

# Comparing cluster distances

## Software:

TOPCAT and ALADIN:

<http://aladin.u-strasbg.fr/java/nph-aladin.pl?frame=downloading>

<http://www.star.bris.ac.uk/~mbt/topcat/#standalone>

Run both Aladin and Topcat.

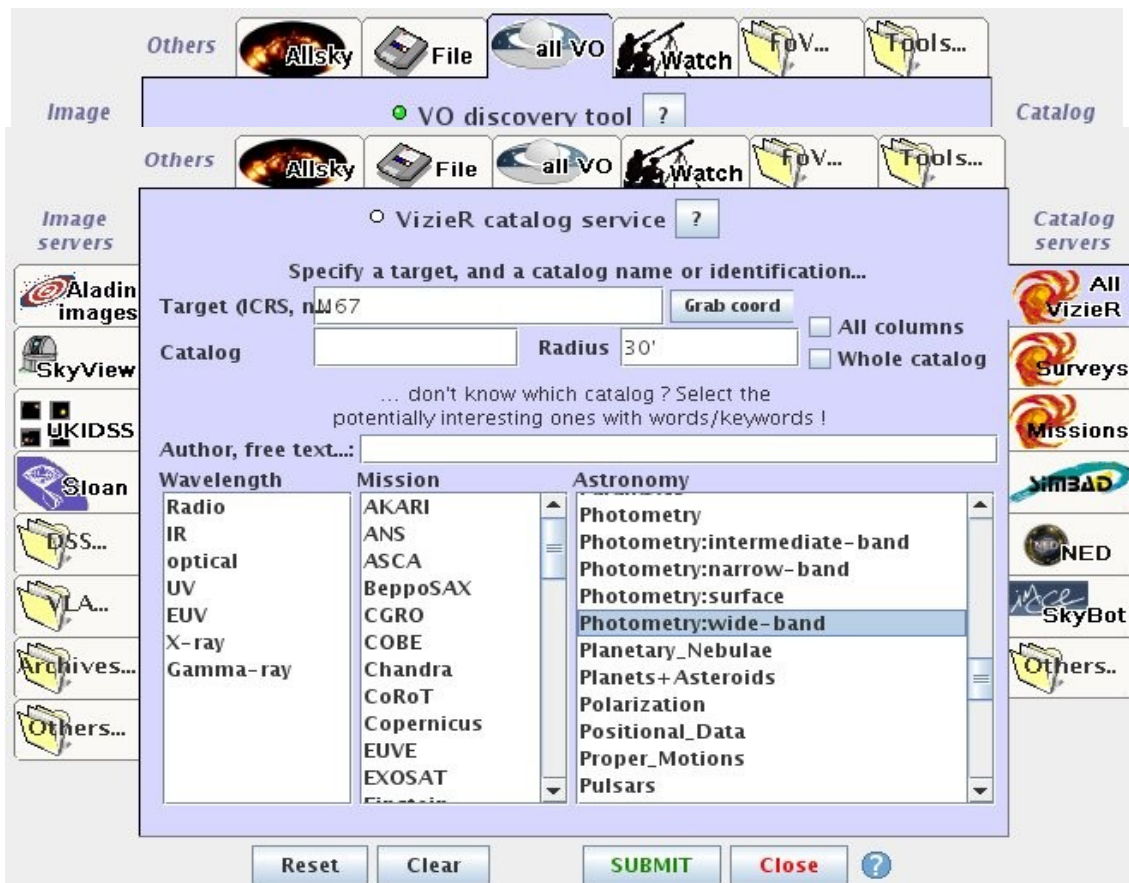
## Produce H-R diagrams

In *Aladin*, select **File** → **Load from the Virtual Observatory**

The “Server selector” window will open. Choose the “all VO” tab. In the Target field type “M67”, in the Radius field type “30' ” Unselect Catalogs and Spectra and click SUBMIT (at the bottom).

From the list of resources, scroll down and choose:

*Aladin* → *POSSII* → *J-DSS2*, press + to expand the list and choose image *705* (size *13.0' x 13.0'*)



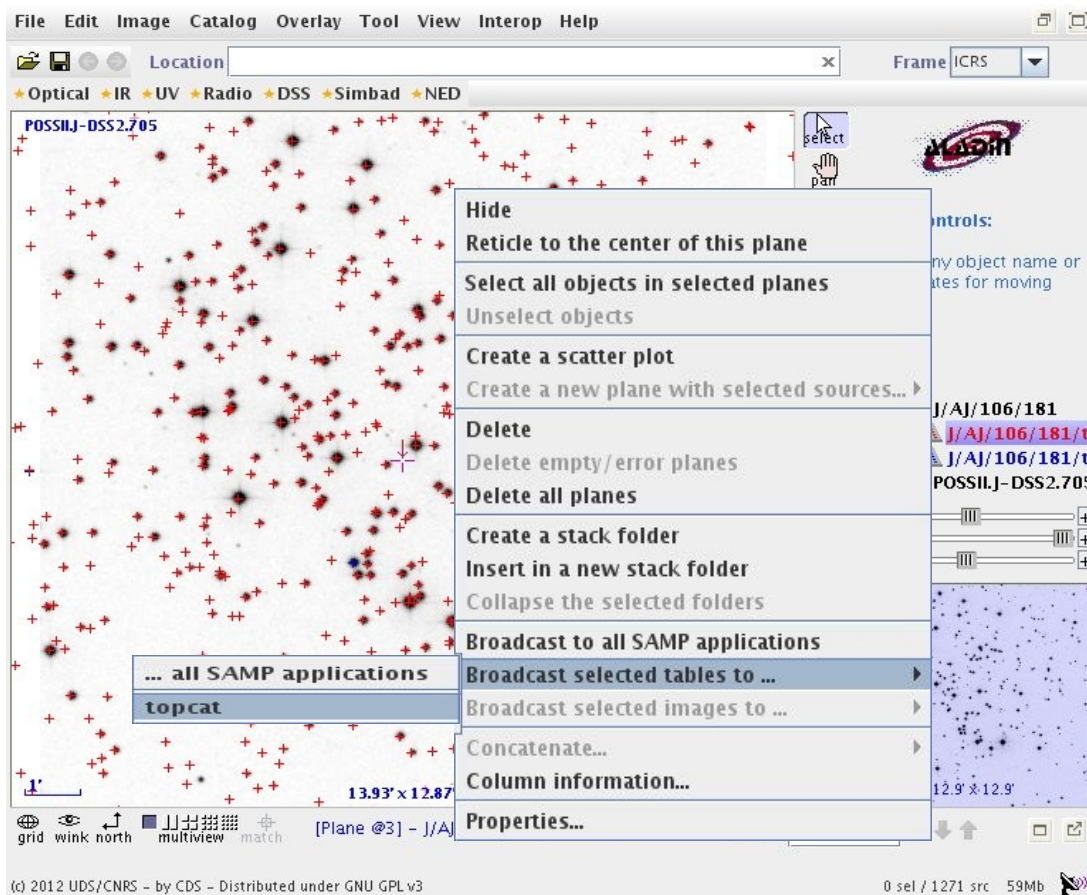
Click the image name. A “Data Info Frame” window will appear with a description of the image, – click “Load”. The image will appear in the main Aladin window. Return to the “Server select” window and choose the „AllVizieR” tab, and in the “Astronomy” list box find and select „Photometry:wide-band”, and click SUBMIT.

In the Catalog window which appears select: „J/AJ/106/181” CCD Photometry of open cluster M67 and click SUBMIT.

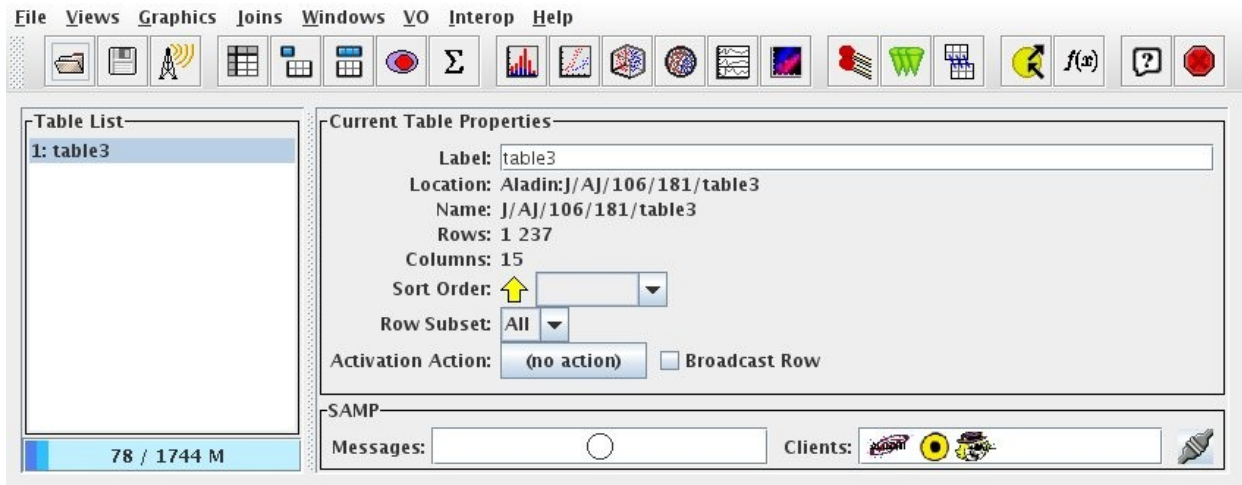
Catalogs				
	Name	Category	Density	Description
<input type="checkbox"/>	II/306	optical	75	The SDSS Photometric Catalog, Release 8 (A...
<input type="checkbox"/>	II/294	optical	53	The SDSS Photometric Catalog, Release 7 (A...
<input type="checkbox"/>	J/ApJS/17...	optical	32	VRI photometry and theta values in open cl...
<input type="checkbox"/>	J/AJ/134/...	optical	23	Secondary standard stars in u'g'r'i'z' (Cl...
<input type="checkbox"/>	J/BaltA/13/1	optical	22	M67 CCD Vilnius photometry (Laugalys+, 2004)
<input type="checkbox"/>	II/272	optical	21	Guide Star Photometric Catalog V2.4 (Bucci...
<input type="checkbox"/>	J/BaltA/7...	optical	19	M67 CCD photometry (Boyle+, 1998)
<input type="checkbox"/>	J/A+A/484...	IR	16	BVI photometry and proper motions in M67 (...)
<input checked="" type="checkbox"/>	J/AJ/106/181	IR	10	CCD photometry of open cluster M67 (Montgo...
<input type="checkbox"/>	II/7A	IR	9	UBVRICKLMNH Photoelectric Catalogue (Morel...
<input type="checkbox"/>	VI/135	IR	8	All-sky spectrally matched Tycho2 stars (P...
<input type="checkbox"/>	J/MNRAS/4...	optical	7	Photometric Classification Catalogue of SD...
<input type="checkbox"/>	J/A+A/527...	optical	6	2XMMi/SDSS DR7 cross-correlation (Pineau+...
<input type="checkbox"/>	J/AJ/136/...	optical	6	SEGUE stellar parameter pipeline. II. (Lee...
<input type="checkbox"/>	J/AJ/141/89	optical	6	SEGUE stellar parameter pipeline. IV. (Smo...
<input type="checkbox"/>	V/52	optical	5	Photometry and Proper Motions in M67 (Frol...
<input type="checkbox"/>	J/A+A/525...	IR	5	Thick disc vertical properties (Katz+, 2011)
<input type="checkbox"/>	II/143A	optical	4	Guide Star Photometric Catalog, Updated Ve...
<input type="checkbox"/>	II/168	optical	4	Homogeneous Means in the UBV System (Mermi...
<input type="checkbox"/>	II/277	IR	4	UBVRI photometry of faint field stars (Ski...

Info. SUBMIT Reset Close

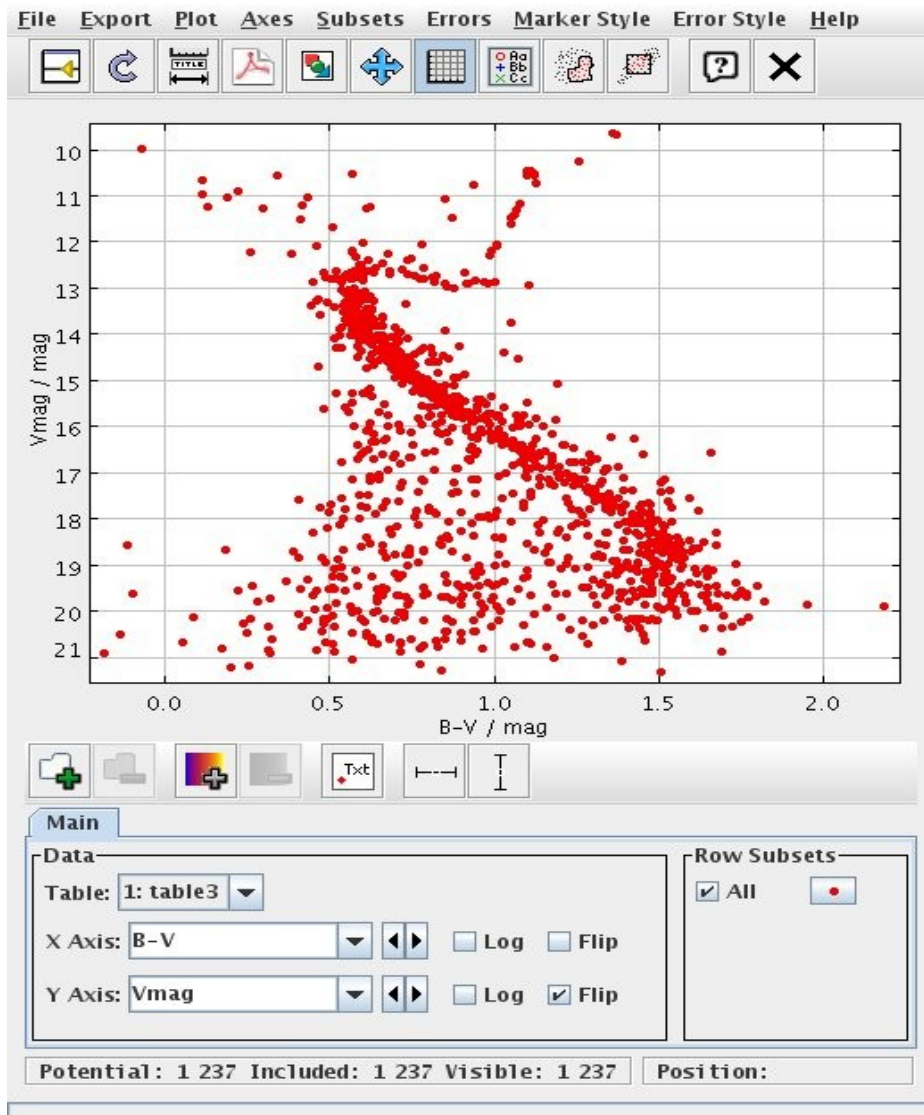
Layers corresponding to the catalog appear in the main Aladin window. Select the catalog layer „*J/AJ/106/181*”. Right click on the first child layer, choose “Broadcast selected tables to...” “topcat”.



The table will appear in **topcat**:



Plot a color-magnitude diagram - select *Graphics* → *Plot* and choose for the x-axis the color index ***B-V***; and for the y-axis choose the apparent magnitude ***Vmag***. Since the magnitude scale should be inverted, select „*Flip*”. We now have an H-R diagram for M67.

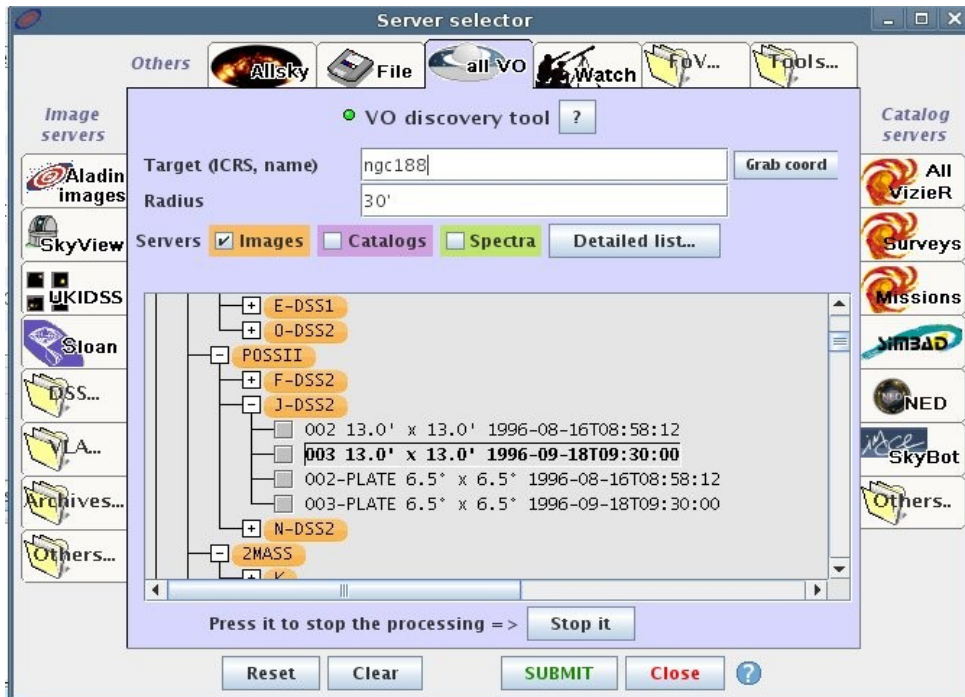




Return to Aladin. Clear the existing layers by selecting one of them, right clicking and choosing “delete all planes”.

Follow the same procedure as before to load an image of **NGC188**.

Enter **NGC188** as the target and select an image:



Go to the VizieR tab again and find the wide-band photometric catalogs which include NGC188. Choose „J/AJ/131/1565 ... UBVI photometry ... “

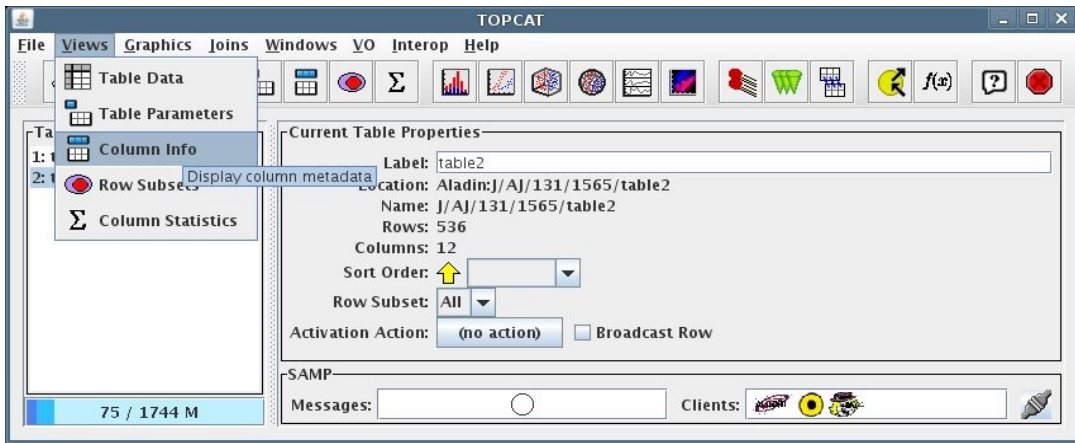
20 catalog(s) found around ngc188				
Catalogs				
	Name	Category	Density	Description
<input type="checkbox"/>	II/272	optical	37	Guide Star Photometric Catalog V2.4 (Bucciarelli+ 2001)
<input checked="" type="checkbox"/>	J/AJ/131/1565	IR	33	UBVI photometry of Berkeley 17 and NGC 188 (Krusberg+, 2006)
<input type="checkbox"/>	J/PASP/116/1012	IR	21	A star catalog for the open cluster NGC 188 (Stetson+, 2004)
<input type="checkbox"/>	J/AJ/118/2894	IR	19	UBVRI CCD photometry in NGC 188 (Sarajedini+, 1999)
<input type="checkbox"/>	J/AJ/133/1409	optical	11	u'g'r'i'z' photometry in NGC 188 (Fornal+, 2007)
<input type="checkbox"/>	II/277	IR	5	UBVRI photometry of faint field stars (Skiff, 2007)
<input type="checkbox"/>	J/AJ/124/601	optical	5	Absolute positions and proper motions in NGC 188 (Platais+...
<input type="checkbox"/>	II/143A	optical	4	Guide Star Photometric Catalog, Updated Version 1 (Lasker+...
<input type="checkbox"/>	J/MNRAS/403/1592	IR	4	Cool stars in galactic clusters (Buzzoni+, 2010)
<input type="checkbox"/>	II/168	optical	3	Homogeneous Means in the UBVI System (Mermilliod 1991)
<input type="checkbox"/>	V/136	optical	3	Teff and metallicities for Tycho-2 stars (Ammons+, 2006)
<input type="checkbox"/>	V/15	optical	2	SAO and Supplementary Data (Ochsenbein 1980)
<input type="checkbox"/>	VI/135	IR	2	All-sky spectrally matched Tycho2 stars (Pickles+, 2010)
<input type="checkbox"/>	II/169	optical	1	Observations in the Geneva Photometric System 4. (Rufener ...
<input type="checkbox"/>	II/182	optical	1	UBV Photometry of Stars with Accurate Positions (Oja 1984-...
<input type="checkbox"/>	V/137D	IR	1	Extended Hipparcos Compilation (XHIP) (Anderson+, 2012)
<input type="checkbox"/>	J/A+A/463/789	IR	1	Blue stragglers in open clusters (Ahumada+, 2007)
<input type="checkbox"/>	J/AJ/133/1470	IR	1	TAROT suspected variable star catalog (Damerdjii+, 2007)
<input type="checkbox"/>	J/MNRAS/403/1491	IR	1	Integrated magnitudes of synthetic star clusters (Pandey+ ...
<input type="checkbox"/>	J/MNRAS/411/435	IR	1	Stellar parameters and extinction (Bailer-Jones, 2011)

and submit it to Aladin and send the layer to Topcat.

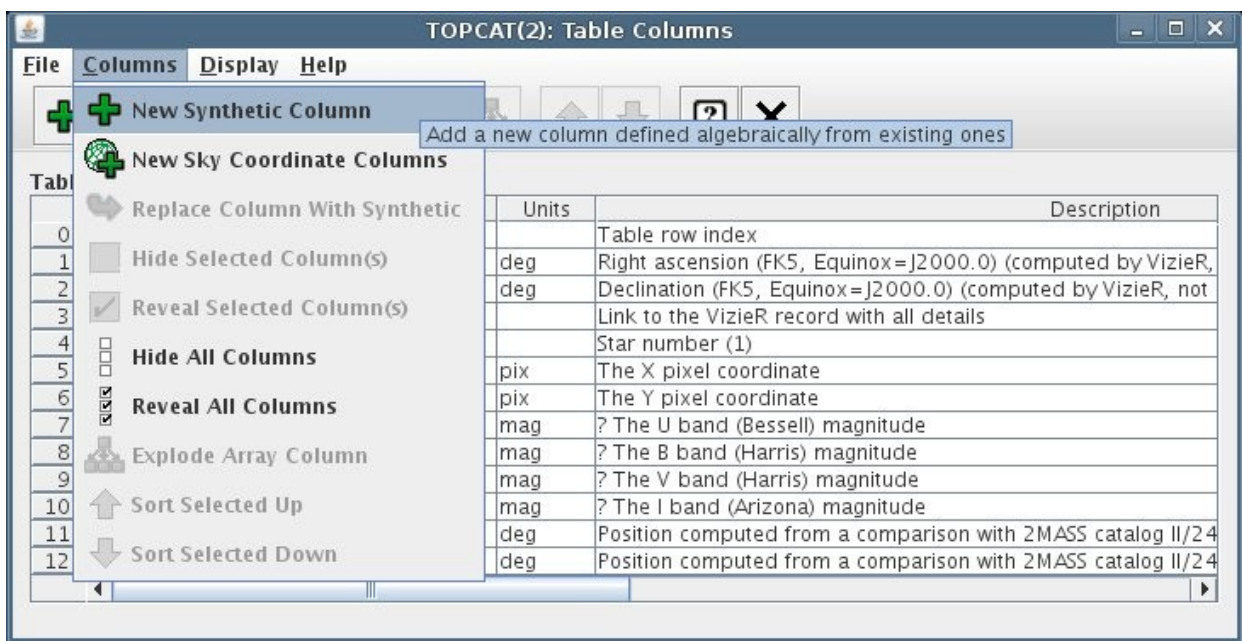
**Topcat** again

A second table will appear in topcat. The column descriptions (*Views* → *Column Info*) show that it

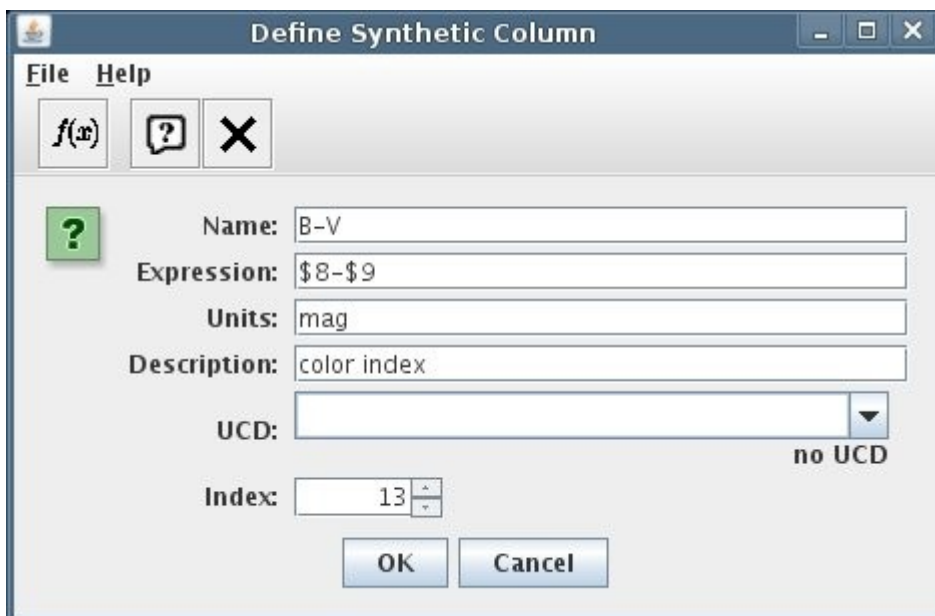
does not contain the color indices  $B-V$ .



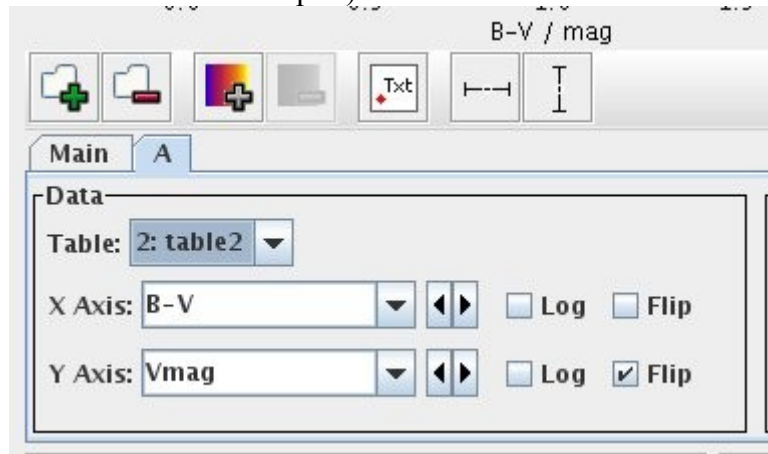
The color index ( $B-V$ ) must therefore be calculated into a new “Synthetic column” (*Columns > New Synthetic column*)



Set the name of the column (eg „ $B-V$ ”), the calculation formula using  $\$n$  for the  $n$ -th column. The B magnitude is in column 8, the V magnitude is in column 9, so the formula is: „ $\$8 - \$9$ ”. Also set the units („*mag*”) and an optional description („*color index*”)

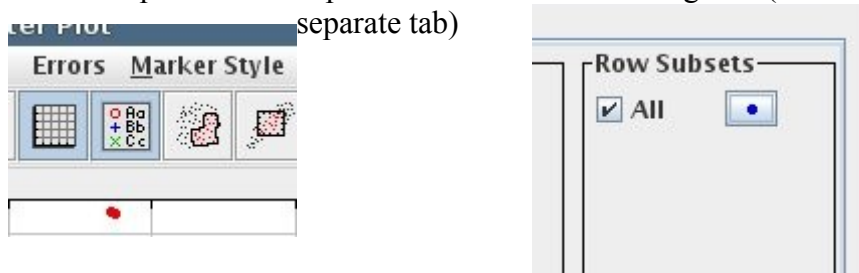


Having defined the data plot the color-magnitude diagram in the “Scatter Plot” window. Add data (green “+” in the bottom left corner of the plot) and choose the second table.

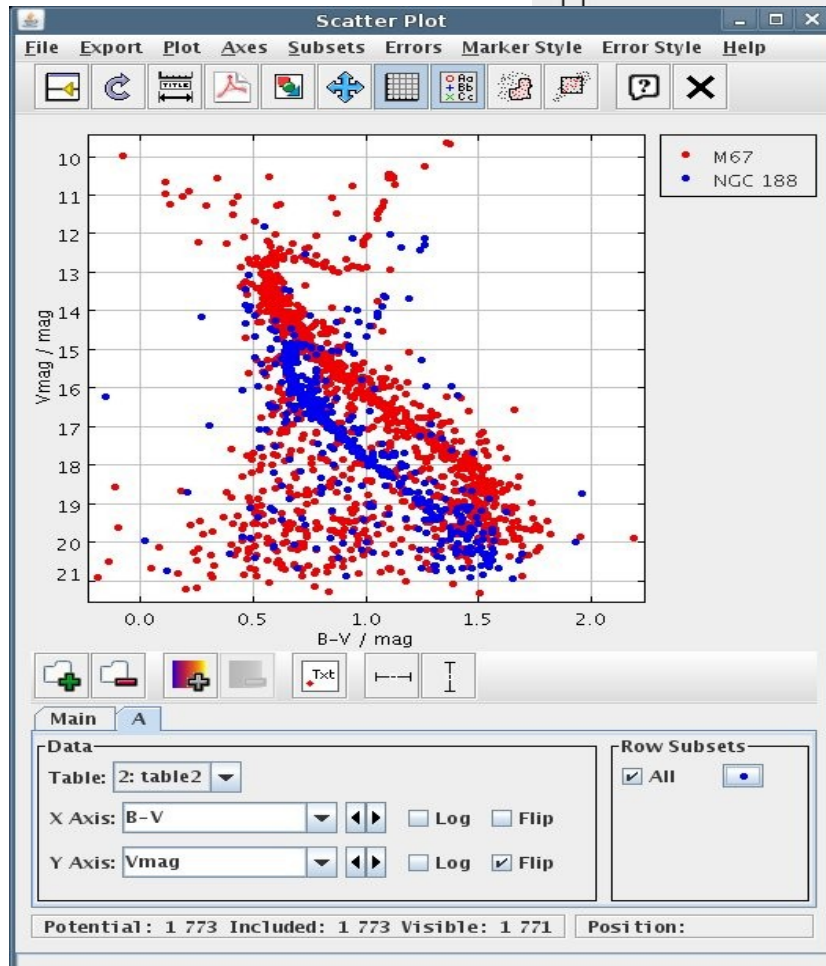


If the column names are the same as in the example they will be selected automatically. Otherwise choose the appropriate columns.

Now you have two H-R diagrams on the same plot. The button in the Row Subsets box lets you change the properties of the points on the plot and the label in the legend. (Each dataset is in a separate tab)



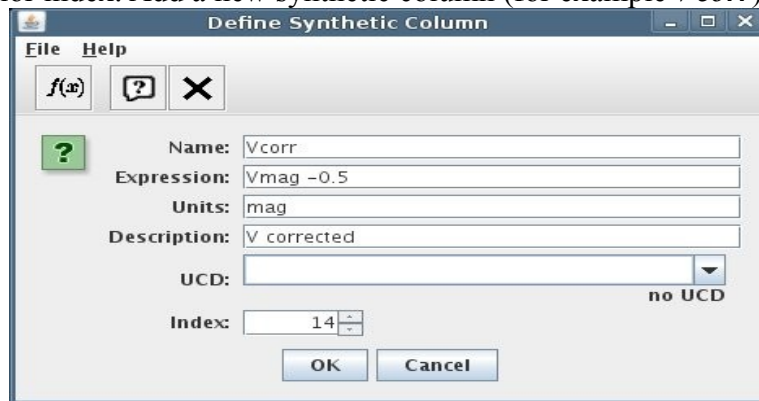
The final diagram:



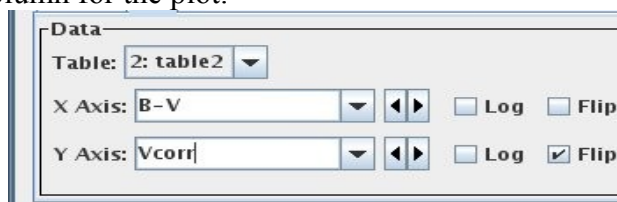


## Determine the ratio of distances

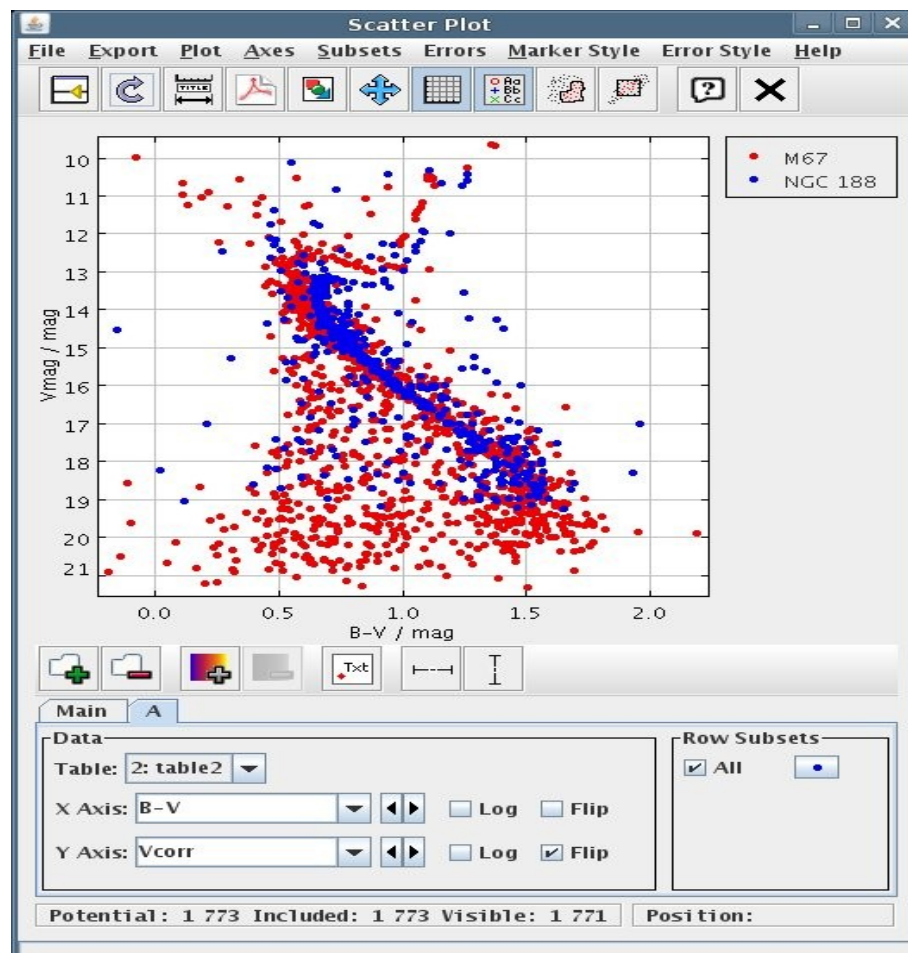
The simplest way to determine the ratio of distances is to overlay the Main Sequence of the clusters on the diagram by adjusting the apparent magnitudes. We can do this by calculating a new column as we did for the color index. Add a new synthetic column (for example *Vcorr*) for *NGC 188*.



And change the Y-axis column for the plot:



The plot on the diagram will move up. We can repeat the operation (replacing the column instead of making a new one, *Columns* → *Replace Column with Synthetic*) or by editing the expression in the column description (In the Topcat “Table Columns” window, double click on the expression in the row corresponding to the “Vcorr” column, change it, and in the Plot window choose *Plot* > *Replot*), until the Main Sequences are overlaid. The shift can be used to determine the ratio of distances.



The difference  $dm = m_1 - m_2$  should be about 1.7 mag (+- 0.1).

Calculating the ratio of distances of the clusters is based on the assumption, that the difference in brightness of stars on the Main Sequence (i.e. of similar spectral types) is a result only of the difference in distance (ignoring extinction in this case) and that their intrinsic (absolute) brightness is the same. Therefore:

$$M = m_1 - 5 \log_{10}(r_1) + 5 \quad \text{for NGC 188}$$

$$M = m_2 - 5 \log_{10}(r_2) + 5 \quad \text{for M67}$$

$$r_1/r_2 = 10^{(1.7/5)} = 10^{0.34} = 2.188$$

in other words, NGC 188 is about twice as far as M67 (in fact the measured distances are 0.8 and 1.6 kpc)