Spectral Analysis of the Constellation Stars of Ursa Minor (The Little Bear)

Anthony S. Harding Jr.
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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Ursa Minor. 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 two-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 collected on the evening of September 15, 2023 (EDT). 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 are 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 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.

This constellation of course rests in the worst part of my skies—the north. Greater numbers of frames were collected when practical to offset the atmospheric unsteadiness associated with this part of my viewing sky. Even so, the signal-to-noise ratios for these captures were higher than normal, and obtaining a good focus was often more difficult.

α Ursae Minoris

Alpha Ursae Minoris, or Polaris, is a pulsating Cepheid variable star, the nearest one to Earth. It has a dimmer companion star, but this may not exert much influence on the spectrum. The star is listed as a late F-type star[1].

The processed spectrum is as follows:

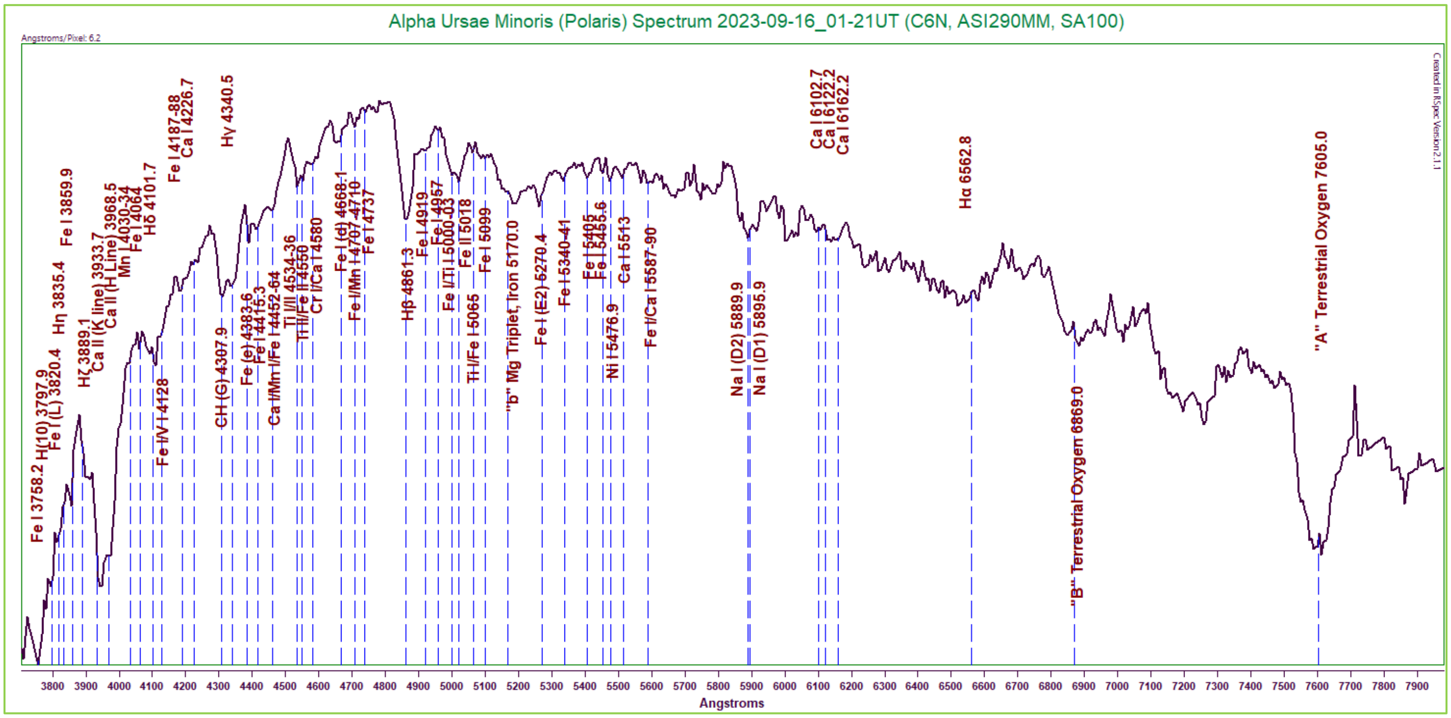

Figure 1: Alpha Ursae Minoris (Polaris) Spectrum (6.2 Angstrroms/pixel)
Capture Details 1: Exposure 194.355ms, Gain 65, 55% of 944 frames stacked

The continuum curve indeed reflects the characteristics of a late F-type or very early G-type star. The hydrogen Balmer lines are visible, though they are often not terribly strong. The calcium H and K lines are very deep, the most notable absorptions in the entire spectrum. The CH (G) band appears alongside the Hγ line, creating a double absorption. The magnesium triplet at 5170 Angstroms is clear, as is the Fe I (E2) line above it at 5270.4 Angstroms. The continuum becomes increasingly noisy, but the sodium doublet at 5890-96 Angstroms appears clearly. Spread throughout the spectrum are a large number of fainter iron lines, plus some calcium, titanium, chromium, and nickel. A very interesting spectrum.

Using Wien's Law, we will attempt to obtain a very rough estimate of the star's temperature, then compare it to accepted values. Using an estimated peak energy wavelength of 4780 Angstroms, the temperature works out to 6062K. The accepted temperature of the star is 6015K[2]. Hey, our guess is not too far off!

β Ursae Minoris

Beta Ursae Minoris, or Kochab, is a double star. However, the companion's separation should preclude any contamination of the spectrum. The star is listed as a middle K-type star[1]. We should expect to see a spectrum different from Polaris, reflecting a cooler star with a lot of metal lines present.

The processed spectrum follows:

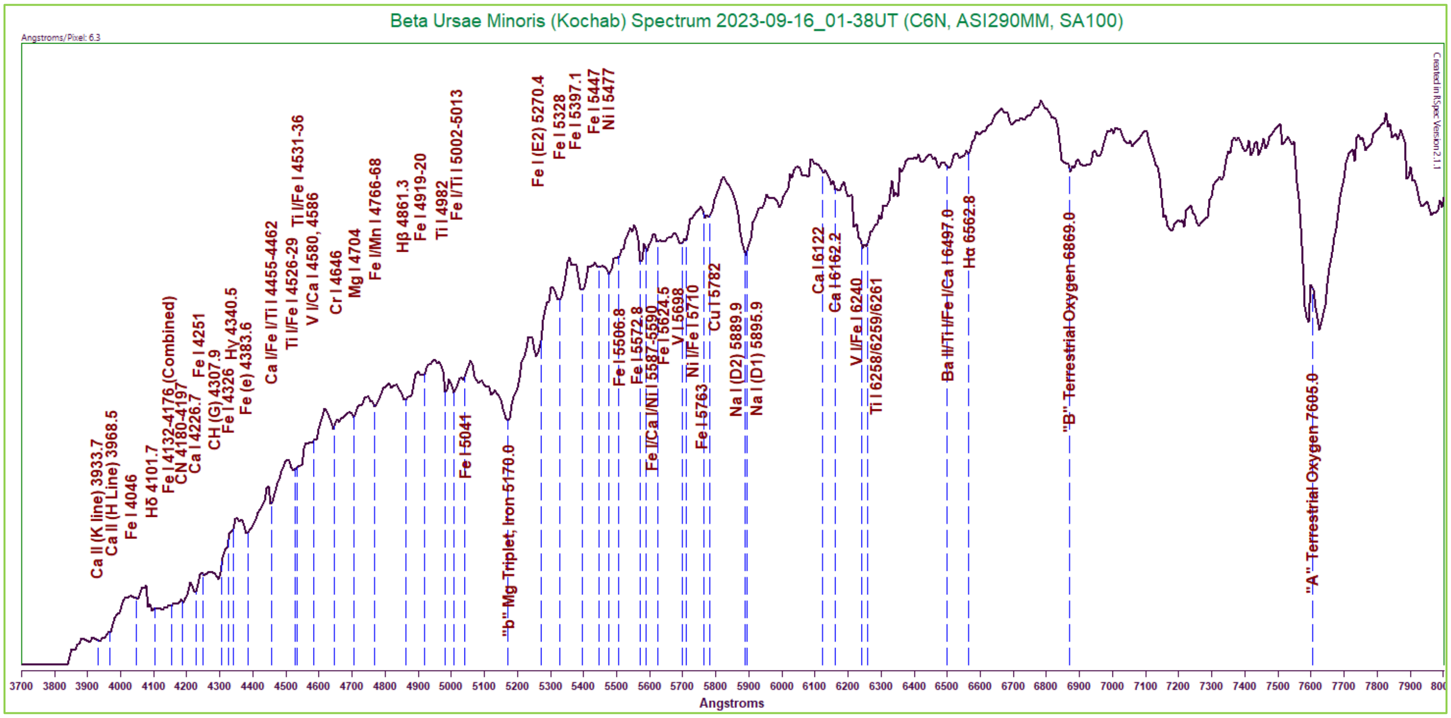

Figure 2: Beta Ursae Minoris (Kochab) Spectrum (6.3 Angstrroms/pixel)
Capture Details 2: Exposure 231ms, Gain 74, 35% of 831 frames stacked

As expected, this spectral curve indeed shows characteristics in line with our expectations. The general curve of the spectrum informs us that we are indeed looking at a cooler star. The hydrogen Balmer lines that are present appear muted. The calcium H and K lines at 3933.7 and 3968.5 Angstroms are identifiable, but they do not appear terribly strong. An amazingly broad dip in the continuum exists in the 4132-4176 Angstroms range, which is caused by a combination of iron lines that our low-resolution spectrum cannot separate. The CH (G) band can also be seen, but does not appear to be terribly prominent. The magnesium triplet at 5170 Angstroms is sharp and deep, cutting an impressive groove out of the continuum. The Fe I (E2) line above it is also easily recognized. The sodium doublet at 5890-96 Angstroms also appears strong, but is a bit weaker than the magnesium triplet. A large number of fainter metal lines can be seen, including a lot of iron, CN, calcium, titanium, vanadium, chromium, nickel, and copper. A nice array of different elements are reflected here.

Applying Wien's Law, we will estimate the star's temperature. Using an estimated peak energy wavelength of 6781 Angstroms, we obtain a result of 4273K. The accepted temperature of Kochab is 4030K[2].

γ Ursae Minoris

Gamma Ursae Minoris, or Pherkad, is regarded as a pulsating variable star of the early A-type[1]. This one we should expect to exhibit the familiar characteristics of that type—strong hydrogen Balmer lines and a curve peaking nearer the lower wavelength range.

The spectrum is presented below:

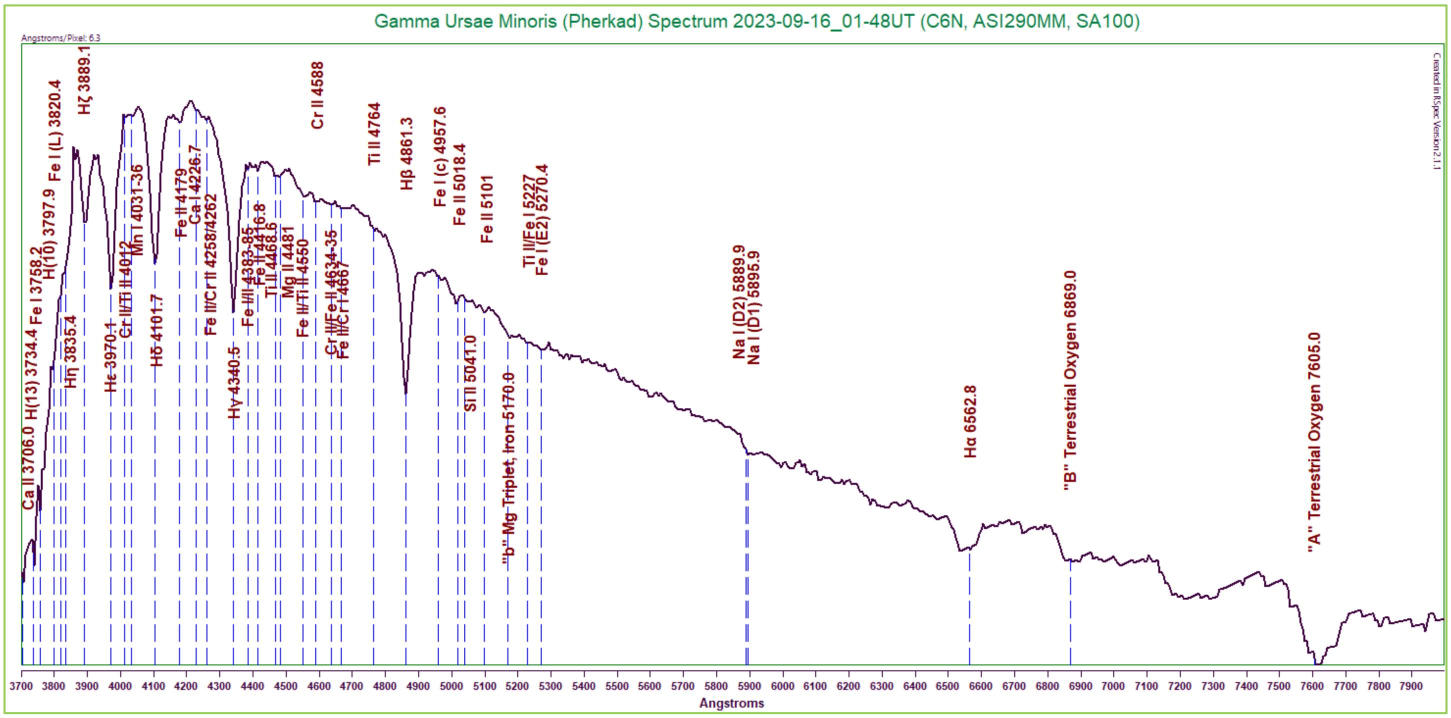

Figure 3: Gamma Ursae Minoris (Pherkad) Spectrum (6.3 Angstrroms/pixel)
Capture Details 3: Exposure 198ms, Gain 151, 30% of 1037 frames stacked

Indeed, this spectrum does show strong, sharp hydrogen Balmer lines, and the curve peaks closer to the lower wavelength region. The magnesium triplet appears weakly here, but together with the two iron lines above it, it causes a slight dip in the continuum. The sodium D1 and D2 lines are also visible, perhaps just slightly stronger. A number of additional weak to very weak metal lines are labeled here, including calcium, iron, chromium, manganese, titanium, magnesium, and silicon.

We will again use Wien's Law to estimate the star's temperature. However, since this is an earlier-type star, we can expect our estimate to be too low. Using an estimated peak energy wavelength of 4209 Angstroms, we calculate a temperature of 6885K. The accepted temperature for the star is listed as 8280K[2].

δ Ursae Minoris

Delta Ursae Minoris, also known as Yildun, is classified as an early A-type star[1]. Therefore, we should expect to see characteristics very similar to those of Pherkad above. The star does have a 12th magnitude companion, but our equipment should not display any trace of this much dimmer component.

The processed spectrum follows:

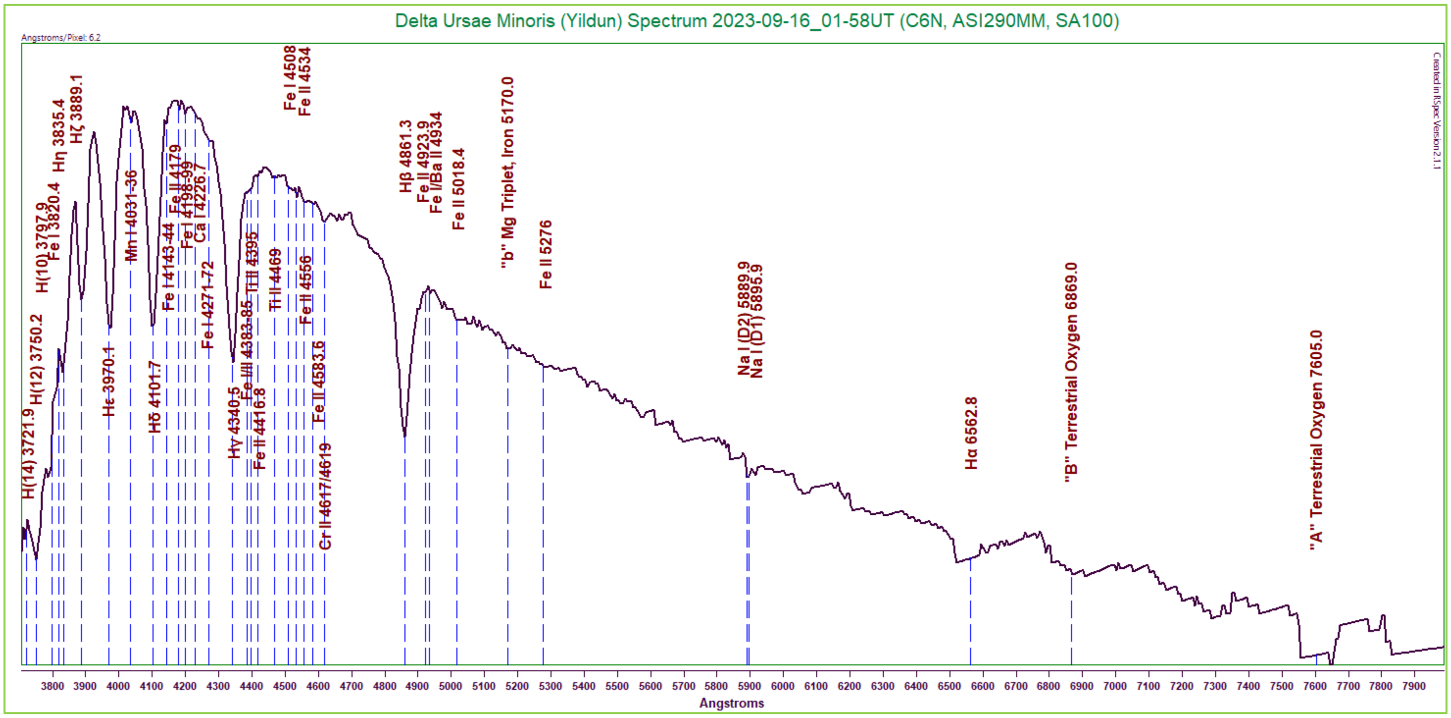

Figure 4: Delta Ursae Minoris (Yildun) Spectrum (6.2 Angstrroms/pixel)
Capture Details 4: Exposure 398ms, Gain 140, 70% of 308 frames stackes

As can be seen, the general shape of the curve is very similar to that of Pherkad. However, there are some specific differences. The hydrogen Balmer lines appear very sharp in this spectrum. The Hη absorption is stronger here, with the Fe I (L) line causing only a slight bump in the continuum below it. We can see that the magnesium triplet is only barely present, being almost subsumed into the noise. The sodium D1 and D2 lines are also weaker. A somewhat different array of faint metal lines are present here, including manganese, iron, calcium, titanium, and chromium.

Again employing Wien's Law, we will obtain a rough estimate of the star's effective temperature. Again, this is an early A-type star, so we can expect our estimate to be too low. Using an estimated peak energy wavelength near 4187 Angstroms, we obtain a temperature of 6921K. The listed temperature for the star is 9911K[2]. As expected, our estimate it far too low.

ε Ursae Minoris

Epsilon Ursae Minoris, or Circitores, is classified as a middle G-type star[1]. It is a spectroscopic, eclipsing binary system. This companion is classifies as a very late A-type star, which may or may not bleed features through onto our spectrum. It will be interesting to see.

The final, processed spectrum follows:

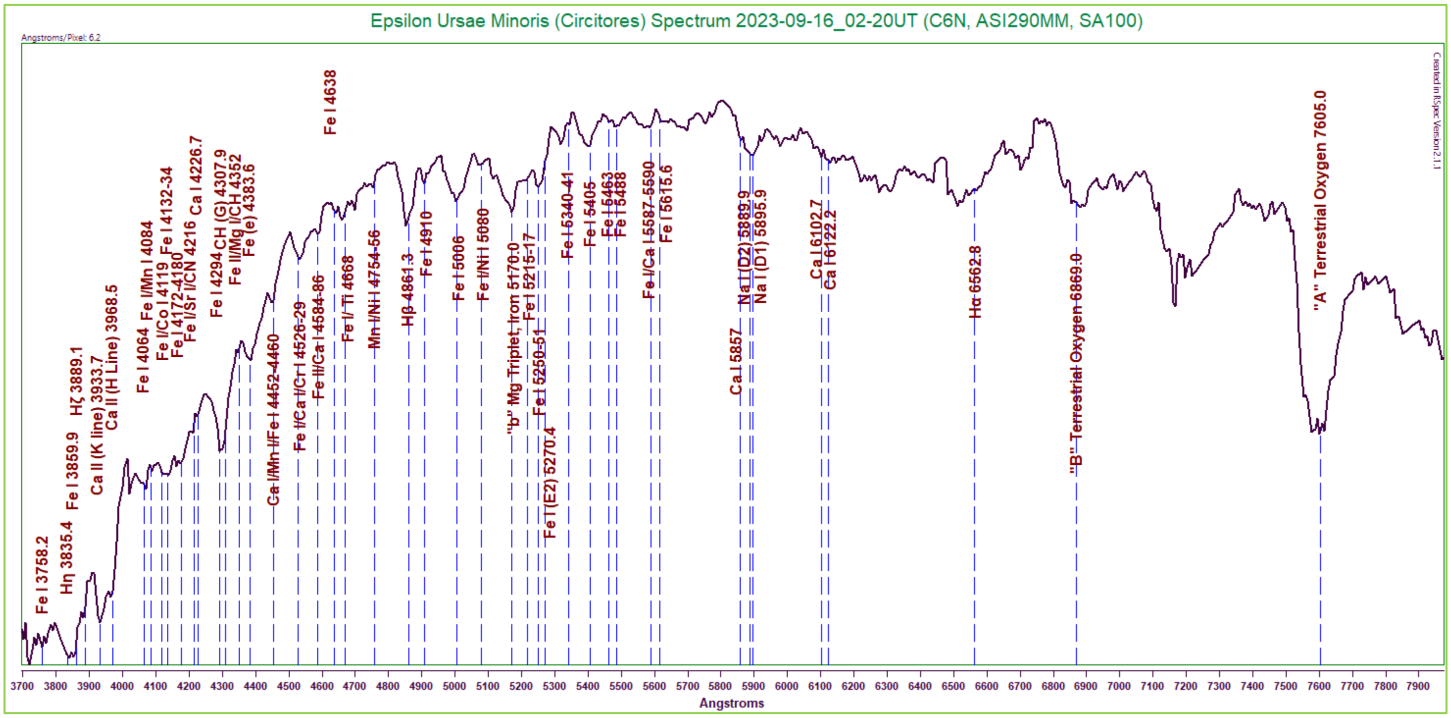

Figure 5: Epsilon Ursae Minoris (Circitores) Spectrum (6.2 Angstroms/pixel)
Capture Details 5: Exposure 808ms, Gain 146, 75% of 192 frames stacked

It appears from the spectrum that the companion star is not contributing anything detectable by our equipment. The noise present in the capture does make line identification sometimes challenging, but we can see many features associated with the G-type primary. Several of the hydrogen Balmer lines are clearly visible, though they generally appear somewhat weak. The calcium H and K lines are easily identified, carving out a deep cut in the continuum around 3933-3968 Angstroms. The CH (G) band is also readily seen at 4307.9 Angstroms. The magnesium triplet at 5170 Angstroms is moderately strong, as well as the adjacent iron lines above it. The sodium doublet at 5890-96 Angstroms is similarly visible. As expected for a G-type star, many additional metal lines are present. These include numerous iron lines, calcium, and manganese.

Wien's Law will be used to estimate the star's temperature, and to compare it to accepted values. With the higher signal noise present, it is difficult to visually estimate the peak energy wavelength, but if a value of 5810 Angstroms is used, the result is 4988K. The accepted temperature is listed as 5215K[2]. All things considered, our estimate is not too bad.

ζ Ursae Minoris

Zeta Ursae Minoris, also called Akfa Farkadain, is a single star of early A-type[1]. Again, we should expect to see features similar to those of Pherkad above, with strong hydrogen Balmer lines visible.

The spectrum is as follows:

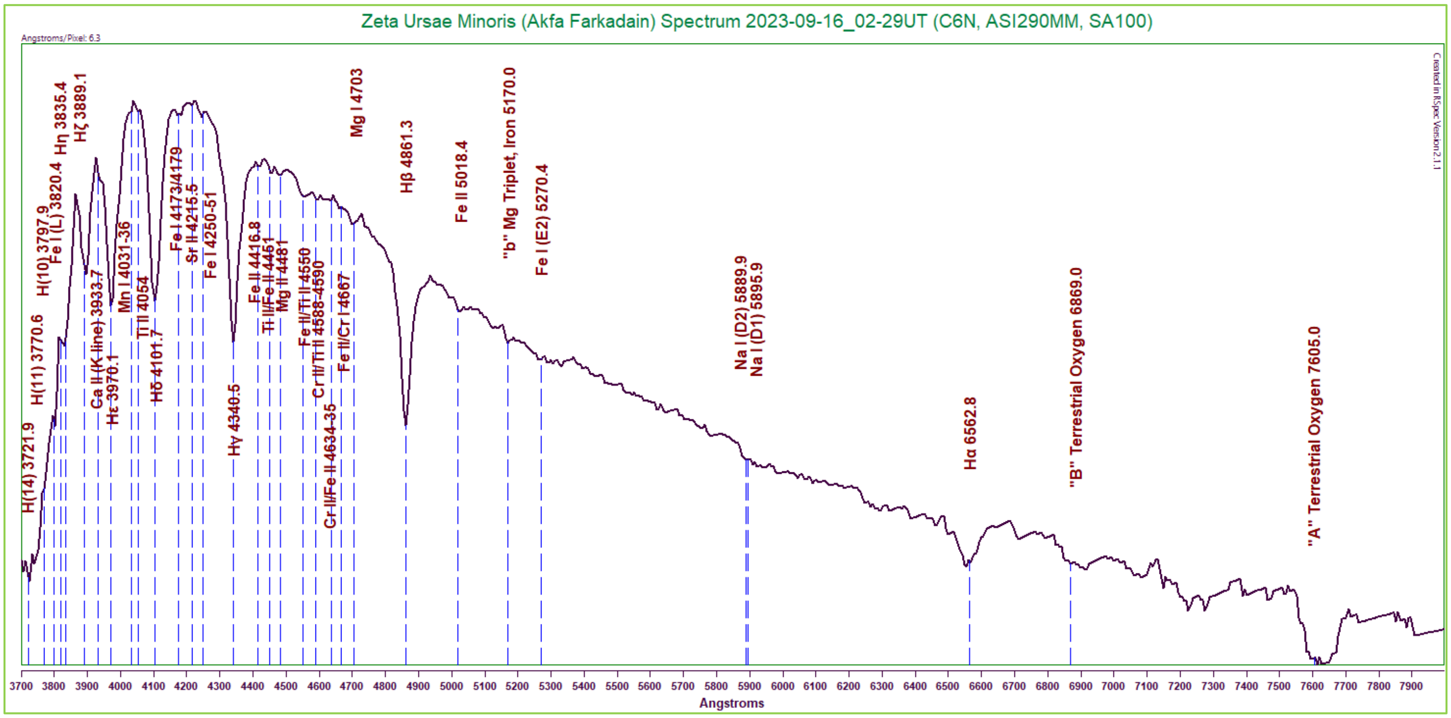

Figure 6: Zeta Ursae Minoris (Akfa Farkadain) Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 499ms, Gain 163, 50% of 496 frames stacked

Once again the features of an early A-type star are clear. The hydrogen Balmer lines are prominent and easily identified. One notable feature is that the calcium K line is just barely beginning to emerge, causing a slight bump on the lower side of the much larger Hε absorption. The magnesium triplet at 5170 Angstroms is very weak. This line and the Fe I (E2) line above it mark the edges of a very subtle dip in the continuum. The sodium doublet is also very weak, but still identifiable. Numerous additional faint metal lines are marked here, including manganese, iron, titanium, strontium, magnesium, and chromium.

Wien's Law can once again be used to roughly estimate the star's effective temperature. Using an estimated peak energy wavelength of 4222 Angstroms, we obtain a result of 6864K. The listed temperature for the star is 8720K[2]. Again, our estimate is much too low for an A-type star.

η Ursae Minoris

Eta Ursae Minoris, or Yed Post, is classified as a middle F-type star[1]. Based on this, the continuum should show a slightly lower temperature than the previous A-type stars, and may begin to show more metal lines, as well.

The spectrum for the star is as follows:

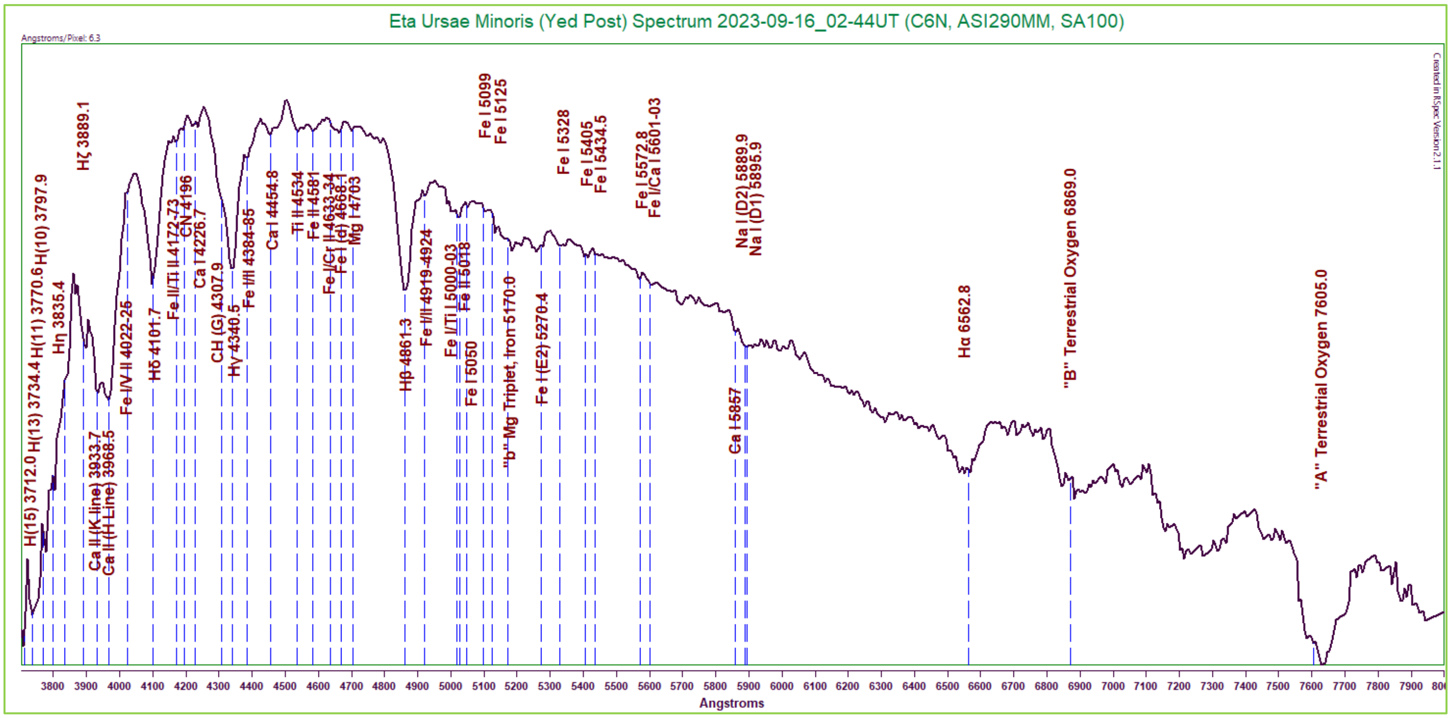

Figure 7: Eta Ursae Minoris (Yed Post) Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 2s, Gain 113, 80% of 87 frames stacked

This curve does indeed show some interesting features. The hydrogen Balmer lines are still present, except for the Hε absorption, which has been buried under the stronger calcium K line. The Hη line appears extremely weak, evident only by a small bump in the continuum. The CH (G) line at 4307.9 Angstroms can be seen as a small bump on the lower side of the Hγ absorption. Both the magnesium triplet at 5170 Angstroms and the sodium doublet at 5890-96 Angstroms are identifiable, though neither of them is exceedingly strong. A number of additional faint metal lines are spread through, including iron, CN, calcium, titanium, and magnesium.

Wien's Law will allow us to obtain a very rough estimate of the star's effective temperature. Using an estimated peak energy wavelength of 4506 Angstroms, we obtain a resultant temperature of 6431K. The accepted temperature for the star is 6858K[2]. All told, our estimate is not too far off.

Conclusion

Despite the relatively bad conditions in the northern sky and the higher signal-to-noise ratios, the results appear to be satisfactory. Some of the noise levels were significant in the dimmer targets, but still allowed the identification of lines in the spectrums. My own proficiency in identifying lines is increasing. Progress!

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