SYMBIOTIC STARS*

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Abstract. I review our current knowledge of symbiotic stars. A great many papers have graced the literature in the fifty years of their study, and many data are available on the spectral variations at optical wavelengths these stars undergo. I do not give extensive references to those data, for previous reviews have done so quite adequately. Rather, I concentrate on the extensive widening of the wavebands within which symbiotic stars have been studied over the past few years, and attempt to synthesise the data into a coherent picture.

Symbiotic stars are most readily explained as interacting binaries, though single star models may still be tenable for some systems. They are made much more complex than most other interacting binaries by the variety of accreting stars, and because gas flows may be highly structured. Moreover, their study is more difficult than that of dwarf novae because the orbital periods are long compared to the activity cycles of the accretion phenomena.

Our data base has expanded enormously with our present spectral catholicism. But there remains much valuable work to be done with even simple equipment on small telescopes. I suggest in a final section areas for future work.

1. What are symbiotic stars?

This review was presented at a conference devoted to binary stars. I shall therefore open with the blunt dogma that symbiotic stars are interacting binaries, in which a late-type giant sheds material onto a more compact companion. In adopting this definition I am patently doing injustice to the many papers in which highly credible models have been constructed describing symbiotic stars as single objects. It would be foolish to dismiss these models so casually, and below I shall refer to some of them more specifically. It would also be as well for the reader to recall that the very term symbiotic star, whilst implying the presence of two interdependent components, has also become synonymous with an object that cannot be dropped into any other descriptive bin (Nussbaumer, 1982). Some of the objects we so designate may indeed be single stars. Certain too is that many are interacting binaries: over the last few years the proportion for which this diagnosis is irrefutable has increased imposingly, whilst our understanding of how the interaction can generate what we call the symbiotic phenomenon has blossomed.

What do we mean when we speak of a symbiotic star? The definition has broadened of late, and now allows inclusion of objects that might not have been considered fifty years ago when the first specimens were found by Mount Wilson

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observers. In Allen (1979) I proposed a set of defining criteria that allowed a catalogue of slightly over 100 examples to be drawn up. Some revision of both the definition and the catalogue has been enforced by data from the International Ultraviolet Explorer (IUE). The present number in my private catalogue is 128.

A current definition must relate to the simultaneous presence of two grossly different temperature regimes – the symbiosis. The cooler of these is a giant of spectral type G or later; the hotter is expressed by emission lines of high excitation, such as He II and [Fe II]. In addition, variability of a nova-like nature has often been considered a defining characteristic, but this I reject for reasons that will become apparent below. Rather, to those stars which undergo frequent outbursts of a few magnitudes on time-scale of a few months, I give the epithet classical symbiotic stars. The principal members of this group are (in right ascension order) AX Per, RW Hya, AG Dra, BF Cyg, CI Cyg, AG Peg, and Z And.

This definition is unsatisfactory because of the looseness of the term 'high excitation'. My 1979 requirement of He II emission (λ 4686) was proved inadequate when IUE began to reveal lines of C IV, He II, etc. in the ultraviolet spectra of stars (such as R Aqr) which did not from optical data alone fulfill my criteria. Unfortunately, there are many late-type stars which exhibit Balmer emission lines, but which certainly do not merit being called symbiotic. Exactly where in this continuum of objects one draws his dividing line is unclear. I prefer to leave the definition vague at the moment, in the belief that within a few years we will be able to use instead the dogma with which I opened this section. Inasmuch as symbiotic stars are interacting binaries, they are relatively low-mass specimens, and are distinct from systems which produce Wolf–Rayet stars. This fact should be borne in mind, for Wolf–Rayet spectral features will be mentioned below.

In what follows I shall not use the terms primary or secondary to describe the components of the symbiotic stars. In systems where mass transfer occurs, this is inevitably confusing. Moreover, as Plavec (1980) comments, different authors mean different things by the terms. In symbiotic stars the distinction is made easier by the two temperature regimes. I refer to the hot star and the cool star. Plavec would call these the gainer and the loser respectively.

2. Previous Reviews

The field of symbiotic stars has become particularly active over the last five years, and reviews dating from the 1970's are already outdated in large part. Of course, they nicely enshrine the history of thinking on the subject. Space does not permit the indulgence of a detailed historical summary, and I merely draw attention to the reviews of Sahade (1965, 1976), and Boyarchuk (1970a, 1975). The first partial review that took significant note of data outside the visible waveband was that of Allen (1979). For the most comprehensive review of these stars the reader is referred to the proceedings of *IAU Colloq.* **70** (Friedjung and Viotti, 1982); there he will find brief reviews by specialists on various aspects of their study. The present paper hopefully presents a more coherent picture than can be achieved in a major meeting such as *IAU Colloq.* **70**, but suffers from the inevitable bias introduced by a single author.

Many papers have been written on individual stars; I have eschewed a complete bibliography, giving references to specific cases of interest to the theme of this review. I apologise to those whom I have neglected: the list of references is already lengthy.

3. Methods of Study

More than any other, the lesson we have learnt from the last five years is that symbiotic stars are a phenomenon of almost the entire electromagnetic spectrum. To restrict one's attention to the optical waveband is to be an ostrich. I now summarise the range of wavelengths at which useful data can and have been obtained.

3.1. X-ray

Only a few symbiotic stars are X-ray sources. The most prominent example is V2116 Oph, a star discovered initially by its X-radiation and formerly known as GX1+4, or 3U 1728-24 (Davidsen *et al.*, 1977). It is the only hard X-ray source known amongst the symbiotic stars, and is further distinguished by its pulsations of period near 2 min. (4 min.?) and large period derivative. Analysis of these pulsations shows the system to contain an accreting neutron star (Mason, 1977), whilst the optical data reveal an M giant.

Soft X-ray sources might be expected in many symbiotic stars, where there is emission from species with ionization potentials exceeding 100 eV. That this is not the case may be attributed to two factors. First, there is a large column depth of neutral hydrogen in front of many; second, the X-ray source has a very steep spectral gradient on the short-wavelength side, a fact suggesting that the X-rays are thermal and emanate from a black-body of temperature a few hundred thousand Kelvin. To date the following have been detected: AG Dra (Anderson *et al.*, 1981), T CrB (Cordova *et al.*, 1981), HM Sge, V1016 Cyg, RR Tel, and possibly AS 295B (Allen, 1981).

From the X-ray data we can determine an equivalent angular size to the emitting object. If the distance is taken from the infrared (see below), then the hot component is typically the size of a white dwarf star.

3.2. Ultraviolet

Despite the pioneering work by Gallagher *et al.* (1979) using the OAO2 satellite on AG Peg, it is IUE that has really taught us about the hot gas and continuum in symbiotic stars. Several groups have been active in this field. A summary of the results is attempted below; Table I gives the major references to ultraviolet data.

Early data from IUE seemed to show the simple continuum from a black body

TABLE I

The major references to ultraviolet data on symbiotic stars

CH Cyg	Hack (1979)
HM Sge, V1016 Cyg	Flower *et al.* (1979)
RW Hya	Kafatos *et al.* (1980)
AG Peg	Keyes and Plavec (1980)
R Aqr	Michalitsianos *et al.* (1980)
EG And	Stencel and Sahade (1980)
Z And	Altamore *et al.* (1981)
T CrB	Krautter *et al.* (1981)
V1016 Cyg	Nussbaumer and Schild (1981)
AG Dra	Altamore *et al.* (1982)
HM Sge, V1016 Cyg, V1329 Cyg	Feibelman (1982)
RX Pup	Kafatos *et al.* (1982)
V1329 Cyg	Kindl and Nussbaumer (1982)
BX Mon, SY Mus (in eclipse?), CL Sco, YY Her	Michalitsianos *et al.* (1982a)
SY Mus (in outburst?)	Michalitsianos *et al.* (1982b)
12 systems	Slovak and Lambert (1982)
CI Cyg	Stencel *et al.* (1982)
V1329 Cyg	Nussbaumer and Schmutz (1983)
RR Tel	Penston *et al.* (1983)
AG Dra (in outburst)	Viotti *et al.* (1983)

of a few 10^5 K underlying emission lines formed in a high-density gas. As more stars were studied, the picture muddied impressively. In many cases the continuum is not well represented by any credible combination of hot star and gaseous continuum. The variability of some systems may provide a way of discriminating various components which, on present data, appear to behave independently (e.g., AG Dra in outburst, references in Table I).

Further, whilst the emission lines have proved a common feature of symbiotic stars, they are in some cases broad and structured and in others unresolved. AG Peg is a prime example of a system with broad lines, the velocities in this case being several hundred kilometres per second. These greatly exceed the orbital velocities, and indicate that gas streams flow between the stars. In most such cases, some evidence of broad emission lines (mostly He II λ4686) can be seen in the optical. These lines have often been taken to imply the existence of a Wolf–Rayet star in the system. However, the IUE line profiles do not resemble those of Wolf–Rayet stars. Moreover, as noted above, symbiotic stars have lower masses and luminosities that the classic Population I Wolf–Rayet stars.

Unquestionably the ultraviolet has contributed significantly to the data bank on symbiotic stars, but it would be an exaggeration to state that it has provided as many answers. The emission-line results have been valuable; a convenient summary of the use to which they can be put is given by Nussbaumer (1982). The difficulty of understanding the continuum data can be appreciated from the following list of potential contributing components: the hot star; an accretion disk, generally of unknown inclination; the boundary between disk and star; free-free, free-bound, and two-photon continua from a stratified nebula, of hydrogen and helium; blended, weak emission lines; scattering of light by dust grains; reddening, part of which may be circumstellar and therefore different from the normal reddening law; radiation from the heated side of the cool star.

The most comprehensive attempt at unravelling the ultraviolet continua of symbiotic stars is that of Kenyon and Webbink (1983).

3.3. Optical

Most data on symbiotic stars have, of course, accumulated in the optical domain. The picture they suggest, nicely summarised by the work of Boyarchuk (1966, 1967a, b, 1969), combines a cool giant with a hot star and the emission nebula the latter excites. The nova-like outbursts are seen to be events centred on the hot component. There is convincing evidence that the bolometric luminosity of the hot star remains fairly constant during such an outburst, whilst the temperature fluctuates.

Several of the symbiotic stars are eclipsing systems, and therefore indisputably binary. The first such to be studied was AR Pav (Thackeray and Hutchings, 1974), and this analysis neatly confirmed Boyarchuk's model of other systems, whilst further demonstrating that a stream of gas flows from the cool star towards the hot companion. More recently, CI Cygni has been shown to undergo eclipses (Pucinskas, 1970; Belyakina, 1979), and it seems likely that SY Mus is another example (Uitterdijk, 1934; Michalitsianos *et al.*, 1982a, b).

Radial velocity data do not assist in detecting orbital motions of these systems. The spectral features of late-type giants are insufficiently sharp to permit easy velocity measurement, whilst the emission lines indicate the complex streaming of the gas rather than any motion of the hot star. The difficulty of deriving even simple evidence of binary motion is poignantly highlighted by the stars AG Peg and V1329 Cyg. In the latter, a binary orbit has indeed been deduced (Grygar *et al.*, 1979), but the mass function, 25 $M_\odot$, is inadmissibly high. Ijima and Mammano (1981) have suggested that the 950 day period is one of outburst rather than orbital motion. In AG Peg the velocity curves do not close around the orbit, and in the analysis of Hutchings *et al.* (1975) gas appeared to be flowing up a potential gradient from the hot star to the cool. In both these cases it is the complex nature of the gas streams that undoubtedly confuses the analysis, a fact noted in the case of AG Peg by Sahade (1976).

The stratified nebula also complicates analysis of optical and ultraviolet emission-line ratios: the H II regions are sufficiently structured that unique values of electron temperature and density are inappropriate. In many studies of physical conditions and elemental abundances the authors have been forced to assume homogeneous, spherical nebulae, and the results of these analyses are questionable.

If estimates of electron temperatures (usually around 10000–15000 K) are meaningful, they indicate photoionization to be more important than shock or other ionization mechanisms.

The majority of objects now classified as symbiotic stars are not known to partake in the nova-like variability considered by Boyarchuk to be a pre-requisite for inclusion in the class. And a few, referred to as the slow novae, do so in a more protracted way, and with much greater increase in brightness. AG Peg, mentioned above, erupted in about 1850, and has not yet returned to its pre-outburst magnitude. RR Tel is progressing at a comparable rate.

Yet, if we were to take single snapshots, these systems would resemble most of the classical symbiotic stars in their optical and ultraviolet spectra, and in many other ways. It seems unrealistic to restrict the definition of symbiotic stars to those whose variability occurs on a convenient timescale. Figure 1 illustrates this point: in it are uncalibrated spectra of two objects secured on the same night with the same equipment. One of these, RT Ser, is the prototype slow nova; the other, lying only a few degrees away in the sky, was until recently classified as a planetary nebula, and is not a known variable. The spectra scarcely differ. The main features of symbiotic spectra are well represented: TiO absorption in the cool continuum of an M giant, a blue continuum due to free-free and free-bound emission from the nebula, and emission lines covering a range of excitations. It would not be difficult to present an essentially identical spectrum of a classical symbiotic star at a suitable phase.

Broad emission lines are a characteristic feature of more than half of the known symbiotic stars. In a few cases the lines are Wolf–Rayet-like. The luminosities are much lower than those of Population I Wolf–Rayet stars; moreover, the rapid evolution of RR Tel's broad-line spectrum (Thackeray and Webster, 1974) argues against the presence of a true Wolf–Rayet star in the system. It is interesting that this progression, towards higher ionization subclass, exactly parallels the evolution that is now believed to occur in population I Wolf–Rayet stars due to the shedding of mass (Moffat, 1981). We should not consider these features as evidence of true Wolf–Rayet stars; rather a condition comparable to that in the atmospheres of the more massive Wolf–Rayet stars is simulated near the hot component.

In RR Tel, the Wolf–Rayet features faded at the same time that the $\lambda 6830$ band appeared. This, and its weaker satellite at $\lambda 7088$, are unidentified features. They are found only in symbiotic stars (and in particular not in Population I Wolf–Rayet stars), and clearly originate at high excitation. The presence of such emission bands suggests the existence of a compact star with escape velocity of order 1000 km s^{-1} or more (Allen, 1980a).

A recent review of optical data is given by Ciatti (1982) in *IAU Colloq.* **70**, and of the photographic infrared in the same publication by Andrillat (1982).

3.4. Infrared

Early infrared observations (Swings and Allen, 1972; Glass and Webster, 1973; Szkody, 1977) served to show that symbiotic stars are merely late-type giants in

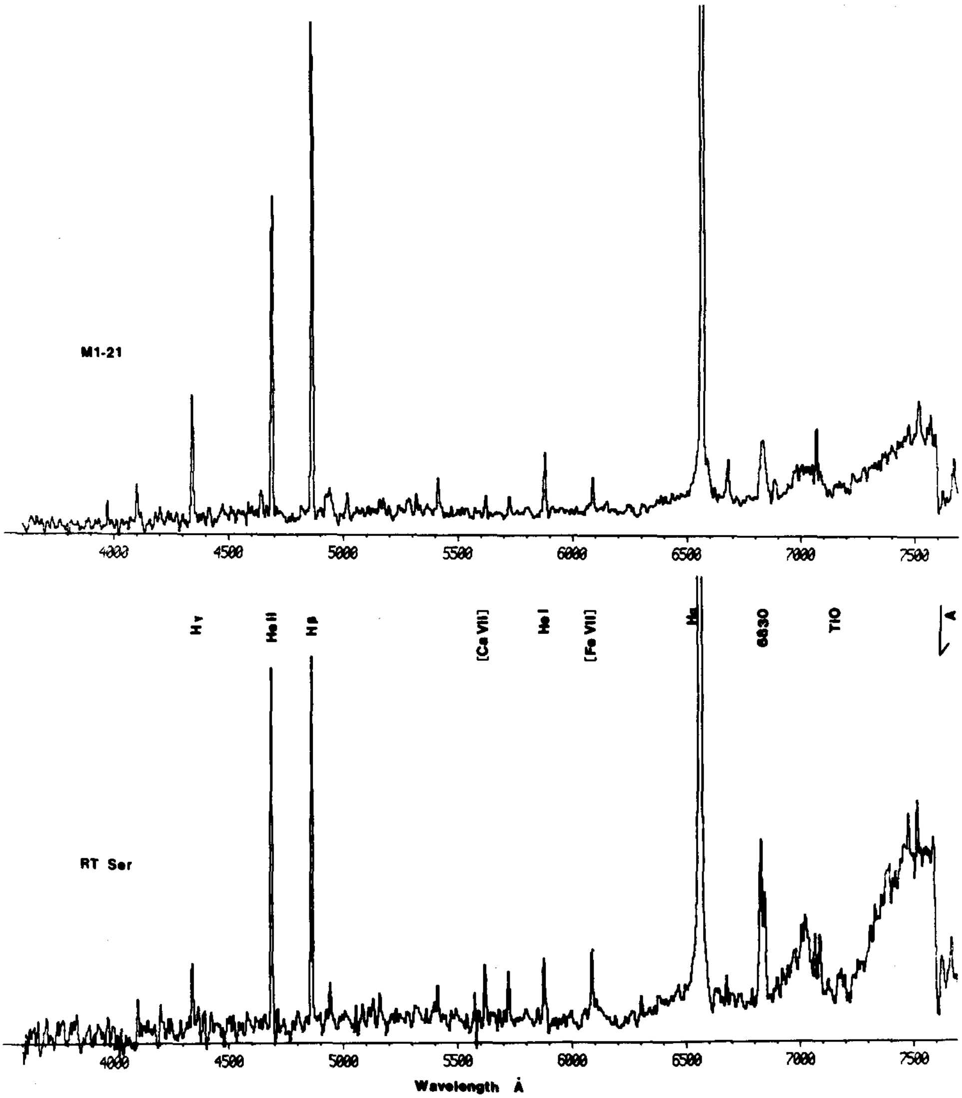

Fig. 1. Low-dispersion optical spectra of two symbiotic stars, M1–21 (originally classified as a planetary nebula) and RT Serpentis (the prototype slow nova). The ordinate on these plots is uncalibrated photon rate. These spectra clearly reveal the high-excitation forbidden lines, the gaseous continuum and the presence of an M giant.

this waveband. Subsequent data showed a subset of them to have circumstellar dust emission in the 1–4 μm range (Webster and Allen, 1975). The distinction into two classes, *S* and *D* according to whether the cool star or dust dominate, remains relevant now almost a decade after its discovery.

The dust itself resembles that found in single late-type giants except that the black-body component is hotter. Roche *et al.* (1983) suggest that the hot

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companion causes the extra heating of conducting grains which form a minority component of the dust. That component may be iron. In this respect alone do the infrared data reveal the symbiotic nature of the systems. In all other respects the late-type giant appears entirely normal. A number of recent papers have suggested that symbiotic stars are cool giants evolving towards planetary nebulae by shedding their outer layers; the infrared evidence is the most damning of that model. The very normality of the cool component not only proves its reality, but also provides a distance estimate to symbiotic stars (Allen, 1980b; Kenyon and Gallagher, 1983).

In a series of papers, Feast and his collaborators have demonstrated that the D-type (dust-rich) systems are Mira variables (Feast *et al.*, 1977, 1983a, b; Whitelock *et al.*, 1983a, b). The division into two infrared classes appears to be determined by whether the cool component is or is not a Mira variable, whilst the much higher mass loss seen in Miras accounts for the existence of good correlations between the infrared class and other parameters (Allen, 1979).

Of particular relevance is the demonstration by Feast *et al.* (1983a) that the Mira variable in RR Tel was quite unaffected by the 7 magnitude flare seen in 1944 and persisting to this day. This provides clear evidence that the outburst in RR Tel is associated with a companion star, even though no direct evidence of binarity has been found.

Recent photometry of S-type symbiotic stars (Taranova and Yudin, 1981a, b, 1982a, b) has shown some slight variability of the cool component. This is encouraging to models in which variations in the ultraviolet flux relate to variations in the mass transfer rate across the inner Lagrangian point. On the other hand, effects due to illumination by the hot companion have not yet been ruled out. Indeed, accurate photometry might offer a way of deriving orbital periods as our aspect of the illuminated hemisphere changes.

Spectroscopy in the 2-micron atmospheric window aids in identifying the cool components of symbiotic stars. There are in this region absorption bands due to water vapour and carbon monoxide. One interesting case has recently come to light in which the CO bands appear in emission (Whitelock *et al.*, 1983c): further examples may yet emerge. If they are common, then spectral classification from the CO bands will cease to be practicable, for fear of infilling by emission.

The late-type star is revealed by the infrared data even if it cannot be seen optically. Some examples have recently been found of systems in which the cool star is highly extinguished. This point will be discussed further in the section on H1-36, below.

Infrared data are summarised by Allen (1982) in *IAU Colloq.* **70**.

3.5. Radio

A continuum survey by Wright and Allen (1978) showed 10 % of symbiotic stars to be detectable with a single dish telescope. Arrays (especially the VLA) overcome the confusion in the galactic plane which so troubles single-dish work, so the proportion detected can be expected to rise.

Almost all detected cases show a spectral index of about +1, intermediate between optically thin (−0.1) and thick (+2) cases. The radio data are interpreted in terms of prolonged mass loss (Wright and Barlow, 1975; Panagia and Felli, 1975; Olnon, 1975). It is significant that all but one of Wright and Allen's detections were classed as D-type in the infrared: such systems can be expected to have undergone considerable mass loss from the cool star.

Some of the radio spectra of symbiotic stars turn over at high frequency to become optically thin. This was attributed by Marsh (1975) to the presence of a neutral cavity generated as a result of spasmodic mass loss. The lack of temporal evolution as the cavity expanded has caused some embarrassment to this model, and a new interpretation was proposed by Allen (1983a, b). This will be enlarged upon below.

Temporal variation has been seen to occur in some systems. Seaquist (1977) found RX Pup to vary rapidly, and no entirely satisfactory explanation of the changes have been forthcoming. More gradual secular changes in the radio flux from some symbiotic stars have also been recorded, as reported in Kwok (1982). The most notable of these has been the fading of V1329 Cyg by an order of magnitude or more between the first detection by Altenhoff and Wendker (1973) and the recent upper limit of Kwok *et al.* (1981).

Of interest also is the recently discovered optical/radio jet in R Aqr (Sopka *et al.*, 1982). As pointed out by Kafatos *et al.* (1983a), the jet appears to have been ejected from the system, and its provocative alignment with another radio source suggests previous ejection episodes. Again, a satisfactory explanation is lacking.

The radio offers in addition to continuum coverage the possibility of detecting orbital motion in systems which emit in one of the maser lines. Several searches have been conducted for OH masers (Lépine and Nguyen-Quang-Rieu, 1974;) Brocka, 1979; Cohen and Ghigo, 1980; Michalitsianos, private communication; Allen and Caswell, unpublished), but without success. An SiO maser is known only in the star R Aqr (Lépine *et al.*, 1978; Zuckerman, 1979). Unfortunately, in this system the orbital period is likely to be very long. The absence of OH emission is surprising in some of the very late-type systems, and probably reflects the influence of the hot companion.

Radio data are also reviewed by Kwok (1982) in *IAU Colloq.* **70**.

4. The Nature of the Hot Star and its Outbursts

As far as I know, the first attempt at explaining the idiosyncracies of the hot star in symbiotic systems was that of Tutukov and Yungel'son (1976), who argued that accretion of gas from the cool star's wind provided a variable ultraviolet source. They in turn were doubtless influenced by observational evidence of accretion, especially in the system AR Pav (Thackeray and Hutchings, 1974). A more detailed analysis of the mechanism for a Main-Sequence star was given by Bath (1977). Later, Paczyński and Rudak (1980) divided the symbiotic stars into two groups according to their optical variability, and related these groups to the accretion rate onto a white dwarf.

In discussing the accretion process it is necessary to have some idea of the type of accreting star. The absence of hard X-rays in all but V2116 Oph precludes a neutron star or black hole as the accretor, and the debate therefore ranges around main sequence stars, subdwarfs or white dwarfs. The latter raises the possibility of a thermonuclear flash, for accreted hydrogen-rich material will spontaneously ignite once its temperature becomes sufficiently high. It should be remembered that conventional novae are currently explained as flashes on white dwarfs accreting gas from a Main-Sequence star. Moreover, detailed modelling of flashes on cold and hot white dwarfs (Fujimoto, 1982a, b; Iben, 1982 and references therein) indicates that the interflash period and characteristic flash time-scale are both functions of the accretion rate. Thus, as suggested by Paczyński and Żytkow (1978), and by Gallagher *et al.* (1979) for the specific case of AG Peg, slow novae may simply be conventional novae governed by slightly different conditions. Further, as I have pointed out (Allen, 1979, 1983b), there seems no reason to deny the possibility of flashes persisting for decades or even centuries. I therefore see no difficulty in the hypothesis that many of the symbiotic stars which have shown no dramatic optical variability are in the throes of a shell flash. This may be a more comfortable explanation of their steady light than the release of gravitational energy from accretion, since accretion tends to be a highly unstable phenomenon.

If a white dwarf accretes hydrogen-rich material at a sufficiently high rate, continuous nuclear burning will occur, and the resulting object will be considerably larger. Plavec (1982) has referred to such stars as subdwarfs, though they are not the conventional Population II subdwarfs. Plavec argued that we may indeed require subdwarfs in order not to release too much accretion energy. Only minor thermonuclear flashes occur on white dwarfs which are burning their accreta steadily.

It is certain that an accretion disk with significant luminosity surrounds the hot component of some symbiotic stars. The flickering seen in optical photometry of CH Cyg (Slovak and Africano, 1978) indicates a disk to be present, and a recent analysis by Duschl (1983) invokes a disk of marginal stability in this system. In CI Cygni (see section 7) the existence of an accretion disk is certainly implied by the eclipse light curve.

We must not be beguiled into believing that accretion is essential to a symbiotic star. There are a few planetary nebulae in which the ionization is as high as exhibited by the symbiotic stars. NGC 6302 and 7027 come to mind, and I know of no claims that either is a binary with accretion flows (though the bipolar morphology of NGC 6302 may suggest this configuration). It is possible that the same evolutionary trend can occur in a binary system, and therefore that a planetary nebula may be forming alongside a red giant. Simple statistical arguments suggest that only a very small proportion of symbiotic stars are such systems, however.

Current thinking amongst the majority of students of symbiotic stars (as expressed by contributors of Friedjung and Viotti (1982), and to the proceedings of a workship held some months earlier on the other side of the Atlantic: Stencel (1981)) is clearly directed towards accretion phenomena in binary systems. One star, the loser, overfills the tidal lobe generated by the presence of its companion, and so transfers mass to the latter. Although the dynamic tidal lobe will not in general equate with the static Roche lobe, it is appropriate to give credit to Roche's work in this area by referring to the tidal lobe as the Roche lobe. In so doing, I follow popular convention. The details that remain to be settled are:

(i) the nature of the accreting star;

(ii) the accretion dynamics: Roche lobe overflow or wind accretion;

(iii) the role (if any) of thermonuclear flashes;

(iv) the structure and stability of any accretion disk.

In a recent study of the ultraviolet continua of 18 symbiotic stars, Kenyon and Webbink (1983) found 5 to involve Main-Sequence accretors. Many of the remainder appeared to be small, hot stars which may have been white dwarfs accreting from the stellar wind.

5. V1016 Cygni: Single Star Concepts

But it would be unreasonable to ignore those models of symbiotic stars that require only single objects. Although many have been proposed, it is particularly convenient here to consider those related to the star V1016 Cyg. In so doing, I set the pattern for the next few sections, in which I will examine a particular star or group of stars to illustrate how our thinking may be directed by specific cases.

In 1965, V1016 Cyg flared into prominence when it brightened by several magnitudes from a faint emission-line star (AS 373: Merrill and Burwell, 1950) to a system likened by Fitzgerald *et al.* (1966) to the symbiotic stars. The outburst resembled those of novae except that the time-scale was very much longer, and there was no observed optically thick phase, during which time only a cool shell absorption spectrum would have been expected. The subsequent development of the spectrum and light curve also shows similarities to novae, but on a much more protracted timescale. V1016 Cyg is, in fact, a slow nova.

Although the symbiotic binary interpretation was championed by several authors, notably Boyarchuk (1968), Mammano and Ciatti (1975), and Taranova and Yudin (1983), proponents of the single-star hypothesis have provided very convincing arguments. Their principal thesis is that we are here viewing a planetary nebula in its formative stages. The most important of these single star models were those of Baratta *et al.* (1974), Ahern *et al.* (1977), Kwok (1977), Flower *et al.* (1979), Nussbaumer and Schild (1981), and Kindl *et al.* (1982). Kwok developed a model in which a fast wind from the newly exposed hot nucleus ripped through the more gradually expanding shell of the former M star. Kindl *et al.*

(1982), analysing IUE data, postulated a spicular wind from the hot star as a means of explaining the observed line profiles.

There is only one feature of these models which I find unsatisfactory: the fact that there is convincing evidence for the continuing presence of a Mira variable in V1016 Cyg. The variability was first noted at infrared wavelengths by Harvey (1974), and it persists, according to Taranova and Yudin (1983). The 2-micron spectrum also shows the CO absorption of a Mira variable (Puetter *et al.*, 1978). Since this is an overtone band, it cannot easily arise in a tenuous nebula, but requires photospheric conditions. If this star has evolved to the point of revealing its core, then it cannot possibly still resemble a Mira.

This argument does not preclude the alternative, though less popular, interpretation in which a cool giant has a particularly active corona. Aller (1954), Gauzit (1955), and Wood (1974) have discussed such hypotheses. Boyarchuk (e.g., 1970a) has argued forcibly against the coronal model, demonstrating that so energetic a corona cannot be maintained. He ignores the electrical discharge theory of Bruce (1975) which might provide an alternative mechanism whereby a corona could be supported. However, I am aware of no way in which any of these coronal models can account for the intense ultraviolet continuum found in all studied symbiotic stars, a continuum which provides adequate radiative ionization to power the observed emission.

There remains one difficulty with the binary interpretation of V1016 Cyg. The distance implied by the infrared luminosity is much greater than the distance inferred from the interstellar reddening, as pointed out by Nussbaumer and Schild (1981). This probably reflects the difficulty of determining the true contribution of the *M* component in a dust-rich system where both stars contribute to the dust heating.

6. RX Puppis: Symbiotic Stars Are Not Always What They Seem

I use the star RX Pup to illustrate how easy it is to be misled by the optical spectrum. At the time of the Henry Draper catalogue, and later when studied by Swings and Struve (1941), RX Pup showed a high-excitation emission-line spectrum very reminiscent of the symbiotic stars, but lacking the cool giant's continuum in the red. When Sanduleak and Stephenson (1973) undertook their objective-prism survey of the southern Milky Way, about 1967, the star showed a strong, blue continuum with relatively few, low-excitation emission lines. This condition persisted into the 1970's, and led Klutz *et al.* (1978) to interpret the system as a single B supergiant. That this was not the case was again demonstrated in the infrared, where a Mira variable is seen (Barton *et al.*, 1979; Whitelock *et al.*, 1983), but more dramatically by the reversion to its former spectrum as the 1980's dawned (Klutz and Swings, 1981; Andrillat, 1982).

Another example, though less well documented, is BI Cru, which showed a high-excitation spectrum in 1962 (Henize and Carlson, 1980), but more recently has been a low-excitation object (Allen, 1974). The fact that the M star remains visible in BI Cru demonstrates that the varying component is associated with the hot companion. Other stars have undergone the same transformations during rapid, large outbursts (Z And: Swings and Struve, 1940; AX Per: Gauzit, 1955). And an optically thick shell dominated RR Tel early in its outburst (Thackeray, 1950; Pottasch and Varsavsky, 1960), and AG Peg around the turn of the century (Merrill, 1929).

The lesson to be learned is clear. Conditions around the hot star can mimic a cooler object. The false photosphere in RX Pup could have been that of an accretion disk, or of a dense wind from the hot component. Neither can yet be ruled out.

The lesson must be applied with caution to other systems. Zipoy (1975) did indeed do so for the star M1–2 (which he considered to be a single star). But we should also question the reality of the apparently cool star in such systems as HD 330036 (Webster, 1966; Lutz, 1977, 1983), AS 210 (Wilde, 1965) and He2–467 (Lutz *et al.*, 1976; Lutz, 1977). And is this the explanation of Herbig's (1960) classification of the cool star in CM Aql as M4, whereas on spectra I secured with the Anglo-Australian Telescope in 1977 the continuum is more like that of an F star?

We should also be alert to the possibility that other systems which currently show scant similarity to symbiotic stars may be different manifestations of the same phenomenon.

7. CI Cygni: Accretion Onto a Main-Sequence Star

One of the classical symbiotic stars is CI Cygni, a system first noted by Merrill and Humason (1932); its optical spectrum was described in detail by Merrill (1933, 1950), Swings and Struve (1940), Tcheng and Bloch (1954), Fehrenbach and Huang (1981) and Iijima (1981). The variability of this star could fuel an unending succession of papers that would not greatly improve our understanding of it. Progress became possible when CI Cyg was discovered to be an eclipsing binary. This fact was first hinted at by Whitney (see Aller, 1954), Hoffleit (1968), and Pucinskas (1972), but became clear in the data of Belyakina (1976, 1979).

With this vital fact at their fingertips, several authors were able to model CI Cygni in considerable detail. Kenyon *et al.* (1982) and Iijima (1982) showed that a bright M4 giant sheds material onto a Main-Sequence star, and that temperatures up to 160000 K are formed, probably at the boundary layer where the accretion disk abuts against the stellar surface. The disk itself has been modelled by Bath and Pringle (1982), who were able to reproduce the optical light curve over several outbursts by suitable mass transfer events. The disk is physically thick, so that simple descriptions as befit dwarf novae are not entirely appropriate.

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The rapid rise and slow fall of the outburst luminosity is readily explained by the sporadic formation and subsequent evolution of the disk. The same characteristic variations are seen in many classical symbiotic stars.

Although CI Cygni must be regarded as the most satisfactorily explained symbiotic star at the time of writing, we should not ignore the work on T CrB a full quarter of a century ago. Despite the absence of eclipses in this system, it was shown spectroscopically to be a binary involving a 1.9 $M_\odot$ Main-Sequence star orbiting a red giant by Kraft (1958; modified by Paczyński, 1965). Later, Webbink (1976) demonstrated that its occasional outbursts can be attributed to accretion events on the Main-Sequence star. T CrB is called a recurrent nova, a designation which belies its similarity to the symbiotic stars during the outbursts. Between outbursts, however, T CrB resides in a much more quiescent, low-excitation state.

The structure of the H II region has been studied in the optical by Mikołajewska and Mikołajewska (1982) and Oliversen and Anderson (1983), and in the ultraviolet by Stencel *et al.* (1982). During eclipse of the hot star and its accretion disk, the H II region is not fully eclipsed. Neither the majority of the forbidden lines nor the high-excitation resonance lines are weakened by eclipse, so these must arise in the outer parts. A complete explanation is not yet available, and it may be that the latter are formed in a shock-excited region where winds from the two stars collide. In this respect, the formulation of Kwok (1977; see also Kwok *et al.*, 1978; Kwok and Purton, 1979) is particularly relevant, even though it presumes a single star interpretation of the slow novae, and hence, a single centre of mass loss. Alternatively, there may be polar plumes where radiatively-driven mass-loss from the hot star is able to escape the dominance of the accretion disk. The narrowness of N V emission in many symbiotic stars also suggests an origin some distance from the hot star.

In Z And, Altamore *et al.* (1981) argue that some of the highest-excitation lines are formed around the cool star. Their arguments rely on a demonstration that the N V emission region has relatively small linear thickness. But this might also pertain to bipolar plumes or to a shock front where winds collide. A mechanism whereby the cool star's coronal activity is enhanced by forced rotation at the orbital period is explored by Friedjung *et al.* (1983). Electron temperatures in the high-excitation regions are presently though to be sufficiently low that only photoionization can sustain the nebula, and this favours an origin as near as possible to the hot star (but see caveat in Section 3.3).

There would be considerable interest in seeking bipolar structure in CI Cyg and other symbiotic systems. Recently, a VLA radio map of V1016 Cyg by Newell (see Hjellming and Bignell, 1982) suggested a bipolar morphology. Direct optical confirmation of this structure was made by Solf (1983). Of course the extensive nebulosity around R Aqr also has a bipolar morphology. The bipolar nebula surrounding He2–104 may be another manifestation of the effect (Allen, 1979).

8. H1-36: A Thermonuclear Flash on a White Dwarf?

The case of H1–36 has been analysed by Allen (1983a, b). In this star the only evidence for the presence of a cool companion is the near-infrared spectrum. The M star is of quite late type, and is probably a Mira variable of long period. It is reddened by about 20 mag. at V, whereas the emission nebula has a scant 2.2 mag. extinction.

Similar, but less extreme instances have been found by Bregman (1982: HM Sge) and Taranova and Yudin (1983: HM Sge and V1016 Cyg). It naturally follows that the Mira variable in these systems is enveloped in its own dust cloud. In H1–36 we can estimate the size of this cloud by the following approach, which is equally applicable to HM Sge and V1016 Cyg, although in their cases not all the relevant data are to hand.

The radio spectral index of H1–36 indicates that prolonged mass loss has occurred. Additionally, the flattening of the radio spectrum above 10 GHz (Purton *et al.*, 1977) shows a neutral cavity to reside within this pattern of outflow. Since there is no temporal evolution of the radio spectrum, the cavity is reasonably static. An interpretation of the optical emission spectrum requires extensive neutral portions of the nebula in order to enhance the low-excitation lines. A central ionizing source in a uniform outflow nebula cannot produce the type of optical spectrum seen in H1–36. All these features are explained by placing the source of ionization outside the centre of mass loss. An inner region around the cool star remains neutral and can shield the dust. From the radio spectrum and an adopted distance of 4.5 kpc (based on the apparent luminosity of the Mira component) can be derived the distance from the cool star to the ionization inner boundary, and hence the separation of the stars. The value I deduce for the latter is 3×10^{16} cm, or 2000 AU. The figure exceeds the limiting separation derived by Tutukov and Yungel'son (1982), who assumed that dust absorption would obscure the entire symbiotic phenomenon rather than just the Mira variable. It also represents about the largest separation known for binary stars.

The Mira by no means fills its Roche-lobe, and accretion must be from the wind. At so large a separation, the accretion rate cannot exceed 10^{-10} $M_{\odot}$ yr^{-1}. Hence not even a white dwarf will liberate sufficient accretion energy to power the observed H II region.

The most attractive alternative is a thermonuclear flash on a white dwarf that has been accreting for about 10^4 yr. Because the Mira will shed about 0.1 $M_{\odot}$ between flashes (unless the orbit is very elliptical), this is probably the first flash to have occurred on this particular dwarf, and it is likely to be quite long-lived. The fact that no photometric variations are known in H1–36 need not therefore distract from this argument.

The parallels with the slow novae are very evident here. HM Sge, RR Tel, and V1016 Cyg, all slow novae, show strong similarities to H1–36 with the exception that their outbursts have been observed to occur. In particular, the radio turnover is observed in V1016 Cyg (whereas in the other two stars it must exist, but at a frequency not yet studied), and the known parameters are sufficiently comparable that the argument can be carried almost verbatim to that system, provided that it is indeed a binary. Recently, Nussbaumer and Schmutz (1983) lent their support to a similar model for the dust-free slow Nova V1329 Cyg.

9. HD 330036: Cool Dust

The dust in H1–36 and its ilk lie quite close to the Mira, and presumably protected by the neutral cavity. Indeed, it is difficult to conceive of a site for dust formation better than the circumstellar cavity. But there are a few symbiotic stars in which the dust is cool, so that its presence is apparent only in data beyond 3 μm wavelength. I have distinguished these as class *D′* (Allen, 1982). The dust must be no hotter than 500 K. In these systems the cool component is not a Mira variable, rather a hotter star of spectral type F–K (these systems are sometimes called the yellow symbiotic stars: Glass and Webster (1973); but see the caveat in Section 6).

Where does the dust lie in these systems? Again our inclination is to locate it in neutral regions shielded from the hard ultraviolet radiation. But it must occupy a niche considerably more distant from the relatively warm giant than the hotter dust we find surrounding cooler Miras. We do not know the orbital periods of these stars, or indeed whether they really are binaries. However, it would seem unlikely that an F or G giant could eject sufficient matter for wind accretion to be effective, so they are probably examples of Roche lobe overflow. A suitable location for the dust remains elusive, and it may be that shielding within the orbital plane offers the only explanation.

The *D′* systems appear not to show silicate emission, in contrast to the majority of the Mira systems (Roche *et al.*, 1983). HD 330036 itself is unique amongst the known symbiotic stars in exhibiting infrared emission bands at 3.3 and 11.3 μm, otherwise known only in (probably carbon-rich) planetary nebulae and H II regions (Allen *et al.*, 1982; Roche *et al.*, 1983). This and other considerations have prompted Lutz (1983) to classify it as a dense planetary nebula forming in a binary system with an F5 giant. In view of the low excitation of HD 330036, such a classification is quite acceptable.

10. Luminosities: Symbiotic Stars in the Magellanic Clouds

For very few of the symbiotic stars do we have a reliable distance. We may estimate this vital parameter by using the late-type component, but we must then assume that the star is a normal giant. The assumption may be unreliable, and considerable discussion has devolved upon this point, particularly for AG Peg (Gallagher *et al.*, 1979; Keyes and Plavec, 1980). In the case of this star, the M giant can fill its Roche lobe only if it is of luminosity class II; the hot star is then likely near its Eddington luminosity, but the height of the system above the galactic plane becomes uncomfortably large. It is the lengthy orbital period (820 days) that forces the dilemma. We may have to face this problem, for in the eclipsing system AR Pav we can be certain that the height above the galactic plane is nearly 2 kpc. For CI Cyg the period is 855 days, but the smaller galactic latitude allows the greater distance, and a bright (i.e., class II) giant is acceptable. Indeed, Plavec (1982) has cogently argued that interacting binaries will most often involve bright (asymptotic branch) giants rather than stars on their first ascent of the giant branch.

We should like to know the luminosities of more of these systems. One obvious approach is to study specimens in the Magellanic Clouds. True, we will tend to locate first the most luminous examples therein, but even they will offer considerable help.

Feast and Webster (1974) first drew attention to some possible symbiotic stars in the Large Magellanic Cloud. Further study of these, together with some candidates kindly provided by Sanduleak, allowed Allen (1980c) to confirm three. Subsequent study suggests that one of these, S18 in the Small Cloud, may not be symbiotic (Shore, private communication). More recently, Walker (1983) has catalogued three more in the Small Cloud.

As so often happens, complications arise in the study of these stars. In half of them the cool components are carbon-rich rather than M-type, so the derived luminosity is not relevant to the Galactic specimens. In another (Sanduleak's object in the LMC) the infrared data indicate that a cool dust shell envelopes a star hotter than 4000 K. Infrared observations of Walker's stars have yet to be made.

Ultraviolet observations of the two LMC specimens were made by Kafatos *et al.* (1983b), but the objects are really too faint for a good continuum shape to be derived. Coupled with uncertainties in the reddening, it is not yet possible to infer a reliable luminosity for the hot components. For S63 Kafatos *et al.* (1983b) find the luminosity of the hot component to approach the Eddington luminosity of a $1\,M_{\odot}$ star.

The LMC star HD 269227 may be closely related to the symbiotics. It combines the emission lines of a WN star with a cool companion (Allen and Glass, 1976; Andrillat *et al.*, 1982), though there is considerable doubt about the validity of a Wolf–Rayet classification. The luminosity of the cool star places it in the supergiant class, and thus HD 269227 is not here considered to be a symbiotic system.

Further work on the Magellanic Cloud symbiotic stars is clearly required.

The very fact that half of the examples in the Magellanic Clouds involve carbon stars is of interest. In our Galaxy only two stars out of more than one hundred are carbon-rich (UV Aur: Sanford, 1944, 1949; UKS-Cel: Longmore and Allen, 1977). Although the numbers are small, there is a clear indication that carbon symbiotic stars are commoner in the Magellanic Clouds. This fact exactly parallels the greater proportion of carbon field stars in the Magellanic Clouds (Blanco *et al.*, 1978). Hence, we infer that symbiosis is a catholic phenomenon, one that can afflict a giant star irrespective of its chemisty. The M components of symbiotic stars are weighted much more towards the later subdivisions of the class than are field stars (Allen, 1980b). We therefore realise that one pre-requisite for a symbiotic star is a cool component capable of shedding mass at a high rate.

11. The λ6830 Band

The unidentified band at λ6830 in about 50 % of symbiotic stars is a sure indication that velocities approaching 1000 km s^{-1} exist (Allen, 1980a). Its structure is complex, often double- or triple-peaked, but not clearly that of a rotating accretion disk (as modelled by Smak, 1981). The implied velocity is marginally consistent with Friedjung's (1981) prediction for an optically thick wind driven by an object exceeding the Eddington luminosity.

If the velocities are circular, as in an accretion disk, they must be lower than the escape velocity at the surface of the hot star. If the velocities represent outflow in a radiation-driven wind, they will tend slightly to exceed the escape velocity (Cassinelli and Castor, 1973; Castor *et al.*, 1975). In either case we may tentatively conclude that the escape velocities of the hot components are of this order. This rules out Main Sequence stars, and leaves the choice of subdwarfs (using Plavec's definition: see section 4) or white dwarfs. The choice between a white dwarf and a subdwarf is dictated by the accretion conditions.

A prediction is that neither the broad λ6830 band nor any Wolf–Rayet-like emission line will be seen in systems involving Main-Sequence accretors. The recent claim by Blair *et al.* (1983) that the λ6830 band is seen in CI Cygni would appear to violate the prediction. Examination of their data suggests that the feature may not be real, confusion having been caused by the steep continuum of the M giant and the neighbouring atmospheric (B-band) absorption.

12. Evolutionary Considerations

The hot components of symbiotic systems may be either Main-Sequence stars or more compact objects. We are therefore dealing not with a single phase in the evolution of some (maybe all) binary stars, but with at least two stages. In one, the more massive of a pair of stars has recently evolved onto the giant branch, and has expanded sufficiently that it either fills its Roche lobe or is otherwise capable of depositing gas onto its companion at a substantial rate. This phase is typified by CI Cygni.

In examples of the other phase, both stars have left the Main Sequence. One has evolved to the white dwarf stage whilst the other is now a giant. In reaching this stage of evolution the system has passed through an earlier mass-transfer episode which may have influenced the evolution (e.g., Rudak, 1982). For a system as widely separated as H1–36, unless the eccentricity is high or there has been a significant increase in the orbital separation, the first mass transfer may have had slight effect. In closer systems the evolutionary history will have been complex.

Models of the mass transfer relevant to CI Cygni and its ilk have been computed by Lauterborn (1970) and by Plavec *et al.* (1973). In these models a class II giant is the mass donor, and eventually a massive white dwarf results. The subsequent evolution is computationally tedious to follow. Webbink (1979a, b) has sketched the likely course of events, with particular relevance (1979b) to the formation of white dwarfs and (1979a) to the recurrent nova T CrB, which (together with RS Oph) can be considered closely related to the symbiotic stars. It is possible that those symbiotic stars involving white dwarf accretors are precursors to dwarf novae. In his excellent review, Plavec (1982) compared the symbiotic stars to several other interacting binaries including Algol systems. The evolutionary sequence that he sketches forms an elaboration of Webbink's ideas. More recently, Trimble (1983) has summarised our current thinking on the evolution of interacting binaries.

The sole example, V2116 Oph, in which accretion is onto a neutron star represents a possible third evolutionary state in which a supernova explosion occurred non-disruptively in a binary system. It should be recalled that a white dwarf can, on accreting sufficient mass, become a supernova (Sugimoto and Nomoto, 1980).

Until we have a more complete understanding of the exact nature of the accreting components, it is unlikely that a definitive evolutionary scheme can be proposed. It may eventually be demonstrated that the symbiotic phase is an important (though short-lived) one in the evolution of many binary systems.

13. Future Prospects

In astronomy, changing fashions cause classes of objects to be studied in depth for periods of typically a decade, after which they are largely ignored until some breakthrough in understanding or instrumentation forces a reappraisal of the scene. Symbiotic stars, largely ignored in the 1960's and early 1970's are, once more, fashionable. In part this is due to the impetus provided by infrared techniques, which allow study of the cool component; in part the opening up of the ultraviolet domain (principally by IUE) is responsible. Important, too, has been our improved observational and theoretical understanding of accretion phenomena, primarily through study of dwarf novae. As the Space Telescope becomes operational, it will permit a new assault on the ultraviolet spectroscopy of symbiotic stars.

But we should not rest on our laurels awaiting the Space Telescope. In this section I give some guidelines to areas I consider ripe for study.

If indeed symbiotic stars are binaries, and if the cool star is often Roche-lobe filling, then as many as one in three should exhibit eclipses. The eclipses may be of the hot star, or merely of part of the emission nebula. It is vital to discover and study all the eclipsing systems. We now have a good understanding of CI Cygni, but only because of the recent discovery of its eclipses. We can do the same with other systems. AX Per and BF Cyg may be other examples (Kenyon, 1982; Oliversen and Anderson, 1983; Pucinskas, 1970). The orbital periods are long, typically a few hundred days, so that occasional observations are all that we require to discover more eclipsing examples. These may be photometric or spectroscopic, and need only a modest telescope. *UBV* photometry on a 0.5 m telescope is a potent tool. It will require many orbits, and hence many years, to disentangle eclipses from the stochastic variations and nova-like outbursts these systems also exhibit. In some cases the relevant data may already exist, in the form of observations by amateur networks such as the AAVSO and the Variable Star Section of the Royal Astronomical Society of New Zealand, or in archival plate material. There are more than one hundred systems out there just waiting for someone to begin monitoring them.

The eclipses do not provide answers to all the questions. High-resolution spectroscopy is essential to define the gas streams. CI Cygni is a case in point: the fact that some of the high-excitation gas is not eclipsed tells us that the nebula is complex. Studies of the velocity structure of a variety of emission lines around the orbit will help to disentangle the complexity. This is also true of systems not known to eclipse. Recall that the binary nature of T CrB and AG Peg were sleuthed spectroscopically (Kraft 1958; Cowley and Stencel, 1973). The programme of echelle spectroscopy by Anderson *et al.* (1980) and Oliversen and Anderson (1982) is a beginning to this work.

Again, in searching for binary motion, we should not ignore such tools as polarimetry, which can reveal orbital motion and determine the orbital inclination (as for the Wolf–Rayet binary HD 50896: McLean, 1980a, b). Variable linear polarization has been found in HM Sge (Efimov, 1979), R Aqr (Nikitin and Khudyakova, 1979) and CH Cyg (Piirola, 1982), though in the latter two it may arise in the M star (Svatoš and Šolc, 1981) rather than in the gas or dust as required if McLean's approach is to reach fruition.

If we can detect SiO maser emission in more of these systems, then the motion of the M star can be monitored with high precision by radio techniques, something which should be regarded as a luxury by optical observers. It appears also that the lines of Fe II and [Fe II], often so numerous in symbiotic stars, arise in the vicinity of the cool star (Boyarchuk, 1970a; and references therein), and so provide another handle on its motion. The advent of CCD detecors may permit better radial velocities of the M components directly from cross-correlation analyses of their TiO bands.

The binary periods are in themselves of interest. Those currently known are so long that in most systems a cool giant could not fill its Roche lobe. Even an asymptotic giant branch star may not do so. Determination of the luminosity of the cool star is of great interest to evolutionary studied. Attempts in the infrared (Kenyon and Gallagher, 1983) are not obviously going to succeed. The 8125 Å CN band is a luminosity discriminant, but is also sensitive to abundances: perhaps a study in which modelling of the H II region yields the abundance will permit luminosity classification from the CN band.

The whole question of accretion from an M giant's wind is raised. It is tempting to suggest that systems which show few or no forbidden lines in their optical spectra are examples of Roche-lobe overflow, so that most of the gas lies in a stream of high density (as in dwarf novae). But this may be wrong. And is the standard accretion model of Bondi and Hoyle (1944) applicable when the stream is neither cold nor collimated, and the M star's mass loss wind crosses the inner Lagrangian point? Or are we in fact viewing systems in which wind accretion is enhanced by partial streaming of the gas, and in which enough angular momentum is transferred with the gas to create a disk-like accretion cloud even in the absence of direct Roche-lobe overflow?

Since the hot star may be driving mass loss radiatively, we seem to require a disk-like accretion flow and two bipolar outflowing lobes, except in cases where thermonuclear shell flashes causes occasional disruption of the steady-state accretion mechanism. Do many of these systems have bipolar symmetry? This question could be answered by rather difficult observations of the type undertaken by Solf (1983), by speckle interferometry, or by aperture synthesis at frequencies of order 10 GHz of the radio-emitting region using the VLA or the University of Manchester's MERLIN facility.

Magnetic fields are important in accretion onto white dwarfs: dwarf novae and similar cataclysmic variables are now subdivided according to whether the field is strong (AM Her systems), weak (intermediate polars) or irrelevant. It would be of interest to seek evidence for magnetic influence in symbiotic stars. This could manifest itself as a cyclotron accretion column, or as modification to the gas flows. If, in fact, most white dwarfs either have stable shells or are undergoing a shell flash, then the effects of magnetic fields may be very hard to detect.

Variability is probably the key to understanding all the contributing components of the ultraviolet continuum, as I indicated above. Further monitoring is certainly needed. Concurrent soft X-ray data would help to define temperatures, but the sensitivity required is greater than offered by EXOSAT. It is, needless to say, unfortunate that we cannot secure observations in the wavelength region 100–900 Å. Variability studies in the infrared also seem of value. Now that we have good data on the Mira variables in D-type systems, we should be turning our attention to the S-types. Can we detect changes with orbital phase due to ellipsoidal deformation and/or heating of one hemisphere of the cool star by its hyperactive companion; or will its own random fluctuations defeat us?

Finally, the field of interacting winds from the two stars needs more thought. It is perhaps early yet to expect wind models to be applied to such complex systems. If so, then we should concentrate on observational attempts to locate the gas emitting both N V and the mysterious λ6830 band.

Let these thoughts stimulate my readers to activity!

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