Publications of the Astronomical Society of the Pacific
107: 132–135, 1995 February

UBV Light Curves of V356 Sagittarii

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Received 1994 October 7; Accepted 1994 November 18

ABSTRACT. We report here UBV observations of the unusual eclipsing binary V356 Sagittarii from 1973, 1974, and 1975. Although there are phase gaps, light-curve form and absolute level differ only slightly from light curves of 23 years earlier in the phases that are covered. Scatter is anomalously large, as in the earlier observations, and seems to be diagnostic of some intrinsic abnormality.

1. INTRODUCTION

V356 Sagittarii (V356 Sgr) is an unusual member of the Algol class of binaries that has received special attention with regard to its evolutionary state but has been observed only occasionally, and then with somewhat perplexing results. A discussion of the evolutionary and observational problems will appear in a forthcoming paper by Polidan and Wilson (1995; hereafter PW). That paper will address several aspects of the V356 Sgr situation and attempt to resolve difficult issues raised by a number of authors, including Popper (1955), Wilson and Caldwell (1978), and Ziolkowski (1985). The assessment in PW will be done in the light of recent observations by Polidan (1988, 1989) that are relevant to the presence or absence of a disk around the higher-mass star, and by Tomkin and Lambert (1994) that establish the extreme carbon underabundance of the lower-mass star. Here we report UBV light curves that help to put some of the star's problems into perspective.

2. THE OBSERVATIONS

V356 Sgr (HD 173787; BD−20 5268) was observed by E.J.W. at Cerro Tololo Inter-American Observatory (CTIO) in 1973, 1974, and 1975 (B, V only in 1975) with the 41-cm reflector, the 61-cm Lowell reflector, and the 102-cm Yale reflector. The phototube was an RCA 1P21 and the filters were the standard UBV filters (Johnson 1955). On the 41- and 61-cm telescopes, the signals were amplified and recorded with the analog equipment ordinarily used at CTIO at that time, while a pulse-counting system was used with the 102-cm telescope. The comparison star (HD 172696 =BD−20 5240; $V=7\overset{m}{.}1$; $B-V=0\overset{m}{.}19$; Sp.=B9) was the one used by Popper (1957) and most other observers. All magnitude differences listed in Tables 1, 2, and 3 are corrected for differential atmospheric extinction and all times are heliocentric. The 1973 and 1975 observations (of these rather bright stars) were 8 s measurements, while the 1974 pulse counting observations were 4 s counts. Nearly twenty years have elapsed since the observations were reduced, and the original paper recording tapes and computer printouts have not survived, so we cannot provide specifics of the transformations to the UBV system or tell the telescope with which particular observations were made. However E.J.W. made sufficient standard-star observations to carry out the transformations, and the listed magnitude differences should be essentially on the UBV system. Although it may seem unnecessary to list the individual observations, rather than averages ("normal points"), we do so for the following reasons. First, the tables are short, even with all observations printed. Second and more important, we shall see in Sec. 3 that unusual fluctuations appear in all V356 Sgr light curves that have been observed to date. The origin of these fluctuations may be investigated by detailed analysis (not to be attempted here) that needs data with fine time resolution.

3. INFERENCES FROM THE LIGHT CURVES

The observations have missing phase regions, as shown by Figs. 1, 2, and 3, but do give useful information about light-curve form and consistency, especially since few photoelectric light curves of V356 Sgr exist. Coverage is not sufficient to justify a solution independent of Popper's (1957) more fully covered curves. However, in separate work (PW), R.E.W. has fitted Popper's light curves from the 1951 season, and the resulting theoretical B,V curves can serve as convenient templates for judging changes between

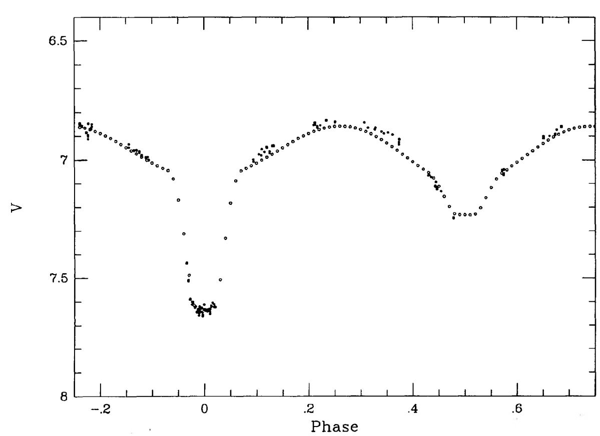

FIG. 1—V Light curve (dots) formed by adding the V magnitude of the comparison star (Popper 1957) to the magnitude differences of Table 1. The circles represent the theoretical light curve fitted to Popper's 1951 observations by R.E.W. No fitting of any kind was done with respect to the Woodward observations, so the illustrated agreement shows the light curve to be nearly the same in 1973–75 as in 1951.

TABLE 1
[JD(Hel.)−2440000.] and V Magnitude Differences

JD	del V	JD	del V	JD	del V	JD	del V
1859.7291	−0.188	1859.7293	−0.190	1859.7298	−0.180	1859.7299	−0.182
1860.7002	−0.245	1860.7003	−0.240	1860.7034	−0.241	1860.7036	−0.236
1860.7386	−0.233	1860.7388	−0.230	1860.7390	−0.228	1860.8132	−0.207
1860.8134	−0.204	1860.8135	−0.206	1860.8441	−0.195	1860.8442	−0.177
1860.8444	−0.189	1860.8484	−0.244	1860.8485	−0.241	1860.9110	−0.230
1860.9112	−0.240	1861.5483	−0.142	1861.5485	−0.156	1861.6392	−0.132
1861.6394	−0.129	1861.6819	−0.132	1861.6821	−0.128	1861.7295	−0.120
1861.7297	−0.126	1861.7682	−0.107	1861.7683	−0.111	1861.8448	−0.101
1861.8449	−0.098	1861.8739	−0.102	1861.8741	−0.102	1861.8890	−0.089
1861.8894	−0.088	1861.8896	−0.090	1862.5286	0.348	1862.5287	0.344
1862.5595	0.419	1862.5596	0.423	1862.5908	0.499	1862.5909	0.502
1862.6191	0.511	1862.6193	0.523	1862.6333	0.518	1862.6334	0.511
1862.7078	0.553	1862.7079	0.556	1862.7282	0.541	1862.7283	0.543
1862.7482	0.555	1862.7483	0.549	1862.7490	0.557	1862.7491	0.549
1862.8047	0.572	1862.8048	0.566	1862.8285	0.546	1862.8287	0.541
1862.8890	0.544	1862.8892	0.552	1862.9027	0.549	1862.9028	0.546
1862.9285	0.554	1862.9286	0.562	2200.7234	0.536	2200.7372	0.531
2200.7758	0.550	2200.7856	0.550	2200.8407	0.536	2200.8511	0.556
2200.9091	0.550	2201.7247	−0.090	2201.7290	−0.081	2201.8186	−0.112
2201.8610	−0.108	2201.9127	−0.122	2202.7484	−0.235	2202.8646	−0.234
2203.6219	−0.246	2203.6846	−0.224	2209.6999	0.531	2209.9225	0.515
2212.6964	−0.218	2212.7075	−0.224	2212.8098	−0.208	2212.8495	−0.201
2212.9186	−0.205	2213.6042	−0.023	2213.6223	−0.024	2213.7366	0.004
2213.7593	0.024	2213.8239	0.043	2214.8629	−0.048	2214.8631	−0.045
2214.8886	−0.033	2214.8888	−0.026	2214.8918	−0.051	2214.8920	−0.048
2215.7981	−0.218	2215.7983	−0.217	2215.8803	−0.228	2215.8804	−0.232
2218.5838	0.551	2218.5842	0.557	2218.5844	0.552	2218.5860	0.560
2218.5862	0.569	2218.6336	0.539	2218.6340	0.554	2218.6747	0.523
2218.6749	0.523	2218.7533	0.541	2218.7535	0.549	2218.7938	0.531
2218.7940	0.528	2218.8414	0.532	2218.8416	0.521	2219.6588	−0.134
2219.6590	−0.134	2219.7462	−0.140	2219.7464	−0.144	2219.7913	−0.125
2219.7915	−0.117	2219.8393	−0.146	2219.8395	−0.149	2219.8637	−0.150
2219.8640	−0.147	2220.5643	−0.237	2220.5645	−0.245	2220.6058	−0.224
2220.6060	−0.230	2220.7612	−0.254	2220.7614	−0.256	2220.9115	−0.251
2220.9118	−0.248	2230.7897	−0.196	2230.7900	−0.196	2230.8988	−0.164
2230.8989	−0.154	2230.9059	−0.175	2230.9062	−0.177	2231.8304	0.157
2231.8306	0.153	2542.8106	−0.017	2542.8108	−0.016	2542.8784	0.020
2542.8788	0.024	2542.9096	0.034	2542.9097	0.028	2544.8331	−0.191
2544.8332	−0.191	2544.9295	−0.199	2544.9297	−0.195	2545.8978	−0.219
2545.8981	−0.224						

1951 and 1973–75. The applied model includes very fast rotation in a double contact configuration (Wilson 1979), but without a thick and opaque disk, as in Wilson and Caldwell (1978). Agreement between the model and the 1951 observations is fairly good, with only small discrepancies, and will be illustrated by PW.

As shown by Figs. 1 and 2 (V and B, respectively), the curves that were fitted to the 1951 Popper data go reasonably well through the Woodward data, so that any epoch-to-epoch changes are small, except that the maximum around phase 0.25 is elevated by about 0.03 mag in the Woodward data. In 1951 that phase region was elevated by about 0.01 mag relative to the overall model fit. Any other changes between the two epochs are quite subtle. The scatter in the Popper and the Woodward observations is about the same and appears to be roughly constant with level on a magnitude scale, which implies that it scales with light level on a light scale (there are not enough observations to make a stronger comment). The standard deviation of an observation is a little over 0.01 mag, which is 3 to 4 times larger than good photoelectric accuracy for such a bright star. All published light curves of V356 Sgr show at least this much scatter, so that the scatter is itself an interesting and distinctive feature of the binary. It seems likely that the scatter is a manifestation of some astrophysical irregularity of unknown cause, acting at both epochs. Inspection of our tables shows that the anomalously large scatter does not arise mainly from cycle to cycle variations, but rather from short time-scale fluctuations. In fact, cycle-to-cycle repetition within the scatter band is rather good. The most obvious candidate for the source of the fluctuations would be irregular flow effects in transferred gas. However, observational limits on the present rate of period change are somewhat in conflict with that idea.

4. BEHAVIOR OF THE ORBITAL PERIOD

According to the evolutionary model and computations of Ziolkowski (1976; 1985), V356 Sgr should be in the rapid stage of mass transfer. The orbital period should accordingly be increasing at an easily detectable rate, even with the poor

TABLE 2
[JD(Hel.)−2440000.] and *B* Magnitude Differences

JD	del *B*	JD	del *B*	JD	del *B*	JD	del *B*
1859.7302	−0.200	1859.7304	−0.203	1860.7005	−0.259	1860.7007	−0.259
1860.7038	−0.259	1860.7039	−0.265	1860.7392	−0.271	1860.7393	−0.258
1860.8137	−0.252	1860.8139	−0.257	1860.8141	−0.242	1860.8446	−0.231
1860.8447	−0.234	1860.8449	−0.234	1860.8487	−0.264	1860.8489	−0.258
1860.9114	−0.227	1860.9115	−0.273	1860.9118	−0.286	1860.9120	−0.294
1861.5487	−0.189	1861.5489	−0.201	1861.6395	−0.165	1861.6397	−0.173
1861.6822	−0.178	1861.6824	−0.164	1861.7298	−0.163	1861.7300	−0.150
1861.7685	−0.130	1861.7687	−0.127	1861.8451	−0.121	1861.8452	−0.117
1861.8744	−0.127	1861.8745	−0.136	1861.8897	−0.127	1861.8899	−0.127
1862.5288	0.395	1862.5289	0.386	1862.5599	0.463	1862.5600	0.471
1862.5912	0.553	1862.5913	0.551	1862.6195	0.571	1862.6196	0.578
1862.6336	0.568	1862.6337	0.566	1862.7081	0.608	1862.7082	0.605
1862.7285	0.592	1862.7286	0.578	1862.7486	0.596	1862.7487	0.599
1862.7493	0.610	1862.7495	0.596	1862.8050	0.632	1862.8052	0.631
1862.8289	0.575	1862.8290	0.579	1862.8894	0.596	1862.8895	0.597
1862.9030	0.603	1862.9032	0.597	1862.9288	0.612	1862.9290	0.604
2200.7236	0.592	2200.7374	0.583	2200.7759	0.592	2200.7858	0.596
2200.8409	0.598	2200.8512	0.606	2200.9093	0.599	2201.7250	−0.113
2201.7292	−0.110	2201.8188	−0.147	2201.8613	−0.144	2201.9130	−0.146
2202.7485	−0.264	2202.8648	−0.272	2203.6221	−0.285	2203.6848	−0.263
2209.7000	0.560	2209.9226	0.587	2212.6966	−0.250	2212.7077	−0.254
2212.8100	−0.222	2212.8497	−0.225	2212.9188	−0.253	2213.6044	−0.068
2213.6230	−0.067	2213.7368	−0.041	2213.7595	−0.021	2213.8240	0.003
2214.8637	−0.069	2214.8890	−0.078	2214.8893	−0.066	2214.8895	−0.071
2214.8922	−0.076	2214.8924	−0.076	2215.7985	−0.248	2215.7987	−0.247
2215.8807	−0.249	2215.8808	−0.251	2218.5847	0.609	2218.5852	0.603
2218.5855	0.604	2218.6345	0.591	2218.6347	0.594	2218.6752	0.576
2218.6754	0.576	2218.7538	0.594	2218.7541	0.591	2218.7943	0.584
2218.7945	0.584	2218.8419	0.575	2218.8422	0.575	2219.6597	−0.150
2219.6599	−0.161	2219.7467	−0.155	2219.7469	−0.157	2219.7918	−0.146
2219.7921	−0.147	2219.8399	−0.179	2219.8401	−0.183	2219.8643	−0.185
2219.8645	−0.188	2220.5648	−0.251	2220.5651	−0.247	2220.6063	−0.260
2220.6066	−0.255	2220.7618	−0.274	2220.7620	−0.270	2220.9120	−0.280
2220.9120	−0.279	2230.7902	−0.237	2230.7904	−0.237	2230.8993	−0.138
2230.8995	−0.137	2230.9064	−0.182	2230.9067	−0.180	2231.8309	0.108
2231.8311	0.107	2542.8110	−0.042	2542.8112	−0.045	2542.8791	−0.023
2542.8793	−0.026	2542.9099	−0.012	2542.9102	−0.014	2544.8334	−0.219
2544.8336	−0.214	2544.9302	−0.221	2544.9303	−0.227	2545.8983	−0.254
2545.8985	−0.258						

TABLE 3
[JD(Hel.)−2440000.] and *U* Magnitude Differences

JD	del *U*	JD	del *U*	JD	del *U*	JD	del *U*
2200.7238	0.894	2200.7376	0.905	2200.7761	0.918	2200.7860	0.921
2200.8411	0.914	2200.8514	0.927	2200.9094	0.913	2201.7252	−0.236
2201.7294	−0.237	2201.8193	−0.257	2201.8615	−0.256	2201.9134	−0.254
2202.7487	−0.376	2202.8650	−0.388	2203.6222	−0.420	2203.6849	−0.427
2209.7001	0.877	2209.9231	0.905	2212.6968	−0.418	2212.7079	−0.423
2212.8103	−0.405	2212.8499	−0.406	2213.6046	−0.285	2213.6232	−0.294
2213.7370	−0.270	2213.7597	−0.266	2213.8244	−0.283	2214.8639	−0.321
2214.8642	−0.328	2214.8897	−0.278	2214.8899	−0.271	2214.8927	−0.283
2214.8931	−0.275	2215.7992	−0.392	2215.7994	−0.391	2215.8811	−0.399
2215.8813	−0.394	2218.5865	0.920	2218.5868	0.932	2218.6351	0.925
2218.6353	0.931	2218.6758	0.907	2218.6760	0.910	2218.7544	0.924
2218.7546	0.922	2218.7949	0.908	2218.7951	0.908	2218.8425	0.884
2218.8427	0.879	2219.6605	−0.290	2219.6607	−0.292	2219.7472	−0.294
2219.7474	−0.299	2219.7924	−0.301	2219.7925	−0.295	2219.8404	−0.310
2219.8406	−0.307	2219.8648	−0.316	2219.8650	−0.315	2220.5654	−0.366
2220.5656	−0.370	2220.6069	−0.382	2220.6071	−0.384	2220.7629	−0.384
2220.7632	−0.384	2220.9125	−0.393	2220.9128	−0.369	2230.7912	−0.425
2230.7914	−0.414	2230.9070	−0.376	2230.9072	−0.357	2231.8314	−0.189
2231.8316	−0.178	2542.8114	−0.252	2542.8116	−0.253	2542.8795	−0.233
2542.8797	−0.227	2542.9104	−0.214	2542.9106	−0.206	2544.8338	−0.344
2544.8340	−0.344	2544.9305	−0.344	2544.9307	−0.346	2545.8988	−0.356
2545.8990	−0.349						

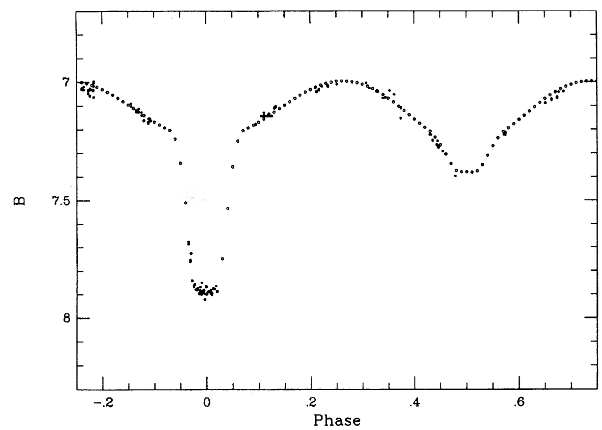

FIG. 2—Analog of Fig. 1 for the *B* curve and Table 2.

data on times of minima now at hand. While one can find statements to the effect that the period seems to be changing, we think that such a conclusion is not warranted by the residuals from a linear ephemeris shown in Fig. 4. At least it seems safe to say that Fig. 4 gives no evidence for the large period change expected for the rapid stage of mass transfer.

Not only are there rather few estimated times of minima (we find only nine that seem worthwhile), but the estimates are unusually inaccurate, due to the long period and the resultant piecewise coverage of individual eclipses. Naturally the O−C data have generated prior interest, and Fig. 4 adds very little to the information already available from Ziolkowski's (1985) Fig. 1. In fact, Ziolkowski already essentially had our times of minima, a mean point of which had been plotted in a graph by Wilson and Caldwell (1978). The

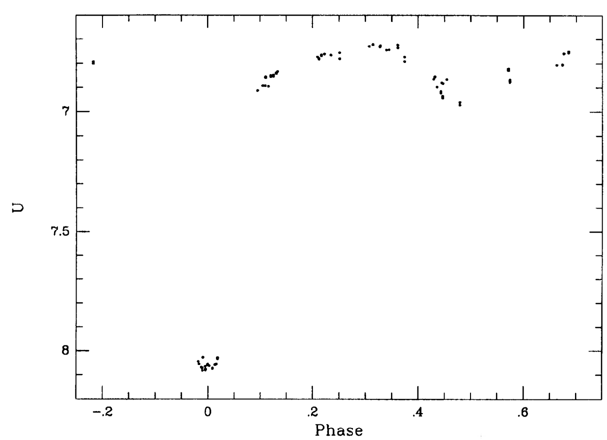

FIG. 3—Analog of Fig. 1 for the *U* curve and Table 3. We have no reference template in *U*.

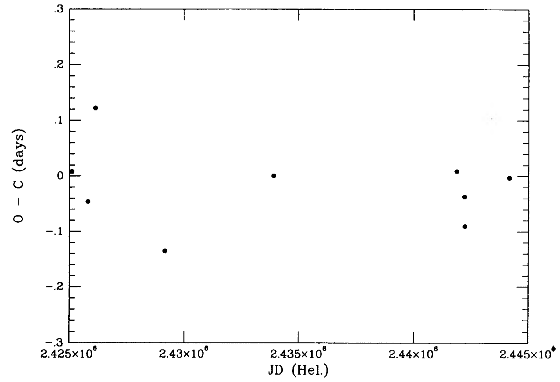

FIG. 4—O−C residuals of observed times of minima (O) from the ephemeris: C=JD (Hel.) 2,433,900.827+8.89610 E.

only differences here are that we now plot E.J.W.'s three separate estimates [JD (Hel.) 2441862.845, 2442200.851, and 2442218.590] and we include the point by Dworak (1977) that was excluded by Kreiner and Ziolkowski (1978) and by Ziolkowski (1985). So far as we can tell, the accuracy of the Dworak point should be similar to that of the others. Except for these minor items, our Fig. 4 looks just like Ziolkowski's Fig. 1, and both suggest that any period change must be quite small at the present epoch. Our figure was made with the same linear ephemeris (see caption) used by Ziolkowski.

E.J.W. expresses thanks to the excellent night assistants at CTIO and to Robert Davis of the Smithsonian Astrophysical Observatory for help at the computer.

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