THE CONTACT BINARY H235 IN THE OPEN CLUSTER NGC 752[1]

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ABSTRACT Photoelectric BVRI light and radial velocity curves of the 0.41^d period eclipsing variable have been analyzed with a new, simplex-enhanced version of the Wilson-Devinney light curve program, and used to explore detached, semi-detached, and contact solutions. The system is best modeled as a W-type W UMa system, with contact parameter, $f = 0.44$, although at time of writing, we cannot rule out the possibility of an A-type system.

INTRODUCTION

The importance of eclipsing binary stars in clusters has been discussed in the context of the distance scale, of star cluster evolution and of binary star studies (Milone and Schiller 1988, 1991). Investigations of the age of the open cluster NGC 752 have been done by Hardy (1979), Twarog (1983) and more recently by Schiller and Milone (1988), who found $\tau = 2.0 \pm 0.2 \cdot 10^9$ y and a distance modulus: $(m - M)_0 = 7.9 \pm 0.2$, corresponding to $r = 380 \pm 40$ pc, in agreement with that obtained from the absolute elements of the eclipsing binary member DS Andromedae: $(m - M)_0 = 8.17 \pm 0.15$, or $r = 430 \pm 30$ pc. A principal conclusion of Schiller and Milone (1988) was that the

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components of DS And evolved independently without substantive mass loss or exchange, unlike H235.

HEINEMANN 235 MODELING

Heinemann 235 or H235 is centrally located in the field of NGC 752. Its variability was noted by Johnson (1953). Ebbighausen (1939) accorded H235 a high probability of membership, on the basis of proper motion. From our study, $V_\gamma = 21 \pm 4$ km/s, within the range for membership.

BVRI photometry obtained by *SJS* at Table Mountain, California in 1989 was used for light curve modeling. 15 Å/mm spectra were obtained at the *DAO* with an image-intensified reticon on the 1.8 m telescope. Reduction details will be discussed elsewhere. The spectra were cross-correlated against three standard stars; the mass ratio was found to be ~6.5:1.

The modeling of H235 was carried out at the University of Calgary with a version of the Wilson-Devinney *DC* (for *Differential Corrections*) program (Milone *et al.* 1992), operating on a Myrias SPS-2 64-processor computer and a simplex-enhancement of this version (Kallrath *et al.* 1992) running on IBM RS6000 platforms, which was used to explore wider ranges in parameter space than is convenient under the non-iterating Wilson-Devinney program (in general, it provides a short-cut from initial parameters to the deepest minimum of parameter space).

Few modeling details can be given here. RV data were given uniform weight. The temperature of the primary component, T_1 was set at 6900K based on the spectral type of the system. T_2 converged to a value close to T_1. Contact, detached, and semi-detached solutions were explored.

An A-type W UMa model was anticipated and satisfactorily modeled but additional trials with the RV curve shifted by 0.5^P (permitted because of the limited precision of the period, which allows a displacement $\leq 0.6^P$ with the light curve), and the reversal of RV curves 1 and 2, showed that a W-type model fits the data slightly better. Accordingly, both sets of solutions are presented in Table I; Σwr^2 shows the W-type model to be preferred but computed light curves of these models are not much different. Here the efficacy of the modeling process must determine which of the RV curve conjunctions coincides with the light curve primary minimum, but proof awaits additional times of minimum and an improved period.

The contact parameter, $f = (\Omega_1 - \Omega)/(\Omega_1 - \Omega_2)$, is relatively large in these models: $f_W = 0.435$, and $f_A = 0.440$. System representations of both models are shown in Fig. 1. In the A-type model the hotter component is slightly more luminous than in the W-type case: the *hotter* component has gained luminosity.

TABLE I H235 Solutions

Parameter/Model /Component:	A-Type 1	2	W-Type 1	2
a ($R_\odot$)	2.49(11)		2.50(9)	
i (deg)	58.9(1)		58.6(3)	
q	0.155(3)		6.46(3)	
v_7 (km/s)	21(4)		21(4)	
Ω	2.074(8)	2.074(8)	10.66(3)	10.66(3)
T (K)	6900	6841(35)	6900	6841(24)
$L_B(4\pi)$	9.62(8)	1.83	1.96(3)	9.46
$L_V(4\pi)$	9.71(7)	1.86	1.96(3)	9.59
$L_R(4\pi)$	9.58(6)	1.84	1.91(2)	9.49
$L_I(4\pi)$	9.46(5)	1.82	1.88(2)	9.39
R_{pole} (a)	0.517(3)	0.230(6)	0.229(3)	0.516(1)
R_{side} (a)	0.571(4)	0.241(7)	0.240(3)	0.571(3)
R_{back} (a)	0.596(6)	0.29(2)	0.287(8)	0.595(4)
Σwr^2	0.0211		0.0149	

Although the component stars of H235 cannot have evolved as isolated stars, it is possible that the system can serve as an evolutionary benchmark for other W UMa systems of similar mass because an age can be assigned to it, assuming that H235 was not formed or significantly hardened by collision subsequent to cluster formation. If so, the hypothesis that systems with initial periods of the order of $\sim 2^d$ evolve into contact system through angular momentum loss finds mild support in this intermediate contact system in a cluster of intermediate age. However, kinematic studies (*see* Guinan and Bradstreet 1988) of field W UMa stars suggest greater ages, on the whole, for these systems (~8 Gy on average), many of which have smaller contact parameters than does H235. The field systems, for which the probability of binary collision is much smaller than for cluster members, presumably merge via a slow angular momentum loss mechanism involving magnetic torques from stellar winds and spin-orbit coupling. This circumstance casts doubt on the notion that the H235 system has evolved to its present state without having undergone a hardening collision, much more likely for binaries than for single stars. Latham et al. (1991) have found many binaries in NGC 752, including virtually all the stars on the upper red hook of the CMD.

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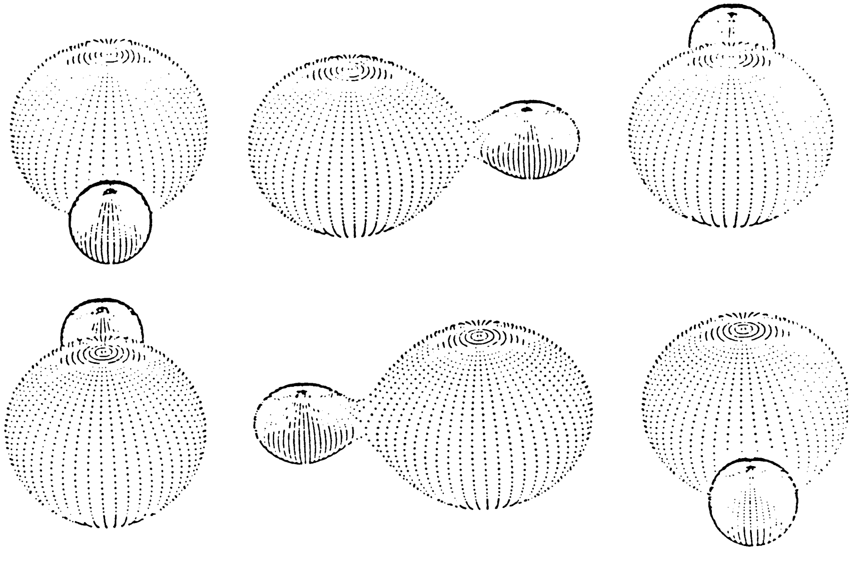

Fig. 1. The A-type (upper) and W-type (lower) models of H235, as drawn by *Binary Maker*, a software package produced and distributed by D.H. Bradstreet.

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