THE ECLIPSING BINARY SYSTEM LB3459

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The extremely blue foreground LMC star LB3459 (= HDE 269696) was reported by Kilkenny, Hilditch and Penfold (1978) to be an eclipsing binary system with a period of 6^h17^m. Preliminary analysis of uvby photometry and data obtained with the University of Cape Town high-speed photometer (Nather 1973) indicated that the system was composed of two degenerate stars, probably O-type subdwarfs.

A more detailed and complete light curve (Kilkenny, Penfold and Hilditch 1979) led to the following solution for the system parameters:

$T = 2443196^d.34870 \pm 0.00005$ (Hel. J.D.)

$P = 0^d.2615398 \pm 0.000\,0002$

$r_1 = 0.138 \pm 0.003$

$r_2 = 0.079 \pm 0.001$

$L_1 = 0.93 \pm 0.003$

$L_2 = 0.07$

$i = 90^\circ.0 \pm 0^\circ.02$

where r_1 and r_2 are the radii of the primary and secondary as a fraction of their separation and the primary contributes 93% of the system light in the visual region of the spectrum ("b" band). The solution assumes the stars to be spherical, to have no mutual interactions (distortion, reflection), and uses a linear limb-darkening coefficient $u_1 = 0.03$ for the primary. This very low value was derived from the best fit to the detailed photometry of the primary eclipse. If the primary has a temperature $T_{eff} \sim 45000^\circ K$ (Kudritzki 1976) then the photometric solution requires the secondary to have $T_{eff} \sim 20\,000^\circ K$ which suggests a system comprising an O-type subdwarf and a hot white dwarf.

In the past two years we have accumulated sizeable amounts of spectroscopic material using the South African Astronomical Observatory (SAAO) 1.9m telescope, the Anglo-Australian 3.6m telescope (AAT) and the IUE satellite. The reductions are still in early stages but some results can be presented.

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From spectra taken at 30 Å/mm with an image-tube spectrograph on the SAAO 1.9m telescope, a velocity curve has been obtained for the primary star. Using Sterne's method for small eccentricities, we derive the following solution:

$K_1 = 32.0 \pm 2.2$ km s^{-1}

$V_0 = +2.3 \pm 1.1$ km s^{-1}

$e = 0.06 \pm 0.05$

$\omega = 345^\circ \pm 71^\circ$

$a_1 \sin i = 1.15 \times 10^5$ km

$f(m) = 0.00089\ M_\odot$

Preliminary velocities from spectra obtained in collaboration with P.W. Hill using an image photon counting system (IPCS) on the AAT indicate excellent agreement with the above value for the semi-amplitude, K_1, and reasonable agreement with the systemic velocity, V_0.

The orbit is almost circular, hence the large error in the longitude of periastron passage. The photometric solution shows that the inclination of the orbit, i, is 90° so that the semi-major axis of the primary orbit is $a_1 \doteq 1.15 \times 10^5$ km.

In Table I are listed the mass of the secondary and the separation and radii of the two stars calculated for a range of primary star masses using the above mass function, f(m).

Table I Solutions for M_2, R, R_1 and R_2 for a range of M_1

$M_1/M_\odot$	$M_2/M_\odot$	M_2/M_1	$R/R_\odot$	$R_1/R_\odot$	$R_2/R_\odot$
0.1	0.02	0.24	0.8	0.12	0.07
0.5	0.06	0.13	1.4	0.19	0.11
1.0	0.10	0.10	1.8	0.25	0.14
1.5	0.13	0.09	2.0	0.28	0.16
2	0.16	0.08	2.2	0.30	0.18
5	0.29	0.06	2.9	0.40	0.23
10	0.46	0.05	3.5	0.48	0.28

The range of masses normally associated with subdwarf O stars, $0.5 - 1.5\ M_\odot$, requires a mass ratio $M_2/M_1 \doteq 0.1$ and a component separation $R \approx 1.5 - 2\ R_\odot$. In this range of solutions, the secondary has a lower mass and larger radius than are usually found in hot white dwarfs (e.g. Greenstein & Sargent 1974).

Our AAT and SAAO spectra extend from 4900 Å down to about 3650 Å. The only lines identified with reasonable certainty so far are the Balmer series to n = 12, He II (4686) and Si IV (4088). The hydrogen lines appear to be slightly asymmetric and are almost certainly blended with He II. N IV (4057) is probably present and a number of faint N IV, N V and O II lines have been tentatively identified.

In the ultra-violet (IUE spectra) the flux increases rapidly towards shorter wavelengths. As a first approximation we have scaled black-body curves to fit the wavelength region ∿ 1700 - 1900 Å and attempted to determine the best fit at shorter wavelengths. These attempts indicate that the temperature of the primary may lie in the region of 60 000 - 70 000°K. The method is not very reliable but we note that in the far ultra-violet, the relative flux in LB 3459 is about a third greater than that of BD +75° 325 (Heap et al 1978) which has an (LTE) estimated temperature of 45 000 - 50 000°K. If the temperature of the primary is as high as 65 000°K, then the photometric solution puts the temperature of the secondary at about 26 000°K.

The short wavelength (1150 - 1900 Å) IUE spectra show an 'absorption' region ∿ 1600 - 1750 Å also observed in BD +75° 325 and a region ∿ 1350 - 1450 Å in which we have tentatively identified some weak interstellar features and non-resonance stellar lines of Si III/Fe V. The Lyman α line is very strong and is probably partly interstellar, although the distance of the system is not well known. Other stellar features include N V (1240), Si IV (1393, 1403), C IV (1549) and possibly He II (1640); these are all relatively weak features.

In conclusion, the primary star seems to be a very hot O-type subdwarf. More exact data on the atmospheric parameters must await the non-LTE analysis which is in progress in collaboration with the Kiel group. The secondary star is something of an enigma; it is about 3^{mag} fainter than the primary and is certainly hot but of rather large radius for a white dwarf. The system has possibly undergone mass transfer twice (e.g. van den Heuvel 1976) or even some kind of "common envelope" phase (Paczynski 1976). Either would result in considerable mass loss from the system and in this context we note that there is no evidence of P Cygni profiles in the visual or ultra-violet spectra and that there is no indication of circumstellar material on H α plates of the LMC region taken with the UK Schmidt in Australia.

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