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CLASSIFICATION OF M-TYPE STARS FROM SPECTRAL SCANS

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ABSTRACT

Continuous spectral scans of 64 M-Type stars in the wavelength region 400-750 nm have been obtained with a bandwidth of 5 nm. The scans have been placed on an absolute energy scale. In this paper we discuss three classification indices formed within the range 530-710 nm of the absolute energy distribution curves. One of the indices has been correlated with the effective temperature of the star.

1. INTRODUCTION

Multiband photoelectric photometry of M-type giants and supergiants has been carried out by several investigators (Helt and Gyldenkerne 1975 and references contained therein). Helt and Gyldenkerne (1975) used narrowband interference filters to isolate spectral regions in the wavelength interval 400-550 nm to devise classification parameters. Moreno (1973) has used the instrumental energy distribution in M-type stars in the interval 300-600 nm to devise a spectral classification scheme. Data on the absolute energy distribution in the spectra of M-type stars are, however, scarce. Beshenova and Kharitonov (1976) have given the absolute energy distribution in several M stars in the wavelength interval 320-800 nm. With a view to obtain the absolute energy distribution in M-type giants and supergiants and to find out spectral and luminosity classification criteria, we have observed a few such stars with the help of a spectrum scanner.

2. OBSERVATIONS

Spectrophotometric scans of 64 M-type stars have been obtained in the wavelength range 400-750 nm on the 52-cm and 104-cm reflectors of Uttar Pradesh State Observatory on several nights during 1975-1978. The scanner used for this purpose consists of a Hilger and Watts monochromator giving a dispersion of 7 nm/mm at the exit slit. An exit slit of 0.7 mm admitting 5 nm of the spectrum was used to record the spectra. Thermo-electrically cooled EMI 9558 B/9658 B photomultipliers and standard d.c. recording techniques were employed.

The observations of each star, after being corrected for atmospheric extinction, were converted to absolute fluxes with the help of standard stars observed each night. The fluxes correspond to the calibration of α Lyr given by Hayes and Latham (1975). In this paper, we discuss three classification criteria devised from the energy distribution curves in the wavelength range 530-710 nm. It is intended to publish the complete data elsewhere. Figure 1 shows the relevant portion of the representative curves of a few supergiant and giant M-type stars of different spectral subclasses.

3. DISCUSSION

From the energy distribution curves in the wavelength range 530-710 nm, three indices, α, β and γ, defined as follows, were formed wherein m_l stands for the monochromatic magnitude at a wavelength l nm.

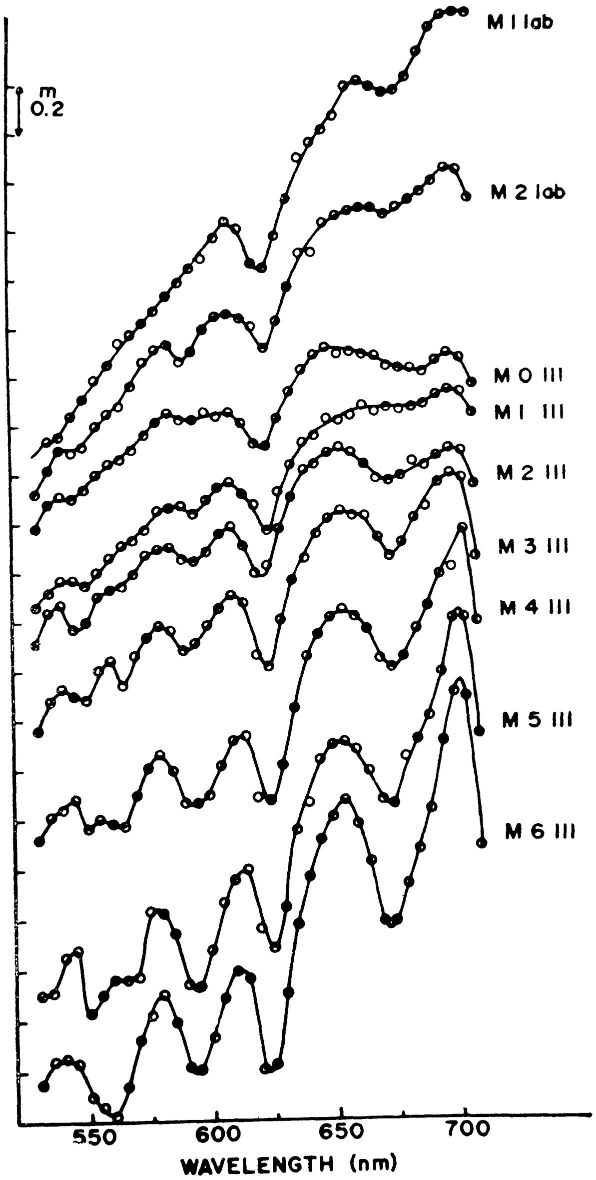

Fig. 1 Absolute energy distribution curves of selected M-type stars of different spectral and liminosity classes. M1 Iab — 6 Gem; M2 Iab-119 Tau; M0III-56 Gem; M1III-β And; M2III-χPeg; M3III—ψ Peg; M4III-51 Gem; M5III-40 Com M6III-g Her.

α : This is the sum of the depths of the TiO band features at 595 nm and 625 nm from the straight line joining the wavelength points 580 and 650 nm of the energy distribution curve.

$\beta = m_{650} - m_{540}$

$\Upsilon = m_{700} - m_{650}$

In figure 2, We have plotted the α index against spectral subclasses taken from Buscombe (1977). This figure shows a correlation between spectral subclasses and the α index. The extension of the boundary lines defining the strip is arbitrary beyond spectral type M6 as there are not many stars of spectral type later than M6 in this sample. For a given value of α , the width of the strip in figure 2 enables us to classify a star to within ± 0.6 subclass. Four supergiants also lie within the strip. Four giants, namely ω Vir, HR 4491, 3 CVn and 4 Dra, two supergiants TV Gem and ψ′ Aur and one bright giant HR 2028 lie above the strip. The positions of these stars in this diagram indicate that these may be later in spectral class than the types listed by Buscombe (1977). The spectral classes assigned to ω Vir, 3 CVn and 4 Dra by Hoffleit (1964) and Helt and Gyldenkerne (1975) are indeed later than those listed by Buscombe (1977). If we adopt these latter spectral subclasses for ω Vir, 3 CVn and 4 Dra, the positions of these stars in figure 2 is shifted towards the right and each falls inside the strip. The remaining stars, namely HR 4491, TV Gem, ψ′ Aur and HR 2028, indicate that they are later by about two subclasses. The spectral subclasses of all observed stars determined with the help of α index along with their spectral subclasses as listed by Buscombe (1977) are given in Table 1. The stars HR 3882 (= R Leo) and HR 5080 (= R Hya are long period variables. In spectral type R Leo varies from M6.5e to M9e and R Hya from M6e to M8e at their respective maximum and minimum lights. The phase of R Leo on the date of observation calculated on the basis of the epoch and period given in Kukarkin *et al.* (1969) is $0^{P}.88$ and that of R Hya calculated similarly comes out to very near the maximum light. R Leo and R Hya, therefore, should have spectral types around M7e and M6e respectively. The α value for R Hya thus seems quite high.

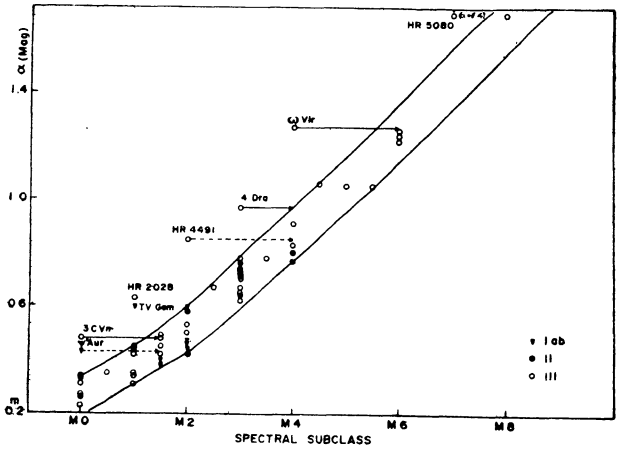

Fig. 2 : Plot of the α index against spectral subclasses.

In figure 3 we have plotted the β index against spectral subclasses. In this figure, the supergiants fall above the giants and therefore this index could be used to separate the supergiants from the normal giants. In figure 4 we have plotted β index against Υ index. In this figure supergiants fall clearly above the giants. Here we have inferred that the differences between the β indices of the supergiants and giants of a given spectral type are not caused largely by interstellar reddening, since we find higher values of the β indices for supergiants compared to those for giants located at similar distances or even much nearer. These indices may thus be useful to separate supergiants from normal giants. However, at present, the sample of supergiants at our disposal is not large enough. Increasing the sample of supergiants may enable us to put more reliance on the β and Υ indices for distinguishing supergiants from normal giants.

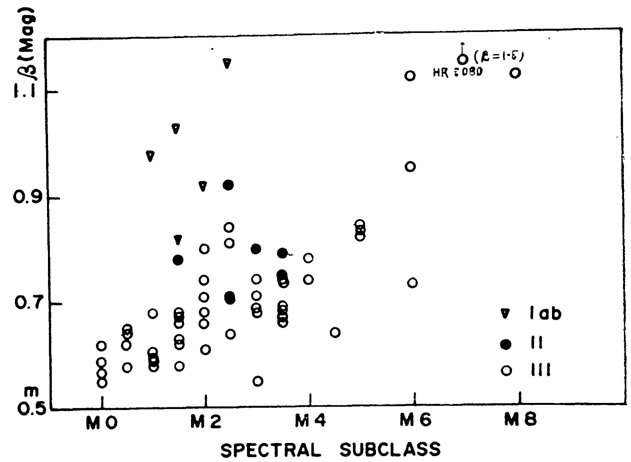

Fig. 3 : Plot of the β index against spectral subclasses.

The index β also gives a linear relationship with the (R — I) index of Johnson *et al.* (1966) as shown in figure 5a. Since the (R — I) index of Johnson *et al.* has been shown to be capable of giving the effective temperatures of M-type giants by Paradijs (1976) and Helt and Gyldenkerne (1975), we have attempted to calibrate our β index in terms of the effective temperature. The (R — I) indices for the observed stars were taken from Johnson *et al.* (1966). The corresponding temperatures for these (R—I) values were read from a T_e-(R—I) curve based on Johnson (1966). These effective temperature values when plotted against β (Figure 5b) give a linear relation of the form,

$$\theta_e = 1.14\beta + 0.73$$
$$\pm .07 \pm .05$$

TABLE 1

Spectral types and effective temperatures of Observed M-type stars

HR No.	Name	α	β	ϒ	Sp. class Buscombe (1977)	Sp. Class This paper	R-I Johnson *et al.* (1966)	T_e°K This paper
45	χ Peg	$0^{m}.48$	$0^{m}.66$	$0^{m}.14$	M2III	M2	$1^{m}.13$	
48	7 Cet	0.44	0.68	0.39	gM1	M1.5III	1.14	
248	20 Cet	0.23	0.59	0.21	M0III	M0	0.91	
337	β And	0.34	0.59	0.09	M0III	M1	1.00	
583	57 Cet	0.34	0.64	0.11	M1III	M0.5	1.04	3453
585	γ Cet	0.42	0.62	0.08	M1III	M1.5		
631	15 Ari	0.64	0.68	0.30	M3III	M3		3348
867	45 Ari	1.26	1.12	0.76	M6III	M6	1.16	2511
911	α Cet	0.44	0.67	0.11	M2III	M1.5	1.62	
921	ρ Per	0.91	0.78	0.37	M4III	M4	1.46	
1003	τ^4 Eri	0.78	0.74	0.28	M3.5III	M3.5	1.00	
1231	ϒ Eri	0.35	0.60	—	M0.5III	M1	1.38	
1496	54 Eri	0.77	0.67	0.28	M4III	M3.5		
1556	o′ Ori	0.65	0.71	0.21	M3IIIs	M3		3274
1693	RX Lep	1.20	1.22	0.87	M6III	M6		2376
1845	119 Tau	0.47	0.92	0.10	M2Iab	M2	1.07	
2011	υ Aur	0.31	0.58	0.11	M1III	M0.5		
2018		0.80	0.78	0.20	M4IIab	M3.5		
2028		0.63	0.71	0.34	M1II	M2.5		
2061	α Ori	0.48	0.82	0.10	M2Iab	M1.5		
2091	π Aur	0.77	0.75	0.25	M3II	M3.5		
2146		0.71	0.80	0.42	M3II	M3		
2168	19 Lep	0.39	0.68	0.17	M2III	M1		3348
HD 42474	WY Gem	0.59	0.92	0.43	M2IIab	M2.5		
2190	TV Gem	0.60	1.15	0.53	M0IIab	M2.5		
2197	6 Gem	0.39	0.98	0.35	M1.5Iab	M1		
2216	η Gem	0.67	0.69	0.26	M3III	M3	1.31	
2286	μ Gem	0.78	0.69	0.25	M3III	M3.5	1.38	
2289	ψ′ Aur	0.43	0.82	0.11	M0Iab	M1.5		
2508		0.42	0.79	0.24	M2IIab	M1.5		
2717	51 Gem	0.83	0.74	0.38	M4III	M4	1.60	
2738	53 Gem	0.59	0.81	0.26	M4III	M2.5		3048
2795	56 Gem	0.27	0.55	0.07	M0III	M0		3714
2905	υ Gem	0.33	0.58	0.08	M0III	M1	0.91	
2938	74 Gem	0.26	0.62	0.09	M0III	M0		3507
3705	α Lyn	0.31	0.62	0.11	M0III	M0.5	0.90	
3769	8 LMi	0.35	0.61	0.14	M1III	M1		3536
3866	ψ Leo	0.53	0.68	0.17	M2III	M2		3348
3882	R Leo	1.70	1.12	1.12	M8III			2511
3950	π Leo	0.50	0.69	0.31	M2III	M2	1.08	
4035	37 Leo	0.42	0.66	0.15	M1.5III	M1.5		3400
4088	44 Leo	0.50	0.67	0.41	M2III	M1.5		3374
4127	46 Leo	0.50	0.71	0.15	M2III	M2		3274
4267	56 Leo	1.05	0.82	0.50	M5.5III	M5	2.05	
4362	72 Leo	0.74	0.68	0.22	M3III	M3.5	1.31	
4483	ω Vir	1.27	0.73	0.48	M4III	M6		3226
4491		0.85	0.67	0.29	M2III	M3.5		3374
4562		0.62	0.64	0.23	M3III	M2.5		3453
4666	2 CVn	0.45	0.67	0.21	M1III	M1.5		3374
4690	3 CVn	0.48	0.61	0.14	M0III	M2		3536
4765	4 Dra	0.97	0.64	0.30	M3III	M4.5		3453
4902	ψ Vir	0.73	0.73	0.27	M3III	M3.5	1.28	
4949	40 Com	1.05	0.84	0.49	M5III	M5	1.79	
5080	R Hya	2.40	1.50	1.01	M7III	—	2.48	

TABLE 1 (Contd)

HR No.	Name	α	β	ϒ	Sp.Class Buscombe (1977)	Sp.Class This paper	R-I Johnson *et al.*(1966)	Te°K This paper
5229		$1^{m}.06$	$0^{m}.83$	$0^{m}.54$	M4.5III	M5	$1^{m}.66$	
6146	g Her	1.24	0.95	0.64	M6III	M6	2.23	
8316	μ Cep	0.46	1.03	0.23	M2Iab	M1.5		
8775	β Peg	0.60	0.71	0.23	M2III	M2.5	1.32	
8795	55 Peg	0.27	0.57	0.44	M1III	M0	1.02	
8934	ϕ Aqr	0.48	0.71	0.20	M1.5III	M2		3274
8904	4 Cas	0.45	0.63	0.11	M1.5III	M1.5		3480
9036	φ Peg	0.67	0.55	0.34	M2.5III	M3		3714
9064	ψ Peg	0.64	0.69	0.27	M3III	M3	1.34	
9089	30 Psc	0.70	0.74	0.28	M3III	M3	1.41	

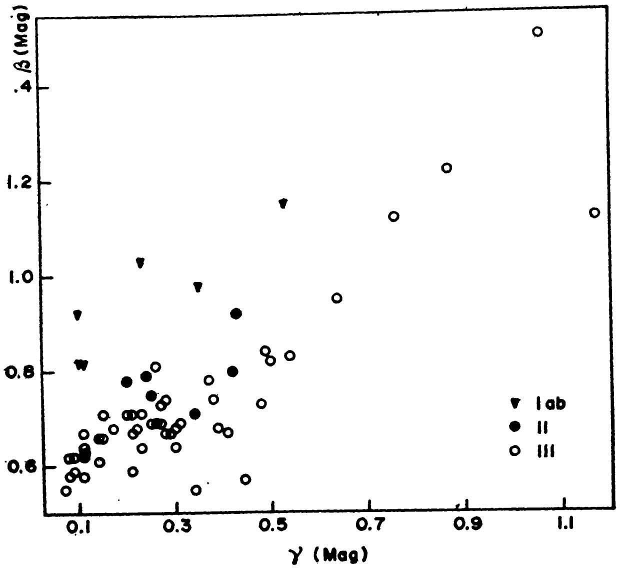

Fig. 4 : Plot of β index against ϒ index. Supergiants lie above the normal giants.

The standard errors of the coefficients result in 7% error in the computed T_e. In obtaining the relationship we have not included the giant HR 5080 for which we got a high value of the β index.

Thus it seems possible to calibrate the β index in terms of the effective temperature of the star. Since we have not applied any reddening correction to the β index, the β -T_e relation given above applies only to unreddened stars. The accuracy of the effective temperatures determined from angular diameters and luminosities, used in deriving the above relation may amount to about ± 7% (Dyck *et al.* 1974). Therefore, the total error in the temperature thus determined amounts to about 10%. The effective temperatures for a few stars for which (R—I) values are not available have been determined with the help of the above relation and are given in the last column of Table 1.

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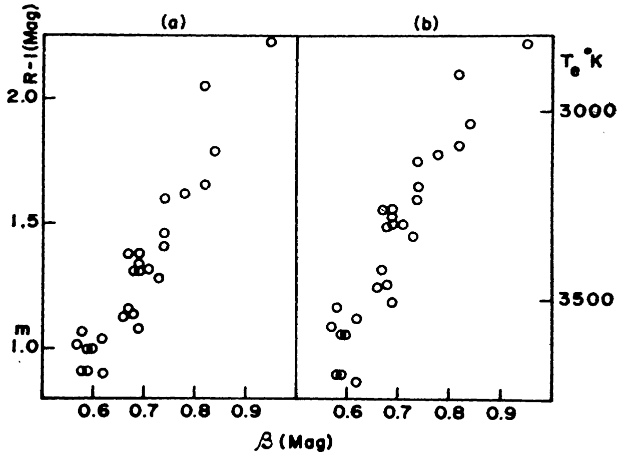

Fig. 5 : (a) Shows a correlation of R-I index with the β index.
(b) Shows the correlation of effective temperature with the β index.

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