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 the Sulaphat's spectrum.

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 for example, a "mean free path" between particle collisions in the photosphere and the star's speed of rotation.

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

1.1 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 16225K for Sulaphat but note large errors can result for hot stars as the peak of emission is well into the UV region of the spectrum so the resulting temperature is very sensitive to small "errors" in the measured spectrum. Luckily line profiles are most sensitive to pressure effects and not temperature and it is possible to input any desired temperature into the simulations.

Figure 2 shows the flattened spectrum of Sulaphat after division by the appropriate Planck curve.

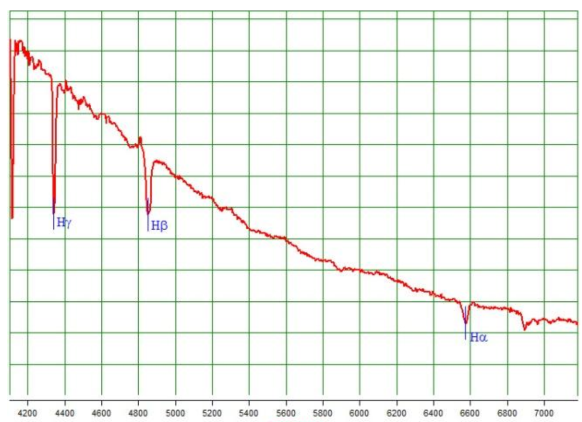

Figure 1: 150 l/mm spectrum of Sulaphat

Figure 2: Flattened line spectrum of Sulaphat.

1.2 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.

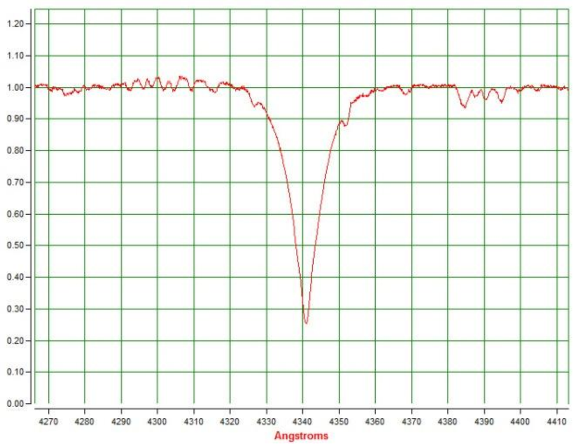

Figure 3: 2400 l/mm spectrum of Sulaphat at H_γ

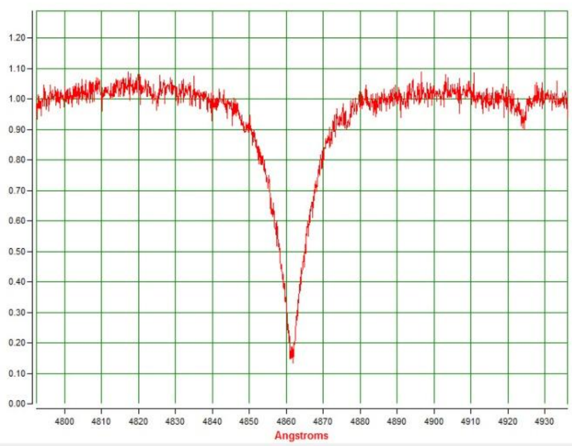

Figure 4: 2400 l/mm spectrum of Sulaphat at H_β

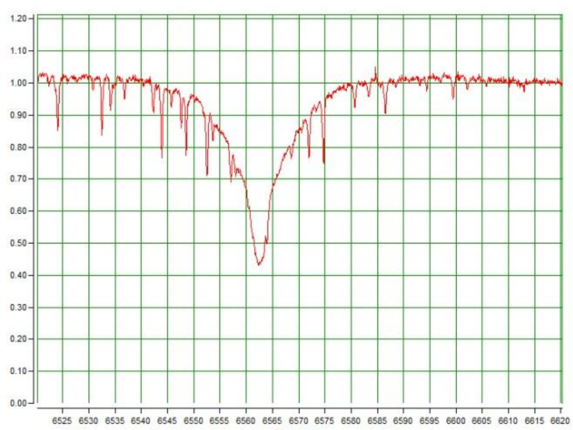

Figure 5: 2400 l/mm spectrum of Sulaphat at H_α

1.3 H_β line analysis

For the H_β absorption line the central wavelength was determined, based on equal areas each side of centre, to be 4861.68A whilst the $A_\beta(\lambda_\beta)$ i.e. minimum profile intensity, value for the normalized absorption line was taken to be 0.18 (after allowing for noise), this value will be required when predicting other absorption lines in the Balmer series. The resulting modelled absorption profile is shown in figure 6 along with the measured profile.

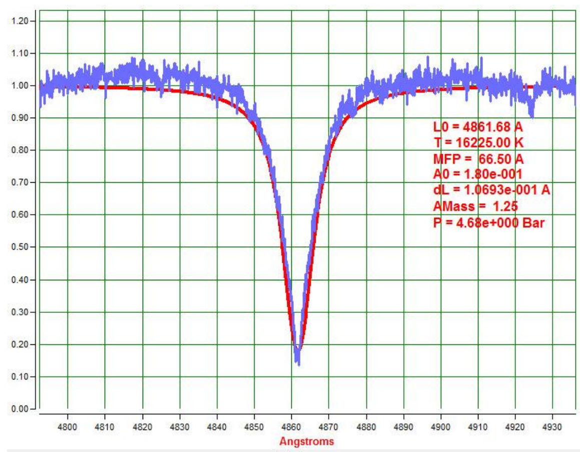

Figure 6: Simulated H_γ absorption line (red) target (blue)

It was assumed that rotation was insignificant for this star. All parameter values appear as labels in the RSpec displayed spectra as can be seen in Figure 6.

1.4 H_γ and H_α line synthesis

The custom software can be used to compute the expected absorption lines at H_γ and H_α wavelengths. The result is depicted in figures 7 and 8 respectively together with the measured line profiles.

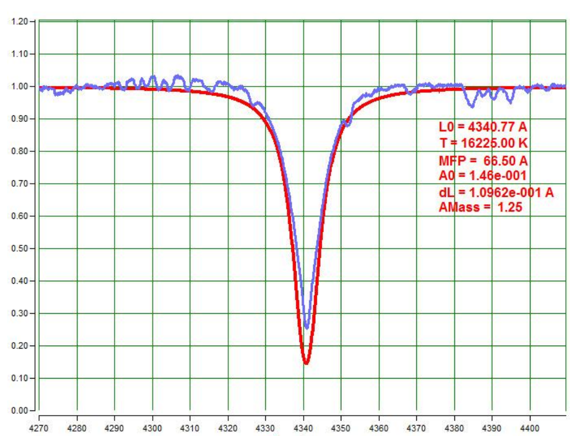

Figure 7: Computed H_γ absorption line (red) $A_\gamma(\lambda_\gamma)$ = 0.146 and measured H_γ line (blue) $A_\gamma(\lambda_\gamma)$ = 0.254

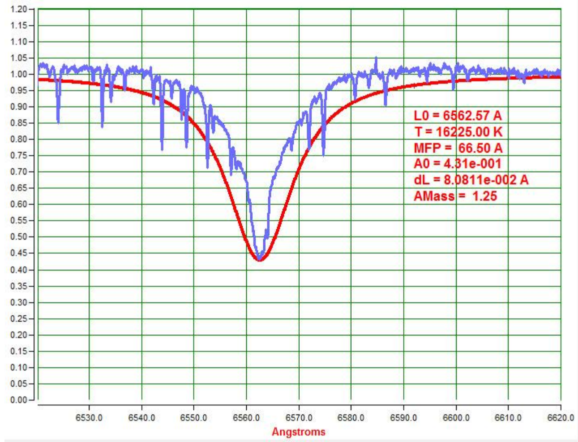

Figure 8: Computed H_α absorption line (red) $A_\alpha(\lambda_\alpha)$ = 0.431 and measured H_α line (blue) $A_\alpha(\lambda_\alpha)$ = 0.443

2. Discussion

At both wavelengths the match between the modelled profile and measurement is quite good.

At H_γ there is a small difference between the predicted and modelled line centre intensity which could be corrected by a small change in simulation temperature or by assuming a departure from a Planckian intensity distribution. This second option has been modelled and the results depicted in figure 9.

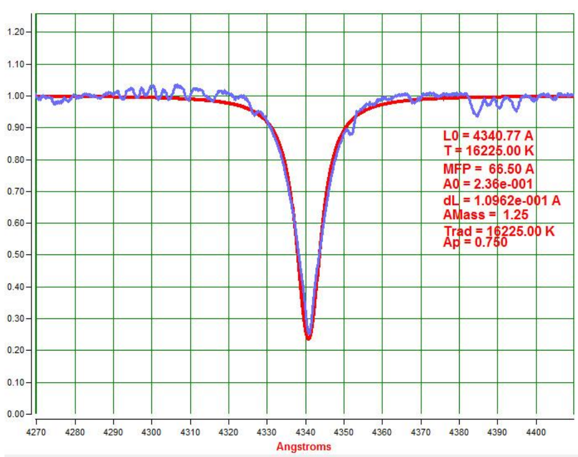

Figure 9: Computed H_γ absorption line (red) $A_\gamma(\lambda_\gamma)$ = 0.236 and measured H_γ line (blue) $A_\gamma(\lambda_\gamma)$ = 0.254

A third possibility may be that the zero level of the spectra has an error associated with it however, I have attempted to eliminate such an error in all my spectra.

At H_α there is a small but obvious difference in the line shape. I have noticed a similar difference, at H_α, in other stars and when it is a strong effect, as in the case of Vega, I have suggested it results from (and sucessfully modelled it as) a failure of the single layer assumption for the photosphere. Assuming this to be the case I have re-modelled the H_α line assuming the first (main) layer of the photosphere (at 16225K) has a central intensity of 0.555 at H_α which is modelled as a departure from a Plankian distribution. There is too little data to go on and predict the properties of the purported second photospheric layer. The result of this modelling is shown in figure 10.

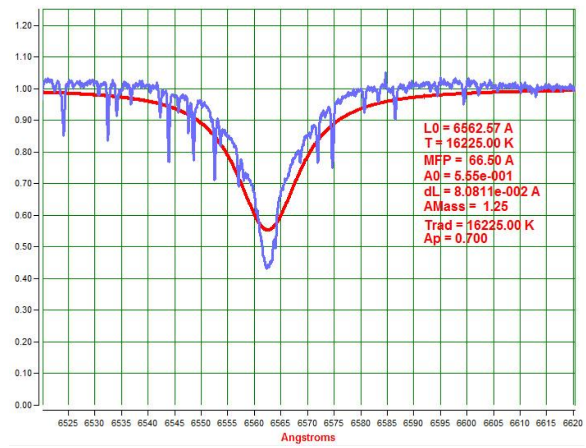

Figure 10: Computed H_α absorption line (red) $A_\alpha(\lambda_\alpha)$ = 0.555 and measured H_α line (blue) $A_\alpha(\lambda_\alpha)$ = 0.443

3. Conclusions

A spectroscopic study of Sulaphat (γ Lyrae) has been performed to determine physical properties of the star. It has been found that:-

- The approximate temperature of the star's photosphere is 16225K.
- The mean free particle path in the photosphere is approximately 66.5A.
- There may be some additional source of absorption that distorts the H_α line profile.