Identification of spectral lines of α Cen A star a possibly at spot maximum

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Abstract

In this paper, we present an analysis of the spectral lines in the region between 6790 Å to 6880 Å of an echelle spectrum from α Cen A (the brighter component of α Cen system). In these very high signal to noise ratio (S/N $\simeq$ 400) spectra, the precision of identified lines is good enough that these lines are comparable to the lines of three major catalogs. 51 lines from 10 chemical elements are identified. The two of the 10 are ScII and CrII with the lines at 6860.935 Å and 6882.520 Å respectively. The identified neutral elements are FeI, SiI, CaI, NiI, CoI, CrI, ViI and TiI. Our analysis indicates that we have probably observed α Cen A at spot activity maximum.

keywords stars : α Cen A.

1 Introduction

The nearest neighbors to the solar system are the stars belonging to the multiple system α Centauri. Currently, few astronomers are interested in stars in the solar neighborhood. However the α Cen stars are an exception to this rule. For the years 1960-1991, at least 229 bibliographic references are given for α Cen A in the SIMBAD catalog, Chmielewski et al. (1992).

α Cen A has been subject of several spectral studies. Most studies have found α Cen A is similar to the Sun, (Demarque et al. 1987, Allen 1983, Hardorp 1980, and Flannery and Ayres 1978), but the star appears to be over-abundant in metal relative to the sun, Furenlid and MeYlan (1990). The comprehensive studies by French and Powell (1971) and England (1980) indicate a metal overabundance relative to the sun by approximately a factor of 2(0.2-0.3 dex). England (1980) adopted an effective temperature for α Cen A which is 50 K cooler than the Sun, while Soderblom (1986) concluded from a study of H_α profiles that the effective temperature of α Cen A is almost within narrow margins of the Sun's effective temperature. Smith et al. (1986) derived the effective temperature of α Cen A as 50 K hotter than the Sun and found

over-abundances of analyzed elements such as Ca and Fe are nearly 0.2 dex. Edvardsson (1988), using England's effective temperature, found similar over-abundance; and Soderblom and Dravins (1984) found Li over-abundance of a factor 2 in α Cen A. A comprehensive analysis of the evolutionary studies of the α Cen A by Flanney and Ayres (1978) assigned an effective temperature which is slightly higher than the Sun's effective temperature and also a higher metal abundance. Furenlid and MeYlan (1990) measured over 500 lines of 26 elements in very high signal to noise ratio spectra of α Cen A and carried out analysis of differential abundance between the sun and α Cen A star. They found that the metal overabundance in α Cen A is nearly 0.12 dex.

The primary purpose of this study is to identify the spectral lines in the spectrum of α Cen A in the region between 6790 $\mathring{A}$ to 6884 $\mathring{A}$ and compare them with the other findings and the solar spectrum.

This paper is organized as follows, in Section 2 : observations, data and reductions. Section 3 : line identification. The discussion is given in Section 4. Finally the conclusions are given in Section 5.

2- Observations, Data and Reductions

High dispersion echelle spectra for α Cen A was observed during two night observing run,by Kordi, in April of 1996 at the Mount Stromlo observatory , Canberra, Australia. Eight Echelle full (2kx2k pixl size) spectral frames with resolution of 100,000 were obtained, covering wavelength range from 6260 t0 6900 $\mathring{A}$, with a few gaps corresponding to the telluric lines between 6870 and 6884 $\mathring{A}$. This spectral region was chosen because it contains sufficient number of lines of different chemical species and telluric lines which can be used for testing instrumental effects. The telluric absorption lines are mainly H_2O and O_2 lines (Griffin 1973).

The echelle was centered at wavelength of 7700 $\mathring{A}$ with a dispersion of 0.05 $\mathring{A}$ per pixel. Each night a 9 bias, 6 dark, and 6 flat frames were taken. Each stellar frame was given an integration time calculated, with exposure times of 100 s, to get a S/N $\simeq$ 400 and flat field frame were integrated to same S/N, bias and dark frames were also obtained. The photon counts on the continuum per pixel reach 60,000 photon per pixel

An observed spectrum might have two kinds of defects. The first one is due to the media between the stars and the detector (mainly the Earth's atmosphere), while the second is due to the characteristics of the CCD detector and the echelle spectrograph. To make the spectrum ready for analysis, one should take out all these defects. FIGARO, a general spectral data reduction package, KAPPA (Kernel Application Package) and SPECDRE (Spectra Data Reduction) package provided by the STARLINK group were used to take out both mansioned effects.

3- Spectral lines identification

We divided the spectra by the mean value to normalize the continuum. The mean was 49242.6 counts equal to 49242x2 photons per pixel. Then we multiply the spectra by 10,000 to let the continuum be in the same level as that of solar spectrum. At the edge where the flatness has some error , the continuum is a little more than 10,000 counts.

By comparing the extracted spectrum of α Cen A with the solar spectrum (Delbouillie et al 1972, 1981), we identified the stellar lines and as well as their wavelengths in the solar spectrum. Later we have refined the identified lines using the Solar table by Moore et al (1965) and Atomic Spectral Line Database from CD-ROM 23 of R. L. Kurucz (http://cfa-www.harvard.edu/amdata/ampdata/kurucz23/sekur.html), which is a collection of atomic line parameters of astronomical interest and provides tools for selecting subsets of lines for typical astrophysical application such as line identification, chemical composition, and model atmosphere calculations. The comparison between our atlas of α Cen A and solar atlas is given in Figures (1-6).

4- Discussion

We used the well identified stellar lines in tables (1)and (2) from Delbouille et al. (1972, 1981) to calibrate the spectra of α Cen A and to circumvent the difficulties arising from using arc emission lines as a reference. These stellar lines are automatically put on throughout the duration of the exposure, and do not require being provided, maintained or operated, which reduces the likelihood of errors. We first generated a 3^{rd} polynomial fit through the position of these lines (results of the fit in the column four in tables (1) and (3)), and then we used it to fit all spectra.

Tables (1) and (2) show the identified lines; column one gives the bin number where the lines are located in the spectra, column two shows the identified wavelength of the lines, column three lists the actual wavelength of lines after calibration of the spectra and column four displays the discrepancy between the stellar lines and the lines on the atlas. We note that the discrepancy is less than $\pm$ 0.01 Å in most of the lines.

Its is interesting to compare in tables (3) and (4) our counts of lines in the present work with similar counts from Moore et al (1965), Furenlid and Meylan (1990) and from Atomic spectral line database from CD-ROM 23 of R. L. Kurucz (http://cfa-www.harvard.edu/amdata/ampdata/kurucz23/sekur.html); and from Vienna Atomic Line Database (VALD). Our counts have been made in the region near the telluric lines from 6790 $\AA$ to 6783 $\AA$.

In tables (3) and (4), the column one shows the lines of α Cen A after comparing with the solar atlas by Delbouilie et al (1972, 1981), column two shows the comparison wavelengths of Atomic spectral line database from CD-ROM 23 of R. L. Kurucz, column three shows the comparison wavelengths of Moore et al (1965), column four shows the comparison spectra from Furenlid and Meylan (1990), column five shows the chemical species taken from the previous references and column six shows the character of the magnetic field in the lines, Moore et al (1965).

Table 1: calibrating lines

Channel	λ from Delbouile et al.	Calculated λ	Discrepancy	Line
34.9726	6786.8359	6786.8569	0.0210	1
145.0186	6793.2588	6793.2559	-0.0029	2
151.2081	6793.6211	6793.6147	-0.0063	3
182.2374	6795.4170	6795.4116	-0.0054	4
189.1634	6795.7983	6795.8125	0.0142	5
194.3484	6796.1221	6796.1123	-0.0098	6
235.0582	6798.4780	6798.4644	-0.0137	7
242.3026	6798.8999	6798.8823	-0.0176	8
272.1392	6800.5991	6800.6025	0.0034	9
331.2389	6804.0039	6804.0020	-0.0020	10
335.9478	6804.2739	6804.2725	-0.0015	11
381.0238	6806.8501	6806.8574	0.0073	12
440.7581	6810.2681	6810.2739	0.0059	13
499.0668	6813.6099	6813.5986	-0.0112	14
522.9283	6814.9521	6814.9565	0.0044	15
618.6025	6820.3730	6820.3838	0.0107	16
764.4445	6828.5991	6828.6060	0.0068	17
847.0219	6833.2358	6833.2344	-0.0015	18
914.7678	6837.0098	6837.0171	0.0073	19
946.9009	6838.8301	6838.8066	-0.0234	20

Table 2: calibrating lines

Channel	λ from Delbouile et al.	Calculated λ	Discrepancy	Line
965.5410	6839.8340	6839.8438	0.0098	21
992.5859	6841.3452	6841.3462	0.0010	22
1005.2039	6842.0420	6842.0464	0.0044	23
1016.8585	6842.6899	6842.6929	0.0029	24
1025.7701	6843.1699	6843.1870	0.0171	25
1034.3347	6843.6621	6843.6616	-0.0005	26
1105.5160	6847.5952	6847.5981	0.0029	27
1123.1133	6848.5669	6848.5688	0.0020	28
1135.0858	6849.2300	6849.2290	-0.0010	29
1156.9004	6850.4409	6850.4307	-0.0103	30
1243.0618	6855.1680	6855.1641	-0.0039	31
1253.1991	6855.7202	6855.7197	-0.0005	32
1281.1237	6857.2520	6857.2485	-0.0034	33
1297.5972	6858.1558	6858.1499	-0.0059	34
1366.9688	6861.9458	6861.9355	-0.0103	35
1377.1962	6862.4888	6862.4922	0.0034	36
1733.5111	6881.7148	6881.7202	0.0054	37
1748.5739	6882.5200	6882.5254	0.0054	38
1758.6715	6883.0698	6883.0649	-0.0049	39

Table 3: Measured lines and Comparison with others

lines of α Cen A	Kurucz	Moore	FM 1990	element	char.
6786.863	6786.856	6786.86	6786.856	FeI	w
6793.259	6793.252	?	?	FeI	
6793.621	?	6793.628	?	FeI-YI	w
6795.798	6795.788	6795.798	6795.788	SiI	
6796.122	6796.122	6796.128	?	FeI	s
6798.478	6798.479	?	?	CaI	
6800.599	6800.596	?	6800.596	SiI	
6804.004	6804.001	?	?	FeI	
6804.276	6804.272	?	?	FeI	
6806.850	?	6806.856	6806.846	FeI	s
6810.268	6810.257	6810.267	6810.256	FeI	s
6813.610	6813.605	6813.616	?	NiI	
6813.923	6813.916	?	?	ViI	
6814.952	6814.942	6814.961	?	CoI	s
6819.590	6819.586	6819.595	?	FeI	s
6820.373	6820.369	6820.374	6820.369	FeI	s
6824.845	6824.825	6824.857		FeI	
6827.945	?	?	?	TiII*	
6828.599	6828.590	6828.596	6828.590	FeI	u
6833.236	6833.224	6833.248	?	FeI	o
6836.619	?	?	?	CrII*	
6837.010	6837.016	6837.013	6837.016	FeI	o
6838.839	?	?	?	FeII*	
6839.834	?	6839.835	6839.831	FeI	s
6841.345	6841.335	6841.341	?	FeI	s
6842.042	?	6842.043	6842.035	NiI	w
6842.690	?	6842.689	?	FeI	u

s : indicates that the line is strong in spot spectrum of the sun (Moore et al.) w : indicates that the line is weak in the spot spectrum. u : indicates that the line is unchanged in the spot spectrum. o : indicates that the line is obliterated in the spot spectrum. $*$: indicates that the line is taken from Vienna Atomic Line Database (VALD).

Table 4: Measured lines and Comparison with others

lines of α Cen A	Kurucz	Moore	FM 1990	element	char.
6843.170	?	?	?	SiI*	
6843.662	?	6843.655	?	FeI	w
6847.595	?	?	?	FeI*	
6848.567	6848.580	6848.566	6848.580	SiI	
6848.860	6848.860	6848.860	?	FeI	
6850.441	?	6850.439	?	NiI	
6851.642	6851.649	?	?	SiI	
6852.721	?	6852.722	?	CrII*	
6854.826	6854.838	?	?	FeI	
6855.168	?	6855.166	?	FeI	s
6855.720	?	6855.723	?	FeI	u
6857.252	?	6857.251	?	FeI	w
6858.156	?	6858.155	?	FeI	u
6860.100	6860.136	6860.099	?	FeI	
6860.290	6860.266	?	?	TiI	
6860.760	6860.760	?	?	SiI	
6860.935	6860.936	?	?	CrII	
6861.946	?	6861.945	?	FeI	s
6881.715	6881.712	6881.716	?	CrI	s
6881.453	?	6881.463	?	FeI+atm	
6862.498	6862.492	6862.496	6862.491	FeI	u
6882.520	6882.520	?	?	ScII	
6883.070	?	6883.070	?	CrI	s
6864.313	6864.313	?	?	FeI	

s : indicates that the line is strong in spot spectrum of the sun (Moore et al.) w : indicates that the line is weaken in the spot spectrum. u : indicates that the line is unchanged in the spot spectrum. o : indicates that the line is obliterated in the spot spectrum. ?: indicates that the line is taken from Vienna Atomic Line Database (VALD).

We find 51 spectral lines in the region of consideration, in which 30 spectral lines belong to FeI, 6 lines to SiI, one line to each CaI, ViI, FeII, CoI, TiII, ScII and TiI, and three lines to NiI and CrII, two line to CrI .

We used more than one atlas for comparing our results, since all lines do not appear in one atlas only, see tables (3) and (4). From tables (3) and (4) we notice that, 21 lines of FeI, 2 lines of SiI and 2 lines of NiI are observed, more than that found by Furenlid and Meylan (1990) in our region of consideration. We identified species (CaI, ViI, CoI, TiI, CrI, CrII, SCII) at new wavelengths which are not listed by Furenlid and Meylan. This means that the physical parameters of the surface of α Cen A, such as effective temperature, may have changed from 1983, date of observations of Furenlid and Meylan, to 1996, date of our observations. When we compare our observations with Moore et al (1965) we found some of these lines, which are not listed in Furenlid and Meylan (1990), are stronger in the sunspot. By comparing the 43 lines, which we carefully identified, with the identifications of an earlier high-resolution spectrum taken by Furenlid and Meylan in 1983, we find that many lines present in 1996 in the spectral region 6790-6880A were not present in 1983. This may suggest that the spectrum of the star changed between1983 and 1996 and this might be due to the presence of spots in 1996. However, it is very unlikely Furenlid and Meylanlisted in their 1990 paper choosed faint lines and left the stronger lines, unless and until they have some unspecified criterion. They chose to measure only a few of the lines is not a satisfactory reason. They have listed FeI 6939.834 (Table 2 in their paper) and NiI 6842.042; and left the stronger lines FeI 6841.345 (Kurucz 6841.335, More 6841.341), FeI 6842.690 and FeI 6843.662 (More 6842.689, More 6843.655) which are found in juxta position to the listed once.

Moreover they have listed lines of small equivalent width and left the stronger and wider lines. From the above discussion, so this may indicate that we observed α Cen A during a cycle of spot activity maximum, and a possible evidence of magnetic field through those lines. In our study, five spectral lines out of a total of 43 spectral lines are not identified.

By comparing our spectrum with the atlases of Jenniskens and Desert (1994); and Tuairisg et al. (2000) for diffuse interstellar bands, we found all spectra are stellar origen.

The measurements of equivalent widths (EW) resulted from the Sun and from our spectrum for alpha Cen A are shown in tables (5 and 6). In this measurements we use SPLAT (spectra line analysis) software provided by STARLINK package.

5- Conclusions

α Cen A holds a special significance in stellar astrophysics. It offers us a chance to study the chemical composition and to understand its surface structure. Accurate line identification together with a comparison with earlier studies may revel the physical changes in α Cen A star during period such as those of spot activity.

In this paper, we made identified the spectral lines of α Cen A star in the region between 6790 $\AA$ to 6884 $\AA$, using Echelle spectroscopic data of very high signal to

Table 5: Measured lines and their equivalent widths in m$\AA$

lines	Our EW.	EW(FM90)	EW (sun)
6786.863	25	35	27^a
6793.259	10	?	26^b
6793.621	16	?	12^a
6795.798	8	15	9^a
6796.122	14	?	26^b
6798.478	4	?	20^b
6800.599	12	23	15^a
6804.004	36	?	26^b
6804.276	23	?	26^b
6806.850	45	46	35^a
6810.268	59	64	51^a
6813.610	14	?	28^b
6813.923	4	?	23^b
6814.952	26	?	27^b
6819.590	19	?	26^b
6820.373	42	53	42^a
6824.845	weak	?	26^b
6827.945	weak	?	
6828.599	57	70	58^a
6833.236	28	?	26^b
6836.619	weak	?	
6837.010	15	26	20^a
6838.839	50	?	
6839.834	29	46	33^a
6841.345	74	?	26^b
6842.042	27	44	29^a
6842.690	40	?	41^a

EW : indicates that the equivalent widths.
a : indicates that the equivalent widths from Moore et al.
b: indicates that the equivalent widths from Kurucz.

Table 6: Measured lines and their equivalent widths in m$\mathring{A}$

lines	Our EW.	EW(FM90)	EW (sun)
6843.170	weak	?	
6843.662	60	?	59^{a}
6847.595		?	
6848.567	16	29	18^{a}
6848.860	weak	?	26^{b}
6850.441	5	?	10^{a}
6851.642	weak	?	14^{b}
6852.721	weak	?	4^{a}
6854.826	weak	?	26^{b}
6855.168	77	?	85^{a}
6855.720	21	?	23^{a}
6857.252	32	?	27^{a}
6858.156	65	?	57^{a}
6860.100	weak	?	26^{b}
6860.290	20	?	22^{b}
6860.760	19	?	14^{b}
6860.935	weak	?	24^{b}
6861.946	32	?	22^{a}
6881.715	15	?	26^{b}
6881.453	5	?	11^{a}
6862.498	43	41	31^{a}
6882.520	23	?	21^{b}
6883.070	24	?	31^{a}
6864.313	11	?	26^{b}

EW : indicates that the equivalent widths.

a : indicates that the equivalent widths from Moore et al.

b: indicates that the equivalent widths from Kurucz.

weak :indicates that the line is weak to get the information for EW.

noise ratio. The precision in the identification of the lines is sufficiently high that we can compare the lines with three major catalog. We identified 51 lines of 10 elements. Two of that belong to elements as ion (ScII and CrII) having spectral lines at the wavelengths 6860.935 $\AA$ and 6882.520 $\AA$, and the remaining FeI, SiI, CaI, NiI, CoI, CrI, ViI and TiI, are neutral elements . In our spectra we did not found diffuse interstellar bands.

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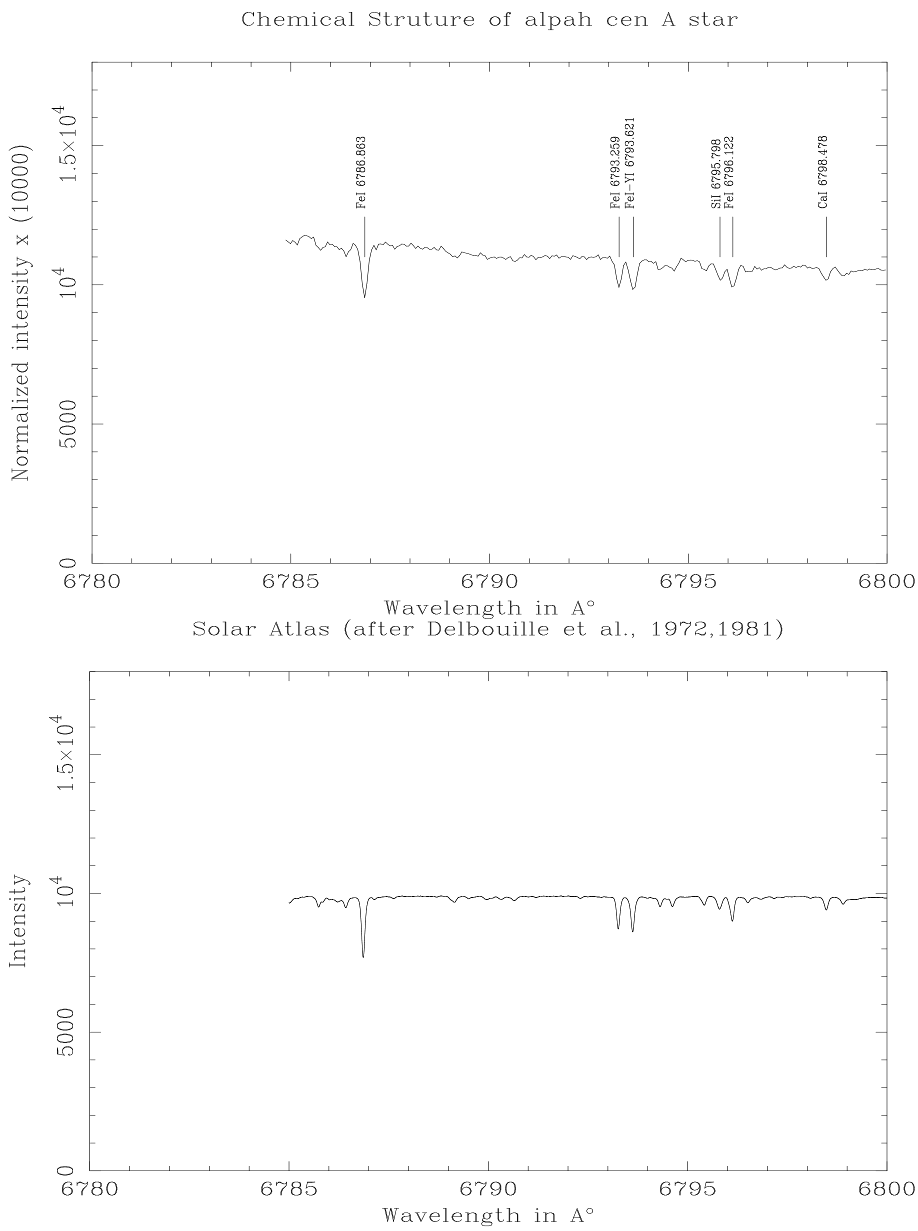

Figure 1: The spectra of α Cen A and the sun in the range of 6780 $\AA$ to 6800 $\AA$

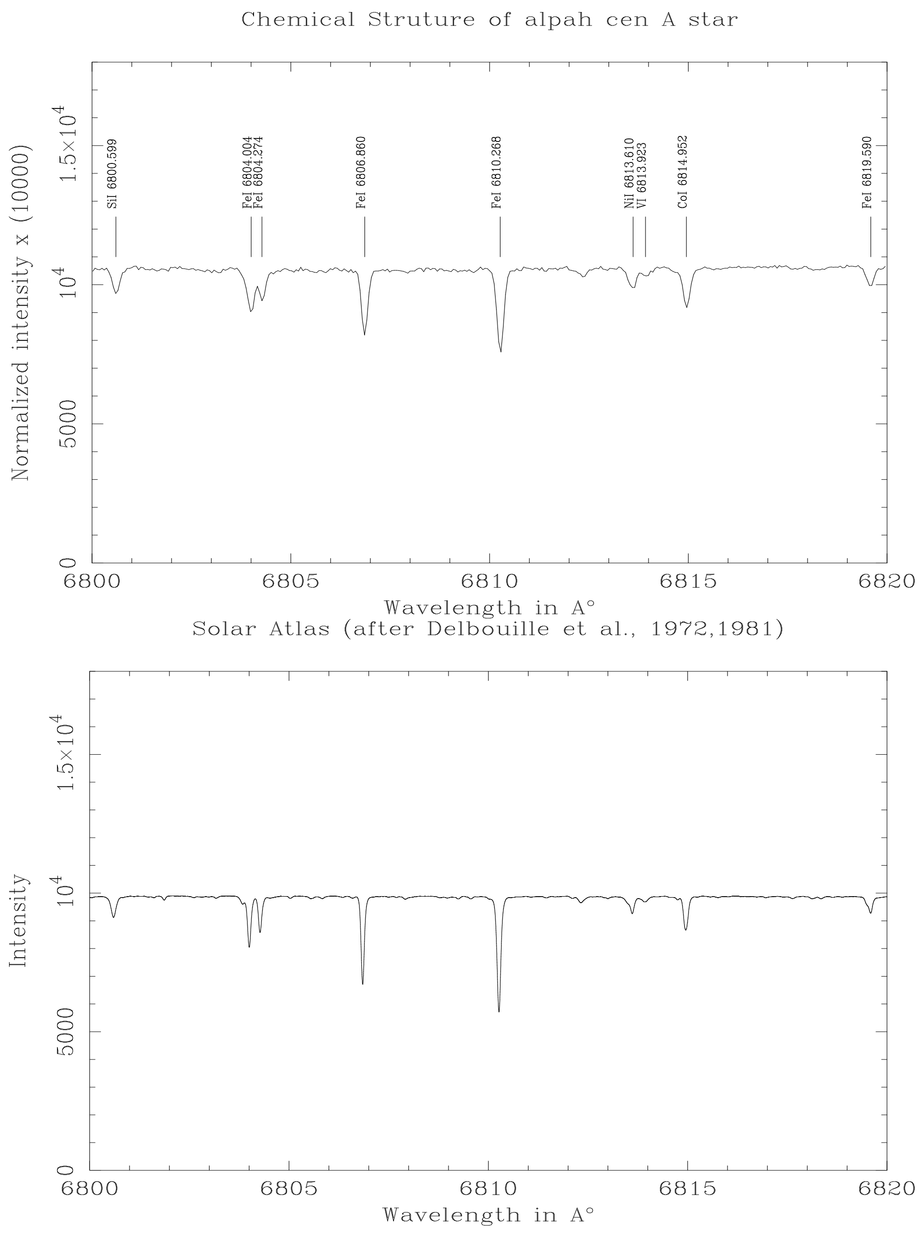

Figure 2: The spectra of α Cen A and the sun in the range of 6800 $\AA$ to 6820 $\AA$