Peculiar Versus Normal Phenomena in A-Type and Related Stars
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CHEMICALLY PECULIAR STARS AMONG SPECTROSCOPIC BINARIES - REVISITED

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ABSTRACT This paper presents a new statistical investigation of peculiar A-type stars (Am, Ap, Hg-Mn) among spectroscopic binary (SB) stars. The relative frequency of Am (CP 1) stars is 55% in the spectral range A1 to A6 of main-sequence stars. The Ap (CP 2) stars amount to 15% in the range B9 to A2. The Hg-Mn stars are concentrated to the spectral types B8 to A0 and reach a relative frequency of 23%. The Am SB stars have the shortest orbital periods and the smallest eccentricities (30% circular) whereas the Ap SB stars show a strong tendency to long periods and highly eccentric orbits (only 10% circular). The masses of the Am stars agree with the masses of non-peculiar SB stars of corresponding spectral type.

I. INTRODUCTION

Many problems related to the origin, evolution and characteristics of peculiar A-type stars (CP stars) are still to be solved. Therefore, as much observational information as possible should be collected to set constraints to the theoretical considerations. One starting-point is the statistical study of the properties of CP stars in the sample of spectroscopic binary stars (SB stars). In my overview of one decade ago (Seggewiss 1981) all selection effects were already discussed carefully. Rapidly growing knowledge in all fields of astronomy makes a new study senseful.

The following data bases are used for this investigation:
(1) Eighth Catalogue of the Orbital Elements of Spectroscopic Binary Systems (Batten et al. 1989) and
(2) General Catalogue of Ap and Am Stars (Renson et al. 1991).
A number of additional catalogues have been consulted, e.g. the General Catalogue of Variable Stars (Kholopov and Samus 1985-1990) and The Bright Star Catalogue (Hoffleit 1982).

II. RESULTS

191 peculiar A-type stars have been found in the catalogue of SB stars: 123 Am, 30 Ap, 28 Hg-Mn, 10 others. This number corresponds to only 3% of the total number of about 6700 known CP stars. The binary CP stars cover, with two exceptions, the range B8 to F0 of spectral types. (For the Am-type stars the CaII K spectral type has been used). In the same range one finds 205 non-peculiar SB stars on and near the main sequence (luminosity classes V and IV) in the SB catalogue.

II.1 Relative frequency

It is not very meaningful to quote the mean fraction of peculiar to non-peculiar stars in broad ranges of spectral class. Instead, the relative frequency is calculated, i.e. the number of peculiar stars of a given peculiarity type divided by the sum of all peculiar and non-peculiar stars as a function of spectral subclass. The result is given in Fig. 1 and TABLE I.

Clearly, Am (CP 1) stars are the most frequent CP stars: The frequency reaches values near 50% and even larger in the spectral range A1 to A6; the maximum value is 73% at spectral type A6, and the weighted mean (weighted by number) is 55%. The binary Ap (CP 2) stars have a maximum frequncy of 19% at spectral type B9 and a mean frequency of 15% in the range B9 to A2. The Hg-Mn (CP 3) stars are restricted to the domain B8 to A0; their mean frequency here is 23%. - The unexpected high frequencies can be compared to the results of a study by Schneider et al. (1987) who report a percentage of 33% Am stars and 13% Ap stars among all (not only A-type) stars brighter than V = 10.1 in a region of 15° around the north galactic pole.

TABLE I Relative frequencies of CP stars among spectroscopic binaries (SB)

CP type		*total number CP-SB*	*relative frequency* maximum %	sp.type	mean %	range	number
Am	CP 1	123	73% at	A6	55% in	A1 - A6	100
Ap	CP 2	30	19	B9	15	B9 - A2	26
Hg-Mn	CP 3	28	27	B9	23	B8 - A0	28

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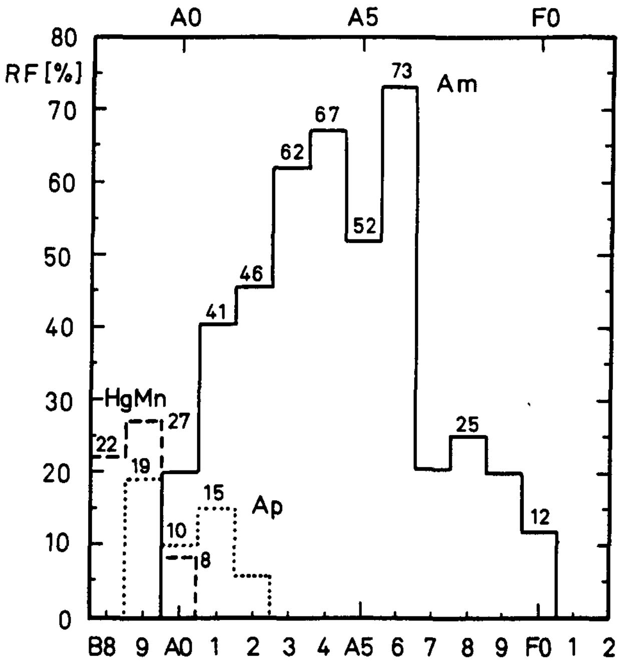

Fig. 1. Relative frequency RF of chemically peculiar SB stars.

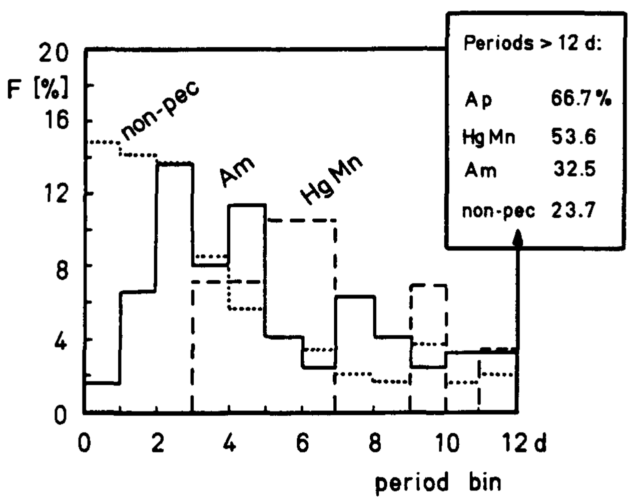

Fig. 2. Fraction F of periods in bins of 1 day and percentage of periods larger than 12 days for CP and non-CP SB stars.

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II.2 Orbital period

The distribution of orbital periods (up to 12 days and larger than 12 days) among CP SB stars is shown in Fig. 2. The comparison sample consists of 283 non-peculiar SB stars of spectral types B8 to F5, IV to V. From Fig. 2 we note a dramatic increase of the fraction of long periods from non-peculiar SB stars via Am and Hg-Mn to Ap stars. For instance, only one quarter of non-peculiar SBs have periods in excess of 12 days and one third of the Am binaries. But half of the Hg-Mn stars and two thirds of the Ap stars have periods larger than 12 days.

II.3 Eccentricity

The distribution of eccentricities reflects that of the periods: The long-period Ap stars have the largest eccentricities while the short-period non-peculiar stars of the comparison sample tend to show the smallest ones. The fraction of circular orbits ($e = 0$) increases in the following way:

Ap stars	10%
Hg-Mn stars	11%
Am stars	30%
non-pec. stars	43%

II.4 Longitude of periastron

The stars of the comparison sample show a strongly enhanced Barr effect (see Batten 1973): About 40% of the longitudes of periastron are concentrated in the first quadrant (0°< <90°). In contrast, the longitudes of the Am-star orbits are smoothly distributed over all quadrants. (The small number of Ap and Hg-Mn stars does not allow a statement for those binaries.)

II.5 Mass

Masses of CP stars can be derived from the subset of SB2 stars which are eclipsing binaries, i.e. with orbital inclination $i \approx 90°$. In addition, the eclipsing systems should be detached in order to eliminate disturbing effects of mass exchange between the components on the determination of the masses.

13 Am (CP 1) stars are detached eclipsing SB2 stars. Four of them are Am + Am (WW Aur, XY Cet, MY Cyg, V624 Her), but only two secondaries allow the attribution of a CaII K subclass (WW Aur and MY Cyg). Therefore, masses of 15 Am stars are available (TABLE II). Most of them have also been discussed by Popper (1980).

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The Am-star masses can be compared to the masses of 30 non-peculiar SB2 components in detached eclipsing systems. The data of TABLE II show no conspicuous differences between the masses of Am stars and those of non-peculiar stars of corresponding spectral type.

TABLE II Masses of Am-SB stars and non-peculiar SB stars which are members of detached eclipsing system (sp spectral type, $M_{\odot}$ solar mass, n number of stars)

sp	Am (CP 1)		non-pec.		sp	Am (CP 1)		non-pec.	
	$M_{\odot}$	n	$M_{\odot}$	n		$M_{\odot}$	n	$M_{\odot}$	n
A0	2.2	1	2.4	6	A5	1.8	2	2.3	2
A1	1.8	1	2.1	4	A7	1.8	1	-	-
A2	1.8	2	2.1	2	A8	1.6	1	1.7	7
A3	2.1	4	1.7	1	F0	1.7	1	1.7	4
A4	2.0	1	2.0	1	F4	1.3	1	1.3	2

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DISCUSSION (Seggewiss)

ABT: Your results on short-period binaries make good sense. If you have a 1-day binary, the rotational and orbital motions are generally synchronized; if I recall correctly, such a star would have a rotational velocity in excess of 100 km s^{-1} and would not be an Ap or Am star.
SEGGEWISS: If we suppose that diffusion is effective in the CP star atmospheres you are, of course, right.
GRIFFIN: Before drawing lasting conclusions about the statistics of these groups of abnormal A stars, one should first become convinced that the detection of the abnormality is independent of observational selection. It is much easier and definitive to detect and quantify abnormalities among sharp-lined objects than it is among stars which are rotating rapidly. I do not believe it has yet been convincingly demonstrated that rapid rotators do not also show signatures of chemical peculiarities. The whole basis of the theoretical explanation of the observed phenomena is of course intricately linked to this question. In addition, the definition of "normality" is evolving: in contrast to the traditional acceptance of Vega and Vega-like stars as "normal" and Sirius and other Am stars as "abnormal", the work of Holweger's group in Kiel shows that Sirius is more representative of A stars than is Vega. The statistics are very sensitive to what one takes as the base-line.
SEGGEWISS: Again, if diffusion is the origin of the abnormalities, then all CP stars should be slow rotators. In my statistical investigation a star is called "normal" if it is normal in the frame of the MK classification.