J. Astron. Space Sci., Vol. 2, No. 1, 1985.

Photoelectic *BV* Light Curves of Algol and the Interpretations of the Light Curves*

Ho - Il Kim
Department of Astronomy and Meteorology, Yonsei University

(Received Aug. 13, 1985)

ABSTRACT

Standardized *B* and *V* photoelectric light curves of Algol are made with the observations obtained during 1982-84 with the 40-cm and the 61-cm reflectors of Yonsei University Observatory. These light curves show asymmetry between ascending and descending shoulders. The ascending shoulder is 0.02 mag brighter than descending shoulder in *V* light curve and 0.03 mag in *B* light curve. These asymmetric light curves are interpreted as the result of inhomogeneous energy distribution on the surface of one star of the eclipsing pair rather than the result of gaseous stream flowing from KOIV to B8V star. The 180-year periodicity, so called great inequality, are most likely the result proposed by Kim *et al.* (1983) that the abrupt and discrete mass losses of cooler component may be the cause of this orbital change. The amount of mass loss deduced from these discrete period changes turned out to be of the order of $10^{-6} - 10^{-5} M_{\odot}$.

1. Introduction

One of the most famous stars Algol(β Persei) was found its variability of brightness first by Italian astronomer Montanari in 1669. What makes the brightness variation was suggested as the eclipsing phenomenon by Goodricke in 1783.

Nowaday, in general, Algol is assumed as a triple system. A B8V primary and a K0IV secondary have a orbit of 2.87 days and this eclipsing pair revolves the bary center of the triple system each

---

* Yonsei University Observatory Contribution No. 34.

in 1.86 years. The third component is classified as a Am star (Fletcher 1964). The recent photometric investigations were summarized by Wilson and De Luccia(1972) and Söderhjelm (1980). The summary of recent spectroscopic work was given by Hill *et al.* (1971). Bachmann and Hershey(1975) summarized the astrometric work. Harnden *et al.*(1975) and Gibson *et al.* (1975) reported the soft X-ray observations and radio observations, respectively. Sahade and Wood(1978) reviewed the historical background and remaining problems of Algol.

In spite of many unsolved problems, unfortunately, investigations are not performed actively in recent years. Besides, in the case of photoelectric observation, the full light curves of Algol have not been made since Chen *et al.* (1977) but Al-Naimiy *et al.* (1984). The lack of observations makes more difficult to solve the problems.

For these reasons, Yonsei University Observatory(hereafter YUO) has listed Algol as one of the program stars, observed the times of minimum light since 1980, and planned to make full light curves of Algol in 1982. The present observations are made with such program of YUO during Sep. 1982 – Feb. 1984. Our main concern on this investigation is aimed the asymmetry appeared in the light curves of Algol and 180-year periodicity so called great inequality.

2. Observations

Twenty-seven nights' observations were made during Sep. 1982 – Feb. 1984 with the 40-cm and 61-cm reflectors of YUO. The two telescopes and instruments used for this observations are already given by Kim(1983) in detail. The observations were made with *BV* filters, which are similar to Johnson's standard ones, and are transformed into the standard magnitude system. The standardization procedure and transformation coefficients are already discussed elsewhere (Kim 1983, Han 1984).

It is difficult to select the comparison and check stars for Algol observation because there are no stars which are similar in spectral type and magnitude near Algol. The selected comparison and check stars are π Per and ω Per, respectively, which have been used by Wilson and De Luccia (1972). The comparison star, π Per, is similar in spectral type with the primary component of Algol but 2.6 mag fainter than Algol. The check star, ω Per, have similar spectral type with secondary component of Algol and have almost same apparent visual magnitude of π Per.

Since the magnitude difference between Algol and comparison star is very large, at all times care was taken to minimize the time interval between the observations of comparison and variable star observations. The atmospheric extinction was determined on individual nights by plotting of the magnitude against air mass of π Per. The probable error of a single observation is calculated

Table 1. *BV* observations of Algol

JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB
249.2990	0.2043	-2.609	-2.714	275.0129	0.1763	-2.588	-2.692	296.2519	0.5794	-2.590	-2.692
.3036	0.2068	2.600	2.711	.0325	0.1790	2.585	2.674	299.9222	0.8595	2.561	2.681
.3132	0.2092	2.592	2.704	.0396	0.1815	2.581	2.673	.9308	0.8624	2.549	2.642
.3267	0.2189	2.594	2.716	.0528	0.1861	2.589	2.679	.9412	0.8661	2.563	2.661
.3329	0.2161	2.589	2.709	.0600	0.1886	2.588	2.678	.9521	0.8699	2.562	2.665
.3395	0.2184	2.590	2.698	.0677	0.1913	2.576	2.670	.9703	0.8762	2.550	2.659
.3607	0.2258	2.599	2.716	.0749	0.1938	2.584	2.678	.9782	0.8790	2.554	2.668
256.0649	0.5639	2.613	2.702	.0826	0.1965	2.584	2.683	.9863	0.8818	2.557	2.662
.0744	0.5672	2.599	2.681	.0967	0.2014	2.586	2.690	.9986	0.8861	2.567	2.670
.0856	0.5711	2.598	2.687	.1034	0.2037	2.603	2.688	300.0188	0.8931	2.555	2.698
.1057	0.5782	2.594	2.661	.2559	0.2569	2.602	2.695	.0279	0.8963	2.562	2.694
.1158	0.5817	2.607	2.708	.2649	0.2601	2.611	2.702	.0369	0.8994	2.557	2.674
.1271	0.5856	2.601	2.672	.2735	0.2630	2.593	2.681	.0946	0.9196	2.535	2.659
.1472	0.5926	2.583	2.680	.2810	0.2657	2.586	2.688	.1017	0.9221	2.527	2.646
262.9627	0.9696	1.863	1.918	.2967	0.2711	2.597	2.683	.1096	0.9248	2.532	2.642
.9720	0.9728	1.792	1.833	.3058	0.2743	2.604	2.682	.1169	0.9274	2.523	2.640
.9904	0.9792	1.648	1.680	.3142	0.2773	2.597	2.702	.1231	0.9295	2.506	2.618
263.0006	0.9828	1.590	1.603	292.9331	0.4219	2.575	2.690	317.2218	0.8918	2.552	2.677
.0078	0.9853	1.535	1.566	.9429	0.4254	2.589	2.697	.2315	0.8962	2.555	2.661
.0168	0.9884	1.489	1.515	.9528	0.4288	2.585	2.693	.2405	0.8993	2.537	2.629
.0242	0.9910	1.464	1.497	.9623	0.4321	2.591	2.697	.2552	0.9045	2.545	2.640
.0358	0.9951	1.483	1.493	.9725	0.4357	2.596	2.709	.2628	0.9071	2.547	2.642
.0423	0.9999	1.530	1.551	.9817	0.4389	2.579	2.696	.2701	0.9096	2.538	2.694
.0497	0.0031	1.589	1.620	.9974	0.4444	2.572	2.687	.2927	0.9175	2.555	2.687
.0587	0.0062	1.626	1.655	293.0094	0.4486	2.580	2.693	.3078	0.9228	2.546	2.638
.0678	0.0097	1.698	1.713	.0232	0.4534	2.584	2.700	320.9153	0.1809	2.611	2.691
.0893	0.0137	1.795	1.848	.0348	0.4574	2.579	2.685	.9247	0.1842	2.584	2.678
.0989	0.0171	1.883	1.930	.0485	0.4622	2.564	2.660	.9443	0.1910	2.565	2.663
.1064	0.0197	1.941	2.003	.2685	0.5388	2.558	2.646	.9608	0.1968	2.578	2.682
.1141	0.0224	2.011	2.081	.2780	0.5422	2.549	2.647	.9706	0.2002	2.571	2.675
.1294	0.0277	2.100	2.191	.2884	0.5459	2.548	2.656	.9798	0.2034	2.578	2.681
.1423	0.0322	2.242	2.347	.3024	0.5507	2.574	2.676	321.1073	0.2479	2.585	2.691
.9557	0.3159	2.610	2.715	.3110	0.5538	2.571	2.673	.1156	0.2508	2.584	2.678
.9636	0.3187	2.605	2.697	.3189	0.5565	2.585	2.679	.1232	0.2534	2.584	2.680
.9723	0.3217	2.608	2.710	295.9171	0.4626	2.552	2.676	.1303	0.2559	2.581	2.688
.9823	0.3252	2.602	2.701	.9263	0.4658	2.557	2.674	.1439	0.2607	2.577	2.671
.9916	0.3284	2.622	2.721	.9353	0.4690	2.553	2.659	.1512	0.2632	2.591	2.692
264.0124	0.3357	2.588	2.677	.9838	0.4859	2.536	2.675	.1602	0.2663	2.602	2.703
.0213	0.3388	2.581	2.653	.9917	0.4887	2.552	2.678	.1693	0.2695	2.584	2.682
.0329	0.3428	2.582	2.690	.9993	0.4913	2.548	2.590	.1857	0.2752	2.609	2.692
.0421	0.3460	2.592	2.699	296.0066	0.4939	2.532	2.566	.1940	0.2781	2.584	2.692
.0626	0.3532	2.586	2.683	.0139	0.4964	2.540	2.658	.2020	0.2809	2.587	2.679
.0749	0.3575	2.581	2.666	.0219	0.4992	2.541	2.666	.2097	0.2836	2.594	2.693
.0855	0.3611	2.589	2.696	.0352	0.5038	2.549	2.669	.2172	0.2862	2.598	2.709
.0947	0.3644	2.591	2.694	.0410	0.5058	2.551	2.670	.2345	0.2923	2.592	2.689
274.9781	0.1600	2.572	2.683	.2116	0.5653	2.581	2.677	.2452	0.2960	2.571	2.692
.9861	0.1628	2.580	2.688	.2209	0.5686	2.585	2.682	.2538	0.2990	2.587	2.691
.9841	0.1656	2.575	2.666	.2284	0.5712	2.577	2.680	.2620	0.3019	2.571	2.678
275.0092	0.1709	2.576	2.679	.2365	0.5740	2.586	2.683	333.9522	0.7276	2.587	2.688
275.0169	0.1736	-2.590	-2.682	296.2436	0.5765	-2.584	-2.678	333.9679	0.7331	-2.609	-2.722

Table 1. Continued

JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB
333.9771	0.7363	-2.600	-2.703	354.9913	0.0652	-2.564	-2.675	387.9846	0.5718	-2.594	-2.700
.9879	0.7401	2.584	2.687	.9984	0.0677	2.576	2.692	388.0011	0.5775	2.599	2.704
.9966	0.7431	2.572	2.692	355.0061	0.0703	2.563	2.687	.0081	0.5800	2.592	2.699
334.0187	0.7508	2.590	2.704	.0217	0.0758	2.571	2.695	.0142	0.5821	2.591	2.691
.0278	0.7540	2.590	2.700	.0347	0.0803	2.560	2.678	.0203	0.5842	2.603	2.696
.0367	0.7571	2.589	2.695	.0437	0.0834	2.568	2.693	.0329	0.5886	2.598	2.694
.0458	0.7603	2.602	2.708	.0506	0.0859	2.564	2.686	.0395	0.5909	2.598	2.702
.0642	0.7667	2.598	2.712	.0577	0.0883	2.575	2.692	.0461	0.5932	2.600	2.711
.0763	0.7709	2.611	2.721	.0654	0.0910	2.580	2.691	390.9339	0.6004	2.605	2.710
.0897	0.7756	2.600	2.707	.0740	0.0490	2.572	2.688	.9402	0.6026	2.608	2.715
.1000	0.7792	2.613	2.719	.0824	0.0969	2.579	2.686	.9464	0.6048	2.607	2.716
.1210	0.7865	2.591	2.702	.0979	0.1024	2.571	2.687	.9518	0.6066	2.607	2.709
.1496	0.7965	2.587	2.692	.1057	0.1051	2.573	2.679	.9565	0.6093	2.609	2.717
.1590	0.7998	2.578	2.684	.1141	0.1080	2.586	2.688	.9644	0.6110	2.599	2.718
.1687	0.8031	2.575	2.693	.1233	0.1112	2.592	2.711	.9700	0.6130	2.605	2.705
.1784	0.8065	2.590	2.699	.1308	0.1138	2.571	2.699	.9840	0.6179	2.603	2.707
.1900	0.8106	2.590	2.711	.1598	0.1239	2.584	2.689	.9894	0.6197	2.611	2.715
.2042	0.8155	2.570	2.693	.1752	0.1293	2.574	2.689	.9968	0.6223	2.615	2.718
.2146	0.8192	2.564	2.642	368.9247	0.9245	2.574	2.701	391.0023	0.6243	2.607	2.713
.2279	0.8238	2.562	2.686	.9368	0.9288	2.541	2.659	.0082	0.6263	2.604	2.710
.2473	0.8306	2.567	2.668	.9421	0.9306	2.536	2.648	.0137	0.6282	2.607	2.711
337.9581	0.1247	2.588	2.688	.9472	0.9324	2.512	2.627	.0197	0.6303	2.604	2.709
.9668	0.1277	2.597	2.700	.9527	0.9343	2.498	2.615	.0307	0.6341	2.595	2.699
.9753	0.1307	2.593	2.698	.9583	0.9363	2.480	2.601	.0372	0.6364	2.595	2.699
.9837	0.1337	2.581	2.688	.9642	0.9383	2.457	2.575	.0440	0.6388	2.594	2.704
.9908	0.1361	2.594	2.694	.9766	0.9426	2.397	2.515	630.0170	0.9824	1.571	1.618
338.0014	0.1398	2.585	2.684	369.0020	0.9515	2.274	2.376	.0236	0.9845	1.536	1.587
.0092	0.1425	2.580	2.685	.0117	0.9549	2.216	2.317	.0299	0.9867	1.511	1.546
.0244	0.1479	2.582	2.690	.0188	0.9574	2.153	2.248	.0358	0.9888	1.505	1.522
.0323	0.1506	2.590	2.701	.0243	0.9593	2.121	2.212	.0414	0.9907	1.485	1.507
.0402	0.1534	2.582	2.685	.0305	0.9614	2.071	2.155	.0474	0.9928	1.474	1.516
.0484	0.1562	2.598	2.698	.0363	0.9635	2.029	2.113	.0530	0.9948	1.485	1.525
.0566	0.1591	2.586	2.693	.0434	0.9659	1.965	2.035	.0585	0.9967	1.493	1.514
.0664	0.1625	2.592	2.709	.0494	0.9680	1.912	1.973	.0639	0.9986	1.508	1.527
.0833	0.1684	2.600	2.701	.0555	0.9702	1.872	1.932	0.721	0.0014	1.547	1.579
.0912	0.1711	2.598	2.702	.0642	0.9732	1.794	1.844	.0783	0.0036	1.628	1.638
.1050	0.1759	2.582	2.696	.0693	0.9750	1.759	1.811	.0837	0.0055	1.666	1.683
.1130	0.1787	2.585	2.698	.0749	0.9769	1.697	1.752	.0894	0.0075	1.662	1.705
.1213	0.1816	2.595	2.703	.0805	0.9789	1.646	1.696	.0952	0.0095	1.712	1.754
.1293	0.1844	2.598	2.707	.0857	0.9807	1.606	1.656	.1006	0.0114	1.753	1.801
.1372	0.1872	2.586	2.695	.0915	0.9827	1.575	1.603	.1061	0.0133	1.804	1.853
.1449	0.1899	2.586	2.693	.0969	0.9846	1.557	1.573	.1193	0.0179	1.801	1.953
.1528	0.1926	2.591	2.696	.1016	0.9862	1.543	1.556	.1285	0.0211	1.971	2.052
.1647	0.1968	2.587	2.696	387.9372	0.5553	2.569	2.681	.1335	0.0229	2.010	2.097
.1775	0.2012	2.597	2.698	.9433	0.5574	2.590	2.704	.1387	0.0347	2.050	2.137
.2022	0.2099	2.580	2.692	.9494	0.5595	2.577	2.685	.1440	0.0265	2.094	2.179
354.9565	0.0530	2.499	2.609	.9553	0.5616	2.582	2.685	.1523	0.0294	2.153	2.246
.9636	0.0555	2.534	2.646	.9662	0.5654	2.605	2.711	.1580	0.0314	2.195	2.293
.9779	0.0605	2.566	2.673	.9719	0.5674	2.592	2.699	.1632	0.0332	2.234	2.330
354.9849	0.0629	-2.562	-2.676	387.9786	0.5697	-2.596	-2.704	630.1688	0.0352	-2.263	-2.362

Table 1. Continued

JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB
630.1745	0.0372	-2.299	-2.398	647.0002	0.9052	-2.564	-2.680	663.1914	0.5520	-2.597	-2.709
.1797	0.0390	2.331	2.430	.0097	0.9085	2.576	2.688	.1970	0.5540	2.602	2.715
.1853	0.0409	2.360	2.470	.0115	0.9091	2.567	2.682	.2075	0.5576	2.604	2.712
.1903	0.0427	2.382	2.489	.0175	0.9113	2.562	2.685	.2151	0.5603	2.597	2.713
.1962	0.0447	2.413	2.524	.0241	0.9136	2.557	2.680	.2199	0.5620	2.603	2.708
.2030	0.0471	2.439	2.551	.0316	0.9162	2.557	2.692	.2247	0.5636	2.601	2.708
.2091	0.0492	2.459	2.575	.0399	0.9191	2.546	2.666	.2303	0.5656	2.599	2.710
.2150	0.0513	2.478	2.595	.0467	0.9214	2.559	2.681	.2402	0.5690	2.603	2.684
.2203	0.0531	2.500	2.616	.0536	0.9239	2.557	2.678	.2447	0.5706	2.598	2.711
.2256	0.0550	2.518	2.635	.0623	0.9269	2.544	2.664	.2495	0.5723	2.603	2.716
.2315	0.0570	2.530	2.650	.0689	0.9292	2.525	2.625	.2544	0.5740	2.603	2.707
.2374	0.0591	2.543	2.660	.0774	0.9322	2.517	2.635	709.9571	0.8619	2.572	2.688
.2429	0.0610	2.553	2.674	.0858	0.9351	2.482	2.591	.9640	0.8643	2.574	2.692
.2483	0.0629	2.558	2.679	.0920	0.9372	2.449	2.551	.9688	0.8659	2.577	2.696
.2537	0.0648	2.565	2.682	.1012	0.9405	2.406	2.522	.9747	0.8680	2.570	2.688
.2594	0.0668	2.569	2.681	.1083	0.9429	2.393	2.500	.9805	0.8700	2.566	2.683
.2676	0.0696	2.580	2.696	.1147	0.9452	2.361	2.464	.9893	0.8731	2.566	2.683
.2736	0.0717	2.568	2.682	.1233	0.9481	2.289	2.400	.9959	0.8754	2.560	2.681
.2794	0.0737	2.568	2.685	.1297	0.9504	2.266	2.366	710.0017	0.8774	2.569	2.682
.2853	0.0758	2.567	2.682	.1365	0.9527	2.228	2.328	.0088	0.8799	2.558	2.679
.2905	0.0776	2.570	2.684	.1430	0.9550	2.183	2.284	.0260	0.8859	2.561	2.680
.2979	0.0802	2.573	2.684	.1736	0.9657	1.955	2.020	.0311	0.8877	2.559	2.682
635.1563	0.7746	2.594	2.700	.1795	0.9678	1.921	1.929	.0372	0.8898	2.563	2.683
.1610	0.7762	2.595	2.694	.1901	0.9715	1.831	1.893	.0497	0.8942	2.563	2.674
.1660	0.7780	2.599	2.706	.1969	0.9738	1.752	1.810	.0625	0.8986	2.558	2.681
.1711	0.7797	2.599	2.709	.2094	0.9782	1.677	1.713	.0679	0.9005	2.558	2.679
.1763	0.7815	2.595	2.705	.2151	0.9802	1.606	1.653	.0738	0.9026	2.563	2.681
.1818	0.7835	2.598	2.706	.2267	0.9842	1.548	1.592	.0793	0.9045	2.559	2.676
.1895	0.7861	2.590	2.701	.2281	0.9847	1.512	1.556	.0996	0.9116	2.559	2.680
.1950	0.7881	2.591	2.699	.2361	0.9875	1.468	1.494	.1094	0.9150	2.563	2.681
.2000	0.7898	2.591	2.701	.2450	0.9906	1.466	1.481	.1146	0.9168	2.567	2.681
.2054	0.7917	2.592	2.700	.2524	0.9932	1.484	1.497	.1200	0.9187	2.562	2.680
.2103	0.7934	2.593	2.704	.2588	0.9954	1.505	1.548	.1251	0.9204	2.556	2.667
.2176	0.7960	2.597	2.705	662.9994	0.4851	2.545	2.675	.1344	0.9237	2.563	2.683
.2228	0.7978	2.585	2.694	663.0046	0.4869	2.562	2.690	.1412	0.9261	2.541	2.658
.2278	0.7995	2.590	2.702	.0103	0.4888	2.554	2.682	718.9121	0.9850	1.529	1.556
.2313	0.8007	2.578	2.697	.0164	0.4910	2.556	2.686	.9183	0.9871	1.502	1.525
.2393	0.8035	2.590	2.701	.0272	0.4947	2.552	2.676	.9246	0.9893	1.484	1.507
.2560	0.8093	2.581	2.688	.0332	0.4968	2.554	2.678	.9342	0.9927	1.485	1.510
.2702	0.8143	2.587	2.692	.0384	0.4987	2.554	2.686	.9384	0.9942	1.480	1.505
.2747	0.8159	2.585	2.692	.0433	0.5004	2.549	2.679	.9439	0.9961	1.494	1.517
.2816	0.8183	2.574	2.693	.0534	0.5039	2.546	2.679	.9498	0.9981	1.513	1.546
.2870	0.8202	2.583	2.697	.0584	0.5056	2.543	2.673	.9564	0.0004	1.553	1.588
646.9455	0.8861	2.576	2.688	.1487	0.5371	2.581	2.698	.9628	0.0026	1.582	1.629
.9526	0.8886	2.581	2.695	.1543	0.5391	2.588	2.713	.9718	0.0058	1.658	1.708
.9656	0.8932	2.563	2.680	.1606	0.5413	2.592	2.704	.9779	0.0079	1.704	1.758
.9724	0.8955	2.572	2.685	.1657	0.5431	2.591	2.703	.9845	0.0102	1.754	1.808
.9802	0.8982	2.560	2.671	.1762	0.5467	2.596	2.707	.9977	0.0148	1.910	1.936
.9875	0.9008	2.566	2.677	.1816	0.5486	2.593	2.705	719.0043	0.0171	1.922	1.994
646.9934	0.9029	-2.564	-2.687	663.1865	0.5503	-2.591	-2.703	719.0138	0.0204	-1.997	-2.082

Table 1. Continued

JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB	JD Hel 2445000+	Phase	ΔV	ΔB
719.0209	0.0229	-2.049	-2.131	727.0308	0.8164	-2.586	-2.705	738.9860	0.9859	-1.506	-1.562
.0285	0.0256	2.125	2.213	.0406	0.8199	2.582	2.703	.9907	0.9875	1.498	1.526
.0356	0.0280	2.160	2.248	.0686	0.8296	2.581	2.694	.9961	0.9894	1.491	1.508
.0435	0.0308	2.235	2.328	.0757	0.8321	2.585	2.695	739.0018	0.9914	1.481	1.485
.0781	0.0429	2.392	2.505	.0851	0.8354	2.586	2.700	.0074	0.9934	1.478	1.495
.0869	0.0460	2.445	2.554	.0918	0.8377	2.581	2.694	.0128	0.9952	1.494	1.519
.0977	0.0497	2.489	2.599	737.9252	0.6159	2.620	2.714	.0194	0.9975	1.503	1.555
.1090	0.0536	2.517	2.626	.9649	0.6298	2.611	2.719	.0268	0.0001	1.546	1.588
726.9250	0.7795	2.596	2.713	.9705	0.6317	2.613	2.719	.0314	0.0017	1.564	1.610
.9315	0.7818	2.591	2.703	.9762	0.6337	2.597	2.709	.0359	0.0033	1.595	1.649
.9378	0.7840	2.599	2.710	738.0056	0.6440	2.610	2.718	.0414	0.0052	1.643	1.696
.9392	0.7845	2.591	2.704	.0384	0.6554	2.607	2.712	.0472	0.0072	1.673	1.760
.9449	0.7865	2.602	2.714	.0438	0.6573	2.598	2.696	.0557	0.0102	1.747	1.840
.9564	0.7905	2.595	2.707	.0544	0.6610	2.594	2.697	.0607	0.0119	1.800	1.884
.9625	0.7926	2.596	2.711	.0611	0.6633	2.606	2.714	.0663	0.0139	1.831	1.951
.9677	0.7944	2.601	2.708	.0670	0.6654	2.610	2.718	.0742	0.0167	1.903	2.034
.9818	0.7994	2.584	2.704	.0740	0.6678	2.593	2.702	751.9697	0.5141	2.557	2.679
.9828	0.7997	2.578	2.696	.0860	0.6720	2.605	2.711	.9770	0.5166	2.557	2.670
.9906	0.8024	2.583	2.695	.9630	0.9779	1.641	1.712	.9835	0.5188	2.573	2.685
.9983	0.8051	2.585	2.707	.9701	0.9803	1.593	1.649	.9939	0.5225	2.571	2.687
727.0085	0.8087	2.590	2.702	.9755	0.9822	1.559	1.606	752.0017	0.5252	2.595	2.694
.0163	0.8114	2.587	2.707	738.9807	0.9840	-1.541	-1.565	752.0119	0.5288	-2.563	-2.669
727.0237	0.8139	-2.585	-2.698								

by the differential magnitudes of check star with comparison star, i.e. $\triangle m$ (Ch∗ – C∗) and found that is ±0.007 mag in both B and V.

During the observation period, a total of 1,034 individual observations is obtained in B and V. The phase of each observations is calculated using the light elements given by Nha *et al.* (1976);

$$\text{Min I} = \text{JD Hel } 2440953.4552 + 2^{d}.8673285E. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The standardized B and V observations are listed in Table 1 with phase computed by Eq.(1). Two times of minimum light obtained by the Kwee-Van Woerden method are JD Hel 2445263.0296 and 2445739.0030.

3. Interpretations of Light Curves

The observed B and V light curves with color curve are presented in Fig. 1. These light curves lack only phase around $0^{p}.4$, but the asymmetry between the descending and ascending shoulders of the primary minimum light is clearly seen. The magnitude differences between the two

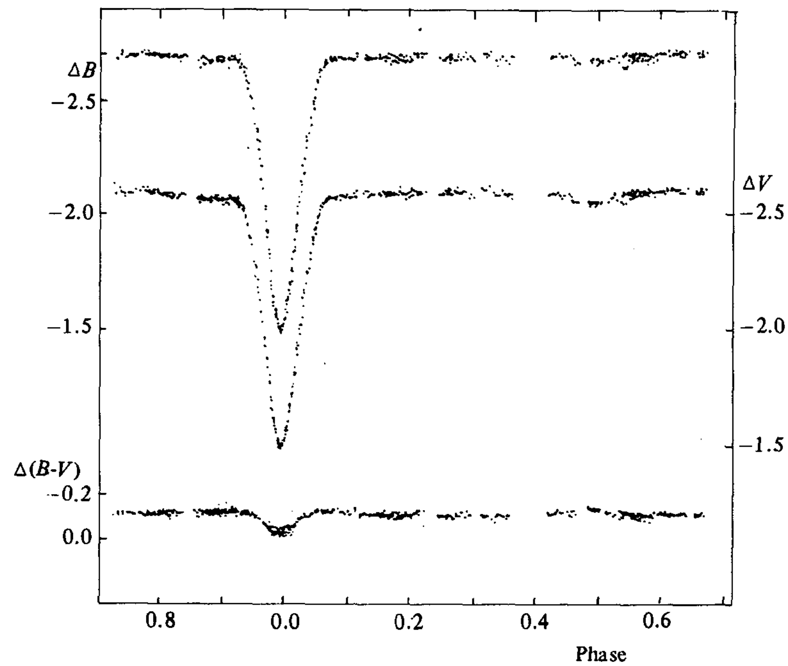

Fig. 1. Standardized B and V light curves and color curve of Algol.

shoulders are 0.02 mag and 0.03 mag in V and B light curves, respectively, as shown in Fig. 2. This asymmetry of Algol light curve has been previous known to many investigators(Chen and Reuning 1966, Chen *et al.* 1977, Al-Naimiy *et al.* 1984). The *UBV* light curves of Al-Naimiy *et al.* made in one year show more conspicuous asymmetry compared with our light curves in spite of the almost same observation period and filters used. The magnitude differences in the light curves of Al-Naimiy *et al.* are 0.12 mag in V, B and U.

Al-Naimiy *et al.* (1984) interpreted the asymmetry of their light curves as a result of the presence of a gaseous stream flowing from the secondary to the primary component. This interpretation, however, contradicts against the assumption raised independently by Longmore and Jameson(1975) and by Harnden *et al.*(1977). With their infrared observations Longmore and Jameson(1975) and, later, by the soft X-ray observations Harnden *et al.*(1977) indicate that the gas stream is optically thin at visual radiation region. The transparent gas stream would not affect on the V light curve of Algol as much as 0.12 mag as seen in the case of Al-Naimiy *et al.* Therefore, the gaseous stream itself cannot be considered as the only cause of the light variations around the shoulders of light curves of Algol.

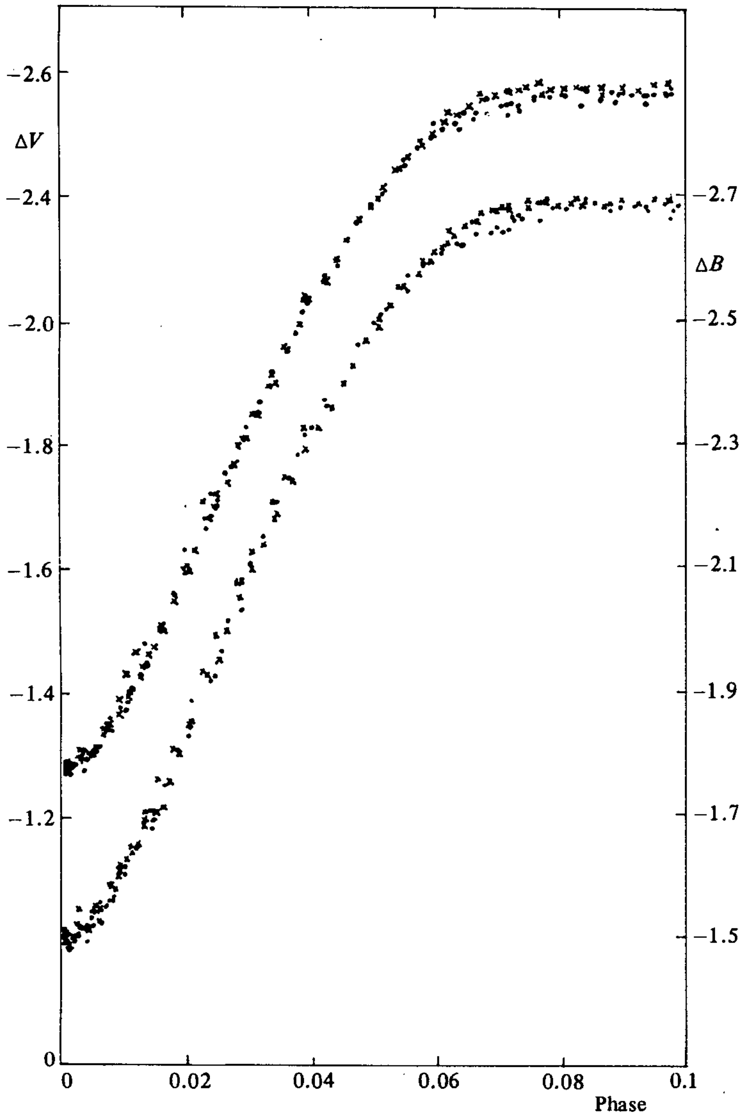

Fig. 2. Standardized B and V light curves for primary eclipse. Crosses and dots denote the descending and ascending branches, respectively.

4. Period Study

The intensive investigations have been concentrated by many workers on the orbital period variations known in the Algol system. Three independent period changes superimposed are widely accepted for the Algol and many investigations are performed to find the causes of these period variations. It is found clearly that the 1.86-year periodicity is the result of light time effect by Algol C(Frieboes-Conde *et al.* 1970). In the meantime, apsidal motion has been suggested to explain the 32-year periodicity by Hill *et al.*(1971) who tried to prove the apsidal motion of Algol AB by the means of spectroscopic evaluations of the longitude of periastron, ω, and their Figure 4 showed successfully that the ω has a linear relation with time and the slop of the relation corresponds to a period of apsidal motion of 32 years. Söderhjelm(1980), on the other hand, suggested the mass loss from the system affected by the stellar magnetic cycle such as solar cycle. This suggestion based on the fact that the solution of Algol light curves can be obtained under the presumption of circular orbital motion, that is, zero orbital eccentricity. To find the reliable cause for the 32-year periodicity, continuous infrared observations of secondary minimum light are required.

Frieboes-Conde *et al.* (1970) and, later, Kim *et al.*(1983) found that the 180-year periodicity, so called great inequality, is caused by the several times of abrupt and discrete orbital period changes. According to Kim *et al.*, there are five times of discrete period changes each in 1932.5, 1944.0, 1952.5, 1968.1, and 1974.0. Among these five, the latest variation is coincident and closely connected with unusually strong radio outburst detected by Gibson *et al.*(1975). This unusual phenomenon makes us to think that the abrupt period changes are the result of the mass transfers between Algol A and B and the mass loss from the system. Assuming the longest period changes as the result of mass loss from the cooler component, the amount of the mass loss can be calculated for each orbital period changes and the results are given in Table 2. The column 1 and 2 of Table 2 are taken from Kim *et al.* (1983). The plus and minus signs in column 2 represent the period increase and decrease, respectively. This calculation is based on the formular of Hall and Neff(1976);

$$\frac{\Delta P_1}{P} = 3\left[\frac{M}{M_c} - \frac{M}{M_h} - \left(\frac{M}{M_c}\right)\left(\frac{M}{M_h}\right)^{1/2} r_r^{1/2}\right]\frac{\Delta M_c}{M} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

and

$$\frac{\Delta P_2}{P} = 3\left[\left(\frac{M}{M_c}\right)\left(\frac{M}{M_h}\right)^{1/2} r_r^{1/2}\right]\frac{\Delta M_c}{M}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where the notations are same as in Hall and Neff. Eq.(2) is for period decrease and Eq.(3) for period increase.

Table 2. Mass loss rates calculated with the five discrete period changes.

Year	ΔP/P	ΔM($M_\odot$)
1932.5	-8.0×10^{-6}	7.7×10^{-6}
1944.0	$+2.0\times10^{-5}$	1.0×10^{-5}
1952.5	-7.3×10^{-6}	7.0×10^{-6}
1968.1	-5.6×10^{-6}	5.4×10^{-6}
1974.0	$+5.3\times10^{-6}$	2.8×10^{-6}

5. Summary

Standardized *B* and *V* light curves of Algol were made mainly from the observations during Sep. 1982 – Feb. 1983 with the supplementary observations during Oct. 1983 – Feb. 1984. These light curves show asymmetry between ascending and descending shoulders. This asymmetry may be partly resulted by the inhomogeneous brightness distribution on the one of two eclipsing components and partly by the mass exchange in the system. There are two contradicting theories for the asymmetry of *V* light curve due to the gas stream between Algol A and B; one supports (Al-Naimiy *et al.* 1984) and the other rejects(Longmore and Jameson 1975, Harnden *et al.* 1977). The further more accurate observations, of course, will give a clue to find reliable cause of the asymmetry appearing in *UBV* light curves of Algol.

The well determined times of secondary minimum light are needed to verify the cause of the 32-year periodicity but there are no useful data available as yet. Because of shallowness of the secondary minimum light in visual light, it is impossible to obtain times of secondary minimum light in *UBV* with good accuracy. The more precise and continuous infrared observations are strongly required.

The 180-year period variation may no longer be the periodic phenomenon. It is merely the result of the several times of discrete and abrupt period changes proposed first by Frieboes-Conde *et al.* (1970) and later by Kim *et al.* (1983) as discussed above and the present analysis supports this. The calculated mass loss rates deduced from the five abrupt period changes are in the range of $3\times10^{-6} - 1\times10^{-5} M_\odot$. This range of mass loss rate is quite common among many close binary systems which are known to have mass exchange. The mechanism to explain such abrupt and enormous amount of mass loss in the Algol system is, however, unsolved as yet.

Acknowledgements

I am greatly indebted to Dr. I. – S. Nha, Master's thesis advisor, who encouraged me for this study. He also read carefully the manuscript. I would like to thank to Mr. Y. – S. Lee for his one night observation and for his kind suggestions in the course of my observations.

This work was done in partial fulfilment of the requirement for a Master's degree in Astronomy at Yonsei University.

REFERENCES

Al-Naimiy, H. M. K., Mutter, A. A. A., Flaih, H. A., and Al-Roubaie, A. H. A. 1984, *Inf. Bull. Var. Stars,* No. 2520.

Bachmann, P. J. and Hershey, J. L. 1975, *Astron. J.,* **80**, 836.

Chen, K. – Y., Merrill, J. E., and Richardson, W. W. 1977, *Astron. J.*, **82**, 69.

Chen, K. – Y. and Reuning, E. G. 1966, *Astron. J.,* **71**, 283.

Fletcher, E. S. 1964, *Astron. J.,* **69**, 357.

Frieboes-Conde, H., Herczeg, T., and Hog, E. 1970, *Astron. Astrophys.,* **4**, 78.

Gibson, D. M., Viner, M. R., and Peterson, S. D. 1975, *Astrophys. J.* (Letters), **200**, L143.

Hall, D. S. and Neff, F. G. 1976, in *Structure and Evolution of Close Binary Systems*, I. A. U. Symp. 73, ed. by P. Eggleton, *et al.* (Dordrecht: Reidel), pp. 283-288.

Han, W. – Y. 1984, Master's thesis, Yonsei University.

Harnden, F. R., Fabricant, D. Jr., Topka, K., Flannery, B. P., Tucker, W. H., and Gorenstein, P. 1977, *Astrophys. J.,* **214**, 418.

Hill, G., Barnes, J. V., Hutchings, J. B., and Pearce, J. A. 1971, *Astrophys. J.,* **168**, 443.

Kim, C. H., Kim, H. – I., Lee, Y. – S., and Nha, I. – S. 1983, *J. Natural Sci. Res. Inst.,* **11**, 123.

Kim, H. – I. 1983, Master's thesis, Yonsei University.

Longmore, A. J. and Jameson, R. F. 1975, *Mon. Not. R. Astr. Soc.,* **173**, 271.

Nha, I. – S., Oh, K. D., and Jeong, J. H. 1976, *Yonsei Nonchong,* **12**, 95.

Sahade, J. and Wood, F. B. 1978, *Interacting Binary Stars* (Oxford: Pergamon), pp. 130-136.

Söderhjelm, S. 1980, *Astron. Astrophys.,* **89**, 100.

Wilson, R. E. and De Luccia, M. R. 1972, *Astrophys. J.,* **177**, 191.