

Rotational velocities of the giants in symbiotic stars – III. Evidence of fast rotation in S-type symbiotics[★]

R. K. Zamanov,^{1†} M. F. Bode,^{2†} C. H. F. Melo,³ I. K. Stateva,¹ R. Bachev,¹
A. Gomboc,^{4†} R. Konstantinova-Antova¹ and K. A. Stoyanov¹

¹*Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko Shousse Blvd., 1784 Sofia, Bulgaria*

²*Astrophysics Research Institute, Liverpool John Moores University, Twelve Quays House, Birkenhead, CH41 1LD*

³*European Southern Observatory, Casilla 19001, Santiago 19, Chile*

⁴*Department of Physics, University of Ljubljana, Jadranska 19, 6100 Ljubljana, Slovenia*

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ABSTRACT

We have measured the projected rotational velocities ($v \sin i$) in a number of symbiotic stars and M giants using high-resolution spectroscopic observations. On the basis of our measurements and data from the literature, we compare the rotation of mass donors in symbiotics with $v \sin i$ of field giants and find that: (i) the K giants in S-type symbiotics rotate at $v \sin i > 4.5 \text{ km s}^{-1}$, which is 2–4 times faster than the field K giants; (ii) the M giants in S-type symbiotics rotate on average 1.5 times faster than the field M giants. Statistical tests show that these differences are highly significant – p-value $< 10^{-3}$ in the spectral-type bins K2III–K5III, M0III–M6III and M2III–M5III and (iii) our new observations of D'-type symbiotics also confirm that they are fast rotators.

As a result of the rapid rotation, the cool giants in symbiotics should have 3–30 times larger mass-loss rates. Our results suggest also that bipolar ejections in symbiotics seem to happen in objects where the mass donors rotate faster than the orbital period.

All spectra used in our series of papers can be obtained upon request from the authors.

Key words: binaries: symbiotic – stars: late-type – stars: rotation.

1 INTRODUCTION

The Symbiotic stars (SSs) are interacting binaries consisting of a cool giant and a hot companion. In most cases, the hot component is a white dwarf (WD), but it can also be a main-sequence star, hot subdwarf or neutron star (see Kenyon 1986; Corradi, Mikołajewska & Mahoney 2003). The symbiotic phase represents a late stage in stellar evolution and about 200 such objects are known (Belczyński et al. 2000). On the basis of their infrared (IR) properties, SSs have been classified into stellar continuum (S) and dusty (D or D') types (Allen 1982). The D-type systems contain Mira variables as mass donors. D'-type symbiotics are characterized by an earlier spectral-type giant (F–K) and lower dust temperatures. Soker (2002) has predicted theoretically that the cool companions in symbiotic

systems are likely to rotate much faster than isolated cool giants or those in wide-binary systems.

This is the third in a series of papers exploring the rotational velocities of the mass donating (cool) components of SSs. In this paper, we present $v \sin i$ measurements and expand our sample of SSs. We then perform comparative analyses and explore theoretical predictions that the mass donors in S-type symbiotics are faster rotators compared with field giants.

2 PROJECTED ROTATIONAL VELOCITY

2.1 Our observations

The new data have been obtained from 2004 October to 2005 February with the same set-up – the FEROS spectrograph at the 2.2 m telescope of ESO (La Silla). These are S- and D'-type SSs with $0^{\text{h}} < \text{RA} < 12^{\text{h}}$, and catalogue magnitude brighter than $v < 12.5$.

The details of the observational set-up, data reduction and the techniques of $v \sin i$ measurements are given in Paper I and II (Zamanov et al. 2005, 2006, hereafter Paper I). Here, we also apply two techniques of $v \sin i$ measurements: full width at half-maximum (FWHM) and Cross-Correlation Function (CCF). The description

[★]Based on: observations obtained in European Southern Observatory (ESO) programs 073.D-0724A and 074.D-0114, data from the Ultraviolet and Visual Echelle Spectrograph (UVES) Paranal Observatory Project (ESO Director's Discretionary Time Program ID 266.D-5655), spectral data retrieved from the ELODIE archive at Observatoire de Haute-Provence (OHP).
†E-mail: rkz@astro.bas.bg (RKZ); mfb@astro.livjm.ac.uk (MFB); andreja.gomboc@fmf.uni-lj.si (AG)

Table 1. Journal of observations and projected rotational velocities. In the table are given as follows: the name of the object, the IR type, date of observation (YYYY-MM-DD), the modified Julian Date (JD - 2400000.5) of the start of the observation, the spectral type. $v \sin i$ is the projected rotational velocity of the cool giant as measured with FWHM and CCF methods. If other measurements of $v \sin i$ exist, they are also given in the last column.

Object	IR	Date-obs	MJD-obs	Sp	$v \sin i$ FWHM [km s ⁻¹]	$v \sin i$ CCF [km s ⁻¹]	Other [km s ⁻¹]
AG Peg	S	2004-10-02	53280.0676	M4III	8.5 ± 1.5	7.5 ± 1.5	4.5 ± 1 ^a
BX Mon	S	2004-11-05	53314.2610	M5III	11.0 ± 1.5	9.4 ± 1.5	6.8 ± 1 ^a
Hen 3-905	S	2005-02-02	53403.1847	M3III	9.2 ± 1.5	7.3 ± 1.5	
LIN 358	S	2004-10-13	53291.0994	K5III	4.8 ± 1.5	5.9 ± 1.5	
PN Sa 3-22	S	2005-02-01	53402.2405	M4.5III	9.7 ± 1.5	9.8 ± 1.5	
V694 Mon	S	2004-11-05	53314.3158	M6III	10.3 ± 1.5	---	
V840 Cen	—	2005-02-01	53402.2858	K5III	31.5 ± 3.0	24.4 ± 3.0	
WRAY 15-157	D'	2004-11-06	53315.3276	G5III	44 ± 5	37 ± 5	
AS201	D'	2004-11-14	53323.3309	F9III	27 ± 3	29.3 ± 3	25 ± 5 ^b

^aFekel, Hinkle & Joyce (2003), ^bPereira et al. (2005).

of the methods is given in section 3 of Zamanov et al. (2007) (hereafter Paper II).

The new data are presented in Table 1. Here, the IR type of the objects and the spectral types of the mass donors are taken from the catalogue of Belczyński et al. (2000). This catalogue lists the spectral type of LIN 358 as a mid-K giant; we assume that it is K5III. For V694 Mon, the CCF method does not give a meaningful result, due to the highly complicated emission/absorption lines in the spectrum. For this object, we will use the result of the FWHM method, for all other objects the CCF measurements are more reliable.

Combining the present set with data from Papers I and II, and from the literature, we have $v \sin i$ measured for all southern S- and D'-type SSs from the Belczyński et al. (2000) catalogue with $v < 12.5$. This sample should have no biases in the rotational speed of the cool giant, even though the sample is flux limited.

2.2 Catalog data

The giants of S-type SSs with measured $v \sin i$ are of spectral types from K2III to K5III and from M0III to M6III.

We searched for published data of $v \sin i$ of giants of similar spectral type and found totally 362 giants in the interval K2-K5III in de Medeiros & Mayor (1999) and Massarotti et al. (2008). In the interval M0III-M6III, we found 10 objects in Glebocki, Gnacinski & Stawikowski (2001), 4 in Hüsch et al. (2004) and 15 in Massarotti et al. (2008).

2.3 Archive spectra

Because we have found only 29 field M giants with measured $v \sin i$, we searched in the archives for spectra of red giants in the interval M0III-M6III.

From the UVES Paranal Observatory Project (Bagnulo et al. 2003), we downloaded spectra of 17 M giants and from the ELODIE archive at Observatoire de Haute-Provence (Moultaka et al. 2004), we took spectra of 11 more objects. We applied the FWHM and CCF methods to measure the $v \sin i$ parameter in each case. The results are summarized in Table 2.

For the CCF measurements, the calibration of UVES values comes from an unpublished paper (Melo et al., in preparation). For ELODIE, we used the same technique as usual but using a $\sigma_0 = 4.9$ km s⁻¹, taken as the average value of Delfosse et al. (1998). This gives an error of ± 2.0 km s⁻¹ in the $v \sin i$.

Table 2. Projected rotational velocities of M giants, based on archive spectra from UVES and ELODIE archives. In the table are given as follows: the name of the object, the spectral type, the projected rotational velocity ($v \sin i$) as measured with FWHM and CCF methods with the corresponding errors.

Object	Sp	$v \sin i$ FWHM [km s ⁻¹]	$v \sin i$ CCF [km s ⁻¹]
UVES			
Menkar	M1.5IIIa	2.5 ± 1.5	2.8 ± 1.5
HD 102212	M1III	1.0 ± 1.0	1.1 ± 1.4
HD 119149	M1.5III	2.3 ± 1.0	1.9 ± 1.5
HD 123934	M1III	1.0 ± 1.0	2.3 ± 0.9
HD 210066	M1III	1.0 ± 1.0	0.6 ± 2.8
HD 92305	M0III	1.7 ± 1.5	1.2 ± 0.7
HD 219215	M2III	1.0 ± 1.0	0.0 ± 1.0
HD 120052	M2III	1.5 ± 1.5	1.0 ± 1.5
HD 11695	M4III	2.5 ± 1.0	3.9 ± 0.9
HD 118767	M5III	7.5 ± 1.5	7.7 ± 1.0
HD 123214	M4III	3.0 ± 1.0	4.4 ± 0.7
HD 130328	M3III	5.5 ± 2.0	8.2 ± 1.7
HD 189124	M6III	5.3 ± 1.0	9.1 ± 0.7
HD 189763	M4III	1.5 ± 1.5	4.5 ± 1.9
HD 213080	M4.5III	1.5 ± 1.5	4.5 ± 0.8
HD 214952	M5III	2.5 ± 1.5	6.3 ± 2.8
HD 224935	M3III	2.5 ± 1.5	3.9 ± 0.6
ELODIE			
HD 006860	M0III	1.5 ± 1.5	5.6 ± 2.0
HD 018191	M6III	12.0 ± 2.0	9.6 ± 2.0
HD 042787	M2III	2.0 ± 1.5	5.2 ± 2.0
HD 046784	M0III	2.8 ± 1.5	5.4 ± 2.0
HD 097778	M3III	5.5 ± 1.5	7.6 ± 2.0
HD 167006	M3III	5.5 ± 1.5	5.2 ± 2.0
HD 168720	M1III	5.0 ± 1.0	5.2 ± 2.0
HD 184786	M4.5III	6.5 ± 2.0	7.8 ± 2.0
HD 216131	M2III	1.0 ± 1.0	2.5 ± 2.0
HD 218329	M2III	3.8 ± 1.5	5.0 ± 2.0
HD 219734	M2III	5.0 ± 1.0	4.9 ± 2.0

3 RESULTS

In Fig. 1, the projected rotational velocity ($v \sin i$) is plotted versus the spectral type of the giant. The error in the spectral type of SSs is adopted as ±0.5. In Fig. 1, it is seen that in the most cases

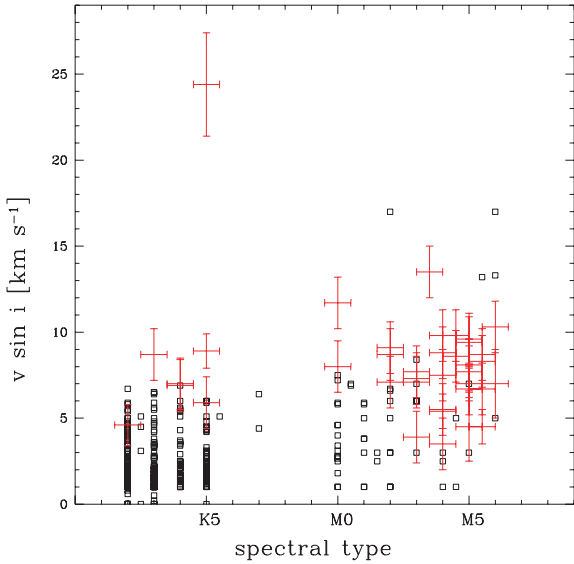


Figure 1. Projected rotational velocity ($v \sin i$) versus the spectral type of the giant in the spectral interval K2III–M6III. S-type SSs are indicated with error bars. The field giants are plotted with squares.

the mass donors in SSs rotate faster than the field giants. To test the visual impression as a mathematical (statistical) approach, we use the Kolmogorov–Smirnov and Mann–Whitney U-tests. These statistical tests are performed in the spectral-type bins K2III–K5III, M0III–M6III and M2III–M5III. These bins are selected following the distribution of symbiotics with known $v \sin i$, and avoiding the interval K6III–K9III, where we do not find symbiotics. It deserves noting that Keenan & McNeil (1989) do not consider K6III–K9III as full spectral subclasses, therefore the lack of objects.

3.1 Bin K2–K5 giants

The histograms for K giants are presented in Fig. 2. From Figs 1 and 2, it is seen that the field giants and the giants in S-type symbiotic

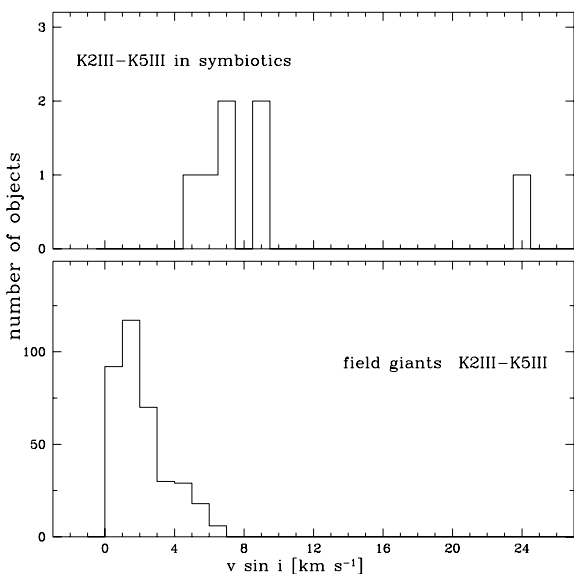


Figure 2. The histogram of $v \sin i$ for K2–K5 giants in symbiotics (upper panel) compared to the relevant distribution for field giants of the same spectral classes (bottom panel).

systems occupy different areas of $v \sin i$ values and that the K giants in S-type SSs rotate faster than field giants.

For the field K giants, typically $v \sin i < 3 \text{ km s}^{-1}$. For K giants in symbiotics, $4.5 \leq v \sin i \leq 25 \text{ km s}^{-1}$.

For 363 field K2III–K5III giants, we calculate a mean $v \sin i = 2.2 \text{ km s}^{-1}$, median $v \sin i = 1.8 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 1.45 \text{ km s}^{-1}$.

For 7 K2III–K5III giants in symbiotics, we get a mean $v \sin i = 9.5 \text{ km s}^{-1}$, median $v \sin i = 7.0 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 6.7 \text{ km s}^{-1}$. If we exclude V840 Cen from the sample, we calculate a mean $v \sin i = 7.0 \text{ km s}^{-1}$, median $v \sin i = 7.0 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 1.6 \text{ km s}^{-1}$. On average SSs rotate 2–4 times faster than the field K giants.

The Kolmogorov–Smirnov test gives a probability of only 7.10×10^{-6} (KS statistics = 0.90) that both distributions arise from the same parent population.

The comparison of the medians (Mann–Whitney U-test) for the symbiotic and field giants gives a probability of the median $v \sin i$ of the symbiotic giants being higher than that of the field giants > 0.99999 (U statistics = 1659).

It is therefore statistically certain that the K giants in symbiotics rotate faster than the field K giants. It has to be noted that the symbiotic V840 Cen rotates unusually fast (see Table 1) and it is the most rapid rotator among giants in the bin K2III–K5III known until now.

3.2 Bin M0–M6 giants

For 53 field M0III–M6III giants, we calculate a mean $v \sin i = 4.8 \text{ km s}^{-1}$, median $v \sin i = 3.8 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 3.6 \text{ km s}^{-1}$.

For 32 M0III–M6III giants in symbiotics, we get a mean $v \sin i = 9.2 \text{ km s}^{-1}$, median $v \sin i = 8.0 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 8.1 \text{ km s}^{-1}$.

The fastest rotator among M giants is the SS Hen 3-1674, which rotates almost at break-up velocity (see Paper II). This object is not plotted on the figures because it is too far from the other values.

The distributions of $v \sin i$ in this bin are plotted in Fig. 3. The Kolmogorov–Smirnov test gives a probability of only 3.5×10^{-7} (KS statistics = 0.60) that both distributions arise from the same parent population.

The comparison of the medians (Mann–Whitney U-test) for the symbiotic and single giants gives a probability of the median $v \sin i$ of the symbiotic giants being higher than that of the field giants 0.999994 (U statistics = 273).

In the above statistical test, we used the FWHM measurements of the UVES and ELODIE spectra. If in the statistical test we use the CCF measurements, we obtain very similar results. The KS-test gives a probability 5×10^{-6} (KS statistics = 0.57) and the U-test gives 0.9999999 (U statistics = 353.5).

3.3 Bin M2–M5 giants

This bin is selected because (i) it is in the mid of symbiotic M giants, and (ii) we have 23 symbiotics and 23 field giants inside. The histograms for M2III–M5III giants are presented in Fig. 4. For the 23 field giants in this bin with known $v \sin i$, we calculate mean $v \sin i = 4.8 \text{ km s}^{-1}$, median $v \sin i = 5.0 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 3.55 \text{ km s}^{-1}$.

For 23 M giants in symbiotics, we get a mean $v \sin i = 7.7 \text{ km s}^{-1}$, median $v \sin i = 7.7 \text{ km s}^{-1}$ and standard deviation of the mean $\sigma = 2.2 \text{ km s}^{-1}$.

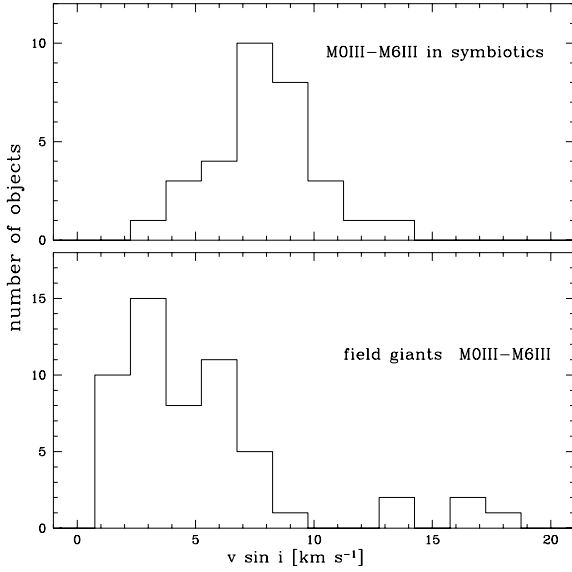


Figure 3. The distribution of $v \sin i$ for M0-M6 giants in symbiotic binaries (upper panel) compared to the distribution for the field M giants (bottom panel).

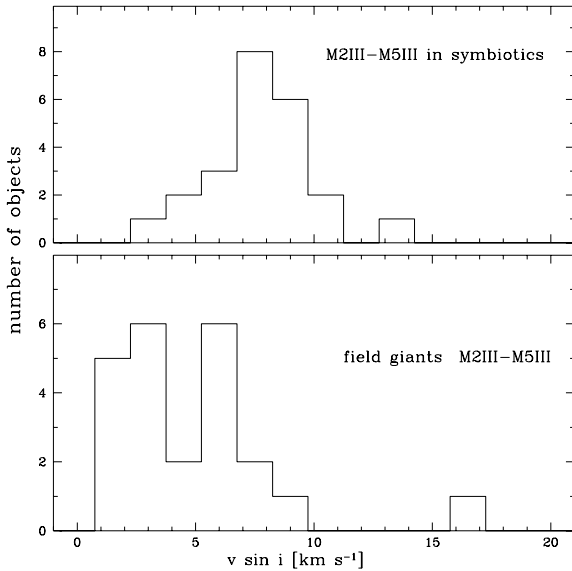


Figure 4. The distribution of $v \sin i$ for the bin M2III-M5III in symbiotic binaries (upper panel) and for the field giants (bottom panel).

The Kolmogorov–Smirnov test gives a probability of 1.1×10^{-4} (KS statistics = 0.65) that both distributions are extracted from the same parent population. The U-test gives a probability of 0.99995 (U statistics = 442.5), for the hypothesis that the median $v \sin i$ of the symbiotic M giants is higher than the median of the single M giants.

If in the statistical tests we use CCF measurements for UVES and ELODIE spectra, we obtain KS statistics = 0.52, probability 10^{-9} and U statistics = 134.5, probability 0.999999.

3.4 Additional checks

From Fig. 1, it is seen that in the M0III spectral class the two fastest rotators are SSs. As an additional check we have performed

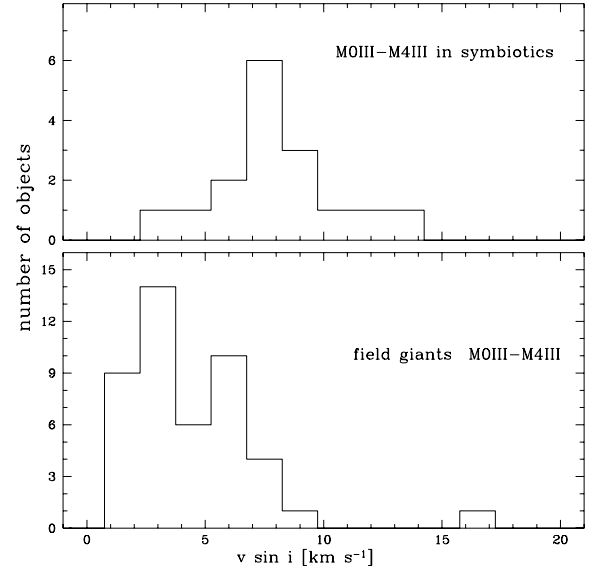


Figure 5. The distribution of $v \sin i$ for the bin M0III-M4III in symbiotic binaries (upper panel) and for the field giants (bottom panel).

statistical test in bin M0III-M4III, where we have 16 symbiotics and 45 field giants inside. The histograms for M0III-M4III giants are presented in Fig. 5. The Kolmogorov–Smirnov test gives a probability of 1×10^{-9} (KS statistics = 0.64) that both distributions are extracted from the same parent population. The U-test gives a probability of 0.999999 (U statistics = 117.5), for the hypothesis that the median $v \sin i$ of the symbiotic M giants is higher than the median of the single M giants. The statistical tests in M0III-M3III (10 SSs and 45 field giants) give 2×10^{-5} (KS statistics = 0.83) and 0.999977 (U=38.0). In bin M4III-M6III (21 SSs and 12 field giants) the tests do not give statistically significant difference: 0.1 (KS statistics = 0.44) and 0.85 (U statistics = 98).

The mean values of $v \sin i$ for the M giants are presented in Table 3. All but one of the mean $v \sin i$ values of SSs are higher than those of the field giants. The majority of the field M giants rotate at about $v \sin i \sim 1\text{--}6 \text{ km s}^{-1}$, while the symbiotic M giants rotate at $v \sin i \sim 4\text{--}14 \text{ km s}^{-1}$.

Our calculations presented above show that the M giants in symbiotics rotate faster (on average 1.5 times faster) than the field M giants, at least for the spectral interval from M0III to M5III.

Table 3. Projected rotational velocities of M giants. In the table are given as follows: the spectral type, the mean projected rotational velocity ($v \sin i$, in km s^{-1}), standard deviation of the mean (σ , in km s^{-1}), the number of objects. In the second column are given the values for the field M giants, in the third – for the SSs.

Sp	Field giants mean $\pm \sigma$ (N)	Symbiotics mean $\pm \sigma$ (N)
M0-M1 III	$3.7 \pm 1.9(23)$	$9.9 \pm 2.6(2)$
M1.5-M2 III	$4.8 \pm 4.1(14)$	$8.3 \pm 1.1(3)$
M2.5-M3 III	$5.5 \pm 2.0(8)$	$6.5 \pm 1.8(4)$
M3.5-M4 III	$2.2 \pm 1.0(3)$	$7.7 \pm 3.3(7)$
M4.5-M5 III	$5.5 \pm 4.0(5)$	$7.9 \pm 1.7(9)$
M5.5-M6 III	$12.1 \pm 5.1(4)$	$7.6 \pm 2.0(6)$

3.5 D'-type symbiotics

There are two D'-type SSs among our new observations. For AS 201, our value of $v \sin i$ confirms the measurement of Pereira, Smith & Cunha (2005). The object is discussed in more detail in Paper I.

WRAY 15-157 is of spectral class G5III. The catalogue of rotational velocities for evolved stars (de Medeiros & Mayor 1999) lists 18 objects from spectral-type G5III. They all rotate with $v \sin i < 15 \text{ km s}^{-1}$. WRAY 15-157 with $v \sin i = 37 \pm 5 \text{ km s}^{-1}$, is an extremely fast rotator for this spectral class.

There are seven D' SSs listed in the catalogue of Belczyński et al. (2000). Rotational velocities are measured for all six southern objects. In Paper I, we have shown that four out of five D'-type symbiotics rotate rapidly. Here, we strengthen our result: five out of the six southern D'-type SSs are very fast rotators. Furthermore, four of them are the fastest rotators in their spectral class.

4 DISCUSSION

4.1 Reasons for the fast rotation

Soker (2002) discussed in detail three possible mechanisms for speeding-up the rotation of the mass donors in SSs: (i) synchronization, (ii) accretion during the main-sequence phase of what is now the red giant and (iii) backflowing material.

In the light of our results (see Paper II), synchronization plays an important role. Other mechanisms that can also operate in single giants as well as in SSs are: (iv) angular momentum dredge up when the convective envelope approaches the core region of the giant (Simon & Drake 1989) and (v) planet engulfment during the giant phase.

The discovery of giant planets around solar-type stars poses the question as to what happens when a main-sequence star evolves into a giant and engulfs the planet (see Massarotti et al. 2008, and references therein). Assuming for a typical M3III star $R_g = 71.5 R_\odot$ and $M = 1.6 M_\odot$, we calculate that an ingestion of a planet with a mass $0.01 M_\odot$ can speed up the rotation of the giant by up to 40 km s^{-1} (see Paper I for more details).

Some of the symbiotics belong to the old disc population (Wallerstein 1981). Smith et al. (1996, 1997) have shown that the symbiotics AG Dra and BD-21°3873 contain metal poor giants. We have selected from Carney et al. (2003, 2008a,b) 40 metal poor K giants with $3900 \leq T_{\text{eff}} \leq 4500$ and $0.5 \leq \log g \leq 1.5$ and $[\text{Fe}/\text{H}] \leq -0.8$. The statistical tests do not indicate statistically significant differences between symbiotic K giants and metal poor giants. Reasons for the fast rotation (and/or line broadening) observed in the spectra of metal poor giants are considered inherited rotation, induced rotation due to a stellar or planetary companion and more recently macroturbulence (see also Carney et al. 2003, 2008b).

Because the SSs rotate faster than the field giants, they probably can help us to understand in which cases the binarity and in which cases the planet ingestion or some other mechanism (i.e. inherited rotation, macroturbulence) is responsible for the fast rotation (or line broadening).

4.2 After-effects of the fast rotation

Fast rotation should enhance the mass loss in the equatorial regions, like the discs of the classical Be stars. The IR discs of D'-type symbiotics are (probably) a direct result of the fast rotation. A circumstellar medium that is significantly denser in the equatorial

regions of the binary than at the poles is already detected in RS Oph (Bode et al. 2007), indicating that circumbinary discs (non-dusty) can also be formed in S-type symbiotics.

Mass-loss rates for the symbiotic giants derived from cm and mm/submm radio observations (Seaquist, Krogulec & Taylor 1993; Mikołajewska, Ivison & Omont 2003), and from IRAS data (Kenyon, Fernandez-Castro & Stencel 1988) are systematically higher than those reported for field giants. The relation between rotation and mass loss is not yet exactly quantified (see Wilkinson et al. 2005). Nieuwenhuijzen & de Jager (1988) find $\dot{M} \propto (v \sin i)^{2.46}$. Following this relation, we estimate that if the symbiotic giants rotate 1.5–4.0 times faster than the field giants, they should have 3–30 times larger mass-loss rates. This matches the observed values (see fig. 2 in Mikołajewska et al. 2003) and means that the rapid rotation of the mass donors is the likely physical reason that increases mass loss in SSs over that exhibited by normal giants.

Smith et al. (1996) point out that the Barium and CH stars are similar to symbiotics but do not trigger symbiotic-like activity. Because the mass loss and/or rotation of the mass donors can be the reasons for the lack of activity, it will be interesting to measure their rotational velocities and to compare them with symbiotics and field giants.

4.3 Jet ejecting symbiotics

Bipolar ejections (jets) are rare phenomena for the accreting white dwarfs in symbiotics (e.g. Leedjävär 2002). Among our sample of SSs with known $v \sin i$ there are four objects with detected jet/blob ejection: RS Oph (Iijima et al. 1994; Zamanov et al. 2005), MWC 560 (Tomov et al. 1990; Schmid et al. 2001), StHα 190 (Munari et al. 2001) and Hen 3-1341 (Tomov, Munari & Marrese 2000).

In the recurrent nova RS Oph, the red giant probably rotates faster than the orbital period (Paper II).

V694 Mon (MWC 560) is seen almost pole on. The jet (orbit) inclination is $i < 16^\circ$ (Schmid et al. 2001) and probably the orbital period $P_{\text{orb}} \approx 1931 \text{ d}$ (see Gromadzki et al. 2007, and references therein). For a typical M6III star, we assume a radius of $147.9 R_\odot$ (van Belle et al. 1999). If we assume that the rotational axis of the red giant is perpendicular to the orbital plane, we calculate a rotation period of the red giant $P_{\text{rot}} \approx 180 \text{ d}$, which means that $P_{\text{rot}} \ll P_{\text{orb}}$.

The rotation period of StHα 190 is $P_{\text{rot}} \leq 5 \text{ d}$ (see Paper I). If we assume the typical orbital period of a symbiotic binary $P_{\text{orb}} \geq 200 \text{ d}$ (see Mikołajewska 2003), then we get $P_{\text{rot}} \ll P_{\text{orb}}$.

The rotation period of Hen 3-1341 is possibly $P_{\text{rot}} \approx 168 \text{ d}$ (assuming $R_g = 57.8 R_\odot$, $i \approx 30^\circ$), which is less than the typical orbital periods of S-type SSs.

These four objects point to the possibility that the jet ejections in symbiotics are detected in systems where the mass donors rotate faster than the orbital period (i.e. $P_{\text{rot}} < P_{\text{orb}}$). In this connection, candidates for detection of such ejections should be considered among the fast rotating SSs V840 Cen, Hen 3-1213, Hen 3-1674 as well as all D'-type symbiotics.

5 CONCLUSIONS

In this paper, we report measurements of the projected rotational velocity ($v \sin i$) of the cool giants in 9 SSs and 28 field giants, using high-resolution spectroscopic observations. Collecting together all available data (from Paper I, II and III as well as from the literature), we compare the rotation of the mass donors in SSs with the rotation of field giants of similar spectral types and find that:

- (i) the symbiotic K giants included in our survey rotate on average more than twice as fast as the field K giants,
- (ii) the M giants in symbiotics are more rapid rotators than most of the field M giants,
- (iii) for the D'-type (yellow) symbiotics, five out of the six southern D'-type SSs are the fastest or among the fastest rotators in their spectral classes,
- (iv) as a result of the rapid rotation SSs should have on average ~ 10 times larger mass loss rates than normal red giants and
- (v) we find suggestions that in the jet-ejecting symbiotics the mass donors rotate faster than the orbital periods.

This is the first observational investigation that clearly confirms theoretical predictions that the mass donors in symbiotics are fast rotators.

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