A Spectroscopic Study of Sulaphat (γ Lyrae)

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Abstract

This paper describes an investigation into what can be learned about the physical properties of the blue star Sulaphat (γ Lyrae) from both low (150 lines/mm) and high (2400 lines/mm) resolution spectra, based on the simple model that the star is a rotating uniformly emitting oblate spheroid with a photosphere that is a single layer in thermal equilibrium. Sulaphat is a hot B9 III star that has evolved away from the main sequence. The aim of this work was to test the ability of a simple stellar model to predict the Hydrogen line profiles in Sulaphat's spectrum and estimate the thickness and pressure of it's photosphere.

1. Introduction

Sulaphat (γ lyr) is classed as a B9 III star i.e. a hot (B9) giant (III) star that has exhausted its supply of Hydrogen in its core and has evolved away from the main sequence.

The aim of this work was to test the ability of a simple stellar model to predict the Hydrogen line profiles in Sulaphat's spectrum.

The stellar model used was that of a, solid body, rotating uniformly emitting oblate spheroid with a photosphere that is a single layer in thermal equilibrium. It is also assumed that the observed absorption lines are formed solely within this photosphere.

Using this model an effective "black body" temperature can be deduced from low resolution (150 lines/mm) spectra provided proper calibration is performed to correct the continuum spectrum for instrument response and atmospheric absorption. High resolution (2400 lines/mm) investigations of individual line shapes can then be used to determine other model parameters.

The theory and computer programs used in this study have been previously described in earlier studies[1].

2. Low Resolution Spectra

Figure 1 shows a low resolution (150 lines/mm) spectrum of Sulaphat, this spectrum was fully calibrated for instrument response and atmospheric absorption using a library reference spectrum. In the figure the Hydrogen α, β and γ line positions have been indicated. Low resolution data can be used to obtain an estimate for the effective temperature of a star. It is simply necessary to divide the spectrum by the particular "Planck wavelength curve" that results in the flattest resultant spectrum. This process yields a temperature estimate of 18025K for Sulaphat.Figure 2 shows the flattened spectrum of Sulaphat after division by the appropriate Planck curve.

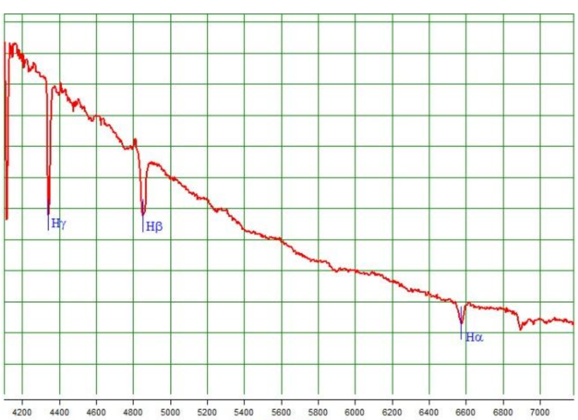


Figure 1: 150 l/mm spectrum of Sulaphat

Figure 2: Flattened line spectrum of Sulaphat

3. High Resolution Spectra

High resolution (2400 line/mm) spectra taken at H_{γ}, H_{β} and H_{α} wavelengths are shown in figures 3, 4 and 5 respectively.

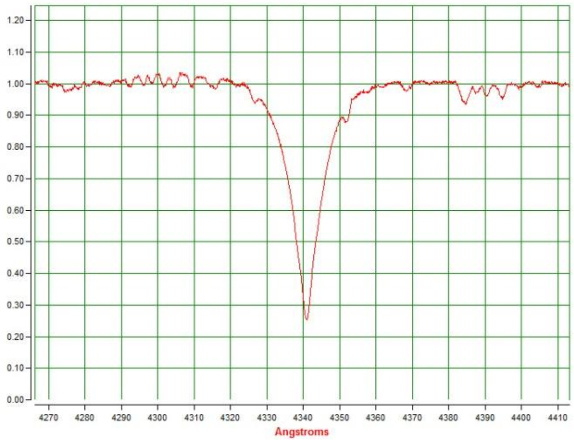


Figure 3: 2400 l/mm spectrum of Sulaphat at H_{γ}

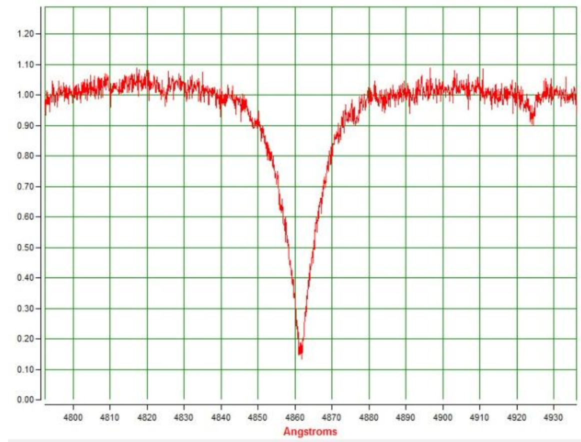


Figure 4: 2400 l/mm spectrum of Sulaphat at H_{β}

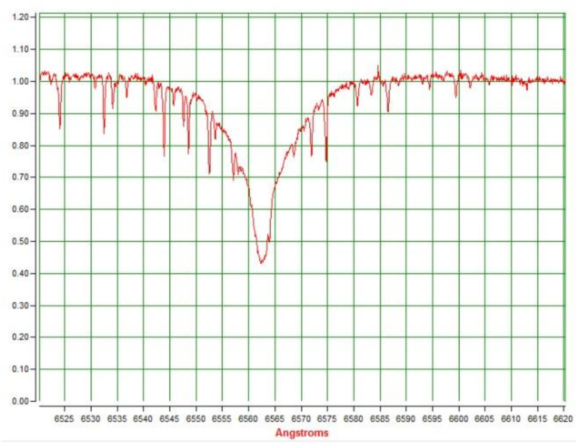


Figure 5: 2400 l/mm spectrum of Sulaphat at H_{α}

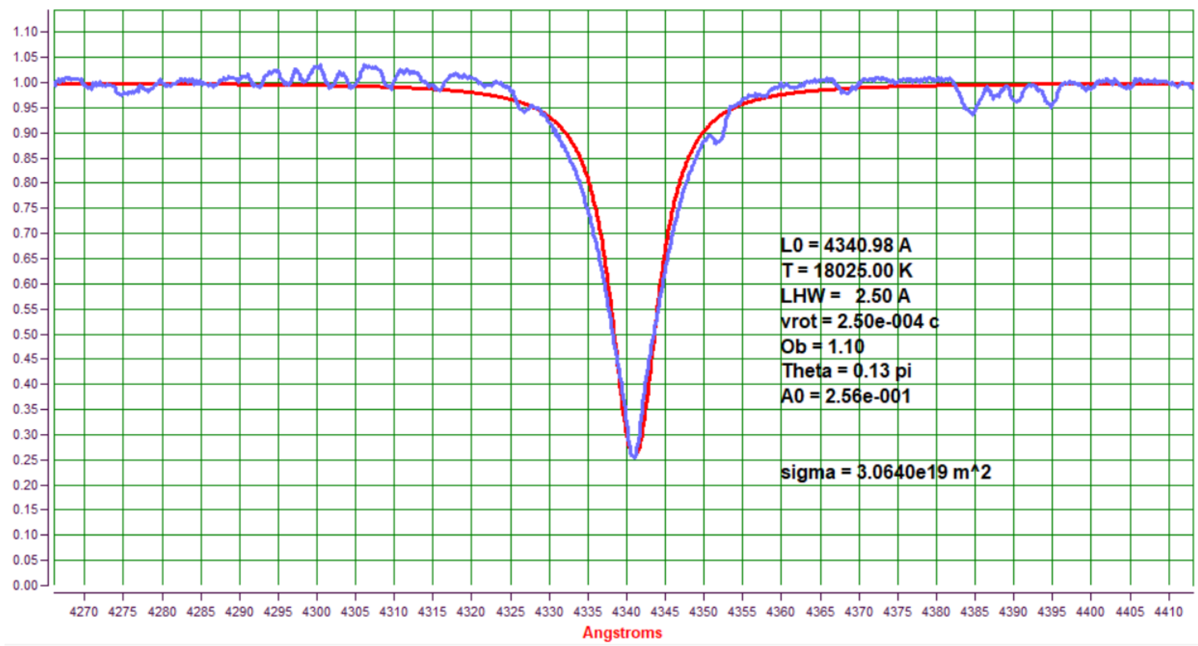
3.1 H_{γ} line analysis

The H_{γ} absorption line was chosen for analysis as it seems, from experience, to be less susceptible to non-thermal equilibrium processes. For the H_{γ} absorption line the central wavelength was determined, based on equal areas each side of centre, to be 4340.98A whilst the $A\gamma(\lambda_{\gamma})$ i.e. minimum profile intensity, value for the normalized absorption line was taken to be 0.256, this value will be required when predicting other absorption lines in the Balmer series. The resulting modelled absorption profile is shown in figure 6 (red curve) along with the measured profile (blue curve). The values of the model parameters are list in this figure along with the calculated photon capture cross-section.

The values for the rotation parameters:- Equatorial surface velocity (vrot), Oblateness (Ob) were obtained from the internet[2] and the viewing angle (theta) measured from the plane of the star's equator was adjusted for a good fit to the line profile.

It can be seen that the simulated line matches the measured line quite well.

Figure 6: Sulaphat Hγ



3.2 H_β and H_α line synthesis

The custom software was used to compute the expected absorption lines at H_β and H_α wavelengths. The result is depicted in figures 7 and 8 respectively (red curves) together with the measured line profiles (blue curves).

Figure 7: Sulaphat Hβ

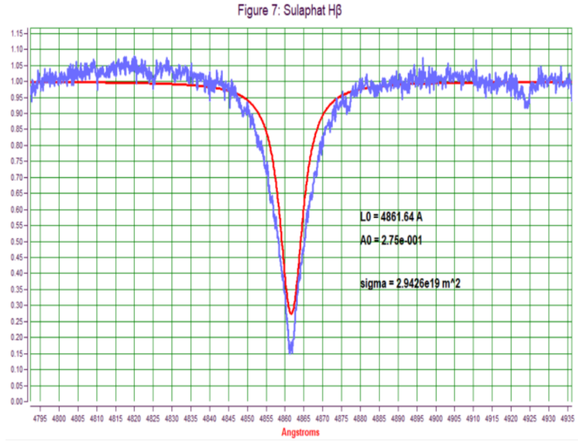
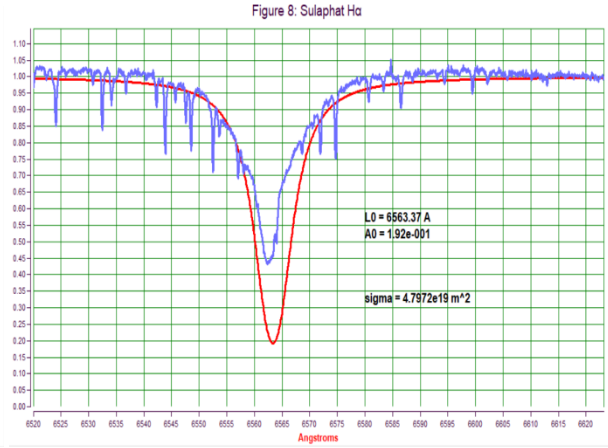


Figure 8: Sulaphat Hα

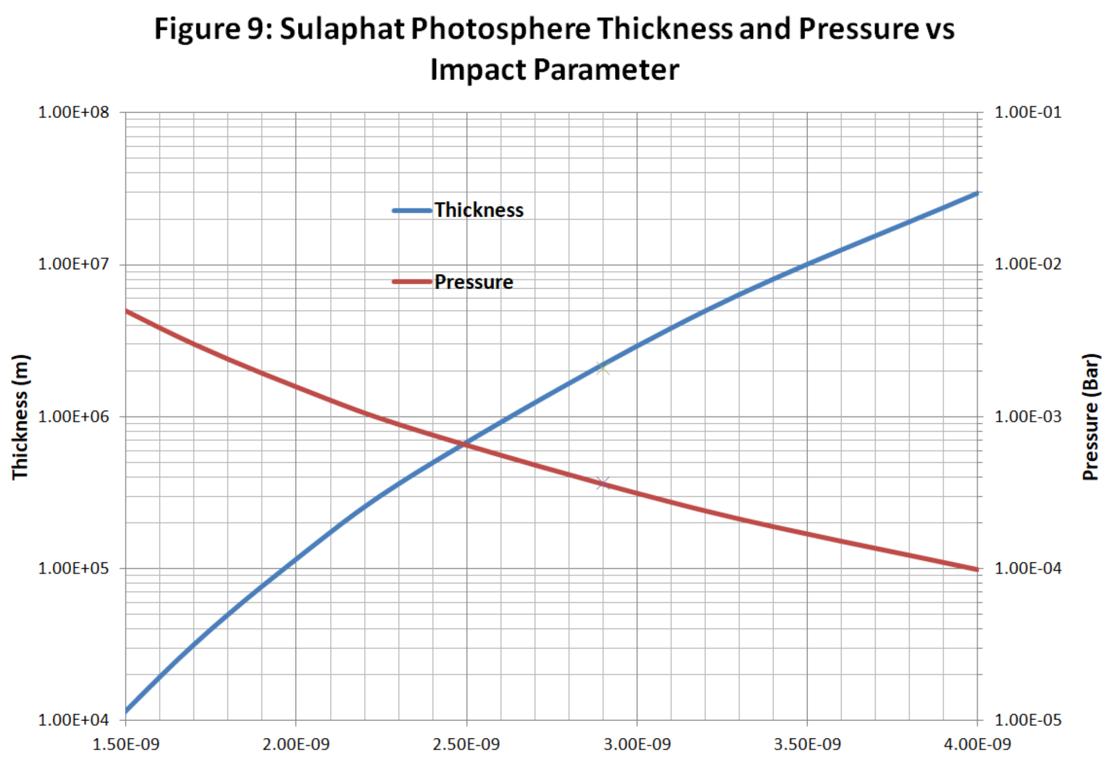


At H_β there is a small difference between the predicted and modelled line centre intensity with the absorption being underestimated by the model. It is possible the zero level of the spectrum has an error associated with it, the absorption is quite deep and therefore sensitive to zero level errors.

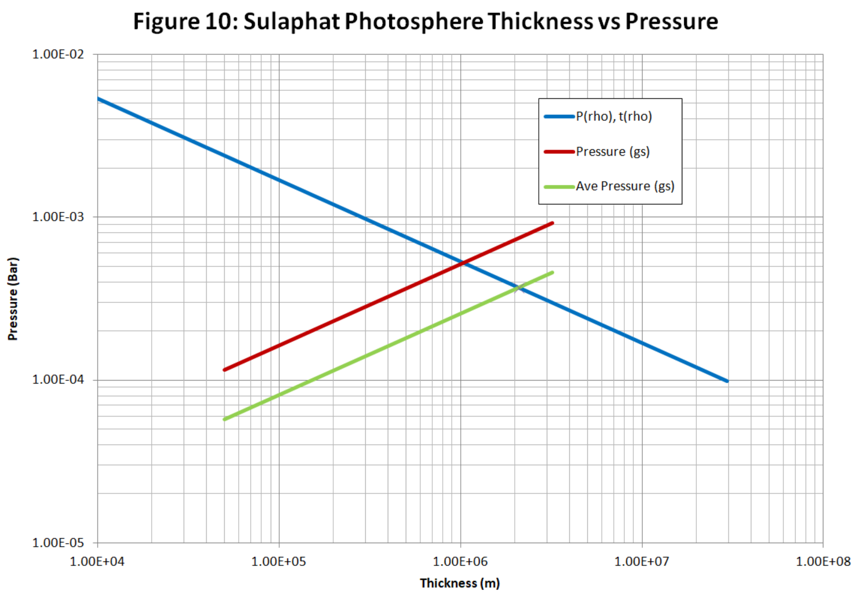
At H_β the absorption is overestimated as seems normal with these hot rotating stars and the actual line appears asymmetric. This asymmetry could be a sign of other factors at work such as emission from an equatorial bulge.

4. Photosphere Pressure and Thickness

The analysis of the H_γ absorption line also yielded a value of 2.8255×10^{20} m^2 for the column density of atoms in the n=2 principle quantum state. This value is split by the custom software into predictions of the pressure and thickness of Sulaphat's photosphere as a function of the impact parameter 'imp'. The result is displayed in figure 9.



As for previous stars studied by the author[1] (Sun, Albireo B, Vega, Deneb, Altair), its is also possible to estimate the pressure of Sulaphat's photosphere as a function of it's thickness given a value for it's surface gravity and the previously mentioned column density of atoms in the Balmer series ground state. The surface gravity is known to be gs = 115 m s^{-2} and Figure 10 shows the result of calculating the photosphere pressure as a function of photosphere thickness given this value. Also shown in this figure is the parameterised (by the impact parameter) curve of pressure vs thickness derived from the data displayed in Figure 10. Taking the average pressure as a half of the base pressure, as calculated from surface gravity, the intersection of these two functions yield an estimate of 3.7e-4 Bar, 2.1e3 km and 2.9e-9 m for the pressure, thickness and impact parameter appropriate to Sulaphat's photosphere.



5. Conclusions

A spectroscopic study of Sulaphat (γ Lyrae) has been performed to determine physical properties of the star. It has been found that the following model parameters reproduce the star's H_γ Blamer line profile reasonably well:-

- A photosphere temperature of 18025K.
- A pressure Lorentzian half width of 2.5A.
- A maximum surface speed due to rotation of $2.5\text{x}10^{-4}$c
- An oblateness factor of 1.1.
- A viewing angle of 0.13π from its equator.

The model slightly underestimates the absorption at H_β whilst at H_α some excess emission is seen as is common with the hot fast rotating stars studied by the author. This H_β excess is possibly due to an equatorial bulge.

6. References

1. www.thewhightstuff.co.uk
2. www.star-facts.com