HOW MASSIVE THE WOLF-RAYET STARS ARE ?

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If the Wolf-Rayet stars are produced by the evolution of massive stars with mass loss (Paczynski 1967,Conti 1976) from O stars to WN stars and thereafter to WC stars,then we may expect to observe a correlation of decreasing mean masses in the same sense as the evolution.Information about the masses of WR stars are obtained from studies of binary systems with WR components.Table 1 presents the today available data for the WN type stars.

Table 1. Minimum masses of WN stars.

HD/name	M(WN)$\sin^3 i$	M(O)$\sin^3 i$	Sp.	
90657	9.5	22	WN4+O6	(a?)
94546	8	23	WN4+O7	
186943	9	17	WN4+O9	
190918	0.7	2.7	WN4.5+O9	
193576	9.5	24	WN5+O6	(a)
CX Cep	5	12	WN5+O8	(a)
211853	25:	40:	WN6+O	(a,b)
311884	40	48	WN6+O5	
214419	23	19	WN7+O?	(a)
92740	64:	24:	WN7+O	

Notes to Table 1:(a)eclipsing system;(b) multiple system (Massey 1980), the mass values quoted here were obtained adopting the HeI absorption velocity curve (Bracher 1968) for the OB component.

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The minimum masses listed in Table 1 suggest that the 10 $M_\odot$ value usually quoted for all WR stars may apply only to the stars with WN4-5 type spectra.It is also evident from Table 1 that the WN6-7 stars are quite massive.This is compatible with the suggestion by Conti (1976)that the "late" WN stars are "transition" types evolving to "early" WN stars.

Only 4 binary systems with WC type components have known double-lined orbits,and all these are of type WC7-8.Their masses are listed in Table 2.

Table 2. Minimum masses of WC stars.

HD/name	M(WC)sin^{3}i	M(O)sin^{3}i	Sp.
152270	1.8	5	WC7+O6
97152	3.6	6	WC7+O7
γ-2 Vel	17	32	WC8+O9
CV Ser	11	23	WC8+O8

None of the systems in Table 2 have been found to be eclipsing,therefore,assuming that the O type companions are normal,all the WC7-8 stars can be considered as having a mean mass value in excess of 15 $M_\odot$.This seems contrary to the possibility that WN4-5 stars can evolve to WC7-8 type stars.

In addition to Table 2,I will also report here preliminary results for the first galactic WC5+O7 system,namely HD 63099.Figure 1 shows the radial velocity variations of this system plotted in a period of 14.7 d, as inferred from spectrograms obtained at CTIO during 1979-80.Assuming that the orbit is circular,the minimum masses of the components result:

$$M(WC5)\sin^3 i = 4.7\ M_\odot \quad ; \quad M(O7)\sin^3 i = 19\ M_\odot$$

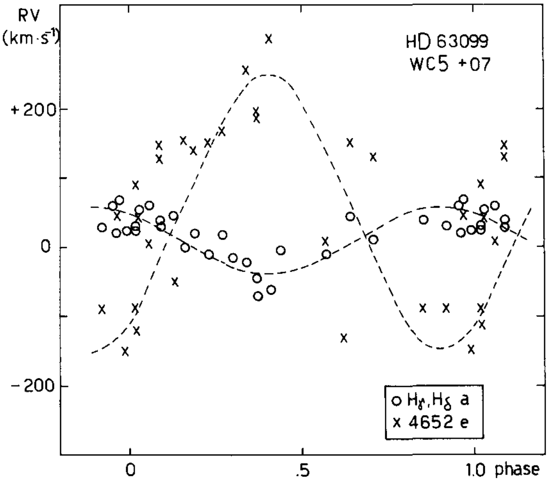

Figure 1.
Radial velocity curves of HD 63099.

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The WC5 star in this system seems to be less massive than the WC7-8 stars in Table 2.

Finally, I would like to remind you once again, that the masses of WR stars are still quite uncertain due to the many problems encountered in studies of WR binaries. Perhaps the most disturbing trouble for the determination of masses is that the different emission lines use to exhibit velocity curves with unequal amplitudes. Generally the velocity curves of lines from highest excitation ions have lower amplitude, and customarily we assume that these are the lines formed closest to the star and therefore should represent the "true" orbital motion. Figures 2 and 3 present

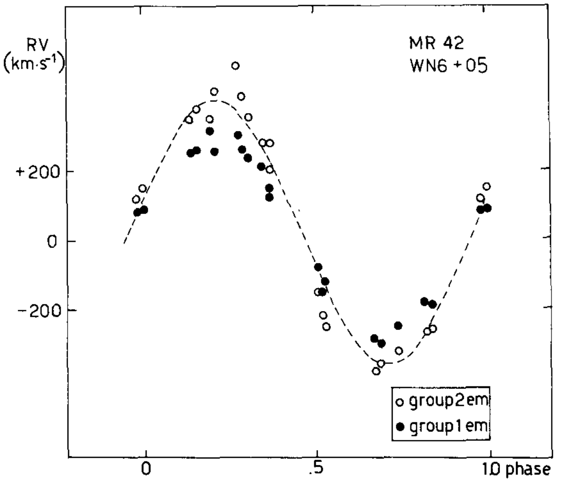

Figure 2. Radial velocity curves of different amplitude in the spectrum of MR 42. Group 1 emission=HeII, Group 2 emission=HeI, H

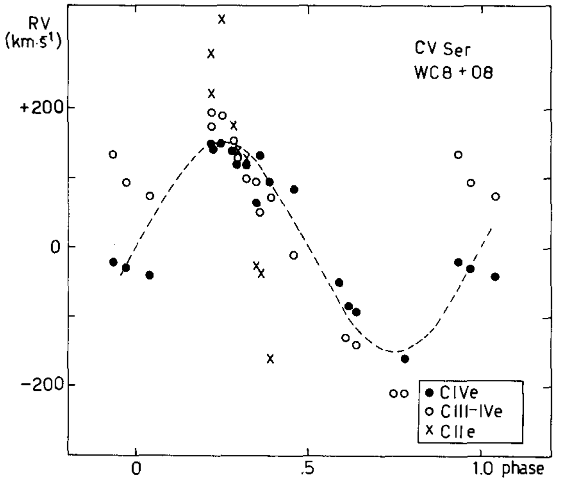

Figure 3. Radial velocity variations of different amplitudes in CV Ser. The dashed curve corresponds to CIV em. (Massey and Niemela 1980).

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this effect for the WN6 star HDE 311884=MR 42 and for the WC8 star CV Ser, respectively. Actually we do not know how much the aforementioned difficulties are biasing the mass values of WR stars.

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(For references to Tables 1 and 2 see Massey 1981, Astrophys.J. in press)
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DISCUSSION

VANBEVEREN: The fact that masses of WC stars are not smaller than the masses of WN stars strongly suggests that WC stars result from ZAMS O stars with masses larger than ~50 $M_\odot$ whereas WN stars result from ZAMS O stars with masses larger than ~30 $M_\odot$. This means that for a number of O stars one has the scenario O→ (Of, OI) WN and only for the most massive O stars one has O→ (Of, OI)→ WN→ WC.

van der HUCHT: In your list of WR binaries the star MRIII (AS 422) is missing. Pesch, Hiltner and Brandt (1960) found a f(M) = 7.7 and P = 22^d . Have you rejected this star from the WR binaries? If not, why has it not been studied for radial velocity solutions? Its current type is WN+WC!

NIEMELA: This is not a list of all WR binaries, only those which have double-lined orbital solution.

SAHADE: I would like to point out that one of the main results from Wirpi's tables is the fact that here is no correlation between the subclass of the WR star and the corresponding mass. This should be taken into account when trying to say something about the masses of the components of single-lined WR binaries particularly now that people are trying to find WR binaries with compact components.