ASTRONOMY AND SPACE SCIENCE
eds. M.K. Tsvetkov, L.G. Filipov, M.S. Dimitrijević, L.Č. Popović,
Heron Press Ltd, Sofia 2007

Rotation of the Mass Donors in Symbiotic Stars

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Abstract. We have measured the projected rotational velocities ($v\ \sin i$) of the mass donors for 40 symbiotic stars using the cross–correlation function (CCF) method and high–resolution spectra obtained with FEROS and the 2.2m telescope at ESO. In a sub–sample of 17 S–type symbiotic stars, we do not find evidence for statistically significant deviation from the synchronization for 15 out of 17 objects. One possible exception from synchronization is the peculiar object RS Oph.

Our study also reveals that mass donors in symbiotic stars rotate faster than single giants of similar spectral types.

1 Introduction

Symbiotic stars (SSs) are interacting binary stars consisting of a red giant transferring mass on to a white dwarf, with orbital periods in the interval 100 d – 100 yr. On the basis of their IR properties, SSs can be classified into star like (S) and dusty (D or D') types. The D type systems contain Mira as a mass donor. The D' type are characterized by the earlier spectral type (F-K) of the cool component. and lower dust temperatures [1].

We have investigated the projected rotational velocities of the mass donors in 40 symbiotic stars. Our aims are: (1) to check theoretical predictions that the red giants in these binaries are co-rotating, for objects with known periods; (2) to perform comparative analysis and to check if they are faster rotators, compared with single giants and those in wide binary systems; (3) to give clues to binary periods, individual mass loss rates, and to select candidates for X-ray observations.

2 Observations and the Technique of $v \sin i$ Measurements

The observations were performed with FEROS at the 2.2m telescope (ESO, La Silla). FEROS is a fibre-fed Echelle spectrograph, providing a high resolution of $\lambda/\Delta\lambda = 48000$, a wide wavelength coverage from about 4000 Å to 8000 Å in one exposure and a high detection efficiency [5]. The 39 orders of the Echelle spectrum are registered with a 2k×4k EEV CCD. All spectra are reduced using the dedicated FEROS data reduction software implemented in the ESO-MIDAS system.

Up to now, our sample includes all objects from the Symbiotic Star Catalogue with $12h$ <R.A.< $24h$, Declination <2°, and brighter than V<12.5 mag. Data for $v\ \sin i$ taken from the literature for 12 northern symbiotics were used, too.

Projected rotational velocities ($v\ \sin i$) have been derived by cross-correlating the observed spectra with a K0-type numerical mask yielding a cross-correlation function (CCF) whose centre gives the radial velocity and width is related to the broadening mechanisms affecting the whole spectra, such as stellar rotation and turbulence for example. Details of the cross-correlation procedure are given in Melo et al. [7]. The accuracy of our measurements is about ± 1.5 km s^{-1} for $v\ \sin i \leq 15$ km s^{-1}, and $\pm 10\%$ for $v\ \sin i \geq 15$ km s^{-1}.

3 Results

For 17 red giants in S–type SSs with known orbital periods, the rotational period versus the orbital period is shown in Figure 1. Among these 17 objects there are only two which deviate considerably from co–rotation: CD–43 14304 and RS Oph. There are concerns that $v\ \sin i$ of CD 43–14304 could be wrong. Hence, RS Oph seems to be the only known symbiotic system which might not be synchronized.

D'-type symbiotics are characterized by an earlier spectral type giant (F-K) and lower dust temperatures. There are 7 such objects listed in the Catalogue of SSs. Rotational velocities have been measured for five of them [11]. Four out of five appeared to be very fast rotators, compared with the catalogues of $v\ \sin i$ for the corresponding spectral types. At least three of them rotate at a substantial fraction (≥ 0.5) of the critical velocity [11]. Hence, in D'-type symbiotics, the cool components rotate faster than the isolated giants of the same spectral class. As a result of rapid rotation, they should have magnetic activity and larger mass loss rate, probably enhanced in the equatorial region.

We have also studied the distribution of the projected rotational velocities ($v\ \sin i$) for our sample of K and M giants in S–type SSs, compared to the distribution of single giants of the same spectral class and luminosity. $v\ \sin i$ data for single giants published in the catalogues of de Medeiros and Mayor [3] (for 238 K2-5 giants) and Glebocki and Stawikowski [4] (for 12 M0-7 giants)

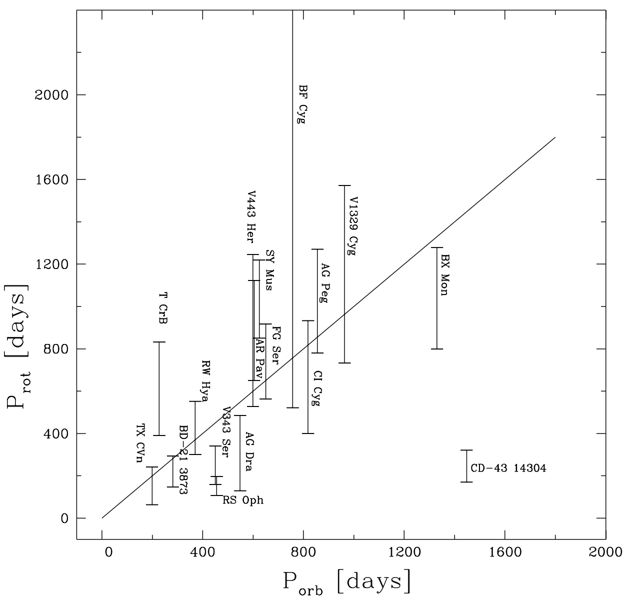

Figure 1. The rotational period of the red giants versus orbital period for 17 S-type symbiotic stars with known orbital periods. The solid line represents synchronization ($P_{orb} = P_{rot}$).

have been used. De Medeiros and Mayor have used the same method (CCF) for $v\ \sin i$ determination we used. Glebocky and Stawikowski have collected data from several catalogues and different methods have been used there, mainly the FWHM method. The relevant histograms for K and M giants are presented in Figures 2 and 3, respectively. They show that isolated giants and giants in S–type symbiotic systems occupy different areas of $v\ \sin i$ values. The giants in S–type symbiotic stars seem to rotate faster than isolated giants.

The Koslmogorov-Smirnov test for the two samples of K giants gives a probability of 10^{-6} (K-S statistics = 0.60) that both distributions arise from the same parent population. This confirms statistically that the K giant in SSs rotate faster than the isolated K giants.

For the two samples of M giants, the Kolmogorov-Smirnov test gives a probability of 0.0074 (K-S statistic = 0.54) that both distributions arise from the same parent population. Again, this means that from a statistical point of view, the M giants in SSs rotate faster than isolated M giants (at the 99% confidence level).

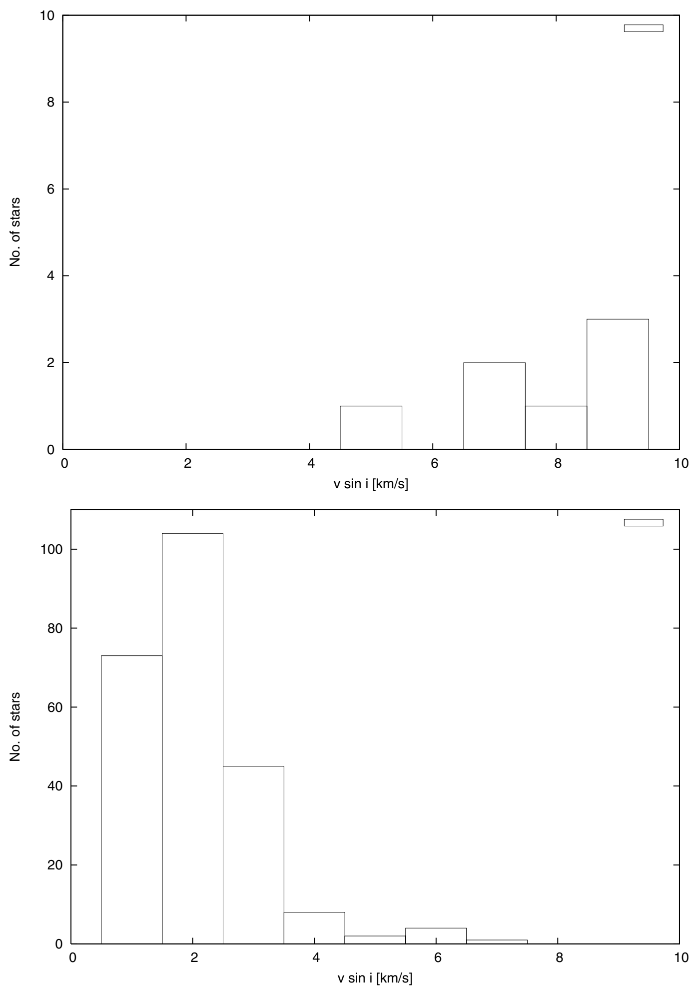

Figure 2. The distribution of $v \sin i$ for 7 K2-K5 giants in S-type symbiotic systems (upper panel) compared to the relevant distribution for 238 isolated giants of the same spectral classes (lower panel).

4 Discussion

The possible reasons for faster rotation of the giants in SSs include:

(i) synchronization, if the time spent by the mass-losing star on the giant branch is longer than the synchronization time. In all symbiotic systems with orbital period $P_{orb} \leq 100$ years, tidal interaction overcomes the angular momentum loss by the wind [10].

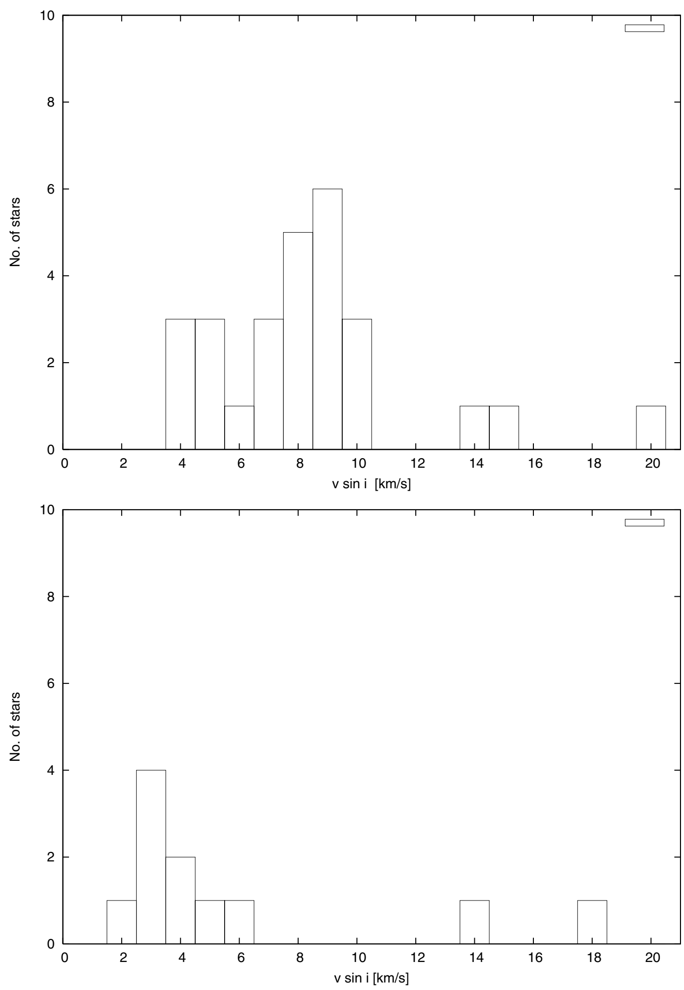

Figure 3. The distribution of $v\ \sin i$ for 28 M0-M7 giants in S-type symbiotic systems (upper panel) compared to the relevant distribution for 12 single M giants (lower panel).

(ii) accretion during the MS phase of what is now the red giant: the initially more massive star in the system, the present white dwarf, had transferred material on to the companion at the stage when it had been a red giant.

(iii) backflowing material: the hot component prevents part of the mass blown by the giant from acquiring the escape velocity for the binary system. This fraction of mass may acquire angular momentum, and if it is accreted back by the giant, it spins-up its envelope.

(iv) angular momentum dredge-up when the convective envelope approaches the core region of the giant [9].

(v) planet engulfment during the giant phase [8].

In the light of our results, synchronization **(i)** probably plays the most important role. Accretion **(ii)** and backflowing material **(iii)** can also contribute fto the faster rotation. Concerning **(iv)** and **(v)**, they can hardly explain the faster rotation in the majority of the giants in SSs. These two mechanisms (angular momentum dredge–up or a large planet engulfment) have to operate also for the spin-up of the isolated giants. However, a very small fraction of the evolved single giants (less than 5%) rotate faster than mean velocities for their spectral class and luminosity [2]. The interior conditions for the angular momentum dredge–up and the acceleration of the rotation in evolved giants are specific ones and do not appear in every evolved giant [6]. Planet engulfment can not be the main explanation for the rotational behavior of the mass donors in symbiotic stars. It is difficult to imagine that every SS had such a planetary system. Also, according to data published in Extrasolar Planets Encyclopedia (http://exoplanet.eu/), the distance of the large planets to the star is very different. Hence, they should be engulfed at different stages of the stellar evolution, and we should not observe such a majority of faster rotating giants, as we found in the mass donors of symbiotic stars. Moreover, these donors have different masses and are also at different evolutionary stages.

5 Conclusions

We have measured the projected rotational velocities ($v\ \sin i$) of 40 symbiotic stars using the CCF method. Among 17 symbiotics with known orbital periods and projected rotational velocities, there is only one (RS Oph) which might not be synchronized. Our results show that the mass donors in these binaries rotate faster than isolated giants. The faster rotation is undoubted for D'-type (yellow) symbiotics and for those harbouring K-type giants as mass donors. For those with M giants it is not so obvious, but still statistically significant.

To strengthen our results, more data on M-type isolated giants and more $v\ \sin i$ measurements of K-type mass donors in symbiotic stars are desirable. We intend to expand our sample with northern and fainter symbiotic stars and isolated red giants.

Since fast rotation at this evolutionary stage presumes the existence of magnetic activity, a further study of X-ray emission and other activity indicators have to be carried out. The most promising candidates in this aspect are Hen 3-1674 ($v \sin i$= 52 km s^{-1}, M5III), RS Oph ($v \sin i$= 14.5 km s^{-1}, M0III) and V343 Ser ($v\ \sin i$= 13.5 km s^{-1}, M3.5III).

References

[1] K. Belczynski, J. Mikolaevska, U. Munari, R.J. Ivison, and M. Friedjung (2000) *A&AS* **146** 407.

[2] J.R. de Medeiros and M. Mayor (1996) *A&A* **314** 499.

[3] J.R. de Medeiros and M. Mayor (1999) *A&AS* **139** 433.

[4] R. Glebocky and A. Stawikowski (2000) *Acta Astron.*, **50** 509.

[5] A. Kaufer, O. Stahl, S. Tubessing, P. Noregaard, G. Avila, P. Francois, and L. Pasquini (1999) *The Messenger* **95** 8.

[6] R. Konstantinova-Antova (2004) in *Stellar Rotation*, Proc. IAU Symp. 215, eds. A. Maeder and P. Eenens; San Francisco: Astronomical Society of the Pacific, p. 287.

[7] C. Melo, L. Pasquini, and J.R. de Medeiros (2001) *A&A* **375** 851.

[8] L. Siess and M. Livio (1999) *MNRAS* **304** 925.

[9] T. Simon and S. Drake (1989) *ApJ* **346** 303.

[10] N. Soker (2002) *MNRAS* **337** 1038.

[11] R.K. Zamanov, M.F. Bode, C.H.F. Melo, J. Porter, A. Gomboc, and R. Konstantinova-Antova (2006) *MNRAS* **365** 1215.