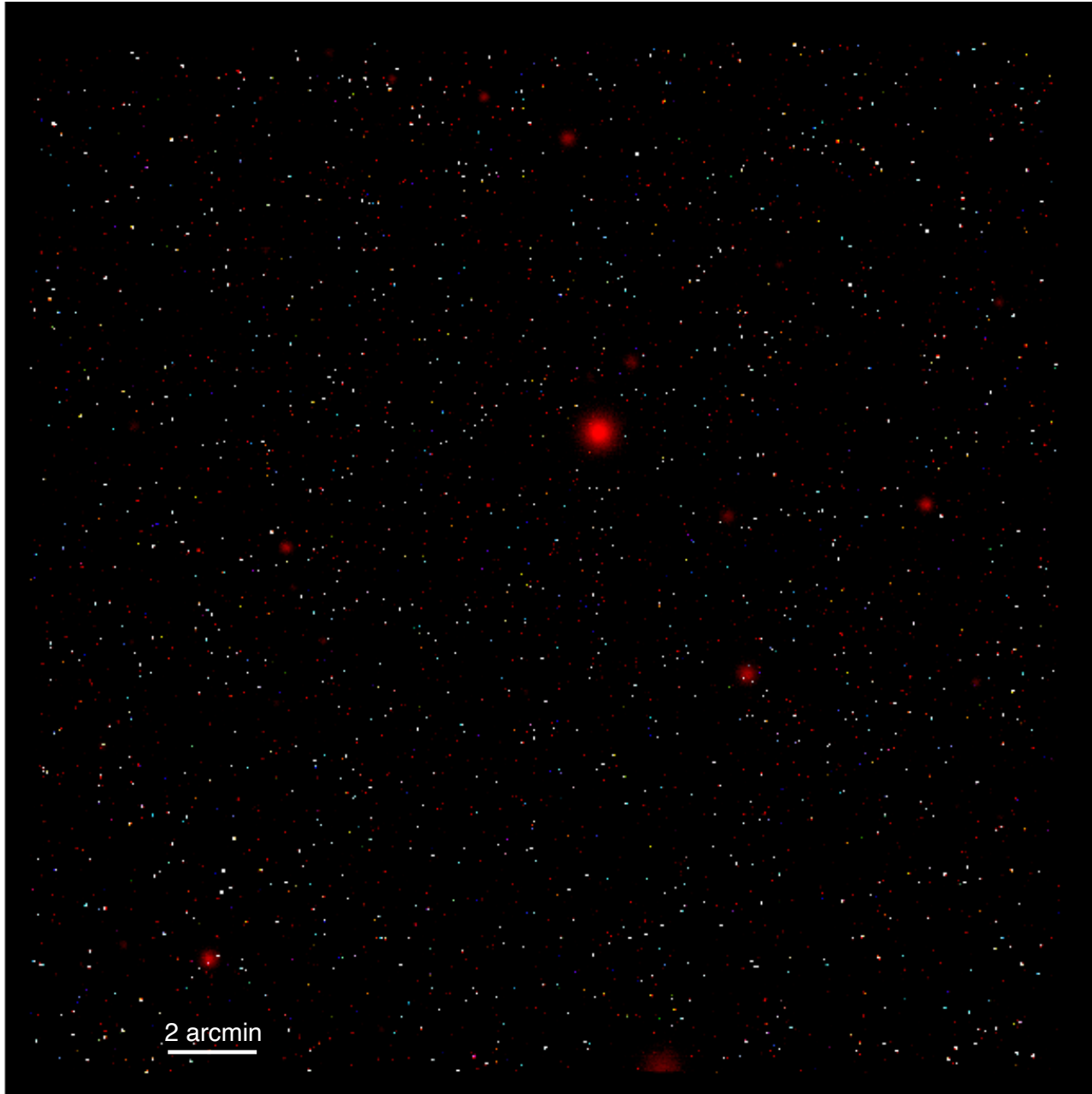


Understanding the AGN population: X-ray surveys



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 a 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)

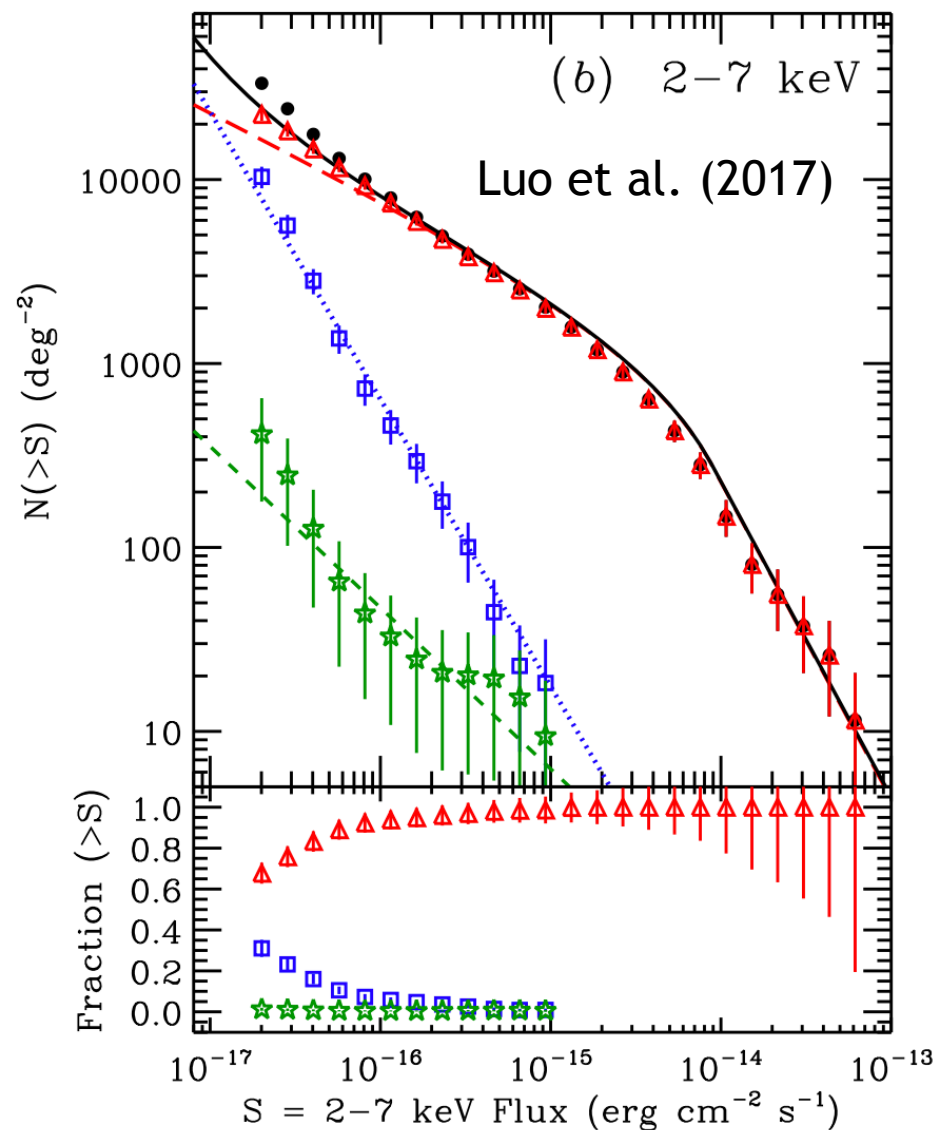
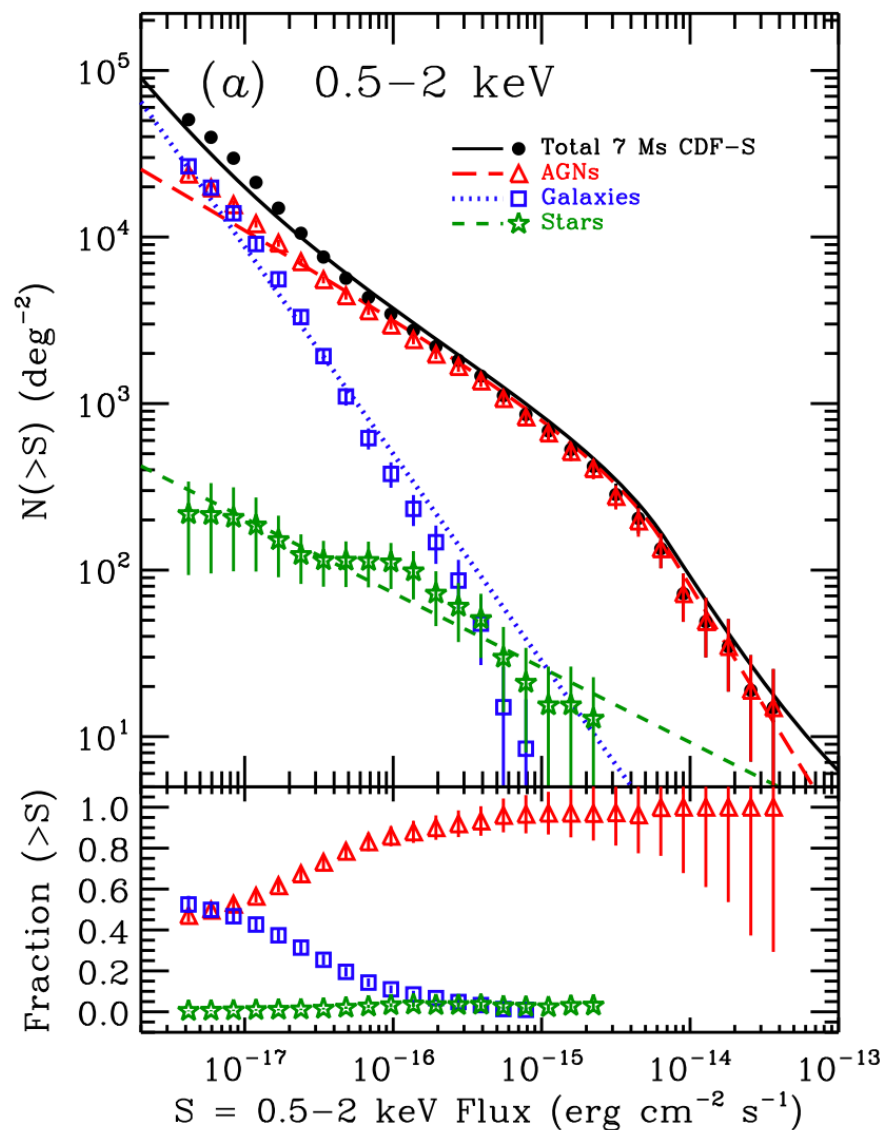
X-rays as a strategic tool in AGN analysis

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1. *cleanest* AGN selection: negligible SF contamination, both in terms of single objects ($L_x > 10^{42}$ erg s $^{-1}$ safely identifies AGN) and of integrated population (galaxy contribution to total X-ray emission becomes significant only at the flux limit of the deepest surveys).

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X-rays as a strategic tool in AGN analysis



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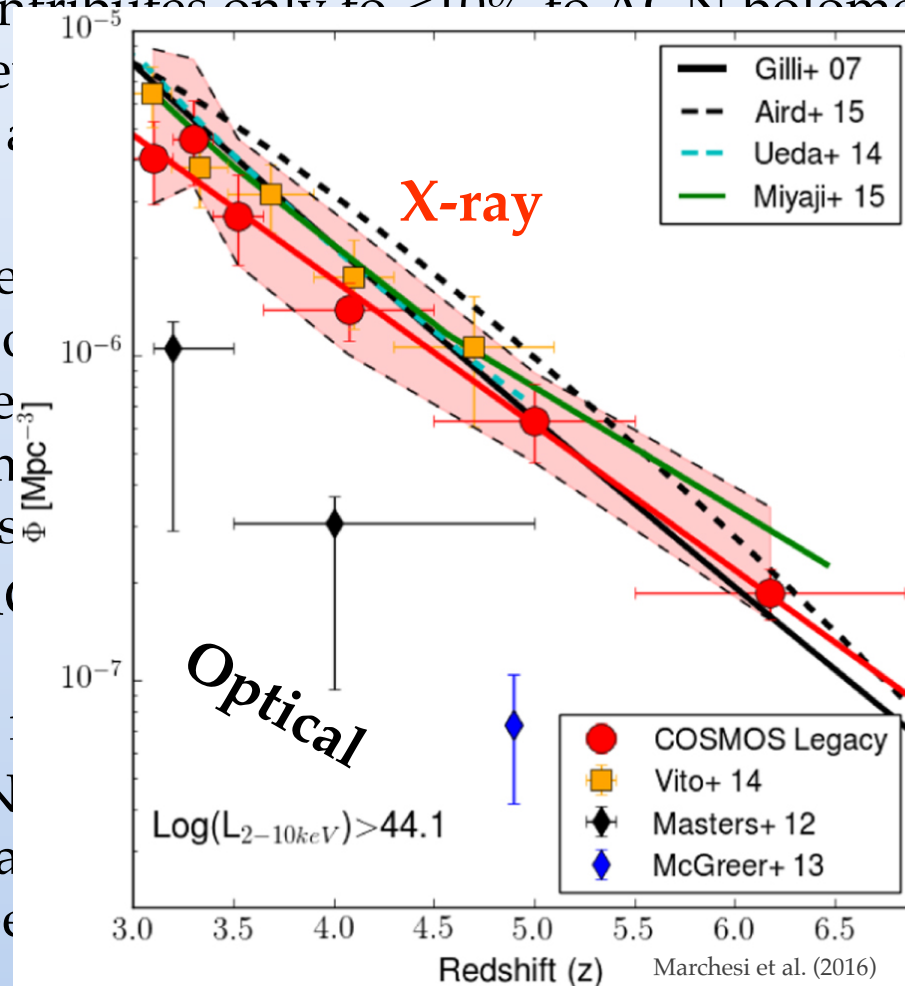
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3. *less biased* AGN selection: less strong obscuration effect at >2 keV. Sampling a class of obscured sources (up to $N_H \sim 10^{24}$ cm $^{-2}$) which cannot be detected by optical surveys.

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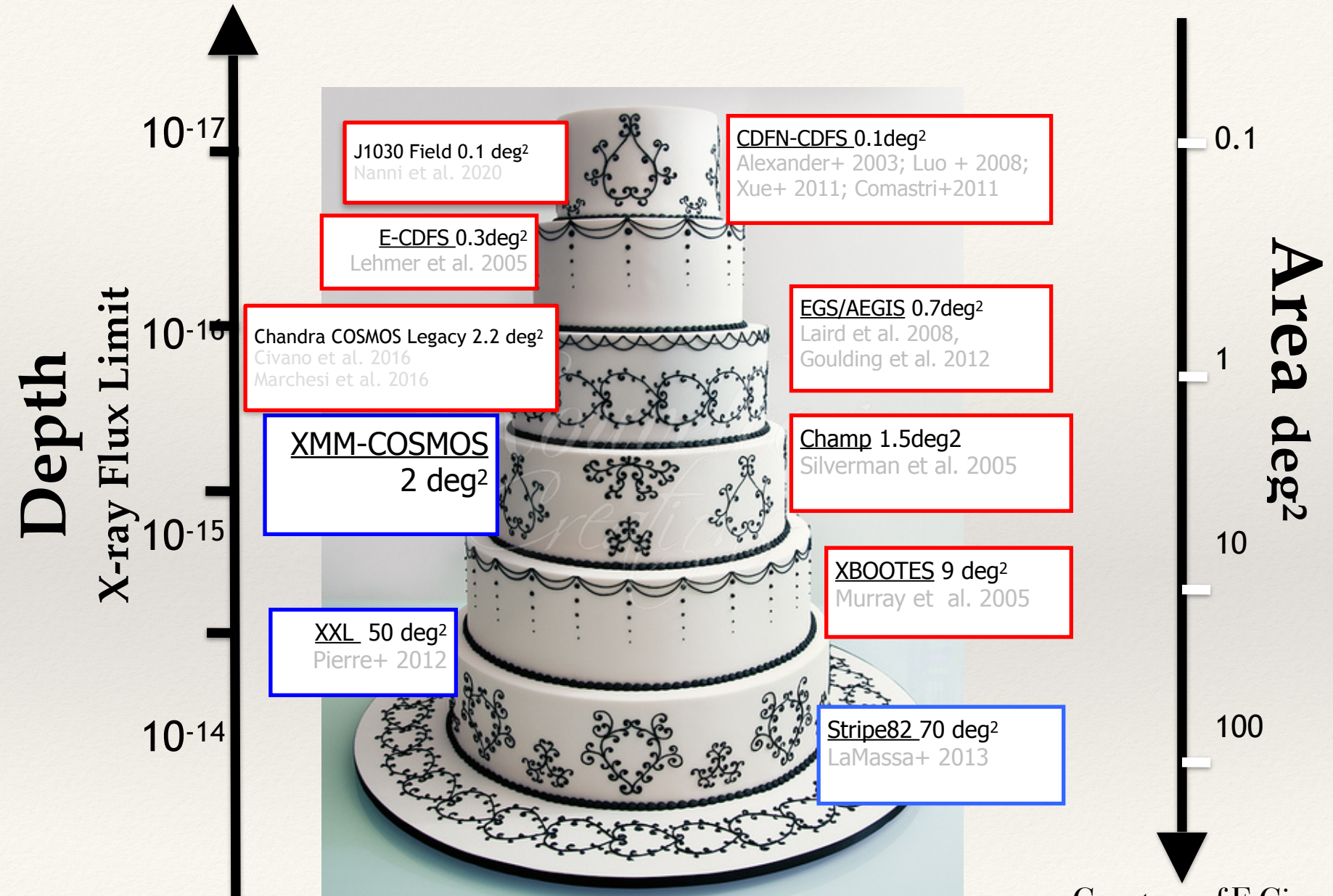
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2. *less luminous* AGN magnitude less contamination,
3. *less biased* AGN selection keV . Sampling a which cannot be



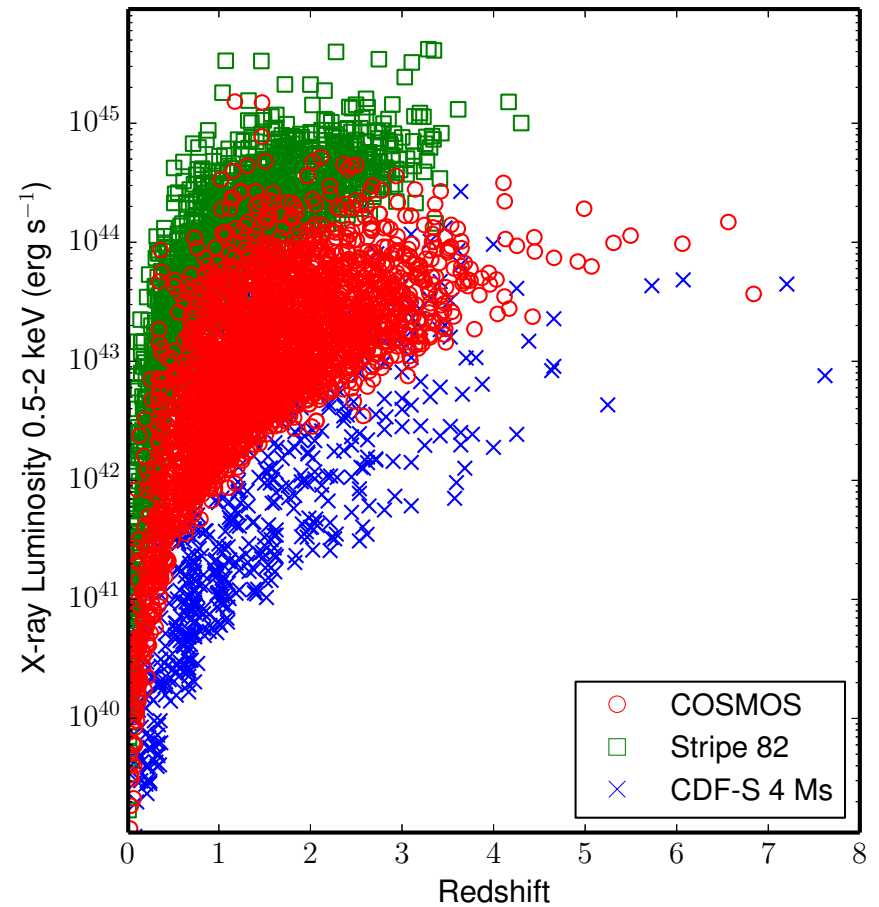
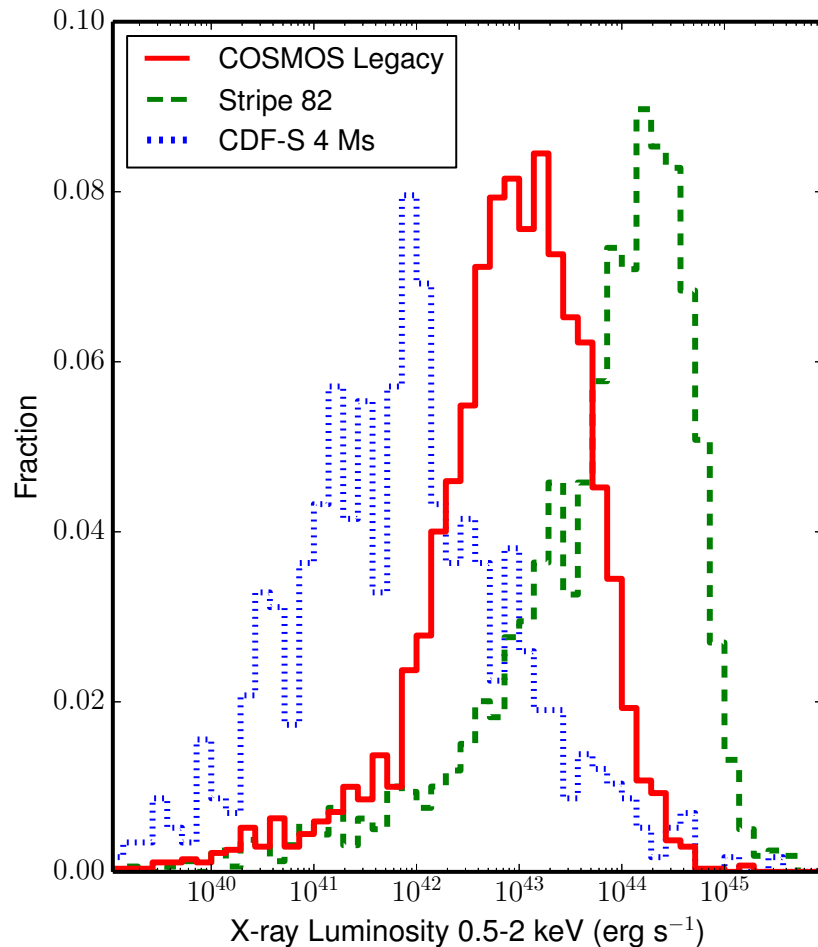
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The X-ray surveys wedding-cake strategy



Courtesy of F.Civano

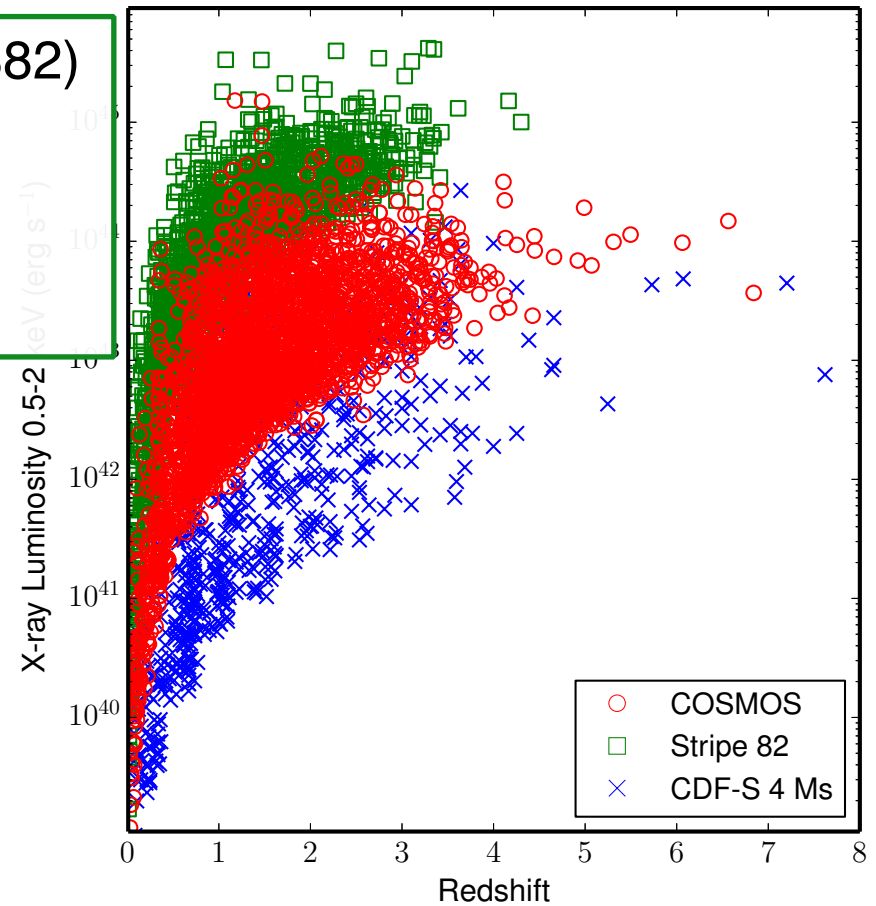
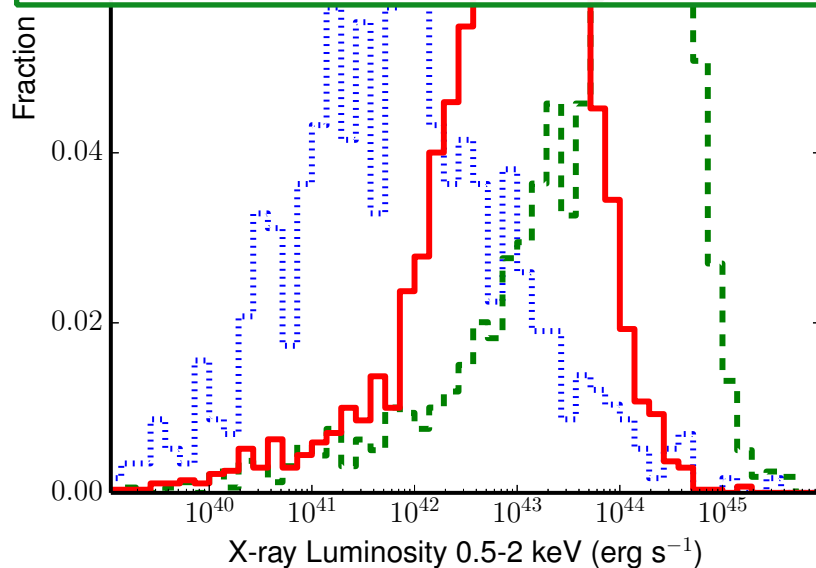
Different surveys for different science



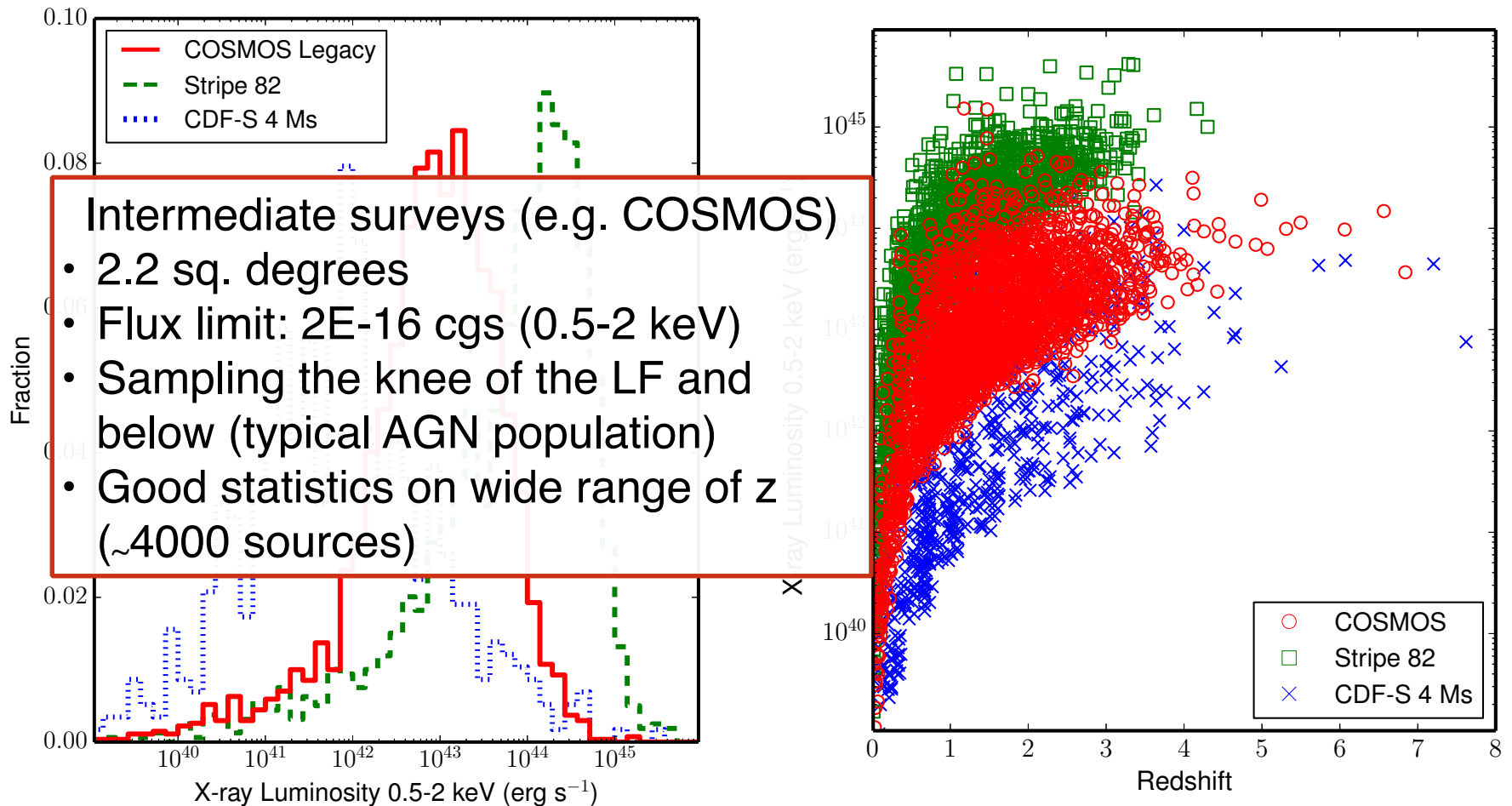
Different surveys for different science

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

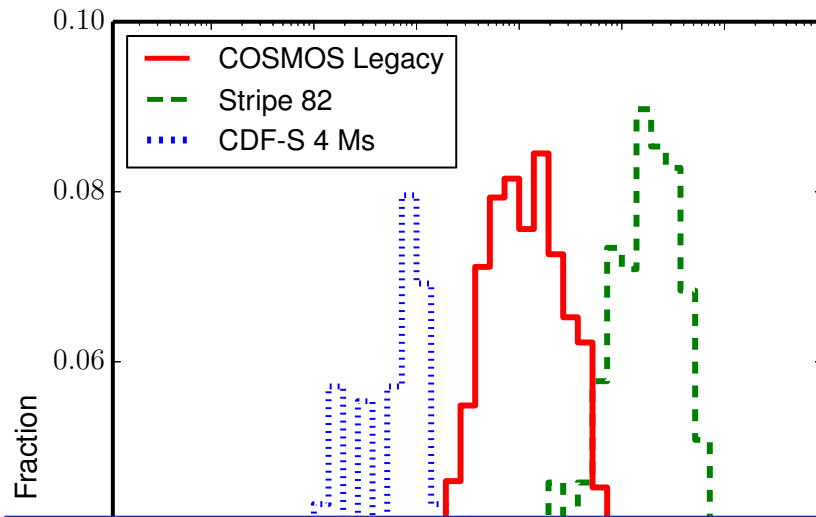
- 70 sq. degrees
- Flux limit: $9E-16$ cgs (0.5-2 keV)
- Looking for rare objects
- Missing low-luminosity objects



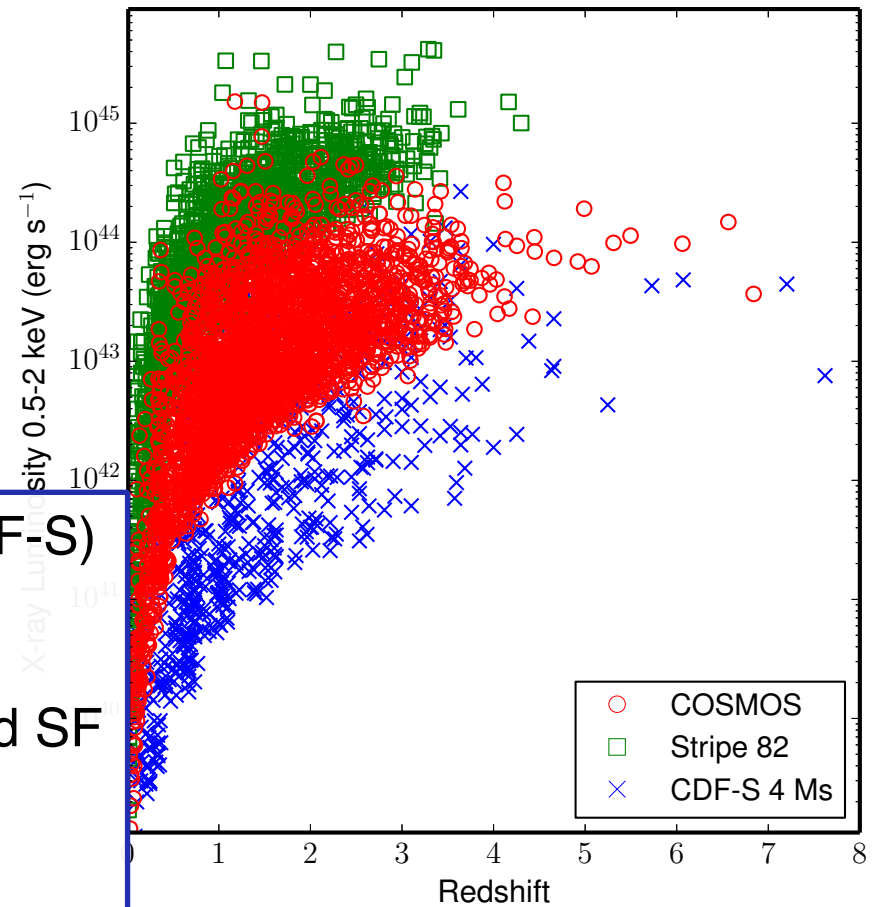
Different surveys for different science



Different surveys for different science



- 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)



Chandra Deep Field-South (CDF-S)

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

≈ 3 Ms *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).

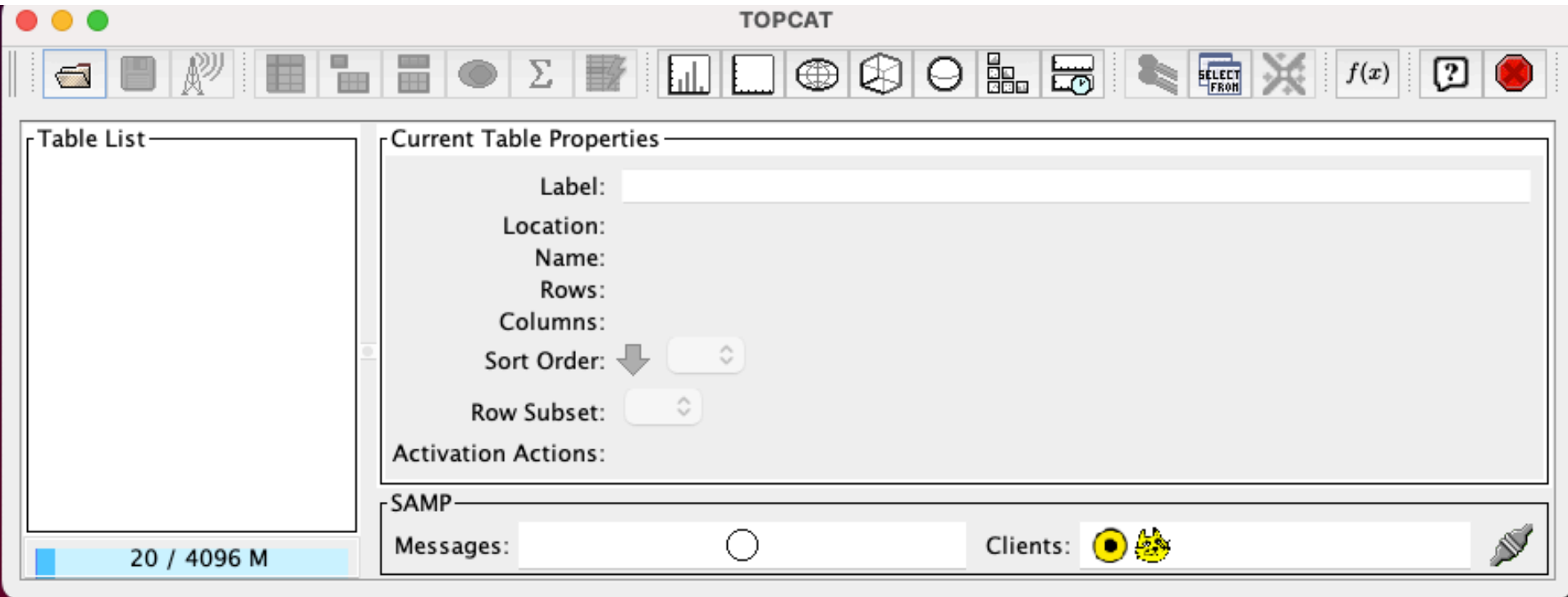
Lab Outline

1) Build the source catalog

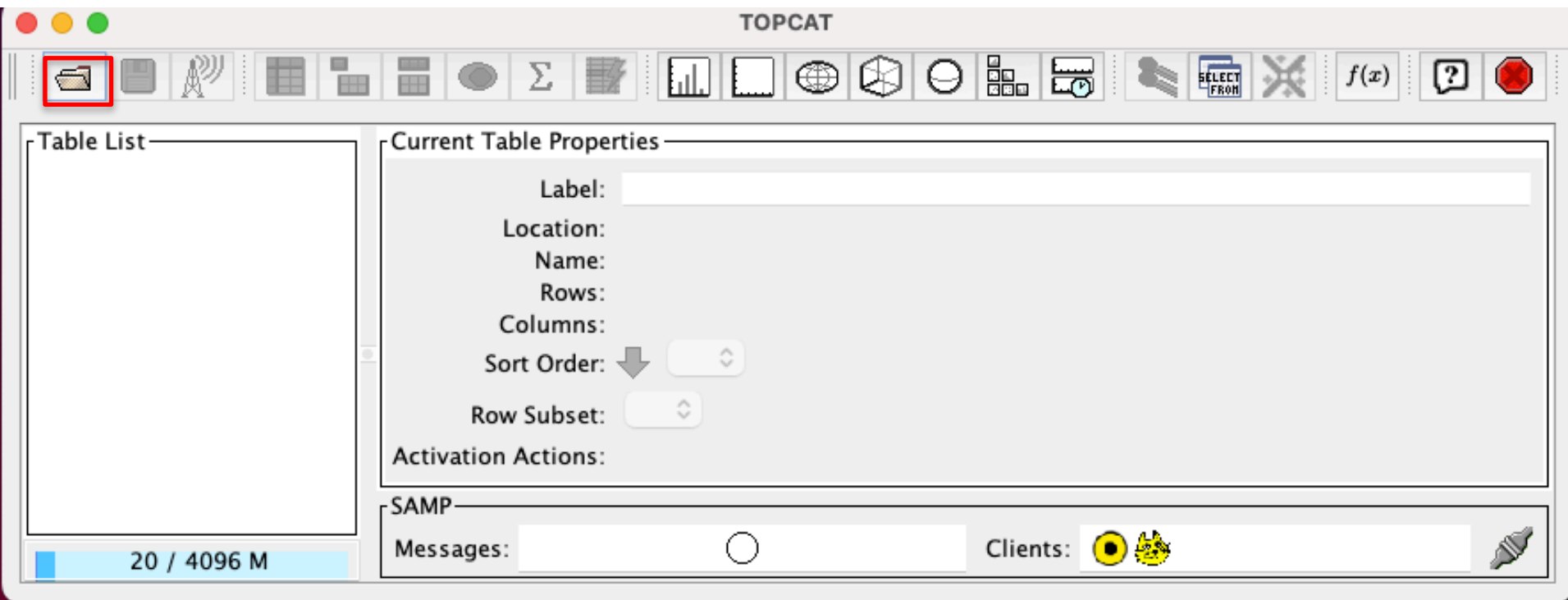
- 1) Cross-correlate the two 500 ks catalogs
(CDFS_4obs_merged_057keV_wavdet_1em4_src.fits;
CDFS_4obs_merged_057keV_wavdet_1em6_src.fits) with the official 7
Ms Chandra source catalog in the CDF-S (Luo et al. 2017).

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.

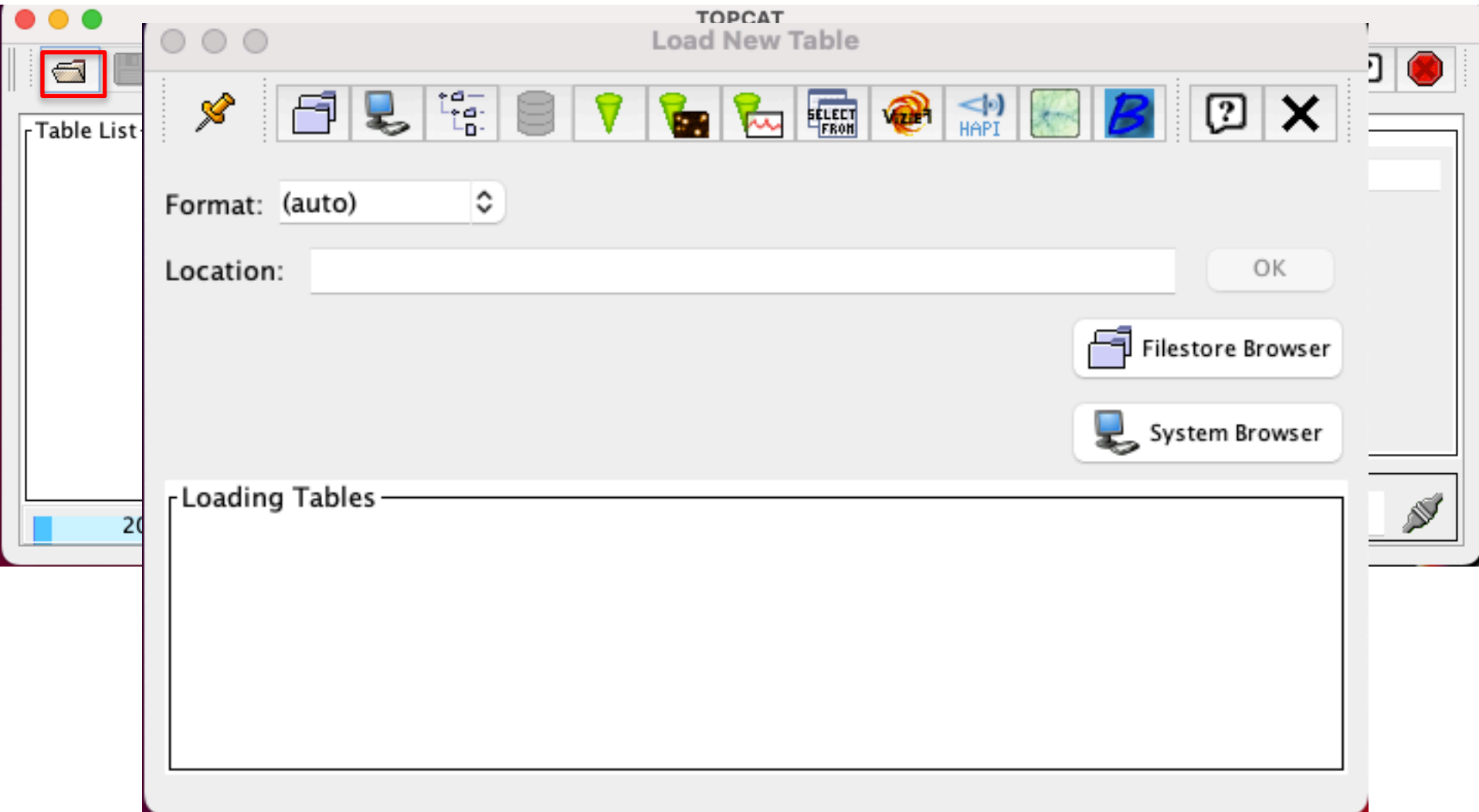
Loading the 500 ks catalogs in Topcat



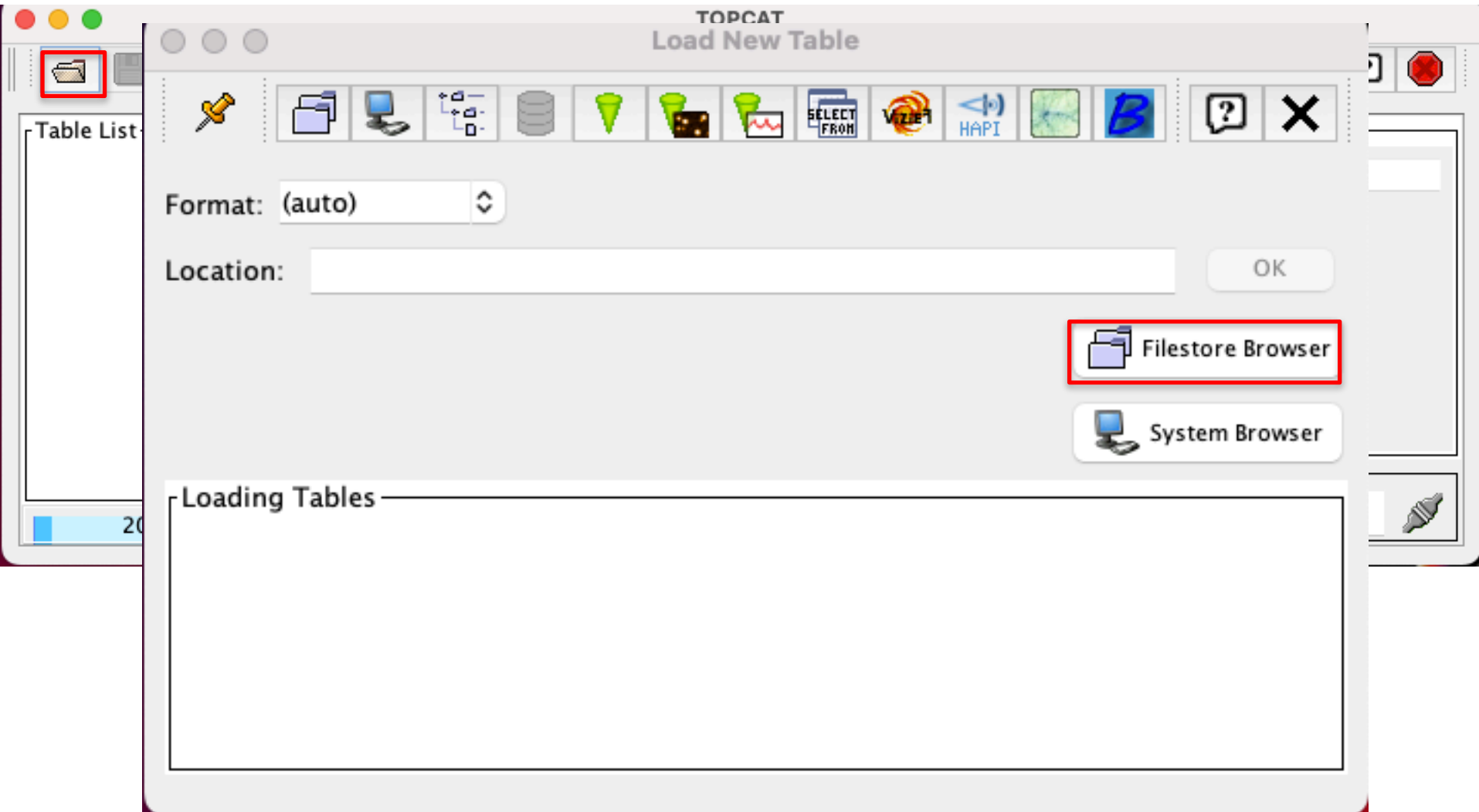
Loading the 500 ks catalogs in Topcat



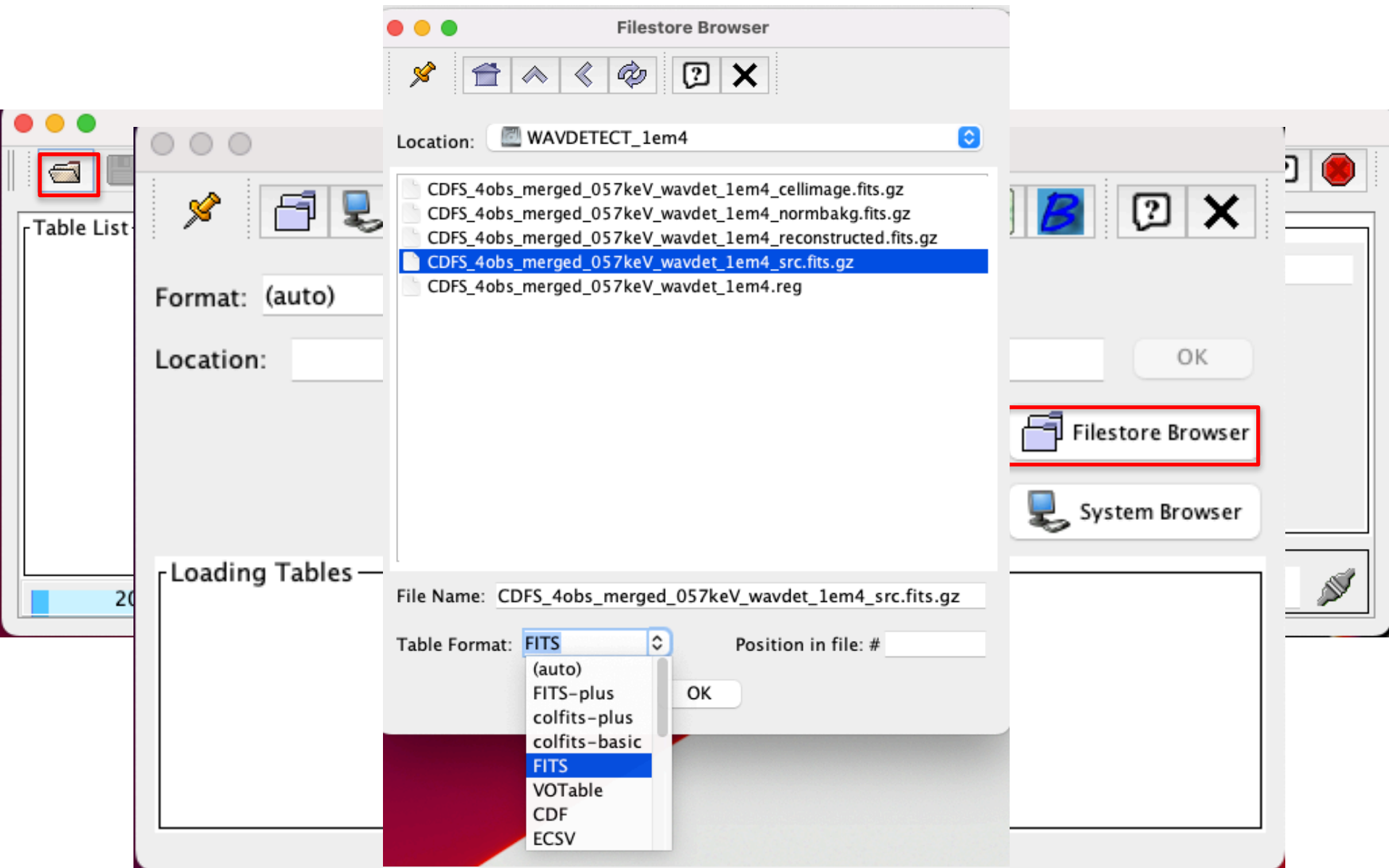
Loading the 500 ks catalogs in Topcat



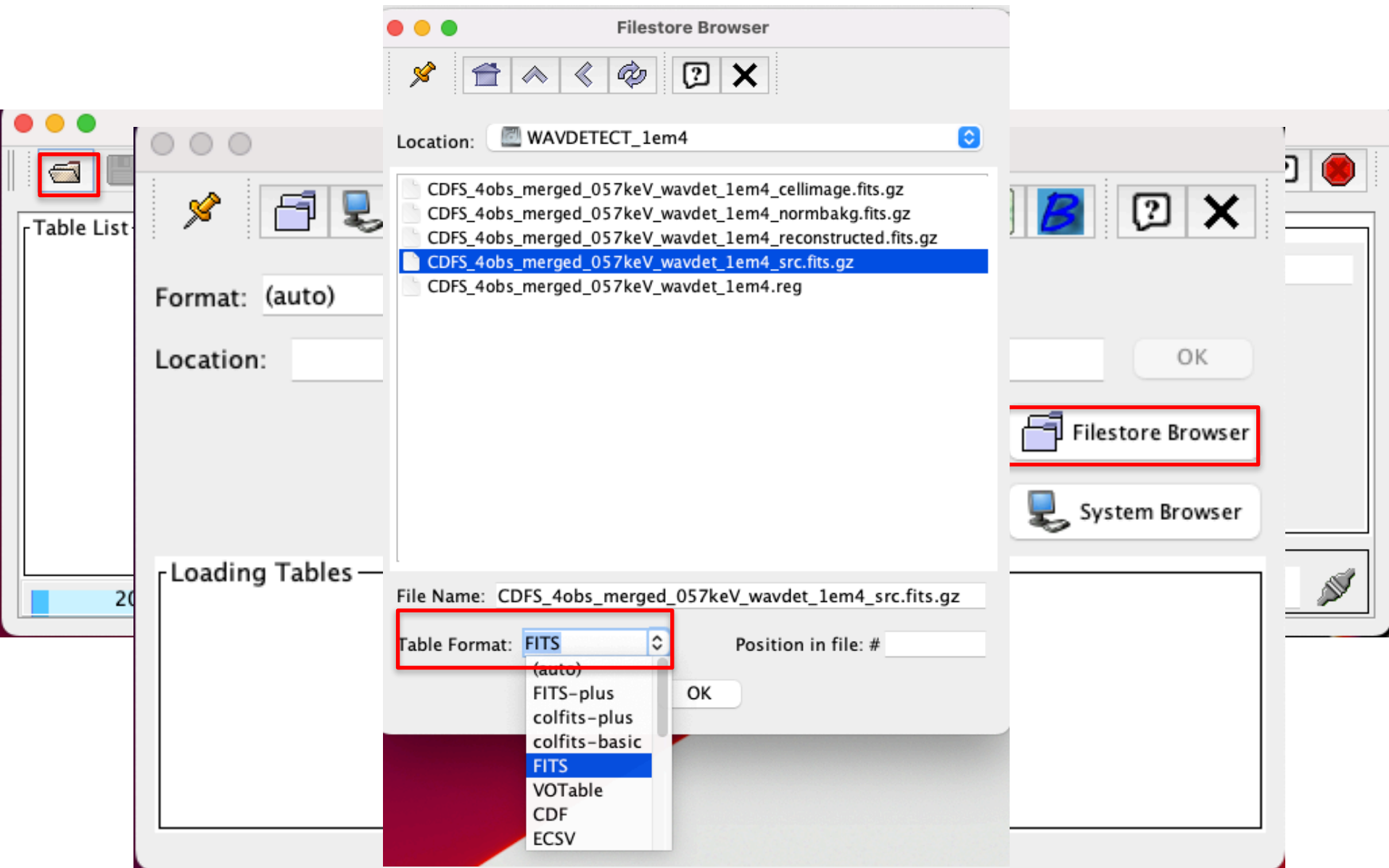
Loading the 500 ks catalogs in Topcat



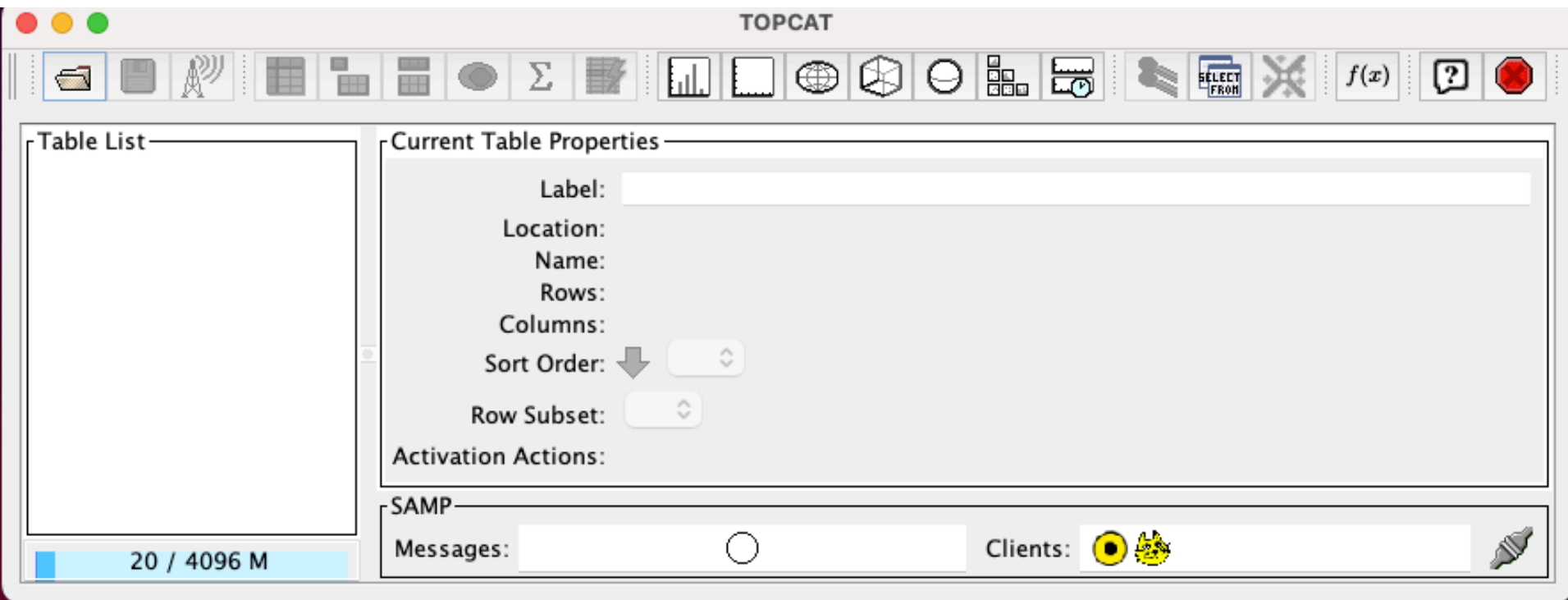
Loading the 500 ks catalogs in Topcat



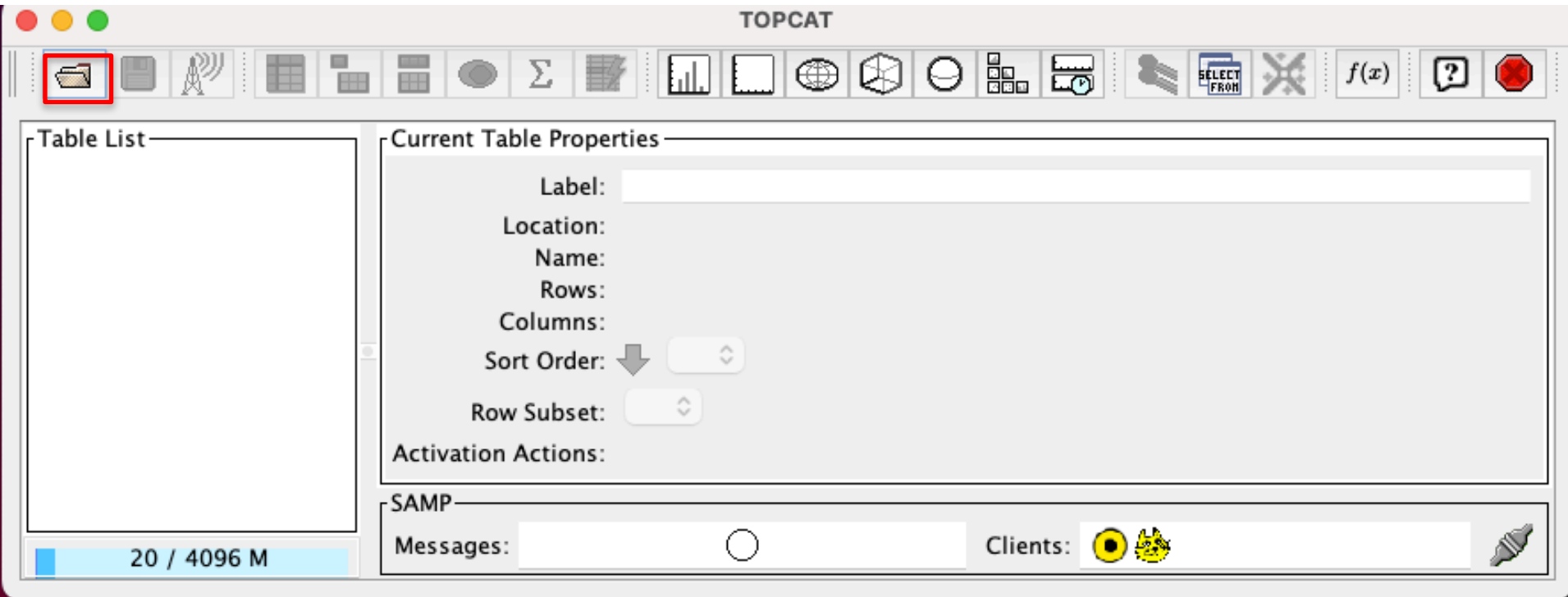
Loading the 500 ks catalogs in Topcat



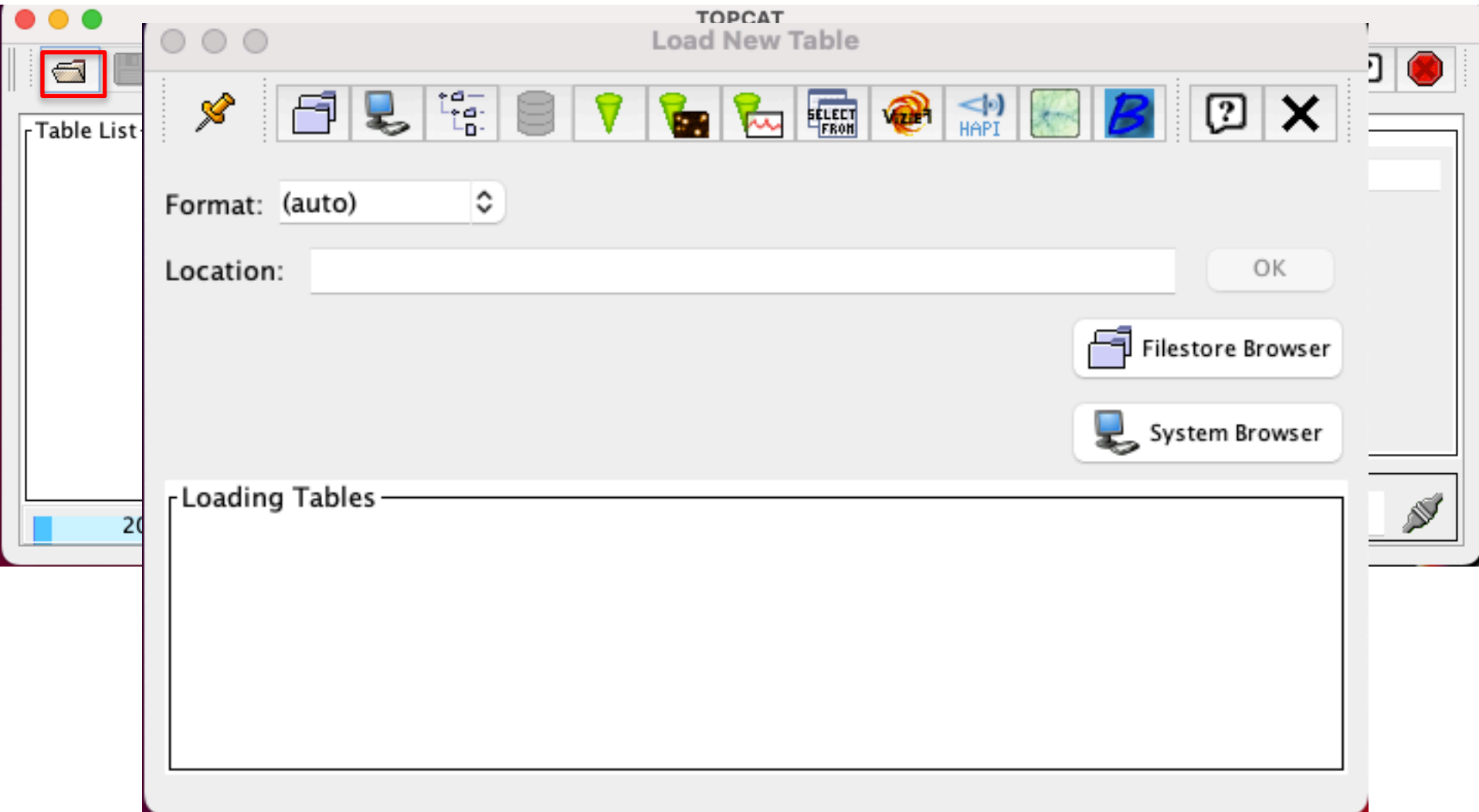
Loading the 7 Ms catalog in Topcat



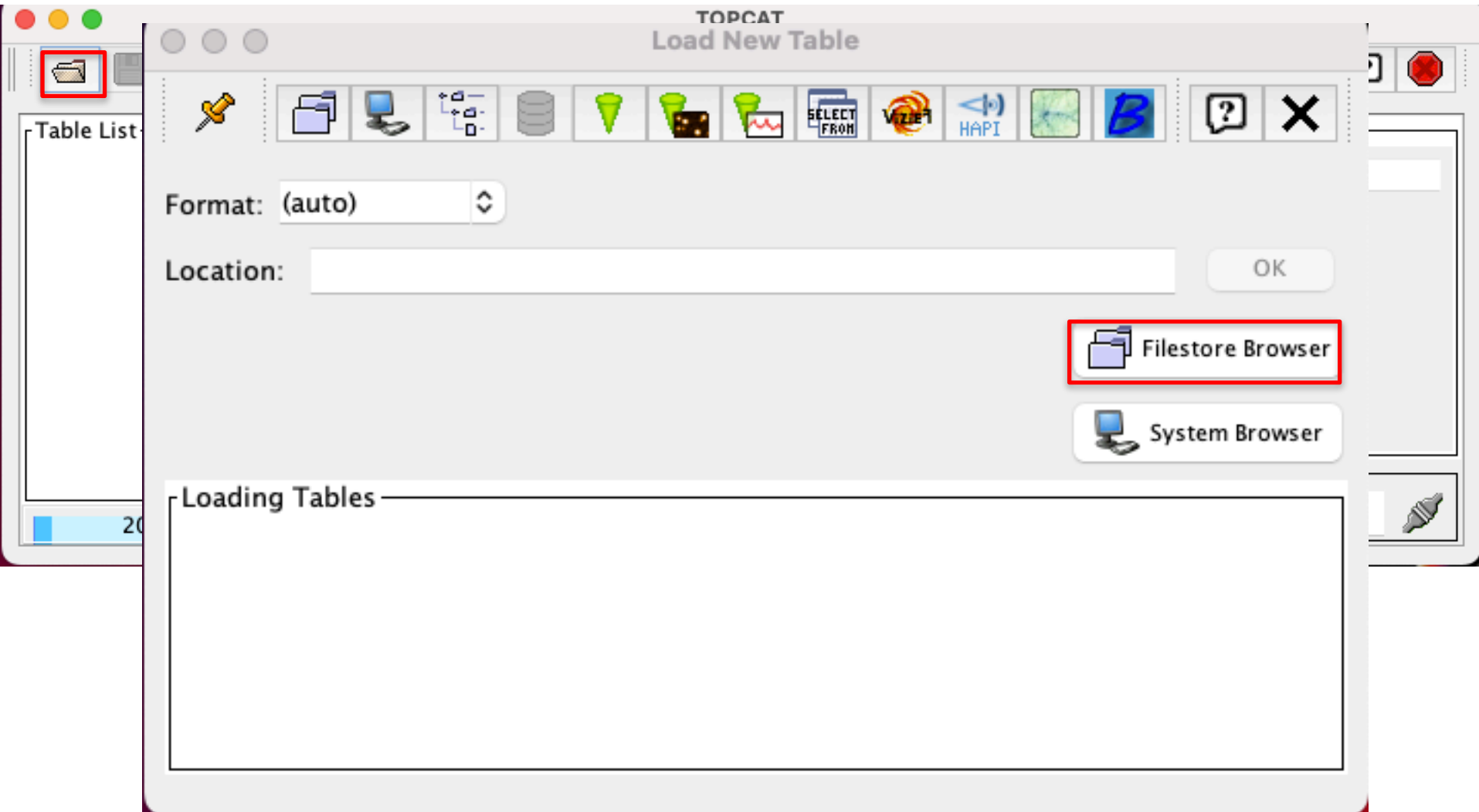
Loading the 7 Ms catalog in Topcat



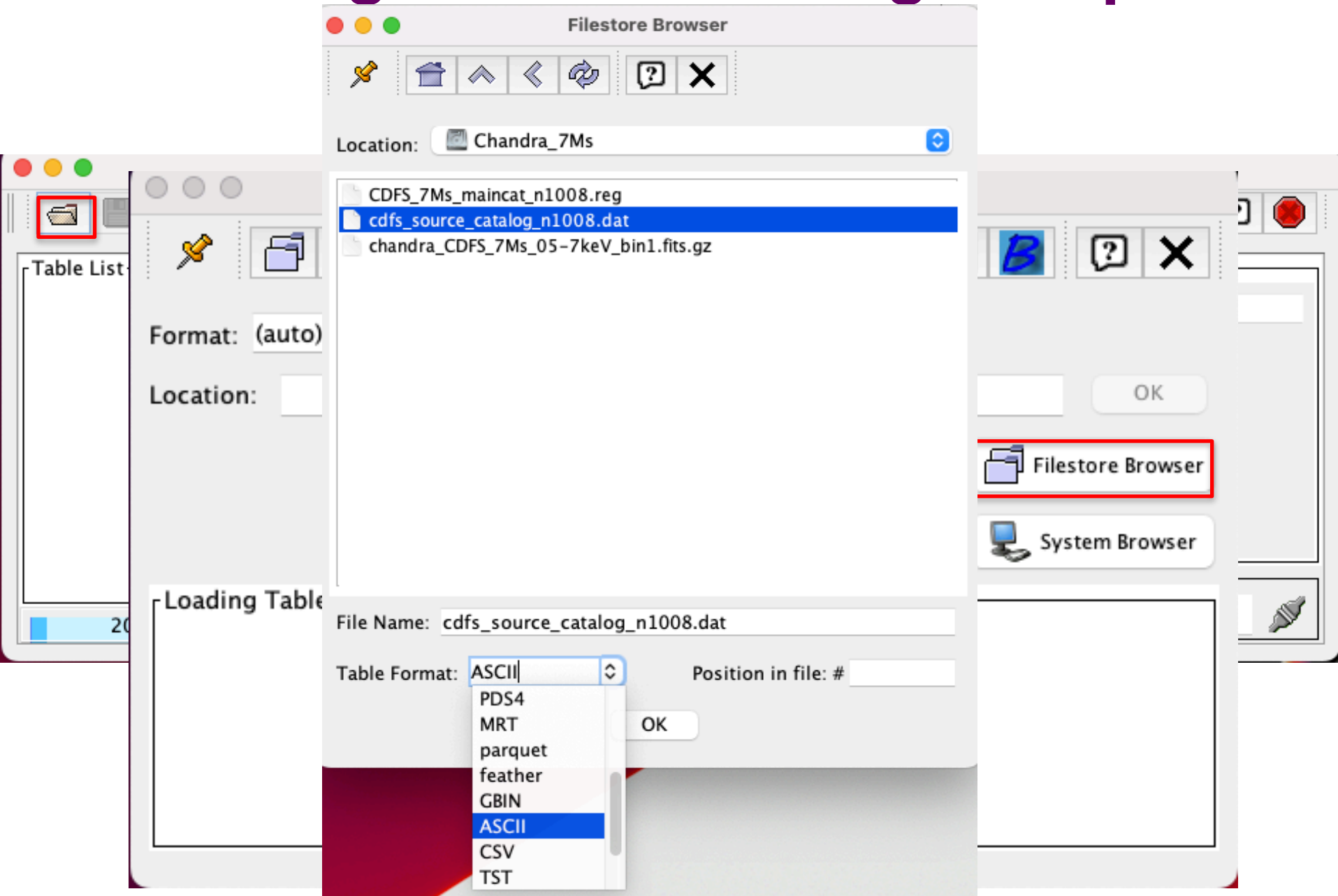
Loading the 7 Ms catalog in Topcat



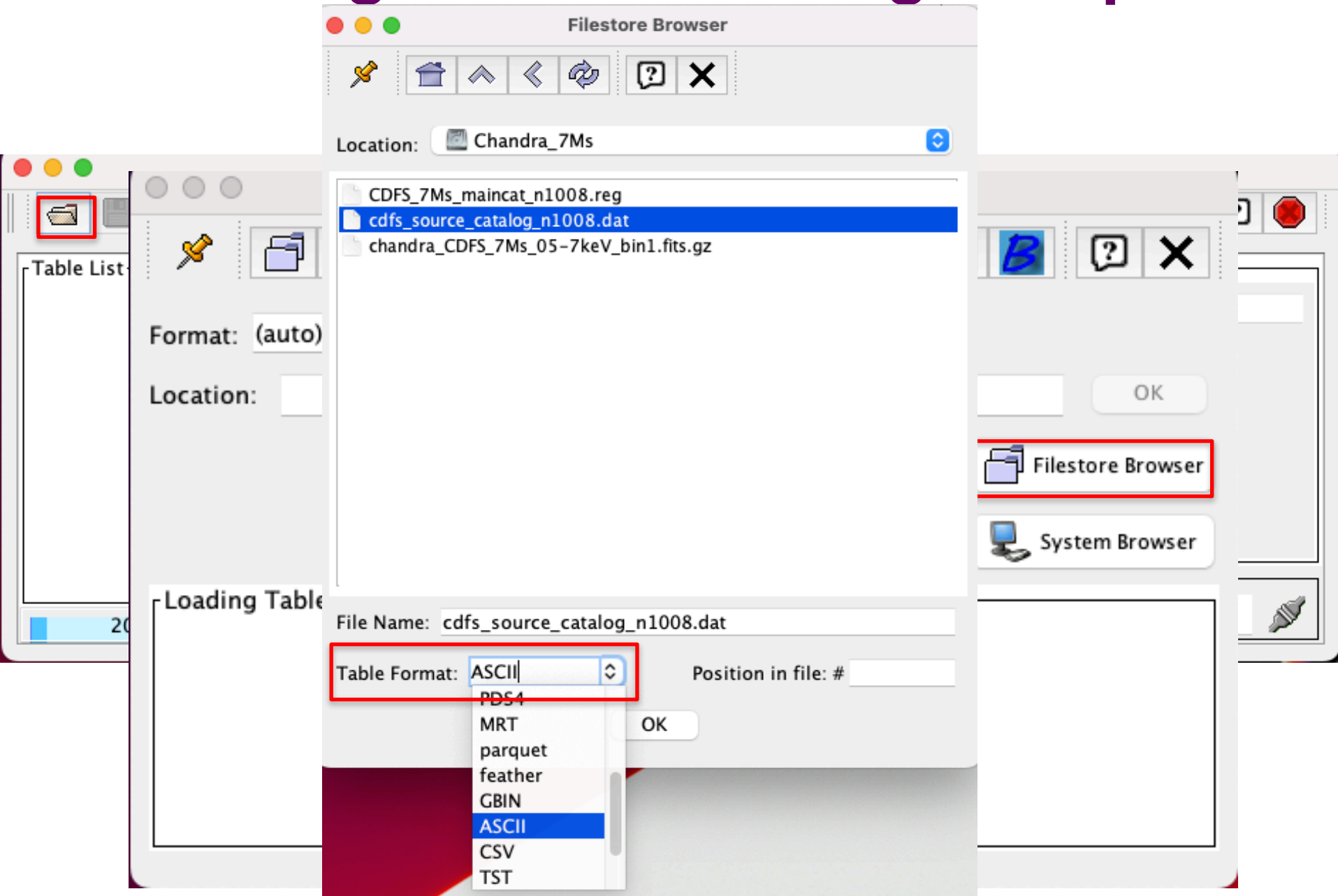
Loading the 7 Ms catalog in Topcat



Loading the 7 Ms catalog in Topcat

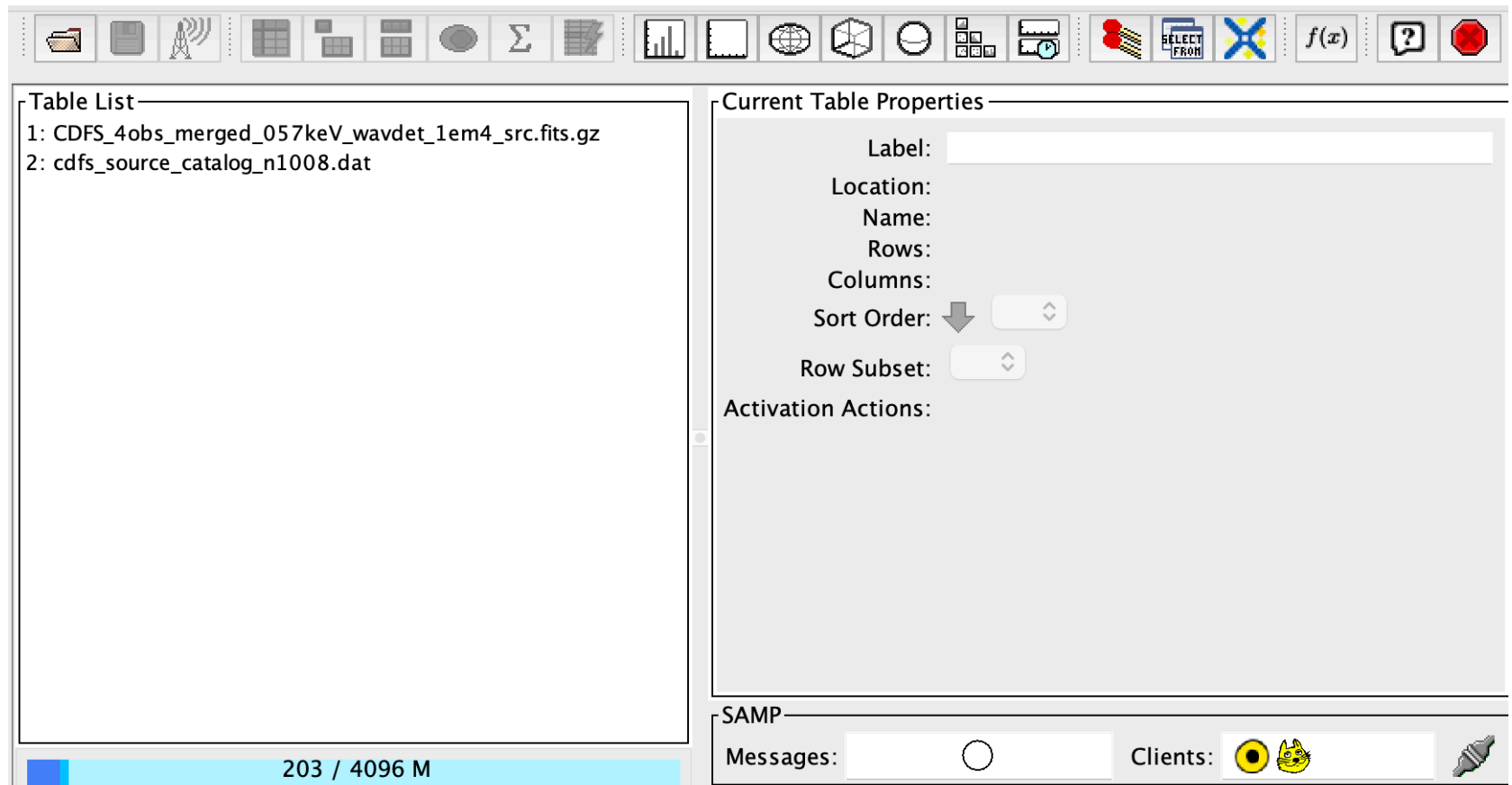


Loading the 7 Ms catalog in Topcat



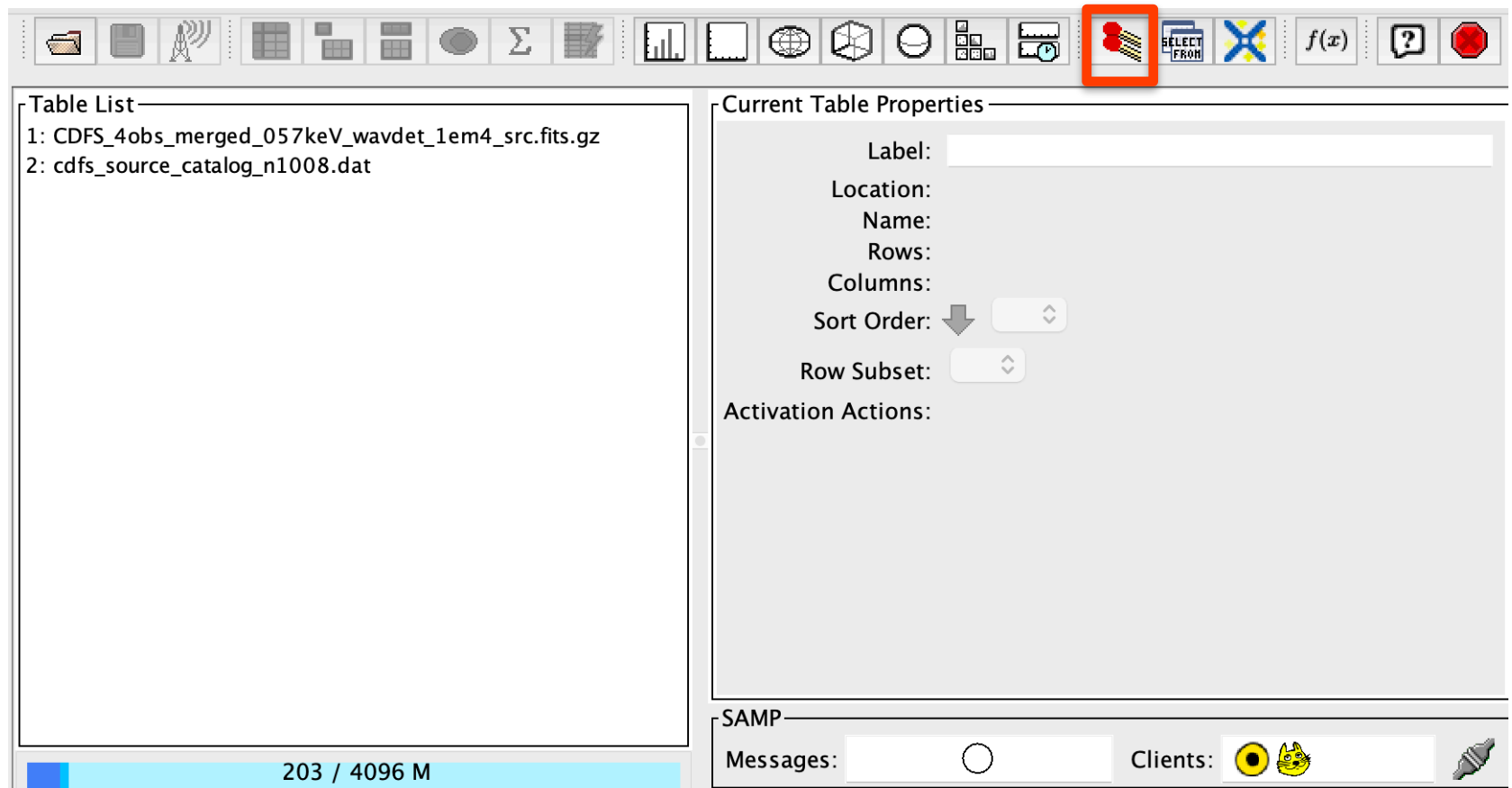
Catalog cross-matching in Topcat

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).



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).



Catalog cross-matching in Topcat

Cross-correlate
with the official
2017), using the

observations
DF-S (Luo et al.
3 arcsec).

Table List

- 1: CDFS_4obs_merged_057keV
- 2: cdfs_source_catalog_n1008

203

Match Criteria

Algorithm: Sky

Max Error: 2 arcsec

Table 1

Table: 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz

RA column: RA degrees

Dec column: DEC degrees

Table 2

Table: 2: cdfs_source_catalog_n1008.dat

RA column: RA degrees

Dec column: Dec degrees

Output Rows

Match Selection: Best match, symmetric


Join Type: 1 and 2

Elapsed time for match: 0 seconds

Populate index maps...

Match succeeded

Go Stop

ts: 

Catalog cross-matching in Topcat

Cross-correlate
with the official
2017), using the

observations
DF-S (Luo et al.
3 arcsec).

The screenshot displays the Topcat software interface for catalog cross-matching. The 'Match Criteria' section is at the top, with 'Algorithm' set to 'Sky' and 'Max Error' set to '2 arcsec'. Below this, 'Table 1' is configured with 'Table: 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz', 'RA column: RA' in 'degrees', and 'Dec column: DEC' in 'degrees'. 'Table 2' is configured with 'Table: 2: cdfs_source_catalog_n1008.dat', 'RA column: RA' in 'degrees', and 'Dec column: Dec' in 'degrees'. The 'Output Rows' section shows 'Match Selection: Best match, symmetric'. A dropdown menu for 'Join Type' is open, showing options: '1 and 2' (selected), '1 or 2', 'All from 1', 'All from 2', '1 not 2', '2 not 1', and '1 xor 2'. The 'Table List' on the left shows the two tables. The bottom status bar indicates 'Elapsed time: 0 seconds', 'Populate in: 0 seconds', and 'Match success: 1 not 2'. The 'Go' and 'Stop' buttons are at the bottom right.

Match Criteria

Algorithm: Sky

Max Error: 2 arcsec

Table List

1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz

2: cdfs_source_catalog_n1008.dat

Table 1

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RA column: RA degrees

Dec column: DEC degrees

Table 2

Table: 2: cdfs_source_catalog_n1008.dat

RA column: RA degrees

Dec column: Dec degrees

Output Rows

Match Selection: Best match, symmetric

Join Type: 1 and 2

Elapsed time: 0 seconds

Populate in: 0 seconds

Match success: 1 not 2

Go Stop

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

The screenshot displays a software interface with a toolbar at the top containing various icons for file operations, data visualization, and analysis. Below the toolbar, the interface is divided into two main panels:

- Table List:** This panel on the left contains a list of data files:
 - 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz
 - 2: cdfs_source_catalog_n1008.dat
- Current Table Properties:** This panel on the right displays configuration options for the selected table:
 - Label:
 - Location:
 - Name:
 - Rows:
 - Columns:
 - Sort Order: (with a dropdown arrow)
 - Row Subset: (with a dropdown arrow)
 - Activation Actions:

At the bottom of the interface, there is a status bar with the following elements:

- A progress bar on the left showing 127 / 4096 M.
- A section labeled "SAMP" containing:
 - Messages: (with a circular icon)
 - Clients: (with three circular icons representing different client types)

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

The screenshot displays a software interface with a toolbar at the top containing various icons for file operations, data visualization, and analysis. A red box highlights a specific icon in the toolbar, which appears to be a red circle with a white 'X' inside. Below the toolbar, the interface is divided into two main sections: 'Table List' on the left and 'Current Table Properties' on the right. The 'Table List' section contains two entries: '1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz' and '2: cdfs_source_catalog_n1008.dat'. The 'Current Table Properties' section contains fields for 'Label:', 'Location:', 'Name:', 'Rows:', 'Columns:', 'Sort Order:', and 'Row Subset:', each followed by a text input field or a dropdown menu. Below these fields is a section for 'Activation Actions:'. At the bottom of the interface, there is a status bar with a progress indicator showing '127 / 4096 M' and a 'SAMP' section with 'Messages:' and 'Clients:' labels, followed by several small icons.

Table List

- 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz
- 2: cdfs_source_catalog_n1008.dat

Current Table Properties

Label:

Location:

Name:

Rows:

Columns:

Sort Order:

Row Subset:

Activation Actions:

SAMP

Messages:

Clients:

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

The screenshot shows a software interface with a 'Match Tables' dialog box open. The dialog box has a title bar with standard window controls. Below the title bar is a toolbar with icons for undo, redo, help, and close. The main area of the dialog is divided into sections for 'Match Criteria', 'Table 1', 'Table 2', 'Output R', 'Match Sel', 'Join Type', 'Elapsed time', and 'Match succeeded'. The 'Match Criteria' section shows 'Algorithm: Sky' and 'Max Error: 3' with a unit dropdown set to 'arcsec'. 'Table 1' is set to '1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz' with 'RA column: RA' and 'Dec column: DEC', both in 'degrees'. 'Table 2' is set to '2: cdfs_source_catalog_n1008.dat' with 'RA column: RA' and 'Dec column: DEC', both in 'degrees'. The 'Join Type' dropdown is open, showing options: '1 and 2', '1 or 2', 'All from 1', 'All from 2', '1 not 2' (which is selected and highlighted in blue), '2 not 1', and '1 xor 2'. The 'Match succeeded' status is shown at the bottom. The background interface includes a 'Table List' on the left with two entries, a toolbar with a function button $f(x)$, and a 'Clients' section at the bottom right with three icons.

Table List

- 1: CDFS_4obs_merged_057keV_wavdet_1em4_
- 2: cdfs_source_catalog_n1008.dat

Match Tables

Match Criteria

Algorithm: Sky

Max Error: 3 arcsec

Table 1

Table: 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz

RA column: RA degrees

Dec column: DEC degrees

Table 2

Table: 2: cdfs_source_catalog_n1008.dat

RA column: RA degrees

Dec column: DEC degrees

Output R

Match Sel

Join Type

- 1 and 2
- 1 or 2
- All from 1
- All from 2
- 1 not 2
- 2 not 1
- 1 xor 2

Elapsed time: 0 seconds

Populate index maps...

Match succeeded

Go Stop

Clients:

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, L_x vs. z plots.

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)

The screenshot displays the XSPEC software interface. At the top is a toolbar with various icons for file operations, data viewing, and analysis. Below the toolbar, the interface is divided into two main panels. The left panel, titled 'Table List', contains a list of two tables: '1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz' and '2: cdfs_source_catalog_n1008.dat', with the second table selected. The right panel, titled 'Current Table Properties', displays details for the selected table: 'Label: cdfs_source_catalog_n1008.dat', 'Location: /Users/stefano/Documenti/work/bologna/laborato', 'Name:', 'Rows: 1,008', 'Columns: 73', 'Sort Order: [dropdown menu]', and 'Row Subset: All'. Below these properties, it shows 'Activation Actions: 1 / 3'. At the bottom of the interface, a status bar indicates '177 / 4096 M' on the left and 'SAMP' on the right, with sub-sections for 'Messages:' and 'Clients:'.

Table List

- 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz
- 2: cdfs_source_catalog_n1008.dat

Current Table Properties

Label: cdfs_source_catalog_n1008.dat

Location: /Users/stefano/Documenti/work/bologna/laborato

Name:

Rows: 1,008

Columns: 73

Sort Order: [dropdown menu]

Row Subset: All

Activation Actions: 1 / 3

177 / 4096 M

SAMP

Messages: [icon]

Clients: [icon] [icon]

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)

The screenshot displays the XSPEC software interface. At the top is a toolbar with various icons for file operations, data manipulation, and visualization. Below the toolbar, the interface is divided into two main panels. The left panel, titled 'Table List', contains a list of two tables: '1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz' and '2: cdfs_source_catalog_n1008.dat'. The second table is selected and highlighted in blue. The right panel, titled 'Current Table Properties', displays details for the selected table: 'Label: cdfs_source_catalog_n1008.dat', 'Location: /Users/stefano/Documenti/work/bologna/laborato', 'Name:', 'Rows: 1,008', 'Columns: 73', 'Sort Order: [up arrow icon] [dropdown menu]', 'Row Subset: All [dropdown menu]', and 'Activation Actions: 1 / 3'. At the bottom of the interface, there is a status bar showing '177 / 4096 M' and a 'SAMP' section with 'Messages:' and 'Clients:' fields.

Table List

- 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz
- 2: cdfs_source_catalog_n1008.dat

Current Table Properties

Label: cdfs_source_catalog_n1008.dat

Location: /Users/stefano/Documenti/work/bologna/laborato

Name:

Rows: 1,008

Columns: 73

Sort Order: [up arrow icon] [dropdown menu]

Row Subset: All [dropdown menu]

Activation Actions: 1 / 3

SAMP

Messages: [circle icon]

Clients: [yellow circle icon] [cat icon]

177 / 4096 M

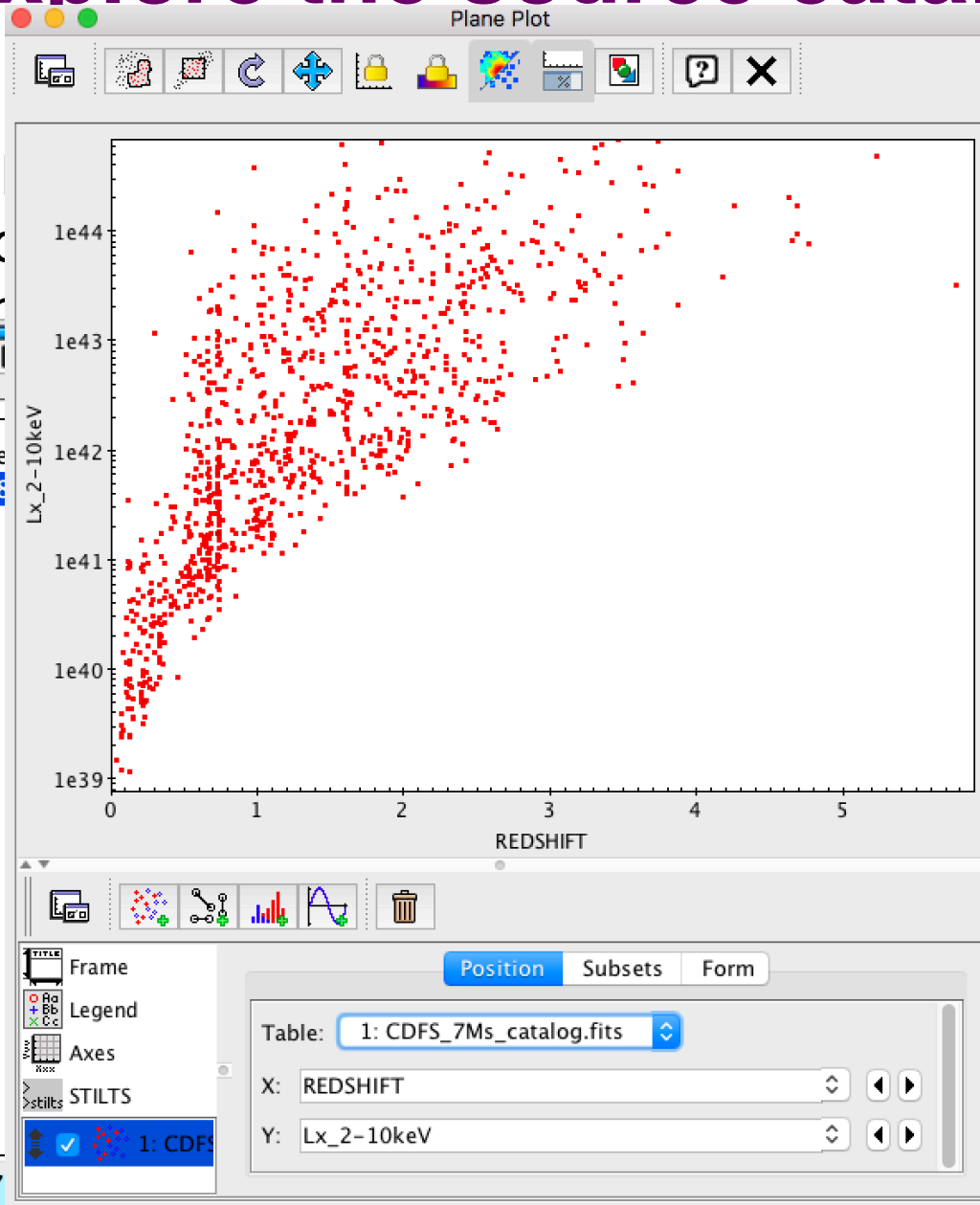
Explore the source catalog

- a. Choose the matches with
matches with
(number of c
positional ur

Table List

- 1: CDFS_4obs_merged_057ke
- 2: cdfs_source_catalog_n1008

177



number of
ne plots
sure time, vs.

n1008.dat

enti/work/bologna/laborato

1: CDFS

177

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)

The screenshot displays the XSPEC software interface. At the top is a toolbar with various icons, including a histogram icon highlighted with a red box. Below the toolbar are two main panels:

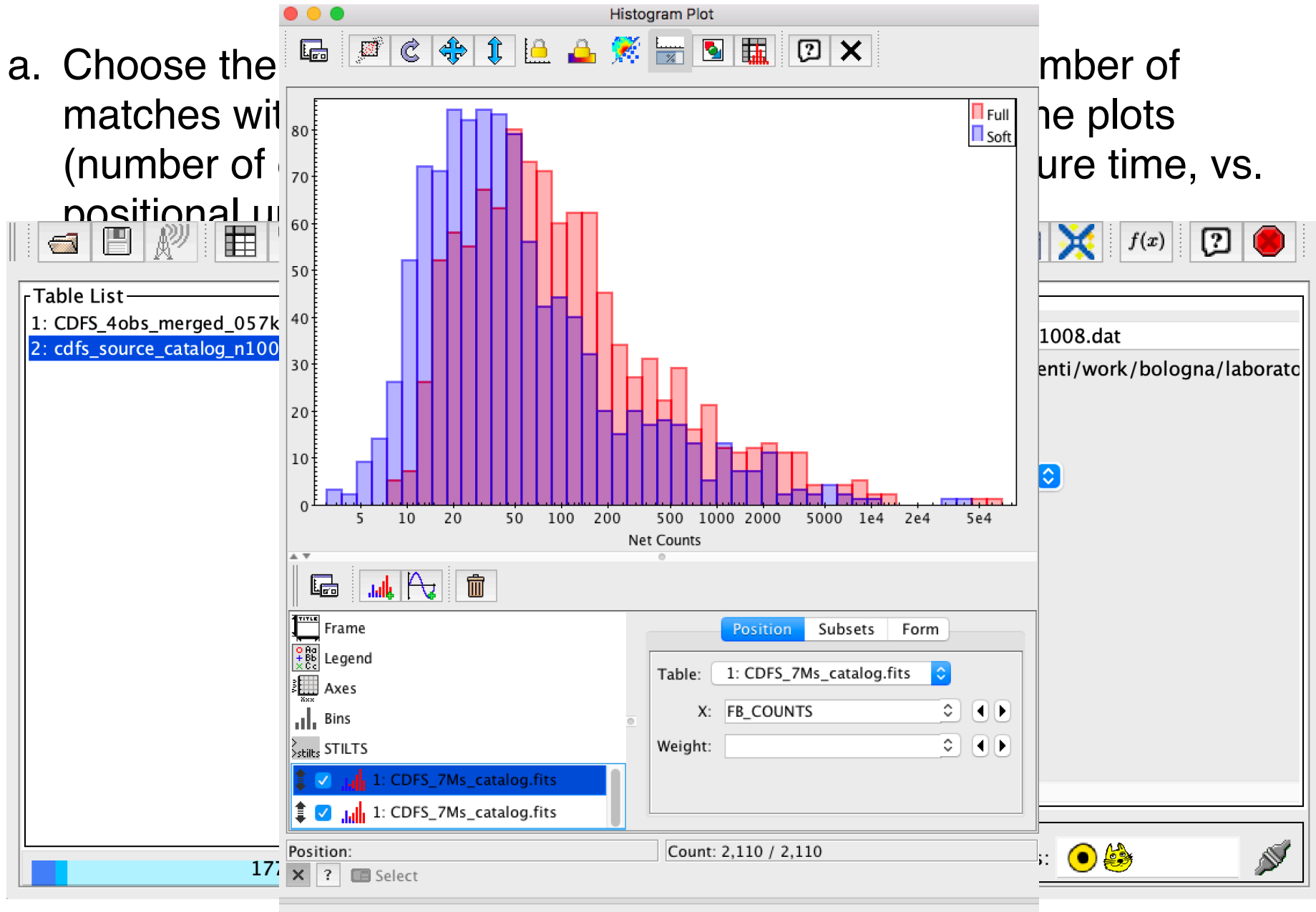
- Table List:** Contains a list of data files. The second file, `cdfs_source_catalog_n1008.dat`, is selected and highlighted in blue.
- Current Table Properties:** Displays details for the selected table:
 - Label: `cdfs_source_catalog_n1008.dat`
 - Location: `/Users/stefano/Documenti/work/bologna/laborato`
 - Name:
 - Rows: 1,008
 - Columns: 73
 - Sort Order:
 - Row Subset: `All`
 - Activation Actions: 1 / 3

At the bottom of the interface, there is a status bar showing `177 / 4096 M` and a panel for **SAMP** (Simple Application Message Protocol) with fields for **Messages:** and **Clients:**, each with a corresponding icon.

Explore the source catalog

a. Choose the matches with
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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, L_x 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.

c.

Table List

- 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz
- 2: cdfs_source_catalog_n1008.dat

Current Table Properties



Label: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits


Location: /Users/stefano/Documenti/work/bologna/laborato

Name: SRCLIST

Rows: 323


Columns: 33




Sort Order:  

Row Subset: All 

Activation Actions: 1 / 3

SAMP

Messages: 

Clients:   

173 / 4096 M

e

/ VS

Explore the source catalog

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

b.

c.

The screenshot shows a software interface for exploring a source catalog. The interface is divided into several sections:

- Toolbar:** Located at the top, it contains various icons for file operations, data manipulation, and visualization. One icon, representing a catalog or table, is highlighted with a red square.
- Table List:** A panel on the left side showing a list of tables. The first table, `1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz`, is selected and highlighted in blue. The second table is `2: cdfs_source_catalog_n1008.dat`.
- Current Table Properties:** A panel on the right side showing the properties of the selected table. The properties are:
 - Label: `CDFS_4obs_merged_057keV_wavdet_1em4_src.fits`
 - Location: `/Users/stefano/Documenti/work/bologna/laborato`
 - Name: `SRCLIST`
 - Rows: 323
 - Columns: 33
 - Sort Order:
 - Row Subset:
 - Activation Actions: 1 / 3
- Status Bar:** At the bottom, it shows the number of rows displayed (173 / 4096 M) and a section for Messages and Clients.

e

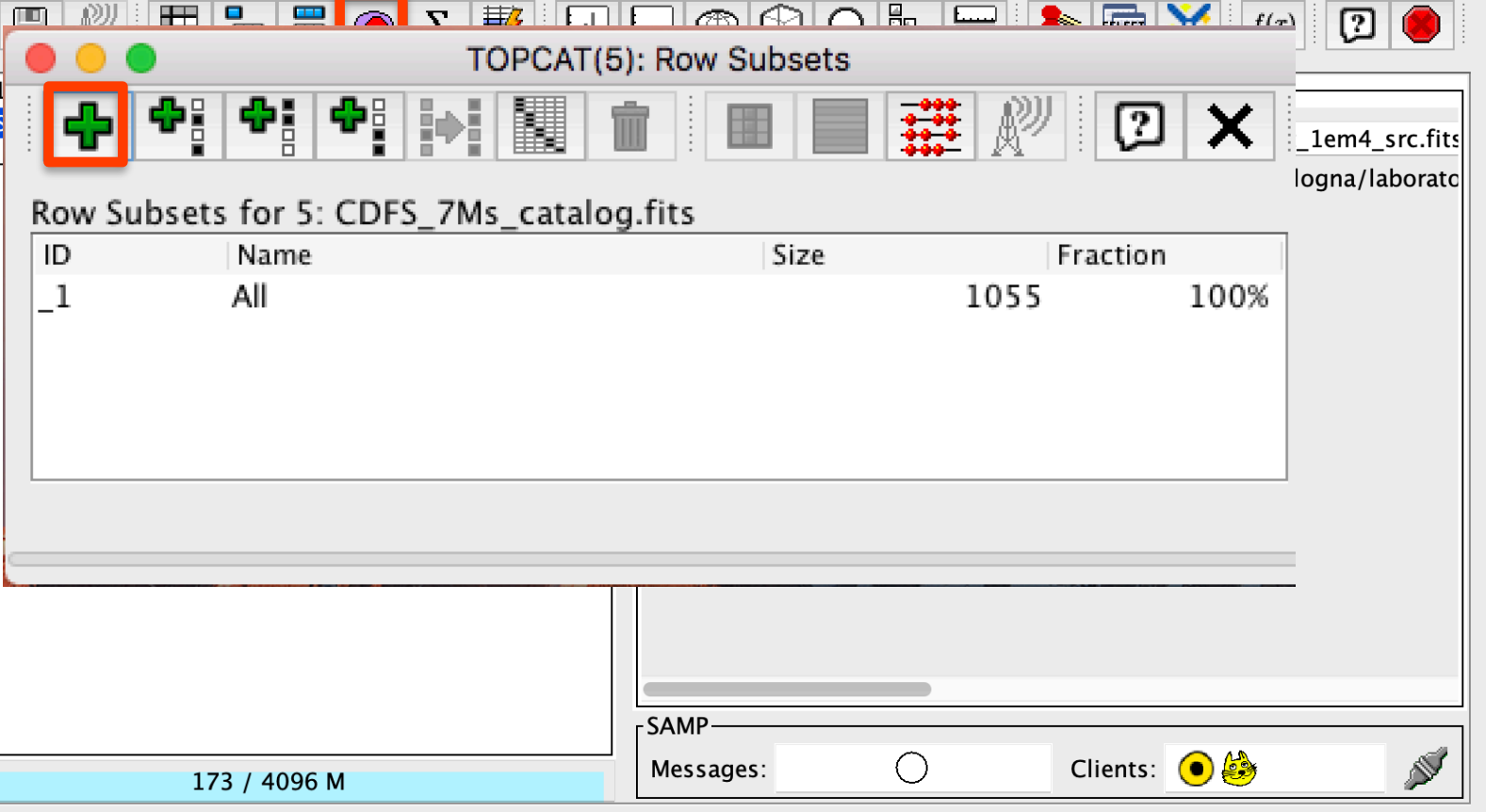
/ VS

Explore the source catalog

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

b.

c.



The screenshot shows the TOPCAT(5) Row Subsets dialog box. The title bar reads "TOPCAT(5): Row Subsets". The toolbar contains several icons, with the first icon (a green plus sign) highlighted by a red square. Below the toolbar, the text "Row Subsets for 5: CDFS_7Ms_catalog.fits" is displayed. A table with the following data is shown:

ID	Name	Size	Fraction
_1	All	1055	100%

At the bottom of the dialog, there is a status bar showing "173 / 4096 M" and a "SAMP" section with "Messages:" and "Clients:" labels.

e

VS

Explore the source catalog

a. Choose a source

b. Define a subset

c. View the subset

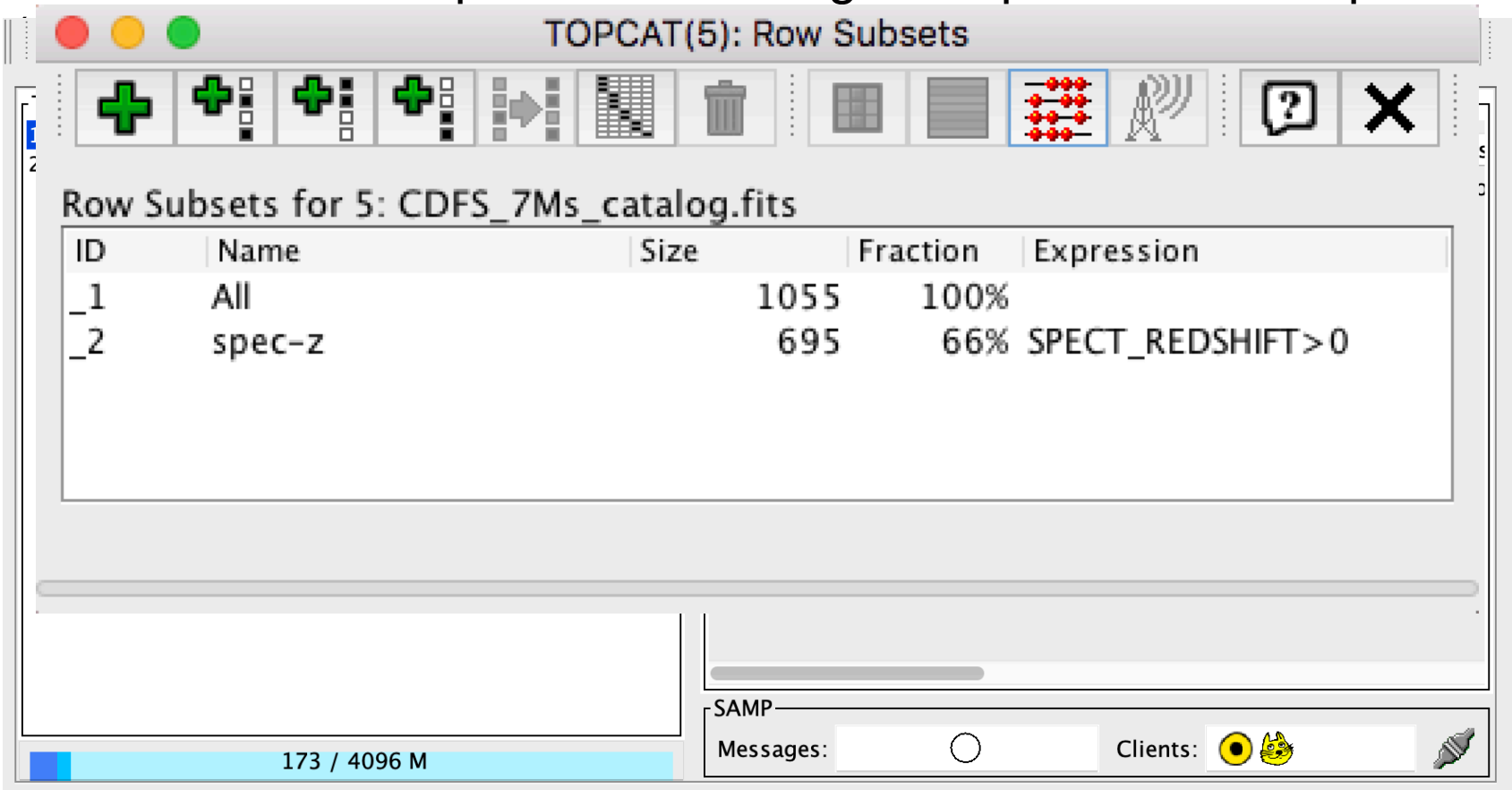
The screenshot shows a software interface with a 'Define Row Subset' dialog box open. The dialog box has a title bar with standard window controls (red, yellow, green buttons). Below the title bar are three icons: a function symbol $f(x)$, a question mark, and a close button. A yellow cartoon cat icon is positioned to the left of the input fields. The 'Subset Name' field contains 'spec-z' with a dropdown arrow. The 'Expression' field contains 'SPECT_REDSHIFT>0' and is highlighted with a blue border. At the bottom of the dialog are 'OK' and 'Cancel' buttons. In the background, a table is visible with columns 'ID' and '_1'. The bottom status bar shows '173 / 4096 M' and a 'SAMP' section with 'Messages' and 'Clients' (including a yellow cat icon).

Explore the source catalog

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

b.

c.



The screenshot shows the TOPCAT(5) Row Subsets window. The title bar reads "TOPCAT(5): Row Subsets". Below the title bar is a toolbar with various icons for adding, deleting, and managing row subsets. The main area displays "Row Subsets for 5: CDFS_7Ms_catalog.fits" and a table with the following data:

ID	Name	Size	Fraction	Expression
_1	All	1055	100%	
_2	spec-z	695	66%	SPECT_REDSHIFT>0

At the bottom of the window, there is a status bar showing "173 / 4096 M" and a "SAMP" section with "Messages:" and "Clients:" labels.

e

/ VS

Explore the source catalog

a. Choose

b.

c.

The screenshot shows a software interface with a 'Define Row Subset' dialog box open. The dialog box has a yellow cat icon, a 'Subset Name' field with 'phot-z', and an 'Expression' field with 'REDSHIFT>0 & !_2'. The background shows a table with columns 'ID' and '_1', and a status bar at the bottom indicating '173 / 4096 M'.

Table 1

1: CDFS

2: cdfs

Row 1

ID

_1

173 / 4096 M

SAMP

Messages: ☐

Clients:

Explore the source catalog

a. Choose

b.

c.

Define Row Subset

TOPCAT(5): Row Subsets

Row Subsets for 5: CDFS_7Ms_catalog.fits

ID	Name	Size	Fraction	Expression
_1	All	1055	100%	
_2	spec-z	695	66%	SPECT_REDSHIFT>0
_3	phot-z	325	31%	REDSHIFT>0 & !_2

173 / 4096 M

SAMP

Messages: ☐ Clients:

e

/ VS

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

The screenshot displays a software interface with a toolbar at the top containing various icons. A red square highlights the summation symbol (Σ) icon. Below the toolbar, the interface is divided into two main panels. The left panel, titled 'Table List', contains a list of two tables: '1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz' and '2: cdfs_source_catalog_n1008.dat', with the second table selected. The right panel, titled 'Current Table Properties', displays details for the selected table: 'Label: cdfs_source_catalog_n1008.dat', 'Location: /Users/stefano/Documenti/work/bologna/laborato', 'Name:', 'Rows: 1,008', 'Columns: 73', 'Sort Order: [up arrow icon] [dropdown arrow icon]', and 'Row Subset: All [dropdown arrow icon]'. Below these properties, it shows 'Activation Actions: 1 / 3'. At the bottom of the interface, there is a status bar with a blue progress indicator, the text '177 / 4096 M', and a 'SAMP' section with 'Messages: [empty circle icon]' and 'Clients: [eye icon] [cat icon] [wrench icon]'.

Table List

- 1: CDFS_4obs_merged_057keV_wavdet_1em4_src.fits.gz
- 2: cdfs_source_catalog_n1008.dat

Current Table Properties

Label: cdfs_source_catalog_n1008.dat

Location: /Users/stefano/Documenti/work/bologna/laborato

Name:

Rows: 1,008

Columns: 73

Sort Order: [up arrow icon] [dropdown arrow icon]

Row Subset: All [dropdown arrow icon]

Activation Actions: 1 / 3

SAMP

Messages: [empty circle icon]

Clients: [eye icon] [cat icon] [wrench icon]

177 / 4096 M

Lab Outline

2) Explore the source catalog

TOPCAT(5): Row Statistics

Row Statistics for 5: CDFS_7Ms_catalog.fits

Name	Mean	SD	Minimum	Max
VLA_DEC	-5.7216	11.2414	-27.9885	
VLA_20_CM_MAG	3.84106	7.57468	0.	
SPECT_REDSHIFT	1.0809	0.784943	0.034	
SPECT_REDSHIFT_FLAG			INSECURE	
REF_SPECT_REDSHIFT	10.6576	6.54157		2
PHOT_REDSHIFT_L10	0.542863	0.848864	0.	
PHOT_REDSHIFT_R11	1.03203	0.749643	0.	
PHOT_REDSHIFT_H14	1.07511	0.787236	0.	
PHOT_REDSHIFT_S14	0.82387	0.80083	0.	
PHOT_REDSHIFT_S15	0.809108	0.814808	0.	
PHOT_REDSHIFT_S16	0.936187	0.826658	0.	
REDSHIFT	1.08991	0.776239	0.038	
REF_REDSHIFT				H14
REDSHIFT_NEG_ERR	0.002921	0.02576	0.	
REDSHIFT_POS_ERR	0.00354	0.026326	0.	

Subset for calculations:

- All
- spec-z
- phot-z

Analyse the data products: spectral fitting

Fit *Chandra* spectra for at least one source 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

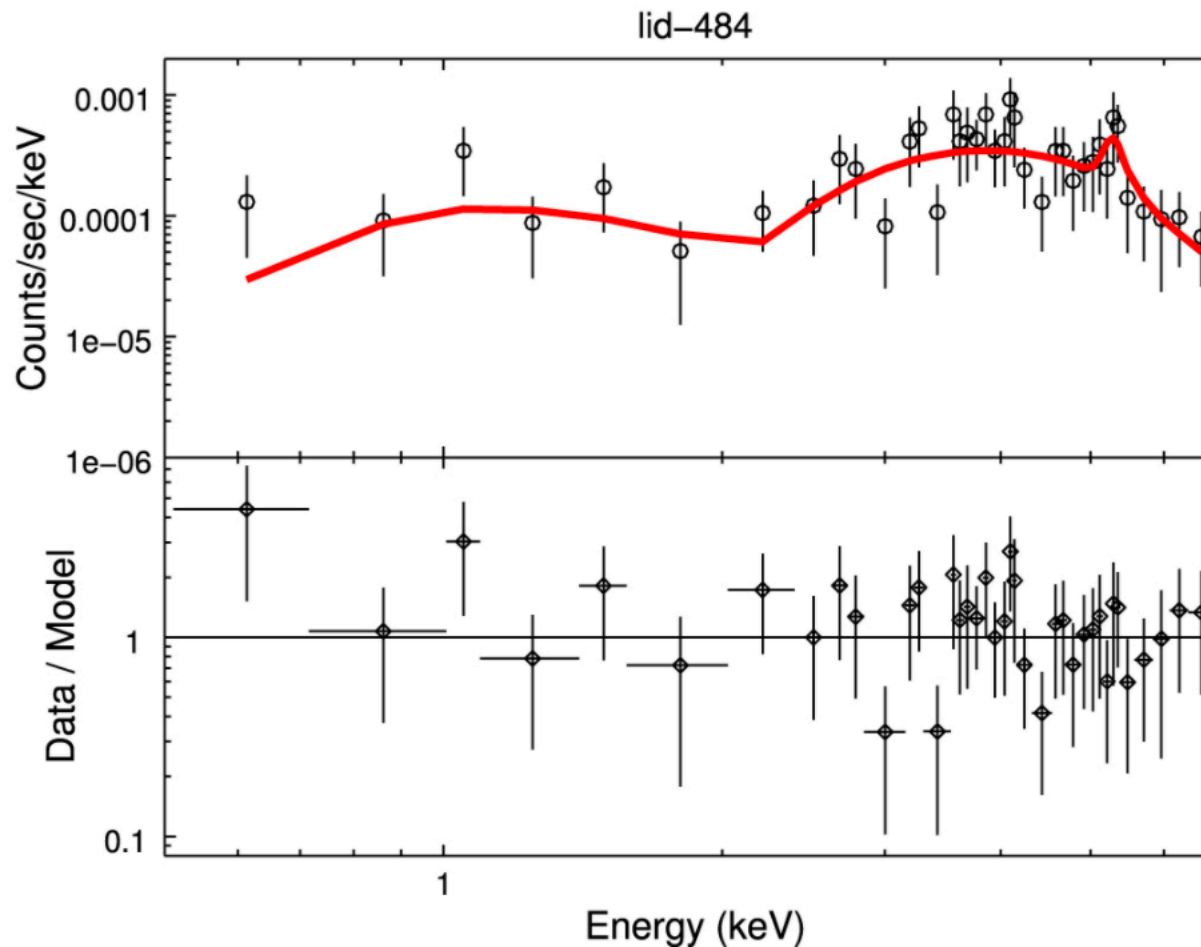
Spectral analysis pipeline

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.**