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SPECTRUM VARIABILITY OF SOME SELECTED BRIGHT CP STARS ON THE MAIN SEQUENCE

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Abstract. The initial findings of a survey for spectrum variations in selected CP stars is reported. It is found that almost all observed mercury–manganese stars are spectrum variables. The implications of chemical anomalies in these stars is briefly discussed. In particular, arguments are advanced against the general assumption that CP3 stars are non-magnetic. The observed low rotational velocities of the CP3 stars is interpreted as rotational braking by magnetic fields mostly in the pre-Main-Sequence stage of evolution of these objects. We advance the hypothesis that high resolution spectroscopic observations of such stars would exhibit Zeeman-broadening in lines that vary in strength and are also sensitive to the magnetic field.

1. Introduction

The chemically peculiar (CP) stars are broadly divided into magnetic and non-magnetic sequences. The mercury–manganese stars are supposed to be non-magnetic and as class represent an extension of the Am phenomenon to higher temperatures (Wolff and Wolff, 1975). The stars which show silicon, chromium, strontium anomalies are in general magnetic stars that behave as rigid rotators with associated light, spectrum, and magnetic field variations.

The theory that accounts for most of the observational results for these objects is the diffusion mechanism first proposed by Michaud (1970). Though some authors have maintained that the complexities of the CP phenomenon cannot be explained by any single theory (e.g., Cowley, 1975), the diffusion mechanism alone seems to account for the variety of observational phenomenon associated with the magnetic and non-magnetic sequence of CP stars.

However, the role of magnetic fields in CP stars and the expected interrelationship between magnetic fields, rotation, age, and the degree of peculiarity, that is actually not found (Hack, 1981), leaves any single theory, that tries to account for all the complexities, vulnerable. A recent review of the non-magnetic stars is by Dworetsky (1985). The braking mechanism for rotation is also poorly understood for the non-magnetic sequence and especially so for the mercury–manganese stars (Hack, 1981).

We decided to look at some of these apparent contradictions rather indirectly. If spectrum variations are characteristic of magnetic CP stars, the mercury–manganese stars, even if weakly magnetic, may show spectrum variations. We could, therefore, use statistically, spectrum variability as a diagnostic tool for the CP stars. In the present paper, we report the preliminary results of the search for spectrum variability amongst bright CP stars on the upper Main Sequence.

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2. The Observations

The list of stars for which the spectra were taken are given in Table I. The remarks column of *The Bright Star Catalogue* (Hoffleit and Jaschek, 1982) was extensively used to produce a first list of candidates that are most likely to be spectrum variables. Most of the columns in Table I are self-explanatory. The spectral types in column 2 are taken from *The Bright Star Catalogue*. The period of light variability taken from Catalano and Renson (1984) when known is given in column 3. Our remarks regarding spectrum variability observed is given in the last column.

The spectra were taken initially with the Zeiss–Cassegrain spectrograph of the 1-m telescope of the Vainu Bappu Observatory at Kavalur. The two standard Schmidt cameras of this spectrograph of effective focal lengths 110 and 175 mm give a dispersion of 80 and 135 Å mm^{-1} in the blue region. It was found that these dispersions are not adequate for finding spectrum variability of weak lines in the CP stars. We, therefore, changed the Zeiss 651 lines per millimeter grating by a Bausch and Lomb 1800 lines per millimeter grating which gives a dispersion of 30 Å mm^{-1} when used with the 175 mm focal length Schmidt camera. Some spectra were taken with the 30-inch telescope with an 1800 lines per millimeter grating and a 135 mm camera. All spectra were taken on IIa–O plates and widened to at least 300 microns.

3. Results and Discussion

The spectra were first visually inspected for spectrum variability. The majority of the spectra were digitized with the PDS machine. Our remarks regarding the spectrum variability observed is given in the last column of Table I. The variability of one of the stars, HD 7817, is already published (Rajamohan and Paranjpye, 1989). The detailed results for HR 4082 (25 Sextantis), where we find that it is mostly the iron lines that vary, is in preparation.

3.1. THE MERCURY–MANGANESE STARS

There are six mercury–manganese stars in Table I. Five of them are found to be probable spectrum variables. Like other magnetic CP stars whose variability is interpreted in terms of the oblique rotator model proposed by Stibbs (1950) and Deutsch (1958), the Hg–Mn stars seem to be related to these class of objects. A similar conclusion was arrived by Hack (1981) based on the chemical anomalies in the magnetic and non-magnetic sequence of stars. Even though these objects do not show any measurable magnetic field (Borra and Landstreet, 1980; Landstreet, 1982). We do find in literature that at least one object, classified as a Hg–Mn star, is also a suspected magnetic star.

The Bright Star Catalogue list totally 52 Hg–Mn stars. The notes to these stars in the catalogue shows that thirteen out of these 52 (25%) are light variable, four are spectrum variables, and one object HR 5049 is listed as a magnetic star. The present study indicates that six more are spectrum variables taking the total to ten. Also Π^1 and Π^2 Bootis form a visual double. While Π^1 Bootis is a Hg–Mn star, Π^2 Bootis is classified as A6V. We find that Π^2 Bootis is a probable spectrum variable.

TABLE I

Stars observed for spectrum variability

HD HR	Spectral type	Period (l) days	Spectrum variability
3322	B8111P	–	Probable
149	Hg–Mn		
24155	B9P	2.53	Variable
1194	Si		
27309	A0P	1.57?	Probable
1341	Si		
33904	B9P	–	Variable
1702	Hg–Mn		
42536	B9.5111P	3.67	–
1957	Si 4200		
56022	A0P	0.92	Variable
2746	Si		
75333	B9P	~6	Variable
3500	Hg–Mn		
90044	B9P	4.37	Variable
4082	Si Cr: Sr:		
90569	A0P	7.9	Variable
4101	Si Cr;		
110073	B8P	–	Probable
4817			
120198	B9P	1.38	Variable
5187	Eu Cr		
129174	B9P	2.24	Probable
5475	Mn–Hg		
129175	A6V	–	Probable
5476			
130559	A1P	–	Variable
5523	Sr Cr Eu		
133652	A0P	–	Variable
5619	Si		
148112	B9P	1.53	Variable
6117	Cr		
148898	A7P	2.99?	Variable
6153			
168733	AP	6.3?	–
6870			
183056	B9P	0.7?	Probable
7395	Si		
183896	AP	2.85	Variable
7416	Cr Eu Sr		
194783	B9P	–	Variable
7817	Hg–Mn		
220933	A0P	6.97	Variable
8915	Hg–Mn		
221507	B9.5IVP	–	Variable
8937	Si Hg Mn Eu		

3.3. ROTATIONAL BRAKING

In a paper that has gone unnoticed, Rajamohan and Venkatakrishnan (1981) showed that amongst binaries too one finds two sequences of binary stars; a synchronous or peculiar sequence and a non-synchronous of normal sequence. They found that the normal binaries have rotational velocities close to the synchronous value only when their radii are within a factor of two of their Roche radii. The synchronous sequence consists of contact binaries and Am binaries that were found to rotate close to the synchronous value whatever be the separation between the components. Theoretical work by Zahn (1975, 1979) shows that the radiative dissipation of dynamical tide is capable of synchronising a binary system within its Main-Sequence lifetime provided the ratio of the separation between the components to the radius of the star is not larger than about seven. In order to explain simultaneously the observed synchronisation amongst Am binaries which was found to be independent of this ratio and the observed chemical peculiarity, they had to invoke the role of magnetic fields in the pre-Main-Sequence stage of evolution. This was necessary because tidal braking cannot account for the observed rotational velocities of Am stars.

We wish to point out a difficulty in the logic regarding the origin of chemical peculiarities in Am stars. For diffusion to be operative, one needs a stable atmosphere provided by the low rotational velocities of these objects. The cause for low rotation is assumed to be caused by the synchronisation of orbital and rotational periods. But theoretically, synchronisation during Main-Sequence lifetime is not possible for Am binaries excepting those that have short orbital periods. Even if we assume that synchronisation occurred during pre-Main-Sequence stage of these stars, we are still left with the question 'Why do single slowly-rotating Am stars exist and also why do we have single slowly-rotating normal stars?'.

As suggested by Moss (1985), a possible scenario for CP stars is that they arrive on the Main Sequence with a Maxwellian distribution of residual fields. This can account for the broad behaviour of the observed rotation, magnetic fields, age, and chemical peculiarity. Supposing Am and Hg–Mn stars represent the low tail end of a Maxwellian distribution of magnetic fields in the PMS stage, then one would expect that some of these objects to be weakly magnetic even on the Main Sequence. The observed variability of spectral lines in the Hg–Mn stars can be interpreted as evidence for the presence of such low residual fields in them. We suggest that the lines that vary are indicative of the region of such fields and, therefore, can be expected to show Zeeman-broadening. High-resolution spectroscopic work is needed to look for this phenomenon in lines that are sensitive to magnetic fields and are also variable.

4. Conclusions

We find that the majority of the CP stars which show light variability are also spectrum variables including the Hg–Mn stars. We suggest that a Maxwellian distribution of magnetic fields in the pre-Main-Sequence stage is probably responsible for the wide variety of observational phenomenon in CP stars. The variability of Hg–Mn stars is interpreted in terms of such residual fields even though it is generally believed they are non-magnetic. It is suggested that one should look for Zeeman-broadening of magnetically-sensitive lines which are also found to have variable linestrength.

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