THE ULTRAVIOLET SPECTRUM OF RX PUPPIS

M. Kafatos and A.G. Michalitsianos
NASA Goddard Space Flight Center
Laboratory for Astronomy and Solar Physics
Greenbelt, MD 20771 USA

ABSTRACT. The UV spectrum of the peculiar star RX Puppis has afforded symbiotic star investigators a wealth of information for unraveling its mysteries. RX Pup and R Aqr, both being of the D-type variety, are now better understood as result of an extended coverage of observations at different wavelengths including radio observations using the VLA. These stars present challenges to our understanding of the symbiotic phenomenon and clues to other astrophysical phenomena like jets. Resolution of the question whether RX Pup has a jet system and an associated system of rings/extended disk or, alternatively, a colliding winds region will be resolved by high resolution radio observations or future observations using the Hubble Space Telescope.

1. INTRODUCTION

RX Puppis is a peculiar, emission line object related to slow novae (Swings and Allen 1972). It contains a 580^d period Mira (Whitelock et al. 1984) with an effective temperature of ∿2400 K (Barton, Phillips and Allen 1979). It, therefore, is a D-type symbiotic. It is not just interesting in itself but also since it may be a link between D-type symbiotics and slow novae.

In the 1940's (Swings and Struve 1941) it displayed a rich high-excitation emission spectrum (cf. Kafatos, Michalitsianos and Feibelman 1982). Night to night variations in the Balmer line intensities were found in 1975 (Swings and Klutz 1976). Multicomponent P-Cygni profiles of the Balmer lines and the stronger Fe II lines were detected in 1976 (Klutz, Simonetto and Swings 1978) with sharp blueshifted absorptions in the Balmer lines ranging up to -1100 km/s. There is an indication of broad P-Cygni structure in the C IV profiles seen by the "International Ultraviolet Explorer" (IUE) although no direct detection of it (Kafatos et al. 1982; Kafatos, Michalitsianos and Fahey 1985). The far UV spectrum of RX Pup obtained with the IUE shows a number of prominent emission lines and a weak continuum. High resolution (HIRES) structure of the strongest UV lines is complex and variable (Kafatos et al. 1985). High excitation lines become present when the star becomes fainter (Allen and

J. Mikolajewska et al. (eds.), The Symbiotic Phenomenon, 245–247.

https://doi.org/10.1017/S0252921100103537 Published online by Cambridge University Press

Wright 1987). In 1982 the UV emission lines became stronger (Kafatos et al. 1985). The multicomponent structure of the C IV profiles seen with IUE is not unique: Recently, observations of the central H II region around R Aqr (Michalitsianos et al. 1987) reveal similar structure as well as HM Sge (Mueller and Nussbaumer 1985). Since R Aqr contains a prominent jet system, there remains the possibility that RX Pup and other D-type symbiotics contain similar structures. RX Pup is a prominent radio source (Seaquist 1977; Hollis et al. 1986; Seaquist and Taylor 1987) and reveals extended radio structure (Hollis et al. 1986) but due to its greater distance compared with R Aqr it does not afford us as much detail as that revealed in high resolution VLA maps of the latter object. The IR properties of RX Pup are complex. The presence of the Mira is only revealed from J and L photometry (Whitelock et al. 1983). The decline in the visual light cannot easily be attributed to variations in either the hot or the cool component (Whitelock et al. 1984).

2. MODELS OF RX PUPPIS

The 1548/1550 C IV intensity ratio has been observed to be always less than unity (Kafatos et al. 1985). Typical velocity differences between individual components are 40 - 50 km/s. The anomalous doublet ratio of the C IV profiles has been attributed to the existence of a hot wind with $700 \lesssim v_w \lesssim 1000$ km/s (Kafatos et al. 1985; Michalitsianos et al. 1987). Michalitsianos et al. (1987) plot the 1548/1550 ratio versus the IUE FES magnitude or versus the C IV line intensity and find an inverse relationship. This they dub the "CIV doublet ratio-intensity effect". It is also found in HIRES profiles of the central H II region surrounding R Aqr. The mass loss in the hot wind in both stars is very small, $\dot{M} \lesssim 10^{-11}$ $M_\odot$/yr, much less than the cool wind emanating from either the Mira or the outer regions of a cool disk. The colliding wind model for RX Pup (Allen and Wright 1988) would meet then with difficulties in the sense that the hot star wind is negligible in terms of dynamics and is only discernible in the C IV profiles. To date two models have been proposed for RX Pup:

Kafatos et al.(1985) proposed a model involving an extended disk which has broken up into rings. Their conclusion is based on the fact that the kinematic properties of the C IV profiles defy a simple colliding wind model and that the components are remarkably constant in velocity space. The rings shroud the hot star but allow photoionizing radiation to escape perpendicular to the equatorial plane. Kafatos et al. (1985) offer the ring model as the most viable since very long orbital periods ($\gtrsim$ 50 yr) are not known for any D-type symbiotic including RX Pup (Whitelock 1987). The system of rings is embedded in the hot wind. A cool wind probably engulfs the Mira and the hot star.

Allen and Wright (1988) have offered a colliding wind model for RX Pup. They argue that the viscosity parameter $\alpha \sim 0.01$ required by the ring model is too low. While the viscosity parameter is low compared to what is suspected for dwarf novae (Pringle 1981) it is still not unreasonably low. As in the Kafatos et al. (1985) work, Allen and Wright (1988) assume the presence of the hot star wind. Their mass loss rates are in the range 10^{-5} - 10^{-4} $M_\odot$/yr, in disagreement with the value that

https://doi.org/10.1017/S0252921100103537 Published online by Cambridge University Press

one obtains from the presence of the absorption trough in the λ1548 profile (Michalitsianos et al. 1987). Moreover, the orbital period of the two stars in the Allen and Wright (1988) model is thousands of year, unreasonably high for the symbiotic phenomenon. Finally, Allen and Wright conclude that the hot star would be radiating $L \sim 5 \times 10^4\ L_\odot$, more than the $10^4\ L_\odot$ luminosity of the Mira (Kafatos et al. 1982). Without the disk/ring system, the hot component in RX Pup should be fully exposed and produce an intense continuum both at optical and UV wavelengths. Such a hot star continuum has never been observed.

Both models have some common properties (the hot star wind) and it is obvious that RX Pup continues to provide many challenges as to its nature. One should perhaps accept the possibility that no simple model can explain all the observed features of RX Pup. We have to emphasize that the models of Seaquist and Taylor (1987) and Allen and Wright (1988) depend on the assumption of the presence of spherically symmetric optically thick winds. If radio observations of RX Pup reveal instead extended structure which implies jet activity, those models will become untenable. Due to the large distance of RX Pup any jet structure in this star similar to R Aqr will have sub-arcsec features. VLA observations and future Hubble Space Telescope observations provide the only available means to discern the structure of this most interesting star. It is obvious that long-term observations will help establish the binary properties and outburst mechanism of RX Puppis.

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