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Infrared Observations of Symbiotic Stars

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Abstract. Near infrared measurements in the J, H and K bands have been carried out for a number of symbiotic stars with the 1.5 m telescope at the Rothney Astrophysical Observatory (RAO). A comparison with the earlier observations shows that the S-type symbiotic stars do not have any significant variation in the infrared flux over the past five years. However a small variation ~ 0·3 magnitude in the infrared flux has been detected for CH Cygni. The observations of HM Sagittae show large decreases in the infrared flux compared to the previous measurements. The variability in the infrared fluxes of both these objects could be attributed to a variation in the temperature due to the cooling of the dust shell. The variability observed for V1016 Cygni is found consistent with the previous measurements.

Key words: Symbiotic stars—infrared photometry—Mira variables—circumstellar dust shell—red giants—extinction—accretion disc

1. Introduction

Symbiotic stars are considered to be interacting binary systems composed of a late type M red giant and a hot component as either an accreting solar type main sequence star or a nuclear shell burning white dwarf (Kenyon and Webbink 1984; Kenyon 1986; Whitelock 1987; Mikolajewska *et al.* 1988). These objects are found to be associated with intense emission lines and show irregular variability in visual brightness and also undergo remarkable spectral changes. Some of them are eruptive variables, e.g. CI Cygni and V1016 Cygni (FitzGerald and Pilavaki 1974). Detailed reviews on the properties of symbiotic stars are found in Swings 1970; Allen 1979; Sahade 1982; Kenyon 1988.

An understanding of the status of the late-type star is important for developing binary models for the symbiotic systems as it effects the transfer of matter needed to activate the hot component. Several symbiotics contain very evolved Mira variables (Whitelock 1987) or lobe-filling normal red giants (Garcia 1986). One expects high mass-loss rates from the cool companion for producing the symbiotic phenomenon. It is important to determine whether red giants exhibit higher mass-loss rates in symbiotic systems compared to single red giants. Infrared observations have been very useful in probing the nature of late-type stars in symbiotic systems.

Near infrared broad band photometry (Webster & Allen 1975) has indicated a 2500 K–3500 K black body and that the S-type symbiotics are associated with normal

M star (Frogel *et al.* 1979). The 2.3 μm CO emission indicates that the cool component for some systems is an evolved red giant or supergiant (Allen 1982; Kenyon & Gallagher 1983). The D–(dusty) type symbiotic stars have infrared spectra with color temperatures of 1000 K resembling obscured M stars (Merrill & Stein 1976). Many of the D-type systems also display periodic variability similar to that of a Mira variable (Allen 1982). The mass transfer in the S-type symbiotics is presumably through the inner Lagrangian point and for the D-type symbiotics the companion accretes the matter from the general stellar wind (Feast *et al.* 1977). The presence of non-Roche lobe filling giants in some symbiotic systems cannot be explained from the existing theories and may provide an important input for understanding the mass transfer in the binary system (Kenyon & Gallagher 1983; Kenyon 1988).

Near infrared observations of symbiotic stars indicate that the late type components in this system range from normal red giants to bright asymptotic giants. The infrared excess requires their cool components to lose more mass than single red giants (Kenyon 1988). Whitelock (1987) showed that symbiotic Miras exhibit an infrared excess which could be attributed to thermal emission from dust and represent a combination of 2500 K Mira with an 800 K dust shell. These objects also show long period infrared variability of 1.5 to 2.0 magnitudes at J band (Whitelock *et al.* 1983; Ipatov *et al.* 1985; Kenyon 1988). Further the (J–K) and (K–L) color diagrams showed that these objects are mostly located along the locus representing the combination of star and dust shell (Whitelock 1987).

IRAS observations showed that in S-type symbiotics the infrared distribution is similar to that of normal M giants and that free-free emission may also contribute to the infrared emission at 12 μm and 25 μm. The D-type symbiotics show infrared distributions similar to Mira variables and the hot components in these binaries appear to lie outside the dust shell surrounding the Mira companion (Kenyon *et al.* 1986). The D-type symbiotics show the presence of silicate features (Roche *et al.* 1983) which do not occur for the S-type symbiotics. It is possible that the infrared excess may also be contributed by the hot component. Thus any model which includes the UV radiation emitted by the hot component should also consider the amount of radiation absorbed or re-emitted at infrared wavelengths by dust grains.

We have carried out infrared photometric measurements in J, H and K bands for symbiotic stars in order to investigate their long term variability. The results are presented and discussed in this paper.

2. Observations and discussions

The observations for ten symbiotic stars were carried out from the 1.5 m telescope at the Rothney Astrophysical Observatory (RAO) Priddis, Alberta during the period August to December 1991. The star brightness was measured by using a liquid nitrogen cooled InSb photometer with a 30″ aperture and standard broad-band JHK filters. Observations were made using the standard techniques of vibrating the secondary of the telescope between the sky and star + sky at a chopping frequency 10 Hz. The star signal is derived by nodding the telescope between two different portions of the sky separated by ~ 60″ in order to reduce the sky background noise and for determining the fluxes accurately. Standard stars such as Alpha Lyrae and Alpha Cygni were used for atmospheric extinction corrections during each night.

Our observations included eight S-type symbiotics and two D-type symbiotics which are considered to be variable symbiotics. After correcting for atmospheric extinction, the magnitudes in the Kitt Peak standard system (Koorneef 1983) were determined using the standard software programs and methods described by Dougherty *et al.* (1991).

The near infrared magnitudes and the errors derived for S-type symbiotic stars are shown in Table 1 and similarly for variable symbiotic stars in Table 2. The magnitudes derived by Kenyon (1988) from the earlier observations and the (J–K) and (H–K) colors are also given in the same table. Figure 1 plots the (J–K) and (H–K) color–color diagram for the S-type symbiotic stars. It is evident from the figure that the near

Table 1. Infrared observations of symbiotic stars.

Name	Obs	J(1.25 m)	H(1.65 m)	K(2.2 m)	J–K	H–K
1. BF CYG	7@	7.48	6.54	6.23(0.04)	1.25	0.31
	3*	7.35(0.29)	6.43(0.05)	6.11(0.02)	1.24	0.32
2. CI CYG	8@	5.76	4.79	4.48(0.02)	1.28	0.31
	3*	5.60(0.23)	4.74(0.17)	4.41(0.12)	1.19	0.33
3. CH CYG	5@	0.76	−0.23	−0.68(0.02)	1.44	0.45
	3*	1.14(0.09)	0.11(0.09)	−0.43(0.13)	1.57	0.54
4. VI329 CYG	6@	8.25	7.27	6.87(0.04)	1.38	0.40
	2*	8.29(0.19)	7.28(0.13)	6.86(0.15)	1.43	0.42
5. AG PEG	6@	5.06	4.17	3.93(0.03)	1.13	0.24
	3*	5.04(0.19)	4.17(0.18)	3.94(0.14)	1.10	0.23
6. AX PER	3@	6.67	5.73	5.45(0.04)	1.22	0.28
	2*	6.69(0.09)	5.71(0.05)	5.49(0.07)	1.20	0.22
7. Z AND	4@	6.13	5.24	4.95(0.03)	1.18	0.29
	2*	6.01(0.01)	5.15(0.07)	4.86(0.10)	1.15	0.29
8. EG AND	3@	3.67	2.79	2.59(0.02)	1.08	0.20
	4*	3.58(0.03)	2.76(0.09)	2.68(0.18)	0.90	0.08

@ S. J. Kenyon (1988).
* Present observations.

Table 2. Infrared observations of variable symbiotic stars.

Name	JD	J(1.25 m)	H(1.65 m)	K(2.2 m)	J–K	H–K
HM SGE	@45981	7.53	5.81	4.25	3.28	1.56
	@46226	7.22	5.59	4.16	3.06	1.43
	@46541	7.53	5.78	4.15	3.38	1.63
	@46718	7.59	5.75	4.11	3.48	1.64
	*48542	8.77(0.02)	6.97(0.02)	5.24(0.03)	3.53	1.73
V1016 CYG	@45981	7.03	5.66	4.33	2.70	1.33
	@46226	7.88	6.60	5.20	2.68	1.40
	@46541	6.63	5.41	4.21	2.42	1.20
	@46718	7.79	6.50	5.16	2.63	1.34
	*48520	6.60(0.24)	5.34(0.05)	4.40(0.09)	2.20	0.94

@ S. J. Kenyon (1988).
* Present observations

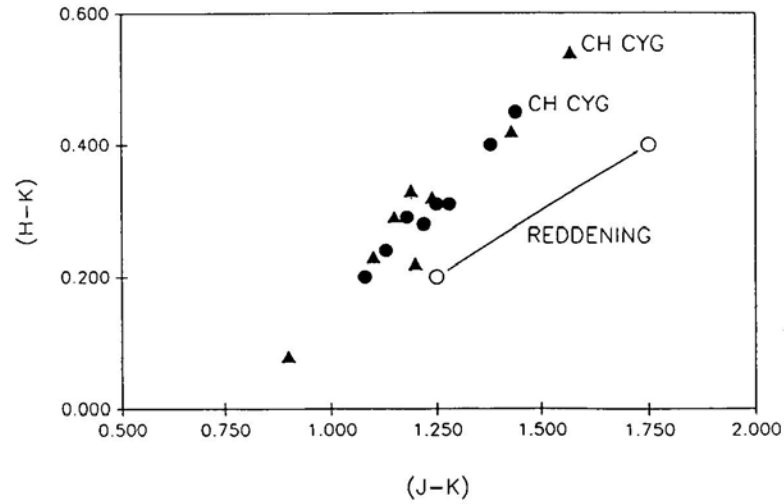

Figure 1. The distribution of S-type symbiotic stars in the (J–K) and (H–K) color–color diagram. The measurements of Kenyon (1988) are indicated by dots (●) and our measurements are shown by triangles (▲). Note the shifting of the position of CH Cygni.

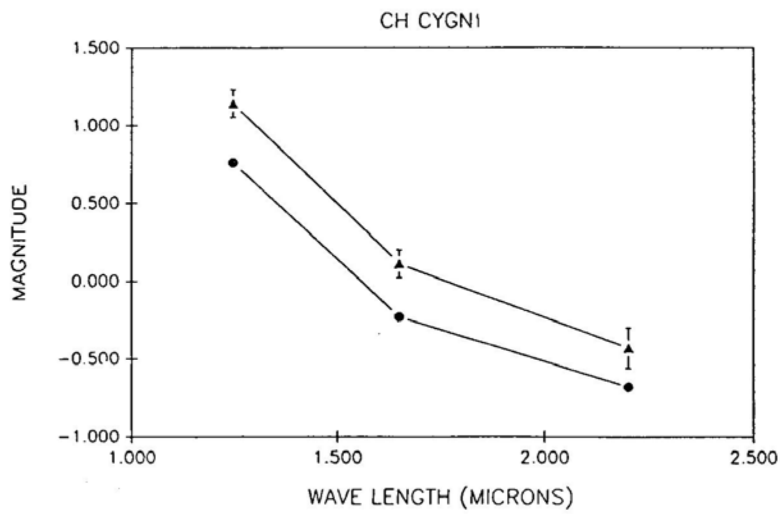

Figure 2. The near infrared energy distribution for CH Cygni. Our measurements are shown by triangles (▲), and the measurements of Kenyon (1988) are shown by dots (●).

infrared fluxes and (J–K) and (H–K) colors for the S-type symbiotic stars (except CH Cygni) do not show any significant departures from the previous measurements. The near infrared spectrum of CH Cygni plotted in Fig. 2 indicates a small decrease in the flux of ~ 0.3 magnitudes in all three bands.

CH Cygni has moved upward right in the color–color diagram, consistent with the reddening law within the errors of observation. Thus the reduction in the infrared emission may be attributed, to a change in temperature or a change in extinction of the dust shell surrounding the stellar object.

CH Cygni has been extensively studied in the past and shows variability in the visual region on time scales of minutes to years (Slovak & Africano 1978). The model for CH Cygni is composed of an M giant and a white dwarf which interacts with the stellar wind of the M giant. Yamashita & Maehara (1979) suggested a 15.75 year orbital period for the object, whereas Hack & Selvelli (1982) argued that the binary hypothesis is not applicable. Optical and near infrared photometry of CH Cygni (Milone *et al.* 1986), showed at least two sources of variation: an M giant and a much cooler source probably a dust shell. The IRAS infrared observations show the presence of a circumstellar shell. From the X-ray observations of CH Cygni, Leahy & Taylor (1987) find short term variability of several minutes observed consistent with the emission from a boundary layer between an accretion disc and a white dwarf. Our observations of variability in the near infrared flux supports the dust shell model. However more observations are required to determine whether the variability is due to changes in the temperature or the extinction of the dust shell.

The near infrared fluxes measured for the two variable symbiotics HM Sagittae and V1016 Cygni are given in Table 2 with the previous measurements (Kenyon 1988) and shown in Figs. 3 and 4. HM Sagittae exhibits a large change of ~ 1 magnitude compared to the observations reported earlier by Kenyon (1988). Further we find that during 1985–1991 (JD. 2446226–2448542) there is a systematic increase in both (J–K) and (H–K) color excess.

Ipatov *et al.* (1985) showed that HM Sagittae continues to undergo changes in the infrared fluxes from 1978–1983 as detected earlier by Taranova & Yudin (1983) and no appreciable changes in the infrared energy spectrum was seen. From observations during 1983–1985, Kenyon (1988) concluded that the infrared spectrum of HM Sagittae is similar to the Mira variables. The near infrared variation in these objects is caused by large amounts of circumstellar absorption rather than dust emission (Whitelock 1987, 1988; Kenyon 1988). The major difference between S and D-type symbiotics is that D-type are associated with very evolved Mira variables and S-type

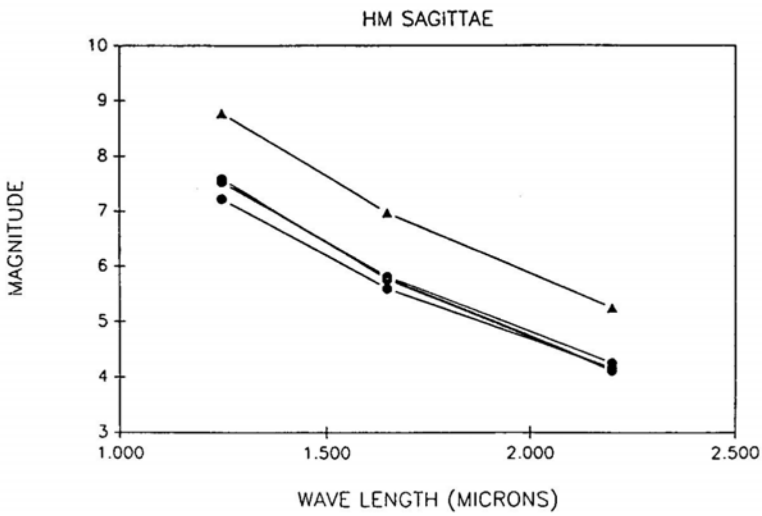

Figure 3. The near infrared energy distribution for HM Sagittae on different Julian dates given in Table 2. Our measurements are shown by triangles (▲) and the measurements of Kenyon (1988) are indicated by dots (●).

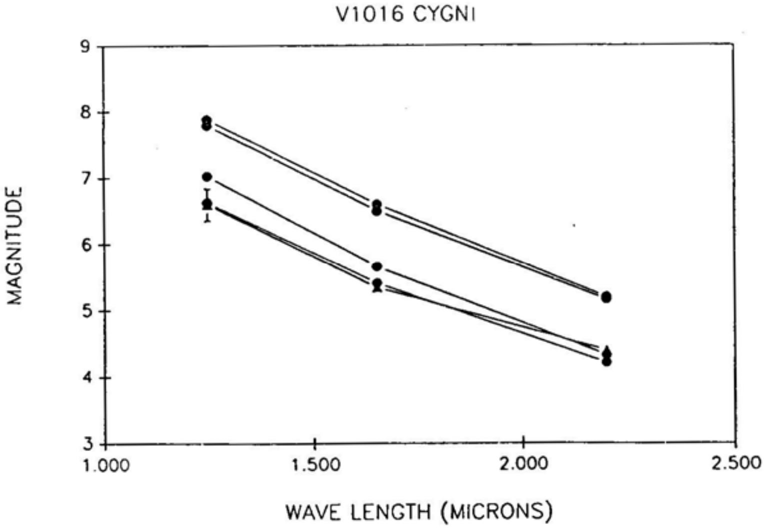

Figure 4. The near infrared energy distribution for V1016 Cygni on different Julian dates given in Table 2. Our measurements are shown by triangles (▲) and the measurements of Kenyon (1988) are indicated by dots (●).

with M giant stars. Recent observations of HM Sagittae (Ipatov *et al.* 1985 and Lorenzetti *et al.* 1985) have established a variability of amplitude ~ 1 mag. at K band over a period of 500 days and suggest that it is highly reddened. The extinction needed to produce a Mira-like distribution from HM Sagittae is E (B–V) ~ 5, assuming the Savage & Mathis (1979) reddening law.

From a study of the spectra of symbiotic nova, Bryan & K wok (1991) suggested a model for HM Sagittae of a detached circumstellar envelope with an inner radius of 1.5×10^{14}cm. The mid and far infrared spectrum is dominated by circumstellar dust emission and the near infrared continuum is primarily due to the reddened photosphere of the cool star. Thronson & Harvey (1981) derive Av ~ 12 from the Brackett line ratios. Anandarao *et al.* (1988) using a two shell model for HM Sagittae, find that the temperature of the dust shell decreases with the time since outburst. From our observations we suggest that the circumstellar dust shell of the symbiotic source indicates further cooling over a period of 6 years and such a conclusion is consistent with the model proposed by Anandarao *et al.* (1988). However more observations in the L and M infrared bands are needed to estimate the changes in the temperature of the dust shell.

For V1016 Cygni the spectral changes in the J, H and K bands are plotted in Fig. 4. Our infrared measurements compare well with themagnitudes reported for the maximum brightness phase of the source by Kenyon (1988). No significant changes in the shape of the infrared spectrum are seen observed for the past five years. Ipatov *et al.* (1985) attributed the excess infrared emission to the formation of an additional thick dust envelope around the cool component of the binary system. The infrared spectral distribution of V1016 Cygni essentially represents a cool star with a blackbody temperature T ~ 2800 K and a dust envelope at a temperature T ~ 900 K–1000 K. Kenyon (1988) suggested that the infrared measurements fit very well that of a heavily reddened Mira variable, and the near infrared variation is produced by the circumstellar absorption (Whitelock 1988; Kenyon 1988, similar to that of HM Sagittae.

3. Conclusions

From the infrared observations of the symbiotic stars presented in the paper we arrive at the following conclusions:

- Most of the S-type symbiotic stars do not show significant variations in the near infrared spectrum over the past several years.
- CH Cygni shows a small reduction in the infrared flux attributable to the changes in the temperature of the dust shell.
- The large reduction in the infrared flux observed for the variable D-type symbiotic star HM Sagittae could have been caused by a significant cooling of the dust shell surrounding the Mira variable.

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