Advanced usage of HiPS and MOCs

Exploring large catalogs within non-trivial spatial coverage, defined by brightness cuts and/or the availability of additional data sets

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-update to Gaia DR2 in June 2018
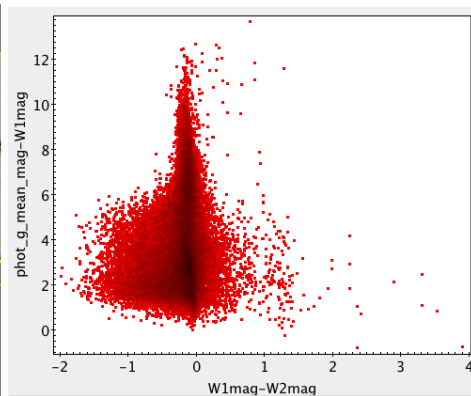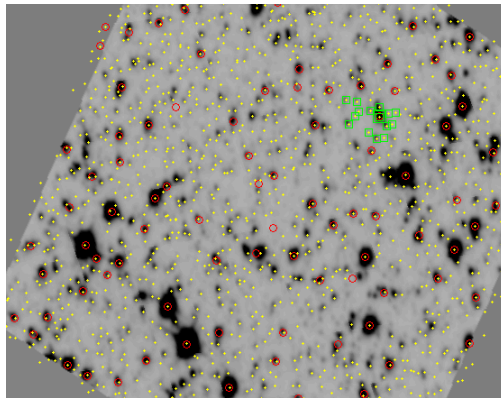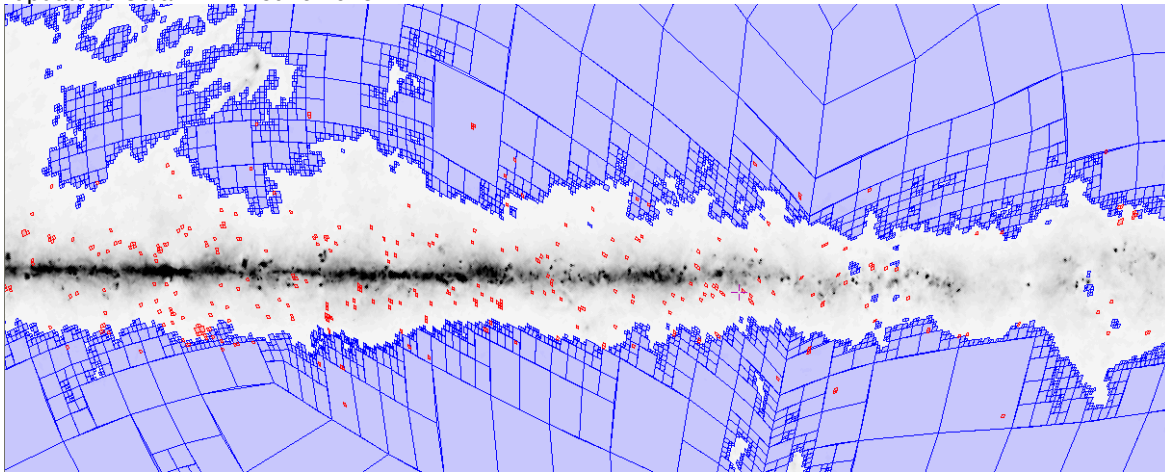
This is a hands-on tutorial demonstrating an advanced usage of Hierarchical Progressive Surveys (HiPS) and Multi-Order Coverage (MOC) maps in Aladin. Using this document, you will learn how to handle a problem like : "I have a set of images. I would like to select regions in my observations that are above a given threshold in another survey (e.g. at low extinction), retrieve objects from very large catalogs (e.g. Gaia + WISE) in these non-trivial shapes and not-necessarily-connected regions, and combine them to visualise some quantities (e.g. color color diagram).

Step 1: Starting

Here are the instructions to install Aladin Desktop v10 and TOPCAT for this tutorial:
- Install and start Aladin desktop:
  - make sure you have java installed (the latest is Oracle Java Runtime Environment - JRE- 8)
  - go to the Aladin desktop webpage here: http://aladin.u-strasbg.fr/java/nph-aladin.pl?frame=downloading and download the AladinBeta.jar file
  - load Aladin Desktop by typing "`java -Xmx2g -jar AladinBeta.jar`" in a terminal. We need the beta version as it incorporates the possibility to query catalogs by MOC (Multi-Order Coverage map) as will be demonstrated in this tutorial and also because Aladin v10 will soon be released…
- Install and start TOPCAT:
  - go to the TOPCAT webpage here: http://www.star.bris.ac.uk/~mbt/topcat/
  - save the topcat-full.jar file available in the Downloads section
  - start TOPCAT by typing "`java -jar topcat-full.jar`" in a terminal

Step 2: Find all Short-Red images associated to the MASH catalog using the VizieR associated data service

The VizieR service at CDS allows you to look for astronomical catalogs that have been published in the literature. Among these catalogs, some contain data associated to the publications and the tables therein. These data can be browsed and explored through the VizieR associated data service, which is linked with the traditional VizieR table service. In the current exemple, we are looking for images associated with the MASH catalog of planetary nebulae (Parker et al. 2006-2008)
- go to the VizieR webpage: http://vizier.u-strasbg.fr

- type MASH in the "Free text search" and click **Find catalogues**
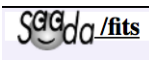
Catalogue	Records	Description		Access	
V/127A ? 🔍	2.895e+3	MASH Catalogues of Planetary Nebulae (Parker+ 2006-2008)		Data Ftp ReadMe Xmatch Tap	

- Click on **Data** to get more information on this catalog.

		MASH Catalogues of Planetary Nebulae (Parker+ 2006-2008)	2006MNRAS.373...79P **ReadMe+ftp** Sαada **/fits**
V/127A		*Post annotation*	spectrum/fits Similar Catalogs
1.V/127A/mash1		(c)The MASH Catalog of Planetary Nebulae (paper I) *(903 rows)*	
2.V/127A/mash2		(c)The MASH-II Supplement (from paper II) *(335 rows)*	
3.V/127A/sp		*List of spectra available in "sp" subdirectory *(Note)* *(1657 rows)*	

It contains different tables (mash1, mash2 and sp). If you click on the name of a table, and then SUBMIT, you can see the catalog and get preview of the different images or spectra that are available with this catalog. The MASH fits files are cut-offs extracted from a larger Halpha and Short Red survey and can be best described as a set of regions of interests around planetary nebulae.

Going back to the overview of the different tables, one could notice the ![SGGda /fits] logo. This means that data fits files are associated to the current catalog. By clicking on it, you will access the VizieR associated data service. This way, you can make data selection, download individual files or visualise the repartition of the data files on the individual files on the sky in Aladin Lite.

You can also get all the data from the ftp website directly. To do so, click on **ReadMe+ftp** in the table summary page or directly on the **Ftp** button on the VizieR main page. Finally, you can use a wget query to get all the MASH fits files by typing the following command in a terminal: `wget -r -np` "ftp://cdsarc.u-strasbg.fr/pub/cats/V/127A/fits/"

For the purpose of this tutorial, **we prepared a subsample of 335 of these Short Red images that will run in a timely manner** but we encourage you to repeat with the full Short Red sample later. **The subsample is available at http://astro.u-strasbg.fr/~bot/BochBot.tar.gz**

Step 3: Build a Hierarchical Progressive Survey (HiPS) of this set of images

HiPS is a Virtual Observatory standard to store, access, visualise and browse data on an allsky projection in a hierarchical tiling, based on the healpix tessellation of the sphere. HiPS stands for Hierarchical Progressive Survey and is described fully in Fernique et al. (2015) and here: http://aladin.u-strasbg.fr/hips/ .
It is possible to build Hierarchical Progressive Surveys of images, data cubes or catalogs. Here, **we will use Aladin Desktop to build a HiPS from the subsample of Short Red MASH images** downloaded before (building the HiPS survey of the full sample takes ~10 minutes).
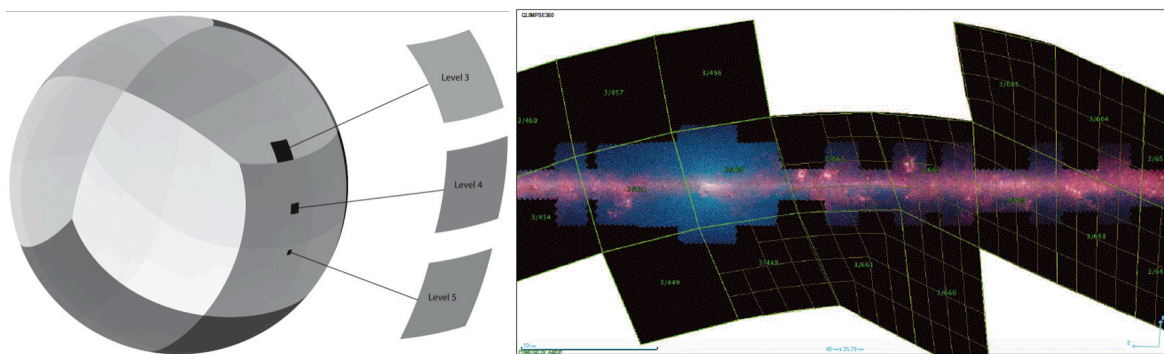
- To build a HiPS from a set of images, go to **Aladin Desktop**. Select "**Tool**" in the menu on top of your screen, then "**Generate a HiPS based on…**" and "**an image collection (FITS, JPEG or PNG)…**". This will open a new window.

- **Fill the "Source" field with the name of the directory containing the MASH Short Red file subsample.** The Target directory and Data name will be automatically defined but can be changed. Click ___Next >___
- In the next panel, you get to choose the final resolution of the HiPS. This will also give you a preliminary estimate of the size it will take on your disk if you data covers the whole sky (don't worry, this is definitely not the case here). **Keep the default values** chosen by Aladin (32 floats, 402.6mas pixels) and **click** ___START___

- Click $\boxed{\text{Next >}}$ and in the new panel, select $\boxed{\text{See final coverage...}}$. This will **create the MOC** (Multi-Order Coverage map) corresponding to the HiPS survey we just created. You can now close the HiPS building window and check the result in the Aladin main window.
- Explore your hierarchical view of the data and its coverage on the sky: zoom in, change the view to a galactic referential, switch to a mollweide view, load a background image, …
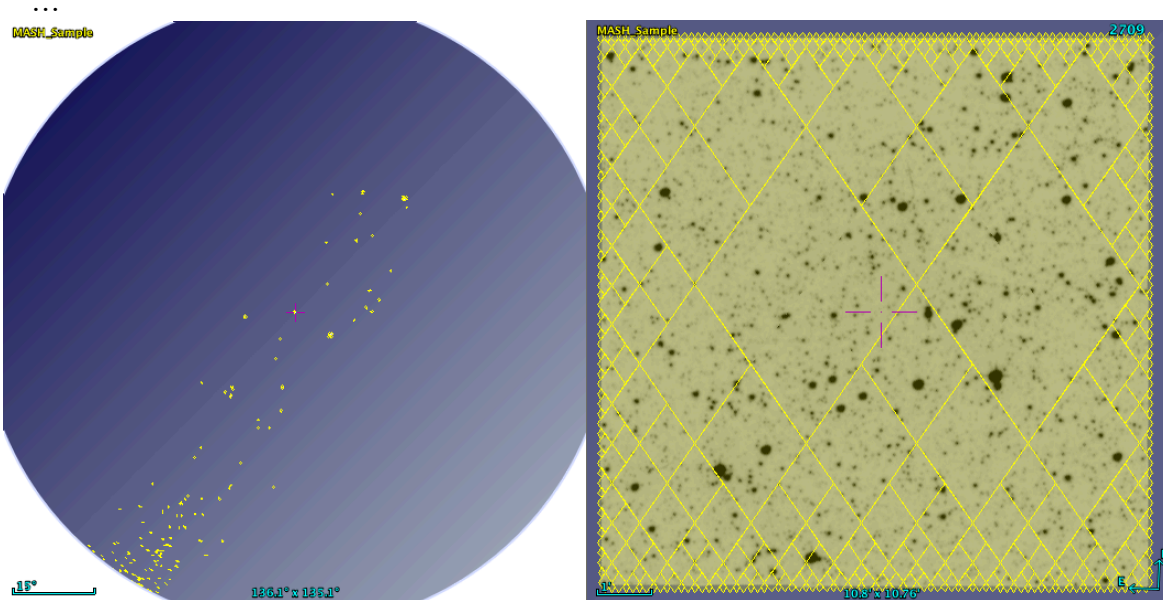
Step 4: Load an archival extinction map and create the MOC of the low extinction regions

Different works (e.g. Schlegel et al. 1998, Schlafly & Finkbeiner 2011, Green et al. 2015 or Dobashi et al. 2013) have created extinction maps of the sky and these maps are publicly available. Some of these maps are all-sky maps, other have higher resolutions, or come from different methods… Such maps are available in healpix format (among others) on the LAMBDA website or the CADE website. For the purpose of this tutorial, we will download the well known all-sky extinction map from Schlegel et al. from the LAMBDA website, load it in Aladin and define as a MOC the low extinction area for which 0<E(B-V)<0.4.

- **Download the maps** from here: https://lambda.gsfc.nasa.gov/data/foregrounds/SFD/lambda_sfd_ebv.fits
- **Load this healpix extinction map in Aladin** by drag and drop or using $\boxed{\overset{\rightharpoondown}{\sqsubseteq}}$, select the $\boxed{\otimes \text{File}}$ tab and fill the path and filename of the fits file (lambda_sfd_ebv.fits)
- do not hesitate to change the colour table of this map, zoom in, zoom out, …
- Click on the name of the extinction plane, then go to the "**Coverage**" menu on top of your screen and select "**Generate a MOC based on …**" and "**the current image**".

- Make sure the selected plane is lambda_sfd_ebv and give the **range [0 ... 0.5]** for the Pixel range. Keep the MOC resolution to Order 10 (3.435′ pixels) which will be enough for the purpose of this tutorial. Then click <u>CREATE</u>
- The coverage of all regions corresponding to pixel values below 0.5 is now available as a MOC in Aladin and displayed
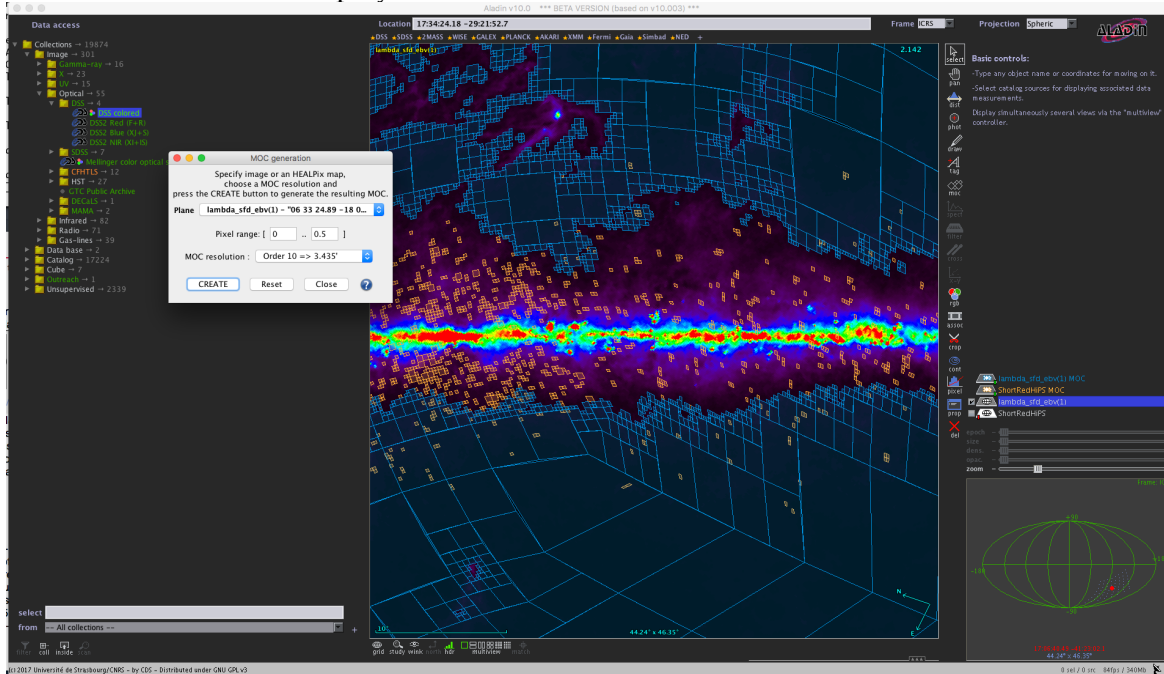
Step 5: find out which regions are covered by the MASH short red images and in the low extinction regions defined above

- Go to the "**Coverage**" menu and select "**Logical Operations...**". Select the two MOC planes (the low extinction regions and the MASH subsample) and compute the **intersection** of both coverages by clicking <u>CREATE</u>
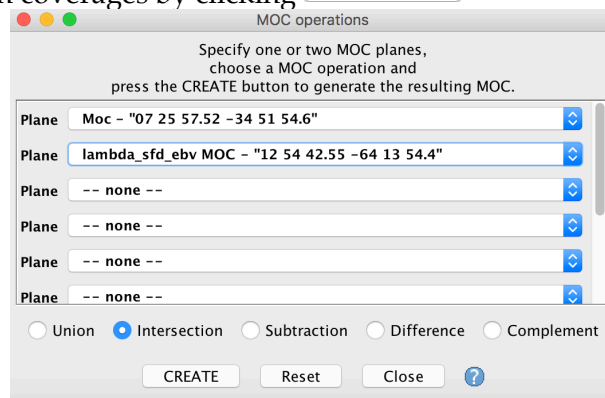
- In the main Aladin window, a new MOC has been created. You can visualise how this corresponds to regions that are the intersection of the two previous coverages. Unselect the two previous MOCs to see more clearly the intersection coverage.

Step 6: query the Gaia catalog by MOC

Without the usage of MOC, querying for Gaia sources in the low extinction regions covered by the MASH subsample would be tedious or even impossible. Indeed, one would need to load the whole catalog and make selections which would not be possible given the size of the catalog. Alternatively, one would need to query the catalogs field by field, which would take time and several queries. Instead, here, we will use the power of MOC files to query large catalogs directly in the covered regions only. We will use the coverage of the low extinction and MASH-covered region to query for sources from the Gaia surveys, in this highly non-continuous and non-trivial shape areas.

• On the left side of the Aladin window, type "**Gaia**" in the select box. A list of all products (images, catalogs, …) containing this keyword is then displayed. In the catalogs, select the **GaiaSource data** in the **Gaia DR 2 (Gaia2)** folder of the available catalogs. Make sure that the intersection coverage plane is selected and choose "**in region or MOC**", then click on the ⬚ Load ⬚ button. The catalog will get queried only in the region defined by the MOC (MASH fields at low extinction).

• If you zoom to one of the MASH images from our sample and at low extinction, you will see the result of the query: WISE sources in each field. If you select sources or click on one, the information from the catalog of each selected source will be displayed

The table at top:

| ra_ep2000	dec_ep2000	errHalfMaj	errHalfMin	errPosAng	ra	dec	source_id	ref_epoch	ra_erro
105.2052…	-26.1542…	0.000	0.000	0	105.2052…	-26.1542…	29207625…	2015.0	0.14
105.2065…	-26.1539…	0.000	0.000	0	105.2065…	-26.1539…	29207625…	2015.0	0.31
105.2335…	-26.1487…	0.000	0.000	0	105.2335…	-26.1487…	29207626…	2015.0	0.0
105.2360…	-26.1557…	0.000	0.000	0	105.2360…	-26.1557…	29207626…	2015.0	0.09
105.2334…	-26.1533…	0.001	0.001	0	105.2334…	-26.1533…	29207626…	2015.0	0.5
105.2400…	-26.1530…	0.002	0.001	0	105.2400…	-26.1530…	29207626…	2015.0	0.56
105.2313…	-26.1522…	0.000	0.000	0	105.2313…	-26.1522…	29207626…	2015.0	0.1
105.2295…	-26.1503…	0.001	0.001	0	105.2295…	-26.1503…	29207626…	2015.0	0.7
105.2420…	-26.1476…	0.000	0.000	0	105.2420…	-26.1476…	29207626…	2015.0	0.2
105.2357…	-26.1471…	0.001	0.000	0	105.2357…	-26.1471…	29207626…	2015.0	0.38
105.2345…	-26.1500…	0.016	0.006	0	105.2345…	-26.1500…	29207626…	2015.0	6.48
105.2141…	-26.1508…	0.000	0.000	0	105.2141…	-26.1508…	29207626…	2015.0	0.2
105.2100…	-26.1492…	0.000	0.000	0	105.2100…	-26.1492…	29207626…	2015.0	0.1
105.2171…	-26.1552…	0.000	0.000	0	105.2171…	-26.1552…	29207626…	2015.0	0.0
105.2186…	-26.1564…	0.000	0.000	0	105.2186…	-26.1564…	29207626…	2015.0	0.14
105.2106…	-26.1501…	0.000	0.000	0	105.2106…	-26.1501…	29207626…	2015.0	0.2
105.2119…	-26.1482…	0.001	0.001	90	105.2119…	-26.1482…	29207626…	2015.0	1.30
105.2091…	-26.1497…	0.000	0.000	0	105.2091…	-26.1497…	29207626…	2015.0	0.09
105.2083…	-26.1496…	0.001	0.000	0	105.2083…	-26.1496…	29207626…	2015.0	0.4
105.2254…	-26.1459…	0.010	0.008	90	105.2254…	-26.1459…	29207627…	2015.0	0.1
105.2327…	-26.1401…	0.000	0.000	0	105.2327…	-26.1401…	29207627…	2015.0	0.2
105.2298…	-26.1384…	0.000	0.000	0	105.2298…	-26.1384…	29207627…	2015.0	0.28
105.2235…	-26.1356…	0.001	0.000	0	105.2235…	-26.1356…	29207627…	2015.0	0.39
105.2340…	-26.1397…	0.004	0.004	90	105.2340…	-26.1397…	29207627…	2015.0	4.10
105.2274…	-26.1494…	0.008	0.006	0	105.2274…	-26.1494…	29207627…	2015.0	6.2
105.2021…	-26.1537…	0.000	0.000	0	105.2021…	-26.1537…	29207627…	2015.0	0.0
105.1986…	-26.1521…	0.000	0.000	0	105.1986…	-26.1521…	29207627…	2015.0	0.2

Step 7: cross-match Gaia and WISE sources in all fields

We now want to find sources in the selected region (observed in the MASH regions of interests and at low extinction) that are common to the WISE and Gaia catalogs. To do so, we will perform a cross-match of the Gaia sources loaded previously with the WISE all sky catalog. We could download the WISE catalog in our fields of interests in the same way we did for Gaia,but with Aladin v10 we can also directly do the Xmatch without loading the catalog.

• At the bottom left of the Aladin window, write "**WISE**" in the select box. Select the Gaia catalog plane on the right in your stack and click on the "**WISE All-Sky Data Release (Cutri+2012)**" in the list of catalogs on the left. Then choose "**via Match**" and Load
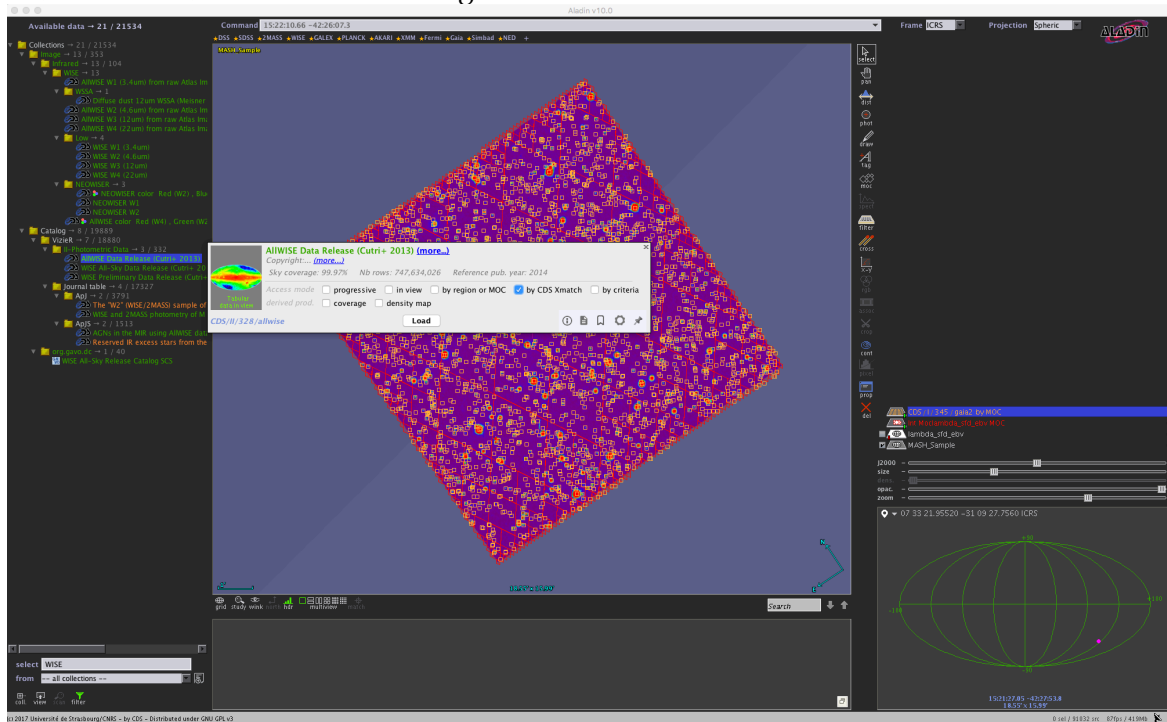
Step 8: send the X-matched catalog to TOPCAT and build a color-color diagram

- right-click on the X-matched catalog plane in the main Aladin window and select "**Broadcast the selected table to…**" then "**topcat**". Your table is then send to the TOPCAT application.

- In the TOPCAT window, click on the plane plotting button
- Select the G Gaia magnitude for the **Y axis (phot_g_mean_mag)** and add **"-W1mag" to compute the Gaia G-WISE W1 color** and write down the expression for the W1-W2 WISE colour for the **X axis (W1mag-W2mag)**
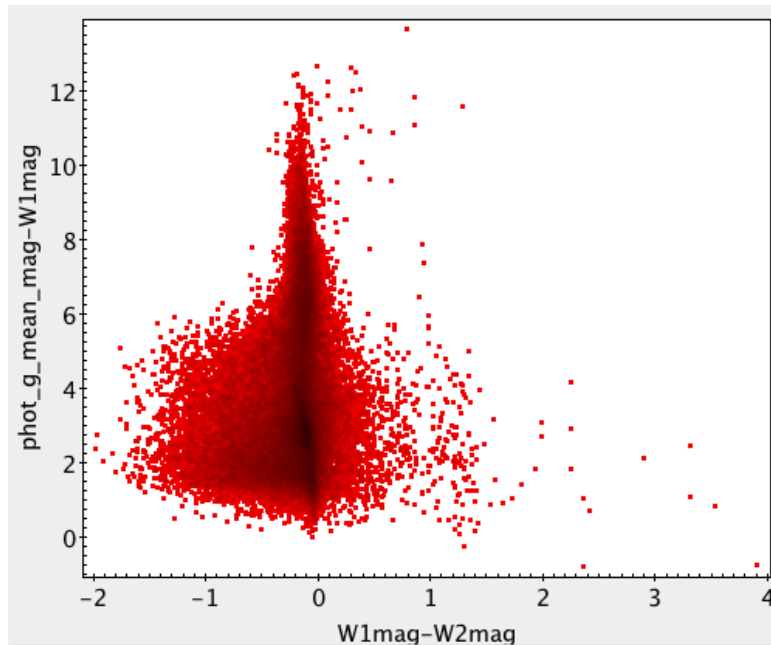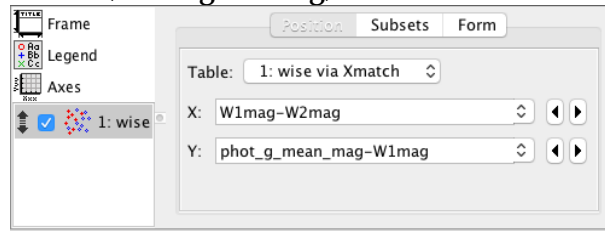
You can now select points or regions in this color-magnitude diagram and visualise their spatial distribution in Aladin, or go further in the science analysis of this sample….