DISTURBED BINARIES : THE EARLY PHASES

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ABSTRACT. The disturbance of components and system parameters by mass transfer during and at the end of core hydrogen burning, as well as at the onset of core helium burning is reviewed. Emphasis is given to the influence of the evolution of the gainer and to the variation of the chemical composition of the surface.

1. Introduction

This paper is restricted to "disturbances" in the sense of mass transfer interaction. It does not deal with disturbances due to magnetic braking or influence of tidal interaction on the rotational behaviour of the components. More general aspects of the latter have been reviewed by Savonije and Papaloizou (1985). The importance of such interactions to clarify apparent anomalies is illustrated by the explanation of the discrepancy between the asynchronous rotation and the circularised orbits in systems containing F, G, or K-type components (Habets and Zwaan, 1988), through the increase of the moments of inertia (Rutten and Pylyser, 1988) and magnetic braking.

There are at least 2 reasons to focus attention to the early disturbance of a binary system:

1. Calculations of close binary evolution, involving the structure of the two components now give a better insight to the occurrence of contact phases and more detailed information on the remnant system (Nakamura and Nakamura, 1984, De Greve, 1986, Packet, 1988). This, in turn, serves to a better evaluation of the further evolution, more especially the advanced common envelope evolution.
2. Implementation of a detailed nuclear network in the computer code results in information of the variation of surface abundances of elements such as carbon and nitrogen during mass transfer (De Greve and Cugier, 1988). Analysis of high dispersion spectra supply us with observational counterparts. From the comparison we may hope to get a better understanding of the process of mass transfer and, subsequently, of mixing processes involved in accretion of matter.

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2. Interaction near the Terminal Age Main Sequence (TAMS)

For a discussion of the interaction of a binary sysem at the end of core hydrogen burning of the primary component (late case A) or at the onset of hydrogen shell burning (case B), we follow the evolution of two detached systems, V539 Ara (6.1 $M_{\odot}$+5.25 $M_{\odot}$, P=3.17d) and QX Car (9.2 $M_{\odot}$+8.5 $M_{\odot}$, P=4.48d). Both systems were extensively studied within the framework of the Copenhagen program on accurate determination of absolute dimensions (Andersen, 1983, Andersen et al., 1983). For both systems sequences were computed with and without convective overshoot of the convective core (respectively given by the characters R and S). Their evolution is extensively described by De Greve (1988).The larger radius of the "overshooting" models forces them into a late case A evolution, whereas the models with classical convective cores evolve into case B interaction. Obviously, overshooting results in less extreme mass ratios and, consequently, in smaller final periods (De Greve, 1986).

The evolution of the surface abundance of hydrogen, carbon and of the carbon to nitrogen fraction is summarized in Figure 1. It was derived using the results obtained by De Greve and Cugier (1988), assuming thermohaline mixing in the envelope of the mass gaining star when hydrogen depleted layers are accreted on top of the latter. It shows clearly that abundances lower than cosmic values, but larger than those expected from simple unperturbed accretion of layers of the primary (Cugier and Hardorp, 1988), are expected during the slow mass transfer phase. Such intermediate values were recently derived for a number of Algol systems (see De Greve and Cugier, 1988, for references).

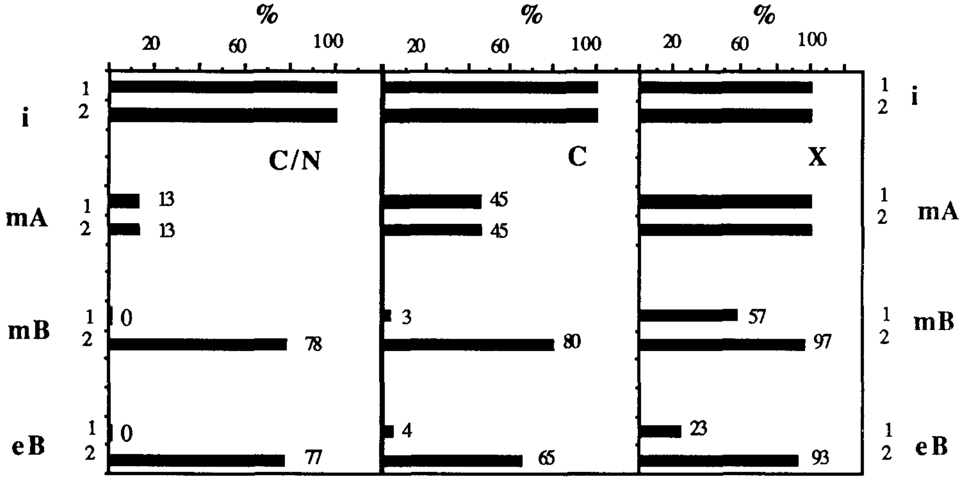

Figure 1. Proportional variation of the surface abundances of carbon-to-nitrogen (C/N), carbon (C) and hydrogen (X), during case AB of mass transfer of the system 9.2 $M_{\odot}$+ 8.5 $M_{\odot}$, P=4.48 d (QX Car), assuming thermohaline mixing when hydrogen depleted layers are accreted by the secondary star. The numbers 1 and 2 refer to the components. The following phases are given:
i= initial state, mA= mid case A, mB= mid case B, eB= end case B.

With regard to the semidetached state, systems with comparable mass such as V356 Sgr (12.1 M_O+4.7 M_O, P=8.9d; Popper, 1980), BF Cen (8.7 M_O+3.8 M_O, P=3.7d; Andersen et al., 1988) and perhaps even u Her (7.8 M_O+2.8 M_O, P=2.05d; Van der Veen, 1985) may have evolved from systems like V549 Ara and QX Car.

3. Mid case A interaction

For the low mass range, the evolution has been investigated by Ron Webbink (1976). For masses of the primary around 12 M_O Nakamura and Nakamura (1984, 1987a,b) found a complex set of scenarios, depending on the initial conditions. One of their important results is the occurrence of reversed mass transfer during the main sequence interaction. The origin of it is shown in Figure 2, for a medium mass system calculated by us (De Greve and Packet, 1988). The Figure gives the evolution of the central hydrogen content by mass as a function of time. The fast accretion first leads to a rejuvenation of the gainer, but during the slow semidetached phase, nuclear burning proceeds at a faster rate than in the primary star. The net result is a faster evolution compared to the primary. Before the end of core hydrogen burning, the secondary fills its own critical surface and reversed mass transfer starts. In this particular system the same situation is repeated once more, again reversing the roles of loser and gainer. This time the outer critical surface is filled and a common envelope phase starts while both components are still on the main sequence.

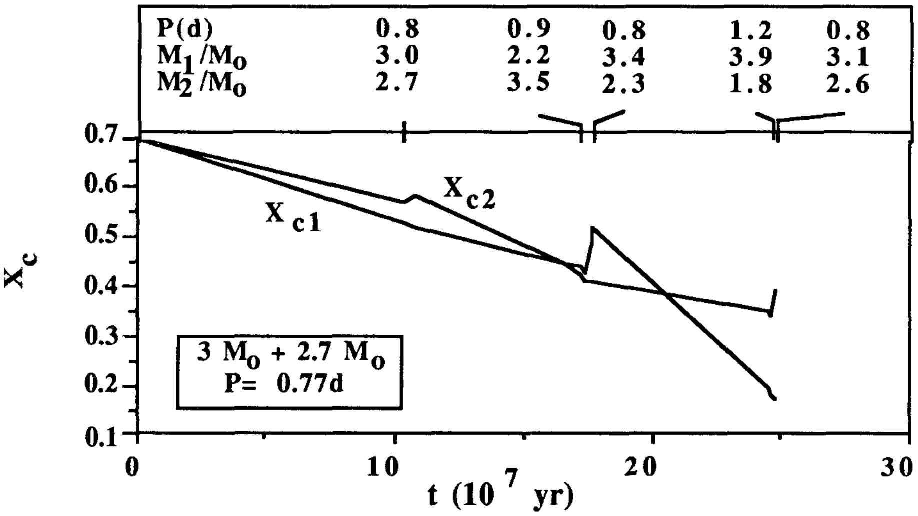

Figure 2. Evolution of the central hydrogen content (by mass) for the two components of an interacting binary system (case A of mass transfer). Characteristics of the system parameters are shown on top.

The net result for systems evolving through mid case A interaction is that the mass ratio and the period are confined to small ranges (resp. 0.3 to 2 and 1 to 2.5 days). Nakamura and Nakamura (1984) indicated what kind of systems follow the interrupted interactive evolution, as a function of initial separation d (expressed as the fraction of the possible main sequence range of values, ZAMS: d=0, TAMS: d=1), and mass ratio. Reversed mass transfer occurs for systems with d=0.7 (q=1) to d=0.5 (q=0.5). Practically all scenarios lead to overflow of the outer critical surface during the interactive phase. Only systems with d>0.5 and q~1 survive the interactive phase for some time. Giants with helium or carbon-oxygen companions only result from systems with d larger than 0.8 (case AB and B).

4. Late case B mass transfer.

Masses and characteristics of systems evolving through mass transfer around the moment of helium ignition in the core, were extensively studied by Iben and Tutukov (1985, and references therein). One of their important results was the derivation of the mass and composition of the degenerate dwarfs, formed by such interaction (probably valid for all case B interactions):

1. In the primary mass range 8.8 to 10.6 M_O, oxygen-neon dwarfs of mass 1.1 to 1.4 M_O are formed.
2. Below 2.3 M_O, down to 1 M_O, helium white dwarfs are formed down to a minimum mass of 0.13 M_O.
3. Carbon-Oxygen dwarfs of masses 0.3 M_O to 1.1 M_O originate from primaries of 2.3 to 8.8 M_O.

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