UV ECLIPSE OBSERVATIONS OF CI CYG

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## INTRODUCTION

Low spectral resolution observations (∿ 6 A) were obtained with the International Ultraviolet Explorer (IUE) during its eclipse phase. Additional data obtained by other IUE groups have been included in our eclipse observations, enabling us to examine the UV spectral properties of this system over nearly an entire orbit that spans early 1979 through mid-1981. Data obtained over this time interval suggest an overall decline in UV emission consistent with the decline of optical emission following the outburst of 1975, where CI Cyg attained an increase of ∿ 3 magnitudes in the visual. The short wavelength spectrum λλ1200-2000 A is characterized by numerous intense high excitation emission lines that become more prominent out of eclipse. The LWR wavelength range λλ2000-3200 A exhibits a few more additional lines of O III, Mg II and He II that are superimposed on continuum that rises gradually with increasing wavelength. Additionally, OH emission bands are identified at λλ3064, 2875 A (cf. Diecke and Crosswhite 1962). Collaborative ground-based observations of CI Cyg with W. Blair of McGraw Hill Observatory suggest the presence of the Balmer continuum jump at λ3646 A, and enables us to ascribe the UV continuum observed with IUE to mainly Balmer free-bound recombination emission.

The variation of UV line intensity with optical phase divides our ensemble of emission lines into two broad groups that are differentiated by ionization potential. Higher excitation permitted lines of N V, for example tend to not weaken in deep eclipse as much as the more moderate excitation emission lines such as Mg II and Si III]. Unblended intercombination lines of N IV], N III], Si III], O III] and C III] indicate clear evidence for eclipse. Permitted lines of N V, C IV and He II appear to increase with time in a secular manner. Mg II appears to have been systematically declining over the observing period. However, very recent spectra obtained well outside of eclipse on 14 August 1981 indicates a substantial enhancement in intensity, for which the doublet has attained intensities comparable to pre-eclipse levels. Variations in C IV λλ1548, 1550 A emission during eclipse are confused owing to



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saturation of these lines. However, the emission lines investigated overall exhibit a relationship between secular change and excitation (see Figure 1).

Except for Balmer continuum and He II λ1640 A, the eclipse in the UV was deeper in the optical intercombination lines, but shallower than optical permitted lines. This is most apparent in the Mg II and N V lines which seemingly did not exhibit eclipse variations as compared to the Balmer continuum that vanished at mid-eclipse. Additionally, absence of variations in the Bowen flourescent excited lines of O III argues for an extended circumstellar nebula in the system that is not significantly affected by eclipse. The general absence of strong forbidden emission and strong emission from permitted lines argues for electron densities in the range $10^4$ to $10^9$ $cm^{-3}$. However, our recent IUE observations of 14 August 1981 that show enhanced Mg II emission also show high excitation ∿ 140 eV emission from forbidden Mg V. The sudden appearance of high excitation forbidden lines well after the hot companion has emerged from eclipse is difficult to explain at present. He II λ1640 A presents different behavior than other permitted lines since it exhibits a rather deep eclipse, contrary to lines such as N V λλ1238, 1242 A (see Figure 2).

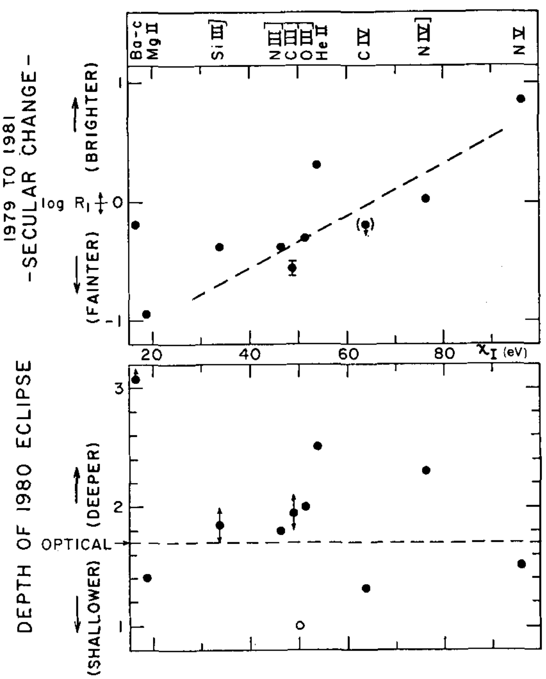


FIGURE 1

## DISCUSSION

These observations are consistent with a binary star model that involves mass transfer from the extended cool envelope of the primary to the compact secondary. The formation of an accretion disc is a transitory phenomena in which viscosity eventually results in the dissipation of the disc over a timescale comparable to the binary orbital period. Emission from a low density circumstellar shell likely explains forbidden lines, for which the illumination of the M giant atmosphere by the intense radiation field of the secondary gives rise to moderate excitation emission, e.g. Mg II λλ2795, 2802 A, and a warm stellar wind from the primary. Secular variations can be used to rule out a simple expanding shell because the higher ionization lines are observed to increase in strength during eclipse, while intercombination lines decrease, contrary to expectation for a radially decreasing density nebula. Rather, we associate the resonance lines of C IV and N V with a large volume emitting region, possibly formed through shock collision from interacting stellar winds from the primary and secondary.

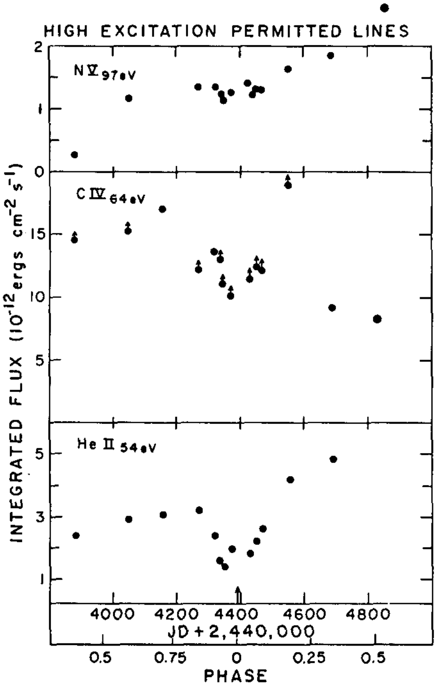


FIGURE 2

The intercombination lines in CI Cyg and Z And show systematic wavelength shifts of +30 ± 10 km $s^{-1}$ relative to the permitted lines, suggesting possible P-Cygni type outflow from the M star (Freidjung et al. 1981; Altamore et al. 1981). A warm wind arising from the M star is reasonable if the giant does not even fill its Roche lobe. If in fact the M star does extend to its Roche limit the stellar wind would become enhanced. The intercombination lines appear to arise from an extended region of increasing ionization toward the hot subdwarf in a Stromgren-like manner. He II λ1640 A, however, strongly reflects eclipse in a manner similar to high excitation intercombination lines, thus departing in behavior from other permitted lines (Figure 2).

The Balmer continuum likely arises from the exterior of a thick accretion disc first demonstrated to exist by Webbink et al.(1981) following the 1975 outburst. We estimate flux of 8 x $10^{-11}$ erg $cm^{-2}$ $s^{-1}$ $A^{-1}$ for the Balmer continuum (λλ2500 to 3646 A). Adopting a distance d ∿ 1500 pc and E(B-V) = 0.5 (Mikolajewska and Mikolajewski 1980), we estimate the Balmer continuum luminosity ∿ 67 $L_\odot$ , which does not include effects of disc inclination.

Scaling laws that relate disc dimensions and luminosities to accretion rates have been developed (cf. Bath et al. 1974, Tylenda 1977 and Mayo et al. 1980), and are

$$L_{disc} \sim 10 \dot{M}_{-8} M R_9^{-1} \quad , \qquad (1)$$

and

$$T_{bl} \sim 3 \times 10^5 M^{\frac{1}{4}} \dot{M}_8^{\frac{1}{4}} R_9^{-0.75} \sim 5 T_{Disc} \quad , (2)$$

where $R_9$ is the inner boundary with radius $10^9$ cm, M is in units $M/M_\odot$ and $\dot{M}_{-8}$ in units of $10^{-8}$ $M_\odot$ $yr^{-1}$. $T_{b1} \sim 50{,}000$ K is obtained from estimates for the Balmer continuum. Equations (1) and (2) are combined to obtain $R_9$ which we find $\sim 10^8$ cm' suggesting that 1 $M_\odot$ white dwarf is present. We stress that this is only a lower limit because we may not have included the disc luminosity, while a main sequence type star $R_9 = 100$ requires $10^{-5}$ $M_\odot$ $yr^{-1}$. The latter corresponds to super-Eddington luminosities if a white dwarf is present, thus mimicing the 1975 outburst. Further analysis is necessary to determine if in fact a white dwarf is present rather than an early main sequence type star, which has important ramifications for the evolution of the system and the mass transfer properties of the binary.

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