A Spectroscopic Study of Altair (α Aql)

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Abstract

This paper describes an investigation into what can be learned about the physical properties of the White star Altair (α Aql) 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. Altair is a hot A7 IV-V rapidly rotating star.

The aim of this work was to test the ability of a simple stellar model to predict the Hydrogen line profiles in Altair's spectrum and to determine the pressure and thickness of Altair's photosphere.

1. Introduction

Altair (α Aql) is classed as a A7 IV-V star i.e. a hot (A7) sub-giant/main-sequence (IV-V) star that is rotating rapidly with an equatorial surface velocity of 9.53×10^{-4}c (Wikipedia). As a result the star is oblate with an equatorial to polar radius ratio of 1.245 and the polar axis is inclined at 6o^{o} to the line of sight (Wikipedia). Figure 1, which was copied from the Wikipedia page, is a representation of the star.

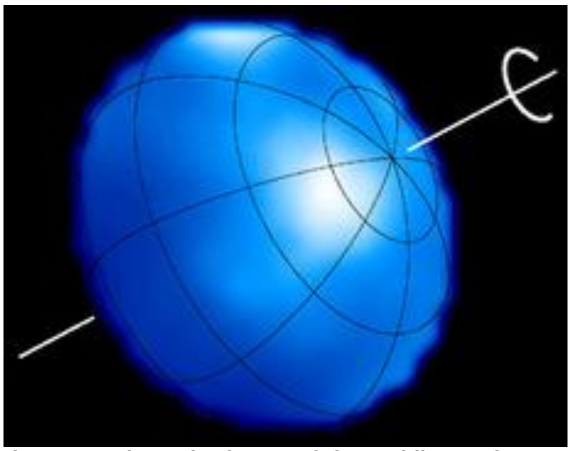


Figure 1: False color image of the rapidly rotating star Altair, made with the MIRC imager on the CHARA array on Mt. Wilson.

The aim of this work was to test the ability of a simple stellar model to predict the Hydrogen line profiles in Altair's spectrum and to determine the pressure and thickness of the star's photosphere. The stellar model used will be that of a solid body (oblate spheroid), rotating and emitting uniformly through a photosphere that is a single layer in thermal equilibrium.

As temperature has a relatively small effect on line profiles, certainly for high pressure dwarf stars, I will assume a uniform temperature over the star. 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 of the Sun and the blue component of Albireo (β Cyg).

1.1 Low Resolution Spectra

Figure 2 shows a low resolution (150 lines/mm) spectrum of Altair, 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.

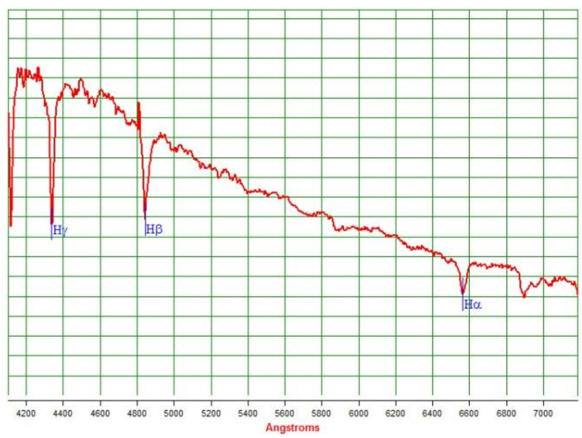


Figure 2: 150 l/mm spectrum of Altair

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 9550K for Altair. Figure 3 shows the flattened spectrum of Altair after division by the appropriate Planck curve.

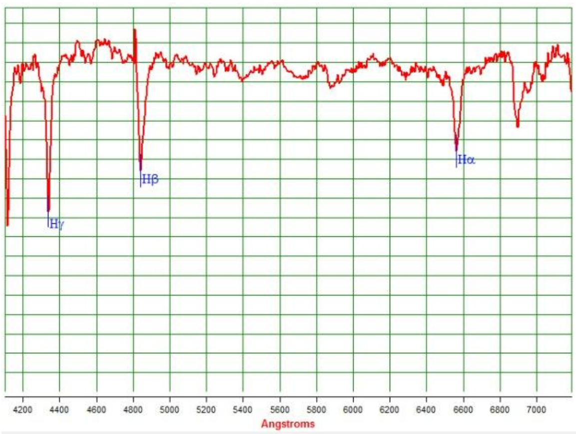


Figure 3: Flattened line spectrum of Altair.

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 4, 5 and 6 respectively. I have chosen to model the H_γ absorption line using the values for the oblateness (ob), equatorial surface velocity (vrot) and viewing angle (theta) stated in the Wikipedia entry, this leaves just the Lorentezian Half-Width (LHW) as a free fitting parameter.

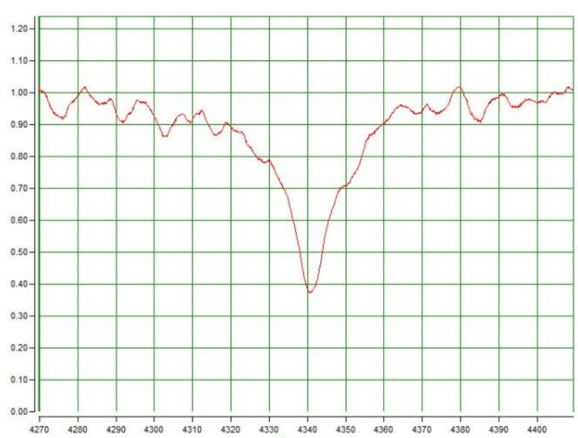


Figure 4: 2400 l/mm spectrum of Altair at H_γ

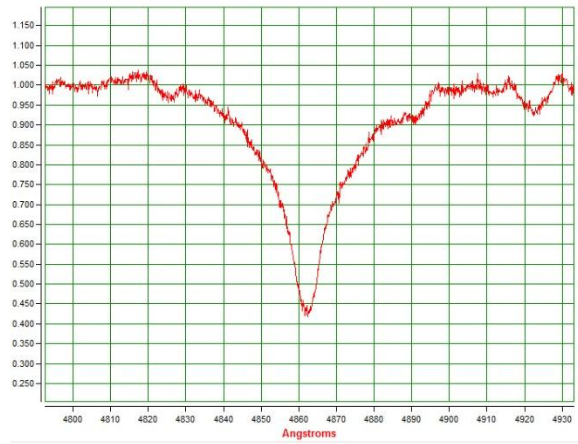


Figure 5: 2400 l/mm spectrum of Altair at H_β

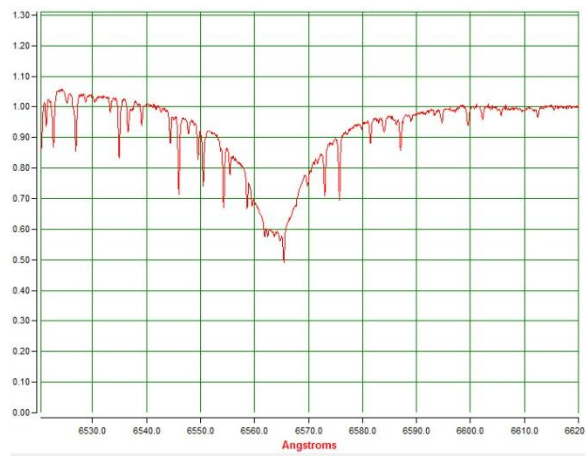


Figure 6: 2400 l/mm spectrum of Altair at H_α

1.3 H_γ line analysis

For the H_γ absorption line the continuum gradient was removed, using my software, and the central wavelength determined, based on equal areas each side of centre. The $A_\gamma(\lambda_\gamma)$ value (Intensity at the absorption line centre A0) was 0.375 Simulations were performed, adjusting the parameter LHW, to achieve a good fit to this profile and the result is depicted in figure 7.

It can be seen that, with LHW = 4.0A, a good fit is achieved in the core of the line but there appears to be some extra emission in the "wings" that is not reproduced by the model. All the parameters used to obtain this fit are displayed in the figure.

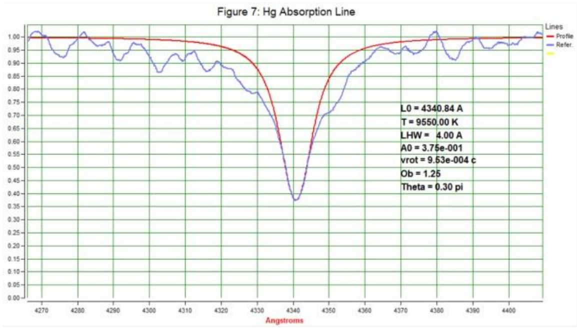


Figure 7: Hg Absorption Line

1.4 H_β and H_α line synthesis

The custom software was then used to compute the expected absorption lines at H_β and H_α wavelengths. The results are depicted in figures 8 and 9 respectively together with the measured line profiles. Whilst the fit is not too bad at H_β we are again seeing considerable additional emission at H_α as we did in the study of Albireo B as well as some additional emission at H_β .

It is possible that the same mechanism suggested as the reason for Albireo B's excesses can be invoked for Altair. Both stars are rapidly rotating so a bulging equator may result in excess emission from, when compared to AlbireoB, a less optically dense region around this bulging equator.

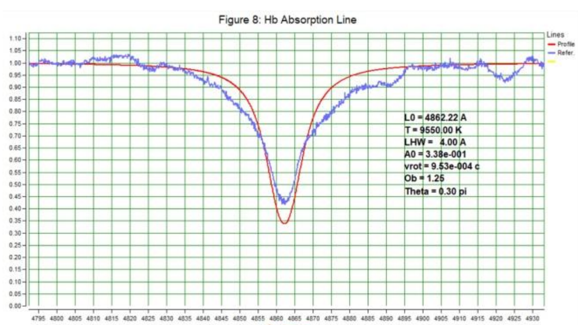


Figure 8: Hb Absorption Line

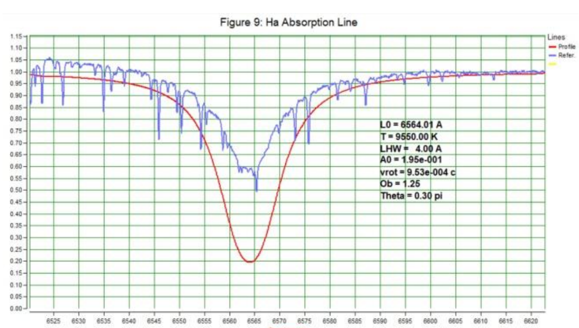
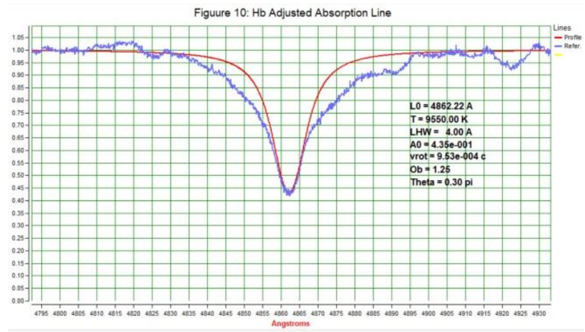


Figure 9: Ha Absorption Line

Figures 10 and 11 show the result of including the effect of additional emission at H_β and H_α respectively, achieved by adjusting the peak absorption value A0.



Figuure 10: Hb Adjusted Absorption Line

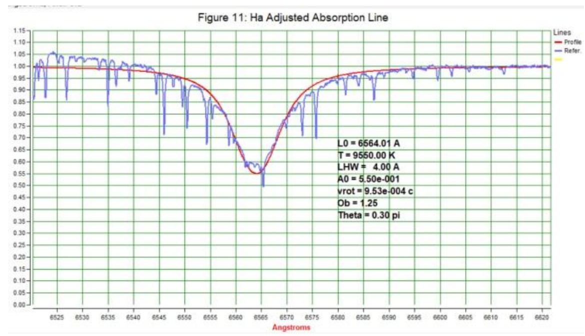


Figure 11: Ha Adjusted Absorption Line

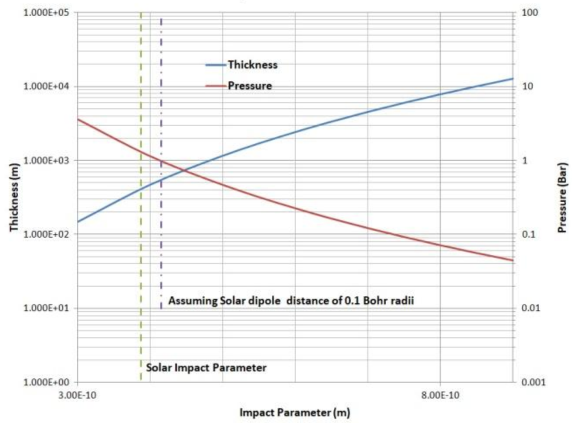
The final values for the adjusted parameter A0 are 0.435 at H_β and 0.55 at H_α. It can be seen that the fit is quite good at H_α though at H_β there is still some additional emission in the wings that is un-accounted for as indeed there was at H_γ.

1.5 Photosphere Pressure and Thickness

The analysis of the H_γ absorption line also yields the final value of $6.6667e^{21}m^2$ 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 Altair's photosphere as a function of the impact parameter 'imp'. The result is displayed in figure 12.

It can be seem that, because of the relatively low number of ionised to neutral state atoms (1.5% approx) this calculation is insensitive to the choice of solar dipole impact separation and the predictions, based on solar calibration, comes out strongly in favour of a pressure of approximately 1Bar with a thickness of approximately 500m i.e. considerably higher in pressure and less in thickness than the Sun.

Figure 12: Altair Photosphere Thickness and Pressure vs Impact Parameter



The vertical dashed lines in this figure indicate the impact parameter values obtained by calibrating the calculation from known Solar properties and from assuming a 0.1A solar dipole separation. The relevant theory is presented in my study of Albireo B.

2. Discussion

Rotation effects can be expected to compromise the assumption of a uniformly emitting spheroid. This fact has been used to propose, as in the case of Albireo B, that the equatorial bulge allows for some additional H_β and H_α emission with the dynamical properties of the star. If this mechanism is valid then the bulge must be less optically thick for Altair as some emission at H_β is seen whereas it was absent in the case of Albireo B at H_β. Such a mechanism would seem to be consistent with the fact that Albireo B is spinning off a decreation disk whilst Altair is not.

Allowing for the proposed addition equatorial emission, a good fit using the known parameter values of oblateness, rotational velocity and viewing elevation was obtained with just the Lorentzian half-width parameter left to adjust. The fit was particularly good at H_α where the additional wing absorption seen at H_γ and H_β was not present. Why this should be the case is not known.

3. Conclusions

A spectroscopic study of Altair (α Aql) has been performed to determine physical properties of the star. My analysis suggests the following properties for the star:-

- The approximate temperature of the star's photosphere is 9550K.
- The pressure Lorentzian half width is 4.0A.
- The maximum surface speed due to rotation is 9.53×10^{-4}c
- the Oblateness factor for the star is 1.245.
- We are viewing the star a 0.3π from its equator.
- Some excess emission, possibly from the equatorial bulge, is present at H_β and to a larger extent at the H_α wavelength.
- Altair's photosphere has a pressure and thickness of approximately 1 Bar and 500m respectively.
- Additional wing absorption, of unknown origin, is present at H_γ and H_β.