Spectral Analysis of the Constellation Stars of Andromeda (The Chained Maiden)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Andromeda. 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 evening of November 14, 2023 (EST). Additional specifics for each capture are included in the header 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 in this header is 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 Andromedae

Alpha Andromedae, known as Alpheratz, is listed as a binary variable star whose primary is a late B-type star[1]. The close secondary, an early-A-type star, should contribute very little to the spectrum, if anything at all. We can expect to see pretty strong hydrogen Balmer lines here, with perhaps a couple traces of helium.

The processed spectrum is as follows:

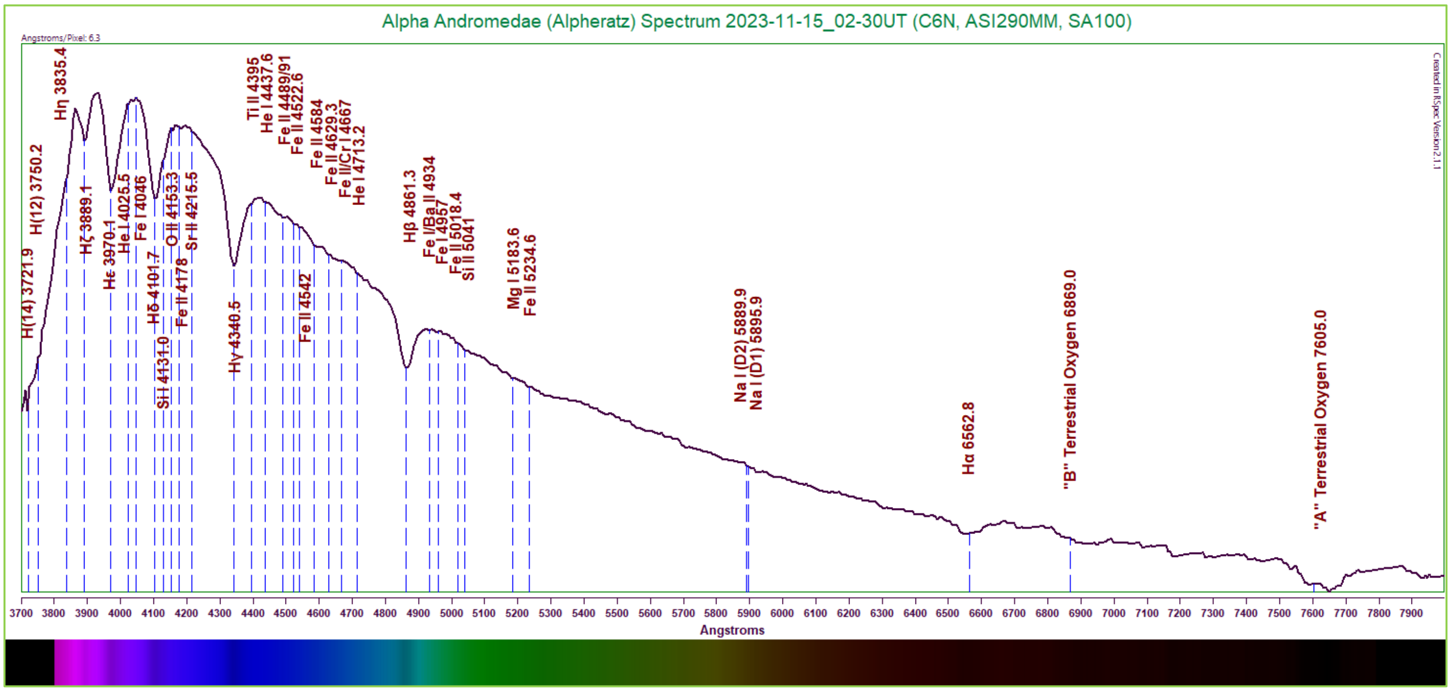

Figure 1: Alpha Andromedae (Alpheratz) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 256ms, Gain 80, 35% of 763 frames stacked

The spectrum is indeed interesting. The shape of the curve matches a late B-type or very early A-type star, with a high temperature. Most of the hydrogen Balmer lines are strong. The Hη line, however, is extremely faint and only causing a slight dip in the continuum. The sodium doublet at 5890-96 Angstroms is marked, but the absorption is extremely slight, if really readable at all, so this is dubious at best. We can see three extremely faint helium lines, at 4025.5, 4437.6, and 4713.2 Angstroms. These are definitely questionable, as their influence on the spectrum curve is slight. The silicon line at 4131 Angstroms is reflected in the slightest deformity on the higher end of the Hδ absorption. Other metals are also marked, but again these only show extraordinarily weakly. These include a good amount of neutral and ionized iron, oxygen, strontium, titanium, silicon, and magnesium.

Using Wien's Law, we will attempt to ascertain a rough estimate of the star's temperature. Being an early-type star, however, we should expect our estimate to be woefully short. Using an estimated peak energy wavelength of 3927 Angstroms, Wien's Law indicates a temperature of 7379K. The listed temperature for the star is 13800K[2]. As expected, our estimate is much too low.

β Andromedae

Beta Andromedae, better known as Mirach, is classified as a very early M-type star[1]. We can expect a curve representing a much cooler star, with numerous metals and TiO bands boldly on display.

The processed spectrum is presented below:

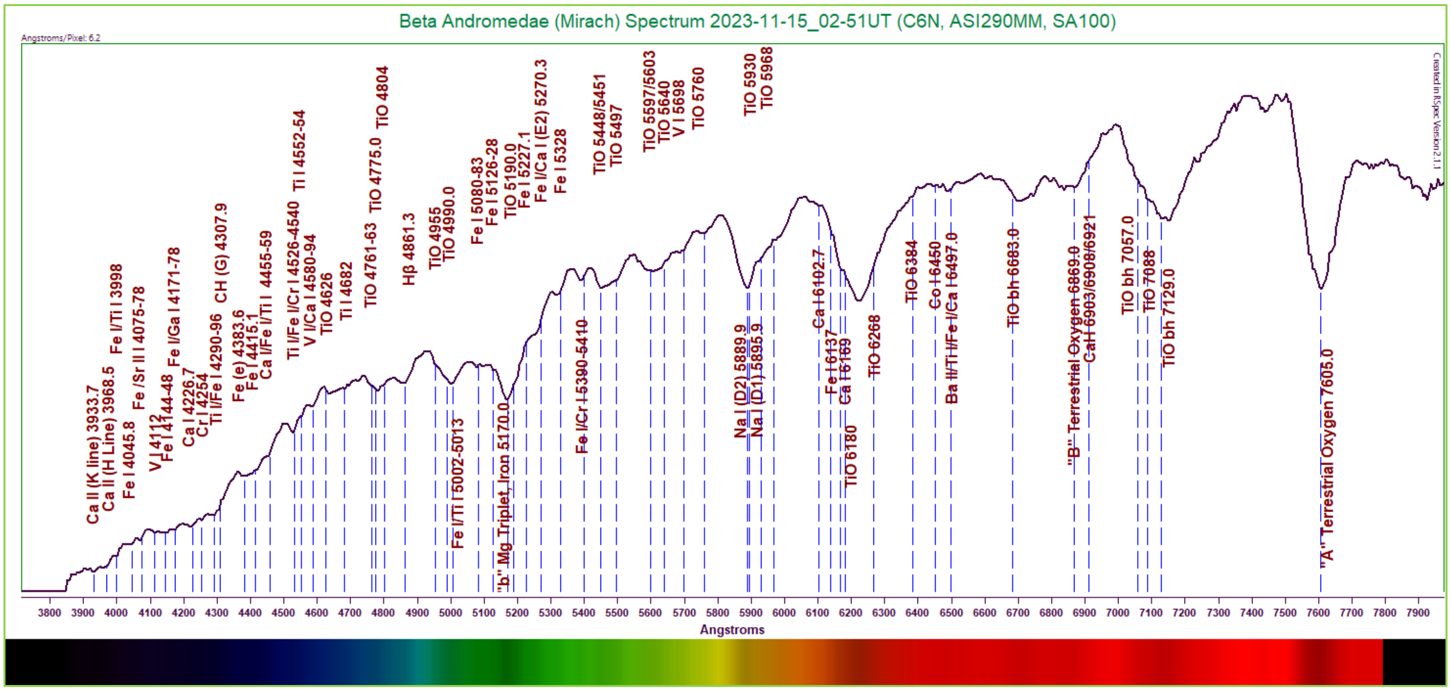

Figure 2: Beta Andromedae (Mirach) Spectrum (6.2 Angstroms/pixel)
Capture Details 2: Exposure 318ms, Gain 68, 75% of 580 frames stacked

Consistent with our expectations, this curve shows many of the expected features—and a shape consistent with a cooler star. The only notable hydrogen Balmer line is the Hβ line, which appears weakened. The calcium H and K lines at 3933-3968 Angstroms also appear very weak. The CH (G) absorption at 4307.9 Angstroms is also weakened, though a bit more prominent. By contrast, the magnesium triplet at 5170 Angstroms is very deep. It sits alongside some iron lines and a TiO line that contribute to its breadth and strength. The sodium doublet at 5890-96 Angstroms is also quite pronounced, and is also enhanced by the adjacent TiO lines above it. We see numerous other TiO lines in this spectrum, ranging from obvious to very faint. Additional faint metal lines are scattered throughout, including iron, vanadium, calcium, chromium, titanium, barium, and one tiny CaH feature at about 6912 Angstroms. This spectrum shows a lot of detail, and the noise levels are low enough to make smaller lines readable.

Using Wien's Law, we will ascertain a temperature estimate. Being a late-type star, our estimate should be much nearer the mark than that for Alpheratz above. Using an estimated peak energy wavelength of 7521 Angstroms, we calculate a temperature of 3853K. The currently accepted temperature of the star is 3842K[2]. Our estimate is indeed extremely close!

γ-1 Andromedae

Gamma Andromedae, known as Almach, is a close double star. The equipment used was just barely able to separate the two for analysis, so we will consider each in turn.

Gamma-1 Andromedae is classified as an early K-type star[1]. We should expect a curve for a cooler star, but warmer than Mirach above. We expect to see lots of metals present throughout the spectrum.

The processed spectrum follows:

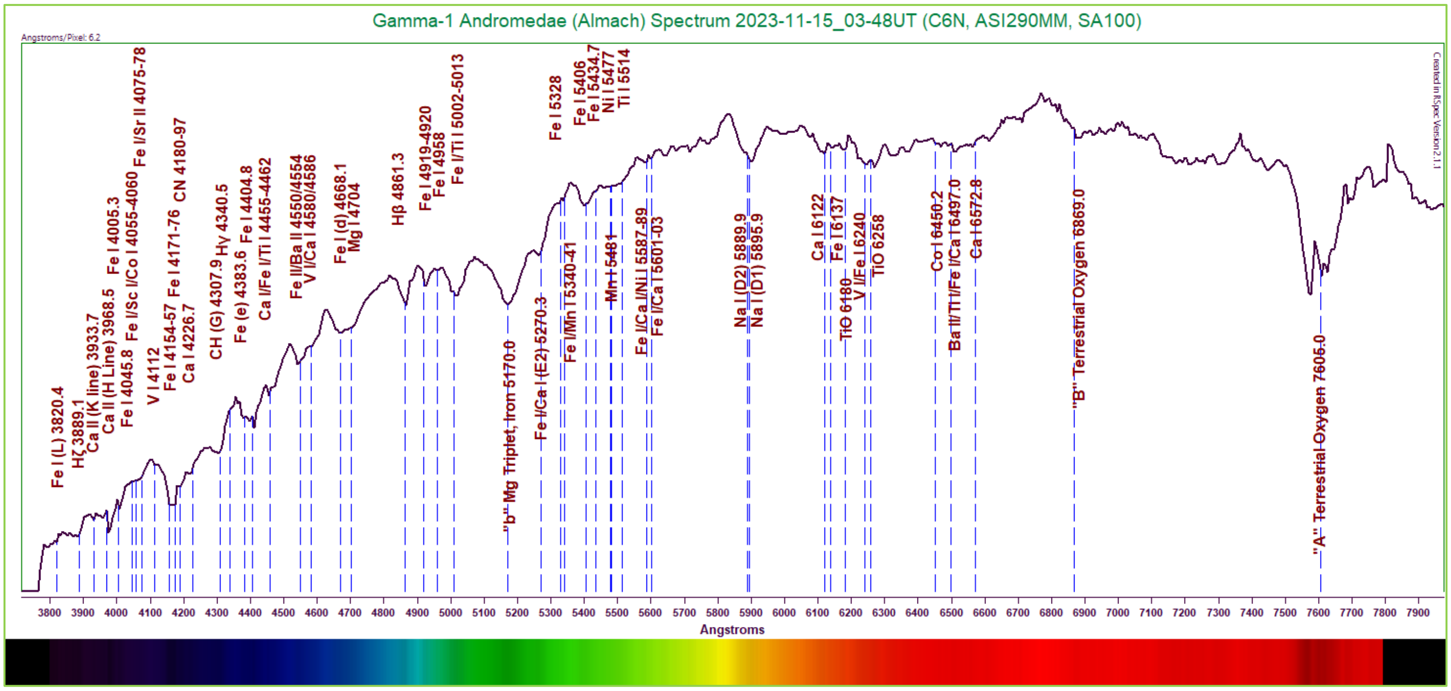

Figure 3: Gamma-1 Andromedae (Almach) Spectrum (6.2 Angstroms/pixel)
Capture Details 3: Exposure 274ms, Gain 101, 75% of 676 frames stacked

Here we can see another cooler star, this one showing a warmer spectrum than Mirach. A few of the hydrogen Balmer lines can be seen. Hζ carves out a nice dip at 3889.1 Angstroms near the lower wavelength region. Hγ presents only a minor alteration in the curve at 4340.5 Angstroms. Hβ is the strongest, cutting a nice, sharp spike out of the continuum at 4861.3 Angstroms. A very nice combined iron absorption presents itself in the 4154-4176 Angstrom range. The CH (G) band is visible, but it is not as deep. The magnesium triplet at 5170 Angstroms is clear, as is the Fe I/Ca I (E2) line above it at 5270.3 Angstroms. The sodium doublet is also well represented. Working our way toward the upper wavelength range, we can identify two very small emergent TiO lines at 6180 and 6258 Angstroms. They appear very weak since the star is not cool enough for them to become prominent. Numerous additional metal lines are spread throughout the spectrum, including iron, vanadium, CN, calcium, magnesium, nickel, manganese, cobalt, and barium.

Using Wien's Law, we will calculate an estimated temperature for the star. Using an estimated peak energy wavelength of 6780 Angstroms, we obtain a result of 4274K. The established temperature of the star is 4250K[2]. Very nice; our estimate is very close.

γ-2 Andromedae

Gamma-2 Andromedae is itself a double star, consisting of a very late B-type star and a very early A-type star[1]. These should produce similar features, and should not cause much in the way of inconsistencies in our low-resolution spectrum. We can expect strong hydrogen Balmer lines here and a curve peaking nearer the low wavelength range.

The processed spectrum is presented here:

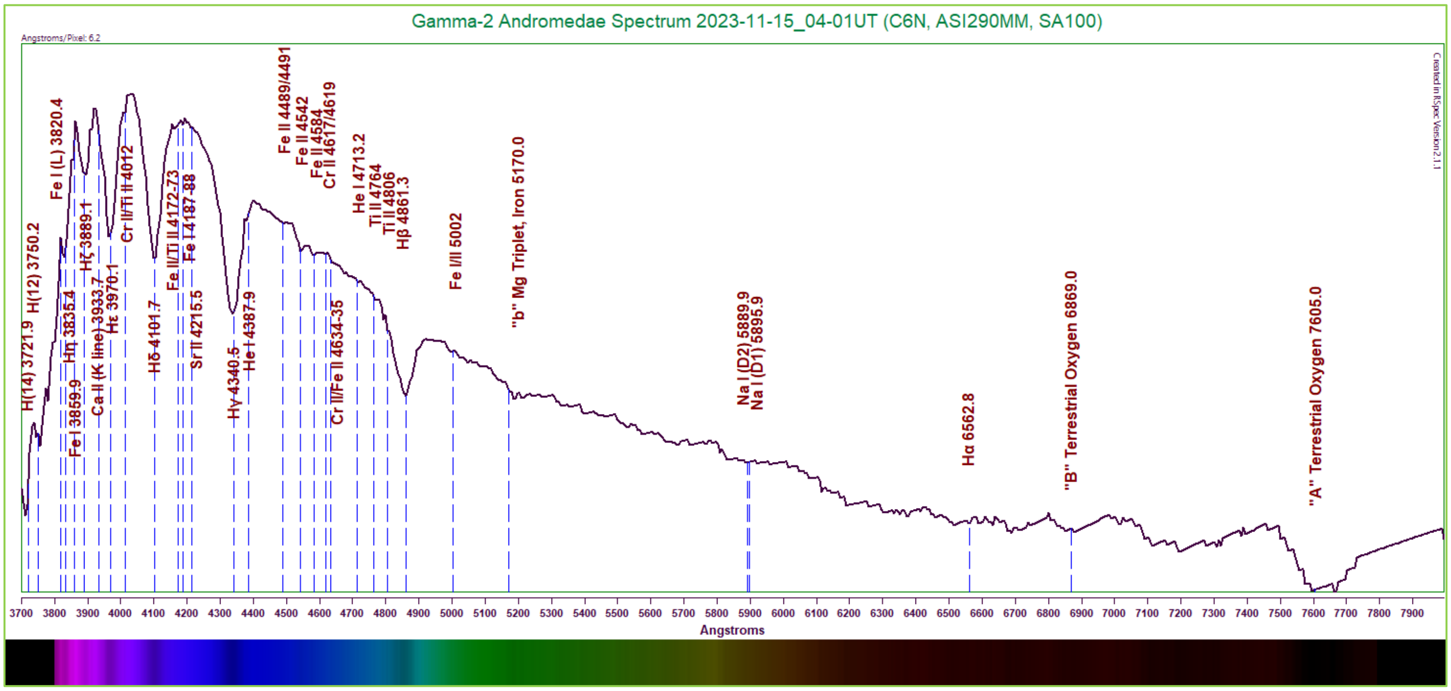

Figure 4: Gamma-2 Andromedae Spectrum (6.2 Angstroms/pixel)
Capture Details 4: Exposure 1s, Gain 95, 100% of 182 frames stacked

As expected, we see a curve reflective of the anticipated type. The hydrogen Balmer lines are strong, except for the Hα absorption. This is due to the high noise levels in the upper wavelength region of the spectrum. The Fe (L) line at 3820.4 Angstroms is quite sharp sitting alongside the Hη line. The calcium K line is just beginning to emerge here, causing a very subtle dip on the lower side of the Hε line. The magnesium triplet is weak here, but still causing a dip in the continuum. Above this point, the noise becomes considerable, but the sodium doublet at 5890-96 Angstroms appears to cause a scoop out of the spectrum as well. Two very faint helium lines can be seen at 4387.9 and 4713.2 Angstroms. Along the lower half of the wavelength range, we can observe several additional faint metal lines. These include iron, chromium, strontium, and titanium.

Wien's Law will again be employed to obtain a rough estimate of the temperature. Again, since this spectrum is for early-type stars, we can expect our estimate to be far too low. Using a peak energy wavelength of 4037 Angstroms, we obtain a temperature of 7178K. No readily available estimate of its actual temperature was at hand, but it can be safely estimated at 10,000K or more.

δ Andromedae

Delta Andromedae is a multiple-star system with an early K-type primary[1,2]. In this case, the primary star should dominate the spectrum. Based on its type, we should expect a star of lower temperature, with numerous metal lines visible.

The processed spectrum follows:

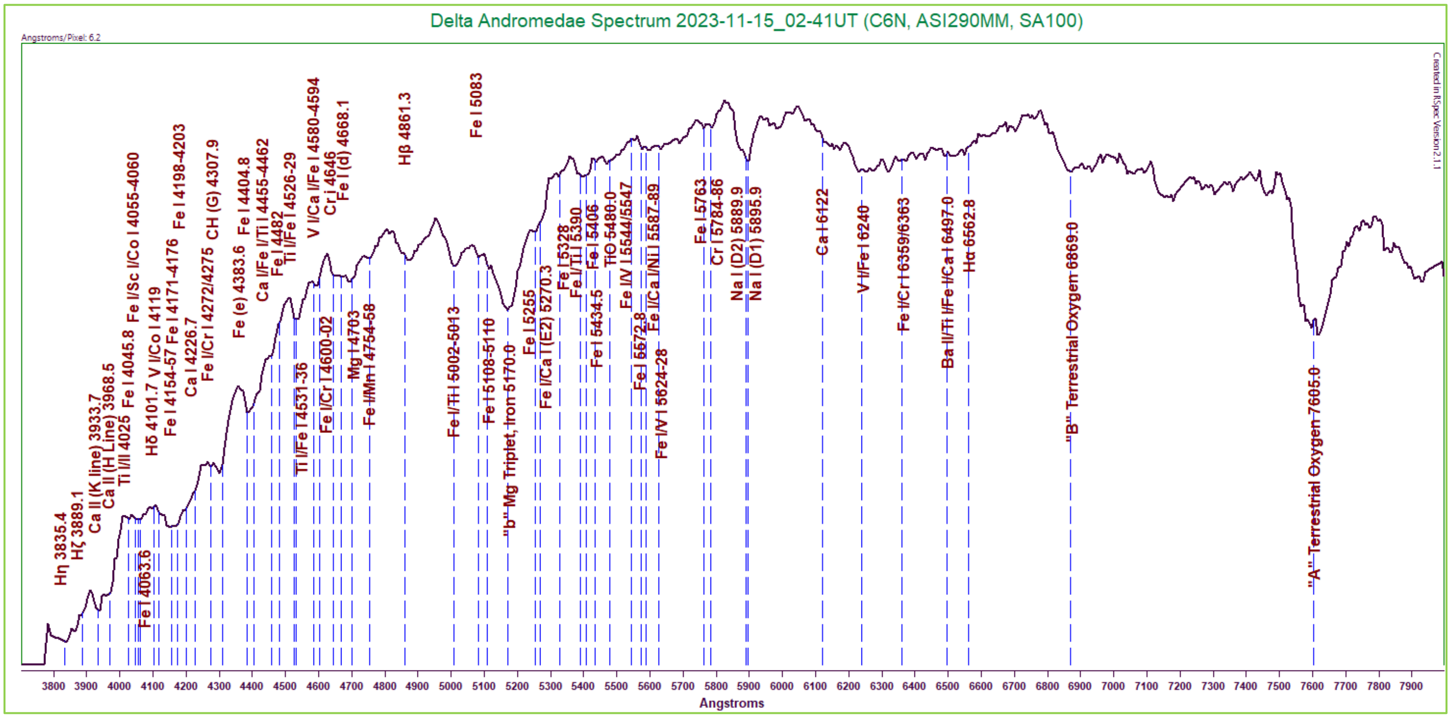

Figure 5: Delta Andromedae Spectrum (6.2 Angstroms/pixel)
Capture Details 5: Exposure 514ms, Gain 98, 80% of 363 frames stacked

This is indeed a very interesting result. Several hydrogen Balmer lines are visible here, ranging from very faint to moderately strong. The Hα line is marked, but the very subtle dip in the continuum and the noise in the vicinity make it difficult to be confident of the identification. It appears to be combined with the barium absorption at 6497 Angstroms to produce a shallow dip. The calcium H and K lines at the lower wavelength range are present, but not terribly strong. We can see a sizeable dip in the continuum being caused by a several combined iron lines in the 4154-4203 Angstroms range. The CH (G) band absorption is sharp and notable at 4307.9 Angstroms. The magnesium triplet at 5170 Angstroms gets the prize for the strongest absorption. Together with several flanking iron lines, it carves out a deep cut in the spectrum. The sodium doublet at 5890-96 Angstroms is also notable, and appears to be broadened on its low side. However, no positive identification of a contributing line could be made with the reference materials used. A great number of additional fainter metal lines are certainly present, as expected. These include titanium, iron, calcium, vanadium, magnesium, and chromium.

We will use Wien's Law to obtain a rough temperature estimate. However, in this case, the peak energy wavelength is not so clear. It appears that it perhaps lies in the region between 6520.0 and 6562.8 Angstroms. Taking an average value using the higher peaks flanking these two, we will use a value of 6409 Angstroms. With this, Wien's Law provides a resulting temperature of 4521K. The established temperature for the star is listed as 4315K[2]. Considering the uncertainties here, our estimate is actually pretty good.

μ Andromedae

Mu Andromedae is classified as a middle A-type star[1]. We can therefore expect a star of moderately high temperature with strong hydrogen Balmer features.

The spectrum is presented below:

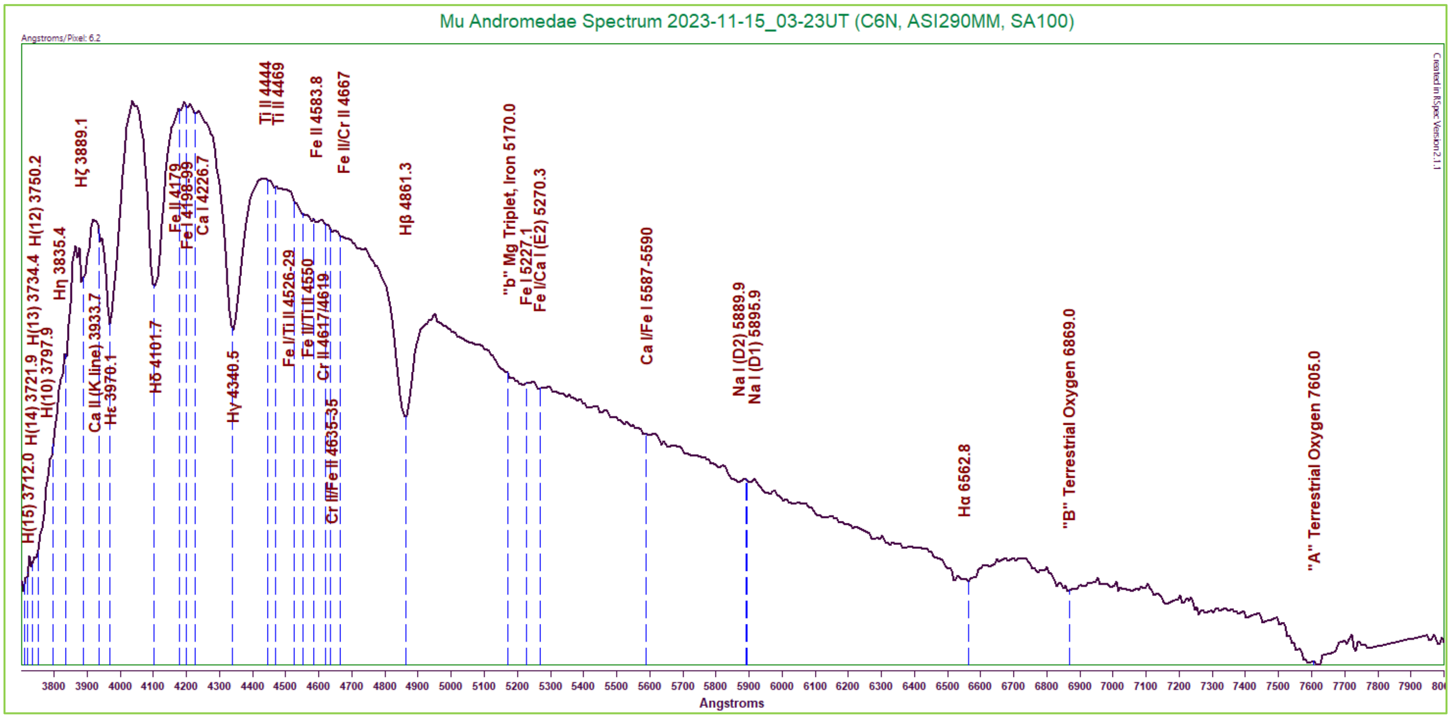

Figure 6: Mu Andromedae Spectrum (6.2 Angstroms/pixel)
Capture Details 6: Exposure 702ms, Gain 119, 75% of 262 frames stacked

The hydrogen Balmer absorptions on this spectrum appear very strong. The calcium K line at 3933.7 Angstroms is beginning to emerge, causing a small bump on the lower side of the Hε absorption. The magnesium triplet at 5170 Angstroms is quite weak, but still causing a noticeable dip in the continuum along with the adjacent iron lines. The sodium doublet is also noted, though it is weak enough to be a questionable identification. Several much fainter metal lines are noted, including iron, titanium, chromium, and calcium.

We will employ Wien's Law to obtain a rough temperature estimate. Since this is an early-type star, we can expect our estimate to come up short, though. Ascertaining the peak energy wavelength is again problematic. This time, the peak appears to occur between the peaks around the Hδ absorption. Using an estimated value of 4116 Angstroms, Wien's Law results in a temperature of 7040K. The established temperature for the star is 7959K[2]. Not too shabby for an A-type star!

ν Andromedae

Nu Andromedae is classified as a spectroscopic double star whose primary is a middle B-type star[1,2]. The primary should overshadow its companion in the spectrum. The hydrogen Balmer lines should still be identifiable, and we should expect to see a curve peaking at low wavelengths, indicative of a high temperature.

The spectrum follows:

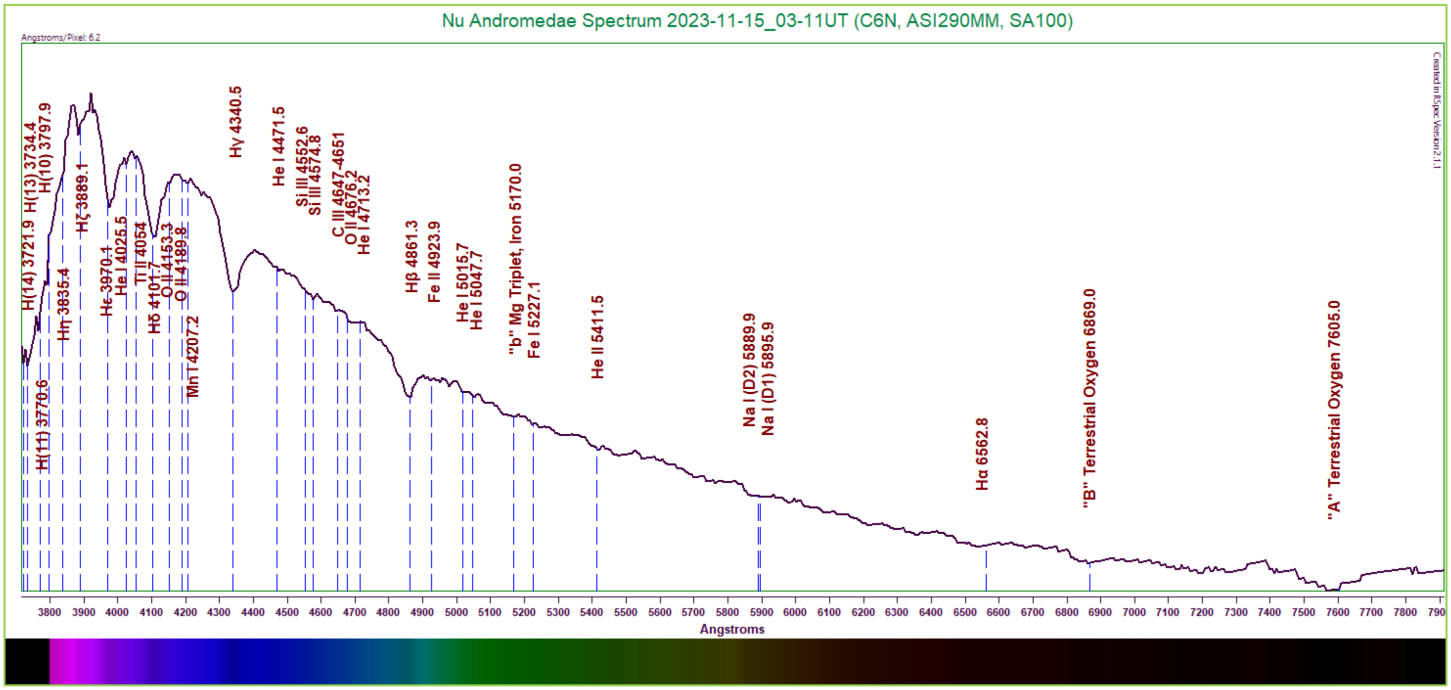

Figure 7: Nu Andromedae Spectrum (6.2 Angstroms/pixel)
Capture Details 7: Exposure 760ms, Gain 113, 80% of 324 frames stacked

The general shape of the curve does seem to match our expectations. The peak near low wavelengths reflects the star's higher temperature. The hydrogen Balmer lines are present, though not as strongly as in the case of A-type stars. The Hα absorption is notably weak. A small but interesting plateau appears in the 4676-4713 Angstroms range, apparently caused by the oxygen and helium lines in that area. The magnesium triplet at 5170 Angstroms seems to be present, but is extremely weak. This makes the identification suspect, but possible. The sodium D1 and D2 lines at 5890-96 Angstroms are more apparent, though still weak. A number of helium lines can seen throughout—at 4025.5, 4471.5, 4713.2, 5015.7, 5047.7, and 5411.5 Angstroms. The last of these is ionized helium. A few additional faint metals are marked, including titanium, oxygen, silicon, and carbon.

Wien's Law will again be used to estimate the temperature. Again, this being an early-type star, our estimate will certainly fall short. Using a peak energy wavelength of 3912 Angstroms, we calculate a temperature of approximately 7408K. The accepted temperature of the star is listed as 14851K[2]. Our estimate is only half of the established value.

Conclusion

I had been looking forward to processing the stars in this constellation, and the results seem to have turned out well. A decent variety of different star types are represented in this collection. I was particularly pleased with Delta Andromedae.

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