SEMI-DETACHED BINARIES: THE ORIGIN AND PRESENT STATUS OF TU MON, SX CAS, AND DM PER*

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Abstract. An attempt is made to trace back the possible progenitor systems of the Algol-type binaries TU Mon, SX Cas, and DM Per. The present characteristics are compared to the result of the evolution of 9 $M_0 + 5.4$ M_0. The position of the hot components in the HRD is discussed with regard to the theoretical models.

1. Introduction

Before coming to the issue of this paper we should like to begin with a synthesis of Kam Leung's paper, because we think that it reflected beautifully some small questions concerning generic relations, that still remain at present (see Figure 1).

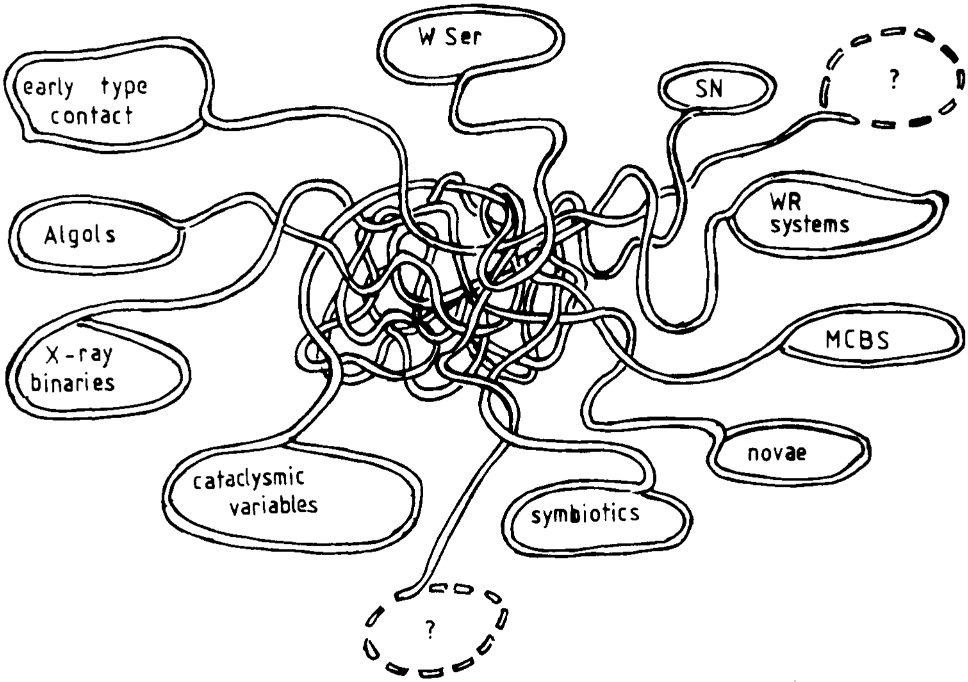

Fig. 1. The knot: the most recent version of the evolution for close binary systems.

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One word on the choice of the systems. At the time the paper was prepared only one (new) evolutionary computation (a test sequence which turned out to be succesfull!) was available. We therefore looked for sd-systems with approximately the same total mass as the theoretical model (14.4 M_0). The present three systems resulted, although we admit that their dimensions are much less well known than those discussed by Popper (1980). We intend to account for that in the future sequences.

In this talk we comment on one aspect of the 'Knot': the relation between semi-detached (sd) binaries and the (unknown) parental systems. Furthermore, we will discuss here only the conservative approach.

From the various review papers on the evolution of close binaries (see Paczynski, 1971, 1980) it follows that the characteristics of the mass transfer as well as the resulting system depend heavily on the initial parameters, i.e., mass of the loser M_{1i}, mass ratio $q_i = M_{2i}/M_{1i}$ and period P_i. But the relationship between these parameters and different kinds of interacting or post-mass-transfer binaries is still unsettled. Plavec (1973) already showed the inconsistencies arising when one tries to match individual systems to individual theoretical computations. Nevertheless, the progress made both in observational techniques and in evolutionary codes, makes it now possible to attack the problem again. SV Cen may serve here as an example (Drechsel *et al.*, 1982; Nakamura and Nakamura, 1982).

In the following sections we try to deduce the initial parameters of three semi-detached systems. Determination of the progenitors of such systems, and their evolution up to now and further, may give important clues to links between Algols, symbiotic stars and W Sepentis stars and the relation with advanced types of interacting binaries.

2. Observational Data and First Estimate of the Progenitor Systems

Table I shows the relevant parameters for the three systems.

TABLE I
Observational data for three sd-systems (references: see text)

System	HD/BD	M_1/M_0	M_g/M_0	$\log L_1/L_0$	P (d)
DM Per	14871	2.3	9.4	1.85	2.73
SX Cas	232121	3.8	9.5	1.91	36.57
TU Mon	−02.2331	2.7	12.7	2.26	5.05

They are derived from the paper of Giuricin *et al.* (1981) for DM Per, from Giuricin and Mardirossian (1981) for the W Serpentis system SX Cas, with spectral types and radius of the cool component taken from Plavec *et al.* (1982), and from Cester *et al.* (1977) for TU Mon. Using the initial mass ratio q_i as a free parameter (between 0 and 1) limits are set on the initial mass M_{1i} of the loser through the relations:

$$M_{1i} \geqq 0.5 \times (M_1 + M_h)$$

and

$$M_{1i} \leqq M_i^{\max}.$$

$M_i^{\max}$ is given by $M_i^{\max} = f^{-1}(M_1 = M_f)$, where

$$M_f = f(M_{1i}) = M_{1i}/(9.645 - 0.342\ M_{1i}),$$

represents the remnant mass at the end of a case B of RLOF for $3 \leqq M_{1i} \leqq 12$ (De Grève, 1980). With $q_i \geqq 0$ this leads to the boundary limits shown in Figure 2. The values of the maximum mass are 12.4 M_0, 16.8 M_0, and 13.5 M_0, respectively, for DM Per, SX Cas, and TU Mon. The corresponding initial periods (assuming conservative mass transfer) are shown in the same figure, with distinction between case A and case B of RLOF. It follows that the progenitor systems of TU Mon are restricted both in mass range (7.5 $M_0 - 13.5\ M_0$) and in period (0.7–12 d).

Tracks of single stars in the H–R-diagram are more or less horizontal after core hydrogen burning (and for $\log T_{\text{eff}} \geqq 4.0$). The mass luminosity relation in that phase, as derived from theoretical models, is given by

$$\log L/L_0 = 4.04\ (\log M/M_0)^{0.81} \qquad \text{for} \quad 1.5 \leqq M/M_0 \leqq 15.$$

With the condition that the radius R_1 equals the critical radius R_R at the onset of

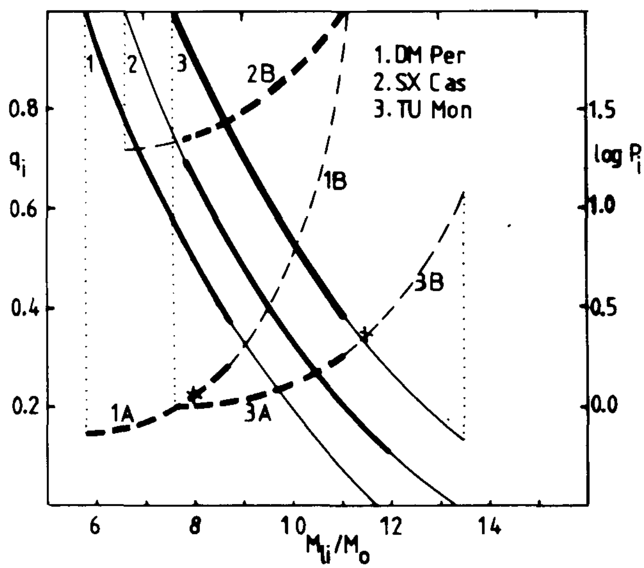

Fig. 2. Possible initial mass ratios (full curves) and initial periods (dashed curves) as a function of initial mass of the loser for 3 sd-systems, assuming conservative mass exchange. The labels of the period curves refer to the systems (1, 2, 3) as well as to the case of mass transfer (A, B), the boundary between A and B (if existing) is indicated by X. The thick parts of the curves represent the values allowed by the mass-luminosity position of the loser (see Section 3).

the mass transfer, the effective temperature at that specific moment can be calculated. So for all the combinations (M_{1i}, q_i, P_i) the location of the onset of mass transfer can easily be determined.

3. The Mass-Luminosity Position

Restraints can be set on the values of q_i and M_{1i} from the position in the $\log M_1 - \log L/L_0$ diagram. In the present study conservative computations are used. The position of the minimum luminosity during early case B mass transfer is given by (Devos, 1983)

$$\log L_{\min} = 0.495\, M_{1i}^{0.634} - 19.581\, q_i^{-0.05} + 19.983,$$

$$M_{\min} = 0.257\, M_{1i}^{1.256} + 10.746\, q_i^{-0.05} - 10.496,$$

in solar units. For early case B the influence of the period is negligible. Comparison of the present values of L_1 and M_1 with families of simplified tracks from the $L_{\min}$ positions to the final position in the mass-luminosity diagram, for different initial masses, leads to the results shown in Figure 2 (thick part of the curves).

4. Comparison with the Evolution of 9 M_0 + 5.4 M_0

As the first one in a series of computations for medium mass close binaries, with simultaneous calculation of both components, a case B of mass transfer was computed for the system $9\, M_0 + 5.4\, M_0$. We found that the system entered into contact when the mass M_1 had decreased to $8\, M_0$ and remained in contact for 8000 yr (until $M_1 = 6\, M_0$), i.e., 25 % of t_{KH}. However it will be difficult to detect the system in that phase because both spectral types (A1 + B1) and luminosity ($\Delta M_V = 1.7$) are largely different. We emphasize that energy transfer between the components was neglected during contact.

Comparison of the observed HRD-positions of the components with those of the theoretical models at the same mass-value is shown in Table II. The last column

TABLE II

Comparison between theoretical (C) and observed (O) HRD positions of the components (at the same mass value) of 3 sd-systems. The differences are defined as Δ = C–O. Last column: see text. The subscripts 1 and g denote loser and gainer respectively

System	$\Delta(\log L/L_0)_1$	$\Delta(\log T_e)_1$	$\Delta(\log L/L_0)_g$	$\Delta(\log T_e)_g$	M_{MS}/M_0
DM Per	1.60	0.13	1.23	0.24	5.5
SX Cas	−0.06	0.14	0.85	0.31	6.7
TU Mon	0.74	0.05	0.42	0.14	8.5

gives the mass of a normal single star corresponding with the present HRD-position of the gainer.

The differences for the loser may mainly be due to the differences in period between theoretical and observed system (as this component is in contact with its critical surface). The observed gainers however, are systematically underluminous, compared to the models. The latter may result from the poor quality of the observations of the three systems (cf. the comment of Giuricin *et al.*, 1981, for DM Per).

On the other hand these results indicate that for modeling observed sd-systems, one has to start with very well known systems. This in turn means that computations must be performed for lower initial masses, as very few high mass systems have reliable absolute dimensions (Popper, 1980).

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