Spectral Analysis of the Constellation Stars of Aurigae (The Charioteer)

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2025-01-09

Abstract

This paper will elucidate the spectral features of the main stars in the constellation Auriga. 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. Stellarium was used to define the stars comprising the constellation lines.

Data Processing Details

All of the spectra obtained for this analysis were collected on the evening of November 7, 2024 (EST). Additional 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 length, 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 are 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. The response curve used in this analysis was generated (using Alpha Lyrae) on the evening of August 31, 2024. 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 Aurigae

Alpha Aurigae, more commonly known as Capella, is a multiple star system with an overall classification of early G-type[1,2]. From this designation, we should expect to see a spectrum similar to that of our own Sun, with a high number of metal lines discernible, especially iron.

The processed spectrum is presented here:

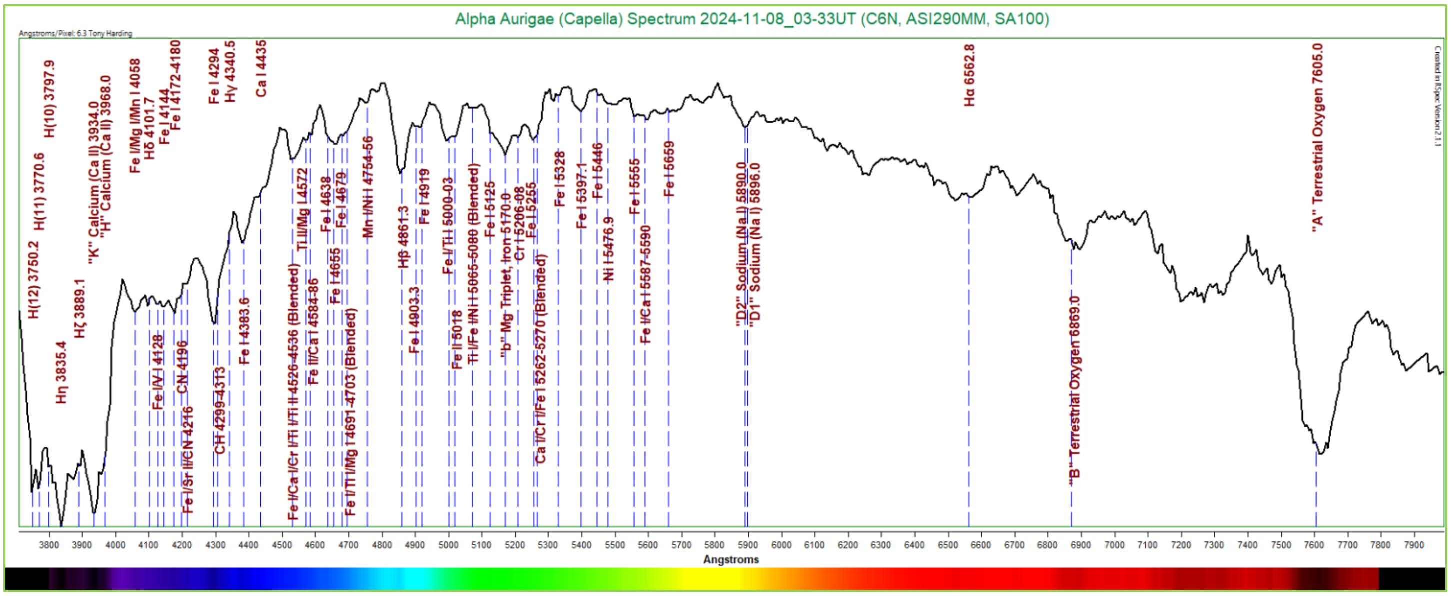

Figure 1: Alpha Aurigae (Capella) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 100ms, Gain 0, 20% of 3686 frames stacked, Integration Time 73s

The general shape of the flux curve does match an early G-type star. Several of the hydrogen Balmer absorptions are evident and showing up unusually strongly. The Hη line is very deep and sharp at 3635.4 Angstroms, and the Hβ feature is also unusually deep. The calcium K and H lines at 3934 and 3968 Angstroms carve out a profound dip in the continuum. The CH molecular absorption at 4299-4313 Angstroms is also very deep and clear, along with the iron line just below it at 4924 Angstroms. The magnesium triplet at 5170 Angstroms is also sharply defined, as is the sodium doublet at 5890-96 Angstroms. Other notable absorptions include lots of iron, molecular CN, calcium, manganese, titanium, and chromium.

We will employ Wien's Law to obtain an effective temperature estimate. In this case, the peak energy wavelength is difficult to determine. It appears to lie between the peaks at 4809 and 5808 Angstroms. Taking the median value, we arrive at 5308 Angstroms. Using this value, we calculate an effective temperature of 5459K. The listed temperatures for the two unresolved components are 4970K and 5730K[2]. The median value of these two is 5350K. Considering the uncertainties in our crude estimate, we are actually fairly close to the mark—only about 2% off the mark.

β Aurigae

Beta Aurigae, also known by the name Menkalinan, is a binary eclipsing variable star system whose components are both classified as early A-type stars[1,2]. We should therefore expect to see strong hydrogen Balmer absorptions in a curve representative of a hotter star.

The finished spectrum is found below:

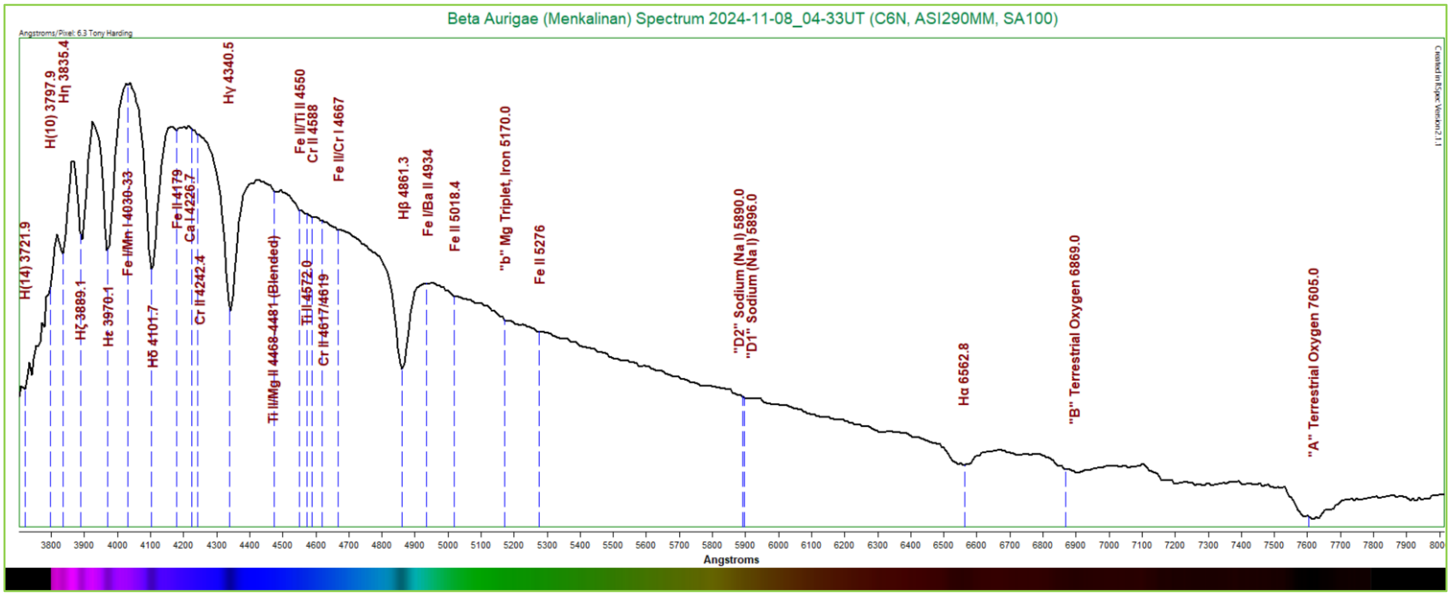

Figure 2: Beta Aurigae (Menkalinan) Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 216ms, Gain 110, 30% of 847 frames stacked, Integration Time 54s

The hydrogen Balmer lines are quite deep and clear here, typical for this classification of star. Even the Hα absorption is pronounced. The magnesium triplet at 5170 Angstroms is visible here as a slight but clear dip in the continuum. The sodium doublet at 5890-96 Angstroms is also very slight. Other fainter metals present include neutral and ionized iron, calcium, chromium, and titanium.

Again employing Wien's Law, we will calculate an effective temperature for the pair of stars. Since the spectrum obtained is for an early A-type star, we must expect that our estimate will fall short. The peak energy wavelength from the spectrum above appears to lie at 4038 Angstroms. Utilizing this value, we calculate an effective temperature of 7176K. The two stars are listed as having temperatures of 9350K and 9200K[2]. Indeed our estimate falls far short.

ζ Aurigae

Zeta Aurigae, known also as Saclateni, is an eclipsing spectroscopic binary star system whose components are classified as middle K-type (primary) and late B-type (secondary)[1,2]. The primary is a giant, and should therefore dominate the spectral features. We can expect to see a flux curve representative of a cooler star, with many metal lines throughout.

The completed spectrum is presented below:

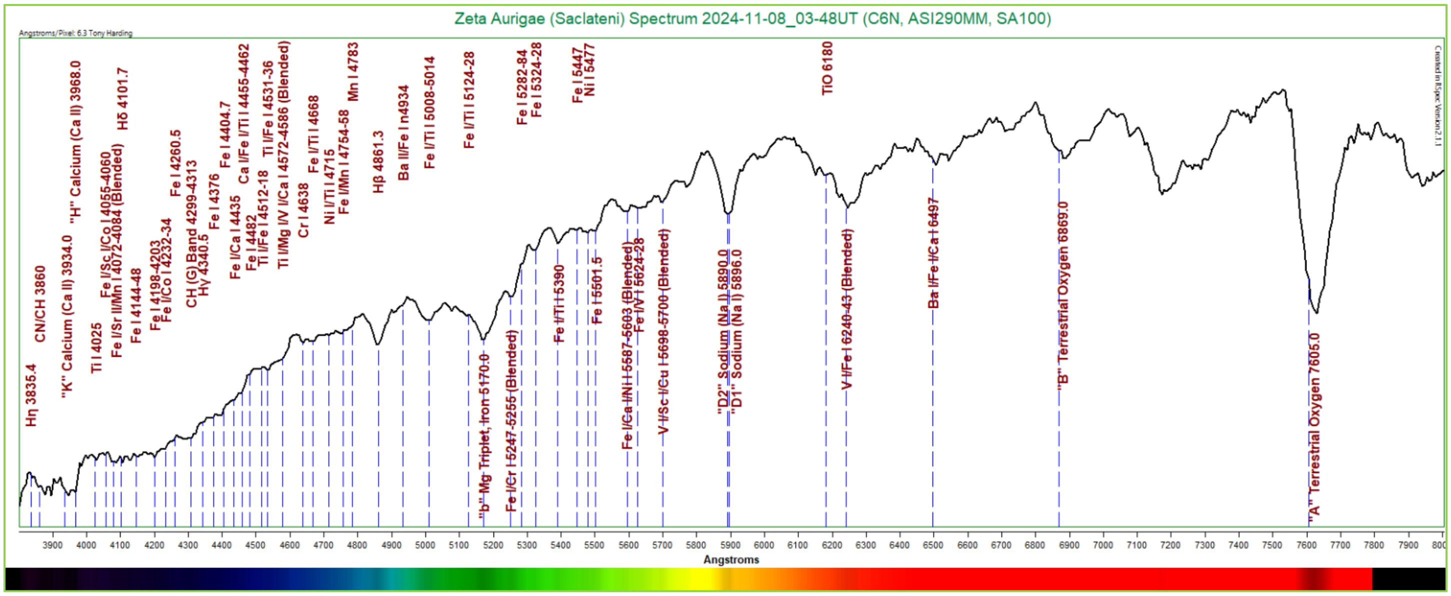

Figure 3: Zeta Aurigae (Saclateni) Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 318ms, Gain 184, 20% of 951 frames stacked, Integration Time 60s

This target presented a challenge when processing (specifically in getting a usable calibration). We can see several of the hydrogen Balmer lines are visible, most notably the Hβ absorption. The ionized calcium K and H lines at 3934 and 3968 Angstroms are relatively small, but still easily identifiable. The molecular absorptions at 3860 (CN/CH) and 4299-4313 (CH) appear weak here. The magnesium triplet is extremely strong and sharp. The sodium D2 and D1 lines are also very deep and easily identified here. A single molecular TiO line can be seen at 6180 Angstroms. Fainter metals noted include titanium, iron, calcium, chromium, nickel, manganese, barium, and vanadium.

Using Wien's Law, we will calculate an effective temperature. Examining the curve above and visually tracing a continuum curve leads to the conclusion that the peak wavelength lies between the peaks at 6977 and 7529 Angstroms. Taking the median value, we get a peak at approximately 7164 Angstroms. With this value we calculate a temperature of 4045K. The listed temperature for the primary star is 3960K[2]. Considering the uncertainties involved, our estimate is not too bad.

θ Aurigae

Theta Aurigae, also known by the name Mahasim, is another binary system, whose primary component is classified as a very early A-type star[1,2]. (The secondary is much dimmer, and should not contribute anything to our low-resolution results.) Based on the primary's type, we can expect a curve representative of a hot star showing obvious hydrogen Balmer absorptions. A smattering of very weak metals may also be visible.

The processed spectrum can be found here:

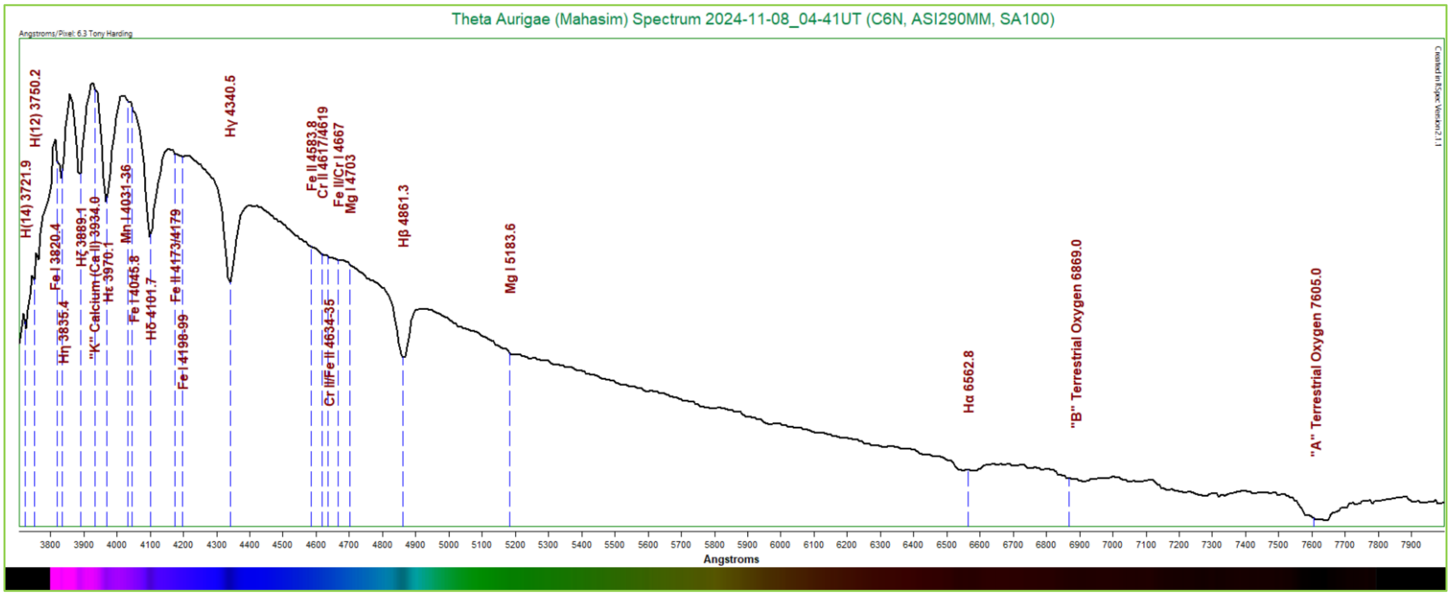

Figure 4: Theta Aurigae (Mahasim) Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 336, Gain 107, 40% of 901 frames stacked, Integration Time 121s

The hydrogen Balmer lines are quite evident here. We can see the ionized calcium K line beginning to emerge, as well, on the lower flank of the Hε absorption. Though the entirety of the magnesium triplet is absent, one component at 5183.6 Angstroms is weakly present. The sodium doublet is not visible here. Several weak or very weak metals are indicated, including manganese, neutral and ionized iron, chromium, and magnesium.

An effective temperature estimate will be calculated using Wien's Law. However, since this is an early-type star we must expect our estimate to fall far short of the mark. The flux curve seems to show the peak energy wavelength lies at 3927 Angstroms. With this value, we calculate a temperature of 7379K. The listed temperature for the star is 10200K[2].

ι Aurigae

Iota Aurigae, also known as Hassaleh, is classified as an early K-type star[1]. Based on this, we can expect a flux curve representative of a cooler star, with lots of metals present.

The processed spectrum is found here:

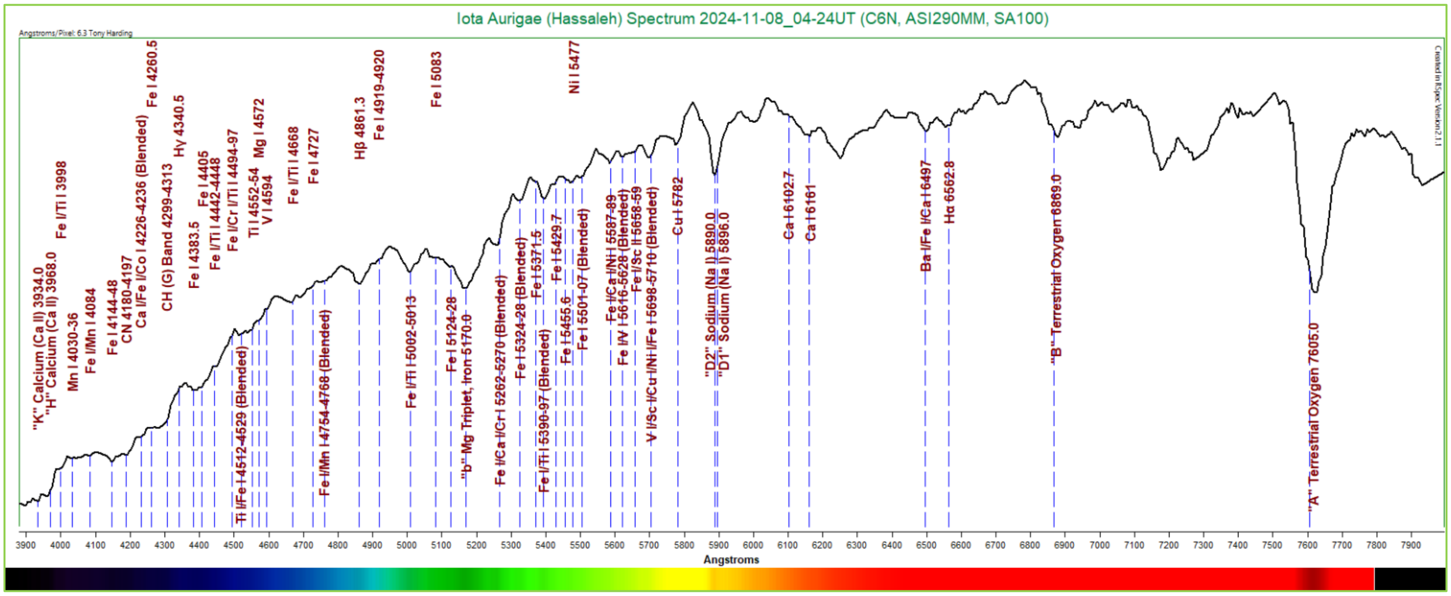

Figure 5: Iota Auriga (Hassaleh) Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 267ms, Gain 119, 25% of 909 frames stacked, Integration Time 60s

The curve above is definitely consistent with a cooler star. We also note a lot of blended lines in our low-resolution result. The hydrogen Balmer lines are not terribly strong here. The ionized calcium doublet at 3934-3968 Angstroms is very weak. We do see some molecular absorptions—at 4180-4197 Angstroms (CN) and the Fraunhofer G Band at 4299-4313 (CH). The magnesium triplet at 5170 Angstroms is sharp and profound here, as is the sodium doublet at 5890-96 Angstroms. Other labeled metals include iron, manganese, titanium, magnesium, vanadium, nickel, copper, calcium, and barium.

Utilizing Wien's Law, we will calculate an effective temperature for the star. From the flux curve above, the peak energy wavelength appears to lie near 6784 Angstroms. With this value, we arrive at a temperature of approximately 4272K. The professionally determined temperature is listed as 4059K[2]. Our estimate is off by slightly more than 5%.

ε Aurigae

While capturing data for Zeta Auriage, two nearby bright stars were evident. Epsilon Aurigae, the first of the two and commonly called by the name Almaaz, is an eclipsing binary system whose primary is classified as either a very late A-type or very early F-type star[1,2]. The secondary star is extremely dim by comparison, and should therefore not contribute any detectable features to our low-resolution results. The star should show significant hydrogen Balmer lines, but also exhibit a fair number of metals spread throughout as well.

The processed spectrum is below:

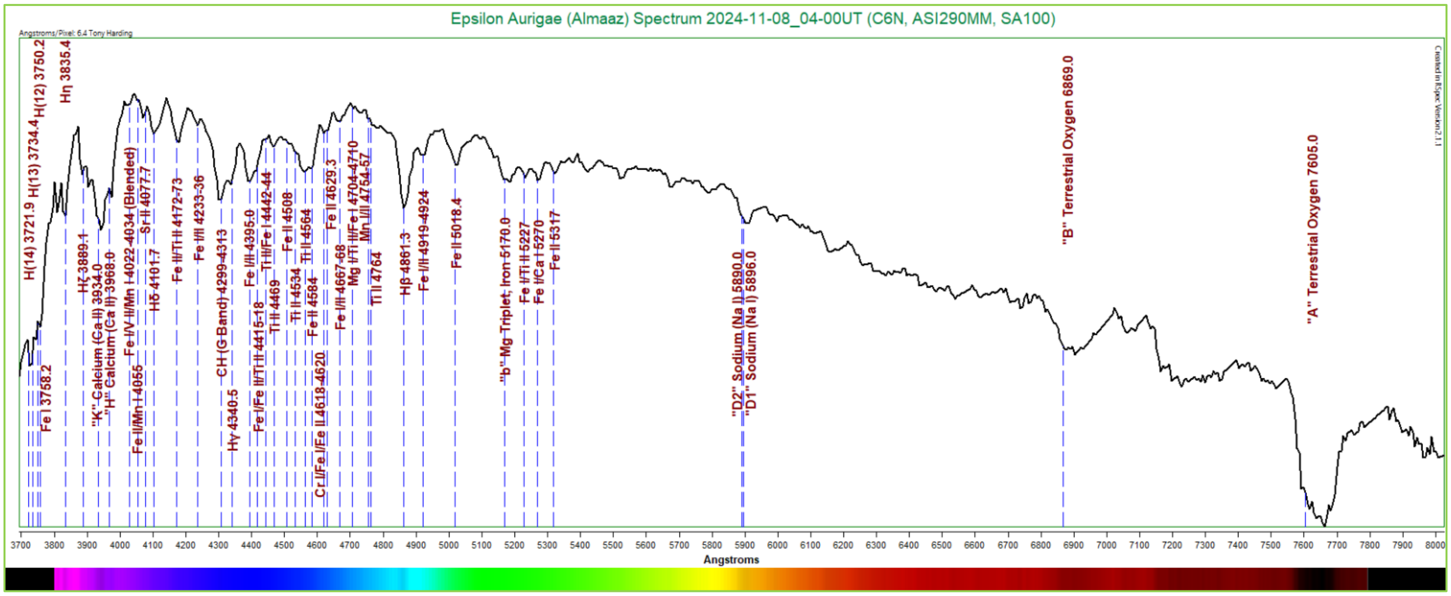

Figure 6: Epsilon Aurigae (Almaaz) Spectrum (6.4 Angstroms/pixel)
Capture Details 6: Exposure 398, Gain 125, 30% of 911 frames stacked, Integration Time 108s

The flux curve generated for this specimen is showing considerable noise, but many of the major features can still be made out. Several of the hydrogen Balmer lines are visible, though the Hα absorption is lost in the continuum noise. The ionized calcium lines at 3934 and 3968 Angstroms appear quite strongly, carving a deep cut out of the continuum. The molecular CH absorption at 4299-4313 is also fairly prominent. The magnesium triplet at 5170 Angstroms is clear, along with a couple iron absorptions just above it. The sodium D2 and D1 lines are also easy to identify. Other labeled metals include iron, strontium, titanium, chromium, magnesium, and manganese.

We will employ Wien's Law to calculate an effective temperature. From the curve above, the peak wavelength appears to lie at 4044 Angstroms. (Note, however, that the line blanketing occurring above that mark makes this determination uncertain.) With this value, we calculate an effective temperature of 7166K. The listed temperature for the star is 7750K[2]. Our estimate is not horrible, but it is still off the mark by more than 7% of the target value.

η Aurigae

Eta Aurigae, also known as Haedus, is the second star noted while capturing data for Zeta Aurigae earlier. It is classified as an early B-type star[1], indicating that we should see a fairly smooth spectrum with moderate hydrogen Balmer lines present. Some helium should also be identifiable.

The finished spectrum is presented here:

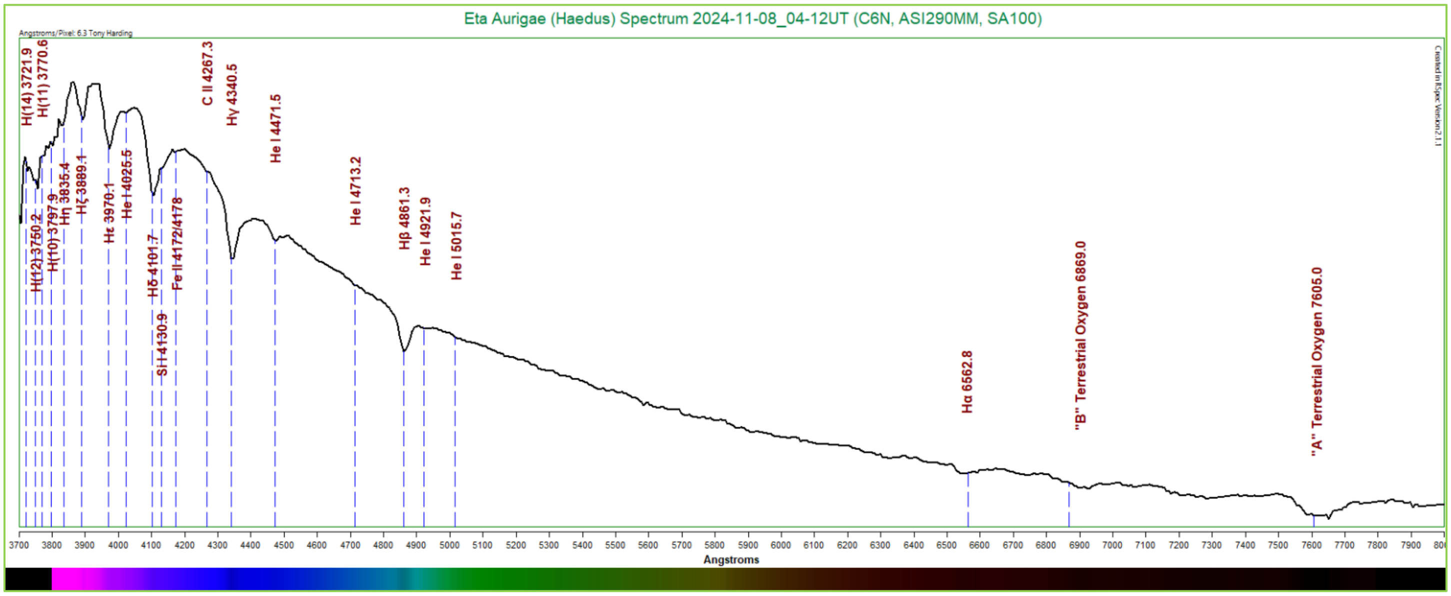

Figure 7: Eta Aurigae (Haedus) Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 314, Gain 131, 30% of 967 frames stacked, Integration Time 91s

The hydrogen Balmer lines here appear moderately strong, as expected. We can also note several neutral helium lines—at 4025.5, 4471.5, 4713.2, 4921.9, and 5015.7 Angstroms. However, some of these are extremely weak and barely discernible from the noise of the continuum. A couple additional metals are marked: neutral silicon at 4130.9 Angstroms, ionized iron at 4172/4178 Angstroms, and ionized carbon at 4267.3 Angstroms.

Using Wien's Law, we will calculate an effective temperature based on our visual-range flux curve. However, these very hot stars emit most of their radiation in the ultraviolet range, which will throw off our estimate. The apparent peak energy wavelength on our spectrum above lies at 3866 Angstroms. With this value, we calculate an effective temperature of 7496K. The professionally determined temperature for the star is listed as 18660K[2]. Indeed, our estimate falls woefully short, as expected.

Conclusion

This was another constellation that was missed the previous year due to extended bad weather. A couple of the stars proved a bit difficult to analyze, particularly with regard to getting a decent wavelength calibration. Even so, the results were acceptable.

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