

AY257 Winter 2019
HMWK5 Example (IRAF)

- [Load up IRAF from Anaconda](#)

or using these instructions:

- [Colorado College IRAF install](#)

- Worked for three recent installs, remember for each session you have to activate iraf27 from your shell:

```
source activate iraf27
```

Start IRAF, go to directory with fits files, load *noao*, *twodspec*, *apextract*

```
bash-3.2$ cl
setting terminal type to xterm...

NOAO/IRAF PC-IRAF Revision 2.16 EXPORT Thu May 24 15:41:17 MST 2012
This is the EXPORT version of IRAF V2.16 supporting PC systems.

Welcome to IRAF. To list the available commands, type ? or ?? . To get
detailed information about a command, type `help <command>'. To run a
command or load a package, type its name. Type `bye' to exit a
package, or `logout' to get out of the CL. Type `news' to find out
what is new in the version of the system you are using.

Visit http://iraf.net if you have questions or to report problems.

The following commands or packages are currently defined:

(Updated on 2013-12-13)

    adccdrom.  deitab.    images.    mtools.    softools.  upsquid.
    cfh12k.    esowfi.    kepler.   nfextern.  squid.     utilities.
    cirred.    finder.    language. noao.      stecf.     vo.
    ctio.      fitsutil.  lists.    obsolete.  stsdas.    xdimsum.
    cutoutpkg. gemini.    mem0.     plot.      system.    xray.
    dataio.    gmisc.    mscdb.    proto.     tables.
    dbms.      guiapps.   mscred.   rvsao.     ucslcris.

ecl> cd /Users/michaelbolte/Dropbox/AY257_18/Homework/Homework5/Homework5Files
ecl> noao
    artdata.    digiphot.  nobsolete.  onedspec.
    astcat.     focas.     nproto.     rv.
    astrometry. imred.     observatory surfphot.
    astutil.    mtlocal.   obsutil.    twodspec.

noao> twod
    apextract.  longslit.

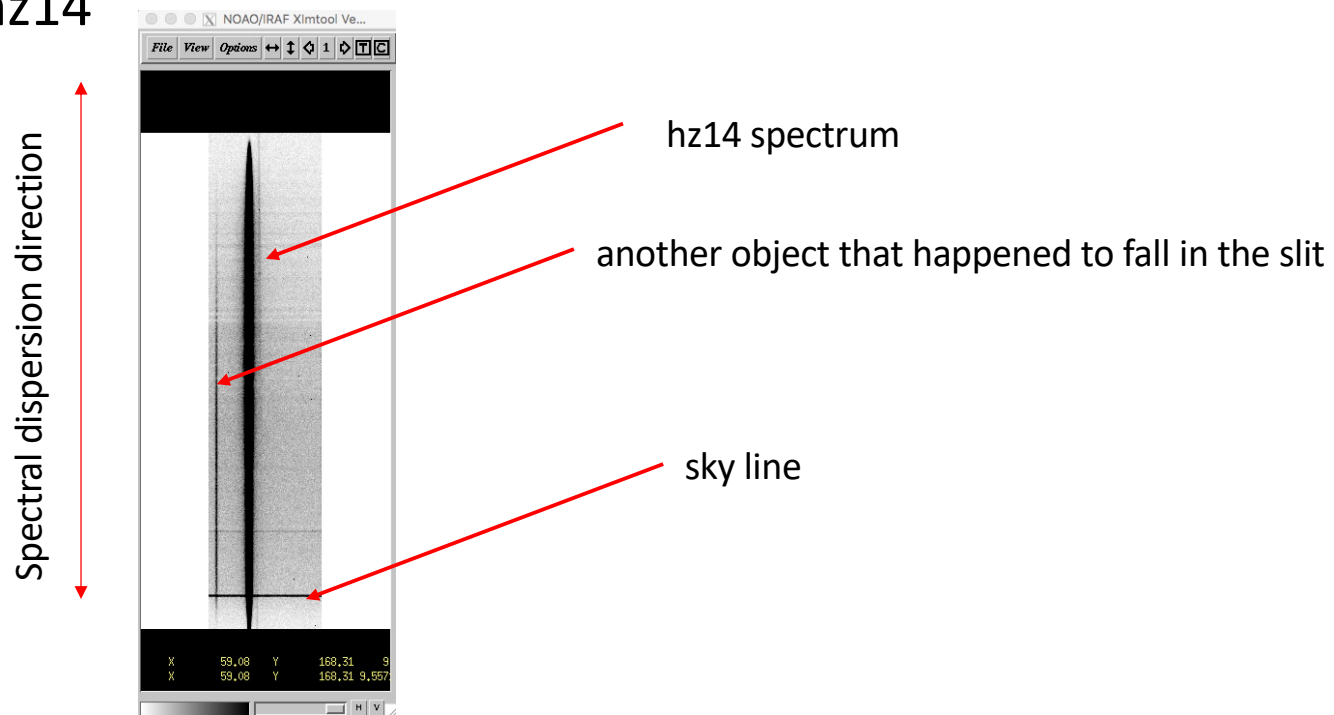
twodspec> apex
    apall        apedit      apflatten   apnormalize  apscatter
    apdefault@  apfind      apmask      apresenter  apsum
    apdemos.    apfit       apnoise     apresize     aprace

apextract> █
```

Find Apertures, trace and extract spectrum

- Will use the spectrophotometric standard hz14 as example.

cl>display hz14



Set
parameters
in *apall*:
epar apall

```
xgterm
I R A F
Image Reduction and Analysis Facility
PACKAGE = apextract
TASK = apall

input =          hz14 List of input images
(output =        hz14) List of output spectra
(apertur=        ) Apertures
(format =        multispec) Extracted spectra format
(referen=        ) List of aperture reference images
(profile=        ) List of aperture profile images

(interac=        yes) Run task interactively?
(find =          yes) Find apertures?
(recente=        yes) Recenter apertures?
(resize =        yes) Resize apertures?
(edit =          yes) Edit apertures?
(trace =         yes) Trace apertures?
(fittrac=        yes) Fit the traced points interactively?
(extract=        yes) Extract spectra?
(extras =        yes) Extract sky, sigma, etc.?
(review =        yes) Review extractions?

(line =          INDEF) Dispersion line
(nsum =          10) Number of dispersion lines to sum or median

# DEFAULT APERTURE PARAMETERS

(lower =         -10.) Lower aperture limit relative to center
(upper =         10.) Upper aperture limit relative to center
(apidtab= []     ) Aperture ID table (optional)

# DEFAULT BACKGROUND PARAMETERS

(b_funct=        chebyshev) Background function
(b_order=         1) Background function order
(b_sampl=        -20:-15,15:20) Background sample regions
(b_naver=        -3) Background average or median
(b_niter=         0) Background rejection iterations
(b_low_r=         3.) Background lower rejection sigma
(b_high_r=        3.) Background upper rejection sigma
(b_grow =         0.) Background rejection growing radius

# APERTURE CENTERING PARAMETERS

(width =         5.) Profile centering width
(radius =        10.) Profile centering radius
(thresh=         0.) Detection threshold for profile centering

# AUTOMATIC FINDING AND ORDERING PARAMETERS

nfind =          1 Number of apertures to be found automatically
(minsep =         5.) Minimum separation between spectra
(maxsep =       100000.) Maximum separation between spectra

More
```

ESC-? for HELP

```
xgterm
I R A F
Image Reduction and Analysis Facility
PACKAGE = apextract
TASK = apall
More
(order = []     increasing) Order of apertures

# RECENTERING PARAMETERS

(aprecen=        ) Apertures for recentering calculation
(npeaks =        INDEF) Select brightest peaks
(shift =         yes) Use average shift instead of recentering?

# RESIZING PARAMETERS

(llimit =        INDEF) Lower aperture limit relative to center
(ulimit =        INDEF) Upper aperture limit relative to center
(ylevel =         0.1) Fraction of peak or intensity for automatic width
(peak =          yes) Is ylevel a fraction of the peak?
(bkg =           yes) Subtract background in automatic width?
(r_grow =         0.) Grow limits by this factor
(avglimi=        no) Average limits over all apertures?

# TRACING PARAMETERS

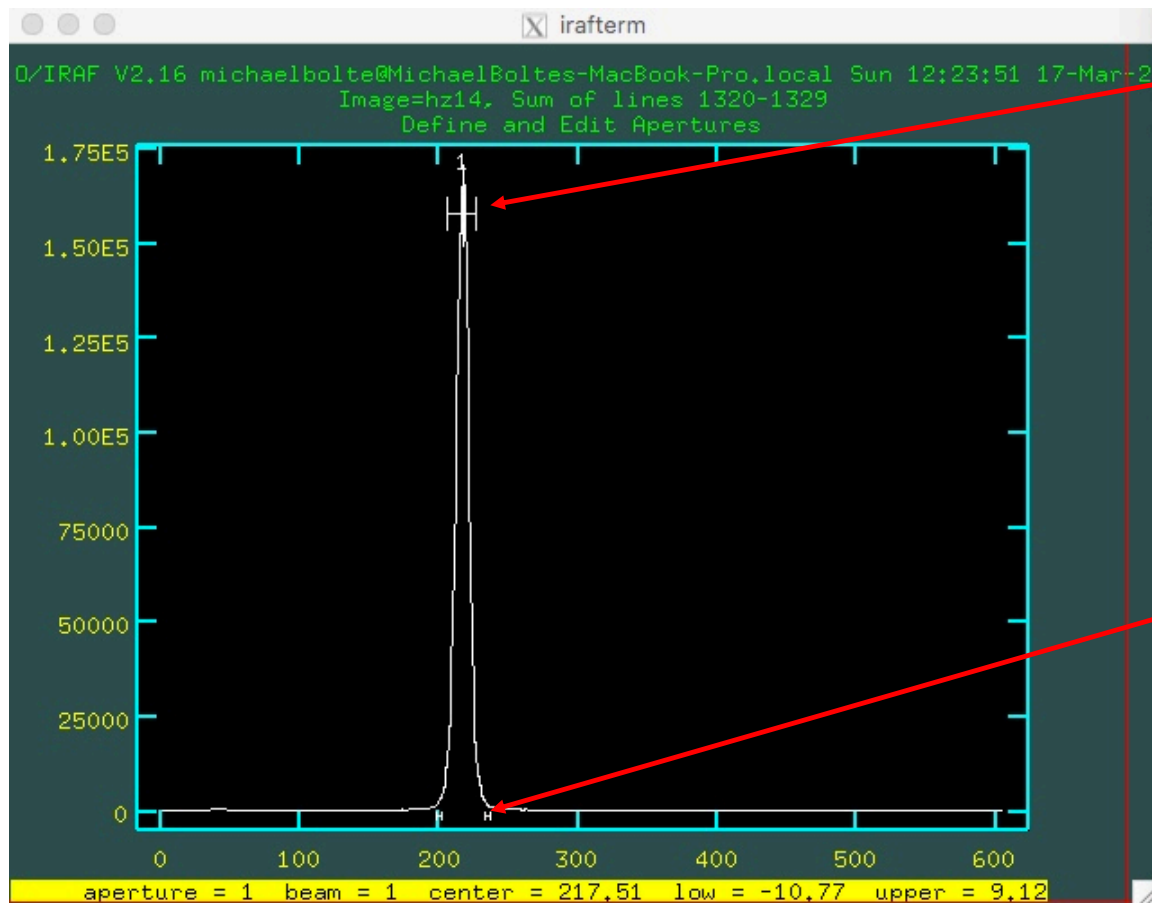
(t_nsum =         10) Number of dispersion lines to sum
(t_step =         10) Tracing step
(t_nlost=         3) Number of consecutive times profile is lost before
(t_funct=        legendre) Trace fitting function
(t_order=         2) Trace fitting function order
(t_sampl=        *) Trace sample regions
(t_naver=         1) Trace average or median
(t_niter=         0) Trace rejection iterations
(t_low_r=         3.) Trace lower rejection sigma
(t_high_r=        3.) Trace upper rejection sigma
(t_grow =         0.) Trace rejection growing radius

# EXTRACTION PARAMETERS

(backgro=        fit) Background to subtract
(skybox =         3) Box car smoothing length for sky
(weights=        variance) Extraction weights (nonelvariance)
(pfit =          fitid) Profile fitting type (fit1d/fit2d)
(clean =         yes) Detect and replace bad pixels?
(saturat=       58000.) Saturation level
(readnoi=         5) Read out noise sigma (photons)
(gain =          2) Photon gain (photons/data number)
(lsigma =         4.) Lower rejection threshold
(usize =         4.) Upper rejection threshold
(nsubaps=         1) Number of subapertures per aperture
(mode =          ql)
```

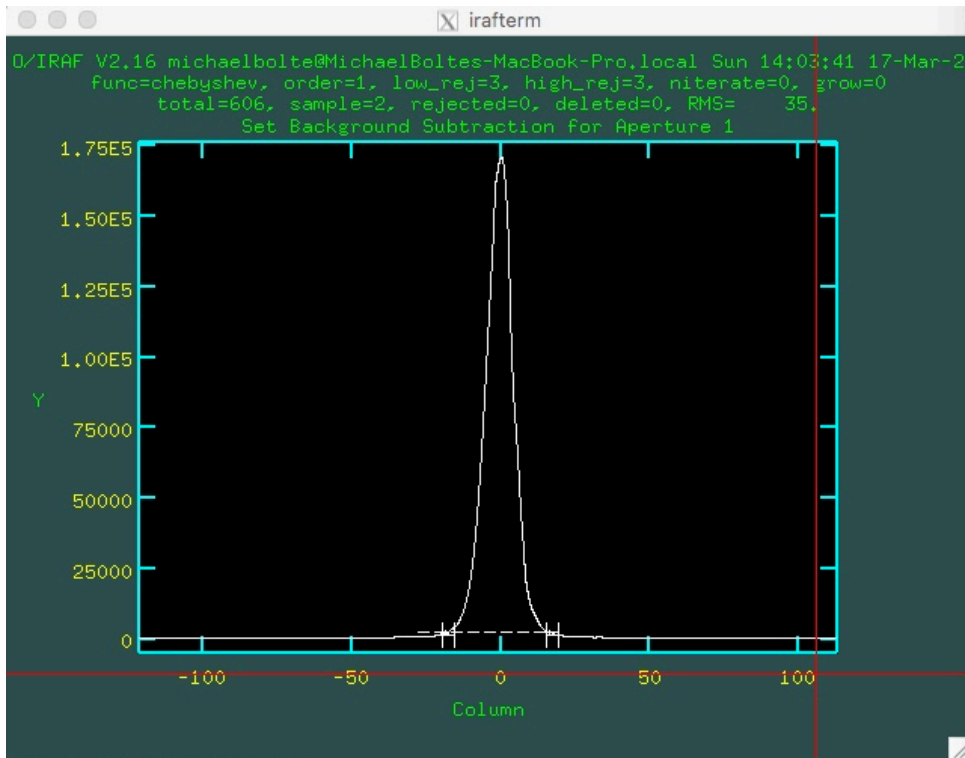
ESC-? for HELP

Graphics window pops up

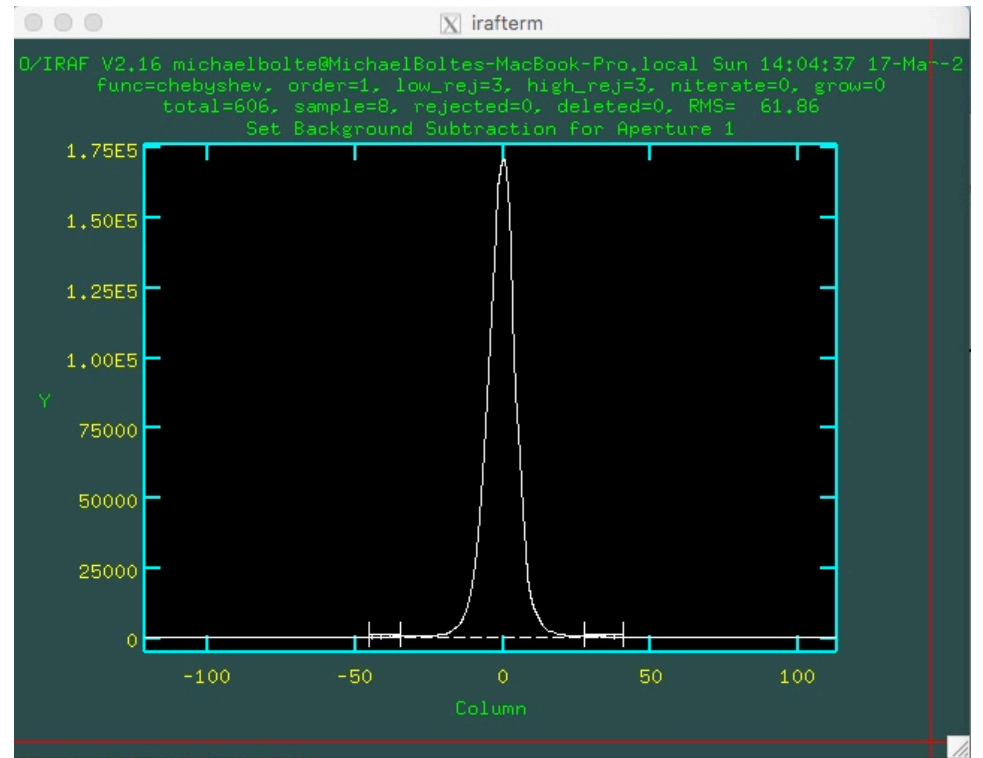


Lower and upper limits of the extraction aperture. Place cursor on lower-side aperture edge and use "l" to reset, place cursor on upper-side edge of the aperture and use "u" to reset

Initial setting of the background apertures had them too close to the aperture with the result that you subtract the stellar spectrum from itself. Typing "b" will put you into the "background set" mode (next slide)



Initial background samples and fit to background level. Got here by typing "b" in previous aperture window. Use "z" to delete the background aperture closest to the cursor, then "s" to define a new aperture with the cursor

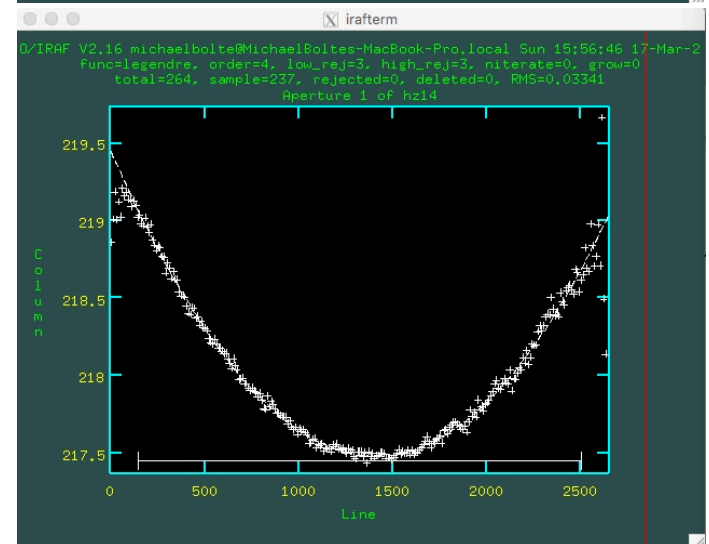
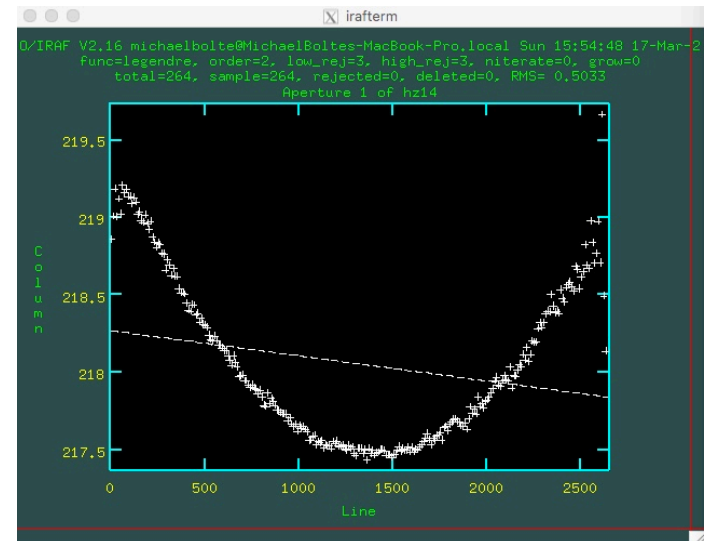


Result of using "z" twice to get rid of the original apertures, "s" twice to define two new sky apertures, then "f" to make the fit between sky apertures. When you are happy with your background apertures and fit, use "q" to go back to the main aperture plot

Trace

When happy with the aperture and background, type “q” from aperture window and respond “yes” to interactively trace the aperture and this will pop up.

In the window use “:o 4”, followed by “f” to set the fitting order to 4 and refit. Note that I used “s” first to reset the sample to ~100 to 2450 on the x axis to avoid using the funny stuff at the end of the trace in the fit.

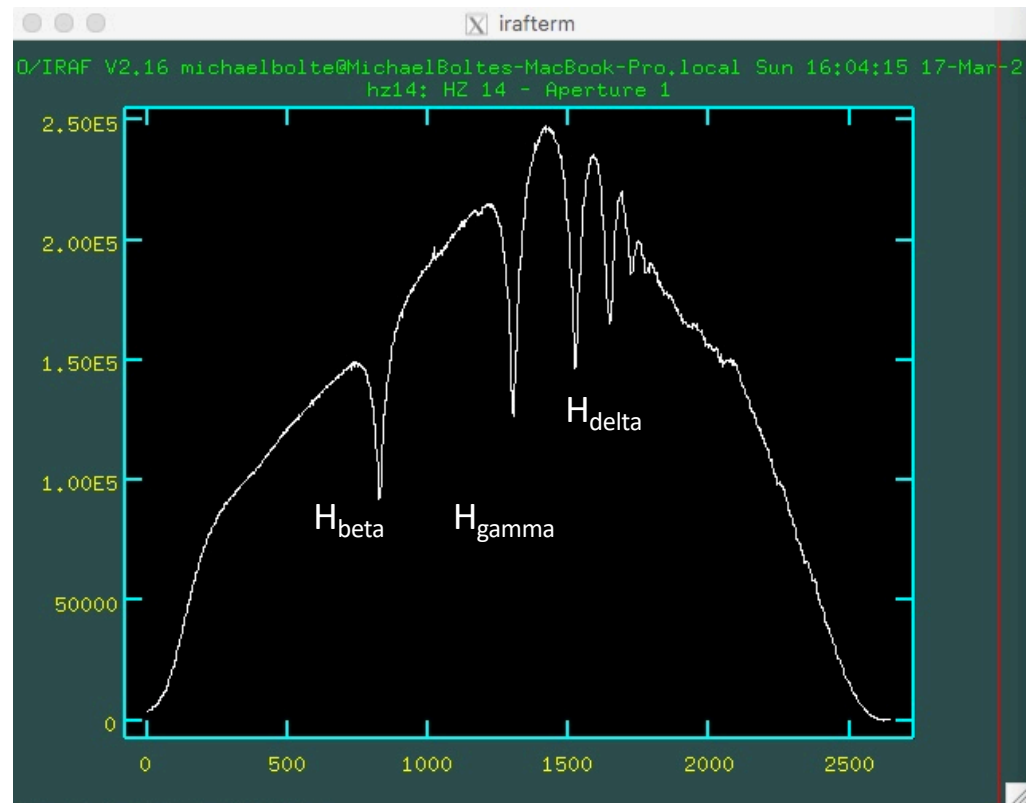


Extract and review the spectrum

Answer “yes” (several times) to questions about extracting and reviewing the spectrum and you have it!

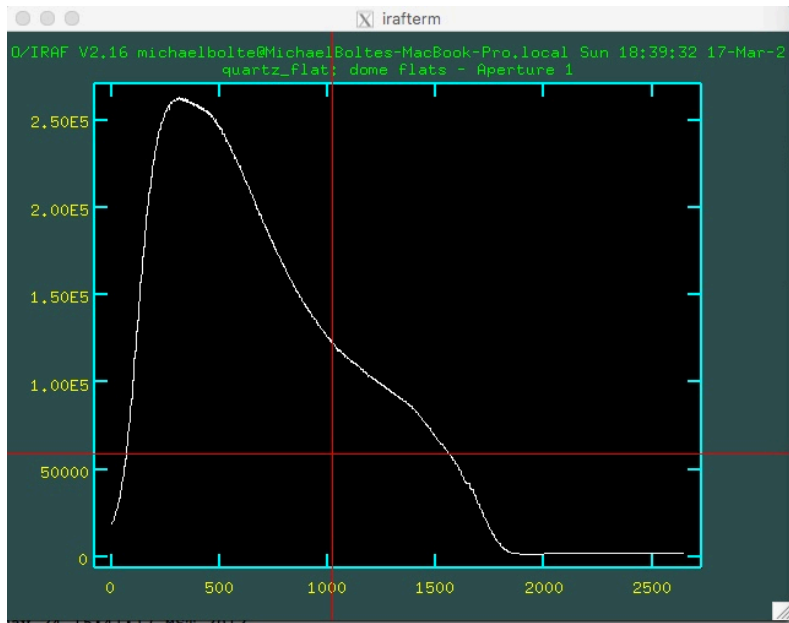
hz14.ms has the extracted spectrum (intensity vs pixel), extracted sky, and a S/N plot

You can go back to *apall* and reset the Default Aperture Parameters and Default Background Parameters and they will be better starting points for subsequent extractions of the other spectra

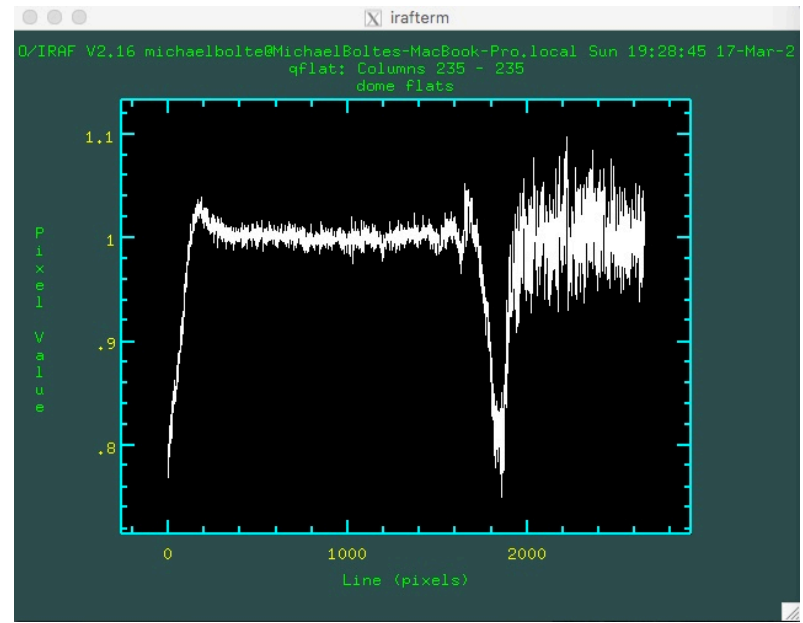


Flat-fielding

- The flat-field image is a spectrum of a quartz lamp: more-or-less a blackbody continuum. In order to use that spectrum as a flat-field the variation in the spectral dimension needs to be removed as that is just the spectrum of the bulb and has nothing to do with the sensitivity of the detector
- You can fit a low-order function to the flat-field and divide it into the original and then extract the same aperture/trace as the stellar spectrum or you can do the extraction and then normalize the extracted spectrum
- I'll try both

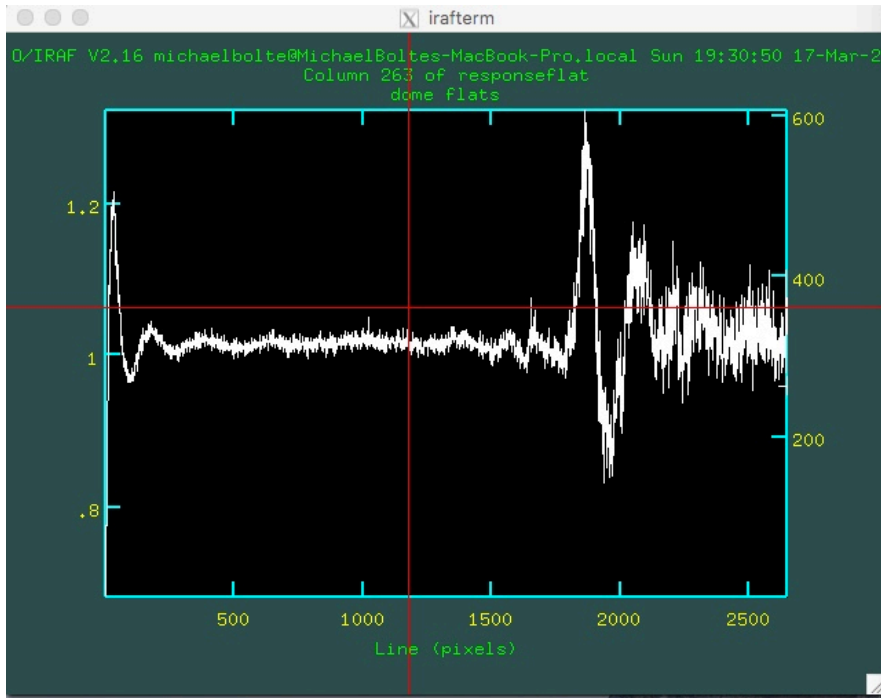


This is the extracted flat

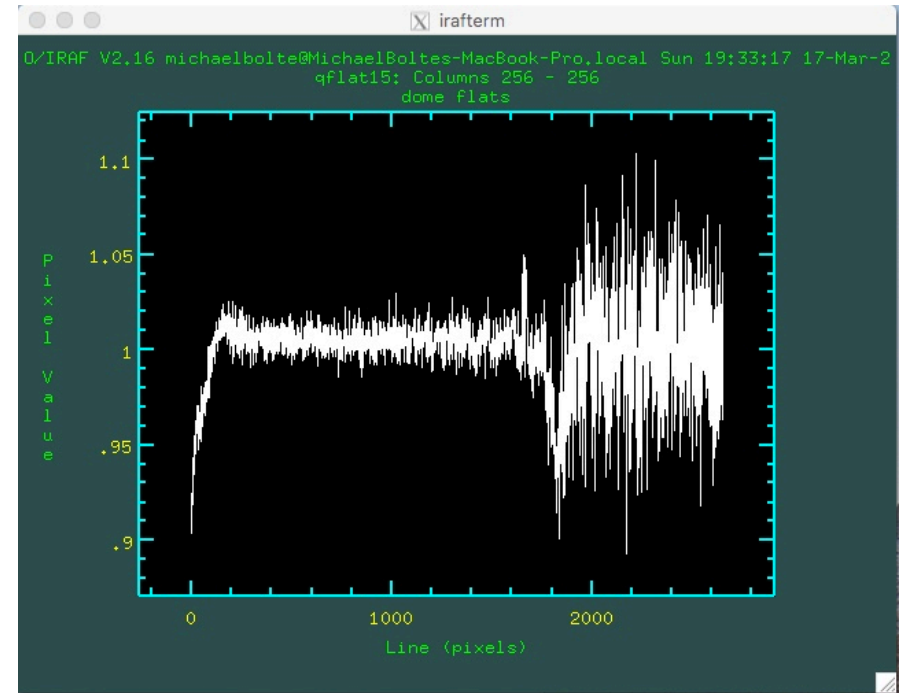


This is after dividing out a 22nd-order polynomial fit

Not very good! Between around pixel 200 and 1600 it is OK but probably do more bad than good to use this



This is a cut along a column after (1) doing a gaussian smooth of the 2-D flat using a 30-pixel kernel and (2) dividing the original image by the smoothed version



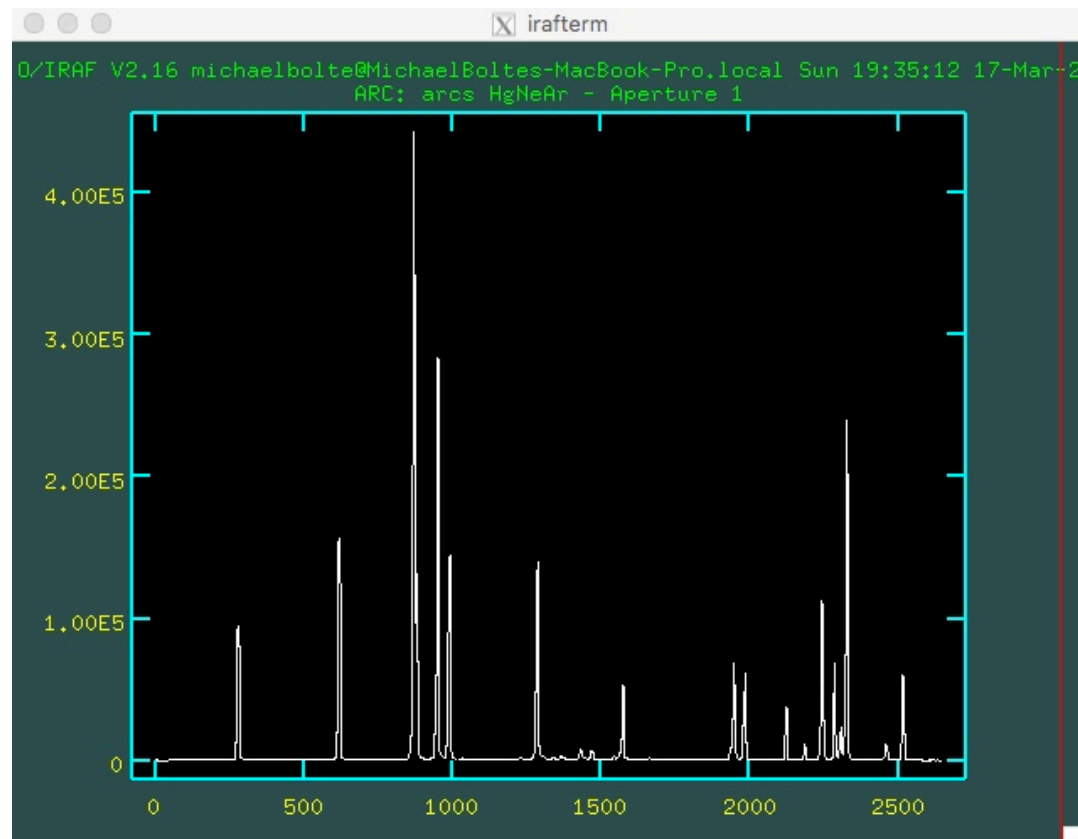
This is a cut along a column after (1) doing a gaussian smooth of the 2-D flat using a 15-pixel kernel and (2) dividing the original image by the smoothed version

This looks better, but not enough light beyond pixel 1700: conclusion, don't flat field

Wavelength calibration

Use `apall` to extract ARC spectrum with the `hz14.ms` aperture/trace as was done with the quartz flat (no background subtract, use aperture based on `hz14.ms`)

identify is the task used to assign wavelengths to arc lines and map pixel to wavelength



Identify

Need to give it:

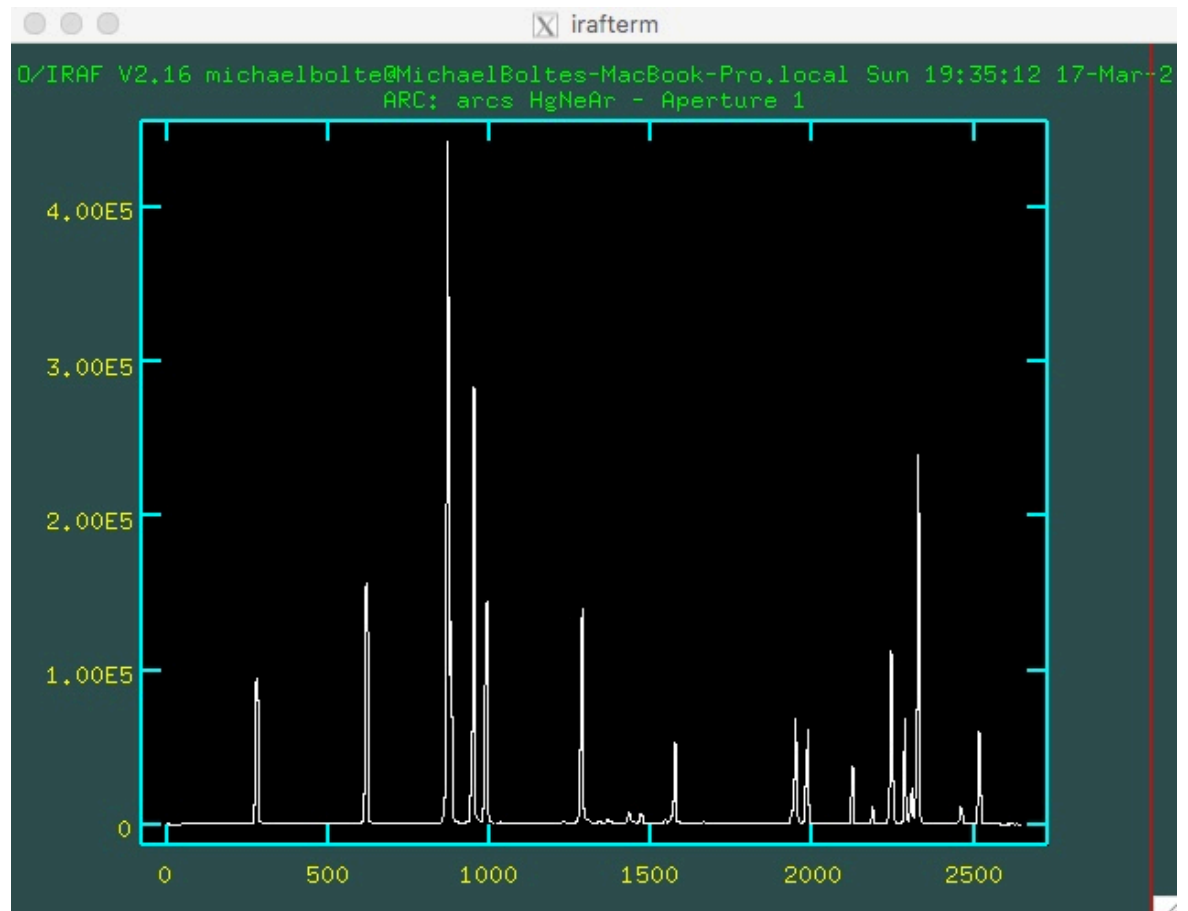
- (1) an arcline spectrum (ARC.ms) and,
- (2) a line list (400_arc.list in the working directory)

```
xgterm
IRAF
Image Reduction and Analysis Facility
PACKAGE = longslit
TASK = identify

images =                Images containing features to be identified
(section= middle line) Section to apply to two dimensional images
(databas= database) Database in which to record feature data
(coordli= 400_arc.list) User coordinate list
(units = ) Coordinate units
(nsum = 10) Number of lines/columns/bands to sum in 2D image
(match = -3.) Coordinate list matching limit
(maxfeat= 50) Maximum number of features for automatic identif
(zwidth = 100.) Zoom graph width in user units
(ftype = emission) Feature type
(fwidth = 4.) Feature width in pixels
(cradius= 5.) Centering radius in pixels
(thresho= 0.) Feature threshold for centering
(minsep = 2.) Minimum pixel separation
(funcio= spline3) Coordinate function
(order = 1) Order of coordinate function
(sample = *) Coordinate sample regions
(niterat= 0) Rejection iterations
(low_rej= 3.) Lower rejection sigma
(high_re= 3.) Upper rejection sigma
(grow = 0.) Rejection growing radius
(autowri= no) Automatically write to database
(graphic= stdgraph) Graphics output device
(cursor = ) Graphics cursor input
crval = Approximate coordinate (at reference pixel)
cdelt = Approximate dispersion
(aidpars= ) Automatic identification algorithm parameters
(mode = ql)
```

Use the cursor on a line a “m” (mark)
to type in three or four line
wavelengths based on 400_arc.pdf
identifications

Note that the wavelength scale is
reversed initially with respect to
400_arc.pdf file

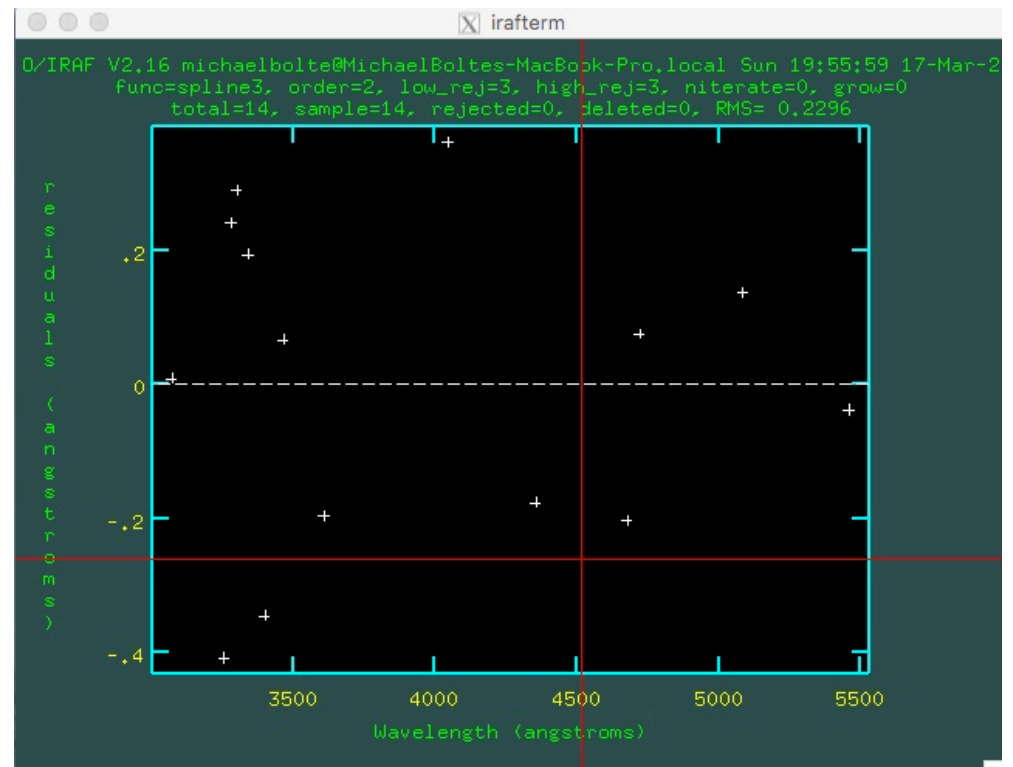


The art of fitting arc lines

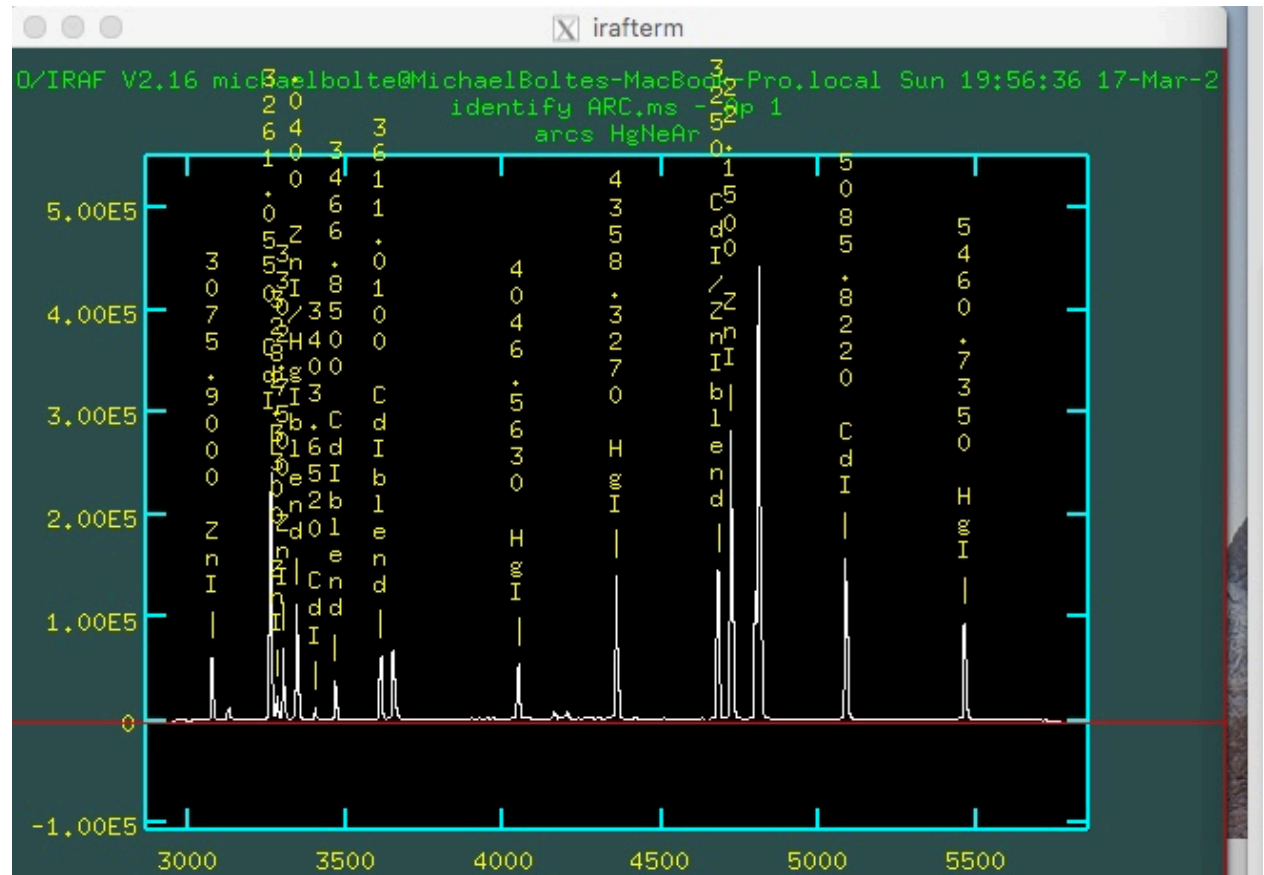
The first time you run *identify*, find a line ID by matching patterns in 400_arc.pdf, center the cursor on it, type “m” and enter the wavelength. Do this for three or four lines then type “f” (for fit)

That will produce the panel on the right. This shows the residual from the best fit of each identified line. The fit order is shown as is the RMS residual. Move the cursor to a point type “d” then “f” and it will refit without that point (put the cursor near the deleted point and type “u” to add it back to the mix). Experiment. Sometimes deleting one or two points will improve the fit a lot.

Type “q” to go back to the spectrum



With the preliminary fit done, now if you center the cursor on a line and click “m”, it will calculate the fit based on the current solution and search through your line list (400_arc.list) for a nearby match and assign that wavelength. Do this for all the clean lines, type “f” again to go to the fitting plot and remove any serious outliers.



Refspec and dispcor

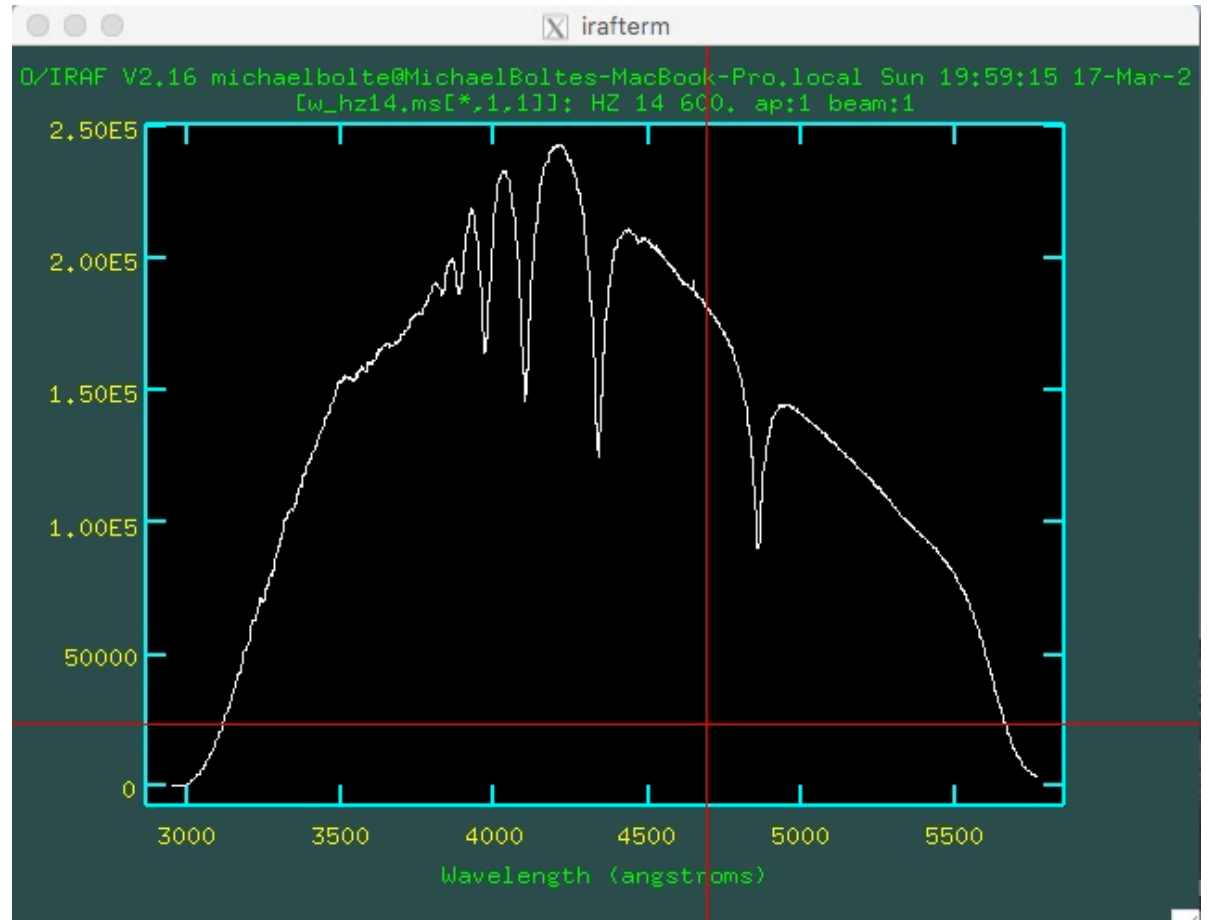
Now associate the arc solution with your extracted stellar spectrum using the task *refspec*

```
twod> refspec hz14.ms ARC.ms
```

Finally, write a linearized wavelength scale into the stellar spectrum header using *dispcor*

```
twod> dispcor hz14.ms w_hz14.ms
```

```
twod> plot w_hz14.ms will produce the plot on the right
```

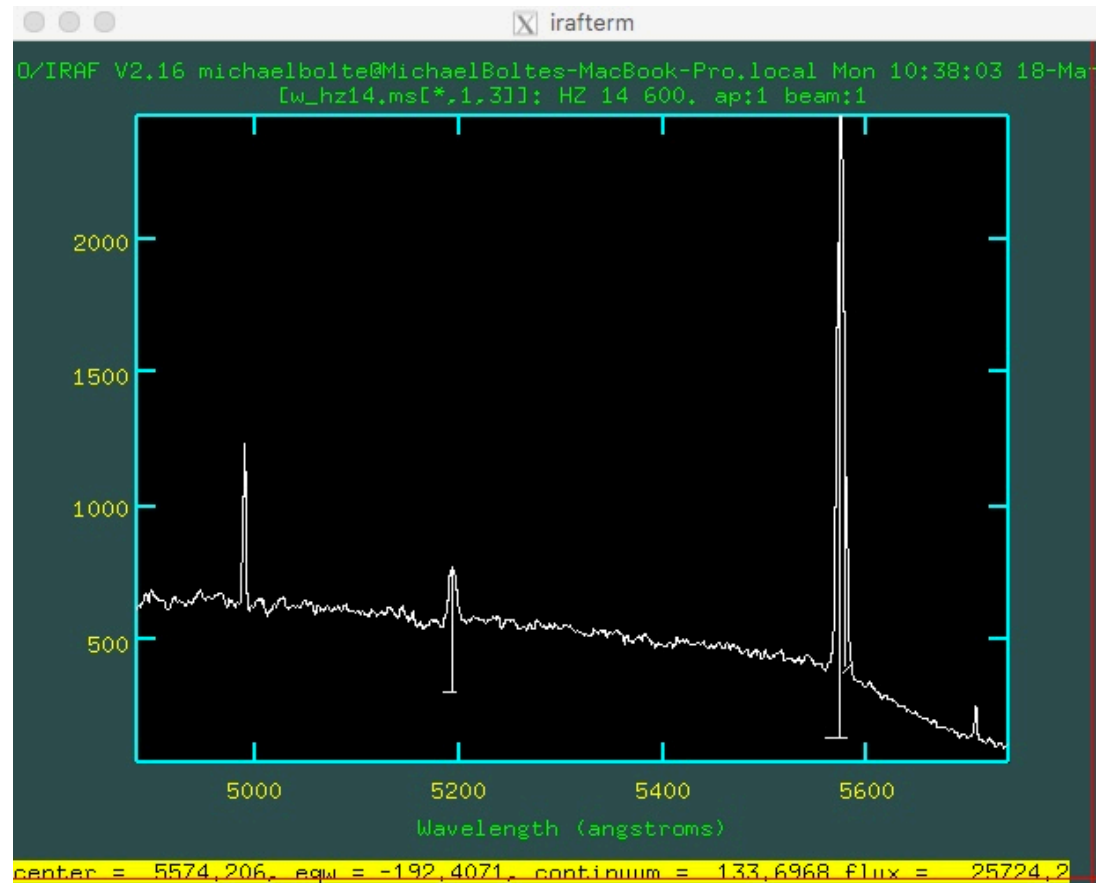


Splot for line centers

If plot "band 3" from w_hz14.ms, this is the extracted sky. The strongest emission line is:

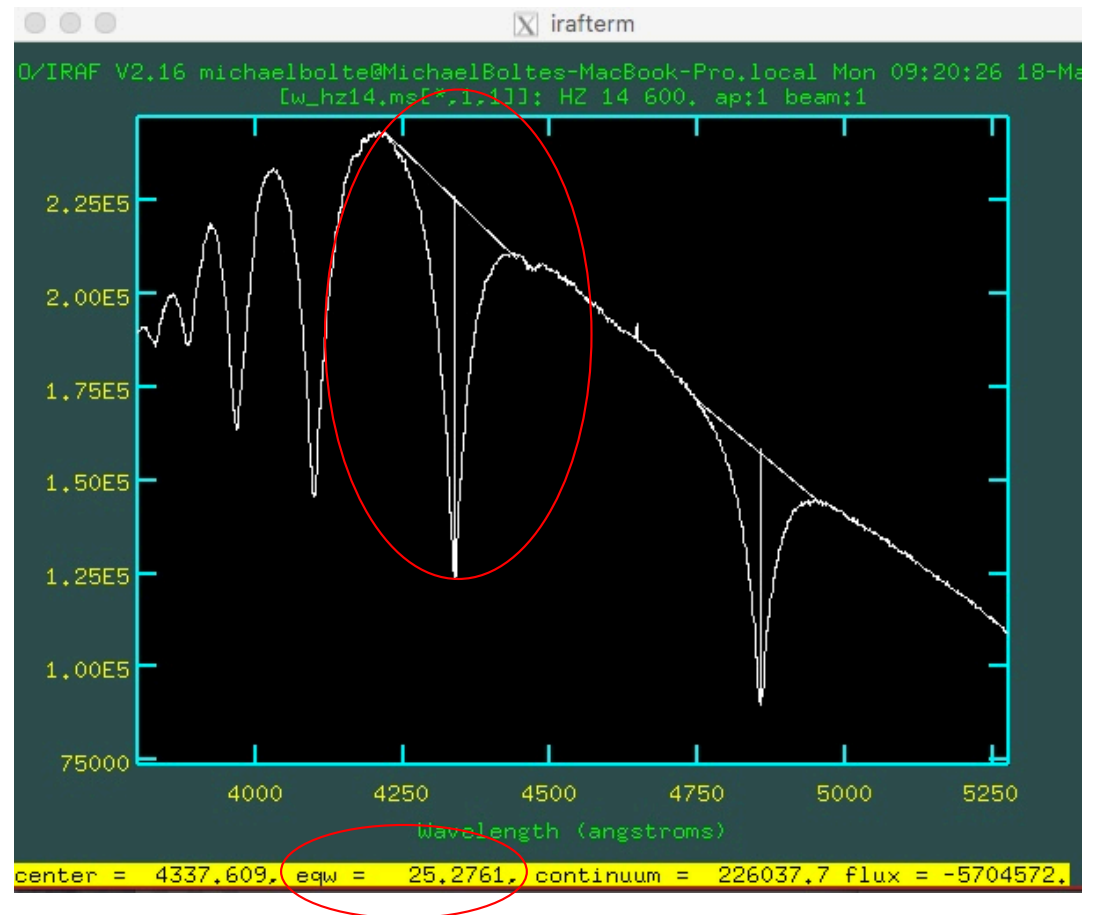
Oxygen forbidden line at 5577.34A,
measured in the spectrum at 5574.2

The arc lamp was observed in the afternoon,
hz14 at night so the 3.1A offset is likely due
to flexure and this offset should be added as
a zeropoint correction to the wavelength
solution for hz14



splot to measure line properties

- For this assignment, you can use splot to measure the hydrogen Balmer line equivalent width.
- Handy commands are “w” for windowing the plot
- “e” for selecting two continuum points and measuring the equivalent width
- H_{gamma} example line center and equivalent width.

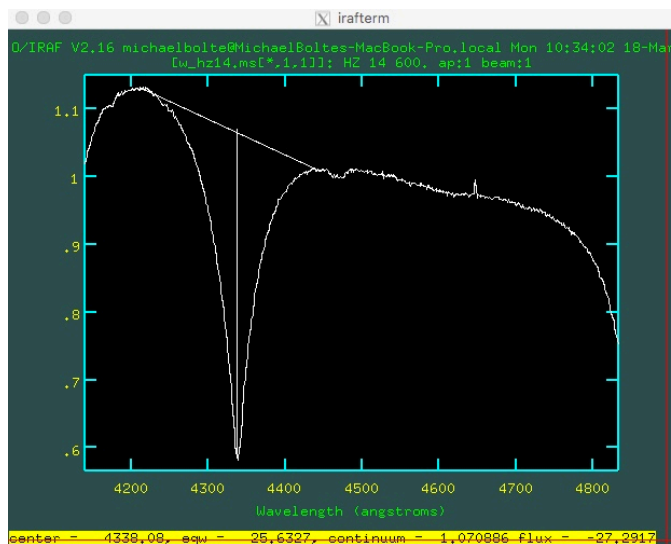


HZ14 radial velocity

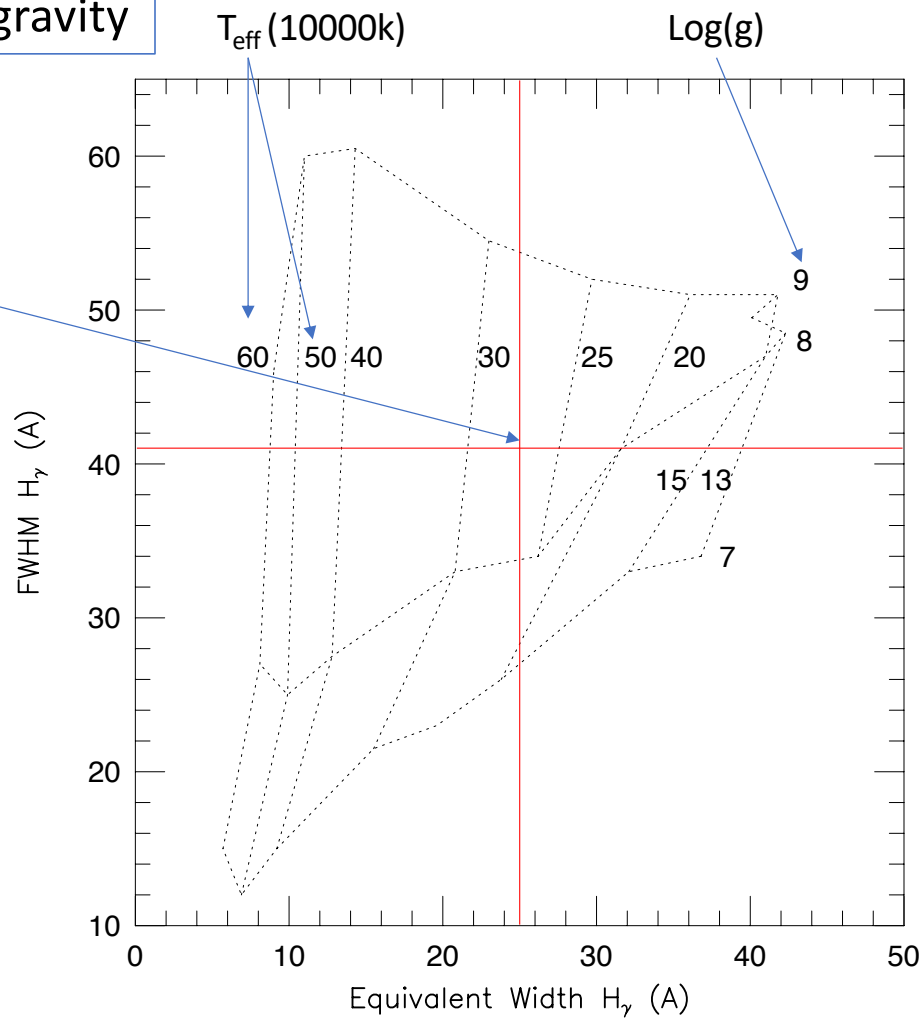
- Measured H γ line center: 4337.61A + 3.1A (offset from sky line) = 4340.71A.
- Rest wavelength for H γ is 4340.46A
- $v = \Delta\lambda/\lambda_0 \times c = 0.05/4340.46 \times 3 \times 10^5 = 3.5 \text{ km/sec}$

HZ 14 surface temperature and surface gravity

Looks like $T_{\text{eff}} \sim 27000\text{K}$, $\log(g) \sim 8.3$



H_γ FWHM=41(A), EW=20.5 (A)



A note

- Most of the candidate white dwarfs were indeed white dwarfs. There were two background QSOs and one G-star

