X-Windows Programs that can be used with SPECTRUM v2.76

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1 Introduction

In this documentation we will cover the use of three X-windows programs that have been designed to operate closely with SPECTRUM. The three programs are `analysis9`, which is a graphical front-end to SPECTRUM which allows the user to easily change abundances and various other parameters and to see their effects in the spectrum, `xmk25`, a general spectrum-plotting program for the visualization of synthetic spectra, spectral classification, and rudimentary equivalent width measurement, and `xeqw3`, a graphical program that enables the easy fitting of line profiles and the calculation of equivalent widths. We briefly describe each program below.

2 Quick Install

All of the programs described in this document have been bundled together into a single tar file, `Xspectrum.tar.gz`. This should be unpacked:

```
tar -xvzf Xspectrum.tar.gz
```

This will create a new directory, `Xspectrum`. The programs `xmk25` and `xeqw3` can be compiled with the single command:

```
make all
```

and then the programs (including `analysis9`) can be installed into `/usr/local/bin` with the command:

```
make install
```

These programs are X-Windows programs which means they can only be compiled if your have the X-Windows development libraries installed on your computer. The X Windows development libraries are included under `xorg-dev` and can be installed using `apt-get` or the graphical package management program `synaptics`. In addition, the program `analysis9` requires the TCL/TK libraries to be installed on your computer.

If you desire these programs to be installed in some other directory instead of `/usr/local/bin` then you must edit the file `Makefile` and replace the line

```
LOCALBIN = /usr/local/bin
```

with the appropriate directory.

3 Analysis9

The program `analysis9` is a graphical front end to SPECTRUM that enables the user to easily change abundances and various other parameters to analyze an observed spectrum. This program must be used in conjunction with the program `xmk25` (it calls `xmk25`). It uses the Tcl/TK language, and so that package must be loaded on your computer. The program can be installed on your computer by copying `analysis9.tcl` to your `bin` directory (usually `/usr/local/bin`). Please ascertain first whether your copy of analysis9.tcl has executable permissions. If it does not, they can be given using the command `chmod a+x analysis9.tcl` in the directory where the program resides.

The graphical interface appears in Figure 1, and is invoked by typing `analysis9.tcl` at the terminal prompt. The usage of `analysis9` is straightforward. Starting at the top of the GUI, an observed spectrum (the one being analyzed) is input with the "Input Observed Spectrum" Button. That spectrum should be in ascii format, with wavelength in the first column and rectified flux in the second. The delimiter should be a space.

The next set of buttons allows entry of the various inputs required by SPECTRUM. Reference should be made to the documentation for that program. Note that if you are using a line list that is in the isotope format, the isotope switch *must* be checked. Also, if the stellar atmosphere model is an Atlas9 or Atlas12 model, check the Atlas9 box.

The computation parameters allow entry of the spectral range of the synthetic spectrum, the computation spacing, and the microturbulent velocity. The remaining computation entries refer to the application of macroturbulent velocity broadening, rotational broadening and smoothing (convolution with a line-spread function). These are applied with a number of SPECTRUM auxiliary programs that are called by analysis9. For more information on these programs, please see the documentation for SPECTRUM.

The first few times you run analysis9 on a given spectrum, you should do it with "Test" selected. Running `analysis9` will compute the spectrum with the selected parameters and then plot it on top of the observed spectrum using xmk25. Running in this mode allows you to adjust the computational parameters (rotational velocity, smoothing, etc.) until you get as close as possible a match between the computed line profiles and the observed line profiles. This will also help you to select the correct metallicity for the atmosphere model to give the best fit with the line strengths in the observed spectrum. It is presumed that you have determined the correct effective temperature and $\log g$ for you star beforehand.

Once you are satisfied with the computational parameters, you may now select "Vary" and use the boxes below to vary the abundances of up to four different elements simultaneously. To vary the abundance of a given element enter for the "Code" its atomic number (for instance, Ca is 20 – don't enter with a decimal point). Then enter the beginning abundance ("0" will give you the default abundance for that element from the atomic data file (`stdatom.dat`) scaled by the metallicity ([M/H]) of the model. A step of 0.1 will then compute spectra with abundances of +0.0, +0.1, +0.2, and +0.3 above the beginning abundance. The step can be negative as well as positive. `analysis9` will compute spectra with those abundances, and then plot them on top of the observed spectrum with different colors. You will be able to see the effects of differing abundances on the line spectrum.

Once you have determined the "best" abundances for the elements in question, select "Best" and enter those values into the boxes below. This will allow the computation of a single spectrum with those optimal elemental abundances.

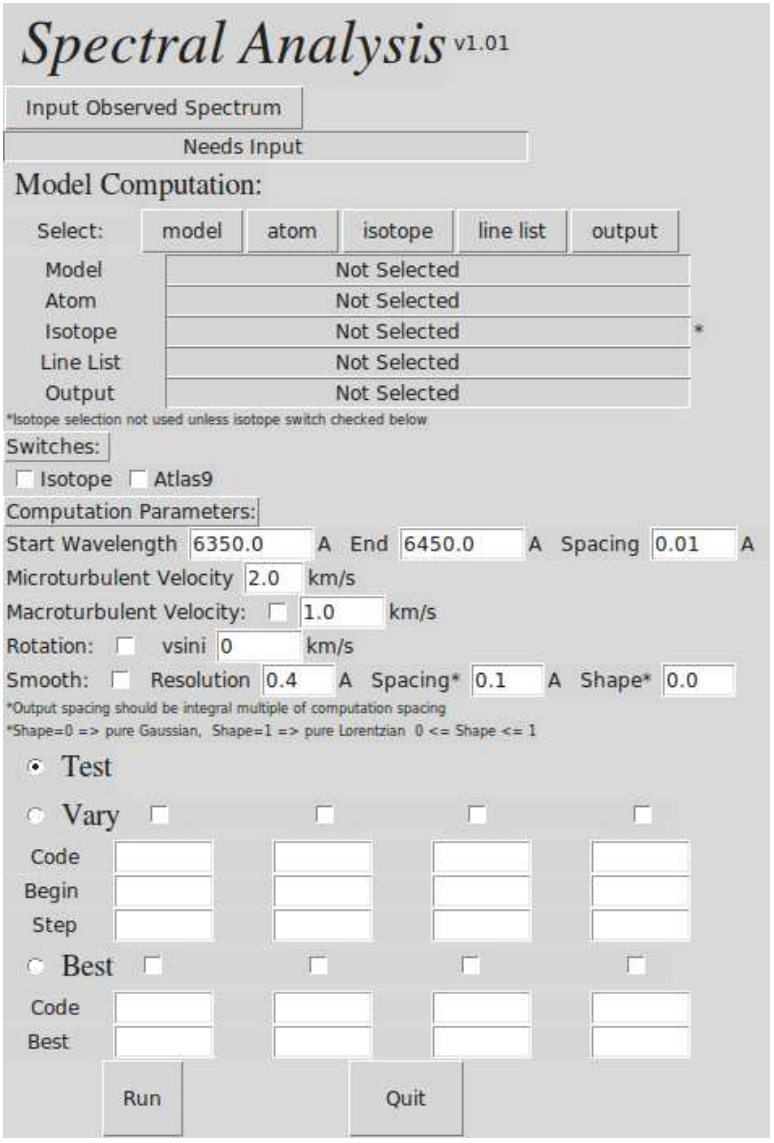

Figure 1: The `analysis9` graphical front end to SPECTRUM

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4 Xmk25

The program `xmk25` is a simple X-Windows-based spectral plotting program designed for use in spectral classification on Linux and UNIX platforms. `xmk25` is distributed as a tarred gzipped file of sources which must be compiled with a "C" compiler such as gcc.

4.1 Compiling and Installing xmk25

To compile `xmk25` on your machine, see §2.

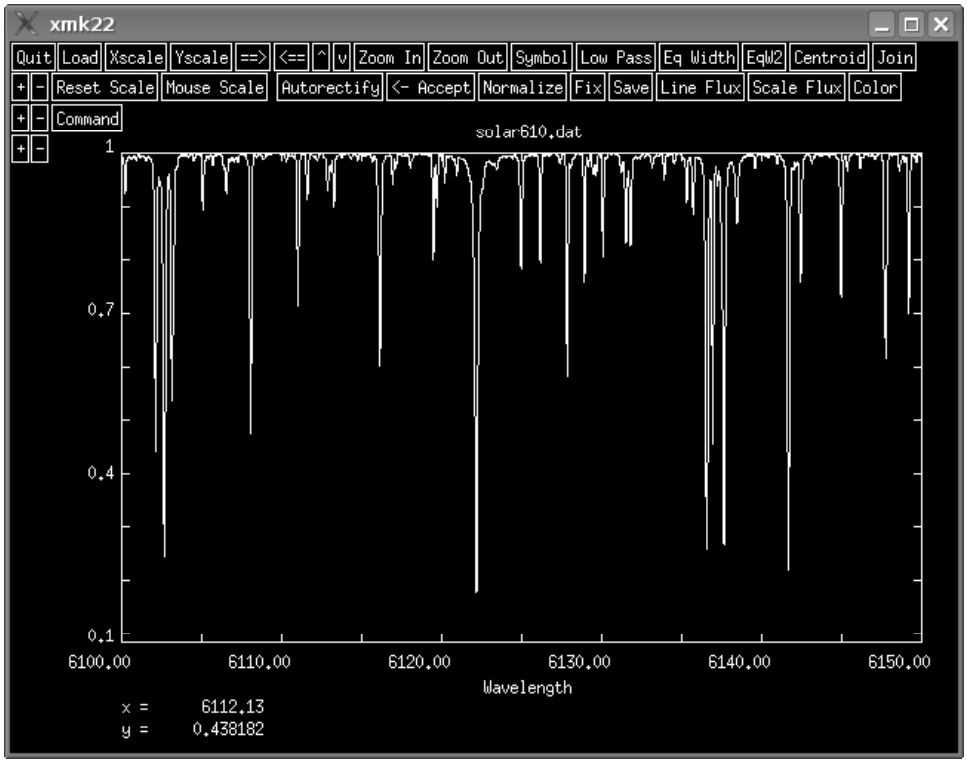

Figure 2: The appearance of `xmk22` when it is used to display the sample spectrum file `solar610.dat`. The rectangles along the top of the frame are buttons which can be activated using the mouse.

4.2 Some Basic Instructions

The program `xmk25` is designed to plot spectra that are in an ascii format with two columns, the first column the wavelength data, the second the flux or intensity data. An example file, `solar610.dat`, is included in the distribution to show you the correct format. The wavelength and flux/intensity data should be delimited by white spaces or a comma, but not by tabs.

To start `xmk25` type "`xmk25`" at the command prompt. The program will respond with a prompt to enter the name of a spectrum file or files. Enter the name of the example spectrum `solar610.dat` and hit return. A window should appear and display the spectrum (see Figure 2).

The background should be black and the foreground white as illustrated. If this is not the case, it is possible that your desktop (KDE, GNOME, etc.) is substituting colors. Go to the setup for your desktop (for KDE, it is the Control Center) and then look under "Colors". You should see a checkbox (for KDE it reads "Apply colors to non-KDE applications"). Uncheck that box, logout and log back in, and run `xmk25` again. This time, hopefully, the colors should be as shown in Figure 2.

For the latest versions of linux I have found that to get the correct colors it is necessary to create an `.Xdefaults` file in the home directory. To get a black background and a white foreground, the contents of the .Xdefaults file should look like:

```
xmk25*foreground: white
```

```
xmk25*background: black
```

If an `.Xdefaults` file already exists, then simply add these lines to the end of the file. You will probably need to reboot so that these changes will take effect.

`xmk25` interacts with the user via the mouse and a terminal window. For instance, if you use your mouse to click on the "Load" button, a prompt will appear in the terminal window asking for the name of a spectrum file. Most other buttons, such as Xscale, Yscale, Zoom In, Zoom Out, are self explanatory. The $\Rightarrow$, $\Leftarrow$, $\wedge$, and $\vee$ buttons enable you to scroll the spectrum. The "+" and "–" buttons on the lefthand side enable one to make fine adjustments in the position of the spectrum with respect to the wavelength scale, handy when displaying two superimposed spectra.

`xmk25` can display multiple spectra. At the prompt in the terminal window, enter the names of the spectra you want to display as a string concatenated with "+" signs, thus:
`spectrum1.flx+spectrum2.flx+spectrum3.flx`
`xmk25` will then prompt you for an offset. If you want the spectra to be superimposed, enter 0. `xmk25` will display all the spectra with the color white, but if you click on the Color button, different colors will be assigned to the different spectra.

Here are short explanations for some of the other buttons:

Symbol: This can be used to represent each point in the spectrum with a symbol. There is a choice of 4 symbol types; you will be prompted to make that choice in the terminal window.

Low Pass: Applies a low-pass filter to the spectrum. See the prompt in the terminal window.

Eq Width: A facility to measure the equivalent width of an absorption line. After clicking on this button, the cursor changes from a cross to $\Downarrow$. Position the cursor at a continuum point just to the left of the absorption line, leftclick, position at a continuum point to the right, leftclick, and the equivalent width will appear in the terminal window. The equivalent width is given in mÅ (assuming the wavelength scale is in Å), and is calculated using trapezoidal integration.

EqW2: Is a slightly more sophisticated equivalent width facility, suitable for somewhat noisy spectra. Four clicks are required in this case, two on either side of the absorption line. Two clicks to the left indicate the range over which the average continuum level will be determined, and likewise the two clicks on the right will determine the average continuum level there. The equivalent width is then calculated via trapezoidal integration.

Centroid: Can be used to calculate the centroid of an emission line. Click the button. A prompt in the terminal window will ask for a pixel radius for calculating the centroid. Center the cursor over the emission line and click. The centroided wavelength will then be calculated and printed to the terminal window.

Reset Scale: Resets scaling of the wavelength and flux axes.

Mouse Scale: Zoom in to a rectangular area defined by the cursor. Move the cursor to the lower lefthand corner of the rectangle, left click, then move to the upper righthand corner, left click again, and the view will be zoomed into the defined area.

Autorectify: A *rectified* spectrum is one in which all the continuum points are at unit intensity. The autorectify facility assists the user in rectifying the spectrum. The underlying algorithm is

a simple one which attempts to locate suitable continuum points in the spectrum. Manual assistance is often required, especially in concave regions of the spectrum. A new continuum point may be added by locating the cursor at the intended point and left clicking. A continuum point may be removed by centering the cursor on the offending point and right clicking. When satisfied, click on the Accept button and the spectrum will be replaced with its rectified form; the result is output to a file with the original name but with an extension of "`.rec`". The rectified file will also have a comment line at the end of the file (the first character of which is a # sign) noting the details of the rectification.

Normalize: This facility will normalize the spectrum to unity at a single point. The normalized spectrum will be saved with the extension "`.nor`", and a comment line at the end of the file will note the details of the normalization.

5 Xeqw3

The program `xeqw3` is used to manually fit line profiles to lines in a stellar spectrum. It is assumed that the stellar spectrum is rectified and that it is in an ascii format with wavelength in the first column and rectified intensity in the second.

The program will need to be compiled. See §2 to learn how to compile and install this program.

5.1 Basic Operation

The program can be started simply by typing `xeqw3` at the linux prompt. The program will first prompt you for an input spectrum. To follow along with the examples below, load the example spectrum `solar610.dat`.

Once you enter the spectrum, the spectrum will be displayed with a superimposed green line profile that you can manipulate with the buttons displayed at both the top and the lefthand side of the screen (see Figure 3).

Use the $\Leftarrow$ and $\Rightarrow$ buttons to move the spectrum so that the green line profile is near to the line situated at 6311Å. Zoom into the spectrum, and then use the "+" and "-" keys to approximately center the green line profile on the spectral line (see Figure 4).

To manually fit the line profile to the spectral line, first use the Depth buttons at the far left to reduce the depth of the green line so that it approximately matches the depth of the observed line. The "<<" and ">>" buttons allow a coarse adjustment, and the "<" and ">" buttons a finer adjustment. Then use the FWHM (full width at half maximum) buttons to adjust the width of the green profile until the width is approximately the same as the width of the observed line at its half depth. Then, use the Wings buttons to adjust the wings of the line to the observed profile. You will probably have to iterate with these buttons a few times, along with using the "+" and "-" buttons to improve your centering until you get a good match. If the match still is not very good, it is likely that the spectral line is a blend (see below). At the end, you should see something very much like Figure 5.

In this example we did not have to rotationally broaden the line profile. In general rotational broadening will be very important for stars earlier than the sun. If you need to rotationally broaden the green line profile, use the Rotation button. If you know the $v \sin i$ of your star you can simply dial that in. If you don't know the $v \sin i$ of your star, you will need to determine it empirically,

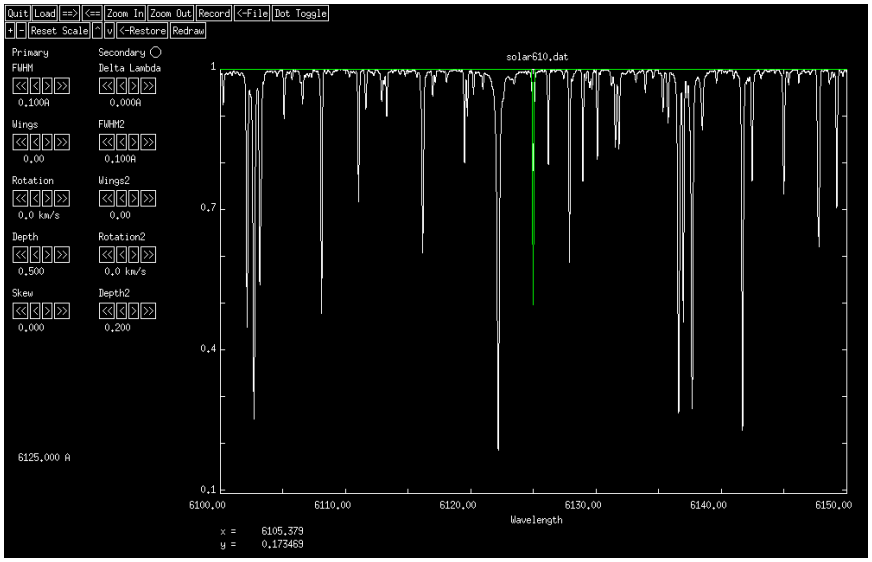

Figure 3: The opening window of the line profile fitting program `xeqw3`. The observed spectrum is in white, and the line profile, which can be manipulated with the buttons both along the top and along the far lefthand side can be seen in green.

and you can use `xeqw3` to do that. Once you have done that, of course, you will need to use the same value of $v \sin i$ for all of the lines that you measure. When you increase the $v \sin i$ you will see something interesting happen. Unlike the buttons that change the depth, the width, and the extent of the wings of the line profile, changing the rotational broadening of the profile does *not*

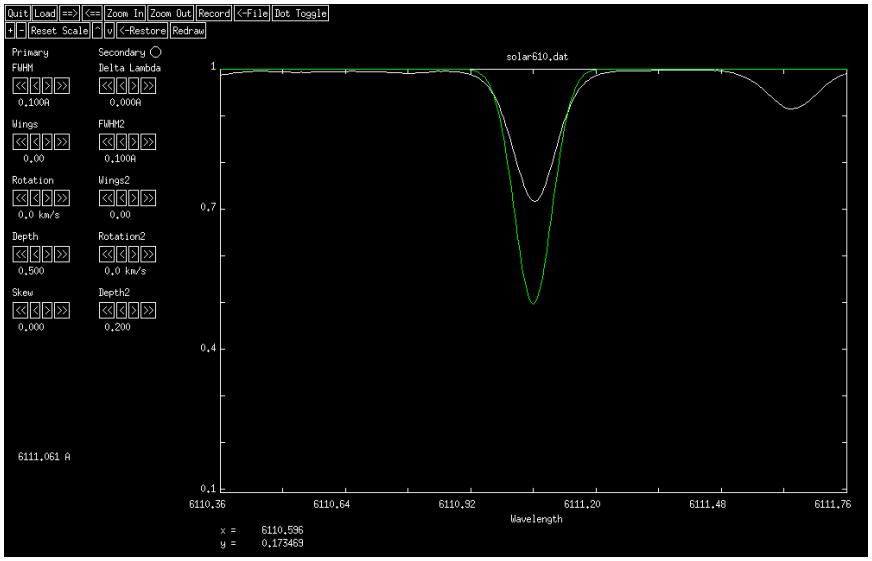

Figure 4: After shifting the spectrum and zooming in the green line profile is approximately centered on the spectral line at 6111.06Å.

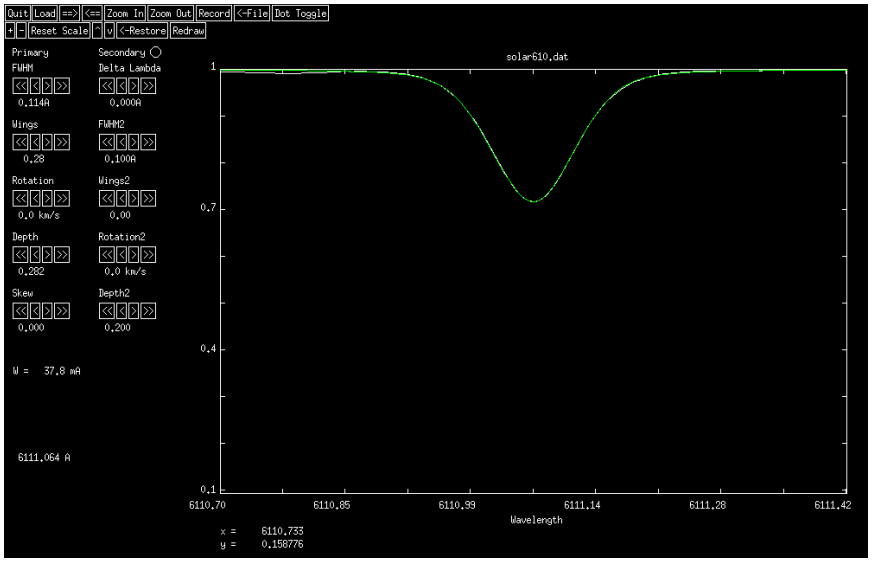

Figure 5: The final fit of the green profile to the observed line. The central wavelength of the line and the equivalent width of the line can be seen at the lower left of the window.

change its equivalent width. So, as $v \sin i$ is increased, you will see the line depth decrease.

Asymmetric line profiles may also be accommodated with the "Skew" parameter. Solar line

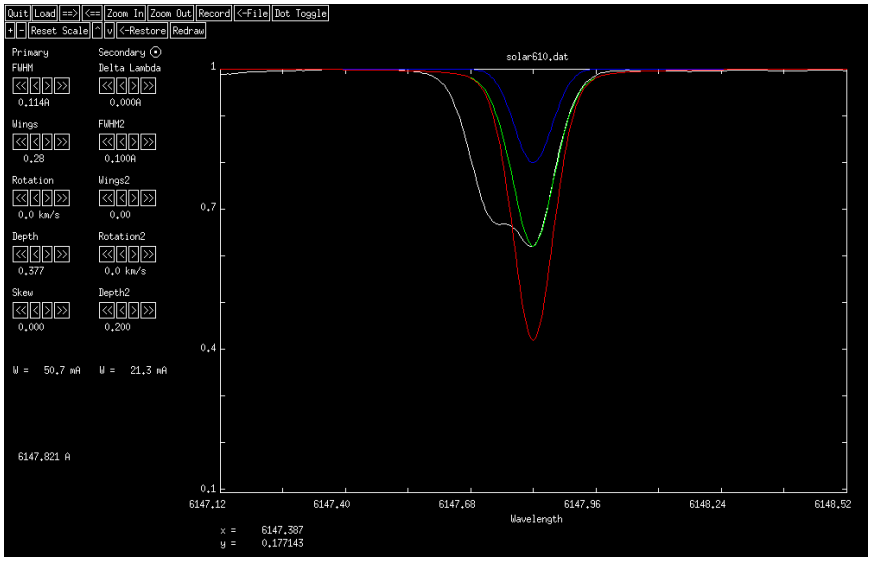

Figure 6: To fit a blended line situate the green line profile over the deepest line in the blend and use the buttons on the far left of the window to adjust that profile to approximately fit that part of the blend. Once the radio button next to "Secondary" is selected a second (blue) line profile appears (you may also have to press "Redraw"). The red line profile is the sum of the green and blue profiles.

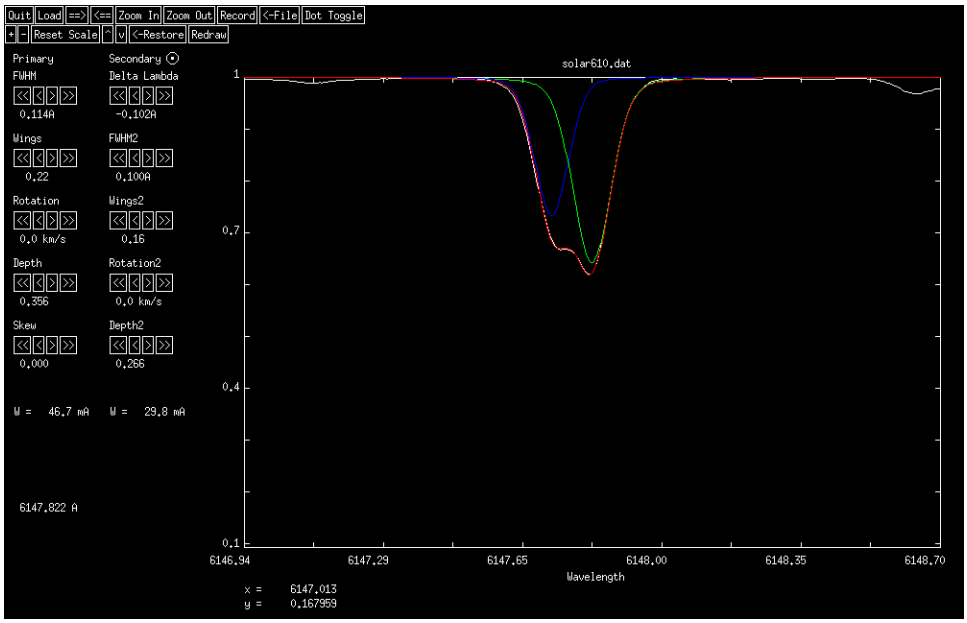

Figure 7: The final fit of the two line profiles to the blended line. The sum of the two profiles – the red profile, is a good fit to the observed profile.

profiles are slightly asymmetric due to velocity fields associated with granulation. There is, however, no guarantee that the skew algorithm incorporated in `xeqw3` will be able to satisfactorily fit the asymmetries in the sun and other stars. Before you attempt to fit a line profile using the skew parameter first make certain that the asymmetry is not due to a blend.

If you want to record the results of your measurement in a file, first press the File button. This will prompt you in the terminal window for a file name. After entering the file name, click on the Record button, and the program will write the line position and the equivalent width to that file. For subsequent lines, simply pressing the Record button will save the results in the same file.

In some cases it is necessary to adjust the continuum of the green line profile to the local continuum of the observed spectrum. This can be accomplished with the "$\hat{}$" and "v" buttons at the top of the window. When you press one of those buttons, the green line profile will change to an orange color. If you want to get back to the original continuum, press those buttons until the line profile changes back to green.

We will now see how to fit a blended profile. Use the $\Rightarrow$ and $\Leftarrow$ buttons to move the profile to the vicinity of the blended line near 6147.78Å. Center the profile on the deepest line of the blend and use the buttons to the far left to approximately fit that deepest line. Now click the radio button next to "Secondary". Once you click on "Redraw" this will create a second line profile. You will actually see two new line profiles – the blue profile is the second line profile that you will be able to manipulate with the second column of buttons on the lefthand side of the window. The red line profile is the sum of the first and second line profiles. (see Figure 6.) The goal is to manipulate the blue line profile until the red line profile fits the observed blended line profile as closely as possible.

The blue line profile may be moved using the Delta Lambda buttons. Then use the Depth2 and FWHM2 buttons, iterating all the time with the Delta Lambda button and the buttons for

the first (green) line to get as close a fit as possible with the observed line profile. The result is shown in Figure 7. This can take considerable trial and error before a good fit is obtained, but with experience the time required will reduce. Finally, the equivalent widths and line centers for the two lines in the blend can be read out at the lower left of the window.