Spectral Analysis of the Constellation Stars of Lyra (The Harp)

Anthony S. Harding Jr.
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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Lyra. The selection of stars was chosen to coincide with those typically used to trace the constellation lines that form the geometric shape of the constellation itself[1]. Though other stars within the boundary of the constellation (as determined by the IAU) may be objects of interest, the analysis is mostly confined to the stars forming the basis of the constellation lines (with a few notable exceptions).

The stars in the constellation will be presented in order of their accepted Bayer designations, using Greek letters to rank them roughly in order of decreasing brightness. Alpha (or α) is usually the brightest star in a constellation. Afterward, Beta (β), Gamma (γ), and so on indicate decreasing apparent magnitude. It is usually the brightest stars that define the constellation lines.

Equipment Used

All spectra used in this analysis were captured using the following equipment and resources:

Telescope: Celestron Advanced C6-N Newtonian Telescope, with an aperture of 6 inches, and a focal length of 750mm. This makes the focal ratio f/5.

Mount: Meade LX85 German Equatorial Go-To Mount. The mount was aligned using the three-star method.

Camera: ZWO ASI290MM monochrome camera. (Prior attempts with a color camera proved incredibly unreliable, so this camera was obtained specifically for this application.)

Transmission Grating: The SA100 grating was employed to produce the spectra used in this analysis. The grating has 100 lines per millimeter.

Capture Software: The ASI Studio suite of programs was used in the capture process. Following capture, the same suite was used to stack images and export them as TIF files for evaluation and analysis.

Analysis Software: Rspec v2.1.1 by Field Tested Systems, LLC.

Reference Material Used in Analysis: The *Spectral Atlas for Amateur Astronomers* by Richard Walker and *Spectroscopy for Amateur Astronomers* by Marc F. Trypsteen and Richard Walker were both used to assist in identifying specific facets of the resulting spectra, and proved invaluable in this process. Wikipedia and Stellarium were also instrumental in obtaining information regarding the various stars.

Data Processing Details

All spectra obtained for this analysis were obtained on the evening of July 18, 2023 (EDT). Other specifics for each capture are included with each star's spectrum in the pages that follow. The times presented there are given in UT, as is desirable for any astronomical work. Also included are the exposure times, number of frames captured, and the percentage of those frames which were applied to the stacking process. The determination of this percentage was subjectively chosen based on the quality of the footage captured—the accuracy of the tracking, the steadiness of the atmosphere at the time, etc.

The tracking of the Meade LX85 mount used in the capture process has limitations regarding its accuracy. Therefore, some gain was applied during the captures in order to shorten the exposure times. This was kept to a minimum, as excessive use of it does compromise the quality of the exposures. No bias, dark, or flat frames were used for these captures, nor were reference stars captured for individual sessions. The captures must therefore be considered “Quick and Dirty,” and so are unsuitable for professional or purely scientific applications. However, this author believes that they are adequate for general demonstration purposes. Refinements to these results are certainly possible if extra steps were taken to account for camera read noise, image defects in the optical train, and specific atmospheric influences that differ from those encountered when generating the initial response curve (Alpha Lyrae on July 18, 2023). Also, no sharpening or other image modifications were made to the stacked images. Most of the spectra therefore show telluric absorption bands; some of these are labeled, where others are not.

α Lyrae (Vega)

Alpha Lyrae, or Vega, is classified as a very early A-type star[2]. This was the most logical starting place, as Vega is commonly used as a calibration star for the purposes of amateur spectroscopy. The calibration was performed and this was used to generate an instrument response curve for the camera employed.

The final results of the spectrum are presented as follows:

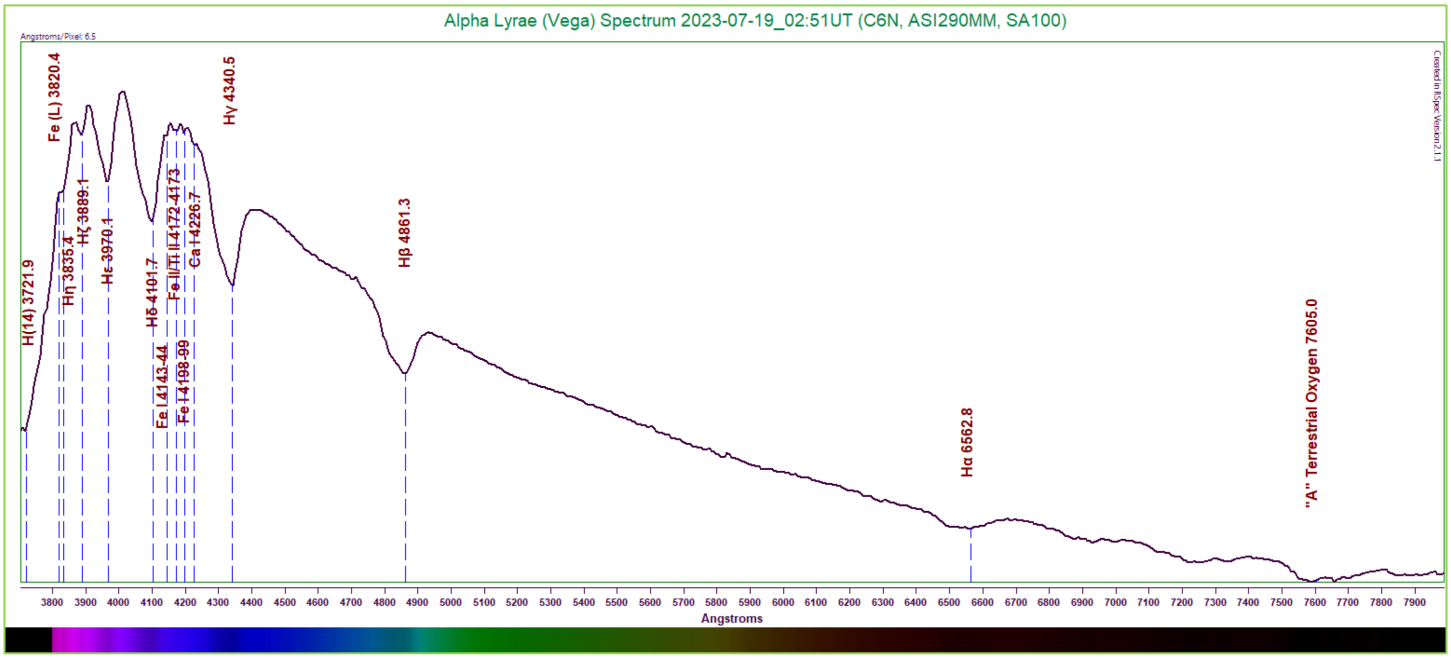

Figure 1: Alpha Lyrae (Vega) Spectrum (6.5 Angstroms/pixel)
Capture Details 1: Exposure 202ms, Gain 0, 85% of 607 frames stacked

As can be clearly seen, the hydrogen Balmer absorption lines are clear. We can even see a very small bump for the H14 line at 3721.9 Angstroms. Also notable is the Fe (L) line blended with the Hη line. Four tiny absorptions appear between the Hδ and Hγ lines, representing the only clearly defined metals visible. The Hα line appears shallow and broad, while other lines in the series are more sharply defined. Another feature noted is the A-band absorption produce by terrestrial oxygen, which should show up regularly in the survey.

A very rough estimation of the effective temperature of the star can be made using Wien's Law. Using an estimated peak wavelength at 4012 Angstroms, the temperature can be estimated at 7223K. (The actual value is approximately 9600K[2].)

β Lyrae (Sheliak)

Beta Lyrae, or Sheliak, is a semi-detached binary star consisting of a late B-type primary star with a B-type companion[2]. It is an eclipsing binary, so the amount of light reaching Earth varies over time as one star occults the other.

The processed spectrum is as follows:

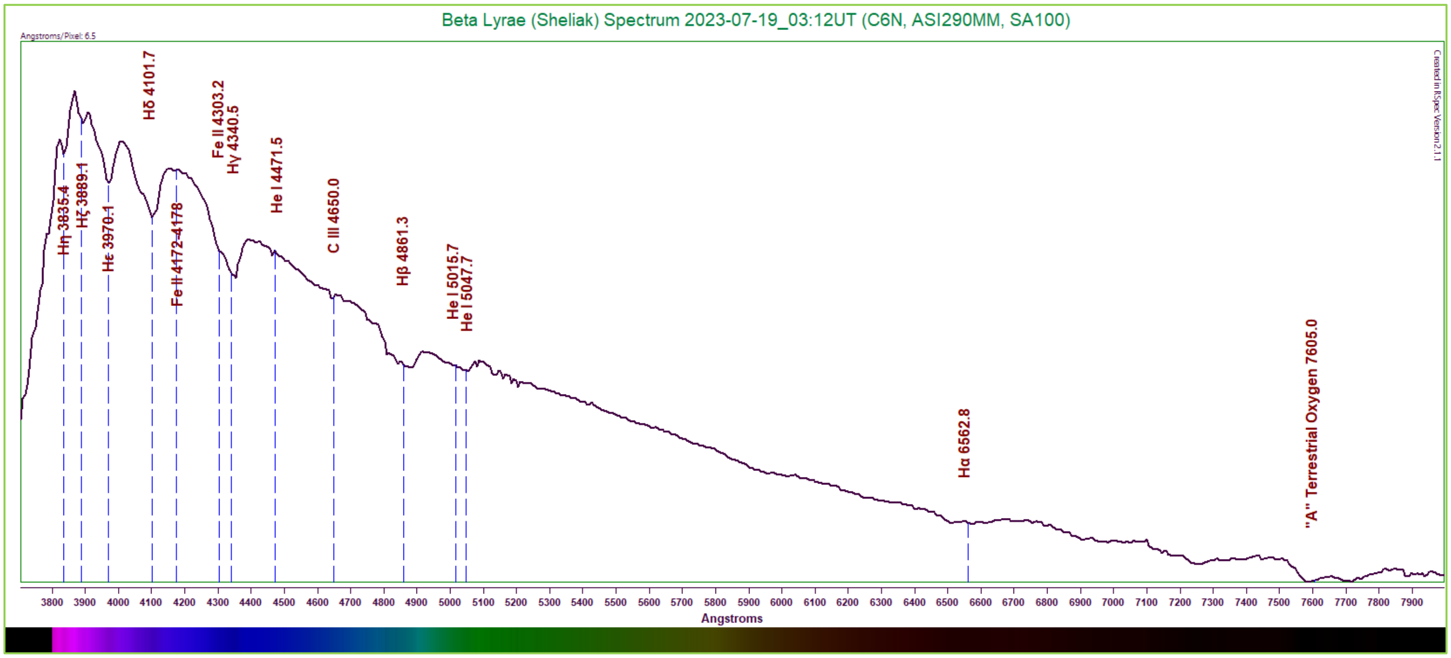

Figure 2: Beta Lyrae (Sheliak) Spectrum (6.5 Angstroms/pixel)
Capture Details 2: Exposure 300ms, Gain 217, 70% of 410 frames stacked

This spectrum shows weaker hydrogen Balmer features than Vega, but the lines are still very identifiable. The Fe II line at 4172 Angstroms is still present, but is also weaker than that of Vega. Some new features appear, though they are not so clear-cut. The ionized iron line at 4303.2 Angstroms shows up as a bump just below the Hγ line. At 4471.5 Angstroms a very weak absorption feature can be seen. At this weak level, it might appear to be part of the noise of the continuum, except that the surrounding continuum is much smoother. This would seem to indicate a weak helium line, but this could be disputed. A bit clearer is the C III line at 4650.0 Angstroms. Another feature is a stair step discontinuity near the Hβ line. This would appear to be a combined absorption from two helium lines. Some roughness in the continuum to the right of this feature is also noted, but could not be positively identified.

Using Wien's Law, we can very roughly estimate the temperature of the pair of stars. Using an estimated peak flux at 3868 Angstroms, this makes the temperature 7492K. The two stars are currently estimated to have temperatures far in excess of this: 13000K and 30000K[2]. The average of these two values is still 21000K, far removed from our estimate.

γ Lyrae (Sulafat)

Gamma Lyrae, or Sulafat, is classified as a very late B-type star[2]. We should expect a spectrum not entirely dissimilar to that of α Lyrae above.

The processed spectrum is as follows:

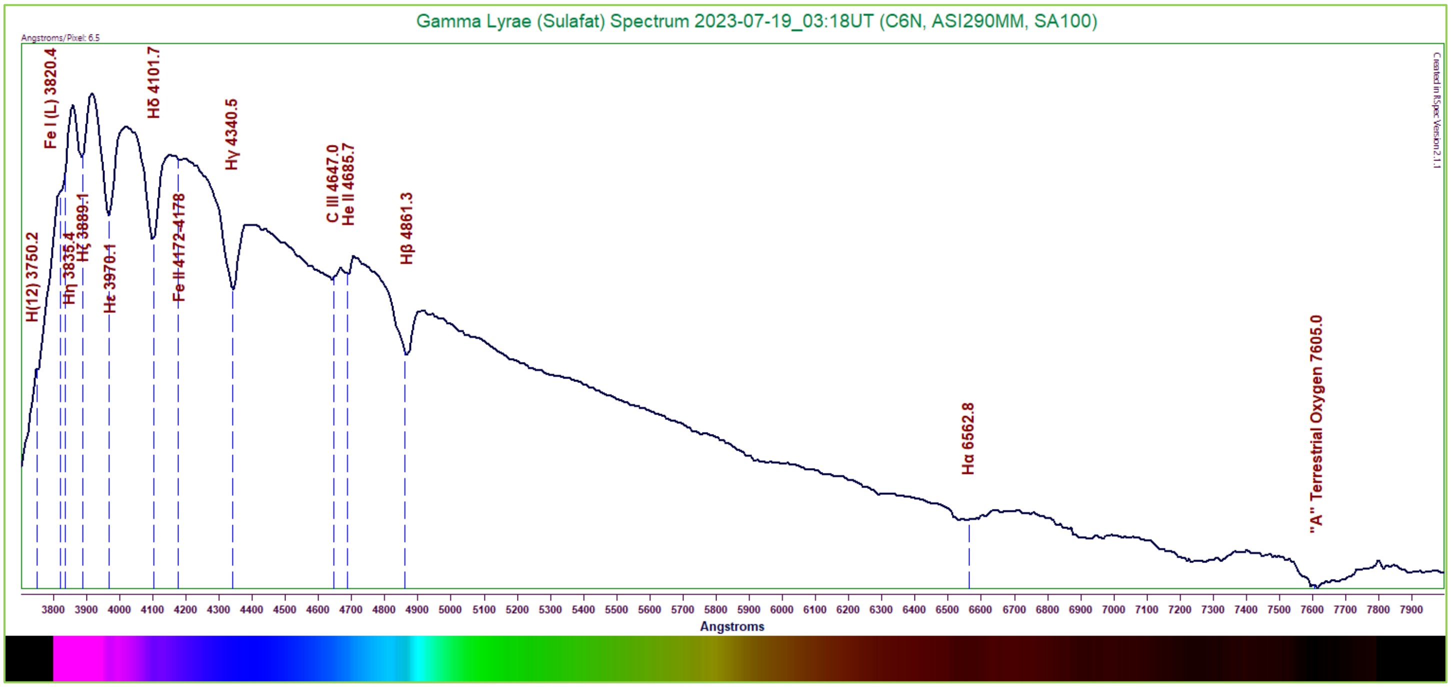

Figure 3: Gamma Lyrae (Sulafat) Spectrum (6.5 Angstroms/pixel)
Capture Details 3: Exposure 202ms, Gain 0, 85% of 607 frames stacked

As expected, this result is very similar to that for Vega. The hydrogen Balmer lines are easily identified. Here we can also see the H (12) line at 3750.2 Angstroms causing a small absorption at the extreme lower wavelength range. Additionally, we can see the bump just below the Hη line for the iron L line, very similar to that noted for Vega previously. Two other lines are C III and He II lines appearing between Hγ and Hβ. This is reminiscent of the dip seen in Sheliak, but rather shifted to the other side of the Hβ line. An odd coincidence.

Applying Wien's Law can give us a very rough temperature estimate. Using an estimated peak energy wavelength of 3917 Angstroms produces a temperature of 7398K. The currently estimated temperature is 10000K[2].

δ-1 Lyrae

The star Delta Lyrae is an easily split double star. For this analysis, we will consider them individually.

Delta-1 Lyrae is classified as an early B-type star[2]. Being hotter than later B types, we should expect to see some helium features in its spectrum.

The processed spectrum of the star is as follows:

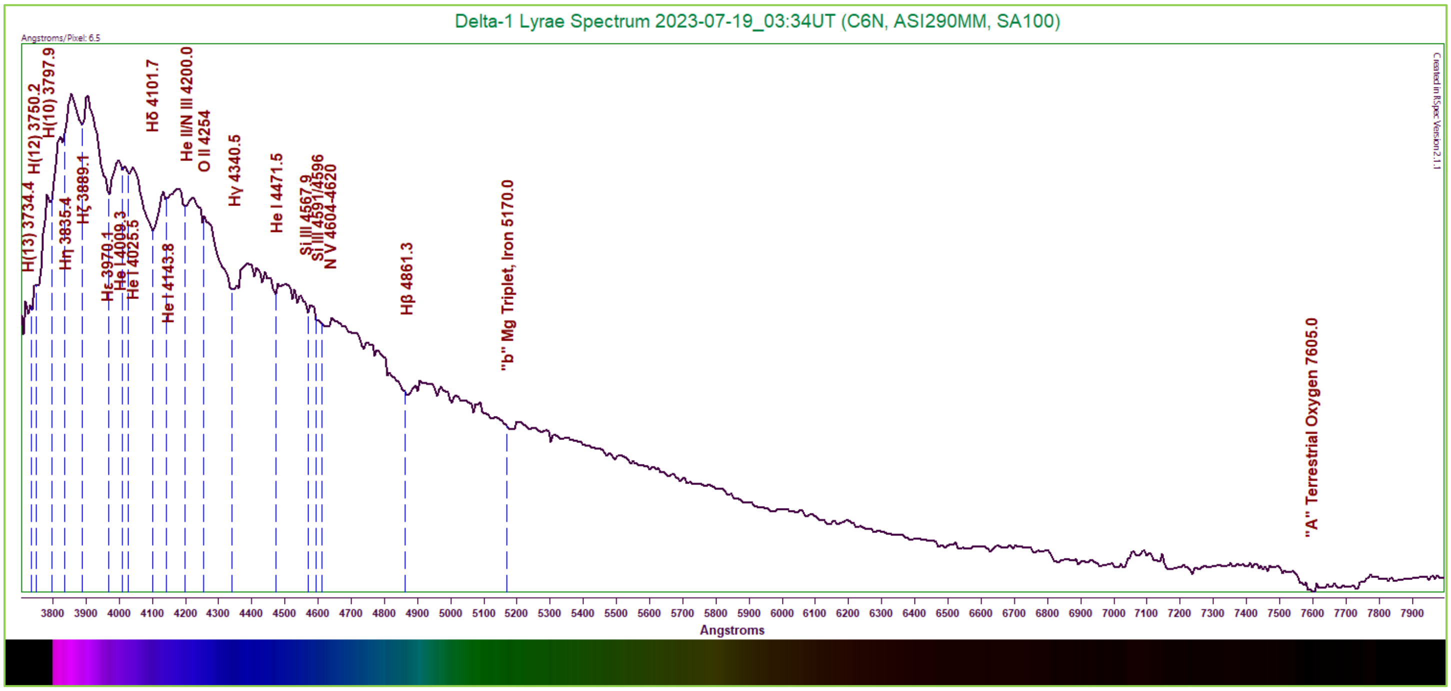

Figure 4: Delta-1 Lyrae Spectrum (6.5 Angstroms/pixel)
Capture Details 4: Exposure 608ms. Gain 276, 80% of 203 frames stacked

In this spectrum, the hydrogen Balmer lines are considerably weaker than in previous examples, and the Hα line is subsumed into the continuum. This may be at least in part be due to the higher gain employed in the capture, which makes the resulting spectrum a bit noisier. We do see, however, several helium absorptions present. These are not extreme, but they are sharp and readily identified. Several other hydrogen absorptions appear neart the lower wavelength range—the H (13), H (12) and H (10) lines just above it. The magnesium triplet is visible at 5170.0 Angstroms, though it is weak. We can also see that the peak of the continuum is at a lower wavelength, indicating a higher temperature, as expected.

Again using Wien's Law, a very rough idea of temperature can be derived. Assuming a peak wavelength of approximately 3855 Angstroms, the temperature estimate is 7517K. The accepted value is 20000K[2].

δ-2 Lyrae

Delta-2 Lyrae brings us to our first middle M-type star[2]. These stars are much cooler, and should show TiO molecular absorption bands in abundance.

The processed spectrum is as follows:

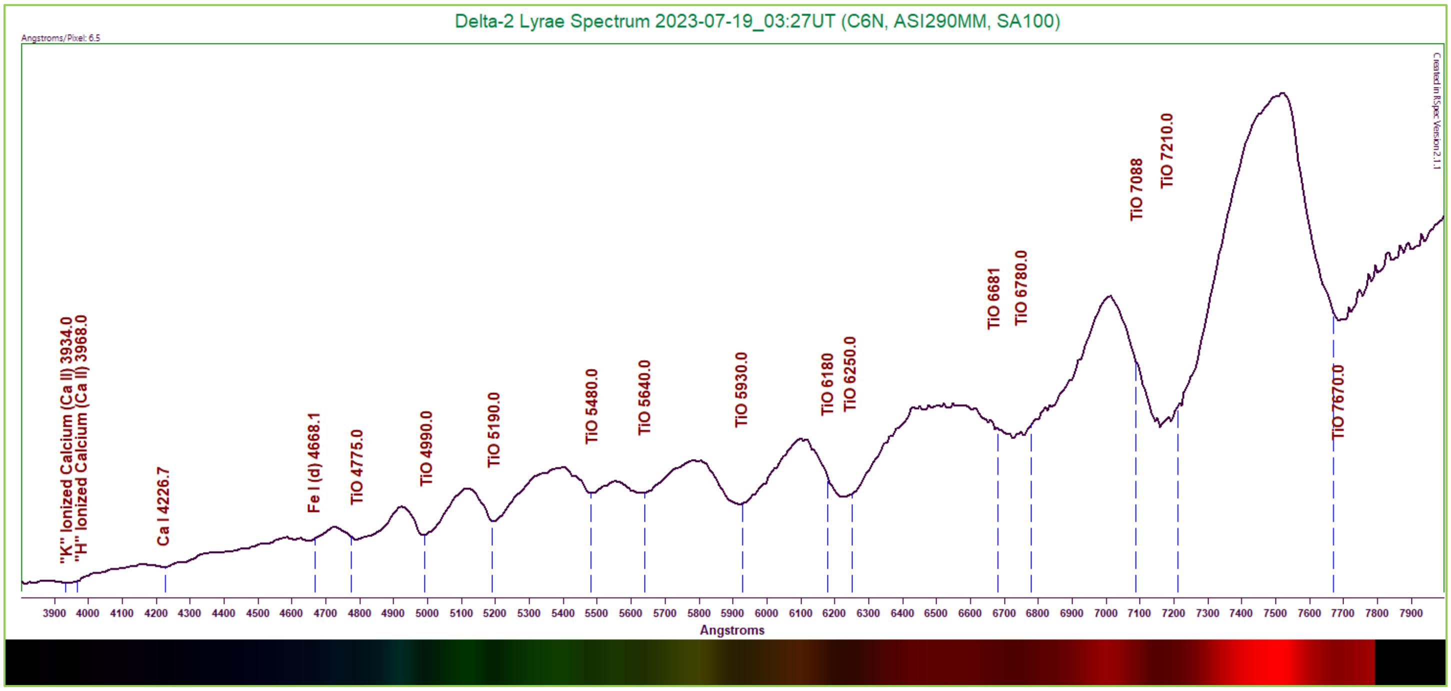

Figure 5: Delta-2 Lyrae Spectrum (6.5 Angstroms/pixel)
Capture Details 5: Exposure 503ms. Gain 270, 85% of 245 frames stacked

Now, this one looks entirely different. Numerous TiO bands are present—deep and broad and unmistakable. This indeed verifies what we expected to see. There are a few other subtle lines—the calcium H and K lines at the extreme lower wavelength range, plus Ca I at 4226.7 Angstroms, and the Fe (d) line at 4668.1 Angstroms. The peak of the continuum is in the longer wavelength range, indicating a much lower effective temperature.

Using an estimated peak energy output at 7522 Angstroms, Wien's Law gives us a roughly estimated temperature of 3705K. The currently accepted value is 3600K. This time our estimate is not so far off base!

ε-1 Lyrae

Epsilon Lyrae is often called the Double-Double. Epsilon-1 and Epsilon-2 are easily split from each other. However, each of these components is also a double, and much more closely spaced from our perspective. My equipment did not permit the two brighter components to be additionally split, so each of them must be considered an amalgamation of both star types, their components overlying each other.

We begin with Epsilon-1 Lyrae, which is an early A-type star with a very early F-type companion star[2]. The F-type star is the smaller component, but it may be possible to pull out some subtle features from it.

The processed spectrum is as follows:

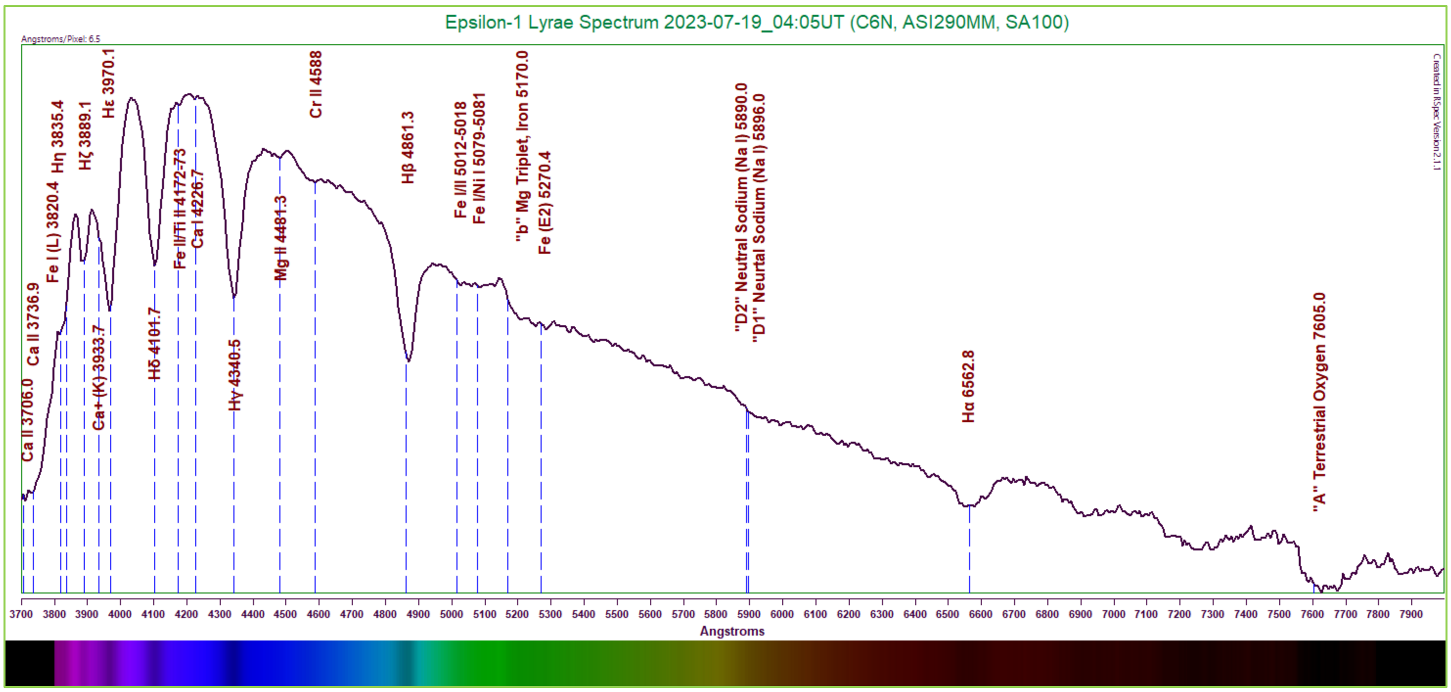

Figure 6: Epsilon-1 Lyrae Spectrum (6.5 Angstroms/pixel)
Capture Details 6: Exposure 572, Gain 258, 80% of 222 frames stacked

Indeed, some weak features of the dimmer companion can be seen here. The typically strong hydrogen Balmer absorptions are obvious. However, we can also make out very weak calcium lines at the extreme lower wavelengths. The Fe I (L) and Hη lines are causing a small step in the continuum at 3820-3835 Angstroms. The calcium K line is causing a very small bump on the lower side of the Hε line. Iron and calcium appear very weakly between the Hδ and Hγ absorptions. Magnesium is also present at 4481 Angstroms, along with chromium at 4588. Three additional iron absorptions can be seen; two around 5015 and 5080 Angstroms, causing a broad combined feature. The third stands on the other side of the magnesium triplet, combining with it to make the resulting absorption appear very broad. There is a hint of the neutral sodium D1 and D2 lines at 5890-96 Angstroms, together causing only a subtle, broad dip in the continuum. The A band absorption of terrestrial oxygen appears here quite broad and deep.

Applying Wien's Law, we can estimate the temperature of the pair of stars. Using an approximation of 4206 Angstroms for the peak energy wavelength, the temperature can be estimated at 6890K. The two stars are currently estimated at 7900K and 7000K[2]. The average of these two is 7450K, which is not terribly dissimilar to our estimate.

ε-2 Lyrae

Epsilon-2 Lyrae is composed of one middle A-type star and one late A-type star[2]. Separately, their spectra should be rather similar, so taken together the pair should be similar to a single A-type star.

The processed spectrum is as follows:

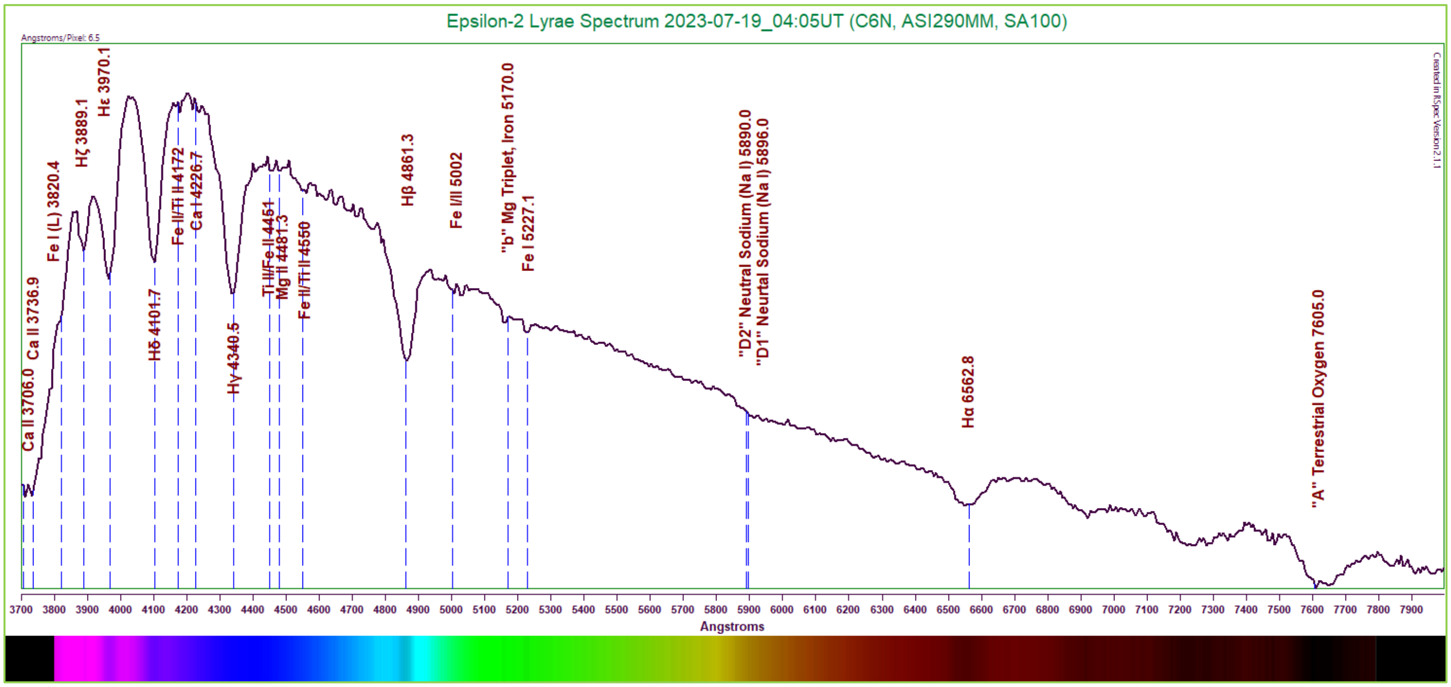

Figure 7: Epsilon-2 Lyrae Spectrum (6.5 Angstroms/pixel)
Capture Details 7: Exposure 572, Gain 258, 80% of 222 frames stacked

At the extreme lower wavelength range, we see two fairly sharp calcium lines. The Fe (L) line is also apparent. The hydrogen Balmer lines appear well in this spectrum. Between the Hδ and Hγ absorptions we can note the weak iron and calcium lines. We also can see additional iron lines and a magnesium line between the much larger Hγ and Hβ lines. More weak iron lines appear at 5002 and 5227 Angstroms, with the magnesium triplet apparent between them. The sodium D1 and D2 lines are causing a subtle dip in the continuum at 5890-96 Angstroms.

Wien's Law can be applied using an estimated peak flux wavelength of 4199 Angstroms. This produces a temperature of approximately 6901K. The two stars are currently estimated at about 7800K each[2].

ζ-1 Lyrae

Zeta Lyrae is another double star. The two main components are readily split, so we will analyze each in turn.

Zeta-1 Lyrae, or Nasr Alwaki I, is an odd star that seems to do its best to confound classifiers. It is itself a double star—a spectroscopic binary—which exhibits characteristics of both middle A-type stars and very early F-type stars[2].

The processed spectrum is as follows:

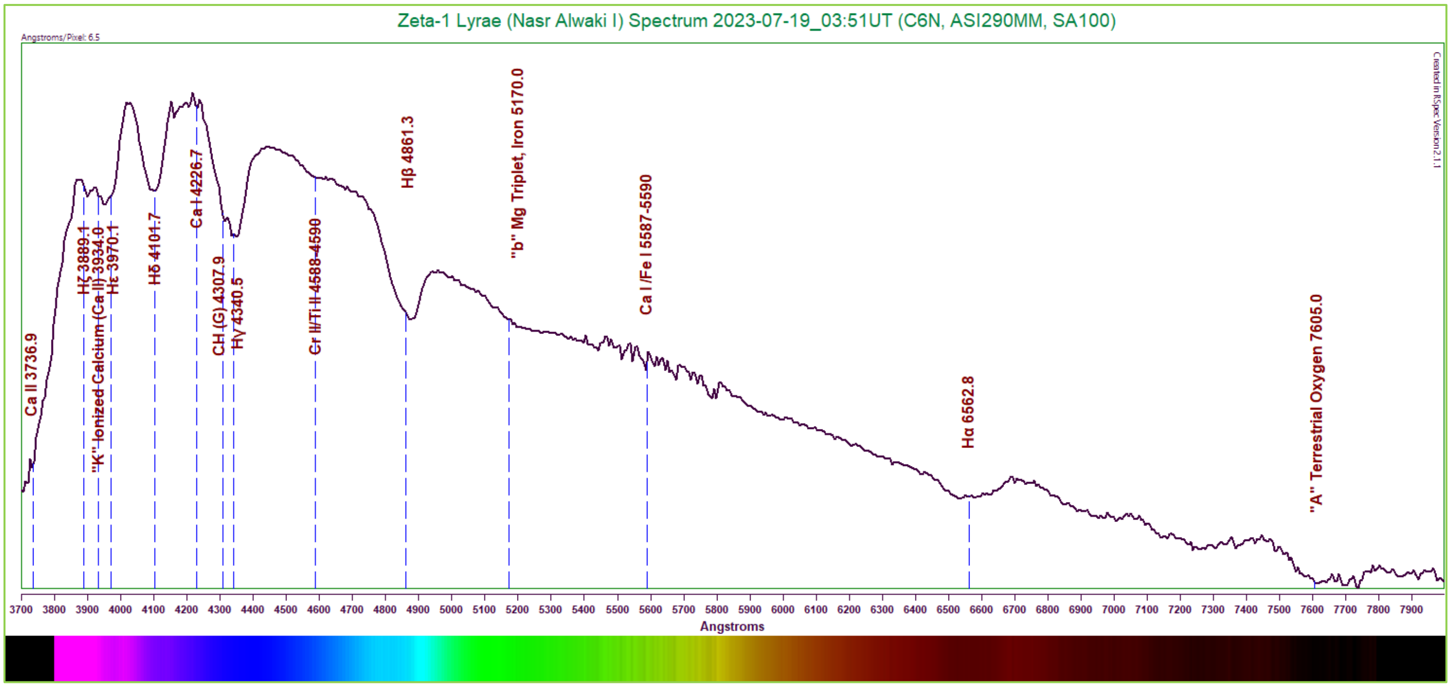

Figure 8: Zeta-1 Lyrae (Nasr Alwaki I) Spectrum (6.5 Angstroms/pixel)
Capture Details 8: Exposure 604ms, Gain 244, 90% of 204 frames stacked

As expected, this star was somewhat difficult to line up with known absorption features. Its hydrogen Balmer features are fairly strong. Some calcium lines are present, but not terribly strong. The CH (G) molecular bump is small but well-defined at 4307.9 Angstroms. The chromium absorption at about 4588 Angstroms is seen as a gentle dip in the continuum, and a similar dip can be seen for the magnesium triplet. The spectrum becomes extremely noisy around the Ca/Fe feature around 5588 Angstroms, so that label is definitely suspect in this case. Several of the weaker absorption bands defied attempts to identify. Definitely a strange beast!

Using an estimated peak flux wavelength of 4219 Angstroms, Wien's Law produces an estimated temperature of 6868K. The current best estimate places the temperature at approximately 7900K[2].

ζ-2 Lyrae

Zeta-2 Lyrae, or Nasr Alwaki II, is a dim, very early F-type star[2]. Unlike Zeta-1 Lyrae, Zeta-2 Lyrae is a single star.

The processed spectrum is as follows:

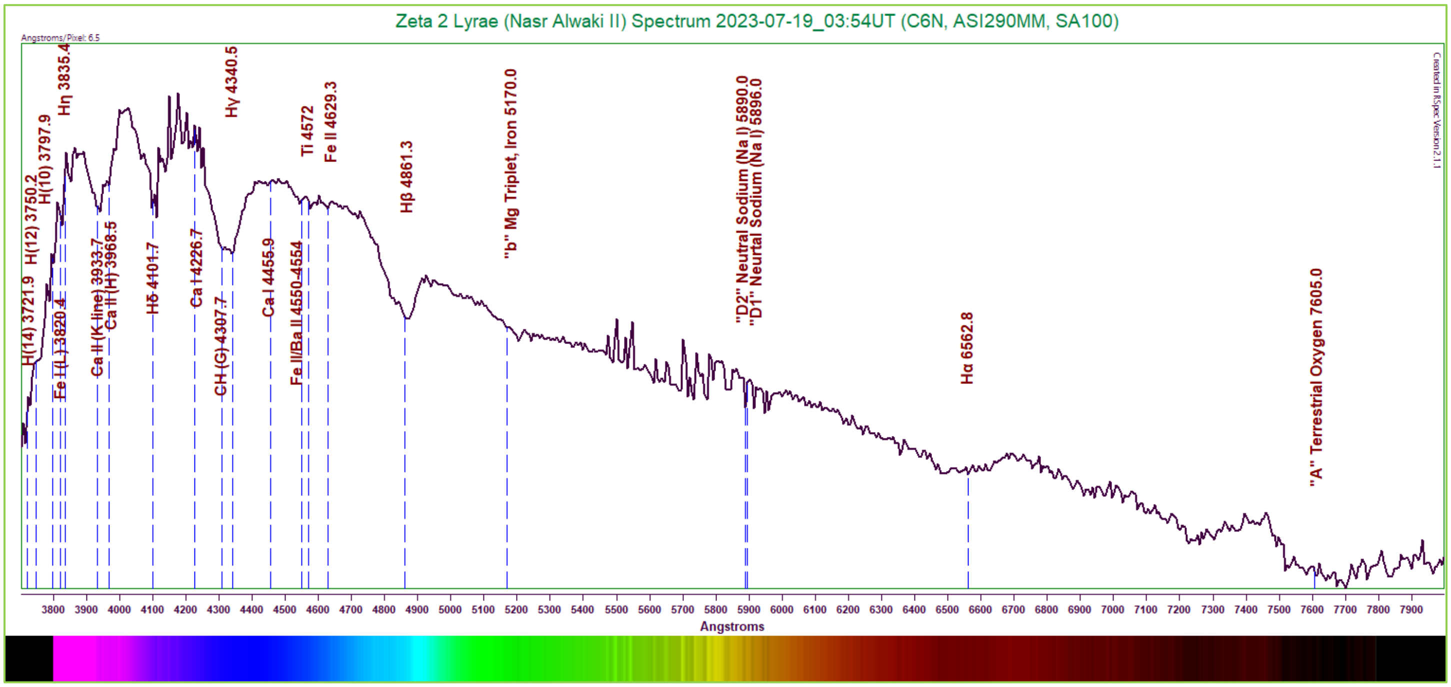

Figure 9: Zeta-2 Lyrae (Nasr Alwaki II) Spectrum (6.5 Angstroms/pixel)
Capture Details 9: Exposure 749.597ms, Gain 273, 85% of 164 frames stacked

Again, this target's spectrum came out rather noisy. At the lower wavelength extreme, we can see several small hydrogen lines. Above them we find a fairly prominent Fe (L) absorption. The remaining hydrogen Balmer lines are visible. The calcium H and K lines are well-represented here. A calcium line is marked at 4226.7 Angstroms, but the noise in the spectrum makes this label suspect. The CH (G) line, however, is very pronounced, sitting alongside the Hγ absorption. Between the Hγ and Hβ lines are several metals weakly displayed, including another calcium line, titanium, and iron. The magnesium triplet is somewhat subdued. The sodium D1 and D2 lines are marked, but again this region of the spectrum shows considerable noise, so this cannot be regarded as a confirmed feature.

Again employing Wien's Law, we can make a very rough estimate of the star's temperature. Using an estimated 4176 Angstroms as the wavelength of peak energy output, the temperature is approximated at 6939K. The current value is listed as approximately 7900K[2].

<u>ΟΣ 525</u>

Having finished with the main stars in the constellation, I also captured footage of this attractive double star. This double star is only very closely separated, so our captured spectrum will be a combination of the two components. The primary is classified as a middle G-type star with a late A-type secondary[1].

The processed spectrum is as follows:

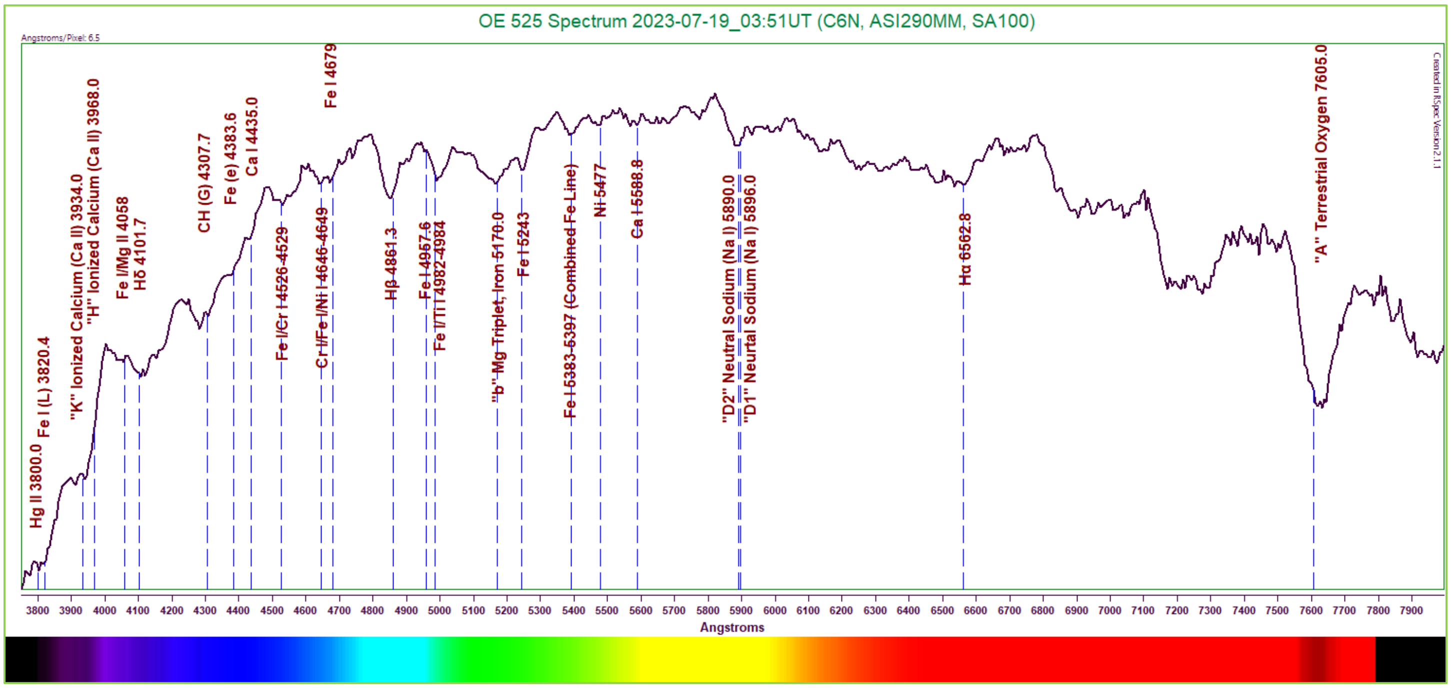

Figure 10: ΟΣ 525 Spectrum (6.5 Angstroms/pixel)
Capture Details 10: Exposure 702ms, Gain 336, 100% of 176 frames stacked

Once again, we are confronted with a spectrum very different from the others. The noise ratio on this one is higher, due to the apparent magnitude of the target, which is pushing deeper into the limits of the equipment used. However, we can identify several prominent features. Starting at the extreme lower end of the wavelength range, there appears a mercury line at 3800 Angstroms, positioned close to the Fe (L) line. The calcium H and K lines are prominent. Some of the hydrogen Balmer lines are still identifiable, most notably Hα, Hβ, and Hδ. Many iron lines are spread throughout the spectrum, the most peculiar of which appears to be the label at 5383-5397 Angstroms. From the resources utilized, this actually appears to be a melded line of different Fe lines combined. The magnesium triplet and the sodium D1 and D2 lines are fairly easy to identify. The task of identifying all the lines was very challenging, and I will not pretend that they are all correct. The general shape of the continuum, however, is consistent with the star type involved.

Applying Wien's Law, and using an estimated peak wavelength of 5822 Angstroms, produces a rough approximation of 4977K for the temperature. No current value was readily located for comparison.

HD 175634

While capturing footage for OΣ 525, I noticed this star very close by. (I had originally identified it incorrectly.) It is classified simply as an A-type star[1].

The processed spectrum is as follows:

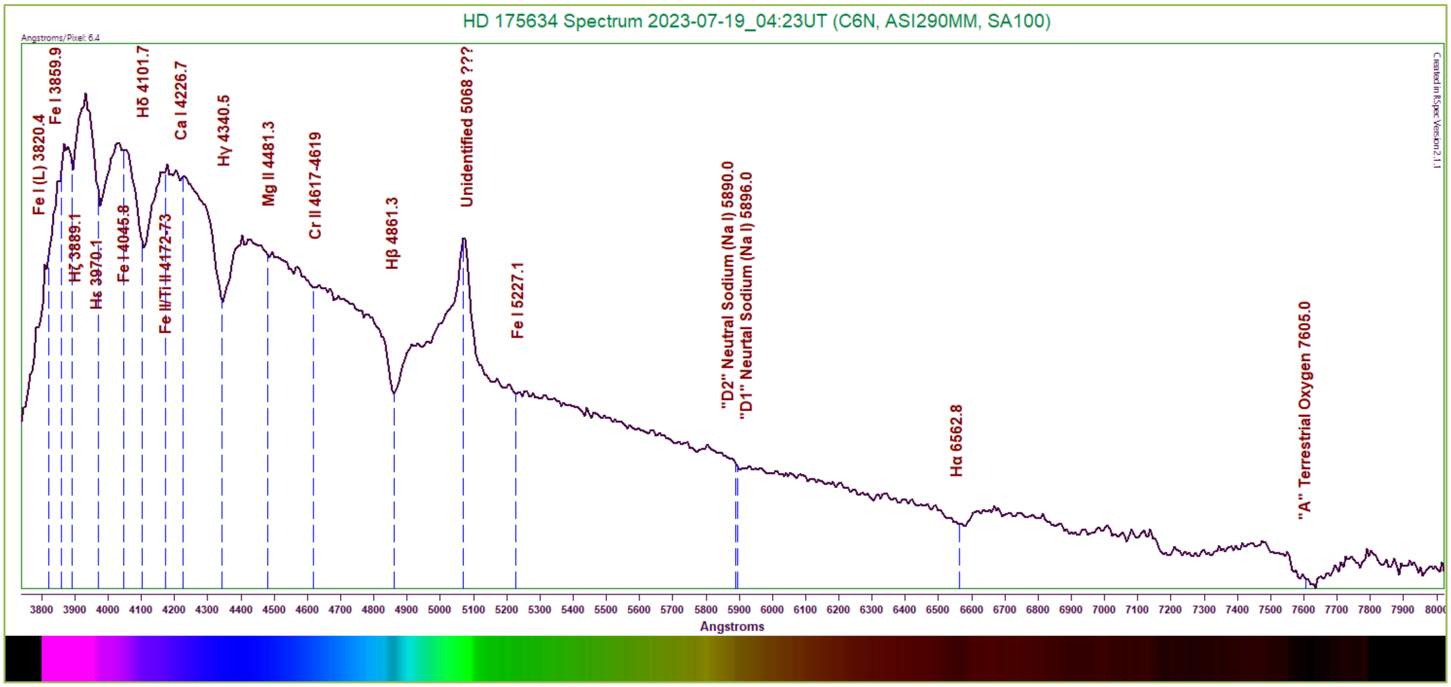

Figure 11: HD 175634 Spectrum (6.4 Angstroms/pixel)
Capture Details 11: Exposure 6s, Gain 250, 100% of 31 frames stacked

Many typical features of A-type stars are present, especially the hydrogen Balmer lines. Two notable iron lines lie at the low wavelength range. Three other iron lines are noted, though they are very weak. The last (at 5227.1 Angstroms) is suspect, as it is scarcely deeper than the noise in the continuum. A weak calcium line can be seen at 4226.7 Angstroms. Between the Hγ and Hβ line lie a magnesium line at 4481.3 Angstroms and a chromium line at 4617 Angstroms. Again, these are very weak. An anomalous spike appears near 5068 Angstroms which certainly does not match the type of star involved. It has been suggested that this may have been caused by a dim foreground that that escaped notice during the capture. I am inclined to agree with this assessment. The sodium D1 and D2 lines are evident, though they are only generating a small dip in the continuum.

A rough estimate of temperature was calculated using Wien's Law and an estimated peak flux wavelength of 3933 Angstroms. The result was 7368K. No currently accepted value could be readily located for comparison.

Conclusion

This was my first completed run through a given constellation to collect and analyze spectra. However, I consider the results very good considering the limitations of the equipment and my own inexperience with this. As time passed, the process became clearer, and analyzing the results has certainly been both challenging and rewarding. I very much look forward to processing the next batch of data.

The temperature estimates were generally the least encouraging, but this can be explained by the fact that Wien's Law is based on the properties of a true black body, which no star exactly matches. It may be possible to apply a correction factor based on stellar classification to correct the results, but much more data will need to be collected before determining if this approach will work to give more accurate results.

It took a long time to get to this point. I wish to thank both Tom Field and Robin Leadbeater, whose assistance in grasping this process and working out the inconsistencies was incalculable!

Contact

Any comments, questions, criticisms, etc. can be directed to anthonyspectro@gmail.com.

References

[1]: As determined using Stellarium v1.1. (Of course, not all sources agree as to the exact stars used in forming the shapes of the constellations. Alternate designations are also applied to most stars.)
[2]: As indicated by Wikipedia.
[3]: *Spectral Atlas for Amateur Astronomers* by Richard Walker
[4]: *Spectroscopy for Amateur Astronomers* by Marc F. Trypsteen and Richard Walker