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QUANTITATIVE ANALYSIS OF γ CAPRICORNI

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Riassunto. — γ Cap è una stella F0p il cui spettro presenta analogie sia con quello delle stelle magnetiche sia con quello delle stelle a righe metalliche. Dalla curva di crescenza si ricava una sovrabbondanza di Ca, Ti, Fe (di un fattore 10), Mn, Sr (di un fattore 10^3), Eu (di un fattore 10^4) uguale o maggiore a quella trovata nelle stelle magnetiche e una sovrabbondanza di Ba (di un fattore 10^3) caratteristica di γ Cap. Manca il doppietto del Li I a λ 6708 che era stato osservato negli spettri delle stelle magnetiche β CrB e γ Equ. γ Cap ha una bassa velocità di turbolenza (1.95 km/sec) come γ Equ e β CrB; il contrario distingue le stelle a righe metalliche.

La principale peculiarità di γ Cap è il disaccordo tra i valori di log P_e ricavati dal numero quantico dell'ultima riga della serie di Balmer (log $P_e = 1.39$), dalla formula di Holtsmark (log $P_e = 2.63$), e dall'equilibrio di ionizzazione del Fe (log $P_e = 1.80$). La ipotesi più plausibile è quella della presenza di uno shell, più esteso di quello di β CrB e γ Equ, in cui si formerebbero le ultime righe di Balmer. Gli altri due valori di log P_e sono più alti di quelli delle stelle normali di tipo spettrale e classe di luminosità uguale a γ Cap (F0 III) e si può spiegare con un eccesso di elettroni liberi dovuto alla sovrabbondanza di metalli.

Abstract. — γ Cap is a F0p star; it is similar to the magnetic and the metallic line stars. We derived an overabundance of Ca, Ti, Fe (by a factor of 10), Mn, Sr (by a factor of 10^3), Eu (by a factor of 10^4) equal or stronger than that found for the magnetic stars and an overabundance of Ba (by a factor of 10^3) which is characteristic of γ Cap. The Li I doublet at λ 6708 which was observed in the spectra of the two magnetic stars γ Equ and β CrB is missing in the spectrum of γ Cap. γ Cap has a low value of the turbulence velocity ($v = 1.95$ km/sec) like γ Equ and β CrB; the contrary occurs in the metallic line stars.

The principal peculiarity of γ Cap is the discrepance between the values of log P_e derived from the quantum number of the last Balmer line (log $P_e = 1.39$), the Holtsmark formula (log $P_e = 2.63$) and the iron ionization equilibrium (log $P_e = 1.80$). The discrepancy between the log P_e values can be explained with the presence of a shell like in β CrB and γ Equ; the γ Cap shell would be more extended than that of the two other magnetic stars and the last visible Balmer lines would be originated in it. The other two values of log P_e are higher than the normal value for the spectral type and luminosity class of γ Cap (F0 III) and could be explained by the overabundance of metals and consequently by the excess of free electrons.

(*) Ricevuta il 22 aprile 1964.

INTRODUCTION

γ Capricorni has been classified F2 according to the Mt. Wilson classification and F0p according to the HD Catalogue.

The main spectral peculiarity is the intensity of the metallic lines which are too strong compared with the spectral type suggested by the hydrogen lines. The hypothesis was proposed that it was a composite spectrum. A study by Hynek (1) concerning the stars with a composite spectrum includes γ Cap. Hynek observes that γ Cap is an intermediate luminosity F star with normal color. According to him it shows a normal F2 spectrum except for the SrII lines and it is probable that the star is not truly composite since the K line is not abnormal, like in other stars as v Sgr, 17 Lep, CI Cyg, which have some similarities with γ Cap.

Hack's classification (2) based upon the intensity of the H_δ and K lines gives the spectral type F0III.

Babcock (3) includes this star among the stars in which the presence of a magnetic field is probable, but not firmly established. On a first inspection the spectrum of γ Cap actually presents some similarities with the spectra of the magnetic and the metallic line stars. The spectral type given by the hydrogen lines is earlier than that given by the metallic lines. Moreover the color B—V gives an intermediate spectral type, and the same has been found for the magnetic stars γ Equ and β CrB (4, 5).

OBSERVATIONS

The spectrograms have been taken at the grating spectrograph of the Merate Observatory. The dispersion is 35Å/mm (in the 2nd order). Due to the low value of δ (— 16°50′) it was impossible to use the same spectrograms for the whole violet region (3600-4600 Å). From each spectrogram taken with different exposure times, the region having better exposure was studied (Table I).

COMPARISON WITH SOME NORMAL, AP AND METALLIC LINE STARS.

A number of unblended lines was selected for comparison of the spectrum of γ Cap with those of some normal, Ap and metallic line stars. The comparison stars are given in Table II.

The comparison of $H\gamma$, H_δ and the CaII K line shows the similarity of γ Cap with the magnetic stars β CrB and γ Equ: the K line is slightly

TABLE I

Date	Spectrogram	Exposure	U.T.	Spectral region
Aug. 14, 1962	Fa 1271	12^m	0^h48^m	3600-460
	Fa 1272	25	1 05	»
Sept. 18, 1962	Fa 1450	5	20 37	»
	Fa 1451	10	20 47	»
	Fa 1452	15	21 02	»
	Fa 1453	30	21 35	»
Sept. 21, 1962	Fa 1470	5	20 35	»
	Fa 1471	10	20 47	»
	Fa 1472	15	21 00	»
	Fa 1473	20	21 20	»
Oct. 7, 1963	H 1842	180	18 54	5600-6900
Oct. 8, 1963	H 1848	120	17 26	4500-5800

TABLE II

Star	Sp. type MK	B — V	Sp. type according to the color (6)
β Cas	F5II	+0.35	F2
ϑ Per	F7V	+0.48	F6
α Per	F5Ib	+0.48	F6
ι Peg	F5V	+0.44	F5
41 Cyg	F2III	—	—
ω Pis	F4IV	—	—
ξ Gem	F5III	—	—
15 Vul	M.L.	+0.15	A5
τ UMa	»	+0.35	F1
63 Tau	»	+0.26	A9
γ Equ	Ap	+0.25	A9
β CrB	»	+0.27	A9
73 Dra	»	+0.07	A2
γ Cap		+0.31	F0

weaker than in the normal stars having the same color, while on the conrary the Balmer lines are stronger. We remark that for the normal stars the ratio $\frac{W\,(H\delta)}{W\,(K)}$ is about equal to one, and for the metallic line stars and the Ap stars is about equal to three. For γ Cap we have $\frac{W\,(H\delta)}{W\,(K)} = 2.8$ (Fig. 1).

The comparison of the metallic lines shows that γ Cap has a metallic spectrum very similar to β Cas (which is the normal star having about the same color and luminosity than γ Cap), to β CrB and to the metallic line stars τ UMa and 63 Tau. The metallic line spectrum of γ Cap is somewhat

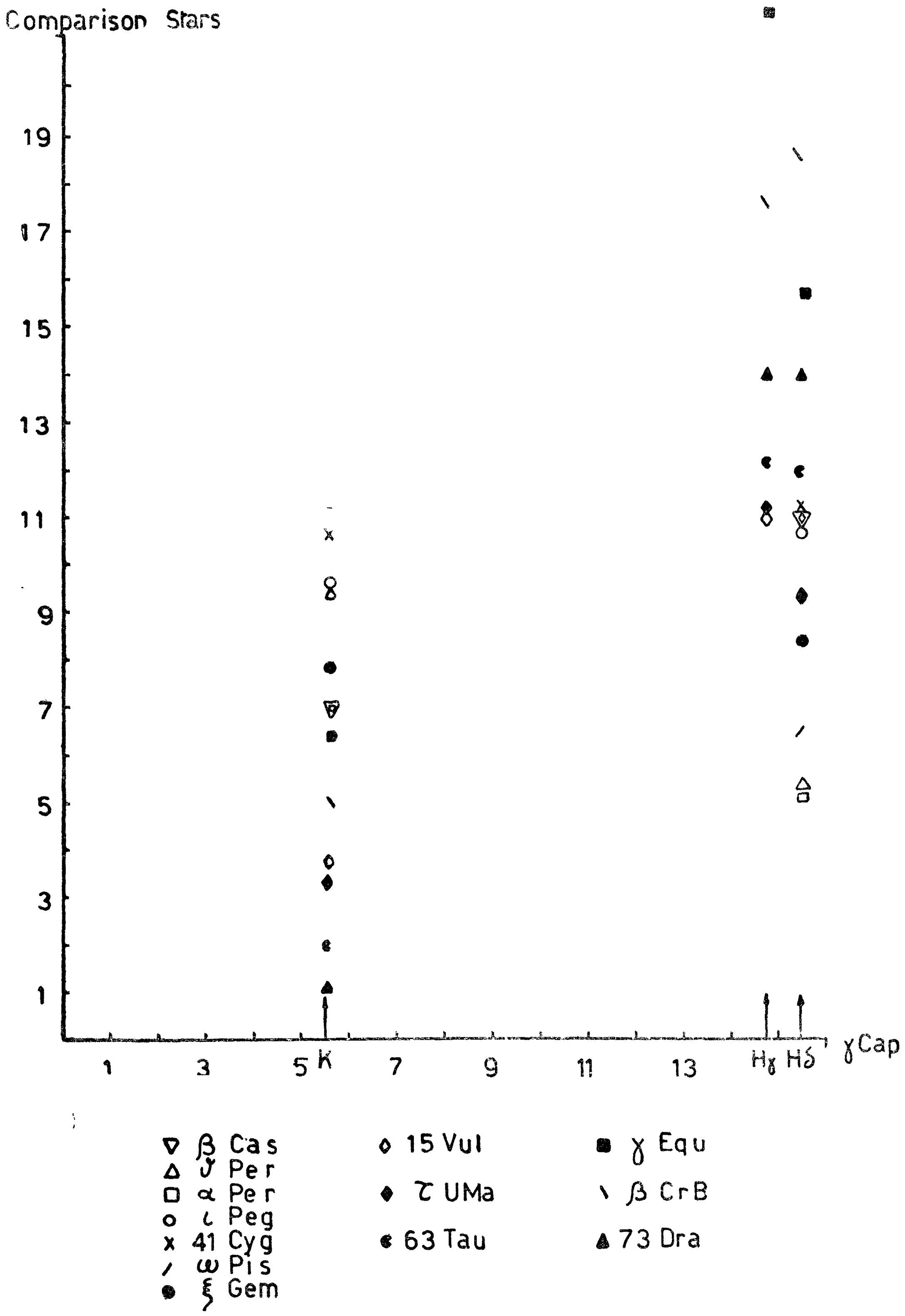
Comparison Stars
19
17
15
13
11
9
7
5
3
1
1
3
5 K
7
9
11
13
Hγ Hδ
γ Cap
▽ β Cas
△ ϑ Per
□ α Per
○ ι Peg
x 41 Cyg
/ ω Pis
● ξ Gem
◊ 15 Vul
♦ τ UMa
● 63 Tau
■ γ Equ
\ β CrB
▲ 73 Dra

Fig. 1

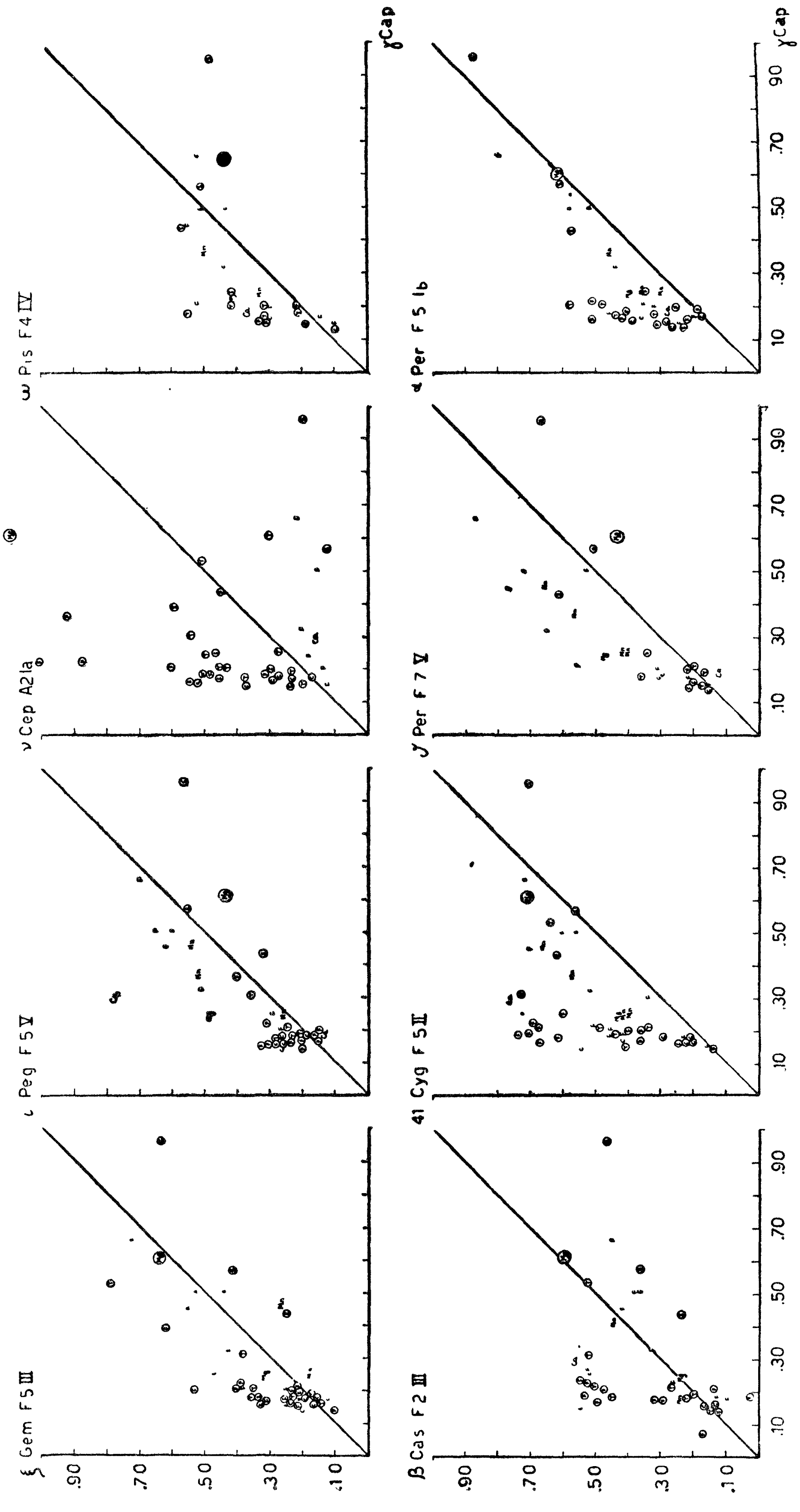
ξ Gem F5 III
ι Peg F5 V
ν Cep A2Ia
ω Pis F4 IV
β Cas F2 III
41 Cyg F5 II
δ Per F7 V
α Per F5 Ib
γ Cap
.90
.70
.50
.30
.10
10
30
50
70
90

Fig. 2 a

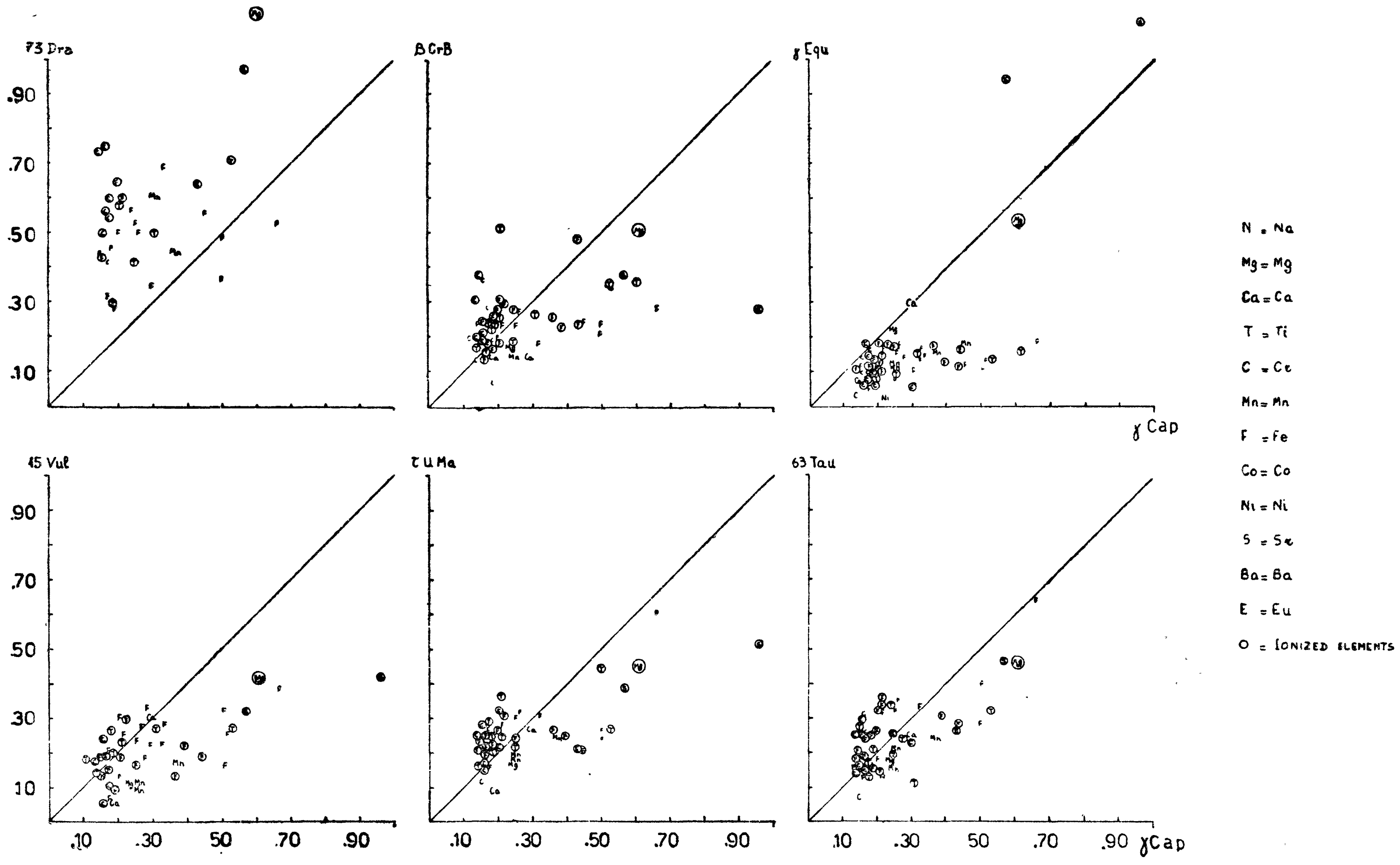
73 Dra
β CrB
γ Equ
45 Vul
τ U Ma
63 Tau
.90
.70
.50
.30
.10
.10
.30
50
.70
.90
γ Cap
N = Na
Mg = Mg
Ca = Ca
T = Ti
C = Ce
Mn = Mn
F = Fe
Co = Co
Ni = Ni
S = Sc
Ba = Ba
E = Eu
O = IONIZED ELEMENTS

Fig. 2 b

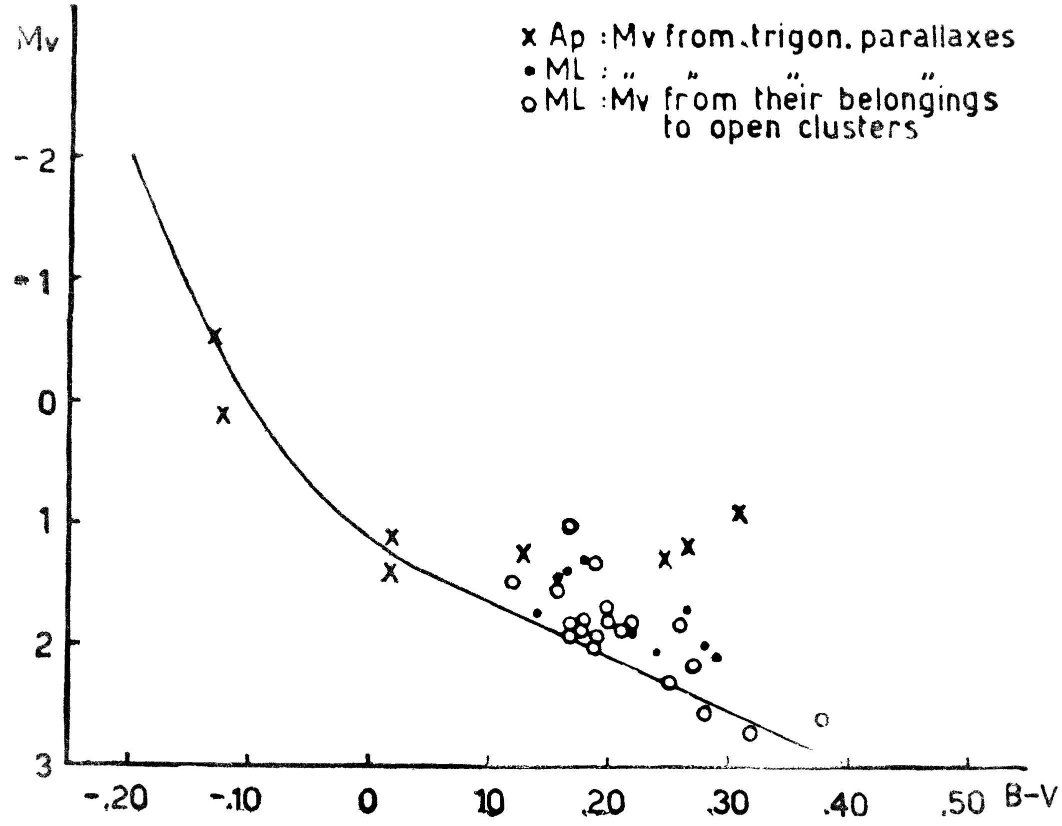

Fig. 3

similar also to these of ξ Gem, ι Peg and ω Psc, in spite of the fact that these three stars are redder than γ Cap. The comparison with the supergiants α Per, 41 Cyg and the giant β Cas indicates a lesser degree of ionization for γ Cap and therefore a larger value of the electron pressure, since the temperature is equal to or higher than the temperature of the comparison stars (Fig. 2a, 2b).

THE ABSOLUTE MAGNITUDE OF γ CAP. POSITION IN THE HR DIAGRAM OF THE AP AND METALLIC LINE STARS.

From the value of the trigonometric parallax given by Jenkins (7) we derive for the absolute magnitude $M_v = +0.80$; Eggen (8) gives $M_v = +0.67$. This value of the absolute magnitude together with the color B—V shows that γ Cap is clearly above the main sequence. Its position in the HR diagram corresponds to a spectral type F0III. We remark that the magnetic stars are placed on the main sequence, with the exception of γ Equ and β CrB which fall in the same position of γ Cap. The metallic line stars are found in the same region above the main sequence (Fig. 3).

CLASSIFICATION OF γ CAP AND STUDY OF THE HYDROGEN SPECTRUM.

Since our spectrograms were underexposed in the ultraviolet, we could not derive the Balmer discontinuity. We use for D the value given by Barbier and Chalonge (9) reduced to the new series of values determined by Chalonge and Divan (10). We find D = 0.305. The value of D, the intensity of Hγ, Hδ and K (2) and the color B-V (11) give the following classifications for γ Cap:

Total intensity of Hγ and Hδ versus spectral type	gives A9III
D versus spectral type	gives F2III
K versus spectral type	gives F1III or IV-V
D versus Hδ	gives F0-F2 IV-V
$\frac{H\delta}{K}$ versus spectral type	gives F2III or IV-V
B—V versus spectral type	gives F0

The number of neutral hydrogen atoms in the 2nd excited state contained in a column of height h and base 1 cm^2 is derived by means of the Minnaert formula, using D = 0.305, $R_c = 0.77$. We find $\log N_{0,2}\, h = 16.67$. We compute the electron density from this value using the Holtsmark formula:

$$\log N_e = 14.68 \text{ (from H}\gamma\text{)}$$
$$\log N_e = 14.82 \text{ (from H}\delta\text{)} \quad .$$

and assuming T = 6800°K (which is the effective temperature corresponding to a spectral class F2III (12) it follows that $\log P_e = 2.64$.

The last visible Balmer line is H20; the Inglis and Teller formula gives another value for the electron density:

$$\log N_e = 13.51$$

and therefore $\log P_e = 1.40$.

The same disagreement between the electron pressure derived by the first Balmer lines and by the quantum number of the last resolved line is found for the other magnetic stars β CrB, γ Equ and 73 Dra (13) (see Table IV).

For example for β CrB $n = 17$; it follows that $\log P_e = 2.11$. The Holtsmark theory gives $\log P_e = 2.80$. For an agreement between the two values it should be necessary to have $n = 13$, a value which is certainly too low, because H_{17} is clearly resolved. The most probable explanation for this disagreement is the presence of a rarefied atmosphere in which the cores of the Balmer lines are formed. Due to the low density of this envelope a larger number of Balmer lines is resolved than in the underlying atmosphere of the star.

THE CURVE OF GROWTH.

The values of log $\frac{W}{\lambda}$ have been computed by the values of the transmissions and half-widths measured on the tracings, by means of a program prepared for the computer IBM 1620 of the Brera Observatory.

The solar log X_f have been read on the solar growth curve given by Wright ([14]) using the log $\frac{W}{\lambda}$ given by the Utrecht Catalogue ([15]). We derived in this manner also the log X_f given by Wright in order to have data more homogeneous, though the differences between the old values given by Wright and the new values derived by us are generally in fairly good agreement.

TABLE III

λ	mult.	—log $\frac{W}{\lambda}$	log X_f	λ	mult.	—log $\frac{W}{\lambda}$	log X_f
Na I				**Ti II**			
5889.95	1	3.75	+1.48	3759.29	13	3.93	+1.46
5895.92	2	3.82	+1.29	4501.27	31	4.33	+0.20
				4300.05	41	3.90	+0.61
Mg I				4290.22	41	3.84	+0.08
				4312.86	41	4.38	+0.52
4167.27	15	4.25	+0.90	4533.96	50	4.26	—0.16
				4563.76	50	4.39	+0.13
Mg II				4399.77	51	4.23	0.00
				4571.97	82	4.33	+0.22
4481.29	4	3.86	—0.26	4028.33	87	4.44	—0.30
				4386.86	104	4.38	—1.20
Ca I				4163.64	105	4.35	—0.04
4226.73	2	4.15	+2.24				
6162.17	3	4.13	+0.60	**Cr I**			
6122.22	3	4.17	+0.45				
6102.72	3	4.11	—0.30	4254.34	1	4.38	+1.31
4318.65	5	4.37	+0.45	4496.36	10	4.33	—0.39
6439.07	18	4.10	+0.39	4545.96	10	4.47	—0.80
6462.57	18	4.28	—0.21	4571.68	32	4.48	—1.68
6499.65	18	4.64	—1.30	4530.75	33	4.42	—1.26
6449.81	19	4.37	—1.02	4527.34	33	4.36	—1.07
6169.25	20	4.23	+0.28	4500.29	150	4.53	—2.01
6717.68	32	4.25	—0.75	4511.90	150	4.45	—1.69

cont. Table III

λ	mult.	$-\log \frac{W}{\lambda}$	$\log X_f$
Cr II			
3761.69	11	4.08	—0.49
4261.92	31	4.38	—1.10
4252.62	31	4.44	—1.80
4275.57	31	4.42	—1.03
4284.21	31	4.45	—0.50
4558.66	44	4.44	—0.99
4588.22	44	4.53	—1.10
4145.77	162	4.37	—1.26
Mn I			
4034.49	2	4.22	+0.78
4033.07	2	4.04	+0.94
4030.75	2	3.94	+1.34
4041.36	5	4.22	+0.14
Fe I			
4427.31	2	4.38	+0.50
4461.65	2	4.25	+0.19
3859.91	4	4.05	+2.36
3922.91	4	4.30	+1.68
3920.26	4	4.11	+1.36
3878.57	4	3.77	+1.86
4152.17	18	4.29	—0.24
3820.43	20	4.05	+2.54
3849.97	20	3.94	+1.79
3865.53	20	4.33	+1.60
3850.82	22	4.13	+1.09
4383.55	41	4.22	+1.97
4404.75	41	4.31	+2.79
4415.12	41	4.24	+1.30
4202.03	42	4.09	+1.17
4147.67	42	4.40	+0.04
4045.81	43	3.77	+2.19
4071.74	43	4.08	+1.83
4005.25	43	3.95	+1.40
4143.87	43	3.91	+1.50
4063.60	43	3.91	+1.92
3815.84	45	3.86	+2.22
6430.85	62	4.18	—0.83
6297.80	62	4.35	—1.44
6265.14	62	4.68	—1.56
6213.44	62	4.41	—1.42
4447.72	68	4.46	+0.64
4494.57	68	4.34	+0.57
4528.62	68	4.37	+0.70
4009.71	72	4.36	+0.20
3949.95	72	3.96	—0.44
6421.35	111	4.15	—1.20
6663.45	111	4.43	—1.35
Fe I (*cont.*)			
5049.82	114	4.10	+0.08
4187.04	152	4.10	—0.83
4187.80	152	4.16	+1.06
4235.94	152	4.11	+1.29
4260.48	152	4.14	+1.60
4299.24	152	4.26	+0.84
4191.44	152	4.19	+0.72
4198.31	152	3.84	+0.42
6593.88	168	4.39	—1.20
6462.73	168	4.50	—1.38
6494.98	168	4.04	0.00
6393.60	168	4.20	—0.60
6252.56	169	4.62	—0.62
3783.56	175	4.25	+0.90
3859.21	175	4.28	+0.92
3785.95	177	4.48	+0.81
6575.02	206	4.48	—1.57
6230.73	207	4.62	—0.04
6065.49	207	4.19	—0.57
6677.99	268	4.51	—0.60
6592.92	268	4.35	—0.60
6546.25	268	4.33	—0.96
3956.68	278	3.90	+0.68
4021.87	278	4.41	+0.30
4957.60	318	4.13	—1.27
4920.51	318	4.14	+1.24
4891.50	318	4.04	+1.04
5006.13	318	3.99	+0.60
4957.30	318	4.44	+0.96
4919.00	318	3.91	+0.91
4890.76	318	4.19	+0.92
4938.82	318	4.02	—0.21
4903.32	318	4.19	+0.10
4878.22	318	4.29	—0.14
6518.37	342	4.40	—1.77
4454.38	350	4.23	—0.61
4476.02	350	4.47	+0.14
4466.55	350	4.39	—1.38
4156.80	354	4.19	+0.28
4181.76	354	4.29	+0.51
4184.89	355	4.28	—0.22
4213.65	355	4.52	—0.39
4768.40	384	4.34	—0.48
4390.95	414	4.24	—0.40
4736.78	554	4.12	+0.31
4707.28	554	4.06	—0.26
4613.21	554	4.08	—1.13
4654.63	554	4.02	—0.44
4607.65	554	4.12	—0.91
4024.73	560	4.15	—0.04
3948.78	604	3.88	—0.04

cont. Table III

λ	mult.	$-\log \frac{W}{\lambda}$	$\log X_f$
Fe I (*cont.*)			
4040.65	655	4.23	—0.50
4966.10	687	4.31	—0.26
4946.39	687	4.22	—0.30
4843.15	687	4.10	—1.17
5039.27	687	4.32	—1.10
5002.80	687	4.09	—0.90
4950.11	687	4.41	—0.93
4907.74	687	4.19	—1.34
4196.22	693	4.25	—0.22
4225.46	693	4.22	+0.42
4227.43	693	3.90	+1.00
4195.34	693	4.24	+0.30
4247.43	693	4.26	+0.60
4461.37	725	4.33	—1.60
4137.00	796	4.21	—0.10
4219.36	800	4.43	—0.20
6400.01	816	4.16	+0.13
6411.66	816	4.27	—0.91
6408.03	816	4.22	—1.30
6246.33	816	4.25	—0.57
6336.83	816	4.38	—0.65
6232.66	816	4.37	—1.27
6302.51	816	4.22	—1.22
4525.14	826	4.28	—0.04
4401.29	828	4.26	—0.26
6003.03	959	4.57	—1.10
5976.80	959	4.22	—1.30
4455.03	974	4.38	—0.48
6008.58	982	4.24	—1.02
6713.14	1013	4.54	—2.22
6157.73	1015	4.23	—1.61
5762.99	1107	4.27	—0.75
6024.07	1178	4.30	—0.53
6419.98	1258	4.36	—0.97
6469.21	1258	4.39	—1.74
5987.06	1260	4.46	—1.34
Fe II			
4233.17	27	4.06	+0.36
4416.82	27	4.38	—0.82
4303.17	27	3.98	—0.45
4385.38	27	4.05	—0.55
4173.45	27	4.37	—0.38
4296.57	28	4.09	—0.79
4258.15	28	4.55	—1.10
4515.34	37	4.35	—0.87
4491.40	37	4.41	—1.04
4520.22	37	4.42	—0.90
4489.18	37	4.25	—1.34
4472.92	37	4.47	—1.67
4582.83	37	4.45	—1.62
Fe II (*cont.*)			
4534.17	37	4.47	—1.38
4583.83	38	4.32	—0.20
4508.28	38	4.42	—0.81
4576.33	38	4.51	—1.46
4541.52	38	4.47	—1.58
4522.63	38	4.10	—0.62
6516.05	40	3.91	—1.58
6432.65	40	4.18	—2.06
5018.43	42	4.15	+0.70
4923.92	42	3.99	+0.44
5991.38	46	4.21	—2.02
5362.86	47	4.31	—1.12
5316.78	47	4.36	—1.26
5316.61	48	4.11	—0.40
5275.99	48	3.92	—0.40
5234.62	48	4.06	—0.92
6456.37	74	4.01	—1.60
6247.56	74	4.26	—1.70
6416.90	74	4.18	—1.80
Co I			
4027.03	3	4.62	—1.37
3957.93	18	4.50	—0.75
4066.36	30	4.37	—0.66
3861.16	33	4.39	+0.63
Ni I			
4436.98	86	4.54	—0.83
4462.46	86	4.43	—1.16
4470.48	86	4.32	—0.88
4288.00	178	4.40	—0.57
Sr II			
4077.71	1	3.62	+1.36
4215.52	1	3.85	+0.96
4305.45	3	4.17	+0.20
Ba II			
4554.03	1	3.87	+0.56
4934.09	1	3.79	+0.84
6141.72	2	3.93	—0.58
6496.90	2	3.95	—1.00
5853.67	2	4.31	—1.53
Eu II			
4205.05	1	3.98	—1.26

A curve of growth has been constructed for the FeI lines and another for the FeII lines (Fig. 4a, 4b).

The vertical shift necessary for bringing the observed curve to coincide with the theoretical curve computed by Menzel gives the turbulence plus thermal velocity:

$$v = 1.95 \text{ km/sec}$$

The low value of v indicated by the sharpness of the spectral lines, is another characteristic common with β CrB and γ Equ. We recall that the metallic line stars, on the contrary, present a turbulence velocity higher than normal. The damping branch of the growth curve is rather uncertain. The most probable value corresponds to $Z = 0.01$. The horizontal shifts to be given to the branches corresponding to different excitation potentials are too uncertain to give a good determination of the excitation temperature. We assume therefore a value derived by the spectral type, assuming

$$\vartheta_* - \vartheta_\odot = -0.10.$$

Values of $\vartheta_* - \vartheta_\odot$ ranging from -0.05 to -0.15 do not change appreciably the shape of the growth curve.

From the horizontal shifts of the growth curve for FeI and FeII with respect to the solar curve of growth we find:

$$\log \frac{X_\star}{X_f} \text{ (FeI)} = +0.10$$

$$\log \frac{X_\star}{X_f} \text{ (FeII)} = +0.40$$

The same values are obtained by averaging the $\log \frac{X_\star}{X_f}$ read on the curve of growth for each single line.

Assuming $(\vartheta_* - \vartheta_\odot)_{\text{exc}} \simeq (\vartheta_* - \vartheta_\odot)_{\text{ion}}$ the Boltzmann-Saha relation gives $\log \frac{P_{e\star}}{P_{e\odot}} = 0.65$ and assuming $\log P_{e\odot} = 1.15$ it follows that $\log P_{e*} = 1.80$. Table IV gives the electron pressures derived by the hydrogen and metallic lines for γ Cap and for the three magnetic stars β CrB, γ Equ and 73 Dra.

TABLE IV

	γ Cap	β CrB	γ Equ	73 Dra
$\log P_e$ (Holtsmark)	2.63	2.80	2.65	2.24
$\log P_e$ (Inglis and Teller)	1.39	2.11	1.69	1.25
$\log P_e$ (ionization equilibrium for FeI and FeII)	1.80	1.70	1.35	1.20

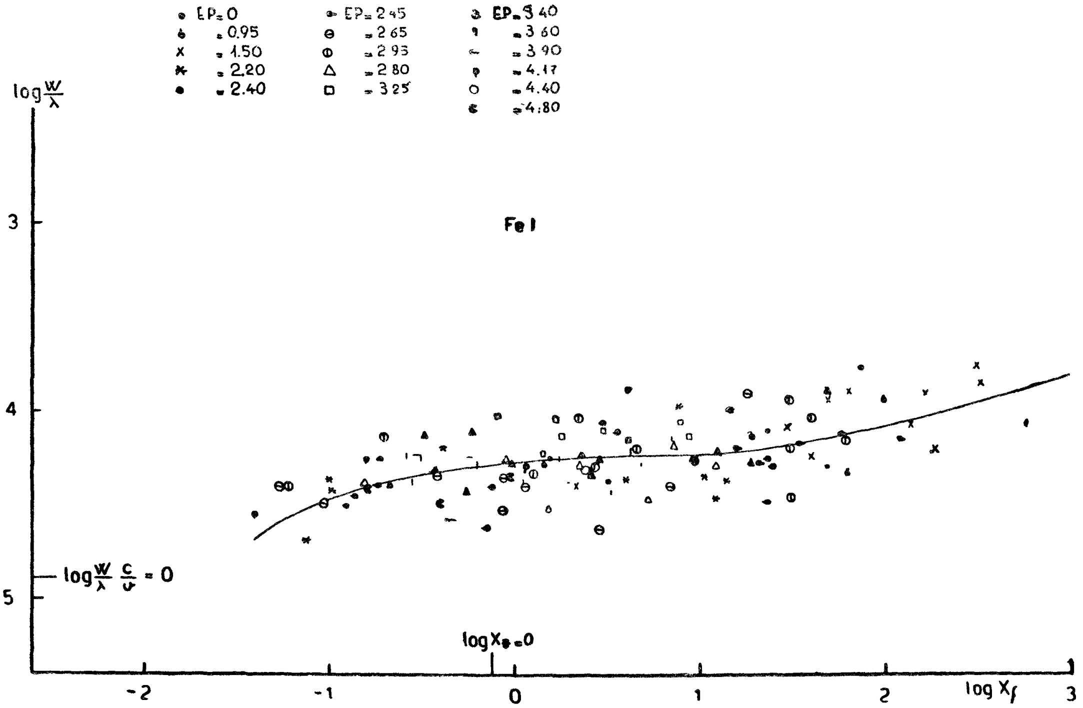

Fig. 4 a

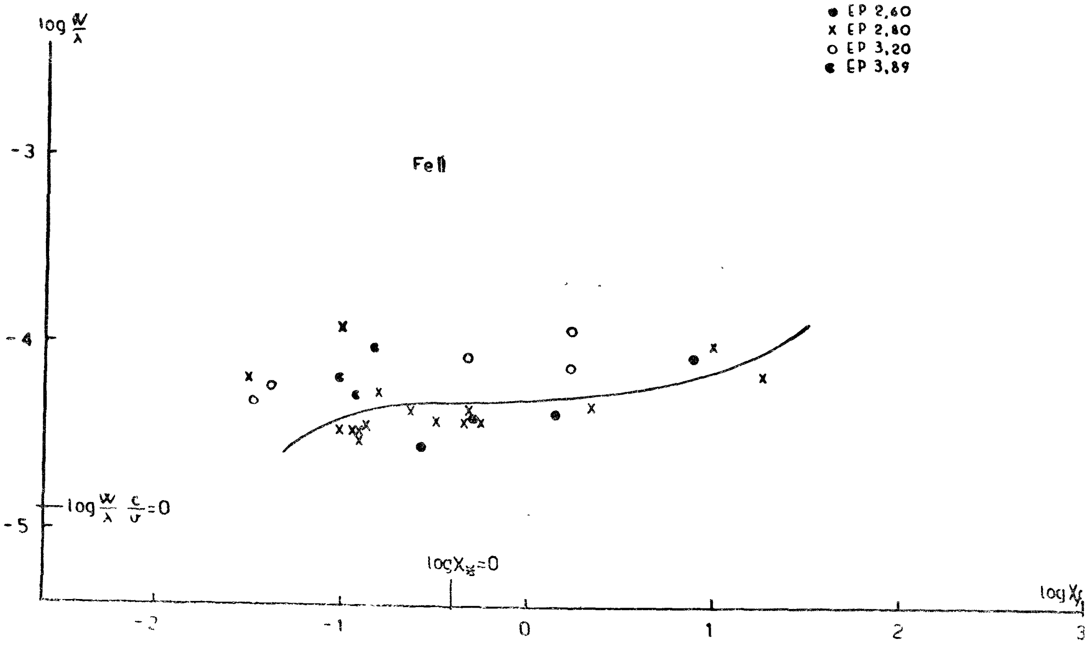

Fig. 4 b

In all the cases the electron pressure given by the Inglis and Teller formula is about one order of magnitude lower than that given by the Holtsmark formula. This has been explained with the presence of a rarefied envelope.

γ Cap differs from the three magnetic stars because the electron repressu

TABLE V

Element	$\log \frac{N_\star}{N_\odot}$	Element	$\log \frac{N_\star}{N_\odot}$
Na from Na I	+2.97	Fe s » Fe I	+1.67
Mg s » Mg I	—1.22	s » Fe II	+1.10
s » Mg II	+2.03	Co » Co I	—0.19
Ca » Ca I	+1.42	Ni » Ni I	—0.82
Ti » Ti II	+1.09	Sr » Sr II	+2.83
Cr s » Cr I	+0.84	Ba » Ba II	+3.02
s » Cr II	+0.19	Eu » Eu II	+4.40
Mn » Mn I	+3.25		

given by the iron ionization equilibrium is higher than that given by the Inglis and Teller formula. This could suggest that the envelope of γ Cap is more extended and the cores of the last Balmer lines are formed just in the outer parts of it.

CHEMICAL COMPOSITION.

Table V gives the total abundances of the elements with respect to the sun. For the opacities k_* and $k_\odot$ it has been assumed (16):

$$\log k_* = +0.02$$
$$\log k_\odot = -0.45$$

The abundance of the Mg derived by the lines of the neutral and ionized element are in strong disagreement; this determination is very uncertain because only one line was measurable for each ionization state.

The overabundance of Sr is very similar to that observed for γ Equ. Also Ba and Eu are strongly overabundant; we remark that usually in the magnetic stars Ba is normal or only slightly overabundant. The presence of strong Y II lines in the spectrum of γ Cap is sure, but the determination of the abundance for this element was impossible because all the lines are blend. Ca, Ti and Fe are overabundant by a factor of 10, and Mn by a factor of 100. The overabundance of these metals mainly of iron with its numerous lines, strongly affects the general aspect of the spectrum and is the main reason for the peculiarity of γ Cap. This confirms the hypothesis of Kopylov (17) that iron contributes to the character of « metallicism » of a star. Moreover the value of P_e suggested by the Holtsmark formula and by the ionization equilibrium that is excessive for an F0III star could be explained by the excess of free electrons due to the metallic excess.

THE CHARACTERISTIC BLENDS OF γ CAP AND THE PRESENCE OF RARE EARTHS.

The comparison of γ Cap with the other normal and magnetic stars has shown the following peculiarity: the existence of strong blends at $\lambda\lambda$ 4085.7 ± 2.5; 3982.0 ± 2; 3949 ± 3; 3941 ± 1.5; 3918 ± 5; 3907 ± 2; 3872 ± 1.5.

Fig. 5 gives the intensity tracings of γ Cap, 73 Dra, γ Equ, β CrB, ι Peg in the spectral region where the strongest blends are present. It is possible that they can be explained by blends of lines of Rare Earths and metallic elements. We have compared these tracings to establishe the presence of Rare Earths which, with the exception of Eu II, have weak lines. From the comparison of the spectral regions where the strongest lines of the Rare Earths fall, we could admit or deny their presence. However the computation of the abundances has not been possible because they are blended lines. The results are summarized as follows:

Sm II Pr II Nd II	Their lines are missing or extremely weak
Gd II Ce II	Their lines are possibly present, but weak

Hf II: All the strongest lines of this element fall in regions too blend to decide if they are present or missing.

La II: Its lines are probably present; some of the strongest lines fall at $\lambda\lambda$ 4086.2, 3949.1, 3922.2, namely in the same regions where the strongest blends and the most difficult to explain are found. The other strong lines of La II are blend with lines of Fe, Ni, Cr. The contribution of La II to λ 4031.68, 4269.50, 4296.05, 4429.90, 4574.87 seems certain.

CONCLUSIONS.

The conclusions of this quantitative study of γ Cap confirm partly the inference derived by visual inspection of the spectrograms. The general aspect of the hydrogen spectrum and the color B—V are very similar to those of the magnetic stars γ Equ and β CrB, which occupy the same position in the HR diagram. The main difference with these two stars is the large excess of barium and the larger abundance of calcium, iron and manganese. Moreover the Rare Earths Gd, Ce, Pr, Nd are not overabundant like in the other magnetic stars. Another important difference is that the Li I doublet at λ 6708 was observed in the spectrograms of γ Equ and β CrB and an

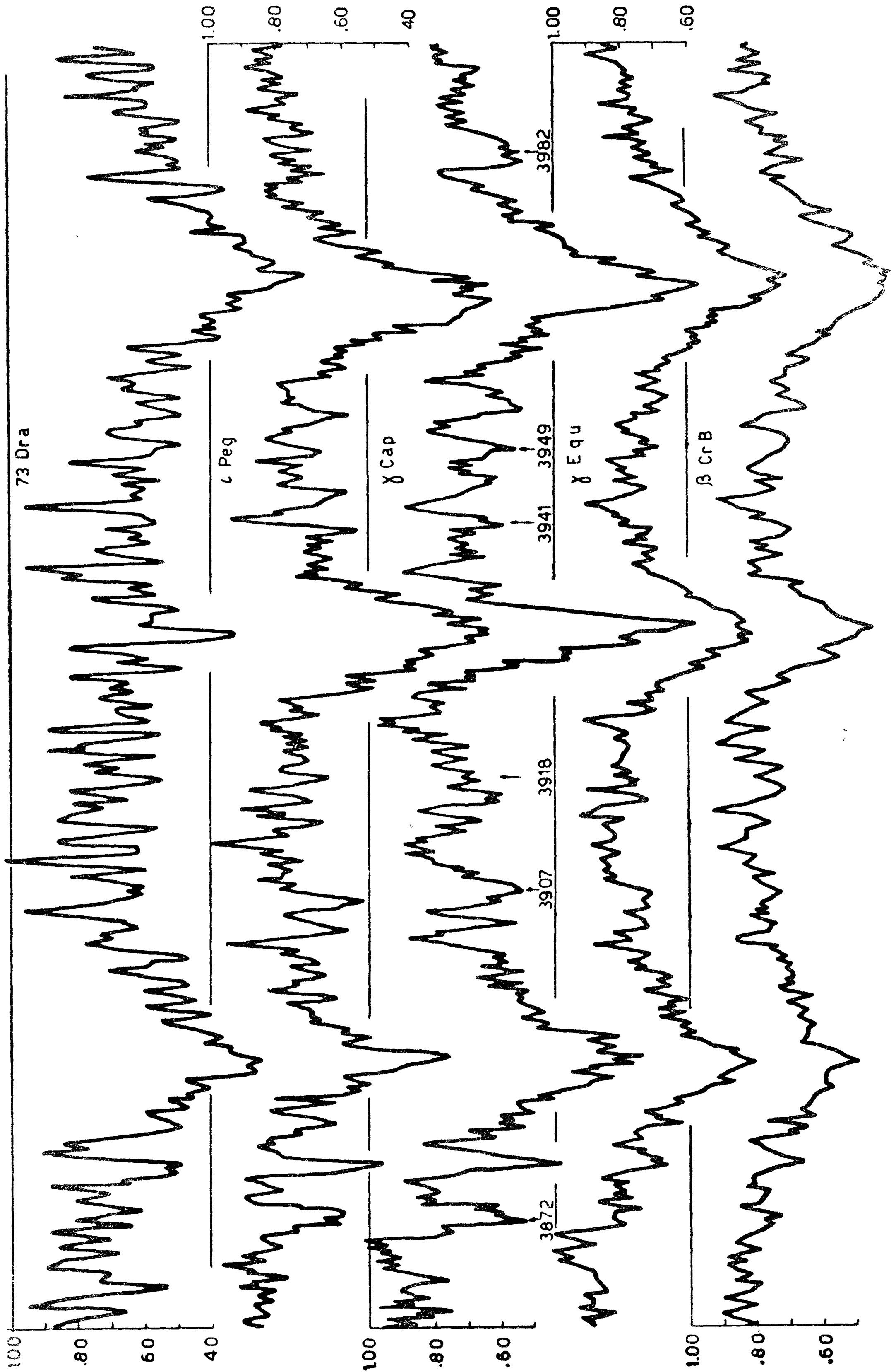
73 Dra
ι Peg
χ Cap
γ Equ
β CrB
3982
3949
3941
3918
3907
3872
1.00
.80
.60
.40

Fig. 5

overabundance of the order of 10^3 was found for this element. On the spectrum of γ Cap no trace of the Li I doublet is visible.

The general aspect of the metallic line spectrum is similar to that of the metallic line stars. However Ca and Ti are overabundant, while in the metallic line stars they are generally underabundant. Another difference with the metallic line stars is that no overabundance of heavy elements and Rare Earths is observed in this class of stars.

Moreover the low value of the turbulence is another difference with the metallic line stars which are usually characterized by values of the turbulence higher than normal. Therefore γ Cap seems more similar to the magnetic stars.

It is difficult to explain all the peculiarities of the spectrum only by differences of chemical composition. The difference between the values of the electron pressure derived by different methods suggests presence of stratification and of a shell.

It is a pleasure, as well as a duty, to acknowledge my indebtedness to Prof. M. Hack, whose assistance far beyond mere conventional guidance, was exceedingly valuable for me in completing this study.

REFERENCES

(1) HYNEK, Perkins Obs. Contr. **1**, 185, 1938.
(2) HACK, Ann. d'Ap. **16**, 417, 1953.
(3) BABCOCK, Ap. J. Suppl. III, 141, 1958.
(4) HACK, Mem. S.A.I. **31**, 279, 1960.
(5) HACK, Mem. S.A.I. **29**, 263, 1958.
(6) JOHNSON AND MORGAN, Ap. J. **117**, 313, 1953.
(7) JENKINS, *General Catalogue of trigonometric stellar parallaxes*, 1952.
(8) EGGEN, A.J. **62**, 45, 1957.
(9) BARBIER AND CHALONGE, Ann d'Ap. **4**, 30, 1941.
(10) CHALONGE AND DIVAN, Ann. d'Ap. **15**, 201, 1952.
(11) JASCHEK AND JASCHEK, Z. f. Ap. **45**, 35, 1958.
(12) KEENAN, *Stars and stellar sistems. Basic astronomical data*, 1963, pag. 91.
(13) FARAGGIANA AND HACK, Mem. S.A.I. **33**, 309, 1962.
(14) WRIGHT, Publ. Dom. Obs. Victoria **8**, 1, 1951.
(15) *Preliminar photometric catalogue of Fraunhofer lines*, Utrecht 1960.
(16) VITENSE, Z. f. Ap. **28**, 81, 1951.
(17) KOPYLOV, Izvestija Krymskoy Astr. Obs. **29**, 251. 1963.