Part 2. The Status of Stellar Variability
Section 2C. Symbiotic Stars

Variability and Orbital Parameters for Symbiotic Stars

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Abstract This paper summarizes briefly the determination of orbital periods from brightness variations, of stellar masses from radial velocity variations, and of orbital inclinations from polarimetric variations for symbiotic systems.

1. Introduction

Symbiotic systems are binaries consisting of a cool giant and a hot component, in most cases a white dwarf. During quiescence the hot component is not seen in the visual range, but its radiation ionizes a fraction of the cool giant's wind, thus producing strong emission lines. Symbiotic systems show a wide range of interaction processes, such as nova-like outbursts and non-spherical mass outflows. Many aspects of these processes are closely related to the orbital parameters discussed here.

2. Orbital periods from variability observations

Amateur astronomers have contributed substantially to our knowledge about orbital periods of symbiotic binaries (Mattei 1993). Visual estimates by amateurs were crucial to the detection of the orbital period for PU Vul (see Garnavich 1996), and were used for improving the periods for such stars as SY Mus (Kenyon and Bateson 1984), AX Per (Mikołajewska and Kenyon 1992), and Z And (Formiggini and Leibowitz 1994).

The detection of orbitally-induced brightness variations in the visual region is relatively difficult during quiescence. Occultation and reflection effects are then restricted to the nebular lines, which contribute usually only little to the total brightness. With UV satellites such as IUE and HST it is possible, however, to see directly the continuum of the hot component, and to detect eclipses and periodic attenuations of the UV spectrum by the cool giant and the associated wind region.

During outbursts, the hot component contributes significantly to the light in the visual region. During these phases it is relatively easy to see in the visual range periodic variations or even eclipses of the hot component by the cool giant (see Figure 1). Outbursting symbiotic systems are therefore targets well suited for period determination from visual brightness monitoring.

Period distribution and eclipse frequency. Orbital periods have been determined for many symbiotic systems. I found the periods for twenty-six systems in the literature (see Mikołajewska 1997 for a similar compilation and references). Figure 2 shows the corresponding period distribution. Typical periods for symbiotic systems are between 300 and 1,000 days, with no system below 200 days.

The high percentage (≈40%) of eclipsing systems is striking. This seems to be a real property of symbiotic systems and not due to a selection effect. Assuming randomly-oriented orbital planes for the surveyed systems, this would indicate that eclipses occur as soon as the orbital inclination is $i \gtrsim 65°$ ($\sin i \gtrsim 0.90$). This in turn tells us that the cool giant and the associated wind region must be about the size of the Roche lobe (which may cause eclipses, too).

Comparison with barium stars. We may learn something about the evolutionary status of symbiotic systems if we compare the period distribution with related barium stars (McClure and Woodsworth 1990). Barium stars are binaries which consist of an (invisible) white dwarf and a G or K giant with peculiar abundances of such elements as enhanced barium and carbon. The cool giant in the barium star system will evolve into an M giant with large mass loss. Some of the lost material may be accreted by the white dwarf companion and trigger nova-like activity that would produce a symbiotic system. Indeed there are systems known, e.g., S32, UKS-Ce1, and AG Dra (Smith *et al.* 1996), which show symbiotic activity and barium star-type abundance peculiarities.

Figure 2 compares the period distribution between symbiotic binaries and barium stars. The symbiotic stars exhibit a clear deficiency of systems with long orbital periods $P \gtrsim 1000$ days. An explanation for this is that mass transfer and symbiotic activity are favored for systems with short periods or small binary separations.

3. Radial velocity curves and stellar masses

We know the radial velocity curve of the red giant for about a dozen symbiotic systems (see, e.g., Mikołajewska 1997). From the radial velocity semi-amplitude K and the orbital period P, we can get information on the stellar masses via the mass function $f_M = M_{hot}(1+q)^2 \sin^3 i \sim PK^3$, where q is the mass ratio of the two components $q = \mathrm{M}_{cool} / \mathrm{M}_{hot}$. All symbiotic systems, except two (see below), have small mass functions $f_M \lesssim 0.03\,\mathrm{M}$. This indicates "typical" masses of $M_{ho} \approx 0.5\,\mathrm{M}$ and $M_{cool} \approx 1.5\,\mathrm{M}$. These values are very similar to the masses derived for barium stars, which supports the close relationship between these two types of binaries.

For AX Per it was possible to measure also the radial velocity curve of the hot component during an outburst when its absorption dominated the visual spectrum (Mikołajewska and Kenyon 1992). Thus the mass ratio could be determined, and because AX Per is an eclipsing system, the masses $M_{hot} = 0.5\,\mathrm{M}$ and $M_{cool} = 1.0\,\mathrm{M}$ of the two components could also be determined.

RS Oph ($f_M = 0.10\,\mathrm{M}$) and T CrB ($f_M = 0.30\,\mathrm{M}$) have much larger mass functions, which indicate larger masses for the hot component $M_{hot} \approx 1$–$2\,\mathrm{M}_\odot$. RS Oph and T CrB are the only systems in the sample which show the short but violent outburst characteristics of recurrent novae. This supports the conclusion that higher M_{hot}-masses are required for fast, recurrent nova outbursts (e.g., Prialnik and Kovetz 1995).

4. Orbital inclination from polarimetric variations

Spectroscopic observations of symbiotic stars often show two strong broad emission lines at 6825Å and 7082Å. These lines are produced by Raman scattering of the O VI 1032Å, 1038Å emission lines by neutral hydrogen. Spectropolarimetric measurements revealed that the Raman lines are strongly polarized.

The production of strongly polarized Raman lines in symbiotic systems can be explained by a scattering geometry, where strong O VI radiation is emitted in the ionized region near the hot component, and converted by neutral hydrogen into Raman photons in the extended atmosphere of the cool giant. Thus the polarization direction of the scattered light is perpendicular to the direction of the incoming light. This means that the resulting polarization direction is perpendicular to the binary axis (the line connecting the two stars).

Due to the binary motion, the scattering geometry rotates relative to the line of sight. This produces a phase-locked rotation in the polarization angle which traces the position angle of the two stellar components. Inclined orbits will further show maxima in the percentage polarization at quadrature and minima at conjunction phases. Using this method, the inclination has been measured for AG Dra ($\sin i = 0.87$) (Figure 3), Z And (0.73), SY Mus (> 0.99), and V1329 Cyg (> 0.995) (Harries and Howarth 1996; Schild and Schmid 1997; Schmid and Schild 1997a, b). The latter two objects are known to be eclipsing, which supports the $\sin i$-values very close to 1.

At the same time, the polarimetric orbits provide the orientation of the orbital plane. Knowledge of orbital inclination and orientation is important for systems with extended nebulosities (e.g., V1329 Cyg) in order to distinguish between polar, meridional, or equatorial mass outflows.

5. Acknowledgements

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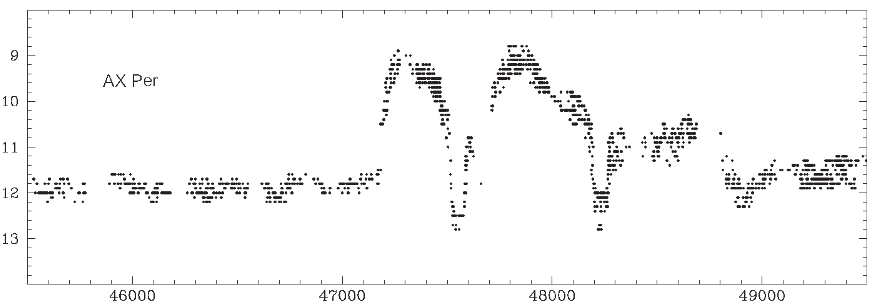

Figure 1. AFOEV light curve for the 1988 outburst of AX Per. Note the eclipses around JD 2447560 and 2448230.

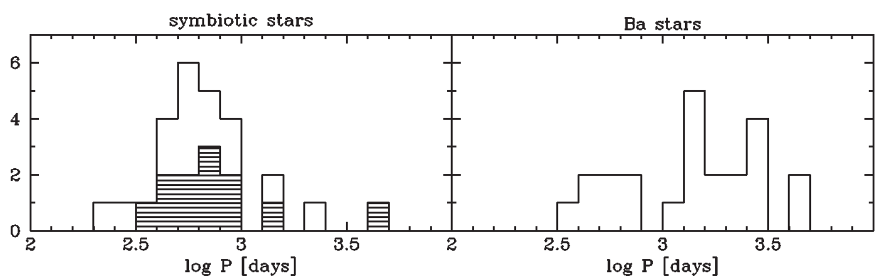

Figure 2. Period distribution for symbiotic systems (left) and barium star-type binaries (right). The subsample of eclipsing symbiotic systems is given as a shaded histogram.

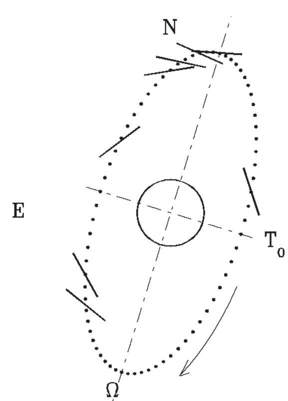

Figure 3. Polarimetric orbit of AG Dra derived from the 6825Å Raman line. The position of the hot component relative to the cool giant is given by dots at 5° intervals. Short lines show the measured polarization angles for the corresponding orbital phase. T_0 is the epoch for conjunction, and Ω the line of nodes of the orbital plane (see Schmid and Schild 1997a).