Spectral Analysis of the Constellation Stars of Delphinus (The Dolphin)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Delphinus. 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 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 are the exposure times, 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. In general, a setting no higher than 200 was usually applied. No dark or flat frames were used for these captures. 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 Delphini

Alpha Delphini, also commonly known as Sualocin, is classified as a multiple star system with a of very late B-type[1,2]. We should expect to see characteristics very similar to early A-type stars, with strong hydrogen Balmer absorptions.

The processed spectrum is as follows:

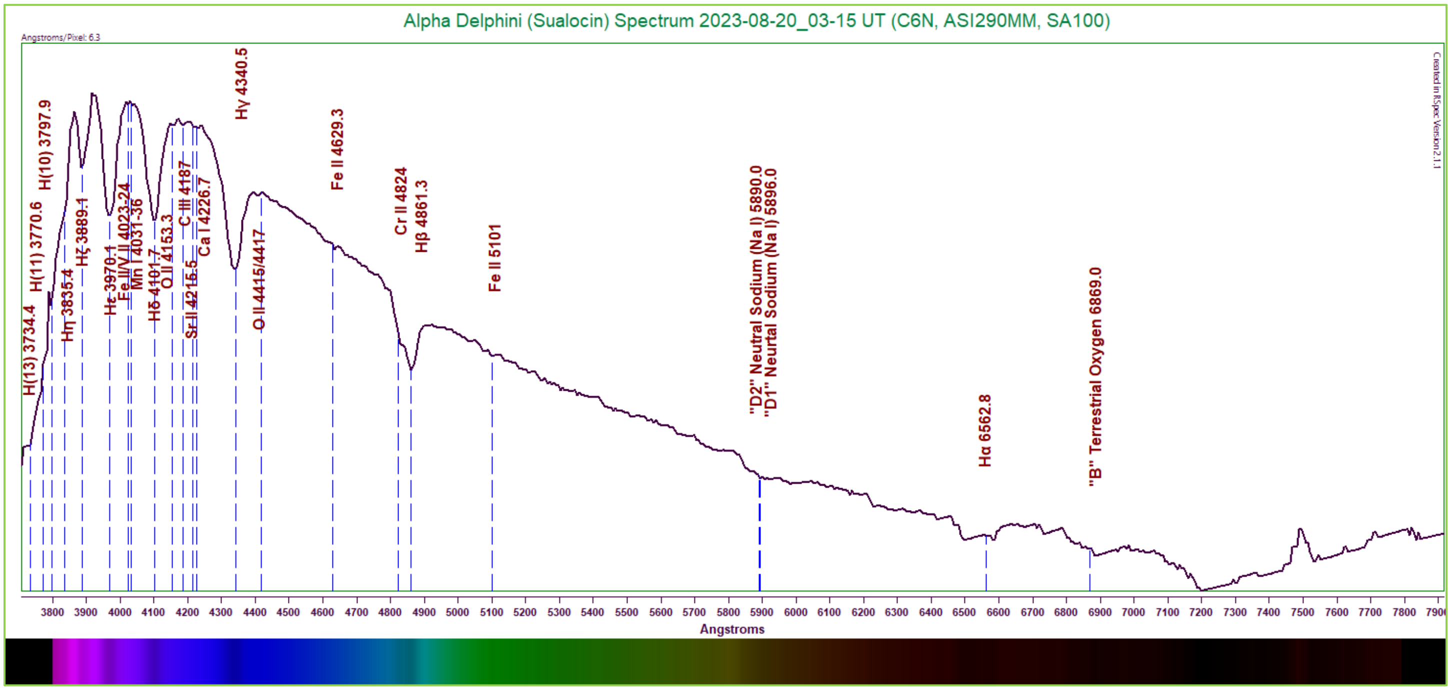

Figure 1: Alpha Delphini (Sualocin) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 492ms, Gain 146, 70% of 310 frames stacked

As expected, the dominant features here are the hydrogen Balmer lines. The continuum curve appears fairly smooth, and peaks at a low wavelength, which is consistent with a hotter, earlier-type star. A few other, faint lines are labeled here. We do not see any helium lines, however. Manganese is similarly faint at about 4033 Angstroms. Iron, calcium, oxygen, strontium, and carbon are also labeled—all extremely faint. On the lower side of the Hβ line, though, we see a significant bump due to ionized chromium. The sodium D1 and D2 lines are causing a noticeable dip in the continuum at 5890 to 5896 Angstroms.

We can use Wien's Law to obtain a very rough estimate of the star's temperature. Of course, this is an early-type star, so we can expect our estimate to be very low compared to the proper value. Using an estimated peak energy wavelength of approximately 3916 Angstroms results in a temperature of 7400K. The established temperature is listed as 11643K[2]. As anticipated, our estimate is much too low.

β Delphini

Beta Delphini, called Rotanev, is a binary star of middle F-type[1]. Both stars in the binary are both of the same general classification, and are too close to be resolved with the equipment used. The spectrum will therefore be combination of the two stars, but there shouldn't be much difference between them to interfere with interpreting the results.

The finalized spectrum is below:

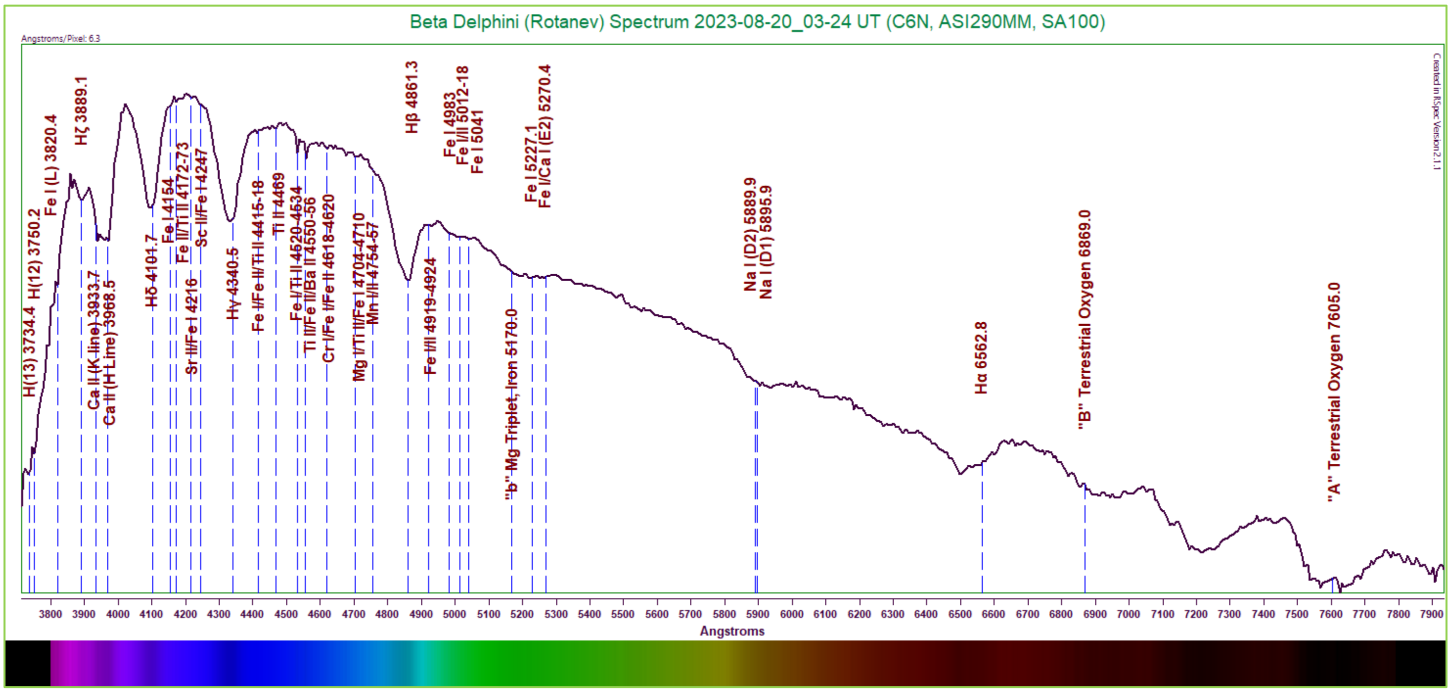

Figure 2: Beta Delphini (Rotanev) Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 721ms, Gain 187, 80% of 213 frames stacked

This looks like a fairly clear F-type spectrum; a little noisy, perhaps, but fairly easy to read. The hydrogen Balmer lines are still quite strong, except for Hε line. Of particular note is the fine representation of the calcium H and K lines, which each show a very distinct absorption, and at about equal strengths. Above the Hδ absorption can be seen a series of faint absorptions—iron, strontium, and scandium. A pair of sharp absorptions around 4520-4556 Angstroms appear to be from iron and titanium. The magnesium triplet and the two iron lines above it create a broad, shallow dip in the continuum, and the sodium D1 and D2 lines are responsible for a deeper absorption also.

Using Wien's Law, we can estimate the effective temperature of the stars from the peak energy wavelength. Using an estimated peak energy wavelength of 4200 Angstroms results in a temperature of approximately 6900K. The accepted temperature of these stars is 6587K[2].

γ-1 Delphini

Gamma Delphini is a close binary system. We will consider each star in turn. The capture of these two was tricky, as they were very close together on the camera sensor. Great care had to be taken with exposures and telescope tube rotation to try and capture and isolate each spectrum. As a result, the signal-to-noise ratio on them is higher than normal.

Gamma-1 Delphini is actually the dimmer of the two stars, and is classified as a late F-type star[1]. We should expect to see a combination of hydrogen Balmer absorptions with metals mixed into the spectrum.

The processed spectrum for γ-1 Delphini follows:

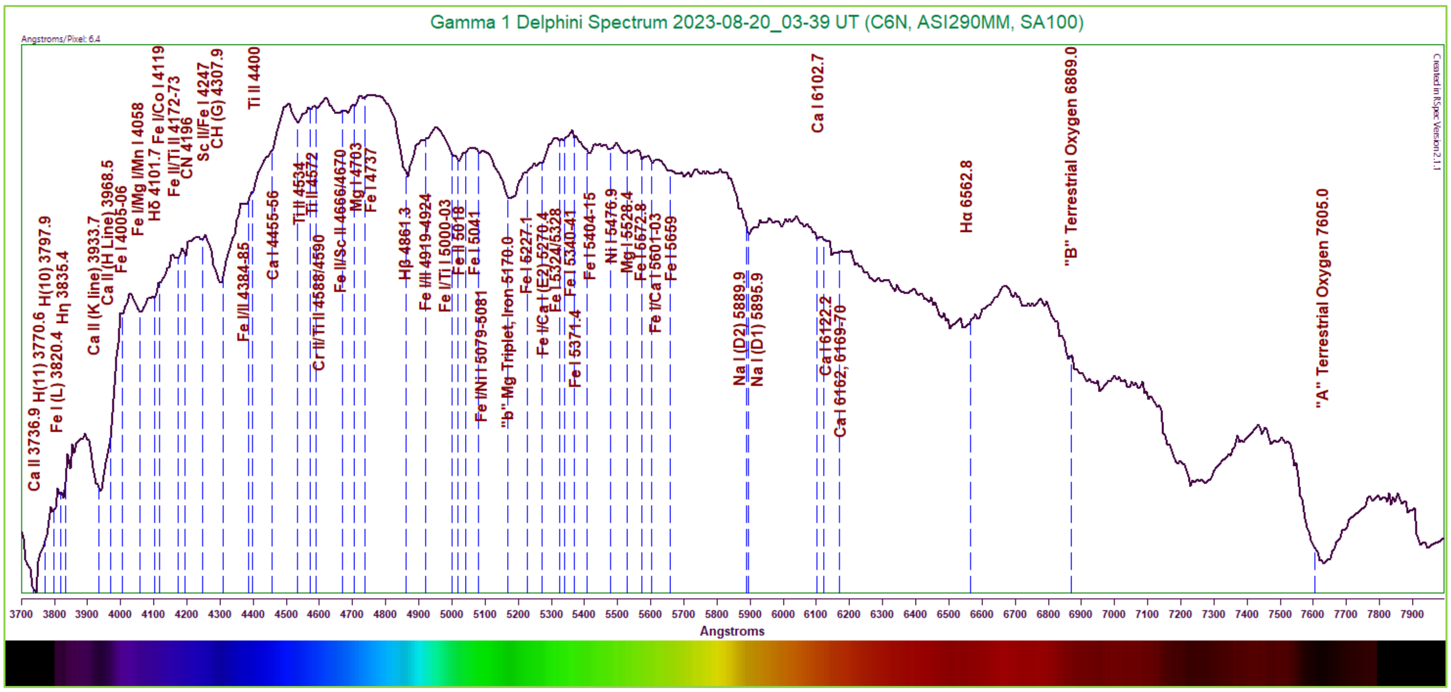

Figure 3: Gamma-1 Delphini Spectrum (6.4 Angstroms/pixel)
Capture Details 3: Exposure 2s, Gain 134, 75% of 172 frames stacked

Ah, now this one shows some interesting features. The Hβ absorption is still somewhat strong, as is Hα. The calcium line at 3736.9 Angstroms appears exceptionally strong, while the Fe I (L) line above it is much weaker. The ionized calcium H and K lines are cutting deep into the continuum. The iron/magnesium/manganese line at 4058 Angstroms is notable, sitting alongside the Hδ line. These two together are cutting pretty deep into the spectrum. A small CN absorption is noted at 4196 Angstroms, while the CH (G) band at 4307.9 Angstroms is much more impressive. The two other deeper absorptions are the magnesium triplet at 5170 Angstroms and the sodium D1 and D2 lines at 5890-96 Angstroms. A sharp cut in the continuum around 6170 Angstroms marks a distinctive collection of calcium lines. The Hα line appears unusually broad and deep here. Other fainter metal lines are scattered throughout the spectrum, including lots of iron, scandium, titanium, calcium, chromium, magnesium, and nickel. A very nice spectrum.

Employing Wien's Law, we will see how close we can get with an estimate of the effective temperature. Using an estimated peak energy wavelength of 4746 Angstroms results in a temperature of 6106K. The established temperature for the star is 6295K[2] All things considered, this is a fairly close estimate.

γ-2 Delphini

Gamma-2 Delphini, or Al Salib, is the brighter of the two binary components. It is classified as an early K-type star[1]. We should expect to see characteristics of a slightly cooler star.

The processed spectrum is below:

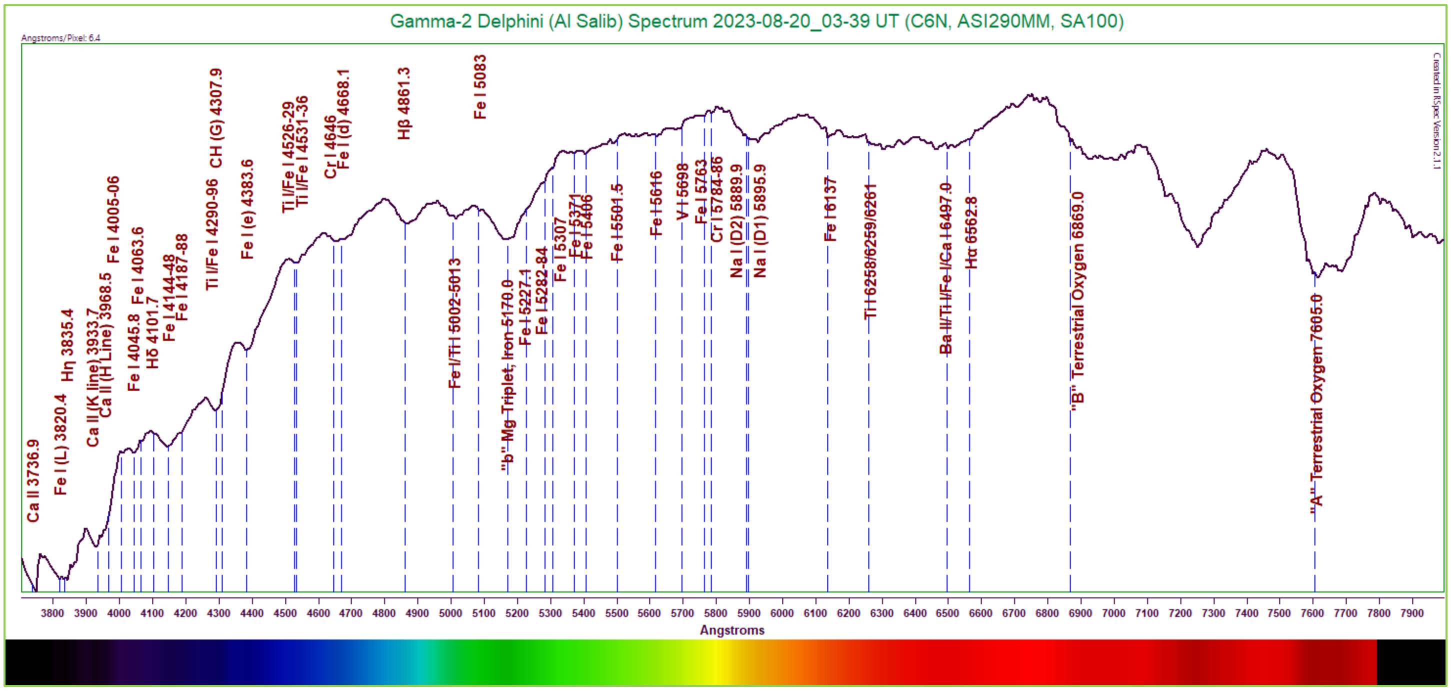

Figure 4: Gamma-2 Delphini (Al Salib) Spectrum (6.4 Angstroms/pixel)
Capture Details 4: Exposure 2s, Gain 134, 75% of 172 frames stacked

We can see from the continuum curve that we are indeed looking at a somewhat cooler star than γ-1 Delphini. The signal-to-noise ratio is better on this one, and we can see a lot of features. We see the familiar calcium and iron lines at the lower wavelength end, plus a significant cut in the spectrum due to the calcium H and K lines. More iron lines above this make distinct absorptions. The iron absorption at 4144-48 Angstroms is particularly strong. The CH (G) band at 4307.9 Angstroms is clear, along with the titanium/iron absorption below it. The Fe I (e) line at 4383.6 Angstroms is another strong iron line. The magnesium triplet is the deepest feature here at 5170 Angstroms. The sodium D1 and D2 lines are also fairly strong at 5890-96 Angstroms. We can see other small absorptions along the spectrum, namely iron, titanium, chromium, vanadium, and barium.

Again using Wien's Law, we will attempt to ascertain a rough estimate of the star's temperature. Estimating a peak energy wavelength of 6753 Angstroms, this results in a temperature of 4291K. The accepted temperature is listed as 4798K[2].

δ Delphini

Delta Delphini, known as Al Ukud, is a very close binary composed of two chemically peculiar stars, one classified as similar to a late A-type star and the other classified as an early F-type star[2]. With any luck, this one may show a strange quirk or two in the spectrum.

The final spectrum is presented below:

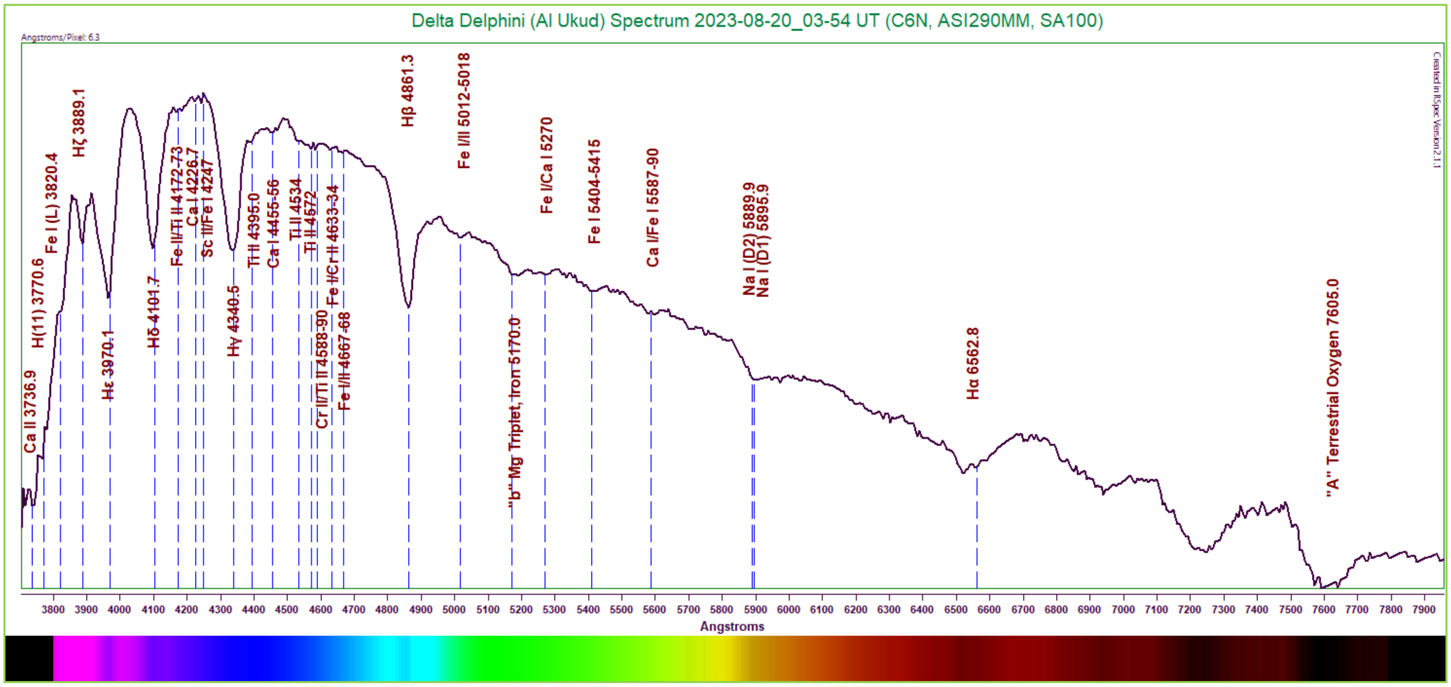

Figure 5: Delta Delphini (Al Ukud) Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 1s, Gain 157, 80% of 125 frames stacked

The main curve of this spectrum looks pretty normal for an early F-type star. However, we can see a seemingly larger than normal number of fine metal lines spread throughout the spectrum. The hydrogen Balmer lines are well-represented here—not quite as strong as in the A-type cousins, but still very clear. The calcium and Fe (L) lines are again identifiable in the extreme lower wavelength region. The finer lines spread throughout the spectrum include iron, calcium, titanium, and chromium. The magnesium triplet is plainly identifiable, as is the trough marking the sodium D1 and D2 lines. The Hα line appears sharper than expected.

We will apply Wien's Law to obtain a very rough estimate of the effective temperature. Using an estimated peak energy wavelength of 4249 Angstroms, we obtain a temperature of 6820K. The listed temperatures for the stars are 7740K and 7110K[2]. Again, our estimate is too low, as expected.

ε Delphini

Epsilon Delphini, or Aldulfin, is classified as a middle B-type star[1]. This one should appear not entirely dissimilar from our first star, Sualocin.

The finished spectrum follows:

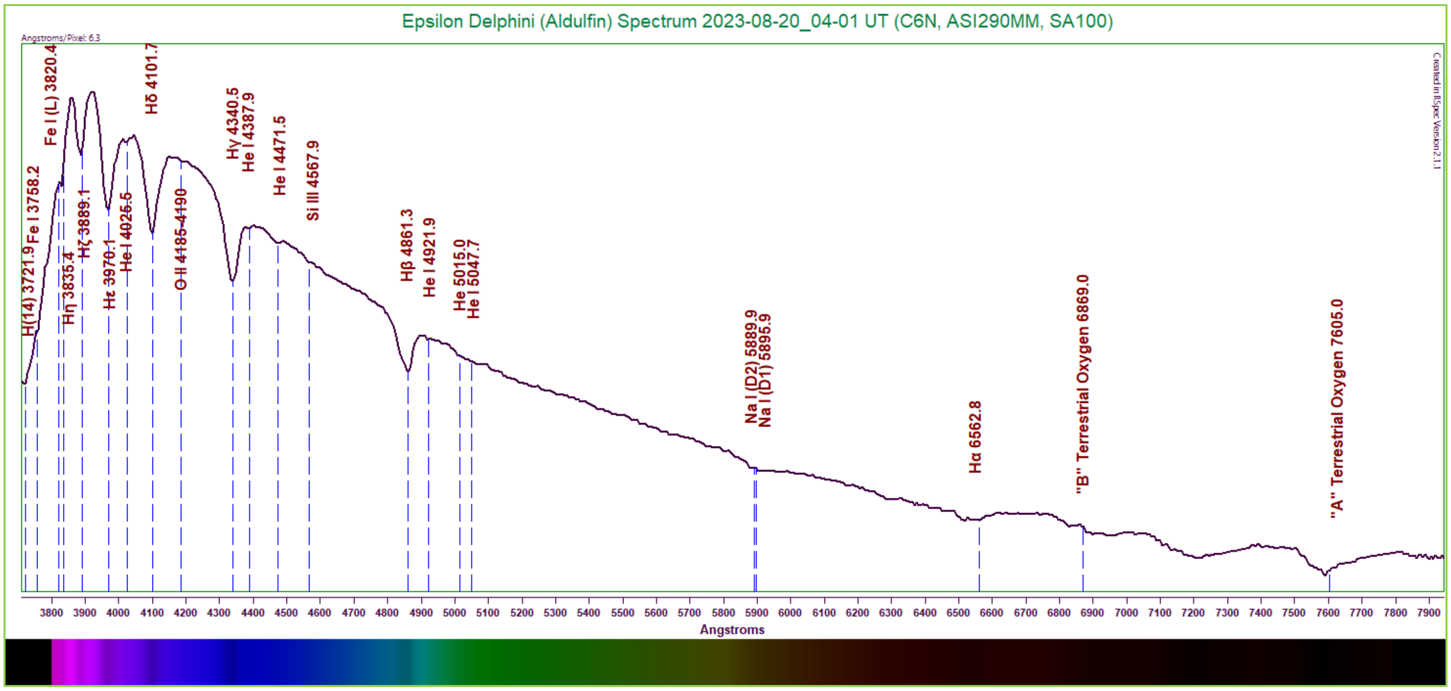

Figure 6: Epsilon Delphini (Aldulfin) Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 1s, Gain 119, 70% of 151 frames stacked

This spectrum appears mostly as expected—hydrogen Balmer lines are pretty strong, and the continuum curve shows an anticipated high temperature for the star. A very faint iron line appears at 3758.2 Angstroms. The Fe I (L) line and the Hη line are combined, but still only present a very small absorption. We can see several helium lines—at 4025.5, 4387.9, 4471.5, 4921.9, , 5015, and 5147.7 Angstroms. The last two are combining to slightly lower the continuum level. Though exceedingly small, two more ionized absorptions are visible—O II at about 4187 Angstroms and Si III at 4567.9 Angstroms. The sodium D1 and D2 lines also cause a dip in the continuum around 5890-96 Angstroms.

Wien's Law will be applied once more to obtain an effective temperature estimate. However, with this being an early-type star, we can expect our estimate to be grossly short of the mark. Using an estimated peak energy wavelength of 3920 Angstroms, the temperature estimate comes out to 7392K. The established temperature for the star is listed as 13614K[2]! Yeah, that's quite a shortcoming in our estimate!

Conclusion

This run went well—no misidentifications or unexpected issues processing the data. The spectra all seemed to align with the stellar types very nicely. These results were very pleasing.

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