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NOTE ON 16 LACERTAE, AN ECLIPSING SYSTEM WITH A β CEPHEI PRIMARY

The single-line spectroscopic binary 16 Lacertae, the primary component of which is a well-known β Cephei variable, was recently discovered by Jerzykiewicz et al. (1978) to be an eclipsing system . The discovery resulted as a by-product of frequency analysis of two extensive series of photoelectric observations of the star. The first series consisted of over one-thousand blue magnitude observations, obtained by the present writer on 31 nights in the summer and autumn of 1965 at the Lowell Observatory. As it turned out, these data could be represented by a synthetic light-curve, having the form of a sum of three sine-wave components with frequencies of 5.9112, 5.5032, and 5.8551 cycles/day, and the corresponding amplitudes of $0^m.020$, $0^m.011$, and $0^m.010$, respectively. The agreement between the observed and computed variation was satisfactory, except that on one night a number of points fell below the synthetic curve by as much as $0^m.040$.

The second series consisted of about five-hundred blue magnitudes, secured by Jarzebowski, Jerzykiewicz, Le Contel, and Musielok in the autumn of 1977 at the San Pedro Mártir Observatory of the National University of Mexico, the Mt.Chiran station of the Haute Provence Observatory, and the Białków station of the Wrocław University Observatory. Three components, with frequencies identical to those determined previously, were also found in these data, although with amplitudes much smaller than in 1965. Again, the synthetic light-curve fitted the observations well, except that on one night several points deviated in much the same manner as on the above-mentioned one night in 1965.

Jerzykiewicz et al. (1978) noticed that the difference between the moments of the greatest deviations in 1977 and 1965, divided by the spectroscopic orbital period of $12^d.097$, amounted to very nearly a whole number. They also found that the orbital phases of the deviating observations corresponded to the point at which the descending branch of the orbital velocity-curve crosses the γ-axis. Jerzykiewicz et al. (1978) concluded, therefore, that the deviations of the observed brightness of 16 Lac from the synthetic light-curves were due to an eclipse. The duration and depth of the eclipse they estimated as equal to $0\overset{d}{.}4$ and $0\overset{m}{.}040$, respectively.

In this note the light-curve of the eclipse of 16 Lacertae derived from the above mentioned 1965 and 1977 observations is presented. Moreover, results of a solution based on the spherical model are briefly discussed - details will be published elsewhere.

In Figure 1 the deviations from the above-mentioned 1965 and 1977 synthetic light-curves are plotted as a function of orbital phase computed according to the following elements:

$$\text{Minimum light} = JD_{\odot}\underset{\pm.005}{2439054.575} + \underset{\pm.00003}{12\overset{d}{.}09684}\cdot E \qquad (1)$$

All observations with orbital phase within the interval 0.95 to 0.05 are shown - points represent the 1965 data obtained on seven nights, while open circles correspond to observations taken on one night in 1977 at the Mt. Chiran and San Pedro Mártir Observatories (left and right of the mid-eclipse phase, respectively). The improved value of the orbital period in eq. (1) was derived by forcing the 1965 and 1977 data to agree in phase along the ascending branch of the light-curve.

According to the spectroscopic orbital elements of Fitch (1969), the orbit of 16 Lacertae is very nearly circular (e=0.035 ±0.03), with K_1= 23.0±0.6 km/sec, $a_1 \sin i$ = 3.82x10^6km, and the mass-function $f(\mathfrak{M}) = 0.0152\,\mathfrak{M}_{\odot}$. From this value of the mass-function one gets the mass ratio $q=\mathfrak{M}_2/\mathfrak{M}_1 < 0.2$, if only $i > 55^{\circ}$ and $\mathfrak{M}_1 > 6\mathfrak{M}_{\odot}$. Thus, from the fact that an eclipse is observed, for any value of $\mathfrak{M}_1$, even remotely consistent with the primary's MK type of B2 IV, it follows that the mass of the secondary is of the order of $1\cdot\mathfrak{M}_{\odot}$, and that a_1+a_2 amounts to at least 3x10^7km. Consequently, the system is a detached one, with the secondary contributing a negligible fraction of total light, unless the radii of the components are very much greater than their main-sequence values. This conclusion is borne out by the circumstance that no proximity effects are observed.

In view of these results, a solution based on the simple

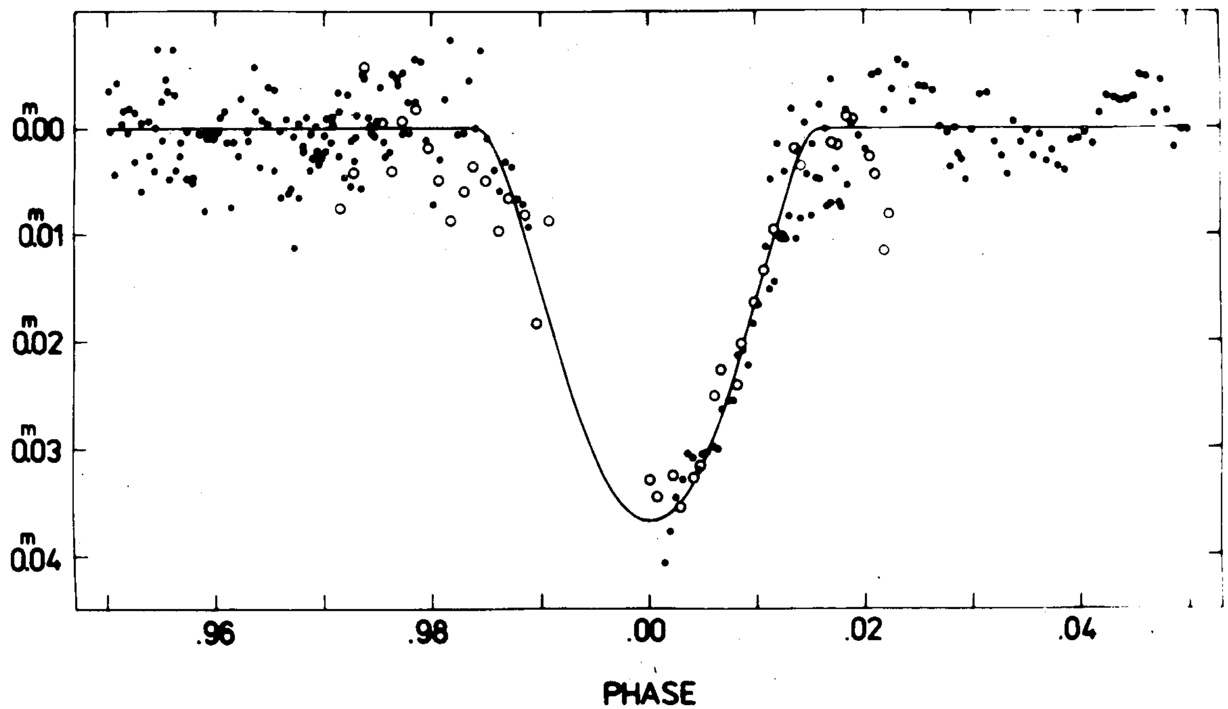

Figure 1. The primary eclipse of 16 Lacertae. The deviations from synthetic light-curves are plotted against the phase of the $12\overset{d}{.}09684$ orbital period. All observations were taken in the blue spectral region. The 1965 and 1977 data are shown with points and open circles, respectively. The line corresponds to the solution presented in Table 1.

spherical model was attempted. The contribution of the secondary to the total light of the system was neglected and for the primary the cosine law of limb darkening was assumed with the limb darkening coefficient of 0.4. Use was made of the Fitch's (1969) spectroscopic orbital elements. A number of trial solutions were computed for different values of radius and mass of the primary. It was found that a satisfactory agreement with the observations can be obtained for a radius consistent with the observed position of the star on the H-R diagram, and its mass derived from Population I evolutionary tracks. These values are $R_1=5.76\ R_\odot$ and $\mathfrak{M}_1=10.1\mathfrak{M}_\odot$, with the star still in the hydrogen-burning stage (Sterken and Jerzykiewicz, in preparation). The solution is given in Table 1, and the corresponding computed light-curve is shown in Fig.1 with a solid line.

Table 1

The Eclipsing System 16 Lacertae

Duration of the eclipse = $0\overset{d}{.}37 \pm 0\overset{d}{.}02$
Depth of the eclipse = $0\overset{m}{.}037 \pm 0\overset{m}{.}002$

$i=84\overset{\circ}{.}14$	
$R_1= 5.76\ R_\odot$	$R_2= 1.21\ R_\odot$
$\mathfrak{M}_1=10.1\mathfrak{M}_\odot$	$\mathfrak{M}_2= 1.26\mathfrak{M}_\odot$
$a_1= 3.84\times10^6$km	$a_2= 30.8\times10^6$km

Using these values it can be easily verified that the system is indeed a detached one, with the radius of the primary amounting to less than one-third of the radius of its Roche lobe. The radius and mass of the secondary are consistent with it being a main-sequence object. The mass ratio is $q=0.125$, by far the smallest known among unevolved eclipsing binaries.

The eclipse is a partial transit. At the mid-eclipse phase about 83 percent of the disc of the secondary is projected onto the primary. This circumstance opens an interesting possibility of investigating the changes of the primary component's geometry, caused by its oscillations, by means of observing the differences in the shape of the eclipse at different epochs.

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