MASSIVE CONTACT BINARY SYSTEMS

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ABSTRACT In recent years very massive single stars have been found to be upward of 90 M☉. Massive contact binary systems have been found among the early-type systems, but their masses are far less than those reported for single stars. The most massive component found is about 60 M☉.

It is generally believed that no late-type very massive stars have been detected (Humphreys and Davidson). This may be due to the large amount of mass loss from stellar wind. Recently, several extremely long-period late-type binary systems have been found to be contact systems. Two systems, UU Cnc and 5 Cet, have their primary components with masses exceeding 40 M☉, and K spectra. This result tends to suggest that close or interacting binary stars may be able to preserve the mass loss from stellar wind within the binary systems.

1. INTRODUCTION

Historically, contact binary systems were synonymous with W UMa systems. W UMa contact binaries were normally associated with short-period, late spectral-type (G or later), and low mass (one solar mass or smaller) systems. A decade and a half ago contact systems consisting of massive components were discovered. At present, we have found contact systems in all spectral-types except for M stars. (This exeception could be due to the selection effect being too faint to be discovered effectively. There are only two confirmed eclipsing systems with M spectra and they are detached pairs.) Since we are primarily dealing with Wolf-Rayet stars and massive stars in this Symposium, we will direct our attention to Wolf-Rayet, and massive type systems in this paper.

K. A. van der Hucht and B. Hidayat (eds.),
Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies, 207–212.

2. MASSIVE EARLY-TYPE SYSTEMS

If we make an arbitrary definition of massive stars being about 20 M⊙ or more, then there are 10 early-type contact systems in the class: 1 Wolf-Rayet systems, 7 O type systems and 2 B type systems. Some of the spectra of these systems are complicated and the measurement of radial velocities are quite difficult. About half of them have asymmetric light curves. The basic observed and derived quantities of these systems are summarized in Table 1. There is still significant uncertainty concerning the spectral-type and temperature relation among the very early-type stars. Thus, it may be unwise to employ the conventional H-R diagram, effective temperature vs luminosity, since both axes involve temperature calibration. It may be more reliable to use a mass vs radius diagram. A log M/M⊙ vs log R/R⊙ plot of these systems is shown in Figure 1. A straight line links up the two components of the same system for identification. Notice that there is only one point for V348 Car in the diagram since the mass ratio of this system is unity. Six of the systems are found in the vicinity of the ZAMS and TAMS. This suggests that they were evolved contact systems under Case A mass loss. On the other hand, V367 Cyg, RY Sct, UW CMa, and V729 Cyg are found to be located above the TAMS line. It is suggested that these systems are evolved contact systems under Case B mass loss. These systems should be located relatively far away from the main sequence in a regular H-R diagram.

It is believed that very massive stars lose significant portions of their mass through stellar wind. The observations suggest that the very massive systems still evolve to the right of the main sequence, and go through the contact phase of binary evolution similar to the lower mass systems. The system with the latest spectral-type is V367 Cyg (a member of W Ser star) with a B8 spectra. The mass, 19 M⊙ (< 40 M⊙), and the spectral-type, B8, of this system do not violate the Humphreys and Davidson (1979) limit.

3. LATE-TYPE SUPERGIANT CONTACT SYSTEMS

Recently, several late-type (G and K) binary stars (5 Cet, UU Cnc, PW Pup, and possibly HD104901B), with periods of a hundred days or longer, were found to be contact or near contact systems (Leung 1988). The shape OF their light-curves is very similar to those of W UMa and β Lyrae systems, except for their extremely long periodicity. Radial velocity curves are available for two of the systems (UU Cnc and 5 Cet). Both of them are found to be single-line spectroscopic binary systems. Their absolute dimensions are determined by means of photometric mass ratios and the combined photometric and spectroscopic solutions. The dimensions suggests

Table 1. Massive O and B Contact Systems

Name	P (days)	Sp Type	M_H	M_C	R_H	R_C	Percent*	Reference
			$M_\odot$		$R_\odot$			
CQ Cep	1.641245	WN7 + O6	26.4	19.8	9.3	8.1	51	Leung, Moffat & Seggewiss 1983
RY Sct	11.12479	O6-7 + O9.5-B0	39:	49:	37:	41.0	41	Milano, Vittone, Ciatti, Mammano & Strazzulla 1981
V729 Cyg	6.5977915	$O7fI_a$ + OfI_a	59	14	33	17	31	Leung & Schneider 1978b
UW CMa	4.393407	O7 + O7f	46:	19:	34:	22:	24	Leung & Schneider 1978a
V382 Cyg	1.8955143	O7.3 + O7.7	27	19	9	8	6	Bloomer, Burke & Millis 1979
TU Mus	1.3872833	O7.8 + O8.2	23.5	15.8	8.0	6.6	6	Andersen & Girønbech 1975
AO Cas	3.523428	O8.5III + O8.5III	29	25	14	13	3	Schneider & Leung 1978
LY Aur	4.00252	O9.5III + (B0.5III)	31.6	21.0	15.6	12.6	6	Li & Leung 1985
V348 Car	5.562107	(B0.5 III) + B1III	35	35	20.5	20.5	?	Hilditch & Lloyd Evans 1985
V367 Cyg	18.5972	B8III + (A)	19	12	39	31	6	Li & Leung 1987

* Percentage of over contact

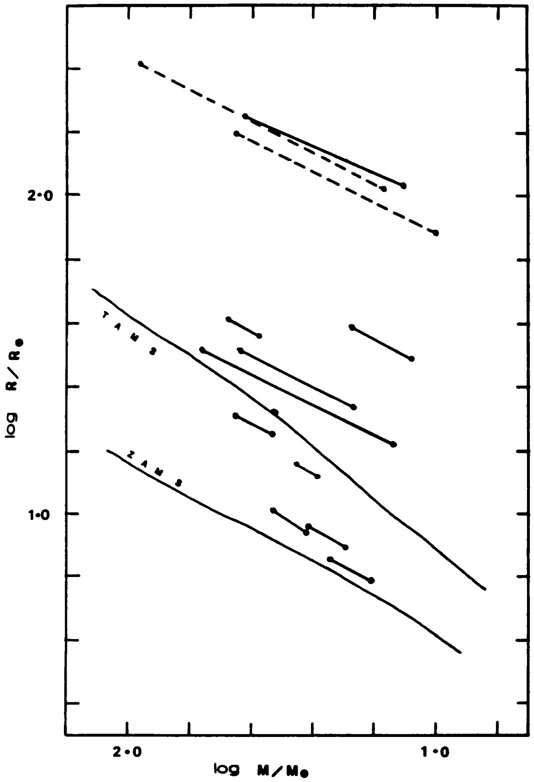

Figure 1. Log M vs Log R diagram of massive contact systems. Broken lines represent the two solutions of 5 Cet.

Table 2. Massive Late-Type Contact Systems

Name	P (days)	Sp Type	M_H	M_C	R_H	R_C	Reference
			$M_\odot$		$R_\odot$		
HD104901B	106	F0 Ib-II					Leung 1988
PW Pup	156	F2epIab					Leung 1988
UU Cnc	96.7	K2 (4)	44	13	184	109	Lee, Nha & Leung 1991
5 Cet*	96.4	K2	46	10	158	76	Li, Leung & Ding 1988
			94	15	264	108	

* See text

that they are massive supergiant and giant stars. The basic observed and derived quantities are listed in Table 2. Note that there are two entries for 5 Cet since there are two values of photometric mass ratios, 0.21 and 0.16 from the photometric solutions. UU Cnc and 5 Cet are located very far above the TAMS line. This suggests that these systems are evolved contact systems under advanced (very long after the hydrogen exhaustion phase of single star evolution) Case B mass loss. These are very massive systems (both of the primary components are larger than 40 $M_\odot$) and consist of late-type (K) supergiants. Generally, single stars (or non-interacting stars) follow the Humphreys and Davidson limit very well. However, for massive stars in an interacting system to be able to evolve to the right of an H-R diagram, the system must be able to preserve mass loss from stellar wind. It would be very interesting to investigate the common envelopes of these systems. It is logical to interpret that the common envelope of such a system must consist of a very deep convective atmosphere. It will be a real challenge to try to make theoretical models for this type of common atmosphere.

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DISCUSSION

Niemela: Are there other determinations of masses for the red stars that you mentioned, and how do those values compare with yours?
Leung: Both systems are simple line spectroscopic binaries. For 5 Cet, Eaton estimated a mass ratio from line profile and obtained small masses. For UU Cnc, there were estimates from photometric analysis. Unfortunately, they only searched for ratios near unity. That is, they found solutions in localized minima in the $\overline{Z} - g$ plane. The global minimum is around 0.3 instead of near unity!

Vanbeveren: I have a comment on the influence of radiation pressure on the evolution and more specifically on the equipotential surfaces in close binaries. Actually from a evolutionary point of view you are interested in what is going on during the Roche lobe overflow process. Now this process can be considered as two processes: you first have the existence of a critical surface, from where you have very huge mass loss to some kind of Lagrangian point and than you have a second process which has left the star. And how does this behave in such a binary? Now I have shown that if you account for shadow effects then the radiation pressure does not modify at all the equipotential surface. *E.g.*, if you assume the Von Zipal theorem, then you simply come up with the same equipotential surfaces as the usual of Roche lobe. But if you have two massive stars in a binary, once the matter has left the star as a consequence of this critical equipotential surface than you may not use any more, according to me at least, the classical computation done for two stars considered as two point masses, as has been done for low mass binaries in the massive binaries. Because there, in the computation of the trajectories of the particles, may be forming an accretion disk, you have to include radiation pressure, as has been done in the stellar wind theory. And if you do that, then the particles may acquire a velocity which is much larger than the escape velocity of the binary. And this was actually the main concern of the influence of radiation pressure on the Roche lobe. It has to be considered as the influence of radiation pressure on the Roche lobe overflow proces as a whole.

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