

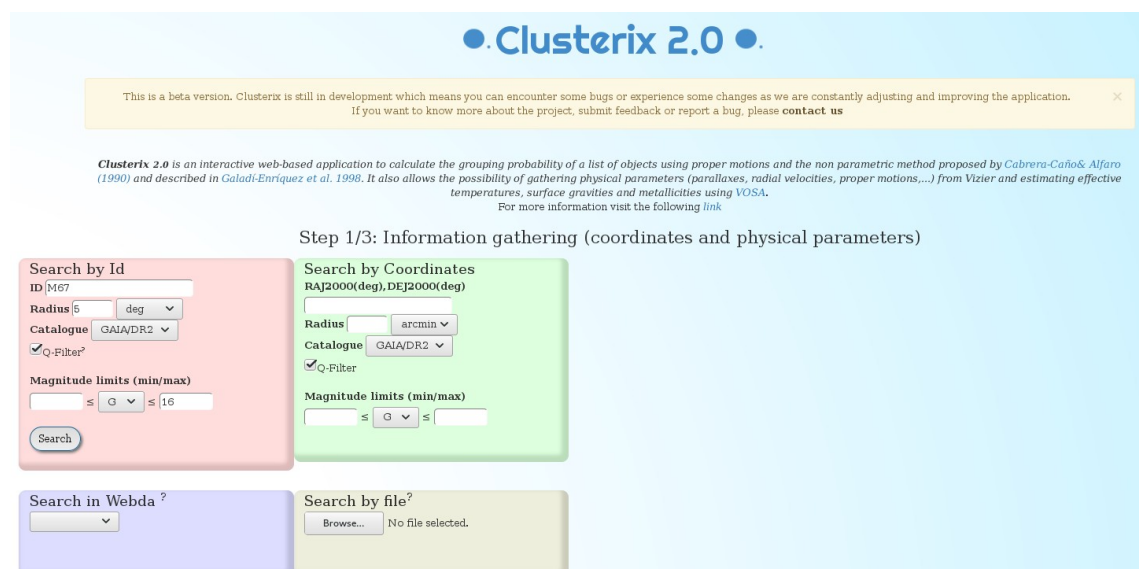
- **Title:** Identification and characterization of stellar cluster members using Clusterix and VOSA.
- **Author:** Enrique Solano. Spanish Virtual Observatory.
- **Last update:** 2020 Mar 1st.
- **VO-Tools:** Clusterix, TOPCAT, VOSA
- **Scientific background:** Open clusters (OCs) are coeval groups of stars formed from the same molecular cloud and, thus, having the same age and initial chemical composition. This makes them ideal targets to study the formation and evolution of stellar objects.

The determination of the mean properties of open clusters requires prior knowledge of their members to optimise the costly process of obtaining and reducing high resolution spectroscopic data on a large scale. Hence, a precise identification of the stars that compose a cluster is critical to accurately determine the kinematic and fundamental parameters of the clusters (age, total mass, etc.), which are essential for studies of Galactic dynamics.

In this tutorial we will work with M67, an old cluster (~ 3.6 Gyr) at about 900 pc with a near solar metallicity and low reddening. M67 is one of the best studied open clusters, considered a cornerstone of stellar astrophysics and used as a calibrator in many surveys. However there is no study covering a large area in spite of some studies on its corona showing that it is an extended cluster. Gaia Collaboration et al. (2018b) studied an area of 1 deg with $G < 20$ and found 1520 members.

Detailed information on Clusterix is given in Balaguer-Núñez et al. (2020MNRAS.492.5811B.)

- **Using Clusterix to estimate cluster membership probabilities.**
 - Go to Clusterix web server → <http://clusterix.cab.inta-csic.es/clusterix/>
 - Fill in the fields as shown in Figure 1. Click “Search”. **DO NOT forget to apply the filter in magnitudes ($G < 16$)!!**



Clusterix 2.0

This is a beta version. Clusterix is still in development which means you can encounter some bugs or experience some changes as we are constantly adjusting and improving the application. If you want to know more about the project, submit feedback or report a bug, please **contact us**

Clusterix 2.0 is an interactive web-based application to calculate the grouping probability of a list of objects using proper motions and the non parametric method proposed by Cabrera-Cañó & Alfaro (1990) and described in Galadí-Enríquez et al. 1998. It also allows the possibility of gathering physical parameters (parallaxes, radial velocities, proper motions,...) from Vizier and estimating effective temperatures, surface gravities and metallicities using VOSA. For more information visit the following link

Step 1/3: Information gathering (coordinates and physical parameters)

Search by Id

ID: M67

Radius: 5 deg

Catalogue: GAIA/DR2

☒ Q-Filter?

Magnitude limits (min/max): ≤ ≤ 16

Search by Coordinates

RAJ2000(deg), DEJ2000(deg)

Radius: arcmin

Catalogue: GAIA/DR2

☒ Q-Filter?

Magnitude limits (min/max): ≤ ≤

Search in Webda ?

Search by file?

No file selected.

Figure 1

- Step 1/3: Information gathering (coordinates and physical parameters)

Search by Id

ID

Radius

Catalogue

☒ Q-Filter?

Magnitude limits (min/max)

≤ ≤

Search by Coordinates

RAJ2000(deg),DEJ2000(deg)

Radius

Catalogue

☒ Q-Filter?

Magnitude limits (min/max)

≤ ≤

Search in Webda ?

Search by file?

No file selected.

J2000

A list of 49308 objects has been created

[Download](#) [Send to VO tools](#)

- Click on “Go to Step 2 / Membership from proper motions” to proceed to **Step2**.

- The second step is to select the *cluster+field* (c+f) and *only field* (f) regions. The definition of these areas is one of the most critical decisions to take by the user, and Clusterix offers several ways to interactively shape and reshape these areas. The simplest option relies on mouse clicks to draw circles that define the *c+f* and *f* regions. The system also includes an easy way to set up a “clean” area around the *c+f* region to avoid a region that could still have a significant number of cluster members.

Alternatively, the user can specify the circular areas directly writing their parameters (in decimal degrees) in the corresponding boxes (format: “ra,dec,radius,”). For this tutorial, fill in the fields with the values given in Figure 3.

Also, in this second step, the user can customize the following parameters:

- Proper motion limits. Maximum value of the total proper motion (to discard objects that clearly cannot belong to the expected cluster population), and maximum value of the total proper motion error (to remove data of dubious quality).
- Magnitude range to further limit the selection done in Step 1.
- Smoothing parameter. Clusterix 2.0 proposes a default value for the smoothing parameter *h*. It represents the radius of the kernel windows used to compute the frequency functions. A large value would blur out the details of the frequency functions, while a small value would yield noisy results. See Balaguer-Núñez’s paper for more information on the *h* parameter.
- Fine tuning values. To avoid meaningless probability values, Clusterix 2.0 restricts the probability calculations to stars with densities γ times above the noise.

Step 2/3: Region selection

Cluster info: M67_300_arcmin_GAIADR2

Selection of the "cluster+field" and "only field" regions

Area definition: ☒ Cluster+Field ☐ Void ☐ Field

Clear

Cluster+field: Cluster+field area
132.85,11.81,0.5; 0.7853981633974483
Void: Void area
132.85,11.81,2.9; 25.635396053292713
Only field: Field area
132.85,11.81,3.7; 16.587609210954113

Membership determination parameters

Proper motion limits (mas/yr)

Maximum μ : Maximum μ err:

15.0 10.0

Magnitude range \leq mag. \leq

Smooth param (mas/yr) (?):

0.8248967489643203

Fine tuning values

γ threshold (?): 15.0

Empirical frequency function min value \leftarrow

0

Probability min value

0

\leq pmRA \leq

\leq pmDEC \leq

Cluster size provided by

Simbad:

Majaxis=25.0 arcmin

Minaxis=25.0 arcmin

Matrix size ?

☒ Normal ☐ High precision

Total number of stars: 37248

Number of stars in the "cluster+field" region: 1070

Number of stars in the "field" region: 7676

Field sample size? 7676

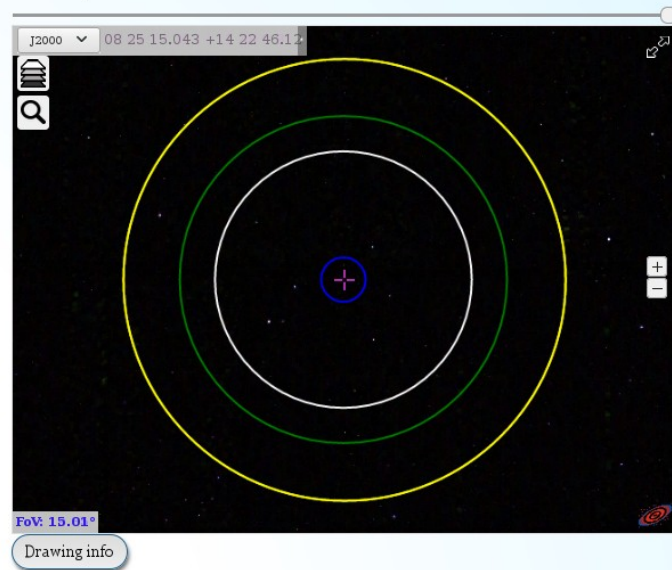


Figure 3.

- The frequency functions computed using the parameters given in Figure 3 are shown in Figure 4.

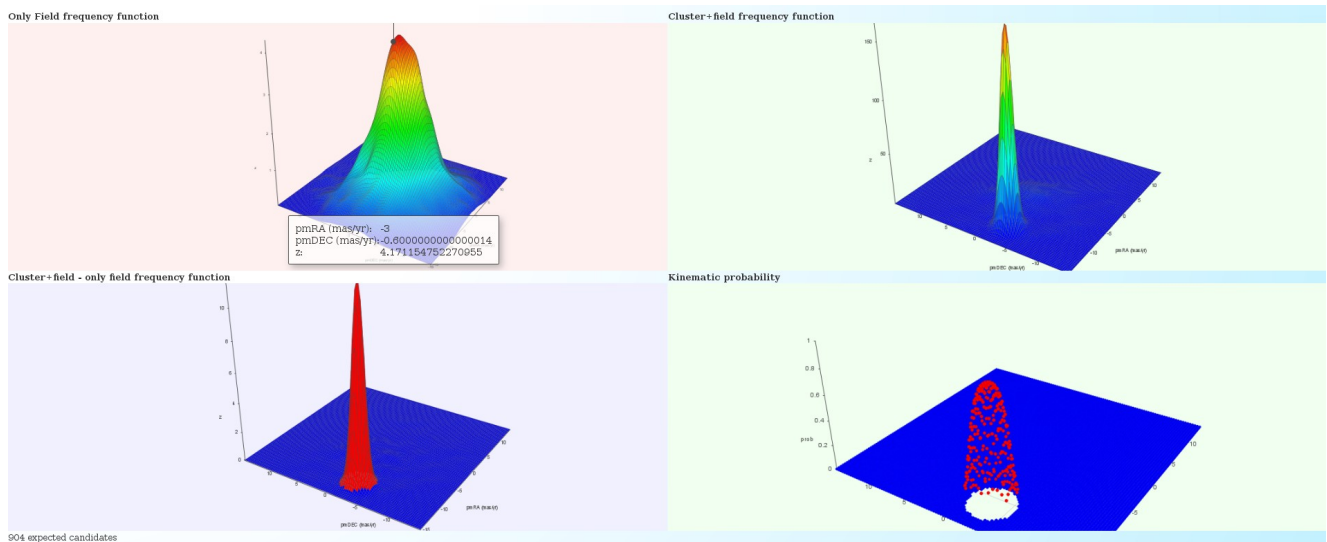


Figure 4

- Once the frequency functions have been computed you can go to **Step 3** by clicking “Go to Step 3”. Here you can find a summary of the main parameters used in the query as well as the list of cluster members. Those with the highest probabilities are ranked first. (Figure 5).

```
# Results were retrieved using Clusterix software
# http://clusterix.cab.inta-csic.es/
# In case of problems, please, report to: clusterix_archive_support@cab.inta-csic.es
#
# Labels:
#
# STAP_ID identifier of star retrieved from the input data
# RA right ascension of a star
# DEC declination of a star
# PM_RA proper motion in alpha
# PM_DEC proper motion in delta
# PROB probability that star belongs to evaluated open cluster
# FLAG N-Membership NM-No membership
#
# Parameters:
#
# CLUSTER INFO: M67_300_atcmain_GAIA2DR2
# PROPER MOTION CUTOFF: 15.00 mas/yr
# PROPER MOTION EXP CUTOFF: 10.00 mas/yr
# SMOOTH PARAMETER: 0.02
# GAMMA FACTOR: 15.00
# QUERY MIN MAG (STEP 1):
# QUERY MAX MAG (STEP 1): 16
# FILTERED MIN MAG (STEP 2):
# FILTERED MAX MAG (STEP 2):
#
# Boundaries can be circles (Ra(J2000)-center,Dec(J2000)-center, radius degrees) or
# polygons (Ra,Dec Ra,Dec Ra,Dec ...). Each boundary is separated by ;
#
# CLUSTER BOUNDARIES:
# 132.85,11.81,0.5;
#
# FIELD BOUNDARIES:
# 132.85,11.81,3.7;
#
# VOID BOUNDARIES:
# 132.85,11.81,2.5;
#
# NUM STARS: 49304
#
# EXPECTED NUMBER OF MEMBERS: 504
#
# For Webda clusters, STAP_ID is the merge of the Data source reference and the star number: Ref_Star
#
# Region values: F = star was inside a "only field" region
#                C = star was inside a "cluster+field" region
#                V = star was outside the selected regions
#
# Highest probability results sample (only 50 first shown).
```

##STAR_NO	RAJ2000	DECJ2000	pmRA	epmRA	pmDEC	epmDEC	P11	eP11	BP	eBP	PP	ePP	G	eG	PV	ePV	PROB	Region
31720	132.970320	11.735483	-11.156	0.074	-3.005	0.049	1.1198	0.0434	15.9063	0.0028	14.8353	0.0014	15.4447	3.0E-4	NaN	NaN	0.9134696	V

Figure 5.

- At the top left of this page there is a button “**Send to VO tools**”. Click here to send the table with the membership probabilities to TOPCAT (NOTE: TOPCAT must be previously open. SAMP broadcasting requires user authorization. A new window (“SAMP Hub Security”) may pop up asking for authorization. If so, click “Yes”). After this, a new table with 49 304 rows will be created.

• Using TOPCAT to visualize the results

- Once the table has been uploaded, we can visualize the results in TOPCAT by doing this:
 - In the TOPCAT main window → *Graphics / Plane Plot*. A new window “*Plane Plot*” will pop up.
 - Select the columns to be plotted (X: RA_PM; Y: DEC_PM). Use the mouse to center / zoom in / zoom out the graphic. You will clearly see the M67 overdensity in the proper motion parameter space (Figure 6).

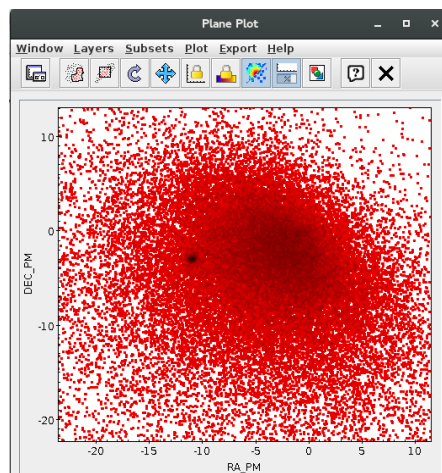


Figure 6.

- Let's now select the M67 members according the probabilities calculated by Clusterix.
 - In the TOPCAT main window → *Views / Row Subsets*. A new window “*Row Subsets*” appears.
 - In the Row Subsets window → *Subsets / New subset*. A new window “*Define Row Subset*” pops up.
 - In the Define Row Subset window → *Subset name: filt; Expression: prob>0.8*. Click “OK”. (Figure 7). 1080 sources will be selected.

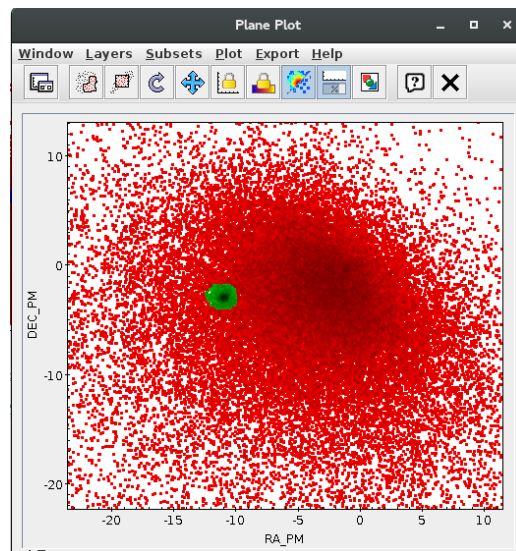


Figure 7

- Alternatively, you can build an histogram with the probability values (TOPCAT main window → *Graphics / Histogram Plot*. A new window “*Histogram Plot*” appears → Select the column to be plotted (X: Prob) and use it to define your probability cut (Figure 8).

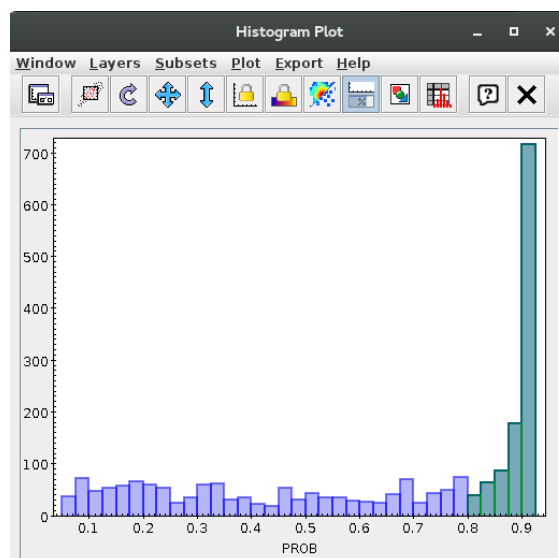


Figure 8

- Let's build now a colour-magnitude diagram with all the sources in the selected field.

- In the TOPCAT main window → *Graphics / Plane Plot*. A new window “*Plane Plot*” will pop up.
- Select the columns to be plotted (X: BP-RP; Y: Gmag).
- Click Axes → Tick “Y Flip”. (Figure 9). If the selected objects (in blue) do not appear, click on *Subset tab* (it is between “Position” and “Form”, see Figure 9) and tick “*filt*”.

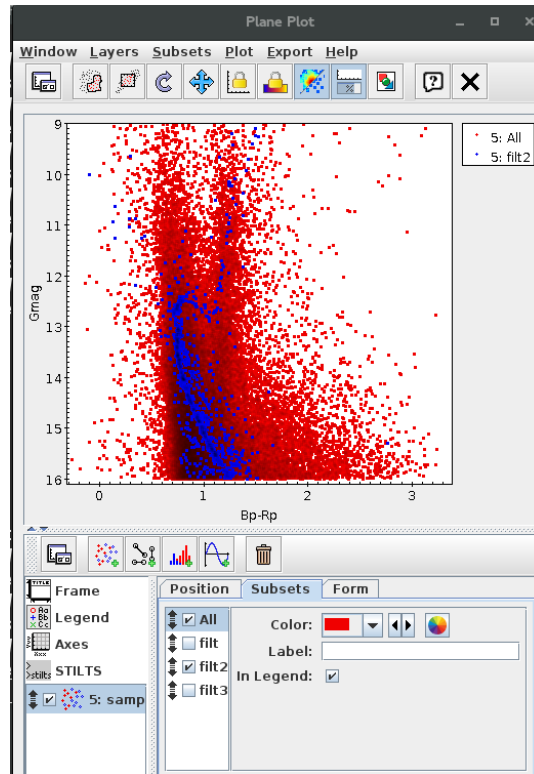


Figure 9.

- The membership selection made by Clusterix is based on proper motions only. Additionally, you can use the information on parallaxes to refine the selection.
- In the TOPCAT main window → *Graphics / Histogram Plot* (X: PLL). In the “Histogram Plot” window, tag “Subset”, deselect “All” and tick “*filt*” (Figure 10).
- Click “Axes” → “Range” → Minimum X: 0.0 / Maximum X: 2.0 to get a zoomed view of the histogram shown in Figure 10.

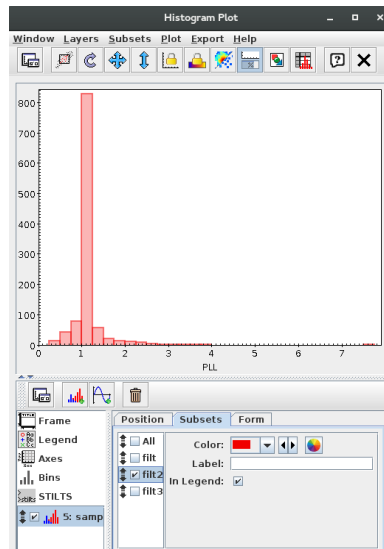


Figure 10

- To perform a sigma clipping in the filtered data (blue subset) we can do the following.
 - In the TOPCAT main window, hit Σ
 - In the “Row Statistics” window → Subset for calculations: **filt**. The value for the mean value and standard deviation for the parallax should be something like 1.16 and 0.36, respectively
 - In the TOPCAT main window → View / Row Subsets. A new window “Row Subsets” appears.
 - In the Row Subsets window → Subsets / New subset. A new window “Define Row Subset” pops up.
 - In the Define Row Subset window → Subset name: *filt2*;
Expression: $\text{filt} \& \& \text{p}ll > 1.16 - 0.36 \& \& \text{p}ll < 1.16 + 0.36$ Click “OK”. 952 sources will be selected. The cluster sequence is now refined in the colour-magnitude diagram (Figure 11).

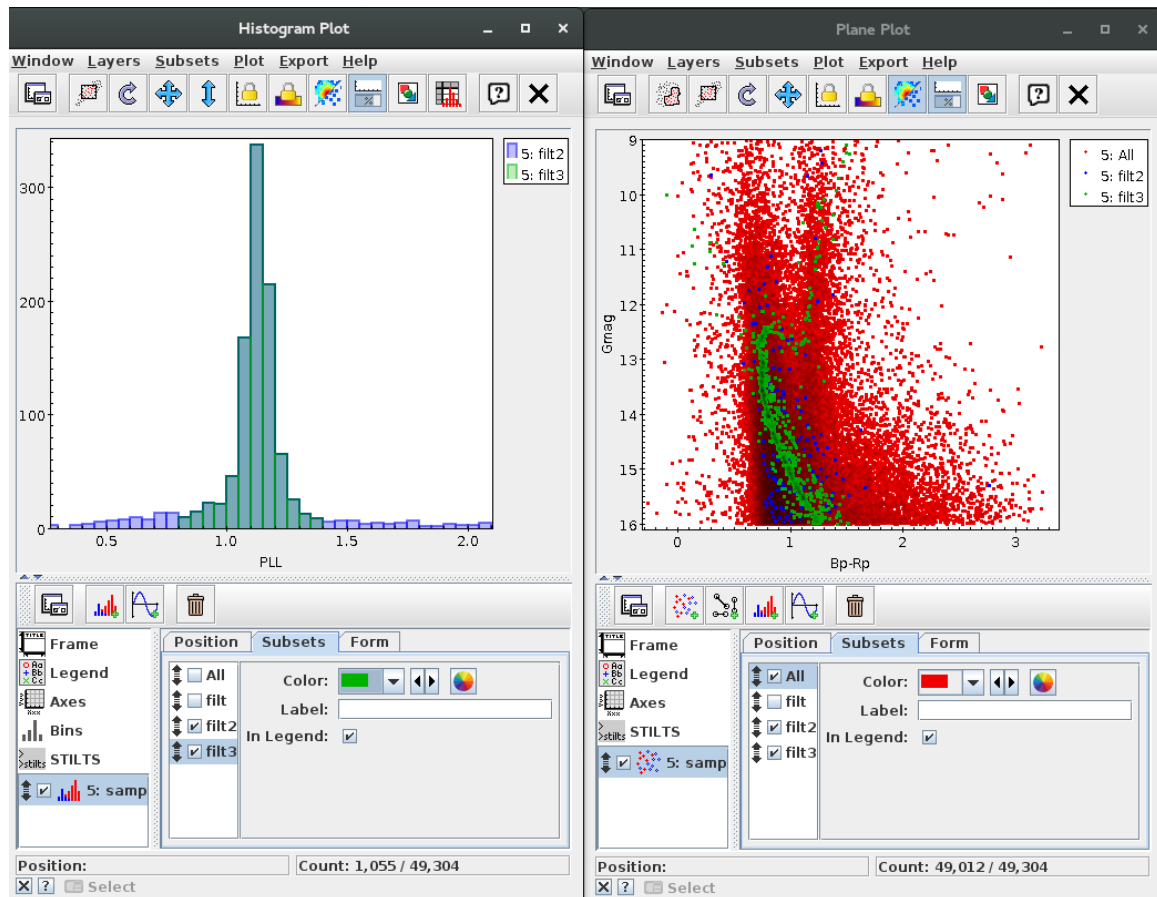




Figure 11

Now we have identified the cluster members, we can do useful thing with them.

- **Distance to the cluster**

- Distances in parsecs are the reciprocal of parallaxes in arcsec. However, inverting parallaxes to get distances is problematic if parallax errors are large, say $> 20\%$
- To select sources with parallax error $< 20\%$
 - In the TOPCAT main window → *View / Row Subsets*. A new window “Row Subsets” appears.
 - In the Row Subsets window → *Subsets / New subset*. A new window “Define Row Subset” pops up.
 - In the Define Row Subset window → *Subset name: filt3*;
Expression: filt2 & &epll/pll < 0.2 Click “OK”. 952 sources will be selected (in this case, all sources selected in the previous step have relative errors in parallax $< 20\%$).
 - Create a new column with the distances derived from parallaxes.
 - In the TOPCAT main window → **Views / Column Info**. A new window “Table Columns” appears
 - In the Table Columns window → **Columns / New Synthetic column**. A new window “Define Synthetic Column” appear.
 - **Name:** *distance*
 - **Expression:** $1000/pll$
 - **Units:** *pc*
 -  Using the Statistics button, will get a mean value for the distance (Subset for calculations: filt3) of 892 pc, quite close to that given in the Introduction (900 pc).

- **Visualizing proper motions**

- Let's visualise proper motions of the *filt3* subset (Figure 12).
 - In the TOPCAT main window: **Graphics / Sky Plot**. A new window “*Sky plot*” will appear.
 - In the “Sky Plot” window, → Form → Hit 
 - “Add sky vector”
 - **Delta Longitude: RA_PM**
 - **Delta Latitude: DEC_PM**

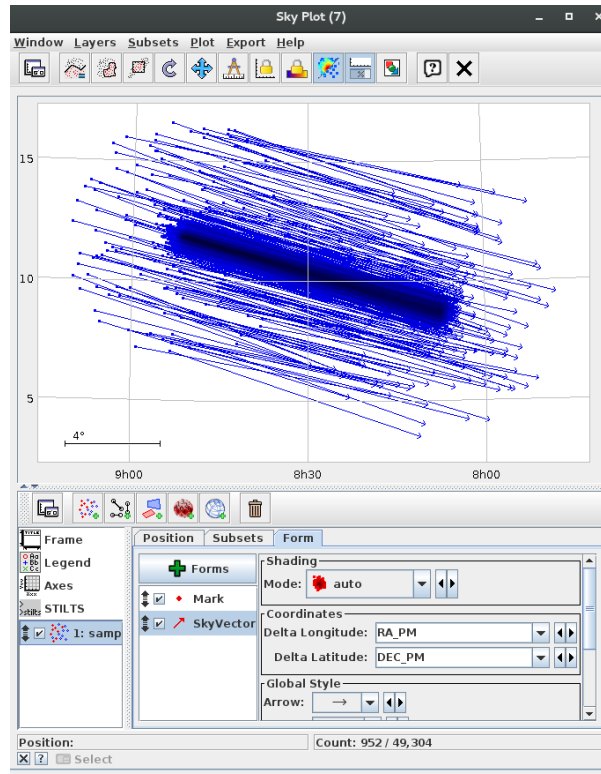


Figure 12

- **Visualizing the cluster members on the sky**

- Open Aladin (java -jar Aladin.jar)
- In Aladin, write *M67* in the **Command** box. A M67 DSS coloured image will be loaded.
- In the TOPCAT main window
 - Row subset: **filt3**
 - Interop / Send table to... Aladin → a new plane in Aladin with the 952 sources will appear.
 - We can see how, thanks to the excellent quality of Gaia DR2 data and VO tools, we have been able to identify cluster members really far away from the cluster center. (Figure 13)

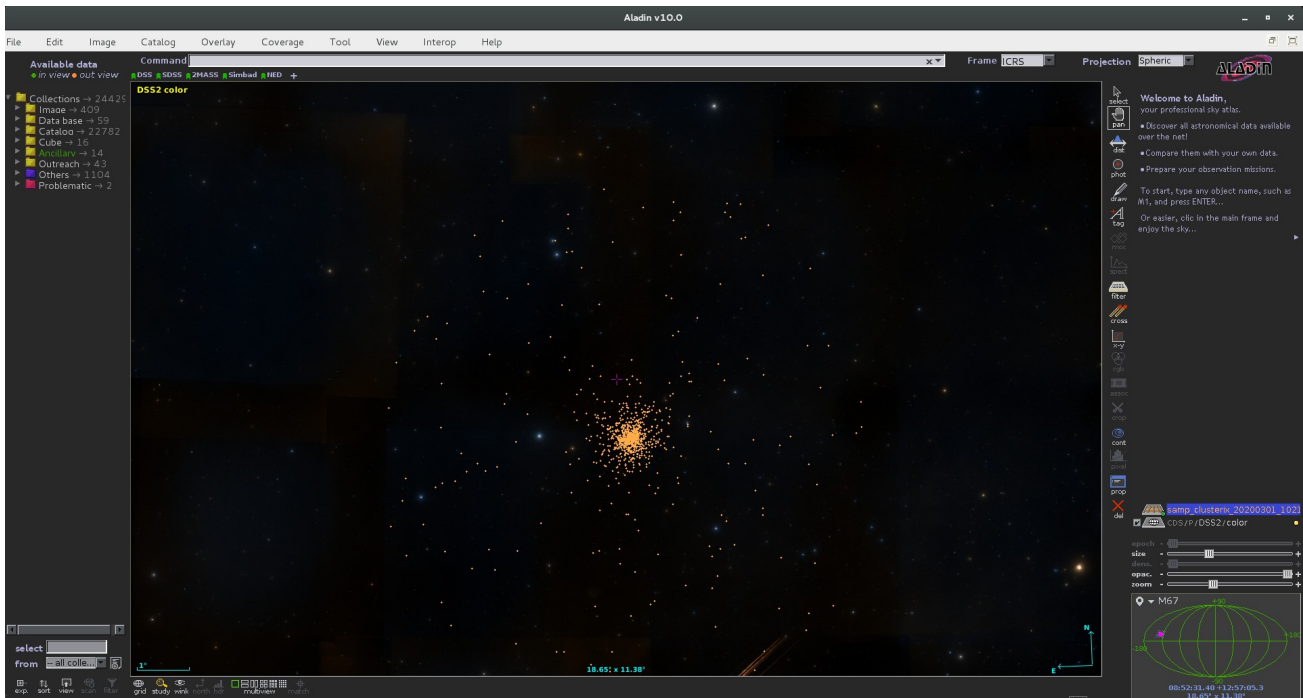


Figure 13

▪ Estimating physical parameters

- The next step is to use VOSA to estimate effective temperatures, luminosities and radii for a subset of these objects.
- Step 1.- Go to <http://svo2.cab.inta-csic.es/theory/vosa/>
- Step 2.- To use VOSA you need to be registered. Click on “Register” and fill in the fields (email, name and passwd).

◦ Tag "Files"

- Step 3.- Upload the `vosa_granada2020.txt` file (available from the web page of the school) in VOSA (“File to upload”). This file is a subset (2 objects, 3 columns – Id, RA, Dec –) of the list of objects obtained in Clusterix Step 3. We will work with this subset in order to speed up the workflow.

Give a description (free text). And then, click “Upload” (do not bother about the File type). The message *“your- file-name has been succesfully uploaded!”* will appear. Click “Continue”. If the message does not appear, go to “your files” section and click “Select”.

◦ Tag "Objects"

- Step 4.- Place the cursor on the “Objects” tag and then click “Distances”. Click “Search for Obj. Distances”. To make the Gaia DR2 distances the “final” distances, do the following: Go to the “Actions for all the objects in the file” panel, tick “Select values by ranking” and choose Gaia2 in the first place. Click “Make all changes”. The Gaia DR2 coordinates will appear in bold in the “Final” column. (Figure 14)

Object distance

This panel allows you to query VO services to search for object distances using the object coordinates.
Take a look to the corresponding [Help Section](#) and [Credits Page](#) for more information.

You have already searched the VO for distances.
If you want to do it again, please

[Delete VO data](#)

[Actions for all the objects in the file](#)

Here you can set the "Final" value of the distance for all the objects at the same time. Depending on the choices that you make, the changes will be done for all the objects in the file when you click the "Make all changes" button.

What values do you trust better?

☐ Select first user value if available. And then, if not, always the VO value with the smallest uncertainty (smaller value for $\Delta Dis/Dis$).

☐ Select always the value with the smallest uncertainty (smaller value for $\Delta Dis/Dis$. If there is no value for ΔDis , we consider it the largest uncertainty).

☒ Select values by ranking:
1: 2:

(Your first option will be chosen for every object if there is a value available. For those objects with no value in the first option, the second option will be chosen. And so on)

Apply changes depending on the uncertainty?

☒ Always

☐ Only when $\Delta Dis/Dis <$

[Make all changes](#)

Object			Final		User		GAIA DR2							
Name	RA (deg)	DEC (deg)	Dis (pc)	ΔDis (pc)	D (pc)	ΔDis (pc)	Δ (arcsec)	RA (deg)	DEC (deg)	Plx (mas)	ΔPlx (mas)	D (pc)	ΔDis (pc)	
17248	131.872333	11.478723	868.712	24.966	<input type="text" value=""/>	<input type="text" value=""/>	0	131.87233325946556	11.478722560417966	1.1511289741265665	0.033081948480270955	868.712	24.966	
32620	132.878097	12.071121	883.845	27.567	<input type="text" value=""/>	<input type="text" value=""/>	0	132.87809661419797	12.07112097508497	1.1314197092334708	0.03528833050081989	883.845	27.567	

[Save Obj. Distances](#)

(Clicking this button you will save the options that you have selected individually in this form.)

Figure 14.

○ Tag “Build SEDs”

- Step 5.- Place the cursor on the “*Build SEDs*” tag and then click “*VO photometry*”. Here we will be able to look for photometric information of our objects in different VO catalogues. In order not to slow down too much the tutorial, click “*unmark All*” and select only 2MASS, WISE and APASS9. Then, click “*Query selected services*” at the bottom of the page. Once this is done, a summary table with the VO photometry (in flux units) will appear (Figure 15).

VO theoretical services VOSA Filter's Models Documents Other Services My data Newsletter Uploads LogOut

This is VOSA 6.0

This project has received funding from the European Union's Seventh Framework Programme (FP7-SPACE-2013-1) for research, technological development and demonstration under grant agreement no. 606740

Files Objects Build SEDs Analyse SEDs HR Diag. Results Help

Stars and brown dwarfs (Change) File: vosa_granada2020.txt (info) (Change)

VO Photometry SED edit/visualize

VO photometry

[Delete this VO photometry](#)

(Flux densities are given in erg/cm²/s/Å)

Object	Misc/APASS.B	SLOAN/SDSS.g	Misc/APASS.V	SLOAN/SDSS.r	SLOAN/SDSS.i	2MASS/2MASS.J	2MASS/2MASS.H	2MASS/2MASS.Ks	WISE/WISE.W1	WISE/WISE.W2
17248	4.45e-15 ± 1.56e-16	4.95e-15 ± 5.25e-16	4.89e-15 ± 2.75e-16	4.42e-15 ± 2.68e-16	3.59e-15 ± 1.36e-16	1.36e-15 ± 3.27e-17	6.50e-16 ± 1.86e-17	2.71e-16 ± 8.00e-18	5.28e-17 ± 1.17e-18	1.49e-17 ± 3.83e-19
32620	4.17e-15 ± 5.92e-16	4.74e-15 ± 6.07e-16	4.69e-15 ± 6.99e-16	4.32e-15 ± 3.94e-16	3.44e-15 ± 2.50e-16	1.34e-15 ± 2.83e-17	6.44e-16 ± 1.30e-17	2.59e-16 ± 5.73e-18	5.03e-17 ± 1.11e-18	1.47e-17 ± 3.92e-19

Figure15

- Step 6.- Place the cursor on the “*Build SEDs*” tag and then click “*SED edit/visualize*”. This tag gives us the possibility of visualising/modifying the SED before the model fitting. VOSA gathers from VO services not only the photometric information but also different metadata of interest (Object name, observing date and information on quality). In particular, VOSA uses the information on quality to automatically identify bad photometric points and remove them from the fitting. Upper limits are treated in a similar way (see, for instance, WISE W3 and W4 for object “17248”). The user can manually override this selection of photometric points by ticking/unticking the appropriate boxes. (Figure 16)

For this use case, do not make any change in the SED edit/visualize section.

Filter	A _{med}	Observed		Dereddened		Point Opts				Actions		Info								
		Obs.Flux	ΔObs.Flux	Flux	ΔFlux	In SED	NoFit	Uplim	Bad	Ignore	Delete	Source	RA (VO)	DEC (VO)	Δ (VO)	Nobjs	Obj.Name (VO)	Obs.Date (VO)	Obs.Qua (VO)	
Misc/APASS.B	4297.17	5.877e-15	4.871e-16	5.877e-15	4.871e-16	✓						APASS	132.02719400	+10.57132000	1.9140095867531	3.753524523726	2	---	---	---
SLOAN/SDSS.g	4640.42	6.701e-15	3.394e-16	6.701e-15	3.394e-16	✓						APASS	132.02719400	+10.57132000	1.9140095867531	3.753524523726	2	---	---	---
Misc/APASS.V	5394.29	6.640e-15	5.198e-16	6.640e-15	5.198e-16	✓						APASS	132.02719400	+10.57132000	1.9140095867531	3.753524523726	2	---	---	---
SLOAN/SDSS.r	6122.33	6.714e-15	2.536e-16	6.714e-15	2.536e-16	✓						APASS	132.02719400	+10.57132000	1.9140095867531	3.753524523726	2	---	---	---
SLOAN/SDSS.i	7439.49	6.845e-15	1.072e-16	6.845e-15	1.072e-16	✓						APASS	132.02719400	+10.57132000	1.9140095867531	3.753524523726	2	---	---	---
2MASS/2MASS.J	12350.00	1.402e-15	3.356e-17	1.402e-15	3.356e-17	✓						2MASS	132.02762200	+10.57095100	0.11103259799037	0	1	08480662+1034154	2000-02-11	[A]
2MASS/2MASS.H	16620.00	6.928e-16	1.978e-17	6.928e-16	1.978e-17	✓						2MASS	132.02762200	+10.57095100	0.11103259799037	0	1	08480662+1034154	2000-02-11	[A]
2MASS/2MASS.Ks	21590.00	2.783e-16	8.972e-18	2.783e-16	8.972e-18	✓						2MASS	132.02762200	+10.57095100	0.11103259799037	0	1	08480662+1034154	2000-02-11	[A]
WISE/WISE.W1	33526.00	5.601e-17	1.909e-18	5.601e-17	1.909e-18	✓						WISE	132.027627700	+10.571031900	0.28801641112594	0	1	---	---	---
WISE/WISE.W2	46028.00	1.551e-17	5.713e-19	1.551e-17	5.713e-19	✓						WISE	132.027627700	+10.571031900	0.28801641112594	0	1	---	---	---
WISE/WISE.W3	115608.00	7.351e-19	0.000e+00	7.351e-19	0.000e+00	✓		✓				WISE	132.027627700	+10.571031900	0.28801641112594	0	1	---	---	---
WISE/WISE.W4	220883.00	1.738e-18	0.000e+00	1.738e-18	0.000e+00	✓		✓				WISE	132.027627700	+10.571031900	0.28801641112594	0	1	---	---	---
Apply changes																				

(Add a new point)

Excess

No infrared excess detected.

You can manually specify where excess applies (please remember to click the 'Change excess' button to apply these changes).

Apply infrared excess from
 Apply UV/blue excess up to Angstroms.

Help

Be careful. If you mark any 'Delete' checkbox and click the 'Apply Changes' button, that point will be deleted without asking for confirmation).

Take into account that:

- Every point marked as 'Ignore' will not be considered for anything. It is as if these points were deleted (but they aren't).
- Every point marked as 'NoFit' will not be used for the fit.
- Every point marked as 'Bad' or 'Uplim' will be automatically marked as 'NoFit' and thus not used for the fit.
- If there exist two or more photometric values corresponding to the same filter (not marked as 'Ignore'), VOSA will calculate an average of the values and this will be the one included in the final SED.

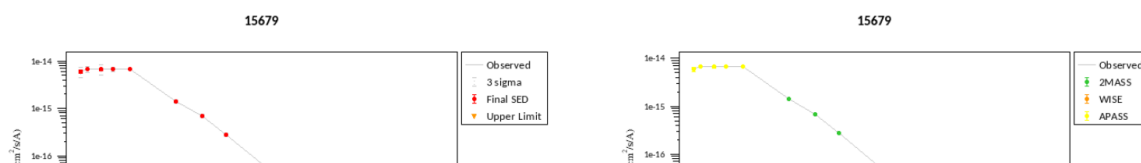


Figure 16

Tag “Analyse SEDs”

- Step 7: Place the cursor on the “Analyse SEDs” tag and then click “Chi-square fit”. Different grids of theoretical models covering different ranges of physical parameters are displayed. For this tutorial select only the “Kurucz ODFNEW /NOVER models”. Click “Next: Select mode params”. (Figure 17).

VO SED Analyzer
This is VOSA 6.0
This project has received funding from the European Union's Seventh Framework Programme (FP7-SPACE-2013-1) for research, technological development and demonstration under grant agreement no. 606740

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Stars and brown dwarfs (Change)
File: vosa_nice.txt (info) (Change)

Chi-square Fit
Template fit
Model Bayes Analysis
Template Bayes Analysis

Model fit

This option allows you to estimate some physical properties (such as effective temperature, surface gravity and luminosity) for each object comparing its SED with those derived from theoretical spectra obtained from VO services.
Take a look to the corresponding Help Section and Credits Page for more information.

First select the models that you want to use for the fit

Mark All
Unmark All
Next: Select model params

☐ AMES-Dusty 2000
The AMES-Dusty Model grid of theoretical spectra. Brown dwarfs/extrasolar planets atmosphere models without irradiation but including dust opacity (fully efficient dust settling). Wavelengths have been converted to air wavelengths.
More info

☐ AMES-Cond 2000
The AMES-Cond Model grid of theoretical spectra. Brown dwarfs/extrasolar planets atmosphere models without irradiation and no dust opacity (no dust settling). Wavelengths have been converted to air wavelengths.
More info

☐ Kurucz ODFNEW /NOVER models
ATLAS9 Kurucz ODFNEW /NOVER models. Newly computed ODFs with better opacities and better abundances have been used.
More info

☐ Husfeld et al models for non-LTE Helium-rich stars
Husfeld et al models for non-LTE Helium-rich stars
More info

☐ BT-Settl-CIFIST
The BT-Settl Model grid of theoretical spectra. With a cloud model, valid across the entire parameter range and using the Caffau et al. (2011) solar abundances. Wavelengths have been converted to air wavelengths.
More info

☐ BT-Settl
The BT-Settl Model grid of theoretical spectra; With a cloud model, valid across the entire parameter range. Wavelengths have been converted to air wavelengths.
More info

Figure 17

- Step 8.- In this window, we can limit the range of physical parameters that will be used for the fit. To save time we will make the following assumptions:
 - Teff: 4000-8000K
 - logg: 4.0-5.0 dex.
 - [M/H]=0.0
 Then, click “*Make the fit*”
- Step 9.- We will see now a summary table with the best fit results. Click on “Show graphs” to have a look at the graphics. If needed, the table can be sent to TOPCAT using the “Send Table to SAMP hub” button. (Figure 18).

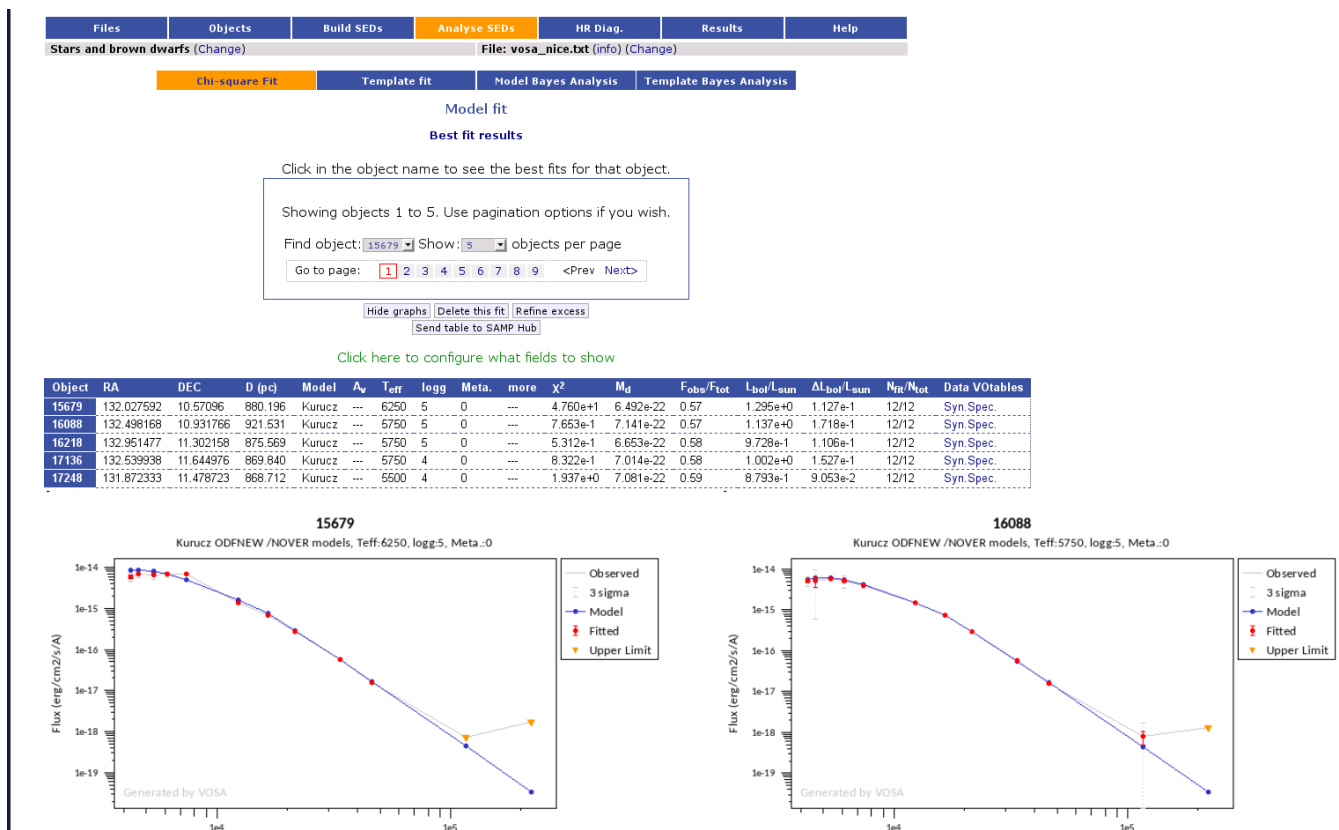


Figure 18

To get information on the radii derived from VOSA, click “*Click here to configure what fields to show*” and tick R1 and R2. Click “*Save config.*” Radii obtained using two different approaches will now appear in the summary table. More information on how VOSA calculates radii can be found at: <http://svo2.cab.inta-csic.es/theory/vosa/helpw4.php?type=star&action=help&what=fit#fit:radius>

Tag “HR diagram”

- Step 10.- Let's estimate now masses and ages from isochrones and evolutionary tracks. Click on “**HR diagram**”. The Siess collection of isochrones and evolutionary tracks will be shown. Select ages between 1-6 Gyr and masses between 0.5-2 solar masses. Click **Make the HR diagram**. A table including the luminosities, masses and ages, as well as the HR diagram will be shown. Click on **Data range** below the HR diagram for a more clear view of the objects (Figure 19). The calculated ages are in agreement with the value given in the Introduction (3.6 Gyr).

Tag “Results”

- Step 11.- Place the cursor on the **Results** tag and then click **Activity Log**. You will find here a summary of all steps executed to carry out the workflow.
- Step 12.- Place the cursor on the **Results** tag and then click **Download Results**. You can save different type of results (plots, VO photometry, HR diagram,...) in different formats.
- Step 13.- Place the cursor on the **Results** tag and click **Download Results**. Click **Retrieve** (do not tick anything). A new window with the message “Tar file successfully created” will appear. By clicking **Download your results** in the tar file (folder info), among other files, you will get a couple of files (refs.dat, refs.bibtex.bib) including the bibliographic references of all the resources you have made use of.

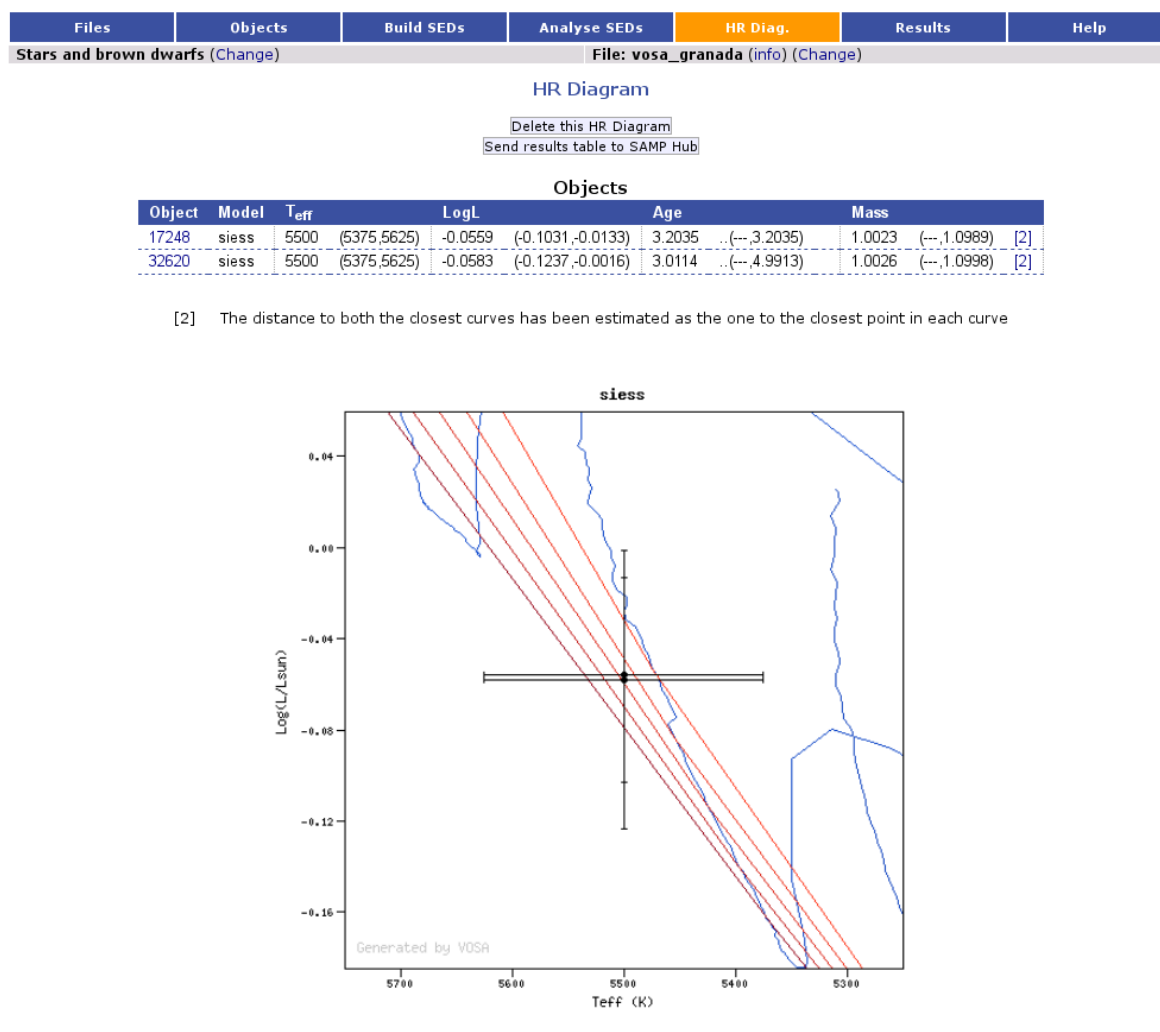


Figure 19