



# VOV. TOPCAT



In this tutorial we will explore how to access catalogues, cross-match tables, filter sources, create subsets, and represent the results using different kind of plots. This tutorial is based on TOPCAT v4.7-1

This tutorial is the second of a series of tutorials dedicated to different Virtual Observatory tools. The series is thought to cover a wide range of tools that permit to address a variety of astrophysical problems. Each tutorial is accompanied by a video that shows the procedure of the proposed exercises. The series of tutorials and videos can be found at:

<https://svo.cab.inta-csic.es/docs/index.php?pagename=Meetings>

- Launch TOPCAT (Tool for OPerations on Catalogues And Tables):
  - Download topcat-full.jar from <http://www.star.bristol.ac.uk/~mbt/topcat/#install>
  - Open a terminal and go to the directory where topcat-full.jar was saved
  - Type: java -jar topcat-full.jar &

## I) Science case: Discovery of Brown Dwarfs mining the 2MASS and SDSS databases with TOPCAT.

(Original case by Enrique Solano. Adapted by Fran Jiménez-Esteban)

- **Scientific background:** Brown dwarfs are objects occupying the gap between the least massive stars and the most massive planets. They are intrinsically faint objects so their detection is not straightforward and, in fact, was almost impossible until the advent of global deep surveys at optical and near-infrared bands.
- **Workflow:** We propose here to mine the 2MASS-PSC and SDSS-DR12 databases to identify T-type brown dwarfs through an appropriate combination of colours in the optical and the infrared, an approach that perfectly fits into the Virtual Observatory.
  - **Discovery:** Search 2MASS-PSC and SDSS-DR12 sources around RA: 08h 30m and DEC: 01d 30m with a 14 arcmin radius.
    - In the TOPCAT main window: *VO* → *VizieR Catalogue Service*. A new window (“*VizieR Catalogue Service*”) is opened.
    - In the *VizieR Catalogue Service* window:
      - *Row selection* box:
        - Change RA, DEC and radius units to “hh:mm:ss”, “dd:mm:ss” and “arcmin”, respectively.
        - Type the coordinates (RA: 08:30:00, DEC: 01:30:00) and radius (14).
      - *Catalogue selection* box: *By keyword* → *Keyword: 2MASS* → *Search catalogues* → Select 11/246. Click **OK** → A table called “*11\_246\_out*” will be uploaded in the TOPCAT main window. It contains 683 sources. Rename it to 2MASS-PSC in the “*Label*” box on the right panel.

- Open again the *VizieR Catalogue Service* window:
  - *Catalogue selection* box: [Surveys](#) → [Select SDSS-DR12](#) → Click **OK** → A new table called "V\_147\_sdss12" will appear in the TOPCAT main window. It contains 12,404 sources. Rename it to SDSS-DR12 in the "Label" box on the right panel.
- **Cross-matching:** Find common sources in 2MASS-PSC and SDSS-DR12 catalogues.
  - In the TOPCAT main window: [Joins](#) → [Pair Match](#) (alternatively you can click on bottom with the two matches of the upper panel). A new window ("Match Tables") is created.
  - In the "Match Table" window
    - In the "Match criteria" box:
      - Algorithm: Sky
      - Max error: 4 arcsec
    - Table1: (2MASS-PSC). RA/Dec columns: RAJ2000, DEJ2000
    - Table2: (SDSS-DR12). RA/Dec columns: RA\_ICRS, DE\_ICRS
    - Output Rows box:
      - Match selection: Best match, symmetric
      - Join Type: 1 and 2
    - Click "Go". A new table "match(1,2)" with 679 sources is created
      - Rename it to 2MASS\_x\_SDSS in the "Label" box on the right panel.
      - Explore the table by double clicking on it or by going to [Views](#) → [Table Data](#) (Alternatively click on the 4th bottom of the upper panel starting from the left)
- **Filtering:** Identify the possible brown dwarfs in the 2MASS\_x\_SDSS table by applying different conditions that this kind of sources fulfill.
  - In this step we will select point sources using the SDSS flag (class=6). "class" is a column of the SDSS-DR12 catalog that provides information on the type of object (3=galaxy, 6=star).
    - In the TOPCAT main window: [Views](#) → [Row Subsets](#) (Alternatively click on the 7th bottom of the upper panel starting from the left)
    - In the "Row Subsets" window: [Subsets](#) → [New subset](#) (Alternatively click on the 1st bottom of the upper panel starting from the left)
    - In the "Define Row Subsets" window:
      - Fill in the "Subset Name" box (for instance, filter).
      - Expression: class==6. Click **OK**. A subset containing 649 point-like sources is created.
  - Now, let's select sources with no detection in the u and g SDSS bands ( $u > 22.0$  and  $g > 22.2$ ), since brown dwarfs are cool objects not detected in the blue DSS bands. And sources fulfilling the brown dwarf criteria provided by Burgasser et al. (2000, Apj, 531, L57):  $(J-H) < 0.3$  and  $(H-K) < 0.3$  magnitude.
    - To include the rest of filtering conditions: In the TOPCAT main window: [Views](#) → [Row Subset](#). Modify the filter expression to: "cl==6 && umag>22.0 && gmag>22.2 && Jmag-Hmag<0.3 && Hmag-Kmag<0.3". Only one source is selected.
  - In the TOPCAT main window select "filter" in the "Row Subset" box in the right panel.



- Save the session:
  - Select “*Session*” tag
  - Click on “*Filestore Browser*”
  - Write a name for the table in “*File Name*” box
  - Output Format: select the format of the file containing the session

Note: This saves the tables, the filters, the subsamples, etc... but this does not save the plots.

## II) Science case: Determine the distance to the Pleiades cluster from TGAS data.

(Original case by Mark Taylor. Adapted by Fran Jiménez-Esteban)

- **Scientific background:** Stars do not form isolated in the space. They form in large groups from the same interstellar cloud. We call them star clusters. Thus, star clusters are large groups of stars that have the same age, similar chemistry, and that keep the same kinematic than the parent interstellar cloud. The Pleiades (M45) is one of the nearest Earth star clusters. It is visible by naked eyes and contains thousands of stars.
- **Workflow:** In this tutorial we will explore the TGAS catalogue to determine the mean parallax of the stars in the Pleiades open star cluster, and obtain its distance.
  - **Discovery:** Acquire TGAS data in Pleiades region.
    - In the TOPCAT main window: *VO* → *Cone Search*
    - In the *Cone Search* window:
      - *Available Cone Service* box:
        - Keywords: TGAS
          - Hit “*Find Services*” and select “*ARI-Gaia*”. The partial URL of the service appears in the *Cone URL* field in the *Cone Parameters* box.
      - *Cone Parameters* box:
        - Object Name: Pleiades. Hit “*Resolve*” to fill in sky position fields.
        - Radius: 5 degrees. Click **OK** → A table with 3,085 entries called “Pleiades-ARI-GAIA-5d” is uploaded in the TOPCAT main window.
  - **Select comoving sources:** Explore the proper motion diagram to separate Pleiades stars from field stars.
    - In the TOPCAT main window: *Graphics* → *Plane Plot* (Alternatively click on the 11th bottom of the upper panel starting from the left)
    - In the *Plane Plot* window:
      - *Position tag*:
        - X: pmra; Y: pmdec.
          - Note overdensity around (20,−45); use mouse to navigate.

- Graphically select this comoving cluster as new Subset:
  - *Subsets* → *Draw Blob Subset* (Alternatively click on the 3<sup>rd</sup> bottom of the upper panel starting from the left). Drag mouse around cluster, hit same button again. The *New Subset* window pops up.
    - New Subset Name: “comoving”. And hit in “Add Subset”.
- Look in *Subsets* tab of plot window; turn *All* and *comoving* subsets off/on
- Look in *Views* → *Row Subsets* in the TOPCAT main window to see new subset
- **Select Pleiades members:** Use the parallax to refine the selection.
  - In the TOPCAT main window: *Graphics* → *Histogram Plot* (Alternatively click on the 10<sup>th</sup> bottom of the upper panel starting from the left)
  - In the *Histogram Plot* window:
    - *Position tag*:
      - X: parallax
        - In *Subsets* tab, make sure only subset “comoving”, and not “All”, is plotted. Rescale plot by hitting on the 4<sup>th</sup> bottom of the upper panel starting from the left, or navigate with mouse. There are some outliers visible, probably not cluster members. We want to create a new subset excluding those parallax outliers.
  - In the TOPCAT main window: *Views* → *Row Subsets* (Alternatively click on the 7<sup>th</sup> bottom of the upper panel starting from the left)
  - In the *Row Subsets* window: *Subsets* → *New Subset* (Alternatively click on the 1<sup>st</sup> bottom of the upper panel starting from the left)
  - In the *Define Row Subset* window:
    - Subset Name: “cluster”
    - Expression: “comoving && parallax > 6 && parallax < 9”
  - Plot only “cluster” subset using *Subsets* tab in histogram plot window
- **Estimate the mean parallax:** Use TOPCAT to do some statistics.
  - In the TOPCAT main window: *Views* → *Column Statistics* (Alternatively click on the 8<sup>th</sup> bottom of the upper panel starting from the left)
  - In the *Row Statistics* window:
    - Subset for calculations: “cluster”
      - Read off *Mean* and *SD* (standard deviation) of columns *parallax*. How far away are the Pleiades? Hint: distance in parsec is the reciprocal of parallax in arcsec. However, inverting parallax to get distance is problematic if parallax errors are large, say > 10%. Let's select sources with good parallax.
  - In the TOPCAT main window: *Views* → *Row Subsets* (Alternatively click on the 7<sup>th</sup> bottom of the upper panel starting from the left)
  - In the *Row Subsets* window: *Subsets* → *New Subset* (Alternatively click on the 1<sup>st</sup> bottom of the upper panel starting from the left)

- In the *Define Row Subset* window:
  - Subset Name: “good distance”
  - Expression: “cluster && parallax\_error/parallax < 0.1”
- Plot only “good distance” subset using Subsets tab in histogram plot window. Let's fit a Gaussian to the parallax distribution
- In the *Histogram Plot* window:
  - *Form* tag. Hit on *Forms* bottom → Add Gaussian.
    - Look in *Report* box the *Mean* and the *SD*.
- **Analyzing:** Use TOPCAT to estimate the mean distance to the cluster and to study the space distribution of its stars
  - In the TOPCAT main window: *Views* → *Column Info* (Alternatively click on the 6th bottom of the upper panel starting from the left)
  - In the *Table Columns* window: *Columns* → *New Synthetic Column* (Alternatively click on the 1st bottom of the upper panel starting from the left)
  - In the *Define Synthetic Column* window:
    - Name: “distance”
    - Expression: “1000/parallax”
    - Units: “pc”
  - In the *Row Statistics* window:
    - Subset for calculations: “good distance”.  
Note: You may need to recalculate by hitting the 3rd bottom from the left
      - How far away are the Pleiades?  $134 \pm 7$  pc
  - Let's study the space distribution. In the TOPCAT main window: *Graphics* → *Cube Plot* (Alternatively click on the 13th bottom of the upper panel starting from the left)
  - In the *Cube Plot* window:
    - *Position tag*:
      - X: ra; Y: dec; Z: distance
        - In *Subsets* tab, make sure only subset “good distance” is plotted. Rescale plot by hitting on the 4th bottom of the upper panel starting from the left. Use the mouse to navigate. 3d navigation is a bit harder. You may use the click the help “?” button at the bottom left for help.

Many other functionalities are available in TOPCAT: concatenate tables, cross-match multiple tables, save tables in Latex format, and many more.... For further information in these and many more functionalities, we refer the user to the TOPCAT manual web page: <http://www.star.bristol.ac.uk/~mbt/topcat/sun253/sun253.html>