Reduction of the FIES spectra

Setup

Login to snabb.astro.uu.se. Make a new directory, e.g. KJELL. Copy the reduction script from directory FIES with command *cp.* E.g. if you are in your new directory do this: cp ~/FIES/reduce.pro .

Get ready by changing directory to your directory with *cd* command, e.g. cd KJELL. Open reduce.pro with your favorite text editor. Various steps of reduction follow a simple cycle: modify reduce.pro (if needed), save it (no need to leave the editor) and re-run the script in IDL with ".r reduce".

Start IDL with *idl* command.

Reduction steps

Find file names of your science targets. For that insert a stop command in the script after FITS files were sorted by file type. IDL is case-insensitive and different commands require separate lines, so insert a new line a stop (column position makes no difference), save and inside IDL say *.r reduce*. Once the code has stopped you can manually print the list science files. E.g.
for i=0,n_elements(spec)-1 do print,i,f[i]+': '+ob[i]

Note file numbers of your science target as well as the two variable stars and then replace the stop command with selecting a subset of science files. E.g. if your files have numbers 0,2,3,4,5,6,9 the selection can be done as spec=spec[[0,2,3,4,5,6,9]].

Run the reduction. Very simple, save the script and run it again. It will take some time. The steps that it will go through are: master bias, master flat, order location, flat field normalization, extraction of ThAr (wavelength calibration) and finally science extraction. After each science frame you will see a plot with provisionary continuum normalization (4 spectral orders at a time). Press any key to continue. Note, how many bad pixels were rejected during master bias and master flat processing. Note also order numbers where continuum normalization of the science spectra failed (negative values).

Wavelength calibration. After completing the main reduction part exit IDL with *exit* command, change directory to subdirectory *reduced* created by the script. Look at all the *.ech files created during reduction and find the one with *thar* in the name. Start IDL again and start the wavelength calibration program with *wavecal,'filename.thar.ech',save='~/FIES/raw/not_fies_thar_2D.sav'*

Start with "Align", then 2D solution, then AutoID. Repeat, 2D solution + AutoID using 150 m/s for rejecting the outliers. Once done, add the wavelength solution to all science *.ech files.

Continuum fitting. This part must be done last as it requires the wavelength solution to be added to all the ech files. It will also help you to learn how to read and manipulate the structures stored in ech files.

A template code "continuum.pro" is now located in FIES directory. It looks like this:

```
restore,'fies_2011-11-14.ord.sav'
```

```
...
;=====================================================
; HR8097: FIuk140052.ech FIuk140053.ech FIuk140054.ech

rdech,e,'FIuk140052.ech',/NOCONT
ee=make_cont(e,blzcoef,param=[15,5.d6,1.d11,1.],/PLOT,/debug)
rdech,e,'FIuk140052.ech',/RAW
wdech,'FIuk140052c.ech',ee.head,ee.spec,sig=ee.sig,cont=ee.cont $
     ,wave=e.wave,orders=ee.orders;,/OVERWRITE

...

end
```

Copy it to your *reduced* directory and prepare to edit. Find your target and copy the example lines given for HR8097. You will need one set for each spectrum (=one ech file). Now change the name of the ech file and you are ready to roll.

The actual procedure is done by *make_cont* function. The line before reads-in the extracted spectrum from an ech file. The two lines after store the final result to a new ech file.

make_cont function has 4 parameters given in square brackets. The first defines the number of inner iterations. The 2nd sets the rigidity of the fit. The 3rd determines how free are the ends of the fit and the very last one is the overall scaling that should be kept to 1. You will have to tune the first 3 parameters. Good practice is to comment out the creation of the new ech file, set the /debug flag, set the number of iterations to 10 and then play with the 2nd parameter until the final fit follows the upper envelope of the spectrum. Keep the 3rd parameter at 10^9 – you will try changing it later. *make_cont* always does 3 out iterations. On each such iteration it first shows the whole spectrum and the fit. At this point it wants you press any key to continue. Then it will automatically go through every spectral order showing in the upper panel the spectrum (white), the continuum (green) and the blaze (blue). Bottom panel shows the normalized spectral order. The 2nd parameter value is somewhere between 10^4 and 10^7. Now you can run *continuum* a few times adjusting the 2nd parameter. Once satisfied, try changing the 3rd parameter and see if you can improve things further. Note that in the UV part of the spectrum no perfect fit is possible simply because of the Balmer jump.

Continuum fit is a computing-intensive step – set aside enough time. If you have several spectra for the same target, you only need to tune the parameters once and they will fit other exposures.

Note how ech files are read. You will need this for the final analysis.