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uvby – β PHOTOELECTRIC PHOTOMETRY OF SELECTED RR LYRAE STARS IN SERPENS

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RESUMEN

Se presenta fotometría fotoeléctrica simultánea en el sistema *uvby-β* de estrellas tipo RR de Lira de la constelación de Serpens. El criterio seguido para la selección de éstas fue que sus períodos fueran razonablemente cortos, que fueran relativamente brillantes y que la muestra incluyera una estrella tipo RRc. Se presentan también curvas de luz para cada estrella.

ABSTRACT

Simultaneous *uvby-β* photoelectric photometry of several RR Lyrae stars in the constellation of Serpens is presented. The criteria followed for the selection of the stars were that their periods be reasonably short, that they be relatively bright and that one RRc star be included. Light curves are presented for each star.

Key words: **PHOTOMETRY – STARS-RR LYRAE – STARS-VARIABLE**

I. INTRODUCTION

The RR Lyrae stars have been known for a ong time and have proved useful both in distance etermination and stellar interior modeling. Alhough, according to Szeidl (1988), more than 4000 ntries have been catalogued in the third edition of he General Catalogue of Variable Stars; in the First, econd and Third Supplements there are only a few hat have been extensively observed.

A further complication is presented by the fact hat at least some RR Lyrae stars show variations in mplitude and/or period of the order of days. These ffects have been long known and are all called he Blazkho effect after their discoverer (Blazkho 925, 1926). More recent analyses (Peniche *et al.* 989) have interpreted these variations as the nodulation caused by the simultaneous excitation f several modes of pulsation. Since in general, he photometric data are acquired by means of ne channel photometers, the further description n phase of the behavior in these modulated stars ould not correctly describe the corresponding hysical situation. This complication has been vercome in the present paper since the telescopehotometer system employed allows the simultaneus acquisition in the *uvby* filters and also in the arrow and wide filter of Hβ.

A further advantage of this photometric system is that it allows, through the $b - y$ and c_1 indices, as van Albada and Boer (1975, hereinafter vAB) have stated in a study carried out to determine the pulsation properties of RR Lyrae stars, the determination of the effective temperature and gravity during the cycle. They state that "the determination of effective temperature and gravity can be achieved with the help of two parameters: the slope of the Paschen continuum and the size of the Balmer jump, which can be derived from data in the Strömgren photometric system".

However, the comparison is not direct as they encountered and listed many difficulties including, first, the removal of the effects of reddening and line blanketing from the observed color indices; second, there were complications from the method of derivation of the atmospheric parameters θ_0 and log g by applying results calculated for atmospheres in hydrostatic and radiative equilibrium to pulsating stars in which differential motions in the atmosphere are known to exist and where the effects of shock waves on the radiation transport may not be negligibly small. Third, they state that "when calculating theoretical colors, the transmission curve of the detecting system must in general be taken into account. For smoothly varying energy distribution however, the *uvby* colors can be accurately determined by using one point in the spectrum only at the effective wavelenght of the filter. This proce-

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dure neglects the effects of curvature of the spectral energy distribution accros the filter".

For the reasons mentioned above we were encouraged to initiate an extensive observational study of this type of star in the Strömgren *uvby*-β system.

II. DATA ADQUISITION

a) *Observations*

The observations were carried out at the Observatorio Astronómico Nacional, México with the 1.5-m telescope at San Pedro Mártir. A pulse-counting spectrophotometer in the *uvby*-β system that allowed the simultaneous observation in each filter was utilized. A brief description of the equipment can be found in Schuster and Nissen (1988).

The observing season ran from June 14 to 22, 1987. The RR Lyrae stars were selected using the criteria of closeness, and consequently, stars in only one constellation were chosen. Serpens was selected due to the relatively high number of RR Lyrae stars in it. Secondary criteria were that the periods be reasonably short, that the stars be relatively bright, below magnitude 15, and that at least one RRc star be included (in this case AP Ser was chosen) since there have been some indications that amplitude variations in this kind of stars can be explained by the simultaneous interaction of several modes as Peniche *et al.* (1989) have found in the RRc type star ST CVn. Table 1 presents the objects observed.

Most program stars were observed with an integration time of 30s followed by a 10s integration of the sky. The standard stars, brighter in general, were observed with an integration time of 20s. The sequence of observation was the following: a set of neighboring problem stars was followed uninterruptedly every night; after each integratio of the star, a sky measurement followed. Th uncertainty in time is 0.001 d.

b) *Reduction*

In orden to be able to transform to the *uvb* β absolute system, a set of photometric standard had to be observed along with the program star One difficulty arose with the primary standar stars customarily utilized to define the absolut system (Crawford and Barnes 1970): their relativel high brightness made them unobservable with th telescope-photometric system used, due both t the high sensitivity of the tubes and the relativel large size of the telescope. Consequently, as i Nissen (1988), secondary standard stars fainter tha magnitude 7.0 were taken from a list provided b Schuster (1987) which was, is its turn, adapte from the catalog of Olsen (1983). Slightly brighte standards were also taken from the latter sourc in such a way that larger interval ranges both i magnitude and color were covered. The standar stars were from population I and II. It should b emphasized that the photometric system defined b these standard stars and Crawford's are essentiall the same as the *uvby*-β standard system (Nisse 1988).

The reduction procedure used was implemente at the Instituto de Astronomía, UNAM by Arellan and Parrao (1989) with a PC package from computer program developed by T.B. Anderse This reduction procedure was utilized to transfor the instrumental system to the absolute system Olsen (1983). In order to decide on the qualit and the accuracy of the obtained photometric dat the values derived for the observed standards wer compared with those of Olsen (1983).

TABLE 1

OBSERVATIONAL DATA ON THE RR LYRAE STARS REPORTED

Object	R.A. (1950)	Dec. (1950)	Epoch 2440000+	Period (d)
AP Ser	15 11 37	10 10.08	28334.2790	0.34132
BH Ser	15 12 42	19 38.20	41482.427	0.4345527
AV Ser	16 01 19	00 44.00	28343.337	0.48755736
AN Ser	15 51 11	13 07.10	14708.950	0.52207162
CS Ser	15 26 05	03 15.80	31176.430	0.5267959
VY Ser	15 28 30	01 51.20	31225.341	0.71409384
AT Ser	15 53 16	08 08.40	41798.579	0.7465465

TABLE 2a

TRANSFORMATION COEFFICIENTS FOR THIS SEASON AT THE OBSERVATORY AT SAN PEDRO MARTIR

	B	D	F	J	H	I	L
SPM	−0.098	0.923	0.899	0.206	0.956	−0.039	1.286

a. The coefficients are defined by the equations given in Crawford and Barnes (1970) and in Crawford and Mander (1968). D, F, H, and L are the slope coefficients for $b-y$, m_1, c_1 and β respectively; B, J, and I the color term coefficients of V, m_1 and c_1.

TABLE 2b

COMPARISON OF THE STANDARDS' DATA WITH THOSE OF OLSEN (1983)

	V	$b-y$	m_1	c_1	β
σ	14	8	9	11	9
N	111	177	159	147	23

a. Differences were calculated and the standard deviation evaluated. N is the number of overlapping stars. Units are 0.001 mag.

The standard stars considered gave the slope and e color-term coefficients of the transformation the absolute system defined by Olsen (1983) Table 2a). A direct comparison between the erived values of these standard stars and the values eported by Olsen (1983) was made. The dispersion as evaluated numerically by means of the standard eviation which is reported in Table 2b.

Therefore, in the present analysis it can be as- med that the photometric values determined for e standard stars have an accuracy, in magnitudes, f δ (v, $b-y$, m_1, c_1, Hβ) of (0.0145, 0.0087, 0.0099, 0.0108, 0.0090).The error for the problem stars is augmented because they are, in all cases fainter. The errors derived for the magnitude values from the measured fluxes are presented in Table 3. A further complication could be caused by the fact that, in some cases, the reported values have been obtained by extrapolation from the standard stars. Specifically, the V magnitudes of all the problem stars are always much fainter than the values of the standard stars. In the same case are the c_1 indices in which they have been extrapolated for the majority of the RR Lyrae stars from the slope determined

TABLE 3

PERCENTUAL ERROR FOR A SINGLE 30s INTEGRATION[a]

ID	u	v	b	y	n	w
AP Ser	2.80	0.49	0.57	1.56	5.59	7.20
BH Ser	22.40	3.46	4.84	15.05	49.48	55.58
AV Ser	3.38	1.36	1.32	3.51	8.11	18.09
AN Ser	3.37	1.03	0.96	1.87	8.45	13.97
CS Ser	8.86	1.63	3.23	7.18	19.50	29.13
VY Ser	1.26	0.57	0.71	1.37	2.52	3.46
AT Ser	2.36	0.56	0.71	1.23	5.67	7.01

a. For each star as a function of the incident flux in units of 0.001 mag.

from the values of the aforementioned standards.

However, the validity of the extrapolations can be justified in the following ways:

V magnitude: The problem of establishing the linearity of the derived magnitudes becomes difficult considering only the primary stars since they are very bright. Secondary standard stars, as has been mentioned, were considered but they were, in all cases, all brighter than 8.5 mag. Consequently, since all the program stars were much fainter, extrapolations were mandatory. In alternative studies by Peniche *et al.* (1990) on the open cluster NGC 7062 carried out with the purpose of establishing cluster membership and delineating the main sequence of the cluster, faint stars up to magnitude 16 were observed. A few of them were also observed photometrically and reported by Hoag *et al.* (1961). A direct comparison in the V filter for those stars observed in common was carried out. The findings were that, from 53 stars within an interval range of 8.5 and 16.0 mag. a mean of the differences between both measurements was 0.0093 mag. Therefore, it can be safely concluded that the derived magnitudes reported in the present paper are valid and correctly describe the behavior of the variation of the RR Lyrae stars.

c_1 *Index*: Although in the standard stars observed in the present paper this index does not bracket those of the program stars, previous determinations of the c_1 and m_1 indices on standard stars in a study carried out by Gronbech, Olsen, and Strömgren (1976) determined that the transformations are linear but differ in the slopes as a function of the $b - y$ color on both sides of a numerical value of this color equal to 0.409. The stars with $b - y < 0.409$ correspond to the spectral range O-G2 in which both the standards stars and the program stars are found. Therefore, one might conclude that the extrapolation done in the present reduction is valid. This has been verified by Arellano *et al.* (1990) who have shown the linearity of the instrumental system employed.

Consequently, the values reported here, although relatively coarse, will permit the determination of the bulk characterization of the physical parameters of the stars.

III. RESULTS

Table 4 presents the listing of the photometric observations reported in the present paper. In this table the stars are ordered by increasing period. The columns give the Heliocentric Julian day, the V magnitude and the colors and indices $b - y$, m_1 and c_1 respectively. Since the Hβ measurements were obtained separately they are reported with their own observing time. Unless otherwise specified, the light curves are shown graphically in Figure 1 the ephemeris and periods adopted to derive them were obtained from the catalog of Kholopov (1987 and are listed in Table 1. Figure 1 also shows the traces described by the RR Lyrae stars in the $(b - y$ $c_1)$ diagram.

IV. DISCUSSION

The following conclusions can be drawn from the photometric data obtained:

i) AP Ser. It is necessary to remark that the ephemerides used were from two sources. The ephemeris was from Eggen (1978) but the period was taken from the more recent paper of de Bruijn and Lub (1986). In their study they reported a period of pulsation of 0.34132d which is the value considered in the elaboration of the phase diagrams. However, from the figures corresponding to this star it becomes immediately apparent that the shift of time of maximum is as much as 0.5 in phase. This could mean either a period variation or an insufficiently determined accuracy in the period. A remarkable hump barely discernible in the V magnitude becomes increasingly important in the $b - y$ color and the c_1 index. On the other hand, m_1 remains constant through all the cycle. The loop described by this star in the $(b - y, c_1)$ diagram is clearly defined.

ii) BH Ser. This star is remarkable in the sense that it does not show the large amplitude reported by Kholopov (1987). In his catalog an amplitude of variation of 1.6 mag is reported, much larger than the value of 0.90 mag derived from the curves of the present paper. A small shift in the time of maxima suggests a period variation.

iii) AV Ser. From the light curves of this star a small shift of 0.1 in phase of the maximum in the V filter which increases in the $b - y$ color and even more in the c_1 index is immediately apparent Although not the whole cycle has been covered, the m_1 index suggests constancy along the cycle.

iv) AN Ser. No clear distinction of the maximum has been shown but apparently, no phase shift is encountered in any filter with respect to a phase value of zero. A small hump at phase 0.6 in all colors in quite conspicuous. The color-color diagram shows a well defined closed loop.

v) CS Ser. This star does not show any peculiarities in the light curves. The phase remains constant in all filters, and maximum values are reached at phase zero which implies, consequently, an accurate determination of the ephemeris and period. The β curve shows a large scatter on the rising branch and a small hump is clearly discernible in the c_1 index.

vi) VY Ser. The ephemeris and period listed for this star describe its behavior correctly. Not many features are worth calling attention to except for a

TABLE 4

PHOTOELECTRIC PHOTOMETRY OF RR LYRAE STARS

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
AP SER						
11.106	0.183	0.057	1.118	2446960.69576	2.709	2446960.69623
11.213	0.222	0.055	0.999	46960.72854	2.704	46960.72905
11.350	0.229	0.068	0.883	46960.76054	2.628	46960.76097
11.397	0.244	0.065	0.855	46960.79307	2.628	46960.79351
11.434	0.244	0.051	0.874	46960.81596	2.682	46960.81639
11.422	0.244	0.059	0.867	46960.83135		
11.399	0.214	0.084	0.842	46960.85057		
10.988	0.168	0.048	1.168	46961.68743	2.713	46961.68792
11.068	0.195	0.046	1.133	46961.71885	2.712	46961.71934
11.152	0.203	0.046	1.065	46961.73682	2.680	46961.73724
11.237	0.223	0.037	1.011	46961.75492	2.685	46961.75538
11.335	0.219	0.064	0.940	46961.76920	2.693	46961.77236
11.327	0.225	0.058	0.911	46961.78465	2.653	46961.78996
11.356	0.233	0.060	0.910	46961.79378		
11.389	0.253	0.043	0.879	46961.81602	2.635	46961.81645
11.403	0.254	0.059	0.824	46961.83730	2.659	46961.83772
11.460	0.240	0.061	0.851	46961.85849	2.711	46961.85892
10.922	0.162	0.047	1.177	46962.67367		
10.941	0.153	0.057	1.176	46962.68029	2.738	46962.68071
10.994	0.153	0.057	1.197	46962.70785	2.756	46962.70828
11.019	0.174	0.051	1.160	46962.72327	2.705	46962.72370
11.040	0.177	0.052	1.150	46962.72971	2.714	46962.73014
11.165	0.194	0.059	1.045	46962.76024	2.680	46962.76070
11.190	0.204	0.057	1.037	46962.76855	2.703	46962.76899
11.297	0.235	0.059	0.885	46962.83588		
11.342	0.225	0.064	0.851	46962.85840		
11.389	0.240	0.052	0.879	46962.86882		
10.929	0.148	0.061	1.157	46963.68510	2.744	46963.68556
10.939	0.146	0.063	1.172	46963.69213		
10.947	0.159	0.052	1.176	46963.71236	2.738	46963.71283
10.993	0.158	0.048	1.178	46963.72011	2.722	46963.72054
11.019	0.159	0.058	1.165	46963.74191	2.731	46963.74234
11.016	0.189	0.038	1.148	46963.74943	2.735	46963.74985
11.107	0.195	0.046	1.094	46963.77123		
11.116	0.208	0.036	1.078	46963.77571		
11.186	0.221	0.032	1.030	46963.79163		
11.299	0.238	0.052	0.897	46963.83309		
11.343	0.228	0.056	0.864	46963.85561		
11.350	0.220	0.068	0.847	46963.86603		
10.981	0.174	0.051	1.045	46965.70180	2.756	46965.70222
10.968	0.153	0.070	1.070	46965.70908	2.759	46965.70953
10.992	0.148	0.056	1.166	46965.73402	2.734	46965.73445
10.938	0.152	0.053	1.171	46965.73840		
10.947	0.159	0.046	1.175	46965.74791		
10.971	0.152	0.060	1.171	46965.76094		
10.983	0.165	0.046	1.179	46965.76667	2.745	46965.76467
11.056	0.172	0.052	1.155	46965.78021		
11.089	0.197	0.034	1.139	46965.80439	2.713	46965.80483
11.095	0.176	0.053	1.074	46967.71009	2.739	46967.70385
11.080	0.159	0.066	1.081	46967.71541	2.748	46967.71587
11.018	0.159	0.058	1.107	46967.72693		
11.018	0.165	0.062	1.079	46967.73370	2.753	46967.73075
11.021	0.171	0.064	1.020	46967.74392		
10.978	0.156	0.055	1.115	46967.76478		
10.960	0.144	0.063	1.166	46967.77893	2.741	46967.77266
10.961	0.144	0.062	1.174	46967.78314		
10.965	0.138	0.071	1.175	46967.78909		
10.995	0.147	0.058	1.183	46967.80775		
10.991	0.157	0.052	1.184	46967.81236		
11.007	0.163	0.049	1.186	46967.81987		
11.018	0.172	0.048	1.165	46967.82718		

TABLE 4 (CONTINUED)

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
11.036	0.181	0.037	1.163	46967.83479	2.713	46967.83946
11.058	0.186	0.044	1.134	46967.84323		
11.085	0.183	0.053	1.114	46967.84777	2.721	46967.84824
BH SER						
12.097	0.118	0.029	1.392	2446961.74168	2.790	2446961.74213
12.207	0.141	0.047	1.323	46961.75932	2.704	46961.75974
12.351	0.163	0.047	1.248	46961.77750	2.722	46961.77795
12.508	0.202	0.048	1.112	46961.79904	2.660	46961.79949
12.624	0.244	0.036	0.999	46961.82136	2.694	46961.82181
12.746	0.238	0.106	0.837	46961.84384	2.637	46961.84420
12.597	0.188	0.087	1.078	46962.67821	2.668	46962.67874
12.736	0.194	0.146	0.948	46962.70484	2.689	46962.70546
12.799	0.243	0.104	0.820	46962.72744	2.585	46962.72787
12.893	0.282	0.109	0.725	46962.76403	2.664	46962.76450
13.061	0.283	0.099	0.753	46963.69031	2.555	46963.69074

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
AV SER						
11.736	0.386	0.056	0.698	2446961.70122		
10.856	0.214	0.057	1.127	46961.72943	2.789	2446961.72985
10.808	0.177	0.047	1.264	46961.74816	2.779	46961.74862
10.878	0.183	0.041	1.332	46961.76531	2.770	46961.76576
10.938	0.212	0.048	1.333	46961.78438	2.750	46961.78481
11.122	0.244	0.032	1.282	46961.80781	2.721	46961.80828
11.200	0.270	0.048	1.156	46961.82915	2.702	46961.82964
11.325	0.303	0.063	1.043	46961.85149	2.664	46961.85193
11.371	0.290	0.069	0.785	46962.68577		
10.762	0.192	0.041	1.237	46962.71441	2.786	46962.71484
10.811	0.202	0.033	1.322	46962.73680	2.748	46962.73723
11.028	0.225	0.052	1.322	46962.77530	2.743	46962.77573
11.469	0.321	0.090	0.856	46962.84711		
11.593	0.358	0.071	0.857	46962.86730		
10.807	0.188	0.049	1.286	46963.69845	2.749	46963.69887
10.957	0.207	0.047	1.336	46963.73138	2.722	46963.73180
11.088	0.254	0.043	1.270	46963.76083	2.739	46963.76159
11.306	0.332	0.027	1.053	46963.80860		
11.471	0.326	0.080	0.873	46963.84434		
11.549	0.327	0.089	0.813	46963.86453		
11.198	0.270	0.049	1.199	46965.72387	2.707	46965.72429
11.288	0.301	0.040	1.128	46965.74317		
11.425	0.338	0.052	0.996	46965.77862		
11.585	0.375	0.050	0.860	46965.81440	2.646	46965.81483
11.950	0.379	0.079	0.770	46965.85943		
11.432	0.328	0.069	0.965	46967.72362	2.663	46967.72404
11.678	0.388	0.065	0.756	46967.78783		
11.752	0.378	0.083	0.741	46967.81729	2.597	46967.81775
11.763	0.396	0.076	0.724	46967.85418		

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
AN SER						
11.134	0.335	0.153	0.738	2446960.71667	2.657	2446960.71721
11.180	0.315	0.171	0.722	46960.74625	2.622	46960.74671
11.250	0.351	0.159	0.691	46960.78314	2.633	46960.78357
11.279	0.349	0.174	0.664	46960.80653	2.624	46960.80696
11.297	0.376	0.140	0.721	46960.82372	2.667	46960.82420
11.342	0.355	0.175	0.685	46960.84052	2.628	46960.84095
11.409	0.351	0.167	0.646	46960.85894	2.645	46960.85937
11.108	0.327	0.151	0.753	46961.72714	2.660	46961.72756
11.099	0.336	0.153	0.737	46961.74592	2.636	46961.74634
11.112	0.327	0.156	0.741	46961.76305	2.637	46961.76347

TABLE 4 (CONTINUED)

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
11.175	0.351	0.139	0.734	46961.80272	2.642	46961.80319
11.248	0.334	0.168	0.685	46961.82626	2.639	46961.82677
11.280	0.351	0.168	0.694	46961.84931	2.631	46961.84975
10.878	0.267	0.134	0.924	46962.68352	2.717	46962.68397
10.974	0.289	0.144	0.851	46962.71226	2.685	46962.71267
11.027	0.316	0.146	0.773	46962.73382		
11.094	0.330	0.155	0.722	46962.77294	2.672	46962.77339
11.086	0.329	0.144	0.730	46962.84396		
11.132	0.348	0.123	0.779	46962.86470		
10.798	0.235	0.128	0.993	46963.69637	2.680	46963.69679
10.869	0.258	0.145	0.893	46963.72346	2.657	46963.72391
10.948	0.290	0.137	0.861	46963.75317	2.691	46963.75359
11.081	0.333	0.135	0.735	46963.80117		
11.087	0.333	0.138	0.743	46963.84119		
11.103	0.328	0.133	0.756	46963.86193		
10.603	0.183	0.097	1.185	46965.72136	2.765	46965.72178
10.683	0.204	0.112	1.105	46965.74104		
10.804	0.215	0.112	1.078	46965.75683		
10.762	0.243	0.112	1.020	46965.77541		
10.879	0.270	0.116	0.939	46965.81207	2.686	46965.81250
10.832	0.230	0.115	0.761	46967.71927	2.662	46967.71968
10.536	0.151	0.101	1.217	46967.78581		
10.652	0.177	0.111	1.167	46967.81496	2.713	46967.81538
10.745	0.228	0.111	1.040	46967.85151	2.702	46967.85195

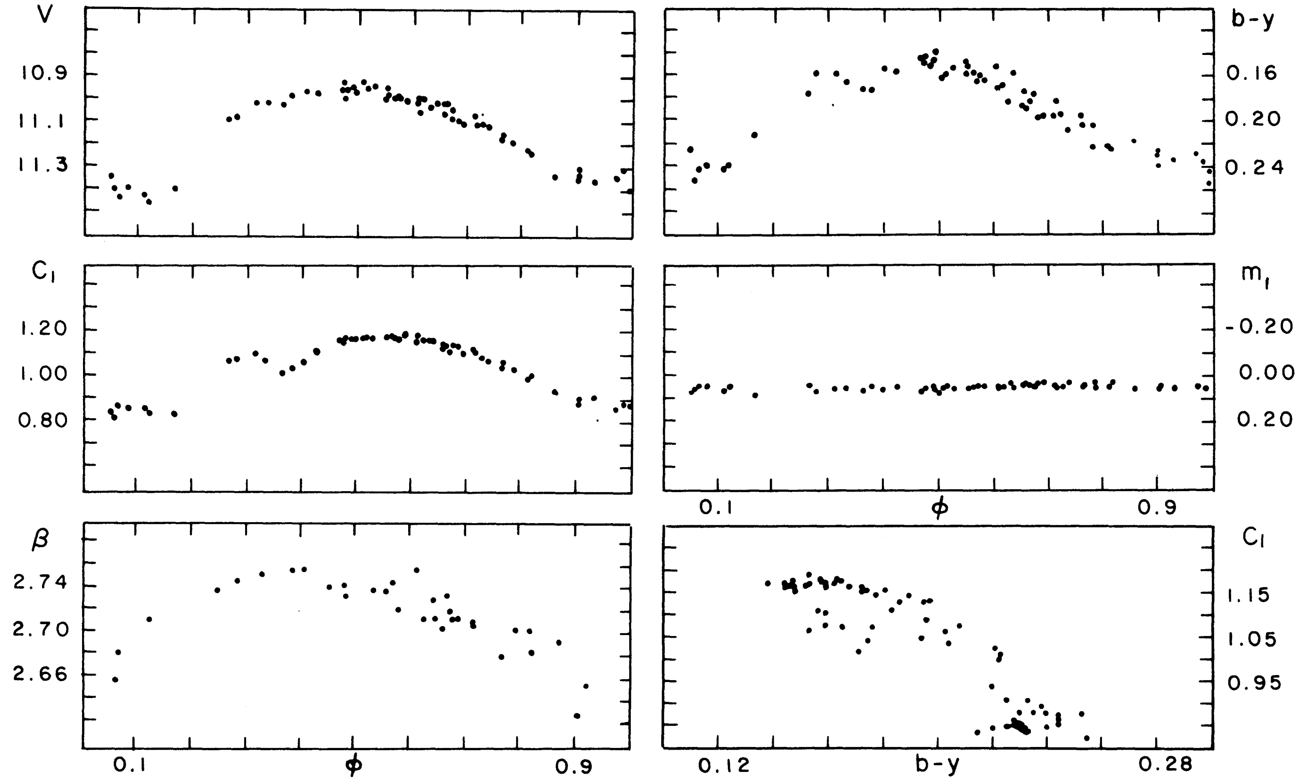
V	$b-y$	m_1	c_1	HJD	Hβ	HJD
				CS SER		
12.706	0.326	0.030	0.727	2446960.70152	2.646	2446960.70220
12.004	0.171	0.066	0.965	46960.76938	2.711	46960.76985
11.800	0.127	0.069	1.215	46960.79648		
11.906	0.147	0.032	1.286	46960.81924	2.727	46960.81967
11.966	0.162	0.046	1.217	46960.83467	2.720	46960.83510
12.088	0.142	0.067	1.126	46960.85381	2.672	46960.85424
12.694	0.335	0.055	0.662	46961.69173	2.628	46961.69218
12.711	0.315	0.069	0.714	46961.72246	2.603	46961.72289
12.651	0.300	0.061	0.720	46961.75847		
12.072	0.195	0.036	0.910	46961.81920	2.618	46961.81964
11.836	0.129	0.058	1.203	46961.84203	2.771	46961.84247
11.842	0.144	0.035	1.303	46961.86238		
12.708	0.338	0.048	0.694	46962.72651	2.627	46962.72697
12.733	0.302	0.060	0.695	46962.76352	2.682	46962.76394
12.679	0.322	0.059	0.692	46963.68989	2.606	46963.69033
12.710	0.317	0.077	0.668	46963.71901	2.604	46963.71969
12.708	0.336	0.070	0.670	46963.74866	2.615	46963.74909
12.798	0.364	0.058	0.572	46963.78859	2.645	46963.81511
12.126	0.195	0.035	1.186	46967.71453	2.765	46967.68085
12.283	0.211	0.039	1.080	46967.74729	2.693	46967.74776
12.400	0.238	0.085	0.884	46967.78261		
12.477	0.258	0.080	0.846	46967.81077	2.684	46967.81119
12.477	0.258	0.080	0.846	46967.81077		

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
				VY SER		
10.198	0.327	0.073	0.692	2446960.69307	2.592	2446960.69395
10.240	0.338	0.064	0.679	46960.73196	2.597	46960.73252
10.265	0.332	0.070	0.660	46960.76466		
10.266	0.331	0.078	0.643	46960.79518		
10.273	0.338	0.060	0.672	46960.81796	2.605	46960.81839
10.268	0.339	0.061	0.674	46960.83338	2.592	46960.83381
10.286	0.331	0.066	0.663	46960.85259	2.596	46960.85301
10.403	0.337	0.063	0.656	46961.68993	2.588	46961.69037

TABLE 4 (CONTINUED)

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
10.358	0.326	0.060	0.660	46961.72093	2.604	46961.72165
10.088	0.288	0.061	0.683	46961.75693	2.626	46961.75737
9.981	0.263	0.048	0.788	46961.77489	2.640	46961.77545
9.939	0.241	0.054	0.892	46961.79677	2.675	46961.79719
9.857	0.229	0.049	0.969	46961.81801	2.687	46961.81843
9.826	0.225	0.047	1.001	46961.84073	2.672	46961.84122
9.841	0.229	0.048	1.016	46961.86086	2.676	46961.86135
10.003	0.282	0.046	0.875	46962.67576	2.628	46962.67618
10.028	0.291	0.051	0.849	46962.70226	2.619	46962.70269
10.050	0.303	0.052	0.806	46962.72516	2.597	46962.72559
10.096	0.312	0.058	0.765	46962.76223	2.619	46962.76267
10.275	0.332	0.064	0.670	46963.68713	2.591	46963.68756
10.285	0.337	0.058	0.681	46963.71714	2.601	46963.71760
10.307	0.331	0.064	0.682	46963.74751	2.582	46963.74799
10.343	0.342	0.053	0.675	46963.78564		
10.379	0.328	0.065	0.656	46963.83791		
10.345	0.322	0.062	0.653	46963.85798		
10.192	0.335	0.055	0.698	46965.70550	2.591	46965.70629
10.237	0.341	0.047	0.689	46965.73619		
10.280	0.337	0.059	0.671	46965.75134		
10.298	0.338	0.057	0.674	46965.80662	2.591	46965.80705
10.389	0.332	0.056	0.691	46965.85303		
10.073	0.291	0.052	0.838	46967.71274	2.621	46967.71324
10.122	0.305	0.051	0.789	46967.74600	2.605	46967.74643
10.161	0.304	0.068	0.748	46967.78120		
10.181	0.316	0.063	0.729	46967.80949	2.604	46967.80992
10.207	0.328	0.060	0.699	46967.84536	2.600	46967.84579

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
				AT SER		
11.760	0.348	0.030	0.694	2446960.71510	2.573	2446960.71552
11.793	0.295	0.088	0.666	46960.74453	2.563	46960.74496
11.843	0.350	0.035	0.688	46960.78159	2.572	46960.78202
11.851	0.315	0.080	0.639	46960.80403	2.570	46960.80448
11.862	0.330	0.052	0.651	46960.82247	2.631	46960.82291
11.837	0.314	0.062	0.658	46960.83863	2.603	46960.83905
11.719	0.295	0.053	0.647	46960.85782	2.654	46960.85826
11.008	0.174	0.042	1.168	46961.69597	2.731	46961.69643
11.063	0.183	0.044	1.187	46961.72617	2.691	46961.72659
11.214	0.187	0.035	1.143	46961.74454	2.680	46961.74504
11.153	0.196	0.051	1.109	46961.76202	2.695	46961.76245
11.202	0.210	0.046	1.073	46961.78024	2.649	46961.78067
11.244	0.243	0.028	1.024	46961.80161	2.653	46961.80204
11.300	0.257	0.017	0.980	46961.82389	2.654	46961.82457
11.348	0.271	0.037	0.922	46961.84704	2.626	46961.84747
11.476	0.303	0.039	0.831	46962.68233	2.640	46962.68279
11.518	0.303	0.053	0.785	46962.70987	2.639	46962.71030
11.533	0.312	0.053	0.755	46962.73210	2.610	46962.73253
11.599	0.312	0.059	0.720	46962.77069	2.610	46962.77118
11.677	0.297	0.063	0.663	46962.84292		
11.740	0.322	0.066	0.684	46963.69491		
11.769	0.318	0.067	0.694	46963.72238	2.576	46963.72288
11.801	0.319	0.076	0.665	46963.75131	2.576	46963.75175
11.841	0.339	0.040	0.676	46963.80029		
11.679	0.302	0.051	0.680	46963.84015		
11.479	0.258	0.063	0.686	46963.86081		
11.561	0.299	0.052	0.755	46965.71126	2.624	46965.71168
11.591	0.319	0.050	0.724	46965.74014		
11.702	0.334	0.047	0.690	46965.81018	2.621	46965.81060
11.128	0.200	0.032	1.156	46967.71768	2.690	46967.71814
11.324	0.215	0.062	1.011	46967.78483		
11.369	0.251	0.036	0.965	46967.81398		
11.427	0.276	0.036	0.900	46967.85017	2.646	46967.85059



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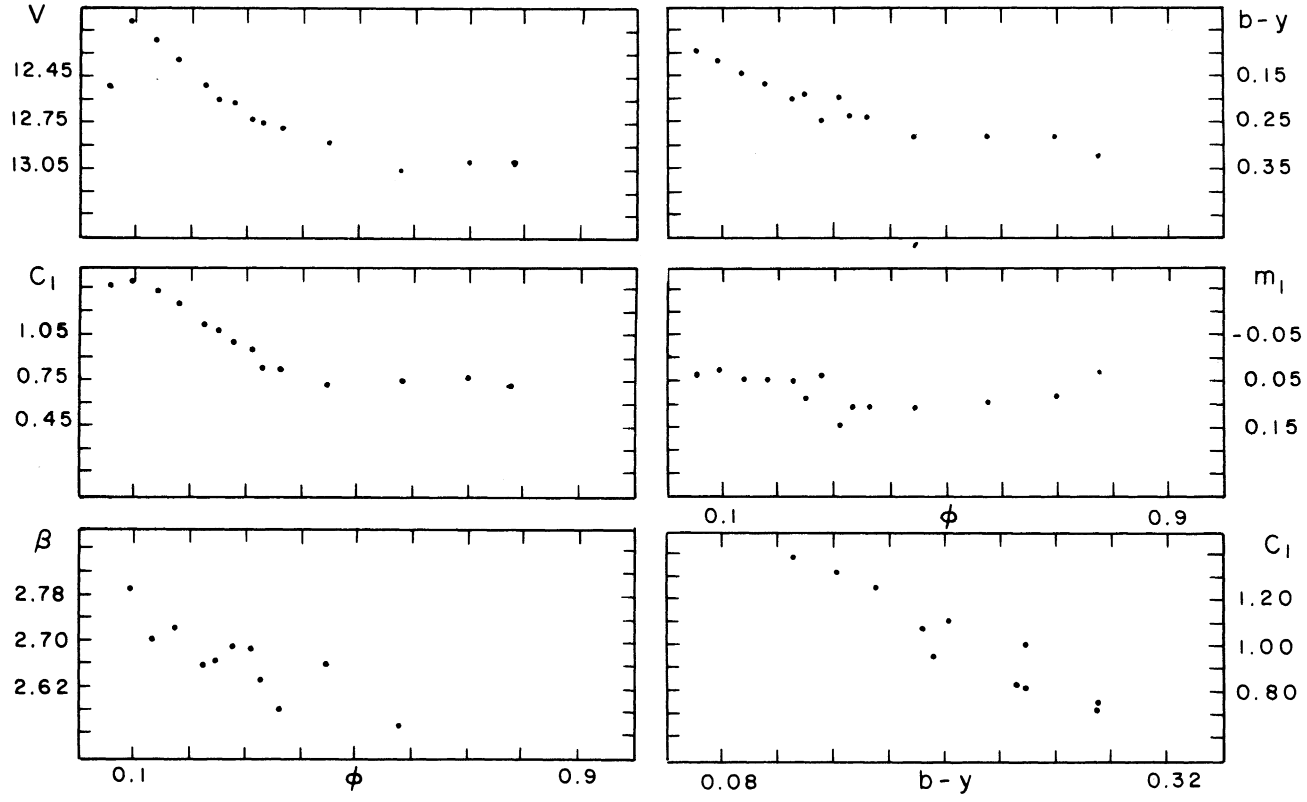
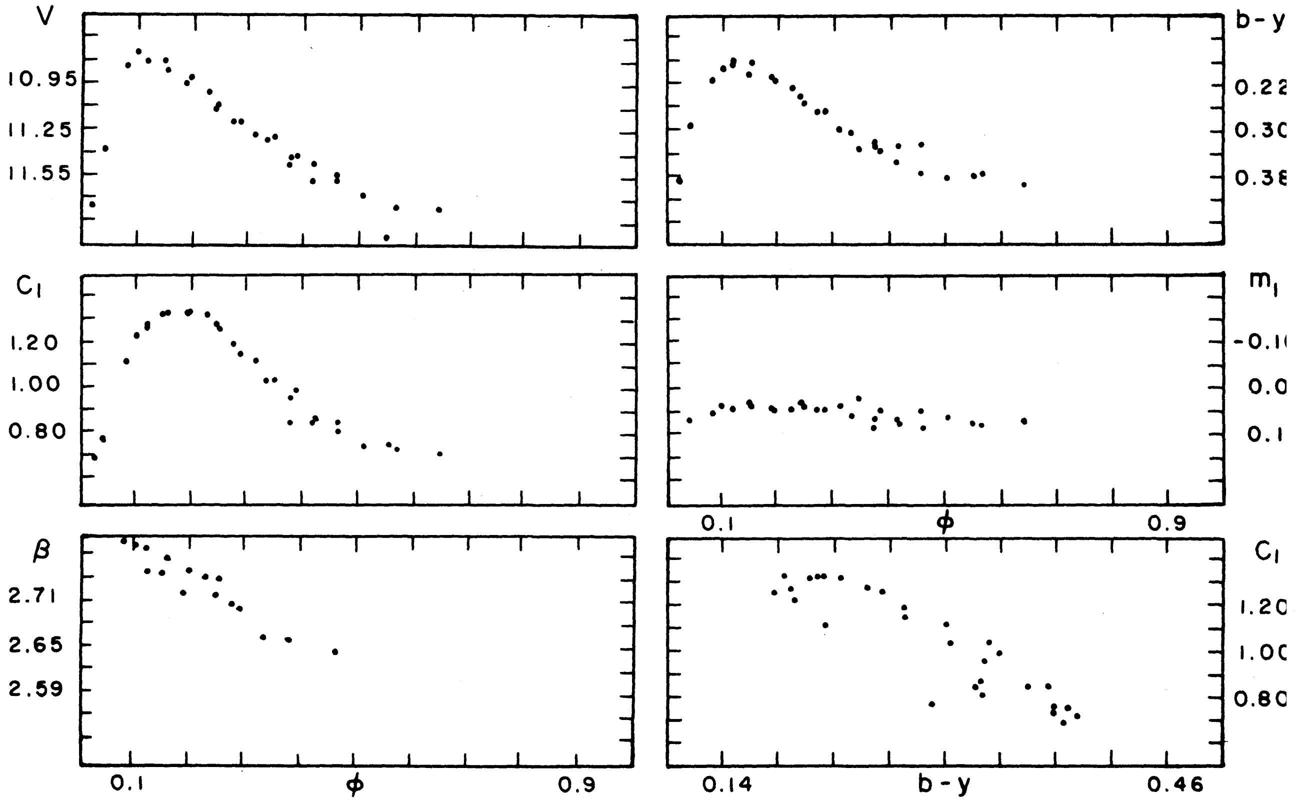


BH SERPENS

Fig. 1. *uvby*-β photoelectric photometry of the RR Lyrae stars.



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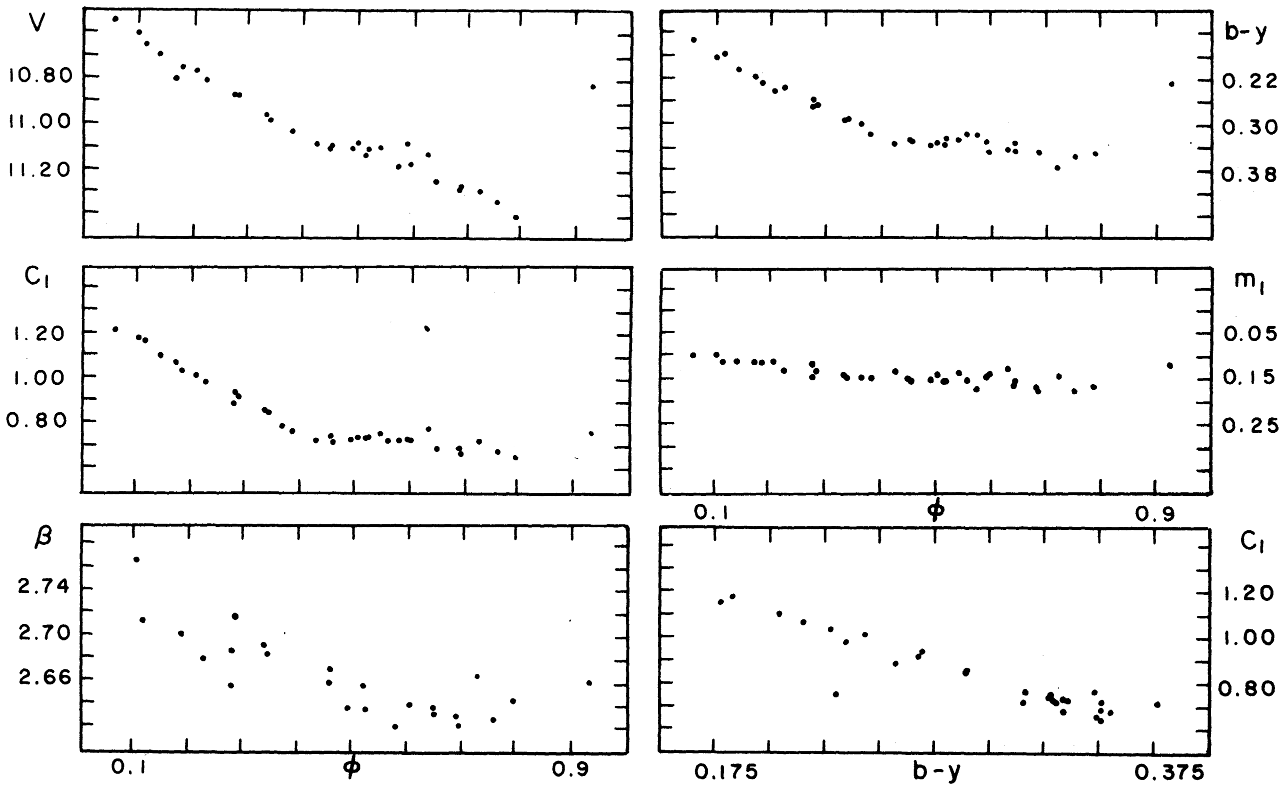

AN SERPENS

Fig. 1. Continued.

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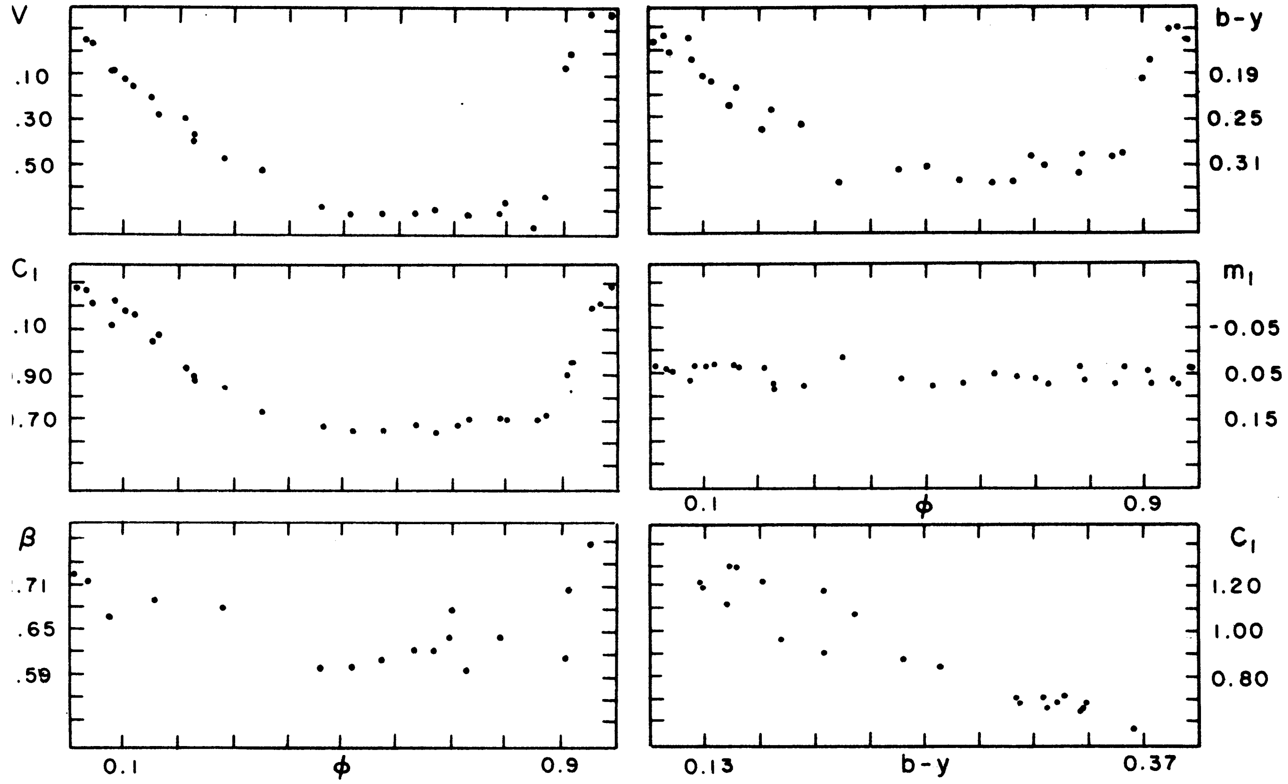

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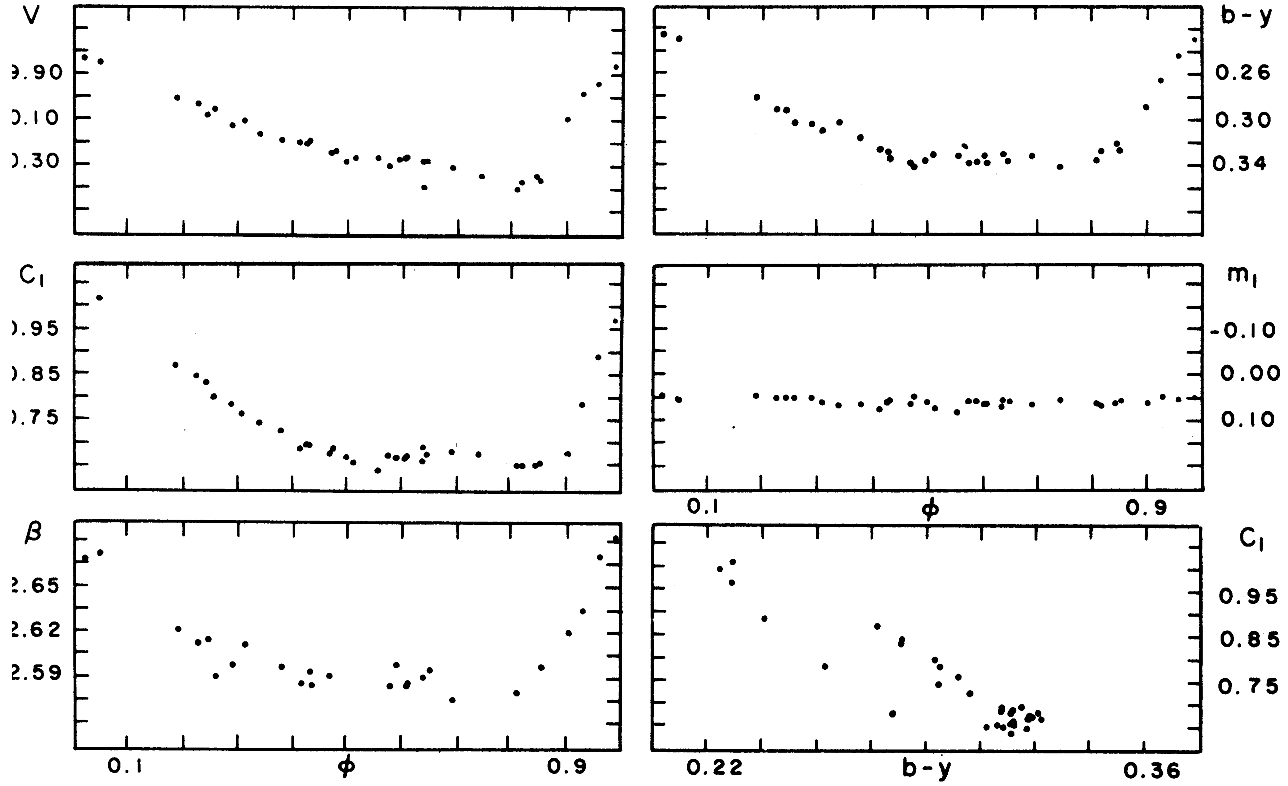

VY SERPENS

Fig. 1. Continued.

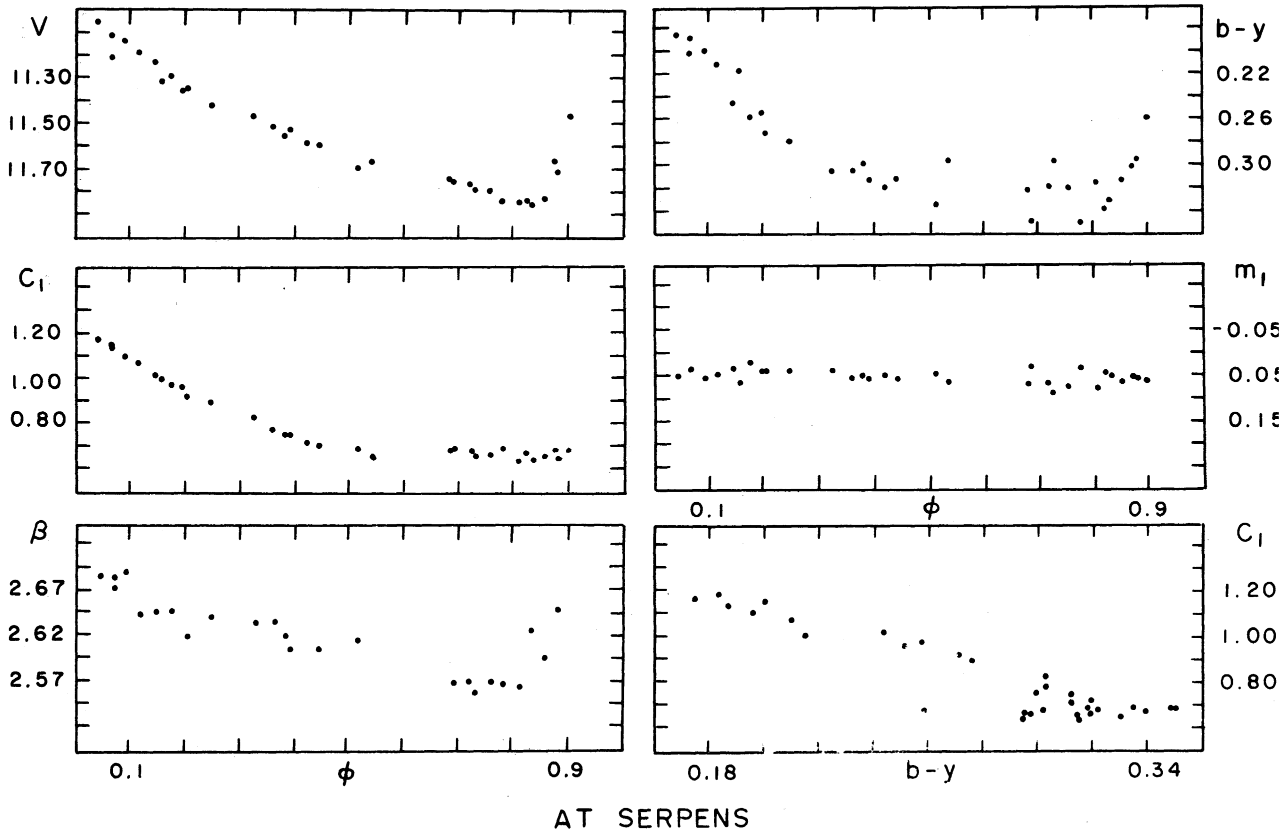

Fig. 1. Continued.

few small humps in the $b-y$ and c_1 indices on the descending branch at about phase 0.5.

vii) AT Ser. Although quite noisy in the $b-y$ and β diagrams, its behavior in the remaining figures, V, c_1 and m_1 is clean and clearly discernible. However, the color-color diagram, due to the noisy behavior of the $b-y$ color is not quite conspicuous. No phase shift in the maxima suggests a period variation.

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