Complex wind dynamics and ionization structure in symbiotic binaries

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Abstract. Aspects of the wind-dynamics in symbiotic binaries, colliding winds and accretion, are reviewed. Inconsistencies between theory and observations of the hot star wind are discussed. If the hot star wind were governed by CAK theory, nearly all symbiotics would be colliding wind binaries. For the case of colliding winds, 3D hydrodynamical simulations reveal that the matter distribution is spirally shaped. Shock confined high-density shells as well as huge voids are found even in the immediate neighborhood of the stars. Synthetic spectra computed on the basis of different 3D hydrodynamical models suggest observational discrimination between them to be possible. Colliding wind models also provide a link between symbiotics and planetary nebulae. Accretion during some time is a necessary condition for symbiotics to exist. However, there is no proof of whether currently accreting systems show the symbiotic phenomenon. Existing accretion models are inconsistent amongst each other, predicting either extended disks or small, high-density accretion wakes. Synthetic spectra allowing to discriminate between two models do not yet exist.

1. Introduction

Symbiotics have a complex dynamical behavior. Observations show variability on time scales of seconds to probably thousands of years. We know of bipolar outflows and jet-like features. Radio observations reveal complex and sometimes time-dependent structures of the circumstellar nebula. IR-emission often shows the presence of dust. From optical and UV spectra we take that the nebula has different velocity and density regimes. Many symbiotics are X-ray bright, revealing the presence of a hot ($\gtrsim 10^7$ K) plasma. Some systems are quiet at the moment, from others we know that they underwent novae or smaller outbursts.

Most of these phenomena are directly or indirectly related to the wind dynamics of symbiotic systems. However, the very number of involved physical
processes and the large range of spatial and temporal scales prevented a consistent, quantitative model of symbiotics so far. But however, many successful attempts towards such a model. They form the basis of this review. In Section 2 we discuss discrepancies between observations and CAK-theory for winds from the hot component. This question is decisive for whether symbiotics are colliding wind or accreting systems. In Section 3, colliding wind models, their link to planetary nebulae, and their spectral response are presented. Accretion models are discussed in Section 4. Finally, a summary is given in Section 5.

2. To what degree can photons from the hot primary drive matter?

It is commonly accepted that the hot components in symbiotics are post AGB-stars which are reborn. There may be some exceptions, where the hot component is a neutron star or an accreting main sequence star. In this review, these exceptions as well as recurrent novae are explicitly excluded. For bringing back a white dwarf from its cooling track to a post AGB state accretion is an absolutely necessary condition. Accretion is also the basis for novae to occur and for shell-flashes proposed to explain symbiotic outbursts. On the other hand, we know of some symbiotics to be colliding wind systems. In this Section we discuss whether winds can be driven from the hot star and whether they can prevent accretion.

Mürset et al. (1991) locate hot stars of symbiotics at the same place in the HR-diagram as central stars of planetary nebulae (CSPNe), when excluding the above mentioned exceptions. Hot primaries of symbiotics have temperatures above 60'000 K, many above 100'000 K, and luminosities between 10 and 10^5 L⊙ with many of them around 1000 L⊙. Since CSPNe often loose mass, we expect fast, radiatively driven winds from the hot component in symbiotics as well.

Theory For radiatively (line-)driven winds CAK theory predicts a momentum-luminosity relation (see e.g. Kudritzki 1998) of

\[ \dot{M}v_\infty \propto R_*^{-0.5}L_*^{1/\alpha} \left[ M_*(1-\Gamma) \right]^{3/2 - 1/\alpha}. \]

Γ is the Eddington factor. α reflects the distribution function of the oscillator strength of all lines involved in the wind driving. Of course, α is a key parameter. In many cases, it is close to 2/3, suggesting that the expression in the square brackets has potentially no influence. As we will see, more attention should be paid to the evaluation of photon-matter interaction for the case of symbiotics.

Observations Comparing with observations (however, with not too hot stars with radii bigger than 0.5 R⊙), Kudritzki (1998) suggests the fits

\[ \dot{M}v_\infty = 10^A \sqrt{R_*/R_\odot} (L_*/L_\odot)^x, \quad v_\infty = Bv_{esc}, \]

with 3 ≤ B ≤ 3.5 and x = 1.5 for CSPNe. For O-supergiants A is 20.65 and one expects a similar value for CSPNe. In hotter CSPNe, the observational detection of winds is demanding. Based on IUE high resolution spectra, Patriarchi & Perinotto (1991) found that nearly all CSPNe with log r = log(R_*/R⊙) > −1 and some with log r < −1 show P-Cygni profiles. This revised an earlier study based on IUE low resolution spectra (Ceruti-Sola & Perinotto 1985), where
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the limit with log $r > -0.5$ was substantially higher. Based on HST/GHRS observation of the CIV 155.0 nm doublet, Patriarchi & Perinotto (1996) report that K1-16 has a wind with 3800 km/s and a mass loss rate as low as $\dot{M} < 2 \cdot 10^{-11} M_\odot/y$. So far, this is one of the fastest winds of CSPNe ever measured.

Symbiotics As long as the stars are not too hot, CAK-theory fits well with the observed evolution of winds after the outburst of symbiotic novae (Vogel & Nussbaumer 1994; Schmid, this volume). But there are severe discrepancies between CAK-theory and observations for systems having a small, hot primary.

For most symbiotics we have no observational evidence for a wind from the hot primary; see e.g. Dumm et al. (2000) for a discussion of the case of RW Hya. In AG Peg, Nussbaumer, Schmutz, & Vogel (1995) observe P-Cygni profiles indicating a wind with 900 km/s. Schmutz (1996) derives from spectra taken in 1970 $R_\ast = 0.5 R_\odot$, $L = 1600 L_\odot$, $v_\infty = 700$ km/s, $\dot{M} = 10^{-6.7} M_\odot/y$. For spectra taken in 1994 he derives $R_\ast = 0.06 R_\odot$, $L \gtrsim 500 L_\odot$, $v_\infty = 950$ km/s, $\dot{M} = 10^{-6.7} M_\odot/y$. From a theoretical point of view, it is hard to understand why the mass loss and the velocity from a shrinking star with decreasing luminosity stay constant. According to CAK-theory ($B = 3, A = 20, x = 1.5$), the wind parameters corresponding to the same temperatures and luminosities would be $v_\infty = 1700$ km/s, $\dot{M} = 8.4 \cdot 10^{-10} M_\odot/y$ (1970) and $v_\infty = 4900$ km/s, $\dot{M} = 1.5 \cdot 10^{-10} M_\odot/y$ (1994). Similarly in EG And. Vogel (1993) derives $v_\infty = 500$ km/s and $\dot{M} = 2 \cdot 10^{-9} M_\odot/y$. The CAK-values corresponding to $T_\ast = 70'000$ K and $L_\ast = 15 L_\odot$ (Mürset et al. 1991) are 7000 km/s and $\dot{M} = 10^{-13} M_\odot/y$.

Thus, either luminosities and temperatures, or wind velocities and mass loss rates derived from observations are wrong, or CAK-theory breaks down for the winds from primaries in symbiotics. One systematic problem in the derivation of luminosities and temperatures by Mürset et al. (1991) and of the mass loss rate in EG And by Vogel (1993) is that a spherically symmetric mass distribution around the red star is assumed. Both, colliding wind and accretion models, however, predict that this is by far not the case. With regard to CAK, Springmann & Pauldrach (1992) note that in very rarefied winds the metals decouple from the bulk of the mass. This may lead to a much lower outflow velocity or even to a fall-back of hydrogen and helium. Porter & Skouza (1999), Porter (this volume), and Krtička & Kubát (this volume) discuss the idea in more detail. From the investigation of Gayley (1995) follows that stars with low Eddington-factors ($\lesssim 5 \cdot 10^{-4}$) are no longer able to drive winds\footnote{We thank Stan Owocki for pointing this out to us.}. However, most of the nowadays accepted values for symbiotics lie above this limit.

Colliding wind models against accretion models Let us assume for a moment that relation (2) is indeed valid for winds from the hot component in symbiotics. Then, assuming typical RGB- or AGB-winds respectively, it can be estimated that all systems with hot components having luminosities above 10 $L_\odot$ are colliding wind systems. Even with very low mass loss rates, high speed winds have enough momentum to prevent circumstellar matter from falling onto the star. The question remains open whether this is true.
3. Colliding winds

Three dimensional computer models for colliding winds, even for comparatively simple physics, are still very demanding and need a lot of computer time. For symbiotics, only a very few have been presented, to our knowledge all by the Zürich group (Nussbaumer & Walder 1993, Walder 1995a, Walder 1995b, Walder 1998). We briefly review their results and add new ones from work in progress.

3.1. Hydrodynamics: Carving, shaping and pushing

We discuss colliding winds at the example of three different 3D hydrodynamical models. In all models, typical for S-type symbiotics, we assume an orbital period of two years, 1.4 M\(_\odot\) for the cool and 0.6 M\(_\odot\) for the hot star, 20 km/s for the cool star wind and 1000 km/s for the hot star wind. The three models differ in the mass loss rates for which we adopt \(\dot{M}_c = 3.14 \times 10^{-7} M\odot/\text{y}, \dot{M}_h = 1.0 \times 10^{-9} M\odot/\text{y}\) (model \textit{weak}), \(\dot{M}_c = 1 \times 10^{-7} M\odot/\text{y}, \dot{M}_h = 2.0 \times 10^{-9} M\odot/\text{y}\) (model \textit{medium}), and \(\dot{M}_c = 3.14 \times 10^{-8} M\odot/\text{y}, \dot{M}_h = 4 \times 10^{-9} M\odot/\text{y}\) (model \textit{strong}). Consequently, the ratio of the momentum flux of the fast wind to that of the slow wind ranges from 1/6 (\textit{weak}), over 1 (\textit{medium}), to 6 (\textit{strong}). For simplicity, we assume that both winds have reached their terminal velocity, and we neglect radiative forces and gravity. This assumption is critical for close systems where the wind-wind interaction zone and even the hot component itself may be located well within the acceleration region of the wind from the red star. Rotation of the stars is also neglected, which is another critical assumption, in particular for AGB stars.

As the hot star works its way through the red giant wind, its own wind pushes material aside, leaving behind a spirally shaped, low density cavity. In the orbital plane as shown in Figure 1, its role as a rotating snow-plow becomes particularly apparent. The opening angle of the spiral depends on the ratio of the momentum fluxes and is small in model \textit{weak} and large in model \textit{strong}. Matter is piled up at the leading edge of the spiral, where a shock bounded high density shell confines the interaction zone (starting in the upper half in the pictures). The trailing edge of the spirally shaped interaction zone is characterized by a huge rarefaction wave, connecting the high-density red star wind with the low density cavity of the fast wind in a smooth, however steep way. As the temperature is approximately constant across this trailing edge, the red-giant wind is re-accelerated by the resulting pressure-gradient. The models, therefore, predict a significant part of the red star wind to be faster than single star winds. The leading and trailing part of the interaction zone are connected by a small zone in the center where the two winds collide head-on.

Looking now at the lower row of Figure 1 we notice in models \textit{weak} and \textit{medium} that the low-density spirally shaped tube carved by the hot star grows in diameter with increasing distance. The tube is eventually filled again when the kinetic pressure of the fast wind is exhausted. However, this will happen on a scale significantly larger than our computational box of \(1 \cdot 10^{15}\) cm cubed. In both models the fast wind is embedded in the red giant wind material. In model \textit{strong} the situation is different. Here the red star wind is basically restricted to a wide, open, high-density spiral. Normal to the orbital plane, the dense red giant wind is pushed away by the fast wind (see Section 3.2).
We conclude that colliding winds force an extreme re-shaping of the circumstellar material. The red star wind is no longer spherically symmetric, nor is it smooth. Both, thin high density shells and huge voids can be found even in the immediate neighborhood of the stars.

Finally, we note that the interaction zone of the colliding winds is inherently unstable. High density knots and filaments are formed. For a further discussion we refer to our contribution on colliding winds in WR+O binaries (this volume), Walder & Folini (1998a), and the recent review of Walder & Folini (1998b). Additionally, instabilities induced by ionization may play an important role in symbiotics (e.g. García-Segura et al. 1999).

3.2. The planetary nebulae link

A common, bipolar, morphology and a similar dynamical behavior suggest a link between some D-type symbiotics and planetary nebulae. We want to make only two remarks here on this important link and refer to the review of Corradi (this volume) comprehensive discussion.
The models discussed in Section 3.1 show that the hot wind is confined by the dense wind from the red star whenever its momentum flux is comparable to or weaker than that of the cold wind. According to our simulations, the circumstellar material should be strongly structured up to about $10^{16}$ cm. However, since the low-density voids occupy only a small volume, ionizing photons are unlikely to penetrate that far and no large-scale optical nebula will be present. But such a scenario may explain the radio measurements, e.g. of AG Peg by Kenny et al. (1991). On the other hand, if the momentum flux of the fast wind is bigger, all material is blown away in direction normal to the orbital plane, whereas in the orbital plane the presence of the red star prevents an unhindered outflow. A bipolar-like structure is likely to extend to scales similar to those of planetary nebulae. But even for a smaller momentum flux of the fast wind a bipolar large-scale structure may form if the circumstellar matter is more concentrated in the orbital plane, e.g. due to accretion before outburst or due to rotation of the red star.

Due to previous or currently on-going wind accretion, symbiotic hot stars have a good chance to be fast rotators and thus carry a larger magnetic field than single white dwarfs. Thus, a new class of magnetic wind models developed for planetary nebula may be of interest for symbiotics. These models show (Chevalier & Luo 1994; Rozyczka & Franco 1996; García-Segura 1997) that rotating, magnetic CSPNe with fields of some hundred Gauss can explain the observed variety of shapes of planetary nebulae. In particular, elliptical and even bipolar nebulae form quite naturally. In addition, due to magnetic stresses, highly collimated jets can be formed (García-Segura et al. 1999). These jets have a very particular velocity law, where the velocity is approximately linearly increasing along the jet-axis. Exactly such a law was observed in the young planetary nebulae MyCn 18 (Bryce et al. 1997). These results prove that the presence of jets in a binary system does not require accretion.

3.3. Spectral response

Spectra remain the main source of information on symbiotics although imaging is becoming more and more important with the new generation of telescopes. Due to the work of Corradi and Schwarz (e.g. Corradi & Schwarz 1993), we have fantastic images of the large scale structure of D-type symbiotics. Radio images have also brought light into nebular substructures of some S-type symbiotics.

There is a long tradition of applying photo-ionization codes to symbiotic systems. Beginning with spherical symmetry (e.g. Nussbaumer and Schild 1981), the models later were extended to axial-symmetry, where the hot star as the ionizing source illuminates the spherically symmetric wind from the cool star (e.g. Nussbaumer & Vogel 1989; Proga, Kenyon, & Raymond 1998). Below we report on first attempts where synthetic spectra are computed on the basis of 2D and 3D hydrodynamical models, and thus include the influence of shocks, the wind-wind interaction zone, and the orbital motion.

Optical and UV 

Based on axi-symmetric hydrodynamical models, Nussbaumer 
& Walder (1993) investigated the influence of the wind-wind interaction zone on the ionization structure and the spectrum of the symbiotic nebula. Remarkably, the low-density cavity of the fast wind as well as the high-density walls
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Figure 2. Phase-dependence of synthetic line profile for [O\textsc{iii}] $\lambda$5008 for the models weak (left), medium (middle), and strong (right) with a hot star of 100 $L_\odot$ and 90'000 K. Profiles are computed for an observer in the orbital plane, phases are increasing from bottom to top, starting at phase zero (eclipse of hot star). Each line profile is plotted against velocity in km/s, negative velocities corresponding to motion towards the observer.

of the wind-wind-interaction zone are as important as the luminosity and the temperature of the ionizing source. In particular, the high-density shells of the interaction zone can block high energy UV-photons, significantly reducing the emission area of highly ionized species. Velocities in these shells are significantly higher than red star wind velocities. Compared to spectra computed from a single wind model, synthetic line profiles based on colliding wind models show significantly broader feet. Lines of highly ionized species are generally broader than lines of lower ionized species. In addition, the line-shapes significantly depend on the line of sight leading, suggesting that we should have a strong variation of the profiles over an orbit of the system.

This was confirmed by the work of Folini (1998) who computed orbital variations of synthetic line profiles on the basis of the hydrodynamical models presented in Section 3.1. It was also shown there that the line profiles as a whole are shifted as a function of orbit. Moreover, it was demonstrated (see Figure 2) that the same line ([O\textsc{iii}]$\lambda$5008) computed for the same ionizing source (100 $L_\odot$ and 90'000 K) may be shifted completely differently in each of the three models. If the line emission stems primarily from the immediate vicinity of the cool companion the line profile shows a maximum blue shift around phase 0. On the other hand, if the emission stems from the interaction zone, maximum blue shift is reached around phase 0.5. It was further shown that for each of the investigated models and ionizing sources it is possible to find ions probing the interaction zone.

X-ray emission Observed strong X-ray emission stood at the beginning of colliding wind models of symbiotics. For the symbiotic novae HM Sge Kwok & Purton (1979) suggested a model where a shocked fast wind from the hot star leads to a spherical hot bubble. In contrast, Wallerstein et al. (1984) and Willson et al. (1984) suggested the observed X-rays to come from the head-on collision of the fast wind from the hot star with the slow, dense wind from the red star. Present models discussed in Section 3.1 suggest something in between.
The collision zone of the two winds, and therefore the distribution of the hot plasma, is spirally shaped. Additionally, the hot star is expected to contribute with a supersoft component to the X-ray spectrum. First computational models of such two-component spectra were published by Walder & Vogel (1993) and Mürset, Jordan & Walder (1995).

**Observations:** In a systematic study of 16 symbiotics Mürset, Wolff, & Jordan (1997) detected 60 percent of them as X-ray sources. All of them but two accreting neutron stars have a supersoft component. Seven show emission of an optically thin plasma with temperatures between 3-20 million Kelvins and the authors suggest an observational relation of \( L_{\text{hot plasma}} = 10^{-5} L_\odot \).

**Theory:** The case of a spirally shaped interaction zone described in Section 3.1 causes the entire fast wind to become shocked, at least for cases where the momentum flux of the red star wind dominates that of the fast wind. The resulting X-ray luminosity can be estimated as

\[
L_{\text{xray}} = x_{\text{eff}} \times L_{\text{mech}} \overset{\text{CAK}}{\approx} x_{\text{eff}} \times 10^{-5} (L_*/L_\odot)^{1.5} L_\odot, \tag{3}
\]

where the efficiency factor \( x_{\text{eff}} \) lies between one and ten percent, depending on model parameters. So \( L_{\text{xray}} \) is for luminous stars probably higher than the observed \( L_{\text{hot plasma}} \) but the observational error bars are still large and in the theoretical prediction for \( L_{\text{xray}} \) circumstellar absorption has been neglected. Concerning temperatures, the highest temperatures are reached in the system center where the flows collide head on. However, the bulk of the fast wind hits the spiraling interaction zone at angles much smaller than 90 degrees and the temperatures reached are smaller.

**Discussion:** Assuming a colliding wind scenario, the X-ray emission is closely linked to the wind parameters. However, X-ray observations of EG And and AG Peg seem inconsistent with their wind parameters derived from observations. CAK fit badly as well, but here the situation may be saved.

Using a one temperature fit to the observed X-ray spectrum Mürset et al. (1997) find \( 1.5 \cdot 10^7 \) K for EG And. The wind parameters derived by Vogel (1993) lead to a theoretical peak temperature of only \( 5.6 \cdot 10^6 \) K, CAK-based wind parameters result in unrealistic \( 1.5 \cdot 10^9 \) K. Nevertheless, CAK-winds are not excluded by the observed X-ray spectrum of EG And for the following reasons. The bulk emission seen in X-rays is cooler than the theoretical peak temperature. Second, if heat conduction were taken into account peak temperatures would be generally reduced. As shown for hot star binaries by Myasnikov & Zhekov (1998) and by Motamen, Walder & Folini (1999) heat conduction becomes important above about \( 10^7 \) K and will reduce the temperature by up to an order of magnitude. For AG Peg the situation is similar but less pronounced. From X-ray observations Mürset et al. (1997) derive \( 3.16 \cdot 10^9 \) K. Observed wind velocities result in a peak temperature of \( 1.5 \cdot 10^7 \) K, CAK based parameters lead to \( 4 \cdot 10^8 \) K. While both sets of wind parameters seem possible, the CAK values may be preferable as again the X-ray observations reflect the bulk and not the peak temperature, and as heat conduction reduces peak temperatures. Finally, when taking observation based wind parameters the efficiency factor \( x_{\text{eff}} \) must be below 0.001 to fit the observed X-ray flux. This is in contradiction with simulations. Moreover, CAK wind values result in \( x_{\text{eff}} \approx 0.1 \), a value which is more realistic.
4. Accretion

According to current knowledge, the existence of every symbiotic system requires accretion at some stage. Yet, some symbiotics are observed to be colliding wind binaries. Is the observed symbiotic phenomenon compatible with accretion as well? The alternative would be that whenever accretion takes place the symbiotic signatures vanish. On observational grounds, this question has not been settled. And while colliding wind models are now compared to observations, accretion models are not yet sufficiently evolved. In the discussion below, most aspects are, however, of more general nature.

Observations: Accretion sets free a relatively small amount of energy but various observational signatures may be explained in terms of accretion. As discussed by M"urset et al. (1991), observed UV nebular spectra from symbiotics require a more compact and hotter ionizing source than the emission from a classical Keplerian accretion disk. On the other hand, Sokoloski & Bildsten (1999) argue that the detected variation of 1682 seconds in the optical emission of Z And may be explained by accretion onto a highly magnetic white dwarf. They attribute the outbursts to classical disk-instabilities of a Keplerian disk. Looking at X-ray observations (temperature, luminosity, time variability), CH Cyg seems to behave like a CV (Ezuka, Ishida & Makino 1998, based on ASCA-spectra). However, according to M"urset et al. (1997) its X-ray properties are different from any other symbiotic system, which all shows significantly lower temperatures that may be explained in terms of colliding winds. However, all these latter observations are ROSAT data only, therefore lacking a high-energy channel.

The case of RW Hya: For RW Hya there are indications that it is a wind accreting system. If true, RW Hya is the first confirmed accreting symbiotic system. Dumm et al. (2000) discovered an unexpected occultation of the hot component at phase $\phi = 0.78$. This occultation is unrelated to the eclipse of the hot component. The occultation lasts approximately $\Delta \phi = 0.04$. The spectral characteristics of this event indicate Rayleigh scattering due to a high column density of neutral hydrogen in the line of sight to the hot star. The authors interpret this observation in terms of an accretion wake filled with highly compressed material, trailing the white dwarf. They corroborate this suggestion with hydrodynamical simulations which show the formation of such a wake at approximately the correct orientation and opening angle.

Theory: Wind accretion in separated but heavily interacting binaries with slow winds is not yet well understood. In S-type symbiotics Bondi-Hoyle-Lyttleton theory is not valid since here the Bondi accretion radius is comparable to the stellar separation. Walder (1997) reports that in such a situation only 6 percent of the formal Bondi-Hoyle value can be accreted, corresponding, however, to 6 percent of the mass loss rate of the secondary. For binaries in which the Bondi accretion radius is small compared to the stellar separation (e.g. HMXRB) 63 percent of the Bondi-Hoyle accretion rate is reached, corresponding, however, to only 0.6 percent of the mass loss rate of the secondary. For D-type symbiotics, where the separation is a factor of 10-20 larger, Bondi-Hoyle-Lyttleton theory may be applicable but we are not aware of any simulations.

Hydrodynamical studies of accreting systems with dynamical parameters comparable to S-type symbiotics were performed by Theuns & Jorissen (1993),
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Bisikalo et al. (1995, 1996), Theuns, Boffin, & Jorissen (1996) and Mastrodemos & Morris (1998). Although there are significant differences between their results (see next paragraph) and despite their insufficient resolution close to the accreting star, all models agree on some issues: 1) A large fraction of the donor-wind is captured by the accretor (up to 10 percent). 2) In the vicinity of the accretor the density is strongly enhanced in the orbital plane and the flow spins. Some authors call this structure a disk. But even though the flow is spinning, it is still advection dominated and far from the regime of a viscous, Keplerian disk. Strong shocks are visible. 3) There is spin up of the accreting star. 4) All show complexly shaped nebulae on a scale of a few stellar separation. The wind from the red star is far from being spherically symmetric.

The models, however, differ in one important aspect. According to Bisikalo et al. (1995, 1996), a very extended (more than 70 R⊙) disk is formed with no sign of a wake. All other results show a much smaller spinning structure with a very prominent wake trailing the accreting star. The main difference between these two simulation and all others is that Bisikalo et al. apply a Roche-potential based on both stars and neglect forces which accelerate the wind from the red star, whereas the other simulations all assume a net accelerating force (driving forces overwhelming gravity) from the donor star, together with gravitation from the accretor. None of the models considers radiative forces from the accreting star which, in fact, could be quite large as discussed in Section 2.

Bisikalo et al. (1996) provide synthetic Hβ-profiles on the basis of their 2D hydrodynamical simulations. On top of a very broad foot – emitted by the disk – a thin nebular line can be found, varying in shape over an orbit. We know of no comparison of these profiles with observations.

We conclude that accretion models predict a highly aspherical distribution of the circumstellar matter with a clear concentration in the orbital plane around the accreting star. Presumably, the disk-like structure is optically thick. Its spectrum can, however, probably not be compared with that of a Kepler disk since the flow is still advection dominated.

5. Summary

To explain the observed number of symbiotic systems, consisting of a hot post-AGB or pre-white dwarf and an evolved low-mass star, accretion must occur at some stage. So far, there is no direct observational proof that accretion takes place in any system we classify as symbiotic. For colliding winds, on the other hand, such evidence most likely exists for at least one system. In fact, the question whether accretion can occur at all in a system we observe as symbiotic is still under debate, as is the question of how the accretion takes place. A classic Keplerian disc is not mandatory.

One of the key questions for both, colliding winds and accretion, is how the matter close to the white dwarf or in its atmosphere responds to the radiation field of this star. The overwhelming majority of symbiotics would have to be colliding wind systems if CAK theory were applicable for the wind of the white dwarf. However, there are inconsistencies between CAK-theory and observations which are not understood up to now. Likewise it has barely been investigated
how infalling, accreting matter would be affected by the radiation field of the accretor. Could radiation pressure in continuum and lines prevent accretion?

In both, colliding wind and accretion systems, the circumstellar matter – consisting of the wind of the red star – is highly structured and by far not spherically symmetric. This will have severe consequences for the nebular spectrum. In all spectral ranges, comparison with observational data is more advanced for colliding wind models than for accretion models. Presently, neither of the two models can be rejected on this basis. In particular, features like jets and bipolarity can also be explained in the frame of colliding wind models.

Comparing typical lifetimes of AGB or RGB stars with typical times for accretion and subsequent shell flashes or novae suggests that several accretion phases can take place during the life of the AGB or RGB star. The primary components in symbiotics then would be alternatingly accreting and wind-shedding stars. Whether the symbiotic phenomenon is observable during both phases is not yet clear. Also the possibility that accretion is accompanied by outflow cannot be ruled out. A strict division between colliding winds and accretion then might not be possible. Other exciting years of theoretical and observational research lie ahead until we have understood symbiotics, stellar systems among the most complex ones.

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