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HV 11417: A PECULIAR M SUPERGIANT IN THE SMALL MAGELLANIC CLOUD

JONATHAN H. ELIAS AND JAY A. FROGEL
Cerro Tololo Inter-American Observatory[1]

AND

ROBERTA M. HUMPHREYS[2]
University of Minnesota
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ABSTRACT

The semiregular Small Magellanic Cloud variable HV 11417 is a cool, luminous star of spectral type M5e I near maximum light. Its spectroscopic and photometric properties resemble those of VX Sgr and similar peculiar galactic M supergiant-like objects. HV 11417 is the first identified extragalactic member of this exotic class of evolved objects. Evidence is presented which suggests that HV 11417 and related galactic stars may be luminous long-period variables rather than true supergiants.

Subject headings: galaxies: Magellanic Clouds — stars: late-type — stars: supergiants

I. INTRODUCTION

Investigations of the late-type stellar populations of the Magellanic Clouds show that their average properties differ significantly both from one another and from those of galactic stars. The outstanding examples are the differences in the relative populations of carbon stars and late M giants (Blanco, Blanco, and McCarthy 1978; Blanco, McCarthy, and Blanco 1980; cf. Blanco 1965) and the increasingly early mean spectral type of the cool supergiants as one proceeds from the Galaxy to the Large Magellanic Cloud and then to the Small Magellanic Cloud (Humphreys 1979).

These differences occur in relatively common stars. A question of some interest is how more exotic, luminous late-type stars are affected. Such stars can be conveniently detected in the infrared, and, since conventional photographic techniques have failed to identify them, a partial survey of the Magellanic Clouds has been carried out by one of us (J. H. E.) at 1.6 μm. This survey detects all sources brighter than a limit of $H \approx +10.5$ (including foreground stars). Follow-up work to the survey is not yet complete, but has already yielded one potentially very interesting star in the SMC of unusually late spectral type: the semiregular variable HV 11417 (as identified by Hodge and Wright 1976; see also Shapley and Nail 1951). The purpose of this *Letter* is to discuss this star.

II. OBSERVATIONS

An underexposed spectrum at 120 Å mm^{-1} obtained on the 1 m telescope with the image-tube spectrograph in 1979 October 14 (UT: JD 2,444,161) showed HV 11417 to be of spectral type late M, with hydrogen emission, but could not be used for accurate classification. A second, high-quality spectrogram was obtained 1979 October 20 (UT: JD 2,444,167) on the CTIO 4 m telescope with the RC image-tube spectrograph; the reciprocal dispersion was 48 Å mm^{-1}. This latter spectrum of HV 11417 is classified M5e I based on direct comparison with galactic M-star standards observed with the same instrument (see Humphreys 1978). This spectrum is shown in Figure 1, together with current spectra of VX Sgr and VY CMa and of galactic standards. Very strong hydrogen emission from Hβ to λ3770 is evident in the spectrum of HV 11417. The narrow or weak Ca I line at λ4226 supports its classification as a supergiant. The Fe I lines at $\lambda\lambda$4376, 4383, and 4389, which are also luminosity indicators, are present but very weak. The entire spectrum short of $\sim\lambda$4500 shows a strong, blue continuum that appears to "veil" or blanket the absorption lines. This blue continuum is a feature of many long-period variables and is also observed in the peculiar stars VX Sgr and VY CMa.

The absorption-line spectrum of HV 11417 very closely resembles the spectrum of VY CMa (M5 I) taken at the same time (Fig. 1). The corresponding spectrum of VX Sgr shown in Figure 1 is classified as M6 I; VX Sgr has been classified as early as M4 I near maximum light (Humphreys and Lockwood 1972), when its spectrum also resembles that of HV 11417. Both VY CMa and VX Sgr have shown strong hydrogen emission lines in the past.

The very late spectral type makes HV 11417 the latest known supergiant in either of the Magellanic Clouds (cf. Humphreys 1979; Lloyd Evans 1978, 1980).

The initial infrared detection of HV 11417 was made on the CTIO 0.9 m telescope by spatial scanning at a wavelength of 1.6 μm (cf. Elias 1978); all subsequent photometry was done using standard techniques on the CTIO 1.5 and 4 m telescopes. The *JHKL*, H_2O, and CO measurements were made with an InSb detector,

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

[2] Visiting Astronomer, Cerro Tololo Inter-American Observatory.

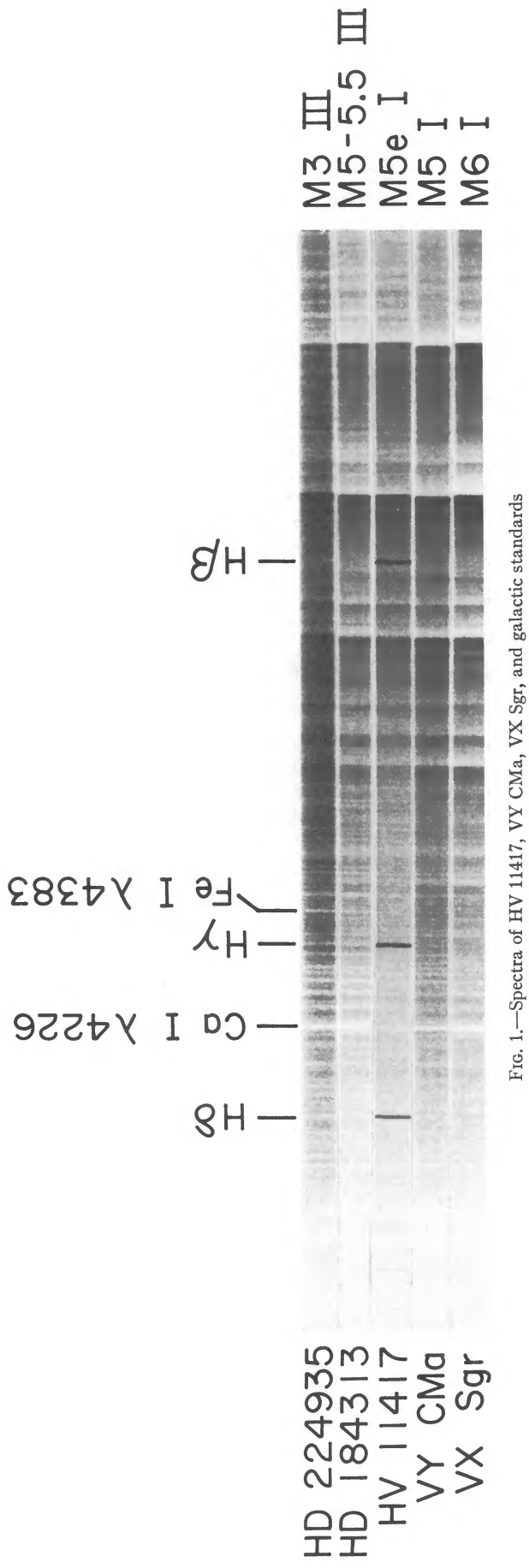

FIG. 1.—Spectra of HV 11417, VY CMa, VX Sgr, and galactic standards

and the 10 μm measurement was made with a germanium bolometer. These measurements are given in Table 1; they have, where necessary, been transformed to the system defined by Frogel *et al.* (1978). Except at 3.5 and 10 μm, uncertainties are primarily due to residuals in the standard star measurements.

The measurements show the star to vary by over 1 mag at H (Fig. 2). Shapley and Nail (1951) give an approximate period of 1000 days, which implies that the first detection was near minimum and the subsequent observations at or before maximum light.

A substantial flux excess is evident at 10 μm, and a comparison of the energy distribution with that of a normal M supergiant (Fig. 3; § III below) suggests the presence of excess flux at 3.5 μm as well.

BVRI photometry was done on HV 11417 on 1979 October 14 (JD 2,444,161) on the CTIO 1.5 m telescope with an RCA 31034 GaAs photomultiplier. The resulting values are $V = 14.11$, $B - V = 1.83$, $V - R = 2.21$, and $V - \mathrm{I} = 4.54$. The $V - \mathrm{I}$ color includes an additional correction needed to transform very red colors observed with the GaAs tube to the Johnson system (Humphreys 1980; the uncorrected $V - I$ color is 4.17); the estimated uncertainty in this color is ± 0.10 mag, while uncertainties in the V magnitude and the other colors are less than ± 0.02 mag.

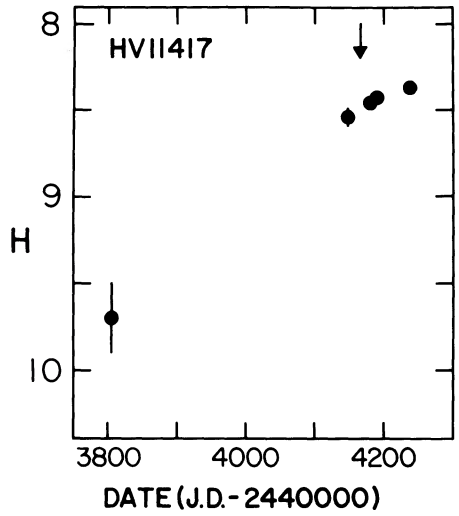

FIG. 2.—Infrared variability of HV 11417. Measured H magnitudes are plotted against time. Uncertainties smaller than ± 0.03 mag are not shown. The arrow marks the time at which the visual photometry and spectroscopy were done.

III. DISCUSSION

HV 11417 is probably a member of the class of peculiar M supergiants of which VX Sgr is a prototype (Humphreys 1974). It shares the three defining characteristics: high-luminosity spectral features, together with long-period variable characteristics, excess infrared flux beyond 3 μm, and substantial variability.

An energy distribution for HV 11417 can be constructed for a point somewhat before maximum light (see Fig. 3) for comparison with other stars. This distribution is produced using the *BVRI* photometry and interpolating the *JHK* measurements. The 10 μm measurement was used uncorrected for variability since any plausible correction would be less than the uncertainty in the measurement, and the L measurement was made fainter by 0.12 mag, corresponding to the change in the K magnitude between mid-October and the time of the actual measurement.

A correction for reddening is required, which is uncertain since the photometry of HV 11417 itself cannot be used with confidence (though it suggests that the reddening is small). Visual photometry and spectral types of nearby stars (Osmer 1973; Azzopardi and Vigneau 1975; Humphreys 1979) combined with our unpublished infrared observations give a value for the total visual extinction A_V of $\sim$0.2 mag. This value is similar to average extinction values for supergiants in the SMC (e.g., Azzopardi and Vigneau 1977).

As a comparison, we use measurements of VX Sgr from somewhat after maximum light (Humphreys and Lockwood 1972: there are no adequate measurements at a point just before maximum). These have been corrected for an extinction A_V of $\sim$1.5 mag (Fawley 1977; Lockwood and Wing 1980). The reddening to VX Sgr is poorly known, and construction of the flux distribution required some interpolation of the infrared photometry. Uncertainties in the intrinsic colors are possibly as large as a few tenths of a magnitude. The extinction law used for the corrections is that given by Lee (1970) except that values in the infrared have been shifted slightly to agree with Becklin *et al.* (1978). Both distributions are shown in Figure 3. The flux distribution of a normal M5 Ia supergiant (Lee 1970; Johnson 1966) is also shown.

Both VX Sgr and HV 11417 deviate from the "nor-

TABLE 1

INFRARED PHOTOMETRY OF HV 11417

DATE (JD 2,440,000)	MAGNITUDES[a]						
	J	H	K	L	[10]	H_2O	CO
3806.....	...	9.70 (20)	...	...	...	...	...
4147.....	9.48 (5)	8.54 (5)	8.19 (5)	...	...	0.45	0.130
4181.....	9.38	8.46	8.10	...	5.69 (10)	0.46 (3)	0.135
4189.....	9.32 (3)	8.43	8.08	...	...	0.43 (4)	0.125
4237.....	9.22	8.37	8.03	7.38 (6)	...	0.39 (4)	0.150

[a] If larger than ± 0.02 mag, uncertainties are given in parentheses in units of 0.01 mag.

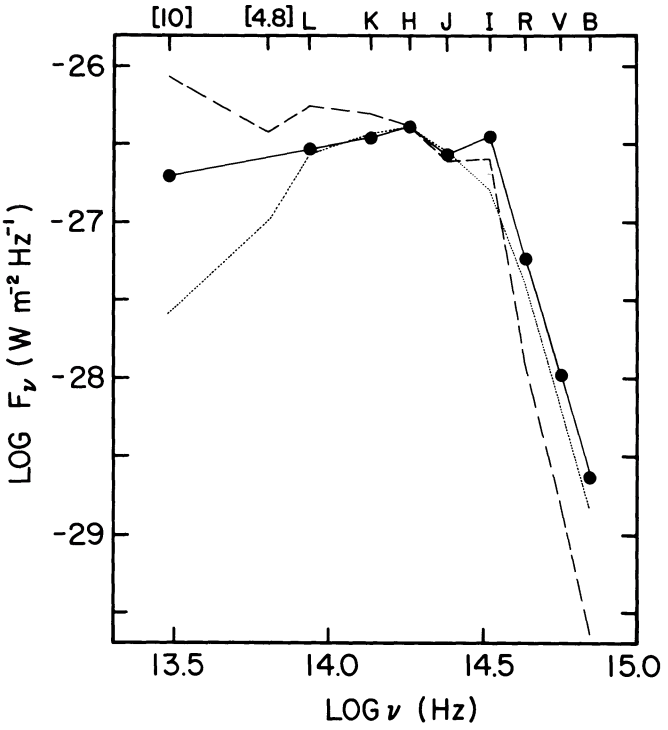

FIG. 3.—Flux distributions of HV 11417 (*filled circles*), corrected for $A_V = 0.2$ mag; of VX Sgr (Humphreys and Lockwood 1972; *dashed line*), corrected for $A_V = 1.5$ mag; and of a "normal" M5 Ia star (Lee 1970; Johnson 1966; *dotted line*). The distributions for VX Sgr and the "normal" curve have been scaled to match HV 11417 at 1.6 μm.

mal" stellar distribution in similar ways. The two largest differences between the unusual stars and the normal distribution are the pronounced excesses at I and longward of 3 μm. The nature and existence of the I "bump" have been disputed (cf. Humphreys 1974; Gilman 1974; Fawley 1977; Lockwood and Wing 1980). The feature is very clearly present in the HV 11417 data, suggesting that, if the star is similar to VX Sgr, it should show substantial veiling in its near-infrared spectrum (cf. Humphreys 1974). The long-wavelength excess is less controversial; it is generally ascribed to emission from hot dust (e.g., Humphreys 1974; Fawley 1977).

VX Sgr is decidedly redder than HV 11417. Small differences in spectral type, uncertainties in the reddening, and different stellar metallicities can all contribute to this; from the available data they cannot be distinguished.

The unusual nature of HV 11417 is accentuated by the substantial gap in spectral type between it and other bright, variable SMC supergiants, which are of earlier spectral type, typically K5 or M0, with bluer colors (Humphreys 1979; Shapley and Nail 1951; Lloyd Evans 1971, 1978, 1980).

Unlike its galactic counterparts, HV 11417 is at a known distance and is unlikely to be heavily reddened, so its luminosity is reasonably well determined. It is not one of the visually brightest M stars in the SMC even near maximum: based on its membership in the SMC, it has an absolute visual magnitude $M_V = -5.1$ near maximum. Photographic values from Shapley and Nail (1951) suggest its visual absolute magnitude varies between about -2.8 and -5.3. The bolometric magnitude of HV 11417 is -8.3 near maximum light, roughly a magnitude fainter than that of the brightest M supergiants. The variation in luminosity, the rather faint maximum, and the large gap in spectral type between HV 11417 and the normal SMC supergiants, suggest that HV 11417 may be an extreme long-period variable which mimics a supergiant at maximum rather than a more evolved or later-type M supergiant. The same may be true of VX Sgr, VY CMa, and similar galactic stars whose luminosities are poorly known.

The narrow-band infrared indices (Table 1) also point to an identification as an extreme long-period variable. The CO index is weaker and the H_2O stronger than in normal supergiants (e.g., Frogel *et al.* 1978), whereas similar values are seen in long-period variables near maximum (e.g., Frogel 1971; Frogel, Persson, and Cohen 1981).

It would be interesting to know whether there are other stars similar to HV 11417 in the Magellanic Clouds. No other such stars have appeared in the 1.6 μm survey results as yet, but it is important to emphasize first, that the regions surveyed comprise only a few percent of the total area of the Magellanic Clouds, and second, that the follow-up work is still incomplete, especially in the LMC. Completion of this work should

provide better statistics, since HV 11417 was well above the survey limit even at minimum, when it was detected.

IV. CONCLUSIONS

HV 11417 is the latest known supergiant in either of the Magellanic Clouds, comparable in spectral type to the latest known supergiants in the Galaxy. Spectroscopically and photometrically it is quite similar to a peculiar, rare subset of these galactic supergiants typified by stars such as VX Sgr and VY CMa. It remains to be seen whether there are other such stars in the Magellanic Clouds. Its relatively low luminosity and large variability suggest that HV 11417 and related galactic stars may be extreme long-period variables rather than true supergiants.

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Note added in proof.—Additional photometry of HV 11417 indicates that it reached maximum light in the infrared shortly after the last observation in Table 1. The measurements made during decline toward minimum show a greatly increased H_2O index, as is characteristic of long-period variables.

JONATHAN H. ELIAS and JAY A. FROGEL: Cerro Tololo Inter-American Observatory, Casilla 63D, La Serena, Chile
ROBERTA M. HUMPHREYS: Department of Astronomy, University of Minnesota, Minneapolis, MN 55455