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SPECTRAL TYPES OF S AND SC STARS ON THE REVISED MK SYSTEM

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ABSTRACT

The catalog of 101 stars provides standards of spectral type in the sequence from MS through S and SC to the carbon stars with weak C_2 bands. In addition to temperature types and C/O indices, intensities of ZrO, TiO, Na D lines, YO, and Li 6708 are given whenever possible. For variables of large amplitude the observations at different dates are tabulated.

Subject headings: stars: carbon — stars: spectral classification — stars: S-type

I. INTRODUCTION-ABUNDANCE INDEX

The difficulties of classifying the stars of type S and the even rarer SC stars have been described by Boeshaar and Keenan (1979), who defined criteria for the revised MK system as applied to these stars. This catalog is designed to complete that work by making available a set of carefully determined types extensive enough to provide a network of standards for the classification of other stars of these groups, or for the selection of representative stars for detailed analysis.

The earlier scheme of classification for the S stars developed by Keenan (1954) was based on the simplistic assumption that the change from type M to type S was due only to the replacement of iron-peak elements (represented by TiO) by *s*-process elements (represented by ZrO). For the stars showing both TiO and ZrO bands this worked fairly well, but with the gradual recognition that the SC stars, sometimes called D line stars (Gordon 1967), formed a group forming a continuous sequence connecting the S stars to the carbon stars (Bidelman 1954; Stephenson 1965; Catchpole and Feast 1971; Greene 1971) it became clear that in these stars the amount of free oxygen available could be of even greater importance than the abundances of the metals in determining the strength of ZrO and other oxide bands. The computations of dissociative equilibrium by Tsuji (1965), Greene (1972), and Scalo and Ross (1976) showed that the ratio C/O was the dominant composition variable, the SC stars being those in which C = O to within about 1%. This was explicitly recognized by Ake (1978, 1979), who introduced a C/O index which we have modified.

C/O *Index*—In the notation of the revised MK classification the temperature type is separated by a slant line from the new C/O abundance index. This index is explained in Table 1. In the first column X represents any temperature type from 0 to 9, though it must be remembered that abundance differences can generally be estimated more accurately among the cooler stars. When the bands of ZrO and/or TiO are present their intensities are given also. This is done because it has not been established that the ratio Zr/Ti is necessarily proportional to C/O. As C/O becomes greater than 1, the C_2 bands begin to appear faintly, and it is useful to add their intensity to the type. As long as the D lines remain very strong, however, it seems useful to classify the spectrum as SC, though at the interface with the carbon stars both designations could be used. Thus WZ Cas at mean brightness can be assigned to type SC 7/10 or C7, 2.

The column in Table 1 headed C/O gives estimates of this abundance ratio based on the calculations of dissociative equilibrium. It is included as a reminder of the extreme sensitivity of the abundance index to this ratio, but the actual numbers will undoubtedly need some revision as better abundance analyses become available.

II. TEMPERATURE TYPE

The problem in assigning types that will be consistent measures of temperature lies in finding criteria that are sensitive, and yet not too much affected by other physical variables.

In type MS, and in S stars with C/O indices of 4 or less, the bands of TiO remain useful just as in the M-stars. It is always safer to use ratios rather than individual band strengths. The ratios of bands arising from levels of different vibrational energy are best, and among those found useful in type M such ratios as TiO [$\alpha(1,3)\lambda 5810/\gamma'(1,0)\lambda 5847$] can still be applied in weak S stars. In these stars VO 5737/TiO 5810 is particularly useful in defining types later than S6, but

TABLE 1

CLASSIFICATION CRITERIA FOR THE SEQUENCE MS–S–SC–C (X = TEMPERATURE TYPE)

SPECTRAL TYPE	CRITERIA FOR C/O	Estimated C/O	CRITERIA FOR TEMPERATURE
MXS	Strongest ZrO bands (λλ6473, 6345, 5718, 5551, 4641) just visible. Also YO 6132.		Same bands and lines as in M-type stars.
SX/1	TiO > > ZrO or YO.	< 0.95	Same bands and lines as in M-type stars.
SX/2	TiO > ZrO.	0.95:	Same bands and lines plus total intensity ZrO + TiO.
SX/3	TiO = ZrO. YO strong.	0.96	TiO + ZrO intensity. Sr I 4607/Ba II 4554 from S0 to S5. ZrO (?) 5305/ZrO 5551. Infrared LaO becomes strong after S5.
SX/4	ZrO > TiO		TiO + ZrO intensity. Sr I 4607/Ba II 4554 from S0 to S5. ZrO (?) 5305/ZrO 5551. Infrared LaO becomes strong after S5.
		0.97	
SX/5	ZrO > > TiO		ZrO intensity. Same ratios as above.
SX/6	ZrO strong, No TiO.	0.98	Zro intensity. Same ratios as above.
SX/7 = SC X/7	ZrO weaker. D lines strong.	0.99	Same ratios as above. λ6456/λ6450.
SC X/8	No ZrO or C_2. D lines very strong.	1.00	λ4607/λ4554 λ6456/λ6450.
SC X/9	C_2 very weak. D lines very strong.	1.02	λ4607/λ4554 λ6456/λ6450.
SC X/10 = C X,2	C_2 weak. D lines strong.	1.1:	λ4607/λ4554

as ZrO becomes dominant over TiO the VO bands rapidly disappear, and in nearly pure S stars are not seen at even the lowest temperatures.

The ZrO bands are so sensitive to abundance differences, both directly and through changes in the continuous opacity, that they are not as satisfactory as TiO for temperature criteria. However, the presence of strong ZrO absorption sets lower limits on the temperature type. We have searched for ratios of bands that can be used, and have found that ZrO (?) 5305/ZrO 5552 is extremely sensitive to temperature in pure S stars (Boeshaar and Keenan 1979). There is a question of the identification of the λ5305 feature, which is never very strong in laboratory spectra of ZrO, but whatever the stellar contributors to the band may be, its rapid increase as the temperature goes down makes the ratio valuable as a practical criterion.

The YO bands at 6132 and 5972 Å appear only in the cooler stars, but in MS stars and weak S stars they are so sensitive to heavy-element abundance that they are not very useful as temperature indicators.

For SC stars as well as for S stars in which C/O is approaching unity, the bands of metallic oxides, even if weakly present, tell little about the temperature. We must turn to atomic lines. The most obvious, of course, are the D lines of sodium, which have been used extensively as temperature indicators in the carbon stars (Keenan and Morgan 1941; Bouigue 1954; Gordon 1967; Yamashita 1972, 1975). Their equally great sensitivity to the opacity due to overlying bands of TiO, ZrO, CN, etc. (and thus to the C/O ratio) has become generally recognized in recent years as largely responsible for the great scatter found when types based on the D lines are plotted against more direct estimates of temperature of either S or carbon stars. Whether luminosity effects also enter the picture remains to be established. In any case, we feel that it is dangerous to give dominant weight to the D lines as temperature indicators for S and SC stars. They must be taken into account, however, in assigning the total type, just as is the λ4227 line of neutral calcium in classifying the stars that are not too red to be observed in the blue.

For all such stars in the earlier subdivisions of types S and SC the ratio Sr I(λ4607)/Ba II(λ4554) is a valuable temperature criterion. Here again it would be dangerous to use this criterion alone, for this ratio should be sensitive to luminosity differences also (and may eventually prove valuable in establishing such differences). These lines are most useful in the SC stars, for they are obscured by bands of TiO, ZrO, and C_2 in the stars in which these bands are strong.

In the red region there are two blended features which give the ratio Ca, Co, V, CN(λ6450)/La, Ca, CN(λ6456), which we have shown (Boeshaar and Keenan 1979, Fig. 2) to be an excellent temperature indicator when observed with moderate dispersion in the SC stars. In that class it fails only for the members of the ^{13}C group, in which the peak between 6450 and 6456 Å disappears because of ^{13}CN absorption. The low-level lines of lanthanum were suggested as temperature criteria by Gordon (1967), but La 6709, which she recommended, is badly blended with lines of Zr and Fe, and is hard to resolve from Li 6708 at very low dispersion.

It is also among the SC stars that the presence of the red bands of CaCl sets an upper limit to the temperature. The O, O heads of the red system, $A^2\Pi$–$X^2\Sigma$, appear as a pair of roughly symmetrical bands which tend to obscure the CN head at about 6206 Å. At the same time the bands of the orange system develop, overlapping the D lines, as can be seen in Figure 2 of Boeshaar and Keenan (1979). It can be seen from the catalog (Table 2) that CaCl is normally observed with appreciable intensity only in types SC 6 or later. On the other hand, examples of discrepant behavior have been reported in Mira variables (Rybski 1973) and can be suspected in other stars (Keenan and Bidelman 1979). Again, we must conclude that the CaCl bands are a useful, but not infallible, temperature criteria.

In column (4) of Table 1 the ranges of usefulness of these temperature indicators are summarized.

III. PRACTICAL APPLICATION OF THE CRITERIA

In order to use all of these criteria it is necessary to record the spectrum of a star in both the blue and the red regions. This extra trouble is worthwhile in view of the complexity of the spectra and the comparative rarity of the S and SC stars. We have not been able to cover the entire spectral range for all of the stars in the catalog, but have tried to do so for as many as possible. Whenever there are entries in any of the last three columns of Table 2, it is an indication that spectrograms extending into the visual or red regions were available.

The recognition of the SC stars is quite easy if spectrograms showing the D lines are available, and we have found that it is not difficult to assign C/O indices. Between indices 6 and 7, where the interface between types S and SC occurs, there is more of a problem in deciding where to place a star, but the decision can be based on the degree to which the temperature type suggested by the ZrO band strengths agrees with that implied by the Ba II/Sr I line ratio and the D line absorption.

We have seen that the criteria for temperature change rather rapidly along the C/O sequence because of the appearance or disappearance of the different band systems. Thus it is not feasible to present a simple table defining all the temperature types for all possible abundance indices. As in the classification of other stars with complicated spectra, it is necessary to define the types by the examples, and we have tried to include in the catalog stars with a sufficient range of types to serve this purpose.

The zero points of the temperature types present another problem. In the original classification of the carbon stars (Keenan and Morgan 1941) C0 was assigned to spectra in which the C_2 Swan bands were first clearly visible at low dispersion. It was then found that type C5 corresponded in temperature approximately to K5 or M0 for the giants. On the other hand, types MS 0 and S0 are naturally chosen to correspond to M0 as closely as possible. Thus there must obviously be some shift in zero point as we make the transition from S to C through the SC stars. The difficulty is increased by the scarcity of the transition stars, and the best that we could do was to establish the temperature types somewhat arbitrarily, and leave to later atmospheric analyses their calibration in terms of effective temperature.

It is possible to make some estimation of the equivalent types in the KM oxygen sequences. Thus the temperature type of CY Cyg is S2 in the catalog, and on coudé spectrograms taken of the red region at Palomar Observatory nine pairs of temperature-sensitive lines of similar elements give an equivalent type of M2.2±0.95. This assumes that CY Cyg has the luminosity of a normal giant, while actually it is probably more luminous (Culver 1971) than a typical S or SC star.

Nevertheless, it appears tht SC0 is roughly equivalent in temperature to M0. When we get to the carbon side of the group, the equivalent C type should then be several subdivisions later than the stars of the earlier types. Apparently the difference is less for the cooler stars with heavily-banded spectra, and SC 7≈C7.

IV. DESCRIPTION OF THE CATALOG

In the first column the variable star designation or the BD number or other identification is given, followed by the HD number in the second column. The type of variability in the third column is in the notation of the Russian general catalogue (Kukarkin *et al.* 1969 –1970).

The 1900 coordinates follow in columns (4) and (5). For variable stars of large amplitude (usually Mira variables) the date on which the type was observed is essential, and is given in Julian days in column (6), followed by the visual magnitude and the phase. The latter data were obtained mainly from the American Association of Variable Star Observers (AAVSO) Reports, supplemented by a few observations from the *Groningen Observations of Variable Stars*, the *Sonneberg Mitteilungen uber Veränderliche Sterne*, and unpublished AAVSO observations very kindly furnished to us by Janet A Mattei, director of the AAVSO.

Column (9) contains the revised type. Intensity estimates for ZrO bands, TiO bands, the sodium D lines, YO bands (usually λ6132), and Li 6708 are given in columns (9)–(13). An x indicates that the features are absent from spectrograms of our dispersion, while 0 indicates the lowest detectable intensity and implies that their presence is doubtful. The remarks in the last column include comments on emission lines when their appearance seems abnormal for the type of variables or the phase at which they were observed. For faint stars additional identifications are sometimes given, "Ste" referring to the Catalog of S Type Stars (Stephenson 1976) and "Vys" to the discovery lists published by Vyssotsky (1942, 1943). An asterisk refers to more extended notes at the end of the table.

The observations of the stars south of −30° declination, and some between 0° and −30°, were obtained by one of us (P.C.K.) while a Visiting Astronomer at the Cerro Tololo Inter-American Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

Many of the observations were made by one of us (P.C.B.) using the Carnegie image tube spectrograph on the 72 inch (1.8 m) Perkins and 42 inch (1.1 m) telescopes at the Lowell Observatory. This spectrograph was kindly made available by Dr. W. Kent Ford, Jr. Partial support for the observations of P.C.B. was made possible by a summer research grant from the Graduate School of the University of Oregon.

To the director and staff of the Hale Observatories we are grateful for the opportunity to classify spectrograms in their collection. To Dr. W. P. Bidelman of the Warner and Swasey Observatory we are greatly indebted for the loan of a set of spectrograms taken by him.

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The arduous task of typing the tables for photographic reproduction was carried out by Delores Chambers.

TABLE 2
Revised MK Spectral Types of S and SC Stars

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
X And	1167	M	$0^h10^m.9$	+46°27'	36854	10.0:	–	S5/6e	5+	x	–	–	–	
					42714	8.7	-12	S2.5/6.5e	2.5	x	–	–	–	
					44131	9.0:	(+10)	S5/7-e	3	x	6.5	–	–	
					44137	9.2:	(+16)	S4/7-e	2	x	–	–	–	
R And	1967	M	0 18.8	+38 01	32120	6.8	- 8	S6/4.5e	6:	4:	–	3.5	–	
					32924	6.6	-14	S6-/5e	5	2	5-	–	–	
					35364	7.5	-13	S6.5/5e	5	2	4+	–	–	
					35369	7.4	- 8	S6.5/4.5e	5.5	4	–	–	–	
					35396	7.6	+20	S6/4.5e	6	4	–	Str.	x:	
					35762	6.1	+ 4	S4:/4:e	3:	2:	–	–	–	
					36219	8.0	+61	S7/4e	6.5	4:	–	4.5	x	
					38816	7.2	+15	S6.5/4.5e	6-	4	–	–	–	
					38998	6.9	-12	S7/5e	7	2:	–	–	–	
					39361	9.4	-44	S7/4.5e	6	4.5	–	–	–	
					39370	8.2:	-35	S7/5-e	7	3	–	–	–	
					39376	8.0:	-29	S7/5e	7	2	–	–	–	
					39436	7.2	+31	S6.5/4e	5	3.5	–	–	–	
					39806	6.9	-14	S5/5e	5	2	–	–	–	
					42716	6.3	+ 8	S5/5e	6	2	–	–	–	
					Normal Max.			S5/4.5e	5	2				
U Cas	4350	M	0 40.8	+47 43	23007	8.2	- 4	S4.5/5e	4.5	2	–	–	–	
					24101	7.4	-11	S4/5e	4	2	–	–	–	
					24134	8.1	+22	S4/5-e	3	2	–	–	–	
					24425	9.0	+22	S6/3e	4.5	4.5	–	–	–	
					34365	9.9	-35	S6/3-e	5-	5+	2-3:	–	–	
					34693	8.7	+17	S4.5/4e	4.5	3-	1-2:	–	–	
					36883	8.4	- 2	S5/4e	5+	3	2+	3	x	
					39373	8.7	+ 7	S5/3e	4	4	–	5:	1	
					42712	9.5	+22	S6/3-e	5	6	–	–	–	
					Normal Max.			S4.5/4e	4	3				
RW And	4489	M	0 41.9	+32 08	35745	8.7	+ 1	S6/2-e	2.5:	6.5	–	–	–	
					35748	8.6	+ 4	S6/2-e	2.5:	6.5	–	–	–	
					35752	8.7	+ 8	S6/2-e	2.5:	6.5		–	–	
RR And	4895	M	0 46.0	+33 50	36849	9.2	+16	S7/3e	5	4	–	4.5	x	
					43400	9.0	max.	S6/3.5e	4+	4	–	3.5	x	
W Cas	5235	M	0 49.0	+58 01	34015	10.0	-55	SC6/9e C_2 3	x	x	8	–	–	
					39717	9.0	+ 8	SC5/9e C_2 2	x	x	–	–	–	
					41325	9.6	-42	SC5/9e C_2 2	x	x	5	–	–	
					43777	9.3	-32	SC6/9e C_2 2	x	x	9-	3:	–	
					43781	9.2	-28	SC6/9e C_2 1	x	x	–	–	–	
					Normal Max.	9.0		SC5/9e C_2 2						

TABLE 2—*Continued*

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
V365 Cas	5840	SRb	$0^h55^m.0$	+56°04'	-	9.5:	-	S6/3-	4+	6-	-	-	-	
BS 363	7351	-	1 08.6	+28 00	-	6.6	--	S3+/2-	1.5	3	2:	1:	-	
RZ Per	-	M	1 23.6	+50 20	34737	10.9	-96	S6/8e	4-	x	8	-	-	
					36220	10.3	-38	S6/8e	4-	x	9:	3:	2	
					36812	(13.5	-145	S7/7e	4.5	0	10	3	2:	
					44086	9.0:	+22	S3/7e	3	x:	6	3.5	-	
BD+21°255	-	-	1 48.8	+21 24	-	8.7:	-	S3/1	1	3	3	1-:	-	
BD+51°471	-	LP	1 55.7	+52 05	-	9.4-10.0	-	S6/1	2	6-	2	1:	-	
W And	14028	M	2 11.2	+43 50	22538	7.9	-19	S7.5/1-e	1	7.5	-	-	-	
					22976	8.5	+33	S7.5/1-e	1	7.5	-	-	-	
					32474	7.7	+12	S8/1-e	1.5	8	Wk.	-	-	
					37207	7.0	+ 1	S7/1e	2	6.5	-	8	-	Bright maximum
					41935	7.0	+ 5	S7.5/1e	1	7.5	-	-	-	Bright maximum
					42713	7.4	- 7	M7Se	0	7	-	-	-	(Ratio ZrO/TiO
					Normal Max.	7.5		S7.5/1-e	1	7.5				varies with cycle, as in χ Cyg)
SU Tri	-	Lb:	2 12.3	+31 17	-	9.0-9.6	-	S4.5/1+	2.5	4.5	1-:	1:	Wk.	
BI And	-	SR	2 19.8	+37 41	-	9.8-11.2	-	S8/4.5 var.	7	4	5	5:	x	LaO strong.
BS 1105	22649	L	3 33.5	+62 54	-	5.1 var.	-	S3.5/2	2+	3	3:	2:	x:	
WX Cam	-	Lb	3 41.5	+52 53	-	10.5 var.	-	S5-/5.5	5-	1	5.5	4-	-	
BD+24°620	-	-	3 59.9	+24 28	-	9.2:	-	S3+/3	3-	2.5	3:	-	-	
BD-2°891	-	-	4 19.3	- 2 41	-	9.3:	-	S2/2:	2-	2	Wk.	2:	Wk.	
BD+12°611	-	-	4 30.1	+12 27	-	10.2:	-	S5.5/1	2-	5	Wk.	-	-	
T Cam	29147	M	4 30.3	+65 57	36319	10.2	-106	S5.5/5e	5+:	1:	4:	4	x:	
					39431	8.2	+ 7	S5/5e	5	2	-	-	-	
					39750	8.7	-46	S5.5/5e	5.5	3	-	-	-	
					42715	8.4	+15	S5/5e	5	2	-	-	-	
					43778	8.7	-45	S6/5e	6	2	6.5	4:	-	
BD+79°156	-	-	4 38.6	+79 49	-	9.7:	-	S4/2	2-	3-	2:	-	-	
BD+38°955	-	SRb:	4 45.7	+38 20	-	8.8:	-	SC5/9 C_2 1:	x	x	11	1.5:	0:	MSB 10, KZP 6136
40[1] Ori	30959	-	4 46.8	+14 05	-	4.24	-	S3.5/1- = MS3.5S	1+	3+	2.5	2-	-	
TV Aur	-	SRb	4 50.6	+48 24	-	9.7 var.	-	S5/6-	2+	4	5.5	-	-	
R Ori	31798	M	4 53.6	+ 7 59	36510	9.6	+18	SC5/9.5e C_2 2: = C6/2e	x	x	-	-	-	SiC_2 2:
					43201	12.9	-117	SC8:/10: C_2 2: = C8,2	-	-	11:	-	-	CaCℓ 3: Plate dark.
					43438	11.2	+110	SC5/10e C_2 3 = C6,2e	x	x	-	-	-	

TABLE 2—*Continued*

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
R Ori	31798	M	$4^h53^m.6$	+ 7°59'	43516	12.6	+185	SC8/10 C_2 2 = C8,2	x	x	12	-	-	CaCℓ 2.5 Near min.
					43718	9.4:	+ 11	SC6/10e C_2 3 = C6,2	x	x	-	-	-	
					43923	12.9	-163	SC8/9.5 C_2 2- = C8,2	x	x	12:	1:	1.5:	
GP Ori	-	I?	4 57.1	+15 11	-	9.6 var.	-	SC7/8-	0:	x	13	1:	1:	
BD+42°1159	-	-	4 58.1	+42 10	-	9.3:	-	S2/2+	1+	1-	3+	0.5:	x:	
RZ Lep	34738	SRb	5 14.5	-22 19	-	8.3-8.4	-	S4/4	4.5	2	2.5	2	x	
	35155	-	5 17.6	- 8 45	-	7.0:	-	S3/2	2	2.5	Wk.	1:	x	
BB Tau	-	Lb	5 46.1	+25 48	-	11: var.	-	SC7/7e = S7/7e	2.5	x:	11	2:	1:	Weak Balmer em. Possibly SRa variable.
FU Mon	44544	SR	6 17.2	+ 3 29	-	8.8 var.	-	S6.5/7.5	1	x	12	2:	3	
BD+15°1200	-	-	6 21.3	+15 57	-	9.6:	-	S4/2	2+	3.5	2:	-	-	
BD+2°1307	-	-	6 31.0	+ 2 02	-	9.4:	-	S3/2	2	3	3.5:	2:	x:	No Balmer em.
CX Mon	-	Lb	6 32.1	+ 1 00	-	11: var.	-	S6:/5+	4	1:	12	4:	0:	*
V372 Mon	-	SR	6 36.5	- 4 30	-	11: var.	-	SC7/7.5	1:	x	12	3:	-	
V613 Mon	49368	SRb:	6 43.0	+ 5 39	-	7.6-7.8	-	S3/2	2.5	3	3:	-	-	
R Lyn	51610	M	6 53.0	+55 27	33005	9.0	-21:	S6/6e	6.5	0	9	-	-	
					36555	10.3	+95:	S6.5/6e	6.5	x:	5:	4.5	2	
					39491	8.1	+ 3	S4/5e	4	1:	-	-	-	
					39847	8.0	-10	S4.5/5e	4.5	1:	-	-	-	
					43924	12.5	(-99)	S6/6-	6:	0:	-	4	x	No Balmer em.
R Gem	53791	M	7 01.3	+22 52	29278	7.3	-19	S5/6e	5	x	-	-	-	
					29649	7.6	-36	S5.5/6e	6	x	-	-	-	
					32230	7.4	+17:	S4/6e	4:	x	8	-	-	
					33379	8.5	+30	S6/6e	6	x	10-	-	-	
					33710	7.4	+25	S4.5/6e	4.5	x	8-	-	-	
					34047	7.7	-38	S6/6e	6	x	-	-	-	
					35197	6.9	+37	S4/6e	3.5	x	4	2.5:	x	
					35528	8.4	-32	S5+/6e	5+	x	7:	3:	x	Very Wk. Balmer em.
					36307	7.4	- 3	S5/6e	5	x	-	4-	x	
					39607	6.9	+ 4	S3.5/6e	3+	x	-	-	-	
					43188	12.8	-191:	S6/6e	5.5	x	10	2+	-	
					43922	13.0:	(-153)	S6.5/6-	6	1	-	4	1:	No Balmer em.
R CMi	54300	M	7 03.2	+10 11	22748	8.3	+17	SC5/10e	x:	x	-	-	-	
					24456	8.1:	- 7	SC4/10e	x:	x	-	-	-	
					32181	8.0:	-34	SC5+/10e	-	x	8:	3:	-	
					34809	10.0	-71:	SC6.5/10e	x	x	11	-	-	
					35198	9.3	-62:	SC6.5/10e	x	x	-	-	1+	
					36308	8.5	+33	SC4.5/10e	x	x	8:	-	-	

TABLE 2—*Continued*

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
R CMi	54300	M	$7^h03^m.2$	+10°11'	43918	10.0:	-126	SC7/10e	1:	x	13	1:	x	
					Normal Max.			S4/10e						
BD-8°1900	-	-	7 20.2	- 8 05	-	10.0:	-	S4/6-	3.5	x:	5	-	-	
FX CMa	58881	SRb	7 22.4	-11 31	-	8.6-8.9	-	S5-/6	3.5	x:	5.5	2+	2:	
GG Pup	-	Lb	7 33.8	-15 50	-	9.5-10.3	-	S5/5	4	1+	5.5	-	-	BD-15°1953
SU Mon	62164	SRb	7 37.5	-10 39	-	7.7-9.0	-	S5/7 to S6/7	3 to 4	0	8:	3.5	x	
T Gem	63334	M	7 43.3	+23 59	24251	8.9	-10	S4/4e	4	3.5	-	-	-	
					24565	8.9	+15	S3/3e	2.5	2.5:	-	-	-	
					28952	9.7	+15	S6/4e	6	-	-	4.5	-	
					34048	8.7	+ 5	S5/4e	4	3	-	-	-	
					35487	8.8	+18	S3/4e	2.5:	1	-	-	-	
					39806	8.7	-12	S2/4e	2-	1	-	-	-	
					Normal Max.			S3/4e						
	63733	-	7 45.3	+23 59	-	8.5	-	S3.5/3	2.5	2	-	-	-	
BD-4°2121	-	-	7 47.4	- 4 52	-	8.7:	-	S5/2.5	3	4	-	2.5:	x	
NQ Pup	64332	Lb	7 48.3	-11 22	-	V7.55-7.68	-	S4.5/2-	2	4	-	-	-	
V Cnc	70276	M	8 16.0	+17 36	22273	8.0	+10	S0/6e	0	x	-	-	-	
					23098	7.8	+18	S1/6e	0+	x	-	-	-	
					23893	7.8:	- 4	S0/6e	0:	x	-	-	-	
					33394	8.0	-16	S2-/6e	2-	x	-	-	-	
					35876	8.4	+14	S1/6e	0+	x	-	-	-	
					39435	8.0	+32	S1.5/6-	1.5	x	-	-	-	
					39922	8.2	-27	S1.5/6e	1.5	x	-	-	-	
					41051	8.0:	(+13)	S2/6e	1	x	3.5	2	0	
					43516	8:	(+30)	S4/6e	4.5	x	4:	3:	-	
					43923	12.4	-103	S6/6e	6	x:	8	2:	2:	
					Normal Max.	7.8		S0.5/6e						
CoD-28°6970	-	?	9 04.9	-28 36	-	9.4-9.7	-	S6.5/5e	6.5	2	3-	4.5	0:	
RR Car	86655	SRb	9 54.8	-58 23	-	8.0 var.	-	M6.5S = S6.5/1-	1.5:	6.5	-	-	-	
BH Cru	-	M	12 10.8	-55 45	40965	7.5	- 7	SC4.5/8-e	0	x	10:	3:	3:	Hen 120 *
					41340	8.4	-58	SC6/8-e	0.5	x	13	2:	3	
					41708	9.5:	?	SC7/8-e	0	x	16:b1	2.5:	3.5	
S UMa	110813	M	12 39.6	+61 38	22427	8.5	-35	S2.5/6e	2.5	x	-	-	-	
					22720	8.8	+48	S5/6e	5	x	-	-	-	
					23809	7.9	-11	S2/6e	2	x	-	-	-	
					33379	8.2	+19	S2/6e	2	x	3.5	-	-	
					33394	8.5	+34	S3/6e	3	x	3:	-	-	
					35565	8.6	-42	S6/6e	6	x:	-	4.5	x	
					35613	8.2	+ 6	S2.5/6e	2.5	x	3+	-	-	
					35857	8.5	+24	S3/6e	3	-	-	-	-	

TABLE 2—*Continued*

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
S UMa	110813	M	$12^h39^m.6$	+61°38'	36265	8.4	-24	S5/6e	5	x	-	3.5	1:	
					39643	8.3	-18	S3/6e	3	x	-	-	-	
					39657	7.5:	- 4	S0.5/6e	1:	x	-	-	-	
					39920	8.5	+35	S2.5/6e	2.5	x	-	-	-	
					43310	7.9	+11	S2/6+e	1+	x	-	-	-	
					Normal Max.	7.8		S1.5/6e						
KZP 1995	114586	?	13 06.3	-56 28	-	8.9-9.3:	-	S5+/2.5	3	4	-	-	-	
UY Cen	115236	SR	13 10.7	-44 11	-	7.7:	-	S6/8-	1:	x	10.5	3	-	
TT Cen	-	M	13 13.3	-60 16	41713	9.6:	?	SC5:/8+	x:	x	12	2:	3-	Possibly Wk C_2
BD+44°2267	-	?	13 16.9	+44 31	-	9.3v	-	S3/4	3-	1.5	3	2:	x	
R Cam	127226	M	14 25.1	+84 17	33374	8.2	- 5	S2/6e	2	x	3:	-	-	*
					35237	9.2:	-51	S6.5/3e	5	4	1:	-	-	
					35276	8.7	-12	S5/6-e	5	x	4:	4	1:	
					35283	8.7	- 5	S3/6e	3	x:	2:	-	-	
					38561	8.3	- 1	S3.5/4e	2.5	2+	-	-	-	
					38565	8.3	+ 3	S4.5/5.5e	4	1:	-	4	-	
					39645	8.3	- 3	S3/3+e	2-	1.5	-	-	-	
					39656	8.2	+ 8	S2/3e	1	1	-	-	-	
					39659	8.2	+11	S2/4:e	2-:	-	3:	1.5:	-	
					39922	9.4	-19	S4.5/2.5e	4-	5	-	-	-	
					41834	8.5:	(+14)	S3.5/3e	2.5	2.5	-	-	-	
					42937	9.6:	(+50)	S6.5/3e	5	5	-	-	-	
					43673	8.7:	(-16)	S4/4e	3.5	3	-	-	-	
					Normal Max.	8.2		S2/5:e						
ST Her	142143	SRb	15 47.8	+48 48	-	6.8-8.5	-	M6.5S	1	6+	3-	-	-	
RR Her	144678	SRa	16 01.5	+50 46	33118	8.9:	-	SC5.5/10	x	x	8-	-	-	C_2 2
					33443	8.4:	-	SC5/10e	x	x	6	-	-	C_2 2
					40735	8.8:	-	SC5/10e	x	x	-	-	-	C_2 2:
					42941	9.1:	-	SC6+/9.5e	x	x	9	2	-	C_2 1.5
ST Sco	149511	SRa	16 30.2	-31 02	-	7.8-9.7	-	S8/4.5 var.	7.5	5	6:	4:	3:	
V635 Sco	156957	Lb	17 15.3	-41 39	-	8.4-8.8:	-	S6/3+	4	3.5	-	-	-	
BD+23°3093	-	-	17 18.0	+23 25	-	10.2:	-	S3.5/2.5	3+	4	-	-	-	
V812 Oph	-	-	17 36.7	+ 6 47	-	10.8:	-	S5+/2.5	3+	5-	-	-	-	
BP Sct	-	Lb	18 25.7	- 9 26	-	12:	-	S5.5/5.5	5	2:	9	4-	-	
BD+36°3157	170970	-	18 27.1	+36 11	-	7.6	-	S3+/1 = M3+5S III:	1+	3 var.	-	-	-	
V2003 Sgr	-	SRb	18 27.1	-19 51	-	12:	-	S5.5/5	5	3	8	4	-	
V679 Oph	172804	Lb	18 37.1	+ 6 43	-	9.0-9.3	-	S5/6-	5	0	5-	4-	1:	
VX Aql		M:	18 54.9	- 1 43	-	14 or 15	-	SC-/8	-	x	-	-	-	
						11	Max.?	SC5-/8e	x	x	12	-	-	

TABLE 2—*Continued*

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
ST Sgr	176592	M	$18^h55^m.9$	-12°54'	34564	9.4	+20	S6.5/2.5e	4	4.5	-	-	-	
					36486	9.3:	-34	S7.5/2.5e	6+	7	-	-	-	
					39658	8.7	- 7	S6/3-e	5	6	-	-	-	
BD+10°3764	-	-	18 57.5	+10 06	-	9.3-9.7	-	SC6:/9e = C6:,2+e	x	x	11	-	x	Wk Hα em.
Ste 589	-	-	18 58.5	+11 50	-	13:	-	S5/5+	5-	1	7	3	-	
V915 Aql	177175	Lb	18 58.5	+12 07	-	8.7	-	S5+/2	3-	5-	-	2	x:	
W Aql	-	M	19 10.0	- 7 13	34219	8.3	+24	S6/6e	6	0:	9	-	-	
					36741	9.1	+56:	S5+/6e	5+	0	-	3	2	
					40053	8.6	-14	S6/6e	6:	x:	-	-	3	
T Sgr	180196	M	19 10.5	-17 19	33884	9.4	+53	S6/6-e	5	1:	5	-	-	
					34219	8.0	+ 4:	S5.5/6-e	5	1:	5	-	-	
					38996	7.8	- 2	S5.5/6e	5	x:	4	4	-	
					39363	7.7	- 7	S5-/6e	4.5	0:	-	-	-	
					39372	7.6	+ 2	S5-/6e	4.5	0:	-	3.5	8	*
					39377	7.7	+ 7	S4.5/6e	4	0	-	-	-	
					39776	9.4	- 5	S5.5/5.5e	5	1	-	-	-	
					42938	8.0	+ 8	S5-/5.5e	4.5	1	-	-	-	
					43307	7.9:	(-17)	S6-/5.5	6-	1+	-	-	-	
					Normal Max.	7.9		S5/6-e						
EP Vul	-	Lb	19 29.1	+23 26	-	10.8:	-	S6.5/5	6	2:	-	-	-	
R Cyg	185456	M	19 34.1	+49 59	22778	7.3	+34	S5/6-e	5	0.5	-	-	-	
					22838	9.2	+94	S7/6-e	7	0	-	-	-	
					33444	6.5	- 8	S4/6e	4	x	6	-	-	
					33863	9.4	-39	S8/6e	8	x	10:	-	-	
					34301	9.0	-48	S6/6e	6	0	11	3	-	
					38608	7.1	- 2	S6/6e	6	-	-	4	3	
					38998	9.4	-58	S7/6e	7-	0:	10:	4	-	
					43369	9.3	+38	S6/6-e	6	0	-	-	-	
					Normal Max.	7.2	S5/6e							
Ste 617	-	-	19 37.1	+67 02	-	9.7:	-	S5-/6:	4.5	x:	6	-	-	Vys 12
χ Cyg	187796	M	19 46.7	+32 40	32774	5.2	+23	S7-/1+e	3-	6.5	-	-	-	
					33164	6.8:	+47	S8.5/2-e	5	8.5	-	-	-	
					33941	7.3	-29	S7/1.5e	3	6.5	2-	4	-	
					34309	8.8	-86	S9/1-e	1	9	-	-	-	
					36088	7.9	-61	S7/1e	2	7	-	4	-	
					36811	5.5	- 4	S6/1e	2	6	-	4	-	
					39334	9.5	+86	S9/1-e	2:	9	-	-	-	
					39660	5.2	+ 3	S6+/2-e	3.5	6+	2:	4	-	
					42940	7.0	-24	S6.5/1e	1.5	6.5	1:	2.5	x	
					43376	5.0	0	S6.5/1.5e	2	6+	-	-	-	
					Normal Max.	5.2		S6+/1e = MS6+						*

TABLE 2—*Continued*

STAR	HD	VAR.	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
BS Cyg	-	M	$19^h49^m.2$	+53°26'	43435	12:	-	SC8/8	x	x	14:	-	x	CaCℓ 5
CM Cyg	-	M	19 55.9	+51 49	44081:	10.7:	-	S4/6.5e	3	x	6	2:	x	
AA Cyg	190629	SRb	20 00.8	+36 32	-	8.4-9.2	-	S6/3	4.5	4.5	6	4.5	3	
S Cyg	-	M	20 03.4	+57 42	41202	9.4:	(-27)	S6/3:e	4-	4:	3:	4-	x:	BD+57°2134
					44089	10.5:	(-15)	S6/3.5e	5-	3.5	2:	4	-	
KZP 8427	191226	I:	20 03.7	+36 17	-	7.4	-	M1S to M3S IIIa	1	1 to 3	-	2	x	
KZP 8465	192446	L	20 09.8	+16 43	-	9.0:	-	S6/1	2-	6	-	-	-	
SZ Cep	193028	M	20 12.9	+76 53	35762	9.0:	(-18)	S4/6e	4	x:	-	-	-	
					42943	9.8:	+10	S6/6e	6	x:	-	-	-	
AD Cyg	195665	Lb	20 27.6	+32 14	-	8.7-9.5	-	S5/5	5	1	5	-	-	
Z Del	195763	M	20 28.1	+17 07	35333	9.6	+12:	S4.5/2e	3-	4+	-	-	-	
FF Cyg	-	M	20 35.1	+37 32	44080	10.8:	(-83)	S5.5/6-e	5.5	0-	9	4	-	
CY Cyg	198164	Lb	20 43.4	+45 41	-	8.7v	-	SC2/7.5	0	x	11	3:	3	
BV Vul	335357	SRa	20 53.0	+28 57	-	10.5-11.5	-	S6.5/6-	6-	1:	5.5	-	-	
V471 Cyg	-	Lb	21 03.2	+38 10	-	10.5-11.5:	-	S5.5/5.5	5.5	0:	8	4	-	
BD+31°4391	-	-	21 11.5	+31 21	-	9.7:	-	S2.5/3.5	2	1.5	3:	-	-	
LX Cyg	-	M	21 52.1	+47 52	43435	14.0:	-225	SC8/8.5e	x	x	19:	-	x:	CaCℓ 6 *
					43811	11.9:	+143	SC7/9-e	0:	x	13	1:	-	CaCℓ 5
					44088	11.5:	(-42)	SC4:/8e	0	x	10+	-	-	CaCℓ 2
RZ Peg	209890	M	22 01.5	+33 01	38645	8.7	- 4	SC6.5/9-e	x	x	14:	-	-	CaCℓ 1 *
					40847	8.3	+ 5	SC6/9-e	x	x	11:	-	0.5	CaCℓ 0: C_2 2:
					41525	11.9	-193	SC9/9-e	1:	x	16:	0:	4.5	CaCℓ 7:
					42241	9.1	+88	SC6.5/9e	x	x	13:	x	4	CaCℓ 0.5: C_2 2:
					42282	9.9	+127	SC7/9-e	x	x	16	-	x	CaCℓ 0: C_2 2-
					42590	8.5	- 4	SC6.5/9-e	0	x	14:	x	3	CaCℓ 1: C_2 1:
					43044	8.7	0	SC5/9-e	-	x	-	-	-	C_2 2- SiC_2 3
					43437	9.5	-39	SC7/9-e	x	x	14	-	x:	CaCℓ 4- C_2 1 SiC_2 4
					43813	10.5:	(-102)	SC8/9-e	0	x	14	1:	-:	CaCℓ 5 C_2 1:
					44088	10.0::	(+173)	SC7/9-e	0:	x	12	1:	-	CaCℓ 2: C_2 1:
					Normal Max.	8.5		SC6/9-e: = C7,1.5e:						
RX Lac	216151	SRb	22 45.4	+40 31	-	8.5-9.2	-	S7.5/1e = M7.5 Se	2	7.5	Wk:	-	x	
SX Peg	-	M	22 45.5	+17 22	33884	9:	-	S5/6.5e	4+	x	8	-	-	
					33920	9.0:	-	S5/6.5e	4+	x	8	-	-	
					35762	8.5:	-	S2.5/6e	2.5:	x	-	-	-	
					39717	9.5:	-	S3/6e	3-	x	-	-	-	Lines seem weak
					40038	9.4:	-	S3/6e	2:	x	-	-	-	Lines seem weak
					43376	8.8:	-12:	S2.5/6.5e	1+	x	-	-	-	
					Normal Max.	8.5		S2.5/6e						

TABLE 2—*Continued*

STAR	HD	VAR	α_{1900}	δ_{1900}	JD 24+	m_v	Phase	Type	ZrO	TiO	Na D-Lines	YO	Li	Remarks
CV Cep	-	SR?	$22^h45^m.9$	+59°08'	43811	10.5:	-	S7/1.5	2	7-	-	-	-	*
					44088	11:	-	S5/2+	3	4	2.5	3-	-	
BS 8714	216672	-	22 49.7	+16 24	-	6.5	-	S4+/1+	1.5	4	3	2	x:	
BD+28°4592	-	-	23 24.8	+28 43	-	9.5:	-	S2/3:	1+	1:	5:	2-:	-	
BG And	-	M	23 26.2	+42 43	33883	9.3:	-	S5-/3e	4.5	4	2+	-	-	
					41201	10.5	+ 9:	S7/3e	6-	6	-	5	-	
WY Cas	-	M	23 52.9	+55 56	43376	8.8	+24	S6/6-e	5+	1	-	-	-	
					43811	8.7	-19	S6.5/6-e	6-	0	-	-	-	
WZ Cas	224855	SRa	23 56.2	+59 48	35708	7.1	-	SC7/10e	x	x	15:	0:	7	CaCℓ 1: *
					36218	7.95	Near Min.	SC8/10e	x	x	16 bl.	1:	8	CaCℓ 4
					37373	7.8:	-	SC7/10e	x	x	-	x	-	CaCℓ 0
					41937	7.0:	Max.?	SC6:/10e	-	-	-	-	-	No SiC_2
					42281	7.1	-	SC6:/10e	x	x	14	-	8	CaCℓ 0
					43776	7.8:	-	SC7/10	x	x	14+ bl.	-	7	CaCℓ 1+
					44132	7.3:	-	SC7/10	x	x	15 bl.	-	-	CaCℓ 2:
W Cet	224960	M	23 57.0	-15 14	34668	8.0	-17	S5.5/2+e	4	5	-	-	-	
					36458	8.4	- 2	S6/3e	5:	5:	-	-	-	
					39366	10.5:	+86	S7/1.5e	3	6.5	-	-	-	
					Normal Max.			S5.5/2e						
IW Cas		M	23 57.6	+48 10	34283	8.6:	Max.?	S4+/6e	4+	x	-	-	-	
					43437	10.7:	[+31:]	S5.5/6e	5	x	9	3	-	

NOTES TO TABLE 2

R Cam. This star is the best known example of a Mira variable which usually has a nearly pure S-type spectrum at maximum light, but shows increasingly strong TiO bands as minimum is approached. This behavior was described by Nassau (1964) on the basis of his sequence of objective-prism spectrograms.

CX Mon. From the three spectrograms available it is difficult to estimate the temperature type. The strong D-lines suggest a later type than that corresponding to the strength of ZrO + TiO.

BH Cru. This remarkable southern Mira has double maxima and a long period of 421 days (Bateson, 1974). The light curve is irregular. The 1971 and 1972 observations precede the fainter maxima by the phases tabulated. The 1973 observation was made near a deeper minimum.

VX Aql = Case 621. Greene and Wing (1975) called attention to the absence of the bands of both ZrO and C_2 in the spectrum of this star.

T Sgr. At the 1966 maximum Palomar coude spectrograms by Greenstein and Keenan showed the strongest Li 6707 line yet observed in a star of type S.

χ Cyg. The data indicate a real variation in the strength of the ZrO bands in different cycles.

LX Cyg. This star is very similar to VX Aql in having a close balance between oxygen and carbon in its atmosphere, as Ake (1975) pointed out.

RZ Peg. This is a difficult star to classify, not least because of the erratic behavior of many of the spectral features. CaCℓ absorption is almost always present, but its correlation with phase is not consistent. The assigned types must be regarded as approximate.

CV Cep. Although listed as a SR variable with a range of less than 1.5 magnitudes, CV Cep showed a remarkable difference in the intensities of the TiO bands between the 1978 and 1979 spectrograms. No trace of hydrogen emission was visible on either date.

WZ Cas. Although this famous lithium star is called an SRa variable we give individual data from the best available spectrograms because of the marked variations of CaCℓ (Keenan and Bidelman, 1979) and some other spectral features. The temperature types are uncertain because the D-line strengths are affected by the CaCℓ bands on some dates, and because there is enough ^{13}CN present to distort the line ratio 6450/6456.

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