OBSERVATIONAL CONSTRAINTS FROM MODELS OF CLOSE BINARY EVOLUTION

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The evolution of a system of 9 M_o + 5.4 M_o is computed from Zero Age Main Sequence through an early case B of mass exchange, up to the second phase of mass transfer after core helium burning. Both components are calculated simultaneously. The evolution is divided into several physically different phases. The characteristics of the models in each of these phases are transformed into corresponding 'observable' quantities. The outlook of the system for photometric observations is discussed, for an idealized case. The influence of the mass of the loser, m_{1i}, and the initial mass ratio q_i is considered.

I. INTRODUCTION.

This talk deals with the following question: how does a computed model of a close binary system in a certain evolutionary phase, look to the observer? As the present results are only the onset of a large project, on various aspects of observing theoretical models, they are subject to severe limitations in the treatment:

- essential one value of the initial mass of the loser is considered,
- only early case B of mass exchange,
- zero eccentricity and spherically symmetric stars,
- uniform brightness distribution for both components,
- inclination i = 90°.

Summarizing we will discuss aspects of a non-existing system, just as most theoreticians do.

II. EVOLUTIONARY PHASES AND TIMESCALES.

The model has initial masses of 9$M_\odot$ and 5.4$M_\odot$, with a period of 2.98dys. Its evolution has been discussed to some extend at IAU Colloquium No. 80 (De Grève and Packet, 1983). The following phases are defined:

A: Main sequence and hydrogen shell burning (29.27 E6 yrs or 82% of the total timescale computed t_t)

B: The mass exchange (2.3E5 yrs or 0.7% of t_t), subdivided in
  B1: A sd-phase at the onset of mass loss (6% of t_B)
  B2: A contact phase, lasting till the loser reaches minimum luminosity (3% of t_B)
  B3: A sd-phase, with large mass transfer rate (10% of t_B)

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B4: A sd-phase, with small mass transfer rate (81% of t_B)

C: Core helium burning (5.54E6 yrs or 16% of t_t)

D: He-shell burning (3.6E5 yrs or 1% of t_t)

E: Case BB of mass transfer, sd with slow mass transfer

III. TRANSFORMATIONS TOWARDS AN 'OBSERVABLE' SYSTEM.

The theoretical results were transformed into color-magnitude diagrams for loser, gainer and for the total system, using the calibration of Flower (1977). Also the magnitude difference $\Delta M_V = M_V$ (gainer) $-M_V$ (loser) was calculated, together with the eclipse depth in magnitude, δ_l adn δ_g, during eclipse of the loser, resp. the gainer. The influence of initial mass ratio was investigated for $q_i = 0.38$, $q_i = 0.6$ and $q_i = 0.9$ (with $m_{1i} = 3\ M_{\odot}$); comparison of results for the masses 9 and 3 $M_{\odot}$ gave some idea about the influence of m_{1i}. The behaviour of several characteristics of both components, during the different phases, is shown in the Domino Table of Evolution (table1), for the 9 + 5.4 system. The columns represent the different evolutionary phases, the rows component parameters (black dot: loser, open circle:gainer). Upper position of a dot simply means largest value of the specific parameters. Changes of role of the components during a phase is indicated by dashed lines. It follows from the table that the system behaves different in bolometric magnitude than in visual magnitude. Moreover there is no direct correlation between changes in radii or temperature and changes in visual magnitude.

Table 1 : The Domino Table of Close Binary evolution (see text).

Phase	H-core H-shell	RLOF	RLOF	RLOF	RLOF	He-Core	He-shell	RLOF 2
State	d pre-RLOF	sd $\dot{M}\uparrow$	c $\dot{M}\uparrow$	sd $\dot{M}\uparrow$	sd $\dot{M}\downarrow$	d	d	sd $\dot{M}\downarrow$
Mass	● ○	● ○	● ○ ○ ●	○ ●	○ ●	○ ●	○ ●	○ ●
bol. lum.	● ○	● ○ ○ ●	○ ●	○ ●	○ ●	○ ●	○ ●	○ ●
radius	● ○	● ○	● ○ ○ ●	○ ● ● ○	● ○	● ○ ● ○ ● ○	● ○	● ○
color (Te)	● ○	● ○ ○ ●	○ ●	● ○	○ ●	● ○ ○ ●	○ ● ● ○	○ ●
$-M_V$	● ○	● ○ ○ ●	○ ●	○ ●	○ ● ● ○	● ○ ○ ●	○ ● ● ○	● ○

IV. RESULTS.

a) In the colour-magnitude diagram the behaviour of the system as a whole is determined by the gainer's rise in M_V, during the first part of the mass exchange. Later it is completely dominated by the M_V evolution of the loser.

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b) the colour of the system remains inaffected by the sharp increase in B-V of the loser during the rapid phase of mass transfer:

$(B-V)_t$: -0.2 to -0.1

$(B-V)_l$: -0.2 to 0.7

c) during the slow phase, for $m_{li} = 9\ M_\odot$ and $q_i < 1$, $\Delta M_V > o$ where as $M_{bol,l} > M_{bol,g}$

d) at the beginning of the slow phase the eclipse depth δ_l is small for large m_{li} ($o^m_. o$ to $o^m_. 8$) large for small m_{li} ($2^m_. 1$ to $3^m_. 2$)

The eclipse depth δ_g evolves towards smaller values during the slow phase.

e) during the semidetached phase the primary minimum may be due to loser or gainer, to cool or hot component, to the more or the less massive star, to the largest or the smallest one. Hence when analysing the observations and dicussing the evolutionary state of the system, we should ask ourselves: who is who on the close binary scene?

References.

De Grève, J.P., Packet, W. : 1983, Astrophys. Space Sci (96, in press)

Flower, P.F.: 1977, Astron. Astrophys. 54, 31.

DISCUSSION

R. Cayrel: Speaking of non existing cases, do you expect circumstances in which the evolution produces the coalescence of the two components of a close binary system?

de Grève: One expects coalescence in a close binary system if much angular momentum is removed from the system. This occurs most probably for extreme initial conditions, especially for small initial mass ratios. Computations for these extreme cases have to be performed in the future.

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