Continuum fitting with CONTFIT tutorial

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About CONTFIT

This is a tutorial to demonstrating CONTFIT. CONTFIT is an interactive continuum fitter, where the user click along where they think the continuum is. These points are used to fit a cubic spline to the data. CONTFIT uses the fitted spline to normalize your input spectrum, as well as it's error spectrum at the same time.

File requirements

In order to run CONTFIT, you obviously need to grab the source file from `https://github.com/trystynb/ContFit/blob/master/tb_contfit.py`.

In addition, make sure you have downloaded MYSPECTRUM.FITS and MYERRORSPECTRUM.FITS. MYSPECTRUM.FITS is a mock 1-D spectrum of a quasar at redshift 0, and MYERRORSPECTRUM.FITS is the associated error spectrum. Feel free to use your own 1D spectrum, but these example spectra are provided for demonstrative purposes.

This tutorial assumes all related files are in the same directory.

Starting up CONTFIT

Main GUI window

To run, simply type `python tb_contfit.py` into the terminal where all the files are located. You will be presented with a window entitled **TB_CONTFIT**. I will refer to this as the main GUI window.

The main GUI window presents you with 5 input fields. They are:

- Input spectrum: The 1D fits spectrum that will be fitted
- Error spectrum: The 1D fits error spectrum associated with Input spectrum
- Output spectrum file (FITS): The filename of the final, continuum-normalized 1D spectrum. This will be created by contfit.
- Output Continuum file (ASCII): The filename of the final continuum, printed in an ASCII format. This will be created by contfit. By default, it is called mycont.dat.
- Wavelength Chunk Size: The size (in the units of your x-axis of Input spectrum) which you will be viewing the spectrum while fitting. By default, it is set to 500.

In the upper left corner of the main GUI window is a Menu button. There are three options within the Menu:

- Tweak Continuum – This button will start the continuum tweaking function. This will be discussed later.
- Tutorial mode on/off – Button toggling a tutorial mode, where pop-up boxes appear telling the user what to do.
- Exit – Exits contfit.

Intializing fields

Let's start by setting each of the 5 input fields. But before we do this, why don't we turn on the tutorial mode. Select the Menu button, and select Tutorial mode on/off. A help message window will pop up, saying *Tutorial mode is now on.*. At any point, if these dialog boxes get annoying, turn them off using the same procedure. One last dialog box will tell you it is off.

First, set the Input spectrum to myspectrum.fits. You can do this by directly typing the filename into the field, or you can click the Search button to the right of the field. This will give you a file menu to search

your computer for the input spectrum. Repeat this for setting the Error spectrum to myerrorspectrum.fits.

Now we need to name the Output spectrum file. Let's call it mynormspectrum.fits. We will leave the Output continuum file to mycont.dat.

Lastly, let's change the Wavelength Chunk Size to 200.

We are now ready to start continuum fitting!

Continuum fitting

To start continuum fitting, click the Fit Continuum button at the bottom of the main GUI window.

Display windows

Two windows will pop-up after the tutorial dialog is closed. The window called Full spectrum display the entire Input spectrum. This is used for reference, so you can check what the whole spectrum looks like, where you have place the spline points.

The important window is entitled Continuum fitting display. This shows a chunk of the Input spectrum, where the size of the chunk is defined by Wavelength Chunk Size. This is the window where you will click the continuum.

Placing the continuum

Lets start fitting the continuum. In the Continuum fitting display, there should be two vertical red lines, one at a wavelength of $\sim$ 1040 and the other at $\sim$ 1250. These lines represent the region where we are fitting the continuum. The red dot indicates the last point in the spline of the continuum. Because we have just started, it is taken as the first pixel of the Input spectrum.

Being careful **not to click before the first vertical line**, click near the top of the spectrum in the Continuum fitting display. A blue line will appear, connecting the red dot and where you have clicked. This blue line will represent the spline that you are drawing. In the Full spectrum window, a red dot will be drawn showing where you have clicked.

Continue to click **rightwards** of the last click, along the top of the spectrum. Because there is an inherent scatter in the spectrum from noise, you can try to click where you actually see where the continuum is.

At a wavelength of about ~ 1200 is a large gap. This is real absorption. To estimate the continuum at this point, you can click up towards where the emission line of the quasar starts (a flux of 1.2×10^{-16}, wavelength of ~ 1225).

Changing Continuum fitting display

CONTFIT tries to prevent setting the y-range of the CONTINUUM FITTING DISPLAY window to any noise spikes that may dominate the spectrum, and occasionally has trouble with emission lines.

If this occurs (which should be somewhat happening in this chunk), you can use the buttons in the bottom left of the display window. **However, BE CAREFUL WHERE YOU CLICK!!!**. If you click rightward of the last point you clicked, it will draw a continuum point. If you click leftward of the first vertical line, you will move to the next wavelength chunk.

What I would recommend is that if you need to use the tools, first attempt to set the display the way you want to by moving the window (with the 4-arrow pan button) such that you can see the feature of interest. Then, zoom (magnifying glass button) into the region you want, starting with the cursor within the blue spline line. Where you release the mouse doesn't matter (thankfully).

Try to use these tools to zoom in a bit on the emission line. It will make fitting the continuum on steep bits easier.

Don't forget to click the last zoom/pan button you used to get rid of that function when you fit the continuum!!!

Fitting emission lines

Because CONTFIT uses a cubic spline, be careful near sudden changes of slope. This is the case near tall, narrow emission lines (e.g. at a wavelength of 1240 in the tutorial). The trick here is to click many times near the peak/inflection point to prevent any ringing.

Moving to the next chunk

Once you have clicked the continuum all the way up to the right vertical line, you won't be able to click anymore. If you have played with the view of the Continuum fitting display, click the home button.

To move to the next wavelength chunk, click leftward of the red dot in the Continuum fitting display.

You will then move to the next chunk of the spectrum. Repeat fitting the continuum, chunk by chunk.

Occasionally Contfit will have a hiccup on the last chunk with whatever bit of the spectrum remains. Occasionally, there will only be a handful of pixels it is waiting for you to click the continuum on. If the two red vertical lines overlap, keep clicking left of the red dot in the Continuum fitting display until it stops bothering you to fit the continuum.

Need more spectrum?

If you ever need more spectrum in the Continuum fitting display, click leftward of the red dot to save your current fits, then click behind it again on the next refreshed window. Contfit will then add the previous chunk onto the next chunk, so the Continuum fitting display shows twice as much spectrum. You can repeat this as many times as you want, until there is no more spectrum to plot. At that point, you will effectively quit out of the continuum fit with a really crappy continuum fit.

Want to abort?

At any point in the fit you screwed up big-time and want to restart the fit, just close the Continuum fitting display. You will effectively stop the fit, and nothing will be saved. You can then restart the fit by clicking the Fit Continuum button.

After the continuum placement

Once you have clicked behind the last red dot, a figure will pop-up with two panels. The top panel shows you the Input spectrum, with the fitted continuum in red, and the spline points as blue circles. The bottom panel shows the normalized input spectrum by dividing the Input spectrum by the red fit line.

To help guide the eye, the continuum ± normalized error spectrum (Error spectrum divided by the red fit) is shown as two green lines. The idea behind this display is to show how much one might expect the scatter to be about the continuum solely from noise. This can be used to guide your eye.

Upon closing this figure, you will save your fit to the respective output files. You will generate two additional files. One is the saved error spectrum, which will be called mynormspectrum_err.fits, or the name of your Output spectrum with _err.fits added. The other file contains the x– and y–coordinates of your spline points (mouse clicks), saved into a Python 'pickle' file called mycont.dat.p (or the name Output Continuum file with .p appended to the end). This file is necessary if you ever want to load your mouse clicks, but more importantly it will be used by the Tweak Continuum feature.

Internal editing of the spline

I should confess here (it is also in the documentation of the code), that the flux of the first and last spline point will be modified internally. As stated above, the first spline point is set to the first point of the spectrum. Contfit will replace the flux of the first point to make it equal to the first value of the mouse click, making the spline a straight line. The same is done for the end of the spectrum, where the last spline point will be the last wavelength in the spectrum, and the same flux as your last mouse click. If you are not satisfied with this assumption, you can use the Tweak Continuum function.

Continuum Tweaking

Sometimes you realize after the fact that there are a couple of places in your continuum where you did a poor job. Instead of re-fitting the entire continuum, wouldn't it be nice to use a tool to tweak it a bit? That's what the Tweak Continuum feature in the Menu on the main GUI window is for.

NOTE: to use the Tweak Continuum function, you must generate a continuum first using the Fit Continuum button in the main GUI window. If you are clever enough and have spline points all ready, you can cheat by making a Python pickle file, with the coordinates of your spline saved as (xspline,yspline), where xspline and yspline are Python lists containing

the x and y coordinates of the spline. However, it might just be quicker to refit the continuum.

Starting Tweak Continuum

Let's start up the Tweak Continuum function by clicking Menu > Tweak Continuum in the main GUI window. A display window will pop up called Continuum Tweaker, and 6 buttons will show up in the main GUI window.

The Continuum Tweaker display has three panel. The top panel shows the spectrum with the continuum (blue line) you generated before you started Tweak Continuum. The middle panel displays your current working continuum (blue line). It is automatically set to your original continuum when initialized. The red points in both panels are the spline points that you have clicked. The bottom panel shows the continuum-normalized spectrum that would be outputted based on the continuum in the second panel. Again, 1± the normalized error spectrum is shown in green to represent the approximate noise at each pixel.

The new buttons in the main GUI window are:

- Refresh Plot refreshes the Continuum Tweaker display.
- Remove Point allows you to remove a spline point.
- Add Point allows you to add a spline point.
- Reopen Window reopens the Continuum Tweaker display if closed.
- Save Spline saves the spline to the Python pickle file (mycont.dat.p)
- Exit will close the Tweak Continuum function, and refit the continuum based on the last saved Python pickle file.

Adjusting display

If at any point you would like to zoom in on a particular region in the Continuum Tweaker display, use the '4-arrow pan' and zoom (magnifying class) buttons on any of the three panels. You will notice that all three panels will move to display the same region in all panels. This way you can compare easily. If you ever need to return to the original view, click the home button

in the bottom left of the CONTINUUM TWEAKER display. Don't forget to click whichever tool again to get back the normal cursor!

Adding a point

The first thing you might want to do is add a new spline point. In the CONTINUUM TWEAKER display, zoom in near one of the ends of the spectrum by using the magnifying glass button, and drawing a box around the end of the spectrum. Click the magnifying glass button again to get the normal cursor.

We can add a point beyond the wavelength range of the spectrum by clicking the ADD POINT button in the main GUI window. Once selected, click where you would like to add the point in the middle panel of the CONTINUUM TWEAKER display. A red point should appear, and the new continuum will be updated, as well as the normalization in the bottom window.

You will only be able to add one point at a time. If you need to add more, you must repeat the process of hitting the ADD POINT button.

Remove a point

To remove a point, hit the REMOVE POINT button in the main GUI window. In the middle panel, click any red point. If you are successful at removing a point, the red point will disappear in the middle window of the CONTINUUM TWEAKER display, and the bottom panel will be updated with the new continuum.

Like the add point feature, you can only remove one point at a time.

One issue you might encounter is sometimes the point isn't removed. If there are multiple points really close to eachother, you will need to zoom in and select the one. CONTFIT will complain if there are more than one point near where you clicked. Another issue might be you recently zoomed or panned the display. Click the appropriate pan/zoom button to return to the regular cursor. The REMOVE POINT function will still be waiting for you to remove a point.

Moving a point

If you want to adjust a point, you will need to add/remove that point to the new location. This can be done in any order.

Using the Add Point and Remove Point buttons, get a feel for how the Tweak Continuum function works and effects the continuum.

Saving the spline

When you are happy with the continuum fit as it is, hit the Save Spline button. You need to do this if you want to save the latest spline. Note that this **WILL NOT** update the top panel, but only the Python pickle file (mycont.dat.p in the case of this tutorial).

Exit Continuum Tweaker

Once you are done with the Tweak Continuum function, you can click the Exit button. This will close the Continuum Tweaker display, and take the most recently saved spline in the Python pickle file (mycont.dat.p) and update the Output spectrum, Output continuum, and nromalized error spectrum files.

If you did not touch the Save Spline button at all in your use of the Tweak Continuum function, you will update the files with your original spline points.

Did you close the Continuum Tweaker display by accident?

If so, you can use the Reopen Window, and it will open the Continuum Tweaker display again. This will not exit the Tweak Continuum function.

End of fitting

Once you are completely done with the spectrum, use the Menu button in the main GUI window, and hit Exit. This will close the main GUI window, and exit. It does not save anything, so it can be used any time as an escape hatch for something gone horribly wrong.

Initialize Contfit from command line

You can initialize the Input spectrum, Error spectrum, Output spectrum, and Output continuum files, and Wavelength Chunk Size from the command line. To do this, you must run:

python tb_contfit.py 'Input spectrum' 'Output spectrum' 'Error spectrum' 'Wavelength Chunk Size' 'Output continuum'

with the appropriate values for each of the 5 parameters.

Bulk fitting

Sometimes we have too many spectra to fit all at once. My trick to do this is make a shell script that opens each file I need to fit with the command above. This is great for three reasons: 1) it fills in all the file names automatically for me, 2) It open Contfit automatically over and over again, 3) At any point I can kill the script, and comment out all the spectra I've all ready done. If I need a break, I can then resume at the next spectra.