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CHEMICAL EVOLUTION OF ALGOL-TYPE STARS

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ABSTRACT The evolution of the chemical abundances at the surface of both components of Algol–type binaries is examined. First, we have examined some mixing processes which can affect element distribution in components of Algol–type stars. Second, the C abundance determinations from theoretical models are compared with values known from observational analysis. We conclude that there is no significant difference in chemical composition in components between case AB and early case B mass transfer. We have found a real difference between systems which evolve from initial mass ratios of 10/4 and 10/9.

INTRODUCTION

It is well known that mass transfer between the components of a close binary affects their surface chemical composition (Paczyński 1971). Evolutionary calculations show that nuclear processed layers are exposed at the surface of the loser (primary – the initially more massive star – donor) and transferred to the gainer (secondary – mass accreting star). Chemical abundance analyses (C, N and O) are available for a few Algol–type systems (Cugier and Hardorp 1988, Cugier 1989, Parthasarathy, Lambert and Tomkin 1983, Tomkin and Lambert 1989). In this paper we shall be interested in the Algol–type binaries and discuss the importance of the different mixing processes in their components. Because available observational data concerns short period Algols ($1^d - 3^d$) we have decided to consider mass transfer in case AB and early case B.

MIXING PROCESSES

We have considered the following mixing mechanisms: ordinary convection, Eddington–Sweet circulation in the whole star and/or near the surface, circulation caused by the accretion effect and mixing due to inversion of the molecular weight (μ) in the outer layers (instability due to Ledoux criterion, thermohaline mixing). The main conclusion may be summarized as follows. Only convection, thermohaline mixing and circulation caused by the accretion effect are important for binary systems in the semi–detached phase. Other

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processes have either a very long timescale in comparison to the mass transfer timescale or affect only the thin outer layers of the envelopes.

ASSUMPTION AND INITIAL CONDITIONS

Our calculations were carried out under the following assumptions:

1) The initial total mass ($M_T = M_{1,0} + M_{2,0}$) and mass ratios ($q_0 = M_{1,0}/M_{2,0}$) are: $M_T = 6\ M_\odot$ and $q_0 = 10/4, 10/9$.

2) All evolutionary calculations were carried out using a standard Henyey–type code (Paczyński 1970). Both components of the binary systems were calculated simultaneously. Only conservative evolution is considered.

3) We included two of the different mechanisms of mixing in our numerical code: the accretion effect and the thermohaline mixing.

RESULTS

Constructing conservative evolutionary models means that we assume the total mass and the total angular momentum of a binary system to be conserved during the process of the mass transfer between the components of the system. We will depart from these principles only in the case when a thick convective envelope has developed in the primary component. In this case loss of angular momentum by a magnetic stellar wind is turned on automatically. The models presented in this part describe the evolution of a few systems with different periods and mass ratios. The chemical evolution for the carbon (C) on the stellar surface for both components in a system exchanging mass in early case B ($M_{1,0} = 4.28\ M_\odot, q_0 = 10/4, P_0 = 1^d.7$) is presented in the figure below.

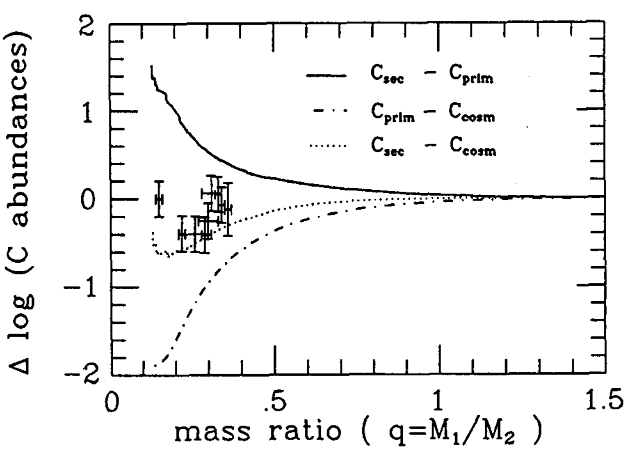

Fig. 1. The carbon abundance of the donor and gainer of the system $M_{1,0} = 4.28\ M_\odot$, q_0=10/4, $P_0 = 1^d.7$, as a function of mass ratio. The nine errorbars presented the carbon abundance for secondaries in Algol–type stars. Note that evolution is from right to left.

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We can see that during the first fast phase of mass transfer to about $t=6.3\times10^4$ yrs and q=1.4 there are no differences in the element abundances between components and cosmic values. Next carbon gradually decreases. During the slower phase of mass transfer the primary presents a very high depletion (−2 dex) of carbon abundance while the secondary shows an intermediate value from −0.4 to −0.6 dex (in the mass ratio range 0.4–0.1). In the secondary envelope accretion effects at first play an important role (to $t=7.\times10^5$yrs); next the thermohaline mixing determines the element distribution in the envelope. We have not found (Sarna 1992) significant differences in the value of the carbon depletion between systems evolved from case AB and B (for this same q_0). However, we have found real differences between systems evolved from initial mass ratios of 10/4 and 10/9. For a system that has undergone mass exchange in case B with orbital parameters: $M_{1,0} = 3.16\ M_\odot, q_0 = 10/9, P_0 = 1^d.617$, when we consider the carbon profile then we notice that depletion of this element is relatively small and equals −0.1 to −0.2 dex for mass ratios in the range 0.6 – 0.1. The depletion is two times less than in case B with $q_0 = 10/4$ (see Fig.1). For the model evolving by case AB mass transfer, with $q_0 = 10/9$ and $M_T = 6\ M_\odot$ the convective layers have developed when hydrogen rich matter was transferred from the mass–losing star. In the convective envelope of the primary $d\mu/dr \sim 0$, and therefore in the secondary envelope the thermohaline convection turns on at the end of mass transfer (because $\tau_{diff} \sim \overline{\mu}/\Delta\mu$).

CONCLUSIONS

The results of our evolutionary investigations can be summarized as follows.
1) The conservative models have explained well the observed carbon abundances in secondary components of Algols.
2) There is no significant difference in the chemical composition between case AB and early case B mass transfer. We have found real differences between systems evolving from initial mass ratios of 10/4 and 10/9. The systems with $q_0=10/4$ show twice the depletion of carbon of those with $q_0=10/9$. Therefore, we conclude that the "correlation" between carbon depletion and the mass ratio probably shows only the bimodality of the initial mass ratio distribution for proto–Algol–type stars.

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