A study of the mass loss rates of symbiotic star systems

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Abstract. The amount of mass loss in symbiotic systems is investigated, specifically mass loss via the formation of jets in R Aquarii (R Aqr). The jets in R Aqr have been observed in the X-ray by Chandra over a four year time period. The jet changes on times scales of a year and new outflows have been observed. Understanding the amount of mass and the frequency of ejection further constrain the ability of the white dwarf in the system to accrete enough mass to become a Type 1a supernova progenitor. The details of multi-wavelength studies, such as speed, density and spatial extent of the jets will be discussed in order to understand the mass balance in the binary system. We examine other symbiotic systems to determine trends in mass loss in this class of objects.

Keywords: symbiotics, mass accretion, R Aqr
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INTRODUCTION

Symbiotic systems, a hot compact object usually a white dwarf and a main sequence red giant, have gained recent attention as the possible progenitors to Type 1A supernovas. To reach a Type 1a SN progenitor the white dwarf must approach 1.4 M⊙, however, most of the white dwarfs in these symbiotic systems have masses < 1 M⊙. An accretion disk around the white dwarf is normally invoked as part of the method of mass transfer from the red giant to the white dwarf. There is great uncertainty as to the method of mass transfer and the efficiency of that transfer from the red giant to the white dwarf as well as the amount of mass loss from the white dwarf in nova events and jets. As of 2000, there were 188 symbiotic systems and at least 15 had extended outflows or jets [1]. R Aquarii is unique as it has a spatially extended and resolved x-ray jet. CH Cyg has been shown to have a jet with x-ray emission but at a much smaller spatial extent [5]. This proceeding delineates the mass involved in the jet of R Aqr as well as a discussion of 5 other symbiotics with jets.

OBSERVATIONS

The Chandra X-ray observations of the R Aqr jet are detailed in Kellogg et al. [11] and Kellogg et al. [12]. The bright x-ray emission in the Northeast (NE) jet moved with a tangential motion equivalent to ~600 km s⁻¹ in 3.3 yr time interval between the two Chandra observations. The SW jet, easily seen in 2000.7 observation is essentially absent in the 2004.0 observation. Initially, the mass of the jet was calculated assuming a cylindrical system. This calculation did not take into account the true spatial extent
TABLE 1.  R Aqr Jet in Multiple Wavelengths

| Quantity                  | Radio \(^{(a)}\) | Optical \(^{(b)}\) | UV | X-ray \(^{(c)}\) |
|---------------------------|------------------|-------------------|----|-----------------|
| Distance from Central Source | 1-9"             | 1-10"             | 1-4" | 10"            |
| Length                    | 10"              | 6"                | 4"  | 5"              |
| Mass (M\(_\odot\))       | 3 \times 10^{-5} | 5 \times 10^{-6}  | 2.3 \times 10^{-5} \(^{(d)}\) | 4 \times 10^{-8} |
| Density (cm\(^{-3}\))    | 2 \times 10^{3}  | 10^{3} (NW)       | 10^{3} \times 10^{4} \(^{(e)}\) | 100             |
| V (km s\(^{-1}\))        | 300              | 80-130            | 36-235 \(^{(f)}\)           | 380             |

\(^{(a)}\) All radio values are taken from Dougherty et al. [3], \(^{(b)}\) All Optical values are taken from Hollis et al. [7], \(^{(c)}\) All x-ray quantities are taken or derived from Kellogg et al. [11, 12], \(^{(d)}\) Kafatos et al. [10], \(^{(e)}\) Meier & Kafatos [13], \(^{(f)}\) Hollis et al. [8]

Mass Loss Through Jets and Outbursts

The two spatially closest symbiotic systems, R Aqr and CH Cyg have x-ray jets. Five other symbiotics are reported to have jets observable in other wavelengths and are summarized in Table 2 although the exact rate and amount of mass loss is unknown as the jets are transient and not monitored in all wavelengths. Red giant mass loss rates through winds in symbiotic systems range from 10^{-9} - 10^{-6} M\(_\odot\) yr\(^{-1}\). If we again assume that 10% of the wind is transfered to the white dwarf the accretion rates are of
TABLE 2. Symbiotic Jets

| Object     | RG Mass Loss Rate (M\(_\odot\)/yr) | Accretion Rate (M\(_\odot\)/yr) | Jet Mass (M\(_\odot\)) | Compact Object |
|------------|-----------------------------------|---------------------------------|------------------------|----------------|
| R Aqr      | 2.7 \times 10^{-7} \(^{(a)}\)     | 10^{-8}                         | 5 \times 10^{-5}      | 0.8 \(^{(b)}\) |
| CH Cyg     | 2.7 \times 10^{-6} \(^{(c)}\)     | 3 \times 10^{-7} \(^{(d)}\)    | 0.44 \(^{(e)}\)      | *              |
| Z And      | 4 \times 10^{-8} \(^{(f)}\)       | \(< 2 \times 10^{-7} \(^{(g)}\) | 0.65 \(^{(h)}\)      | 0.5 \(^{(i)}\) |
| MWC 560    | 5 \times 10^{-7} \(^{(j)}\)       | 1 \times 10^{-11}              |                        |                |
| StH\(\alpha\) 190 \(^{(j)}\) | 5 \times 10^{-8} \(^{(j)}\)    | 2.5 \times 10^{-7}              |                        | 0.5 \(^{(i)}\) |

* a. Hollis et al. [6], b. Hollis et al. [9], c. Skopal et al. [20], d. Galloway & Sokoloski [5], e. lower limit from Ezuka et al. [4], f. Seaquist & Taylor [19], g. Brocksopp et al. [2], h. Schmid & Schild [17] (i) All MWC560 values taken from Schmid et al. [18], (j) Munari et al. [15], (k) Munari et al. [16]

the order \(10^{-10} - 10^{-7}\) M\(_\odot\) yr\(^{-1}\). Since jet formation is also poorly understood, 10% of the accreted mass on the white dwarf could go into the jet giving an available jet mass rate of \(10^{-11} - 10^{-8}\) M\(_\odot\) yr\(^{-1}\).

The red giant winds in Table 2 range from \(10^{-8} - 10^{-6}\) M\(_\odot\) yr\(^{-1}\), giving accretion rates of \(10^{-9} - 10^{-7}\) M\(_\odot\) yr\(^{-1}\). The jet masses from observations however, vary from \(10^{-5}\) to as little as \(10^{-11}\) M\(_\odot\) in StH\(\alpha\) 190. These jet masses imply that the rate at which the mass of the jet is ejected must be higher than expected.

In CV’s it is proposed that in order to form a jet the mass accretion rate had to be between \(10^{-7} - 10^{-6}\) M\(_\odot\) yr\(^{-1}\)[21]. However, as gleaned from Table 2, symbiotics form jets, even x-ray jets (strong jets), with lower accretion rates than the CVs. As for symbiotics, it seems that jet formation can occur with accretion rate from the red giant to the white dwarf as low as \(10^{-8}\) M\(_\odot\) yr\(^{-1}\).

**CONCLUSIONS**

Can the white dwarfs in symbiotic systems accrete enough mass to become Type Ia progenitors? There is a balance that needs to be struck with the outflow of material and the influx of material onto the white dwarf. Symbiotics have the correct population to be the progenitors of Type Ia [14]. The determining factor is the mass accretion rate onto the white dwarf. Three parameters are necessary, the red giant wind to white dwarf mass transfer rate, the disk to white dwarf mass transfer rate and the formation of the jet by the white dwarf. By careful observations, simulations and modeling of these parameters, a further constraint on the possibility of growing symbiotic white dwarfs can be reached.

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