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PHOTOELECTRIC PHOTOMETRY OF EPSILON AURIGAE

Epsilon Aurigae was observed during the period 1982-1985 at the Jagiellonian University Observatory in Cracow (Fort Skała) and at the Station in the Bieszczady Mountains ($\lambda=-1^h29^m$, $\varphi=49^\circ10'$). These observations were made in coordination with the observational campaign of the star (Genet,Stencel 1982)

Two instruments in Cracow: the 500 mm Cassegrain reflector (hereafter denoted as R) and the 350 mm Maksutov reflector (denoted as M) as well as the 203 mm refractor (denoted as A) at the Mountain Station, equipped with one-channel photometers with UBV filters and photomultipliers: an EMI 9789 QB at the R-telescope and a Russian made FEU 92 at the others, were used in the presented observations. All these systems are close to the standard UBV system. The diaphragms used were: 24,40 and 122 arcsec, respectively.

The differential photometry of ε Aurigae in respect to λ Aurigae as comparison star were performed during 102 nights. The accepted magnitudes of the comparison star: $U=5^m.456$, $B=5^m.332$, $V=4^m.710$ are mean values of measurements from the Photometric Catalogue (Blanco et al. 1968). We attempted to make several measurements in each observational season, their actual number is given in column denoted N. However, for a number of reasons, it was not always possible. Due to this, our data are of unequal quality, so we decided to present them in different tables. When a number of individual measurements in B or V is greater than 5, observations are given in Table I, whereas for N<6 they are given in Table II. There are but a few observations in U-band, so they are listed in the separate Table III. Each measurement has been corrected for atmospheric extinction and the measurement means, reduced to the UBV system, are given in the respective column of each Table. The moments of observations, expressed in heliocentric MJD, are means of individual moments of measurements. The transformation formulae from instrumental ubv system to the UBV system are:

$$U_\lambda - U_\varepsilon = u_\lambda - u_\varepsilon + a_u\,((U-B)_\lambda - (U-B)_\varepsilon)$$
$$B_\lambda - B_\varepsilon = b_\lambda - b_\varepsilon + a_b\,((B-V)_\lambda - (B-V)_\varepsilon)$$
$$V_\lambda - V_\varepsilon = v_\lambda - v_\varepsilon + a_v\,((B-V)_\lambda - (B-V)_\varepsilon)$$

where the values of coefficients are :

instrument	a_u	a_b	a_v
R	+.0017 ±.0187	−.2846 ± .0100	−.1034 ± .0012
M		+.030 ±.012	−.146 ±.008
A		+.0143 ±.0025	−.1252 ±.0030

Atmospheric extinction was determined for each night. Sometimes, particularly when the differences of air masses for both stars were small throughout the observational season the mean coefficients were accepted ($C_V=0\overset{m}{.}4$ and $C_B=0\overset{m}{.}55$ for Cracow, $C_V=0\overset{m}{.}2$ and $C_B=0\overset{m}{.}35$ for the Mountain Station). In such cases in the column denoted ext we give admissible error in photometry, assuming fifty percent change in the accepted values of the extinction coefficient. In all cases this error did not exceed $0\overset{m}{.}005$. Measurements were recorded on paper tapes and due to small dynamics of the receiver its different ranges had to be used. These differences were determined for each night and the determination errors are also introduced into values presented in the column denoted SD. This does not apply to the R-telescope observations after MJD 45671.0, in which a digital receiver was used. The column denoted SD gives the standard deviation of measurements, together with mentioned above determination error, however it is meaningful only when the number of observations is sufficiently large.

The observed B and V light curves, along with colour index B-V, are presented in Figure 1. It can be seen from the light curves that in addition to the eclipsing variability ε Aurigae shows additional brightness changes. They are especially well discernible during totality. These changes are well above measurement errors and they have been reported also by other authors (see Hopkins and Stencel 1983). Their analysis will be published later. We have not been lucky enough to record supected flare activity of the star (Nha and Lee 1983). Our observations confirm the anomaly reported by Osi et al.(1984) and Boyd et al.(1984) near the third contact predicted by Gyldenkerne (1970). In both colours the rapid increase of brightness and its subsequent decrease can be observed. Moreover, near the fourth contact after the maximum we observed brightness decrease in both colours, as well as changes of B-V colour index.

As can be seen from Figure 1 the colour changes are very small. It seems that mean values of B-V index calculated separately for different phases are somewhat different, but these differences are small, slightly greater than 1σ level of significance. These means are denoted in Figure 1 by crosses.

The determination of time of contacts from our observations is difficult. Nevertheless, it seems that the second contact occurred a little earlier than predicted, whereas the third and the fourth contacts later than predicted.. Timing of minimum is difficult too, because light curve is asymmetric.

Table I : B, V photometry of Epsilon Aurigae

Date	MJD	B	SD	N	ext	MJD	V	SD	N	ext	inst	observer
Apr 5/6 1982	$45064^{d}.821$	$3^{m}.506$	$\pm^{m}.005$	9	-	$45064^{d}.804$	$2^{m}.989$	$\pm^{m}.004$	9	-	R	MW
Jul 29/30	180.067	3.706	.009	9	-	180.044	3.126	.005	11	-	R	MW
Oct 2/3	245.010	4.013	.016	6	-	245.040	3.473	.008	6	-	M	SZ
Oct 5/6	248.001	4.069	.012	7	.002	248.001	3.518	.006	6	.001	M	SZ
Oct 22/23	265.096	4.096	.003	11	-	265.071	3.547	.002	11	-	A	MW
Oct 22/23	265.095	4.081	.016	7	-	265.094	3.601	.006	7	-	M	SZ
Oct 29/30	272.091	4.105	.004	13	.002	272.051	3.572	.004	15	-	R	MW
Nov 6/7	280.062	4.159	.003	11	-	280.042	3.634	.002	11	-	R	MW
Nov 7/8	281.062	4.167	.006	10	-	281.041	3.642	.002	10	-	R	MW
Nov 11/12	285.054	4.188	.003	12	-	285.032	3.646	.003	11	-	R	MW
Nov 21/22	294.992	4.231	.020	10	-	294.992	3.696	.017	7	-	M	SZ
Nov 27/28	301.007	4.282	.003	10	-	300.990	3.737	.002	10	-	R	MW
Jan 12/13 83	346.870	4.289	.007	9	.001	346.869	3.728	.005	9	.001	M	SZ
Feb 24/25	389.845	4.349	.009	10	.002	389.846	3.794	.006	9	.002	M	SZ
Feb 25/26	390.875	4.364	.004	10	-	390.901	3.780	.004	11	-	M	MW
Mar 12/13	405.865	4.355	.005	10	-	405.842	3.798	.002	12	-	A	MW
Mar 13/14	406.771	4.351	.006	10	-	406.744	3.800	.006	9	-	A	MW
Mar 13/14	406.745	4.348	.008	8	.001	406.796	3.807	.009	9	.001	M	SZ
Apr 17/18	441.819	4.263	.005	12	-	441.790	3.708	.005	12	-	M	MW
Aug 19/20	566.024	4.329	.017	7	-	566.003	3.660	.012	7	-	M	SZ
Aug 22/23	569.000	4.214	.010	8	-						M	SZ
Aug 26/27	573.050	4.258	.012	8	-						M	SZ
Aug 30/31	577.003	4.292	.012	9	-	576.972	3.779	.004	9	-	M	SZ
Sep 2/3	579.972	4.306	.008	6	-	579.972	3.731	.030	6	-	M	SZ
Sep 8/9	585.986	4.312	.022	7	-	585.987	3.792	.007	9	-	M	SZ
Sep 15/16	593.015	4.377	.005	16	-	593.019	3.795	.005	16	-	M	SZ
Sep 27/28	604.956	4.342	.004	12	-	604.957	3.766	.004	11	-	M	SZ
Sep 29/30	607.111	4.327	.010	9	.002	607.112	3.768	.006	9	.001	M	SZ

Table I (cont.)

Date	MJD	B	SD	N	ext	MJD	V	SD	N	ext	inst	observer
Oct 1/2 1983	$609^{d}.092$	$4^{m}.344$	$\pm^{m}.005$	19	$^{m}.002$	$609^{d}.091$	$3^{m}.767$	$\pm^{m}.004$	19	$^{m}.001$	M	SZ
Oct 1/2	609.144	4.305	.004	12	-	609.120	3.769	.003	13	-	R	MW
Oct 5/6	613.129	4.324	.009	6	.001	613.128	3.740	.009	6	.001	M	SZ
Oct 18/19	626.154	4.331	.004	11	.001	626.125	3.758	.004	11	.001	M	SZ
Oct 27/28	635.068	4.315	.006	16	.001	635.068	3.754	.006	16	,001	M	SZ
Oct 27/28	635.107	4.287	.004	11	-	635.084	3.751	.003	11	-	R	MW
Nov 8/9	45647.086	4.296	.005	13	.001	45647.045	3.713	.003	12	.001	A	MW
Nov 9/10	648.040	4.302	.006	10	.001	648.040	3.719	.004	10	.001	M	SZ
Nov 11/12	650.052	4.302	.006	13	.001	650.052	3.708	.007	13	.001	M	SZ
Dec 2/3	670.977	4.338	.006	30	.001	670.978	3.714	.006	30	.001	M	SZ
Dec 3/4	672.033	4.330	.024	12	.001	671.986	3.757	.003	14	.001	R	MW
Dec 4/5	672.937	4.324	.006	13	.001	672.936	3.765	.006	13	.001	M	SZ
Dec 4/5						672.966	3.718	.022	6	.002	R	MW
Dec 5/6	673.998	4.370	.005	20	.001	674.035	3.748	.005	20	.001	M	SZ
Dec 11/12	679.992	4.344	.003	10	.001	679.966	3.753	.003	10	.001	A	MW
Dec 12/13	681.051	4.334	.006	18	.001	681.052	3.747	.007	18	.001	M	SZ
Dec 14/15	682.921	4.312	.008	8	.001	682.908	3.747	.008	8	.001	M	SZ
Dec 14/15	682.976	4.352	.002	10	-	682.950	3.759	.002	10	-	A	MW
Dec 15/16	683.980	4.339	.003	10	-	683.947	3.748	.001	10	.001	A	MW
Dec 29/30	697.895	4.323	.007	19	.001	697.895	3.749	.005	19	.001	M	SZ
Dec 29/30	697.962	4.294	.002	13	.001	697.920	3.746	.002	19	.001	R	MW
Jan 11/12 84	710.861	4.251	.005	15	.001	710.861	3.691	.006	15	.001	M	SZ
Jan 11/12	710.922	4.216	.006	12	.001	710.864	3.703	.002	13	.002	R	MW
Jan 12/13	711.883	4.265	.005	12	.001	711.882	3.701	.006	12	.001	M	SZ
Jan 12/13						711.882	3.699	.002	12	.001	R	MW
Jan 16/17	715.942	4.256	.006	8	.001	715.946	3.711	.008	8	.001	M	SZ
Jan 23/24	722.894	4.271	.009	7	.001	722.895	3.719	.007	7	.001	M	SZ
Feb 18/19						748.767	3.664	.003	16	.001	R	MW
Feb 29/Mar 1	759.755	4.227	.010	6	.001	759.756	3.599	.009	6	.001	M	SZ
Feb 29/Mar 1	759.793	4.190	.005	7	.001	759.756	3.603	.002	14	.001	R	MW
Mar 1/2	760.806	4.184	.003	15	-	760.772	3.592	.004	14	.001	R	MW
Mar 14/15						773.760	3.473	.001	6	.001	R	MW
Mar 19/20	778.862	3.985	.002	11	-	778.781	3.407	.004	14	-	R	MW

Table I (cont.)

Date	MJD	B	SD	N	ext	MJD	V	SD	N	ext	inst	observer
Mar 19/20 84	778^d.827	3^m.981 ±	^{m}.009	16	-	778^d.827	3^m.393 ±	^{m}.006	16	-	M	SZ
Mar 24/25	783.790	3.955	.008	7	-	783.791	3.339	.007	8	-	M	SZ
Mar 27/28	786.842	3.885	.010	7	-						M	SZ
Apr 3/4	793.832	3.832	.012	8	-	793.833	3.248	.012	8	-	M	SZ
Apr 14/15						804.802	3.175	.014	6	-	M	SZ
Apr 15/16	805.793	3.751	.008	6	-	805.806	3.202	.010	6	-	M	SZ
Apr 25/26	815.797	3.703	.010	7	-	815.818	3.131	.009	6	-	M	SZ
Jul 31/Aug 1						913.075	3.036	.004	10	-	R	MW
Aug 14/15	45927.060	3.626	.009	8	-	45927.060	3.124	.011	8	-	M	SZ
Aug 19/20	932.019	3.583	.008	8	-	932.018	3.057	.006	8	-	M	SZ
Aug 22/23	935.025	3.603	.007	6	-						M	SZ
Aug 24/25						937.091	3.058	.006	11	-	A	MW
Sep 13/14	957.076	3.660	.004	8	-	957.022	3.062	.002	8	-	A	SZ
Sep 24/25	967.991	3.638	.006	8	-	967.988	3.062	.005	10	-	M	SZ
Sep 30/Oct 1	974.067	3.631	.006	6	-	974.067	3.058	.005	6	-	M	SZ
Oct 18/19	991.999	3.518	.010	7	-	991.999	2.985	.009	7	-	M	SZ
Oct 18/19						992.098	3.000	.004	14	.002	R	MW
Oct 19/20	993.084	3.506	.002	12	.003	993.093	2.996	.001	12	.002	R	MW
Oct 30/31	46004.082	3.542	.004	12	-	46004.049	3.007	.006	12	-	A	MW
Nov 4/5	009.033	3.523	.007	7	-						M	SZ
Nov 4/5	009.070	3.518	.004	12	-	009.090	3.010	.006	12	-	R	MW
Nov 7/8	012.067	3.519	.004	12	-	012.047	3.009	.001	11	-	R	MW
Nov 12/13						017.032	3.021	.011	14	-	R	MW
Nov 14/15						019.037	3.034	.007	12	.001	R	MW
Nov 30/Dec 1	034.997	3.548	.006	13	.001	034.973	3.026	.003	12	.002	R	MW
Dec 2/3	036.977	3.527	.003	11	.002	037.004	3.003	.003	10	.001	R	MW
Jan 15/16 85	080.919	3.654	.004	11	-	080.887	3.083	.005	11	-	A	MW
Jan 16/17	081.856	3.661	.002	11	.001	081.832	3.084	.002	11	.001	A	MW
Jan 28/29	093.985	3.560	.007	7	-	093.944	3.036	.006	8	-	M	SZ

Table II : B, V photometry of Epsilon Aurigae

Date	MJD	B	SD	N	ext	MJD	V	SD	N	ext	inst	observer
Sep 11/12 82	$45223^{d}.994$	$3^{m}.709$	$\pm^{m}.038$	3	$^{m}.002$	$45223^{d}.995$	$3^{m}.148$	$\pm^{m}.021$	3	$^{m}.002$	M	SZ
Sep 12/13	225.011	3.876	.010	5	-	225.011	3.377	.016	5	-	M	SZ
Sep 15/16	228.012	3.842	.030	3	-	228.011	3.364	.011	3	-	M	SZ
Sep 17/18	230.053	3.843	.030	4	.002	230.064	3.347	.009	2	.001	M	SZ
Sep 29/30	241.995	4.005	.008	5	-	241.997	3.443	.007	5	-	M	SZ
Oct 21/22	263.997	4.085	.040	2	-	263.998	3.570	.016	2	-	M	SZ
Oct 27/28						270.036	3.538	.020	2	.004	R	MW
Oct 27/28	270.055	4.221	.045	2	.001	270.054	3.625	.007	2	.001	M	SZ
Mar 23/24 83	416.803	4.288	-	1	.002	416.802	3.755	-	1	.001	M	SZ
Aug 22/23						568.999	3.667	.014	5	-	M	SZ
Aug 26/27						573.093	3.710	.009	2	-	M	SZ
Oct 13/14	621.084	4.324	.011	5	.001	621.083	3.761	.008	5	.001	M	SZ
Oct 24/25	632.049	4.300	.012	3	.001	632.048	3.704	.012	2	.001	M	SZ
Dec 3/4	671.898	4.324	.015	3	.001	671.898	3.743	.014	3	.001	M	SZ
Jan 2/3 1984	701.924	4.300	.010	5	.001	701.924	3.725	.009	5	.001	M	SZ
Jan 8/9	707.942	4.267	.005	5	.001	707.943	3.707	.009	5	.001	M	SZ
Jan 12/13	711.899	4.235	.006	4	.001						R	MW
Feb 7/8	737.825	4.303	-	1	.001	737.833	3.715	.010	3	.001	M	SZ
Feb 13/14	743.754	4.293	.009	5	.001	743.754	3.698	.009	5	.001	M	SZ
Mar 1/2	760.874	4.139	.021	2	.002	760.874	3.498	.008	5	.002	M	SZ
Mar 14/15	773.820	4.132	-	1	-	773.816	3.452	.010	4	-	M	SZ
Mar 20/21						779.776	3.408	.021	4	.001	R	MW
Mar 21/22						780.768	3.386	.007	4	.005	R	MW
Mar 21/22						780.774	3.426	.048	2	.001	M	SZ
Mar 27/28						786.847	3.308	.012	4	-	M	SZ
Apr 14/15	804.808	3.743	.008	5	-						M	SZ
Jul 11/12						893.035	2.907	.017	2	-	M	SZ
Jul 31/Aug 1	913.018	3.475	.038	5	-	913.018	2.866	.037	4	-	M	SZ

Table II (cont.)

Date	MJD	B	SD	N	ext	MJD	V	SD	N	ext	inst	observer
Aug 27/28 84	45940^{d}.044	3^{m}.571	±^{m}.012	5	-	45940^{d}.044	3^{m}.036	±^{m}.006	5	-	M	SZ
Sep 2/3	945.917	3.596	.040	3	-	945.918	3.004	.030	2	-	M	SZ
Oct 1/2	975.014	3.671	.016	2	.003	975.014	3.140	.006	2	.002	M	SZ
Oct 20/21	993.943	3.519	.008	2	-	993.946	2.979	.011	2	-	M	SZ
Nov 4/5						46009.033	2.992	.006	5	-	M	SZ
Nov 14/15	46019.053	3.519	.005	3	-						R	MW
Aug 3/4	916.068	3.530	.038	5	-	916.062	3.037	.018	5	-	M	SZ
Aug 9/10	922.020	3.584	.007	4	-	922.020	3.113	.016	4	-	M	SZ
Aug 13/14	926.070	3.569	.006	4	-	926.071	3.045	.016	4	-	M	SZ
Aug 22/23						935.025	3.055	.013	5	-	M	SZ
Aug 23/24	936.022	3.622	.012	5	-	936.023	3.053	.011	5	-	M	SZ

Table III : U photometry of Epsilon Aurigae

Date	MJD	U	SD	N	inst	observer
Apr 5/6 1982	45064^{d}.837	3^{m}.890	±^{m}.005	8	R	MW
Jul 29/30	180.078	4.128	.014	3	R	MW
Nov 6/7	280.082	4.616	.003	11	R	MW
Nov 7/8	281.082	4.629	.003	10	R	MW

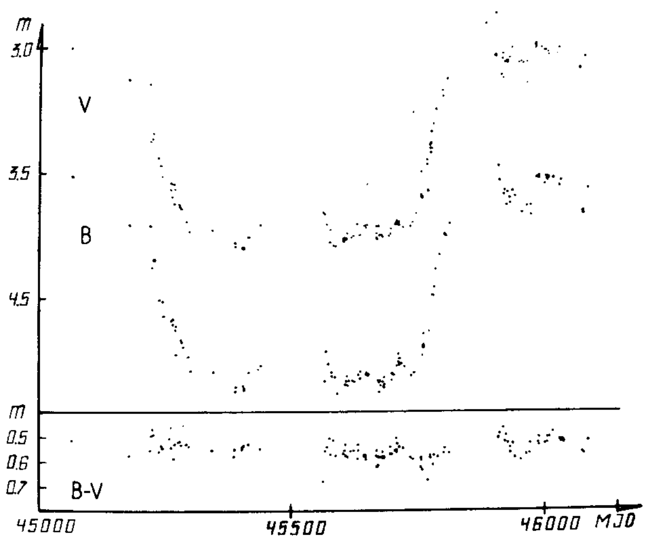

Figure 1 : B and V light curve of Epsilon Aurigae and B-V changes

Taking into account ingress and egress observations only, the classic tracing-paper method yields : minimum MJD hel. = $45510^d \pm 5^d$, fitting of Gaussian plus quadratic term gives : minimum MJD hel = $45512^d.2 \pm 0^d.1$ and fitting of straight lines (Gyldenkerne 1970) gives MJD hel=$45511^d.0$ as division value of the second-third contact segment in half.

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