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A CCD PHOTOMETRIC SURVEY OF VARIABLE STARS IN THE FIELD OF NGC 188

X. B. Zhang, L. Deng, B. Tian, and X. Zhou
Beijing Astronomical Observatory and Beijing Astrophysics Center, National Astronomical Observatories, Beijing 100012, China
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ABSTRACT

The results of a recent CCD photometry survey of variables in a 1° field covering the old open cluster NGC 188 are presented. A total of 16 short-period variables were identified during five nights, among which eight are new variables in the program field. By adopting the method of phase-dispersion minimization, the periods for seven of the eight new variables are determined. The main properties, the classifications, as well as the memberships are discussed for all of these variable stars, based on the behavior of light curves, the locations in the color-magnitude diagram, and the results of proper motions. Among the eight new objects, six are W UMa binaries, in which one definitely is and two probably are members of the cluster. A detached or semidetached eclipsing binary with an orbital period longer than 1 day is found, which is a likely cluster star. In addition, a field star with a peculiar light curve is detected, which can be classified as a RRd–type variable. Moreover, revised basic data for the eight old variables are given according to our observations. V8 can be classified as an RS CVn–type star with light variations larger than 0.2 mag.

Key words: binaries: general — open clusters and associations: individual (NGC 188) — stars: variables: general

1. INTRODUCTION

Studies of variable stars in clusters have special interest for the understanding of stellar evolution and the nature of the host cluster. Recent works on variable stars in clusters can be found in Jahn, Kaluzny, & Rucinski (1995), Branly & van Hamme (1996), Kaluzny, Krzeminski, & Mazur (1996), and Park & Nemec (2000). NGC 188, as one of the oldest open clusters, has been one of the most frequently and intensively investigated targets, not only because of its disputed age, but also owing to its richness in variable stars.

First of all, NGC 188 possesses an exceedingly large population of W UMa–type binaries. Early in 1964 four W UMa systems (EP Cep, EQ Cep, ER Cep, and ES Cep) were discovered in the cluster (Hoffmeister 1964; Efremov et al. 1964). Later Kaluzny & Shara (1987) found three more contact binaries during a CCD survey. This indicates that contact binaries are somehow enriched in NGC 188. Because of their peculiar observational properties, such as the so-called light-curve paradox, W UMa–type stars have been a challenge to the current theory of stellar structure and evolution since 1960s (Lucy 1968; Mochnacki 1985; Rucinski 1993), although they are the most common kind of close binaries in the solar neighborhood. Taking advantage of knowing the age of the cluster, NGC 188 is the best object for contact binary research. Furthermore, there are some other types of variables (Kaluzny & Shara 1987; Kaluzny 1990; Mazur & Kaluzny 1990) and numerous probable blue stragglers (Leonard & Linneil 1992; Dinescu et al. 1996) in the cluster.

Open clusters, especially the old ones, are highly dynamically evolved systems, which show strong evidence for mass segregation and low-mass star evaporation. NGC 188 is known to possess an extended halo of angular size reaching 1° (Keenan, Innanen, & House 1973). To this aim, observations looking for variable stars in a wide range around a cluster are needed in order to get a more complete sample. As a wide-field sky-survey project, the BATC (Bejing-Arizona-Taiwan-Connecticut) multicolor sky survey shows the advantages of open cluster study (Fan et al. 1996; Chen et al. 1999; Deng et al. 1999). Because of these advantages, we started variable star searching in open clusters in the BATC program. The first target was NGC 188.

In this paper we present the results of the BATC variable survey on NGC 188. Sections 2–4 describe the observations and methods of the data reduction, variable searching, and period determination for identified variable stars. In § 5 we present the color-magnitude diagram (CMD) for the cluster. The memberships of the variables are also discussed. A star-by-star discussion is given in the §§ 6 and 7.

2. OBSERVATIONS AND DATA REDUCTION

We observed NGC 188 in two runs, 2000 February 29 to March 1 and September 23–25. All observations were carried out with the 60/90 cm Schmidt telescope at Xinglong Station of Beijing Astronomical Observatory. The telescope and main instruments used in this work are the same as those of the standard BATC multicolor sky survey, which has been documented in publications (Fan et al. 1996; Zheng et al. 1999). The photometric system consists of 15 intermediate-band filters (350–490 Å) covering a spectral range 3000–10000 Å. In our observations, the BATC[09] i filter was employed, which is centered at 6660 Å with a bandwidth of 490 Å. A total number of 230 images was collected in the two runs. With a 2k × 2k CCD camera, the field of view for each image is about 1°, with an image scale of $1''.67$ pixel^{-1}. The exposure time was 60 or 120 s, depending on the weather conditions; the average dead time between two frames was about 10 minutes.

During data reduction after the first run, it was found that the northern part of field for about one-third of the images was misfocussed, which might have been caused by the displacement of the CCD camera. During the second observation run, the camera mounting was carefully checked to ensure optimized image quality. Because NGC 188 is very close to the celestial north pole, the positioning of the cluster on our CCD camera is just upside down between the two runs.

Multicolor photometry of NGC 188 was collected by our group during earlier observing runs. Deep images of 13 colors for the field have been collected. In this work, part of the deep photometry data will be applied for the discussion of the variables in the CMD.

The data were processed using automated point-spread function (PSF)–fitting photometry, which is mainly based on the UNIX version of DAOPHOT II (Stetson 1987), with a modification on the PSF star selection procedure (Z. J. Jiang 1999, private communication; Deng et al. 2001). By using such a pipeline utility, all images are reduced noninteractively.

For the purpose of variable searching, a self-calibration is made for all the images so that the light variations of single stars can be detected. To do this, we take one image with the best seeing and highest signal-to-noise ratio (S/N) as the reference frame. From this image a large number of bright stars are picked up as the initial standard stars. Starting with these initial standards, we can compile a joint catalog of all stars in all of the 230 frames. By carefully excluding stars with large deviations, about 100 " good " standard stars are chosen as the final standards. With these standard stars, the magnitudes of all stars measured in each image are corrected with respect to the reference frame. Then an absolute calibration is made according to a previous deep photometry taken on the same field (Yan et al. 2000). After that the light curves for all objects measured in the field can be derived.

3. THE SEARCH FOR VARIABLE STARS

To search for the variable stars, a large number of probable variable candidates are preselected according to the amplitudes of their light variations. The two sets of data collected in the two runs were analyzed separately in the same manner. A star is selected as a variable candidate if (1) it presents a larger deviation ($>3\,\sigma$) in its light curve compared with that of other stars of similar magnitude; (2) it has been measured on at least 30 frames in each run. In this manner we got about 100 variable candidates for further analysis.

After detailed visual examination of the light curves for all the candidates, spurious variables were rejected. For uncertain objects we went back to the images to make sure that they were not sitting on bad pixels or close to the bright wings of saturated stars. Finally, objects detected on both runs were selected as certain variables. There is one star, which presents significant light variations in the first run, that is likely a long-period eclipsing binary. We decided to add this star to the sample of variables, although it presented no obvious light changes in the second run. As a result, a total number of 16 certain variables was obtained, among which eight stars are the variables previously discovered by Hoffmeister (1964; also Efremov et al. 1964) and Kaluzny & Shara (1987). The remaining eight objects are the newly discovered variables.

Up to this work, there were a total number of 11 variables known in this field (three known variables were not detected; see § 6) named V1 to V11 (Kaluzny 1990; Mazur & Kaluzny 1990). Following this sequence we give the temporary identification numbers, V12 to V19, to the eight newly discovered variables in this work. The ID numbers are given to the new variables according to their distances from the cluster center; i.e., V12 is the nearest object to the cluster center and V19 is the farthest away from the center. The rectangular and equatorial coordinates of all the variables observed are listed in Table 1. For a cross identification, the identification numbers for stars, which can be found in the catalog of Dinescu et al. (1996), are also listed. Figure 1 shows the finding chart, on which the X and Y coordinates (in pixels) correspond to the data given in Table 1. To make the chart clear, we plot only the stars brighter than 18 mag in the i filter. In the large panel (*top left*) of Figure 1, rings I–III defined by Sandage (1962) are indicated by the solid circles. For the following discussion, we define a new region named ring IV with a radius of 710 pixels (more than twice that of ring III) denoted by a dashed circle. Finding charts

TABLE 1

Coordinates of the Variables in the Field of NGC 188

ID	$ID_{Dinescu}$	Name	X	Y	α	δ
V1	...	EP Cep	1027.71	954.92	00 46 54.15	85 21 44.1
V2	...	EQ Cep	1052.47	1142.17	00 47 33.50	85 16 24.8
V3	765	ER Cep	1178.28	1187.82	00 50 27.77	85 15 09.0
V4	766	ES Cep	1194.68	1150.77	00 50 50.21	85 16 12.4
V5	754	V371 Cep	1087.78	1159.91	00 48 22.65	85 15 55.3
V6	...	V370 Cep	1039.68	1170.51	00 47 16.51	85 15 35.9
V7	...	V369 Cep	991.83	1224.19	00 46 12.23	85 14 02.5
V8	...	V372 Cep	1219.36	1085.63	00 51 24.31	85 18 03.9
V12	407	...	1273.50	1347.86	00 52 37.74	85 10 35.2
V13	1526	...	1212.97	847.14	00 51 15.15	85 24 51.7
V14	...	...	880.97	1916.62	00 44 10.29	84 54 13.7
V15	1221	...	1660.06	866.97	01 01 50.73	85 24 00.7
V16	1219	...	1683.26	872.41	01 02 23.29	85 23 49.6
V17	1910	...	491.90	660.78	00 33 48.98	85 29 22.6
V18	...	...	1905.25	853.28	01 07 39.69	85 23 59.8
V19	...	...	1970.70	1238.81	01 08 31.75	85 12 54.2

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds (J2000.0).

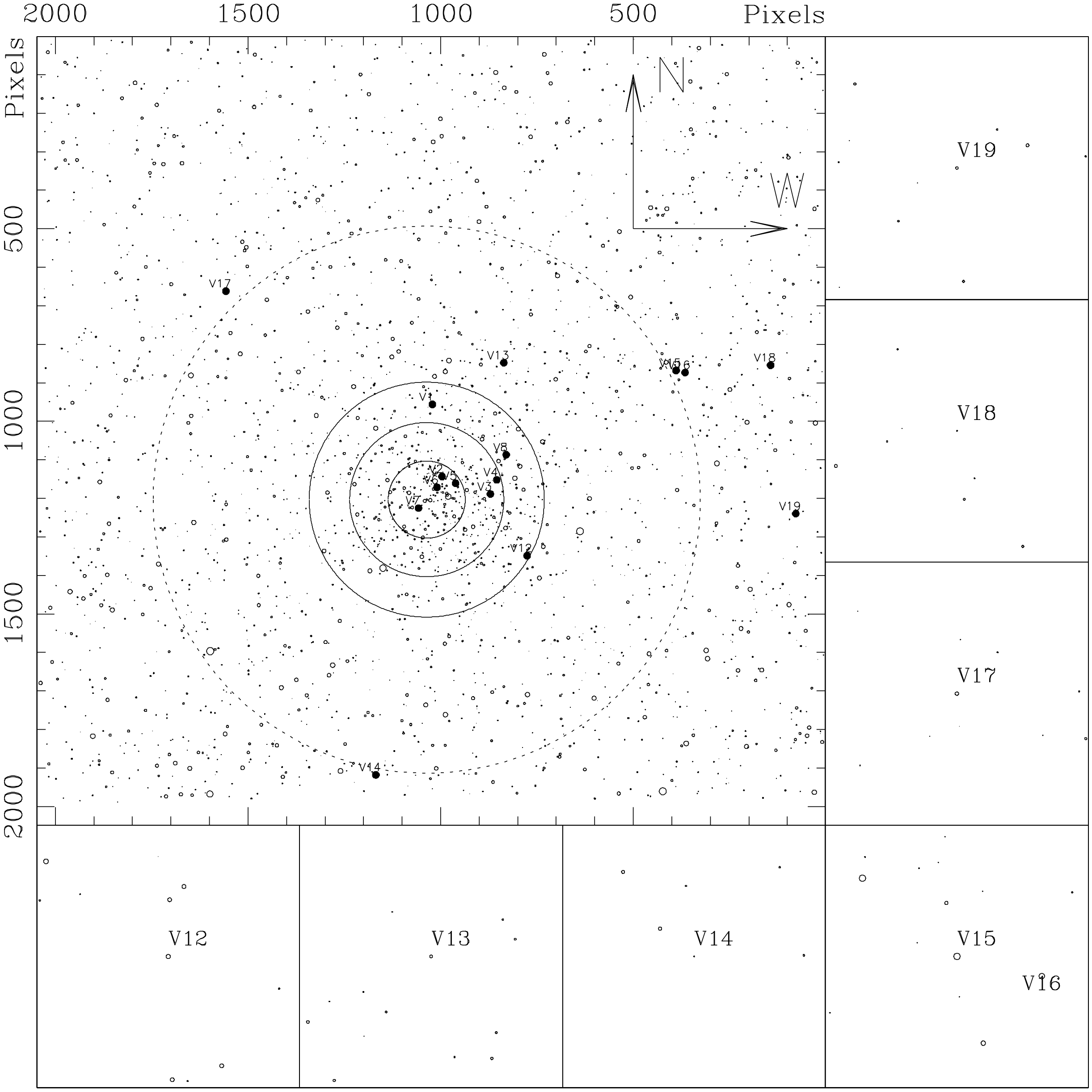


FIG. 1.—Finding chart for the variables in the program field (*top left, big panel*), in which normal stars are plotted using open circles, and the variables are filled dots. Sandage's rings I–III are indicated by the three solid circles. The dashed-line circle denotes ring IV, which has a radius of 710 pixels, 100 pixels larger than twice Sandage's ring III. Detailed finding charts covering field of view of $2' \times 2'$ are given for the eight new variables in the small panels, each labeled with the star identification given in Table 1. The orientations of the small finding charts are the same as the bigger one.

for the eight new variables with a field of view $2' \times 2'$ square are plotted as the small panels in Figure 1.

4. PERIOD DETERMINATION AND LIGHT CURVES

To determine the approximate periods of the newly discovered variables, V13, V14, V15, V17, V18, and V19, the phase dispersion minimization (PDM) method (Stellingwerf 1978) is adopted. To do that, a code was developed which gives us the main characteristics of light curves such as the periods, maximum magnitudes and amplitudes of light variations. To check the precision of period determinations, an examination was made for the four well-known variables EP Cep, EQ Cep, ER Cep, and ES Cep in the cluster. The results of this examination are optimistic. The period of ER Cep is 0.28534 days with the PDM code as illustrated in Figure 2. As a result, the periods derived in this way match closely the previous values by Kaluzny & Shara (1987, for V1) and Kaluzny (1990, for V2, V3, and V4) within an accuracy of about 0.0001 days. In this way, the periods of all the newly discovered variables except V12 can be defined. Considering the time resolution and time base of our observations, the accuracy of the periods is around 0.0001 days.

For the old variables a classical $O - C$ period analysis is made as well. Adopting the previous minimum times (Kaluzny & Shara 1987; Kaluzny 1990) and the newly determined times of minima with the K-W method (Kwee & van Woerden 1956) in this work, the revised periods are given for V1, V2, V3, V4, and V5 (Table 2), which are based on linear fitting. No new periods can be obtained for V6 and

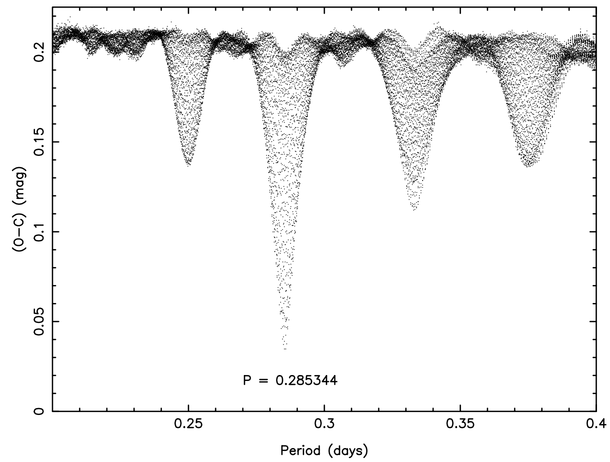


FIG. 2.—Illustration of period determination for the old variable ER Cep with the PDM code, where the $O - C$ is the residual for each trial period. The minimum indicates the most likely period for the star.

V7 because of the poor data for the two stars in this survey. In the case of V8, no definite minimum times can be derived from its light curve; the period is estimated with the PDM code.

Table 3 gives the basic data for all the 16 variables. The first column gives the star's identification number. For the old variables periods quoted from the literature are given in the second column (Kaluzny & Shara 1987; Kaluzny 1990). Column (3) gives the periods determined by the present work. In columns (4) and (5) the maximum brightness and amplitudes of light variations in *i* band are derived for all the variables. The classifications of the variables given in the sixth column are made based on the following discussions.

5. THE CMD OF THE CLUSTER AND MEMBERSHIP OF THE VARIABLES

With the deep photometry data as mentioned above, we can plot the *c* versus $c-i$ CMD of NGC 188, as shown in the top panel of Figure 3. Stars within Sandage's ring III (with a radius of 305 pixels) are plotted using plus signs; those outside the ring are in tiny dots. The locations on the CMD for all the variables are indicated, with the data listed in Table 4. For V6 and V7 no measurements are available in the *c* band, and therefore they are not shown in the CMD.

To have an idea about the membership probability of the variables, we plot the CMDs for stars in three separate regions in the bottom three small panels of Figure 3. The left panel is for the central region within ring III, the central one for the annulus defined by 305 (ring III) $< r <$ 710 (ring IV) pixels, and the right panel is for all the stars outside the 710 pixels circle. It is clearly seen that most of the stars within Ring III are likely cluster members, very few field stars in this area can be seen on the CMD. In the second region the CMD shows still a clear trace of cluster members. About one-third of the stars concentrate along the isochrone. It implies that about one-third of the stars located in the expanded region might be members of the cluster. Stars outside ring IV make a featureless CMD as shown by the right panel of Figure 3.

Dinescu et al. (1996) gave a large table with the data of proper motions and the membership probabilities for NGC 188. Eight stars from our catalogue of variables can be found in their table. These variables are listed in the column headed "PMP" (proper-motion membership probability) in Table 4. To discuss the cluster membership for a star, the PMP is an important criterion, but it is not absolute. In Table 4 one can see that the PMP assigned to V4 is very low (that is partly due to a close visual companion of the star), while it is still treated as a cluster member (Kaluzny & Shara 1987) when its spatial location and position in the CMD are taken into account. For the newly discovered variables, the membership is discussed based on the proper-motion data and the spatial locations and the positions on the CMD.

As indicated in the finding chart, V12 is located within ring III. It has a very high PMP of 0.98 and is certainly a member of the cluster. Although V13 is located outside ring III (but within the ring IV region), it has a PMP of 0.76; therefore it can be classified as a cluster member. In the CMD V13 is located slightly above the main sequence among candidate binary stars. The other six new variables are all located outside ring IV. V14, V16, V18, and V19 are definitely field stars. V15 and V17 are located very close to ring IV on the finding chart. Their positions in the CMD are almost on the binary branch of the cluster. Their membership in the cluster cannot be completely excluded, although their PMPs are low according to Dinescu et al. (1996).

6. THE EXISTING VARIABLES IN NGC 188

Before this work, a total of 11 variables had been found in NGC 188. Ten of the old variables were observed during our program; eight of them were measured with obvious light variations. V9 and V10 show marginal light variations, so no firm conclusions can be drawn. The last one (V11)

TABLE 2
NEW TIMES OF MINIMA FOR THE FIVE OLD W UMA–TYPE BINARIES IN NGC 188

Variable	HJD 2,451,000 +					
V1	605.0249	605.3008	813.0571	...	...	...
	30	33	36	...	...	...
V2	604.0470	605.1221	605.2749	811.2161	812.1248	813.0413
	29	21	31	28	33	27
V3	811.2380	812.0956	813.0969	...	...	...
	18	18	26	...	...	...
V4	604.3223	605.0063	605.1756	605.3571	811.1735	...
	22	26	25	31	30	...
V5	605.0520	813.0897	...	...	...	...
	17	8	...	...	...	...

TABLE 3
THE BASIC PARAMETERS OF VARIABLES IN THE FIELD OF NGC 188

ID (1)	*P* (old) (2)	*P* (new) (3)	*i* (max) (4)	Amp. (5)	Type (6)
V1	0.28974188	0.289744	16.16	0.45	W UMa
V2	0.3069030	0.306905	16.05	0.75	W UMa
V3	0.2857299	0.285728	15.27	0.72	W UMa
V4	0.3424579	0.342457	15.20	0.42	W UMa
V5	0.5859790	0.585984	15.49	0.30	W UMa
V6	0.3304345	...	15.68	0.20	W UMa
V7	0.3281916	...	15.70	0.57	W UMa
V8	4.028	2.9772	12.79	0.20	RS CVn
V12	...	> 1	14.47	0.55	EA
V13	...	0.3606	15.42	0.20	W UMa
V14	...	0.2766	17.16	0.52	W UMa
V15	...	0.3215	12.62	0.12	W UMa
V16	...	0.5005	13.10	0.58	RRd
V17	...	0.3165	14.79	0.43	W UMa
V18	...	0.2887	16.86	0.28	W UMa
V19	...	0.3072	15.85	0.39	W UMa

added to the cluster by Kaluzny (1990) was claimed to be an RS CVn–type with weak light variations of 0.03 mag, which is under the limit of our photometric precision.

Figure 4 shows the light curves of the four well-known W UMa systems V1–V4. The main data of their light curves are given in Table 3. The phased light curves of V5, V6, and V7 are plotted in Figure 5. V5 is a W UMa binary with a relatively long period. *B* and *V* light curves were presented by Kaluzny & Shara (1987) and Kaluzny (1990), respectively. The period was refined to be 0.5859790 days by Kaluzny (1990). We got a well-covered *i* light curve, which shows high asymmetry beyond its eclipses. Our data give a period of 0.585985 days for the star. The light curve of V6 is somewhat noisy due to its faintness. The measurements of V7 are relatively few for it is close to the bright wing of a saturated star. Thus no new periods can be derived for the two stars. We just plot the light curves for them phased with the very recent revised period given by Kaluzny (1990).

V8 is the most interesting object among the variables found previously in NGC 188. Kaluzny & Shara (1987) firstly measured the light variations with a change of 0.1 mag in 1 day. A period of 2.667 days was assigned to the star, and the variable was determined to be an FK Com object. Later Kaluzny (1990) and Mazur & Kaluzny (1990) added more measurements with which they gave a revised period of 4.028 days. During our survey more than 170 measurements were recorded for the variable during five nights. The real-time light curve is given in Figure 6, which shows one descending and two continuous ascending branches with an amplitude of 0.21 mag. The light curve phased with a period of 4.028 days is also presented in Figure 6. It shows that the light curve is somewhat featureless. Trying with the PDM code, a period of 2.9772 days is derived. With the new probable period, the phased light curve is also shown in Figure 6. From the light curves it is clear that the variability of V8 is not due to eclipse, but is very likely caused by surface spot activity. In the CMD V8 is located in the upper right area far beyond the turnoff of the isochrone. It infers that the variable is an evolved object if it is a cluster member. Therefore we would like to believe that V8 is probably a RS CVn object, as suggested by Mazur & Kaluzny (1990).

TABLE 4
COLORS AND MEMBERSHIPS OF THE VARIABLES IN FIELD OF NGC 188

ID	*c* (4210 Å)	*i* (6600 Å)	*c*−*i*	PMP	Memb.
V1	17.54	16.21	1.13	...	Yes
V2	17.50	16.20	1.30	...	Yes
V3	16.54	15.62	0.92	0.88	Yes
V4	16.54	15.27	1.27	0.36	Yes
V5	17.29	15.70	1.59	0.94	Yes
V6	...	15.85	...	...	Yes
V7	...	15.64	...	...	Yes
V8	14.15	12.86	1.29	...	Yes
V12	15.94	14.48	1.46	0.98	Yes
V13	16.59	15.56	1.03	0.76	Yes
V14	20.22	17.28	2.94	...	No
V15	13.36	12.65	0.71	0.00	?
V16	14.10	13.49	0.61	0.00	No
V17	16.03	15.06	0.97	0.00	?
V18	18.13	17.08	1.05	...	No
V19	17.25	15.83	1.42	...	No

7. THE NEWLY DISCOVERED VARIABLES

There are a total number of eight new variables discovered in and around NGC 188 during this survey. Two of the stars are definite and two are probable members of the cluster.

V12: The real time light curve for this star is shown in Figure 7. It presents obvious light variability of definite EA type caused by eclipse. We recorded only one complete eclipse on the second night of the first run, which has a depth of 0.57 mag and a time duration of about 0.3 days. No complete eclipses were measured on the other four nights, but the detected light variations might be regarded as part of the eclipses. The orbital period of the eclipsing binary therefore cannot be determined accurately. For an EA-type eclipsing binary, the orbital period is generally at least 4 times longer than the time duration of the eclipses. Thus the period of V12 should be longer than 1 day. The binary has a color

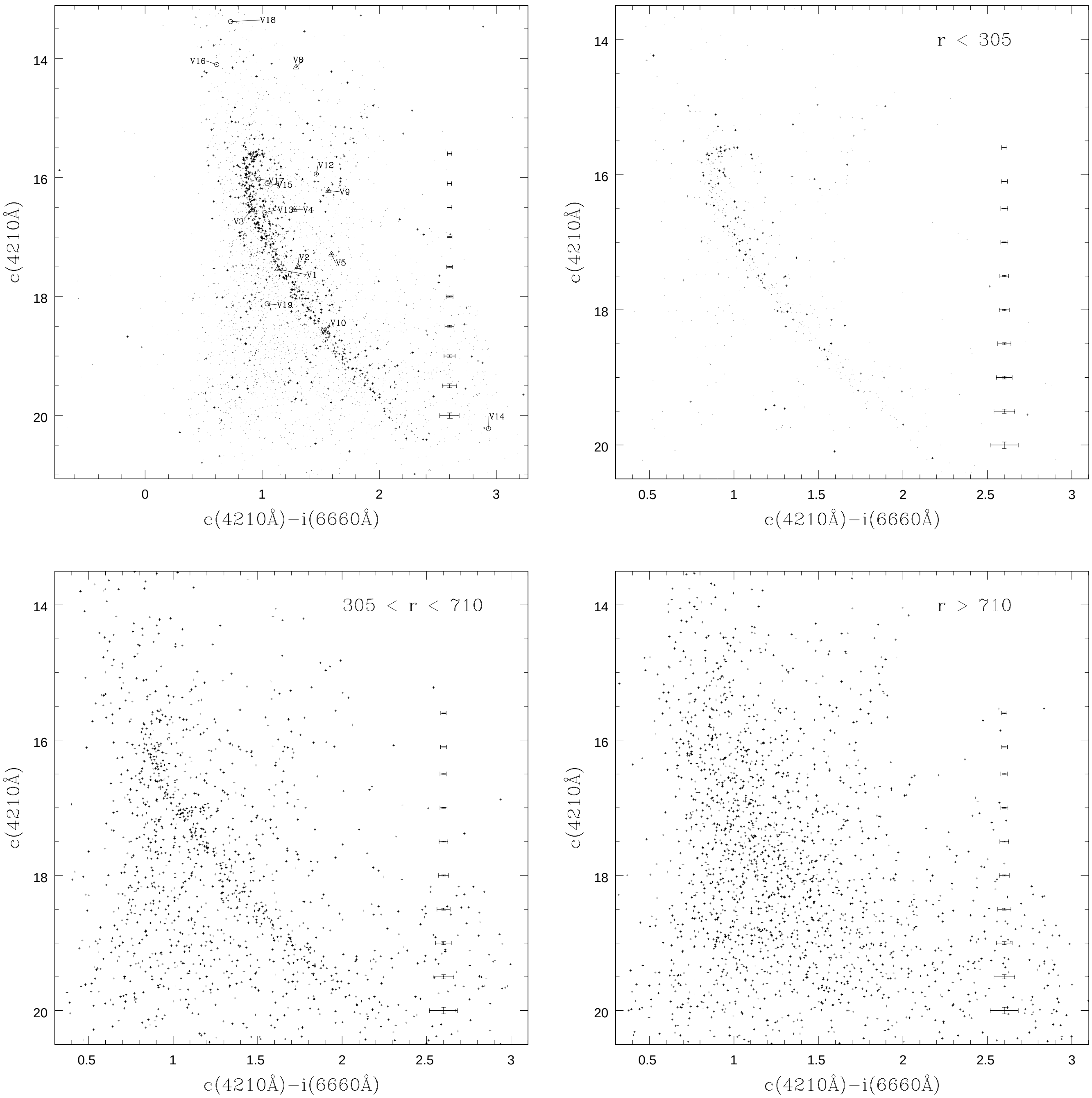


FIG. 3.—Color-magnitude diagram for NGC 188. The top left panel is for all stars observed in the program field. Stars within ring III are plotted as plus signs; others are tiny dots. Error bars are given for the different magnitudes. The other panels are the CMDs for stars in different regions of the field. The top right panel is for stars within ring III, on which stars within ring I are represented by plus signs and those between ring I and ring III are tiny dots. The bottom left panel is for stars between ring III and IV, and the one on the bottom right for stars outside ring IV.

indices of $B-V = 0.45$ (Dinescu et al. 1996). In the CMD it is located far beyond the binary branch. We suggest that this eclipsing binary is a detached or semidetached system.

V13: This star is a certain member of the cluster although it is located about 11′ due northeast of the cluster center. It presents a sine-like light curve (Fig. 7), but one with very sharp minima and maxima, implying that it could be a pulsating variable rather than an eclipsing binary. In the CMD, however, it is located just on the binary branch. Taking the binary picture for the star, it can be classified as a W UMa object with a period of 0.3606 days. Thus it is the eighth W UMa variable found in the field of NGC 188. Further observations of that star are strongly recommended.

V14: This is the faintest variable discovered during our survey, with a maximum brightness of about 17.2 mag on the *i* band, near the detection limit of our observation. The light curve has a convincing deep eclipse of about 0.7 mag, and it presents the EB shape when phased with a period of 0.2766 days (Fig. 8). It is very probably a background W UMa binary.

V15: This is a bright eclipsing binary of about 12.6 mag in the *i* band located in the cluster outskirts. The light curve shown in Figure 8 is of the EW type, with an amplitude of 0.12 mag. It is obviously a W UMa–type system. In the CMD the star is situated just on the binary sequence, but it has a PMP of 0.0. It is likely a field star.

V16: This star is bright field variable with a peculiar light curve. The real-time light curve displayed in Figure 9 presents slowly descending and quick ascending branches, which suggest that the star is a pulsating variable. Two complete minima and three maxima with brightnesses differing between each other were obtained, respectively, in the two observing runs. The maximum light variation amplitude is as large as 0.58 mag. A color index of $B-V = 0.24$ given by Dinescu et al. (1996), suggesting a spectral type of A8–A9 (Schmidt-Kaler 1982) for the object. For small data coverage no accurate pulsating period can be determined by the power spectral analysis. Trying with the PDM method, however, we get a very probable period of about 0.5 days. It is too long for normal δ Scuti stars and rather short for a Cepheid. Thus V16 is more likely a background RR Lyr variable. When phased with a period of 0.5005 days, the light curve presents clearly high asymmetry and rapid changes from one period to another. Period modulations are clearly seen. V16 is very likely a new field RR Lyr star of the d type. More observations are needed for this variable.

V17: This object is a certain W UMa binary system. Its membership in the cluster is uncertain, although it is located far away from the cluster center and has a very low PMP. The period is determined to be 0.3165 days, with which a smooth light curve is obtained as shown in Figure 10.

V18: This faint field star is located very far outside the cluster center. The light curve (Fig. 10) is of EB-type, with an amplitude of about 0.28 mag. A period of 0.2887 days is given. It is suggested to be another field W UMa binary.

V19: This is a field W UMa binary with a period of 0.3072 days. The phased light curve is plotted in Figure 10.

8. DISCUSSIONS AND CONCLUSIONS

In summary, we present a time-series CCD photometry survey on a 1° field centered on the old open cluster NGC 188. A total number of 16 variable stars were detected during the observations. Eight are new variables in the field. Analyzed with the PDM and $O-C$ method, periods for 15

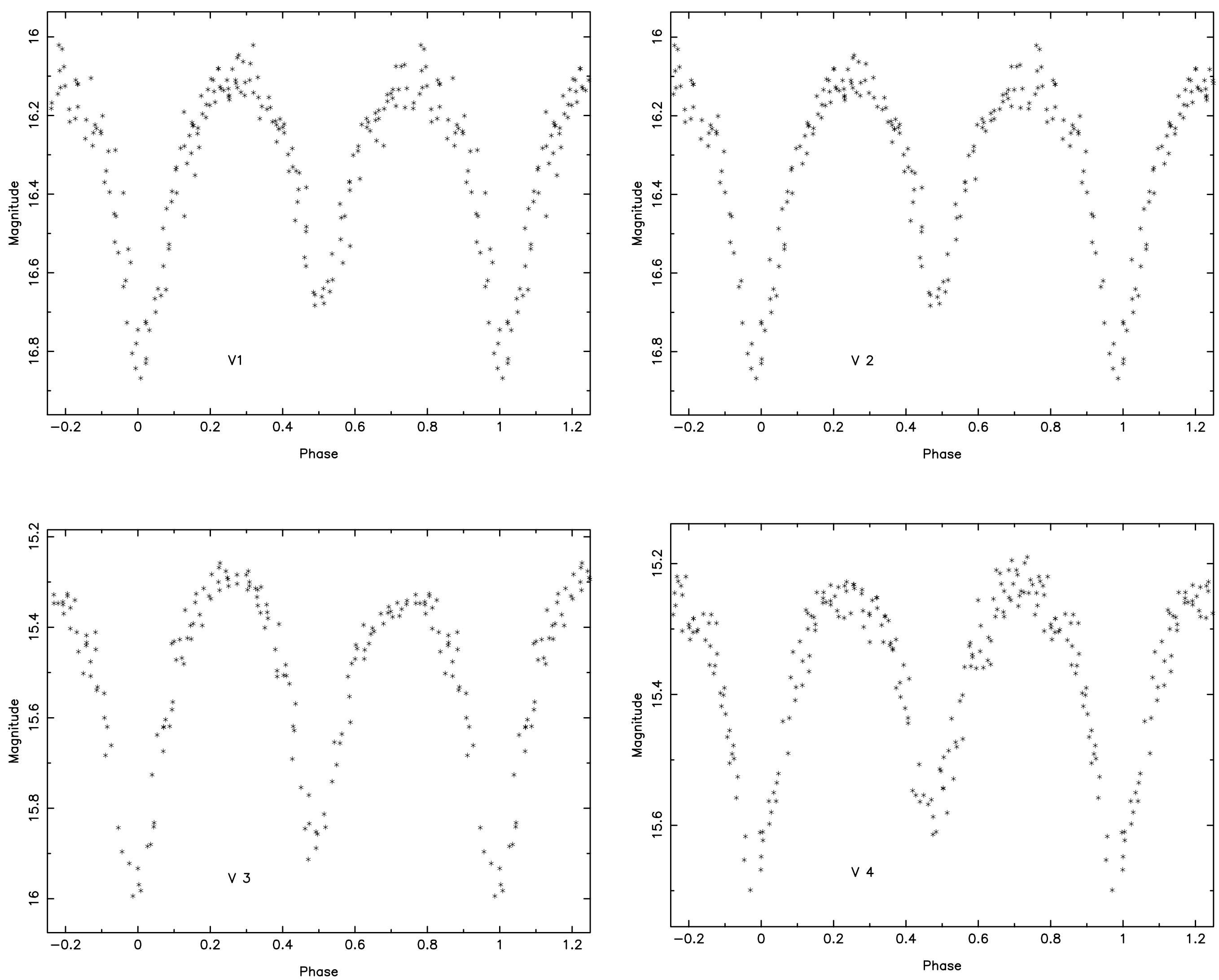


FIG. 4.—Phased light curves for the four well-known variables EP Cep, EQ Cep, ER Cep, and ES Cep in NGC 188, from our CCD photometry

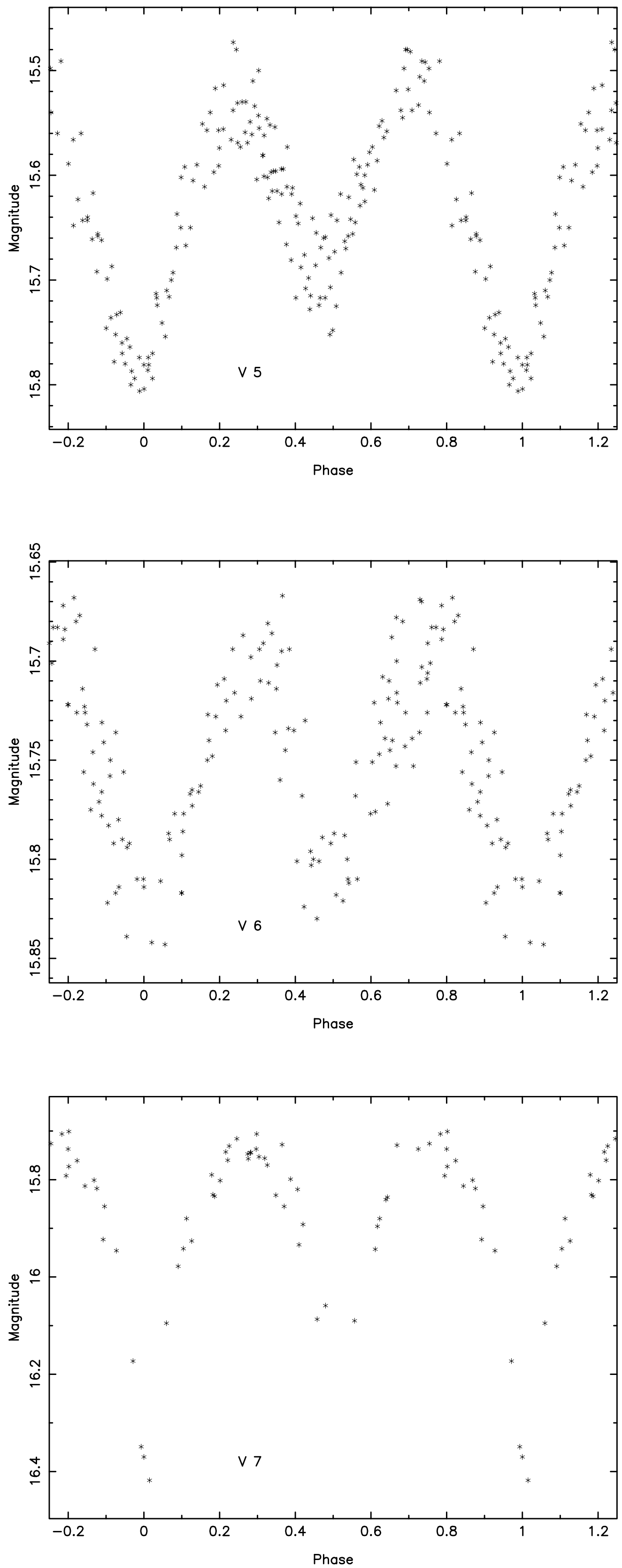


FIG. 5.—Phased light curves for the three old cluster variables V5, V6, and V7 in NGC 188.

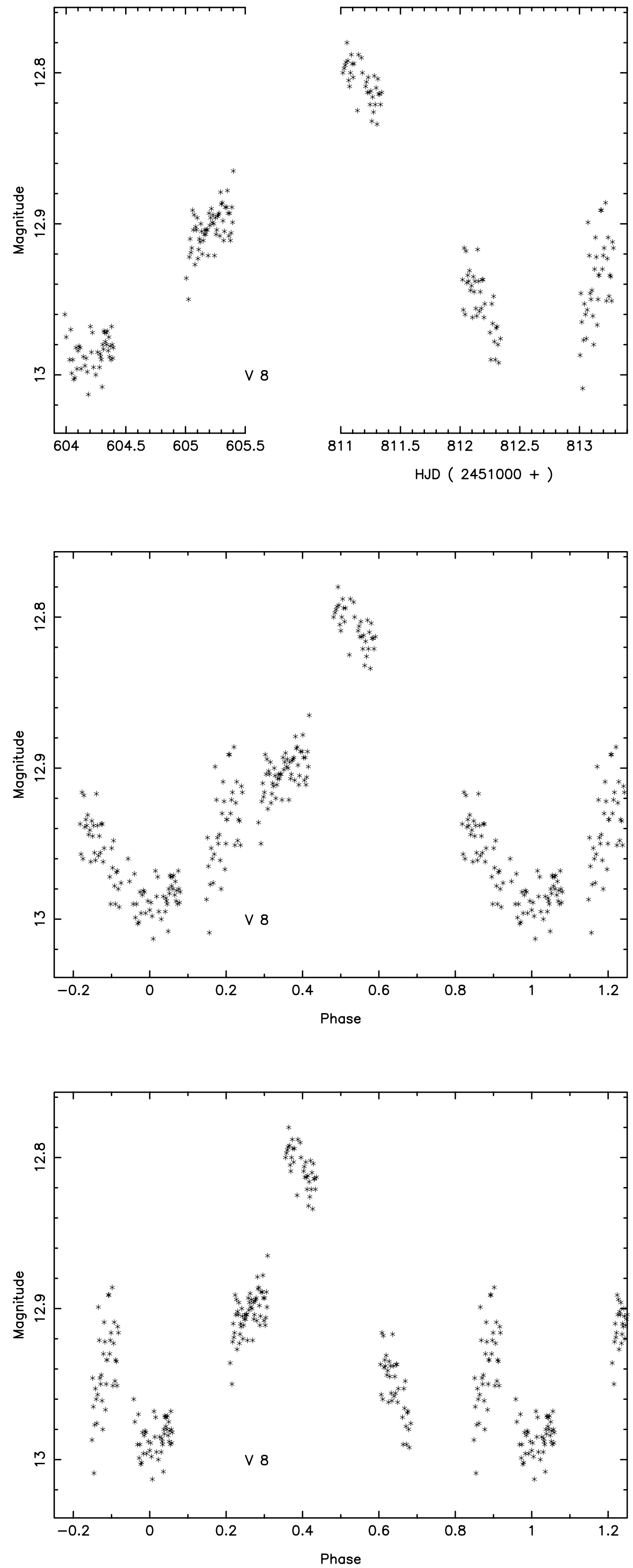


FIG. 6.—Real-time and phased light curves of V8. The light curve presented in the middle panel is phased by $P = 2.9772$ days. The light curve in the bottom panel is phased with the period of 4.028 days.

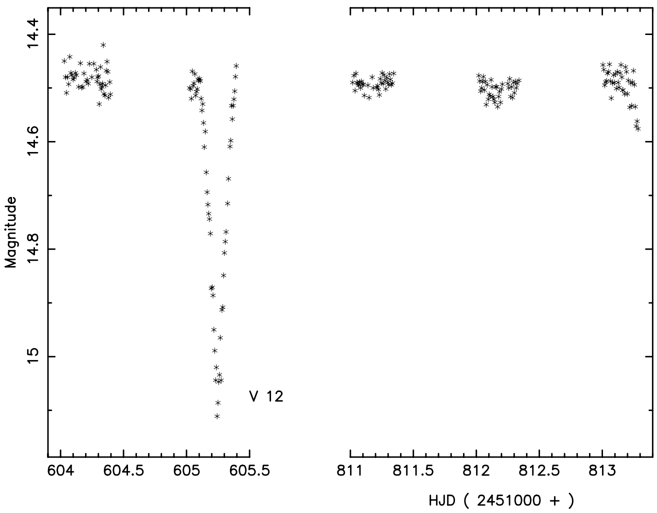


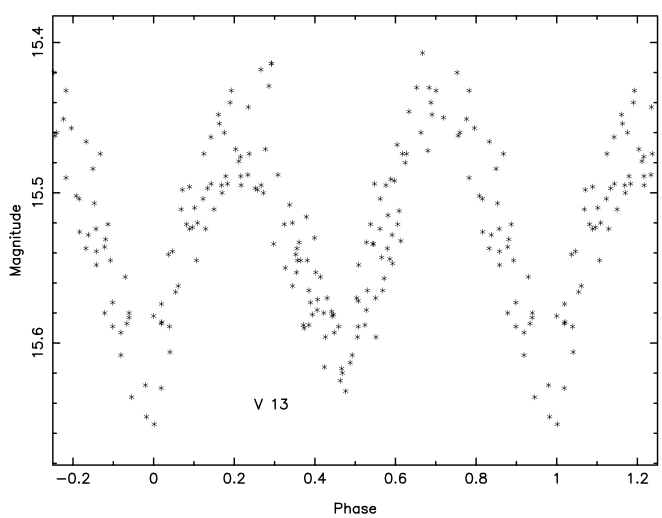
FIG. 7.—Real-time light curve for the new cluster variable, V12

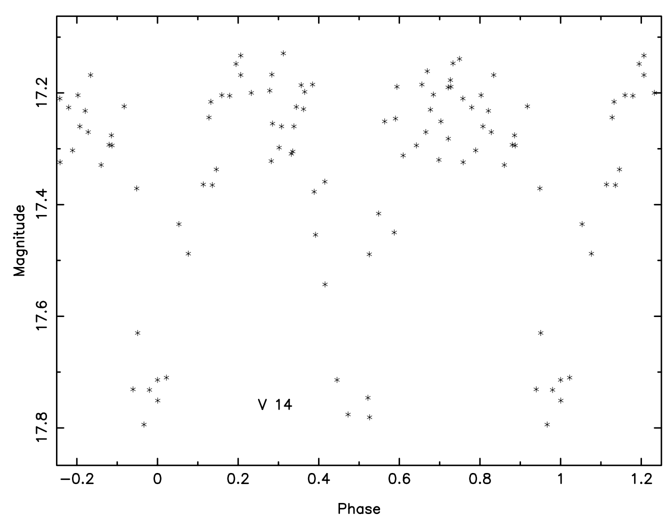
out of the 16 variables are given. The properties as well as the classifications of the variables are presented.

Most of the new variables are W UMa–type binaries. Among the six newly discovered W UMa stars, V13 is a definite member of the cluster, and V15 and V17 are probable cluster objects, although their memberships are uncertain. Thus the count of W UMa stars in NGC 188 will be at least eight. That should be an important result for the study of W UMa stars in clusters. In addition, we find a detached or semidetached eclipsing binary with a period longer than 1 day.

A large amount of data is obtained for the variable V8, and a revised period of light variations is derived. It is clear that V8 is very likely an RS CVn system, with an amplitude of light variation larger than 0.2 mag.

In spite of these interesting variables mentioned above, V16 is a newly discovered variable with very peculiar properties. It is clearly a pulsating field star, with a spectral type of A8–9. Analysis of its light curve indicates that it is likely a field RRd–type star.





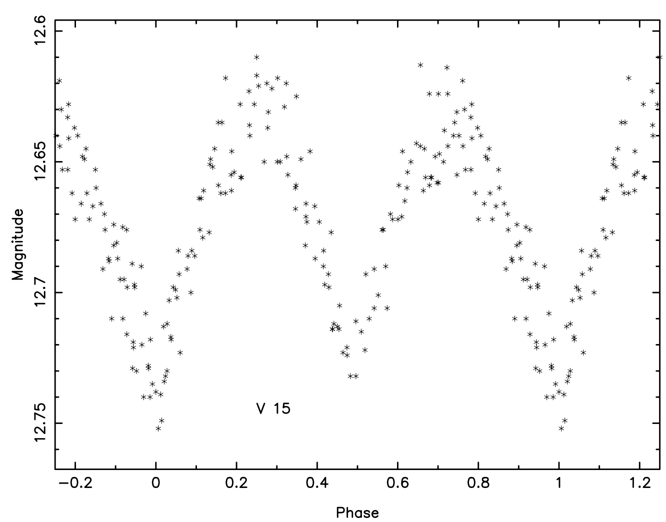


FIG. 8.—Phased light curves for three new variables, V13, V14, and V15

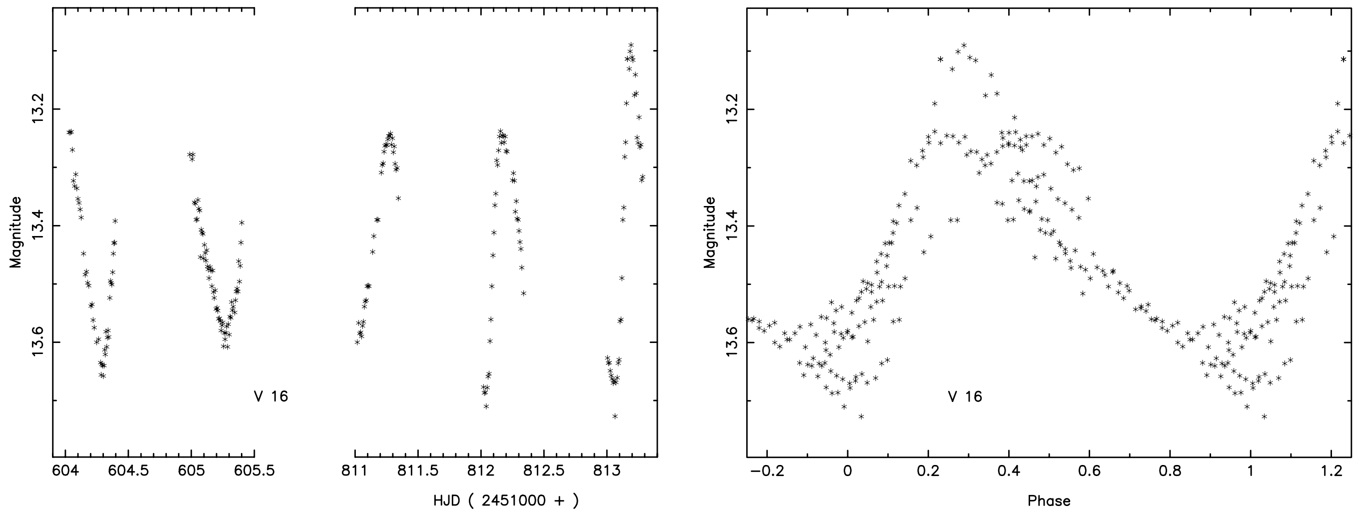


FIG. 9.—Real-time and phased light curves for the new variable, V16

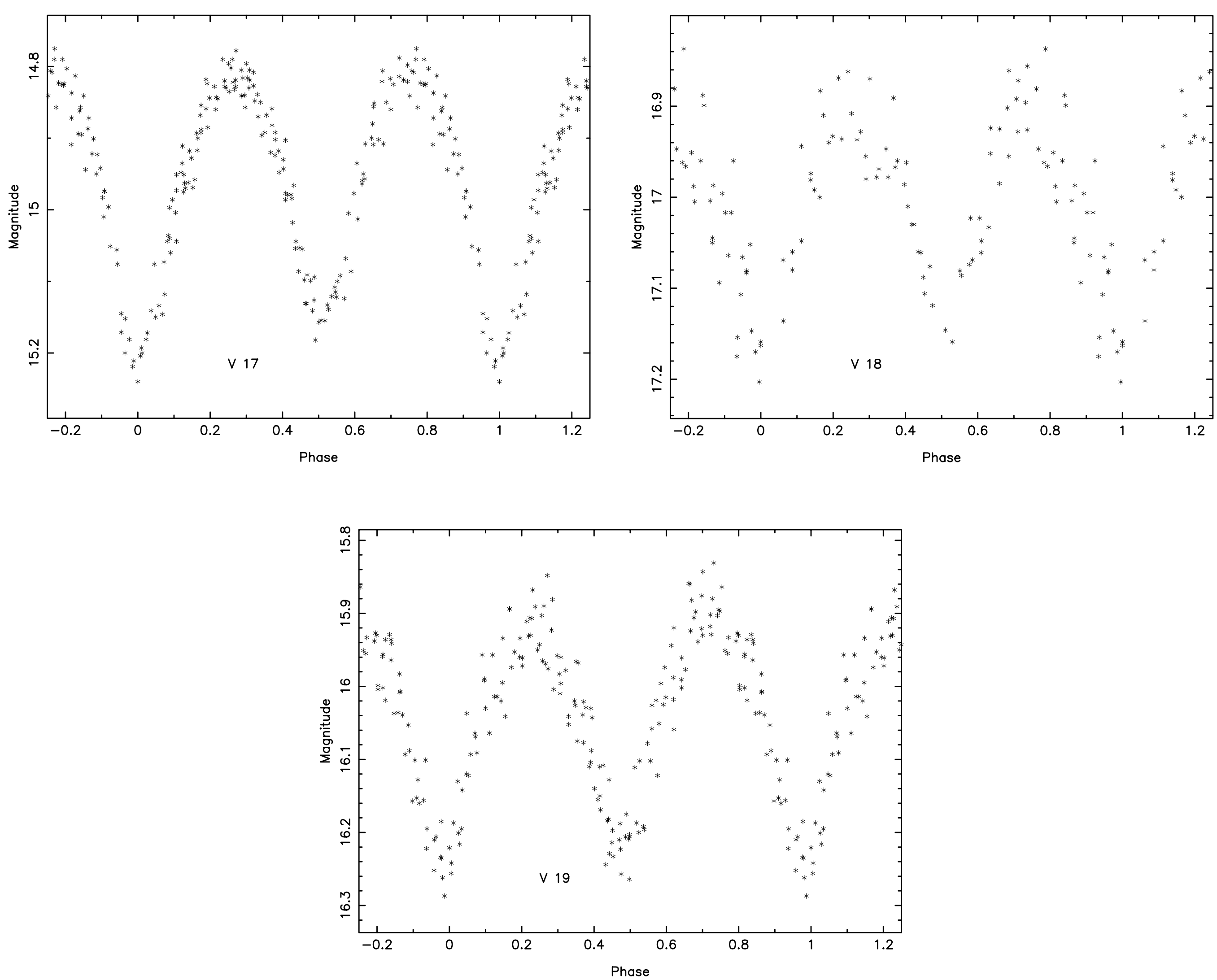


FIG. 10.—Phased light curves of three new variables, V17, V18, and V19

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