Spectral Analysis of the Constellation Stars of Aquila (The Eagle)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Aquila. 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 confined to the stars forming the constellation lines.

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. 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 obtained on the evening of August 16, 2023 (EDT). Additional specifics for each capture are included 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 are the exposure, 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.

One difficulty was encountered in the processing of the data for this run. While capturing footage of the stars for later processing, it was later discovered that I had inadvertently mislabeled two of the stars. When processed, the stars did not appear to be correct for their respective spectral types. Some investigation led to discovering that the names of Epsilon Aquilae and Zeta Aquilae had been accidentally interchanged! This was corrected, and the data was included in the analysis, but only after a lot of time-consuming head scratching! I will definitely have to take greater care in the future to avoid such transpositions again.

α Aquilae

Alpha Aquilae, commonly known as Altair, is classified as a late A-type pulsating variable star[1]. We should expect to see mostly hydrogen Balmer features in its spectrum, with perhaps some other traces mixed in as the temperature should be lower than that of early A-type stars.

The processed spectrum follows:

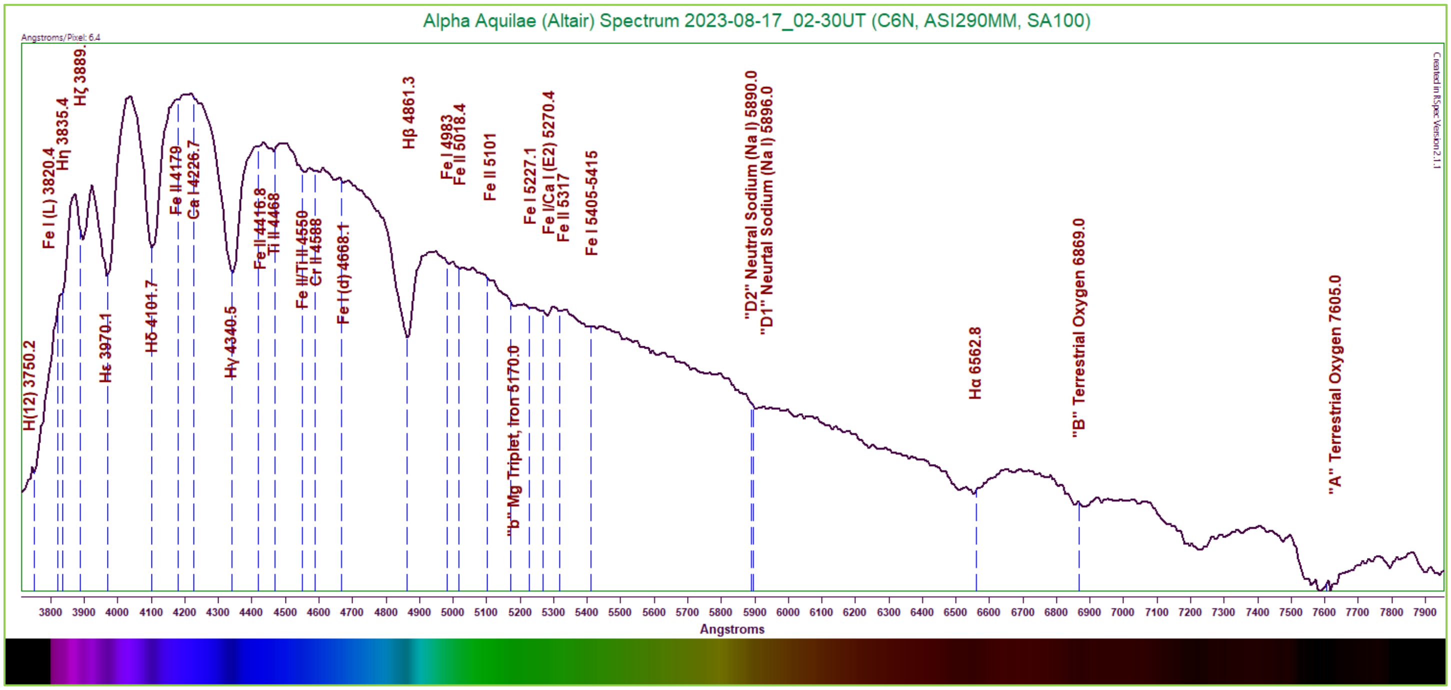

Figure 1: Alpha Aquilae (Altair) Spectrum (6.4 Angstroms/pixel)
Capture Details 1: Exposure 125ms, Gain 59, 50% of 997 frames stacked

We can see the expected hydrogen Balmer lines displayed very prominently. The Fe I (L) and Hη lines are weak, but they blend together to create a bump in the continuum. The ionized iron and neutral calcium lines at 4179 and 4226.7 Angstroms are very subtle, but again it is identifiable. A series of five faint lines appear between the Hγ and Hβ lines, produced by iron, titanium and chromium. The magnesium triplet and the several iron lines create a slight, broad trough in the continuum. The sodium D1 and D2 lines create a more noticeable absorption around 5890-96 Angstroms.

We now apply Wien’s Law to obtain a very rough temperature estimate. Using an estimated peak energy wavelength of 4212 Angstroms, the resultant temperature comes out to approximately 6880K. The currently accepted temperature estimates range from 6820K to 8621K[2]. Our estimate is fairly well in line with the lower region of this range.

β Aquilae

Beta Aquilae, named Alschairn, is designated as a triple star, with the brightest component classified as a late G-type star[1]. The other components are too dim to register with the equipment used, so the main star in the system should dominate the spectrum. The detailed spectrum should appear quite different from that of Altair above.

The processed and labeled spectrum is as follows:

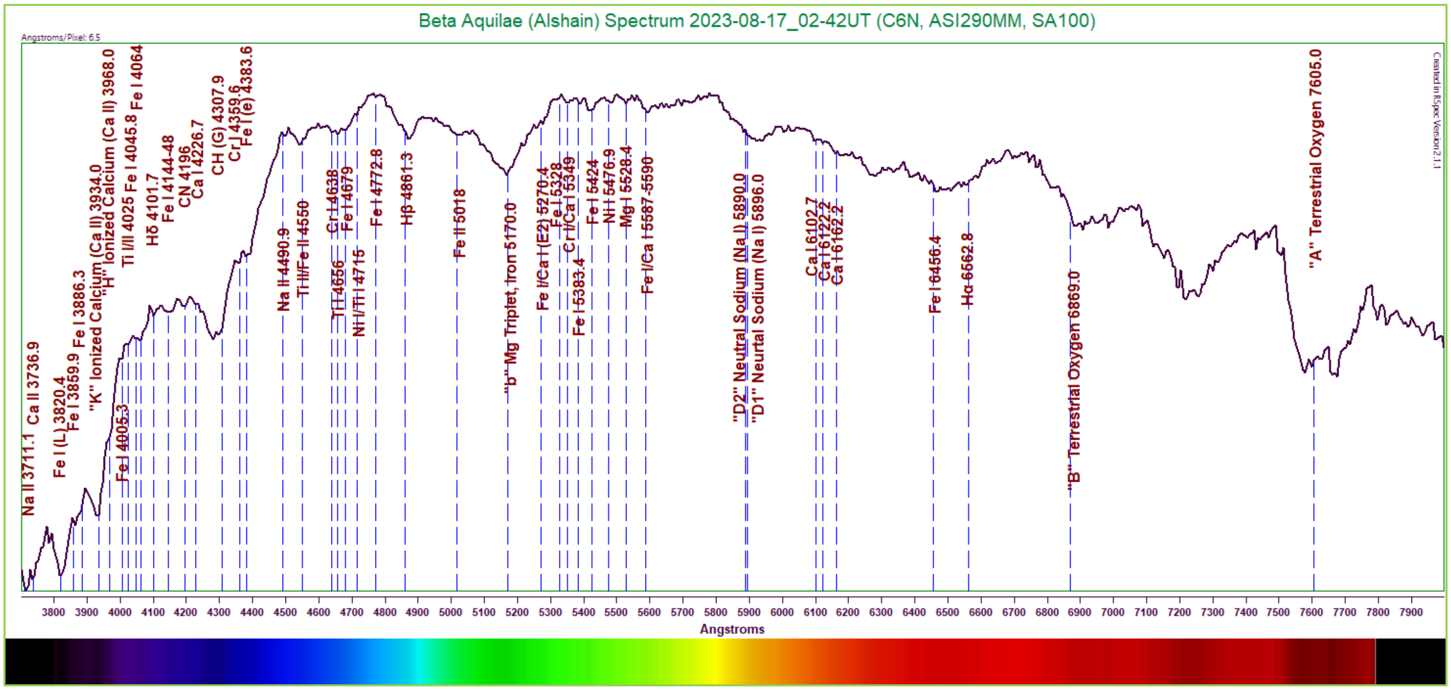

Figure 2: Beta Aquilae (Alshain) Spectrum (6.5 Angstroms/pixel)
Capture Details 2: Exposure 626.21ms, Gain 146, 70% of 198 frames stacked

As expected, the spectrum for Alschain does appear quite different from that of Altair. Being a cooler, late G-type star, we see a lot of faint metal lines, particularly iron. An ionized sodium line appears at the extreme short wavelength region at 3711.1 Angstroms, right beside the familiar calcium line at 3736.9 Angstroms. The Fe I (L) line appears quite deep, and the calcium H and K lines are also easy to identify. Moving up the wavelength scale, we encounter a large number of faint metal lines—three iron lines between 4025 and 4064 Angstroms, along with the CN band at 4196 Angstroms and calcium at 4226.7 Angstroms. The CH (G) band absorption is very deep, cutting a nice trough in the continuum. Afterward, we encounter more faint metal lines—sodium, titanium, chromium, iron, nickel, and magnesium. The Hβ line is significantly weakened here. The magnesium triplet at 5170 Angstroms is strong by contrast, followed by a weak Fe I/Ca I (E2) line at 5270.4 Angstroms. Another series of faint lines are labeled for chromium, iron, magnesium, and calcium. The dip caused by the sodium D1 and D2 lines is notable, but not as deep as the magnesium triplet. The Hα line is broad and somewhat shallow, assisted by the adjacent iron absorption at 6456.4 Angstroms. This one has a lot going on!

Applying Wien's Law, we can obtain a very rough estimate of the effective temperature of the star. Visually extrapolating from the continuum line is difficult in this case, but it appears that the peak energy wavelength is approximately 5779 Angstroms. This results in a temperature of 5014K. The accepted temperature is 5071K[2]. Our estimate is very close!

γ Aquilae

Gamma Aquilae, commonly called Tarazed, is classified as an early K-type star[1]. It does have a companion star, but it is far enough away to not interfere with the spectrum. We should expect to see some prominent aspects of cooler stars with this one.

The processed spectrum follows:

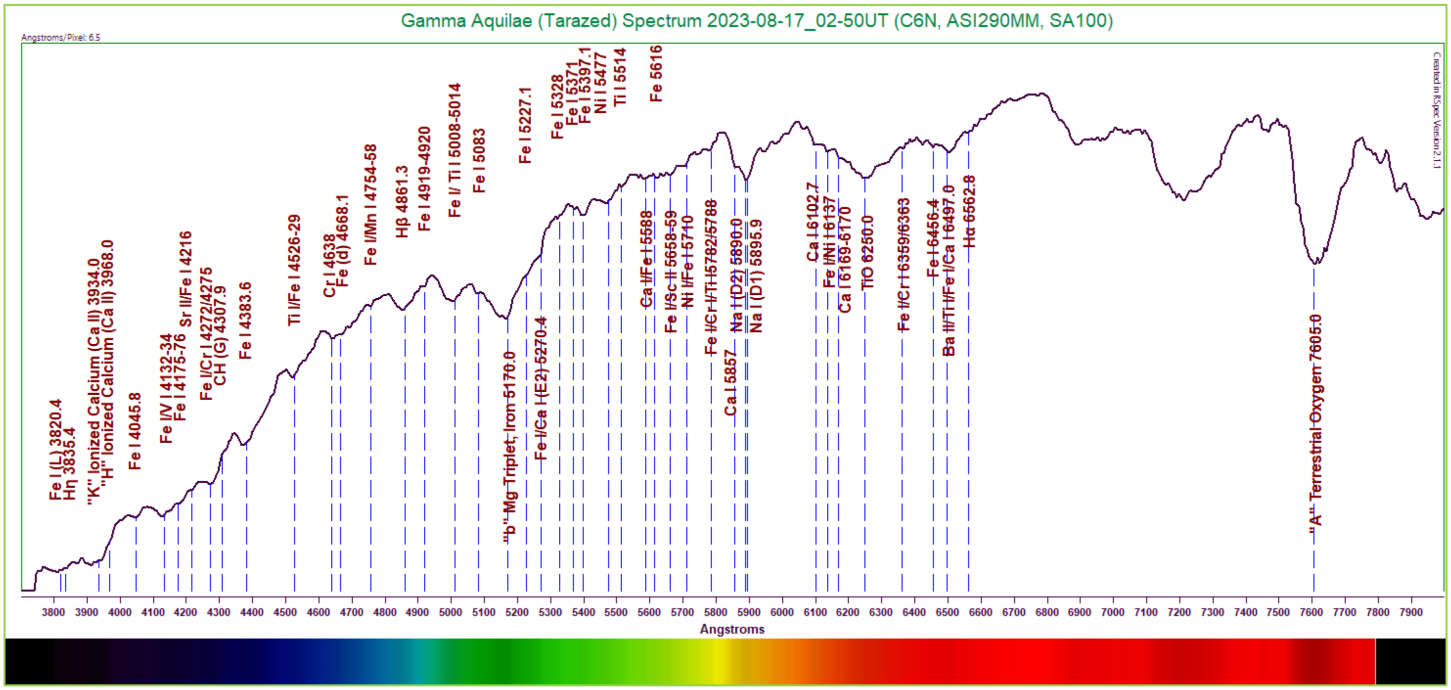

Figure 3: Gamma Aquilae (Tarazed) Spectrum (6.5 Angstroms/pixel)
Capture Details 3: Exposure 503ms, Gain 101, 85% of 278 frames stacked

Now we see a lot of features characterizing stars approaching later types. Starting at the lower wavelength region, we see the Fe I (L) line and Hη line are blending to create a broad but shallow dip in the continuum. The calcium H and K lines are evident, though not terribly strong. Spread throughout the spectrum are faint lines of iron, strontium, titanium, chromium, nickel, calcium, and barium. The CH (G) band at 4307.9 Angstroms is identifiable, though not terribly deep. The two most prominent absorptions are the magnesium triplet at 5170 Angstroms, and the sodium D1 and D2 lines around 5890-96 Angstroms. We can even see the calcium line jut below at 5857 Angstroms quite clearly. The general shape of the curve is consistent with a cooler start.

Applying Wien's Law, we can gain a rough estimate of the star's effective temperature. Estimating a peak energy wavelength of about 6785 Angstroms results in a temperature of 4271K. The established temperature is 4098K[2]. Our estimate is within 200K of the accepted value—not too bad.

δ Aquilae

Delta Aquilae, also known by the names Almizan I and Deneb Olkab, is an early F-type star[2]. It possesses an astrometric companion, but its features should be subsumed by the primary in the spectrum. We can expect it to possess some characteristics of hotter, A-type stars perhaps mixed with some emergent elements of the cooler G-types.

The spectrum follows:

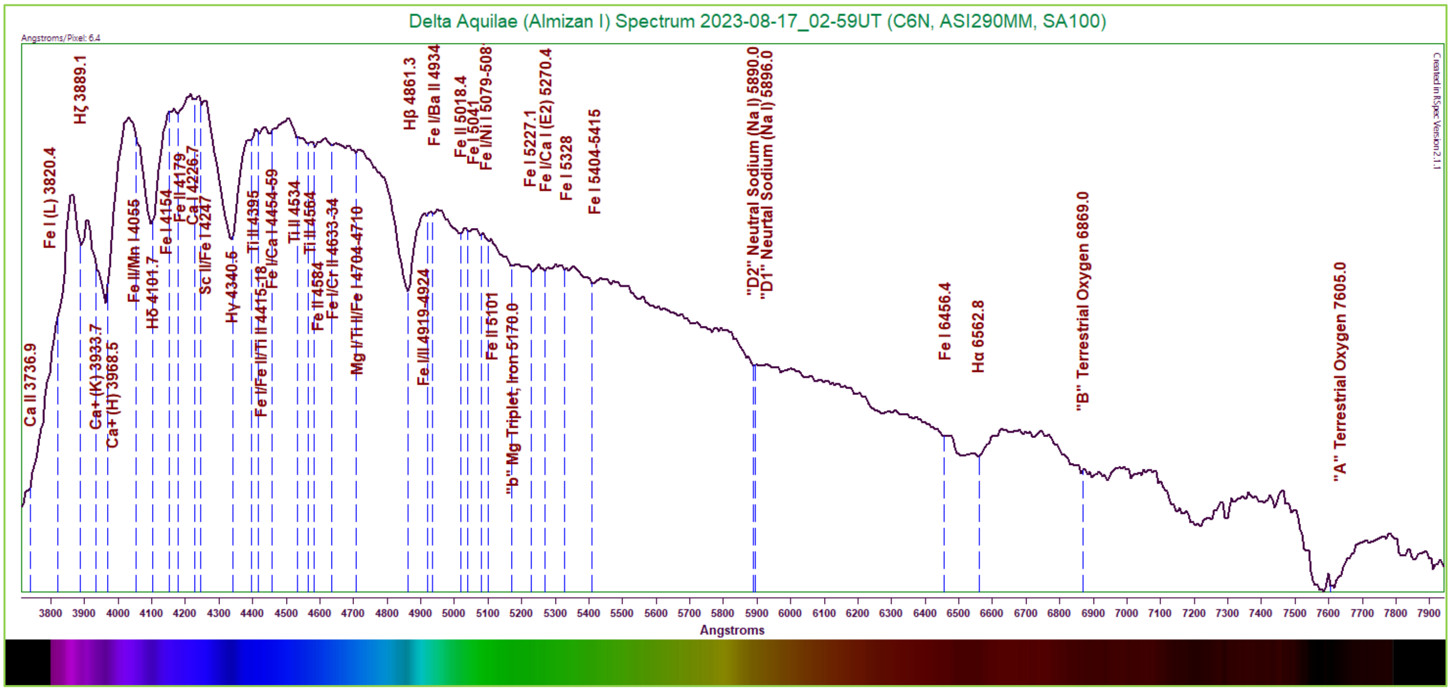

Figure 4: Delta Aquilae (Almizan I) Spectrum (6.4 Angstroms/pixel)
Capture Details 4: Exposure 343ms, Gain 184, 80% of 420 frames stacked

We do indeed see a lot of the familiar hydrogen Balmer lines here. The calcium line at 3736.9 Angstroms is very weak, and the Fe I (L) line at 3820.4 Angstroms is very subtle, causing only a barely noticeable bump. The calcium H and K lines are causing a steep dive in the continuum just above the Hζ absorption. We see some faint metals above the Hδ line—neutral and ionized iron, neutral calcium, ionized scandium. Above the Hγ line is another set—ionized titanium, neutral iron, ionized titanium, and neutral magnesium. The magnesium triplet at 5170 Angstroms is causing a broad, shallow dip in the continuum, aided by its flanking iron lines. The sodium D1 and D2 lines at 5890-96 Angstroms are causing something similar. The Hα line appears unusually well-defined here.

Using Wien's Law with an estimated peak energy wavelength of 4217 Angstroms, we can very roughly estimate the star's temperature as 6829K. The accepted value for the effective temperature is 7016K[2].

ε Aquilae

Epsilon Aquilae, also known as Deneb al Okab Borealis, is a spectroscopic binary star. However, the minor influence of the secondary should be dominated by the primary, an early K-type star[1]. We should therefore expect to see some characteristics similar to those of Tarazed above.

The spectrum is as follows:

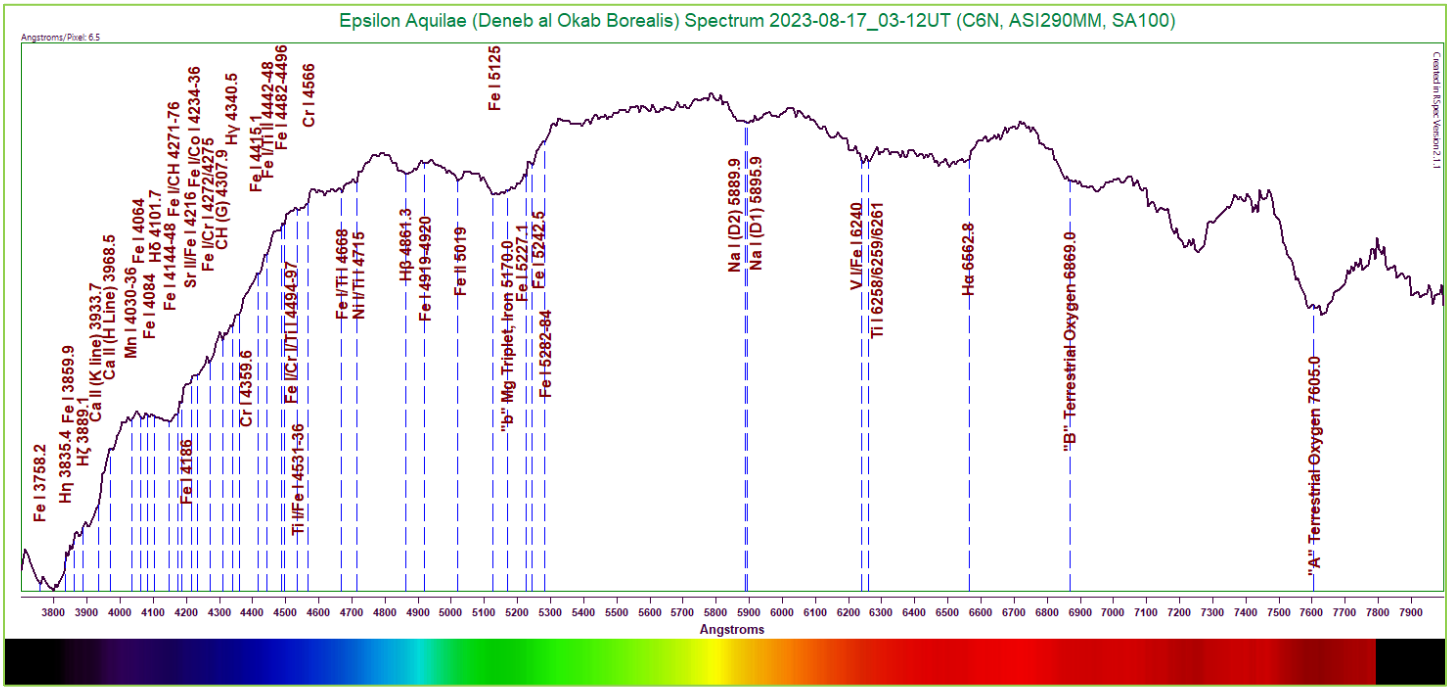

Figure 5: Epsilon Aquilae (Deneb al Okab Borealis) Spectrum (6.5 Angstroms/pixel)
Capture Details 5: Exposure 604ms, Gain 160, 75% of 302 frames stacked

This spectrum curve does generally resemble that of Terazed, but there are some important differences as well. This spectrum appears noisier, hiding some of the subtler features seen with Tarazed. Several iron lines populate the extreme low wavelength region. The calcium H and K lines appear extremely muted. Near the Hδ line, we see iron absorptions. These blend together, causing a significant dip in the continuum. The iron and CH absorptions around 4272-4307 Angstroms appear extremely weak. Several more iron lines are evident, though again they are very faint. The magnesium triplet and the sodium D1 and D2 lines are evident. A number of additional faint metal lines are marked, but many may be suspect identifications due to the high noise level.

Using Wien's Law, we can gain a very rough estimate of the star's temperature. Utilizing an estimated peak energy wavelength of 5788 Angstroms, the effective temperature works out to approximately 5007K. The accepted value of the temperature is 4760K[2].

ζ Aquilae

Zeta Aquilae, or Deneb al Okab Australis, is classified as a very early A-type star[1]. It is actually a binary star, but the companion is too dim to interfere in our spectrum capture. We should expect to see strong hydrogen Balmer lines in this one.

The processed spectrum follows:

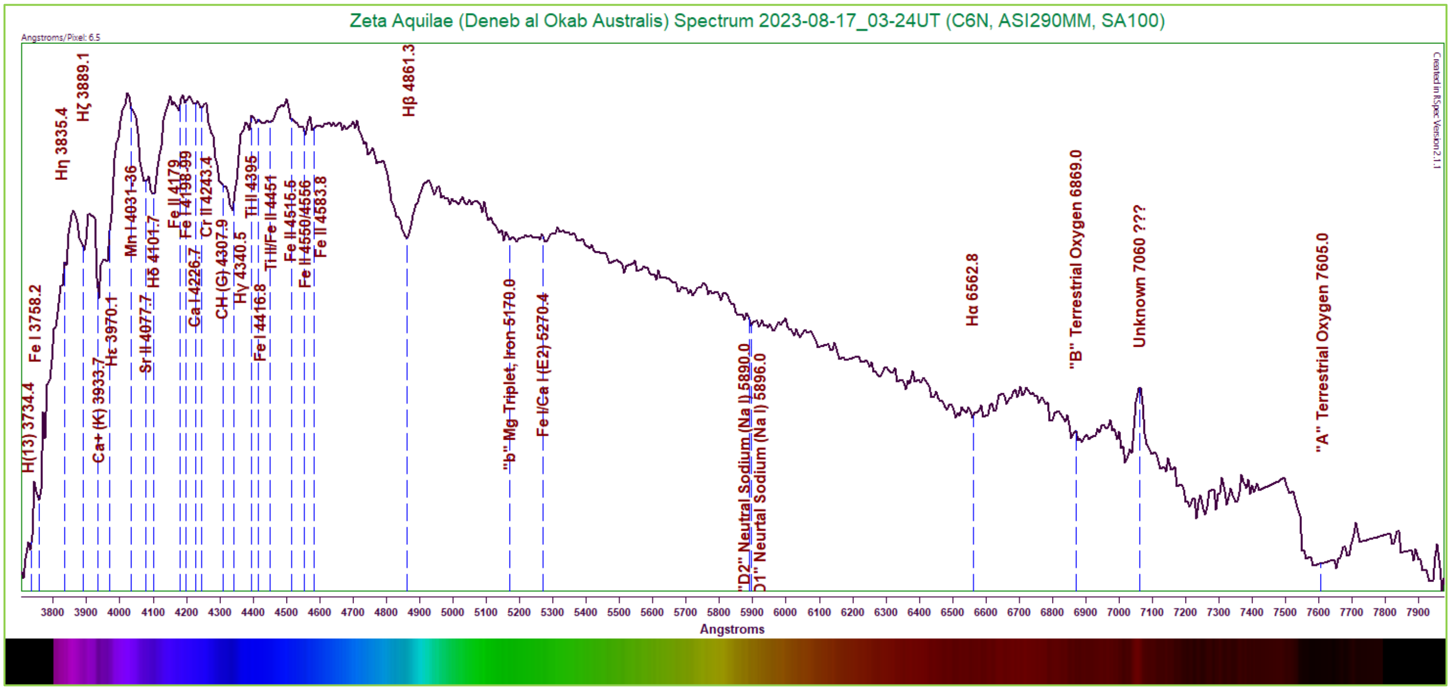

Figure 6: Zeta Aquilae (Deneb al Okab Australis) Spectrum (6.5 Angstroms/pixel)
Capture Details 6: Exposure 4s, Gain 184, 100% of 61 frames stacked

As expected, the profile curve fits the general shape of an A-type star fairly well. Unfortunately, the noise level is again higher than we would like to see. The hydrogen Balmer lines are quite pronounced. At the extreme low end of the wavelength scale, ionized calcium and neutral iron lines are evident. The calcium K line can be seen alongside the Hε line. A faint strontium line is surprisingly visible at 4077.7 Angstroms. A quadruplet of faint features sits between the Hδ and Hγ lines—ionized iron, neutral iron, neutral calcium, and ionized chromium. The CH (G) band shows up as a good-sized bump just below the Hγ line. Some titanium and iron lines are visible between 4395 and 4583 Angstroms, as well. The magnesium triplet and the Fe I/Ca I (E2) line create a broad dip in the continuum. The location of the sodium D1 and D2 lines is marked, but the identification is subject to doubt since the continuum is very noisy in this region. An emission feature shows up at about 7060 Angstroms where none would be expected; it is possible that this may be a very dim field star that was caught in the path of the spectrum during capture.

Again we employ Wien's Law to gain a rough estimate of the star's temperature. Using a peak energy wavelength of 4024 Angstroms, the temperature works out to approximately 7201K. The established temperature of the star is 9620K[2]. As with other early type stars, our estimate falls short.

η Aquilae

Eta Aquilae is another multiple star system. However, its primary is separated from the other stars by an adequate amount, so there should be no problem. The primary is classified as a middle F-type Cepheid variable[2], but being a variable, it swings between F- and G-types during its oscillations. The spectrum should show some interesting features, depending upon the time the capture was made relative to its variability cycle.

The processed data is presented below:

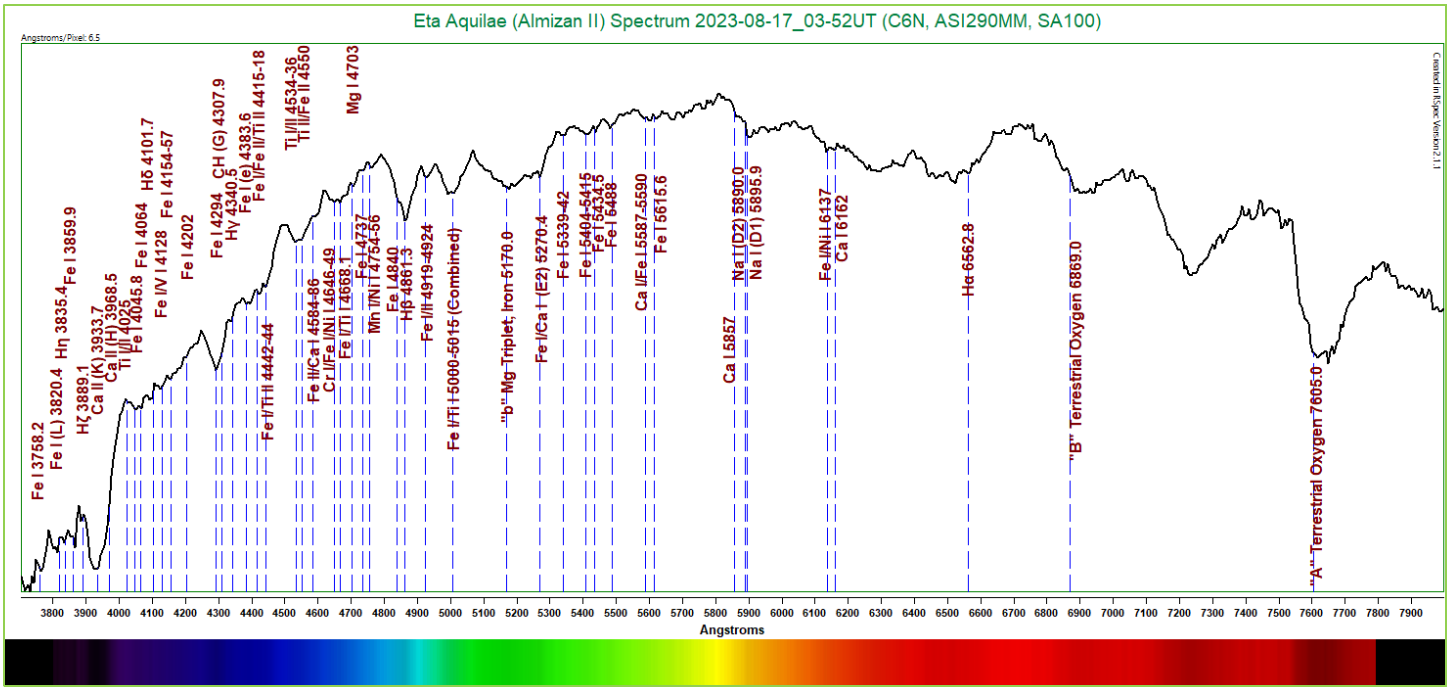

Figure 7: Eta Aquilae (Almizan II) Spectrum (6.5 Angstroms/pixel)
Capture Details 7: Exposure 499ms, Gain 199, 70% of 367 frames stacked

Well, this one certainly looks interesting! The curve resembles a later-middle-type star, perhaps a G-type. A large number of metal lines are present throughout, including copious iron absorptions, calcium, titanium, chromium, and manganese. The sharpest dips in the continuum occur at the calcium H and K lines around 3933-3968 Angstroms, the CH (G) band at 4307.9 Angstroms, and the Hβ line at 4861.3 Angstroms. The magnesium triplet and Fe I/Ca I (E2) lines again create a broad absorption around 5170-5270 Angstroms. The sodium D1 and D2 lines also create an obvious dip in the continuum, though it is less pronounced.

Let's see what we arrive at for a temperature. Using a peak energy wavelength of 5812 Angstroms, Wien's Law provides us with a rough estimate of 4986K. The listed temperature for the star, which must certainly be an average due to its pulsating nature, is approximately 6000K[2].

θ Aquilae

Theta Aquilae, or Almizan III, is a double star, but the separation of its components presents no problems. The primary is considered a very late B-type star[1]. We can expect to see features consisted with a hot star, perhaps even with a couple helium features present.

The processed spectrum is presented below:

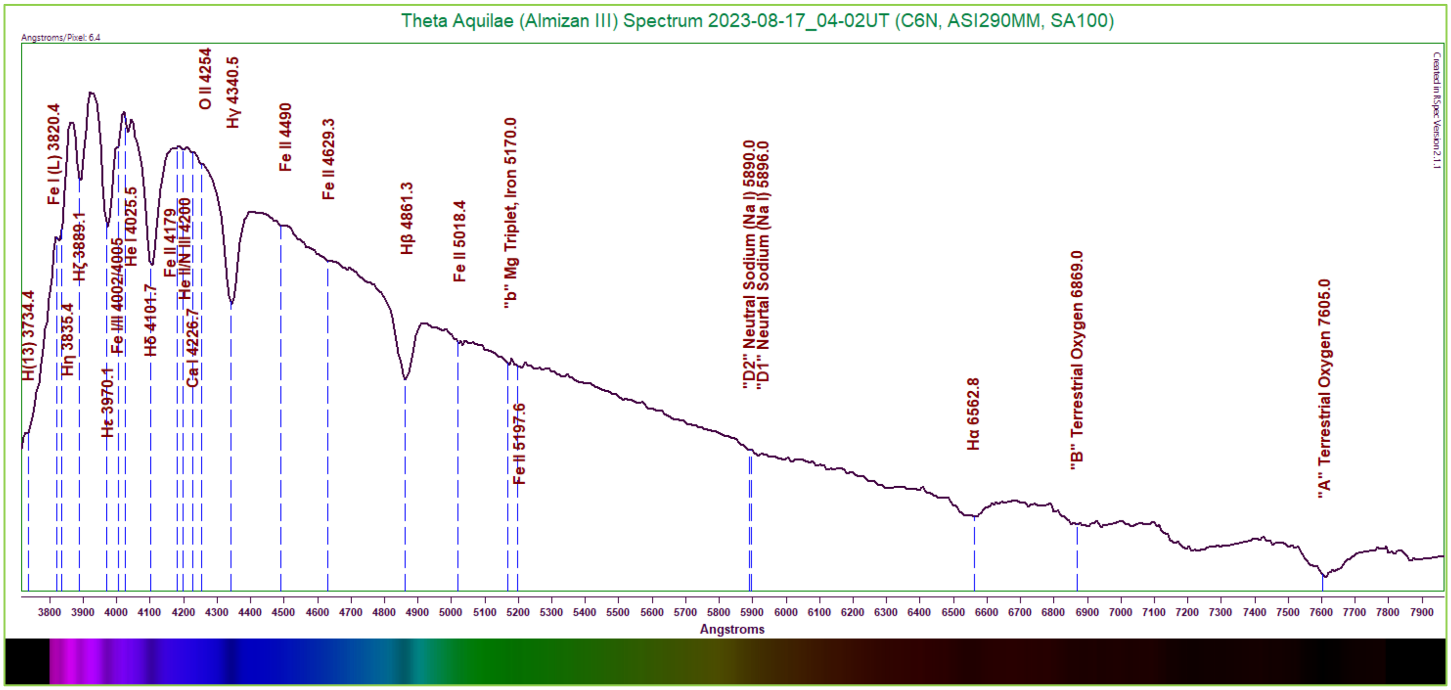

Figure 8: Theta Aquilae (Almizan III) Spectrum (6.4 Angstroms/pixel)
Capture Details 8: Exposure 434ms, Gain 149, 80% of 420 frames stacked

As expected, we see features typical of a late B-type star. The hydrogen Balmer lines are very strong and clear. Even the Hα line appears more crisply defined than normal. We can also spot a few other very faint lines. Helium is present at 4025.5 and 4200 Angstroms. One extremely fain but definite bumps from ionized oxygen can be seen at 4254 Angstroms. The magnesium triplet is labeled, but it is possible that this is simply noise in the continuum. A slight reduction in the continuum is also noted at the sodium D1 and D2 lines.

Again employing Wien's Law, we can gain a very rough estimate of the star's effective temperature. Using a peak energy wavelength of 3920 Angstroms, the temperature comes out to 7392K. The accepted value is 10300K[2]. As anticipated, our estimate is much too low. This has been the case for the earlier stellar types.

λ Aquilae

Lambda Aquilae, also called Al Thalimain Prior or Al Thalimain I, is a late B-type star[1]. We should therefore expect to see features very similar to Almizan III above, but with fewer (or no) helium traces.

The spectrum is presented below:

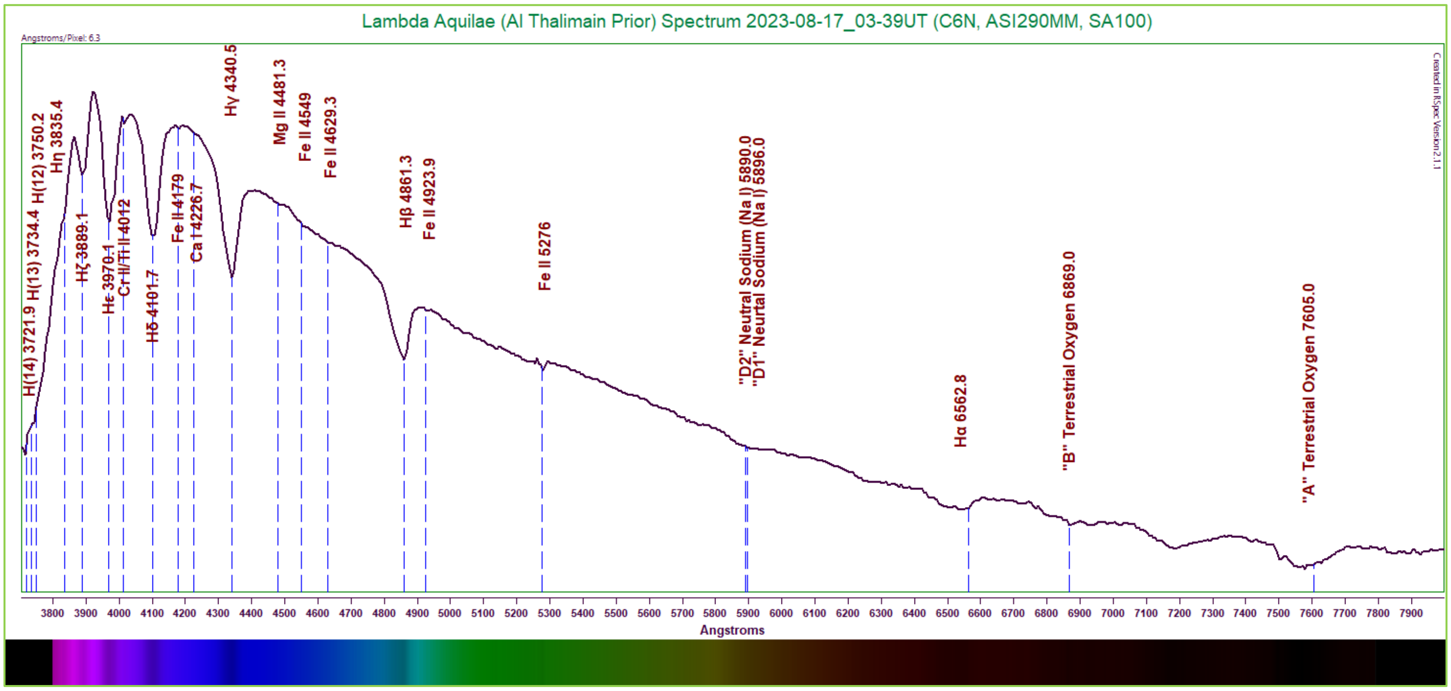

Figure 9: Lambda Aquilae (Al Thalimain Prior) Spectrum (6.3 Angstroms/pixel)
Capture Details 9: Exposure 572, Gain 154, 60% of 407 frames stacked

Again, we are presented with a typical late B-type or early A-type spectrum. The hydrogen Balmer lines are strong, but we do not see the helium lines that were emergent for Almizan III. The Hη line appears extremely weak here, only being evident by a very subtle change in the continuum. Above the Hε line, we can see a single ionized chromium/titanium line at 4102 Angstroms. We can also note an ionized iron line appearing at 4179 Angstroms, followed by neutral calcium at 4226.7 Angstroms. Both of these are extremely weak, but can be spotted from the smooth continuum surrounding them. Above the Hγ absorption, a handful of other extremely weak lines are marked, including magnesium and several more iron lines. These are mostly only causing very subtle changes in the continuum, and so are subject to skepticism. A noticeable dip appears for the sodium D1 and D2 lines at 5890-86 Angstroms.

Using Wien's Law, we will again estimate the effective temperature of the star. Using a peak energy wavelength of 3921 Angstroms, we arrive at a temperature of 7391K. The accepted temperature is listed as 11780K[2]. Once again our estimate for such an early type star is well under the mark.

Conclusion

This was the third run through constellation stars for this project. After the difficulty encountered when accidentally capturing data from a wrong star last time, I was trying to be very careful. However, I somehow transpose labeling on two stars during the capture session. Otherwise, the entire process continues to improve as I gain experience.

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