The A-Star Puzzle
Proceedings IAU Symposium No. 224, 2004
J. Zverko, J. Žižňovský, S.J. Adelman, & W.W. Weiss, eds.

DOI: 10.1017/S1743921305009312

A preliminary analysis of the sharp-lined A3V star 95 Leo

Aysegul Teker[1], Dursun Kocer[1] and Saul J. Adelman[2]†

[1]Istanbul Kultur University, Department of Mathematics and Computer Scienes, E5 Karayolu, Sirinevler, 34191, Istanbul, Turkey
email: a.teker@iku.edu.tr, d.kocer@iku.edu.tr

[2]Department of Physics, The Citadel, 171 Moultrie Street, Charleston, SC 29409, USA
email: adelmans@citadel.edu

Abstract. We have started an analysis of the sharp-lined superficially normal A3IVp star 95 Leo. We are using 2.4 Å mm^{-1} spectrograms covering $\lambda\lambda 3830-4934$ obtained with the 1.22-m telescope of the Dominion Astrophysical Observatory using CCD detectors. Their mean signal-to-noise ratios are $\geqslant$ 200. The spectrograms are rectified and measured with the interactive computer graphics program REDUCE of Graham Hill and his associates. In measuring the spectrum with the VLINE routine, we use the fixed parameter feature to deconvolute metallic line blends and to measure weak lines. Effective temperature and surface gravity estimates based on spectrophotometry and Hγ profile fitting were given in the literature as 8300 K and 3.65, respectively.

Keywords. Line: identification, techniques: spectroscopic, stars: fundamental parameters, stars: individual: (95 Leo)

1. Introduction

95 Leo (HD 103578, BD+16^{o}2319, GC 16311, HR 4564, HIP 58159) is a relatively sharp-lined A-type spectroscopic binary star. Its spectral type is given as A3 IVp by Abt & Morell (1995). Royer *et al.* (2002) note it is a SB2 binary. Adelman *et al.* (1980) investigated 95 Leo using UBV and *ubvy* photometry to obtain effective temperatures of 8650 and 8350 K, respectively. Adelman *et al.* (2002) obtained $T_{\rm eff}$ = 8331 K, $\log g$ = 4.14 using $ubvy\beta$ photometry and $T_{\rm eff}$ = 8300 K, $\log g$ = 3.65 using spectrophotometry and Hγ profile fitting.

2. Observations and reductions

For 95 Leo we obtained Dominion Astrophysical Observatory (DAO) 2.4 Å mm^{-1} SITe-2 or SITe-4 CCD spectrograms with a typical signal-to-noise ratio of 200 and a wavelength coverage of 63 or 144 Å, respectively. The two pixel resolution is 0.072 Å which corresponds to a resolving power of 62500. Nineteen spectrograms were obtained in the spectral range $\lambda\lambda 3830-4934$ including sections containing the Hβ and the Hγ regions. A central stop removed light from the beam in the same manner as the secondary mirror of the telescope. We rectified the exposures with the interactive computer graphics program REDUCE (Hill & Fisher 1986) and applied a 3.5% correction for scattered light in the dispersion direction (Gulliver, Hill & Adelman 1996) for many of SITe-2 spectrograms. To illustrate the program REDUCE, Figure 1 shows the normalization of the spectrogram

† Visiting Observer, Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics, 5071 West Saanich Road, Victoria, BC, V9E 2E7, Canada

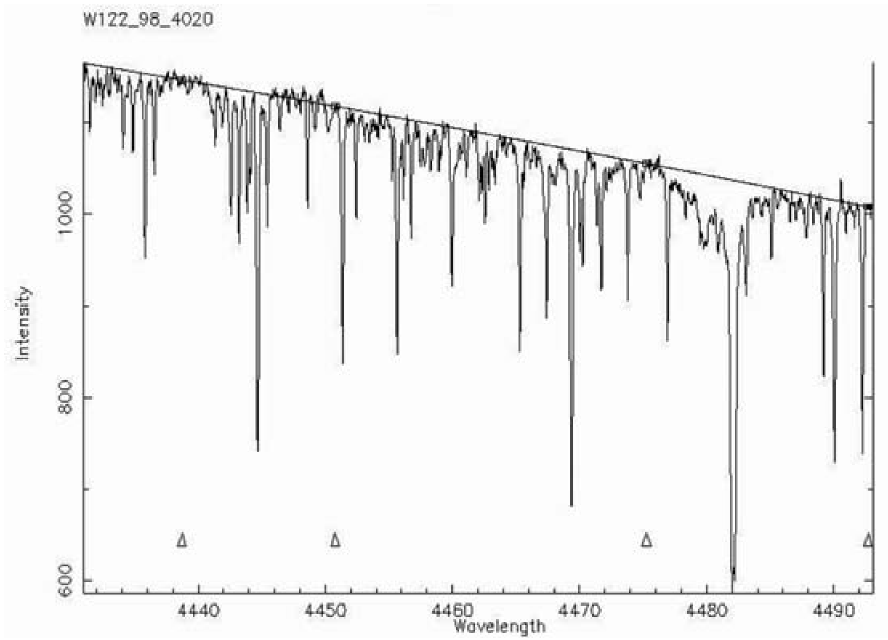

Figure 1. Normalization of the $\lambda\lambda\,4430 - 4493$ section of the 95 Leo spectrum

covering $\lambda\lambda$4430-4493. The radial velocities were found from the comparisons of the stellar and laboratory wavelengths after corrections were applied for the Earth's orbital velocity. The radial velocity of one spectrum was measured and we obtained a value of -65.88 $\pm$ 0.2 km s^{-1}. The radial velocity of the star is given as -21.4 $\pm$ 0.9 km s^{-1} by Evans (1979).

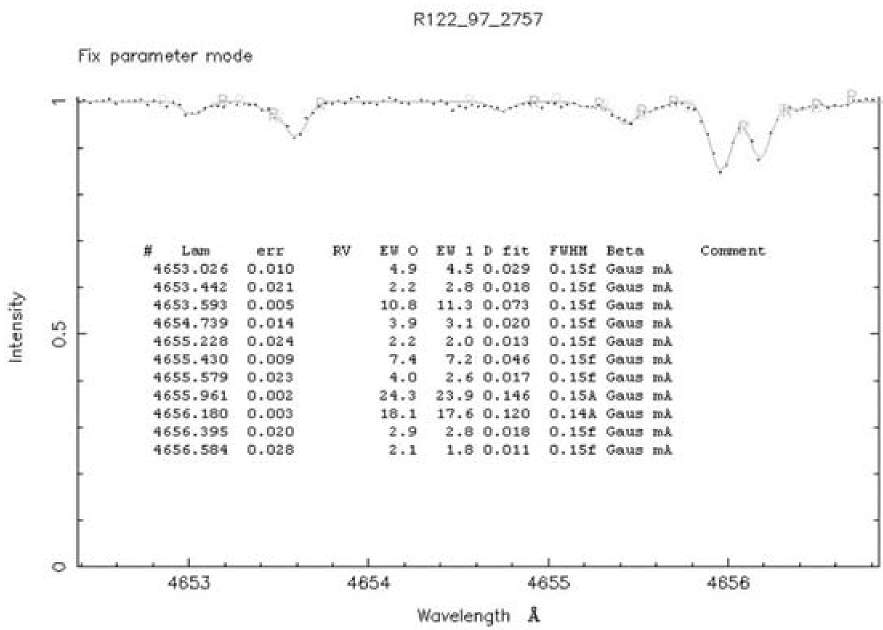

Figure 2. Measuring the spectrum of 95 Leo with VLINE

https://doi.org/10.1017/S1743921305009312 Published online by Cambridge University Press

Table 1. Line measurements of 95 Leo ($\lambda\lambda$ 4650 − 4713 region)

Observed λ(Å)	W_λ (mÅ)	Depth	Width (FWHM)(Å)	Laboratory λ(Å)	Identification(s)
4653.026	4.5	0.029	0.146	4654.048	–
4653.442	2.8	0.018	0.146	4654.464	Fe I(39)4654.501(5)
4653.593	11.3	0.073	0.146	4654.615	Fe I(554,821)4654.6050,.6286(3)
4654.739	3.1	0.020	0.146	4655.761	Ti II(38)4655.7771(5)
4655.228	2.0	0.013	0.146	4656.250	–
4655.430	7.2	0.046	0.146	4656.452	Ti I(6)4656.468(25)
4655.579	2.6	0.017	0.146	4656.601	–
4655.961	23.9	0.146	0.154	4656.983	Fe II(43)4656.974(1)
4656.180	17.6	0.120	0.138	4657.203	Ti II(59)4657.2005(33)
4656.395	2.8	0.018	0.146	4657.418	Co I(156)4657.390((1))
4656.584	1.8	0.011	0.146	4657.607	(Fe I(346)4657.598((1)))
4657.828	5.0	0.032	0.146	4658.851	–
4658.020	3.0	0.020	0.146	4659.043	–
4660.752	2.6	0.016	0.146	4661.776	Zr II(129)4661.78(5)
4662.030	8.0	0.052	0.146	4663.054	Al II(2)4663.054(0)
4662.372	3.0	0.019	0.146	4663.396	Cr I(186)4663.328(40); Co I(156)4663.403(12)
4662.681	14.8	0.095	0.146	4663.705	Fe II(44)4663.700(0)
4662.825	2.7	0.017	0.146	4663.849	Cr I(186)4663.832(55)
4663.319	1.8	0.011	0.146	4664.343	(Ni I(147)4664.32( ))
4663.770	3.1	0.020	0.146	4664.794	Cr I(186)4664.80(60)
4664.275	2.7	0.017	0.146	4665.299	(Fe I(1115)4665.24())
4664.556	7.8	0.050	0.146	4665.580	Ni II(KX)4665.548(p)
4664.781	4.2	0.027	0.146	4665.805	Fe II(26)4665.80(p)
4664.980	2.3	0.015	0.146	4666.004	–
4665.234	2.1	0.013	0.146	4666.259	Cr I(99)4666.215(25)
4665.545	6.6	0.043	0.146	4666.570	Cr I(186)4666.512(55)
4665.726	37.6	0.236	0.150	4666.751	Fe II(38)4666.750(2)
4665.971	4.4	0.029	0.146	4666.996	Ni I(146)4666.994(2)
4666.205	4.5	0.029	0.146	4667.230	(Cr I(99)4667.181(30))
4666.423	15.7	0.101	0.146	4667.448	Fe I(822)4667.4531(6)
4666.653	4.6	0.030	0.146	4667.678	(Ti I(6)4667.585(25))
4666.797	4.5	0.029	0.146	4667.822	Ni I(163)4667.766(3)
4667.105	12.7	0.082	0.146	4668.130	Fe I(554)4668.1344(6)
4667.423	4.0	0.025	0.146	4668.448	Ti I(77)4668.357(2)
4667.619	9.1	0.058	0.146	4668.644	–
4667.890	4.5	0.029	0.146	4668.915	(La II(76)4668.91(250))
4668.147	8.9	0.057	0.146	4669.172	Fe I(821)4669.1711((4))
4668.334	7.9	0.051	0.146	4669.359	(Sm II(7)4669.396(500)); Cr I(186)4669.336(50)

3. Line identifications

For each line we used the program VLINE (Hill & Fisher 1986) to measure the equivalent width, the central wavelength, the line depth and the FWHM (full width at half maximum) of the fitted profile. The lines with equivalent widths ⩾ 20 mÅ usually showed Gaussian profiles and were so fit. In measuring the spectrum with VLINE, the fixed parameter feature was applied, particulary to the line widths, as needed to better fit close blends. To illustrate the process Figure 2 shows the measurements of a spectrum section.

Our initial rotational velocity estimate based on non-blended, clearly single, medium-strength lines with rotational profiles near λ4481 is 4.7 km s^{-1}. Lines with equivalent

https://doi.org/10.1017/S1743921305009312 Published online by Cambridge University Press

widths near 12 mÅ are sufficiantly weak to be unaffected by atomic line broadening, macroturbulance and microturbulance and are clearly on the linear part of the curve-of-growth. In comparison Abt & Morrell (1995) find $v \sin i = 10\,km\,s^{-1}$ for 95 Leo using lower resolution spectra than us.

The stellar lines were identified with the general references A Multiplet Table for Astrophysical Interest (Moore 1945), and Wavelengths and Transition Probabilities for Atoms and Atomic Ions, Part I (Reader & Corliss 1980) as well as Huldt *et al.* (1982) for Ti II, Iglesias & Valesco (1964) for Mn II, Nave *et al.* (1994) for Fe I, and Johansson (1978) for Fe II. A sample of the line identifications is presented in Table 1 for the region centered at 4685 Å. Lines of Mg I, Al II, Ca I, Sc II, Ti I, Ti II, VI, Cr I, Cr II, Mn I, Mn II, Fe I, Fe II, Co I, Ni I, Ni II, Zn I, Sr II, Zr II, La II, Pr II, Nd II and Sm II were found in the one region measured so far. We anticipate being able to obtain elemental abundances for most of these species after we have found additional lines in other spectral regions.

Acknowledgements

SJA's participation was partially supported by grants from The Citadel Foundation. He thanks Dr. James E. Hesser, Director of the Dominion Astrophysical Observatory for the observing time.

References

Adelman, S. J., Pyper, D.M., & White, R. 1980, *ApJS* 43, 491.

Adelman, S.J., Pintado, O.I., Nieva, F., Rayle, K.E., & Sanders, Jr., S.E. 2002, *A&A* 392, 1031.

Abt, H.A., & Morrell, N. I. 1995, *ApJS* 99, 135.

Evans, D.S. 1979, The Revision of The General Catalogue of Radial Velocities, IAU Symp. 30, 57.

Gulliver, A. F., Hill, G., & Adelman, S. J. 1996, in Model Atmospheres and Spectrum Synthesis, eds. S. J. Adelman, F. Kupka, & W. W. Weiss, ASP Conf. Ser., 108, p. 232.

Hill, G., & Fisher, W. A. 1986, *Publ. Dom. Astrophys. Obs. Victoria* 16, No. 13.

Hoffleit, D. 1982, The Bright Star Catalogue, 4th revised edition, Yale University Observatory, New Haven, CT.

Huldt, S., Johansson, S., Litzen, U., & Wyart J.-F. 1982, *Phys. Scripta* 25, 401.

Iglesias, L., & Valesco, R. 1964, Publ. Inst. Opt. Madrid, No. 23.

Johansson, S. 1978, *Phys. Scripta* 18, 217.

Moore, C. E. 1945, A Multiplet Table of Astrophysical Interest, Princeton University Observatory.

Nave, G., Johansson, S., Learner, R.C.M., Thorne, A.P., & Brault, J.W. 1994, *ApJS* 94, 221.

Reader, J., & Corliss C. H. 1980, NSRDS-NBS 68, Part 1, US Government Printing Office, Washington, DC.

Royer, F., Grenier, S., Baylac, M.-O., Gomez, A.E., & Zorec, J. 2002, *A&A* 393, 897.