Spectral Analysis of the Constellation Stars of Cepheus (The King)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Cepheus. The selection of stars was arbitrarily 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 confined to the stars forming the constellation lines.

The stars in the constellation will generally 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 are used to indicate decreasing apparent magnitude. It is usually the brightest stars that define the constellation lines. Of course, there are deviations from this rule that have been retained for historical consistency.

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.

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 of the spectra obtained for this analysis were collected on the evenings of October 7, 2023 and October 10, 2023 (EDT). Additional specifics for each capture are included in the header for 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 in this header are the 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.

This is another constellation that sits in the worst part of my skies: the north. One aborted attempted to capture data was made on October 7th, when it was interrupted by heavy cloud cover that arrived well ahead of predictions. Data for most of the stars was obtained on the evening of October 10th. The signal-to-noise ratios for these data are less than ideal, as I was fighting some moderate light pollution in that area of the sky, as well as some fairly unsteady seeing conditions to boot.

α Cephei

Alpha Cephei, also known as Alderamin, is classified as a late A-type star[1]. We should expect to still see some prominent hydrogen Balmer lines typical of A-type stars, with some slightly stronger metal lines present.

The Spectrum is presented below:

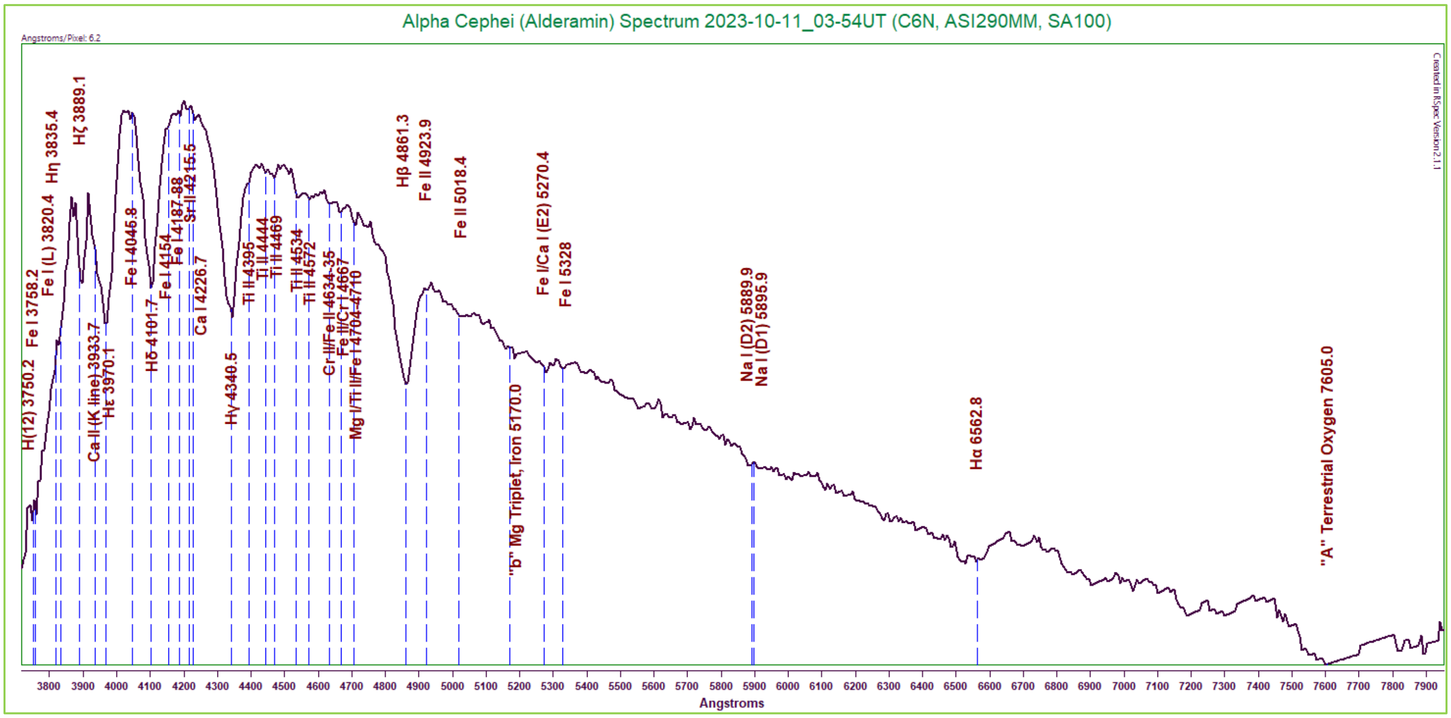

Figure 1: Alpha Cephei (Alderamin) Spectrum (6.2 Angstroms/pixel)
Capture Details 1: Exposure 191ms, Gain 83, 30% of 1266 frames stacked

As expected, we can definitely see the strong hydrogen Balmer lines here. The Hη bump is quite weak here, and also adjacent Fe I (L) line at 3820.4 Angstroms. The calcium K line is represented by a bump on the lower side of the Hε line. The magnesium triplet at 5170 Angstroms is marked, along with the Fe I/Ca I (E2) line at 5270.4 Angstroms. If examined carefully, they are seen to collectively create a small, broad dip in the continuum. The sodium D1 and D2 lines at 5890-96 Angstroms are also causing a small reduction in the continuum level. This star seems to show a lot of titanium lines between the Hγ and Hβ lines. Some other additional metal lines can be seen, including more iron, strontium, calcium, chromium, and magnesium. A very interesting spectrum on this one.

We will apply Wien's Law to obtain a very rough estimate of the effective temperature. Using a peak energy wavelength of approximately 4202 Angstroms, we obtain an effective temperature of about 6896K. The established temperature for the star is listed as 7700K[2]. As expected for an early-type star, our estimate is a bit too low.

β Cephei

Beta Cephei, or Alfirk, is classified as a double star, with its components *very* close together. Of course, the equipment used in obtaining the spectrum was not able to separate the two, so our spectrum will be a combination of the two. Their combined characteristics fall into the very early B-type[1] category. The spectrum should show a curve consistent with a very hot star, peaking in the lower wavelength range. Some hydrogen Balmer lines will probably be weakly visible, and perhaps some helium features as well.

The processed spectrum follows:

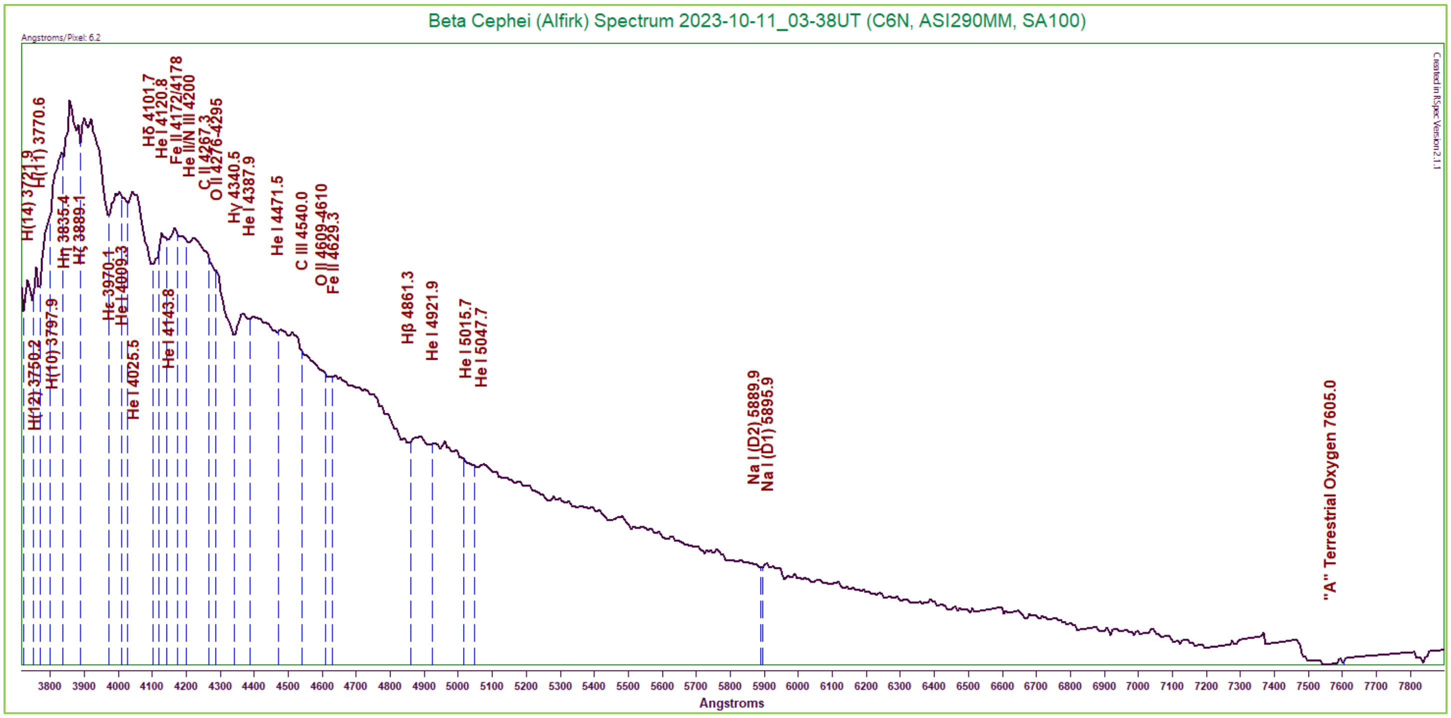

Figure 2: Beta Cephei (Alfirk) Spectrum (6.2 Angstroms/pixel)
Capture Details 2: Exposure 213ms, Gain 95, 50% of 1132 frames stacked

We can clearly see from the shape of the curve that this is a hot star—the peak energy falls in the very low wavelength range. The hydrogen Balmer series lines can be seen, but they are noticeably weaker than in later A-type stars. The sodium doublet at 5890-96 Angstroms is visible, but is extremely weak. A number of fainter features are visible here, including many small helium absorptions. Iron, carbon, and oxygen are also present, though weakly.

Using Wien's Law, we will obtain a very rough estimate of the star's effective temperature. Of course, being a very hot, early-type star, we can expect our estimate to be much too low. Using an estimated peak energy wavelength of 3858 Angstroms, we obtain a result of 7512K. The established temperature of the pair is listed as 27000K[2]. To say our estimate is "short" would be a galactic understatement!

γ Cephei

Gamma Cephei, called Errai, is a binary star with an early K-type primary star and a middle M-type secondary star[1]. The primary is by far the more luminous of the two, and should dominate the spectrum. We should therefore expect to see a curve representing a cooler star, with numerous metal lines present.

The processed spectrum appears below:

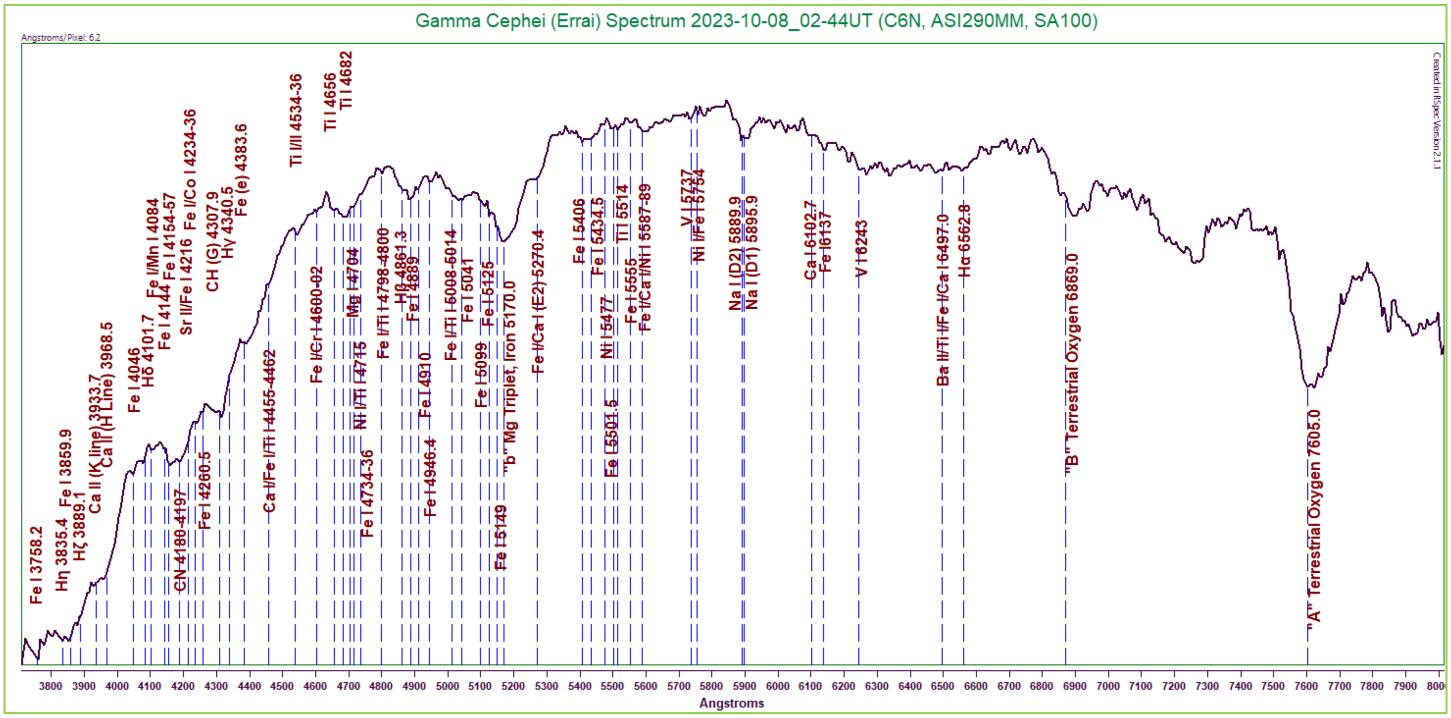

Figure 3: Gamma Cephei (Errai) Spectrum (6.2 Angstroms/pixel)
Capture Details 3: Exposure 499ms, Gain 110, 30% of 726 frames stacked

This star was captured during the initial session that was later interrupted by clouds. Getting a decent calibration on this spectrum was a bit more of a struggle than expected, but the results are not terrible. Many of the hydrogen Balmer lines are present here, but most are weakened. The calcium H and K lines around 3933-3968 Angstroms are also muted in this spectrum, showing a smooth curving scoop rather than a sharper cut. The CN absorption at 4180-4197 is quite notable here. The CH (G) line at 4307.9 Angstroms is likewise easily identified. By far the strongest absorption in the spectrum is the magnesium triplet at 5170 Angstroms. The cut into the continuum is both deep and broad, being assisted by flanking iron lines. The sodium doublet at 5890-96 Angstroms is not nearly as deep, but still carves a nice groove out of the spectrum. A good number of fainter metal lines are seen throughout this spectrum, including iron, strontium, calcium, titanium, magnesium, nickel, vanadium, and barium.

Using Wien's Law, we will calculate an effective temperature for the star. Adopting a peak energy wavelength of 5844 Angstroms, the calculation results in a temperature of 4959K. The star's accepted temperature is listed as 4792K[2]. Our estimate is not too bad, even if it is a bit high.

ζ Cephei

Zeta Cephei is classified as an early K-type star[1], and is also listed as a possible eclipsing binary[2]. We should see a spectrum curve not entirely dissimilar from Errai above—a cooler star showing large numbers of metal lines.

The star's spectrum is below:

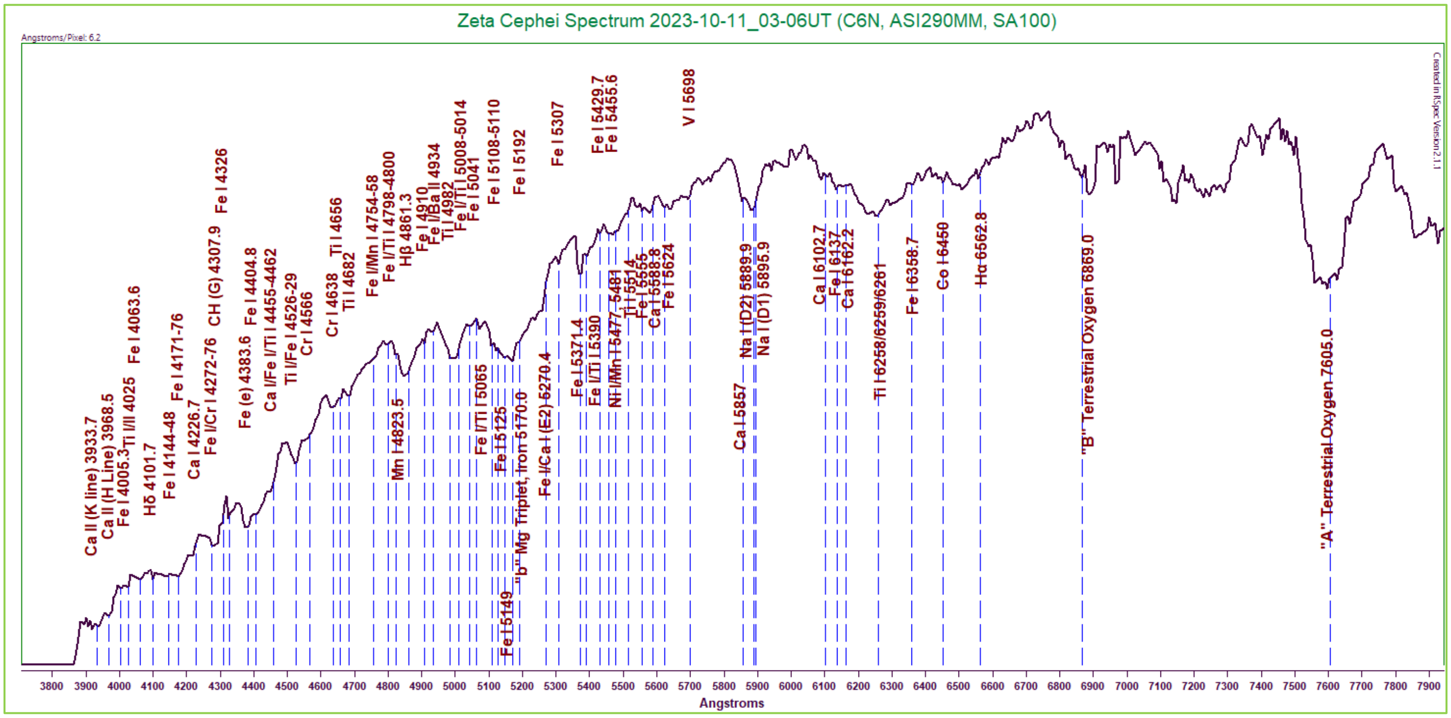

Figure 4: Zeta Cephei Spectrum (6.2 Angstroms/pixel)
Capture Details 4: Exposure 517ms, Gain 77, 30% of 468 frames stacked

We can see here a curve somewhat similar to Gamma Cephei. However, there are some notable differences. This star is slightly cooler, which is reflected in the shape of the curve. The calcium H and K lines are not deep, but they are noticeable in the extreme lower wavelength range. The CH (G) line at 4307.9 Angstroms is small, but stands out reasonably well from the continuum. Between 4383 and 4462 Angstroms, a notable dip is taken out of the continuum due to a collection of iron and calcium lines. The magnesium triplet is on beautiful display here at 5170 Angstroms, showing a deep groove cut into the spectrum, appearing widened by flanking iron lines. The sodium doublet at 5890-96 Angstroms is also well shown, as is the calcium line just below it. A good number of fainter metal lines are indicated, including iron, titanium, calcium, chromium, manganese, and nickel.

Using Wien's Law, we will again attempt to obtain a rough estimate of the star's effective temperature. Accepting an estimated peak energy wavelength of 6804 Angstroms, we arrive at a result of 4259K. The established temperature of the star is 4072K[2]. Again, our estimate for the cooler star is closer to the mark.

ι Cephei

Iota Cephei is classified as a very early K-type star[1]. As with the last two stars analyzed, we can expect to see similar results—a star cooler than our Sun with a lot of metal lines present.

The processed spectrum is presented here:

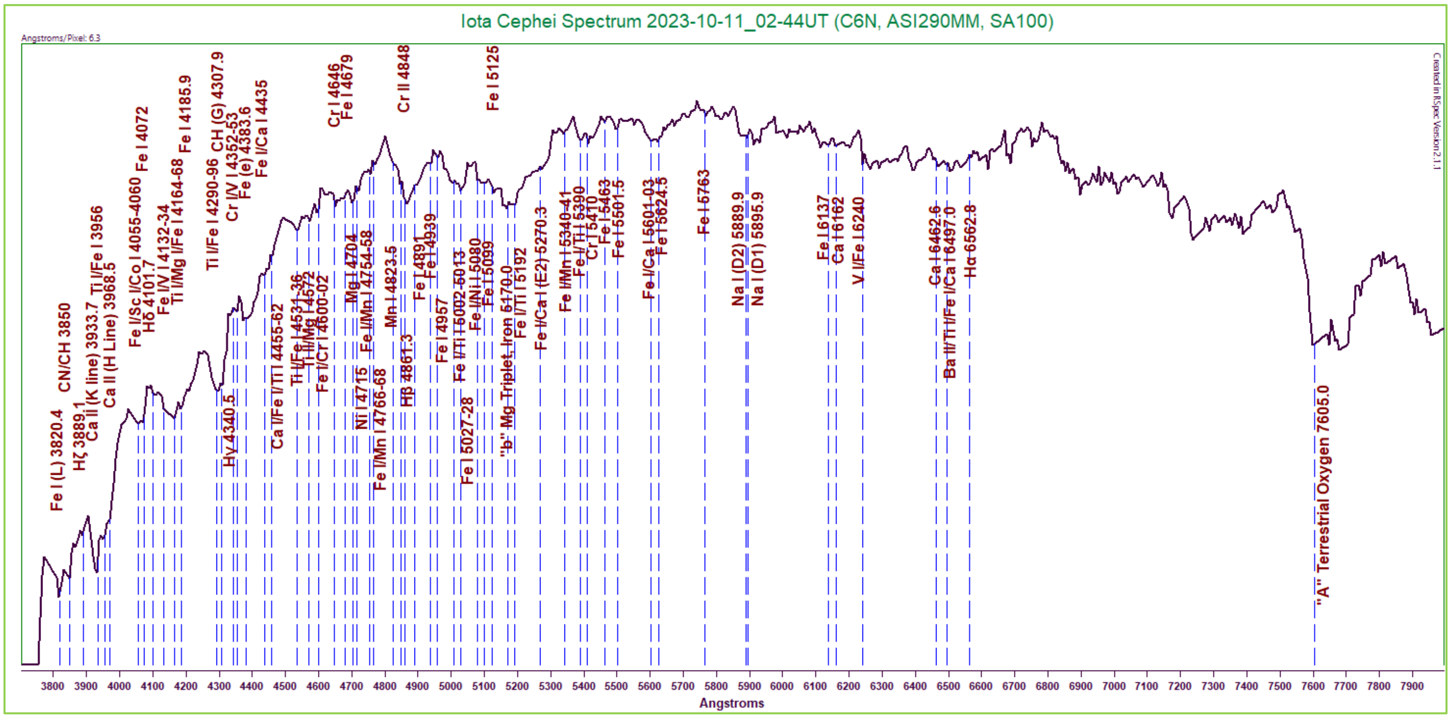

Figure 5: Iota Cephei Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 477ms, Gain 77, 20% of 384 frames stacked

Ah, this one shows the extent of the low signal-to-noise ratio during this run. Some features are still clear, however. The weakened hydrogen Balmer lines can be seen where applicable. The calcium H and K lines are present, making a good showing near the low wavelength region. The CH (G) absorption at 4307.9 Angstroms marks out a nice groove in the continuum as well. The magnesium triplet at 5170 Angstroms is again a major feature, but the noise ratio in the capture makes it appear a bit blocky. The sodium doublet at 5890-96 Angstroms is also quite recognizable. A great number of very faint metal lines are indicated, but since this spectrum's noise levels are high, a number of them could simply be that—noise. Among the additional metals marked, we have a lot of iron, with CN, titanium, chromium, calcium, magnesium, manganese, and vanadium mixed in.

Using Wien's Law with an estimated peak energy wavelength of 5849 Angstroms, we arrive at a very rough temperature estimate of 4954K. The listed temperature for the star is 4798K[2]. Of the effective temperature estimates made during this run, this is one of the closest.

π Cephei

This star was noted while capturing data for Errai. Pi Cephei, also called Al Aghnam II, is a triple star system. The components are too close for the equipment used to separate, so our spectrum will be a combination of them. The primary is either an early G-type or late G-type star[1,2], as sources disagree on the classification. The secondary is listed as a middle K-type star[2], with the tertiary being a late to very late A-type star[2]. The primary is expected to dominate the spectrum.

The processed spectrum is presented below:

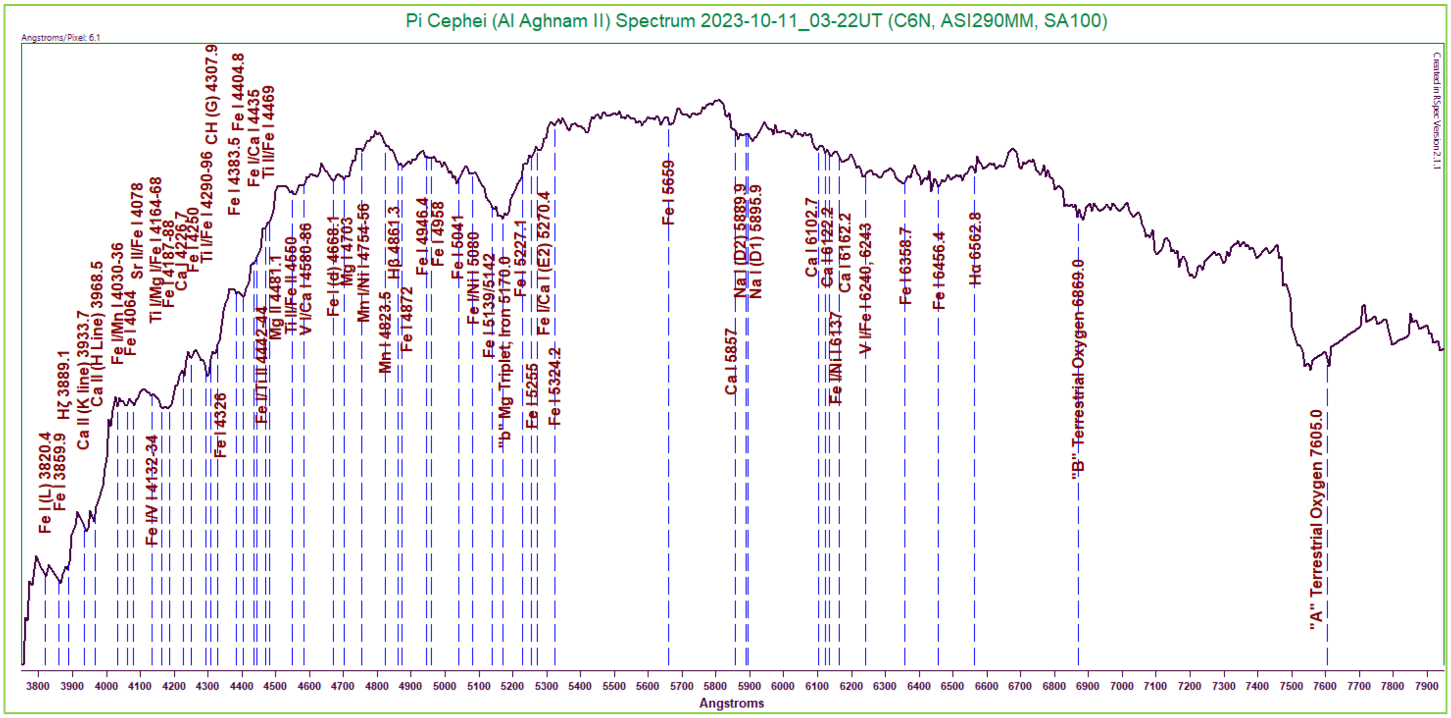

Figure 6: Pi Cephei (Al Aghnam II) Spectrum (6.1 Angstroms/pixel)
Capture Details 6: Exposure 387ms, Gain 95, 50% of 809 frames stacked

The spectrum curve does indeed show a cooler star, with numerous metal absorptions present. The only clearly present hydrogen Balmer line is the Hβ line, and it definitely appears muted. The calcium H and K lines are evident in the lower wavelength range (3933.7-3968.5 Angstroms). A fairly deep, broad dip in the continuum can be seen due to titanium and iron in the 4164-4188 Angstroms range. The CH (G) line is also clearly represented at 4307.7 Angstroms, with the titanium/iron line just below it. The strongest absorption is that of the magnesium triplet at 5170 Angstroms. The sodium D1 and D2 lines are also well represented. The spectrum also shows a large number of fainter metal lines along its length. These include numerous iron lines, strontium, titanium, calcium, magnesium, vanadium, and manganese.

We will employ Wien's Law to determine a rough estimate of the effective temperature. Using an estimated peak energy wavelength of 5810 Angstroms we obtain a result of 4988K. The established temperature of the star is listed as 5226K[2]. Our estimate in this case is a bit too low.

Conclusion

This run proved challenging, even more so than that for the stars in Ursa Minor. The northern sky, when combined with mediocre conditions, provided something of an obstacle in capturing useable spectra. The results, though passable, lacked some detail and clarity. Some of the raw captures frankly looked too dim and weak to provide useful data. However, the process of reducing and analyzing the data showed that some useful (if limited) results were to be had.

My proficiency with the software and the processes involved continues to improve, which is a very welcome thing to note!

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