Be STARS AS INTERACTING BINARIES

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At the last IAU Symposium on Be stars held in Bass River, MA in 1975, several of us (including P. Harmanec, M. Plavec, R.S. Polidan, and myself) suggested that Be stars are mass transfer binaries and represent the higher mass counterparts to the familiar Algol systems. Although a number of alternatives to the rotational hypothesis have been presented at this symposium (including "chromospheric" activity and non-radial pulsation) and some of these may well explain certain objects, I strongly believe that binary mass transfer is responsible (either directly or indirectly) for the circumstellar envelopes observed in a large percentage of Be stars.

Why is it reasonable to consider the binary hypothesis? Four replies come immediately to mind. First, the frequency of spectroscopic binaries among B stars is high, 36% (Abt and Levy 1978) and, according to Plavec (1970) most of the unevolved, detached spectroscopic binary systems observed today should undergo mass exchange at some point during their post main sequence evolution. Second, the mass losing secondary (MLS) is the logical source of some of the matter in the envelope since, for early B stars, V_{eq}/V_{cr} appears to be less than 0.85 (Slettebak 1979). Third, the MLS is the logical source of the high angular momentum which Be stars, as a class, seem to display. This high angular momentum undoubtedly aids in the establishment and/or support of the envelope. Finally, some Be stars which usually do not look unusual in the visible portion of the spectrum are confirmed spectroscopic binaries (e.g. HR 2142, HR 7084). Alternatively, some Algol systems are spectroscopically similar to Be stars (e.g. TT Hya, AU Mon).

The primary reason that many researchers have been reluctant to accept the binary hypothesis is that few Be stars have been confirmed to be spectroscopic binaries. But several factors conspire against us to make it quite difficult to detect binary motion. These include the fact that we expect the semi-amplitude for the radial velocity variation to be small and, more often than not, the spectral lines are broad complex features containing both absorption and weak emission components which render the measurements more uncertain than those for sharper

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symmetrical lines. Uncertainties in the radial velocities from such complex features are usually about 10 - 15 km s^{-1}. Therefore, if the semi-amplitude, K, for the radial velocity curve is less than the latter value, it is indeed a challenge to find a solution for the orbit.

Now, we expect the mass ratio, q, for an interacting binary Be star to be less than 0.3 and the systemic mass to be in the range 5 - 15 $M_{\odot}$. The maximum expected value of K (assuming that the system is viewed equator-on) as a function of orbital period, computed for q = 0.1 and 0.3 and ΣM = 5 and 15$M_{\odot}$, is shown in Figure 1. As one can readily see from the curves, for all but the high mass systems containing more equal components, only the binaries of relatively short period ($<50^d$) can be easily detected. Since a q of 0.1 is probably more representative of the interacting binary Be stars than the larger values considered, it appears reasonable to assume that there are a large number of intermediate to long period systems which have not yet been discovered.

Orbits have recently been determined for two relatively long period interacting binary Be stars, HR 2142 (Peters 1981) and ϕ Per (Poeckert 1981). In each case, the semi-amplitude of the velocity curve is small (9.4 and 16.8 km s^{-1} for HR 2142 and ϕ Per, respectively). Despite the low values of K, orbits for both stars were

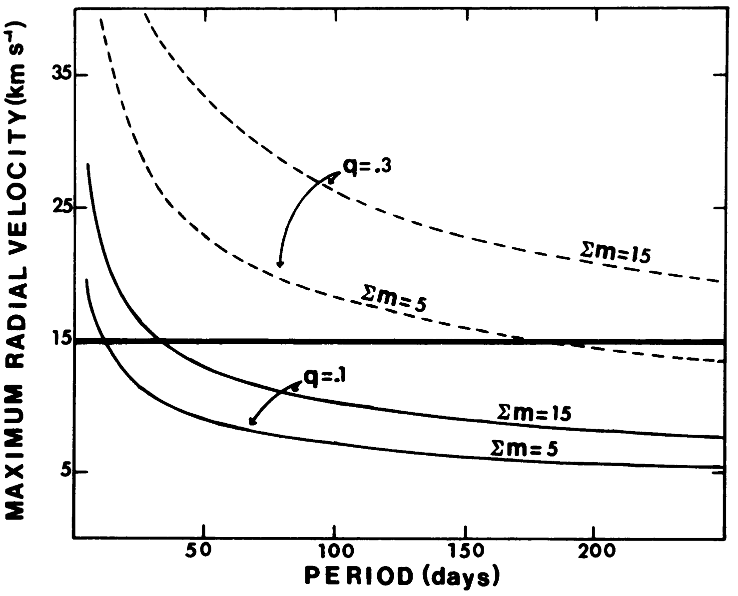

Fig. 1 - The maximum expected semi-amplitude for the radial velocity curve versus orbital period. Computations for two pertinent mass ratios and values of the systemic mass are presented. The bold, horizontal line separates the domain of easy detection (above) from that in which detection is more difficult.

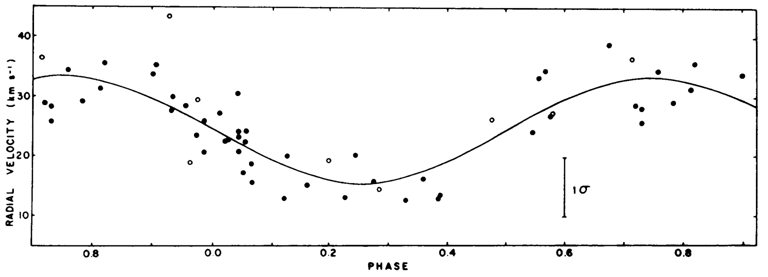

Fig. 2 - Radial velocity curve for HR 2142. Parameters from the orbital solution (indicated by the solid curve) are: P = $80^{d}.860$, T = 2441990.5, V_o = 24.1 km s^{-1}, K = 9.4 km s^{-1}, f(m) = 0.007.

obtained with a minimum of difficulty because the periods for these systems were known apriori. In the case of HR 2142, the period had already been determined from the strict periodicity of the short-termed, conspicuous shell phases (Peters 1976). The orbital solution for HR 2142, shown in Figure 2, is discussed in more detail in Peters (1981).

Since it is clearly advantageous to have some idea of the period when one searches for Be binaries, I offer the following suggestion. Polidan (1979) found a remarkably good correlation between the intensity of the infrared Ca II triplet emission (present in about 20% of the Be stars, a high percentage of which are confirmed binaries) and the period of the system. He determined that $I \alpha P^{4/3}$ (log I/log P = 1.20±.20, I in energy units). One could, therefore, use Polidan's results along with a measurement of the IR Ca II triplet emission strength to obtain an initial estimate for the period. This combined with good spectral data and careful measurements should lead to the discovery of many more interacting binary Be stars.

At this symposium much emphasis has been placed on the fact that Be stars lose mass, or at least develop circumstellar envelopes, episodically. Such behavior is compatible with the binary model as changes in the circumstellar disk are a result of variable mass transfer which is often observed in Algol binaries. The discovery of variable N V and C IV in Be stars has been offered as evidence that the Be phenomenon is a "chromospheric" one. However, it should be mentioned that N V and C IV have been observed in the interacting binary Be stars AU Mon (B5V) and HR 7084 (B3V) and their presence is most assuredly associated with the gas streams in these systems (Peters and Polidan 1982).

Ultimately, the success of the binary model for Be stars will depend upon the number of spectroscopic binaries that are found and confirmed. It is clear what the objective of our future endeavors should be.

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REFERENCES

Abt, H.A., Levy, S.G.: 1978, Astrophys.J.Suppl 36,pp.241-258.
Peters, G.J.: 1976, in A. Slettebak (ed.), 'Be and Shell Stars', IAU Symp. 70, pp.417-428.
Peters, G.J.: 1981, in preparation.
Peters, G.J., and Polidan, R.S.: 1982, this volume, pp.405-409.
Plavec, M.: 1970, Publ. Astron.Soc.Pacific 82,pp.957-995
Poeckert, R.: 1981, Publ.Astron.Soc.Pacific 93, in press.
Polidan, R.S.: 1979, Ph.D. dissertation, UCLA.
Slettebak, A.: 1979, Space Science Reviews 23, pp.541-580.

Koubsky: Has the Calcium emission been detected in systems of small period?

Peters: The systems of short period do not appear to display IR CaII triplet emission.

Giovannelli: What is the confidence level of the fit with the sinus of the HR2142 data you have shown?

Peters: The uncertainties in K, v_o and T are .9, .6, and 1.1, respectively.

Endal: I would like to make 3 comments about your statement that observed rotation velocities are inevitably less than 85% of the critical value.
1. For rapid rotators, the observed velocities may contain substantial errors.
2. The critical velocity is usually based on nonrotating, unevolved models. Rotation and evolution can substantially reduce the critical velocity.
3. It is not at all clear that $v/v_{crit}=1$ is necessary for instability.

Peters: Investigations published to date suggest a minimum of .85 for v/v_{crit}. I'm sure that the value of this ratio will be debated for years to come.

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