IRAF SPECTROSCOPY

Aim:

This report entails conducting spectroscopy on image data of J0840+3633, utilizing observations captured at the IUCAA Giravali Observatory (IGO).

The objective is to acquire proficiency in fundamental reduction steps, techniques for identifying spectral features, and the calibration steps integral to the data analysis process.

Introduction:

Situated in Maharashtra, India, the IGO observatory is a 2-meter class optical telescope operated by IUCAA. It is equipped for spectrometric studies with the IUCAA Faint Object Spectrograph and Camera (IFOSC) instrument mounted at its Cassegrain port.

- The instrument features a 2k x 2k back-illuminated, thinned CCD.
- The CCD covers the wavelength region from 3500Å to 8509Å.
- The instrument includes a calibration unit with lamps dedicated to calibration-related observations.

This experiment aims to analyze the raw observational data obtained from IGO for a well-known source, with the objective of identifying its spectral features.

Procedure:

1. **Creating a master bias:**

   Sucessfully generated a master bias file, **bias.fits**, by employing the **noao.imred.ccdred.zerocombine** command on all four bias files.

2. **Subtracting Master Bias from all other files:**

   I've deducted the master bias file, bias.fits, from the flat (halogen) files, object (J0840+3633) files, standard star (Hiltner600) files, and lamp (HeNe lamp) files. Since it's a pixel-wise operation on files of identical sizes, I executed this operation using the '**imarith**' command, performing the subtraction within '**xgterm**'.

3. **Creating Master flat:**

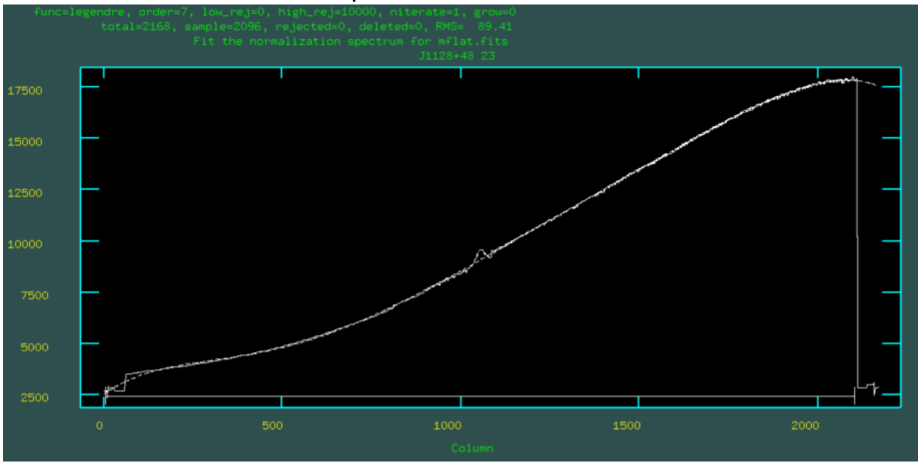
   I generated a master flat file by combining all three flat (halogen) files using the **noao.imred.ccdred.flatcombine** command. The master flat is essential for creating a normalized flat file.

4. **Normalising the flat:**

   Initially, I defined the dispersion axis with the '**dispaxis = 1**' command within **noao.onedspec**. Subsequently, using the command line '**noao.imred.specred.response**,' I generated the normalized flat file '**nflat.fits**' based on the '**mflat.fits**' file. It's noteworthy that I configured the threshold parameter within '**epar response**' to be '**threshold=500**'. This adjustment was made to normalize two dark patches near the CCD edges, as I observed that in future '**apall**' operations, the small values at these edges could pose significant issues.

To perform function fitting, I chose a range of dispersion axes for fitting by pressing the '**s**' key twice. Subsequently, I fitted the plot using a Legendre function with 7th-order polynomials.

Although the root mean square (r.m.s.) value obtained for this plot fitting is 89.41, I followed instructions to fit the plot through visual estimation. Below is the fitted plot.



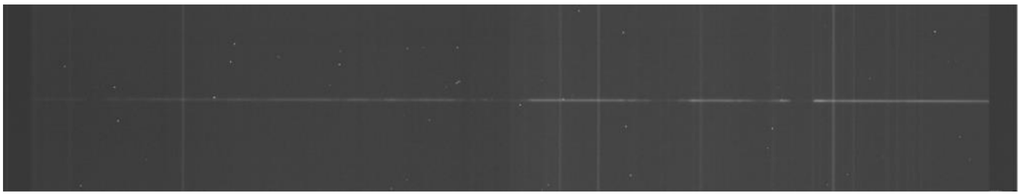
5. <u>Dividing by the normalized flat</u>:

I generated a 'divide_list' containing the names of lamp files, standard star files, and object files. Subsequently, I divided all those files by the normalized flat file 'nflat.fits' using the 'imarith' command with the '/' operation. Following this operation, I obtained bias-subtracted and flat-fielded files for those FITS files.

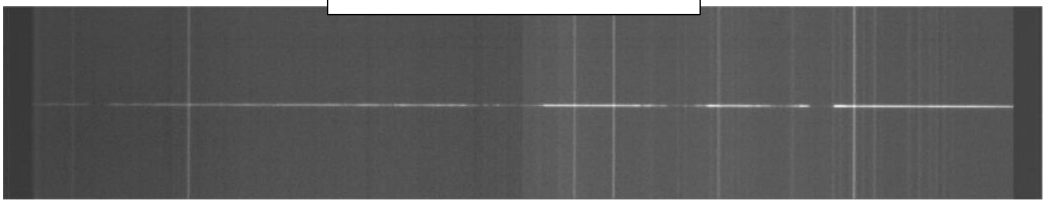
6. <u>Removal of Cosmic Rays</u>:

To eliminate cosmic rays from all the object and standard star FITS files, I have employed the command '**noao.imred.crutil.crmedian.**' The '**crmedian**' function calculates the median of pixel values at each position in an image to detect and eliminate cosmic-ray events. In my system, using '**@filelist**' as an input resulted in an error message, 'can't open images.'

Therefore, I addressed this by individually providing the corresponding FITS files as input to remove cosmic rays from each file (object and standard star) one at a time."



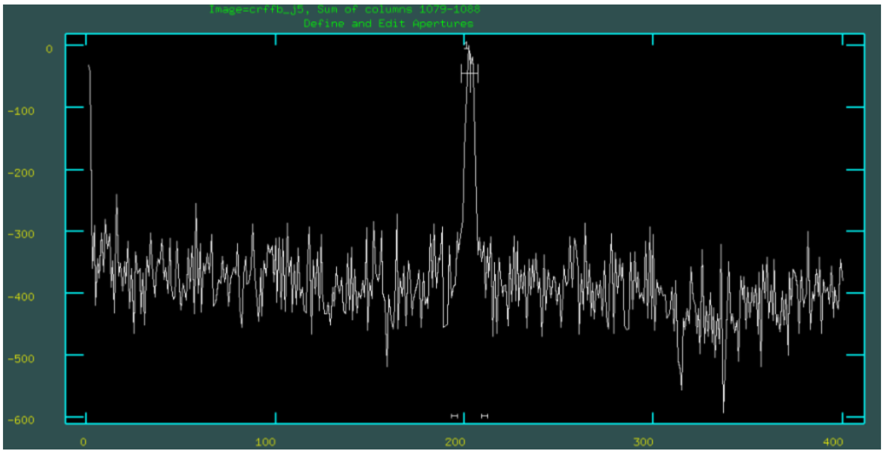
Before CR removed



After CR removed

7. Tracing and Extracting the spectrum:

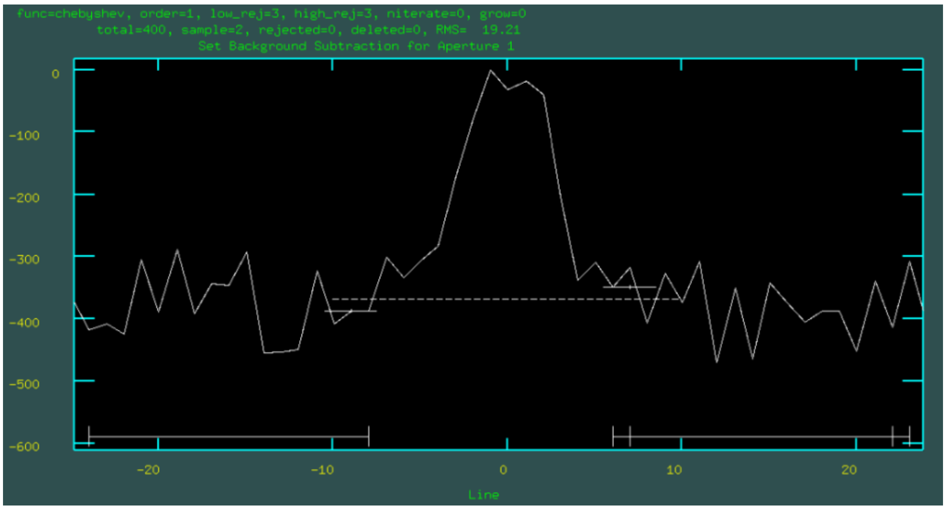
- The provided spectrum is a 1D spectrum, confined to a specific range of pixels on the CCD.
- Tracing these pixels along the dispersion axis is necessary for extracting the 1D spectrum.
- The process involves three main steps: selecting the aperture and background, tracing the spectrum, and extracting the spectrum along the trace.
- The "**noao.twodspec.apextract.apall**" functionality was utilized for these steps.
- The parameter "line = 1084" was specified, representing the pixel number along the row where the CCD transition occurs in IGO data.
- Upon answering affirmatively to several prompts, an IRAFterm interactive plot was opened, displaying counts versus pixels (perpendicular to the dispersion axis.
- By default, the tool selected an aperture and two background regions.



Chosen aperture and default background(arnd pixel value 200)

- Pressing the "q" button resulted in zooming the plot near the aperture.
- The default background was deleted by pressing the "z" key.
- Pressing "s" four times allowed the selection of two background regions based on personal preference.

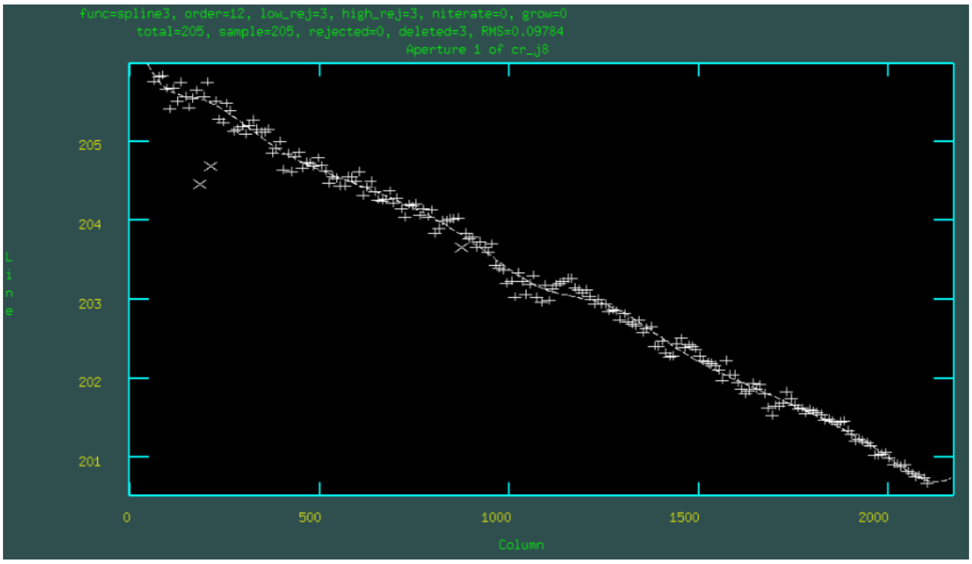
The selected background regions are shown in the below image,



Subsequently, in the background plot, I pressed the "q" key, and after responding affirmatively to all questions, it initiated another interactive plot for "fitting" the background. I applied the Spline3 function with an order of 12 for the background fit.

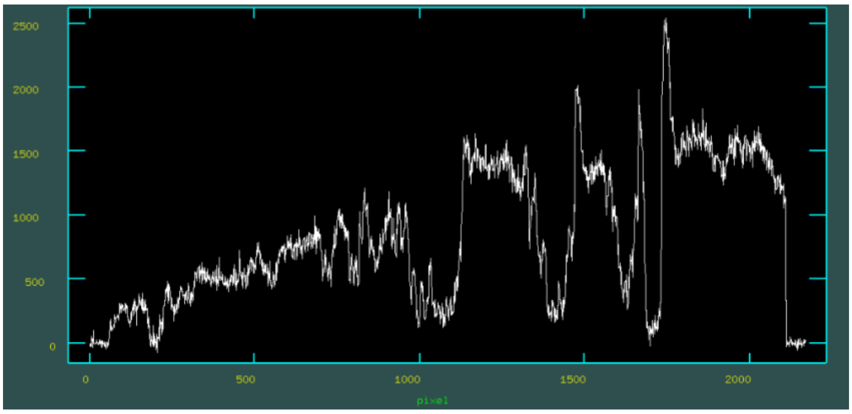
The root mean square (r.m.s.) value for the fit was 0.09784.

Fitted Background is shown in the image below,



- <u>Tracing of the spectrum</u>:

  Following the completion of the final task, I saved the output spectrum once more by pressing "q" and appended the extension ".0001" to my FITS file's name. The spectrum was traced with a single aperture, resulting in the file extension ".0001" due to the singular aperture configuration. Through this operation, I obtained the spectrum without wavelength calibration.

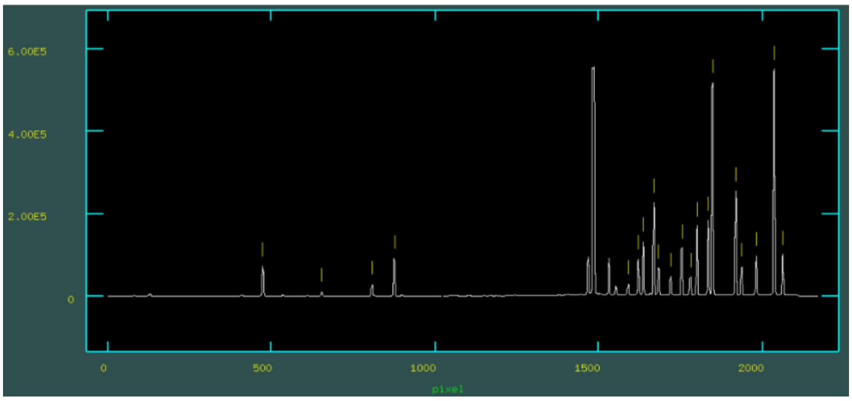
- <u>Extracting of the spectrum from the rest of the fits files</u>:

  I utilized the trace obtained in the previous step as a reference. Subsequently, I performed the "**apall**" operation on other object files, lamp files, and standard star files, extracting their spectra relative to the traced spectrum from the preceding step.

8. <u>Identify lines from the lamp file for wavelength calibration and fit the dispersion</u>:

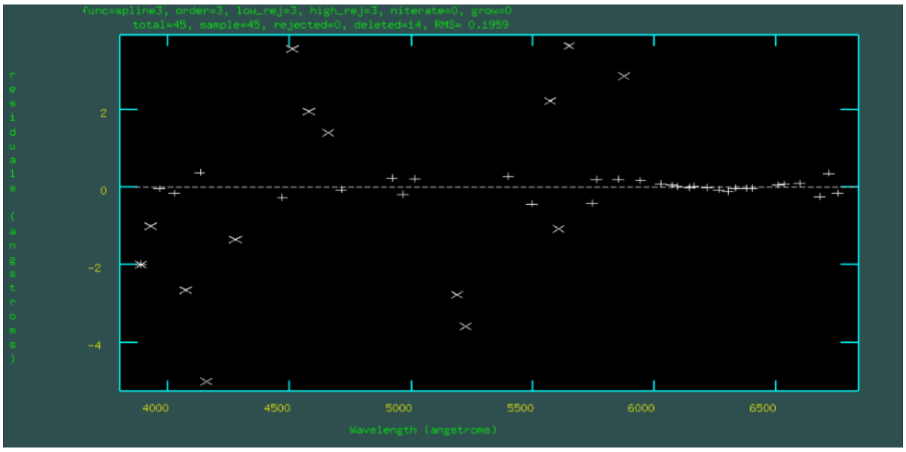
I utilized the "**noao.onedspec.identify**" command to showcase the different emission lines of the He-Ne lamp.

Below the figure the emission spectrum of He – Ne lamps used for calibration with marked peaks.



An interactive plot was subsequently opened. I initially identified all the peaks on the plot by pressing "y." For certain emission lines, I assigned wavelength values by placing the cursor on the respective peak. When the cursor was positioned on a peak, I used the "m" key followed by pressing "enter" to assign the wavelength value corresponding to that peak.

- Pressing "n" allows moving to the next peak for identification.
- Using the "-" key navigates to the previous peak.
- Pressing "d" deletes a marked peak for which no value is desired to be assigned.



Fitting of wavelength vs pixels plot

9. <u>Applying this reference to identify lines from the lamp and fit the dispersion</u>:
In this step, I utilized the file from the previous stage as my reference. Using the "**noao.onedspec.refspec**" command and specifying that file as my reference, I performed wavelength calibration on all the other lamp, object, and standard star files.

10. <u>Dispersion correction</u>:

- Used the "**noao.onedspec.dispcor**" command to obtain final wavelength-calibrated spectra.

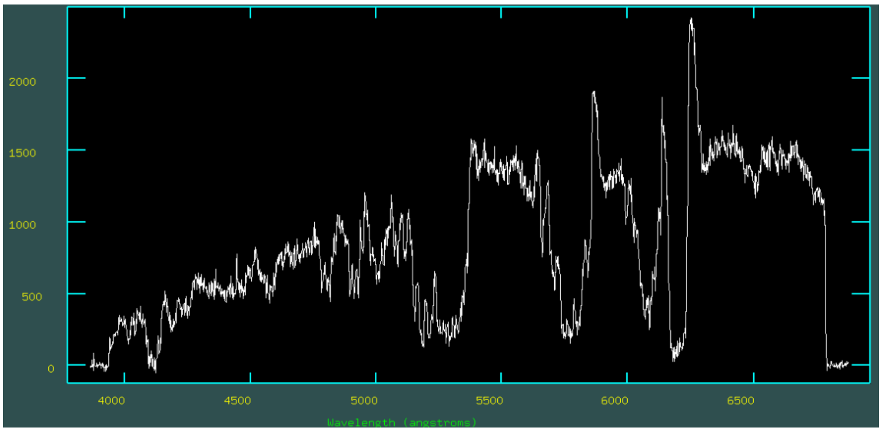
- Provided lamp, standard star, and object files as input.

- Obtained the output files that were both wavelength calibrated and dispersion corrected.

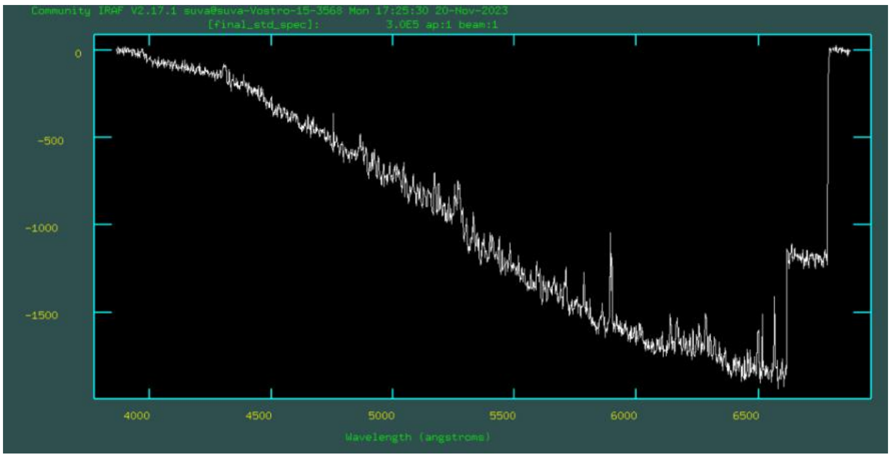
11. <u>Combining different Spectrum</u>:

- Used the "**noao.onedspec.scombine**" command to combine all object and standard star spectra.

- Expectation of an improved signal-to-noise ratio (SNR) in the final spectra.

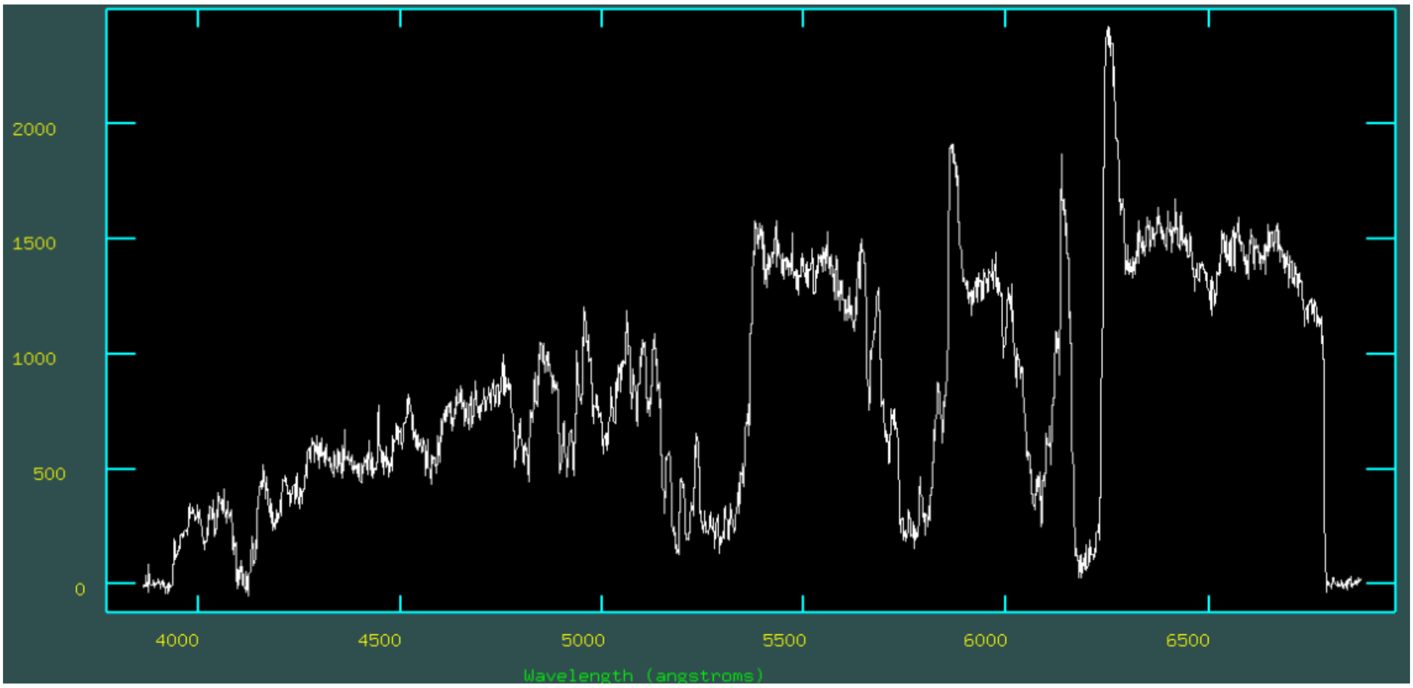


Combined spectra



Combined standard star spectra

Result & Conclusions:



- The spectrum lacks flux calibration, allowing only relative comparisons of absorption patterns.

- Distinct absorption line forests observed in object J0804+3633's spectrum suggest the presence of metals.

- Notable absorption line regions include 4100 Å to 4200 Å, 4500 Å to 4600 Å, 4700 Å to 4800 Å, and around 5000 Å, as well as 5200 Å to 5400 Å, 5700 Å to 5900 Å, 6000 Å to 6100 Å, and 6200 Å to 6250 Å.

- Initial considerations suggest the object may be an M-type star, but the TiO absorption pattern does not match.

- The broad absorption line forest around 5200 Å to 5400 Å is likely due to Iron (Fe).

- Matching with Fe-(II) lines around 2300 Å suggests a potential redshift.

- Calculated redshift is approximately $z \approx 5300{-}2300 \approx 1.3$, thus we have a **QSO with a cosmological redshift**.