Peculiar Versus Normal Phenomena in A-Type and Related Stars
ASP Conference Series, Vol. 44, 1993
M.M. Dworetsky, F. Castelli, and R. Faraggiana (eds.)

CP STARS AT HIGH GALACTIC LATITUDE: PHOTOMETRY NEAR THE GALACTIC POLES*,†

H.SCHNEIDER
Universitäts-Sternwarte, Geismarlandstr.11, D-3400 Göttingen, Germany

ABSTRACT The results of photometric observations of early type stars in regions around the Galactic poles are presented. The aim of these investigations was to search for CP2 and CP1 and to establish new and more precise frequencies for such objects including fainter stars.
A mean frequency of 24.7% was found for the CP1 stars, 23.7% for the hot CP2, and 11.7% for the cooler ones, but with large differences between the two regions investigated.
Furthermore, a substantial number of stars (20) were found to be good candidates for λ Boo stars.

INTRODUCTION

When investigating CP stars as a whole sample it is important to know how rare are these objects or, in other words, what are their incidences in respect to normal stars in the same spectral range, what are the frequencies of the different subclasses?

In the past several authors have published frequencies of CP stars. Table I gives a short synopsis of the major papers. Here the source of the obtained values is given in column five, while the data base is noted under remarks.

All these values are based on selected samples like open clusters, on restricted spectral ranges (e.g. A5-A9), on incomplete lists like the one of Osawa (1965) or the old version of the *Bright Star Catalogue* (1962). But these published values seems not to be very satisfactory. New and better frequencies of CP stars including fainter stars are needed and to obtain such values was one of the major goals. Another aim of these investigations is to look for a possible gradient of the galactic distribution of CP stars. But the observations presented here are only a first step of a long-term project.

In the good old days of photographic plates CP stars could be detected only spectroscopically. But going to fainter stars it became a very time consuming job because of awful long integration time needed to obtain a reasonable spectrum.

* in collaboration with F.A.Catalano and F.Leone, Catania, Italy
† based in part on observations obtained at ESO, La Silla, Chile

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

The situation changed when Maitzen (1976) introduced the so-called Δa photometry. Two groups of CP stars (CP2 and CP4 with magnetic fields) are characterized, beside others, by a more or less strong flux depression at $\lambda 5200$. The depth of this depression is measured in this photometric system using three interference filters. It could be shown in the following time that all CP2 stars found before spectroscopically are also detectable by means of the Δa photometry (see e.g. Maitzen&Vogt, 1983). Stars up to $V = 11\overset{m}{.}0$ can be reached easely in reasonable time with this method even with smaller telescopes.

TABLE I. Published incidences of CP1 and CP2 stars

	author	type	freq.		range	remarks
cluster:						
1976	Hartoog	CP1	26.0%	lit.	A5–A9	36 cluster
		CP2	4.6%	lit.	B5–A5	36 cluster
			5.2%	obs.	B5–A5	7 cluster
1979	Abt	CP1	12.5%	obs.	A0–F0	11 cluster
		CP2 hot	6.6%	obs.	B5–A0	10 cluster
		CP2 cool	5.8%	obs.	A0–F0	7 cluster
1981	North&	CP2 hot	10.0%	obs.		
	Cramers	CP2 cool	5.0%	obs.		
field:						
1973	Smith	CP1	20.0%	lit.	A0–F1	peak of 50% at A6
1976	Hartoog	CP1	28.0%	lit.	A5–A9	BSC north of -20
			27.0%	lit.	A5–A9	Michigan Vol.1
		CP2	7.7%	lit.	B5–A5	BSC north of -20
			7.0%	lit.	B5–A5	Michigan Vol.1
1979	Abt	CP1	10.4%	lit.	A0–F0	
		CP2 hot	6.5%	lit.	B5–A0	Osawa + BSC
		CP2 cool	5.4%	lit.	A0–F0	Osawa + BSC
1984	North	CP2 hot	8.0%	lit.		BSC
		CP2 cool	5.0%	lit.		BSC

The photometric method to search for CP stars is much faster as the spectroscopic one but has also its disadvantages. Beside the fact that only CP2 and CP4 stars (with magnetic fields) can be detected the dereddening, especially in the case of fainter stars, can arise serious problems.

Going to fainter stars the interstellar absorption plays a more and more important rôle. To correct these effects algorithms have been developed in the past. But the procedures are strictly valid only for normal stars. CP stars are known to be too blue for their spectral type and this results in too low corrections. So, in some extreme cases it may happen that the CP star remains undetected, hidden in the bulk of normal stars, just because of wrong dereddening.

A way out of this dilemma would be observations in regions where no substantial reddening is expected: the regions of the Galactic poles.

OBSERVATIONS AND REDUCTION

For both regions (≈ 15°around the NGP, ≈ 20°around the SGP) Strömgren observations of early type stars have been published by Hill *et al.* (1982) and McFadzean&Hilditch (1982) for the North Galactic Pole (NGP) and the South Galactic Pole (SGP), respectively.

We have observed in the Δa system nearly all stars from these lists up to $V_0 = 10^{m}.1$ and with $(b-y)_0 < 0.210$, alltogether 191 star in the region of NGP and 163 in the case of SGP. In most cases more than two measurements were obtained, in the NGP region 23 stars have only one. The oberservations in the North were carried out with the 90cm telescope of the Catania observatory (Sicily) and the ones in the South with the ESO 50cm telescope at La Silla (Chile), respectively.

Intrinsic Strömgren Values

Hill *et al.* gave also intrinsic values for the NGP stars which will be used here. In the case of the SGP the observations have been dereddened using the algorithms published by Moon (1985). But in both samples the uncertainties in the dereddening of CP stars remain and will influence the obtained incidences.

Published Peculiarity Types

All program stars were checked for peculiarities by means of a preliminary version of the *General Catalogue of Ap and Am Stars* (Renson *et al.* , 1991; in the following abbreviated to GCAAS). A substantial number of CP stars could be found. More objects are found in the North as in the South, undoubtedly a selection effect.

THE m_0 vs. $(b-y)_0$ DIAGRAM

It is known, that CP1 stars (and in many cases CP2 stars, too) show a larger m_1 index as normal stars. Crawford (1979) introduced a $\delta m_1 = -0.01$ limit ($\delta m_1 = m_1(\mathrm{st}) - \mathrm{m}_1(\mathrm{obs})$) and suggested that all stars with larger negative values are CP1 stars.

Because of available Strömgren photometry for the program stars the corresponding diagrams (Figures 1 and 2) were produced using the intrinsic values and checked for unknown CP1 stars. In the figures the solid line represents the relatio for normal stars (Crawford, 1979; Hill *et al.* , 1983), the upper broken line the $\delta m_0 = -0.01$ limit.

CP1 Stars ($(b-y)_0 \geq 0.0$)

A substantial number of stars are situated above this limit and were not known as CP1 before (19 in the case of NGP, 17 in the case of SGP, respectively) and not CP2. These new ones are denoted as *suspected* because spectroscopic observations should confirm these findings.

On the other hand some of the known CP stars do not exeed the limit. It might be that the latter objects are spurious dereddened or they are unresolved

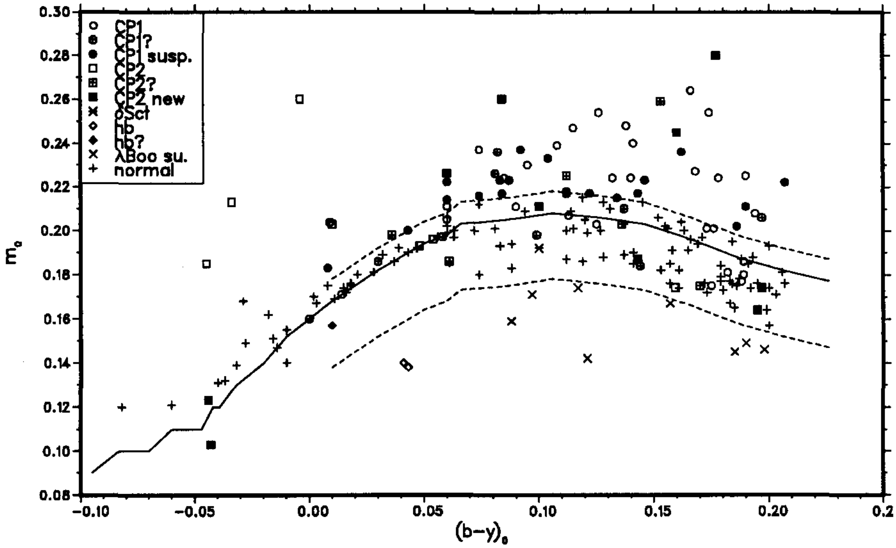

Fig. 1. The m_0 vs. $(b-y)_0$ diagram for the NGP stars. The solid line presents the standard relation, the upper broken line the $\delta m_0 = -0.01$ limit, the lower one a $\delta m_0 = 0.03$ limit. Symbols are explained in the legend. 'CP1?' means that the classification is doubtful in the catalogue of GCAAS, 'CP1 susp.' that the star is found in this investigation. For the explanation of the CP2 stars see Figure 4.

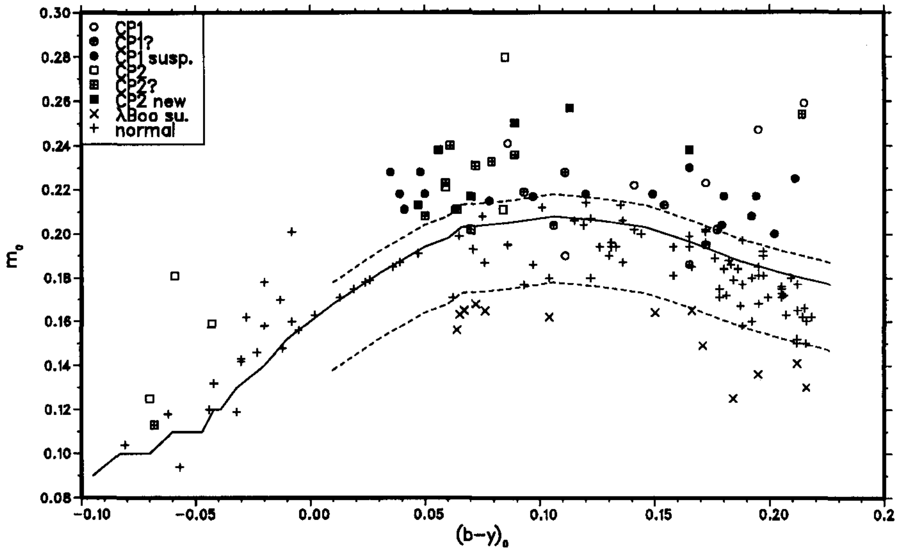

Fig. 2. The m_0 vs. $(b-y)_0$ diagram for the SGP stars. Symbols are explained in the legend. For more explanations see Figure 1.

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

binaries where the integrated colors feign a normal star. Nevertheless, in doubtful cases (no positive peculiarity type in GCAAS) these objects were rejected.

Alltogether 53 CP1 stars have been found in the NGP region and 25 in the SGP region, respectively. The total numbers of stars is 174 an 142, respectively. The frequencies relative to the normal stars in the same $(b-y)_0$ range are listed in Table II.

λ Bootis Stars ($(b-y)_0 > 0.06$)

A substantial number of stars situated below the standard relation show a more or less clear separation from the others. A limit of $\delta m_0 = 0.03$ was introduced as an educational guess and all objects below this are taken as λ Boo stars or candidates, respectively. So far Faraggiana&Gerbaldi observed three of the stars with IUE and found one to be normal, one is a good candidate and another one shows stronger characteristics as the prototype of this peculiarity group itself.

These results were unexpected and it seems that the m_0 vs. $(b-y)_0$ diagram provides a powerful tool to detect λ Boo stars!

Horizontal Branch Stars

In the sample of Hill *et al.* three horizontal branch stars (one doubtful) are included. The two positive stars are clearly separated in the m_0 vs. $(b-y)_0$ diagram while the doubtful but hotter one shows only a marginal deviation from the standard relation.

THE a vs. $(b-y)_0$ DIAGRAM

This diagram is used to look for unknown CP2 stars. First the normality line (i.e. the loci of normal stars) was constructed (straight lines in Figures 3 and 4) and the Δa indices were estimated. Only stars with more than two measurements were taken in consideration.

As one can see the scattering around this line is somewhat larger in the case of the NGP. This is also reflected in the mean deviation for one star: 0.0034 (NGP) and 0.025 (SGP), respectively. The detection limit of 3σ corresponds to 0.0103 in the case of the NGP and to 0.0075 in the case of the SGP, respectively. To be on the safe side an additional 4σ limit was introduced,too. All stars with $3\sigma < \Delta a < 4\sigma$ are denoted as *suspected* CP2 stars. Note that the normality lines show different shapes because of the different equipment used in the North and in the South.

Hot CP2 Stars ($(b-y)_0 < 0.0$)

Two new out of five CP2 stars in total (in Figure 3 only four are drawn in because one outstanding CP2 star, α^2 CVn, was too bright to observe) could be detected in the NGP area and one suspected out of four in the SGP area, respectively. The total numbers of stars is 17 and 21, respectively. The frequencies relative to the normal stars in the same $(b-y)_0$ range are listed in Table II.

Cooler CP2 Stars ($(b-y)_0 > 0.0$)

Nine and six new CP2 stars, respectively, could be found as positive CP2 in this $(b-y)_0$ range, four and nine, respectively, as suspected. One NGP star known

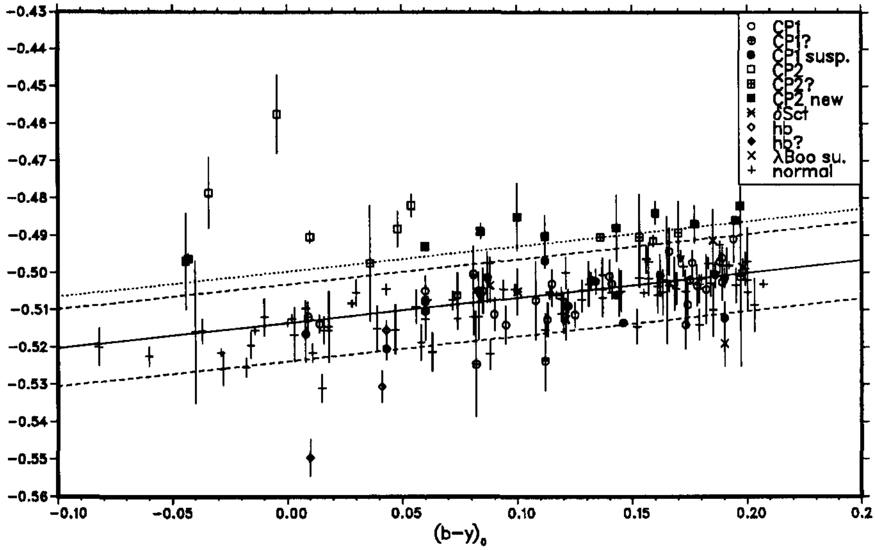

Fig. 3. The a vs. $(b-y)_0$ diagram for the NGP stars with two or more measurements. The mean error in a is indicated. The solid line presents the normality line, the broken lines the upper and lower 3σ limit, respectively, the upper dotted line the 4σ limit. Symbols are explained in the legend. 'CP2?' means that the star is situated below the 4σ but above the 3σ limit. Stars above 4σ are denoted as new.

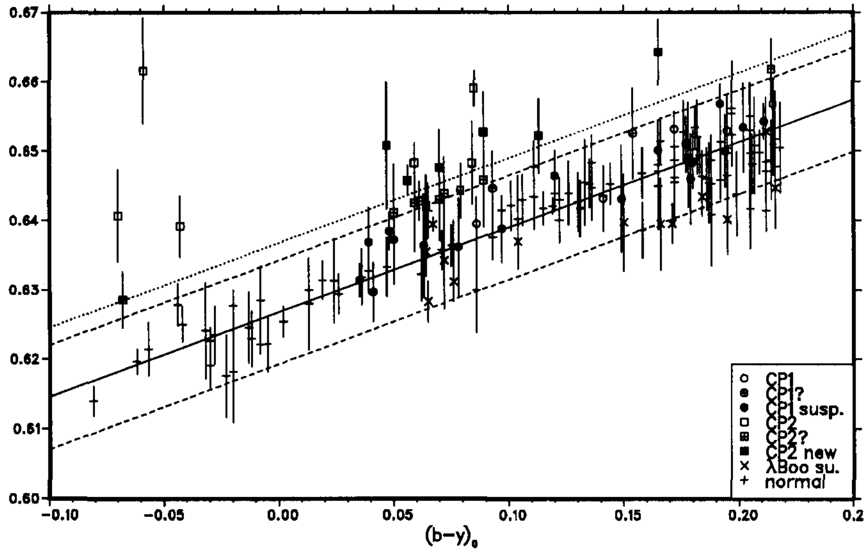

Fig. 4. The a vs. $(b-y)_0$ diagram for the SGP stars. For explanation see Figure 3.

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

to be a CP2 shows only a marginal Δa value. In both of the regions 18 CP2 stars could be found. The total numbers of stars is 174 and 142, respectively. The frequencies relative to the normal stars in the same $(b-y)_0$ range are listed in Table II.

TABLE II. Frequencies of peculiar objects

type	$(b-y)_0 < 0.0$ %	no.	$(b-y)_0 \geq 0.0$ %	no.
NGP: 191 stars				
CP1 (all)			30.6	53/174
CP2 (all)	29.4	5/17	11.0	19/174
δ Sct			0.6	1/174
λ Boo cand.			5.4	7/130 *
hb			1.7	3/174
wHe	5.9	1/17		
other pec. (?)	29.4	5/17		
total	64.7	11/17	47.3	82/174
normal	35.3	6/17	52.7	92/174
reliable only:				
CP1 (δm_0)			23.0	40/174
CP2 (4σ)			6.9	12/174
total			29.9	52/174
other pec.			3.5	6/174
SGP: 163 stars				
CP1 (all)			17.6	25/142
CP2 (all)	19.0	4/21	12.7	18/142
λ Boo cand.			10.0	13/129 *
wHe	4.8	1/21		
CP3	4.8	1/21		
other pec. (?)	33.0	7/21		
total	61.9	13/21	40.1	57/142
normal	38.1	8/21	59.9	85/142
reliable only:				
CP1 (δm_0)			9.2	13/142
CP2 (4σ)			5.6	8/142
total			14.8	21/142

* only in the intervall $(b-y)_0 \geq 0.06$

OTHER PECULIAR STARS

As mentioned before CP stars other as CP1 or CP2 are not detectable by the methods used here. But from the literature one CP3, two CP4, one δ Sct were found. Furthermore, a number of hot stars show a larger deviation in m_0 but no peculiarities were published. They might be CP3 or CP4 stars, too.

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

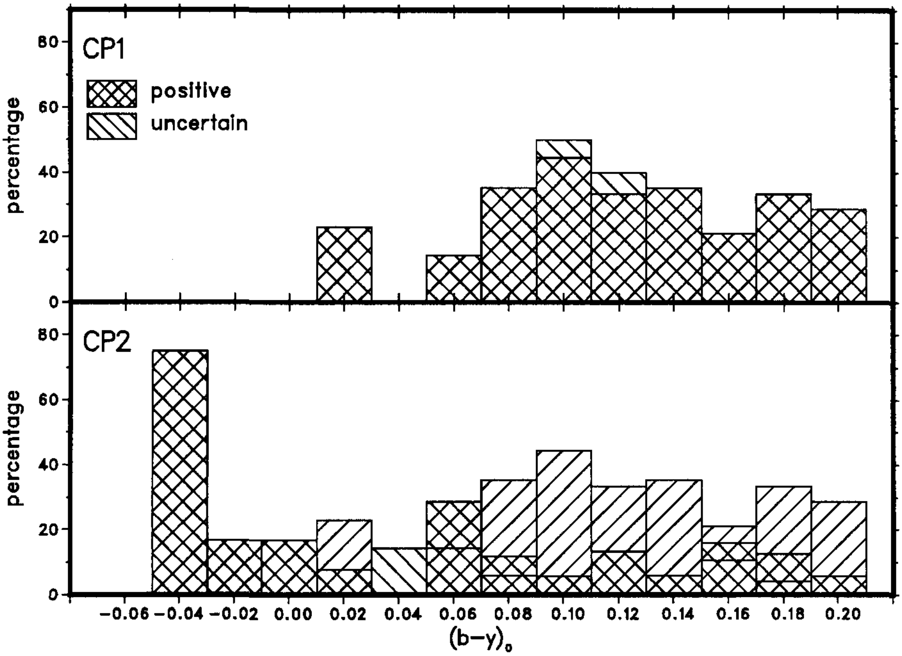

Fig. 5. Distribution of CP1 (upper panel) and CP2 (lower panel) stars relative to $(b-y)_0$ in the area of the NGP.

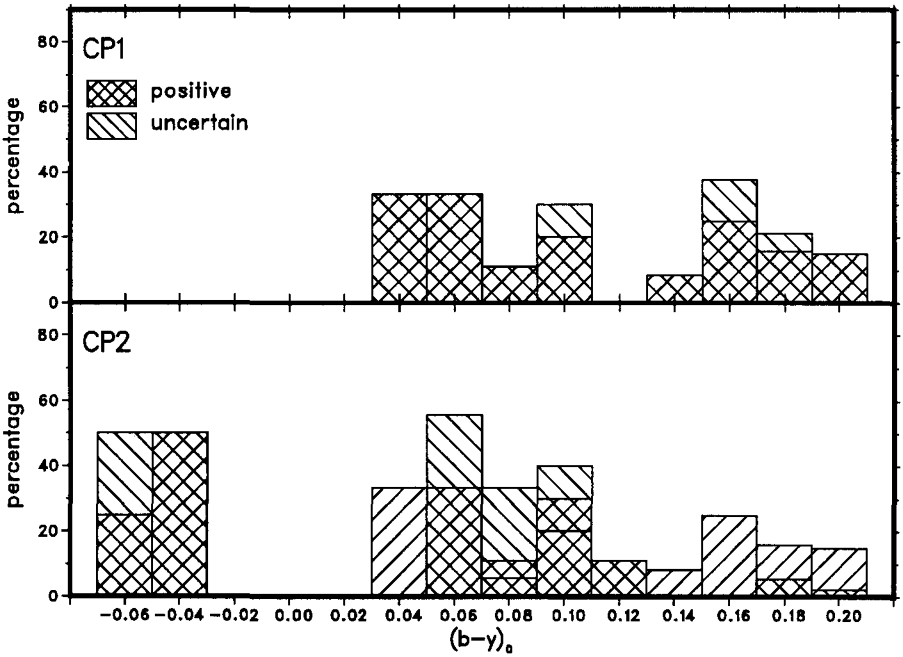

Fig. 6. Distribution in the area of the SGP.

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

But spectroscopic observations are needed to confirm the peculiarities of these objects.

DISCUSSIONS

The frequencies listed in Table II shows that at least in the regions of the Galactic poles peculiar stars of the upper main sequence are not so rare objects as suggested before but reaching a incidence of nearly 50% in total. Taking in account uncertainties like the dereddening procedures or the impossibility of photometric detection of CP3 or (non-magnetic) CP4 stars the presented values should be taken as a lower limit. It seems that the normal stars are the rare objects at least in the investigated spectral range!

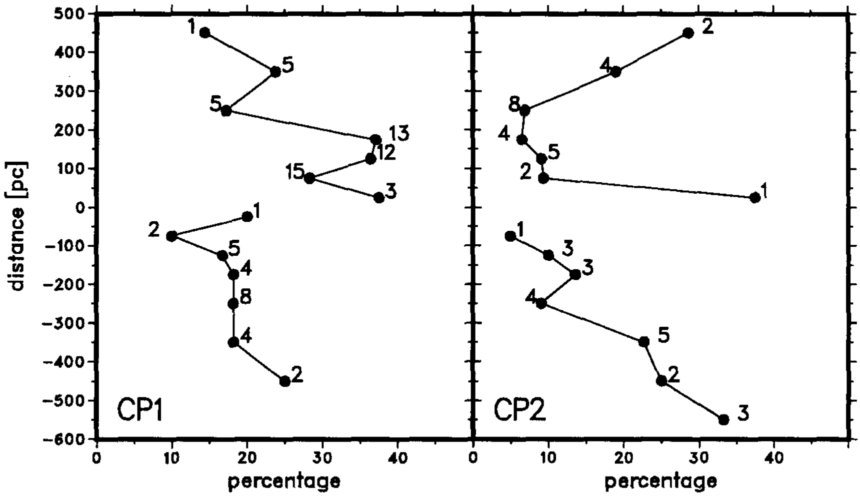

Fig. 8. Distance vs. frequency for the CP1 and CP2 stars. The number of stars per distance interval is indicated.

The frequencies of CP1 and CP2 stars are much higher as those published by Abt. But in the light of new investigations (see Schneider's paper on *Statistics of CP stars in a magnitude-limited sample: the Bright Star Catalogue* in this proceedings) the mean frequencies are more or less normal.

But there are real differences between the two areas investigated. The incidence of CP1 stars at the NGP is nearly twice as big as at the SGP. Also, the distribution of CP stars relative to $(b-y)_0$ is quit different (Figures 5 and 6). Especially the missing stars at $-.03 < (b-y)_0 < .05$ in the case of the SGP are conspicuous. No explanation for these findings can be given so far.

The distribution of V_0 of normal as well as peculiar stars. is also different (Figure 7) The frequency of normal NGP stars is increasing reaching fairly constant value for stars fainter than $V_0 = 8\overset{m}{.}0$ but the SGP stars are monotonously increasing. At the NGP the frequencies of CP1 and averaged CP stars show a similar distribution as the normal stars but with a moderate peak

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

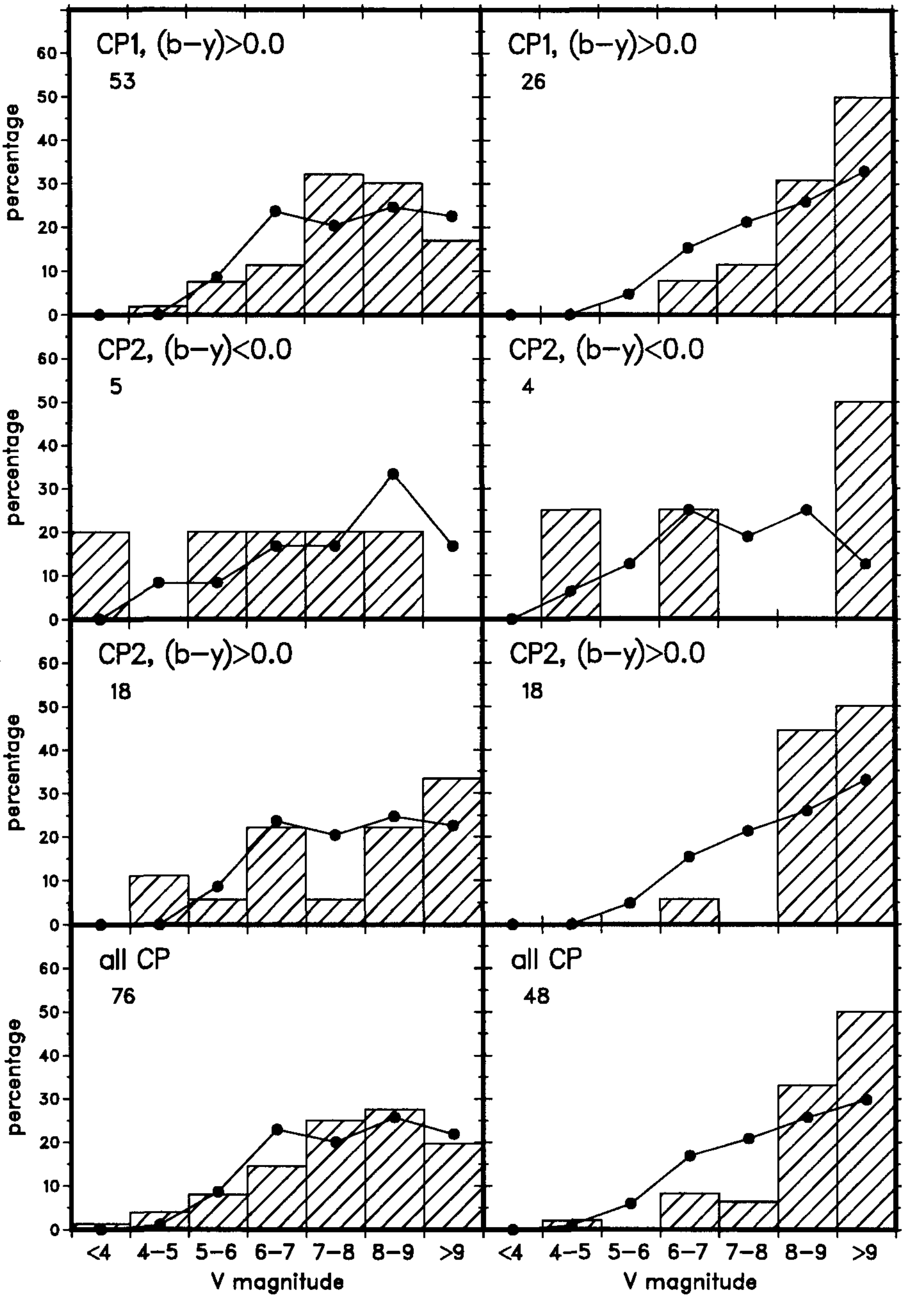

Fig. 7. Distribution of CP stars relative to V_0. Left side NGP, right side SGP. The straight lines present the distribution of normal stars in the same range. The number of stars per sample is indicated.

https://doi.org/10.1017/S0252921100021059 Published online by Cambridge University Press

around $V_0 = 8 \overset{m}{.} 0$. But the peculiar star at the SGP show a significant excess of fainter stars while the brighter ones are underabundant. Does this means that at the edges of the Galactic disk the incidence of CP stars is increasing relative to the normal stars?

The latter statement is more a speculation than a suggestion. But it seems worth to toy a bit with this. Therefore, the distances of all stars were calulated (in the case of the NGP stars the published values by Hill *et al.* were used) and averages over certain intervals estimated. The resulting frequencies relative to the total number of stars in the interval are presented in Figure 8. The behaviour of the CP1 stars is not so clear. Here the larger hump at $\approx$ 100pc is strongly influences by the fact that the Coma cluster (Mel 111), well known for its richness of CP1 stars, is located there. But the CP2 stars show an increasing towards the outer part of the Galactic disks, very similar in both directions. Even taking in account all the uncertainties in finding and reducing CP stars, this is very remarkable. But the significance is low because of the low numbers of stars. To be honest the number of CP star per interval is indicated in Figure 8.

CONCLUSIONS

The frequencies found in this investigation are quit different in particular but normal taking the average.

The finding of larger incidences at the outer parts of the Galactic plane is very speculative. Observations up to at least $V_0 = 12 \overset{m}{.} 0$ are needed to check it.

To compare the results of the polar regions with the plane and to look for a possible dependance of the frequencies with the Galactic latitude observations in selected areas are planned for the next future. I hope that at the next meeting on this topic I will be able to report new and interesting results of the appearance of CP stars in the Galactic plane.

REFERENCES

Abt,H.A., 1979, *Ap. J.*, **230**,485

Crawford,D.L., 1979, *Ap. J.*, **84**,1858

Hartoog,M.R., 1976, *Ap. J.*, **205**,807

Hilditch,R.W., Hill,G., Barnes,J.V., 1983, *M.N.R.A.S.*, **204**,241

Hill,G., Barnes,J.V., Hilditch,R.W., 1982, *Publ. DAO* Vol.**XVI**, No.10

Hoffleit,D., 1962, *Bright Star Catalogue*, Yale Uni.Obs., New Haven

Maitzen,H.M., 1976, *Astr. Ap.*, **51**,223

Maitzen,H.M., Vogt,N., 1983, *Astr. Ap.*, **123**,48

McFadzean,A.D., Hildtich, R.W., 1982, *M.N.R.A.S.*, **205**,525

Moon,T.T., 1985, Comm. Univ. London Obs. No.**78**

North,P., Cramer,N., 1981, in *Les Etoiles de Composition Chimique Anormale du Debut de la Sequence Principale*, 23^{rd} Liége Astrophys. Coll., p.55

Osawa,K., 1965, *Ann. Tokyo Astron. Obs. Ser. II* **9**,121

Renson,P., Gerbaldi,M., Catalano,F.A. (**GCAAS**), 1991, *Astr. Ap. Suppl.*, **89**,429