IUE AND ROSAT SURVEY OBSERVATIONS OF SYMBIOTIC STARS

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ABSTRACT The set of long-period, interacting binary stars, known as Symbiotics, offer an excellent opportunity to examine the atmospheric structure and state of evolution of the red giant and AGB stars in such systems. Mass transfer, leading to UV and X-ray enhancements, is modulated as a function of mass loss rate, stellar wind acceleration and homogeneity, and degree of Roche lobe filling by the red giant. In addition, many of these sources exhibit radio lobes indicative of jets, suggesting the formation of large scale jets and shocks. We report here some preliminary results of coordinated IUE and ROSAT all sky survey (RIASS) observations of selected Symbiotics, including AG Dra and CH Cyg. While the line fluxes in AG Dra have declined since the early 1980s, the X-ray emission measure appears to have increased. The upper limit on X-ray output of CH Cyg provides new constraints for the dust formation and starspot models in that system.

Keywords: ultraviolet spectra; IUE; X-ray observations; ROSAT; interacting binaries; symbiotic stars

INTRODUCTION

For several decades, cool evolved stars in binary systems have been studied by use of the hot companion as a probe of the atmospheric structure. The yellow and red supergiants in widely separated ζ Aur and VV Cep binaries (see Hack and Strickland, 1987) have been successfully explored in this way. The analysis of red giants in binaries has been complicated by stronger effects of interaction (see Stencel 1987), although a promising attempt to map the velocity profile in EG And has been made by Vogel (1991), using some of the original eclipse discovery IUE data of Stencel (1984). Further progress should be possible using eclipsing symbiotics containing either Mira/AGB stars or first ascent red giant branch primary stars (see Judge, these Proceedings).
The study of the class of long period interacting binaries, known as symbiotic stars, underwent a renaissance as a result of early Einstein X-ray detections and the first few years of IUE observations of these sources. Known optically for their combination of red giant (cool, molecular absorption bands) and nebular (semi-forbidden emission lines) spectral features, IUE spectra have clarified in many cases the nature of the hot companion by revealing the far UV continuum characteristic of 50,000K sources. Einstein and EXOSAT observations have placed constraints on high temperature emission measures in the presumed disks in these interacting binaries. In addition, access to the UV transitions of abundant ions has made it possible to derive more precise motions and abundances in these systems (cf. Nussbaumer and Stencel 1978). The analogy between symbiotics and active galactic nuclei, in terms of morphology (radio and optical jets) and spectra (emission line profiles) has begun to receive increasing attention (cf. Penston 1987; Judge 1991).

Nevertheless, symbiotics exhibit a bewildering array of observed phenomena that defy simple interpretation. For example:
- UV emission lines of AG Peg and RX Pup for example, are broad and complex, and differ from ion to ion. These differences could arise from formation in an extended accretion or wind-wind shock structure;
- R Aqr is enveloped in a vast, arc minute sized bipolar nebula, with jets. This is thought to be the residue of a hundred year old thermal pulse of the Mira, modulated by the binary interaction;
- thermal emission at radio wavelengths has a spectral index average of about 0.9 that is not readily explained;
- Mira symbiotics show greatly reduced maser emission in OH, H$_2$O and SiO compared to normal Miras, etc. This could depend on the far UV ionizing flux of the hot companion.

In each case, the "normal" behavior of a red giant or AGB star is changed by the intervention of the companion's mass, radiation field and stellar wind. Therefore, the extent of change as a function of companion type, could provide a way to reveal the underlying red giant characteristics.

Prior to ROSAT, only a handful of the symbiotics were observed by X-ray telescopes. The majority of these appear to be very soft X-ray sources. Analysis of the limited spectral information suggests the signal originates in a moderate density region at temperatures of several times 10$^5$K. Theory argues that such heated regions would occur in the wind-wind shock interface between the components of the binary. Thus, it is plausible that the majority of all known symbiotics are X-ray sources at some level.

**CASE STUDIES: AG Dra and CH Cyg**

AG Dra is (so far) the brightest X-ray symbiotic. It is an essentially unreddened, dust-free (s-type) object with a K3 spectrum plus emission lines of H I and He II (Kenyon 1986). Kenyon and Webbink (1984) argued that the 1981 outburst was powered by thermonuclear runaway processes. Reportedly, the ROSAT WFC also detected AG Dra (G. Bromage, private communications).

Viotti et al. (1984) report on the IUE spectral changes during the 1980-83 outburst. Comparing recent spectra with these (Figure 2), it is clear that AG Dra is relatively quiescent compared with the outburst epoch.
Anderson, et al. (1981) reported the Einstein detection of AG Dra and derived a log column density ($N_H$) of 20.5 and log emission measure [EM] of 55.4 and a log Temperature of 6.04 [K]. Preliminary ROSAT survey observation reductions find log $N_H = 20.1$, log EM = 55.8 and log $T = 5.8$. Therefore, one has the impression that the system has cooled slightly since the flare event in the early 1980s.

For the case of AG Dra, the observed He II 4686 flux indicates approximately $2 \times 10^{44}$ He$^+$ ionizing photons are absorbed every second into the AG Dra nebula. The luminosity in absorbed He$^+$ photons, about $2 \times 10^{44}$ ergs/sec, exceeds the luminosity of the source deduced from the X-ray flux by a factor of two! The degradation of the X-rays by the surrounding nebula thus causes an underestimate in the actual source luminosity, which can be recovered only by an accurate estimate of the soft X-rays absorbed locally. Since V1016 Cyg and HM Sge also have strong and variable He II 4686 emission lines, the X-rays emitted by these objects are poorly determined.

A second example of how symbiotics might contribute to understanding of red giant star mass loss behavior is given by CH Cyg (HD182917). In addition to showing an M7 III (SRb) spectrum, there is evidence for a magnetic white dwarf companion and associated multi-periodicities of 500 sec, 100 days and 770 days (Mikolajewski et al. 1990) in addition to the arc-second size bipolar nebula observed optically and at radio wavelengths. Taranova (1990) had proposed that some of the long term variations in the Mira-like behavior could be explained in terms of dust condensation in the outer atmosphere, whereas Mikolajewski et al. (1991) argue for the presence of large, long-lived starspots.

Maggio, et al. (1990) report an Einstein X-ray flux upper limit of $1.5 \times 10^{-13}$ ergs/cm$^2$/s. Preliminary analysis of ROSAT data suggests an upper limit of this order, as well. AO1 pointed observations (Kafatos) may show differently.

The IUE observations suggest continued decline since the flare-like events of the early 1980s, when compared with Mikolajewska, Hack and Selvilli (1988) who analyzed the 1979-1986 spectra.

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