

Astro257: Assignment 5

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1. PURPOSE

Spectra allow us to classify celestial objects, determine chemical compositions, measure relative velocity, and much more. Because these scientific measurements are so powerful and prevalent in the field, understanding the process of extracting spectra is vital to a budding astronomer. In this assignment, I will generate spectra for a few stars and white dwarfs to determine effective temperatures and surface gravities.

2. WAVELENGTH SOLUTION

Unfortunately, since I couldn't get IRAF working properly on my computer, I necessarily ended up building many of the necessary tools in **Jupyter Notebooks**.

I started by first examining the file headers to confirm that the information was correctly displayed (i.e. correct filters and titles), and all seemed to be in order.

I then take the arc lamp exposure and extract a spectrum by averaging all but the 100 rows on the edges. This produces the results in Figure 1. I then found the peaks in the 1d spectrum and used these to determine the center of a Gaussian on each peak. I could then map the peak centers onto wavelength values from the provided lists. Finally, I fit a 6th order Legendre polynomial to the center/ wavelength pairs to get a wavelength solution that maps pixel values onto wavelength ones, and this is shown in Figure 2.

Unfortunately, the fit is not a very good one, as the RMS uncertainty in the map is $\sim 5\text{\AA}$. This means that efforts in determining a line-of-site velocity will fail using this solution, so I do not present that here. If time allowed, I would spend more time on the wavelength calibration to push the RMS value much lower and calculate the offset of hydrogen features from their rest positions in each spectrum.

3. SPECTRA EXTRACTION

The process for extracting spectra is similar to extracting the spectrum from an arclamp, except that the

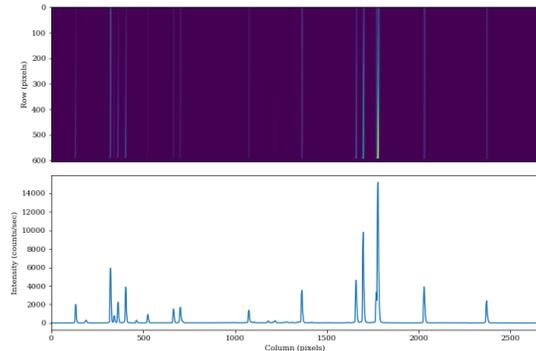


Figure 1. The arclamp spectrum extraction. Top: The 2d arclamp exposure. Bottom: The result of averaging the 2d array from the 50th row to the 50th from the end.

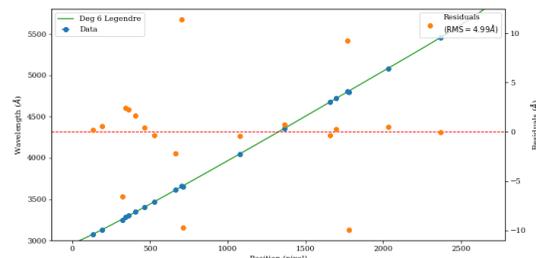


Figure 2. A map of pixel value to wavelength. The peaks in the bottom panel of Figure 1 are mapped onto wavelength values to generate the blue data points, and the green line is the resulting fit with a 6th order Legendre polynomial. Orange points are the residuals of this fit, which is characterized by an RMS uncertainty of 4.99\AA .

star does not fill the slit and the sky is also in the exposure. This means that we need a few more steps to account for this. Specifically, I divide each 2d spectrum by the exposure time for easier comparison and then divide that by the quartz lamp exposure to properly account for the effect of the detector itself.

Next, I find the for position of the peak intensity in each each column to isolate the star. I use these peaks as a function of column to find the trace function that describes the star light's row position as a function of column value. Finally, I assume that the light is Gaussian in the column dimension, and thus fit a curve to de-

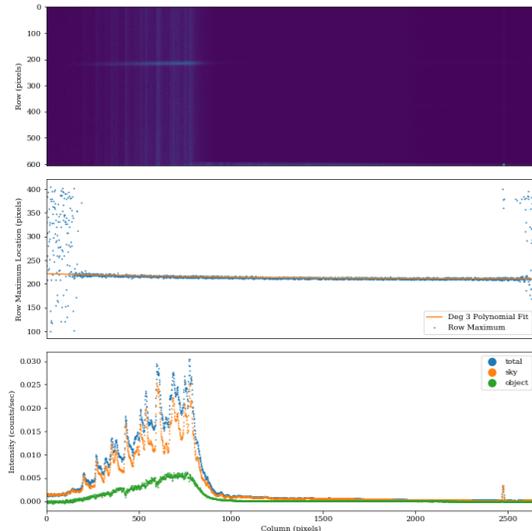


Figure 3. The extracted spectrum from file `n2168_RA4.fits`. Top: The 2d spectrum divided by its exposure time and the scaled quartz lamp exposure. Middle: A traceplot of each row’s maximum’s position as a function of column value with corresponding 3rd order polynomial fit. Bottom: The result of collapsing the 2d array in the top panel along the determined trace line in the middle panel. The object is anything found within 3σ of the traseline while the sky is estimated from any light outside that region.

termine where 99% (3σ) of the star’s light is contained and where the night sky is dominant (i.e. wherever is more than 3σ from the trace line).

Using the trace function and the determined Gaussian width, I collapse the 2d array into a 1d spectrum for both the object and the night sky. An example for this result and the previous steps is shown in Figure 3.

4. FLUX CALIBRATION

To get the intensity units into something physical, we need to compare our spectra to a standard. Luckily, Hz14 is one such object.

First, I extract the 1d spectrum for Hz14 as described above and apply the wavelength solution determined in §2. Next, I use the known physical flux measurements within sets of wavelength windows to create a map of counts/sec to f_ν . To get a functional form of this map, I use the `scipy.interpolate.interp1d` function in `python`. The result of this function is shown in Figure 4, and it visually matches previous results quite closely (Figure 3f in Massey et al. 1988).

Once satisfied with the function that transforms counts/hour to physical units, it is straightforward to find the flux calibrated spectrum of the other stars in our sample.

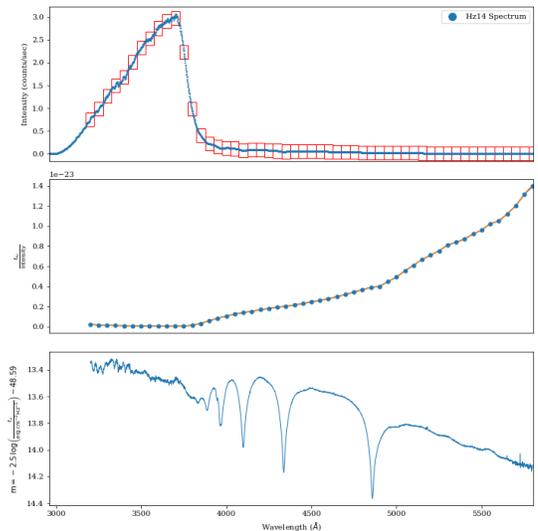


Figure 4. The extracted and calibrated spectrum of Hz14. Top: The 1d spectrum of Hz14 before calibration, with red boxes showing the wavelength regions where physical flux units are defined. Middle: The known physical flux divided by the average intensity in each red box from the top panel and corresponding cubic interpolation. Bottom: The result of applying the continuous function in the middle panel to the spectrum in the top panel (NOTE: The y-axis is in AB magnitudes).

5. STELLAR CLASSIFICATION

The extracted, wavelength-solved, calibrated spectra for all the stars in our sample are shown in Figure 5. Based on these spectra, it looks like almost all of the targets are indeed white dwarfs. The notable exception is from file `n2168_vH1.fits`, as it does not seem to have the same peak around 3500\AA that the other objects have, so I will conclude that this is the only non-white dwarf in our sample.

6. WD PARAMETERS

Finally, we can use the calibrated spectra to determine the FWHM and equivalent width at the H_γ feature. Since H_γ should be around 4341.635\AA (offset from Doppler shifting), it appears as though many of our spectra show this feature strongly. I start by fitting a Lorentzian shape to the flux, and then use its parameters to find the FWHM and equivalent width. An example of this is shown in Figure 6, which comes from the data of file `n2168_WB6.fits`; Table 1 shows the resulting H_γ measurements for the well-behaved spectra in our sample.

These measurements can then be used to estimate the effective temperature and surface gravity by comparing with a known relationship. Unfortunately, I can’t seem to understand the plot of this relationship (i.e. the plot

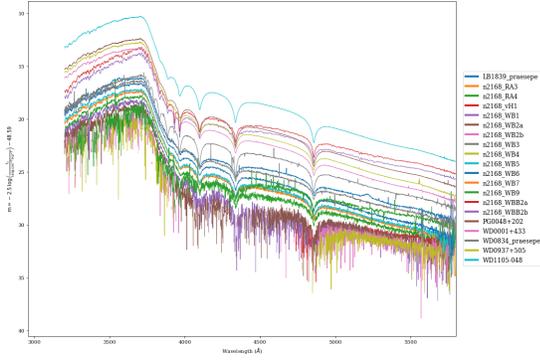


Figure 5. The extracted and calibrated spectrum of Hz14. Top: The 1d spectrum of Hz14 before calibration, with red boxes showing the wavelength regions where physical flux units are defined. Middle: The known physical flux divided by the average intensity in each red box from the top panel and corresponding cubic interpolation. Bottom: The result of applying the continuous function in the middle panel to the spectrum in the top panel (NOTE: The y-axis is in AB magnitudes).

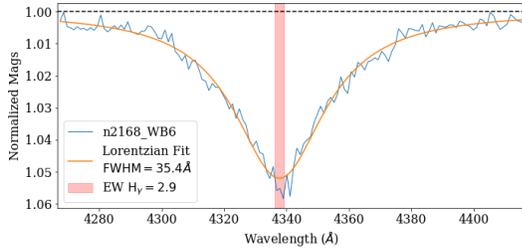


Figure 6.

of `wd.ps` from online), so I will leave this as an exercise to the reader.

Table 1. Measured H_γ parameters from extracted spectra.

File Name	EW H_γ (\AA)	FWHM (\AA)
LB1839_praesepe.fits	2.1	30.6
n2168_RA3.fits	2.8	35.5
n2168_RA4.fits	2.9	35.3
n2168_WB1.fits	19.8	67.5
n2168_WB2a.fits	10.8	53.5
n2168_WB3.fits	2.7	18.4
n2168_WB5.fits	2.9	36.7
n2168_WB6.fits	2.9	35.4

Table 1 continued

Table 1 (*continued*)

File Name	EW H_γ (\AA)	FWHM (\AA)
n2168_WB9.fits	9.9	98.9
n2168_WBB2a.fits	1.5	15.3
n2168_WBB2b.fits	1.4	15.4
PG0048+202.fits	3.8	30.7
WD0001+433.fits	2.7	31.4
WD0834_praesepe.fits	1.7	26.4
WD0937+505.fits	3.1	30.8
WD1105-048.fits	4.6	31.0