THE ECLIPSING BINARY UX MONOCEROTIS

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ABSTRACT

On twenty nights during the 1954–1955 season, 333 three-color photoelectric observations were made of UX Monocerotis. The observations confirm the variability of the A-type component. Calculations of the absolute dimensions of the system indicate that the A-type star is everluminous for its mass and that in the H-R diagram it falls in the region occupied by the RR Lyrae stars and cluster-type cepheids. A study of the light and color variations of the A-type star indicates the existence of two distinct types of variability—intrinsic variability and variable obscuration.

I. INTRODUCTION

The light-variability of the eclipsing binary UX Monocerotis was discovered by Miss Woods (1926) at the Harvard College Observatory. The geometrical elements of the system were derived by Mrs. Shapley (Woods and Shapley 1926). The primary eclipse was found to be total, with a range of 1.74 mag. The light-elements as derived by Hertzsprung from Miss Woods' observations were

$$\text{Primary minimum} = \text{JD } 2418602.84 + 5.90464E .$$

Because of the scatter of the observations, the light at maximum was suspected of variability. It is primarily due to this variability that the shallow secondary eclipse has never been satisfactorily observed. Wyse (1934), at the Lick Observatory, observed the spectrum of the system both in and outside eclipse. He concluded that the star which is eclipsed at primary minimum has spectral type A5 and the eclipsing star is dG1p. Gaposchkin (1947) undertook a spectroscopic investigation of the system at the McDonald Observatory. The spectrum was found to be peculiar in many ways. The Ca II resonance lines and the hydrogen absorption lines undergo marked changes with the phase and from cycle to cycle. Hydrogen appears in emission and varies in strength with the phase. Also, the Ca II and hydrogen absorption lines indicated a decidedly larger velocity amplitude than did the metallic lines. Struve (1947) made a new spectroscopic investigation of UX Mon based on 152 spectrograms taken at the McDonald Observatory. He confirmed the spectroscopic peculiarities discovered by Gaposchkin and further found that noticeable spectral changes occur in time intervals of the order of 1 hour. Struve proposed a model in which he attributed the strange behavior of the hydrogen and Ca II absorption lines to gas streaming and prominence action above the surfaces of both stars. The largest peculiar velocities are of the order of 200 km/sec. It was also discovered that the hydrogen emission seems to be confined to a region which is occulted toward the latter part of primary minimum. During the 1949–1950 season Hiltner, Struve, and Jose (1950) observed UX Mon photoelectrically in one color ($\lambda_{\text{eff}} = 5300$ A) at the McDonald Observatory. The observations confirmed the suspicion of Mrs. Shapley that the maximum light fluctuates. The variations did not appear to be present during primary minimum, indicating that the variability is associated with the brighter, A-type component which is being eclipsed.

II. THE OBSERVATIONS

The spectroscopic investigation by Struve and the photoelectric observations by Hiltner *et al.* have indicated that it might be profitable to study the nature of the short-period light and color variations of UX Mon. This is the primary purpose of the present investigation. On twenty nights from December 7, 1954, to February 15, 1955, a total of 333 photometric observations of UX Mon was made in each of three colors—blue, yellow, and ultraviolet. All observations were made with a photoelectric photometer attached to the 36-inch Crossley reflector of the Lick Observatory. The light-receiver was an RCA 1P21 photomultiplier tube, and the filters were 2-mm GG-14 (yellow), 0.4-mm C-3060 plus 1-mm BG-12 (blue), and C-9863 (ultraviolet). The comparison stars observed were the same as those used by Hiltner, i.e., HD 65939 and HD 65779. In addition, 22 Morgan and Johnson photometric and spectral-type standard stars were observed. The observations of UX Mon are given in Table 1. The first column of the table gives the phase as computed on the basis of the ephemeris,

$$\text{Primary minimum} = \text{JD } 2435129.722 + 5.904604E\,.$$

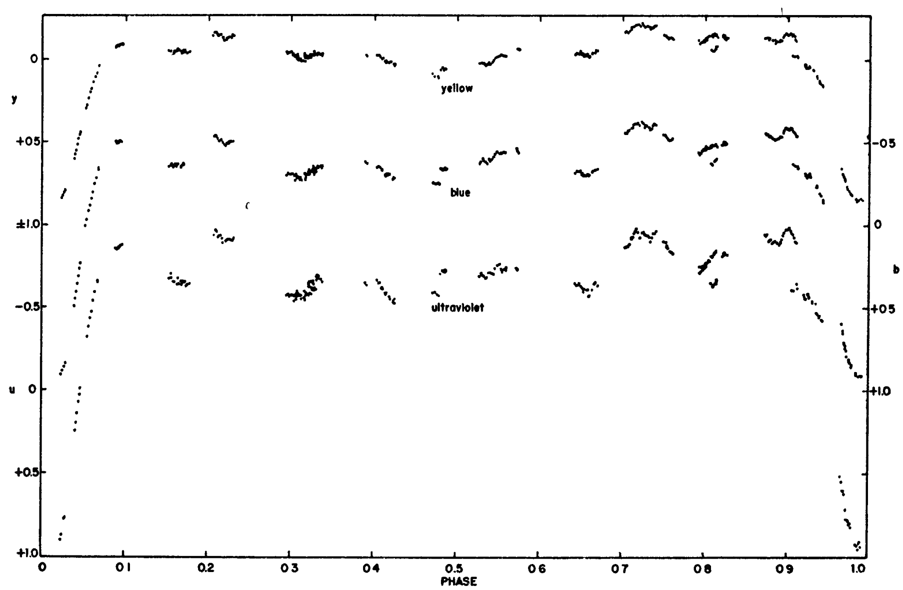

FIG. 1.—Three-color photoelectric observations of UX Monocerotis

The next three columns of the table give the blue, yellow, and ultraviolet magnitudes of the variable as compared to HD 65939. The observations have been plotted in Figure 1. The observations of the color standards indicate that the instrumental color system is essentially the same as the U, B, V system except for zero point. The transformations are

$$B - V = (b - y)_i + 0.573 \qquad \text{and} \qquad U - B = (u - b)_i - 0.737\,.$$

The colors of HD 65939 on the instrumental system are $(b - y)_i = +0.162$ and $(u - b)_i = +0.963$.

III. DISCUSSION

The derivation of the geometrical elements of UX Mon from the present observations has already been published (Lynds 1956). The adopted values for the elements are $k = 0.522$, $r_g = 0.358$, and $i = 83\overset{\circ}{.}6$, where k is the ratio of the radii, r_g is the radius of the larger component in terms of the separation of the stars, and i is the inclination of the orbit. The larger of the two components is the fainter, G-type star. These elements, when combined with the spectroscopic elements by Struve, yield for the absolute dimensions of the system, $R_A = 4.4\,R_\odot$, $R_G = 8.4\,R_\odot$, $M_A = 1.5\,M_\odot$, and $M_G = 3.4\,M_\odot$. A cross-

1957ApJ...126...69L

TABLE 1

THREE-COLOR PHOTOELECTRIC OBSERVATIONS OF UX MONOCEROTIS

Phase	b	y	u	Phase	b	y	u	Phase	b	y	u
8 Dec 1954				3 Jan 1955				8 Jan 1955			
0.4026	-0.351	-0.027	-0.676	0.8200	-0.489	-0.146	-0.812	0.6596	-0.306	-0.026	-0.577
.4053	-0.352	-0.023	-0.649	.8217	-0.505	-0.154	-0.836	.6627	-0.326	-0.042	-0.610
.4059	-0.349	-0.019	-0.650	.8222	-0.493	-0.139	-0.830	.6634	-0.332	-0.047	-0.611
.4082	-0.333	-0.005	-0.617	.8225	-0.493	-0.138	-0.820	.6663	-0.336	-0.046	-0.640
.4086	-0.338	-0.005	-0.621	.8229	-0.506	-0.148	-0.837	.6671	-0.336	-0.059	-0.654
.4092	-0.334	-0.006	-0.622	.8244	-0.494	-0.132	-0.824	0.6703	-0.342	-0.060	-0.635
.4098	-0.334	-0.007	-0.618	.8249	-0.506	-0.141	-0.829	9 Jan 1955			
.4124	-0.308	+0.010	-0.592	0.8267	-0.498	-0.137	-0.823	0.8067	-0.377	-0.068	-0.651
.4130	-0.303	+0.022	-0.578	4 Jan 1955				.8089	-0.376	-0.063	-0.624
.4137	-0.310	+0.011	-0.589	0.9652	+0.589	+0.651	+0.512	.8096	-0.373	-0.060	-0.638
.4142	-0.312	+0.009	-0.592	.9668	+0.631	+0.680	+0.543	.8120	-0.396	-0.076	-0.648
.4166	-0.309	+0.018	-0.565	.9672	+0.647	+0.684	+0.596	.8125	-0.397	-0.084	-0.647
.4172	-0.311	+0.016	-0.564	.9686	+0.705	+0.699	+0.593	.8132	-0.405	-0.086	-0.673
.4178	-0.306	+0.015	-0.568	.9691	+0.714	+0.725	+0.600	0.8138	-0.407	-0.085	-0.666
.4184	-0.308	+0.016	-0.549	.9694	+0.719	+0.710	+0.600	11 Jan 1955			
.4225	-0.291	+0.029	-0.540	.9699	+0.738	+0.736	+0.624	0.1514	-0.354	-0.051	-0.674
.4231	-0.285	+0.037	-0.534	.9715	+0.754	+0.756	+0.714	.1536	-0.357	-0.050	-0.702
.4238	-0.284	+0.037	-0.526	.9720	+0.787	+0.773	+0.768	.1543	-0.365	-0.048	-0.673
0.4240	-0.284	+0.033	-0.551	.9744	+0.813	+0.782	+0.769	.1568	-0.351	-0.038	-0.653
11 Dec 1954				.9748	+0.805	+0.785	+0.782	.1578	-0.361	-0.048	-0.651
0.9024	-0.374	-0.035	-0.614	.9752	+0.830	+0.801	+0.802	.1585	-0.367	-0.053	-0.653
.9079	-0.365	-0.031	-0.611	.9755	+0.831	+0.798	+0.804	.1610	-0.350	-0.047	-0.639
.9112	-0.366	-0.033	-0.653	.9772	+0.842	+0.812	+0.792	.1618	-0.367	-0.060	-0.680
.9120	-0.350	-0.021	-0.619	.9775	+0.851	+0.813	+0.823	.1629	-0.366	-0.058	-0.638
.9199	-0.322	+0.021	-0.580	.9828	+0.884	+0.831	+0.810	.1660	-0.350	-0.052	-0.649
.9204	-0.307	+0.031	-0.560	.9833	+0.901	+0.845	+0.924	.1667	-0.353	-0.040	-0.634
.9211	-0.308	+0.026	-0.568	.9861	+0.904	+0.836	+0.932	.1671	-0.357	-0.041	-0.660
.9217	-0.297	+0.038	-0.559	.9867	+0.906	+0.840	+0.957	.1696	-0.366	-0.056	-0.647
.9244	-0.312	+0.044	-0.584	.9884	+0.903	+0.831	+0.915	.1703	-0.360	-0.054	-0.654
.9251	-0.320	+0.029	-0.589	.9889	+0.905	+0.831	+0.905	.1729	-0.362	-0.046	-0.630
.9256	-0.310	+0.036	-0.577	0.9905	+0.907	+0.841	+0.932	.1736	-0.335	-0.038	-0.635
.9261	-0.301	+0.037	-0.566	6 Jan 1955				0.1764	-0.353	-0.046	-0.641
.9267	-0.297	+0.040	-0.567	0.2941	-0.296	-0.042	-0.574	12 Jan 1955			
.9273	-0.299	+0.036	-0.567	.2958	-0.314	-0.035	-0.582	0.3041	-0.272	-0.007	-0.569
.9299	-0.276	+0.051	-0.548	.2972	-0.309	-0.043	-0.566	.3065	-0.283	-0.008	-0.595
.9303	-0.280	+0.054	-0.537	.2988	-0.302	-0.044	-0.574	.3072	-0.286	0.000	-0.584
.9307	-0.279	+0.055	-0.546	.3006	-0.304	-0.027	-0.578	.3099	-0.279	+0.004	-0.568
.9344	-0.251	+0.088	-0.527	.3010	-0.310	-0.035	-0.575	.3107	-0.284	-0.001	-0.569
.9351	-0.233	+0.102	-0.476	.3026	-0.293	-0.018	-0.540	.3112	-0.282	+0.011	-0.574
.9376	-0.199	+0.116	-0.464	.3030	-0.299	-0.026	-0.567	.3119	-0.272	+0.011	-0.550
.9380	-0.199	+0.125	-0.453	.3048	-0.298	-0.023	-0.558	.3159	-0.277	+0.009	-0.545
.9386	-0.185	+0.134	-0.447	.3053	-0.306	-0.024	-0.576	.3169	-0.284	-0.009	-0.590
.9391	-0.186	+0.131	-0.454	.3058	-0.298	-0.029	-0.583	.3197	-0.315	-0.007	-0.629
.9414	-0.161	+0.141	-0.434	.3062	-0.300	-0.022	-0.566	.3204	-0.330	-0.019	-0.647
0.9424	-0.144	+0.151	-0.426	.3147	-0.304	-0.021	-0.558	.3211	-0.331	-0.023	-0.654
3 Jan 1955				.3152	-0.310	-0.038	-0.597	.3218	-0.321	-0.017	-0.625
0.7916	-0.443	-0.126	-0.751	.3171	-0.300	-0.024	-0.575	.3247	-0.335	-0.028	-0.655
.7934	-0.430	-0.104	-0.713	.3175	-0.308	-0.024	-0.589	.3253	-0.335	-0.033	-0.650
.7940	-0.437	-0.109	-0.721	.3192	-0.303	-0.020	-0.577	.3259	-0.353	-0.040	-0.660
.7955	-0.439	-0.112	-0.745	.3197	-0.305	-0.017	-0.572	.3266	-0.343	-0.033	-0.640
.7960	-0.448	-0.112	-0.736	.3219	-0.310	-0.021	-0.587	.3302	-0.344	-0.033	-0.666
.7965	-0.459	-0.125	-0.757	.3224	-0.309	-0.027	-0.583	.3309	-0.352	-0.040	-0.687
.7970	-0.466	-0.124	-0.758	.3241	-0.322	-0.032	-0.616	.3315	-0.353	-0.036	-0.680
.7991	-0.461	-0.118	-0.741	.3246	-0.319	-0.029	-0.605	.3321	-0.349	-0.037	-0.693
.7995	-0.466	-0.134	-0.762	.3265	-0.311	-0.027	-0.605	.3327	-0.346	-0.038	-0.689
.8000	-0.462	-0.131	-0.771	.3269	-0.319	-0.032	-0.616	.3333	-0.347	-0.033	-0.680
.8005	-0.463	-0.126	-0.750	.3291	-0.332	-0.030	-0.607	.3358	-0.359	-0.031	-0.671
.8010	-0.476	-0.138	-0.772	0.3295	-0.319	-0.024	-0.609	.3365	-0.349	-0.026	-0.653
.8015	-0.472	-0.143	-0.777	7 Jan 1955				0.3373	-0.358	-0.034	-0.654
.8032	-0.470	-0.145	-0.778	0.4700	-0.260	+0.085	-0.590	13 Jan 1955			
.8037	-0.469	-0.149	-0.788	.4728	-0.253	+0.103	-0.591	0.4795	-0.342	+0.063	-0.710
.8042	-0.472	-0.146	-0.785	.4761	-0.255	+0.103	-0.581	.4818	-0.340	+0.047	-0.727
.8048	-0.473	-0.147	-0.786	0.4771	-0.249	+0.114	-0.572	.4826	-0.341	+0.062	-0.720
.8070	-0.481	-0.149	-0.814	8 Jan 1955				.4846	-0.341	+0.055	-0.722
.8075	-0.476	-0.154	-0.809	0.6422	-0.315	-0.034	-0.643	.4851	-0.346	+0.050	-0.726
.8078	-0.478	-0.148	-0.820	.6443	-0.326	-0.043	-0.635	.4859	-0.343	+0.061	-0.717
.8083	-0.488	-0.161	-0.819	.6464	-0.325	-0.038	-0.635	0.4866	-0.341	+0.057	-0.727
.8101	-0.488	-0.161	-0.831	.6474	-0.324	-0.042	-0.646	3 Feb 1955			
.8105	-0.485	-0.159	-0.836	.6480	-0.327	-0.053	-0.645	0.0225	+0.906	+0.835	+0.895
.8110	-0.485	-0.159	-0.836	.6499	-0.309	-0.034	-0.629	.0242	+0.877	+0.822	+0.867
.8114	-0.489	-0.153	-0.836	.6506	-0.317	-0.038	-0.628	.0262	+0.856	+0.800	+0.768
.8121	-0.494	-0.159	-0.845	.6527	-0.300	-0.025	-0.600	.0279	+0.837	+0.793	+0.761
.8125	-0.490	-0.160	-0.842	.6535	-0.307	-0.035	-0.618	.0513	+0.006	+0.292	-0.257
.8129	-0.486	-0.151	-0.838	.6557	-0.304	-0.027	-0.613	.0531	-0.033	+0.272	-0.324
.8134	-0.489	-0.159	-0.847	.6566	-0.312	-0.035	-0.605	.0548	-0.080	+0.231	-0.386
0.8151	-0.480	-0.143	-0.817	0.6587	-0.300	-0.021	-0.572	0.0564	-0.117	+0.196	-0.434

TABLE 1 - CONTINUED

Phase	b	y	u
3 Feb 1955			
0.0583	-0.160	+0.173	-0.473
.0603	-0.199	+0.137	-0.540
.0624	-0.248	+0.105	-0.596
.0645	-0.282	+0.081	-0.541
.0666	-0.331	+0.037	-0.666
0.0671	-0.344	+0.040	-0.657
4 Feb 1955			
0.2059	-0.532	-0.146	-0.938
.2075	-0.537	-0.164	-0.964
.2089	-0.535	-0.163	-0.956
.2106	-0.523	-0.150	-0.927
.2124	-0.506	-0.147	-0.932
.2145	-0.509	-0.149	-0.931
.2159	-0.495	-0.129	-0.913
.2175	-0.485	-0.114	-0.889
.2205	-0.486	-0.117	-0.902
.2219	-0.490	-0.126	-0.907
.2235	-0.492	-0.133	-0.910
.2250	-0.498	-0.140	-0.911
.2266	-0.498	-0.132	-0.906
.2283	-0.500	-0.148	-0.902
0.2300	-0.502	-0.142	-0.922
5 Feb 1955			
0.3891	-0.383	-0.025	-0.652
0.3908	-0.372	-0.014	-0.634
6 Feb 1955			
0.5269	-0.371	+0.023	-0.690
.5288	-0.385	+0.022	-0.709
.5304	-0.399	+0.025	-0.698
.5321	-0.391	+0.027	-0.695
.5342	-0.380	+0.031	-0.677
.5360	-0.378	+0.024	-0.686
.5379	-0.398	+0.018	-0.711
.5398	-0.389	+0.026	-0.712
.5418	-0.394	+0.011	-0.707
.5439	-0.413	-0.003	-0.700
.5460	-0.431	-0.016	-0.735
.5480	-0.439	-0.021	-0.755
.5508	-0.434	-0.026	-0.768
.5531	-0.439	-0.028	-0.734
.5549	-0.437	-0.026	-0.724
0.5567	-0.441	-0.023	-0.729

Phase	b	y	u
6 Feb 1955			
0.5587	-0.440	-0.023	-0.742
.5720	-0.464	-0.066	-0.738
.5730	-0.447	-0.067	-0.728
0.5741	-0.440	-0.060	-0.735
7 Feb 1955			
0.7029	-0.558	-0.175	-0.865
.7045	-0.559	-0.176	-0.873
.7062	-0.572	-0.174	-0.878
.7082	-0.577	-0.181	-0.888
.7099	-0.593	-0.199	-0.927
.7113	-0.590	-0.191	-0.931
.7127	-0.612	-0.206	-0.947
.7146	-0.615	-0.214	-0.965
.7163	-0.618	-0.217	-0.980
.7183	-0.619	-0.219	-0.962
.7207	-0.607	-0.207	-0.927
.7226	-0.626	-0.226	-0.955
.7247	-0.617	-0.213	-0.957
.7265	-0.596	-0.205	-0.945
.7282	-0.606	-0.208	-0.940
.7299	-0.605	-0.209	-0.939
.7317	-0.595	-0.201	-0.930
.7336	-0.584	-0.197	-0.905
.7353	-0.589	-0.198	-0.924
.7370	-0.610	-0.204	-0.952
.7386	-0.620	-0.210	-0.952
0.7403	-0.615	-0.211	-0.968
8 Feb 1955			
0.8722	-0.555	-0.143	-0.947
.8737	-0.556	-0.139	-0.942
.8750	-0.554	-0.138	-0.946
.8764	-0.540	-0.127	-0.908
.8779	-0.541	-0.134	-0.914
.8795	-0.536	-0.124	-0.920
.8810	-0.532	-0.126	-0.898
.8829	-0.528	-0.125	-0.906
.8843	-0.521	-0.111	-0.907
.8856	-0.532	-0.120	-0.900
.8869	-0.529	-0.117	-0.888
.8884	-0.532	-0.121	-0.881
0.8898	-0.542	-0.124	-0.904

Phase	b	y	u
8 Feb 1955			
0.8910	-0.538	-0.121	-0.899
.8923	-0.540	-0.122	-0.916
.8940	-0.565	-0.145	-0.940
.8953	-0.580	-0.156	-0.962
.8965	-0.595	-0.165	-0.980
.8979	-0.592	-0.162	-0.977
.8991	-0.590	-0.161	-0.980
.9005	-0.584	-0.157	-0.981
.9020	-0.590	-0.163	-0.987
.9037	-0.592	-0.165	-0.970
.9050	-0.581	-0.154	-0.960
.9064	-0.572	-0.161	-0.949
.9078	-0.565	-0.150	-0.930
.9091	-0.546	-0.129	-0.906
0.9104	-0.546	-0.123	-0.902
9 Feb 1955			
0.0379	+0.492	+0.597	+0.303
.0391	+0.447	+0.570	+0.250
.0403	+0.405	+0.548	+0.194
.0417	+0.357	+0.513	+0.139
.0431	+0.314	+0.480	+0.072
.0444	+0.269	+0.456	+0.026
0.0456	+0.236	+0.441	-0.011
13 Feb 1955			
0.7490	-0.549	-0.154	-0.902
.7514	-0.548	-0.147	-0.898
.7526	-0.536	-0.142	-0.870
.7537	-0.533	-0.139	-0.880
.7550	-0.522	-0.128	-0.860
.7570	-0.517	-0.138	-0.843
.7582	-0.518	-0.141	-0.839
.7595	-0.530	-0.136	-0.840
0.7609	-0.525	-0.135	-0.831
15 Feb 1955			
0.0873	-0.498	-0.076	-0.859
.0888	-0.493	-0.083	-0.849
.0901	-0.497	-0.085	-0.855
.0914	-0.498	-0.085	-0.859
.0928	-0.504	-0.090	-0.867
.0942	-0.504	-0.095	-0.876
0.0956	-0.502	-0.093	-0.879

TABLE 2

AVERAGE MAGNITUDES AND COLORS OF THE A STAR

Date	b	y	u	b-y	u-b	Date	b	y	u	b-y	u-b
3 Jan	-0.079	+0.494	-0.524	-0.573	-0.445	4 Feb	-0.118	+0.504	-0.678	-0.622	-0.560
6 Jan	+0.171	+0.704	-0.239	-0.533	-0.410	5 Feb	+0.041	+0.676	-0.338	-0.635	-0.379
8 Jan	+0.144	+0.666	-0.300	-0.522	-0.444	7 Feb	-0.248	+0.395	-0.692	-0.643	-0.444
9 Jan	+0.047	+0.616	-0.331	-0.569	-0.378	8 Feb	-0.213	+0.458	-0.709	-0.671	-0.496
11 Jan	+0.090	+0.654	-0.348	-0.564	-0.438	13 Feb	-0.152	+0.507	-0.604	-0.659	-0.452
12 Jan	+0.149	+0.719	-0.306	-0.570	-0.455	15 Feb	-0.142	+0.535	-0.633	-0.677	-0.491

section of the system in the plane of rotation is illustrated schematically in Figure 2, in which L_2 represents the interior Lagrangian solution to the three-body problem. The curve passing through L_2 represents a Jacobian surface. In view of Struve's hypothesis of the presence of prominence action and gas streaming in the system, it is interesting to compute the velocity of escape from either of the stars. The velocity considered is that which a particle at the surface of each star must have so that its zero-velocity surface (Moulton 1914) is identical with the critical Jacobian surface shown in Figure 2. It is found that the velocities of escape from the A star and G star are 194 and 175 km/sec, respectively. These velocities are referred to the rotating frame of reference, and the actual observed velocities will be larger or smaller, depending on position in the system and orientation of the velocity vector. However, it is clear that these velocities are of the same order of magnitude as the prominence velocities observed by Struve.

It is readily apparent from Figure 1 that the variations in brightness of the A-type star render the system somewhat intractable. However, there is some information available concerning the nature of the G star and the average state of the A star. The brightness of the outer face of the G-type star is given by the brightness of the system at primary minimum. From the present observations we have, for primary minimum, $y = +0.837$, $b = +0.905$, and $u = +0.929$, where y, b, and u represent magnitudes relative to HD 65939. The corresponding colors relative to HD 65939 are $b - y = +0.068$ and $u - b = +0.024$. When transformed to the U, B, V system, these become $B - V = +0.803$ and $U - B = +0.250$. The determination of the light and color of the A-type star offers additional difficulties. We must know how much of the combined light outside eclipse is due to the G star. As a first approximation, we can simply subtract the light of the outer face of the G star from the average light of the system outside eclipse. If this is done, we find, for the A star, $y = +0.519$, $B - V = +0.160$, and $U - B = -0.200$. To improve this estimate, we should take into account the influence on the G star of geometrical ellipticity, gravity darkening, and reflection effect. Since in the present case there is no way of determining and including these effects (Lynds 1956), either empirically or theoretically, it will suffice to attempt a correction for one of the larger effects, photometric ellipticity (Russell and Merrill 1952), to give us a measure of how much we can expect our results to be in error. Let us assume that the light of the G star varies according to

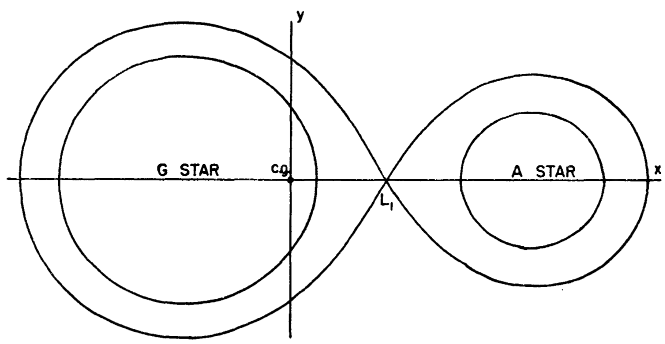

FIG. 2 —Cross-section of UX Monocerotis in the plane of rotation

$$l_G = a_0 + a_2 \cos 2\theta , \qquad \text{where} \qquad a_2 = -\frac{a_0}{(4 - Nz)} Nz , \tag{1}$$

in which θ is the phase angle, z is the geometrical ellipticity, and N is the photometric ellipticity factor. The quantity z may be computed from equilibrium theory and the value of l_G may then be averaged for the non-eclipse light. If this average is compared to a similar average of the actual non-eclipse light of the system, we should have a measure of the brightness of the "average" A star. These calculations have been made using $N = 2.6$ for all three colors. The result is $y = +0.581$, $B - V = +0.130$, and $U - B = -0.212$ for the A star. We see that these values are only a little different from those found in the first approximation. Since the effect just considered is one of the larger perturbations, we may feel fairly confident that these latter values for the magnitude and colors of the A star are not too much in error. Certainly, the short-period fluctuations of the star are greater than the uncertainties of these estimates.

If we compare the foregoing colors of the A and G components with colors of standard stars by Morgan and Johnson, we find that neither of the stars has colors corresponding to main-sequence stars. This is illustrated in Figure 3. The co-ordinates used in the diagram are related to the instrumental colors by

$$(b - y)^* = (b - y)_i - 0.368 \quad \text{and} \quad (u - b)^* = (u - b)_i - 0.088 .$$

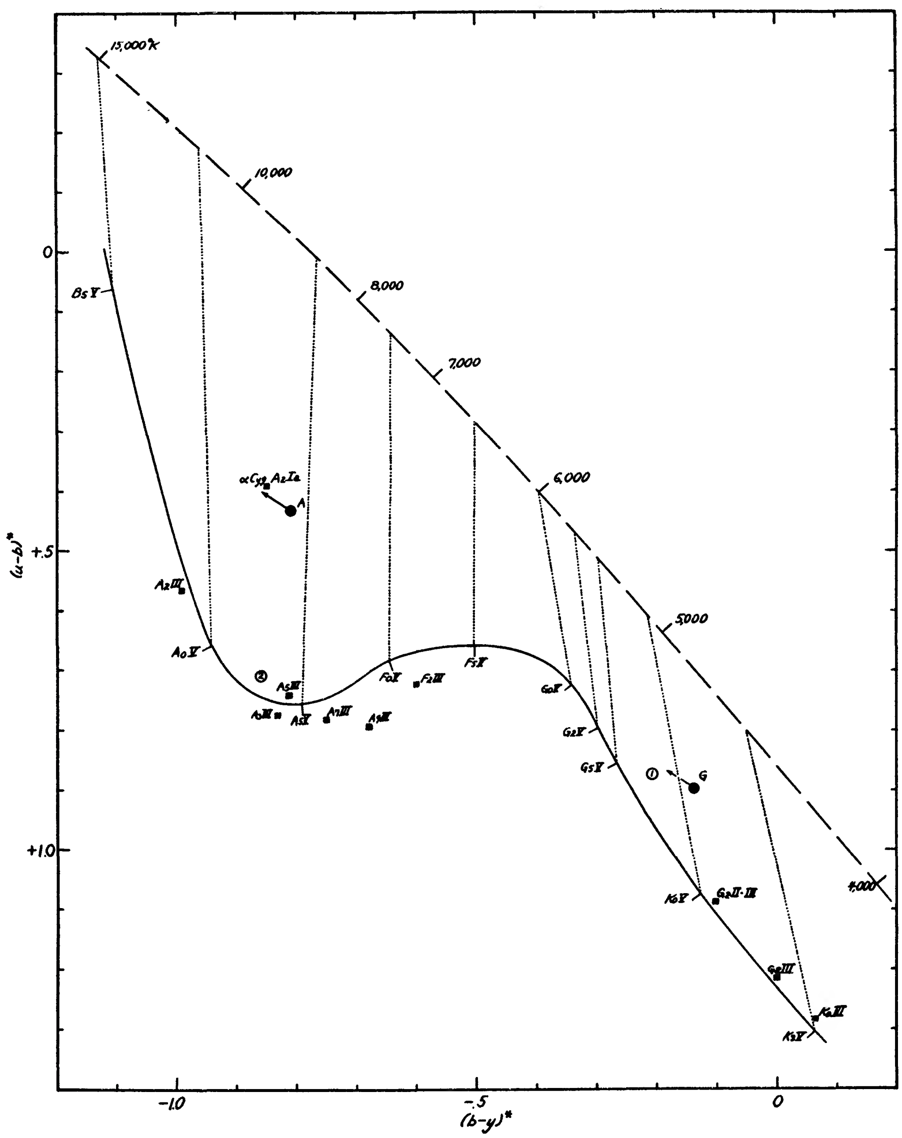

FIG. 3.—Two-color diagram, showing the location of the components of UX Monocerotis

The solid curve represents the Morgan and Johnson main sequence, and the dashed curve represents the colors of black bodies of various temperatures. The relation between the two curves depends on the solar energy-curve as determined by Pettit (1940) and the assumption that the sun has a spectral type of G2 V. The straight dotted lines connect points on the black-body curve with main-sequence spectral types of the same temperature on Kuiper's effective temperature scale (Keenan and Morgan 1951). The A and G components of UX Mon are plotted in Figure 3 as filled circles. The open circles represent the two comparison stars used in the present investigation. It is seen that both components of UX Mon and particularly the A star exhibit an apparent ultraviolet excess. The question arises as to what extent the system is influenced by interstellar reddening. According to Weaver (1955), the amount of interstellar extinction in the direction of the system probably does not exceed 0.5 mag/kpc in the photographic region. If we anticipate a later determination of the distance of the system, we can estimate the corresponding amount of reddening. The heads of the arrows in Figure 3 show the unreddened positions of the components under these assumptions. It is seen that we may be able in this way to account for the color of the G star, but the A star seems to have a real ultraviolet excess. This conclusion is borne out by the spectral types of the stars. Wyse classified the components of UX Mon as A5 and dG1p. A re-examination of the plates taken by Wyse reveals that the Sr II 4077 line in the G star's spectrum is strong enough relative to the iron lines to indicate luminosity class III. This point has also been noted by Struve. Gaposchkin classified the stars as A7p and G2p. Finally, the stars were classified by the author from the spectra taken by Struve; the resulting types are A5 III–IV and G2 III. These are quite consistent with the masses and dimensions of the components. Also, the spectral types, together with the measured colors, tend to indicate that the effects of reddening on the system are quite small and probably do not exceed the amount indicated in Figure 3. Consequently, an adjustment of the data for reddening does not seem justified at this time and will not be attempted.

The ultraviolet excess of the A star is at present an unexplained phenomenon. Although the A giants observed by Johnson do not seem to show an ultraviolet excess, the supergiants do. It is interesting that the colors of the A-type component of UX Mon are quite similar to the colors of the A2 I*a* supergiant, α Cygni. It cannot be maintained that the A star is a supergiant; however, it is suggested that the reason for the similarity is that the A star has an atmosphere closely resembling that of a supergiant, that is, one tenuous and extended enough that the role of neutral hydrogen as a source of continuous opacity is relatively suppressed. Additional support for this hypothesis is presented below.

If we could assume that the two components of UX Mon radiate like black bodies, we could derive from their relative brightness the difference between the reciprocal temperatures. Although this is a poor assumption when working in only one color, the average of such determinations in each of the three colors of the present observations should have some meaning, since these colors cover a considerable portion of the spectrum which is significant energywise. Such determinations have been made, with the result that $\Delta(1/T)$ is essentially the same for all three colors; the average is $\Delta(1/T) = 6 \times 10^{-5}\,^{\circ}\,K^{-1}$. This value is not entirely consistent with the spectral classifications adopted. The best compromise is to assign temperatures of 7770° and 5490° K to the A and G stars, respectively. On the temperature scale given by Keenan and Morgan (1951) these correspond to spectral types A9 and F9 III. This kind of disagreement between spectroscopic and photometric data is not uncommon. Several explanations for such discrepancies, some of which may be applicable to the present case, have been discussed by Wyse (1934). However, in UX Mon the most probable explanation is that the radiation at the photosphere of the A star is relatively dilute compared with that at the photosphere of the G star. This is, of course, consistent with the already noted ultraviolet excess of the A star.

In order to compute roughly the absolute magnitudes of the components of UX Mon, it should suffice to use the formula

$$M_v = C_v - 5 \log_{10}(R) + \frac{28400}{T} + x$$

(Goldberg and Aller 1943), where $C_v = -0.24$ and x is -0.10 and -0.01 for the A and G stars, respectively. The temperatures adopted for this purpose are 7770° and 5490° K for the A and G components, respectively. The resulting absolute magnitudes are $M_v(\mathrm{A}) = +0.10$ and $M_v(\mathrm{G}) = +0.36$. These values are probably correct to within a few tenths of a magnitude. Figure 4 gives a color-magnitude diagram adapted from the work of Johnson and Morgan (1953). The main sequence and the giant sequence are represented by the continuous curves; the dashed curve is a representation of the color-magnitude diagram of the globular cluster M3 as determined by Sandage (1953). The A- and G-type components of UX Mon have been plotted as filled circles. In view of the A star's variability, it is interesting that it falls so near the cluster-variable gap of M3. The luminosities just derived also indicate that the G star conforms very well to the

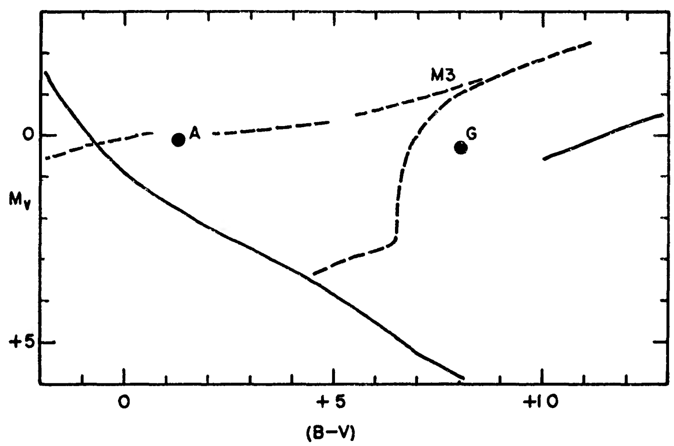

FIG. 4.—Color-luminosity diagram, showing the location of the components of UX Monocerotis

empirical mass-luminosity law, while the A star is overluminous. Finally, the distance of the system derived from the luminosities is approximately 530 parsecs, a visual extinction of 0.2 mag. having been taken into consideration.

IV. THE LIGHT-VARIATION OF THE A-TYPE COMPONENT

The non-eclipse light-variations of UX Mon are readily apparent in Figure 1. Of course, the variations of the A star are larger than those shown in the brightness of the system. The two most probable explanations for the variability of the A-type component are intrinsic variability and variable obscuration. The position of the star in the H-R diagram suggests the first explanation; the spectroscopic peculiarities of the system suggest the second. As an intrinsic variable, the A component would presumably be related to the RR Lyrae class of variables. If variable obscuration is the source of variability, we would expect it to arise in an inhomogeneous envelope surrounding the A star. Such an envelope could, in fact, be simply a variable extension to the atmosphere of the A star. In discussing the observational data in connection with these two hypotheses, it is convenient to divide the non-eclipse variations of UX Mon into two classes. First, there are the relatively small variations which occur in a few hours and may amount to 0.04 mag. in yellow light. Second, there are the larger variations which appear to take place from night to night and are sometimes larger than 0.1 mag. in yellow light.

In order to obtain the night-to-night variations of the A star, we average the observations of each night when the A star was not in eclipse. If we then remove the light of the G star by means of equation (1), we should have a good approximation to the average brightness of the A star for each observing run. Such values, given in magnitudes with respect to HD 65939, are listed in Table 2. For our present purpose the important aspect of the data is whether or not the color displays a relation to the light during the course of the variations. Therefore, in Figure 5, *a*, *b*, *c*, the $b - y$ color has been plotted against magnitude in all three colors for the nightly averages of the A star. It can be seen that there is in all three cases some evidence of a correlation between color and brightness, in the sense that the star appears to be bluer when it is bright. The correlation appears to be best in blue light. Thus the data are consistent with the hypothesis that the largest part of the variability is intrinsic. The dashed line in Figure 5, *b*, represents the average be-

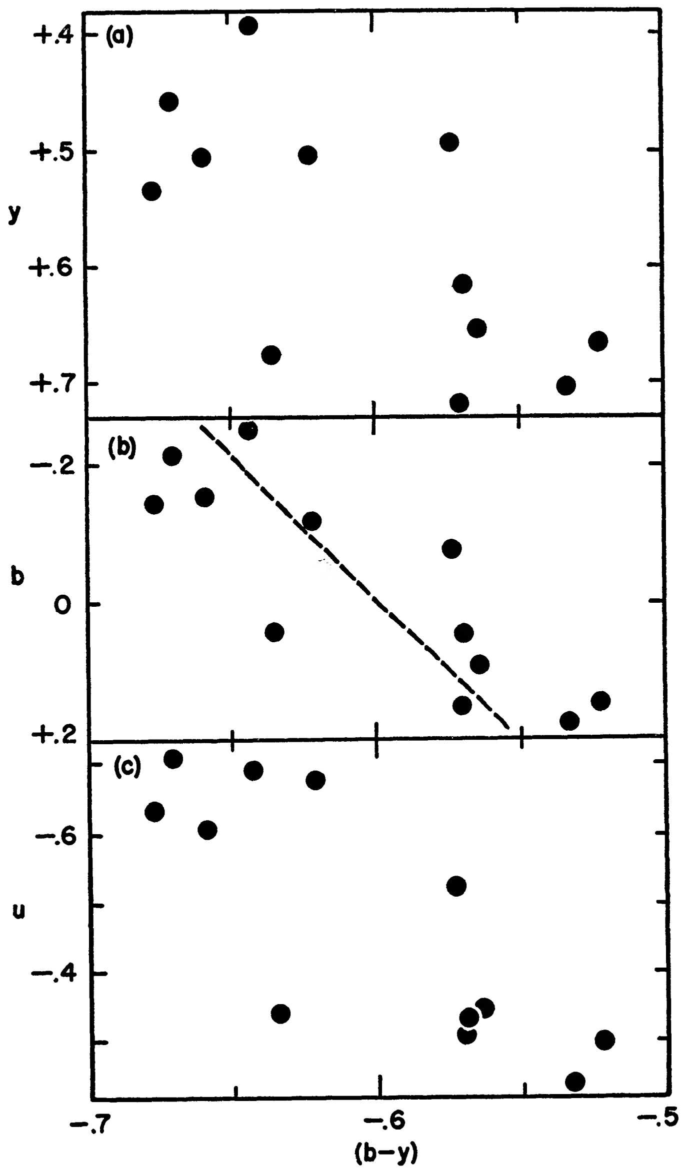

FIG. 5.—The correlation between magnitude and color of the A-type component. The values plotted are nightly averages.

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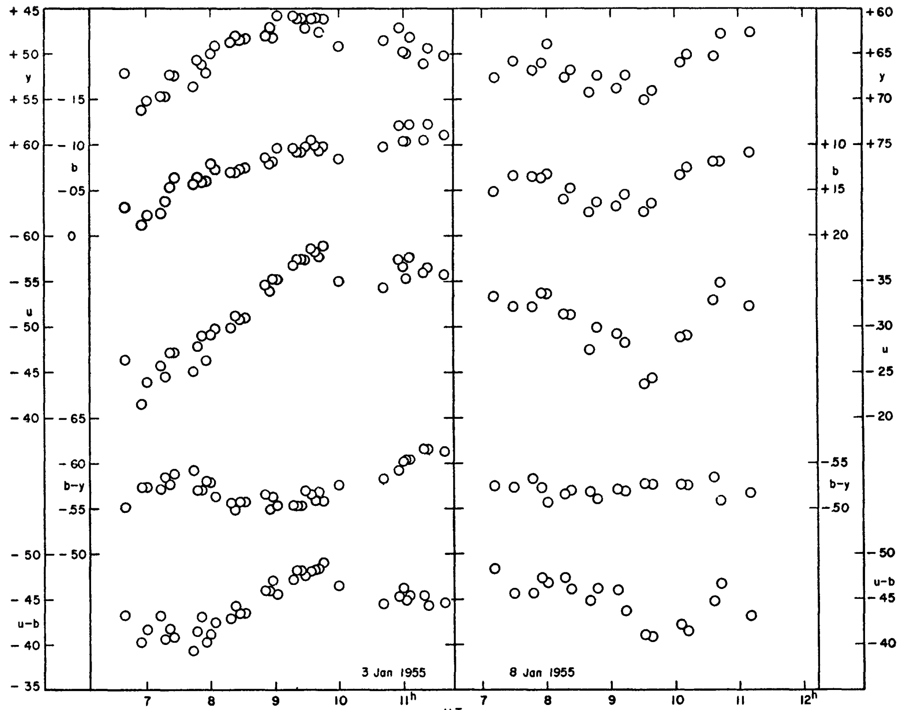

FIG 6 —Light- and color-curves for the A-type component of UX Monocerotis

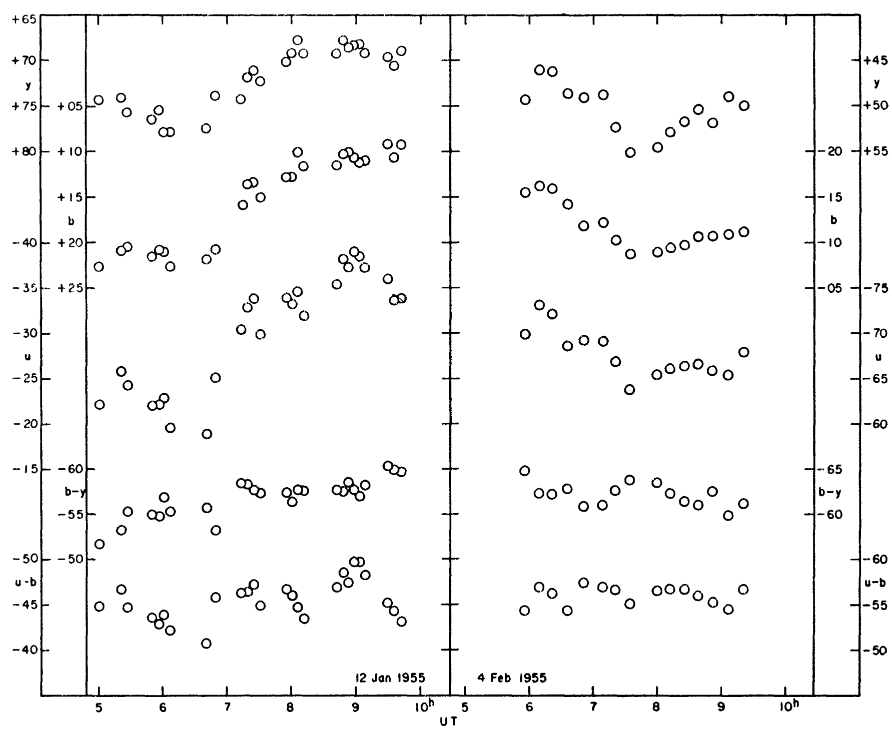

FIG 7.—Light- and color-curves for the A-type component of UX Monocerotis

havior of RR Lyrae (Hardie 1955). On the other hand, if variable obscuration were the responsible mechanism, the data would require that the obscuring material exhibit a redward-decreasing absorption coefficient in the blue-yellow region. However, it is fairly certain that material with such a property cannot be present in the system in sufficient quantity.

The scatter exhibited in Figure 5 makes it seem clear that a simple pulsation cannot alone account for the apparently erratic behavior of the A star. Also, there is little evidence in the present observational material of a periodicity in the variations. This may be due to the involvement of the star in a binary system; however, it is more probably due to an interfering effect, such as variable obscuration. If so, the details of the short time-scale variations should be of some help. Plotted in Figures 6, 7, and 8 are light- and color-curves of the A star for six nights when the star was most extensively observed. Removal of the light of the G star was accomplished in the usual way. The magnitudes

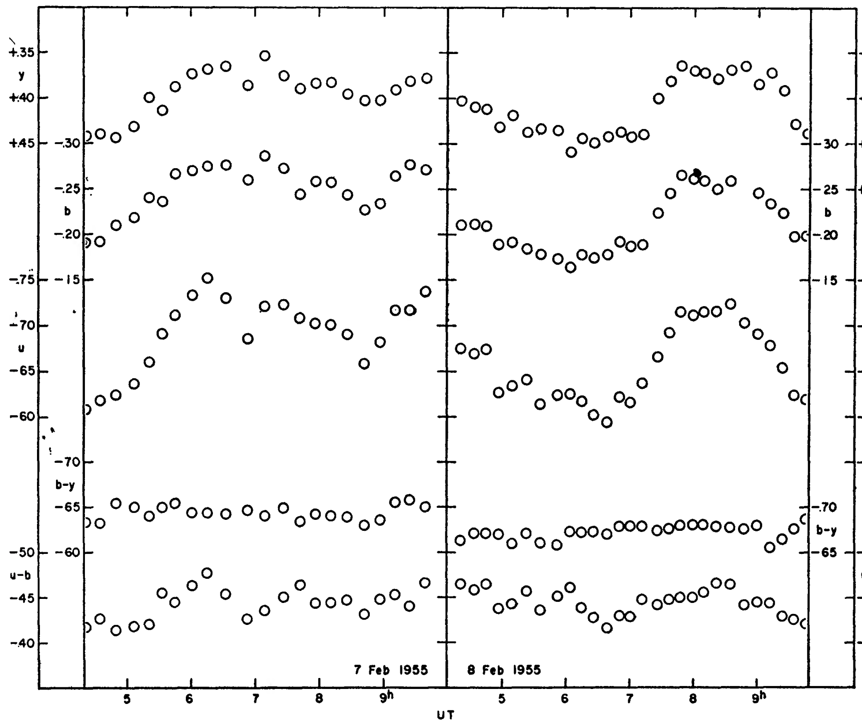

FIG. 8.—Light- and color-curves for the A-type component of UX Monocerotis

and colors are referred to HD 65939. It is seen that only for the observations of January 12 does the $b - y$ color variation follow the light-variation in a way compatible with the hypothesis of intrinsic variability. On January 3 the relation between the variation in light and the variation in color seemed to be completely anomalous. On February 4 the star actually became bluer as a minimum in light was reached. Finally, on February 7 and 8 the color was, for the most part, constant, while the light underwent variations of the order of 0.1 mag. The fact that there seems to be a difference between the relative behavior of light and color on a single night and the statistical relation which we found from the nightly averages tends to lend support to the idea that there are two separate mechanisms producing the observed light-variations. It is interesting that the time scale for the fluctuations indicated in Figures 6–8 is of the order of the transit time across the disk of the A star corresponding to a velocity of 200 km/sec.

In conclusion, it appears that the A component of UX Mon is an irregular intrinsic variable related to the RR Lyrae stars, with the variations either induced or modified by the association of the star in a close binary system. Additional peculiarities in the light and color variation of the star seem to be extrinsic and are probably produced in a turbulent extension of its atmosphere. The extended atmosphere is undoubtedly not in equilibrium and is being continually replenished either by the pulsation process itself or by gas streaming from the G component (Kranje 1951).

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