INVESTIGATION OF POSSIBLE ABUNDANCE ANOMALIES IN CLOSE BINARIES OF SPECTRAL TYPES A0-A2 & F5-F6

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1. Observations

This investigation was originally conceived as a follow-up on a work by Abt (1965), in which he finds the close binaries, with periods of about 1–100 days, and with spectral types of about A4–F2 (IV–V), to be all Am stars. The stars to be observed were chosen from the 'Fifth Catalogue of the Orbital Elements of Spectroscopic Binary Stars' (Moore and Neubauer, 1948). The criteria in making the selection were that the spectral types are A0–A2 and F5–F6 (IV–V) and that the periods are between about 1–100 days.

Spectra of 11 binary systems were obtained at the Coude focus of the 84-inch reflector of the Kitt Peak National Observatory during three nights in May 1967. In addition to the binary stars, 5 standard spectrum stars, i.e. α Lyr (A0V), θ Leo (A2 V), σ Boo (F2 V), ι Peg (F5 V) and 110 Her (F6 V), were observed to provide comparisons. The dispersion used was 13·5 Å/mm. Typically 2 or 3 spectra were obtained for each object. A spot densitometer was employed to furnish calibrations for the plates.

2. Discussion of the Observations

The spectra obtained were first examined on a spectrocomparator. Tracings of the spectra were obtained using a microdensitometer with a slit width corresponding to about 0·07 Å.

Conti's criterion was adopted in investigating metallicity for the binary stars in the A0–A2 region, although other spectral features were also examined. Conti (1965) has reported that metallicity can be found for early A-type stars using the relative weakness of the Sc II line at 4246 Å and the relative strength of the Sr II line at 4215 Å. This ratio, which is called Sc/Sr, is close to unity for a normal star in this spectral region.

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In case of the stars in the F5–F6 region, strengths of Balmer lines and metallic lines were compared with those of the spectra of the standard spectrum stars.

The results are tabulated in Table 1.

In the spectrum of δ Lib, both Sc II and Sr II are too weak to be compared meaningfully. In case of ω UMa, the blending of lines are such that it is not possible to evaluate Sc/Sr reliably. The spectra of TX Leo are rather unusual. The ratio Sc/Sr is slightly greater than unity, while, in the spectra of θ Leo, Sc/Sr is never greater than unity.

50 Dra is a double-line system. In two out of the three spectra obtained for this binary system, the spectral lines of the two components are well separated, making it possible to examine the lines of each component separately. Corresponding lines of both components are of similar intensity. The Sc/Sr for both components are distinctly smaller than unity indicating that both primary and secondary components are metallic. In another double-line system, η Vir, the separations of the spectral lines of the two components were very small at the time the two spectra were obtained, and it is not possible to evaluate Sc/Sr for the components separately.

HR 5317, which is classified as F6 IV in the *Catalogue of Bright Stars* (Hoffleit, 1964) has Balmer lines stronger than those of 110 Her (F6 V), while its metallic lines indicate a later spectral type than 110 Her. This is a characteristic of a metallic-line star. The difference in spectral types, as may be determined independently from the Balmer lines and from the metallic lines, appears to be about 3/10 of a spectral type. It was also found that there exists an apparent overabundance of calcium. An apparent overabundance of calcium was reported several years ago by Preston (1961) for an early to middle F type star HD 174 704, which he classifies as a metallic-line star. HR 4536, classified as F5 in the B.S. Catalogue, shows metallic lines which are slightly stronger than those of ι Peg (F5 V). The Balmer lines of HR 4536 are only very slightly stronger than those of ι Peg, and the difference in spectral types, as determined from the Balmer lines and from the metallic lines, appears to be about 1/10 of a spectral type.

In this survey, when metallicity is found in a binary system, it appears to be stronger for a binary with a shorter period, although it is not possible to make any generalization with the limited number of binary systems observed in this study.

It is to be noted that 9 out of 11 close binary systems, if we include ω UMa classified as a metallic-line star by Conti (1965), are found to have metallic characteristics.

3. Concluding Remarks

According to Abt (1961) all metallic-line stars are members of spectroscopic binary systems. Also, according to more recent work by Abt (1965), which was quoted earlier, all short-period binaries in the spectral range about A4 to F2 (IV–V) are found to be Am stars.

The possibility may be considered that metallicity is a norm rather than a peculiarity for close binaries, at least within a certain spectral range.

Table 1

Preliminary results on metallicity in close binaries

Star	BS (= HR) No.	V	B-V	BS Sp	Lick Binary Catalog No.	P (days)	Sc/Sr	Metallicity	Comments
δ Lib	5586	4·92	−0·01	A0	271	2·33	?	?	Eclips. Var.
–	6641	6·28	–	A0	328	2·82	$\ll 1$	yes	
ω UMa	4248	4·75	–	A1 V	208	15·84	? c*	?	Conti finds Sc/Sr < 1. Double-line system.
50 Dra	7124	5·36	–	A1	359	4·12	$\ll 1$	yes	Both components show metallicity.
ϕ Aql	7610	5·23	−0·02	A1 V	384	3·32	$\ll 1$ c	yes	
TX Leo	4148	5·63	–	A2	201	2·45	$\gg 1$	no	Eclips. var.
η Vir	4689	3·88	+0·02	A2 V	231	71·9	< 1 c	yes	Double-line system. Var.?
–	6917	5·83	+0·06	A2 V	346	9·61	$\ll 1$	yes	
ι Del	7883	4·42	+0·04	A2 V	409	11·04	$\ll 1$ c	yes	
–	4536	5·72	–	F5	222	32·86	–	(yes)	Balmer and metallic lines slightly stronger than ι Peg (F5 V).
–	5317	5·93	+0·47	F6 IV	262	2·70	–	yes	Balmer and metallic lines stronger than 110 Her (F6 IV).

*c Indicates stars observed also by Conti (1965).

Further investigations of close binaries in the middle to late F spectral region are desirable. This is especially so in view of the fact that the absence of deep convective zones for stars earlier than the early F type has been suggested by some to have relevance on metallicity.

Some years ago, F. B. Wood suggested, in a somewhat different context, a possibility that secondary components of close binary systems are metal-rich. A systematic spectroscopic investigation, at high dispersion, of double-line systems, particularly in the early A region, may yield useful information on the metallicity in secondary components. For F-type stars, an investigation of metallicity in double-line systems may be a rather difficult undertaking due to the absence of a convenient criterion.

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DISCUSSION

Batten: I think this approach is important. There are over 70 known spectroscopic binaries with spectral types A4-F2 that have not yet been classified as Am. Until these are checked, it seems premature to generalize about the percentages of binaries among Am stars and normal A stars.

Koch: The hot component of δ Librae is earlier than A0 (on the evidence of the UBV photometry) so that the conclusions from the systems tested are more unanimous than might appear from the slide shown.

Kondo: The hot component of δ Librae is possibly a star earlier than A0. Perhaps B9·5. I agree with Dr. Koch on this point, and it may more correctly be said that 9 out of 10 systems observed show some measure of metallicity, since δ Librae should perhaps be excluded from the list.

Mestel: I believe, Dr. Abt has stated that A stars in long-period binaries ($P > 100$ days) were

invariably rapid rotators and *normal* in their spectra. Does anyone know whether this is universally agreed, and whether Dr. Abt still holds to this?

Kondo: Dr. Abt has suggested a possibility in his paper (1965) that slower rotation in close binary systems have relevance on metallicity. I am not aware if he has revised his views.

Batten: I understand Abt's view, with which I do not agree, is that Am stars may be in either short- or long-period systems but that normal A stars are only in long-period systems.

Fliegel: To my knowledge, no definitive study has appeared concerning meridional circulation in binaries. However, it appears possible that the metallicity in Dr. Kondo's stars may be produced by the enhancement in binaries of such circulation which brings up material from the depths of the stars.

R. C. Smith: I have recently studied meridian circulation in surface layers of early-type stars. In addition to the circulation reversal noted by Öpik (1951)* and Mestel (1966)* I find a second reversal very near the surface. There are therefore three distinct circulation zones, and it is very unlikely that meridional circulation could bring material up from the deep interior and produce abundance anomalies.

* Öpik, E.J. (1951) *Mon. Not. R. astr. Soc.*, **111**, 278.
Mestel, L. (1966) *Z. Astrophys.*, **63**, 196.

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