ULTRA-SHORT PERIOD CEPHEIDS IN THE LMC

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Six Cepheids in the Large Magellanic Cloud have been discovered with periods less than one day. They lie at the faint, blue end of the instability strip as would be expected but form a separate Period-Luminosity relation from that for normal Cepheids. Membership in the LMC is based upon the existence of the P-L relationship. Several of the variables have uncertain periods although all apparently have periods under one day. One additional variable has tentatively been identified as a bright Anomalous Cepheid.

In 1971 Cecilia Payne-Gaposchkin published, along with her extensive LMC Cepheid data, the identification, periods and magnitudes for 29 "foreground RR Lyrae" in the direction of the LMC. The distinguishing characteristic that resulted in their being identified as RR Lyrae was that the periods were less than one day. While examining this list of stars for other purposes, I noticed that the stars could be divided into two groups, one with magnitudes brighter than 16 and those fainter than 16. Two additional distinguishing characteristics also became apparent in time. The fainter group was distributed similar to the faint short period Cepheids and formed a rough period-luminosity relation separate from the Cepheids. The brighter group was randomly distributed across the LMC and showed no correlation of period with luminosity.

Observing time was requested at Cerro Tololo for the purpose of obtaining photometry of some of these variables in the faint group. Five nights on the 1.5 meter telescope was assigned for this project. Of the 16 variables in the faint group, seven were chosen for observation. An eighth star was included which, from another project, it was discovered to have similar properties as the variables in the faint group. The observations took place from December 29, 1978 to January 2, 1979. A three channel photometer was utilized in U, B, and V. Half of the first and last nights were lost due to instrumentation problems and weather conditions. After the data was fully reduced, a periodogram routine was used to search the data for periods ranging from 0.1 to 10 days. It was of the greatest importance to confirm the

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periods to be under one day. The results of the data reduction and the period search are given in the following table. One variable appears to be a normal Cepheid with period around 7 days. Since the observations covered only 5 days, the period is only roughly known. Since there is nothing peculiar about this variable it will not be discussed further.

8 OBSERVED LMC VARIABLES

ID	P	P (pub.)	V	B - V	VAMP
HV12732	7	0.86?	15.22	0.72	0.45
W 3	0.68	1.56?	15.22	0.72	0.46
HV12691	0.62	0.63	16.05	0.40	0.82
HV12718	0.57	0.56	15.33	0.41	0.90
HV12871	0.33	0.48	16.67	0.44	0.55
W 2	0.78	0.76	15.77	0.44	0.40
HV12741	?	0.49	16.65?	0.43?	>0.35
HV12852	?	0.47	15.65?	0.45?	>0.60

Of the remaining 7 variables, all appear to have periods under one day. Five appear to have reasonably well determined light curves but 2 have either complex light curves or insufficient data to determine the light curve. The variable W 3 was the one variable not in the original list by Payne-Gaposchkin. For reasons given later, it is believed to be an Anomalous Cepheid. Although the light curve appears to be normal, there are problems with the way the data fits together from one night to the next. The period should still be considered preliminary. It is particularly interesting to note that the colors of all the remaining variables are quite similar. They range from 0.40 to about 0.45. The variables chosen to be observed were selected from those in the outer parts of the LMC in order to avoid as much as possible differential reddening effects. The small range in color for these 6 variables suggests they may form a homogeneous type of variable.

In examining the light curves (Figures 1 through 5) it is apparent that the form of the curve is similar to normal short period Cepheids. They do not have the flat minima that is seen in the Cepheids with periods under one day in the SMC or in some RR Lyrae. The complete details of the light curves cannot be seen due to the limited data now available.

In Figure 6 the real time variations for HV 12741 and HV 12862 are given. Although no definitive period could be determined it is possible to conclude that these two stars are definitely variable and that their period of variation must be less than one day. In attempting to determine a period it was found that typically several nights data would fit well together to give a normal light curve but one or more nights data would not fit the first data. Indeed, in the case of

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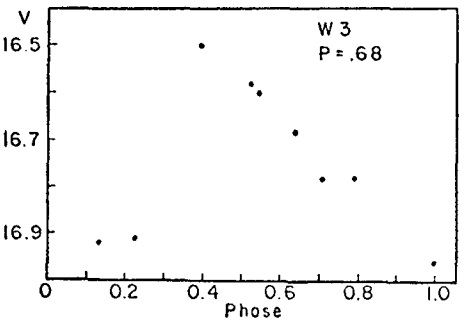

Figure 1

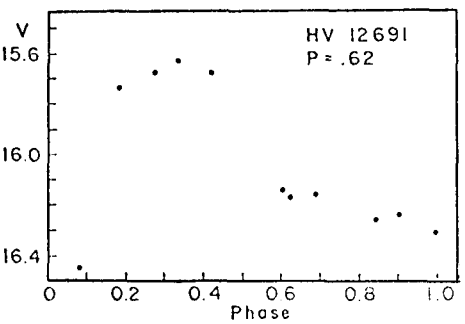

Figure 2

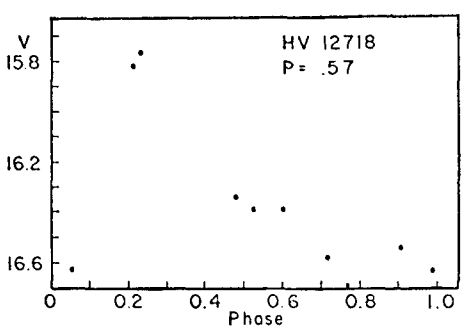

Figure 3

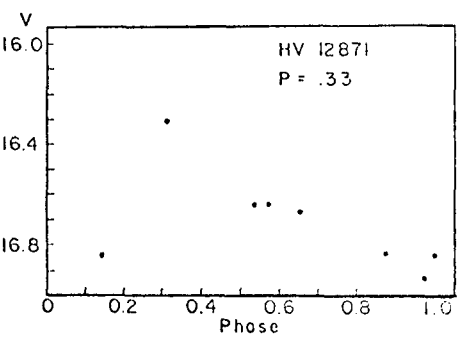

Figure 4

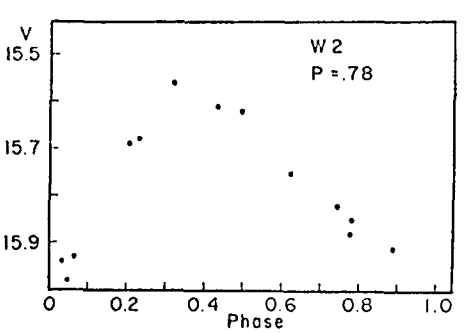

Figure 5

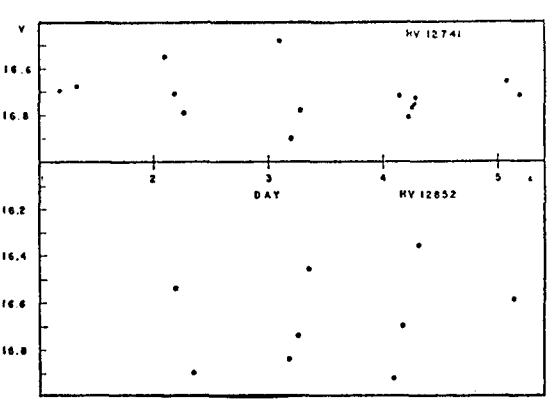

Figure 6

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HV 12852. the last three nights data fit together to give the ascending section of a light curve with a period around half a day but the two observations on day 2 simply do not fit this pattern. These and other "odd" data points have been checked for their reliability and no problems have yet to be found. The data for these two variables is suggestive of that for a double-mode pulsator but the data is insufficient to draw a definite conclusion.

Figure 7 is a Color-Magnitude diagram for LMC Cepheids taken from Connolly(1975). The dots are the normal Cepheids, the Xs are from this present work. The 7 day Cepheid is well placed in the center of the instability strip as one would expect. W 3 which is the Anomalous Cepheid is the faintest of all the variables and because of its slightly redder color appears separated from the rest. The other six variables can be seen in the blue side of the instability strip and mixing to some degree with the shortest period Cepheids. Since they seem to make up the faint continuation of the Cepheid instability strip, they are being referred to here as Ultra-Short Period Cepheids. The similarity in colors give an almost vertical distribution.

The Period-Luminosity diagram for various types of pulsating stars is given in Figure 8. The Ultra-Short Period Cepheids appear as triangles. HV 12862 are plotted with the best determined periods that can be found at this time. They are essentially the same periods as given by Payne-Gaposchkin. Even if these two variables are not included, it is evident that there is a unique period-luminosity relationship for these variables. The only exception is the variable W 3 which appears to be a bright Anomalous Cepheid. The existance of this period-luminosity relation is strong evidence for these variables to be all at the same distance, i.e. in the LMC. Up until now, this has been assumed. Obviously this figure and the last both assume this association with the LMC. Although this assumption leads one to believe that these variables are highly unusual, by assuming they are all foreground stars forces one to accept this period-luminosity relation as a mere coincidence. It must be remembered that all the stars in the original faint group showed a rough period-luminosity relation and although a few may be exceptions, the above observations seem to indicate the period-luminosity relation is real. Indeed, the brighter group of variables act just as one would expect from foreground RR Lyrae, there is a wide spread in magnitude and no correlation with period.

One cannot simply explain away these variables as overtone pulsators. An unacceptably high overtone would be required yet the light curves are neither sinusoidal nor low amplitude. One must keep in mind that at least some of these variables may be in several modes of pulsation. If so, they are the first to be discovered in the LMC. Observations are now planned to observe several of the light curves in detail in order to determine how repetitive the light curves are. Radial velocities are also going to be determined in order to establish their association with the LMC.

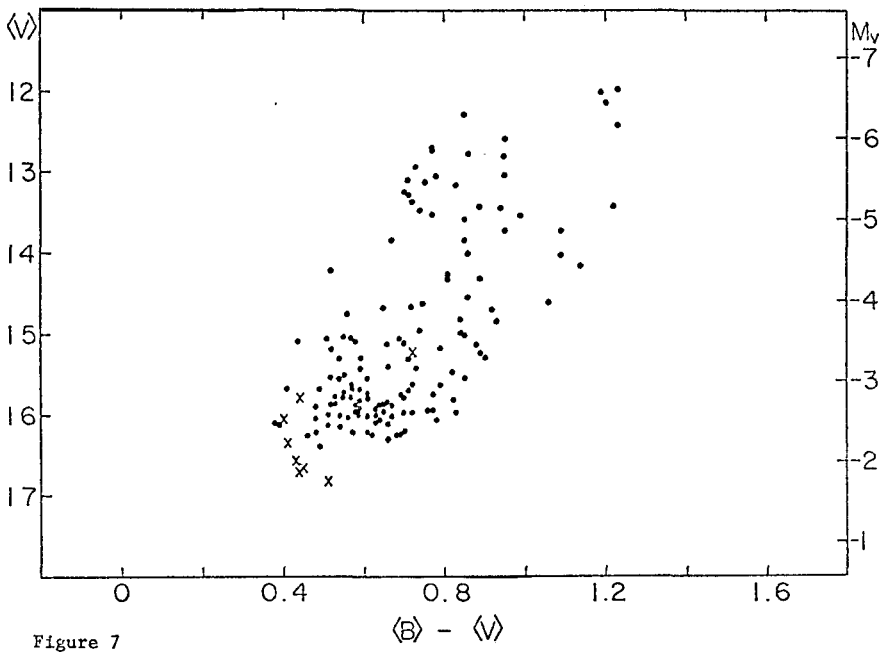

Figure 7

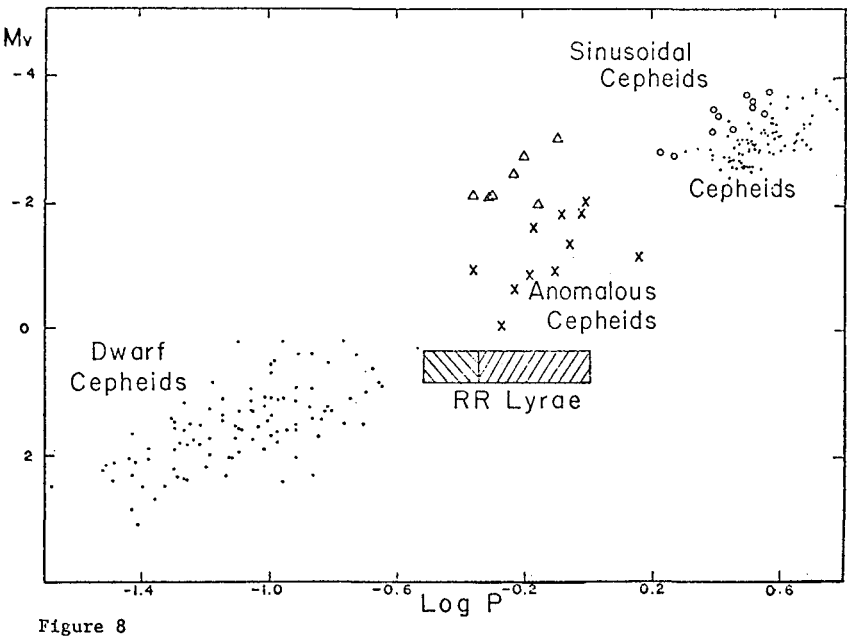

Figure 8

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While studying these variables one must remember that LMC variables in this magnitude range have been little studied. Because they are fainter than most Cepheids yet much brighter than RR Lyrae, many of these variables could have been overlooked in the large variable star discovery surveys.

DISCUSSION

ROBINSON: How do you know that these are not just RR Lyrae stars in the galactic halo?

CONNOLLY: It would be hard for me to conceive of how they could be hanging out there in the halo all at the same distance. It is tempting to say that they are just RR Lyrae stars and let's not worry about it, but they would be too bright to be in the LMC by about three magnitudes. They are also kind of faint to be in our halo.

LUB: One argument against the stars being RR Lyrae stars is that they are too red, don't you think?

CONNOLLY: Yes. They look a little too red to me. Also, their distribution in the LMC is different. If you look at the foreground RR Lyrae stars it is obvious that they are distributed at random, but these seem to fall in the areas where you find the short period Cepheids. They are in distinct clouds in the LMC.

PERCY: In the case of those Cepheids where you were not able to derive the periods, did you look for something very short like a dwarf Cepheid? There are a couple of dwarf Cepheids reported in the direction of globular clusters and it may well be that you are seeing a couple fairly well out but within our galaxy.

CONNOLLY: Yes. I did look at periods shorter than 0.1 day but nothing would come together. It was very frustrating.

BREGER: I hate to say this, but if indeed you were looking at dwarf Cepheids, and I am not saying they are, some of them may have more than one mode. If there are two excited modes, then your two excellent data points would be insufficient.