

# The Virtual Observatory

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# What VO is not!

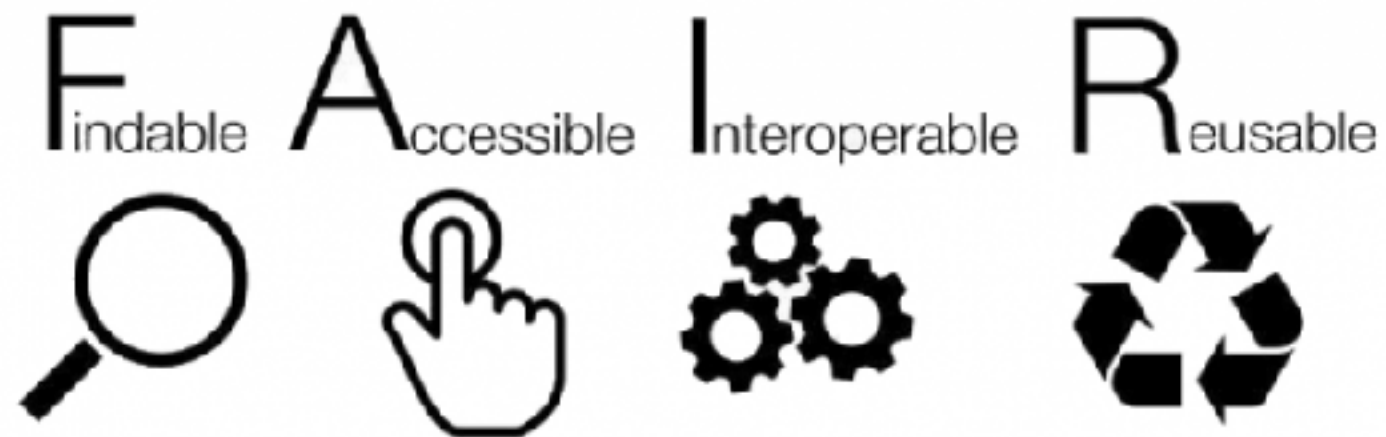
- VO is not a big big computer with a big big archive of astronomical data
- VO is not a big big archive of data
- VO is not a website

# An analogy: internet

- “Internet” exists because of a series of protocols (http, ftp, pop,...) and a series of standards (html,...)
- you use internet through a series of programs (browser, email client,...) which use the standards for you

# Virtual Observatory

- Goal: Easy and efficient access and analysis of the information hosted in astronomical archives.
- Making data “FAIR”



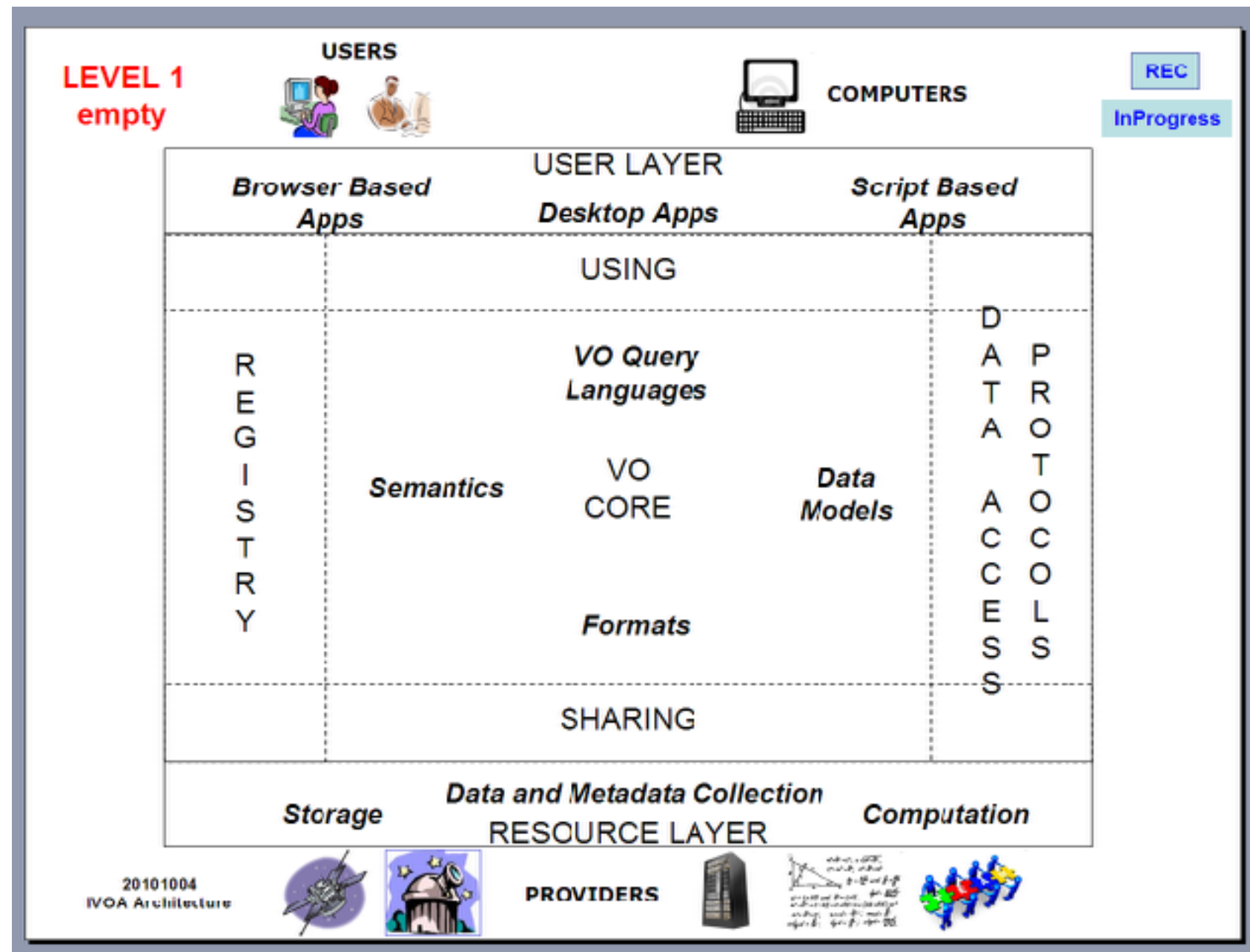


# Layers

Astronomers  
are here

VO offers  
an interface  
to access  
the data

Data can be  
wildly heterogeneous



# Example

- Water can be “agua”, “acqua”, “water”, “wasser”,...
- but it is always H<sub>2</sub>O
- A user wants “agua”, “acqua”, “water”, “wasser”,...
- H<sub>2</sub>O is your resource
- VO offers you a platform so that everybody can share “water” in their preferred language (without the need to learn other languages or chemistry)

# A bit of names

- Basic protocols (explained in the next slides):
  - SCS - Simple Cone Search
  - SIAP - Simple Image Access Protocol
  - SSAP - Simple Spectrum Access Protocol
  - TAP - Table Access Protocol
  - SAMP - Simple Application Messaging Protocol
- The registry

# SCS

Simple query protocol for retrieving records from a catalogue of astronomical sources.

- Basic cone search: RA, DEC and Radius
- The service responds to a basic HTTP request
- Returns a VOTable document (XML based tables with metadata)
- The details of the objects to return are not standardized, a verbose parameter allow request more or less detail

# SIAP

Return links to astronomical images within a specified position.

- Rectangular search: RA, DEC and Angular size
- The service respond to a basic HTTP request
- Returns a VOTable document with links to the images and metadata
- Metadata includes: position (ICRS), Julian Date, format, length in each axis, pixel scale
- Services can provide: Cutouts, Atlas Images or Pointed Image Archive
- Not a mandatory format, services can provide different formats (Fits, graphics...)

# SSAP

SSAP services are archives that return astronomical one-dimensional spectra within a specified position and radius.

- Similar to SIA protocol, spatial search that returns a VOTable with metadata and link to download the spectra
- Filtering criteria include band, time and format  
Additional filtering criteria, in advanced providers, like redshift,
- spatial resolution, signal to noise, ...
- Returned data can be based on Spectrum data model or be proprietary.

# TAP

Provide query-driven access to astronomical tables and databases

- Provide access to catalogues stored in Relational Databases
- Queries need to be formulated in the standard ADQL (SQL selects plus geometric and math functions)
- Table description is provided through specific requests
- Can be synchronous or asynchronous (appropriate for big results)
- The results can be in different formats (VOTable, Fits binary tables, CSV)

# SAMP

SAMP is a messaging protocol that enables astronomy software tools to interoperate and communicate.

- A protocol for desktop application interoperability
- A framework for loosely-coupled, asynchronous, RPC-like and/or event-based communication
- SAMP has a hub-based architecture. The hub is a single service used to route all messages between clients.



# The Registry

- The “yellow pages” of the Virtual Observatory
- There are at least three different registries (which are supposed to update each other periodically)
- Once one person creates a service, he/she informs the registry.
- VO Tools query a registry to know which service is offered.

**Let's use this!**

# We will use:

- Aladin

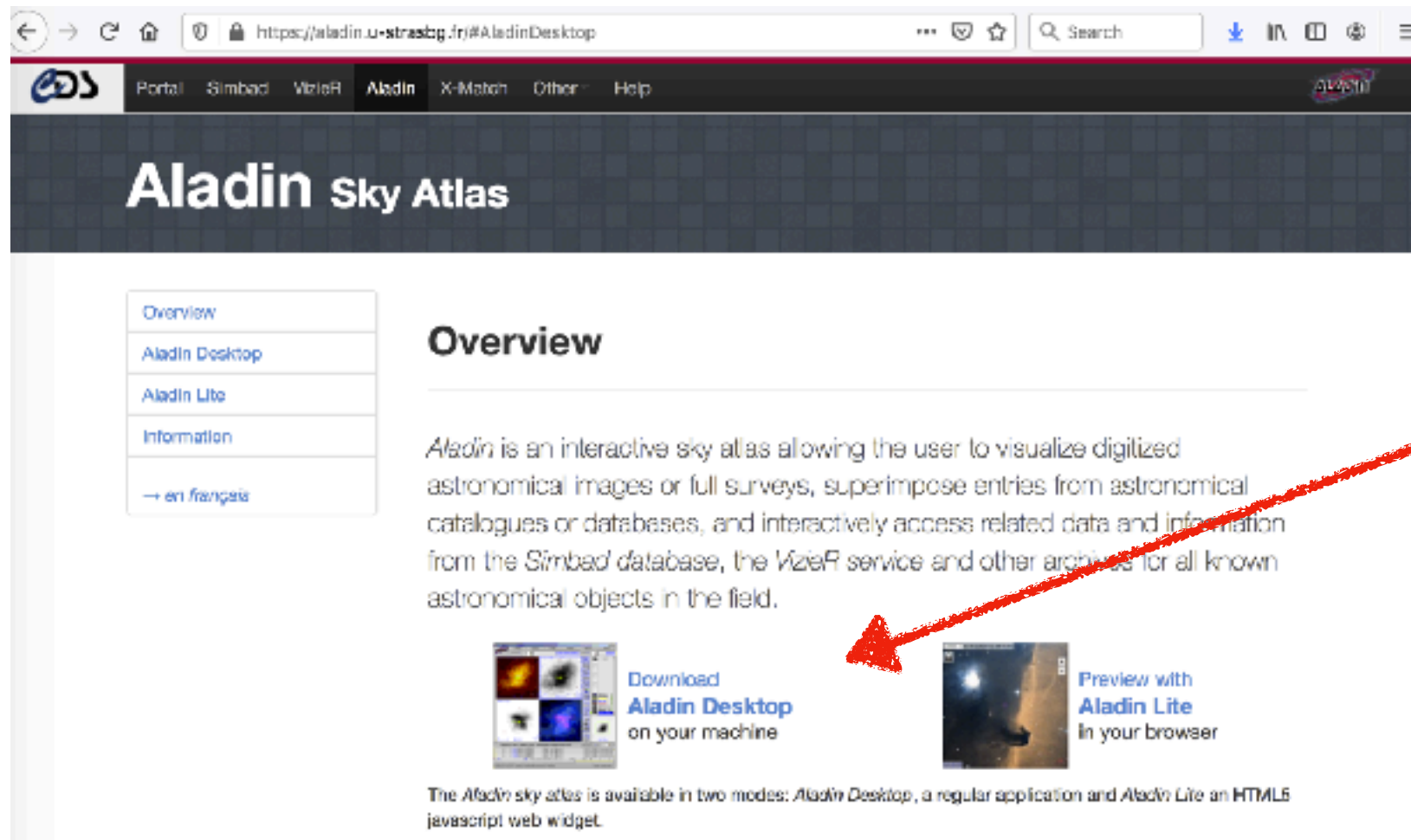
The VO Sky-Atlas

- Topcat

The Tool for Operations on  
Catalogues And Tables

# Install Aladin

- Go to <https://aladin.u-strasbg.fr/>



The screenshot shows the Aladin sky Atlas website. The browser address bar displays <https://aladin.u-strasbg.fr/#AladinDesktop>. The website header includes navigation links: Portal, Simbad, Vizier, Aladin, X-Match, Other, and Help. The main heading is "Aladin sky Atlas". A left sidebar contains links for Overview, Aladin Desktop, Aladin Lite, Information, and a language switch to French. The main content area is titled "Overview" and contains a paragraph describing Aladin as an interactive sky atlas. Below the text are two options: "Download Aladin Desktop on your machine" (with a thumbnail of the desktop application) and "Preview with Aladin Lite in your browser" (with a thumbnail of the browser preview). A red arrow points from the "Download!" text on the right towards the "Download Aladin Desktop" option.

**Download!**

# Install Aladin

- On Linux or Mac, I normally download the Aladin.jar and the Aladin (the Unix shell script launcher)
- Feel free to experiment!

## Official version v10.076



Any Operating System (*WebStart java installer*)

- 1) [Click here](#)
- 2) Follows the instructions...

### • OS specific packages



Aladin.exe

Windows

- 1) [Download it](#) on your desktop
- 2) That's all



Aladin.dmg

Mac

- 1) [Download it](#) and open it
- 2) Copy aladin.app in your application folder
- 3) [Check your security](#) configuration



Linux

- 1) [Download it](#) and untar it
- 2) Use aladin shell launcher

### • Piece by piece:

- [Aladin.jar](#): The software
- [Aladin](#): Unix shell script launcher
- [AladinSrc.jar](#): Source package (see [GPL v3](#) licence)

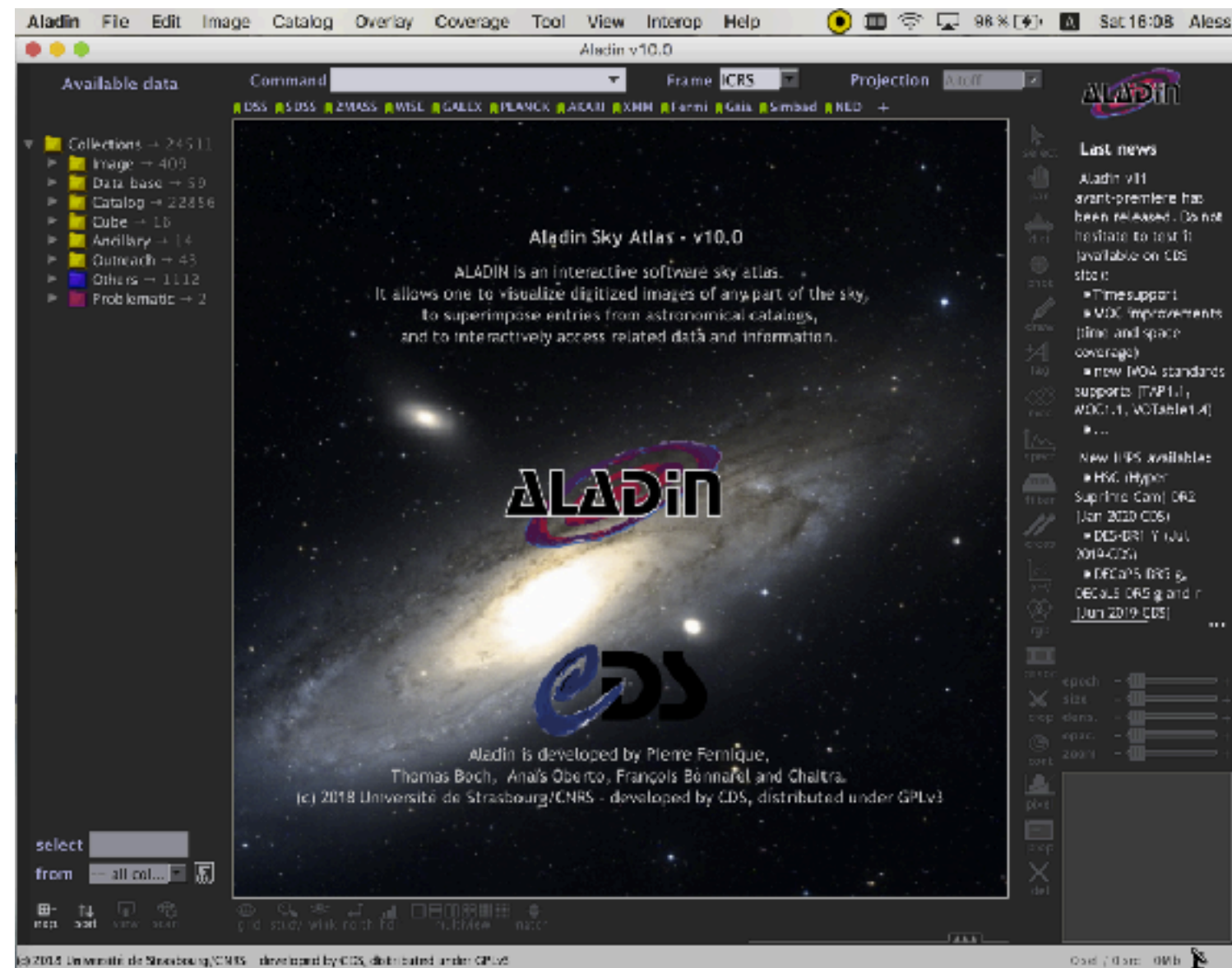
# Launch Aladin

- from the directory where you downloaded the program:

```
chmod a+x Aladin
```

```
./Aladin
```

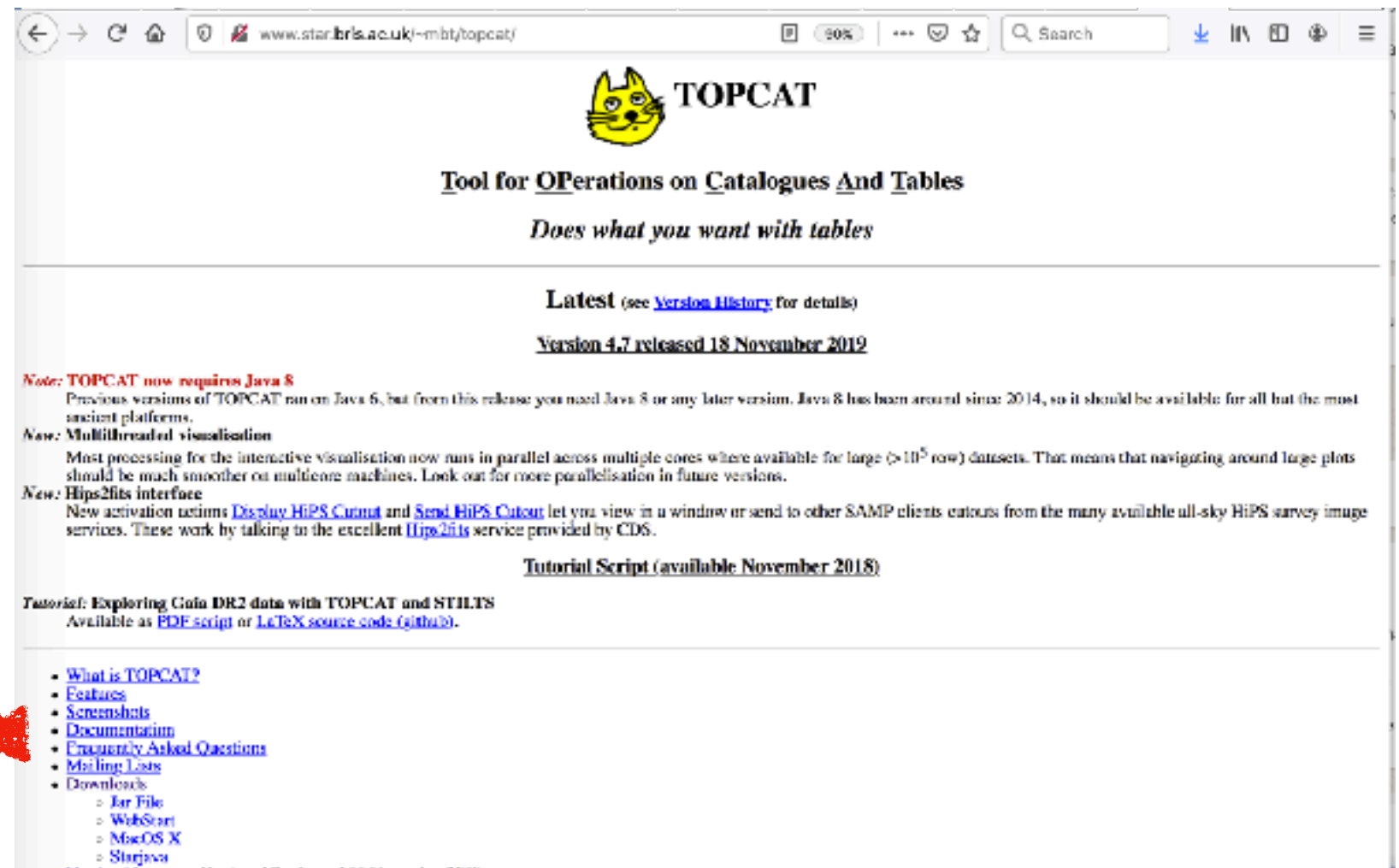
What I see at startup




# Install Topcat

- Let's go to <http://www.star.bris.ac.uk/~mbt/topcat/>

**Download!**



← → ↻ 🏠 🔒 www.star.bris.ac.uk/~mbt/topcat/ 90% 🔍 Search ⏴ ⏵ 🗄️ 🌐 ☰

 **TOPCAT**

**Tool for Operations on Catalogues And Tables**

*Does what you want with tables*

---

**Latest** (see [Version History](#) for details)

**Version 4.7 released 18 November 2019**

**Note: TOPCAT now requires Java 8**  
Previous versions of TOPCAT ran on Java 6, but from this release you need Java 8 or any later version. Java 8 has been around since 2014, so it should be available for all but the most ancient platforms.

**New: Multithreaded visualisation**  
Most processing for the interactive visualisation now runs in parallel across multiple cores where available for large (>10<sup>5</sup> row) datasets. That means that navigating around large plots should be much smoother on multicore machines. Look out for more parallelisation in future versions.

**New: Hips2fits interface**  
New activation actions [Display HIPS Catalog](#) and [Send HIPS Catalog](#) let you view in a window or send to other SAMP clients catalogues from the many available all-sky HIPS survey image services. These work by talking to the excellent [Hips2fits](#) service provided by CDS.

**Tutorial Script (available November 2018)**

**Tutorial: Exploring Gaia DR2 data with TOPCAT and STILTS**  
Available as [PDF script](#) or [L<sup>A</sup>T<sub>E</sub>X source code \(github\)](#).

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- [What is TOPCAT?](#)
- [Features](#)
- [Screenshots](#)
- [Documentation](#)
- [Frequently Asked Questions](#)
- [Mailing Lists](#)
- [Downloads](#)
  - [Jar File](#)
  - [WebStart](#)
  - [MacOS X](#)
  - [Starjava](#)



# Install Topcat

- (Again) on Linux or Mac, I prefer to download the jar file and the startup script:

www.star.bris.ac.uk/~mbt/topcat/#install

## Downloads

TOPCAT is written in the Java language using the Java 2 Standard Edition version 8, and should run on any Java SE 8 or more recent system. This means it can be run on a wide range of platforms, without requiring any recompilation - you just need to ensure that you have a suitable Java Runtime Environment (JRE). If you don't have Java installed, or have an unsuitable version, you can obtain the Java SE for Linux, Mac OS X, MS Windows and Solaris from [Oracle's web site](#) (you only need the "JRE" rather than the "JDK" download, unless you will be doing development work). Java SE Runtime Environments (sometimes called JVMs or Java Virtual Machines) for other platforms may be available from operating system vendors. OpenJDK is also suitable.

If starting TOPCAT fails with an error like `java.lang.UnsupportedClassVersionError`, you have a version of Java that is too old, and you should upgrade to Java 8 or later. If you're unable or unwilling to do that and you only have the rather ancient Java 6, you can still use TOPCAT version [v4.6.3](#) or older.

Having got Java, there are several ways to download TOPCAT, described in rough order of advisability in the following subsections. More information on how to run the program having obtained it can be found in SUN/253's section on [Invoking TOPCAT](#).

### Standalone Jar File

The most convenient form for downloading is to pick up a single Jar file containing the required classes:

- [topcat-full.jar](#) (32.3M) - core facilities plus some optional extras
- [topcat-lite.jar](#) (25.6M) - core facilities

(Note: if you try to download these directly your browser may say something about a failed security check. Make sure that you save it to a file, for instance by right-clicking in Firefox).

On Unix-like operating systems, download one or other of these jar files and the startup script [topcat](#) into the same directory, then `chmod +x topcat`, and you can just run the command:

```
topcat
```

On non-Unix systems the script won't work, and you can use a command like:

```
java -jar topcat-*.jar
```

or invoke it in some other system-dependent way such as by clicking on it.

Here!

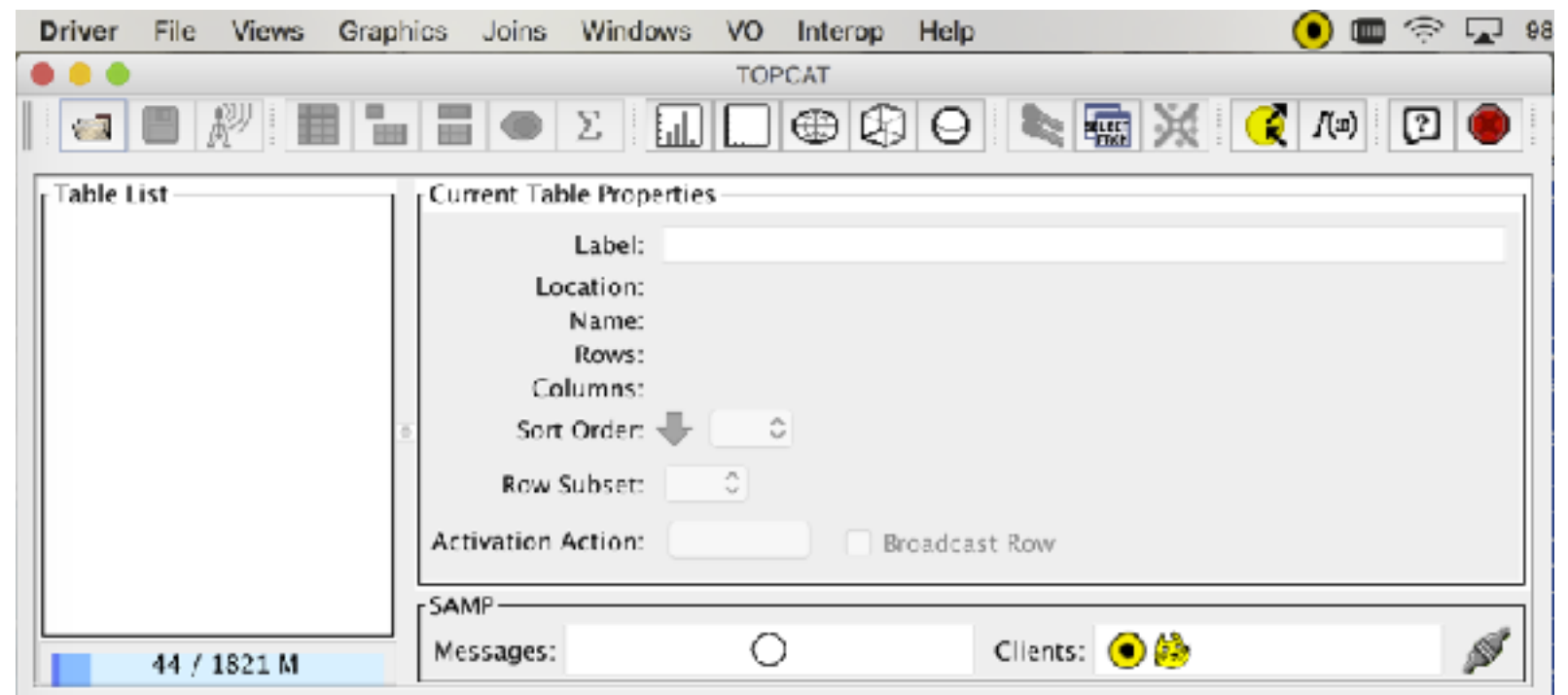


# Launch Topcat

- from the directory where you downloaded the program:

```
chmod a+x topcat
```

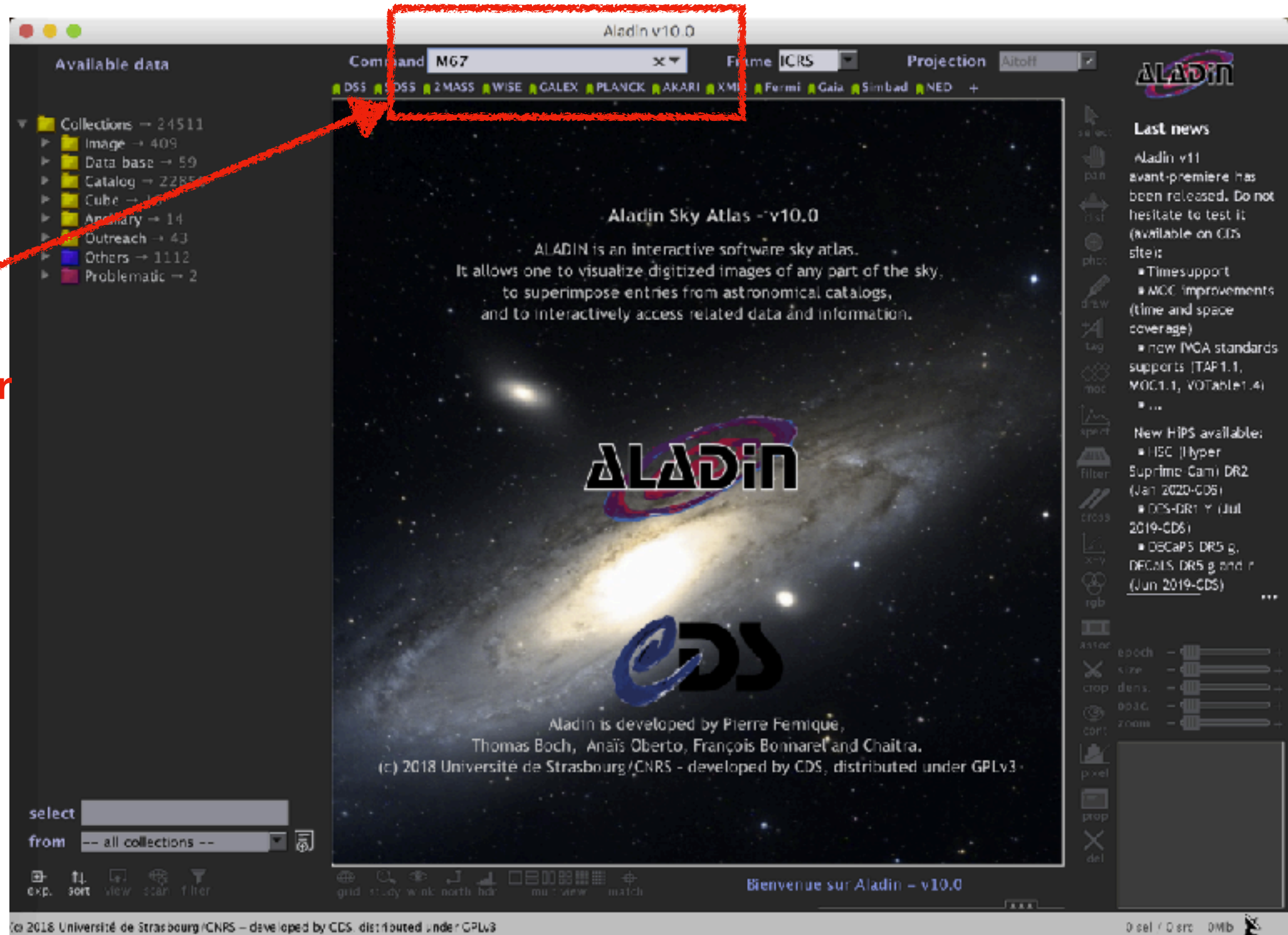
```
./topcat
```



What I see at startup

# **Example #1: Stars in M67**

# Go to M67



Type "M67"  
in the command bar

If it can resolve  
the name of your  
object, Aladin will  
pop up a colour  
image of it

# Zoom on M67

The default field of view is very large.

Let's zoom in (a 15' x 15' will make you feel like a wide field on a large optical ground-based telescope)

Aladin v10.0

Command **M67** Frame **ICRS** Projection **Altoff**

Available data  
in view out view

- Collections → 24511
  - Image → 409
  - Data base → 59
  - Catalog → 22856
  - Cube → 16
  - Ancillary → 14
  - Outreach → 43
  - Others → 1112
  - Problematic → 2

DSS2 color

select pan dist prot draw tag moc zoom cross xy tab as soc ema cont label print del

Last news  
Aladin v11 avant-première has been released. Do not hesitate to test it (available on CDS site):

- Timesupport
- MOC improvements (time and space coverage)
- new IVOA standards supports (TAP1.1, MOC1.1, WOTable1.4)

New HIPS available:

- HSC (Hyper Suprime-Cam) DR2 (Jan 2020-CDS)
- DES-DR1 Y (Jul 2019-CDS)
- DECaPS DR5 g, DECaLS DR5 g and r ...

epoch size dens. opac. zoom

M67

00:51:37.02 -11:48:14.4  
12:34:17.02 -11:48:14.4

15' 12:34:17.02 x 12:34:17.02

(c) 2018 Université de Strasbourg/CNRS - developed by CDS, distributed under GPLv3 0 sel / 0 src 298Mb



# M67

**Much better!**

**Open clusters  
are pretty.**

**On the left, you  
have the  
catalogues  
which have data  
in your field of view  
(in green)**

**Let's grab  
something  
useful.**



# M67

Write  
“abundance”  
in the box down  
here

Many catalogues  
will show up.

You care for one  
called “The  
Cannon”

Double click on  
“The Cannon”

The screenshot shows the Aladin v10.0 interface. At the top, it displays 'Available data → 584 / 24511' and 'Command' with a dropdown menu. The 'Frame' is set to 'ICRS' and 'Projection' is 'Aitoff'. A toolbar on the right includes icons for select, pan, dist, phot, draw, tag, map, spect, filter, cross, zoom, epoch, size, emp, opac, zoom, pixel, prop, and del. The main window shows a star field with the title 'DSS2 color'. A list of data sources is visible on the left, including 'Star identifiers, coordinates, phot', 'High-resolution GC abundances. II.', 'Carbon-enhanced metal-poor (CEMP)', and 'The Cannon: a new approach to de...'. A red arrow points from the text 'Double click on “The Cannon”' to the 'The Cannon' entry in the list. A red box highlights the 'select' button and the text input field containing 'abundance' at the bottom of the list.



# M67: abundances

After you double click, a new “plane” opens here.

On some stars, now there are markers: can you see them?

The screenshot shows the Aladin v10.0 interface. The top bar includes 'Available data → 584 / 24511', 'Command', 'Frame | CRS', and 'Projection | Aitoff'. The left sidebar lists various data collections, with 'DSS2 color' selected. The central panel displays a star field with a purple crosshair marker on one star. The right sidebar contains a 'Welcome to Aladin' message and various tool icons. The bottom status bar shows coordinates and other technical details.

# M67: individual stars

Available data → 584 / 24511  
● in view ● out view

Command [ ] Frame ICRS Projection Aitoff

DSS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Fermi Gaia Slmbad NED +

DSS2 color

select abundance  
from -- all collections --

RAJ2000	DEC2000	V	AP	IL	Teff	log...	e 10...	Fe...
172.8745377	11.788	V12+R		08512990+11471198	4751	2.07	0.007	0.02

epoch size dens. opac. zoom

RD+12 1926

0851:17.96 + 11:48:00.6  
14.97' x 11.57'

© 2018 Université de Strasbourg/CNRS - developed by CD3, distributed under GPLv3

1 sel / 42 src 424Mb

If you click on a star,  
you get its data



# M67

**Let's get some  
SDSS magnitudes,  
shall we?**

# M67 - SDSS data

Same as before,  
we type “sdss” in  
the box below  
and we look for a  
photometric  
catalogue.

The screenshot displays the Aladin v10.0 interface. The main window shows a star field labeled "DSS2 color" with a size of 14.97' x 11.57'. The left sidebar contains a tree view of available data, including SDSS color and band data, HST data, and various catalogues. The bottom left has a search box with "sdss" entered and a dropdown menu set to "all collections". The bottom right shows a table of data for the selected object, with the following columns and values:

RA J2000	DEC J2000	V	A <sup>2</sup>	ID	Teff	a...	cl...	e...	Fe...
152.8745833	11.738	vizier		08512890+147168	4361	3	2.07	0.007	0.02

The interface also includes a toolbar with various tools like select, pan, dist, phot, draw, tag, map, spect, filter, cross, and zoom. A "Data discovery tree" panel on the right provides information about the data sources and a search bar.

Click, for this example, on “SDSS DR8”

(just one click, not double-click)

Select “in view” and then “Load”

Aladin v10.0

Command: 08:51:35.76 +11:50:00.4    Frame: ICRS    Projection: Aitoff

Available data → 897 / 24511  
• in view • out view

- SDSS9 color (g, r, i, z)
- SDSS9 color
- SDSS9 band r
- SDSS9 band i
- SDSS9 band z
- HST → 6 / 28
  - HLA → 3 / 8
    - HLA-SDSSg : F475W
    - HLA-SDSSr : F625W
    - HLA-SDSSz : F850LP
    - HST-SDSSg includes the
    - HST-SDSSr includes the
    - HST-SDSSz includes the
- Catalog → 832 / 22856
  - VizieR → 796 / 21419
    - I-Astrometric Data → 1 / 26
      - GPS1 - Gaia-PS1-SDSS
    - II-Photometric Data → 7 / 35
      - SDSS-DR8 - The SDSS P**
      - SDSS-DR6 - The SDSS P
      - SDSS-DR4 - The SDSS P
      - SDSS-DR3 - The SDSS P
      - SDSS-DR5 - The SDSS P
      - SDSS-DR7 - The SDSS P
      - Sloan Digital Sky Survey-II
      - Confirmed SDSS-II St
    - V-Combined Data → 2 / 144
      - SDSS-DR12 - The SDSS P
      - SDSS-DR3 - The SDSS P
    - VI-Miscellaneous → 4 / 45
      - All-sky spectrally matched
      - [DR7Fit.dat] DR7 sta
      - [SDSSPTFit.dat] SDSS
      - [SDSSSouthFit] The u
      - [SloanFit\_Sloan Catal

select: sdss  
from: all collections

select data in view

SDSS-DR8 - The SDSS Photometric Catalog, Release 8 (Adelman-Roemer et al.)  
Provenance: CDS  
Coverage: 36.48%    Reference pub. year: 2011    Nb rows: 324,960,076  
Access mode:  in view     by region & MOC     by CDS Xmatch     by criteria  
derived prod.:  coverage     density map

CDS/II/306/sdss8    Load    08 51 17.06160 +11 48 00.5760 14.97'

RA:2000	DEC:2000	V	A <sup>h</sup>	ID	Teff	e...	lcp...	e to...	Te...
132.8745833	11.798	VizieR		DR5:12490114768	4387	3	2.07	0.007	0.02

08:51:17.96 - 11:48:00.6  
14.97' x 11.57'

© 2018 Université de Strasbourg/CNRS - developed by CDS, distributed under: GPLv3    1 sel / 42 src    50fps / 427Mb



Now you have a lot of markers!

How do we use this information?

Maybe we can cross-match the data...

Aladin v10.0

Available data → 897 / 24511  
in view out view

- SDSS9 color (g, r, i, z)
- SDSS9 color
- SDSS9 band r
- SDSS9 band i
- SDSS9 band z
- HST → 6 / 28
  - HIA → 3 / 8
    - HIA-SDSSg : F475W
    - HIA-SDSSr : F625W
    - HIA-SDSSz : F850LP
  - HST-SDSSg includes the
  - HST-SDSSr includes the
  - HST-SDSSz includes the
- Catalog → 832 / 22856
  - VizieR → 796 / 21419
    - I-Astrometric Data → 1 / 26
      - GPS1 - Gaia-PS1-SDSS
    - II-Photometric Data → 7 / 35
      - SDSS-DR8 - The SDSS P
      - SDSS-DR6 - The SDSS P
      - SDSS-DR4 - The SDSS P
      - SDSS-DR3 - The SDSS P
      - SDSS-DR5 - The SDSS P
      - SDSS-DR7 - The SDSS P
    - Sloan Digital Sky Survey-II
      - Confirmed SDSS-II S
    - V-Combined data → 2 / 144
      - SDSS-DR12 - The SDSS P
      - SDSS-DR9 - The SDSS P
    - VI-Miscellaneous → 4 / 46
      - All-sky spectrally matched
      - [DR7Fit.dat] DR7 sta
      - [SDSSPTFit.dat] SDSS
      - [SDSSSouthFit] The u
      - [SloanFit] Sloan Cata

Command [ ] Frame ICRS Projection Aitoff

DSS SDSS ZMASS WISE GALEX PLANCK AKARI XMM Fermi Gaia Simbad NED +

DSS2 color

14.97° x 11.57°

Search [ ]

select scss  
from -- all collections --

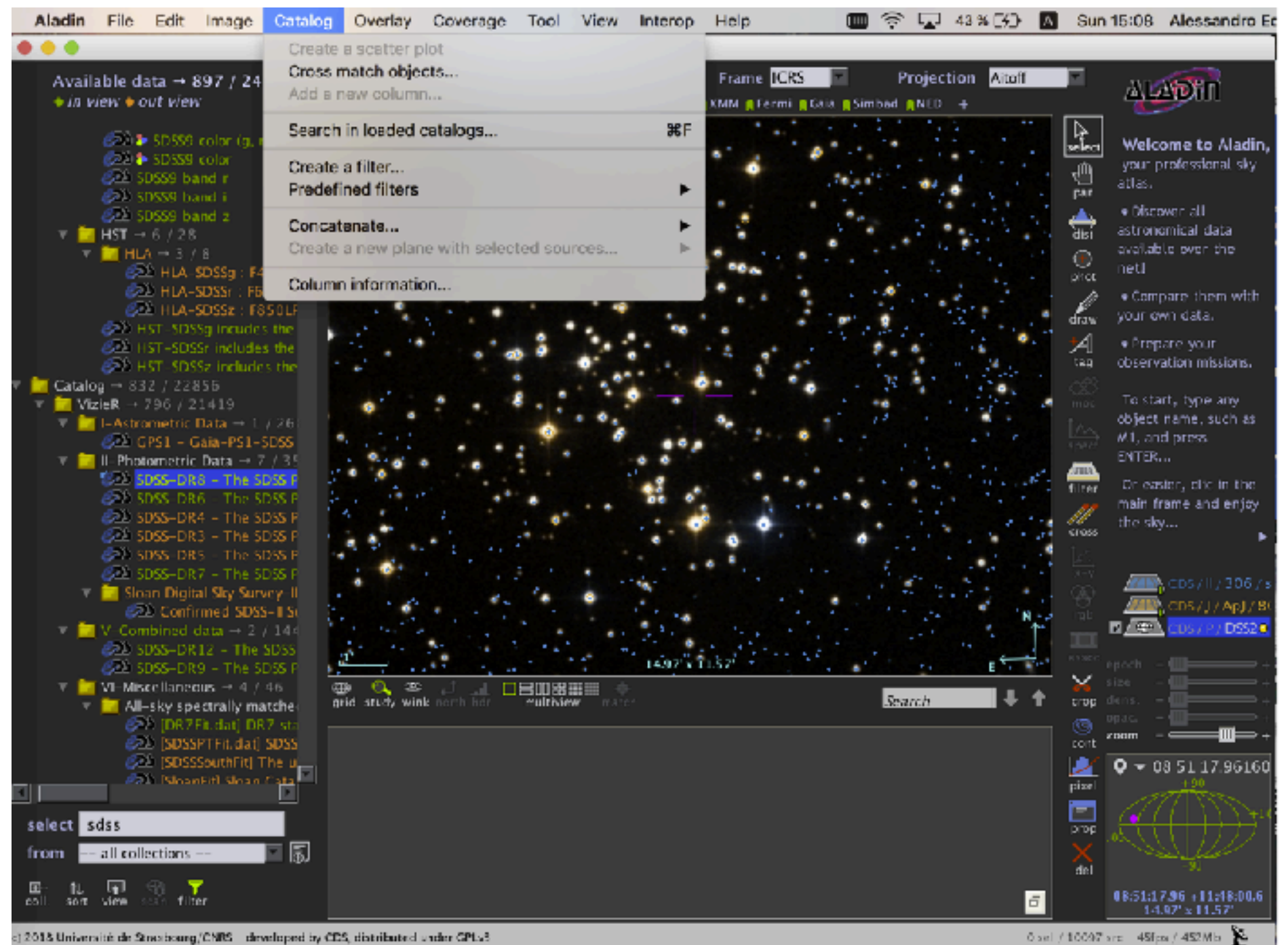
coll. sort view scan filter

08 51 17.96160  
+90  
-90  
14 57 x 11 57  
0851:17.96 +1148:00.6  
14.97° x 11.57°

0 sel / 10097 src 45fps / 420Mb

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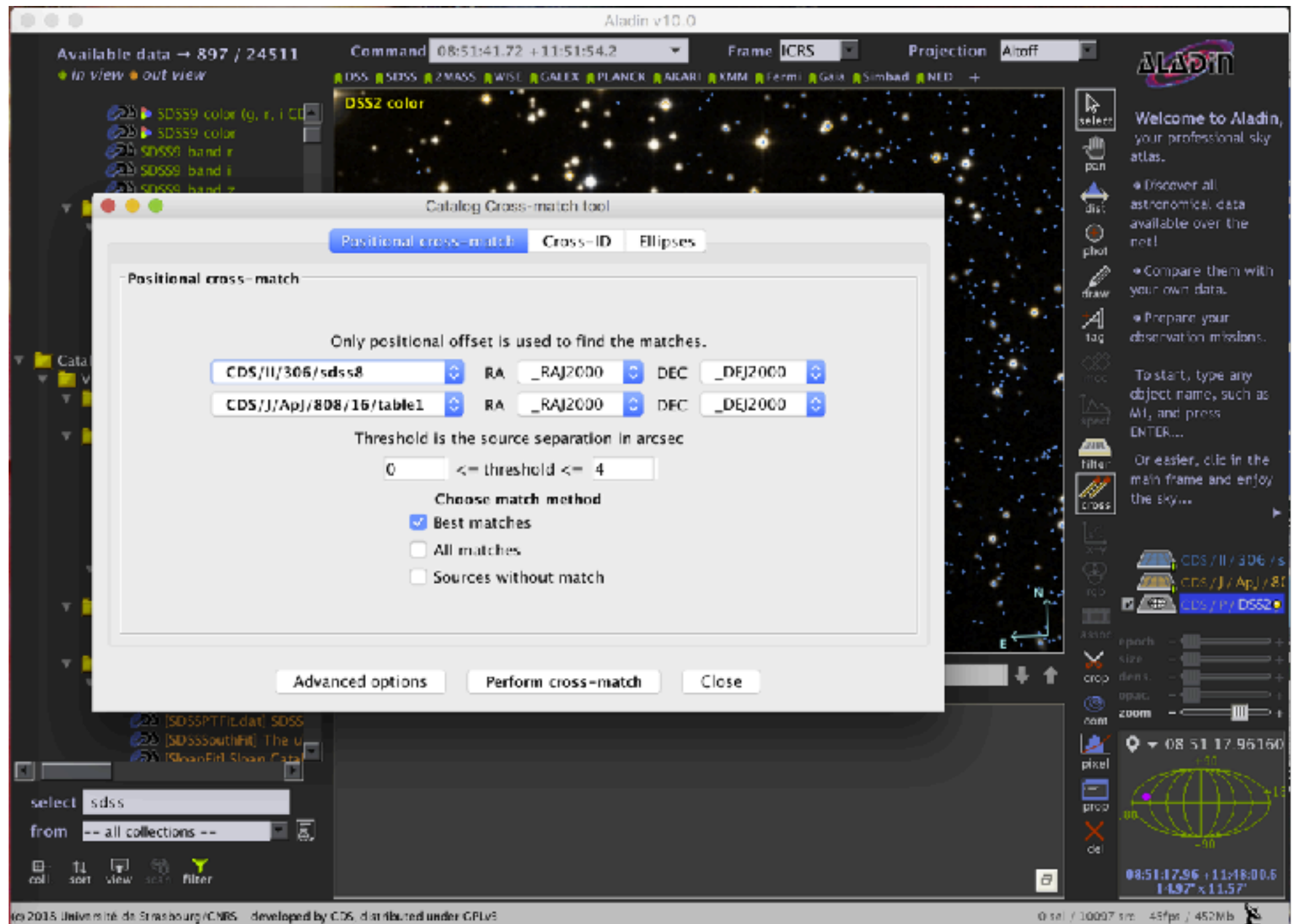
Find  
“Catalog” ->  
“Cross match  
objects”





For this test, we will use the default parameters.

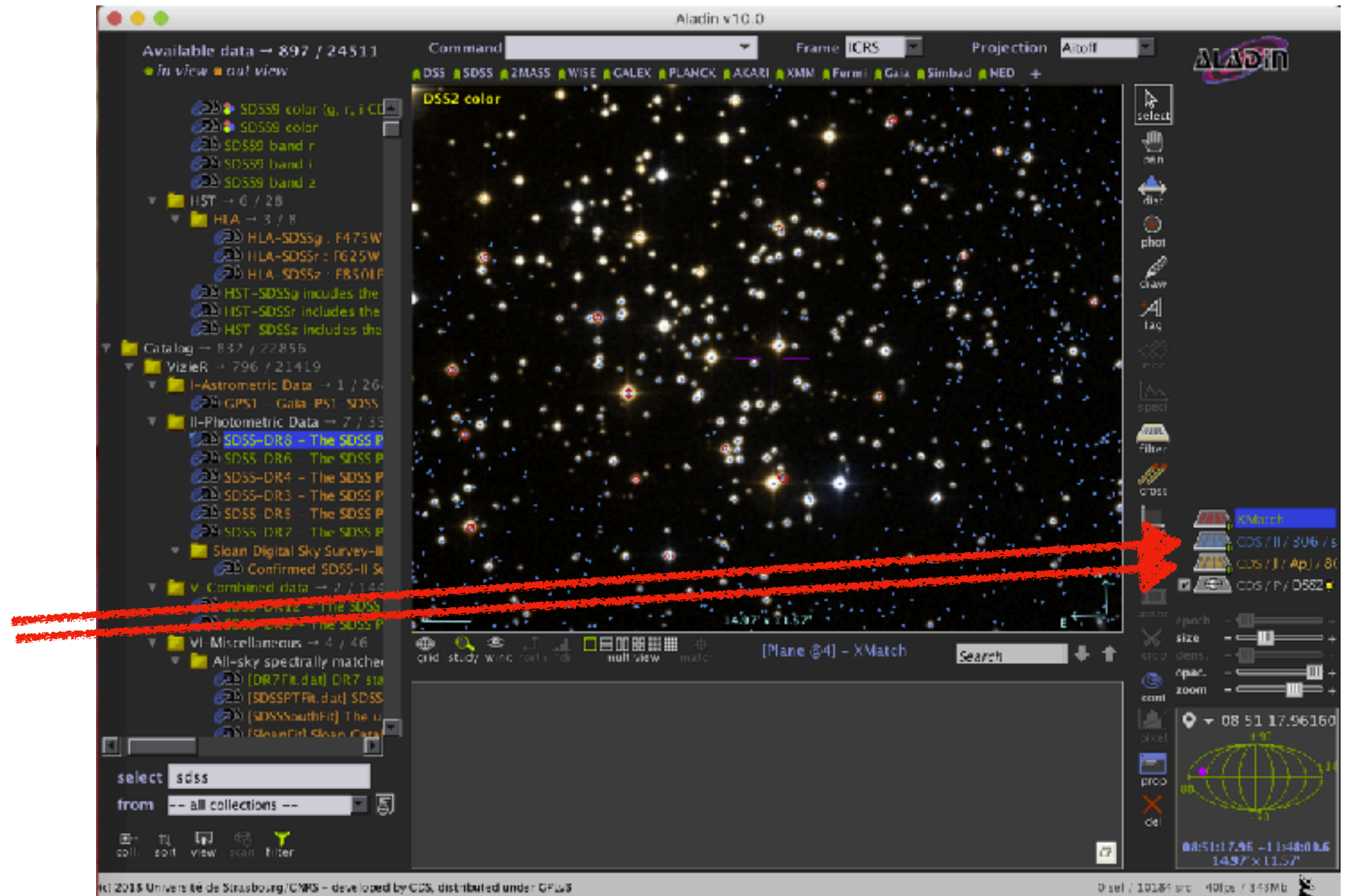
Click on “Perform cross-match” and then “Close”



You have a new plane.

Things are getting messy with the markers, right?

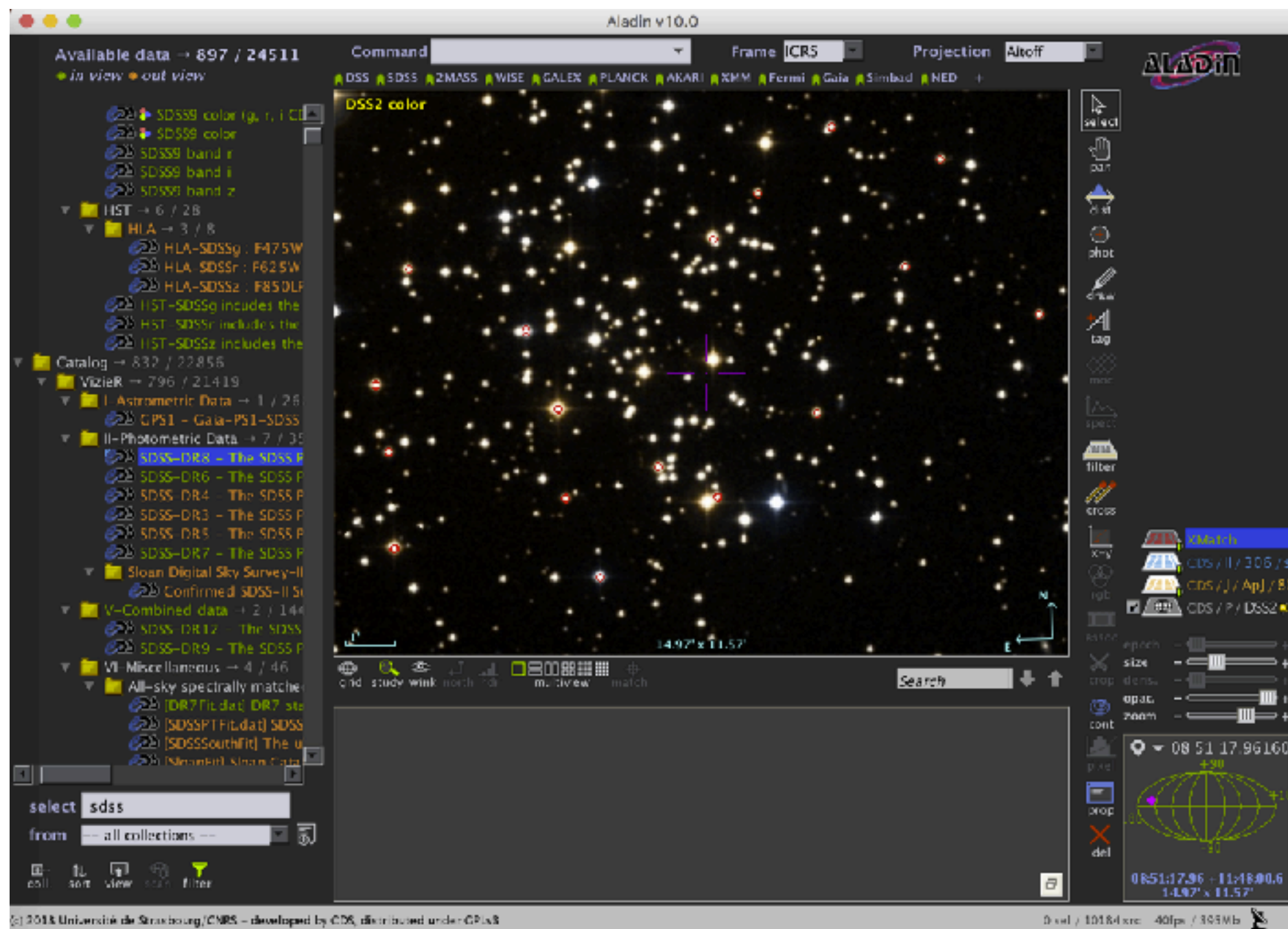
Let's click on these icons to deactivate them.



Now you only have the red markers.

Good!

But how do you use this information now?

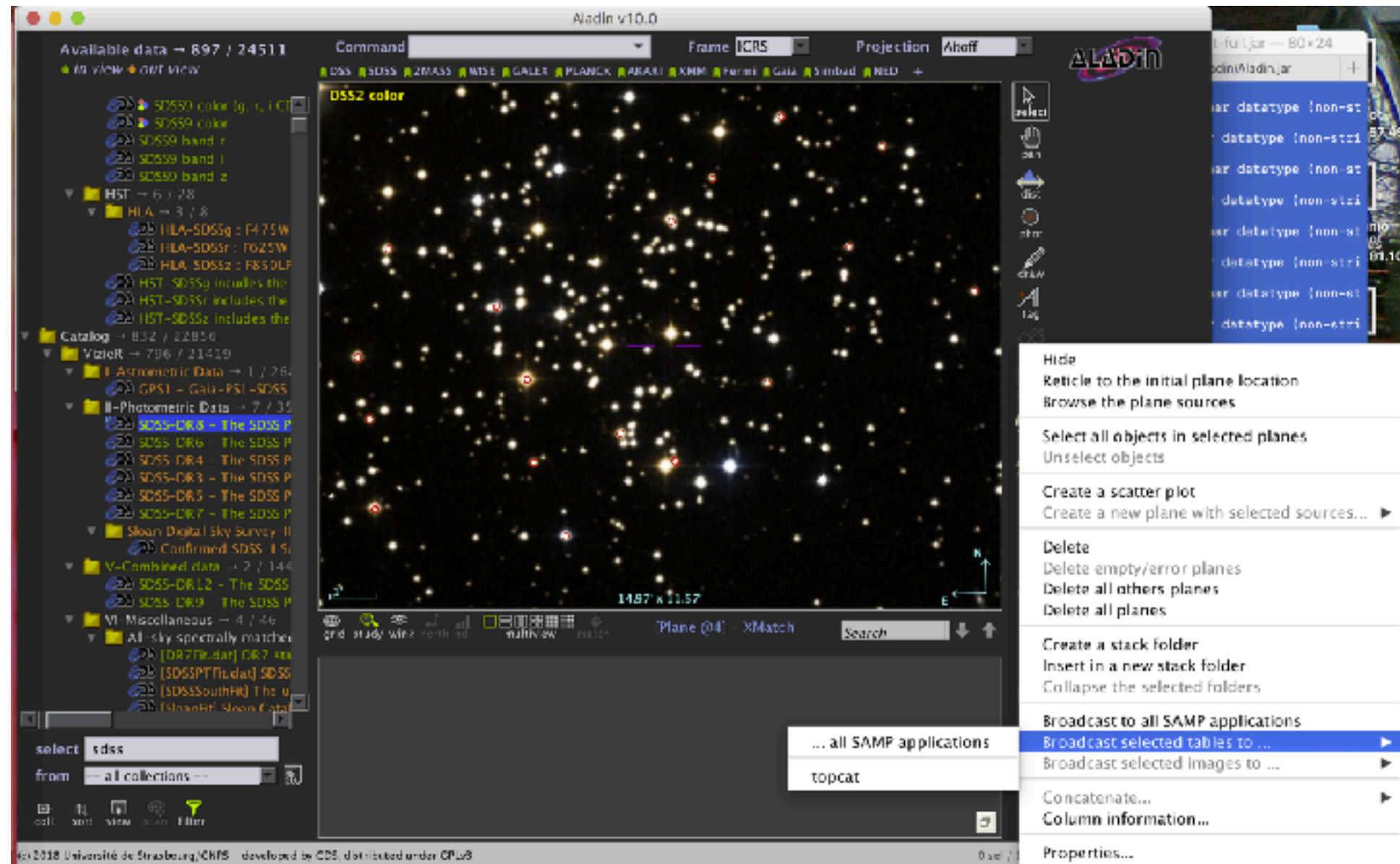




Right click on the red “X-Match” and look for the “Broadcast selected tables to” and then “Topcat”

(you must have Topcat running)

Click there and go to Topcat

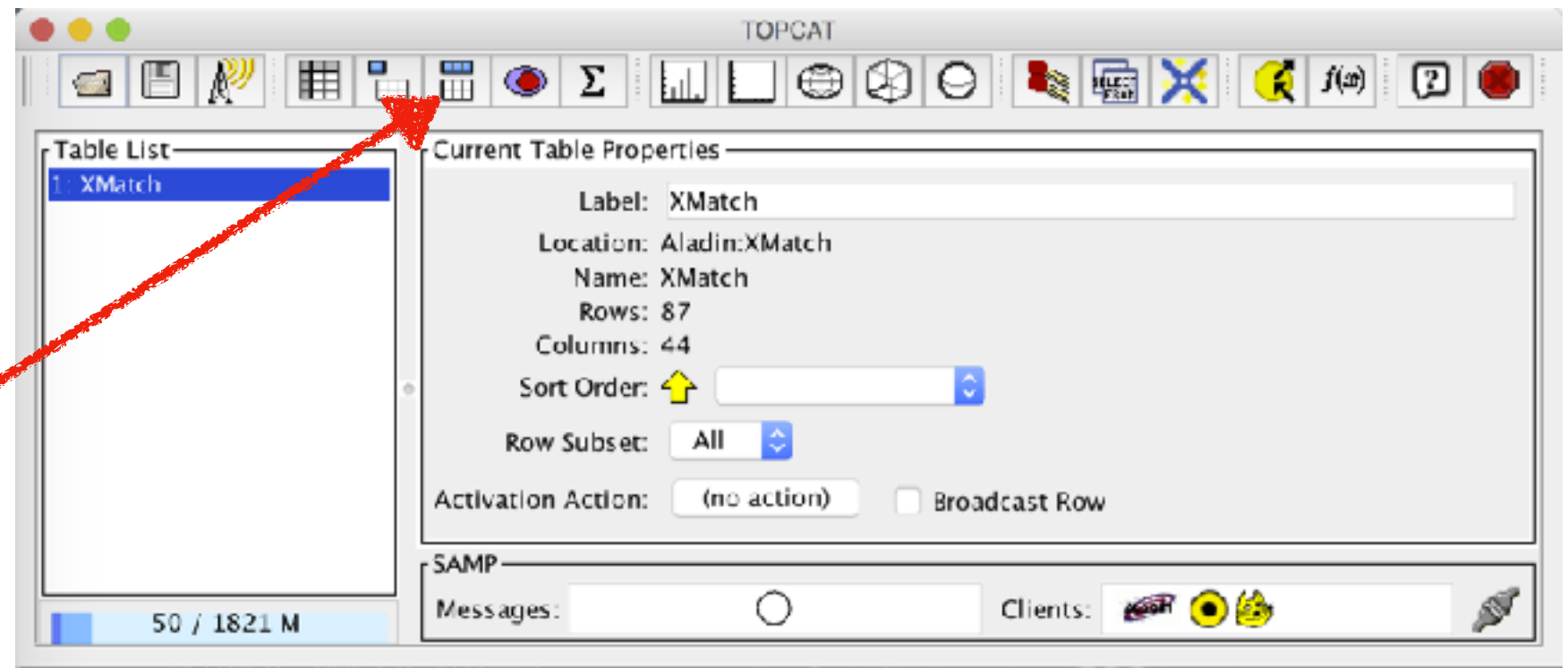


**This is the power of the interoperability of VO!**

**Now let's get acquainted with our table.**

**This icon is the command to get the information on the content of the table.**

**It should always be the first thing we do when opening a new table.**

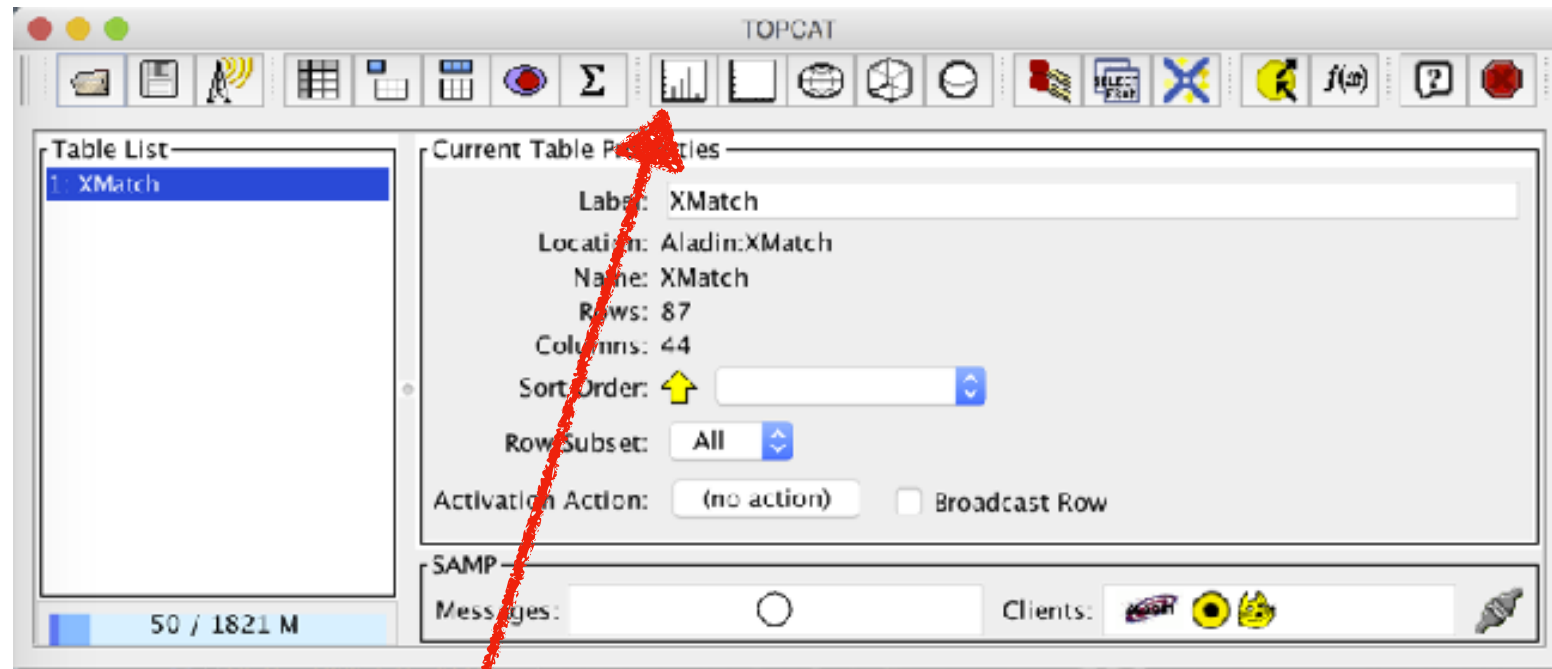


Spend some time to understand what you have in your table.

TOPCAT(1): Table Columns

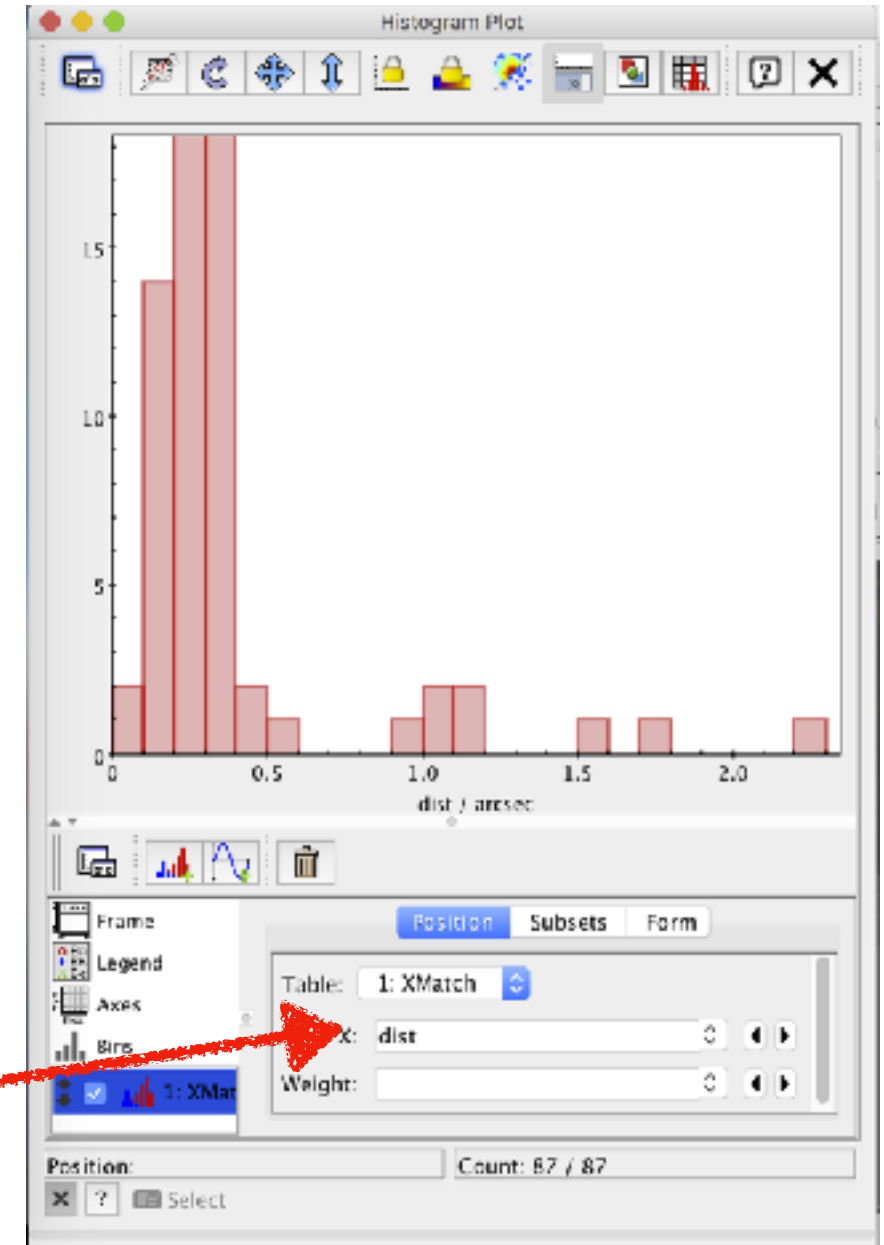
Table Columns for 1: XMatch

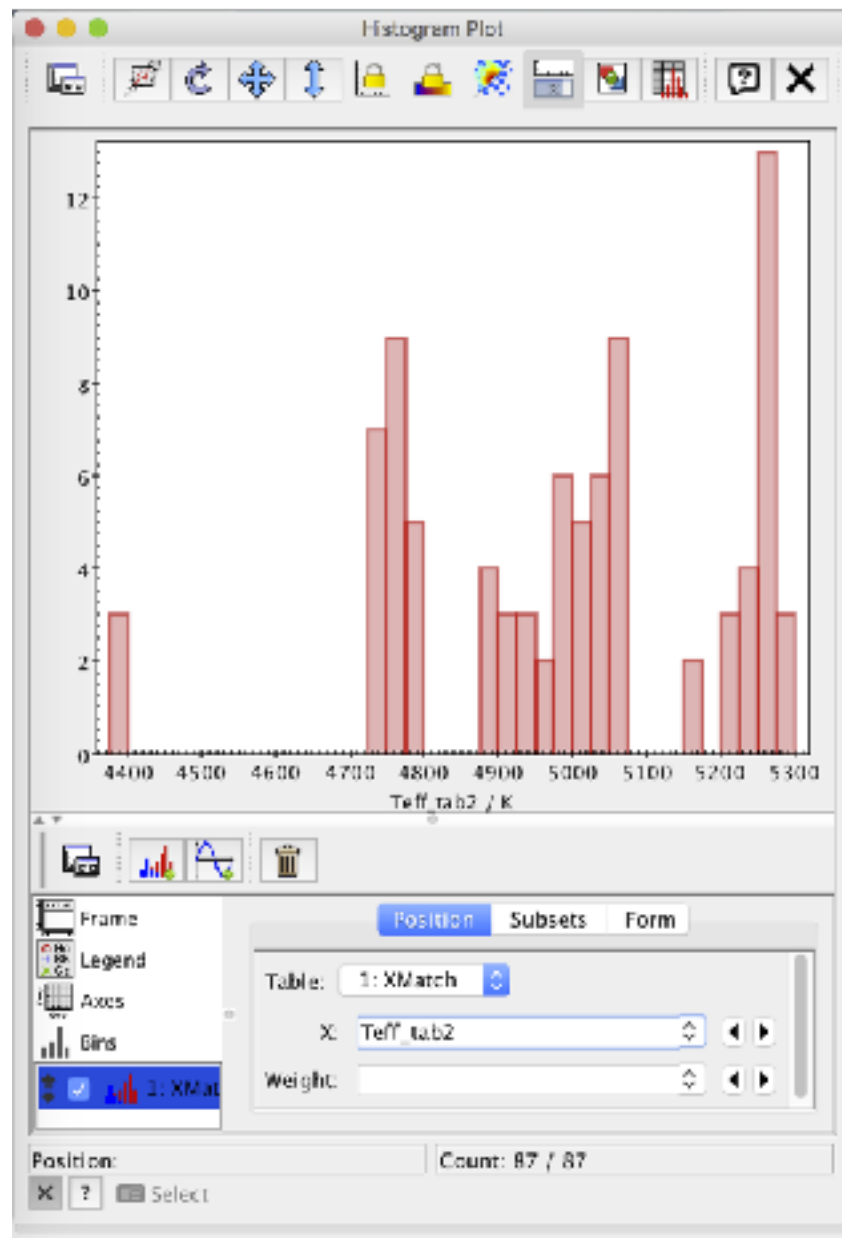
	Visible	Name	ID	Class	Units	Domain	Description
0	<input type="checkbox"/>	Index	\$0	Long			Table row index
1	<input checked="" type="checkbox"/>	dist	\$1	Double	arcsec		Distance between 2 cross-matc
2	<input checked="" type="checkbox"/>	_RAJ2000_tab1	\$2	Double	deg		Right ascension (FK5, Equinox=
3	<input checked="" type="checkbox"/>	_DEJ2000_tab1	\$3	Double	deg		Declination (FK5, Equinox=J200
4	<input checked="" type="checkbox"/>	_V_tab1	\$4	String			Link to the VizieR record with al
5	<input checked="" type="checkbox"/>	mode_tab1	\$5	Short			[1,2] 1: primary (469,053,874
6	<input checked="" type="checkbox"/>	q_mode_tab1	\$6	Character			[+] '+' indicates clean photome
7	<input checked="" type="checkbox"/>	cl_tab1	\$7	Short			Type (class) of object (3=galax)
8	<input checked="" type="checkbox"/>	SDSS8_tab1	\$8	String			SDSS DR8 name, based on J200
9	<input checked="" type="checkbox"/>	m_SDSS8_tab1	\$9	Character			[*] The asterisk indicates that 2
10	<input checked="" type="checkbox"/>	Im_tab1	\$10	String			Image from SDSS-serverur
11	<input checked="" type="checkbox"/>	RA_ICRS_tab1	\$11	Double	deg		Right Ascension of the object (IC
12	<input checked="" type="checkbox"/>	DE_ICRS_tab1	\$12	Double	deg		Declination of the object (ICRS)
13	<input checked="" type="checkbox"/>	zsp_tab1	\$13	Double			? Spectroscopic redshift (when S
14	<input checked="" type="checkbox"/>	umag_tab1	\$14	Float	mag		? Model magnitude in u filter, AI
15	<input checked="" type="checkbox"/>	e_umag_tab1	\$15	Float	mag		? Mean error on umag (err_u)
16	<input checked="" type="checkbox"/>	gmag_tab1	\$16	Float	mag		? Model magnitude in g filter, AI
17	<input checked="" type="checkbox"/>	e_gmag_tab1	\$17	Float	mag		? Mean error on gmag (err_g)
18	<input checked="" type="checkbox"/>	rmag_tab1	\$18	Float	mag		? Model magnitude in r filter, AF
19	<input checked="" type="checkbox"/>	e_rmag_tab1	\$19	Float	mag		? Mean error on rmag (err_r)
20	<input checked="" type="checkbox"/>	imag_tab1	\$20	Float	mag		? Model magnitude in i filter, AB
21	<input checked="" type="checkbox"/>	e_imag_tab1	\$21	Float	mag		? Mean error on imag (err_i)
22	<input checked="" type="checkbox"/>	zmag_tab1	\$22	Float	mag		? Model magnitude in z filter, AI
23	<input checked="" type="checkbox"/>	e_zmag_tab1	\$23	Float	mag		? Mean error on zmag (err_z)
24	<input checked="" type="checkbox"/>	Q_tab1	\$24	Short			Quality of the observation (0=ui
25	<input checked="" type="checkbox"/>	ObsDate_tab1	\$25	Double	yr	DecYear->Time	Mean Observation date
26	<input checked="" type="checkbox"/>	objID_tab1	\$26	Long			SDSS unique object identifier (2)
27	<input checked="" type="checkbox"/>	_RAJ2000_tab2	\$27	Double	deg		Right ascension (FK5, Equinox=
28	<input checked="" type="checkbox"/>	_DEJ2000_tab2	\$28	Double	deg		Declination (FK5, Equinox=J200
29	<input checked="" type="checkbox"/>	_V_tab2	\$29	String			Link to the VizieR record with al
30	<input checked="" type="checkbox"/>	AP_tab2	\$30	Short			? Apoge version (4412 or 4413
31	<input checked="" type="checkbox"/>	ID_tab2	\$31	String			Stellar identifier (1) \linkRole{2N
32	<input checked="" type="checkbox"/>	Teff_tab2	\$32	Float	K		[3140/5722] Effective tempera
33	<input checked="" type="checkbox"/>	e_Teff_tab2	\$33	Float	K		[1/285] The 1(sigma) uncertain
34	<input checked="" type="checkbox"/>	log(g)_tab2	\$34	Float	[cm/s <sup>2</sup> ]		[-1.4/5.2] Log surface gravity
35	<input checked="" type="checkbox"/>	e_log(g)_tab2	\$35	Float	[cm/s <sup>2</sup> ]		[0.003/0.6] The 1(sigma) unce
36	<input checked="" type="checkbox"/>	[Fe/H]_tab2	\$36	Float	[-]		[-3/3.4] Metallicity



**This icon allows us to make histogram of a given column of our table.**

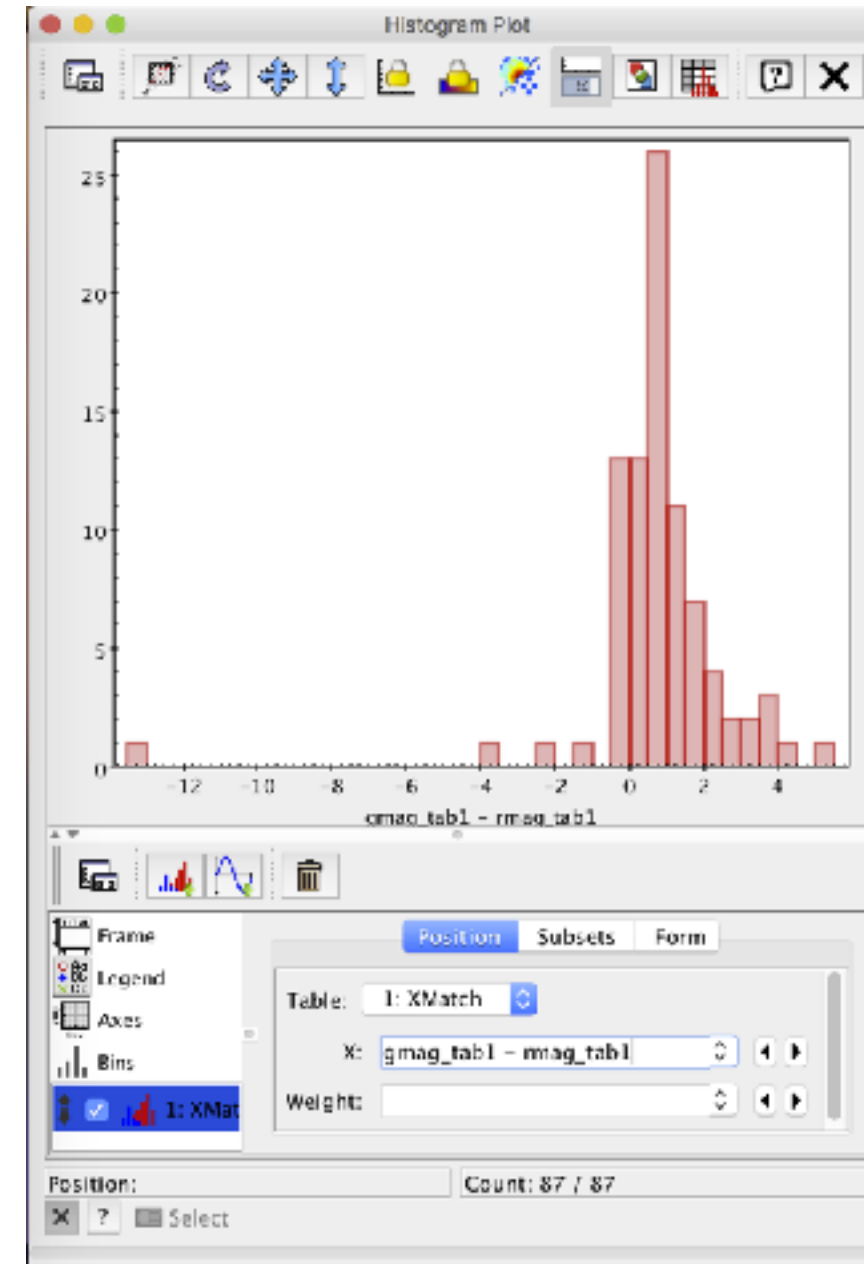
**By default, it shows the first column, which is often not too informative.**



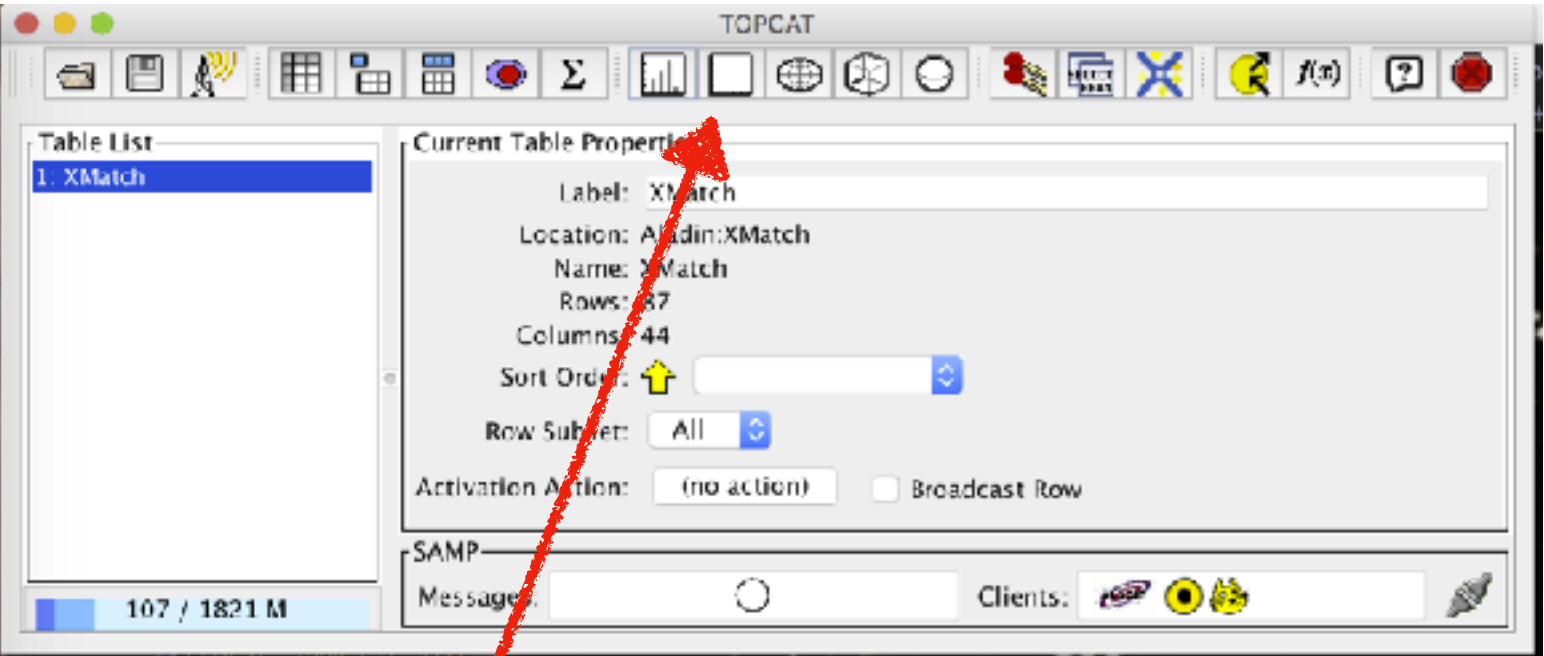


**You can choose a more interesting column (e.g. the effective temperatures of the stars)**

**Or you can do algebraic operations between columns (interesting *g-r* colour distribution, don't you think?)**

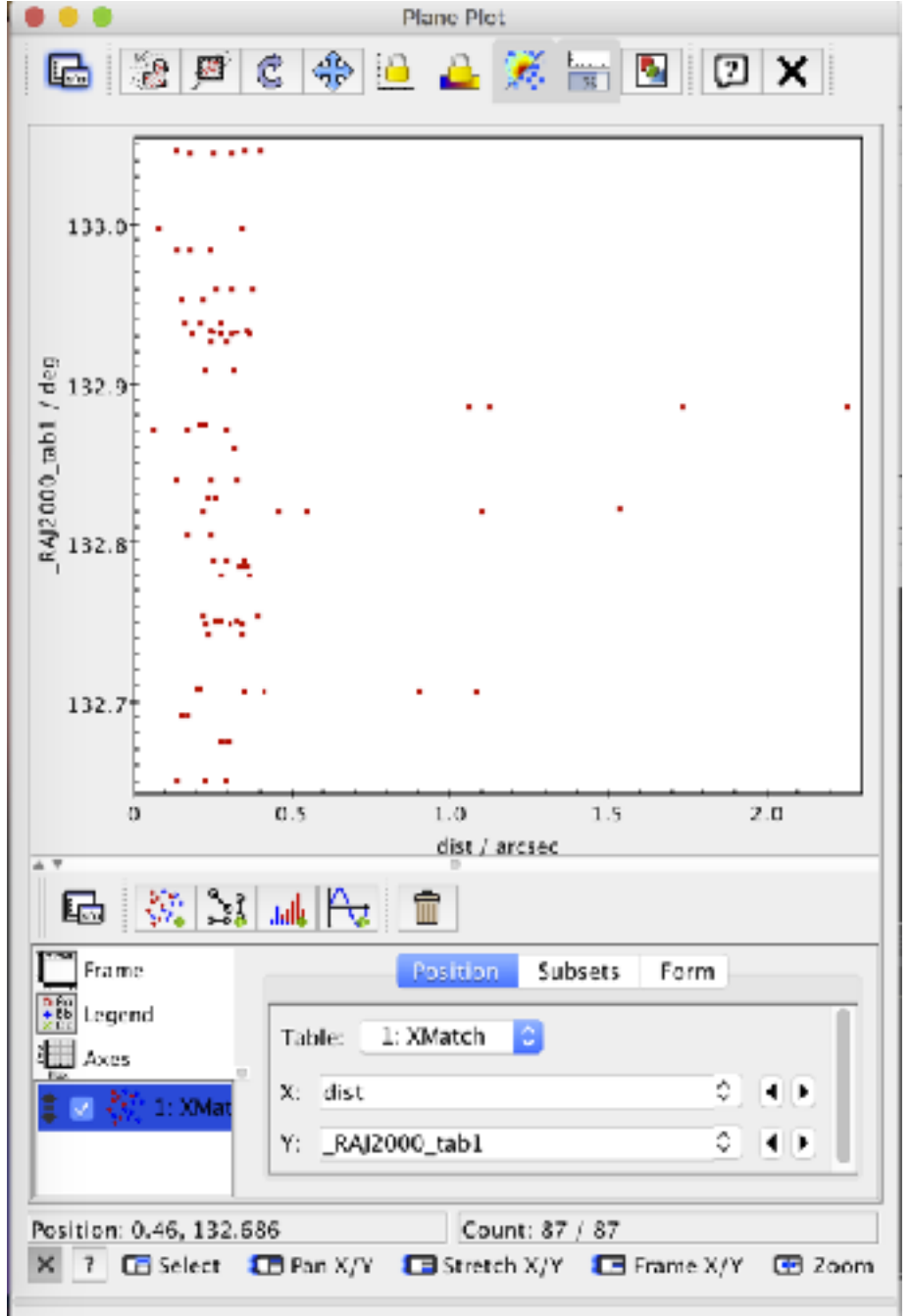






**This icon is for scatter plots.**

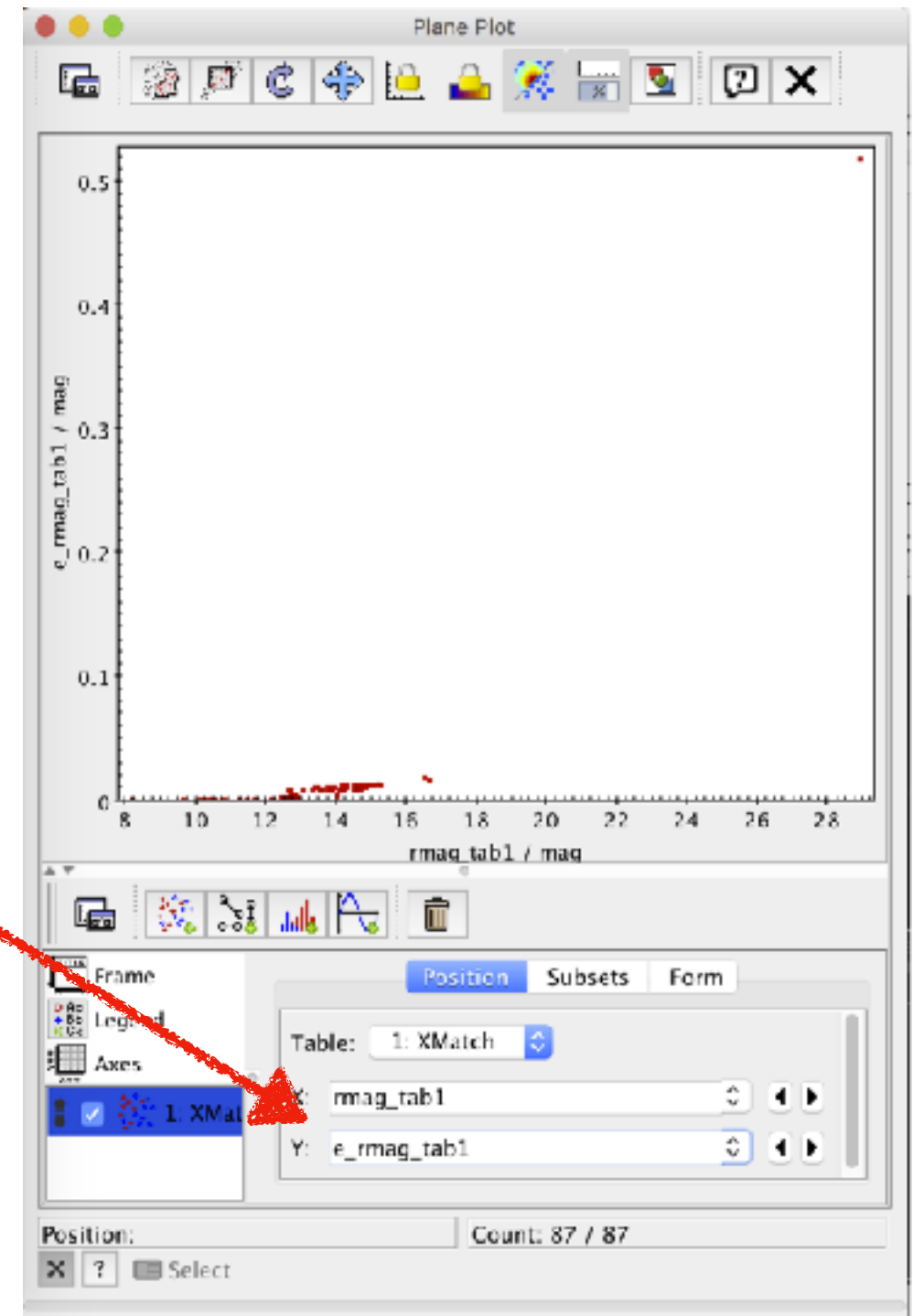
**Again, the default is not very useful.**



Here I plot the error in r magnitude as function of r magnitude.

There is one outlier which creates problems.

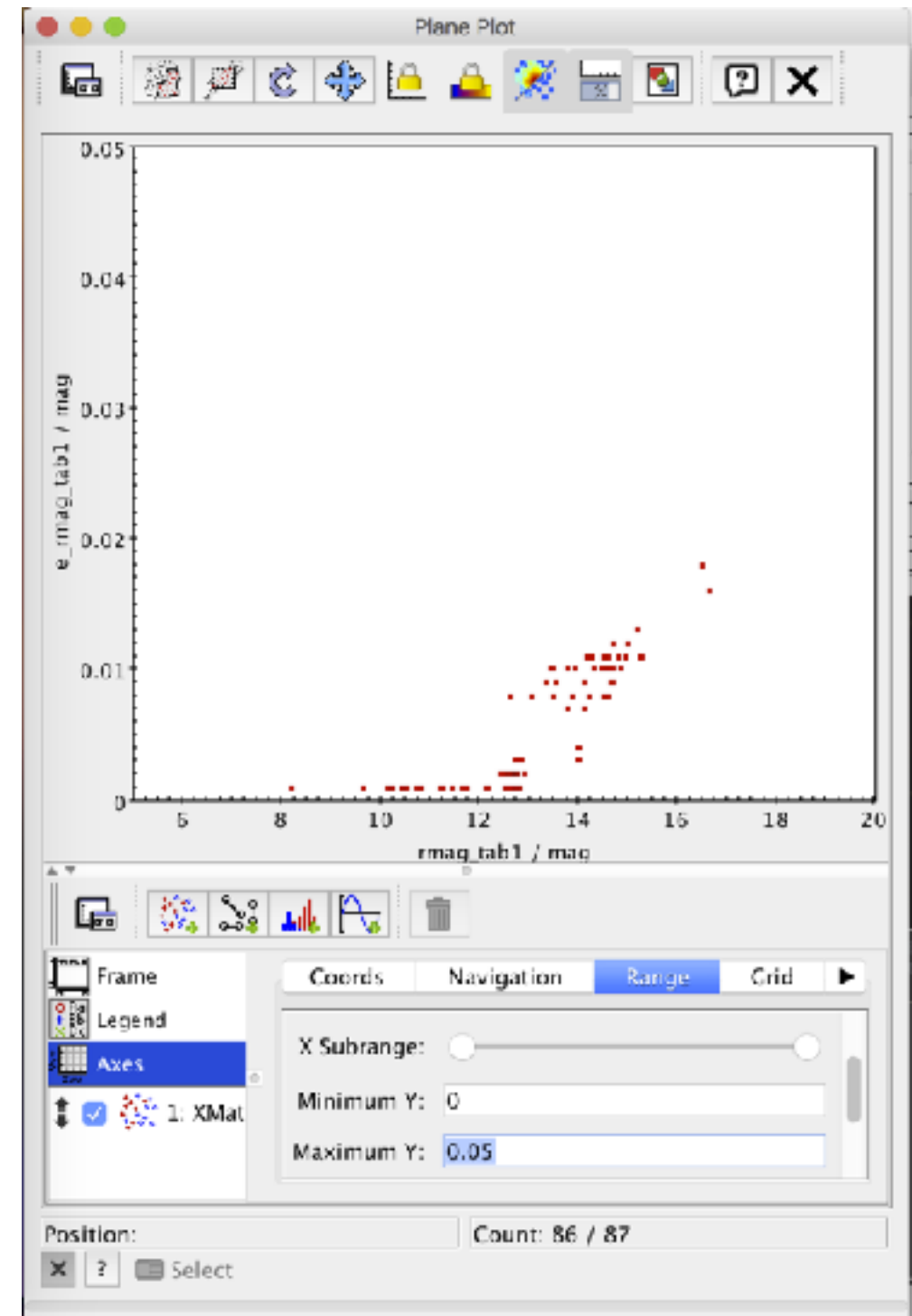
With the mouse I can zoom in and out to have a better look at my data.



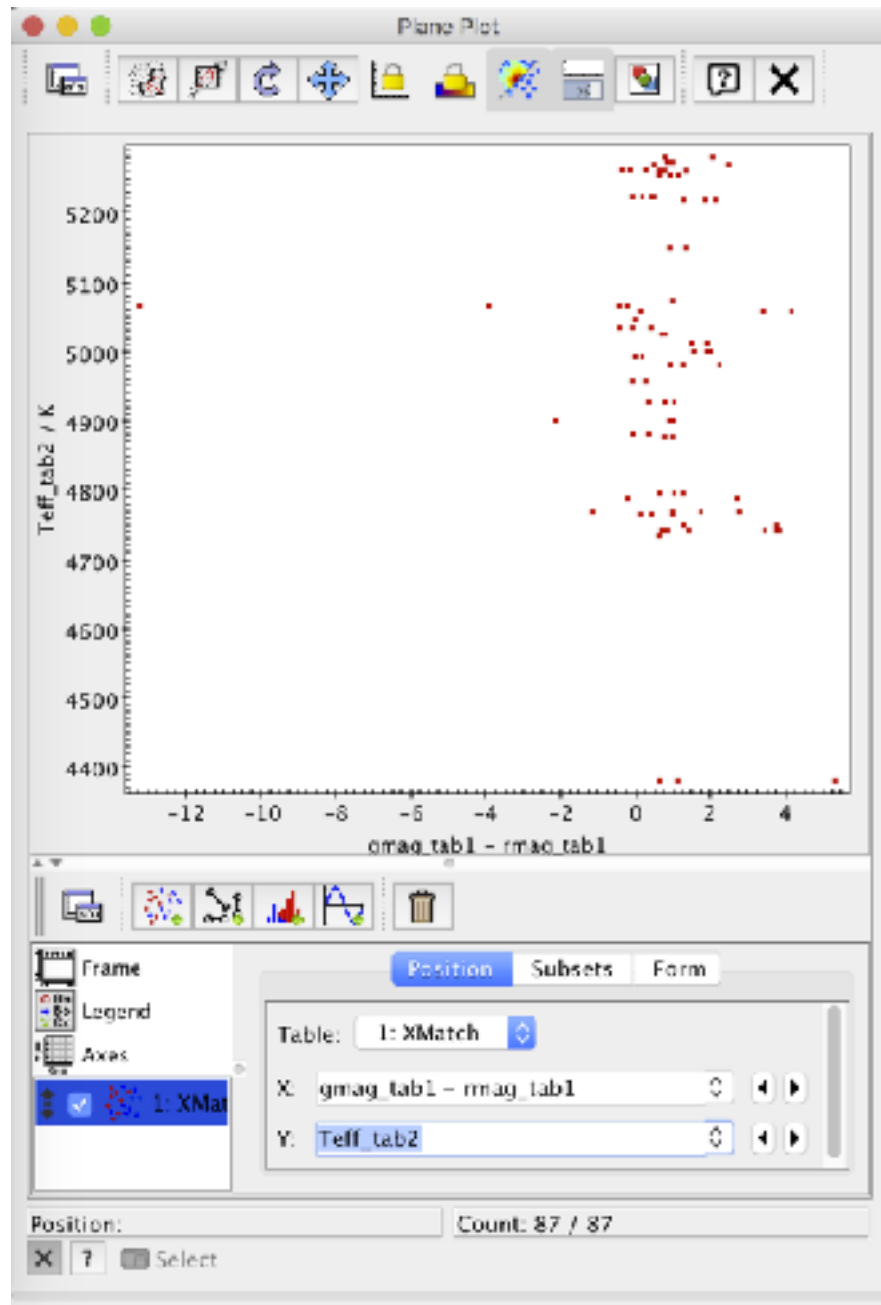
**You can go to  
“Axes” -> “Range”  
and adjust the  
limits by hand.**

**In this example I  
use:**

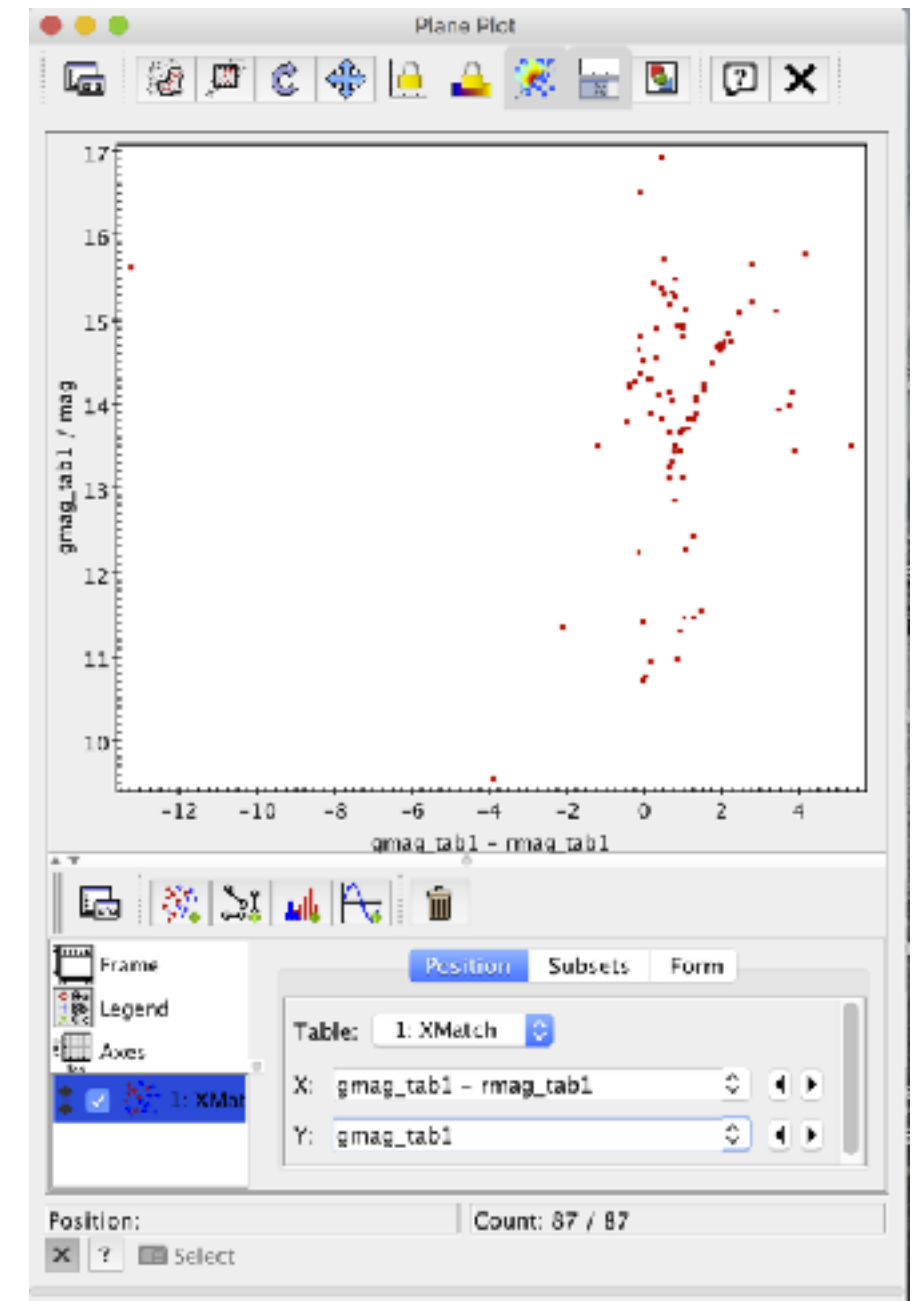
**minimum X: 5  
maximum X: 20  
minimum Y: 0  
maximum Y: 0.05**





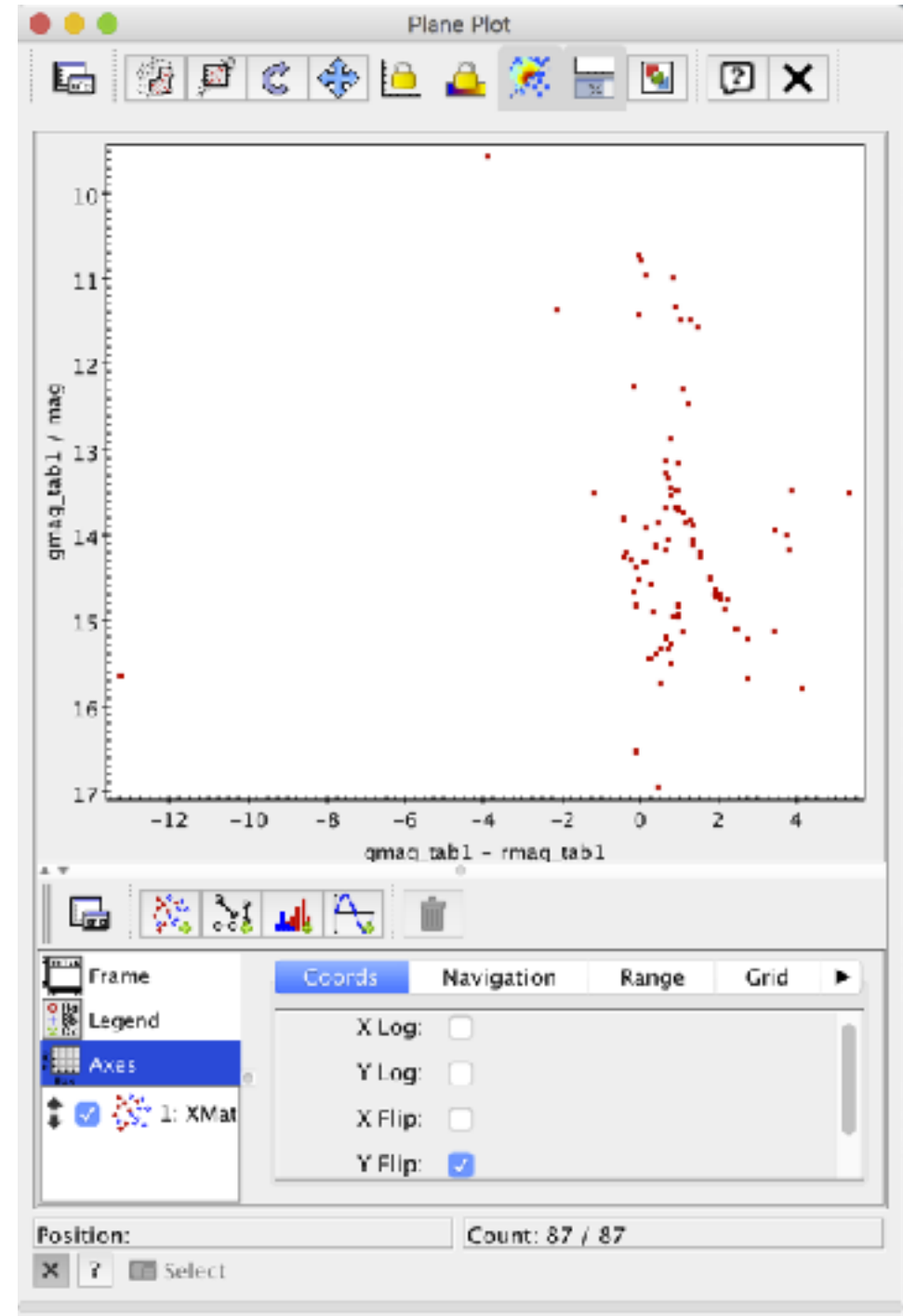


**As we said, we can also use algebraic expressions: so we can compare the effective temperatures with the g-r colour or make a colour-magnitude diagram**



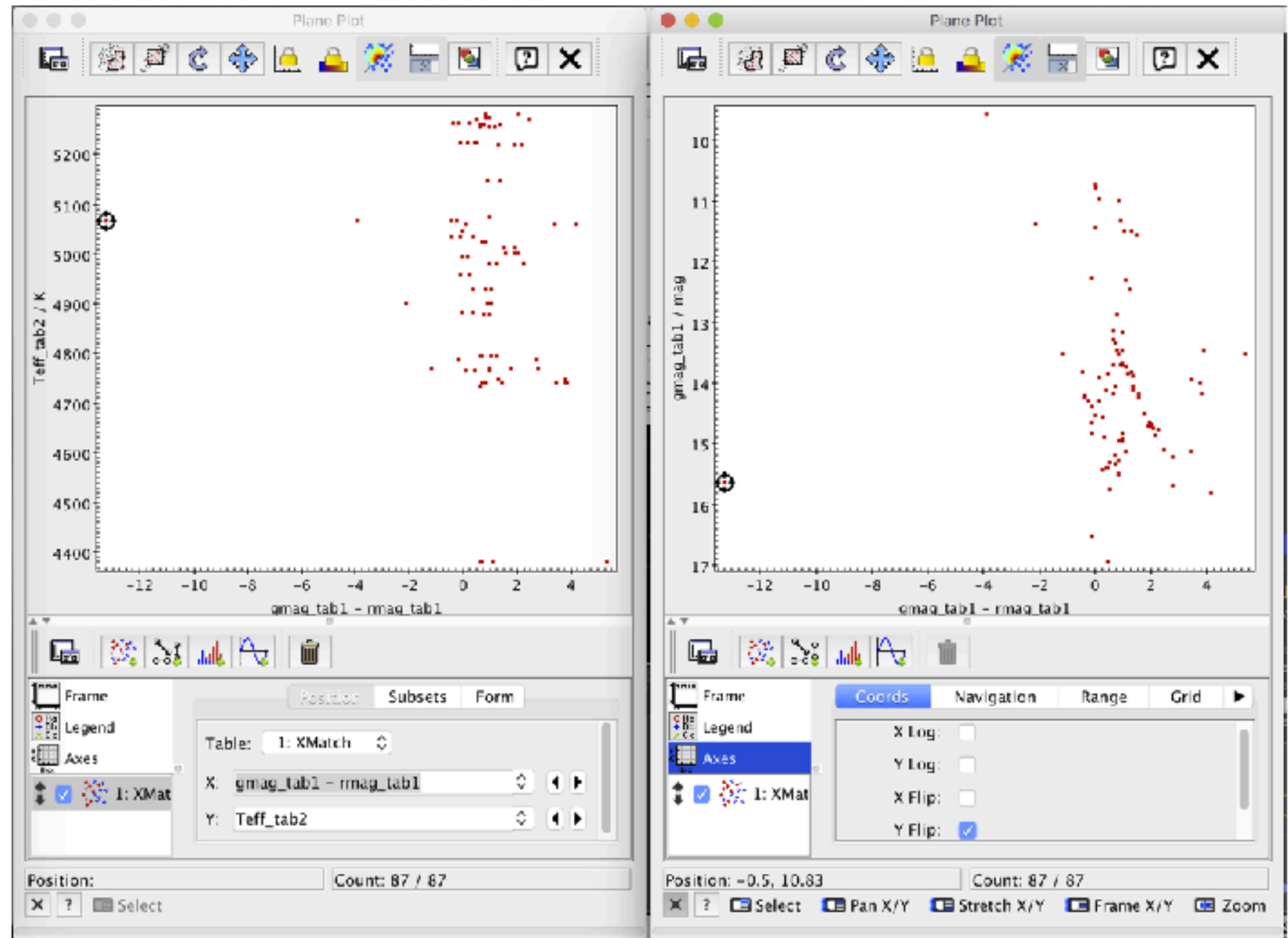
... but the colour magnitude diagram looks weird, right?

To get magnitude decreasing as y increases, we just go to “Axes” -> “Coords” -> “Y flip”



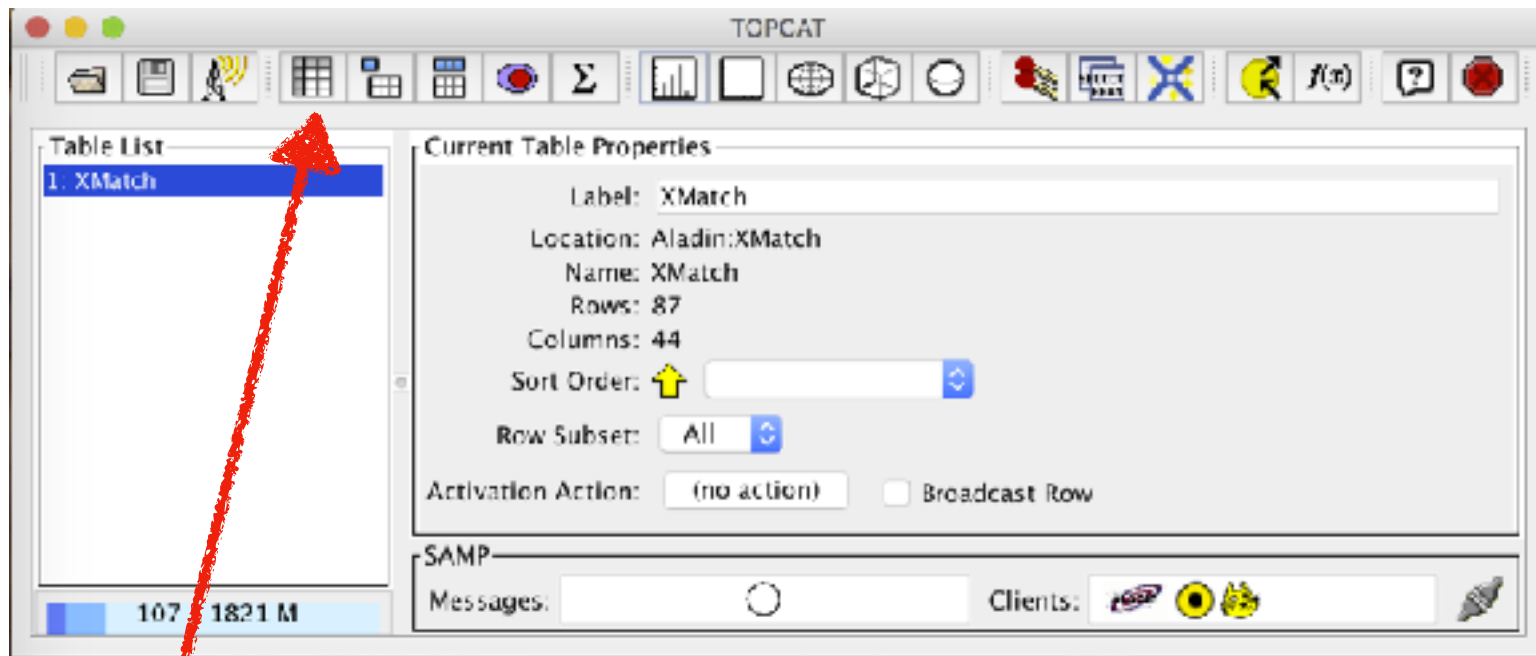
that outlier is a bit disturbing...

(good thing, you click on one plot, and it gets marked on the other)



The 2.5" distance between the matches in our two tables suggests that it is not the same object (you could have told from the image already)

This button allows you to browse through your table. If you click on the outlier in your plot, it will be highlighted in the table!

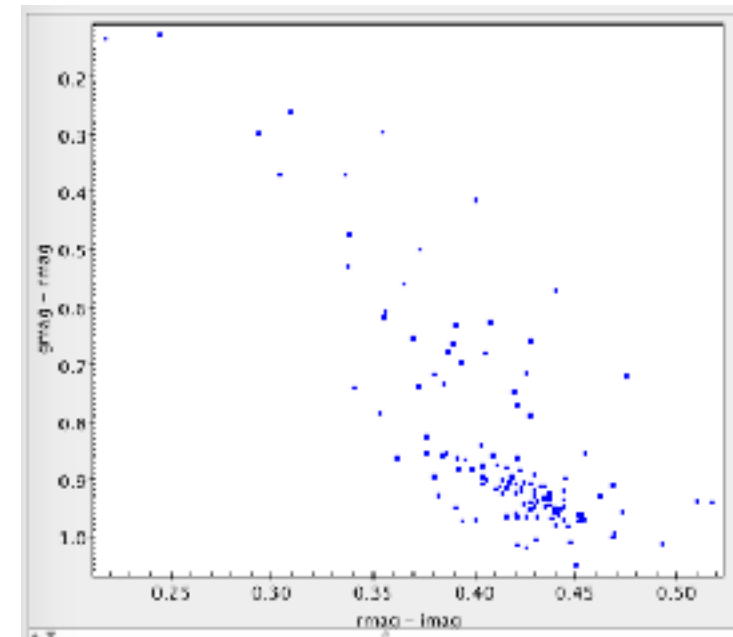
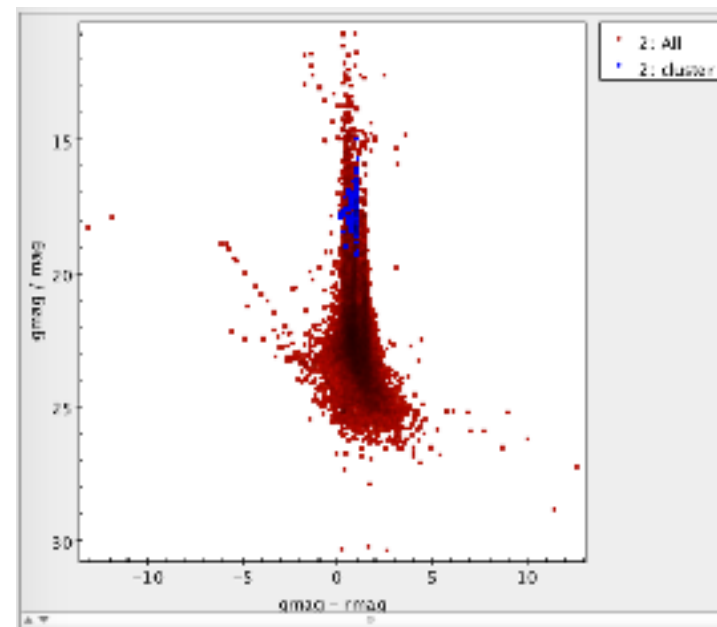
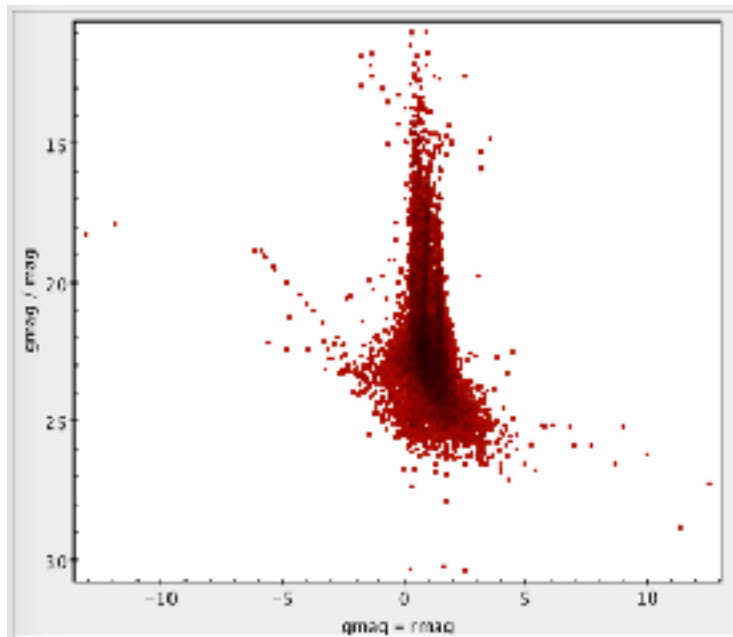


The screenshot shows the 'Table Browser for 1: XMatch' window. It displays a table with columns: dist, RA\_2000 tab1, DEJ2000 tab1, V tab1, mode t..., q mode..., cl tab1, and SDSS8 tab1. Row 56 is highlighted in blue, corresponding to a distance of 2.2553. A red arrow points from the 'XMatch' table in the previous screenshot to this row.

	dist	RA_2000 tab1	DEJ2000 tab1	V tab1	mode t...	q mode...	cl tab1	SDSS8 tab1
50	0.2703	132.93777	11.79601	VizieR	1		6	J085145.06+114745.6
51	0.1561	132.93779	11.79604	VizieR	2		6	J085145.07+114745.7
52	0.21	132.93775	11.79612	VizieR	2		6	J085145.06+114746.0
53	1.1207	132.8859	11.81415	VizieR	2		6	J085132.61+114850.9
54	1.0504	132.88588	11.81416	VizieR	1		3	J085132.61+114850.9
55	1.73	132.88568	11.81491	VizieR	1		3	J085132.56+114853.6
56	2.2553	132.8859	11.81506	VizieR	2		6	J085132.61+114854.2
57	0.2069	132.70807	11.82014	VizieR	2		6	J085049.93+114912.5
58	0.1947	132.70805	11.82024	VizieR	1		6	J085049.93+114912.8
59	0.2934	132.92635	11.83549	VizieR	2		6	J085142.32+115007.7
60	0.2463	132.92637	11.8355	VizieR	1		6	J085142.32+115007.7
61	0.2168	132.75438	11.83629	VizieR	2		6	J085101.05+115010.6
62	0.3903	132.75433	11.8364	VizieR	1		6	J085101.03+115011.0

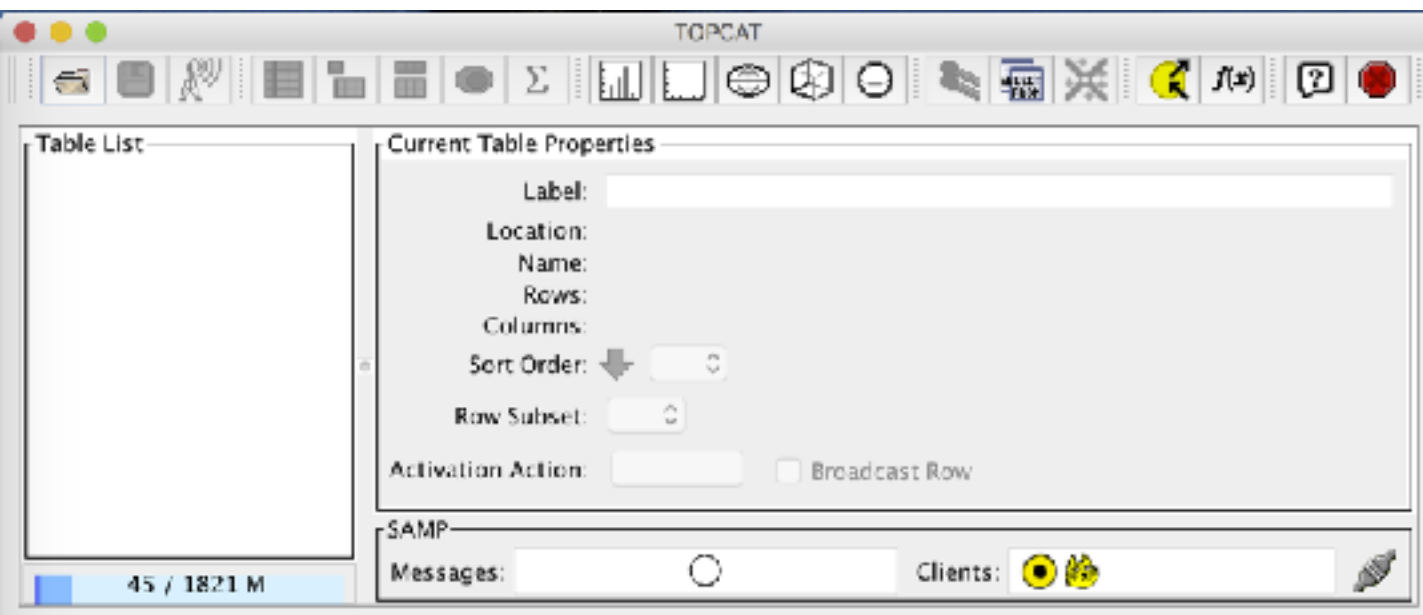
# Exercise #1

- Can you make a colour magnitude (e.g.  $g$  vs.  $g-r$ ) and a colour colour magnitude diagram ( $g-r$  vs.  $r-i$ ) of the galaxy cluster Abell 2255?
- Can you make the same but mixing SDSS and AllWISE?



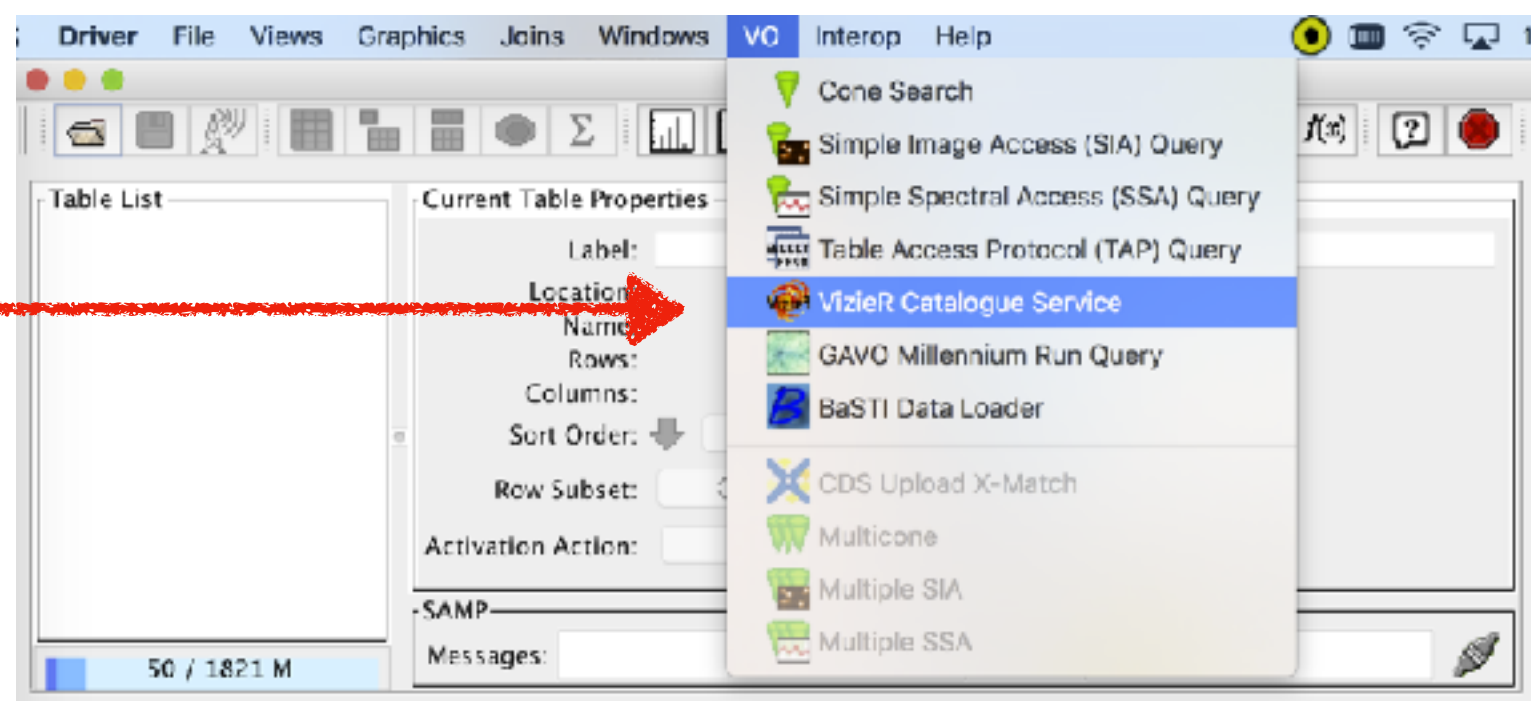
**Yes, there is a trick  
that you don't  
know yet**

**Example #2:**  
**Bright Stars Catalog**



With a nice clean start of Topcat

Look for VizieR Catalogue Service



**This window has a lot of interesting features.**

**We only care for:**  
-) get “all rows”  
-) get an unlimited number of sources we can download  
-) output columns “standard”

The screenshot shows the VizieR Catalogue Service window. The 'VizieR Server' field is set to 'http://vizier.u-strasbg.fr/'. Under 'Row Selection', 'Cone Selection' is selected, and 'All Rows' is also selected. The 'Maximum Row Count' is set to 50000. Under 'Column Selection', 'Output Columns' is set to 'standard'. The 'Catalogue Selection' section shows 'By Category' selected, with 'Radio', 'Millimeter', and 'IR' checked under 'Wavelength', 'AKARI', 'ANS', and 'ASCA' under 'Mission', and 'Abundances', 'Ages', and 'AGN' under 'Astronomy'. The 'Search Catalogues' button is visible. At the bottom, there is an 'OK' button.

Wavelength: Radio, Millimeter, IR  
Mission: AKARI, ANS, ASCA  
Astronomy: Abundances, Ages, AGN

Sub-Table Details:  Include Obsolete Tables:

Search Catalogues Cancel Search

Name	Popularity	Density	Description	Wavelengths	Astronomy
------	------------	---------	-------------	-------------	-----------



We search for  
“bright stars”

We find our  
catalogue and click  
on “ok”

We can order by  
“popularity”

VizieR Catalogue Service

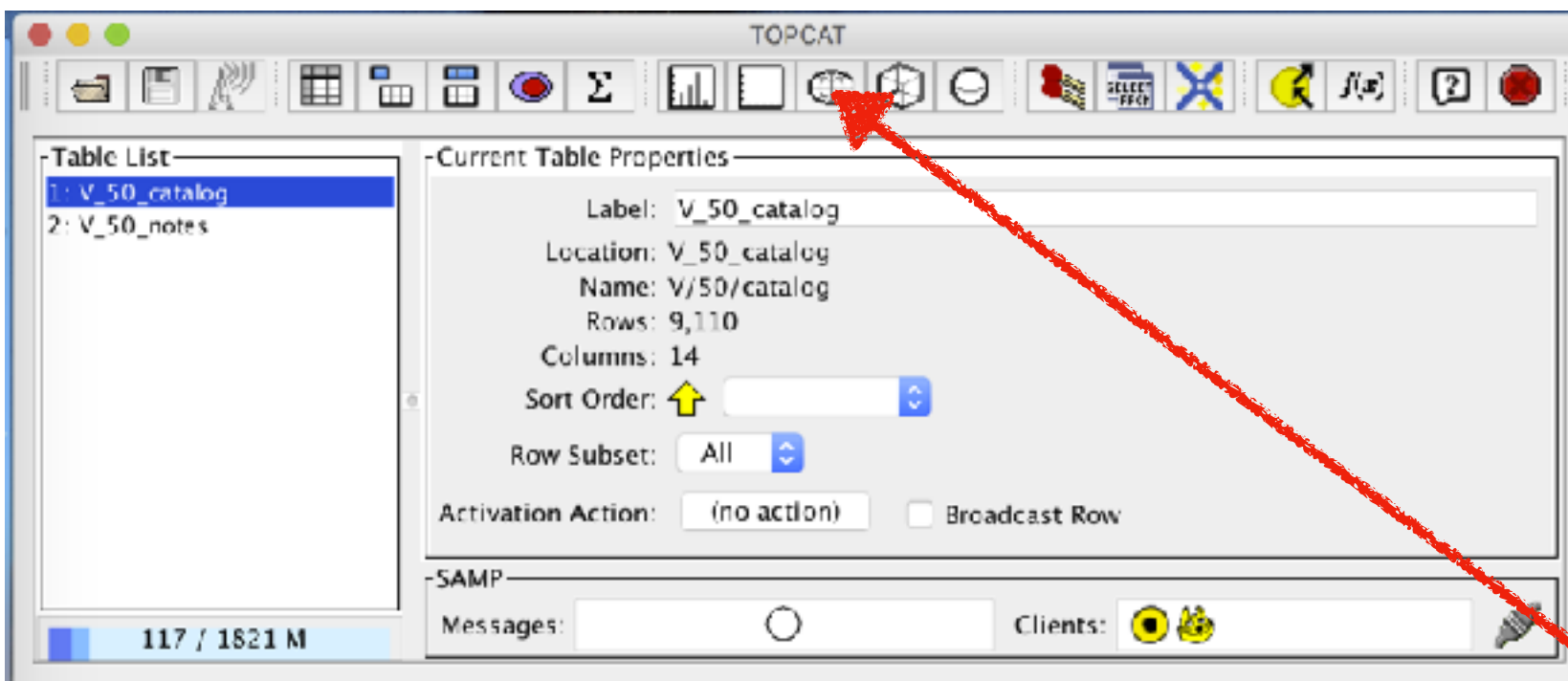
VizieR Server  
Server:

Row Selection  
 Cone Selection  
Object Name:  Resolve  
RA:  degrees (J2000)  
Dec:  degrees (J2000)  
Radius:  degrees  
 All Rows  
Maximum Row Count:

Column Selection  
Output Columns:

Catalogue Selection  
By Category | **By Keyword** | Surveys | Missions  
Keywords:   
 Sub-Table Details  Include Obsolete Tables

Name	Popula...	Density	Description
V/137D	391327		0 Extended Hipparcos Compilation (XH
IV/38	334667		0 TESS Input Catalog - v6.0 (TIC-6) (St
J/AJ/156/102	294203		0 The TESS Input Catalog and Candidat
J/PASP/120/1128	180799		0 Calibrated griz magnitudes of Tycho :
<b>V/50</b>	<b>155593</b>		<b>0 Bright Star Catalogue, 5th Revised Ed</b>
I/294A	134951		0 The UCAC2 Bright Star Supplement (U
I/328	47206		0 Catalogue of bright IDS stars (Lipaeva



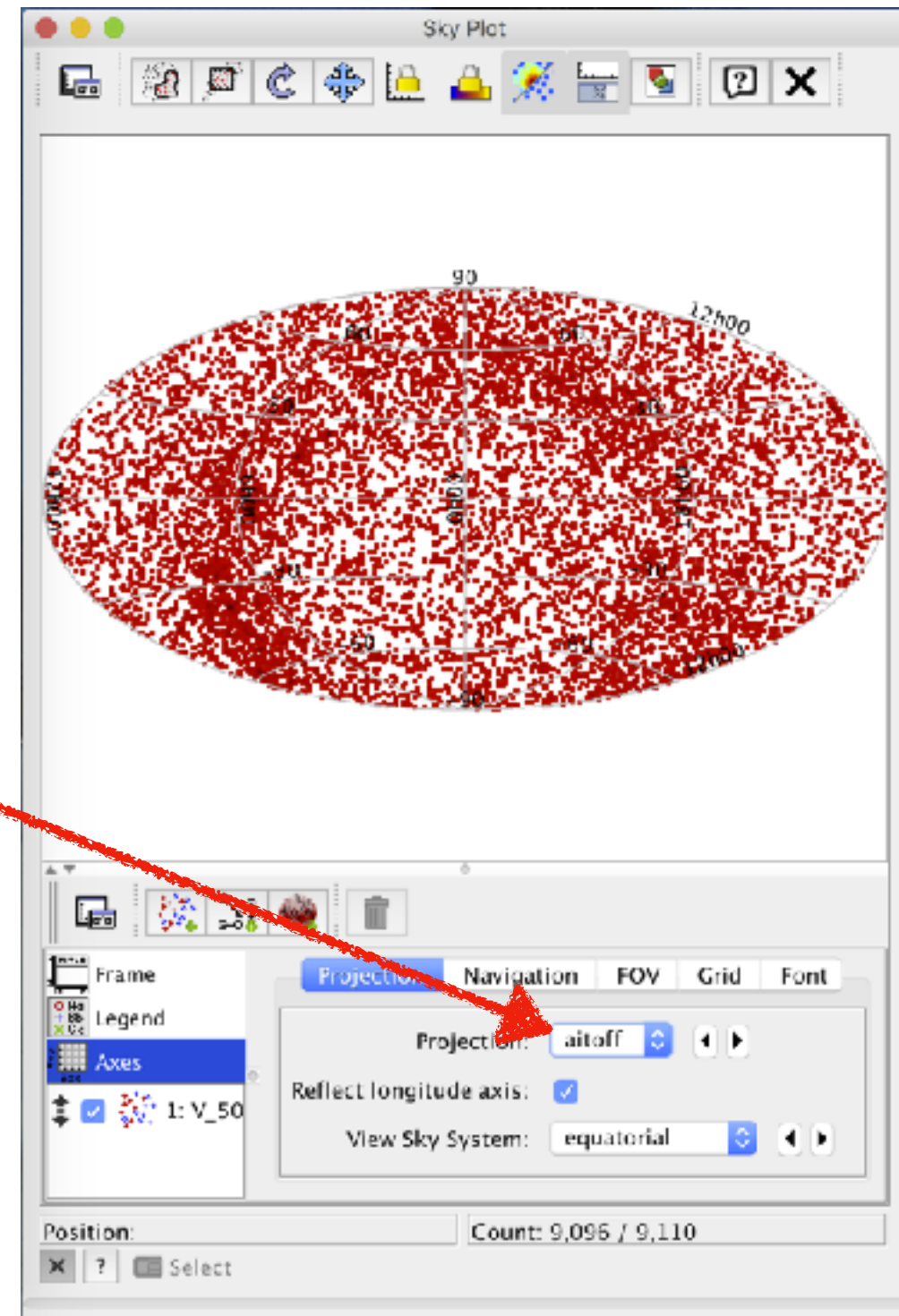
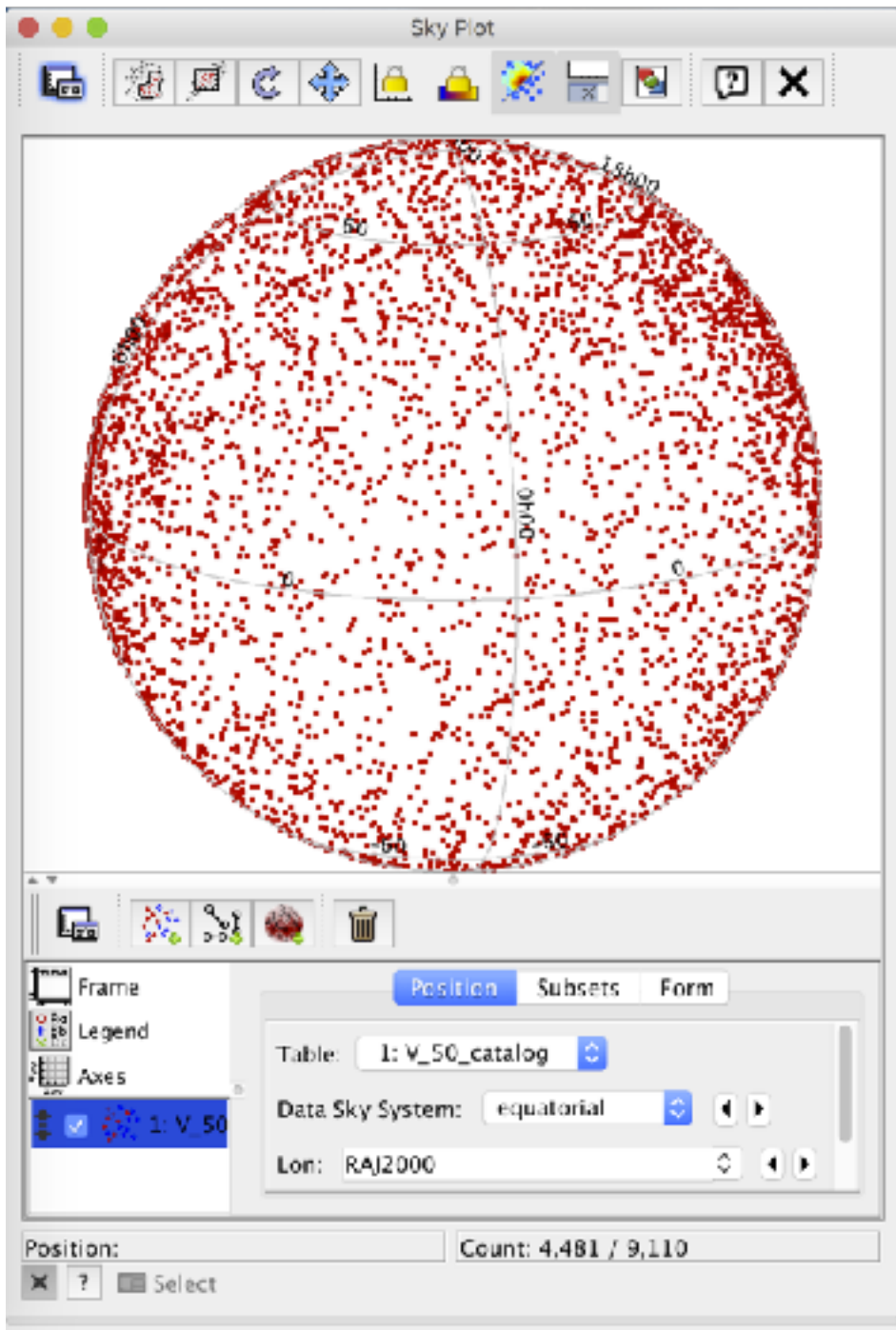
**It is a table of 9110 rows and 14 columns.**

**You already know how to display the table and check the meaning of its columns.**

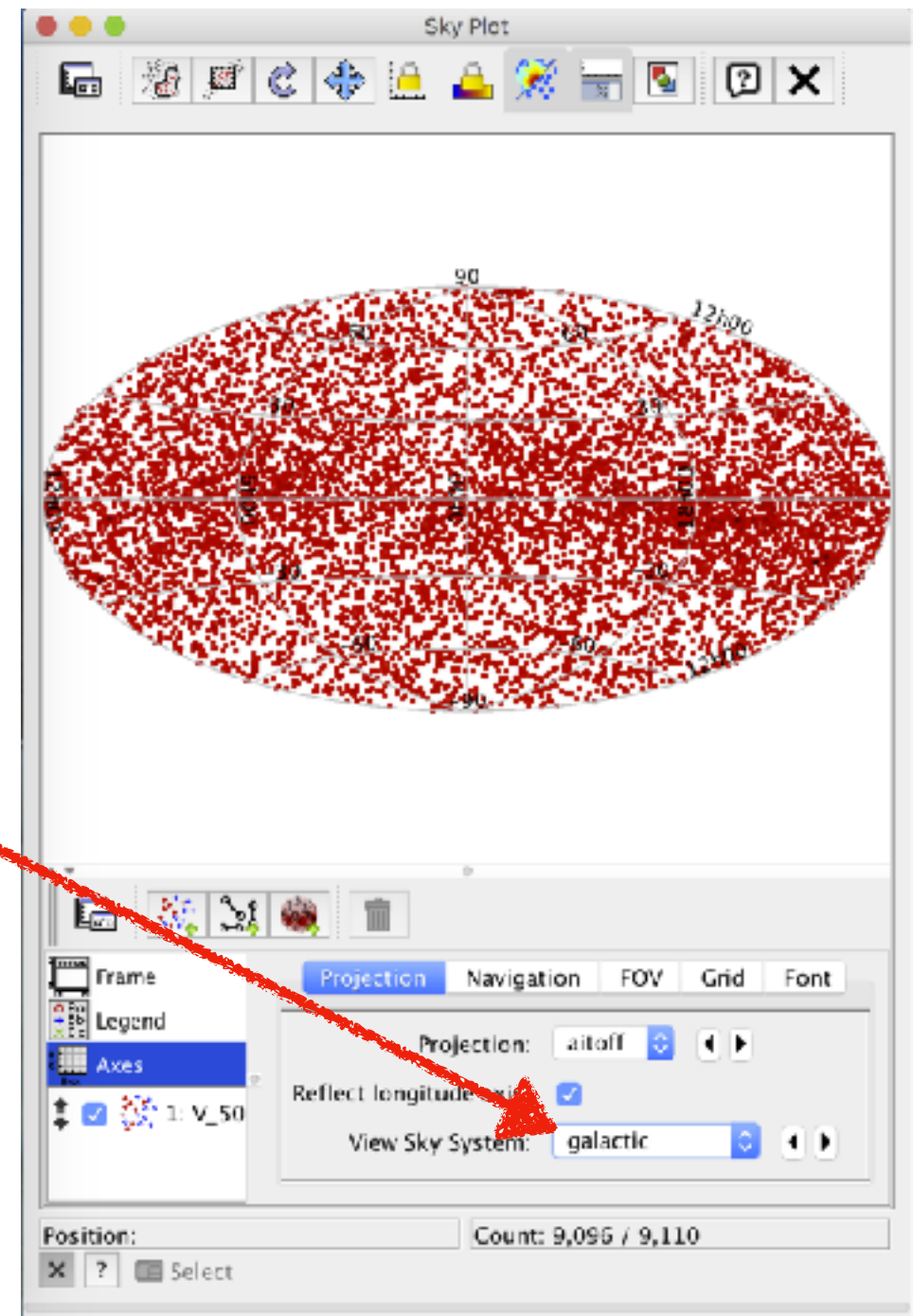
**So let's click on this other icon...**

**This is a sky projection. Yet a “ball with points” is not too helpful.**

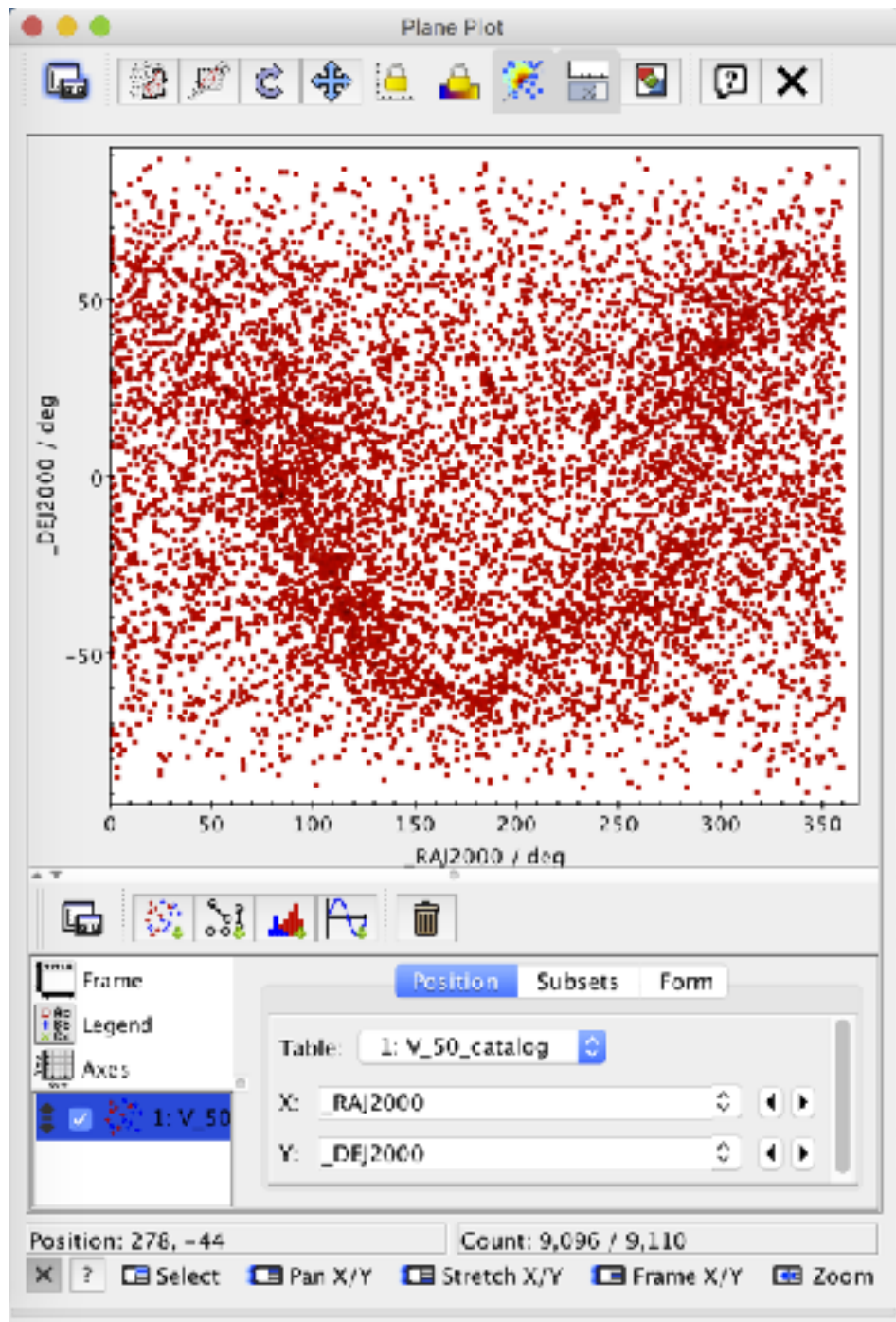
**If we go to “Axes” and ask for the “aitoff” projection, we can see it better. Can you recognise the plane of the Milky Way?**



**Can you see the Milky Way better if you use a Galactic reference system?**

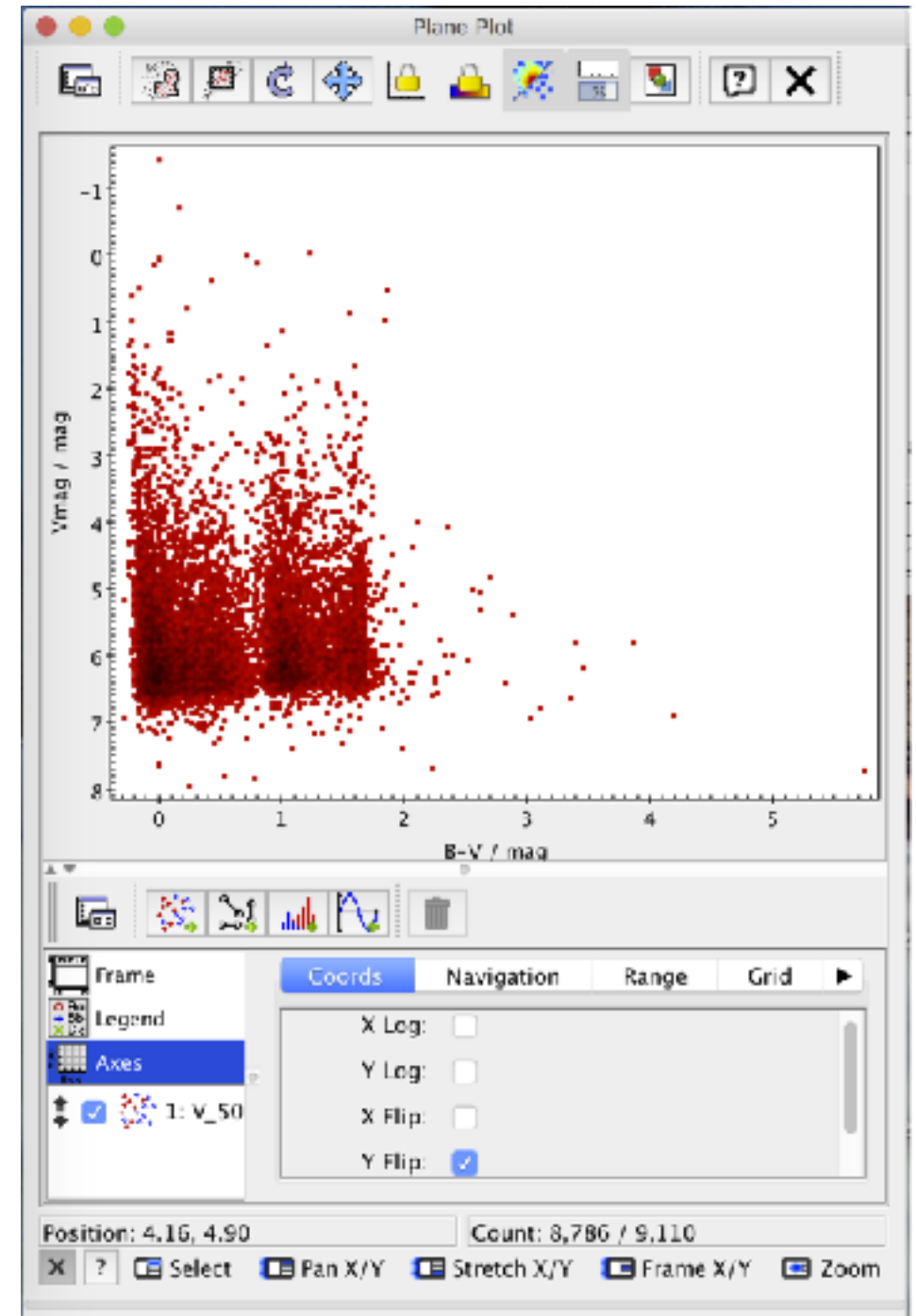




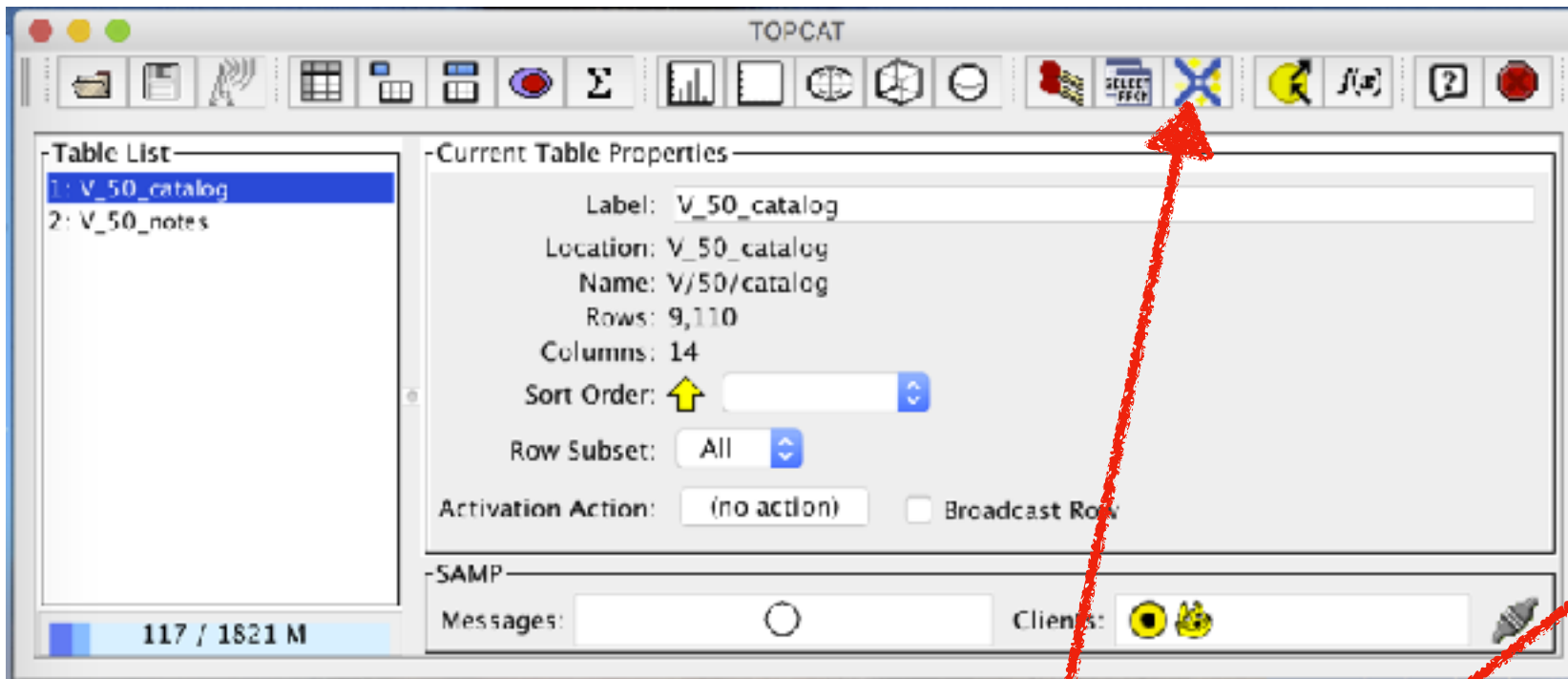


The default scatter plot [left] is nice (also here you can see the plane of the Milky Way) but let's see if we can get a colour-magnitude diagram [right].

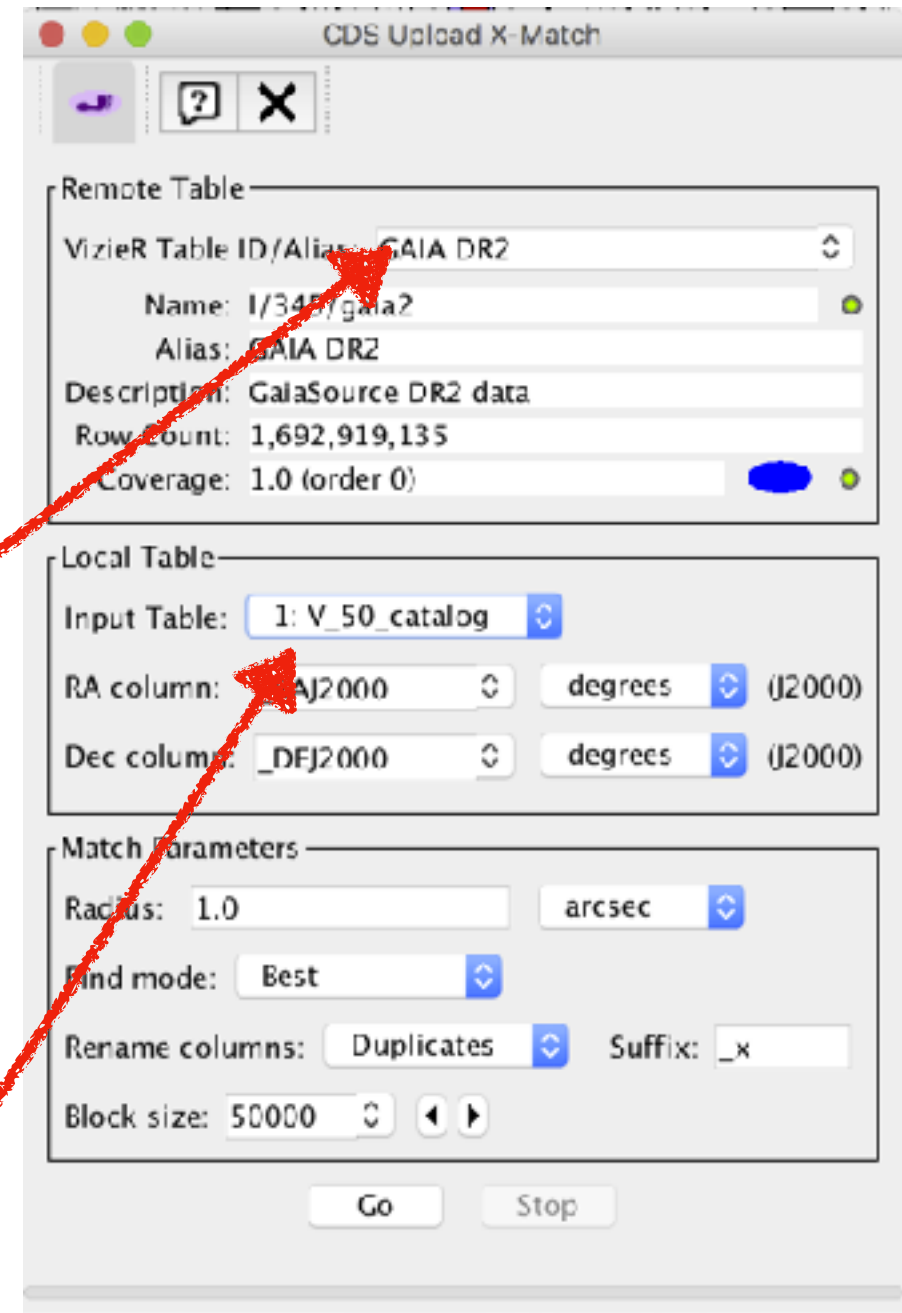
It does not look right. If only I could have distances...







To query very big tables, you can use this button.

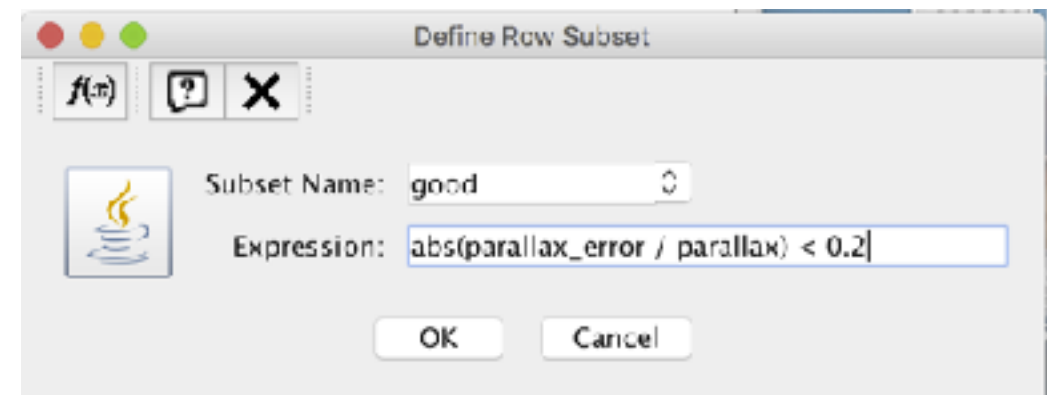
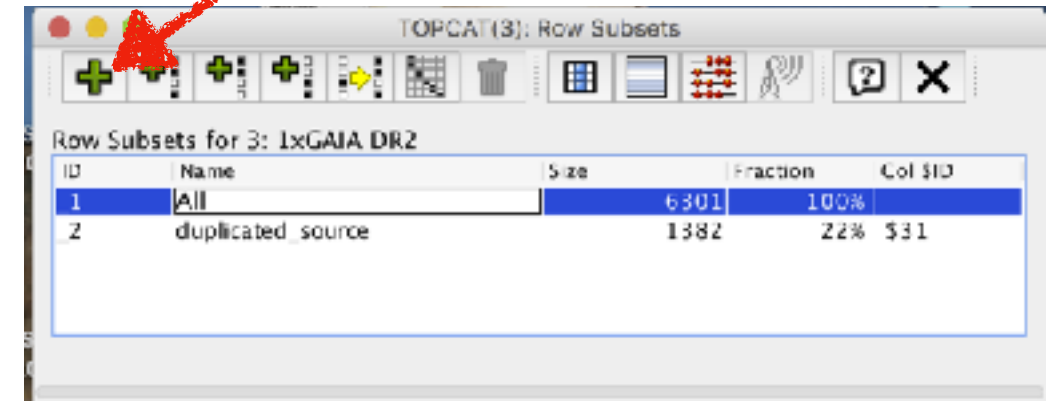
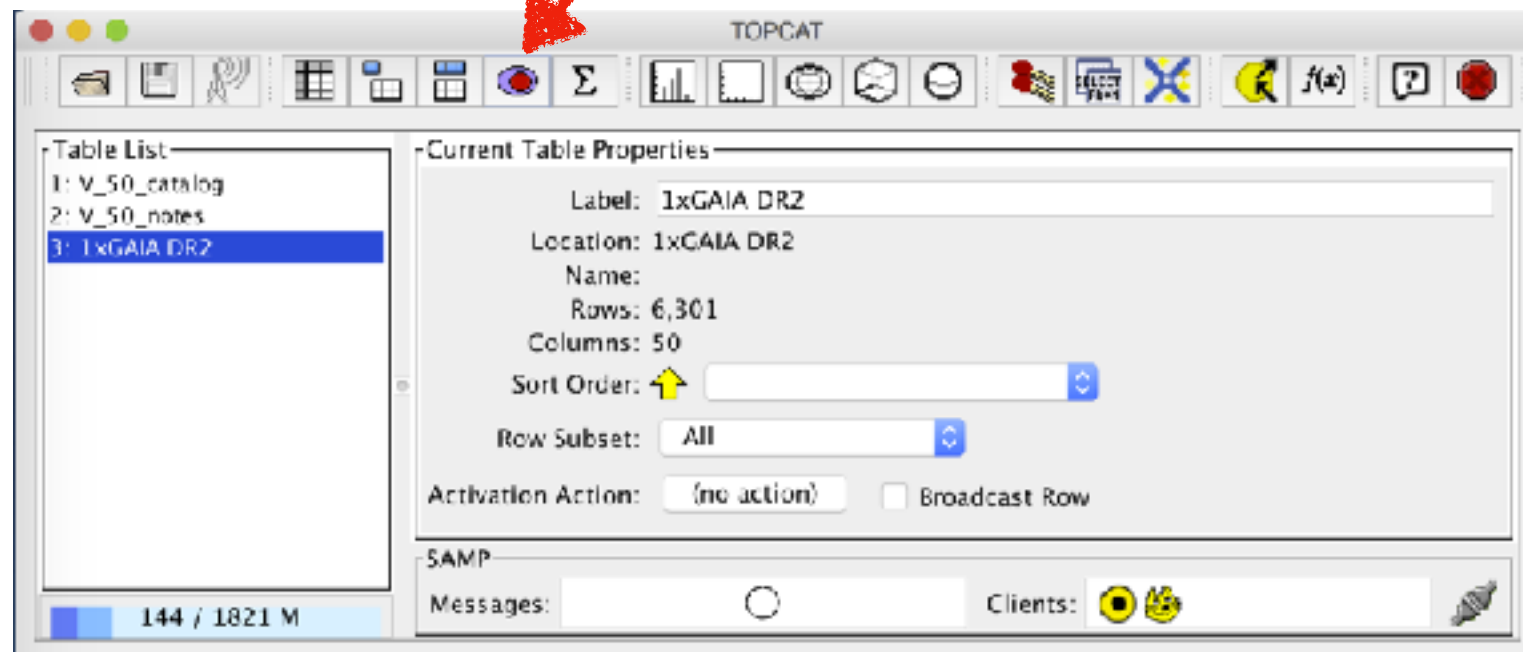


For this case we use Gaia DR2 (I know that there is a “distances” table but I prefer this one) and our table...  
... and click on “Ok”

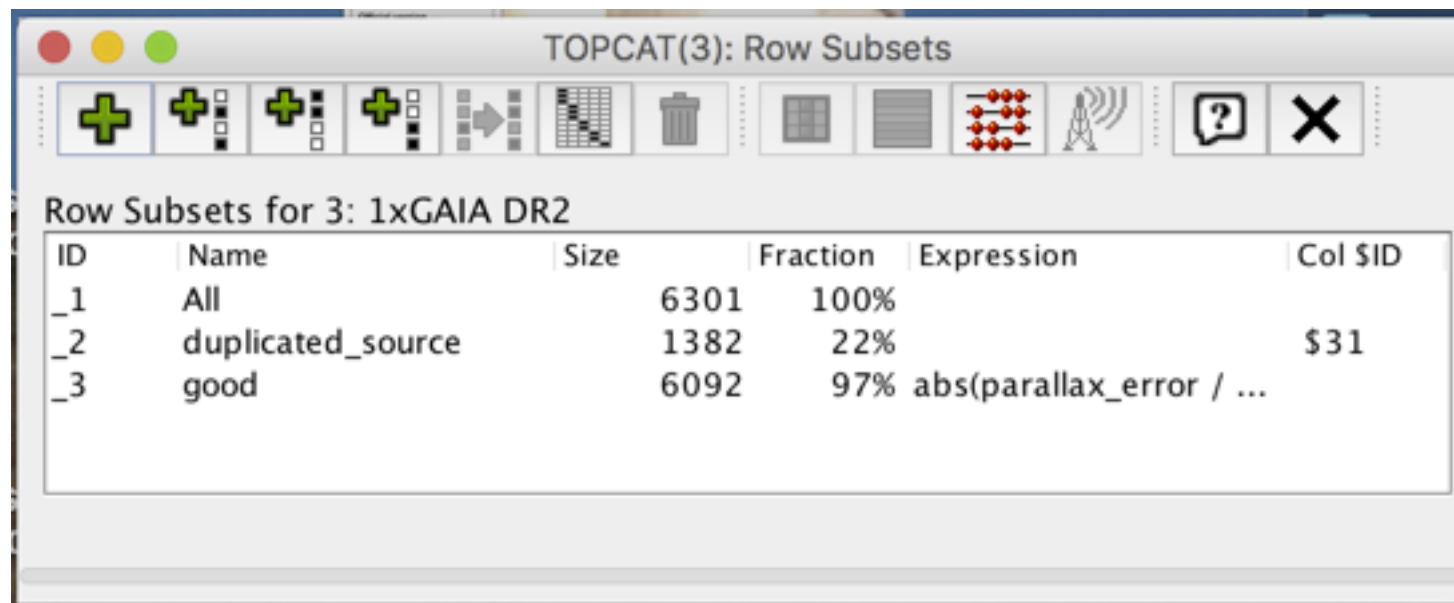
Luri et al. (2018) have shown that, in Gaia DR2, you can assume that the distance is the inverse of the parallax only if the error on the parallax is smaller than 20%.

We need to make a subsample... and we do it using this button.

Select the first line and click on the “+”



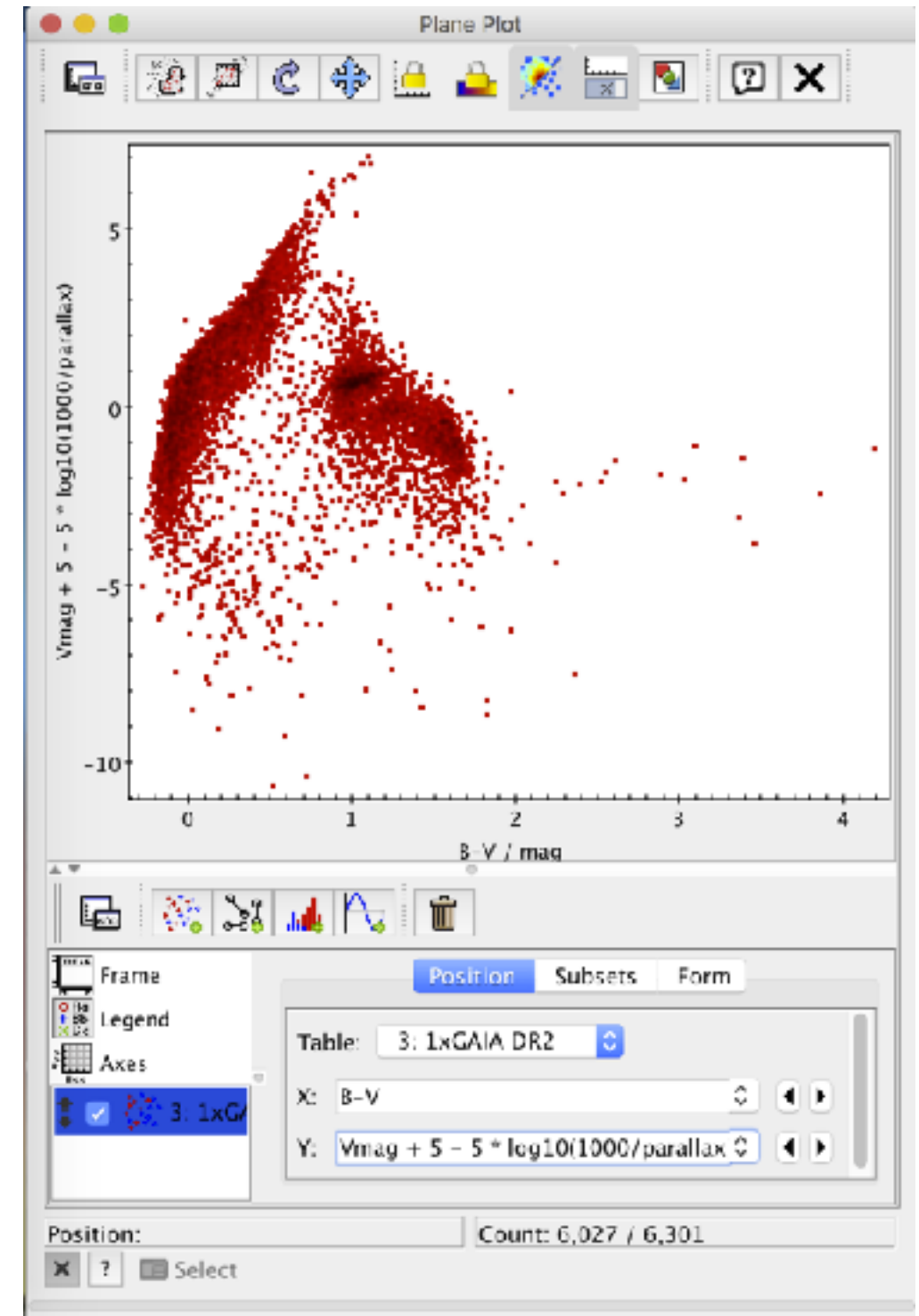
After you click on “ok”, your sub-sample “good” is going to have 6092 objects.



ID	Name	Size	Fraction	Expression	Col SID
_1	All	6301	100%		
_2	duplicated_source	1382	22%		\$31
_3	good	6092	97%	abs(parallax_error / ...	

Let's try again to make a colour-magnitude diagram.

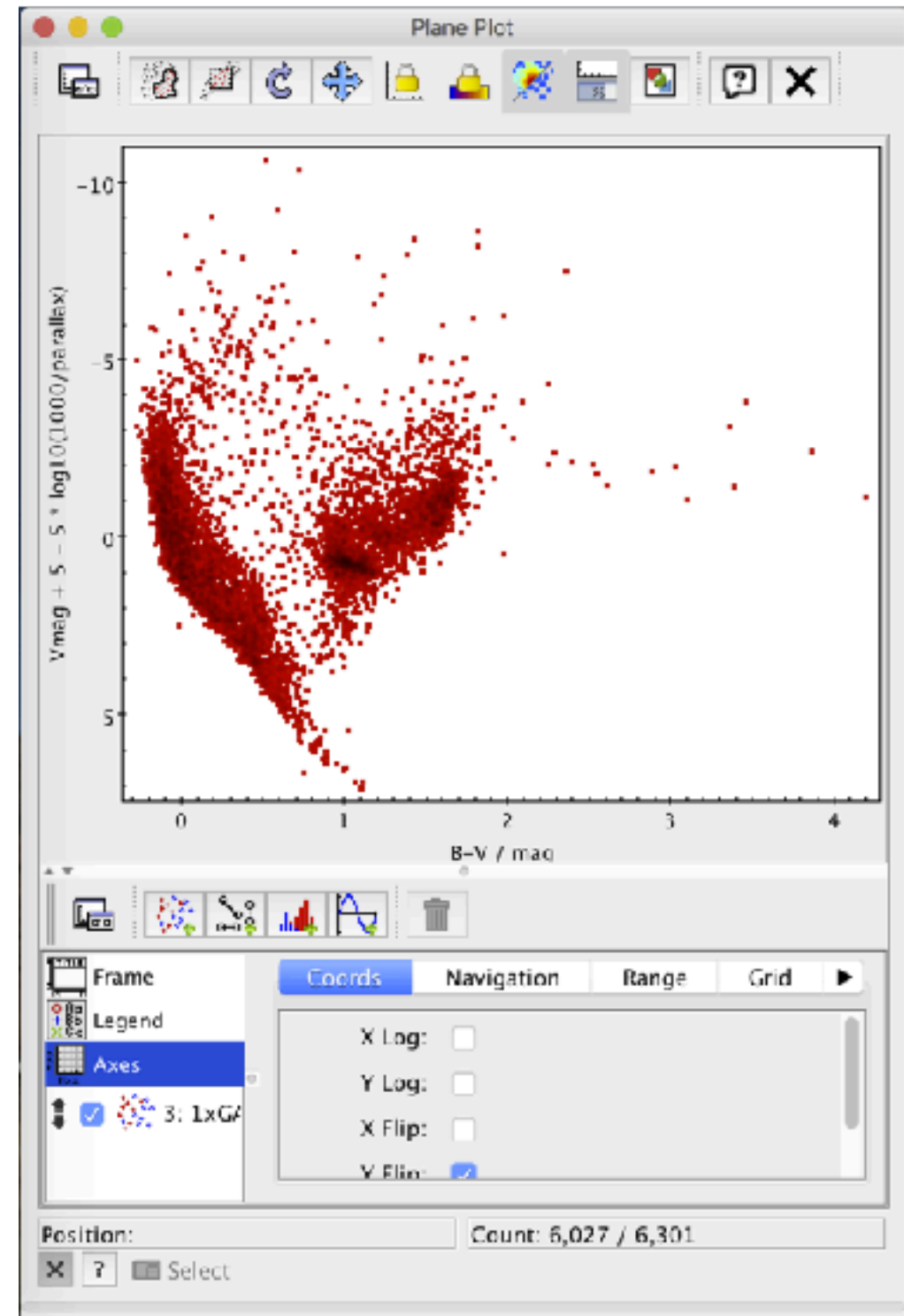
There are two issues with the plot at our right. Can you spot them?



The first one is easy: the y-axis was not the one we, astronomers, are used to.

The usual “Axes” -> “Coords” -> “Y Flip” fixes it.

The second is less trivial.

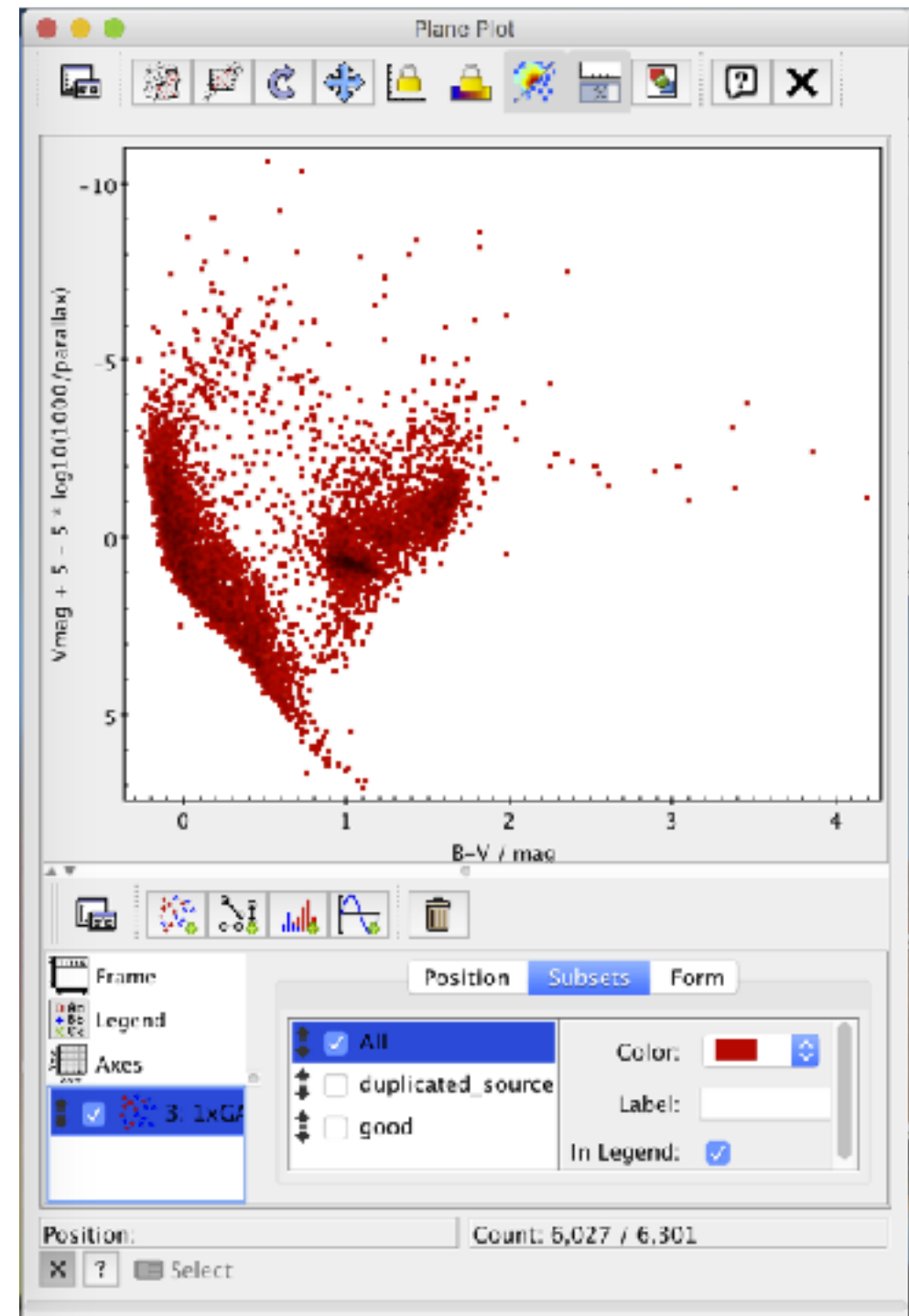


Go back to where you were inserting the columns to plot.

Go to “subset”.

You see now that you are plotting all the data, not only the good ones.

Let's plot only the good ones.

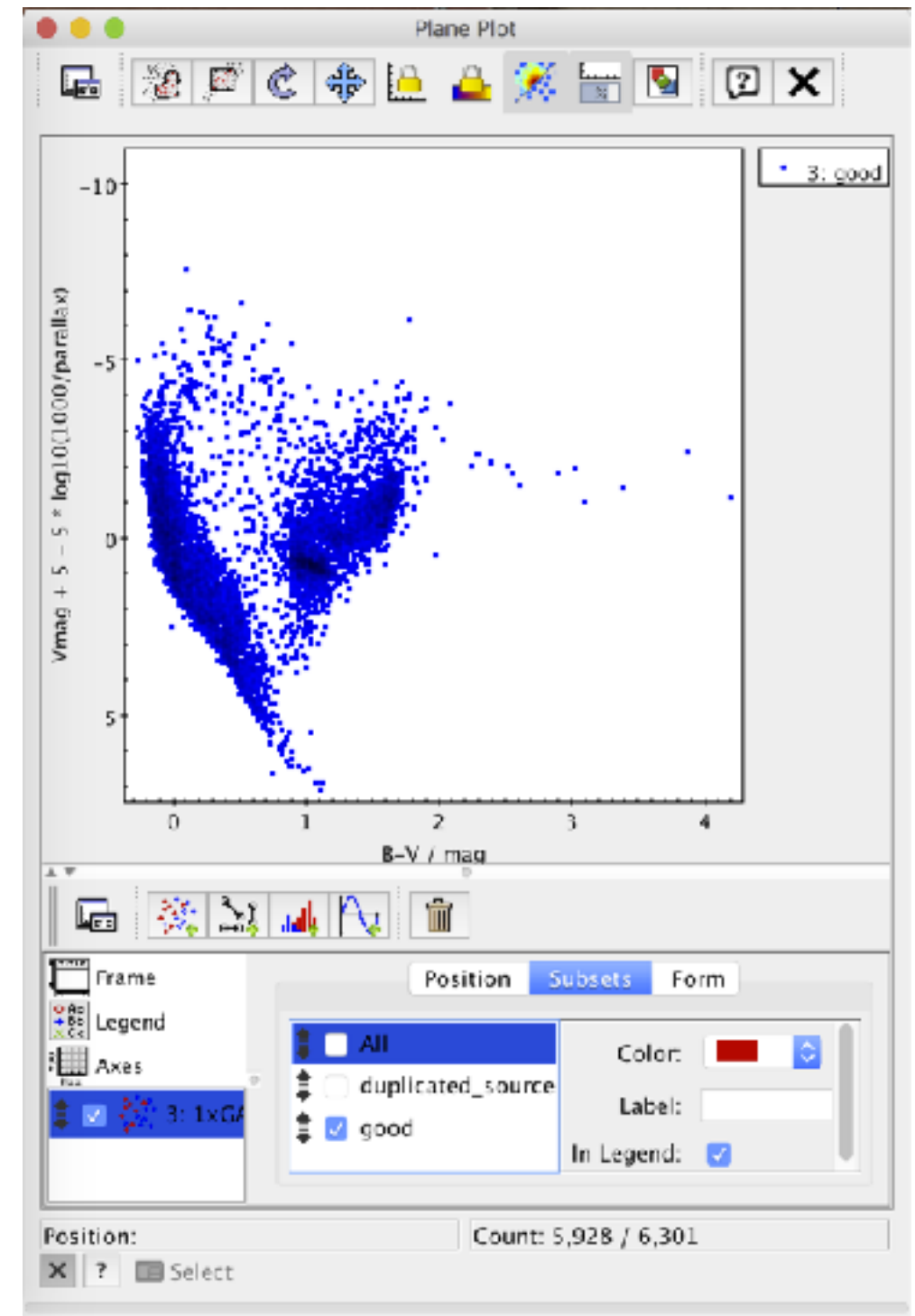


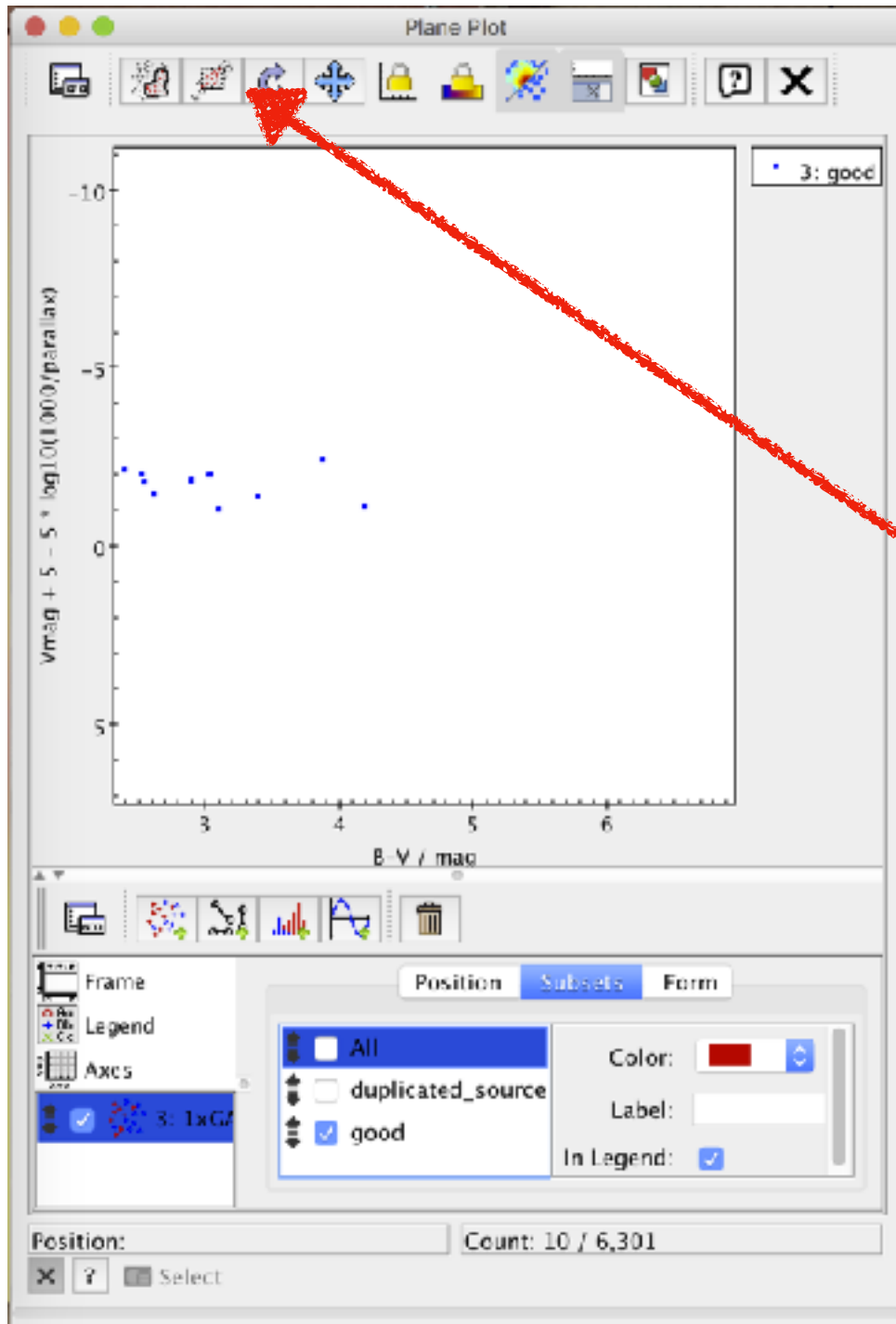


**Just tick on “good” and untick “All”.**

**I find these objects with  $B-V > 2.5$  very intriguing.**

**Select only that region (either with “Axes” or zooming with the mouse).**

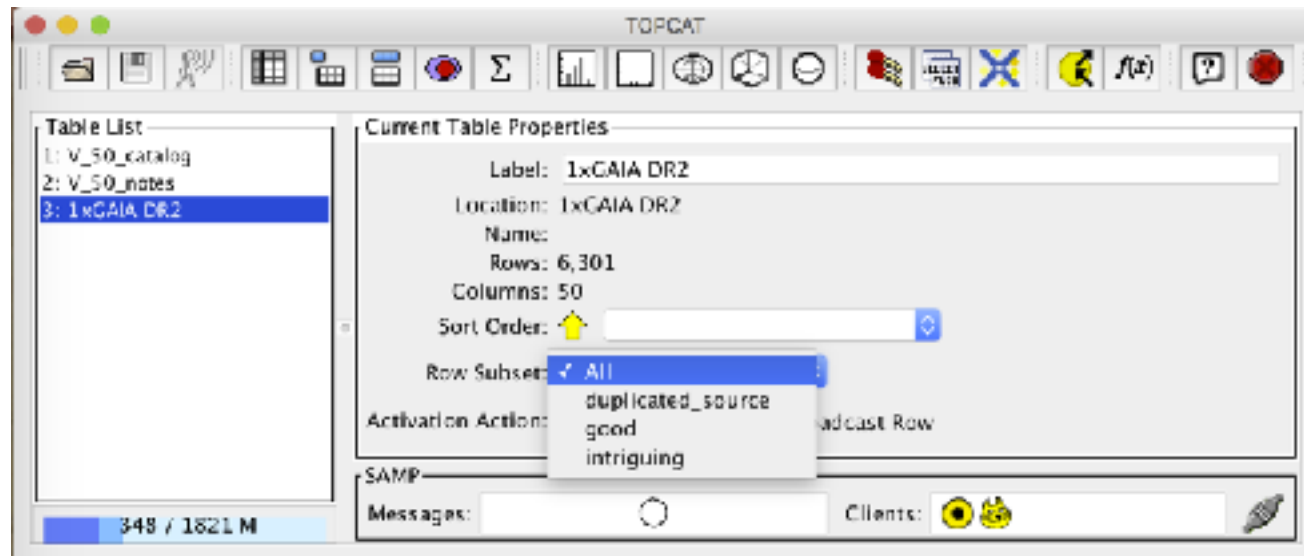




The 'New Subset' dialog box has a title bar with the text 'New Subset'. It contains a text input field for 'New Subset Name' with the value 'intriguing'. Below this are three buttons: 'Add Subset', 'Add and Set Current Subset', and 'Transmit Subset'. To the right of the 'Transmit Subset' button is a dropdown menu currently showing 'All Clients'. At the bottom right is a 'Cancel' button. A red arrow points to the 'Add Subset' button.

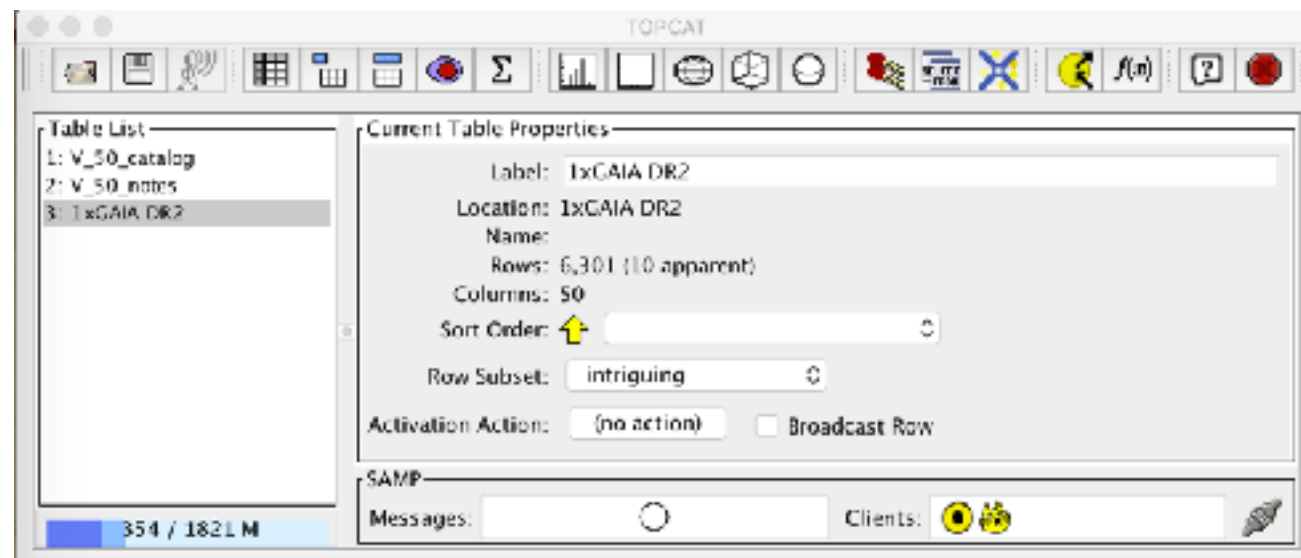
**Click on this button and this window will open.**

**Name the new subset "intriguing" and click on "Add Subset"**



If I pick only this “intriguing” subset, I see that there are only 10 stars and all (but one) are carbon stars.

The one which is not a carbon star is HD 91793.



Let's check her out on Simbad (which, by the way, is a VO-service)

TOPCAT(3): Table Browser

Table Browser for 3: 1xGAIA DR2



	RAJ2000	DEJ2000	Vmag	B-V	SpType	NoteFlag	ra_epoch2000	dec_epoch2000
310	01 26 58.1	-32 32 35	5.79	3.86	C6II	*	21.74206	-32.54318
1404	05 45 39.4	+20 41 42	6.95	3.03	CSII	*	86.41422	20.69504
2776	10 35 12.9	-39 33 46	5.38	2.88	N0:	*	158.80355	-39.56259
2804	10 45 04.0	+67 24 41	6.	2.39	CSII	*	161.26579	67.41138
3277	12 45 07.8	+45 26 25	4.99	2.54	C7I	*	191.28261	45.44025
3831	15 14 19.1	-70 04 46	5.81	3.38	CS.5	*	228.57989	-70.07948
4800	18 50 20.0	-07 54 27	6.8	3.09	CSII	*	282.58349	-7.90762
4884	19 04 24.2	-05 41 05	6.9	4.19	CSII	*	286.10065	-5.68484
5681	21 42 01.1	+35 30 37	6.07	2.52	C6.3	*	325.50451	35.5102
6218	23 46 23.5	+03 29 12	5.04	2.6	CSII	*	356.59797	3.48681

## SIMBAD Astronomical Database - CDS (Strasbourg)

What is SIMBAD ?

<i>Queries</i>
<a href="#">basic search</a>
<b><a href="#">by identifier</a></b>
<b><a href="#">by coordinates</a></b>
<a href="#">by criteria</a>
<a href="#">reference query</a>
<b><a href="#">scripts</a></b>
<b><a href="#">TAP queries</a></b>
<a href="#">options</a>
<a href="#">Display all user annotations</a>

<i>Documentation</i>
<b><a href="#">User's guide</a></b>
<a href="#">Query by urls</a>
<a href="#">Nomenclature Dictionary</a>
<a href="#">Object types</a>
<a href="#">List of journals</a>
<a href="#">Measurement description</a>
<a href="#">Spectral type coding</a>
<a href="#">User annotations documentation</a>
<a href="#">Acknowledgment</a>

<i>Information</i>
<a href="#">Presentation</a>
<a href="#">Image thumbnails</a>
 <b><a href="#">BETA - Mobile version</a></b>
<a href="#">SimWatch </a>
<b>Release:</b>
<b>SIMBAD4 1.7 - May-2018</b>
<a href="#">Release history</a>

## SIMBAD: basic query

**other query modes :**

Identifier query

Coordinate query

Criteria query

Reference query

Basic query

Script submission

TAP

Output options

Help

**basic query :**

*identifier, coordinates (radius=10 arcmin), or bibcode*

SIMBAD search

clear

help

[Install the Simbad basic search in your tool bar](#)





# HD 91793

**other query modes :**

- Identifier query
- Coordinate query
- Criteria query
- Reference query
- Basic query
- Script submission
- TAP
- Output options
- Help

C.D.S. - SIMBAD4 rel 1.7 - 2020.03.29CEST21:54:07

**Available data :** [Basic data](#) • [Identifiers](#) • [Plot & images](#) • [Bibliography](#) • [Measurements](#) • [External archives](#) • [Notes](#) • [Annotations](#)

## Basic data :

### V\* U Ant -- Carbon Star

Other object types: \* (HD,CD,...), C\* ([Ref](#),C\*,...), V\* (AN,V\*,...), IR (IRAS,2MASS), LP\* ([Ref](#)), FIR ([Ref](#))

**ICRS coord. (ep=J2000) :** 10 35 12.8508908507 -39 33 45.320533564 (Optical) [ 0.1258 0.1517 90 ] A [2018yCat.1345....0G](#)

**FK4 coord. (ep=B1950 eq=1950) :** 10 32 59.3578867283 -39 18 12.592153492 [ 0.1258 0.1517 90 ]

**Gal coord. (ep=J2000) :** 276.2241196712291 +16.1418970559406 [ 0.1258 0.1517 90 ]

**Proper motions mas/yr :** -31.372 2.371 [0.228 0.267 90] A [2018yCat.1345....0G](#)

**Radial velocity / Redshift / cz :** V(km/s) 41.00 [4.4] / z(-) 0.000137 [0.000015] / cz 41.00 [4.40]  
C [2006AstL...32..759G](#)

**Parallaxes (mas):** 3.5717 [0.2043] A [2018yCat.1345....0G](#)

**Spectral type:** C-N3 B [2009ApJ...705.1298D](#)

**Fluxes (9) :**

U	15.32	[-]	C	<a href="#">2002yCat.2237....0D</a>
B	8.22	[-]	C	<a href="#">2002yCat.2237....0D</a>
V	5.38	[-]	C	<a href="#">2002yCat.2237....0D</a>
R	3.18	[-]	C	<a href="#">2002yCat.2237....0D</a>
G	4.1351	[0.0043]	C	<a href="#">2018yCat.1345....0G</a>
I	1.86	[-]	C	<a href="#">2002yCat.2237....0D</a>
J	1.28	[-]	C	<a href="#">2002yCat.2237....0D</a>
H	0.08	[-]	C	<a href="#">2002yCat.2237....0D</a>
K	-0.51	[-]	C	<a href="#">2002yCat.2237....0D</a>

SIMBAD  with radius

Interactive [AladinLite](#)

10 35 12.851 -39 33 45

FoV: 9.87'

2MASS  DSS  SDSS

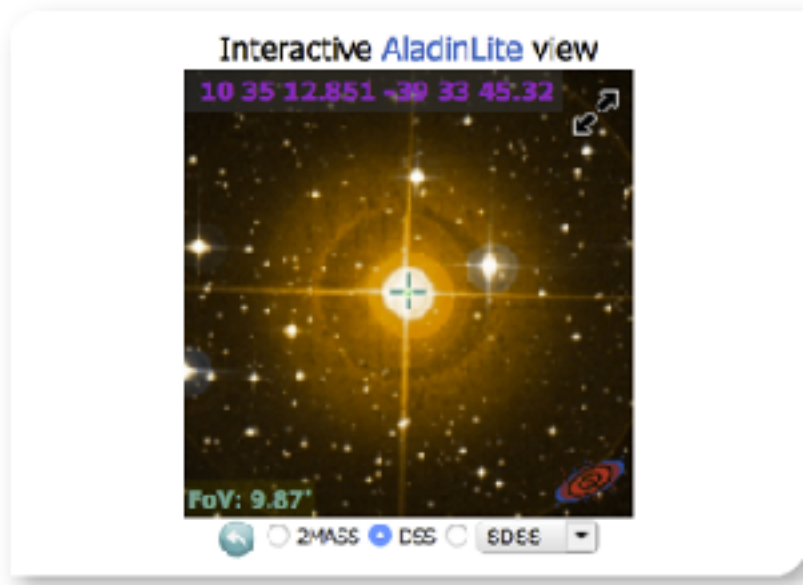
VizieR photometry v

within radius

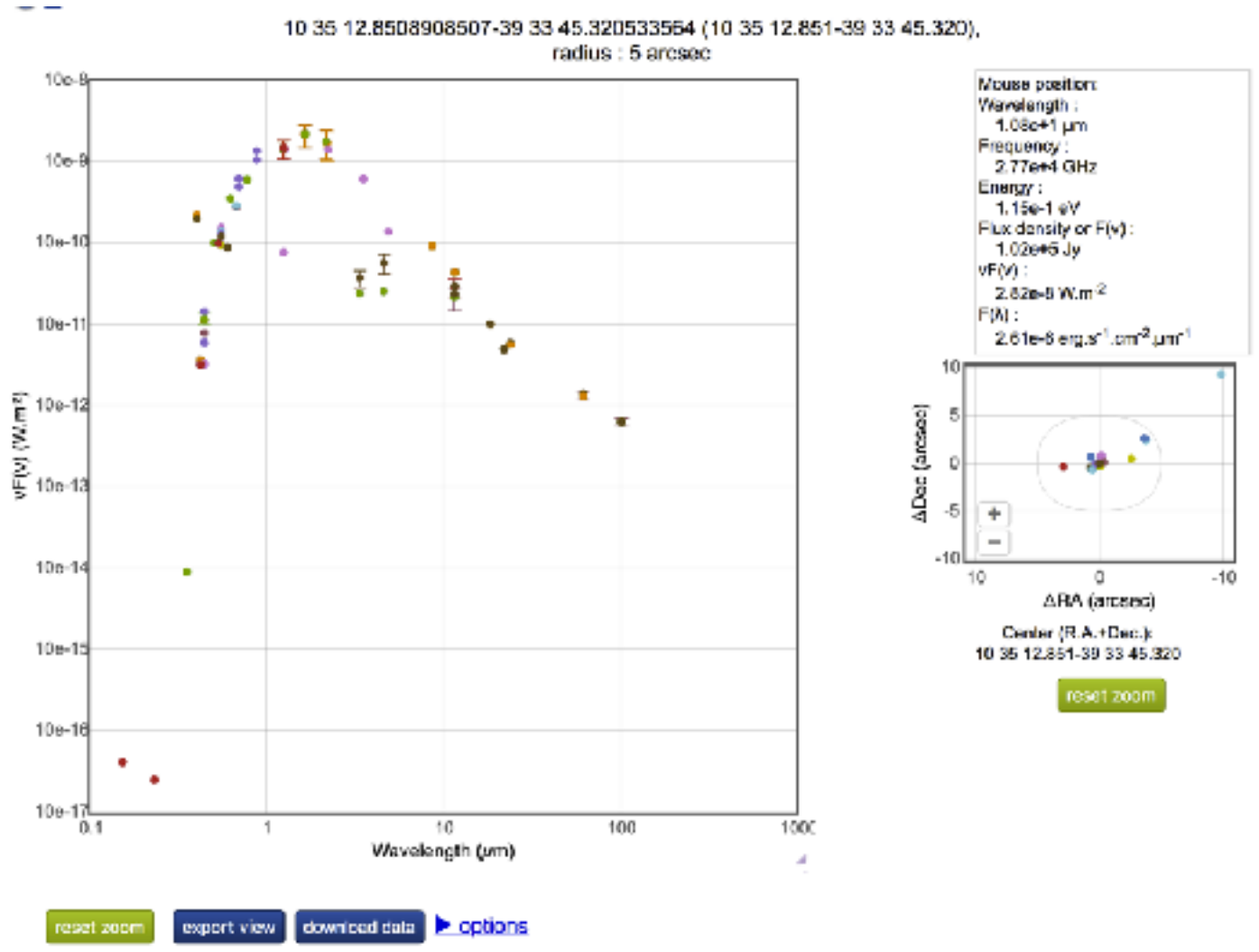
Who said she was not a carbon star? :-)

I would like you to focus on the right side of the page.

SIMBAD query around with radius 2 arcmin



VizieR photometry viewer  
Search within radius 5 arcsec



The photometry viewer allows us to plot the SED of any object in Simbad!

# Exercise #2

- Can you make a colour-colour magnitude diagram of the bright stars using AllWISE magnitudes? For example a J-H vs W1-W2 colour-colour diagram? And a B-V vs W1-W2 colour-colour diagram?

# Exercise #3

- Instead of using the bright stars catalogue, can you use the “SDSS quasar catalog, fourteenth data release (Paris+, 2018)”?
- Can you match it with SDSS and AllWISE?
- Do you find any magnitude or colour which correlates with the redshift?

# For further reading

Tutorials are available here <http://www.euro-vo.org/?q=science/scientific-tutorials>

I suggest (in order):

[http://www.euro-vo.org/sites/default/files/documents/tutorial-brown-dwarfs\\_2019Apr.pdf](http://www.euro-vo.org/sites/default/files/documents/tutorial-brown-dwarfs_2019Apr.pdf)

[http://www.euro-vo.org/sites/default/files/documents/tutorial-topcat-stilts\\_2018Nov.pdf](http://www.euro-vo.org/sites/default/files/documents/tutorial-topcat-stilts_2018Nov.pdf)

[http://www.euro-vo.org/sites/default/files/documents/tutorial-abell1656\\_2019Apr.pdf](http://www.euro-vo.org/sites/default/files/documents/tutorial-abell1656_2019Apr.pdf)

[http://www.euro-vo.org/sites/default/files/documents/tutorial-herbig-stars\\_2017Nov.pdf](http://www.euro-vo.org/sites/default/files/documents/tutorial-herbig-stars_2017Nov.pdf)



# VO Tools

## **List of VO Tools (you can also find many tutorials)**

<http://www.ivoa.net/astronomers/applications.html>

## **VO - software for catalogues**

<http://www.star.bris.ac.uk/~mbt/topcat/>

<http://www.star.bris.ac.uk/%7Embt/stilts/> (in fact, stilts is the “engine” behind Topcat)

## **VO - software for images (and catalogues)**

<https://aladin.u-strasbg.fr/aladin.gml>

## **VO - software for spectra**

<http://cassis.irap.omp.eu/>

<http://star-www.dur.ac.uk/%7Epdraeper/splat/splat-vo/>

# Two extra tools

- The Virtual Observatory SED Analyser (VOSA); allows to analyse the SED of any stellar source
  - <http://svo2.cab.inta-csic.es/theory/vosa/>
- The Spanish Virtual Observatory Discovery Tool; allows to find data about astrophysical sources
  - <http://sdc.cab.inta-csic.es/SVODiscoveryTool/jsp/searchform.jsp>
- Both tools developed, hosted and maintained by the Spanish Virtual Observatory <https://svo.cab.inta-csic.es/main/index.php>

# Summary

- VO is a framework which allows you to distribute, access and analyse data in a standardised way
- VO data access is very (at times “too”) easy
- “With great power, comes great responsibility”
- Understand what you are doing and know your tables
- It’s not “do it or do it not”, in this case there is also try