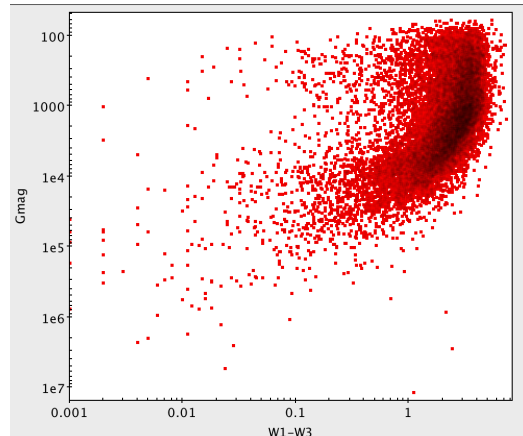
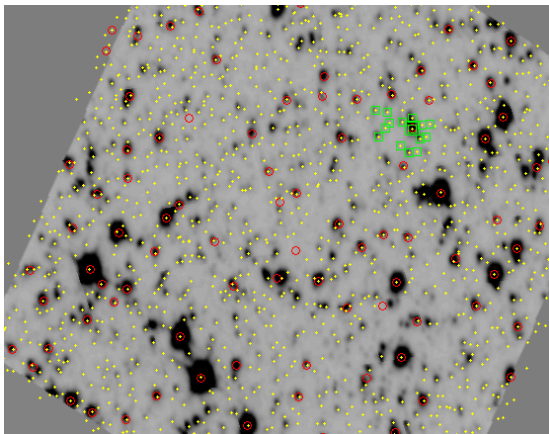
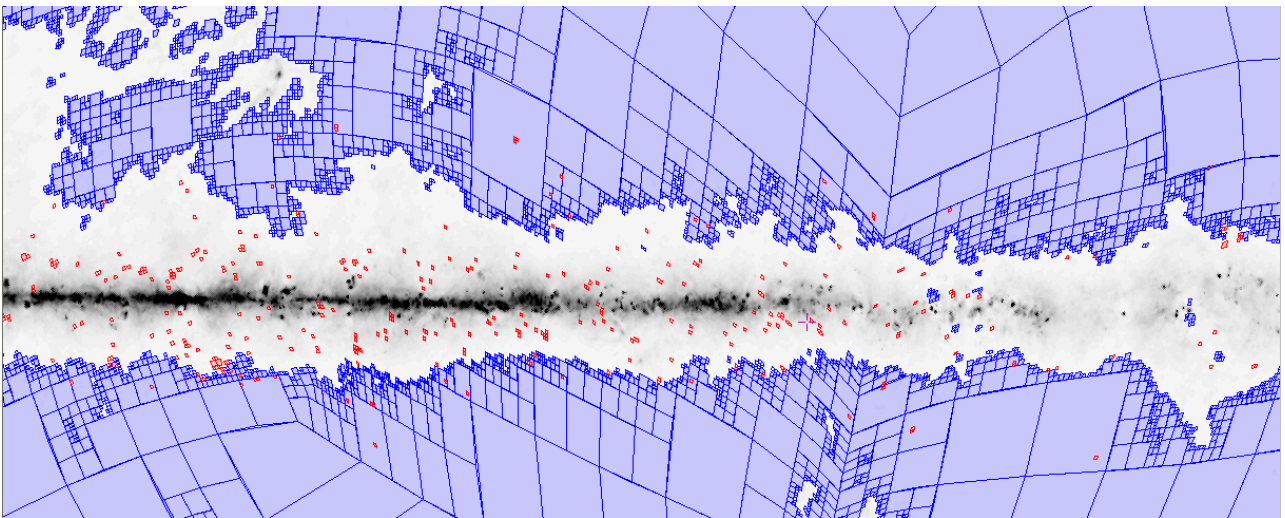

Advanced usage of HiPS and MOCs

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

Thomas Boch and Caroline Bot, CDS

Detecting the Unexpected, Discovery in the Era of Astronomically Big Data

Space Telescope Science Institute, February 27 — March 2, 2017



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 an image survey. 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 magnitude diagram).

Step 1: Starting


For the workshop Detecting the unexpected @ STScI, everything should be ready and installed on the Virtual machine. If you want to do it again later on your own machine, here are the instructions to have everything ready:

- 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 Aladin.jar file
 - load Aladin Desktop by typing “**java -Xmx2g -jar Aladin.jar -beta**” in a terminal. The -beta option will start the latest beta version. We need this latest version as it incorporates the possibility to query catalogs by MOC (Multi-Order Coverage map) as will be demonstrated in this tutorial.
- 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 from the MASH survey 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 



Catalogue	Records	Description	Access
V/127A	2.895e+3	MASH Catalogues of Planetary Nebulae (Parker+ 2006-2008)	Data Ftp ReadMe Xmatch Tap

- Click on  to get more information on this catalog.

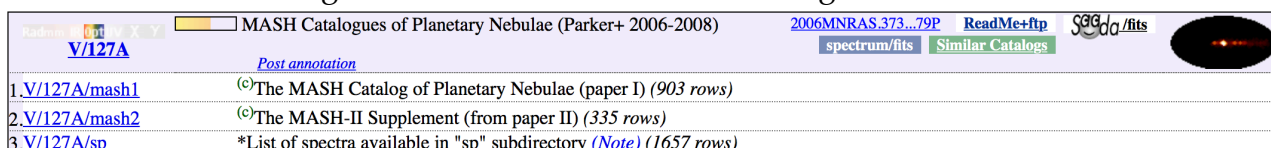
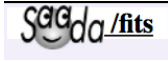



Table Name	Description
V/127A/mash1	The MASH Catalog of Planetary Nebulae (paper I) (903 rows)
V/127A/mash2	The MASH-II Supplement (from paper II) (335 rows)
V/127A/sp	*List of spectra available in "sp" subdirectory (Note) (1657 rows)

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.

Going back to the overview of the different tables, one could notice the  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.

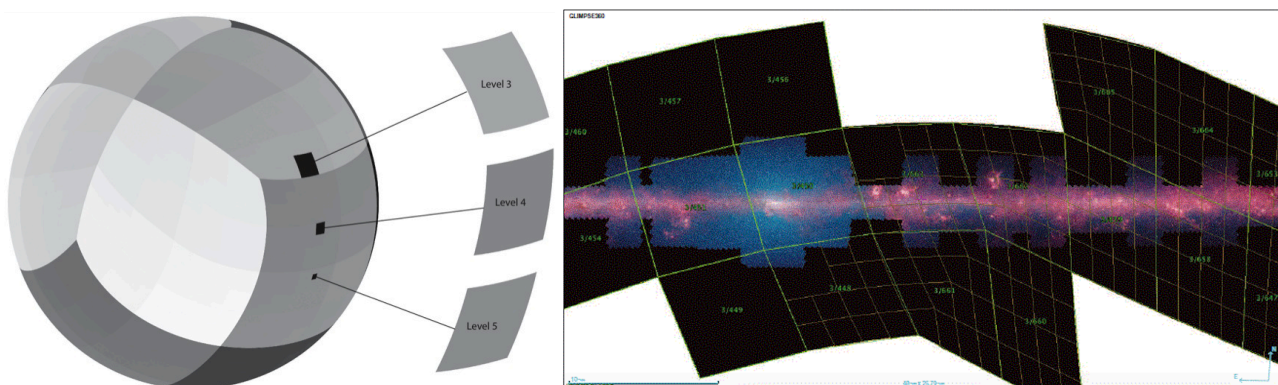
You can also get all the data from the ftp website directly. To do so, click on [ReadMe+ftp](#) in the table summary page or directly on the  button on the VizieR main page. Finally, you can use a wget query to get all the MASH fits files by typing the following command in a terminal: `wget -r -np "ftp://cdsarc.u-strasbg.fr/pub/cats/V/127A/fits/"`

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

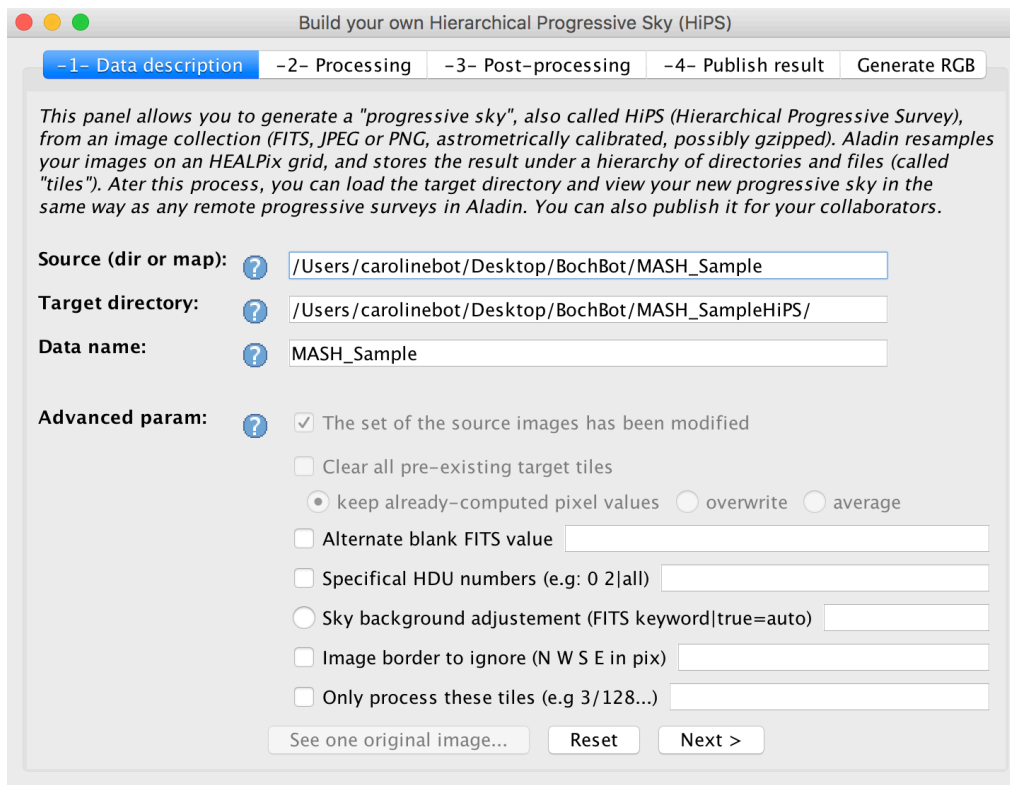
Step 3: Build a Hierarchical Progressive Survey (HiPS) of this set of images

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/>.

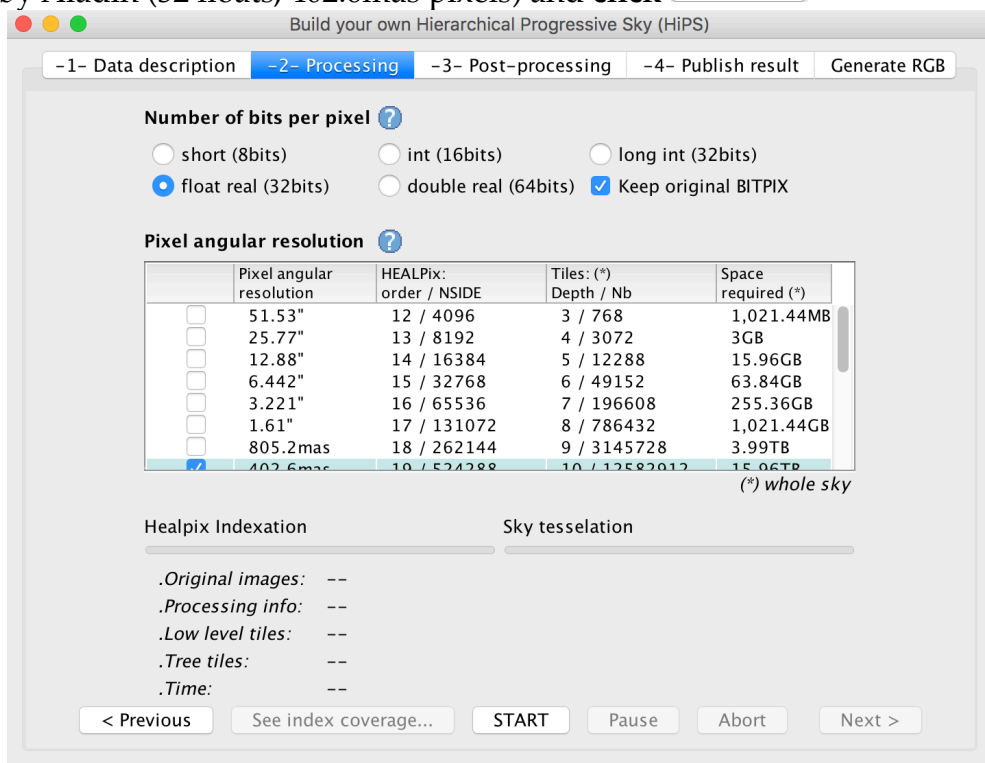
It is possible to build Hierarchical Progressive Surveys of images, data cubes or catalogs. Here, we will use Aladin Desktop to build a HiPS from the subsample of Short Red MASH images downloaded before (building the HiPS survey of the full sample takes ~10 minutes).



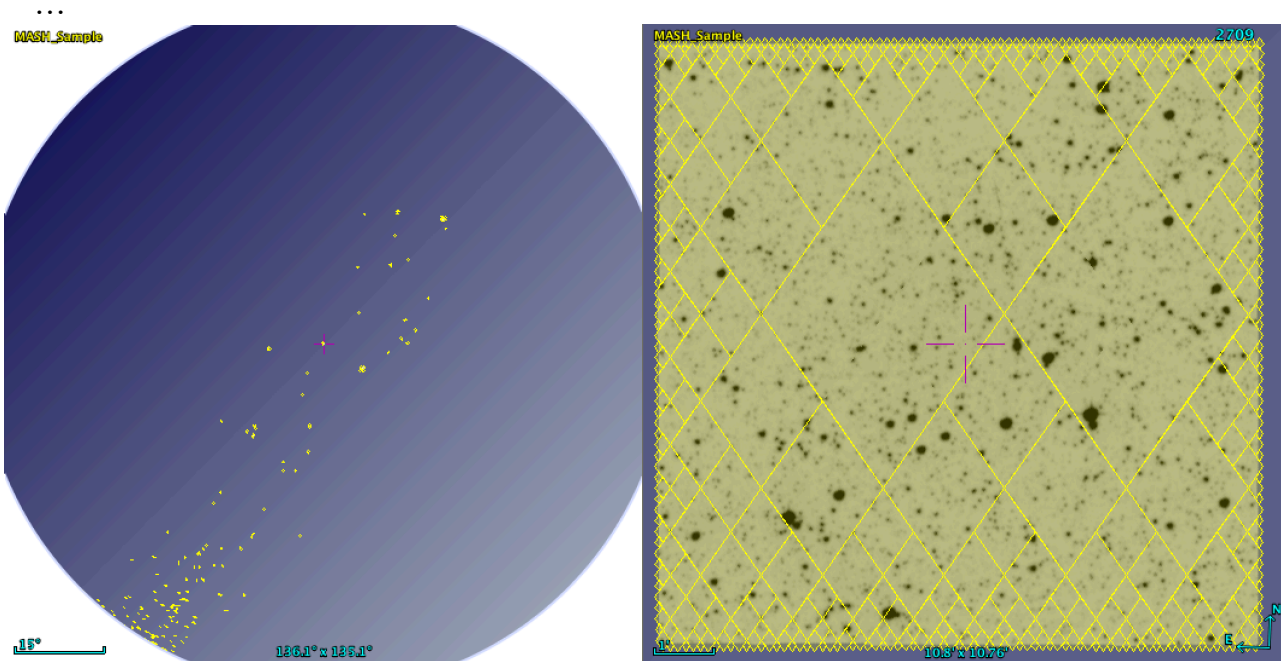
- To build a HiPS from a set of images, go to **Aladin Desktop**. Select “Tool” in the menu on top of your screen, then “Generate a HiPS based on...” and “an image collection (FITS, JPEG or PNG)...”. This will open a new window.



- 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
- 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**





- Click **Next >** and in the new panel, select **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,

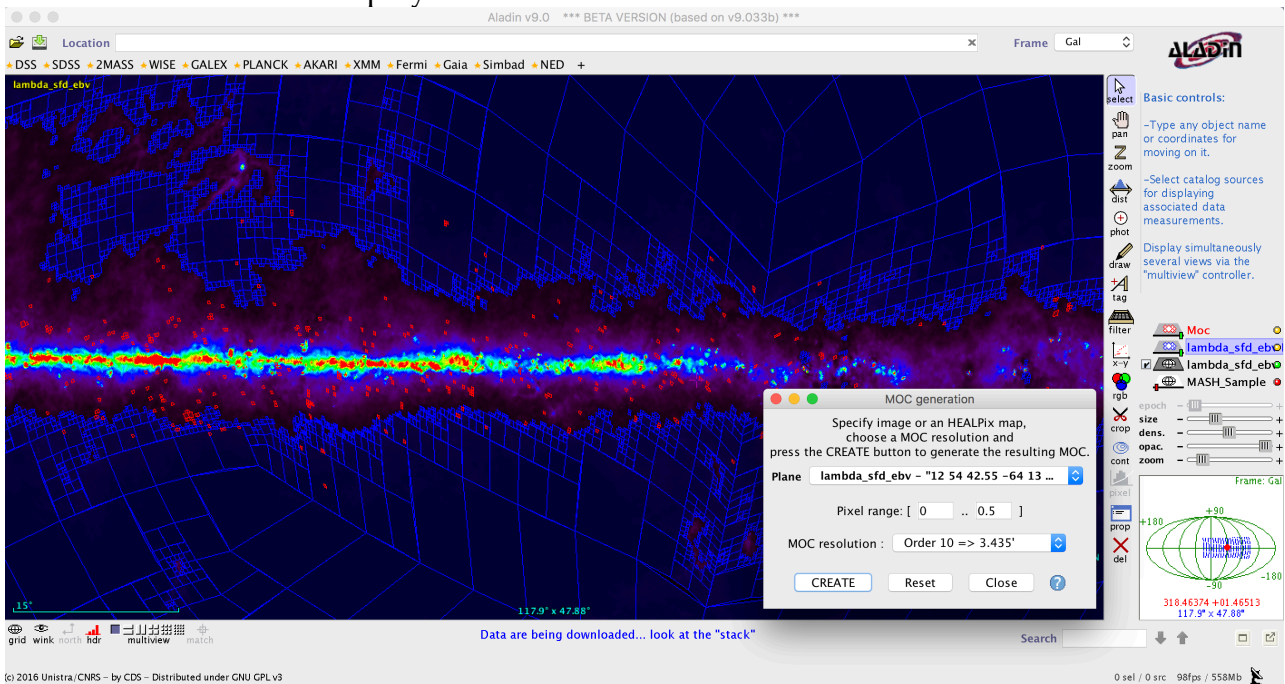


Step 4: Load an archival extinction map and create the MOC of the low extinction regions

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 $0 < E(B-V) < 0.4$.

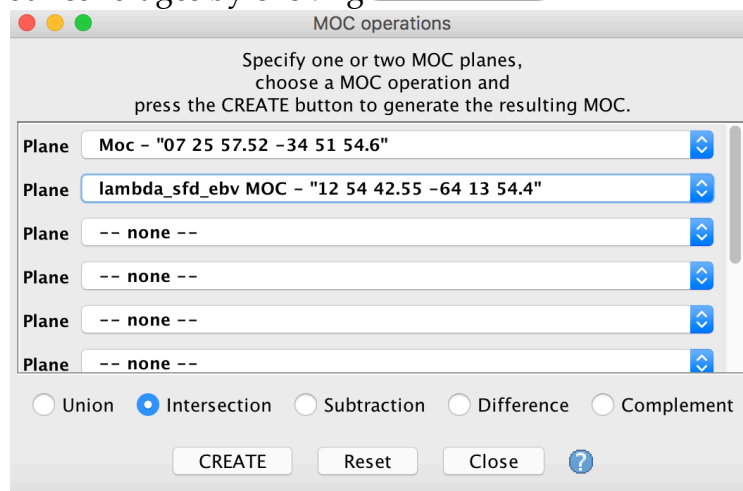
- **For the workshop “detecting the unexpected” @ STScI, the map** has already been downloaded from the LAMBDA website and **is available on the Virtual Machine**. Alternatively, it can be obtained here: https://lambda.gsfc.nasa.gov/product/foreground/ebv_map.cfm
- **Load this healpix extinction map in Aladin** by drag and drop or using , select the  **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 **CREATE**
- 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 **CREATE**

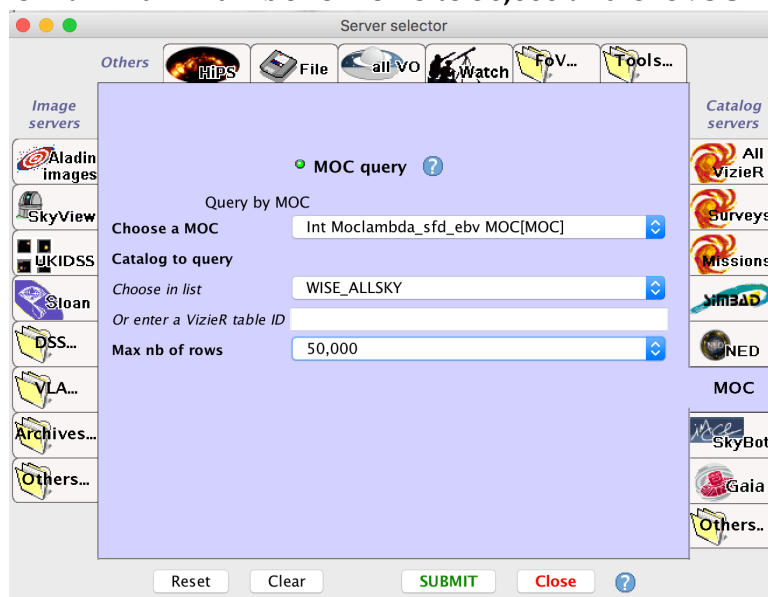


- In the main Aladin window, a new MOC has been created. You can visualise how this corresponds to regions that are the intersection of the two previous coverages. Unselect the two previous MOCs to see more clearly the intersection coverage.

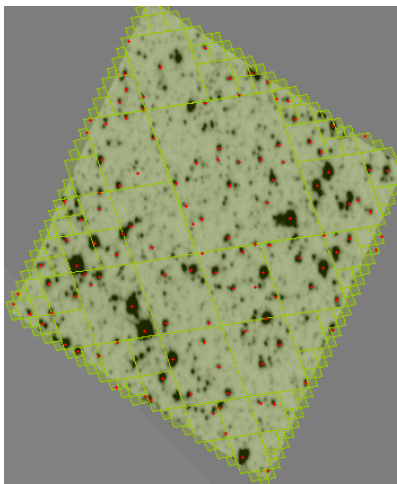
Step 6: query the WISE and Gaia catalogs by MOC

Without the usage of MOC, querying for WISE and 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 catalogs and make selections which would not be possible given the size of the catalogs. 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 WISE and the Gaia surveys, in this highly non-continuous and non-trivial shape areas.

- Click on . In the server selector window, select the **MOC** tab on the right. **Select the MOC corresponding to the intersection computed above and select the WISE ALL_SKY catalog.** This corresponds to the WISE All-Sky Data Release by Cutri et al. 2012. **Change the maximum number of rows to 50,000** and click SUBMIT.

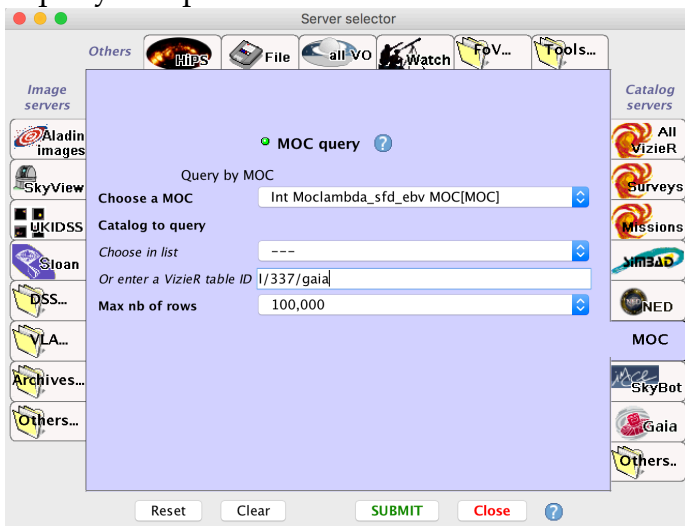
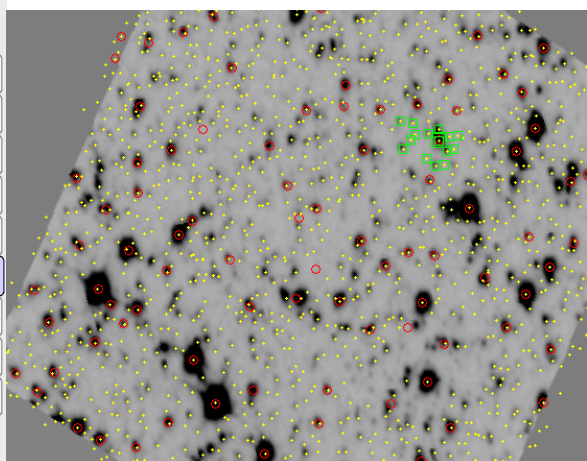


- If you zoom to one of the MASH images from our sample and at low extinction, you will see the result of the query: WISE sources in each field. If you select sources or click on one, the information from the catalog of each selected source will be displayed



	WISE_ALLSKY	RAdeg	DEdeg	errHalfMaj	errHalfMin	errPosAng	W1maq	W2maq	W3maq
<input type="checkbox"/>	J175520.91-370322.8	268.837126	-37.056351	0.083	0.079	154	9.721	9.870	9.862
<input type="checkbox"/>	J175520.47-370308.0	268.835333	-37.052238	0.190	0.177	100	13.186	13.309	12.548
<input type="checkbox"/>	J175517.29-370250.1	268.822076	-37.047253	0.082	0.078	168	9.537	9.641	9.759
<input type="checkbox"/>	J175518.33-370246.6	268.826392	-37.046278	0.067	0.064	155	8.592	8.707	8.721
<input type="checkbox"/>	J175516.56-370238.0	268.819029	-37.043907	0.105	0.101	151	11.685	11.721	12.529
<input type="checkbox"/>	J175523.21-370338.8	268.846713	-37.060790	0.117	0.111	134	12.257	12.377	12.321
<input type="checkbox"/>	J175522.13-370318.1	268.842232	-37.055032	0.074	0.070	137	8.383	8.562	8.423
<input type="checkbox"/>	J175523.46-370316.4	268.847772	-37.054576	0.113	0.112	123	11.545	11.683	11.807
<input type="checkbox"/>	J175522.47-370257.9	268.843667	-37.049428	0.141	0.133	124	12.325	12.386	12.457
<input type="checkbox"/>	J175525.17-370254.1	268.854887	-37.048364	0.187	0.179	108	12.637	12.717	12.518
<input type="checkbox"/>	J175524.42-370237.1	268.851783	-37.043640	0.082	0.077	166	9.886	10.058	10.295
<input type="checkbox"/>	J175525.40-370235.7	268.855855	-37.043261	0.714	0.485	11	13.539	13.377	12.184
<input type="checkbox"/>	J175522.87-370232.8	268.845300	-37.042470	0.132	0.122	139	12.459	12.689	12.406
<input type="checkbox"/>	J175526.20-370220.5	268.859194	-37.039048	0.202	0.197	98	12.833	13.091	12.491
<input type="checkbox"/>	J175524.12-370214.7	268.850509	-37.037436	0.132	0.125	112	11.841	11.965	11.846
<input type="checkbox"/>	J175526.01-370202.2	268.858389	-37.034031	0.087	0.083	165	10.564	10.773	10.199
<input type="checkbox"/>	J175525.59-370146.6	268.856630	-37.029619	0.268	0.260	103	17.382	16.411	11.123
<input type="checkbox"/>	J175526.80-370143.8	268.861088	-37.028857	0.080	0.075	152	10.048	10.283	10.466
<input type="checkbox"/>	J175527.93-370126.5	268.866402	-37.024037	0.153	0.141	127	12.535	12.657	12.441
<input type="checkbox"/>	J175530.54-370113.2	268.877283	-37.020355	0.071	0.069	145	7.576	7.801	7.625
<input type="checkbox"/>	J175530.26-370040.2	268.876892	-37.011183	0.111	0.107	113	12.429	12.446	12.429
<input type="checkbox"/>	J175530.88-370037.5	268.878699	-37.010417	0.229	0.217	34	13.712	13.942	12.403
<input type="checkbox"/>	J175530.63-370028.8	268.877627	-37.008805	0.338	0.209	103	11.973	12.059	12.010
<input type="checkbox"/>	J175520.86-370237.9	268.836921	-37.043688	0.077	0.074	155	8.522	8.657	8.667
<input type="checkbox"/>	J175523.28-370221.7	268.847017	-37.039389	0.222	0.209	123	13.009	13.386	12.515
<input type="checkbox"/>	J175520.85-370216.1	268.836892	-37.037821	0.191	0.180	116	13.304	13.542	12.585
<input type="checkbox"/>	J175518.35-370214.4	268.826473	-37.037339	0.697	0.645	98	14.243	14.711	12.478

- Make another **MOC query**, but this time of the Gaia catalog. To do so, unselect the WISE_ALLSKY in the catalog list and instead, write **"I/337/gaia"** in the **VizieR table ID**. VizieR table IDs can be found out by querying the VizieR service by text search. In this example, you would simply type **"gaia"** in the text section and select the catalog of your interest (Gaia DR1 source catalog, Gaia Collaboration, 2016) and see the ID of the table you would like to query. Change the **maximum number of rows to 100,000** for this query and press **SUBMIT**.

Sources from both catalogs available in each region are now available

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

We now want to find sources in the selected region (observed by the MASH survey and at low extinction) that are common to the WISE and Gaia catalogs. To do so, we will perform a cross-match.

- Go to the **"Catalog"** menu on top of your screen and select **"Cross match objects..."**. Check that both catalog planes are selected and that the RA and DEC columns make sense. You can keep the source separation to a threshold of 4 arcseconds or update it to 3" to reflect the minimum resolution of the WISE data (FWHM of 6.1"). Then select **"Best matches"** and **Perform cross-match**.

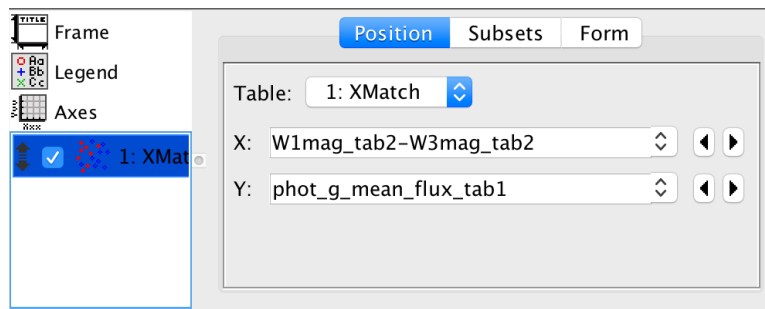


Step 8: send the X-matched catalog to TOPCAT and build a color-magnitude diagram

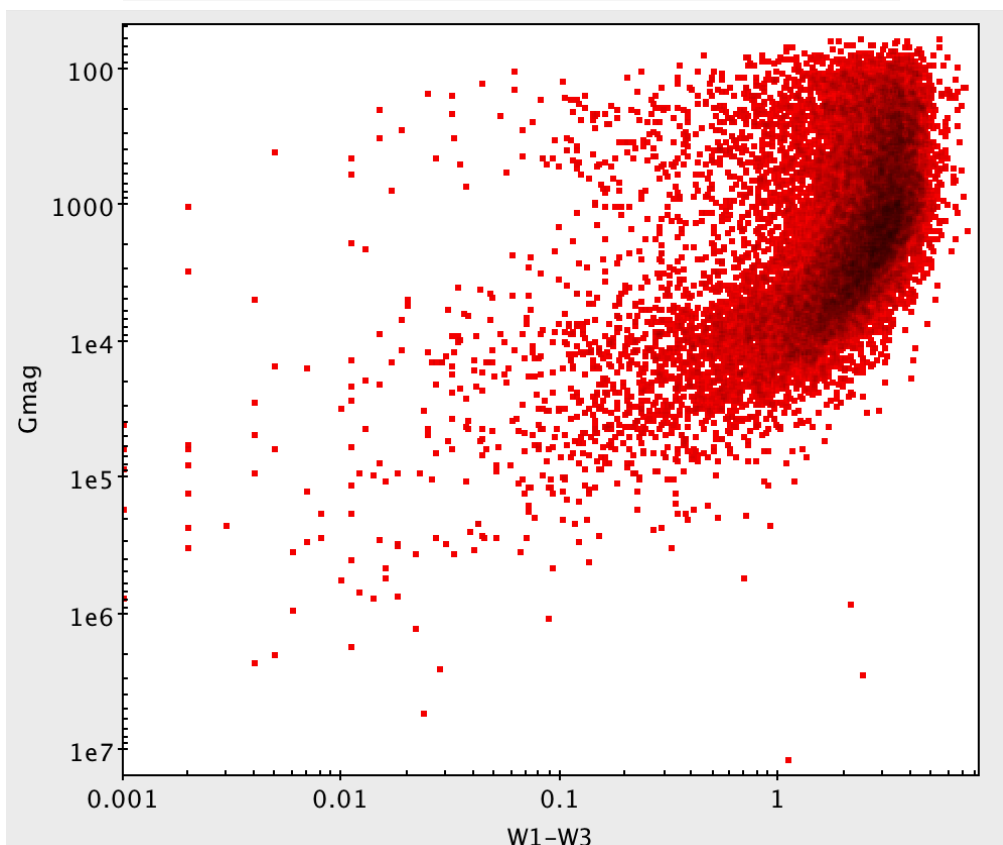
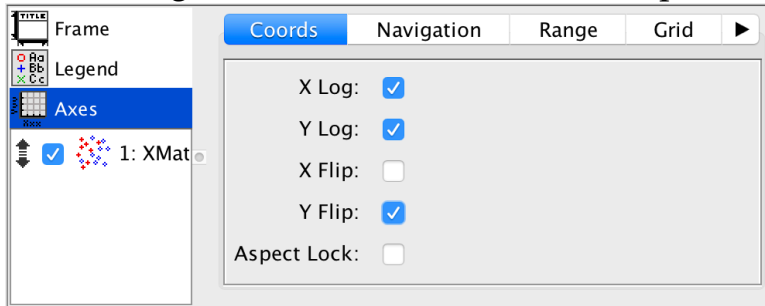
- right-click on the X-matched catalog plane in the main Aladin window and select “Broadcast the selected table to...” then “topcat”. Your table is then send to the TOPCAT application.



- In the TOPCAT window, click on the plane plotting button
- Select the G Gaia magnitude for the Y axis (**phot_g_mean_flux_tab1**) and write down the expression for the W1-W3 WISE colour for the X axis (**W1mag_tab2-W3mag_tab2**)



- In the axis panel, select a **log scale** for the X and Y axis and **flip the G magnitude axis**



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....

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