Astroinformatics 2009: 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 step-by-step instructions will take you through obtaining a VOTable from the internet, manipulating the table in TOPCAT, querying a Cone Search server within TOPCAT, crossmatching the results and making various pretty plots.

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

We will be using a VOTable of the Covino et al. sources. There are many ways to get VOTables -- in this case we shall use the US VO portal @ http://www.us-vo.org/

Head to the 'Directory' section (like a Yellow Pages of VO resources)

Search for '`rass chamaeleon`' (there should be 4 results found)

On the first result select 'Full Record' to see more information about the resource

Feel free to explore the various sections (e.g. About the Resource Providers, Data Coverage Information)

Select 'Search Me' under the Simple Cone Search heading to query the resource directly from the webpage

We would like to return *all* the information about *all* the X-ray sources. Do an All Sky Search with All Columns returned

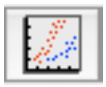
Using the filters at the top of the page, limit the results to `dec: <-50` and `class: T TAU*`. There should now be 94 sources remaining.

Export the results to an XML File (VOTable) using the button at the top of the screen

Open up TOPCAT  and load the VOTable  (then Filestore Browser)

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 4 clustered sources from Covino et al.?

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.

What are the Galactic coordinates doing? Add an auxiliary axis  showing galactic latitude (`bii`). Already we are visualising additional dimensions in our data. If they are indeed young stars what does the latitude distribution tell us about the distances to the sources?

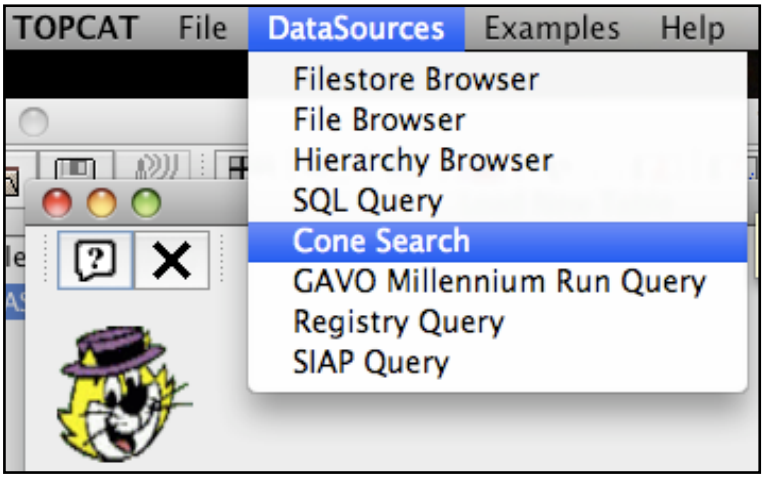
Act Two: Cone Searching and Cross Matching within TOPCAT

Given how tightly clustered the 4 stars are, their similar ages and the fact that 3/4 have similar radial velocities 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, *proper motions* (angular motion on the sky) should be the same.

We could repeat the process above and find a suitable proper motion catalogue on the 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 DataSources menu select Cone Search:



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

Search 0.5 degrees radius around RA = 130.5 deg, Declination = -79.0 deg. This should return a 16522 row, 27 column table (6 Mb download in VOTable format)

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

We now need to find our 4 stars amongst the 16522 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 (check the `offset` column in the the RASS table) 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 4 rows but now 16+27+1=44 columns). The new `Separation` column shows the distance in arcsec between the cross matched positions. Note that only 1/4 of the stars has a NOMAD proper motion and `Vmag`. The other 3 are presumably too faint on the DSS plates NOMAD uses.

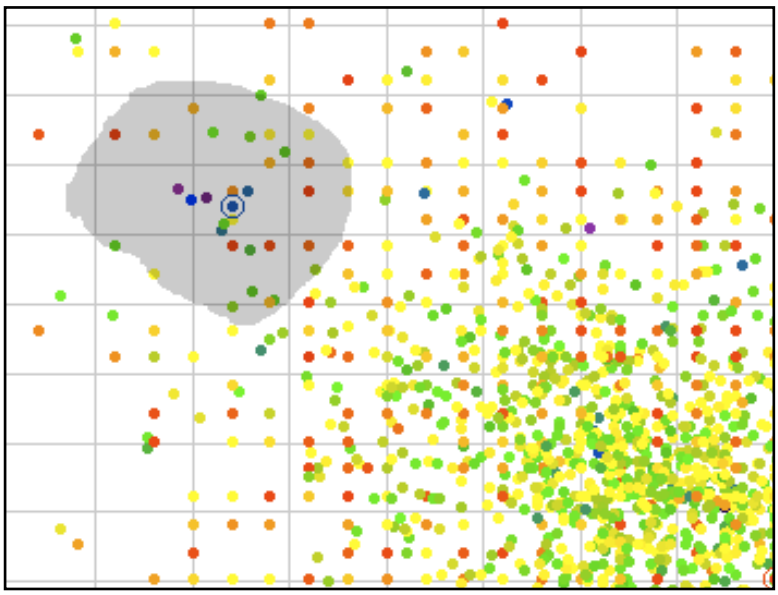
Plot a scattergram of all the NOMAD sources: `pm_ra` versus `pm_dec`. Most stars have small proper motions (<100 mas/yr in each direction). Have a look at the error bars if you like.

Add the 4 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...

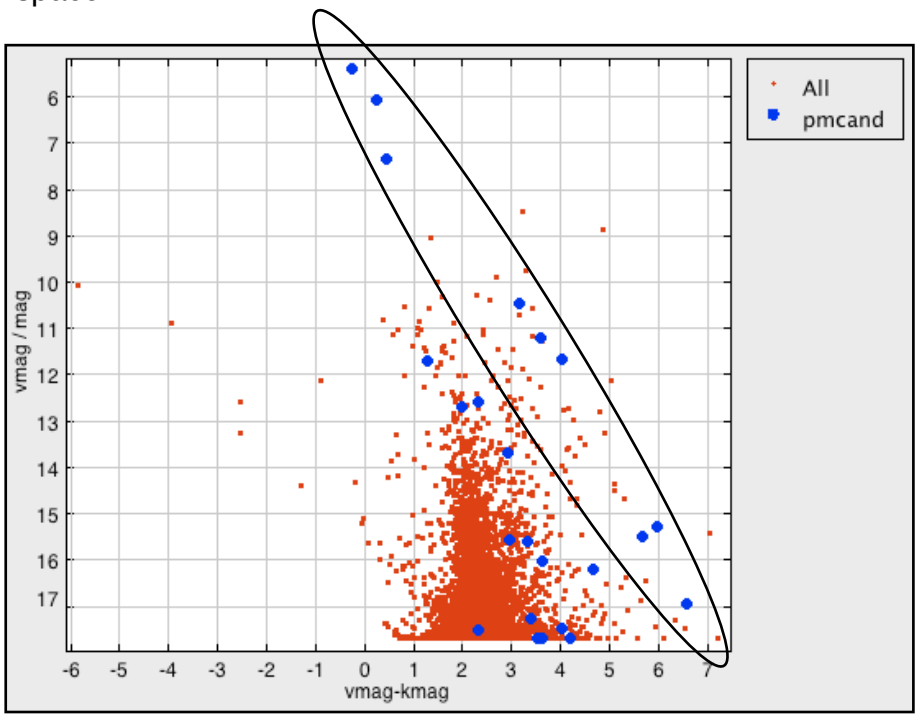
Select the Draw Region tool from the top menu.  Given the largish errors in the proper motions draw a wide region around the clustered points and click again to confirm.  This creates a row subset of sources.



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 `vmag-kmag` versus `vmag`

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 SAMP/PLASTIC and the 'Interop' menu. Overlay some images on your objects.