SOME OBSERVATIONS OF DX AQUARII

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Abstract. *U*, *B*, *V* photoelectric observations of the eclipsing binary system DX Aqr, secured in 1981, have been presented. Present results, when compared with earlier ones (cf. Srivastava and Sinha, 1985), suggest that the features of the system are changing. Some new features are reported.

1. Introduction

Earlier after tracing the history of the system DX Aqr (cf. Srivastava and Sinha, 1985), we emphasized the need for securing new observations for the system for elucidating the uncertainties noticed by us.

2. Observations and Results

Results of six nights of observations, secured during the period October 1981–December 1981, using BD-17°6421 as a comparison star and the same instrumental and reduction techniques as used earlier, are reported here.

The ranges of nightly standard deviations for the comparison star, obtained on four nights, in *U*, *B*, and *V* filters are respectively $0\overset{\mathrm{m}}{.}023$ to $0\overset{\mathrm{m}}{.}079$, $0\overset{\mathrm{m}}{.}019$ to $0\overset{\mathrm{m}}{.}022$, and $0\overset{\mathrm{m}}{.}012$ to $0\overset{\mathrm{m}}{.}039$; the corresponding average being $\pm 0\overset{\mathrm{m}}{.}047$, $0\overset{\mathrm{m}}{.}021$, and $0\overset{\mathrm{m}}{.}020$. The *U*, *B*, and *V* observations are listed in Tables IV, V, and VI, respectively. The corresponding light curves are shown in Figure 1. Here the solid lines represent the smoothened light curves considering that the system belongs to Algol class (as inferred in earlier communication) and the dotted lines indicate the superposed variations. Also, observed points are shown as filled circles and some reflected points are shown as open circles.

The amplitudes of primary minimum in *U*, *B*, and *V* filters are $0\overset{\mathrm{m}}{.}470$, $0\overset{\mathrm{m}}{.}410$, and $0\overset{\mathrm{m}}{.}230$, while the amplitudes of secondary minimum in these respective filters are $0\overset{\mathrm{m}}{.}160$, $0\overset{\mathrm{m}}{.}250$, and $0\overset{\mathrm{m}}{.}210$. The durations of primary minimum in *U*, *B*, and *V* filters are $0\overset{\mathrm{d}}{.}125$, $0\overset{\mathrm{d}}{.}115$, and $0\overset{\mathrm{d}}{.}105$, while the corresponding durations of secondary minimum are $0\overset{\mathrm{d}}{.}095$, $0\overset{\mathrm{d}}{.}100$, and $0\overset{\mathrm{d}}{.}105$. The average amplitudes of primary and secondary minima are $0\overset{\mathrm{m}}{.}37$ and $0\overset{\mathrm{m}}{.}21$, while the corresponding average durations are $0\overset{\mathrm{d}}{.}12$ and $0\overset{\mathrm{d}}{.}10$. These depths and durations, when compared to earlier results (cf. Srivastava and Sinha, 1985), reveal that the average depth of primary minimum has hardly increased, while in contrast, the average depth of secondary minimum has increased considerably; and the average duration of primary minimum has nearly reduced to half, while in contrast, the average duration of secondary minimum has reduced moderately. In addition, the present results show that the *U*, *B*, and *V* depths of primary minimum on J.D. 2444899 are $0\overset{\mathrm{m}}{.}47$, $0\overset{\mathrm{m}}{.}41$, and $0\overset{\mathrm{m}}{.}23$, while the corresponding depths of primary minimum on J.D. 2444936 are

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TABLE I

Minima of DX Aqr

Sl. no.	Epoch of minima, J.D. (Hel.)	Period	O–C based on Strohmeier's (1966) epoch and present period
	Primary minima:		
1	2444899.2360 ± $0^{\rm d}.0007$	$0^{\rm d}.4605934$	− $0^{\rm d}.0175$
2	2444936.1190 ± $0^{\rm d}.0007$	$0^{\rm d}.4605954$	+ $0^{\rm d}.0179$
	Mean	$0^{\rm d}.4605944$	+ $0^{\rm d}.0002$
	Secondary minimum:		
1	2444944.1300 ± $0^{\rm d}.0007$	$0^{\rm d}.4605926$	− $0^{\rm d}.0315$

TABLE II

Features of DX Aqr

Sl. no.	Details/Results	Srivastava and Sinha (1985)	Srivastava (present work)
1	Year of observations	1976–1979	1981
2	Year of observations	*UBV* pe photometry	*UBV* pe photometry
3	Epoch, J.D. (Hel.)	2441139.1594	2444899.2360 2444936.1190
4	Period	$0^{\rm d}.472502$	$0^{\rm d}.460594$
5	Amplitude of primary minimum	$0^{\rm m}.35$	$0^{\rm m}.37$
6	Amplitude of secondary minimum	$0^{\rm m}.13$	$0^{\rm m}.21$
7	Duration of primary minimum	$0^{\rm d}.24$	$0^{\rm d}.12$
8	Duration of secondary minimum	$0^{\rm d}.15$	$0^{\rm d}.10$
9	Duration of totality	$0^{\rm d}.05$	$0^{\rm d}.04$
10	Shift of primary minimum from its expected position	− $0^{\rm d}.03$	$0^{\rm d}.00$
11	Shift of secondary minimum from its expected position	+ $0^{\rm d}.03$	− $0^{\rm d}.03$
12	Nature of primary eclipse	Total, occultation	Total, occultation
13	Nature of secondary eclipse	Total, annular	Total, annular
14	Spectral type of maximum	F5IV	F5III
15	Spectral type of primary component	A8III	A3II
16	Spectral type of secondary component	F6IV	F8III
17	Type of the system	EA	EA or EB (?)
18	Colour out side eclipses	Varying	Varying

$0^{\rm m}.35$, $0^{\rm m}.26$, and $0^{\rm m}.21$. This indicates that the depths of two present primary minima differ by $0^{\rm m}.12$ and $0^{\rm m}.15$ in *U* and *B* filters, while their amplitudes in *V* filter remain almost the same within the error of observations. The branches of both minima are asymmetric as observed earlier. Descending branch of primary minimum is less steep than the ascending branch, while the ascending branch of secondary minimum is less steep than the descending branch.

TABLE III

Colour indices of DX Aqr

Sl. no.	Phase	Present observations			Eearlier observations (Srivastava and Sinha, 1985)		
		$\Delta(B-V)$	$\Delta(U-B)$	Sp.	$\Delta(B-V)$	$\Delta(U-B)$	Sp.
1	Maximum (combined colour of both components)	$+0^{m}.39$	$+0^{m}.11$	F5III	$+0^{m}.41$	$+0^{m}.04$	F5IV
2	Tip of primary minimum (colour of secondary component)	$+0^{m}.57$	$+0^{m}.17$	F8III	$+0^{m}.47$	$+0^{m}.06$	F6IV
3	Tip of secondary minimum) (complete colour of primary component and partial colour of secondary component)	$+0^{m}.43$	$+0^{m}.02$	F5III	$+0^{m}.34$	$+0^{m}.06$	F2IV
4	Colour of primary component	$+0^{m}.04$	$-0^{m}.02$	A3II	$+0^{m}.20$	$+0^{m}.07$	A8II

TABLE IV

Standard U magnitudes of DX Aqr

J.D. (Hel.)	Phase	Δm	J.D. (Hel.)	Phase	Δm	J.D. (Hel.)	Phase	Δm
2444899.1076	$-0^{d}.1459$	$2^{m}.597$	904.2556	$0^{d}.4063$	$2^{m}.675$	927.1971	$0^{d}.3079$	$2^{m}.898$
.1130	−0.1405	2.668	.2640	0.4147	2.637	.2022	0.3130	2.869
.1329	−0.1206	2.698	907.1038	0.0302	2.789	.2125	0.3233	2.731
.1404	−0.1131	2.869	.1107	0.0371	2.685	.2180	0.3280	2.778
.1474	−0.1061	2.773	.1166	0.0430	2.667	.2272	0.3380	2.730
.1578	−0.0957	2.709	.1248	0.0512	2.703	.2338	0.3446	2.657
.1663	−0.0872	2.667	.1298	0.0562	2.715	936.1056	0.0045	2.850
.1746	−0.0789	2.737	.1383	0.0647	2.712	.1186	0.0175	3.236
.1803	−0.0732	2.775	.1418	0.0682	2.783	.1245	0.0234	3.217
.1903	−0.0632	2.734	.1521	0.0785	2.808	.1367	0.0256	3.149
.1977	−0.0558	2.819	.1606	0.0870	2.767	.1457	0.0446	2.989
.2069	−0.0466	2.866	.1664	0.0928	2.785	.1577	0.0567	2.829
.2140	−0.0395	2.841	.1760	0.1024	2.783	.1783	0.0773	2.718
.2215	−0.0320	2.910	.1839	0.1103	2.843	.1894	0.0884	2.765
.2307	−0.0228	3.033	.1932	0.1196	2.822	944.1002	0.1690	2.909
.2357	−0.0178	3.097	.1993	0.1257	2.786	.1100	0.1788	2.884
904.1236	0.2642	2.716	.2085	0.1349	2.856	.1169	0.1857	2.912
.1566	0.2973	2.734	.2150	0.1414	2.850	.1266	0.1954	2.906
.1655	0.3062	2.684	.2243	0.1507	2.844	.1326	0.2014	2.850
.1756	0.3163	2.682	.2299	0.1563	2.818	.1424	0.2112	2.852
.1815	0.3222	2.695	.2384	0.1648	2.774	.1512	0.2200	2.918
.1929	0.3336	2.706	.2439	0.1693	2.787	.1619	0.2307	2.816
.1988	0.3495	2.646	927.1669	0.2777	2.890	.1717	0.2405	2.727
.2092	0.3599	2.601	.1724	0.2832	2.898	.1869	0.2557	2.583
.2159	0.3666	2.626	.1802	0.2910	2.901	.1939	0.2627	2.647
.2502	0.4009	2.775	.1865	0.2973	2.794			

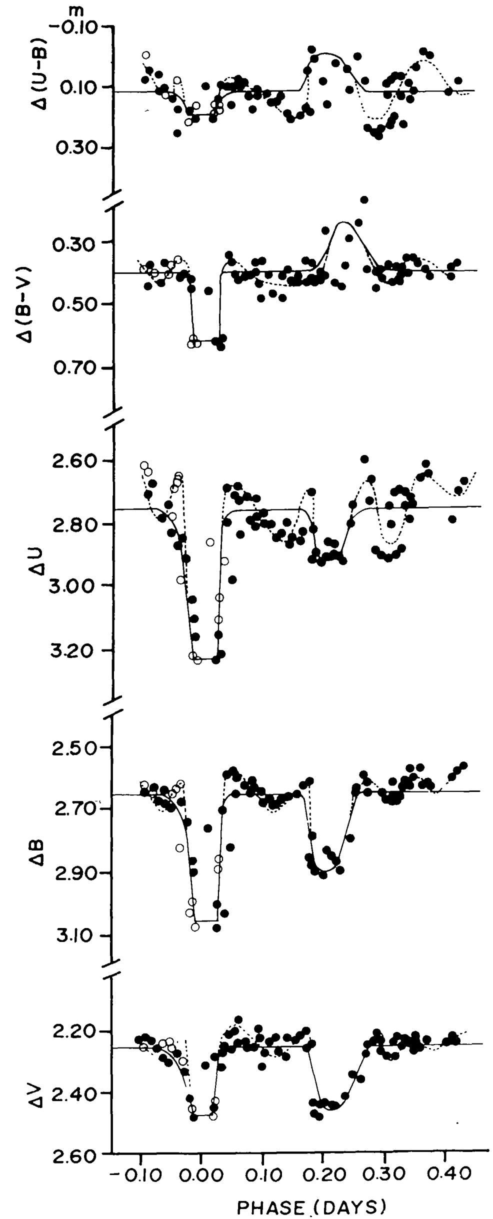

Fig. 1. Light and colour curves of DX Aqr. The solid lines indicate the smoothened light and colour curves. The dotted lines represent the superposed variations. Solid circles represent the observed points and open circles represent the reflected points.

The primary eclipse is a total occultation and the secondary eclipse is an annular one. The durations of totality of primary minimum in *U*, *B*, and *V* filters are $0^{d}.045$, $0^{d}.040$, and $0^{d}.035$. The average being $0^{d}.04$, which is $0^{d}.01$ less than the earlier reported.

Present light curves do not enable us to say whether the system belongs to EA or EB type.

TABLE V

Standard B magnitudes of DX Aqr

J.D. (Hel.)	Phase	Δm	J.D. (Hel.)	Phase	Δm	J.D. (Hel.)	Phase	Δm
2444899.1079	$-0\overset{d}{.}1456$	$2\overset{m}{.}495$	904.2561	$0\overset{d}{.}4068$	$2\overset{m}{.}564$	927.1976	$0\overset{d}{.}3084$	$2\overset{m}{.}685$
.1132	−0.1403	2.565	.2644	0.4151	2.561	.2027	0.3135	2.667
.1334	−0.1201	2.651	907.1041	0.0305	2.702	.2128	0.3236	2.611
.1407	−0.1128	2.807	.1112	0.0376	2.586	.2184	0.3284	2.558
.1478	−0.1057	2.763	.1171	0.0435	2.576	.2277	0.3385	2.601
.1583	−0.0952	2.641	.1252	0.0516	2.597	.2342	0.3450	2.561
.1668	−0.0867	2.634	.1305	0.0569	2.649	936.1060	0.0049	2.765
.1750	−0.0785	2.668	.1387	0.0651	2.639	.1188	0.0177	3.082
.1806	−0.0729	2.674	.1423	0.0687	2.656	.1249	0.0238	3.012
.1906	−0.0629	2.647	.1524	0.0788	2.641	.1372	0.0261	3.025
.1980	−0.0555	2.695	.1611	0.0875	2.645	.1463	0.0453	2.828
.2074	−0.0461	2.628	.1668	0.0932	2.673	.1582	0.0572	2.631
.2145	−0.0390	2.677	.1764	0.1028	2.669	.1792	0.0782	2.605
.2220	−0.0315	2.736	.1843	0.1107	2.698	.1899	0.0889	2.669
.2311	−0.0224	2.861	907.1938	0.1202	2.683	944.1007	0.1695	2.866
.2360	−0.0175	2.896	.1998	0.1262	2.669	.1108	0.1796	2.902
904.1242	0.2649	2.643	.2091	0.1355	2.671	.1174	0.1862	2.904
.1579	0.2986	2.653	.2160	0.1424	2.647	.1270	0.1958	2.826
.1662	0.3069	2.615	.2250	0.1514	2.643	.1331	0.2019	2.850
.1761	0.3168	2.624	.2305	0.1569	2.625	.1428	0.2116	2.863
904.1819	0.3226	2.641	.2389	0.1653	2.606	.1517	0.2205	2.897
.1934	0.3341	2.628	.2446	0.1700	2.787	.1625	0.2313	2.792
.1992	0.3499	2.624	927.1673	0.2781	2.645	.1722	0.2410	2.628
.2097	0.3604	2.628	.1729	0.2837	2.645	.1874	0.2562	2.591
.2164	0.3671	2.639	.1807	0.2915	2.672	.1943	0.2631	2.419
.2507	0.4014	2.596	.1880	0.2978	2.668			

3. Epoch and Period

The epochs of two primary and a secondary minima have been determined with a graphical accuracy of $0\overset{d}{.}0007$, and are listed in Table I alongwith the O–C values based on Strohmeier's (1966) epoch and the present period. These O–C values suggest that the primary minimum falls nearly at its expected position, while the secondary minimum is shifted earlier by $0\overset{d}{.}03$ from its expected position. In the earlier photometry, the primary minimum was shifted earlier and the secondary minimum later by $0\overset{d}{.}03$. The period of the system DX Aqr has been derived on the same lines as reported earlier (cf. Srivastava and Sinha, 1985), and new ephemeris are given as under:

$$\text{Pr. Min.} = \text{J.D. } 2436814.440 + 0\overset{d}{.}4605944E \quad (\pm 0\overset{d}{.}0000010)\,.$$

4. Colour and Luminosity Classification

The colour indices $[\Delta(B - V)$ and $\Delta(U - B)]$ throughout the cycle are given in Table VII and are plotted on the top of Figure 1. Differential colour indices derived from the two photometries are given in Table III. Due to a number of complications, including large

TABLE VI

Standard V magnitudes of DX Aqr

J.D. (Hel.)	Phase	Δm	J.D. (Hel.)	Phase	Δm	J.D. (Hel.)	Phase	Δm
2444899.1083	$-0^d.1452$	$2^m.104$	904.2566	$0^d.4073$	$2^m.238$	927.1980	$0^d.3088$	$2^m.292$
.1137	−0.1398	2.192	.2647	0.4154	2.247	.2034	0.3142	2.252
.1337	−0.1198	2.256	907.1046	0.0310	2.283	.2132	0.3240	2.231
.1411	−0.1124	2.242	.1116	0.0380	2.253	.2187	0.3287	2.230
.1481	−0.1054	2.231	.1173	0.0437	2.217	.2284	0.3392	2.273
.1585	−0.0950	2.214	.1257	0.0521	2.201	.2347	0.3455	2.216
.1673	−0.0862	2.233	.1308	0.0572	2.235	936.1063	0.0052	2.317
.1755	−0.0780	2.257	.1391	0.0655	2.239	.1193	0.0182	2.466
.1810	−0.0725	2.251	.1428	0.0692	2.258	.1252	0.0241	2.289
.1915	−0.0620	2.288	.1529	0.0793	2.256	.1384	0.0266	2.323
.1985	−0.0550	2.305	.1616	0.0880	2.221	.1468	0.0458	2.266
.2077	−0.0458	2.235	.1673	0.0937	2.324	.1585	0.0575	2.166
.2148	−0.0387	2.275	.1770	0.1034	2.277	.1797	0.0787	2.249
.2223	−0.0312	2.337	.1849	0.1113	2.241	.1904	0.0894	2.191
.2314	−0.0221	2.428	.1942	0.1206	2.221	944.1011	0.1699	2.443
.2363	−0.0172	2.480	.2001	0.1265	2.269	.1111	0.1799	2.484
904.1246	0.2653	2.261	.2097	0.1361	2.291	.1177	0.1865	2.487
.1589	0.2996	2.291	.2166	0.1430	2.229	.1273	0.1964	2.443
.1668	0.3075	2.251	.2254	0.1518	2.229	.1336	0.2024	2.445
.1766	0.3173	2.229	.2310	0.1574	2.226	.1432	0.2120	2.438
.1824	0.3231	2.265	.2393	0.1655	2.261	.1522	0.2210	2.468
.1938	0.3345	2.250	.2450	0.1704	2.258	.1628	0.2316	2.421
.1999	0.3506	2.244	927.1676	0.2784	2.206	.1727	0.2415	2.348
.2102	0.3609	2.255	.1726	0.2844	2.267	.1879	0.2565	2.368
.2168	0.3675	2.244	.1812	0.2920	2.273	.1946	0.2635	2.269
.2512	0.4019	2.244	.1885	0.2983	2.269			

scatter in U observations and contamination by visual companion, it is difficult to fix the colour indices of the system and the comparison star. Thus, for the sake of simplicity, it is assumed that the colour indices of the comparison star do not alter the colour indices of the variable. Such assumption places the spectral classes of the system DX Aqr in the vicinity of spectral classes of the system given by Olsen (1976) from his photometry. However, the complications and the above mentioned limitations allow us only to say that the spectral classes given in Tables II and III are tentative.

The brightness and colour of the system is changing outside the eclipses and these brightness changes reflect in the same pattern both in the light and colour curves. Also, the colour curves show redder colours before first and after fourth contacts of both minima. The spectral classes of the components and the system, given in Table III, show some variation. We are unable to comment on their reality. In this context, it is important to remember that the spectral type of the visual companion has been variously given.

The results derived from the two photometries, attempted by the author, are presented in Table II for ready reference.

TABLE VII

Standard colour indices of DX Aqr

Phase	Δ(B − V)	Δ(U − B)
J.D. 2444899		
$-0^{\rm d}.146$	$0^{\rm m}.391$	$0^{\rm m}.102$
−0.140	0.373	0.103
−0.120	0.395	0.047
−0.113	0.565	0.062
−0.106	0.532	0.010
−0.095	0.427	0.068
−0.087	0.401	0.033
−0.079	0.411	0.039
−0.073	0.423	0.101
−0.063	0.359	0.087
−0.056	0.390	0.124
−0.046	0.393	0.238
−0.039	0.402	0.164
−0.032	0.399	0.174
−0.022	0.433	0.172
−0.018	0.416	0.201
J.D. 2444904		
0.265	0.382	0.073
0.299	0.362	0.081
0.307	0.364	0.069
0.317	0.395	0.058
0.323	0.376	0.054
0.334	0.378	0.078
0.350	0.380	0.022
0.360	0.373	−0.027
0.367	0.395	−0.013
0.401	0.395	0.119
0.407	0.365	0.084
0.415	0.352	0.066
J.D. 2444907		
0.031	0.419	0.087
0.038	0.333	0.099
0.044	0.359	0.091
0.052	0.396	0.106
0.057	0.414	0.066
0.065	0.400	0.073
0.069	0.398	0.127
0.079	0.385	0.167
0.088	0.424	0.122
0.093	0.349	0.112

Phase	Δ(B − V)	Δ(U − B)
$0^{\rm d}.103$	$0^{\rm m}.392$	$0^{\rm m}.114$
0.111	0.457	0.145
0.120	0.462	0.139
0.126	0.400	0.117
0.136	0.380	0.185
0.142	0.418	0.203
0.151	0.414	0.201
0.157	0.397	0.193
0.165	0.345	0.168
0.170	0.356	0.173
J.D. 2444927		
0.278	0.439	0.245
0.284	0.378	0.253
0.292	0.398	0.229
0.298	0.399	0.126
0.308	0.393	0.213
0.314	0.415	0.202
0.324	0.380	0.120
0.328	0.328	0.220
0.339	0.328	0.129
0.345	0.345	0.096
J.D. 2444936		
0.005	0.448	0.085
0.018	0.617	0.154
0.024	0.723	0.205
0.026	0.702	0.124
0.045	0.562	0.161
0.057	0.465	0.198
0.078	0.356	0.113
0.089	0.478	0.096
J.D. 2444944		
0.170	0.423	0.043
0.180	0.418	−0.018
0.186	0.417	0.018
0.196	0.383	0.080
0.202	0.251	0.155
0.212	0.425	−0.011
0.221	0.429	0.021
0.231	0.371	0.024
0.241	0.280	0.099
0.256	0.223	−0.008
0.263	0.150	0.228

5. Features of DX Aqr and Discussion

Compared to our earlier investigations (cf. Srivastava and Sinha, 1985), similar type of colour and light variations, and reddening of colour indices before first and after fourth contacts of both eclipses are the new features reported here.

In the light of our earlier photometry (cf. Srivastava and Sinha, 1985) and on comparing the results of the two photometries (Table II), we feel that the period, depths of primary and secondary minima, durations of minima and their shifts from their expected positions, duration of totality and colour indices are changing.

Variations in the light and colour indices, and changing period, duration of totality, depths and durations of minima suggest the presence of intrinsic light variations either due to one or both components of the system or alternatively the presence of a third body and possibly mass transfer between the components. The changing, unequal shifts and durations of primary and secondary minima indicate the presence of eccentricity or alternatively the existence of apsidal motion. Asymmetries in the branches of minima and changing 'out of eclipse' features call attention to the need of search for tidal intraction.

6. Conclusion

Present results reveal that the period of the system DX Aqr is nearly half the periods reported earlier by Strohmeier (1966), Olsen (1976), and Paffhausen and Seggewiss (1976). The amplitudes of primary and secondary minima, the durations of eclipses, the duration of totality and colour indices are changing. The light outside eclipses does not repeat its earlier pattern. The primary eclipse is a total occultation, and the eccentricity is a definite possibility. Light and colour variations outside the eclipses and the reddening of colours before first and after fourth contact of both eclipses in comparison to colours at maximum alongwith the rotation suggested by Olsen (1976) demand notice to search for the presence of an atmosphere, ring or shell around the components.

Present knowledge, available photometric and spectroscopic data desire patience for any detailed analysis of the system. Spectroscopic data and results given by Paffhausen and Seggewiss (1976) are insufficient as they do not reveal the characteristic features of individual components.

Future photometry from larger telescopes is desirable to eliminate the contamination of light from visual companion. New spectroscopic results are needed to understand the picture of individual components, colour variations and rotation. More observations around primary and secondary minima are required to confirm the reality of changing O–C residuals and their cause. Outside eclipse observations are desirable to confirm the type of the system and to locate tidal interaction effects.

Lastly, the present picture of the system is interesting but far from clear.

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