Spectral Analysis of the Constellation Stars of Cetus (The Whale)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Cetus. 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 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.

Data Processing Details

All of the spectra obtained for this analysis were obtained on the evenings of December 14, 2023 and January 4, 2024 (EST). 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 Ceti

Alpha Ceti, or Menkar, is classified as an early M-type variable star[1]. We should be able to see prominent TiO lines here, along with a curve representing a cooler star.

The processed spectrum is as follows:

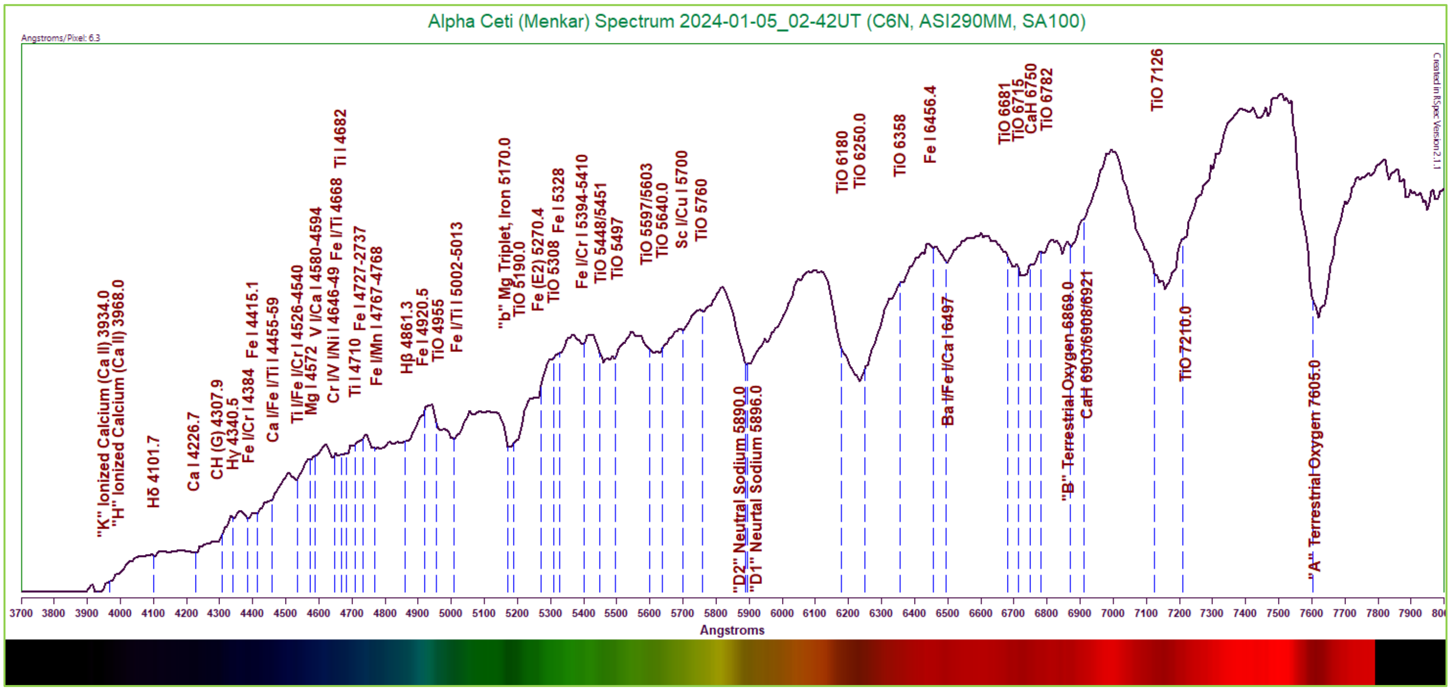

Figure 1: Alpha Ceti (Menkar) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 231ms, Gain 86, 50% of 808 frames stacked

This spectrum does indeed match our expectations. The curve peaks at a longer wavelength, and we see numerous TiO absorptions of varying strengths, ranging from intense to faint. The calcium H and K lines are barely visible at the extreme lower wavelength range. Several of the hydrogen Balmer series can be spotted, but they are all very subtle. The CH (G) band is marked, causing a small but noticeable dip in the continuum. The magnesium triplet at 5170 Angstroms and the sodium doublet at 5890-96 Angstroms are also quite noticeable. Here, the sodium doublet is definitely stronger. Several calcium, iron, titanium, chromium, scandium, and barium lines are also marked.

Using Wien's Law, we will attempt to estimate the star's temperature. Using a visually estimated peak energy wavelength of 7506 Angstroms, we arrive at a result of approximately 3861K. The listed value for the temperature is 3795K[2]. All told, our estimate is not very far off mark.

β Ceti

Beta Ceti, commonly called Diphda, is a very late G-type or very early K-type star[1,2]. We should see a star hotter than Menkar, but cooler than our Sun, showing numerous metal lines throughout.

The processed spectrum is as follows:

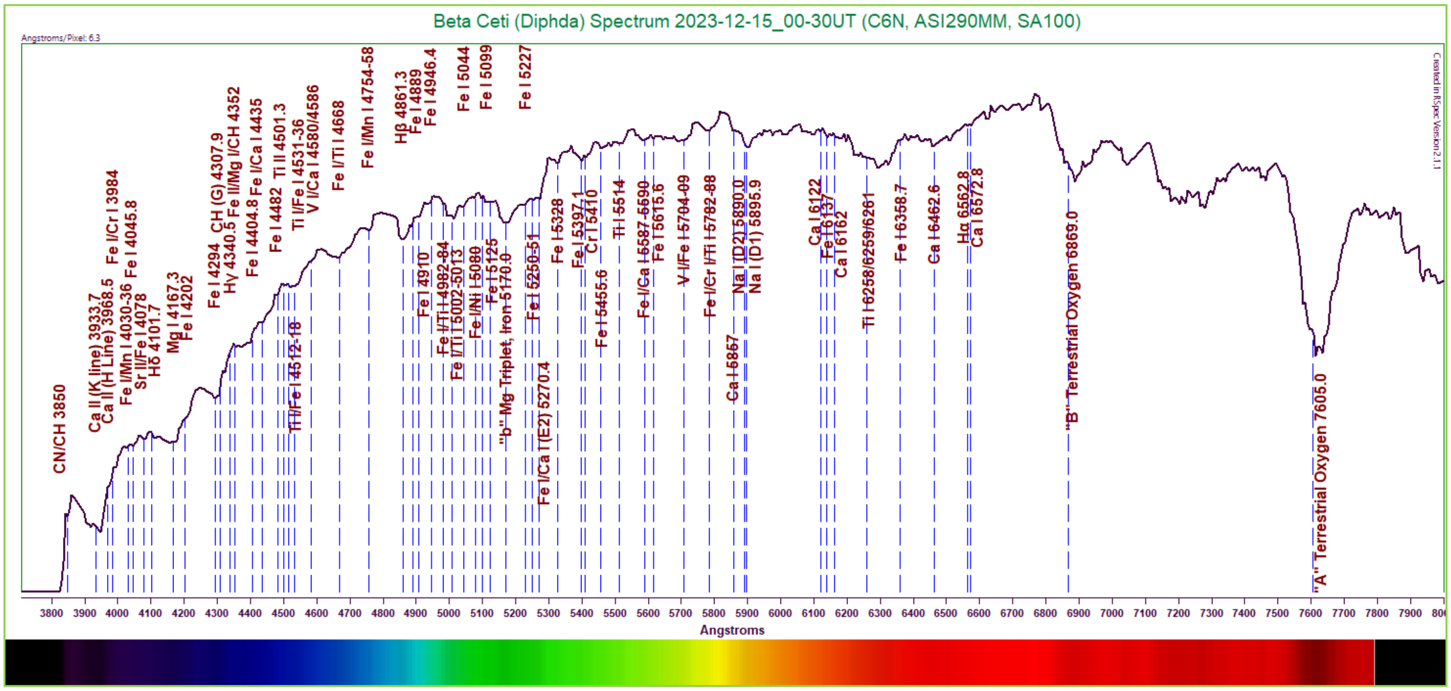

Figure 2: Beta Ceti (Diphda) Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 242ms, Gain 45, 20% of 1072 frames stacked

This is certainly a busy spectrum. The curve represents a star warmer than Menkar, but not nearly as hot as the A-types. The calcium H and K lines can be clearly seen carving a dip into the continuum in the low wavelength region. Only some of the hydrogen Balmer lines are represented, and none very strongly. The Hβ line is probably the strongest. The CH (G) band is clear just below the Hγ line. The iron line at 4294 Angstroms causes the absorption to appear with a flat-bottomed trough. The magnesium triplet at 5170 Angstroms is clear; the absorption is broadened by the flanking iron lines. The sodium doublet at 5890-96 Angstroms is also easy to recognize, but it is a bit weaker. Though, in this case the calcium line just below it at 5857 Angstroms is distinctly visible. Numerous other metal lines are sprinkled through this spectrum, including lots of iron, strontium, magnesium, titanium, vanadium, chromium, and calcium.

Wien’s Law will be used to estimate the star’s effective temperature. Using a visually estimated peak energy wavelength of 6762 Angstroms, we arrive at an estimate of 4285K. The established temperature of the star is listed as 4797K[2].

γ Ceti

Gamma Ceti, also referred to by the tongue-tying name Kaffaljidhma, is a close double star composed of an early A-type primary and a middle F-type secondary. The two are too close for our equipment to separate, so we will be looking at a combination spectrum. We should expect, however, that the primary will mostly dominate the spectrum.

The processed spectrum is below:

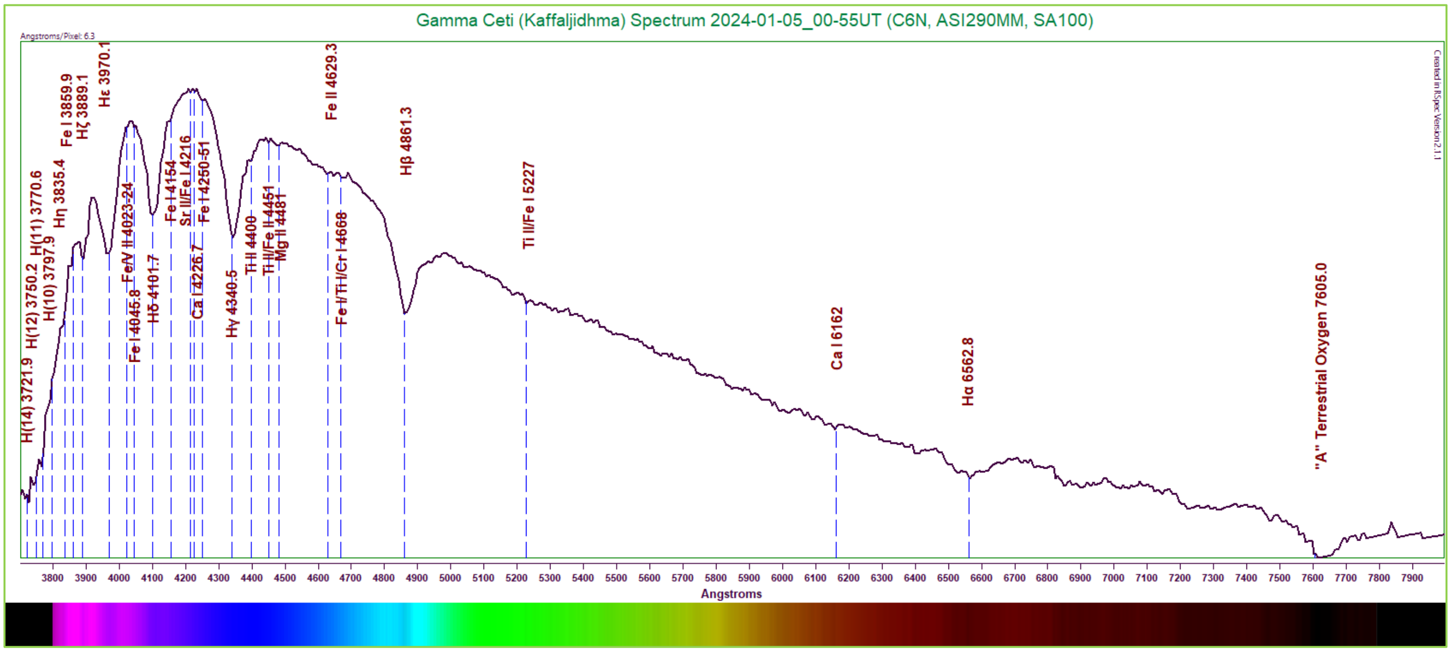

Figure 3: Gamma Ceti (Kaffaljidhma) Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 271ms, Gain 154, 20% of 1372 frames stacked

Indeed we can see that the middle A-type primary star dominates the spectrum. The hydrogen Balmer lines are deep and clear. One iron line at 3859.9 Angstroms appears very crisp to the lower side of the Hζ line. A number of other very faint lines are sprinkled throughout, including iron/vanadium, strontium, titanium, magnesium, and calcium. There is no trace of either the magnesium triplet or sodium doublet here.

Wien's Law can be used to obtain a rough estimate of the star's temperature. Being an earlier-type star, however, we can expect our estimate to fall short. Using a peak energy wavelength of 4235 Angstroms, we obtain a resulting temperature of approximately 6843K. The established temperature for the star is listed as 8551K[2].

δ Ceti

Delta Ceti, called Al Kaff al Jidhmah III, is a pulsating variable star of the early B-type[1]. From this, we can expect to see a high-temperature star with faded hydrogen Balmer lines as well as perhaps some helium lines present

The processed spectrum follows:

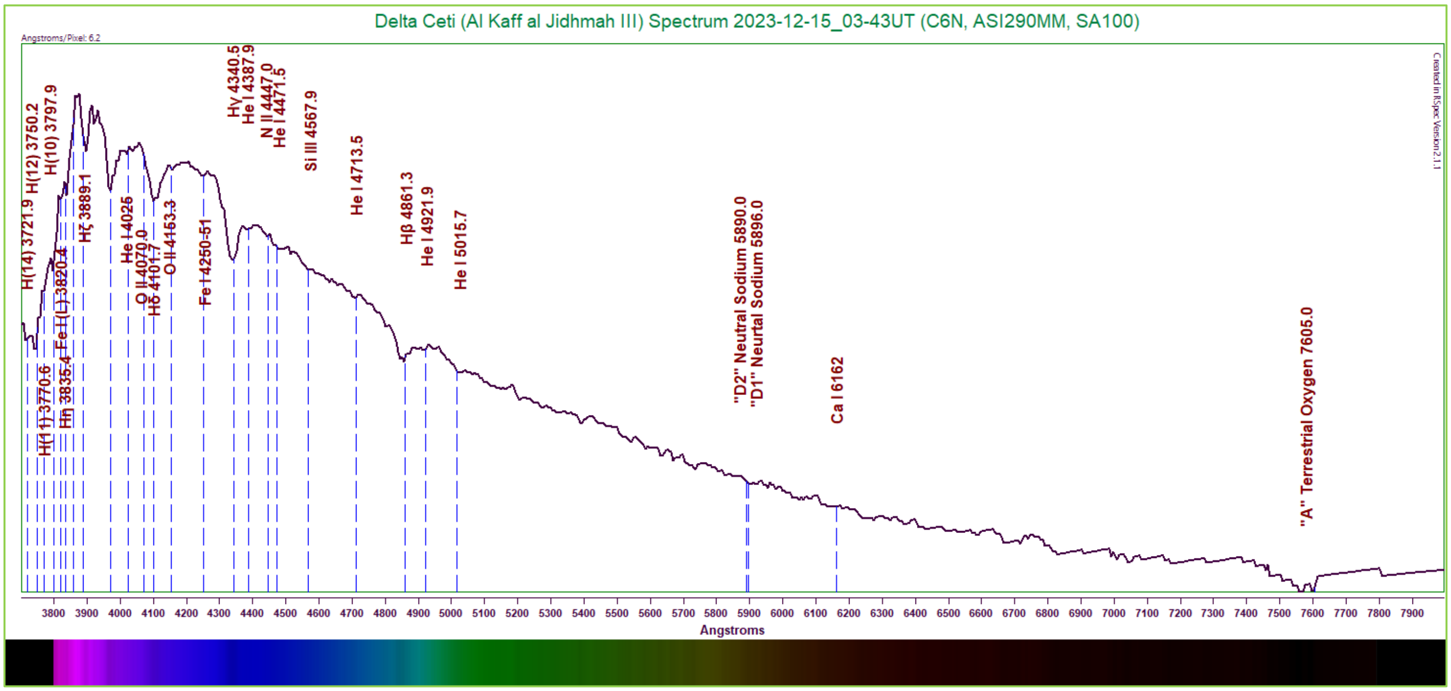

Figure 4: Delta Ceti (Al Kaff al Jidhmah III) Spectrum (6.2 Angstroms/pixel)
Capture Details 4: Exposure 307ms, Gain 125, 35% of 815 frames stacked

This spectrum seems to match our expectations. The curve peaks in the lower wavelength range, indicating great heat. Also, the hydrogen Balmer lines, though mostly present, appear weakened compared to the star's A-type cousins. The Fe (L) makes an appearance at 3820.4 Angstrom, combining with the Hη line to create the distinctive stair-step. We can indeed spot many faint helium lines in the spectrum, along with oxygen and silicon. The sodium doublet is actually visible, creating a very faint absorption at 5890-96 Angstroms.

Using Wien's Law, we will calculate an estimated effective temperature. Since this is such an early star, we can certainly expect our estimate will fall far short of the correct value. Using an estimated peak energy wavelength of 3872 Angstroms, we arrive at a temperature of 7484K. The star's accepted temperature is approximately 21900K[2]. As expected, our estimate is far too low!

ε Ceti

Epsilon Ceti, also referred to as Sadr al Kaitos III, is a spectroscopic binary star considered to be of the middle F-type[1,2]. We should expect to find a moderately hot star showing hydrogen Balmer lines, but also exhibiting numerous metals as well.

The spectrum is presented below:

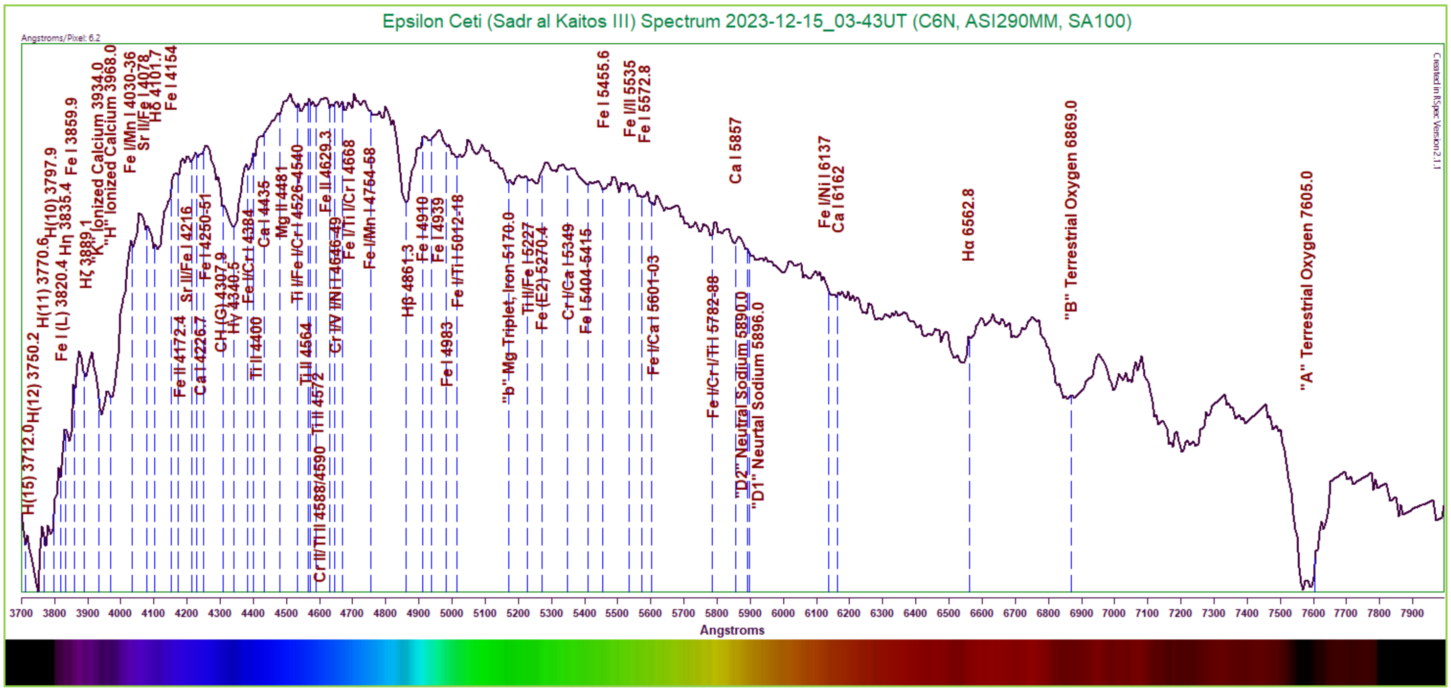

Figure 5: Epsilon Ceti (Sadr al Kaitos III) Spectrum (6.2 Angstroms/pixel)
Capture Details 5: Exposure 862, Gain 178, 65% of 290 frames stacked

Here we have another busy spectrum. Most of the hydrogen Balmer absorptions are present, though not overly strong. The Fe I (L) line at 3820.4 Angstroms is visible, as is the nearby iron line at 3859.9 Angstroms. The calcium H and K lines are very prominent, completely overpowering the Hε line we would otherwise see there. The CH (G) line is visible as a small bump on the lower side of the Hγ line. The magnesium triplet at 5170 Angstroms is relatively weak, but broadened by the iron lines above it. The sodium doublet is weaker still, and only barely discernible. Throughout the entire spectrum are numerous metal lines. These include iron, strontium, calcium, titanium, magnesium, and chromium. Most of these are very faint, but a few do manage to cut deeper grooves into the continuum.

Employing Wien's Law, we will attempt to estimate the temperature of the star. In this case, a visual estimate of the peak energy wavelength is tricky to obtain. It appears to lie between two peaks at roughly 4512 and 4705 Angstroms. Taking the median value between these two, we will use a value of about 4609 Angstroms. Using this, Wien's Law produces and estimated effective temperature of 6387K. The established temperature is listed as 6537K[2]. Considering the estimations involved, our estimate is actually pretty close!

ζ Ceti

Zeta Ceti, or Baten Kaitos, is another very close double star, this time of the very early K-type[1]. This should produce a spectrum not entirely dissimilar to that of Diphda above.

The processed spectrum follows:

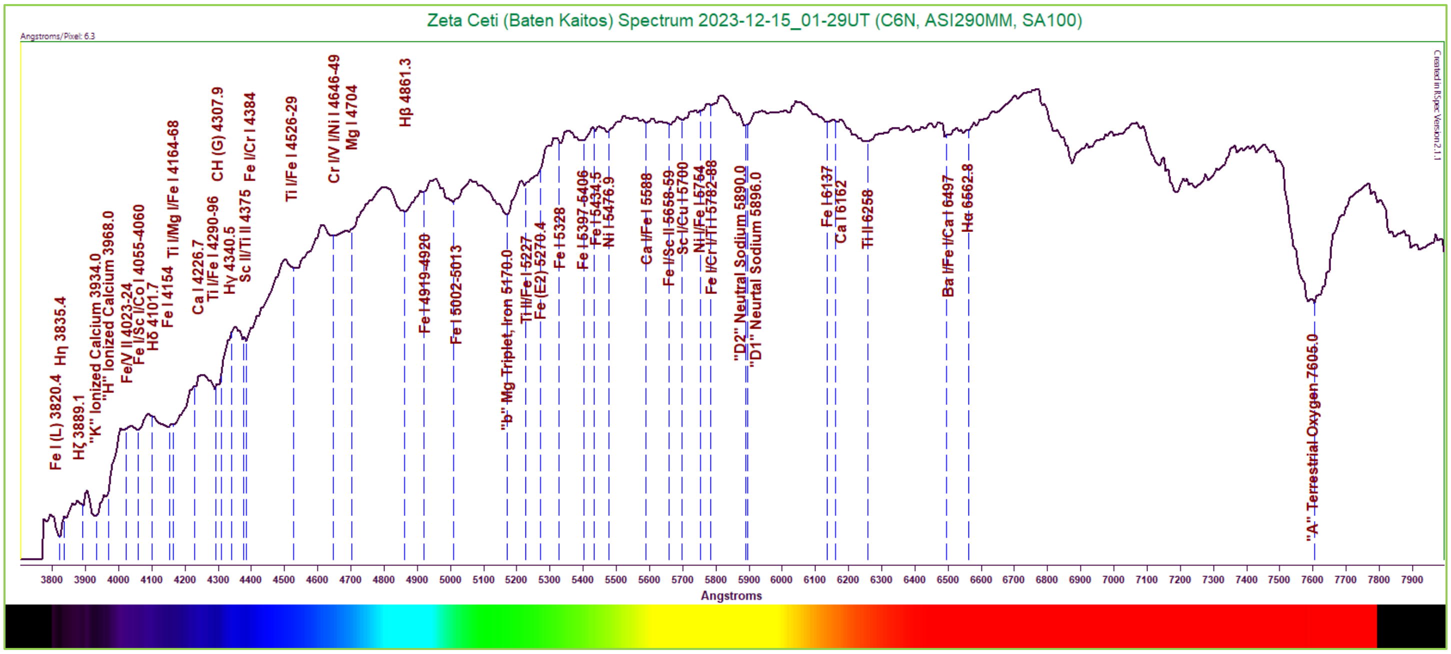

Figure 6: Zeta Ceti (Baten Kaitos) Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 318ms, Gain 172, 30% of 770 frames stacked

This is another very interesting one. The hydrogen Balmer lines are weak, as expected. The Fe (L) and Hη lines are melded together, but still only create a moderate absorption. The calcium H and K lines are deeper, but not as pronounced as in some earlier stars. The iron and titanium absorptions in the 4154-4168 Angstroms range are creating a more notable and broader absorption. The neutral titanium/iron line at 4290-96 Angstroms sits just below the CH (G) band, creating another (narrower) absorption of note. The magnesium triplet at 5170 Angstroms is also a notable feature, carving out a sharp dip in the continuum alongside the iron lines above it. The sodium doublet at 5890-96 Angstroms is also easily identified, even if it is a bit weaker. A large number of other faint metal lines are spread throughout the spectrum, including iron, calcium, scandium, chromium, titanium, and barium.

Using Wien's Law, we will attempt to estimate the effective temperature. Using a visually estimated peak energy wavelength of 6769 Angstroms, we arrive at a result of 4281K. The established temperature of the star is listed as 4581K[2]. Though our estimate is slightly too low, it is not terribly far off the mark.

η Ceti

Eta Ceti, known as Dheneb or Deneb Algenubi, is regarded as an early K-type star[1]. This means we should see a spectrum similar to that of Zeta Ceti above.

The processed spectrum is presented here:

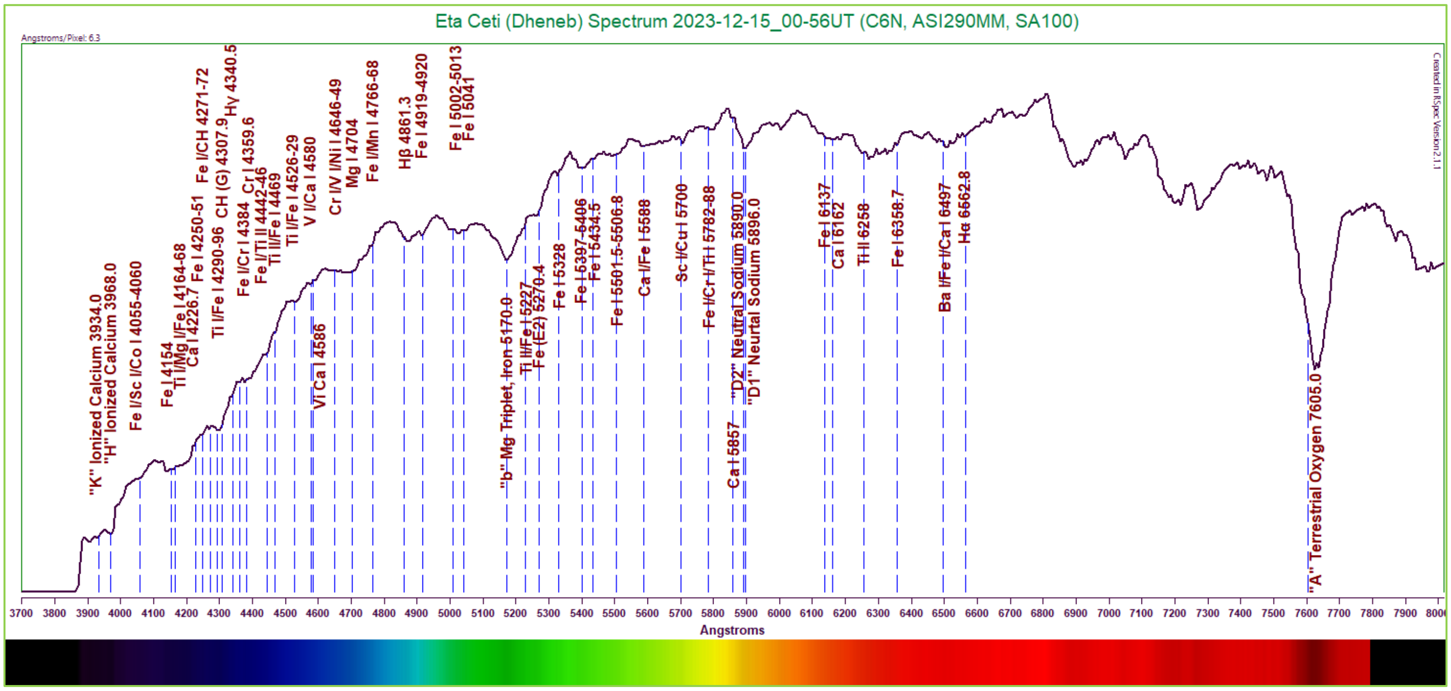

Figure 7: Eta Ceti (Dheneb) Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 245ms, Gain 160. 20% of 1019 frames stacked

Indeed, this spectrum looks very similar to that of Zeta Ceti. The calcium H and K lines are a bit more subdued, but still present. The same Fe I and Ti I combined absorption appears in the 4054-4168 Angstroms range. The CH (G) band is plainly visible, though it is not clearly separated from the titanium line just below it. A chromium and magnesium combination absorption of moderate size is in the 4646-4704 Angstroms range. The magnesium triplet is very plain, again combined with the two iron absorptions above it to create a broad dip in the continuum. The sodium doublet is also visible in the 5890-96 Angstroms range. A number of the same faint metal absorptions are again visible, including iron, titanium, calcium, chromium, vanadium, scandium, and barium.

Using Wien's Law, we will again attempt to estimate the star's effective temperature. Using an estimated peak energy wavelength of 6808 Angstroms, we calculate a temperature of approximately 4256K. The star's listed temperature is 4543K[2]. Once again, our estimate is just a bit too low. However, these temperatures both come out as slightly lower than that for Zeta Ceti, which matches our expectations that Eta Ceti should be slightly cooler.

θ Ceti

Theta Ceti, also known as Al Naymat I, is classified as a very early K-type star[1]. Once again, this means we should expect to see very similar features to those of the last two stars in the survey.

The spectrum follows:

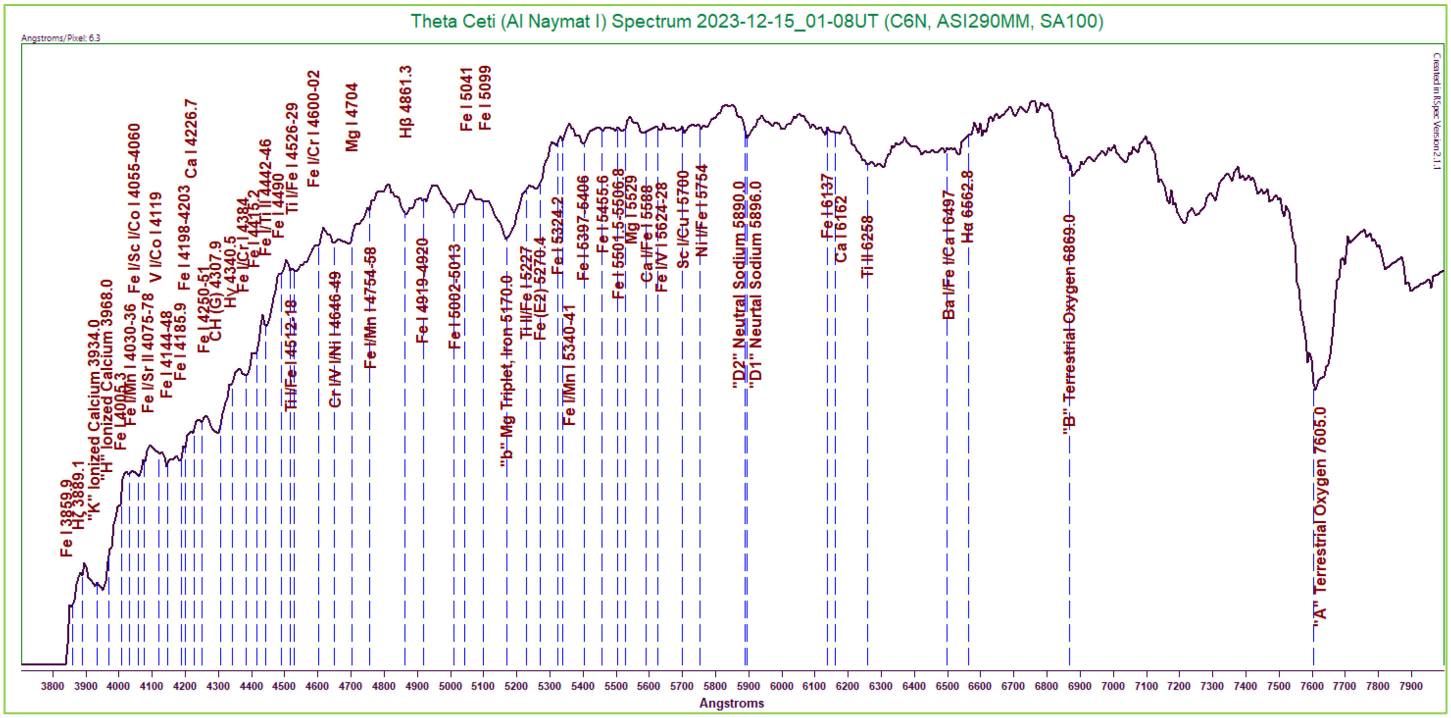

Figure 8: Theta Ceti (Al Naymat I) Spectrum (6.3 Angstroms/pixel)
Capture Details 8: Exposure 256.048ms, Gain 160, 25% of 1010 frames stacked

Once again we see the familiar curve for a very early K-type star. This one seems to show increased detail. The hydrogen Balmer lines are again weakened, but still present. The calcium H and K lines are cutting a sizeable groove into the continuum. Two iron lines at 4144-4186 Angstroms are also creating a significant absorption. The CH (G) band is visible here also. The magnesium triplet and sodium doublet appear similarly to the last few targets. Numerous tiny metal absorptions are sprinkled throughout, including iron, vanadium, calcium, titanium, chromium, magnesium, scandium, nickel, and barium.

We will again use Wien's Law to estimate the star's effective temperature. We should see a similar result to the recent targets of the same type. Using an estimated peak energy wavelength of 6757 Angstroms, we obtain a result of 4289K. The star's listed temperature is 4660K[2].

ι Ceti

Iota Ceti, also called Deneb Kaitos Shemali, is yet another early K-type star[1]. Another curve with similar properties to the last several is what we should expect here.

The processed spectrum is below:

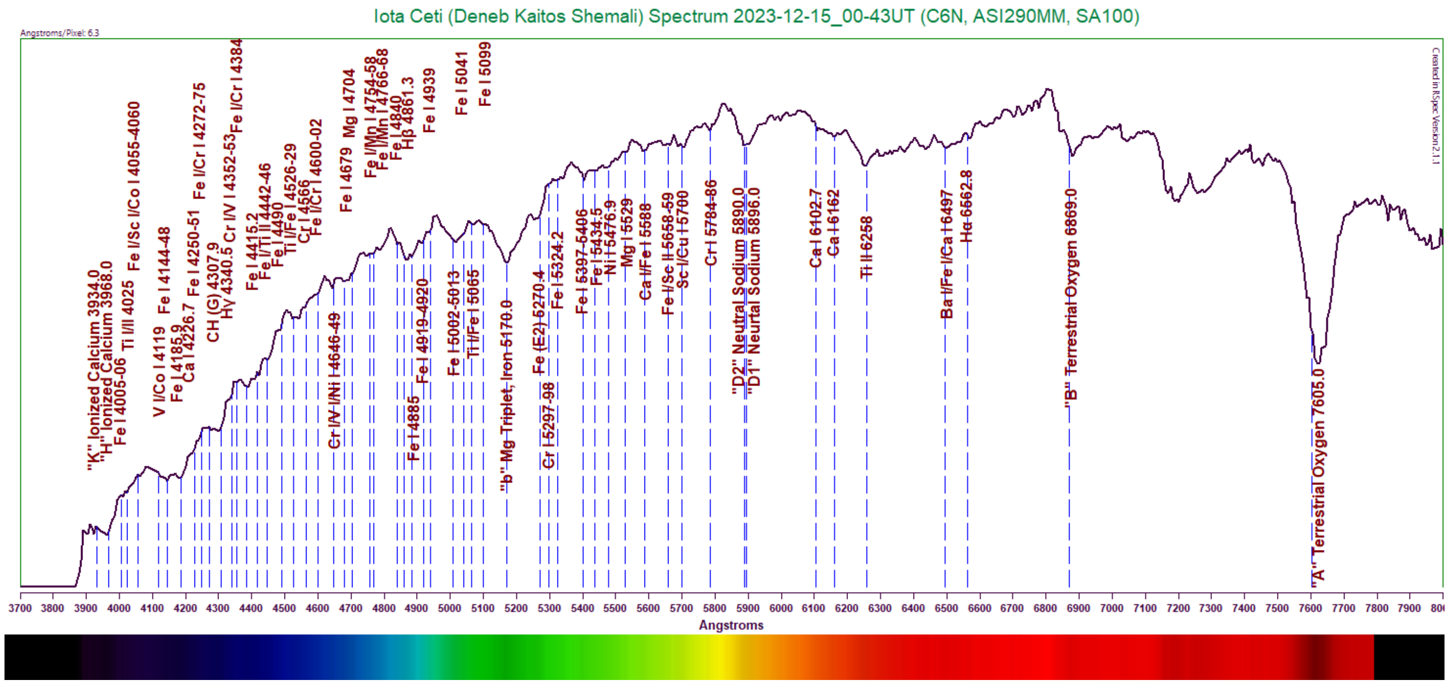

Figure 9: Iota Ceti (Deneb Kaitos Shemali) Spectrum (6.3 Angstroms/pixel)
Capture Details 9: Exposure 231ms, Gain 175, 20% of 1051 frames stacked

Déjà vu! Another early K-type spectrum! The by-now familiar features of the early K-types are readily apparent here. The calcium H and K lines, neutral iron at 4144-4186 Angstroms, the CH (G) band, the magnesium triplet, and the sodium doublet all present very familiar characteristics. Again, a large number of additional very faint metal lines are marked, including iron, titanium, vanadium, calcium, chromium, magnesium, scandium, and barium. After the last several stars in the survey, this one presents no great surprises.

Wien’s Law will be utilized again to obtain a temperature estimate. Using an estimated peak energy wavelength of 6803 Angstroms, our calculation results in a temperature of 4260K. The established temperature of the star is listed as 4446K[2]. Once again, we find our estimate it close, but just a tad too low.

λ Ceti

Lambda Ceti, also sometimes called Menkar, is classified as a middle B-type star[1]. (Yay! Something other than a K-type!) We can expect to see a very hot star with reduced hydrogen Balmer lines, but perhaps with a few helium lines visible.

The spectrum is below:

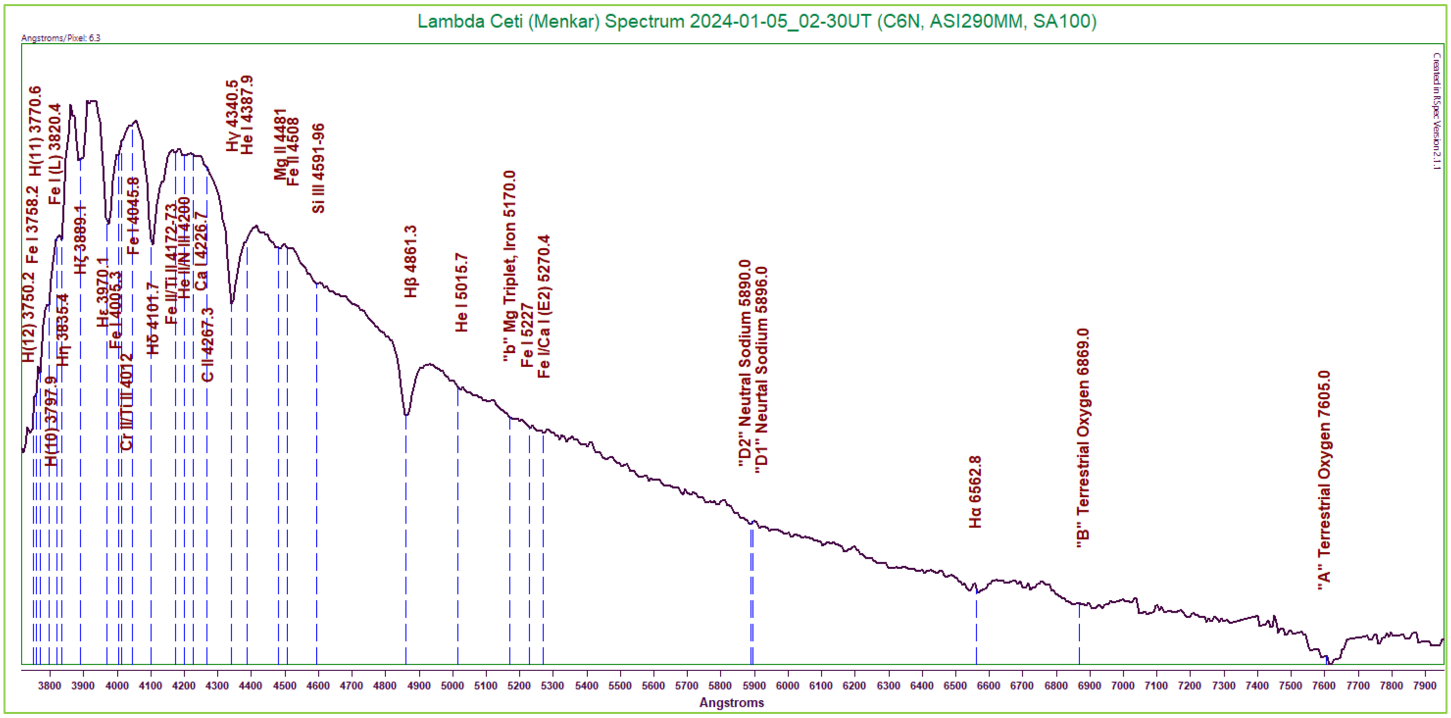

Figure 10: Lambda Ceti (Menkar) Spectrum (6.3 Angstroms/pixel)
Capture Details 10: Exposure 341ms, Gain 175, 35% of 383 frames stacked

Here we can easily see a hotter star reflected in the curve, which peaks at a much lower wavelength. The hydrogen Balmer lines are pretty clear, except the Hα line, which is weak. The Fe (L) line at 3820.4 Angstroms is alongside the Hη line, causing a flat step in the continuum. The other iron lines appear extremely weak by comparison. We can see helium at 4200, 4387.9, and 5015.7 Angstroms, but these are extremely weak. The magnesium triplet at 5170 Angstroms is causing only a tiny dip in the continuum. The sodium doublet at 5890-96 is a bit more pronounced, but not much. A handful of other faint metals are indicated, including chromium, carbon, magnesium, and silicon.

Using Wien's Law, we will attempt to calculate a temperature estimate. Keep in mind, however, that this is an earlier-type star, so we must expect our estimate to be very low. Using an estimated peak energy wavelength of 3911 Angstroms, we calculate a temperature of 7409K. The currently accepted temperature of the star is 13940K[2]. Our estimate is low by almost a factor of 2.

μ Ceti

Mu Ceti, called Al Kaff al Jidhmah IV, is a very close double star classified as very late A-type[1]. We should expect to see a star cooler than Lambda Ceti above, with some more metals beginning to emerge along the continuum.

The processed spectrum is presented here:

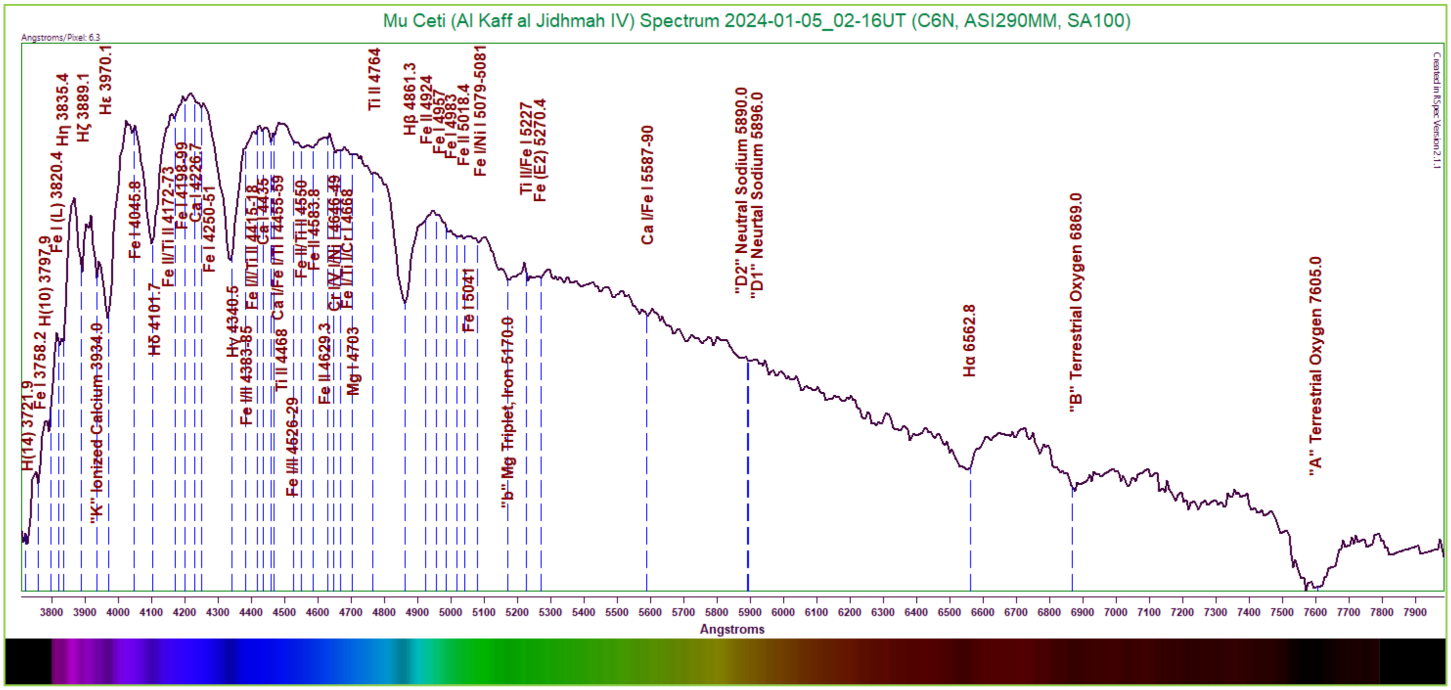

Figure 11: Mu Ceti (Al Kaff al Jidhmah IV) Spectrum (6.3 Angstroms/pixel)
Capture Details 11: Exposure 539ms, Gain 154, 40% of 455 frames stacked

We do see here several characteristics of a star between early A-types and late F-types. The hydrogen Balmer lines are pretty clear here. We can also recognize the calcium K line, while the H line has not yet overpowered the Hε line. Above the Hβ line, the continuum becomes quite noisy, but the magnesium triplet is marked by a recognizable dip in the continuum. The sodium doublet is much more subtle, causing only a very slight scoop in the curve. A number of other faint metal lines are present in the curve. Iron is visible as a weak absorption at the extreme low wavelength range at 3758.2 Angstroms. The Fe (L) line is recognizable alongside the Hη line, together causing the step in the continuum there. At 4550-4583 Angstroms, ionized iron lines are causing a significant absorption. A number of other faint lines are marked, including more iron, calcium, titanium, chromium, and magnesium.

Using Wien's Law, we will calculate the effective temperature of the star. We can still probably expect our estimate to be too low. Using an estimated peak energy wavelength of 4219 Angstroms, we obtain a temperature of 6868K. The star's accepted temperature is listed as 7141K[2]. Our estimate is too low, but actually a bit closer than anticipated.

ν Ceti

Nu Ceti is a double star classified as a late G-type star[1]. From this we should expect to see a star a little warmer than the K-types analyzed previously, but cooler than our own Sun. We should also expect a significant number of metal lines throughout.

The spectrum appears below:

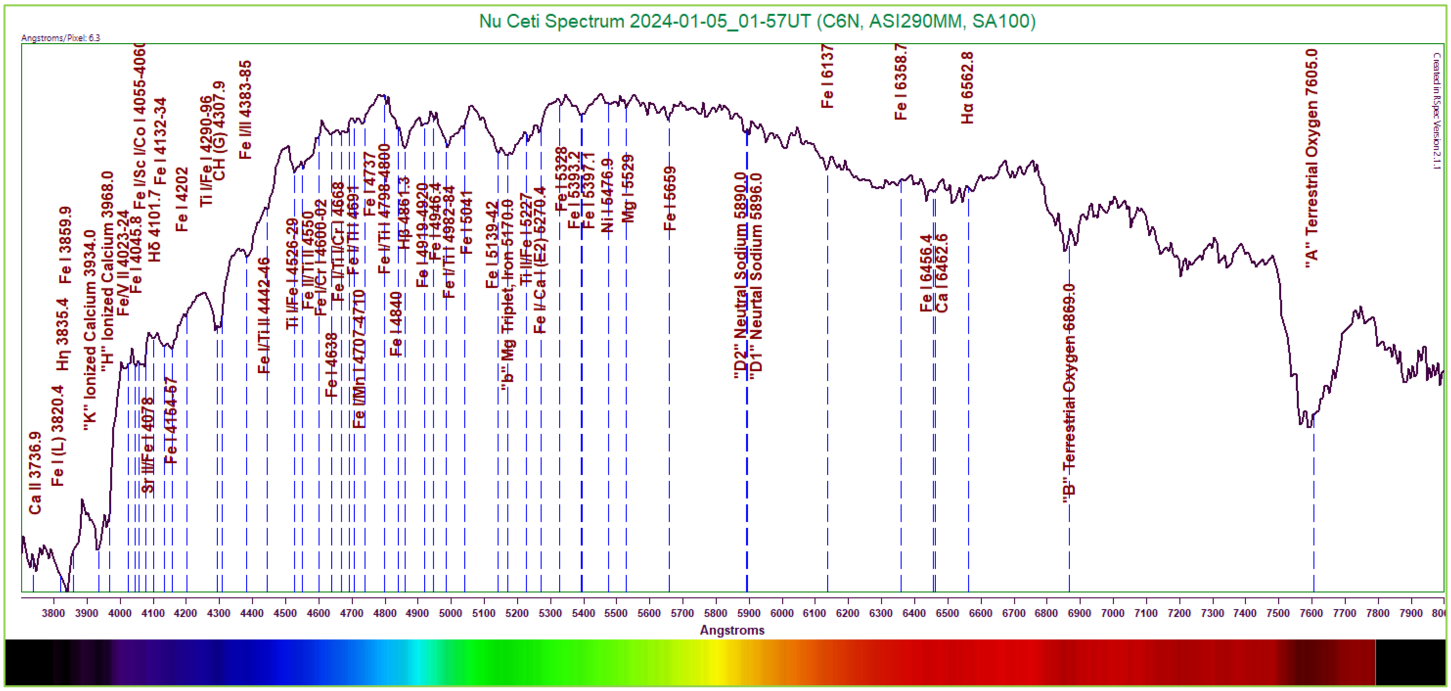

Figure 12: Nu Ceti Spectrum (6.3 Angstroms/pixel)
Capture Details 12: Exposure 688ms, Gain 187, 30% of 532 frames stacked

This is a very complex looking spectrum! We do see from the general shape of the curve that we are dealing with a star a bit warmer than the K-types encountered earlier. Some of the hydrogen Balmer lines are visible, though none are terribly strong. The Ca II line at 3736.9 Angstroms is evident in the extreme low wavelength range. The Fe (L) and Hη lines are carving a deep gouge out of the continuum, with the Fe I line at 3859.9 Angstroms above them causing a small bump. The calcium H and K lines are very prominent here. The CH (G) line, with its accompanying iron/titanium line just below it, is also easily identifiable. The magnesium triplet at 5170 Angstroms, combined with three surrounding iron lines, is causing a familiar, broad valley in the continuum, though it is not extremely deep. The sodium doublet at 5890-96 Angstroms is very faint by comparison. A large number of fainter metal lines are spread throughout this spectrum, including lots of iron lines, titanium, nickel, magnesium, and calcium. A very busy spectrum!

Using Wien's Law, we will attempt to calculate the star's effective temperature. In this case, the peak energy wavelength is difficult to determine visually, but it appears to be near 5454 Angstroms. Using this value, we obtain a resulting temperature of 5313K. The listed temperature for the star is 5164K[2]. Our estimate is actually fairly close.

ξ-1 Ceti

Xi-1 Ceti, also known by the name Al Kaff al Jidhmah I, is a spectroscopic double star classified as a late G-type star[1,2]. We should expect to see some characteristics similar to Nu Ceti, above.

The spectrum is presented here:

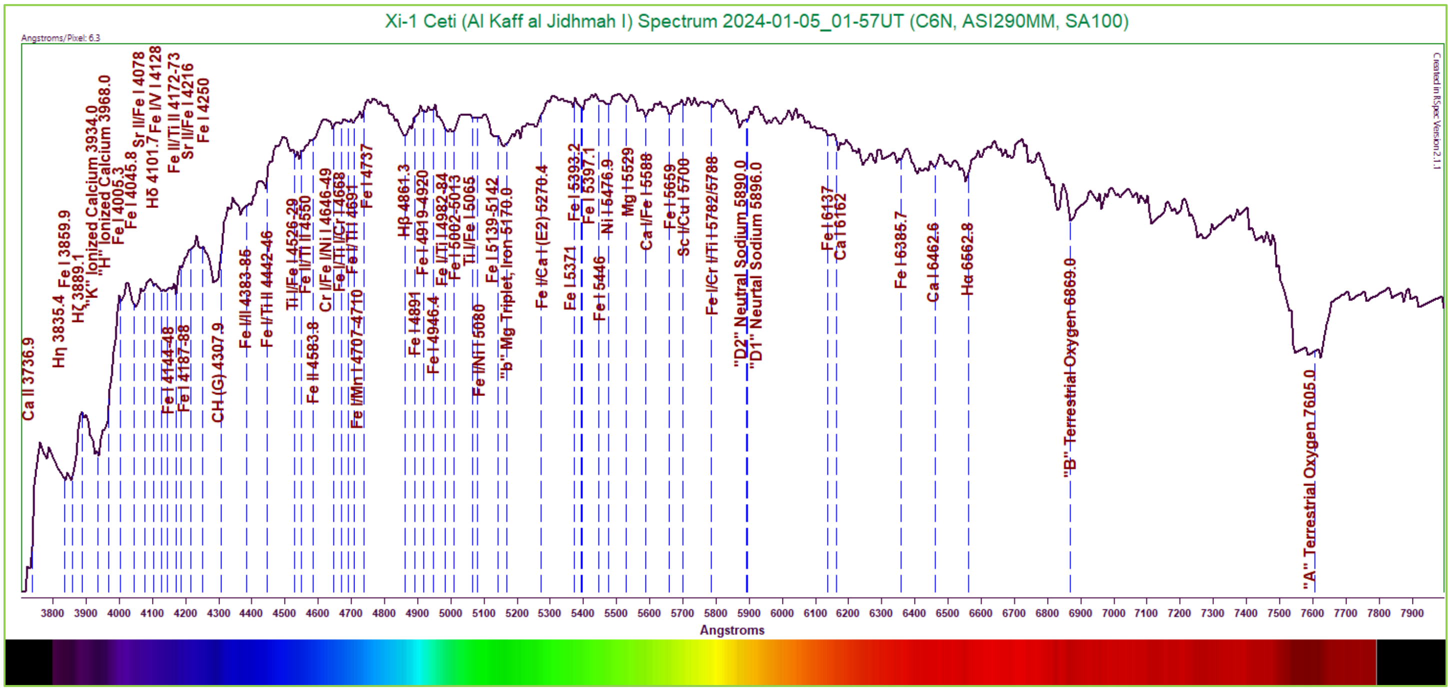

Figure 13: Xi-1 Ceti (Al Kaff al Jidhmah I) Spectrum (6.3 Angstroms/pixel)
Capture Details 13: Exposure 347ms, Gain 175, 20% of 1046 frames stacked

Again, we are presented with a very busy spectrum. The hydrogen Balmer lines that are visible are weakened, which is expected. The calcium H and K lines are very strong again here. The CH (G) band is easily recognizable, as well. The magnesium triplet is also identifiable, sitting at the bottom of a trough in the continuum. The sodium doublet is weak in this one. At the extreme low end of the wavelength scale, the calcium line at 3736.9 Angstroms is evident by a tiny bump in the continuum line. Above it, however, the Hη and Fe I lines are combining to create a significant valley. Once more, we see numerous other lesser absorption lines spread throughout the continuum, including lots of iron, strontium, titanium, chromium, nickel, magnesium, calcium, and scandium. The curve of the spectrum also indicates a star slightly earlier than that of Nu Ceti previously.

We will once again employ Wien's Law to obtain a temperature estimate. As with the last star in the survey, it is a bit difficult to visually estimate the peak energy wavelength with any accuracy. The best guess seems to place this value at 5507 Angstroms. Using this value, our calculation yields a temperature of 5262K. The currently accepted temperature of the star is 5184K[2]. Considering the uncertainty is guessing the peak energy wavelength, our calculation is pretty close!

ξ-2 Ceti

Xi-2 Ceti, also called Al Kaff al Jidhmah II, is classified as a very late B-type star[1]. This one should look quite different from most of our recent stars, showing a much higher temperature and demonstrating strong hydrogen Balmer lines.

The finished spectrum is below:

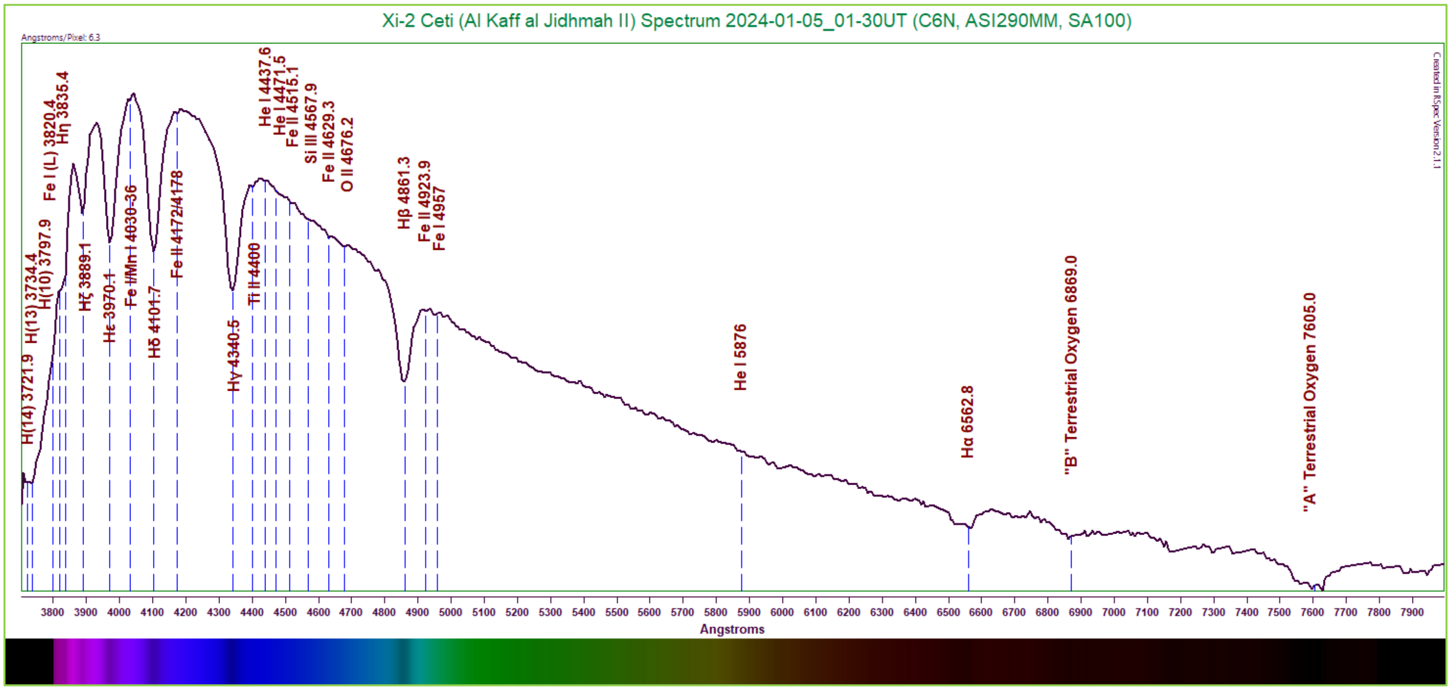

Figure 14: Xi-2 Ceti (Al Kaff al Jidhmah II) Spectrum (6.3 Angstroms/pixel)
Capture Details 14: Exposure 369ms, Gain 199, 25% of 822 frames stacked

Here we can see the typical very late B-type or very early A-type curve. The hydrogen Balmer lines are clear and strong. We can see the Fe I (L) line at 3820.4 combining with the Hη line to produce a sizeable step in the continuum. A very small iron/manganese line is visible at 4030-36 Angstroms, as well as an ionized iron at 4172/4178 Angstroms. Between the Hγ and Hβ lines we observe a series of tiny absorptions from helium, iron, silicon, and oxygen. Two more very faint iron line lies just above the Hβ absorption.

Using Wien's Law, we will estimate the temperature. However, since this is an earlier star, we can expect our estimate to fall short. Accepting a peak energy wavelength of 4044 Angstroms, we calculate a temperature of 7166K. The established temperature of the star is listed as 10630K[2].

o Ceti

Omicron Ceti, more commonly called Mira, is a middle to late M-type pulsating variable star. It is the prototype of a class of variables called Mira variables. The star fluctuates between the middle and late M-types as it pulsates. We should see a spectrum with plenty of TiO bands proudly standing out along the continuum. The curve should also represent a very cool star.

The spectrum follows:

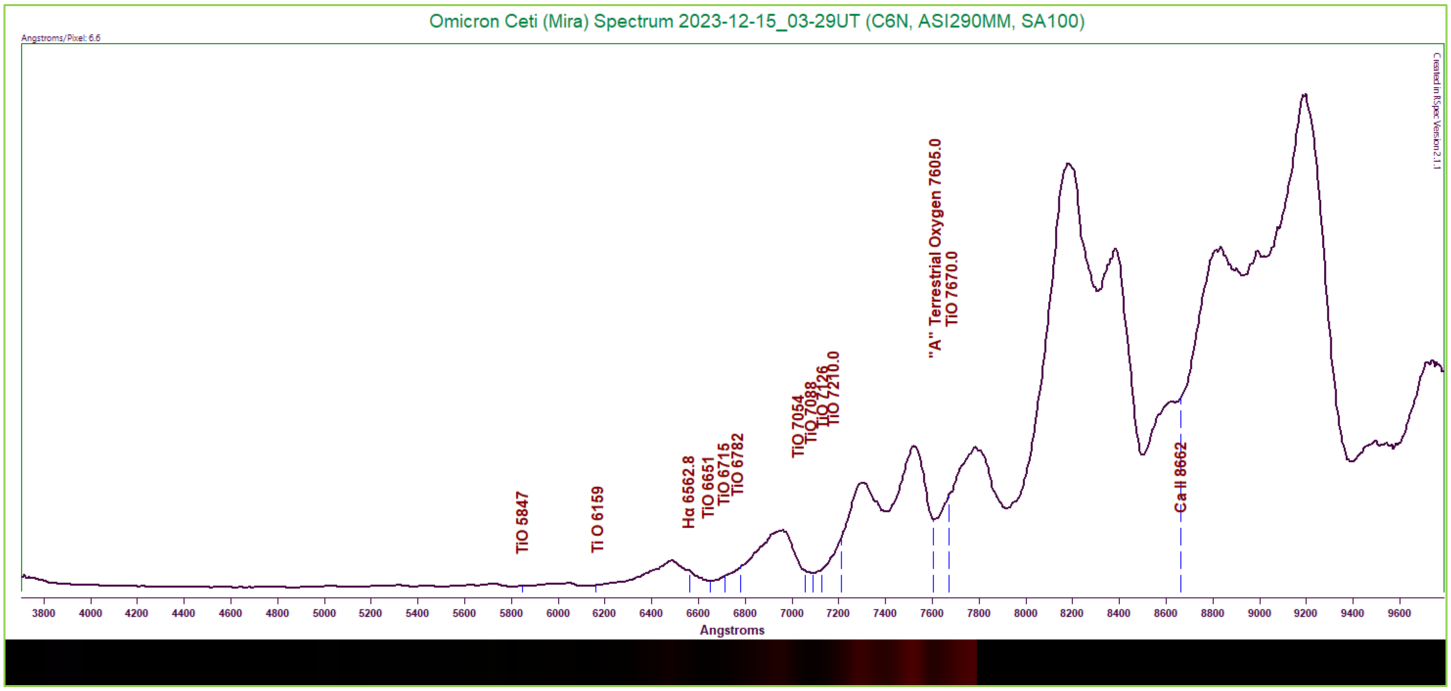

Figure 15: Omicron Ceti (Mira) Spectrum (6.6 Angstroms/pixel)
Capture Details 15: Exposure 3s, Gain 196, 80% of 80 frames stacked

This one provided some new challenges along the way. When performing the capture, the spectrum just looked…off. It looked wider and more expansive then the others. Several repeat captures produced the same weird results, however. Could this be due to the dimness of the target? I couldn’t see how that could be. Analyzing the spectrum also proved quite problematic—until I realized that this star generates its peak energy in the infrared range! At first, I couldn’t seem to nail down a good absorption to use as a fine calibration point. Plus, considering the dimness of the target, the spectrum provided little detail to go on. Finally, I was able to nail down what I was looking at (at least, I hope).

And this one certainly looks very different. In order to ascertain the peak energy wavelength for later estimating the temperature, the wavelength range had to be extended on the long (right) end. Some bleedover from the second order spectrum is certainly reflected here, but the levels on the first order short wavelength range were very low, so the contamination should prove minimal. The peak of the curve is far into the low wavelength region, indicating the expected cool temperature. The lack of features in the lower third of the wavelength range is a testament to the difficulty of the capture.

The first TiO bands appear at 5847 and 6159 Angstroms, showing only the smallest of dips in the continuum, and are possibly false identifications due to their weakness. The next group, at 6651, 6715, and 6782 Angstroms carve a generous scoop out of the spectrum. The next four accomplish the same, between 7054 and 7210 Angstroms. Hα shows a tiny emission at 6265.8 Angstroms. The Ca II absorption at 8662 is represented by a large bump in the spectrum. Many deep absorptions are not labeled, as the reference materials used do not include much information about the infrared region of spectral curves.

The main goal with extending the wavelength range was to ascertain a peak energy wavelength to use for estimating the temperature. Using a peak energy wavelength of 9197 Angstroms, Wien's Law results in a temperature of 3151K. The star's temperature fluctuates as it pulses, between 2918K and 3192K[2].

π Ceti

Pi Ceti, referred to as Sadr al Kaitos IV, is a late B-type star[1]. We should see pretty strong hydrogen Balmer lines here, hopefully with a helium line or two.

The processed spectrum is below:

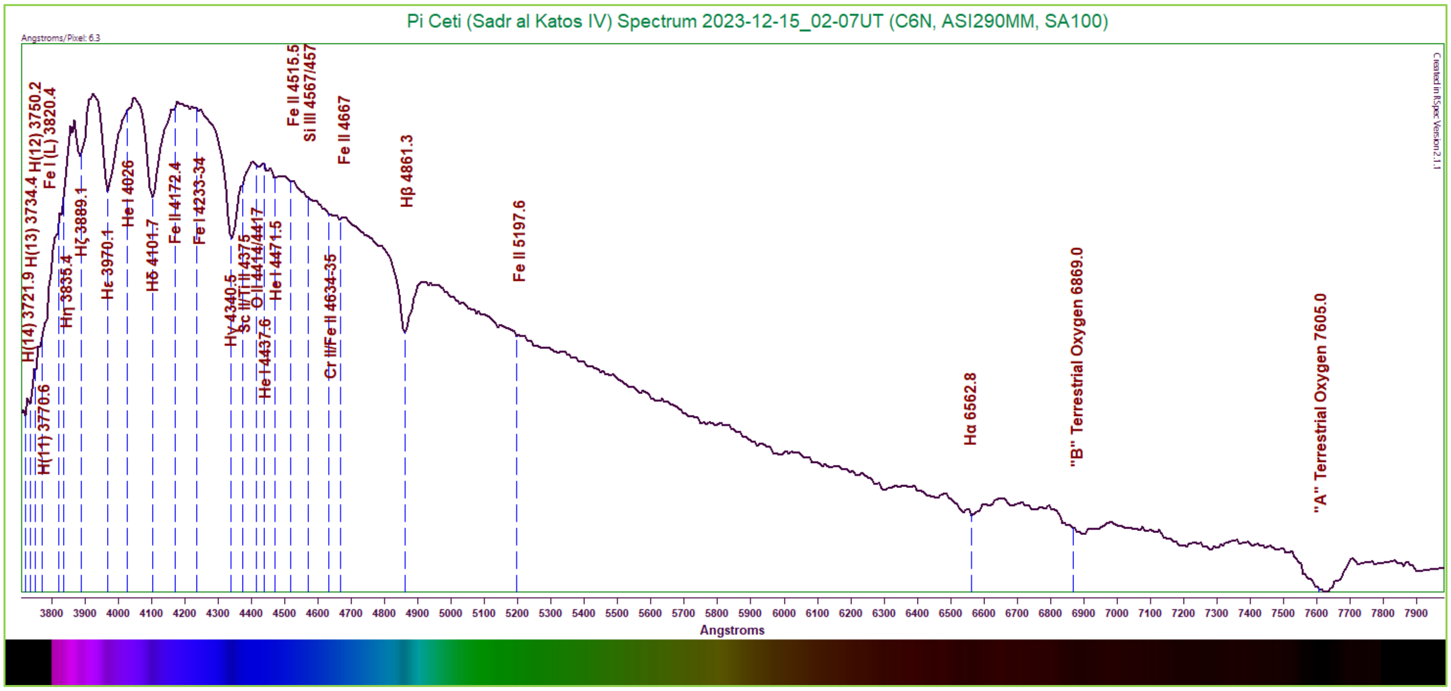

Figure 16: Pi Ceti (Sadr al Kaitos IV) Spectrum (6.3 Angstroms/pixel)
Capture Details 16: Exposure 713, Gain 163, 60% of 343 frames

Indeed this does look like a B-type star of the later type. The hydrogen Balmer lines are present and pretty easily recognized, though not overly strong. The Fe I (L) line at 3820.4 Angstroms appears distinct from the Hη line, the two forming consecutive little hiccups in the continuum. Helium lines do appear, at 4026, 4437.6, and 4471.5 Angstroms. These are all weak, but obviously separated from the continuum. A small number of additional very faint metals can be seen, including iron, scandium, oxygen, silicon, and chromium.

Employing Wien's Law, we will calculate the effective temperature of the star. Since this is a B-type star, however, we can be sure that our estimate will be entirely too low. Using a visually estimated peak energy wavelength of 3925 Angstroms, the calculation yields a result of 7383K. The established temperature of the star is 12900K[2].

ρ Ceti

Rho Ceti, also called Sadr al Kaitos I, is classified as a very early A-type star[1]. We should see deep, broad hydrogen Balmer lines on this one, perhaps with a few very faint metals sprinkled in.

The processed spectrum follows:

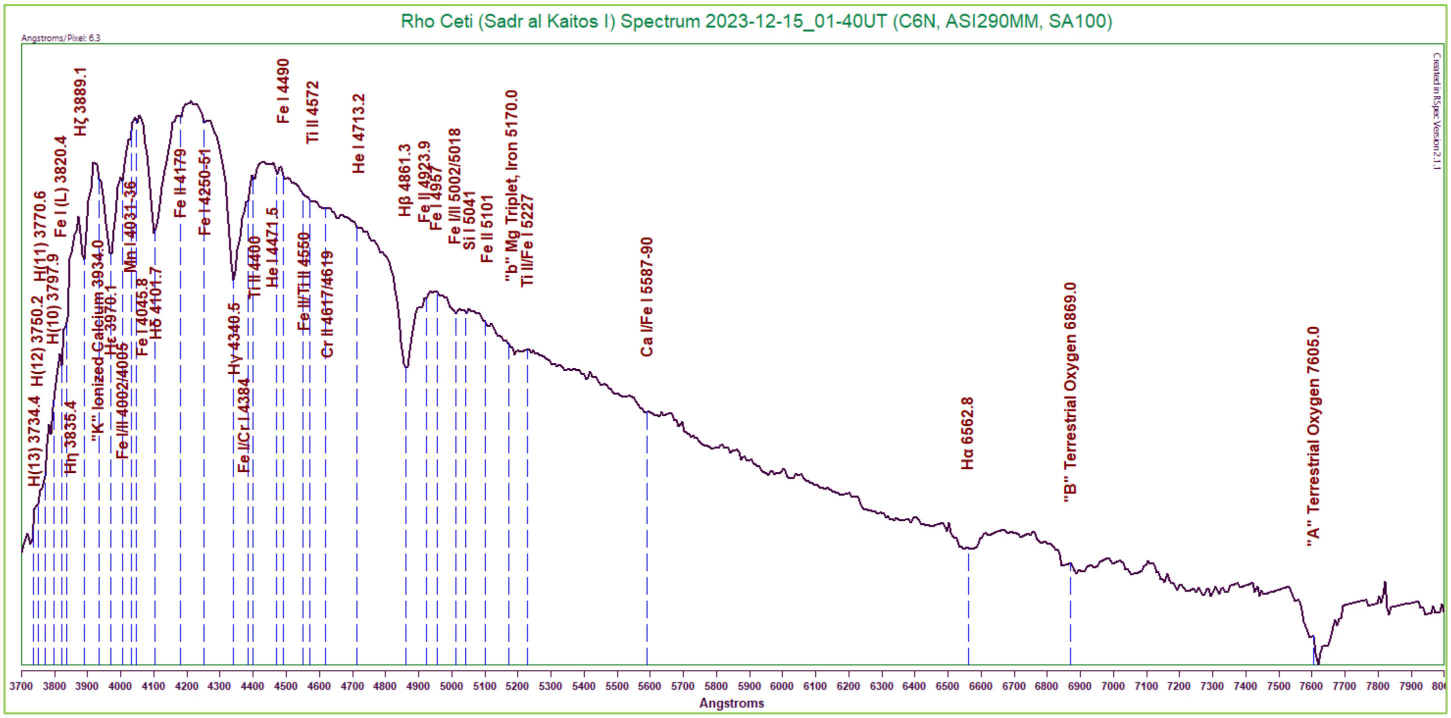

Figure 17: Rho Ceti (Sadr al Kaitos I) Spectrum (6.3 Angstroms/pixel)
Capture Details 17: Exposure 612ms, Gain 181, 55% of 403 frames stacked

The shape of this spectrum curve and its major features matches what we expect from an early A-type star. The hydrogen Balmer lines are strongly and easily identified. The Fe I (L) line at 3820.4 Angstroms and the Hη line above it are separate and distinct here, though both are weak. We see two helium lines, one at 4471.5 Angstroms and another at 4713.32 Angstroms. The calcium K line at 3934 Angstroms is emerging, making itself known by a small bump on the lower side of the Hε absorption. The magnesium triplet at 5170 Angstroms is notable, but also very weak. A good number of other faint metal lines are accounted for, including iron, manganese, titanium, chromium, siliscon, and calcium.

Wien's Law will again be used to estimate the star's temperature. Again, since this is an earlier-type star, our estimate can be expected to be too low. Using an estimated peak energy wavelength of 4214 Angstroms, we calculate a temperature of 6877K. The listed temperature for the star is 8905K[2]. The estimate does fall short by quite a bit.

σ Ceti

Sigma Ceti, called Sadr al Kaitos II, is regarded as a middle F-type star[1]. We can expect the curve to reflect a cooler star than Rho Ceti above, with a much greater number of metal lines apparent.

The final spectrum follows:

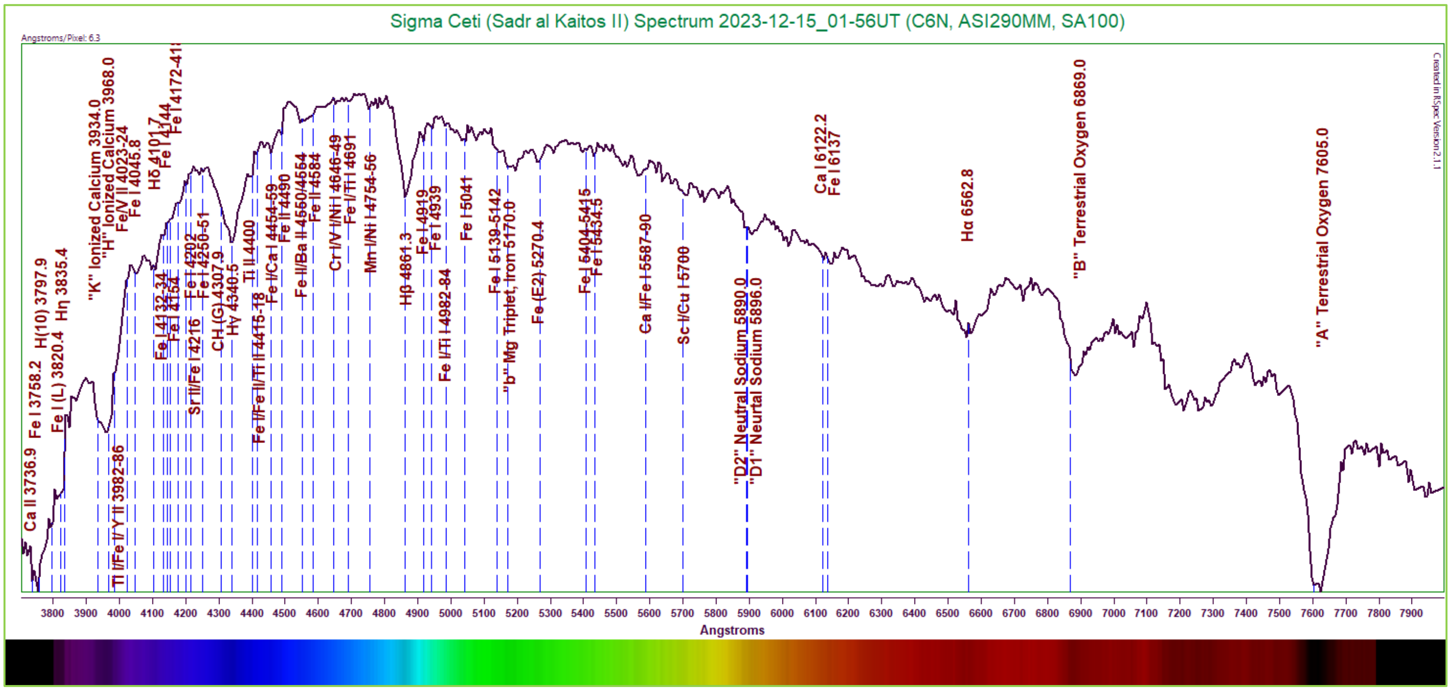

Figure 18: Sigma Ceti (Sadr al Kaitos II) Spectrum (6.3 Angstroms/pixel)
Capture Details 18: Exposure 713ms, Gain 184, 35% of 428 frames stacked

This is another very interesting one. The spectrum curve reflects a star that is still somewhat hot, but also displays a great number of metal lines. The hydrogen Balmer lines are still pretty strong, except for the Hε line, which has been subsumed by the calcium H line. Together with the K line, the two cut quite a deep gouge into the continuum. The Fe I (L) line is again combined with the Hη line to create a flat step at 3820.4-3853.4 Angstroms. The CH (G) line is also visible as a subtle bump on the lower side of the Hγ line. The magnesium triplet makes a showing, but it is a bit weak. The sodium doublet at 5890-96 Angstroms is also weak, but easily recognized. A large number of less prominent metal lines are marked, including titanium, iron, strontium, chromium, manganese, calcium, and scandium. This is indeed a busy spectrum.

Using Wien's Law, we will calculate an effective temperature for the star. Using a visually estimated peak energy wavelength of 4710 Angstroms, we obtain a temperature of 6152K. The listed temperature for the star is 6527K[2]. In this case, our estimate is just a bit too low, but not altogether horrible.

τ Ceti

Tau Ceti, called Al Naymat II, is classified as a late G-type star[1]. This being the case, we should expect to find a star a little cooler than our Sun displaying a lot of metal lines, particularly iron.

The processed spectrum is presented here:

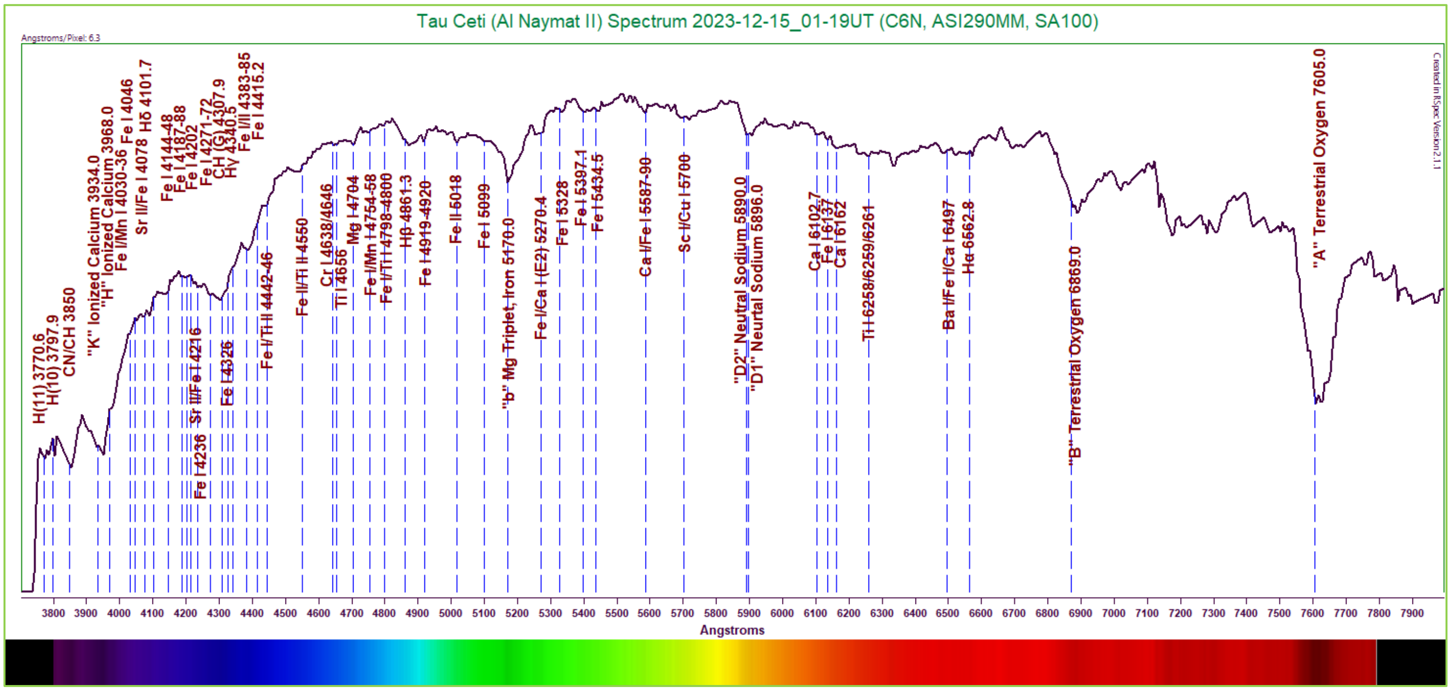

Figure 19: Tau Ceti (Al Naymat II) Spectrum (6.3 Angstroms/pixel)
Capture Details 19: Exposure 296ms, Gain 146, 20% of 1014 frames stacked

This curve does show features of a G-type star, with the curve peaking in the central region. As expected, the hydrogen Balmer lines that are visible are notably weakened. The CN/CH absorption at 3850 Angstroms appears very clearly. The calcium H and K lines are cutting pretty deeply into the continuum. The CH (G) band is also prominent at 4307.9 Angstroms. The magnesium triplet at 5170 Angstroms is a nice, sharp cut, followed by a good reduction for the Fe (E2) line above it. The sodium doublet at 5890-96 is more subdued, but still easily recognized. In addition, numerous other fainter metal lines are marked, including lots of iron lines, strontium, chromium, titanium, magnesium, calcium, scandium, and barium.

Using Wien's Law, we will again ascertain a temperature estimate. The peak energy wavelength appears to lie around the 5518 Angstroms mark. Using this value, we calculate a temperature of 5252K. The currently accepted temperature of the star is 5320K[2]. As we can see, for this cooler star our estimate is fairly close.

Conclusion

This was a big one, with a good number of dimmer stars. Apart from the confusion during the capture and analysis of Mira, the process was not too bad—save for the time required to capture and examine 19 stellar spectra! A great number of G- and K-type stars seem to be among this sampling, which provided great opportunities to hone my line identification skills.

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