UBV PHOTOMETRY OF ER VULPECULAE

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Abstract. *UBV* photometry of RS CVn-type eclipsing binary system ER Vulpeculae has been presented. The period comes out to be $0^{d}698093$. The average depths of primary and secondary minima are, respectively, $0^{m}_{.}21$ and $0^{m}_{.}12$. The colours at various phases have been given. A dip is seen around phase $0^{p}_{.}73$ as was seen in the observations of Arevaló *et al.* (1988). Large scatter is present in the observations as noticed earlier, and may be due to activity of the components.

1. Introduction

ER Vulpeculae (= BD + 27°3952 = HD 200391, $7^{m}_{.}3$, GOV, G5V) is a short period RS CVn-type eclipsing binary, which was discovered in 1946. Northcott and Bakos (1956) showed it to be a spectroscopic binary, who later (1967) confirmed its eclipsing binary nature photometrically. Photometry of ER Vul was also carried out by Abrami and Cester (1973), Kadouri (1981), Al-Naimiy (1981), Zeilik *et al.* (1982a, b), Arevaló and Fuensalida (1985), Arevaló *et al.* (1988), Ibanoglu *et al.* (1985). Hall and Kreiner (1980) presented its period study.

2. Observations

Six nights of *U*, *B*, and *V* observations of ER Vulpeculae have been secured in the time interval, October 1983 to October 1984. Two nights of observations were secured through the 104-cm reflector of Uttar Pradesh State Observatory, using a cooled (– 20 °C) EMI 9658B photomultiplier tube. The observations were recorded using d.c. techniques and *UBV* filters of Johnson and Morgan system. Four nights of observations were secured on the 38-cm reflector of this Observatory, these were secured using a cooled (– 20 °C) 1P21 photomultiplier tube and the same set of filters and techniques.

Two comparison stars BD + 27°3946 (= HD 200270) and BD + 27°3953 (= HD 200468) were used to begin with. Later BD + 27°3946 was finally chosen to obtain the differential magnitudes, in the sense variable *minus* comparison, owing to better constancy of this star compared to the other. The standard stars were observed to reduce the data to the standard system.

The average nightly standard deviations have been calculated on three nights and come out to be $\pm 0^{m}_{.}035$, $\pm 0^{m}_{.}031$ and $\pm 0^{m}_{.}025$ for *U*, *B*, and *V* filters, respectively.

3. Epoch and Period

Epochs and periods of ER Vul have been given by various authors, and listed in Table I.

During the course of our observations, the *UBV* light curves of ER Vul have been

TABLE I

Epoch and period of ER Vul

Northcott and Bakos (1967)	$2\,435\,050.5524 + 0^{d}.698084E$
Al-Naimiy (1981)	$2\,440\,182.3212 + 0^{d}.698082E$
Ibanoglu *et al.* (1985)	$2\,440\,182.2593 + 0^{d}.69809510E$
	$2\,440\,182.2621 + 0^{d}.69809409E$
Srivastava *et al.* (this paper)	$2\,440\,182.266\ \ + 0^{d}.6980931E$

fairly covered except between phases $0^{p}.20$ to $0^{p}.30$, which is no limitation in discussing the results.

Two primary and one secondary minima have been determined graphically and are given below:

Primary minimum, J.D. (Hel.)	Secondary minimum, J.D. (Hel.)
$2\,445\,614.1372$	$2\,445\,652.1844$
$2\,445\,993.1749$	

TABLE II

Standard U magnitudes of ER Vul

J.D. (Hel.)	Phase	ΔU (var.-comp.)	J.D. (Hel.)	Phase	ΔU (var.-comp.)
$2\,445\,614 +$			$2\,445\,652 +$		
.1088	0.9719	$-0^{m}.079$	.1699	0.4934	$-0^{m}.089$
.1319	0.0050	$+0.041$	.1726	0.4973	-0.128
.1417	0.0190	-0.016	.1839	0.5135	-0.056
.1575	0.0417	-0.007	.1867	0.5175	-0.056
.1678	0.0564	-0.033	.1899	0.5221	-0.067
.1824	0.0773	-0.043	.1976	0.5331	-0.073
.1979	0.0983	-0.075	.1993	0.5355	-0.058
.2156	0.1249	-0.121	.2142	0.5569	-0.131
.2450	0.1670	-0.111	.2169	0.5608	-0.159
.2704	0.2034	-0.125	.2174	0.5615	-0.138
650.1918	0.6599	-0.163	.2196	0.5646	-0.125
651.1342	0.0098	-0.046	654.1524	0.3333	-0.174
.1481	0.0297	$+0.005$	.2018	0.4041	-0.131
.1580	0.0439	-0.038	993.1693	0.9661	-0.010
.1801	0.0756	-0.064	.1807	0.9824	-0.128
.1857	0.0836	-0.040	.1853	0.9890	-0.002
.2026	0.1078	-0.105			
.2143	0.1246	-0.105	$2\,446\,004 +$		
.2230	0.1370	-0.097	.1918	0.7555	-0.076
652.1463	0.4596	-0.118	.1994	0.7664	-0.073
.1569	0.4748	-0.113	.2062	0.7762	-0.123
.1599	0.4791	-0.074	.2192	0.7948	-0.064

Standard differential magnitudes in U, B, and V are given in Table II and $\Delta(B - V)$ and $\Delta(U - B)$ colours are listed in Table III.

The phases have been calculated from ephemeris:

$$\text{Pr. min.} = \text{J.D. } 2\,440\,182.266 + 0^{\text{d}}\!6980931E.$$

4. Discussion of Light and Colour Curves

The light curves and colour curves of ER Vul are given in Figure 1. The filled circles indicate the observed points, while the open circles represent some reflected points for

TABLE III

Standard *B* magnitudes of ER Vul

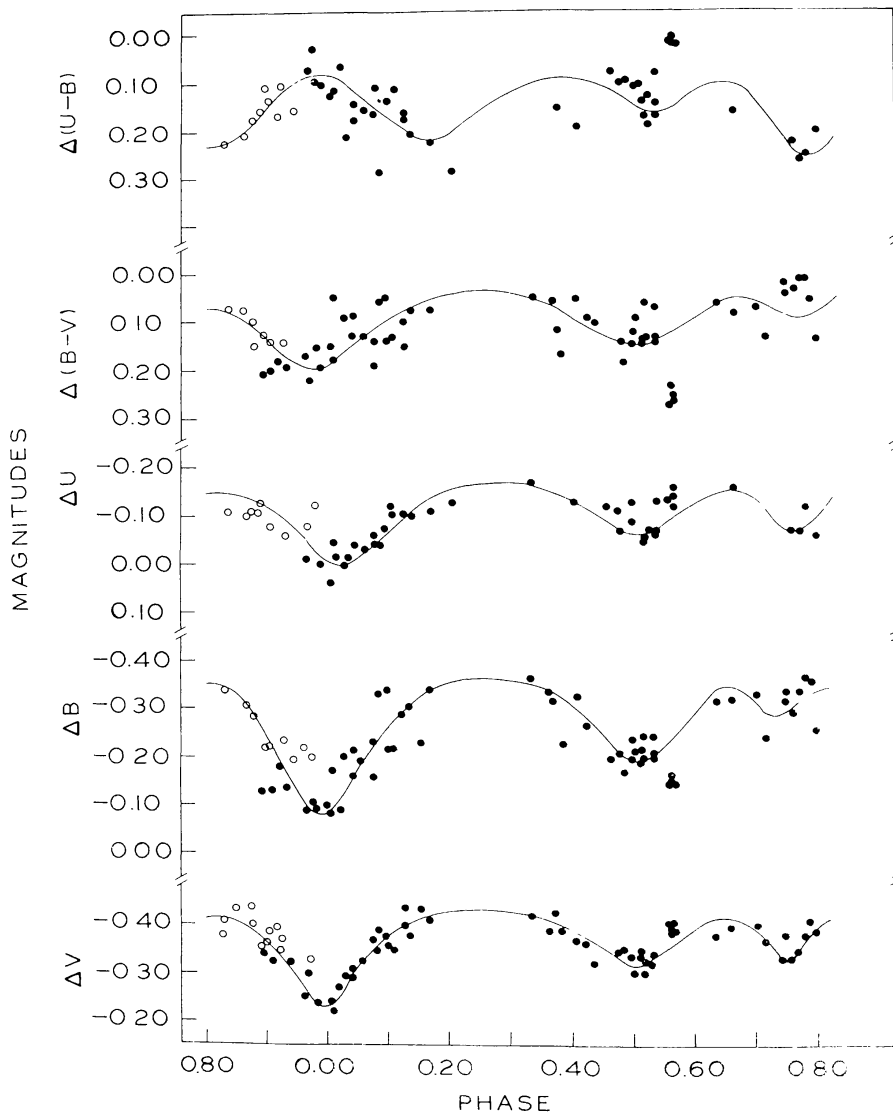| J.D. (Hel.)	Phase	ΔB (var.-comp.)	J.D. (Hel.)	Phase	ΔB (var.-comp.)
2 445 614 +			2 445 652 +		
.1098	0.9728	$-0^{m}\!111$	.1972	0.5325	$-0^{m}\!245$
.1325	0.0059	-0.090	.1980	0.5337	-0.213
.1425	0.0202	-0.087	.1990	0.5351	-0.204
.1581	0.0425	-0.160	.2147	0.5576	-0.145
.1684	0.0573	-0.195	.2163	0.5599	-0.165
.1824	0.0773	-0.158	.2178	0.5620	-0.155
.1975	0.0990	-0.220	.2190	0.5638	-0.147
.2162	0.1258	-0.290	654.1528	0.3339	-0.366
.2464	0.1690	-0.338	.1746	0.3651	-0.336
.2714	0.2048	-0.417	.1796	0.3723	-0.318
650.1730	0.6329	-0.318	.1870	0.3829	-0.228
.1923	0.6606	-0.321	.2022	0.4046	-0.327
651.1346	0.0104	-0.168	.2131	0.4203	-0.268
.1485	0.0303	-0.202	.2236	0.4353	-0.415
.1585	0.0446	-0.216	993.1183	0.8930	-0.133
.1804	0.0760	-0.235	.1283	0.9074	-0.128
.1862	0.0843	-0.331	.1375	0.9205	-0.178
.1944	0.0961	-0.337	.1477	0.9352	-0.136
.2029	0.1082	-0.223	.1698	0.9668	-0.089
.2147	0.1251	-0.289	.1812	0.9831	-0.088
.2235	0.1377	-0.305	.1859	0.9899	-0.104
.2356	0.1551	-0.233			
652.1467	0.4602	-0.198	2 446 004		
.1593	0.4782	-0.210	.1526	0.6994	-0.331
.1628	0.4833	-0.171	.1622	0.7131	-0.238
.1722	0.4967	-0.198	.1832	0.7432	-0.319
.1732	0.4982	-0.238	.1854	0.7464	-0.337
.1744	0.4999	-0.215	.1920	0.7558	-0.302
.1830	0.5122	-0.191	.1998	0.7670	-0.338
.1842	0.5139	-0.215	.2065	0.7766	-0.374
.1872	0.5182	-0.245	.2125	0.7852	-0.362
.1895	0.5215	-0.199	.2196	0.7954	-0.264

Fig. 1.   Light and colour curves of ER Vul.

visual inspection. The light curve in *B* shows comparatively large scatter; this fact is in turn reflected in both the colour curves.

Minima are of unequal durations. The durations of primary and secondary minima are $0^{d}28$ and $0^{d}22$, respectively. It shows that slight eccentricity of 0.12 may be present in the system.

The average depths of primary and secondary minima are respectively $0\overset{m}{.}21$ and $0\overset{m}{.}12$. Thus, the depths have not changed considerably compared to the values given in the catalogues. A definite change of nearly $0\overset{m}{.}07$ is visible around phase $0\overset{p}{.}73$ which is also seen in the observations of Arevaló (1988) and may be due to the effect of gas streams.

TABLE IV

Standard *V* magnitudes of ER Vul

J.D. (Hel.)	Phase	ΔV (var.-comp.)	J.D. (Hel.)	Phase	ΔV (var.-comp.)
2 445 614 +			2 445 652 +		
.1112	0.9753	− 0.^{m}333	.1891	0.5209	− 0.^{m}326
.1331	0.0067	− 0.240	.1968	0.5320	− 0.317
.1431	0.0210	− 0.271	.1984	0.5343	− 0.339
.1591	0.0440	− 0.290	.2150	0.5580	− 0.411
.1697	0.0591	− 0.336	.2158	0.5592	− 0.394
.1840	0.0796	− 0.345	.2183	0.5628	− 0.414
.1981	0.0998	− 0.363	.2188	0.5635	− 0.396
.2168	0.1266	− 0.437	654.1531	0.3343	− 0.420
.2475	0.1706	− 0.414	.1749	0.3655	− 0.391
.2725	0.2064	− 0.339	.1799	0.3727	− 0.434
650.1735	0.6336	− 0.379	.1874	0.3832	− 0.393
.1927	0.6611	− 0.398	.2026	0.4052	− 0.373
651.1350	0.0110	− 0.222	.2136	0.4210	− 0.360
.1491	0.0312	− 0.294	.2239	0.4357	− 0.317
.1589	0.0452	− 0.308	993.1190	0.8950	− 0.343
.1808	0.0766	− 0.373	.1287	0.9079	− 0.326
.1866	0.0849	− 0.394	.1382	0.9216	− 0.355
.1950	0.0969	− 0.383	.1484	0.9362	− 0.324
.2035	0.1091	− 0.353	.1706	0.9680	− 0.256
.2153	0.1260	− 0.389	.1819	0.9842	− 0.242
.2240	0.1385	− 0.381	.1868	0.9912	− 0.301
.2360	0.1556	− 0.436			
652.1477	0.4616	− 0.431	2 446 004 +		
.1588	0.4775	− 0.348	.1530	0.7000	− 0.401
.1623	0.4825	− 0.349	.1626	0.7137	− 0.370
.1717	0.4960	− 0.343	.1835	0.7437	− 0.335
.1740	0.4993	− 0.359	.1857	0.7468	− 0.377
.1749	0.5006	− 0.302	.1923	0.7563	− 0.330
.1824	0.5113	− 0.335	.2001	0.7674	− 0.350
.1847	0.5146	− 0.351	.2069	0.7772	− 0.380
.1882	0.5196	− 0.305	.2130	0.7859	− 0.412
			.2201	0.7961	− 0.394

Colours at various phases have been determined and are given as follows:

Star	Phase	*B* − *V*	*U* − *B*	Sp.
ER Vul	Maximum	+ 0.^{m}65	+ 0.^{m}64	G0
	Pr. min.	+ 0.72	+ 0.53	G5
	Sec. min.	+ 0.64	+ 0.63	G0
BD + 27°3946		+ 0.58	+ 0.44	F8

The luminosity classes were not ascertained in the light of large scatter present in the system.

TABLE V

Colours of ER Vul

Phase	$\Delta(U - B)$	$\Delta(B - V)$	Phase	$\Delta(U - B)$	$\Delta(B - V)$
0.9728	0″032	0″222	0.5215	0″131	0″127
0.0059	0.131	0.150	0.5325	0.172	0.072
0.0202	0.071	0.183	0.5337	0.145	0.126
0.0425	0.152	0.131	0.5351	–	0.136
0.0573	0.161	0.132	0.5576	0.014	0.267
0.0783	0.115	0.187	0.5599	0.006	0.229
0.0990	0.144	0.143	0.5620	0.017	0.259
0.1258	0.169	0.147	0.5838	0.022	0.248
0.1690	0.227	0.076	0.3339	0.192	0.054
0.2048	0.292	− 0.079	0.3651	–	0.055
0.6329	–	0.061	0.3723	–	0.116
0.6606	0.159	0.077	0.3829	–	0.165
0.0104	0.122	0.054	0.4046	0.196	0.047
0.0303	0.208	0.092	0.4203	–	0.092
0.0446	0.178	0.092	0.4353	–	0.098
0.0760	0.171	0.139	0.8930	–	0.210
0.0843	0.290	0.063	0.9074	–	0.197
0.0961	–	0.047	0.9205	–	0.177
0.1082	0.119	0.130	0.9352	–	0.189
0.1251	0.184	0.100	0.9668	0.078	0.167
0.1377	0.209	0.075	0.9831	0.101	0.154
0.1551	–	0.203	0.9899	0.106	0.196
0.4602	0.080	0.232	0.6994	–	0.070
0.4775	0.097	0.188	0.7131	–	0.132
0.4825	0.097	0.179	0.7432	–	0.016
0.4960	0.109	0.145	0.7464	–	0.040
0.4982	0.109	0.121	0.7558	0.226	0.028
0.4990	–	0.087	0.7670	0.265	0.012
0.5122	0.144	0.144	0.7766	0.251	0.006
0.5139	0.169	0.136	0.7852	–	0.050
0.5182	0.189	0.061	0.7954	0.200	0.130

The colour curves show very large distortion around the primary minimum, which is uninterpretable due to large scatter present in the system. The primary and secondary minima appear asymmetric.

5. Summary

Our 1983–1984 *UBV* photometry reveals that the depths of the minima have remained the same compared to earlier catalogued values. Large scatter is present in the system. The durations of eclipses are unequal and the branches of minima are asymmetric, these facts are indicative of the presence of small eccentricity. Colour curves are highly distorted around the primary minimum. A dip is seen at phase 0ᵖ73, and may be due to gas streams.

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