Spectral Analysis of the Constellation Stars of Leo (The Lion)

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Abstract

This paper will elucidate the spectral features of the main stars in the constellation Leo. The selection of stars was chosen to coincide with those typically used to trace the constellation lines that form the geometric shape of the constellation itself[1]. Though other stars within the boundary of the constellation (as determined by the IAU) may be objects of interest, the analysis is confined to the stars forming the constellation lines.

The stars in the constellation will generally be presented in order of their accepted Bayer designations, using Greek letters to rank them roughly in order of decreasing brightness. Alpha (or α) is usually the brightest star in a constellation. Afterward, Beta (β), Gamma (γ), and so on indicate decreasing apparent magnitude. It is usually the brightest stars that define the constellation lines. Of course, there are deviations from this rule that have been retained for historical consistency.

Equipment Used

All spectra used in this analysis were captured using the following equipment and resources:

Telescope: Celestron Advanced C6-N Newtonian Telescope, with an aperture of 6 inches, and a focal length of 750mm. This makes the focal ratio f/5.

Mount: Meade LX85 German Equatorial Go-To Mount. The mount was aligned using the three-star method.

Camera: ZWO ASI290MM monochrome camera.

Transmission Grating: The SA100 grating was employed to produce the spectra used in this analysis. The grating has 100 lines per millimeter.

Capture Software: The ASI Studio suite of programs was used in the capture process. Following capture, the same suite was used to stack images and export them as TIF files for evaluation and analysis.

Analysis Software: Rspec v2.1.1 by Field Tested Systems, LLC.

Reference Material Used in Analysis: The *Spectral Atlas for Amateur Astronomers* by Richard Walker and *Spectroscopy for Amateur Astronomers* by Marc F. Trypsteen and Richard Walker were both used to assist in identifying specific facets of the resulting spectra, and proved invaluable in this process. Wikipedia and Stellarium were also instrumental in obtaining information regarding the various stars.

Data Processing Details

All of the spectra obtained for this analysis were obtained on the evening of April 5, 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.

α Leonis

Alpha Leonis, more commonly referred to by the common name Regulus, is a late B-type star[1]. Based on this, we can expect to see prominent hydrogen Balmer lines, with perhaps a helium line or two and possibly some weak metal lines. We can also expect a curve peaking close to the low wavelength range, indicative of a very hot star.

The processed spectrum is as follows:

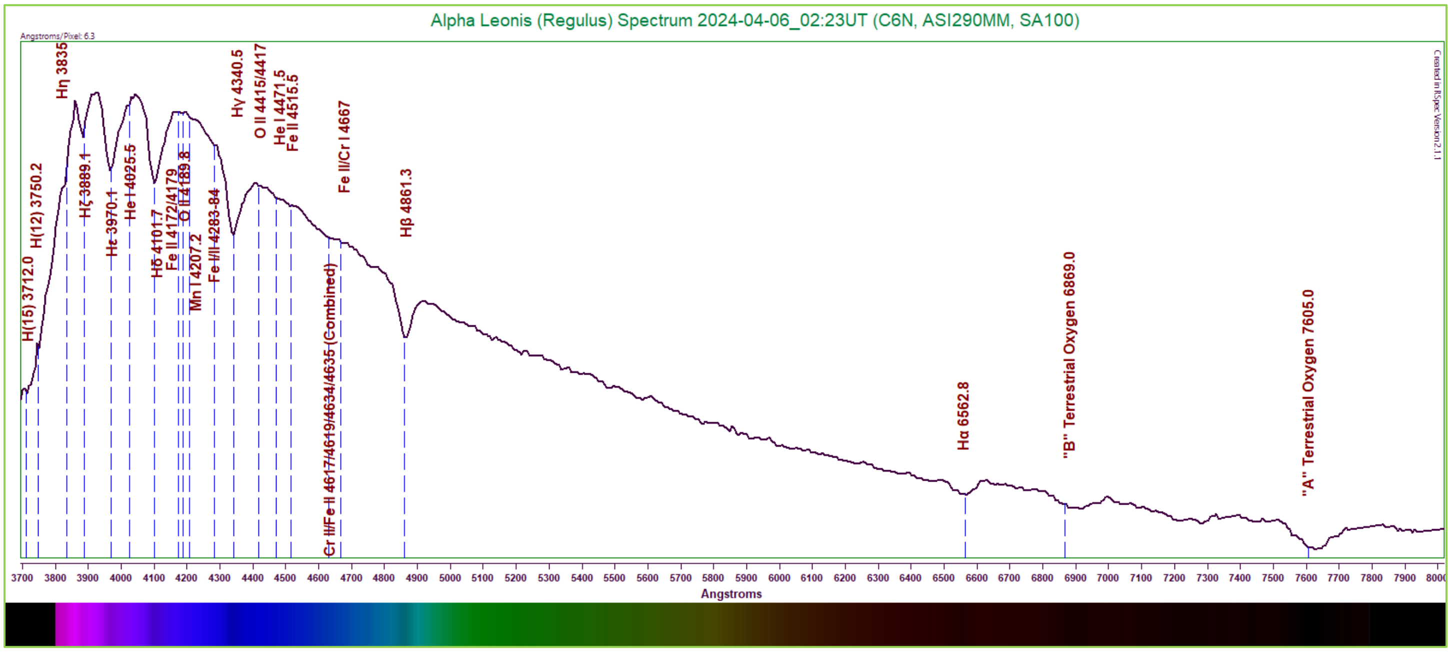

Figure 1: Alpha Leonis (Regulus) Spectrum (6.3 Angstroms/pixel)
Capture Details 1: Exposure 162ms, Gain 42, 20% of 1132 frames stacked

As expected, the hydrogen Balmer lines are quite strong. Even the Hη line appears distinct near the lower wavelength region, along with the much smaller but identifiable H(15) and H(12) lines below it. Two very faint helium lines appear, at 4025.5 and 4471.5 Angstroms. As for metals, most of them are extremely weak, but several are marked here, including iron, oxygen, manganese, and chromium. A nice scoop appears for the chromium/iron line due to a combination blending together in the 4617-4635 Angstroms range.

Employing Wien's Law, we will estimate the star's effective temperature. However, this is a hotter star, whose peak energy wavelength lies below the wavelength range of our camera. This will skew our result, making it fall far short of the star's actual temperature, but we will proceed with the demonstration. Using a visually estimated peak energy wavelength of 3929 Angstroms, obtain a result of approximately 7375K. The listed value for the temperature is 11668K[2].

β Leonis

Beta Leonis, commonly called Denebola, is classified as an early A-type star[1]. From this, we can expect to see strong hydrogen Balmer lines, with a scattering of weak metals peeking through. The star's continuum peak should represent a star a bit cooler than Regulus above.

The processed spectrum is as follows:

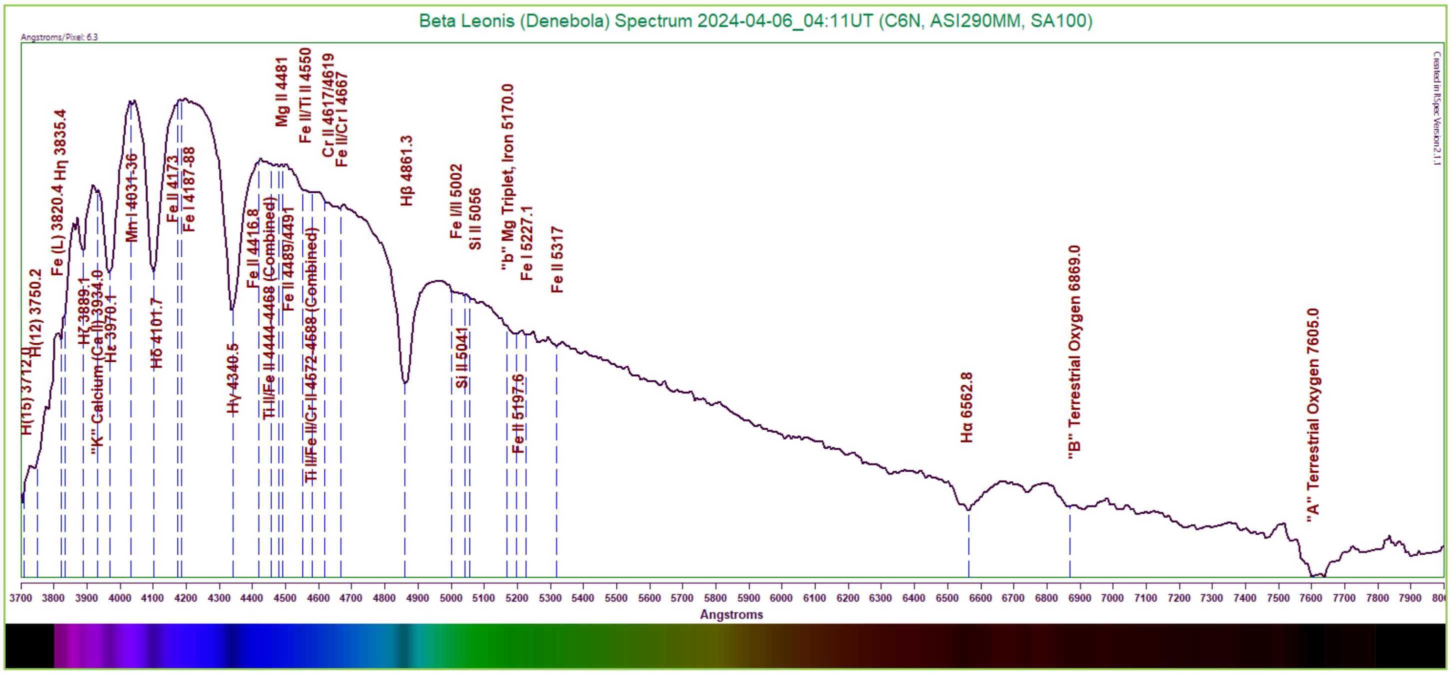

Figure 2: Beta Leonis (Denebola) Spectrum (6.3 Angstroms/pixel)
Capture Details 2: Exposure 296ms, Gain 48, 40% of 822 frames stacked

The hydrogen Balmer lines appear very deep here. The Hη line at 3835.4 Angstroms is separated from the Fe (L) line at 3820.4 Angstroms, the two causing the noted stair-step pattern. The calcium K line is a miniscule dip on the lower side of the Hε line. The magnesium triplet at 5170 Angstroms is visible, joined with the adjacent iron line at 5197.6 Angstroms. The sodium doublet is not visible in this spectrum. Other metal features are marked, including manganese, numerous iron lines, titanium, magnesium, chromium, and silicon. The silicon lines are exceptionally weak, and therefore present dubious identifications.

We can employ Wien's Law again to estimate the star's effective temperature. The continuum peak appears to lie where the strong Hδ line is overshadowing it. However, we can average the flanking peaks to arrive at an approximate peak at 4119 Angstroms. Using this value, we arrive at an estimate of 7035K. The established temperature of the star is listed as 8500K[2]. Our estimate is too low, as expected considering the type of star involved.

γ-1 Leonis

Gamma-1 Leonis, also known as Algieba, is a double star, with the primary classified as an early K-type star[1]. (The secondary is far away from the primary, and should pose no problems for the analysis.) We should expect to see a curve representative of a cooler star, with large numbers of metals present.

The finished spectrum is presented here:

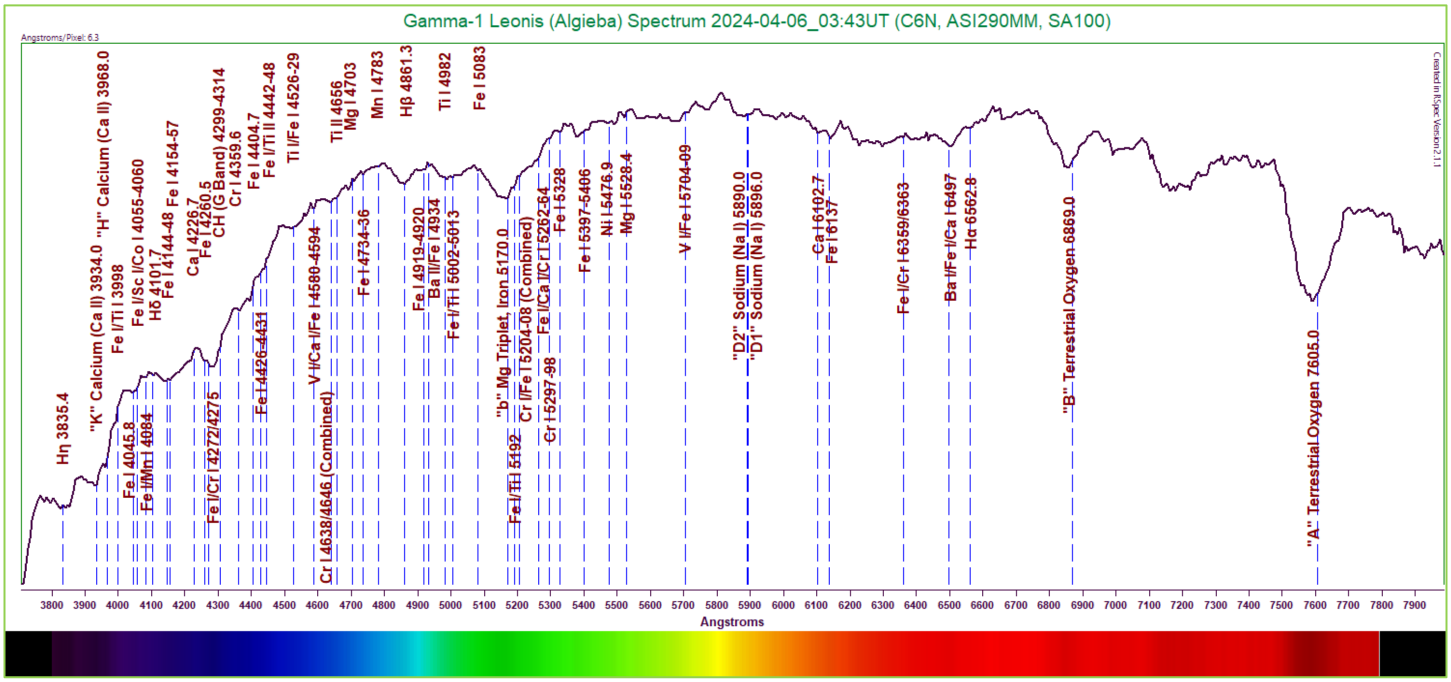

Figure 3: Gamma-1 Leonis (Algieba) Spectrum (6.3 Angstroms/pixel)
Capture Details 3: Exposure 242ms, Gain 74, 50% of 1248 frames stacked

We do indeed see a cooler star represented here. There aren't many strong absorption features, excepting the A and B Terrestrial Oxygen lines. The hydrogen Balmer lines that can be seen are moderate to weak in strength. The calcium H and K lines are present, but also appear somewhat weak. The CH (G) band at 4299-4314 Angstroms is notable. The magnesium triplet at 5170 Angstroms is the most prominent apparent feature. The sodium doublet at 5890-96 Angstroms also appears reduced, but is recognizable by the scoop the features carve into the continuum. (The relative weakness of most of the lines may be at least partially due to the star being a giant.)

We will employ Wien's Law as a means of estimating the star's temperature. The peak energy wavelength for this spectrum is a bit difficult to estimate, but if we use a value of 5813 Angstroms we arrive at a temperature of 4985K. The listed temperature for the star is 4457K[2]. Our estimate is too high in this case, but with the difficulty of visually estimating the peak wavelength, the inaccuracy is not unexpected.

δ Leonis

Delta Leonis, or Zosma, is a double star whose primary is classified as a middle A-type star[1]. The secondary component is far enough removed to not interfere with the spectrum of the primary. For this type of star, we can expect to see strong hydrogen Balmer lines, with metals becoming more apparent. In all, it should resemble the results obtained for Denebola above, but with a slightly cooler temperature.

The processed spectrum is presented below:

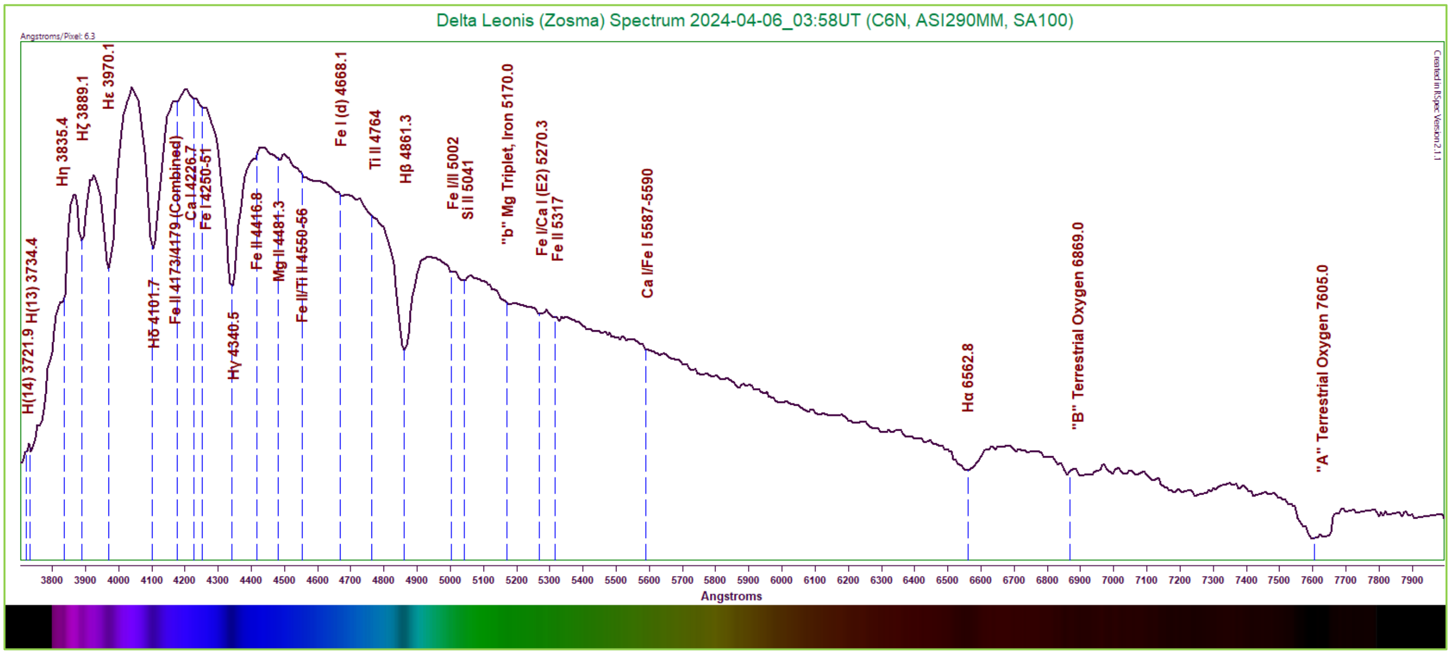

Figure 4: Delta Leonis (Zosma) Spectrum (6.3 Angstroms/pixel)
Capture Details 4: Exposure 401ms, Gain 53, 40% of 605 frames stacked

This spectrum indeed looks like a classic A-type star. The continuum is fairly smooth, and peaks toward the left end. The hydrogen Balmer lines appear deep and strong. The Hη line is presenting its customary "step" in the continuum. The magnesium triplet at 5170 Angstroms is weak, but noticeable. Several other metal lines are noted, including ionized and neutral iron, calcium, magnesium, titanium, and silicon. A very nice spectrum.

We will again employ Wien's Law to gain a temperature estimate for the star. Once more, we should expect our estimate to fall short due to the type of star involved, but we should arrive at an estimate that is slightly lower than that obtained for Denebola earlier. Using a peak energy wavelength of 4121Angstroms (by averaging the values of the flanking peaks of the Hδ line), Wien's Law indicates a temperature of approximately 6988K. The listed value for the temperature of the star is 8296K[2]. Our estimate is again too low, but it is worth noting that it is slightly lower than our estimate obtained for Denebola (7035K).

ε Leonis

Epsilon Leonis, also called Algenubi, is an early G-type star[1]. This means we can expect a complex spectrum with lots of metals present—similar in many ways to our own Sun. Lots of iron and other elements should be identifiable in the spectrum.

The processed spectrum follows:

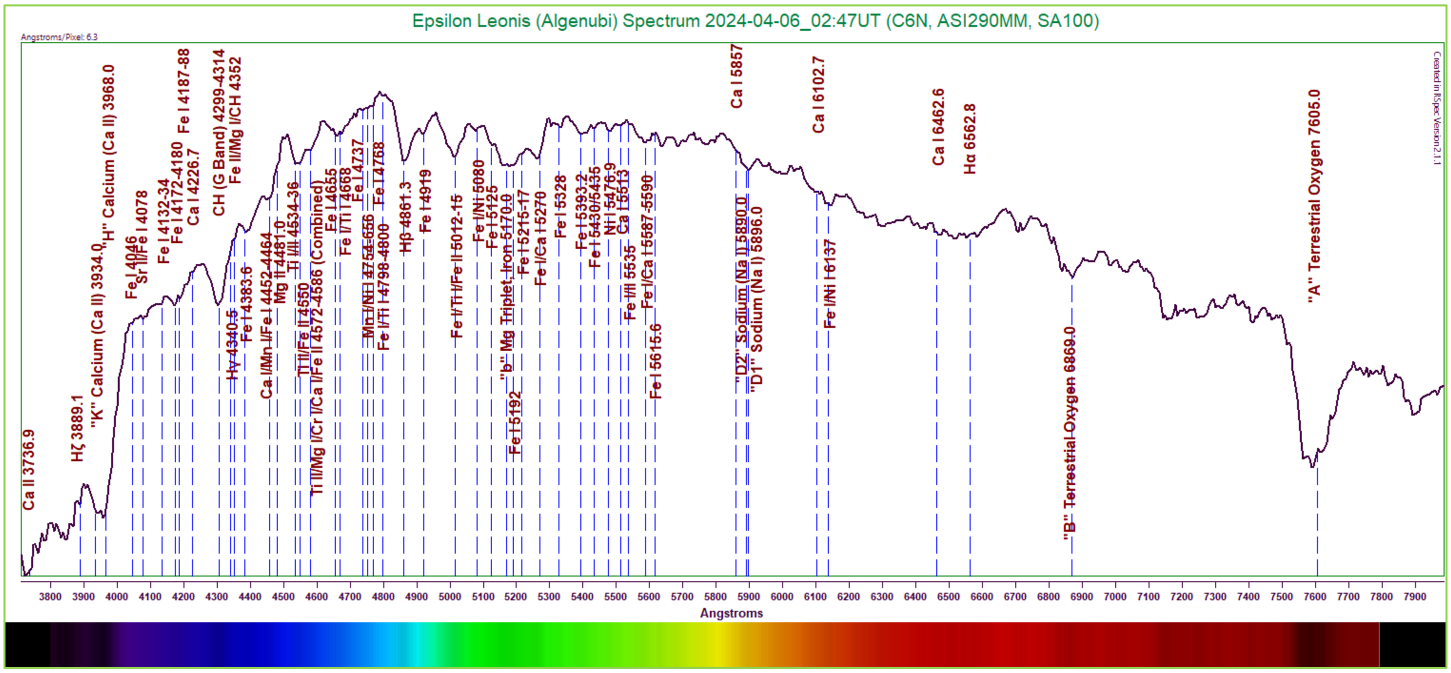

Figure 5: Epsilon Leonis (Algenubi) Spectrum (6.3 Angstroms/pixel)
Capture Details 5: Exposure 343ms, Gain 143, 30% of 1063 frames stacked

This spectrum appears quite busy. The hydrogen Balmer lines that are present are only moderately strong at best. The Hζ line is particularly faint, while the Hγ line is only evidenced by the slightest deviation in the continuum above the CH (G) band at 4299-4314 Angstroms. Three ionized calcium lines boldly appear in the lower wavelength region—at 3736.9, 3934, and 3968 Angstroms (the last two being the calcium K and H lines). All of these are pronounced. The aforementioned CH (G) molecular band is very strong here as well. The magnesium triplet at 5170 Angstroms is quite notable, being broadened by the adjacent iron line at 5192 Angstroms. The iron/calcium line at 5270 Angstroms is also prominent nearby. The sodium doublet at 5890-96 Angstroms is small by comparison, but easily recognized. A small deviation in the continuum occurs due to the calcium line at 5857 Angstroms just below it. Numerous other metal lines are present, ranging from moderately strong to very faint. These include iron, strontium, calcium, magnesium, titanium, manganese, and nickel. This is definitely an interesting specimen.

We can again employ Wien's Law to obtain a temperature estimate. Visually estimating the peak energy wavelength here is tricky. It appears to lie in the vicinity of the magnesium triplet at 5170 Angstroms. A continuum curve could be drawn to obtain a more accurate peak wavelength, but since we have been sticking to strictly visual and averaging estimates during this survey, we will accept this value and continue. Using 5170 Angstroms as the approximate peak, we arrive at a temperature of 5605K. The accepted temperature of this star is 5248K[2]. Our estimate is not entirely accurate, but at least we are in the right neighborhood!

ζ Leonis

Zeta Leonis, also called Adhafera, is an optical double star whose primary is a very early F-type star[1]. The companion star is far removed from the primary, and will cause no issues with the analysis. Based on the type of star involved, we can expect to still see relatively strong hydrogen Balmer absorptions in a star somewhat hotter than our own Sun. We can also expect a fair number of metal absorptions to be present.

The finished spectrum is presented here:

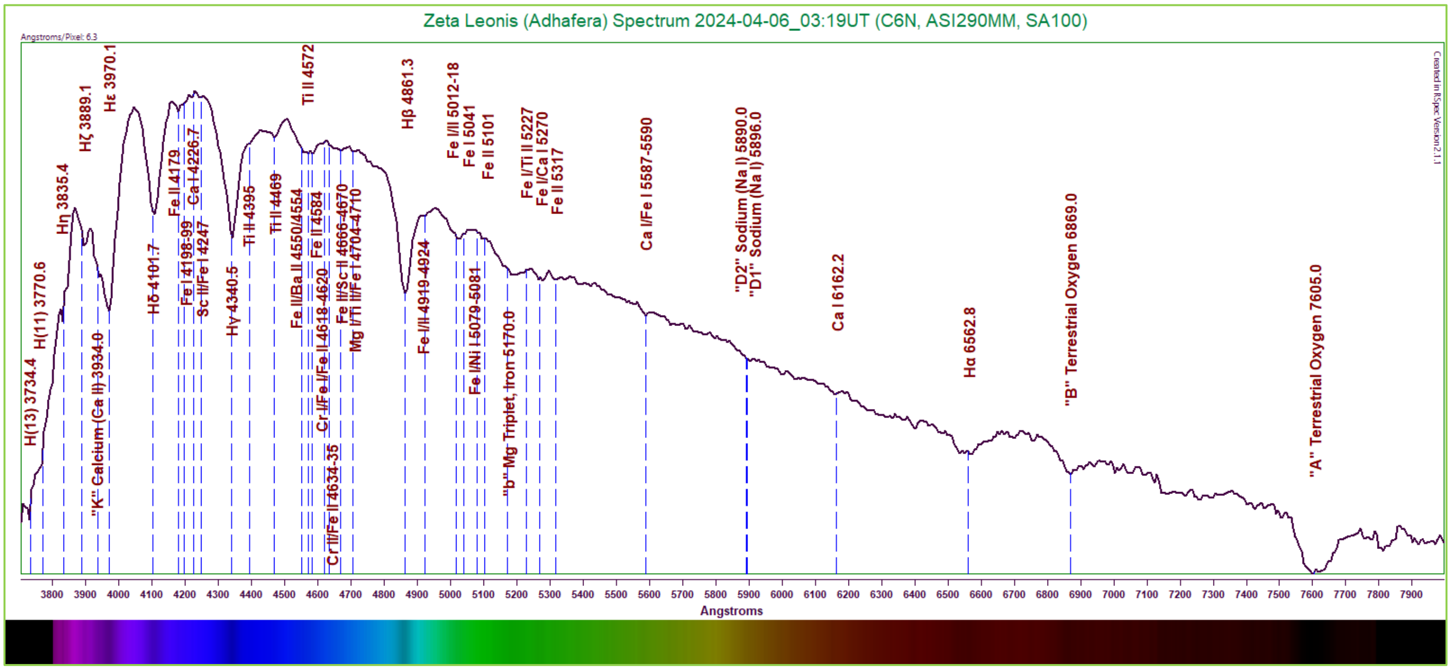

Figure 6: Zeta Leonis (Adhafera) Spectrum (6.3 Angstroms/pixel)
Capture Details 6: Exposure 332, Gain 178, 30% of 735 frames stacked

Here we can see a spectrum curve demonstrating an "almost A-type" curve, but just a little cooler. The hydrogen Balmer lines appear well. At 3934 Angstroms, we can see the calcium K line beginning to emerge just below the Hε line (which is very deep). The magnesium triplet is also clear at 5170 Angstroms, though not as strong as the hydrogen Balmer series. The sodium doublet at 5890-96 Angstroms is evident, but it is faint. As anticipated, the spectrum shows a good number of fainter metal lines throughout, including neutral and ionized iron, calcium, scandium, ionized titanium, chromium, and magnesium.

Using Wien's Law, we will estimate the star's effective temperature. Visual inspection of the curve seems to show that the peak energy wavelength is at approximately 4229 Angstroms. With this value we obtain a temperature of 6852K. The accepted temperature of the star is listed as 6782K[2]. Our estimate is only 70K removed from the actually temperature.

η Leonis

Eta Leonis, also called Al Jabhah, is a multiple star system whose primary is a very early A-type star[1,2]. The companions are extremely close, but we expect the primary to dominate our results. Being a very early A-type star, we can expect to see fewer metals present than in Adhafera above, and also a higher temperature. The hydrogen Balmer lines should also be prominent.

The finished spectrum is presented below:

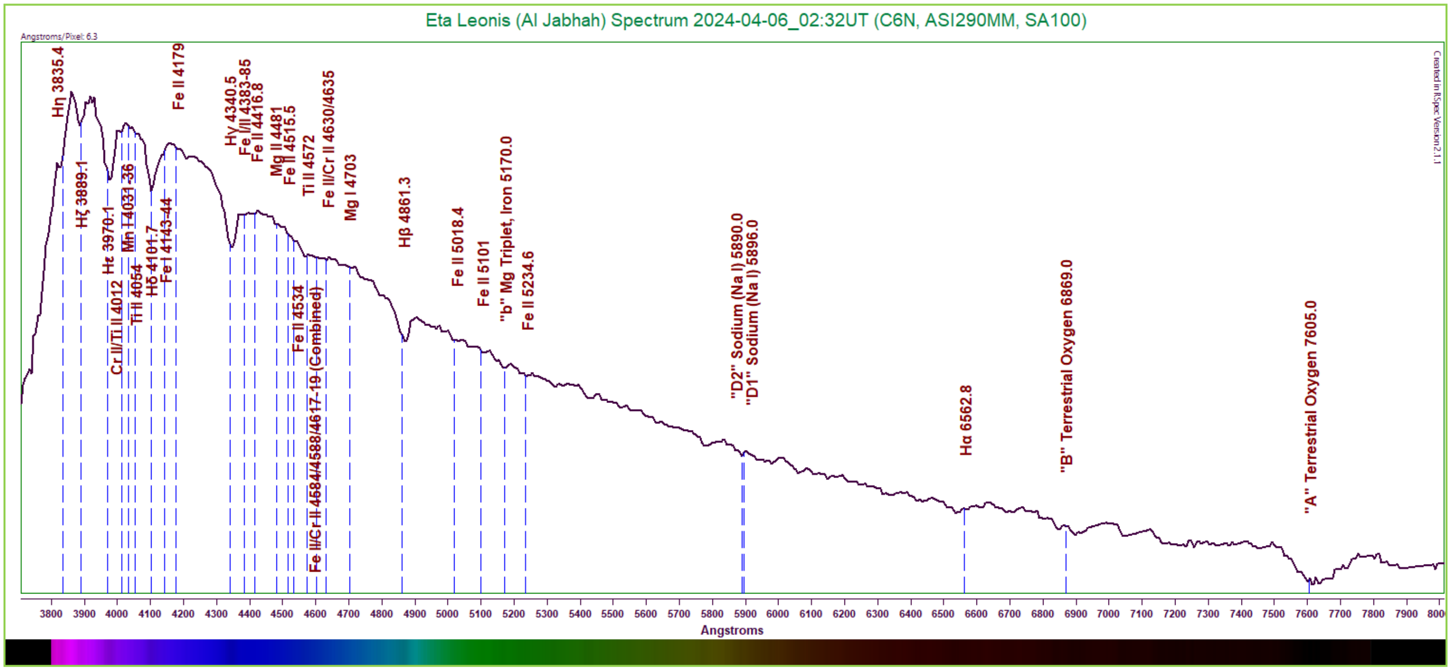

Figure 7: Eta Leonis (Al Jabhah) Spectrum (6.3 Angstroms/pixel)
Capture Details 7: Exposure 342, Gain 125, 20% of 1066

This first obvious notable thing about this spectrum is the apparent weakness of the hydrogen Balmer lines, which would seem to be extremely atypical of this type. Even the other lines are extremely faint. This is caused by the fact that the star is a supergiant, with lower gas pressure at its photosphere. Proceeding with the analysis, we can note the presence of the hydrogen Balmer series of absorptions, even if they do appear weakened. A considerable flattening of the spectrum can be seen in the 4572-4636 Angstroms range, due to a combination of finer lines of titanium, iron, and chromium. Both the magnesium triplet at 5170 Angstroms and the sodium doublet at 5890-96 Angstroms appear very weak—barely discernible from the noise of the continuum. Identifying the other metals in the spectrum was challenging due to the intensity reduction of all the absorptions due to its high luminosity, but those marked include chromium, manganese, titanium, iron, and magnesium. Many of these are uncertain as a result of the low "surface" pressure of the star.

Again we will enlist the aid of Wien's Law for temperature estimation. Once again, due to the class of the star, we should expect our estimate to fall far short. Visually estimating a peak energy wavelength near 3861 Angstroms, we obtain a temperature of 7505K. The accepted temperature of the star is 9600K[2].

θ Leonis

Theta Leonis, commonly known as Chertan, is classified as an early A-type star[1]. We can expect very strong hydrogen Balmer lines in this star, with a temperature somewhat lower than Al Jabhah above. A few metals will undoubtedly be identifiable, if weakly.

The processed spectrum follows:

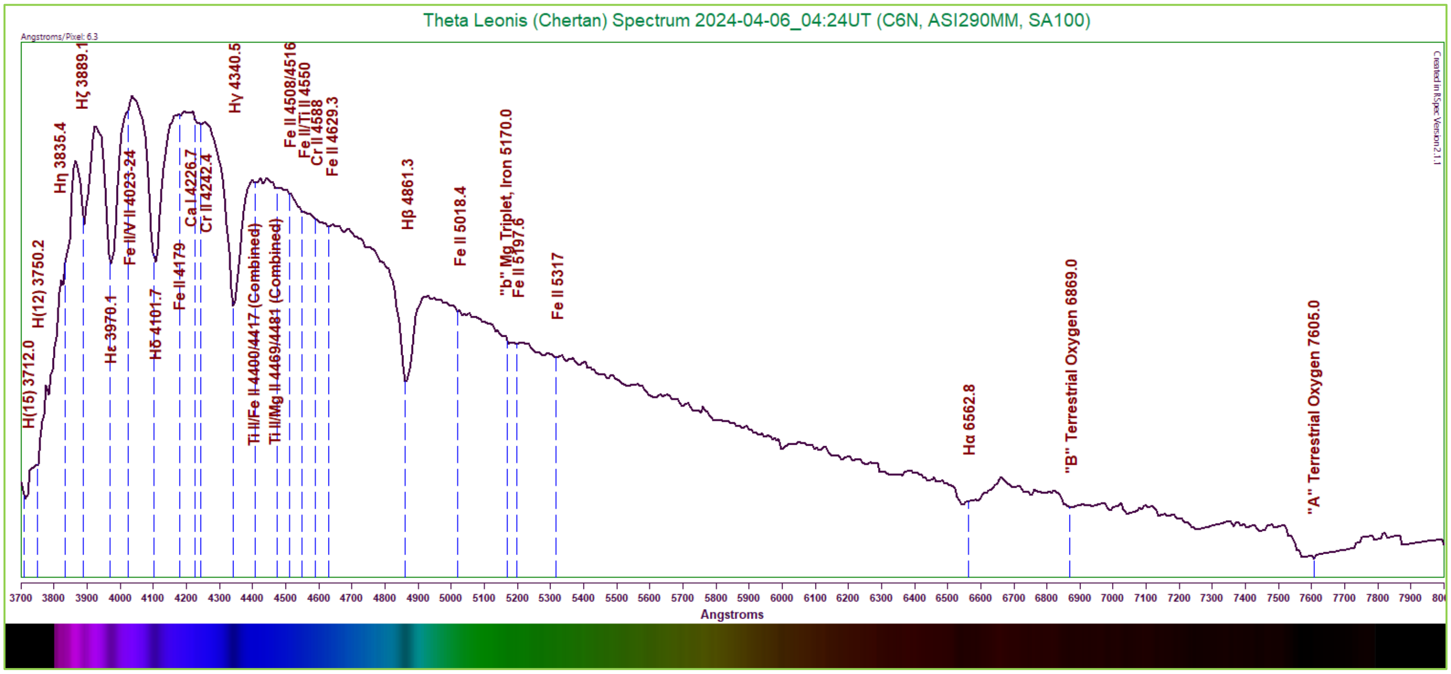

Figure 8: Theta Leonis (Chertan) Spectrum (6.3 Angstroms/pixel)
Capture Details 8: Exposure 310, Gain 134, 60% of 784 frames stacked

Unlike with Al Jabhah previously, here we can see strong, deep hydrogen Balmer lines. A small but notable dip in the continuum occurs at 4226.7-4242.4 Angstroms, caused by neutral calcium and ionized chromium. The little scoop is quite obvious. A second, less noticeable, dip can be seen between 4550 Angstroms and 4629 Angstroms. This one is less obvious, being caused by a succession of lines of iron and chromium. The magnesium triplet is visible at 5170 Angstroms, though it is weak. Other marked fainter metal lines include iron and titanium. The iron line at 5317 Angstroms is marked, but this is a dubious identification due to the noise in the surrounding continuum.

Wien's Law can be applied to obtain a temperature estimate, but once more we are dealing with a hotter star and can expect our estimate to be far too low. Adopting a visually estimated peak energy wavelength of 4037 Angstroms, we arrive at a temperature of 7178K. The currently listed temperature for the star is 9350K[2]. Though our estimate is too low, as expected, our estimate is indeed a little lower than that obtained for Al Jabhah above (7505K).

μ Leonis

Mu Leonis, sometimes referred to by the name Rasalas, is classified as an early K-type star[1]. From this, we can expect a cooler star with a lot of metals reflected in its spectrum. The magnesium triplet should appear quite boldly here.

The processed spectrum is presented here:

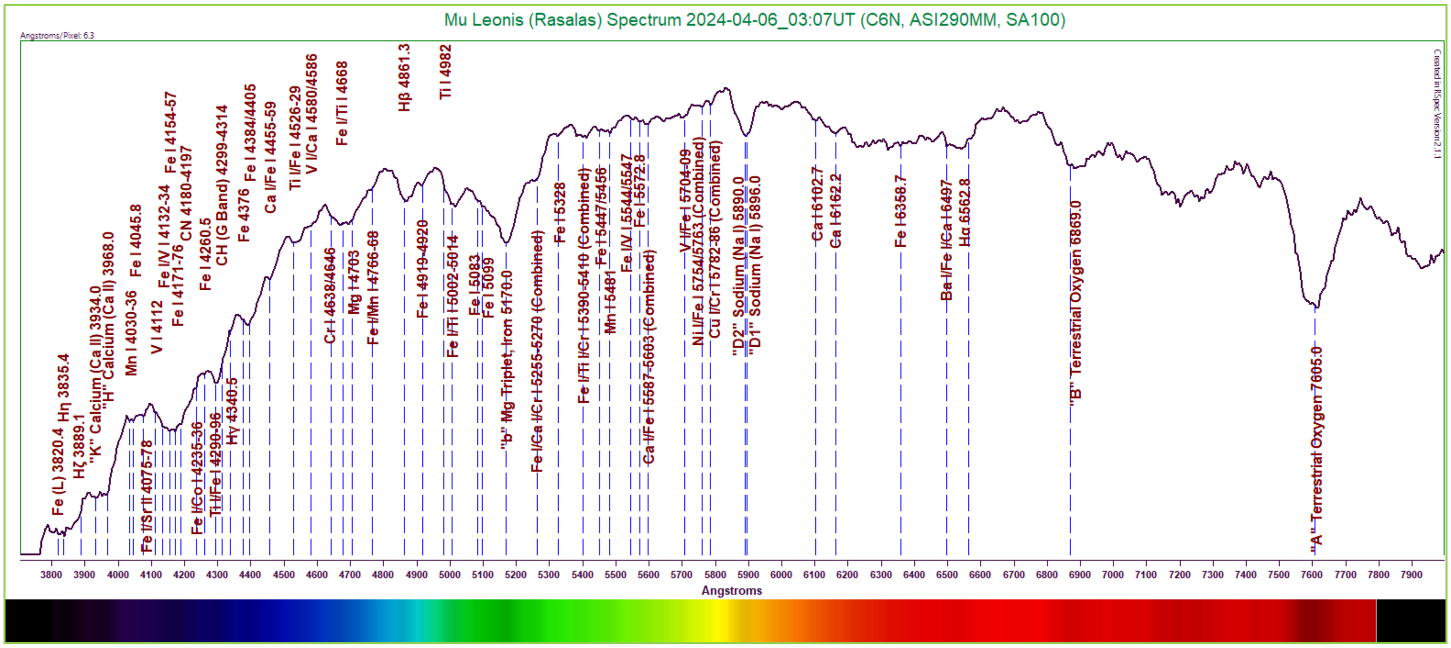

Figure 9: Mu Leonis (Rasalas) Spectrum (6.3 Angstroms/pixel)
Capture Details 9: Exposure 416ms, Gain 187, 35% of 589 frames stacked

This spectrum is indeed representative of a moderately cool star, with the peak of the curve occurring just above the middle of our wavelength range. Though some of the hydrogen Balmer lines are still evident, none are particularly strong. The calcium H and K lines at 3934 and 3968 Angstroms are carving out a decent-sized trough in the continuum. A magnificent valley is also present in the 4112-4197 Angstroms range. This is caused by a combination of lines including vanadium, iron, and CN. Another significant valley can be found at 4290-4314 due to titanium and the CH (G) band. A third such trough can be seen in the 4638-4768 Angstroms range. This one is wider, being composed of chromium, magnesium, and iron. The magnesium triplet at 5170 Angstroms is our most prominent feature in this spectrum. The absorption appears sharp and wide. The iron E2 line is combined with others to produce a significant bump in the continuum above it at 5255-5270 Angstroms. The sodium doublet at 5890-96 Angstroms is also quite strong and sharp. One more blended feature can be easily identified at 6497-6563 Angstroms, composed of barium and the Hα line. This spectrum definitely has character!

We will employ Wien's Law to ascertain an effective temperature. Using an estimated peak energy wavelength of 5829 Angstroms, we obtain a temperature of 4971K. The listed temperature for the star is 4436K[2]. In this case, our temperature estimate is a little too high.

35 Leonis

While capturing data for Zeta Leonis above, this star drew attention to itself. A short detour was made to capture data for it. The star is a spectroscopic binary classified as an early G-type star[1,2]. This indicates we should see details similar to our own Sun—a moderate temperature star with a lot of metals present.

The spectrum is presented below:

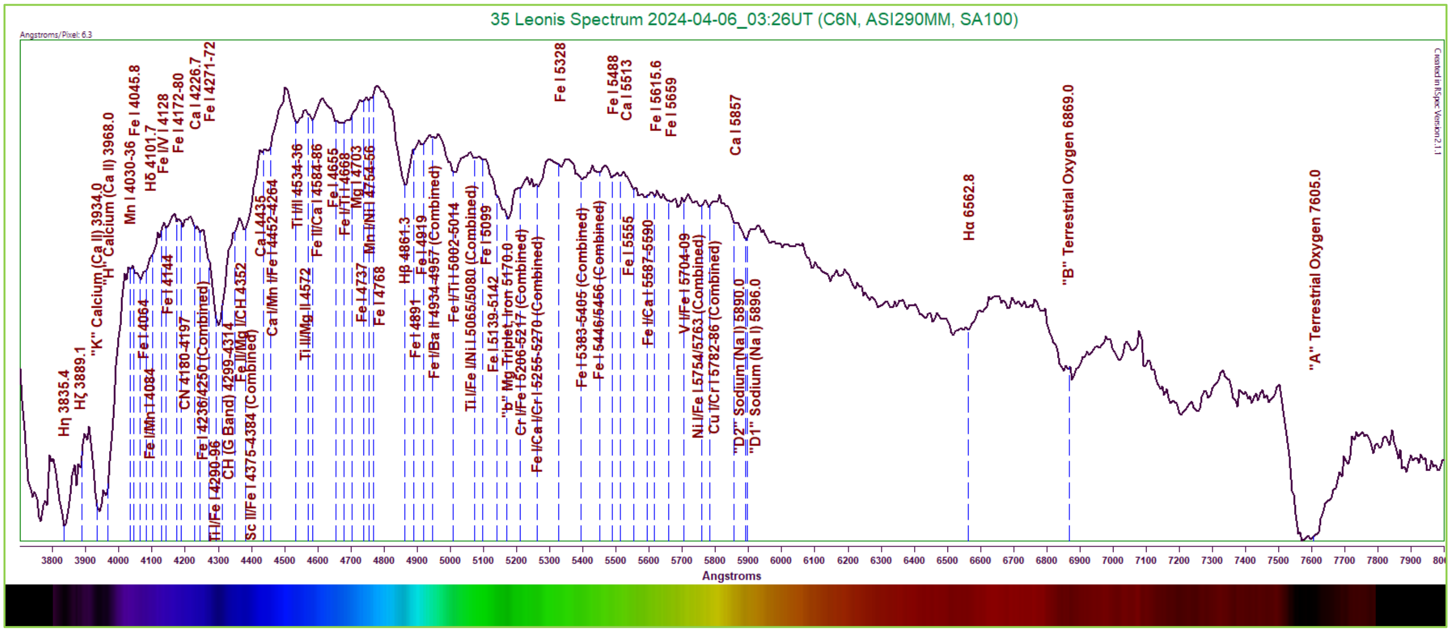

Figure 10: 35 Leonis Spectrum (6.3 Angstroms/pixel)
Capture Details 10: Exposure 3s, Gain 196, 75% of 117 frames stacked

This one is certainly a busy specimen. Some of the hydrogen Balmer lines are visible, with some being quite strong. The calcium H and K lines at 3934 and 3968 Angstroms are carving a deep gouge out of the continuum. Another deep groove can be seen at the CH (G) band absorption at 4299-4314 Angstroms. The magnesium triplet at 5170 Angstroms is also fairly strong, competing in depth with the Hβ line below it. The sodium doublet at 5890-96 Angstroms is smaller, but it is sharply defined. We can even see the calcium line at 5857 Angstroms below it. Many of these lines are crowded together, so care must be taken when tracing the labels.

Using Wien's Law, we will estimate the star's temperature. The peak energy wavelength appears to lie near the peak at 4779 Angstroms. Using this value results in a temperature of 6063K. The listed temperature for the star is 5480K[2]. In this case, our temperature estimate is too high.

Conclusion

Leo is a large constellation on the sky. No unusual problems were encountered in acquiring the spectra, but a couple of the targets did provide a small amount of trouble getting good calibrations. Still, the results obtained were good and revealed a lot of detail.

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