Spectral Analysis of the Constellation Stars of Corona Borealis (The Northern Crown)

Anthony S. Harding Jr.
2024-06-17

Abstract

This paper will elucidate the spectral features of the main stars in the constellation Corona Borealis. 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). Finally, due to an invalid listing on Wikipedia for one of the stars, the website www.universeguide.com was consulted.

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.

This constellation was one of the first that I attempted to gather data for last year when trying in vain to get the color camera to work. By the time I had ascertained the cause of my errors and obtained a new camera, this target area was no longer viable. I felt some satisfaction in reacquiring the data and processing it.

<u>α Coronae Borealis</u>

Alpha Coronae Borealis, known commonly as Alphecca, is an eclipsing binary star whose primary (which is more than 74x more luminous then its secondary) is classified as either a very early or early A-type star[1,2]. Sources seem to disagree on the details. Since the secondary is so comparatively dim, we should not expect it to contribute anything to our low-resolution spectrum. We should see a fairly typical A-type curve, with very strong hydrogen Balmer lines.

The processed spectrum is as follows:

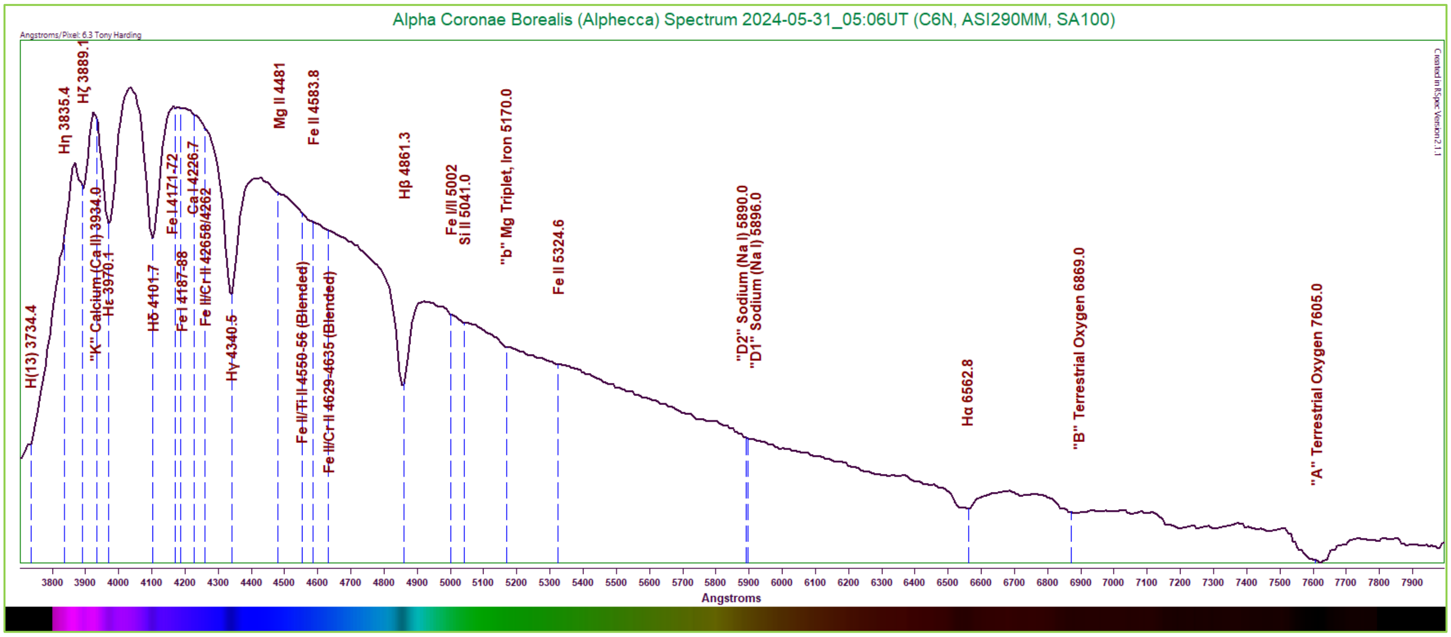

Figure 1: Alpha Coronae Borealis (Alphecca) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 347ms, Gain 110, 40% of 707 frames stacked, Integration Time 98s

The results for this star clearly indicate an A-type star. The hydrogen Balmer lines are very strong and clear. The calcium K line at 3934 Angstroms is just beginning to manifest, causing a slight bump on the extreme lower wings of the Hε absorption. The magnesium triplet is very weak, causing only a small divot in the continuum line. The sodium doublet is extraordinarily weak, and may be interstellar in nature. Several other extremely faint metals are indicated, including iron, calcium, magnesium, and silicon. These should all be regarded dubiously due their incredibly low strength.

We will employ Wien's Law to calculate an effective temperature for the star. However, considering the type of star involved, we must certainly anticipate that the result will come in far under the actual value. Accepting a peak energy wavelength of 4038 Angstroms, Wien's Law returns a result of 7176K. The listed temperature is 9700K[2]. Indeed, our estimate is much too low.

β Coronae Borealis

Beta Coronae Borealis, also called Nusakan, is an extremely close double star whose primary star is an early F-type[1]. The primary is much more luminous than the secondary, so our spectrum should only reflect the properties of the primary. Considering the type, we should expect to see fairly strong hydrogen Balmer absorptions, along with a number of accompanying metals. The star is considered chemically peculiar, and though such features are not often visible in low-resolution spectra, we should keep an eye out for unusual characteristics.

The processed spectrum is presented here:

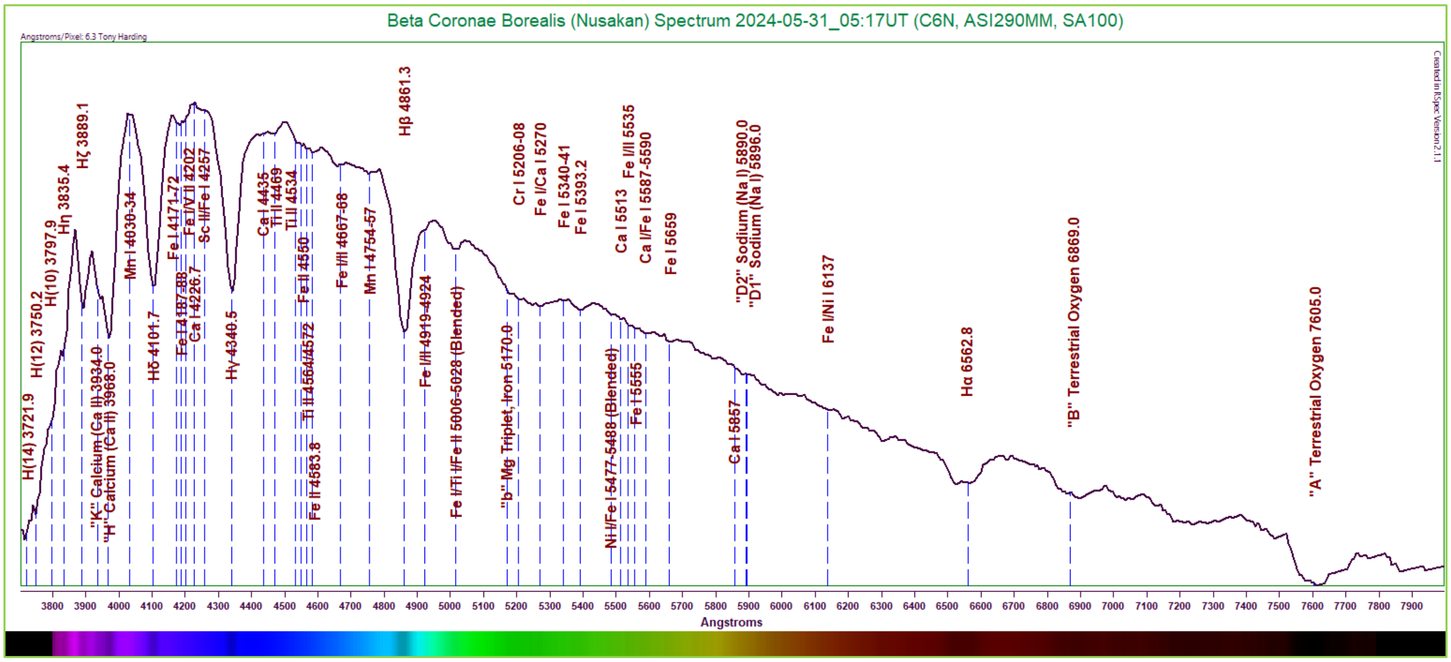

Figure 2: Beta Coronae Borealis (Nusakan) Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 430ms, Gain 166, 60% of 567 frames stacked, Integration Time 195s

We can see some strong hydrogen Balmer lines here—except the Hε line, which has been overpowered by the calcium II H line at 3968 Angstroms. The accompanying calcium II K line is distinctly visible here as well, though it is not nearly as strong. A combined dip occurs at 4534-4583 Angstroms due to titanium and iron. A blended iron/titanium line at 5006-5028 is also quite prominent. The magnesium triplet appears a bit odd; a chromium absorption at 5206-08 Angstroms sits beside it along with the more common iron line at 5270 Angstroms. The effect is an uncommonly broad and deep gouge out of the continuum. The sodium doublet at 5890-96 Angstroms appears much smaller, but is identifiable. A number of additional very faint metals are present, including manganese, iron, calcium, scandium, titanium, and nickel.

Using Wien's Law, we will calculate an effective temperature for the star, then compare this to the professionally derived value. Visually estimating the location of the peak wavelength seems to indicate that it lies between the peaks at 4027 and 4229 Angstroms. Taking the midpoint between these two gives us 4128 Angstroms. Using this value in our calculation, we receive an estimated temperature of 7020K. The accepted value for the temperature of the star is 7980K[2]. Our estimate is too low.

γ Coronae Borealis

Gamma Coronae Borealis is a very close binary system. The individual components are much too close to be separated by our equipment. They are a very late B-type star and an early A-type star[2]. However, the combined result is regarded as a very early A-type star[1]. We can expect to see primarily strong hydrogen Balmer absorptions here.

The finished spectrum is found below:

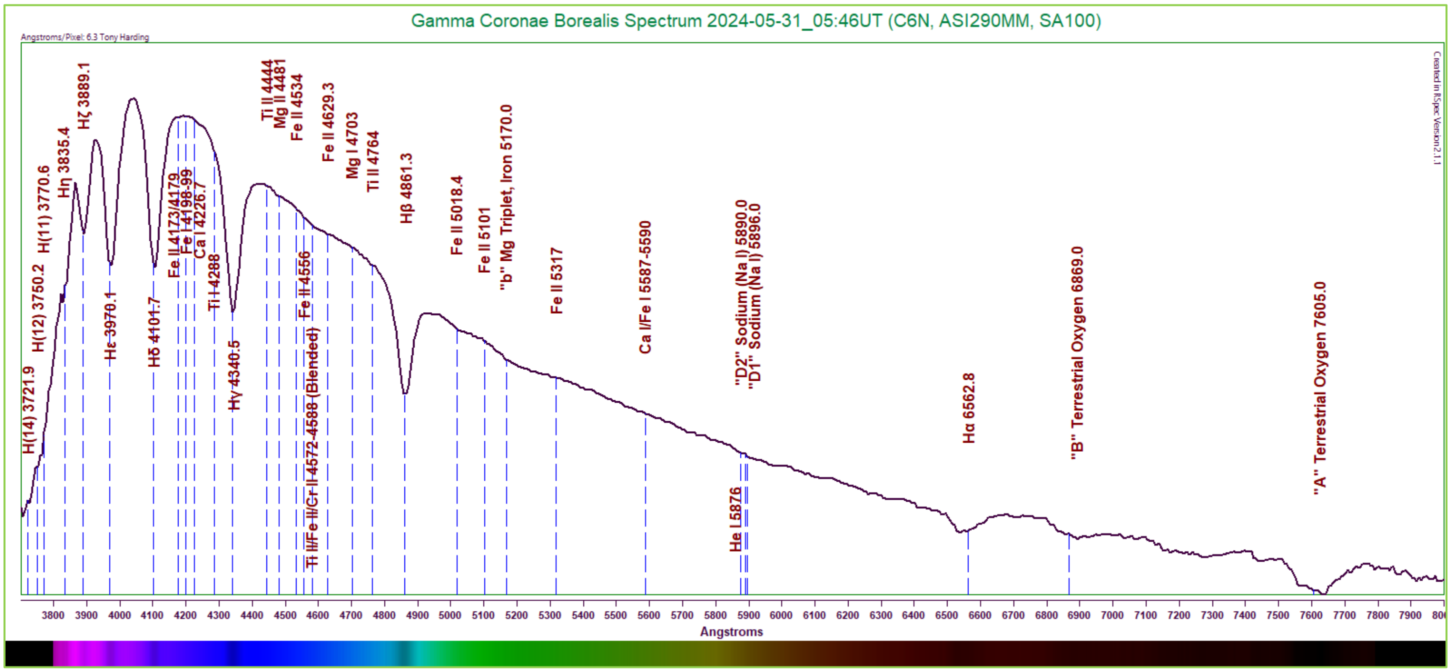

Figure 3: Gamma Coronae Borealis Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 390ms, Gain 199, 65% of 778 frames, Integration Time 197s

This spectrum seems to match the expected very early A-type in shape and data content. The hydrogen Balmer absorptions are very strong and sharply defined. A broad blended absorption at 4572-4588 Angstroms is betrayed by a subtle but broad scoop in the continuum due to titanium, iron, and chromium. The magnesium triplet at 5170 Angstroms is also visible as a subtle dip in the continuum. The sodium doublet at 5890-96 Angstroms is also visible, though quite weak. The neutral helium line at 5876 Angstroms can even be discerned. A number of additional very faint metals are indicated, including neutral and ionized iron, calcium, titanium, and magnesium. A calcium/iron line is marked at 5587-5590 Angstroms, but this must be regarded as a dubious identification due to its extremely low strength.

Wien's Law will again be used to obtain an effective temperature estimate. But, since this pair of stars falls among the earlier types, our estimate is certain to be too low. A quick look at the curve shows a peak energy wavelength of 4038 Angstroms. Using this value, we calculate a temperature of 7176K. The temperature listed for the star in our usual source is 7649K[2], but this value is much too low and must be in error. An alternate source reports a temperature of 9551K[6], which is much closer to the expected temperature. Using this latter value as a basis for comparison, we can indeed see that our estimate is too low.

δ Coronae Borealis

Delta Coronae Borealis is a variable star that fluctuates in brightness by only a small amount. No companion star is known, which would make it an intrinsic variable. The star is classified as a middle G-type star[1]. From this, we can expect to see a star just slightly cooler than our own Sun, replete with metal lines spread throughout its spectrum.

The processed spectrum can be found here:

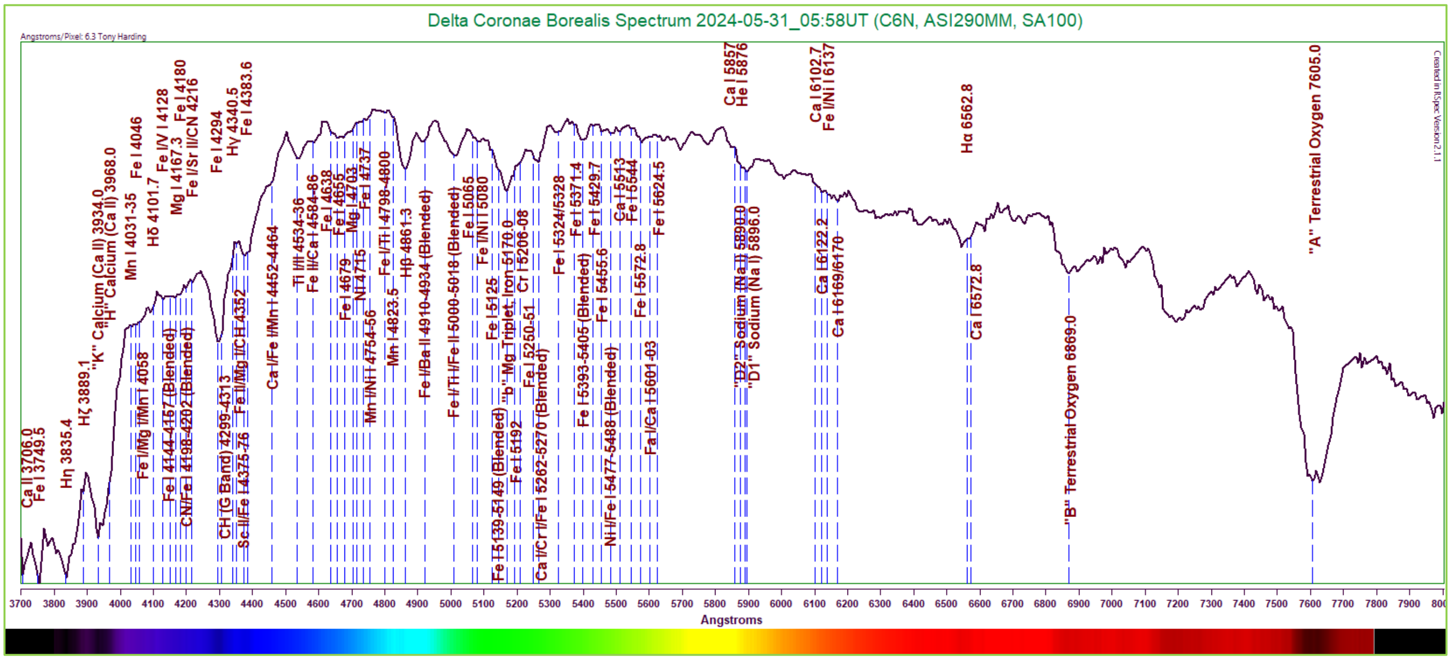

Figure 4: Delta Coronae Borealis Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 637ms, Gain 196, 71% of 403 frames stacked, Integration Time 115s

A typical curve of the expected type is presented above. Most of the hydrogen Balmer lines are present, but they range from only moderate in strength to very weak. The Hε line is missing, having been consumed by the much stronger calcium II H line. The two calcium II lines near the lower wavelength range (H and K; 3968 and 3934 Angstroms) are carving out an impressively cut deep into the continuum. A nice scoop is visible at 4031-4058 Angstroms, caused by manganese, iron, and magnesium. A small but notable plateau occurs at 4144-4157 due to a blend of iron lines. The CH (G) band at 4299-4313 Angstroms is also quite impressive. The magnesium triplet at 5170 Angstroms is very strong, both in depth and sharpness. It is attended by a bevy of iron and chromium absorptions. The sodium D2 and D1 lines are easily identified. Two lines just below it—from helium and calcium, are caught as well. (These are often difficult to catch in low-resolution spectra, especially in a star of this type.) A large number of faint metal absorptions are present, including calcium, iron, magnesium, CN, scandium, titanium, nickel, and manganese. Since many of these lines are tightly packed together, take great care when tracing the labels.

We will employ Wien's Law to estimate the star's temperature. Looking at the curve, we see no clearly defined peak. Estimating the path of the continuum would seem to suggest that the peak lies somewhere between 4764 and 5823 Angstroms. This is a large range, and the margin for error is high, but if we take the average of these two points we arrive at an estimated peak wavelength of 5294 Angstroms. Plugging this value into Wien's Law, we calculate a temperature of 5474K. The actual temperature of the star is listed as 5180K[2]. Considering the large uncertainty in our peak energy wavelength estimate, our result is not too far off.

ε Coronae Borealis

Epsilon Coronae Borealis is a very close double star whose primary is classified as an early K-type star[1,2]. The two cannot be separated with the equipment used. The primary star greatly outshines the secondary, so for the purposes of our low-resolution analysis it should pose no problems. We should expect to see a cooler star showing lots of metals in its spectrum.

The processed spectrum is below:

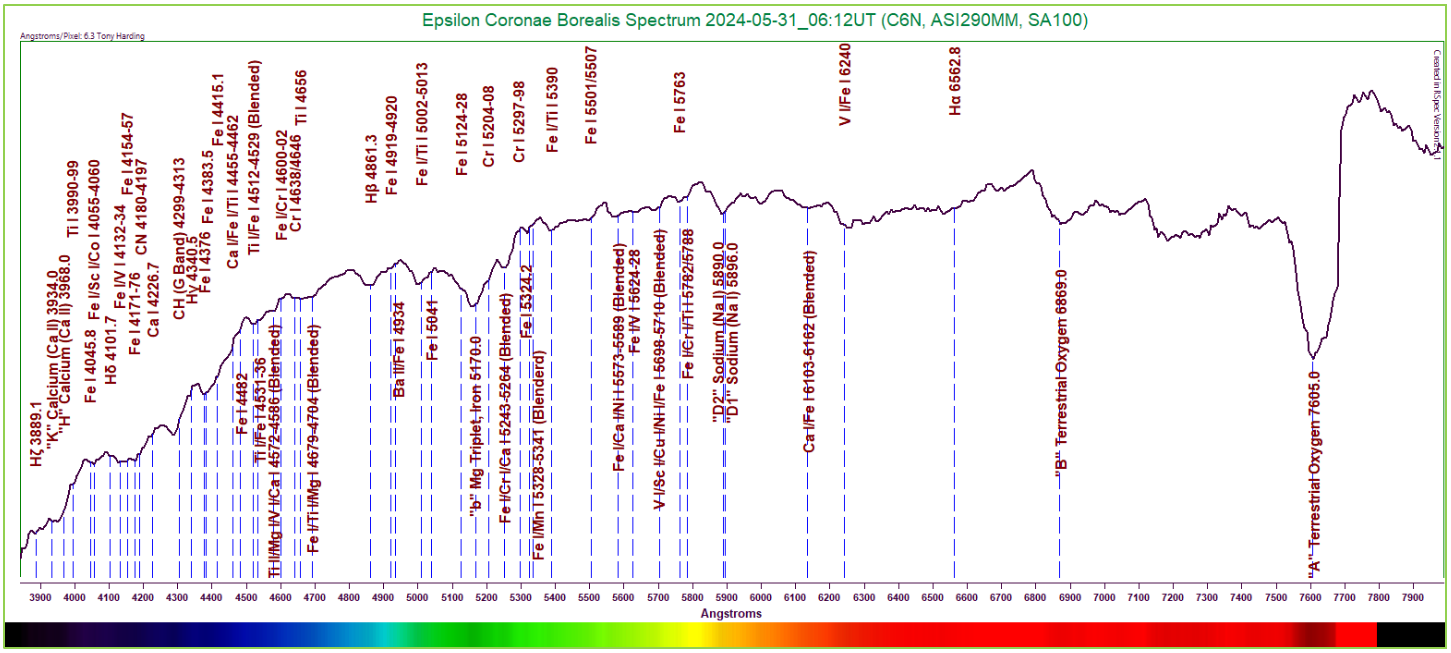

Figure 5: Epsilon Coronae Borealis Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 546ms, Gain 192, 50% of 705 frames stacked, Integration Time 192s

The spectral curve definitely reflects a cooler star. The hydrogen Balmer lines that are visible appear weak here at best. The calcium II K and H lines at 3934 and 3968 Angstroms are also weakened. The CH (G) band at 4299-4313 Angstroms is still fairly clear, though it also appears somewhat weakened. The magnesium triplet at 5170 Angstroms is very strong, while the sodium doublet at 5890-96 Angstroms appears weaker, but still very distinct. This spectrum shows a greater number of blended lines than expected. The most profound one is the calcium/iron blend at 6103-6162 Angstroms, a truly immense range for the scoop out of the continuum. Additional metal lines are labeled, including titanium, iron, CN, calcium, chromium, barium, and vanadium.

Employing Wien's Law, we will calculate an effective temperature estimate for the star. However, this particular spectrum shows a very large anomaly at the high wavelength region, where the continuum jumps up unexpectedly. If we omit this region when considering the location of the peak energy wavelength, then the peak appears to be at 6790 Angstroms. Using this visual estimation, we calculate a temperature of 4268K. The listed temperature for the star is 4365K[2]. Our estimate is thus less than 100K removed from the actual value. Not bad.

θ Coronae Borealis

Theta Coronae Borealis is another very close double star which our equipment is not able to resolve. The primary is considered a middle B-type star[1,2], while the dimmer secondary is considered an early A-type[2]. Our low-resolution spectrum will be a combination of the two, but the primary is expected to dominate most of the spectral features. Based on this, we can expect moderately strong hydrogen Balmer lines, with perhaps some neutral helium absorptions visible as well.

The processed spectrum follows:

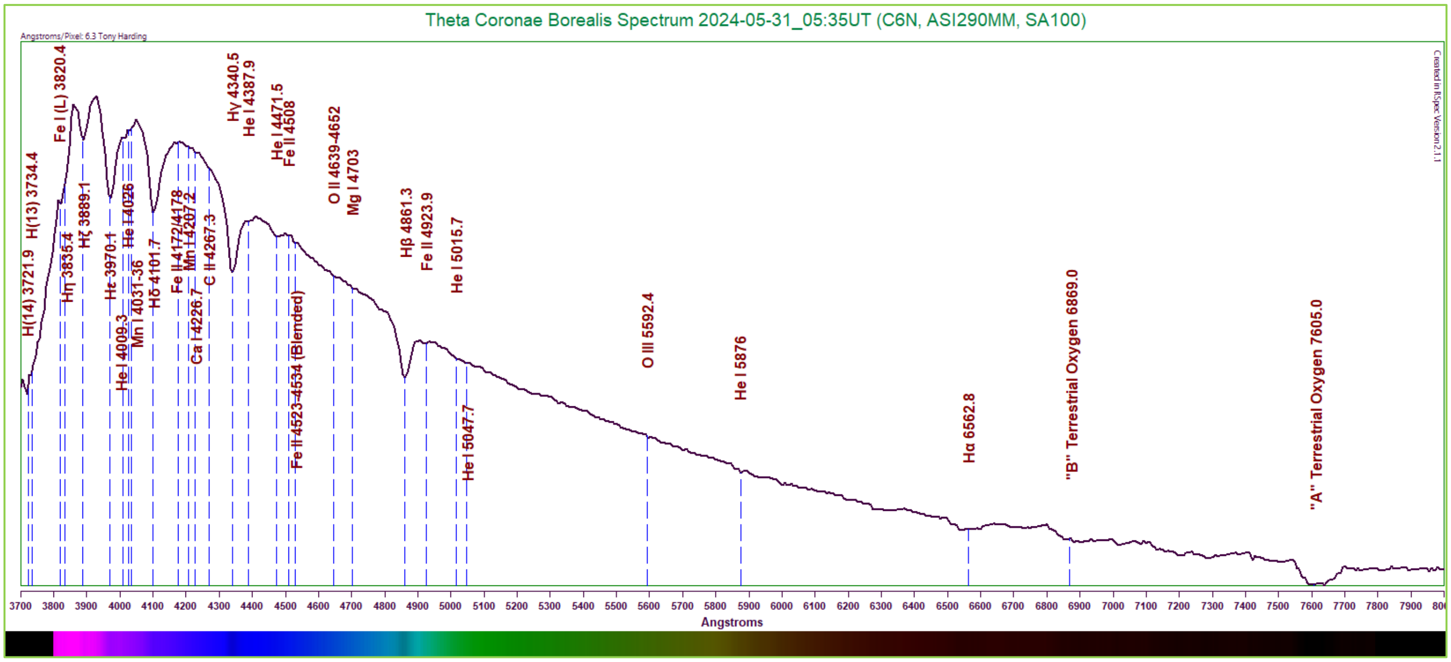

Figure 6: Theta Coronae Borealis Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 579ms, Gain 169, 40% of 322 frames stacked, Integration Time 74s

The result for this star does seem to indicate a B-type star; the curve is relatively smooth, and the hydrogen Balmer lines are only moderately represented. We do see a number of neutral helium absorptions—at 4009.3, 4026, 4387.9, 4471.5, 5015.7, 5047.7, and 5876 Angstroms. They all appear weakly here, but confidence in the identifications is high. A few other absorptions from typical B-type stars are indicated, such as ionized carbon at 4276.3 Angstroms, ionized oxygen at 4639-4652 Angstroms, and doubly ionized oxygen at 5592.4 Angstroms. We can also see a few absorptions that may indicate the companion star is actually contributing features to the spectrum. These include manganese, iron, calcium, and magnesium. A very interesting result.

Using Wien's Law, we will calculate an effective temperature estimate for the star. However, since this is a B-type star we must expect our estimate to fall woefully short. A visual inspection of the curve shows that the peak lies somewhere between the flanks of the Hζ absorption. Taking an average value between these gives us a peak energy wavelength of 3891 Angstroms. With this value, Wien's Law returns a temperature estimate of approximately 7447K. The actual temperature of the star is 14000K[2]. As expected, our estimate is extremely low, by a factor of 1.8x in this case.

ι Coronae Borealis

Iota Coronae Borealis is a spectroscopic binary star, whose primary is classified as a very early A-type star[1,2]. Considering this, we can expect to see strong hydrogen Balmer lines, with a few weak metals also present.

The finished spectrum is found below:

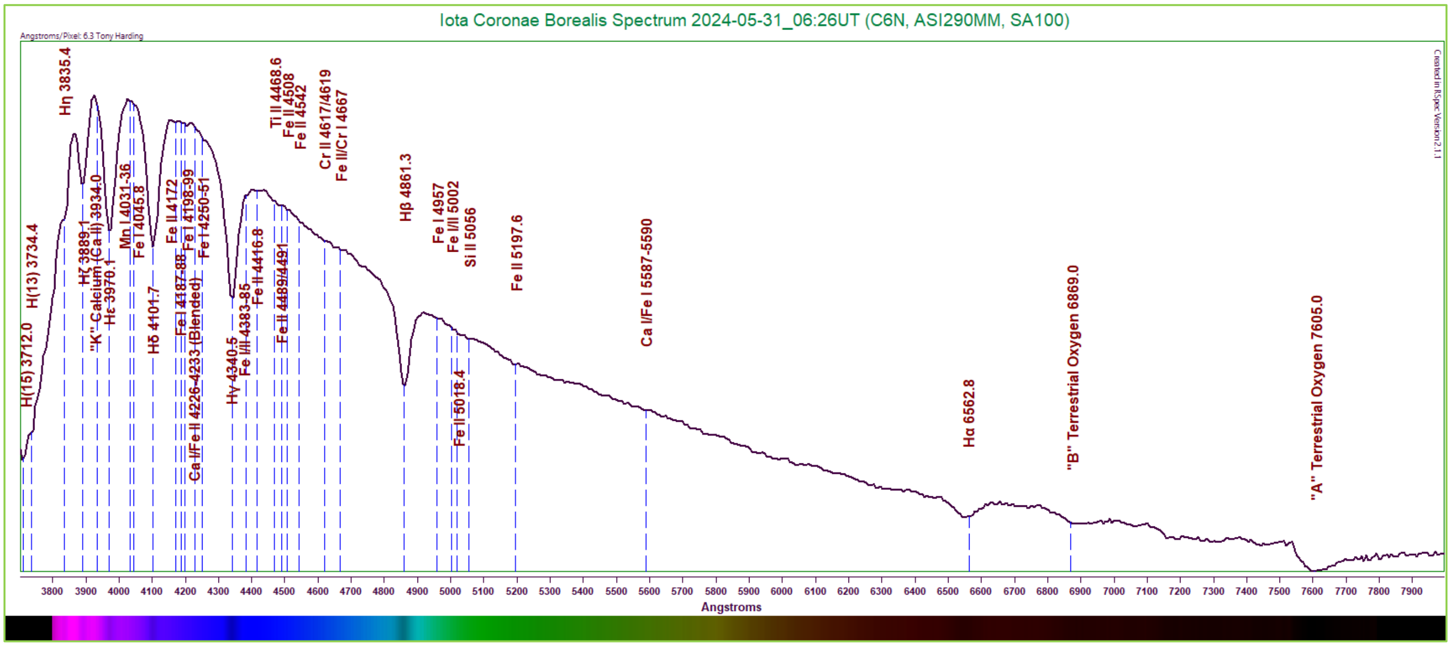

Figure 7: Iota Coronae Borealis Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 877ms, Gain 199, 40% of 413 frames stacked, Integration Time 144s

Here we see a fairly smooth curve showing prominent hydrogen Balmer lines. We can see a hint of the calcium II K line at 3934 Angstroms on the lower wing of the Hε absorption, but it is very subtle. There is no trace of either the magnesium triplet or sodium doublet here. A number of very faint metals can be see, including manganese, iron, calcium, titanium, chromium, and silicon.

Wien's Law will again be applied for temperature estimation. Once more, since this a very early A-type star, we will see that the estimate falls far short. From the curve above, the peak energy wavelength appears to lie at 3925 Angstroms. Using this value, we calculate an effective temperature of 7383K. The listed temperature for the star is 10727K[2]. Indeed, our estimate is very short of the mark.

Conclusion

The data for this constellation was acquired on the same night as that for the stars of Libra. The only surprise encountered during the data analysis was the incorrect temperature listing for Gamma Coronae Borealis on Wikipedia. Otherwise, the processes seemed to go well.

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)
[6]: As found on www.universeguide.com