# 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

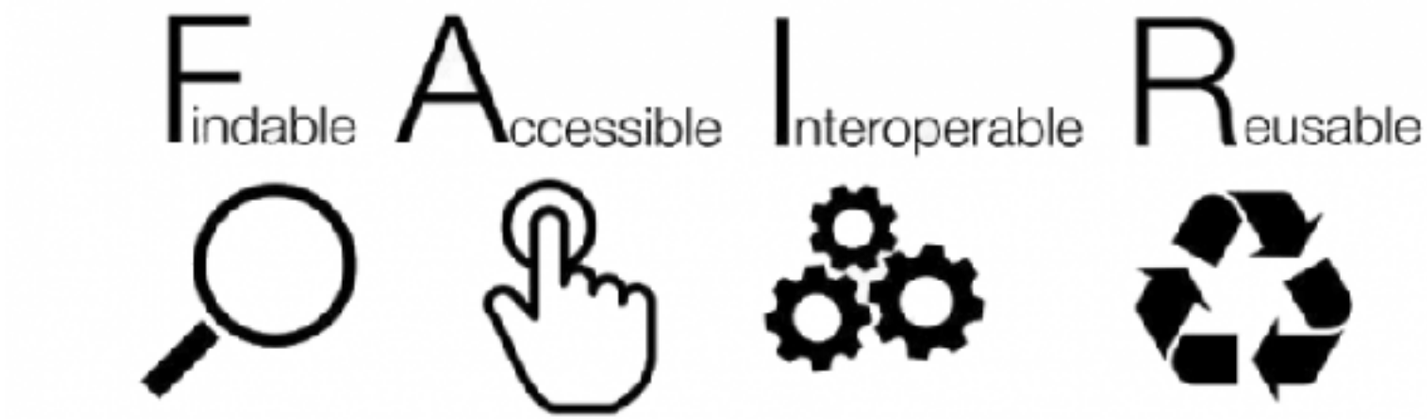
- “Internet” exists because of a series of protocols (http, ftp, pop,…) and a series of standards (html,…)

- 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”

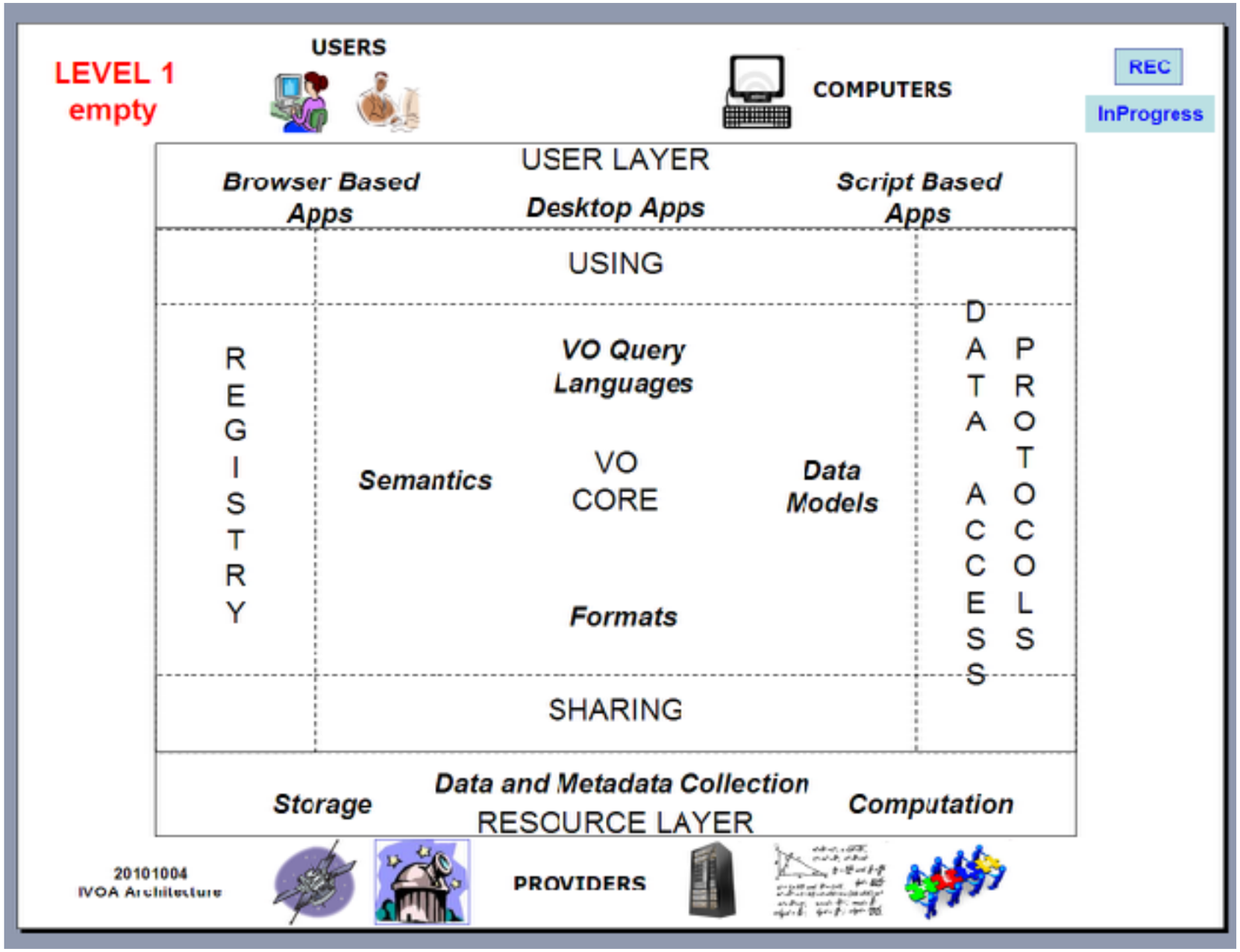


# Layers

**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 $H_2O$

- A user wants “agua”, “acqua”, “water”, “wasser”,…
- $H_2O$ 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 standarized, 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
  Aditional filtering criteria, in advanced providers, like redshift,
- spatial resolution, signal to noise, ...
- Returned data can be based on Spectrum data model or be propietary.

# 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 funtions)
- 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

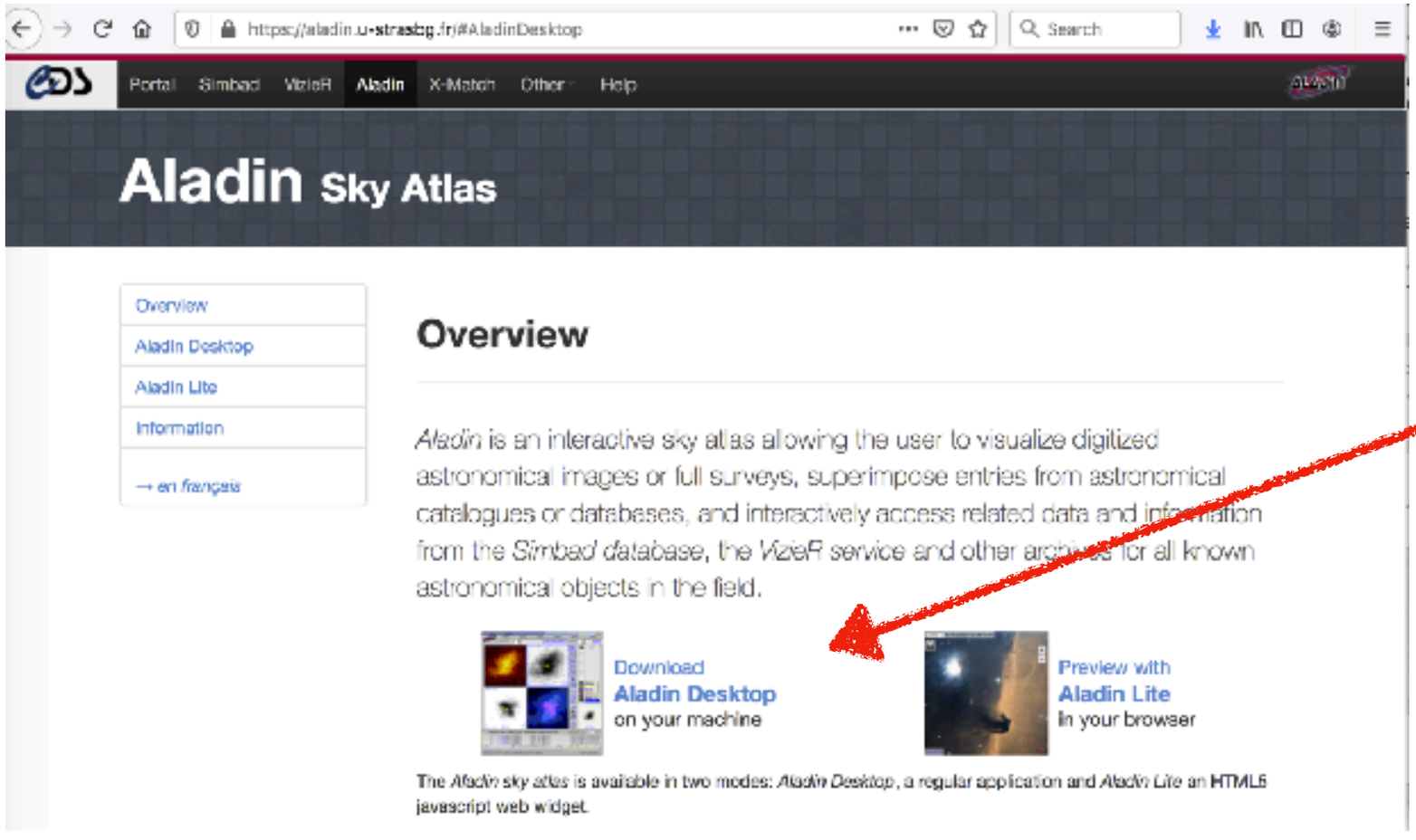
The VO Sky-Atlas

- Topcat

The Tool for Operations on Catalogues And Tables

# Install Aladin

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

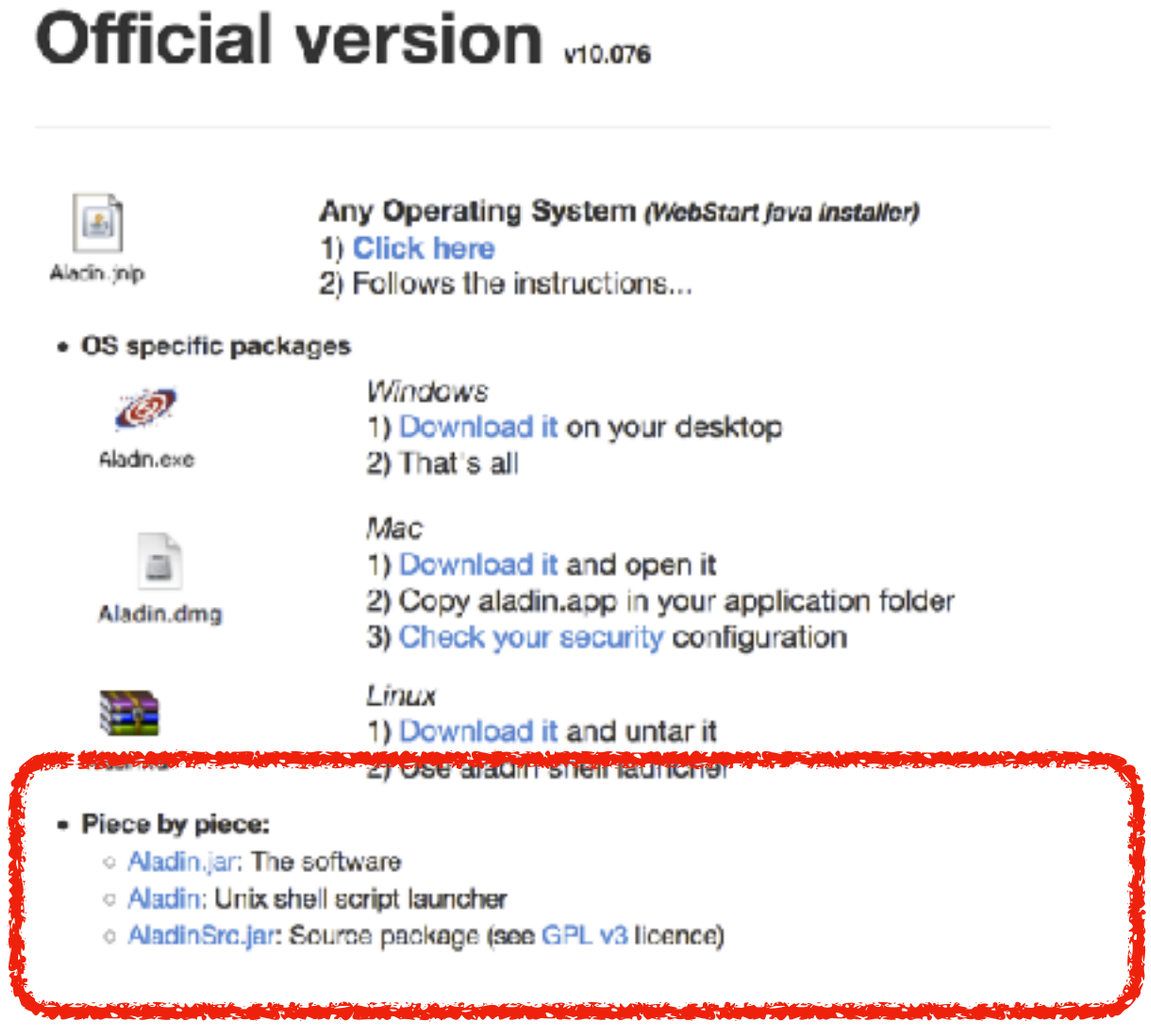



**Download!**

# Install Aladin

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

- Feel free to experiment!



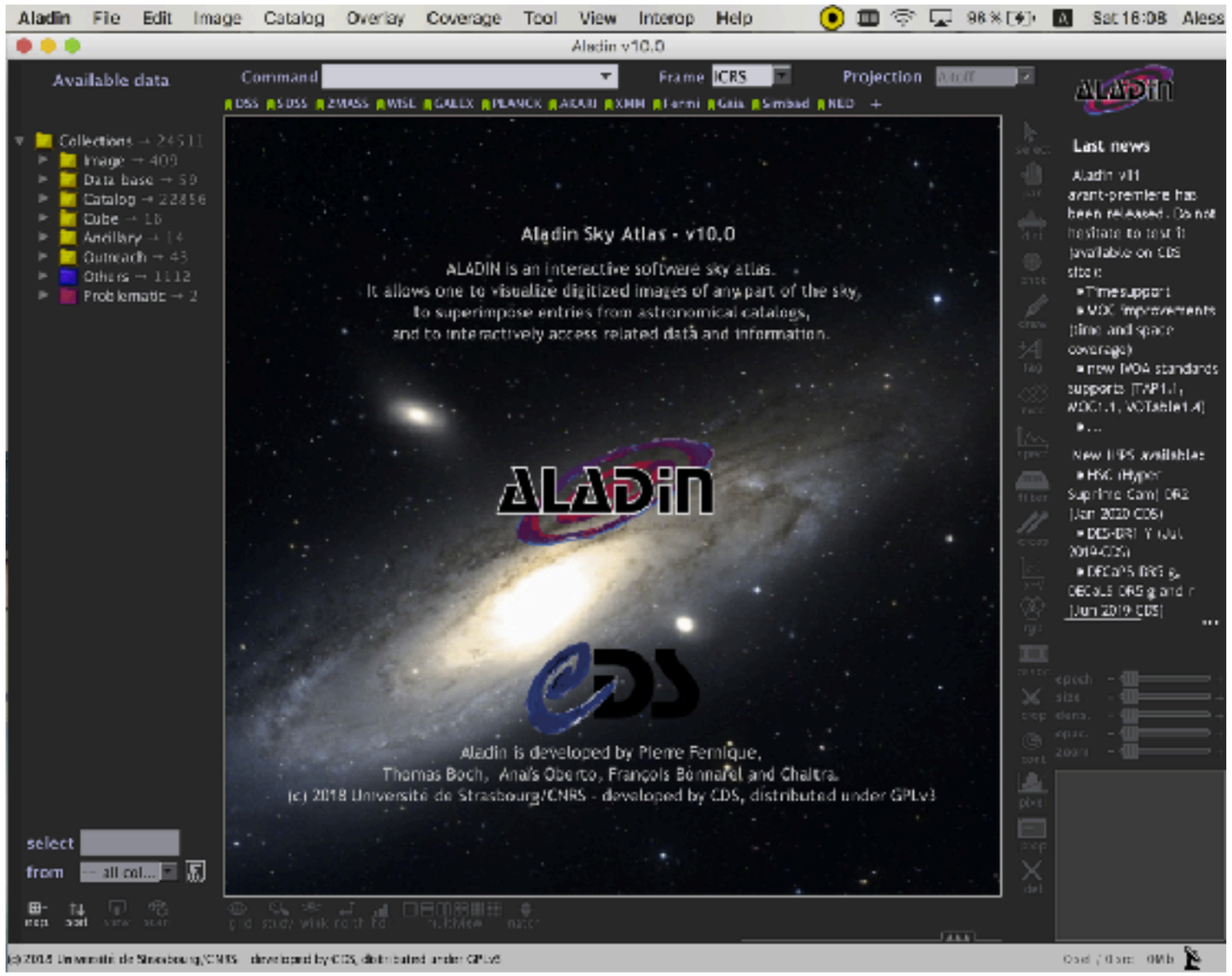
# Launch Aladin

- from the directory where you downloaded the program:

```
chmod a+x Aladin

./Aladin
```

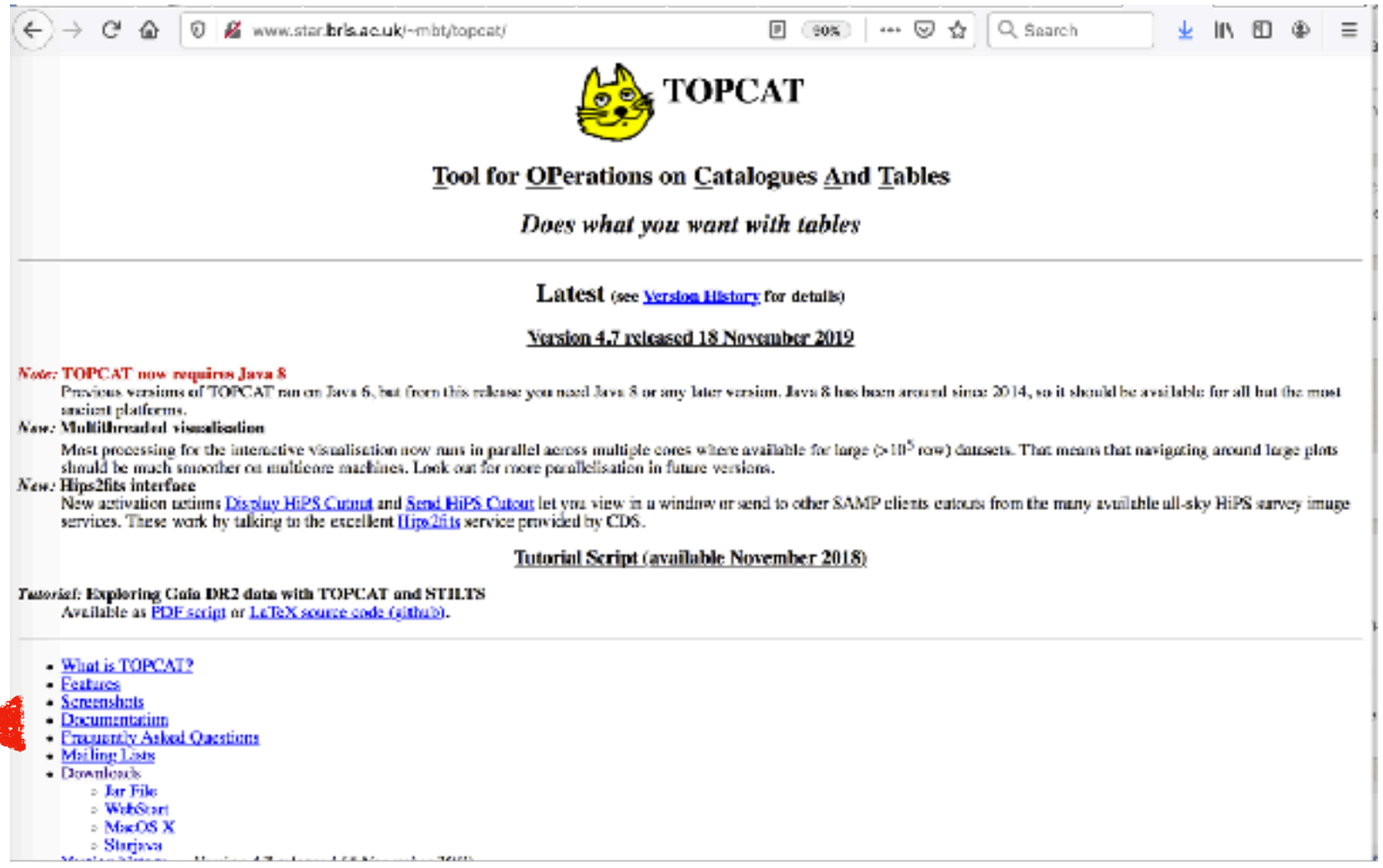
What I see at startup



# Install Topcat

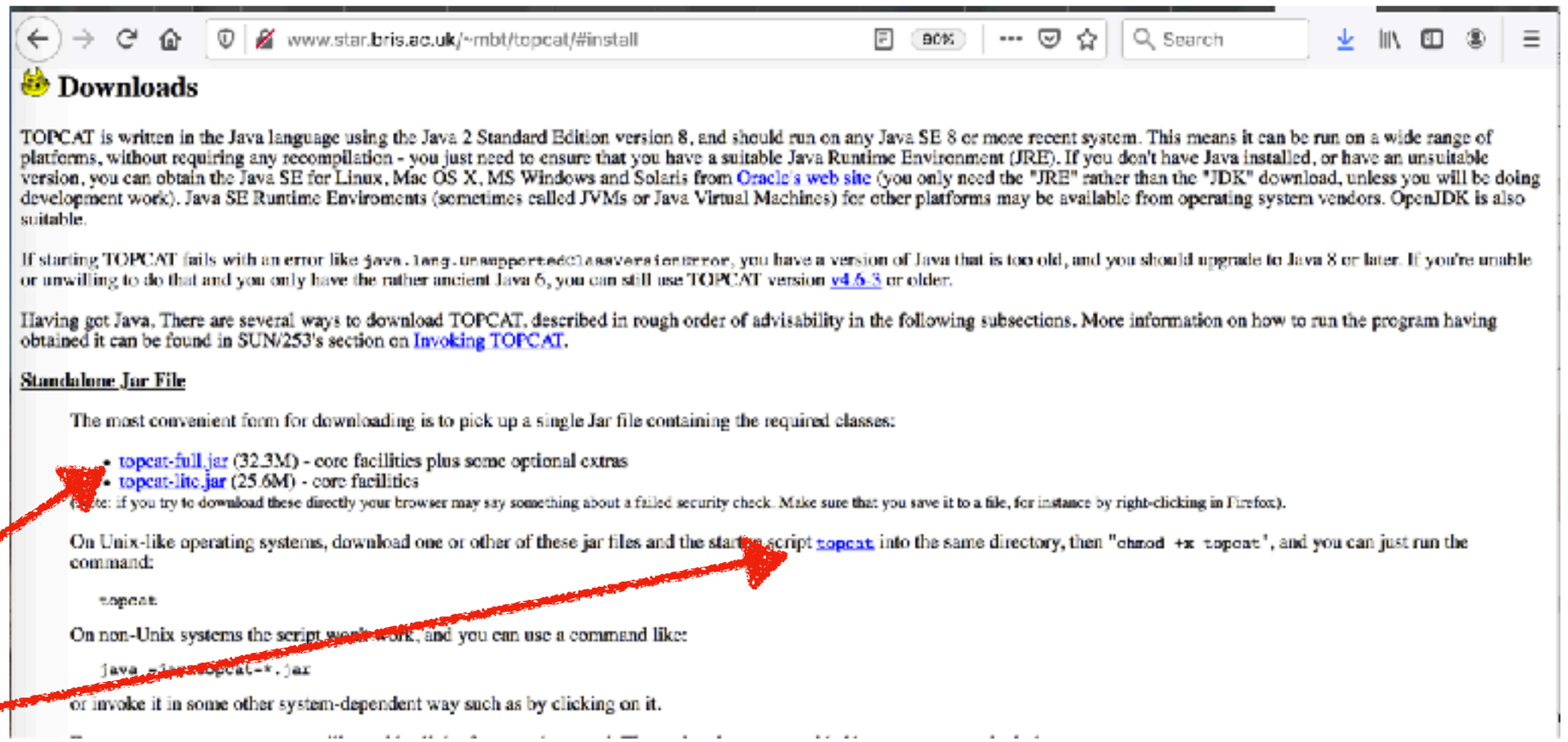
- Let's go to http://www.star.bris.ac.uk/~mbt/topcat/

**Download!**



# Install Topcat

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



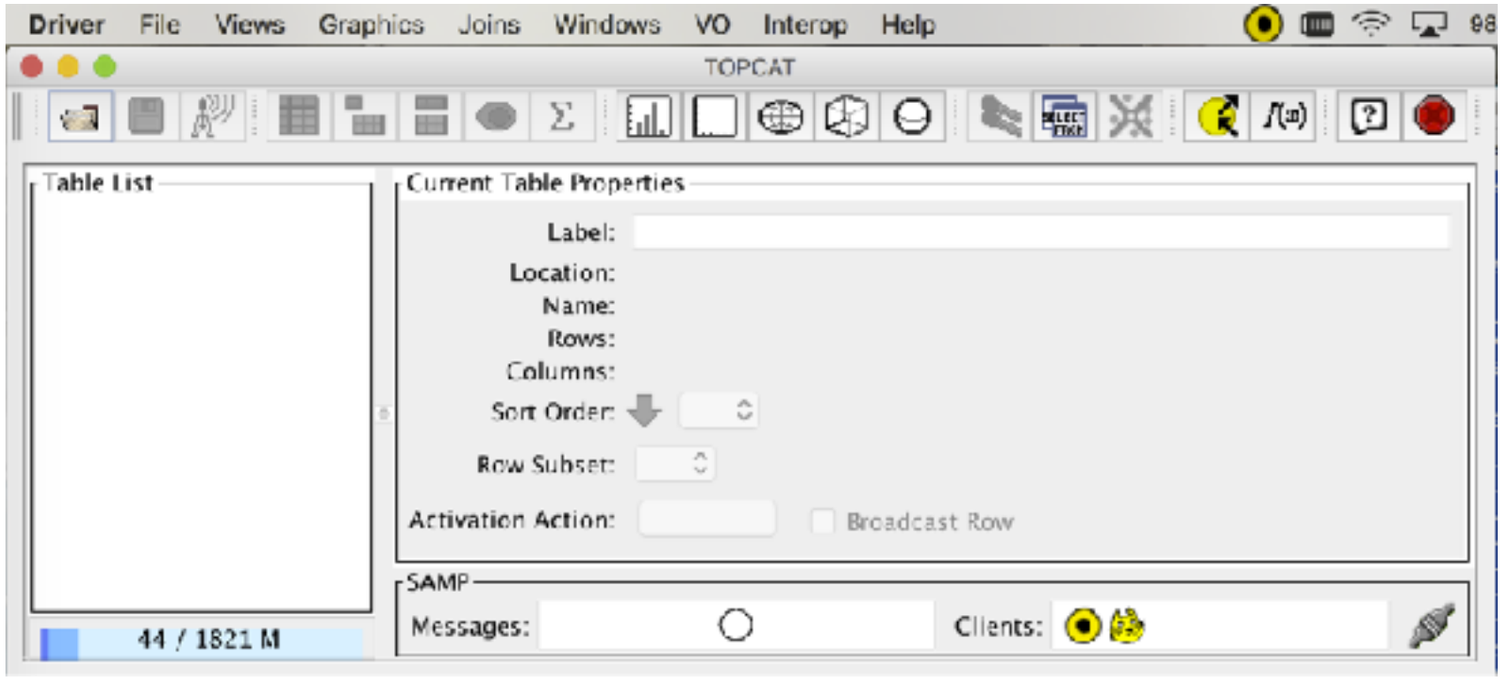

**Here!**

# 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

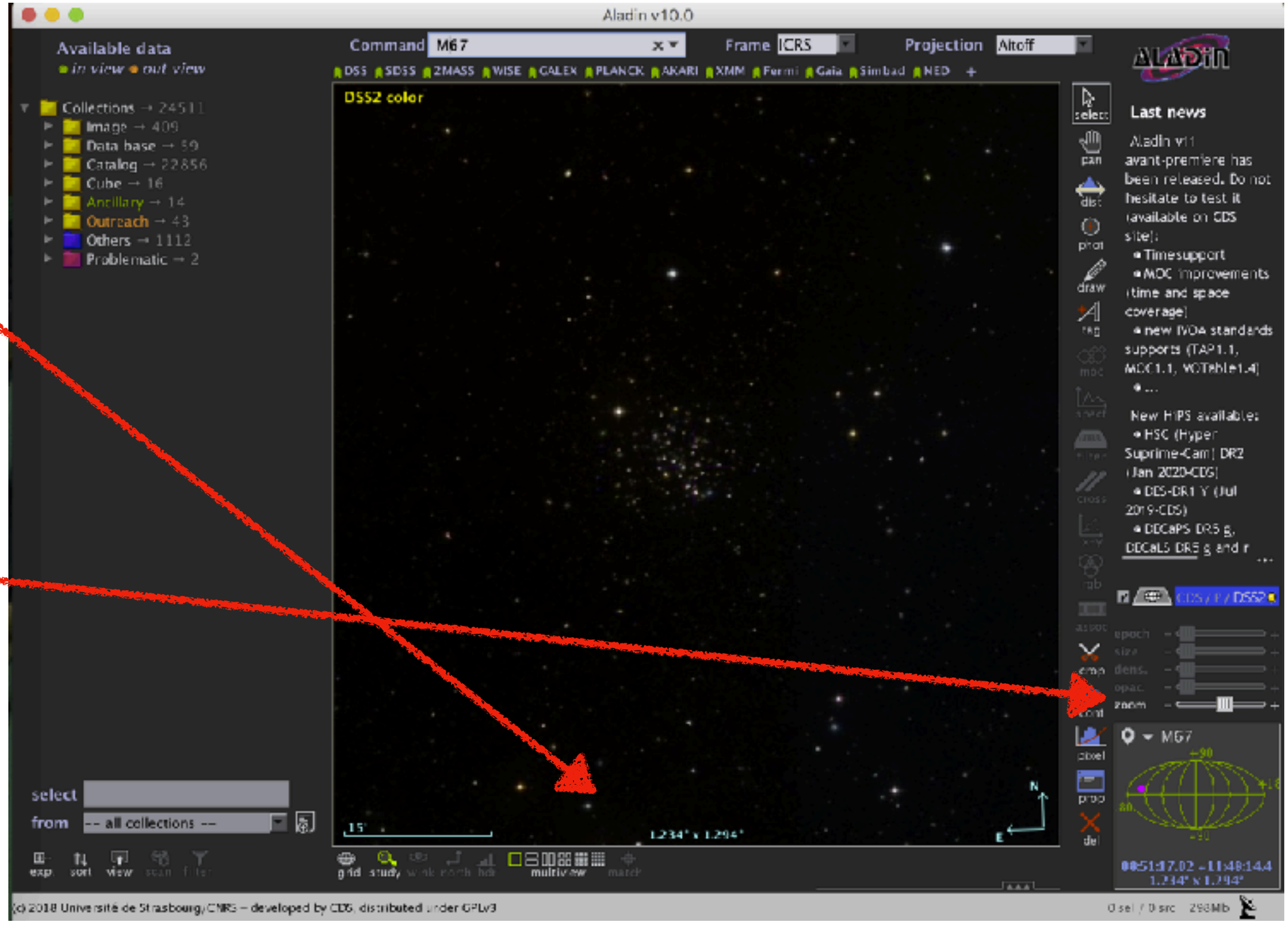
**Type “M67” in the command bar**

**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)**



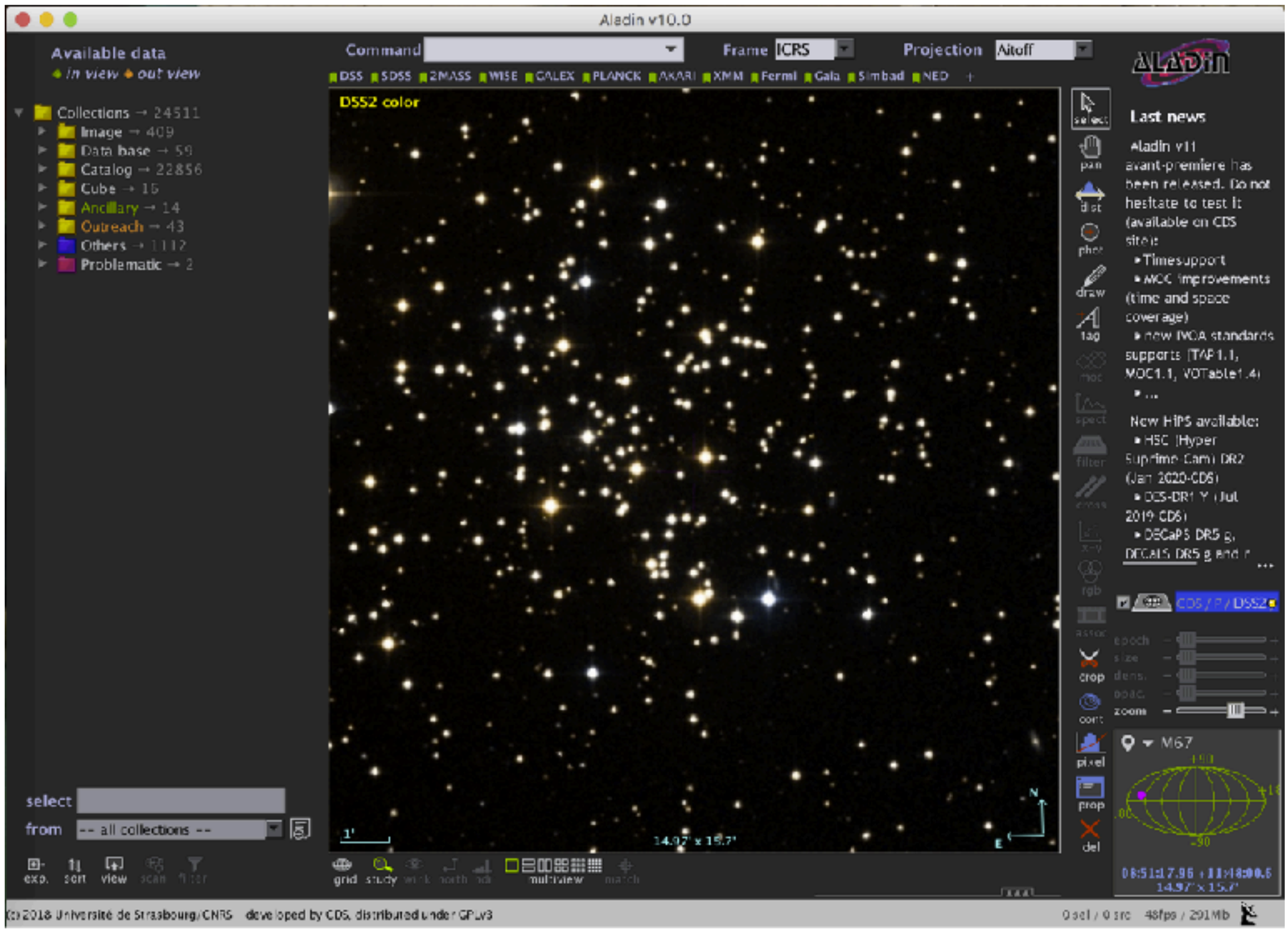
# M67

**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.**



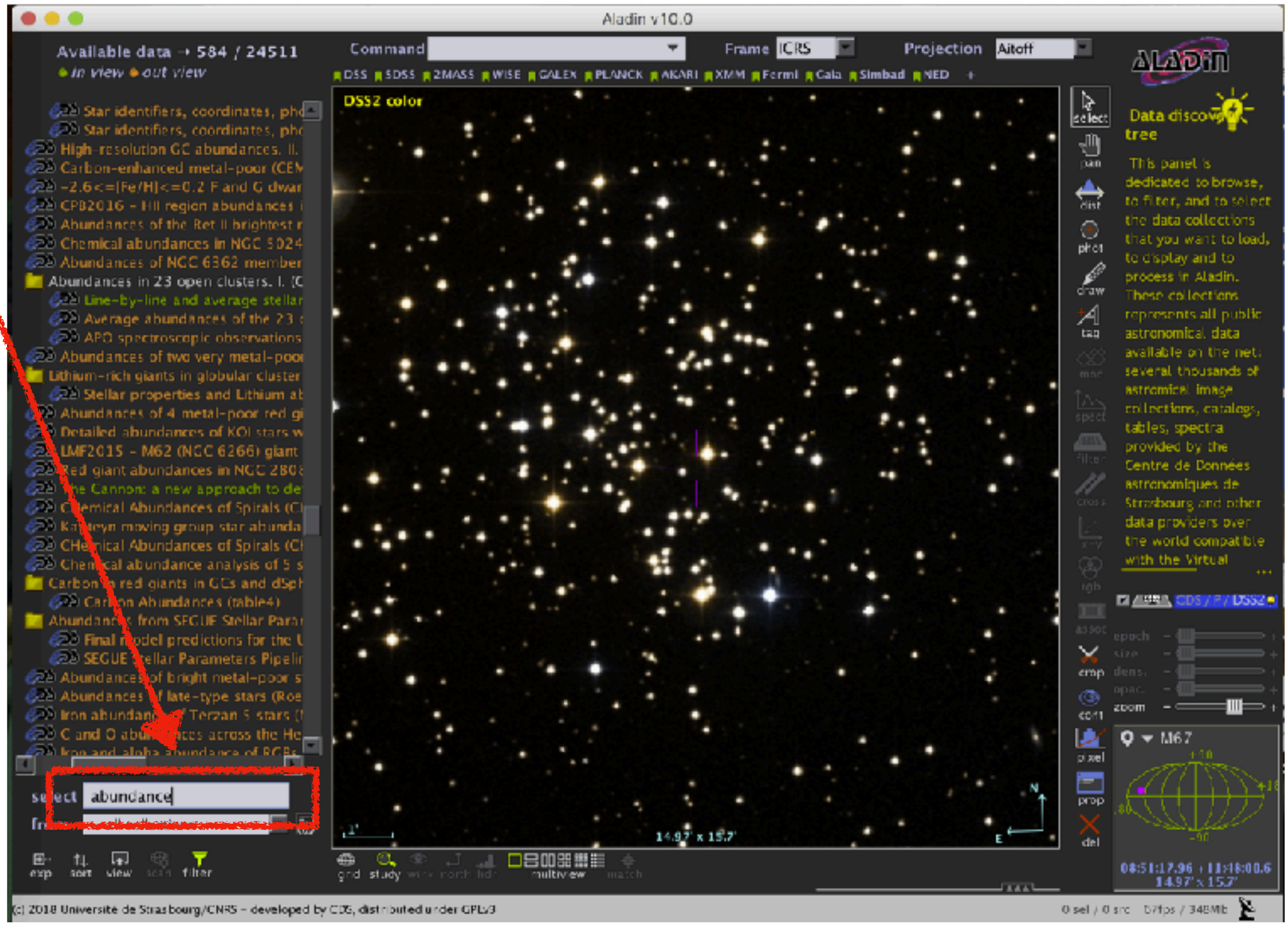
# M67

**Write “abundance” in the box down here**

**Many catalogues will show up.**

**You care for one called “The Cannon”**

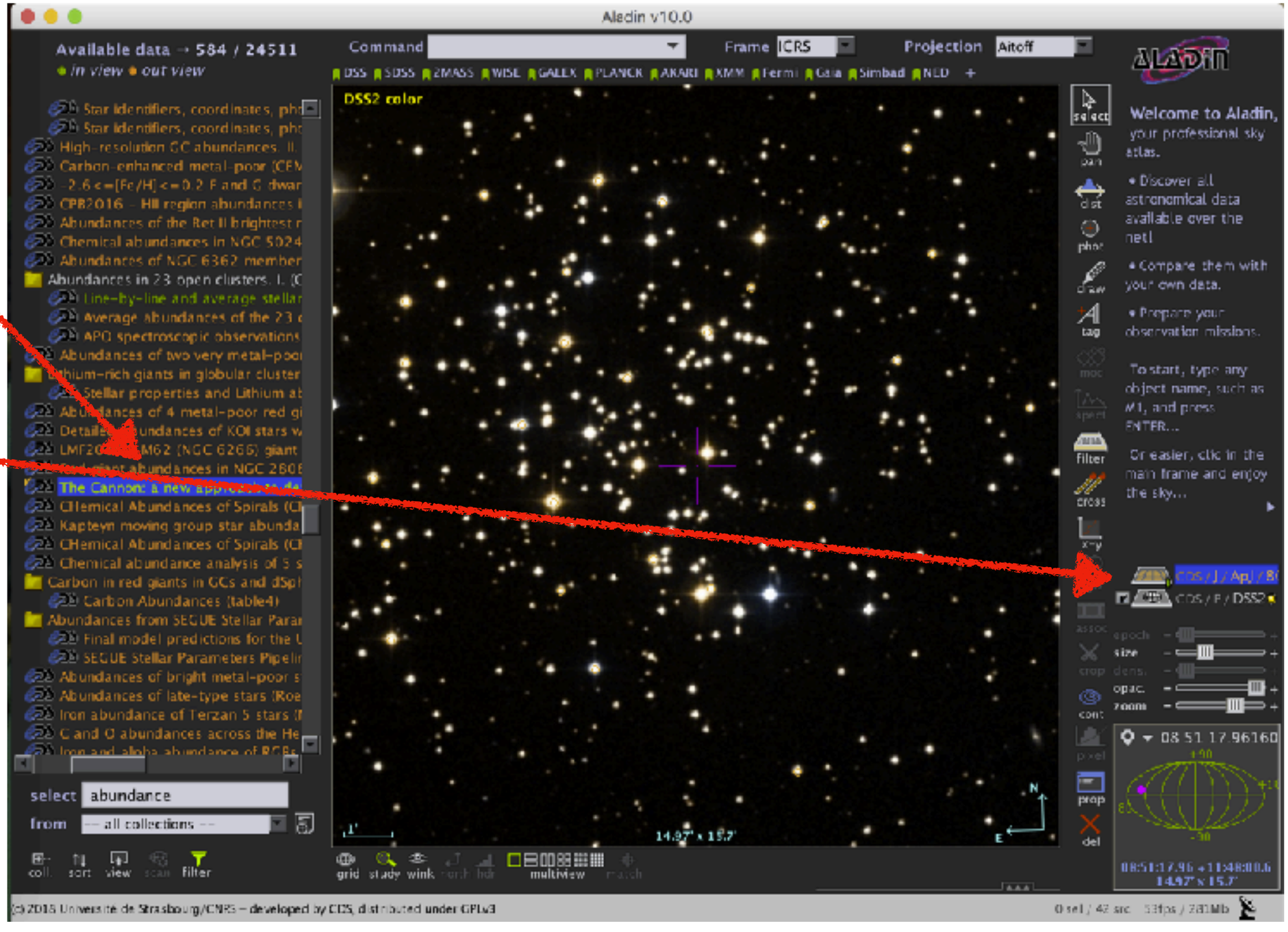
**Double click on “The Cannon”**



# M67: abundances

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

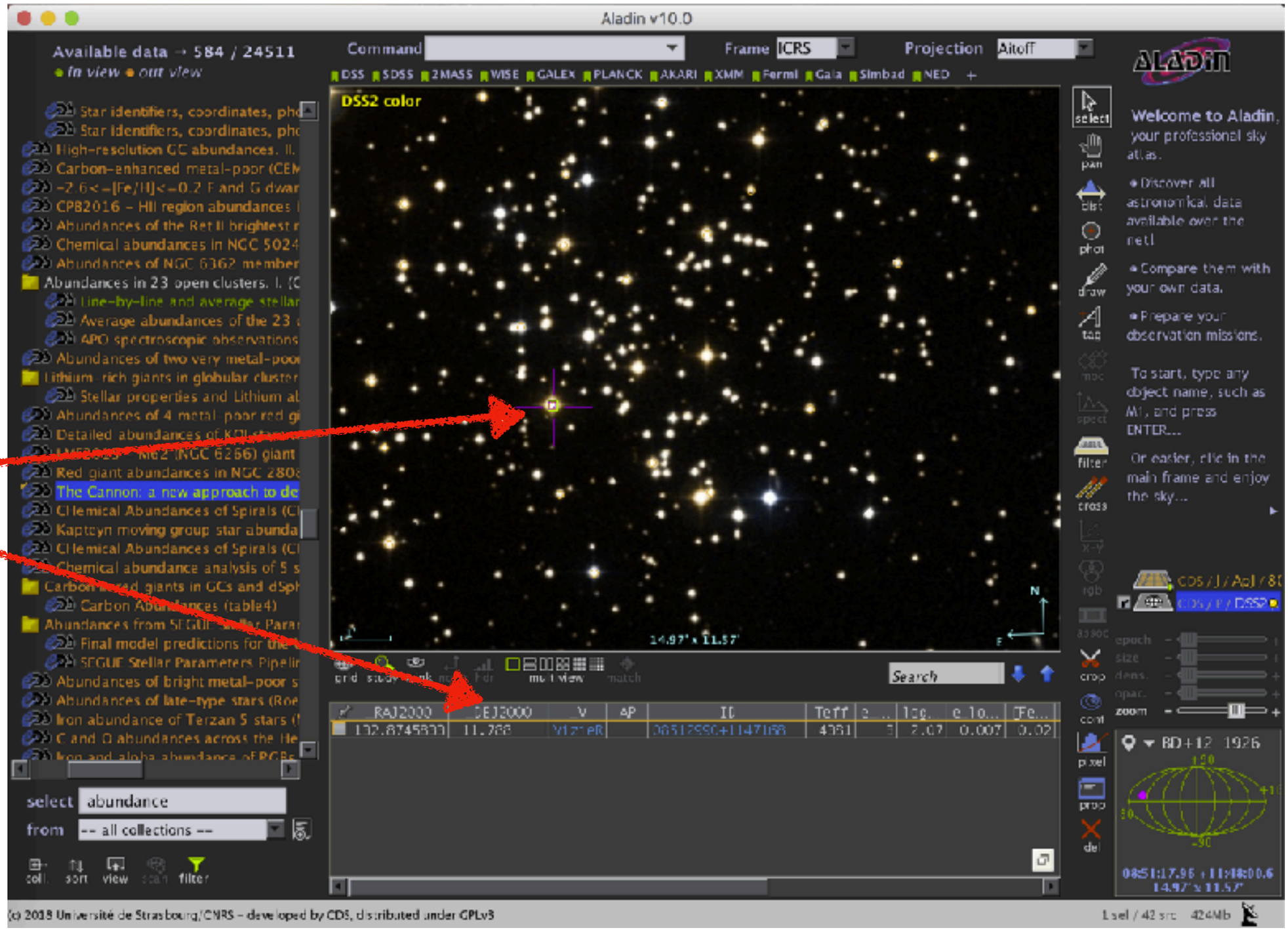
**On some stars, now there are markers: can you see them?**



# M67: individual stars

**If you click on a star,**

**you get its data**

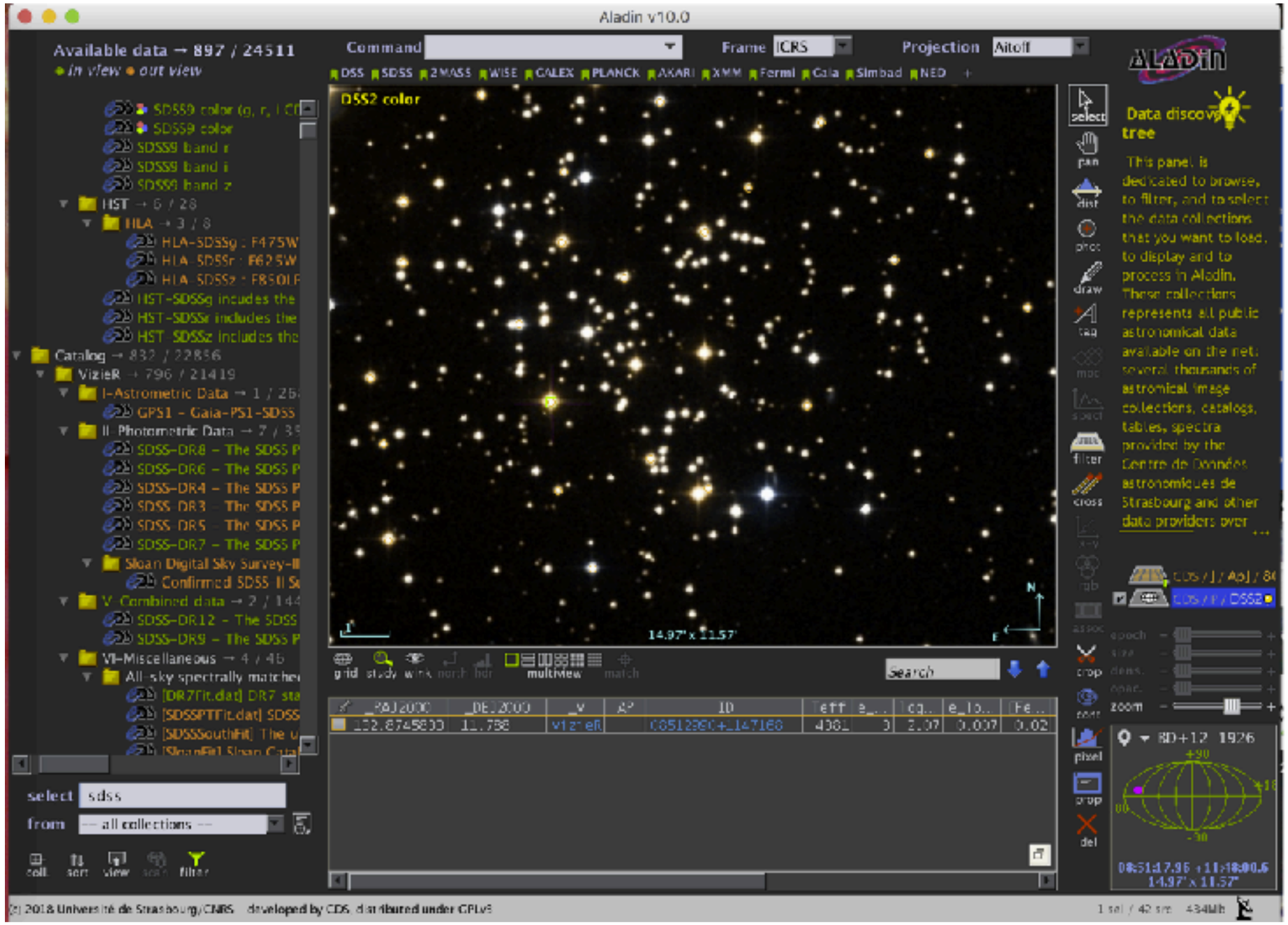


# M67

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

# M67 - SDSS data

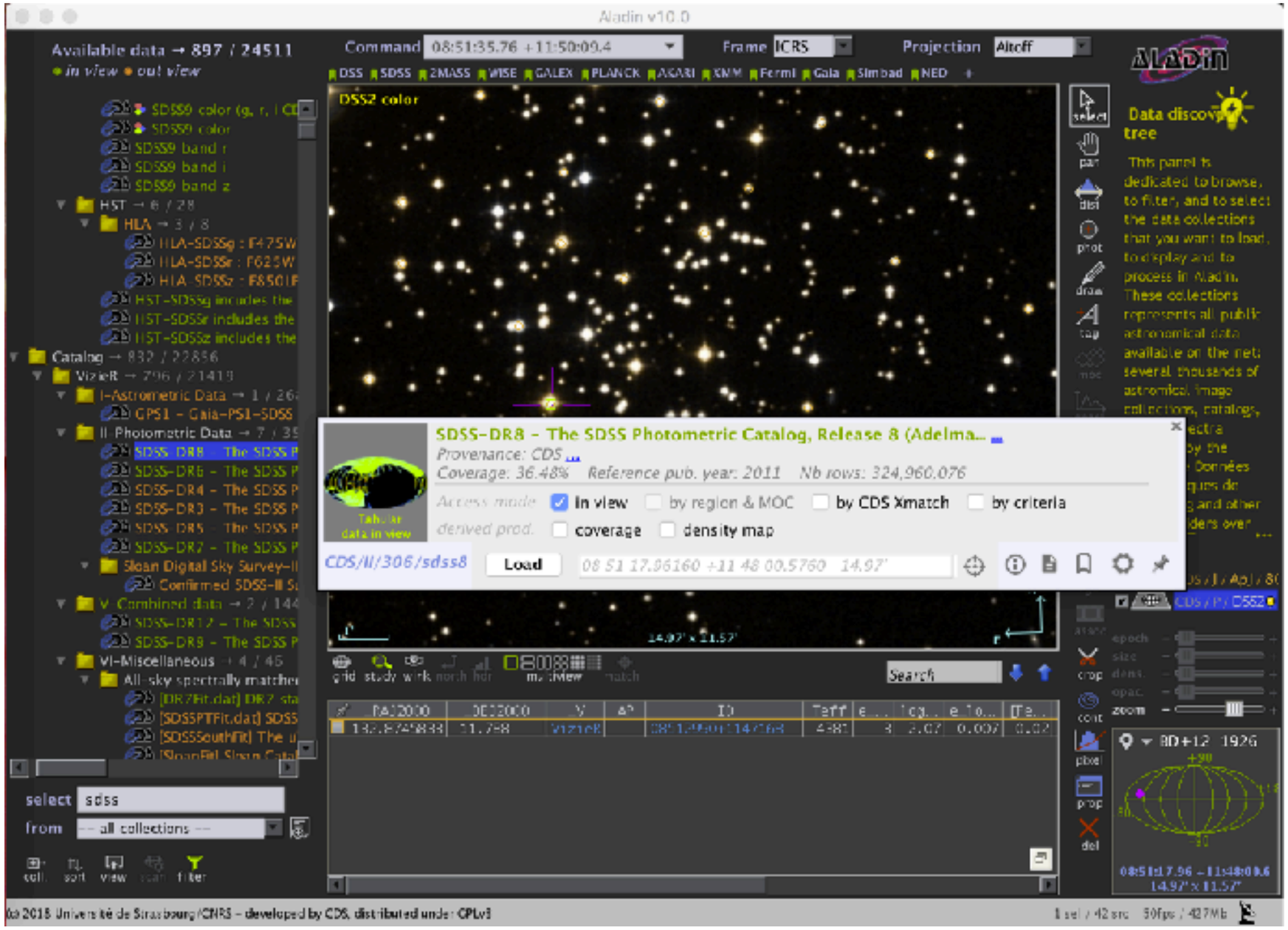
**Same as before, we type “sdss” in the box below and we look for a photometric catalogue.**



**Click, for this example, on “SDSS DR8”**

**(just one click, not double-click)**

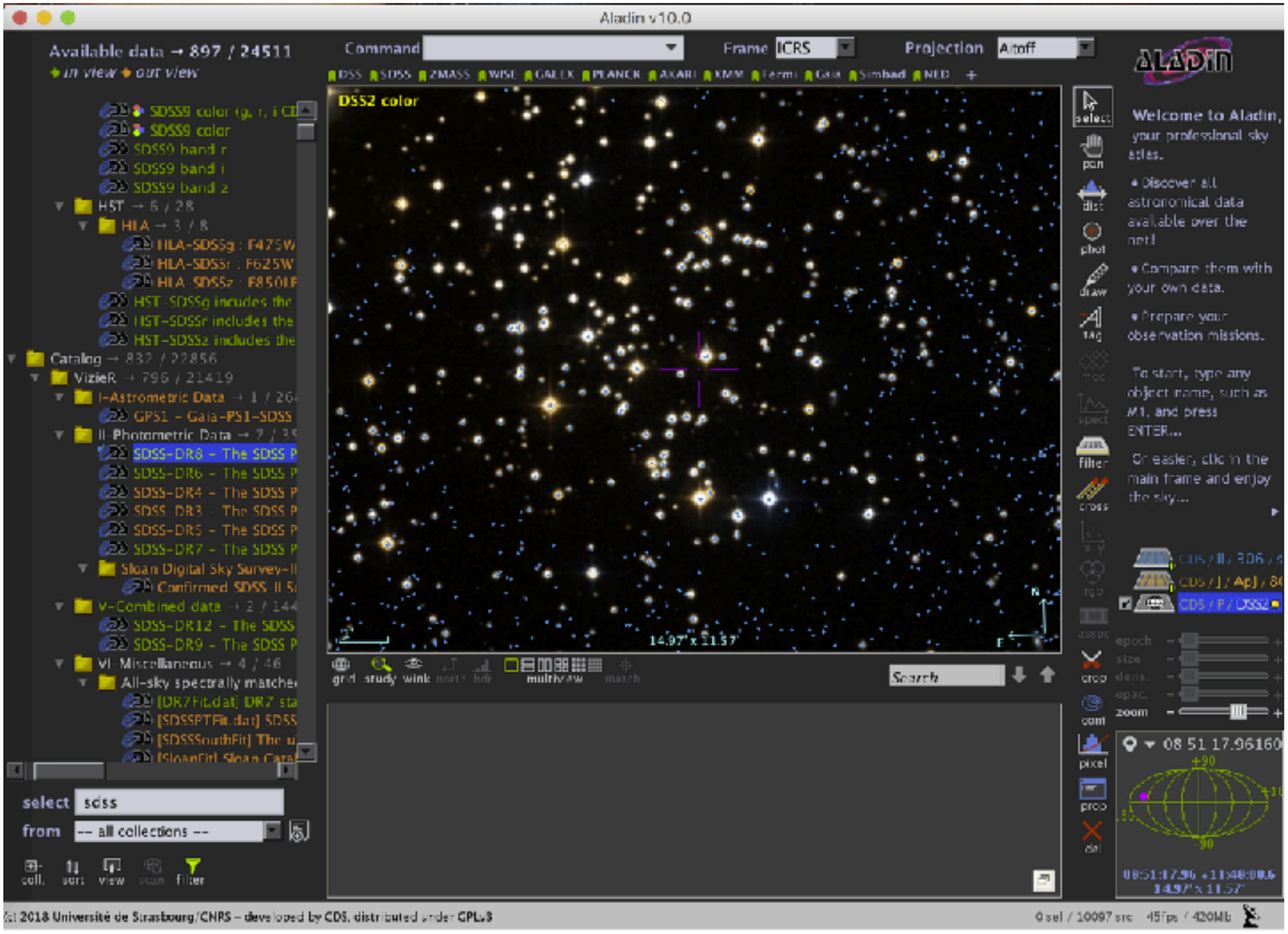
**Select “in view” and then “Load”**



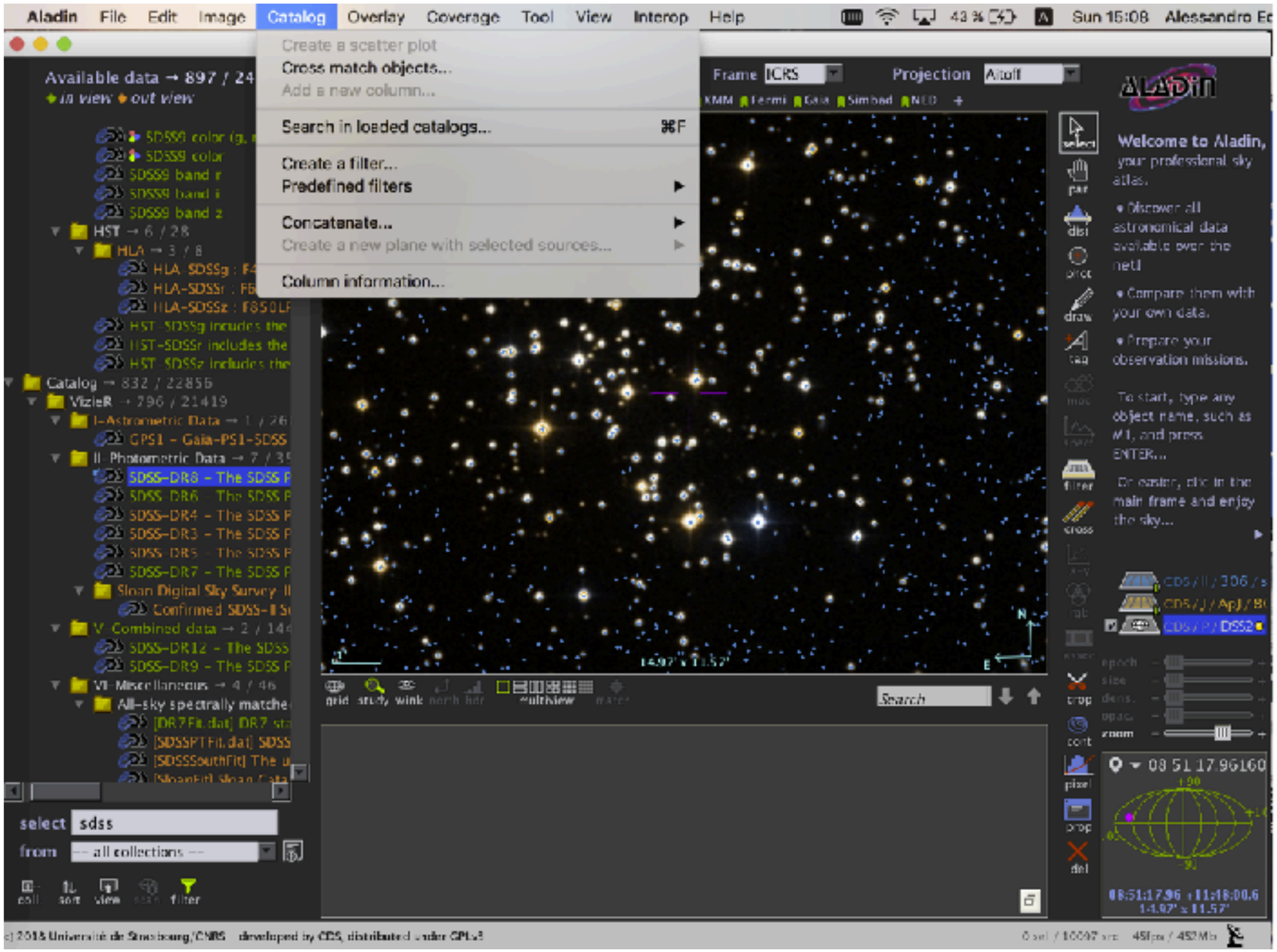
**Now you have a lot of markers!**

**How do we use this information?**

**Maybe we can cross-match the data…**

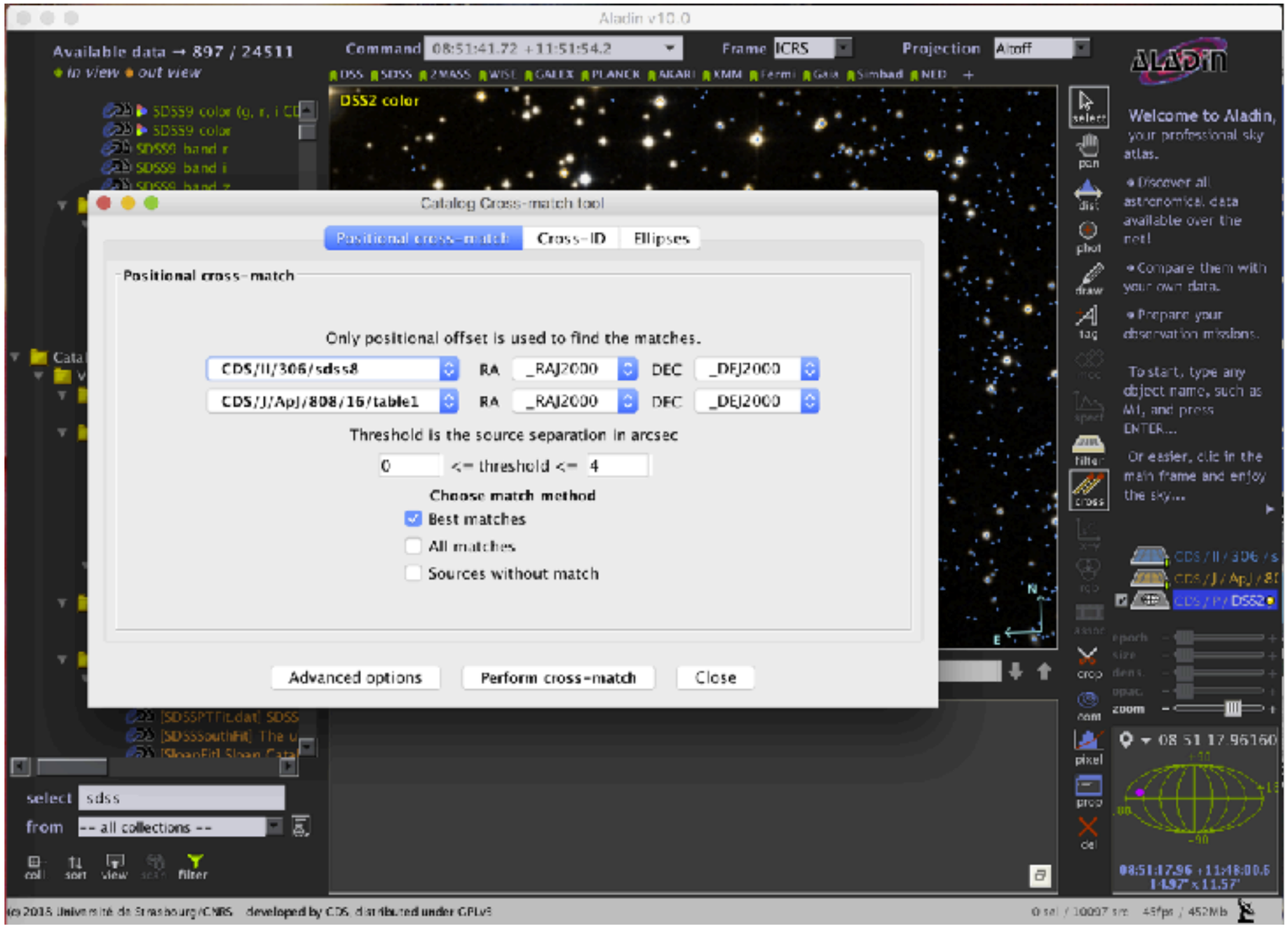


**Find**
**“Catalog” ->**
**“Cross match objects”**



**For this test, we will use the default parameters.**

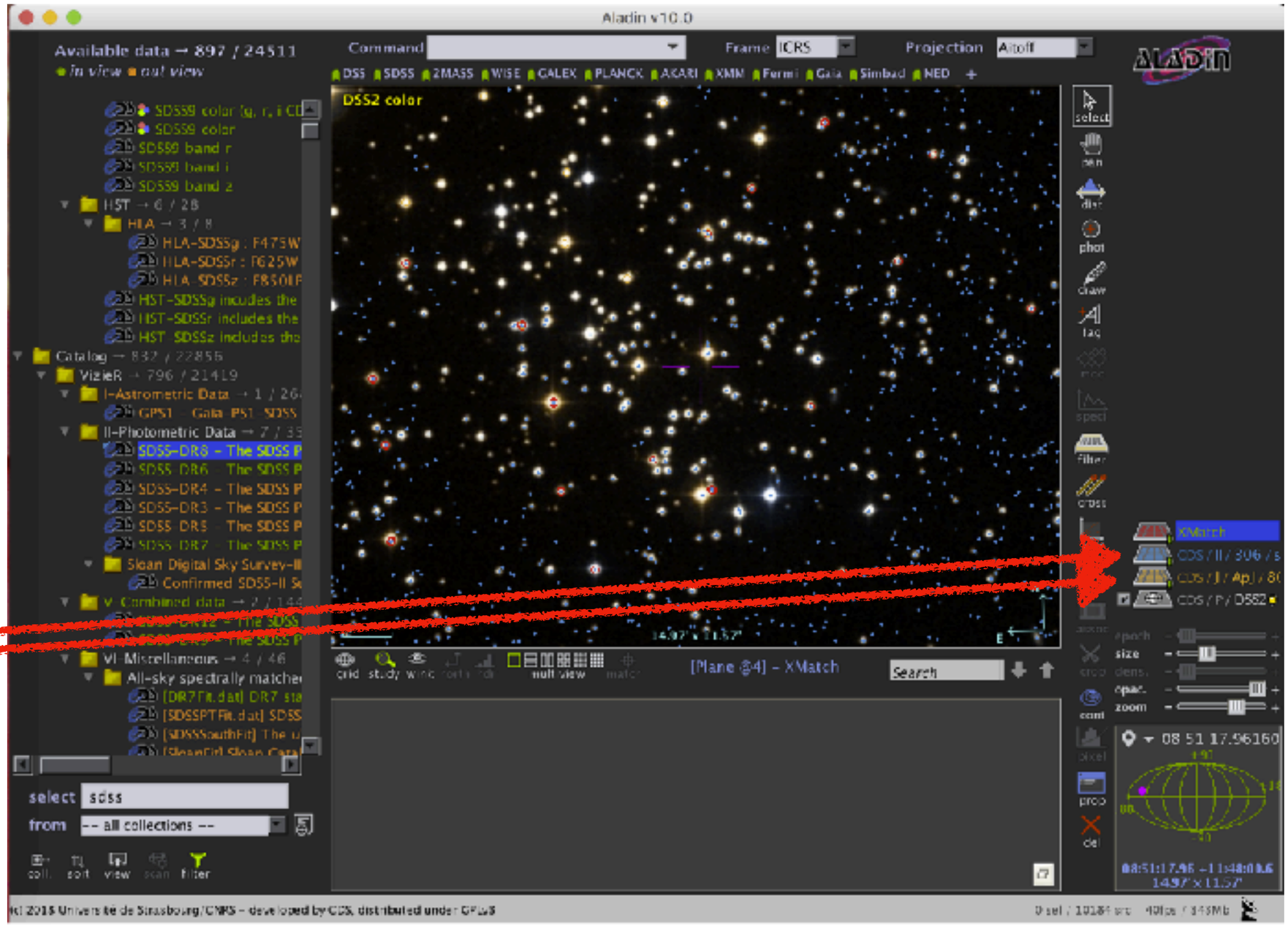
**Click on “Perform cross-match” and then “Close”**



**You have a new plane.**

**Things are getting messy with the markers, right?**

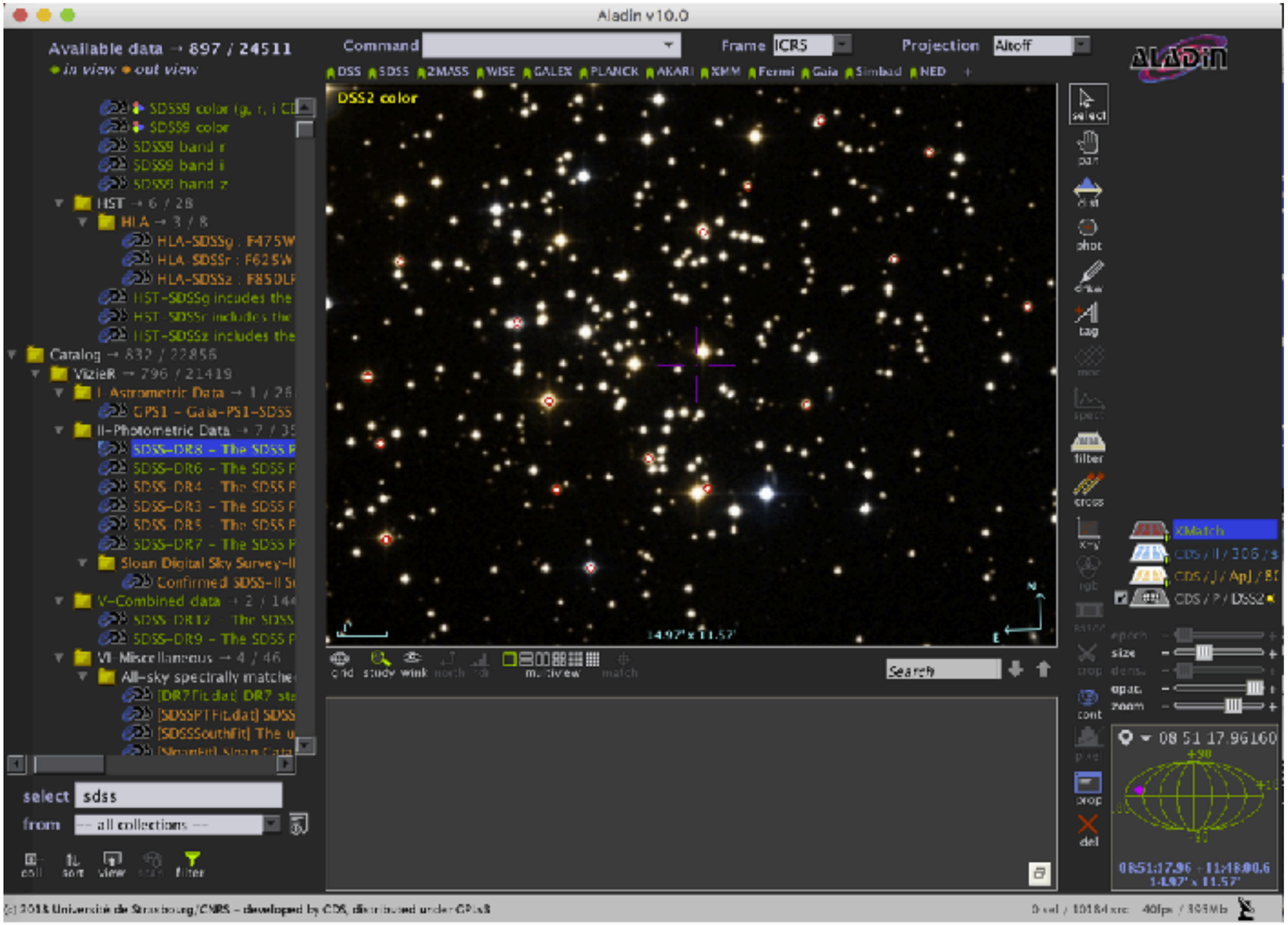
**Let's click on these icons to deactivate them.**



**Now you only have the red markers.**

**Good!**

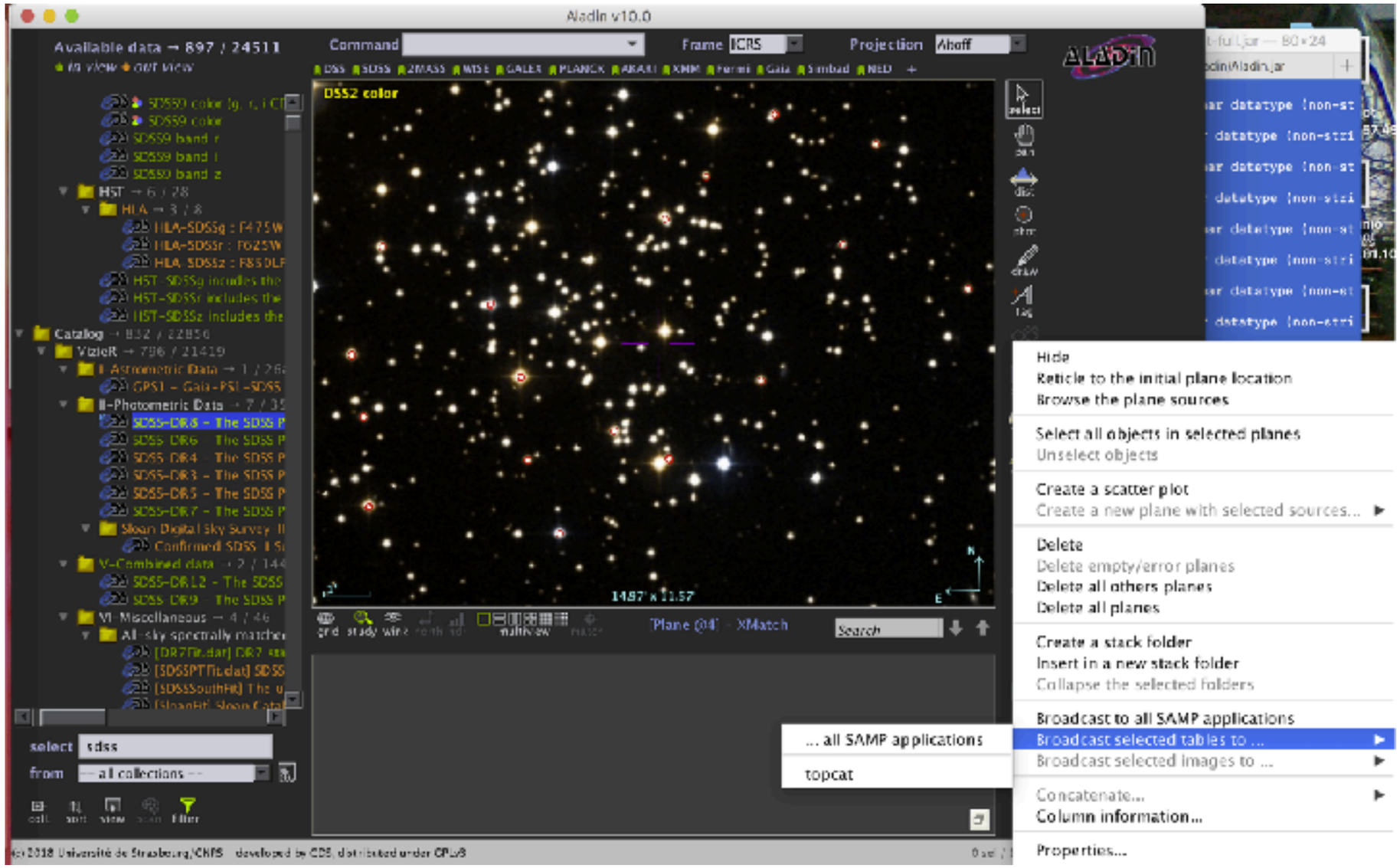
**But how do you use this information now?**



**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**

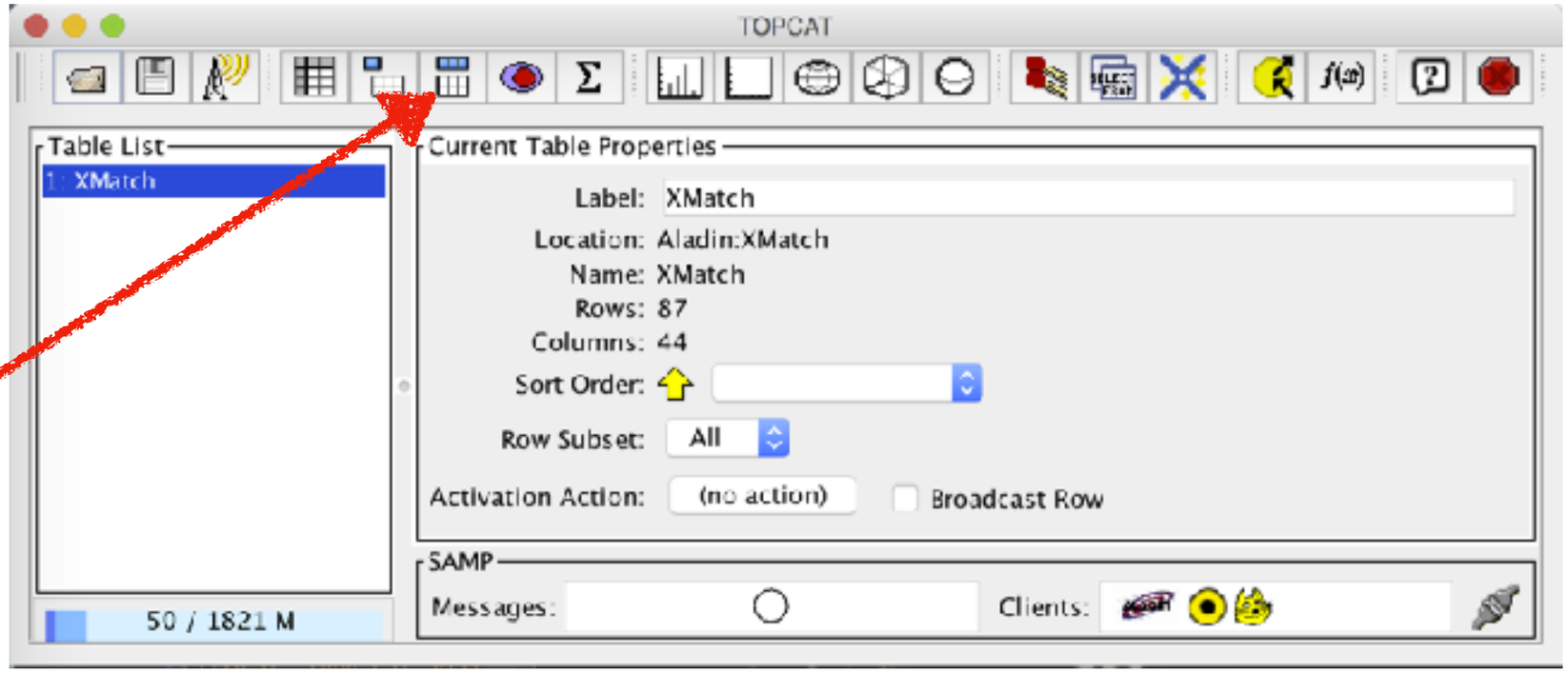


**This is the power of the interoperability of VO!**

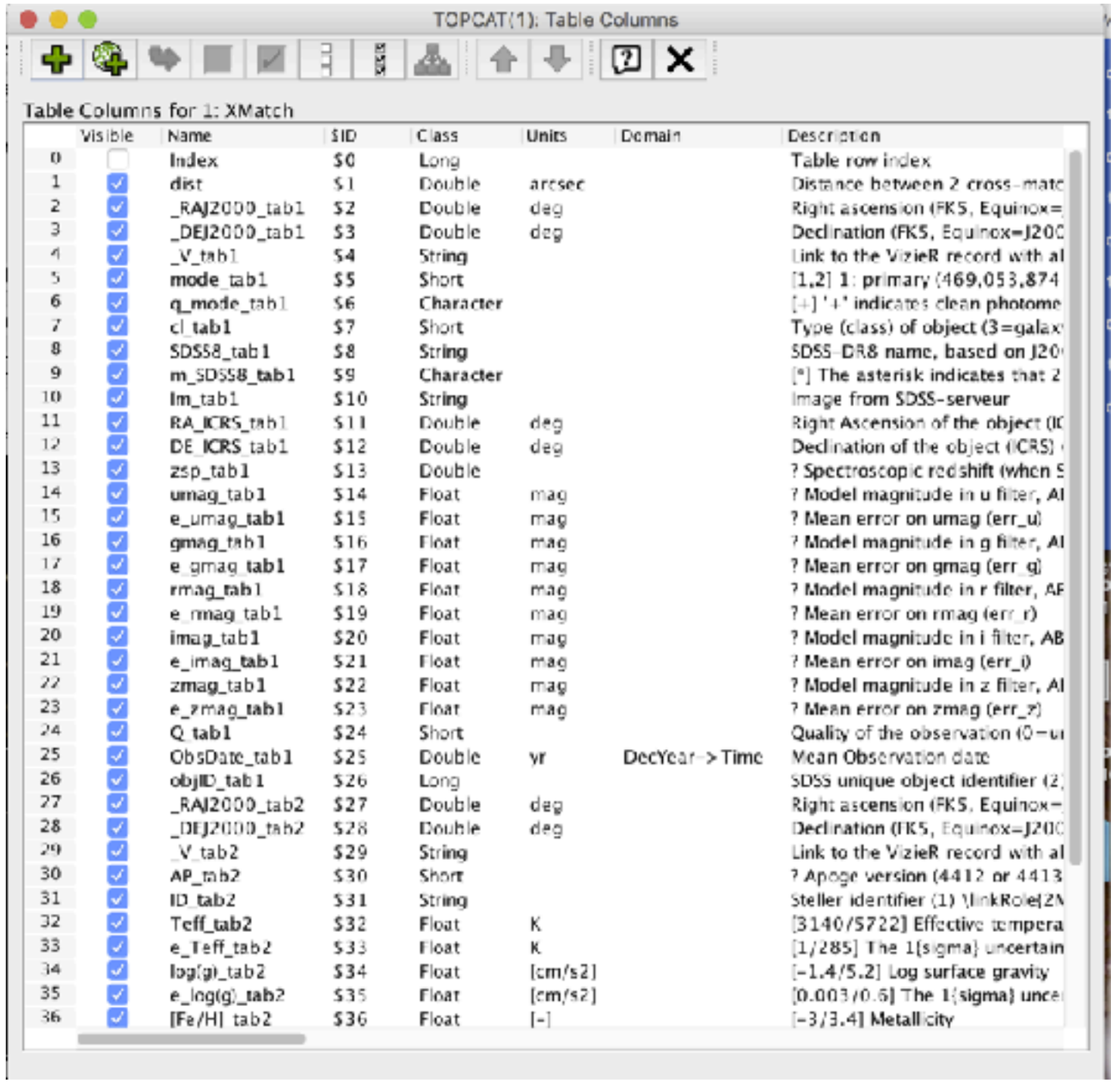
**Now let's get acquainted with our table.**

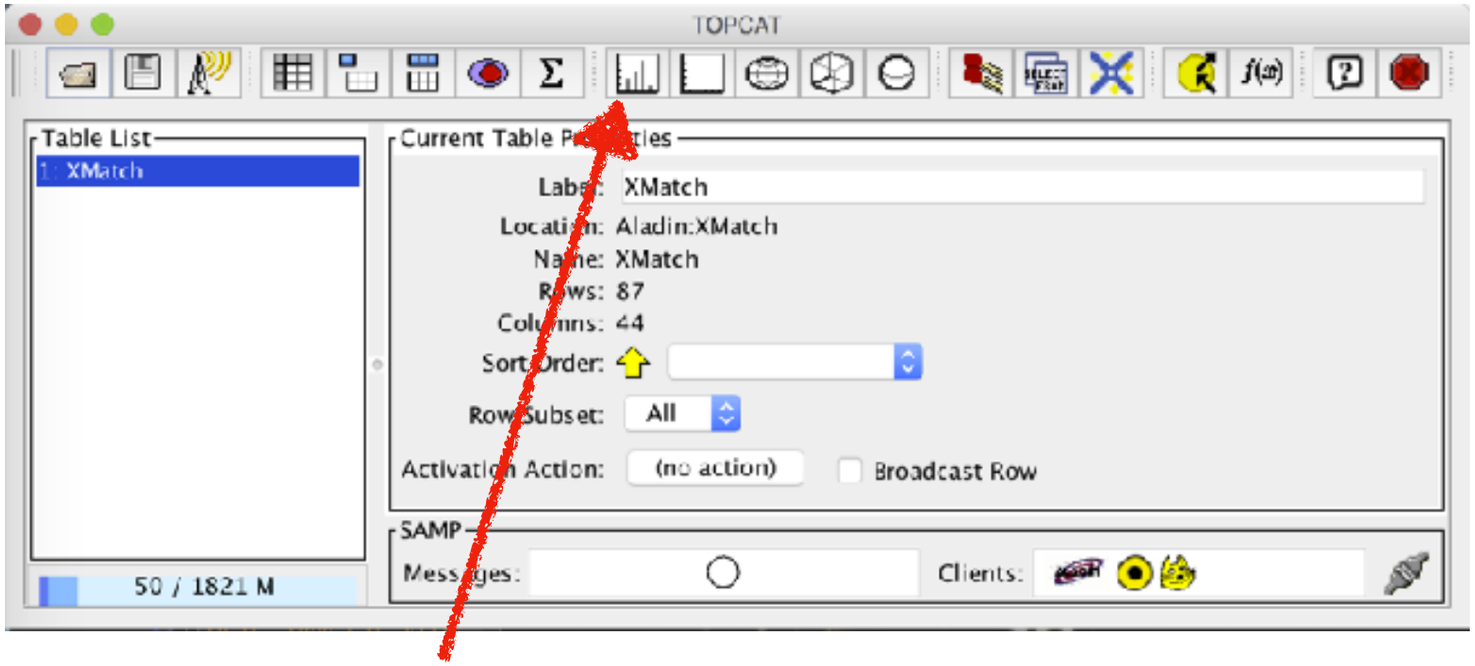
**This icon is the command to get the information on the content of the table.**

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

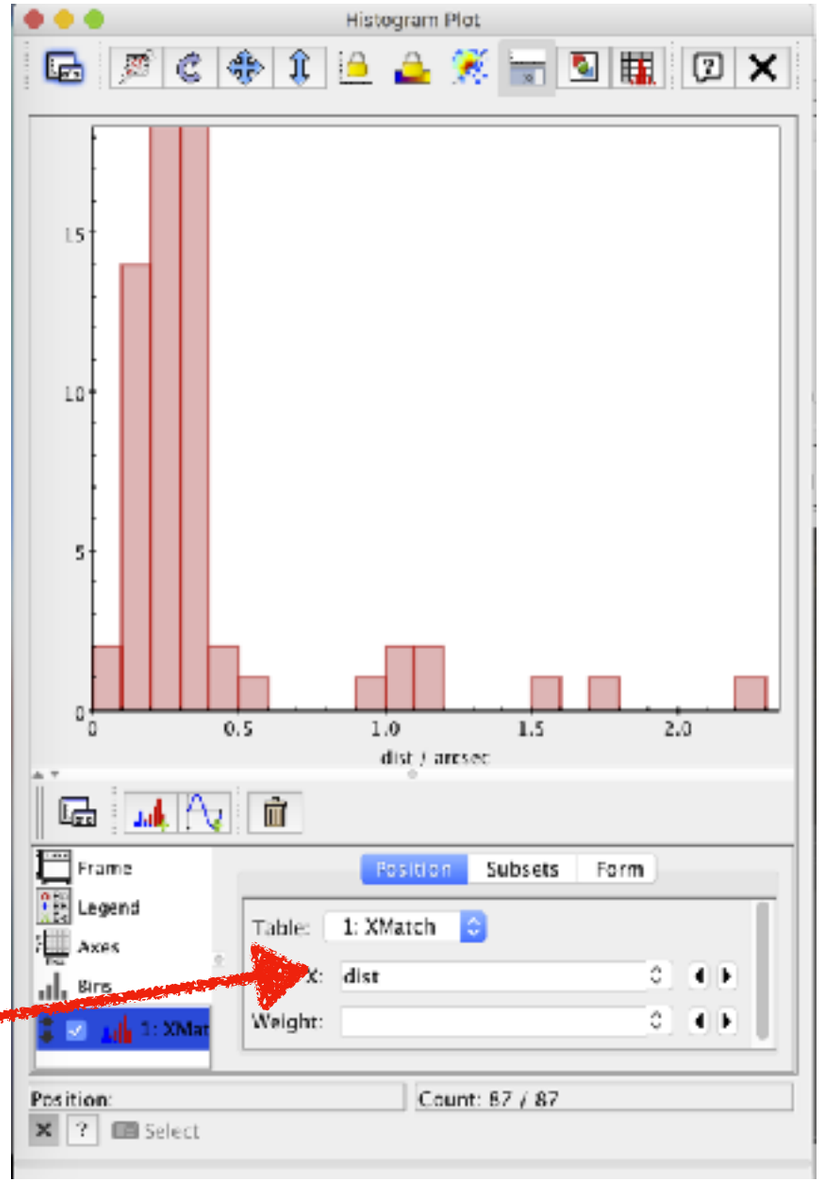


**Spend some time to understand what you have in your table.**

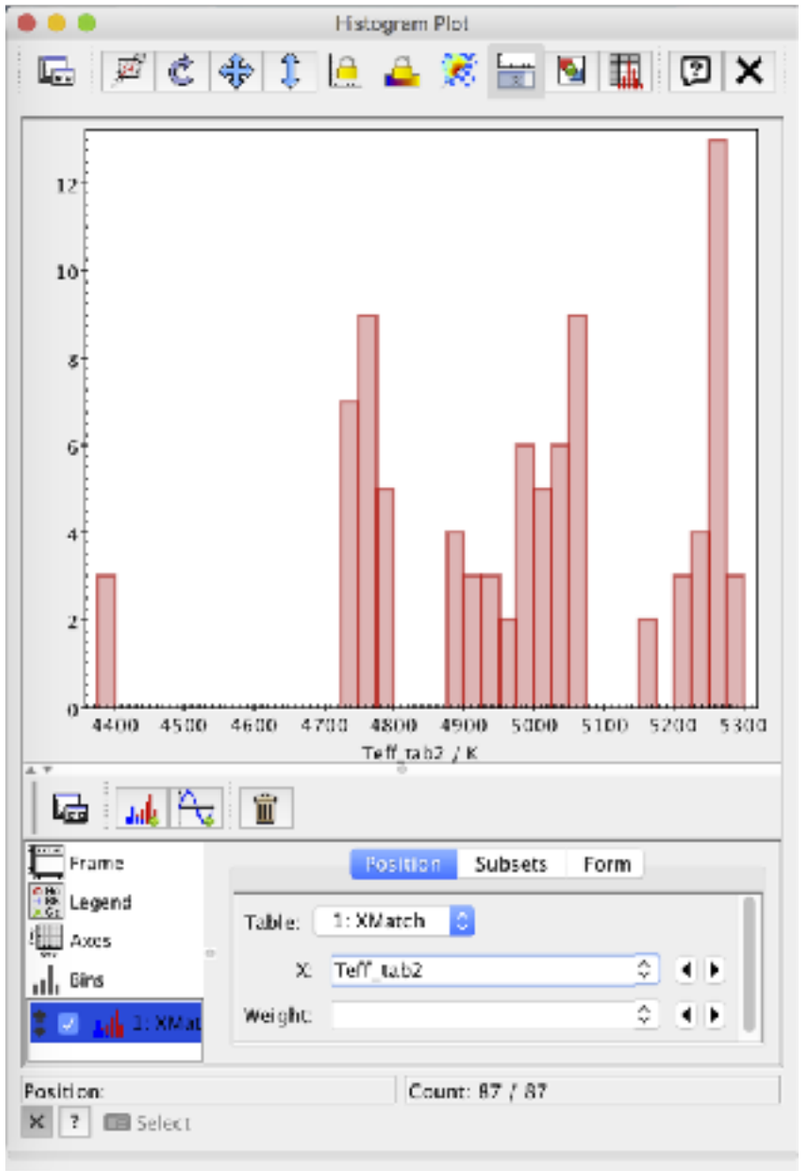





**This icon allows us to make histogram of a given column of our table.**

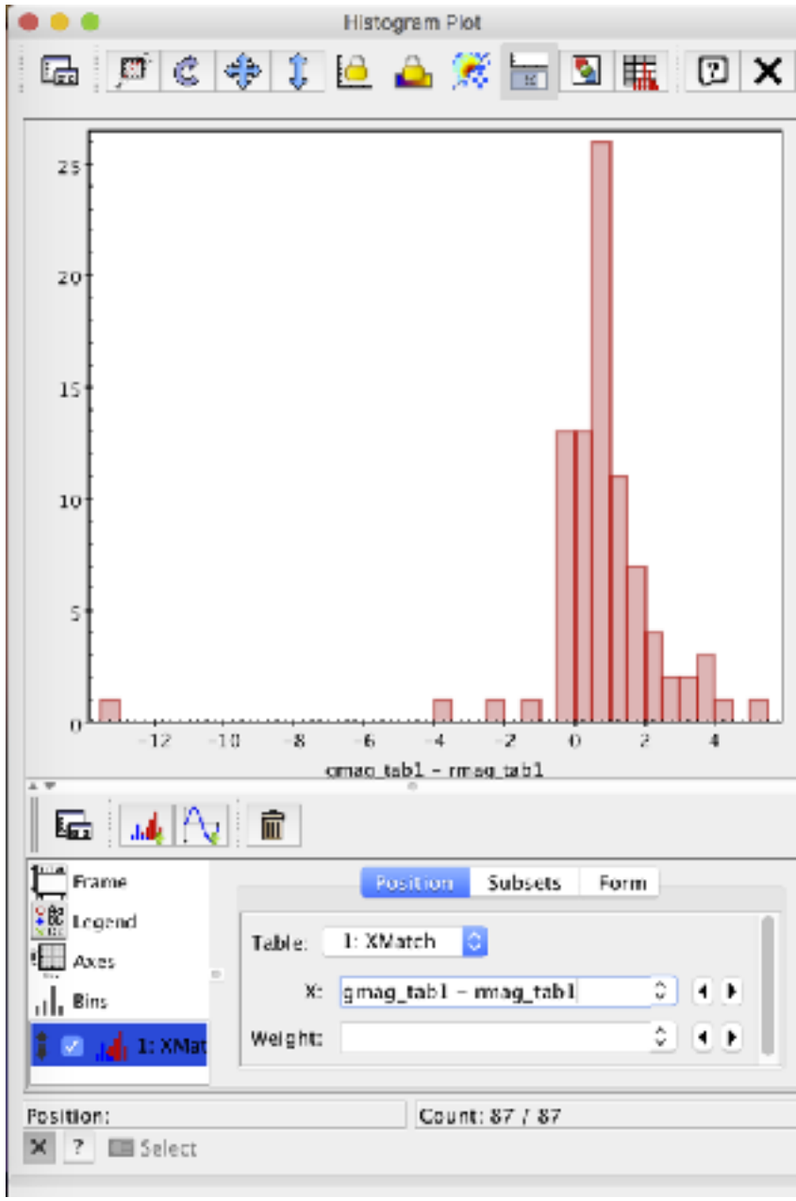


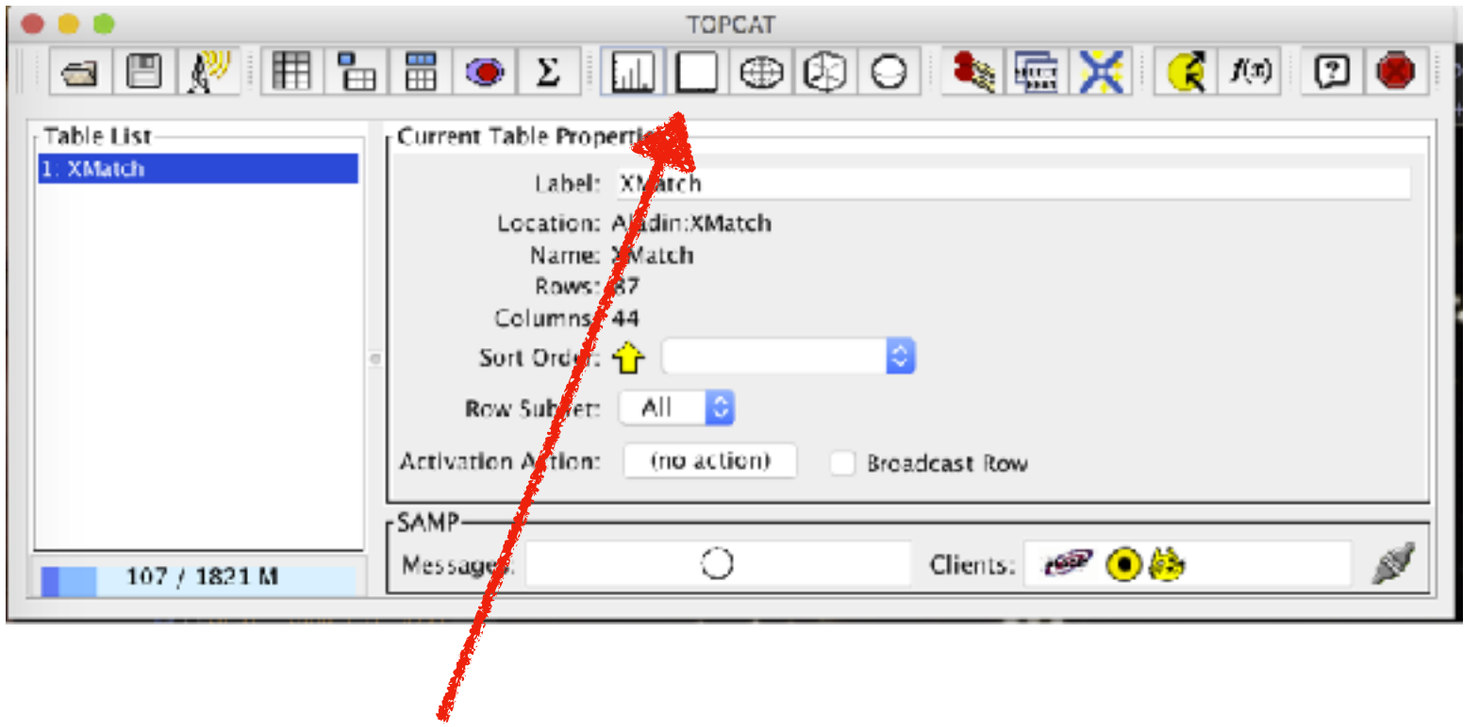

**By default, it shows the first column, which is often not too informative.**




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

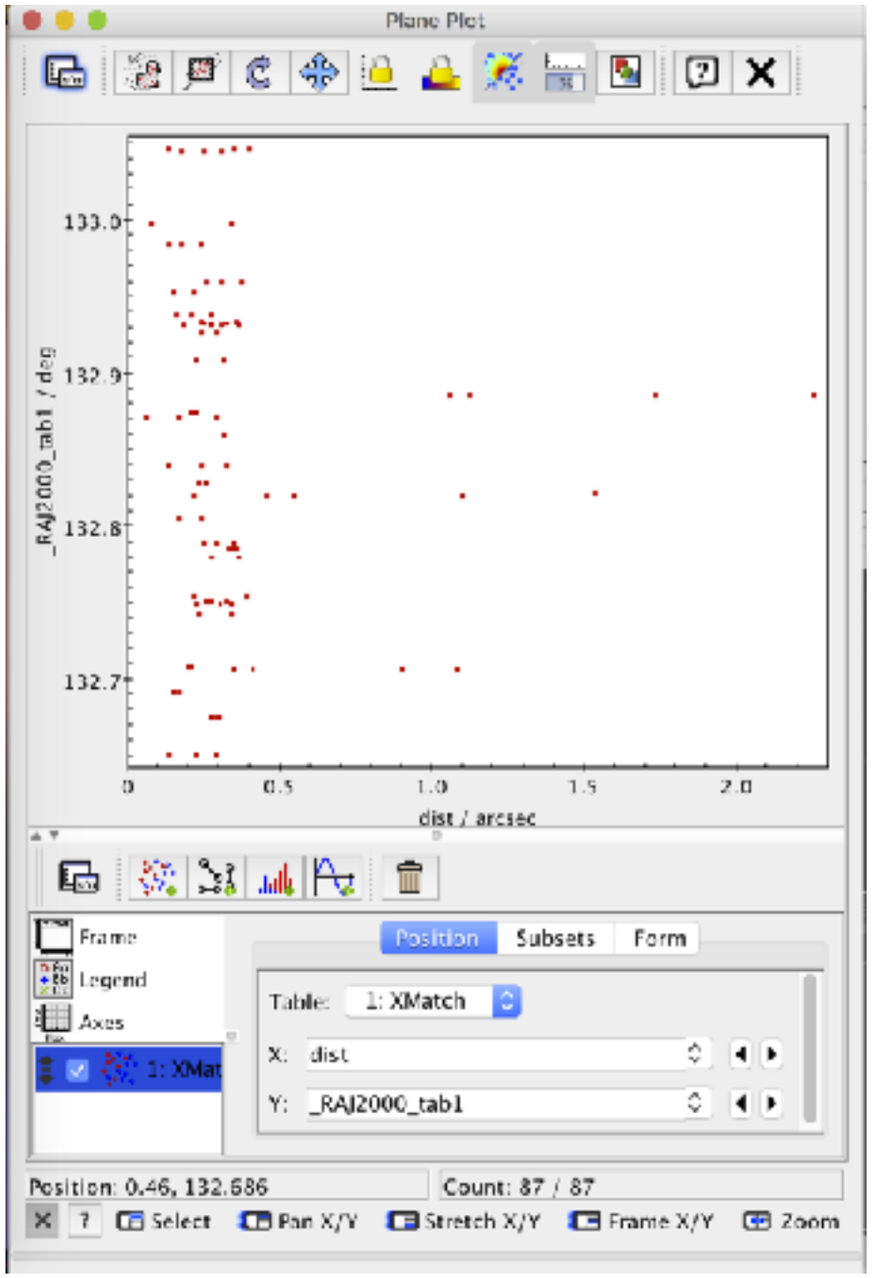
**Or you can do algebraic operations between columns (interesting *g-r* colour distribution, don't you think?)**






**This icon is for scatter plots.**

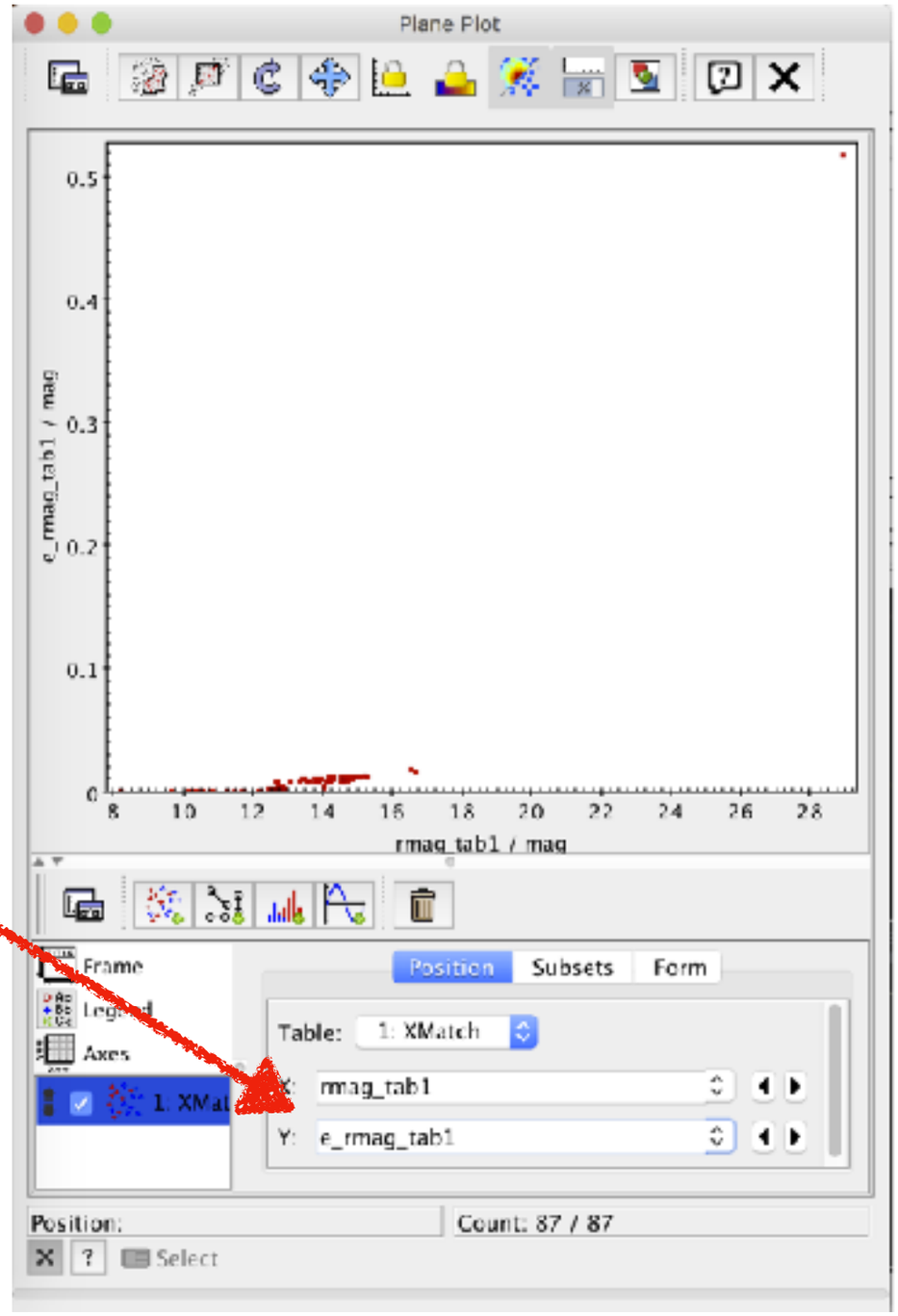
**Again, the default is not very useful.**



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

**There is one outlier which creates problems.**

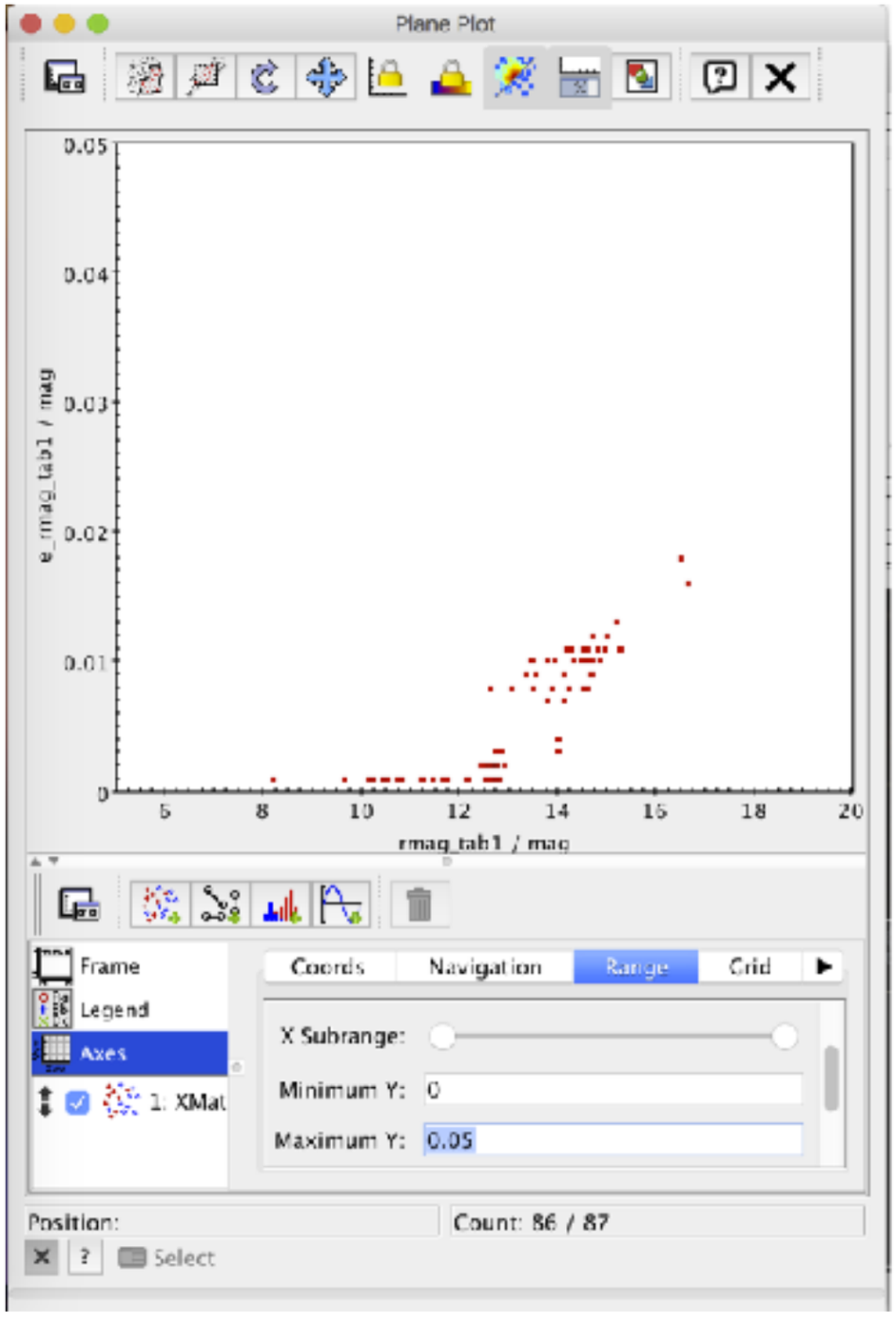
**With the mouse I can zoom in and out to have a better look at my data.**

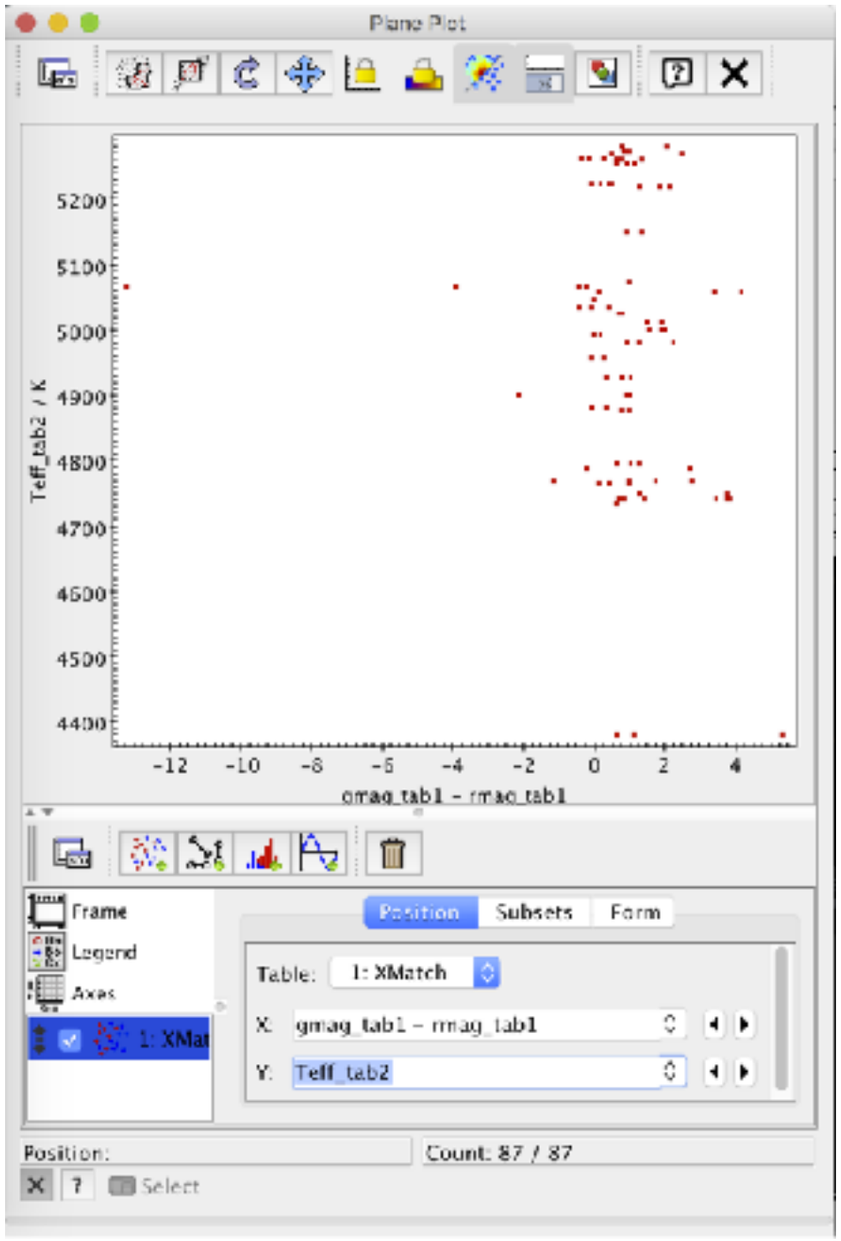


**You can go to “Axes” -> “Range” and adjust the limits by hand.**

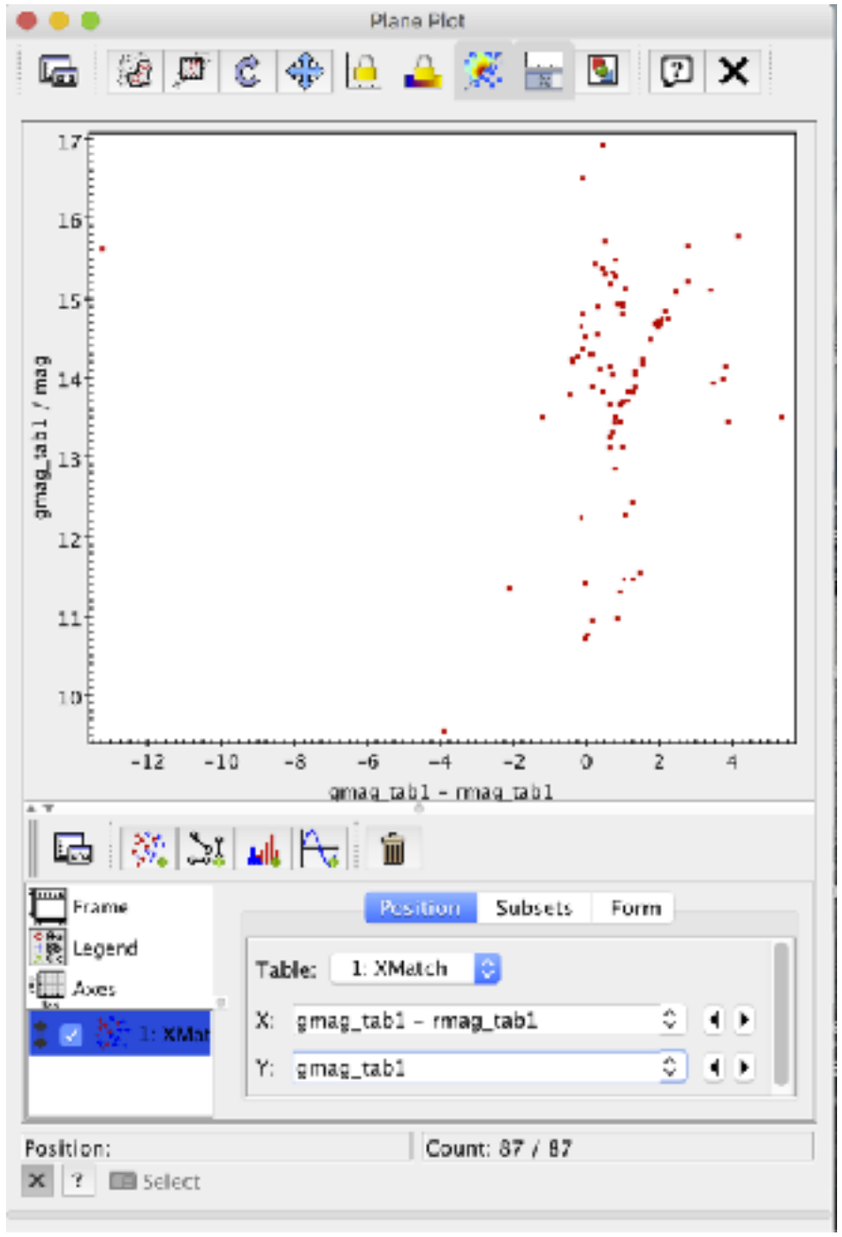
**In this example I use:**

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



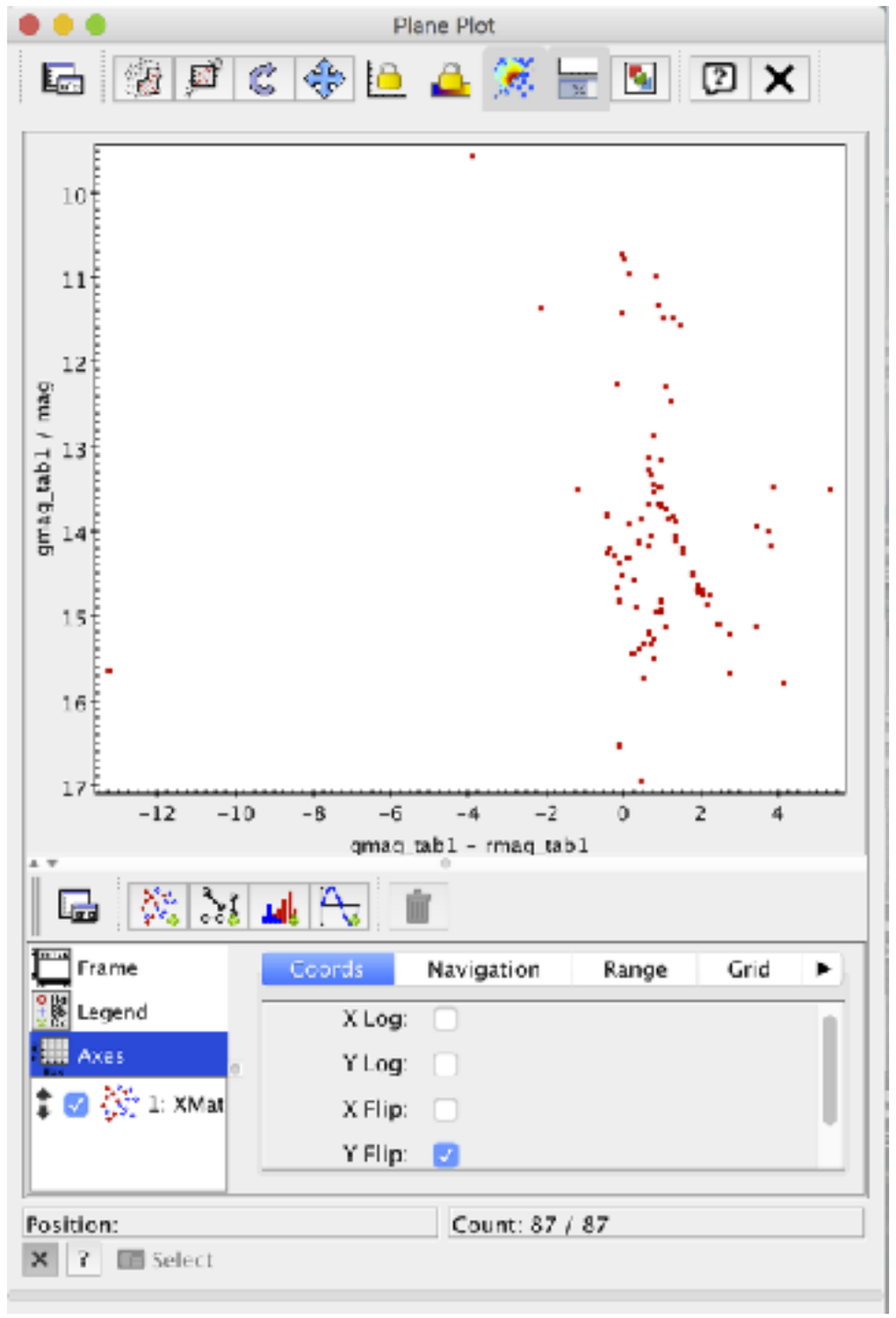



**As we said, we can also use algebraic expressions: so we can compare the effective temperatures with the g-r colour or make a colour-magnitude diagram**



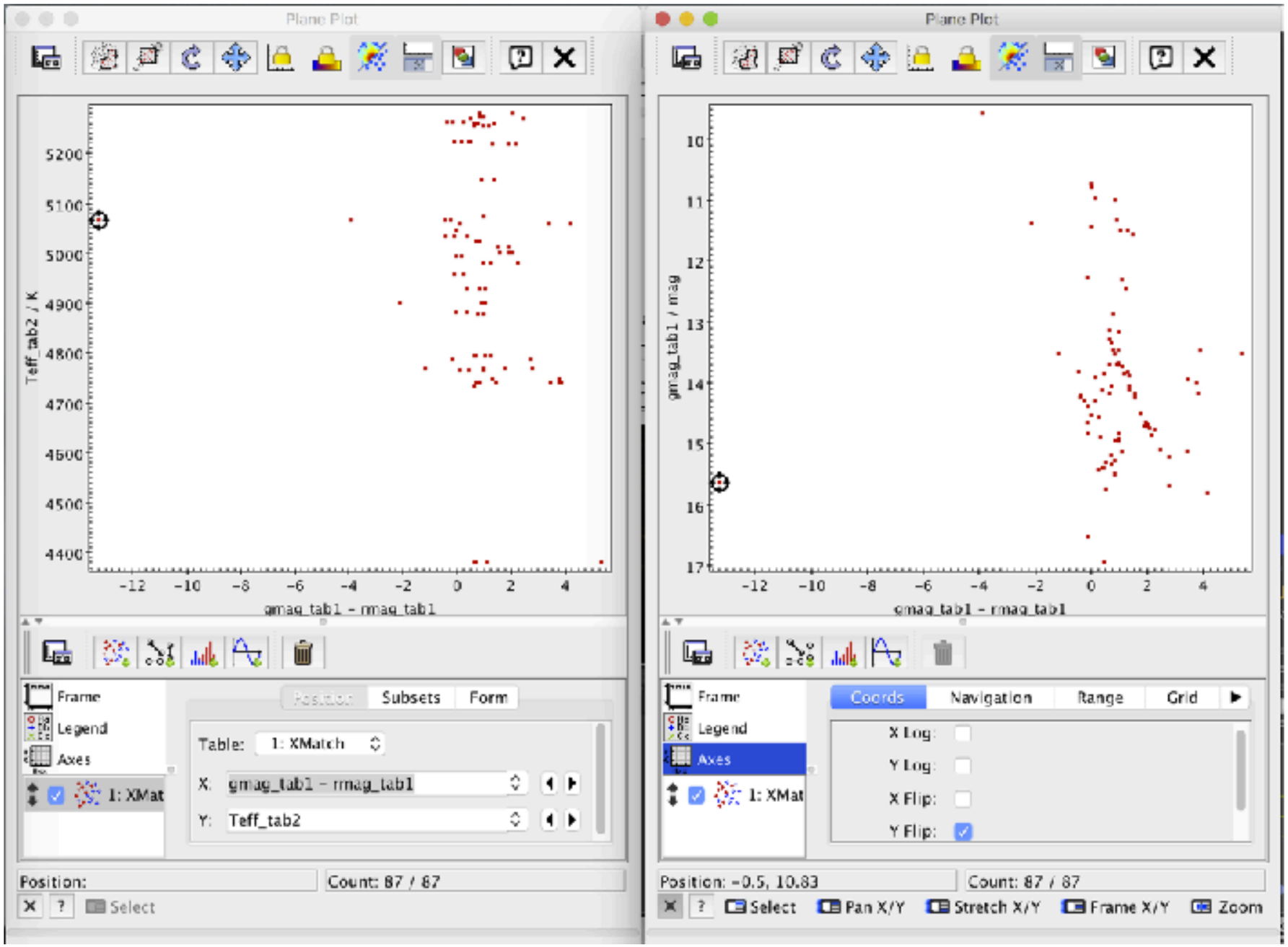
**… but the colour magnitude diagram looks weird, right?**

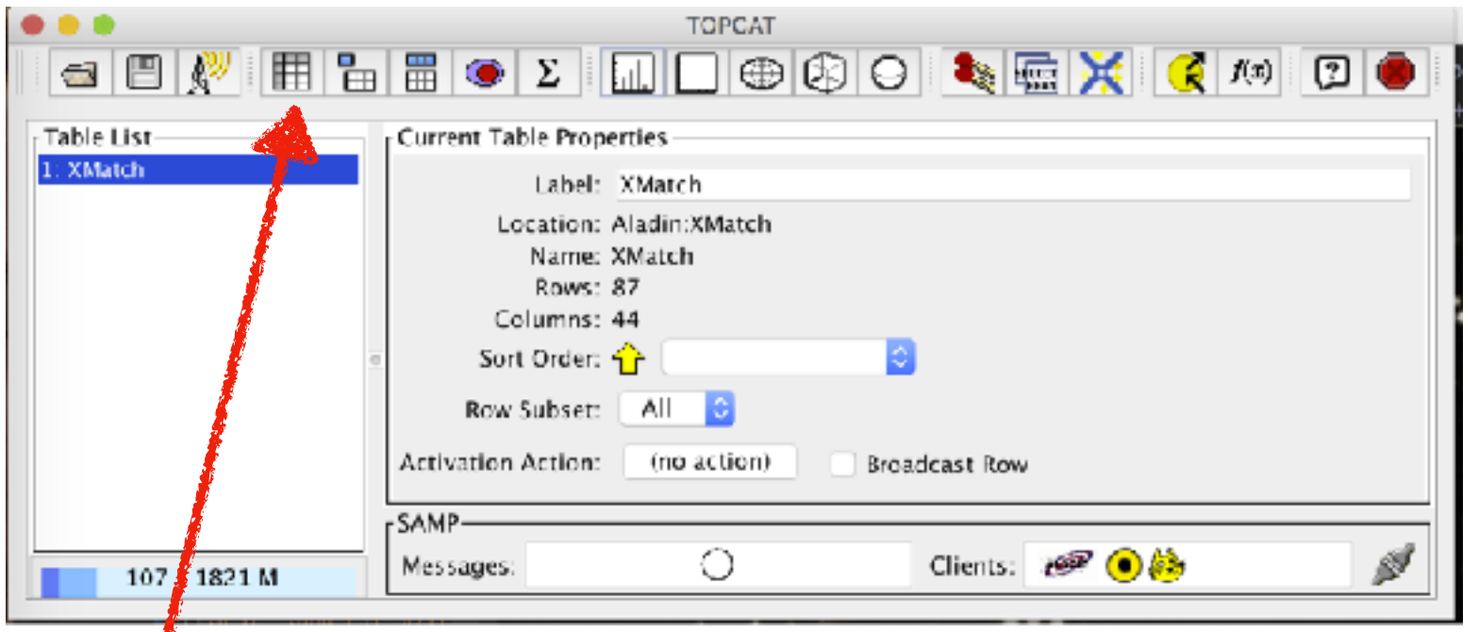
**To get magnitude decreasing as y increases, we just go to “Axes” -> “Coords” -> “Y flip”**



**that outlier is a bit disturbing…**

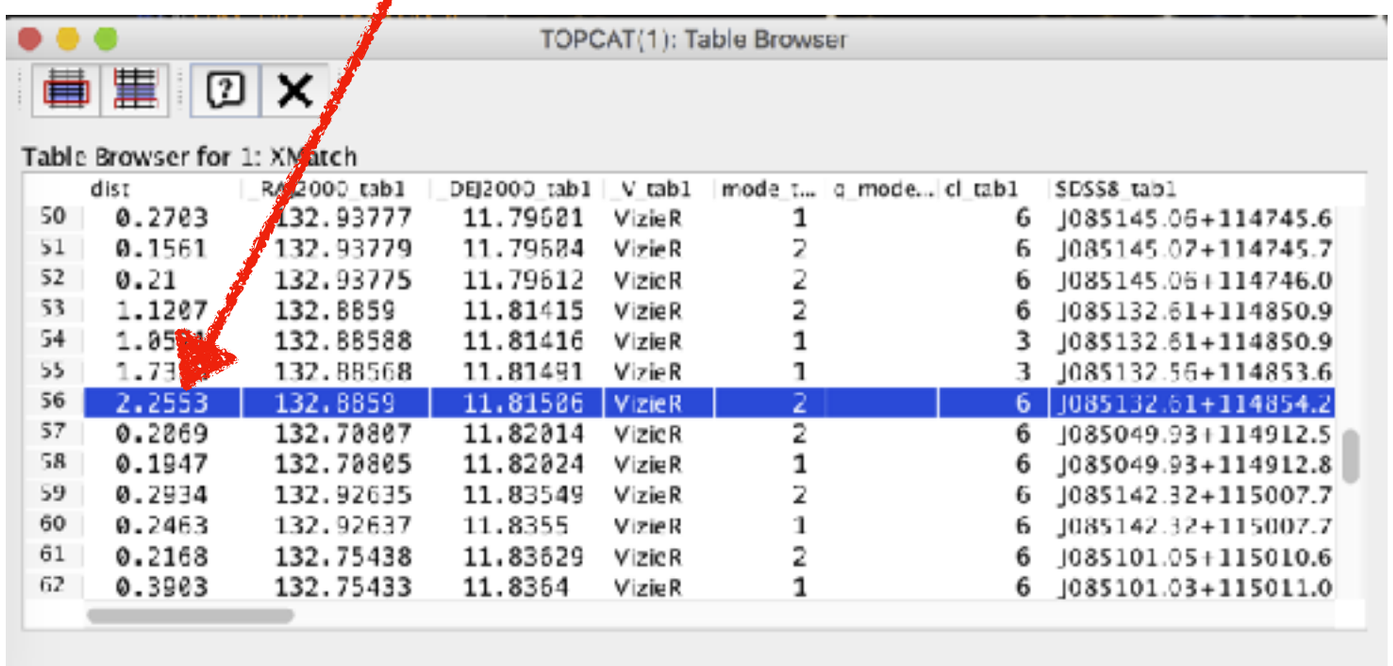
**(good thing, you click on one plot, and it gets marked on the other)**






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 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)

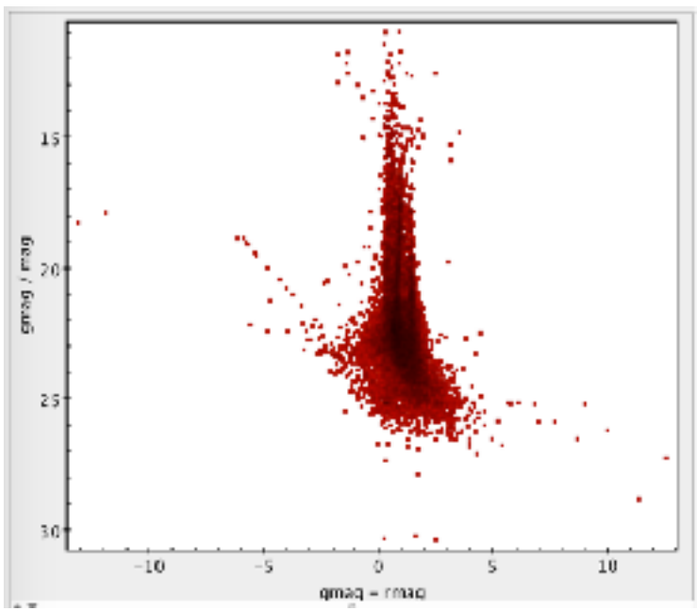


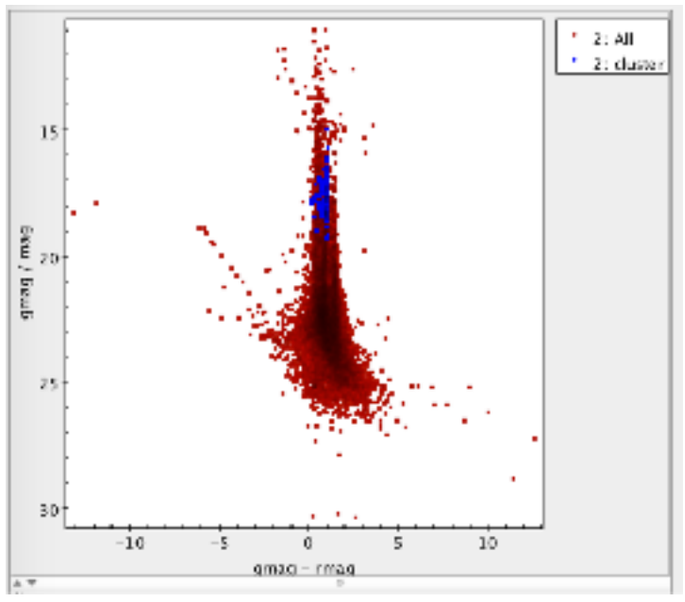

| | dist | RA2000_tab1 | DEJ2000_tab1 | V_tab1 | mode_t... | g_mode... | cl_tab1 | SDSS8_tab1 |
|---|---|---|---|---|---|---|---|---|
| 50 | 0.2703 | 132.93777 | 11.79601 | VizieR | 1 | | 6 | J085145.06+114745.6 |
| 51 | 0.1561 | 132.93779 | 11.79584 | VizieR | 2 | | 6 | J085145.07+114745.7 |
| 52 | 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 | 1.05[illegible] | 132.88588 | 11.81416 | VizieR | 1 | | 3 | J085132.61+114850.9 |
| 55 | 1.73[illegible] | 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 |

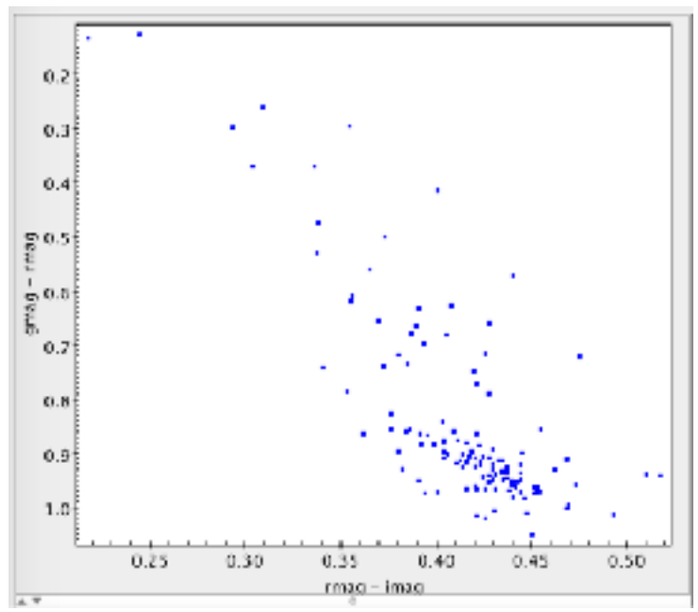
# Exercise #1

- 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? g-r vs W1-W2?



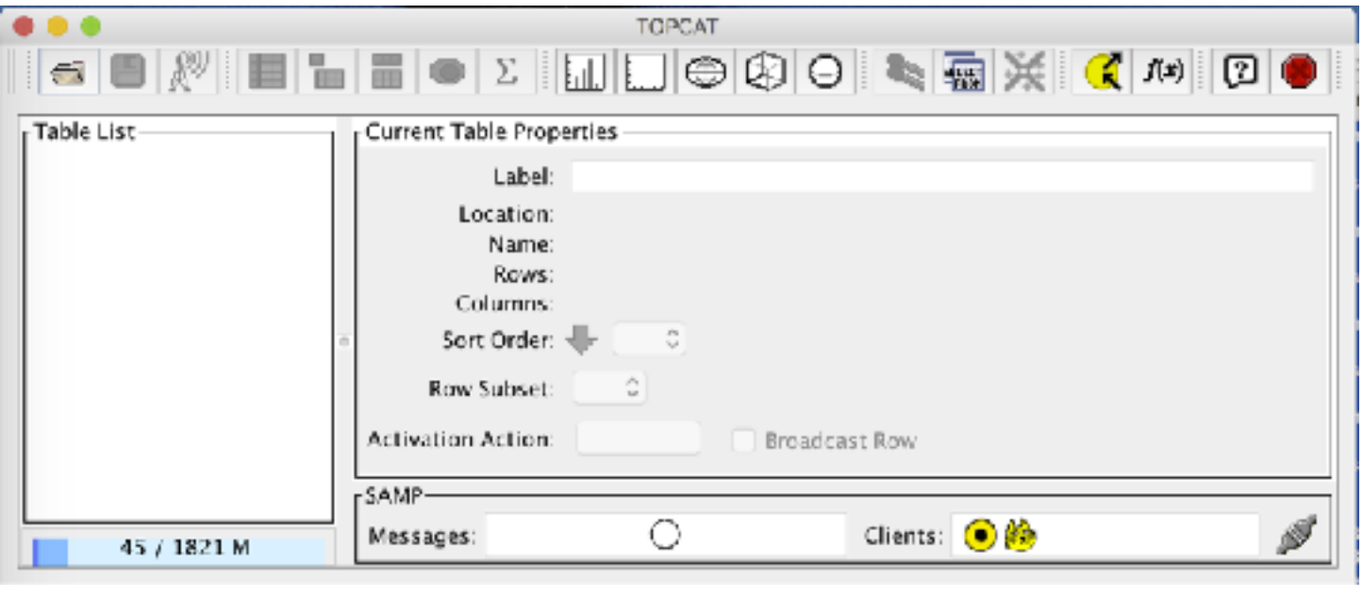




**Yes, there is a trick that you don't know yet**

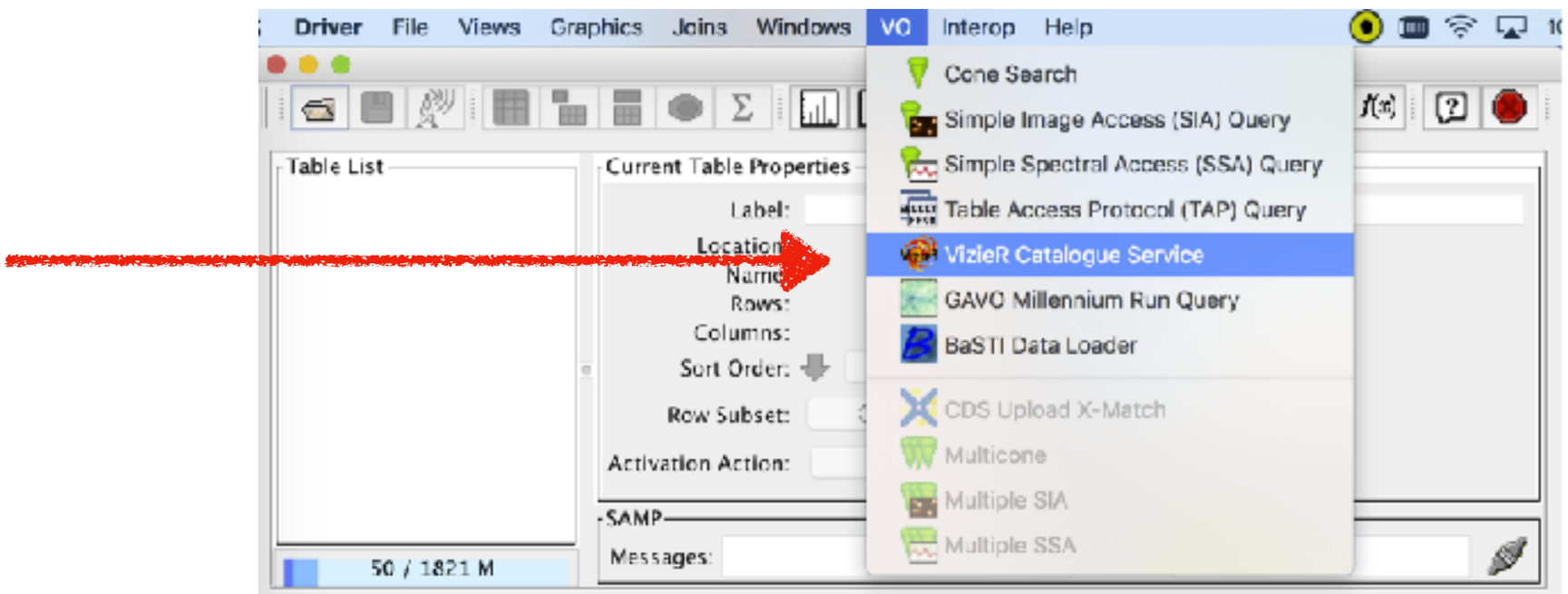
# Example #2:

# Bright Stars Catalog



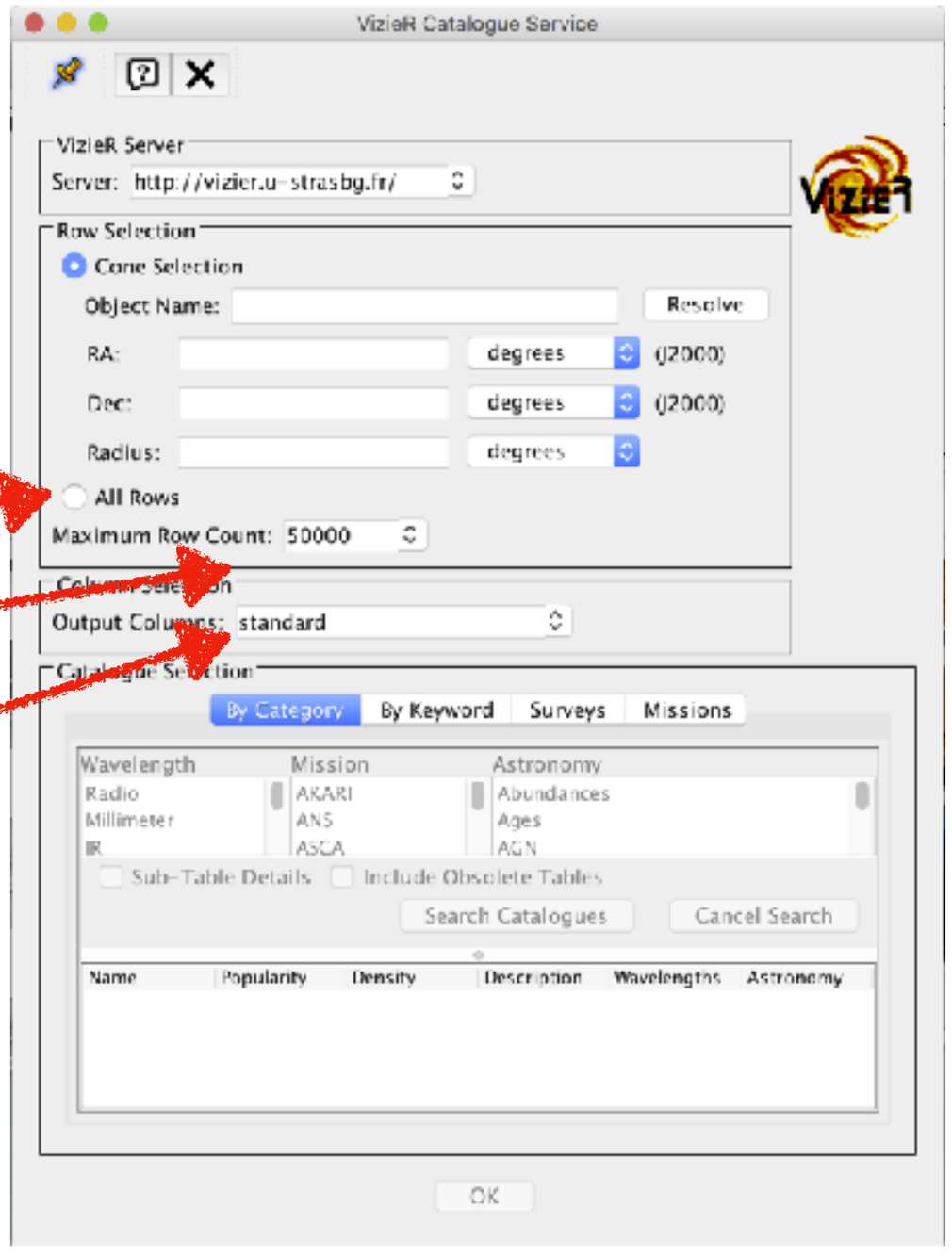

With a nice clean start of Topcat

Look for VizieR Catalogue Service



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

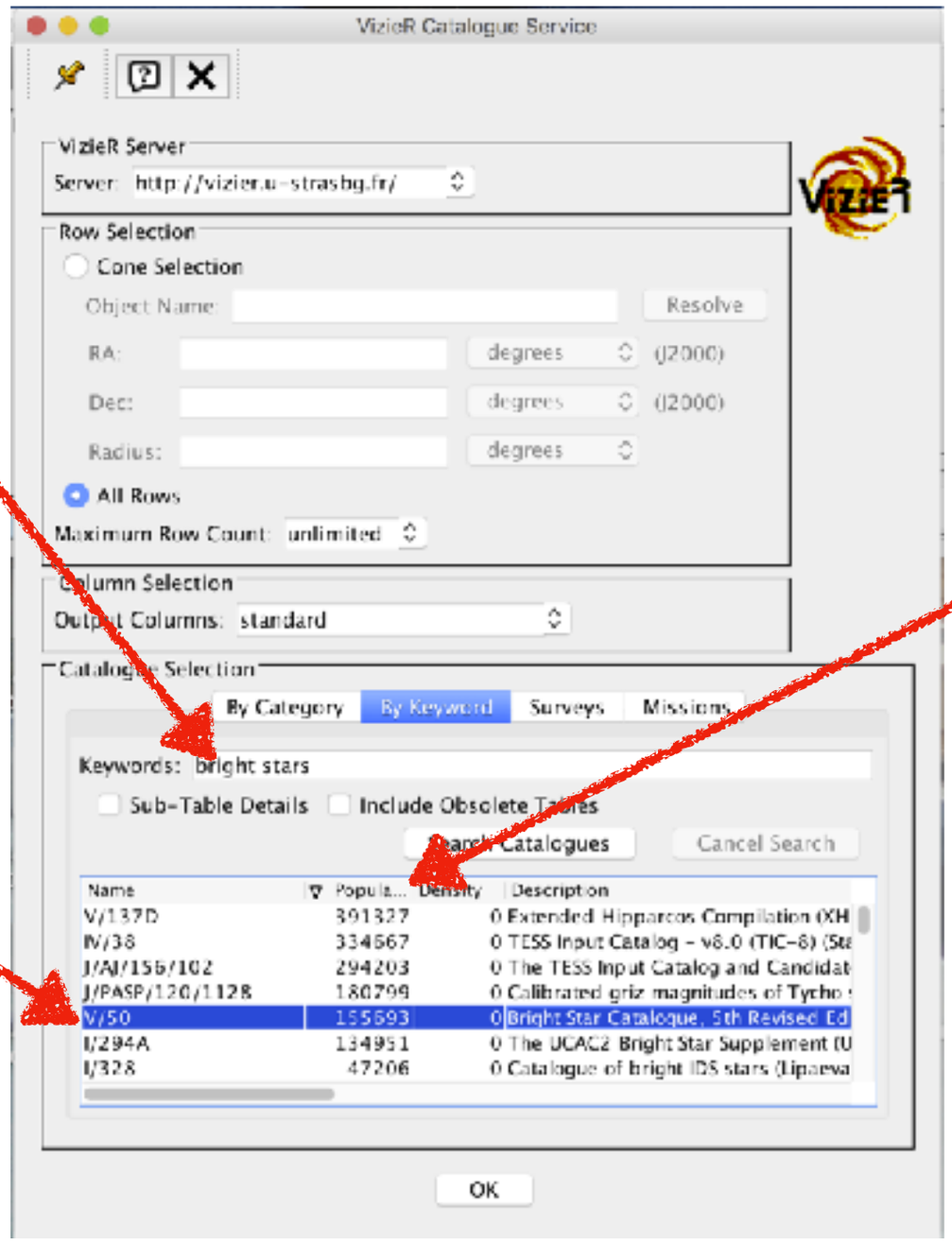
**We only care for:**
**-) get “all rows”**
**-) get an unlimited number of sources we can download**
**-) output columns “standard”**

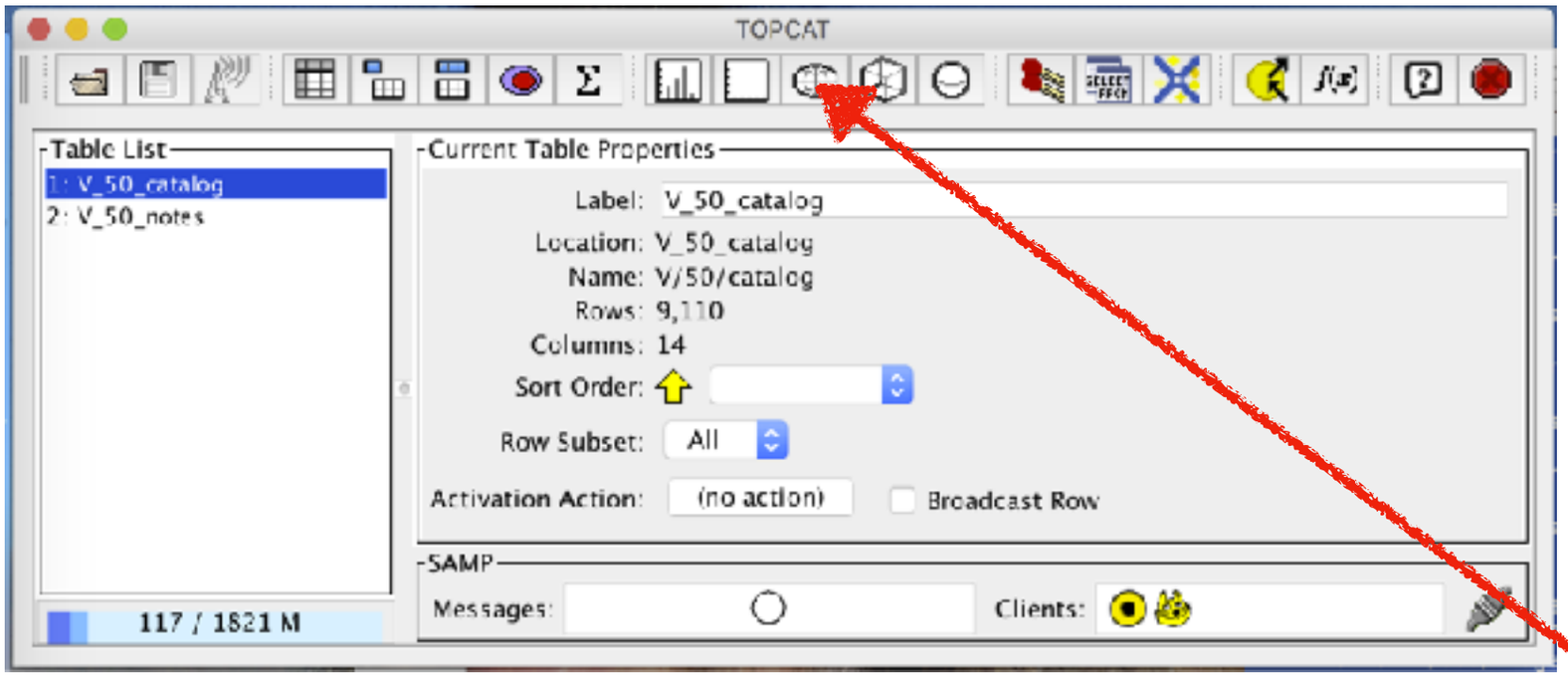


We search for “bright stars”

We find our catalogue and click on “ok”

We can order by “popularity”

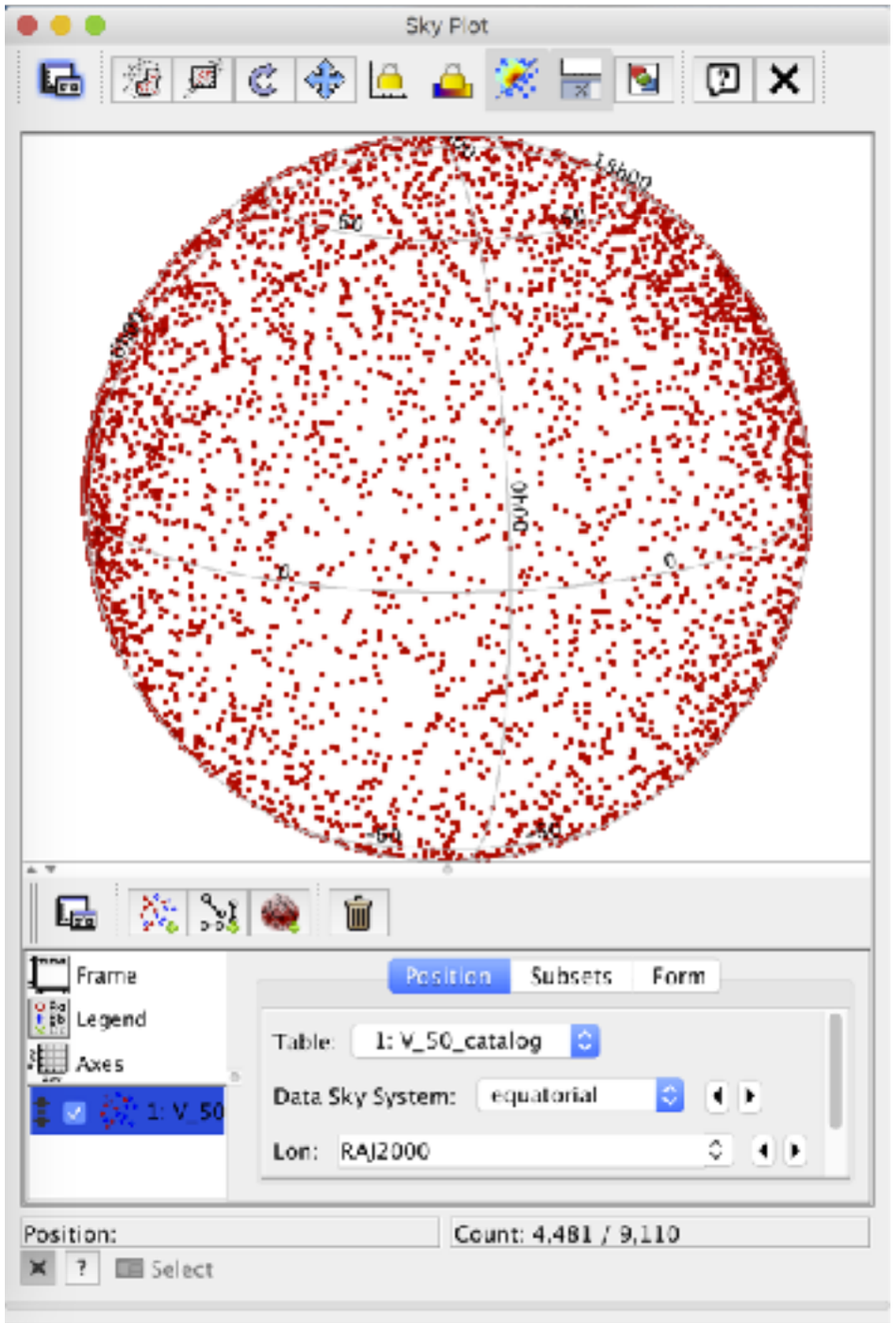





**It is a table of 9110 rows and 14 columns.**

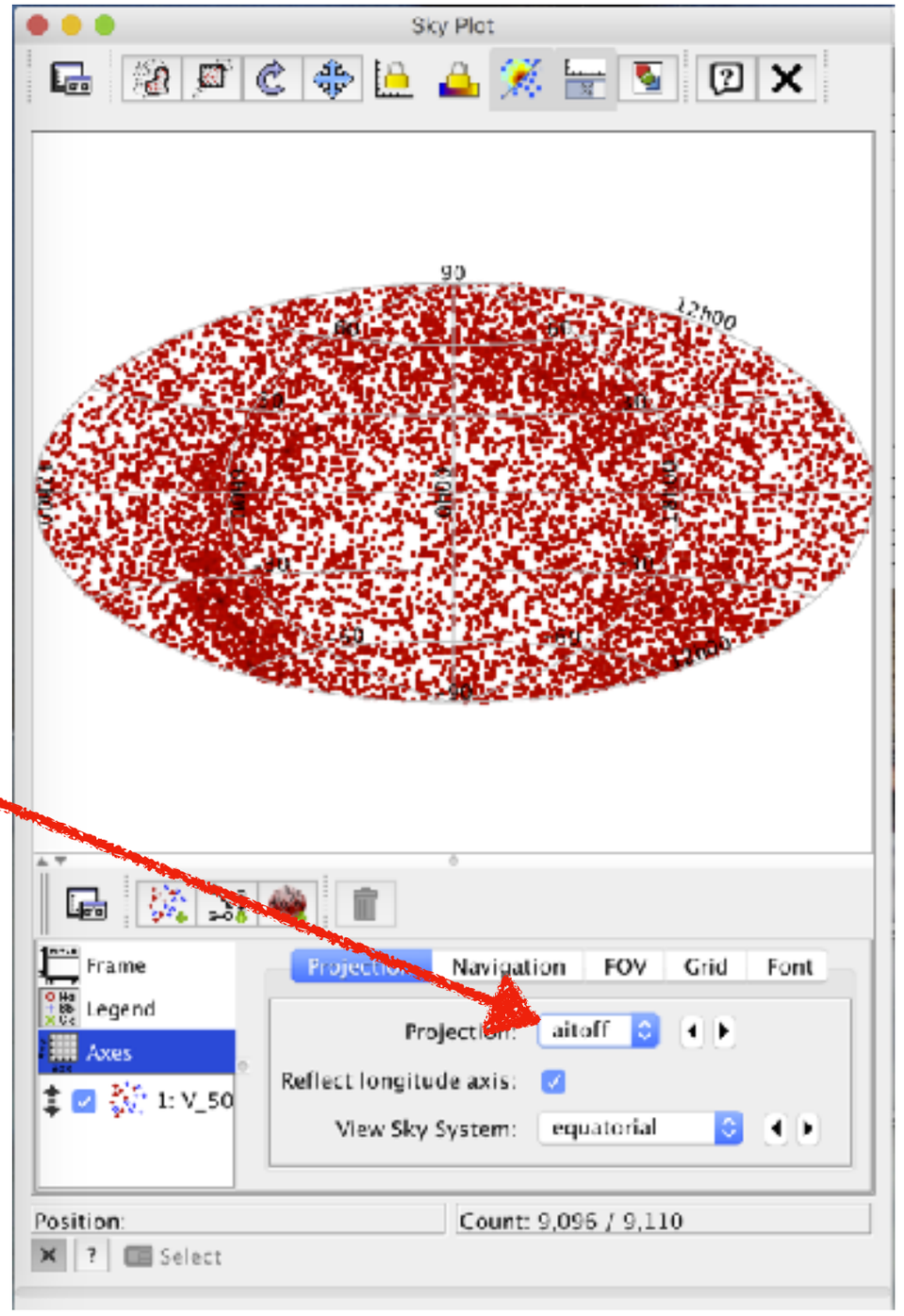
**You already know how to display the table and check the meaning of its columns.**

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

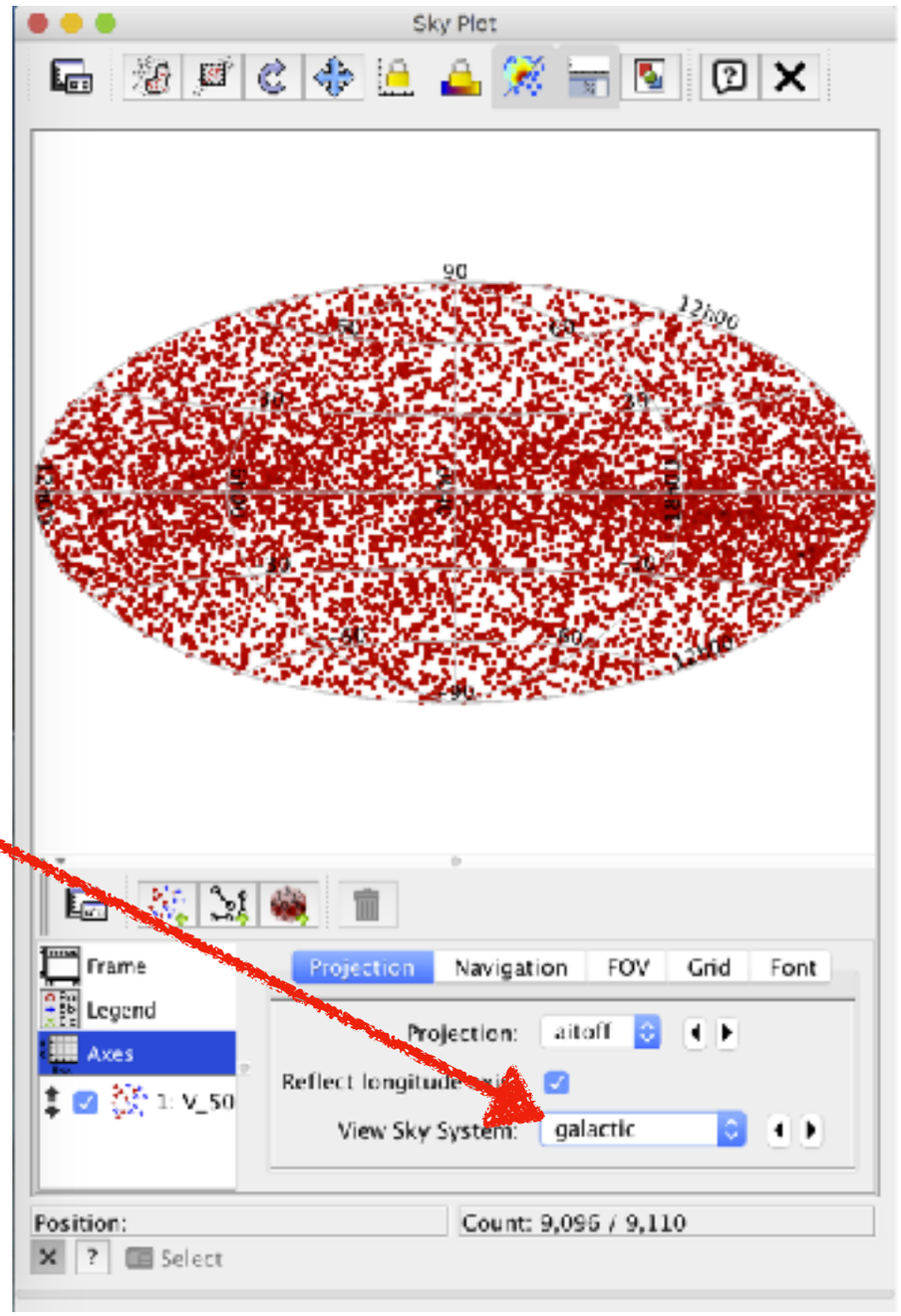


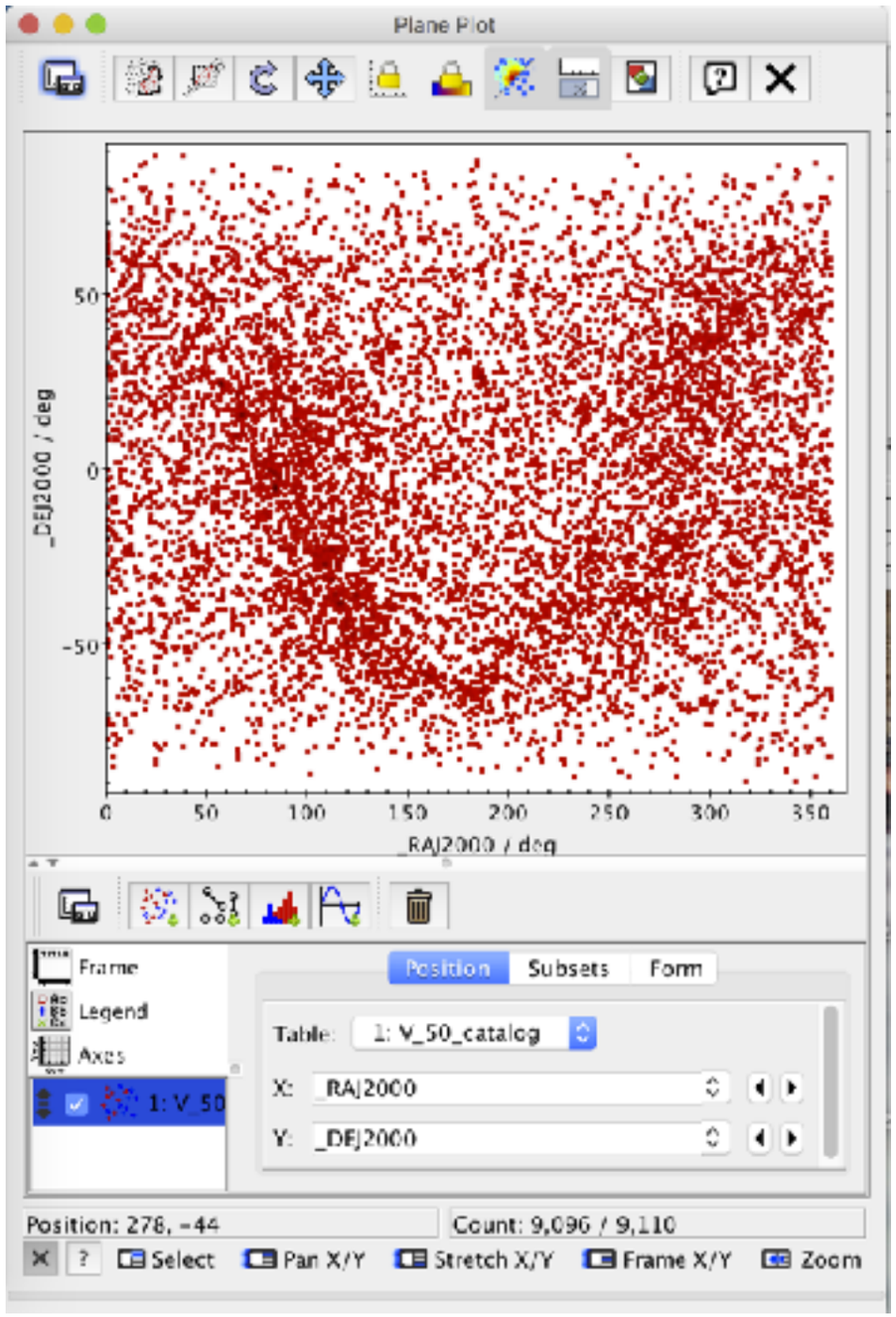

**This is a sky projection. Yet a "ball with points" is not too helpful.**

**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?**



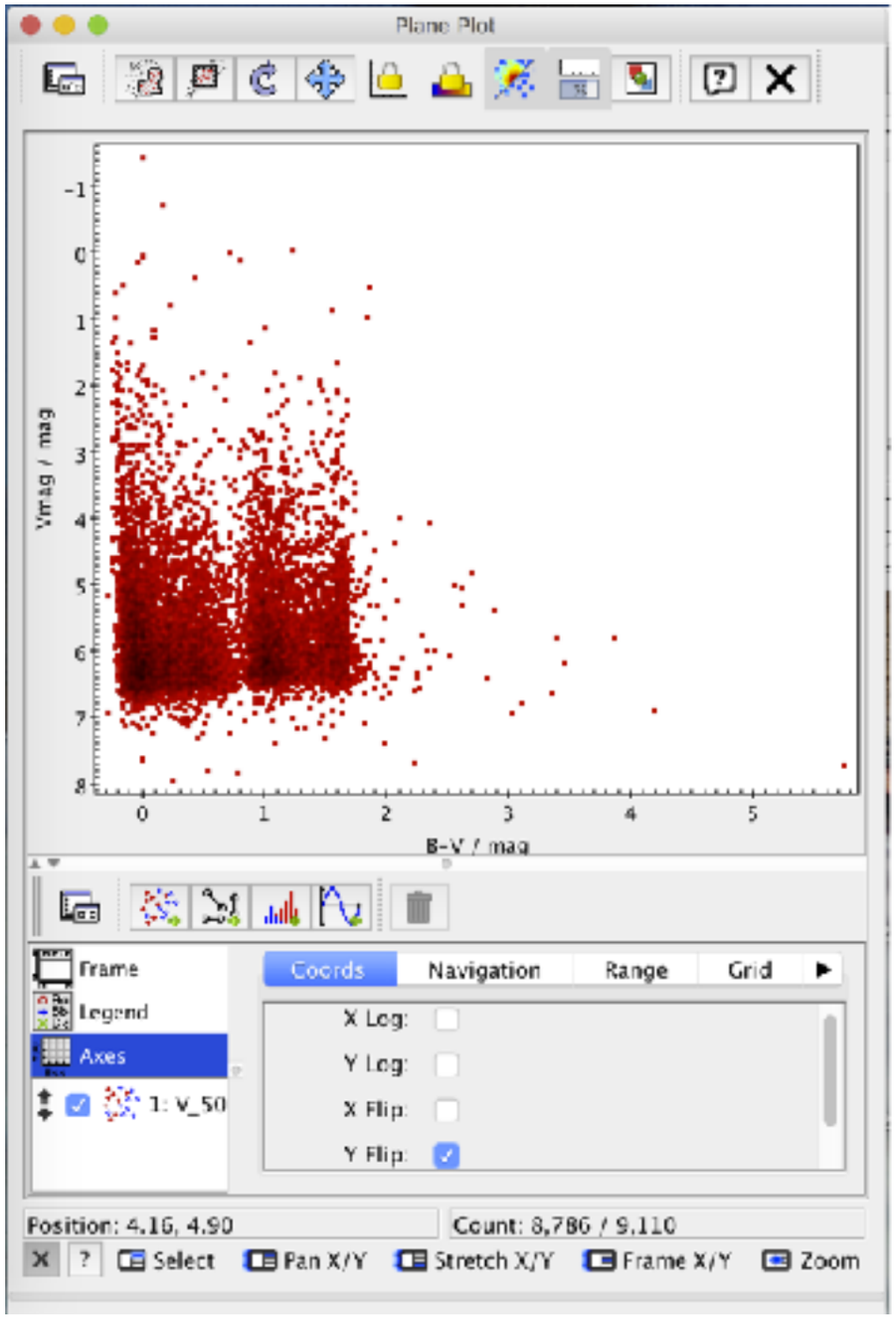
**Can you see the Milky Way better if you use a Galactic reference system?**

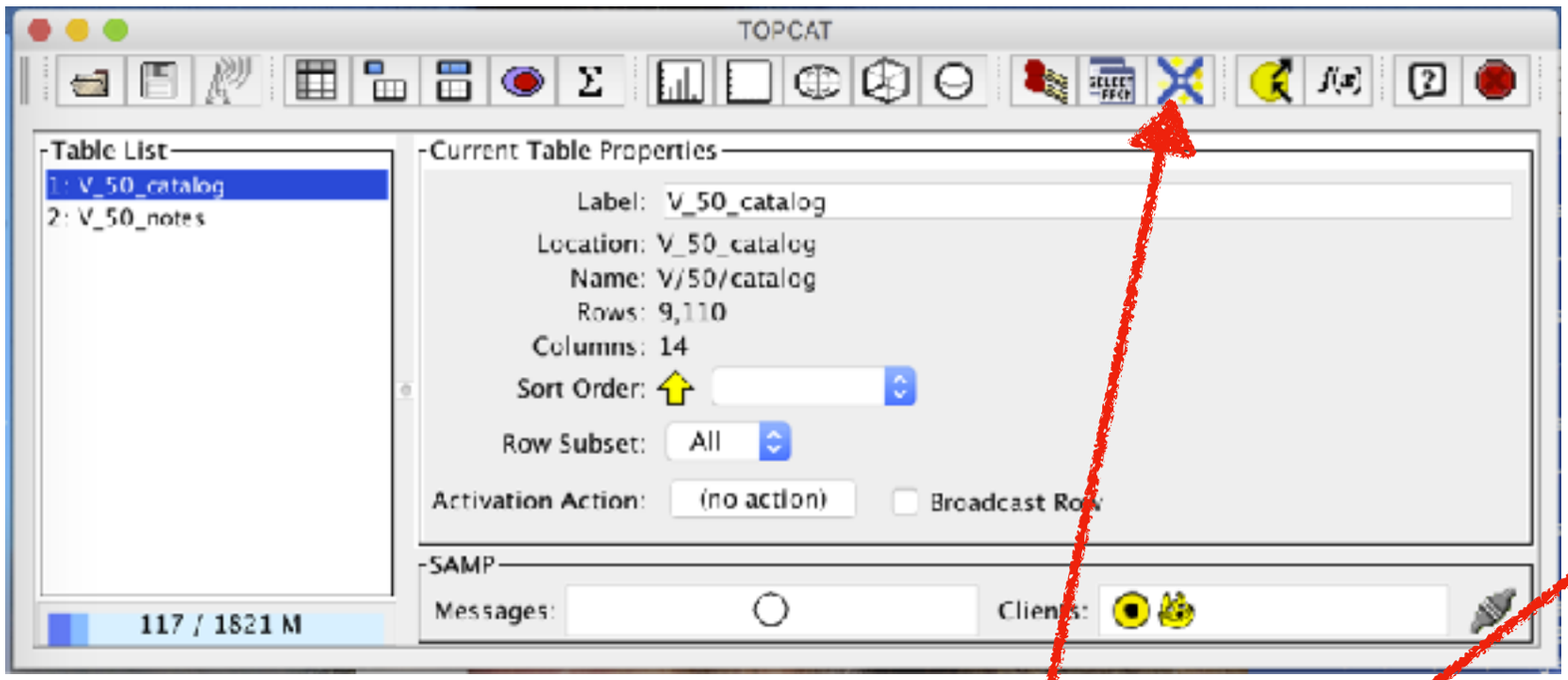


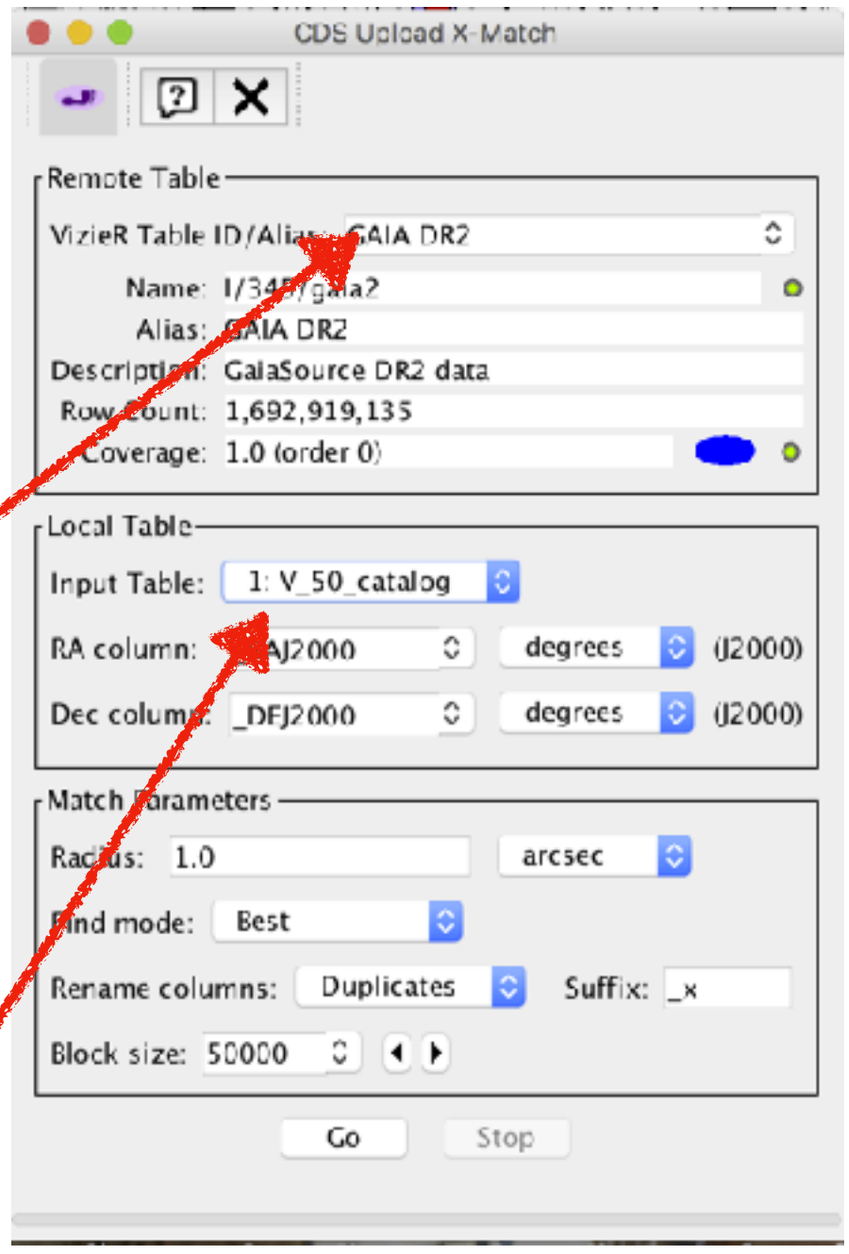



**The default scatter plot [left] is nice (also here you can see the plane of the Milky Way) but let's see if we can get a colour-magnitude diagram [right].**

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





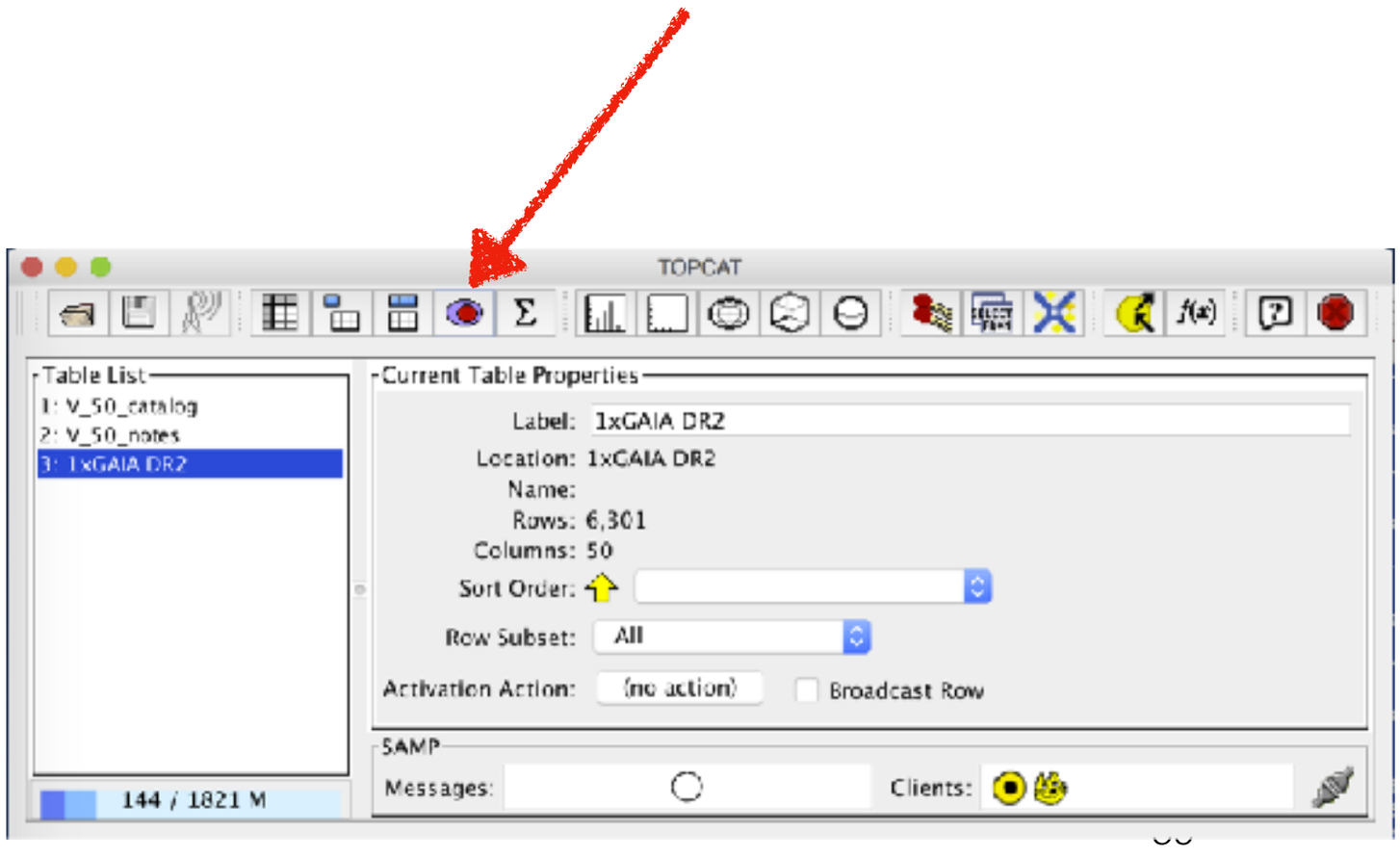

**To query very big tables, you can use this button.**

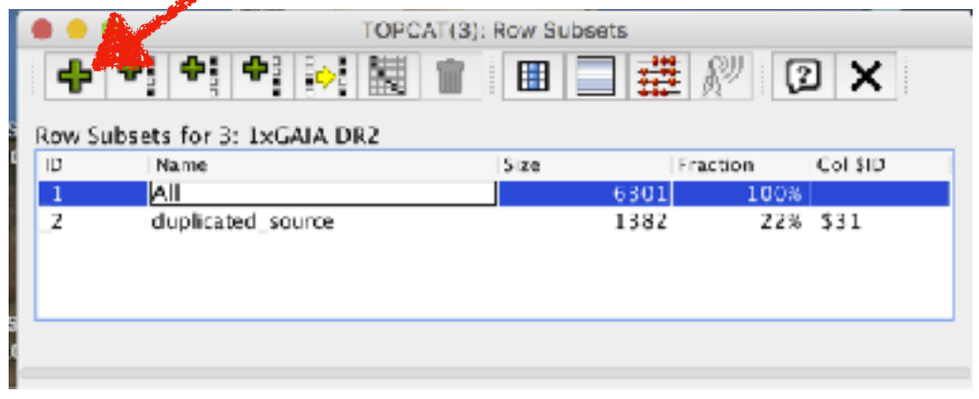
**For this case we use Gaia DR2 (I know that there is a "distances" table but I prefer this one) and our table…**
**… and click on "Ok"**

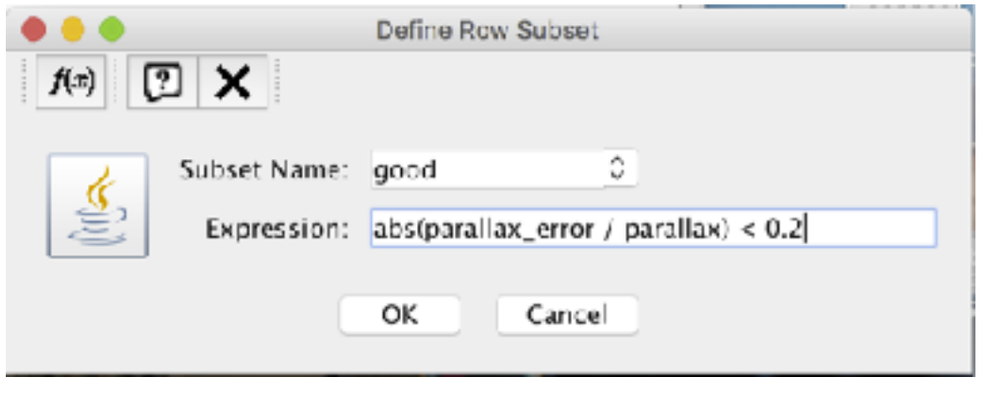
**Luri et al. (2018) have shown that, in Gaia DR2, you can assume that the distance is the inverse of the parallax only if the error on the parallax is smaller than 20%.**

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

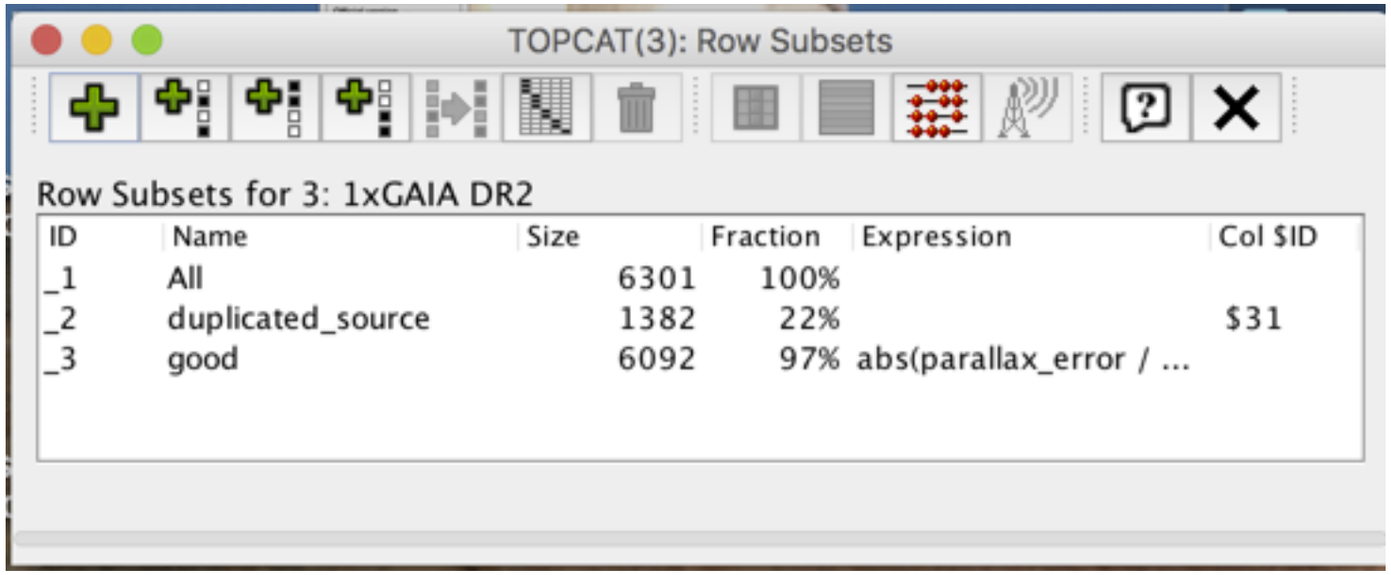
**Select the first line and click on the “+”**



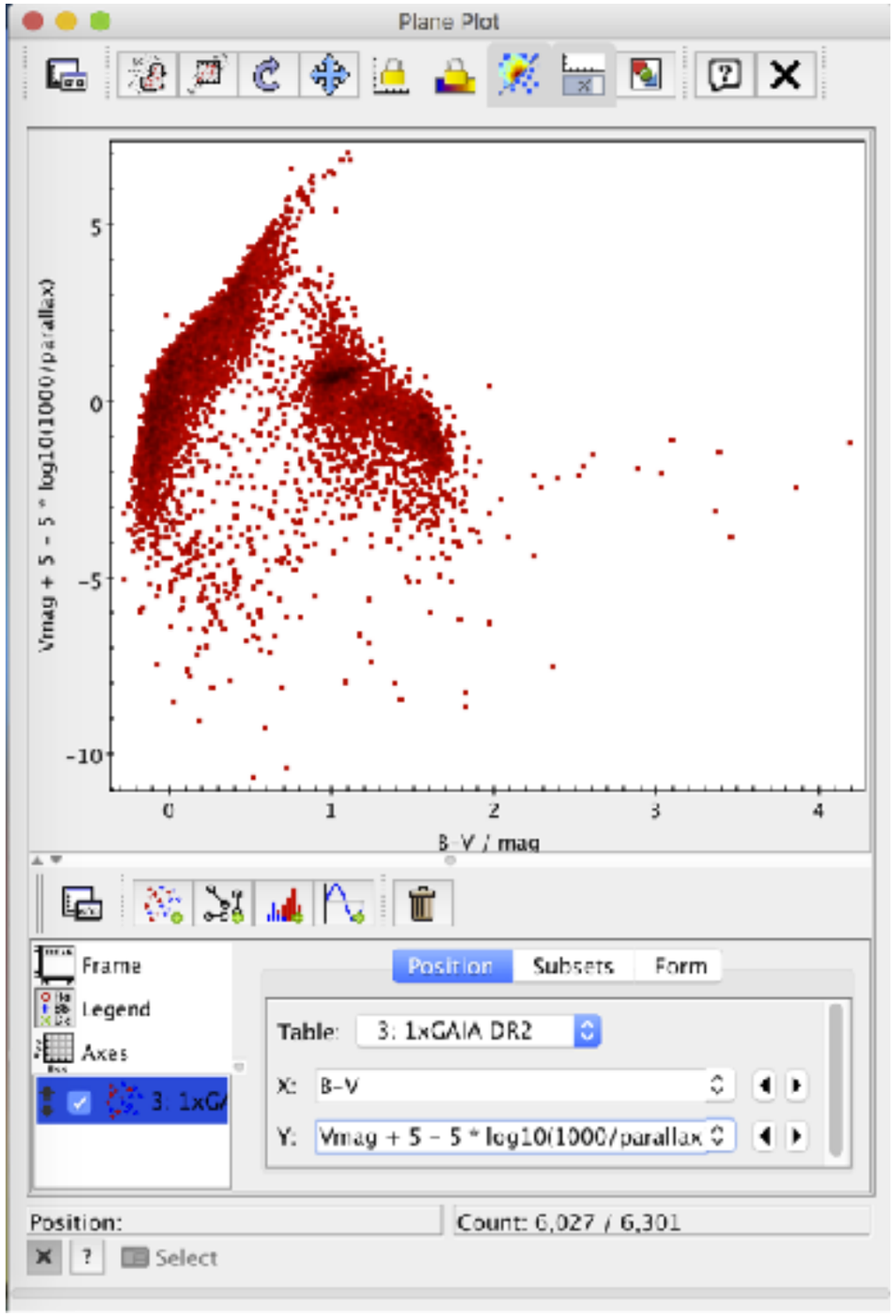



**After you click on “ok”, your sub-sample “good” is going to have 6092 objects.**




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

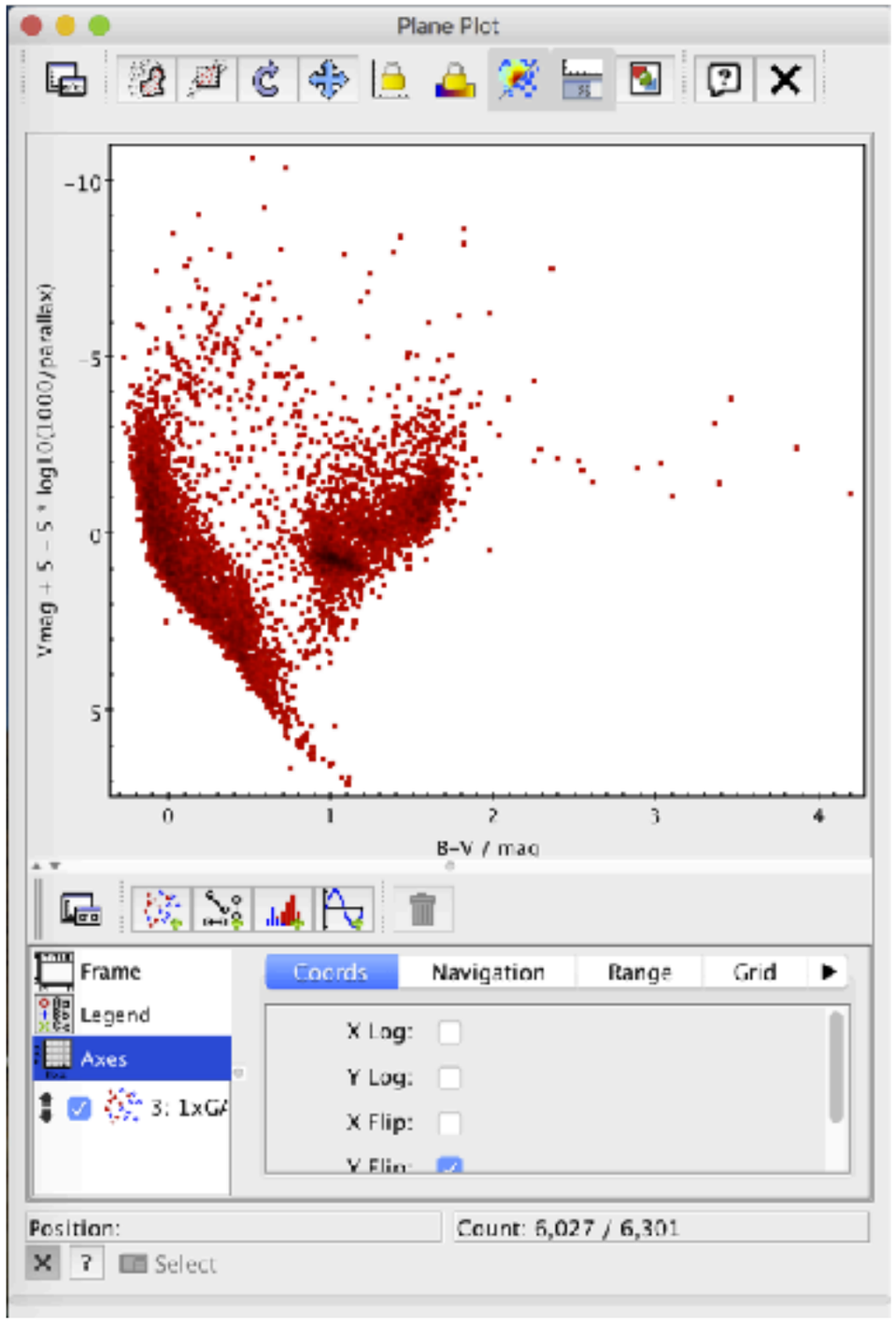
**There are two issues with the plot at our right. Can you spot them?**



**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.**

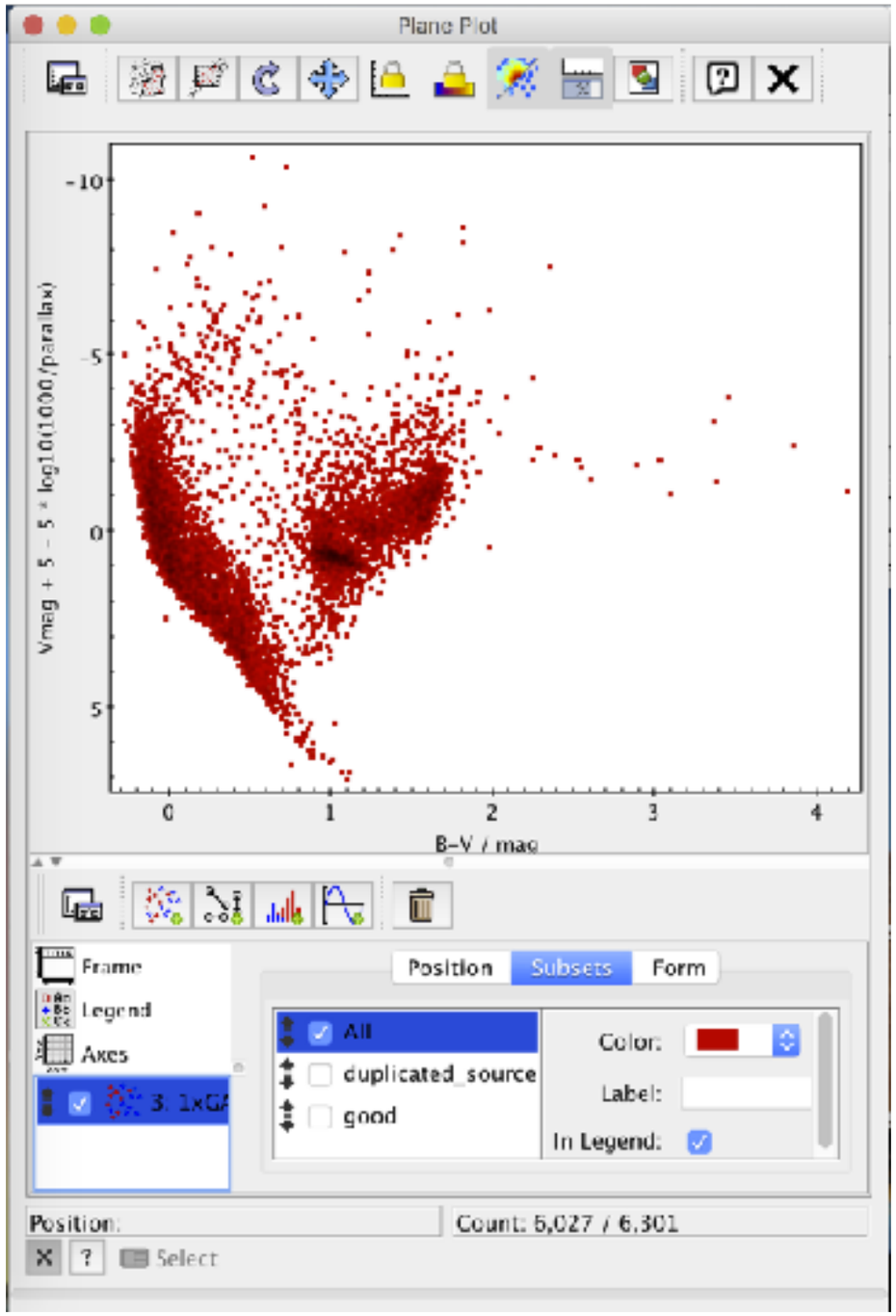


**Go back to where you were inserting the columns to plot.**

**Go to “subset”.**

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

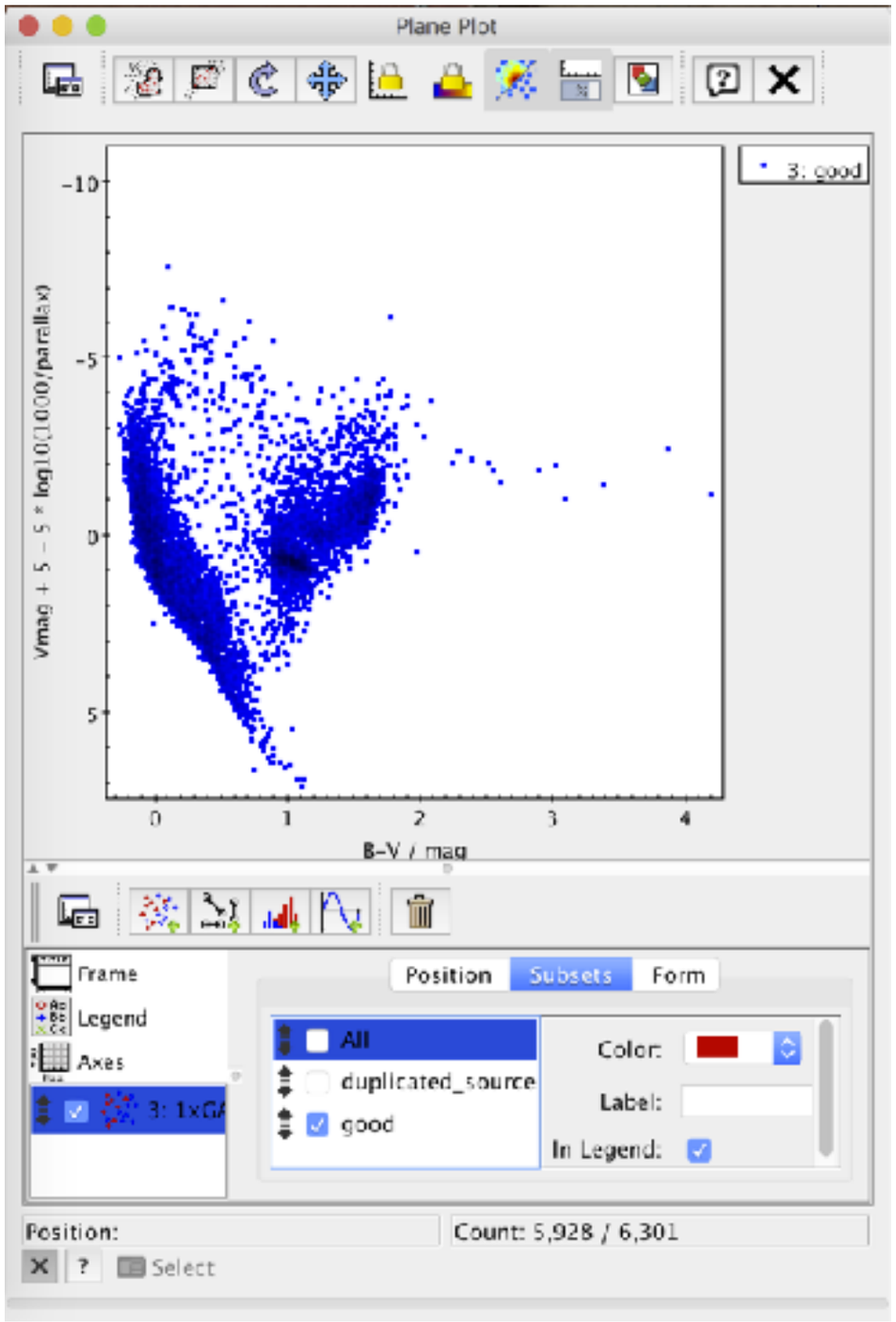
**Let’s plot only the good ones.**

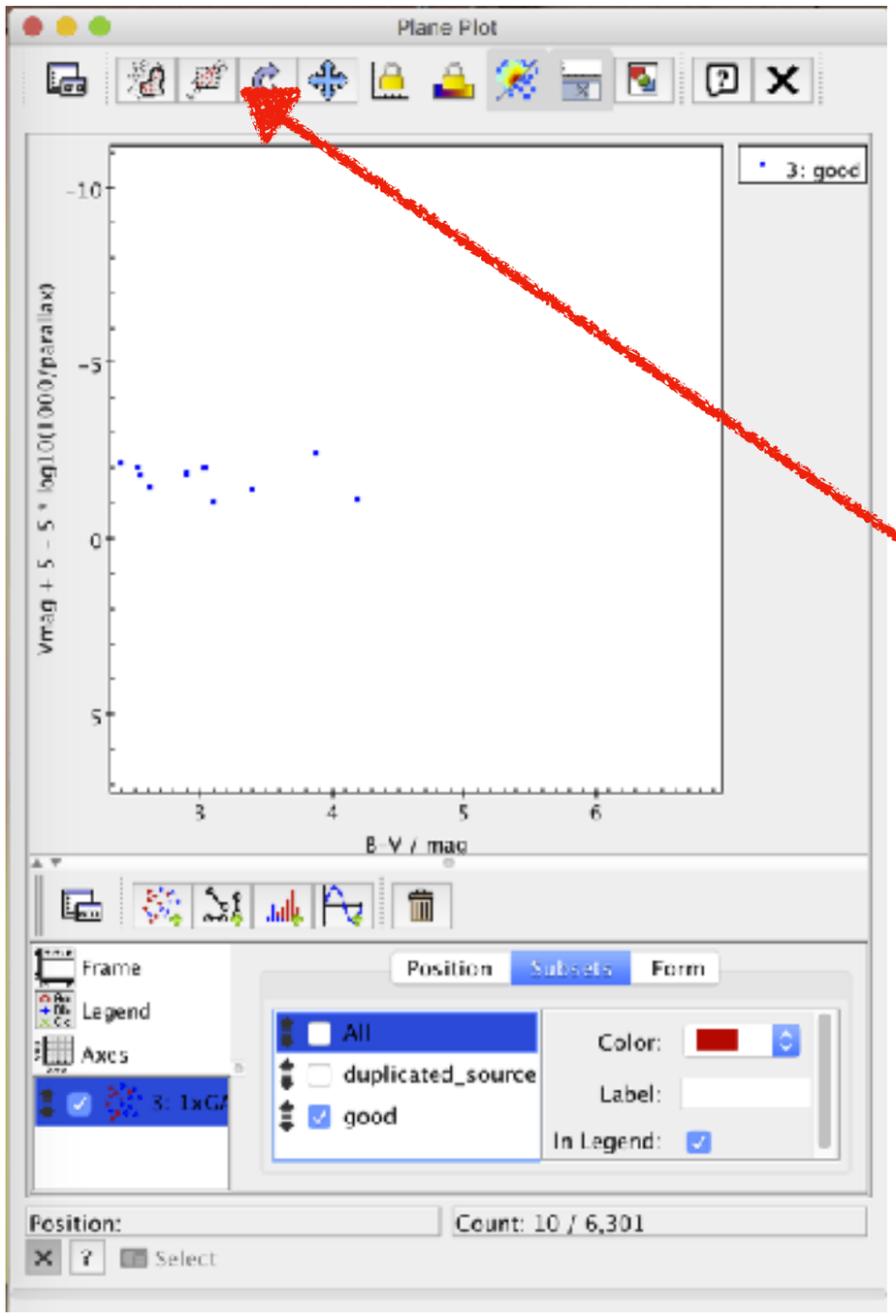


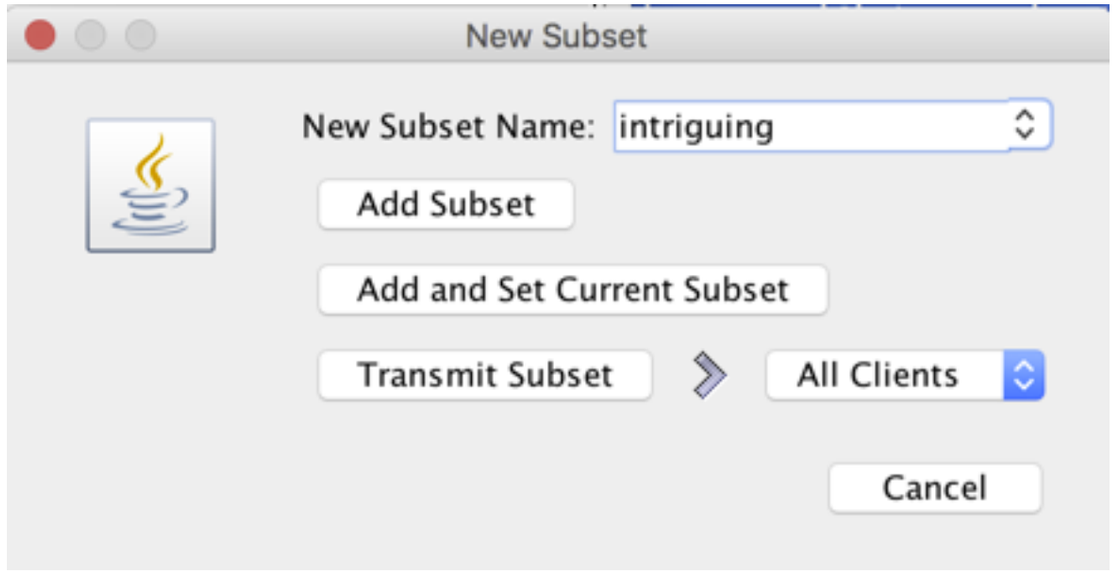
**Just tick on “good” and untick “All”.**

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

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

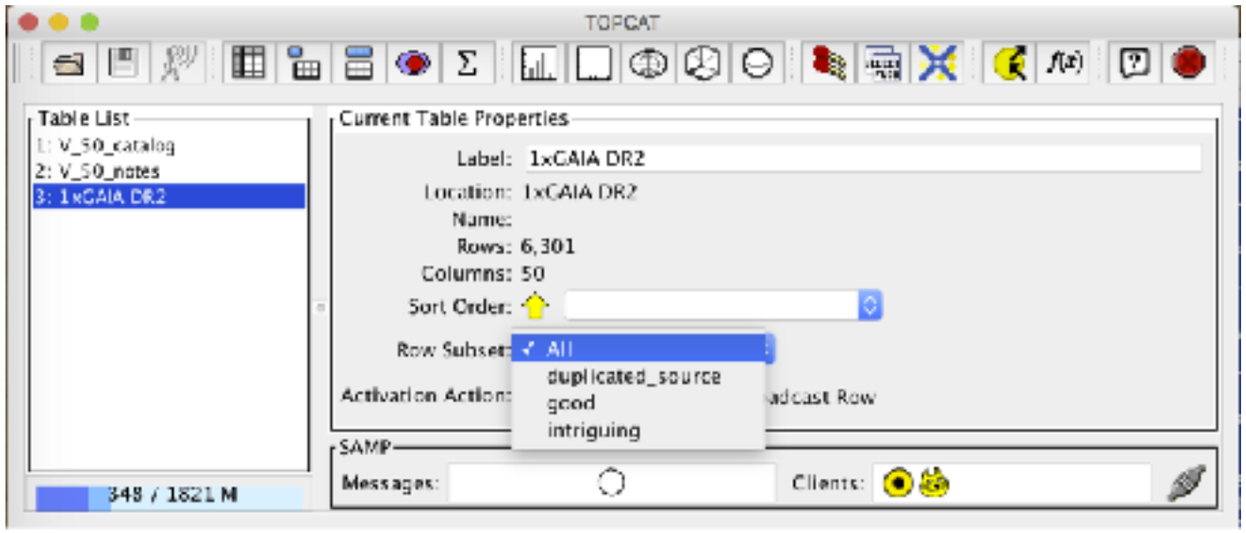




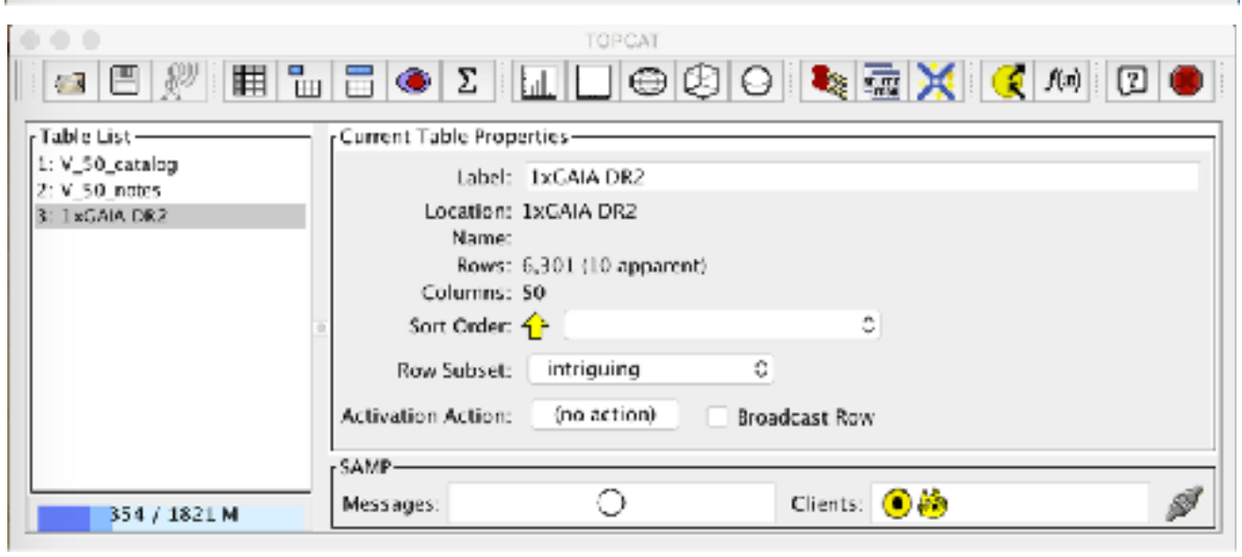

**Click on this button and this window will open.**

**Name the new subset “intriguing” and click on “Add Subset”**

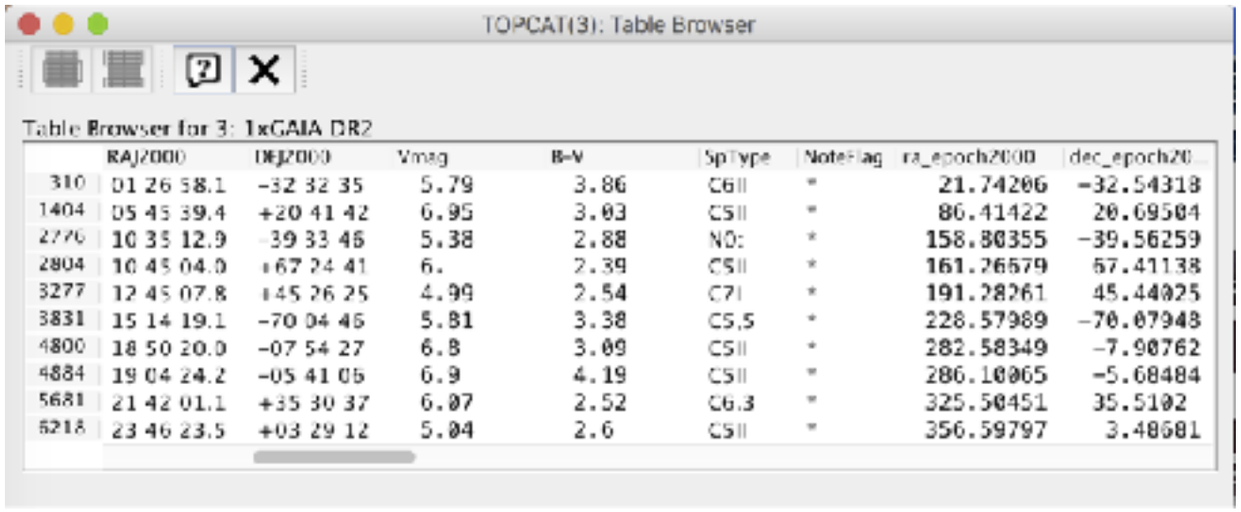



**If I pick only this “intriguing” subset, I see that there are only 10 stars and all (but one) are carbon stars.**

**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)**




| | RAJ2000 | DEJ2000 | Vmag | B-V | SpType | NoteFlag | ra_epoch2000 | dec_epoch20 |
|---|---|---|---|---|---|---|---|---|
| 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 | C5II | * | 86.41422 | 20.69504 |
| 2770 | 10 35 12.9 | -39 33 46 | 5.38 | 2.88 | NO: | * | 158.80355 | -39.56259 |
| 2804 | 10 45 04.0 | +67 24 41 | 6. | 2.39 | C5II | * | 161.26679 | 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 | C5,5 | * | 228.57989 | -70.07948 |
| 4800 | 18 50 20.0 | -07 54 27 | 6.8 | 3.09 | C5II | * | 282.58349 | -7.90762 |
| 4884 | 19 04 24.2 | -05 41 05 | 6.9 | 4.19 | C5II | * | 286.10065 | -5.68484 |
| 5681 | 21 42 01.1 | +35 30 37 | 6.07 | 2.52 | C6.3 | * | 325.50451 | 35.5102 |
| 5218 | 23 46 23.5 | +03 29 12 | 5.04 | 2.6 | C5II | * | 356.59797 | 3.48681 |

simbad.u-strasbg.fr/simbad/ 90% Search

Portal | Simbad | VizieR | Aladin | X-Match | Other | Help

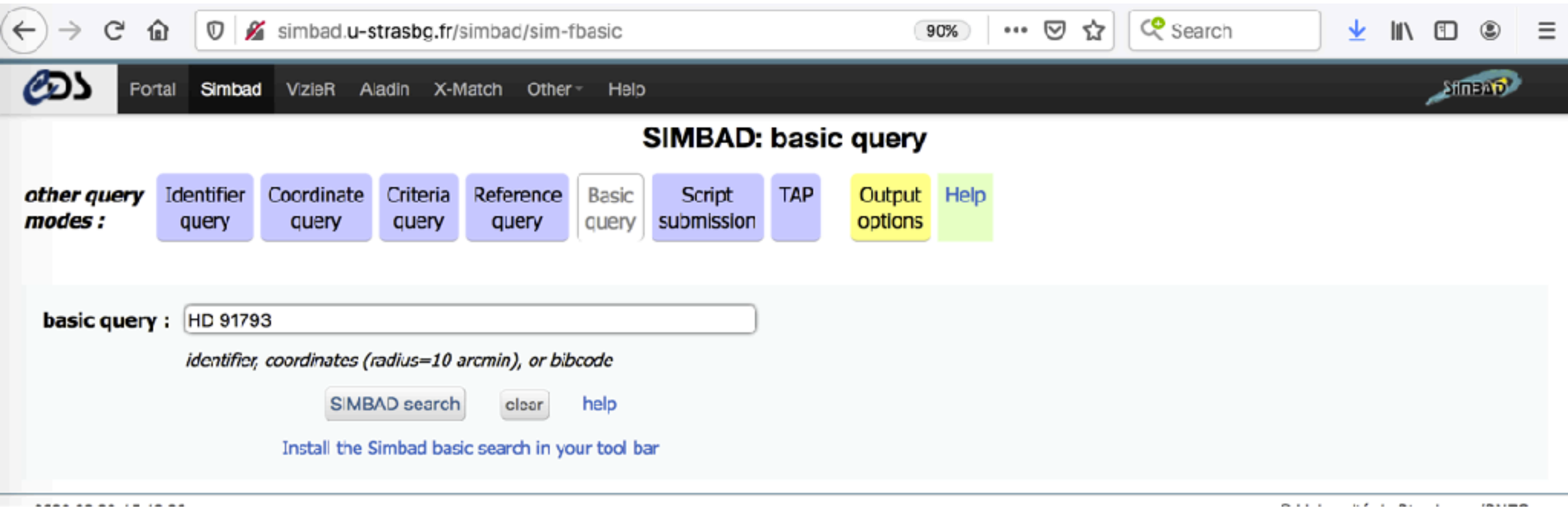
# SIMBAD Astronomical Database - CDS (Strasbourg)

What is SIMBAD ?

| Queries |
| --- |
| basic search |
| **by identifier** |
| **by coordinates** |
| by criteria |
| reference query |
| **scripts** |
| **TAP queries** |
| |
| options |
| |
| Display all user annotations |

| Documentation |
| --- |
| **User's guide** |
| |
| |
| Query by urls |
| Nomenclature Dictionary |
| Object types |
| List of journals |
| Measurement description |
| Spectral type coding |
| User annotations documentation |
| Acknowledgment |

| Information |
| --- |
| Presentation |
| |
| Image thumbnails |
| |
| **BETA - Mobile version** |
| |
| SimWatch |
| |
| Release: |
| SIMBAD4 1.7 - May-2018 |
| Release history |


simbad.u-strasbg.fr/simbad/sim-fbasic
90%
Search
Portal
Simbad
VizieR
Aladin
X-Match
Other
Help
SIMBAD: basic query
other query modes :
Identifier query
Coordinate query
Criteria query
Reference query
Basic query
Script submission
TAP
Output options
Help
basic query :
HD 91793
identifier, coordinates (radius=10 arcmin), or bibcode
SIMBAD search
clear
help
Install the Simbad basic search in your tool bar

Portal | Simbad | VizieR | Aladin | X-Match | Other | Help

# 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

SIMBAD query around with radius 2

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..759C

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

Spectral type: C-N3 B 2009ApJ...705.1298D

Fluxes (9) :
U 15.32 [~] C 2002yCat.2237....0D
B 8.22 [~] C 2002yCat.2237....0D
V 5.38 [~] C 2002yCat.2237....0D
R 3.18 [~] C 2002yCat.2237....0D
G 4.1351 [0.0043] C 2018yCat.1345....0G
I 1.86 [~] C 2002yCat.2237....0D
J 1.28 [~] C 2002yCat.2237....0D
H 0.08 [~] C 2002yCat.2237....0D
K -0.51 [~] C 2002yCat.2237....0D

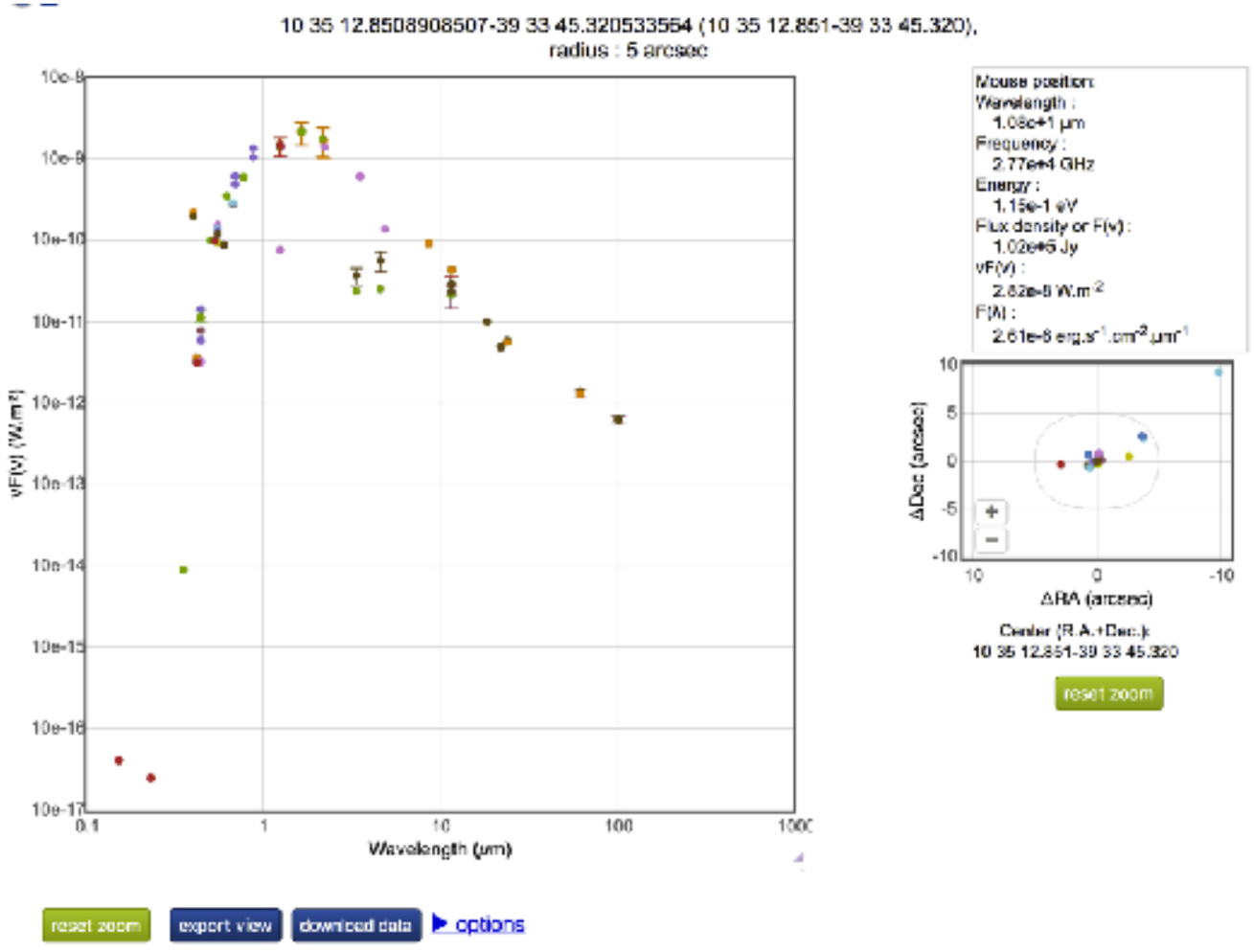
Interactive AladinLite


VizieR photometry

Search within radius

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

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


**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-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-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/%7Epdraper/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