FUSE_REGISTER

D. Lindler, July 2002

FUSE_REGISTER is an interactive IDL tool for registering, scaling, and coadding FUSE spectra. It is called by typing `fuse_register` on the IDL command line with no input parameters. The routine will allow you to register and coadd multiple readouts for the same detector segment/channel or register, scale, and merge data from all segments/channels.

**FILE SELECTION**

When you first enter FUSE_REGISTER, the file selection widget shown in Figure 1 will appear. The currently selected files are listed on the right. Use the Select File(s) button to select files. To remove a file from the list, highlight it by clicking on the file name and press the Remove From List button. Press the Remove All button to remove all of the currently selected files.

![Figure 1: FUSE_REGISTER file specification](image)

When the "Select File(s)" button is pressed, a file selection widget (as shown in Figure 2 for SUN/UNIX computers) will appear. To change directories, edit the Filter line (1) or click on the directory in the Directories Box (2). Then hit the Filter Button (4). Alternately you can hit <carriage return> when in the Filter text box (1) or double click on the directory in the Directories box without hitting the filter button. The list of files will appear in the Files box (3). Select the file you want. The name of the selected file will appear in the Selection box (5). Hit the OK button (6) to select the file. Alternately, you can just double click on the file within the Files box (3) to select it. Note: Both the Directories Box and the Files Box have scroll bars if all of the files or directories do not fit within the portion visible on the screen. The files in the Files box are those in the specified directory with names with the form *.fit. If your desired file does not have a name using the standard convention you will either need to input the name in the
Selection box (5) or modify the filter in the Filter Box (1). If you change your mind about selecting a file, just hit the Cancel button (7).

You can select multiple files in the Files Box (3). Select the first file, hold down the <control key> and then select the other files. If all of the files are sequential in the Files Box (3), select the first file, the press and hold down the <shift key>, and then select the last file. When all files have been selected, hit the OK button (6).

A quick way to select files, especially when the directory contains a large number of files, is to edit the filter (1) so that only the desired files are listed in the Files Box (3). Then simply select the first file on the list, hold down the <shift key>, and select the last file on the list.

When you press the OK button, Control will be returned to the widget in Figure 1. You may continue selecting files. When all files have been selected, press the Process button to begin the real work.

**SPECTRAL DISPLAY**

When the Process button is pressed, the spectra are loaded into the widget shown in Figure 3. The spectra are plotted in window (1) and the errors are plotted in window (2). The spectra are plotted with different colors shown in the boxes (7) along with the names (9). The plot parameters can be controlled using the fields under the plots (3) and (5) and the main menu (4). In addition, the check boxes (8) can be clicked to turn on/off individual plots. Before continuing,
one of the first things you may want to do (particularly if your data is noisy) is specify the smoothing parameter **N Smooth** (3). This will apply a mean filter to both the spectral and error plots.

The x and y range of the plot can be changed using the **UN Zoom ALL**, **Un Zoom**, and **Zoom** buttons on the menu bar. When you push the Zoom button you must position the cursor in the plot window (1) at one corner of the region (box) you want to zoom to. Push the left mouse button and repeat for the opposite corner of the region. Alternately, you can zoom without first pushing the **Zoom** button by: placing the cursor at one corner of the box, pushing and holding the center mouse button while dragging the cursor to the opposite corner, and releasing the center mouse button. A second method of changing the X and Y range of the plot is to enter values into the **X Min**, **X Max**, **Y Min**, and **Y Max** fields below the plot (3 and 5). The **Y Offsets** field can
be used to offset the individual spectra in the Y direction. The two arrow buttons on the main menu bar can be used to move the wavelength scale to the left or right. The wavelength range of the error plot is the same as the spectral plot. The only way to change the y-scale of the error plot is to enter the values in the fields below the plot.

The left and right arrow buttons on the main menu bar can be used to move the wavelength range displayed to the left or the right.

The Linestyles button will allow you to change the colors or line styles of the plot. See the documentation for LINE_PLOT for additional information on changing line styles.

**WAVELENGTH REGISTRATION**

There are two methods available to register the wavelengths of the spectra. You can visually match the scales or you can cross correlate the spectra in a specified wavelength range. First pick a spectrum that you intend to keep the wavelengths fixed. Next zoom to region(s) of overlap between this spectrum and the others. To adjust the wavelengths of the other spectra, first select the spectrum by clicking on the appropriate box in the column of boxes (7). The background of the selected spectrum will change from white to yellow. To adjust the wavelengths:

1. Push the **Drag** button on the main menu bar.
2. Place the cursor on any point within the plot window (1).
3. Push and hold the left mouse button.
4. Drag the spectrum to its new location.
5. Release the mouse button.

You will notice that the values in the widget column (10) have changed. These are the wavelength offsets for each spectrum and can be manually entered if desired. Repeat the registration process for each spectrum. If a spectrum does not overlap your original reference spectrum, register it with a spectrum already registered to the original reference.

Another approach to registration is to use cross-correlation. Select a reference spectrum by clicking on the appropriate box in column (7). Zoom to a region with visible spectral features where it overlaps one of the other spectra. Next push the **Xcorr** button in column (6) for the spectrum you want to shift. A wavelength offset will be computed by cross-correlation of the spectrum with the reference spectrum. If cross-correlation fails because the shift is too large, first manually drag the spectra to align them and then use cross-correlation to refine the offsets.

**SCALING THE SPECTRA**

If an object is better centered in the aperture for one channel, its flux levels will be higher than in the other channels. In this case you may want to adjust the scale of one spectrum to match another. Pick a spectrum you want to rescale by clicking on its box in column (7). The box will be highlighted in yellow. To rescale the spectrum:
1. Push the **Scale** button on the main menu bar.
2. Place the cursor on any point within the plot window (1).
3. Push and hold the left mouse button.
4. Drag the point to its new y location.
5. Release the mouse button.

**REMOVING BAD DATA**

Before coadding the data, you may want to remove bad data points (data at the ends of the spectra, "worm" data, etc.). Select the spectrum you want to edit by pushing the appropriate box in column 7. Then press the **Edit Mask** button. This will load the spectrum into the LINE_EDIT widget. Refer to the documentation for LINE_EDIT on how to mask the undesired data points.

**COADDING THE SPECTRA**

After the spectra have been registered and bad data removed, they can be coadded and merged. The controls in the lower left corner (8) of the widget in Figure 3 control coaddition. Three methods of weighting are available:

1. Use the scalar weights specified in column 11 of the widget (Figure 3). These are initially set to the exposure times but can be manually adjusted.
2. Weight using the propagated statistical errors. The weight for each point is set to [1.0/variance]. To avoid problems where the counts approach zero, the variances are smoothed with a mean filter (as specified in the N Smooth field) prior to computation of the weights.
3. Weight each spectrum equally.

In spectral overlap regions, data can be resampled onto the same wavelength scale using either nearest neighbor or linear interpolation.

Once the desired coaddition parameters are selected, push the **Coadd Spectra** button to coadd and merge the data. Only data plotted (as specified in the selection boxes in column 8 of the widget shown in figure 3) are coadded. The coadded spectrum is overplotted as a thick black line. Even if the spectra are smoothed when plotting, the unsmoothed spectra are coadded.

Don't Forget to use the **Write/Fits Table** button on the main menu to write the spectrum to a file before you exit the widget.

If you exit the widget before writing the results to an output table, all of your work will be lost. The routine writes the results into a FITS binary table with columns WAVE, FLUX, and ERROR. This table can be read back in in subsequent calls to FUSE_REGISTER. This allows you to register and coadd multiple readouts for each segment/channel and then call the routine.
again to merge the segments. Even if smoothing is specified when plotting (NSmooth), the coadded spectrum written to disk is unsmoothed.

The Write/PS file button will write the currently displayed plots to a postscript file.

Also note that any data placed into a binary table with columns WAVE, FLUX, and ERROR can be read into and processed by the widget. For example, you could read model data, use it to register the FUSE data, and the merge the FUSE data while ignoring the model data by un-checking the box in column (8) of the widget.

**MANUAL SETUP OF THE REGISTRATION WIDGET**

In many cases, the registration of FUSE spectra can be automated. However you may want to use the widget in Figure 3 to display and verify the registration or to coadd the data that has already be registered. To avoid having to write the registered data back into data files which must then be re-read by FUSE_REGISTER, you can load the data directly into the registration widget. The calling sequence is as follows.

To load the first spectrum:

```
xregister_1d, wave, flux, error, mask, init=1
```

or

```
xregister_1d, wave, flux, error, mask, /init
```

To load the remaining spectra:

```
xregister_1d, wave, flux, error, mask
```

or

```
xregister_1d, wave, flux, error, mask, init=0
```

And finally after the spectra are loaded to activate the widget:

```
xregister_1d, /process
```

The input parameters are:
- wave - wavelength vector
- flux - flux vector
- error - error vector
- mask - (optional) mask of good data values (1 = good, 0 = bad)

In addition the following optional keyword inputs can be specified:

- weight - scalar weight for the spectrum when coadding
- ptitle - main plot title
title - title for each spectrum (e.g. the filename or other identification)
xtitle - x title for the plots
ytitle - y title for the plots
xrange - initial x-range to plot
yrange - initial y-range to plot
/modal - make this a modal widget if called from another widget.
group - group id of the base widget if called from another widget.

The coadded spectrum can be returned in the following optional output keyword parameters:

wout - coadded wavelength vector
fout - coadded flux vector
errout - propagated errors
woffset - vector of wavelength offsets computed for each spectrum
fscale - vector of computed scale factors for each spectrum.

xregister_1d is not FUSE specific and can be used for data taken with any instruments.