Spectral Analysis of the Constellation Stars of Vulpecula (The Fox)

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2024-08-05

Abstract

This paper will elucidate the spectral features of the main stars in the constellation Vulpecula. 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 July 25, 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 attempted last year, but continued difficulties were encountered resulting in the incorrect targets being captured several times. This run proved that the experience gained since then has enabled me to overcome that issue.

α Vulpeculae

Alpha Vulpeculae, better known Anser, is classified as a very early M-type star[1]. From this classification we can expect to see a spectrum showing a lot of TiO lines, but also some characteristics pertaining to later K-type stars as well. The energy distribution curve should show a peak near the upper end of the wavelength scale.

The processed spectrum is as follows:

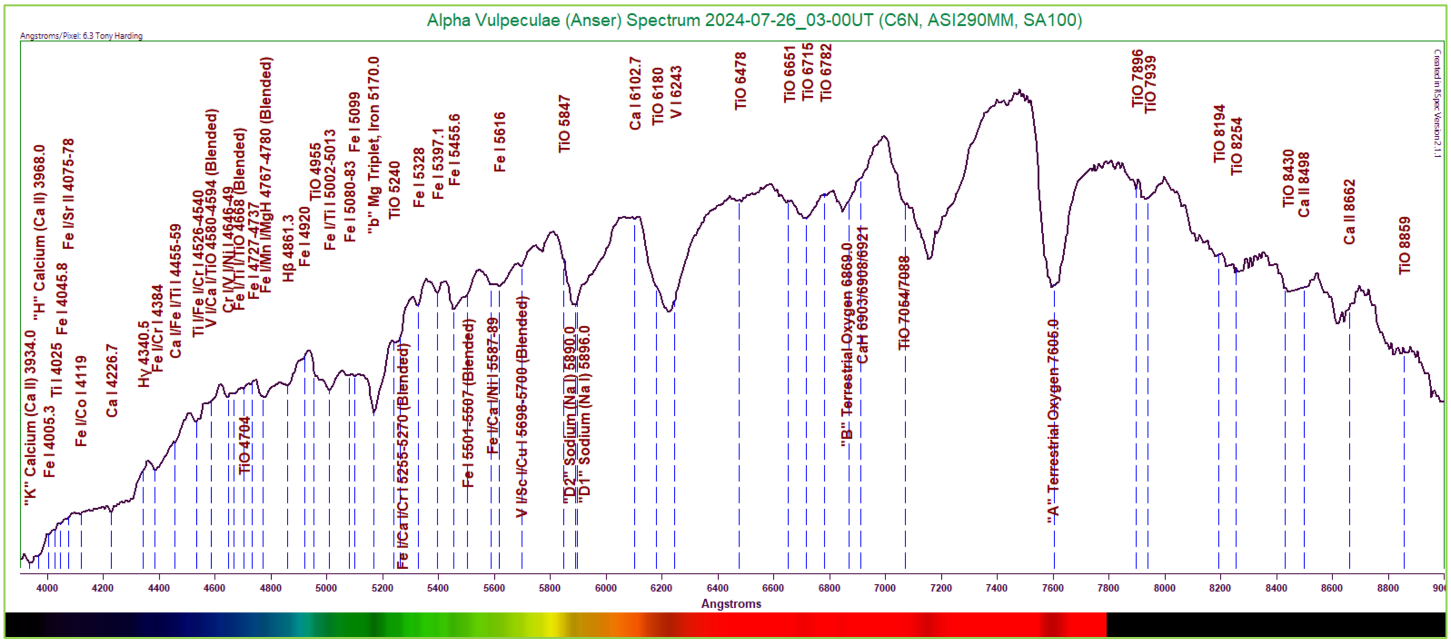

Figure 1: Alpha Vulpeculae) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 492ms, Gain 202, 50% of 736 frames stacked, Integration Time 181s

For this one, the scale has been adjusted from the normal 3700-8000 Angstroms to 3900-9000 Angstroms. This was done to accommodate the full spectrum, including extending into the near infrared. Only a couple of the hydrogen Balmer lines are visible, namely Hγ and Hβ. A good number of molecular TiO lines are visible, with even a couple being blends with elements. Two of the infrared ionized calcium lines are visible at 8498 and 8662 Angstroms, though the third one of the “set” is missing. The Ca II K and H lines at 3934 and 3968 Angstroms are visible at the extreme lower wavelength end. These are not strong, but still distinctly identifiable. The magnesium triplet at 5170 Angstroms is very strong and sharply defined here, carving a nice cut out of the continuum. The sodium doublet is also very strong at 5890-96 Angstroms. A couple additional molecular absorptions are visible besides the TiO bands, including MgH (blended with iron and manganese) at 4780 Angstroms, and CaH at 6903-6921 Angstroms. Other fainter metals present include iron, titanium, calcium, vanadium, and chromium.

Employing Wien’s Law, we will calculate an effective temperature. A visual inspection of the curve indicates the peak energy wavelength lies at 7482 Angstroms. Using this value, we arrive at an estimate of 3873K. The listed temperature for the star is 3690K[2]. Our estimate is off by less than 200K—not too shabby.

15 Vulpeculae

15 Vulpeculae is a mildly variable star classified as a middle A-type star[1]. This indicates we should see strong hydrogen Balmer lines, along with a smattering of metals. The shape of the spectrum curve should reflect a much hotter star than indicated for Alpha Vulpeculae above.

The spectrum for the star is presented here:

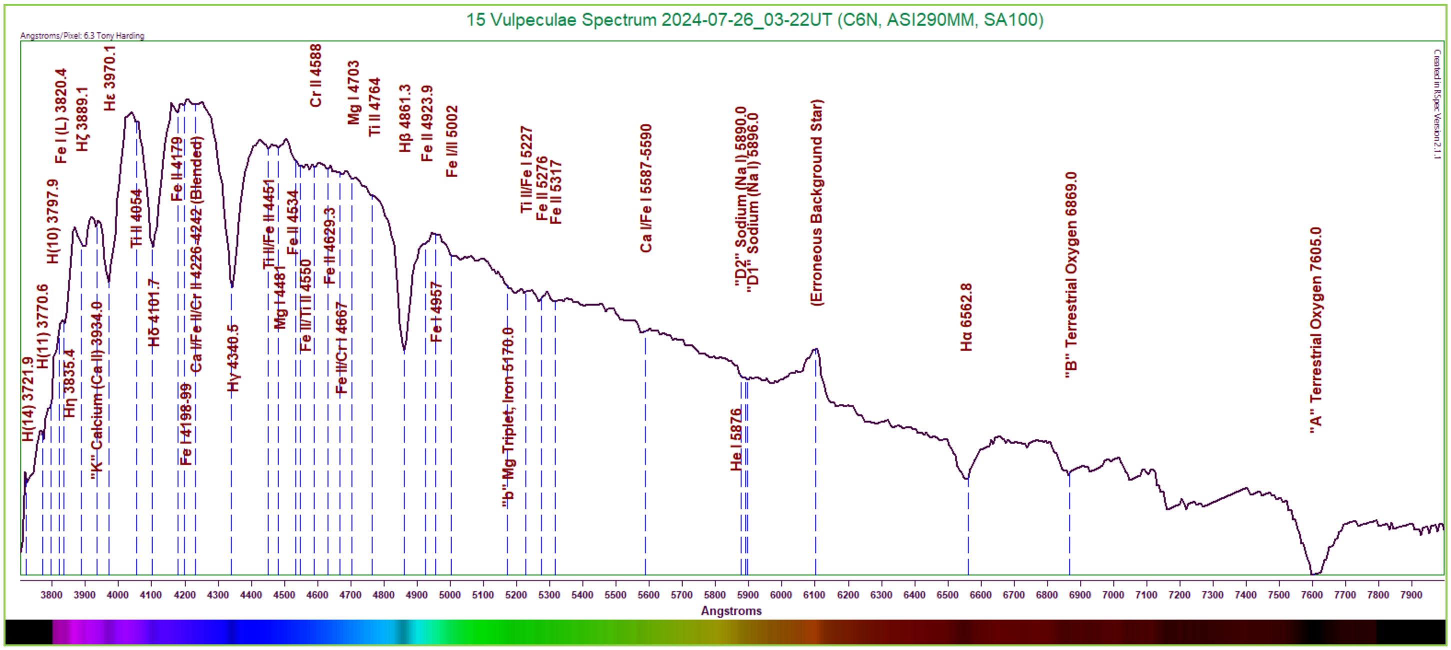

Figure 2: 15 Vulpeculae Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 800ms, Gain 166, 65% of 455 frames stacked, Integration Time 236s

We can see that the hydrogen Balmer lines are strong here, and very sharply defined. Even the Hα line is strong. The ionized calcium K line at 3934 Angstroms is present, but quite weak. Despite this, it is also sharply defined. The magnesium triplet at 5170 Angstroms is also visible, but it is weak and not well defined. The sodium D2 and D1 lines at 5890-96 Angstroms also appear weak and not at all sharp. However, the helium line just below them at 5876 Angstroms can be seen broadening the trough there. An anomaly at roughly 6102 Angstroms is seen, caused by an undetected field star during the capture. Other faint metals present include iron, titanium, calcium, and magnesium.

Using Wien's Law, we will calculate an effective temperature for the star. However, we must bear in mind that this is a middle A-type star, and our estimate will come out much too low. A visual examination of the spectrum curve indicates a probably peak energy wavelength of 4160 Angstroms. Using this value, Wien's Law returns an estimated temperature of 6966K. The listed temperature for the star is 8084K[2]. Indeed, our estimate is far too low.

8 Vulpeculae

This star forms a wide optical doublet with Alpha Vulpeculae, and was obvious in the view when capturing that previous target. A capture was made to add it to the report. 8 Vulpeculae is a classified as a very early K-type star[1]. We can expect to see a cooler star showing lots of metals and a curve representative of the lower temperature.

The finished spectrum is found below:

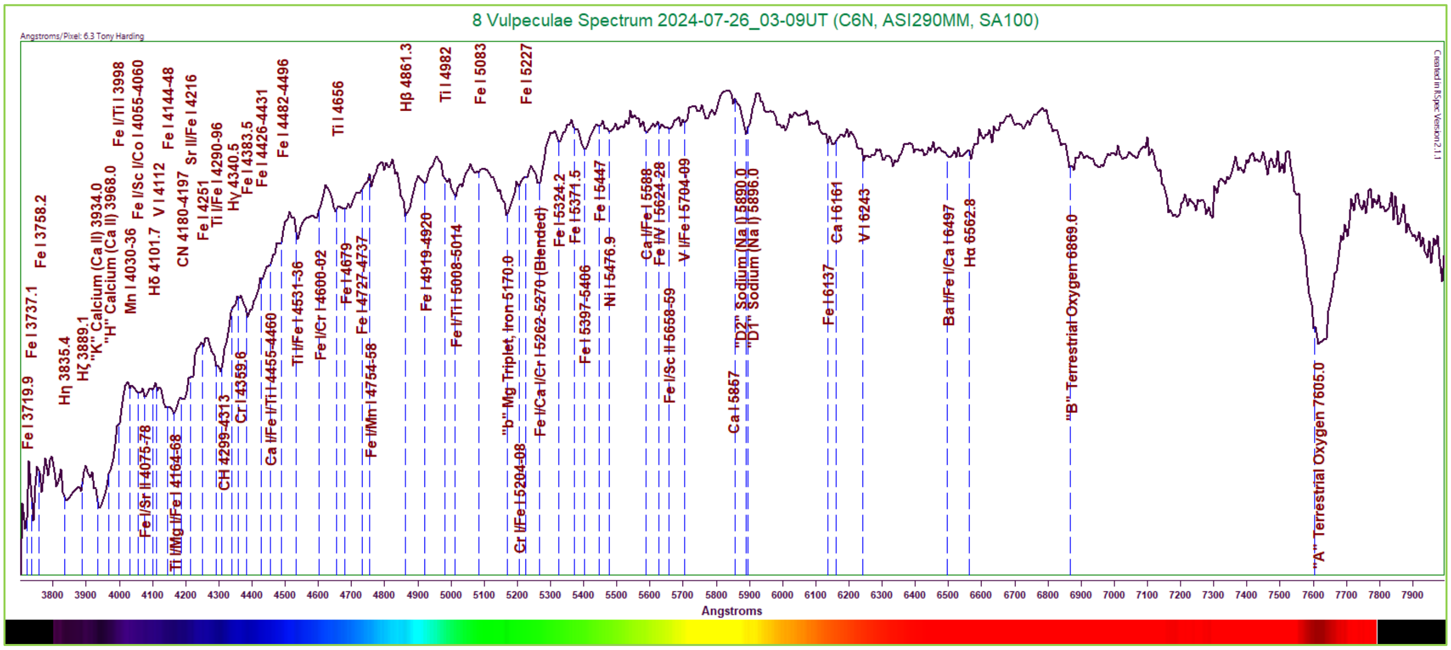

Figure 3: 8 Vulpeculae Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 2s, Gain 181, 25% of 179 frames stacked, Integration Time 89s

Though the spectrum appears a bit noisy, the major features are still identifiable. The hydrogen Balmer lines that are visible are only moderately strong at best. Three iron lines are noted at the extreme lower wavelength region, at 3719.9, 3737.1, and 3758.2 Angstroms. The Ca II K and H lines at 3934 and 3968 Angstroms are easily visible if not terribly strong. A nice trough at 4144-4197 Angstroms appears quite broad and deep; this is caused by iron and the CN molecule. The CH (G Band) absorption at 4299-4313 Angstroms is also quite strong, and is aided by the titanium/iron absorption just below it. The magnesium triplet at 5170 Angstroms is sharp and fairly deep. The sodium doublet at 5890-96 Angstroms is moderately strong and very sharp. Other fainter metals present include iron, manganese, vanadium, strontium, titanium, chromium, calcium, nickel, and barium.

Again employing Wien's Law, we will calculate an effective temperature for the star. From a quick visual inspection of the curve above, the peak energy wavelength appears to lie at approximately 5839 Angstroms. Plugging this value into Wien's Law, we obtain an estimate of 4963K. The currently listed value for the star's temperature is 4915K[2]. Our estimate is very close!

10 Vulpeculae

While slewing the scope toward 15 Vulpeculae earlier, this conspicuous star was noted. I swung back around to grab a spectrum. 10 Vulpeculae is believed to be a binary system, but the companion is not visible. The visible primary is classified as a late G-type star. We should therefore expect to see a star with lots of iron and a curve showing a tendency toward cooler temperatures.

The processed spectrum follows:

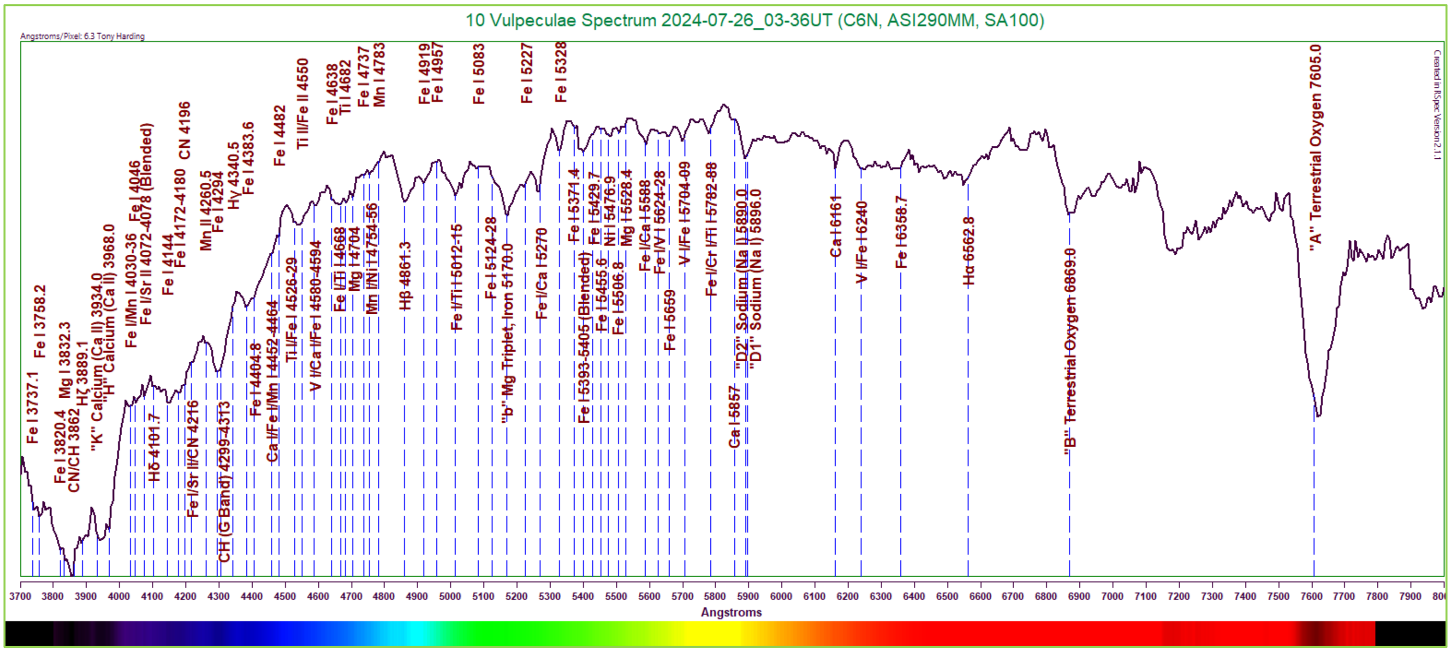

Figure 4: 10 Vulpeculae Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 2s, Gain 178, 35% of 175 frames stacked, Integration Time 122s

The curve represented above does appear to coincide with our expectations; the peak is near the center of the wavelength range. Only some of the hydrogen Balmer lines are evident, namely Hζ, Hδ, Hγ, Hβ, and Hα. These range in strength from moderate to very weak. Near the lower wavelength range, we see the molecular CN/CH absorption at 3862 Angstroms; it is very strong here. The Ca II K and H lines at 3934 and 3968 Angstroms are also fairly strong and easily identified. The CH (G Band) at 4299-4313 Angstroms is also very prominent. The magnesium triplet at 5170 Angstroms is very deep and sharp. The sodium D2 and D1 lines at 5890-96 Angstroms are combined to provide a sharp cut in the continuum, with the calcium line visible just below at 5857 Angstroms. Other fainter absorptions noted include lots of iron, magnesium, manganese, calcium, titanium, vanadium, and nickel.

We will again employ Wien's Law to obtain a rough temperature estimate. From the spectrum curve above, the peak would appear to lie near 5825 Angstroms. Using this value, we calculate an effective temperature of 4975K. The listed temperature for the star is 5008K[2]. We are off by only 32K, making the estimate very close!

Conclusion

I continued to entertain reservations about the data acquisition on this one. With the tremendous and repeated difficulties encountered last year, I was fearful of a repeat performance. However, the processing of the data revealed that those fears were misplaced. It is very gratifying to finally get this constellation successfully completed!

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