Spectral Analysis of the Constellation Stars of Equuleus (The Little Horse)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Equuleus. 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 obtained on the evening of August 19, 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 length, 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.

α Equulei

Alpha Equulei, commonly named Kitalpha, is a very close binary star. The two components are classified as middle G-type for the primary, and either very late B-type[1] or early A-type[2] for the secondary. We could see some interesting features on this one.

The processed spectrum is as follows:

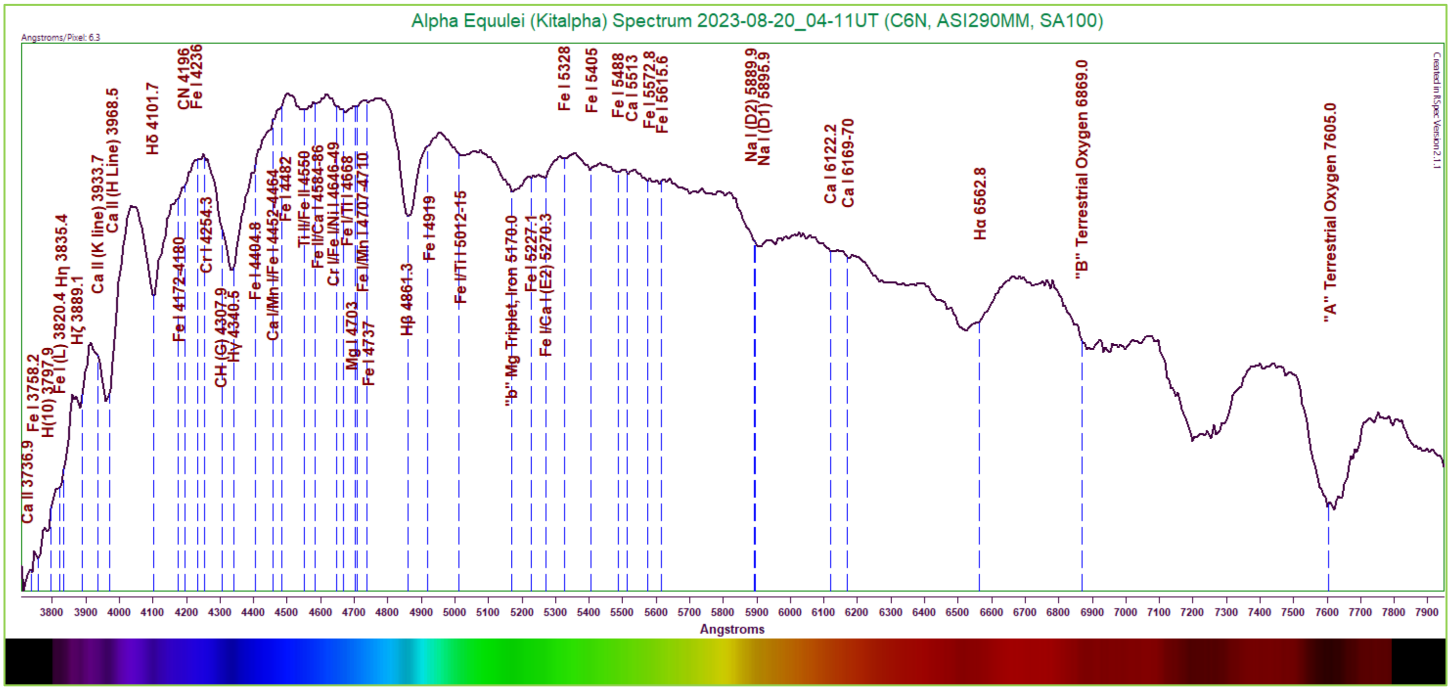

Figure 1: Alpha Equulei (Kitalpha) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 1s, Gain 157, 85% of 125 frames stacked

Indeed, this spectrum shows a healthy assortment of different absorptions! The hydrogen Balmer lines are pretty well-represented throughout. The lower wavelength range is positively crowded with faint absorptions—calcium, iron, and hydrogen. The calcium H and K lines are obvious, causing a moderately deep cut in the continuum. The CH (G) band shows up very weakly as a slight bump just below the Hγ line. Iron at 4404.8 Angstroms is an extremely small absorption, as is the calcium/manganese/iron line above it and the iron line above that. The next few lines are a bit more pronounced, indicating titanium, iron, and/or chromiuim. The magnesium triplet at 5170 Angstroms is a moderate absorption here, appearing broadened by the iron lines above it. The sodium doublet at 5890-96 Angstroms cuts a deeper groove in the continuum. The Hα line even appears deep. This one turned out to have some very interesting properties.

Using Wien's Law, we will attempt to ascertain a very rough estimate of the stars' effective temperature. Of course, our estimate will be for a combination of both stars. Using an estimated peak energy wavelength of 4502 Angstroms, the resultant temperature is 6437K. The two stars' accepted temperatures are 5100K for the primary (G-type) and 8150K for the secondary (B-type)[2]. Our estimate actually falls between the accepted values, so I would tend to regard this as a reasonably good guess!

β Equulei

Beta Equulei is classified as an early A-type star. We should be able to see the typical hydrogen Balmer series lines, as well as an energy peak in the shorter wavelength range.

The processed spectrum is presented here:

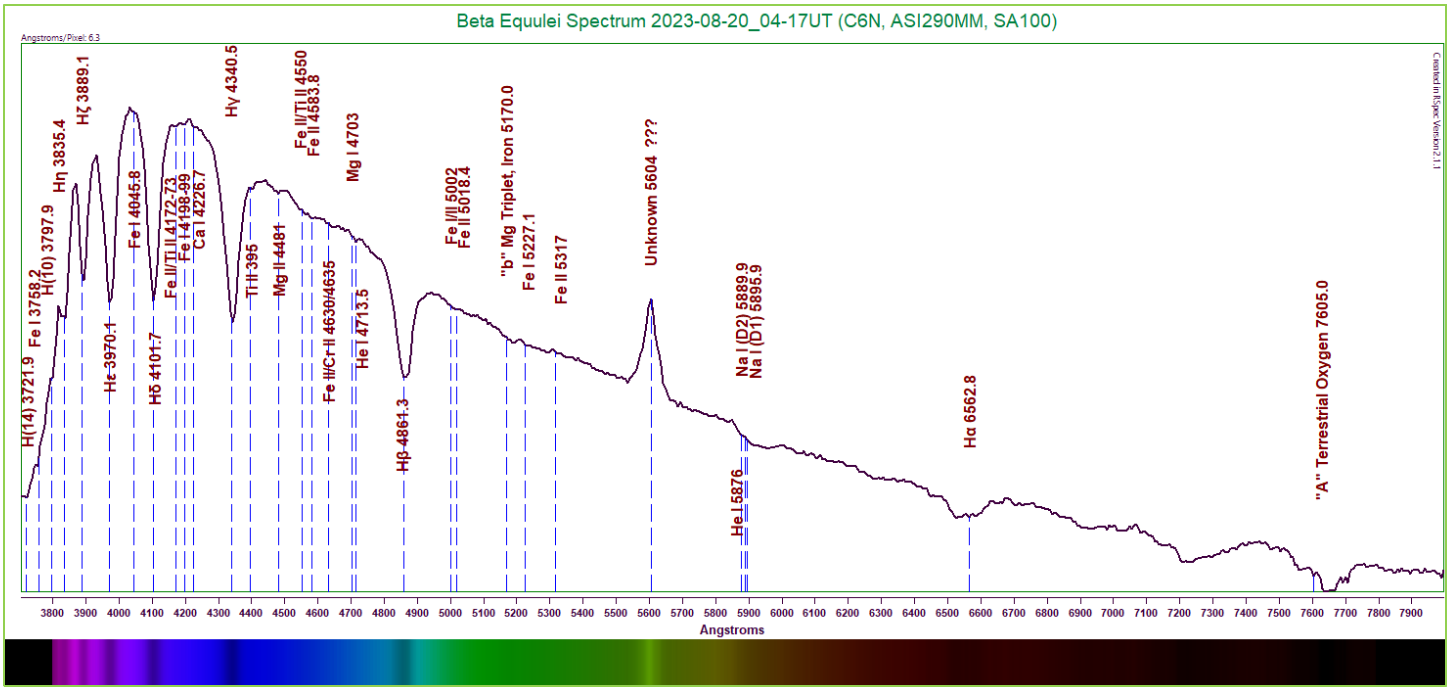

Figure 2: Beta Equulei Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 2s, Gain 166, 85% of 67 frames stackes

The typical features of A-type stars are represented here in the deep hydrogen Balmer lines. A single, weak iron line is poised at 3758.2 Angstroms, surrounded by hydrogen Balmer features. The Hη line appears unusually sharp here. Between the Hε and Hδ lines, a single neutral iron line can be seen at 4045.8 Angstroms. Between the Hδ and Hγ lines are three very subtle lines—two iron lines and a calcium line. The titanium absorption at 4395 Angstroms and the magnesium line at 4481 Angstroms are notable here, as well. The magnesium triplet is at 5170 Angstroms is detectable, along with the typical iron line above it at 5227.1 Angstroms. The sodium doublet is much more pronounced, and shows a slight bump due to helium just below it. With this one we have another anomaly—the spike at approximately 5604 Angstroms. As before, this is probably a dim field star that was accidentally captured with the spectrum.

With Wien’s Law, we will again attempt to ascertain an estimate of the effective temperature. However, since this is an early-type star, we should accept that the estimate will be woefully low. Using a peak energy wavelength of 4033 Angstroms, the estimated temperature is 7185K. The accepted temperature of this star is 9000K[2]. As expected, our estimate is indeed too low.

γ Equulei

Gamma Equulei is a close double star that exhibits some peculiar traits. It is both a double and a variable, and is classified as a very late A-type star[1]. We should expect to see a star in a sort of boundary between A-types and F-types.

The processed spectrum is as follows:

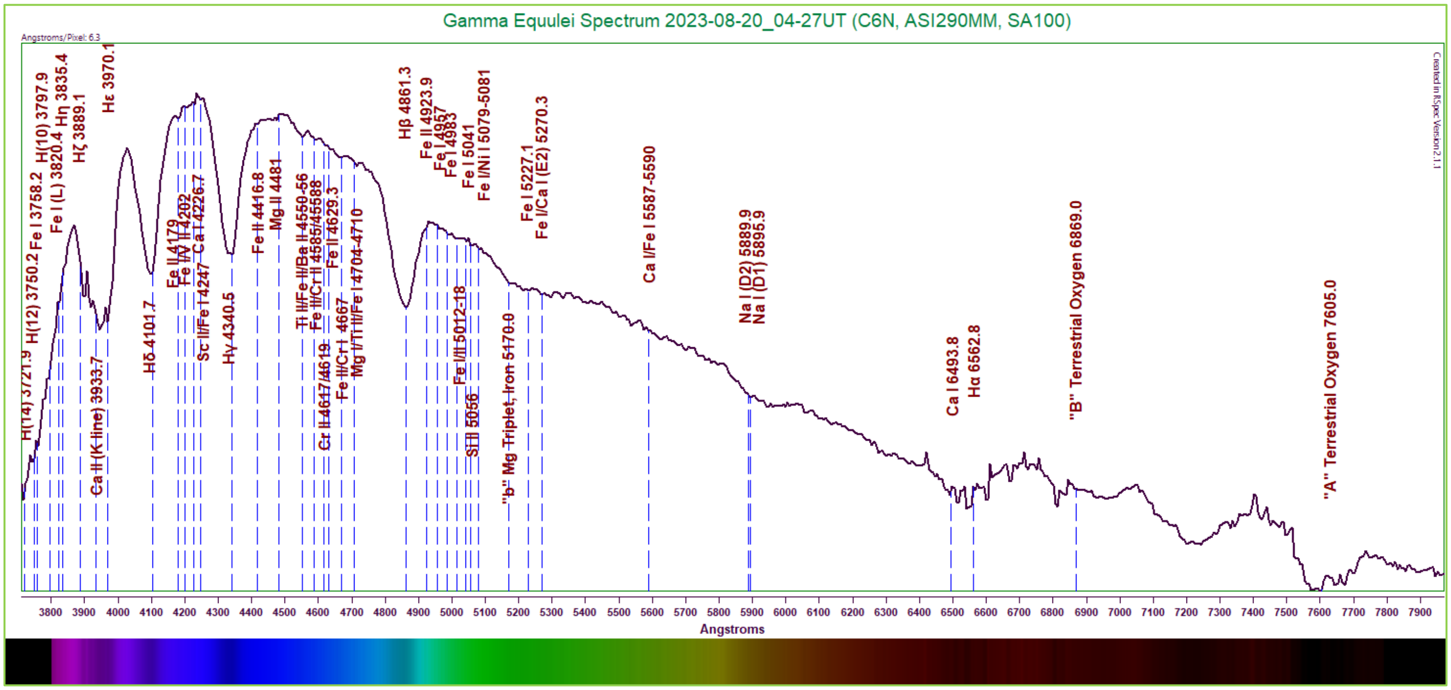

Figure 3: Gamma Equulei Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 2s, Gain 134, 40% of 117 frames stacked

We can clearly see some strong hydrogen Balmer absorptions. The calcium H line appears profoundly, sitting alongside the Hε line. Again, we see multiple tiny absorptions between the Hδ and Hγ lines, this time showing iron, calcium, and scandium. The magnesium triplet at 5170 Angstroms appears muted but present, causing a broad, shallow dip in the spectrum along with the two adjacent iron lines above. The sodium doublet at 5890-96 Angstroms is more pronounced, but about equally as broad. A calcium line at 6493.8 Angstroms is found alongside the Hα line, but the excessive noise in the area makes this identification uncertain. Many other very faint lines are marked along the continuum, including iron, magnesium, titanium, chromium, and silicon.

Using Wien's Law and an estimated peak energy wavelength of approximately 4233 Angstroms, we arrive at an effective temperature estimate of 6846K. The established temperature for the star is 7550K[2].

δ Equulei

There seems to be some disagreement regarding this double star and the exact characteristics of the two components. However, the secondary appears to be far enough removed from the primary to not introduce any problems into analyzing its spectrum. The star is generally regarded as late F-type[1].

The spectrum for the star appears below:

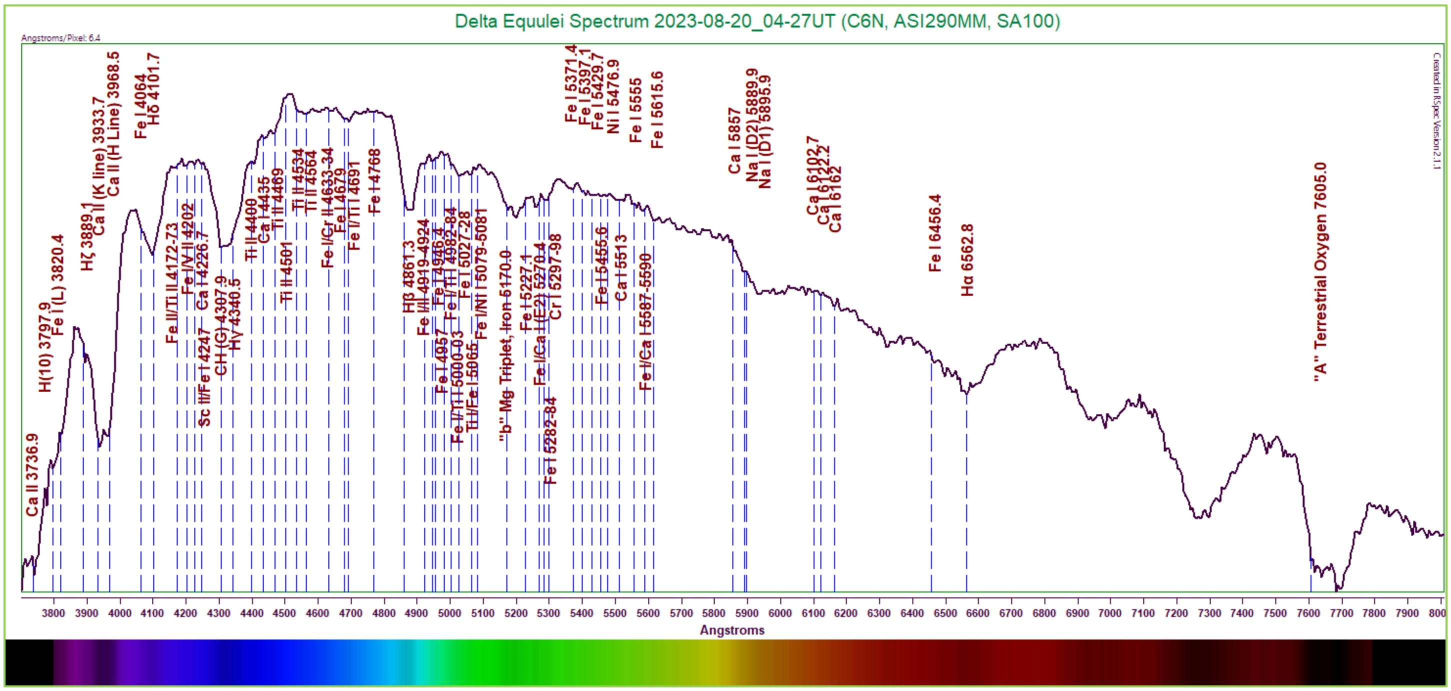

Figure 4: Delta Equulei Spectrum (6.4 Angstroms/pixel)
Capture Details 4: Exposure 2s, Gain 137, 30% of 117 frames stacked

This star's spectrum does not fail to fascinate. The dimness of the star made the resulting spectrum rather noisy, and this spectrum presented some challenges in getting a reasonable calibration, not to mention trying to identify absorptions. But many lines can be easily identified. Starting at the lowest wavelength range, the calcium line at 3736.9 Angstroms is visible. The Fe I (L) line above it is small, but carves a distinct cut out of the continuum. The Hζ line is very muted, but still identifiable. The calcium H and K line doublet-cut is nothing short of impressive! The Hδ line is quite sharp and prominent here. We find four distinct, small absorptions above the Hδ line—iron/titanium, iron/vanadium, calcium, and scandium. The next feature is really cool; the CH (G) band and the Hγ line (at 4307.9 and 4340.6 Angstromns, respectively) are of roughly equal strength, and are carving a deep ravine out of the continuum. Above this impressive gap, we can note a large number of titanium lines, with iron and calcium mixed in. Hβ is notable, and appears flattened at its trough. The magnesium triplet, along with two smaller iron lines above it, carve out a fairly deep gouge in the continuum. The sodium doublet is perhaps slightly stronger, with a faint calcium line visible just below it at 5857 Angstroms. The Hα absorption also seems to be a bit stronger than expected. This one provides many very interesting results.

Again employing Wien's Law, we will attempt to ascertain an approximate effective temperature for the star. Using an estimated peak energy wavelength of 4511 Angstroms, we obtain a temperature of 6424K. The accepted temperature of the star is 6200K[2]. The estimate is closer than expected!

6 Equulei

While capturing footage of γ Equulei, my eye was continually drawn to this apparently very blue star nearby. This impressed me, since I am not particularly good at perceiving color visually in the eyepiece. I couldn't pass up the opportunity to add it to the list.

6 Equulei is classified as an early A-type star[1]. This means we should be able to see the strong hydrogen Balmer lines typical of this type.

The processed spectrum follows:

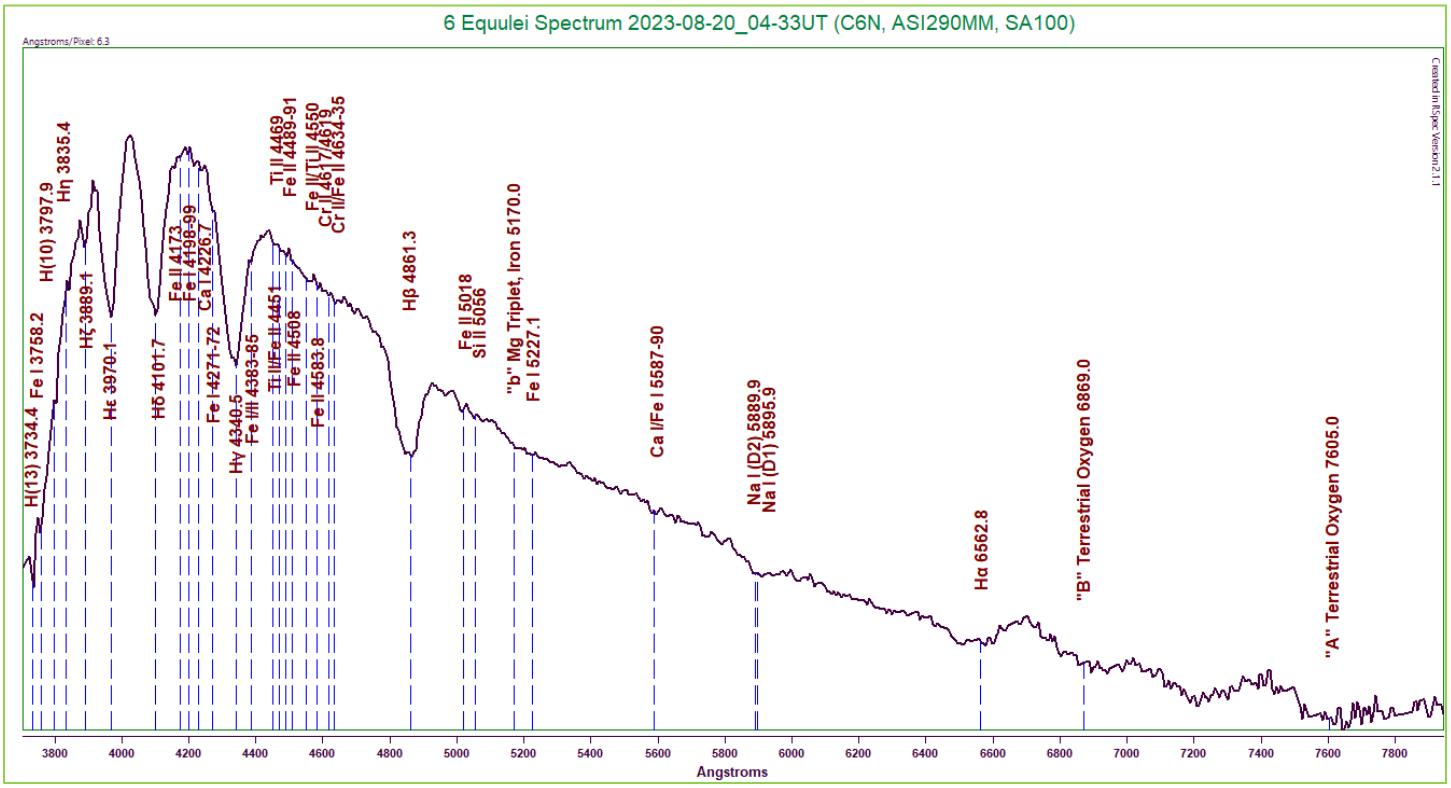

Figure 5: 6 Equulei Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 3s, Gain 149, 40% of 60 frames stacked

There really aren't any surprises here. The classic early A-type spectrum curve is present, with strong hydrogen Balmer lines. We do see the iron line at 3758.2 Angstroms is small, but distinct. The Fe I (L) and Hη lines appear separate and clear. We can see a number of emergent metals spread throughout the spectrum, including iron, calcium, titanium, chromium, and silicon. Most of these are very faint, and therefore subject to scrutiny. The magnesium triplet at 5170 Angstroms is beginning to emerge, while the sodium doublet at 5890-96 Angstroms is quite a bit stronger.

Using an estimated peak energy wavelength of 4026 Angstroms, Wien's Law allows us to obtain a very rough estimate of the effective temperature. The result is 7198K. The temperature of this star is not known with customary accuracy, but it lies at approximately 9078K[2]. As we should have anticipated, our temperature estimate for this early-type star was low.

Conclusion

These spectra were captured during the same evening as those for Delphinus. The only unanticipated result was the odd spike in the spectrum for Beta Equulei. Otherwise, the results seem to have turned out fairly well, especially considering the low apparent magnitude of the stars involved.

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