SPECTROGRAPHIC OBSERVATIONS OF THE 1962 ECLIPSE OF 32 CYGNI

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RIASSUNTO. — Le osservazioni spettrografiche dell'eclisse di 32 Cygni nel 1962 danno i seguenti risultati: inizio della fase parziale, fra il giorno giuliano 2437800 e ...805; fine fra ...827 e ...832; metà eclisse ...816. La riga K cromosferica è apparsa fra 43 e 33 giorni prima dell'inizio della totalità ed è scomparsa circa 46 giorni dopo la fine.

Si sono determinate le variazioni di intensità della K cromosferica e di parecchie altre righe cromosferiche e si sono misurate le velocità radiali di righe prevalentemente di origine cromosferica, nel periodo compreso fra il 19 marzo e il 21 agosto 1962.

Si è determinato il rapporto α fra i continui della stella B e della stella K fra 4300 e 3500 A e si è stimato il valore della discontinuità di Balmer nello spettro della stella B. Lo spettro di quest'ultima è stato ricostruito sottraendo dallo spettro fuori eclisse lo spettro K della totalità ridotto nel rapporto $k = 1/(1 + \alpha)$. Il tipo spettrale della compagna è B5 IV o V, ed è molto simile a quello della compagna di 31 Cygni.

ABSTRACT. — The spectrographic observations of the eclipse of 32 Cygni give the following results: beninning of the partial phase, between J. D. 2437800 and ...805; end of the partial phase, between J. D. ...827 and ...832. Mid-eclipse: J. D. ...816. The chromospheric K line appears for the first time in the interval 43 to 33 days before the beginning of totality and disappears about 46 days after the end of totality.

The variations of the total intensity of the K chromospheric line, of the central depths of several chromospheric lines and of the radial velocities are given. The ratio $\alpha = I_{cB}/I_{cK}$ in the spectral range 4300-3500 is determined and an estimate is made of the value of the Balmer discontinuity of the B star. The spectrum of the B star is constructed by subtraction of the K-type spectrum reduced by the factor $k = 1/(1 + \alpha)$ from the composite spectrum B + K. The spectral type for the B component is B5 IV or V, and is very similar to the B component of 31 Cygni.

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INTRODUCTION

The binary star 32 Cygni was observed from March 19 to August 21, 1962 with the grating spectrograph at the Zeiss reflector. The dispersion is 22 A/mm in the spectral range $\lambda\lambda$ 3500-4350 (third order).

The present investigation is based upon 37 spectrograms obtained mainly by all four authors (Table I).

The radial velocity measurements were done by Gökgöz and Kendir; several spectrograms were measured also by Faraggiana and Hack. No systematic differences were found among the four observers. The microphotometer tracings and the identification of the lines were made by Faraggiana and Kendir. The reduction of the tracings and their interpretation is mainly due to Faraggiana and Hack.

EPOCH OF THE ECLIPSE

Wellmann (1) gives the following period for 32 Cygni: $P = 1149^d.0 \pm 0.4$. According to the General Catalogue of Variable Stars the period is $1148^d.0$ and mid-eclipse was predicted for June 3, 1962. The length of total eclipse of the B-type star is about 13 days and the length of partial eclipse is about 4 days.

From a visual inspection of the spectrograms (2) based upon the comparison of the intensities of the H and K lines of Ca II we estimated that the partial phase began after May 16 (J. D. 2437800) and before May 21 (J. D. ...805) and finished after June 10 (J. D. ...826) but before June 16 (J. D. ...831). Therefore we estimated that mid-eclipse occurred between May 31 and June 1 (J. D. $\backsim$ ...816). These estimates are not contradicted by the quantitative measurements of the intensities of the chromospheric lines.

A photometric investigation by Herczeg and Schmidt (3) gives as the most probable epoch for mid-eclipse J. D. 2437815.0 or 2437816.0. According to these photometric observations in the blue and in the ultraviolet the partial phase began about J. D. ...800 (UV) or 805 (B) and finished about J. D. ...825 (B) or 830 (UV). These values are in good agreement with our estimates.

Using the epochs of mid-eclipse adopted by Wright (4) ($T_0 = 2433224.0$), by Wellmann (5) ($T_0 = 2434373.3$) and by the General Catalogue ($T_0 = 2434374.3$) and adopting for the present eclipse $T_0 = 2437815.5$ we find for the period: $P = 1147.9$; $P = 1747.4$; $P = 1147.1$ respectively.

From our observations it follows that the first appearance of the chromospheric K line occurred after April 13 (no trace of the chromospheric

TABLE I

Spectrum	Date	J. D.	Quality
H 1026	March 19, 1962	2437742.67	good
K 1053	April 12, 1962	766.67	good
G 1058	April 13, 1962	767.67	good
H 1066	April 23, 1962	777.62	good
H 1082	April 27, 1962	781.55	underexposed
G 1088	May 15, 1962	799.54	good
H 1098	May 16, 1962	800.62	out of focus
H 1104	May 21, 1962	805.55	good
H 1112	May 22, 1962	806.55	very good
H 1120	May 23, 1962	807.58	good
H 1125	May 24, 1962	808.55	fairly good
H 1126	June 3, 1962	819.46	dedoubled
H 1127	June 4, 1962	819.55	dedoubled
H 1128	June 4, 1962	819.62	very good
H 1129	June 9, 1962	825.44	good
H 1130	June 9, 1962	825.50	underexposed
G 1134	June 10, 1962	826.50	dedoubled
Fa 1138	June 17, 1962	832.56	underexposed
Fa 1144	June 18, 1962	834.48	slightly doubled
P 1150	June 20, 1962	835.52	weak
Fa 1153	June 21, 1962	837,46	weak
K 1156	June 22, 1962	838.46	weak
G 1163	July 8, 1962	853.62	fairly good
K 1167	July 9, 1962	854.62	underexposed
Fa 1189	July 17, 1962	862.62	good
Fa 1200	July 19, 1962	864.52	good
K 1212	July 21, 1962	866.52	underexposed
G 1216	July 22, 1962	867.55	good
K 1220	July 23, 1962	868.52	weak
G 1227	August 9, 1962	886.46	good
Fa 1236	August 11, 1962	887.52	good
Fa 1257	August 12, 1962	889.52	good
Fa 1268	August 13, 1962	890.52	good
Fa 1284	August 14, 1962	891.52	good
K 1289	August 16, 1962	892.55	good
K 1296	August 18, 1962	895.50	good
L 1306	August 21, 1962	898.52	fairly good

K line was visible) and April 23 (a sharp chromospheric K line is clearly visible), namely between 43 and 33 days before totality begins. The last chromospheric K line was observed on July 8, about 32 days after the end of totality. The next spectrogram was taken July 17, and presents a feature which can be interpreted as an emission component of the K line (Fig. 1). The same feature is visible on the two following spectrograms of July 19 and July 22; the presence of the absorption chromospheric line is doubtful. The chromospheric K line is certainly absent in the spectrogram of August 9, 64 days after the end of totality.

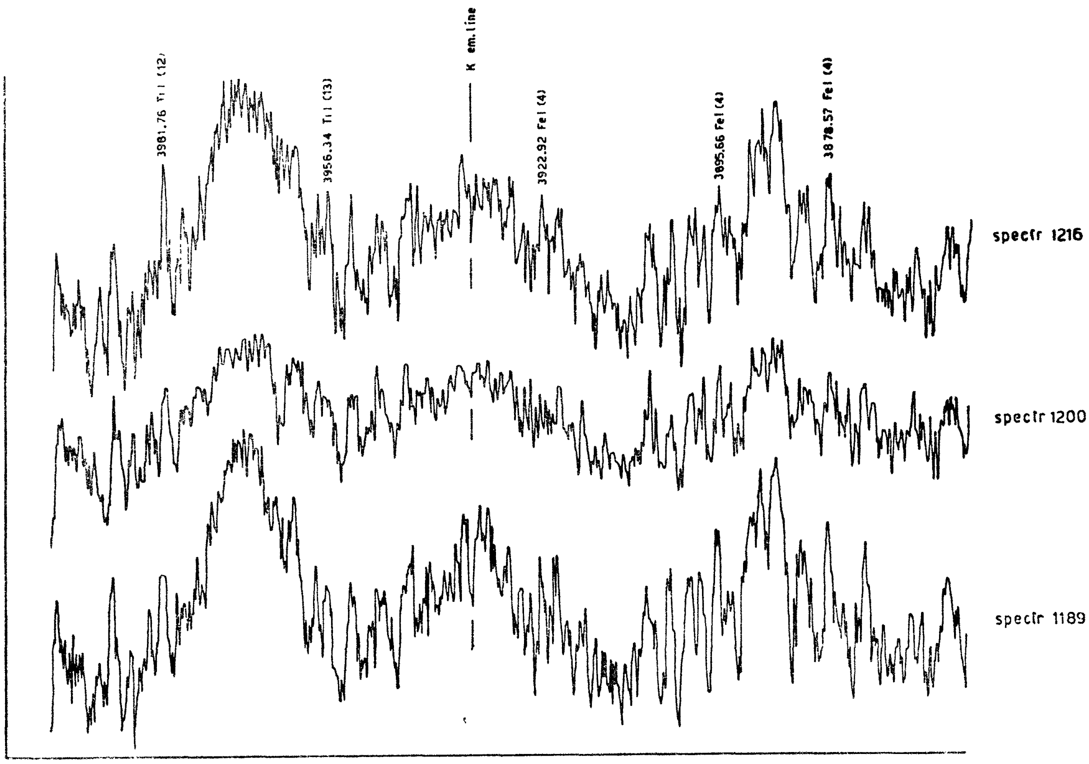

Fig. 1

INTENSITY VARIATIONS OF THE CHROMOSPHERIC LINES

Fig. 2 shows the variation of the equivalent width of the chromospheric K line. The equivalent widths have been measured in the usual way relatively to a continuum which is the sum of the continuum of the B star and of the absorption contour of the K line due to the K-type star. The results of the previous eclipses, observed by Wellmann ([1]) and by Wright and McDonald ([5]) are reported for comparison. The dispersions (19.9 A/mm and 32.5 A/mm at λ 3933) are comparable with our dispersion (22 A/mm). The agreement between our results and those of the previous eclipses is generally good; however the intensities observed about 40 days before and 40 days after mid-eclipse are lower by a factor of $\sim$ 2 than those observed previously. This could be correlated with the fact that the first chromospheric K line became observable only forty days before mid-eclipse and not 70 or 60 days before as was the case for the eclipses of 1949, 1952-53 and 1959.

Fig. 3 (a, b) gives the variations of the central depths of the chromospheric lines. The sudden increase of the central depths during the partial phases, is remarkable clearly showing the period of geometrical eclipse.

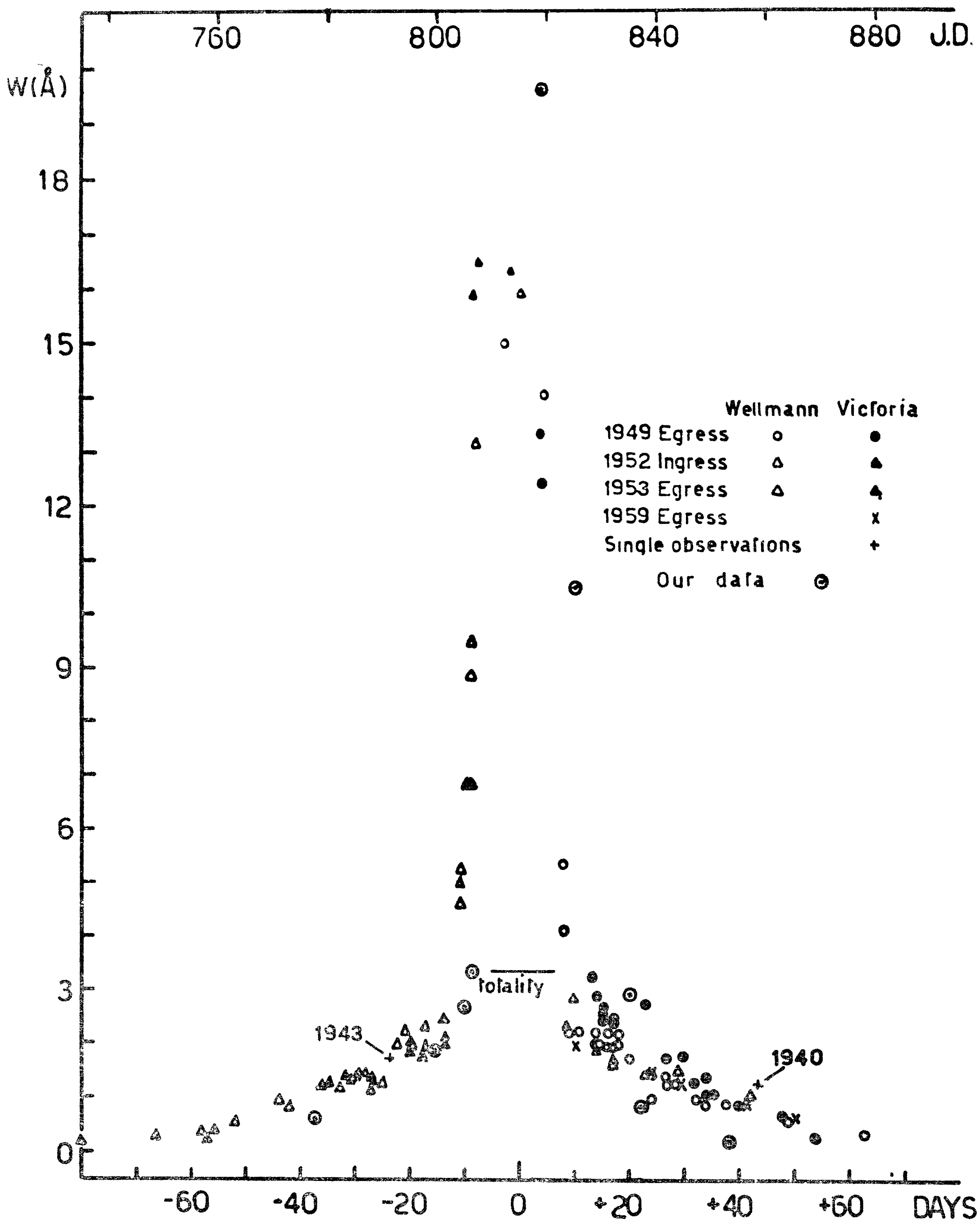

Fig. 2

RADIAL VELOCITIES OF THE CHROMOSPHERIC LINES

Radial velocities were measured using the same lines used for 31 Cygni (6), namely the lines in the spectral region $\lambda\lambda$ 4070-3500 where the contribution of the K star is relatively small, and the lines are mainly due to the chromo-

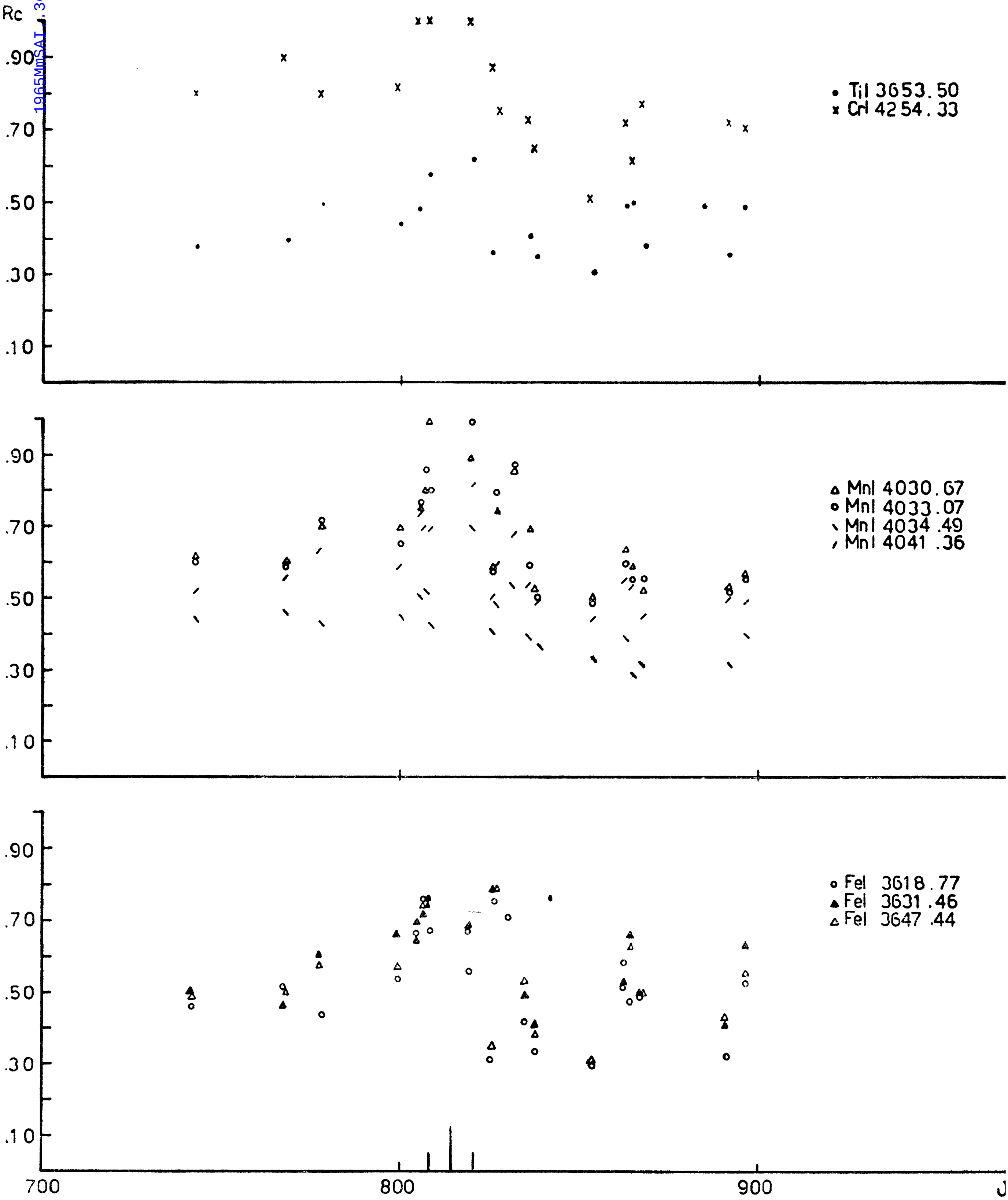
Rc
.90
.70
.50
.30
.10
• TiI 3653.50
x CrI 4254.33
MnI 4030.67
MnI 4033.07
MnI 4034.49
MnI 4041.36
FeI 3618.77
FeI 3631.46
FeI 3647.44
700
800
900

Fig. 3a

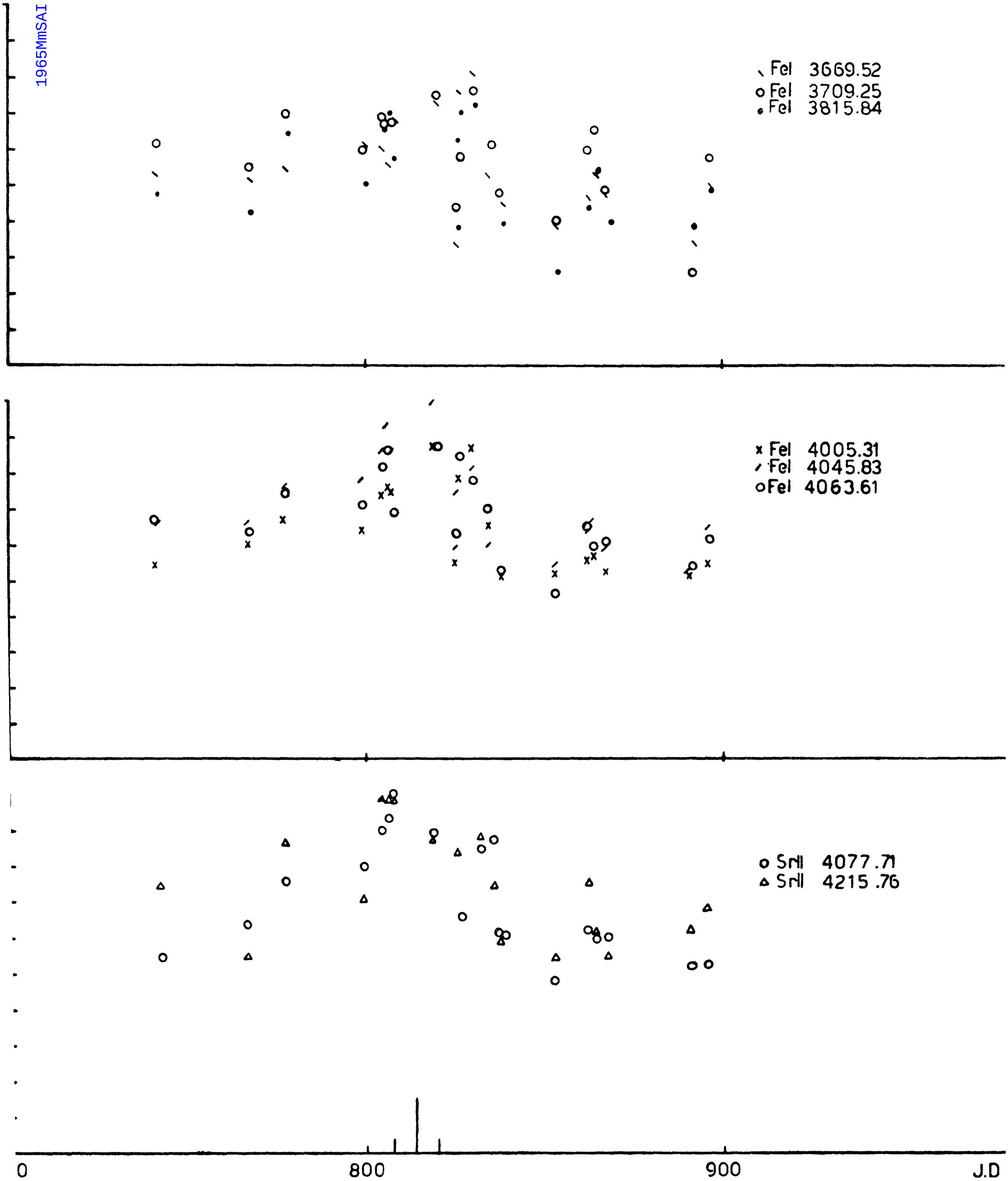
FeI 3669.52
FeI 3709.25
FeI 3815.84
FeI 4005.31
FeI 4045.83
FeI 4063.61
SrII 4077.71
SrII 4215.76
0
800
900
J.D

Fig. 3b

sphere of the K star. The results are shown in Fig. 4. The orbital velocity curves derived by the Ottawa observations (1910-1917) and by the Victoria observations (1936-1950) are shown ([4]). Our observations indicate a value about 12 km/sec more negative than the Ottawa curve. This difference is partly instrumental. Determinations of radial velocity of the standard star β Gem (K 0) have been made using two spectrograms taken in the same conditions as 32 Cygni; the radial velocity we derive is 5.4 km/s more negative than that given in the Lick Catalogue of Radial Velocities (— 2.1 km/s ± 1.0 km/s instead of + 3.3 km/s ± 1 km/sec.

The radial velocities of the chromospheric lines have the same behavior observed in 31 Cygni, namely they have values 10 to 20 km/s more negative than the orbital velocity before and after geometrical eclipse. The chromospheric K line usually shows negative velocities higher than the other chromospheric lines. The feature observed on the spectrogram of July 17, if interpreted as an emission component of the K line has a radial velocity 40 km/s more positive than the orbital velocity. The results are given in Table II.

TABLE II

		Radial velocity (km/sec)					
Spectr.	J. D.	Mg I 3 E.P. = 2.7	Ca II (K line)	Mn I 2 E.P. = 0.0	Fe I 4 and 5 E.P. = 0.0	Fe I 20 and 21 E.P. = 1.0	Fe I 43 and 45 E.P.=1.5
H 1026	2437742.67	—13	—32	(—31.5)	—24.5	—29.5	—35.0
K 1053	766.67	—16	—18.5	(—37.5)	—25.5	—12.5	—25.0
G 1058	767.67	—34		(—44.6)	—25.5	—21	—25
H 1066	777.62	—26	—27	(—33)	—25	—25	—20
G 1088	799.54	—28	—38	(—26.5)	—20.0	—15.5	—15
H 1104	805.50	—16	—19	—32	—18	—14	—15
H 1112	806.55	—10		—27	—18	—15	—19
H 1120	807.58	—15		—21	—24	—17.5	—15.5
H 1128	819.62	—17		—30.5	—21.5	(—9	—17
H 1129	825.44	—7		—16	—13	—9.5	—13
H 1130	825.50	(—27)		—35	(—27)	—25.5	—17
Fa 1138	832.56	(—14.5)		(—33)	(—26.5)	—10	—13
P 1150	835.52	—27	—47	—40.5	(—30.5)	—28.5	—32
G 1163	853.62	(—18)	—36	—16	—19	— 3.8	— 3.0
Fa 1189	862.62	—20	+37 (*emission*)	—22	—14	—18	—10
Fa 1200	864.52	—20		—33	—32	(—27)	—24
G 1216	867.55			(—37)	—22.5	(—33)	—22
G 1227	886.46	—4		(—16.5)	—14	—13	— 6
Fa 1284	891.52	— 4.5		(—19)	—13	—11	—13
K 1289	892.55	—10.5		(—27)	— 6	— 8	— 8

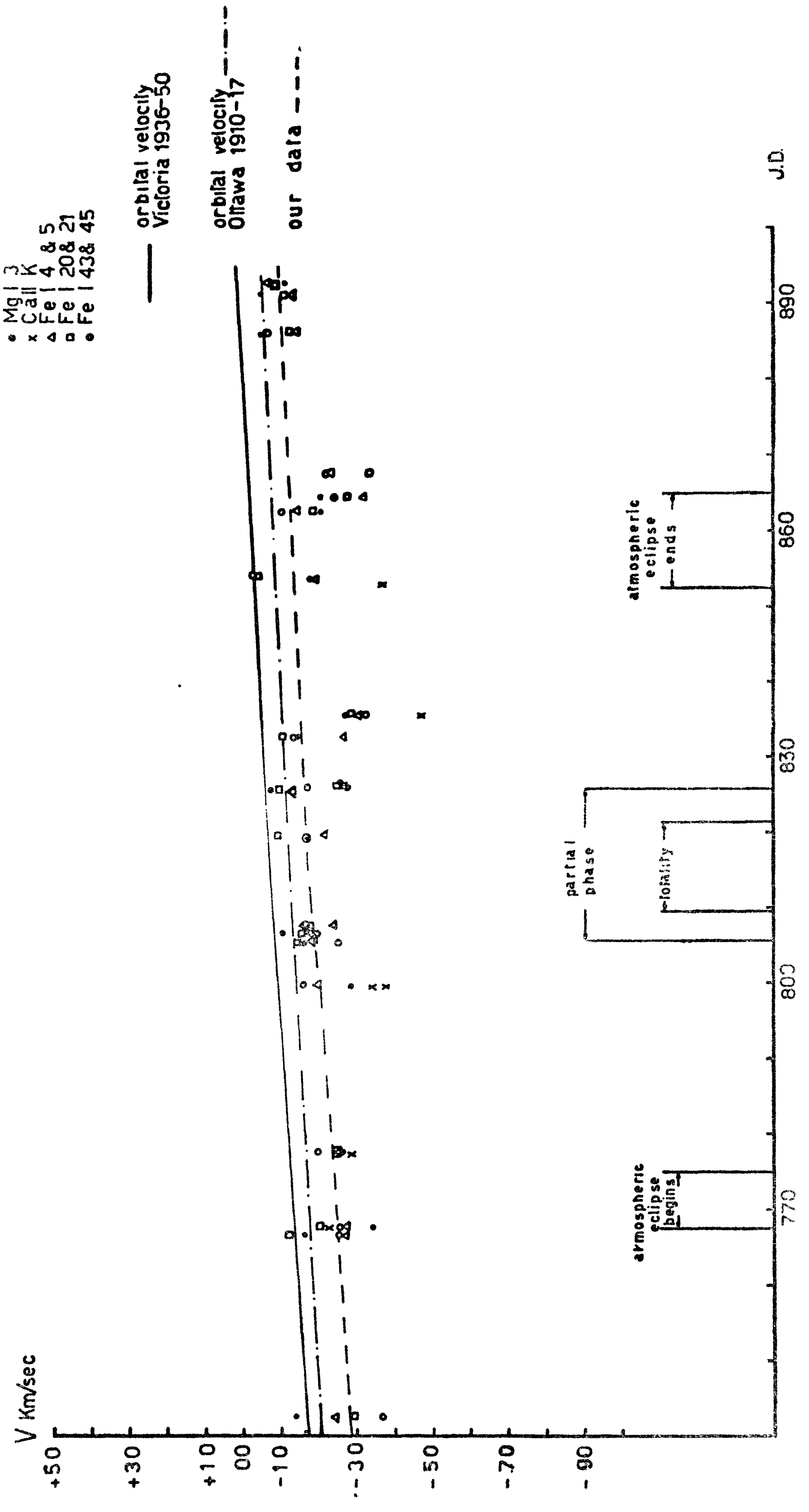
V Km/sec
+50
+30
+10
00
-10
-30
-50
-70
-90
770
800
830
860
890
J.D.
Mg I 3
Ca II K
Fe I 4 & 5
Fe I 20& 21
Fe I 43& 45
orbital velocity Victoria 1936-50
orbital velocity Ottawa 1910-17
our data
atmospheric eclipse begins
partial phase
totality
atmospheric eclipse ends

Fig. 4

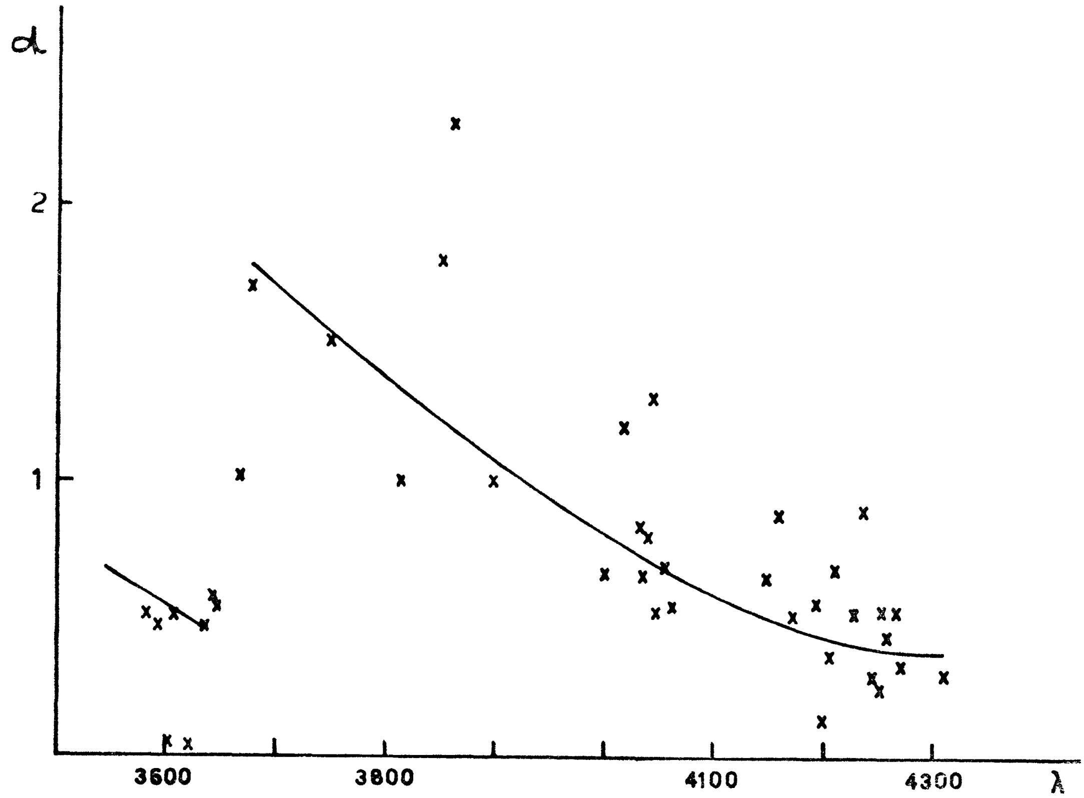

Fig. 5

DETERMINATION OF THE RATIO BETWEEN THE CONTINUOUS SPECTRA OF THE B- AND K- TYPE STAR.

The usual method (6) has been used to derive the ratio $\alpha = I_{cB} / I_{cK}$ between the continuum of the B-type and the continuum of the K-type star. Table III gives the values of the equivalent widths W_K and W_{BK} of the lines used for this determination. Fig. 5 gives α versus λ. Although the scatter of the values is large, the jump at λ 3700, due to the Balmer discontinuity of the B star, is clearly visible. A determination of the discontinuity is difficult because of the uncertainty of the continuum of the K-type star. Using the value of α just before the discontinuity, $\alpha_{3700} = 1.6$ and for the value after the discontinuity $\alpha_{3650} = 1.0$, it follows that D = 0.21. It we take $\alpha_{3650} = 0.6$ for α after the discontinuity, it follows that D = 0.43 which is a value too high for an early B-type star, and can be imputed to the uncertainty which affects the continuum of the K-type star.

Wellmann (1) has derived the values of α for 32 Cygni, using different series of plates at Ann Arbor (eclipses of 1949 and 1952) with dispersions of 19 and 38 A/mm; at David Dunlap Observatory (eclipses of 1949 and 1952-53)

Table III

λ	identification	W_K	W_{BK}	α
3581.19	Fe I (23)	.89	.59	.51
3593.49	Cr I (4)	.75	.51	.47
3605.33	Cr I (4)	.48	.46	.05
3610.46	Ni I (18)	.62	.41	.51
3618.77	Fe I (23)	.52	.50	.04
3631.46	Fe I (23)	.79	.54	.46
3647.84	Fe I (23)	.89	.53	.58
3649.51	Fe I (291)	.72	.46	.57
3669.52	Fe I (291)	.94	.46	1.02
3679.82 } 3679.91 }	Cr I (48) Fe I (5)	1.15	.43	1.70
3759.29	Ti II (13)	1.03	.41	1.50
3815.84	Fe I (45)	.88	.44	1.00
3859.89	Fe I (4)	1.62	.56	1.80
3865.53	Fe I (20)	1.35	.41	2.30
3899.71	Fe I (4)	1.10	.55	1.00
4005.25	Fe I (43)	1.10	.67	.66
4018.10	Mn I (5)	.75	.34	1.20
4030.75	Mn I (2)	1.25	.76	.65
4033.07	Mn I (2)	1.25	.68	.84
4034.49	Mn I (2)	1.06	.59	.80
4041.36	Mn I (5)	.85	.37	1.30
4045.83	Fe I (43)	1.30	.84	.55
4058.93	Mn I (5)	.88	.52	.69
4063.61	Fe I (43)	1.23	.80	.54
4152.77	Cr I (261)	1.06	.65	.63
4161.05	Cr II (162)	.84	.45	.87
4177.60	Fe I (18)	1.02	.68	.50
4191.44	Fe I (152)	1.12	.72	.55
4202.03	Fe I (42)	.97	.86	.14
4210.35	Fe I (152)	.90	.66	.37
4215.52	Sr II (1)	1.48	.88	.69
4235.94	Fe I (152)	1.20	.79	.52
4239.72	Mn I (23)	.95	.62	.53
4246.82	Sc II (7)	.91	.48	.90
4250.46	Fe I (152)	1.13	.89	.27
4254.33	Cr I (1)	1.38	1.10	.25
4258.32	Fe I (3)	1.15	.75	.53
4260.48	Fe I (152)	1.22	.85	.43
4271.76	Fe I (42)	1.58	1.03	.53
4274.80	Cr I (1)	1.44	1.07	.33
4315.09	Fe I (71)	1.23	.94	.30

with dispersion 33 A/mm and at Hamburger Sternwarte (eclipse 1952-53) with dispersion 65 A/mm. At λ 3800 he finds $\alpha = 2.06$ and at λ 4300, $\alpha = 1.00$. These values are much higher than those we have found (1.4 and 0.4 respectively). According to our determinations the wave length at which primary and secondary are equally bright is λ ∾ 3950, in good agreement with the value given by McKellar and Petrie (7) but in disagreement with Wellmann ($\lambda \backsim 4300$). As discussed in our previous paper on 31 Cygni (6) these disagreements are mainly due to the different criteria adopted in tracing the continuum of the K star. Since from the general appearance of the spectrum it is evident that the B spectrum becomes predominant only at $\lambda \leq 3900$ we believe our criterion for tracing the continuum is preferable. This criterion is the same that we adopted for 31 Cygni, namely joining the points of greatest intensity at $\lambda\lambda$ 3501.5; 3626.5; 3691.8; 3780.0; 4018.4; 4051.6; 4081.5; 4216.5; 4244.1; 4279.1; 4316.3; 4349.5.

Our values of α are in excellent agreement with those derived by Wright (4) during the eclipse of 1949. However it must be remembered that the results of Wright were obtained using the spectra of γ Dra and ξ Cyg as the K-type star, since no spectrum of totality could be obtained.

THE B-TYPE SPECTRUM

The spectrum of the B-type star has been constructed by the usual procedure (4, 6) (Fig. 6). Table IV gives the results, and the comparison with 31 Cygni.

TABLE IV

Spectral feature	32 Cygni	Possible classification	31 Cygni
H 7	6.8 A	B5 IV-V	7.1 A
H 8	4.7	»	4.3
H 9	4.6	»	5.1
3819 He I	1.2	B4 IV-V	1.5
n	15 or 16	B3 or earlier, V	14 0r 15
D	$0.21 \leq D \leq 0.43$	B2 $\leq$ sp $\leq$ B7, III or V	$0.30 \leq D \leq 0.36$

The B component of 32 Cygni appears to be very similar to the B component of 31 Cygni. The more probable spectral type is B5 IV or V.

We are indebted to Mrs. Mildred Shapley Matthews for the measurements of the tracings. These measurements were reduced to intensity in unity of the continuum by means of the electron computer IBM 1620 of the Brera Observatory using a program prepared by R. Faraggiana.

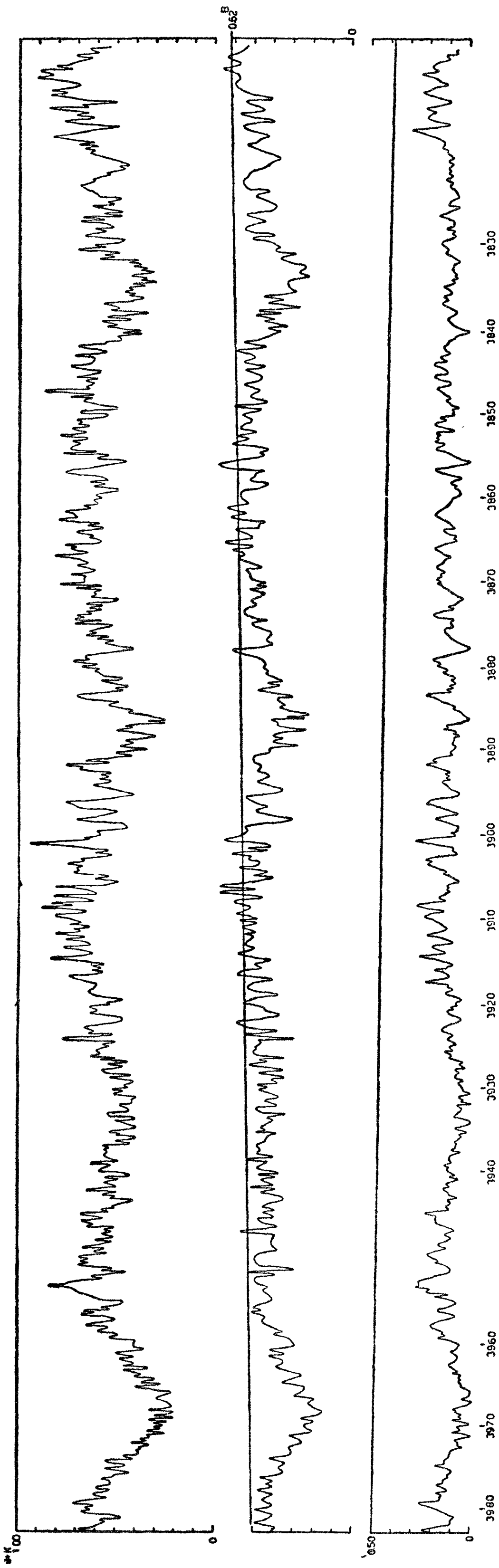
3830
3840
3850
3860
3870
3880
3890
3900
3910
3920
3930
3940
3960
3970
3980

Fig. 6

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