INFRARED SPECTROSCOPY OF SOUTHERN P CYGNI STARS

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ABSTRACT

Investigations of the 1.0 – 2.5 μm spectra of high luminosity P Cygni stars reveal the presence of several new emission features. All stars measured show emission in the Brackett and Paschen lines of H I, but the emission strengths of He I 1.083, 1.700, and 2.058 μm relative to the H I lines show large variations. Emission lines of [Fe II] are seen at 1.257 and 1.644 μm in several stars and are particularly strong in HR Car. An interesting subset of these stars show the first-overtone CO bands in emission. The presence of this molecular component associated with hot P Cygni stars has not been inferred from previous optical or UV spectroscopy.

INTRODUCTION

Despite their rich optical emission line spectra, the spectra of high luminosity P Cygni stars have until recently received little attention at infrared wavelengths. Circular variable filter spectra of several P Cygni stars have been reported (e.g., Whitelock <u>et al.</u> 1983), but their low resolution makes detailed analysis impossible. Intermediate resolution spectra of P Cygni stars can now be obtained using grating spectrometers and permit detailed study of their infrared emission lines.

OBSERVATIONS AND RESULTS

Infrared spectra of the high luminosity southern P Cygni stars AG Car, CD–27 11944, HR Car, η Car, GG Car, BI Cru, CPD–52 9243, HD 87643, and CPD–57 2874 have been measured in the range 1.0 – 2.5 μm using a cold infrared grating spectrometer. These objects show rich infrared emission line spectra on strong continua due to hot dust emission or free-free emission (AG Car, CD–27 11944, and HR Car). Atomic emission lines of He I, H I, Fe II, [Fe II], and Mg II are present in different objects. The large strengths of high order Brackett lines in many objects indicate clear deviations from

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optically thin Case B recombination theory due to high optical depth in the H I lines. Low excitation [Fe II] emission lines are present in HR Car, CPD-52 9243, η Car, and possibly AG Car. Densities of 10^4 - 10^5 cm^{-3} are inferred from ratios of these [Fe II] lines in η Car (Allen, Jones, and Hyland 1985) and HR Car.

First-overtone CO emission is present in the spectra of HR Car, GG Car, CPD-52 9243, BI Cru, and CPD-57 2874. The same feature was seen earlier in low resolution spectra of CPD-52 9243 and BI Cru (Whitelock *et al.* 1983). CO molecules can not survive in the hot photospheres of these stars ($T \sim 10^4$ K) so this emission must have a circumstellar origin. Either the outer regions of the stellar wind cool sufficiently for CO molecules to associate, or the CO molecules are remnants of an earlier phase of mass loss when the star was a red supergiant (Lamers, de Groot, and Cassatella 1983). Rotational temperatures $T_{rot} \geq 3000$ K are inferred from the band shapes. Vibrational temperatures in the range $2000 \text{ K} \leq T_{vib} \leq 5000$ K account for the relative strengths of the 2-0, 3-1, and 4-2 vibrational bands.

DISCUSSION

The presence of five emission regions is suggested. He I recombination lines require a He II region (I.P. = 24.6 eV) close to the star. Optically thick H I lines are formed in a part of the stellar wind where hydrogen is ionized (I.P. = 13.6 eV) which probably extends beyond the He II zone. The ionization potential of Fe II (16.2 eV) is such that Fe II can exist within the H II volume, but densities in this part of the stellar wind are probably too high for appreciable forbidden Fe II emission. CO emission must originate in part of the stellar wind where hydrogen is neutral since the dissociation potential of CO is 11.1 eV. Fe II is the predominant ionization state in this excitation range, but two pieces of evidence suggest that the CO emitting region is closer to the star than the [Fe II] emitting region. Firstly, no strong correlation exists between the presence of CO and [Fe II] emission features. Secondly, Scoville, Krotkov, and Wang (1980) conclude that CO emission is a dominant coolant in high temperature molecular gases at densities exceeding 10^7 cm^{-3}. This suggests, although it far from proves, that the CO emission originates from regions at higher densities, and hence closer to the star, than those emitting the observed [Fe II] lines. A cool dust component is seen in several objects. The presence or absence of each component then depends on the precise run of both temperature and density in the stellar wind.

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