THE ASTROPHYSICAL JOURNAL, 272:116–117, 1983 September 1

A COMMENT ON RED SUPERGIANT VARIABLES IN THE SMC

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Received 1982 November 29; accepted 1983 February 16

ABSTRACT

Infrared photometric observations of two suspected supergiant carbon stars in the Small Magellanic Cloud (SMC) show that these stars have mean luminosities no greater than those of known C stars in the Clouds and hence are not candidates for the "missing" bright C stars. Some suspected supergiant counterparts to oxygen rich Mira-type variables are also shown to be quite distinct from supergiants and are more likely luminous asymptotic giant branch stars.

Subject headings: galaxies: Magellanic Clouds — galaxies: stellar content — stars: carbon — stars: long-period variables — stars: supergiants

I. INTRODUCTION

Lloyd Evans (1980) has called attention to a group of eight red large-amplitude variables in the Small Magellanic Cloud (SMC). He has suggested that all eight stars, two of which are carbon stars, are supergiant analogs of Mira variables. Because of the importance of ascertaining whether or not there are such luminous C stars (Iben and Renzini 1983; Cohen *et al.* 1981, hereafter CFPE), infrared photometry and bolometric luminosities have been obtained for Lloyd Evans's two candidates. This brief paper presents and interprets these data as well as new data for two of the other stars discussed by Lloyd Evans.

II. THE CARBON STARS

On the basis of spectroscopic observations, Lloyd Evans (1980) has classified two Cordoba variables, CV 78 and 84, as carbon stars.[2] Infrared colors and magnitudes were obtained for these stars with CTIO's InSb photometer D-3 on the 4 and 1.5 m telescopes. These data, given in Table 1, are on the CTIO/CIT system defined by the standards of Elias *et al.* (1982).

Estimates of the visual magnitudes of these two stars were made when the infrared observations were obtained. A comparison of these estimates with the magnitude ranges and periods given by Lloyd Evans (1980) suggests that the observations on JD 2,445,339 were made at times close to maximum light while the earlier observations correspond to times of minimum light. Additional infrared photometry by Wood, Bessell, and Fox (1983) of CV 78 are intermediate to the values given in Table 1. The means of the bolometric magnitudes of the two stars lie at or close to the bright side of the unbiased carbon star luminosity function in Figure 9 of CFPE and are not inconsistent with that function. However, it is clear from Table 1 that for part of its cycle CV 78 does rise just above the brightest interval of the CFPE luminosity function.

The main conclusion then, from the data presently available, is that *these carbon variables are not supergiants and in the mean do not have bolometric luminosities greater than those of other SMC and LMC carbon stars.* Therefore, they are not candidates for the "missing" luminous asymptotic giant branch carbon stars predicted by theory (e.g., CFPE; Iben 1981; see also review by Iben and Renzini 1983).

[1] Cerro Tololo Inter-American Observatory is supported by the National Science Foundation under contract AST 78-27879.

[2] As an aid to finding these stars on a more commonly available set of charts, I give offsets, measured at the telescope, with respect to objects on the Hodge and Wright SMC Atlas. CV 78 is 1^m2^s8 west and 2'26" north of S33. CV 84 is 1^s4 west and 1'49" south of S28.

TABLE 1

THE CARBON VARIABLES

STAR	JD	REDDENING CORRECTED[a]							
		K_0	$(J-K)_0$	$(H-K)_0$	$(K-L)_0$	H_2O	CO	BC_K	M_{bol}[b]
CV 78	2,444,659	10.56	1.43(3)	0.48	...	...	...	3.02	−5.52
	2,445,339	9.70	1.18	0.35	0.53(7)	0.115	0.215	2.82	−6.58
CV 84	2,444,659	10.66(3)	1.46(3)	0.48	...	...	...	3.04	−5.37
	2,445,339	10.19	1.08	0.28	...	0.115	0.315	2.72	−6.19

[a] Numbers in parentheses are photometric uncertainties when greater than ±0.02 mag. $E(B-V)_0 = 0.11$ was assumed (see CFPE). This implies $A_K = +0.03$, $E_{J-K} = 0.06$, $E_{H-K} = 0.02$, $E_{K-L} = 0.01$, $E(H_2O) = 0.005$, and $E(CO) = -0.005$.

[b] Bolometric corrections to the K magnitudes were calculated from the $(J-K)_0$ colors as in Frogel, Persson, and Cohen 1980 with a value of $(m-M)_0 = 19.1$.

III. THE OXYGEN STARS

The two M type red variables of largest amplitude listed by Lloyd Evans (1980), HV 838 and 11295, have been observed in the infrared by Catchpole and Feast (1981). Much more complete phase coverage in the infrared is available from the recent study of late-type supergiants by Elias, Frogel, and Humphreys (1983, hereafter EFH2). They have determined the range in bolometric magnitude to be -7.2 to -6.9 for HV 838 and -6.9 to -5.9 for HV 11295. Furthermore, EFH2 show that these two stars are representative of a small but *quite distinct* group of stars characterized by large-amplitude infrared variability (>0.5 at K) and large H_2O indices (>0.4 mag). HV 11417 (Elias, Frogel, and Humphreys 1980, hereafter EFH1) is another member of this group and has a range in M_{bol} from -8.1 to -6.1 (EFH2). The vast majority of true SMC supergiants in EFH2, on the other hand, exhibit small amplitude variability (<0.2 mag at K). Even though EFH2 obtained infrared data for 96 luminous red stars in the LMC, they could find no counterparts in the LMC to the small group of large-amplitude, red, SMC variables. Sufficiently deep infrared (H and K) surveys of several areas in the SMC and LMC by J. H. Elias (1982, private communication) and Frogel and Richer (1983) have led to the same result.

Elias, Frogel, and Humphreys (1980, 1983) have argued that although stars like HV 838, 11295, and 11417 mimic supergiants when near maximum light, their large-amplitude infrared variations and strong H_2O indices point to their being relatively low-mass (relative to supergiants) extreme long-period variables (LPV) on the asymptotic giant branch, rather than bona-fide massive supergiants as claimed by Lloyd Evans (1980). This is in accord with the conclusions of Wood, Bessell, and Fox (1981, 1983) who claim that for LPVs of constant period, one can separate luminous asymptotic giant branch stars from core helium burning supergiants. The results of EFH1 and EFH2 referred to here strengthen Wood, Bessell, and Fox's conclusion since these results show that there are marked photometric differences between the two groups independent of period or luminosity.

An implication of the discussion in the previous paragraph is that the procedure of combining stars from apparently quite different evolutionary states, and hence masses, to obtain a period-luminosity law as done by Catchpole and Feast (1981) is not valid (cf. Wood, Bessell, and Fox 1981, 1983).

Finally, while the luminosities of some of the large-amplitude red variables appear to be correct, they do not seem to occur at anywhere near the required space density to account for the missing bright asymptotic giant branch stars (Iben and Renzini 1983; Frogel and Richer 1983; Frogel and Iben 1983).

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