CURVE-OF-GROWTH ANALYSES OF

ARCTURUS AND 31 CYGNI A

by

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ABSTRACT

Equivalent widths of 1,411 lines of Arcturus (K2 III), were measured in the spectral region $\lambda\lambda$3985-6770. Use was made of direct-intensity tracings of high-resolution spectra taken with the 96-inch camera of the 48-inch telescope of the Dominion Astrophysical Observatory. These spectra had dispersions of 2.2 A/mm. in the violet and 3.2 A/mm. in the blue to red spectral regions. A *Photometric Atlas of the Spectrum of Arcturus* (Griffin 1968) provided an additional set of tracings for this star.

A total of 938 intensity measurements were also made of lines of 31 Cygni A (K3 Ib), a member of a spectroscopic binary of the ζ Aurigae type, in the same spectral region. The spectra of this star, taken with the Littrow spectrograph of the 72-inch telescope at the D. A. O., had dispersions of 4.6 A/mm. in the violet and 7.5 A/mm. in the blue to red spectral regions.

Experimental gf-values were used in the construction of absolute curves of growth from which the following atmospheric parameters were obtained:

	ARCTURUS	31 CYGNI A
**Excitation Temperature (K)	3920 ± 40	3450 ± 50
**Microturbulence (km./sec.)	2.4 ± 0.2	5.1 ± 0.2
Ionization Temperature (K)	4000 ± 50	3570 ± 50
Log of Electron Pressure	-1.36 ± 0.1	-2.28 ± 0.1

**Numerical values were derived from the curves of growth for neutral iron.

Abundances of chemical elements were obtained on the basis of coarse analysis. On the scale defined by log N(Ti) = 4.00, the abundances were found to be similar to the scale of solar abundances; that is, within a factor of two (a typical probable error for such determinations). The present results for Arcturus, however, indicate that the heavier elements - those centered on the iron peak and the "rare earth" elements - may be slightly underabundant.

The ionized elements showed a markedly higher excitation temperature and lower microturbulence than the neutral elements. From these facts may be inferred the probable stratification of elements in the atmospheres of the two stars.

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CHAPTER 1

GENERAL INTRODUCTION

The analysis of stellar absorption lines, in the study of stellar atmospheres, yields considerable information regarding temperatures, pressures, chemical abundances, and turbulent motions. Such information may be derived by comparison of theoretically determined line profiles with observation - the model atmosphere approach (see Aller 1963, page 356). However extensive theory and exceptional observations are required. A major complication to contend with, in this method, is the effect of instrumental distortion. The finite resolution of any spectrograph must broaden an infinitely sharp line into some shape characteristic of the instrument. Because of this, there is not necessarily a close resemblance between the spectrum being observed and the observations being made of it, even if a high-resolution spectrograph is used (see Griffin, 1969). Difficulties are increased when late-type stars are considered because of the very numerous lines present in their spectra - lines which are usually blended. A method then of determining abundances, etc., not from line contours, but from total absorption, a quantity which is affected to a lesser extent than the line profile, has great advantages.

The profile of an absorption line is generally expressed by the residual intensity R(λ), where R(λ) is the fraction of continuous intensity that remains at wavelength λ. The total energy subtracted from the continuum by the line, the line strength E, may be written as:

$$E = \int_{-\infty}^{+\infty} I_c(1 - R(\lambda))d\lambda \qquad (1.1)$$

where I_c is the continuum intensity. The use of rectified intensitometer tracings (Wright 1966, page 83) allows the quantity I_c to be removed from the integral sign since the continuum is normalized at a constant height above the zero-intensity line. The total absorption due to a spectral line is measured in terms of its equivalent width; that is, the width of a line of equal strength whose $R(\lambda)$ is zero in the region covered by the line and unity elsewhere (see Figure 1). For such a line

$$E = I_c W \qquad (1.2)$$

where W is the equivalent width. Thus the equivalent width of a narrow line may be written as:

$$W = \int_{-\infty}^{+\infty} (1 - R(\lambda))d\lambda \qquad (1.3)$$

It is most easily obtained by measuring the area of the line profile on direct-intensity photographic or photoelectric tracings.

The curve which expresses a relationship between the equivalent width of a spectral line and the product $N_i f_{ik}$, where N_i is the number of atoms acting to produce the line and f_{ik} is its oscillator strength, is called a curve of growth. The curve of growth traces the increase in strength of a given absorption line as the number of

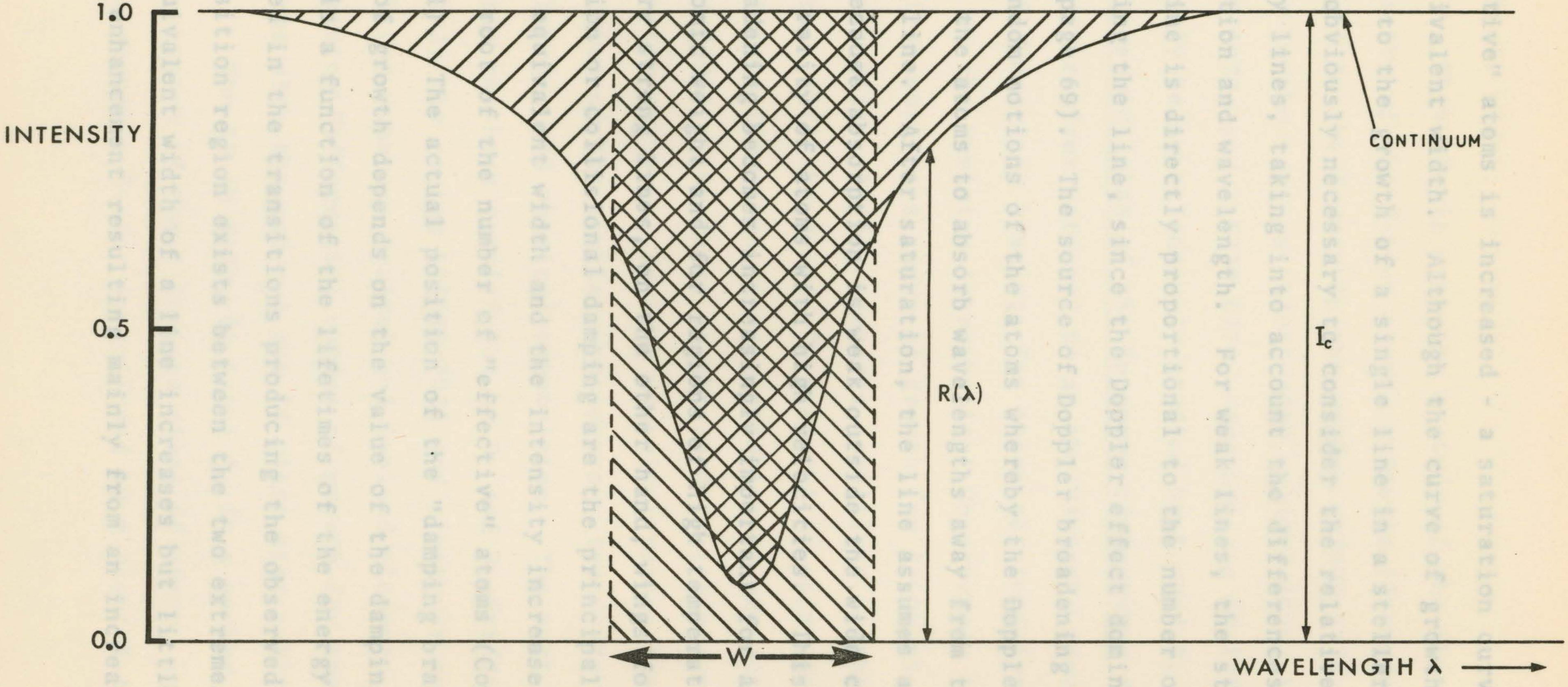

Figure 1. Illustration of the meaning of "equivalent width"

"effective" atoms is increased - a saturation curve for an equivalent width. Although the curve of growth ideally refers to the growth of a single line in a stellar atmosphere, it is obviously necessary to consider the relative intensities of many lines, taking into account the differences in excitation and wavelength. For weak lines, the strength of a line is directly proportional to the number of atoms producing the line, since the Doppler effect dominates (Cowley 1970, page 69). The source of Doppler broadening lies in the random motions of the atoms whereby the Doppler effect causes the atoms to absorb wavelengths away from the center of the line. After saturation, the line assumes a bell-shaped form because absorption is weak outside the wide core, owing to the rarity of atoms with high velocities. This source of broadening becomes increasingly important for atoms of low atomic weight and for regions of high temperature. For very strong lines, on the other hand, wings formed by radiation or collisional damping are the principal contributors to the equivalent width and the intensity increases as the square root of the number of "effective" atoms (Cowley 1970, page 71). The actual position of the "damping branch" of the curve of growth depends on the value of the damping constant, which is a function of the lifetimes of the energy levels involved in the transitions producing the observed lines. A transition region exists between the two extremes where the equivalent width of a line increases but little, the slight enhancement resulting mainly from an increase in the line's width.

This thesis presents a study of the line intensities in spectra of the K-type stars, α Bootis (Arcturus) and 31 Cygni A; the former in the region λλ3985-6770 and the latter in the regions λλ3985-4080, λλ4200-4500, λλ4850-5330, λλ5480-6070, and λλ6220-6770. Arcturus, a K2 III_p star, is currently being extensively studied by R. and R. Griffin. A Photometric Atlas of the Spectrum of Arcturus (Griffin, 1968), hereafter referred to as the "Atlas", provides a set of comparison tracings for those obtained from spectra taken at the Dominion Astrophysical Observatory in Victoria. The first work on a curve of growth for Arcturus, that of Miss van Dijke (1946), compares conditions in the giant, Arcturus, with the dwarf, 70 Ophiuchi A, using measurements of selected lines and visual estimates of many others. Wright (1950), the first to obtain detailed curves of growth for Arcturus, derives numerical values for the parameters of the stellar atmosphere - temperatures, turbulences, and chemical composition. The most recent analysis has been carried out by R. and R. Griffin (1967), who study the region λλ5000-7025 and construct curves of growth for numerous neutral and ionized elements as well as deriving differential curves of growth for comparison of Arcturus with the sun and the G8 giant star ε Virginis.

The K3 Ib star, 31 Cygni A, is a member of a binary system of the ζ Aurigae class of stars, in which a main-sequence B-star is eclipsed by a giant K-type star with an extensive atmosphere. By investigation of observed intensities obtained when the B-star passed from first to second contact (ingress to eclipse) and from third to fourth contact (egress from eclipse), Wright (1959) estimates the composition and temperature distributions in the chromosphere of 31 Cygni A. The present study makes use of spectra taken between second and third contacts of the 1951 eclipse; that is, during total eclipse of the B-star, which lasted from approximately August 10 until October 12 (McKellar and Petrie, 1958).

CHAPTER 2

THE DATA

2.1 Observations and Measurements

Details of the spectrograms that have been used in this investigation are given in Tables I and II, the respective observers being listed in column eight of each of the two tables. The spectra of 31 Cygni A were taken with the Bausch & Lomb grating No-84 used in the Littrow mounting of the spectrograph at the Cassegrain focus of the 72-inch telescope. The region λλ3985-4600 was obtained in the third order of the grating with a dispersion of 4.6 Angstroms per millimeter while the spectral range λλ4600-6770 was obtained in the second order with a dispersion of 7.5 Angstroms per millimeter. For all spectra the slit-width was kept at 0.002 millimeters.

The high-dispersion, high-resolution spectra of Arcturus were taken with the 96-inch camera of the spectrograph at the coude´ focus of the 48-inch telescope. (For detailed descriptions of the D. A. O. spectrographs see E. H. Richardson (1968)). With regard to the individual spectra, the numbers in the column of Table II labelled "Instrument" may be interpreted as follows: the first two figures to the left indicate the focal length of the camera (in inches); the first figure on the right, the order of the grating; and the center figure(s) the number of hundred lines per millimeter of the grating. For instance,

TABLE I

ARCTURUS SPECTROGRAMS USED FOR EQUIVALENT WIDTH MEASUREMENTS

PLATE NO.	DATE	JULIAN DATE 2,430,000+	INSTRUMENT	EMULSION	DISPERSION A/mm.	SPECTRAL REGION	OBSERVER
511	1963 Jan. 12	8042.058	9663	IIaO	2.2	Ultraviolet	K. O. Wright
805	1963 June 10	8190.720	9662	IIaD	3.2	Yellow	K. O. Wright
807	1963 June 10	8190.771	9662	IIaD	3.2	Red	K. O. Wright
809	1963 June 11	8191.719	9662	IIaF	3.2	Red	K. O. Wright
1173	1964 Feb. 26	8451.943	9663	IIaO	2.2	Violet	E. K. Lee
1201	1964 Mar. 13	8467.951	9662	IIaD	3.2	Yellow	K. O. Wright
1202	1964 Mar. 13	8468.032	9663	IIaO	3.2	Blue	K. O. Wright
1233	1964 Apr. 3	8488.870	96121	IIaD	3.2	Green	K. O. Wright
1234	1964 Apr. 3	8488.920	96121	IIaO	3.2	Blue	K. O. Wright
1235	1964 Apr. 3	8488.966	9663	IIaO Bkd	2.2	Violet	K. O. Wright
1236	1964 Apr. 3	8489.017	9663	IIaO Bkd	2.2	Ultraviolet	K. O. Wright
1300	1964 May 2	8517.719	96121	IIaD	3.2	Green	K. O. Wright

TABLE II

31 CYGNI A SPECTROGRAMS USED FOR EQUIVALENT WIDTH MEASUREMENTS

PLATE NO.	DATE	JULIAN DATE 2,430,000+	INSTRUMENT	EMULSION	DISPERSION A/mm.	SPECTRAL REGION	OBSERVER
42379	1951 Aug. 12	3870.877	Litt GIII	IIaO	4.6	Violet	A. McKellar
42381	1951 Aug. 13	3871.788	Litt GIII	IIaO	4.6	Violet	G. J. Odgers
42383	1951 Aug. 14	3872.819	Litt GIII	IIaO	4.6	Violet	K. O. Wright
42395	1951 Aug. 17	3875.711	Litt GII	IID	7.5	Yellow	L. H. Aller
42396	1951 Aug. 17	3875.732	Litt GII	IIF	7.5	Red	L. H. Aller
42397	1951 Aug. 17	3875.789	Litt GII	IID	7.5	Yellow	L. H. Aller
42398	1951 Aug. 17	3875.888	Litt GII	IIF	7.5	Red	L. H. Aller
42399	1951 Aug. 17	3875.972	Litt GII	IID	7.5	Yellow	L. H. Aller
42403	1951 Aug. 18	3876.710	Litt GII	103aD	7.5	Blue	K. O. Wright
42404	1951 Aug. 18	3876.726	Litt GII	IID	7.5	Green	K. O. Wright
42405	1951 Aug. 18	3876.812	Litt GII	103aD	7.5	Blue	K. O. Wright
42406	1951 Aug. 18	3876.897	Litt GII	IID	7.5	Green	K. O. Wright
42407	1951 Aug. 18	3876.901	Litt GII	103aD	7.5	Blue	K. O. Wright
42677	1951 Sept. 22	3911.810	Litt GII	103aF	7.5	Red	K. O. Wright

9662 refers to the use of the 96-inch camera and a grating with 600 lines per millimeter taken to second order. The dispersion of the Arcturus plates was 2.2 Angstroms per millimeter in the violet and 3.2 Angstroms per millimeter in the blue to red spectral range. The region λλ3985-6770 was covered with a sufficient number of plates and settings of the grating to ensure enough overlap to intercompare intensities obtained from different regions. For Arcturus the slit was maintained at a width of 0.0035 millimeters. Representative spectra of the two stars are illustrated in Figure 2. In order to compare the resolutions of the two spectrographs, spectra of Arcturus, previously taken at the D. A. O. using the same instrument from which the spectra of 31 Cygni A were made, have been included (labelled α Bootis (1)). The similarity of the spectra of 31 Cygni A and Arcturus is quite apparent with the lines of 31 Cygni A being slightly stronger than those in Arcturus. This however might be expected since 31 Cygni A has a much more extensive atmosphere, and hence a greater number of "effective absorbers", than does Arcturus.

Intensity tracings were made, for the most part by Dr. K. O. Wright, for the region of each plate listed in Tables I and II. The usual procedure was followed (Wright 1966, page 83) using the microphotometer and two stages of the intensitometer in order to rectify the continuum to read one hundred per cent. The continuum was drawn on the logarithmic tracing, before conversion to direct intensity,

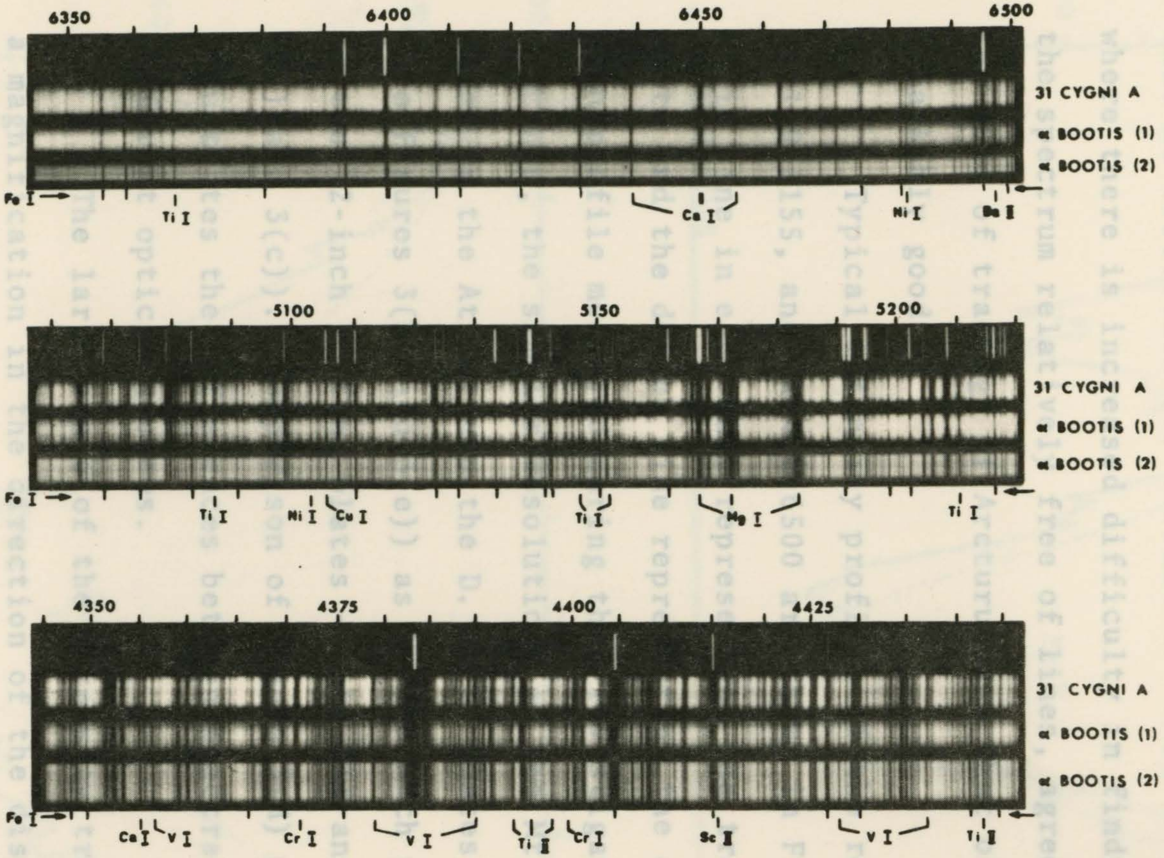

Figure 2. Spectra of 31 Cygni A and α Bootis in the regions λλ6345-6500, λλ5060-5220, and λλ4345-4445. The spectra of 31 Cygni A and those of Arcturus denoted by α Bootis (1) were taken using the Littrow spectrograph (BL 84 grating) on the 72-inch telescope, while those denoted by α Bootis (2) were taken using the 96-inch camera of the 48-inch telescope. The spectra α Bootis (1) are included only for comparison of relative resolutions--they have not been used in equivalent width determinations. (For each section the wavelength scale is placed above the spectra and identification of prominent lines below.)

as the mean of the galvanometer deflections at parts of the spectrum which appeared to be undisturbed by lines. The height of the continuum was later checked by comparison with the Atlas values, and in all but a very few cases, it was felt that no correction was warranted. Even in the violet regions, where there is increased difficulty in finding portions of the spectrum relatively free of lines, agreement between the two sets of tracings of Arcturus and that of 31 Cygni A was remarkably good.

Typical intensity profiles of the regions λλ4403-4408, λλ5149-5155, and λλ6492-6500 are shown in Figure 3; the solid line in each part representing the tracing of a single plate and the dotted line representing the estimated observed mean profile measured during this investigation. From these tracings, the similar resolutions of the Mt. Wilson plates (used in the Atlas) and the D. A. O. plates are noticeable (see Figures 3(b) and 3(e)) as is the much poorer resolution of the 72-inch grating plates - Litt GII and GIII (see Figures 3(a) and 3(c)). Comparison of Figure 3(d) with Figure 3(e) illustrates the differences between spectra taken with different optical systems.

The large scale of the intensity tracings, each having a magnification in the direction of the dispersion of two hundred times that of the plates, permitted accurate wavelength identifications by interpolation between strong, unblended, easily-identified lines. Identifications were made with the help of "A Multiplet Table of Astrophysical

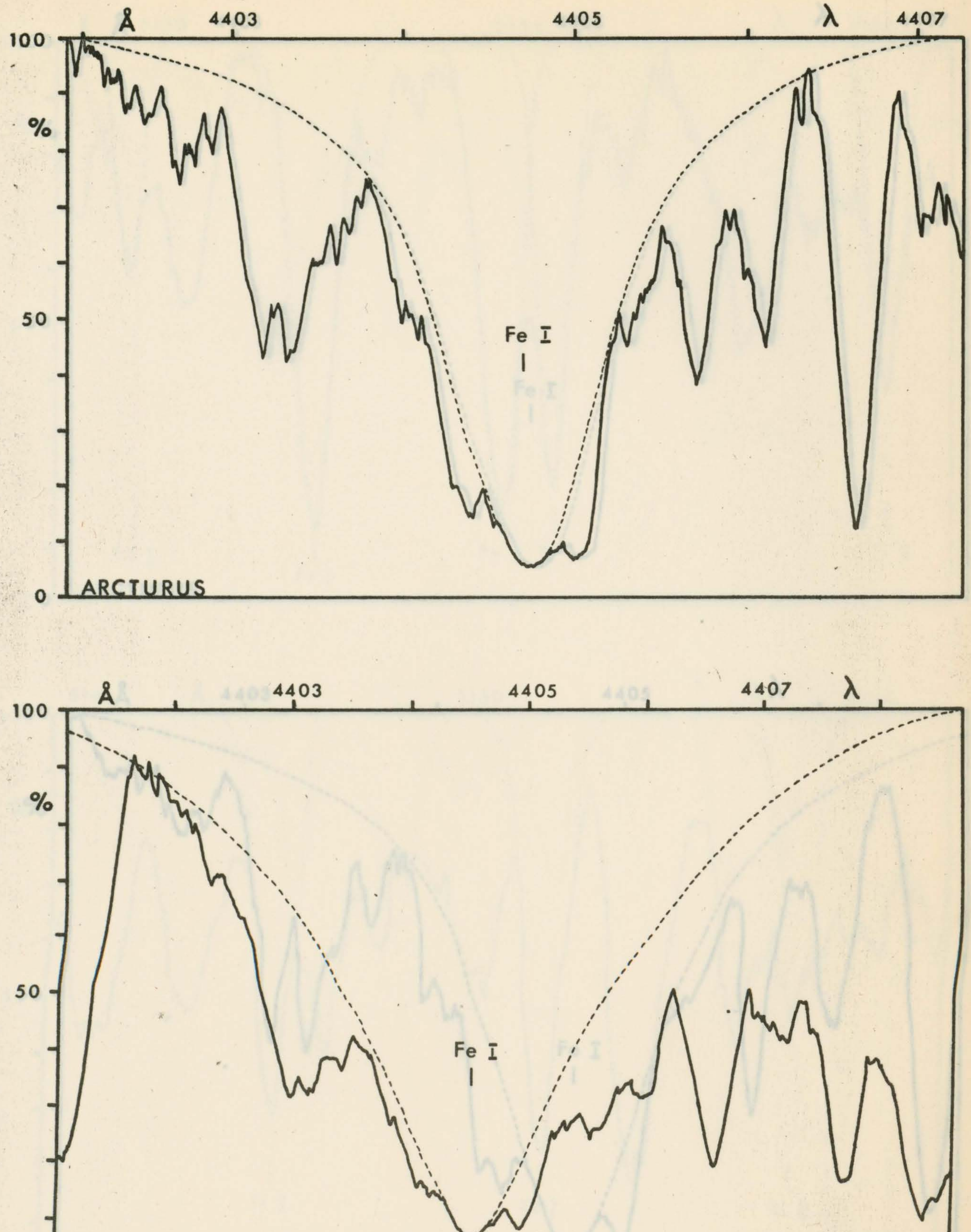

Figure 3(a). Sample direct-intensity tracings of Arcturus and 31 Cygni A in the blue spectral region.

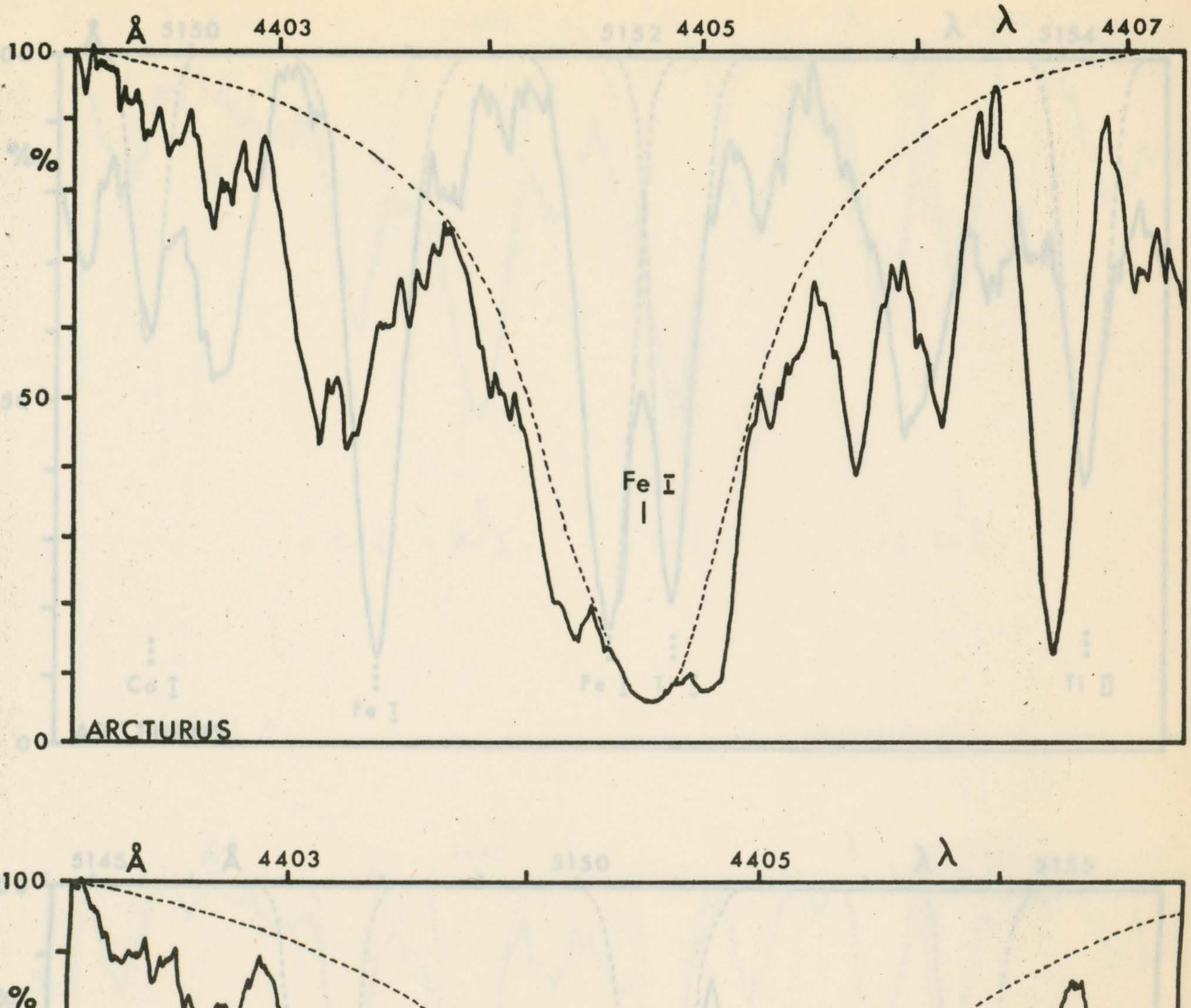

Figure 3(b). Sample direct-intensity tracings of high-dispersion spectra of Arcturus in the blue spectral region.

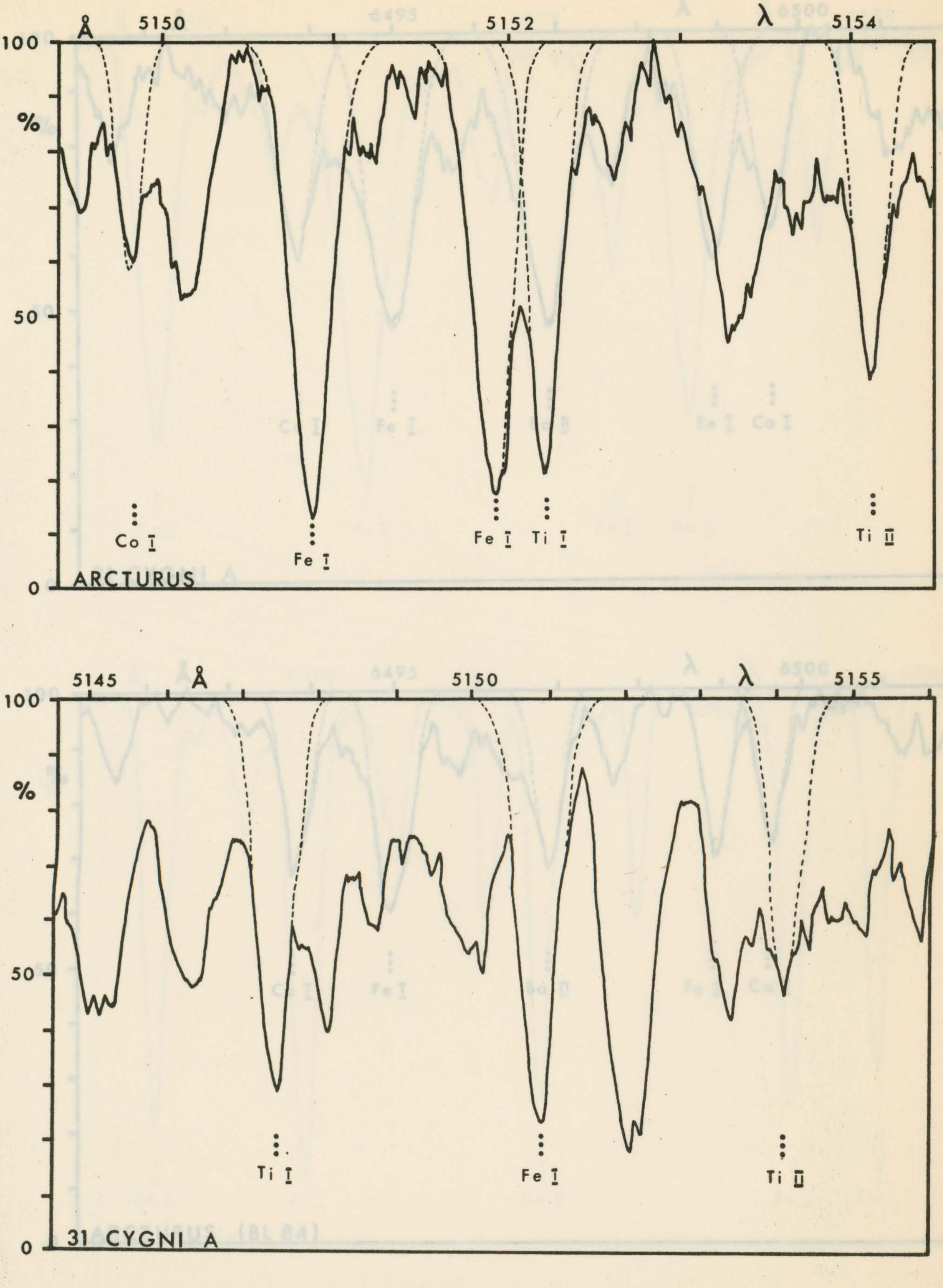

Figure 3(c). Sample direct-intensity tracings of Arcturus and 31 Cygni A in the green spectral region.

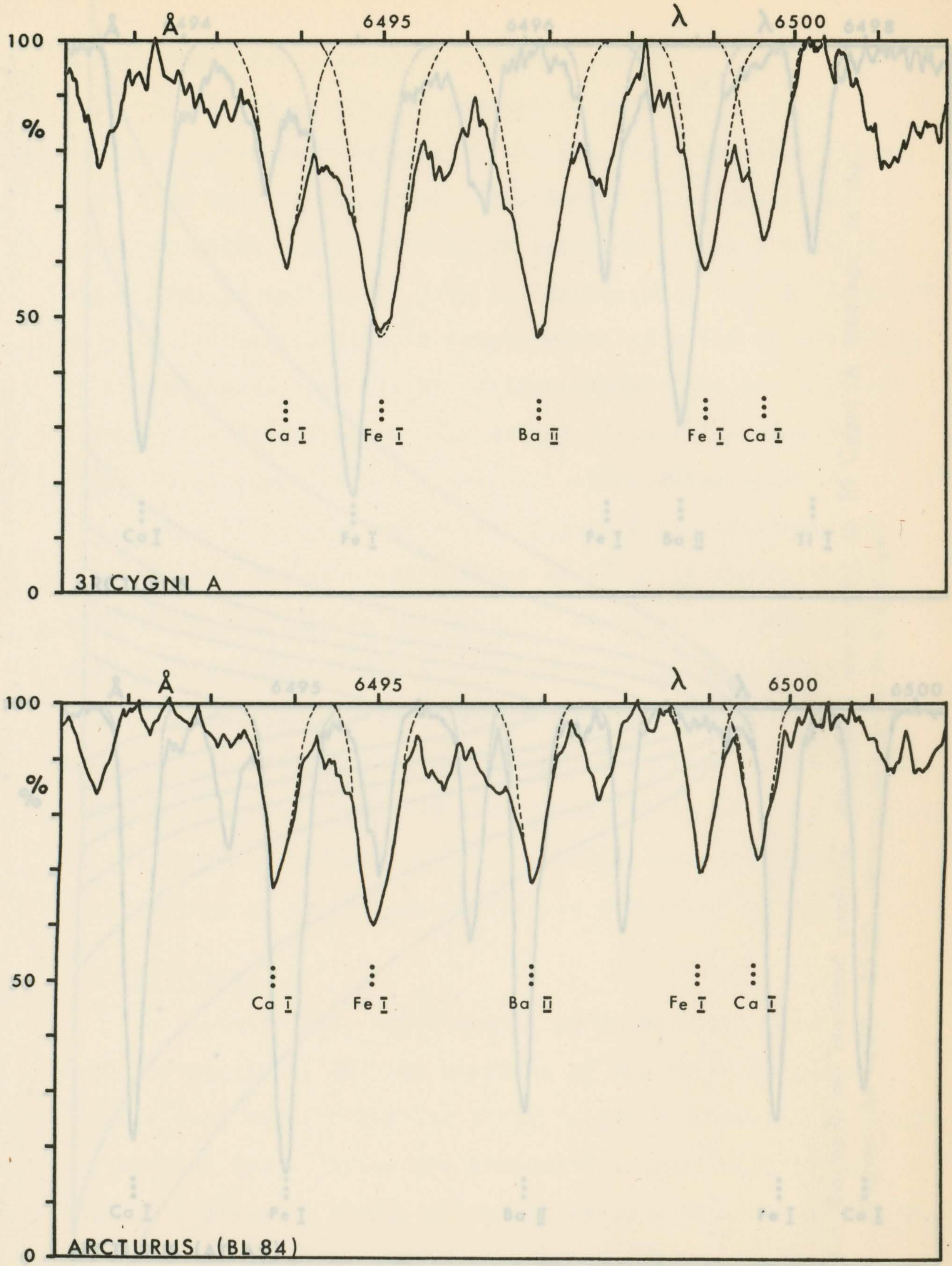

Figure 3(d). Sample direct-intensity tracings of spectra, taken with the same optics, of Arcturus and 31 Cygni A in the red spectral region.

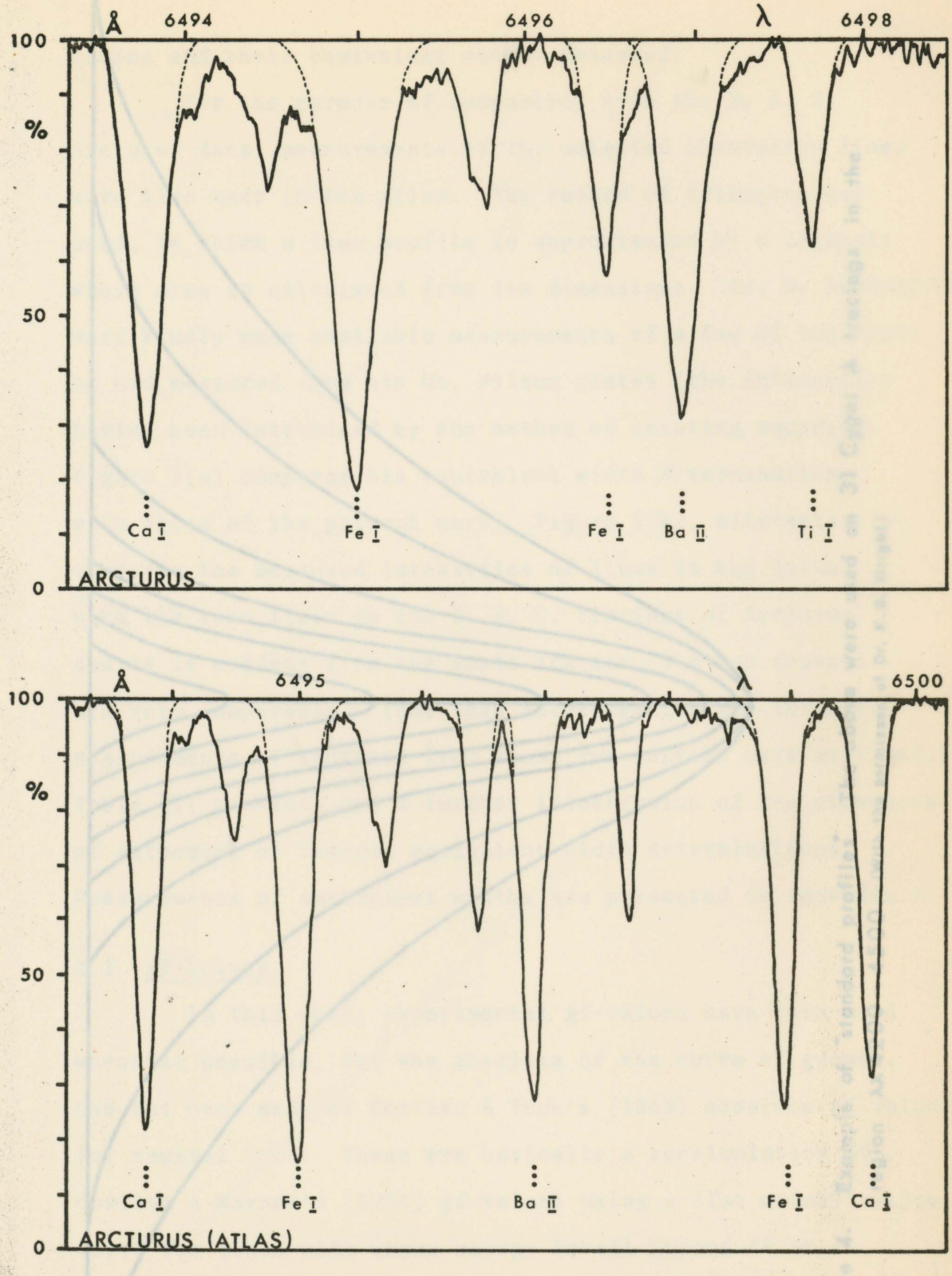

Figure 3(e). Sample direct-intensity tracings of high-dispersion spectra of Arcturus in the red spectral region.

Interest, Revised Edition" by C. E. Moore (1945) and "The Spectrum of β Pegasi" by D. N. Davis (1947). After a line had been identified, its apparent profile was drawn symmetrically about the center of the absorption feature as the mean of two or more superposed tracings. In general only pure lines with good line profiles were chosen for measuring equivalent widths and close blends were omitted. Equivalent widths of these mean profiles were, for Arcturus, measured with a planimeter. Equivalent widths of the 31 Cygni A lines were measured largely by the method of standard profiles; as described by Wright (1950):

> "When all lines in a given region had been sketched on the tracings, they were superimposed in turn on one another with their mid-points on a common line and mean profiles for representative central intensities were drawn. These mean profiles were measured with the planimeter and equivalent widths of other lines in the region were interpolated from the mean profiles . . . . Separate sets of standard profiles were drawn for each wavelength region to allow for differences in wavelength."

Representative standard profiles for 31 Cygni A are shown in Figure 4. Preliminary measurements of many of the selected lines of 31 Cygni A had been completed by Dr. K. O. Wright. Most of these lines were remeasured: some of them needed considerable corrections as consultation with the Atlas revealed them to be blended. Additional lines were also

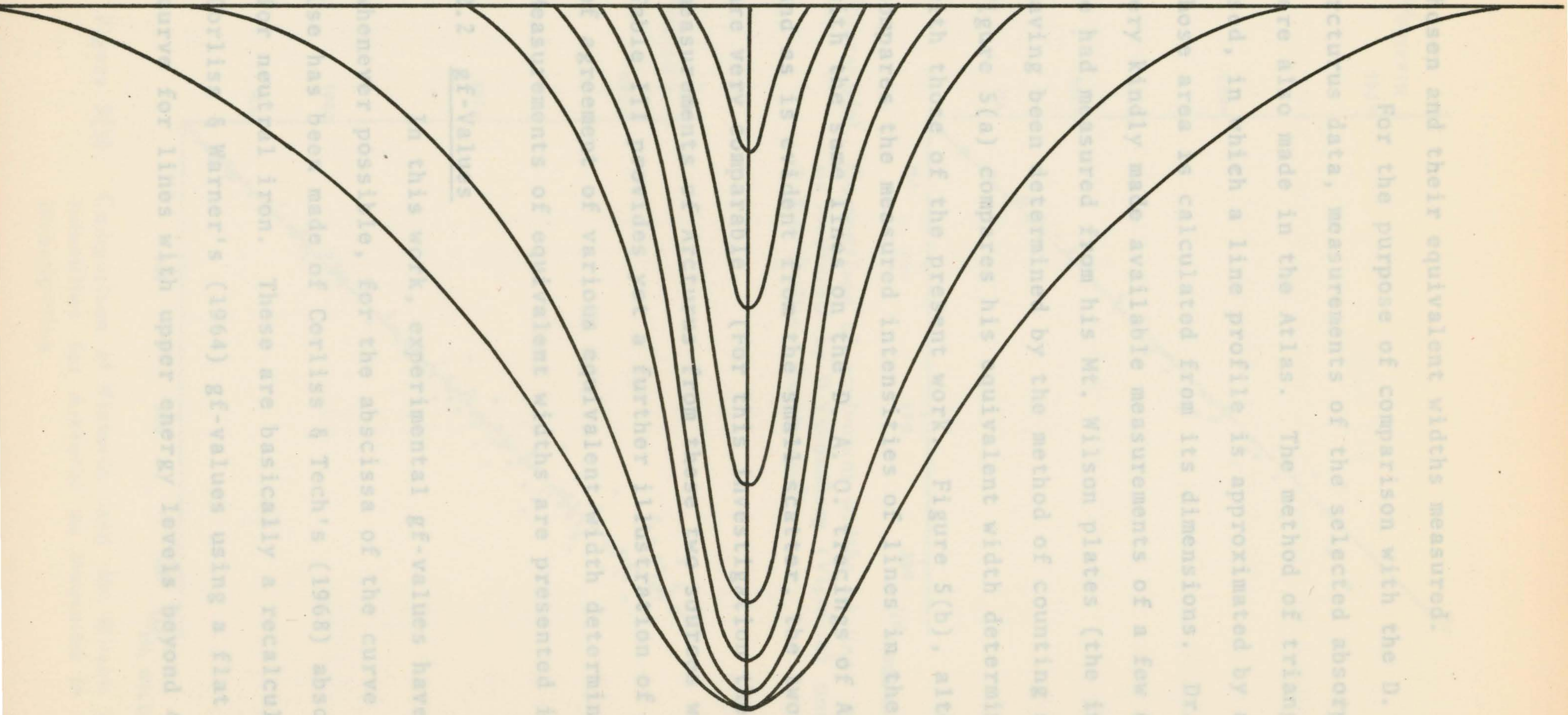

Figure 4. Example of "standard profiles". The above were used on 31 Cygni A tracings in the region λλ 4200 - 4500. (With the permisson of Dr. K.O. Wright)

chosen and their equivalent widths measured.

For the purpose of comparison with the D. A. O. Arcturus data, measurements of the selected absorption lines were also made in the Atlas. The method of triangles was used, in which a line profile is approximated by a triangle whose area is calculated from its dimensions. Dr. R. F. Griffin very kindly made available measurements of a few of the lines he had measured from his Mt. Wilson plates (the intensities having been determined by the method of counting squares). Figure 5(a) compares his equivalent width determinations with those of the present work. Figure 5(b), alternatively, compares the measured intensities of lines in the Atlas with the same lines on the D. A. O. tracings of Arcturus; and as is evident from the small scatter, the two sources are very comparable. (For this investigation the intensity measurements of Arcturus from these two sources were averaged.) Table III provides yet a further illustration of the closeness of agreement of various equivalent width determinations. Measurements of equivalent widths are presented in Appendix A.

2.2 gf-Values

In this work, experimental gf-values have been used whenever possible, for the abscissa of the curve of growth. Use has been made of Corliss & Tech's (1968) absolute gf-values for neutral iron. These are basically a recalculation of Corliss & Warner's (1964) gf-values using a flat normalization curve for lines with upper energy levels beyond 48 kK -

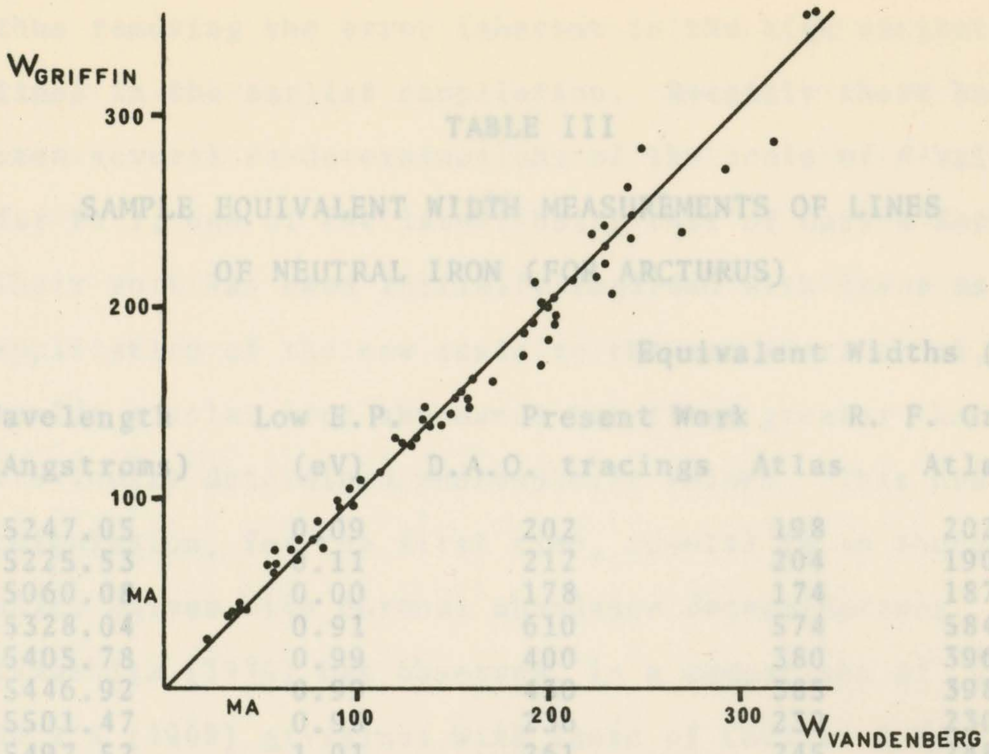

Figure 5(a). Comparison of equivalent widths of lines in the Atlas as measured by D. VandenBerg (Victoria) and by R. & R. Griffin (Cambridge).

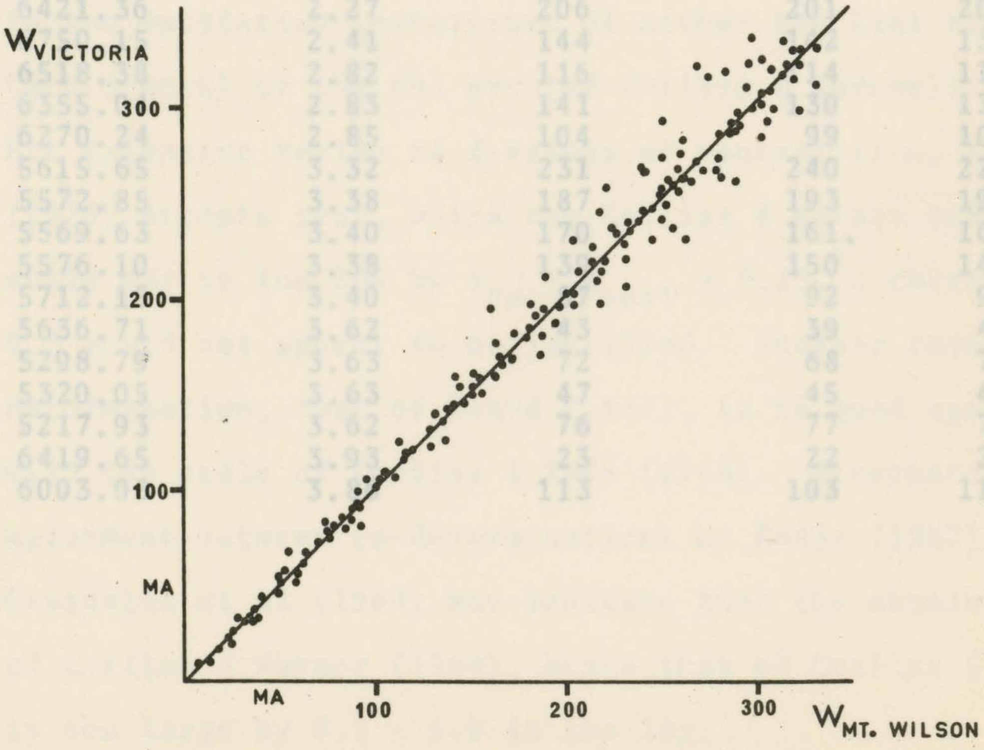

Figure 5(b). Comparison of Victoria and Mt. Wilson (Atlas) Intensities for Arcturus as measured in this investigation.

TABLE III

SAMPLE EQUIVALENT WIDTH MEASUREMENTS OF LINES OF NEUTRAL IRON (FOR ARCTURUS)

		Equivalent Widths (mA)		
Wavelength (Angstroms)	Low E.P. (eV)	Present Work D.A.O. tracings	Atlas	R. F. Griffin Atlas
5247.05	0.09	202	198	202
5225.53	0.11	212	204	190
5060.08	0.00	178	174	187
5328.04	0.91	610	574	584
5405.78	0.99	400	380	396
5446.92	0.99	430	385	398
5501.47	0.95	236	230	230
5497.52	1.01	261	245	248
5051.64	0.91	259	250	282
5083.34	0.95	226	230	221
5150.84	0.99	229	214	214
5145.11	2.19	141	136	149
5198.71	2.21	193	187	183
5049.83	2.27	242	234	206
6421.36	2.27	206	201	201
6750.15	2.41	144	142	138
6518.38	2.82	116	114	114
6355.04	2.83	141	130	130
6270.24	2.85	104	99	100
5615.65	3.32	231	240	223
5572.85	3.38	187	193	190
5569.63	3.40	170	161.	162
5576.10	3.38	139	150	145
5712.15	3.40	87	92	95
5636.71	3.62	43	39	45
5298.79	3.63	72	68	73
5320.05	3.63	47	45	43
5217.93	3.62	76	77	78
6419.65	3.93	23	22	27
6003.03	3.86	113	103	110

thus removing the error inherent in the high excitation lines in the earlier compilation. Recently there have been several re-determinations of the scale of f-values for Fe I; one of the latest being that of Garz & Kock (1969). Their work has been initially regarded with favor as application of the new scale to the sun (Garz et al, 1969) yields a solar iron abundance ten times greater than previously determined photospheric values. This new calculation, for the first time, results in an abundance which agrees with coronal abundance determinations. However Yamashita (1970) has observed, in a comparison of Garz & Kock's (1969) gf-values with those of Corliss & Warner (1964), that there is a strong dependence on the energy of the upper level from which the line originates. This observation suggests an error of approximately $\Delta\theta = 0.3$ in the excitation temperature of either the Kiel arc (of Garz & Kock) or the NBS arc (of Corliss & Warner). In his extensive review of f-values of neutral iron, Yamashita (1970) accepts that, while the Corliss & Warner temperature scale may be too low by $\theta_{cw} = \theta_{best} + 0.10$, a correction of 0.3 would not appear to be justified. Another recent determination, that of Byard (1967), is in good agreement with the scale of Corliss & Tech (1968). Alternately, good agreement between re-determinations by Roder (1962) and Grasdalen et al (1969) may indicate that the absolute scale of Corliss & Warner (1964), hence that of Corliss & Tech (1968), is too large by 0.5 - 1.0 in the log.

Thus, because of the present controversy and because of the lack of a definitive paper on this very critical topic, use has been made of the most complete set of gf-values to date; that of Corliss & Tech (1968)*. Table IV lists the sources of gf-values for the specific atoms considered in the present curve of growth study.

*NOTE: At the time of writing of this thesis, a communication received from Wares has indicated that the gf-values of Corliss & Tech (1968) for neutral iron contain a large energy-dependent error, in the sense that their absolute scale is too high by about 0.17 dex/volt ("dex" meaning "in the log"). This error is believed to arise from an incorrect furnace temperature used by King & King (1938), whose gf-values were heavily weighted in the compilation of Corliss & Warner (1964). Wares has also made known further re-determinations of the f-value scale for iron; including that of Wolnik et al (1970) and that of Bridges & Weise (1970), both of which are in agreement with the work of Garz & Kock (1969).

Further work is now needed to confirm the degree to which the f-values of Corliss & Tech (1968) are in error and to define a new scale of oscillator strengths for Fe I. Because of the most recent work, the results derived in this thesis based on neutral iron should be considered with some doubt. The excitation temperatures of Fe I may be too low by approximately $\Delta\theta = 0.15$ and abundances may be too low by about a factor of five (Wolnik et al, 1970).

At the present time however, the Corliss & Tech (1968) data seem to be the most consistent data for the range in wavelength and excitation potential considered in this work. Therefore, although they may require modification, they seem to be the best scale of f-values available.

TABLE IV

BIBLIOGRAPHY OF ABSOLUTE gf-VALUES

NEUTRAL ATOM	SOURCE(S) OF ABSOLUTE gf-VALUES
Hydrogen	Wiese et al (1968)
Sodium	Lambert & Warner (1968a)
Magnesium	Wiese et al (1969)
Aluminum	Wiese et al (1969)
Silicon	Lambert & Warner (1968b)
Calcium	Lambert & Warner (1968c)
Scandium	Corliss & Bozman (1962)
Titanium	Tatum (1961)
Vanadium	Corliss & Bozman (1962)
Chromium	Corliss & Bozman (1962)
Manganese	Corliss & Bozman (1962)
Iron	Corliss & Tech (1968)
Cobalt	Corliss & Bozman (1962)
Nickel	Corliss (1965)
Copper	Corliss & Bozman (1962)
Zinc	Corliss & Bozman (1962)
Strontium	Corliss & Bozman (1962)
Yttrium	Corliss & Bozman (1962)
Zirconium	Corliss & Bozman (1962)
Molybdenum	Corliss & Bozman (1962)
Barium	Corliss & Bozman (1962)
Ytterbium	Corliss & Bozman (1962)

IONIZED ATOM	SOURCE(S) OF ABSOLUTE gf-VALUES
Scandium	Warner (1968)
Titanium	Warner (1967), Warner (1968)
Vanadium	Warner (1968)
Chromium	Warner (1968)
Iron	Warner (1968)
Strontium	Corliss & Bozman (1962)
Yttrium	Corliss & Bozman (1962)
Zirconium	Corliss & Bozman (1962)
Barium	Lambert & Warner (1968c)
Lanthanum	Corliss & Bozman (1962)
Cerium	Corliss & Bozman (1962)
Praseodymium	Corliss & Bozman (1962)
Neodymium	Corliss & Bozman (1962)
Samarium	Corliss & Bozman (1962)
Europium	Corliss & Bozman (1962)
Gadolinium	Corliss & Bozman (1962)

CHAPTER 3

THE CALCULATIONS

3.1 Curves of Growth

Reference may be made to Wright (1948) and Ambartsumian (1958, page 147) or to most standard references in astrophysics for a theoretical discussion of the concept of a curve of growth and the principles underlying it. For the purposes of this thesis, it is sufficient to regard the theoretical curve of growth as a prediction as to how the equivalent width of a line, W, varies with $N_i f_{ik}$. This prediction is based on a specific model atmosphere, usually Milne-Eddington or Schuster-Schwarzchild (see Cowley 1970, page 66), and mechanism(s) of line formation, usually pure scattering or pure absorption (see Aller 1963, page 180). It is further assumed that there exists a specific value of the electron pressure and of the temperature that will adequately describe the state of ionization of each particular element and the coefficient of continuous absorption.

The theoretical curves of growth by Wrubel (1949), based on Chandrasekhar's (1947) exact solution of the equation of transfer for the Milne-Eddington model, are used throughout this thesis. Assumptions basic to this model are:

(1) that the ratio σ_ν/κ_ν of the line scattering coefficient to the continuous absorption coefficient is constant throughout the atmosphere, and,

(2) that the source function in the continuum is the Planck temperature function $B_\nu(T)$ which is a linear function of the optical depth τ_ν in the continuum,

$$\text{i.e.} \quad B_\nu(T) = B^0 + B^1\tau_\nu \tag{3.1.1}$$

The coefficients B^0 and B^1 give a measure of the limb darkening. They may be estimated for stars other than the sun (for which limb darkening is observed directly) from the relation (see Wright, 1950):

$$\frac{B^0}{B^1} = \frac{8\,k\,T_0\,\kappa_\nu}{3\,h\,\nu\,\bar{\kappa}}\,, \tag{3.1.2}$$

where k is Boltzmann's constant,

h is Planck's constant,

T_0 is the boundary temperature of the star,

$\bar{\kappa}$ is the mean coefficient of continuous absorption,

ν is the frequency of the observed line, and

κ_ν is the absorption coefficient in the neighborhood of the line.

Figure 6 illustrates Wrubel's curves of growth for $B^0/B^1 = 2/3$, the set of curves which has been used throughout this work. These curves of growth have been calculated in terms of log (W/b), where b is the Doppler width of the line:

$$b = \lambda\dot{v}/c \tag{3.1.3}$$

as a function of η_0 which, by definition, is given by the expression:

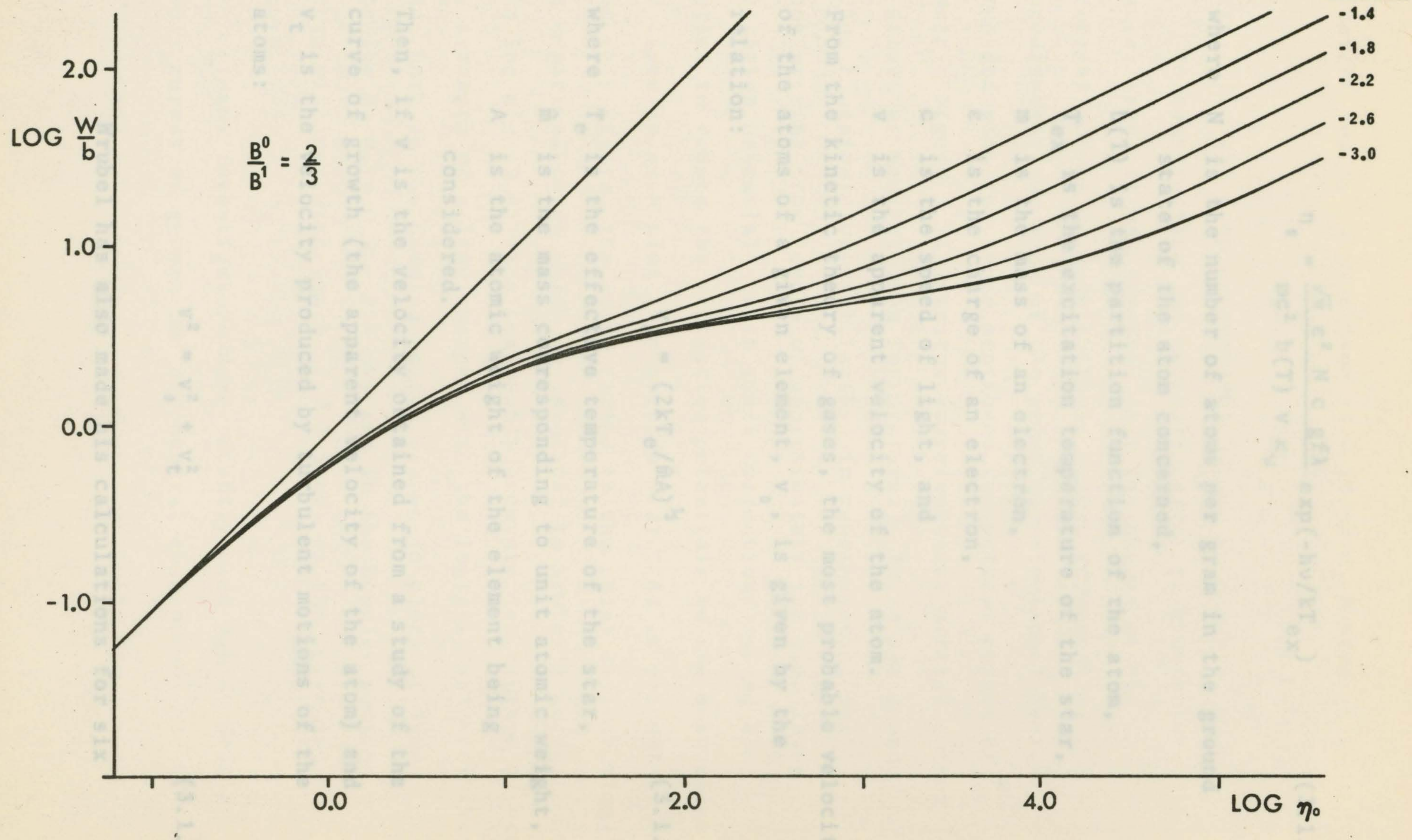

Figure 6. Wrubel's theoretical curves of growth based on the Milne-Eddington model.

$$\eta_0 = \frac{\sqrt{\pi}\,\varepsilon^2\,N\,c\,gf\lambda}{mc^2\,b(T)\,v\,\kappa_\nu}\exp(-h\nu/kT_{ex}) \qquad (3.1.4)$$

where N is the number of atoms per gram in the ground state of the atom concerned,
$b(T)$ is the partition function of the atom,
T_{ex} is the excitation temperature of the star,
m is the mass of an electron,
ε is the charge of an electron,
c is the speed of light, and
v is the apparent velocity of the atom.

From the kinetic theory of gases, the most probable velocity of the atoms of a given element, v_0, is given by the relation:

$$v_0 = (2kT_e/\hat{m}A)^{\frac{1}{2}} \qquad (3.1.5)$$

where T_e is the effective temperature of the star,
$\hat{m}$ is the mass corresponding to unit atomic weight, and
A is the atomic weight of the element being considered.

Then, if v is the velocity obtained from a study of the curve of growth (the apparent velocity of the atom) and v_t is the velocity produced by turbulent motions of the atoms:

$$v^2 = v_0^2 + v_t^2 \qquad (3.1.6)$$

Wrubel has also made his calculations for six values of log a, ranging from -1.0 to -3.0, where:

$$a = \frac{\Gamma\lambda}{4\pi v} \qquad (3.1.7)$$

where Γ is the damping constant.

In constructing the absolute curves of growth for neutral iron, it was observed that the shapes of the empirical curves of growth (those curves representing approximately the mean of the point distributions) best coincided with the above mentioned theoretical curves of growth. Figure 7 illustrates representative partial curves of growth of neutral iron for Arcturus. These are graphs of log F against log(gfλ), (with λ in centimeters), for lines arising from levels of approximately the same lower excitation potential - with small corrections having been applied to reduce the excitation potentials to the mean value for lines in each plot (see Section 3.2). As is evident from this figure, the curve fitted to the point distributions (an empirical curve which is identical to Wrubel's curve with log a = -2.0) is a reasonably accurate description of how the strength of a line changes with the log(gfλ) value of that line, both in the damping region (shown in plots of lines with low E. P. = 0.9 - 2.4 eV) and in the Doppler section (plots of lines with low E. P. ≥ 3.5 eV) of the curve of growth.

Many investigators have recently used van de Held's (1931) curves of growth for exponential absorption -

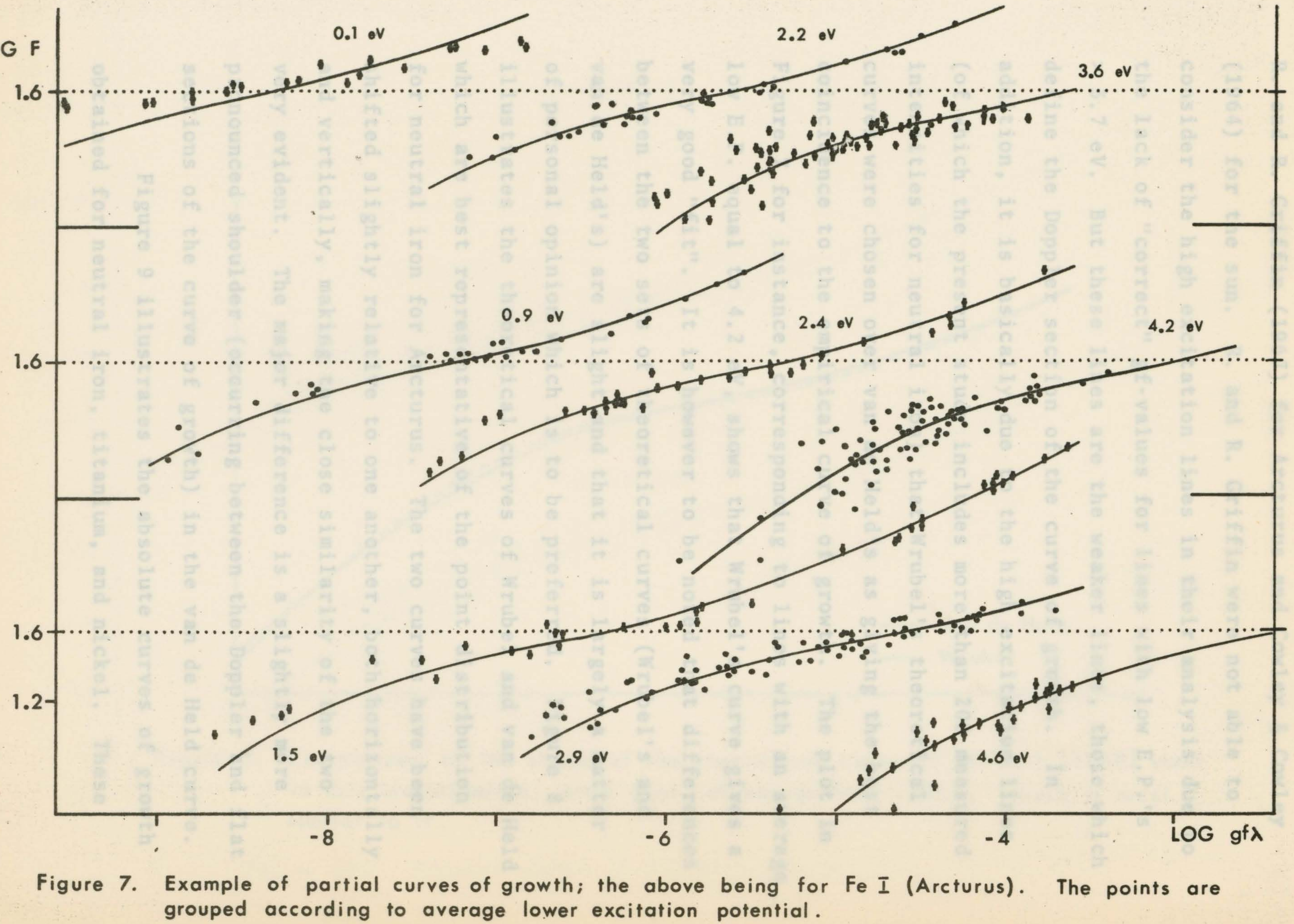

Figure 7. Example of partial curves of growth; the above being for Fe I (Arcturus). The points are grouped according to average lower excitation potential.

R. and R. Griffin (1967) for Arcturus and Cowley & Cowley (1964) for the sun. R. and R. Griffin were not able to consider the high excitation lines in their analysis due to the lack of "correct" gf-values for lines with low E.P.'s > 3.7 eV. But these lines are the weaker lines, those which define the Doppler section of the curve of growth. In addition, it is basically due to the high excitation lines (of which the present study includes more than 200 measured intensities for neutral iron) that Wrubel's theoretical curves were chosen over van de Held's as giving the best coincidence to the empirical curve of growth. The plot in Figure 7 for instance, corresponding to lines with an average low E.P. equal to 4.2 eV, shows that Wrubel's curve gives a very good "fit". It is however to be noted that differences between the two sets of theoretical curves (Wrubel's and van de Held's) are slight and that it is largely a matter of personal opinion which is to be preferred. Figure 8 illustrates the theoretical curves of Wrubel and van de Held which are best representative of the point distribution for neutral iron for Arcturus. The two curves have been shifted slightly relative to one another, both horizontally and vertically, making the close similarity of the two very evident. The major difference is a slightly more pronounced shoulder (occurring between the Doppler and flat sections of the curve of growth) in the van de Held curve.

Figure 9 illustrates the absolute curves of growth obtained for neutral iron, titanium, and nickel. These

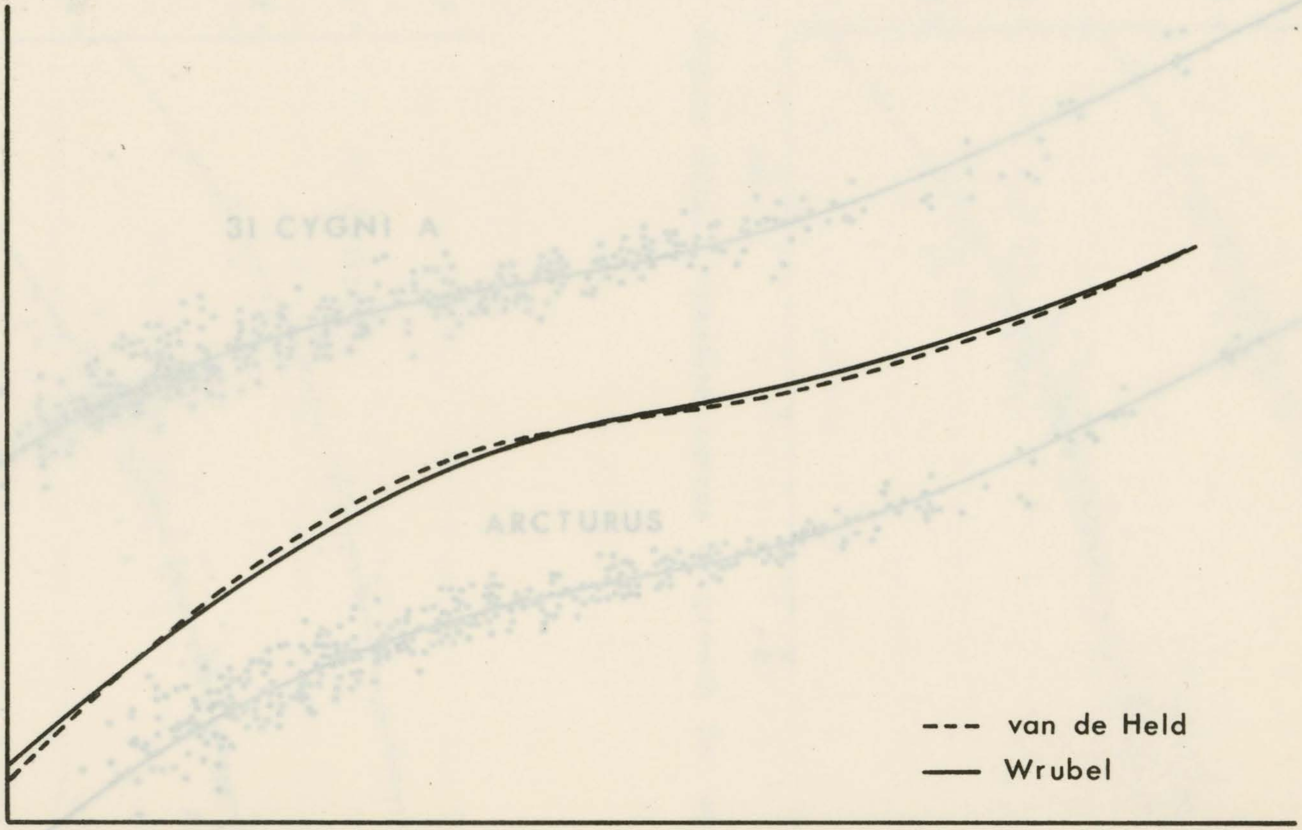

Figure 8. Comparison of the shape of the theoretical curve of Wrubel (1949) used in this investigation, with that, of van de Held (1931), which is most similar to it.

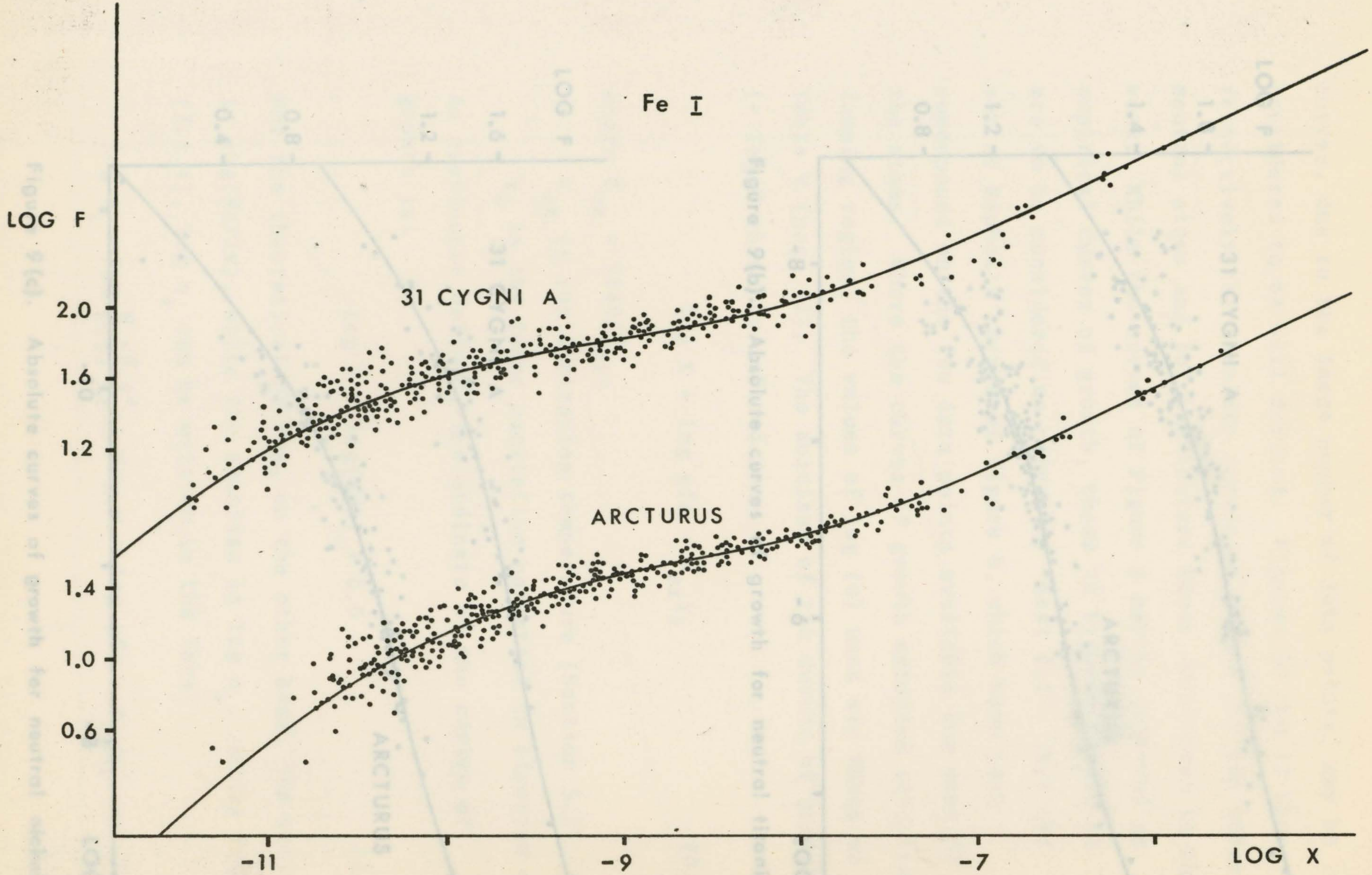

Figure 9(a). Absolute curves of growth for neutral iron.

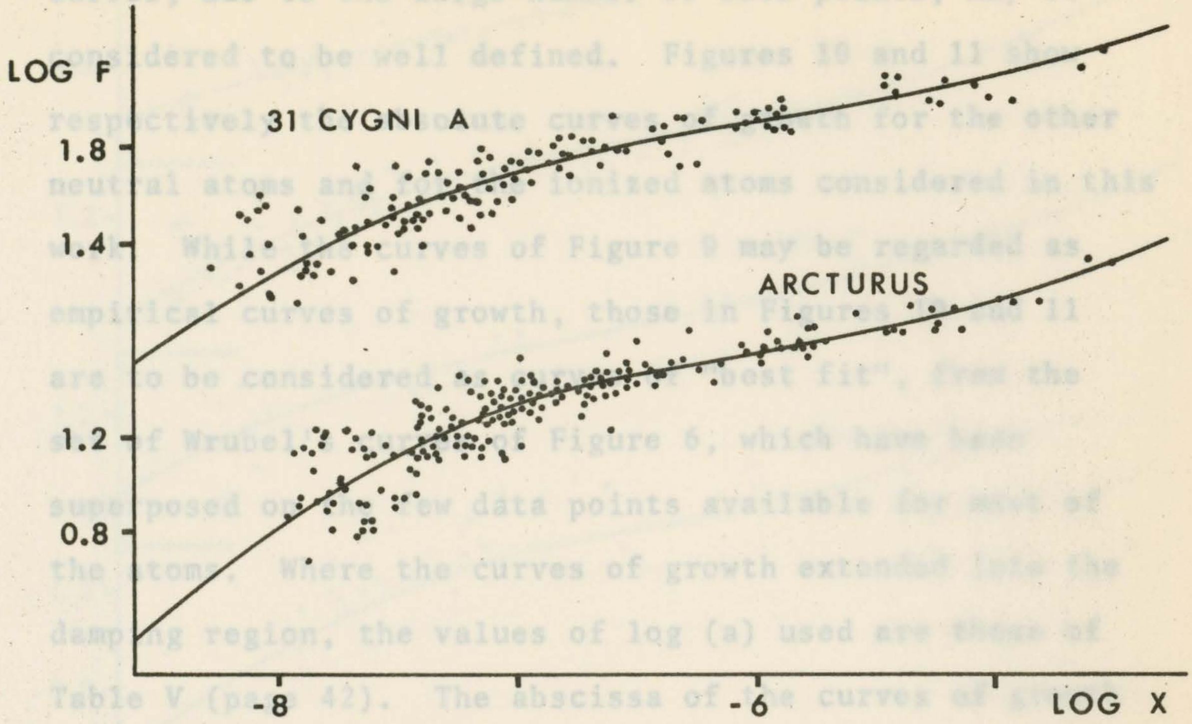

Figure 9(b). Absolute curves of growth for neutral titanium.

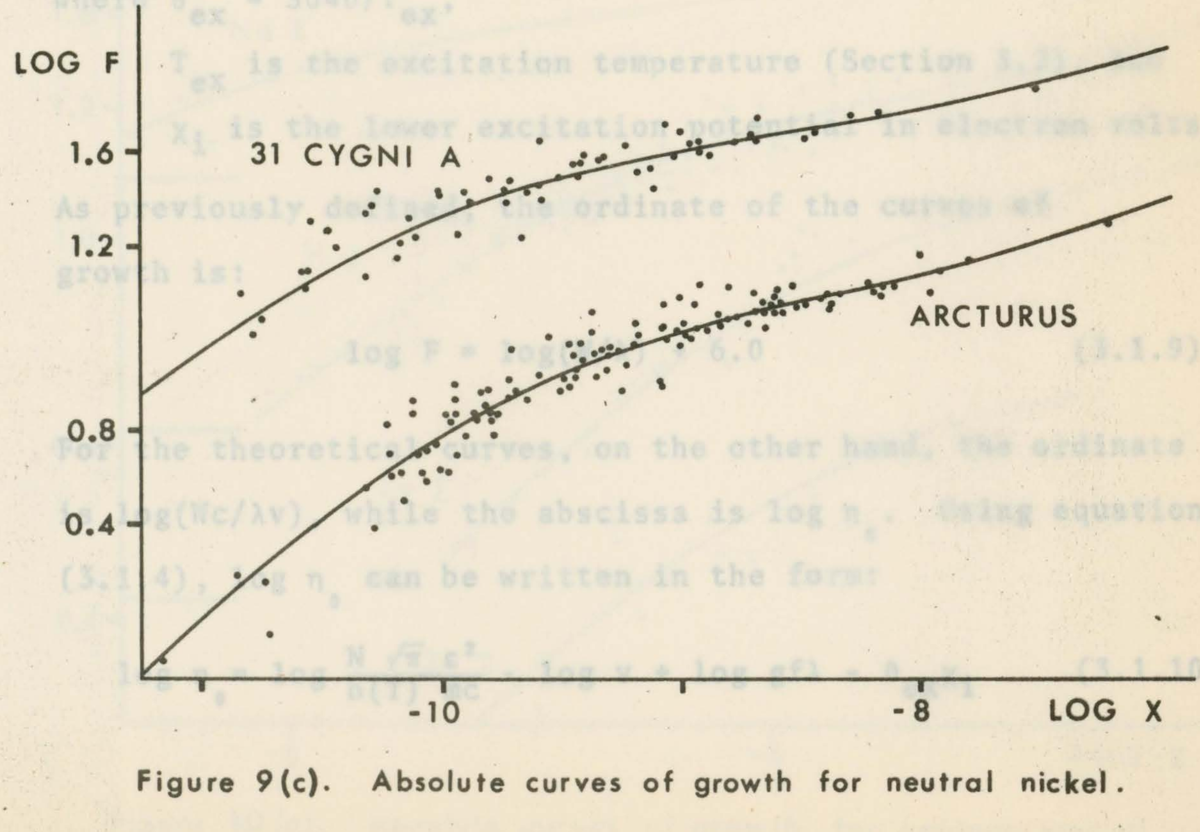

Figure 9(c). Absolute curves of growth for neutral nickel.

curves, due to the large number of data points, may be considered to be well defined. Figures 10 and 11 show respectively the absolute curves of growth for the other neutral atoms and for the ionized atoms considered in this work. While the curves of Figure 9 may be regarded as empirical curves of growth, those in Figures 10 and 11 are to be considered as curves of "best fit", from the set of Wrubel's curves of Figure 6, which have been superposed on the few data points available for most of the atoms. Where the curves of growth extended into the damping region, the values of log (a) used are those of Table V (page 42). The abscissa of the curves of growth is log X which is defined as:

$$\log X = \log gf\lambda - \theta_{ex}\chi_i \tag{3.1.8}$$

where $\theta_{ex} = 5040/T_{ex}$,

T_{ex} is the excitation temperature (Section 3.2), and

χ_i is the lower excitation potential in electron volts.

As previously defined, the ordinate of the curves of growth is:

$$\log F = \log(W/\lambda) + 6.0 \tag{3.1.9}$$

For the theoretical curves, on the other hand, the ordinate is $\log(Wc/\lambda v)$, while the abscissa is $\log \eta_0$. Using equation (3.1.4), $\log \eta_0$ can be written in the form:

$$\log \eta_0 = \log \frac{N\sqrt{\pi}\,\varepsilon^2}{b(T)\,mc} - \log v + \log gf\lambda - \theta_{ex}\chi_i \tag{3.1.10}$$

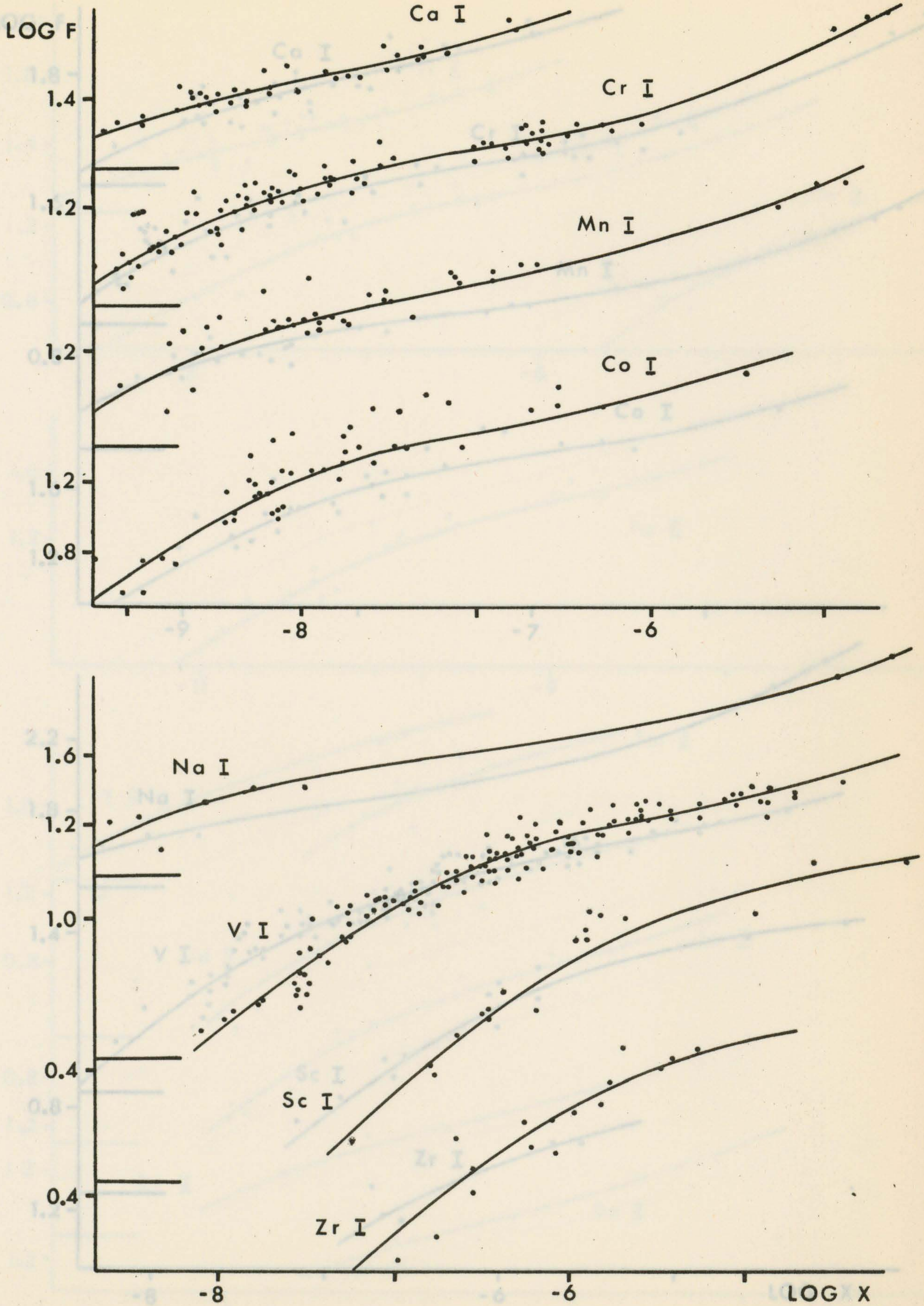

Figure 10 (a). Absolute curves of growth for various neutral elements of Arcturus.

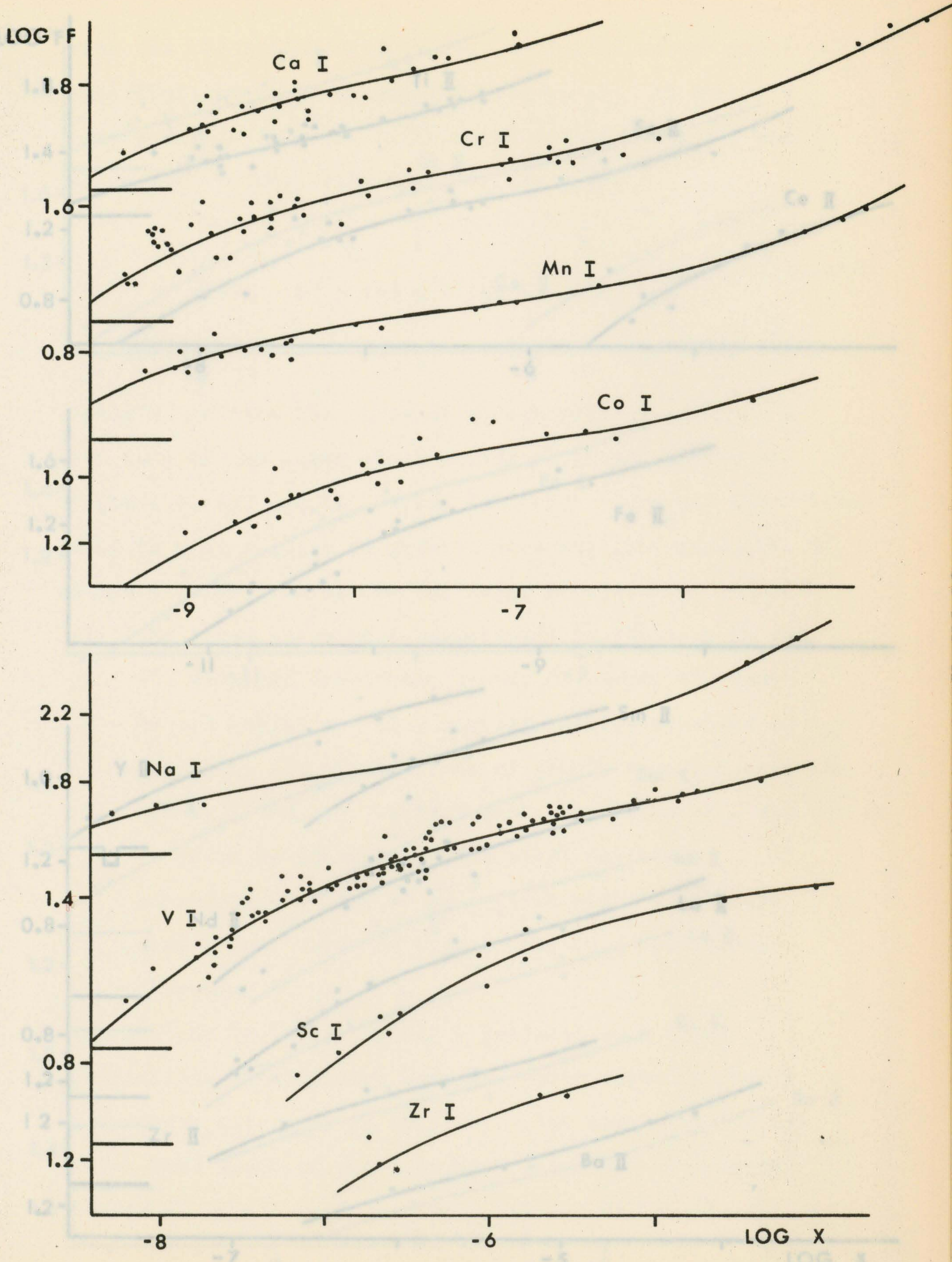

Figure 10 (b). Absolute curves of growth for various neutral elements of 31 Cygni A.

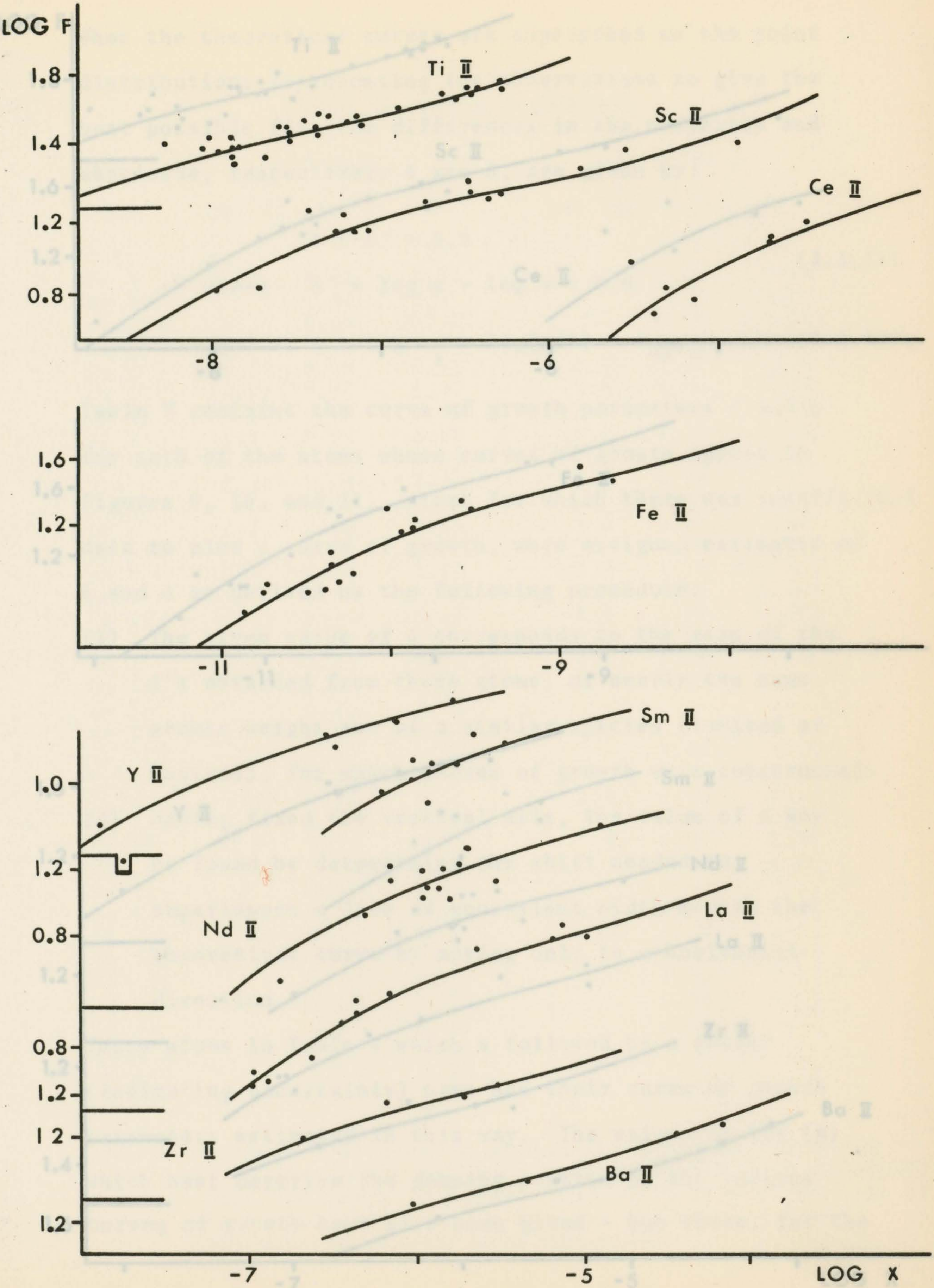

Figure 11(a). Absolute curves of growth for ionized elements of Arcturus.

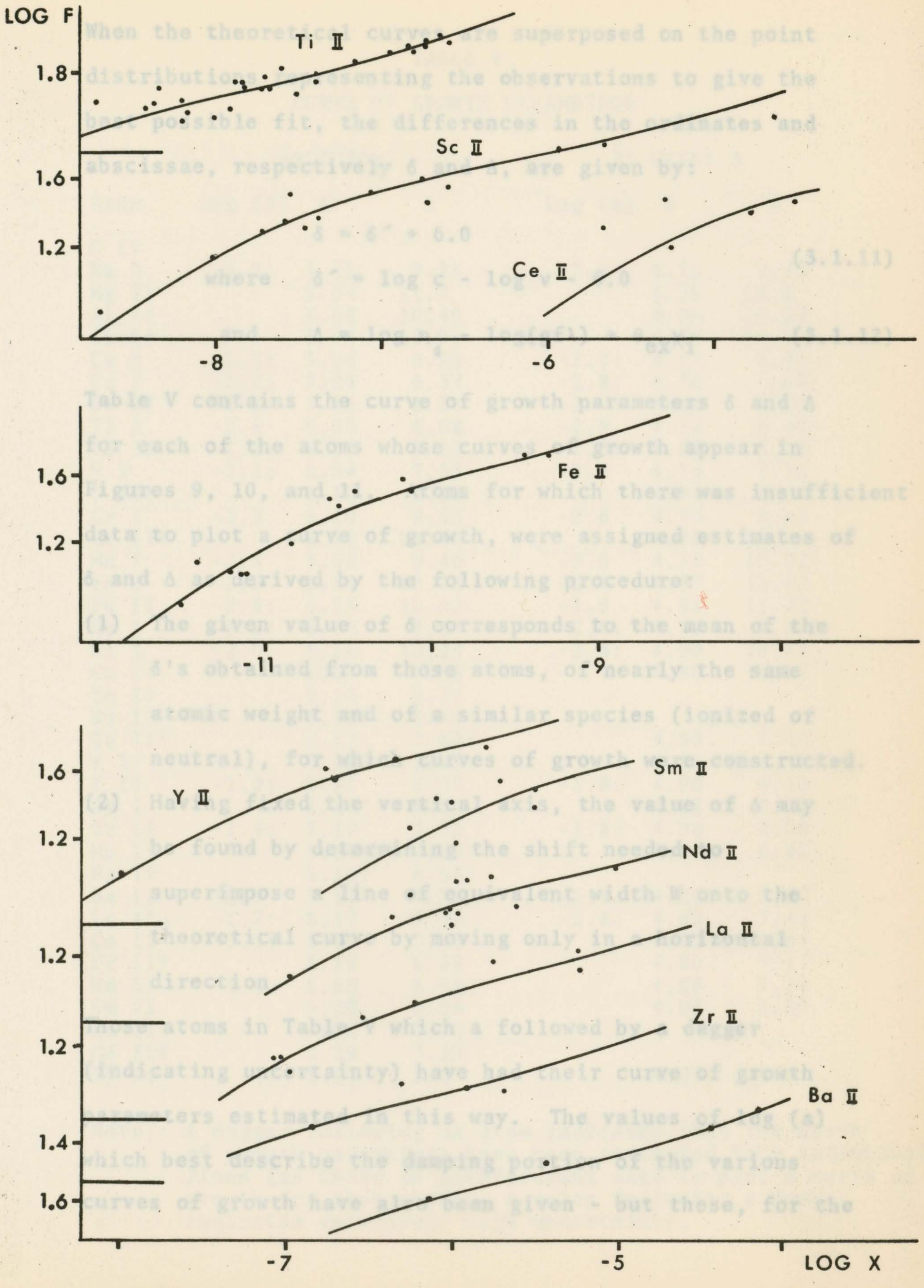

Figure 11(b). Absolute curves of growth for ionized elements of 31 Cygni A.

When the theoretical curves are superposed on the point distributions representing the observations to give the best possible fit, the differences in the ordinates and abscissae, respectively δ and Δ, are given by:

$$\delta = \delta' + 6.0 \quad \text{where} \quad \delta' = \log c - \log v - 6.0 \qquad (3.1.11)$$

$$\text{and} \quad \Delta = \log \eta_0 - \log(gf\lambda) + \theta_{ex}\chi_i \qquad (3.1.12)$$

Table V contains the curve of growth parameters δ and Δ for each of the atoms whose curves of growth appear in Figures 9, 10, and 11. Atoms for which there was insufficient data to plot a curve of growth, were assigned estimates of δ and Δ as derived by the following procedure:

(1) The given value of δ corresponds to the mean of the δ's obtained from those atoms, of nearly the same atomic weight and of a similar species (ionized or neutral), for which curves of growth were constructed.

(2) Having fixed the vertical axis, the value of Δ may be found by determining the shift needed to superimpose a line of equivalent width W onto the theoretical curve by moving only in a horizontal direction.

Those atoms in Table V which a followed by a dagger (indicating uncertainty) have had their curve of growth parameters estimated in this way. The values of log (a) which best describe the damping portion of the various curves of growth have also been given - but these, for the

TABLE V

CURVE OF GROWTH PARAMETERS

	ARCTURUS			31 CYGNI A		
Atom	Log (a)	δ	Δ	Log (a)	δ	Δ
H I†						
Na I	-3.2	5.01	9.26	-2.9	4.76	9.43
Mg I†		5.04	12.2		4.76	12.9
Al I†		5.04	10.40		4.76	10.57
Si I†		5.04	12.96		4.76	13.33
Ca I	-2.2:	5.04	9.95	-2.2:	4.77	9.95
Sc I	-2.2:	5.04	6.37	-2.8:	4.76	6.68
Sc II	-2.2:	5.15	8.30	-2.0:	4.90	8.40
Ti I	-2.2	5.00	8.08	-2.6	4.71	8.32
Ti II	-2.2:	5.15	9.62	-2.0:	4.85	9.66
V I	-2.2:	5.04	7.53	-2.6	4.74	7.75
V II†		5.15	9.25		4.90	9.40
Cr I	*-2.3*	*5.10*	*9.33*	*-2.6*	*4.76*	*9.62*
Cr II†		*5.15*	*10.80*		*4.90*	*11.08*
Mn I	-2.4	5.05	9.40	-3.0	4.78	10.02
Fe I	-2.0	5.06	10.75	-2.4	4.77	11.40
Fe II	-1.8:	5.15	10.92	-1.8	4.91	11.32
Co I	-2.2:	5.07	8.67	-2.6:	4.80	9.34
Ni I	-2.0	5.16	10.24	-2.6:	4.90	10.84
Cu I†		5.10	9.65		4.80	10.02
Zn I†		5.10	9.75			
Sr I†		5.10:	6.40:			
Sr II†		5.17:	7.60:		4.90:	7.40:
Y I†		5.10:	5.85:		4.80:	6.18:
Y II	-1.9:	5.17	8.00	-1.8:	4.90	8.10
Zr I		5.12	6.38		4.82	7.02
Zr II	-1.8:	5.17	7.72	-1.8:	4.90	8.08
Mo I†		5.10:	6.20:		4.80:	6.85:
Ba I†		5.10:	4.55:			
Ba II	-1.9	5.17	7.50	-1.8:	4.86	7.67
La II	-1.7:	5.17	6.98	-1.8:	4.90	7.40
Ce II	-1.8:	5.19	5.52		4.90	5.92
Pr II†		5.19	6.85		4.90	7.17
Nd II	-1.8:	5.20	6.95		4.90	7.26
Sm II		5.20	6.68		4.91	6.80
Eu II†		5.20	7.70			
Gd II†		5.20	7.10			
Yb I†		5.10	5.6		4.80	5.4

Note: A dagger following an atom indicates that the curve of growth parameters have been estimated from individual lines (as there is insufficient data to plot a curve of growth for that atom). A colon following a number indicates relatively high uncertainty.

most part, are uncertain because of the lack of sufficient data for most atoms.

3.2 Excitation Temperatures

The excitation temperature, as derived from a specific atom, is determined from the relative shift between the abscissa of the theoretical curve and that for the plot for each excitation potential. Such a shift, $\Delta\log X$, is given by:

$$\Delta\log X = \log \eta_0 - \log(gf\lambda) \qquad (3.2.1)$$

Assuming little or no variation in turbulent velocity with excitation potential, using equation (3.1.10), one has:

$$\Delta\log X = \text{Constant} - \theta_{ex}\chi_i \qquad (3.2.2)$$

Figure 7 illustrates the relative horizontal shifts of multiplets which are grouped according to lower excitation potential. The curves through the point distributions cross the reference ordinate $\log F = 1.6$ (for example) at progressively larger values of the abscissa as the average excitation potential increases. The excitation temperature is determined by plotting the relative horizontal shifts against the average lower excitation potential of the multiplets; the gradient of the best straight line through the points (by equation (3.2.2)) giving $5040/T_{ex}$. Figure 12 shows the plots for neutral iron and titanium; Table VI gives the resulting excitation temperatures.

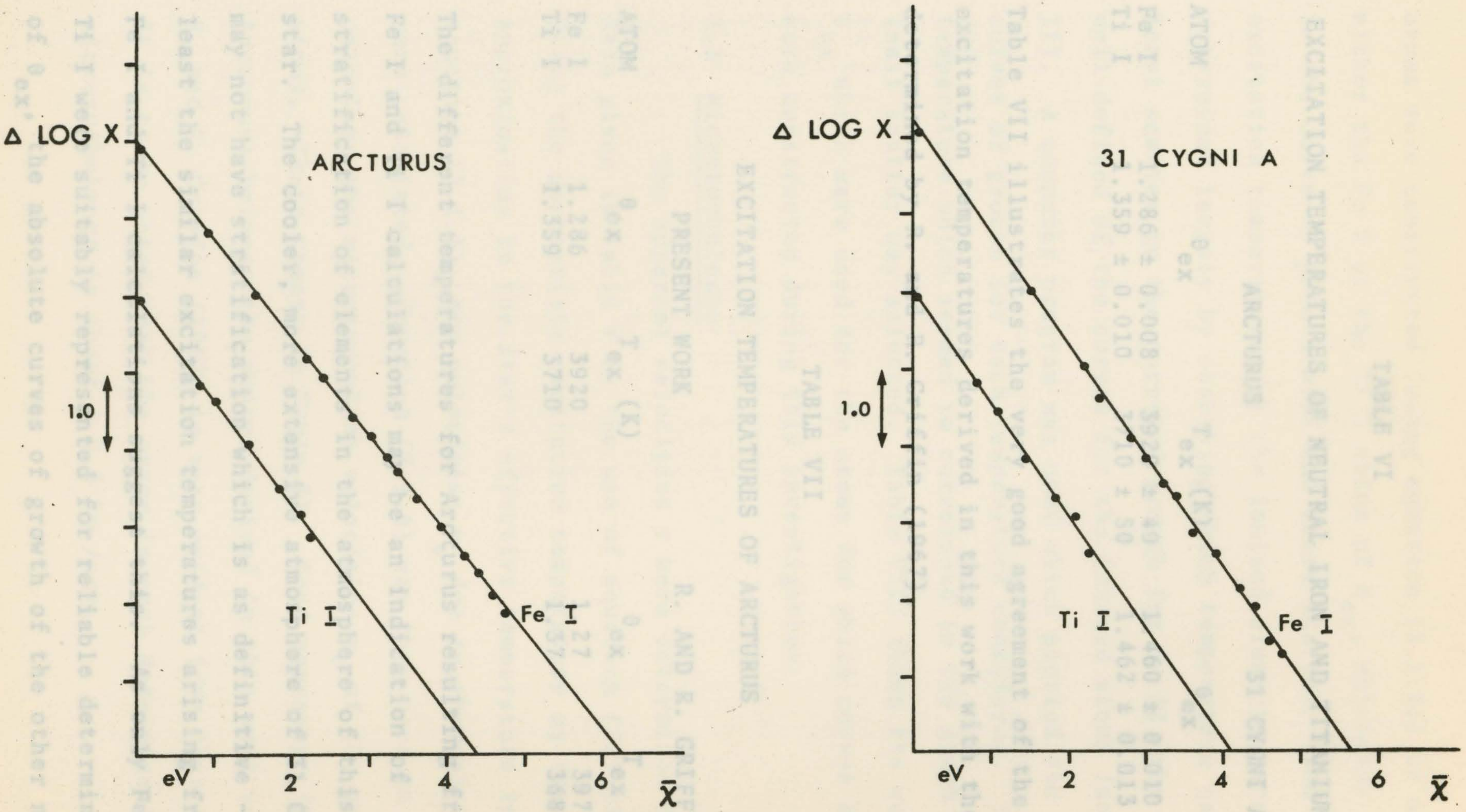

Figure 12. Curve-of-growth shifts for Ti I and Fe I plotted against average excitation potential. The gradients of the straight lines (least squares solutions) give θ_{exc}.

TABLE VI

EXCITATION TEMPERATURES OF NEUTRAL IRON AND TITANIUM

ATOM	ARCTURUS θ_{ex}	 T_{ex} (K)	31 CYGNI A θ_{ex}	 T_{ex} (K)
Fe I	1.286 ± 0.008	3920 ± 40	1.460 ± 0.010	3450 ± 50
Ti I	1.359 ± 0.010	3710 ± 50	1.462 ± 0.013	3450 ± 70

Table VII illustrates the very good agreement of the excitation temperatures derived in this work with those determined by R. and R. Griffin (1967).

TABLE VII

EXCITATION TEMPERATURES OF ARCTURUS

ATOM	PRESENT WORK θ_{ex}	 T_{ex} (K)	R. AND R. GRIFFIN (1967) θ_{ex}	 T_{ex} (K)
Fe I	1.286	3920	1.27	3970
Ti I	1.359	3710	1.37	3680

The different temperatures for Arcturus resulting from the Fe I and Ti I calculations may be an indication of stratification of elements in the atmosphere of this giant star. The cooler, more extensive atmosphere of 31 Cygni A may not have stratification which is as definitive - at least the similar excitation temperatures arising from the Fe I and Ti I calculations suggest this. As only Fe I and Ti I were suitably represented for reliable determinations of θ_{ex}, the absolute curves of growth of the other neutral atoms were constructed (using equation (3.1.8)) by using either the Fe I or the Ti I value of θ_{ex}, whichever resulted in the curve of growth with the least scatter. The excitation temperatures of the ionized elements were determined largely by observing which temperature gave the least scatter to the curve of growth for Sc II, the most well-defined of the curves for the ionized atoms (see Figure 11). A computer program was used which plotted the absolute curves of growth for each temperature considered. The temperature which seemed to correspond to the graph with the least scatter was selected. Table VIII shows the values of θ_{ex} which were used for the atoms for which curves of growth were constructed during this investigation.

3.3 Microturbulence

The apparent velocities v were determined from the data given in Table V by the use of equation (3.1.11). Using the appropriate excitation temperature as the best approximation to the star's effective temperature in equation (3.1.5), the velocities v_0 due to thermal motion were calculated. Equation (3.1.6) was then used to calculate the microturbulent velocities v_t of the various atoms. These appear in Table IX. Good agreement (for Arcturus) between the values derived in this work and by R. and R. Griffin (1967) is also evident from this table. It is to be noted that the error in each determination of microturbulence is about ± 0.3 km./sec.

TABLE VIII

VALUES OF θ_{ex} USED FOR VARIOUS ATOMS OF ARCTURUS AND 31 CYGNI A

	ARCTURUS		31 CYGNI A
ATOM	DAVB*	RRG†	DAVB*
Na I	1.36	1.37	1.46
Ca I	1.36	1.37	1.46
Sc I	1.36	1.37	1.46
Sc II	1.20	1.20	1.41
Ti I	1.359	1.37	1.462
Ti II	1.20	1.20	1.41
V I	1.36	1.37	1.46
Cr I	1.36	1.37	1.46
Mn I	1.29	1.30	1.46
Fe I	1.286	1.27	1.460
Fe II	1.20	1.20	1.41
Co I	1.29	1.27	1.46
Ni I	1.29	1.27	1.46
Y II	1.20	1.20	1.41
Zr I	1.29	1.37	1.46
Zr II	1.20	1.20	1.41
Ba II	1.20		1.41
La II	1.20		1.41
Ce II	1.20	1.20	1.41
Nd II	1.20	1.20	1.41
Sm II	1.20		1.41

*Results derived during the course of this project.

†Results derived by R. and R. Griffin (1967).

TABLE IX

MICROTURBULENT VELOCITIES OF VARIOUS ATOMS OF ARCTURUS AND 31 CYGNI A

	ARCTURUS		31 CYGNI A
ATOM	DAVB*	RRG†	DAVB*
Na I	2.4	2.2	5.0
Ca I	2.4	2.2	5.0
Sc I	2.5	2.2	5.1
Sc II	1.7	1.7	3.6
Ti I	2.7	2.2	5.6
Ti II	1.8	1.7	4.1
V I	2.5	2.2	5.4
Cr I	2.1	1.9	5.1
Mn I	2.4	2.2	4.9
Fe I	2.4	2.2	5.0
Fe II	1.8	1.5	3.5
Co I	2.3	2.0	4.7
Ni I	1.8	1.7	3.6
Y II	1.8	1.6	3.7
Zr I	2.1	1.5:	4.5
Zr II	1.8	1.5	3.7
Ba II	1.8		4.0
La II	1.9		3.7
Ce II	1.8	1.7	3.7:
Nd II	1.8	1.7	3.7
Sm II	1.8:		3.6:

*Results derived during the course of this work.

†Results derived by R. and R. Griffin (1967).

A colon following a number indicates relatively high uncertainty.

3.4 Ionization Temperatures and Electron Pressures

Following Unsold (1955, page 431) and Wright (1959), Saha's equation:

$$\frac{N_1}{N_0} P_e = \frac{b_1(T)\ \sqrt{(2\pi m)^3}\ \sqrt{(kT_i)^5}}{b_0(T)\qquad h^3} \exp(-\chi_0/kT_i) \qquad (3.4.1)$$

where N_0 is the number of neutral atoms observed,

N_1 is the number of ionized atoms observed,

P_e is the electron pressure,

T_i is the ionization temperature,

$b_0(T)$ is the partition function of the neutral atom,

$b_1(T)$ is the partition function of the ionized atom,

χ_0 is the ionization potential of the neutral atom;

and Boltzmann's equations:

$$\frac{N_{1,t}}{N_1} = \frac{g_{1,t}}{b_1(T)} \exp(-\chi_{1,t}/kT) \qquad (3.4.2)$$

$$\frac{N_{0,s}}{N_0} = \frac{g_{0,s}}{b_0(T)} \exp(-\chi_{0,s}/kT) \qquad (3.4.3)$$

where $N_{1,t}$ and $N_{0,s}$ are the number of ionized and neutral atoms in excited states t and s of excitation potentials $\chi_{1,t}$ and $\chi_{0,s}$ respectively, and $g_{1,t}$ and $g_{0,s}$ are the statistical weights of these states,

may be combined to give:

$$\log \frac{N_{1,t}/g_{1,t}}{N_{0,s}/g_{0,s}} = \theta_i\{\bar{\chi} - (\chi_0 + \chi_{1,t} - \chi_{0,s})\} + \log 2 \quad (3.4.4)$$

where $$\bar{\chi} = (2.5\log T_i - 0.48 - \log P_e)/\theta_i \quad (3.4.5)$$

and $\theta_i = 5040/T_i$.

Measurements of spectral lines of atoms in both neutral and ionized states were made for scandium, titanium, vanadium, chromium, iron, yttrium, and zirconium. The data for solving equation (3.4.4) are presented in Tables X and XI where the terms of equation (3.4.4) have been simplified as follows:

$$A = \log N_{1,t} - \log g_{1,t} - \log N_{0,s} + \log g_{0,s} \quad (3.4.6)$$

and $$B = \chi_0 + \chi_{1,t} - \chi_{0,s} \quad (3.4.7)$$

Using equations (3.1.10), (3.1.11), and (3.1.12); substituting numerical values for the various constants; and following Wright (1959); the following is obtained:

$$\log \frac{N_{1,t}}{g_{1,t}} \text{ or } \log \frac{N_{0,s}}{g_{0,s}} = \Delta - \delta + \theta_i\chi_i + 12.30 \quad (3.4.8)$$

The values of the first ionization potentials, χ_0, have been taken from Aller (1963, page 114). The data of Table X have been plotted in Figure 13 where A has been plotted against B - the gradient of the best straight line through

TABLE X

PRELIMINARY DATA FOR CALCULATION OF IONIZATION TEMPERATURES

ATOM STATE	$\frac{\chi_0}{\chi_{1,t},\ \chi_{0,s}}$	LOG $N_{1,t}/g_{1,t}$ or LOG $N_{0,s}/g_{0,s}$	
		ARCTURUS	31 CYGNI A
Sc I	6.54		
a^{2}D	0.01	13.62	14.21
a^{4}F	1.44	11.67	12.12
Sc II			
a^{1}D	0.31	15.09	15.36
a^{3}F	0.61	14.72	14.94
a^{3}P	1.51	13.64	13.67
Ti I	6.82		
a^{3}F	0.02	15.36	15.88
a^{5}F	0.82	14.26	14.71
a^{3}P	1.06	13.94	14.36
b^{3}F	1.44	13.42	13.81
a^{5}P	1.73	13.03	13.38
a^{3}G	1.87	12.84	13.18
Ti II			
a^{2}F	0.60	16.05	16.26
a^{2}D, a^{2}G	1.13	15.41	15.52
a^{2}P	1.23	15.29	15.38
b^{2}D, a^{2}H	1.57	14.89	14.90
b^{2}P	2.06	14.30	14.21
V I	6.74		
a^{4}F	0.04	14.74	15.25
a^{6}D	0.29	14.40	14.89
a^{4}D	1.05	13.36	13.83
a^{4}H	1.86	12.26	12.69
V II			
a^{3}P	1.45	14.64	14.76
Cr I	6.76		
a^{7}S	0.00	16.53	17.16
a^{5}S	0.98	15.20	15.73
a^{5}G	2.52	13.09	13.47
a^{5}P	2.70	12.86	13.22
a^{3}G, a^{3}F	3.09	12.33	12.65

TABLE X (continued)

ATOM STATE	χ_0 $\chi_{1,t}$, $\chi_{0,s}$	LOG $N_{1,t}/g_{1,t}$ or LOG $N_{0,s}/g_{0,s}$ ARCTURUS	 31 CYGNI A
Cr II			
b^4P, b^4F	3.83	13.34	13.01
b^4G	4.12	13.00	12.64
Fe I	7.87		
a^5D	0.06	17.92	18.84
a^5F	0.96	16.76	17.53
a^3F	1.55	16.00	16.67
a^5P	2.19	15.15	15.73
z^7D	2.45	14.84	15.35
b^3F	2.58	14.67	15.16
z^7F	2.84	14.34	14.78
z^5D	3.25	13.81	14.19
z^5P, b^3D	3.63	13.32	13.63
z^5F	3.91	12.96	13.22
y^5F	4.25	12.52	12.73
y^3F, y^5P	4.57	12.11	12.26
y^3D	4.71	11.93	12.05
Fe II			
b^4P	2.58	14.97	15.05
b^4F, a^6S	2.86	14.64	14.68
a^4G	3.19	14.24	14.21
b^4D	3.88	13.41	13.24
Y I	6.38		
a^2D	0.03	13.06	13.67
a^4F	1.35	11.22	11.81
Y II			
a^3D	0.13	14.97	15.46
a^3F	1.03	13.89	14.05
Zr I	6.84		
a^3F	0.07	13.47	14.40
a^5F	0.66	12.71	13.54
Zr II			
a^2D	0.54	14.20	14.72
a^2F	0.71	14.00	14.48

TABLE XI

DATA FOR CALCULATION OF IONIZATION TEMPERATURES

ATOMS STATES	B†	A*	
		ARCTURUS	31 CYGNI A
Sc II/Sc I			
a^1D/a^2D	6.84	1.47	1.15
a^1D/a^4F	5.41	3.42	3.24
a^3F/a^2D	7.14	1.10	0.73
a^3F/a^4F	5.71	3.05	2.82
a^3P/a^2D	8.04	0.02	-0.54
a^3P/a^4F	6.61	1.97	1.55
Ti II/ Ti I			
a^2F/a^3F	7.40	0.69	0.38
a^2F/a^5F	6.60	1.79	1.55
a^2F/a^3P	6.36	2.11	1.90
a^2F/a^5P	5.69	3.02	2.88
a^2P/a^3F	8.03	-0.07	-0.50
a^2P/a^3P	6.99	1.35	1.02
a^2P/a^5P	6.32	2.26	2.00
a^2P/a^3G	6.18	2.45	2.20
b^2P/a^3F	8.86	-1.06	-1.67
b^2P/a^3P	7.82	0.32	-0.15
b^2P/a^5P	7.15	1.27	0.83
V II/V I			
a^3P/a^4F	8.15	-0.10	-0.49
a^3P/a^6D	7.90	0.24	-0.13
a^3P/a^4D	7.14	1.28	0.93
a^3P/a^4H	6.33	2.38	2.07
Cr II/Cr I			
b^4P/a^7S	10.59	-3.19	-4.15
b^4P/a^5S	9.61	-1.86	-2.72
b^4P/a^5P	7.89	0.25	-0.21
b^4G/a^7S	10.88	-3.53	-4.52
b^4G/a^5S	9.90	-2.20	-3.09
b^4G/a^5G	8.35	-0.09	-0.83
b^4G/a^3G	7.79	0.67	-0.01
Fe II/Fe I			
b^4P/a^5D	10.39	-2.95	-3.77
b^4P/a^5F	9.49	-1.79	-2.46
b^4P/a^3F	8.90	-1.03	-1.60
b^4P/b^3F	7.87	0.30	-0.09

TABLE XI (continued)

ATOMS STATES	B†	A* ARCTURUS	 31 CYGNI A
Fe II/Fe I (cont.)			
b^4P/z^5D	7.20	1.16	0.88
b^4F/a^5F	9.77	-2.12	-2.85
b^4F/a^5P	8.54	-0.53	-1.04
b^4F/b^3F	8.15	-0.03	-0.48
b^4F/z^3F	6.82	1.68	1.36
b^4F/y^3D	6.02	2.71	2.63
a^4G/a^5D	11.00	-3.68	-4.63
a^4G/a^3F	9.51	-1.76	-2.46
a^4G/z^7D	8.61	-0.60	-1.14
b^4D/a^5F	10.79	-3.35	-4.28
b^4D/z^7D	9.30	-1.43	-2.11
Y II/Y I			
a^3D/a^2D	6.48	1.91	1.79
a^3D/a^4F	5.16	3.75	3.65
a^3F/a^2D	7.38	0.83	0.38
a^3F/a^4F	6.06	2.67	2.24
Zr II/Zr I			
a^2D/a^3F	7.31	0.83	0.32
a^2D/a^5F	6.72	1.49	1.18
a^2F/a^3F	7.48	0.53	0.08
a^2F/a^5F	6.89	1.29	0.94

* $A = \log N_{1,t} - \log g_{1,t} - \log N_{0,s} + \log g_{0,s}$.

† $B = \chi_0 + \chi_{1,t} - \chi_{0,s}$.

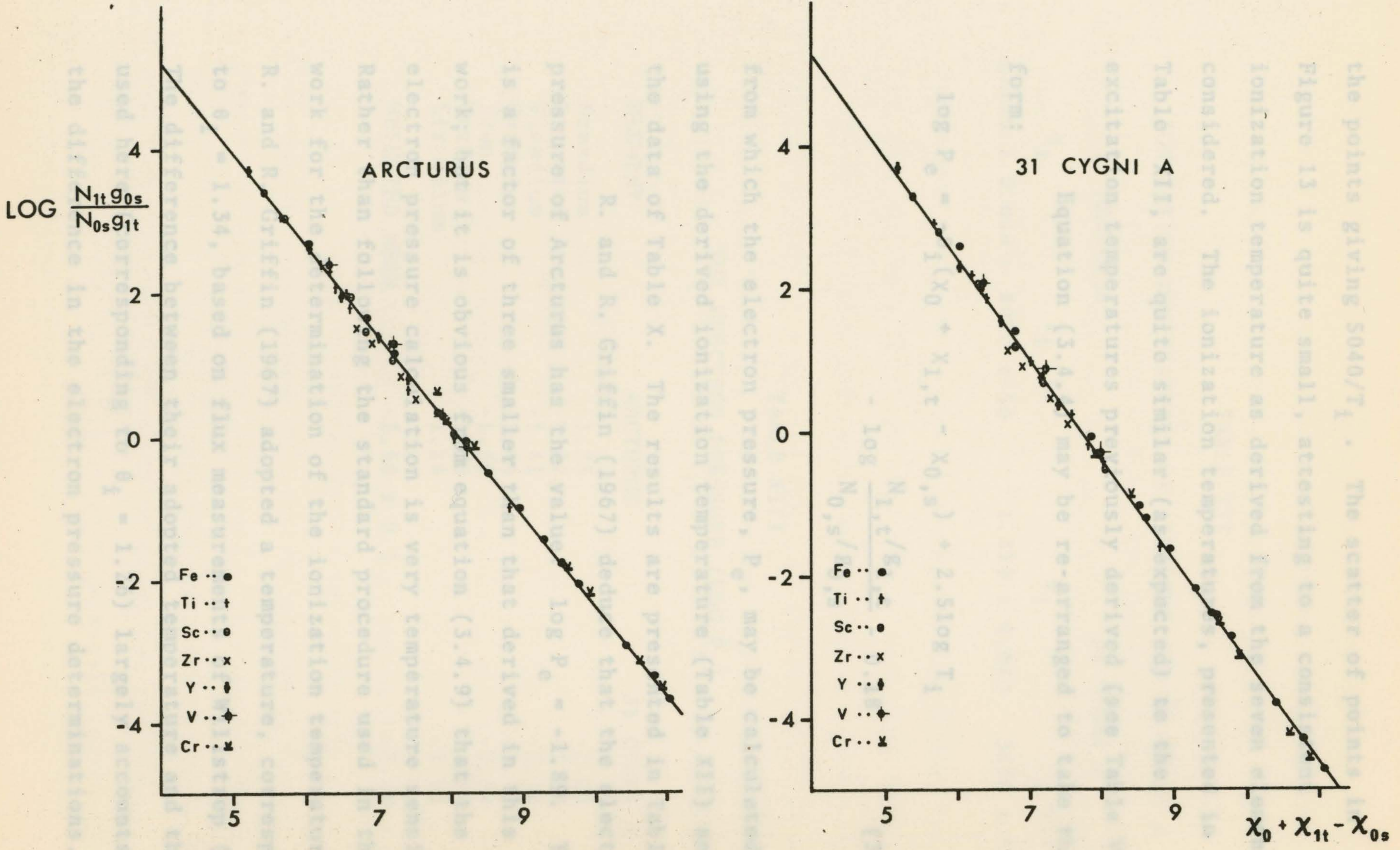

Figure 13. Ionization temperature derived from the Saha and Boltzmann equations. The gradient of the straight lines (least squares solutions) give θ_{ion}

the points giving $5040/T_i$. The scatter of points in Figure 13 is quite small, attesting to a consistent ionization temperature as derived from the seven elements considered. The ionization temperatures, presented in Table XII, are quite similar (as expected) to the excitation temperatures previously derived (see Table VI).

Equation (3.4.4) may be re-arranged to take the form:

$$\log P_e = -\theta_i(\chi_0 + \chi_{1,t} - \chi_{0,s}) + 2.5\log T_i - \log \frac{N_{1,t}/g_{1,t}}{N_{0,s}/g_{0,s}} - 0.18 \qquad (3.4.9)$$

from which the electron pressure, P_e, may be calculated using the derived ionization temperature (Table XII) and the data of Table X. The results are presented in Table XIII.

R. and R. Griffin (1967) deduce that the electron pressure of Arcturus has the value: $\log P_e = -1.89$. This is a factor of three smaller than that derived in this work; but it is obvious from equation (3.4.9) that the electron pressure calculation is very temperature sensitive. Rather than following the standard procedure used in this work for the determination of the ionization temperature, R. and R. Griffin (1967) adopted a temperature, corresponding to $\theta_i = 1.34$, based on flux measurements of Willstrop (1961). The difference between their adopted temperature and that used here (corresponding to $\theta_i = 1.26$) largely accounts for the difference in the electron pressure determinations.

TABLE XII

IONIZATION TEMPERATURES OF ARCTURUS AND 31 CYGNI A

ARCTURUS		31 CYGNI A	
θ_i	T_i (K)	θ_i	T_i (K)
1.259 ± 0.010	4000 ± 50	1.412 ± 0.010	3570 ± 50

TABLE XIII

THE ELECTRON PRESSURE (LOG P_e)

ELEMENT	ARCTURUS	31 CYGNI A
Scandium	-1.35	-2.21
Titanium	-1.32	-2.25
Vanadium	-1.41	-2.38
Chromium	-1.44	-2.25
Iron	-1.38	-2.34
Yttrium	-1.36	-2.24
Zirconium	-1.14	-2.02
WEIGHTED MEAN	-1.36 ± 0.1	-2.28 ± 0.1

The lack of agreement between the ionization temperature derived by curve of growth procedure and that deduced from flux measurements is not known at this time.

3.5 Chemical Composition

From equation (3.4.8), the number of atoms in the ground state of the rth ionized state, N_r, is given by:

$$\log N_r = \Delta - \delta + 12.30 + \log b_r(T) \qquad (3.5.1)$$

For most atoms, the partition functions calculated by Cayrel & Jugaku (1963) are used here. For other atoms for which no such calculations are available, the partition functions have been assumed equal to the statistical weight of the ground state (cf. Unsöld 1968, page 90), the configuration of which was taken from Melissinos (1966, page 497).

Following Yamashita (1967), the total number of atoms of a given element is given by:

$$\log N = \log N_r + \log \frac{N_0 + N_1}{N_r}\ , \quad r = 0,\ 1 \qquad (3.5.2)$$

For the calculation of the ionization correction, the last term of the above equation, Saha's equation with the ionization temperatures and electron pressures listed in Tables XII and XIII have been used. Because the stars considered in this thesis are late-type stars, hence fairly cool stars, second ionization of atoms has not been considered - the contribution to N from this source would

TABLE XIV

THE NUMBER OF ATOMS PER GRAM OF STELLAR MATERIAL

	ARCTURUS			31 CYGNI A		
ELEMENT	(1)	(2)	(3)	(1)	(2)	(3)
H I						
Na I	16.85	3.40	20.25	17.27	3.43	20.70
Mg I	19.46	0.91	20.37	20.43	0.63	21.06
Al I	18.43	1.89	20.32	18.87	1.79	20.66
Si I	21.17	0.19	21.36	21.81	0.08	21.89
Ca I	17.22	2.78	20.00	17.49	2.67	20.16
Sc I	14.64	2.24	16.88	15.22	2.05	17.27
Sc II	16.77	0.00	16.77	17.09	0.00	17.09
Ti I	16.74	1.90	18.64	17.25	1.69	18.94
Ti II	18.47	0.01	18.48	18.78	0.01	18.79
V I	16.38	1.67	18.05	16.88	1.46	18.34
V II	17.99	0.01	18.00	18.34	0.02	18.36
Cr I	17.45	1.54	18.99	18.07	1.35	19.42
Cr II	18.76	0.01	18.77	19.26	0.02	19.28
Mn I	17.43	0.95	18.38	18.32	0.68	19.00
Fe I	19.37	0.60	19.97	20.29	0.35	20.64
Fe II	19.67	0.13	19.80	20.28	0.26	20.54
Co I	17.36	0.43	17.79	18.26	0.23	18.49
Ni I	18.82	0.35	19.17	19.66	0.19	19.85
*Cu I	17.18	0.39	17.57	17.82	0.21	18.03
Zn I	16.98	0.02	17.00			
Sr I	13.66	3.30	16.90			
Sr II	15.05	0.00	15.05	15.11	0.00	15.11
Y I	14.07	2.28	16.35	14.65	2.12	16.77
Y II	16.27	0.00	16.27	16.59	0.00	16.59
Zr I	14.97	1.73	16.70	16.03	1.51	17.54
Zr II	16.44	0.01	16.45	17.01	0.01	17.02
*Mo I	14.24	1.19	15.43	15.19	0.95	16.14
*Ba I	11.75	3.92	15.67			
*Ba II	14.93	0.00	14.93	15.41	0.00	15.41
La II	15.53	0.00	15.53	16.16	0.00	16.16
*Ce II	14.27	0.00	14.27	14.96	0.00	14.96
*Pr II	15.79	0.00	15.79	16.38	0.00	16.38
*Nd II	15.94	0.00	15.94	16.55	0.00	16.55
*Sm II	15.53	0.00	15.53	15.94	0.00	15.94
*Eu II	15.75	0.00	15.75			
*Gd II	15.90	0.00	15.90			
*Yb I	12.80	2.65	15.45	12.88	2.52	15.40

(1) The number of atoms in a given stage of ionization.
(2) The ionization correction.
(3) The number of atoms per gram of stellar material.
* Atoms for which the partition function is assumed equal to the statistical weight of the ground state.

be negligible. Hence only r = 0 and r = 1 are considered in the previous equation. Table XIV gives details of the results.

An estimate of the number of hydrogen atoms per gram of stellar material is not included in Table XIV because of the inapplicability of curve of growth procedure to the abundance determination of hydrogen. The equivalent width of a line of hydrogen, rather than being most sensitive to the number of atoms, is instead "controlled" by Stark broadening. Also, because of the high excitation potential of the n = 2 state (10.15 eV) of hydrogen, in comparison with the mean kinetic energy, populations of atoms in various energy levels are very sensitive to departures from local thermodynamic equilibrium.

The number of atoms was derived from both neutral and ionized atoms for several elements and, in general, the agreement is quite good. Because a larger number of lines is usually available for a neutral atom, the determination of the number of neutral atoms may be regarded as being more reliable than that of the number of ionized atoms. However, the ionization correction is generally quite large for neutral atoms (in the derivation of the total number of atoms of a given element) and as previously stated (Section 3.4) this correction is very sensitive to the adopted ionization temperature and electron pressure. The number of ionized atoms, on the other hand, is essentially insensitive to the ionization correction. As a result of these considerations, mean values have been adopted and final results are presented in Table XV. The solar abundance derived from the detailed analysis of the curve of growth by Goldberg et al (1960), with additions and corrections as given by Müller (1966), is also listed in Table XV. Systematic differences between the absolute scale of gf-values used in the present work and that used in the determination of solar abundances derived by the other observers have been adjusted by adding corrections to the solar abundances. In this table the titanium abundance has been normalized to log N = 4.00. Titanium has been chosen as the "standard" over hydrogen and silicon, either of which is more frequently adopted as the reference element in curve of growth literature, because the curve of growth for titanium is much more accurately defined. Also, titanium was chosen over iron because of the present doubt (see Section 2.2) in the scale of gf-values for iron. In addition to the scale of abundances, Table XV contains the number of lines, due to the neutral and to the ionized atoms, which have been measured.

In order to detect any anomalies in the abundances of elements of Arcturus and 31 Cygni A, the abundances derived for these two stars are compared with the solar abundance. Table XVI contains the logarithmic abundances of Arcturus and 31 Cygni A relative to the sun. Only those elements for which more than five lines have been measured are included in this table. The reason for this is that the

TABLE XV

LOGARITHMIC ABUNDANCES

	ARCTURUS			31 CYGNI A			SUN
ELEMENT	LOG N	A	B	LOG N	A	B	LOG N
H		4			3		11.29
Na	5.69	8		5.83	5		5.59
Mg	5.81	4		6.19	4		6.65
Al	5.76	2		5.79	2		5.49
Si	6.80	6		7.02	5		6.53
Ca	5.44	38		5.29	29		5.44
Ti	4.00	192	31	4.00	137	26	4.00
Sc	2.27	17	17	2.32	12	14	2.09
V	3.46	126	2	3.48	95	2	3.19
Cr	4.32	84	2	4.49	49	1	4.30
Mn	3.82	41		4.13	22		4.03
Fe	5.33	560	18	5.72	375	13	5.86
Co	3.23	48		3.62	28		3.62
Ni	4.61	114		4.98	58		4.59
Cu	3.01	3		3.16	3		2.79
Zn	2.44	2					2.91
Sr	1.44	2	1	1.07		1	1.99
Y	1.75	4	6	1.81	2	5	2.49
Zr	2.02	16	4	2.41	5	4	1.94
Mo	0.87	3		1.27	2		1.59
Ba	0.76	1	4	0.54		1	1.39
La	0.97		13	1.29		8	1.32
Ce	-0.29		8	0.09		5	1.07
Pr	1.23		2	1.51		2	0.74
Nd	1.36		15	1.68		12	1.92
Sm	0.97		10	1.03		7	0.91
Eu	1.19		1				0.25
Gd	1.34		1				0.42
Yb	0.89		1	0.53		1	1.57

A - Number of lines measured due to the neutral atom.
B - Number of lines measured due to the ionized atom.

TABLE XVI

LOGARITHMIC ABUNDANCES RELATIVE TO THE SUN

ELEMENT	ARCTURUS	31 CYGNI A
Na	+0.10	+0.24
Si	+0.27	+0.49
Ca	0.00	-0.15
Sc	+0.18	+0.23
Ti	0.00	0.00
V	+0.27	+0.29
Cr	+0.02	+0.19
Mn	-0.21	+0.10
Fe	-0.53	-0.14
Co	-0.39	0.00
Ni	+0.02	+0.39
Zr	+0.08	+0.47
La	-0.35	-0.03
Ce	-1.36	-0.98
Nd	-0.56	-0.24
Sm	+0.06	+0.14

abundances, of those elements for which there are as few as one or two measured intensities, cannot be regarded as significant. The abundances may be erroneous because of the possibility of failure of properly taking blends into account. Even the line identifications may be uncertain.

It is to be noted that the method of coarse analysis is used throughout this investigation; hence, one can expect the abundances to have uncertainties of a factor of two. With this in mind, it is to be observed in Table XVI that the chemical abundances of elements of Arcturus and 31 Cygni A very nearly reflect the solar abundance, with only a few deviations. The elements around the peak of the iron group in Arcturus seem to be slightly underabundant, with the iron abundance down by a factor of three. The "rare earths"; lanthanum, neodymium, and especially cerium, are also underabundant in Arcturus. One notes however that the abundances of those elements for which many lines have been measured in this analysis; calcium, chromium, and nickel, are almost identical with the corresponding solar abundance. While 31 Cygni A has a large underabundance of cerium, this star seems to have a slight overabundance of silicon (uncertain), nickel, and zirconium. Other than this, the chemical abundances of 31 Cygni A are quite similar to the solar abundances.

CHAPTER 4

SUMMARY AND CONCLUSIONS

By following standard curve of growth procedure, measured line intensities of 29 elements have been used to derive the various atmospheric parameters of Arcturus and 31 Cygni A. Table XVII gives a summary of these parameters, presenting the values which have been derived from both the neutral and ionized atoms. The higher excitation temperature, the lower turbulent velocities, and the larger value of log a (hence a larger damping constant) for the ionized atoms, all provide evidence of stratification of elements in the atmospheres of the two stars. Arcturus shows a more defined stratification than 31 Cygni A as the neutral elements themselves seem to be observed in different regions of the atmosphere - depending on the ionization potential and the atomic weight of the element. It is to be remarked also, while on this topic, that in plotting the absolute curve of growth for iron for Arcturus, the high-excitation lines appeared to have a slightly lower turbulent velocity than the low-excitation lines.

The relatively low standard errors associated with the quantities in Table XVII are a measure of the excellent quality of the high-dispersion spectra (especially for Arcturus) used in this investigation. The results for Arcturus agree well with the results of previous studies of

TABLE XVII

SUMMARY OF THE ATMOSPHERIC PARAMETERS

θ_{ex} (iron)	1.286 ± 0.008	1.460 ± 0.010
θ_{ex} (titanium)	1.359 ± 0.010	1.462 ± 0.013
θ_{ex} (ions)	1.20 ± 0.02	1.41 ± 0.025
T_{ex} (iron)	3920 ± 40	3450 ± 50
T_{ex} (titanium)	3710 ± 50	3450 ± 70
T_{ex} (ions)	4200 ± 100	3580 ± 125
Mean v_t (neutral atoms)	2.4 ± 0.2	5.0 ± 0.2
Mean v_t (ions)	1.8 ± 0.2	3.7 ± 0.3
Mean log a (neutral atoms)	-2.2 ± 0.1	-2.6 ± 0.1
Mean log a (ions)	-1.9 ± 0.1	-1.9 ± 0.2
θ_i	1.259 ± 0.010	1.412 ± 0.010
T_i	4000 ± 50	3570 ± 50
Mean log P_e	-1.36 ± 0.1	-2.28 ± 0.1

this star; especially those of R. and R. Griffin (1967).

As mentioned in the introduction of this thesis, Wright (1959) discusses the temperature and composition distributions in the chromosphere of 31 Cygni A. Figures 14 and 15 illustrate his results. It is to be noted that the few points of Figure 15 which are a result of the present work have had a correction added to the values of Log N. This correction is needed to reconcile the definitions of N. For this work, N represents the number of atoms (of a particular element) per gram of stellar material, whereas in the results of Wright (1959), N represents the number of atoms per square centimeter in a column above the photosphere (in the line of sight). These two definitions are characteristic of the Milne-Eddington and Schuster-Schwarzchild model atmospheres respectively. Wright (1950) compares the theoretical curves of growth based on these two model atmospheres and the differences in ordinates and abscissa between the two curves of growth, when inserted in equation (3.5.1), yield the differences in log N. As a result of these considerations, 0.30 has been subtracted from those data points of Figure 15 which have been derived in this work.

Considering the excitation temperature of 3450 K and the ionization temperature of 3570 K derived for 31 Cygni A in this investigation and superimposing these values on the graph of Figure 14, one concludes that the spectra of 31 Cygni A reflect the conditions at a "mean"

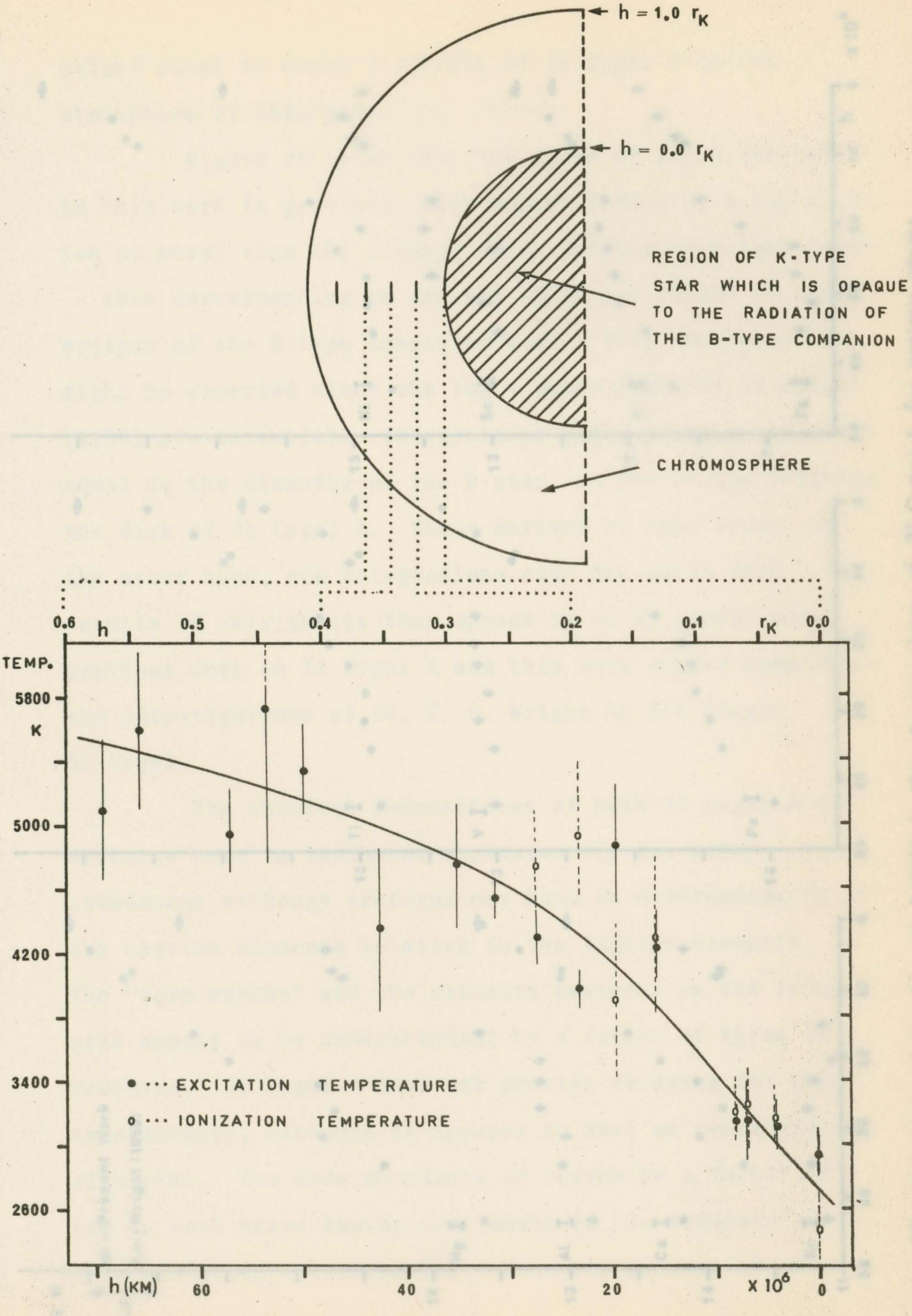

Figure 14. Temperature distribution in the chromosphere of 31 Cygni A.
(With the permisson of Dr. K.O. Wright)

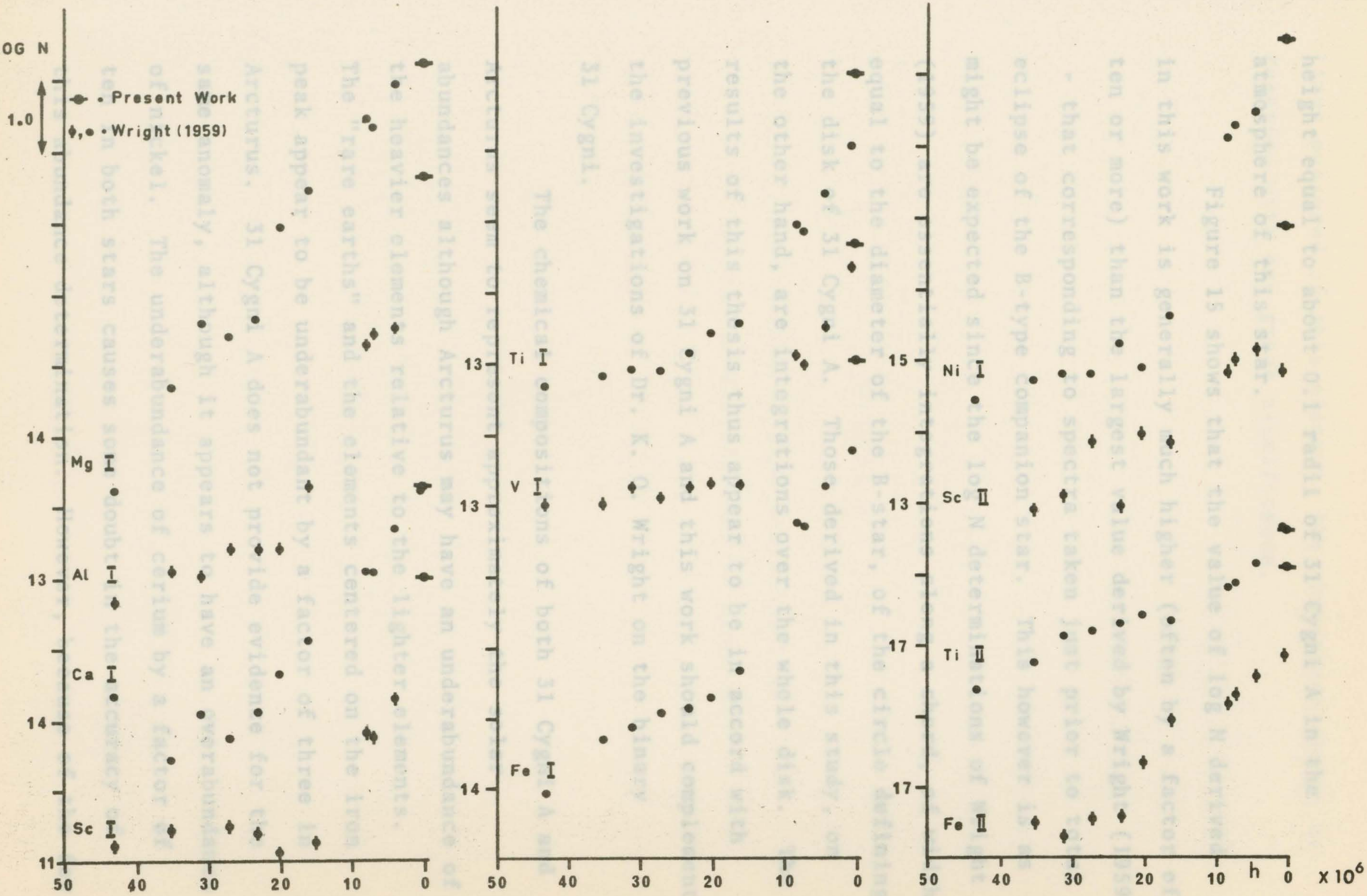

Figure 15. Variation of log N with height in the chromosphere of 31 Cygni A for various atoms.

height equal to about 0.1 radii of 31 Cygni A in the atmosphere of this star.

Figure 15 shows that the value of log N derived in this work is generally much higher (often by a factor of ten or more) than the largest value derived by Wright (1959) - that corresponding to spectra taken just prior to total eclipse of the B-type companion star. This however is as might be expected since the log N determinations of Wright (1959) are essentially integrations along a chord, of width equal to the diameter of the B-star, of the circle defining the disk of 31 Cygni A. Those derived in this study, on the other hand, are integrations over the whole disk. The results of this thesis thus appear to be in accord with previous work on 31 Cygni A and this work should complement the investigations of Dr. K. O. Wright on the binary 31 Cygni.

The chemical compositions of both 31 Cygni A and Arcturus seem to represent approximately the solar abundances although Arcturus may have an underabundance of the heavier elements relative to the lighter elements. The "rare earths" and the elements centered on the iron peak appear to be underabundant by a factor of three in Arcturus. 31 Cygni A does not provide evidence for the same anomaly, although it appears to have an overabundance of nickel. The underabundance of cerium by a factor of ten in both stars causes some doubt in the accuracy of this abundance determination. However, because of the few lines measured of this element, the abundances cannot be regarded with any great significance.

APPENDIX A

OBSERVATIONS OF LINE INTENSITIES IN SPECTRA OF ARCTURUS AND 31 CYGNI A

DESCRIPTION OF CONTENTS

Column one: multiplet number of the line as found in "A Multiplet Table of Astrophysical Interest, Revised Edition" (Moore, 1945).

Column two: laboratory wavelength of the line in Angstroms.

Column three: lower excitation potential in electron volts.

Column four: excitation potentials of the lower and upper levels involved in the transition in kaysers.

Column five: logarithm of the absolute gf-value multiplied by the wavelength in Angstrom units.

Column six: intensity measurements* of Arcturus representing the mean of the values measured from Dominion Astrophysical Observatory intensity tracings and from *A Photometric Atlas of the Spectrum of Arcturus* (Griffin, 1968). The data are given, in addition to W in milli-angstroms, in terms of log F, where F is the Fraunhofer unit - a dimensionless quantity equal to

$$10^6(W/\lambda).$$

Column seven: intensity measurements* of 31 Cygni A derived from Dominion Astrophysical Observatory intensity tracings.

NOTE: Columns six and seven also list estimates of the relative reliabilities of individual line measurements. A weight of 2 indicates that the line is essentially blend-free whereas a weight of .5 indicates that a good deal of blending is present. Evidence of partial blending is denoted by the number 1.

*No corrections of the type mentioned by Griffin (1969) for instrumental distortion have been incorporated into these measurements.

H I

						ARCTURUS			31 CYGNI A	
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	6562.80	10.15	82259	97492	4.53	1172	2.25	2	1685	2.41	2
1	4861.32	10.15	82259	102824	3.67	810	2.22	2	1340	2.44	2
1	4340.46	10.15	82259	105292	3.19	690	2.20	2	1120	2.41	1
1	4101.73	10.15	82259	106632	2.86	692	2.23	1			

Na I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	5889.97	0.0	0	16973	3.88	831	2.15	2	2200	2.57	1
1	5895.94	0.0	0	16956	3.58	652	2.04	2	1950	2.52	1
5	6160.75	2.10	16973	33201	2.52	68	1.05	1			
5	6154.23	2.09	16956	33201	2.22	97	1.20	1			
6	5688.22	2.10	16973	34549	3.35	143	1.40	2	260	1.66	1
6	5682.65	2.09	16956	34549	3.04	146	1.41	1	263	1.67	1
9	4982.83	2.10	16973	37037	2.79	104	1.32	1	200	1.60	1
12	4668.57	2.10	16973	38387	2.42	83	1.25	1			

Mg I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	4571.10	0.0	0	21870	-1.74	261	1.76	1	378	1.92	1
2	5183.62	2.70	21911	41197	3.55	1720	2.52	2	2289	2.65	2
2	5172.70	2.70	21870	41191	3.33	1582	2.49	2	2100	2.61	2
2	5167.34	2.70	21850	41197	2.85	1070	2.32	2	1630	2.50	1

Al I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY	LEVELS	LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
5	6696.03	3.14	25348	40278	2.49	87	1.11	1	145	1.34	1
5	6698.67	3.14	25348	40272	2.18	57	0.93	1	106	1.20	1

Si I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY	LEVELS	LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
9	5793.08	4.93	39760	57017	2.28	39	0.83	1	82	1.15	1
10	5690.43	4.93	39760	57329	1.90	52	0.96	1	102	1.25	1
10	5701.10	4.91	39460	57296	2.02	42	0.87	1			
10	5665.56	4.90	39683	57329	2.01	47	0.92	1	94	1.22	1
16	5948.54	5.08	40992	57798	2.53	82	1.14	1	125	1.32	1
17	5772.15	5.08	40992	58312	2.38	52	0.96	1	110	1.28	1

Ca I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY	LEVELS	LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	6572.78	0.0	0	15210	-0.49	170	1.41	1	248	1.58	1
2	4226.73	0.0	0	23652	3.58	3080	2.86	1	6100	3.16	1
3	6162.17	1.89	15316	31540	3.40	260	1.63	2			
3	6122.22	1.88	15210	31540	3.22	243	1.60	2			
3	6102.72	1.87	15158	31540	2.74	194	1.50	2			
4	4454.78	1.89	15316	37757	3.75	293	1.82	1	615	2.14	.5
4	4425.44	1.87	15158	37748	3.09	189	1.63	2	352	1.90	.5
4	4455.89	1.89	15316	37752	2.93	215	1.68	2	458	2.01	1
4	4456.62	1.89	15316	37748	1.86	125	1.45	2	245	1.74	.5
5	4302.53	1.89	15316	38552	3.77	246	1.76	1	445	2.01	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOGgfλ	W	LOG F	WT.	W	LOG F	WT.
5	4318.65	1.89	15316	38465	3.24	199	1.66	2	408	1.98	1
5	4283.01	1.88	15210	38552	3.24	180	1.62	1	400	1.97	1
18	6439.07	2.51	20371	35897	3.73	205	1.50	2	330	1.71	2
18	6493.78	2.51	20335	35730	3.38	172	1.42	2	279	1.63	2
18	6471.66	2.51	20371	35819	2.91	129	1.30	1	219	1.53	1
18	6499.65	2.51	20349	35730	2.77	142	1.34	2	209	1.51	2
19	6455.60	2.51	20349	35835	2.27	102	1.20	2	162	1.40	2
19	6449.81	2.51	20335	35835	2.99	146	1.36	2	203	1.50	1
20	6169.56	2.51	20371	36575	3.07	149	1.38	1			
20	6169.05	2.51	20349	36555	2.86	137	1.35	2			
20	6166.44	2.51	20335	36548	2.49	121	1.29	2			
20	6161.29	2.51	20349	36575	2.48	105	1.23	2			
20	6163.76	2.51	20335	36555	2.34	111	1.26	1			
21	5588.75	2.51	20371	38259	3.89	183	1.52	2	285	1.71	2
21	5594.45	2.51	20349	38219	3.66	181	1.51	2	300	1.73	2
21	5598.47	2.51	20335	38192	3.52	193	1.54	2	307	1.74	2
21	5601.26	2.51	20371	38219	3.21	142	1.40	2	229	1.61	2
21	5581.97	2.51	20349	38259	3.21	154	1.44	2	269	1.68	2
21	5590.11	2.51	20335	38219	3.09	122	1.34	2	241	1.63	1
22	5262.25	2.51	20335	39333	3.18	191	1.56	1	297	1.75	1
22	5261.70	2.51	20335	39335	3.01	139	1.42	1	250	1.68	1
23	4585.87	2.51	20371	42171	3.30	177	1.59	1	296	1.81	1
23	4578.56	2.51	20335	42170	2.82	117	1.41	2	199	1.64	.5
32	6717.68	2.70	21850	36732	3.03	166	1.39	1	248	1.57	1
33	5349.47	2.70	21850	40538	3.36	140	1.42	2			
36	4526.94	2.70	21850	43933	3.03	119	1.42	2	211	1.67	1
47	5857.45	2.92	23652	40720	3.94	169	1.46	2	322	1.74	1
48	5512.96	2.92	23652	41786	3.26	113	1.31	2	191	1.54	1

Sc I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	6344.83	0.0	0	15757	0.82	6	−0.02	1	35	0.74	1
1	6413.35	0.02	168	15757	1.37	32	0.70	1	80	1.10	1
2	6210.68	0.0	0	16097	2.21	105	1.23	1	165	1.42	1
4	5342.96	0.0	0	18711	1.52	27	0.70	1			

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
7	4023.69	0.02	168	25014	4.01	135	1.53	2	277	1.84	1
7	3996.61	0.0	0	25014	3.44	134	1.53	1	256	1.81	1
12	5671.81	1.44	11677	29304	4.10	105	1.27	2	189	1.52	2
12	5686.84	1.43	11610	29190	4.01	75	1.12	1	160	1.45	1
12	5724.08	1.43	11558	29023	3.16	14	0.40	1	43	0.88	1
13	5081.56	1.44	11677	31351	4.32	86	1.23	1	200	1.60	.5
13	5083.72	1.43	11610	31275	4.08	66	1.11	2	92	1.26	.5
14	4743.81	1.44	11677	32752	4.07	71	1.18	1			
15	5520.50	1.86	15042	33151	4.18	36	0.81	2	74	1.13	1
16	5484.62	1.84	14926	33154	4.07	29	0.72	2	52	0.98	1
17	5356.10	1.86	15042	33707	4.10	25	0.67	1			
19	5392.08	1.98	16027	34567	4.06	21	0.58	1			
19	5375.35	1.96	15882	34480	3.90	12	0.35	1			

Sc II

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
7	4246.83	0.31	2541	26081	3.82	295	1.84	1	428	2.00	1
14	4400.40	0.61	4883	27602	2.92	154	1.54	1	278	1.80	1
14	4420.67	0.62	4988	27602	1.33	86	1.29	1	150	1.53	1
14	4374.47	0.62	4988	27841	3.19	185	1.63	1	280	1.81	1
15	4320.75	0.61	48832	8021	3.86	194	1.65	1			
22	5318.36	1.36	10945	29742	1.91	34	0.81	1	75	1.15	1
23	5031.04	1.36	10945	30816	3.32	114	1.36	1	185	1.57	1
24	4670.41	1.36	10945	32350	3.16	132	1.45	1	201	1.63	.5
25	5552.24	1.45	11736	29742	1.36	22	0.60	1	37	0.82	1
28	6245.62	1.51	12154	28161	2.75	88	1.15	1	155	1.39	1
28	6320.84	1.50	12101	27918	1.84	39	0.79	1			
29	5667.15	1.50	12101	29742	2.40	70	1.09	1	115	1.31	.5
29	5684.20	1.51	12154	29742	2.66	79	1.14	2	120	1.32	1
29	5669.04	1.50	12101	29736	2.52	81	1.15	2	130	1.36	1
29	5640.99	1.50	12101	29824	2.58	99	1.24	1			
29	5657.88	1.51	12154	29824	3.07	116	1.31	1	196	1.54	.5
31	5526.82	1.77	14261	32350	3.77	119	1.33	2	169	1.49	2

Ti I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
3	5460.51	0.05	387	18695	1.09	132	1.38	2			
3	5426.26	0.02	170	18594	0.92	117	1.33	2			
4	5210.39	0.05	387	19574	2.87	290	1.75	1	630	2.08	1
4	5192.98	0.02	170	19422	2.76	230	1.65	1	490	1.97	1
4	5219.71	0.02	170	19323	1.39	164	1.50	2	326	1.80	2
4	5152.20	0.02	170	19574	1.65	169	1.52	2	295	1.76	1
4	5147.48	0.0	0	19422	1.66	174	1.53	2	435	1.93	1
5	5064.66	0.05	387	20126	2.79	225	1.65	2	468	1.97	1
5	5039.95	0.02	170	20006	2.61	230	1.66	2	510	2.01	.5
5	5009.65	0.02	170	20126	1.43	155	1.49	2	420	1.92	1
5	4997.10	0.0	0	20006	1.56	143	1.46	2	370	1.87	1
6	4681.92	0.05	387	21740	2.58	197	1.62	1			
6	4667.59	0.02	170	21588	2.43	260	1.75	1			
6	4656.47	0.0	0	21740	2.26	196	1.62	2			
6	4715.30	0.05	387	21588	0.83	128	1.44	1			
6	4693.68	0.02	170	21470	0.86	131	1.45	2			
7	4562.63	0.02	170	22081	1.00	117	1.41	2	250	1.74	1
9	4112.71	0.05	387	24695	1.98	166	1.61	1			
12	4008.93	0.02	170	25107	2.57	183	1.66	1	425	2.03	1
12	3998.64	0.05	387	25388	3.54	355	1.95	1	605	2.18	1
12	3989.76	0.02	170	25227	3.40	372	1.97	1	535	2.13	.5
35	5366.65	0.81	6599	25227	1.55	73	1.13	2			
35	5389.18	0.81	6557	25107	1.47	73	1.13	2			
37	5246.57	0.83	6743	25798	1.74	102	1.29	2	239	1.66	1
38	4981.73	0.84	6843	26911	4.31	312	1.80	2	475	1.98	1
38	4991.07	0.83	6743	26773	4.19	300	1.78	1	475	1.98	.5
38	4999.51	0.82	6661	26657	4.11	285	1.76	2	522	2.02	2
38	5016.17	0.84	6843	26773	3.14	164	1.51	2	365	1.86	2
38	5020.03	0.83	6743	26657	3.29	195	1.59	2	421	1.92	2
38	5022.87	0.82	6661	26564	3.25	195	1.59	1	450	1.95	1
38	5024.84	0.81	6599	26494	3.09	176	1.54	2	419	1.92	1
38	5045.41	0.84	6843	26657	2.21	105	1.32	1	237	1.67	1
38	5043.59	0.83	6743	26564	2.40	121	1.38	2	290	1.76	1
39	4926.16	0.81	6599	26893	1.98	93	1.28	2	179	1.56	2
41	4781.72	0.84	6843	27750	2.16	114	1.38	1			
42	4534.78	0.83	6743	28788	3.98	206	1.66	2	400	1.95	1
42	4555.49	0.84	6843	28788	3.14	178	1.59	2	335	1.87	1
42	4548.77	0.82	6661	28639	3.31	158	1.54	2	336	1.87	1
42	4544.69	0.81	6599	28596	3.11	203	1.65	1	357	1.90	1
42	4512.74	0.83	6743	28896	3.20	174	1.59	2	390	1.94	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
42	4518.03	0.82	6661	28788	3.32	177	1.59	2	326	1.86	1
42	4522.80	0.81	6599	28703	3.29	208	1.66	1	430	1.98	.5
42	4527.31	0.81	6557	28639	3.16	186	1.61	1	356	1.90	.5
43	4299.64	0.82	6661	29912	2.79	195	1.66	1	330	1.89	.5
44	4301.09	0.83	6743	29915	3.82	239	1.74	1	530	2.09	1
44	4300.56	0.82	6661	29907	3.73	248	1.76	1	525	2.09	1
44	4287.40	0.83	6743	30060	3.28	165	1.59	2	311	1.86	1
44	4286.01	0.82	6661	29986	3.30	205	1.68	2	380	1.95	.5
44	4290.94	0.81	6557	29855	3.24	229	1.73	1	305	1.85	.5
44	4281.38	0.81	6557	29907	2.45	128	1.48	1	275	1.81	1
45	4314.35	0.83	6743	29915	2.48	73	1.23	1			
48	6743.12	0.90	7255	22081	2.29	132	1.29	1	259	1.58	1
49	6599.11	0.90	7255	22405	1.78	103	1.20	1	207	1.50	1
69	6126.22	1.06	8602	24921	2.48	124	1.31	2			
69	6064.63	1.04	8437	24921	2.04	100	1.22	2	176	1.46	1
71	5918.55	1.06	8602	25494	2.25	112	1.28	1	197	1.52	1
71	5903.33	1.06	8602	25537	2.35	81	1.14	2	165	1.45	2
71	5880.31	1.05	8492	25494	2.42	92	1.19	2	195	1.52	1
72	5866.46	1.06	8602	25644	3.23	163	1.44	2	295	1.70	2
72	5899.32	1.05	8492	25439	2.75	150	1.41	2	280	1.68	1
72	5922.12	1.04	8437	25318	2.43	131	1.34	2	214	1.56	2
72	5937.82	1.06	8602	25439	1.81	104	1.24	2	168	1.45	1
72	5941.76	1.05	8492	25318	2.31	131	1.35	2	231	1.59	1
74	5295.79	1.06	8602	27480	2.33	102	1.28	2	198	1.57	1
74	5282.39	1.05	8492	27418	2.12	101	1.28	1	202	1.58	1
74	5284.39	1.04	8437	27335	1.98	103	1.29	2	180	1.53	1
75	4723.17	1.06	8602	29769	2.17	140	1.47	1			
75	4722.62	1.05	8492	29661	2.38	106	1.35	1			
76	4690.80	1.06	8602	29915	2.09	75	1.21	2			
77	4675.12	1.06	8602	29986	2.30	118	1.40	1			
78	4405.68	1.05	8492	31184	2.17	66	1.18	1			
80	4065.10	1.05	8492	33085	2.85	118	1.46	1			
80	4060.26	1.05	8492	33114	2.96	125	1.49	2	248	1.79	1
102	6556.07	1.45	11777	26773	2.79	129	1.30	2	245	1.57	2
102	6554.23	1.44	11640	26893	2.68	106	1.21	2	208	1.50	2
102	6497.69	1.44	11640	27026	2.20	63	0.99	1	121	1.27	1
102	6508.14	1.42	11532	26893	2.24	55	0.93	1	131	1.30	1
103	6366.35	1.45	11777	27480	2.56	93	1.16	1	189	1.47	1
103	6336.10	1.44	11640	27418	2.48	77	1.08	1	143	1.35	1
104	6258.10	1.44	11640	27615	3.52	164	1.42	1	382	1.79	1
104	6312.24	1.45	11777	27615	2.72	86	1.14	2	153	1.38	1
104	6303.75	1.44	11640	27499	2.78	86	1.13	2	167	1.42	2
106	5512.53	1.45	11777	29912	3.44	152	1.44	2	338	1.79	1

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
106	5514.54	1.44	11640	29769	3.45	136	1.39	2	280	1.71	1
106	5514.35	1.42	11532	29661	3.32	129	1.37	2	280	1.71	1
106	5471.21	1.44	11640	29912	2.08	78	1.15	2			
106	5481.87	1.42	11532	29769	2.67	101	1.27	1	166	1.48	.5
107	5449.16	1.44	11640	29986	2.36	53	0.99	2			
107	5490.15	1.45	11777	29986	3.00	113	1.32	2	227	1.62	2
108	5474.23	1.45	11777	30039	2.67	98	1.25	2	200	1.56	1
108	5453.65	1.44	11640	29971	2.23	79	1.16	2			
108	5438.32	1.42	11532	29915	1.94	41	0.88	1			
109	5145.47	1.45	11777	31206	3.32	126	1.39	2	281	1.74	1
109	5113.44	1.44	11640	31191	3.11	132	1.41	2	279	1.74	1
109	5087.07	1.42	11532	31184	2.71	126	1.40	1	275	1.73	.5
109	5109.44	1.44	11640	31206	2.79	77	1.18	2			
110	5035.91	1.45	11777	31629	3.88	186	1.57	2	403	1.90	1
110	5036.47	1.44	11640	31489	3.77	167	1.52	1	430	1.93	.5
110	5038.40	1.42	11532	31374	3.67	152	1.48	1	325	1.81	1
110	5071.48	1.45	11777	31489	2.86	120	1.38	2	263	1.71	1
110	5065.99	1.44	11640	31374	2.59	131	1.41	1	260	1.71	1
113	4453.32	1.42	11532	33981	3.43	145	1.51	2	280	1.80	1
126	4820.42	1.50	12118	32858	3.05	137	1.45	2			
145	4617.27	1.74	14106	35758	3.95	134	1.46	2			
145	4623.09	1.73	14028	35577	3.65	141	1.49	1			
145	4639.67	1.74	14106	35653	3.56	120	1.41	1			
145	4639.37	1.73	14028	35577	3.63	116	1.40	1			
145	4639.95	1.73	13982	35528	3.31	111	1.38	1			
145	4656.04	1.74	14106	35577	2.53	81	1.24	1			
145	4650.02	1.73	14028	35528	2.91	91	1.29	2			
145	4645.19	1.73	13982	35503	2.91	110	1.37	1			
146	4465.81	1.73	14028	36415	3.58	112	1.40	2	260	1.77	1
146	4471.24	1.73	13982	36341	3.61	123	1.44	2	263	1.77	1
148	4284.99	1.73	14028	37359	3.83	174	1.61	1	277	1.81	1
148	4276.43	1.73	13982	37359	3.17	103	1.38	2			
153	6092.81	1.88	15220	31629	3.05	53	0.94	1			
153	6146.22	1.87	15108	31374	2.91	41	0.82	1			
154	5953.17	1.88	15220	32014	3.59	134	1.35	2	191	1.51	.5
154	5965.84	1.87	15157	31914	3.56	127	1.33	2	200	1.53	2
154	5978.56	1.87	15108	31830	3.49	108	1.26	2	184	1.49	2
155	5389.99	1.87	15108	33656	3.18	75	1.14	1			
156	5283.45	1.87	15157	34079	3.47	97	1.26	1	200	1.58	1
157	4885.08	1.88	15220	35685	3.91	174	1.55	1	341	1.84	1
157	4899.91	1.87	15157	35560	3.79	140	1.46	1	220	1.65	.5
157	4913.62	1.87	15108	35454	3.87	128	1.42	2	260	1.72	1
157	4915.24	1.88	15220	35560	3.26	75	1.19	2	130	1.42	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
159	4440.35	1.87	15108	37623	3.68	99	1.35	1	230	1.71	1
160	4449.15	1.88	15220	37690	3.99	135	1.48	2	305	1.84	1
160	4450.90	1.87	15157	37618	3.87	141	1.50	1	279	1.80	1
160	4453.71	1.87	15108	37555	3.58	122	1.44	1	272	1.79	1
160	4463.54	1.88	15220	37618	2.82	79	1.25	1	150	1.53	1
161	4417.28	1.88	15220	37852	3.91	126	1.46	1	225	1.71	1
162	4265.71	1.87	15108	38544	2.83	68	1.20	2			
173	5013.30	2.01	16268	36209	4.15	130	1.41	2			
173	5001.01	1.99	16106	36096	3.67	103	1.31	2	264	1.72	1
173	4989.15	1.97	15976	36014	3.36	106	1.33	2	190	1.58	.5
173	4978.20	1.96	15877	35959	3.24	108	1.34	2	194	1.59	1
173	4964.75	1.96	15877	36014	2.72	69	1.15	1	161	1.51	1
183	5223.64	2.08	16875	36014	2.91	76	1.16	2	163	1.49	.5
183	5194.04	2.09	16961	36209	3.01	86	1.22	2	186	1.55	.5
183	5201.10	2.08	16875	36096	2.96	91	1.24	2	202	1.59	1
184	4503.78	2.13	17215	39413	3.42	63	1.15	1	129	1.46	1
185	4017.77	2.08	16875	41757	4.07	87	1.34	1	200	1.70	1
185	4015.38	2.08	16817	41714	3.74	100	1.40	2	175	1.64	1
186	4016.28	2.13	17215	42107	3.48	52	1.11	1	94	1.37	.5
188	4003.81	2.13	17215	42185	3.94	104	1.42	1	221	1.74	.5
188	4002.49	2.11	17075	42053	3.70	83	1.32	2	197	1.69	.5
188	3999.36	2.09	16961	41959	3.64	64	1.20	1	122	1.48	.5
197	6149.74	2.15	17424	33680	3.02	30	0.69	1			
199	5062.11	2.15	17424	37173	3.07	79	1.19	2	175	1.54	1
199	5069.35	2.14	17370	37091	3.57	83	1.21	1			
200	4928.34	2.14	17370	37655	3.51	102	1.32	1	201	1.61	1
200	4948.19	2.17	17540	37744	3.13	47	0.97	1	120	1.38	1
200	4941.58	2.15	17424	37655	2.98	42	0.93	1			
201	4880.91	2.14	17370	37852	3.23	70	1.16	1	133	1.44	1
202	4731.17	2.17	17540	38671	3.57	69	1.17	1			
202	4742.11	2.14	17370	38451	3.16	52	1.04	1			
204	4360.49	2.17	17540	40467	3.51	101	1.36	1	222	1.71	.5
216	4995.08	2.24	18145	38160	3.38	41	0.91	2			
220	4188.69	2.23	18062	41929	4.01	155	1.57	1			
227	5999.68	2.23	18037	34700	3.58	55	0.96	2	99	1.22	1
228	5739.51	2.24	18141	35560	3.76	56	0.99	1	105	1.26	1
229	5565.49	2.23	18037	36000	3.83	87	1.19	1	170	1.48	.5
231	4856.01	2.25	18193	38780	4.06	144	1.47	1			
231	4870.14	2.24	18141	38669	3.94	134	1.44	2	240	1.69	1
233	4759.28	2.25	18193	39198	4.02	108	1.36	1			
233	4758.12	2.24	18141	39152	4.01	109	1.36	1			
233	4747.68	2.24	18141	39198	3.25	42	0.94	1			
234	4346.11	2.23	18037	41040	3.86	65	1.18	1			

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
238	6091.17	2.26	18288	34700	3.42	82	1.13	2			
239	5823.71	2.26	18288	35454	3.45	41	0.84	2	104	1.25	1
240	5644.14	2.26	18288	36000	4.05	116	1.31	1	253	1.65	1
249	5662.16	2.31	18695	36351	3.56	88	1.19	2	173	1.49	1
249	5675.44	2.30	18594	36209	3.74	92	1.21	2	171	1.48	1
249	5689.47	2.29	18525	36096	3.23	67	1.07	2	127	1.35	1
249	5713.92	2.28	18463	35959	3.47	39	0.83	1	113	1.30	1
249	5716.48	2.29	18525	36014	3.58	50	0.94	1	104	1.26	1
249	5720.48	2.28	18483	35959	3.42	36	0.80	1	76	1.12	1
260	4805.43	2.33	18912	39716	4.41	94	1.29	2			
260	4796.22	2.32	18818	39662	4.08	61	1.11	1			
265	5477.71	2.42	19574	37825	4.07	86	1.20	1	160	1.47	1
265	5488.20	2.39	19323	37539	3.90	69	1.10	2	135	1.39	1
269	5648.58	2.48	20126	37825	3.92	65	1.06	1	138	1.39	1
269	5679.94	2.46	19938	37539	3.52	45	0.90	1	110	1.29	.5
287	5503.90	2.57	20796	38960	4.04	66	1.08	2	158	1.46	1
288	5120.42	2.57	20796	40320	4.63	138	1.43	2	288	1.75	1
293	6220.49	2.67	21588	37660	3.76	54	0.94	2	99	1.20	.5
294	5064.07	2.68	21740	41481	3.88	51	1.00	1			
298	5259.99	2.73	22081	41087	3.91	35	0.82	2			
300	5351.08	2.77	22405	41087	4.23	45	0.92	2			
309	5804.26	3.32	26911	44135	4.57	51	0.94	1	107	1.27	1
309	5766.35	3.28	26564	43902	4.76	35	0.79	1	82	1.15	1

Ti II

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
18	4493.53	1.08	8710	30959	1.20	98	1.34	1	237	1.72	1
19	4443.80	1.08	8710	31207	2.95	234	1.72	2	401	1.96	1
19	4450.49	1.08	8744	31207	2.13	150	1.53	1	245	1.74	.5
20	4337.92	1.08	8710	31756	2.74	184	1.63	1	345	1.90	.5
20	4344.29	1.08	8744	31756	1.82	141	1.51	2	222	1.71	1
30	4545.14	1.13	9118	21114	1.95	117	1.41	1	228	1.70	1
31	4468.49	1.13	9118	31491	3.06	232	1.72	1	460	2.01	1
31	4501.27	1.12	8998	31207	2.86	204	1.66	1	428	1.98	1
31	4444.56	1.12	8998	31491	1.72	132	1.47	1	250	1.75	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
40	4470.86	1.17	9396	31757	1.84	121	1.43	2	252	1.75	1
40	4417.72	1.16	9396	32029	2.49	167	1.58	2	324	1.87	1
40	4464.46	1.17	9364	31757	2.17	135	1.48	2	200	1.65	.5
41	4320.97	1.16	9396	32532	1.37	120	1.44	1			
50	4533.97	1.24	9976	32026	3.04	222	1.69	1	410	1.96	1
50	4563.76	1.22	9851	31756	2.81	217	1.68	1	359	1.90	1
50	4589.96	1.24	9976	31756	1.93	139	1.48	2			
51	4394.06	1.22	9851	32603	2.13	152	1.54	1	291	1.82	1
60	4544.01	1.24	10025	32026	1.58	123	1.43	1	202	1.65	.5
60	4524.73	1.23	9931	32026	1.60	79	1.24	1	160	1.55	1
60	4568.31	1.22	9873	31757	1.73	90	1.29	1	156	1.53	1
61	4395.85	1.24	10025	32767	2.06	134	1.49	2	270	1.79	1
61	4398.31	1.22	9873	32603	1.55	87	1.29	2	139	1.50	1
61	4409.52	1.23	9931	32603	1.57	100	1.35	1			
69	5336.81	1.57	12758	31491	2.33	125	1.37	2	199	1.57	1
70	5226.53	1.56	12629	31756	2.75	148	1.45	2			
82	4571.97	1.57	12677	34543	3.39	225	1.69	1	410	1.95	.5
87	4028.33	1.89	15258	40075	2.87	145	1.56	1	211	1.72	1
92	4805.11	2.06	16625	37431	2.88	144	1.48	1			
93	4421.95	2.06	16625	39233	2.51	94	1.33	1	167	1.58	.5
94	4350.83	2.06	16625	39603	2.17	104	1.38	1	201	1.66	.5
94	4316.81	2.05	16516	39675	2.57	96	1.35	2	180	1.62	.5

V I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	5632.46	0.07	553	18302	0.68	35	0.80	1	110	1.29	1
3	4881.56	0.07	553	21033	2.56	235	1.68	1	392	1.90	1
3	4875.48	0.04	323	20828	2.45	179	1.57	1	420	1.94	1
3	4864.74	0.02	137	20688	2.32	171	1.55	2	341	1.85	1
3	4851.48	0.0	0	20606	2.14	206	1.63	2	345	1.85	.5
3	4827.45	0.04	323	21033	1.79	189	1.59	2	347	1.86	1
3	4831.64	0.02	137	20828	1.81	151	1.49	2	332	1.84	1
3	4832.43	0.0	0	20688	1.70	145	1.48	2	331	1.84	1
4	4594.11	0.07	553	22314	2.86	212	1.66	1			
4	4586.36	0.04	323	22121	2.65	196	1.63	1	361	1.90	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
4	4580.40	0.02	137	21964	2.52	168	1.57	1	295	1.81	.5
4	4577.17	0.0	0	21841	2.40	163	1.55	2	260	1.75	1
4	4635.18	0.07	553	22121	1.76	109	1.37	2			
4	4619.77	0.04	323	21964	2.08	113	1.39	2			
4	4606.15	0.02	137	21841	1.71	138	1.48	1			
5	4332.82	0.02	137	23211	2.48	183	1.63	1	380	1.94	.5
5	4330.02	0.0	0	23088	2.42	164	1.58	2	337	1.89	1
5	4309.80	0.04	323	23520	2.01	178	1.62	1			
6	4259.31	0.02	137	23609	1.85	121	1.46	2	198	1.67	.5
19	6243.10	0.30	2425	18438	2.63	190	1.48	1	355	1.75	1
19	6251.82	0.29	2311	18302	2.21	156	1.40	2	280	1.65	2
19	6256.90	0.27	2220	18198	1.68	96	1.19	2	218	1.54	1
19	6296.49	0.30	2425	18302	2.00	119	1.28	1	293	1.67	1
19	6292.83	0.29	2311	18198	2.06	138	1.34	2	289	1.66	2
19	6285.16	0.27	2220	18126	2.04	117	1.27	2	218	1.54	1
19	6274.65	0.27	2153	18086	1.97	121	1.29	1	238	1.58	1
19	6199.19	0.29	2311	18438	2.41	164	1.42	2			
19	6216.37	0.27	2220	18302	2.40	169	1.43	2	305	1.69	1
19	6242.81	0.26	2112	18126	1.97	134	1.33	2	215	1.54	1
20	6150.15	0.30	2425	18680	2.04	142	1.36	2			
20	6189.35	0.27	2220	18372	1.10	49	0.90	1			
20	6213.87	0.30	2425	18513	1.88	111	1.25	2	268	1.63	1
20	6224.50	0.29	2311	18372	1.86	121	1.29	2	230	1.57	1
20	6233.20	0.27	2220	18259	1.74	104	1.22	2	208	1.52	2
20	6240.13	0.27	2153	18174	1.50	79	1.10	1	187	1.48	1
20	6268.82	0.30	2425	18372	1.88	118	1.28	2	235	1.57	2
20	6266.32	0.27	2220	18174	1.68	94	1.18	2	186	1.47	2
21	4460.29	0.30	2425	24839	3.33	216	1.69	2	424	1.98	2
21	4459.76	0.29	2311	24728	3.01	171	1.58	2	312	1.84	1
21	4437.84	0.29	2311	24839	2.82	170	1.58	2	324	1.86	1
21	4441.68	0.27	2220	24728	2.92	200	1.65	1	398	1.95	1
21	4444.21	0.27	2153	24648	2.80	170	1.58	1	348	1.89	.5
21	4419.94	0.27	2220	24839	2.07	105	1.38	2	242	1.74	1
21	4428.52	0.27	2153	24728	2.48	156	1.55	2	291	1.82	1
21	4436.14	0.26	2112	24648	2.63	153	1.54	2	270	1.78	1
22	4379.24	0.30	2425	25254	4.12	242	1.74	2	525	2.08	.5
22	4389.97	0.27	2220	24993	3.69	223	1.71	2	408	1.97	1
22	4395.23	0.27	2153	24899	3.55	225	1.71	1	403	1.96	.5
22	4400.58	0.26	2112	24830	3.14	171	1.59	1	305	1.84	.5
22	4406.64	0.30	2425	25112	3.39	199	1.66	1			
22	4407.64	0.29	2311	24993	3.46	266	1.78	1	492	2.05	1
22	4408.20	0.27	2220	24899	3.55	201	1.66	1	425	1.98	1
22	4429.80	0.30	2425	24993	2.39	160	1.56	1	325	1.87	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
22	4426.00	0.29	2311	24899	2.68	199	1.65	1	352	1.90	.5
22	4421.57	0.27	2220	24830	2.81	170	1.59	1	284	1.81	.5
22	4416.47	0.27	2153	24789	2.80	200	1.66	1	321	1.86	1
23	4392.07	0.27	2153	24915	1.95	107	1.39	1	186	1.63	.5
24	4218.71	0.30	2425	26122	1.89	96	1.36	1	162	1.58	.5
24	4189.84	0.29	2311	26172	2.32	103	1.39	2			
27	4115.18	0.29	2311	26605	3.73	193	1.67	2			
27	4116.47	0.27	2220	26506	3.33	222	1.73	1			
27	4128.07	0.27	2220	26438	3.57	225	1.74	1			
27	4123.57	0.27	2153	26397	3.39	214	1.72	1			
27	4099.80	0.27	2220	26605	3.53	153	1.57	2			
27	4105.17	0.27	2153	26506	3.52	195	1.68	2			
34	6090.22	1.08	8716	25131	3.65	133	1.34	2			
34	6119.52	1.06	8579	24915	3.31	115	1.27	2			
34	6135.38	1.05	8476	24771	2.97	103	1.22	1			
34	6039.73	1.06	8579	25131	3.19	100	1.22	2	190	1.50	1
34	6081.44	1.05	8476	24915	3.20	117	1.28	1			
34	6111.67	1.04	8413	24771	2.97	122	1.30	1			
35	5727.03	1.08	8716	26172	3.50	167	1.46	2	265	1.67	1
35	5698.52	1.06	8579	26122	3.64	175	1.49	2	337	1.77	1
35	5703.56	1.05	8476	26004	3.51	136	1.38	1	252	1.65	1
35	5743.45	1.08	8716	26122	2.62	95	1.22	2	218	1.58	.5
35	5737.06	1.06	8579	26004	2.91	108	1.28	2	200	1.54	2
35	5727.66	1.05	8476	25931	2.77	106	1.27	2	186	1.51	1
36	5670.85	1.08	8716	26345	3.06	138	1.39	2	218	1.58	1
36	5731.25	1.06	8579	26022	2.91	133	1.37	1	256	1.65	1
37	5627.64	1.08	8716	26480	3.18	129	1.36	2	236	1.62	1
37	5624.89	1.05	8476	26249	2.40	75	1.12	2	188	1.52	1
37	5626.01	1.04	8413	26183	2.29	76	1.13	1	189	1.53	.5
37	5668.36	1.08	8716	26353	2.62	79	1.14	2	164	1.46	1
37	5657.44	1.06	8579	26249	2.61	72	1.10	2	159	1.45	1
37	5646.11	1.05	8476	26183	2.47	71	1.10	1	177	1.50	1
37	5584.50	1.06	8579	26480	2.72	66	1.07	2	150	1.43	1
37	5604.94	1.04	8413	26249	2.39	68	1.09	2	139	1.39	1
41	4095.49	1.06	8579	32989	3.82	126	1.49	2			
48	6531.43	1.21	9825	25131	2.73	80	1.09	1	151	1.36	1
48	6543.51	1.19	9637	24915	2.10	28	0.63	1	100	1.18	1
48	6565.88	1.18	9545	24771	1.69	18	0.44	1	62	0.98	1
48	6605.97	1.19	9637	24771	2.40	51	0.89	1	132	1.30	1
48	6452.34	1.19	9637	25131	2.50	68	1.02	1	158	1.39	1
48	6504.17	1.18	9545	24915	2.39	63	0.98	2	133	1.31	2
49	6002.31	1.21	9825	26480	2.14	23	0.58	1	58	0.99	1
50	4932.03	1.21	9825	30095	2.34	61	1.09	1	143	1.46	1

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
50	4880.56	1.19	9637	30121	2.53	64	1.12	1	132	1.43	.5
84	6326.84	1.86	15063	30864	3.17	28	0.64	1	80	1.10	1
84	6339.09	1.85	15001	30771	3.06	54	0.93	1	105	1.22	1
84	6349.48	1.85	14949	30694	3.00	19	0.48	1	70	1.05	1
84	6357.30	1.84	14910	30636	2.99	19	0.48	1	50	0.90	1
87	4452.01	1.86	15063	37518	4.36	127	1.46	1	250	1.75	1
87	4462.36	1.85	15001	37404	4.35	158	1.55	1	272	1.79	1
87	4468.01	1.84	14910	37285	3.61	50	1.05	1	125	1.45	.5
88	4276.96	1.85	14949	38324	4.26	100	1.37	2			
88	4284.06	1.84	14910	38246	4.23	111	1.41	1	203	1.68	.5
89	3992.80	1.85	15001	40038	4.09	124	1.49	1	242	1.78	.5
92	5772.42	1.92	15572	32891	3.26	32	0.75	1	91	1.20	.5
99	4524.22	1.88	15265	37362	3.73	47	1.02	1	135	1.47	.5
100	4540.01	1.88	15265	37285	3.16	28	0.79	1			
108	4721.51	1.94	15724	36898	3.17	18	0.58	1			
109	4560.71	1.94	15724	37644	4.07	64	1.14	1	130	1.45	1
113	4807.53	2.12	17136	37931	3.86	66	1.14	1			
113	4786.51	2.07	16729	37615	3.71	135	1.45	2			
113	4750.98	2.05	16573	37615	3.35	50	1.02	1			
113	4748.52	2.03	16450	37503	3.26	23	0.69	1			
113	4746.63	2.02	16361	37423	3.03	16	0.53	1			
121	4050.96	2.12	17182	41861	4.49	63	1.19	1	122	1.48	1
123	5128.53	2.28	18438	37931	3.87	58	1.05	1	125	1.39	1
123	5138.42	2.26	18302	37758	3.85	62	1.08	1	130	1.40	1
129	5507.75	2.35	19023	37175	3.70	26	0.67	1	70	1.11	1
131	5240.87	2.36	19145	38221	3.95	39	0.87	1	104	1.30	1
135	5725.64	2.36	19078	36539	3.69	24	0.62	1	63	1.04	1
135	5734.01	2.35	19026	36461	3.46	20	0.54	1			
142	5830.72	3.10	25112	42257	4.33	18	0.49	1	36	0.79	1
142	5817.53	3.09	24993	42177	4.10	13	0.35	1			

V II

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
9	4036.78	1.47	11908	36674	2.19	89	1.35	1	176	1.64	1
9	4002.94	1.42	11515	36489	2.32	85	1.33	1	188	1.67	1

Cr I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
1	4254.35	0.0	0	23499	3.36	852	2.30	1	2190	2.71	1
1	4274.80	0.0	0	23386	3.24	813	2.28	1	2072	2.69	1
1	4289.72	0.0	0	23305	3.05	728	2.23	1	1597	2.57	1
6	6330.10	0.94	7593	23386	1.28	107	1.23	2	195	1.49	2
8	5051.90	0.94	7593	27382	1.05	98	1.29	1	175	1.54	1
8	5072.92	0.94	7593	27300	1.45	117	1.36	2	230	1.66	.5
9	4942.50	0.94	7593	27820	1.69	177	1.56	1	330	1.82	1
9	4964.93	0.94	7593	27729	1.40	126	1.41	2	288	1.76	1
10	4545.96	0.94	7593	29585	2.69	157	1.54	2	321	1.85	2
18	5345.81	1.00	8095	26796	2.75	223	1.62	2			
18	5296.69	0.98	7927	26802	2.36	187	1.55	2	400	1.88	1
18	5348.32	1.00	8095	26787	2.44	183	1.53	2			
18	5298.27	0.98	7927	26796	2.65	210	1.60	1	370	1.84	.5
18	5300.75	0.98	7927	26788	1.76	135	1.41	2	260	1.69	1
18	5247.56	0.96	7751	26802	2.28	174	1.52	2	365	1.84	1
20	5123.46	1.03	8308	27820	1.13	109	1.33	1	205	1.60	.5
21	4646.17	1.03	8308	29825	3.18	184	1.60	2			
21	4652.16	1.00	8095	29585	2.88	177	1.58	2			
21	4651.28	0.98	7927	29421	2.70	143	1.49	2			
21	4600.75	1.00	8095	29585	2.64	155	1.53	2			
21	4616.14	0.98	7927	29585	2.71	161	1.54	2			
21	4626.19	0.96	7811	29421	2.67	147	1.50	2			
21	4591.39	0.96	7811	29585	2.48	144	1.50	1			
21	4613.37	0.96	7751	29421	2.29	127	1.44	1			
22	4344.51	1.00	8095	31106	3.31	194	1.65	2	396	1.96	1
22	4339.45	0.98	7927	30965	3.06	191	1.64	1	320	1.87	.5
22	4337.57	0.96	7811	30859	2.88	195	1.65	2	368	1.93	1
22	4339.72	0.96	7751	30787	2.57	185	1.63	1	325	1.87	.5
22	4371.28	1.00	8095	30965	2.74	216	1.69	1	440	2.00	.5
22	4351.05	0.96	7811	30787	2.57	181	1.62	1	400	1.96	1
22	4373.25	0.98	7927	30787	1.85	125	1.46	2	285	1.81	.5
30	4885.78	2.53	20521	40983	2.99	83	1.23	2	160	1.52	1
31	4789.32	2.53	20519	41393	3.73	131	1.44	1			
32	4571.68	2.53	20519	42387	3.57	99	1.34	1			
33	4529.85	2.53	20519	42589	2.88	67	1.17	1			
33	4541.07	2.53	20524	42539	3.06	84	1.26	1	155	1.53	1
33	4535.15	2.53	20521	42565	3.18	84	1.27	2	131	1.46	1
35	4126.52	2.53	20519	44746	3.76	88	1.33	1			
38	3991.12	2.53	20517	45566	4.63	114	1.46	2	216	1.73	1
59	5238.97	2.70	21848	40930	2.83	50	0.98	1	115	1.34	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
60	5144.67	2.70	21857	41289	2.72	78	1.18	1	158	1.49	1
62	4697.06	2.70	21841	43125	3.40	69	1.17	1			
62	4700.61	2.70	21857	43125	3.18	50	1.03	1			
81	4622.76	2.97	24092	45719	3.29	48	1.01	1			
81	4498.73	2.90	23512	45734	3.55	65	1.16	1	123	1.44	.5
94	5329.17	2.90	23499	42258	3.60	112	1.32	1	217	1.61	1
94	5275.69	2.88	23305	42255	3.28	104	1.30	1	220	1.62	1
94	5329.72	2.90	23499	42256	2.97	77	1.16	1	151	1.45	.5
96	4319.64	2.88	23305	46449	3.46	40	0.97	1	80	1.27	.5
99	4693.95	2.97	24056	45354	3.68	54	1.06	1			
99	4695.15	2.97	24056	45349	3.28	40	0.93	1			
104	4346.83	2.97	24056	47055	3.84	78	1.25	1			
119	5712.78	3.00	24282	41782	3.19	49	0.93	1	129	1.35	1
119	5719.82	3.00	24304	41782	2.67	16	0.46	1	50	0.94	1
129	4410.30	3.00	24300	46968	3.37	41	0.97	1			
143	4887.01	3.07	24897	45354	4.09	123	1.40	1			
143	4870.80	3.07	24834	45358	4.13	119	1.39	2	206	1.63	.5
144	4836.86	3.09	25038	45707	3.15	41	0.93	1			
145	4756.11	3.09	25038	46058	4.55	99	1.32	1			
145	4737.35	3.07	24897	46000	4.16	94	1.30	2			
145	4730.71	3.07	24834	45966	4.06	76	1.21	1			
145	4724.42	3.07	24897	46058	3.69	71	1.18	1			
150	4511.90	3.07	24897	47055	4.02	89	1.30	1	204	1.66	1
166	4954.81	3.11	25177	45354	4.03	84	1.23	2	202	1.61	1
166	4936.33	3.10	25106	45358	4.02	89	1.26	2	161	1.51	1
186	4718.43	3.18	25772	46959	4.49	99	1.32	1			
186	4708.04	3.15	25549	46783	4.37	87	1.27	1			
186	4666.51	3.13	25360	46783	3.93	76	1.21	1			
186	4663.83	3.10	25089	46525	3.90	84	1.25	1			
188	5783.93	3.31	26796	44081	3.58	85	1.17	2	165	1.46	1
193	5214.13	3.35	27176	46349	3.50	35	0.83	1	83	1.20	1
197	4492.31	3.36	27223	49477	4.04	51	1.06	1	120	1.43	.5
201	5243.40	3.38	27382	46449	3.71	46	0.94	1	129	1.39	.5
201	5192.00	3.38	27382	46637	4.10	61	1.07	2	100	1.28	.5
201	5200.19	3.37	27300	46525	3.79	60	1.06	1	123	1.37	.5
203	5628.64	3.41	27597	45358	3.60	29	0.72	1	74	1.12	1
225	5272.01	3.43	27820	46783	3.84	46	0.94	1	150	1.45	1
225	5287.19	3.42	27729	46637	3.25	25	0.67	1	66	1.10	1
225	5312.88	3.43	27820	46637	3.67	41	0.88	1	68	1.11	1
225	5318.78	3.42	27729	46525	3.66	32	0.79	2			
225	5340.44	3.42	27729	46449	3.43	37	0.85	2			
231	4767.86	3.54	28682	49650	3.86	34	0.85	1			
268	4001.44	3.87	31378	56362	4.65	58	1.16	1	125	1.49	1
282	6661.08	4.17	33816	48824	4.22	17	0.41	1			

Cr II

		LOW				ARCTURUS			31 CYGNI A		
MULT.	λ	E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
30	4848.25	3.86	31169	51789	2.56	65	1.13	1	140	1.46	1
44	4588.20	4.07	32837	54626	3.01	56	1.09	1			

Mn I

		LOW				ARCTURUS			31 CYGNI A		
MULT.	λ	E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	5394.67	0.0	0	18532	0.46	188	1.54	1			
1	5432.55	0.0	0	18402	0.04	230	1.63	1			
2	4030.76	0.0	0	24802	3.13	575	2.15	1	1205	2.48	1
2	4033.07	0.0	0	24788	2.97	570	2.15	1	1056	2.42	1
2	4034.49	0.0	0	24779	2.73	405	2.00	1	932	2.36	1
4	5420.36	2.13	17282	35726	2.52	189	1.54	1			
4	5516.77	2.17	17568	35690	2.30	138	1.40	1	290	1.72	1
4	5505.87	2.17	17568	35726	2.10	114	1.32	1	217	1.60	1
4	5537.76	2.18	17637	35690	2.25	117	1.33	1	225	1.61	1
5	4041.36	2.11	17052	41790	4.54	224	1.74	2	415	2.01	1
5	4055.54	2.13	17282	41933	4.08	205	1.70	1	332	1.91	1
5	4070.28	2.18	17637	42199	3.31	122	1.48	1			
5	4018.10	2.11	17052	41933	3.95	206	1.71	1	330	1.91	1
5	4048.76	2.15	17452	42144	3.86	195	1.68	1	300	1.87	1
5	4082.94	2.17	17569	42054	3.86	163	1.60	2			
16	4823.52	2.31	18705	39431	3.83	208	1.64	2			
16	4783.42	2.29	18532	39431	3.79	227	1.68	1			
16	4754.04	2.27	18403	39431	3.81	192	1.61	2			
20	4965.88	2.88	23297	43429	2.95	88	1.25	1	145	1.47	.5
21	4762.38	2.88	23297	44289	4.28	151	1.50	1			
21	4766.43	2.91	23549	44524	4.13	159	1.52	1			
21	4765.86	2.93	23720	44696	3.93	117	1.39	2			
21	4761.53	2.94	23819	44815	3.71	116	1.39	2			
21	4739.11	2.93	23720	44815	3.56	99	1.32	1			
21	4671.69	2.88	23297	44696	2.92	33	0.86	1			
22	4451.59	2.88	23297	45754	4.34	136	1.49	2	246	1.74	1
22	4470.14	2.93	23720	46084	3.80	90	1.30	1	176	1.60	1

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
22	4436.35	2.91	23549	46084	3.82	118	1.42	1	196	1.65	.5
22	4453.00	2.93	23720	46170	3.71	100	1.35	1			
22	4502.22	2.91	23549	45754	3.83	101	1.35	1	162	1.56	1
22	4498.90	2.93	23720	45941	3.86	98	1.34	2	210	1.67	.5
23	4265.92	2.93	23720	47155	4.00	97	1.36	2			
23	4257.66	2.94	23819	47299	4.02	97	1.36	1	224	1.72	.5
27	6021.80	3.06	24802	41404	3.94	146	1.39	2	224	1.57	2
27	6016.64	3.06	24788	41404	3.78	145	1.38	2	240	1.60	2
27	6013.50	3.06	24779	41404	3.63	151	1.40	2	230	1.58	2
28	4457.04	3.06	24788	47218	3.35	74	1.22	2	141	1.50	.5
32	5255.32	3.12	25266	44289	3.52	88	1.23	1	150	1.46	.5
32	5117.94	3.12	25281	44815	3.39	48	0.98	1			
42	5377.63	3.83	31001	49591	4.20	67	1.10	1			
42	5399.49	3.84	31076	49591	3.90	54	1.00	1			

Fe I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
1	5166.29	0.0	0	19351	0.03	233	1.65	1	400	1.89	.5
1	5247.06	0.09	704	19757	-0.78	200	1.58	2	375	1.85	.5
1	5254.96	0.11	888	19913	-0.51	241	1.66	2	410	1.89	.5
1	5250.21	0.12	978	20020	-0.74	205	1.59	2	420	1.90	1
1	5110.41	0.0	0	19562	0.37	286	1.75	2	659	2.11	1
1	5168.90	0.05	416	19757	0.22	322	1.79	1	667	2.11	1
1	5225.53	0.11	888	20020	-0.54	208	1.60	2	398	1.88	1
1	5060.08	0.0	0	19757	-1.64	180	1.55	2	423	1.92	1
2	4375.93	0.0	0	22846	1.05	350	1.90	1	608	2.14	1
2	4427.31	0.05	416	22997	1.14	332	1.87	1	612	2.14	.5
2	4461.65	0.09	704	23111	0.94	303	1.83	1	545	2.09	1
2	4482.17	0.11	888	23193	0.80	320	1.85	1	660	2.17	1
2	4489.74	0.12	978	23245	0.25	222	1.70	2	540	2.08	.5
2	4347.24	0.0	0	22997	-1.37	146	1.53	2	375	1.94	2
2	4445.48	0.09	704	23193	-1.22	150	1.53	1	344	1.89	1
2	4471.68	0.11	888	23245	-1.49	148	1.52	1	371	1.92	1
2	4389.25	0.05	416	23193	-0.26	202	1.66	2	430	1.99	1
2	4216.19	0.0	0	23711	0.64	301	1.85	1	480	2.06	1
3	4149.77	0.05	416	24507	-1.20	188	1.66	1			

		LOW				ARCTURUS			31 CYGNI A		
MULT.	λ	E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
3	4258.32	0.09	704	24181	-0.04	256	1.78	1			
3	4232.73	0.11	888	24507	-0.47	181	1.63	2	433	2.01	.5
13	6358.69	0.86	6928	22650	-0.20	198	1.49	2	390	1.79	1
13	6648.12	1.01	8155	23193	-0.84	70	1.02	1	145	1.34	1
13	6280.62	0.86	6928	22846	-0.19	178	1.45	1	340	1.73	1
13	6400.32	0.91	7377	22997	-0.10	180	1.45	2	310	1.69	1
13	6498.95	0.95	7728	23111	-0.41	158	1.39	2	300	1.66	1
13	6574.24	0.99	7986	23193	-0.82	112	1.23	2	226	1.54	2
13	6625.04	1.01	8155	23245	-1.29	99	1.17	1	168	1.40	1
14	5956.70	0.86	6928	23711	-0.28	163	1.44	2	269	1.65	1
15	5269.54	0.86	6928	25900	2.37	695	2.12	1	1110	2.32	.5
15	5328.04	0.91	7377	26140	2.27	592	2.05	1	950	2.25	.5
15	5371.49	0.95	7728	26340	2.13	483	1.95	2			
15	5405.78	0.99	7986	26479	1.98	385	1.85	2			
15	5434.53	1.01	8155	26550	1.77	309	1.76	2			
15	5397.13	0.91	7377	25900	1.85	373	1.84	1			
15	5446.92	0.99	7986	26340	1.84	403	1.87	1			
15	5501.47	0.95	7728	25900	1.08	230	1.62	2	400	1.86	2
15	5506.78	0.99	7986	26140	1.30	254	1.66	2	478	1.94	2
15	5497.52	1.01	8155	26340	1.25	253	1.66	2	487	1.95	2
16	5012.07	0.86	6928	26875	1.29	268	1.73	2	570	2.06	.5
16	5051.64	0.91	7377	27167	0.99	258	1.71	1	500	2.00	.5
16	5083.34	0.95	7728	27395	0.97	228	1.65	2	550	2.03	.5
16	5123.72	1.01	8155	27666	0.92	244	1.68	1	587	2.06	.5
16	4939.69	0.86	6928	27167	0.51	210	1.63	2	471	1.98	.5
16	4994.13	0.91	7377	27395	0.80	199	1.60	1	434	1.94	1
16	5079.74	0.99	7986	27666	0.80	211	1.62	2	461	1.96	1
16	5127.36	0.91	7377	26875	0.80	206	1.61	1	450	1.94	.5
16	5142.93	0.95	7728	27167	0.99	266	1.71	.5	670	2.11	.5
16	5150.84	0.99	7986	27395	1.01	221	1.63	2	508	1.99	.5
16	5151.92	1.01	8155	27560	0.88	236	1.66	2	380	1.87	.5
17	4690.38	1.01	8155	29469	-0.66	55	1.07	1			
18	4177.59	0.91	7377	31307	1.20	307	1.87	1			
18	4152.17	0.95	7728	31805	1.17	330	1.90	1			
18	4139.93	0.99	7986	32134	0.78	174	1.62	2			
34	6710.31	1.48	11976	26875	-0.63	83	1.09	2	170	1.40	2
34	6581.22	1.48	11976	27167	-0.30	92	1.15	2	170	1.41	2
36	5194.94	1.55	12561	31805	2.09	233	1.65	2	407	1.89	1
36	5216.28	1.60	12969	32134	2.07	228	1.64	2	466	1.95	2
36	5332.90	1.55	12561	31307	1.37	180	1.53	2	396	1.87	2
36	5307.36	1.60	12969	31805	1.26	160	1.48	2	313	1.77	2
37	5328.53	1.55	12561	31323	2.23	169	1.50	1	313	1.77	.5
38	4733.60	1.48	11976	33096	1.30	197	1.62	1			

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
38	4798.74	1.60	12969	33802	0.71	99	1.32	1			
38	4643.22	1.48	11976	33507	-0.76	49	1.02	1			
39	4602.94	1.48	11976	33695	2.20	220	1.68	2			
39	4680.30	1.60	12969	34329	0.62	128	1.44	1			
39	4531.15	1.48	11976	34040	2.09	245	1.73	1	515	2.06	1
39	4592.66	1.55	12561	34329	1.75	195	1.63	1			
39	4632.92	1.60	12969	34547	1.36	216	1.67	1			
39	4547.02	1.55	12561	34547	0.82	154	1.53	1	338	1.87	.5
39	4602.00	1.60	12969	34692	1.16	145	1.50	2			
40	4672.84	1.60	12969	34363	-0.20	61	1.12	1			
40	4765.48	1.60	12969	33947	0.33	139	1.46	1			
41	4383.55	1.48	11976	34782	4.15	1957	2.65	1	3390	2.89	1
41	4404.75	1.55	12561	35257	3.89	1380	2.50	2	2950	2.83	1
41	4415.12	1.60	12969	35612	3.51	745	2.23	1	1480	2.53	1
41	4294.13	1.48	11976	35257	2.95	550	2.11	1	780	2.26	.5
41	4337.05	1.55	12561	35612	2.49	312	1.86	1	590	2.13	.5
41	4367.91	1.60	12969	35856	1.44	182	1.62	1			
42	4271.76	1.48	11976	35379	3.83	1365	2.50	2	2070	2.69	1
42	4307.90	1.55	12561	35768	3.95	1581	2.56	1	2950	2.84	1
42	4325.76	1.60	12969	36079	4.00	1290	2.47	2	2240	2.71	.5
42	4202.03	1.48	11976	35768	3.37	960	2.36	1	1545	2.57	1
42	4250.79	1.55	12561	36079	3.35	575	2.13	1	1050	2.39	.5
42	4147.67	1.48	11976	36079	2.12	235	1.75	1			
43	4045.82	1.48	11976	36686	4.27	2125	2.72	1	3480	2.93	1
43	4063.60	1.55	12561	37163	4.05	1430	2.55	1	2370	2.77	.5
43	4071.74	1.60	12969	37521	4.03	1290	2.50	1	1960	2.68	.5
43	4005.24	1.55	12561	37521	3.51	710	2.25	1	1255	2.50	1
43	4143.87	1.55	12561	36686	3.50	745	2.25	1			
43	4132.06	1.60	12969	37163	3.42	580	2.15	1			
62	6430.85	2.17	17550	33096	2.24	212	1.52	2	388	1.78	2
62	6335.34	2.19	17727	33507	1.94	192	1.48	1	334	1.72	1
62	6297.80	2.21	17927	33802	1.49	146	1.37	2	264	1.62	2
62	6265.14	2.17	17550	33507	1.80	175	1.45	2	323	1.71	1
62	6219.29	2.19	17727	33802	1.75	162	1.42	2	328	1.72	1
62	6213.44	2.21	17927	34017	1.64	159	1.41	2			
62	6137.00	2.19	17727	34017	1.41	136	1.35	2			
62	6173.34	2.21	17927	34122	1.39	139	1.35	2			
64	6082.71	2.21	17927	34363	0.86	102	1.23	2			
64	6240.66	2.21	17927	33947	1.12	116	1.27	1	230	1.57	1
66	5202.34	2.17	17550	36767	2.53	233	1.65	1	414	1.90	1
66	5145.10	2.19	17727	37158	1.31	138	1.43	1	264	1.71	1
66	5131.48	2.21	17927	37410	1.79	159	1.49	2	290	1.75	.5
66	5079.23	2.19	17727	37410	2.26	174	1.53	2	360	1.85	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
66	5250.65	2.19	17727	36767	2.20	186	1.55	2	437	1.92	.5
66	5198.71	2.21	17927	37158	2.22	191	1.57	2	403	1.89	2
67	4817.77	2.21	17927	38678	0.99	107	1.35	2			
68	4528.62	2.17	17550	39626	3.46	455	2.00	1	794	2.24	1
68	4494.57	2.19	17727	39970	3.30	367	1.91	1	635	2.15	1
68	4482.26	2.21	17927	40231	3.12	315	1.85	1	650	2.16	1
68	4459.12	2.17	17550	39970	3.15	295	1.82	1	540	2.08	.5
68	4442.34	2.19	17727	40231	3.15	289	1.81	2	532	2.08	1
68	4447.72	2.21	17927	40405	3.07	265	1.78	2	530	2.08	1
68	4430.62	2.21	17927	40491	2.63	189	1.63	1	368	1.92	.5
69	4447.13	2.19	17727	40207	1.76	129	1.46	2	211	1.68	1
69	4478.04	2.19	17727	40052	0.96	75	1.22	2	167	1.57	1
69	4442.84	2.17	17550	40052	1.76	135	1.48	1	233	1.72	1
70	4338.26	2.17	17550	40594	1.55	148	1.53	2	261	1.78	.5
70	4292.29	2.19	17727	41018	1.67	147	1.54	1	315	1.87	.5
71	4282.41	2.17	17550	40895	3.47	241	1.75	1	500	2.07	.5
72	4001.66	2.17	17550	42533	2.51	150	1.58	1	260	1.81	.5
109	6608.03	2.27	18378	33507	0.49	62	0.97	1			
109	6481.88	2.27	18378	33802	1.41	135	1.32	2	210	1.51	1
109	6392.55	2.27	18378	34017	0.68	71	1.05	2	155	1.38	1
111	6421.36	2.27	18378	33947	2.27	203	1.50	2	317	1.69	2
111	6750.15	2.41	19552	34363	1.72	143	1.33	2	230	1.53	1
111	6663.45	2.41	19552	34556	1.77	153	1.36	2	267	1.60	1
111	5322.05	2.27	18378	37163	1.76	117	1.34	2	217	1.61	2
111	5049.82	2.27	18378	38175	2.70	238	1.67	1	428	1.93	.5
111	5273.38	2.47	20038	38996	2.36	162	1.49	1	258	1.69	1
111	4924.78	2.27	18378	38678	1.81	172	1.54	2	333	1.83	1
111	5141.75	2.41	19552	38996	2.14	140	1.44	2	299	1.76	1
111	4848.88	2.27	18378	38996	0.90	96	1.30	2			
115	4630.12	2.27	18378	39970	1.84	91	1.29	1	180	1.59	1
115	4834.51	2.41	19552	40231	1.00	130	1.43	1			
115	4574.72	2.27	18378	40231	1.60	117	1.41	1	246	1.73	1
115	4794.36	2.41	19552	40405	0.73	51	1.03	1			
115	4439.88	2.27	18378	40895	1.65	100	1.35	2	197	1.65	1
152	4260.48	2.39	19351	42816	4.26	607	2.15	1	1020	2.38	1
152	4222.22	2.44	19757	43435	3.28	216	1.71	1			
152	4187.80	2.41	19562	43435	3.75	298	1.85	1			
152	4187.04	2.44	19757	43634	3.79	261	1.79	1			
152	4250.12	2.46	19913	43435	3.88	374	1.94	1	468	2.04	.5
152	4233.61	2.47	20020	43634	3.72	240	1.75	1	355	1.92	.5
153	4011.71	2.44	19757	44677	1.76	86	1.33	2	200	1.70	1
168	6593.88	2.42	19621	34782	1.79	154	1.37	2	268	1.61	2
168	6494.98	2.39	19390	34782	2.95	262	1.61	2	503	1.89	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
168	6393.60	2.42	19621	35257	2.71	216	1.53	1	378	1.77	1
169	6252.56	2.39	19390	35379	2.51	215	1.54	1	325	1.72	1
169	6191.56	2.42	19621	35768	2.70	222	1.56	2			
169	6136.62	2.44	19788	36079	2.85	209	1.53	2			
169	6344.15	2.42	19621	35379	1.48	132	1.32	2	247	1.59	2
170	5916.25	2.44	19788	36686	1.67	118	1.30	2	209	1.55	2
206	6609.12	2.55	20641	35768	1.54	128	1.29	1	167	1.40	1
206	6575.02	2.58	20875	36079	1.58	118	1.26	2	227	1.54	1
206	6475.63	2.55	20641	36079	1.58	107	1.22	1	252	1.59	1
207	6137.70	2.58	20875	37163	2.84	197	1.51	2			
207	6065.49	2.60	21039	37521	2.75	195	1.51	2	315	1.72	2
207	6322.69	2.58	20875	36686	1.87	126	1.30	2	217	1.54	1
207	6200.32	2.60	21039	37163	1.83	115	1.27	2			
209	5701.55	2.55	20641	38175	2.36	143	1.40	2	276	1.68	1
209	5615.30	2.58	20875	38678	2.24	126	1.35	2	180	1.51	1
209	5567.40	2.60	21039	38996	1.77	125	1.35	1	225	1.61	1
214	4319.46	2.60	21039	44184	1.13	58	1.13	2	165	1.58	1
215	4275.72	2.55	20641	11023	1.35	120	1.45	1			
217	4106.27	2.58	20875	45221	2.17	157	1.58	1			
218	4011.41	2.55	20641	45563	2.14	104	1.42	1	210	1.72	1
268	6677.99	2.68	21716	36686	2.90	201	1.48	1	292	1.64	1
268	6592.92	2.72	21999	37163	2.72	184	1.45	2	318	1.68	2
268	6546.24	2.75	22249	37521	2.64	169	1.41	2	294	1.65	.5
268	6703.57	2.75	22249	37163	1.30	83	1.09	1	141	1.32	1
269	6180.21	2.72	21999	38175	1.71	114	1.27	2			
273	4266.97	2.72	21999	45428	2.76	128	1.48	2	250	1.77	.5
273	4242.59	2.72	21999	45563	1.75	108	1.41	1			
276	3998.06	2.68	21716	46721	3.54	139	1.54	1	240	1.78	.5
279	3995.99	2.72	21999	47017	2.93	122	1.48	2	280	1.85	.5
318	4957.60	2.80	22650	42816	4.08	450	1.96	.5	700	2.15	.5
318	4891.50	2.84	22997	43435	3.86	265	1.73	2	560	2.06	.5
318	4871.32	2.85	23111	43634	3.80	244	1.70	2	395	1.91	1
318	4859.75	2.86	23193	43764	3.36	193	1.60	2	330	1.83	1
318	5006.13	2.82	22846	42816	3.37	221	1.64	2	409	1.91	.5
318	4919.00	2.85	23111	43435	3.71	231	1.67	1	545	2.04	1
318	4890.76	2.86	23193	43634	3.60	265	1.73	2	490	2.00	1
318	4872.14	2.87	23245	43764	3.64	234	1.68	1	460	1.98	.5
318	5044.22	2.84	22997	42816	2.09	125	1.40	2	280	1.74	.5
318	4985.55	2.85	23111	43163	2.67	164	1.52	2	309	1.79	1
318	4938.82	2.86	23193	43435	3.07	164	1.52	2	321	1.81	1
318	4903.32	2.87	23245	43634	3.09	200	1.61	1	300	1.79	.5
319	4571.45	2.86	23193	45061	1.37	67	1.17	1			
319	4525.87	2.87	23245	45334	1.58	78	1.24	1	166	1.56	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
342	6518.38	2.82	22838	38175	1.88	115	1.25	2	202	1.49	2
342	6355.04	2.83	22947	38678	2.04	135	1.33	1	228	1.55	1
342	6270.24	2.85	23052	38996	1.89	102	1.21	2	204	1.51	2
342	6311.51	2.82	22838	38678	1.56	70	1.05	1	155	1.39	1
342	6229.23	2.83	22947	38996	1.68	84	1.13	1	164	1.42	1
346	4741.53	2.82	22838	43923	2.51	115	1.38	2			
346	4707.49	2.83	22947	44184	2.37	107	1.36	1			
346	4683.56	2.82	22838	44184	2.12	92	1.30	1			
347	4685.04	2.83	22947	44285	1.39	58	1.09	1			
349	4635.85	2.83	22947	44512	2.21	84	1.26	1			
350	4466.55	2.82	22838	45221	3.83	238	1.73	1	505	2.05	.5
350	4476.02	2.83	22947	45282	3.79	222	1.70	2	389	1.94	1
350	4443.20	2.85	23052	45552	3.43	167	1.58	1	322	1.86	.5
350	4454.38	2.82	22838	45283	3.14	133	1.48	1			
352	4207.13	2.82	22838	46601	2.92	136	1.51	2			
352	4245.26	2.85	23052	46601	3.18	206	1.69	1	335	1.90	1
354	4181.76	2.82	22838	46745	4.07	273	1.81	1			
354	4175.64	2.83	22947	46889	3.71	181	1.64	2			
354	4125.88	2.83	22947	47177	2.59	113	1.44	1			
354	4126.88	2.83	22947	47172	1.77	85	1.31	1			
355	4213.65	2.83	22947	46673	3.07	150	1.55	1			
355	4203.99	2.83	22947	46727	3.41	169	1.61	2	286	1.83	1
356	4121.81	2.82	22838	47093	3.12	162	1.59	1			
356	4122.52	2.83	22947	47197	3.00	119	1.46	1			
357	4091.56	2.82	22838	47272	2.37	96	1.37	2			
383	5232.95	2.93	23711	42816	4.11	265	1.70	2	559	2.03	2
383	5281.80	3.03	24507	43435	3.47	185	1.54	1	331	1.80	1
383	5192.35	2.99	24181	43435	3.90	217	1.62	1	436	1.92	.5
383	5068.77	2.93	23711	43435	3.11	161	1.50	2	348	1.84	1
383	5191.46	3.03	24507	43764	3.76	208	1.60	1	430	1.92	.5
384	4800.14	3.03	24507	45334	1.34	48	1.00	1			
384	4726.16	2.99	24181	45334	1.65	52	1.04	1			
384	4877.59	2.99	24181	44677	1.47	71	1.16	2			
409	4647.44	2.94	21716	45295	3.20	140	1.48	1			
409	4618.76	2.94	23784	45428	2.38	118	1.41	1			
409	4661.98	2.98	24119	45563	2.22	93	1.30	1			
412	4358.50	2.94	23784	46721	2.77	154	1.55	2	271	1.79	.5
414	4348.94	2.98	24119	47107	2.26	103	1.38	2	183	1.62	1
415	4365.90	2.98	24119	47017	2.21	88	1.31	2	168	1.59	.5
419	4258.96	3.00	24339	47812	2.42	107	1.40	1	200	1.67	.5
422	4089.23	2.94	23784	48231	2.62	93	1.36	1			
423	4120.21	2.98	24119	48383	3.23	142	1.54	2			
467	4786.81	3.00	24336	45221	2.90	130	1.43	2			

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
467	4874.36	3.06	24772	45282	1.48	65	1.12	1			
472	4517.53	3.06	24772	46902	2.54	133	1.47	1	234	1.71	1
473	4372.99	3.00	24336	47197	1.88	89	1.31	1	196	1.65	.5
476	4387.90	3.06	24772	47556	3.03	117	1.43	1	246	1.75	1
476	4450.32	3.10	25092	47556	2.35	106	1.38	1	223	1.70	.5
478	4195.62	3.00	24336	48163	2.92	149	1.55	1			
482	4220.35	3.06	24772	48460	3.09	140	1.52	1	235	1.75	.5
482	4248.23	3.06	24772	48305	3.12	156	1.56	1	233	1.74	.5
482	4267.83	3.10	25092	48516	3.32	180	1.63	1	265	1.79	1
515	4439.64	3.03	24575	47093	1.77	61	1.14	1	100	1.35	.5
516	4436.92	3.03	24575	47107	2.27	135	1.48	1	206	1.67	1
517	4343.70	3.03	24575	47590	2.55	137	1.50	1	238	1.74	1
518	4369.77	3.03	24575	47453	3.49	219	1.70	1	389	1.95	.5
522	4199.10	3.03	24575	48383	4.46	221	1.72	2	382	1.96	.5
527	4017.15	3.03	24575	49461	3.50	211	1.72	2	320	1.90	.5
553	5324.19	3.20	25900	44677	4.20	215	1.61	1	410	1.89	1
553	5283.63	3.23	26140	45061	3.92	189	1.55	1	314	1.77	.5
553	5263.31	3.25	26340	45334	3.53	155	1.47	1	301	1.76	1
553	5253.50	3.27	26479	45509	2.92	110	1.32	2	244	1.67	1
553	5217.40	3.20	25900	45061	3.35	130	1.40	2	245	1.67	2
553	5215.18	3.25	26340	45509	3.55	154	1.47	2	320	1.79	2
553	5229.86	3.27	26479	45595	3.53	148	1.45	2	288	1.74	1
553	5393.17	3.23	26140	44677	3.63	158	1.47	2			
553	5339.94	3.25	26340	45061	3.62	152	1.45	2			
553	5302.31	3.27	26479	45334	3.68	154	1.46	2	281	1.72	1
553	5273.18	3.28	26550	45509	3.45	134	1.41	1	225	1.63	.5
554	4736.78	3.20	25900	47006	3.65	167	1.55	1			
554	4707.28	3.23	26140	47378	3.44	143	1.48	1			
554	4668.14	3.25	26340	47756	3.38	169	1.56	1			
554	4637.51	3.27	26479	48037	3.08	110	1.38	1			
554	4613.21	3.28	26550	48221	2.81	109	1.38	1			
554	4625.05	3.23	26140	47756	3.04	117	1.40	1			
554	4607.66	3.25	26340	48037	3.02	118	1.41	1			
554	4598.12	3.27	26479	48221	2.98	115	1.40	1			
554	4574.24	3.20	25900	47756	2.03	72	1.20	2	153	1.52	1
555	4504.84	3.25	26340	48532	2.20	80	1.25	1	211	1.67	1
556	4000.27	3.25	26340	51331	2.77	105	1.42	1	184	1.66	1
557	4080.89	3.28	26550	51048	2.75	101	1.39	2			
557	4013.64	3.20	25900	50808	2.77	148	1.57	1	230	1.76	.5
560	4016.43	3.27	26479	51370	3.04	104	1.41	2	194	1.68	.5
586	4975.42	3.29	32134	52214	2.35	122	1.39	1	160	1.51	.5
588	4788.76	3.22	26106	46982	2.75	117	1.39	1			
588	4839.55	3.25	26351	47008	2.39	104	1.33	2	233	1.68	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
591	4658.29	3.25	26351	47812	1.75	38	0.92	1			
594	4595.36	3.29	26628	48383	2.73	130	1.45	1			
597	4327.92	3.29	26628	49727	2.81	131	1.48	1	233	1.73	.5
597	4330.96	3.25	26351	49434	2.28	92	1.33	1			
598	4346.56	3.29	26628	49628	2.90	147	1.53	1			
603	4006.31	3.25	26351	51305	3.57	105	1.42	1	215	1.73	.5
630	4838.09	3.24	26225	46889	1.15	40	0.92	1			
633	4808.16	3.24	26225	47017	1.83	63	1.11	1			
633	4873.75	3.29	26624	47136	1.58	39	0.90	1			
633	4791.25	3.26	26406	47272	2.00	83	1.24	1			
633	4780.82	3.29	26624	47136	1.47	30	0.79	1			
635	4776.07	3.29	26624	47556	1.94	59	1.09	1			
638	4556.94	3.24	26225	48163	1.91	59	1.11	1	154	1.53	1
641	4566.52	3.29	26624	48516	2.37	86	1.28	1	165	1.56	1
645	4377.79	3.26	26406	49243	2.31	87	1.30	1	142	1.51	.5
685	6271.29	3.32	26875	42816	1.80	54	0.93	1	108	1.24	.5
686	5615.65	3.32	26875	44677	4.26	235	1.62	2	390	1.84	1
686	5586.76	3.35	27167	45061	4.09	198	1.55	2	336	1.78	2
686	5572.85	3.38	27395	45334	4.03	190	1.53	2	355	1.80	1
686	5569.62	3.40	27560	45509	3.82	165	1.47	2	277	1.70	1
686	5576.10	3.42	27666	45595	3.44	143	1.41	2	235	1.62	2
686	5658.83	3.38	27395	45061	3.60	161	1.46	1	327	1.76	1
686	5784.69	3.38	27395	44677	2.14	54	0.97	1	138	1.38	.5
686	5712.14	3.40	27560	45061	2.70	90	1.20	2	176	1.49	.5
687	4966.10	3.32	26875	47006	3.39	163	1.52	2	260	1.72	.5
687	4946.39	3.35	27167	47378	2.96	142	1.46	2	258	1.72	1
687	4910.03	3.38	27395	47756	2.76	122	1.40	2	240	1.69	.5
687	4863.65	3.42	27666	48221	2.50	127	1.42	1	270	1.74	.5
687	4875.90	3.32	26875	47378	2.30	106	1.34	2	220	1.65	.5
687	4855.68	3.35	27167	47756	2.37	116	1.38	2			
687	4838.52	3.40	27560	48221	2.32	105	1.34	1	219	1.66	1
687	5002.80	3.38	27395	47378	2.67	99	1.30	2	256	1.71	1
687	4950.11	3.40	27560	47756	2.62	113	1.36	2	207	1.62	1
687	4907.74	3.42	27666	48037	2.38	97	1.30	2	170	1.54	.5
688	4679.23	3.35	27167	48532	2.43	75	1.20	1			
688	4807.72	3.35	27167	47961	2.32	89	1.27	1			
689	4205.55	3.40	27560	51331	3.16	139	1.52	1	248	1.77	.5
692	4264.21	3.35	27167	50611	2.96	127	1.47	1	255	1.78	1
693	4238.82	3.38	27395	50980	4.23	185	1.64	1	320	1.88	1
693	4195.34	3.32	26875	50704	3.89	163	1.59	1			
693	4196.22	3.38	27395	51219	3.69	140	1.52	2			
693	4147.35	3.32	26875	50980	2.49	84	1.31	1			
694	4154.81	3.35	27167	51229	4.01	184	1.65	2			

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
694	4087.10	3.32	26875	51335	3.11	108	1.42	2			
695	4126.19	3.32	26875	51103	3.39	150	1.56	1			
695	4090.98	3.35	27167	51604	2.73	95	1.36	1			
695	4157.79	3.40	27560	51604	3.96	171	1.62	2			
695	4158.80	3.42	27666	51705	3.61	142	1.53	1			
698	4084.50	3.32	26875	51351	3.85	162	1.60	1			
698	4082.13	3.40	27560	52050	3.07	101	1.40	2			
718	5029.62	3.40	27543	47420	2.18	84	1.22	1	185	1.57	1
750	4844.00	3.53	28605	49243	2.26	99	1.31	1			
752	4705.46	3.53	28605	49851	2.48	73	1.19	1			
753	4789.65	3.53	28605	49477	3.49	128	1.43	1			
767	4059.73	3.53	28605	53230	3.36	116	1.46	2	162	1.60	1
786	5365.40	3.56	28820	47453	3.37	109	1.31	2			
791	5028.13	3.56	28820	48703	3.21	125	1.40	2	290	1.76	.5
792	4927.45	3.56	28820	49109	2.34	88	1.25	1	182	1.57	1
793	4809.95	3.56	28820	49604	1.86	42	0.95	1			
795	4587.13	3.56	28820	50614	2.87	88	1.28	1			
796	4502.59	3.56	28820	51023	2.38	52	1.07	1	113	1.40	1
797	4432.57	3.56	28820	51374	2.98	86	1.29	2	133	1.48	1
816	6400.01	3.59	29056	44677	4.09	169	1.42	2	305	1.68	1
816	6411.66	3.64	29469	45061	3.80	154	1.38	2	280	1.64	1
816	6408.03	3.67	29733	45334	3.41	121	1.28	2	200	1.49	2
816	6246.33	3.59	29056	45061	3.49	136	1.34	1	239	1.58	1
816	6301.52	3.64	29469	45334	3.58	151	1.38	2	236	1.57	1
816	6336.84	3.67	29733	45509	3.52	127	1.30	2	203	1.51	2
816	6232.66	3.64	29469	45509	3.07	114	1.26	2	201	1.51	2
816	6302.51	3.67	29733	45595	3.19	117	1.27	2	191	1.48	2
820	4596.06	3.59	29056	50808	2.92	97	1.32	1			
820	4673.17	3.64	29469	50862	3.27	121	1.41	1			
820	4701.05	3.67	29733	50999	2.58	86	1.26	1			
820	4643.47	3.64	29469	50999	3.21	99	1.33	1			
820	4690.15	3.67	29733	51048	3.02	78	1.22	1			
821	4678.85	3.59	29056	50423	3.83	130	1.45	1			
821	4619.29	3.59	29056	50699	3.40	112	1.39	1			
821	4704.96	3.67	29733	50981	3.13	93	1.29	1			
822	4728.56	3.64	29469	50611	3.31	116	1.39	1			
822	4638.02	3.59	29056	50611	3.43	108	1.37	1			
823	4560.10	3.59	29056	50980	2.59	87	1.28	1			
823	4596.43	3.64	29469	51219	2.28	54	1.07	1			
825	4433.79	3.59	29056	51604	3.23	122	1.44	1			
827	4481.62	3.67	29733	52040	3.14	88	1.29	1	135	1.48	1
828	4484.23	3.59	29056	51351	3.88	117	1.42	2	215	1.68	1
828	4401.29	3.59	29056	51771	3.58	141	1.51	2			

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
828	4446.84	3.67	29733	52214	3.28	115	1.41	1	211	1.68	.5
829	4523.40	3.64	29469	51570	2.62	79	1.24	1	158	1.54	1
830	4388.41	3.59	29056	51837	3.84	131	1.47	2	241	1.74	1
830	4423.86	3.64	29469	52067	2.85	94	1.33	2	179	1.61	1
830	4485.68	3.67	29733	52020	3.44	107	1.38	2	230	1.71	1
830	4433.22	3.64	29469	52020	3.70	145	1.51	2	306	1.84	.5
830	4469.38	3.64	29469	51837	4.02	137	1.49	1	285	1.80	1
843	5242.50	3.62	29313	48383	3.53	125	1.38	1	204	1.59	1
868	5636.69	3.62	29357	47093	2.56	45	0.90	1	105	1.27	.5
871	5539.27	3.63	29372	47420	2.25	39	0.85	1	108	1.29	1
872	5529.13	3.63	29372	47453	2.12	37	0.83	1	108	1.29	1
875	5298.78	3.63	29372	48239	2.62	70	1.12	2	130	1.39	.5
877	5320.05	3.63	29372	48163	2.28	46	0.93	2	108	1.31	.5
880	5217.93	3.62	29357	48516	2.82	76	1.17	1	123	1.37	1
880	5223.19	3.62	29320	48460	2.51	55	1.02	1	92	1.24	.5
883	4979.59	3.62	29357	49433	1.92	47	0.97	2			
884	5054.65	3.62	29357	49135	2.18	70	1.14	1	173	1.53	1
894	4542.42	3.62	29357	51365	2.59	79	1.24	1			
896	4536.51	3.63	29372	51409	2.00	44	0.99	1	84	1.27	.5
903	4360.81	3.63	29372	52297	2.59	101	1.36	1	201	1.66	.5
906	4088.57	3.62	29357	53808	3.20	77	1.27	1			
907	4239.37	3.63	29372	52954	2.84	112	1.42	1	156	1.57	.5
915	4010.18	3.63	29372	54301	2.53	54	1.13	1	78	1.29	1
926	5543.18	3.68	29799	47834	2.99	81	1.16	1	165	1.47	1
928	5379.58	3.68	29799	48383	2.95	89	1.22	2			
929	5288.54	3.68	29799	48703	2.97	95	1.25	1	200	1.58	1
935	4700.17	3.68	29799	51069	2.82	85	1.26	1			
945	3996.97	3.68	29799	54811	3.78	97	1.39	1	188	1.67	.5
958	6220.77	3.86	31307	47378	2.34	33	0.73	1	80	1.11	1
958	6419.68	3.93	31805	47378	2.43	24	0.57	1	47	0.86	1
959	6003.03	3.86	31307	47961	3.37	108	1.26	2	172	1.46	1
959	5976.80	3.93	31805	48532	3.25	98	1.22	1	155	1.41	1
959	5952.75	3.97	32134	48928	3.22	83	1.15	2	118	1.30	.5
959	6096.69	3.97	32134	48532	2.84	57	0.97	2			
965	5001.87	3.86	31307	51294	4.12	123	1.39	2	285	1.76	1
965	5014.95	3.93	31805	51740	4.03	147	1.47	2	328	1.82	.5
965	5022.24	3.97	32134	52040	3.76	125	1.40	2	319	1.80	1
965	5099.09	3.97	32134	51740	3.14	100	1.29	1			
966	4885.44	3.86	31307	51771	3.02	106	1.34	2	160	1.52	1
966	4978.61	3.97	32134	52214	3.33	166	1.52	1	300	1.78	1
971	4593.54	3.93	31805	53569	2.65	63	1.14	1			
973	4392.58	3.86	31307	54067	3.01	61	1.15	1	99	1.35	.5
982	6008.58	3.87	31323	47961	3.42	119	1.30	.5	189	1.50	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
982	5934.66	3.91	31686	48532	3.40	108	1.26	2	174	1.47	2
982	5883.84	3.94	31937	48928	3.36	95	1.21	2	170	1.46	.5
982	5809.24	3.87	31323	48532	2.96	75	1.11	2	133	1.36	2
984	5005.72	3.87	31323	51294	4.03	137	1.44	2	275	1.74	.5
984	4985.26	3.91	31686	51740	3.64	111	1.35	2	160	1.51	.5
984	4896.44	3.87	31323	51740	2.80	66	1.13	1	122	1.40	1
984	4911.79	3.91	31686	52040	2.69	65	1.12	2	130	1.42	1
984	5048.46	3.94	31937	51740	3.37	95	1.27	1	248	1.69	1
985	4904.39	3.91	31686	52050	2.98	89	1.26	2	180	1.56	1
985	4930.33	3.94	31937	52214	2.99	105	1.33	1	200	1.61	.5
986	4905.15	3.91	31686	52067	2.33	64	1.12	1	112	1.36	.5
993	4279.48	3.87	31323	54683	3.18	97	1.36	1			
993	4264.74	3.94	31937	55379	3.07	100	1.37	1	161	1.58	1
994	4243.79	3.87	31323	54880	3.08	85	1.30	1	169	1.60	1
1015	6157.73	4.06	28744	91090	3.34	91	1.17	1			
1015	6380.75	4.17	37654	94330	3.41	77	1.08	1	139	1.34	1
1016	6436.43	4.17	37654	92980	2.57	17	0.41	1	65	1.00	1
1018	6027.06	4.06	28744	94610	3.49	94	1.19	2	140	1.37	2
1018	6165.37	4.12	34134	96280	3.16	63	1.01	2			
1025	5487.75	4.12	34135	16300	3.71	111	1.31	1	202	1.57	1
1026	5587.58	4.12	34135	13050	3.39	58	1.02	1	91	1.21	.5
1028	5329.99	4.06	28745	16300	3.49	81	1.18	1	130	1.39	.5
1029	5403.82	4.06	28745	13740	3.77	82	1.18	2			
1029	5476.30	4.12	34135	16680	3.53	98	1.25	1	150	1.44	1
1030	5464.29	4.12	34135	17080	3.06	53	0.99	2			
1031	5293.96	4.12	34135	22970	3.04	52	0.99	2	115	1.34	1
1034	5236.20	4.17	37655	28580	3.32	52	1.00	1	119	1.36	1
1042	4735.85	4.06	28745	39830	3.63	84	1.25	1			
1042	4800.65	4.12	34135	42370	3.42	105	1.34	1			
1042	4798.27	4.17	37655	46000	3.27	58	1.08	1			
1043	4729.03	4.06	28745	40140	3.28	56	1.07	1			
1052	6725.39	4.09	30964	79610	2.47	32	0.67	1	51	0.88	1
1052	6653.88	4.14	35074	85320	2.05	18	0.42	1			
1061	5483.12	4.14	35075	17400	3.20	69	1.10	.5	90	1.22	.5
1062	5476.57	4.09	30965	13510	4.03	126	1.36	1	175	1.50	.5
1062	5473.91	4.14	35075	17710	3.70	96	1.24	2			
1062	5543.93	4.20	40175	20500	3.49	84	1.18	2	132	1.38	1
1064	5386.34	4.14	35075	20670	2.87	50	0.97	1			
1066	4983.86	4.09	30965	31550	4.08	133	1.43	2	200	1.60	.5
1066	4988.96	4.14	35075	35460	3.59	109	1.34	2	187	1.57	1
1066	4969.93	4.20	40175	41320	3.51	99	1.30	1	174	1.54	1
1066	4886.34	4.14	35075	39670	3.54	118	1.38	2			
1066	4917.24	4.17	38025	41320	3.22	85	1.24	1	163	1.52	1

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
1067	4982.51	4.09	30965	31610	4.10	144	1.46	2	250	1.70	.5
1067	4983.26	4.14	35075	35690	3.94	130	1.42	2	247	1.70	1
1067	4967.90	4.17	38025	39250	3.48	113	1.36	1	198	1.60	.5
1068	4910.33	4.17	38025	41610	3.43	92	1.27	2	180	1.56	1
1068	4910.57	4.20	40175	43760	3.37	97	1.30	2	180	1.56	1
1068	4835.86	4.09	30965	37690	2.91	78	1.21	1			
1070	4892.87	4.20	40175	44490	3.26	79	1.21	2	158	1.51	.5
1070	4918.02	4.21	41225	44490	3.21	68	1.14	1			
1083	5940.97	4.16	36955	5230	2.92	33	0.74	1			
1086	5793.93	4.20	40405	12940	3.11	45	0.89	2	100	1.24	1
1086	5741.86	4.24	43295	17400	3.31	42	0.86	2	100	1.24	1
1086	5814.82	4.26	45475	17400	3.13	37	0.81	1	79	1.14	1
1087	5638.27	4.20	40405	17710	3.77	102	1.26	1	166	1.47	1
1087	5641.45	4.24	43295	20500	3.62	96	1.23	2	174	1.49	1
1087	5775.09	4.20	40405	13510	3.60	74	1.11	2	125	1.34	1
1087	5705.48	4.28	46925	22140	3.45	51	0.95	2	108	1.28	1
1087	5873.22	4.24	43295	13510	3.23	31	0.72	1	86	1.16	1
1088	5635.84	4.24	43295	20673	0.34	51	0.95	2	102	1.26	1
1089	5162.29	4.16	36955	30610	4.47	146	1.45	1	313	1.78	1
1089	5126.22	4.24	43295	38310	3.61	103	1.30	1	220	1.63	.5
1089	5072.08	4.26	45475	42580	3.69	109	1.33	1	220	1.64	1
1089	5243.79	4.24	43295	33940	3.57	82	1.20	2	161	1.49	1
1090	5137.39	4.16	36955	31550	4.19	114	1.35	1	222	1.64	1
1090	5090.79	4.24	43295	39670	3.93	129	1.40	1	265	1.72	1
1090	5148.06	4.26	45475	39670	3.86	90	1.24	1	150	1.46	.5
1091	5228.39	4.20	40405	31610	3.83	89	1.23	1	198	1.58	.5
1091	5159.07	4.26	45475	39250	3.78	87	1.22	1	225	1.64	.5
1091	5197.94	4.28	46925	39250	3.31	53	1.01	1	116	1.35	.5
1092	5133.69	4.16	36955	31690	4.61	172	1.53	1	387	1.88	1
1092	5078.98	4.28	46925	43760	4.12	114	1.35	2	190	1.57	.5
1092	5067.16	4.20	40405	37690	3.52	101	1.30	1	224	1.65	1
1094	5074.76	4.20	40405	37390	4.25	127	1.40	2	253	1.70	1
1095	5072.69	4.20	40405	37480	3.42	85	1.22	1	170	1.53	.5
1095	5148.23	4.24	43295	37480	4.10	105	1.31	1	150	1.46	.5
1097	4962.56	4.16	36955	38410	3.18	79	1.20	2	153	1.49	1
1102	4256.79	4.24	43295	78140	3.03	58	1.13	1			
1103	4112.97	4.16	36955	80020	4.18	134	1.51	1			
1107	5762.99	4.19	39475	12940	4.16	130	1.35	1	208	1.56	1
1107	5717.84	4.27	45565	20403	0.75	72	1.10	2	148	1.41	1
1107	5618.63	4.19	39475	17400	3.54	65	1.07	2	134	1.38	1
1108	5661.36	4.27	45565	22140	3.19	35	0.79	1	74	1.12	1
1108	5522.46	4.19	39475	20500	3.16	60	1.04	2	109	1.30	1
1112	5004.03	4.19	39475	39250	3.09	65	1.11	1			

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
1113	4945.63	4.19	39475	41610	2.84	65	1.12	1	122	1.39	.5
1128	5856.08	4.28	46375	17080	3.38	52	0.95	1	102	1.24	1
1144	5441.32	4.29	47825	31550	2.97	46	0.93	2			
1144	5466.40	4.35	52575	35460	3.72	94	1.24	1			
1145	5389.48	4.40	56125	41610	4.12	101	1.27	2			
1145	5398.28	4.43	58565	43760	4.00	80	1.17	2			
1145	5546.49	4.35	52575	32820	3.52	76	1.13	2	115	1.32	1
1145	5461.55	4.43	58565	41610	3.10	42	0.89	1			
1146	5424.07	4.30	48445	32750	4.92	163	1.48	1			
1146	5383.37	4.29	47825	33530	4.90	164	1.48	2			
1146	5369.96	4.35	52575	38740	4.80	141	1.42	2			
1146	5367.47	4.40	56125	42370	4.72	128	1.38	2			
1146	5364.87	4.43	58565	44910	4.64	127	1.38	2			
1147	5315.08	4.35	52575	40670	3.20	50	0.97	1	116	1.34	1
1148	5417.04	4.40	56125	40670	3.18	47	0.94	2			
1159	5653.89	4.37	53795	30610	3.39	53	0.97	1	106	1.27	1
1160	5624.06	4.37	53795	31550	3.65	67	1.08	1	128	1.36	1
1161	5619.60	4.37	53795	31690	3.26	45	0.91	1	118	1.32	1
1163	5445.04	4.37	53795	37390	4.41	125	1.36	2			
1163	5463.28	4.42	57685	40670	4.37	108	1.30	2			
1163	5462.97	4.45	60795	43790	4.22	104	1.28	2			
1164	5560.23	4.42	57685	37480	3.55	85	1.19	2			
1163	5349.74	4.37	53795	40670	3.28	57	1.03	2	125	1.37	1
1165	5415.20	4.37	53795	38410	4.94	158	1.47	2			
1165	5410.91	4.45	60795	45550	4.78	124	1.36	2			
1166	5180.06	4.45	60795	53790	3.77	104	1.30	1			
1166	5285.13	4.42	57685	46830	3.40	42	0.90	1	85	1.21	.5
1174	6627.56	4.53	66865	17710	3.10	34	0.71	1	55	0.92	1
1175	5983.70	4.53	66865	33940	3.96	81	1.13	2	131	1.34	1
1175	5997.80	4.59	71635	38310	3.59	68	1.06	1	110	1.26	1
1175	5927.80	4.63	75215	43860	3.77	52	0.95	1	74	1.10	1
1176	6079.02	4.63	75215	39670	3.60	54	0.95	1			
1176	5929.70	4.53	66865	35460	3.52	49	0.91	1	70	1.07	1
1177	6093.66	4.59	71635	35690	3.36	36	0.77	1			
1178	6024.07	4.53	66865	32820	4.50	119	1.30	2	201	1.52	1
1178	6020.17	4.59	71635	37690	4.26	102	1.23	1	205	1.53	1
1178	6007.96	4.63	75215	41610	3.92	67	1.05	2	130	1.34	2
1179	5816.36	4.53	66865	38740	4.03	82	1.15	1	173	1.47	1
1179	5855.13	4.59	71635	42370	3.61	29	0.69	1	54	0.97	.5
1180	5862.36	4.53	66865	37390	4.25	101	1.24	2	152	1.41	1
1180	5930.17	4.63	75215	43790	4.46	107	1.26	2	144	1.39	1
1180	5752.04	4.53	66865	40670	3.91	58	1.00	1	106	1.27	1
1181	5859.61	4.53	66865	37480	4.11	94	1.21	1	146	1.40	1

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
1181	5905.67	4.63	75215	44490	4.03	65	1.04	1	118	1.30	1
1182	5686.53	4.53	66865	42670	4.19	76	1.13	1	133	1.37	.5
1183	5554.90	4.53	66865	46830	4.12	109	1.29	1	173	1.49	1
1183	5565.71	4.59	71635	51250	4.29	100	1.25	1	178	1.50	1
1183	5679.02	4.63	75215	51250	4.14	67	1.07	2	117	1.31	1
1195	6733.16	4.62	74105	22570	3.26	37	0.74	1	51	0.88	1
1197	6633.76	4.54	67675	18370	3.69	72	1.04	1	133	1.30	2
1197	6533.97	4.54	67675	20670	3.19	50	0.88	1	103	1.20	1
1206	4749.93	4.54	67675	78140	3.43	48	1.00	1			
1207	4661.54	4.54	67675	82130	3.71	21	0.66	1			
1228	6667.73	4.56	69765	19690	2.54	20	0.48	1			
1234	5902.53	4.57	70765	39830	3.35	45	0.88	1			
1253	6569.23	4.71	81755	33944	0.16	92	1.15	1	167	1.41	1
1253	6597.61	4.77	86785	38310	3.54	45	0.83	1	81	1.09	1
1254	6330.86	4.71	81755	39670	3.49	37	0.77	2	68	1.03	1
1255	6494.51	4.71	81755	35690	3.59	39	0.78	1			
1258	6419.98	4.71	81755	37480	4.36	90	1.15	2	157	1.39	1
1258	6496.46	4.77	86785	40670	4.09	81	1.09	1			
1258	6338.90	4.77	86785	44490	3.78	48	0.88	1	100	1.20	.5
1258	6634.12	4.77	86785	37480	3.28	39	0.77	1			
1259	6055.99	4.71	81755	46330	4.16	79	1.12	1	109	1.26	1
1259	6078.50	4.77	86785	51250	4.20	75	1.09	2			
1259	6102.18	4.81	89965	53790	4.25	90	1.17	2			
1260	5984.80	4.71	81755	48800	4.33	88	1.17	1			
1260	5987.06	4.77	86785	53760	4.18	80	1.13	1	125	1.32	1

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MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
27	4233.17	2.58	20831	44447	2.20	154	1.56	1	220	1.72	1
37	4555.89	2.83	22810	44754	1.87	92	1.31	1	145	1.50	1
37	4491.40	2.85	23021	45290	1.56	82	1.26	1	145	1.51	1
37	4520.23	2.81	22637	44754	1.79	104	1.36	1	172	1.58	1
38	4620.51	2.83	22810	44447	1.03	54	1.07	1			
40	6432.65	2.88	23318	38859	0.96	42	0.81	1	65	1.00	1
40	6516.08	2.89	23318	38660	1.23	53	0.91	1	100	1.19	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
42	4923.92	2.88	23318	43621	2.76	142	1.46	1	250	1.71	1
43	4731.44	2.88	23318	44447	1.41	102	1.34	1			
46	5991.38	3.14	25429	42115	0.93	30	0.70	1	43	0.86	1
48	5264.80	3.19	25805	45044	1.48	48	0.96	1			
49	5234.62	3.21	25982	45080	1.97	83	1.20	2	136	1.41	1
49	5197.57	3.22	26055	45290	1.93	81	1.19	2	150	1.46	.5
49	5425.27	3.19	25805	44233	1.06	39	0.86	1			
49	5325.56	3.21	25982	44754	1.13	41	0.89	1	66	1.09	1
74	6456.38	3.89	31483	46967	2.37	47	0.86	1	65	1.00	1
74	6247.56	3.87	31388	47390	2.25	42	0.83	1	64	1.01	1
74	6149.24	3.87	31368	47626	1.83	30	0.69	1			

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						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	4252.31	0.10	816	24326	0.86	220	1.71	1	371	1.94	.5
1	4285.79	0.17	1407	24733	0.52	148	1.54	1	199	1.67	.5
3	4027.04	0.17	1407	26323	1.07	187	1.67	1	353	1.94	1
3	4057.20	0.22	1809	26450	0.72	176	1.64	1	290	1.85	1
15	4727.94	0.43	3483	24628	0.52	150	1.50	1			
16	4020.90	0.43	3483	28346	2.02	185	1.66	2	300	1.87	1
16	3987.12	0.51	4143	29216	1.24	165	1.62	1	220	1.74	.5
16	4019.30	0.58	4690	29563	1.00	125	1.49	2	201	1.70	1
28	4121.32	0.92	7442	31700	3.59	213	1.71	1			
29	4110.54	1.04	8461	32782	2.81	241	1.77	2			
30	4066.37	0.92	7442	32028	2.50	177	1.64	1	280	1.84	1
31	3995.31	0.92	7442	32465	3.76	239	1.78	1	443	2.04	.5
32	3997.91	1.04	8461	33467	3.09	167	1.62	1	273	1.83	1
37	6282.63	1.73	14031	29949	2.13	121	1.29	1	200	1.50	1
37	6189.00	1.70	13796	29949	1.94	98	1.20	1			
37	6093.13	1.73	14036	30444	1.97	82	1.13	1			
37	6116.98	1.78	14399	30743	1.88	59	0.99	1			
38	5530.77	1.70	13796	31871	2.14	106	1.28	1	173	1.50	1
39	5483.34	1.70	13796	32028	2.54	141	1.41	1	234	1.63	1
39	5369.58	1.73	14036	32654	2.48	134	1.40	1			
39	5301.06	1.70	13796	32654	2.33	100	1.27	1	170	1.51	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
39	5247.93	1.78	14399	33449	2.72	107	1.31	2	190	1.56	1
54	6771.06	1.87	15184	29949	2.25	112	1.22	1	160	1.37	.5
54	6678.81	1.95	15774	30743	1.80	37	0.74	1			
58	4086.31	1.87	15184	39649	3.34	203	1.70	1			
58	4068.54	1.95	15774	40346	3.12	101	1.40	2	151	1.57	1
59	4023.40	1.95	15774	40622	2.35	118	1.47	2	184	1.66	.5
82	5915.54	2.13	17234	34134	2.38	59	1.00	2	124	1.32	2
83	5235.21	2.13	17234	36330	2.99	110	1.32	1	150	1.46	1
90	5590.73	2.03	16471	34352	2.42	77	1.14	1	166	1.47	1
92	4899.52	2.03	16471	36875	2.32	80	1.21	1			
112	5647.22	2.27	18390	36092	2.69	72	1.11	2	115	1.31	1
150	4517.11	3.11	25233	47365	3.58	67	1.17	1	131	1.46	1
156	4693.21	3.22	26063	47365	3.99	51	1.04	1			
158	4867.88	3.10	25139	45676	4.54	126	1.41	1	240	1.69	1
158	4813.48	3.20	25938	46707	4.20	89	1.27	1			
158	4792.86	3.24	26232	47091	4.41	79	1.22	1			
170	5212.71	3.50	28346	47524	4.43	65	1.09	1			
170	5146.74	3.55	28777	48202	4.29	119	1.37	1			
172	5352.05	3.56	28845	47524	4.47	61	1.06	1	100	1.27	1
190	5342.71	4.00	32431	51143	4.78	53	1.00	1	101	1.28	1
190	5343.39	4.01	32465	51174	4.48	95	1.25	1	150	1.45	1
191	5334.84	4.00	32431	51170	3.95	33	0.79	1			
192	5325.28	4.00	32431	51202	4.25	21	0.59	1			
195	5454.56	4.05	32842	51170	4.34	32	0.76	1			
196	5444.57	4.05	32842	51207	4.44	33	0.78	1			
196	5381.75	4.22	34196	52772	4.11	13	0.37	1			
197	5312.66	4.19	33946	52764	4.39	20	0.58	1	34	0.81	1

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						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
42	6128.98	1.68	13521	29833	0.76	90	1.17	1			
42	6007.31	1.68	13521	30163	0.85	85	1.15	2	147	1.39	2
43	6643.64	1.68	13521	28569	1.96	183	1.44	2	293	1.64	2
44	6327.60	1.68	13521	29321	1.00	102	1.21	2	195	1.49	2
44	5847.00	1.68	13521	30619	0.80	95	1.21	2	156	1.43	2

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
45	6191.18	1.68	13521	29669	1.65	157	1.41	2			
45	6108.12	1.68	13521	29888	1.49	123	1.30	2			
45	5748.35	1.68	13521	30913	1.02	100	1.24	2	210	1.56	1
47	5578.72	1.68	13521	31442	1.49	133	1.38	2	240	1.63	1
48	5137.07	1.68	13521	32982	2.17	176	1.54	2	282	1.74	1
49	5102.96	1.68	13521	33112	1.37	130	1.41	1	270	1.72	.5
49	4976.32	1.68	13521	33611	1.11	106	1.33	2	188	1.58	1
50	5003.74	1.68	13521	33501	1.10	86	1.23	2			
51	4519.98	1.68	13521	35639	1.57	103	1.36	1	172	1.58	1
52	4331.64	1.68	13521	36601	2.27	130	1.48	2	270	1.79	.5
57	6767.77	1.82	14729	29501	2.22	159	1.37	1	316	1.67	.5
58	6177.24	1.82	14729	30913	0.51	59	0.98	2			
59	5476.90	1.83	14729	32982	3.16	253	1.66	2	390	1.85	.5
64	6532.88	1.93	15610	30913	1.07	68	1.02	1	159	1.39	1
66	6482.80	1.93	15610	31031	1.69	118	1.26	2	180	1.44	1
68	5754.66	1.93	15610	32982	2.12	136	1.37	2	256	1.65	1
68	5796.08	1.95	15734	32982	0.67	44	0.88	1	99	1.23	1
68	5892.87	1.99	16017	32982	1.98	150	1.41	2	265	1.65	1
70	5587.86	1.93	15610	33501	1.88	120	1.33	2	251	1.65	1
70	5424.64	1.95	15734	34163	1.70	106	1.29	1			
70	5435.86	1.99	16017	34409	1.85	106	1.29	2			
71	4762.63	1.93	15610	36601	1.92	100	1.32	1			
71	4790.97	1.95	15734	36601	0.93	53	1.04	1			
86	4470.48	3.40	17415	49778	4.24	108	1.38	2	204	1.66	1
97	6621.14	3.60	29013	44112	1.96	6	-0.04	1			
98	4714.42	3.38	27261	48467	4.57	156	1.52	1			
98	4648.65	3.42	27580	49086	4.47	103	1.35	2			
98	4756.51	3.48	28068	49086	4.14	105	1.34	1			
98	4715.76	3.54	28578	49778	4.07	97	1.31	1			
98	4686.21	3.60	29013	50346	3.99	77	1.22	1			
98	4814.60	3.60	29013	49778	2.72	37	0.89	1			
101	4701.35	3.48	28068	49333	3.06	64	1.13	1			
111	5017.58	3.54	28542	48467	3.56	114	1.36	2	232	1.66	1
111	4998.22	3.60	29084	49086	3.64	70	1.15	2	140	1.45	1
111	5012.44	3.70	29833	49778	3.86	80	1.20	2	155	1.49	.5
111	4912.02	3.77	30392	50745	3.56	64	1.12	1	130	1.42	.5
111	4866.27	3.54	28542	49086	4.11	100	1.31	1	180	1.57	.5
111	4831.17	3.60	29084	49778	3.99	93	1.29	1			
111	4873.44	3.70	29833	50346	3.94	88	1.26	2	176	1.56	1
111	5157.98	3.60	29084	48467	2.90	39	0.88	1			
111	5010.02	3.77	30392	50346	3.45	53	1.02	1	140	1.45	.5
112	4873.25	3.74	30163	50678	3.03	47	0.99	1			
113	5128.09	3.70	29833	49328	2.55	38	0.87	1			

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
114	4937.35	3.60	29084	49333	3.71	108	1.34	2			
114	5131.77	3.70	29833	49314	3.35	71	1.14	2	140	1.44	1
115	4675.60	3.60	29084	50466	2.79	32	0.84	1			
126	6432.00	3.54	28569	44112	1.85	10	0.19	1			
127	6370.35	3.54	28569	44263	2.58	27	0.63	1	82	1.11	1
127	6772.32	3.66	29501	44263	3.65	69	1.01	1	117	1.24	1
130	4855.41	3.54	28569	49159	4.24	115	1.38	2			
130	4852.55	3.54	28569	49171	3.26	66	1.13	2			
131	4829.02	3.54	28569	49271	3.98	97	1.30	2			
131	5042.18	3.64	29501	49328	3.75	78	1.19	2			
132	4752.42	3.64	29501	50537	3.72	83	1.24	2			
132	4913.97	3.74	30192	50537	3.69	75	1.18	2	135	1.44	1
143	5080.53	3.65	29481	49158	4.62	129	1.40	2	275	1.73	1
143	5035.36	3.63	29321	49175	4.50	115	1.36	2	220	1.64	1
143	4984.11	3.78	30619	50678	4.38	105	1.32	2	165	1.52	.5
144	5010.94	3.63	29321	49272	3.47	60	1.08	1	160	1.50	.5
145	4945.44	3.80	30619	50834	3.22	70	1.15	1	122	1.39	.5
145	4995.65	3.63	29321	49333	2.57	36	0.86	2			
146	4763.94	3.65	29481	50466	3.77	138	1.46	1			
148	4946.03	3.80	30619	50832	2.79	43	0.94	1			
149	4400.87	3.65	29481	52197	3.33	96	1.34	1			
161	5099.93	3.68	29669	49271	4.10	107	1.32	1	227	1.65	1
162	5084.09	3.68	29669	49333	4.17	98	1.29	1	160	1.50	1
163	4806.99	3.68	29669	50466	3.87	77	1.20	2			
163	4731.80	3.83	30913	52041	3.61	63	1.13	1			
164	5094.41	3.83	30913	50537	3.23	53	1.02	1	120	1.37	.5
165	4752.12	3.68	29669	50706	3.33	60	1.10	1			
177	5115.39	3.83	30923	50466	4.23	90	1.24	2	202	1.60	1
177	4935.83	3.94	31786	52040	4.01	75	1.18	2	152	1.49	1
192	5468.10	3.85	31031	49314	2.91	23	0.62	1			
194	5081.11	3.85	31031	50706	4.59	116	1.36	2	250	1.69	.5
205	5589.36	3.90	31442	49328	3.28	34	0.79	1			
206	5593.74	3.90	31442	49314	3.56	53	0.97	1	100	1.25	1
207	5032.73	3.90	31442	51306	3.10	45	0.95	1	107	1.33	.5
209	5176.56	3.90	31442	50754	3.77	70	1.13	1	130	1.40	1
210	5155.76	3.90	31442	50832	4.25	98	1.28	2	200	1.59	.5
215	5628.35	4.09	32982	50745	3.14	18	0.50	1	40	0.85	1
218	5637.12	4.09	32982	50717	3.46	48	0.93	1	111	1.29	1
219	5600.02	4.09	32982	50834	3.33	56	1.00	1			
220	5694.98	4.09	32982	50537	3.80	52	0.96	2	125	1.34	.5
222	5411.22	4.09	32982	51457	3.57	46	0.93	2			
226	6204.61	4.09	32973	49086	3.21	27	0.64	1			
227	6424.86	4.17	33611	49171	3.11	16	0.39	1			

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
228	6176.81	4.09	32973	49158	3.97	72	1.06	2			
228	6223.99	4.10	33112	49175	3.29	35	0.75	1			
229	6186.72	4.10	33112	49272	3.35	47	0.88	1			
230	6111.07	4.09	32973	49333	3.30	45	0.87	1			
230	6118.10	4.09	32973	49314	2.13	4	-0.18	1			
232	5682.20	4.10	33112	50706	3.95	59	1.02	1			
234	5641.88	4.10	33112	50832	3.39	33	0.77	2	60	1.03	1
234	5805.22	4.17	33611	50832	3.75	48	0.92	1	68	1.07	1
235	4701.53	4.09	32973	54237	4.20	59	1.10	1			
244	6272.64	4.26	34409	50346	2.66	10	0.20	1			
246	6384.67	4.15	33501	49159	3.43	32	0.70	1	85	1.12	.5
246	6300.34	4.26	34409	50276	4.26	59	0.97	1	111	1.25	1
247	6378.26	4.15	33501	49175	3.60	46	0.85	1	102	1.20	1
247	6053.69	4.23	34163	50678	3.28	25	0.62	2	63	1.02	1
248	6130.13	4.26	34409	50717	3.34	25	0.62	1			
249	6598.60	4.23	34163	49314	3.48	28	0.63	1			
249	6086.28	4.26	34409	50834	3.68	49	0.90	1			
250	5614.78	4.15	33501	51306	3.85	51	0.96	1	82	1.16	1
250	5392.33	4.15	33501	52041	3.04	21	0.59	1			
254	4821.12	4.15	33501	54237	3.68	45	0.97	1			
259	5643.08	4.16	33590	51306	3.27	30	0.73	1	48	0.93	1
264	6635.13	4.42	35639	50706	3.63	35	0.72	1			
274	4971.35	4.54	36601	56711	4.31	77	1.19	1	143	1.46	.5

Cu I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
2	5105.54	1.38	11203	30784	2.01	183	1.56	2	388	1.88	2
2	5782.13	1.64	13245	30535	2.19	174	1.48	1	273	1.67	1
7	5218.20	3.80	30784	49942	4.10	79	1.18	1	130	1.40	1

Zn I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
2	4810.53	4.06	32890	53672	4.54	75	1.20	1			
2	4722.16	4.01	32501	53672	4.36	68	1.16	1			

Sr I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
2	4607.33	0.0	0	21698	3.09	102	1.35	2			
5	4811.88	1.84	14899	35675	3.75	42	0.94	1			

Sr II

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
1	4077.71	0.0	0	24517	2.83	655	2.21	2	1180	2.46	1

Y I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	LOG F	WT.	31 CYGNI A W	LOG F	WT.
2	6435.00	0.07	530	16066	2.22	32	0.70	1	95	1.17	1
3	6023.41	0.0	0	16597	1.26	6	0.01	1	40	0.82	1

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
4	4643.70	0.0	0	21529	2.76	47	1.01	1			
13	4819.64	1.35	10937	31680	2.91	20	0.62	1			

Y II

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
5	4398.02	0.13	1045	23776	2.39	135	1.49	2	250	1.75	1
20	5087.42	1.08	8743	28394	2.84	80	1.20	1	180	1.55	1
20	5200.41	0.99	8003	27227	2.67	94	1.26	2	216	1.62	1
20	5289.82	1.03	8323	27227	1.48	18	0.53	1	50	0.98	1
22	4883.69	1.08	8743	29214	3.19	114	1.37	2	240	1.69	2
35	5402.78	1.83	14018	32284	2.33	33	0.79	1			

Zr I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
2	6127.44	0.15	1241	17556	2.39	51	0.92	1			
2	6143.19	0.07	570	16844	2.11	48	0.89	1			
2	6134.55	0.0	0	16297	1.91	41	0.83	1			
3	5955.35	0.0	0	16787	1.44	15	0.40	1	85	1.15	1
4	5879.80	0.15	1241	18244	2.10	26	0.65	1			
5	4575.52	0.0	0	21849	2.30	87	1.28	1	182	1.60	.5
24	6140.46	0.52	4186	20467	1.91	9	0.17	1			
24	6192.96	0.54	4376	20519	1.72	7	0.05	1			
26	5385.14	0.52	4186	22751	2.40	36	0.82	1			
27	5311.40	0.52	4197	23019	2.02	29	0.74	1	120	1.35	1
43	4687.80	0.73	5889	27215	3.66	81	1.24	1			
43	4739.48	0.65	5249	26343	3.36	66	1.14	1			
43	4815.63	0.60	4871	25630	2.99	55	1.06	1			

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
43	4805.87	0.68	5541	26343	2.64	24	0.69	1			
45	4241.69	0.65	5249	28818	3.43	66	1.19	1	165	1.59	1
47	5664.51	0.63	5102	22751	2.25	21	0.56	1	85	1.18	1

Zr II

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
15	4211.88	0.52	4248	27984	2.41	110	1.42	1	235	1.75	.5
16	3998.97	0.56	4506	29505	3.10	115	1.46	1	204	1.71	1
40	4317.31	0.71	5753	28909	2.16	65	1.18	1	130	1.48	1
41	4208.98	0.71	5753	29505	3.08	101	1.38	2	220	1.72	1

Mo I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
4	5570.45	1.33	10768	28715	3.19	40	0.86	1	85	1.18	1
5	6030.66	1.52	12346	28924	3.07	22	0.56	1	45	0.87	1
5	5751.40	1.41	11454	28837	2.63	6	0.02	1			

Ba I

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
7	5971.70	1.14	9216	25957	3.69	3	-0.37	1			

Ba II

MULT.	λ	LOW E.P.	ENERGY	LEVELS	LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
1	4554.04	0.0	0	21952	3.84	275	1.78	1	675	2.17	1
1	4934.10	0.0	0	20262	3.55	263	1.73	1	580	2.07	1
2	6496.91	0.60	4874	20262	3.39	181	1.45	2	460	1.85	1
2	5853.69	0.60	4874	21952	2.69	126	1.33	2	256	1.64	1

La II

MULT.	λ	LOW E.P.	ENERGY	LEVELS	LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
8	4661.51	0.0	0	21442	1.63	44	0.97	1			
10	4086.72	0.0	0	24463	3.01	110	1.43	1			
19	6320.39	0.17	1394	17212	1.22	28	0.65	1	85	1.13	1
25	4322.51	0.17	1394	24523	2.02	57	1.12	1	129	1.47	1
27	3995.75	0.17	1394	26414	3.02	104	1.42	2	180	1.65	1
33	6390.48	0.32	2592	18236	1.40	23	0.56	1	82	1.11	1
36	5122.99	0.32	2592	22106	1.93	45	0.95	1			
36	5303.55	0.32	2592	21442	1.49	21	0.60	1	58	1.04	.5
40	3988.52	0.40	3250	28315	3.34	131	1.52	1	234	1.77	1
41	4238.38	0.40	3250	26838	2.83	104	1.39	1	203	1.68	1
47	6358.13	0.71	5718	21442	1.06	5	−0.13	1			
50	4526.12	0.77	6227	28315	2.55	55	1.08	1	110	1.39	.5
65	4748.73	0.92	7473	28526	2.48	25	0.72	1			

Ce II

MULT.	λ	LOW E.P.	ENERGY	LEVELS	LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
1	4562.36	0.14	3854	25766	3.59	67	1.17	1	115	1.40	1
2	4418.78	0.38	6968	29592	3.68	51	1.06	1	107	1.38	.5

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
13	5330.58	0.39	7012	25766	2.99	21	0.60	1			
15	5274.24	0.56	8424	27379	3.42	25	0.68	1	77	1.16	.5
17	4773.94	0.44	7455	28396	3.12	27	0.75	1			
30	6043.39	0.72	9726	26268	3.05	8	0.12	1			
57	4486.91	0.29	2382	24663	3.03	61	1.14	1	139	1.49	1
59	4349.79	0.70	4266	27250	3.22	36	0.91	1	88	1.31	.5

Pr II

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
37	5135.13	0.95	7660	27128	2.82	60	1.07	1	134	1.42	1
37	5292.63	0.65	5226	24115	2.60	45	0.93	2	106	1.30	1

Nd II

						ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	4959.13	0.06	513	20673	2.10	78	1.20	1	200	1.61	1
3	4811.34	0.06	513	21292	1.91	66	1.14	1			
10	4061.09	0.47	3802	28419	3.64	113	1.44	1	197	1.69	.5
10	4358.17	0.32	2585	25524	2.66	98	1.35	2	205	1.67	.5
36	4021.34	0.32	2585	27446	2.83	53	1.12	1	112	1.44	.5
43	5255.51	0.20	1650	20673	2.29	61	1.07	1	140	1.43	.5
46	5089.84	0.20	1650	21292	1.92	42	0.92	1	134	1.42	.5
48	5092.80	0.38	3067	22698	2.49	53	1.02	1	137	1.43	1
49	4446.39	0.20	1650	24139	2.36	73	1.22	1	194	1.64	1
50	4385.66	0.20	1650	24445	2.46	79	1.26	1			
58	4541.27	0.38	3067	25081	2.28	77	1.23	1	170	1.57	1
73	5548.47	0.55	4438	22456	1.78	12	0.34	1	62	1.05	.5

					ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS	LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
75	5249.59	0.97	7869 26913	3.35	53	1.01	1	149	1.45	1
75	5319.82	0.55	4438 23230	2.77	65	1.09	2	120	1.35	.5
78	5811.57	0.86	6931 24134	2.24	16	0.45	1			

Sm II

					ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS	LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
3	4676.91	0.04	327 21702	2.28	56	1.08	1			
15	4329.02	0.18	1489 24583	2.73	71	1.21	1	130	1.48	1
23	4577.69	0.25	2003 23842	2.26	43	0.97	1			
23	4499.48	0.25	2003 24222	2.07	39	0.94	1	79	1.24	.5
27	4318.94	0.28	2238 25385	2.86	69	1.20	1	100	1.36	1
27	4244.70	0.28	2238 25790	2.39	30	0.85	1	59	1.14	1
36	4642.24	0.38	3053 24588	2.55	49	1.03	1			
37	4262.68	0.38	3053 25606	2.79	84	1.29	1	154	1.56	1
41	4523.91	0.43	3499 25598	2.50	64	1.15	1	123	1.43	1
49	4519.63	0.54	4386 26506	2.74	57	1.10	1	116	1.41	1

Eu II

					ARCTURUS			31 CYGNI A		
MULT.	λ	LOW E.P.	ENERGY LEVELS	LOG gfλ	W	LOG F	WT.	W	LOG F	WT.
1	4129.70	0.0	0 24208	3.31	264	1.81	1			

Gd II

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
115	5140.84	1.57	12704	32150	2.95	28	0.74	2			

Yb I

MULT.	λ	LOW E.P.	ENERGY LEVELS		LOG gfλ	ARCTURUS W	ARCTURUS LOG F	ARCTURUS WT.	31 CYGNI A W	31 CYGNI A LOG F	31 CYGNI A WT.
2	3987.98	0.0	0	25068	3.18	55	1.14	1	97	1.39	1

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