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THE MAGNETIC STAR γ EQUULEI

Comparison of high and mean dispersion spectrograms. Spectrovariability.

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RIASSUNTO. — a) Si confrontano le larghezze equivalenti di spettrogrammi di gran dispersione (2.8 A/mm) con quelle di spettrogrammi di media dispersione (35 A/mm). Questo confronto, insieme con la curva di crescenza di γ Equ costruita con i dati degli spettrogrammi a gran dispersione, ci permette di impiegare γ Equ come stella standard per il nostro programma di analisi quantitative delle stelle magnetiche.

b) Si studiano gli spettri di γ Equ presi lungo un periodo di 40 giorni per appurare se γ Equ sia o no spettrovariabile. Si conclude che γ Equ non è spettrovariabile, o se lo è, deve avere un periodo molto lungo.

ABSTRACT. — a) A comparison is made between the equivalent widths measured on high dispersion spectrograms (2.8 A/mm) and mean dispersion spectrograms (35 A/mm). The agreement between them is good. This comparison, and the curve of growth constructed for γ Equ using the high dispersion data, enables us to use γ Equ as standard star for our program of quantitative analyses of magnetic stars.

b) Several spectrograms taken during a period of about 40 days are measured in order to decide whether or not γ Equ is a spectrovariable star. From our results it appears that it is not variable, or, if so, the period is very long.

INTRODUCTION

A quantitative analysis of the atmosphere of γ Equ has been previously made using spectrograms taken at Mt. Palomar on July 29 and July 30, 1953 (^{1}). The dispersion of these is 4.5 A/mm and the spectral region λλ 6700-3800. The aims of this new investigation are the following:

1) to study an additional spectrogram of γ Equ taken at Mt. Wilson on October 15, 1951, having a dispersion of 2.8 A/mm and covering the spectral region λλ 3700-4800, and to compare these results with those of the previous research.

2) to look for an eventual variation of the spectral lines observed by Morgan (^{2}) but not confirmed by Deutsch (^{3}).

(*) Ricevuta il 20 aprile 1963.

This comparison of the results given by high and mean dispersion spectrograms makes it possible to use γ Equ as standard star for the current program in Merate of quantitative analyses of magnetic stars.

COMPARISON OF THE EQUIVALENT WIDTHS DERIVED WITH DIFFERENT EQUIPMENTS.

The agreement between the total intensities measured in 1951 (2.8 A/mm) and in 1953 (4.5 A/mm) is very good. We have therefore thought it unnecessary to repeat the quantitative analysis using the 1951 plate.

The comparison of the total intensities measured on high and average dispersion plates is more interesting and represents a proof of the degree of reliability of quantitative measurements made with mean dispersion spectrograms. Table I gives the list of spectrograms, and Table II gives the list of lines which are not blended on the average dispersion spectrograms, and the corresponding central depths, half-widths and equivalent widths measured on the Merate and Mt. Wilson plates. The contours of the lines are strongly affected by the different dispersion but the agreement between the total intensities is satisfactory.

TABLE I

Date	Spectrogram	S.T.	Exposure	U.T.
Oct. 16, 1951	Ce 7548		103^m	4^h01^m
Aug. 13, 1962	Fa 1246	22^h10^m	10	0 10
Aug. 13, 1962	Fa 1259	21 45	20	23 40
Aug. 14, 1962	Fa 1269	21 55	12	23 45
Aug. 15, 1962	Fa 1270	22 13	20	0 05
Aug. 16, 1962	Fa 1285	22 28	15	0 15
	Fa 1286	22 47	25	0 35
Aug. 17, 1962	K 1290	0 00	10	1 45
	K 1291	0 15	20	2 00
Aug. 20, 1962	K 1300	23 57	20	1 30
Sept. 18, 1962	Fa 1448	19 30	8	19 07
	Fa 1449	19 45	20	19 22
Sept. 20, 1962	Fa 1462	20 15	10	19 40
	Fa 1463	20 27	30	19 52
Sept. 21, 1962	Fa 1468	20 32	8	20 00

TABLE II

		Merate			Mt. Wilson		
		R_c'	$\Delta\lambda$	W	R_c	$\Delta\lambda$	W
4588.22	Cr I	.17	.768	.131	.67	.216	.145
4583.83	Fe II	.19	.768	.146	.68	.250	.170
4576.33	Fe II	.21	.768	.161	.53	.197	.104
4571.97	Ti II	.13	.768	.100	.624	.256	.154
4563.76	Ti II	.13	.768	.100	.478	.220	.105
4558.66	Cr I	.17	.768	.131	.72	.27	.194
4515.34	Fe II	.20	.768	.154	.59	.22	.130
4508.28	Fe II	.19	.768	.146	.485	.197	.096
4501.27	Ti II	.19	.768	.146	.608	.25	.152
4496.86	Cr I	.17	.768	.131	.60	.22	.135
4489.19	Fe II	.19	.768	.146	.63	.265	.164
4481.$^{13}_{33}$	Mg II	.37	1.4	.52	profile		.535
4468.49	Ti II	.19	.768	.146	.615	.197	.121
4443.80	Ti II	.23	.768	.177	.637	.214	.136
4417.72	Ti II	.14	.768	.108	.57	.20	.114
4416.82	Fe II	.16	.768	.123	.58	.214	.124
4415.12	Fe I	.15	.768	.115	.65	.236	.153
4404.75	Fe I	.15	.768	.115	.675	.25	.169
4395.03	Ti II	.20	.768	.154	.715	.22	.157
4385.38	Fe II	.20	.768	.154	.60	.214	.128
4383.54	Fe I	.23	.768	.177	.637	.214	.136
4312.$^{6}_{8}$	Ti II	.24	.768	.185	.565	.23	.129
4300.05	Ti II	.28	.85	.238	.67	.214	.143
4296.58	Fe II	.21	.768	.162	.555	.22	.122
4274.81	Cr I	.24	.768	.185	.72	.22	.158
4271.76	Fe I	.24	.768	.185	.70	.18	.126
4233.29	Fe II	.27	.85	.230	.68	.25	.170
4226.74	Ca I	.39	1.2	.47	.78	.38	.294
4215.52	Sr II	.43	1.47	.632	profile		.95
4205.05	Eu II	.27	.85	.23	.466	.365	.170
4167.27	Mg I	.26	.85	.22	.683	.33	.224
4077.71	Sr II	.49	1.75	.85	profile		1.11
4045.81	Fe I	.34	.95	.32	.704	.252	.178
4041.36	Mn I	.21	.768	.162	.61	.197	.120
4034.49	Mn I	.20	.768	.154	.63	.197	.124
4033.07	Mn I	.28	.85	.238	.677	.23	.155
4030.75	Mn I	.29	.85	.248	.75	.25	.187
3995.31	Co I	.21	.768	.162	.55	.214	.118
3913.46	Ti II	.20	.768	.154	.57	.214	.124
3859.91	Fe I	.18	.768	.138	.72	.21	.151
3853.65	Si II	.14	.768	.108	.47	.18	.085
3825.88	Fe I	.16	.768	.123	.70	.197	.138

THE CURVE OF GROWTH

An empirical curve of growth for γ Equ is obtained by combining the two curves for Fe I and Cr I constructed using the solar log X_f. The comparison with the Menzel theoretical curve gives $\log \frac{c}{v} = 5.34$,

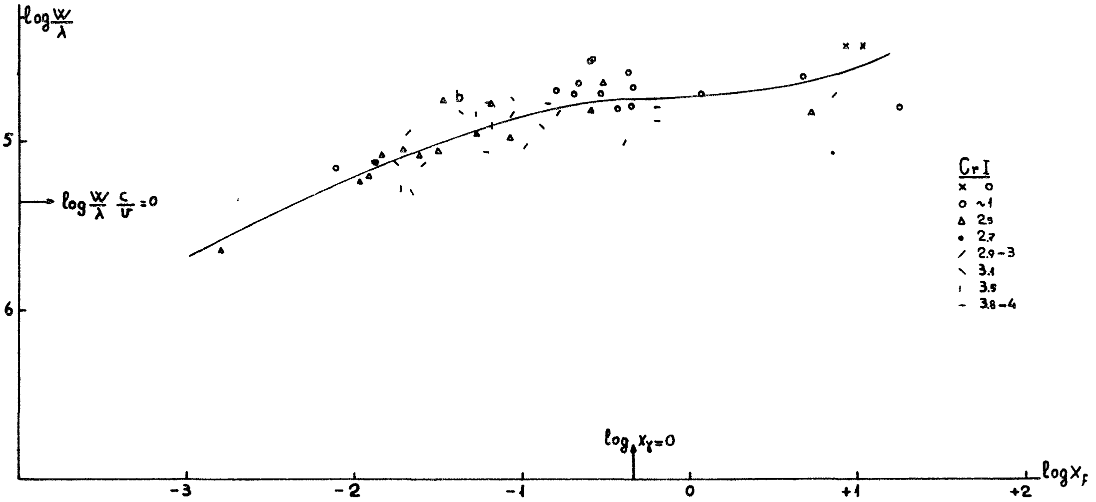

Fig. 1 a

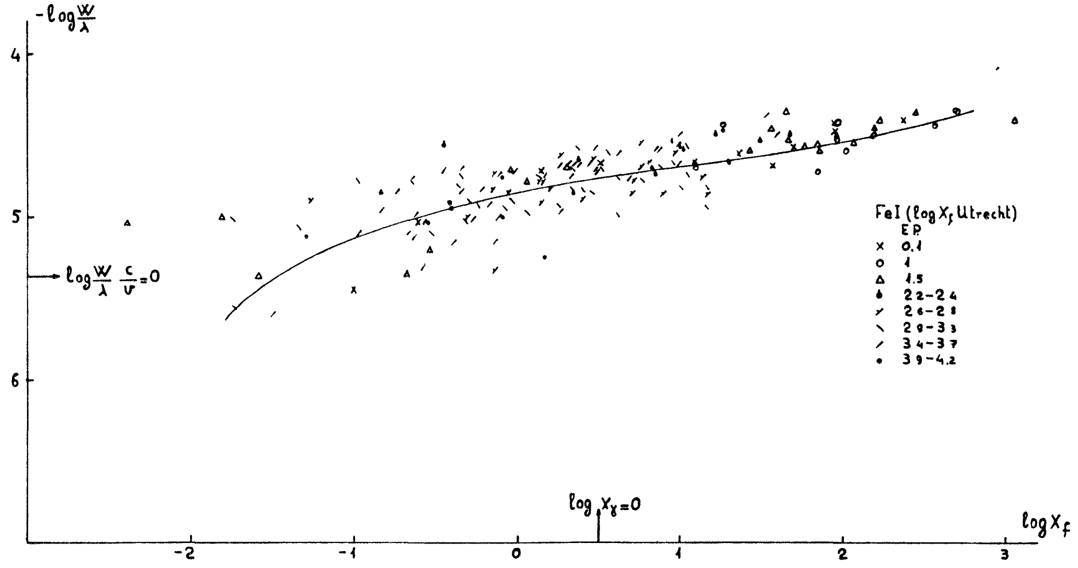

Fig. 1 b

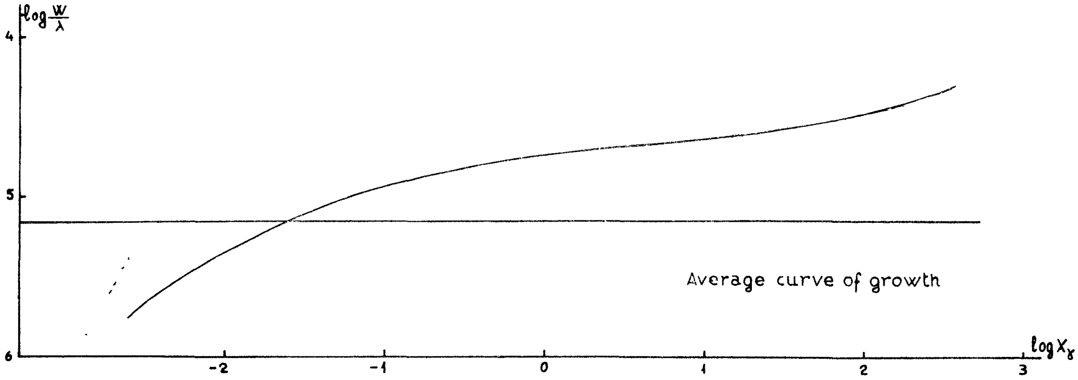

Fig. 1 c

log $v = 5.14$, $v = 1.38$ km/s. This curve and the log X_γ which can be derived by reading off the value corresponding to a given value of log (W/λ) can be used in quantitative analysis investigations of other magnetic stars (Fig. 1). From the difference log $\frac{W}{\lambda}$ (γ Equ) — log $\frac{W}{\lambda}$ (star) derived by measurements of spectrograms taken in Merate with the same equipment the corresponding difference in the abscissae of the curve of growth, log X_γ — log X_* is read. By this procedure the possible errors in the quantitative analyses due to instrumental influence on the line intensities and to the blends are strongly reduced.

SPECTROVARIABILITY OF γ EQU.

The series of spectrograms of γ Equ in the summer of 1962 was taken for the purpose of studying the possible spectrovariability of this magnetic star. Morgan (2) found that λ 4558 Cr II is strongly variable. Deutsch (3) in a following investigation of the A-type spectrovariables was not able to confirm such variability, but he used three spectrograms only. From the graphs of Fig. 2 we conclude that γ Equ is not a spectrovariable, or, if so, has a very long period. The variation of λ 4558 observed by Morgan probably can be explained by the proximity of this line to a strong blend at λ 4557; on spectrograms of slightly different quality the two lines can either be separated, or blended giving a single strong line.

INFLUENCE OF THE WIDTH OF THE ZEEMAN CONFIGURATION UPON THE LINE CONTOURS.

A proportionality law between the half-widths $\Delta\lambda$ and the widths of the magnetic configuration Z was found for the magnetic star β C Bo (4); a search for a similar relation was made for γ Equ but our previous results were negative, $\Delta\lambda$ being independent from Z. In the case of the present investigation we have looked again for such a relation using the spectrogram with dispersion 2.8 A/mm, but $\Delta\lambda$ appears to be constant for small and large values of Z (fig. 3), confirming the previous investigation made with the two spectrograms with dispersion 4.5 A/mm. It is possible that the magnetic field is not completely irregular as Babcock suggests (5), but variable with a period of about 5 years (see fig. 4, where the values measured by Babcock are plotted). In this case we are able to understand why the spectra of July 1953 and

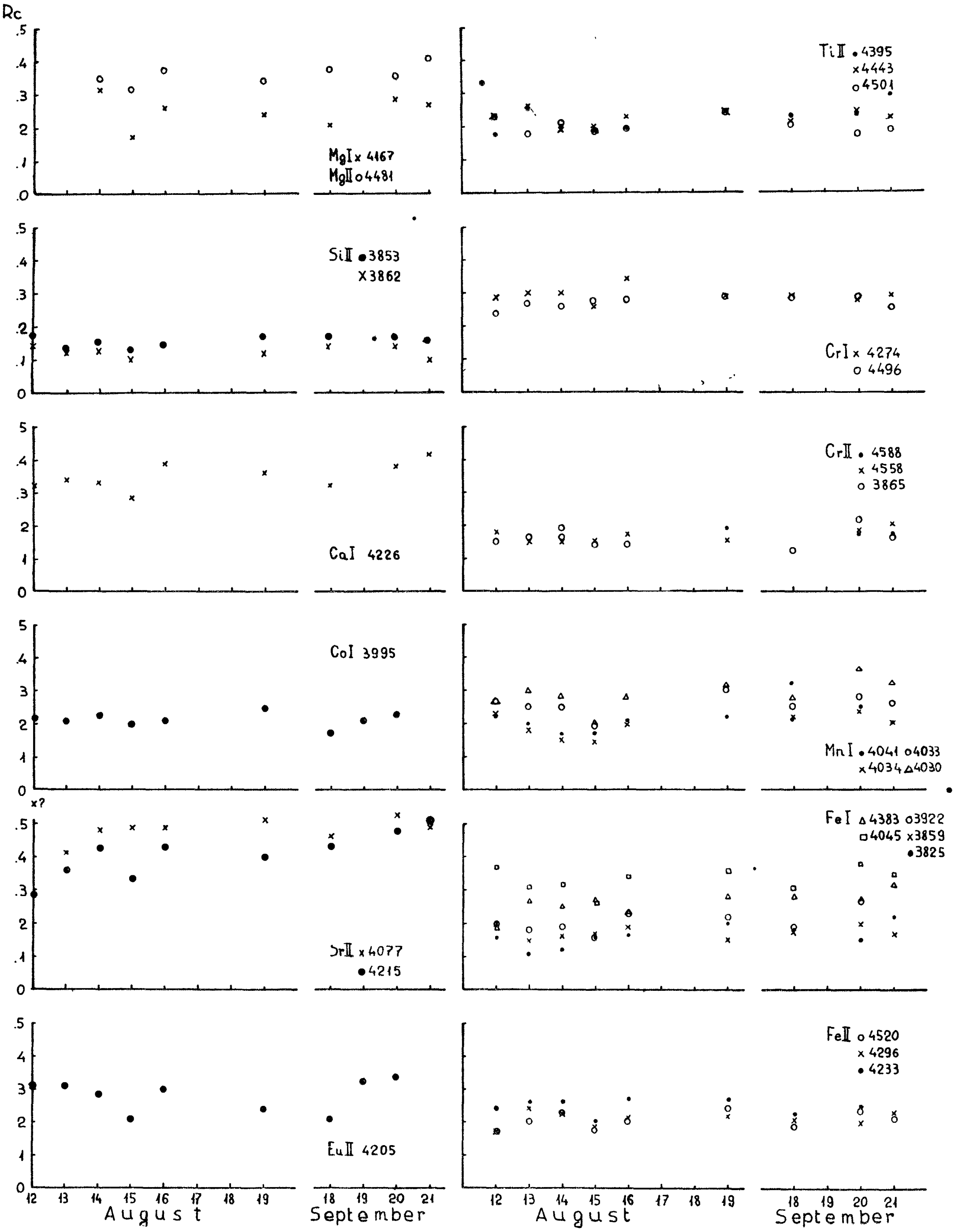
Rc
.5
.4
.3
2
.1
.0
MgI x 4467
MgII o 4481
TiII • 4395
x 4443
o 4501
SiII • 3853
X 3862
CrI x 4274
o 4496
CaI 4226
CrII • 4588
x 4558
o 3865
CoI 3995
MnI • 4041 o 4033
x 4034 △ 4030
x?
SrII x 4077
• 4215
FeI △ 4383 o 3922
□ 4045 x 3859
• 3825
FeII o 4520
x 4296
• 4233
EuII 4205
12 13 14 15 16 17 18 19
August
18 19 20 21
September

Fig. 2

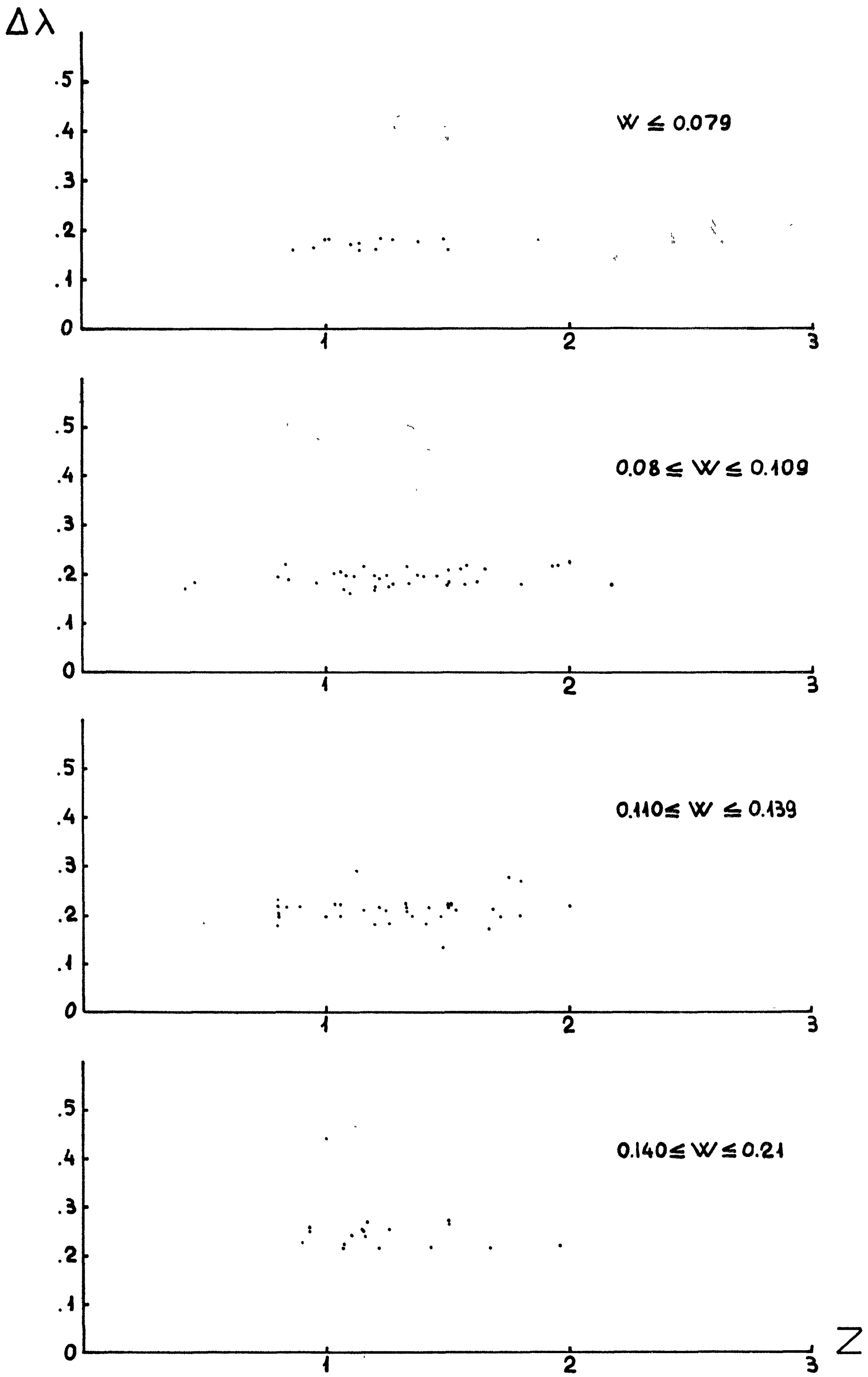

Fig. 3

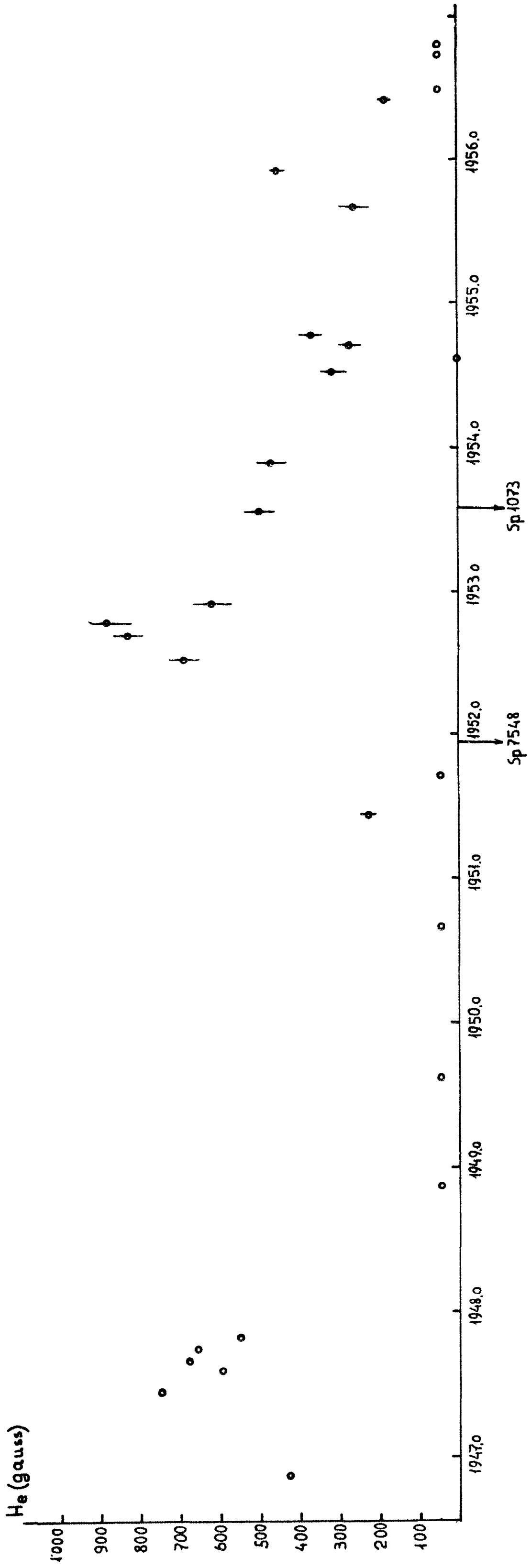
H_e (gauss)
1000
900
800
700
600
500
400
300
200
100
1947,0
1948,0
1949,0
1950,0
1951,0
1952,0
1953,0
1954,0
1955,0
1956,0
Sp 7548
Sp 1073

Fig. 4

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October 1951 which should correspond to phases almost symmetrical around the maximum (and magnetic field of about 400 gauss) give analogous results. Moreover a field of 400 gauss is probably too low to give an appreciable dependence of $\Delta\ \lambda$ upon Z.

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