STIS Observations of the Transition Region of Alpha Cen A (G2 V)

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Abstract. We report on STIS observations of the G2 V star α Cen- tauri A (HD 128620), a star very similar to the Sun. The high resolution echelle spectra obtained with the E140H and E230H gratings cover the complete spectral range 1133-3150 Å with a resolution of 2.6 km/s. This beautiful spectrum contains a very large number of emission and absorption lines. We present here a preliminary study of the E140H spectrum. Of particular interest are the shapes of transition region lines (e.g., Si IV, C IV), the density sensitive intersystem lines, and the He II 1640 Å line. The purpose of this study is to compare the α Cen A UV spectrum with the solar one to determine how the atmosphere and heating processes in α Cen A differ from the Sun as a result of the small differences in gravity, age, and chemical composition of the two stars.

1. Introduction

We present here preliminary results from the study of the UV spectrum of α Cen A acquired by the STIS instrument on HST (Woodgate et al. 1998). Although we will find some small differences between α Cen A and the Sun, the
Figure 1. The E140H spectrum of α Cen A.
STIS α Cen A spectrum will likely become the most useful "solar spectrum" because unlike the existing solar data it:

- is a true disk average
- has high spectral resolution
- has excellent photometric and wavelength calibration
- has very high S/N
- covers the full 1133-3150 Å region with uniform spectral resolution and calibration.

2. Observations

The E140H spectral data were acquired on Feb 12 1999 with 3 exposures of 4695 s each, centered at 1234, 1416, and 1598 Å, respectively. The E140H mode ensures an average dispersion of λ/228,000 Å per pixel, which corresponds to a resolving power of 2.6 km/s. The E140H grating is used with the FUV-MAMA detector, that we operated in TIME-TAG mode.

The data were reduced by using the STIS team IDL-based software, including the CALSTIS and TIME_TAG IDL routines. Wavelength calibration was carried out using on-board lamp spectra taken once per orbit to correct for thermal motions and other non-repeatable effects. To check the accuracy of the wavelength scale, we measured the centroids of emission lines recorded in adjacent orders, and found that the results agree to within less than 1 bin. The spectrum was corrected for scattered light that severely affects the region close to the Ly-α by using the IDL ECHELLE.SCAT routine (Lindler 1999) in the STIS TEAM software package.

3. The UV spectrum of α Cen A

In Figure 1 we show the E140H spectrum of α Cen A. We have measured 670 emission lines in the spectrum. The most intense chromospheric lines of O I, Si II, and C II have central reversals. Interstellar medium absorption features are measurable in the line profiles of the D I 1215.4 Å, H I 1215.7 Å, O I 1302 Å, C II 1334 Å, and Si II 1526 Å lines. For line identification see Pagano et al. (2000). Several intersystem lines are present in the spectrum of the α Cen A, including the O IV] UV 0.01 intercombination multiplet $2s^22p^2P_J^p - 2s2p^24P_J^p$, that are excellent diagnostics of electron density in the range $10^9 < N_e < 10^{12}$ cm$^{-3}$ (Brage et al. 1996, and references therein), the N IV] line at 1486 Å, and the O III] line at 1666 Å. In this paper we report on some very preliminary results from the analysis of the E140H spectrum.

3.1. The Broad Wings of the Transition Region Emission Lines

As shown by Wood et al. (1997) the strongest transition region emission lines of α Cen A have broad profiles. We found, in fact, that the Si IV and C IV profiles cannot be fit by a single Gaussian profile, but require 2 components: one narrow plus one broad Gaussians (see Figure 2 and Table 1). This bi-modal structure of the transition region lines was observed for several RS CVn-type stars (i.e., Capella and HR 1099), main sequence type stars (i.e., AU Mic,
Table 1. Two-Gaussian Fits to the Si IV and C IV Transition Region Lines.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Narrow Component</th>
<th>Broad Component</th>
<th>Flux</th>
<th>FWHM</th>
<th>Flux Ratio</th>
<th>Velocity Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$v_{rad}^N$ (km s$^{-1}$)</td>
<td>$v_{rad}^B$ (km s$^{-1}$)</td>
<td>$F_{tot}$</td>
<td>$v_{BC-V_{NC}}$</td>
<td>$F_{BC}/F_{tot}$</td>
<td></td>
</tr>
<tr>
<td>Si IV 1393Å</td>
<td>4.8±0.4</td>
<td>5.182±0.004</td>
<td>3.8±0.5</td>
<td>3.020±0.004</td>
<td>0.37</td>
<td>-1.1</td>
</tr>
<tr>
<td>Si IV 1402Å</td>
<td>4.1±0.5</td>
<td>2.027±0.012</td>
<td>3.4±0.6</td>
<td>2.136±0.011</td>
<td>0.51</td>
<td>-0.6</td>
</tr>
<tr>
<td>C IV 1548Å</td>
<td>6.4±0.3</td>
<td>7.698±0.090</td>
<td>5.1±0.4</td>
<td>9.050±0.011</td>
<td>0.54</td>
<td>-1.3</td>
</tr>
<tr>
<td>C IV 1550Å</td>
<td>6.5±0.2</td>
<td>5.833±0.010</td>
<td>3.6±0.3</td>
<td>2.871±0.011</td>
<td>0.33</td>
<td>-2.9</td>
</tr>
<tr>
<td>F.W. Average</td>
<td>5.8±0.9</td>
<td>4.4±0.7</td>
<td></td>
<td></td>
<td>0.45±0.09</td>
<td>-1.6±0.8</td>
</tr>
</tbody>
</table>

* The line velocity relative to the star, assuming a stellar radial velocity of -22.9 km/s.
* in unit of 10$^{-13}$ erg cm$^2$ s$^{-1}$.

Procyon, α Cen A, and α Cen B), and the giants 31 Com, β Cet, β Dra, β Gem, and AB Dor (cf. Linsky & Wood 1994, Wood et al. 1997, Linsky et al. 1995, Pagano et al. 2000). Wood et al. (1997) showed that the narrow components can be produced by turbulent wave dissipation or Alfvén wave heating mechanisms, while the broad components, that resemble the explosive events on the Sun, are diagnostics for microflare heating.

![Si IV and C IV line profiles](image)

Figure 2. The Si IV and C IV line profiles. The solid and dashed lines indicate the centroids of the narrow and broad Gaussian components, respectively, required to best fit the broad wings of these transition region lines.

The fluxes in the broad and narrow Gaussians of α Cen A are comparable, and the flux-weighted broad/total flux ratio is 0.45 ± 0.09. This ratio is very close to the one found for the dM1 star AU Mic (see Pagano et al. 2000) and
is typical for the most active stars studied by Wood et al. (1997). The flux-weighted average of the FWHMs are \( \sim 42 \pm 4 \) km s\(^{-1}\) for the narrow and broad components, respectively. By comparison, explosive events on the Sun produce transition region lines as broad as FWHM \( \sim 100 \) km s\(^{-1}\) (Dere, Bartoe, & Brueckner 1989).

Both the narrow and broad components are redshifted with respect to the stellar photosphere, but with a greater amount for the narrow components. This was already observed by Wood et al. (1997), who measured the Si IV 1393 \( \AA \) line of \( \alpha \) Cen A in GHRS/HST spectra.

4. The He II 1640 \( \AA \)

The He II H\( \alpha \) line at 1640 \( \AA \), which is actually a multiplet of seven lines with wavelengths between 1640.322 to 1640.533 \( \AA \), is generally thought to be formed by one of two processes: collisional excitation in a 10\(^{5}\) K plasma (e.g., Jordan 1975) or recombination and cascades in the chromosphere following photoionization of neutral helium by coronal X-rays (e.g., Zirin 1975). An empirical discriminant between these two formation mechanisms is that the collisional excitation model predicts a broad profile centered at a laboratory wavelength of 1640.438 \( \AA \), whereas one recombination model predicts a narrower profile dominated by the \( 2p \ ^2P_{3/2} \rightarrow 3d \ ^2D_{5/2} \) transition centered at 1640.474 \( \AA \) and by the \( 2p \ ^2P_{1/2} \rightarrow 3d \ ^2D_{3/2} \) (the fifth and first lines of the multiplet, respectively).
In Figure 3 we plot the $\alpha$ Cen A spectrum in the region of the He II 1640 Å line corrected for the stellar radial velocity of -29.4 km/s (cf. Pourbaix et al. 1999 for the orbital elements). Other than the He II line, the plotted spectral region shows a Fe II line, a S I line, and a feature that we tentatively attribute to a blending of the O II 1640.5140 & 1640.6556 lines with the He II multiplet. The seven short vertical lines in Figure 3 indicate the laboratory wavelengths of the seven lines in the multiplet. The two stronger lines in the recombination model (Feldman et al. 1975) are shown with a thickest line. We find that the He II 1640 Å line is well-fit by only one broad Gaussian. The dotted vertical line in Figure 3 indicates the wavelength of the Gaussian centroid, that is very close to the line centroid predicted by the collisional excitation model (Jordan 1975) indicated by the dashed line. We conclude that collisional excitation is the most likely mechanism for explaining the He II feature observed in the $\alpha$ Cen A spectrum.

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References

Pagano, I., Linsky, J.L., Robinson, R.D., Carkner, L., Woodgate, B., & Timothy G. 2000, this proceedings