THE PECULIAR STAR RX PUPPIS

M. Kafatos
Department of Physics, George Mason Univ., Fairfax, Va., U.S.A.
A. G. Michalitsianos
Laboratory for Astronomy and Solar Physics, NASA, Goddard Space Flight Center, Greenbelt, Md., U.S.A.

ABSTRACT

We have obtained the first high dispersion observations of RX Puppis in the wavelength region 1200 - 3200 Å with the "International Ultraviolet Explorer" (IUE). The anomalies we observed in lines such as He II, C III], C IV, N III], N IV], O III], and Si III], that show split line profiles, Doppler displaced component(s) suggest dynamic activity in circumstellar material that probably has the form of rings and/or gas streamers between the cool giant and the hot companion. The Mg II lines show P-Cygni structure arising in the Mira primary. The continuum cannot be due to a star earlier than A0 II and it may arise in an accretion disk around the hot secondary. Moreover, the line emission requires photoionization either from a hot subdwarf or the inner accretion disk.

1. INTRODUCTION

RX Pup is classified as a symbiotic variable in the "General Catalogue of Variable Stars". As noted by Swings (1970), no evidence of a late-type star was found in its spectrum. Observations by Sanduleak and Stephenson (1973) revealed low-excitation emission lines. An M star could not be confirmed in slit spectra taken by Swings and Klutz (1976) and Klutz, Simonetto and Swings (1978). Swings and Klutz (1976) suggested that RX Pup could be compared to η Carinae or slow-novae like objects. Feast, Robertson and Catchpole (1977) detected variability in the 1-4μ region and argued from this that a Mira is present in RX Pup. Klutz et al. (1978), however, discounted the presence of an M-type star and argued instead that the optical continuum is that of a late B or early A-type giant. The existence of a Mira has been confirmed by the presence of the steam absorption band at 1.9μ (Barton, Phillips and Allen 1979). They concluded that RX Pup is a symbiotic star with a Mira primary. Multi-component P-Cygni profiles of the Balmer lines-and strongest Fe II lines-were detected in 1976 (Klutz et al. 1978). Sharp, blue-shifted absorptions ranging up to 1100 km s^{-1} were seen in 1975, 1976 and 1977.

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2. OBSERVATIONS AND DATA ANALYSIS

We obtained IUE low and high resolution spectra of RX Pup in the SWP region of the spectrum (1200 - 2000 A) and low resolution LWR spectrum (2000 - 3200 A) on Sept. 20, 1980 and June 11, 1981. A high resolution spectrum in the LWR region of the spectrum was also obtained on June 11, 1981. The spectrum of RX Pup is dominated by strong UV lines superimposed on a weak continuum in the SWP part of the spectrum and a fairly rapidly rising continuum in the LWR part of the spectrum. The strongest SWP lines are Si IV and O IV] at $\sim$ 1400 A, N IV] at 1486 A, C IV at $\sim$ 1550 A, He II at 1640 A, O III] at $\sim$ 1666 A, N III] at $\sim$ 1750 A, Si III] and C III] at 1892 and 1909 A respectively. Weaker lines of O I and Si II at $\sim$ 1305 and $\sim$ 1816 A, respectively are also seen. The LWR lines are primarily He II at 2511, 2733 and 3203 A, the Bowen fluorescence lines of O III at 3024, 3047 and 3133 A as well as He I at 2829 and 3188 A. The Sept. 20, 1980 observations are discussed in greater detail elsewhere (Kafatos, Michalitsianos and Feibelman 1981). We found that the continuum remained essentially the same over the two dates. The lines, though, varied somehow the greatest changes being in the Mg II ($\sim$ 3 times increase) and the O III 3133 A line ($\sim$ 2 times increase in the latest observations) the overall fluxes being in the range of $\sim 10^{-11}$ ergs cm^{-2} s^{-1} for the strongest features. The

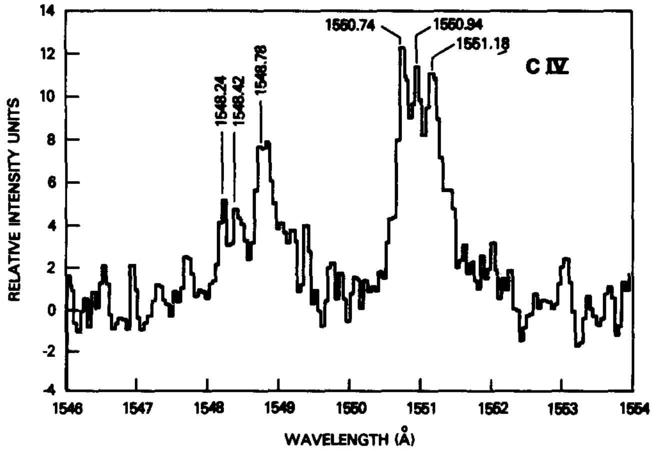

Figure 1. C IV profiles of Sept. 20, 80

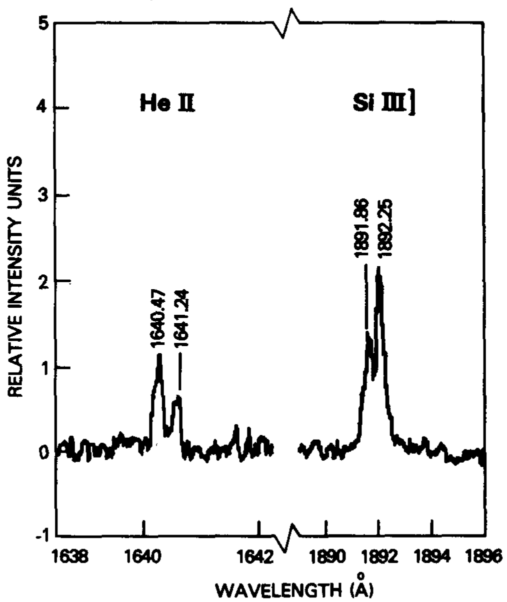

Figure 2. He II and Si III profiles of Sept. 20, 80

high resolution line profiles show complex structure and demonstrate the importance of such observations. Even though the low resolution line emission is similar to other symbiotics such as RW Hydrae (Kafatos, Michalitsianos and Hobbs 1980) the high resolution line profiles are unique. The C IV doublet observed on Sept. 20, 1980 shows components at the rest wavelengths of the two lines as well as two components redshifted from the rest wavelengths by $\sim$ 40 and 90 km s^{-1} (Figure 1). The June 11, 1981 profiles show the same overall flux but significant variations in the detailed profiles, the 1548 A component being much stronger at the latest observation. The He II line shows two components, the strongest centered near the rest wavelength, the weaker redshifted by $\sim$ 170 km s^{-1} (Figure 2). The O III] and Si III] (Figure 2) lines show similar structure, two components located more or less symmetrically on either side of the rest wavelength. The C III] shows a single component while the N III] and N IV] profiles are asymmetric, the red wing dropping abruptly. Larger velocity separations are associated with higher ionization stages. These results were substantially the same in the latest observations. The Mg II profiles obtained on June 11, 1981 are the only ones showing P-Cygni structure in the UV. The separation of the emission from the absorption component is $\sim$ 80 km s^{-1}, this velocity being of the magnitude expected in the Mira primary. Finally, the N V doublet was unseen in Sept. 1980 and became observable in June 1981, indicating an increase in the level of ionization.

Klutz et al. (1978) obtained a value of $\sim$ 1 kpc for this object and E_{B-V} in the range 0.7 - 1.0. Feast et al. obtained $E_{B-V} \sim 0.3$. We estimated values in the range 0.4 - 1.1 using theoretical line ratios of He II (Seaton 1978) and the O III fluorescence intensities (Osterbrock 1974). We find that the UV continuum mimics that of an early F to an early A-type depending on the value of E_{B-V}, but not earlier than A0, contrary to the contention of Klutz et al. (1978) about the existence of a B-type star. For $E_{B-V} = 0.7$, and parameters appropriate to the UV line emission region (T_e = 15,000 K, $n_e \sim 10^9$ - 10^{10} cm^{-3}, $L \gtrsim 10^{13}$ cm) free-free continuum and bound-free continuum make up a substantial contribution to the total observed UV continuum.

We have carried out detailed theoretical analysis of the observed semiforbidden line ratios of C III], N III], N IV], and O IV] (cf. Nussbaumer and Schild 1979). We also used the results of Kafatos and Lynch (1980) for the forbidden lines, which-if present at RX Pup-are very weak. The results are presented in great detail in Kafatos et al. (1981) and are summarized here. We find that electron densities in the line emitting region are $n_e \sim 10^9$ - a few$\times 10^{10}$ cm^{-3} and the size of the line emitting region L $\gtrsim 10^{13}$ cm. The electron temperature is harder to estimate but we find upper limits of 30,000 K at least where the semiforbidden lines and He II $\lambda\lambda$1640 arise. Very likely $T_e \sim$ 15,000 K. We find that carbon is depleted by a factor of $\sim$ 7 similarly to R Aqr (Michalitsianos, Kafatos and Hobbs 1980) and RW Hya (Kafatos et al. 1980). The line analysis implies photoionization in RX Pup, similarly to what Nussbaumer and Schild (1981) find for V1016 Cygni.

3. DISCUSSION AND CONCLUSIONS

The Bowen resonance-fluorescence lines of O III can be used to estimate the number of photons below 228 A (He II Ly continuum photons). We find this number to be 1/10 - 1/30 of the hydrogen Ly continuum photons. The source of the photoionization may be a hot subdwarf or an accretion disk/boundary layer, or a combination of the two.

We find that when we compare the stellar flux F_ν-estimated from our UV line analysis-with theoretical stellar models (e.g. Hummer and Mihalas 1970) that the effective temperature of the secondary star is in the approximate range 75,000 K $\lesssim T_{eff} \lesssim$ 100,000 K and 4.5 $\lesssim$ log g $\lesssim$ 6.0. Such a star would be located in the central stars of planetary nebulae region (Kafatos et al. 1980).

The photoionizing photons may alternatively arise from an accretion disk and its inner boundary layer region. The velocity structure of the line profiles is suggestive of rings of material around and/or streamers onto a secondary. An accretion disk model may not be applicable at all times in RX Pup but it presents an interesting theoretical limit. We have derived a number of useful relations that can be used to obtain the relevant disk accretion parameters from a number of quantities which are in principle observable (Kafatos et al. 1981). We find that the boundary layer temperature (cf. Bath et al. 1974) is in the approximate range 90,000 K - 110,000K. Accretion rates onto the secondary are in the range $\sim 10^{-6}$ - a fewx10^{-5} $M_\odot$/yr and the secondary is very likely a main sequence star. To this date the best candidate of a main sequence secondary accreting material from the M-type primary is CI Cygni (Bath and Pringle 1980; Stencel et al. 1981). Future observations of RX Pup will help in determining whether an accretion disk is required.

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