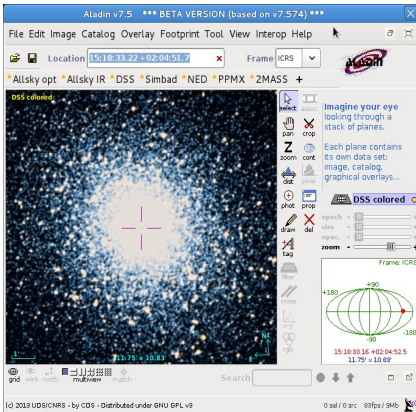


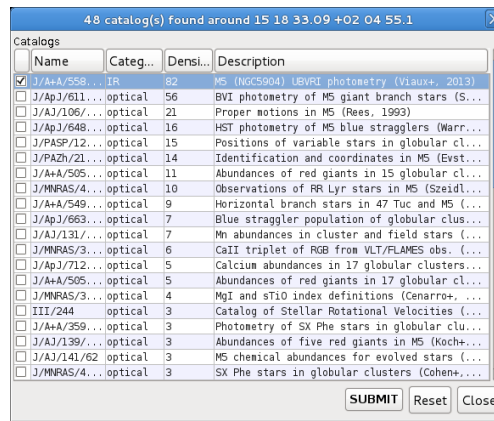
## Study of the turn-off point of globular star clusters

Start Aladin and Topcat.



In Aladin enter “M5” in the location field: the Aladin window shows the allsky map centered on the M5 globular cluster. Zoom out (use the mouse wheel or the zoom bar in the right part of the screen) in order to have a better view of the cluster.



Load a catalog of stars belonging to the cluster containing information on BVR photometry: open the server selector window (*File -> open*). On the left side there are image servers while in the right side there are catalog servers. Select the *All Vizier* tab, enter 12' as *search radius* (we know that the apparent diameter of M5 is about 23'), optical in the *wavelength* list and *globular clusters* in the *astronomy* list. Submit the query. Aladin returns a list of available catalogs, select “M5 UBVRI photometry” and load it.




Broadcast the catalog to Topcat (right click on it in the stack on the right part of the main Aladin window -> *broadcast selected table to -> Topcat*).

Move to Topcat. Rename the catalog as “photometryM5” (*current table properties -> label*) and open the table columns window (  ), have a look to column \$IDs. Create a new column with the colour index B-V corrected for reddening: *add a new column* (  ) -> name “B-V”, expression “\$6 -\$8 - 0.03”. Create a new column with the V band absolute magnitude of the stars belonging to the cluster (the distance of the M5 cluster is 7300 pc) – name: V\_Mag, expression: “\$8 + 5 - 5\*log10(7300)”.

Build the HR diagram of the cluster: plot (*graphics -> scatter plot*) B-V versus V\_Mag, flip the y axis.

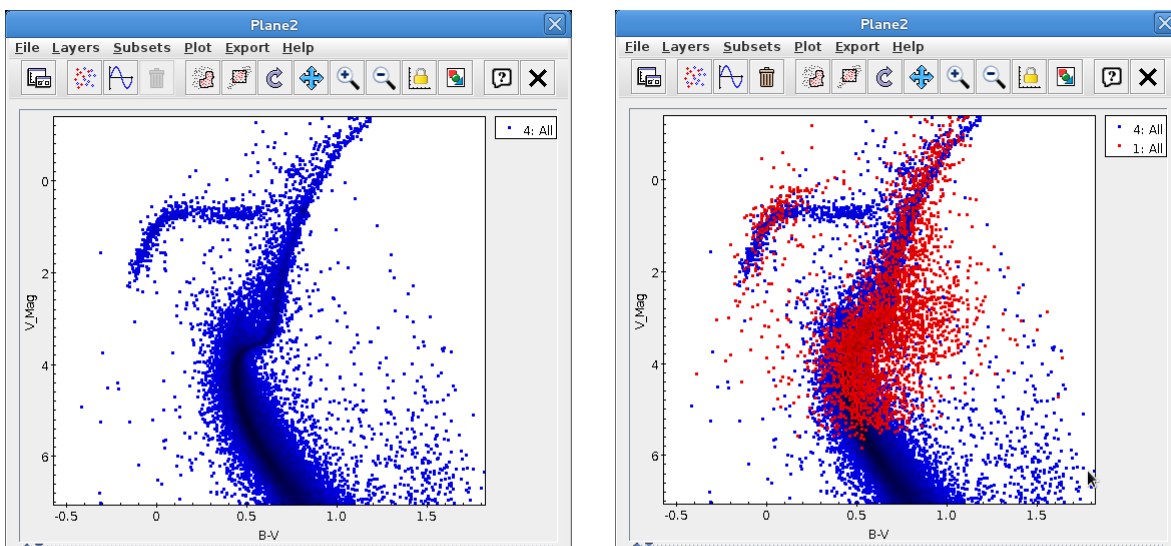
Came back to Aladin and repeat the same steps with the globular cluster M13. Useful data of M13: apparent diameter 23', distance 7695 pc, catalog "Colour magnitude diagram of M13". If missing, add the V\_Mag column to the M13 catalog.

Now plot on the same plane the HR diagram of both clusters and compare them. On the scatter plot window with the HR diagram of M5 click the icon  in order to add a new series of data.

Try to identify the turn-off point of the two clusters. The turn-off point is the most blue point of the main sequence.



In order to have a better visualization you can create a plot with density contours: *graphics -> plane layer plot*. Build the HR diagram of M5 (B-V and V\_Mag), then *layers -> add table layer* to overplot the HR diagram of M13.

Looking at the plot the turn-off points are about B-V=0.42, V\_Mag=4.20 for M5 and B-V=0.35, V\_Mag=4.00 for M13.



A more precise method to obtain the turn-off point of a cluster is to scan the cluster by slices of magnitude in order to compute the mean colour of the star population.

Looking at the HR diagram of M5 we note that the turn-off point is in the V\_Mag range 3.5 -> 4.75, so we work with 5 subsets 0.25 mag wide.

In Topcat select the table with data of M5 and then open the row subset window (  ). Create a new subset (  ) called *s1* with the expression "\$15>=3.5 && \$15<3.75", go on with *s2*, *s3*, *s4* and *s5*.

ID	Name	Size	Fraction	Expression
1	All	63012	100%	
7	s1	1633	3%	\$15>=3.5 && \$15<3.75
8	s2	1937	3%	\$15>=3.75 && \$15<4
9	s3	2277	4%	\$15>=4 && \$15<4.25
10	s4	2702	4%	\$15>=4.25 && \$15<4.5
11	s5	2922	5%	\$15>=4.5 && \$15<4.75

Now create a table with statistics for each subset, in particular *quartile* and *median* for both B-V and V\_Mag: in the main window of Topcat open the row statistics ( $\Sigma$ ), in the *display* menu select *quartile1* and *median*. You can deselect the other but keep at least *name*, *mean*, *median* and *quartile1*. Select the first subset and read the values.

Name	Mean	Quartile1	Median
RAJ2000			
DEJ2000			
Umag	18.7227	18.853	18.721
e_Umag	0.017164	0.0066	0.0139
Bmag	18.9186	18.852	18.913
e_Bmag	0.008592	0.0033	0.0051
Vmag	18.4425	18.381	18.442
e_Vmag	0.007406	0.0029	0.0046
Rmag	18.1169	18.105	18.166
e_Rmag	0.017164	0.0066	0.0139
Imag	17.7999	17.742	17.802
e_Imag	0.007897	0.0037	0.0053
B-V	0.44615	0.426999	0.441001
V_Mag	4.12586	4.06439	4.12539

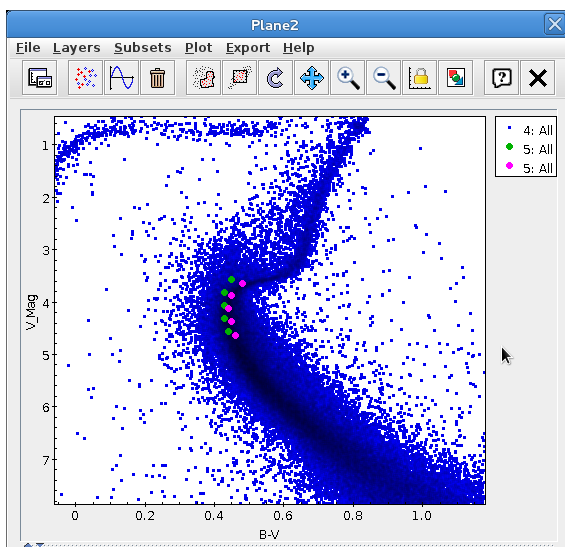
Subset for calculations: s3

Go on with the other subsets and write down the results in an ascii file as the following:

```
[Giulia@VAIO GlobCluster]$ more HR_M5_V.txt
# bin V_Mag_q V_Mag_m B-V_q B-V_m
3.50 3.57 3.64 0.45 0.48
3.75 3.81 3.88 0.43 0.45
4.00 4.06 4.12 0.43 0.44
4.25 4.31 4.38 0.43 0.45
4.50 4.56 4.63 0.44 0.46
```

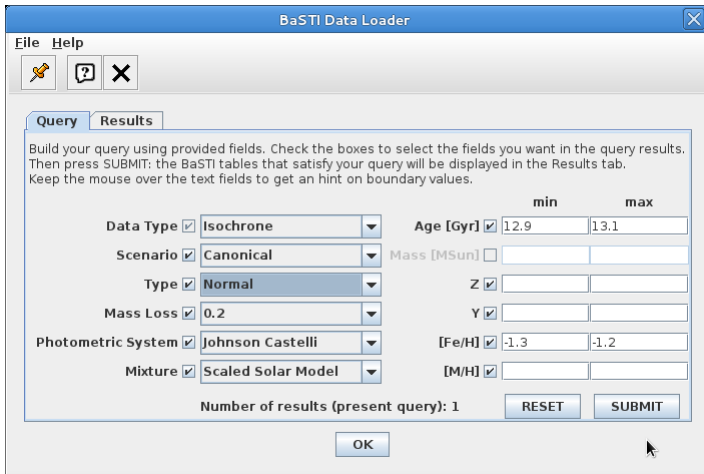
Save it on your pc and load it in Topcat as a new table (*file -> load table -> format "ascii"*).

Came back to the plot window of the M5 HR diagram and add two new planes. In the first one plot quartile of B-V (B-V\_q) versus quartile of V\_Mag (V\_Mag\_q), in the second one median of B-V (B-V\_m) versus median of V\_Mag (V\_Mag\_m).

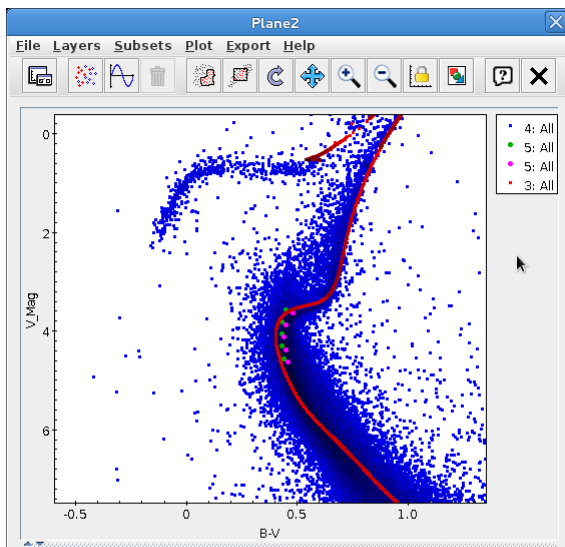


It is clear that the turn-off point belongs to the s3 subset, so we can take the mean values of B-V and B\_Mag of such subset. Read them in the row statistic window. The values of the turn-off point of the M5 cluster turn out to be B-V=0.45 and V\_Mag=4.12.

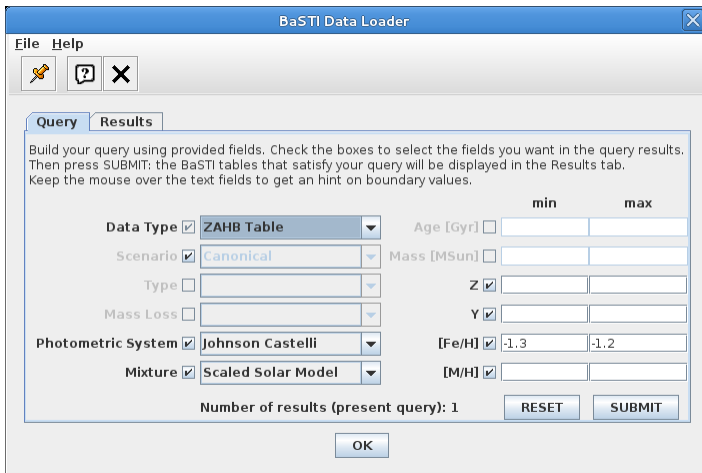
The estimated age of M5 is 13 Gyr. Check this value querying the VO for a theoretical isochrone, overplot it on the HR diagram and verify that it intersects the turn-off point. In Topcat open the BaSTI data loader window (VO -> *BaSTI data loader*) and set the following parameters (estimated metallicity of M5 is -1.29):



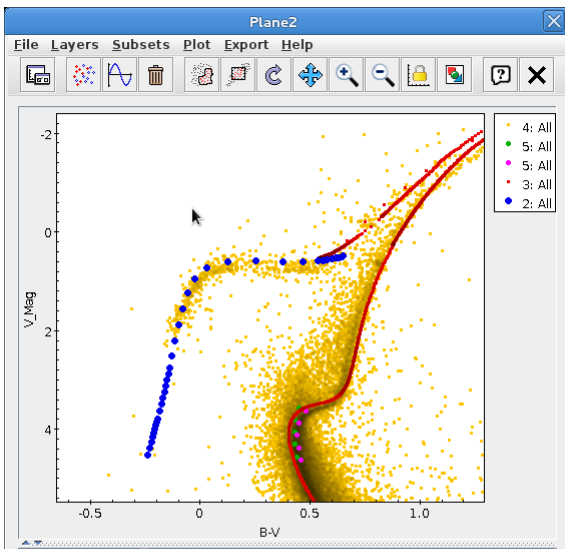
Submit the query, the result is one theoretical isochrone: select and load it. Overplot the isochrone on the M5 HR diagram.



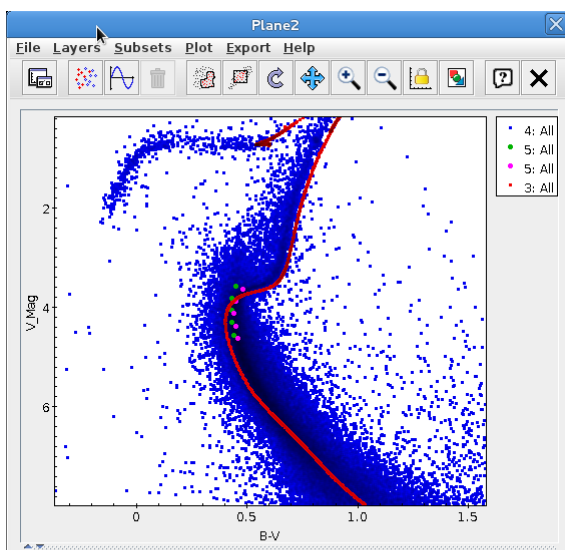
Last step, correct the isochrone for the vertical shift of the ZAHB of M5: open the Basti data loader and load a ZAHB table with M5 parameters.



Overplot the ZAHB table on the M5 HR diagram and estimate the vertical shift of the ZAHB (about 0.2 mag).



Add a new column in the isochrone table with corrected V\_Mag ( $V\_Mag\_ok = V\_Mag + 0.2$ ) and replot the isochrone using the new values for V\_Mag.



The isochrone with age = 13 Gy and  $[Fe/H] = -1.29$  fits the photometric data of M5, confirming the age of the cluster.

If you still have a small amount of time, do the same procedure with M13 (age = 11.65 Gyr,  $[Fe/H] = -1.33$ ) and compare the results, or try other theoretical curves for M5..