SALT LONGSLIT DATA REDUCTION NOTES

The things missing from the SALT/pysalt data reduction wiki that make a new user's life difficult It is recommended that you use this in combination with the wiki tutorials though.

When you've downloaded your SALT data, there will be three folders: doc, product, and raw. Open the doc folder, and you will find various files with information about how the observation went. They are HTML files so they will open in your web browser. The Astronomer's Log has info about the observing run, with notes on seeing, weather conditions, and any technical difficulties that may have occurred. The most relevant document is the "Observation Sequence" document, which will tell you which files are which in your product and raw folders. Look for your program by the far right column (PI) or your science target names.

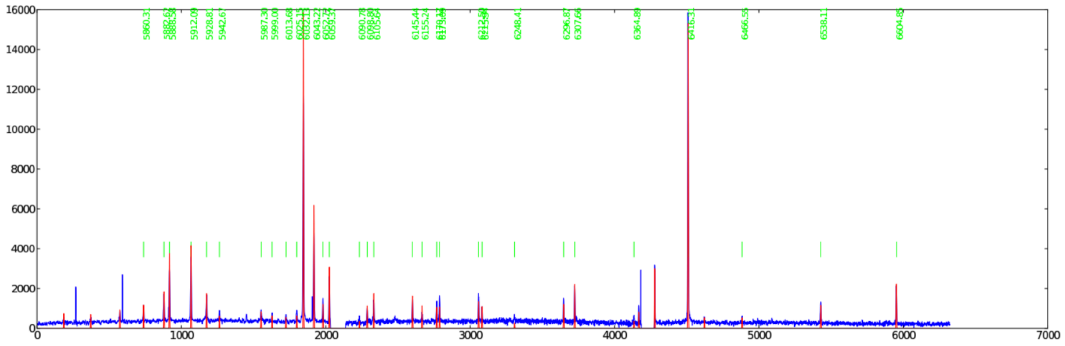
Files starting with an S (ex: S201605010001) are Salticam acquisition images. Those with a P (ex: P201605010001) are the science images, arcs, and flats. Biases start with an R but are usually not included in the delivered data products.

Go to the product folder. The files will have prefixes of mbxgp- added to the file names in the observing sequence document, which were added in the reduction pipeline (one letter for each correction step such as bias subtraction, gain correction, etc. Note that cosmic ray correction is not performed in the pipeline, and you need to run *saltcrclean* yourself). Using the observation sequence document from the doc folder, figure out which one is your arc lamp. You will need to go get the line list and plot corresponding to the lamp used. Look at the header of your arc lamp file (in ds9 or whatnot) to find out which lamp was used. The line lists are located here (you might need to make a SALT web manager account to access this):

http://pysalt.salt.ac.za/lineatlas/lineatlas.html

Open the appropriate line plot file and scroll through to find the one that matches the grating resolution and angle used in your observation. For example, I'm using the argon lamp with the PG2300 grating at an angle of 47 degrees. I've noticed that sometimes the dispersion in the plots here don't perfectly match what you will see in your *specidentify* GUI, but the patterns are still the same.

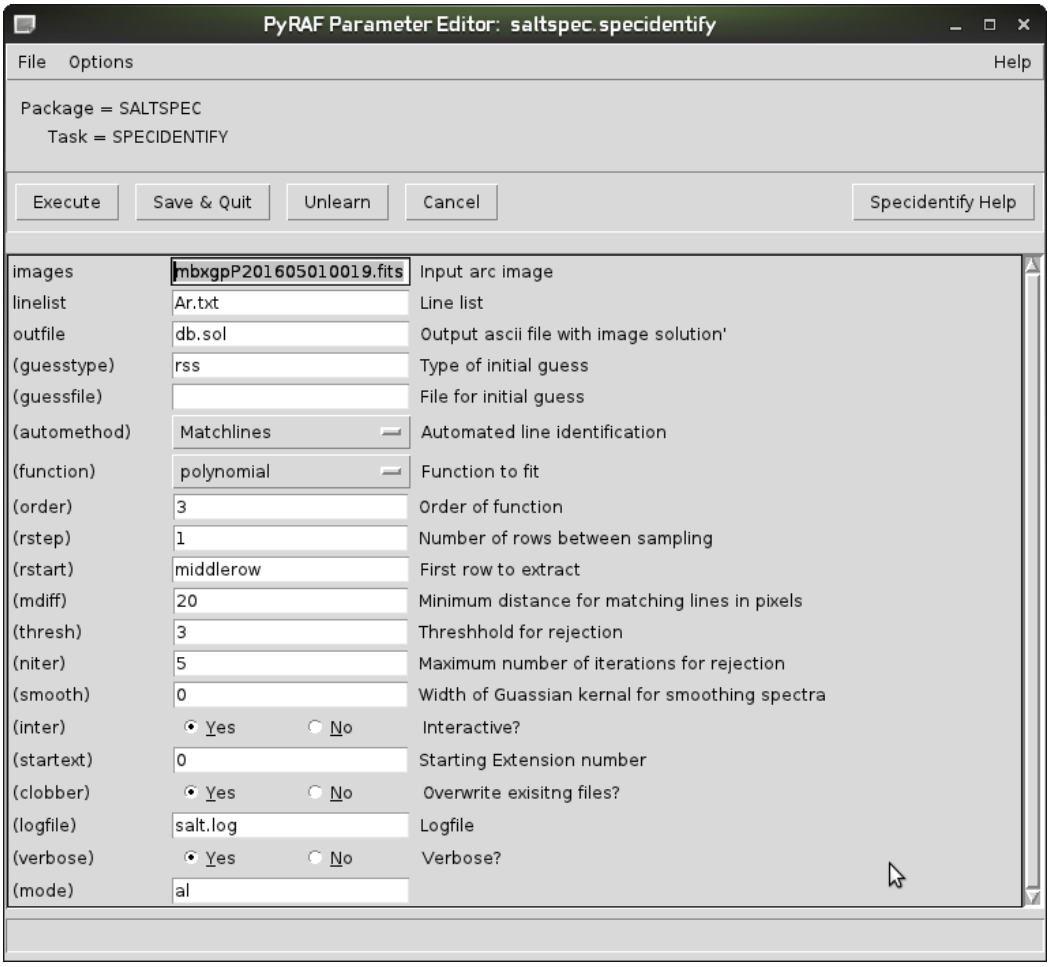
Figure 23: 1020 — 426: Ar PG2300 GR = 47.000 AR = 91.771 $\lambda\lambda = 5742 - 6651$



You'll need to copy the corresponding line atlas from that website as well. Save it as a text file wherever you are going to work on the data.

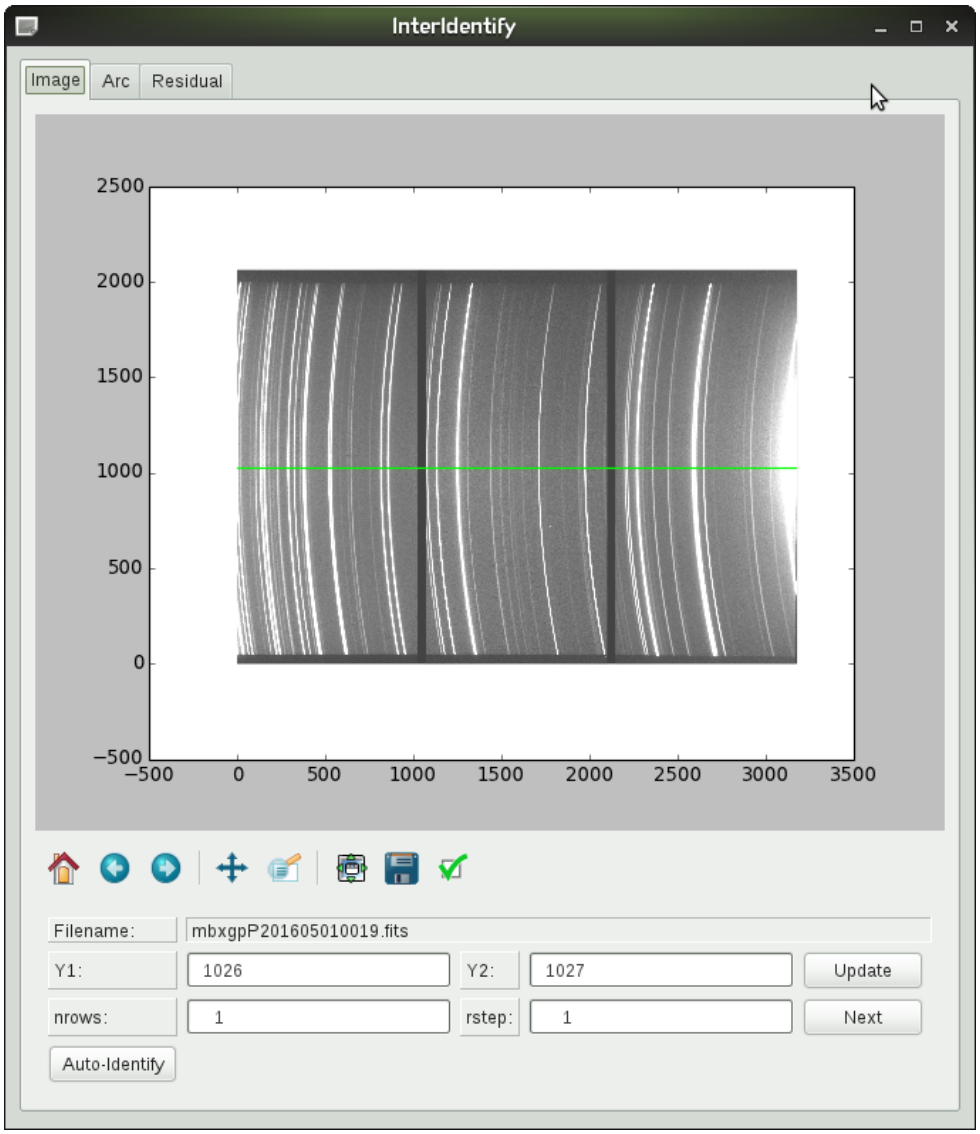
Now let's get started with pyraf.

In your terminal, start pyraf. Once running, type *pysalt*. Pysalt will start up, and you'll then want to load the *saltred* and *saltspec* packages (by typing saltred and saltspec). You probably started in whatever directory your login.cl file is in, so now cd into where you're keeping your data. I like to do all of the reduction in a separate directory from the product folder, as the file naming conventions and middle-step reduction files generated make it pretty messy. In this separate directory, I have my lamp.txt file, a copy of the product file containing my arc lamp, and a copy of the product files of the science target (for however many exposures you did). Since we are working with the product data, we will skip all the steps like gain, bias, cross-talk, etc corrections and start directly at the *specidentify* step. Type epar specidentify to input parameters:



Edit the images field to the name of your arc lamp file, the line list field to your line list (mine is Ar.txt). The outfile field will contain your wavelength solution, and it's fine to leave it as db.sol

or edit it to whatever you want it called. Set guesstype to rss. **Change the function dropdown to legendre** (mine says polynomial because I forgot to change it for the screenshot). Make sure the “interactive” toggle is set to yes. Click the execute button at the top to bring up the interidentify GUI.

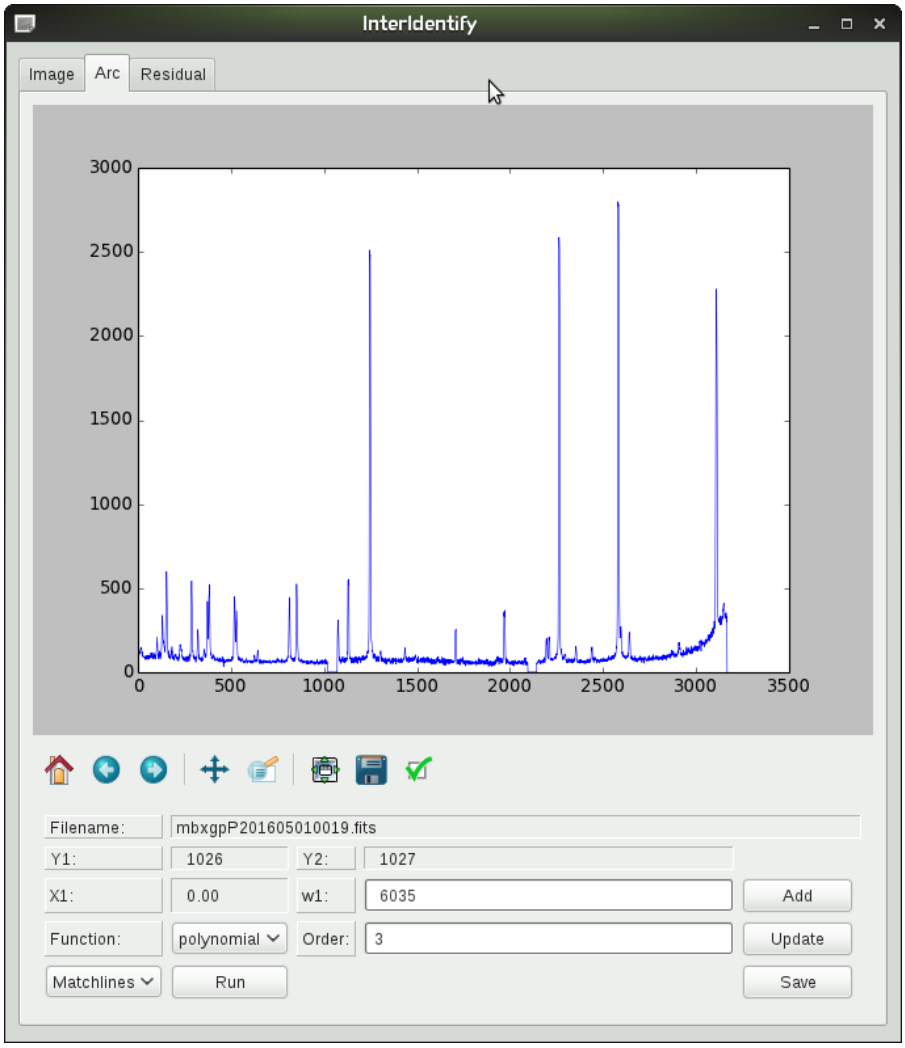


This is your 2D arc lamp image. The green line indicates the row of the CCD that is currently extracted on the Arc tab. You can change the number of rows you extract with the nrows field, but this isn’t necessary unless your arc is really faint or something. On this image tab, you *will* want to edit the rstep field to something like 25-30. This sets the step size with which you will move through the CCD to pin down wavelength solutions. If you are pressed for time, you can set the step size to larger values, but be warned that your sky subtraction will be significantly worse if you identify less rows of the CCD. **This process is tedious and takes about an hour at the 25-30 row step size, but is necessary for a good sky subtraction until someone can come**

up with better software that deals with the line curvature. Once you have done this, go to the Arc tab.

Aside: You might try auto-identify, but I have yet to get any remotely useable results from that method. If you press this button, it will move through the CCD at the step size you specified and find a wavelength solution for each of those rows. In the terminal, it will print out the rows it solved and the rms. Usually the rms is unacceptably high, and gets worse the more rows it does automatically, leading to a terrible solution. If you use a small step size, it will take awhile to run. If you ran auto-identify, once the terminal stops printing row values, end the specidentify step by clicking the x button at the top of the GUI and the db.sol file will write out in your working directory. **Do not do auto-identify if you also did manual wave solutions, as it will overwrite anything you did by hand** (I first assumed one identified a few rows by hand then auto-identified the rest…don't be fooled!)

Now on the Arc tab you should have something like this:



At this point, you'll want to look at the line plot like the one on the first page of these notes. Pick 4 lines spaced out through the spectrum (at least one on each chip). You're going to be typing these a lot, so write their wavelengths down or memorize them.

Aside: A brief note from numerical analysis. You've set your fitting method to a 3rd order legendre polynomial. These have single unique solutions when you have N+1 points (where N is the polynomial order). Thus 4 lines will return the tightest fit with the lowest rms. Adding more lines (N+M) means you no longer have a single unique solution, and your rms will go up.

Start with the first line you matched from the arc plots. Hover your mouse over that line in the GUI, and press 'c' to centroid on that line. In the w1 field below the plot, you'll see the wavelength is incorrect, so delete it and type the correct value then click the 'add' button. It seems like the button behavior can be kind of finicky, so be sure you click well within the button area, and don't accidentally click twice. Go through all four of your lines, and when you're done, type 'f' to fit then 'z' to display the fit. A bunch of red lamp lines should appear, now lined up well with your blue arc spectrum. If you go to your residuals tab, it should be some small rms value like 1e-11 to 1e-12 ish (look at the y-axis and the info at the bottom of the GUI). If you're satisfied with the fit, go back to the arc tab and click the save button. In the terminal, it will print out that a wavelength solution has been saved for the current row.

Now go to the image tab again. You'll click the next button, and the green line will move up the CCD the amount specified in rstep. Go to the arc tab and you'll see a fresh arc spectrum. Do the same thing as the previous paragraph. Repeat the identify, fit, save process until you reach the top of the CCD. Then in Y1 enter 100 and Y2 enter 101, to start at the bottom of the CCD and finish the process. When you've gotten back to the middle of the CCD, press the x button at the top of the GUI to write out the solution file and end specidentify. Look in your working directory to be sure the solution file is there, and you may want to open it to make sure all the rows saved correctly.

Aside: As you work, you may get an error on your row fits saying that "N=4 must not exceed M=0" and this is I believe related to the add button being picky about clicking too many times (or forgetting to click add on a line). If you get this error just go through and hit c and add on each of your lines again then repeat the fit. If it doesn't work again, just move on. It's okay to skip a few as long as you have enough row solutions to form a good sky curvature fit.

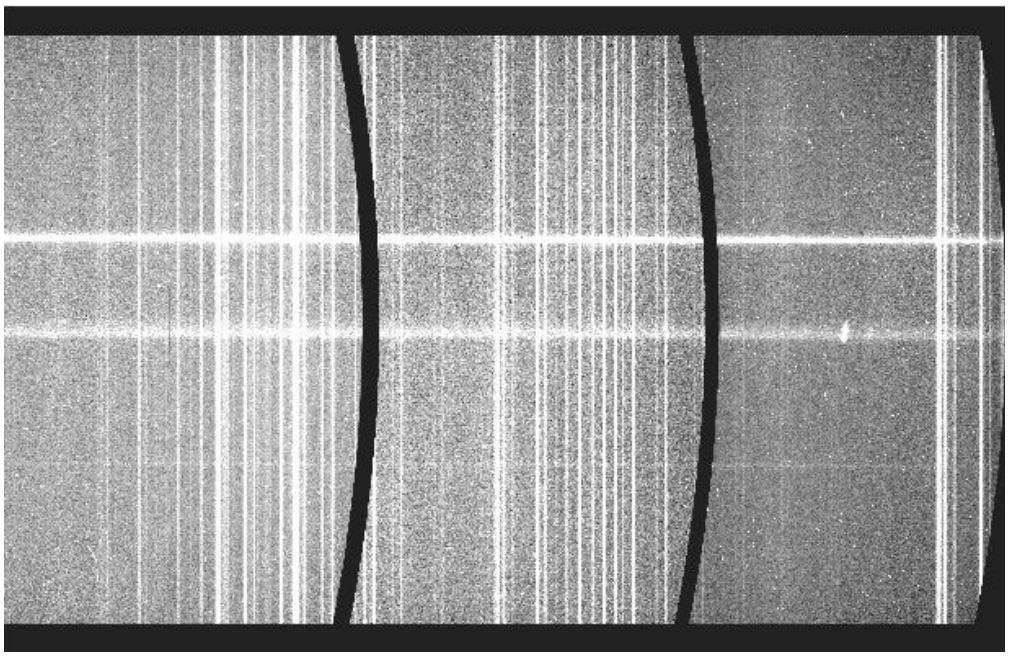
I don't know if the 20-30 row step size is absolutely necessary for a good sky subtraction as the I've only done a dense solution (75 or so rows) or a sparse solution with only 10 or so rows. It may be possible to fewer rows so feel free to try a wider step size.

Now that you have your wave solutions, you need to apply it to the 2D spectrum. If you haven't removed the cosmic rays with *saltcrclean* yet, do so now. I use all the default settings, which does an okay but not great job removing them as *saltcrclean* is pretty rudimentary. Now you'll want to type epar specrectify and edit the fields according to the things in this command (or just copy paste it into the command line). **Make sure your image is your science image, not**

your arc lamp! Additionally, make sure the solution file is the one you just made. The 'outpref' field means that the file created will have the same name as the input file, but with an x appended to the beginning.

specrectify(images='mbxpP200610190015.fits', solfile='db.sol', outimages=' ', outpref='x', caltype='line', function='legendre', order='3', inttype='interp', w1='None', w2='None', dw='None', nw='None', blank='0.0', clobber='yes', logfile='salt.log', verbose='yes')

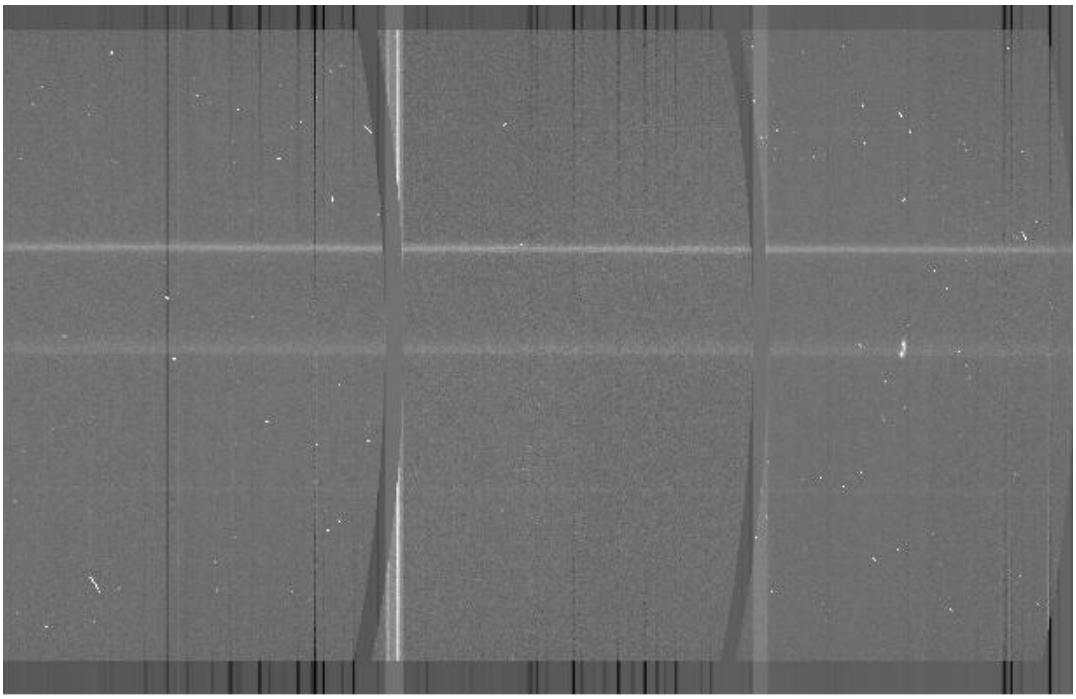
Open the rectified image in ds9 to be sure that the curvature has been properly removed. It should look something like this:



Now you want to do a sky subtraction to get rid of all of those lines. Do epar specsky, or enter the following command. Edit the "section" field to the desired range of the CCD you want to use. I try to pick a range of about 100 rows close but not super close to my science target. Again be sure you're applying the sky subtraction to the correct file (your rectified science image from specrectify).

specsky(images='xmbxpP200610190015.fits', outimages=' ', outpref='s', section='1234:1370', clobber='yes', logfile='salt.log', verbose='yes')

Now you should have a sky-subtracted image in your working directory. Look at it with ds9. It should look something like the following:

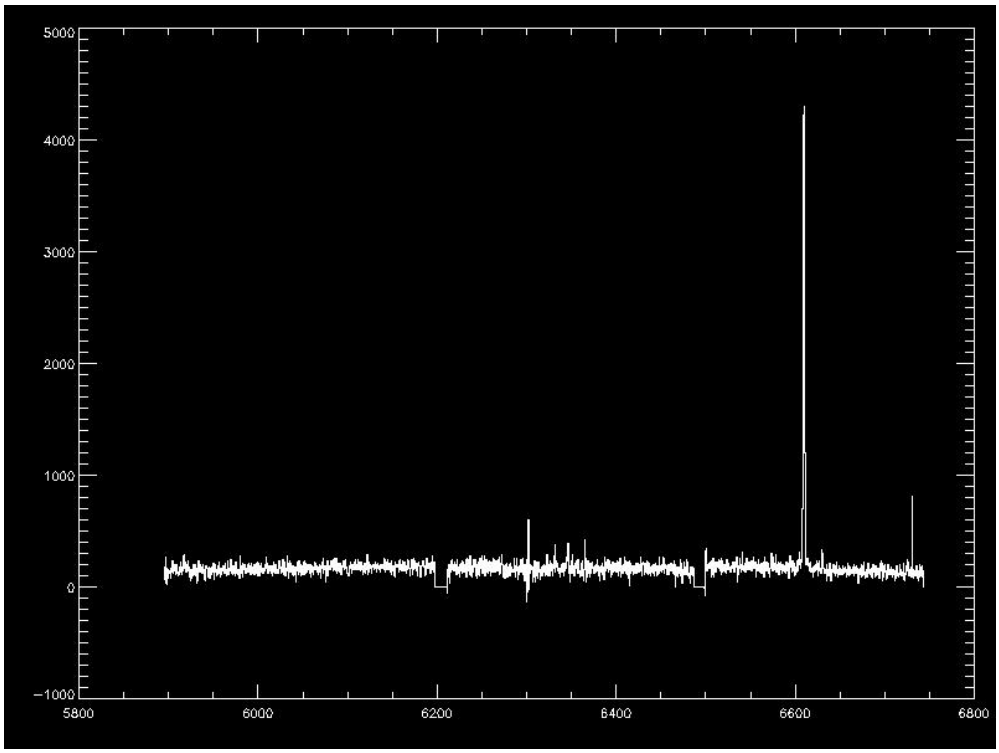


There are still artifacts of the skylines present in this image, as the solution is not perfect, but this is still a pretty good, useable sky subtraction. The chip gaps cause some weird subtraction artifacts, and the overscan regions are pretty bad too, but these don't tend to hurt the science target. If you look very closely at the sky subtracted images in ds9, you might be able to see faint concentric rings that ripple through the image. This is a "phantom pupil". Additionally, if your data is very far in the red, you may see heavy fringing affects. There are currently no fringe or phantom pupil correction methods available for SALT. ☹ Another possible "weird effect" is a Littrow Ghost. This appears as an image of your slit or a star like object that does not get dispersed. It's an interior reflection effect within the instrument optics due to RSS using a holographic grating. The SALT FAQ page has more about this.

Now the final step is extracting your spectrum. Epar specextract, or do the following command:

specextract(images='sxmbxpP200610190015.fits', outfile='sxmbxpP200610190015.txt', method='normal', section='1006:1050', thresh='3.0', minsize='3.0', outformat='ascii', convert='yes', clobber='yes', logfile='salt.log', verbose='yes')

Be sure you use your sky subtracted science image, and designate a named .txt file for the spectrum to be written into. In the 'section' field, input the row region containing your science target. Use ds9 to find your best aperture. Once you have it extracted, use your favorite programming language to take a look. Here's a quick and dirty example:



You can see in the middle that the sky subtraction doesn't quite get the really strong lines completely out, and there are a few cosmic rays that made it through the rudimentary cosmic ray cleaning.

Congrats, you're now the owner of a shiny new reduced spectrum.

This document is a work in progress and based on my own trials and tribulations. I recommend contacting salthelp@saao.ac.za for any questions you can't find the answer to here or in the documentation, as they are all exceedingly prompt and helpful.

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