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PHOTOMETRY AND PERIOD BEHAVIOR OF SELECT W UMA TYPE STARS

M.A. Hobart[1], J.H. Peña[2], R. Peniche[2],
E. Rodríguez[3], R. Garrido[3], M. Ríos-Berúmen[2,4],
M. Ríos-Herrera[2,4], and O. López-Cruz[5]

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RESUMEN

Se reportan observaciones fotométricas recientes de los sistemas tipo W UMa: LZ Her, ER Ori, YY Eri y RZ Tau. De los tiempos de mínimo obtenidos de las actuales observaciones junto con los recopilados en la literatura se determinan efemérides lineales y cuadráticas para los tres últimos sistemas. De los términos cuadráticos en las efemérides se determinan los valores de cambio de los períodos.

ABSTRACT

Recent photoelectric data on the W UMa systems LZ Her, ER Ori, YY Eri and RZ Tau are reported. Linear and quadratic ephemerides are determined from the times of minima obtained in the present paper and those compiled from the literature; the rates of change in the periods are calculated from the quadratic terms in the ephemerides.

Key words: **BINARIES - ECLIPSING — STARS - VARIABLES - OTHER**

1. INTRODUCTION

The W Ursae Majoris systems are eclipsing variable stars whose light curves have maxima which are strongly curved and minima which are nearly equal in depth. These systems are also spectroscopic double stars and the spectra usually contain absorption lines from both components. The eclipsing variables are excellent laboratories for studying a wide variety of processes since they offer probes of tidal dissipation, mass transfer or loss, angular momentum transfer or loss, magnetic activity and stellar evolution and their usefulness extends far beyond their textbook role in the determination of stellar masses and radii.

Before 1950 most light curves were photographically or visually observed, and hence the orbital elements were very unreliable. However, current accurate photometry enables high precision measurements that can reveal orbital period changes on the order of one part in 10^5–10^6. This is important because deviations from an assumed ephemeris can build up over many orbits. Attempts to determine the long term variation of the period are being made for those stars for which a sufficient number of observations have been accumulated over the past half century so that the behavior of the period can be studied over that length of time. For other stars, multicolor photometry is presented. In 1986, an observational project on W UMa stars was started involving the Observatorio Astronómico Nacional at San Pedro Mártir, B.C. and the Observatorio José Arbol y Bonilla at Zacatecas, Zac. (hereinafter OAN-SPM and OJAB, respectively). The purpose of this research was to acquire photoelectric data from these kinds of systems in order to obtain accurate times of minima to increase the time span of the minima reported and to improve the knowledge of the period behavior of the stars under consideration. In the present paper, new photoelectric observations of the W UMa systems LZ Her, ER Ori, YY Eri and RZ Tau are presented and an analysis of their periods is attempted. Tables 1 and 2 list the coordinates and magnitudes of the observed stars, as well as a brief description of the instrumentation employed.

LZ Her was reported to be an SX Phe star (Frolov & Irkaev 1984), and as such, it was observed as part of a systematic study of this kind of star. The true

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[1] Universidad Veracruzana.

[2] Instituto de Astronomía, Universidad, Nacional Autónoma de México.

[3] Instituto de Astrofísica de Andalucía, Spain.

[4] Universidad Autónoma de Zacatecas, México.

[5] University of Toronto and Instituto Nacional de Astrofísica, Optica y Electrónica, México.

TABLE 1

COORDINATES AND MAGNITUDES OF THE OBSERVED STARS

Star	Id.	R.A. (1950)	Dec.	Mag	Type
LZ Her	....	$17^h47^m35^s$	+29° 19′	14.4	W UMa
C1	....	17 47 41	+29 17	13.6	ref.
C2	....	17 43 33	+29 21	12.9	ref.
ER Ori	BD −08° 1050	5 08 51	−8 37	9.4	W UMa
C1	BD −08° 1051	5 08 56	−8 41	8.9	ref.
YY Eri	BD −10° 858	4 09 47	−10 35.7	8.4	W UMa
C1	BD −10° 860	4 10 10	−10 41.6	8.2	ref.
C2	BD −10° 872	4 12 25	−10 41.6	8.4	ref.
RZ Tau		4 33 43	+18 39.2	10.4	W UMa
C1	BD +18° 656	4 32 54	+18 42.1	8.7	ref.
C2	BD +18° 657	4 33 00	+18 26.1	9.5	ref.

TABLE 2

SUMMARY OF OBSERVATIONS

Star	Observing Season	Telescope	Photometry	Accuracy of Minima (d)
LZ Her	1986	OAN 1.5-m	*uvby*	....
ER Ori	1986	OAN 0.84-cm	*V*	0.0066
YY Eri	1986	OAN 0.84-cm	*V*	0.0038
	1987	OJAB 0.50-cm	*UBV*	0.0067
	1988	OJAB 0.50-cm	*V*	0.0050
RZ Tau	1989	OAN 0.84-cm	*V*	0.0077
	1989	OAN 1.5-m	*uvby*	....

W UMa nature of this system was established from the new observations (Garrido et al. 1987) and the period was determined to be 0.334 d. ER Ori is one of several W UMa stars that has been extensively observed. The first data were reported by Florja (1931). Kwee (1958) carried out a study of the variations in the period of this system and with a time span in the observations of twenty five years, he determined that the period varied rapidly around HJD 2443500. With this finding in mind, new observations of this system were undertaken.

Another very well-studied W UMa system is YY Eri which was discovered by Hoffmeister (1932) and has been regularly observed since then. RZ Tau is a system with few observations whose status as a W UMa star was established by Oosterhoff (1930) who determined its period. This star was considered for the acquisition of new data to test the constancy of its period.

2. OBSERVATIONS

The observations were done at two different observing sites and with three different telescopes to which different photometers were attached. At the OAN-SPM the *uvby*-β observation were carried out at the 1.5-m telescope with a multi-photometer that allows the simultaneous acquisition of data in each filter. Observations in the *V* filter of Johnson's system were done at the 0.84-m telescope to which a cooled photoelectric photometer was attached. At the OJAB the observations were done with a 0.50-m telescope and an uncooled photometer.

TABLE 3

PHOTOELECTRIC OBSERVATIONS OF LZ HER

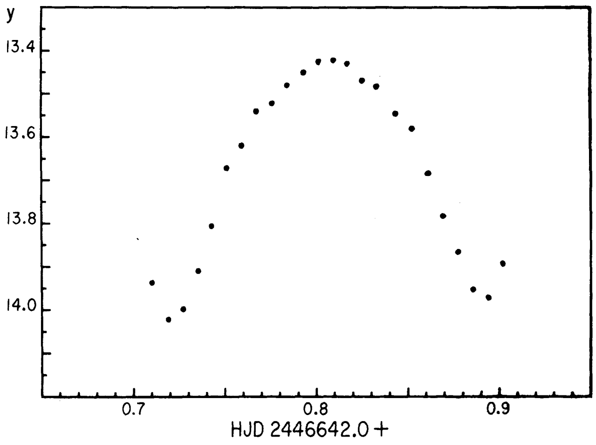
HJD 2446642.0+	V	b–y	m_1	c_1
0.7030	13.831	0.469	0.246	0.308
0.7098	13.937	0.476	0.237	0.306
0.7187	14.021	0.480	0.230	0.304
0.7268	13.998	0.495	0.238	0.259
0.7350	13.911	0.469	0.274	0.276
0.7427	13.808	0.480	0.232	0.337
0.7508	13.673	0.494	0.190	0.331
0.7590	13.620	0.473	0.222	0.288
0.7671	13.542	0.468	0.240	0.289
0.7757	13.523	0.464	0.234	0.284
0.7842	13.480	0.472	0.209	0.308
0.7928	13.452	0.459	0.238	0.288
0.8011	13.425	0.461	0.259	0.222
0.8091	13.421	0.466	0.251	0.226
0.8169	13.430	0.482	0.222	0.278
0.8248	13.470	0.443	0.303	0.233
0.8328	13.483	0.476	0.244	0.285
0.8431	13.547	0.478	0.227	0.292
0.8519	13.580	0.497	0.212	0.291
0.8603	13.685	0.481	0.242	0.273
0.8687	13.783	0.478	0.253	0.235
0.8771	13.867	0.494	0.238	0.247
0.8854	13.953	0.486	0.273	0.300
0.8936	13.970	0.482	0.317	0.240
0.9020	13.893	0.503	0.208	0.267

2.1. LZ Herculis

The observations of this system for the night of July 30–31, 1986 were carried out at the OAN-SPM with the 1.5-m telescope. Since the primary standards were too bright for the instrumentation employed, suitable secondary *uvby*-β standard stars were selected from a list compiled by Olsen (1983). A reduction program package (Nabaphot, by Arellano Ferro, & Parrao 1988) was applied to reduce the data. From the data of the standard stars the typical final observational uncertainties for a single observation were estimated. They were 0.021, 0.008, 0.008 and 0.010 in V, b–y, m_1 and c_1 respectively. The method used in the data acquisition and reduction has been previously reported (Peniche et al. 1990). The final results are presented in Table 3 in which columns 2 to 5 contain the V magnitude, b–y, m_1 and c_1 respectively. Column 1 ists the time of observation in HJD. Figure 1 shows the corresponding light curve.

2.2. ER Orionis

The observations of ER Ori were undertaken at the OAN-SPM with the 0.84-m telescope. To ncrease the number of data points, the comparison stars were not the stars previously utilized by other observers. Instead, two stars, C1 and C2, which are much closer to ER Ori were considered as comparison and were in the field of the photometer eyepiece, within 4 arcmin of the problem star (see Figure 2). ER Ori is a double visual with a very faint companion. No corrections for differential extinction were necessary. The sequence of the observations was V, C1, V, C2, Sky where V stands for ER Ori, C1 is the comparison star and C2 is the check star. Each run consisted of a 60 s integration of the reference stars and sky and three 60 s integrations of the variable. The reduction of the data was made differentially with the standard



Fi.g 1. Light curve of LZ Her in the V magnitude of the Stromgren photometric system.

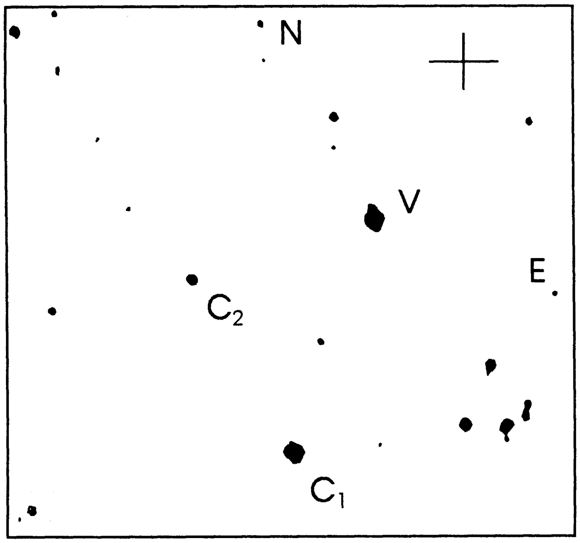


Fig. 2. ID chart for ER Ori and the constant and check stars. The bars are 5 s and 1′ in right ascension and declination.

TABLE 4

PHOTOMETRY OF ER ORI

HJD 2446770+	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV
5.779	0.197	5.848	-0.080	5.945	-0.192	7.826	-0.240	7.893	0.223
5.782	0.232	5.851	-0.114	5.948	-0.107	7.829	-0.240	7.895	0.235
5.786	0.293	5.852	-0.116	5.950	-0.130	7.829	-0.235	7.897	0.240
5.787	0.306	5.855	-0.098	5.953	-0.080	7.831	-0.223	7.899	0.268
5.789	0.349	5.856	-0.130	5.954	-0.080	7.834	-0.221	7.900	0.293
5.791	0.360	5.858	-0.147	7.758	-0.184	7.835	-0.215	7.902	0.318
5.792	0.360	5.860	-0.152	7.758	-0.190	7.836	-0.162	7.904	0.330
5.792	0.364	5.863	-0.152	7.762	-0.201	7.838	-0.207	7.905	0.386
5.793	0.380	5.864	-0.161	7.763	-0.196	7.840	-0.182	7.906	0.397
5.794	0.384	5.868	-0.174	7.764	-0.196	7.844	-0.184	7.906	0.408
5.794	0.375	5.869	-0.183	7.767	-0.196	7.845	-0.184	7.908	0.411
5.795	0.384	5.872	-0.183	7.768	-0.201	7.847	-0.170	7.909	0.422
5.797	0.387	5.873	-0.183	7.769	-0.201	7.849	-0.162	7.909	0.427
5.798	0.391	5.875	-0.188	7.774	-0.212	7.852	-0.154	7.911	0.430
5.799	0.382	5.876	-0.192	7.774	-0.218	7.853	-0.148	7.913	0.422
5.800	0.393	5.888	-0.237	7.776	-0.212	7.854	-0.142	7.913	0.419
5.803	0.378	5.889	-0.241	7.779	-0.229	7.855	-0.137	7.914	0.419
5.804	0.366	5.892	-0.241	7.779	-0.232	7.858	-0.131	7.916	0.413
5.807	0.346	5.893	-0.246	7.781	-0.240	7.859	-0.126	7.917	0.411
5.812	0.284	5.897	-0.241	7.783	-0.268	7.861	-0.131	7.918	0.411
5.812	0.266	5.899	-0.237	7.784	-0.251	7.862	-0.123	7.919	0.408
5.815	0.232	5.901	-0.246	7.786	-0.254	7.865	-0.084	7.920	0.438
5.816	0.210	5.903	-0.255	7.786	-0.263	7.866	-0.070	7.922	0.436
5.818	0.199	5.906	-0.250	7.789	-0.268	7.868	-0.059	7.922	0.413
5.820	0.195	5.907	-0.228	7.791	-0.263	7.868	-0.045	7.923	0.408
5.822	0.150	5.910	-0.241	7.791	-0.251	7.873	-0.039	7.925	0.374
5.824	0.131	5.911	-0.237	7.794	-0.279	7.873	-0.031	7.926	0.357
5.827	0.076	5.913	-0.241	7.796	-0.285	7.874	-0.025	7.928	0.316
5.828	0.072	5.915	-0.237	7.797	-0.276	7.875	-0.011	7.929	0.307
5.831	0.045	5.918	-0.246	7.799	-0.279	7.878	0.022	7.931	0.263
5.832	0.039	5.919	-0.246	7.801	-0.276	7.879	0.045	7.932	0.246
5.834	0.009	5.928	-0.210	7.812	-0.268	7.880	0.050	7.934	0.229
5.835	0.004	5.929	-0.201	7.813	-0.265	7.881	0.078	7.934	0.223
5.838	-0.034	5.933	-0.188	7.813	-0.260	7.885	0.112	7.936	0.196
5.840	-0.040	5.934	-0.188	7.817	-0.254	7.887	0.140	7.937	0.179
5.842	-0.056	5.939	-0.152	7.817	-0.246	7.888	0.145	7.940	0.156
5.843	-0.038	5.940	-0.152	7.824	-0.249	7.892	0.198	7.940	0.112
5.847	-0.058	5.943	-0.152	7.825	-0.251	7.893	0.265	...	...

method reported in Maupomé et al. (1991). The data presented, in Table 4 and in Figure 3 were not transformed to the *UBV* system. The accuracy of the data points was determined from the standard deviation of the C1-C2 points also shown in Figure 3 and is equal to 0.022 mag; the time interval between successive points is 0.005 d while the accuracy in time for each point is 0.0007 d.

2.3. *YY Eridani*

The observations of this star took place at the OAN-SPM and OJAB observatories. The method of acquisition of data and its reduction is the same as in Hobart, Peña, & Peniche (1991). The observations are given in Table 5. None of these data has been transformed into the standard system. For the OAN-SPM data the accuracy in the data points i 0.011 mag, while for the OJAB data the accurac is 0.017 mag. The light curves in phase for thes observations are shown in Figures 4a and 4b.

2.4. *RZ Tauri*

The present observations of this star were unde taken at the OAN-SPM using two different piec of equipment as shown in Table 2. For the dat in Johnson's system the standard method of acqu sition and reduction outlined in Maupomé et a (1991) was used, whereas for the data in the *uvby*-system the same instrumentation as for LZ Her w employed. The seasonal transformation coefficien and errors of the *uvby* photometry have been r ported elsewhere (Peña et al. 1994). The transfo

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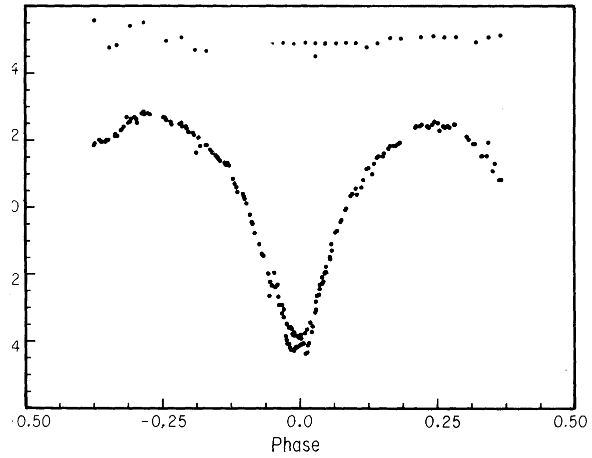


. 3. Light curves in phase of ER Ori in the V fil- for the observed nights. The period used was P = 233994 d, found in the present paper. The upper nts correspond to C1-C2.

ition errors of the standard stars of the present re- ctions when transforming the instrumental pho- netry onto the standard system of Olsen (1983) e 0.012, 0.007, 0.011, 0.011 and 0.009 for V,), m_1, c_1 and β respectively. The photoelectric by data are given in Table 6 while the observa- ns in the Johnson's V filter, which have not been transformed into the standard system, are given in Table 7. The light curve for the y observations is shown in Figure 5a and the light curves in phase of the observations in the V filter, with a precision of 0.017 mag, are shown in Figure 5b. The times of minimum light were determined as above.

3. ANALYSIS

The procedure employed to analyze the period behavior of ER Ori, YY Eri and RZ Tau consisted of calculating the O–C residuals obtained by means of a linear ephemeris for the complete sets of minima compiled from the literature plus those found in the present reported observations. These ephemerides were determined by the method described in Hobart et al. (1989). If the residuals, when plotted, showed evidence of change in the period of the star considered, a quadratic fit was derived to obtain the corresponding ephemeris.

3.1. ER Orionis

The determination of the times of minimum light were obtained from the minima of the second order polynomial mean squares fit obtained from the light points in the vicinity of the apparent minimum values of the light curves. The precision in the times of minimum were estimated by solving for Δt in the expression obtained from the difference

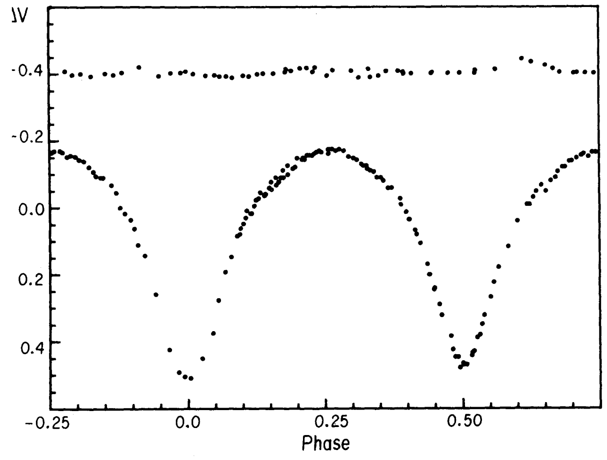
TABLE 5

V OBSERVATIONS OF YY ORI

HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV
6774.721	-0.018	6778.733	0.036	6799.729	-0.164	7457.831	-0.254
4.727	0.098	8.738	0.080	9.735	-0.171	7.839	-0.264
4.734	0.264	8.740	0.107	9.751	-0.161	7.849	-0.274
4.740	0.331	8.774	0.170	9.758	-0.147	7.857	-0.254
4.744	0.344	8.746	0.201	9.783	-0.110	7.861	-0.244
4.747	0.349	8.748	0.241	6818.595	-0.077	7.866	-0.214
4.754	0.290	8.751	0.290	8.596	-0.077	7.875	-0.154
4.760	0.214	8.759	0.425	8.599	-0.037	7458.765	-0.024
4.764	0.116	8.760	0.447	8.601	-0.041	8.769	-0.084
4.768	0.031	8.763	0.478	8.604	0.004	8.774	-0.114
4.771	-0.013	8.765	0.469	8.605	0.093	8.776	-0.124
4.777	-0.098	8.770	0.442	8.608	0.129	8.780	-0.154
4.780	-0.152	8.771	0.429	8.610	0.218	8.784	-0.184
4.786	-0.183	8.774	0.380	8.614	0.231	8.788	-0.194
4.789	-0.206	8.776	0.349	8.616	0.249	8.793	-0.204
4.795	-0.237	8.781	0.268	8.620	0.303	8.796	-0.194
4.798	-0.250	8.783	0.223	8.625	0.366	8.802	-0.214
4.802	-0.273	8.786	0.179	8.628	0.392	8.806	-0.214
4.805	-0.286	8.792	0.116	8.630	0.392	8.809	-0.224
4.810	-0.308	8.797	0.040	8.631	0.352	8.813	-0.224
4.813	-0.308	8.802	-0.009	8.637	0.406	8.819	-0.224
4.819	-0.317	8.804	-0.009	8.642	0.245	8.824	-0.204
4.828	-0.335	8.806	-0.031	8.644	0.214	8.831	-0.204
4.848	-0.290	8.808	-0.049	8.646	0.187	8.834	-0.204

TABLE 5 (CONTINUED)

HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV
4.851	-0.277	8.811	-0.067	8.651	0.102	8.837	-0.184
4.857	-0.250	8.813	-0.049	8.653	0.066	8.841	-0.154
4.871	-0.170	8.816	-0.080	8.655	0.062	8.845	-0.114
4.875	-0.125	8.819	-0.089	8.657	0.035	8.850	-0.094
4.879	-0.094	8.820	-0.107	8.661	-0.041	8.855	-0.064
4.887	0.040	8.823	-0.121	8.663	-0.010	8.858	-0.024
4.890	0.085	8.825	-0.121	8.666	-0.081	8.866	0.066
4.894	0.161	8.828	-0.139	8.668	-0.104	8.870	0.146
4.900	0.223	8.829	-0.139	8.674	-0.135	8.876	0.296
4.904	0.286	8.832	-0.147	8.677	-0.162	8.881	0.416
4.907	0.304	8.834	-0.156	8.680	-0.135	8.887	0.456
4.909	0.308	8.836	-0.161	8.684	-0.171	8.891	0.486
4.912	0.273	8.838	-0.152	8.688	-0.206	8.896	0.496
4.915	0.228	8.841	-0.165	8.690	-0.193	8.901	0.476
4.919	0.161	8.843	-0.165	8.692	-0.247	8.904	0.426
6778.633	0.085	8.846	-0.165	8.695	-0.273	8.908	0.276
8.634	0.080	8.848	-0.170	8.699	-0.287	8.912	0.186
8.636	0.049	8.851	-0.170	8.702	-0.273	8.917	0.126
8.638	0.031	8.853	-0.165	8.705	-0.273	8.920	0.066
8.641	0.018	8.855	-0.152	8.708	-0.269	8.924	0.006
8.641	0.018	8.857	-0.156	8.730	-0.220	8.928	-0.014
8.643	-0.004	8.860	-0.152	8.733	-0.198	8.933	-0.104
8.644	-0.022	8.862	-0.143	8.737	-0.189	7459.769	-0.214
8.646	-0.027	8.865	-0.139	8.740	-0.198	9.775	-0.224
8.649	-0.036	8.868	-0.121	8.742	-0.193	9.778	-0.234
8.649	-0.040	8.871	-0.107	8.745	-0.153	9.782	-0.239
8.652	-0.058	8.872	-0.094	8.748	-0.139	9.784	-0.244
8.653	-0.054	8.875	-0.089	8.750	-0.122	9.789	-0.244
8.656	-0.067	8.876	-0.089	8.753	-0.126	9.792	-0.234
8.657	-0.076	8.881	-0.067	7457.763	0.076	9.797	-0.224
8.659	-0.089	8.884	-0.045	7.769	0.206	9.804	-0.184
8.660	-0.089	8.886	0.000	7.779	0.336	9.809	-0.174
8.663	-0.098	8.889	0.018	7.785	0.336	9.816	-0.134
8.666	-0.116	8.892	0.036	7.794	0.276	9.822	-0.054
8.667	-0.121	8.894	0.063	7.809	0.126	9.827	0.016
8.671	-0.143	8.896	0.112	7.815	0.026	9.835	0.156
8.672	-0.143	6788.685	-0.242	7.819	-0.024	9.839	0.246
8.674	-0.156	8.693	-0.164	7.830	-0.024	9.843	0.336
8.675	-0.156	8.734	0.261	7.835	-0.124	9.847	0.416
8.678	-0.161	8.741	0.629	7.840	-0.164	9.851	0.456
8.680	-0.165	8.771	-0.214	7.845	-0.174	9.858	0.456
8.681	-0.170	6798.613	-0.100	7.850	-0.184	9.862	0.426
8.682	-0.165	8.627	-0.105	7.853	-0.199	9.866	0.386
8.687	-0.161	8.652	-0.047	7.862	-0.204	9.869	0.316
8.688	-0.174	8.674	0.104	7.866	-0.204	9.873	0.256
8.690	-0.170	8.682	0.196	7.763	0.426	9.876	0.206
8.693	-0.174	8.710	0.308	7.766	0.436	9.881	0.106
8.695	-0.170	8.718	0.145	7.769	0.426	9.885	0.036
8.698	-0.152	8.730	0.012	7.772	0.376	9.888	-0.004
8.701	-0.147	8.737	-0.024	7.778	0.326	9.891	-0.044
8.703	-0 143	8.751	-0.089	7.780	0.236	9.896	-0.084
8.707	-0.125	8.760	-0.105	7.786	0.126	9.899	-0.114
8.708	-0.125	8.772	-0.128	7.789	0.066	9.902	-0.134
8.711	-0.112	6799.633	-0.023	7.795	0.006	9.905	-0.144
8.713	-0.107	9.640	0.057	7.798	-0.024	9.909	-0.154
8.717	-0.089	9.657	0.389	7.804	-0.094	9.913	-0.154
8.718	-0.080	9.663	0.379	7.809	-0.144	9.916	-0.154
8.721	-0.058	9.676	0.205	7.812	-0.184	9.919	-0.149
8.723	-0.058	9.681	0.118	7.817	-0.214	9.924	-0.144
8.728	-0.027	9.709	-0.104	7.822	-0.234	...	...
8.731	0.013	9.715	-0.120	7.827	-0.244	...	...



ig. 4a. Light curves in phase for the observed nights at AN-SPM in the *V* filter of YY Eri. The period used was = 0.3214959 d, found in the present paper. The points the upper part correspond to C1-C2.

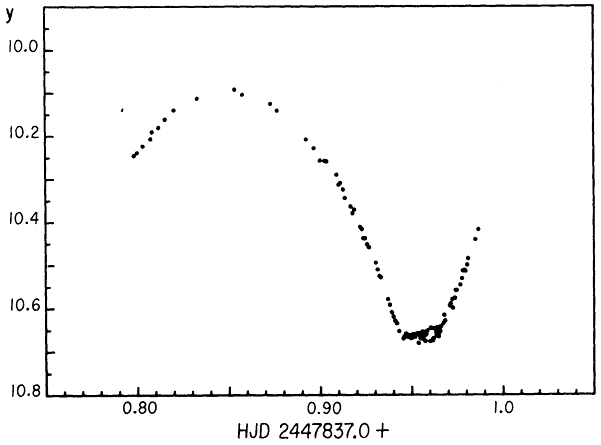
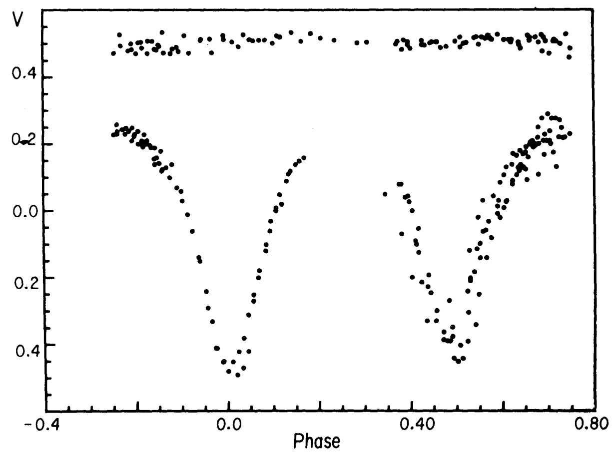


Fig. 5a. Light curve in the *V* magnitude of the Stromgren photometric system of RZ Tau.



ig. 4b. Light curves in phase for the observed nights at JAB in the *V* filter of YY Eri. The period used was P = .3214959 d, found in the present paper. The points in he upper part correspond to C1-C2.

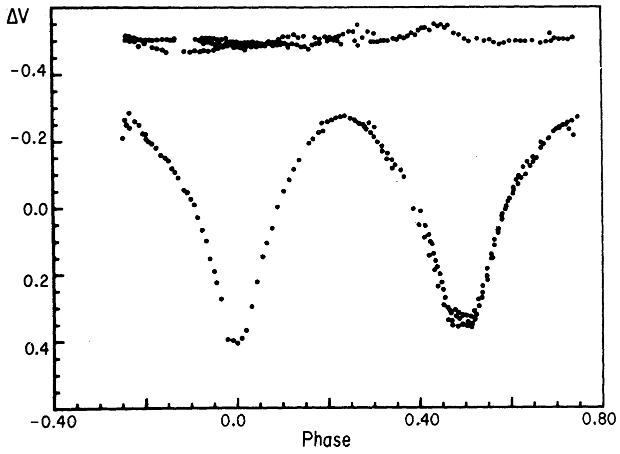


Fig. 5b. Light curves in phase of RZ Tau in the *V* filter for the observed nights. The period used was P = 0.4156731 d found in the present paper. The points in the upper part correspond to C1-C2.

f the quadratic polynomial evaluated in t_{min} + Δt and t_{min}. This procedure was used in the orresponding analysis of the other stars and the stimated precisions are shown in the sixth column f Table 2. The photoelectric data obtained from he observations of ER Ori are summarized in able 4 while the corresponding light curves in hase are plotted in Figure 3.

For this system, the linear ephemeris obtained rom the total of the gathered times of minima was:

$$\mathrm{HJD}_{min} = 2436508.7851\ (\pm\ 0.0035)\ +$$
$$+\ 0.4233990\ (\pm\ 1.02 \times 10^{-7})\ E.$$

The residuals calculated from this ephemeris are shown in Figure 6a. It is apparent that the period indeed had two changes, one at approximately HJD 2434366 and the other at HJD 2436215. As a following step, the whole set of minima was divided in two groups. The first group contained the minima between HJD 2426327.338 and HJD 2434366.564, while the second group contained the minima between HJD 2436215.5793 and HJD 2446777.9180. The analysis of the times of minima between HJD 2434366.5640 and HJD 2436215.5793 was not attempted since only four times of minima were available. The linear

TABLE 6

uvby PHOTOMETRY OF RZ TAU
(HJD 2447837.0+)

HJD	V	b–y	m_1	c_1	HJD	V	b–y	m_1	c_1
0.7984	10.245	0.417	0.099	0.582	0.9518	10.666	0.410	0.112	0.600
0.8001	10.238	0.411	0.104	0.574	0.9523	10.660	0.408	0.107	0.617
0.8032	10.223	0.426	0.082	0.591	0.9533	10.658	0.419	0.099	0.600
0.8075	10.206	0.413	0.099	0.587	0.9537	10.681	0.391	0.128	0.593
0.8083	10.190	0.417	0.098	0.575	0.9547	10.664	0.407	0.119	0.576
0.8119	10.180	0.411	0.094	0.595	0.9549	10.669	0.406	0.126	0.570
0.8154	10.161	0.397	0.125	0.574	0.9550	10.659	0.424	0.091	0.605
0.8203	10.140	0.408	0.115	0.562	0.9551	10.670	0.389	0.141	0.573
0.8331	10.113	0.404	0.117	0.568	0.9554	10.670	0.379	0.155	0.573
0.8535	10.092	0.413	0.105	0.579	0.9556	10.669	0.410	0.100	0.583
0.8577	10.104	0.405	0.114	0.571	0.9557	10.654	0.428	0.080	0.632
0.8731	10.125	0.413	0.108	0.550	0.9561	10.667	0.408	0.106	0.600
0.8767	10.141	0.401	0.125	0.563	0.9562	10.668	0.413	0.109	0.597
0.8924	10.208	0.413	0.109	0.572	0.9563	10.656	0.410	0.120	0.593
0.8966	10.228	0.404	0.136	0.531	0.9572	10.655	0.407	0.113	0.611
0.9001	10.257	0.406	0.131	0.534	0.9573	10.659	0.428	0.076	0.671
0.9027	10.258	0.411	0.115	0.569	0.9574	10.676	0.414	0.082	0.646
0.9038	10.259	0.422	0.103	0.561	0.9579	10.661	0.413	0.109	0.584
0.9092	10.290	0.415	0.120	0.557	0.9584	10.652	0.424	0.103	0.588
0.9103	10.313	0.423	0.091	0.612	0.9602	10.677	0.412	0.092	0.631
0.9111	10.309	0.420	0.095	0.600	0.9605	10.646	0.424	0.120	0.561
0.9127	10.324	0.417	0.101	0.606	0.9615	10.675	0.398	0.130	0.583
0.9136	10.344	0.412	0.114	0.568	0.9618	10.670	0.420	0.094	0.578
0.9167	10.364	0.407	0.121	0.572	0.9623	10.647	0.434	0.094	0.588
0.9177	10.380	0.392	0.143	0.569	0.9630	10.648	0.431	0.092	0.617
0.9187	10.371	0.417	0.105	0.606	0.9634	10.656	0.429	0.092	0.560
0.9218	10.411	0.420	0.101	0.598	0.9637	10.663	0.418	0.108	0.566
0.9228	10.416	0.422	0.089	0.610	0.9641	10.644	0.445	0.058	0.598
0.9237	10.437	0.410	0.110	0.592	0.9647	10.665	0.412	0.099	0.606
0.9247	10.438	0.425	0.101	0.586	0.9651	10.655	0.413	0.110	0.599
0.9257	10.452	0.420	0.095	0.578	0.9656	10.653	0.418	0.103	0.598
0.9267	10.459	0.420	0.099	0.603	0.9660	10.642	0.413	0.108	0.609
0.9305	10.494	0.423	0.106	0.591	0.9673	10.635	0.419	0.101	0.586
0.9314	10.510	0.433	0.078	0.598	0.9678	10.616	0.428	0.102	0.573
0.9323	10.525	0.423	0.097	0.589	0.9683	10.629	0.431	0.082	0.598
0.9332	10.529	0.423	0.099	0.608	0.9708	10.594	0.422	0.106	0.574
0.9369	10.579	0.432	0.092	0.593	0.9713	10.589	0.417	0.117	0.552
0.9380	10.592	0.423	0.106	0.584	0.9721	10.579	0.418	0.106	0.581
0.9391	10.609	0.414	0.107	0.586	0.9726	10.599	0.411	0.110	0.575
0.9399	10.619	0.403	0.127	0.574	0.9736	10.576	0.420	0.101	0.567
0.9409	10.629	0.405	0.120	0.600	0.9741	10.558	0.434	0.096	0.576
0.9419	10.635	0.416	0.111	0.586	0.9746	10.559	0.429	0.090	0.585
0.9430	10.653	0.404	0.117	0.604	0.9767	10.546	0.419	0.090	0.610
0.9454	10.670	0.394	0.129	0.583	0.9776	10.531	0.417	0.100	0.588
0.9459	10.666	0.408	0.120	0.560	0.9780	10.513	0.429	0.097	0.553
0.9468	10.659	0.409	0.114	0.611	0.9790	10.511	0.420	0.105	0.550
0.9478	10.666	0.410	0.109	0.588	0.9795	10.513	0.416	0.105	0.603
0.9486	10.662	0.409	0.112	0.606	0.9805	10.499	0.409	0.122	0.558
0.9495	10.669	0.403	0.119	0.600	0.9809	10.484	0.434	0.077	0.588
0.9499	10.669	0.403	0.124	0.570	0.9851	10.440	0.416	0.106	0.566
0.9504	10.661	0.417	0.117	0.544	0.9867	10.417	0.422	0.101	0.570
0.9514	10.663	0.400	0.120	0.586	...	...	...	...	...

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TABLE 7

V OBSERVATIONS OF RZ TAU
(HJD 2447800+)

HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV
27.885	-0.260	28.028	-0.041	28.905	-0.247	34.866	0.147	35.862	0.293
7.888	-0.252	8.031	-0.082	8.908	-0.247	4.870	0.106	5.866	0.338
7.892	-0.249	8.784	0.103	8.911	-0.234	4.875	0.061	5.870	0.354
7.895	-0.235	8.787	0.138	8.915	-0.216	4.880	-0.003	5.875	0.357
7.899	-0.224	8.790	0.179	8.921	-0.211	4.886	-0.050	5.879	0.351
7.902	-0.212	8.794	0.225	8.924	-0.250	4.891	-0.084	5.884	0.344
7.905	-0.197	8.797	0.271	8.927	-0.240	4.895	-0.115	5.888	0.350
7.909	-0.185	8.801	0.309	8.939	-0.223	4.900	-0.143	5.892	0.322
7.914	-0.163	8.803	0.341	8.942	-0.207	4.909	-0.193	5.897	0.272
7.918	-0.144	8.807	0.327	8.944	-0.200	4.913	-0.207	5.902	0.218
7.921	-0.129	8.810	0.334	8.947	-0.193	4.918	-0.226	5.907	0.152
7.926	-0.112	8.833	0.353	8.951	-0.180	4.922	-0.230	5.912	0.076
7.929	-0.092	8.817	0.356	8.955	-0.158	35.738	-0.255	5.916	0.020
7.944	0.010	8.821	0.359	8.959	-0.150	5.743	-0.253	5.921	-0.018
7.948	0.055	8.824	0.337	8.962	-0.142	5.748	-0.252	5.926	-0.059
7.951	0.082	8.828	0.297	8.965	-0.119	5.752	-0.254	5.931	-0.095
7.954	0.109	8.831	0.256	8.968	-0.107	5.757	-0.258	5.935	-0.121
7.957	0.160	8.835	0.206	8.971	-0.090	5.761	-0.263	5.939	-0.137
7.961	0.200	8.839	0.154	8.976	-0.054	5.765	-0.269	5.944	-0.151
7.964	0.247	8.842	0.114	8.979	-0.046	5.769	-0.272	5.954	-0.190
7.968	0.301	8.846	0.064	8.982	-0.026	5.773	-0.275	5.959	-0.208
7.971	0.318	8.849	0.025	8.985	-0.009	5.778	-0.268	5.963	-0.228
7.975	0.307	8.853	-0.003	8.988	0.028	5.782	-0.263	5.968	-0.241
7.978	0.316	8.856	-0.027	8.992	0.066	5.786	-0.253	5.972	-0.247
7.982	0.324	8.860	-0.052	8.996	0.099	5.791	-0.242	5.976	-0.255
7.985	0.324	8.864	-0.069	8.999	0.153	5.795	-0.254	5.980	-0.260
7.989	0.327	8.867	-0.088	29.003	0.190	5.800	-0.241	5.985	-0.271
7.992	0.311	8.871	-0.099	9.005	0.224	5.807	-0.169	5.989	-0.265
7.996	0.277	8.875	-0.124	9.009	0.274	5.811	-0.145	5.993	-0.285
28.000	0.236	8.878	-0.136	34.834	0.394	5.816	-0.118	5.998	-0.260
8.004	0.184	8.881	-0.148	4.839	0.397	5.835	0.004	36.002	-0.249
8.008	0.141	8.885	-0.178	4.843	0.405	5.840	0.052	6.008	-0.222
8.011	0.097	8.885	-0.195	4.847	0.391	5.845	0.090	...	...
8.014	0.068	8.892	-0.206	4.851	0.367	5.849	0.144	...	...
8.018	0.036	8.899	-0.235	4.856	0.296	5.854	0.188	...	...
8.021	0.006	8.902	-0.238	4.861	0.223	5.857	0.237	...	...

phemeris calculated from the data corresponding the first group was:

$$\mathrm{HJD}_{min} = 2436508.7851\ (\pm\ 0.0035)\ + \\ +\ 0.4233957\ (\pm\ 2.61 \times 10^{-7})\ \mathrm{E}\ \ ,$$

hose O–C residuals are shown in Figure 6b and sted in the third column of Table 8. A quadratic phemeris was then calculated, yielding

$$\mathrm{HJD}_{min} = 2436508.7851\ (\pm\ 0.0035\ )\ + \\ +\ 0.4233979\ (\pm\ 2.61 \times 10^{-7})\ \mathrm{E}\ + \\ +\ (1.51 \pm 0.14) \times 10^{-10}\ \mathrm{E}^2/2\ \ .$$

The O–C residuals obtained are plotted in Figre 6c and listed in the fourth column of Table 8.

The same procedure was followed to analyze the cond group obtaining the linear ephemeris

$$\mathrm{HJD}_{min} = 2436508.7851\ (\pm\ 0.0035\ )\ + \\ +\ 0.4233994\ (\pm\ 1.98 \times 10^{-7})\ \mathrm{E}\ \ .$$

Although, a quadratic ephemeris was obtained, the residuals calculated were almost identical to those obtained from the linear ephemeris.

The O–C residuals calculated for the second set are plotted in Figure 6d and are listed in the third column of Table 8.

3.2. *YY Eridani*

When the total number of the times of minima of YY Eri was analyzed, the following linear ephemeris was found

$$\mathrm{HJD}_{min} = 2440232.6240\ (\pm\ 0.0035)\ + \\ +\ 0.3214959\ (\pm\ 7.92 \times 10^{-8})\ \mathrm{E}\ \ ,$$

which produced the residuals shown in the third column of Table 9 and plotted in Figure 7.

TABLE 8

TIMES OF MINIMA AND O–C RESIDUALS FOR LINEAR AND QUADRATIC FITS OF ER ORI

HJD 2400000+	Min.	$(O–C)_L$	$(O–C)_Q$	Ref.
26327.3380	I	-0.05067	0.00185	1
26336.4400	II	-0.05167	0.00087	1
26386.1840	I	-0.05667	-0.00395	1
26387.2450	II	-0.05416	-0.00144	1
26409.2670	II	-0.04873	0.00406	1
26420.2710	II	-0.05302	-0.00019	1
26600.2089	II	-0.05830	-0.00488	2
27430.4970	II	-0.04917	0.00659	3
27873.3640	II	-0.05407	0.00270	4
28566.4600	II	-0.05683	0.00118	5
28906.4450	II	-0.05858	-0.00010	5
29265.4810	II	-0.06214	-0.00327	5
29283.6870	II	-0.06215	-0.00327	6
29291.5190	I	-0.06297	-0.00408	6
29291.7350	II	-0.05867	0.00022	6
29307.6120	I	-0.05901	-0.00010	6
29311.6360	II	-0.05727	0.00164	6
29547.8930	II	-0.05507	0.00402	6
29549.7900	I	-0.06335	-0.00425	6
29552.7570	I	-0.06012	-0.00102	6
29556.7800	II	-0.05938	-0.00028	6
29570.7520	II	-0.05944	-0.00033	6
29577.7380	II	-0.05947	-0.00035	6
29651.6140	II	-0.06602	-0.00686	6
29660.5210	II	-0.05033	0.00884	6
29664.5360	II	-0.05759	0.00158	6
29671.5210	II	-0.05861	0.00056	6
29671.5240	II	-0.05561	0.00356	6
29675.5440	II	-0.05787	0.00130	6
29686.5510	II	-0.05916	0.00002	6
31175.4200	II	-0.06115	-0.00206	3
32941.4070	II	-0.05762	-0.00106	4
32971.8950	II	-0.05411	0.00238	7
33682.3540	II	-0.05309	0.00161	8
33929.6175	II	-0.05264	0.00134	9
33960.9464	II	-0.05507	-0.00118	10
33979.1533	II	-0.05418	-0.00035	4
34366.5640	II	-0.05055	0.00204	7
		$\sigma_L = 0.0042$	$\sigma_Q = 0.0031$	
36215.5793	II	-0.00173	.....	4
36227.6482	I	0.00029	.....	4
36508.7851	I	0.00000	.....	4
37260.7457	I	0.00330	.....	4
37309.6472	II	0.00217	.....	4
41626.4160	I	0.00261	.....	11
41641.8595	II	-0.00797	.....	12
41646.9568	II	0.00854	.....	12
41664.3099	II	0.00226	.....	11
41990.5429	I	0.00608	.....	13
42023.3516	II	0.00131	.....	14
42030.5501	II	0.00198	.....	14
42433.6250	II	0.00069	.....	15
42446.5400	I	0.00201	.....	16
42751.5930	II	-0.00424	.....	16
42760.7030	I	0.00267	.....	16
43211.6160	II	-0.00467	.....	17
43479.6470	I	0.01452	....	17
44252.3400	I	0.00366	....	18
44577.2932	II	-0.00217	.....	19
44610.1053	I	-0.00352	.....	19
44611.1622	II	-0.00512	.....	19
44612.2221	I	-0.00371	.....	19
46775.7990	I	0.00236	.....	20
46777.9180	I	0.00436	.....	20
		$\sigma_L = 0.0047$		

References. (1) Taylor & Alexander 1940; (2) Florja 1931; (3) Tsesevich 1954; (4) Binnendijk 1961; (5) Tecza 1939; (6) Alexander 1940; (7) Ashbrook 1953; (8) Szczepanowska 1955; (9) Kwee 1958; (10) Huruhata et al. 1957; (11) Kizilirmak & Pohl 1974; (12) Hilditch & Hill 1975; (13) Zavatti & Burchi 1975; (14) Burchi & Zavatti 1975; (15) Mallama et al. 1977; (16) Stephan 1977; (17) Stephan 1978; (18) Pohl et al. 1982; (19) Yang & Qingyao 1982; (20) Hobart et al. 1993.

3.3. RZ Tauri

The times of minima yielded the linear ephemeris

$$\mathrm{HJD}_{min} = 2437676.575\ (\pm\ 0.0035) + \\ + 0.4156731\ (\pm\ 7.7 \times 10^{-8})\ E\ .$$

The O–C residuals are given in the third column of Table 10 and are sketched in Figure 8a which makes a changing period apparent.

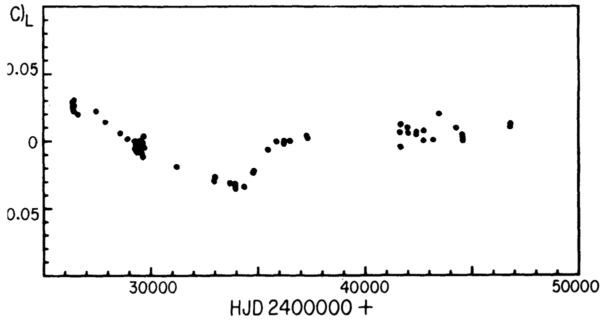
The quadratic fit produced the following ephemeris

$$\mathrm{HJD}_{min} = 2437676.575\ (\pm\ 0.0035\ ) + \\ + 0.4156737\ (\pm\ 7.7 \times 10^{-8})\ E + \\ + (1.03 \pm 0.012) \times 10^{-10}\ E^2/2\ .$$

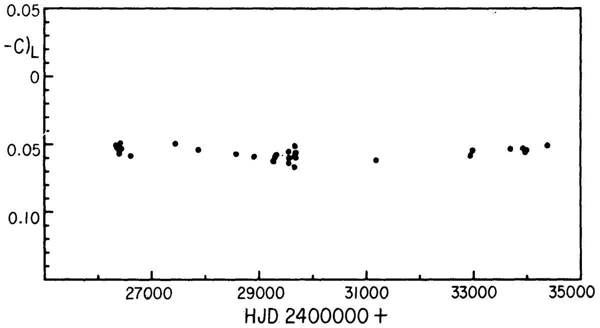
The fourth column of Table 10 gives the O–C residuals for the quadratic ephemeris, while Fig ure 8b shows these residuals for this case.

4. DISCUSSION

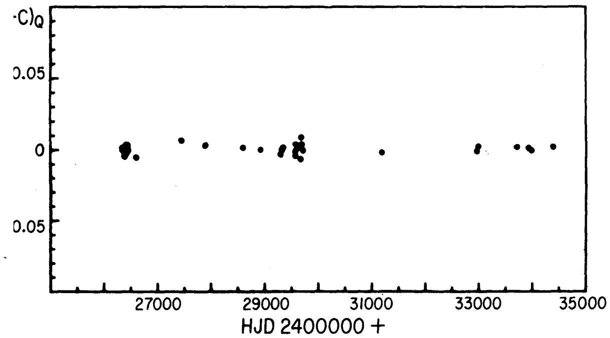
From the analyses of the available data carrie out in this paper, it is clear that no trend can b observed in the period behavior of the systems con sidered. Some have periods which are decreasin while in others the periods are increasing. Fo ER Ori, it is apparent that there were two change of period, one around HJD 2434366 and the othe around HJD 2436215. Before the first date, th period was increasing continuously at a rate o 1.13 s/century. After HJD 2436215, the period ha shown no appreciable change.



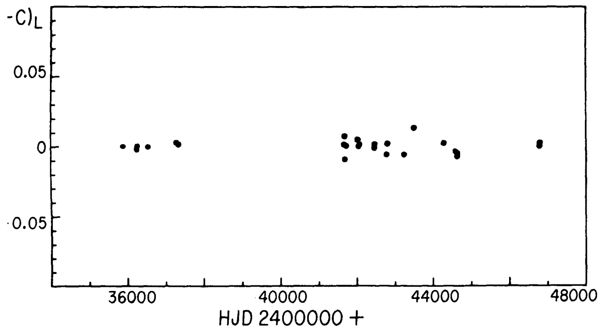
g. 6a. O–C residuals versus HJD for ER Ori using the ear ephemeris for the complete set of minima HJD_{min} 2436508.7851 + 0.4233990 E.



g. 6b. O–C residuals versus HJD for the first oup of minima using the linear ephemeris HJD_{min} = 36508.7851 + 0.4233957 E.



g. 6c. O–C residuals versus HJD for the first group minima using the quadratic ephemeris HJD_{min} = 36508.7851 + 0.4233979 E + (1.51×10^{-10}) $E^2/2$.



ig. 6d. O–C residuals versus HJD for ER Ori for the last oup of minima using the linear ephemeris HJD_{min} = 436508.7851 + 0.4233994 E.

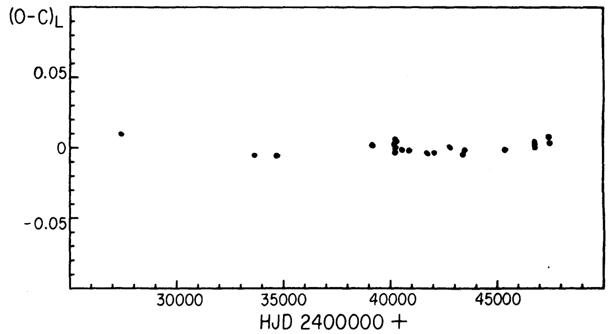


Fig. 7. O–C residuals versus HJD for YY Eri using the linear ephemeris HJD_{min} = 2440232.6240 + 0.3214959 E.

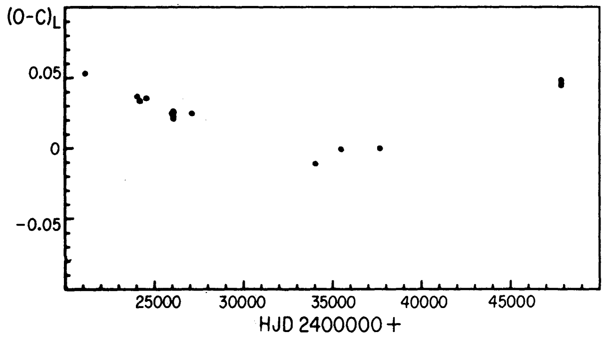


Fig. 8a. O–C residuals versus HJD for RZ Tau using the linear ephemeris HJD_{min} = 2437676.575 + 0.4156731 E.

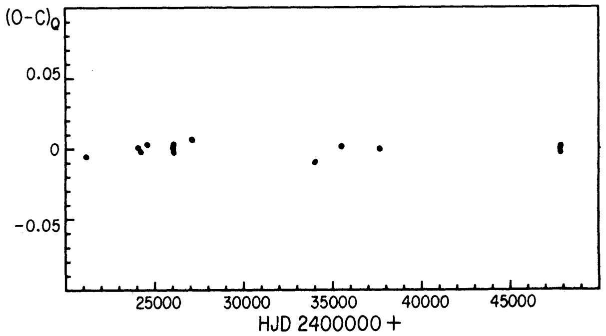


Fig. 8b. O–C residuals versus HJD using the quadratic ephemeris HJD_{min} = 2437676.575 + 0.4156737 E + (1.03×10^{-10}) $E^2/2$.

The period of YY Eri does not change appreciably, while RZ Tau shows a continuously increasing period with a rate of change of 0.78 s/century. As a general conclusion we can assert that more observations, on a regular basis, of these kinds of systems are necessary in order to improve the determination of their period changes. A compilation of the results of the periods, quadratic coefficients, rates of period change and time spans of observations are given in Table 11.

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TABLE 9

TIMES OF MINIMA AND O–C RESIDUALS OF YY ERI

HJD 2400000+	Min.	$(O-C)_L$	Ref.	HJD 2400000+	Min.	$(O-C)_L$	Ref.	HJD 2400000+	Min.	$(O-C)_L$	Ref.
27364.4400	I	0.01023	1	40200.6380	II	0.00284	5	43461.7270	I	-0.00165	11
33617.5198	I	-0.00490	2	40201.4399	I	0.00100	6	45356.9456	II	-0.00128	12
34647.5926	I	-0.00488	3	40208.6790	II	0.00644	5	46774.7457	I	0.00197	13
39120.2503	I	0.00206	4	40232.6240	I	0.00000	5	46774.9090	II	0.00452	13
39124.1085	I	0.00231	4	40233.5860	I	-0.00249	5	46778.7648	II	0.00237	13
39162.2058	II	0.00234	4	40237.6130	II	0.00581	5	46798.6983	II	0.00313	13
39165.0999	II	0.00298	4	40556.6910	II	-0.00085	5	46799.6610	II	0.00134	13
39165.2596	I	0.00193	4	40868.5418	II	-0.00106	7	46818.6288	II	0.00088	13
39166.2241	I	0.00194	4	41680.3167	I	-0.00326	8	47458.8953	I	0.00833	13
39167.1886	I	0.00196	4	42032.0335	I	-0.00296	2	47459.8550	I	0.00354	13
39181.1742	II	0.00249	4	42760.7080	II	0.00112	9			$\sigma_L = 0.0035$	
39187.1216	I	0.00221	4	43398.5500	II	-0.00471	10				

References. (1) Prager 1941; (2) Strauss 1976; (3) Kwee 1958; (4) Bhattacharyya 1967; (5) Baldwin 1973; (6) Pohl & Kizilirmak 1970; (7) Kizilirmak & Pohl 1971; (8) Kizilirmak & Pohl 1974; (9) Stephan 1977; (10) Ebersberger et al. 1978 (11) Stephan 1978; (12) Budding 1983; (13) Hobart et al. 1993.

TABLE 10

TIMES OF MINIMA AND O–C RESIDUALS FOR LINEAR AND QUADRATIC FITS OF RZ TAU

HJD 2400000+	Min.	$(O-C)_L$	$(O-C)_Q$	Ref.	HJD 2400000+	Min.	$(O-C)_L$	$(O-C)_Q$	Ref.
21110.3930	I	0.05282	-0.00416	1	35480.3657	II	-0.00060	0.00126	7
24031.9351	II	0.03670	0.00165	1	37639.5802	I	0.00010	0.00016	7
24177.4172	II	0.03322	-0.00087	1	37639.7885	II	0.00057	0.00062	7
24535.3140	II	0.03550	0.00372	2	37640.6188	II	-0.00048	-0.00043	7
25972.4927	I	0.02454	0.00124	1	37642.6979	II	0.00026	0.00031	7
26011.3600	II	0.02640	0.00332	1	37676.5750	I	0.00000	0.00000	7
26016.3454	II	0.02373	0.00067	1	47827.9828	II	0.04774	0.00182	8
26017.3864	I	0.02554	0.00249	1	47828.8143	II	0.04790	0.00197	8
26030.4760	II	0.02144	-0.00154	3	47835.8790	II	0.04616	-0.00017	8
27069.2463	II	0.02472	0.00708	4	47837.9562	II	0.04499	-0.00101	8
33987.0496	I	-0.01117	-0.00970	5			$\sigma_l = 0.0201$	$\sigma_q = 0.0031$	
35462.4918	II	-0.00055	0.00130	6					

References. (1) Oosterhoff 1930; (2) Tsesevich 1955; (3) Rybka 1930; (4) Mergentaler 1934; (5) Huruhata & Kitamura 1953; (6) Hindeder 1960; (7) Binnendijk 1963; (8) Hobart et al. 1993.

TABLE 11

MAIN RESULTS

Star	Period (day)	Quadratic Coefficient	dP/dt (s/century)	Time Span of observ. (yr)
LZ Her	0.334	....	....	....
ER Ori	0.4233957	$+1.51 \times 10^{-10}$	+1.13	22
ER Ori	0.4233994	....	....	33
YY Eri	0.3214959	....	....	55
RZ Tau	0.4156731	$+1.03 \times 10^{-10}$	+0.78	73

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. Garrido and E. Rodríguez: Instituto de Astrofísica de Andalucía, Apdo. de Correos 2144, E-18080 Granada, Spain.
.A. Hobart: Facultad de Física, Universidad Veracruzana, Apartado Postal 270, 91190 Xalapa, Ver., México.
. López-Cruz: University of Toronto, Dept. of Astronomy, Toronto, Ontario M5S 1A7, Canada.
. Peniche and J.H. Peña: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D.F., México.
. Ríos-Berúmen and M. Ríos-Herrera: Universidad Autónoma de Zacatecas, Apartado Postal 275, 98000 Zacatecas, Zac., México.