THE HYDROGEN-DEFICIENT IRREGULAR VARIABLE STAR V348 SGR

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ABSTRACT

The distribution of the reddening material around V 348 Sgr has been studied using the IUE low resolution spectra. The nebula surrounding the star has a reddening of E(B-V) = 0.3 which seems to be caused mainly by the foreground interestellar medium. The reddening in the chromosphere (CII emission line region) is E(B-V)~ 0.9. The star shows variable circumstellar reddening and extinction. The nebula appears to be carbon poor and nitrogen rich whereas earlier optical studies show that in the chromosphere the abundance of carbon, helium, neon are enhanced and hydrogen is very deficient. Thus there seem to be chemical separation between the nebula and the star.

1 INTRODUCTION

V348 Sgr is thought to be one of the hottest R CrB stars known. It undergoes visual light minima of over 5 magnitudes at irregular intervals (Ref.7, 10). The star is surrounded by a small nebulosity extending about 8 to 10 arc seconds and is prominently seen when the star is at light minimum (Ref.5). The spectrum at maximum (Refs.5, 11) showed emission lines predominantly due to CII, HeI and HI was conspicuous by its absence. In contrast at light minimum the spectrum is dominated by emission lines of HI and λ3727 of [OII] and CII was absent or very weak. The spectrum at light minimum is attributed mostly to the nebula around the star. From the OII absorption lines Houziaux (Ref.12) inferred the spectral type as B2, and derived a color excess of E(B-V) ~ 0.59.

Feast and Glass (Ref.3) and later Webster and Glass (Ref.17) have detected large amount of infrared excess in the star, a characteristic of R CrB stars, with a black body temperature of 900 K indicative of circumstellar dust.

Recently Dahari and Osterbrock (Ref.2) made a detailed study of spectrum obtained at different phases from maximum (V = 12) to minimum (V = 18.4). This study confirmed the spectral characteristics seen earlier and, in addition, showed that strong NeI emission spectrum was present when the star is at intermediate brightness (V 15 to 16). They interpret the spectral characteristics with a model similar to that invoked for the light variations of R CrB stars. At maximum light the star is surrounded by a hydrogen-poor, carbon-rich chromosphere where both CII, HeI and NeI spectrum originate (Te ~ 2×10^4 K). The minima are caused by the formation of dust from the ejected gas which obscures both the star and the chromosphere.

One of the interesting aspects of this study is the distribution of the reddening material. They (Ref.2) derive E(B-V) = 1.4 or 1.5 for the nebula from the Balmer decrement. The E(B-V) of the chromosphere which, is presumably located closer to the star, is estimated as 0.9 from the curve of growth analysis of CII lines. Earlier the reddening of the star was estimated by Houziux as E(B-V) = 0.59. The interstellar reddening in the direction of this star is supposed to be E(B-V) ~ 0.4 (Ref.14) or 0.2-0.3 (Ref.4). Thus it appears that most of the reddening is circumstellar and its distribution seems to be peculiar in the sense that the star in the centre has least amount of reddening whereas chromosphere and nebula have more reddening. In this paper we estimate reddening in various regions using UV spectra.

2 IUE OBSERVATIONS

The IUE observations discussed here have been procured from the data banks at VILSPA and the details are given in table 1. These observations are in the low resolution mode using the large aperture (10"x23").

The spectra show a prominent λ2200 absorption (figs.1,2) as was seen earlier by Heck et al. (Ref.8). All the LWR images show the emission at λ 2470 due to [OII] at both faint phase (LWR 8772) and light maximum (LWR 3949) (fig.1). Since the optical region is dominated by emission lines of CII we looked for CII in these UV spectra. Only image SWP 4521 shows emission prominently at λ1760 (fig.2) probably due to CII. No other conspicuous emission lines can be seen.

The continuum spectrum and some of the spectral features shown by SWP 4521 and LWR 3949, 3969

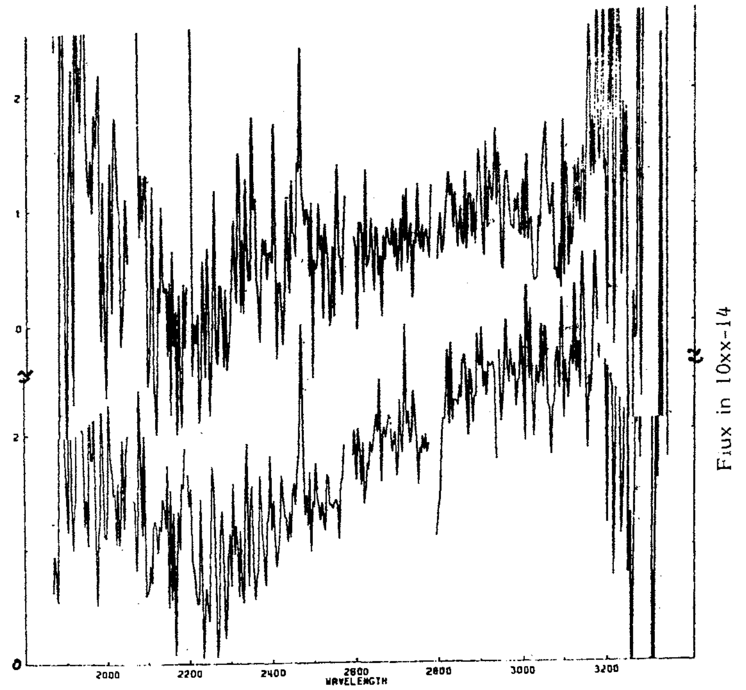

Figure 1. Spectrum obtained at light maximum LWR 3949 (lower) and when the star is at Mv ~ 15. LWR 8773 (upper) both show [OII] omission at λ2470.

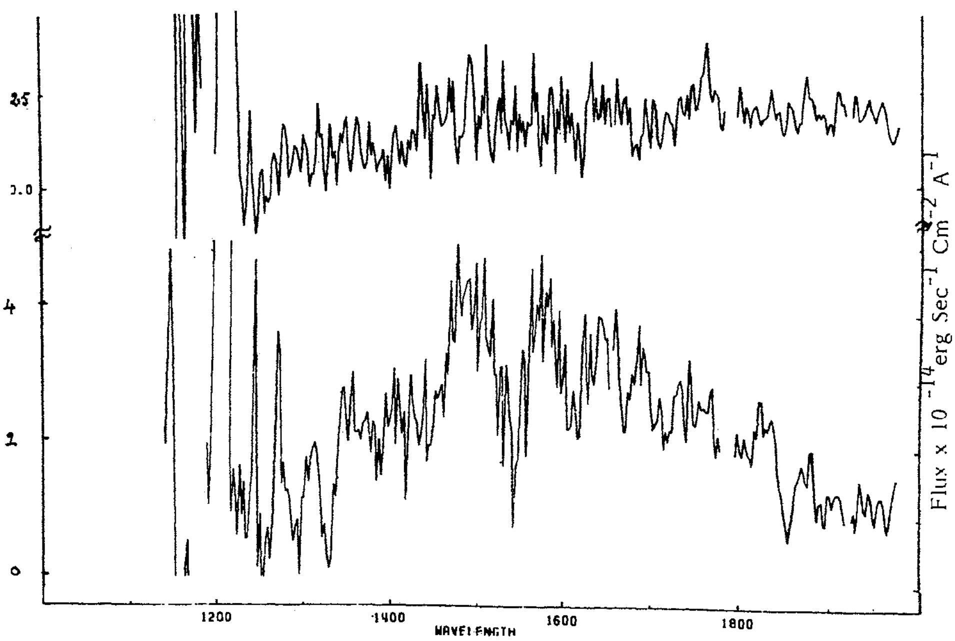

Figure 2. Short wavelength spectra. SWP 4521 (upper) showing λ1760 emission obtained at maximum light. SWP 10078 obtained when the star is at Mv ~ 15.

are quite different from that illustrated by Heck et al.(Ref.8) obtained in 1981 September, thus showing that variations occur even at light maximum.

3 REDDENING AND EXTINCTION

3.1 The nebula

The reddening in the nebula is estimated in two ways using [OII] lines, and the radio flux at 14.5 GHz.

It was shown by Adams and Seaton (Ref.1) that the lines of λ2470 and λλ7320, 30 of [OII] can be used to estimate the reddening. They calculate the theoretical ratio of the fluxes λ2470 to λλ7320, 30 as 0.74. We use the optical observations made by Dahari and Osterbrock (Ref.2) together with the IUE observations. It has been assumed that the flux in the lines has not changed between these two epochs; both were obtained at light maximum. Assuming that the nebula extends to 9" with uniform surface brightness we estimate the total flux from the nebula of λλ7320, 30 as 4.88×10^{-13} erg $cm^{-2}s$.

The flux of λ2470 of [OII] was measured on the spectra of LWR 3949 as $9.77\text{-}5.94 \times 10^{-14}$ erg $cm^{-2} s^{-1}$. The resolution of both Lick IDS spectra and IUE spectra are comparable. Using Seaton's (Ref.16) reddening curve for the general interstellar medium the observed flux ratio compared with the theoretical ratio leads to E(B-V) = 0.26 to 0.36. The allowance for the uncertainty that the nebula is not completely seen in the IUE aperture would further reduce the value of E(B-V).

Further corroboration to the above estimate of reddening comes from the radio observations. V348 Sgr was observed by Purton et al. (Ref.15) at 5, 6.2, 8.9 and 14.5 GHz. Only the flux measurement at 14.5 GHz has less probable error and is 6±3 mJy. Although the errors are high at other frequencies, they still indicate that the radio flux is optically thin at 14.5 GHz. Using the flux density observed at 14.5 GHz and assuming that this is due to free-free emission, Hβ flux is estimated as $1.5\text{-}2.1 \times 10^{-15}$erg $cm^{-2}s^{-1}$.

However, the observed flux of Hβ at light minimum as given by Dahari and Osterbrock is 4.07×10^{-15} erg $cm^{-2}s^{-1}$, roughly a factor of 2 larger even without correcting for reddening - thus there might be contamination to the nebular Hβ flux from the chromospheric spectrum even at minimum light. If we assume that Hγ is relatively unaffected by such contamination a comparison of observed and calculated flux leads to E(B-V) = 0.15 (assuming Seaton's curve). Thus a low value of reddening is indicated. With all the uncertainties involved it is consistent with a value of E(B-V) ~ 0.3 derived earlier for the nebula and same as the value estimated for the interstellar medium in this direction.

3.2 Chromosphere

It was pointed out by Nussbaumer and Storey (Ref.13) that λ 6582, λ1761, λ 2386 of CII and occur from the same upper term and have comparable A values and thus can be used to estimate the reddening provided the lines are optically thin. λ 6582 seems to be strongly in emission at many of the phases in the light curve. As mentioned earlier at light maximum λ 1761 occurs in emission (SWP4521) but there is no discernible emission feature at λ2836. If we assume that both lines λ1760 and λ 6582 have been unaffected by optical depth effects then a comparison of these fluxes of λ1760 and λ 6582 would lead to an estimate of E(B-V) for the chromosphere. Taking the A values from Nussbaumer and Storey (Ref.13) the expected ratio is Fλ 6582/F λ1760 = 0.219. After correcting the observed fluxes for E(B-V) = 0.9 using Seaton's (Ref.16) reddening curve, the ratio obtained is 0.21. Thus this estimate of E(B-V) = 0.9 agrees with the one already given by Dahari and Osterbrock.

3.3 The central star

The variability of the energy distribution even at the light maximum and also in the faint phases probably indicates variable circumstellar reddening. Heck et al. (Ref.8) estimate that the UV spectrum at maximum (obtained 1981 September 22) is consistent with E(B-V) = 0 .59 using Seaton's (Ref.16) reddening curve and T(eff) of 29000 K. A study of the differential energy distribution with the 1979 observation would probably show changes in the nature of the circumstellar particles. We tried to change the energy distribution of the 1979 observation (SWP 4521 + LWR 3969, 49) to match Heck et al.'s observation by correcting with (changing) different E(B-V) values. Use of Seaton's reddening curve seemed inappropriate. It looked that we needed a reddening curve which gives more absorption at short wavelengths and less absorption at λ 2200, similar to the reddening curve given by Nandy et al. (Ref.12) for LMC. However the curve below λ 1470 is not adequately matched.

The reddening curve to represent the absorption at light drop at V ~ 15.0 (SWP 10078 + LWR 8773) appears to be different from that described above. A comparison with observation of Heck et al. shows that the minimum energy distribution has less absorption at wavelengths below λ2190 and more in the region of longword increasing with wavelength. Qualtitatively this reddening is similar to the circumstellar extinction curve seen around the star Herschel 36 (Ref.9). Hecht et al. (Ref.9) interpreted this as due to the occurrence probably close to the star of large graphite particles relative to the size distribution causing the normal IS reddening. We did not attempt to fit the observations of V348 Sgr during minimum with any reddening curve but with the analogy of Herschel 36, larger particle size seems to be required (assuming the composition to be the same) than in the previous instance.

4 ABUNDANCES OF THE NEBULA

Estimation of carbon abundance in the nebula is of considerable interest. The absence of CII] λ 2326 emission does show that carbon is underabundant. Following Harrigton et al. (Ref.6) an upper limit to the N (C^+) / N (O^+) ratio is estimated, using [OII] λ2470 flux, as 0.01. Since most of the gas phase C is expected to be in C^+ form and O in O^+ form, this probably would reflect the true abundance ratio of N(C)/N(O) indicating underabundnace of carbon. In contrast the solar value N(C)/N(O) is 0.6. It was indicated by Dahari and Osterbrock that nitrogen abundance might be enhanced.

5 CONCLUSION

The distribution of reddening material in V348 Sgr seems to occur close to the star mostly within the chromospheric region and the nebula is dust free.

This is similar to the situation seen in the hydrogen depleted planetary nebulae like Abell 30.

The chromosphere seems to show greater abundance of carbon, helium and neon, hydrogen being very deficient indicative of mixing with products of helium bruning, whereas, the nebula seem to be carbon poor, nitrogen rich indicative of CN cycle processed material. There seem to be clear abundances separation betwen the nebula and the chromosphere probably indicating that there was very little mixing of carbon to the envelope before the ejection of the nebula.

Table 1.

I U E Data

Image No.	Year	Day	Exposure (Minutes)	Mv
S W P 4521	1979	66	39	12
L W R 3949	1979	66	70	12
L W R 3969	1979	68	76	12
S W P 10078	1980	254	70	15
L W R 8773	1980	254	48	15

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