



Astroinformatics 2011: TOPCAT Tutorial

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

Get the files and presentation from:
<http://www.mso.anu.edu.au/~murphysj/topcat/>

The overall goal of this tutorial is to try and identify the nature of a cluster of X-ray sources near the Chamaeleon star-forming region and see if we can find any additional X-ray faint members. This can easily be accomplished using TOPCAT and a few Virtual Observatory tools.


These instructions will take you through obtaining a VOTable from the internet, manipulating the table in TOPCAT, querying a Cone Search server, crossmatching the results and making various pretty plots. All the while doing science!



Act 1: Getting and manipulating a VOTable of Chamaeleon X-ray sources


We will be using a VOTable of the Alcalá et al. sources. There are many ways to get VOTables -- in this case we shall use the ViZieR service via ADS.


Do an ADS Search for Author='^Alcalá', Year=1995. On the abstract page, select 'On-line Data' to go straight to ViZieR.
(or go to <http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/A+AS/114/109>)

This is the ROSAT all-sky survey of X-ray sources in Chamaeleon. We would like to return the whole catalogue as a VOTable. In the Query Setup section select an unlimited number of entries and VOTable output format. Submit the query.

Open up TOPCAT  and drag and drop the file into the Table List.

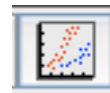
Double click on the table in the Table List to see the table. You can also explore the table metadata  or column metadata  (units, datatypes, descriptions).

The first thing we can ask is where on the sky are our sources. For the sake of pretty 3D goodness do a spherical plot. 

Can you identify the clustered sources some distance from the Cha clouds? For the sake of clarity, let's get rid of that pesky hanger-on to the far north of the rest of sources. Use the subset tool to lasso tool to select the bulk of the sources and add them as a subset. 

Because we want to only work with these sources from now on, select the subset you just defined in the Row Subset box the main TOPCAT window.

Perhaps a cartesian projection would be better. Make a scatter plot



of RA vs Dec and flip the RA axis to get the right orientation on the sky.



ROSAT was an X-ray satellite, so what are the X-ray counts doing? Add an auxiliary axis showing the count rate. Already we are visualising additional dimensions in our data.

Act Two: Cone Searching and Cross Matching within TOPCAT

Given how tightly clustered the X-ray sources at RA = 130 deg are, we might (rightly) suspect that these stars belong to a young cluster. *Are there any other X-ray-faint members below the detection threshold of ROSAT?*

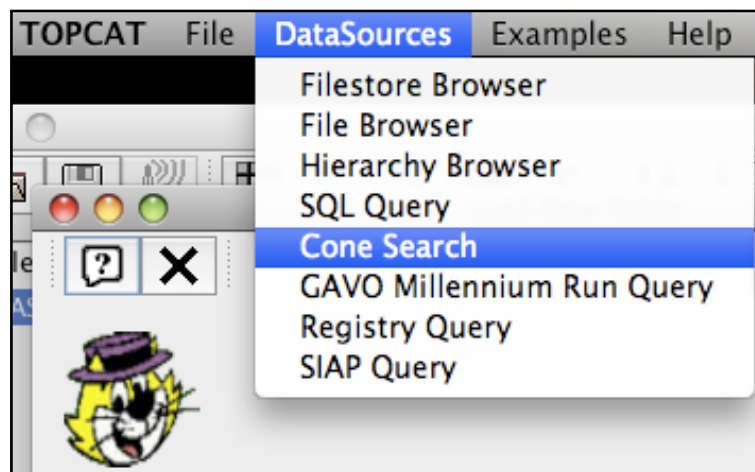
What we need is another property that all cluster members share, irrespective of X-ray luminosity. Space motion is one, but is hard to obtain without radial velocities and distances. However, the cluster star's *proper motions* (angular motion on the sky) should be similar.

We could repeat the process above and find a suitable proper motion catalogue on a VO portal, or through ViZieR etc. But TOPCAT provides the ability to do *Cone Searches* of a specific region of sky. The Cone Search is a VO standard for querying catalogues of objects or observations on the sky. In this example we shall use the US Naval Observatory's NOMAD catalogue.

In the main TOPCAT window select the Open icon



and from the Data-Sources menu select Cone Search:



Search for 'nomad' and select the last entry in the list (The Naval Observatory Merged Astrometric Dataset, hosted by astronnet.ru).

Search 0.5 degrees radius around RA = 130.0 deg, Declination = -79.0 deg. This should return a 16,706 row, 27 column table (6 Mb download in VOTable format).



Make a histogram of the 2MASS *J* magnitude '*j_{mag}*' and switch to a logarithmic Y-axis. What can you say about the completeness of the *J* detections?

We now need to find the stars we are interested in amongst the 16,706 NOMAD sources. In the main TOPCAT window select the two table cross match tool



There are various cross matching methods available. 'Sky' is the most common. Given the poor positional accuracy of the X-ray data a 1 **arcmin** max error is probably appropriate. Select the two tables and cross match away (keep the Output Rows set to 'Best Match Only').

Examine the new table (it should only have 6 rows but now 9+27+1=37 columns). The new `Separation` column shows the distance in arcsec between the cross matched positions. Note that only 1/3 of the stars has a NOMAD proper motion and `Vmag`. The other stars are presumably too faint on the DSS plates NOMAD uses.

Plot a scattergram of all the NOMAD sources: `pm_ra` versus `pm_dec`. Most stars have small proper motions (<100 mas/yr in each direction). Have a look at the error bars if you like.

Add the cross match results to the plot.

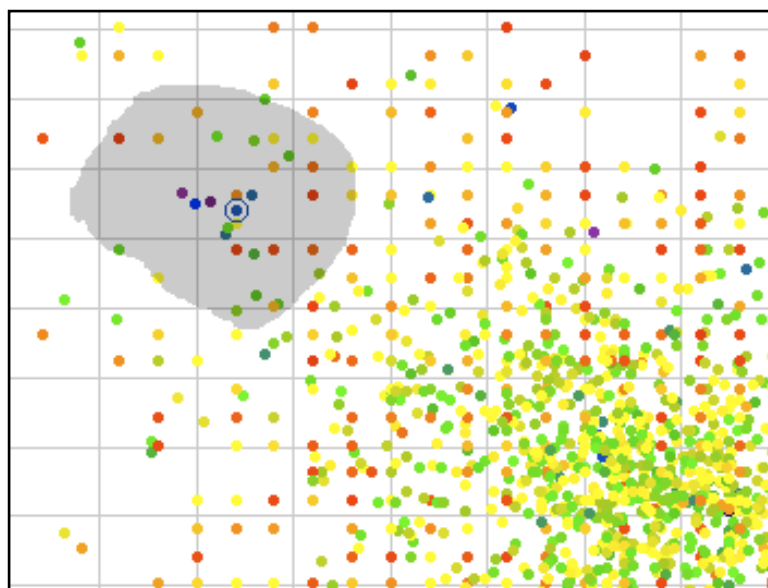


If you zoom into the region around the one good X-ray star there seems to be a few points clustered around that proper motion. Intriguing...

We expect nearby, pre-main sequence stars to be brighter than field stars. To visualise this in conjunction with the proper motion add an auxiliary axis of `jmag`. Low and behold the stars with similar proper motions are systematically brighter than many others. Very intriguing...



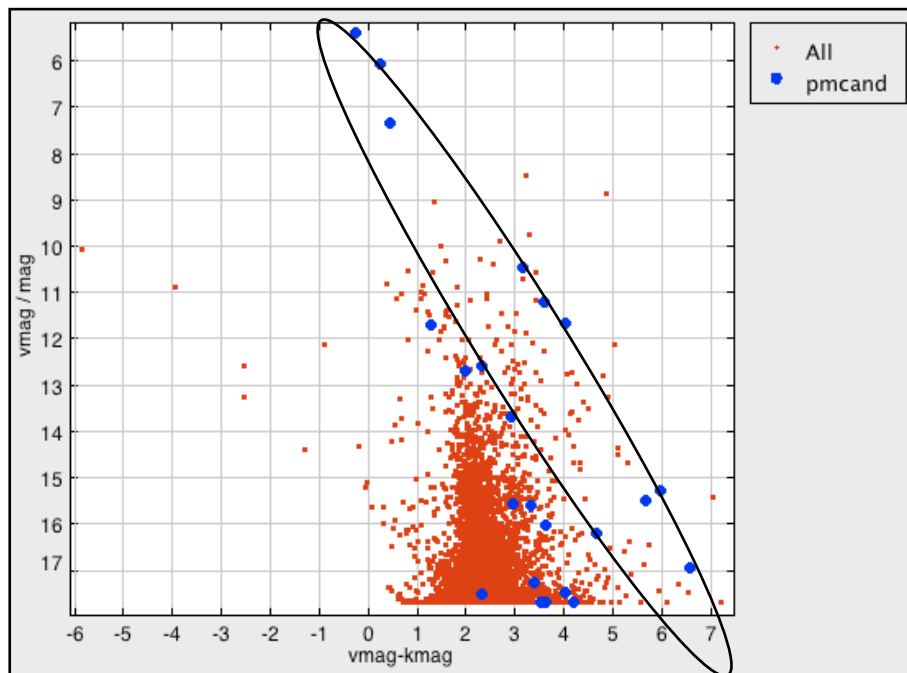
Select the Lasso tool from the top menu. Given the largish errors in the proper motions draw a wide region around the clustered points and click again to confirm. This creates a row subset of sources.



Act Three: Finding new cluster members with TOPCAT

Don't close the proper motion plot just yet. What does the colour-magnitude diagram look like? Select the NOMAD table again and make another scatter plot of the colour $v_{\text{mag}} - k_{\text{mag}}$ versus v_{mag}

Make the proper motion subset visible on the CMD. Several of the stars obviously lie in a line, elevated above the bulk of the stars. This is the cluster isochrone in the V , $V-K$ colour space.



We can now select cluster members having appropriate proper motions **and** photometry. Deselect the red points (Row Subset: 'All'), leaving only the proper motion subset. Draw a region around the cluster isochrone.

Add all the stars back to the plot. Bring up the table of the NOMAD sources. Select points on the CMD that lie close the cluster isochrone. TOPCAT automatically selects the same object in all open plot and table windows. Given the errors in the data some objects have proper motions and photometry that could still be consistent with membership in the cluster.

In fact, the stars we have found are members of the 'Eta Chamaeleontis' cluster, an 8 Myr-old cluster of stars 97 pc from the Sun. The 18 cluster members were discovered over the course of many years by a very similar process. We have done it in 15 min or so.

Act Four: Checking membership

I have placed a VOTable of known members and their properties on the website (<http://www.mso.anu.edu.au/~murphysj/topcat/>). Grab a copy and cross match it against the NOMAD sources. Why couldn't we find the other members?

Extra for experts: Send your candidates to Aladin using the 'Interop' menu. Overlay some images on your objects.

