Spectral Analysis of the Constellation Stars of Libra (The Scales)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Libra. 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 generally 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 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. An additional resource was used in identifying infrared features in M-type stars: the SAO/NASA ADS database. Specifically, the paper entitled *The Infrared Spectral Classification of M-Type Stars* by Stewart Sharpless (U.S. Naval Observatory, 1956).

Data Processing Details

All of the spectra obtained for this analysis were obtained on the evening of May 30, 2024 (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 lengths, 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-2 Librae

Alpha Librae is actually a double star whose components are separated by a good enough distance to be resolved by our instrument. The brighter of the two is Alpha-2 Librae, which we will examine here since it is the star which anchors the constellation lines. (Data was collected for the other component as well, and will be examined at the end of this report.)

Alpha-2 Librae, known by the tongue-twisting name Zubenelgenubi II, is a spectroscopic binary star of the early A-type[1,2]. We can expect a curve representative of the type, with very strong hydrogen Balmer absorptions and an apparent peak toward the lower part of the wavelength range.

The processed spectrum is as follows:

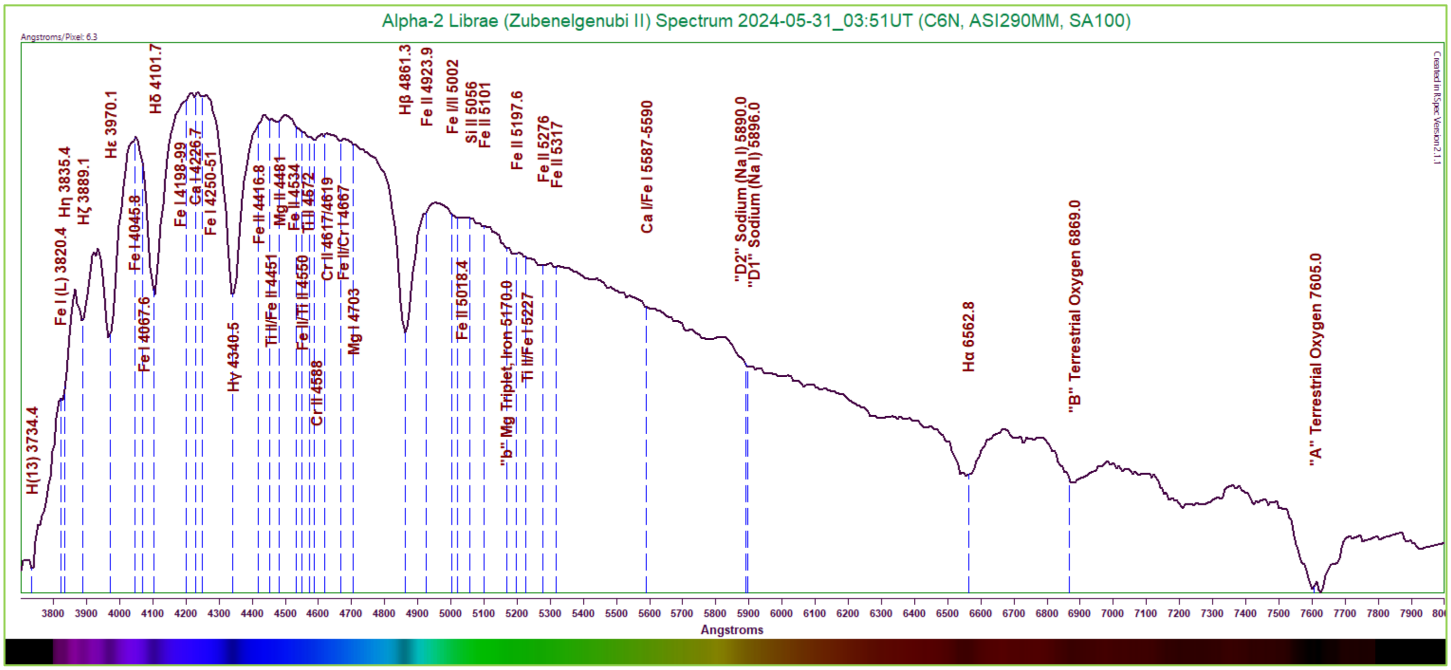

Figure 1: Alpha Librae (Zubenelgenubi II) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 325ms, Gain 160, 35% of 938 frames stacked, Integration Time 106s

The spectrum displayed above is very detailed for a star of this type. The general shape of the curve shows an A-type star, with very strong hydrogen Balmer lines as expected. Even the Hη line—here combining with the Fraunhofer L neutral iron line to produce a small plateau in the curve—appears strong. The common calcium line at 4226.7 Angstroms is clear, though small. Magnesium II at 4481 Angstroms, another common line, is also quite clear. The magnesium triplet at 5170 Angstroms, along with its attendant iron lines, is producing a notable dip in the continuum. The sodium doublet (D2 and D1 lines) at 5890-96 Angstroms is also producing a strong dip. A number of additional metal lines are noted, including neutral and ionized iron, titanium, several chromium absorptions, magnesium, silicon, and calcium.

Using Wien's Law, we will calculate an approximate effective temperature for the star. We must bear in mind, however, that since this is an early A-type star, our estimate is certain to be too low. From a visual inspection of the curve, it appears that the peak energy wavelength lies at approximately 4238 Angstroms. Using this value, we arrive at a temperature estimate of approximately 6838K. The professionally determined temperature is actually 8128K[2]. Indeed, Wien's Law returns a value that is much too low.

β Librae

Beta Librae, known by the name Zubeneschamali, is a late B-type star[1,2]. Given this, the star should show fairly strong hydrogen Balmer lines, with perhaps a neutral helium line or two faintly displayed. The spectral energy curve should a peak nearer the low wavelength range indicative of its high temperature.

The spectrum is presented below:

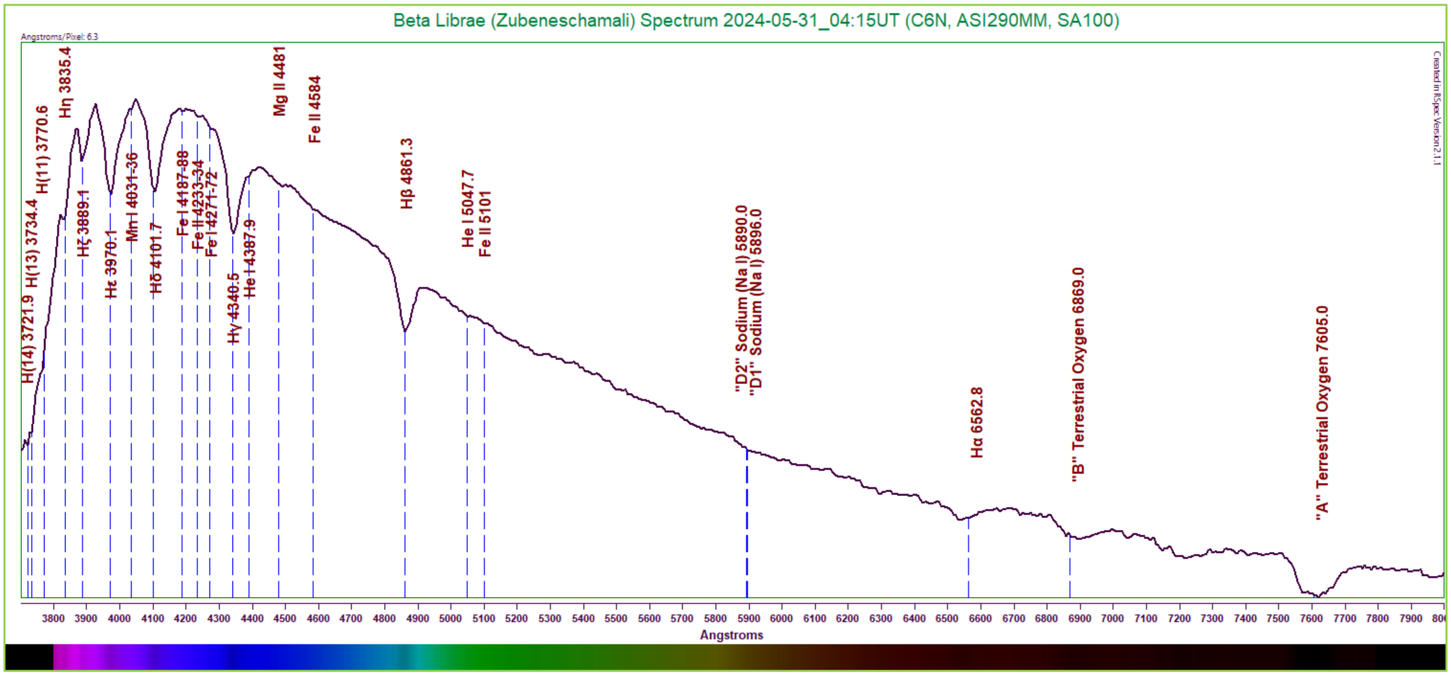

Figure 2: Beta Librae (Zubeneschamali) Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 307, Gain 134, 20% of 1183 frames stacked, Integration Time 72s

The resulting spectrum appears quite smooth. The hydrogen Balmer lines are evident, but not as strong as in Alpha-2 Librae above. We can see two neutral helium lines labeled, at 4387.9 and 5047.7 Angstroms. Both of these are very weak. The common ionized magnesium line at 4481 Angstroms is notable here, producing and small but definite scoop out of the continuum. The sodium doublet at 5890-96 Angstroms is quite subtle, but present. This probably indicates an interstellar source. A number of additional weak to very weak metals are indicated, including manganese, and both neutral and ionized iron.

Using Wien's Law, we will calculate an effective temperature for the star. Since this is an earlier-type star, our estimate will fall far short of the actual value, but we will proceed with the demonstration to confirm this. A quick visual evaluation of the curve seems to indicate that the peak energy output lies somewhere between the wings of the Hε absorption. Averaging the values of the flanking peaks, we get a value of 3989 Angstroms. Plugging this value into Wien's Law returns an effective temperature estimate of 7265K. The star's listed temperature is 12300K[2]. Our estimate falls very short, as expected.

γ Librae

Gamma Librae, known by the name Zubenelhakrabi, is a late G-type star[1]. The star is a suspected very close double star, which our equipment is certainly unable to separate[2]. Assuming this classification is correct, we can expect to see a star a little cooler than our own Sun, with copious numbers of metal lines spread throughout.

The finished spectrum can be found below:

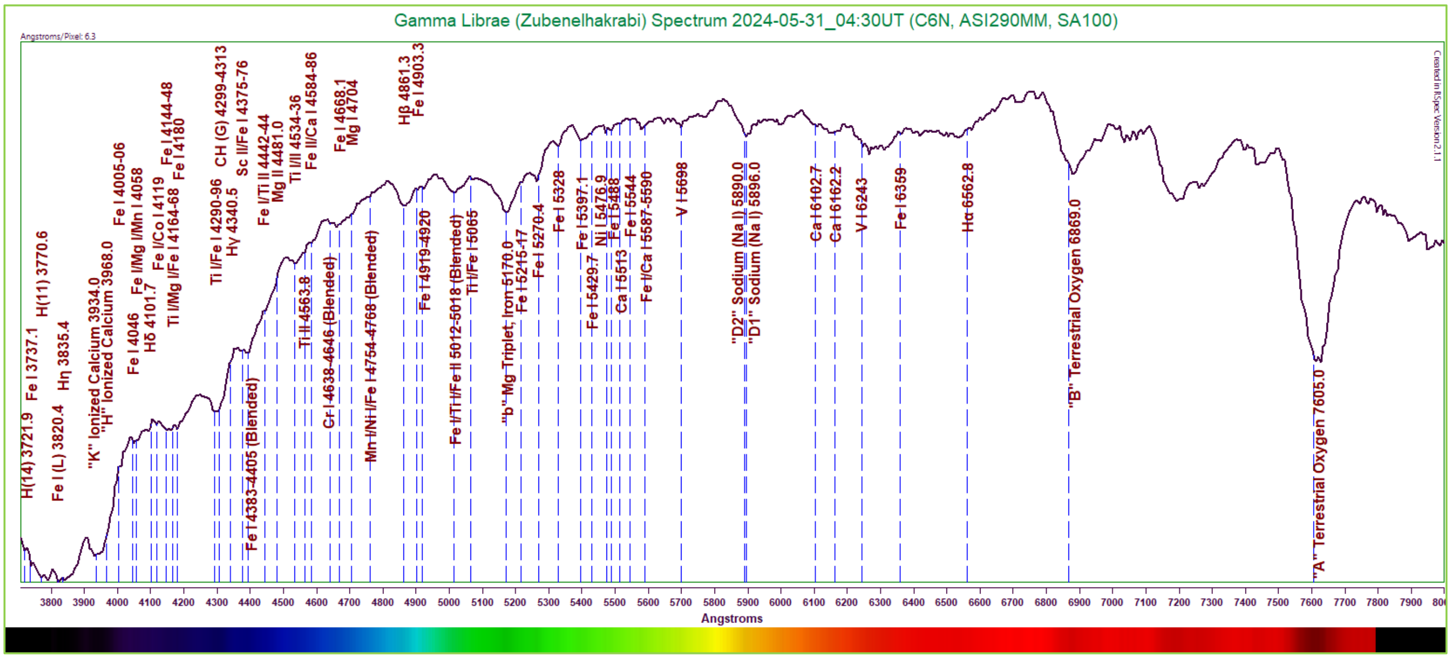

Figure 3: Gamma Librae (Zubenelhakrabi) Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 771ms, Gain 196, 20% of 502 frames stacked, Integration Time 77s

This curve looks definitely distinct from the last two. Several of the hydrogen Balmer lines are marked, but they range in strength from moderately weak to very weak. Note that the Hα line is marked, but it is a somewhat dubious identification due to the noise in the area. Near the low wavelength region, we can see the calcium K and H lines at 3934 and 3968 Angstroms respectfully. Together they cause a significant chunk to be taken out of the continuum. Another nice gouge can be seen in the 4119-4180 Angstroms range, this one primarily caused by iron and titanium lines. The CH (G) band is clear at 4299-4313 Angstroms, along with the titanium line just below it at 4290-96 Angstroms. An iron/titanium blend of significant size is also present at 5012-18 Angstroms. The magnesium triplet at 5170 Angstroms is deep and sharp. The sodium D lines are also clear, though not quite as strong. A good number of additional faint metals are marked, including iron, scandium, magnesium, titanium, chromium, manganese, nickel, calcium, and even some vanadium.

Using Wien's Law, we will calculate an estimated effective temperature for the star. The peak energy wavelength in this case is not easy to visually estimate, but it appears to lie between the continuum peaks at 5825 and 6758 Angstroms. Using the midpoint of 6292 Angstroms, Wien's Law returns an estimated temperature of approximately 4606K. The listed temperature for the star is 4826K[2]. Considering the great uncertainty in determining the peak of the energy distribution curve, our estimate, though a bit too low, is not terribly bad.

θ Librae

Theta Librae is classified as a very late G-type star[1]. We should expect to see a star somewhat similar to Gamma Librae above, with lots of metal lines on a curve representing a star slightly cooler. The calcium K and H lines, the magnesium triplet, and the sodium doublet should be approximately as strong as in the previous specimen.

The finished spectrum is found here:

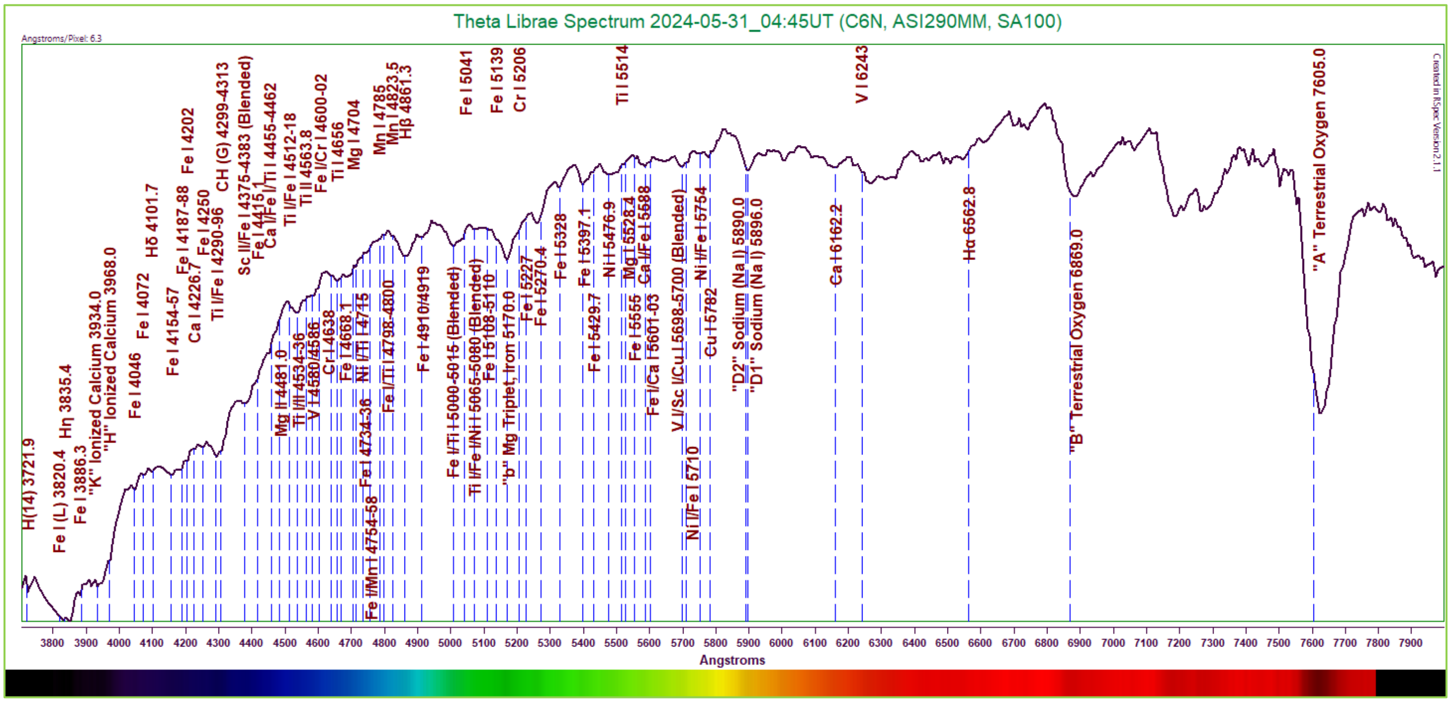

Figure 4: Theta Librae Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 891ms, Gain 181, 50% of 410 frames stacked, Integration Time 182s

Indeed, this spectral curve does resemble that obtained for Gamma Librae, but this one appears more detailed. The hydrogen Balmer lines are again considerably weak. The Hα line is marked, but the noise in the continuum in that area is high, making the identification dubious. The calcium K and H lines at 3934 and 3968 Angstroms are carving a deep gouge out of the continuum. Titanium and the CH (G) band also cut a sharp dip at 4290-4313 Angstroms. The magnesium triplet at 5170 Angstroms is sharply represented, along with its typical flanking iron lines. The sodium doublet at 5890-96 Angstroms is very clear as well. A great amount of fainter metal absorptions are marked, including iron, calcium, titanium, scandium, magnesium, vanadium, nickel, manganese, chromium, and copper. Be cautious when tracing the marked absorptions, as these tend to be packed very closely together!

Employing Wien's Law, we will attempt an effective temperature estimate. Visually examining the curve above, the peak wavelength is admittedly difficult to detertmine. An imaginary curve would seem to peak in the region below the lower wing of the Fraunhofer B line for atmospheric oxygen. At a rough guess, this appears to lie at approximately 6419 Angstroms. Using this value, we calculate a temperature of 4514K. The listed temperature for the star is 4739K[2]. Again, considering the uncertainties employed here, the estimate is not terribly far off. (Of course, a proper continuum curve could be actually plotted to possibly refine the estimate.)

σ Librae

Sigma Librae, also known as Brachium, is a pulsating variable classified as an early M-type star[1]. We should therefore expect to see some classic M-type characteristics, including a flux curve peaking near the high end of the wavelength region and the presence of numerous TiO bands.

The finished spectrum is presented here:

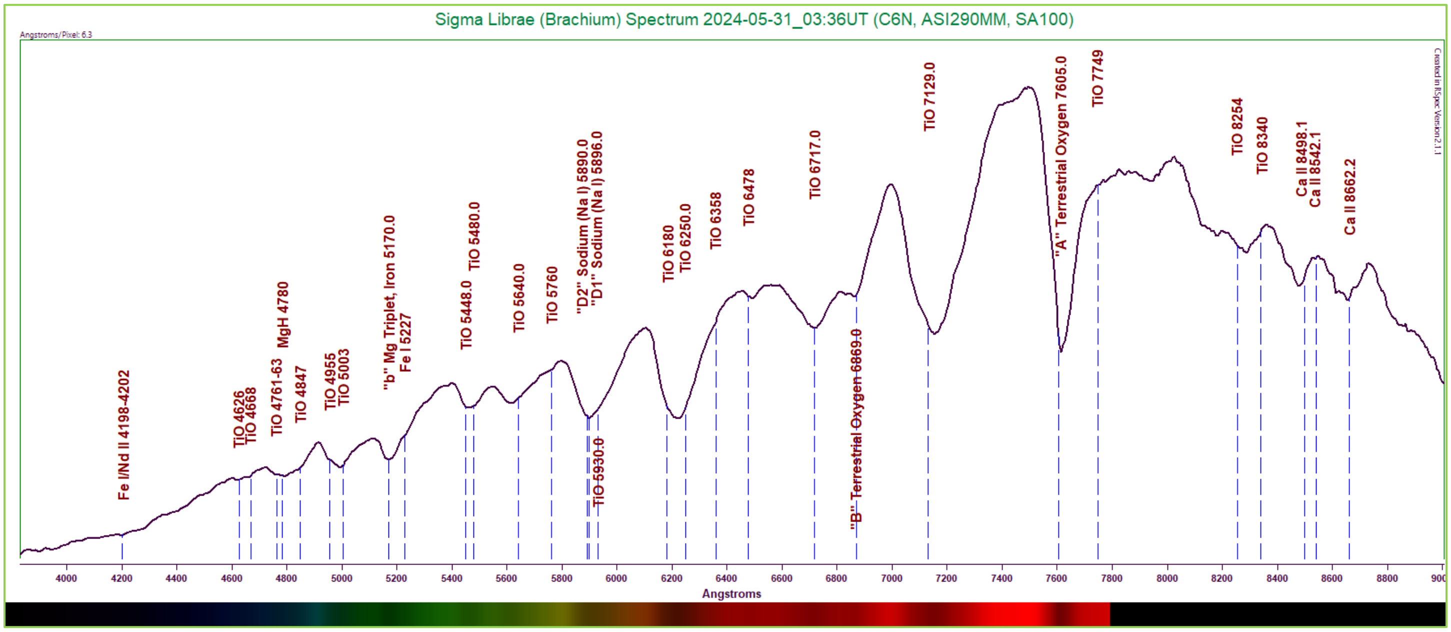

Figure 5: Sigma Librae (Brachium) Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 496ms, Gain 202, 50% of 747 frames stacked, Integration Time 185s

Ah, here we see a fairly representative M-type spectrum. Note that the wavelength range has been altered here, showing from 3800 to 9000 Angstroms. We can easily identify the magnesium triplet at 5170 Angstroms. There is even one of its attendant iron lines present at 5227 Angstroms, which is very weak but surprising nonetheless. The sodium doublet appears very strong at 5890-96 Angstroms, aided by the TiO line at 5930 Angstroms. We can see numerous TiO lines throughout the spectrum. Near the low end of the spectrum, a tiny absorption from neutral iron/ionized neodymium is seen. Near the extreme upper end, the infrared ionized calcium triplet is also visible.

Using Wien's Law, we will calculate a temperature estimate for the star. Using a visually estimated peak energy wavelength of 7496 Angstroms, we arrive at an effective temperature of 3866K. The listed temperature for the star is 3596K[2]. Our estimate is a bit too high in this case.

α-1 Librae

Alpha-1 Librae is the secondary component of the double star system including Alpha-2 Librae. Called Zubenelgenubi I, it is an early F-type star[1]. We should expect to see easily identifiable hydrogen Balmer lines, with numerous weak metals as well.

The spectrum is found below:

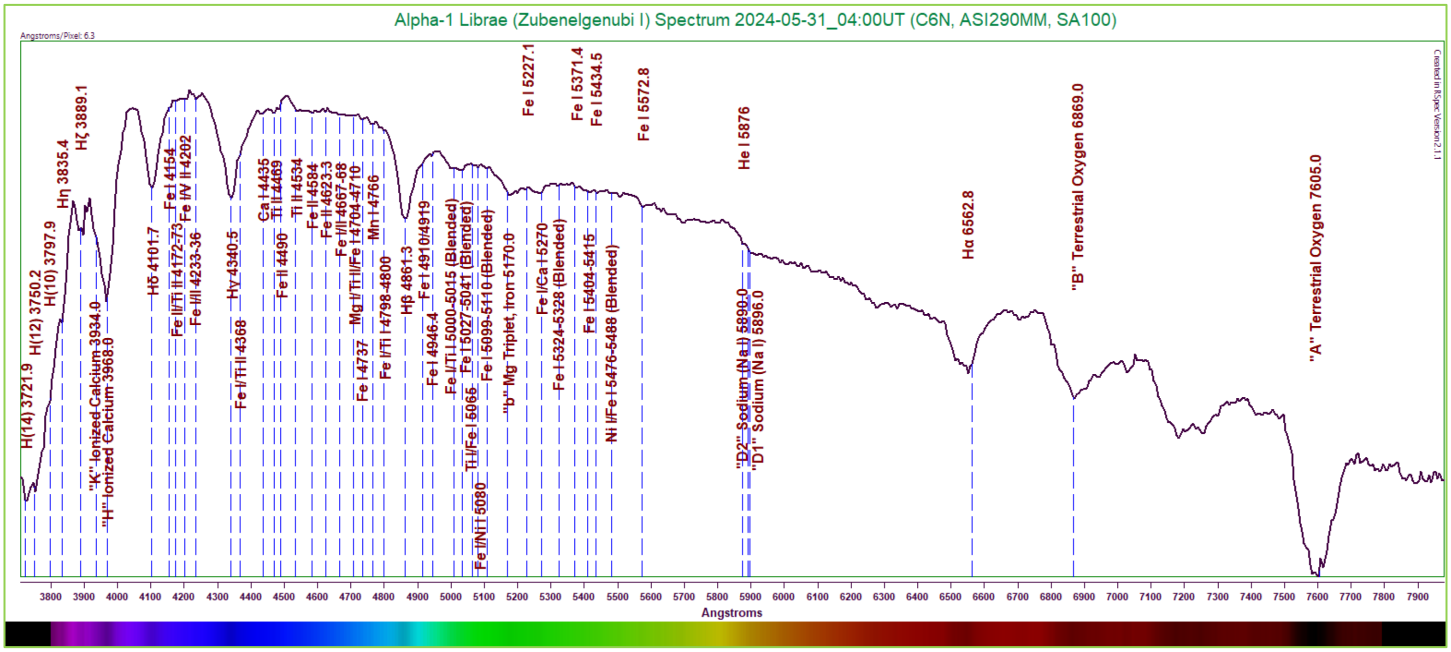

Figure 6: Alpha-1 Librae (Zubenelgenubi I) Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 2s, Gain 193, 65% of 176 frames stacked, Integration Time 228s

The general shape of this curve supports the expected stellar type. Most of the hydrogen Balmer lines are visible, with the exception of the Hε line which is overtaken by the calcium H line at 3968 Angstroms. The calcium K line at 3934 Angstroms is extremely weak, only causing a subtle bend in the lower wings of the calcium H line. One part of the spectrum appears to be saturated with very faint absorptions—between 4534 and 4710 Angstroms. The spectral curve is flattened in this region, apparently due to a small forest of lines running together—iron and titanium mostly. Very interesting. Another item is the combination of two iron blends between 5000 and 5041 Angstroms. Together, the blends are causing a notable dip. The magnesium triplet at 5170 Angstroms is notable for its sharpness if not its depth. The sodium doublet at 5890-96 Angstroms is fairly strong, and appears to be attended by the neutral helium line just below it at 5876 Angstroms—a feature that can be difficult to discern. Numerous additional very faint metals are indicated, including iron, calcium, titanium, magnesium, manganese, and nickel.

Wien's Law will again be used to establish an estimated effective temperature, which we will then compare to the currently accepted value. Looking at the curve, the peak would appear to lie between the wings of the Hγ absorption. If we use the wavelength of this absorption (4340 Angstroms), we calculate a temperature of 6677K. The established temperature for the star is 6653K[2]. Our temperature estimate is uncommonly close to the actual value!

Conclusion

No surprises were encountered in the acquisition and processing of the spectra. The analysis of Sigma Librae has served to show an improvement in my ability to recognize features in M-type stars. This is a welcome change.

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
[5]: SAO/NASA ADS Database, *The Infrared Spectral Classification of M-Type Stars* by Stewart Sharpless (U.S. Naval Observatory, 1956)