Spectral Analysis of the Constellation Stars of Perseus (The Hero)

Anthony S. Harding Jr.
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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Perseus. 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 apparent 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 captured for this analysis were obtained on the evening of December 13, 2023 (EST). One star (Gamma Persei) was initially thought to be an incorrectly identified star, so the report was delayed until the constellation came back into a good position. However, a second capture conducted on August 31, 2024 (EDT) seemed to confirm that the initial identification was correct. 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 included are the exposure, 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 Persei

Alpha Persei, also called Mirfak, lies at the heart of the Alpha Persei Cluster and is classified as a middle F-type star[1]. Based on this, we can expect to see a moderately hot star showing hydrogen Balmer lines, with some conspicuous metal lines mixed in.

The processed spectrum is presented here:

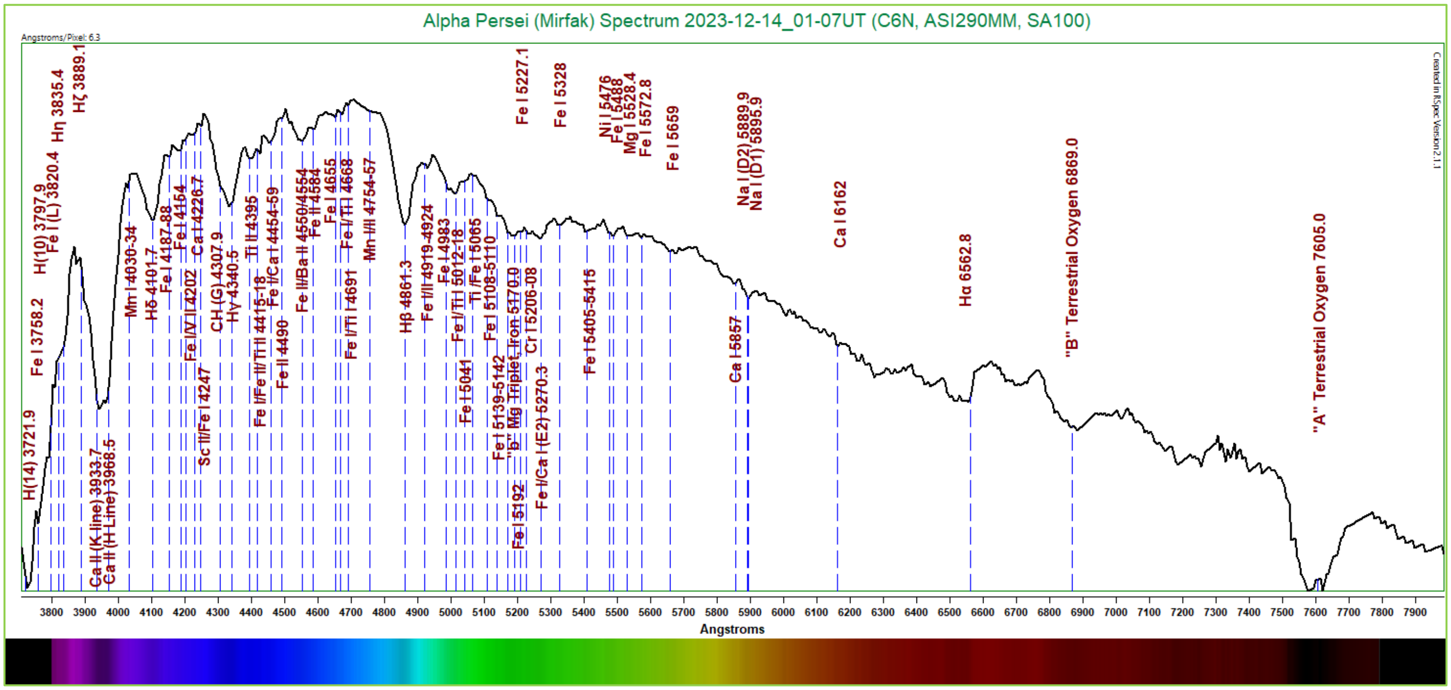

Figure 1: Alpha Persei (Mirfak) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 216ms. Gain 53, 30% of 1134 frames stacked

This spectrum shows numerous interesting features. The visible hydrogen Balmer lines range from strong to very weak. The Hζ line, for example, is only evident as a gentle diversion along the low side of the calcium K line. By contrast, the Hβ line is very sharp and strong. Near the lower wavelength region, we can see the Fe I (L) and Hη lines causing the familiar stair step pattern in the continuum. Returning to the calcium H and K lines, we can see an exceptional pair of very strong absorptions here! By contrast, the CH (G) absorption at 4307.9 Angstroms is just barely visible as a bump on the lower side of the Hγ line. The magnesium triplet at 5170 Angstroms, along with its flanking iron and chromium lines, is cutting a broad, jagged gouge out of the continuum. The sodium doublet at 5890-96 Angstroms is remarkably faint by comparison. A large number of fainter metal lines are spread throughout the spectrum. These include, manganese, lots of iron, calcium, scandium, titanium, nickel, and magnesium.

Using Wien's Law, we will attempt to ascertain an estimate of the star's temperature. Using a peak energy wavelength of approximately 4711 Angstroms, we arrive at a temperature of 6151K. The currently accepted temperature for the star is 6350K[2]. Our estimate seems to be a bit low, which may be due to the lack of a clear-cut peak on our resulting spectrum curve. Still it's not bad for a low-resolution estimate.

β Persei

Beta Persei, better known as Algol, the Demon Star of Perseus, is a well-known eclipsing binary star of late B-type[1]. The companion star was not eclipsing the primary at the time; it is also cooler and much less luminous than the primary, and so shouldn't contribute much to our low-resolution spectrum. We should therefore expect to see strong hydrogen Balmer lines present here from the primary, with only a few metals identifiable.

The spectrum is presented below:

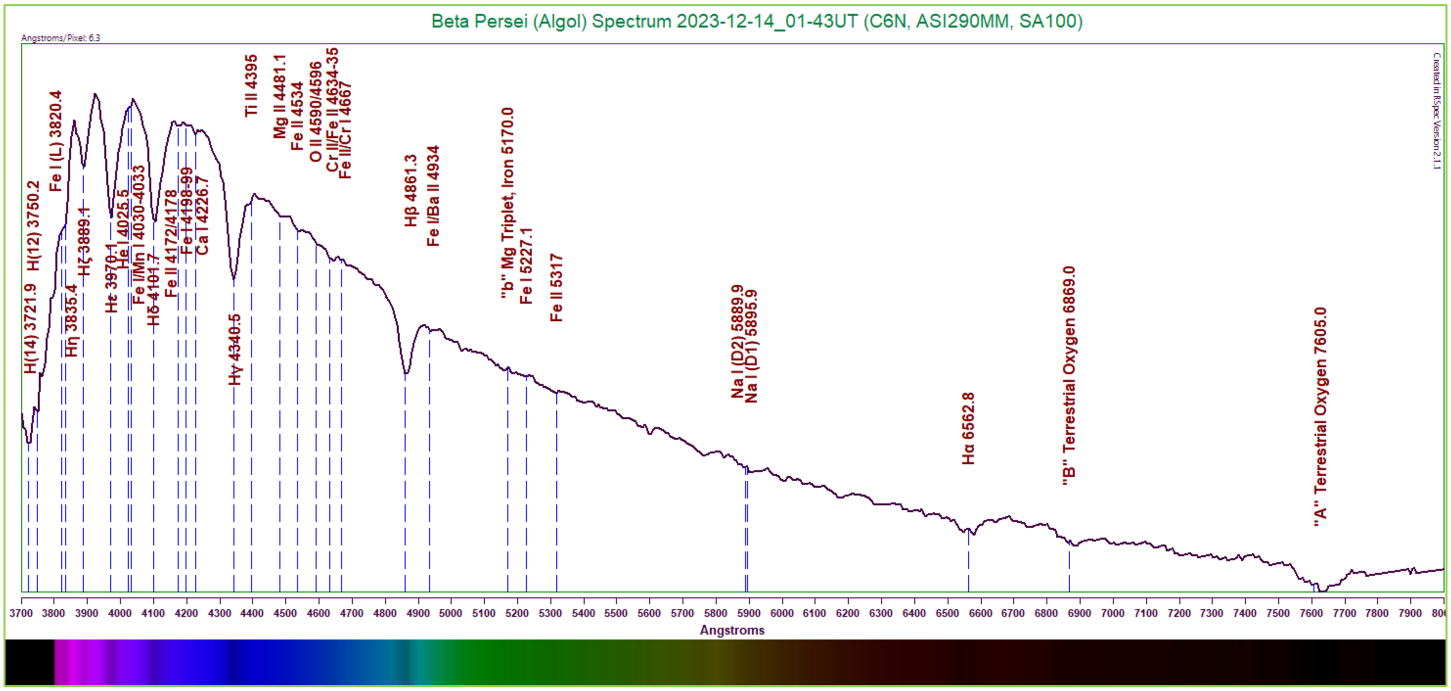

Figure 2: Beta Persei (Algol) Spectrum
Capture Details 2: Exposure 216ms, Gain 50, 35% of 1051 frames stacked

The hydrogen Balmer lines are indeed fairly strong, though not so deep as those of later A-type stars. The Fe I (L) and Hη lines are combining to form a step in the continuum at 3820-3835 Angstroms. One helium line can be seen at 4025.5 Angstroms, combining with the iron/manganese line above it at 4030-4033 Angstroms. Together they carve a small scoop out of the continuum. The magnesium triplet is marked, but the noise in the continuum makes its identification uncertain. The same applies to the iron line at 5227.1 Angstroms. The sodium doublet at 5890-96 Angstroms is more evident, but still very weak. Several other faint metal lines can be seen along the spectrum, including iron, calcium, titanium, magnesium, oxygen, and chromium.

We will employ Wien's Law to establish a rough estimate of the star's temperature. However, since this is a hotter star, we can expect our estimate to fall far short of the mark. Accepting a peak energy wavelength of 3923 Angstroms, we calculate an effective temperature of 7387K. The accepted temperature of the star is 13000K[2]. Indeed, our estimate is way too low!

γ Persei

Gamma Persei is an eclipsing binary star whose primary is classified as a very late G-type star[1]. This report was delayed due to an unexpected result the first time around. However, a recapture this year seems to confirm the appropriate star was indeed captured the first time around. In fact, the first capture was cleaner than the follow-up. Still, some doubt remains regarding the results. The secondary is an early A-type star, but it should be far enough from the primary to not interfere. We can thus expect the primary star to be somewhat cooler than our Sun, showing numerous metal lines in its spectrum.

The processed spectrum follows:

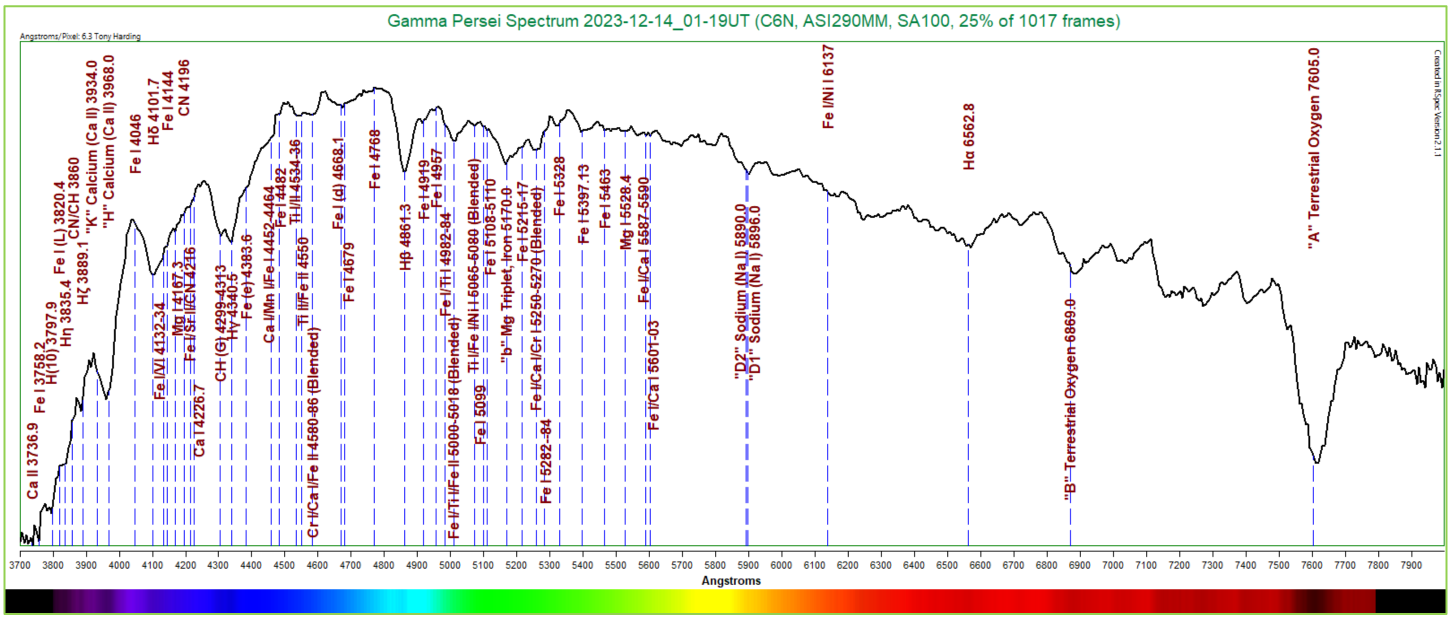

Figure 3: Gamma Persei Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 242ms, Gain 143, 25% of 1017 frames stacked

We can see a lot of metal lines spread throughout this spectrum. The two strongest absorptions are the Hβ line and the calcium H line. The calcium K line is visible as only a small hump just below the K line. The CH (G) absorption is plain, sitting just below the Hγ line. The magnesium triplet at 5170 Angstroms is quite conspicuous. The sodium D2 and D1 lines at 5890-96 Angstroms is small but distinct. Other metal lines present include calcium, iron, the CN/CH molecule, magnesium, and titanium.

Using Wien's Law, we will attempt to obtain a temperature estimate for the star. Using an estimated peak energy wavelength of 4769 Angstroms, we arrive at a temperature of 6076K. The established temperature of the star is 4970K[2]. Our estimate in this case is definitely too high. (It was later pointed out that this star is actually an unresolved binary, and as such is throwing off the peak energy wavelength.)

δ Persei

Delta Persei is a very close double star classified as a middle B-type star[1]. The equipment used was certainly not able to separate the two components, and the secondary is much dimmer than the primary. We can therefore not anticipate the secondary contributing anything to the low-resolution spectrum. We should see a very hot star with weakened hydrogen Balmer absorptions and a few helium lines.

The spectrum is presented below:

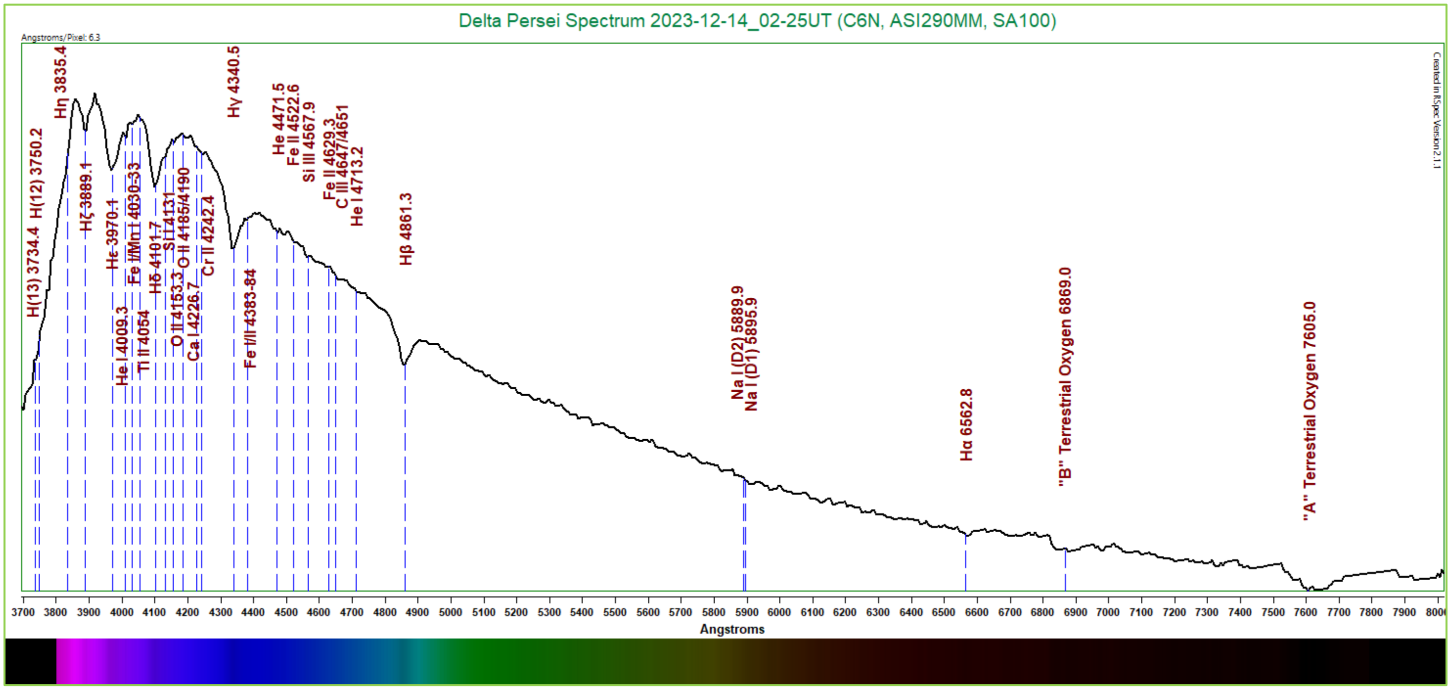

Figure 4: Delta Persei Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 358ms, Gain 86, 40% of 682 frames stacked

This spectral curve definitely represents a hot star. The hydrogen Balmer lines are present, but weakened considerably compared to the star's A-type cousins. The Hη line is only evidenced by a subtle step in the continuum at 3835.4 Angstroms. Three very faint helium lines can be seen at 4009.3, 4471.5, and 4713.2 Angstroms. The sodium doublet is marked, but the identification is questionable, since the strength of it is not entirely different from the general noise in the spectrum. Other very faint metals can be seen, including iron, titanium, silicon, oxygen, calcium, chromium, and carbon.

We will employ Wien's Law to estimate the star's effective temperature. Again, this being an early-type star, we must be prepared for the estimate to fall woefully short. Using a peak energy wavelength of 3923 Angstroms, we obtain a resulting temperature of 7387K. The accepted temperature of the star is listed as 14890K[2]. Our estimate is too low by a factor of 2.

ε Persei

Epsilon Persei is classified as a multiple star system whose primary is a very early B-type star[1,2]. The companion stars are all very dim, however, so we need not concern ourselves with their contribution to the spectrum. We can expect the star to be even hotter than Delta Persei above. The hydrogen Balmer lines should be further weakened, but we should perhaps see some clearer helium absorptions.

The processed spectrum is presented here:

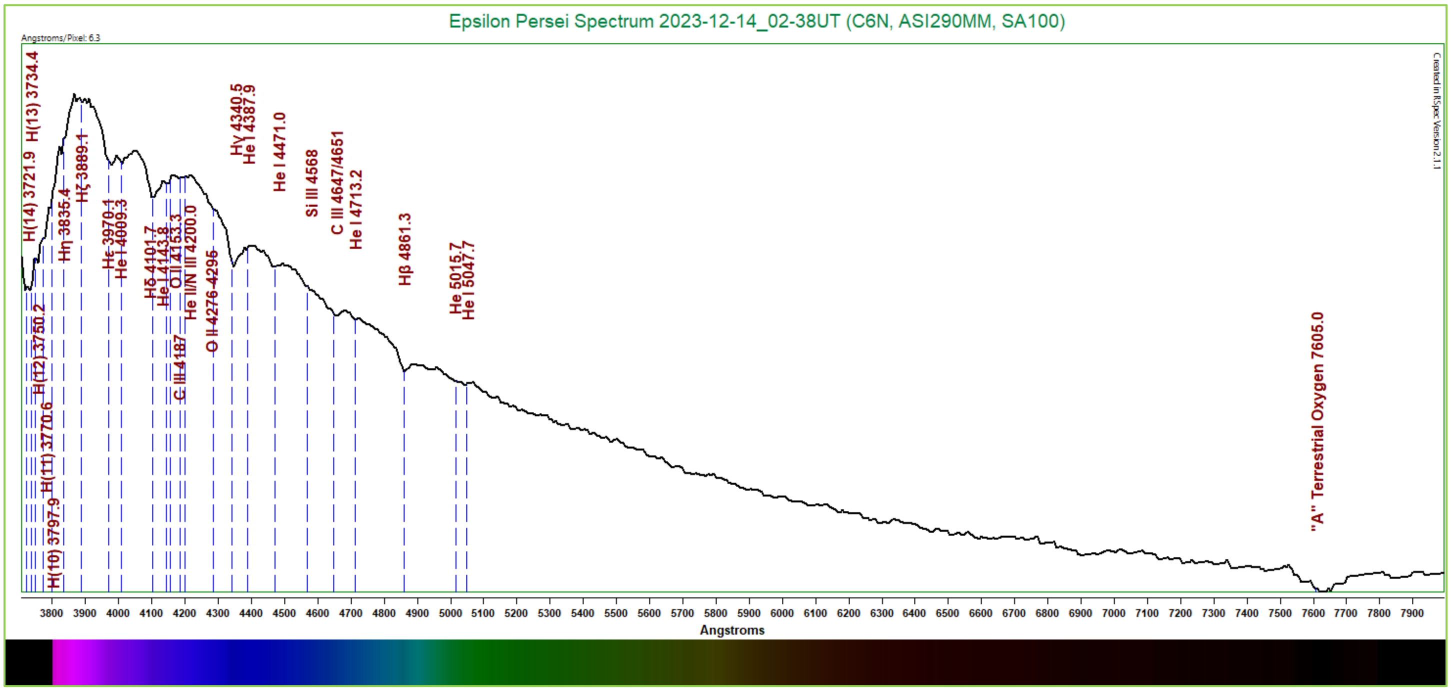

Figure 5: Epsilon Persei Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 310ms, Gain 83, 40% of 784 frames stacked

The hydrogen Balmer lines are indeed weaker here than those of Delta Persei, as expected. More helium lines can be seen, as well. One of them, at 4009.3, is sitting next to the Hε line causing a double-toothed absorption. A series of metals can be seen in the spectrum, including carbon, oxygen, silicon, and carbon.

Using Wien's Law, we will estimate the effective temperature of the star. As before, our estimate will certainly fall far short. Using a peak energy wavelength of 3864 Angstroms, we obtain a resulting temperature of approximately 7500K. The star is listed as having a temperature of 26500K[2]. Wow, our estimate is off by a factor of 3!

ζ Persei

Zeta Persei, sometimes called Atik despite Omicron Persei sharing the same name, is classified as an early B-type star[1]. This means we should see similar characteristics to those of Epsilon Persei above.

The processed spectrum is presented below:

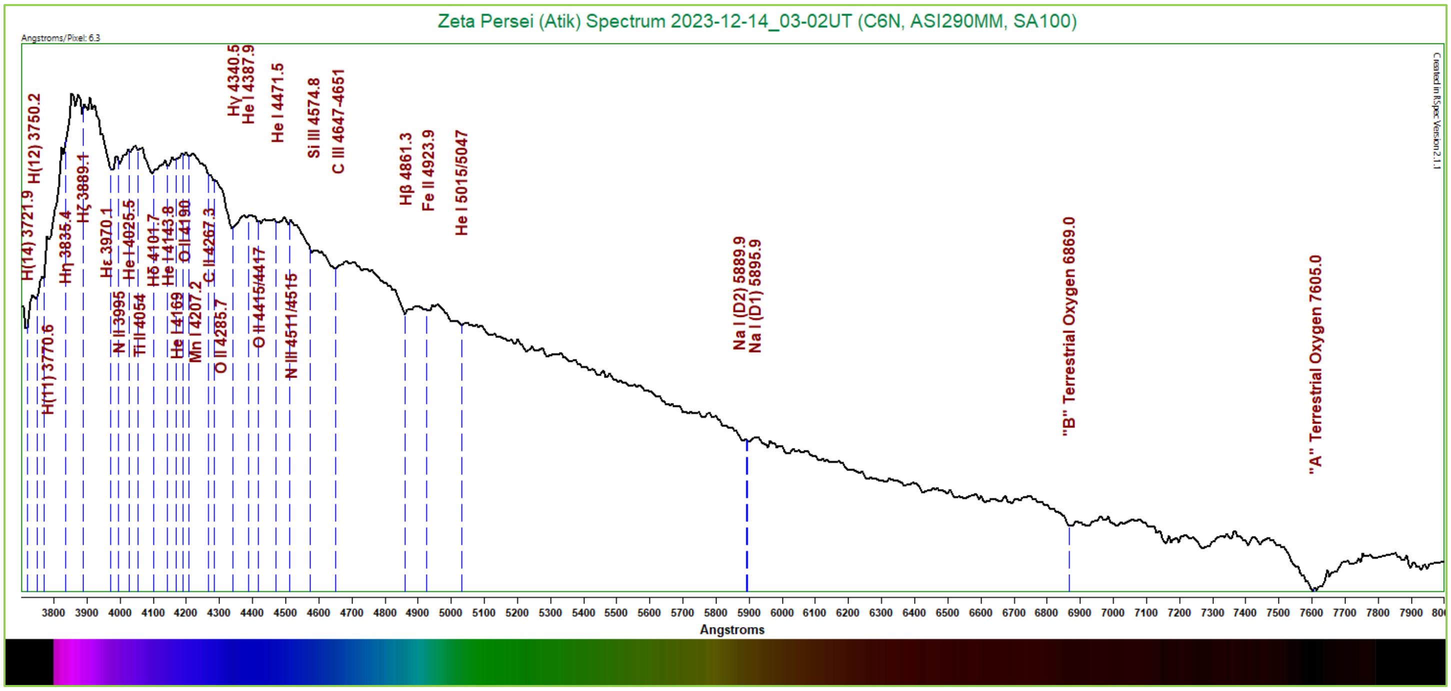

Figure 6: Zeta Persei (Atik) Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 430ms, Gain 74, 30% of 564 frames stacked

Here we see a curve of similar general shape to that of Epsilon Persei, but it definitely shows some differences. The hydrogen Balmer lines are generally weaker. The Hα line is reduced into the continuum noise. The remaining lines in the series appear muted. Despite this, however, we can still see a small absorption from the Hη line at 3835.4 Angstroms. Several helium lines can be seen along the spectrum, at 4025.5, 4143.8, 4169, 4387.9, and 4471.5 Angstroms, with an additional combined dip due to lines at 5015 and 5047 Angstroms. The sodium doublet at 5890-96 Angstroms is visible, but weak. Additional faintly visible metals are marked, including nickel, titanium, carbon, oxygen, and silicon.

Using Wien's Law, we will calculate a rough estimate of the star's temperature. With this being a hot, early-type star, we can be certain that our estimate will be very short of the mark. Using a peak energy wavelength of 3853 Angstroms, our resulting temperature is 7521K. The accepted temperature for the star is listed as 20800K[2]. As expected, our estimate is entirely too low.

η Persei

Eta Persei is a double star whose primary is an early K-type star[1]. From this we can anticipate a cooler star with lots of metal absorptions present.

The star's spectrum is presented below:

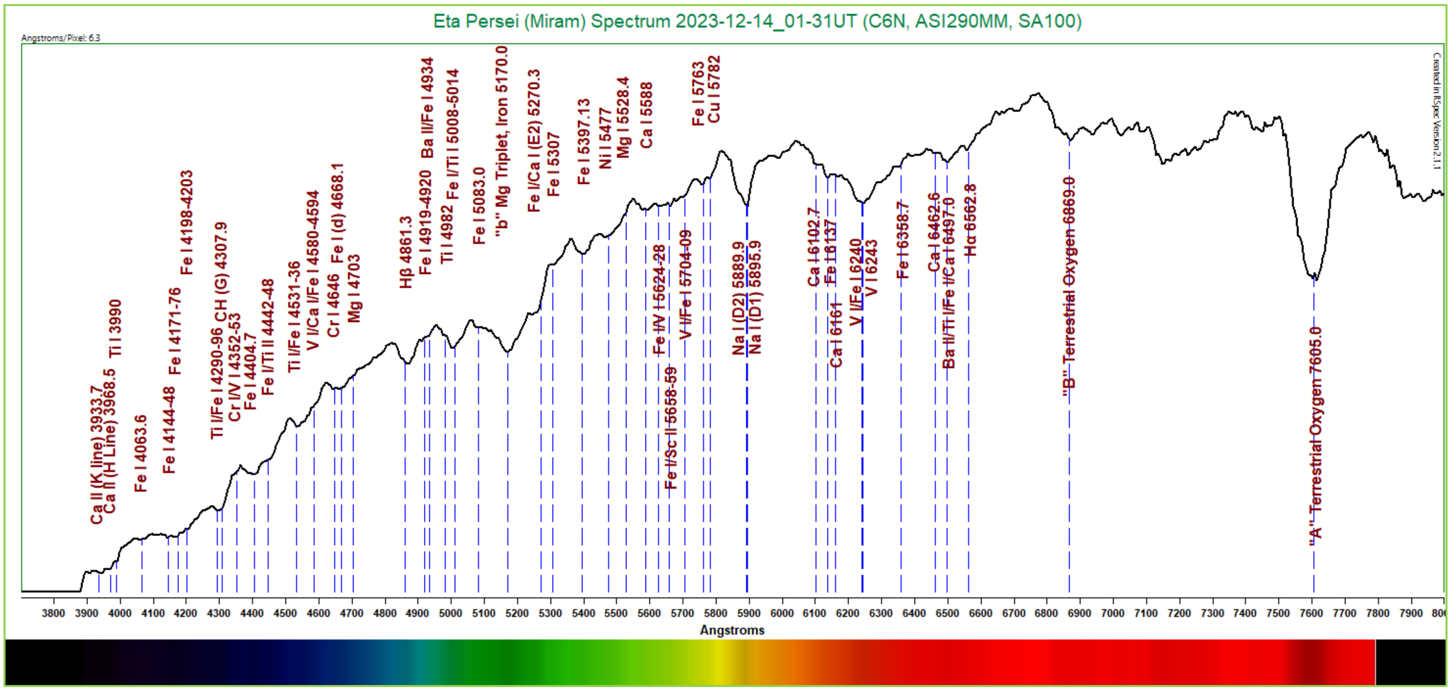

Figure 7: Eta Persei (MIram) Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 470ms, Gain 143, 50% of 406 frames stacked

We can see from the general shape of the curve that this is indeed a cooler star. The few visible hydrogen Balmer lines are significantly weakened. The calcium H and K lines are combined with a titanium line above them to create a nice broad trough. Another lies in the 4144-4203 Angstroms, caused by a combination of iron lines. The GH (G) absorption is evident, with the titanium line just below it discretely visible. The magnesium triplet at 5170 Angstroms is our deepest absorption here, flanked by two iron lines. The sodium D1 and D2 lines are also obvious at 5890-96 Angstroms, together causing a fairly sharp and deep absorption. Numerous other fainter metal lines are visible throughout the spectrum, including iron, chromium, vanadium, magnesium, barium, nickel, and copper. A very nice spectrum.

Using Wien's Law, we will estimate the star's temperature. Since this one is a cooler star, our estimate should be much closer to the mark. Using an estimated peak energy wavelength of 6777 Angstroms, we calculate a temperature of 4276K. The accepted temperature for the star is listed as 3986K[2]. Though our estimate is a little high, we are much closer than for the last few (hotter) stars in the survey.

ξ Persei

Xi Persei, also known as Menkib, is a late O-type[1] star. It may have a companion, but the overpowering light of the primary will drown it out. We can expect a very hot star with greatly reduced hydrogen Balmer lines, plus some helium lines evident.

The spectrum follows:

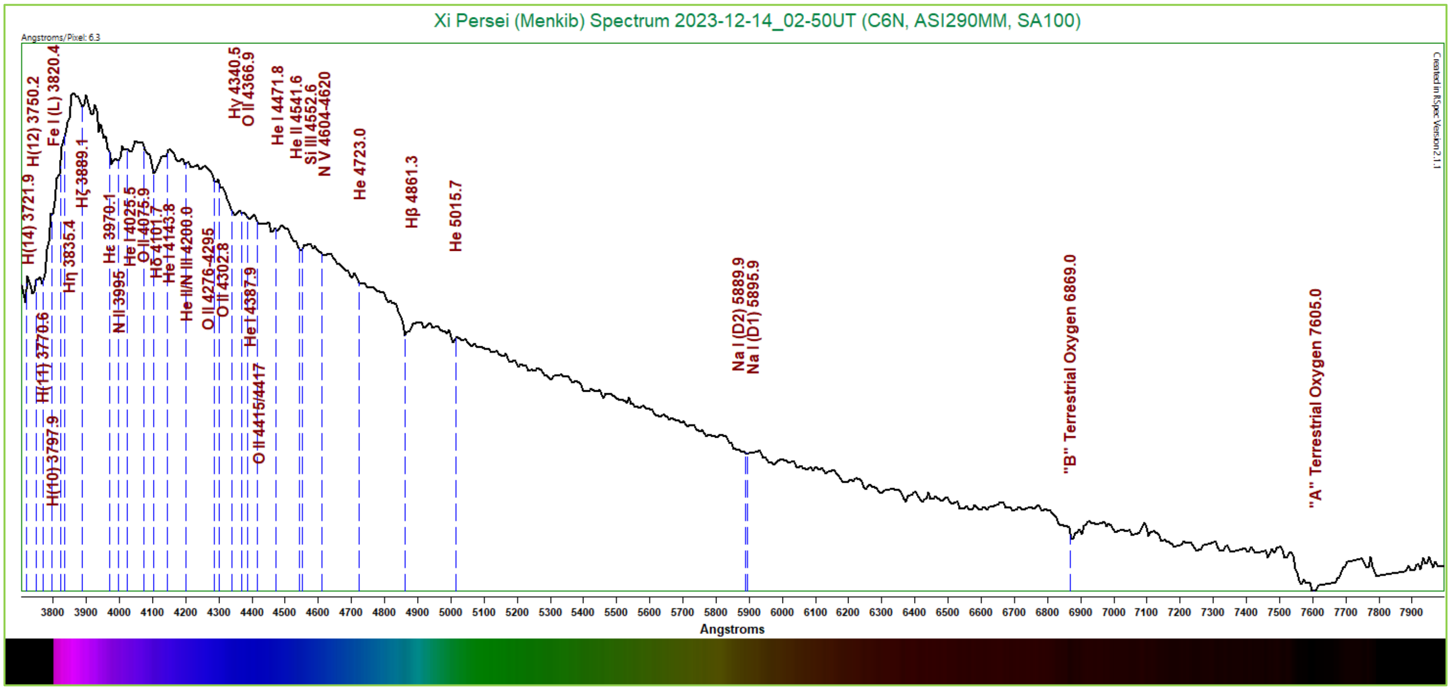

Figure 8: Xi Persei (Menkib) Spectrum (6.3 Angstroms/pixel)
Capture Details 8: Exposure 398ms, Gain 154, 30% of 611 frames stacked

As can be seen, the hydrogen Balmer lines in this star are very weak. In fact, there are few notable absorptions visible from the series. The deepest appears to be the Hε line at 3970.1 Angstroms. The Hα line is not identifiable at all, being reduced down to the noise level of the continuum. Several helium lines can be seen at 4025.5, 4143.8, 4200, 4387.9, 4471.8, 4541.6, 4723, and 5015.7 Angstroms. The sodium D1 and D2 lines are represented only by a slight dip in the continuum. Some other additional faint metal lines are marked, including nitrogen, oxygen, and silicon.

Wien's Law can again be used to ascertain an approximate temperature. Being an exceptionally early-type star, however, means that our estimate will be incredibly low. Using an estimated peak energy wavelength of 3863 Angstroms, we calculate a temperature of 7501K. The established temperature for the star is listed as 35000K[2]. It is clear to see that the earlier the star type, the more inaccurate our estimates become. This one's estimate is off by a factor of 5!

o Persei

Omicron Persei, or Atik, is a close binary star system of early B-type[1,2]. We can therefore again expect to see a very hot spectroscopic curve showing weakened hydrogen Balmer lines, with perhaps a few helium lines evident.

The processed spectrum follows:

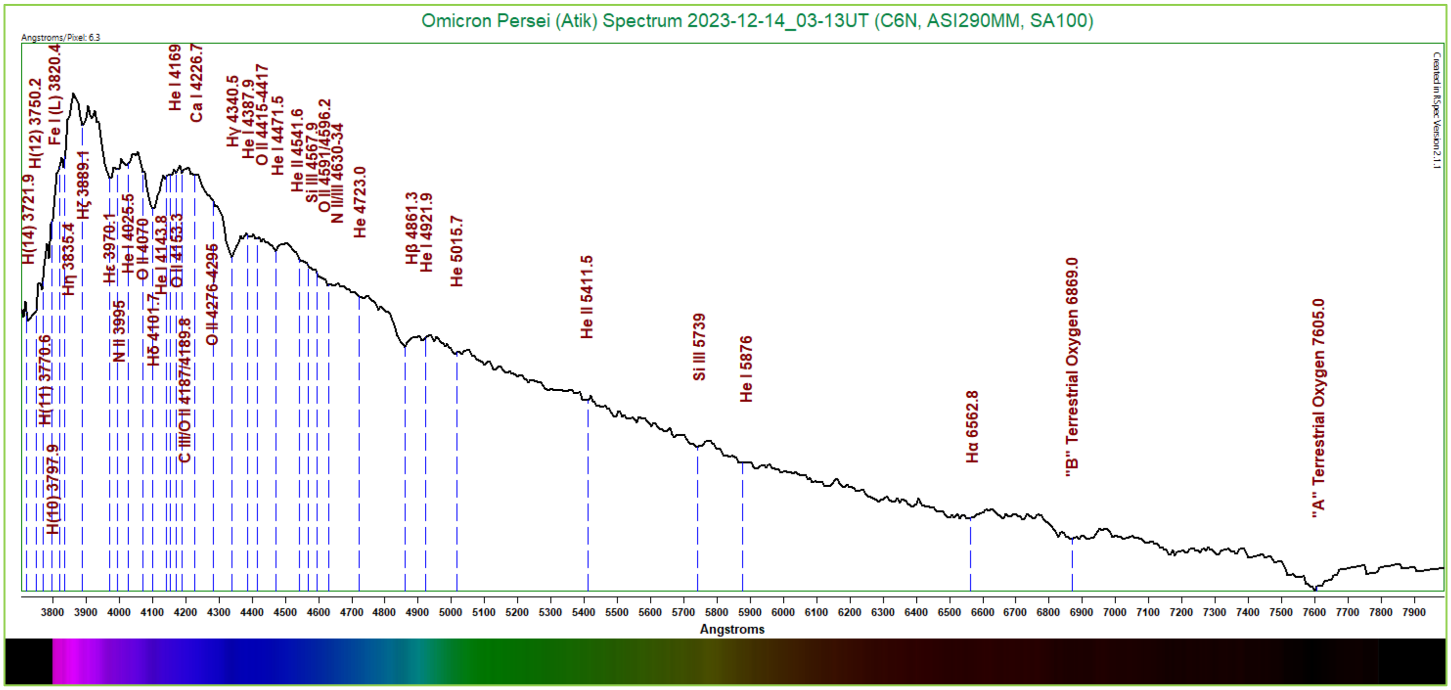

Figure 9: Omicron Persei (Atik) Spectrum (6.3 Angstroms/pixel)
Capture Details 9: Exposure 398ms, Gain 134, 30% of 610 frames stacked

The resulting curve indeed matches our expectations. We see relatively weak hydrogen Balmer lines. The Hα absorption is only evidenced by a very subtle dip in the continuum. The Fe I (L) and Hη lines can be seen causing their stair step near the lower end of the wavelength range. A good number of helium lines are present here at 4025.5, 4143.8, 4169, 4387.9, 4471.5, 4541.6, 4921.9, 5015.7, and 5411.5 Angstroms, plus an extremely weak one at 5876 Angstroms. Additional fainter metal lines are spread throughout, including nitrogen, oxygen, carbon, calcium, and silicon. A very interesting result.

Again using Wien's Law, we will estimate the temperature. Once again, we can expect our estimate to fall far short, since this is an early-type star. Using a peak energy wavelength of 3863 Angstroms, we calculate a temperature of 7501K. The listed temperature for the star is 22700K[2].

ρ Persei

Rho Persei, also known as Gorgonea Tertia, is classified as a middle M-type star[1]. Since this is a late-type star, we can expect to see a curve representing a very cool star with notable TiO lines spread throughout.

The spectrum is presented below:

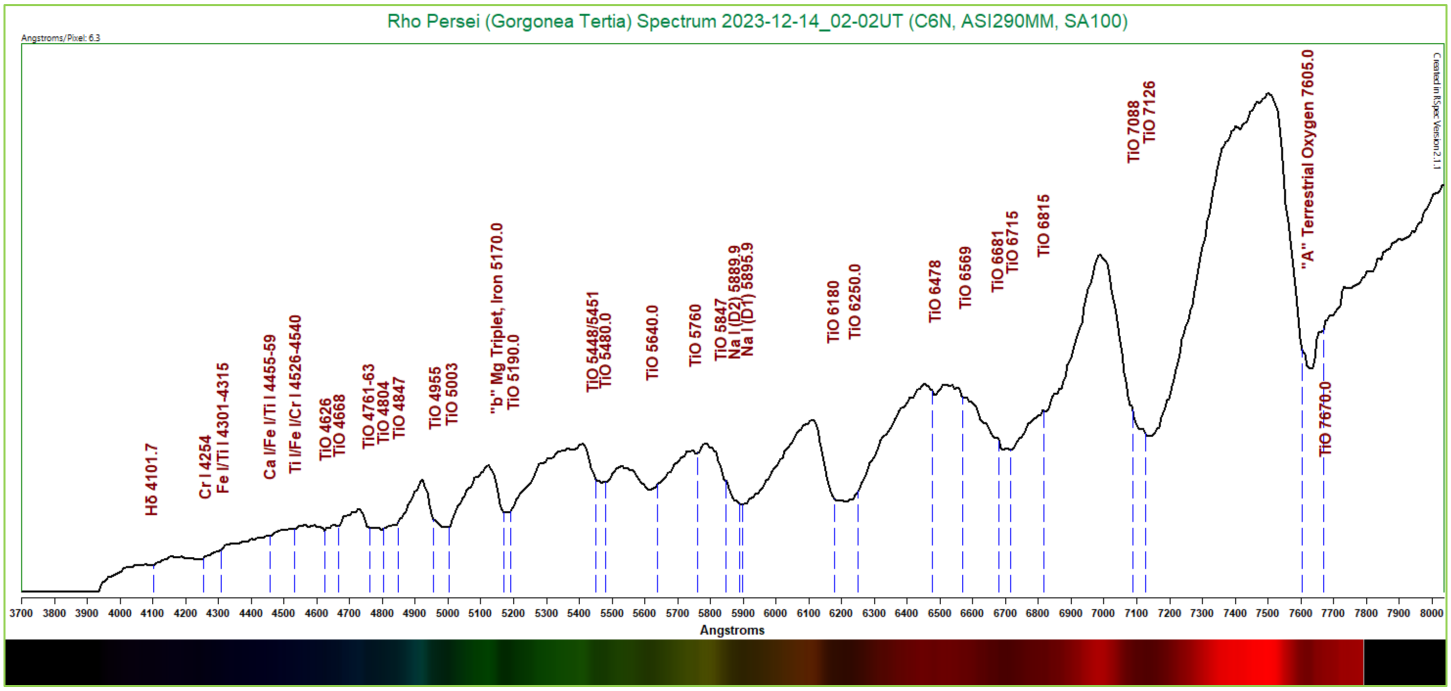

Figure 10: Rho Persei (Gorgonea Tertia) Spectrum (6.3 Angstroms/pixel)
Capture Details 10: Exposure 496ms, Gain 71, 50% of 379 frames stacked

Here we can see the typical curve of a late-type star. The peak is at much longer wavelengths, and numerous TiO absorptions are obvious. The only clearly identifiable hydrogen Balmer line is the Hδ line at 4101.7 Angstroms, and it is very weak. The magnesium triplet at 5170 Angstroms is obvious, and appears broadened by an adjacent TiO line. The sodium doublet at 5890-96 Angstroms is also easily identified. Only a few other metal lines are noted in the lower wavelength region, and they are extremely weak. These include chromium, iron, calcium, and titanium.

Using Wien's Law, we will calculate an estimated temperature for the star. Using a peak energy wavelength of 7472 Angstroms, we obtain a result of 3878K. The listed temperature for the star is 3479K[2]. As expected, our estimate is much closer than those derived for earlier, much hotter stars.

16 Persei

16 Persei is classified as an early F-type star[1]. For this one, we can expect to see stronger hydrogen Balmer lines, with numerous metal features mixed in.

The processed spectrum is presented here:

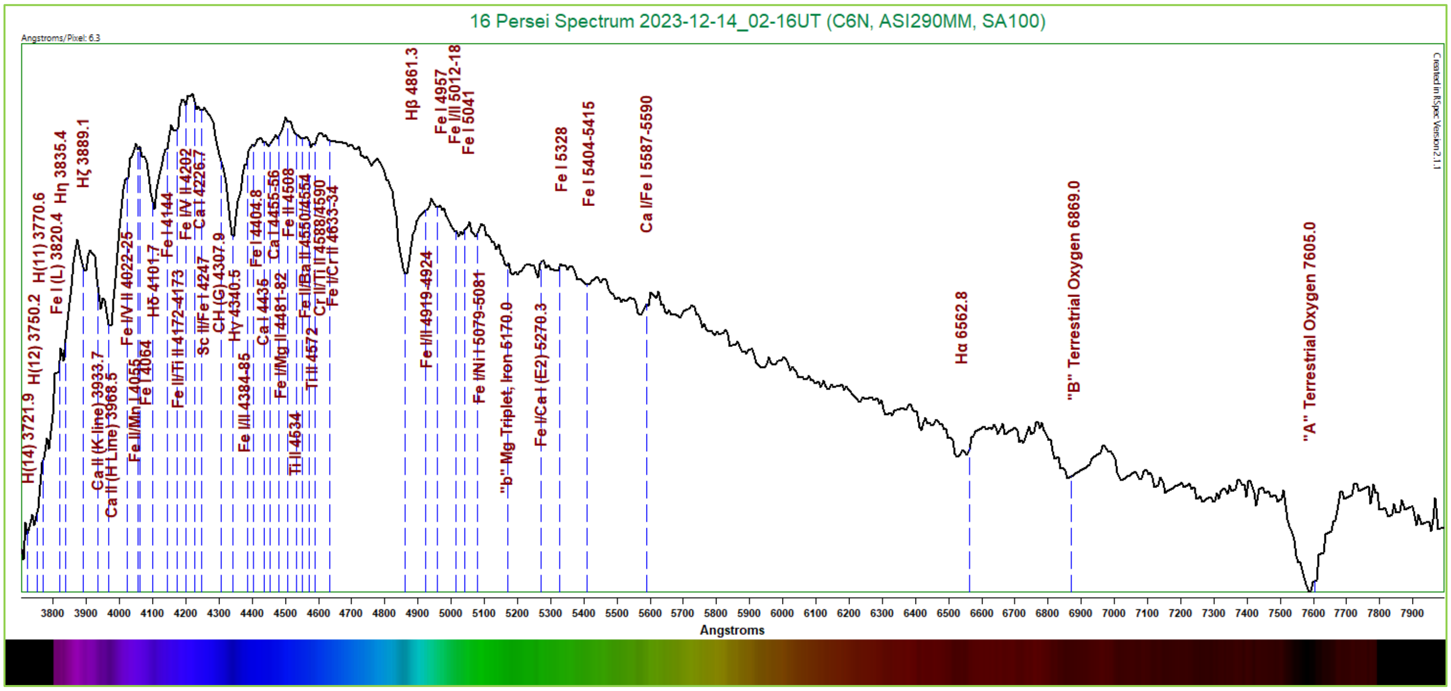

Figure 11: 16 Persei Spectrum (6.3 Angstroms/pixel)
Capture Details 11: Exposure 419ms, Gain 160, 60% of 466 frames stacked

This one turned out noisier than usual, and created some difficulties in calibration. However, the most of the hydrogen Balmer lines are seen to be fairly strong, with the exception of the missing Hε line. The Fe I (L) and Hη line are again creating a stair-step pattern near the lower wavelength region. The calcium H and K lines are prominent as well, causing a double-toothed absorption at 3933-3968 Angstroms. the CH (G) band absorption is just barely visible as a deformity on the lower side of the Hγ line. The magnesium triplet at 5170 appears only moderately strong, causing a notable but not exceptional dip in the continuum. Beyond there, the noise overwhelms most identification efforts. Numerous closely-spaced fainter metal lines can be seen, including lotsa of iron, calcium, scandium, titanium, and chromium. These are crammed very closely together, so be careful when tracing lines on the diagram above.

Using Wien's Law, we will calculate an estimated effective temperature for the star. Using an estimated peak energy wavelength of 4120 Angstroms, our resulting temperature is approximately 7034K. The accepted temperature of the star is listed as 7004K[2]. Wow! The estimate is very close!

Conclusion

I had some concerns when setting out to capture stars in this region, as it is quite busy. I thought that it might occasionally be difficult to capture the targets without background stars interfering. However, this ended up not presenting any problems. The constellation afforded a nice variety of targets, and contains a good selection of hotter stars.

The results for Gamma Persei continue to be troubling. A good number of details obtained in the spectrum seem to match an A-type star instead of the expected very late G-type. Even if the secondary were close to the primary, its luminosity should be too low to contribute much to the much more luminous primary. A third capture needs to be made to verify the features with relative certainty.

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