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Light Curve and Photometric Elements of AR Aurigae

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Photoelectric observations of the eclipsing binary AR Aur have been carried out in four spectral regions at approximately the same wave-lengths as the Strömgren u, v, b, y system and in two regions round H_β. The peak wave-lengths close to u, v, b, y are all located in the continuum of the spectrum where limb darkening coefficients are available from the litterature, and in these cases the photometric elements have been determined. From the u, v, b, y and H_β observations spectral types and absolute magnitudes have been determined for the components.

Key words: eclipsing binary — photometric elements

1. Introduction

AR Aur is an eclipsing binary the components of which are main sequence stars of spectral type B 8 and B 9.5 (Popper, 1959). Photographic registration of the light curve was carried out by Nassau (1936) and photoelectric observations by Huffer and Stebbins. Only the normal points of these later observations have been published (Huffer and Eggen, 1947). Photometric elements of the AR Aur system have been computed by Nassau (1936), Huffer and Eggen (1947), Grygar (1963), and Tabachnik (1968). In the present paper photoelectric observations in six colours are presented. The chosen peak wave-lengths are in close agreement with the intermediate-band u, v, b, y, system of Strömgren (1963) and that of the β index (Crawford, 1958). Based on these observations an element analysis was carried out for the four wave-length regions which are situated in the stellar continuum. The deviations between elements computed for different colours estimate the mean errors. From mean elements a check of the limb darkening coefficients was carried out. Spectroscopic elements of the system have been determined by Harper (1938) and Wyse (1936). The masses of the components determined from the radial velocity curve and the light curve furnish a possibility by means of stellar models to determine a theoretical value of the ratio of the radii. This value agrees closely with that determined from the light curve. Further, by means of the β and $u - b$ index the absolute magnitude and the spectral type of each component can be obtained.

2. The Observations

The observations were carried out at the Lowell Observatory, Flagstaff, Arizona, USA in the period 1965–1968. The telescope used was the 24-inch Morgan reflector equipped with a one-channel photometer. An EMI 6256 S/A photomultiplier was used. The names, peak wave-lengths, and the half widths of the filters are given in Table 1, where index F is used to distinguish the filters used in Flagstaff from those of the standard system. u_F, v_F, b_F, y_F have approximately the same peak wave-lengths as those defining the u, v, b, y system but smaller half widths.

Table 1. *Characteristics of the filters*

Filter	Peak wave-length, Å	Half width, Å
$H_\beta(191)$	4843	191
$H_\beta(37)$	4863	37
u_F	3546	86
v_F	4053	75
b_F	4747	57
y_F	5494	122

As comparison stars HR 1726 and HR 1749 were used, HR 1726 as primary comparison star and HR 1749 only as check star. Information on these stars and AR Aur taken from the Bright Star Catalogue (Hoffleit, 1964) is given in Table 2.

For the nights of the eclipses, where AR Aur and HR 1726 were observed during several hours, the extinction coefficients, $k(\lambda)$ were determined from the observations of HR 1726. For nights where no

Table 2. *Information on the variable and the comparison stars*

HR	Name	α_{2000}	δ_{2000}	Sp	m_V
1726	16 Aur	$5^h18^m11^s$	+33°22′	K3 III	4.7
1728	17 AR Aur	5 18 19	+33 45	B9	5.8—6.5
1749	20 ϱ Aur	5 21 49	+41 48	B5 V	5.1

extinction coefficients have been determined, mean values from observations on 10 nights were applied. These values are given below:

λ	3546	4053	4747	4843	4863	5494
$k(\lambda)$	0.600	0.368	0.230	0.232	0.219	0.181

For the filter of largest half width – H_β (191) – the spectral-type dependence of the extinction coefficient was examined. From the stellar intensity distribution, the transmission curve of the filter, the sensitivity function of the telescope, and $k(\lambda)$ the zenit mean extinction for a given star may be computed. For an A0 star (α Lyrae) and a K 1 star (26 Cyg) with intensity distributions given by Gyldenkerne and Johansen (1969) the mean coefficients were determined. The sensitivity of the telescope and photometer was not known and therefore treated as a constant. No significant difference between the extinction coefficient of the A and the K star was found; this means that for H_β (191) and thus for all filters the same extinction coefficients should be applied to observations of AR Aur, HR 1726, and HR 1749 disregarding any dependence on spectral type.

3. Indications of a Possible Variability of HR 1726

The magnitude differences between the comparison stars are given in Table 3. It is obvious that $m_{1726}-m_{1749}$ observed on JD 2439148 and JD 2439154 differ about three times their mean error from observations on other nights. The differences from the mean value of $m_{1726}-m_{1749}$ obtained on other nights are given in Table 4. Observations of AR Aur on these nights cover the phases 0.52–0.55 on JD 2439148 and 0.97–0.04 on JD 2439154. It is difficult to compare the observations during the eclipse with observations at the same phase, but we can compare observations just after the eclipse with observations just before the eclipse carried out on different nights. Also in this case a systematic difference in $m_{1726} - m_{\mathrm{AR\,Aur}}$ has been found. It indicates in both cases a decrease in the intensity of HR 1726. The differences between values measured on these nights

Table 3. $m_{1726} - m_{1749}$. *Observations on* JD 2439148 *and* JD 2439154 *are not included in the mean values*

JD	$H_\beta(191)$	$H_\beta(37)$	u_F	v_F	b_F	y_F
2439098	−0.130	−0.242	2.601	1.488	0.053	−0.705
	−0.135	−0.253	2.595	1.494	0.044	−0.711
	−0.125	−0.242	2.597	1.507	0.057	−0.698
	−0.128	−0.250	2.587	1.496	0.055	−0.696
9100	−0.138	−0.257	2.577	1.493	0.035	−0.713
	−0.141	−0.243	2.583	1.491	0.045	−0.705
	−0.133	−0.254	2.577	1.489	0.047	−0.714
9137	−0.142	−0.259	2.581	1.484	0.042	−0.706
9148	−0.109	−0.236	2.617	1.529	0.072	−0.694
9154	−0.117	−0.238	2.614	1.526	0.058	−0.703
	−0.096	−0.211	2.643	1.564	0.086	−0.673
9169	−0.127	−0.248	2.607	1.503	0.047	−0.706
9172	−0.134	−0.262	2.577	1.487	0.043	−0.725
9468	−0.139	−0.247	2.591	1.492	0.044	−0.724
9470	−0.133	−0.256	2.598	1.507	0.054	−0.707
9572		−0.240	2.656	1.511	0.065	−0.718
9777	−0.136	−0.248				
	−0.141	−0.248				
	−0.139	−0.255				
	−0.133	−0.240				
9919	−0.114	−0.217	2.636	1.510	0.068	
	−0.142	−0.244	2.601	1.500	0.062	
	−0.132	−0.234	2.655	1.500	0.051	
	−0.126	−0.235	2.656	1.511	0.058	
9920	−0.133	−0.246		1.493	0.044	
	−0.144	−0.235		1.495	0.046	
	−0.119	−0.233		1.503	0.045	
9921		−0.263	2.619	1.495	0.050	−0.722
		−0.246	2.638	1.503	0.063	−0.710
9927	−0.128	−0.247	2.613	1.501	0.053	
	−0.142	−0.240	2.607	1.502	0.056	
9929	−0.140	−0.253	2.584	1.479	0.046	
	−0.152	−0.261	2.572	1.479	0.037	
	−0.139	−0.261	2.630	1.481	0.046	
9933	−0.136	−0.256	2.631	1.497	0.052	
	−0.144	−0.273	2.615	1.488	0.039	
	−0.147	−0.258		1.502	0.046	
mean values	−0.135	−0.248	2.607	1.496	0.050	−0.711
mean error of one observation	0.008	0.011	0.026	0.009	0.008	0.009

and the mean values for the remaining nights are given in Table 4.

HR 1726 is a single line spectroscopic binary. Its spectroscopic elements have been computed by Christie (1936). These elements give a satisfactory correspondence between the time of decrease in intensity and the eclipse computed from the elements.

The time of expected mid-eclipse is JD 2439175, the time observed is JD 2439148–2439154. If the period of 434.8 days is only 0.5 days in error, this discrepancy is explained. Accepting this correction to the period the secondary eclipse will occur near JD 2439378. No observations are obtained round this epoch.

If the systematic differences are due to variability of HR 1726 the variation is so slow that a correction constant over the night can be applied. This is seen from Fig. 4, where crosses indicate corrected observations on JD 2439148 and 2439154, open circles observations on other nights. A small variation during the night should not influence the determination of the elements since these are computed from both ingress and egress phases after a reflection in mid-eclipse.

Table 4. *Deviations from the mean values of* $m_{1726} - m_{1749}$ *and* $m_{1726} - m_{\text{AR Aur}}$ *for* JD 2439148 *and* 2439154. *The uncertainty of one observation is given in Table 3 and explained in the text*

	JD	$H_\beta(191)$	$H_\beta(37)$	u_F	v_F	b_F	y_F
$m_{1726} - m_{1749}$	2439148	0.026	0.012	0.010	0.033	0.022	0.013
$m_{1726} - m_{1749}$	9154	0.029	0.024	0.022	0.049	0.022	0.019
$m_{1726} - m_{\text{AR Aur}}$	9148	0.005	0.006	0.009	0.003	0.003	0.004
$m_{1726} - m_{\text{AR Aur}}$	9154	0.017	0.023	0.041	0.025	0.015	0.008
Weighted means	9148	0.008	0.008	0.014	0.011	0.007	0.005
Weighted means	9154	0.021	0.024	0.040	0.034	0.018	0.012

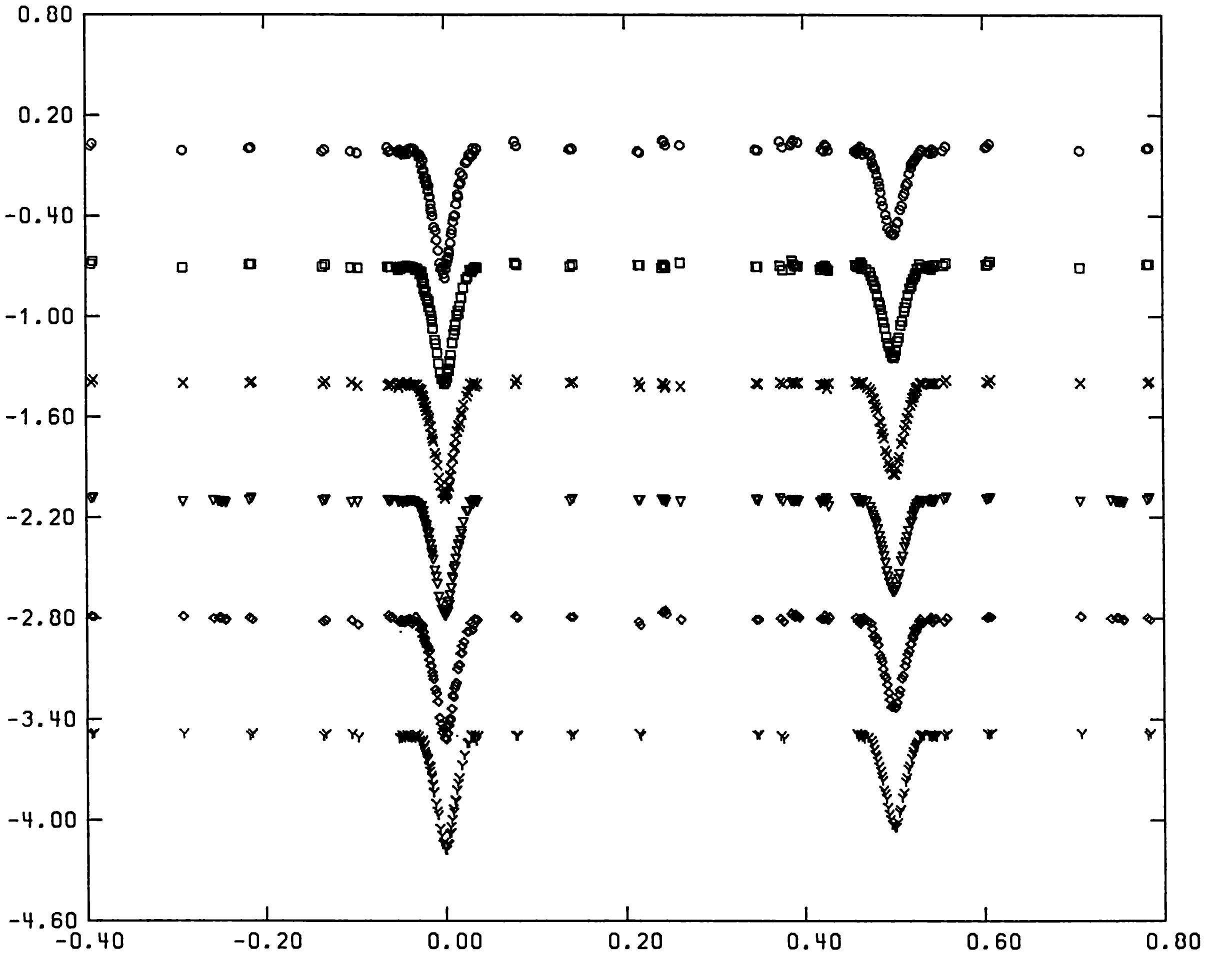

Fig. 1. $m_{1726} - m_{\text{AR Aur}}$. The magnitude differences outside eclipse are normalized to a multiple of $-0^m\!.7$ depending on the colour. The meaning of the symbols are: u_F: ○, v_F: □, b_F: ×, $H_\beta(191)$: ▽, $H_\beta(37)$: ◇, and y_F: Y

1*

Table 5. Magnitude differences between HR 1726 and AR Aur

HJD - 2400000	HJD fraction	H_β(191) Δm	phase	HJD fraction	H_β(37) Δm	phase	HJD fraction	u_F Δm	phase	HJD fraction	v_F Δm	phase	HJD fraction	b_F Δm	phase	HJD fraction	y_F Δm	phase
39096	.8248	-1.781	.0034	.8239	-2.027	.0032	.8245	0.338	.0034	.8253	-0.186	.0036	.8252	-1.558	.0036	.8249	-2.289	.0035
39096	.8365	-1.690	.0063	.8362	-1.946	.0062	.8364	0.417	.0063	.8379	-0.113	.0066	.8370	-1.467	.0064	.8367	-2.219	.0063
39096	.8496	-1.593	.0094	.8489	-1.810	.0093	.8493	0.538	.0094	.8501	-0.003	.0096	.8499	-1.362	.0095	.8496	-2.096	.0094
39096	.8598	-1.520	.0119	.8592	-1.743	.0118	.8595	0.621	.0118	.8604	0.072	.0121	.8601	-1.293	.0120	.8598	-2.029	.0119
39098	.7070	-1.111	.4587	.7063	-1.339	.4585	.7069	1.012	.4586	.7075	0.463	.4588	.7074	-0.898	.4588	.7072	-1.627	.4587
39098	.7243	-1.128	.4629	.7237	-1.344	.4627	.7242	1.015	.4628	.7249	0.451	.4630	.7246	-0.906	.4629	.7244	-1.631	.4629
39098	.7339	-1.123	.4652	.7334	-1.352	.4651	.7337	1.017	.4651	.7344	0.442	.4653	.7342	-0.910	.4652	.7330	-1.641	.4650
39098	.7406	-1.128	.4668	.7402	-1.339	.4667	.7404	0.995	.4667	.7411	0.442	.4669	.7409	-0.904	.4669	.7406	-1.645	.4668
39098	.7574	-1.130	.4709	.7576	-1.359	.4709	.7581	1.007	.4710	.7589	0.437	.4712	.7586	-0.933	.4712	.7585	-1.650	.4711
39098	.7731	-1.162	.4747	.7723	-1.371	.4745	.7726	1.000	.4745	.7733	0.421	.4747	.7731	-0.945	.4747	.7729	-1.668	.4746
39098	.7790	-1.186	.4761	.7785	-1.403	.4760	.7788	0.984	.4760	.7795	0.398	.4762	.7793	-0.962	.4762	.7790	-1.691	.4761
39098	.7855	-1.210	.4777	.7849	-1.448	.4775	.7851	0.944	.4776	.7859	0.373	.4778	.7857	-0.994	.4777	.7854	-1.721	.4776
39098	.7902	-1.229	.4788	.7898	-1.445	.4787	.7901	0.924	.4788	.4907	0.365	.4789	.7905	-1.002	.4789	.7903	-1.751	.4788
39098	.7944	-1.244	.4798	.7935	-1.468	.4796	.7941	0.917	.4797	.7951	0.341	.4800	.7945	-1.032	.4798	.7944	-1.761	.4798
39098	.8000	-1.262	.4812	.7995	-1.463	.4811	.7997	0.904	.4811	.8004	0.324	.4813	.8002	-1.052	.4813	.7999	-1.790	.4812
39098	.8069	-1.294	.4828	.8064	-1.499	.4827	.8067	0.868	.4827	.8074	0.280	.4829	.8072	-1.077	.4829	.8070	-1.824	.4828
39098	.8148	-1.334	.4847	.8140	-1.559	.4845	.8143	0.832	.4846	.8151	0.240	.4848	.8148	-1.135	.4847	.8146	-1.852	.4847
39098	.8198	-1.367	.4860	.8192	-1.580	.4859	.8194	0.802	.4859	.8202	0.225	.4861	.8199	-1.142	.4860	.8196	-1.883	.4860
39098	.8245	-1.392	.4871	.8239	-1.599	.4870	.8241	0.766	.4871	.8249	0.197	.4872	.8247	-1.182	.4872	.8243	-1.905	.4871
39098	.8296	-1.419	.4883	.8292	-1.643	.4882	.8294	0.715	.4882	.8303	0.161	.4885	.8298	-1.209	.4883	.8296	-1.963	.4883
39098	.8351	-1.454	.4897	.8345	-1.680	.4896	.8348	0.686	.4896	.8355	0.122	.4898	.8354	-1.238	.4898	.8351	-1.984	.4897
39098	.8413	-1.494	.4912	.8408	-1.696	.4911				.8418	0.086	.4913	.8416	-1.312	.4913	.8413	-2.012	.4912
39098	.8483	-1.546	.4928	.8473	-1.735	.4925	.8475	0.633	.4926	.8489	0.034	.4929	.8486	-1.333	.4929	.8478	-2.065	.4927
39098	.8547	-1.575	.4943	.8542	-1.784	.4942	.8545	0.601	.4943	.8552	-0.002	.4944	.8549	-1.384	.4944	.8547	-2.106	.4943
39098	.8594	-1.610	.4955	.8590	-1.826	.4954	.8593	0.554	.4954	.8600	-0.024	.4956	.8597	-1.406	.4955	.8595	-2.137	.4955
39098	.8670	-1.640	.4974	.8665	-1.870	.4973	.8668	0.534	.4974	.8680	-0.061	.4976	.8673	-1.418	.4975	.8670	-2.168	.4974
39098	.8748	-1.665	.4993	.8743	-1.854	.4992	.8745	0.518	.4992	.8754	-0.083	.4994	.8752	-1.449	.4994	.8748	-2.171	.4993
39098	.8812	-1.666	.5008	.8806	-1.873	.5006	.8809	0.513	.5007	.8817	-0.091	.5009	.8814	-1.453	.5008	.8811	-2.184	.5008
39098	.8870	-1.658	.5022	.8863	-1.869	.5020	.8865	0.518	.5021	.8873	-0.078	.5023	.8871	-1.452	.5022	.8867	-2.182	.5021
39098	.8923	-1.637	.5035	.8918	-1.843	.5034	.8920	0.546	.5034	.8927	-0.050	.5036	.8925	-1.417	.5035	.8922	-2.155	.5035
39098	.9002	-1.590	.5054	.8997	-1.794	.5053	.9000	0.583	.5054	.9008	0.007	.5056	.9005	-1.373	.5055	.9003	-2.095	.5055
39098	.9057	-1.561	.5067	.9052	-1.768	.5066	.9055	0.590	.5066	.9061	0.029	.5068	.9059	-1.350	.5067	.9057	-2.079	.5067
39098	.9145	-1.485	.5089	.9140	-1.699	.5088	.9142	0.664	.5088	.9149	0.104	.5090	.9148	-1.269	.5090	.9145	-2.007	.5089
39098	.9217	-1.457	.5106	.9212	-1.681	.5105	.9215	0.687	.5106	.9222	0.128	.5107	.9219	-1.244	.5107	.9217	-1.979	.5106
39098	.9299	-1.401	.5126	.9293	-1.624	.5125	.9295	0.746	.5125	.9305	0.188	.5129	.9303	-1.189	.5127	.9299	-1.913	.5126
39098	.9357	-1.373	.5140	.9361	-1.593	.5141	.9354	0.762	.5139	.9361	0.210	.5141	.9360	-1.158	.5141	.9358	-1.889	.5140
39098	.9429	-1.341	.5157	.9425	-1.555	.5156	.9428	0.807	.5156	.9434	0.238	.5158	.9423	-1.117	.5155	.9431	-1.838	.5157
39098	.9496	-1.304	.5173	.9487	-1.535	.5171	.9489	0.821	.5171	.9499	0.281	.5173	.9496	-1.084	.5173	.9493	-1.820	.5172
39098	.9572	-1.256	.5192	.9565	-1.495	.5190	.9567	0.877	.5191	.9578	0.322	.5193	.9576	-1.038	.5193	.9572	-1.774	.5192
39098	.9662	-1.215	.5214	.9667	-1.445	.5215	.9670	0.934	.5216	.9667	0.358	.5215	.9665	-0.997	.5214	.9661	-1.733	.5213
39098	.9746	-1.188	.5233	.9738	-1.401	.5231	.9741	0.946	.5232	.9751	0.381	.5234	.9749	-0.974	.5234	.9745	-1.707	.5233
39098	.9817	-1.165	.5251	.9810	-1.419	.5249	.9812	0.954	.5250	.9823	0.405	.5252	.9820	-0.936	.5252	.9815	-1.691	.5250
39098	.9869	-1.144	.5264	.9864	-1.403	.5263	.9867	0.967	.5264	.9874	0.414	.5266	.9871	-0.950	.5265	.9868	-1.676	.5264
39098	.9956	-1.137	.5285	.9952	-1.359	.5285	.9954	0.979	.5285	.9911	0.441	.5275	.9909	-0.928	.5274	.9956	-1.639	.5285
39099	.0018	-1.124	.5299	.0013	-1.347	.5298	.0015	0.995	.5299	.0024	0.467	.5301	.0021	-0.906	.5300	.0018	-1.630	.5299
39100	.7356	-1.130	.9493	.7351	-1.365	.9492	.7354	1.009	.9492	.7361	0.448	.9494	.7359	-0.906	.9494	.7356	-1.652	.9493
39100	.7456	-1.129	.9517	.7451	-1.354	.9516	.7453	1.018	.9516	.7460	0.448	.9518	.7458	-0.909	.9517	.7456	-1.652	.9517
39100	.7545	-1.129	.9539	.7540	-1.355	.9535	.7543	0.991	.9538	.7550	0.444	.9540	.7556	-0.919	.9541	.7545	-1.639	.9539
39100	.7642	-1.131	.9562	.7624	-1.366	.9558	.7626	0.991	.9558	.7635	0.449	.9560	.7630	-0.916	.9559	.7627	-1.649	.9558
39100	.7696	-1.128	.9575	.7690	-1.356	.9574	.7694	0.998	.9575	.7701	0.450	.9576	.7698	-0.909	.9576	.7696	-1.635	.9575
39100	.7759	-1.134	.9591	.7754	-1.361	.9590	.7757	1.012	.9591	.7764	0.456	.9592	.7761	-0.905	.9592	.7759	-1.649	.9591
39100	.7809	-1.131	.9603	.7806	-1.349	.9603	.7807	0.996	.9603	.7814	0.448	.9605	.7812	-0.919	.9604	.7810	-1.643	.9604
39100	.7891	-1.127	.9622	.7887	-1.349	.9621	.7889	1.023	.9622	.7896	0.446	.9623	.7893	-0.926	.9623	.7891	-1.649	.9622
39100	.7941	-1.126	.9635	.7936	-1.375	.9634	.7939	1.025	.9635	.7947	0.452	.9637	.7945	-0.919	.9636	.7942	-1.648	.9636
39100	.8011	-1.131	.9651	.8006	-1.362	.9650	.8009	1.020	.9651	.8016	0.448	.9652	.8014	-0.920	.9652	.8011	-1.642	.9651
39100	.8089	-1.131	.9670	.8083	-1.360	.9669	.8087	1.024	.9670	.8085	0.446	.9669	.8084	-0.922	.9669	.8082	-1.654	.9668
39100	.8131	-1.132	.9680	.8126	-1.336	.9679	.8128	1.022	.9679	.8136	0.432	.9681	.8133	-0.916	.9680	.8131	-1.633	.9680
39100	.8237	-1.141	.9706	.8242	-1.361	.9707	.8244	0.999	.9707	.8244	0.439	.9707	.8239	-0.918	.9706	.8237	-1.644	.9706
39100	.8290	-1.151	.9719	.8283	-1.375	.9718	.8289	0.990	.9719	.8296	0.428	.9721	.8292	-0.938	.9720	.8291	-1.666	.9720
39100	.8355	-1.160	.9735	.8351	-1.381	.9734	.8353	0.992	.9735	.8361	0.420	.9737	.8358	-0.944	.9736	.8356	-1.681	.9735
39100	.8404	-1.176	.9747	.8400	-1.402	.9746	.8403	0.974	.9746	.8410	0.405	.9748	.8406	-0.959	.9747	.8405	-1.678	.9747
39100	.8464	-1.198	.9761	.8459	-1.425	.9760	.8461	0.930	.9760	.8468	0.367	.9762	.8466	-0.978	.9762	.8464	-1.712	.9761
39100	.8510	-1.218	.9772	.8506	-1.456	.9771	.8508	0.899	.9772	.8516	0.352	.9774	.8514	-1.009	.9773	.8510	-1.734	.9772
39100	.8557	-1.244	.9784	.8553	-1.461	.9783	.8555	0.897	.9783	.8562	0.348	.9785	.8559	-1.021	.9784	.8557	-1.753	.9784
39100	.8644	-1.272	.9805	.8639	-1.497	.9799	.8662	0.852	.9809	.8639	0.301	.9803	.8636	-1.047	.9803	.8644	-1.778	.9805
39100	.8702	-1.311	.9819	.8697	-1.514	.9817	.8700	0.829	.9818	.8706	0.257	.9820	.8705	-1.102	.9819	.8702	-1.819	.9819
39100	.8771	-1.320	.9835	.8766	-1.534	.9834	.8769	0.805	.9835	.8777	0.244	.9837	.8776	-1.116	.9837	.8771	-1.825	.9835
39100	.8829	-1.385	.9849	.8822	-1.623	.9848	.8825	0.737	.9848	.8834	0.190	.9851	.8833	-1.169	.9850	.8830	-1.890	.9850
39100	.8881	-1.418	.9862	.8875	-1.664	.9861	.8876	0.695	.9861	.8883	0.158	.9862	.8881	-1.213	.9862	.8879	-1.935	.9862
39100	.8922	-1.450	.9872	.8918	-1.686	.9870	.8919	0.650	.9871	.8926	0.124	.9872	.8924	-1.241	.9872	.8922	-1.978	.9872
39100	.9385	-1.781	.9984	.9379	-2.000	.9982	.9383	0.318	.9983	.9394	-0.219	.9986	.9389	-1.568	.9985	.9388	-2.274	.9984
39100	.9453	-1.795	.0000	.9447	-2.048	.9999	.9450	0.293	.9999	.9457	-0.243	.0001	.9455	-1.580	.0001	.9452	-2.313	.0000
39100	.9496	-1.791	.0011	.9500	-2.062	.0012	.9502	0.253	.0013	.9509	-0.234	.0015	.9507	-1.575	.0014	.9504	-2.318	.0013
39100	.9514	-1.809	.0015															
39137	.7319	-1.135	.8972	.7314	-1.355	.8970	.7316	1.009	.8971	.7324	0.447	.8973	.7321	-0.905	.8972	.7318	-1.629	.8971
39137	.7604	-1.133	.9041	.7597	-1.381	.9039	.7600	1.000	.9040	.7610	0.444	.9042	.7606	-0.924	.9041	.7603	-1.649	.9040
39138	.7351	-1.129	.1398	.7343	-1.337	.1396	.7345	1.019	.1396	.7358	0.453	.1399	.7351	-0.908	.1398	.7347	-1.637	.1397
39138	.7452	-1.117	.1422	.7457	-1.335	.1423	.7459	1.024	.1424	.7467	0.465	.1426	.7464	-0.903	.1425	.7462	-1.631	.1424
39139	.7062	-1.113	.3746	.7057	-1.345	.3745	.7060	1.068	.3746	.7069	0.457	.3748	.7065	-0.904	.3747	.7062	-1.640	.3746
39139	.7187	-1.126	.3776	.7181	-1.361	.3775	.7185	1.036	.3776	.7192	0.432	.3778	.7189	-0.913	.3777	.7187	-1.655	.3776
39148	.5816	-1.249	.5212	.5812	-1.460	.5211	.5814	0.913	.5212	.5821	0.337	.5214	.5819	-1.017	.5213	.5816	-1.748	.5212
39148	.5896	-1.203	.5232	.5892	-1.430	.5231	.5894	0.943	.5231	.5901	0.379	.5233	.5898	-0.990	.5232	.5896	-1.709	.5232
39148	.5958	-1.182	.5247	.5952	-1.420	.5245	.5954	0.957	.5246	.5987	0.394	.5254	.5962	-0.965	.5248	.5958	-1.694	.5247
39148	.6012	-1.167	.5260	.6005	-1.401	.5258	.6008	0.969	.5259	.6015	0.411	.5261	.6013	-0.949	.5260	.6010	-1.686	.5259
39148	.6180	-1.137	.5300	.6175	-1.366	.5299	.6178	1.001	.5300	.6185	0.446	.5302	.6182	-0.913	.5301	.6181	-1.645	.5301
39148	.6247	-1.130	.5317	.6243	-1.370	.5316	.6245	1.014	.5316	.6251	0.448	.5318	.6250	-0.904	.5317	.6247	-1.635	.5317

Table 5 (continued)

HJD - 2400000	HJD fraction	H_β(191) Δm	phase	HJD fraction	H_β(37) Δm	phase	HJD fraction	u_F Δm	phase	HJD fraction	v_F Δm	phase	HJD fraction	b_F Δm	phase	HJD fraction	y_F Δm	phase
39148	.6297	-1.136	.5329	.6292	-1.366	.5328	.6294	1.020	.5328	.6302	0.443	.5330	.6299	-0.915	.5329	.6298	-1.635	.5329
39148	.6558	-1.128	.5392	.6551	-1.351	.5390	.6553	1.007	.5391	.6560	0.449	.5392	.6558	-0.908	.5392	.6556	-1.639	.5391
39148	.6620	-1.124	.5407	.6617	-1.350	.5406	.6619	1.008	.5407	.6626	0.456	.5408	.6624	-0.912	.5408	.6621	-1.632	.5407
39148	.6667	-1.128	.5418	.6661	-1.338	.5417	.6664	1.000	.5417	.6671	0.444	.5419	.6669	-0.907	.5419	.6667	-1.642	.5418
39148	.6719	-1.131	.5431	.6711	-1.365	.5429	.6714	0.999	.5429	.6725	0.436	.5432	.6719	-0.913	.5431	.6716	-1.637	.5430
39148	.6785	-1.118	.5447	.6781	-1.349	.5446	.6783	1.023	.5446	.6791	0.458	.5448	.6788	-0.910	.5447	.6785	-1.637	.5447
39148	.6837	-1.130	.5459	.6833	-1.349	.5458	.6836	1.005	.5459	.6842	0.455	.5460	.6840	-0.911	.5460	.6837	-1.637	.5459
39148	.6884	-1.122	.5470	.6879	-1.344	.5469	.6881	1.014	.5470	.6887	0.463	.5471	.6886	-0.911	.5471	.6883	-1.643	.5470
39154	.5857	-1.179	.9734	.5852	-1.411	.9732	.5856	0.969	.9733	.5863	0.405	.9735	.5860	-0.960	.9734	.5858	-1.688	.9734
39154	.5956	-1.208	.9758	.5950	-1.451	.9756	.5954	0.929	.9757	.5966	0.356	.9760	.5962	-0.987	.9759	.5956	-1.714	.9758
39154	.6040	-1.242	.9778	.6035	-1.475	.9777	.6037	0.892	.9777	.6045	0.315	.9779	.6043	-1.029	.9779	.6040	-1.741	.9778
39154	.6093	-1.264	.9791	.6087	-1.491	.9789	.6087	0.859	.9789	.6098	0.298	.9792	.6095	-1.050	.9791	.6092	-1.768	.9791
39154	.6144	-1.290	.9803	.6140	-1.511	.9802	.6143	0.832	.9803	.6149	0.276	.9804	.6147	-1.074	.9804	.6145	-1.786	.9803
39154	.6200	-1.323	.9817	.6196	-1.545	.9816	.6198	0.807	.9816	.6205	0.245	.9818	.6203	-1.100	.9817	.6200	-1.823	.9817
39154	.6264	-1.359	.9832	.6258	-1.591	.9831	.6261	0.772	.9831	.6268	0.208	.9833	.6266	-1.137	.9833	.6264	-1.851	.9832
39154	.6333	-1.391	.9849	.6328	-1.627	.9848	.6330	0.736	.9848	.6338	0.183	.9850	.6335	-1.170	.9849	.6332	-1.877	.9849
39154	.6395	-1.436	.9864	.6391	-1.664	.9863	.6393	0.667	.9863	.6400	0.140	.9865	.6397	-1.220	.9864	.6395	-1.929	.9864
39154	.6452	-1.477	.9878	.6446	-1.705	.9876	.6449	0.625	.9877	.6455	0.081	.9878	.6452	-1.257	.9878	.6451	-1.975	.9877
39154	.6527	-1.543	.9896	.6531	-1.766	.9897	.6534	0.557	.9897	.6540	0.013	.9899	.6538	-1.330	.9898	.6536	-2.044	.9898
39154	.6589	-1.579	.9911	.6584	-1.789	.9910	.6587	0.536	.9910	.6596	-0.009	.9912	.6594	-1.353	.9912	.6589	-2.089	.9911
39154	.6643	-1.621	.9924	.6638	-1.839	.9923	.6641	0.479	.9923	.6648	-0.064	.9925	.6646	-1.402	.9925	.6643	-2.112	.9924
39154	.6719	-1.699	.9942	.6717	-1.935	.9942	.6715	0.417	.9941	.6724	-0.127	.9943	.6720	-1.475	.9942	.6718	-2.192	.9942
39154	.6789	-1.734	.9959	.6785	-1.971	.9958	.6787	0.341	.9959	.6795	-0.184	.9961	.6792	-1.523	.9960	.6789	-2.233	.9959
39154	.6852	-1.776	.9974	.6844	-2.023	.9972	.6847	0.305	.9973	.6862	-0.221	.9977	.6853	-1.562	.9975	.6850	-2.287	.9974
39154	.6973	-1.809	.0004	.6967	-2.054	.0002	.6970	0.278	.0003	.6978	-0.249	.0005	.6976	-1.599	.0004	.6973	-2.317	.0004
39154	.7069	-1.789	.0027	.7062	-2.028	.0025	.7065	0.306	.0026	.7073	-0.219	.0028	.7041	-1.566	.0020	.7038	-2.284	.0019
39154	.7151	-1.728	.0047	.7147	-1.978	.0046	.7150	0.358	.0046	.7157	-0.159	.0048	.7155	-1.519	.0048	.7151	-2.224	.0047
39154	.7212	-1.690	.0061	.7208	-1.937	.0060	.7210	0.402	.0061	.7238	-0.123	.0068	.7216	-1.461	.0062	.7214	-2.183	.0062
39154	.7277	-1.648	.0077	.7272	-1.881	.0076	.7275	0.462	.0077	.7282	-0.078	.0078	.7280	-1.419	.0078	.7278	-2.140	.0077
39154	.7331	-1.584	.0090	.7326	-1.800	.0089	.7329	0.517	.0090	.7337	-0.006	.0092	.7334	-1.356	.0091	.7331	-2.075	.0090
39154	.7407	-1.534	.0108	.7400	-1.759	.0107	.7405	0.589	.0108	.7413	0.046	.0110	.7410	-1.299	.0109	.7408	-2.023	.0109
39154	.7498	-1.473	.0130	.7489	-1.727	.0128	.7491	0.628	.0129	.7499	0.103	.0131	.7496	-1.244	.0130	.7494	-1.964	.0130
39154	.7548	-1.429	.0143	.7543	-1.646	.0141	.7546	0.693	.0142	.7553	0.159	.0144	.7551	-1.200	.0143	.7548	-1.924	.0143
39154	.7610	-1.386	.0158	.7603	-1.623	.0156	.7616	0.752	.0159	.7616	0.187	.0159	.7613	-1.161	.0158	.7609	-1.892	.0157
39154	.7744	-1.308	.0190	.7738	-1.548	.0189	.7740	0.823	.0189	.7751	0.264	.0192	.7744	-1.087	.0190	.7742	-1.816	.0189
39154	.7849	-1.255	.0215	.7844	-1.484	.0214	.7846	0.865	.0215	.7854	0.323	.0217	.7852	-1.041	.0216	.7849	-1.756	.0215
39154	.7992	-1.191	.0250	.7987	-1.425	.0249	.7990	0.940	.0249	.7998	0.375	.0251	.7996	-0.986	.0251	.7994	-1.685	.0250
39154	.8057	-1.188	.0266	.8052	-1.425	.0264	.8055	0.951	.0265	.8063	0.389	.0267	.8060	-0.961	.0266	.8057	-1.683	.0266
39154	.8157	-1.137	.0290	.8152	-1.374	.0289	.8155	0.989	.0289	.8163	0.428	.0291	.8161	-0.915	.0291	.8157	-1.636	.0290
39154	.8228	-1.142	.0307	.8225	-1.413	.0306	.8226	0.978	.0307	.8236	0.419	.0309	.8234	-0.922	.0308	.8230	-1.646	.0308
39154	.8281	-1.147	.0320	.8276	-1.386	.0319	.8280	0.985	.0320	.8288	0.428	.0322	.8287	-0.925	.0322	.8281	-1.652	.0320
39154	.8335	-1.128	.0333	.8331	-1.349	.0333	.8334	1.026	.0333	.8341	0.438	.0335	.8339	-0.908	.0334	.8337	-1.637	.0334
39154	.8400	-1.125	.0348	.8396	-1.352	.0347	.8398	1.007	.0348	.8406	0.446	.0350	.8404	-0.928	.0349	.8401	-1.667	.0348
39154	.8472	-1.134	.0366	.8467	-1.354	.0364	.8469	1.026	.0365	.8478	0.444	.0367	.8474	-0.914	.0366	.8472	-1.641	.0366
39169	.5975	-1.117	.6041	.5969	-1.341	.6040	.5972	1.033	.6040	.5980	0.463	.6042	.5978	-0.901	.6042	.5975	-1.627	.6041
39169	.6053	-1.115	.6060	.6048	-1.332	.6059	.6050	1.039	.6060	.6057	0.467	.6061	.6054	-0.907	.6061	.6052	-1.631	.6060
39169	.6157	-1.108	.6083	.6153	-1.335	.6082	.6155	1.055	.6082	.6162	0.483	.6084	.6160	-0.889	.6083	.6158	-1.624	.6083
39170	.6779	-1.127	.8654	.6773	-1.363	.8652	.6775	1.009	.8653	.6782	0.450	.8654	.6780	-0.912	.8654	.6779	-1.641	.8654
39170	.6893	-1.121	.8681	.6885	-1.354	.8679	.6886	1.021	.8679	.6896	0.464	.8682	.6893	-0.901	.8681	.6891	-1.628	.8681
39172	.6702	-1.119	.3472	.6697	-1.352	.3471	.6699	1.018	.3471	.6709	0.453	.3474	.6707	-0.908	.3473	.6703	-1.634	.3472
39172	.6801	-1.124	.3496	.6804	-1.349	.3497	.6807	1.016	.3497	.6801	0.452	.3496	.6800	-0.912	.3496	.6801	-1.632	.3496
39177	.6694	-1.114	.5564	.6686	-1.360	.5562	.6689	1.016	.5562	.6699	0.459	.5565	.6696	-0.904	.5564	.6692	-1.637	.5563
39177	.6807	-1.107	.5591	.6808	-1.342	.5591	.6817	1.038	.5593	.6808	0.472	.5591	.6807	-0.891	.5591	.6810	-1.628	.5592
39178	.6082	-1.121	.7834	.6082	-1.341	.7834	.6084	1.027	.7835	.6084	0.465	.7835	.6084	-0.909	.7835	.6086	-1.638	.7835
39178	.6188	-1.110	.7860	.6182	-1.351	.7858	.6184	1.030	.7859	.6189	0.467	.7860	.6190	-0.901	.7860	.6187	-1.627	.7860
39218	.6196	-1.128	.4605	.6196	-1.356	.4605	.6196	1.000	.4605	.6194	0.454	.4604	.6194	-0.915	.4604	.6194	-1.640	.4604
39218	.6372	-1.127	.4647	.6368	-1.358	.4646	.6370	1.038	.4647	.6378	0.476	.4649	.6375	-0.906	.4648	.6372	-1.634	.4647
39218	.6448	-1.137	.4666	.6443	-1.355	.4665	.6453	0.994	.4667	.6461	0.465	.4669	.6458	-0.903	.4668	.6456	-1.653	.4668
39219	.6464	-1.130	.7088	.6460	-1.332	.7087	.6464	1.014	.7088	.6472	0.445	.7090	.6470	-0.909	.7089	.6466	-1.627	.7089
39220	.6415	-1.134	.9495	.6410	-1.365	.9494	.6412	1.004	.9494	.6421	0.432	.9496	.6418	-0.934	.9496			
39220	.6520	-1.128	.9520	.6514	-1.366	.9519	.6517	1.013	.9520	.6525	0.437	.9522	.6522	-0.919	.9521	.6519	-1.637	.9520
39220	.6610	-1.138	.9542	.6598	-1.367	.9539	.6604	1.006	.9541	.6619	0.450	.9544	.6614	-0.921	.9543	.6609	-1.643	.9542
39468	.8287	-1.158	.9755	.8284	-1.387	.9754	.8288	0.976	.9755	.8289	0.420	.9756	.8287	-0.949	.9755	.8291	-1.667	.9756
39468	.8355	-1.188	.9772	.8349	-1.426	.9770	.8351	0.958	.9771	.8358	0.382	.9772	.8356	-0.989	.9772	.8354	-1.697	.9771
39469	.8217	-1.124	.2157	.8210	-1.363	.2155	.8213	1.010	.2156	.8220	0.460	.2157	.8218	-0.904	.2157	.8216	-1.627	.2157
39469	.8289	-1.125	.2174	.8282	-1.384	.2172	.8284	1.003	.2173	.8292	0.460	.2175	.8287	-0.930	.2174	.8286	-1.639	.2173
39470	.8334	-1.128	.4604	.8330	-1.360	.4603	.8334	1.020	.4604	.8343	0.454	.4606	.8338	-0.915	.4605	.8336	-1.636	.4604
39470	.8430	-1.127	.4627	.8425	-1.373	.4626	.8427	1.026	.4626	.8434	0.457	.4628	.8432	-0.914	.4627	.8429	-1.631	.4627
39572				.6221	-1.332	.0788	.6223	1.068	.0788	.6228	0.472	.0789	.6226	-0.913	.0789	.6224	-1.639	.0788
39572				.6293	-1.341	.0805	.6294	1.041	.0805	.6299	0.462	.0806	.6297	-0.891	.0806	.6296	-1.639	.0806
39777	.9664	-1.124	.7429	.9662	-1.345	.7428												
39777	.9906	-1.131	.7487	.9904	-1.342	.7487												
39777	.9978	-1.128	.7505	.9972	-1.340	.7503												
39778	.0033	-1.134	.7518	.0032	-1.341	.7518												
39778	.0103	-1.135	.7535															
39778	.0182	-1.130	.7554	.0180	-1.354	.7554												
39778	.0247	-1.139	.7570	.0246	-1.350	.7570												
39919	.6164	-1.793	.0020	.6162	-1.988	.0020	.6160	0.330	.0019	.6159	-0.237	.0019	.6157	-1.577	.0019			
39919	.6237	-1.787	.0038	.6235	-1.973	.0037	.6234	0.367	.0037	.6232	-0.214	.0037	.6231	-1.569	.0037			
39919	.6304	-1.746	.0054	.6302	-1.950	.0054	.6301	0.377	.0053	.6299	-0.173	.0053	.6298	-1.529	.0053			
39919	.6760	-1.397	.0164	.6758	-1.619	.0164	.6757	0.738	.0164	.6755	0.170	.0163	.6754	-1.170	.0163			
39919	.6827	-1.363	.0181	.6826	-1.553	.0180	.6824	0.811	.0180	.6822	0.213	.0179	.6821	-1.148	.0179			
39919	.6886	-1.322	.0195	.6884	-1.510	.0194	.6883	0.882	.0194	.6881	0.267	.0194	.6880	-1.100	.0193			
39920	.6084	-1.120	.2420	.6083	-1.308	.2419				.6079	0.445	.2418	.6078	-0.910	.2418			
39920	.6152	-1.125	.2436	.6151	-1.301	.2436	.6149	1.076	.2435	.6148	0.462	.2435	.6146	-0.915	.2435			
39920	.6210	-1.121	.2450	.6209	-1.298	.2450	.6207	1.069	.2449	.6205	0.456	.2449	.6204	-0.932	.2449			
39920	.6266	-1.132	.2464	.6264	-1.317	.2463	.6263	1.047	.2463	.6261	0.448	.2462	.6260	-0.922	.2462			
39920	.6934	-1.130	.2625	.6934	-1.350	.2625	.6931	1.047	.2625	.6929	0.474	.2624	.6928	-0.929	.2624			
39927	.6203	-1.122	.9378	.6200	-1.325	.9378	.6199	1.033	.9377	.6197	0.451	.9377	.6196	-0.924	.9377			
39927	.6270	-1.129	.9395	.6267	-1.341	.9394	.6266	1.007	.9394	.6264	0.448	.9393	.6263	-0.913	.9393			
39927	.6351	-1.124	.9414	.6350	-1.335	.9414	.6348	1.014	.9413	.6346	0.450	.9413	.6344	-0.918	.9413			
39929	.6120	-1.134	.4195	.6117	-1.345	.4195				.6114	0.434	.4194	.6112	-0.919	.4193			
39929	.6199	-1.124	.4214	.6196	-1.347	.4214	.6194	1.021	.4213	.6192	0.449	.4213	.6190	-0.919	.4212			
39929	.6284	-1.128	.4235	.6282	-1.326	.4235	.6280	1.011	.4234	.6279	0.444	.4234	.6277	-0.917	.4233			
39929	.6352	-1.112	.4252	.6350	-1.345	.4251	.6348	1.049	.4251	.6346	0.457	.4250	.6345	-0.910	.4250			
39929	.6420	-1.127	.4268	.6418	-1.351	.4267	.6416	1.039	.4267	.6414	0.442	.4266	.6412	-0.939	.4266			
39929	.6491	-1.156	.4285	.6488	-1.336	.4284	.6486	1.017	.4284	.6484	0.431	.4283	.6483	-0.909	.4283			
39933	.6083	-1.124	.3867	.6080	-1.316	.3866	.6078	1.047	.3865	.6077	0.435	.3865	.6075	-0.912	.3865			
39933	.6150	-1.123	.3883	.6148	-1.329	.3882	.6146	1.060	.3882	.6143	0.486	.3881	.6141	-0.903	.3881			
39933	.6220	-1.129	.3900	.6218	-1.332	.3899	.6216	1.074	.3899	.6214	0.466	.3898	.6212	-0.901	.3898			
39933	.6281	-1.126	.3915	.6279	-1.321	.3914				.6275	0.455	.3913	.6272	-0.911	.3912			
39933	.6344	-1.122	.3930	.6342	-1.329	.3929				.6337	0.456	.3928	.6335	-0.907	.3928			
39933	.6419	-1.129	.3948	.6416	-1.336	.3947	.6414	1,065	.3947	.6412	0.455	.3946	.6410	-0.906	.3946			

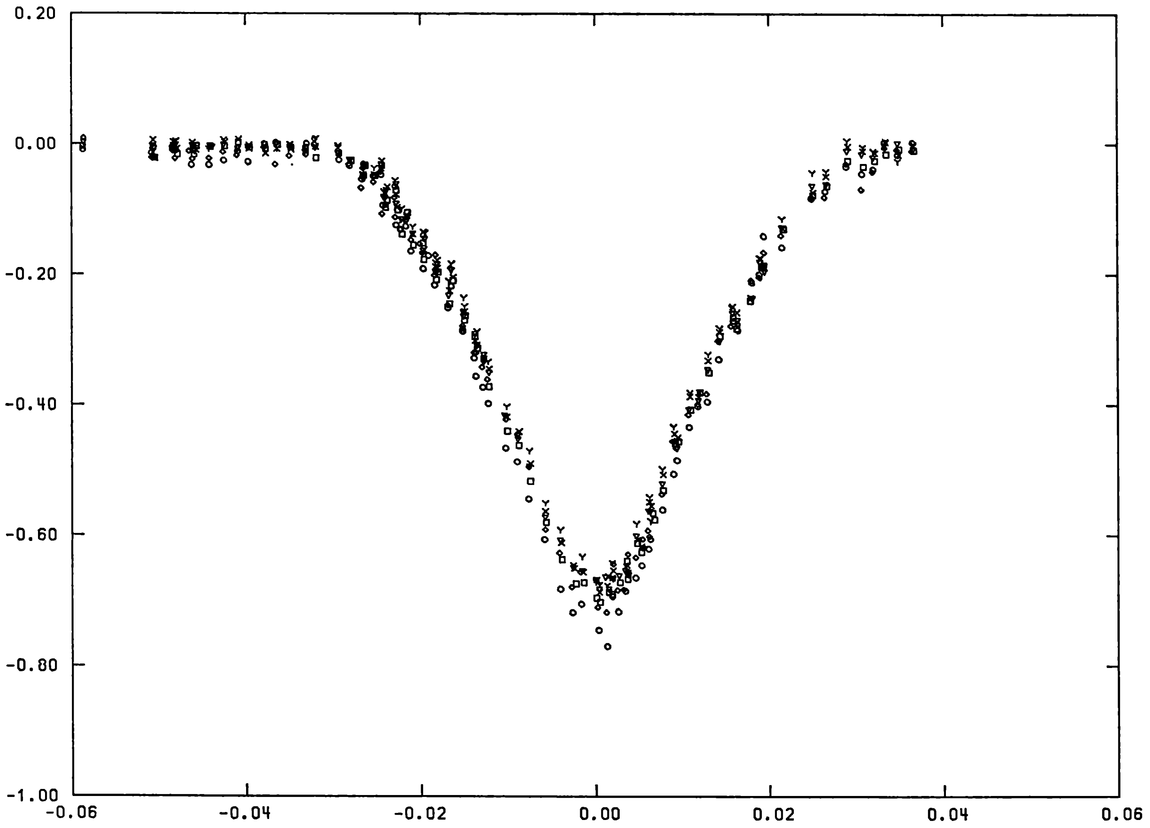

Fig. 2. $m_{1726} - m_{\mathrm{AR\,Aur}}$ obtained through the primary minimum. The magnitude differences outside the eclipse are for each colour normalized to unity. For symbols see Fig. 1

4. The Light Curve of AR Aur

Every observation of AR Aur is referred to the mean of two observations of HR 1726. For the nights JD 2439148 and JD 2439154 corrections for the systematic deviation have been applied. Weighted means of the magnitude change of HR 1726 relative to HR 1749 and AR Aur have been computed. These corrections are given in Table 4; they have been subtracted from the observed $m_{1726}-m_{\mathrm{AR\,Aur}}$ values. The mean error of one observation is obtained from the observations of the comparison stars, and given in Table 3. The large error of u_F may be due to some systematic fluctuations of $m_{1726}-m_{1749}$. They have not been found in other filters and may not be real. Mean error of u_F in the winter 1965/66, where the majority of the observations were carried out, is 0.010.

In Table 5 the magnitude differences $m_{1726} - m_{\mathrm{AR\,Aur}}$ are given, each referring to one reading of the variable. The heliocentric Julian date is given. From the ephemeris given by Woodward (1943) the phase has been computed. However the primary mid-eclipse was found to occur at a phase equal to 0.0027 $\pm$ 0.0001 and the secondary at 0.5025 $\pm$ 0.0001. The values were estimated by eye for each colour and the mean for the six colours computed. In Table 5 a correction to the computed phase equal to -0.0026 has been applied. The lightcurve is shown in Figs. 1, 2, and 3.

5. Photometric Elements

The photometric elements of the system were computed by means of the method of Kopal (1959) using an Algol programme written and described by West (1965). For the observations in u_F, v_F, b_F, and y_F which are wave-length regions in the continuum, the elements have been found for each colour separately. The differences measure the uncertainty of the elements. It should be mentioned that the observations in these colours can not be regarded as fully independent since they have been carried out on the same nights where similar systematic differences may exist. Observations corrected for the above mentioned systematic differences on JD

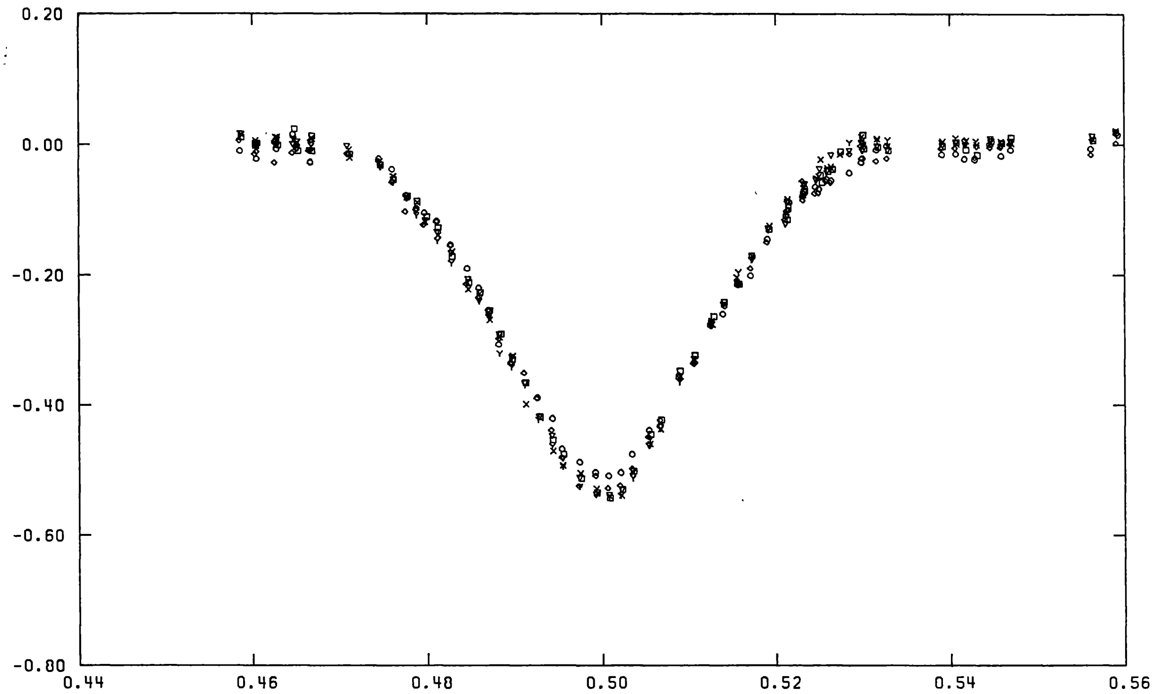

Fig. 3. $m_{1726} - m_{\mathrm{AR\ Aur}}$ obtained through the secondary minimum. The magnitude differences outside eclipse are for each colour normalized to unity. For symbols see Fig. 1

2439148 and JD 2439154 have been used for the element determination.

The eccentricity of the system is zero. This is apparently true since the secondary minimum occurs at a phase difference 0.4998 from the primary, which value is consistent with that found by Huffer and Eggen (1947). Further, the eccentricity determined in the spectroscopic study of Harper (1938) was found equal to 0.009 ± 0.010.

A linear approximation of the limb darkening was adopted, where the intensity of a point on the surface of the star is described by the relation

$$I = I_0(1 - u + u\cos v)\,. \tag{1}$$

u is the limb darkening coefficient, and v the angle between the actual radius of the star and the line of sight. Since the spectral types of the components are almost identical the same value of u was applied for each star. The values have been taken from Kopal (1959).

The rectification constants are found from a Fourier analysis where the light variation, l, outside the minima is approximated by the expression

$$l = A_0 + A_1\cos\theta + A_2\cos 2\theta \tag{2}$$

where θ is the phase angle. From these coefficients the rectification constants C_0, C_1 and C_2 due to reflection and z due to ellipticity are computed statistically according to the formulae given by Russell and Merrill (1952). The Fourier coefficients and the rectification constants are given in Table 6. They are in no cases larger than four times their mean errors, and the influence of reflection and ellipticity thus uncertain. The rectification have been performed according to the equations

$$l_{\mathrm{rect.}} = \frac{1 + C_0 + C_1\cos\theta + C_2\cos 2\theta}{(A_0 + C_0) + (A_2 + C_2)\cos 2\theta}\,, \tag{3}$$

$$\sin^2\Theta = \sin^2\theta/(1 - z\cos^2\theta)\,. \tag{4}$$

The eclipsing star at primary minimum has the radius r_a, the eclipsed star the radius r_b expressed in units of the distance between the stars. Further r_b/r_a is denoted by k. In the Kopal method an assumed first approximation of the k-value yields a new value of k, from which new improved values can be obtained, etc. The final value of k has been found if the iteration converges. Then also r_a, r_b and the inclination, i, are determined. In other cases a light curve can be computed from assumed values of k, the radii and the inclination. In a grid of the assumed parameters the combination yielding the smallest mean error is accepted as the best elements. In case of b_F

Table 6. *Fourier coefficients with mean errors and rectification constants*

Filter	A_0	A_1	A_2	C_0	C_1	C_2	z
H_β(191)	0.9997 ±0.0008	—0.0023 ±0.0010	—0.0007 ±0.0011	0.0039	0.0023	0.0013	0.0031
H_β(37)	0.9994 ±0.0017	—0.0044 ±0.0020	—0.0077 ±0.0022	0.0039	0.0044	0.0013	0.0111
u_F	1.0080 ±0.0025	—0.0059 ±0.0026	—0.0126 ±0.0035	0.0039	0.0059	0.0013	0.0248
v_F	1.0044 ±0.0014	—0.0023 ±0.0015	—0.0043 ±0.0019	0.0039	0.0023	0.0013	0.0086
b_F	1.0072 ±0.0012	—0.0028 ±0.0012	0.0001 ±0.0016	0.0039	0.0028	0.0013	0.0018
y_F	0.9948 ±0.0012	—0.0038 ±0.0011	—0.0049 ±0.0016	0.0039	0.0038	0.0013	0.0096

and y_F the procedure converged, in the case of u_F and v_F the last method has been applied. Since a rectification according to ellipticity has been carried out before the element determination, the direct solution yields a fictive value, i_r, of the inclination. The true value, i, can be obtained from the relation

$$\cos^2 i = (1 - z) \cos^2 i_r \,. \tag{5}$$

In Table 7 the elements determined for the four colours together with mean values and their mean errors are given.

Table 7. *Photometric elements*

Filter	k	r_a	r_b	i
u_F	1.008	0.1004	0.1012	88.46
v_F	0.988	0.1019	0.1008	88.29
b_F	0.903	0.1061	0.0958	88.24
y_F	1.086	0.0951	0.1033	88.46
Mean elements	0.996	0.1009	0.1003	88.36
Mean errors of mean elements	0.038	0.0023	0.0016	0.06

For the H_β regions which contains a spectral line, the computation of elements was not performed, since the limb darkening is not known. However accepting the mean values of the elements it is possible to estimate the limb darkening in case of these spectral regions. Further, computing the u_F, v_F, b_F, and y_F light curves from the mean elements one obtains small discrepancies from the observed depth of the minima, but changing the limb darkening coefficients one removes these differences. The limb darkening thus obtained is listed in Table 8 together with the values given by Kopal (1959) and those given by Grygar (1965). The computed values approach those of Grygar. Further uncertainties of the computed limb darkening coefficients are given. These are found from the uncertainty of the depths of the minima disregarding uncertainties of the mean elements.

Table 8. *Limb darkening coefficients. The uncertainty of u_{Computed} is discussed in the text*

Filter	u_{Kopal}	u_{Grygar}	u_{Computed}
H_β(191)			0.59 ± 0.04
H_β(37)			0.46 ± 0.14
u_F	0.40	0.49	0.62 ± 0.17
v_F	0.74	0.63	0.69 ± 0.07
b_F	0.66	0.55	0.55 ± 0.08
y_F	0.61	0.48	0.54 ± 0.06

A new determination using the values given by Grygar was carried out for two colours. In no case the elements could be determined from a convergence of k. Therefore the last method described above was applied. However it was not possible to determine elements of less scatter than those listed above. Fig. 4 shows the rectified intensities plotted against rectified phase angle for the b_F observations. The computed light curve based on the limb darkening coefficient given by Kopal and that computed from the mean elements and the corrected u value are almost identical. In Fig. 4 these curves coincide, which gives an idea of the uncertainty of element determination.

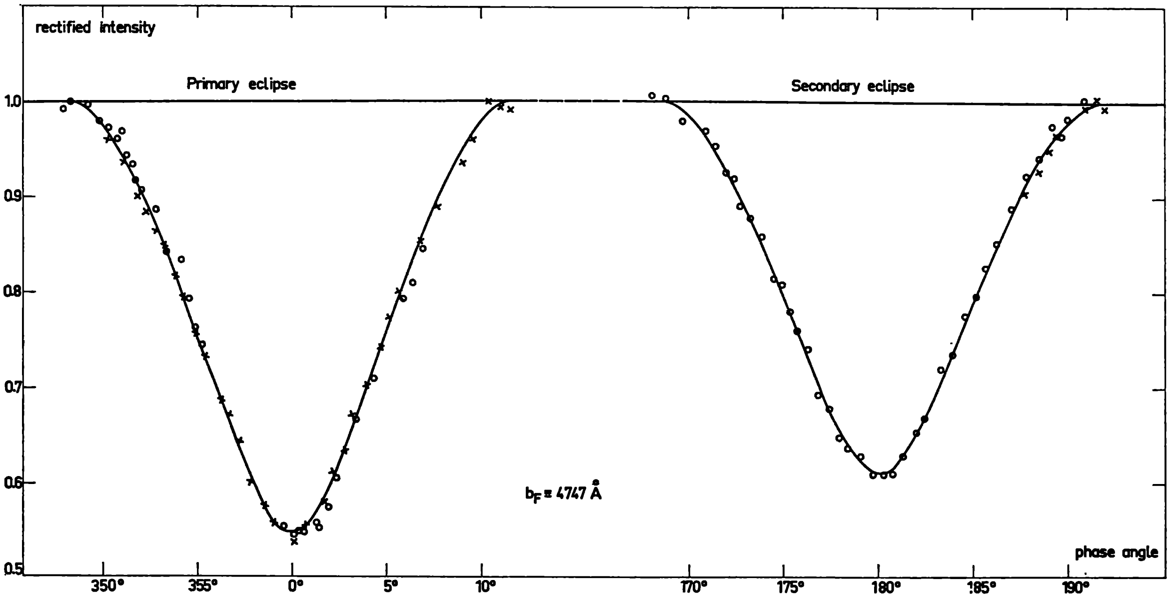

Fig. 4. Rectified intensities $I_{\text{rect.}}$ plotted against the rectified phase angle Θ for b_F. × are observations carried out on JD 2439148 and JD 2439154, corrected for the systematic deviation. O are observations carried out on other nights. The curve represents the computed intensities

Table 9. *Photometric elements of* AR Aur *determined by different authors*

Author	k	r_a	r_b	i
Nassau	0.919	0.110	0.101	88°.8
Huffer and Eggen	1.000	0.0983	0.0983	88.5
Grygar	0.998	0.0989	0.0986	88.45
Tabachnik	1.000	0.0986	0.0986	88.46
Johansen	0.996	0.101	0.100	88.36

Element determinations for AR Aur have been carried out by Nassau (1936), Huffer and Eggen (1947), Grygar (1963) and Tabachnik (1968): the elements of Nassau are based on his photographic observations. The elements of Huffer and Eggen, those of Grygar and those of Tabachnik are all based on the photoelectric observations by Huffer and Stebbins. The investigation made by Grygar differs from those of Huffer and Eggen, and Tabachnik in so far that he has applied a non linear limb darkening coefficient. The elements are listed in Table 9. The five determinations are in close agreement.

6. Spectral Types and Absolute Magnitudes of the Components

In Table 10 the intensity of each component is given for each colour. a refers to the star, which is the eclipsing one at the primary minimum. For each

Table 10. *Intensities and magnitudes of the components of* AR Aur. *For each colour the intensity of the system has been normalized to unity. The large uncertainty for y_F is probably due to the few observations outside the minima*

Filter	I_a	I_b	m.e. of I	m_a	m_b	m.e. of
H_β(191)	0.460	0.540	0.004	0.843	0.669	0.009
H_β(37)	0.452	0.548	0.007	0.862	0.653	0.015
u_F	0.435	0.565	0.007	0.904	0.620	0.015
v_F	0.459	0.541	0.004	0.846	0.667	0.009
b_F	0.464	0.536	0.004	0.834	0.677	0.009
y_F	0.453	0.547	0.015	0.860	0.655	0.032

colour the intensity of the system is normalized to unity. Although the wavelength regions used are slightly deviating from those given by Strömgren (1963) and Crawford (1958) the indices m_1, c_1, $b-y$, $u-b$ and β may be determined for each component. The transformation to these indices was established by Johansen and Gyldenkerne (1969). The values are given in Table 11. In a plot of β against $u-b$ for B-type stars (Strömgren, 1966) both components are obviously situated close to the zero age line in regions of the diagram which corresponds to B 9 V for a and B 8 V for b. This is in agreement with the spectral types found by Popper (1959). The masses of the components were derived by Huffer and Eggen (1947) in connection with earlier spectroscopic observations. The values are 2.30 $M_\odot$ for component a and 2.55 $M_\odot$

Table 11. *Photometric indices of the components*

Index	component a	component b	mean error
m_1	0.176	0.121	0.013
c_1	0.919	0.833	0.009
$b-y$	−0.062	−0.008	0.018
$u-b$	1.147	1.059	0.010
β	2.868	2.817	0.009

for component b; the mean error is about 0.08 $M_\odot$. From the β values and the calibration of these into absolute visual magnitude, given by Fernie (1965), M_{va} and M_{vb} are determined equal to 1.15 and 0.82; the difference is 0.33 and agrees with the values of Table 10. The scatter of the calibration is 0.3 for late B stars, however the error for magnitude differences of almost identical stars might be smaller.

From the mass values and the colour differencies it is concluded that r_b is larger than r_a. Further since the minimum value of the projected distance of the star centers equal to $\cos i = 0.029$ is larger than $r_b - r_a$, the primary eclipse is found to be a partial transit. A rough estimate of the value of k may be obtained from a comparison with stellar models (Kelsall and Strömgren, 1966). For main-sequence stars of same age and chemical composition, the difference in bolometric magnitude, the ratio of effective temperatures and radii are only functions of the stellar masses. For zero age Population I stars with composition $X = 0.70$, $Y = 0.27$ and $Z = 0.03$ the values are

$$M_{\mathrm{bol}\,a} - M_{\mathrm{bol}\,b} = 0.42 \pm 0.20\,, \tag{6}$$

$$\log T_{ea} - \log T_{eb} = -0.031 \pm 0.015\,, \tag{7}$$

$$k = 1.05 \pm 0.03\,. \tag{8}$$

The errors are determined from the mean error of the stellar masses.

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References

Christie, W.H. 1936, *Ap. J.* **83**, 433.
Crawford, D.L. 1958, *Ap. J.* **128**, 185.
Fernie, J.D. 1965, *A. J.* **70**, 575.
Grygar, J. 1963, *B.A.C.* **14**, 127.
Grygar, J. 1965, *B.A.C.* **16**, 195.
Gyldenkerne, K., Johansen, K. T. 1969, *Astron. Astrophys.* Sup. Ser. (in press).
Harper, W.E. 1938, *Publ. Dom. Astr. Obs. Vic.* **6**, 311.
Hoffleit, D. 1964, *Catalogue of Bright Stars.* New Haven, Connecticut Yale University Observatory
Huffer, C.M., Eggen, O.J. 1947, *Ap. J.* **106**, 106.
Johansen, K. T., Gyldenkerne, K. 1969, *Astron. Astrophys.* (in press).
Kelsall, T., Strömgren, B. 1966, Calibration of the Hertzsprung-Russel Diagram in Terms of Age and Mass for Main-Sequence B and A Stars. In *Vistas in Astronomy* **8**, Ed. A. Beer and K. Aa. Strand, Pergamon Press, Oxford p 159.
Kopal, Z. 1959, Close Binary Systems, Chapman and Hall Ltd. London.
Nassau, J.J. 1936, *A. J.* **45**, 137.
Popper, D.M. 1959, *Ap. J.* **129**, 659.
Russell, H.N., Merrill, J.E. 1952, *Contr. Princeton Univ. Obs.* **26**, 36.
Strömgren, B. 1963, Quantitative Classification Methods, in *Basic Astronomical Data*, Ed. K. Aa. Strand, Univ. Chicago Press, Chicago p 136.
Strömgren, B. 1966, Spectral Classification through photoelectric narrowband Photometry, in *Annual Review of Astron. and Astrophys.* **4**, Annual Review, Inc., Palo Alto, Calif. U.S.A., p. 433.
Tabachnik, V.M. 1965, Astr. Zu. **45**, 1048. *Soviet Astron.-A.J.* **12**, 830.
West, R.M. 1965, *Publ. o. m. Medd. f. Københavns Obs.* **184**.
Woodward, E.J. 1943, *Harvard Bull.* **917**.
Wyse, A.B. 1936, *P.A.S.P.* **48**, 24.

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