A STUDY OF THE ECLIPSING BINARY BETA AURIGAE

Larry G. S. Toy

December 1968

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

809-201

A STUDY OF THE ECLIPSING BINARY BETA AURIGAE

Larry G. S. Toy

Smithsonian Astrophysical Observatory and Harvard College Observatory
Cambridge, Massachusetts

Berkeley Astronomy Department, University of California

Received ____________________

ABSTRACT

The present study has led to the determination of the average effective temperature and surface gravity of the two components of the eclipsing binary system β Aur. By use of photoelectric spectrum scans fitted to Mihalas's (1966) line-blanketed model atmospheres in conjunction with detailed abundance analyses, an effective temperature, $T_{eff} = 8750°K$, and surface gravity, log g = 3.7, were derived. The abundance analyses indicate similar chemical compositions for both components. Both members of this system appear to show abundance anomalies reminiscent of mild Am stars.

I. INTRODUCTION

The eclipsing binary system β Aur provides the opportunity to derive the physical parameters, effective temperature, and surface gravity of a star by two independent methods. The system, a pair of A2 IV (V = 1.90, B-V = +0.04) stars (Popper 1959), has been the subject of several investigations (Stebbins 1911; Shapley 1915; Nekrasova 1936; Piotrowski 1948; and Smith 1948). Most recently, Popper (1959), using a light curve measured by Stebbins (1911), an orbital solution by Piotrowski (1948), and a parallax by Jenkins (1952), derived an average effective temperature for the two components of β Aur of 10500°K and a surface gravity of log g = 4.0. (An average determination of these parameters for both stars was possible because

809-201

detailed examination of the combined spectrum and the consistency of colors throughout the eclipses indicated very similar effective temperatures and surface gravities for the two components.) Because of the shallow eclipses and the consequent uncertainty of the orbit, the uncertainty of the parallax, and the primitive nature of Stebbins' photoelectric device, Popper concluded that his determinations could be subject to significant error. Further, the effective temperature derived for β Aur is quite inconsistent with the effective temperatures determined for Vega (9500°K) and Sirius (10300°K) by Hanbury Brown, Davis, Allen, and Rome (1967) from interferometric measurements. Because Vega is classified as A0 V with B-V = 0.00 and Sirius is classified as A1 IV with B-V = -0.01, the higher T_{eff} derived for β Aur would seem to be inconsistent with the T_{eff} deduced for these stars. The possible error in the effective temperature determination of β Aur may arise from any of the sources of error outlined above.

The present study to determine the physical parameters of β Aur was undertaken with the use of data of a different nature from those employed by Popper. From a comparison of photoelectric spectrum scans of the star with stellar atmosphere models, the possible range of effective temperatures and surface gravities was determined. Next, high-dispersion photographic spectra were used to obtain equivalent widths for a detailed abundance determination. The effective temperature and surface gravity used in the analysis were chosen by examination of the ionization equilibrium and abundance-versus-excitation-potential plots for iron, computed at various effective temperatures and surface gravities. A check of the surface gravity was also made by comparison of observed and computed hydrogen-line profiles.

II. EFFECTIVE-TEMPERATURE AND SURFACE-GRAVITY DETERMINATIONS

To establish the effective temperature and surface gravity for the stars, we compared the average of seven photoelectric spectrum scans of β Aur with the fluxes predicted from a grid of model stellar atmospheres. The scans, taken during non-eclipse portions of the period, were made with an f/5 photoelectric spectrum scanner (Code and Liller 1962) and a 20 Å bandpass used at the Newtonian focus of the 61-inch Wyeth reflector of Harvard College Observatory. The scans were reduced at seven wavelengths between λ 3400-λ 5060. An additional set of photoelectric spectrum scans was also made by B. Taylor, who used the Wampler scanner at the Lick Observatory Crossley reflector. These scans confirmed the photometry done at Harvard. By comparing these scans with the hydrogen line-blanketed models of Mihalas (1966) and using the absolute calibration of Vega proposed by Wolff, Kuhi, and Hayes (1968), we derived $T_{eff} = 8750°K$ and log g = 3.7. The surface gravity was also checked by a comparison of observed Hγ line profiles with theoretically computed profiles supplied by Peterson (1967), based on the semi-empirical approach of Edmonds, Schlüter, and Wells (1967). This determination agrees well with the value of log g = 3.65 obtained by Olson for both components of the system; the value of log g determined by Olson was again a result of a comparison with the Peterson calculation.

III. ABUNDANCE DETERMINATION

The abundance analysis was based on equivalent widths determined in the regions λ 3900-λ 4500 from two high-dispersion (3 Å/mm) photographic spectra taken at the coudé focus of the 100-inch Mount Wilson reflector by Struve (Struve and Driscoll 1953). The David Mann microdensitometer of the Harvard College Observatory Shock Tube Laboratory was used to reduce the spectra. Output appeared in density in both analog and punch-card forms. To minimize errors in the reduction from density to log intensity caused by non-uniformities in the plates, we took calibration measurements for every 10-mm (30 Å) region of the plates. We obtained equivalent widths by iteratively fitting theoretical line contours to the observed points in log intensity by employing a least-squares technique, and then by numerically integrating the contours in intensity. Our line-fitting technique was necessitated by the numerous blended profiles in the spectrum caused both by the small difference between the radial velocities of the two components and the fact that the line profiles for each component are rotationally broadened. The least-squares solution as coded for the CDC 6400 digital computer is described elsewhere (Grasdalen and Toy 1968).

We estimate the errors in the calculated equivalent widths as $0.15\ W_\lambda$ for $W_\lambda > 150$ mÅ and $0.30\ W_\lambda$ for $W_\lambda < 150$ mÅ. The derivation of the equivalent widths for the two stars from the combined spectrum was facilitated by the assumption that the similarity of the two stars in effective temperature implied almost identical slopes of the Paschen continuum in the spectral range considered. This assumption is confirmed in Figure 1, where measured equivalent widths of the two components are plotted against each other.

The abundance determination was performed by the method described by Strom, Gingerich, and Strom (1966). In this procedure a model atmosphere and assumed abundance are used to calculate for each line the line opacity for a series of optical depths. A theoretical profile is computed, and the equivalent width is then calculated. The abundance is varied until the observed equivalent width is bracketed by theoretical values.

IV. RESULTS

For both components of β Aur, a model atmosphere with the parameters $T_{eff} = 8750°K$ and $\log g = 3.7$ was chosen. The accuracy of this choice of atmospheric parameters was further checked by examination of plots of the abundances deduced for individual Fe 1 lines against the lower excitation potential of the lines and of the ionization equilibrium for Fe 1 and Fe 2 as computed for trial effective temperatures and surface gravities in the range suggested by the observations. Table 1 gives the ionization-equilibrium values calculated for effective temperatures and surface gravities bracketing the chosen values.

We note that the derived T_{eff} and log g are also consistent with the spectral types and luminosity classes of the β Aur components. Furthermore, assuming a change in effective temperature from Popper's value of 10500° to our deduced value of 8750° for the observed luminosity implies a decrease in log g from Popper's value of 4.0 to 3.75, closely matching the value derived from the abundance analysis and observations. The estimated error in T_{eff} is ±250° and in log g is ±0.2.

We obtained a value for the microturbulent velocity parameter v_t for each component by plotting the abundances deduced for each Fe I line against its measured equivalent width. In both cases, the value of v_t yielding the smallest slope in this relation was 8 km/sec. An error of ±1 km/sec is possible in this choice of v_t.

The equivalent-width and abundance calculations for the lines observed in β Aur A and B are given in Tables 2 and 3, followed by remarks concerning the choice of gf values. Table 4 gives the average abundances for each element in each star, comparing these values with those derived for normal A stars by Conti and Strom (1968a, b). The abundances are logarithmic relative to H = 12.00. A summary of the various temperature and surface-gravity determinations is given in Table 5.

The deduced abundances indicate the following anomalies with respect to the normal A stars:

a) slight underabundances of scandium and calcium (0.3 dex)
b) slight overabundance of zirconium (0.3 dex)
c) strong overabundance of barium (1.0 dex)
d) overabundance of nickel (0.6 dex)
e) overabundance of titanium (0.4 dex).

Aside from e), these abundance anomalies are reminiscent of those associated with the classical Am and early-type analogs of Am stars. Moreover, as is the case for most Am stars, the turbulent velocity deduced for each component of β Aur is large.

It is perhaps not surprising, however, that this system shows Am characteristics, since close A-type binary systems with slowly rotating components ($v \sim 30$ km/sec for both components of β Aur) are prime candidates for membership in either of the two classes of Am stars.

V. CONCLUSION

The methods of determination of effective temperature and surface gravity made in this study indicate a self-consistent set of atmospheric parameters for β Aur. The values of T_{eff}, we find, are consistent with the scale of T_{eff} for early A stars suggested by the values derived for Sirius and Vega. In view of these results we suggest that further photometric study of the properties of this important system is definitely necessary.

I am indebted to Dr. Stephen Strom for suggesting the problem, for the model atmosphere computer program, and for many useful discussions. The assistance of Mr. Gary Grasdalen in many phases of data reduction is also gratefully acknowledged, as is the observational assistance of Dr. William Liller and Mrs. Nancy Morrison. The Crossley scans were graciously made by Mr. Benjamin Taylor. Some of the computation time was supplied by the University of California Computer Center. This work was also supported in part by Contract NGR 22-024-001 with the National Aeronautics and Space Administration.

REFERENCES

Code, A. D., and Liller, W. 1962, in Astronomical Techniques, ed. W. A. Hiltner (Chicago: University of Chicago Press), p. 281.

Conti, P. S., and Strom, S. E. 1968a, Ap. J., **152**, 483.

__________. 1968b, Ap. J., in press.

Corliss, C. H. 1965, J. Res. N. B. S., **69A**, 87.

Corliss, C. H., and Bozman, W. R. 1962, N. B. S. Monog., 53.

Corliss, C. H., and Warner, B. 1964, Ap. J. Suppl., **8**, 395.

Edmonds, F. N., Jr., Schlüter, H., and Wells, D. C., III. 1967, Mem. R. A. S., **71**, 271.

Grasdalen, G. L., and Toy, L. G. 1968, to be published.

Groth, H.-G. 1961, Zs. f. Ap., **51**, 231.

Hanbury Brown, R., Davis, J., Allen, L. R., and Rome, J. M. 1967, M. N., **137**, 393.

Jenkins, L. F. 1952, General Catalogue of Trigonometric Stellar Parallaxes (New Haven: Yale University Observatory).

Kohl, K. 1964, Zs. f. Ap., **60**, 115.

Mihalas, D. 1966, Ap. J. Suppl., **13**, 1.

Nekrasova, S. 1936, Engelhardt Obs. Bull., No. 7, 18.

Olson, E. C. 1968, Ap. J., **153**, 187.

Peterson, D. 1967, private communication.

Piotrowski, S. L. 1948, Ap. J., **108**, 510.

Popper, D. M. 1959, Ap. J., **129**, 647.

Shapley, H. 1915, Princeton Contr., No. 3, 1.

Smith, B. 1948, Ap. J., **108**, 504.

Stebbins, J. 1911, Ap. J., **34**, 112.

Strom, S. E., Gingerich, O., and Strom, K. M. 1966, Ap. J., **146**, 880.

Struve, O., and Driscoll, C. 1953, Pub. A. S. P., **65**, 195.

Warner, B. 1967, Mem. R. A. S., **70**, 165.

Wolff, S. C., and Kuhi, L. V., and Hayes, D. 1968, Ap. J., **152**, 871.

TABLE 1

IONIZATION EQUILIBRIA PREDICTED FOR IRON FOR VARIOUS VALUES OF T_{eff} AND log g

		Abundances*			
		β Aur A		β Aur B	
T_{eff}	log g	Fe 1	Fe 2	Fe 1	Fe 2
8750	3.7	6.60	6.59	6.56	6.64
8500	3.7	6.40	6.51	6.37	6.56
9000	3.7	6.78	6.65	6.75	6.71
8750	3.3	6.68	6.62	6.65	6.56
8750	4.0	6.55	6.65	6.51	6.71

*These abundances for Fe 1 and Fe 2 are given as log (abundance), with H normalized at 12.

TABLE 2

EQUIVALENT-WIDTH AND ABUNDANCE DETERMINATIONS FOR INDIVIDUAL LINES FOR BETA AURIGAE A

Wavelength	Element and Ion	Excitation Potential	Multiplet Number	log gf	Ref.*	W_λ	Abundance
3944.01	Al 1	0.	1	-0.82	CB	159	5.74
3961.52	Al 1	0.01	1	-0.51	CB	213	5.69
4554.03	Ba 2	0.	1	-0.55	CB	422	4.19
†4226.73	Ca 1	0.	2	0.17	KO	150	5.22
4283.01	Ca 1	1.87	5	-0.37	CB	15	6.11
4454.78	Ca 1	1.89	4	0.36	KO	13	5.40
4254.35	Cr 1	0.	1	-0.27	CB	100	5.47
4242.38	Cr 2	3.87	31	-0.77	WA	93	5.11
4269.28	Cr 2	3.85	31	-1.81	WA	27	5.54
3922.91	Fe 1	0.05	4	-1.44	CW	97	6.60
3927.92	Fe 1	0.11	4	-1.30	CW	262	7.25
3930.30	Fe 1	0.09	4	-1.31	CW	63	6.26
4005.25	Fe 1	1.56	43	-0.09	CW	252	6.95
4021.87	Fe 1	2.76	278	-0.12	CW	94	7.02
4045.82	Fe 1	1.48	43	0.66	CW	367	6.64
4063.60	Fe 1	1.56	43	0.44	CW	276	6.51
4066.98	Fe 1	2.83	358	-0.23	CW	145	7.44
4071.74	Fe 1	1.61	43	0.42	CW	112	5.84
†4118.55	Fe 1	3.57	801	1.21	CW	57	5.93
4143.87	Fe 1	1.56	43	-0.12	CW	148	6.52
4147.67	Fe 1	1.48	42	-1.50	CW	102	7.61
†4153.91	Fe 1	3.40	695	0.47	CW	60	6.60
†4154.81	Fe 1	3.37	694	0.37	CW	43	6.53
4181.76	Fe 1	2.83	354	0.41	CW	76	6.41
†4247.43	Fe 1	3.37	693	0.52	CW	30	6.27
4282.41	Fe 1	2.18	71	-0.16	CW	94	6.67
4307.91	Fe 1	1.56	42	0.32	CW	297	6.72
4325.64	Fe 1	1.61	42	0.36	CW	135	6.01
4383.55	Fe 1	1.48	41	0.51	CW	225	6.18
4404.75	Fe 1	1.56	41	0.25	CW	189	6.33
4415.12	Fe 1	1.61	41	-0.13	CW	105	6.33
4447.72	Fe 1	2.22	68	-0.58	CW	6	6.53
4459.12	Fe 1	2.18	68	-0.50	CW	54	6.72
4476.02	Fe 1	2.84	350	0.14	CW	57	6.53
†4485.68	Fe 1	3.68	830	-0.20	CW	22	7.16
†4044.01	Fe 2	5.55	172	-1.97	G	75	7.78
†4122.64	Fe 2	2.57	28	-2.55	G	135	6.83
4178.60	Fe 2	2.58	28	-2.00	WA	208	6.63
4258.16	Fe 2	2.70	28	-2.59	WA	94	6.73

TABLE 2 (Cont.)

Wavelength	Element and Ion	Excitation Potential	Multiplet Number	log gf	Ref.*	W_λ	Abundance
4296.57	Fe 2	2.70	28	-2.36	WA	99	6.53
4351.77	Fe 2	2.70	27	-1.76	WA	202	6.44
4416.82	Fe 2	2.78	27	-2.09	WA	120	6.43
†4472.92	Fe 2	2.83	37	-2.65	G	51	6.56
4489.18	Fe 2	2.83	37	-2.23	WA	63	6.24
4491.40	Fe 2	2.85	37	-2.09	WA	187	6.80
4508.28	Fe 2	2.85	38	-1.76	WA	109	6.09
4515.34	Fe 2	2.84	37	-1.91	WA	123	6.30
4520.22	Fe 2	2.81	37	-1.87	WA	127	6.27
4238.38	La 2	0.40	41	-0.82	CB	30	2.89
4167.27	Mg 1	4.33	15	-1.00	KO	34	7.13
4390.58	Mg 2	9.96	10	-0.56	KO	100	7.79
4433.99	Mg 2	9.96	9	-0.93	KO	69	7.92
4055.54	Mn 1	2.14	5	0.47	CB	43	5.14
4359.58	Ni 1	3.40	86	-0.09	C	43	6.67
4015.50	Ni 2	4.03	12	-0.95	WA	200	5.98
4246.83	Sc 2	0.31	7	0.09	CB	204	2.78
4320.74	Sc 2	0.60	15	-0.32	CB	51	2.54
4374.46	Sc 2	0.62	14	-0.55	CB	16	2.54
4128.05	Si 2	9.79	3	0.22	G	180	7.71
4130.88	Si 2	9.80	3	0.40	G	141	7.38
†4077.71	Sr 2	0.	1	+0.16	G	208	1.88
3913.46	Ti 2	1.12	34	-0.24	WA	129	3.66
4012.37	Ti 2	0.57	11	-1.68	WA	282	5.39
4163.64	Ti 2	2.59	105	0.20	WA	183	4.42
4287.89	Ti 2	1.08	20	-1.56	WA	174	5.15
4294.10	Ti 2	1.08	20	-0.90	WA	196	4.58
4312.86	Ti 2	1.18	41	-1.06	WA	144	4.57
4337.92	Ti 2	1.08	20	-0.90	WA	103	4.14
4367.66	Ti 2	2.59	104	-0.39	WA	46	4.21
4394.06	Ti 2	1.22	51	-1.47	WA	22	4.22
4395.03	Ti 2	1.08	19	-0.50	WA	226	4.32
4399.77	Ti 2	1.24	51	-1.06	WA	105	4.41
4411.08	Ti 2	3.09	115	-0.07	WA	63	4.35
4417.72	Ti 2	1.16	40	-1.18	WA	22	3.90
4450.49	Ti 2	1.08	19	-1.41	WA	31	4.13

TABLE 2 (Cont.)

Wavelength	Element and Ion	Excitation Potential	Multiplet Number	log gf	Ref.*	W_λ	Abundance
4464.46	Ti 2	1.17	40	-1.66	WA	60	4.66
4468.49	Ti 2	1.13	31	-0.65	WA	204	4.39
4488.32	Ti 2	3.12	115	0.01	WA	60	4.26
4501.27	Ti 2	1.12	31	-0.79	WA	114	4.10
3916.42	V 2	1.43	10	-0.85	WA	160	4.23
4374.94	Y 2	0.40	13	-0.14	CB	114	5.17
4149.22	Zr 2	0.79	41	-0.13	CB	115	3.18
4379.78	Zr 2	1.52	88	-0.19	CB	50	3.37

*References for gf values
C Corliss (1965)
CB Corliss and Bozman (1962)
CW Corliss and Warner (1964)
G Groth (1961)
KO Kohl (1964)
WA Warner (1967).

†Corrections to gf values in Table 2.
Lines marked with a dagger had a choice of possible gf values or were modified in value. The author thanks Mr. Gary Grasdalen for a valuable discussion that led to these choices.

Wavelength	Element	log gf	Ref.*	Remarks
4226.73	Ca 1			KO was chosen because of possible errors in CB caused by self-absorption in resonance line. Cf. Katterbach, K. 1964, Internal Report, Max Planck Institute. MPI/PA/27/64.
4118.55	Fe 1	+0.31	to CW	Corrections to these lines were made as suggested by Huber and Tobey (Huber, M., and Tobey, F.L. 1968, Ap. J., 152, 609) because of inappropriate normalization of gf values dependent on upper excitation potentials.
4153.91	Fe 1	+0.14	to CW	
4154.81	Fe 1	+0.12	to CW	
4247.43	Fe 1	+0.07	to CW	
4485.68	Fe 1	+0.20	to CW	
4044.01	Fe 2	+0.65	to G to convert to WA	Corrections vary because of differing lower excitation potentials. Cf. WA.
4122.64	Fe 2	+0.96	to G to convert to WA	
4472.92	Fe 2	+0.96	to G to convert to WA	
4077.71	Sr 2			G computed from Bates-Damgaard method chosen over CB because of possible errors caused by self-absorption in resonance line.

TABLE 3

EQUIVALENT-WIDTH AND ABUNDANCE DETERMINATIONS FOR INDIVIDUAL LINES FOR BETA AURIGAE B

Wavelength	Element and Ion	Excitation Potential	Multiplet Number	log gf	Ref.*	W_λ	Abundance
3944.01	Al 1	0.	1	-0.82	CB	142	5.66
3961.52	Al 1	0.01	1	-0.51	CB	187	5.56
4554.03	Ba 2	0.	1	-0.55	CB	508	4.38
†4226.73	Ca 1	0.	2	0.17	KO	88	4.89
4254.35	Cr 1	0.	1	-0.27	CB	70	5.27
4274.80	Cr 1	0.	1	-0.39	CB	135	5.77
4242.38	Cr 2	3.87	31	-0.77	WA	112	5.13
4261.92	Cr 2	3.86	31	-0.96	WA	123	5.37
4275.57	Cr 2	3.86	31	-1.08	WA	123	5.49
4285.21	Cr 2	3.85	31	-1.39	WA	124	5.80
3920.26	Fe 1	0.12	4	-1.48	CW	70	6.51
3922.91	Fe 1	0.05	4	-1.44	CW	61	6.35
3927.92	Fe 1	0.11	4	-1.30	CW	220	7.11
3997.39	Fe 1	2.73	278	0.38	CW	97	6.52
4000.47	Fe 1	2.99	426	-0.74	CW	64	7.58
4005.25	Fe 1	1.56	43	-0.09	CW	319	7.33
4009.71	Fe 1	2.22	72	-0.43	CW	18	6.40
4045.82	Fe 1	1.48	43	0.66	CW	202	5.94
4063.60	Fe 1	1.56	43	0.44	CW	178	6.10
4066.98	Fe 1	2.83	358	-0.23	CW	135	7.39
4067.98	Fe 1	3.21	559	0.24	CW	72	6.79
4071.74	Fe 1	1.61	43	0.42	CW	135	5.95
†4118.45	Fe 1	3.57	801	1.21	CW	76	6.08
4143.42	Fe 1	3.05	523	0.61	CW	37	6.03
4143.87	Fe 1	1.56	43	-0.12	CW	186	6.69
4235.94	Fe 1	2.42	152	0.31	CW	130	6.56
†4238.82	Fe 1	3..40	693	0.47	CW	37	6.40
4260.48	Fe 1	2.40	152	0.63	CW	177	6.44
4307.91	Fe 1	1.56	42	0.32	CW	229	6.45
4325.64	Fe 1	1.61	42	0.36	CW	174	6.19
4404.75	Fe 1	1.56	41	0.25	CW	112	5.96
4447.72	Fe 1	2.22	68	-0.58	CW	12	6.55
4459.12	Fe 1	2.18	68	-0.50	CW	70	6.85
4476.02	Fe 1	2.84	350	0.14	CW	82	6.72
†4485.68	Fe 1	3.68	830	-0.20	CW	12	7.11
†4044.01	Fe 2	5.55	172	-1.97	G	74	7.78
†4122.64	Fe 2	2.57	28	-2.55	G	136	6.84
4173.45	Fe 2	2.58	27	-2.01	WA	175	6.49
4296.57	Fe 2	2.70	28	-2.36	WA	196	7.01
4303.18	Fe 2	2.70	27	-2.00	WA	259	6.92

TABLE 3 (Cont.)

Wavelength	Element and Ion	Excitation Potential	Multiplet Number	log gf	Ref.*	W_λ	Abundance
4351.77	Fe 2	2.70	27	-1.76	WA	183	6.35
†4369.40	Fe 2	2.77	28	-2.66	G	25	6.34
4416.82	Fe 2	2.78	27	-2.09	WA	107	6.35
†4472.92	Fe 2	2.83	37	-2.65	G	87	6.83
4491.40	Fe 2	2.85	37	-2.09	WA	75	6.20
4508.28	Fe 2	2.85	38	-1.76	WA	150	6.29
4515.34	Fe 2	2.84	37	-1.91	WA	114	6.26
4167.27	Mg 1	4.33	15	-1.00	KO	37	7.15
4390.58	Mg 2	9.96	10	-0.56	KO	85	7.67
4433.99	Mg 2	9.96	9	-0.93	KO	106	8.21
4359.58	Ni 1	3.40	86	-0.09	C	30	6.56
4015.50	Ni 2	4.03	12	-0.95	WA	256	6.21
4246.83	Sc 2	0.31	7	0.09	CB	125	2.42
4320.74	Sc 2	0.60	15	-0.32	CB	22	2.32
4374.46	Sc 2	0.62	14	-0.55	CB	12	2.52
4128.05	Si 2	9.79	3	0.22	G	105	7.33
†4077.71	Sr 2	0.	1	+0.16	G	226	1.97
3913.46	Ti 2	1.12	34	-0.24	WA	238	4.20
4012.37	Ti 2	0.57	11	-1.68	WA	279	5.38
4053.81	Ti 2	1.89	87	-0.88	WA	183	5.05
4163.64	Ti 2	2.59	105	0.20	WA	136	4.20
4290.23	Ti 2	1.16	41	-0.79	WA	259	4.78
4294.10	Ti 2	1.08	20	-0.90	WA	238	4.78
4301.93	Ti 2	1.16	41	-1.11	WA	129	4.54
4314.98	Ti 2	1.16	41	-1.02	WA	192	4.74
4386.86	Ti 2	2.60	104	-0.46	WA	121	5.16
4395.03	Ti 2	1.08	19	-0.50	WA	202	4.20
4395.85	Ti 2	1.24	61	-1.53	WA	70	4.66
4411.08	Ti 2	3.09	115	-0.07	WA	12	4.00
4417.72	Ti 2	1.16	40	-1.18	WA	30	3.94
4443.80	Ti 2	1.08	19	-0.74	WA	72	3.77
4450.49	Ti 2	1.08	19	-1.41	WA	54	4.30
4464.46	Ti 2	1.17	40	-1.66	WA	72	4.75
4468.49	Ti 2	1.13	31	-0.65	WA	217	4.45
4488.32	Ti 2	3.12	115	0.01	WA	43	4.13
4501.27	Ti 2	1.12	31	-0.79	WA	83	3.92
3997.13	V 2	1.48	9	-1.03	WA	114	4.21

TABLE 3 (Cont.)

Wavelength	Element and Ion	Excitation Potential	Multiplet Number	log gf	Ref.*	W_λ	Abundance
4374.94	Y 2	0.40	13	-0.14	CB	97	5.07
4050.32	Zr 2	0.71	43	-0.96	CB	202	4.48
4149.22	Zr 2	0.79	41	-0.13	CB	163	3.51
4379.78	Zr 2	1.52	88	-0.19	CB	30	3.21

*Key to references for gf values found at end of Table 2.

†Corrections to gf values in Table 3:

Wavelength	Element	Remarks
4226.73	Ca 1	See Table 2.
4118.45	Fe 1	See Table 2.
4238.82	Fe 1	+0.10 to CW See Table 2.
4485.68	Fe 1	See Table 2.
4044.01	Fe 2	See Table 2.
4122.64	Fe 2	See Table 2.
4369.40	Fe 2	+0.96 to G to convert to WA. See Table 2.
4472.92	Fe 2	See Table 2.
4077.71	Sr 2	See Table 2.

TABLE 4

THE ABUNDANCE VALUES OF BETA AURIGAE A AND B COMPARED WITH THOSE OF NORMAL A STARS

Element and Ion	Number lines β Aur B	Number lines β Aur B	β Aur B	β Aur B	Normal A stars (Conti and Strom 1968)
Mg 1	1	1	7.13	7.15	7.4
Mg 2	2	2	7.86 ± 0.05	7.94 ± 0.19	
Al 1	2	2	5.71 ± 0.02	5.61 ± 0.04	5.7
Si 2	2	1	7.58 ± 0.15	7.33	7.8
Ca 1	3	1	5.58 ± 0.17	4.89	5.8
Sc 2	3	3	2.62 ± 0.06	2.42 ± 0.03	2.8
Ti 2	18	19	4.10 ± 0.07	4.47 ± 0.08	4.7
V 2	1	1	4.23	4.21	3.5
Cr 1	1	2	5.47	5.52 ± 0.17	5.4
Cr 2	2	4	5.28 ± 0.16	5.45 ± 0.10	
Mn 1	1		5.14		5.2
Fe 1	26	25	6.60 ± 0.06	6.56 ± 0.06	6.6
Fe 2	13	12	6.59 ± 0.08	6.64 ± 0.09	
Ni 1	1	1	6.67	6.56	6.0
Ni 2	1	1	5.98	6.21	5.2
Sr 2	1	1	1.88	1.97	2.1*
Y 2	1	1	2.60	2.51	2.5
Zr 2	2	3	3.32 ± 0.03	3.73 ± 0.28	3.0
Ba 2	1	1	4.19	4.38	3.1
La 2	1		2.89		3.0

*Scaled by gf value difference between Corliss and Bozman (1962) and Groth (1961).

TABLE 5

COMPARISON OF T_{eff} AND log g DETERMINATIONS FOR BETA AURIGAE

Source	T_{eff}	log g
Popper (1959) (eclipse solution)	10500°K	4.0
Scanner	8300-9100	3.4-3.8
Hβ and Hγ profiles Olson (1968)	--	3.65
Ionization equilibrium	8750	3.7
Spectral type—luminosity class—absolute magnitude	8900	3.75
Final choice	8750 ± 250	3.7 ± 0.2

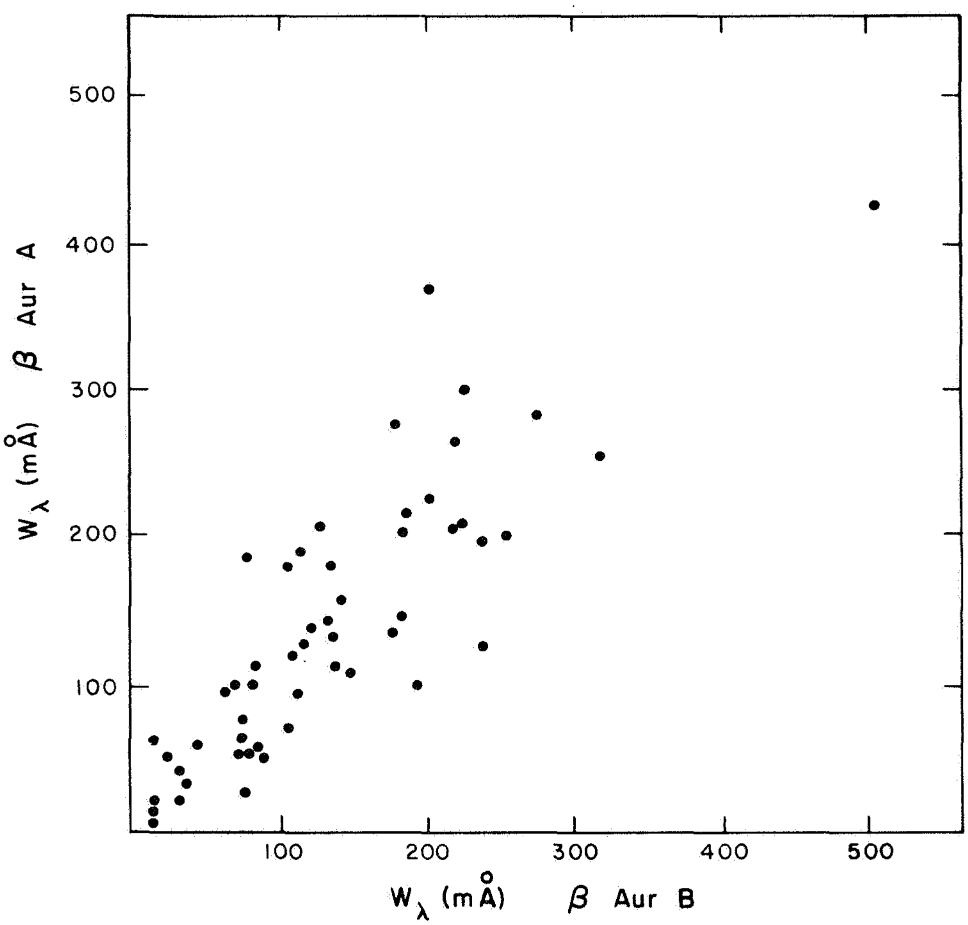

Fig. 1.— Comparison of equivalent widths of lines measured in both Beta Aurigae A and B.