PHOTOELECTRIC ELEMENTS OF AR LACERTAE

R. K. SRIVASTAVA
Uttar Pradesh State Observatory, Naini Tal, India

(Received 4 November, 1980)

Abstract. Geometrical elements of the system AR Lacertae have been obtained and its colour has been discussed. The absolute dimensions have been obtained on the basis of the spectroscopic elements given by Sanford (1951). The primary component lies fairly close to the Main Sequence on the log m–log R plot and the secondary falls away from the Main Sequence. The values of the Roche constants indicate that AR Lacertae is a detached system.

1. Introduction

The system AR Lac (= BD + 45°3813 = HD 210334 = HV 2980) was found to be a variable by Miss Leavitt (1903) and its light variability was confirmed by Wendel (1907). Jacchia (1929) and Loreta (1929, 1930) established it to be an eclipsing binary. Light variation of the system was also confirmed by Parenago (1930, 1938), Schneller and Plaut (1932), Zverev (1936) and Himpel (1936). Using a wedge photometer, Himpel (1936) noticed a hump during primary minimum. Wood (1946) presented the elements and called attention to the probability of intrinsic light variation in one of the components. Kron (1947) obtained the photoelectric observations for the system and noted irregularities during the partial phases and first proposed an explanation based on the presence of 'star spots' on the photosphere of the primary (G5) component.

Chambliss (1976) discussed 2000 three-colour photoelectric observations and found intrinsic variation of the order of $0\overset{m}{.}04$ in the light curve. Catalano and Rodono (1967) confirmed luminosity variation and found irregular period changes. They observed persistent (nearly sinusoidal) wave-like distortion in the light curve outside eclipse which migrates slowly towards decreasing orbital phase.

Harper (1933) presented first spectrographic elements. Wyse (1934) classified the spectra of the system as G5 and K0. He noted that the K0 component had sharp H and K emission lines, superposed on broad absorption, and placed it intermediate between a giant and a dwarf, both in view of density and luminosity. Sanford (1951) presented the spectroscopic elements of AR Lac. Struve (1952) discussed the spectra of the system in the light of 'turbulent spot' hypothesis. Popper (1967) listed the masses for the components. Hall *et al.* (1976) found both a persistent wave-like feature and an intrinsic light variation.

Hjellming and Blankenship (1973) first reported variable radio emission from the system. Gibson and Hjellming (1974) observed a relatively strong radio flare of the 'Algol type' at 2695 and 8085 MHz. Oliver (1974) and Hall (1975) classified AR Lac as a member of RS Canum Venaticorum group.

Astrophysics and Space Science **78** (1981) 123–140. 0004–640X/81/0781–0123$02.70.

2. Observations

The star was observed photoelectrically on the 38 cm reflector of Uttar Pradesh State Observatory using a 1P21 photomultiplier thermoelectrically cooled to −20 °C and conventional *U*, *B*, and *V* filters of the Johnson and Morgan system. The photocurrent was recorded using standard d.c. techniques. A total of 16 nights of observations were secured during the period October 1975 to January 1976.

The observations were reduced to the standard *UBV* system with the aid of constants derived from the observations of six standard stars (α Lac, β Lac, 4 Lac, 5 Lac, 6 Lac and 11 Lac) of various spectral types.

The particulars of the variable and the comparison star together with the standard deviations of the individual observation are given in Table I.

The standard deviations (listed above) derived from the observations of several nights chosen randomly, show a moderate scatter. However, any noticeable variability in the above-mentioned comparison star has not been found.

We first chose BD + 44°4044 and BD + 44°4041 as the comparison stars, but the former was found to be better than the latter in view of the constancy of instrumental magnitude in all the three filters.

A total of 226 observations in *U*, 236 in *B* and 233 in *V* have been secured and are listed in Tables VI, VII, and VIII, respectively.

TABLE I

Data of the variable and the comparison star

Star	α_{1855}	δ_{1855}	m_v (BD)	Average standard deviation of the individual observation in *U*, *B*, and *V* filters
AR Lacertae = BD + 45°3813 = HD 210334 = HV 2980 = HR 8448	$22^h02^m50\overset{s}{.}2$	+ 45°01′.9	$6\overset{m}{.}2$	—
Comparison star = BD + 44°4044	$22^h00^m21\overset{s}{.}4$	+ 44°33′.0	$6\overset{m}{.}3$	± $0\overset{m}{.}022$ (*U*) ± $0\overset{m}{.}015$ (*B*) ± $0\overset{m}{.}016$ (*V*)

3. Epoch and Period

By a graphical method, the following times of minima have been determined from our observations:

Primary minima JD (Hel)	Secondary minima JD (Hel)
(1) 2442700.304 (±0.001)	(1) 2442701.314 (±0.001)
(2) 2442716.199 (±0.001)	(2) 2442715.167 (±0.001)
(3) 2442730.095 (±0.001)	(3) 2442717.187 (±0.001)

If we use the epoch given by Guarnieri *et al.* (1975) and our observations, a new period has been determined as

$$\text{JD } 2439376.4928 + \underset{(\pm 0.000010)}{1^{\mathrm{d}}.983191E}\,.$$

Periods given by various authors are listed in Table II.

Rügemer's (1931) elements showed that the period of the system was linear. Wood (1946) reported that his photoelectric observations indicated an abrupt period change occurring shortly after Dugan and Wright (1939) completed their survey. It was suggested that the period has changed from $1^{\mathrm{d}}.983244$ (Rügemer, 1931) to $1^{\mathrm{d}}.983216$ (Wood, 1946). Plavec *et al.* (1961) indicated that erratic or semi-regular period changes may be present in the system.

Using the epoch JD 2426624.3762, they gave a revised period of $1^{\mathrm{d}}.9832155$, which was based on a least-squares solution of 21 minima. Theokas (1977) identified a period change of $-0^{\mathrm{d}}.000028$ over an eight year span. Ahnert (1949, 1965, 1966), Svechnikov (1955), Wroblewski (1956), Makarov *et al.* (1957), Alexandrovich (1959), Karetnikov (1959, 1961), Obůrka (1964, 1965), Dueball and Lehmann (1965), Pohl and Kizilirmak (1966, 1970), Blanco and Catalano (1970) and Hall (1972), have devoted their efforts to the observations of primary minimum and period studies.

The primary minimum was found to be shifted in phase by $-0^{\mathrm{d}}.008$ ($\pm 0^{\mathrm{d}}.001$) in the present observations. The fair agreement in the amount of shift in both the primary and the secondary minimum excluded the possibility of apsidal motion being present in the system.

TABLE II

Periods given by various authors

Author	Epoch and period
Jacchia (1930)	JD 2425555.428 + $1^{\mathrm{d}}.98311$
Rügemer (1931)	2426624.378 + 1.983244
Himpel (1936)	2426626.334 + 1.983433
Gainullin (1943)	2429692.4112 + 1.983295
Wood (1946)	2426624.378 + 1.983216
Sanford (1951)	2426624.338 + 1.98321525
Karetnikov (1961)	2426624.378 + 1.983216
Plavec *et al.* (1961)	2426624.3762 + 1.9832155
Karle (1962)	2437569.7977 + 1.983216
Ahnert (1966)	2432889.336 + 1.983237
Cester (1967)	2426624.3687 + 1.983223
Guarnieri *et al.* (1975)	2439376.4928 + 1.983200
Chambliss (1976)	2439376.4955 + 1.9831987
Srivastava (present observations)	2442716.1986 + 1.983198

The O − C diagram given by Guarnieri *et al.* (1975) shows an increase and a decrease in period. Our O − C diagram also conforms to the increase and decrease pattern of the period. Biermann and Hall (1973) have presented a model to explain such period changes in Algol-like binaries. The peculiarities in the behaviour of the period of the system will be discussed elsewhere.

4. Determination of Elements

The elements of the system have been determined by the method of Russell and Merrill (1952) using Merrill's (1950) tables. The values of depths taken are

Primary eclipse: *U* $0^m.88$; *B* $0^m.67$; *V* $0^m.58$;

Secondary eclipse: *U* $0^m.24$; *B* $0^m.27$; *V* $0^m.31$.

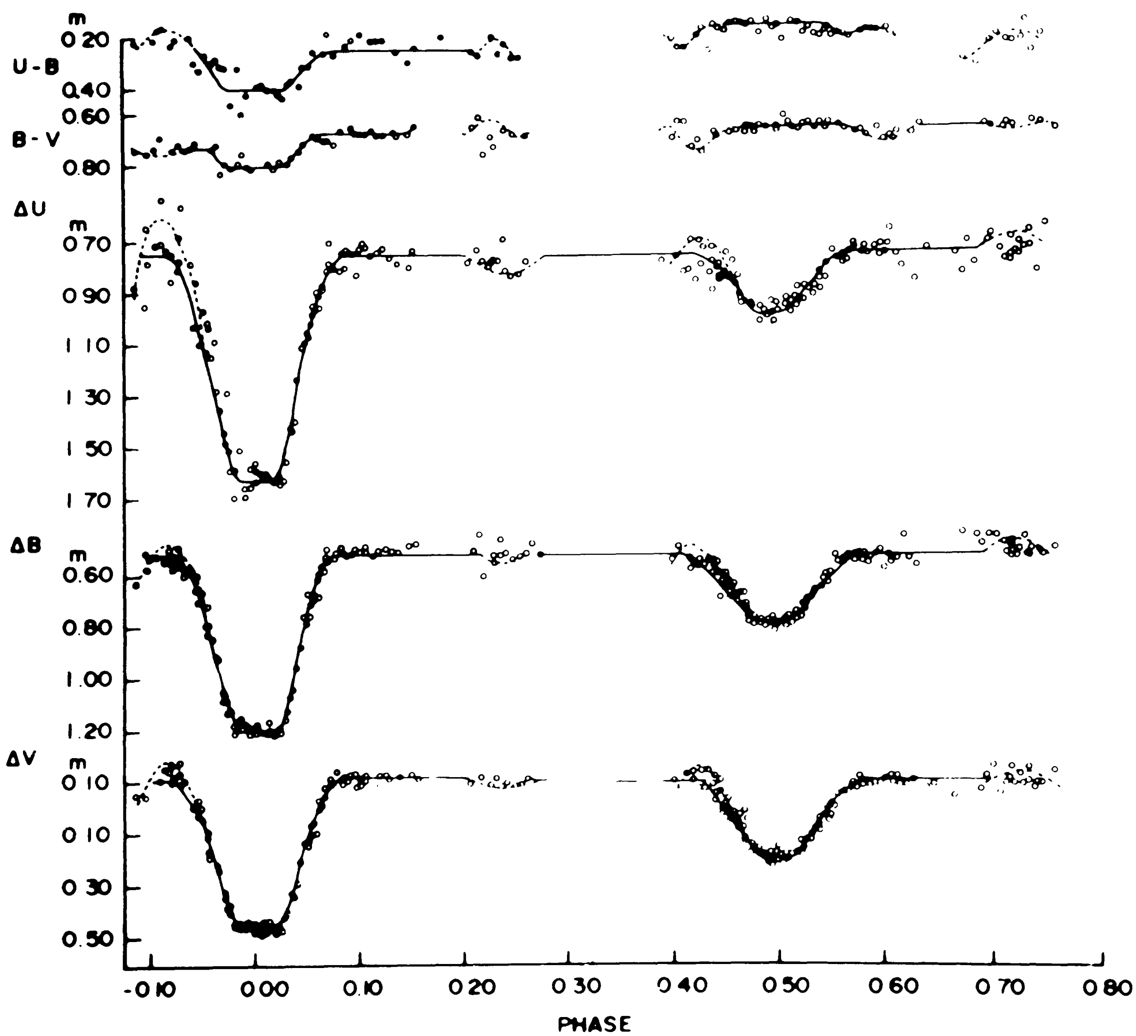

Fig. 1. Light and colour curves of AR Lacertae. Solid line represents the computed curve. Dashed portions indicate some physical changes in the system.

TABLE III

Light elements of AR Lacertae in U, B and V filters
$k = 0.50$; $\alpha_0^{oc} = 1.0$; $\alpha_0^{tr} = 1.1643$

Elements	U	B	V	Mean
x (assumed)	0.8	0.8	0.8	0.8
L_1	0.555	0.460	0.415	—
L_2	0.445	0.540	0.585	—
θ_e	30°.8	27°.2	30°.0	29°.3
θ_i	5°.2	7°.1	4°.7	5°.7
i	75°.6	77°.1	76°.0	76°.2
r_1	0.176	0.158	0.172	0.169
r_2	0.351	0.315	0.343	0.336
J_1/J_2	5.000	3.407	2.842	3.750

The nomographic solution indicates that the primary eclipse is total, which is in agreement with the observations of Jacchia (1929) and Loreta (1929, 1930), who established AR Lac as an eclipsing binary with flat-bottomed primary and shallow secondary. Wood (1946) also found the primary minimum to be a total eclipse and gave the duration of totality as $0^{d}.076$.

If we assume that $x = 0.8$ for both eclipses, the value of $k = 0.50$ can be determined by several trials, in order to make the computed values of the elements agree with the observations (Figure 1).

The light elements of the system are given in Table III wherein subscripts 1 and 2 refer to the primary and secondary components, respectively.

5. Absolute Dimensions

The absolute elements of system, listed in Table IV, have been derived by use of spectroscopic elements given by Sanford (1951)

$$a_1 \sin i = 3.167 \times 10^6 \text{ km} ,$$

$$a_2 \sin i = 3.151 \times 10^6 \text{ km} ,$$

$$m_1 \sin^3 i = 1.29_\odot ,$$

$$m_2 \sin^3 i = 1.30_\odot .$$

In determining the absolute visual and bolometric magnitudes, we have assumed $T_{(\odot)} = 5730$ K, $T_1 = 6150$ K (F8 v) and $T_2 = 5220$ K (G9 v; Arp, 1958).

The computed points have been determined from the relation

$$\sin^2 \theta = A + B\psi ,$$

where θ is the phase, A and B are constants for this particular system, and ψ is a function of (x, k, α); the computed curves are shown with solid lines (Figure 1).

TABLE IV
Absolute dimensions of AR Lacertae in U, B and V filters

Element	U	B	V	Mean
A ($R_\odot$)	6.51	6.51	6.51	6.51
$m_1(\odot)$	1.41	1.41	1.41	1.41
$m_2(\odot)$	1.42	1.42	1.42	1.42
$R_1(\odot)$	1.145	1.028	1.119	1.097
$R_2(\odot)$	2.284	2.049	2.232	2.188
$\rho_1(\odot)$	0.221	0.308	0.240	0.256
$\rho_2(\odot)$	0.029	0.039	0.031	0.033
M_1(bol)	$4\overset{m}{.}09$	$4\overset{m}{.}33$	$4\overset{m}{.}15$	$4\overset{m}{.}19$
M_2(bol)	$3\overset{m}{.}32$	$3\overset{m}{.}55$	$3\overset{m}{.}36$	$3\overset{m}{.}41$
M_1(vis)	$4\overset{m}{.}41$	$4\overset{m}{.}65$	$4\overset{m}{.}47$	$4\overset{m}{.}51$
M_2(vis)	$3\overset{m}{.}78$	$4\overset{m}{.}01$	$3\overset{m}{.}83$	$3\overset{m}{.}87$

6. Colour and Luminosity Classification

The colours of the comparison star were obtained on several nights, the average colours being $B - V = +0\overset{m}{.}057$ and $U - B = -0\overset{m}{.}017$. These values fairly agree with the A1 v colour sequence of Arp (1958). However, on fitting these colours to the above class of the Main Sequence, the $U - B$ value shows an ultraviolet excess of the order of $0\overset{m}{.}07$.

The colours of both the components in various phases are given in Table V. The colours of the secondary component have been derived by finding $\Delta(B - V)$ and $\Delta(U - B)$ values at the primary minimum phase and then incorporating the colours of the comparison star. The colours of the primary component have

TABLE V
Colour indices

Phase	$B - V$	$U - B$	Sp.
Comparison star (BD + 44°4044)	$+0\overset{m}{.}06$	$-0\overset{m}{.}02$	A1 v
Maxima (combined colour of both components)	$+0\overset{m}{.}69$	$+0\overset{m}{.}21$	G5 v
Tip of primary minimum (colour of the secondary component)	$+0\overset{m}{.}78$	$+0\overset{m}{.}42$	G9 v–iv
Primary component	$+0\overset{m}{.}52$	$+0\overset{m}{.}02$	F8 v
Tip of the secondary minimum (complete colour of primary component and partial colour of secondary component)	$+0\overset{m}{.}65$	$+0\overset{m}{.}18$	G2 v

been obtained in the following manner. The differential magnitudes (ΔU, ΔB, ΔV) have been read out at the tip of the primary minimum (where the light of only the secondary component is observable) and also during the maxima (where the combined light of both components is recorded). These are then converted into their respective intensities. The intensities of the secondary component have been subtracted from the combined intensities of both components, thereby yielding the intensity of the primary component alone. On converting these intensities into magnitudes and obtaining the $B - V$ and $U - B$ values, we obtain the colour of the primary component, which is listed in Table V.

The $B - V$ and $U - B$ values of individual observations, throughout the cycle, have been calculated (top of Figure 1). These show a distinct variation and hump around phase (0.089) in the $U - B$ plot, indicating an ultraviolet excess of the order of $0\overset{m}{.}08$ from the average colour level, which is not significantly noticeable in the $B - V$ plot. $B - V$ and $U - B$ values of various phases are given in Table IX.

The spectral classes given by various authors are:

Star	Wyse (1934)	Popper (1967)	Chambliss (1976)	Srivastava (present observations)
Primary Component	G5	G2	G2	F8
Secondary component	K0	K0	K0	G9

TABLE VI

Standard U magnitudes of AR Lacertae

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 692.1658	−0.1157	$+0\overset{m}{.}876$	2442 695.2534	+0.4412	$+0\overset{m}{.}825$
.1814	−0.1078	0.943	.2577	0.4434	0.719
.1843	−0.1063	0.647	.2682	0.4487	0.802
.1948	−0.1010	0.781	.2719	0.4505	0.841
.2015	−0.0977	0.716	.2824	0.4558	0.840
.2125	−0.0921	0.706	.2922	0.4607	0.812
.2231	−0.0868	0.724	.3160	0.4728	0.789
.2370	−0.0856	0.743	.3200	0.4748	0.848
.2473	−0.0746	0.809	700.1659	−0.0811	0.850
.2491	−0.0737	0.767	.1804	−0.7382	0.674
.2587	−0.0688	0.807	.1928	−0.0676	0.574
.2695	−0.0634	0.786	.2061	−0.0608	1.029
.2799	−0.0581	0.855	.2188	−0.0544	1.096
.2914	−0.0523	0.968	.2320	−0.0478	1.122
.3028	−0.0466	1.030	.2572	−0.0351	1.351
.3154	−0.0402	1.087	.2710	−0.0281	1.286
695.2177	+0.4232	0.687	.2736	−0.0268	1.510
.2210	0.4249	0.703	.2850	−0.0210	1.582
.2336	0.4312	0.692	.2952	−0.0159	1.505
.2428	0.4359	0.723	.3054	−0.0108	1.690

Table VI (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 701.1154	+0.3970	+0ᵐ.774	2442 716.2139	+0.0102	+1ᵐ.599
.1299	0.4043	0.768	.2283	0.0175	1.630
.1412	0.4100	0.754	.2393	0.0230	1.610
.1528	0.4159	0.813	.2488	0.0278	1.630
.1649	0.4220	0.815	.2598	0.0334	1.423
.1764	0.4278	0.849	.2711	0.0391	1.400
.1876	0.4334	0.792	.2816	0.0444	1.103
.2199	0.4497	0.844	.2928	0.0501	1.051
.2228	0.4512	0.776	.2962	0.0517	1.017
.2325	0.4561	0.748	.3067	0.0570	0.961
.2429	0.4613	0.841	.3168	0.0621	0.962
.2534	0.4666	0.855	.3274	0.0674	0.806
.2658	0.4729	0.943	717.0722	0.4430	0.716
.2768	0.4784	0.935	.0831	0.4485	0.744
.2869	0.4835	0.910	.0936	0.4538	0.803
.2969	0.4886	1.023	.1041	0.4591	0.840
.3169	0.4986	0.967	.1147	0.4645	0.798
.3273	0.5039	1.025	.1249	0.4696	0.819
.3371	0.5088	1.029	.1352	0.4748	0.909
715.0925	0.4448	0.778	.1459	0.4802	0.943
.1033	0.4502	0.796	.1486	0.4815	0.946
.1141	0.4556	0.824	.1795	0.4971	0.948
.1246	0.4610	0.836	.1888	0.5018	0.988
.1350	0.4662	0.869	.1956	0.5068	0.978
.1459	0.4717	0.905	.2075	0.5128	0.991
.1568	0.4772	0.935	.2179	0.5180	0.960
.1676	0.4827	0.953	.2283	0.5232	0.914
.1824	0.4903	0.961	.2388	0.5285	0.937
.1919	0.4949	0.978	.2488	0.5336	0.887
.2031	0.5006	0.933	730.0663	−0.0049	1.578
.2130	0.5055	0.945	.0765	+0.0003	1.631
.2232	0.5107	0.978	.0865	0.0038	1.594
.2334	0.5158	0.929	.0928	0.0085	1.609
.2430	0.5207	0.976	.1027	0.0135	1.608
.2528	0.5256	0.960	.1127	0.0185	1.613
.2574	0.5279	0.937	.1239	0.0242	1.643
.2673	0.5329	0.936	.1340	0.0292	1.553
.2771	0.5379	0.887	.1448	0.0347	1.435
.2875	0.5431	0.884	.1569	0.0509	1.052
.2982	0.5485	0.851	.1671	0.0560	0.943
.3088	0.5539	0.798	.1764	0.0607	0.910
.3196	0.5593	0.747	.1869	0.0660	0.866
716.0997	−0.0473	1.012	.1979	0.0716	0.698
.1097	−0.0423	1.146	.2078	0.0765	0.800
.1197	−0.0373	1.277	.2193	0.0823	0.803
.1298	−0.0322	1.439	.2298	0.0876	0.793
.1329	−0.0306	1.479	.2522	0.0989	0.825
.1420	−0.0260	1.587	.2626	0.1042	0.697
.1508	−0.0216	1.699	731.0613	0.4957	1.000
.1741	−0.0098	1.655	.0729	0.5027	0.975
.1838	−0.0049	1.655	.0837	0.5081	0.973
.1933	−0.0002	1.557	.0954	0.5140	0.951
.2040	+0.0016	1.587	.1061	0.5194	0.937

Table VI (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 731.1168	+0.5248	$+0^{m}.885$	2442 742.1867	+0.1066	$+0^{m}.710$
.1386	0.5358	0.880	.1987	0.1127	0.745
.1499	0.5415	0.861	.2111	0.1189	0.727
.1606	0.5469	0.824	.2226	0.1247	0.719
.1709	0.5521	0.789	.2351	0.1311	0.754
.1947	0.5641	0.769	.2479	0.1375	0.780
.2054	0.5695	0.758	.2715	0.1494	0.793
.2154	0.5745	0.752	.2828	0.1551	0.730
.2248	0.5793	0.720	771.0808	0.6761	0.759
.2352	0.5845	0.728	.1055	0.6885	0.709
.2453	0.5896	0.728	.1188	0.6952	0.799
.2567	0.5954	0.745	.1438	0.7078	0.716
.2685	0.6013	0.734	.1562	0.7141	0.689
.2791	0.6066	0.769	.1685	0.7203	0.745
.2907	0.6125	0.722	.1814	0.7268	0.702
741.0679	0.5425	0.908	776.1070	0.2105	0.776
.0787	0.5480	0.892	.1179	0.2160	0.728
.0890	0.5531	0.854	.1272	0.2207	0.769
.1235	0.5705	0.788	.1377	0.2259	0.788
.1338	0.5757	0.786	.1472	0.2307	0.760
.1443	0.5810	0.725	.1693	0.2419	0.818
.1566	0.5872	0.749	777.1240	0.7233	0.782
.1677	0.5928	0.760	.1343	0.7285	0.788
.1931	0.6056	0.719	.1448	0.7338	0.761
.2031	0.6107	0.753	.1563	0.7396	0.723
.2131	0.6157	0.656	.1687	0.7458	0.680
.2234	0.6209	0.766	784.0783	0.2299	0.772
.2351	0.6268	0.810	.0904	0.2360	0.771
.2590	0.6389	0.867	.1027	0.2422	0.685
.2840	0.6515	0.741	.1158	0.2488	0.835
742.0605	0.0430	1.231	.1300	0.2559	0.826
.0718	0.0487	1.090	.1436	0.2628	0.777
.0824	0.0541	0.981	.1693	0.2758	0.802
.0933	0.0596	0.895	785.0684	0.7291	0.829
.1047	0.0653	0.872	.0802	0.7351	0.764
.1156	0.0708	0.773	.0925	0.7413	0.743
.1421	0.0842	0.728	.1058	0.7480	0.743
.1519	0.0891	0.726	.1191	0.7547	0.833
.1626	0.0945	0.734	.1322	0.7613	0.758
.1744	0.1004	0.715			

TABLE VII

Standard *B* magnitudes of AR Lacertae

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 692.1653	−0.1159	$+0^{m}.638$	2442 692.2249	−0.0859	$+0^{m}.546$
.1838	−0.1066	0.511	.2366	−0.0800	0.525
.1944	−0.1013	0.578	.2468	−0.0748	0.561
.2009	−0.0980	0.522	.2485	−0.0740	0.527
.2120	−0.0924	0.524	.2580	−0.0692	0.599
.2225	−0.0871	0.545	.2689	−0.0636	0.568

Table VII (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 692.2793	−0.0584	$+0^{m}.657$	2442 715.1039	+0.4505	$+0^{m}.601$
.2909	−0.0526	0.699	.1145	0.4559	0.614
.3021	−0.0469	0.814	.1251	0.4612	0.648
.3149	−0.0405	0.795	.1355	0.4665	0.690
695.2161	+0.4224	0.581	.1464	0.4724	0.721
.2195	0.4243	0.543	.1575	0.4776	0.756
.2325	0.4307	0.543	.1682	0.4830	0.767
.2412	0.4351	0.562	.1830	0.4904	0.779
.2523	0.4407	0.546	.1923	0.4951	0.801
.2567	0.4329	0.546	.2037	0.5009	0.771
.2671	0.4481	0.549	.2135	0.5058	0.797
.2709	0.4500	0.695	.2237	0.5109	0.791
.2810	0.4551	0.628	.2339	0.5161	0.766
.2910	0.4602	0.689	.2436	0.5210	0.770
.3148	0.4722	0.675	.2537	0.5261	0.756
.3200	0.4748	0.676	.2580	0.5282	0.767
700.1650	−0.0815	0.548	.2678	0.5332	0.713
.1668	−0.0807	0.575	.2775	0.5381	0.691
.1791	−0.0744	0.493	.2880	0.5393	0.673
.1912	−0.0684	0.583	.2987	0.5488	0.619
.2043	−0.0617	0.581	.3094	0.5542	0.605
.2176	−0.0550	0.705	.3201	0.5596	0.525
.2308	−0.0484	0.797	716.0806	−0.0570	0.601
.2519	−0.0377	0.918	.0907	−0.0519	0.664
.2560	−0.0320	1.084	.1001	−0.0471	0.718
.2699	−0.0286	1.084	.1101	−0.0421	0.843
.2726	−0.0273	1.137	.1202	−0.0370	0.924
.2838	−0.0216	1.207	.1302	−0.0320	1.053
.2940	−0.0165	1.175	.1333	−0.0304	1.059
.3042	−0.0114	1.154	.1426	−0.0257	1.126
.3141	−0.0064	1.189	.1513	−0.0213	1.183
.3240	−0.0014	1.205	.1744	−0.0096	1.175
701.1305	+0.4046	0.542	.1844	−0.0046	1.191
.1417	0.4103	0.493	.1939	+0.0002	1.181
.1533	0.4161	0.549	.2044	0.0055	1.202
.1655	0.4223	0.538	.2144	0.0065	1.215
.1771	0.4281	0.563	.2183	0.0125	1.169
.1881	0.4337	0.576	.2289	0.0178	1.206
.2081	0.4438	0.592	.2398	0.0233	1.193
.2203	0.4499	0.605	.2493	0.0281	1.161
.2233	0.4514	0.622	.2603	0.0337	1.068
.2331	0.4564	0.641	.2716	0.0393	0.957
.2435	0.4616	0.670	.2821	0.0446	0.763
.2540	0.4669	0.694	.2934	0.0503	0.672
.2663	0.4731	0.731	.2966	0.0519	0.766
.2774	0.4787	0.784	.3073	0.0573	0.680
.2874	0.4838	0.788	.3172	0.0623	0.682
.2975	0.4889	0.791	.3278	0.0626	0.567
.3077	0.4940	0.805	717.0726	0.4432	0.596
.3174	0.4989	0.794	.0837	0.4488	0.547
.3278	0.5041	0.805	.0941	0.4541	0.595
.3378	0.5092	0.788	.1045	0.4593	0.625
715.0930	0.4450	0.571	.1152	0.4647	0.641

Table VII (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 717.1254	+0.4698	+0.ᵐ688	2442 741.0685	+0.5413	+0.ᵐ688
.1357	0.4750	0.718	.0792	0.5482	0.623
.1464	0.4804	0.765	.0896	0.5534	0.630
.1471	0.4818	0.790	.1241	0.5708	0.558
.1800	0.4974	0.776	.1343	0.5760	0.550
.1893	0.5021	0.779	.1449	0.5813	0.522
.1961	0.5070	0.789	.1571	0.5875	0.551
.2079	0.5130	0.768	.1683	0.5931	0.565
.2185	0.5143	0.768	.1935	0.6058	0.508
.2289	0.5235	0.742	.2036	0.6109	0.554
.2392	0.5306	0.720	.2135	0.6159	0.540
.2493	0.5338	0.701	.2239	0.6212	0.541
730.0668	−0.0046	1.219	.2357	0.6226	0.448
.0770	+0.0005	1.204	.2474	0.6330	0.541
.0870	0.0055	1.196	.2597	0.6392	0.566
.0933	0.0087	1.210	742.0607	0.0431	0.882
.1032	0.0137	1.198	.0724	0.0490	0.785
.1133	0.0188	1.217	.0831	0.0544	0.702
.1244	0.0244	1.210	.0939	0.0599	0.614
.1345	0.0295	1.130	.1163	0.0711	0.532
.1453	0.0349	1.042	.1426	0.0824	0.493
.1564	0.0511	0.771	.1525	0.0894	0.514
.1676	0.0563	0.696	.1633	0.0948	0.498
.1769	0.0610	0.597	.1750	0.1007	0.507
.1874	0.0663	0.583	.1874	0.1070	0.490
.1985	0.0719	0.547	.1994	0.1130	0.517
.2083	0.0768	0.518	.2117	0.1193	0.501
.2198	0.0826	0.496	.2231	0.1250	0.496
.2304	0.0879	0.518	.2358	0.1314	0.502
.2415	0.0935	0.512	.2484	0.1378	0.509
.2527	0.0992	0.511	.2719	0.1496	0.483
.2630	0.1044	0.503	.2833	0.1554	0.476
731.0618	0.4971	0.844	771.0949	0.6832	0.438
.0733	0.5029	0.814	.1194	0.6955	0.450
.0843	0.5084	0.788	.1317	0.7017	0.485
.0959	0.5143	0.796	.1444	0.7081	0.457
.1067	0.5197	0.790	.1567	0.7144	0.455
.1175	0.5252	0.766	.1690	0.7206	0.486
.1282	0.5306	0.738	.1819	0.7271	0.488
.1392	0.5361	0.696	776.1070	0.2108	0.504
.1504	0.5418	0.666	.1183	0.2162	0.442
.1613	0.5472	0.651	.1278	0.2210	0.606
.1713	0.5523	0.601	.1382	0.2262	0.542
.1952	0.5643	0.556	.1479	0.2311	0.555
.2059	0.5697	0.542	.1585	0.2364	0.457
.2159	0.5748	0.528	.1700	0.2422	0.513
.2253	0.5795	0.533	777.1246	0.7236	0.518
.2357	0.5848	0.518	.1348	0.7287	0.529
.2459	0.5899	0.521	.1453	0.7340	0.538
.2573	0.5957	0.536	.1568	0.7398	0.461
.2690	0.6016	0.527	.1693	0.7461	0.533
.2797	0.6069	0.587	784.0790	0.2302	0.522
.2912	0.6127	0.523	.0909	0.2362	0.522

Table VII (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 784.1166	+0.2492	$+0^m.539$	2442 785.0808	+0.7354	$+0^m.508$
.1306	0.2563	0.528	.0931	0.7416	0.526
.1442	0.2631	0.516	.1064	0.7483	0.506
.1573	0.2697	0.473	.1197	0.7550	0.513
.1697	0.2760	0.520	.1327	0.7615	0.527
785.0689	0.7294	0.516	.1467	0.7686	0.503

TABLE VIII

Standard *V* magnitudes of AR Lacertae

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 692.1646	−0.1163	$-0^m.044$	2442 700.2845	−0.0213	$+0^m.443$
.1833	−0.1068	−0.040	.2946	−0.0162	0.440
.1941	−0.1014	−0.116	.3047	−0.0111	0.463
.2004	−0.0928	−0.151	.3146	−0.0062	0.442
.2115	−0.0926	−0.107	.3246	−0.0011	0.446
.2219	−0.0874	−0.148	701.1311	+0.4050	−0.097
.2244	−0.0861	−0.145	.1423	0.4106	−0.078
.2361	−0.0802	−0.167	.1539	0.4164	−0.121
.2463	−0.0751	−0.128	.1661	0.4226	−0.100
.2480	−0.0742	−0.173	.1776	0.4284	−0.067
.2574	−0.0695	−0.101	.1886	0.4339	−0.063
.2682	−0.0640	−0.095	.2086	0.4441	−0.020
.2787	−0.0587	−0.032	.2207	0.4501	+0.008
.2903	−0.0529	−0.001	.2238	0.4517	0.026
.3015	−0.0472	+0.109	.2337	0.4567	0.006
.3142	−0.0408	0.194	.2440	0.4619	0.054
695.2204	+0.4246	−0.138	.2546	0.4672	0.076
.2331	0.4310	−0.135	.2669	0.4734	0.130
.2419	0.4354	−0.136	.2779	0.4790	0.143
.2528	0.4409	−0.089	.2878	0.4840	0.167
.2572	0.4431	−0.117	.2982	0.4892	0.182
.2678	0.4485	−0.101	.3082	0.4943	0.213
.2714	0.4503	−0.064	.3179	0.4991	0.184
.2819	0.4556	−0.030	.3283	0.5044	0.174
.2916	0.4605	+0.026	.3383	0.5094	0.187
.3030	0.4662	0.031	715.0935	0.4453	−0.043
.3153	0.4724	0.013	.1045	0.4517	+0.003
.3193	0.4744	0.051	.1150	0.4561	0.019
700.1654	−0.0833	−0.098	.1257	0.4615	0.046
.1673	−0.0804	−0.117	.1359	0.4667	0.086
.1798	−0.0741	−0.090	.1469	0.4722	0.134
.1921	−0.0679	−0.070	.1582	0.4779	0.177
.2055	−0.0612	0.000	.1688	0.4833	0.163
.2183	−0.0547	+0.056	.1835	0.4907	0.197
.2315	−0.0480	0.115	.1929	0.4954	0.204
.2525	−0.374	0.220	.2140	0.5061	0.186
.2567	−0.0353	0.246	.2241	0.5111	0.186
.2706	−0.0283	0.384	.2344	0.5163	0.186
.2731	−0.0270	0.380	.2441	0.5212	0.180

Table VIII (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 715.2514	+0.5263	+0^m.184	2442 730.0874	+0.0057	+0^m.466
.2584	0.5284	0.155	.0938	0.0090	0.482
.2683	0.5334	0.126	.1038	0.0140	0.478
.2781	0.5384	0.090	.1141	0.0192	0.484
.2885	0.5436	0.092	.1249	0.0247	0.472
.2992	0.5486	0.023	.1352	0.0293	0.404
.3099	0.5544	−0.011	.1458	0.0352	0.342
.3206	0.5558	−0.048	.1579	0.0514	0.107
716.0811	−0.0567	−0.032	.1680	0.0565	0.052
.0911	−0.0517	+0.045	.1774	0.0612	0.005
.1006	−0.0469	0.094	.1879	0.0665	−0.041
.1106	−0.0413	0.169	.1989	0.0721	−0.087
.1207	−0.0368	0.248	.2088	0.0770	−0.135
.1307	−0.0307	0.351	.2203	0.0828	−0.090
.1338	−0.0302	0.324	.2310	0.0882	−0.102
.1430	−0.0255	0.404	.2421	0.0938	−0.078
.1517	−0.0206	0.453	.2533	0.0995	−0.081
.1749	−0.0094	0.440	.2636	0.1047	−0.101
.1849	−0.0044	0.452	731.0627	0.4975	+0.228
.1944	−0.0005	0.493	.0739	0.5032	0.203
.2051	+0.0058	0.434	.0849	0.5087	0.225
.2151	0.0108	0.480	.0965	0.5146	0.191
.2187	0.0127	0.434	.1072	0.5200	0.172
.2293	0.0180	0.466	.1179	0.5254	0.130
.2403	0.0235	0.458	.1288	0.5309	0.124
.2498	0.0283	0.431	.1397	0.5364	0.105
.2608	0.0339	0.333	.1511	0.5421	0.070
.2721	0.0396	0.295	.1618	0.5475	−0.003
.2826	0.0449	0.134	.1717	0.5525	−0.001
.2939	0.0506	0.152	.1957	0.5646	−0.055
.2971	0.0522	0.070	.2064	0.5700	−0.064
.3078	0.0576	0.102	.2164	0.5750	−0.074
.3177	0.0626	−0.005	.2258	0.5798	−0.072
.3284	0.0679	−0.072	.2361	0.5850	−0.085
717.0730	0.4434	−0.049	.2464	0.5902	−0.103
.0842	0.4491	−0.060	.2577	0.5959	−0.095
.0946	0.4543	−0.017	.2695	0.6018	−0.087
.1050	0.4596	+0.015	.2917	0.6130	−0.122
.1157	0.4650	0.061	741.0689	0.5430	+0.050
.1259	0.4701	0.079	.0797	0.5485	0.057
.1363	0.4753	0.124	.0901	0.5537	0.043
.1469	0.4807	0.160	.1246	0.5711	−0.058
.1497	0.4821	0.184	.1349	0.5763	−0.094
.1804	0.4976	0.174	.1454	0.5816	−0.109
.1898	0.5023	0.177	.1578	0.5878	−0.093
.1965	0.5027	0.191	.1688	0.5934	−0.087
.2084	0.5132	0.191	.1940	0.6061	−0.110
.2190	0.5186	0.182	.2041	0.6112	−0.092
.2293	0.5237	0.127	.2141	0.6162	−0.120
.2397	0.5290	0.115	.2244	0.6214	−0.085
.2497	0.5340	0.123	.2362	0.6274	−0.081
730.0674	−0.0043	0.482	.2480	0.6333	−0.102
.0774	+0.0008	0.486	.2601	0.6394	−0.073

Table VIII (continued)

JD (Hel)	Phase	Δm	JD (Hel)	Phase	Δm
2442 741.2851	+0.6520	$-0\overset{m}{.}089$	2442 771.1826	+0.7274	$-0\overset{m}{.}155$
742.0613	0.0438	+0.209	776.1080	0.2110	−0.088
.0730	0.0493	0.128	.1188	0.2164	−0.110
.0836	0.0547	0.057	.1387	0.2265	−0.089
.0944	0.0601	−0.024	.1483	0.2313	−0.100
.1058	0.0659	−0.075	.1704	0.2424	−0.088
.1169	0.0715	−0.104	777.1251	0.7238	−0.112
.1431	0.0847	−0.117	.1353	0.7290	−0.087
.1530	0.0897	−0.125	.1459	0.7343	−0.131
.1639	0.0951	−0.136	.1573	0.7041	−0.150
.1755	0.1010	−0.112	.1698	0.7464	−0.067
.1879	0.1073	−0.122	784.0794	0.2304	−0.106
.2001	0.1134	−0.079	.0915	0.2365	−0.080
.2122	0.1195	−0.119	.1170	0.2494	−0.082
.2236	0.1253	−0.124	.1311	0.2565	−0.088
.2365	0.1318	−0.110	.1447	0.2634	−0.108
.2490	0.1381	−0.115	.1579	0.2700	−0.090
.2724	0.1499	−0.129	785.0693	0.7296	−0.089
.2839	0.1557	−0.111	.0813	0.7356	−0.095
771.0817	0.6765	−0.041	.0936	0.7418	−0.099
.1199	0.6958	−0.070	.1069	0.7485	−0.097
.1323	0.7020	−0.122	.1201	0.7552	−0.093
.1449	0.7084	−0.159	.1332	0.7618	−0.034
.1573	0.7147	−0.053	.1473	0.7689	−0.140
.1696	0.7209	−0.096	—	—	—

TABLE IX

Standard colours of AR Lacertae

Phase	$B-V$	$U-B$	Phase	$B-V$	$U-B$
−0.1159	$+0\overset{m}{.}739$	$+0\overset{m}{.}221$	−0.0035	$+0\overset{m}{.}802$	^{m}—
−0.1013	0.751	—	+0.0030	0.760	+0.384
−0.0980	0.730	0.210	0.0066	0.799	0.377
−0.0924	0.688	0.165	0.0122	0.787	0.393
−0.0871	0.750	0.162	0.0183	0.803	0.393
−0.0807	0.733	0.231	0.0233	0.779	0.417
−0.0744	0.714	0.206	0.0263	0.791	0.430
−0.0688	0.734	0.199	0.0316	0.787	0.372
−0.0627	0.727	0.194	0.0349	0.757	0.359
−0.0577	0.707	0.296	0.0432	0.735	0.384
−0.0531	—	0.326	0.0468	0.700	0.306
0.0475	0.727	0.262	0.0519	—	0.305
−0.0421	0.731	0.296	0.0568	0.675	0.247
−0.0383	0.715	0.286	0.0611	0.686	0.274
−0.0338	0.828	0.309	0.0670	0.695	0.256
−0.0288	0.787	0.315	0.0715	0.693	0.179
−0.0299	0.805	0.454	0.0768	0.710	0.265
−0.0165	0.785	0.313	0.0835	0.656	0.254
−0.0134	0.748	0.492	0.0887	—	0.227
−0.0080	0.798	0.418	0.0935	0.647	0.205

Table IX (*continued*)

Phase	$B-V$	$U-B$	Phase	$B-V$	$U-B$
+0.0970	+0^{m}.671	^{m}—	+0.5056	+0^{m}.670	+0^{m}.166
0.1026	0.669	+0.184	0.5014	0.621	0.221
0.1070	0.669	—	0.5160	0.645	—
0.1130	0.653	0.211	0.5204	0.659	0.145
0.1193	0.677	0.209	0.5258	0.668	0.152
0.1250	0.677	0.206	0.5308	0.650	0.196
0.1332	0.669	—	0.5360	0.642	0.172
0.1378	0.681	0.254	0.5427	0.666	0.198
0.1496	0.669	0.293	0.5478	0.645	0.205
0.1554	0.644	0.237	0.5515	0.663	0.188
0.2108	0.649	0.255	0.5542	0.646	0.176
0.2162	0.609	0.269	0.5596	—	0.205
0.2210	0.751	—	0.5643	0.661	0.196
0.2282	0.687	0.217	0.5703	0.668	0.206
0.2311	0.712	0.194	0.5754	0.671	0.213
0.2363	0.627	0.264	0.5804	0.676	0.178
0.2422	0.658	0.222	0.5861	0.681	0.197
0.2492	0.678	0.279	0.5915	0.695	0.184
0.2563	0.673	0.281	0.5957	0.688	0.192
0.2631	0.681	0.244	0.6016	0.671	0.190
0.4046	0.696	0.209	0.6064	0.715	—
0.4103	0.628	0.244	0.6118	0.703	0.182
0.4161	0.617	0.247	0.6159	0.717	—
0.4243	0.719	—	0.6212	0.683	0.208
0.4294	0.711	0.201	0.6271	—	0.345
0.4344	0.726	0.172	0.6330	0.690	0.309
0.4407	—	0.262	0.6832	—	0.377
0.4437	0.675	0.160	0.6955	—	0.332
0.4492	0.695	0.177	0.7017	0.664	—
0.4554	0.683	0.185	0.7081	0.673	0.242
0.4606	0.680	0.157	0.7144	—	0.217
0.4660	0.668	0.149	0.7221	0.663	0.245
0.4713	0.677	0.152	0.7376	0.665	0.241
0.4751	0.656	0.160	0.7416	0.672	0.169
0.4809	0.669	0.150	0.7472	0.659	0.296
0.4838	0.680	—	0.7550	0.663	0.228
0.4897	0.651	0.190	0.7615	0.618	—
0.4959	0.659	0.139	0.7686	0.690	—
0.5012	0.659	0.174	—	—	—

7. Interstellar Extinction and Ultraviolet Excess

Using the $(B-V)$, M_v and Sp., $(B-V)_0$ and $(U-B)_0$ tables of Allen (1973) and the present colour values given in Table V, we conclude that the primary component does belong to the Main Sequence and the secondary is a subgiant.

Furthermore, assuming that the relations (Golay, 1974)

$$Q=(U-B)-0.72(B-V)\ ,$$

$$(B-V)_0=0.332Q\ ,$$

and

$$(U-B)_0 = +0.10 + 3.80(B-V)_0$$

generally hold to obtain the intrinsic colour indices, we have computed the colour indices of the components as:

	Q	$(B-V)_0$	$(U-B)_0$	$E(B-V)$	$E(U-B)$
Primary	-0.35	$-0\overset{m}{.}12$	$-0\overset{m}{.}36$	$0\overset{m}{.}64$	$0\overset{m}{.}38$
Secondary	-0.14	$-0\overset{m}{.}05$	$-0\overset{m}{.}09$	$0\overset{m}{.}83$	$0\overset{m}{.}51$

The above colour excesses indicate that the two components exhibit interstellar extinction values which differ from each other by more than $0\overset{m}{.}1$. We attribute this to the fact that the secondary component, which is generally held responsible for light curve peculiarities, is reddened by more than $0\overset{m}{.}1$ by its own physical conditions. This value seems to be of the same order as that found by Hall (1972) for the cool component of the system RS CVn.

8. Evolution

The following values of the Roche constants have been derived:

$$C_0 = 4.0\ , \quad C_1 = 7.2\ , \quad C_2 = 4.3\ .$$

These values are in agreement with those derived by Kopal and Shapley (1956). The value of C_0 has been read out from the table (Kopal, 1959, p. 136) corresponding to a mass ratio of 1.007. Since $C_1 > C_0$ and $C_2 > C_0$, we infer that the system is detached.

On plotting the quantities concerned on the log m–log R plot (cf. Kopal, 1955), we find that the primary component lies nearly on the Main Sequence while the secondary component is situated away from it – a fact indicating that the secondary component is more evolved than the primary. This fact is also reflected in the M_{bol}–Sp. type plot. Also, the values of Roche constants show that $C_2(=4.3)$ is fairly near to C_0 (=4.0), which further confirms the above-mentioned fact that the secondary component is evolved and is near to filling its Roche lobe.

9. Interesting Features

Some of the interesting features seen in the present light curves can be summarised as follows:

(i) Additional light of the order of $0\overset{m}{.}10$ just preceding primary minimum in all the filters and of the order of $0\overset{m}{.}05$ just preceding the secondary minimum (around phase −0.09 in both the minima) – these appear as humps on the shoulders of both eclipses;

(ii) additional light of the order of $0^{m}.05$ in all the filters around phase 0.74 and a minor depression of the order of $0^{m}.03$ in these filters around phase 0.24;

(iii) ultraviolet excess of the order of $0^{m}.10$ in the secondary component; and

(iv) large scatter as well as distortion in the descending branch of the secondary minimum.

We have not dealt with these features in the present paper; they will be discussed in a later paper.

Acknowledgements

We are grateful to Dr C. D. Kandpal for his helpful discussions and useful suggestions.

References

Ahnert, P.: 1949, *Astron. Nachr.* **277**, 187.
Ahnert, P.: 1965, *Mitt. Veränderl. Sterne* **2**, 1970.
Ahnert, P.: 1966, *Mitt. Veränderl. Sterne* **24**, 137.
Alexandrovich, Y. R.: 1959, *Astron. Circ.* **205**, 19.
Allen, C. W.: 1973, *Astrophysical Quantities*, Athlone Press, London, pp. 204 and 206.
Arp, H. C.: 1958, in *Handbuch der Physik*, **51**, 83.
Biermann, P. and Hall D. S.: 1973, *Astron. Astrophys.* **27**, 249.
Blanco, C. and Catalano, S.: 1970, *Astron. Astrophys.* **4**, 482.
Catalano, S. and Rodono, M.: 1967, *Mem. Soc. Astron. Italiana* **38**, 395.
Cester, B.: 1967, *Mem. Soc. Astron. Italiana* **38**, 707.
Chambliss, C. R.: 1976, *Publ. Astron. Soc. Pacific* **88**, 762.
Dueball, J. and Lehmann, P. B.: 1965, *Astron. Nachr.* **288**, 167.
Dugan, R. S. and Wright, F. W.: 1939, *Princeton Contr.* No. 19, 53.
Gainullin, A. Sh.: 1943, *Engelhardt Astron. Obs. Bull.* **22**, 3.
Gibson, D. M. and Hjellming R. M.: 1974, *Publ. Astron. Soc. Pacific* **86**, 652.
Golay, M.: 1974, *Introduction to Astronomical Photometry*, D. Reidel Publ. Co., Dordrecht, Holland, p. 138.
Guarnieri, A., Bonifazi, A., and Battistini, P.: 1975, *Astron. Astrophys. Suppl. Ser.* **20**, 199.
Hall, D. S.: 1972, *Publ. Astron. Soc. Pacific* **84**, 323.
Hall, D. S.: 1975, *IAU Coll.* **29**, 287.
Hall, D.S., Richardson, T. D., and Chambliss, C. R.: 1976, *Astron. J.* **81**, 1138.
Harper, W. E.: 1933, *J. Roy. Astron. Soc. Canada* **27**, 146.
Himpel, K.: 1936, *Astron. Nachr.* **261**, 233 (6253).
Hjellming, R. M. and Blankenship, L.: 1973, *Nature* **243**, 81.
Jacchia, L.: 1929, *Gaz, Astron.* **16**, 19.
Jacchia, L.: 1930, *Astron. Nachr.* **237**, 249.
Karetnikov, V. G.: 1959, *Astron. Circ.* **207**, 16.
Karetnikov, V. G.: 1961, *Perem. Zvezdy* **13**, 420.
Karle, J. H.: 1962, *Publ. Astron. Soc. Pacific* **74**, 244.
Kopal, Z.: 1955, *Ann. Astrophys.* **18**, 405.
Kopal, Z.: 1959, *Close Binary Systems*, Chapman and Hall, London, p. 136.
Kopal, Z. and Shapley, M. B.: 1956, *Jodrell Bank Ann.* **1**, 208.
Kron, G. E.: 1947, *Publ. Astron. Soc. Pacific* **59**, 261.
Leavitt, H.: 1903, *Harvard Circ.*, No. 130, p. 4.
Loreta, E.: 1929, *Gaz. Astron.* **16**, 10.
Loreta, E.: 1930, *Gaz. Astron.* **17**, 7.

Makarov, V., Mandel, O., and Panaioti, A.: 1957, *Astron. Circ.* **187**, 16.
Merrill, J. E.: 1950, *Princeton Contr.* No. 23.
Obůrka, O.: 1964, *Bull. Astron. Inst. Czech.* **15**, 250.
Obůrka, O.: 1965, *Bull. Astron. Inst. Czech.* **16**, 212.
Oliver, J. P.: 1974, Ph.D. Thesis, Univ. California, Los Angeles, California, U.S.A.
Parenago, P.: 1930, *Astron. Nachr.* **238**, 209 (5701).
Parenago, P.: 1938, *Publ. Sternberg* **12**, 35 (1).
Plavec, M., Smetanová, M., and Pěkný, Z.: 1961, *Bull. Astron. Inst. Czech.* **12**, 117.
Pohl, E., and Kizilirmak, A.: 1966, *Astron. Nachr.* **289**, 191.
Pohl, E. and Kizilirmak, A.: 1970, *Inf. Bull. Variable Stars*, p. 456.
Popper, D. M.: 1967, *Ann. Rev. Astron. Astrophys.* **5**, 85.
Rügemer, H.: 1931, *Astron. Nachr.* **245**, 39 (5859).
Russell, H. N. and Merrill, J. E.: 1952, *Princeton Contr.* No. 26.
Sanford, R. F.: 1951, *Astrophys. J.* **113**, 299.
Schneller, H. and Plaut, L.: 1932, *Astron. Nachr.* **245**, 387.
Struve, O.: 1952, *Publ. Astron. Soc. Pacific* **64**, 20.
Svechnikov, M. A.: 1955, *Perem. Zvezdy* **10**, 262.
Theokas, A. C.: 1977, *Astrophys. Space Sci.* **52**, 213.
Wendel, O. C.: 1907, *Astron. Nachr.* **175**, 357.
Wood, F. B.: 1946, *Princeton Contr.* No. 21, p. 10.
Wroblewski, A.: 1956, *Acta Astron.* **6**, **146**.
Wyse, A. B.: 1934, *Lick Obs. Bull.* **17**, 37 (464).
Zverev, M.: 1936, *Publ. Sternberg* **8**, 43 (1).