Spectral Analysis of the Constellation Stars of Pisces (The Fishes)

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Abstract

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

Most of the spectra obtained for this analysis were obtained on the evening of November 15, 2023 (EST). One target was misidentified during this run (Phi Piscium); this was reacquired on the evening of December 13, 2023 (EST). 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 times, 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 dark or flat frames were

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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 is composed mostly of dimmer stars, which mandated care when capturing the spectra for the stars. Some of the captures required more gain to accomplish, which of course introduces more noise into the signal. However, even with this limitation, the results seemed to be acceptable during the capture process.

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α Piscium

Alpha Piscum, also called Alrescha, is a tight double star, the members being very early and early A-type stars[1]. The equipment used was unable to separate the two components, so we will be looking at a combined spectrum of the two. Based on their type, we can expect very prominent hydrogen Balmer lines to be visible.

The processed spectrum is as follows:

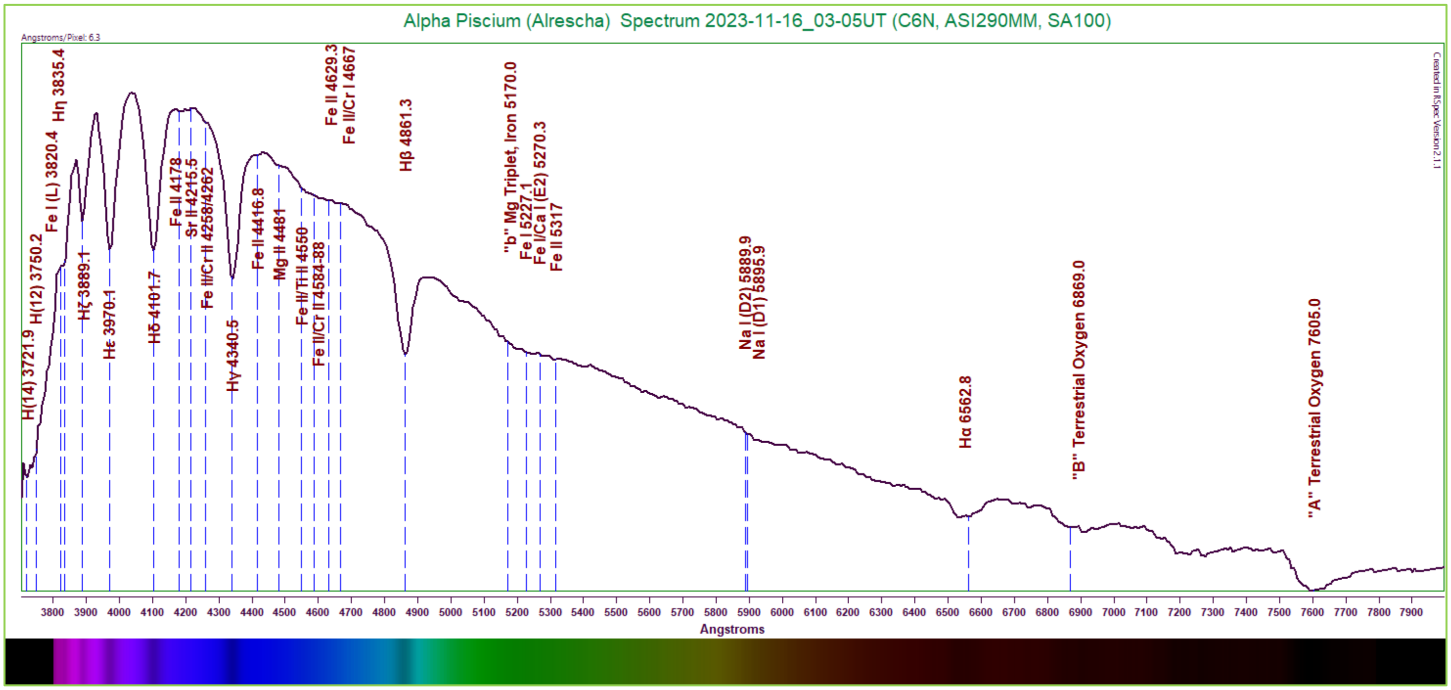

Figure 1: Alpha Piscium (Alrescha) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 1s, Gain 110, 80% of 241 frames stacked

Here we clearly see the classic, strong hydrogen Balmer lines typical of A-type stars. Even the Hα absorption appears well-defined t 6562.8 Angstroms. The Fe I (L) line and the Hη line create a somewhat pronounced step in the continuum at 3820-3835 Angstroms. A very broad decline in the continuum can be seen in the 4550-4667 Angstroms range, being a result of several ionized iron lines. Another notable dip can be seen around the magnesium triplet at 5170 Angstroms. The sodium doublet at 5890-96 Angstroms is marked, but is extraordinarily weak. In addition to these, we can see faint iron, strontium, and magnesium lines as well.

With Wien's Law, we will attempt to ascertain a rough estimate of the temperature. However, since the stars are very early or early A-type stars, our estimate will certainly be much too low. Using a peak energy wavelength of 4033 Angstroms, we obtain a result of 7185K. The accepted temperature of these stars is around 10100K[2].

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γ Piscium

Gamma Picium is classified as a very late G-type star[1]. We should expect to find a star a little cooler than our Sun, showing numerous metal lines evident throughout.

The processed spectrum is presented below:

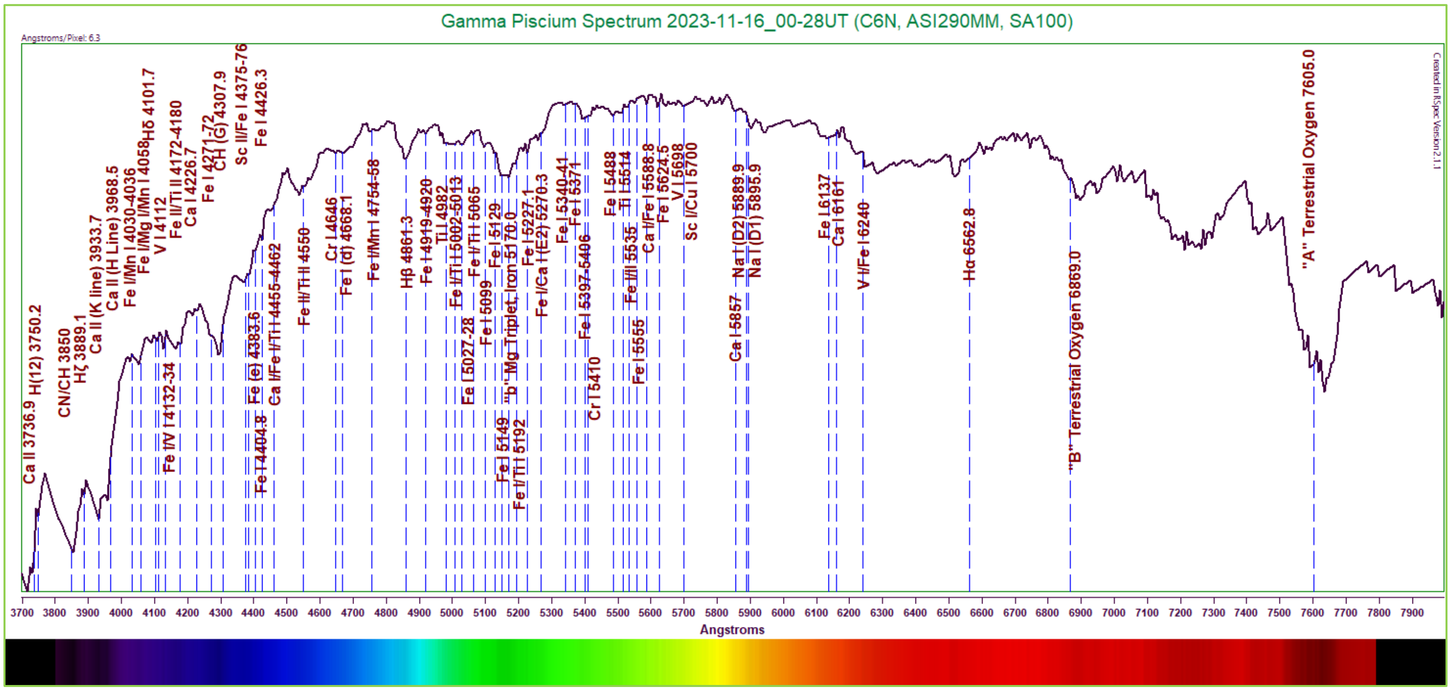

Figure 2: Gamma Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 565ms, Gain 101, 40% of 430 frames stacked

Here we see a very busy spectrum! The shape of the curve seems consistent with a G-type star, peaking around the middle wavelength range. Several hydrogen Balmer lines are visible, though not all. An unusual absorption appears just below the Hα line, but a positive identification was elusive. Near the lower wavelength range, the CN/CH absorption at 3850 Angstroms cuts a very sharp groove into the continuum. The calcium H and K lines appear to cut sharp grooves as well, though not quite as deep. The CH (G) absorption is also quite prominent at 4307.9 Angstroms. The magnesium triplet at 5170 Angstroms is visible, but is not extremely deep. The line appears to be broadened by the Fe I line at 5149 Angstroms, making the bottom of the trough appear flattened. The sodium doublet at 5890-96 Angstroms is marked, but the absorption appears quite weak. A large number of additional relatively weak metal lines are noted throughout the spectrum, including calcium, lots of iron, vanadium, scandium, chromium, and titanium. Many of these are very closely spaced, so use care when tracing lines!

Using Wien's Law, we will estimate the temperature of the star. Using an estimated peak energy wavelength of 5830 Angstroms, we obtain a result of 4970K. The currently accepted temperature is listed as 4833K[2]. Our estimate is a touch too high, but not too bad!

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δ Piscium

While capturing 62 Piscium (presented later), this star was quite prominent in the field, so a short detour was made to capture it. Delta Piscium, also called Kuton 1, is classified as a middle K-type star[1,2]. That being the case, we should expect to see a curve representative of a cooler star. The spectrum should show a generous amount of small metal lines throughout, with perhaps some TiO lines beginning to emerge.

The spectrum is presented here:

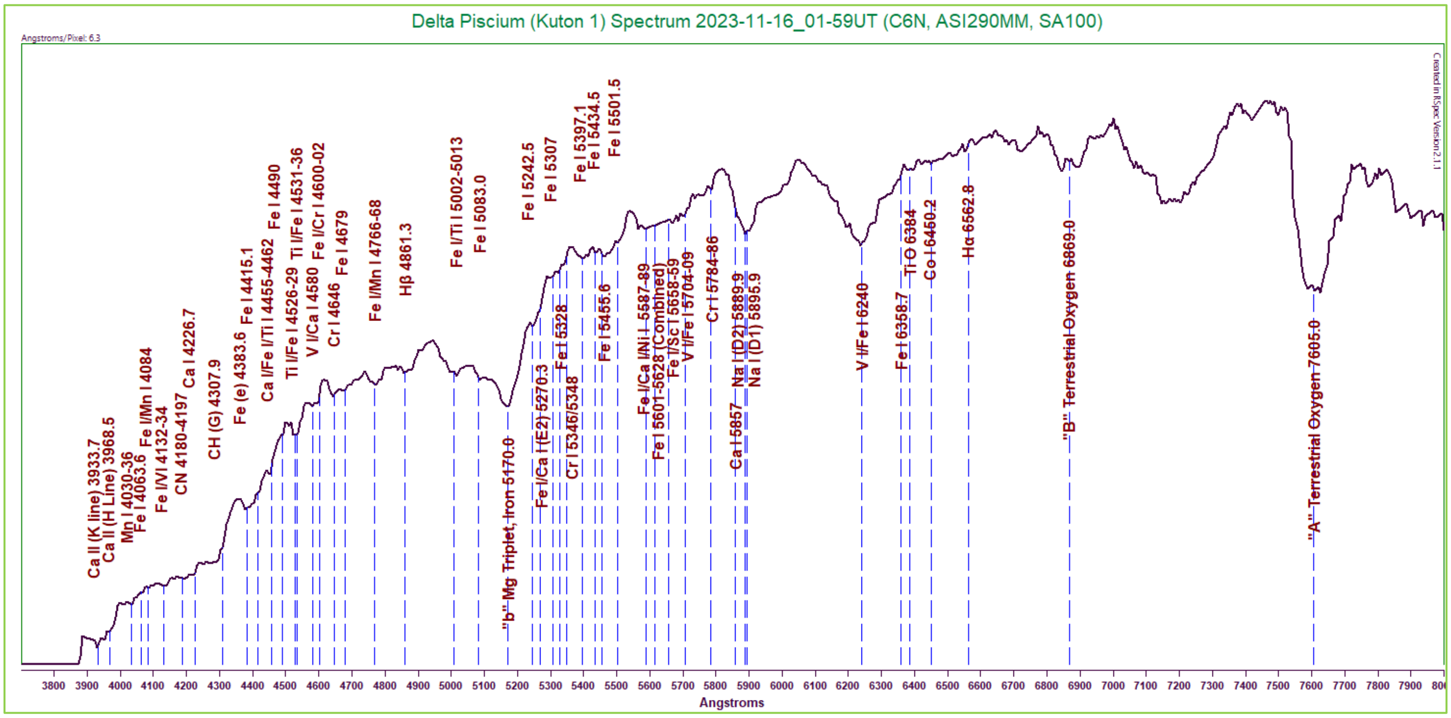

Figure 3: Delta Piscium (Kuton 1) Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 1s, Gain 107, 50% of 249 frames stacked

The spectrum for this one is very interesting. Only two of the hydrogen Balmer lines are visible—Hβ and Hα—and they are very weak. The calcium H and K lines are present at the lower end of the wavelength scale, but they appear muted. The CH (G) absorption is easily identified, being a bit stronger. A smaller absorption at 4526-4536 Angstroms appears with a flattened trough. This is due to a combination of titanium/iron lines. The magnesium triplet at 5170 Angstroms is profound, cutting a deep gash into the continuum. The sodium doublet at 5890-96 Angstroms is also quite strong, and is being broadened on its lower side by the calcium line at 5857 Angstroms. The vanadium/iron line at 6240 Angstroms is quite extraordinary as well. We can see one emergent TiO line at 6384 Angstroms. Numerous additional faint metal lines are scattered throughout the continuum, including manganese, iron, CN, calcium, chromium, and vanadium.

Using Wien's Law, we will attempt to estimate the temperature. Using an apparent peak energy wavelength of 7462 Angstroms, we get a result of 3883K. The established temperature of the star is 3963K[2]. Our estimate came in just a little too low.

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<u>ε Piscium</u>

Epsilon Piscium is a suspected very close double star, whose primary is a very late G-type star[1,2]. We should therefore expect to see a star whose temperature is a bit lower than our Sun, showing numerous metal lines. Overall, the results should strongly resemble those for Gamma Piscium, above.

The processed spectrum follows:

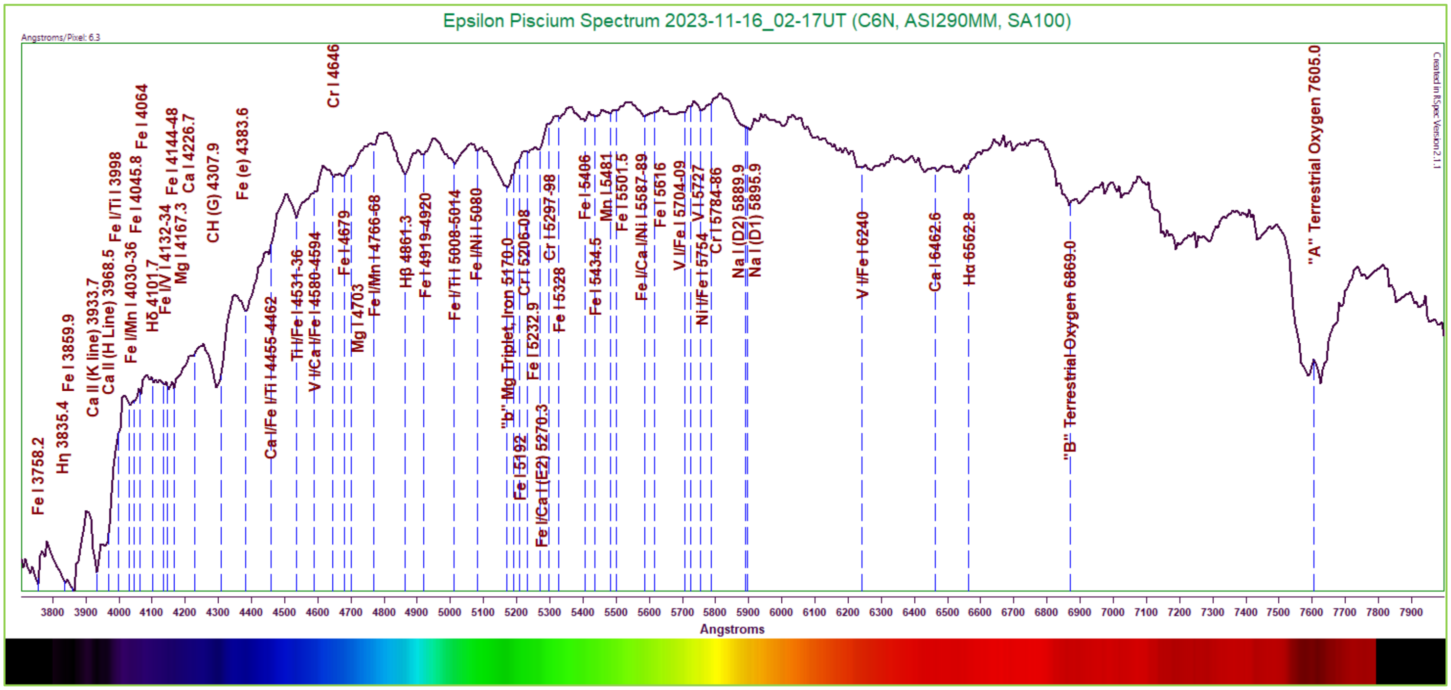

Figure 4: Epsilon Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 1s, Gain 143, 50% of 242 frames stacked

This spectrum does exhibit many features seen in Gamme Piscium previously. Several of the hydrogen Balmer lines are visible, but certainly not all. Near the lower wavelength region, the Hη and Fe I lines in the 3835-3860 Angstroms range are causing a big cut in the spectrum. The calcium H and K lines above them are also carving out a nice, sharp dip in the continuum. The CH (G) absorption is quite notable at 4307.9 Angstroms. The magnesium triplet at 5170 Angstroms is obvious, as are the sodium D1 and D2 lines at 5890-96 Angstroms. Both appear slightly muted, but are still easily recognizable. A good number of additional fainter metal lines are marked, including iron, magnesium, calcium, titanium, vanadium, chromium, manganese, and nickel.

Using Wien's Law, we will ascertain a rough estimate of the temperature. Accepting a peak energy wavelength of 5817 Angstroms, we find a result of 4982K. The accepted temperature for the star is 4814K[2]. Our estimate is pretty close, and conforms to our expectations.

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η Piscium

Eta Piscium, also known as Alpherg, is a close binary star whose primary is classified as a late G-type star[1]. The companion is too close to be separated with the equipment used, but it is also much dimmer and so shouldn't contribute anything to our spectrum. We can expect a spectrum not entirely dissimilar from Epsilon Piscium above, but with a slightly higher temperature.

The finished spectrum is presented here:

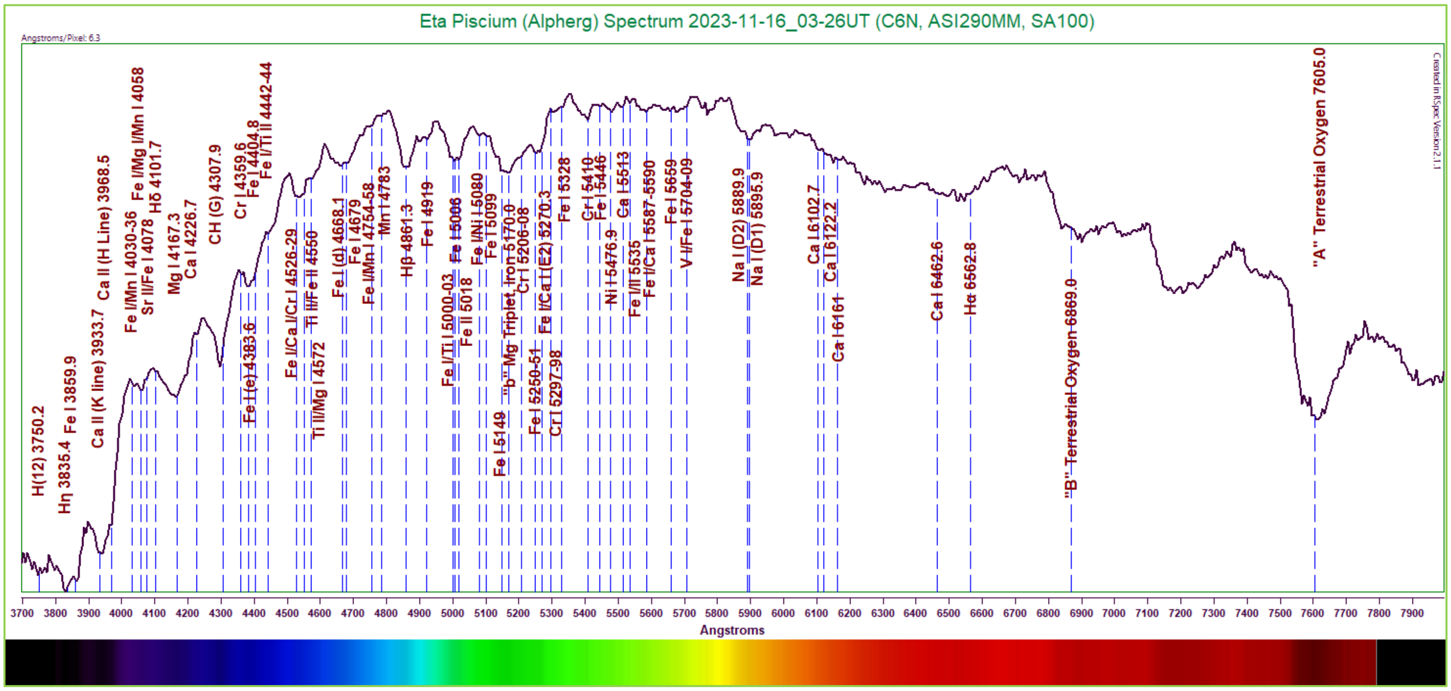

Figure 5: Eta Piscium (Alpherg) Spectrum
Capture Details 5: Exposure 895ms, Gain 101, 20% of 304 frames stacked

As expected, this result is similar to that for Epsilon Piscium above, but some differences can be seen. Some of the hydrogen Balmer lines are visible; the Hη line is particularly strong. The calcium H and K lines are quite prominent. The magnesium line at 4167.3 Angstroms appears very boldly, as does the CH (G) absorption at 4307.9 Angstroms. The trio of iron lines in the 5000-5018 Angstroms range are cutting fairly deeply into the continuum, rivaling the Hβ line below them. The magnesium triplet at 5170 Angstroms is quite notable, and appears broadened by flanking iron and chromium lines. The sodium doublet at 5890-96 Angstroms is not quite as strong, but is still causing a sharp gouge into the spectrum. A number of additional fainter metal lines are scattered throughout this spectrum, including lots of iron, strontium, magnesium, calcium, chromium, titanium, manganese, nickel, and vanadium.

We will again use Wien's Law to estimate the effective temperature. Using an estimated peak energy wavelength of 5358 Angstroms, we obtain a result of 5408K. The established temperature for the star is listed as 4937K[2]. Our estimate is a bit high, but it is consistent with the comparison to Epsilon Piscium, as this star should be slightly hotter.

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θ Piscium

Theta Piscium is classified as a very early K-type star[1]. This indicates a cooler star showing significant metal lines.

The processed spectrum is presented below:

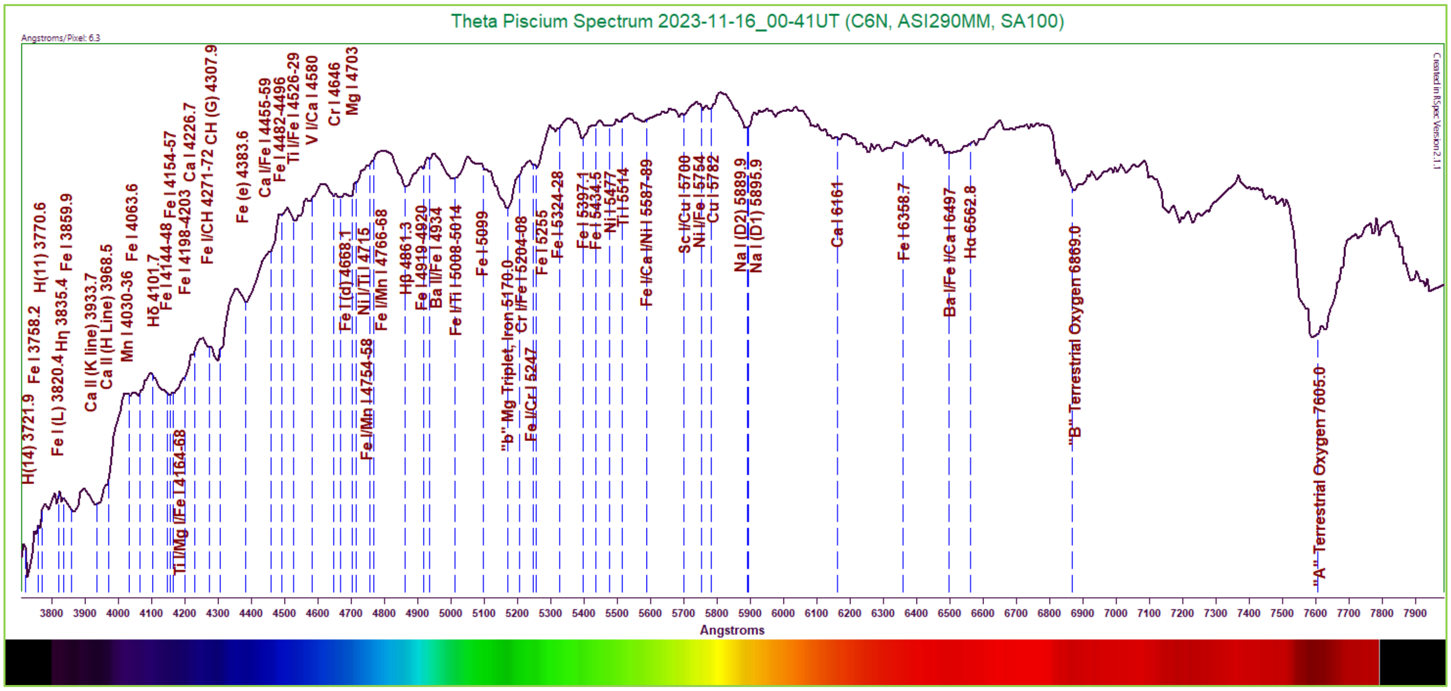

Figure 6: Theta Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 1s, Gain 137, 80% of 241 frames stacked

We see here another star with numerous iron lines throughout. Several hydrogen Balmer lines are visible. A significant, combined absorption appears in the 3820-3860 Angstroms range, with two iron absorptions flanking the Hη line. The calcium H and K lines are visible here, cutting a moderate chunk out of the continuum. Above this, another combined absorption appears, this time at 4144-4168 Angstroms. This one is caused by iron and titanium. The CH (G) line is also fairly strong at 4307.9 Angstroms. The Fe I (e) line at 4383.6 Angstroms appears very strong, as well. A third notable combined absorption appears in the 4646-4703 Angstroms range. This is a combination of chromium, iron, nickel, and magnesium. The magnesium triplet at 5170 Angstroms is cutting a sharp groove in the spectrum, with chromium and iron "steps" above it. The sodium D1 and D2 lines at 5890-96 Angstroms are also visible, though not as sharp as the magnesium triplet. Numerous additional faint metal lines can be seen along the spectrum, including iron, manganese, calcium, titanium, vanadium, magnesium, barium, chromium, nickel, and scandium.

Wien's Law can provide a rough estimate of the star's temperature. Using an estimated peak energy wavelength of 5815 Angstroms, we obtain a temperature of 4983K. For comparison, the accepted temperature of the star is listed as 4684K[2].

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ι Piscium

Iota Piscium is listed as a late F-type star[1]. This one should yield results quite different from the last few. We should see stronger hydrogen Balmer lines, and a curve representing a hotter star.

The spectrum is presented here:

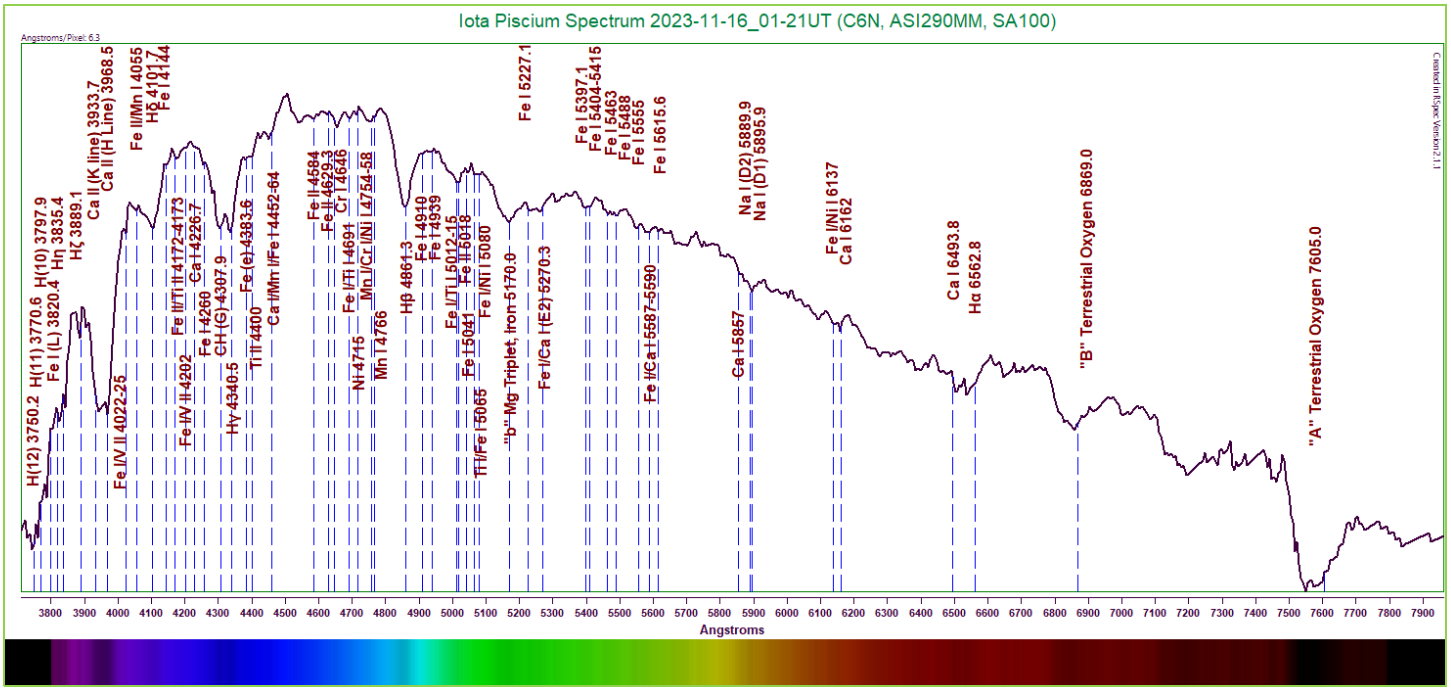

Figure 7: Iota Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 1s, Gain 113, 80% of 242 frames stacked

Though we see a large number of metal lines present, most of the hydrogen Balmer lines are identifiable. The Hε line is overtaken by the calcium H and K lines, though. The The Fe I (L) line and Hη line appear jagged here, probably due to the increased noise in the resulting spectrum. The CH (G) absorption can be seen alongside the Hγ line, appearing at almost the same strength. The magnesium triplet at 5170 Angstroms is pretty clear, carving out a moderate groove in the continuum. The sodium doublet at 5890-96 Angstroms is less pronounced, but still readily identifiable. A large number of additional faint metal lines are present, particularly lots of iron. Also present are calcium, titanium, chromium, nickel, and manganese.

Using Wien's Law, we will make a rough estimate of the temperature. Using a peak energy wavelength of 4506 Angstroms, we calculate a temperature of 6431K. The listed temperature for this star is 6288K[2]. This seems unusual, to calculate a temperature for an F-type star and obtain a result that is too high. Very interesting.

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κ Piscium

Kappa Piscium is classified as an early A-type star[1]. We can expect to see the very prominent hydrogen Balmer absorptions on this one, along with a spectrum curve indicating a hot star.

The spectrum is shown below:

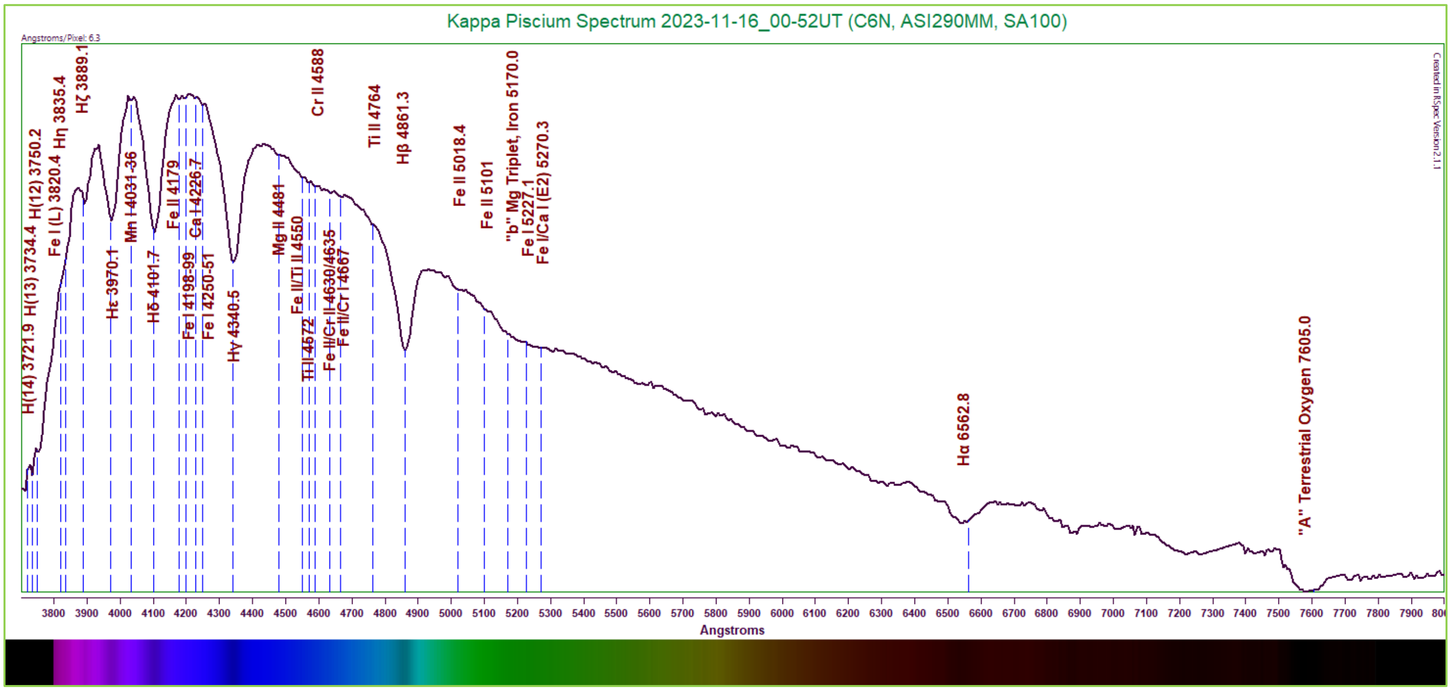

Figure 8: Kappa Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 8: Exposure 1s, Gain 205, 705 of 241 frames stacked

This rather clean-looking spectrum is indicative of an A-type star, with the energy level peaking near the lower wavelength region. The noise levels also appear unusually low for the greater exposure time and gain used in the capture. The hydrogen Balmer lines are exceptionally clear and deep. Even the Hα line is very clear. The Fe I (L) and Hη lines are only causing the most gentle change in the continuum path. The magnesium triplet at 5170 Angstroms is visible as a broad but gentle dip in the spectrum. This appears broadened due to the flanking iron lines. The sodium D1 and D2 lines are not detectable. Some other additional metal lines are present, but they are all very weak. These include manganese, lots of iron (both neutral and ionized), titanium, and chromium.

Wien's Law can be used to estimate the star's temperature, but since this is an early-type star we can certainly expect our estimate to be far too low. Using a peak energy wavelength of 4168 Angstroms, we obtain a result of 6953K. The currently accepted temperature of the star is 10961K[2].

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λ Piscium

Lambda Piscium is classified as a late A-type star[1]. Like with Kappa Piscium above, we can expect relatively strong hydrogen Balmer lines—though not quite as bold as those for Kappa. A slightly cooler temperature should also be evident by the star's curve.

The spectrum for Lambda Piscium follows:

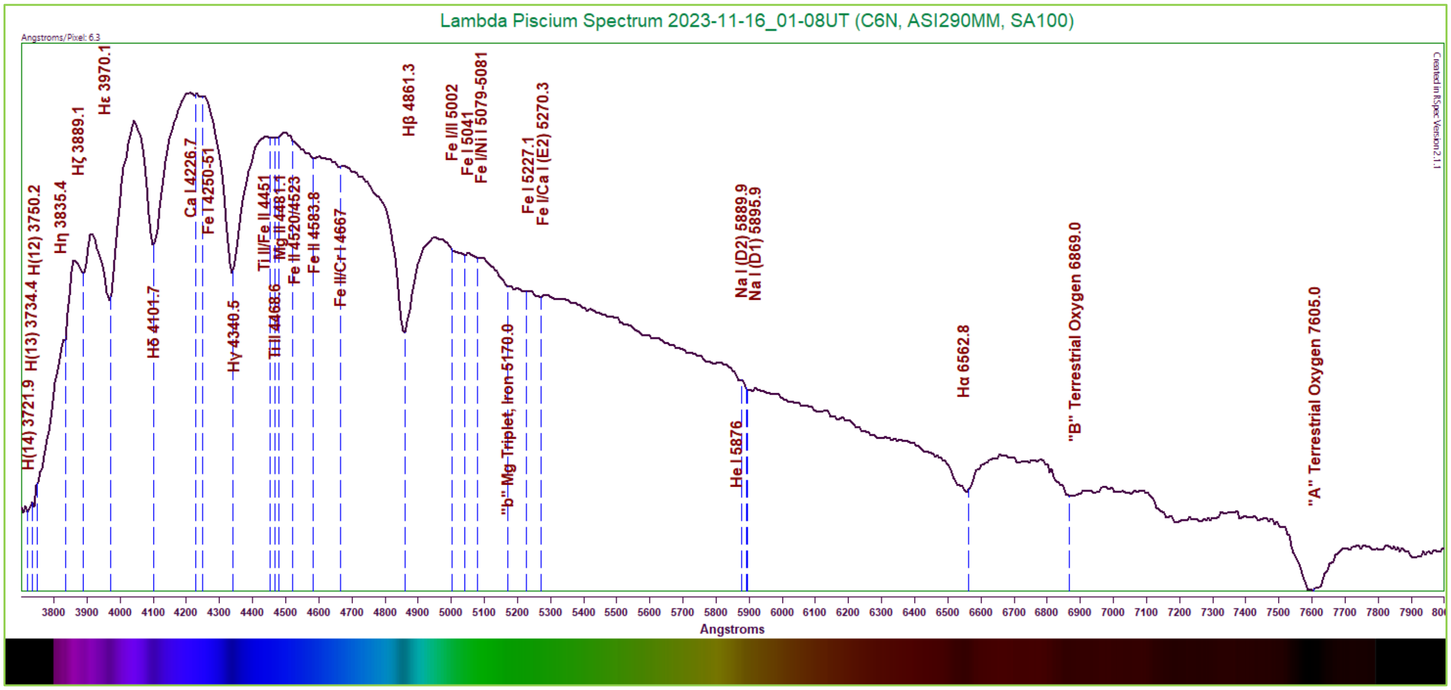

Figure 9: Lambda Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 9: Exposure 1s, Gain 208, 50% of 225 frames stacked

Again, we can clearly see the prominent hydrogen Balmer lines. The Hη line is causing a stair-step in the continuum; the Hα line is again distinct. A trio of lines in the 4451-4481 Angstroms range are causing a small plateau in the curve. This appears to be caused by ionized titanium and ionized magnesium. The magnesium triplet at 5170 Angstroms is visible as a distinct dip in the continuum. This is aided and broadened by the iron lines above it. The sodium doublet at 5890-96 Angstroms is visible here, causing a small but notable cut in the spectrum. Just below it is a solitary He I line at 5876 Angstroms. Several other very faint metal lines can be seen, including calcium and iron.

Using Wien's Law, we will estimate the star's temperature. Adopting a peak energy wavelength of 4231 Angstroms, we obtain a resulting temperature of 6849K. The established temperature of the star is 7734K[2]. Our estimate is low, but since this is a late A-type star, we are not exceedingly short.

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μ Piscium

Mu Piscium is classified as an early-to-middle K-type star[1,2]. We can expect to see a curve indicative of a cooler star, with numerous metals present and possibly an emergent TiO line or two visible.

The spectrum is below:

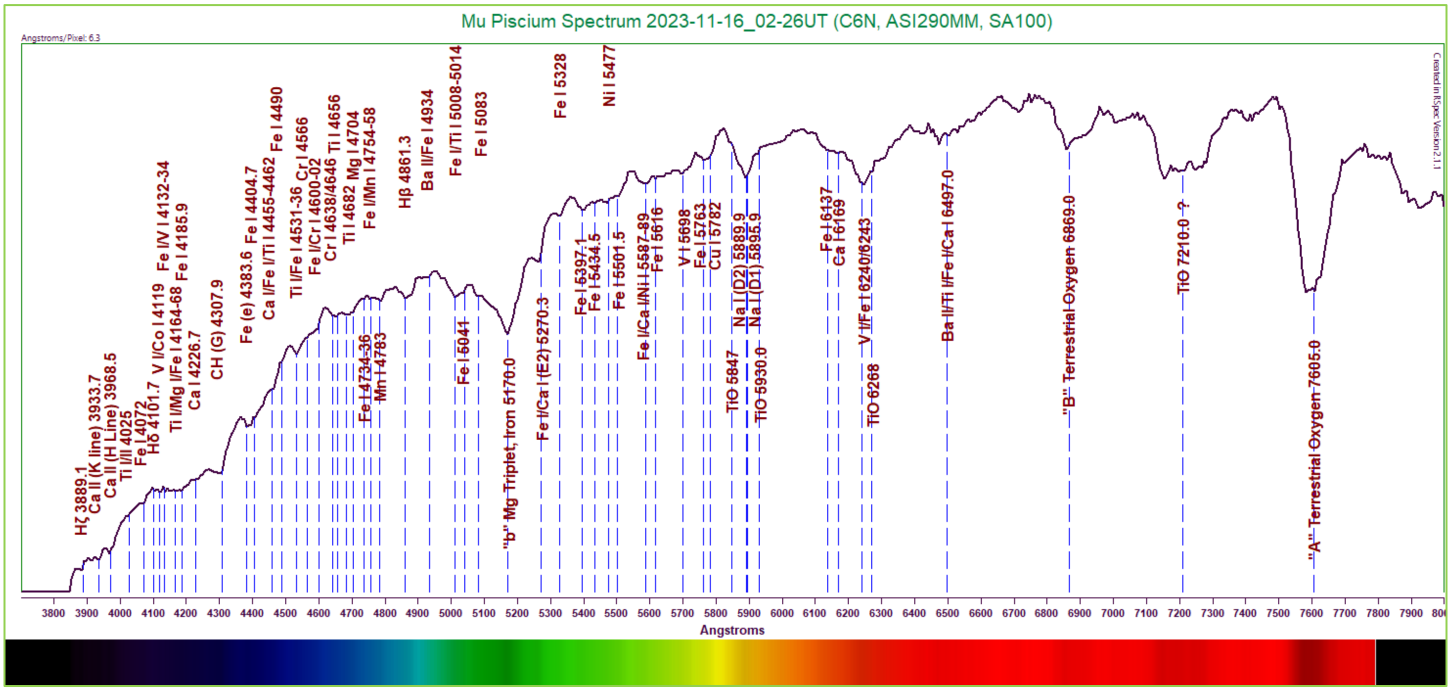

Figure 10: Mu Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 10: Exposure 1s, Gain 154, 60% of 243 frames stacked

The shape of the resulting spectrum does match our expectations for an early K-type star. A few of the hydrogen Balmer lines can be seen, but they are extremely weak. A combination of absorptions in the 4101-4186 Angstroms range are collectively causing a gentle swoop in the curve. This is being caused by the Hδ line along with vanadium, iron, and titanium. The CH (G) line is showing prominent and sharp groove at 4307.9 Angstroms, even though it is not exceedingly strong. Another combination of absorptions can be seen at 4638-4704 Angstroms range, this time due to chromium, titanium, and magnesium. The magnesium triplet is easily the deepest apparent absorption, carving a deep gouge out of the continuum. The Fe I/Ca I (E2) line at 5270.3 Angstroms above it is also very notable. The sodium doublet at 5890-96 Angstroms is also distinctive. There appear to be two extremely small TiO lines flanking it. One more TiO line is marked at 7210 Angstroms, but this is definitely questionable. A lot of other faint metal lines are spread throughout this spectrum, including titanium, calcium, chromium, barium, nickel, vanadium, and copper. A very interesting spectrum.

Using Wien's Law, we will estimate the effective temperature of the star. This particular curve, however, presents us with no immediately obvious peak. Performing an average between nearby tall peaks, we find it lies somewhere near 7119 Angstroms. Applying this value to Wien's Law yields a temperature of 4071K. The currently accepted value for the star's temperature is 4126K[2]. Considering the uncertainties in choosing a peak wavelength, our estimate is not bad!

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ν Piscium

Nu Piscium is listed as an early K-type star[1]. That being the case, we should expect a result very similar to that obtained for Mu Piscium above.

The spectrum of Nu Piscium is presented here:

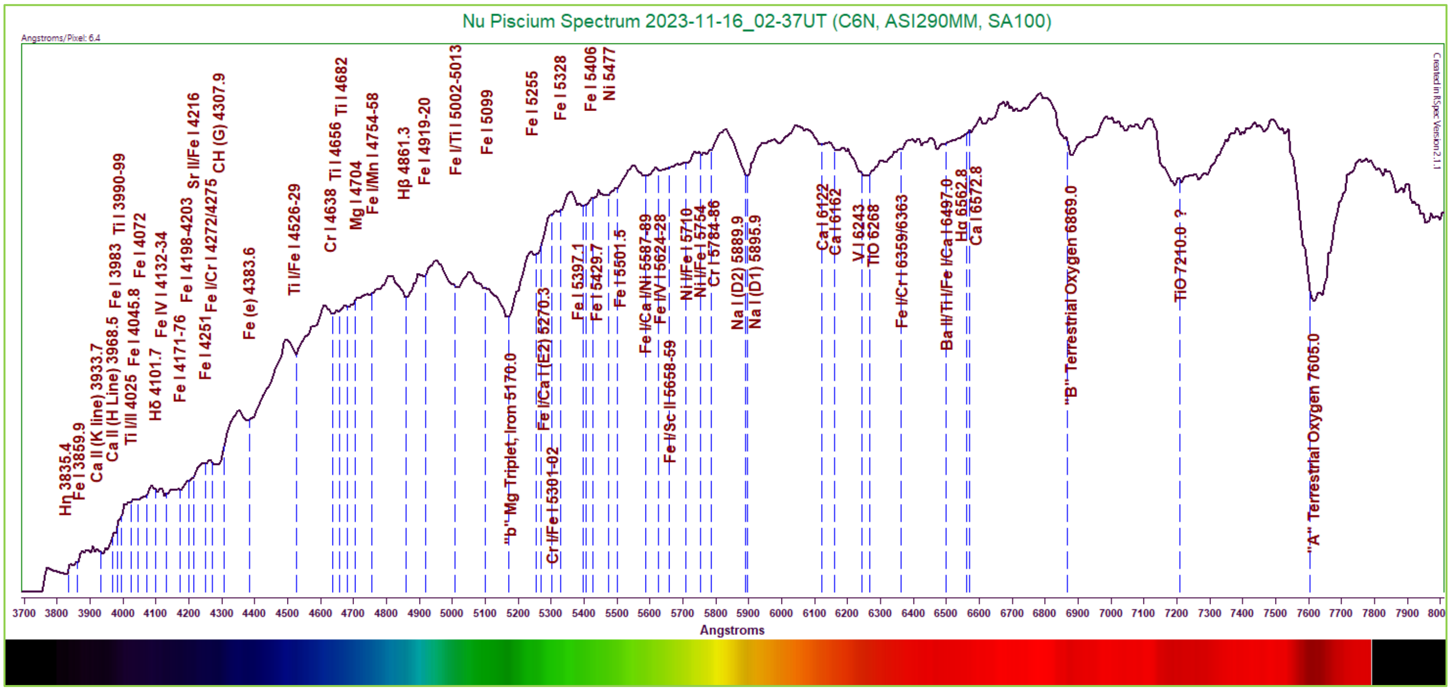

Figure 11: Nu Piscium Spectrum (6.4 Angstroms/pixel)
Capture Details 11: Exposure 1s, Gain 143, 55% of 242 frames stacked

This spectrum does indeed bear a striking resemblance to that of Mu Piscium previously. Several hydrogen Balmer lines can be seen, but all are relatively weak. The calcium H and K lines at 3933-3968 Angstroms are causing a notable dip in the continuum, but the absorption is decidedly weakened. The CH (G) absorption at 4307.9 Angstroms is stronger, as is the Fe I (e) line at 4383.6 Angstroms. A good-sized cut in the spectrum can also be seen at 5002-5013 Angstroms, caused by iron. The magnesium triplet at 5170 Angstroms is very strong here. Just above it, two iron lines at 5255 and 5270 Angstroms combine to make a smaller but notable dip in the continuum line. A flattened area on the curve between 5624 and 5710 Angstroms appears due to a combination of iron and nickel lines. The sodium D1 and D2 lines at 5890-96 Angstroms are pretty clear, cutting a nice groove into the spectrum. One TiO line appears to be emerging alongside the vanadium line at 6243-6268 Angstroms. Another somewhat flattened area of the spectrum can be seen in the 6497-6573 Angstroms range, this time due to barium, Hα, and calcium. One more TiO line is marked at 7210 Angstroms, but the noise in the spectrum in that range makes the identification dubious. Other faint metal lines are marked along the spectrum, including iron, titanium, strontium, magnesium, chromium, nickel, and vanadium.

Employing Wien's Law, we will estimate the temperature of the star. Using an estimated peak energy wavelength of 6782 Angstroms, we arrive at a temperature of 4273K. The currently listed temperature for the star is 4154K[2]. Our estimate is only about 125K off!

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ξ Piscium

Xi Piscium is classified as a late G-type star[1]. Based on this, we can expect a curve representing a star with a temperature a bity lower than our own Sun, with numerous metal lines present throughout.

The processed spectrum is presented below:

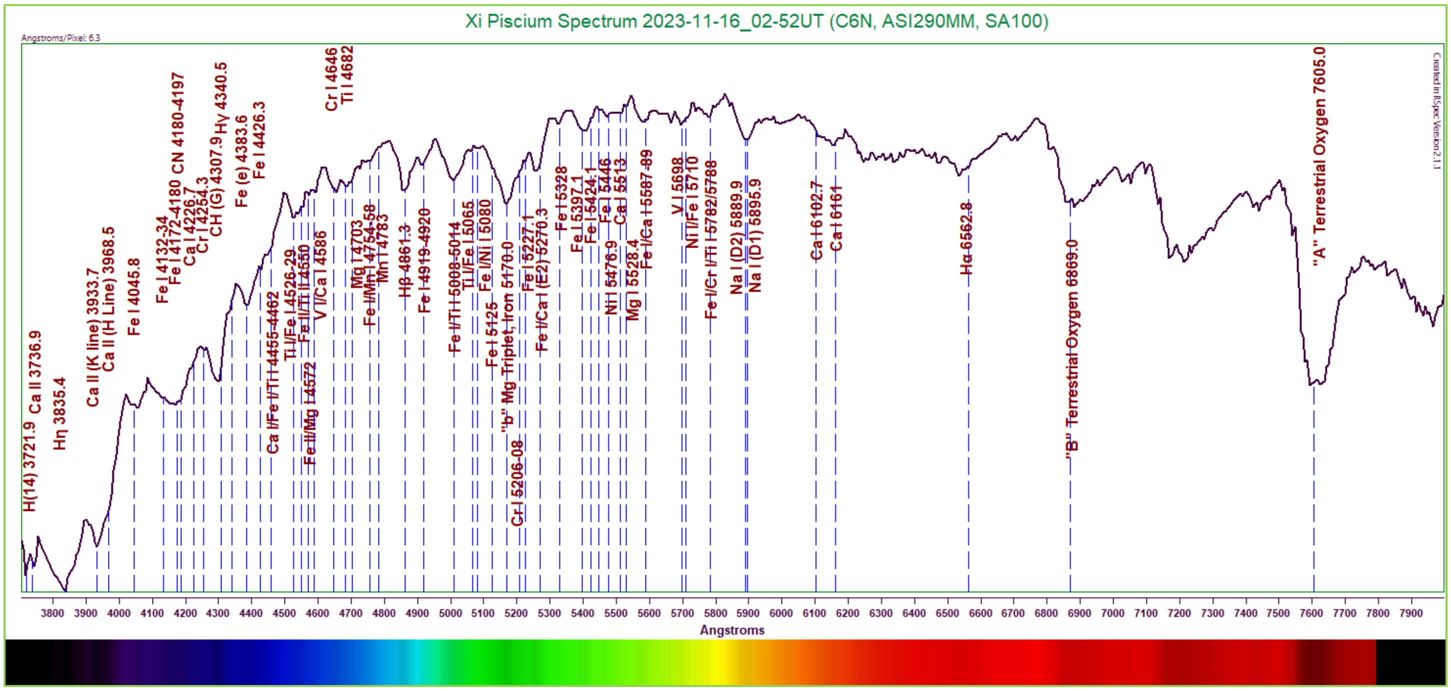

Figure 12: Xi Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 12: Exposure 1s, Gain 166, 65% of 242 frames stacked

The familiar pattern of a G-type star can be seen here—a curve for a middle-temperature star, and plenty of metal lines present. Many of the hydrogen Balmer lines can be seen, but most are not that strong. The exception is the Hη line at 3835.4 Angstroms, which is profoundly deep. The calcium H and K lines are also carving a deep gouge out of the continuum. Another deep, but broad, absorption lies in the 4134-4197 Angstroms range. This is due to a combination of iron and CN. The magnesium triplet at 5170 Angstroms is easily identifiable, but not quite as strong as in some later-type stars. The sodium doublet at 5890-96 Angstroms is also visible and moderately strong. A good number of additional faint metal lines are scattered throughout, including calcium, iron, chromium, titanium, vanadium, magnesium, manganese, and nickel.

Using Wien's Law, we will estimate the star's effective temperature. Using an estimated peak energy wavelength of 5829 Angstroms, we obtain a resulting temperature of 4971K. The established temperature of the star is listed as 4947K[2]. Our rough estimate is very close to the mark!

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ο Piscium

Omicron Piscium, also called Torcular, is classified as a late G-type or early K-type star[1,2]. The star is a binary system, but the companion is not bright enough to contribute to our low-resolution spectrum. We can expect a spectrum not entirely dissimilar from that of Xi Piscium above, with a comparable temperature and elemental abundances.

The finished spectrum follows:

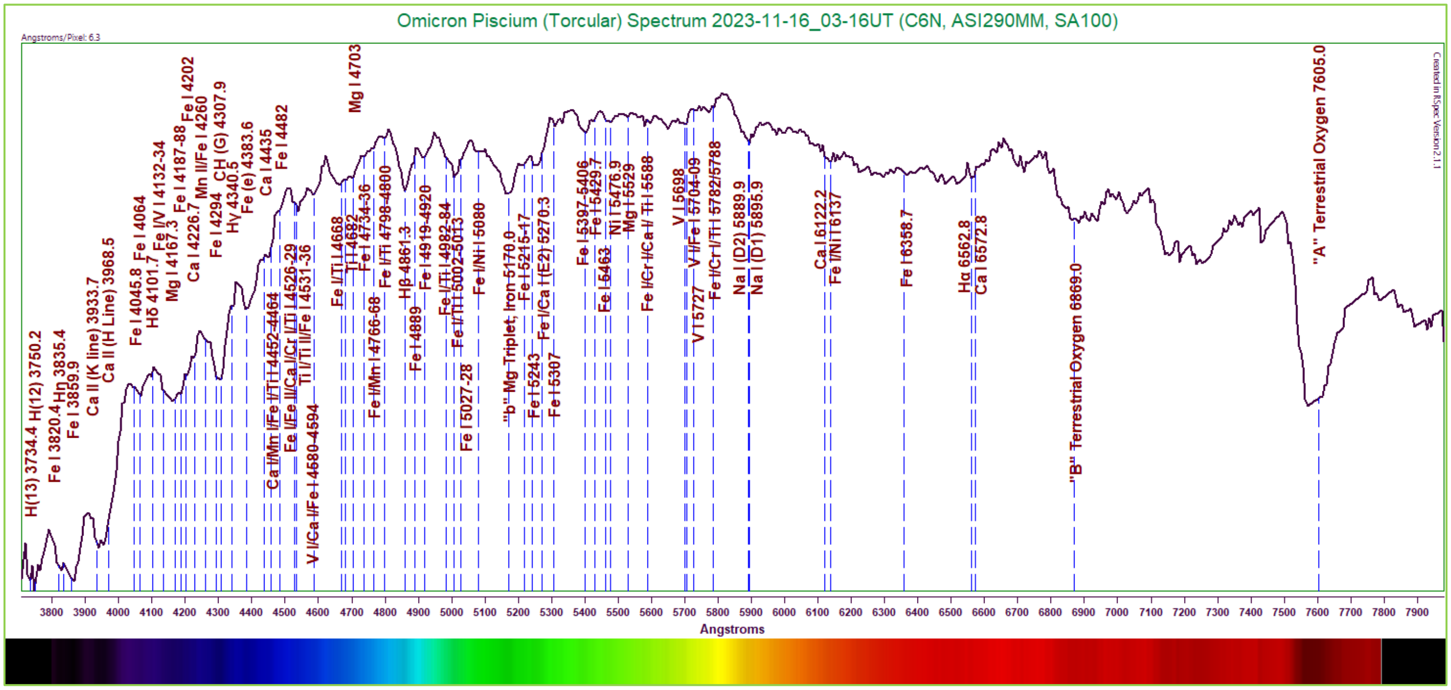

Figure 13: Omicron Piscium (Torcular) Spectrum (6.3 Angstroms/pixel)
Capture Details 13: Exposure 1s, Gain 116, 40% of 243 frames stacked

As expected, we can see that this spectrum does indeed resemble that of Xi Piscium. Many of the same metal lines can be seen, and the general shape of the curve is very familiar. Some hydrogen Balmer lines can be seen, the strongest of which is the Hβ line. The Hα line is being slightly broadened by an adjacent calcium line, causing the trough of the absorption to appear flattened. A very strong iron line can be seen near the low wavelength region at 3859.9 Angstroms. The calcium H and K lines are prominent here, as well. The magnesium absorption at 4167.3 Angstroms is also quite strong. The CH (G) band at 4307.9 Angstroms is quite deep and sharp, aided by the iron line just below it which is causing the flattened trough in the line. Another substantial absorption is seen at 4668-4703 Angstroms. This is due to a combination of iron, titanium, and magnesium. The magnesium triplet at 5170 Angstrom is prominent here also. The sodium D1 and D2 lines are causing a sharp groove in the continuum at 5890-96 Angstroms, though it is a bit weaker. A great number of additional metal lines are marked throughout the spectrum, including iron, magnesium, calcium, manganese, titanium, vanadium, and nickel. The noted absorptions are often space very close together, so be careful when tracing lines on the spectrum!

Employing Wien's Law, we will again obtain an estimate of the star's effective temperature. Using a peak energy wavelength of 5813 Angstroms, we obtain a result of 4985K. The currently accepted temperature of the star is 5004K[2]. Again, our estimate is extremely close to the accepted value.

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σ Piscium

Sigma Piscium is a spectroscopic binary, whose components are very late B-type stars[1,2]. This means we can expect very strong hydrogen Balmer absorptions comparable to those in the very early A-type stars. We should also see a curve peaking more toward the lower wavelength range, indicating a high temperature.

The processed spectrum is presented here:

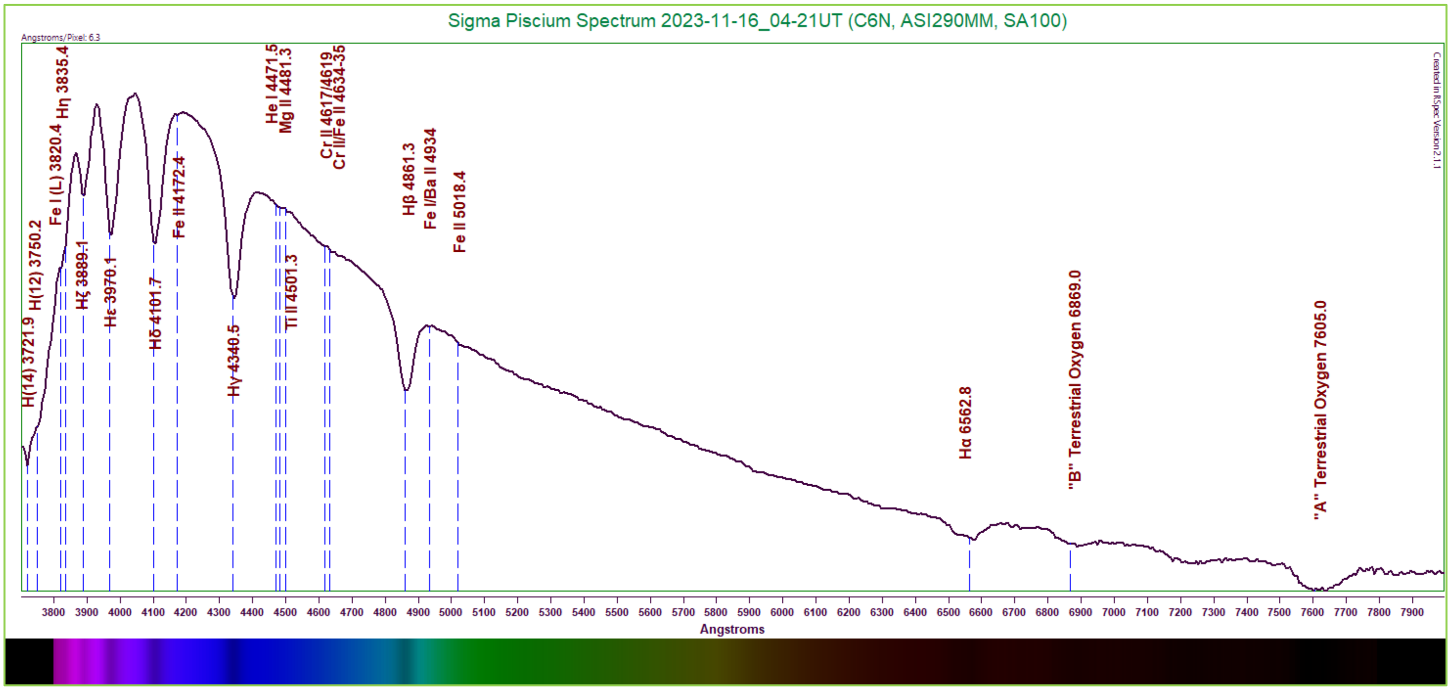

Figure 14: Sigma Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 14: Exposure 3s, Gain 154, 90% of 80 frames stacked

This is a very clean-looking spectrum! The shape of the curve is appropriate for the type of star involved, and the hydrogen Balmer lines are mostly deep and clear. The exception is the Hη line, which is only causing a small bump in the continuum along with the Fe I (L) line at 3820-3835 Angstroms. Very few additional lines can be seen, and the ones that can are extraordinarily weak. At 4471-4481 Angstroms, however, we can see a very small combined dip in the spectrum due to neutral helium and ionized magnesium. Two closely spaced ionized chromium lines at 4617-4635 Angstroms can just barely be seen. The only other lines of note in our result are a few extremely faint iron lines.

We will again employ Wien's Law to obtain a temperature estimate, but since this is an early-type star we can certainly expect our estimate to come out too low. Using an estimated peak energy wavelength of 4044 Angstroms, we obtain a result of 7166K. No reference temperature was readily available.

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υ Piscium

Upsilon Piscium is classified as a single, early A-type star[1]. We should see a spectrum similar to that of Sigma Piscium above, but with a slightly lower temperature.

The spectrum is presented below:

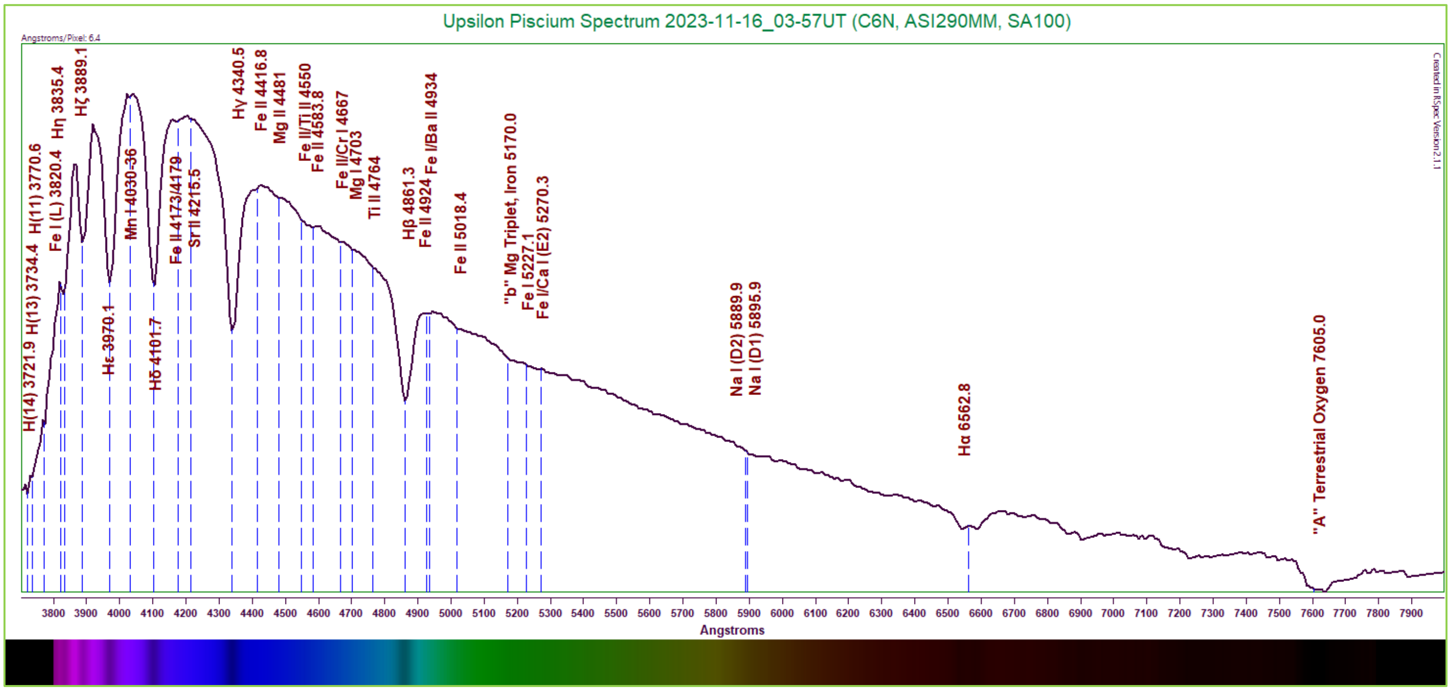

Figure 15: Upsilon Piscium Spectrum (6.4 Angstroms/pixel)
Capture Details 15: Exposure 2s, Gain 125, 95% of 116 frames stacked

This spectrum does indeed resemble that of Sigma Piscium above—a relatively smooth curve with deep hydrogen Balmer lines. Some differences are visible, though. The Hη line along with the Fe I (L) line near the lower wavelength region (3820-3835 Angstroms) are causing a much more obvious absorption. The magnesium triplet at 5170 Angstroms, along with the two very faint iron lines above it, is causing a subtle scoop in the continuum that is definitely noticeable. The sodium doublet at 5890-96 Angstroms is also visible, though just barely. Many more metal lines are visible here than in Sigma Piscium. These include manganese, quite a bit of iron (mostly ionized), magnesium, and titanium.

We will employ Wien's Law to obtain a rough temperature estimate. Since this is an early-type star, though, our estimate will certainly come up short. The peak energy wavelength is estimated at 4031 Angstroms, where the peak between the Hδ and Hε absorptions lies. This gives us a resulting temperature of 7189K. The listed temperature for the star is 9183K[2].

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φ Piscium

This star is the one which was misidentified on the initial run and had to be reacquired later. Phi Piscium is a multiple star system, whose primary visible components are very early K-type stars[1,2]. We can therefore expect to find a spectrum curve appropriate for a cooler star, with numerous metal lines evident throughout.

The processed spectrum follows:

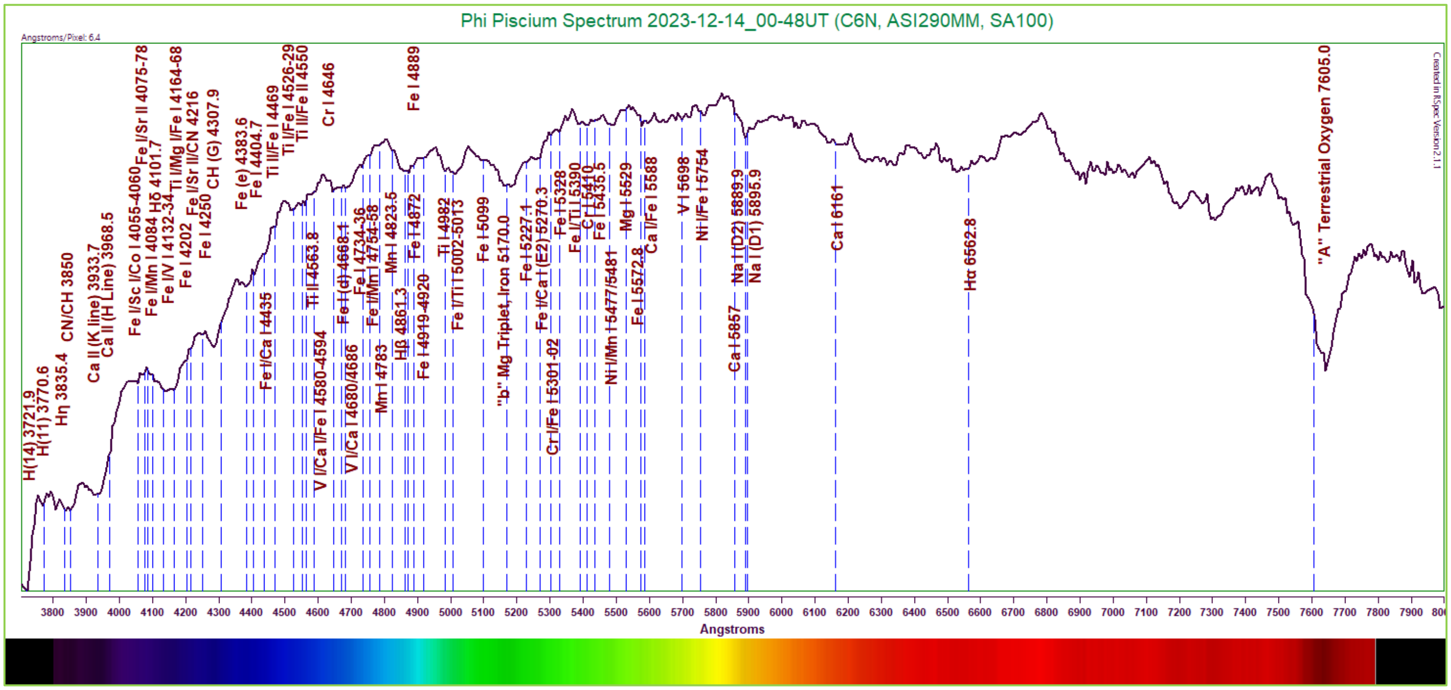

Figure 16: Phi Piscium Spectrum (6.4 Angstroms/pixel)
Capture Details 16: Exposure 1s, Gain 143, 20% of 375 frames stacked

Now this is a busy-looking spectrum! We can definitely see from the shape of the curve that this is a cooler star. Several hydrogen Balmer lines are visible. The Hη and CN/CH lines at 3835-3580 Angstroms are causing a fairly deep absorption. The Hβ line appears slightly broadened by the iron line just above it. The calcium H and K lines are also notable. Another noticeable absorption is visible in the 4132-4168 Angstroms range, caused by a combination of iron and titanium. The CH (G) line at 4307.9 Angstroms is easily identified. Another combination absorption appears at 4646-4686 Angstroms, caused by chromium, iron, and vanadium. The magnesium triplet at 5170 Angstroms is strong here, and is flanked by iron lines causing a profound dip in the continuum. The sodium doublet is also present, though weaker. The nearby calcium line below it is visible as well. This spectrum presents a great number of fainter metal lines along its length. These include iron, titanium, vanadium, manganese, nickel, and magnesium. Again, these lines are at times very closely spaced, so be careful when tracing lines on the diagram above.

With Wien's Law, we will attempt to ascertain a rough estimate of the temperature. This particular curve, however, does not readily show its peak wavelength. Rather, the peak would appear to lie between the crests at 5819.7 and 6784.6 Angstroms. Choosing the middle point, we will use a peak energy wavelength of 6302 Angstroms. Plugging this into Wien's Law, we obtain a result of 4598K. The established temperature of the star is 4720K[2]. Not a bad estimate, all things considered.

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ω Piscium

Omega Piscium is classified as a middle F-type star[1]. We can expect to see some weakened hydrogen Balmer lines, with some metal absorptions becoming apparent on a curve representing a moderately hot star.

The processed spectrum is presented here:

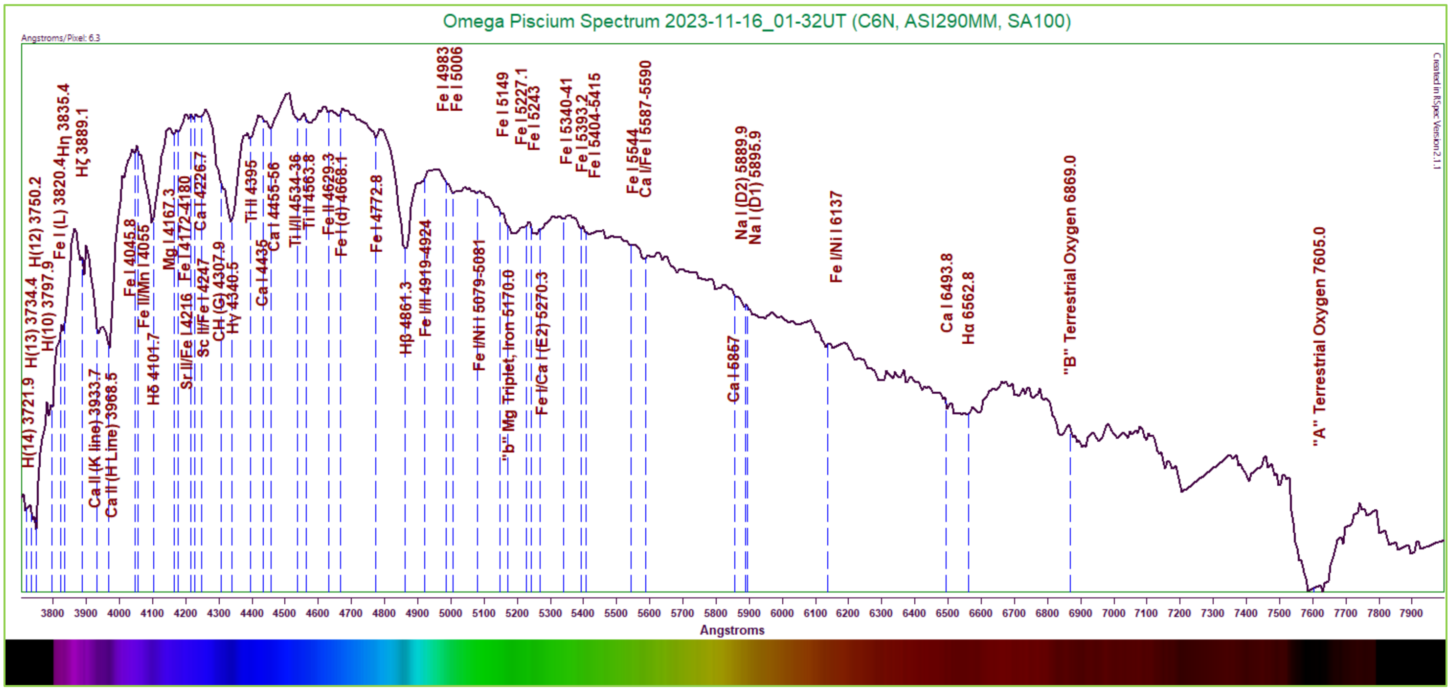

Figure 17: Omega Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 17: Exposure 1s, Gain 110, 60% of 244 frames stacked

The spectrum contains many interesting features. Most of the hydrogen Balmer lines are visible, with the exception of the Hε line which has been overpowered by the calcium H and K lines. Near the lower wavelength range, the Fe I (L) line is only causing a mild bump in the continuum, whereas the adjacent Hη line is creating a small, sharp absorption. The magnesium triplet at 5170 Angstroms is easily recognized, with the Fe I/Ca I (E2) line above it also causing a significant groove in the spectrum. The sodium doublet is comparatively weak at 5890-96 Angstroms. A good number of additional faint metal lines are identifiable, including many iron lines, magnesium, strontium, calcium, and titanium. The spectrum seems to show a star that is almost transitional, being between the hotter A-types and the moderate-temperature G-types. Very nice.

Wien's Law again gives us the ability to establish a rough estimate of the star's temperature. Using a peak energy wavelength of 4514 Angstroms, we obtain a result of 6420K. The established temperature of the star is listed as 6641K[2]. All-in-all, our estimate is not too bad.

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9 Piscium

9 Piscium lies very close to Kappa Piscium, so a short detour was made to capture its spectrum. 9 Piscium is regarded as a very early K-type star[1]. That being the case, we can expect to see a cooler star with numerous metal lines.

The processed spectrum is below:

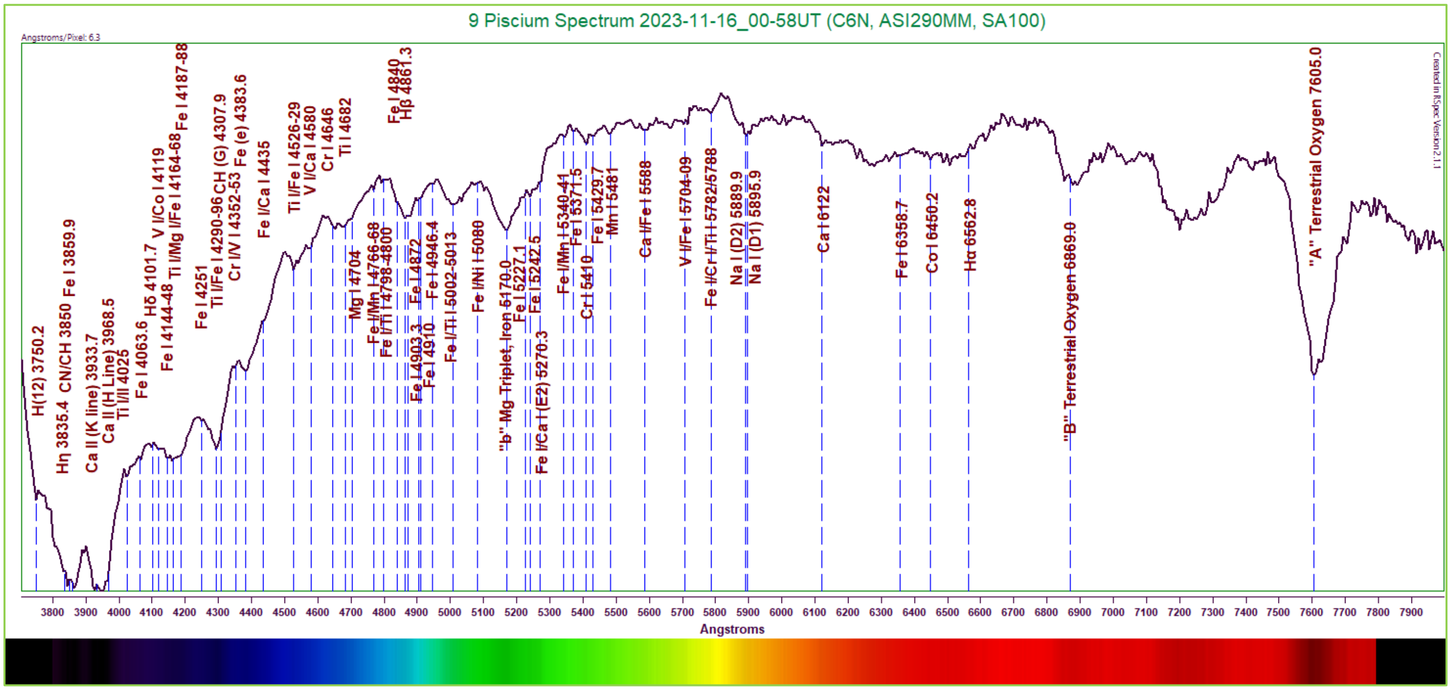

Figure 18: 9 Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 18: Exposure 3s, Gain 208, 85% of 80 frames stacked

Again, a number of very interesting features are visible in this one. Several hydrogen Balmer lines are visible here, though most are not very strong. The Hβ line is the most prominent, and is being broadened by the adjacent iron line at 4840 Angstroms. Near the bottom end of the wavelength scale, the Fe I line at 3859.9 Angstroms is quite strong. The calcium H and K lines above it seem to mirror the deep absorption. A significant combined absorption can be seen at 4144-4188 Angstroms. This is due to iron and titanium lines. The CH (G) absorption at 4307.9 Angstroms is stronger, with the titanium line just below it sharpening the trough of the feature. The magnesium triplet at 5170 Angstroms is very strong here, with the iron E2 line above it contributing greatly to the width of the dip. The sodium doublet at 5890-96 Angstroms can also be seen, but it is much weaker. Numerous other faint metal lines are noted, including titanium, iron, vanadium, chromium, magnesium, and cobalt.

Employing Wien's Law, we will attempt to obtain a rough estimate for the temperature of the star. Using an estimated peak energy wavelength of 5817 Angstroms, our result comes out to 4982K. A reference temperature for the star was not readily available.

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41 Piscium

This star, also designated d Piscium, is classified as an early K-type star[1]. Again, we should expect to see a curve indicative of a cooler star, with numerous metal lines along its length. The results should be very similar to those obtained for 9 Piscium above.

The spectrum is presented below:

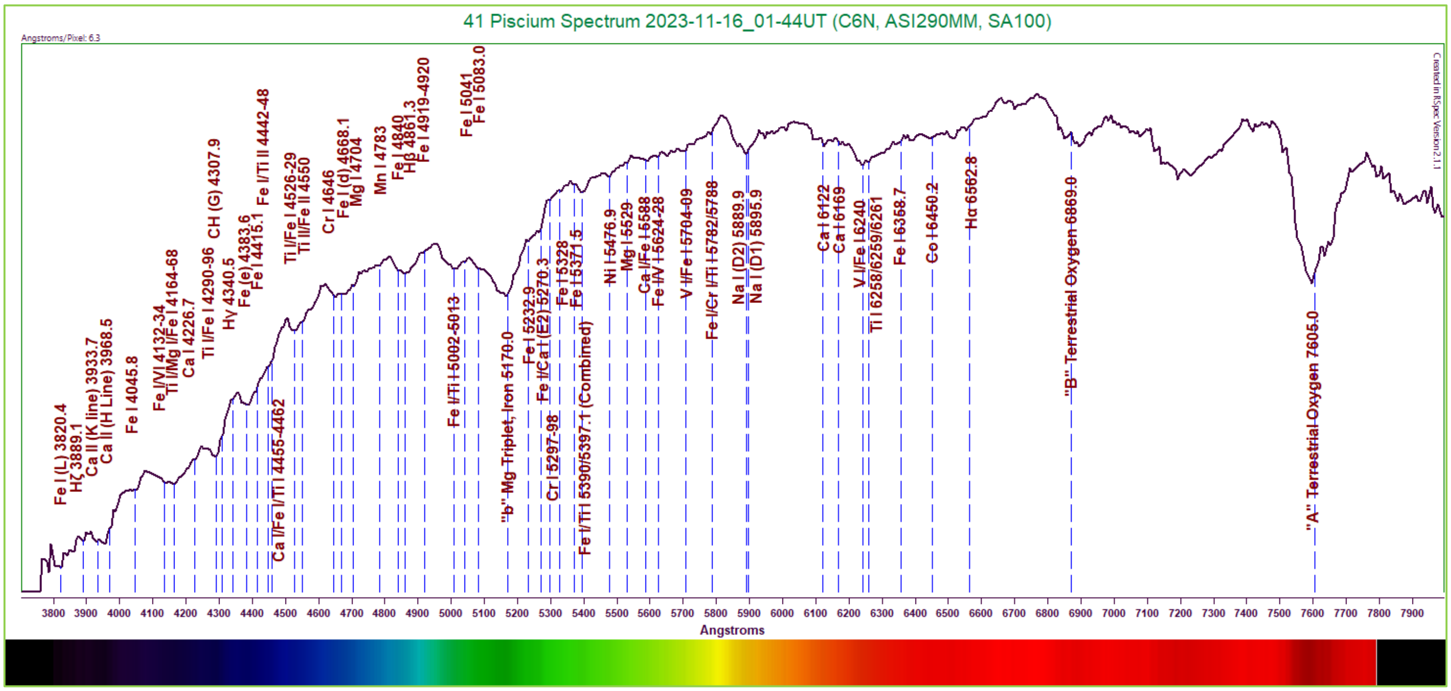

Figure 19: 41 Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 19: Exposure 2s, Gain 131, 80% of 117 frames stacked

This curve does resemble that which was obtained for 9 Piscium previously. Many of the same absorptions can be clearly seen here, but there are some pretty obvious differences, too. The hydrogen Balmer lines that are visible appear a bit weaker. The Hβ line is still being broadened by the iron line just below it at 4840 Angstroms. At the lower wavelength region, we can see the Fe I (L) line at 3820.4 Angstroms is causing a small but significant dip in the continuum. The calcium H and K lines are still visible, but are considerably weakened. Between 4132 and 4226 Angstroms, a combination of lines is causing another significant dip in the spectrum. This is due to iron, titanium, and calcium. The CH (G) line is again visible, and the titanium line just below it is again sharpening the groove (though not as sharply as that observed for 9 Piscium above). The magnesium triplet is very pronounced. The iron lines above it are contributing to the gouge in the continuum. This combined feature is actually stronger than that observed for 9 Piscium. The sodium D1 and D2 lines are obvious, but the absorption is not nearly as deep as the magnesium triplet. Numerous other faint metal lines are evident, including iron, calcium, titanium, chromium, magnesium, manganese, nickel, vanadium, and cobalt. A very interesting spectrum, to be sure.

Using Wien's Law, we will estimate the temperature of the star. Using a peak energy wavelength of 6769 Angstroms, we obtain a result of 4281K. No established temperature was readily located for comparison purposes.

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62 Piscium

62 Piscium is regarded as a late G-type star[1]. From this, we can expect a star slightly cooler than our Sun, with numerous fine metal lines throughout the spectrum.

The processed spectrum follows:

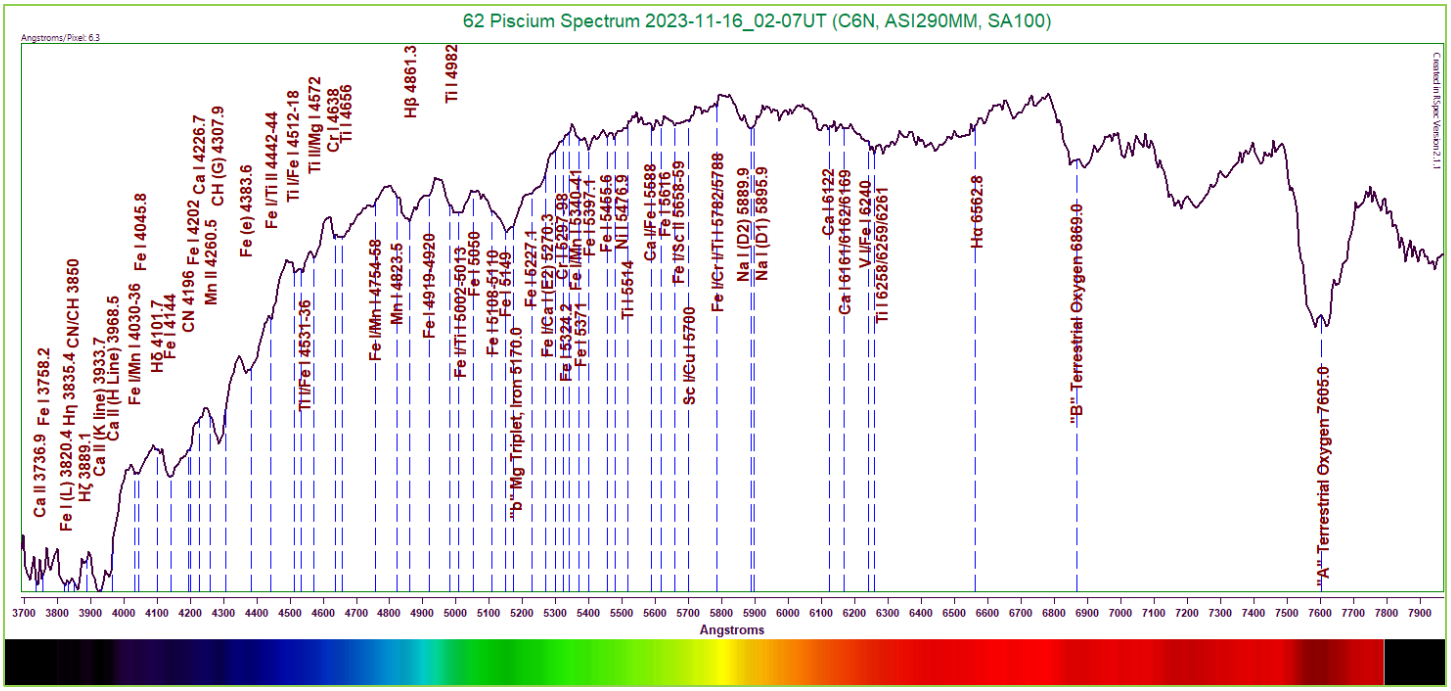

Figure 20: 62 Piscium Spectrum (6.3 Angstroms/pixel)
Capture Details 20: Exposure 2s, Gain 172, 65% of 116 frames stacked

Once again, our expectations are reflected in the curve. The visible hydrogen Balmer lines are a touch stronger than the last two targets, but still a bit on the weak side. The CN/CH absorption at 3850 Angstroms is notable. The calcium H and K lines are creating a deep absorption as well. We can see a pair of iron lines at 4030-4045 Angstroms creating a small absorption, but with a flattened trough. A CN absorption at 4196 Angstroms is also noteworthy. The CH (G) line is strong here, carving out a sharp groove in the continuum. The Fe I (e) line at 4383.6 Angstroms appears quite strong. The magnesium triplet at 5170 Angstroms is again the strongest absorption in the spectrum. The flanking iron lines help create a large valley in the continuum. The sodium doublet at 5890-96 Angstroms is easily identified, but it is not exceptionally strong. Numerous additional faint metal lines are scattered throughout the spectrum, just as expected. These include calcium, iron, manganese, titanium, chromium, nickel, and scandium. These finer lines can be very closely spaced, so use caution when tracing lines on the diagram above.

Using Wien's Law, we will attempt to ascertain an estimate of the star's temperature. Using a peak energy wavelength of 6803 Angstroms, we arrive at a resulting temperature of 4260K. No reference value for the temperature was readily available.

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Conclusion

Capturing the spectra for this one was rough, as the constellation is huge and composed of dimmer stars. The initial run captured all twenty stars included here, but one of these was misidentified. A follow-up capture easily corrected this mistake. The initial run was nothing short of exhausting!

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

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