No. 71 PHOTOELECTRIC UBV OBSERVATIONS OF RR LYRAE VARIABLE STARS

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ABSTRACT

Photoelectric observations on the *UBV* system are given for 113 RR Lyrae stars, which include most of the brighter northern stars in van Herk's list of variables of known proper motion or radial velocity. Magnitudes and colors at both maximum and minimum light were obtained for 107 stars, while 6 stars were observed only at maximum light.

1. Introduction

Knowledge of accurate intrinsic magnitudes and colors of RR Lyrae stars is essential for the solution of many problems encountered in investigations of galactic structure. The results of two recent efforts to improve the absolute magnitude calibration of these stars, with discussions based on stars having new or improved radial velocity or proper motion data, have recently been published (Woolley, Harding, Cassells, and Saunders 1965; van Herk 1965). Both of these papers suffered from a lack of extensive, accurate photometry for these stars. At the suggestion of Professor J. Oort of Leiden Observatory, we undertook, starting in the fall of 1963, to obtain photoelectric *UBV* magnitudes and colors at maximum and minimum light of all the brighter RR Lyrae stars accessible to us, selected from a list provided by Dr. van Herk. The major portion of this paper presents the observations we have obtained to the present time; a fuller discussion of these will follow in a later paper.

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2. The Observations

All our observations were made with standard single-channel photometers equipped with filters for the *UBV* system and 1P21 photomultipliers. With the exception of those on VX Hydrae, all the observations on RR Lyrae stars were made without using nearby comparison stars as intermediaries; instead they were tied directly to the *UBV* system by nightly observations on the *UBV* standard stars (Johnson and Harris 1954). The RR Lyrae star measures, numbering altogether about 17,000 for 113 stars, are listed in Table 1.

The observations in Table 1 that have a "C" following the epoch were obtained at LPL's Catalina observing stations with the 21-in., 28-in., or 60-in. telescope; most of these measures were made by Wiśniewski with the assistance of Messrs. A. S. Latham, T. A. Lee, D. L. Steinmetz, and M. Wirick. The photometers on the Catalina telescopes are equipped for automatic digital data logging, and the reduction of the Catalina observations was carried out by the LPL data-processing group under the supervision of Mr. R. I. Mitchell and Mrs. Kathryn

Sheffer, with programs written for use on the University of Arizona's IBM 1401-7072 computing system.

The measures designated by a "K" following the epoch in Table 1 were secured by Fitch with the 36-in. telescope at the Kitt Peak observing station of Steward Observatory. The observations obtained prior to June 1964 were made with a D. C. amplifier and strip-chart recorder, whereas all later observations were made with a charge-storage integrator and recorded directly on IBM punch-cards. Assistance in preparing observing cards, measuring recorder tapes, etc., was rendered by Messrs. P. Steffey, L. Smith, G. Chapman, A. Stockton, and A. Sanyal. All these observations were reduced on the IBM 1401-7072 with a program written by Fitch.

Since the Kitt Peak measures were made with one-minute exposures in the order star yellow, star blue, star violet, sky violet, sky blue, sky yellow, star yellow, etc., the yellow and violet measures were easily reduced to the time of the blue measure by linear interpolation. The Catalina measures varied in exposure times and were made in the sequence star blue, sky blue, star yellow, sky yellow, star violet, sky violet, star blue, etc., so that the time interval between successive star measures was sometimes rather large. Wherever possible, the yellow and violet measures were reduced to the time of the blue filter measure by quadratic interpolation. Whenever meaningful interpolation was not possible, as with observation sets separated by a time interval greater than 0.04 day, the times for the individual filter measures are given in Table 1.

All the V, B, and U magnitudes were plotted against either phase or date, and wherever the data were adequate, smooth curves were drawn through the observed points. From these curves, we estimated the magnitudes (and therefore colors) at minimum and maximum light, as well as the observed epoch of maximum light; this information concerning the individually observed maxima and minima is presented in Table 2. Data for maximum and minimum that appears on the same line in Table 2 were obtained on the same night.

For some stars the light variation repeats itself accurately from cycle to cycle, but significant variations in phase or height of maximum or depth of minimum have been observed for other stars. Whenever more than one minimum or maximum was observed on the same star, the weighted average was taken. Table 3 gives our best estimates for each star of V, $B-V$, and $U-B$ at minimum and maximum light, together with the Bailey type (S represents the short period group with $P < 0.23$ day), Preston's (1959) ΔS, the period (taken from the *GCVS* or the Cracow ephemeris), the *observed* rise time $(M-m)/P$, the *observed* V amplitude (to the nearest 0.1 mag), and mean values of V, $B-V$, and $U-B$ computed as follows. For stars with rapid rises and very asymmetric light curves, mean luminosity lies much nearer to minimum light than to maximum. Accordingly, we have chosen to calculate the mean magnitude and colors as functions of the skewness and the observed values at minimum and maximum. That is, we assume that for $(M-m)/P = 0.5$, the mean lies halfway between the extremes, whereas for $(M-m)/P = 0.1$, the mean lies one third of the way from minimum to maximum, and that a linear interpolation between these limits is adequate. Writing $X = 2.25 - 2.5\ (M-m)/P$, we have $<V> = (XV_{\min} + V_{\max}) / (X+1)$, with similar expressions for $<B-V>$ and $<U-B>$.

3. *Discussion*

Detailed analysis of these measures will be given in a later publication, but several points should be mentioned here.

First, with regard to individual stars, we found that on our initial observation list two had been improperly classified; BC Eri is a W UMa star of period 0.53 day, and BE Mon is a two-day Cepheid. The observational material on the short-period star VX Hya, which has a very strongly excited overtone, has been discussed elsewhere by Fitch (1966), and the mean values given here are based on that paper. In the case of VX Her, observations on one night are anomalous, remaining at nearly constant brightness for at least two hours, some 0.7 mag fainter than at another well-observed minimum. One would ordinarily suppose that the wrong star had been observed, but this particular star is so easily identified that there remains the distinct possibility that VX Her may be a member of an eclipsing binary system; further observations will be made to settle the matter.

Second, with regard to internal accuracy, on three nights the same star was observed nearly simultaneously from both the Kitt Peak and Catalina stations (X Ari on JD2439032, SW DRA on JD2438511, and RR Leo on JD2438823), and on these occasions the maximum discrepancy between any simultaneously measured V, B, or U magnitudes was only 0.035 mag, while the average discordance was about

0.015 mag — values that are not larger than the errors of the individual observations. The magnitude and color systems at the two stations are quite equivalent.

Finally, Sturch (1966) recently published the results of an extensive set of *UBV* measures on RR Lyrae stars that supplements the present series. His stars were of Bailey type *a, b* only, selected without reference to the availability of velocity data, and in general were observed only on the descending branch somewhat prior to minimum light. For the 53 stars observed in common, the average difference between Sturch's values (S) and the University of Arizona values (A) at minimum light is $V_S - V_A = -0.042$ mag, $(B - V)_S - (B - V)_A = -0.003$ mag, and $(U - B)_S - (U - B)_A = -0.015$ mag. We conclude that the color systems are consistent and that the mean difference in the V magnitudes reflects the fact that most of Sturch's measures were made before minimum light was reached.

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