PHOTOELECTRIC AND SPECTROSCOPIC OBSERVATIONS OF UX URSAE MAJORIS*

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ABSTRACT

Some eighteen hundred photoelectric observations of the eclipsing variable UX UMa were made (by Walker) in three colors with the 60- and 100-inch reflectors at Mount Wilson and are described in Section I. They show the asymmetry and stillstand on the rising branch of principal minimum that were discovered by Linnell. Eclipse is preceded by an increase in light of 0.10 mag. and is (at the present time) followed by a rise of about half that amount. The rapid, irregular fluctuations in the light of the system, also discovered by Linnell, were confirmed; their durations range from 1 to 20 minutes, while their amplitudes in the ultraviolet may be as large as 0.18 mag. They are less conspicuous at longer wave lengths. The depth of primary minimum is not always the same; furthermore, its depth increases, the shorter the wave length of observation. No secondary minimum has been observed. In Section II are described spectroscopic observations made (by Herbig) with a continuous-recording technique and a low-dispersion (430 A/mm at $H\gamma$) spectrograph at the 36-inch Crossley reflector of the Lick Observatory. The spectrum of the primary star is of type O, with very wide and shallow absorption lines. Narrow absorption is observed at the H lines in the ultraviolet (particularly $H8$–$H11$) during the later parts of some cycles. The radial velocity given by these narrow H lines is approximately constant, with a value of about +350 to +400 km/sec. Weak emission at $H\beta$ and rather strong emission at *He* II λ 4685, neither of which is of constant intensity, vary in velocity throughout the cycle. The increases in brightness of UX UMa before and after primary minimum are due to an intensification of the continuous spectrum and are not accompanied by an enhancement of the emission lines. The variation of the spectrum of UX UMa through the eclipse cycle, like the details of the light-curve, is not always the same. A tentative model that seems to explain some of the features of this remarkable system is discussed in Section III.

I. INTRODUCTION AND PHOTOMETRIC OBSERVATIONS

The very short period (4^h43^m) of the eclipsing variable UX Ursae Majoris, together with its Algol-type light-curve, indicate that the two components must be unusually small and dense. The observations of Struve (1948) have shown, moreover, that the spectroscopic behavior of the system is peculiar. It was felt, accordingly, in view of the presently unique nature of the object, that the collection of more observational information was highly desirable.

The earlier work on UX UMa has been reviewed by Linnell (1950), and the most recent discussions of the system have been by him and by Parenago (1950). Linnell obtained the first photoelectric observations of the star in 1949. More recently, a very extensive series of photoelectric observations in three colors was made by Johnson, Perkins, and Hiltner (1954) during the years 1951–1953. The observations of UX UMa described in the present paper were made without knowledge of the work of Johnson *et al.*, and the discussion and conclusions are based for the most part on our own results. We were much interested, however, in reading (through the kindness of Dr. Hiltner) the Johnson, Perkins, and Hiltner paper in advance of publication, and we have attempt-

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ed to arrive at conclusions that are in harmony with both the McDonald observational results and our own material.

Photoelectric observations of UX UMa were obtained on seven nights in 1953 with a photometer attached to either the 60- or the 100-inch reflector of the Mount Wilson Observatory. The specific purposes of the investigation were threefold: (1) to study the peculiar features of the light-curve discovered by Linnell (1949, 1950); (2) to increase our knowledge of the star by obtaining light-curves in yellow, blue, and ultraviolet light; and (3) to attempt to correlate the features of the light-variation with changes in the spectrum or velocity of the star, by use of measurements of the light secured simultaneously with spectroscopic observations made at the Lick Observatory.

The photometer was used with an Emitron 5659 end-on multiplier tube, which was operated without refrigeration. The three filters were: yellow, 1.7 mm of Schott GG 11; blue, 1 mm of Schott BG 12 plus 2 mm of Schott GG 13; ultraviolet, 2.6 mm of Corning 9863. The output of the multiplier tube was amplified and displayed on a Brown recording potentiometer geared to a chart speed of 12 inches per hour.

The photometer mounting is provided with an eyepiece for offset guiding during the observations. The procedure adopted was to monitor the variable almost continuously, with only occasional breaks to observe the sky or the extinction stars. The emphasis was placed upon obtaining very complete and detailed light-curves in a given color. Usually only one color was observed on any one night. However, on two nights yellow and ultraviolet observations were obtained for the purpose of investigating the variation in the color of the star throughout the 5-hour period.

In reducing the observations, the brightness of the star was in most cases read, for convenience, on the minute and half-minute. The accuracy of reading the time from the recorder sheet was about ± 3 seconds. The observations were corrected for extinction, with coefficients derived each night from a red and a blue comparison star, but the data have been left on the instrumental system. The primary comparison star was BD+52°1722, which also served as the blue extinction star. A near-by red star was used as the second comparison star.

The (approximately eighteen hundred) individual measurements of the magnitude of UX UMa through the yellow, blue, and ultraviolet filters are given in Tables 1, 2, and 3, respectively. The tables list the magnitude difference, UX UMa *minus* BD+52°1722, together with the heliocentric Julian date of the observation and the phase computed from the elements of Johnson, Perkins, and Hiltner (1954):

$$\text{Minimum} = \text{JD } 2427341.2221 + 0^{d}196671379E\,.$$

The individual light-curves, plotted against the phase expressed in units of the period, are shown in Figures 1–7. The observations on April 23 were obtained with the 100-inch telescope and the others with the 60-inch reflector.

The observations confirm the existence of the asymmetry of the rising branch of the light-curve between 0.03 and 0.10P and of the stillstand between 0.05 and 0.07P discovered by Linnell. They differ from Linnell's observations in showing that at the present time the primary eclipse is preceded by an increase in light of 0.10 mag., in all colors, which occurs between phases 0.73 and 0.92P. Primary minimum begins at phase 0.92P. This amplitude and duration are approximately twice the height and length of the rise that follows the eclipse; this following "shoulder" occurs between 0.11 and 0.18P. The total interval between the beginning of the shoulder before eclipse and the end of the shoulder following the minimum is 0.45P, which agrees with the interval of 0.48P found by Linnell. A comparison of the present observations with those of Linnell and of Johnson *et al.* suggests that the interval of anomalous brightness has shifted relative to the phase of minimum light since Linnell's observations in 1949.

TABLE 1

YELLOW OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
485.76020	0.2894	+2.777	490.74546	0.6376	+2.760	490.90865	0.4673	+2.740
.76992	.3388	2.782	.74615	.6411	2.781	.91907	.5203	2.747
.77895	.3847	2.752	.74789	.6499	2.748	.91976	.5238	2.761
.78902	.4359	2.803	.74962	.6587	2.729	.92080	.5291	2.790
.79180	.4501	2.786	.75032	.6623	2.730	.92115	.5309	2.780
.79735	.4783	2.824	.75240	.6729	2.763	.92150	.5327	2.748
.80187	.5013	2.834	.75379	.6799	2.738	.92184	.5344	2.739
.80812	.5330	2.799	.75517	.6869	2.748	.92254	.5379	2.738
.81263	.5560	2.784	.75587	.6905	2.730	.92323	.5414	2.738
.87548	.8755	2.644	.75900	.7064	2.723	.93400	.5962	2.744
.87895	.8932	2.736	.76490	.7364	2.730	.93608	.6068	2.760
.87930	.8950	2.674	.76664	.7453	2.718	.93851	.6191	2.782
.88207	.9091	2.692	.76907	.7576	2.757	.94997	.6774	2.769
.88520	.9250	2.722	.76976	.7611	2.746	.95206	.6880	2.762
.88575	.9278	2.733	.77046	.7647	2.718	.95414	.6986	2.729
.88728	.9355	2.752	.77184	.7717	2.746	.95553	.7057	2.739
.88777	.9380	2.741	.78157	.8212	2.642	.95622	.7092	2.739
.89562	.9780	3.489	.78296	.8282	2.680	.95691	.7127	2.737
.89596	.9797	3.514	.79407	.8847	2.652	.95796	.7180	2.699
.89735	.9867	3.704	.79684	.8988	2.654	.95823	.7194	2.690
.89770	.9885	3.703	.79823	.9059	2.653	.95934	.7251	2.710
.89874	.9938	3.763	.80657	.9483	2.765	.95969	.7268	2.737
.89909	.9956	3.761	.80935	.9624	2.939	.96073	.7321	2.725
.90048	.0027	3.751	.80969	.9641	2.966	.96108	.7339	2.730
.90082	.0044	3.748	.81108	.9712	3.180	.96351	.7463	2.689
.90194	.0101	3.677	.81143	.9730	3.233	.96490	.7533	2.701
.90221	.0115	3.647	.81247	.9783	3.371	.96525	.7551	2.704
.90256	.0132	3.608	.81282	.9801	3.428	.96636	.7608	2.696
.90395	.0203	3.444	.81316	.9818	3.493	.96664	.7622	2.686
.90430	.0221	3.386	.81420	.9871	3.606	.96691	.7636	2.681
.90457	.0235	3.328	.81455	.9889	3.633	.96941	.7763	2.683
.90569	.0292	3.205	.81490	.9906	3.673	.97983	.8292	2.662
.90603	.0309	3.157	.81594	.9959	3.723	.98087	.8345	2.663
.90624	.0320	3.126	.81629	.9977	3.728	.98886	.8752	2.647
.90742	.0380	3.015	.81642	.9984	3.723	.99060	.8840	2.648
.90812	.0415	3.005	.81768	.0048	3.717	.99164	.8893	2.639
.90916	.0468	2.952	.81802	.0065	3.711	518.67894	.6688	2.776
.90950	.0485	2.932	.81816	.0072	3.705	.67963	.6723	2.813
.90985	.0503	2.924	.81906	.0118	3.653	.68033	.6759	2.834
.91089	.0556	2.887	.81941	.0136	3.593	.68137	.6812	2.848
.91124	.0574	2.884	.81976	.0154	3.553	.68172	.6829	2.837
.91332	.0679	2.845	.82115	.0224	3.371	.68241	.6864	2.796
.91506	.0768	2.840	.82150	.0242	3.322	.68380	.6935	2.799
.91575	.0803	2.827	.82185	.0260	3.251	.68449	.6970	2.799
.91714	.0874	2.802	.82289	.0313	3.102	.68866	.7182	2.862
.91784	.0909	2.791	.82324	.0330	3.082	.68935	.7217	2.847
.92131	.1086	2.720	.82428	.0383	3.022	.69074	.7288	2.836
.92270	.1156	2.769	.82462	.0401	2.993	.69144	.7324	2.803
.92339	.1192	2.743	.82497	.0418	2.973	.69318	.7412	2.789
.92548	.1298	2.719	.82601	.0471	2.892	.69457	.7483	2.772
.92687	.1368	2.727	.82636	.0489	2.881	.69873	.7694	2.756
.92756	.1404	2.756	.82671	.0507	2.872	.70047	.7783	2.744
.92895	.1474	2.746	.82775	.0560	2.858	.70602	.8065	2.749
.92964	.1509	2.786	.82809	.0577	2.852	.70741	.8136	2.727
.93659	.1863	2.762	.82948	.0648	2.821	.70810	.8171	2.720
.93728	.1898	2.760	.82983	.0666	2.811	.70949	.8241	2.720
.93937	.2004	2.751	.83156	.0754	2.816	.71435	.8489	2.733
.94978	.2533	2.765	.83365	.0860	2.799	.71574	.8559	2.732
.95187	.2640	2.773	.83643	.1001	2.752	.71644	.8595	2.698
.95256	.2675	2.756	.83782	.1072	2.732	.71713	.8630	2.711
.95464	.2780	2.733	.83990	.1177	2.722	.71852	.8701	2.687
.95534	.2816	2.752	.84129	.1248	2.756	.72304	.8930	2.700
.96506	.3310	2.786	.84963	.1672	2.730	.72373	.8965	2.700
.96749	.3434	2.745	.85136	.1760	2.747	.72442	.9001	2.736
.97721	.3928	2.779	.86038	.2219	2.770	.72477	.9018	2.710
.97895	.4017	2.778	.86212	.2307	2.767	.72512	.9036	2.693
.98138	.4140	2.753	.86420	.2413	2.771	.72547	.9054	2.693
490.70865	.4504	2.745	.87324	.2873	2.739	.72894	.9230	2.725
.71282	.4716	2.752	.87601	.3014	2.775	.72963	.9265	2.740
.71629	.4892	2.745	.87879	.3155	2.734	.73033	.9301	2.742
.72949	.5564	2.741	.88921	.3685	2.737	.73241	.9407	2.780
.73434	.5810	2.730	.89198	.3826	2.744	.73380	.9477	2.839
.73643	.5917	2.731	.89407	.3932	2.753	.73449	.9513	2.870
.74338	.6270	2.730	.90379	.4426	2.724	.73518	.9548	2.900
.74476	.6340	2.739	.90657	.4567	2.735	.73588	.9583	2.950

TABLE 1

YELLOW OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
518.73623	0.9601	+3.000	518.80185	0.2938	+2.813	518.93657	0.9788	+3.493
.73727	.9654	3.087	.80672	.3185	2.821	.93692	.9805	3.532
.73761	.9671	3.128	.80741	.3220	2.813	.93727	.9823	3.566
.73796	.9689	3.180	.80880	.3291	2.820	.93762	.9841	3.624
.73831	.9708	3.235	.80949	.3326	2.811	.93797	.9859	3.648
.73866	.9725	3.280	.81435	.3573	2.798	.93970	.9947	3.761
.73901	.9742	3.332	.81505	.3609	2.810	.94005	.9965	3.794
.73935	.9760	3.380	.81474	.3644	2.805	.94040	.9982	3.810
.73970	.9777	3.439	.81713	.3714	2.832	.94074	.0000	3.800
.74005	.9795	3.491	.81782	.3750	2.846	.94109	.0017	3.772
.74040	.9813	3.548	.82199	.3962	2.806	.94144	.0035	3.769
.74074	.9830	3.590	.82269	.3997	2.808	.94178	.0052	3.786
.74109	.9848	3.630	.82338	.4032	2.814	.94213	.0070	3.788
.74144	.9866	3.652	.82477	.4103	2.812	.94248	.0088	3.768
.74178	.9883	3.687	.82546	.4138	2.812	.94283	.0106	3.722
.74213	.9901	3.723	.83206	.4474	2.845	.94317	.0123	3.687
.74248	.9919	3.760	.83241	.4491	2.815	.94352	.0141	3.656
.74282	.9936	3.775	.83727	.4739	2.842	.94387	.0159	3.586
.74317	.9954	3.787	.83797	.4774	2.848	.94526	.0229	3.413
.74352	.9972	3.800	.83935	.4844	2.836	.94561	.0247	3.334
.74387	.9989	3.799	.84456	.5109	2.830	.94595	.0264	3.282
.74421	.0007	3.792	.84700	.5233	2.826	.94630	.0282	3.235
.74456	.0025	3.782	.85185	.5480	2.818	.94664	.0300	3.165
.74491	.0042	3.763	.85255	.5515	2.826	.94699	.0317	3.112
.74525	.0060	3.730	.85324	.5551	2.834	.94734	.0335	3.100
.74560	.0077	3.715	.85463	.5621	2.836	.94769	.0353	3.091
.74734	.0166	3.567	.85532	.5656	2.836	.94838	.0388	3.059
.74768	.0183	3.512	.86054	.5922	2.802	.94908	.0424	3.019
.74803	.0201	3.462	.86227	.6010	2.792	.94977	.0459	2.986
.74838	.0219	3.410	.86296	.6045	2.772	.95047	.0494	2.969
.74873	.0237	3.347	.86852	.6327	2.807	.95116	.0529	2.936
.74908	.0254	3.302	.86922	.6363	2.809	.95185	.0564	2.930
.74942	.0272	3.250	.87130	.6469	2.789	.95255	.0600	2.909
.74977	.0289	3.200	.87824	.6822	2.782	.95394	.0671	2.909
.75012	.0307	3.147	.87894	.6857	2.796	.95463	.0706	2.919
.75047	.0325	3.110	.87963	.6892	2.817	.95533	.0741	2.930
.75081	.0342	3.080	.88171	.6998	2.813	.96088	.1024	2.799
.75116	.0360	3.056	.88241	.7034	2.810	.96227	.1094	2.804
.75185	.0395	3.012	.88310	.7069	2.841	.96713	.1341	2.774
.75255	.0431	2.970	.88727	.7281	2.794	.96921	.1447	2.789
.75324	.0466	2.947	.88796	.7316	2.777	.96991	.1483	2.830
.75394	.0502	2.942	.88866	.7352	2.770	.97025	.1500	2.856
.75463	.0537	2.921	.88935	.7387	2.774	542.68731	.7423	2.735
.75532	.0572	2.915	.89144	.7493	2.735	.69009	.7565	2.755
.75671	.0642	3.879	.89213	.7528	2.752	.69078	.7600	2.745
.75741	.0678	2.877	.89699	.7775	2.752	.69148	.7635	2.748
.75810	.0713	2.869	.89769	.7811	2.760	.69217	.7670	2.755
.75880	.0749	2.868	.89838	.7846	2.741	.69287	.7706	2.795
.76297	.0961	2.799	.89977	.7916	2.715	.69356	.7741	2.739
.76366	.0996	2.762	.90046	.7951	2.749	.69425	.7776	2.739
.76435	.1031	2.741	.90602	.8234	2.725	.69495	.7812	2.735
.76505	.1066	2.791	.90672	.8270	2.719	.69564	.7847	2.734
.76574	.1102	2.769	.90880	.8376	2.726	.69634	.7883	2.732
.76713	.1172	2.773	.91366	.8623	2.700	.69703	.7918	2.759
.76782	.1207	2.782	.91435	.8658	2.702	.69773	.7953	2.747
.76852	.1243	2.766	.91644	.8764	2.678	.70050	.8094	2.731
.76991	.1314	2.778	.91713	.8799	2.683	.70120	.8130	2.716
.77060	.1349	2.823	.92199	.9046	2.706	.70189	.8165	2.705
.77130	.1384	2.778	.92269	.9082	2.714	.70259	.8200	2.718
.77685	.1666	2.798	.92338	.9117	2.702	.70328	.8235	2.729
.77755	.1702	2.807	.92477	.9188	2.710	.70398	.8271	2.732
.77894	.1773	2.826	.92546	.9223	2.727	.70537	.8342	2.735
.77963	.1808	2.812	.92616	.9258	2.736	.70606	.8377	2.714
.78519	.2090	2.816	.92685	.9293	2.770	.70675	.8412	2.718
.78588	.2126	2.817	.93102	.9505	2.894	.70745	.8447	2.724
.78796	.2231	2.811	.93172	.9541	2.922	.71092	.8624	2.673
.78866	.2267	2.811	.93241	.9576	2.963	.71162	.8659	2.705
.78935	.2302	2.817	.93380	.9647	3.078	.71231	.8695	2.711
.79630	.2655	2.806	.93414	.9664	3.110	.71300	.8730	2.691
.79699	.2690	3.806	.93449	.9682	3.162	.71370	.8765	2.676
.79769	.2726	2.814	.93484	.9700	3.206	.71439	.8800	2.686
.79838	.2761	2.814	.93518	.9717	3.256	.71648	.8907	2.709
.79977	.2832	2.835	.93553	.9735	3.321	.71717	.8942	2.725
.80046	.2867	2.792	.93588	.9752	3.384	.71995	.9083	2.735
.80116	.2902	2.823	.93623	.9770	3.425	.72064	.9118	2.735

TABLE 1

YELLOW OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
542.72134	0.9154	+2.694	542.75398	0.0813	+2.872	542.83106	0.4732	+2.824
.72203	.9189	2.705	.75467	.0848	2.872	.83523	.4945	2.825
.72273	.9224	2.703	.75536	.0883	2.828	.83592	.4980	2.854
.72412	.9295	2.725	.75606	.0919	2.820	.83662	.5015	2.841
.72481	.9330	2.746	.75675	.0954	2.795	.83731	.5050	2.823
.72550	.9365	2.763	.75745	.0990	2.781	.83870	.5121	2.820
.72620	.9401	2.776	.75814	.1025	2.775	.83939	.5156	2.855
.72689	.9436	2.800	.75884	.1060	2.750	.84009	.5192	2.849
.72759	.9471	2.826	.75953	.1095	2.759	.84078	.5227	2.847
.72794	.9489	2.843	.76023	.1131	2.739	.84425	.5403	2.804
.72828	.9507	2.854	.76092	.1166	2.753	.84495	.5439	2.816
.72863	.9524	2.877	.76300	.1272	2.784	.84564	.5474	2.806
.72898	.9542	2.899	.76370	.1308	2.798	.84634	.5509	2.832
.72933	.9560	2.918	.76717	.1484	2.784	.84773	.5580	2.824
.72967	.9577	2.928	.76787	.1520	2.802	.84842	.5615	2.823
.73002	.9595	2.968	.76856	.1555	2.803	.84912	.5651	2.829
.73037	.9613	2.998	.76925	.1590	2.785	.84981	.5686	2.821
.73072	.9631	3.025	.76995	.1625	2.789	.85398	.5898	2.830
.73106	.9648	3.050	.77134	.1696	2.780	.85467	.5933	2.814
.73141	.9666	3.100	.77203	.1731	2.782	.85537	.5969	2.818
.73175	.9683	3.142	.77273	.1767	2.781	.85606	.6004	2.816
.73210	.9701	3.187	.77342	.1802	2.786	.85675	.6039	2.814
.73245	.9719	3.220	.77412	.1837	2.792	.85814	.6109	2.800
.73280	.9736	3.270	.77481	.1872	2.811	.85884	.6145	2.796
.73384	.9789	3.434	.77550	.1907	2.800	.85953	.6180	2.789
.73419	.9807	3.484	.77967	.2120	2.802	.86370	.6392	2.825
.73453	.9824	3.534	.78037	.2155	2.797	.86439	.6427	2.821
.73488	.9842	3.599	.78106	.2190	2.789	.86509	.6463	2.826
.73523	.9860	3.614	.78175	.2225	2.788	.86578	.6498	2.826
.73558	.9878	3.653	.78245	.2261	2.784	.86717	.6569	2.793
.73592	.9895	3.658	.78384	.2332	2.776	.86787	.6604	2.801
.73627	.9913	3.681	.78453	.2367	2.797	.86856	.6639	2.795
.73662	.9931	3.709	.78523	.2402	2.795	.86925	.6674	2.814
.73697	.9948	3.714	.78904	.2596	2.776	.87342	.6886	2.786
.73731	.9966	3.719	.78939	.2614	2.796	.87412	.6922	2.813
.73766	.9983	3.730	.79009	.2649	2.816	.87481	.6957	2.799
.73800	.0001	3.733	.79078	.2684	2.816	.87550	.6992	2.783
.73835	.0019	3.738	.79148	.2720	2.825	.87689	.7063	2.790
.73870	.0036	3.723	.79217	.2755	2.824	.87759	.7098	2.806
.73905	.0054	3.728	.79356	.2826	2.818	.87828	.7133	2.793
.73939	.0071	3.708	.79425	.2861	2.817	.87898	.7169	2.792
.73974	.0089	3.683	.79495	.2896	2.814	.88245	.7345	2.736
.74009	.0107	3.652	.79565	.2932	2.798	.88314	.7381	2.739
.74044	.0125	3.627	.79600	.2950	2.772	.88384	.7416	2.740
.74078	.0142	3.585	.79981	.3144	2.840	.88453	.7451	2.766
.74113	.0160	3.571	.80050	.3179	2.827	.88523	.7487	2.775
.74148	.0178	3.512	.80120	.3214	2.828	.88592	.7522	2.775
.74183	.0196	3.477	.80189	.3249	2.834	.88731	.7593	2.740
.74217	.0213	3.411	.80328	.3320	2.838	.88800	.7628	2.721
.74252	.0231	3.235	.80398	.3356	2.838	.88870	.7663	2.751
.74356	.0283	3.200	.80467	.3391	2.845	.88939	.7698	2.755
.74391	.0301	3.152	.80537	.3426	2.855	.89287	.7875	2.726
.74425	.0319	3.114	.80884	.3603	2.814	.89356	.7910	2.729
.74460	.0336	3.100	.80953	.3638	2.817	.89425	.7945	2.757
.74495	.0354	3.071	.81023	.3673	2.828	.89495	.7981	2.716
.74530	.0372	3.051	.81092	.3708	2.825	.89564	.8016	2.714
.74564	.0389	3.064	.81231	.3779	2.824	.89634	.8052	2.712
.74599	.0407	3.041	.81300	.3814	2.813	.89703	.8087	2.725
.74634	.0425	3.022	.81370	.3850	2.803	.89842	.8157	2.726
.74669	.0443	3.020	.81439	.3885	2.811	.89912	.8193	2.742
.74703	.0460	3.005	.81474	.3903	2.812	.89981	.8228	2.754
.74738	.0478	2.990	.81787	.4062	2.819	.90050	.8263	2.748
.74773	.0495	2.981	.81856	.4097	2.832			
.74808	.0513	2.964	.81925	.4132	2.821			
.74842	.0531	2.959	.81995	.4168	2.808			
.74877	.0548	2.949	.82134	.4238	2.823			
.74912	.0566	2.939	.82203	.4273	2.820			
.74947	.0584	2.920	.82273	.4309	2.814			
.74981	.0601	2.917	.82342	.4344	2.813			
.75016	.0619	2.909	.82620	.4485	2.814			
.75050	.0636	2.909	.82689	.4520	2.829			
.75120	.0672	2.888	.82759	.4556	2.833			
.75189	.0707	2.883	.82828	.4591	2.822			
.75259	.0743	2.879	.82967	.4662	2.844			
.75328	.0778	2.872	.83037	.4697	2.820			

TABLE 2

BLUE OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
484.66718	0.7318	+2.355	484.76301	0.2190	+2.381	484.83245	0.5721	+2.399
.66787	.7353	2.348	.76370	.2226	2.391	.83314	.5756	2.395
.66856	.7388	2.357	.76440	.2261	2.379	.83384	.5792	2.390
.66926	.7424	2.349	.76509	.2296	2.383	.83453	.5827	2.384
.69842	.8906	2.263	.76578	.2331	2.376	.83592	.5898	2.397
.69912	.8942	2.271	.76648	.2367	2.377	.83662	.5933	2.400
.69981	.8977	2.277	.76717	.2402	2.375	.83731	.5968	2.419
.70051	.9013	2.281	.76856	.2473	2.379	.83801	.6004	2.397
.70815	.9401	2.332	.76926	.2508	2.376	.84148	.6180	2.427
.70884	.9436	2.362	.76995	.2543	2.375	.84218	.6216	2.416
.70954	.9472	2.381	.77064	.2578	2.376	.84287	.6251	2.411
.71023	.9507	2.421	.77134	.2614	2.375	.84356	.6286	2.412
.71093	.9542	2.478	.77620	.2861	2.380	.84426	.6313	2.413
.71162	.9577	2.519	.77690	.2897	2.375	.84495	.6357	2.404
.71301	.9648	2.587	.77829	.2967	2.380	.84565	.6392	2.403
.71440	.9719	2.830	.77898	.3002	2.407	.84634	.6428	2.394
.71509	.9754	2.997	.77968	.3038	2.402	.84704	.6463	2.394
.71578	.9789	3.114	.78037	.3073	2.389	.84773	.6498	2.401
.71648	.9825	3.216	.78106	.3108	2.390	.84842	.6533	2.413
.71717	.9860	3.297	.78176	.3144	2.384	.84912	.6569	2.401
.71787	.9895	3.366	.78245	.3179	2.384	.84981	.6604	2.420
.71925	.9965	3.410	.78314	.3214	2.384	.85050	.6639	2.431
.72064	.0036	3.443	.78384	.3250	2.379	.85189	.6710	2.418
.72134	.0072	3.396	.78592	.3355	2.380	.85259	.6745	2.399
.72203	.0107	3.346	.78662	.3391	2.390	.85328	.6780	2.398
.72272	.0142	3.277	.78731	.3426	2.399	.85398	.6816	2.408
.72342	.0177	3.189	.78801	.3462	2.401	.85467	.6851	2.408
.72411	.0213	3.071	.79148	.3638	2.408	.85536	.6886	2.415
.72481	.0248	2.944	.79218	.3674	2.384	.85606	.6922	2.398
.72550	.0283	2.825	.79357	.3744	2.399	.85676	.6957	2.407
.72619	.0318	2.716	.79426	.3779	2.390	.86023	.7134	2.404
.72689	.0354	2.674	.79495	.3814	2.399	.86093	.7169	2.411
.72759	.0389	2.627	.79565	.3850	2.395	.86162	.7204	2.400
.72829	.0425	2.600	.79634	.3885	2.408	.86231	.7239	2.405
.72898	.0460	2.580	.79704	.3921	2.410	.86301	.7275	2.393
.72968	.0496	2.557	.79773	.3956	2.407	.86370	.7310	2.399
.73037	.0531	2.543	.79842	.3991	2.406	.86440	.7346	2.406
.73106	.0566	2.414	.79912	.4026	2.399	.86509	.7381	2.408
.73176	.0602	2.416	.79981	.4062	2.386	.86578	.7416	2.392
.73245	.0637	2.423	.80051	.4097	2.389	.86648	.7452	2.380
.73315	.0672	2.431	.80398	.4274	2.394	.86717	.7487	2.362
.73384	.0707	2.413	.80467	.4309	2.374	.86856	.7557	2.366
.73523	.0778	2.381	.80884	.4521	2.377	.86925	.7592	2.355
.73592	.0813	2.375	.80954	.4556	2.390	.86995	.7628	2.335
.73662	.0849	2.359	.81093	.4627	2.390	.87064	.7663	2.350
.73731	.0884	2.353	.81162	.4662	2.407	.87134	.7699	2.355
.73800	.0919	2.345	.81231	.4697	2.413	.87482	.7876	2.334
.74148	.1096	2.330	.81301	.4733	2.418	.87551	.7911	2.325
.74218	.1131	2.337	.81370	.4768	2.403	.87620	.7946	2.307
.74357	.1202	2.339	.81440	.4803	2.398	.87690	.7981	2.312
.74426	.1237	2.363	.81509	.4838	2.388	.87759	.8016	2.322
.74495	.1272	2.365	.81578	.4874	2.406	.87829	.8052	2.339
.74565	.1308	2.363	.81648	.4909	2.407	.87898	.8087	2.359
.74634	.1343	2.352	.81717	.4944	2.407	.87968	.8123	2.360
.74704	.1378	2.360	.81856	.5015	2.410	.88037	.8158	2.354
.74773	.1414	2.373	.81925	.5050	2.412	.88106	.8193	2.347
.74842	.1449	2.378	.81995	.5086	2.389	.88176	.8228	2.332
.74912	.1484	2.385	.82064	.5121	2.403	.88245	.8264	2.325
.74981	.1519	2.390	.82134	.5156	2.408	.88314	.8299	2.346
.75051	.1555	2.386	.82203	.5192	2.409	.88384	.8334	2.372
.75189	.1625	2.373	.82273	.5227	2.394	.88453	.8369	2.369
.75259	.1661	2.365	.82620	.5404	2.413	.88523	.8405	2.368
.75328	.1696	2.397	.82690	.5439	2.401	.88592	.8440	2.346
.75398	.1731	2.400	.82759	.5474	2.395	.88662	.8476	2.323
.75467	.1766	2.402	.82829	.5510	2.391	.88731	.8511	2.294
.75954	.2014	2.348	.82898	.5545	2.396	.88801	.8546	2.314
.76023	.2049	2.304	.82968	.5580	2.405	.89218	.8758	2.281
.76093	.2085	2.337	.83037	.5616	2.397	.89287	.8793	2.276
.76162	.2120	2.364	.83106	.5651	2.400	.89357	.8829	2.269
.76232	.2155	2.383	.83176	.5686	2.398	.89426	.8864	2.262
						.89495	.8899	2.259

TABLE 2

BLUE OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
484.89565	0.8935	+2.285	484.96440	0.2430	+2.405	519.72648	0.9952	+3.520
.89634	.8970	2.281	.96509	.2466	2.389	.72682	.9969	3.540
.89704	.9005	2.277	.96578	.2501	2.383	.72717	.9987	3.525
.89773	.9040	2.280	.96648	.2536	2.382	.72752	.0004	3.540
.89842	.9076	2.279	.96717	.2571	2.389	.72787	.0022	3.535
.89912	.9111	2.278	.96786	.2606	2.390	.72821	.0039	3.541
.89981	.9146	2.270	.97343	.2890	2.417	.72856	.0057	3.500
.90259	.9288	2.287	.97412	.2925	2.423	.72890	.0075	3.460
.90328	.9323	2.307	.97481	.2960	2.340	.72925	.0092	3.423
.90815	.9570	2.501	.97551	.2995	2.421	.72960	.0110	3.400
.90884	.9605	2.537	.97620	.3030	2.420	.72995	.0128	3.362
.90954	.9641	2.596	.97690	.3066	2.427	.73030	.0146	3.340
.91023	.9676	2.675	.97759	.3101	2.416	.73064	.0163	3.277
.91093	.9712	2.802	.97967	.3207	2.388	.73203	.0234	3.046
.91162	.9747	2.966	.98037	.3242	2.407	.73238	.0252	2.960
.91231	.9782	3.107	.98106	.3277	2.406	.73273	.0269	2.900
.91301	.9817	3.223	.98175	.3313	2.408	.73307	.0287	2.833
.91370	.9852	3.332	.98245	.3348	2.419	.73342	.0304	2.774
.91440	.9888	3.397	.98314	.3383	2.422	.73377	.0322	2.717
.91509	.9923	3.444	519.67682	.7426	2.343	.73412	.0340	2.660
.91578	.9958	3.503	.67752	.7462	2.356	.73446	.0357	2.651
.91648	.9994	3.511	.67891	.7533	2.356	.73481	.0375	2.633
.91717	.0029	3.501	.67960	.7568	2.381	.73516	.0393	2.621
.91787	.0065	3.466	.68030	.7603	2.386	.73585	.0428	2.601
.91856	.0100	3.437	.68446	.7815	2.396	.73655	.0464	2.590
.91925	.0135	3.331	.69175	.8186	2.324	.73724	.0499	2.586
.92064	.0205	3.133	.69210	.8203	2.294	.73794	.0534	2.576
.92134	.0241	2.979	.69280	.8239	2.278	.73863	.0569	2.553
.92204	.0277	2.827	.69349	.8274	2.277	.73932	.0604	2.524
.92273	.0312	2.702	.69488	.8345	2.287	.74002	.0640	2.539
.92343	.0347	2.642	.69835	.8521	2.269	.74037	.0658	2.541
.92412	.0382	2.607	.69905	.8557	2.295	.74071	.0675	2.522
.92482	.0418	2.579	.69974	.8592	2.303	.74106	.0693	2.530
.92551	.0453	2.559	.70044	.6827	2.324	.74280	.0781	2.492
.92620	.0488	2.544	.70113	.8663	2.331	.74349	.0816	2.482
.92690	.0524	2.524	.70182	.8698	2.309	.74384	.0834	2.476
.92759	.0559	2.515	.70217	.8715	2.290	.74696	.0993	2.449
.92828	.0594	2.513	.70252	.8733	2.317	.74731	.1011	2.420
.92898	.0629	2.510	.70287	.8751	2.289	.74766	.1028	2.400
.92967	.0664	2.509	.70321	.8768	2.282	.74835	.1064	2.396
.93106	.0735	2.435	.70391	.8804	2.293	.74905	.1099	2.391
.93245	.0806	2.431	.70738	.8980	2.302	.74974	.1134	2.400
.93314	.0841	2.413	.70807	.9015	2.295	.75044	.1170	2.385
.93384	.0877	2.397	.70946	.9086	2.325	.75182	.1240	2.382
.93453	.0912	2.377	.71016	.9122	2.304	.75252	.1276	2.404
.93523	.0947	2.352	.71085	.9157	2.344	.75321	.1311	2.412
.93592	.0982	2.347	.71363	.9298	2.337	.75391	.1346	2.402
.93801	.1089	2.332	.71432	.9333	2.358	.75807	.1558	2.393
.93870	.1124	2.327	.71502	.9369	2.358	.75877	.1593	2.396
.94286	.1335	2.362	.71641	.9439	2.372	.75946	.1628	2.405
.94356	.1371	2.373	.71710	.9475	2.412	.76085	.1699	2.424
.94425	.1406	2.378	.71780	.9510	2.457	.76155	.1735	2.410
.94495	.1441	2.357	.71849	.9545	2.489	.76224	.1770	2.413
.94565	.1477	2.359	.71919	.9581	2.536	.76571	.1946	2.431
.94634	.1512	2.361	.71988	.9616	2.598	.76641	.1982	2.443
.94704	.1548	2.373	.72057	.9651	2.666	.76710	.2017	2.449
.94912	.1653	2.368	.72092	.9669	2.708	.76780	.2052	2.424
.94981	.1689	2.349	.72127	.9687	2.750	.76815	.2070	2.441
.95051	.1724	2.364	.72231	.9739	2.942	.76953	.2140	2.424
.95120	.1759	2.354	.72266	.9757	3.009	.76988	.2158	2.450
.95189	.1794	2.346	.72300	.9775	3.077	.77057	.2193	2.441
.95259	.1830	2.362	.72335	.9792	3.147	.77127	.2229	2.419
.95328	.1865	2.366	.72370	.9810	3.214	.77196	.2264	2.415
.95884	.2148	2.369	.72405	.9828	3.268	.77266	.2300	2.421
.95954	.2183	2.378	.72439	.9845	3.319	.77717	.2529	2.449
.96023	.2218	2.396	.72474	.9863	3.347	.77752	.2547	2.447
.96092	.2253	2.390	.72509	.9881	3.394	.77821	.2582	2.433
.96162	.2289	2.386	.72544	.9899	3.436	.78030	.2688	2.430
.96231	.2324	2.388	.72578	.9916	3.466	.78099	.2723	2.437
.96370	.2395	2.417	.72613	.9934	3.490	.78168	.2758	2.438

TABLE 2

BLUE OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
519.78516	0.2935	+2.441	519.86641	0.7066	+2.424	519.92196	0.9891	+03.54
.78585	.2970	2.444	.86710	.7101	2.422	.92231	.9909	3.57
.78655	.3006	2.442	.86780	.7137	2.429	.92266	.9927	3.59
.78724	.3041	2.462	.86849	.7172	2.439	.92300	.9944	3.62
.78828	.3094	2.481	.86919	.7208	2.448	.92335	.9962	3.65
.78863	.3112	2.450	.86988	.7243	2.452	.92370	.9979	3.63
.78932	.3147	2.459	.87544	.7526	2.413	.92405	.9997	3.65
.79002	.3182	2.467	.87613	.7561	2.404	.92439	.0014	3.64
.79766	.3571	2.447	.87682	.7596	2.415	.92474	.0032	3.63
.79974	.3677	2.433	.87752	.7631	2.423	.92509	.0050	3.61
.80044	.3712	2.441	.87891	.7702	2.410	.92544	.0068	3.58
.80113	.3747	2.441	.87960	.7737	2.411	.92578	.0085	3.56
.80530	.3959	2.445	.88030	.7773	2.401	.92613	.0103	3.54
.80599	.3994	2.444	.88099	.7808	2.399	.92648	.0121	3.477
.80669	.4030	2.435	.88238	.7878	2.371	.92682	.0138	3.438
.80807	.4100	2.458	.88307	.7914	2.370	.92717	.0156	3.395
.80877	.4136	2.445	.88377	.7949	2.359	.92752	.0174	3.317
.81363	.4383	2.462	.88446	.7984	2.370	.92856	.0226	3.111
.81432	.4418	2.443	.89002	.8267	2.330	.92891	.0244	3.069
.81502	.4453	2.437	.89071	.8302	2.346	.92925	.0262	2.969
.81571	.4489	2.444	.89141	.8338	2.350	.92960	.0279	2.899
.81710	.4559	2.450	.89349	.8443	2.405	.92995	.0297	2.833
.81780	.4595	2.452	.89418	.8478	2.404	.93030	.0315	2.801
.81849	.4630	2.468	.89835	.8690	2.392	.93064	.0332	2.768
.81919	.4665	2.458	.89905	.8726	2.384	.93099	.0350	2.748
.81988	.4701	2.455	.89974	.8761	2.367	.93134	.0368	2.719
.82057	.4736	2.456	.90044	.8797	2.385	.93168	.0385	2.685
.82127	.4771	2.453	.90113	.8832	2.377	.93203	.0403	2.667
.82266	.4842	2.475	.90148	.8850	2.384	.93238	.0421	2.659
.82335	.4877	2.483	.90252	.8902	2.368	.93307	.0456	2.631
.82821	.5124	2.477	.90321	.8938	2.355	.93377	.0491	2.586
.82891	.5160	2.477	.90391	.8973	2.370	.93446	.0526	2.575
.82960	.5195	2.476	.90460	.9008	2.377	.93516	.0562	2.563
.83168	.5301	2.469	.90877	.9220	2.364	.93585	.0597	2.552
.83238	.5336	2.483	.90946	.9255	2.369	.93655	.0633	2.527
.83794	.5619	2.495	.91016	.9291	2.381	.93724	.0668	2.512
.83863	.5654	2.494	.91085	.9326	2.389	.93863	.0739	2.516
.84002	.5725	2.473	.91155	.9362	2.397	.94314	.0968	2.419
.84071	.5760	2.479	.91224	.9397	2.403	.94349	.0986	2.411
.84141	.5795	2.489	.91432	.9502	2.483	.94418	.1021	2.409
.84210	.5830	2.476	.91502	.9538	2.562	.94488	.1056	2.396
.84280	.5866	2.463	.91571	.9573	2.589	.94974	.1303	2.422
.84349	.5901	2.475	.91641	.9609	2.628	.95044	.1339	2.418
.84766	.6113	2.449	.91710	.9644	2.689	.95113	.1374	2.407
.84835	.6148	2.444	.91745	.9662	2.717	.95182	.1409	2.415
.84905	.6184	2.446	.91780	.9679	2.780	.95252	.1445	2.419
.85113	.6289	2.448	.91814	.9697	2.848	.95321	.1480	2.411
.85182	.6325	2.446	.91849	.9714	2.907	.95877	.1763	2.469
.85668	.6572	2.460	.91884	.9732	2.992	.95946	.1798	2.432
.85877	.6678	2.502	.91918	.9750	3.058	.96016	.1833	2.454
.85946	.6713	2.486	.91953	.9767	3.150	.96085	.1868	2.446
.86016	.6749	2.486	.91988	.9785	3.199	.96571	.2115	2.446
.86155	.6819	2.454	.92092	.9838	3.417			
.86224	.6854	2.452	.92127	.9856	3.461			
.86571	.7031	2.432	.92162	.9874	3.488			

TABLE 3

ULTRA VIOLET OBSERVATIONS

Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag	Helioc JD 2434+	Helioc Phase	Δ Mag
485.76298	0.3035	+1.629	490.75046	0.6630	+1.618	490.90726	0.4602	+1.601
.77305	.3547	1.617	.75066	.6640	1.626	.90761	.4620	1.612
.78173	.3989	1.603	.75101	.6658	1.657	.90796	.4638	1.632
.78971	.4394	1.627	.75136	.6676	1.697	.90830	.4655	1.646
.79284	.4554	1.599	.75170	.6693	1.697	.90934	.4708	1.625
.79874	.4854	1.686	.75274	.6746	1.720	.90969	.4726	1.613
.80360	.5101	1.682	.75309	.6764	1.700	.91004	.4744	1.611
.80950	.5401	1.682	.75344	.6781	1.697	.91038	.4761	1.599
.81471	.5666	1.653	.75448	.6834	1.677	.91073	.4779	1.593
.87687	.8826	1.552	.75622	.6923	1.644	.91990	.5245	1.668
.88034	.9003	1.619	.75969	.7099	1.643	.92046	.5274	1.663
.88277	.9126	1.564	.76525	.7382	1.656	.92219	.5362	1.600
.88603	.9292	1.563	.76560	.7400	1.673	.92393	.5450	1.658
.88659	.9320	1.636	.76594	.7417	1.695	.92462	.5485	1.655
.88805	.9395	1.599	.76733	.7488	1.710	.93469	.5997	1.689
.88867	.9426	1.593	.76803	.7523	1.733	.93712	.6121	1.707
.89631	.9815	2.517	.76872	.7558	1.744	.93920	.6226	1.730
.89666	.9832	2.557	.77080	.7664	1.706	.95102	.6827	1.714
.89700	.9850	2.633	.77115	.7682	1.733	.95310	.6933	1.656
.89805	.9903	2.724	.77150	.7700	1.760	.95483	.7021	1.692
.89839	.9920	2.763	.77219	.7735	1.742	.95657	.7110	1.745
.89944	.9973	2.848	.77254	.7753	1.716	.95677	.7120	1.711
.89978	.9991	2.843	.77288	.7770	1.703	.95726	.7145	1.653
.90013	.0009	2.343	.78192	.8229	1.526	.95761	.7163	1.622
.90117	.0062	2.742	.78226	.8247	1.551	.95810	.7188	1.618
.90152	.0080	2.704	.78261	.8265	1.568	.95837	.7201	1.620
.90180	.0094	2.680	.78365	.8317	1.571	.95865	.7215	1.629
.90291	.0150	2.518	.79546	.8918	1.517	.95900	.7233	1.646
.90325	.0167	2.485	.79892	.9094	1.473	.96004	.7286	1.703
.90360	.0185	2.397	.80692	.9501	1.557	.96038	.7303	1.712
.90464	.0238	2.128	.80726	.9518	1.594	.96122	.7346	1.680
.90499	.0256	2.085	.81039	.9677	1.816	.96142	.7356	1.660
.90534	.0274	2.026	.81074	.9695	1.881	.96177	.7374	1.640
.90645	.0330	1.865	.81178	.9748	2.146	.96212	.7392	1.626
.90673	.0344	1.827	.81212	.9765	2.235	.96386	.7480	1.606
.90707	.0362	1.783	.81351	.9836	2.505	.96421	.7498	1.609
.90846	.0432	1.733	.81386	.9854	2.565	.96455	.7515	1.618
.90881	.0450	1.732	.81525	.9924	2.724	.96560	.7569	1.653
.91020	.0521	1.716	.81559	.9941	2.745	.96594	.7586	1.656
.91055	.0539	1.700	.81663	.9994	2.802	.96622	.7600	1.658
.91159	.0592	1.648	.81698	.0012	2.787	.96705	.7643	1.619
.91194	.0609	1.648	.81733	.0030	2.780	.96737	.7657	1.611
.91228	.0627	1.668	.81837	.0083	2.715	.96872	.7727	1.554
.91263	.0644	1.696	.81872	.0101	2.665	.97011	.7798	1.573
.91437	.0733	1.686	.81892	.0111	2.624	.97045	.7815	1.606
.91645	.0839	1.645	.82046	.0189	2.396	.98053	.8328	1.532
.91853	.0944	1.631	.82081	.0207	2.329	.98157	.8381	1.554
.92200	.1121	1.626	.82220	.0278	1.973	.98955	.8787	1.500
.92409	.1227	1.579	.82254	.0295	1.910	.99129	.8875	1.525
.92478	.1262	1.584	.82358	.0348	1.798	.99233	.8928	1.526
.92617	.1333	1.598	.82393	.0366	1.784	541.69363	.6898	1.723
.92825	.1439	1.592	.82532	.0436	1.714	.69641	.7040	1.735
.92874	.1464	1.620	.82567	.0454	1.695	.69710	.7075	1.708
.93798	.1933	1.600	.82705	.0524	1.634	.69780	.7111	1.699
.93867	.1968	1.594	.82740	.0542	1.630	.69849	.7146	1.721
.94006	.2039	1.614	.82844	.0595	1.616	.69919	.7181	1.735
.94075	.2074	1.631	.82879	.0613	1.613	.70057	.7251	1.758
.95048	.2569	1.621	.83018	.0683	1.621	.70127	.7287	1.726
.95117	.2604	1.607	.83052	.0701	1.621	.70474	.7463	1.647
.95325	.2710	1.637	.83260	.0806	1.608	.70543	.7498	1.643
.95395	.2745	1.630	.83435	.0895	1.619	.70613	.7534	1.656
.95603	.2851	1.602	.83712	.1036	1.596	.70682	.7569	1.679
.95673	.2887	1.625	.83886	.1125	1.567	.70717	.7587	1.705
.96645	.3381	1.639	.84059	.1213	1.600	.70752	.7605	1.684
.96853	.3487	1.728	.84198	.1283	1.613	.70821	.7640	1.652
.97825	.3981	1.656	.85032	.1707	1.577	.70891	.7675	1.664
.98034	.4087	1.618	.85206	.1796	1.591	.70960	.7711	1.643
.98207	.4175	1.633	.86142	.2272	1.605	.71030	.7746	1.693
490.70935	.4540	1.660	.86316	.2360	1.593	.71099	.7781	1.672
.71351	.4751	1.659	.86490	.2449	1.601	.71238	.7852	1.736
.71490	.4822	1.653	.87462	.2943	1.604	.71308	.7887	1.700
.71698	.4928	1.672	.87740	.3084	1.581	.71377	.7923	1.668
.73087	.5634	1.659	.87948	.3190	1.570	.71863	.8170	1.669
.73573	.5881	1.653	.89060	.3755	1.557	.71932	.8205	1.665
.74407	.6305	1.633	.89337	.3896	1.590	.72002	.8240	1.635
.74685	.6446	1.749	.89545	.4002	1.614	.72071	.8275	1.627
.74754	.6481	1.714	.90448	.4461	1.623	.72210	.8346	1.645
.74823	.6516	1.665	.90483	.4479	1.631	.72280	.8382	1.645
.74893	.6552	1.633	.90518	.4497	1.620	.72349	.8417	1.645
.74958	.6585	1.620	.90553	.4514	1.608	.72419	.8452	1.646
			.90587	.4532	1.601			

TABLE 3

ULTRA VIOLET OBSERVATIONS

Helioc JD 2434 +	Helioc Phase	Δ Mag	Helioc JD 2434 +	Helioc Phase	Δ Mag	Helioc JD 2434 +	Helioc Phase	Δ Mag
541.72488	0.8487	+1.684	541.76272	0.0411	+1.854	541.82766	0.3713	+1.722
.72557	.8523	1.711	.76307	.0429	1.823	.82835	.3748	1.757
.72592	.8540	1.738	.76342	.0447	1.801	.82905	.3784	1.745
.72627	.8558	1.713	.76377	.0465	1.806	.82974	.3819	1.725
.72696	.8593	1.691	.76412	.0483	1.804	.83044	.3855	1.724
.72766	.8629	1.658	.76446	.0500	1.778	.83182	.3925	1.660
.72835	.8664	1.612	.76481	.0518	1.760	.83252	.3960	1.676
.72870	.8682	1.569	.76516	.0536	1.758	.83321	.3996	1.713
.72905	.8699	1.561	.76551	.0553	1.769	.83391	.4031	1.666
.72974	.8735	1.620	.76585	.0571	1.777	.83460	.4066	1.632
.73044	.8770	1.629	.76655	.0606	1.766	.83530	.4102	1.650
.73391	.8947	1.623	.76724	.0641	1.766	.84016	.4349	1.679
.73460	.8982	1.608	.76794	.0677	1.754	.84085	.4384	1.722
.73530	.9017	1.626	.76863	.0712	1.759	.84155	.4420	1.731
.73599	.9052	1.656	.76932	.0747	1.760	.84190	.4437	1.698
.73669	.9088	1.653	.77002	.0783	1.731	.84224	.4455	1.725
.73738	.9123	1.632	.77071	.0818	1.720	.84259	.4473	1.754
.73807	.9158	1.642	.77141	.0853	1.720	.84363	.4525	1.772
.73877	.9194	1.583	.77210	.0888	1.727	.84432	.4560	1.758
.73946	.9229	1.626	.77280	.0924	1.706	.84502	.4596	1.749
.74016	.9264	1.650	.77349	.0959	1.696	.84571	.4631	1.743
.74085	.9299	1.682	.77419	.0995	1.676	.84641	.4667	1.763
.74155	.9335	1.684	.77488	.1030	1.653	.84676	.4685	1.798
.74224	.9370	1.677	.77557	.1065	1.618	.85057	.4878	1.749
.74294	.9406	1.679	.77627	.1100	1.601	.85127	.4914	1.730
.74363	.9441	1.686	.77696	.1135	1.629	.85196	.4949	1.718
.74467	.9494	1.716	.77766	.1171	1.641	.85266	.4985	1.705
.74502	.9511	1.745	.77835	.1206	1.649	.85335	.5020	1.733
.74537	.9529	1.765	.77905	.1242	1.660	.85405	.5055	1.718
.74571	.9546	1.768	.77974	.1277	1.661	.85544	.5126	1.743
.74606	.9564	1.774	.78044	.1312	1.665	.85613	.5161	1.753
.74641	.9582	1.783	.78113	.1348	1.654	.85682	.5196	1.756
.74675	.9599	1.813	.78460	.1524	1.675	.85752	.5232	1.759
.74710	.9617	1.832	.78530	.1560	1.677	.86099	.5408	1.709
.74745	.9635	1.862	.78599	.1595	1.674	.86169	.5444	1.713
.74780	.9653	1.910	.78669	.1630	1.656	.86238	.5479	1.712
.74814	.9670	1.951	.78738	.1665	1.686	.86307	.5514	1.698
.74849	.9688	1.996	.78807	.1700	1.701	.86377	.5549	1.705
.74884	.9706	2.041	.78877	.1736	1.691	.86446	.5584	1.693
.74919	.9723	2.101	.78946	.1771	1.694	.86655	.5691	1.694
.74953	.9741	2.181	.79016	.1807	1.651	.86724	.5726	1.707
.74988	.9759	2.250	.79051	.1824	1.626	.86794	.5761	1.673
.75023	.9776	2.360	.79085	.1841	1.654	.86863	.5797	1.666
.75057	.9794	2.419	.79155	.1877	1.671	.87210	.5973	1.684
.75092	.9811	2.479	.79294	.1948	1.696	.87280	.6009	1.661
.75127	.9829	2.546	.79363	.1983	1.660	.87349	.6044	1.698
.75162	.9847	2.595	.79432	.2018	1.657	.87419	.6079	1.697
.75196	.9864	2.621	.79780	.2195	1.678	.87488	.6114	1.720
.75231	.9882	2.656	.79849	.2230	1.661	.87627	.6185	1.663
.75266	.9900	2.696	.79919	.2266	1.675	.87696	.6220	1.646
.75300	.9917	2.755	.79988	.2301	1.675	.87766	.6256	1.660
.75335	.9935	2.805	.80057	.2336	1.673	.88182	.6467	1.701
.75370	.9953	2.835	.80127	.2372	1.692	.88252	.6503	1.716
.75405	.9971	2.855	.80266	.2442	1.673	.88321	.6538	1.652
.75439	.9988	2.867	.80335	.2477	1.682	.88391	.6573	1.683
.75474	.0006	2.854	.80682	.2654	1.640	.88460	.6609	1.703
.75509	.0023	2.848	.80752	.2689	1.641	.88599	.6679	1.707
.75544	.0041	2.811	.80821	.2724	1.641	.88669	.6715	1.711
.75578	.0059	2.801	.80891	.2760	1.677	.88738	.6750	1.719
.75613	.0076	2.770	.80960	.2795	1.714	.88807	.6785	1.742
.75717	.0129	2.610	.81030	.2831	1.741	.88877	.6821	1.750
.75752	.0147	2.590	.81065	.2848	1.743	.89224	.6997	1.741
.75787	.0165	2.540	.81099	.2866	1.731	.89294	.7033	1.721
.75821	.0182	2.492	.81238	.2936	1.695	.89363	.7068	1.722
.75856	.0200	2.429	.81307	.2972	1.693	.89432	.7103	1.683
.75891	.0218	2.333	.81377	.3007	1.671	.89502	.7138	1.636
.75925	.0235	2.247	.81724	.3184	1.723	.89571	.7173	1.661
.75960	.0253	2.176	.81794	.3219	1.751	.89710	.7244	1.601
.75995	.0271	2.083	.81863	.3254	1.760	.89780	.7280	1.601
.76030	.0288	2.025	.81932	.3289	1.726	.89849	.7315	1.614
.76064	.0306	1.978	.82002	.3325	1.705	.89884	.7333	1.639
.76099	.0323	1.966	.82141	.3396	1.693	.90266	.7527	1.682
.76134	.0341	1.959	.82210	.3431	1.716	.90335	.7562	1.636
.76168	.0359	1.939	.82280	.3466	1.704	.90405	.7598	1.595
.76203	.0376	1.914	.82349	.3501	1.706	.90474	.7633	1.607
.76238	.0394	1.893	.82696	.3678	1.730			

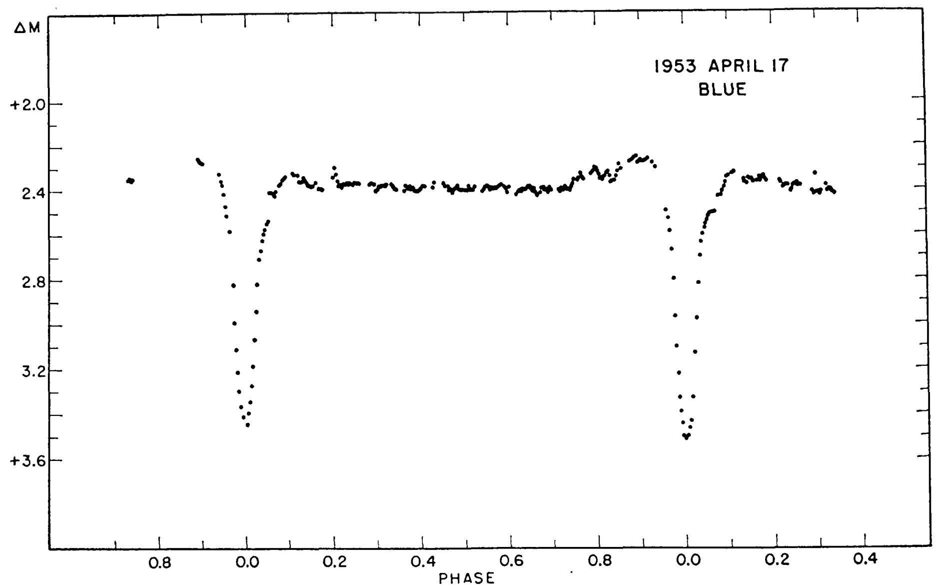

FIG. 1.—Photometric observations of UX UMa. The ordinate is the magnitude difference, UX UMa *minus* BD+52°1722, reduced to no atmosphere. The abscissa is the phase computed from zero phase = Minimum = JD 2427341.2221 + $0^{d}\!.196671379E$.

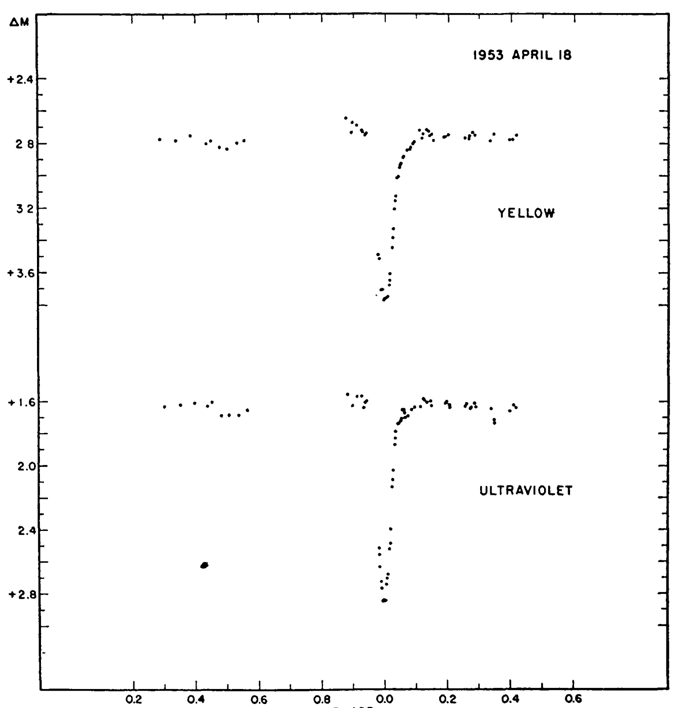

FIG. 2.—Photometric observations of UX UMa. Ordinate and abscissa as in Fig. 1

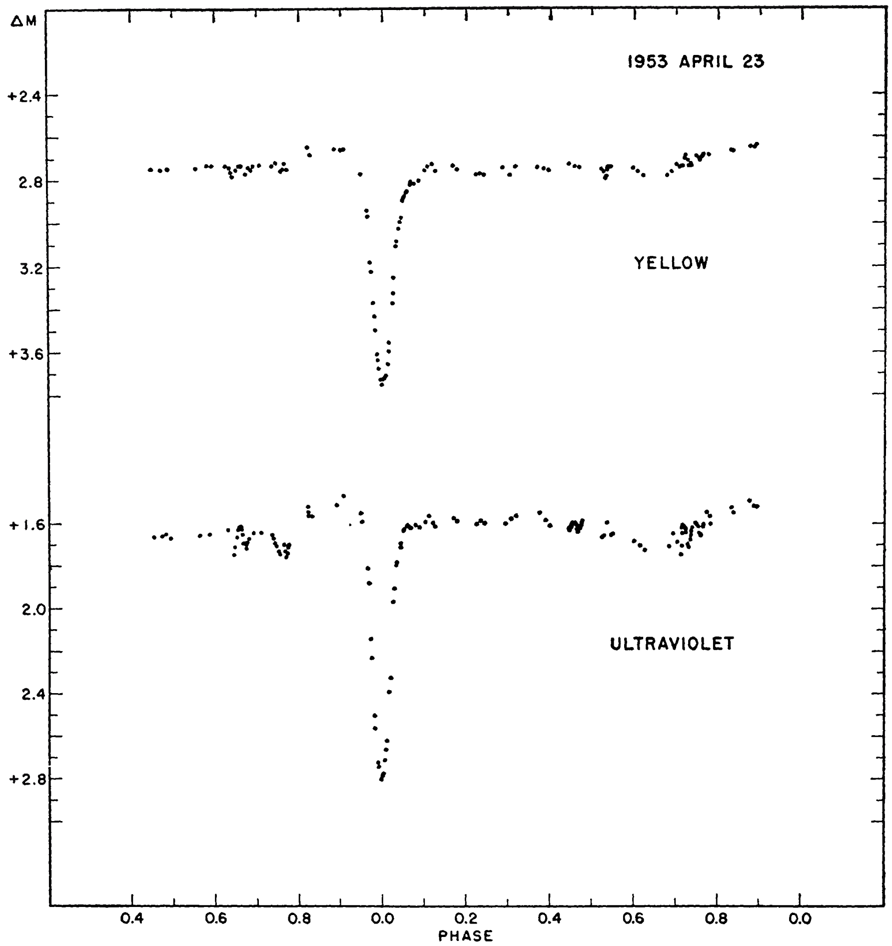

FIG. 3.—Photometric observations of UX UMa. Ordinate and abscissa as in Fig. 1

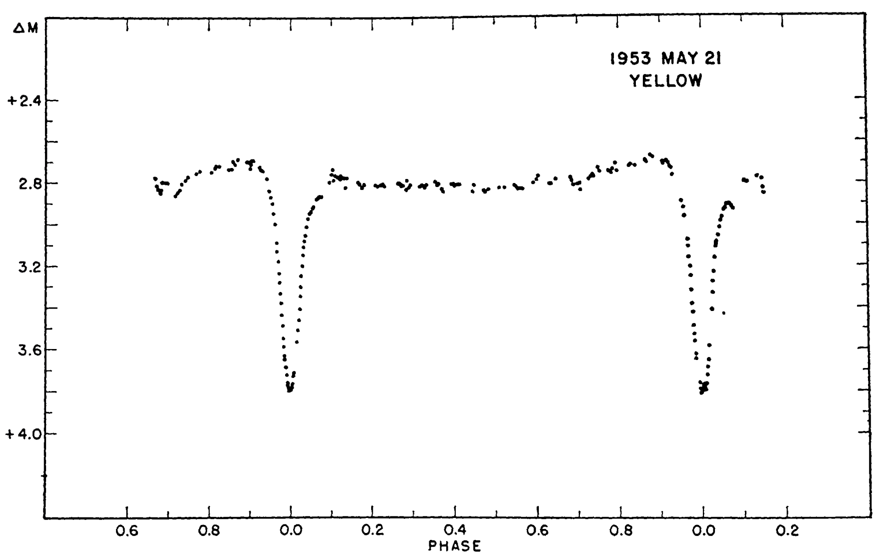

FIG. 4.—Photometric observations of UX UMa. Ordinate and abscissa as in Fig. 1

The light-curves show clearly the short-period, intrinsic fluctuations discovered by Linnell. Their lengths range between 1 and 20 minutes, and their amplitudes (in the ultraviolet) between 0.01 and 0.18 mag. Their amplitude in yellow light is about 0.4 as large as in ultraviolet. Fluctuations shorter than about 1 minute in length may be present, but very quick changes such as these tend to become indistinguishable from variations due to seeing. These rapid changes occur throughout the cycle, but there may be a tendency for the largest to fall between phases 0.4 and 0.9*P*.

Another feature of the light-curve brought out by the present investigation (and also pointed out by the McDonald workers) is a gradual decrease in the light of the star from

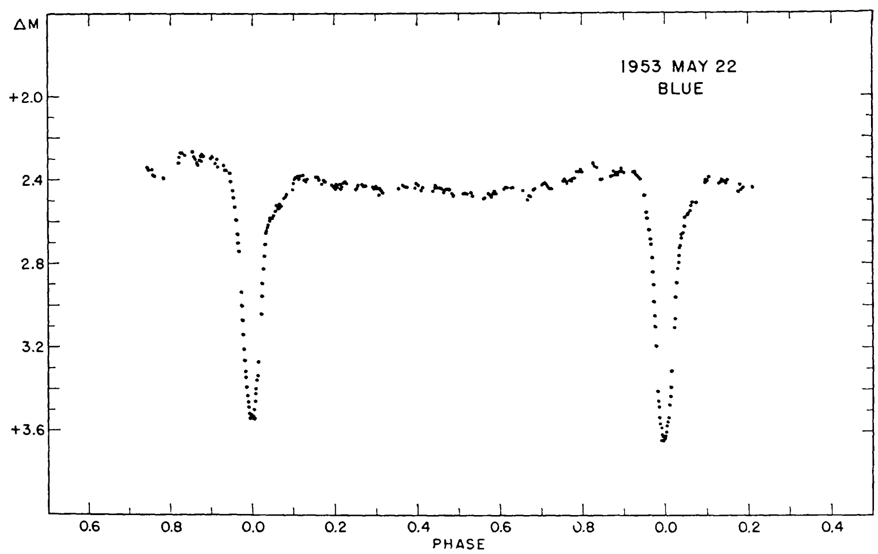

FIG. 5.—Photometric observations of UX UMa. Ordinate and abscissa as in Fig. 1

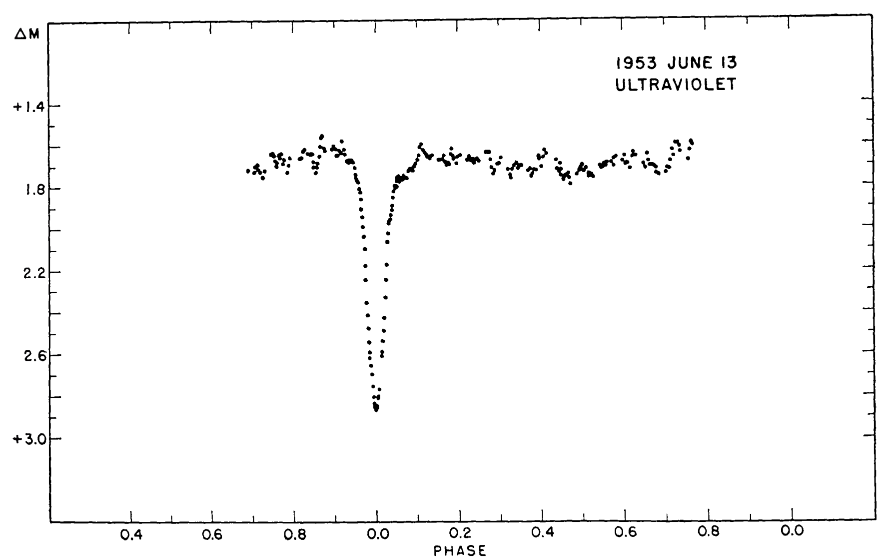

FIG. 6.—Photometric observations of UX UMa. Ordinate and abscissa as in Fig. 1

phase 0.19 until 0.73P, when the shoulder preceding eclipse begins. No secondary minimum has been detected.

The depth of primary minimum, measured from the light-level between phases 0.2 and 0.4P, is about 1.0 mag. in the yellow, 1.1 mag. in the blue, and 1.2 mag. in the ultraviolet. The depth of minimum is not always the same, even for two successive cycles. Examples are the light-curves of May 21 and June 14 in the yellow and the two minima observed on May 22 in the blue.

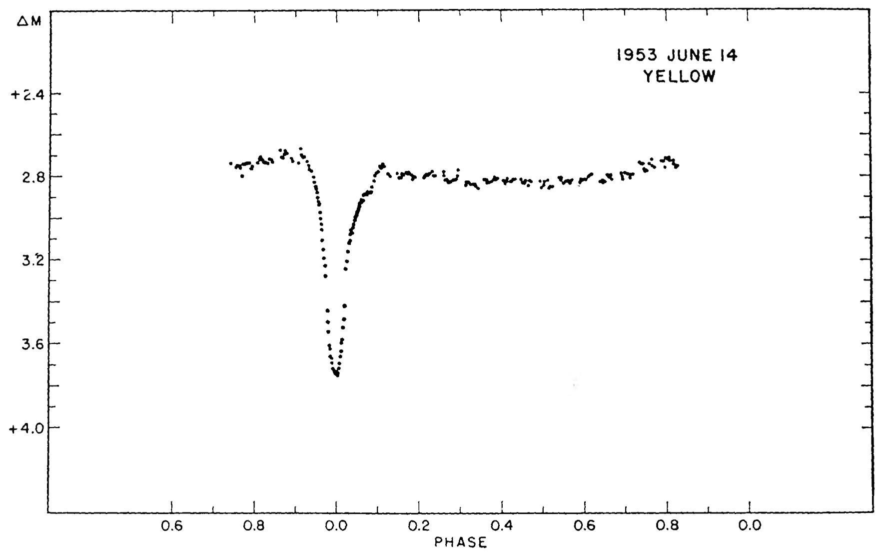

FIG. 7.—Photometric observations of UX UMa. Ordinate and abscissa as in Fig. 1

TABLE 4

OBSERVED MINIMA OF UX URSAE MAJORIS

Helioc. JD 2434+	O−C (Day)	Color	Helioc. JD 2434+	O−C (Day)	Color
484.71988...	−0.00005	B	518.7438....	−0.0003	Y
484.91650...	− .00010	B	518.9409....	+ .0001	Y
485.89956...	− .00040	Y	519.72732...	− .00011	B
485.89973...	− .00023	UV	519.92399...	− .00011	B
490.81668...	− .00006	UV	541.75455...	− .00008	UV
490.81674...	0.00000	Y	542.73792...	−0.00006	Y

The observed times of minimum light are listed in Table 4, together with the residuals from the elements given earlier, in the sense of observed *minus* predicted date. The largest residual is only 0.0004 day. The large residuals, which have been reported elsewhere (Walker 1953), were obtained by measuring the times of minimum light directly on the original Brown potentiometer sheets; they have not been substantiated by the complete reduction of the observations. Most of the large residuals result from asymmetries and disturbances of the lower portion of the light-curve at primary minimum, which changes from cycle to cycle. It is not clear whether these irregularities have the same origin as the short-period fluctuations observed outside eclipse. The present results are not adequate to confirm or deny the existence of the variation in the time of minimum light with wave length, found by Johnson and his co-workers.

If the color of UX UMa between phases 0.2 and 0.4P is regarded as normal, then the two-color light-curves of April 18 and April 23 reveal the following ultraviolet-yellow color variations:

1. As already mentioned, the star is redder than normal during primary eclipse, between phases 0.98 and 0.02P.

2. The observations of April 23 indicate that the star was redder than normal between phases 0.4 and 0.9P. This result is probably connected with the presence of large intrinsic light-fluctuations during this interval. As already mentioned, these fluctuations have about 0.4 the range in the yellow that they exhibit in the ultraviolet. Within this phase interval, the star appeared reddest during the minima of the rapid variations.

3. The ultraviolet brightness of the star is greater than normal between phases 0.03 and 0.09P, during the asymmetric portion of the ascending branch of primary minimum. Maximum ultraviolet brightness coincides with the occurrence of the stillstand between phases 0.05 and 0.07P.

4. The color is normal on the shoulder after eclipse and at the top of the shoulder before eclipse.

Because of the peculiarities of the light-curve, it does not seem worth while at this time to attempt to improve upon the solution that was made by Linnell for the geometrical elements of the eclipsing system.

II. SPECTROSCOPIC OBSERVATIONS

The first published spectroscopic observations of UX UMa were made by G. P. Kuiper (1941), who described the spectrum as that of "a subdwarf primary with very faint lines of type B3." A later low-dispersion spectrogram taken by O. Struve (1945) showed "only broad H absorption lines." A spectrogram taken by N. U. Mayall in 1948 with the same spectrograph that was used in the present investigation shows only a featureless early-type continuous spectrum. This plate was exposed at phase 0.24P.[1] A new series of nine spectrograms was obtained by Struve (1948)[2] with a dispersion of 330 A/mm at $H\gamma$, and our knowledge of the spectroscopic properties of the system has rested, up to the present time, upon Struve's brief discussion of these observations.

The new Lick observations were made with the nebular spectrograph of the Crossley reflector, which gives a dispersion of 430 A/mm at $H\gamma$. The emulsion used was Eastman II*a*-O, baked for 3 days at 50° C. In order to secure as complete a record as possible of any transient changes that might take place in the spectrum of UX UMa, the star was moved once, slowly and uniformly, along a long slit at the proper rate to produce a well-exposed spectrogram. The uniform motion was produced with the aid of a moving wire in the guiding eyepiece. This wire was advanced by a micrometer screw a small distance every 2 minutes, and a guide star was kept on this moving intersection. It would have been possible to obtain the spectrum of an entire cycle, with good time resolution, on a single spectrogram. In order to cut down the contribution of sky radiations, however, three separate exposures, each 90–100 minutes in length and about 0.65 mm wide, were used to cover each cycle. The three spectra were combined in printing (see Figs. 8 and 9) to produce a nearly continuous record of the spectroscopic changes of UX UMa over an interval of almost 5 hours. This method of observing has, in addition to the advantage of nearly continuous recording, the feature of making visible weak lines that might not be seen on narrower spectra. Sixteen spectrograms were obtained on seven nights in

[1] The phases in this section are computed from the elements of Johnson, Perkins, and Hiltner that were used in Sec. I.

[2] Reproductions of Struve's spectrograms have been published by A. P. Linnell (1949).

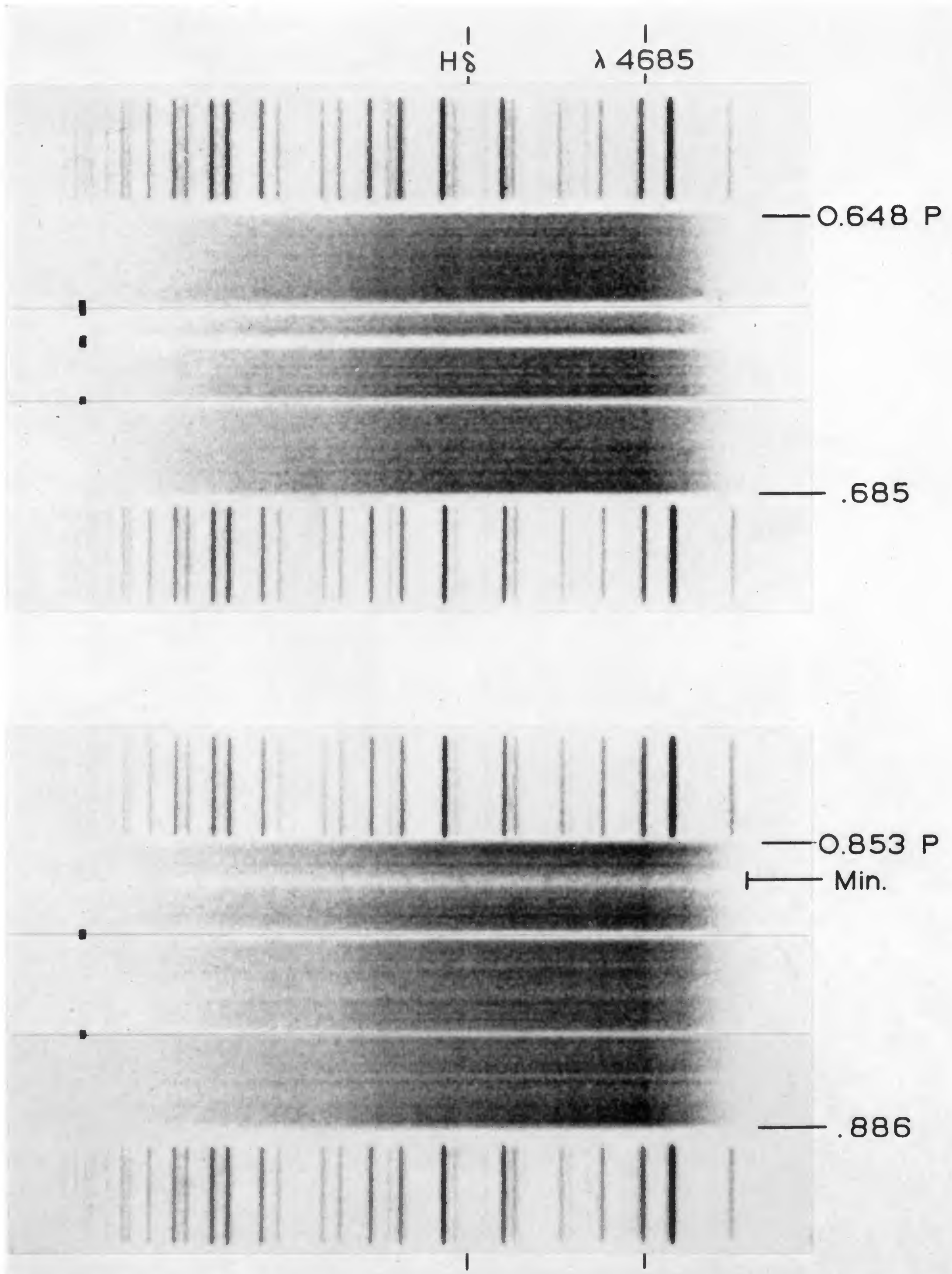

FIG. 8.—The spectrum of UX Ursae Majoris. *Above:* The spectrum on April 15, 1953, beginning at phase 0.648*P* at the top and continuing with a constant time scale to phase 0.685*P* in the following cycle, at the bottom. The black marks near the left edge indicate gaps in the spectrum that were caused by actual interruptions of the exposure. Most of the other horizontal streaks were caused by guiding irregularities. The depression at λλ 3750–3850 is at least partly spurious (see text). *Below:* The spectrum on May 11, 1953, arranged and marked in the same manner. *Min.* marks the position of primary minimum.

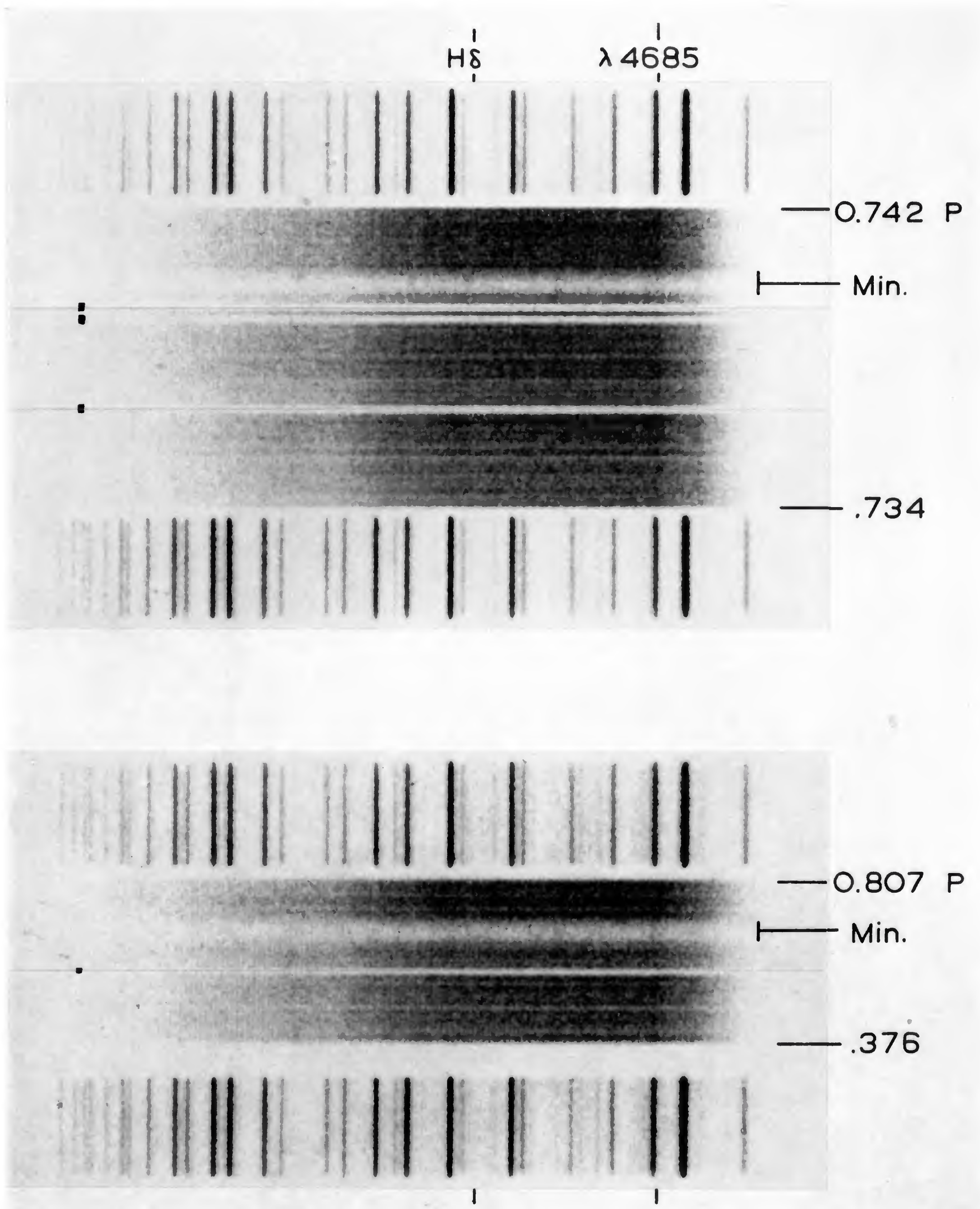

FIG. 9.—The spectrum of UX Ursae Majoris. *Above:* The spectrum on June 13, 1953, beginning at phase 0.742*P* at the top and continuing with a constant time scale to phase 0.734*P* in the following cycle, at the bottom. The black marks near the left edge indicate gaps in the spectrum that were caused by actual interruptions of the exposure. Most of the other horizontal streaks were caused by guiding irregularities. *Min.* marks the position of primary minimum. The depression at λλ 3750–3850 is, at least partly, spurious (see text). *Below:* The spectrum on June 14, 1953, arranged and marked in the same manner.

April, May, and June, 1953, with this technique, and the details of these observations are given in Table 5.

The continuous spectrum of UX UMa is that of a rather blue star: on plates exposed properly for the photographic region, the continuum extends well to shortward of λ 3500. Rather weak emission of variable intensity is present at $H\beta$ for most of the cycle; but the most conspicuous, as well as the most nearly permanent, line feature on the Lick spectrograms is *He* II λ 4685 in emission. Unless the spectrum of UX UMa has changed, it is remarkable that λ 4685 was not seen by the earlier spectroscopic observers. Broad, very shallow absorption lines can usually be seen at $H\gamma$, $H\delta$, and $H\epsilon$ throughout

TABLE 5

SPECTROGRAPHIC OBSERVATIONS OF UX URSAE MAJORIS

Plate No.	UT (Geocentric)		JD (Heliocentric) 2434000+	Phase (Periods)
	Date 1953	Exposure		
CS-1485	Apr. 15	4^h21^m – $5^h54^m.5$	482.684–.749	0.648–0.979
1486*a*		6 04.5–7 38	482.756–.821	.014– .345
1486*b*		7 42 –9 15	482.824–.888	.360– .685
1492*a*	May 11	4 24 –5 56	508.685–.749	.853– .179
1492*b*		6 02 –7 37.5	508.753–.820	.199– .540
1493		7 41 –9 16.5	508.822–.888	.550– .886
1496*a*	May 16	5 29.5–6 59	513.730–.792	.505– .821
1496*b*		7 08 –8 39.5	513.798–.862	.851– .176
1498	May 17	6 42 –8 15.5	514.780–.845	.844– .175
1500*a*	June 5*	5 00 –6 31.5	533.708–.772	.086– .411
1500*b*		6 35.5–8 07	533.775–.838	.427– .747
1502*a*	June 13†	4 53.5–6 25	541.704–.767	.742– .063
1502*b*		6 28 –7 59.5	541.769–.833	.073– .399
1503		8 02.5–9 34	541.835–.899	.409– .734
1504*a*	June 14‡	4 48.5–6 18	542.700–.762	.807– .122
1504*b*		6 20 –7 29.5	542.764–.812	0.132–0.376

* Clouds. McDonald photoelectric observations. † Mount Wilson photoelectric observations.

‡ McDonald and Mount Wilson photoelectric observations.

most of the cycle, except for a short time after minimum light, when they are very weak or absent. During the later phases of some cycles, narrow absorption lines were observed at the higher *H* lines.

The variation of the spectrum through the eclipse cycle, which was discovered by Struve, is not always the same. Therefore, a condensed description of the changes of several spectral features throughout the individual cycles is given in Table 6. In this table, a solid horizontal rule crossing a single column indicates that the corresponding phase is better defined than is one marked by a dotted line. The heavy rules completely across the table at top and bottom indicate the phases when the observations began and ended, respectively. The cycles are designated by their numbers in the equation of Johnson, Perkins, and Hiltner for the time of minimum.

The observations described in Table 6 lead to the following conclusions:

1. The spectrum of UX UMa varies throughout the 0.197-day eclipse cycle, but, al-

though the details of this variation are not the same in every cycle, the general pattern is similar.

2. The narrow H absorption lines of high quantum number ($H8$ and higher) were found in about half the cycles observed. They appear first at phases approximately midway in the cycle. They persist until minimum light, after which they have always disappeared. The very wide, shallow H absorption lines, seen best at $H\delta$, are usually visible for most of the cycle except at phases just following minimum light. These broad lines have been seen or suspected every cycle, and they do not seem to be affected by the appearance or nonappearance of the lines of higher quantum number. It is likely that the two sets of features have, in general, different places of origin: the wide lines probably

TABLE 6

VARIATIONS IN THE SPECTRUM OF UX URSAE MAJORIS

APRIL 15, 1953: E=36311-2*

Phase (Periods)	$H\beta$ Emission	λ 4685 Emission	H Absorption: $H\delta$	H Absorption: $H8$–$H10$	λ 4471 Absorption
0.648					
0.7—					
0.8—	Faintly present	Faint	Fairly strong, wide	Fairly strong	Present
0.9—					
0.0—	Minimum				
0.1—	Faintly present	Faint		Absent	Present?
0.2—	....	↓		....	
0.3—	↓	Increase in strength	Faintly present; wide, shallow	$H8$ present	
0.4—	Increase in strength	↓		....	Present
0.5—	↓	↓		Present?	
0.6—	Fairly strong	Fairly strong			
0.685					

* Minimum was missed while plateholders were being changed and the focus of the star on the slit checked. The K line of Ca II was present in absorption from phase 0.2 to 0.7P. Weak emission to shortward of λ 4685 was present from about phase 0.7 to 0.3 or 0.4. These spectrograms are reproduced in the upper part of Fig. 8.

1954ApJ...120..278W

TABLE 6—*Continued*

MAY 11, 1953: $E=36443-4$†

Phase (Periods)	$H\beta$ Emission	λ 4685 Emission	*H* Absorption: $H\delta$	*H* Absorption: $H8-H10$	λ 4471 Absorption
0.853					
0.9—	Weakly present?	Strong, diffuse	Present	Present	Present
0.0—	Minimum				
0.1—			Probably absent	Probably absent	
0.2—					
0.3—	Very weak				
0.4—		Strong			
0.5—	....	Diffuse	Faintly present; wide, shallow	Faint	Faintly present
0.6—					
0.7—	Fairly strong				
0.8—		Diffuse			
0.886					

† For about 10 minutes while the variable was near the bottom of primary minimum, the continuous spectrum was too faint to register and only the rather diffuse emission lines $H\beta$ through $H\epsilon$ (and possibly $H8$ and $H9$ as well) and λ 4685 were visible. The presence of very weak emission to shortward of λ 4685 was suspected from 0.2 to 0.4*P*, and perhaps later. These spectrograms are reproduced in the lower part of Fig. 8.

1954ApJ...120..278W

TABLE 6—*Continued*

MAY 16, 1953: E=36469–70‡

Phase (Periods)	$H\beta$ Emission	λ 4685 Emission	H Absorption		λ 4471 Absorption
			$H\delta$	$H8$–$H10$	
0.505 0.6— 0.7— 0.8—	Weak	Moderately strong; diffuse	Faintly present; wide	Very faint or absent	Absent
0.9—	Very weak or absent		Present?		Present?
0.0—	Minimum				
0.1— 0.176	Present?	Moderately strong	Very faint or absent	Absent	(Plate defect)

‡ At minimum light, $H\beta$, $H\gamma$, and λ 4685 were weakly present in emission. A bright line may have been present to shortward of λ 4685 just preceding and following minimum.

MAY 17, 1953: E=36474–5§

Phase (Periods)	$H\beta$ Emission	λ 4685 Emission	H Absorption		λ 4471 Absorption
			$H\delta$	$H8$–$H10$	
0.844 0.9—	Very faint or absent	Moderately weak	Present; wide	Present	Absent
0.0—	Minimum				
0.1— 0.175	Weak	Moderately weak; diffuse?	Present?	Absent	Faintly present?

§ At minimum light, λ 4685 was, as usual, the strongest emission line, followed by $H\beta$, $H\gamma$, and $H\delta$. Emission was presen to shortward of λ 4685 from about phase 0.9P to just before minimum.

TABLE 6—*Continued*

JUNE 5, 1953: $E=36571$

PHASE (PERIODS)	$H\beta$ EMISSION	λ 4685 EMISSION	H ABSORPTION: $H\delta$	H ABSORPTION: $H8$–$H10$	λ 4471 ABSORPTION
0.086					
0.2—		Moderately strong			Fairly strong
0.3—	Weak		Very faint		Weak
0.4—				Absent	
0.5—		Weak			
0.6—	(Plate defect)	Medium strength	Faint, wide		Absent
0.7—					
0.747					

TABLE 6—*Continued*

JUNE 13, 1953: $E=36611-2$‖

Phase (Periods)	$H\beta$ Emission	λ 4685 Emission	H Absorption: $H\delta$	H Absorption: $H8$–$H10$	λ 4471 Absorption
0.742					
0.8–0.9	Weak	Strong	Faint, wide	Weak	Faintly present?
0.0	Minimum				
0.1–0.3	Weak → Increase in strength	Strong	Faint	$H8$ present	Faintly present
0.4–0.5	Strong	Diffuse	Moderately strong; wide		Probably absent
0.6–0.7	Moderately strong	Strong			
0.734					

‖ The He II line λ 4685 and the H lines from $H\beta$ to $H8$ are in emission at minimum light. Emission to shortward of λ 4685 was present after about phase 0.8P, through minimum, and probably after minimum as well. These spectrograms are reproduced in the upper part of Fig. 9.

TABLE 6—*Continued*

JUNE 14, 1953: E=36616–7#

Phase (Periods)	$H\beta$ Emission	λ 4685 Emission	H Absorption: $H\delta$	H Absorption: $H8$–$H10$	λ 4471 Absorption
0.807					
0.9—	Absent	Moderately weak	Very wide, shallow	Fairly strong	Faint
0.0—	Minimum				
0.1—	Absent	Moderately weak	Faintly present?	Absent	Moderately strong
0.2—	Very faintly present	Diffuse			
0.3—			Absent		
0.376					

λ 4685 is fairly strong in emission at minimum light, while the bright Balmer lines $H\beta$ through $H\epsilon$ or $H8$ appear only faintly. These spectrograms are shown in the lower part of Fig. 9.

originate in the primary star, while the ultraviolet lines may be produced in an extended envelope, as was suggested by Struve.

3. Of all the spectral features studied, bright *He* II λ 4685 most nearly maintains a constant intensity throughout the cycle, but it is stronger in some cycles than in others. Compare, for example, the upper and lower panels of Figure 8.

4. No obvious pattern for the intensity variations of the $H\beta$ emission line has been discovered, except that the line has a tendency to be stronger at intermediate phases (0.4–0.7P) than it does in the neigborhood of minimum light.

5. The somewhat diffuse emission spectrum observed at minimum light (λ 4685 is the strongest line, followed by the H lines) has a much slower Balmer decrement than that observed outside eclipse. It is unlikely that the spectrum at minimum could be produced from that just before eclipse simply by removing the continuous spectrum of the primary star.

The spectrograms taken on nights when simultaneous Mount Wilson or McDonald photoelectric observations were also available have been examined in an effort to detect any spectral changes that might be correlated with the "flares" observed in the light-curve. Only one very tentative correlation could be found: there is some reason to suspect that the seemingly erratic widenings of the λ 4685 emission line may occur at about the same time as the flares in the light-curve. Unfortunately, the present material is too scanty to make possible a firm statement. If this association of λ 4685 width with short-lived maxima in the light-curve is real, it is very reminiscent of the phenomenon of "nitrogen flaring" observed in certain novae during their decline in light (Wright 1930). In novae, the flaring affects *He* II λ 4685 as well as the fluorescent *N* III lines, and it is associated with temporary increases in the light of the star, as is suspected to be the case in UX UMa.

A word of caution must be inserted with regard to the spectra of UX UMa reproduced in Figures 8 and 9. Test exposures of artificial light-sources having continuous spectra have been obtained with the Crossley nebular spectrograph, after the light was first reflected from the primary mirror. These spectrograms show the presence of a wide, very shallow absorption band lying approximately between λ 3750 and λ 3850. The wide absorption shown at about this position in the spectra of UX UMa seems to be somewhat stronger than in the test exposures which may be due to reinforcement in the star by the overlapping wings of broad *H* lines. Nevertheless, there can be little doubt that the conspicuous depression in the near ultraviolet, seen in Figures 8 and 9, is, to a large extent, of instrumental or photographic origin.

The Lick spectrograms were not intended for the determination of the radial velocity

TABLE 7

RADIAL-VELOCITY MEASUREMENTS OF UX URSAE MAJORIS

Plate No.	Phase Interval (Periods)	$H\beta$ Emission (Km/Sec)	λ 4685 Emission (Km/Sec)	*H* Absorption Lines (Km/Sec)
CS-1485....	0.65–0.81	—	—	+440 $H\epsilon$, $H8$, $H10$
	.81– .98	—	+260:*d*	+430 $H\epsilon$, $H8$, $H9$, $H10$
1486*a*...	.24– .34	−140	+150:*d*	+360 $H8$
1486*b*...	.36– .47	—	−210	—
	.47– .58	—	− 80	—
	.58– .68	−460	−190:	—
1492*a*...	.85– .98	—	−480:*d*	+430 $H8$, $H9$
	.98– .02	—	− 50:	—($H\gamma$, $H\delta$ emission = +20 km/sec)
	.02– .18	−130	−250	—
1492*b*...	.20– .30	—	+ 60 *d*	—
	.30– .40	−170:	+ 60	+430: $H8$*
	.40– .54	−440	− 50	+350 $H8$, $H9$, $H10$
1493....	.55– .66	−360	+180:*d*	+300? $H\epsilon$
	.66– .77	− 30	−280:	—
	.77– .89	—	−750?*d*	+440 $H\epsilon$, $H9$
1496*a*...	.50– .61	−170	—*d*	—
	.61– .71	+200:	−500	—
	.71– .82	+100:	−210:*d*	—
1496*b*...	.85– .98	—	+270:*d*	—
	.98– .02	—	−210:	—
	.02– .18	—	− 50:*d*	—
1498....	.84– .98	—	+400	+260: $H8$
	.98– .02	—	+ 40:	—($H\gamma$ emission = +90 km/sec)
	.02– .18	+ 20	—	—
1502*a*...	.74– .85	—	+140:*d*	+420 $H\epsilon$, $H8$, $H9$, $H11$
	.85– .98	—	+ 60	—
	.98– .02	−130:	+ 70:	—($H\gamma$, $H\delta$, $H\epsilon$, $H8$ emission = −90 km/sec)
1502*b*...	.10– .22	—	+340:	—
	.22– .30	—	+160:*d*	—
	.30– .40	—	+300	—
1503....	.41– .55	−440	−200:*d*	—
	.55– .73	−150	−250	—
1504*a*...	.81– .98	—	—	+250: $H8$
	.98– .02	—	—	—
	.02– .12	—	−210:	—
1504*b*...	.13– .25	—	−360:	—
	0.25–0.38	—	−670?*d*	—

* $H8$ phase, 0.37–0.42.

of UX UMa, because it was felt that the present observational technique, which involved only one passage of the star along the slit, might introduce guiding error into the radial velocities. Observations of early-type stars of constant velocity with the same technique, however, have failed to reveal any serious systematic errors ascribable to this procedure. Nevertheless, the unusual character of the radial-velocity results for UX UMa makes it desirable that they be independently confirmed.

The spectrum of UX UMa is very difficult to measure for radial velocity, because of the weakness of its features. This fact, coupled with the low dispersion that had to be

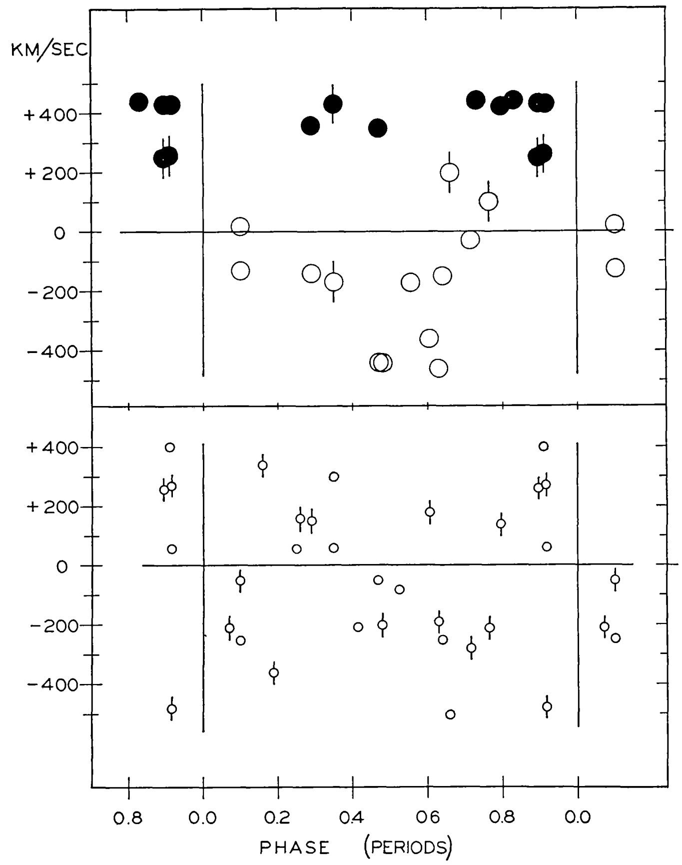

FIG. 10.—Radial velocities measured in the spectrum of UX Ursae Majoris. In the upper panel, the open circles represent the velocities obtained from the $H\beta$ emission line, while the filled circles indicate the velocities measured for the high-quantum number H absorption lines. The smaller open circles in the lower panel show the velocities obtained from the He II λ 4685 emission line. In both panels, a vertical bar through a point indicates a measurement of lower weight. The sizes of the circles and the length of the vertical bars are not intended to correspond to the uncertainties of the velocities in either panel.

used (on the present plates, at $H\beta$ a displacement of 1 μ corresponds to a velocity of 39 km/sec), is responsible for the very low precision of the velocities. Only three features could be measured with any consistency: emission $H\beta$, λ 4685, and the high H absorption lines. The very wide, shallow features observed at $H\gamma$, $H\delta$, and $H\epsilon$ were too indefinite for velocity determination. In Table 7, a dash indicates that the corresponding line was unmeasurable or not seen. A colon follows velocities of lower weight than those not so indicated, and a d in the column for λ 4685 indicates that the line was not well defined at that time. The data of Table 7 are plotted in Figure 10.

If the velocities are taken at their face value, then these conclusions may be drawn from the data:

1. The displacements of the $H\beta$ emission line suggest a velocity variation with a minimum at phase 0.5 or 0.6P. Unfortunately, this line is usually quite faint between phase 0.8P and minimum light; this fact accounts for the lack of measures in that interval, which would be of great value in establishing the reality of the velocity variation.

2. The displacements of the H absorption lines of higher quantum number ($H8$–$H11$, and sometimes $H\epsilon$) correspond to an approximately constant velocity of +350 to +400 km/sec. The real uncertainty of these velocities is much larger than one would infer from the rather small dispersion about their mean.

3. Much of the scatter in the displacement of λ 4685 is due to its frequently diffuse character. There is no conspicuous regularity to its velocity variation, but there may be a tendency for its displacement to change in approximately the same way as does that of the $H\beta$ emission line.

It is difficult to assign a spectral type to the primary component of UX UMa because significant features in its spectrum undergo interference from other lines that should not be considered in the classification. For example, the radial-velocity evidence shows that the high H absorption lines are not formed in the primary star, and hence they must be disregarded. It is of interest that, on some occasions, a very weak emission has been observed shortward of λ 4685. This emission probably is a blend of the *N* III lines at $\lambda\lambda$ 4634–4641, although an identification with *C* III $\lambda\lambda$ 4647–4651 cannot be ruled out. On some plates there is also an apparent emission line near λ 4525. A similar feature at that wave length, found on low-dispersion spectra of stars of spectral type near O6, is apparently a gap between weak absorption lines. Therefore, the spectrum of UX UMa resembles that of an Of star with bright $H\beta$; but, since the radial-velocity information has not served to demonstrate clearly an association of the *He* II emission with the primary star, the f designation is only tentative. The lack of a conspicuous Balmer jump and the weakness of the wide H lines are, however, in harmony with a classification of the primary star as of type O rather than early B. The assignment to type O is substantiated by the presence of the high-excitation lines of *He* II and, probably, *N* III; for, whether they originate immediately in the primary component or not, that star probably is the source of their excitation.

III. INTERPRETATION AND DISCUSSION

Possible interpretations of the features of the light-curve of UX UMa have been discussed by Linnell. He suggested that the bright shoulder on the light-curve between phase 0.7P and primary minimum and the lesser (in 1953) shoulder following minimum were due either to a hot spot on the primary star or to a luminous region some distance above its surface. We propose to discuss and extend the second possibility in the light of the more extensive information now available. We advance for consideration an interpretation of the observational features of UX UMa in terms of the model shown schematically in Figure 11. For lack of better information, the relative dimensions and masses of the components that were used in the construction of Figure 11 are those determined by Linnell; but, in view of the difficulty in discussing the peculiar light-curve of this variable and doubt as to the applicability of the ordinary mass-luminosity relationship, these values may very well not be correct. If the hump preceding minimum light is due to the presentation at the most favorable aspect of a mass of hot material situated well above the surface of the primary and (in 1953) located asymmetrically with respect to the line joining the two stars, then the asymmetry on the rising branch of primary minimum between phases 0.03 and 0.10P is due to the occultation of this bright region by the fainter star. The phase of the asymmetry shows that the bright region must effectively lie about 1 radius above the surface of the primary, as was pointed out by Linnell. The extension of the bright region in the direction perpendicular to the orbit plane may vary, so that the only correlation to be expected between the intensity of the shoulders and that of the asymmetry is that the asymmetry should never occur unless the bright shoulders are present; but the converse may not always be true.

It is clear that the radiation of the postulated hot cloud is essentially continuous with wave length, for the spectra show that only the continuum grows stronger just before minimum (see especially Fig. 9, *top*), and there is no enhancement of the bright lines at this phase. The sudden appearance at about phase 0.7P of the contribution of this bright region must be due, not to its appearance from behind the disk of the brighter star, but

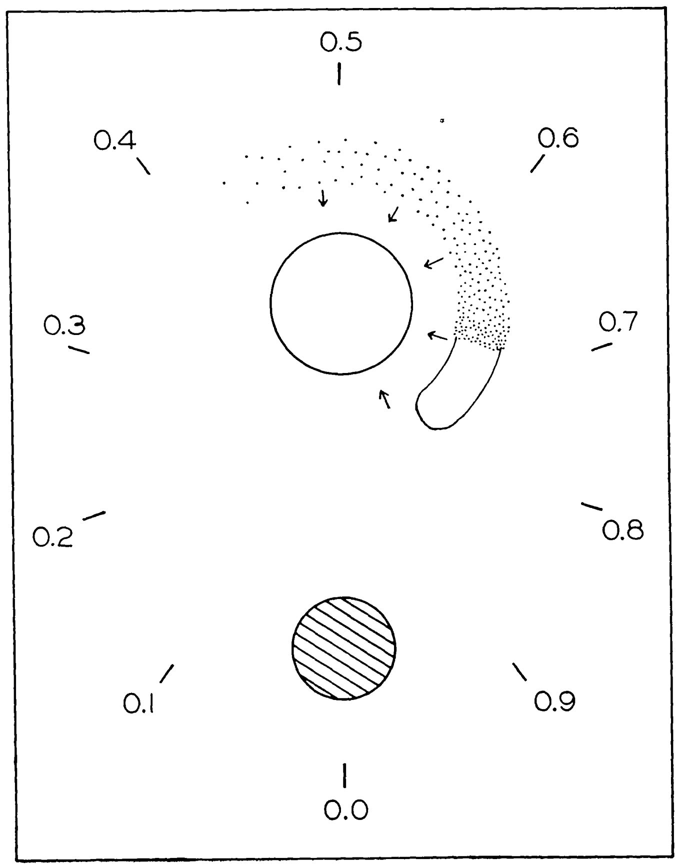

FIG. 11.—Schematic diagram of proposed model of the system of UX Ursae Majoris. The relative dimensions and separation of the components correspond to the elements of Linnell; the disk of the fainter star is shaded. The stippled portion of the cloud near the primary star is cooler than the part not so marked. The arrows indicate material falling into the bright star from the cloud. Phases are indicated around the edges of the diagram and are in units of the period.

rather to its being uncovered by an extensive region of cooler gas that is seen projected upon the disk of the primary at earlier phases. After minimum, the bright region is occulted by the secondary component, and the anomalous ultraviolet brightness of the system at this phase may be explained if we suppose that the color of the bright cloud is redder than that of the primary star. The less favorable aspect of the bright region after minimum would explain the smaller shoulder following eclipse.

In this picture, the cooler mass of gas that hides the hot region until phase 0.7P may also be responsible for the gradual reddening of the system between about 0.4 and 0.9P, and it is presumed to be associated with the gas that produces the high-quantum number

H absorption lines. This cooler cloud may merge continuously with the hotter, and both are shown as parts of a continuous arc in Figure 11. Certainly, as one considers regions of the cooler cloud that are projected upon the disk at earlier phases, the blocking effectiveness of the cloud decreases until its last vestiges, the high *H* absorption lines, are only occasionally seen at phases earlier than about 0.4 or $0.5P$. The large positive displacement of these lines (+350 to +400 km/sec) suggests that they are produced by cool gas descending from the surrounding cloud to the primary star.

The facts that the bright $H\beta$ line usually is strongest between phases 0.4 and $0.7P$ and that its velocity variation reaches a minimum value near phase $0.6P$ indicate that the $H\beta$ emission originates somewhere in that portion of the arc of cool gas that is approaching the observer at phase $0.6P$. It may be that some contribution to *He* II λ 4685 is produced in the same region, but the rather small variation of the strength of λ 4685 with phase suggests that it must, in general, be of more widespread origin. The process responsible for the maintenance of the luminous region apparently does not operate smoothly, as shown by the changes in the spectrum and light-curve in different cycles. The possibility of a considerable change in the nature or location of the luminous region is indicated by the existence of abnormal cycles such as that whose light-curve was observed by Johnson *et al.* on May 29, 1952. A more gradual change in the characteristics of the hypothetical gaseous cloud must be responsible for the weakening of the shoulder that follows minimum, and the strengthening of the shoulder that precedes eclipse, which seem to have taken place since Linnell's observations in 1949 (see Sec. I). Finally, we do not believe that it is clear which star is the source of the material in the arc or cloud which we have postulated around the brighter component in order to explain the observations.

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