



**National and Kapodistrian
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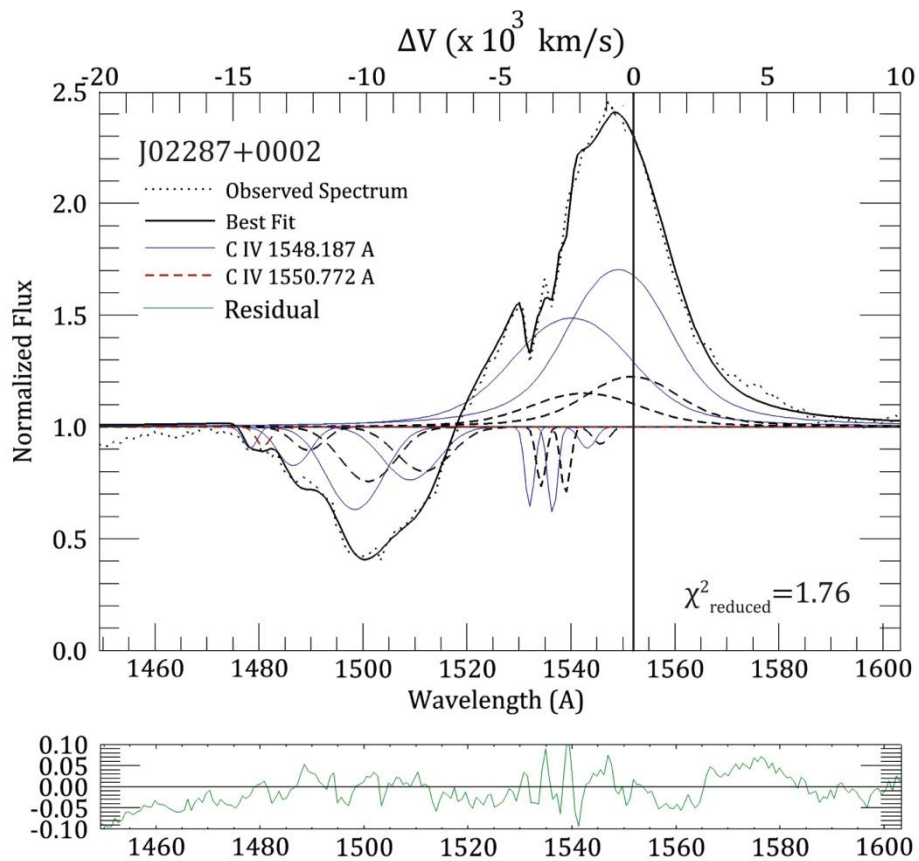
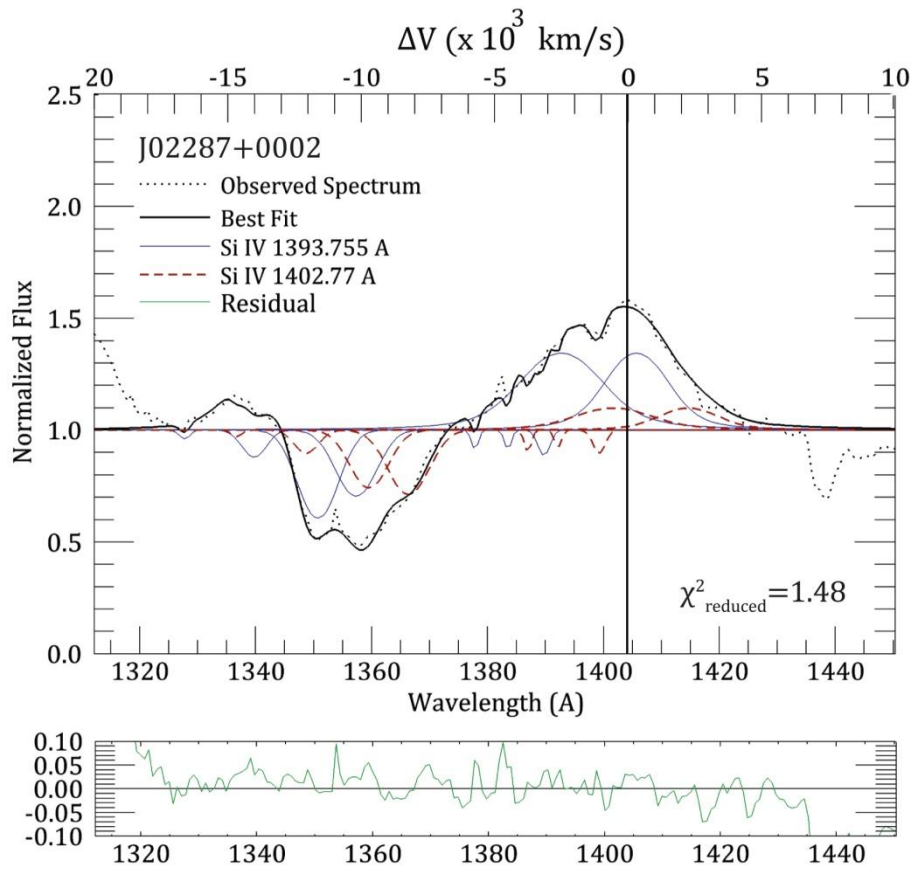


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ASTA - A Spectral Analysis Tool

Version 1.4

User's Manual



Contents

Overview	1
Getting Started	2
Installation	2
Uninstalling ASTA_v1.4	2
Requirements and Compatibility	2
Displaying a spectrum	2
The horizontal top toolbar	3
File	3
Tools	5
Export	6
Statistical analysis	7
The vertical left toolbar	10
Other Tools	12
Resize Working Areas	12
Plot Tools	13
χ^2 goodness of fit	13
y-axis noise slider	13
z-redshift factor	13
grid	13
Example: SDSS J114548.38+393746.6 (BAL Quasar)	14
Example: Narrow Absorption Lines	29

Overview

ASTA is a spectral analysis software for displaying, fitting and analyzing astronomical spectra emission and absorption line spectra. The software is based on the GR theoretical model produced by the Astrophysical Spectroscopy Team of the National and Kapodistrian University of Athens.

ASTA is able to fit, process and analyze:

- Simple spectral lines that can be simulated by a classic distribution such as Gauss, Lorentz or Voigt. In these cases, ASTA has the ability to calculate the line function of an observed spectral line and calculate the physical parameters of the region that produces the spectral line. ASTA also incorporates two new mathematical distributions formulated by the Astrophysical Spectroscopy Team of the National and Kapodistrian University of Athens. These distributions are called Rotation (Danezis et al., 2007, Lyratzi et al., 2007) and Gauss-Rotation (Danezis et al., 2007, Lyratzi et al., 2007). Rotation distribution is used in the case the region that produces a spectral line rotates around its own centre. Accordingly, Gauss-Rotation distribution is used in the case that the region producing a spectral line is characterized by both random motions and rotation.

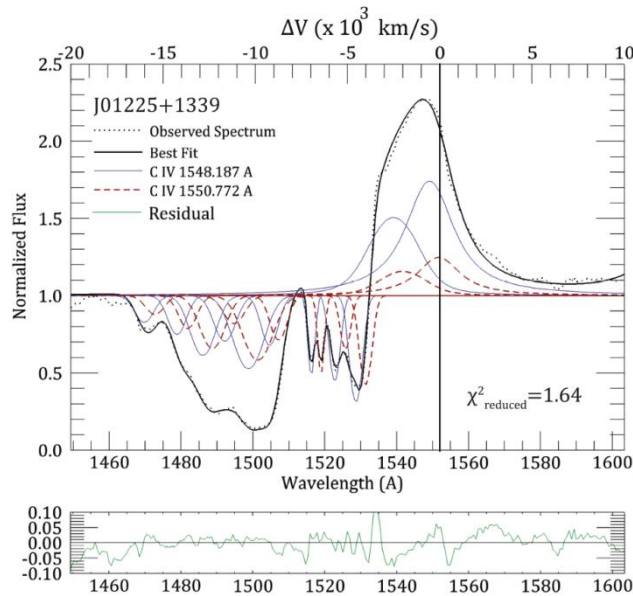


Figure I. Best fit of the C IV region of the BAL Quasar J01225+1339. The black dotted line denotes the observed spectrum while black, thick solid line corresponds to the best fit. With blue thin solid line we denote the shorter wavelength member of a doublet (blue: 1548.187 Å) while with the red dashed line we denote the longer wavelength member of a doublet (red: 1550.772 Å). The zero velocity corresponds to the longer wavelength member of a doublet. Below the fit we present a panel with the residual, which appears in green thin line. Furthermore, the reduced χ^2 is given for every fit. Note that the value of the reduced χ^2 serves only as a qualitative measure of the fit and should not be interpreted as indicating the probability of the fit (Stathopoulos, D. et al. 2015, JApA, 36, 495).

- Spectral lines that exhibit complex and asymmetric profiles and as a consequence are the product of the synthesis (blend) of individual components

of the same ion. Characteristic examples of this case are the Broad Absorption Lines (BALs) and Broad Emission Lines (BELs) found in the spectra of Quasars, the Discrete Absorption Components (DACs) and Satellite Absorption Components (SACs) seen in the spectra of Hot Stars and Hot Emission Stars. Other astronomical objects exhibiting complex profiles are Wolf Rayet stars, Cataclysmic Variable stars and Super Novae. In the case of complex and asymmetric spectral lines, such as the ones mentioned, ASTA can provide the analysis of the complex profiles to the uniquely determined individual components it consists of. As a result, ASTA can calculate the physical parameters describing each, uniquely determined, individual component.

- In the case of broad and complex spectral line profiles, ASTA does not provide only the multicomponent analysis of the profiles. It also provides the interpolation polynomial that can simulate (fit) pretty accurately the complex spectral profiles which consist of individual components (see **Figure I**).

Getting Started

Installation

Installing ASTA_v1.4 in your system is a straightforward task. Navigate in the CD and double click on *welcome.exe*. The *Welcome Screen Menu* appears with documentation and installation options. You can view information about ASTA user guide, ASTA team, ASTA_v1.4 software and video tutorials. To install ASTA_v1.4 in your system click on *install ASTA_v1.4* button and follow the steps in the installation wizard.

Uninstalling ASTA v1.4

To uninstall ASTA_v1.4 from your computer follow the windows procedure as in any other windows application. Click Start, Control Panel, Uninstall a program. Find ASTA in the list of your installed applications and follow the windows uninstaller wizard. Navigate to Program Files(x86) to delete files that have been created by the user.

Requirements and Compatibility

ASTA_v1.4 supports Windows XP SP2, Windows 7/8/10 32 and 64bits. Minimum RAM required is 2GB, however please take under consideration that a large amount of real time calculations take place and older systems might run in lower performance. In case you meet compatibility issues please don't hesitate to contact our support team.

Displaying a spectrum

To start ASTA double click on ASTA_v1.4 icon found on desktop or under Start Menu. When ASTA appears it should look like this (Fig. 1):

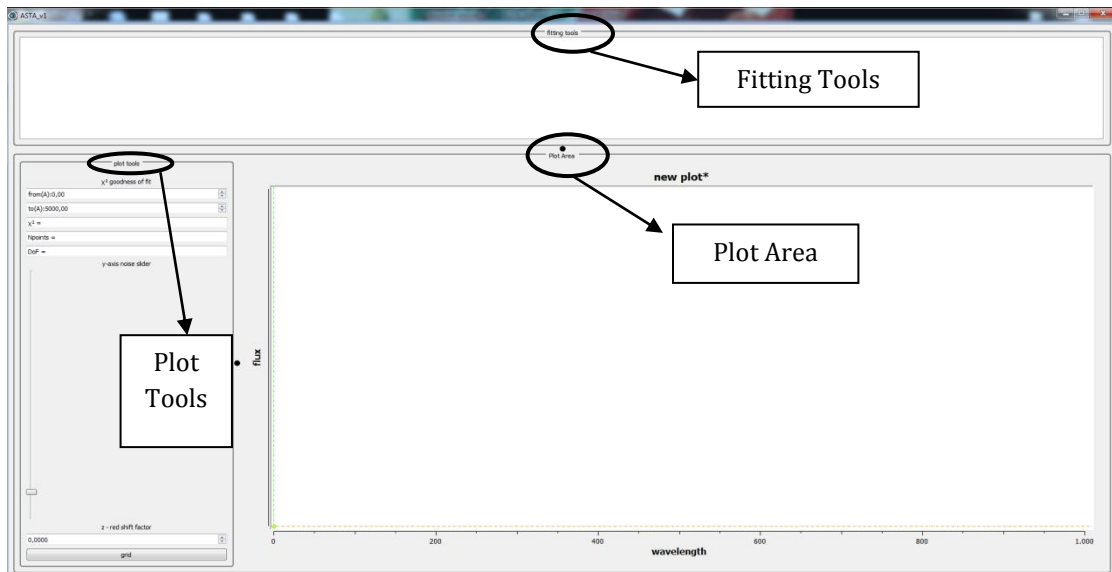


Figure 1

This is the main browser window. In order to reveal the toolbars slide the cursor either on the left side or the upper side of the main window, like in Fig.2.

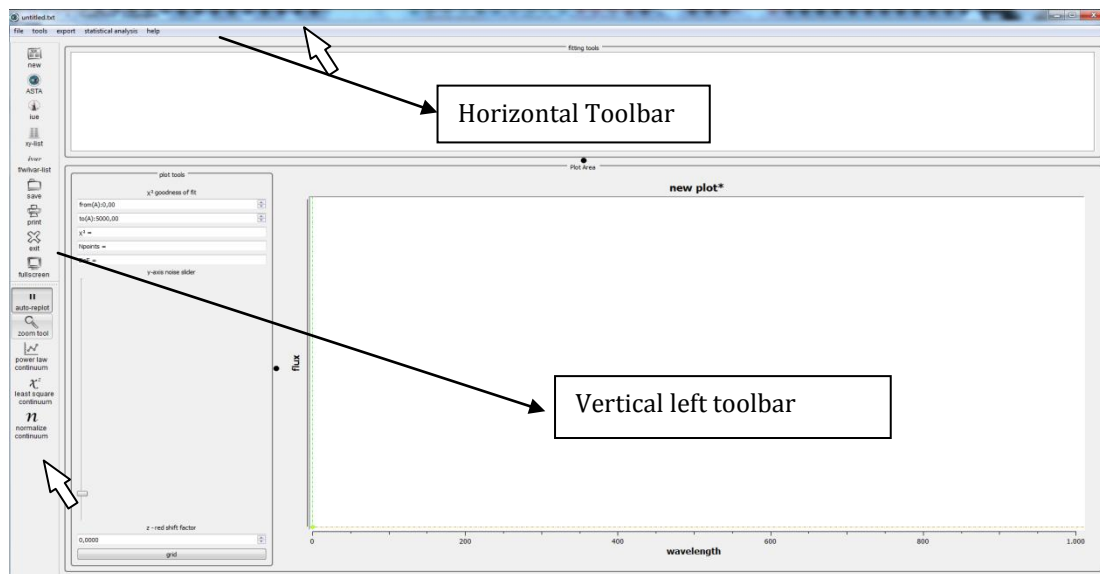


Figure 2

The horizontal, top toolbar has the following buttons: File, Tools, Export, Statistical Analysis, Help.

File

- **new:** Create a new ASTA project
- **open saved project:** open a project you have previously worked with and you have saved as "*name.asta*"
- **open IUE ascii file:** open an ascii file downloaded from the IUE database that consists of two columns wavelength and flux separated by a single space

- **open xy list (flux vs wave):** open an ascii (the "filename extension" should be *.txt*) file downloaded from the IUE database that consists of two columns wavelength and flux separated by a single space
- **open wavelength/flux/ivar spectrum:** open an ascii file (the "filename extension" should be *.txt*) containing three columns, wavelength, flux, inverse variance. Both three columns should be separated by single spacing from one another
- **save:** save a project you are already working on and you have previously saved as "name.asta"
- **save project as:** save a new project using the extension *.asta*
- **save component parameters table to file:** Let's assume that you are already working on a project e.g. fitting the C IV broad absorption and broad emission lines ($\lambda\lambda$ 1548.187, 1550.772 Å) of a Quasar (Broad Absorption Line Quasar-BALQSOs) like the one in Fig. 3a. You have achieved the best fit by fitting multiple components (Gaussians) and now you want to fit the C IV broad absorption and emission lines of the same Quasar but from a different epoch in order to study the variability. You can save component parameters table to file, open the new C IV spectrum and load component parameters in order to avoid inserting the parameters' values of the first fit to the second one
- **load component parameters:** you can load the parameters' values of a fit to a new one
- **print**
- **exit the application**

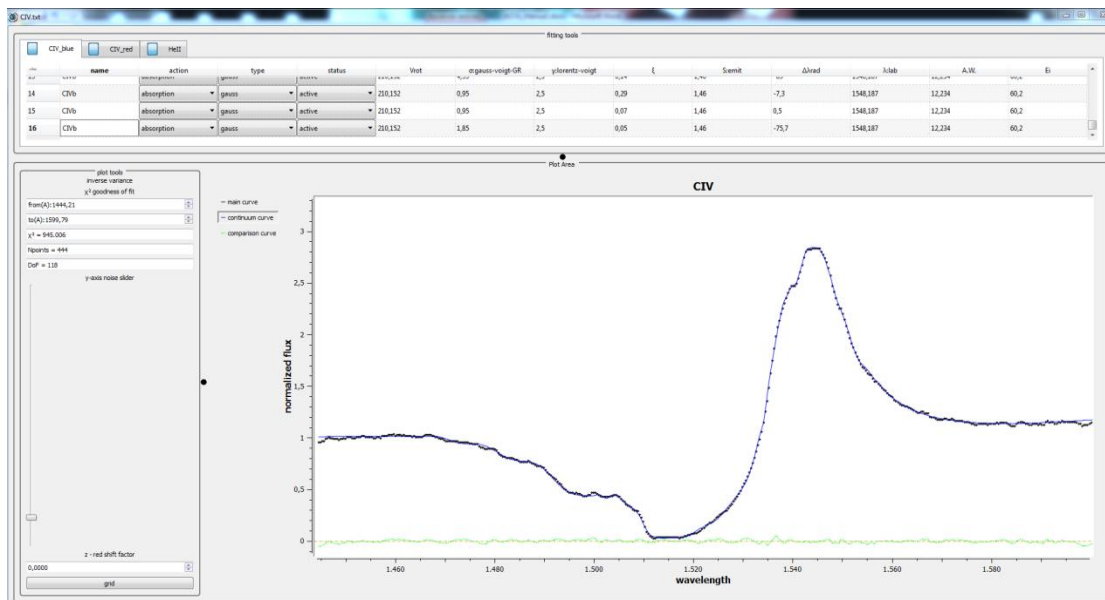


Figure 3a

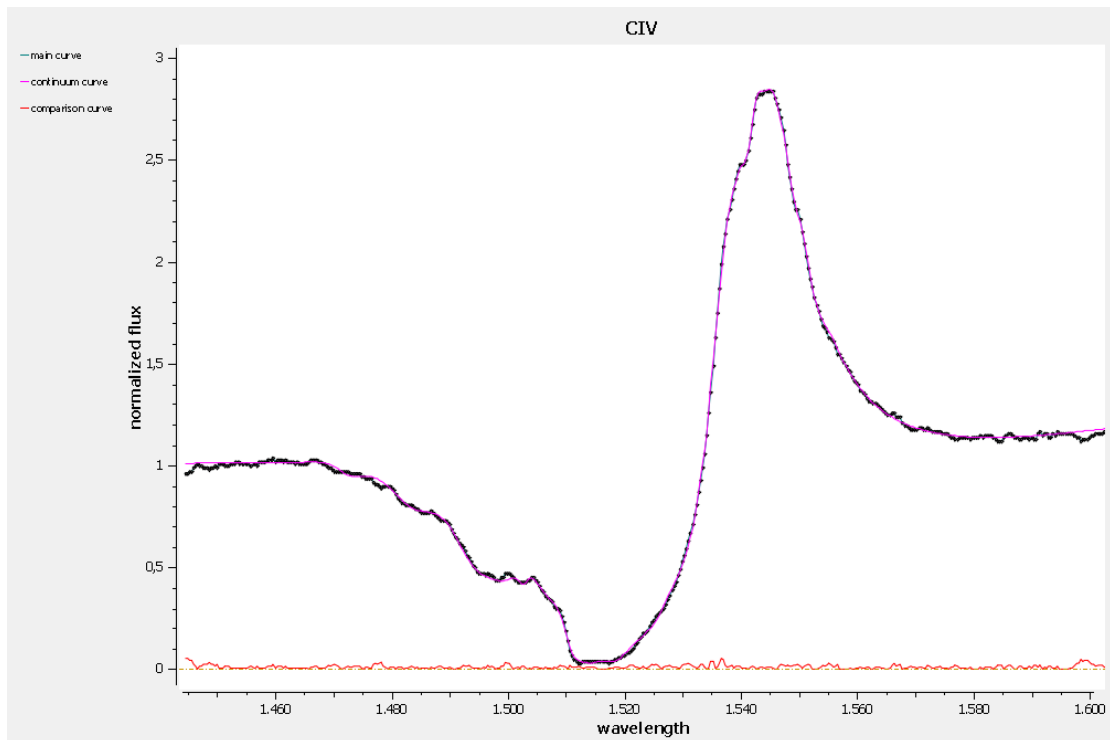


Figure 3b. Black dotted line: observed spectrum; blue line: best fit; green line: residual

Tools

- **Set full screen mode:** Sets the program in full screen mode. The user can exit full screen mode by clicking again the same button.
- **Configure:** When the user presses configure a dialog box called "Config Dialog" opens. In this box the user can manipulate the form and the color of the observed spectrum (*main curve*) the continuum or best fit (*continuum curve*) and the residual (*comparison curve*), see Fig. 4.
- **normalize:** As soon as the continuum is drawn, the user can click on this button to get the normalized spectrum.
- **new model set:** inserts a new line (for more information see page 20, point 7)
- **insert Gaussian noise to model line:** the user can insert Gaussian noise to the observed spectrum or the best fit.
- **apply moving average smooth filter to spectrum:** the user can smooth the observed spectrum by applying a moving average filter. When the button is pressed a new window (called "ASTA moving average smooth filter tool" see Fig. 5) emerges that displays the spectrum and has a field named "*please set the number of moving points*". The user chooses the number of moving points and the smoothed spectrum is displayed. The user can change the number of moving points and observe the new smooth. Once the user is satisfied with the smooth, he/she can press "apply moving average smoothing filter to spectrum" and the smoothed spectrum appears in the main window of the program. If the user doesn't want to make any changes in the spectrum, he/she can press "*close (no changes will be applied on spectrum)*".

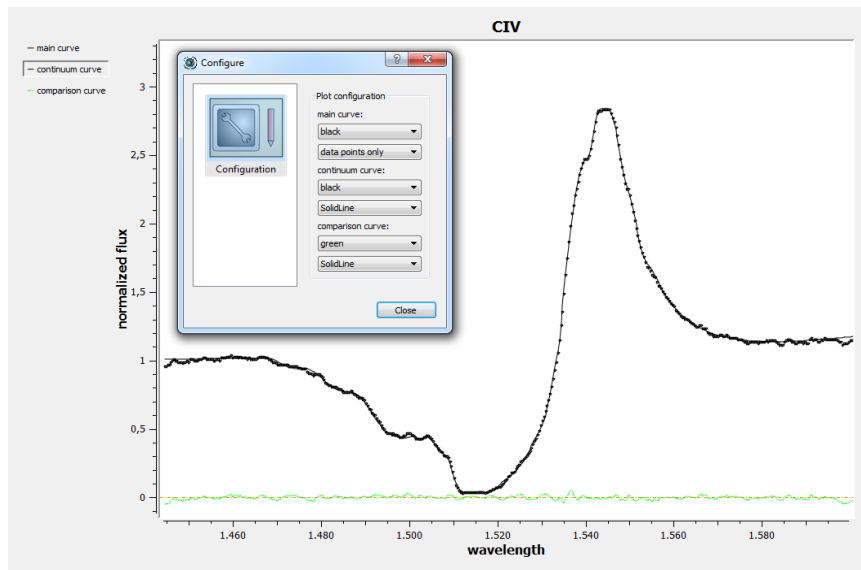


Figure 4

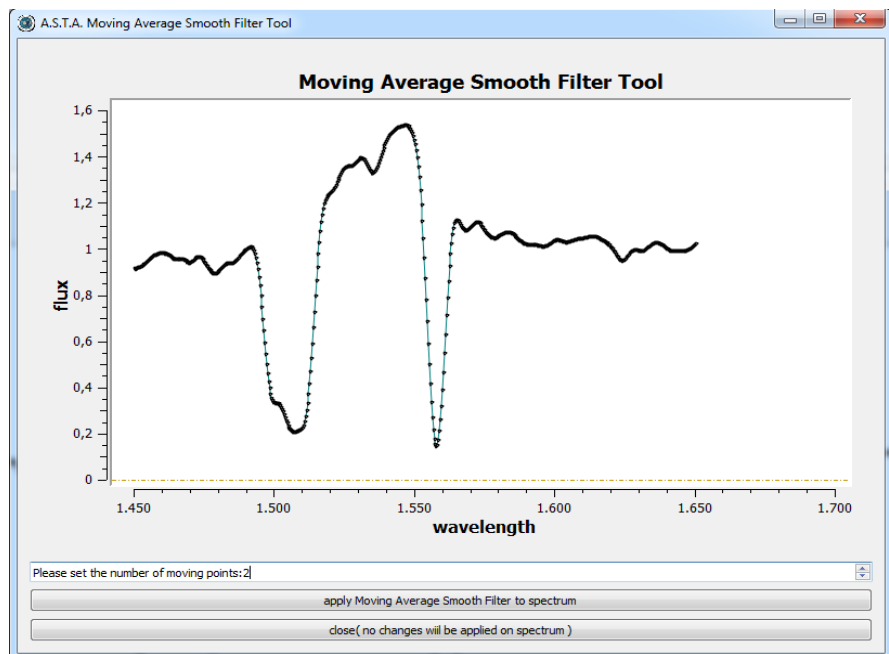


Figure 5

export

- **export results to html:** exports results to an html file that can be opened in any browser (drag and drop or double click).
- **export current plot to image file:** exports the best fit on an image file (bmp, jpg, pdf)
- **export model line points to a single 2 column txt file:** In the case that the user has achieved the best fit, by pressing this button he/she can export a txt file with the best fit (the txt file contains two columns: wavelength and modeled flux).

- **export separately all component line points to 2 column txt files:** Let's assume that the user has performed a multicomponent fit of C IV resonance lines in the case of a BAL Quasar (see Figs. 3a, 3b). The user has used 16 Gaussian components for the 1548.187 Å line and 16 Gaussian components for the 1550.772 Å line. By pressing the button "*export separately all component line points to 2 column txt files*" the user can export 32 txt files where each one contains two columns with the wavelength and flux of each component.
- **export comparison line point to 2 column txt file:** the user can export the residual on a txt file.
- **export normalized spectrum data points to txt file:** After the process of normalization the user can export the data points (wavelength-flux) of the normalized spectrum to a txt file.

Statistical analysis

- **carry out a sum of squares (SSE) test between two curve fittings:** Let's assume that the user has performed two different fits of the same C IV spectrum and now he/she wants to compare them and test which fit is better. By choosing this command a new window called "sum of squares due to error (SSE) Widget" pops up (see Fig. 6a). This window has two plot areas. Below each plot area there is a button "browse". By selecting these buttons the user can choose the saved projects ("name1.asta", "name2.asta") he/she wants to compare (see Fig. 6b). Above the left plot area there are two fields where the user can choose the wavelength range he/she wants to perform the comparison. After selecting the wavelength range, the user can press the "refresh plots" button on the upper right corner and then only the wavelength ranges under comparison appear (see Fig. 6c). Finally, in order to perform the SSE test the user presses the "start SSE test" button on the lower right corner of the window and the result appears on the white box at the bottom of the window (see Fig. 6d).

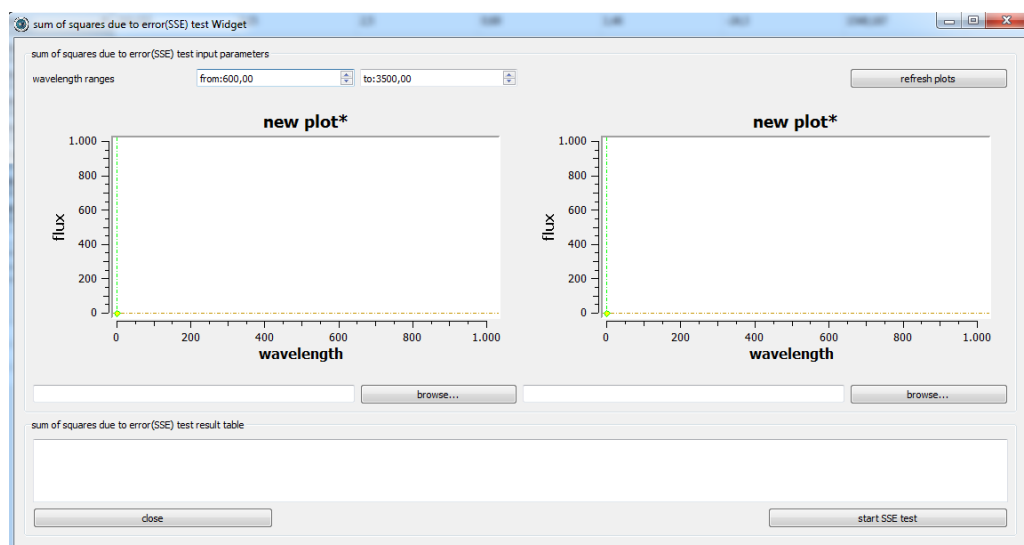


Figure 6a

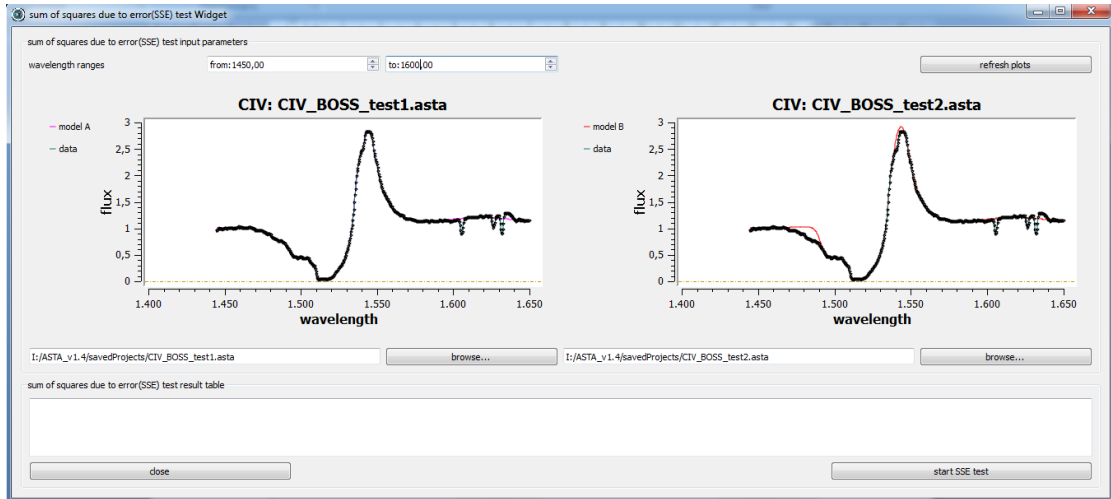


Figure 6b

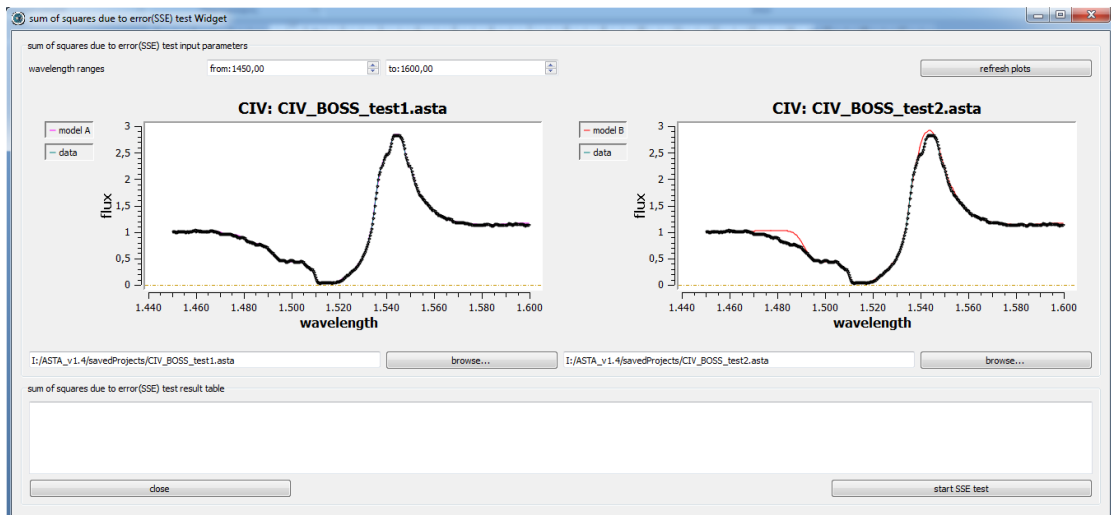


Figure 6c

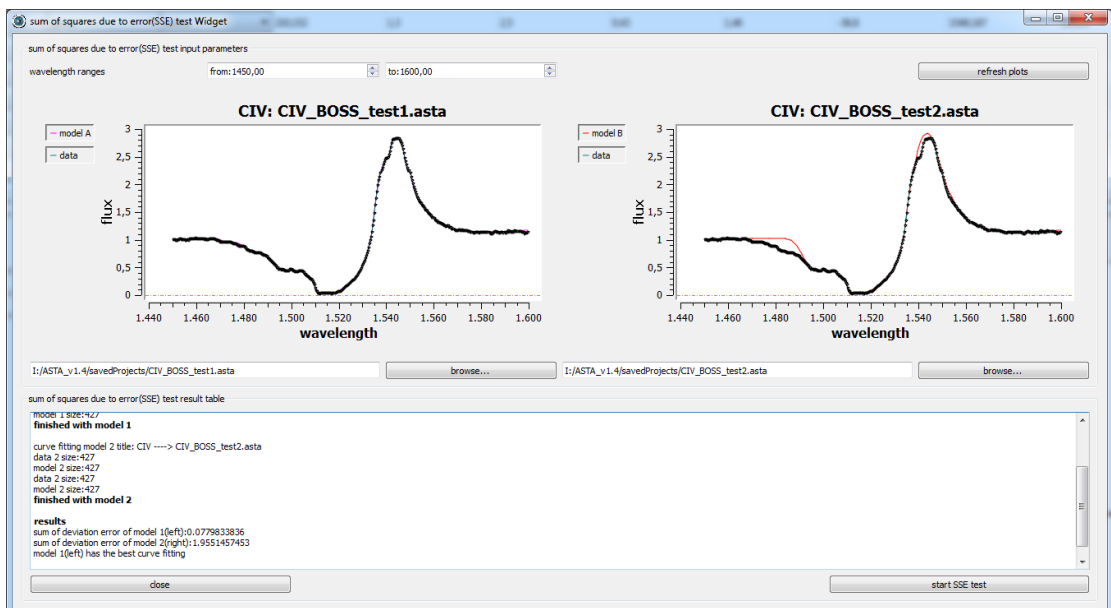


Figure 6d

- carry out a **Pearson chi-square test of a curve fit**: The user can perform a Pearson chi-square test of the best fit he/she has performed. Once the command is chosen, a window called "chi-square test" pops up (see Fig. 7a). By choosing the browse button the user can select the saved project (name.asta) for which he/she wants to perform the Pearson chi-square test. On the left upper corner the user can choose the wavelength range into which the Pearson's chi-square test will be performed. Using the button "refresh plots" the user can observe only the range he/she chose to perform the test. Finally, by pressing "start chi-square test" the test is performed and the results appear on the lower white box (see Fig. 7b).

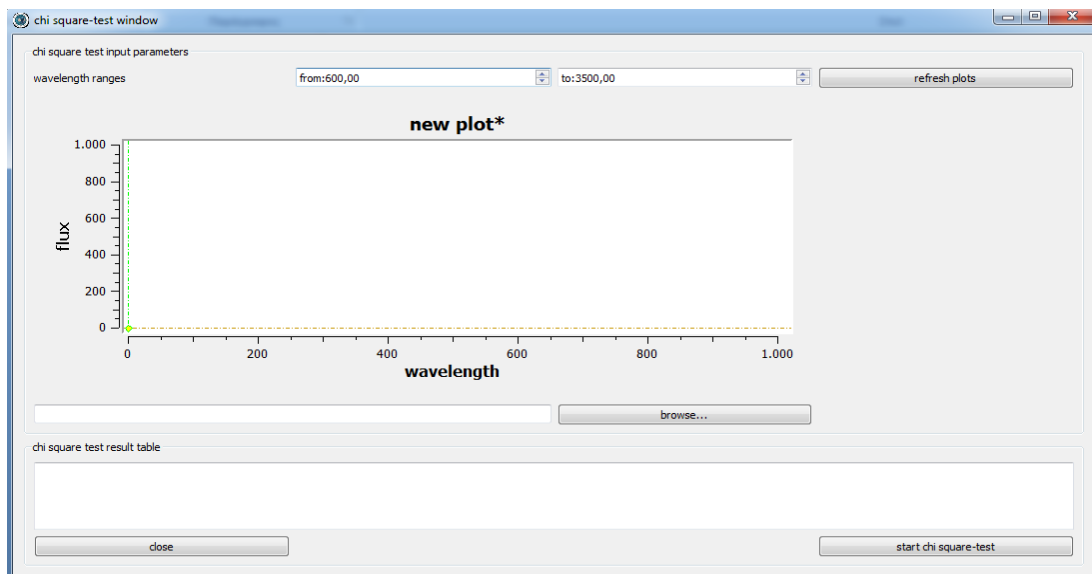


Figure 7a

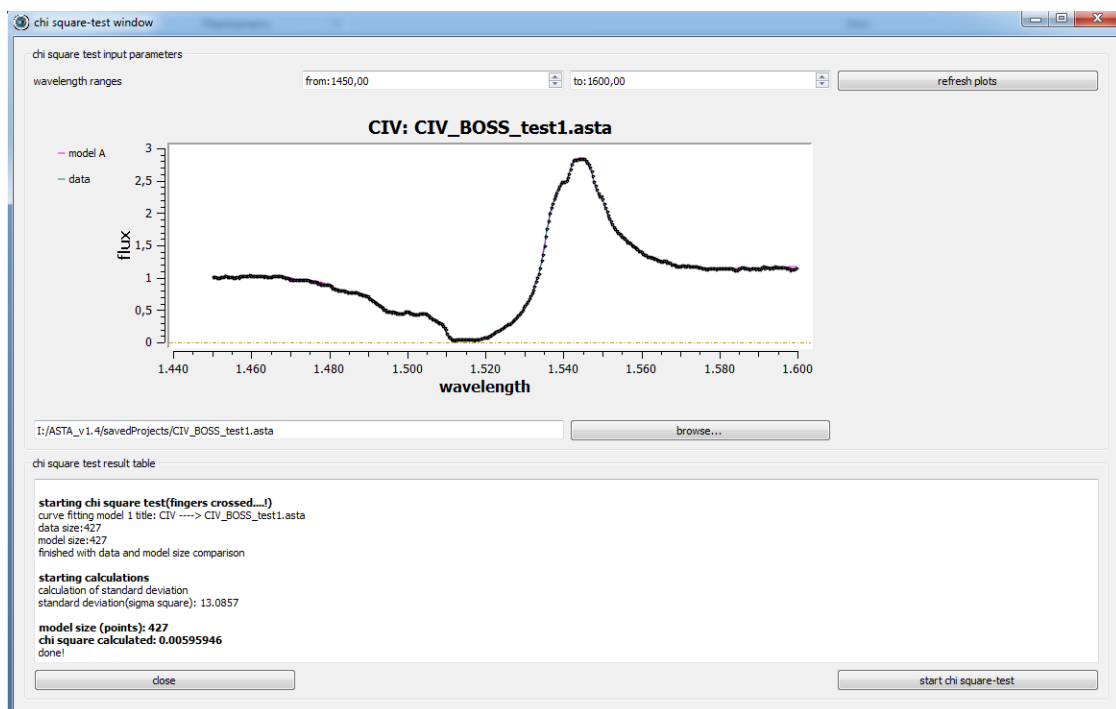


Figure 7b

- **carry out F-test between two curve fittings:** The user can perform an F-test in order to compare two different fits among each other. Once the command is chosen, a window called "F-test Widget" pops up. The procedure in order to perform the F-test is the same as in the case of SSE test (see above).

The vertical left toolbar has the following buttons: new, ASTA, IUE, xy-list, f/wvl/ivar-list, save, print, exit, full screen, auto-replot, zoom-tool, power law continuum, least squares continuum, normalize.

- **new:** Create a new ASTA project
- **ASTA:** open a project you have previously worked with and you have saved as "*name.asta*"
- **IUE:** open an ascii file downloaded from the IUE database that consists of two columns wavelength and flux separated by a single space
- **xy-list (flux vs wave):** open an ascii (the "filename extension" should be *.txt*) file downloaded from the IUE database that consists of two columns wavelength and flux separated by a single space
- **f/wvl/ivar-list:** open an ascii file (the "filename extension" should be *.txt*) containing three columns, wavelength, flux, inverse variance. Both three columns should be separated by single spacing from one another.
- **save:** save a project you are already working on and you have previously saved as "name.asta"
- **print:** print current plot
- **exit:** exit program
- **full screen:** full screen mode.
- **auto-replot:** pauses and un-pauses the fitting process (for more details see Tip 1 on page 24)
- **zoom-tool:** By pressing this button and then holding left click and dragging, the user can create a rectangular area around the region he/she wants to zoom in. If the user is not satisfied with the selected area he/she can use right click of the mouse to un-zoom and then zoom again in a different region. If the users clicks the zoom tool button again then he/she cannot go back and un-zoom to the previous state, i.e the zoom area has been determined. There is also another use of the zoom tool. If the user activates the zoom tool, then he/she can place the cursor at any point inside the plot area window and then the wavelength and flux of the corresponding point is displayed.
- **power law continuum:** The user can perform a power law continuum fit using the equation,

$$F(\lambda) = F_{\lambda_*} \left(\frac{\lambda}{\lambda_*} \right)^\alpha$$

where:

α is the spectral index

λ_* is the reference wavelength

F_{λ_*} is the flux at λ_*

Once the button "power law continuum" is pressed a window pops up (see Fig. 8a). The first step is to select areas of interest for the continuum, i.e. wavelength regions that the fitting process must consider. The regions can be selected by left clicking and dragging in the main window. The wavelength regions can be changed by clicking inside the pop up window (see Fig. 8b). The user then chooses the value of λ_* and the program calculates the $F(\lambda_*)$. Once this procedure is done, the user can press "normalize" (in the vertical left toolbar) and the spectrum is normalized (see Fig 8c).

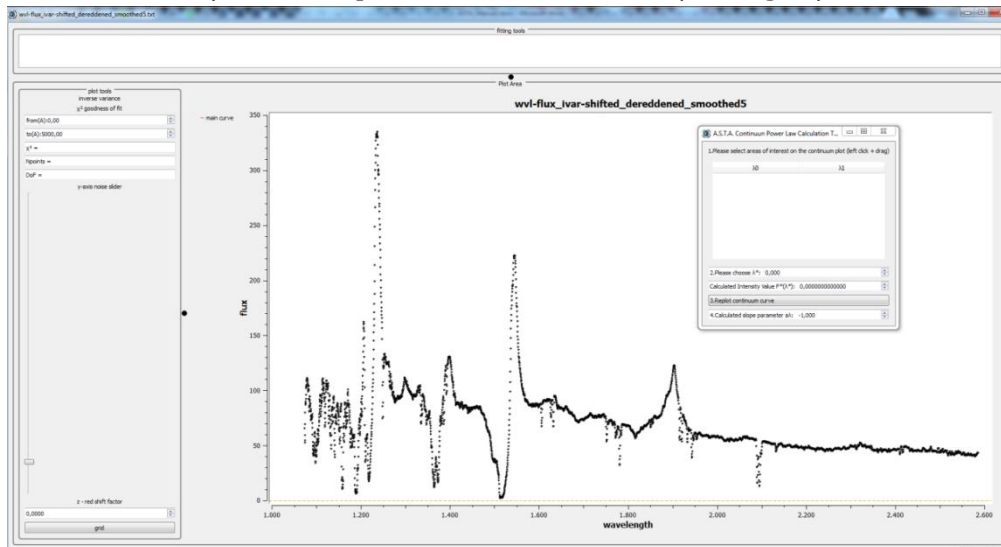


Figure 8a

1. Please select areas of interest on the continuum plot (left click + drag)

	λ_0	λ_1
1	1270	1290
2	1445	1465
3	1685	1705
4	1965	2000

2. Please choose λ_* : 2000,000
 Calculated Intensity Value $F^*(\lambda_*)$: 59,2400016784668

3. Replot continuum curve

4. Calculated slope parameter a_λ : -1,061

1. Spectral Regions that are free from strong spectral features. The power law continuum will pass from those regions. By double clicking the user can change the wavelength values

2a. The user chooses the value of λ_*

2b. The value of $F(\lambda_*)$ is calculated by the program

3. User presses this button and the power law is calculated

By double clicking on one of these numbers the user can delete a chosen window.

Figure 8b

4. The spectral index a_λ is calculated by the program

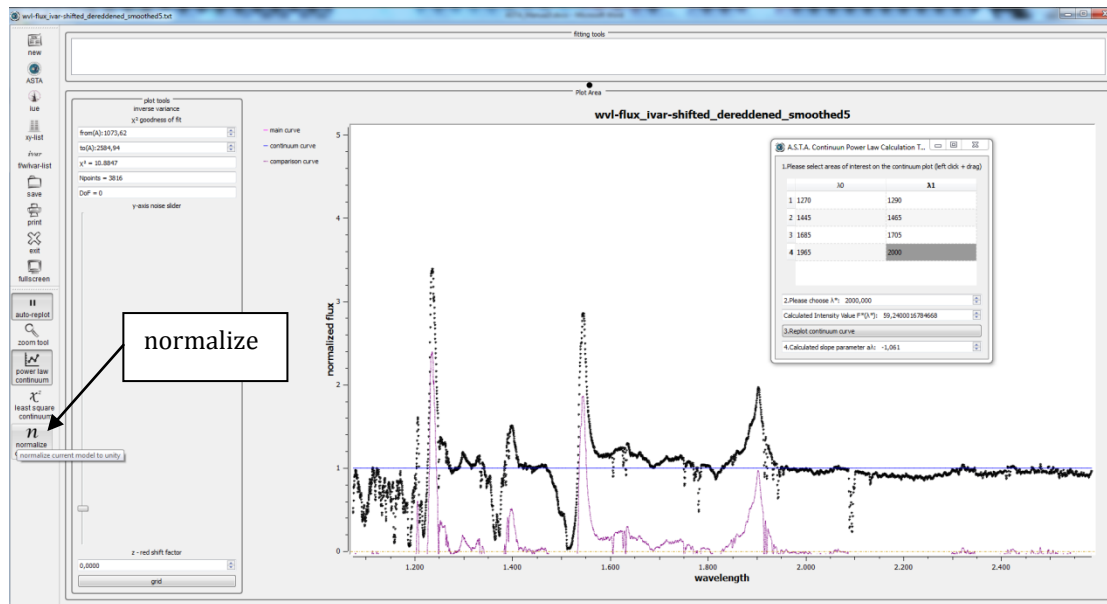


Figure 8c

- **least square continuum:** draws the best-fitting continuum curve to a given set of points by minimizing the sum of squares of the residuals of the points from the curve. The set of points are chosen by the user. The user can choose the first point by left clicking on the desired point; the next points are selected by right clicking. The final point is selected by left clicking. Once the final point is selected the continuum is drawn. By clicking the normalize button the spectrum becomes normalized.

Other Tools

- In the main window there are two black dots (see Fig. 9a) that the user can use in order to resize the working areas (see Fig. 9b).

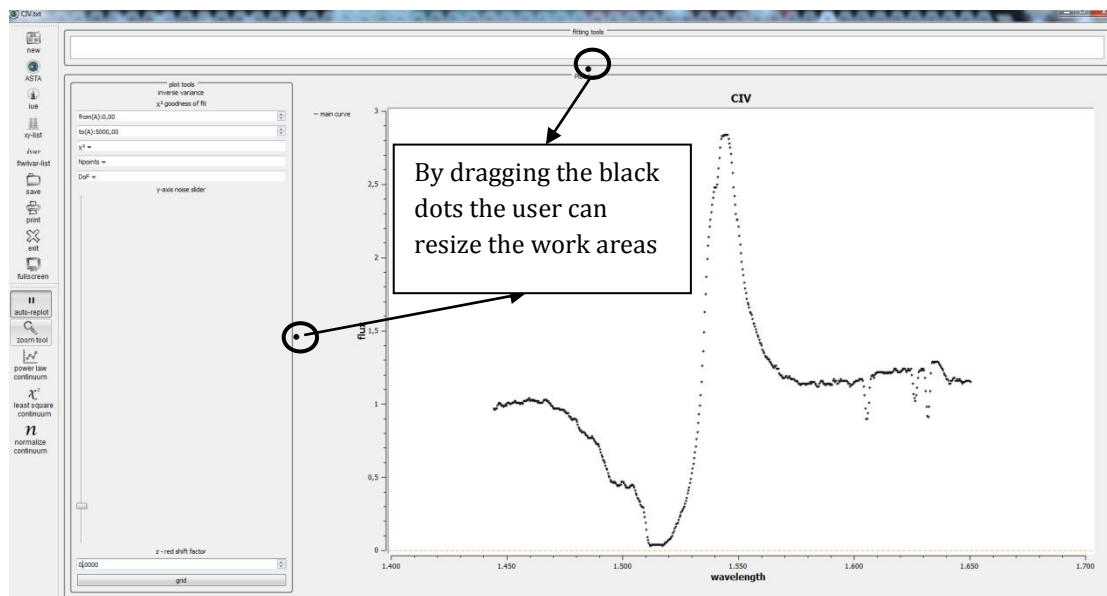


Figure 9a

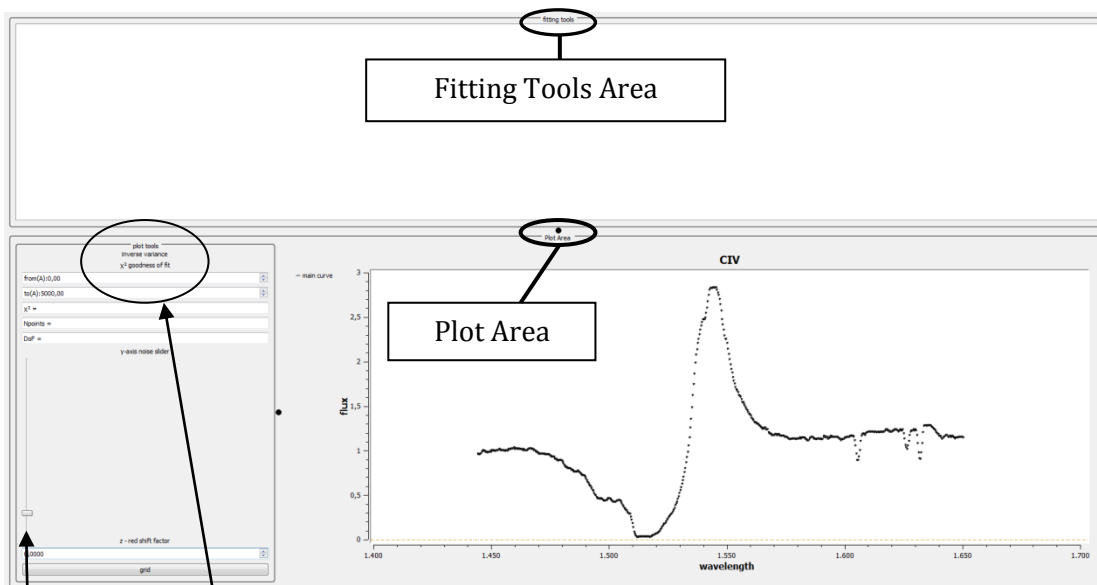


Figure 9b

- On the **left window** of the plot area there are the "*plot tools*": i) χ^2 goodness of fit, ii) y-axis noise slider, iii) z-redshift factor, iv) grid.
 - i) **χ^2 goodness of fit:** Every time the user changes a fitting parameter the new χ^2 is displayed (if the simulated spectrum is a txt file containing three columns i.e. wavelength-flux-inverse variance then the program performs a χ^2 test taking into account the inverse variance. If the simulated spectrum is a txt file containing only two columns, i.e. wavelength-flux, then the program performs a Pearson χ^2 test). The user can also select the wavelength region for which the test will be performed (see Fig 9c).
 - ii) **y-axis noise slider:** performs zoom-in or zoom-out in the y axis only.
 - iii) **z-redshift factor:** The user can insert the redshift of the astronomical body which is simultaneously removed.
 - iv) **grid:** The user can activate or deactivate the grid form the plot area.

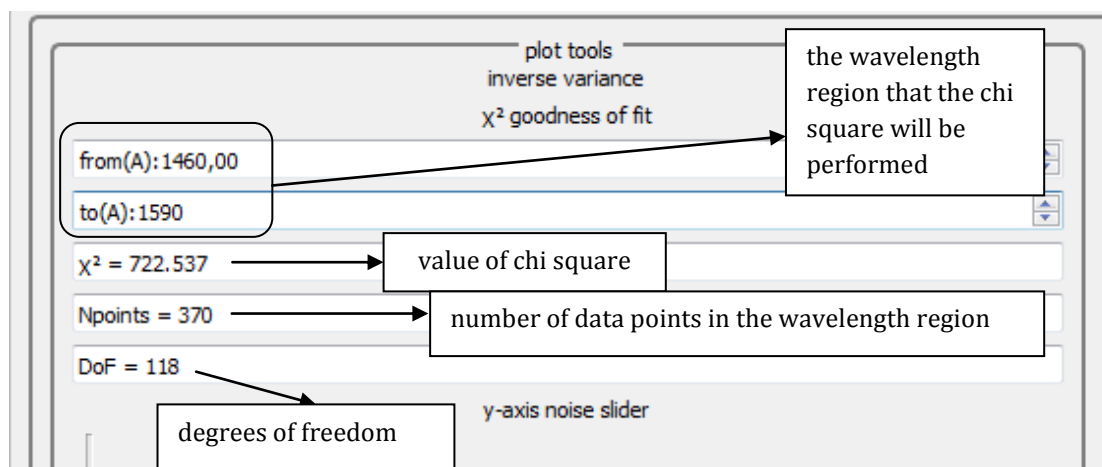


Figure 9c

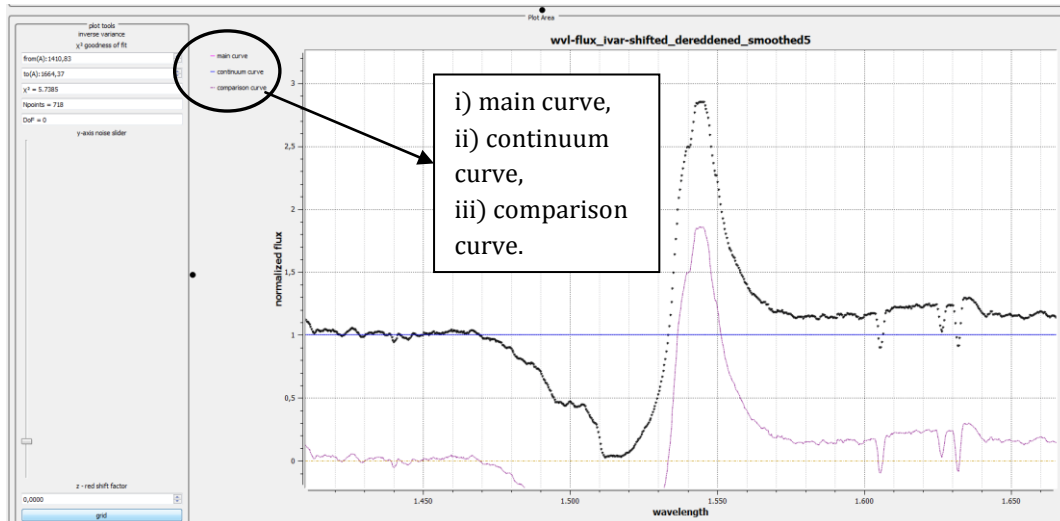


Figure 10

Example SDSS J114548.38+393746.6

We would like to fit Si IV and C IV broad emission and absorption lines of the BAL Quasar SDSS J114548.38+393746.6. The data of the observed spectrum (downloaded as a fits file from the SDSS DR 10 database) have been converted to an ascii file named "spectrum.txt" The txt file contains three columns separated by single spacing form one another. The three columns are wavelength-flux-ivar (ivar stands for inverse variance).

1. We go to horizontal toolbar and we select file->open wavelength/flux/ivar spectrum (see Fig. 11).

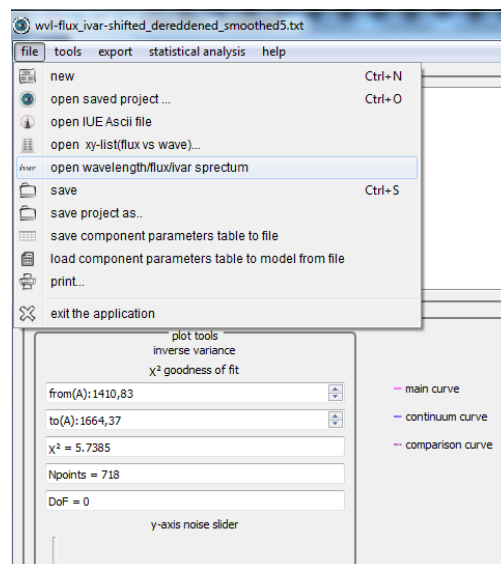


Figure 11

2. We navigate to the folder that contains the file "spectrum.txt" and we open it (see Fig. 12).
3. The redshift of the BAL Quasar is $z=2.56$. We put this value in the field "z-red shift factor" which can be found at the bottom of the plot tools window (see Figure 13). One the values is added the redhsift is removed and the redshifted spectrum is displayed.

- We pick the "power law continuum tool" and the corresponding window pops up. By holding left click and dragging we choose the wavelength regions which are free from strong lines from which the power law will pass (see Fig. 13a). By left clicking and dragging the wavelength windows are not determined accurately, so on the pop up window we click on the fields containing the wvl windows and we change them as we want (see Fig 13b). Then we choose λ_* and $F(\lambda_*)$ is calculated (see Fig 13c). We press "replot continuum curve" and the spectral index is calculated and the continuum curve is drawn (see Fig. 13d). After that we press the "normalize" button which is located on the vertical left toolbar and the spectrum becomes normalized (see Fig 13e).

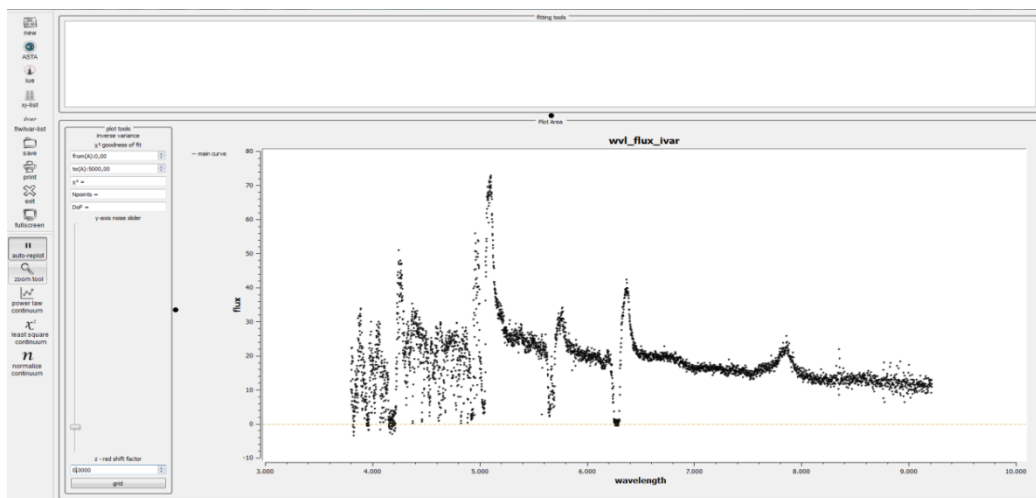


Figure 12

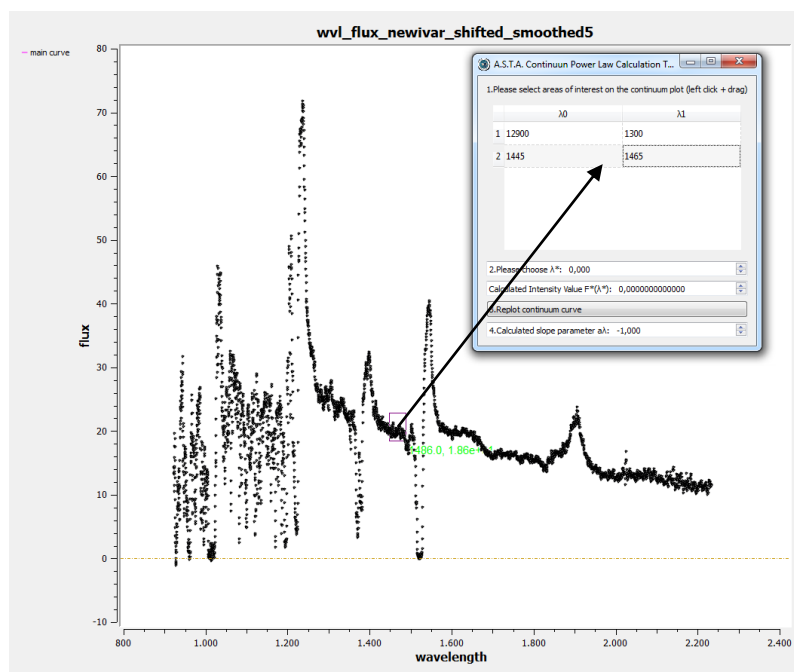


Figure 13a

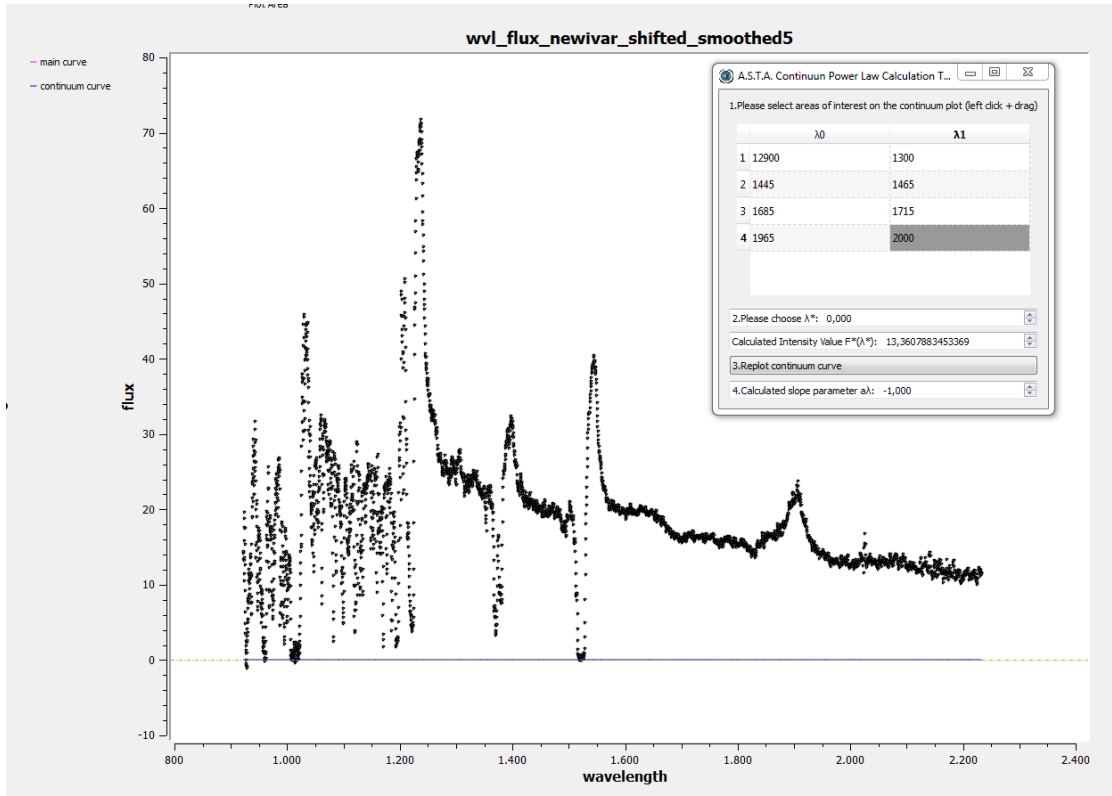


Figure 13b

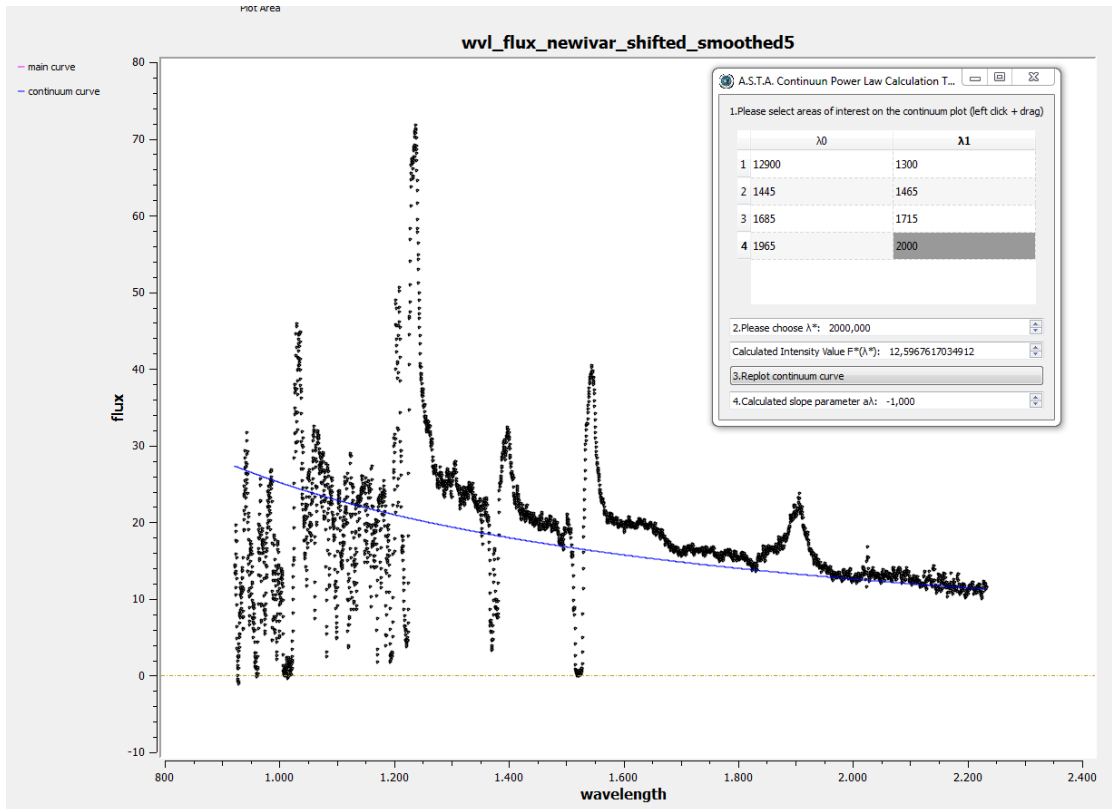


Figure 13c

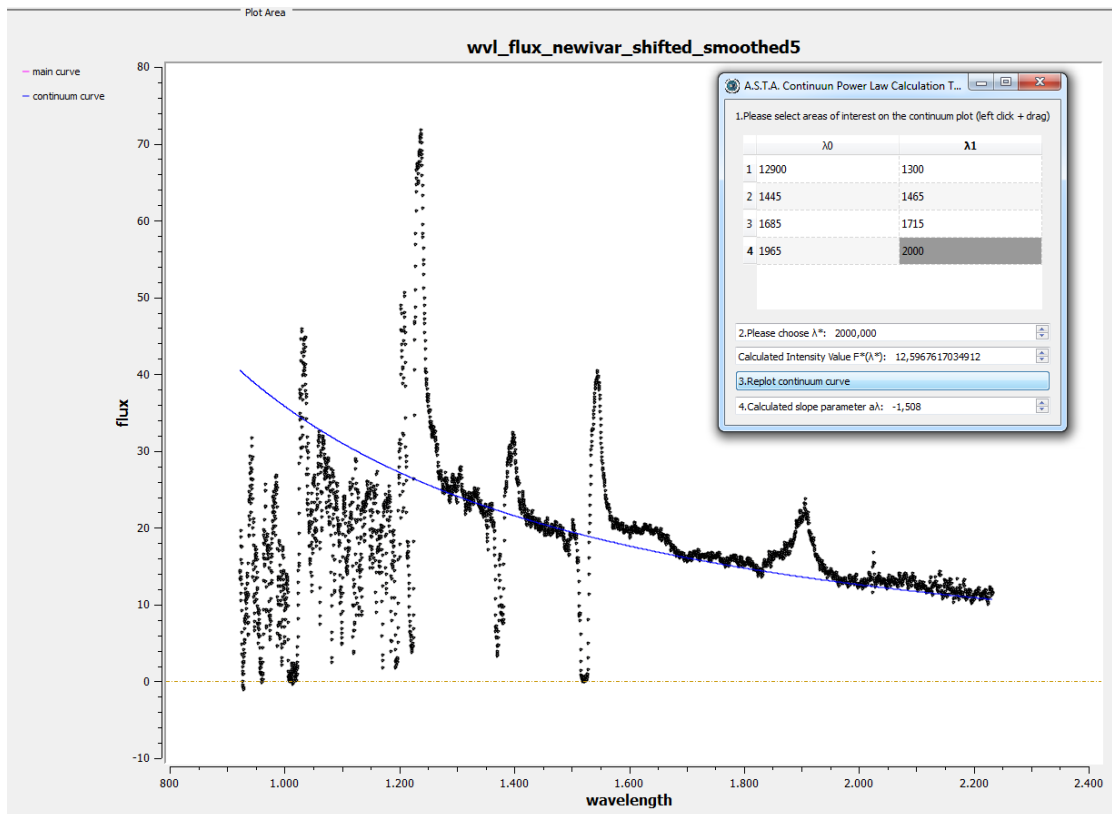


Figure 13d

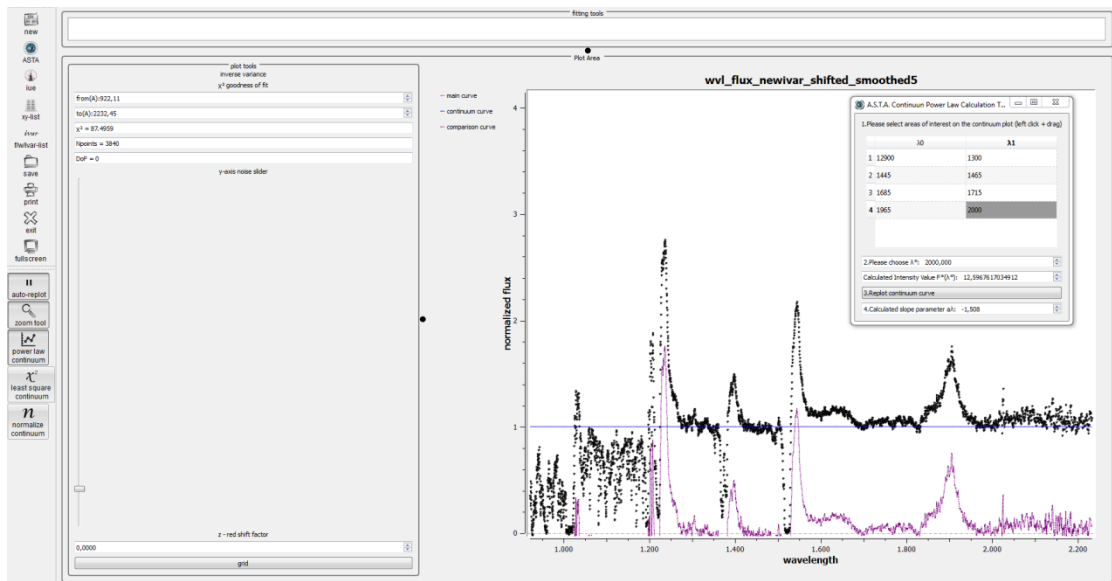


Figure 13e

5. We can also smooth the spectrum by using the moving average smoothing filter which can be found under tools-> apply moving average smoothing filter to spectrum. The new window pops up and in the field "Please select the number of moving points" we enter 5 points. (see Fig 14).

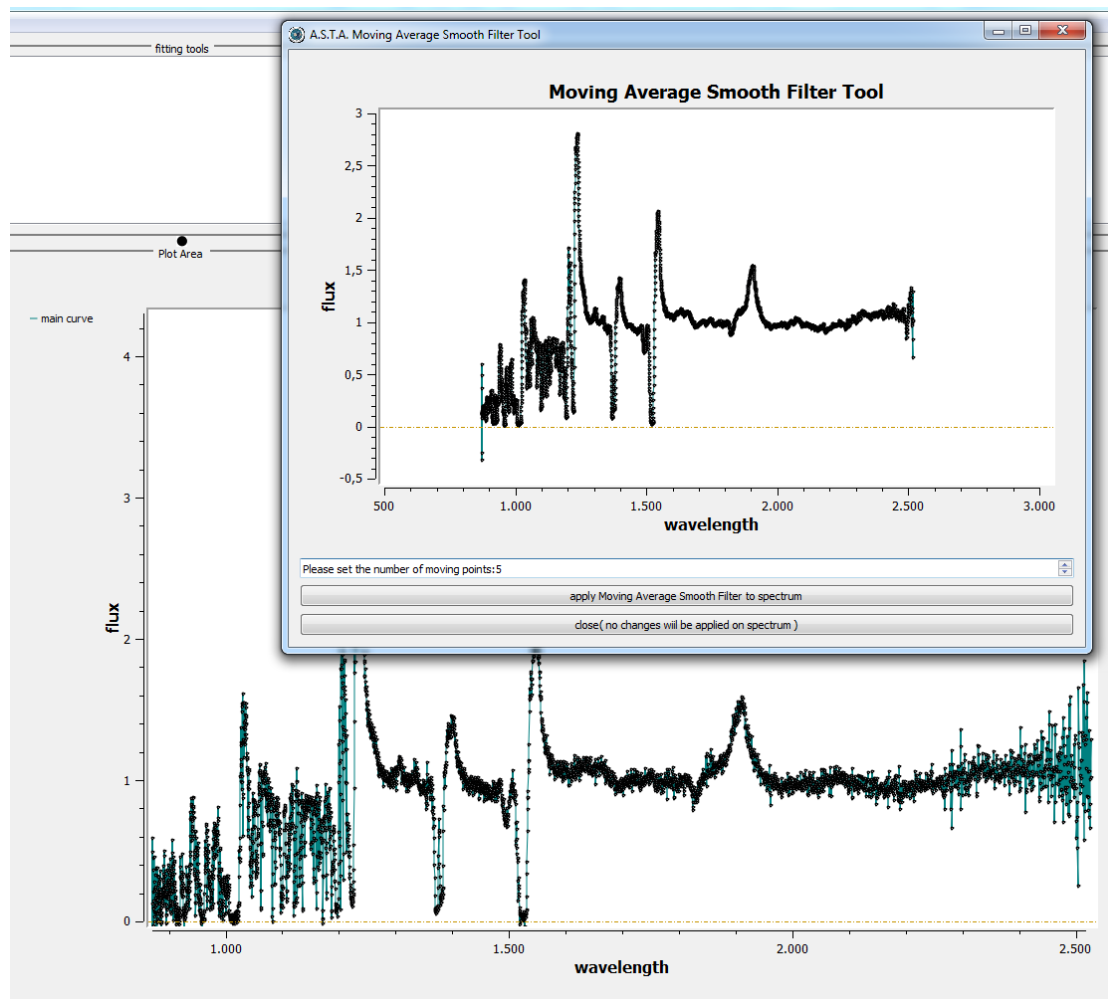


Figure 14

6. We can now export the normalized and smoothed spectrum to a txt file for any other use. We can also save our work as a .asta file by selecting "file-> save project as".

In general the software works smoothly in a limited wavelength region (e.g 300 Å). As the wavelength region gets larger, the software becomes slower. There are two ways we can cut a wavelength region.

- i) We can open the exported file we saved and delete the wavelength regions we don't want and then open the new file. When we open the new txt file, we can observe the normalized spectrum but not the normalized continuum curve. So we have to normalize the spectrum again (but now the continuum is a straight line at normalized flux=1). In order to do so we select the " x^2 least square continuum" tool from the vertical, left toolbar and we click inside the plot area on two point at normalized flux=1 (see Figs. 15a, b, c). After that we select "normalize" from the vertical toolbar and the spectral region of interest is normalized and we are ready to begin the fitting process.

ii) The user can cut the desired wavelength region and get rid of the unwanted data points by using the normalize button during the continuum fitting process. The process is as follows:

a) When performing a least squares continuum follow the steps: Select the least squares continuum by clicking on the button. Perform the process as described in page 12. Once the desired points are selected and the curve is drawn, click on the zoom tool button. Choose the desired region you want to cut. Deselect the zoom tool and press the normalize button. The normalized spectrum, cut in the desired region appears.

b) When performing a power law continuum fit follow the steps: Select the power law continuum by clicking on the corresponding button. Perform the process as described in pages 10-12. Before pressing the normalize button, deselect the power law continuum by clicking on the corresponding button. Click on the zoom tool and choose the region you want to cut. Deselect the zoom tool and select the power law continuum tool. Press normalize and you have the desired region normalized.

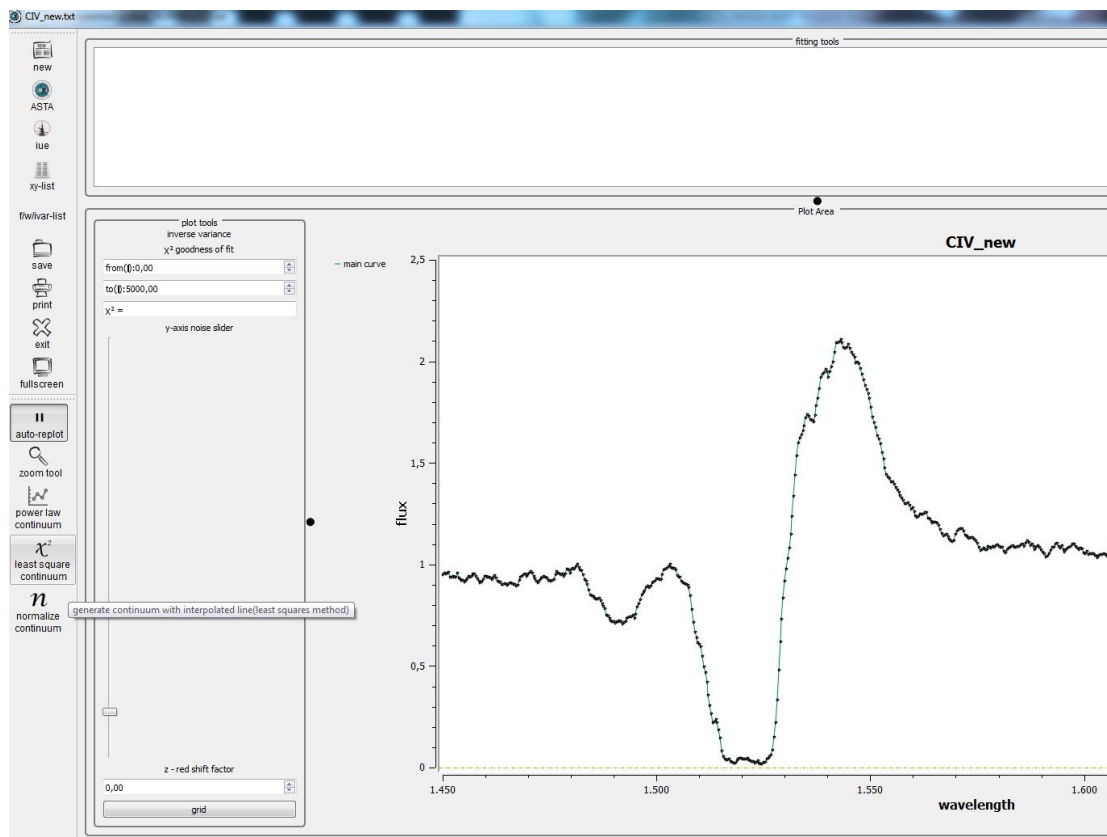


Figure 15a

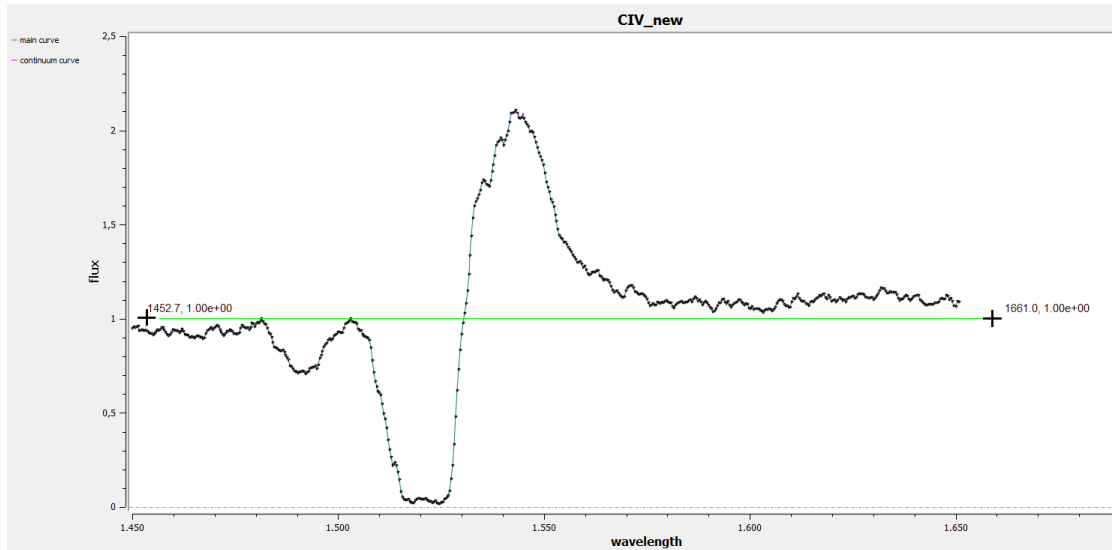


Figure 15b

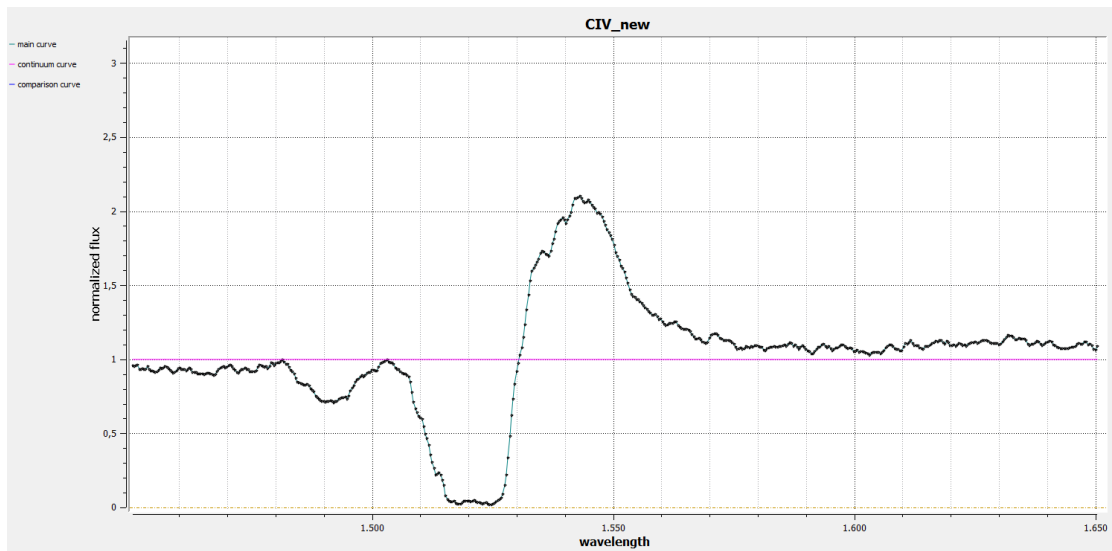


Figure 15c (Normalized C IV spectral region from 1450-1650 Å)

- Fitting Process:** For the fitting process we are going to use the "fitting tools" (see Fig. 16). The most prominent ions in the wavelength region 1450-1700 Å are the C IV resonance lines ($\lambda\lambda$ 1548.187, 1550.772 Å) and He II (λ 1640.4 Å). The C IV resonance lines are considered as two individual lines. We go to the horizontal toolbar and select: *tools->new model set*. Then a window pops up asking: "*please specify the name of the new set*". We add "*CIV_blue*" (blue stands for the λ 1548.187 Å line). Then the first line is inserted in the fitting tools area. We now want to add a set for the 1550.772 Å line so we go *tools->new model set* and to the pop up window we right *C IV_red* and a new set is added to the fitting tools area. Finally we go once again to *tools->new model set* and in the pop up window we write HeII, and the He II model set appears in the fitting tools area (see Fig. 17a). In the fitting tools area we can now see three different tabs: CIV_blue, CIV_red and HeII (see Fig. 17b).

IMPORTANT!!! Any new line corresponds to a new SET.

We move to the first set (CIV_blue) which means in the first tab, where we can observe the following fields:

- **insert ion:** we set the name of the of the ion (in our case CIVb)
- **action:** we select between absorption and emission
- **type:** we select between five different distributions i.e. Gauss, Rotation, Voigt, Gauss-Rotation, Lorentz
- **status:** we can select to activate or deactivate the component
- **Vrot:** Assuming that the broadening of a spectral line is due to rotation the user can choose the value of Vrot in km/s. Vrot is available only for distributions Rotation and Gauss-Rotation.
- **σ : Gauss-Voigt-GR:** The user can input the value of σ (standard deviation). The parameter σ is available only for distributions Gauss, Gauss-Rotation, Voigt
- **γ : Lorentz-Voigt:** The user can input the value of γ which is the scale parameter of the Lorentz (Cauchy) distribution. γ is available only for Lorentz and Voigt (Guass+Lorentz) distributions
- **ξ :** the optical depth at line center
- **S:emit:** is the Source Function (for emission lines only)
- **$\Delta\lambda_{rad}$:** displacement of a component form the laboratory wavelength (negative for blueshift, positive for redshift)
- **λ_{lab} :** laboratory wavelength
- **A.W.:** Atomic Weight
- **E_i :** ionization energy

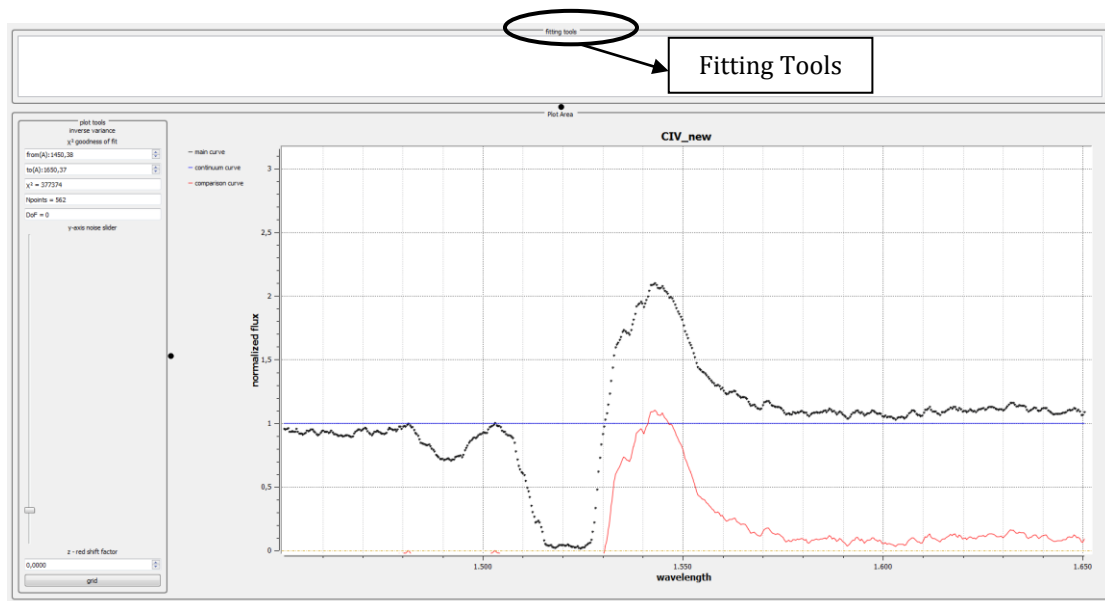


Figure 16

1. We begin by filling in the above fields for the first Set (C IV_blue):

- insert ion: CIVb
 - action: emission
 - type: Voigt
 - status: inactive (until we fill in all the other fields)
 - Vrot: because we have chosen Voigt distribution we do not fill in this field
 - σ : we set $\sigma=2$ (arbitrary value)
 - γ : we set $\gamma=2$ (arbitrary value)
 - ξ : we set $\xi=1$ (arbitrary value)
 - S_emit: we set S= 1 (arbitrary value)
 - $\Delta\lambda_{rad}$: we set $\Delta\lambda_{rad} = 0$ (initially we assume that the component is not displaced from the laboratory wavelength)
 - λ_{lab} : for the CIVb component we set $\lambda_{lab} = 1548.187 \text{ \AA}$
 - A.W.: 12.0107
 - E_i : 64.4939
 - Finally, in action field we select activate and the spectral line appears in the plot area (see Fig. 18).
2. We move on to the second Set (CIV_red) and we fill in the required fields:
- insert ion: CIVr
 - action: emission
 - type: Voigt
 - status: inactive (until we fill in all the other fields)
 - Vrot: because we have chosen Voigt distribution we do not fill in this field
 - σ : we set $\sigma=2$ (arbitrary value)
 - γ : we set $\gamma=2$ (arbitrary value)
 - ξ : we set $\xi=1$ (arbitrary value)
 - S_emit: we set S= 0,5 (arbitrary value)
 - $\Delta\lambda_{rad}$: we set $\Delta\lambda_{rad} = 0$ (initially we assume that the component is not displaced from the laboratory wavelength)
 - λ_{lab} : for the CIVb component we set $\lambda_{lab} = 1550.772 \text{ \AA}$
 - A.W.: 12.0107
 - E_i : 64.4939
 - Finally, in action field we select activate and the synthesis of spectral components (CIV_blue synthesized with CIV_red) appears in the plot area (see Fig. 19).
3. By manipulating the values of the parameters σ , γ , ξ , S, $\Delta\lambda_{rad}$ we try to simulate the C IV broad emission. If we are not satisfied with the fit (as given by the x^2) we can add one more component to the fit.
4. We move to the First Set (the first set represents the 1548.187 \AA line which can be of multicomponent nature, so under the first set we add all the 1548.187 components) by clicking on the CIV_blue tab. Once in the first set

we click on the button which is exactly under the CIV_blue tab and above number 1 (see Fig. 20a) and a new component is added (see Fig. 20b). We do the same thing for the CIV_red Set. Again we choose the values of the parameters and we activate the components and the synthesis appears on the plot area (see Fig. 21).

5. We can also move to the He II tab and try to fit He II. Following the same procedure as above we choose the corresponding parameters for the He II emission line. The final fit is shown in Fig. 22.

6. The next step is the broad absorption of C IV. We move on to the CIV_blue Set and we add a new component by pressing the button shown in Figs. 20a, b. We do the same for the CIV_red Set (see Fig. 23). We fill in the required fields as follows:

- insert ion: CIVb
 - action: absorption
 - type: Gauss
 - status: inactive (until we fill in all the other fields)
 - Vrot: because we have chosen Gauss distribution we do not fill in this field
 - σ : we set $\sigma=3$ (arbitrary value)
 - γ : because we have chosen Gauss distribution we do not fill in this field
 - ξ : we set $\xi=0.53$ (arbitrary value)
 - S_emit: because we have chosen absorption we do not need to fill in this field
 - $\Delta\lambda_{rad}$: we set $\Delta\lambda_{rad} = 0$ (initially we assume that the component is not displaced from the laboratory wavelength)
 - λ_{lab} : for the CIVb component we set $\lambda_{lab} = 1548.187 \text{ \AA}$
 - A.W.: 12.0107
 - E_i : 64.4939
 - Finally, in action field we select activate and the spectral line appears in the plot area
-
- insert ion: CIVr
 - action: absorption
 - type: Gauss
 - status: inactive (until we fill in all the other fields)
 - Vrot: because we have chosen Gauss distribution we do not fill in this field
 - σ : we set $\sigma=3$ (arbitrary value)
 - γ : because we have chosen Gauss distribution we do not fill in this field
 - ξ : we set $\xi=0.52$ (arbitrary value)
 - S_emit: because we have chosen absorption we do not need to fill in this field
 - $\Delta\lambda_{rad}$: we set $\Delta\lambda_{rad} = 0$ (initially we assume that the component is not displaced from the laboratory wavelength)

- λ_{lab} : for the CIVr component we set $\lambda_{lab} = 1550.772 \text{ \AA}$
- A.W.: 12.0107
- E_i : 64.4939
- Finally, in action field we select activate and the spectral line appears in the plot area

By manipulating the values of parameters of the absorption components we try to achieve the best fit. The synthesis of all components from all sets is shown in Fig. 23. We can keep on adding components and trying to fit the whole absorption trough. **The number of components and the fitting process depends on the user, who can use χ^2 , F-test and SSE tests in order to conclude to the best fit. The method our team proposed for fitting the broad absorption components of C IV and Si IV and guarantee the uniqueness of the fit can be found in Stathopoulos, D. et al. [2015JApA...36..495S](#).**

In Fig. 24 one can also see the individual component that compose the whole profiles of C IV and Si IV (the best fit of both ions has been obtained by using the criteria of Stathopoulos, D. et al. [2015JApA...36..495S](#)). The user can export all the individual components by selecting: "*export->export separately all component line points to 2 column txt files*". The best fit can be exported by selecting: "*export-> export model line points to a single 2 column txt file*". Now the user can plot the best fit along with the individual components, but using another software. Finally the user can export all results to an html file by selecting: "*export-> export results to HTML*". The exported file, when opened in any browser will look like Fig. 25.

-Tip 1. *Every time the user changes a value of a parameter it takes some seconds for the program to respond. So, if the user wants to change the values of more than one parameter he/she can use the "auto-replot" button which can be found in the vertical toolbar. Once the button is pressed, the user can change the values of as many parameters he/she wants without having to wait for the program to respond as all the calculation are paused. Once the user un-pauses, it takes some second for the program to do the calculations due to all the changes and produce the new fit.*

-Tip 2. *When the user double clicks on the button that holds the number of the component the whole row is deleted (see Fig. 17b).*

-Tip 3. *By clicking inside the square box at the left of the name of each set, the user can deactivate and activate the whole Set (see Fig 17b).*

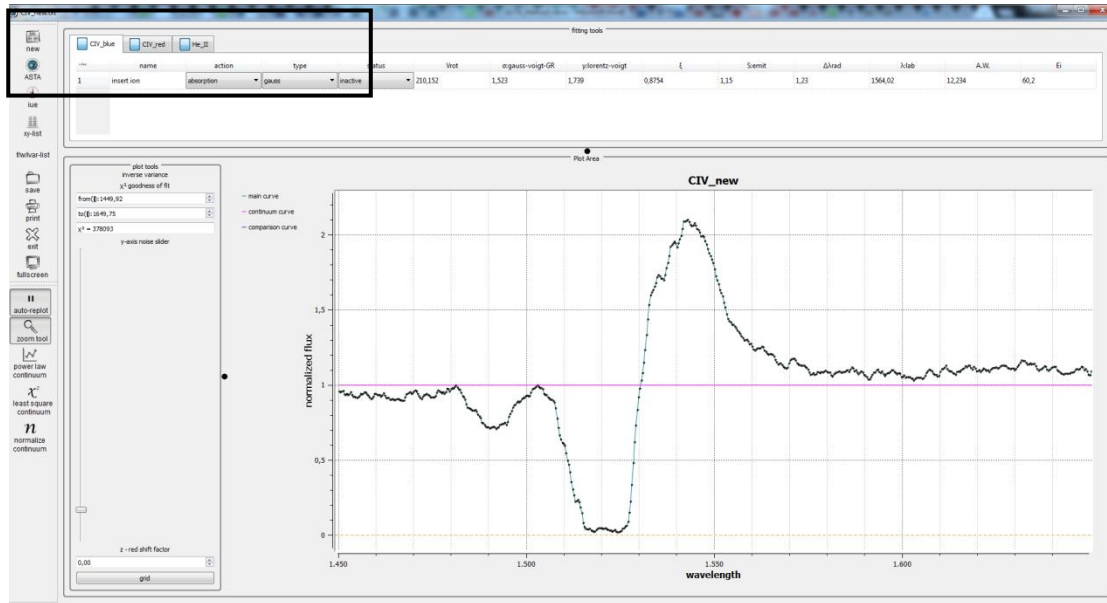


Figure 17a

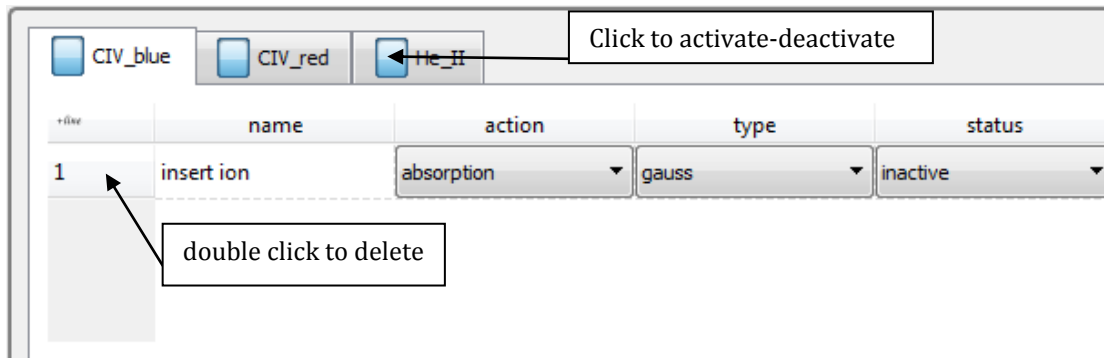


Figure 17b

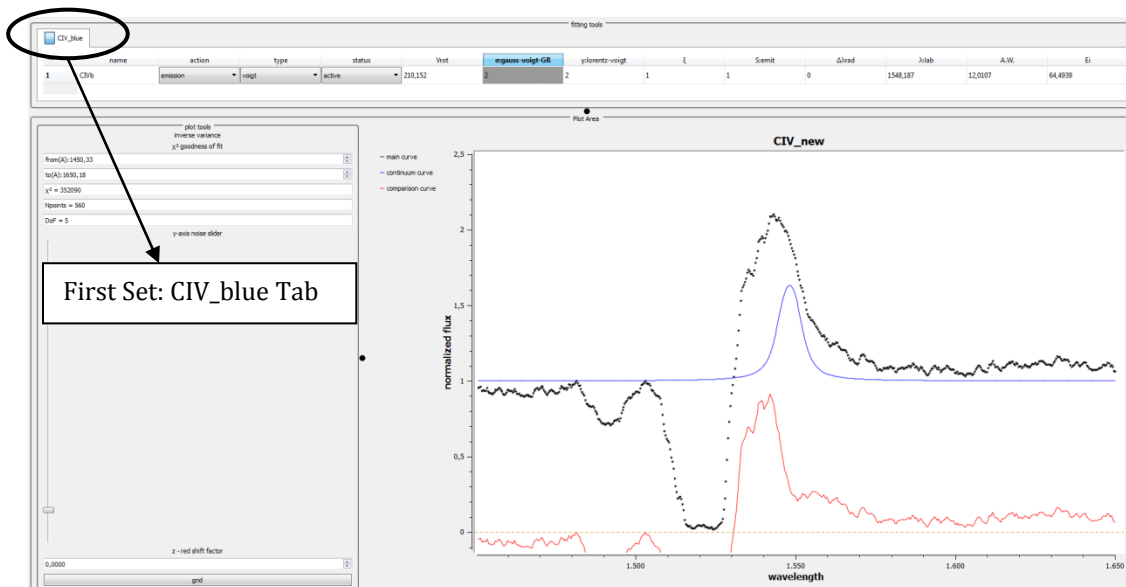


Figure 18

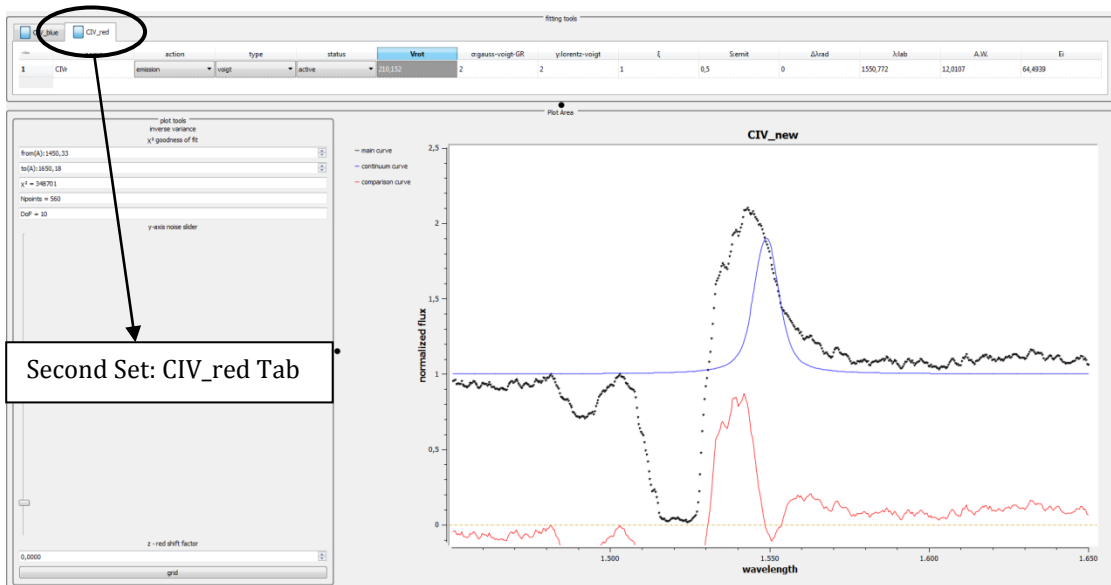


Figure 19

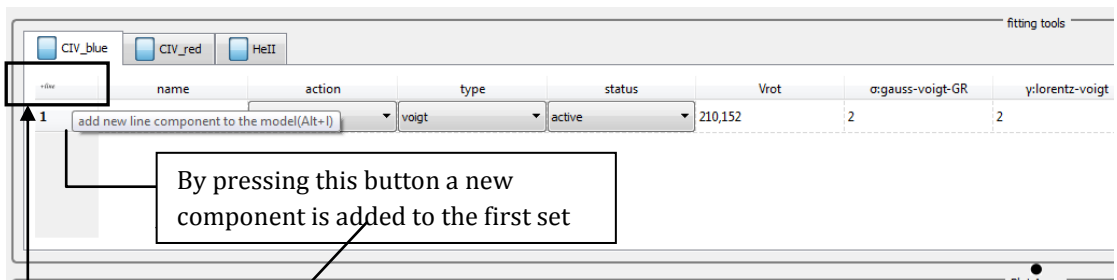


Figure 20a

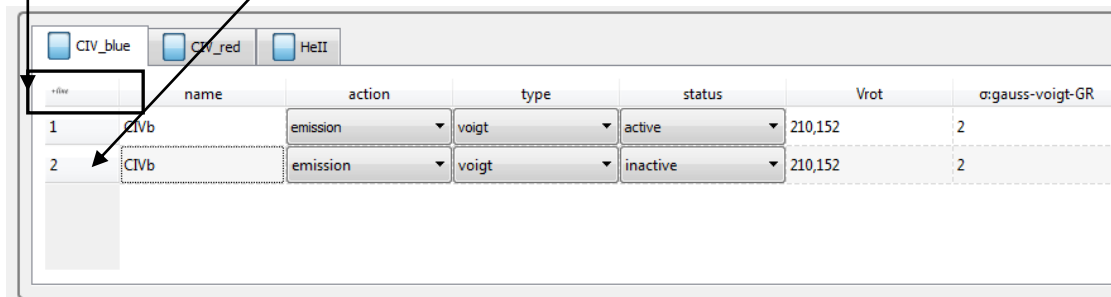


Figure 20b

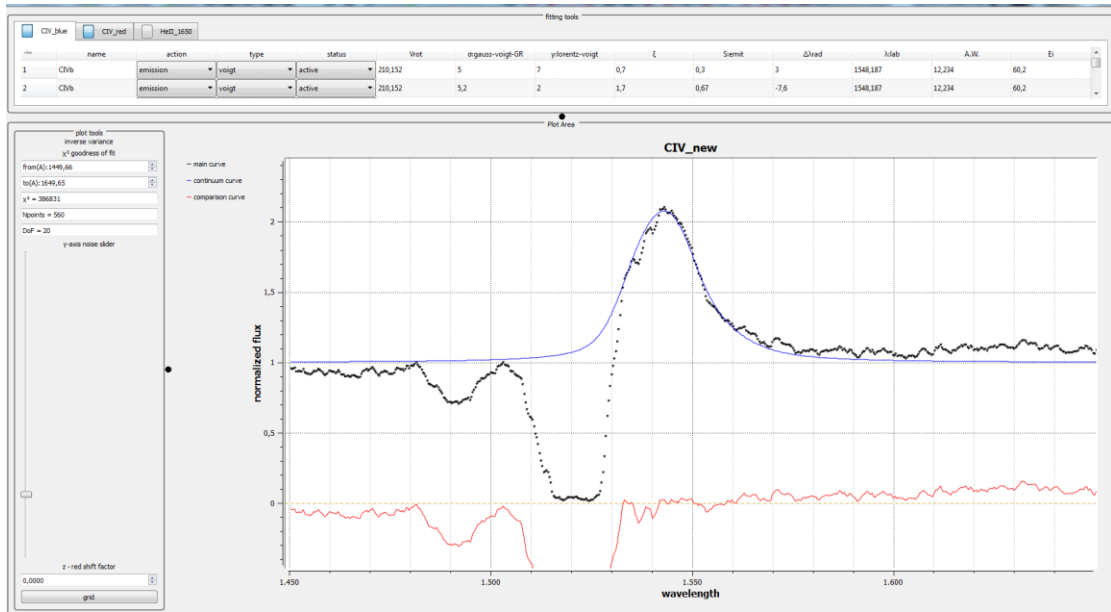


Figure 21

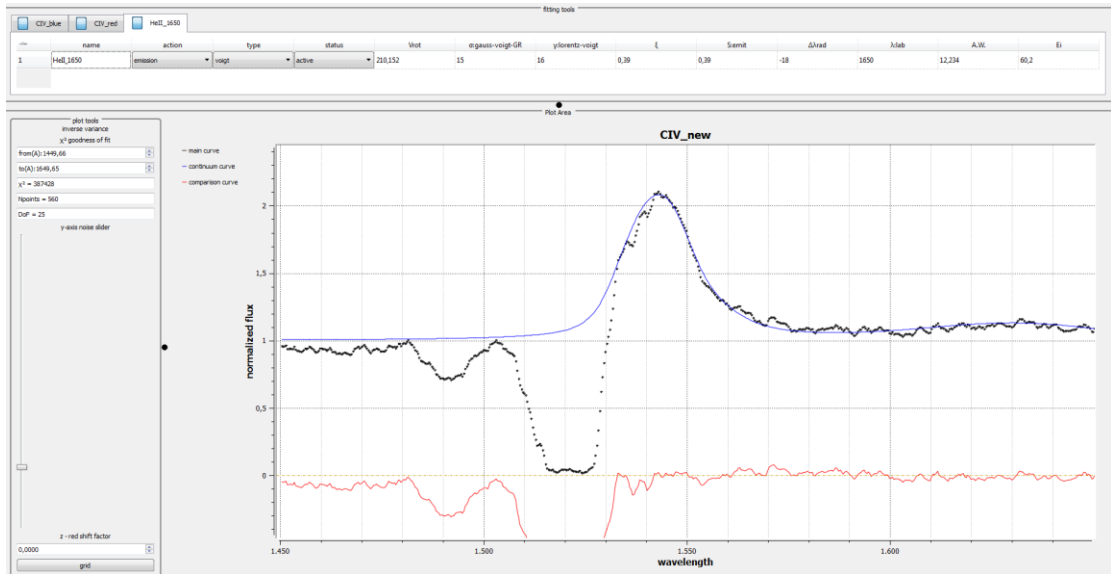


Figure 22

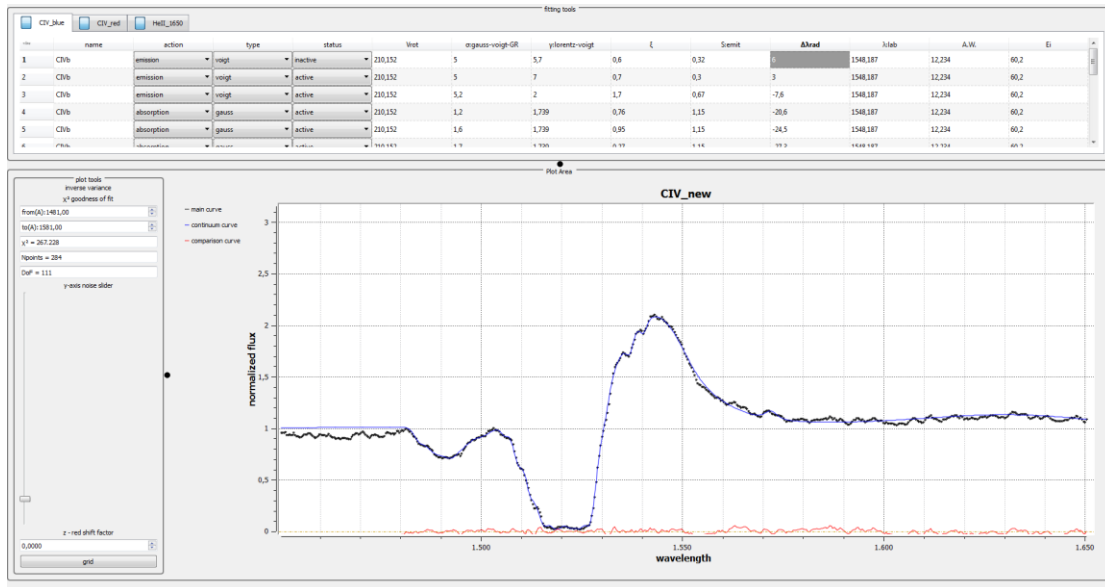


Figure 23

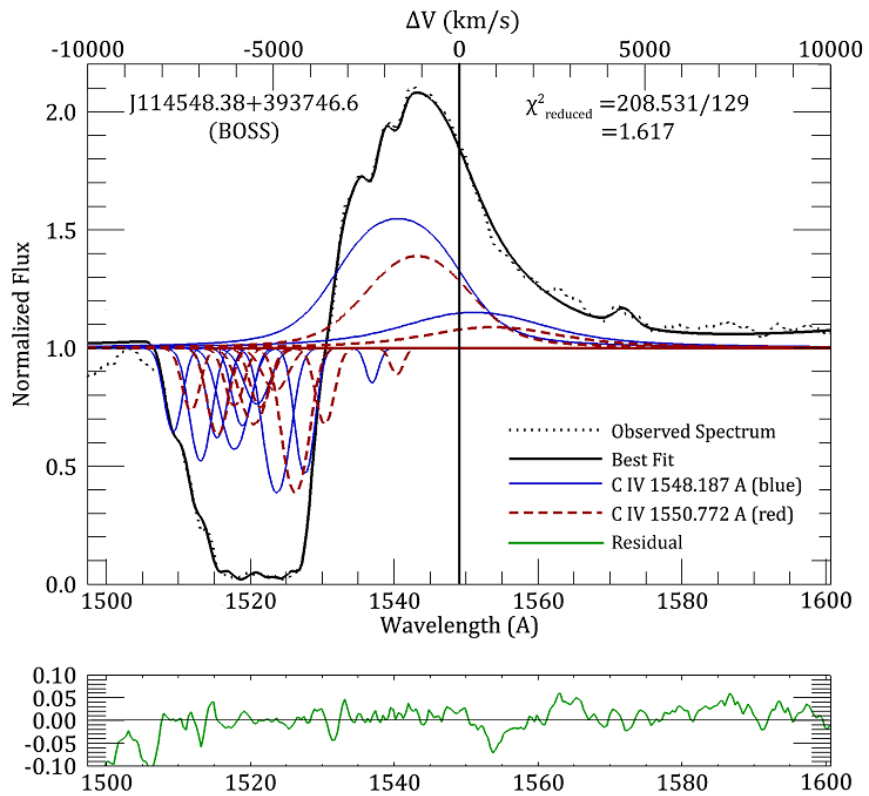
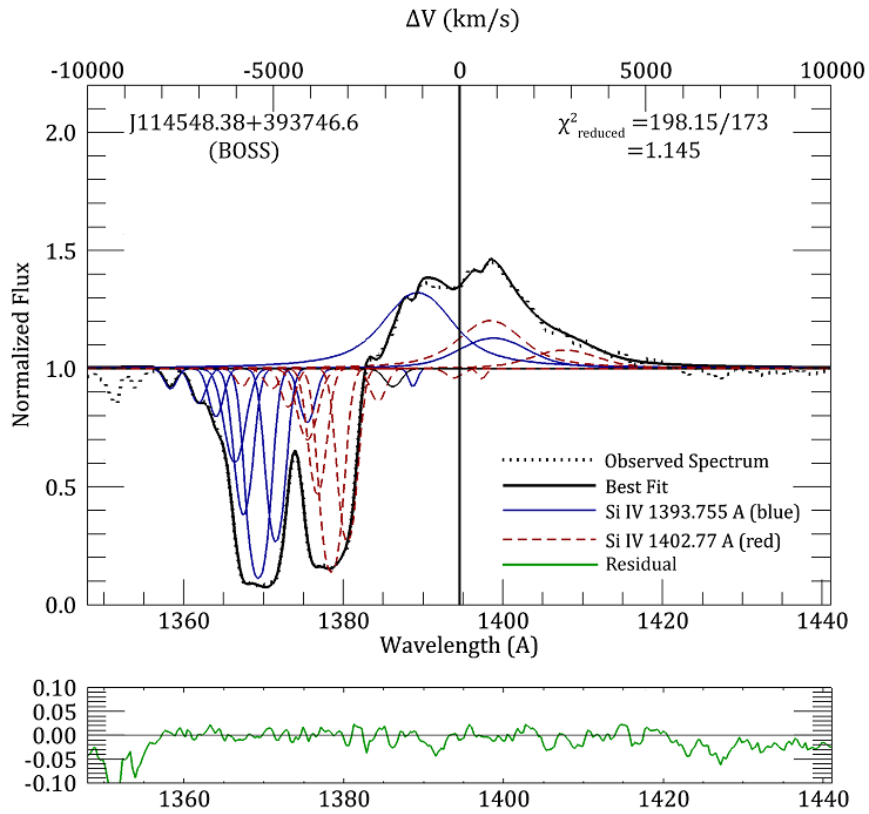


Figure 24

component	action	type	$\Delta\lambda_{width}$	V_{rot}	σ	γ	ξ	$S_{emission}$	τ	$\Delta\lambda_{rad}$	λ_0	FWHM	V_{radial}	V_{random}	$E_{ab/em}$	col. density	%
CIVb	emission	voigt	199.99	X	5	7	0.7	0.3	0.21	3	1551.19	24.186	581.325	1138.56	4.84047	4.10774e+09	TBA
CIVb	emission	voigt	199.99	X	5.2	2	1.7	0.67	1.139	-7.6	1540.59	19.266	-1472.69	1192.25	12.2796	1.04207e+10	TBA
CIVb	absorption	gauss	8.78992	X	1.2	X	0.76	X	X	-20.6	1527.59	2.82578	-3991.77	277.475	1.78047	1.51095e+09	TBA
CIVb	absorption	gauss	11.9299	X	1.6	X	0.95	X	X	-24.5	1523.69	3.76771	-4747.49	370.914	2.80327	2.37892e+09	TBA
CIVb	absorption	gauss	11.5601	X	1.7	X	0.27	X	X	-27.3	1520.89	4.00319	-5290.06	394.822	1.04834	8.89646e+08	TBA
CIVb	absorption	gauss	9.09998	X	1.3	X	0.4	X	X	-29.3	1518.89	3.06127	-5677.61	302.32	1.13757	9.65371e+08	TBA
CIVb	absorption	gauss	12.9299	X	1.8	X	0.56	X	X	-30.4	1517.79	4.23868	-5890.76	418.9	2.09428	1.77726e+09	TBA
CIVb	absorption	gauss	8.71997	X	1.25	X	0.48	X	X	-32.8	1515.39	2.94353	-6355.82	291.364	1.2789	1.0853e+09	TBA
CIVb	absorption	gauss	9.75	X	1.35	X	0.65	X	X	-35.1	1513.09	3.17901	-6801.5	315.151	1.77226	1.50398e+09	TBA
CIVb	absorption	gauss	8	X	1.15	X	0.44	X	X	-38.9	1509.29	2.70804	-7537.85	269.138	1.09259	9.27198e+08	TBA
CIVb	absorption	gauss	5.30994	X	0.85	X	0.16	X	X	-11.25	1536.94	2.0016	-2179.97	195.349	0.322433	2.73625e+08	TBA

Figure 25

- column 1: component name
- column 2: emission/absorption
- type: distribution used
- $\Delta\lambda_{width}$: Full Width at Zero Intensity (FWZI)
- V_{rot} : value of rotational velocity
- σ : standard deviation
- γ : scale parameter
- ξ : optical depth at line center
- $S_{emission}$: source function
- τ : the product $S_{emission} \times \xi$
- $\Delta\lambda_{rad}$: displacement of a component from the laboratory wavelength
- FWHM: Full Width at Half Maximum
- V_{radial} : radial velocity of the corresponding component (calculated using the non relativistic Doppler formula. The user can use the relativistic Doppler formula and the value of $\Delta\lambda_{rad}$ to calculate the radial velocity when necessary).
- V_{random} : random velocities of ions
- $E_{ab/em}$: Equivalent Width of the corresponding emission or absorption component
- col. density: column density

ASTA software is built for multicomponent analysis of complex and very broad absorption and emission lines. However, this doesn't mean that simple and classical spectral lines cannot be treated (see Example below in the case of Narrow Absorption Lines). On the contrary the simplest the spectral line the easier for the software to simulate it.

We assume that the C IV broad, absorption and emission is of multicomponent nature

Narrow Absorption Lines

We give another example but now in the case of usual absorption lines. The Quasar under study is SDSS J00027.01+030715.5.

In the case of C IV doublet we have used two components i.e. CIV_blue line (first Set) is composed of two components, CIV_red line (second Set) is composed of

two components. See Figure 26 for more details. Check also the χ^2 value ($\chi^2 = 7.86502$). The degrees of freedom for this fit are 6 (19 data points minus 12 free parameters minus 1). The reduced chi-square is $\chi_{red}^2 = 7.86502/6 = 1.3108$.

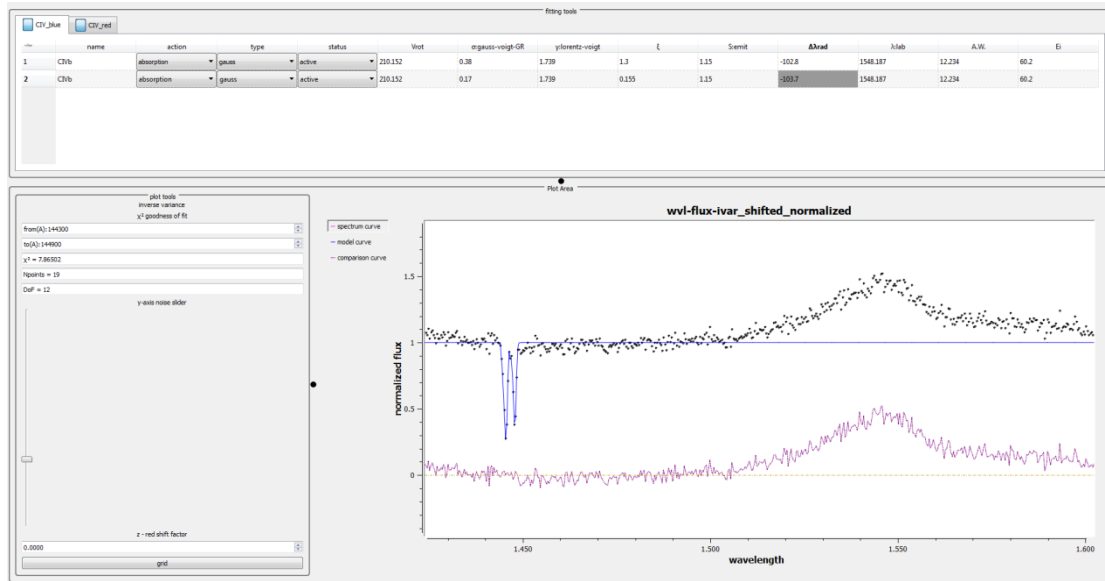


Figure 26