THE MASSIVE ECLIPSING BINARY RY SCUTI

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ABSTRACT

We have analyzed Ciatti et al's (1980) UBV lightcurves of the massive eclipsing binary RY Sct. The B0 primary, being considerably overluminous and oversized for its mass, is certainly appreciably evolved. That this star is nearly filling its Robe lobe strongly supports the idea that it is undergoing a phase of mass transfer (case B), through Robe lobe overflow, towards its more massive secondary companion. In view of its properties, RY Sct, which represents an uncommon evolutionary stage, is lively to evolve into a Wolf-Rayet binary systems.

INTRODUCTION

The massive early-type eclipsing binary RY Sct, whose optical spectrum, classified as around B0e, is mainly characterized by strong emission features, is believed to be surrounded by a small nebula which is responsible for the radio emission (Hughes and Woodsworth, 1973) and for the pronounced infrared excess (Geisel, 1970) dominated by emission from silicate grains (Grasdalen et al., 1979). The spectroscopic observations indicate that the system consists of two very massive stars, the most probable values for the minimun masses being $M_1 \cdot \sin^3 i \sim 34\ M_\odot$ for the primary (i.e. the star eclipsed at the deeper minimum) and $M_2 \cdot \sin^3 i \sim 43\ M_\odot$ for the secondary component. (Cowley and Hutchings, 1976).

UBV photoelectric lightcurves of RY Sct have been published very recently (Ciatti et al., 1980). The character of the light variation emphasizes that the effects of interaction between the two components are large. Although this complicated binary system is far outside the framework of usual models of lightcurve analysis, it is worth exploring these lightcurves in order to improve our present knowledge of this binary.

C. W. H. de Loore and A. J. Willis (eds.), Wolf-Rayet Stars: Observations, Physics, Evolution, 383–386.

LIGHTCURVE ANALYSIS

We have decided to process its UBV observations by means of Wood's (1972) lightcurve synthesis computer model. Both the primary star and the secondary eclipsing object have been treated as tidally distorted triaxial ellipsoids which show gravity and limb darkening, as well as the reflection effect. We recall that in the case of RY Sct the secondary eclipsing body is not simply the secondary star, otherwise this member should be cooler than its companion, which, on the basis of the He I recombination lines, must be hotter (King and Jameson, 1979). In this attempt at exploring the photoelectric lightcurves of RY Sct it seems reasonable to tentatively regard the secondary body as a geometrically thick ellipsoidal disk which masks the secondary star, in analogy to the thick-disk model proposed by Wilson (1974) in his analysis of the lightcurve of β Lyrae. In our computations the main variable parameters are the orbital inclination angle i, the quadrature magnitude, the unperturbed fractional radius r_1 of the primary star, the ratio $K=r_2/r_1$ of the unperturbed radii, and the (equatorial) temperature relative to the secondary body. We have considered as fixed parameters the limb darkening coefficients, the gravity-darkening exponents and the reflection albedos. The equatorial temperature of the primary has been assumed to be 30,000° K. The mass ratio has been kept fixed at its more plausibile spectroscopic value q=1.25. We have found that the eclipses are partial ($i \sim 75°$) and that the primary minimum is an occultation (with $r_1 \sim 0.31$, $K \sim 1.6$).

DISCUSSION

Straightforward estimates for the primary's radius and luminosity result from our photometric elements and the most probable values for the minimum masses (i.e. $R_1 \sim 29\ R_\odot$ and $\log(L_1/L_\odot) \sim 5.8$ with temperature T_1=30,000° K and masses $M_1 \sim 38\ M_\odot$, $M_2 \sim 47\ M_\odot$). With these fundamental quantities, the primary B0 star cannot be near the main sequence, but it is considerably evolved.

The dimensions of the secondary object, which appears to be appreciably flattened, turn out to be larger than those of its corresponding Roche lobes. This situation, which is obviously hard to accept, is very likely a spurious result due to the simplicity of the model adopted for the secondary object. Our formal result can be regarded as an indication that the shape of the secondary body differs considerably from that of an ellipsoid. On evolutionary grounds this component, which is intrinsically hotter and more massive than the primary, is expected to lie on the main sequence.

That the primary member appears to nearly fill its inner critical surface strongly supports the view that this star is undergoing a phase of mass transfer (through Roche lobe overflow) towards the secondary, in favour of which the masses appear to be already reversed. Owing to its relatively long orbital period RY Sct has passed or is still passing through a case B mass transfer. This binary probably represents as uncommon evolutionary stage. In fact, it is known that several post-mass exchange case B massive remnants are classified as Wolf-Rayet systems; but only very few massive binaries,including RY Sct, are still observed to be composed of O-or B-type stars after the occurrence of a case B mass transfer. This leads us to suspect that in these cases we are facing a relatively short-lived evolutionary stage. A search through the literature has revealed that the following OB-type massive stars are probably in the same evolutionary stage as RY Sct, i.e. in the post-Roche lobe overflow stage relative to case B mass transfer: the eclipsing subsystem of QZ Car (Leung et al., 1979), V453 Sco (Woodward and Koch, 1975); and perhaps UW CMa (Hutchings, 1977), V448 Cyg (Stothers, 1972 and references cited therein), and V729 Cyg (Leung and Schneider, 1979). In accordance with some current evolutionary schemes (Vanbeveren and de Loore, 1980) RY Sct as well as the above-mentioned related massive binaries, are probably on their way to becoming Wolf-Rayet system, since they are characterized by larger and less unequal masses than Wolf-Rayet binaries.

As a final remark, the large value of the mass of the primary of RY Sct seems to be inconsistent with the results of non-conservative evolutionary calculations of massive close binaries, which include stellar wind mass loss, if we believe that main sequence progenitors of more than 100 $M_\odot$ cannot exist. Besides, the absolute luminosity of the primary is appreciably lower than the value conforming to the theoretical mass-luminosity relation for post-mass-exchange massive remnants (Vanbeveren and De Grève, 1979).

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