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Running TopCat

This tutorial goes through downloading TopCat, creating a TopCat project and importing databases (Gaia, starhorse, etc.), plotting these and creating subgroups, Pair-Matching, and concatenating. The basics of using TopCat.

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1) **Downloading TopCat**
    a. Click THIS link to go to the TopCat homepage (There are also tutorials here).
    b. Click the 'Downloads' link and download the standard version, topcat-full.jar file for Windows and topcat-full.dmg for MacOS. You are welcome to download another, but this one is recommended.
        i. To be able to run this file, you need a Java runtime environment. For Windows and MacOS, type 'java -version' into your command prompt to check. If you do not have one, click THIS link to download the recommended system on Windows and THIS one for MacOS.
    c. Once downloaded, you should be able to click the file and open TopCat!
2) **Using Cone Search**
    a. Cone search gives you the ability to search for a database and use it to reference an object and its field!
    b. To access this, click the 'VO' drop down menu and search your desired database under 'Keywords:' (we'll use Gaia EDR3 for this representation).
    c. After typed, hit ENTER and you'll see it brings up all the databases with the Keyword Gaia EDR3. We want to use the first database that comes up, which has an immense amount of information.
    d. Click this and type your object's name under 'Object Name:' and then enter the radius of which you'd like to search. For now, we will use Christmas Tree cluster (NGC 2264), an open cluster, with a radius of 16" (Usually you'd use arcmin (') or arcsecs (")).

e. Click the cell data icon  and you'll see all the stars imported from Gaia and their respective information! The designation is the stars' name under the Gaia archive.
f. Now so we do not lose our amazing table, go to the dropdown 'file' and click 'Save Tables/Sessions'. Go to the session tab and under 'Output Format' select votable, which is widely used for TopCat. Then select the location where you'd like to store the project file under 'System Browser'.

3) PLOTTING!

a. Using the database we imported, we can plot histograms  , plane plots  , sky plots  , 3D plots using Cartesian coordinates  , and 3D plots using spherical coordinates  . There is one more called a time series, but you will rarely use this.
b. Click on the plane plot and you will see the graph with y-axis being dec and x-axis being ra. The sky plot has in the same axes but different terminology due to the axes being Latitude and Longitude.
c. Going back to the plane plot, make the x-axis pmra (proper motion ra) and y-axis pmdec (proper motion dec). you can create a subset by using  . Once clicked, zoom in on the smaller, dense region to the lower half and circle it, then re-click the icon and name it 'Proper'. After, click 'Add Subset' and you'll see a blue region.
d. Below the plot, click on the 'Subsets' tab and dis-select 'All'. Now you have just the 'Proper' subset (You can also change the color of the subset by clicking the subset and selecting your preferred color).
e. Now, open the histogram plot and under subsets select the one we made and dis-select 'All'. Click  to re-size your plot and change the x-axis to 'parallax' (1/distance) and leave the weight alone.
f. Zoom in until you have approximately 1.32 and 1.45 bounds and make a subset of these by clicking  . This creates a subset of the bounds in the window. Then name it 'Close' and click 'Add Subset'.

i. We want to do this with the pmdec vs. pmra because we want stars with approximately the same velocities. We also did the parallax histogram because we want stars approximately with same parallax.

g. After we create this subset, go back to the plane plot, which you'll see is 2 colors now. Dis-select the first subset we made and leave the parallax set.

h. Next, change the axes to phot_g_mean_mag vs. bp_rp and flip the y-axis by selecting the 'Axes' tab to the left. You might know what we are doing now, but if you do not, you are about to make a Hertzsprung-Russel Diagram (HRD).

i. Next, we are going to use the distance modulus to estimate the absolute magnitude along the y-axis. This equation is:

$$phot\ g\ mean\ mag + \left(5 - 5 * log10\left(\frac{1000}{parallax}\right)\right)$$

(should be able to copy/paste). Where 'log10' is a log with base 10 and we divided the parallax by 1000 because TopCat defaults the parallax angle in milli degrees. After hitting enter, you have created an HRD!

4) Pair-Matching Databases

a. Pair-Matching in TOPCAT is taking information from one database, that you Cone Searched for, and matching it to another. So, before we do this, do a Cone Search for 15 MON again, with the same parameters but using the Keyword 'starhorse', and click on the first one. After clicking ok, notice how much smaller this database is to the last we made. This is because this database's variables account for dust extinction! Gaia can only get so many stars to account for this, therefore there are fewer than the last one.

b. After this is done, let's see how many stars from this database are in the last one we made. We can do this by using the Pair-Matching feature  . There is also features for Triple, Quadruple, and Quintuple pairs. Click this and select the 2 databases Table 1 and 2, leaving the default settings. After clicking go, it shows how many pairs were found.

c. Let's now do a plane plot and set the x and y to 'BP-RP0' and 'MG0' then flip the y-axis, like we did last time. We do not need to use the distance modulus because the starhorse database already calculated the absolute magnitude for us!
    i. Now this is an HRD of the entire cluster, with FOV of 16', while accounting for dust extinction! If you'd like, you can repeat the previous tutorial **'PLOTTING!',** using this database.
    ii. You can also re-name the database by changing the 'Label' and clicking enter.

5) Concatenating Tables

a. Concatenating is a fancy word for joining tables with the SAME column names. An example is doing a Cone Search for 100 individual stars within 3" and joining or concatenating them into a single database.
b. To do this, use Gaia's EDR3 dataset, like we used before, and search for 15 random stars, of your choice, with a radius of 3". If it gives an error saying no star is found, make the radius larger, but use ".
c. After you have 15 individual tables, under the tab 'Joins' click on 'Concatenate Tables'. Select the first star as the Base table and the second as the Appended table. After, select Concatenate and repeat the process while changing the Base and Appended tables to the most recent (1->2, 2->3, 3->4, etc.).
d. After, change the name of the database you created and display the table to see how it joined. You can now run wild with your imagination on what you want to do with your database!
e. Don't forget to save your work!!

As a conclusion to the tutorial, these are the simple, useful, and fun operations TOPCAT can do! There is a lot more functionality and thousands of databases this program offers. But that material is very extensive and should be a rabbit hole you as the learner should go down!