UV PROPERTIES OF SYMBIOTIC STARS

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1. INTRODUCTION

Symbiotic stars are suspected to be binary systems of large dimensions in which one star is a cool primary giant (regular M-giant or Mira-type variable) and the secondary a hot subdwarf (Boyarchuk 1982) or even a main-sequence star with an accretion disk around it (Bath and Pringle 1982). Observations of symbiotic stars in the far ultraviolet with the "International Ultraviolet Explorer" (IUE) enable us to determine the properties of the system in the binary picture. A number of critical observations are needed to do this including an estimate of the photoionizing radiation and the temperature of the photoionizing source.

2. UV LINES AND CONTINUUM

Observations of semi-forbidden lines in the UV enable us to obtain estimates of the relevant physical parameters in the photoionized nebula surrounding the system (n_e, the electron density, T_e, the electron temperature). Various semi-forbidden lines have been observed in symbiotic star systems (e.g. Kafatos, Michalitsianos and Hobbs 1980) including the N III], N IV], C III], O III], O IV], Si III] lines. These lines permit the determination of nebular parameters (Nussbaumer 1982). The minimum size of the nebula can also be obtained both from semi-forbidden and allowed lines. The line flux can be written as

$$F \propto n_e^2 \, L^3 \, f_g / d^2 \qquad (1)$$

where F is the line flux, d is the distance of the source, f_g is a geometric factor $\lesssim 1$ (the equality holds when the region is spherical) and L is the minimum size of the region. Using the observed C III] λλ 1909 and He II λλ 1640 strengths, I find that L ranges from a low of a few x 10^{12} cm in Z And through typical values of a few x 10^{13} cm in RW Hya and SY Mus to a high of a few x 10^{14} cm in giant systems such as R Aqr and V1016 Cyg. The electron densities range from a low of a few x 10^6 cm^{-3} in R Aqr and V1016 Cyg to typical values of a few x 10^9 - a few x 10^{10} cm^{-3} in most symbiotics. Typical electron temperatures are $T_e \lesssim 20,000$ K. The UV continuum either directly shows the existence of a hot subdwarf (RW Hya, for example) or is flat (R Aqr) or slightly rises with increasing

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λ indicating a free-free, recombination nebular continuum (RX Pup). Reddening corrections can be applied and these are typically E_{B-V} ∿.3. The distances are unknown for most systems but based on estimates of the red giant luminosity are in the range of 1000 pc.

3. HOT SUBDWARF MODELS

In symbiotics where the stellar continuum can be observed a lower limit to the effective temperature can be obtained and this is typically 30,000 - 40,000 K. Applying the Stromgren criterion to the photoionized nebula the number of hydrogen Lyman continuum photons can be obtained and from the O III fluorescence lines the He II Lyman continuum can be obtained. Obtaining the ratio of these two continua the effective temperature of the hot subdwarf is estimated and from the total number of photoionizations in the nebula the size of the subdwarf can be obtained. I find that T_{eff} ranges from 80,000 K to 125,000 K for most symbiotics. The companion of R Aqr has to be cooler than 35,000 K. The symbiotic star hot subdwarfs are typically a few x 100 - a few x 1000 $L_\odot$ and, therefore are similar to the central stars of planetary nebulae.

4. ACCRETION DISK MODELS

Alternatively, some symbiotics may contain main sequence companions or subdwarfs but with an effective photosphere equal to that of a main sequence star. This model has been applied with success to CI Cyg (Bath and Pringle 1982). I have derived equations that give estimates of the accretion rate onto the secondary $\dot{M}$, the effective photospheric radius of the compact star R_*, the disk luminosity L_d, the efficiency of accretion β (of changing accreted mass into radiation) and the cosine of the angle between the line of sight and the perpendicular to the disk. What one needs is the total number of photoionizing photons and an estimate of the inner boundary layer temperature (obtained from the presence of certain high excitation ions). I find that typically $R_* \sim$ a few x 10^{10} cm, $L_d \sim$ a few hundred $L_\odot$, $\dot{M} \sim$ a few x 10^{-5} $M_\odot$/yr and $\beta \sim$ a few x 10^{-6}. The disk luminosities are at most a few percent of the Eddington luminosity and, therefore, quiescent accretion onto a companion with an effective photosphere of a main sequence star can explain the quiescent state of symbiotic stars. The accretion becomes, of course, much higher during outbursts. The presence of an accretion disk is very plausible in the case of systems like CI Cyg and R Aqr (Michalitsianos and Kafatos, present volume) but may not be required in all symbiotics at all times.

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