + 2008;
Xue+ 2011; Comastri+2011

E-CDFS 0.3deg²
Lehmer et al. 2005

Chandra COSMOS Legacy 2.2 deg²
Civano et al. 2016
Marchesi et al. 2016

EGS/AEGIS 0.7deg²
Laird et al. 2008,
Goulding et al. 2012

XMM-COSMOS
2 deg²

Champ 1.5deg2
Silverman et al. 2005

XBOOTES 9 deg²
Murray et al. 2005

XXL 50 deg²
Pierre+ 2012

Stripe82 70 deg²
LaMassa+ 2013

Area deg²

0.1

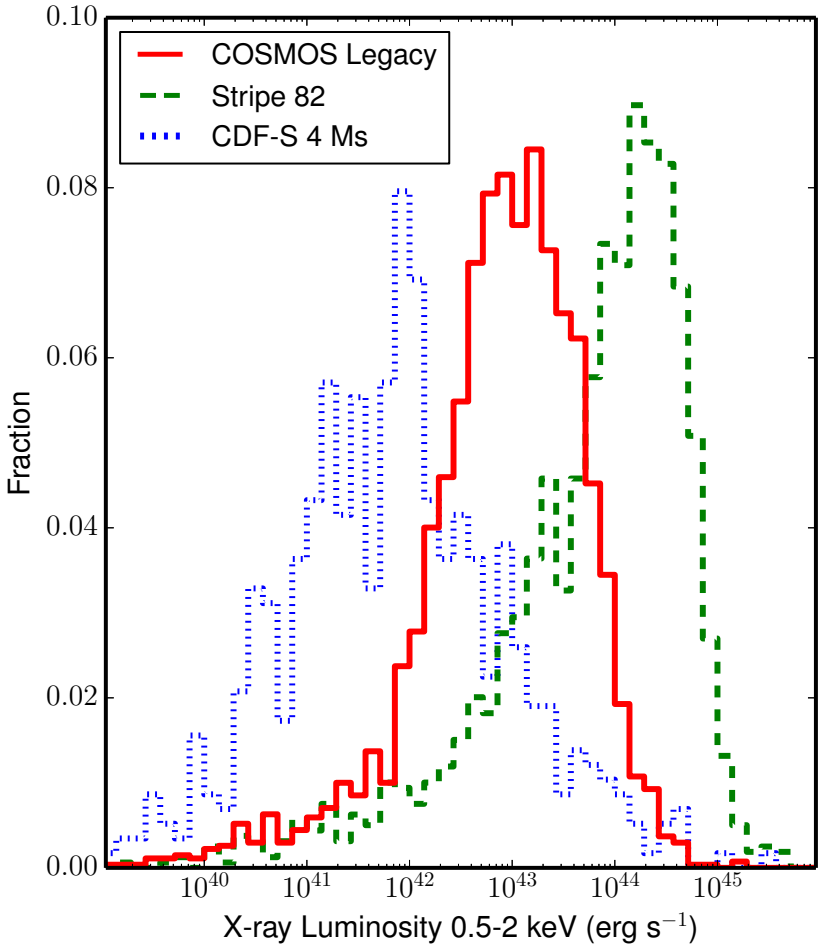
1

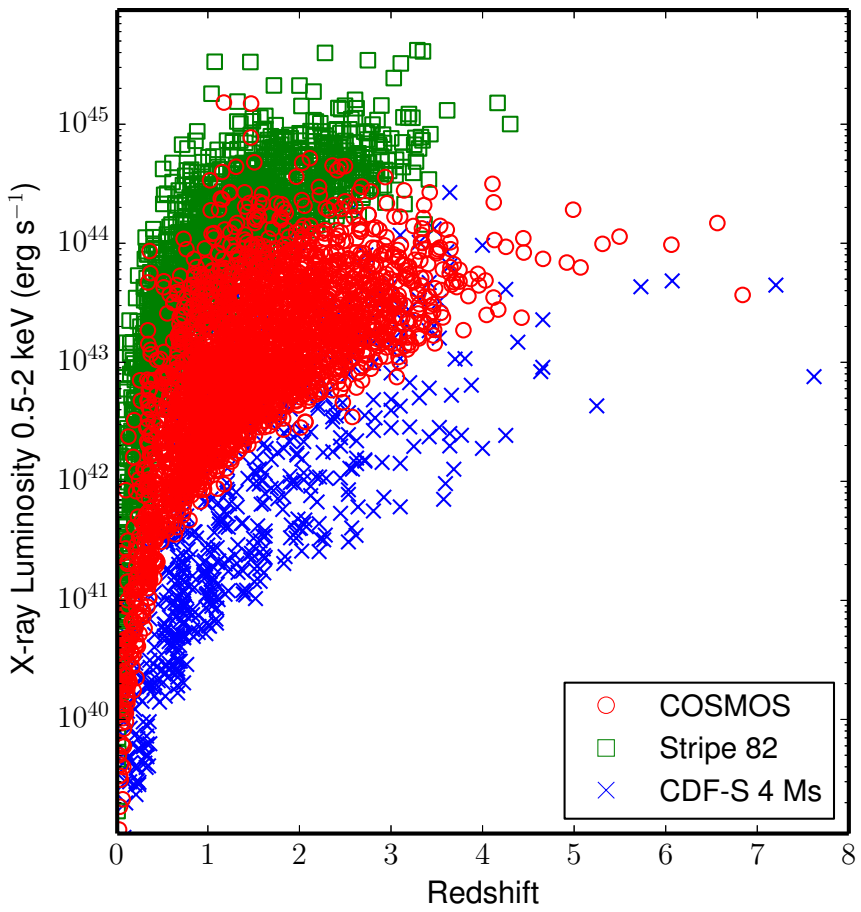
10

100

Courtesy of F.Civano

Different surveys for different science



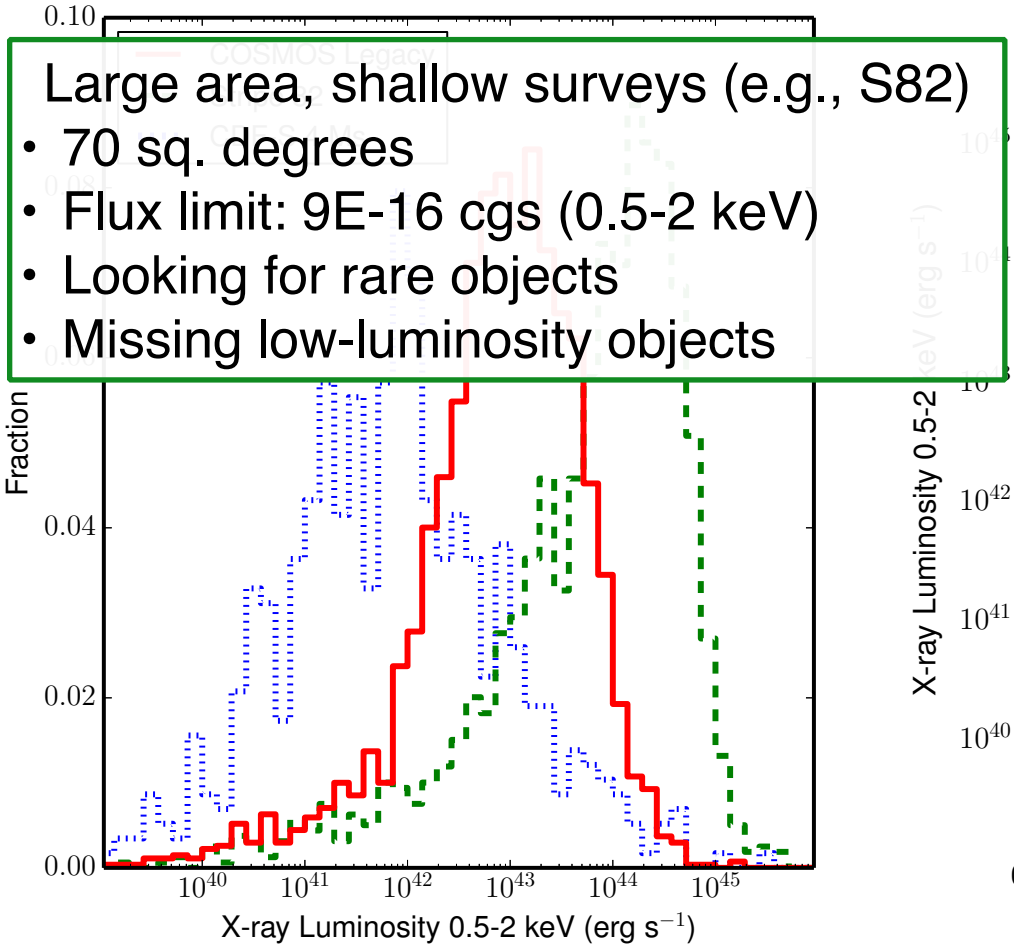


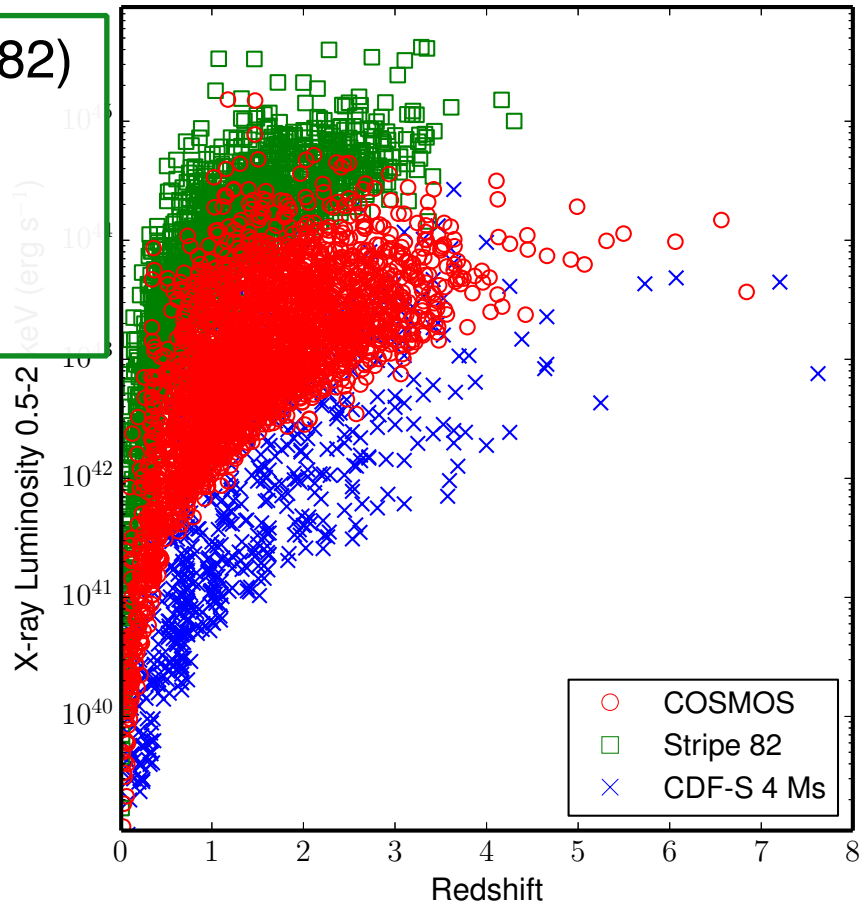
Marchesi et al. 2016

Different surveys for different science

Large area, shallow surveys (e.g., S82)

- 70 sq. degrees
- Flux limit: 9E-16 cgs (0.5-2 keV)
- Looking for rare objects
- Missing low-luminosity objects





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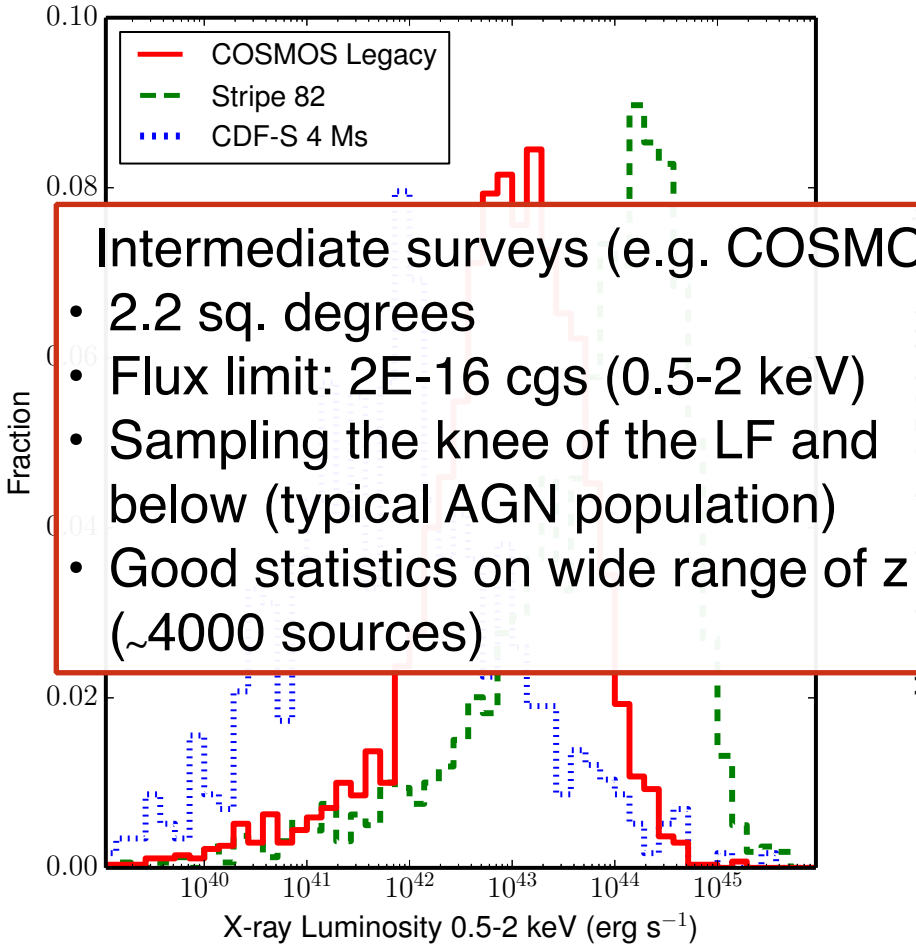
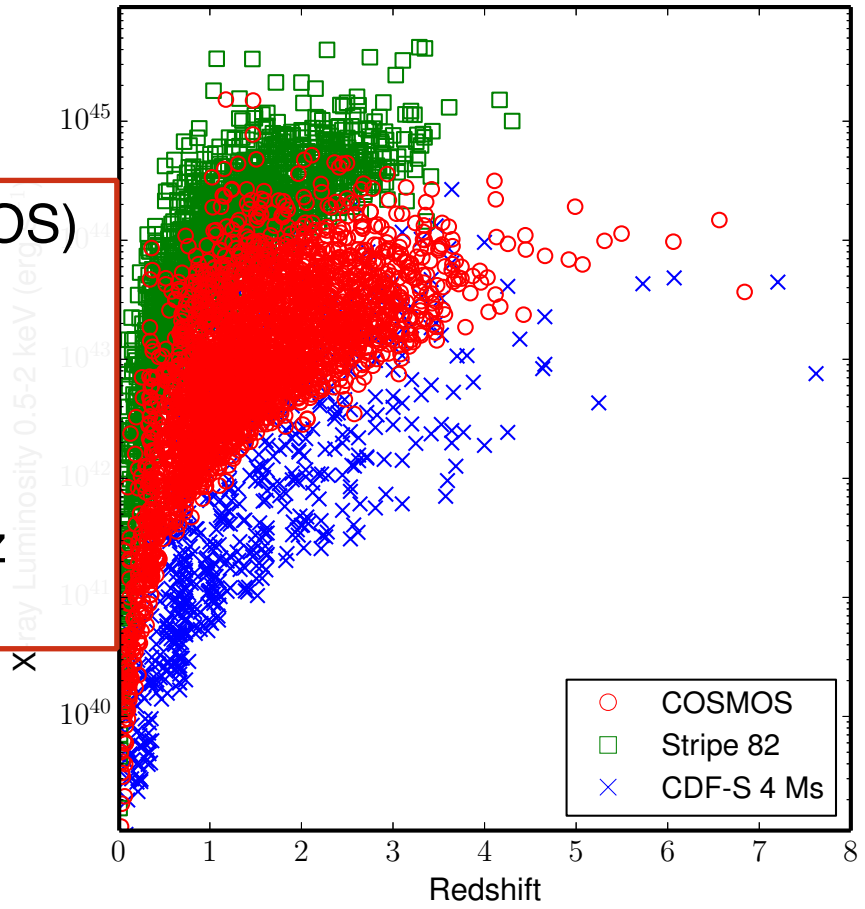


Intermediate surveys (e.g. COSMOS)

- 2.2 sq. degrees
- Flux limit: 2E-16 cgs (0.5-2 keV)
- Sampling the knee of the LF and below (typical AGN population)
- Good statistics on wide range of z (~4000 sources)



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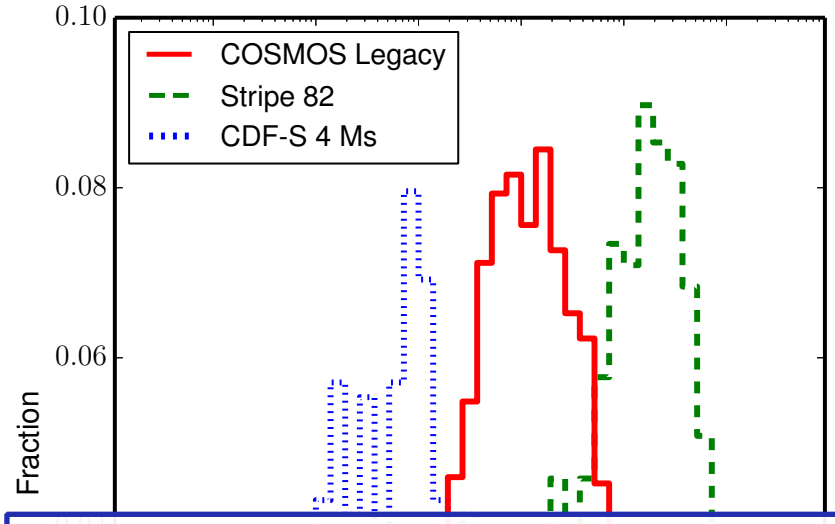
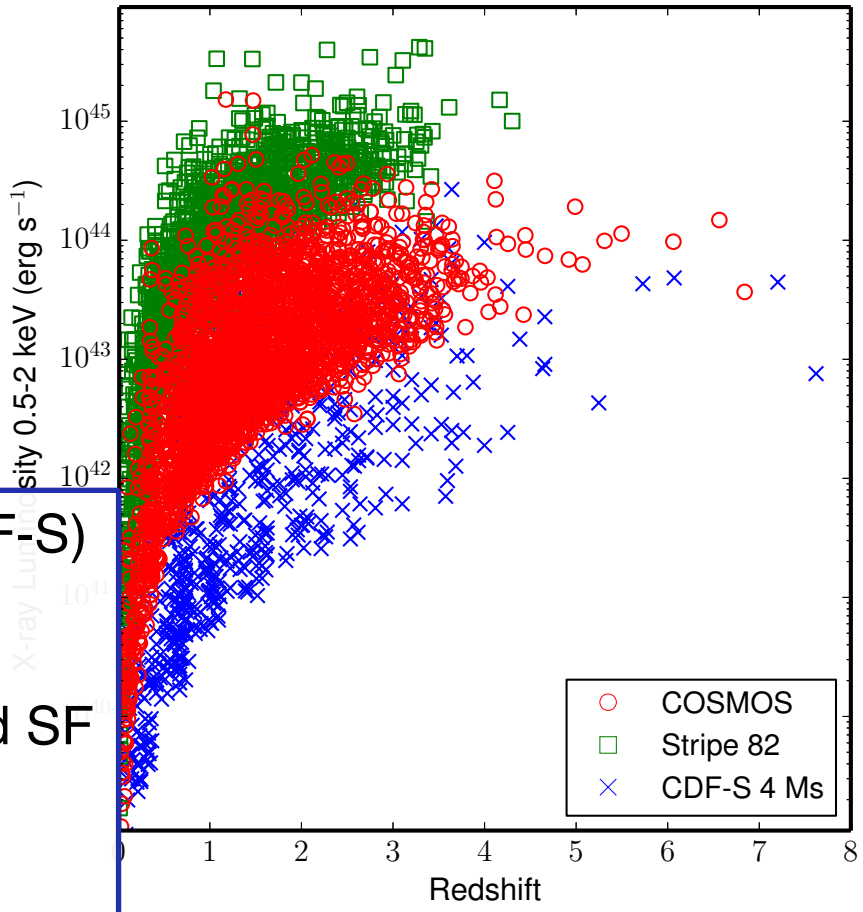




Deep, pencil beam surveys (e.g. CDF-S)

- 0.1 sq. degrees
- Flux limit: 6E-18 cgs (0.5-2 keV)
- Detection of low luminosity AGN and SF galaxies
- Smaller number of objects (~1000 sources)

Marchesi et al. 2016

Chandra Deep Field-South (CDF-S)

≈7Ms *Chandra* exposure (last obs. at March 2016)

≈3Ms XMM-*Newton* exposure

Deep multi-wavelength coverage

One of the legacy fields (no deeper field for the next 20 yrs)

Chandra: good on-axis PSF (i.e., excellent angular resolution) and low background
➔ Sensitive to faint and distant AGN

XMM-*Newton*: larger effective area (hence photon statistics), but much worse angular resolution and higher background
➔ Better for X-ray spectroscopy of relatively bright AGN

This Lab Outline: Exploring the deepest existing X-ray survey

In this lab, you will explore the Chandra Deep Field 7 Ms survey; deepest X-ray field currently existing, and learn how to study and characterize a population of sources through the investigation of their properties (as reported in catalogs)

1. **Understand the parameters affecting the source catalog**: We will provide you with a series of catalogs performed using different detection parameter setups over 500 ks out of the 7 Ms of observations of the Chandra Deep Field. You will cross-match the sources in this low-exposure catalogs with those in the official 7Ms source catalog, using different criteria.
2. **Explore the source catalog**: For one of the newly produced catalogs, produce some relevant plots, and compare quantities with those reported in the 7Ms source catalog
3. **Analyse the data products**: Fit the X-ray spectra of a few, particularly interesting sources.

Lab Outline

We ran for you the Chandra CIAO **wavdetect** tool to search sources on a **500 ks observation** (1/14th of the total 7 Ms field).

You will have two different catalogs, that have been produced using two different **significance thresholds** (i.e., your detections can be more or less reliable; **sigthresh**=1E-6; 1E-4).

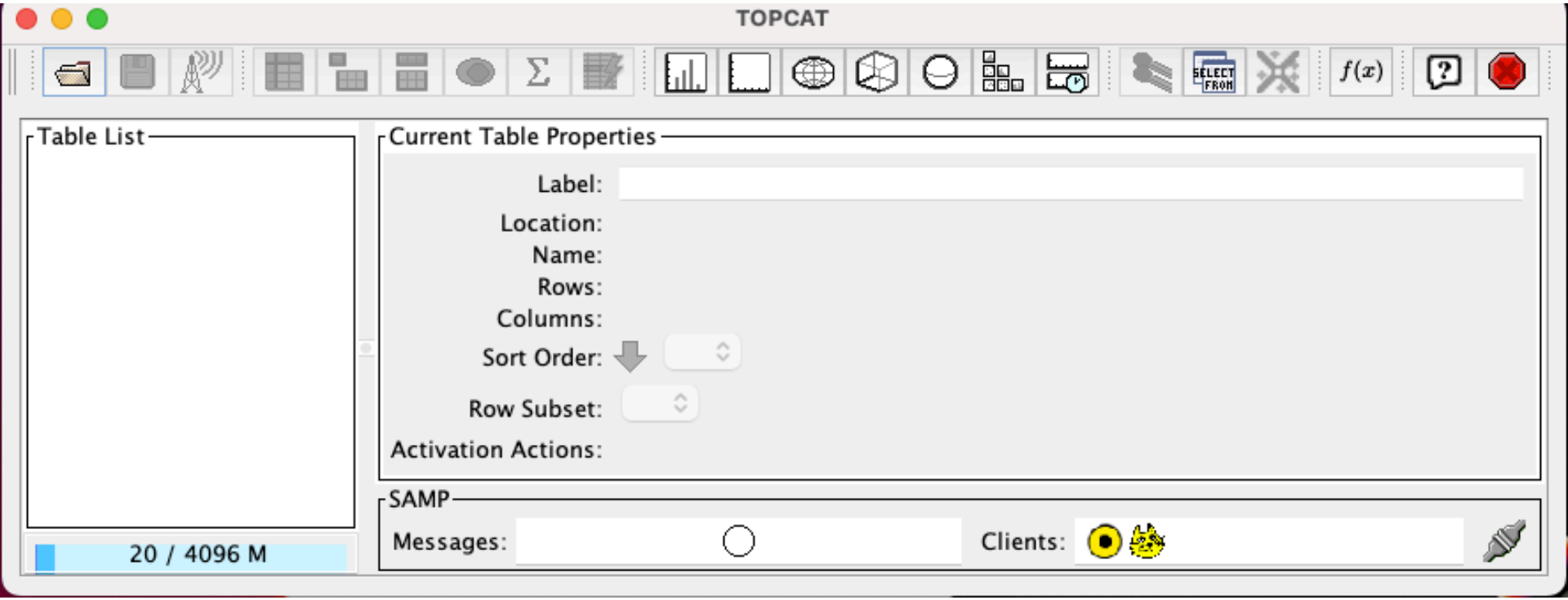
sigthresh parameterizes the (overall) **reliability** of the catalog generated with wavdetect: the smaller the value, the smaller the number of sources that are expected to be spurious (i.e., not real targets, but background fluctuations).

Lab Outline
1) Build the source catalog

1) Cross-correlate the two 500 ks catalogs (CDFS_4obs_merged_057keV_wavdet_1em4_src.fits; CDFS_4obs_merged_057keV_wavdet_1em6_src.fits) with the official 7 Ms Chandra source catalog in the CDF-S (Luo et al. 2017).

Compute the number of 7Ms sources found in the 500 ks mosaic using the two different 500 ks catalogs and three different matching radii (1/2/3”). Overall, you will thus have 6 catalogs.

Loading the 500 ks catalogs in Topcat



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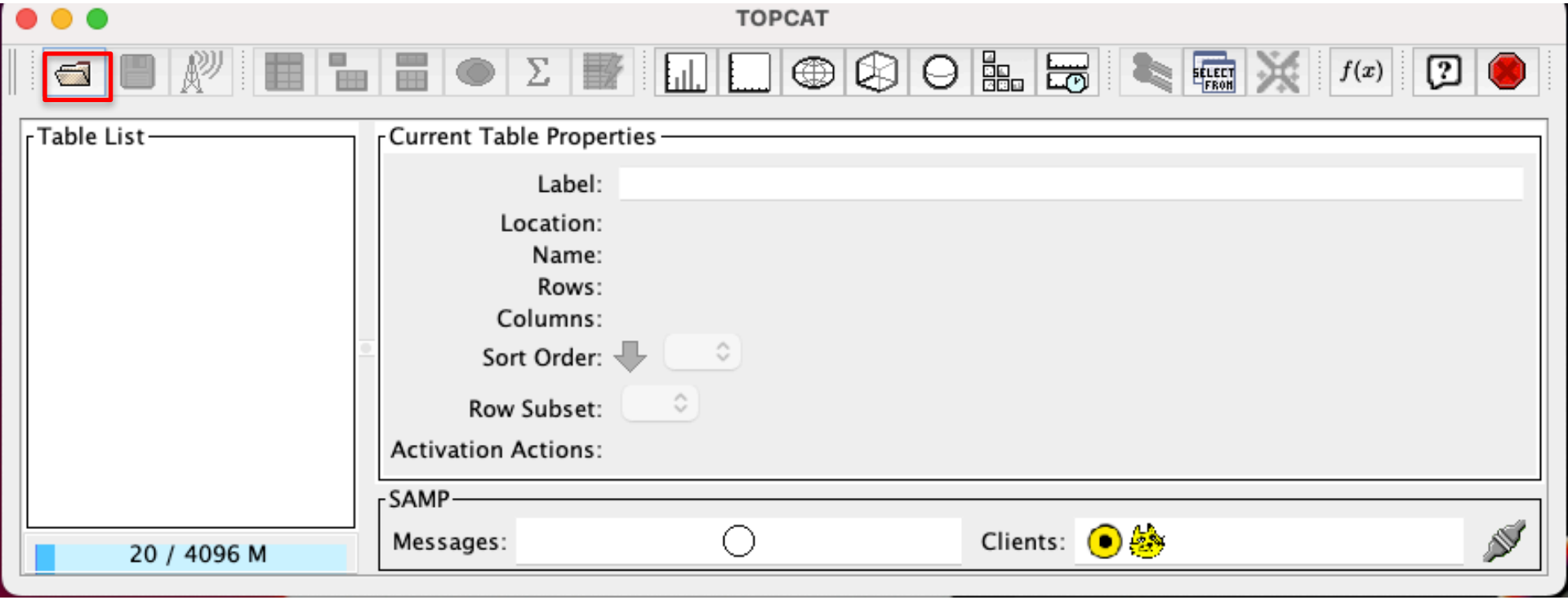

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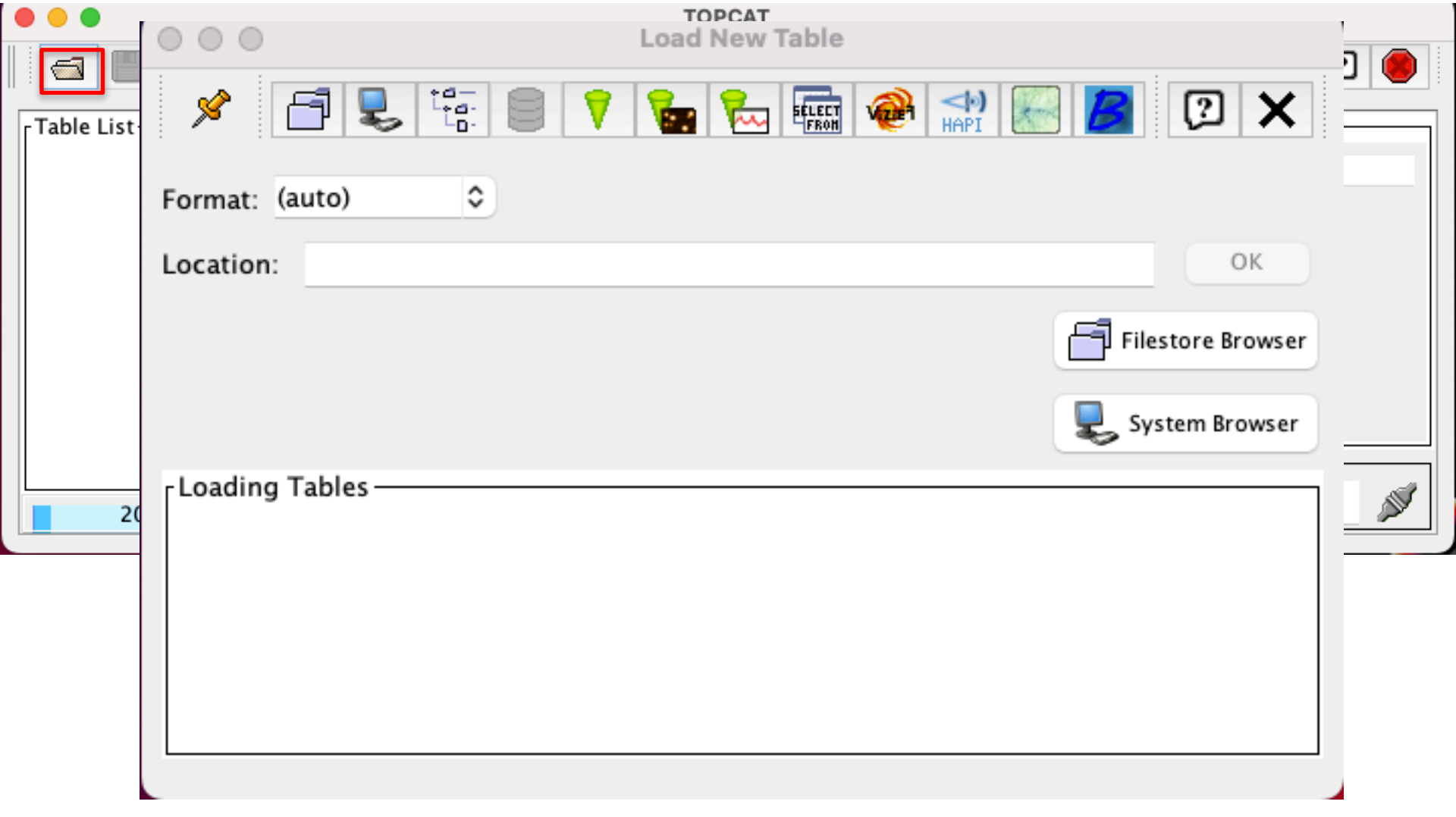

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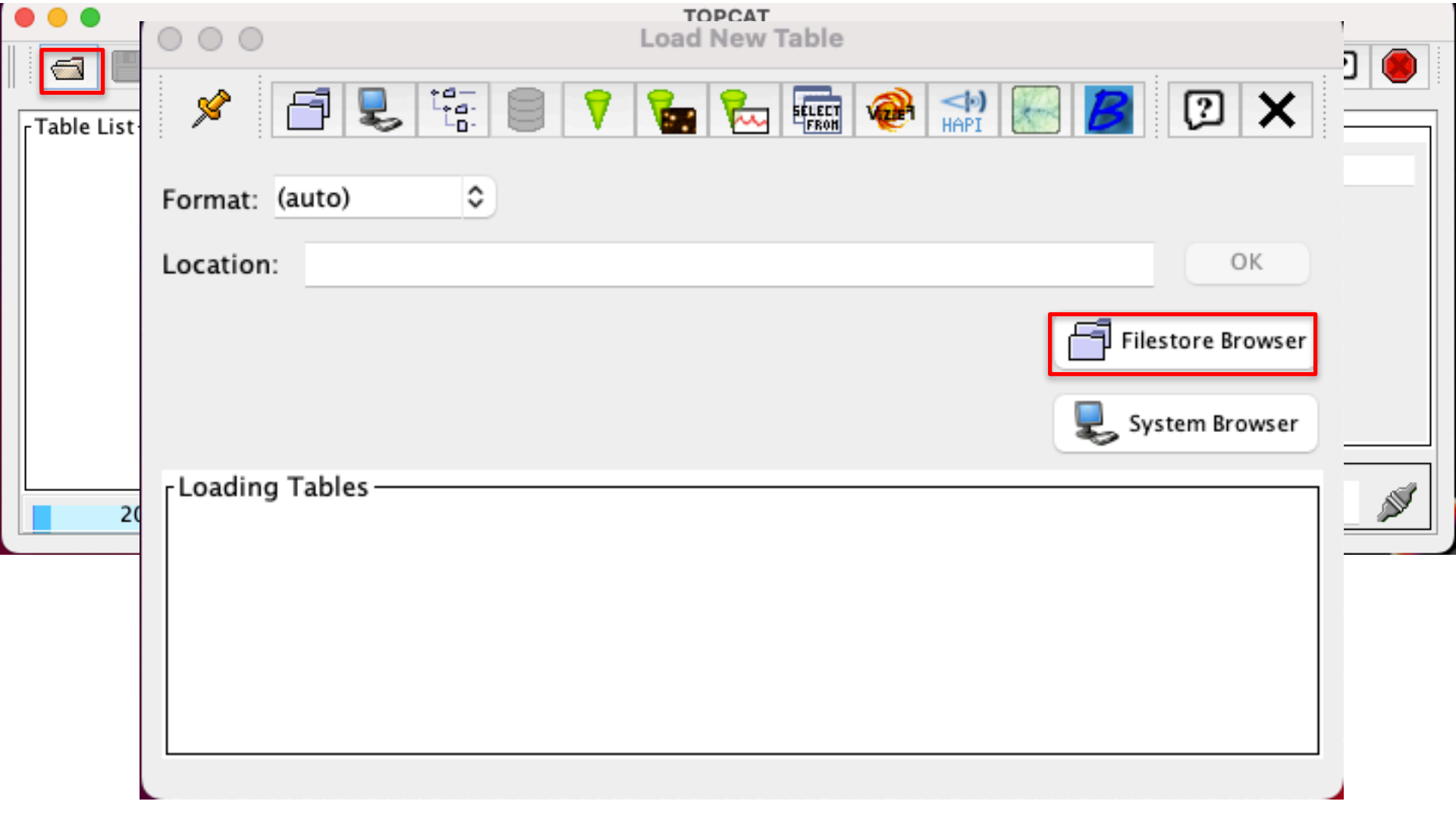

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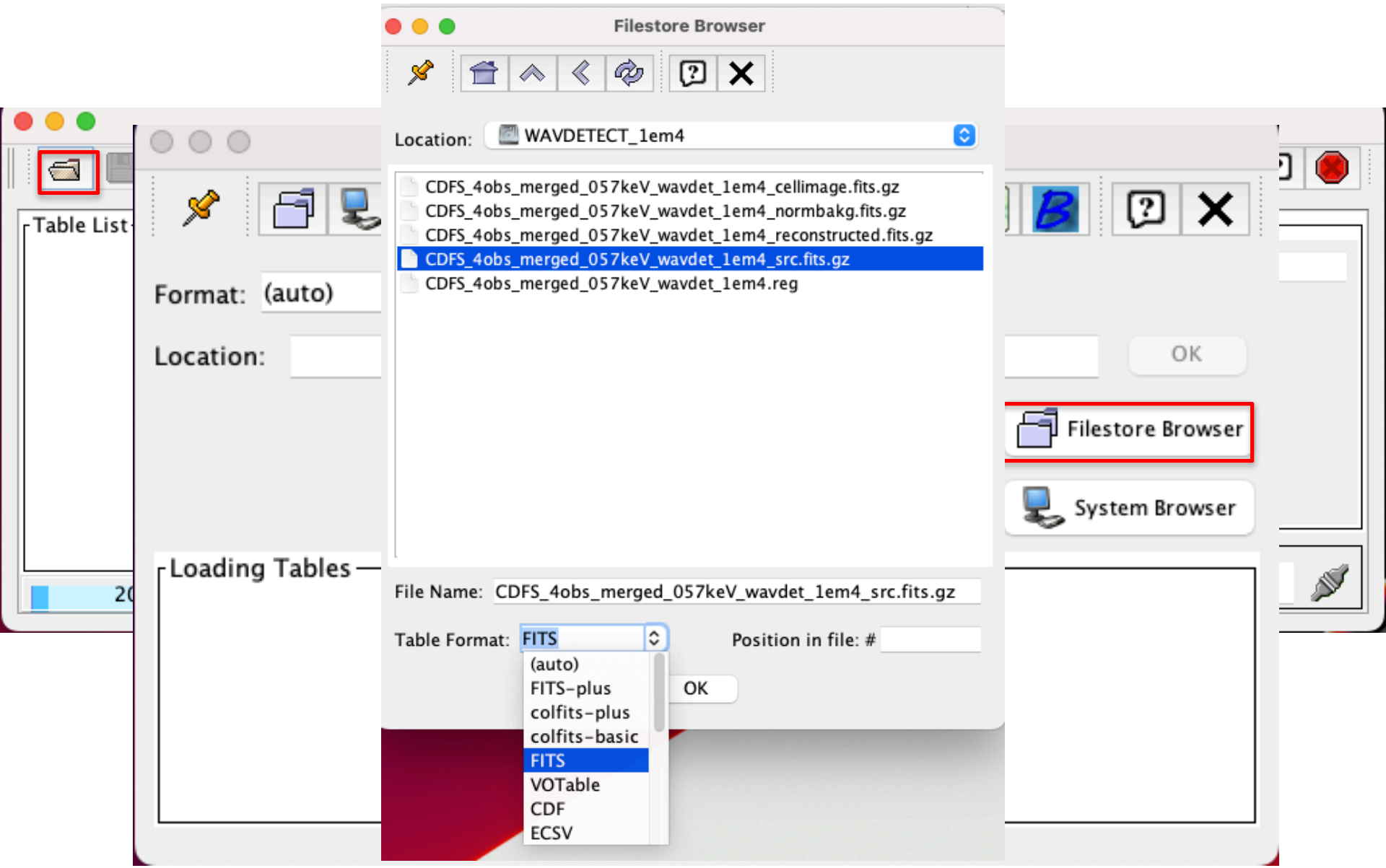

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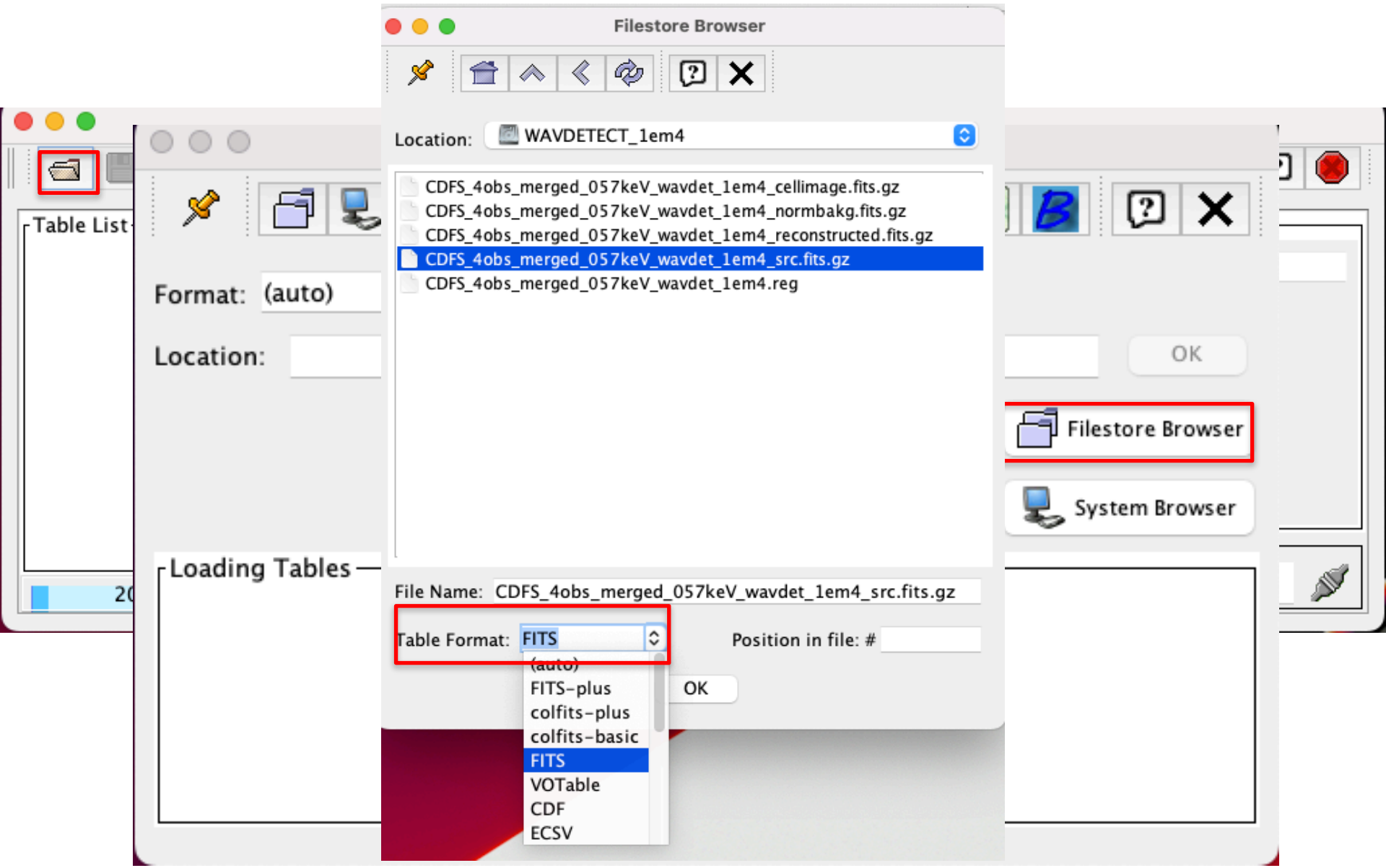
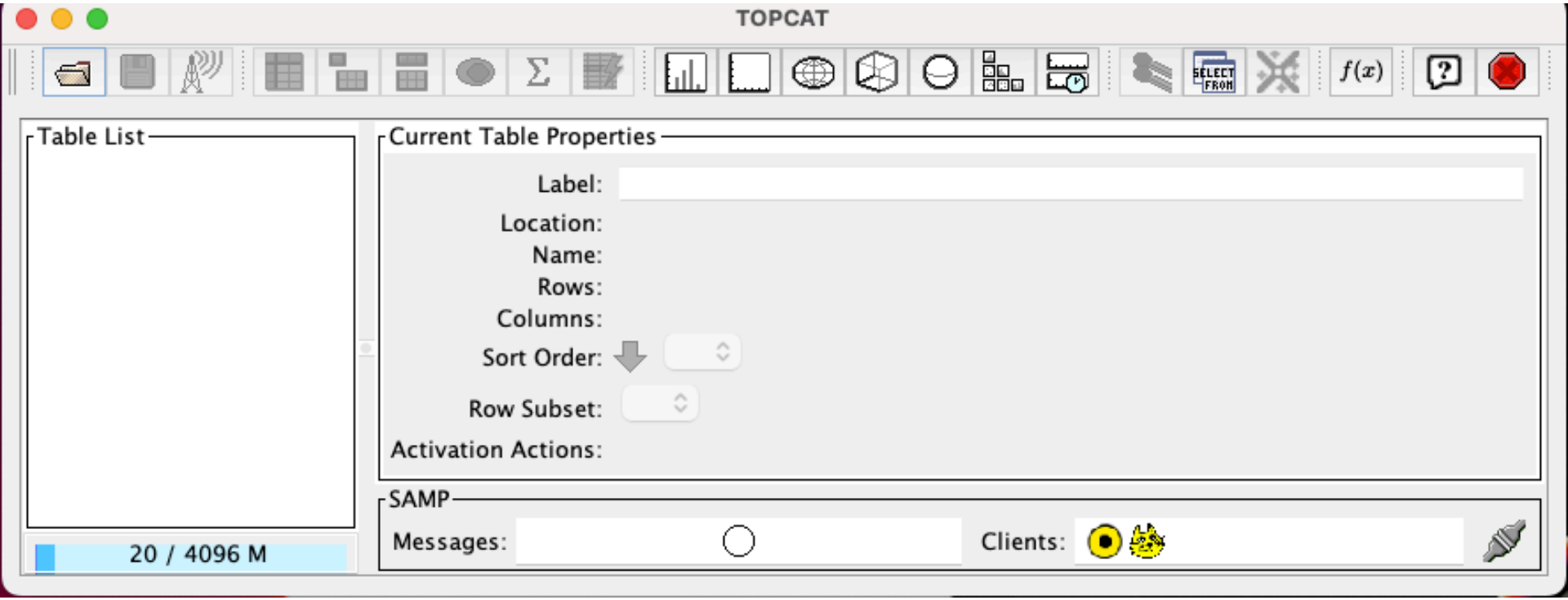


Loading the 7 Ms catalog in Topcat



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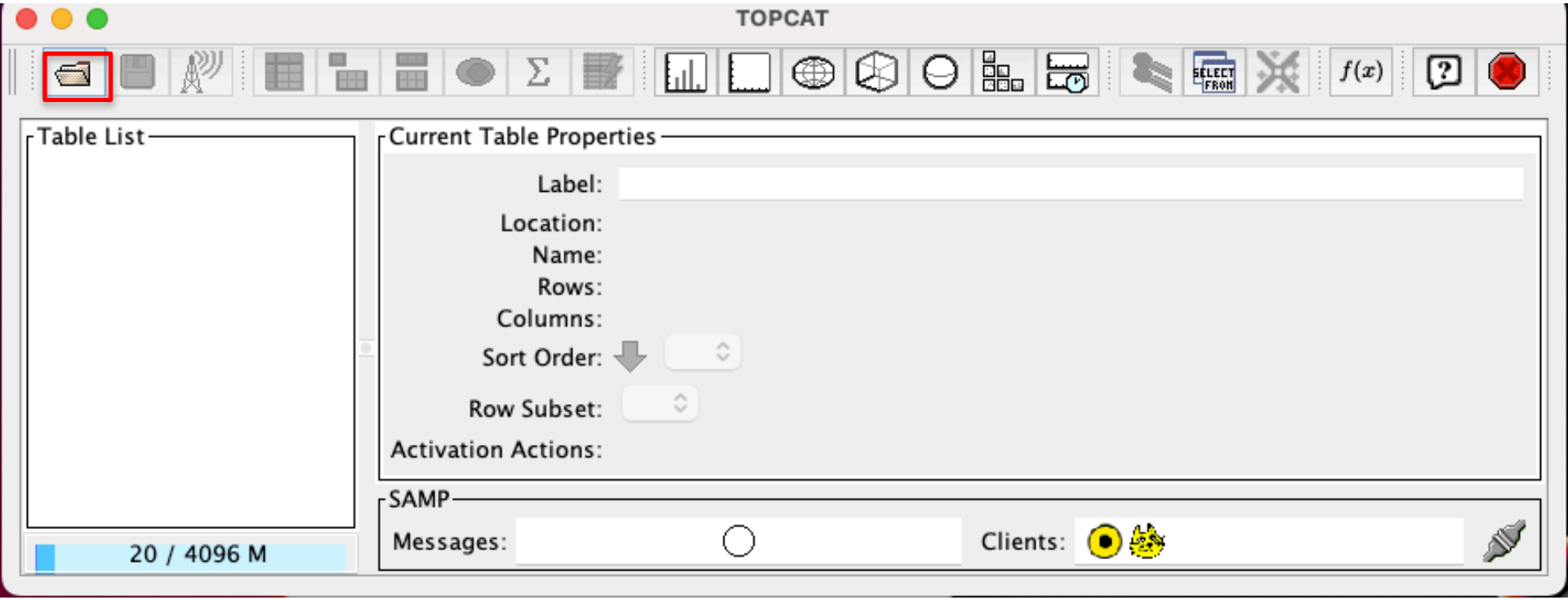

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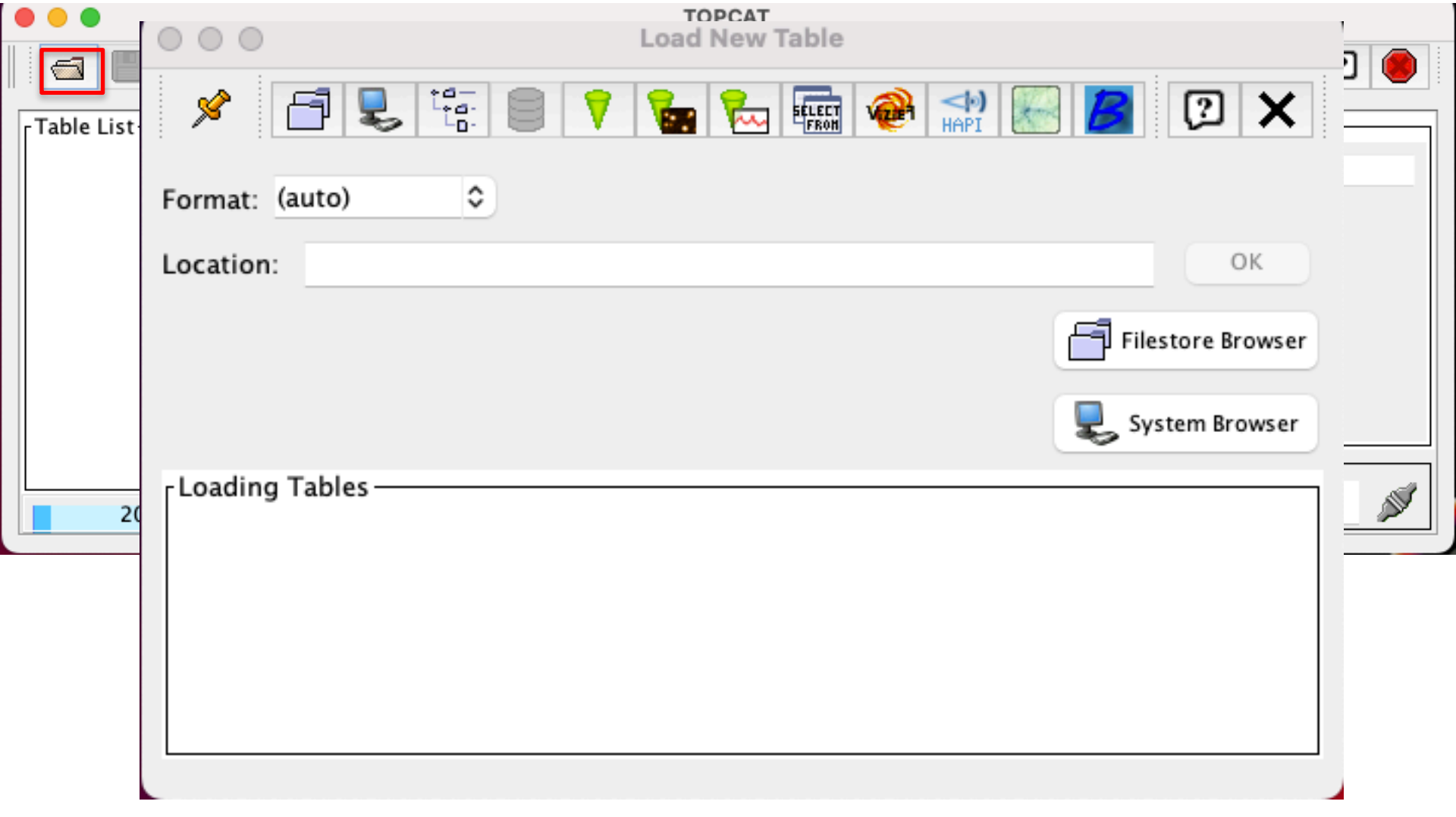

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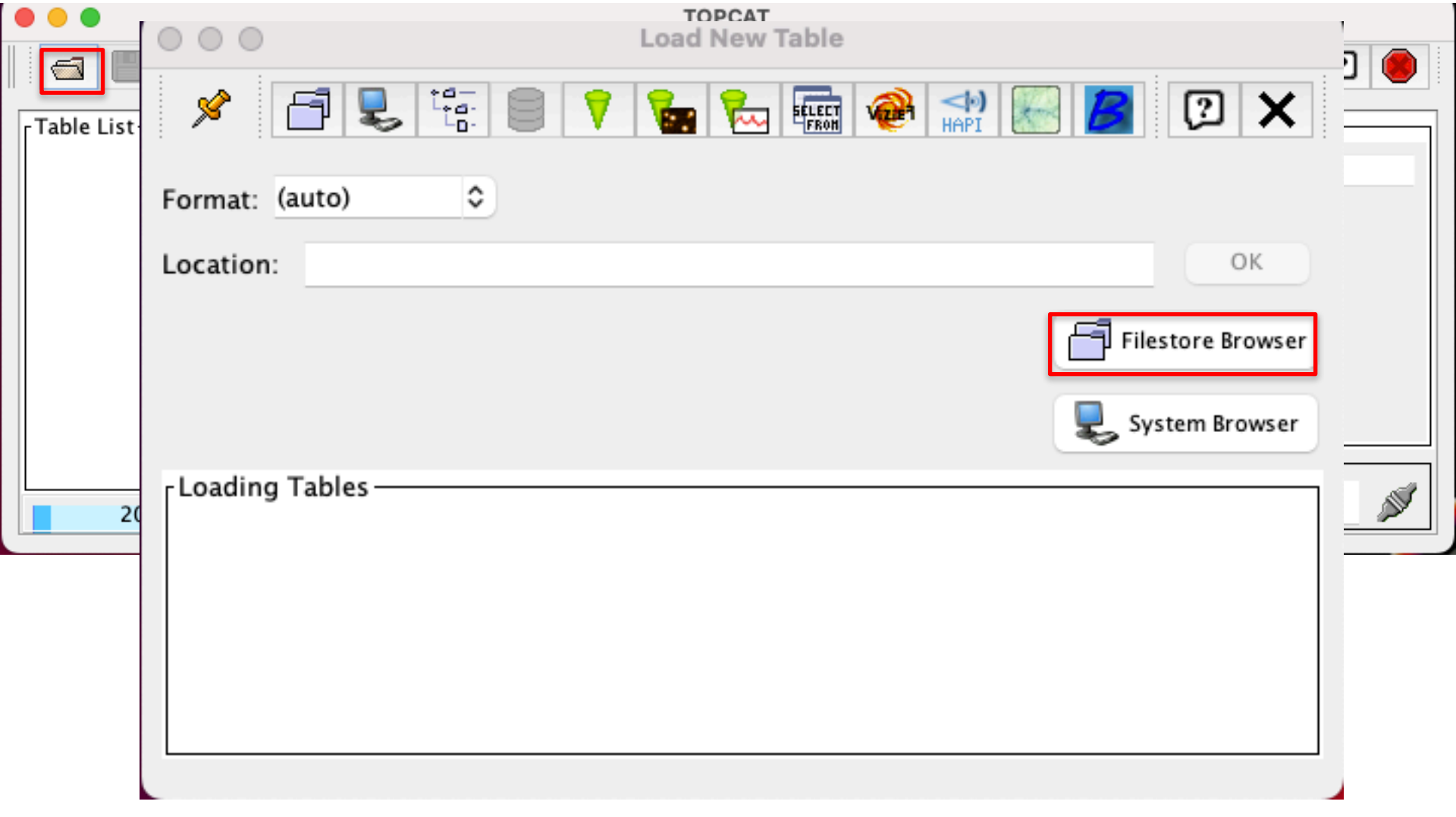

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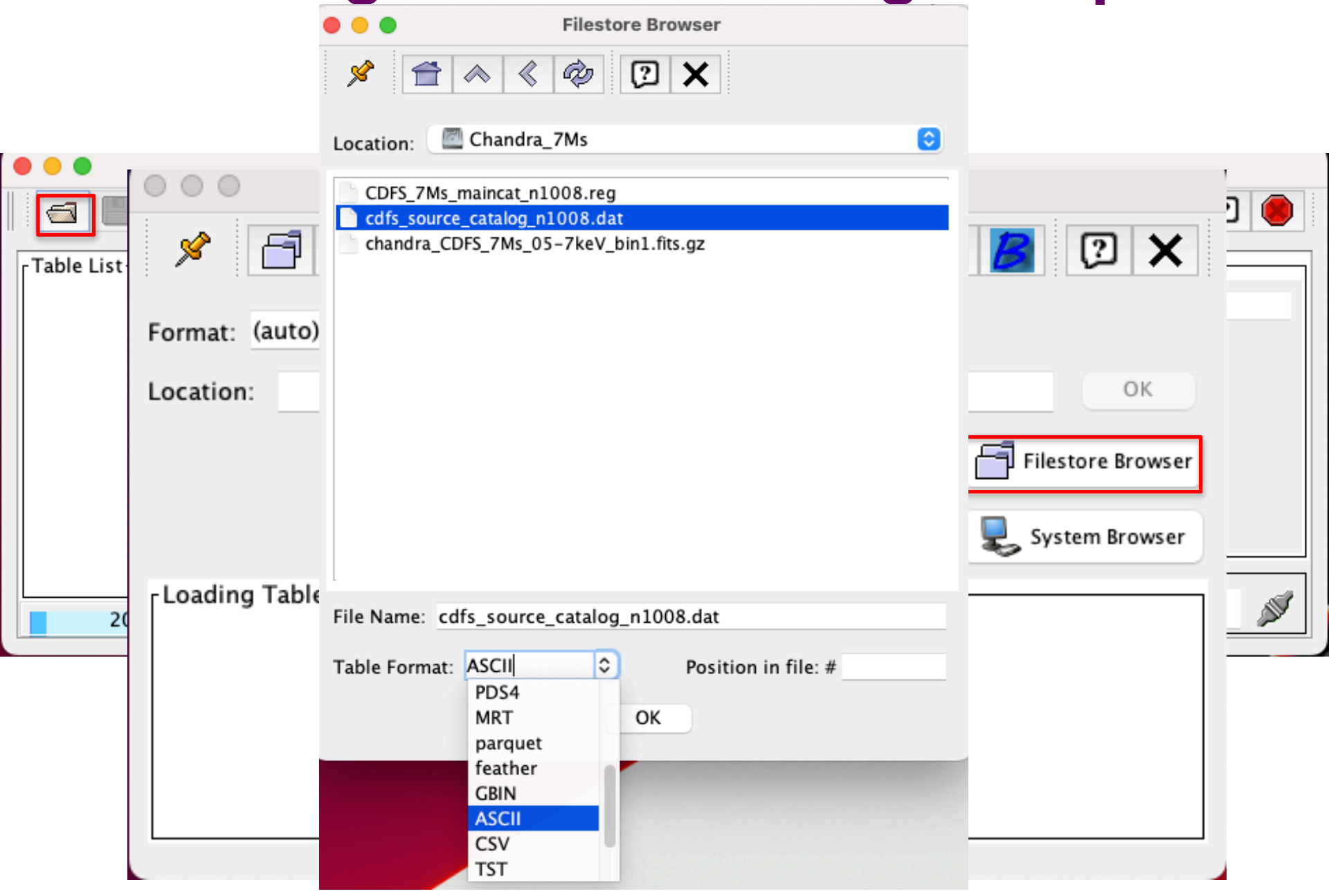

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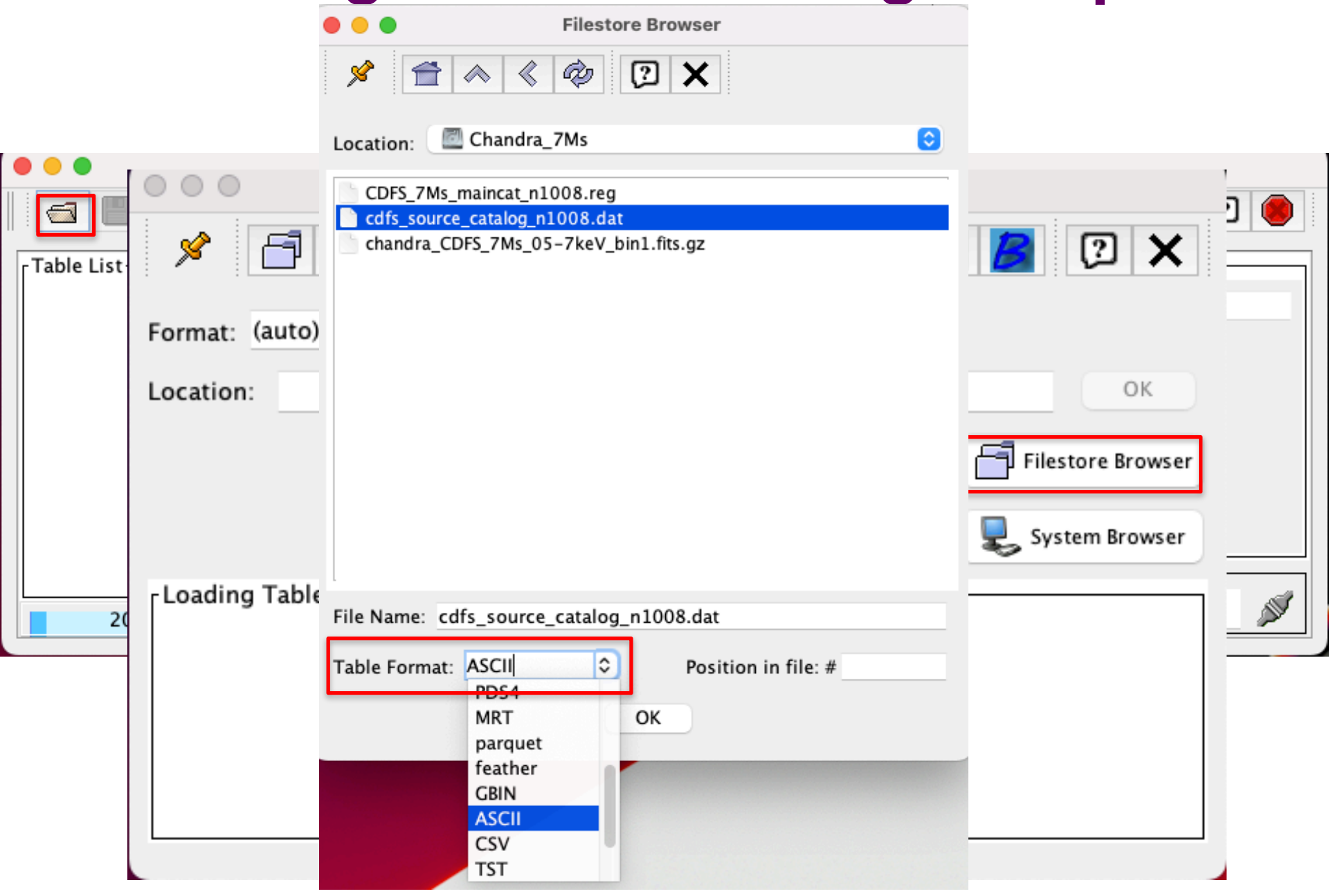
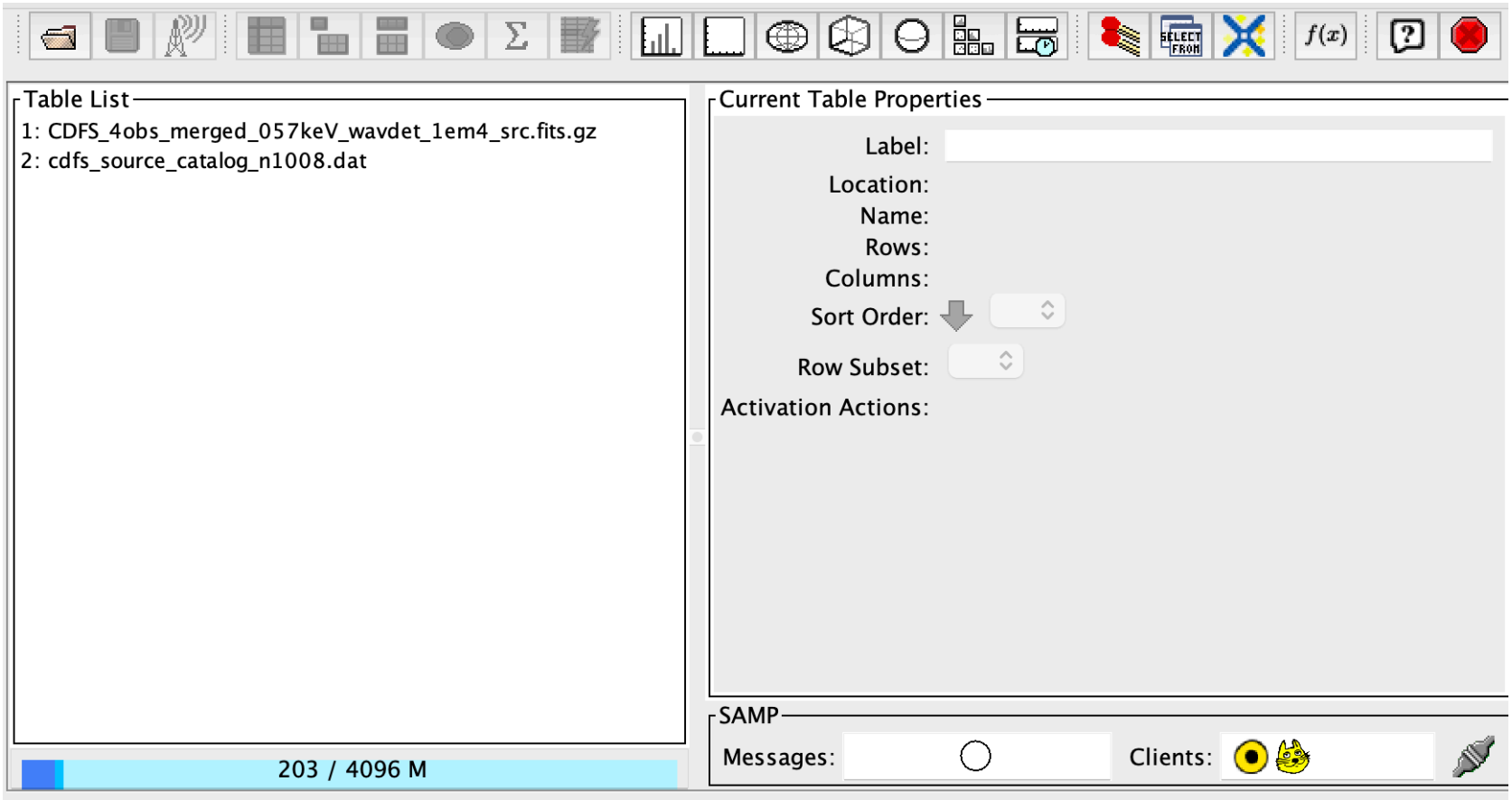


Catalog cross-matching in Topcat

Cross-correlate the source lists obtained in the 500 ks observations with the official 7 Ms Chandra source catalog in the CDF-S (Luo et al. 2017), using three different cross-matching radii (1,2,3 arcsec).



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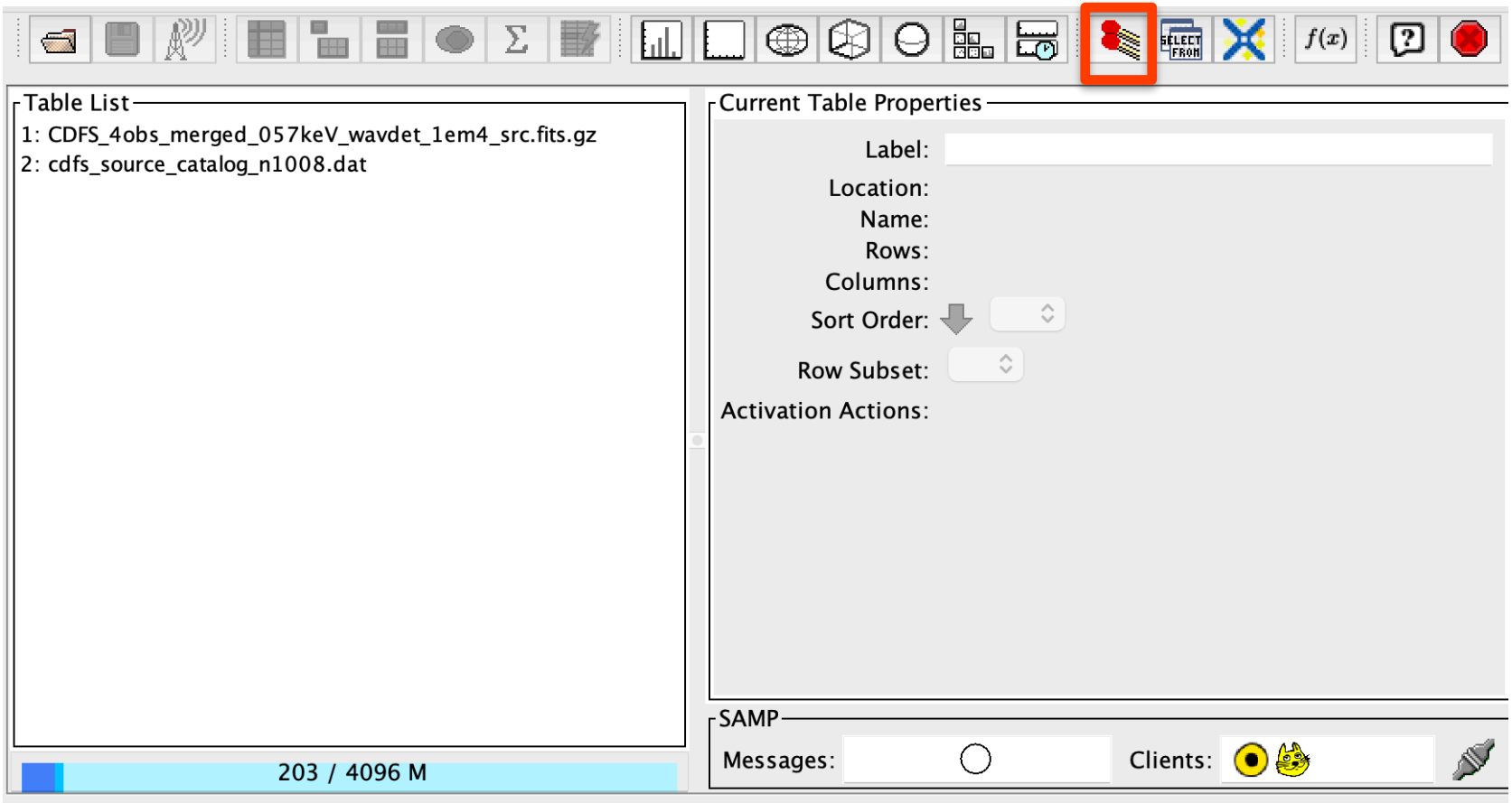
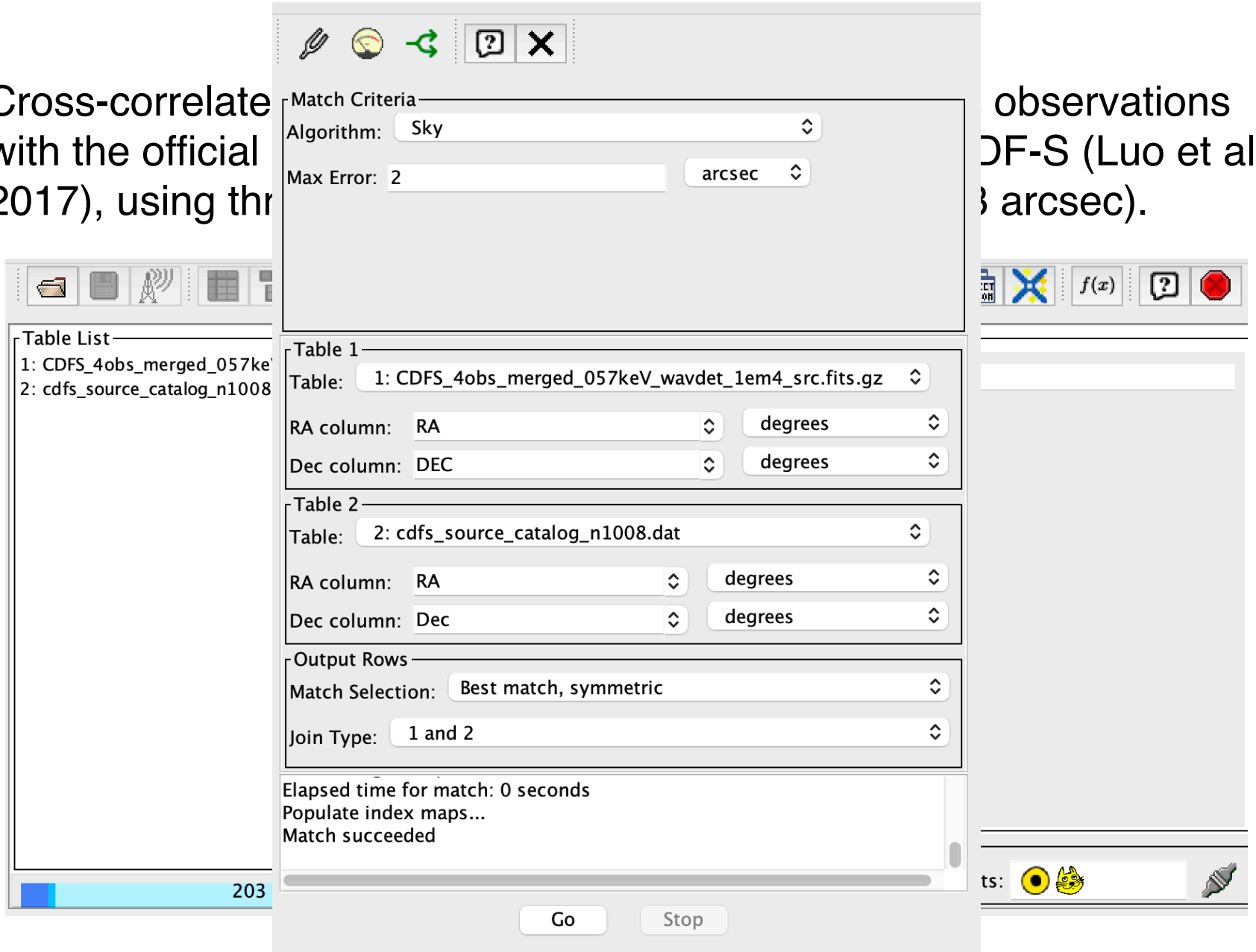


Catalog cross-matching in Topcat

Cross-correlate observations with the official DF-S (Luo et al. 2017), using thr arcsec).



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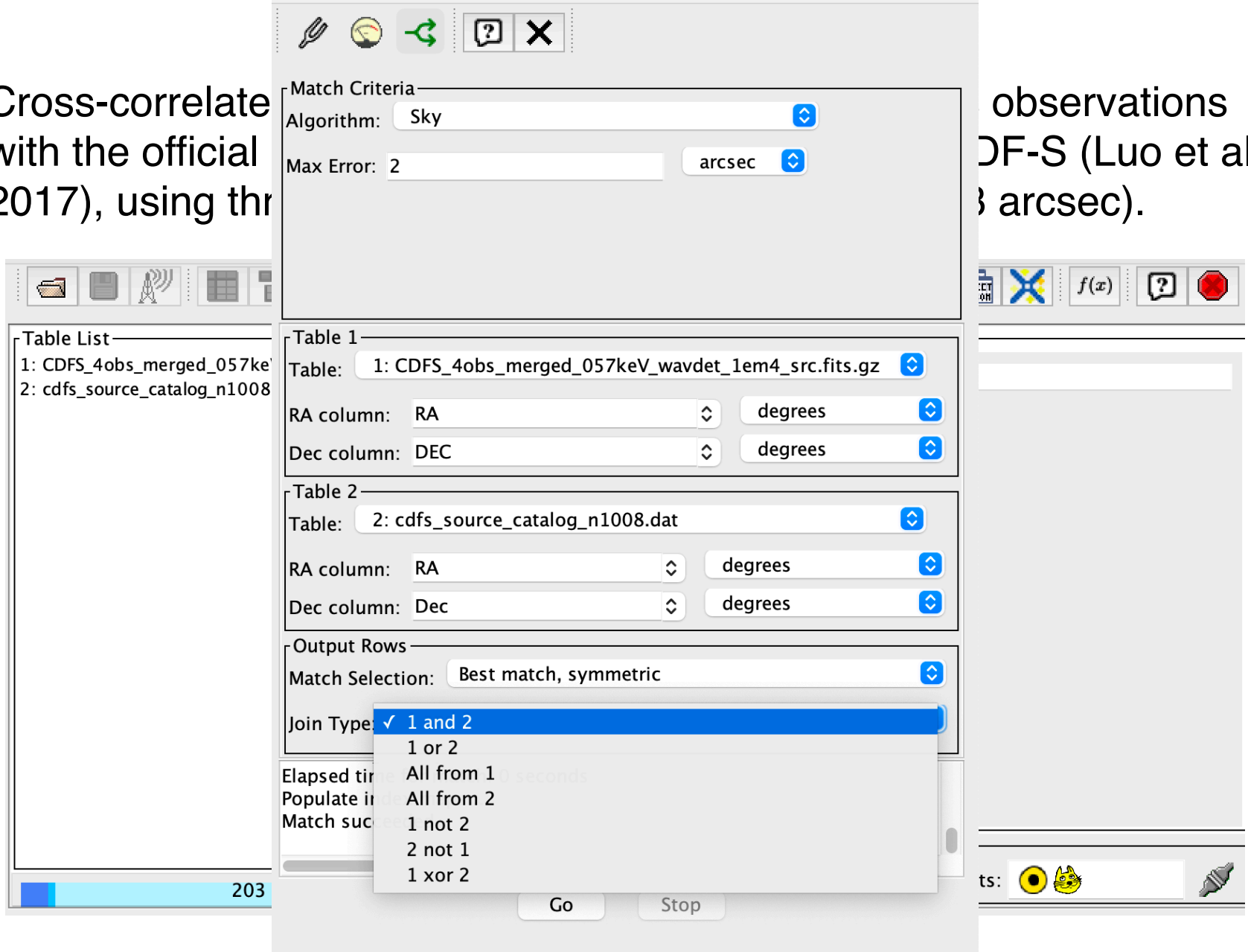


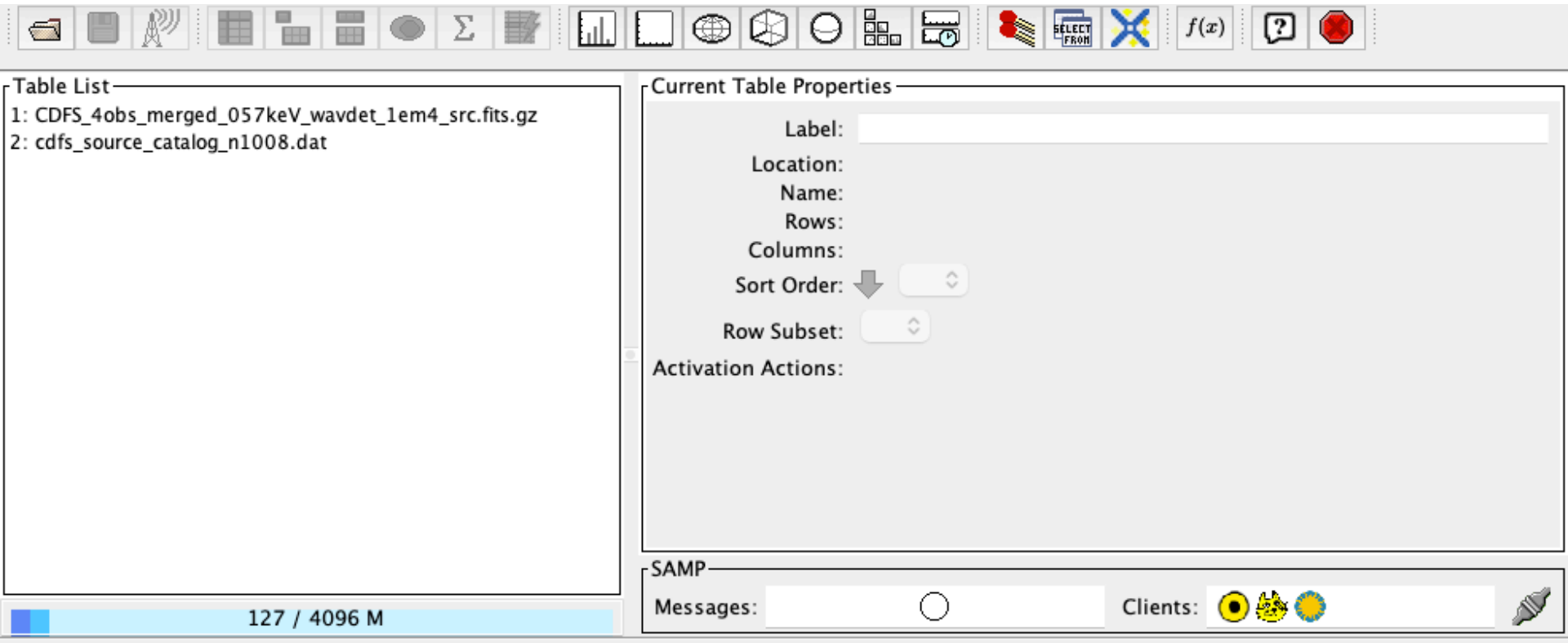
Search for sources in the 500 ks catalog missing in the 7 Ms/1

Create a catalog of all sources in the sig_thresh=1E-4, 500 ks catalog (CDFS_4obs_merged_057keV_wavdet_1em4_src.fits) that **do not** have a counterpart within 3" in the 7 Ms catalog.

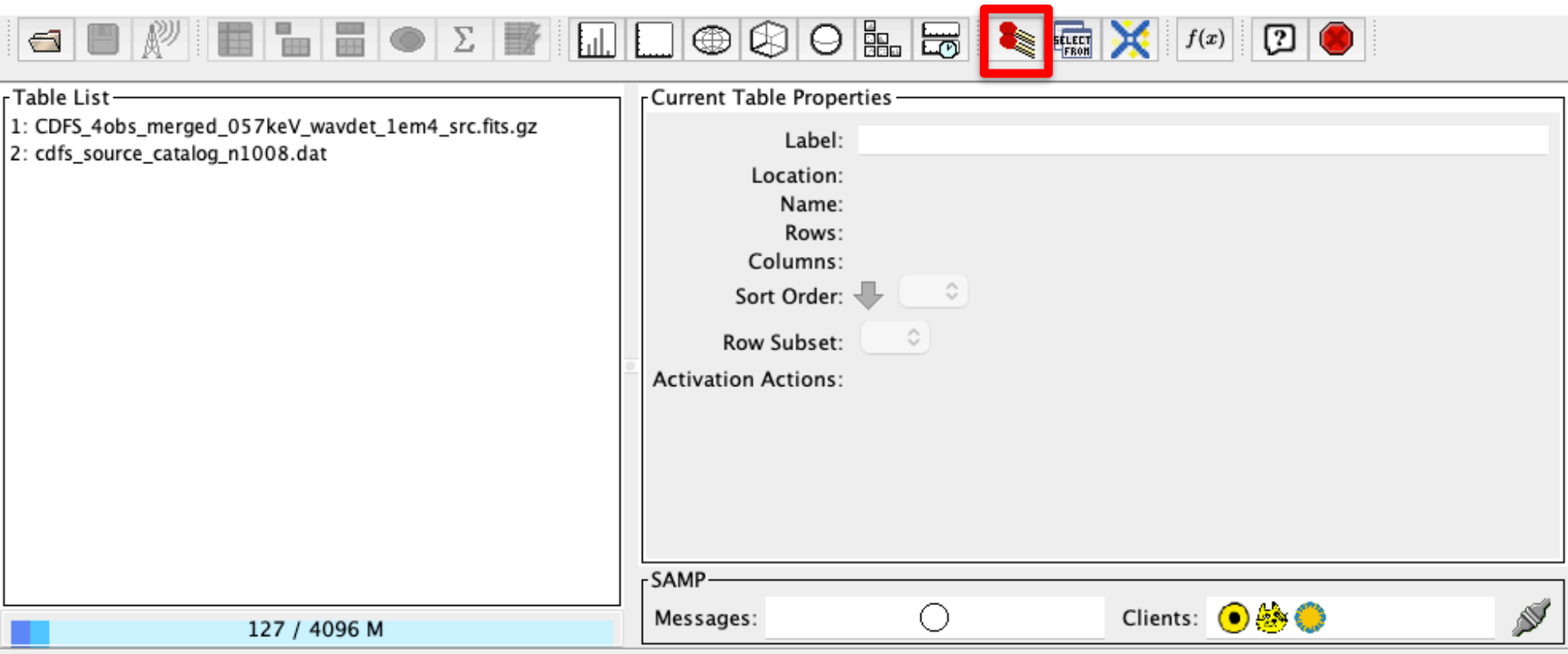
Using Topcat, produce a **plot** of number counts vs src_significance with the two samples (sources with a counterpart vs sources without a counterpart) plotted in different colors, and compute the **median, 1st and 3rd quartile** of the two quantities (see following slides for tutorial) for both samples.

Then, give your **interpretation** of these numbers, and of the plot, trying to understand the nature of the sources detected in the 500 ks catalog and missing from the 7 Ms one (variability? Something else?).

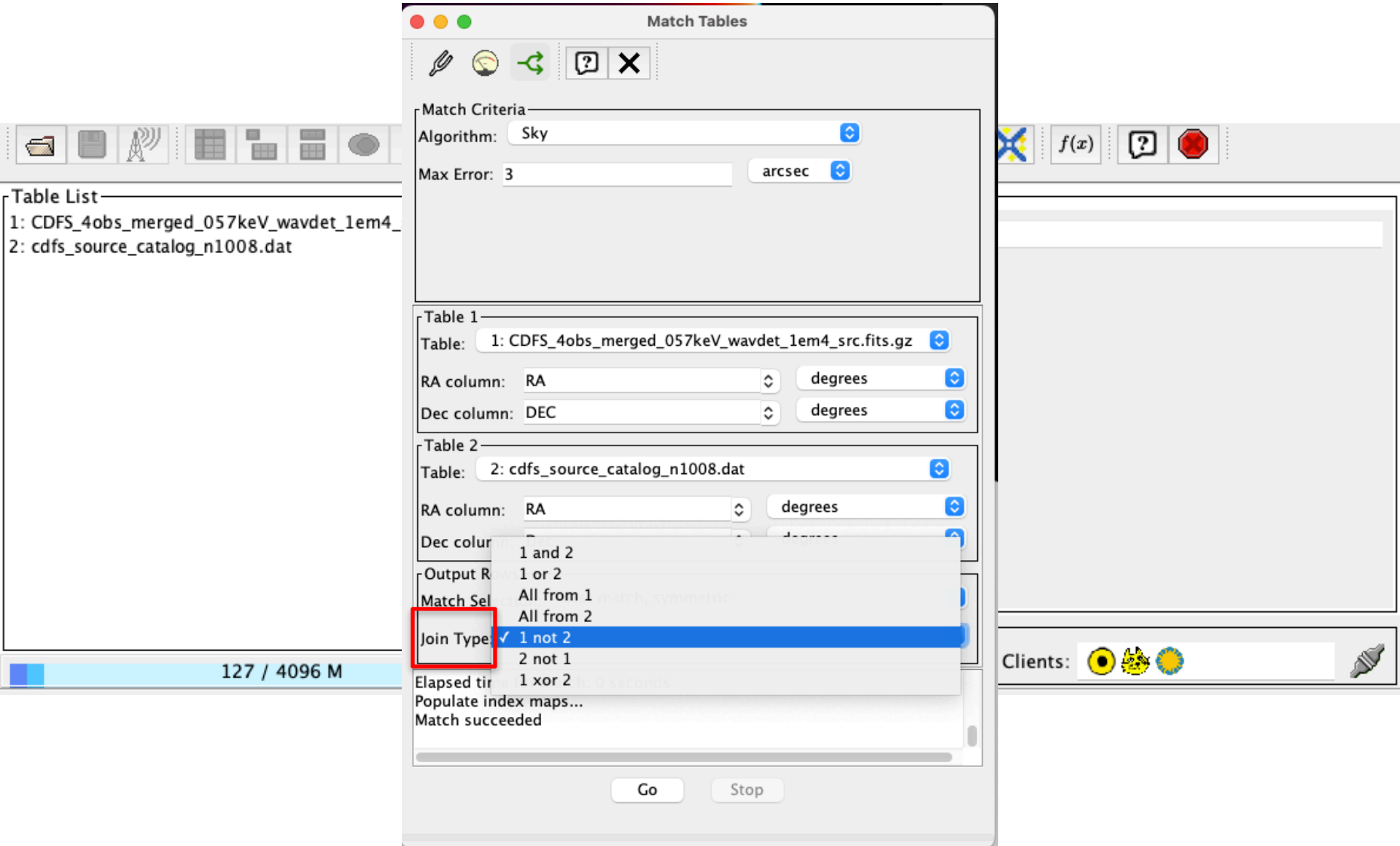
Search for sources in the 500 ks catalog missing in the 7 Ms



Search for sources in the 500 ks catalog missing in the 7 Ms



Search for sources in the 500 ks catalog missing in the 7 Ms



Search for sources in the 500 ks catalog missing in the 7 Ms/2

Redo the same operation, this time using CDFS_4obs_merged_057keV_wavdet_1em6_src.fits and a 2" maximum separation, to compute the number of sources detected in the 500 ks mosaic with sig_thresh=1E-6 that are **not** in the 7Ms catalog.

Using Topcat, produce a **plot** of RA and DEC for these sources vs the whole 7 Ms catalog: are the objects randomly spread across the field of view, or do you see some visual trend? What can be inferred from this figure?

Then, open both the 7 Ms mosaic and the 500 ks one with **ds9**, and overload the **7Ms catalog region file** in both of them. Search in the mosaic the source(s) without counterpart in the 7 Ms having src_significance>7 (and thus very likely to be real): how does it look like in the 7 Ms mosaic, and why it is not detected there?

Explore the source catalog

a. Choose the catalog you built that contains largest number of matches with the CDF-S 7 Ms one) and produce some plots (number of counts vs. source significance, vs. exposure time, vs. positional uncertainty)
b. Use the information from the 7Ms source catalog to produce the redshift distribution histogram, Lx vs. z plots.

Explore the source catalog

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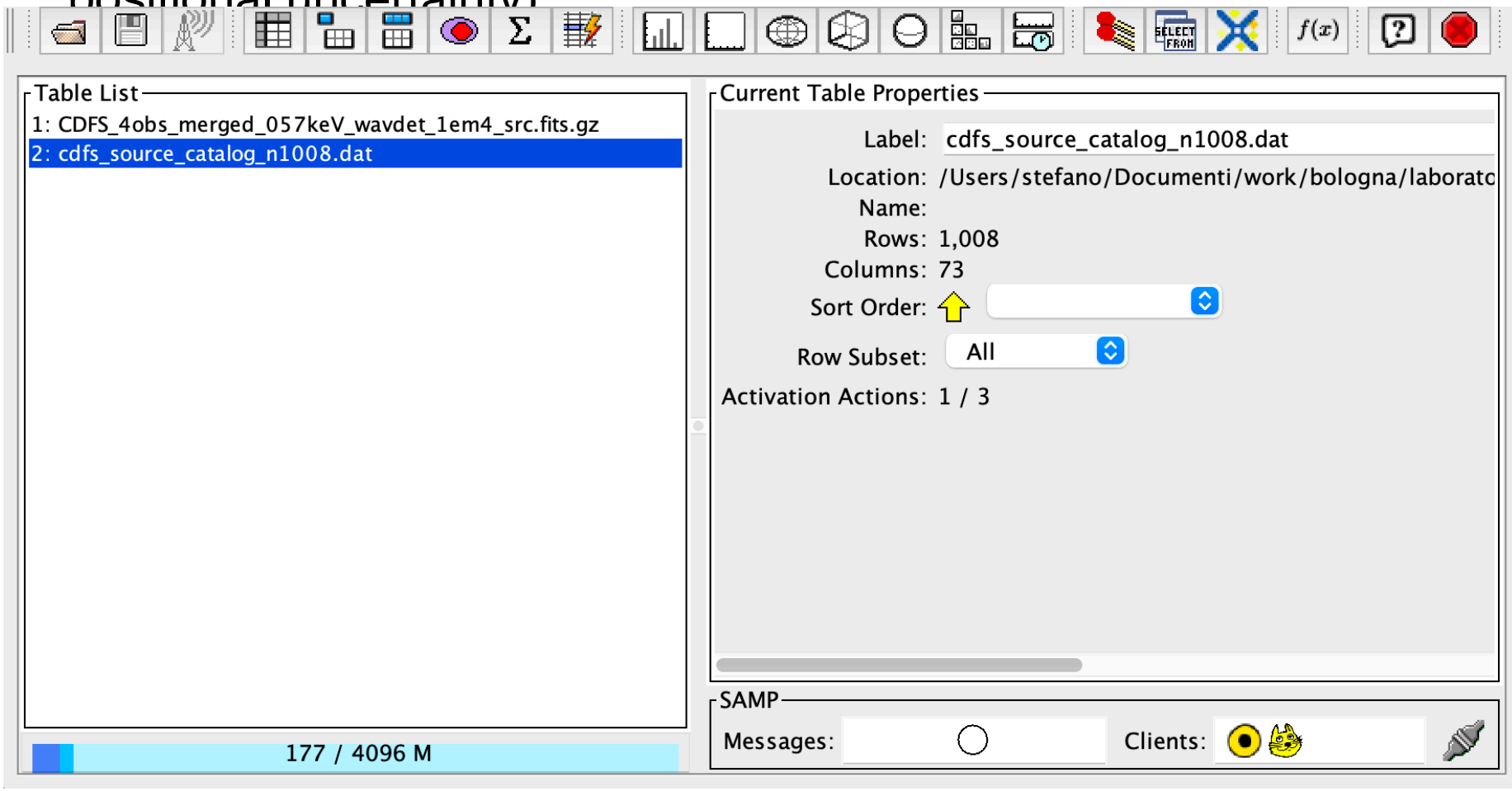

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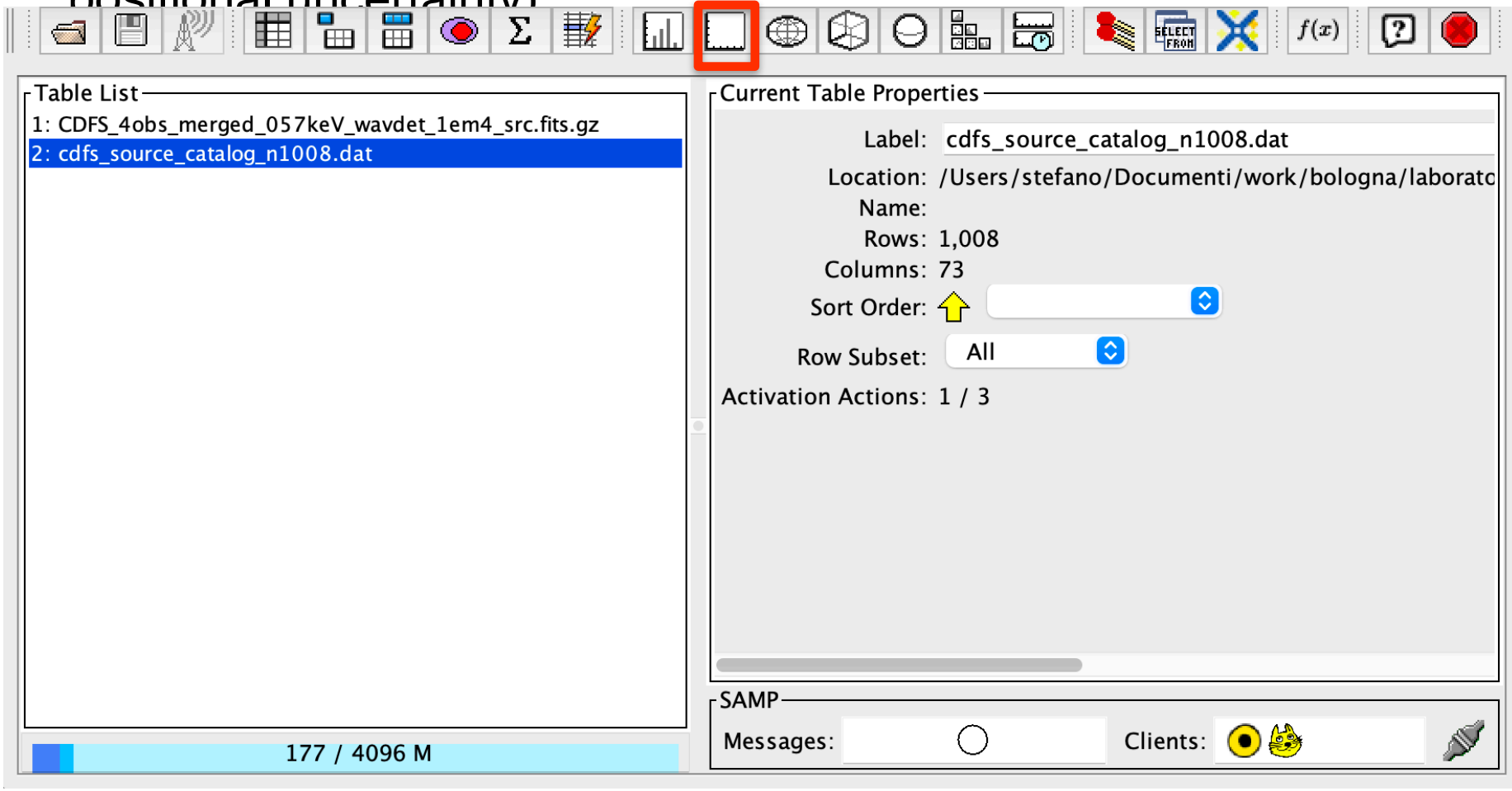

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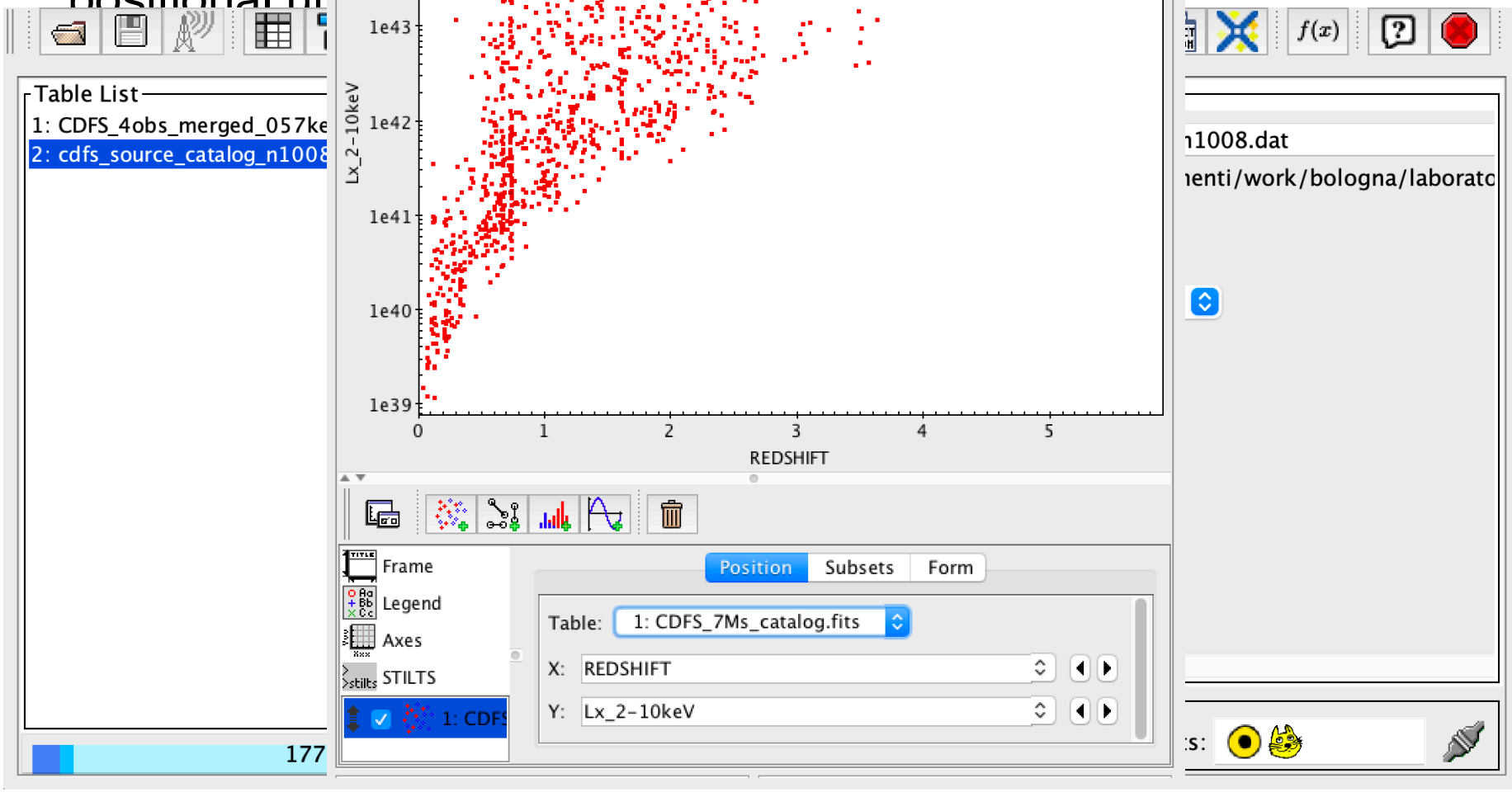

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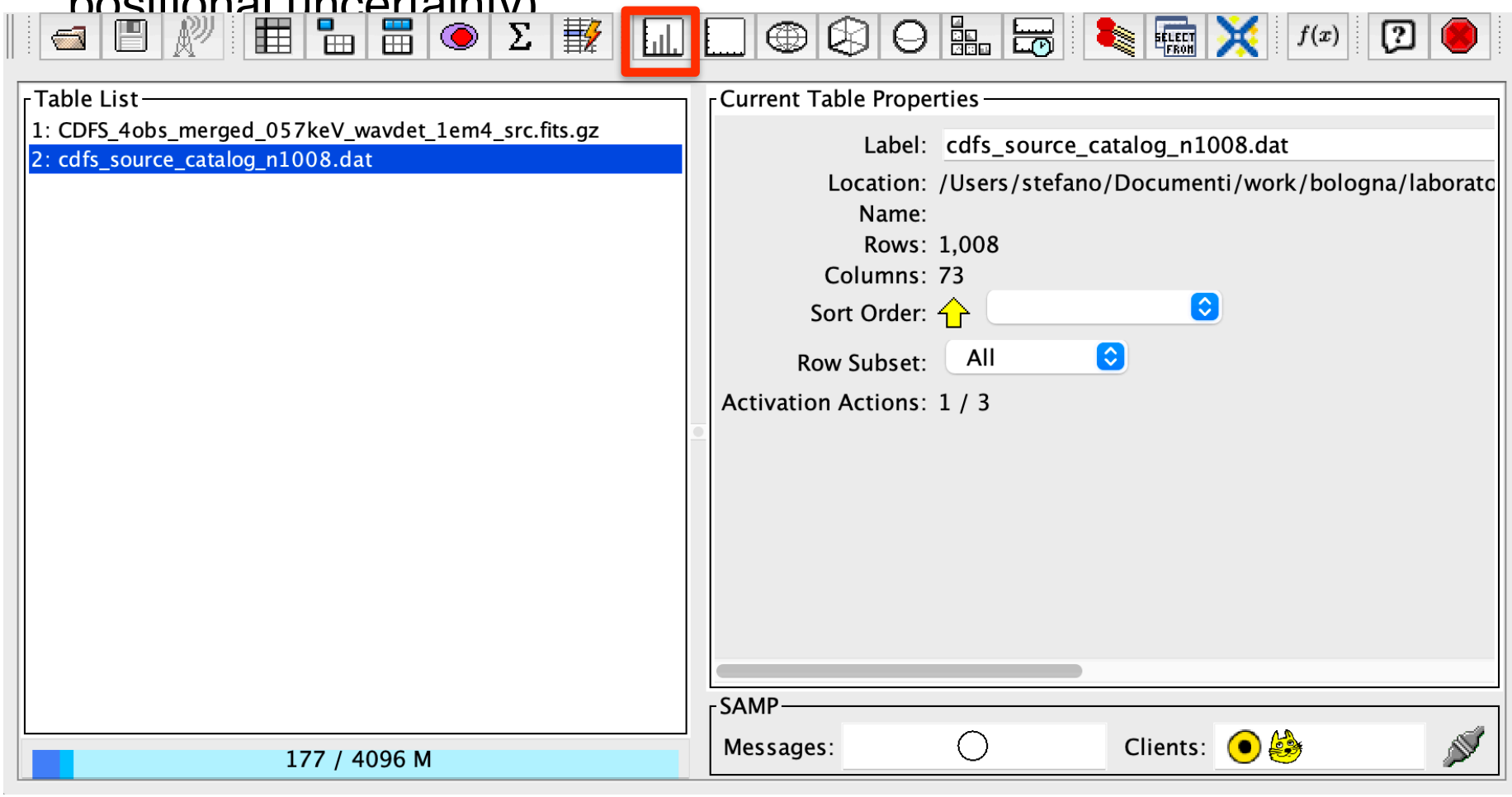

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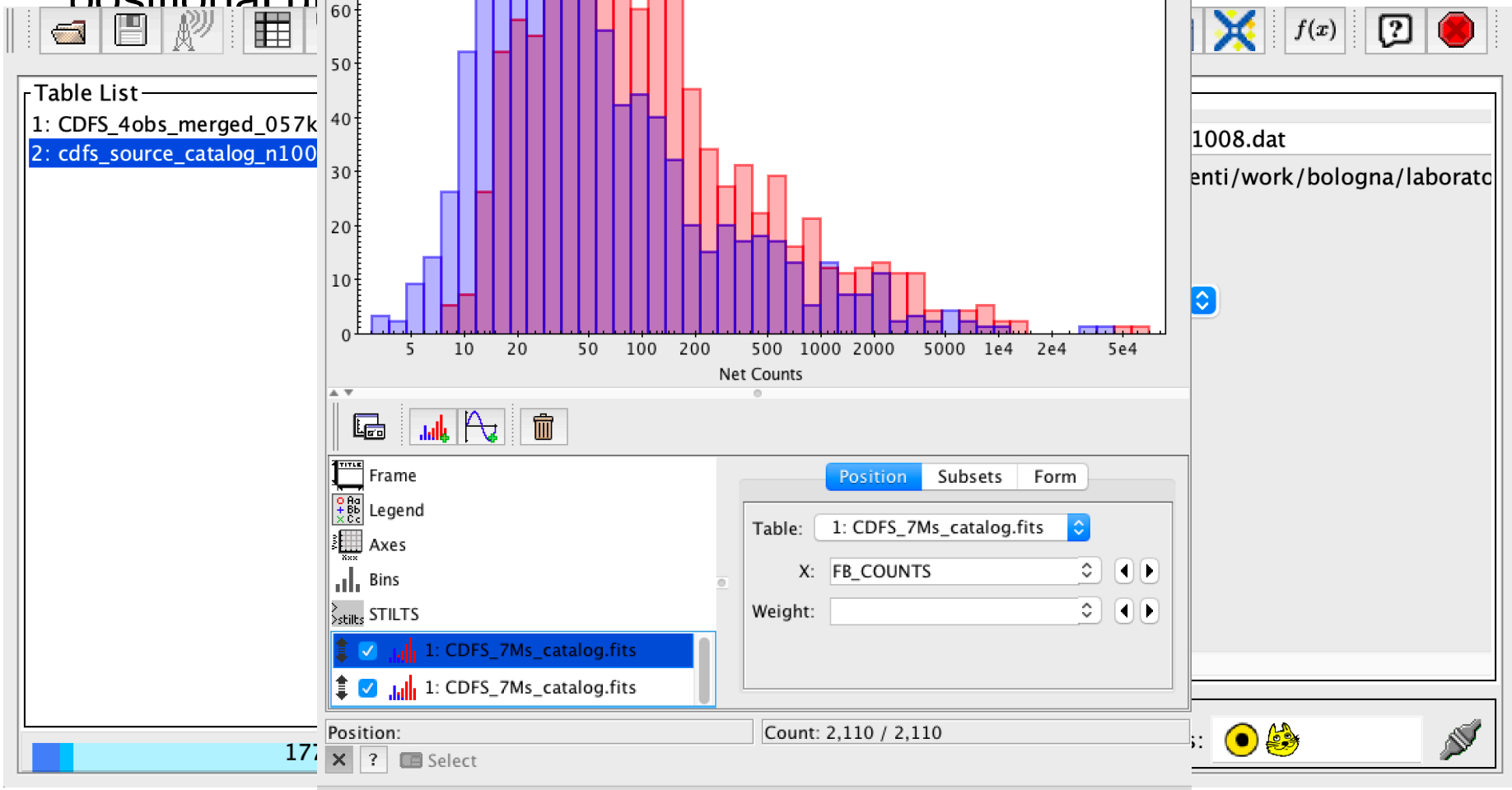


Explore the source catalog

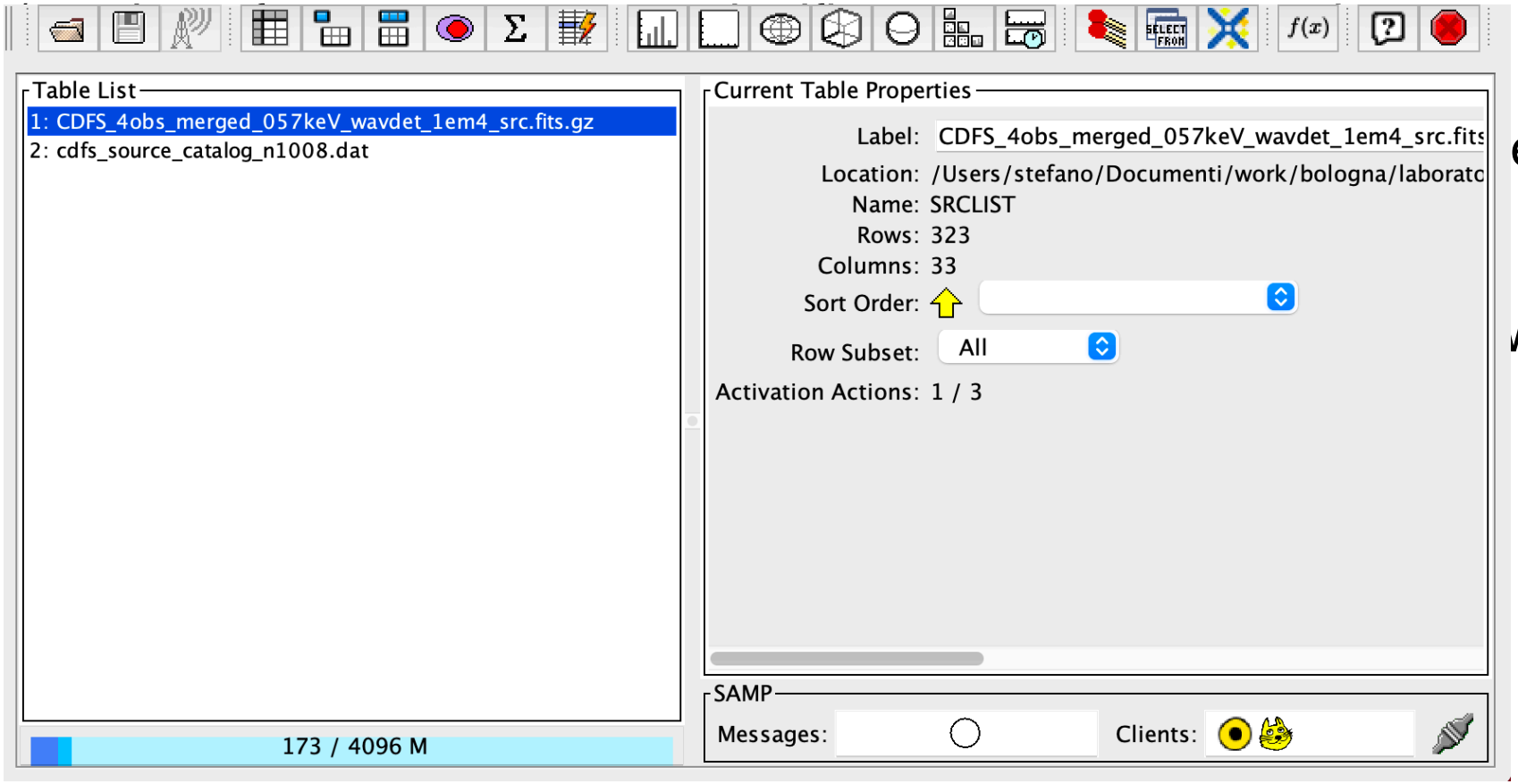
a. Choose one of the produced catalogs and produce some plots (number of counts vs. source significance, vs. exposure time, vs. positional uncertainty, etc.)
b. For the sources associated with the 7 Ms source catalog, produce the redshift distribution histogram, Lx vs. z plot, etc.
c. Repeat the operation done in b. after creating subsamples of sources from the 7 Ms source catalog (e.g., spec-z vs phot-z; low vs high band-ratio…). Are there any noticeable trends?

Explore the source catalog

a. Choose one of the produced catalogs and produce some plots

b. e

c. v vs

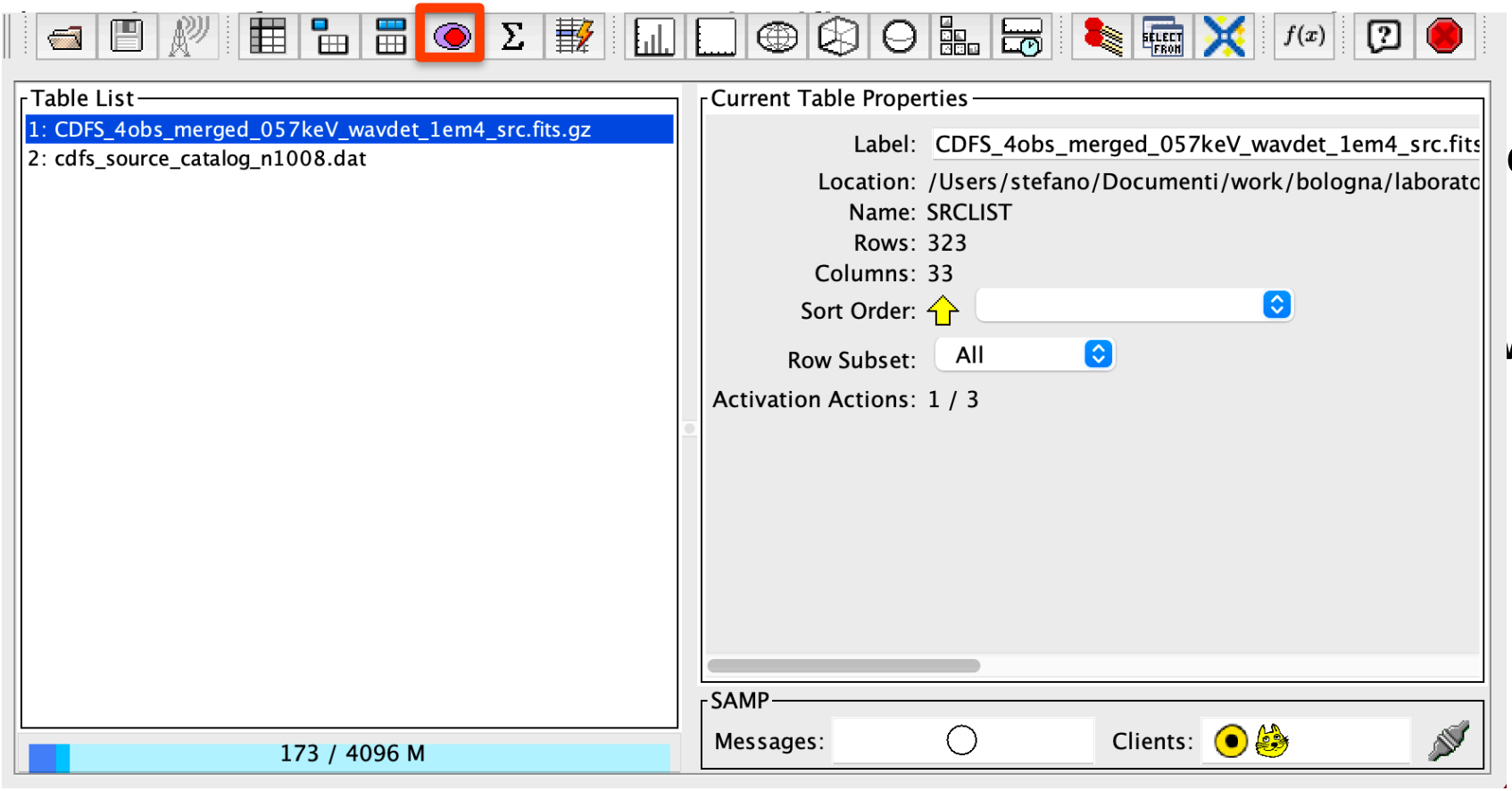


Explore the source catalog

a. Choose one of the produced catalogs and produce some plots

b.

c.

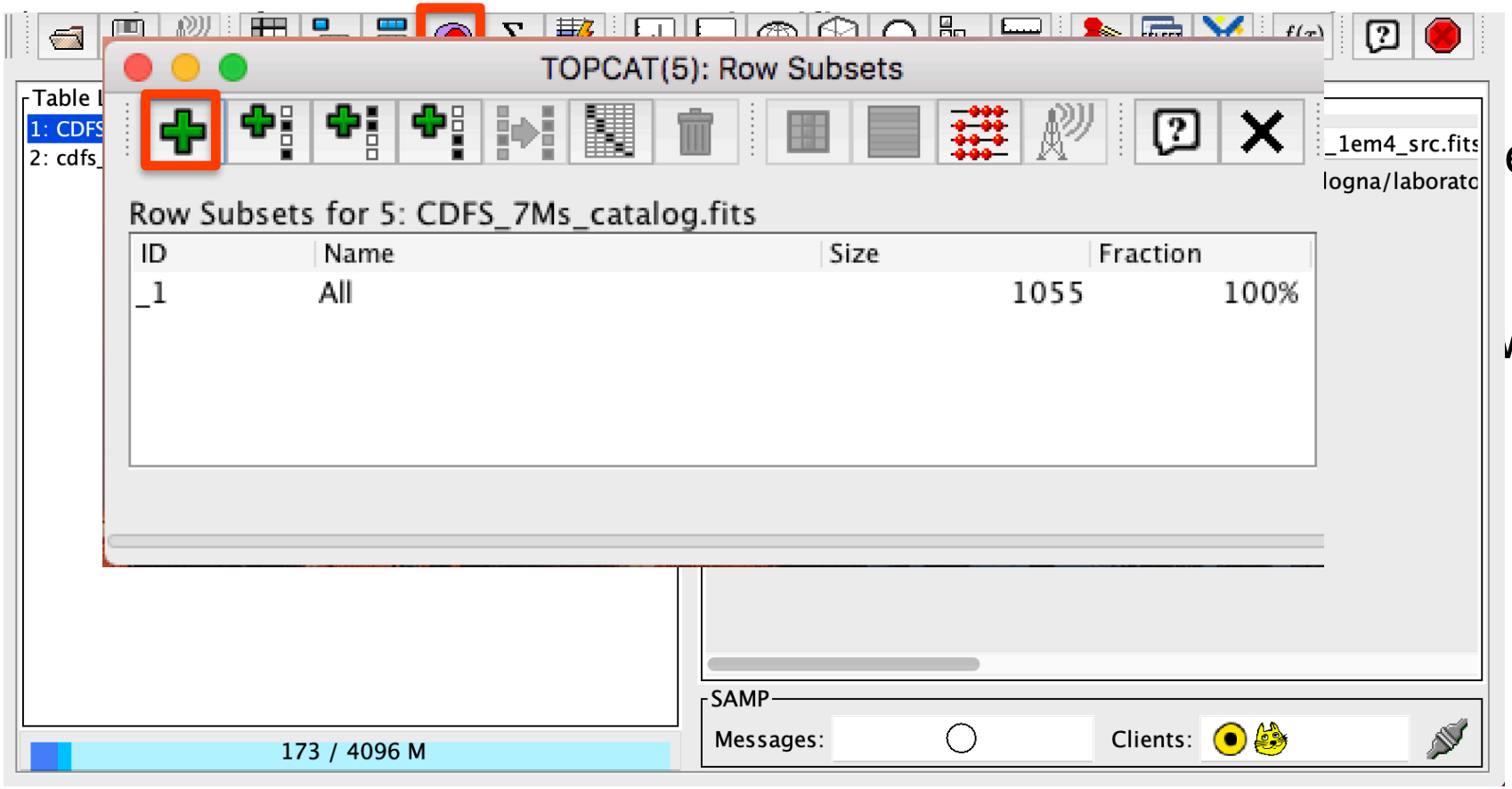


Explore the source catalog

a. Choose one of the produced catalogs and produce some plots

b.

c.

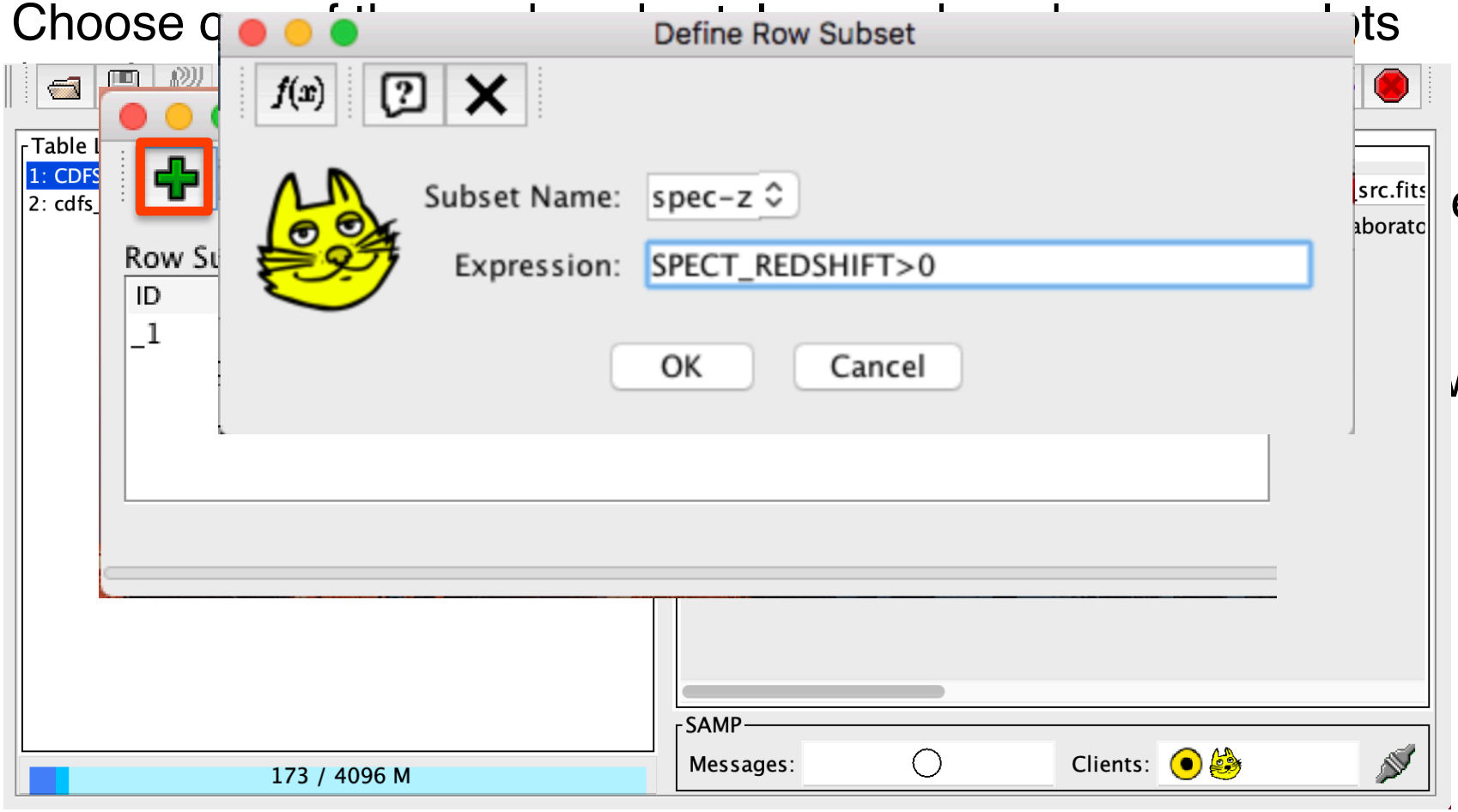


Explore the source catalog

a. Choose o… f t… …ts

b. …e

c. …v vs

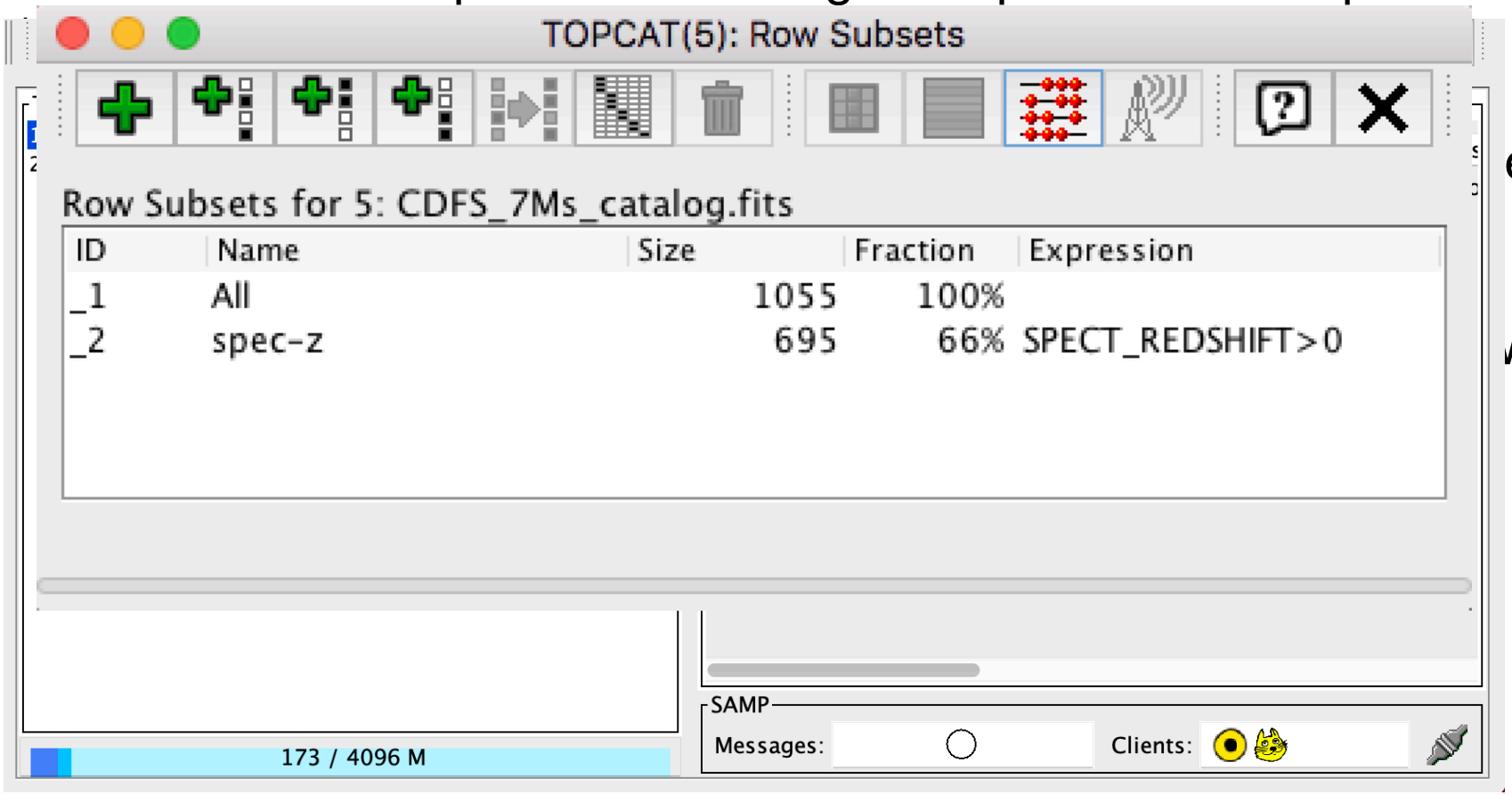


Explore the source catalog

a. Choose one of the produced catalogs and produce some plots

b.

c.

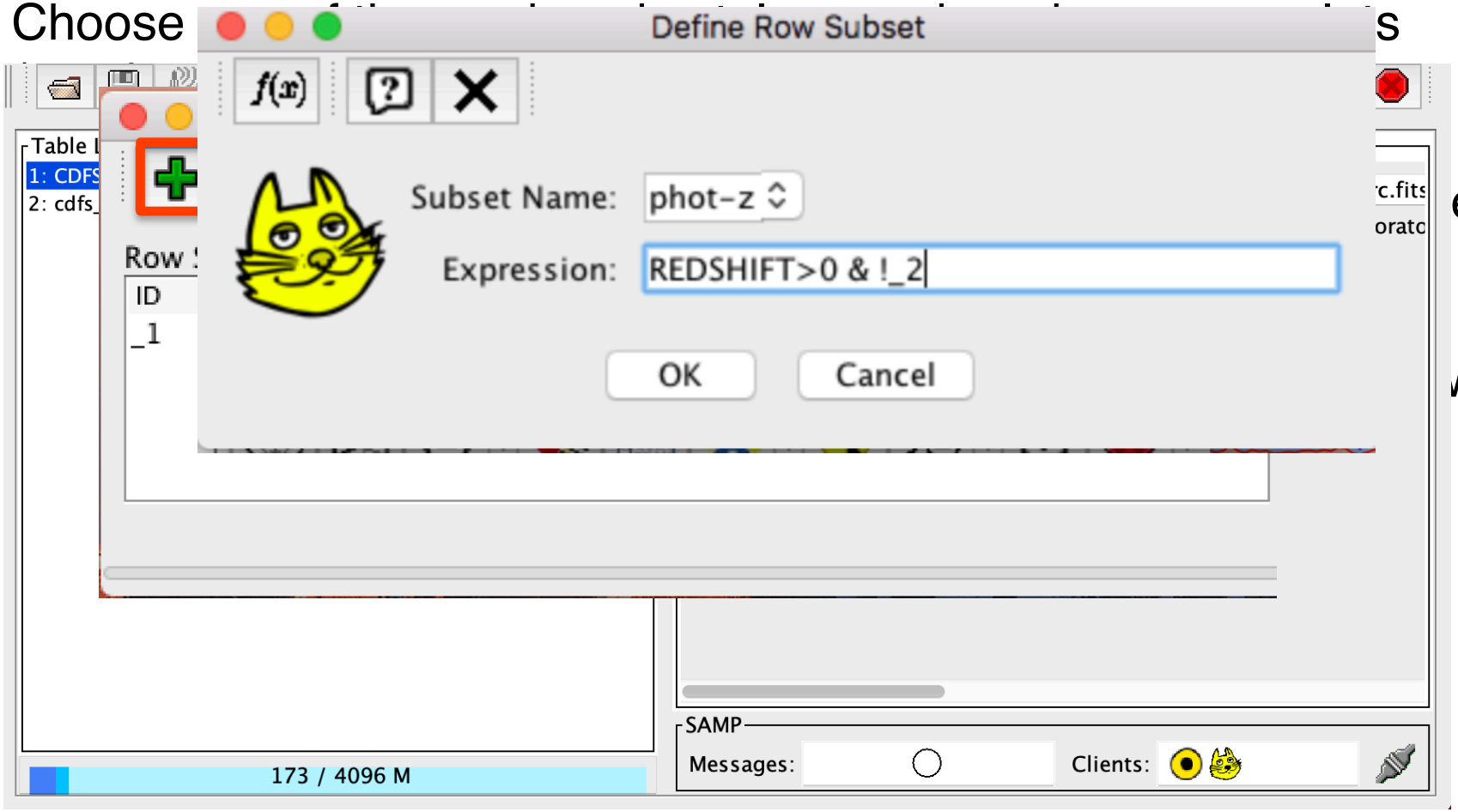


Explore the source catalog

a. Choose s

b. e

c. v vs

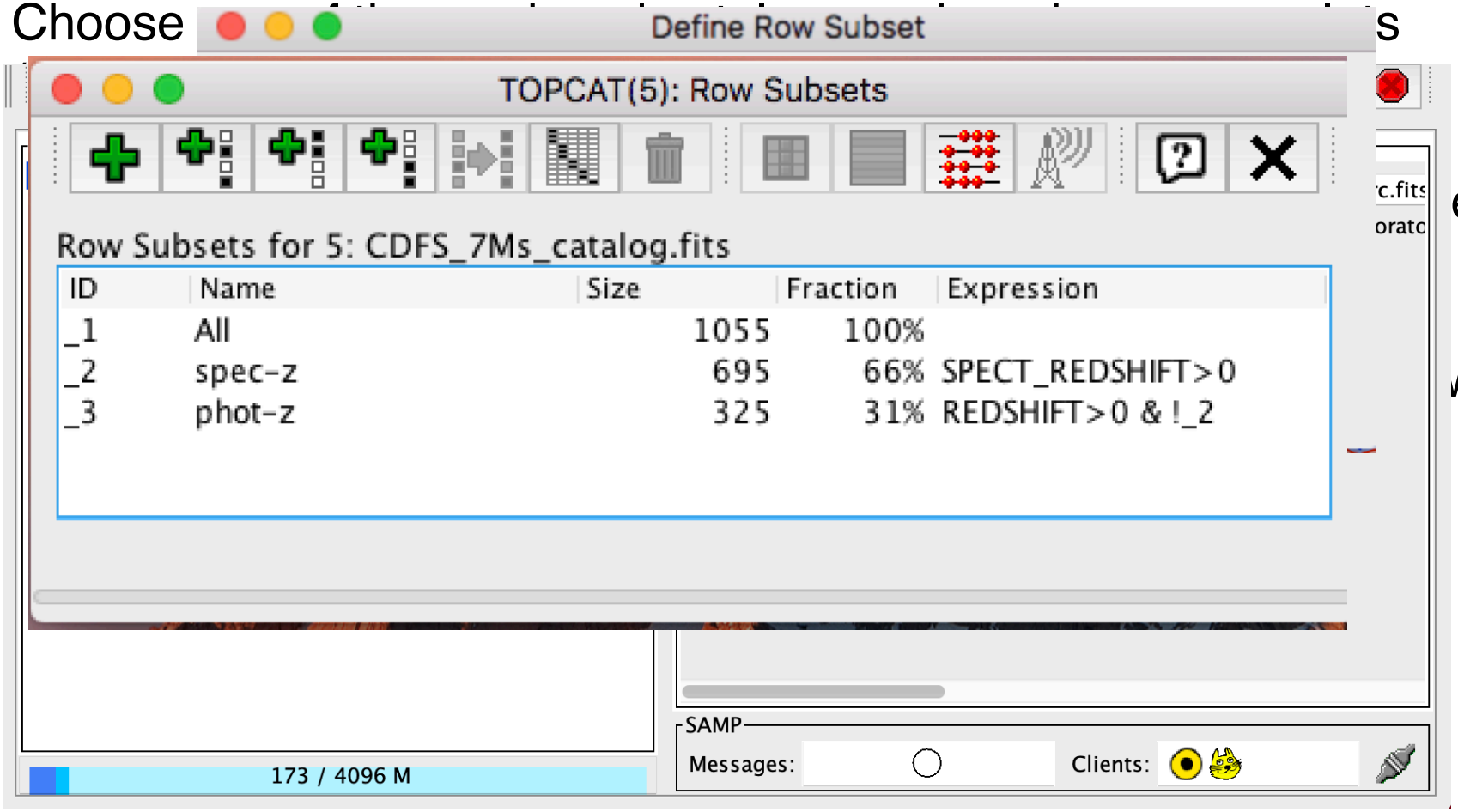


Explore the source catalog

a. Choose

b.

c.

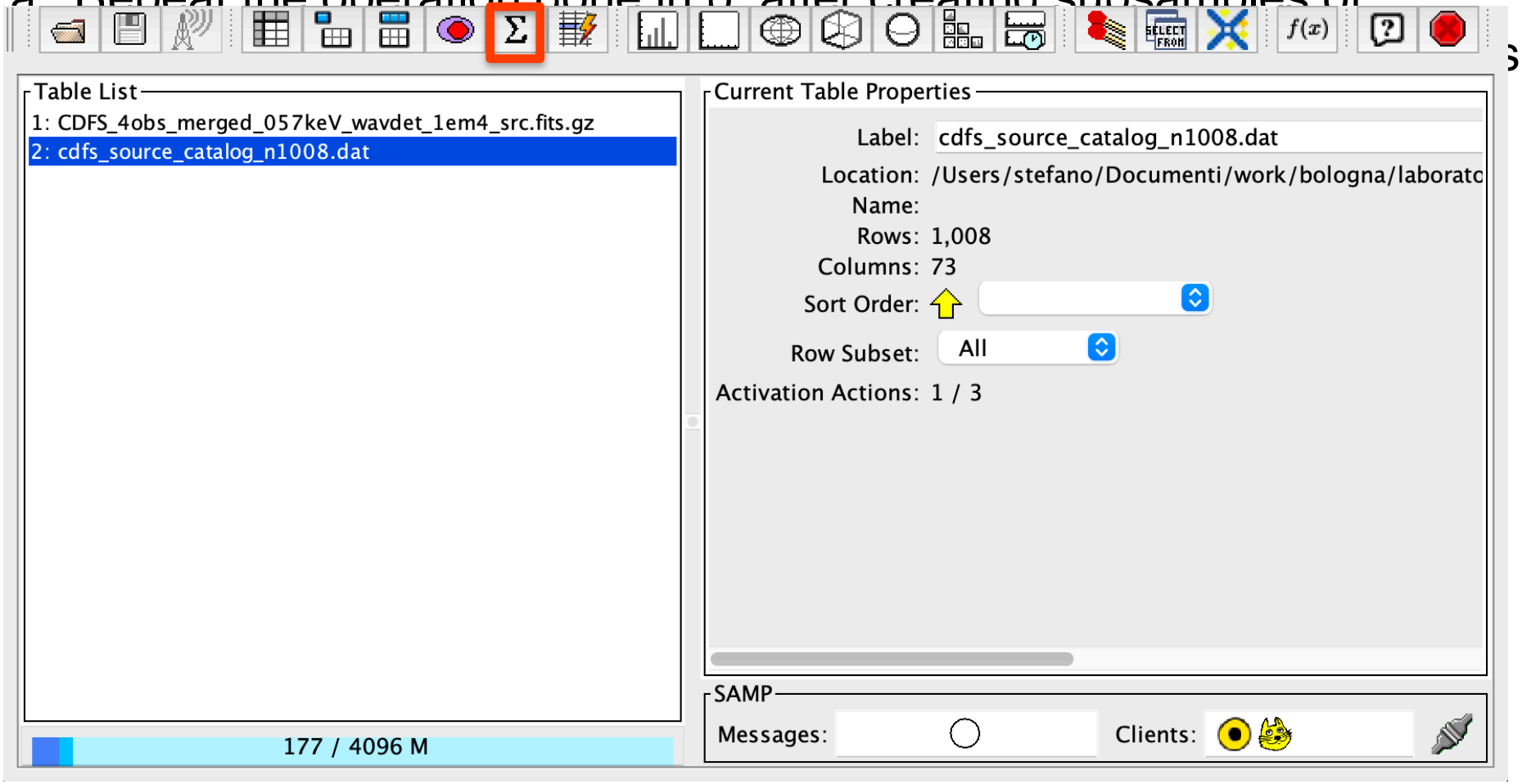


Lab Outline
2) Explore the source catalog

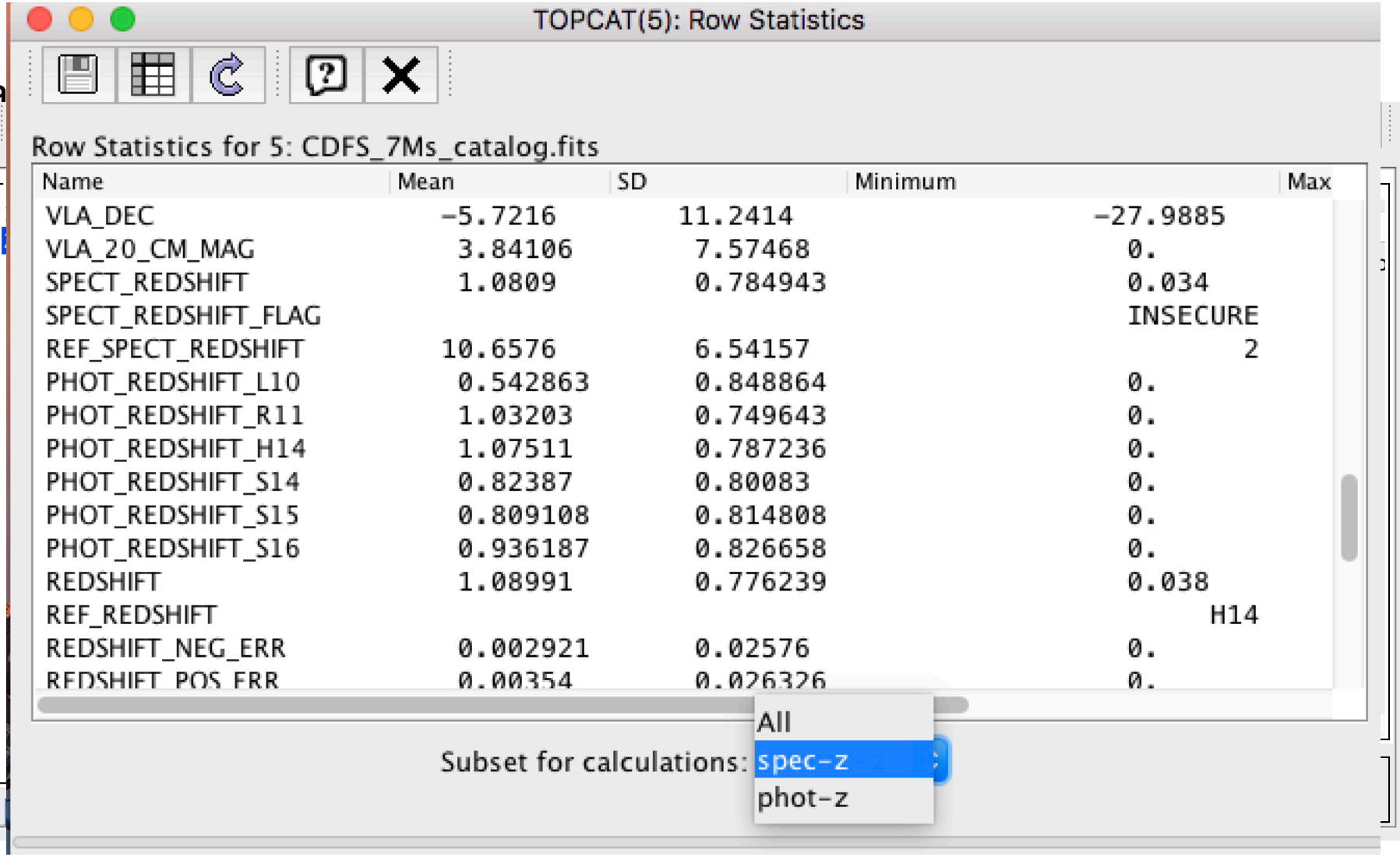
a. Repeat the operation done in b. after creating subsamples of sources from the 7 Ms source catalog (e.g., spec-z vs phot-z; low vs high band-ratio…). Are there any noticeable trends?
b. The trends can also be quantified using the Topcat statistics tool.

Lab Outline
2) Explore the source catalog

a. Repeat the operation done in b. after creating subsamples of



Lab Outline
2) Explore the source catalog



Analyse the data products: spectral fitting

Fit *Chandra* spectra for at least one souce whose properties suggest potential interesting outcome (e.g, high-z, high obscuration based on hardness ratio…).

XID_Luo17	Source coordinates	z	Opt. Class + Info
551	03:32:29.85 -27:51:05.71	3.700	NL (Comastri+11)
746	03:32:39.66 -27:48:50.64	3.064	NL (Vito+13)
730	03:32:38.91 -27:57:00.48	0.298	NL
242	03:32:13.24 -27:42:40.96	0.605	NL

IDs reported in the spectral files we provide

All spectra and response matrices are provided

3. Analyse the data products: spectral fitting

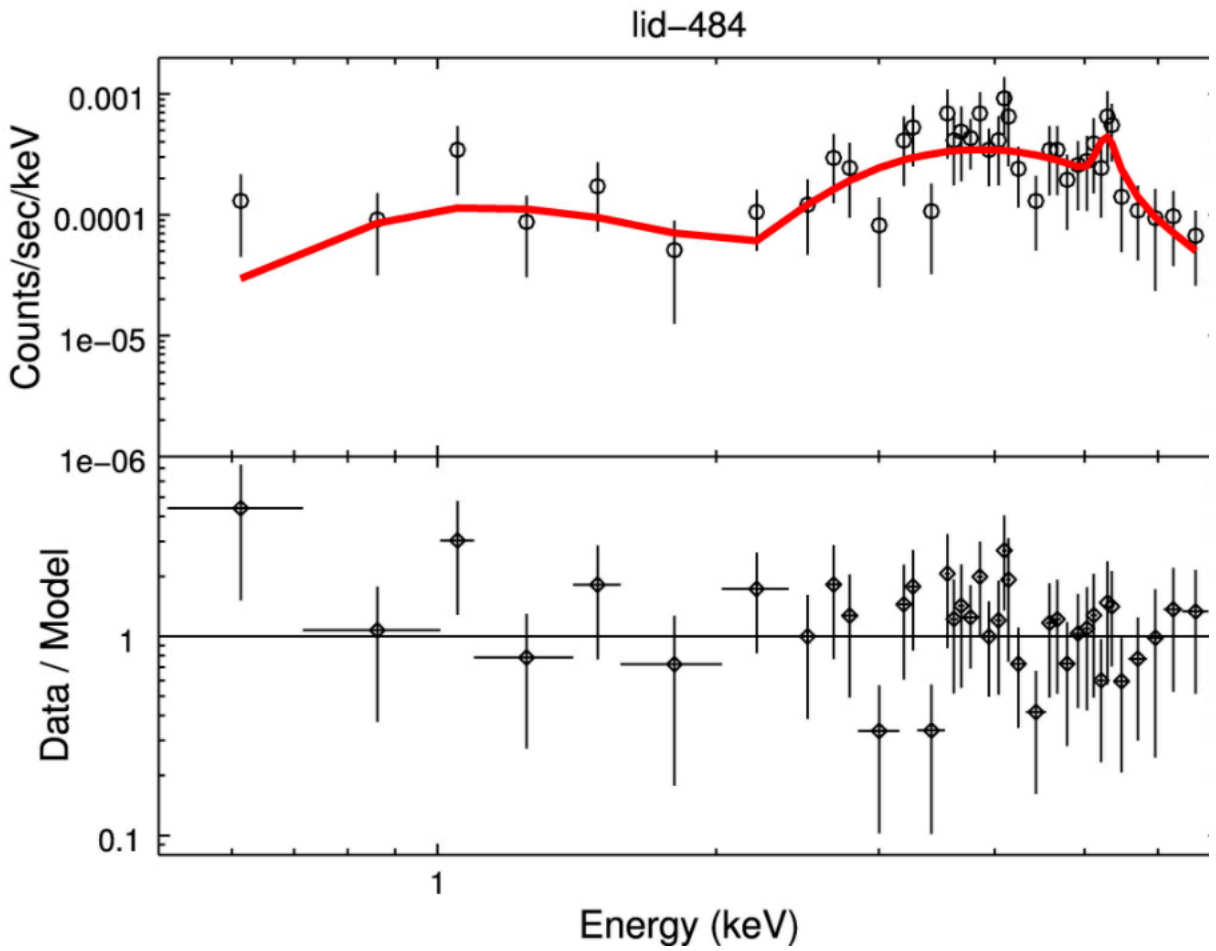
Spectral analysis pipeline

1. Choose one of the four sources
2. Group the spectra (*grppha*) accordingly to the quality of the data
3. Load spectra in XSPEC
4. Define a spectral model and fit it to the data. Step by step approach: starting with an absorbed power law, then adding additional components (e.g., secondary power law to account for scattered emission, Gaussian to model Iron line at 6.4 keV…)
5. Once a physically justified model is obtained, save the X-ray spectral parameters (including errors) and produce confidence contours

PLAN (III)

OPTIONAL

a. Re-run the procedure for a second source, better if at a different redshift range.



Main publications

- Xue Y.Q. et al. 2011, ApJS, 195, 10 **4 Ms Chandra source catalog.**
- Vito F. et al. 2013, MNRAS, 428, 354 **High-redshift AGN population in the CDF-S**.
- Luo B. et al. 2017, ApJ Suppl., 228, 2 **The Chandra Deep Field-South Survey: 7 Ms Source Catalogs.**