J. Astrophys. Astr.(1990) **11**, 37–42

Emission Spectrum of Hot R OB Star MV Sgr*

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Received 1989 August 23; accepted 1989 October 18

Abstract. The new spectroscopic observation of MV Sgr obtained at ESO in 1987 July shows enhanced emission lines of He I λ3889, [S II] λ4068 relative to the observations discussed by Jeffrey *et al.* (1988). The presence of [S II] λ4068 indicates the presence of planetary-nebulae-like envelope around the star. Although the radial velocity of the absorption lines and Fe II emission lines do agree with the velocity given by Jeffrey *et al.*, the [S II] λ4068 and probably He I emission lines appear to behave differently.

Key words: stars, R CrB type—stars, nebulosities—stars, individual

1. Introduction

MV Sgr is one of the hot R CrB stars with $T_{\rm eff}$ = 15400 ± 400 K (Drilling *et al.* 1984) which shows light variations of R CrB type with magnitude range 12–16. The spectrum near maximum light has been described by Herbig (1964, 1975) who discovered the presence of emission lines mostly due to Fe II in addition to a hydrogen-deficient B-typestar absorption spectrum. The emission lines consisting of Hα, Fe II, He I, Si II, N I and O I dominate the red part of the spectrum which led Herbig to propose that the Fe II emission is associated with gaseous component that has excitation temperature substantially lower than the colour temperature of the B star. In the ultraviolet (UV), the low-excitation lines mainly due to Fe II, Si II, C I, O I, AI II exist in absorption (Rao & Nandy 1982) indicative of the low temperature gas seen against the continuum of the B-type star. Moreover, Rao & Nandy (1982) also reported variability in the strengths of these circumstellar absorption lines.

Recently higher resolution blue spectra obtained around light maximum have been analysed by Jeffrey *et al.* (1988) who find that the photospheric spectrum is hydrogen-deficient by about the same degree as the helium star HD 124448, but is under-abundant in metals N, Si by 1 dex and carbon is underabundant by 2 dex relative to HD 124448. Their CASPEC spectrum obtained with ESO 3.6 metre telescope when the star was about a magnitude fainter showed more emission-line activity. They also discovered that the Fe II emissions are split with peak separation of 68.2 km s^{-1} and FWHM of 131 ±18 km s^{-1}. The central minimum of the emission is nearly at line

* Based on observations collected at the European Southern Observatory, La Silla, Chile.

centre and therefore the mean emission-line centre gives a radial velocity very close to the one given by the absorption lines. MV Sgr also seems to show variability in the emission lines of Hα, He I. In this paper we describe the emission line spectrum which showed many interesting changes relative to that described by Jeffrey *et al.* (1988).

2. Observations

The observations were obtained in 1987 July 30, with ESO 1.5 metre spectrographic telescope using the Boller & Chivens spectrograph and a CCD detector combination giving a dispersion of 39 Å mm^{-1} in the blue which corresponds to 0.58 Å per pixel. The wavelength region covered was from λ3705 to λ4300. The wavelength calibration was done with He-Ar source which was observed just after the stellar exposure. The flux calibration was done using three Standard stars, Kopff 27, LTT 7987 and LTT 9239. The spectrum reductions were done using the MIDAS package at ESO, Garching. The flux-calibrated spectrum is shown in Fig. 1.

It appears that these observations have been obtained when the star was slightly below maximum light (*i.e.* at $m_v \sim 13.2$) according to AAVSO visual estimates (Mattei 1989, Personal communication).

3. Results and discussion

The spectrum is mostly dominated by absorption lines predominantly due to He I, O II and N II. Several of the early members of He I triplet series have emission components emerging through the absorption *e.g.* λ4026. Some of these identifications are shown in the figure. Incidentally, Jeffrey *et al.* (1988) have reported that nearly all He I lines are found in absorption including λ3889 (their Table 2) whereas our spectrum (Fig. 1) shows He I λ3889 very strongly in emission.

3.1 *Radial Velocities*

The wavelength calibration of our spectrum is done using the He–Ar comparison source. A third degree polynomial fits the 22 comparison lines across the spectrum with a standard deviation of 0.087 Å corresponding to 6.4 km s^{-1} at 4100 Å. We have measured the radial velocity of 14 stellar absorption lines(12 He I, one N II, one CII) which show that the radial velocity of MV Sgr on JD 2447006.7 as – 95 ± 8 (s.d.) km s^{-1} . This value is in good agreement with the measurements of Jeffrey *et al.* (1988). They derive – 91 ± 7 km s^{-1} using 9 lines on JD 2445153.2 and – 96 ± 4 km s^{-1} using 4 lines on JD 2446163.7 which indicates no large-scale radial velocity variations.

We could measure only one interstellar line of Ca II at λ3933 which gives a radial velocity +19 km s^{-1} in good agreement with + 20 km s^{-1} obtained by Jeffrey *et al.* (1988).

3.2 *The Emission Lines*

As mentioned by Jeffrey *et al.* (1988) and also by Herbig (1975), the emission lines are mostly due to Fe II, Ti II, Ca II, Si I *etc.* All the lines in Table 6 of Jeffrey *et al.* (1988)

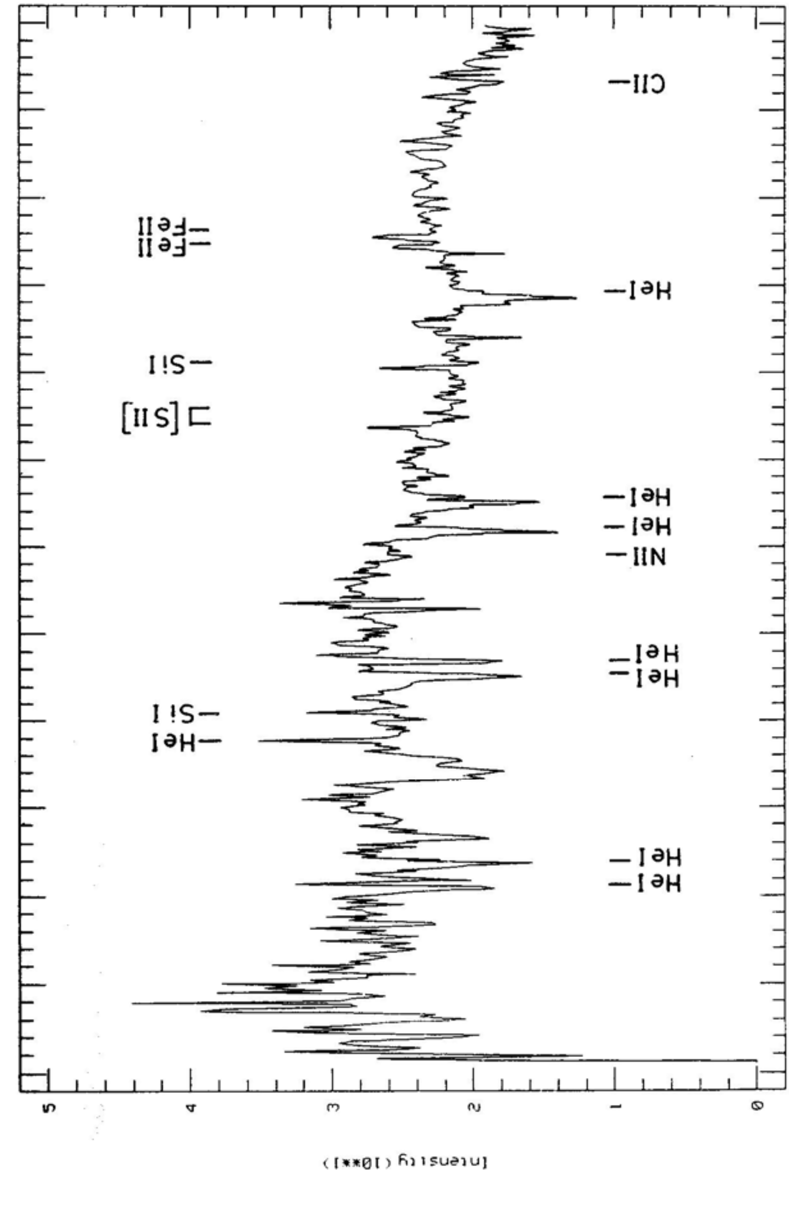

Figure 1. Flux-calibrated spectrum of MV Sgr in the wavelength region 3705 Å to 4300 Å.

which occur in this wavelength range of $\lambda\lambda$3705–4300 Å are present in our spectrum. In addition, we see He I λ 3889 line very strongly in emission. It is actually the strongest emission feature in the spectrum. The emission features of Si I multiplet No. (2) at λ4102.9, λ3905.5 are also strong but the intensity ratio is not 1:81 as expected from the log*gf* values (Wiese, Smith & Miles 1969) but appears more like 1:1 probably reflecting the optical depth effects. There is a strong emission feature at λ4068.19 that was not mentioned by Jeffrey *et al.* (1988) and could be identified with [S II] λ4068.62. The other line of [S II] doublet at λ4076.22 is expected to be 5 times weaker, also seems to be present but it is on the red wing of the absorption feature at λ4075 (CII + O II (1)).

Earlier Herbig (1964) had identified the emission feature at λ6715 as due to [S II] λ6717, λ6731, although he did not mention these features in the description of his 1973 Aug. spectra (Herbig 1975). Examination of the prints of these spectra (EC 11629) kindly sent by Herbig does show presence of weak emission feature at λ6718. Since the [S II] lines seem to be present, we looked for the presence of other nebular lines at λ6548 and 16583 of [N II] and [O II] $\lambda\lambda$7320, 30. There again is a weak feature at λ6548. The 16583 feature is blended with the line listed by Herbig at λ6586.2 as exceedingly broad emission due to Fe II (–) (an unclassified strong line of Fe II) and the absorption lines of $\lambda\lambda$6578, 82 of C II.

There is a feature at λ7330 corresponding to [O II]. The other line of the doublet at λ7320 is blended with the broad emission λ7323.6. The possible presence of [O I] λ6300 ha been commented on by Herbig (1975).

According to Jeffrey *et al.* (1988) the FWHM of Fe II emission lines is 131 ± 18 km s^{-1} , this corresponds to 3–4 pixels on our spectrum. A comparison of the λ4068 feature (also 13889) with Fe II lines at λ4173.4, λ4178.9 does indicate that λ4068 is sharper than Fe II lines. Thus the presence of λ4068.62 [S II] does confirm the presence of the nebular lines from a low-density nebula.

3.3 *Radial Velocities of Emission Lines*

We list in Table 1 the radial velocity of some of the emission lines and their fluxes (measured above the continuum).The radial velocities of Fe II, Si I, Ca II are consistent with absorption velocity –95 k m s^{-1} . Jeffrey *et al.* (1988) find the mean of 31 emission lines as – 81 ± 17 (s.d.) km s^{-1} and Herbig (1975) finds from the measurement of 11 relatively unblended emissions a value of –96 ± 13 (s.d.) km s^{-1}. Thus, the radial velocity of the emitting material Fe II, Si I, Ca II etc is essentially the same as that of the star.

However, the two strong emission lines of [S II] 14068.22 and He I λ3889 show a radial velocity quite different from the stellar velocity. One possibility is that the He I line may be superposed on a strong underlying stellar absorption line that could displace the centre of emission. At the position of the nebular line 14068 no strong absorption is seen in the tracing of HD 124448 (Westin 1980).

The radial velocities of other strong He I emission lines in the red region as calculated from the measured wavelengths of Herbig (1975) indicate that these radial velocities are similar to the radial velocity measured for λ3889 by us (Table 1). However, Hα radial velocity seems to be consistent with – 96 km s^{-1} stellar velocity. The central emission in He I λ4026 is red-shifted to – 3.4 km s^{-1} although the absorption core gives a radial velocity of —92 km s^{-1} .

Table 1. Radial velocities and fluxes of emission lines.

Wavelength	Radial Velocity $km\,s^{-1}$	F 10^{-12} $erg\,s^{-1}\,cm^{-2}$	Wavelength Å	Radial Velocity $km\,s^{-1}$	F 10^{-12} $erg\,s^{-1}\,cm^{-2}$
He I			[S II]		
3888.65	−42	12.6	4068.62	−32	5.2
5875.62	−56*		4076.22		1.4
6678.15	−26*				
7281.35	−32*				
Fe II			Si I		
4173.45	−124	7.0	3905.53	−90	5.1
4178.86	−96	9.6	4102.03	−80	6.8
4233.17	−121	4.1			
4258.15	−83	4.5			
			Ca II		
			3968.47	−90	

* From Herbig (1975); λ7065.4 is probably blended with Fe. II.

Thus, there is a possibility that the nebular velocity might be different from that of the star. However, this is based on almost a single line of [S II], although in He I lines the emission component also seems to agree with the radial velocity. Further confirmation with better observations are essential.

3.4 *Discussion*

The nebular lines might be strong in our 1987 July spectrum because the stellar continuum was fainter than on the other occasions. There is also a possibility that emission lines have varied in strength. Jeffrey *et al.* (1988) found that the relative strength of the He I λ6678 to Hα was the reverse of that given by Herbig's observation *i.e.* He I was stronger than Hα.

The description of emission spectrum and infrared excess in MV Sgr is similar to that of the high luminosity B supergiants in LMC which show doubling in emission lines of Fe II, He I, Si II, in addition to the nebular lines of [N II] and [S II] (Zickgraf *et al.* 1986). In MV Sgr, the ratio of the [S II] line 24068 to $\lambda\lambda$6717 + 31 apears to be greater than one.

The presence of the [S II], [N II] and [O II] lines in MV Sgr indicates the existence of a low-density planetary nebula around the star. Then the question would be whether the star of T_{eff} ~ 15400 K and log g ~ 2.5 could photoionize the nebula and sustain it. The temperature is apparently too low for photoionization. It is however possible that the photoionization could have occurred at an earlier time when the star was hotter.

Further observations are essential, particularly during a light minimum to establish the nature of the nebulosity and radial velocity differences among emission lines in MV Sgr.

Acknowledgement

We would like to thank Prof. G. H. Herbig for sending the prints of his spectra to one of us (NKR). NKR would also like to thank ESO, Garching for their hospitality during his visit there and for letting him use their facilities. We would like to thank J. Mattei of AAVSO for sending the visual observations of MV Sgr.

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