
# ASTERICS - H2020 - 653477

# Abell 1656: the Coma Cluster of Galaxies

Massimo Ramella & Giulia Lafrate
*INAF - Osservatorio Astronomico di Trieste*

Caroline Bot & Thomas Boch
*updated for the doctoral day in Paris*

Jenny G. Sorce
*updated with the new template for ASTERICS & new plots*

01.31.2017

# Contents

# 1 Introduction

Goal:

- Examine the Coma cluster of galaxies (Abell 1656) using VO data and tools in order to perform a quick evaluation of the mean redshift and velocity dispersion of the cluster.
- Use redshifts and photometry (Petrosian r magnitude) of the SDSS survey and then add redshifts of the CAIRNS survey (Rines et al. 2003) in order to improve the completeness of the redshift sample.
- Look for hydrogen lines in HST spectra in the direction of this cluster and check whether the lines are consistent with foreground or with galaxy velocities.

Softwares needed for this tutorial are Aladin, TOPCAT and CASSIS.

# 2 Display the region of Abell 1656 in Aladin

- In Aladin, enter 'A1656' (Coma Cluster) in the **Location** slot of the main window.
- Zoom/unzoom to work with galaxies in a region with radius about 40' around the Coma cluster. At the distance of Coma, 40' corresponds to 1.1 Mpc (with $H_0$=71 $\mathrm{km\ s^{-1}\ Mpc^{-1}}$, $\Omega_\Lambda$=0.73 and $\Omega_m$=0.27), a region large enough for our purposes. Tip: in order to check the radius of the region being displayed, the small white box in the bottom left corner of Aladin gives you its area. As a second option draw a 40' long arrow with the **dist** button 

.

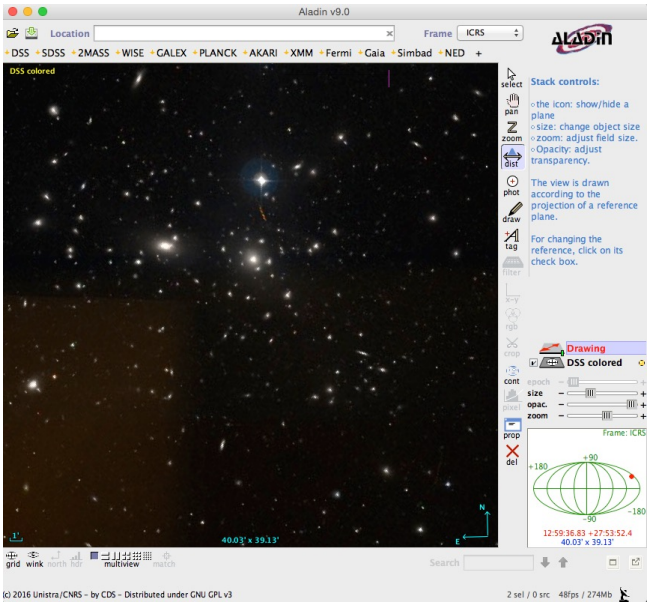



Figure 1: Abell 1656 (Coma Cluster) in Aladin

# 3 Load the SDSS-DR9 catalog and select galaxies

- Load the SDSS-DR9 catalog from the **Surveys** tab in the SERVER SELECTOR window, radius 40', tick the box **All columns**.

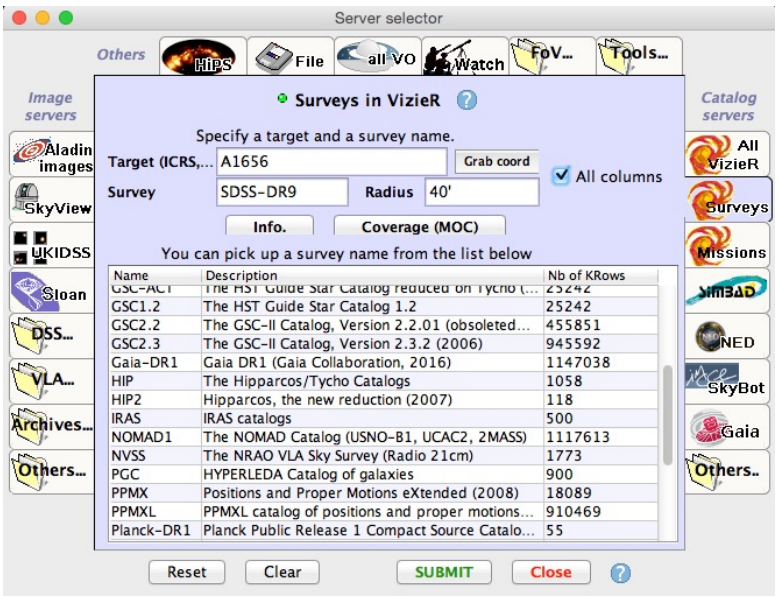



Figure 2: Load SDSS-DR9 from the SERVER SELECTOR.

- Filter SDSS and leave only galaxies (cl=3) that are also SDSS primary sources (mode=1):

  - In the main Aladin window, select the catalog plane, click on the **Filter** button  and write the following syntax in the **Advanced mode** tab: ‘ ${cl}=3&&${mode}=1{draw} ’
  - In the filter window, click on **Apply** and then **Export** to build a new plane with only filtered sources.

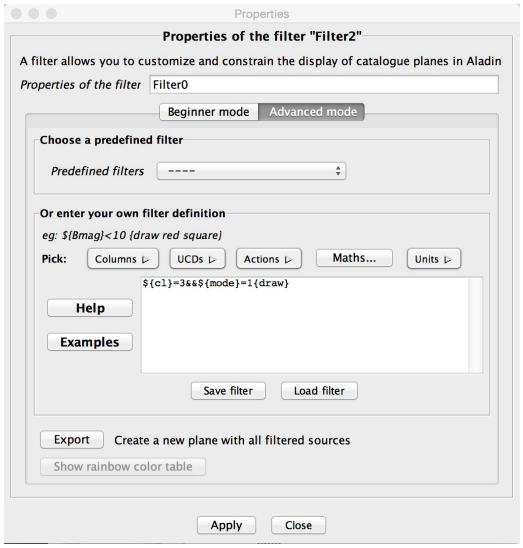



Figure 3: Filtering with Aladin

- Rename this new plane SDSSgalaxies using the **Properties** button  . The new filtered catalog should have 23771 sources  .

- Broadcast the filtered catalog to TOPCAT. You can do so by right-clicking on the catalog plane and selecting **Broadcast select table to...**> **topcat**. Beware that TOPCAT must be launched for this function to be enabled.

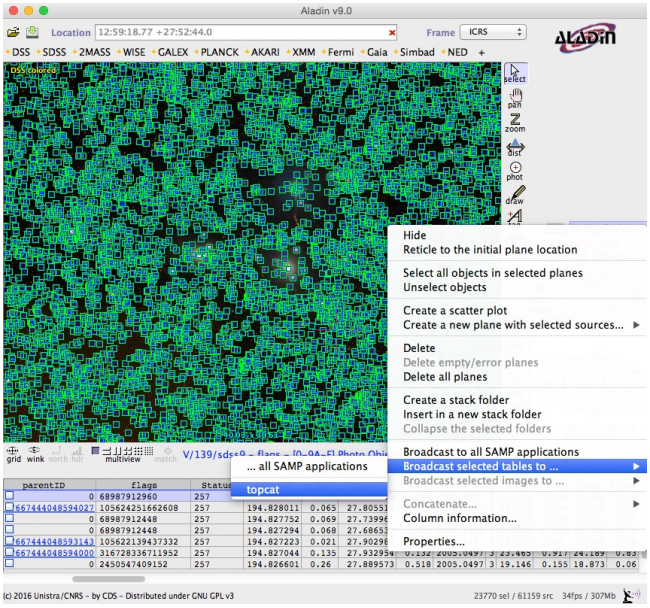



Figure 4: Broadcasting the filtered catalog to TOPCAT.

- In TOPCAT, display the column metadata, deselect all and select only the four columns needed: RAJ2000 ($15), DECJ2000 ($17), zsp ($31) and rPmag ($83).

# 4 Identify the brightest sources as being stars contaminating the sample

- In the main TOPCAT window, open the subset window and build a subset of the brightest sources (with magnitudes rPmag<11.7):
  - Click on to define a new row subset.
  - **Subset name**: 'stars'.
  - **Expression**: '$83<11.7' (Note: TOPCAT expressions do not differentiate small/capital letters and SDSS contains both rpmag and rPmag. In this case you have to use $ID of the column rather than its name. $ID can be found with **Views** → **Column Info** or in the main TOPCAT window).

- In the main TOPCAT window, select the 'stars' subset of the SDSSgalaxies catalog Row Subset: Stars and broadcast it to Aladin (**Interop** → **Send table to** → **Aladin** or ).

- In the main TOPCAT window, select Broadcast Row, open the table and move through the rows. The selected entries will be displayed in Aladin. Check that you are seeing stars.

# 5 Build a subset of galaxies with photometry (rPmag) and redshift (zsp) in SDSS

- In the main TOPCAT window, open the subset window again and build a subset of galaxies (no stars, i.e. rPmag>11.7) with magnitude rPmag brighter than 17.77 (completeness limit of the SDSS spectroscopic sample) and redshift information. This can be done with the subset expression: ' zsp>0 && $83<=17.77 && $83>11.7 '. Call this subset 'zsp17'.

- In the main window of TOPCAT select the subset ‘zsp17’ and duplicate the table (**File** → **Duplicate Table**).
- Rename the new table to ‘zsp17’.

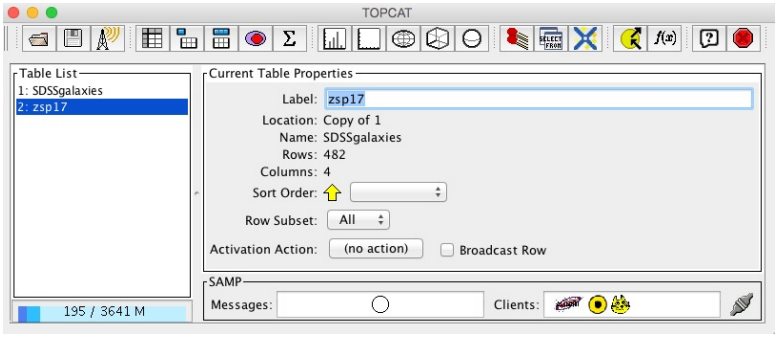



Figure 5: Duplicating and renaming the table with TOPCAT.

# 6 Improve the completeness with other sources of redshifts in VizieR

- In TOPCAT, build the subset ‘nozsp17’ that contains galaxies with similar magnitude selection as before but no redshifts (use ‘!(zsp>0)’ instead of ‘zsp>0’ in the above expression). The new subset has 140 entries.
- Select the subset ‘nozsp17’ in TOPCAT main window, duplicate the table and rename the new table ‘nozsp17’.
- In TOPCAT main window, search optical catalogs with redshifts:
  - Go to **VO** → **VizieR catalog service**
  - Select **Cone selection**: **Object name**=‘A1656’, click on **resolve**, **radius**=‘ 40’ ’. Then select **All Rows**.
  - In the **catalog selection** section: select the **by Keywords** tab and enter ‘redshifts Rines’, load the **Rines+ 2003** catalog. Two tables are loaded. Delete the cluster catalog to keep only the galaxy one (**File** → **Discard Table(s)**).

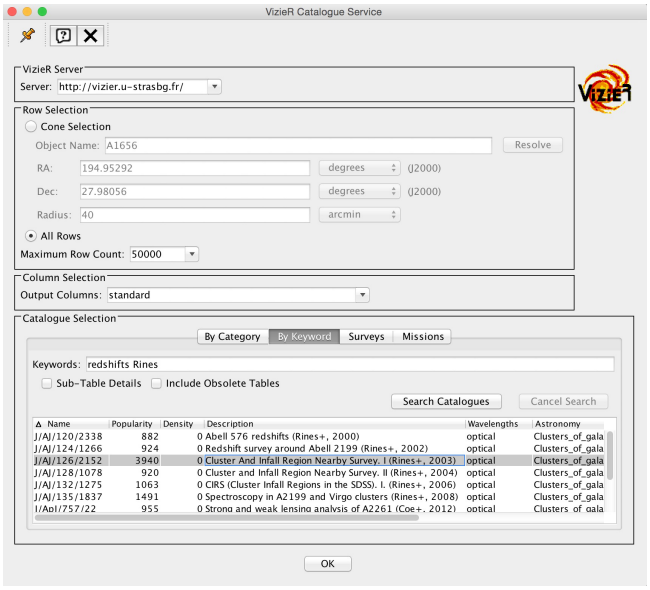



Figure 6: Loading a catalog from VizieR with TOPCAT.

- Find redshifts in Rines+ catalog for galaxies without redshift in rPmag17:
  - X-match the ‘nozsp17’ and the Rines catalog (**Joins** → **pair match** or  )
  - Use **sky** algorithm with ‘ 5” ’ max error and choose **Best match, symmetric**.

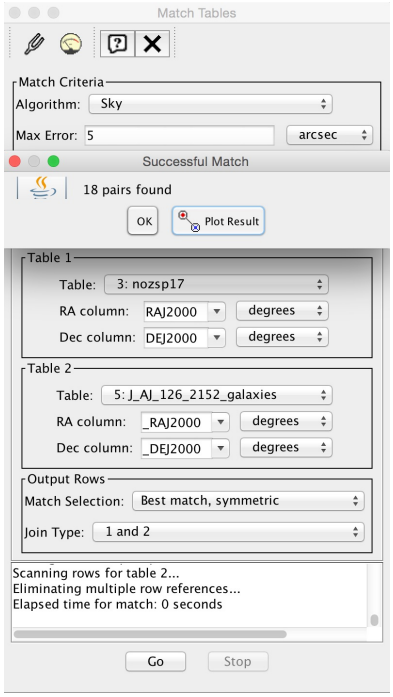



Figure 7: X-matching with TOPCAT.

# 7 Build the final catalog including Rines+ redshifts

- Add a new column to ‘zsp17’ catalog to get the apparent radial velocity cz:
  - Click **Table Columns**  , then do **Columns** → **New Synthetic Column** or click 
  - **Name**: ‘czsp’

- **Expression**: ‘ toInteger(zsp*300000) ’

- Concatenate ‘zsp17’ and match tables (**Joins** → **Concatenate Tables**). Fill in the **Appended Table** tabs. The final catalog contains 500 galaxies.

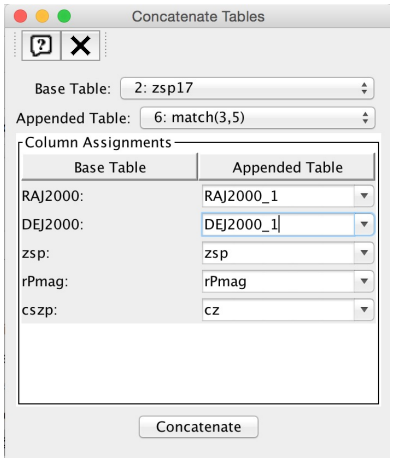
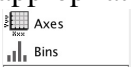



Figure 8: Concatenating with TOPCAT.

# 8 Determine the cz distribution, <cz> and dispersion in TOPCAT

- View the histogram of ‘czsp’ values with 

- Isolate the main peak of Coma in the histogram by selecting the appropriate region scrolling your mouse or playing with **Axes** (**Range** tab) and **Bins** (**Bin size**) 

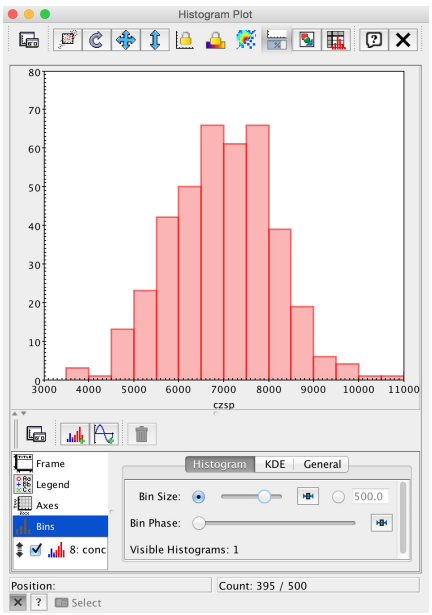




Figure 9: Main peak of the Coma cluster.

- Build a new subset named ‘Coma’ using the range of cz observed in the histogram (proceed as before to build new subsets).

- Select this Coma subset in the main window of TOPCAT and open the **Row Statistics** window  . You will find something like <cz>≈7000km s$^{-1}$ and SD≈1000km s$^{-1}$ both in excellent agreement with more refined analyzes.

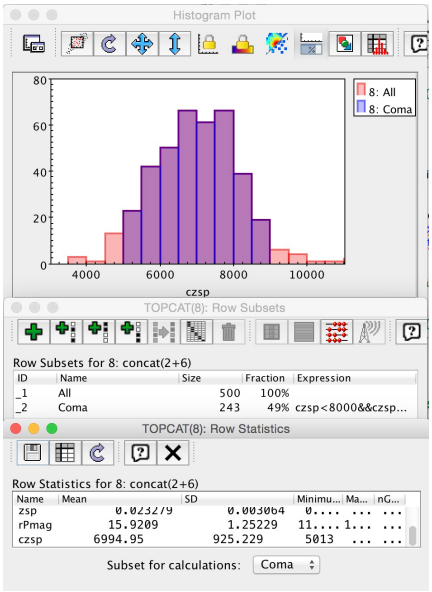



Figure 10: Statistics with TOPCAT.

# 9 Look for HST spectra in the Coma Cluster

- Go back to the Aladin window. Open the server selector  and select  :
  - **Target**: 'A1656'
  - **Radius**: ' 60' '
  - Unselect the **Images** and **Catalogs** servers (in order to get information on all spectra - and only spectra - available in this region)
  - Click on **submit**

- Browse the different menus and look at the **S** appearing on the image for some services. Each **S** corresponds to the location of a spectrum.

- Open the **Hubble Space Telescope Spectra** menu and click on **y1hi1402t, 1257+2840**. This opens the DATA INFO FRAME that gives access to information about this observation.

- Click on **FoV in stack** and visualize the slit location on the image in the main Aladin window.

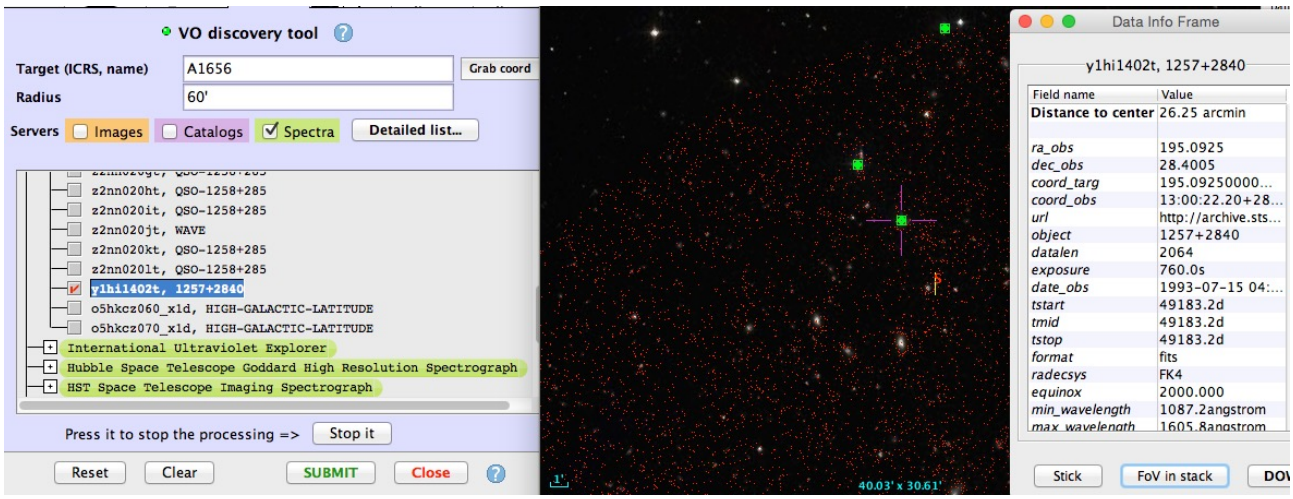



Figure 11: All the above steps in Aladin.

- In the terminal, launch CASSIS: ./cassis.run
- Go back to the Aladin window and in the DATA INFO FRAME, select **Load in...** > **Cassis**.

# 10 Visualize and analyze the HST spectrum with CASSIS

- Click on 

in the SPECTRUM MANAGER window
- In CASSIS main window, choose the **spectrum analysis**  option and then click 

. The spectrum is now displayed in the CASSIS main window. Two lines are clearly visible: one around 1250 Angström and one around 1350 Angström.

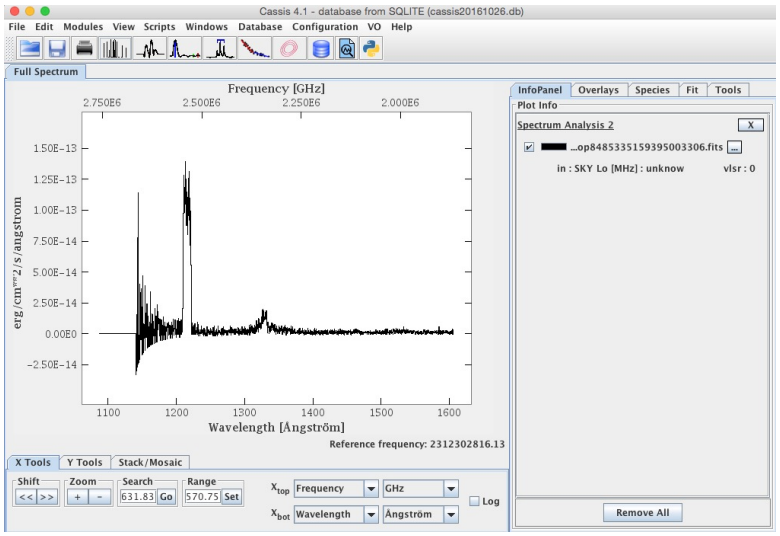



Figure 12: Spectrum with CASSIS.

- To check that these are hydrogen lines (Ly$\alpha$), one at the local velocity, the other at the velocity of the Coma cluster:
  - Select the **Species** tab. Choose the **Full NIST** database in the **Template** section.

- Unselect all species by clicking on the **Sel.** column.
- Select the sole **HI** line by ticking only this line.
- The maximum **Eup threshold** is by default too low for our case. Remove the '150.0K' and replace it with ' * ' to get all the HI transitions without any threshold in energy.
- Tick **show signal** and click **Display** at the bottom of the window. A green tick appears below the largest of the two lines. This confirms that this line is an Hydrogen line at a zero velocity. Clicking on the green tick gives more information on the line parameters. A right click allows you to edit the overlay (useful for a copy-paste).

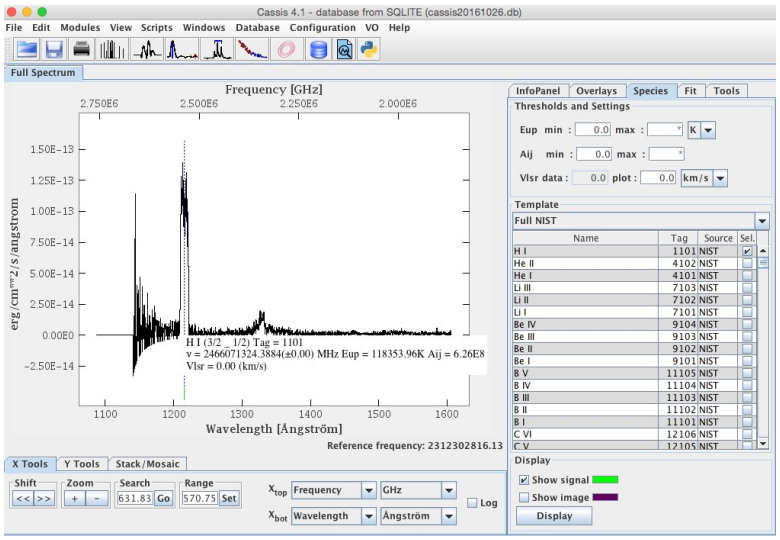



Figure 13: Spectrum with CASSIS.

- To look for the LSR velocity of the galaxy in the Field of View from SIMBAD:

  - Go back to the Aladin window and center the image on the HST spectral slit using pan
  - Open the SERVER SELECTOR and select the SIMBAD tab.
  - Click on Grab coord and in the main Aladin window click on the central position of the spectral slit.
  - Expand/Reduce the region scrolling your mouse to encompass the whole spectral Field of View (∼50").
  - Click on submit in the SERVER SELECTOR. A new plane is built in Aladin. It contains all SIMBAD objects in this region.
  - Click on the Seyfert 1 galaxy that falls on the slit. Its name is NAME X COMAE GALAXY in SIMBAD.

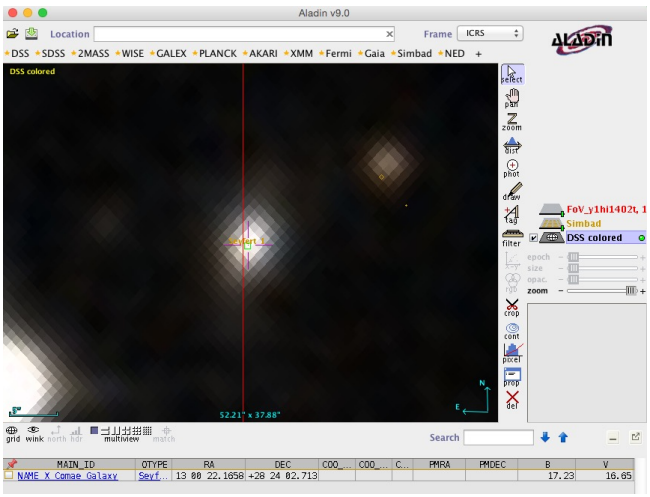



Figure 14: Visualization of all the above steps.

- Clicking on the name of this galaxy opens a web browser with all the SIMBAD information for this object.
- The radial velocity for this galaxy is 26,091 $\mathrm{km\ s^{-1}}$.
- Note that this galaxy is not part of the Coma cluster since the velocity of the Coma cluster is 6845 $\mathrm{km\ s^{-1}}$. This value can be found with SIMBAD looking for A1656.

- Go back to CASSIS and change the **VIsr data** field from ' 0 ' to ' 26,091 ' $\mathrm{km\ s^{-1}}$. The green tick corresponding to the HI line moves right under the second fainter line in the HST spectrum. This confirms that this line is associated to the Seyfert 1 galaxy.

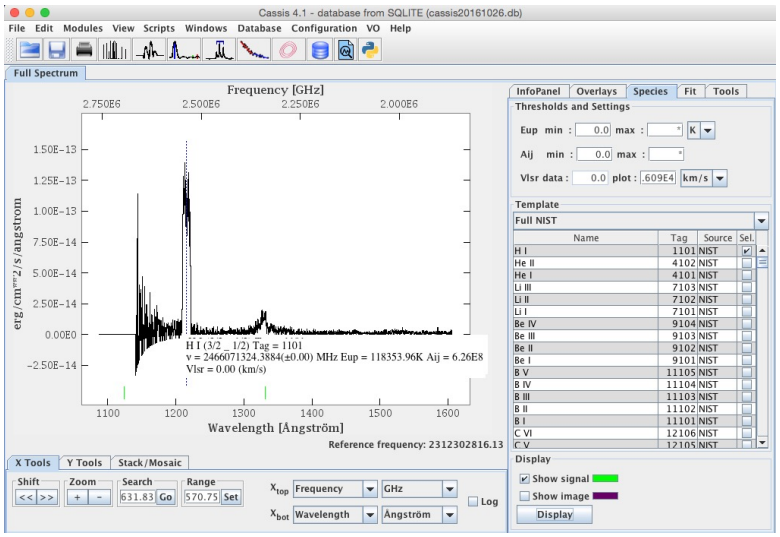



Figure 15: HI line of the Seyfert 1 galaxy.

# 11 Fit a gaussian and a continuum to the hydrogen line

- Load a small portion of the spectrum, centered on the HI line of the Seyfert 1 galaxy and fit the line with a Gaussian profile and a continuum:
  - Start with erasing the current plot in the **InfoPanel** tab by clicking on the cross.
  - If necessary, go back to Aladin, send the HST spectrum of 2157+2840 back to CASSIS and

click on 

in the SPECTRUM MANAGER window.

- Use the **spectrum analysis**  option but reducing the wavelength range: 1300 to 1375 Angström and click 

.

- In CASSIS main window, select the **Fit** tab and add two components using the **Manage Components** menu: a polynomial baseline and a Gaussian line.
- Change the **degree** of the polynomial to ' 0 ' in order to fit a constant baseline.
- For the Gaussian component, the purple/blue fields should be filled with initial values in order to start the fitting procedure. They can be filled by hand but a useful way of filling them in is: use the middle button of your mouse to click and drag the region of the line or alternatively with a trackpad press both ctrl+alt and click and drag to draw the region. Beware that the Gaussian parameters should stay violet/blue (do not click on any of them) if you want them to fill in automatically. The position of the peak (**xo**), its height (**Io**) and the width of the line (**FWHM**) are estimated automatically from the selection. This selection, visible in purple/blue on Figure 16, can be erased using the **reset** buttons in **Selections [with middle-click-and-drag**.
- Click on **Fit current** to perform a fit of the line+baseline. The different components of the fit can be selected or deselected in the **InfoPanel**.
- Go back to the **Fit** panel and note the central wavelength of this line as inferred from the best fit: 1327 Angström.

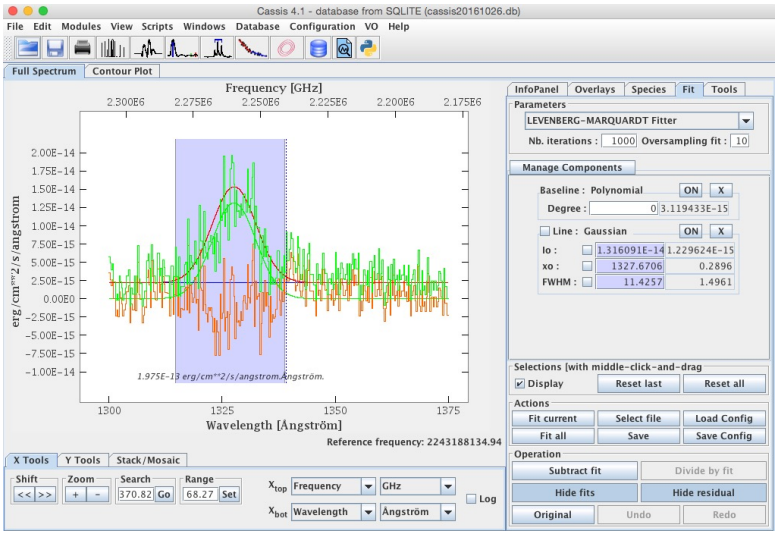



Figure 16: Fit of the spectrum.

- Given that the rest wavelength for the Lyman $\alpha$ line is 1216.5 Angström, the velocity of the galaxy is v=c$\times\Delta\lambda/\lambda_0$=27,420 $\mathrm{km\ s^{-1}}$ or in redshift, z=v/c=0.0914.
- This value can be compared to the value given in SIMBAD.