

Variability of C III and Si III lines in the ultraviolet spectral region of the magnetic Bp star α Centauri

SOKOLOV N.A.

Central Astronomical Observatory at Pulkovo, St. Petersburg 196140, Russia

E-mail: n_sokolov58@mail.ru

Abstract

The variability of twice ionized lines of carbon and silicon in the ultraviolet spectral region of the magnetic Bp star α Centauri is investigated. This study is based on the archival *International Ultraviolet Explorer* data obtained through the large aperture and in the low-dispersion mode. A comparison of the average *IUE* high-dispersion spectrum of α Cen with full synthetic spectrum as well as those including only lines of one element showed that six C III and six Si III lines are responsible for the depressions of the flux at $\lambda\lambda$ 1175.5 and 1300 Å, respectively. Investigation of the variability of flux in the core of depression at λ 1775.5 Å indicate that the fluxes do not vary within errors of measurements. On the other hand, the fluxes in the core of depression at λ 1300 Å varies significantly with amplitude of ~ 0.2 mag. Moreover, the variability of this depression are in anti-phase with helium lines in the visual spectral region.

1 Introduction

α Centauri (HD 125823, HR 5378, V761 Cen) belongs to the Si-subclass. The star is a striking helium variable, ranging in helium spectral type from B2 to B8 with a period of 8.81 d (Jaschek et al., 1968). Norris (1968) found that the He I λ 4471 varies from 300 to 2200 mÅ and the changes are so conspicuous that α Cen can be considered a He-weak star at one extremum He-rich at the other one. In detailed study of this star Norris (1971) showed the equivalent widths of all neutral helium lines have similar extreme variations. On the other hand, the metallic lines show a very little or no changes of their intensity. In particular, the lines of Si II show no variation, while the lines of Si III show the variation in anti-phase with respect to the helium lines.

Our goal is to investigate the variability of C III and Si III lines in the ultraviolet spectral region using low-dispersion spectra which are presented in the *IUE* Newly Extracted Spectra (INES) database from the *IUE* satellite.

2 Observational data and analysis

The series of *IUE* spectra of α Cen obtained with Short Wavelength Prime (SWP) camera was received from the INES archive. In all cases, the spectra were obtained through the large aperture (9.5" x 22") and in the low-dispersion mode (~ 6 Å). All SWP spectra were obtained with exposure time 2.148 second. Finally, 13 SWP spectra were investigated and distributed quite smoothly over the period of rotation. Additionally, three spectra (SWP 14071, SWP 14080, SWP 14088) obtained in May 1981 were received from the INES archive. These spectra were obtained through the large aperture in the high-dispersion mode. In our study we used them only for identification of the observed depressions in the spectrum of α Cen.

To analyze the *IUE* spectra of α Cen the linearized least-squares method was used. An attempt was made to describe the light curves in a quantitative way by adjusting a Fourier series. Based on the fact that the light variations of α Cen are well approximate by single-wave (Catalano & Leone, 1996), we used for each light curve a least square fit with a function of the type:

$$F(\lambda, T') = A_0(\lambda) + A_1(\lambda) \cos(\omega T' + \phi_i(\lambda)), \quad (1)$$

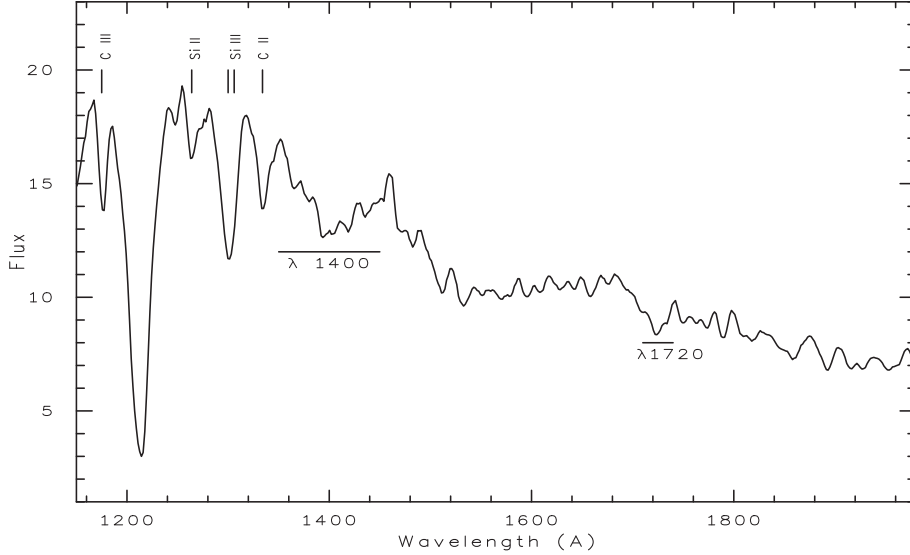


Figure 1: The average distribution of energy in $10^{-10}\text{erg s}^{-1}\text{cm}^{-2}\text{\AA}^{-1}$ for *a* Cen. The conspicuous depressions and features are shown by vertical and horizontal lines, respectively.

where $F(\lambda, T')$ is a flux for the given λ , $T' = T - T_0$ and $\omega = 2\pi/P$. The T_0 and P are zero epoch and rotational period of the ephemeris, respectively. The coefficients $A_0(\lambda)$ of the fitted curves define the average distribution of energy over the cycle of the variability while the coefficients $A_1(\lambda)$ define the semi-amplitude of the flux variations for the given λ .

In order to minimize the uncertainties in the coefficients of the fitted curves, the light curves were determined by averaging three nearest fluxes for a given λ :

$$F(\lambda) = \frac{F(\lambda - \lambda_{step}) + F(\lambda) + F(\lambda + \lambda_{step})}{3}, \quad (2)$$

where λ_{step} is equal 1.676 \AA for SWP camera. As far as the errors in $F(\lambda)$ are concerned, we computed them by taking into account the the errors in the fluxes as presented in *INES Catalog*, according to the standard propagation theory of errors.

3 Identification of of C III and Si III depressions in spectrum of *a* Cen

Figure 1 displays the average distribution of energy ($A_0(\lambda)$) of *a* Cen over the cycle of the variability in the spectral region from 1150 to 1950 \AA . One can see from Fig. 1 that the deepest depressions of the flux are in the far-UV spectral region at $\lambda\lambda$ 1175.5, 1265, 1300 and 1335 \AA . It is well known that Si II appears as the main absorber with the strong resonance lines at λ 1260–64 \AA (Artru & Lanz, 1987) On the other hand, the depression at λ 1335 \AA appear from C II resonance doublet at λ 1334.5–1335.7 \AA in the spectrum of *a* Cen.

In order to identify which elements are responsible for depressions at $\lambda\lambda$ 1175.5 and 1300 \AA the synthetic single-element spectra were calculated for C, Si and Fe with Piskunov (1992) program SYNTH. Mainly, the lines of these elements dominate in the far-UV spectral region of *a* Cen. Also, the synthetic spectra with all elements included were computed. The information about spectral lines were taken from the Vienna Atomic Line Database (VALD-2, Kupka et al., 1999). Note that VALD-2 allows to compute the synthetic spectrum for stars with abundances significantly different from the solar or scaled solar composition. The adopted atmospheric parameters of *a* Cen are

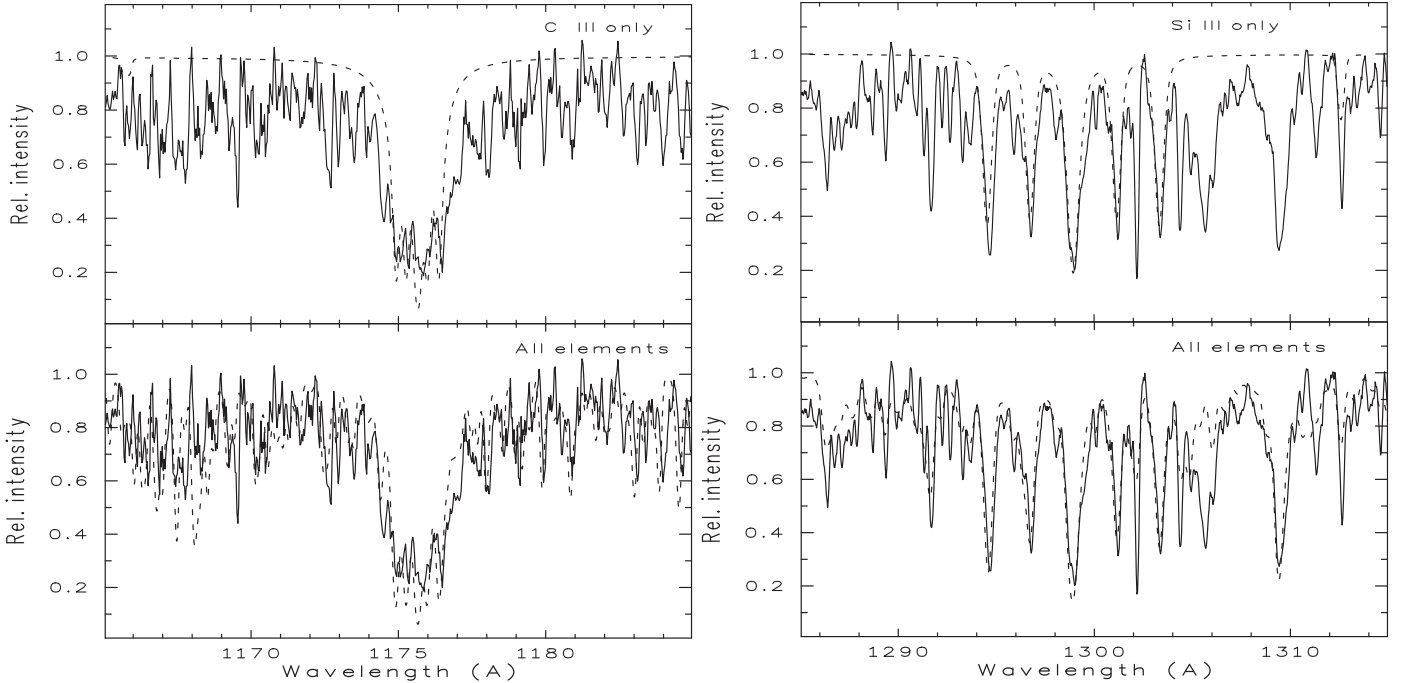


Figure 2: The average *IUE* high-dispersion spectrum of *a* Cen (solid line) compared to synthetic spectra (dashed line). The synthetic spectrum labeled 'All elements' was calculated with all elements. Left panel: The C III only is synthetic spectrum showing only C III lines at $\lambda 1175 \text{ \AA}$. Right panel: The Si III only is synthetic spectrum showing only Si III lines at $\lambda 1300 \text{ \AA}$.

the same as were used by Bohlender et al. (2010). The model computation was performed with $T_{\text{eff}} = 19000 \text{ K}$, $\log g = 4.0$ and $v_{\text{micro}} = 2 \text{ km s}^{-1}$. Experience showed that the spectral lines of twice ionized carbon and silicon mainly produce the deepest depressions at $\lambda\lambda 1175.5$ and 1300 \AA , respectively.

In order to confirm our hypothesis, the average high-dispersion spectrum was computed using *IUE* images SWP 14071, SWP 14080 and SWP 14088 which were obtained at phases 0.296, 0.393 and 0.509, respectively. For all depressions the best agreement between the average *IUE* high-dispersion spectrum of *a* Cen and the synthetic spectra with all elements is reached if the elements have solar scaled composition except for C and Si, their abundances were reduced to $\log(N/N_{\text{total}})$ of -4.0 and -5.0 , respectively. A comparison of the average *IUE* high-dispersion spectrum of *a* Cen with full synthetic spectrum as well as those including only lines of C III shows that this element is responsible for the depression of the flux at $\lambda 1175.5 \text{ \AA}$ (see Fig. 2). Practically, six C III lines are responsible for depression of the flux at $\lambda 1175.5 \text{ \AA}$. On the other hand, Si III appears as the main absorber by the six strong resonance lines near $\lambda 1300 \text{ \AA}$. Although, there is the some influence on this depression by Si II resonance doublet at $\lambda 1304\text{--}1309 \text{ \AA}$. The list of these spectral lines are given in Table 1.

3 Results

To measure the absorption in the cores of the depressions at $\lambda 1175.5$ and 1300 \AA we have formed the photometric indices a_{1175} and a_{1300} , expressed in magnitudes:

$$a_{1175} = \frac{1}{2}(m_{1165} + m_{1185}) - m_{1175}, \quad (3)$$

Table 1: List of the spectral lines which produce depressions in the spectrum of *a* Cen

Depression (Å)	Ion	Wavelength (Å)	E. P. (eV)	log <i>gf</i>
1175.5	C III	1174.930	6.496	-0.468
	C III	1175.260	6.493	-0.565
	C III	1175.590	6.496	-0.690
	C III	1175.710	6.503	0.009
	C III	1175.987	6.496	-0.565
	C III	1176.370	6.503	-0.468
1300.0	Si III	1294.545	6.553	-0.037
	Si III	1296.726	6.537	-0.127
	Si III	1298.892	6.553	-0.257
	Si III	1301.149	6.553	-0.127
	Si III	1303.323	6.585	-0.037
	Si II	1304.370	0.000	-0.423
	Si II	1309.276	0.036	-0.123
	Si III	1312.591	10.276	-0.840

$$a_{1300} = \frac{1}{2}(m_{1281} + m_{1318}) - m_{1300}, \quad (4)$$

where all filters are $\sim 5 \text{ \AA}$ wide for the a_{1175} and the a_{1300} indices. These indices are analogous to the a_{1400} index of Shore & Brown (1987). The choice of the filter wavelengths was dictated by the low-dispersion *IUE* spectra of *a* Cen, although the average high-dispersion spectrum indicate that some filters can be affected by small spectral lines, as is illustrated by Fig. 2.

Figure 3 exhibits the variations of the measured absorption in the depressions at $\lambda\lambda 1175$ and 1300 \AA versus the rotational phase. The solid lines represent least-squares fits by one-frequency cosine functions. It should be noted that the phases were computed according to the new determinations of the ephemeris obtained by Sokolov (2011). First of all, the least-square fit gives the

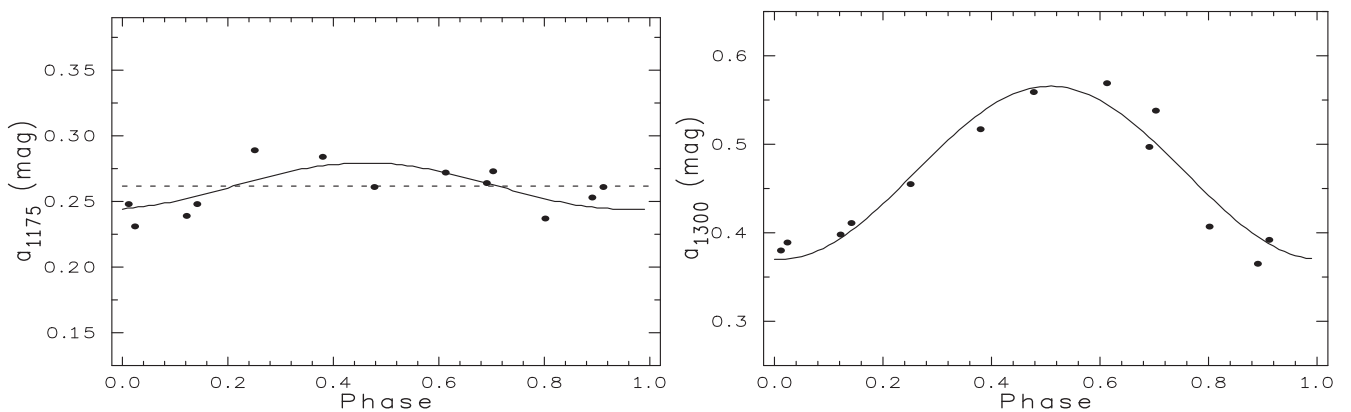


Figure 3: Left panel: Phase diagram of the a_{1175} index. Right panel: Phase diagram of the a_{1300} index. Solid lines are the least-squares fits. Dashed line indicate the average value of a_{1175} index.

semi-amplitude of the a_{1175} index which is equal to 0.018 mag. But, the standard deviation of the residual scatter around the fitted curve is equal to 0.014 mag. In other words, the photometric index a_{1175} does not vary within errors of measurements, as is illustrated by Fig. 3. On the other hand, the photometric index a_{1300} varies significantly. Thus, the least-square fit gives the semi-amplitude of the a_{1300} index which is equal to 0.098 mag. Although, the standard deviation of the residual scatter around the fitted curve is equal only 0.023 mag.

For the first time, Norris (1971) has noted that the lines of N II, Si III and Fe III vary at anti-phase with helium lines. Most significant is the fact that while Si III λ 4552 varies by 50 mÅ, the line Si II λ 4130 does not vary at all. Our result also indicates that Si III lines centered on λ 1300 Å in the ultraviolet spectral region vary at anti-phase with helium lines in the visual spectral region. It should be noted that Si III lines centered on λ 1300 Å varies much more than Si III line λ 4552 in the visual spectral region. In conclusion, an additional investigation is needed in order to do a final conclusion about the variability of a Cen in the ultraviolet spectral region.

References

- Artru M.-C., Lanz T., 1987, A&A, 182, 273
- Bohlender D.A., Rice J.B., Hechler P., 2010, A&A, 520, A44
- Catalano F.A., Leone F., 1996, A&A, 311, 230
- Jaschek M., Jaschek C., Kucwicz B., 1968, Nature, 219, 1137
- Kupka F., Piskunov N., Ryabchikova T.A., Stempels H.C., Weiss W.W., 1999, A&AS, 138, 119
- Norris J., 1968, Nature, 219, 1342
- Norris J., 1971, ApSJ, 23, 235
- Piskunov N.E., 1992, in Glagolevskij Yu.V., Romanyuk I.I., eds, Stellar Magnetism. Nauka, St. Petersburg, p.92
- Shore S.N., Brown D.N., 1987, A&A, 184, 219
- Sokolov N.A., 2011, MNRAS, in preparation