EVOLUTIONARY COMPUTATIONS OF THE EARLY-TYPE CONTACT BINARY SV CENTAURI

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Abstract. Evolutionary models of the early-type contact binary SV Centauri are recalculated with contact condition taken into account. Two types of the contact condition are employed in the contact phase. With the initial masses of 13.4 and 7.0 M\(_\odot\) for the component stars, the observed features such as the rate of mass transfer, the degree of contact, and the positions of both components in the H-R diagram can be reproduced. In agreement with the conclusion given in the previous paper (Nakamura et al., 1978), this indicates that the binary system SV Cen is actually in the rapid phase of mass transfer preceding the reversal of the mass ratio.

In contrast to the steadily increasing character of the rate of mass transfer shown in the previous paper, however, the rate of mass transfer suddenly turns to decrease as soon as the system evolves into the contact phase. This decreasing character continues until the rate drops to a minimum. In such contact phase the radius of the primary component remains almost unchanged, the secondary component increases its radius slowly, and the degree of contact increases in a definite way. Except a slight difference in the degree of contact evaluated, the use of different expressions for the contact condition does not produce practically any appreciable difference in the results.

1. Introduction

The eclipsing binary SV Centauri has been observed to show an outstanding period decrease for the past eighty years (e.g., Paczyński, 1971; Irwin and Landolt, 1972; Rucinski, 1976). And it has been thought to belong to the class of early-type contact binaries (Wilson and Starr, 1976; Leung, 1977, 1980). In the previous paper (Nakamura et al., 1978; hereafter referred to as Paper I), it was examined whether such a configuration of SV Cen can be reproduced with a binary-star evolution program and it was found that the system is in the rapid phase of mass transfer prior to the mass-ratio reversal.

As described in Paper I, the following parameters are well known for this system (Wilson and Starr, 1976): the orbital separation \(A = 16.1\) R\(_\odot\), the mass of the more massive component (henceforward referred to as the primary component) \(M_1 = 11.1\) M\(_\odot\), the mass of the less massive (secondary) component \(M_2 = 9.3\) M\(_\odot\), the rate of mass transfer from the primary component to the secondary component \(M_1 = -4 \times 10^{-4}\) M\(_\odot\) yr\(^{-1}\), and the degree of contact \(f = 0.67\). The luminosity and effective temperature are also known to be \(\log L_1/L_\odot = 3.45\) and \(\log T_{\text{eff},1} = 4.21\) for the primary component and \(\log L_2/L_\odot = 4.04\) and \(\log T_{\text{eff},2} = 4.36\) for the secondary component, respectively. In Paper I,
however, these temperatures and luminosities have been corrected by $\Delta \log T_{\text{eff}} = +0.053$ and $\Delta \log L/L_\odot = +0.21$ for both components by taking into account a new calibration by Code et al. (1976). For the degree of contact, a somewhat larger value of $f = 0.90$ than that by Wilson and Starr (1976) is derived by Rucinski (1976).

The models computed in Paper I were succeeded in reproducing the observational quantities such as the rate of mass transfer, luminosities, and effective temperatures of both components. In their computations, however, the components were treated separately even in the contact phase, and therefore the degree of contact was not introduced, though it is one of the important observational quantities to be theoretically reproduced. In this paper, by revising the evolution program so as to enable proper treatment for the contact stages, we try to recalculate the evolutionary models of SV Cen.

2. Numerical Procedures

2.1. Model construction and initial parameters

Computations are performed under the following approximations which were employed in Paper I: conservations of the total mass and of the orbital angular momentum (the spin angular momentum of the component stars is neglected), circular orbit, and the Roche model.

The adopted computer code is the one described in Paper I, but some modifications have been applied to it. One of them is the way of estimation for the mass-transfer rate in the semi-detached stages. While an explicit scheme was used in Paper I, in the present paper is applied an implicit scheme which is similar to that of Savonije (1978). Another one is introduction of the contact condition which is described in the next subsection.

In Paper I, $M_{1,0} = 12.4 \, M_\odot$ was derived as a probable initial mass for the primary component of SV Cen (subscript 0 designates the initial parameters). However, considering the effect of contact, we choose slightly larger masses—i.e., $M_{1,0} = 13.4 \, M_\odot$ (Case I) and $12.9 \, M_\odot$ (Case II). From the present orbital period $P = 1.659 \, \text{d}$ (Irwin and Landolt, 1972) we get the following initial parameters: $13.4 \, M_\odot + 7.0 \, M_\odot (q_0 = M_{2,0}/M_{1,0} = 0.52)$, $P_0 = 2.211 \, \text{d}$, and $A_0 = 19.5 \, R_\odot$ (Case I), and $12.9 \, M_\odot + 7.5 \, M_\odot (q_0 = 0.58)$, $P_0 = 2.015 \, \text{d}$, and $A_0 = 18.3 \, R_\odot$ (Case II).

For the initial chemical composition we choose $X_0 = 0.70$, $Y_0 = 0.26$, and $Z_0 = 0.04$ as before.

2.2. Contact condition and degree of contact

In the contact stages we calculate the rate of mass transfer under the usual contact condition that both components have equal surface potentials. Then, the