# Spectral Analysis of the Constellation Stars of Cassiopeia (The Queen)

Anthony S. Harding Jr.
2023-09-18

## Abstract

This paper will elucidate the spectral features of the main stars in the constellation Cassiopeia. 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 10, 2023 (EDT). 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 length, 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.

Some concern was entertained regarding the ability to capture decent spectra in this section of the sky. My northern skies are the worst for astronomical pursuits from my home viewing location. The target stars were indeed shimmering moderately badly. However, some persistence allowed the capture of enough frames for each target to extract usable data. Of course, the relative brightness of the stars was a definite help.

## α Cassiopeiae

Alpha Cassiopeiae, commonly named Schedar, is listed as a double star[1], but its companion will not interfere with this analysis. It is also listed as a variable, being of the very early K-type[2]. We can expect to see a star showing lots of metal lines, and displaying a curve consistent with a relatively low temperature.

The processed spectrum is as follows:

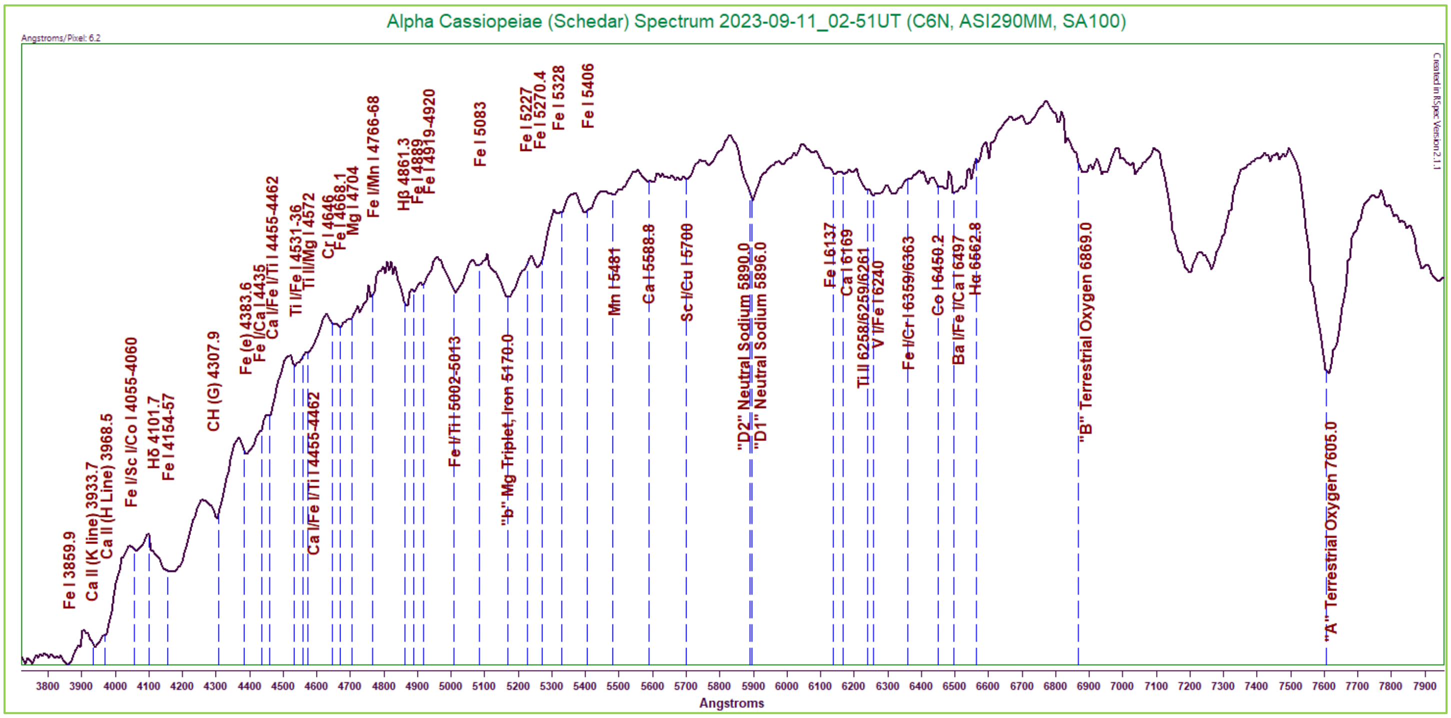


*Figure 1: Alpha Cassiopeiae (Schedar) Spectrum (6.2 Angstroms/pixel)*
*Capture Details 1: Exposure 525ms, Gain 89, 50% of 349 frames stacked*

The spectrum curve does indeed reflect what was expected—a lower temperature star with plenty of metal lines. The hydrogen Balmer lines that are present but appear somewhat weak. The Fe I line at 3859.9 Angstroms carves out a nice absorption at the extreme low wavelength range. The calcium H and K lines are prominent in this area, as well. The iron absorption at 4154-57 Angstroms is impressive. The CH (G) line at 4307.9 Angstroms is easily identifiable. The magnesium triplet at 5170 Angstroms is clear, along with two iron lines above it causing the continuum to dip considerably. The sodium doublet at 5890-96 Angstroms appears sharp and deep. We can see a lot of other fainter metal lines, including iron, calcium, titanium, chromium, magnesium, manganese, cobalt, scandium, vanadium, and barium.  This specimen has a lot to offer.

Using Wien's Law, we can approximate the star's effective temperature. Using an estimated peak energy wavelength of 6782 Angstroms, the temperature works out to 4273K. The established temperature for the star is listed as 4552K[2]. Being a cooler star, we can see that our estimate is not terribly far off base.

## β Cassiopeiae

Beta Cassiopeiae, also known as Caph, is classified as an early F-type variable star[1]. We should therefore expect a spectrum showing reasonably strong hydrogen Balmer lines, with some faint metals peeking through.

The final spectrum is presented as follows:

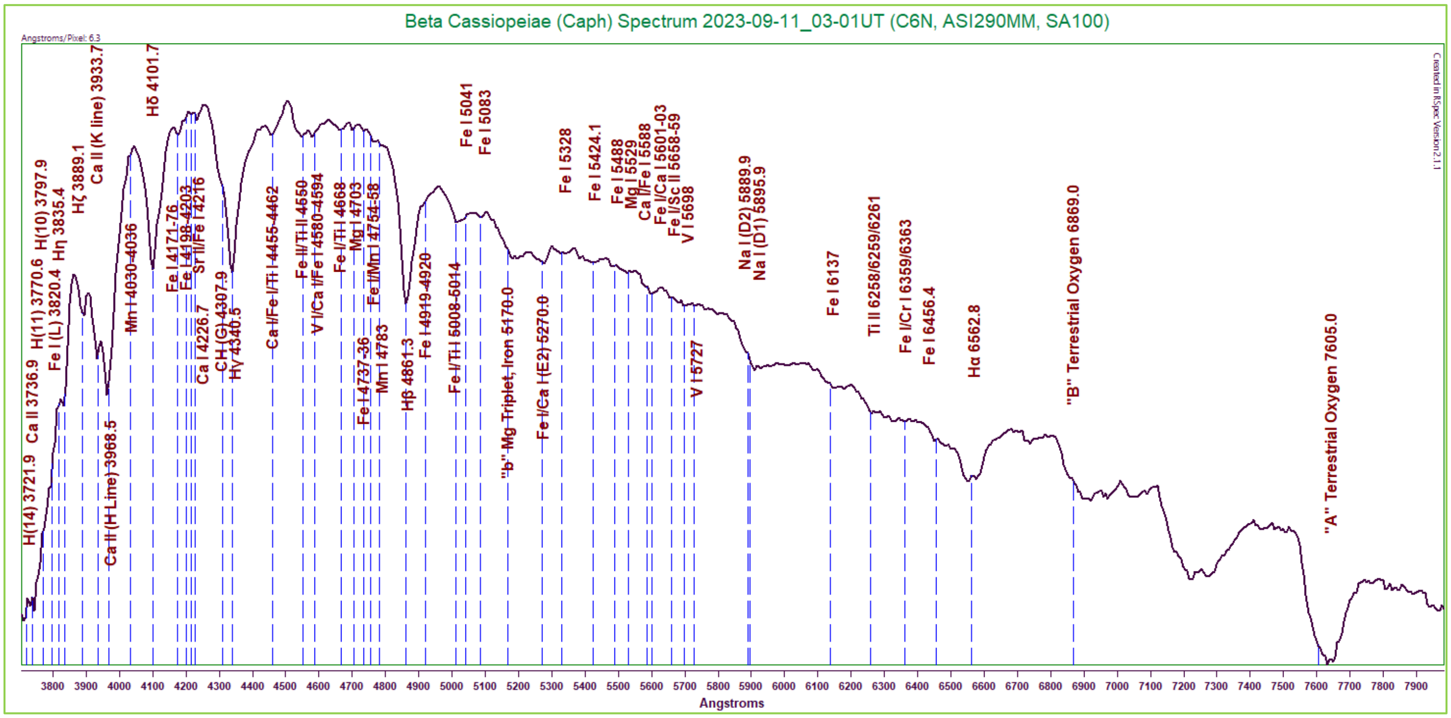


*Figure 2: Beta Cassiopeiae (Caph) Spectrum (6.3 Angstroms/pixel)*
*Capture Details 2: Exposure 525ms, Gain 107, 60% of 349 frames stacked*

Ah, now this one shows a very interesting combination of absorptions! The hydrogen Balmer lines are quite strong here. The Hα line is unusually well represented. The calcium H and K lines at 3933-3968 Angstroms are carving out a nice, deep groove. The magnesium triplet at 5170 Angstroms is notable, along with the iron line above it. The sodium doublet at 5890-96 Angstroms is also significant. A number of fainter metal lines can be seen, including calcium, lots of iron, strontium, vanadium, magnesium, manganese, and titanium.

We will apply Wien's Law to obtain a rough estimate of the star's temperature. However, since this star leans toward the hotter end of the temperature scale, we can certainly expect our estimate to be too low. Applying an estimated peak energy wavelength of approximately 4504 Angstroms, the temperature calculation yields a result of 6434K. The accepted temperature for the star is 7079K[2]. Indeed our estimate is too low, but not obscenely so.

## γ Cassiopeiae

Gamma Cassiopeiae is also known as Navi. It is a multiple-star system, with the primary classified as a very early B-type star[1]. The star's companions are too dim to contribute anything to our analysis. We can expect to see a very hot star here, with reduced hydrogen Balmer lines, but perhaps with a few visible helium traces visible.

The processed spectrum is below:

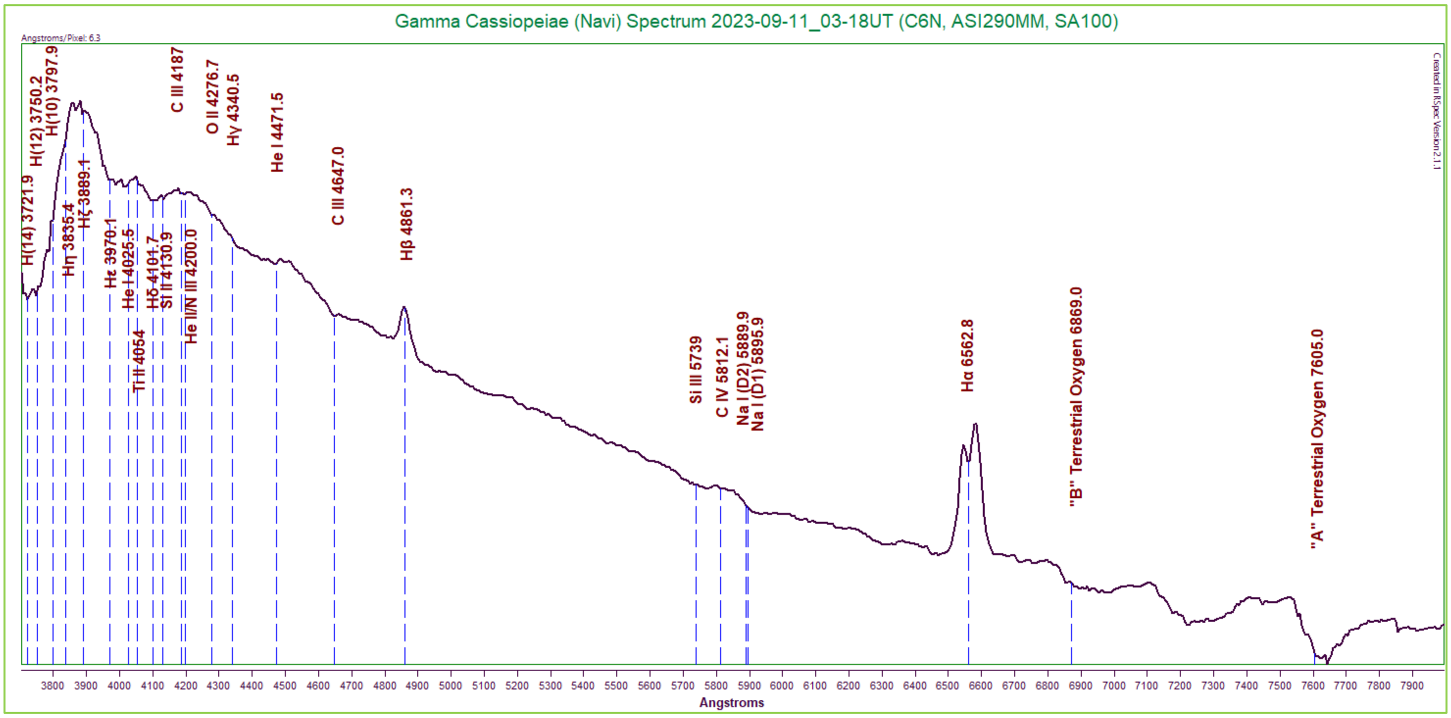


*Figure 3: Gamma Cassiopeiae (Navi) Spectrum (6.3 Angstroms/pixel)*
*Capture Details 3: Exposure 310ms, Gain 110, 50% of 397 frames stacked*

Now this one shows some very unusual characteristics. First and most noticeable are the two emission lines, for Hα and Hβ! (When capturing the raw spectrum, these two bright spots were noticed in the raw spectrum. Thinking they may be field stars behind the spectrum, the telescope tube was rotated to pivot them out of the way. However, a ninety degree pivot of the tube did not move the spots away from the spectrum. That was clear evidence that this star was actually showing bright emission characteristics.) The rest of the hydrogen Balmer lines are fairly weak. Most notable are the subtle, broad dips at the Hε and Hγ marks. Very unusual. Several helium lines are visible at 4025.5, 4200, and 4471.5 Angstroms. Other noteworthy lines include titanium, strontium, carbon, oxygen, and silicon. The peak of the curve is close to the extreme left end of our spectrum, reflecting a very high temperature.

Although using Wien's Law will undoubtedly result in a temperature estimate that is extremely low, we will complete the exercise for the sake of consistency. Using an estimated peak energy wavelength of 3881 Angstroms, the resulting temperature is approximately 7467K. The established temperature for the star is listed as 25000K[2]. Wow, this is the hottest star surveyed so far!

## **δ Cassiopeiae**

Delta Cassiopeiae, commonly known as Ruchbah, is classified as a middle A-type star[1]. It is also an eclipsing binary star, but we should not expect the companion to contribute much (if anything) to our low-resolution spectrum. We should see relatively strong hydrogen Balmer lines, with some metals beginning to show up as well.

The processed spectrum follows:

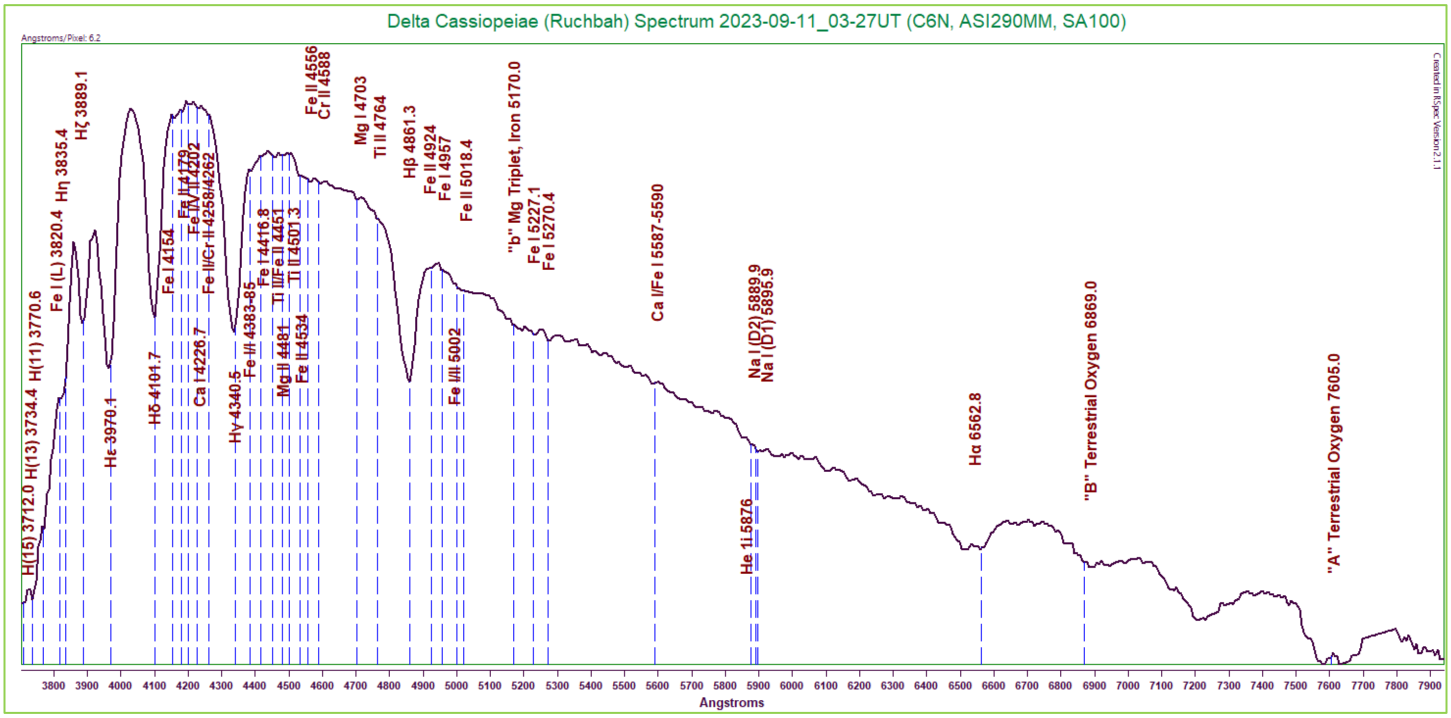


*Figure 4: Delta Cassiopeiae (Ruchbah) Spectrum (6.2 Angstroms/pixel)*
*Capture Details 4: Exposure 332ms, Gain 140, 65% of 549 frames stacked*

Indeed, we do see characteristics consistent with A-type stars—namely the strong hydrogen Balmer lines. Near the low wavelength region we can see that the Fe I (L) and Hη lines are combined to demonstrate a flat step in the continuum. Between the Hδ and Hγ lines, we see several small absorptions, namely neutral and ionized iron, plus neutral calcium. A similar thing is observed between the Hγ and Hβ lines, with more iron, titanium, magnesium, and chromium. The magnesium triplet at 5170 Angstroms is only causing a slight dip in the continuum here; the same applies to the sodium doublet at 5890-96 Angstroms. Several more faint lines can be seen in the spectrum above the Hβ absorption, including iron, calcium, and single helium line just below the sodium doublet.

We will again employ Wien's Law to obtain a very rough estimate of temperature. Again, we are dealing with a hotter, A-type star here, so we can expect our estimate to be far too low. Using a peak energy wavelength of 4196 Angstroms, the result is a temperature of 6906K. For comparison purposes, the established temperature of the star is listed as 7980K[2]. This is in line with our expectations.

## ε Cassiopeiae

Epsilon Cassiopeiae, or Segin, is a singular star of early B-type[1]. We should expect a continuum curve implying a high temperature, with reduced hydrogen Balmer absorptions present.

The completed spectrum is presented here:

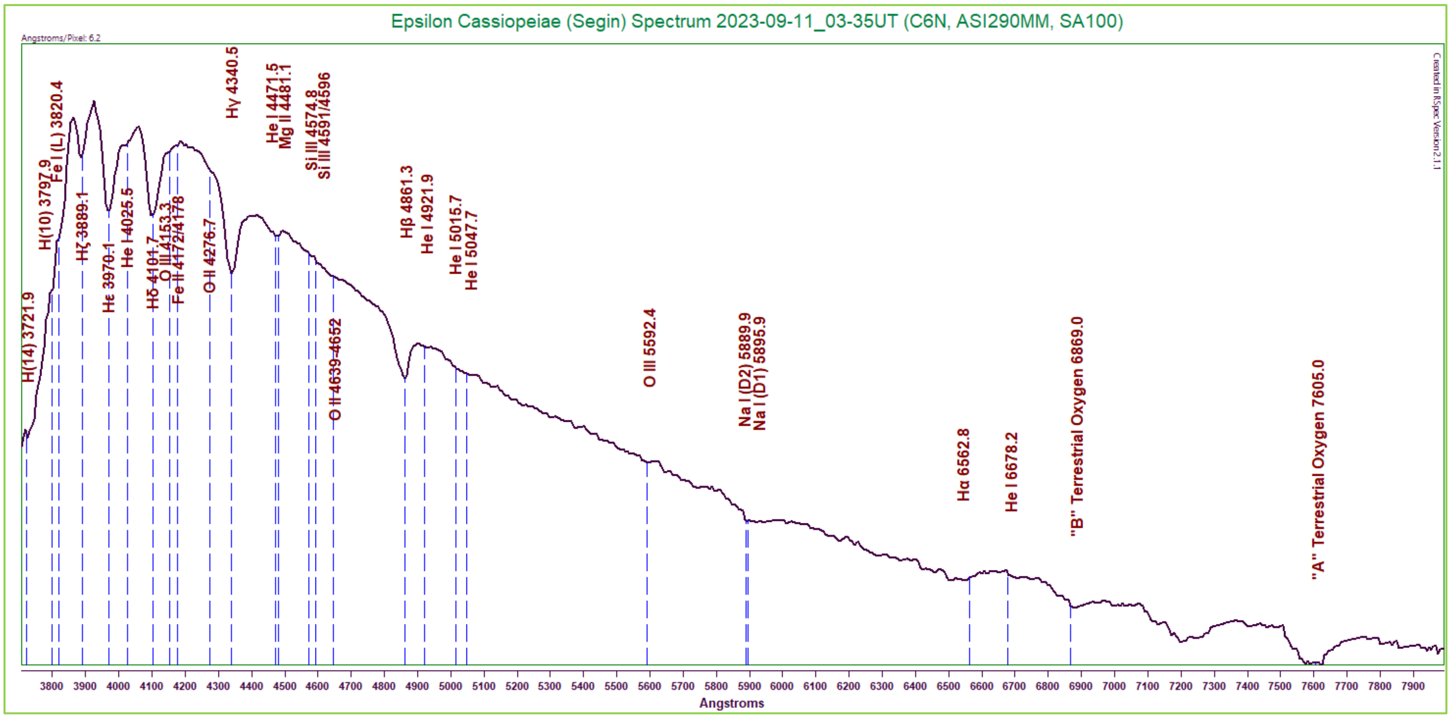


*Figure 5: Epsilon Cassiopeiae (Segin) Spectrum (6.2 Angstroms/pixel)*
*Capture Details 5: Exposure 474ms, Gain 149, 50% of 511 frames stacked*

Again, we are seeing characteristics more or less in line with our expectations. The hydrogen Balmer lines are mostly present, but weaker than those in A-type stars. The Hη line appears to be missing, leaving the Fe I (L) line to carve out a step in the continuum on its own. A peculiar, very subtle dip in the continuum occurs where two helium lines sit at 5015-5047 Angstroms. The drop is just barely noticeable, but it does appear to be distinct from the continuum. Other small helium lines appear at 4025.5, 4471.5, 4921.9, and 6678.2 Angstroms. Several ionized oxygen lines also can be seen at 4153.3, 4276.7, 4639-4652, and 5592.4 Angstroms. A significant double absorption can be noted at 4471-4481 Angstroms due to one of the helium lines very close to a magnesium line. The sodium doublet at 5890-96 Angstroms is surprisingly notable as well. A few other faint metals are marked, including iron and silicon.

Employing Wien's Law will certainly result in an estimate that is far too low, but we will proceed nonetheless. Using an estimated peak energy wavelength of 3924 Angstroms, our resultant temperature is 7385K. The established temperature for the star is listed as 15174K[2]. Our estimate fall short by a factor of 2.

## Conclusion

The captures of the raw data did come out better than anticipated. This was a pleasant surprise considering the unsteadiness and light pollution of my northern sky. All told, this report represents a very interesting collection of stars.

## 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