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vZ1055=AQ – A NEW HORIZONTAL BRANCH VARIABLE STAR REDWARD OF THE RR LYRAE GAP IN THE GLOBULAR CLUSTER M3

vZ1055 (von Zeipel, 1908) is a horizontal branch star redward of the RR Lyrae instability strip in the globular cluster M3 (see Figure 1). The proper motion study (Cudworth, 1979) shows that vZ1055 is a cluster member (membership probability Pc=0.99). The position of the star in seconds of arc relative to the cluster center is: x=48", y=264". The magnitude and color listed in Table III by Cudworth (1979) are V=15.67, B−V=0.40. From our CCD photometry its V=15.69 and B−V=0.48. On the other hand, Johnson and Sandage (1956) give AQ (one of their photometric standards) V=15.68, B−V=0.48. From the identification chart and the photometric value we judge that vZ1055=AQ.

Here we report the light variation of vZ1055. The CCD data we used are the same as that used for analysing the variation of vZ1140=II−54, i.e., it was observed by Yao Bao-an and Chen Fu-xiang with the TH-7882 CCD attached to the Cassegrain focus of the 2.16-meter reflector (f/9) at the Beijing Observatory in March 1993. This detector contains 576×384 pixels (pixel size $23\times23\mu$) at a scale 0."244/pixel, thus covering a 2.'43×1.'56 field. Four series of 300- or 600-second exposures taken in rapid succession over an interval of about 5.0, 4.2, 6.2 and 4.6 hours were obtained on March 16, 17, 18 and 19 (90 yellow, 5 blue). The seeing was between 1."3 and 3."2 (FWHM). After deleting 6 poorly guided exposures, 84 yellow CCD frames were used to analyse the light variation. The same star AO (V=14.70, B−V=0.72) (Johnson and Sandage, 1956) was used as the comparison star. The distance between AQ and AO is 77."8 and the difference in B−V is 0.24, in addition, the observations were obtained with the air mass less than 1.3 so the differential extinction correction was neglected.

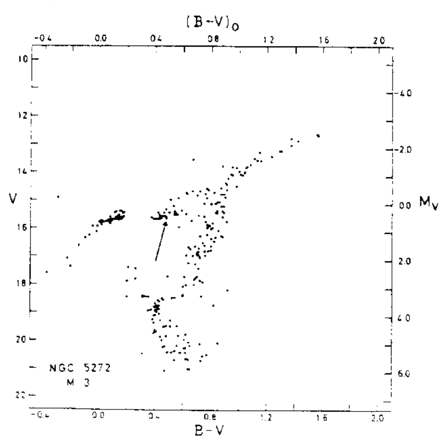

Figure 1

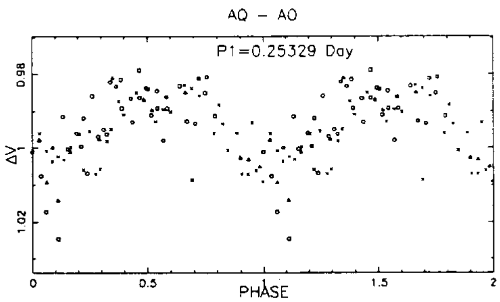

Figure 2

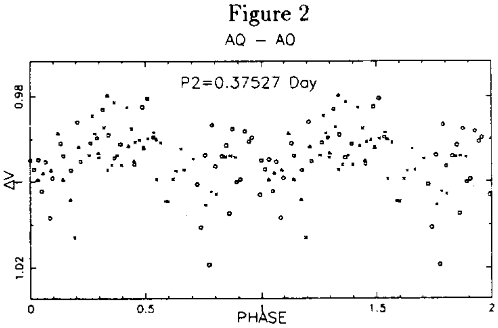

Figure 3

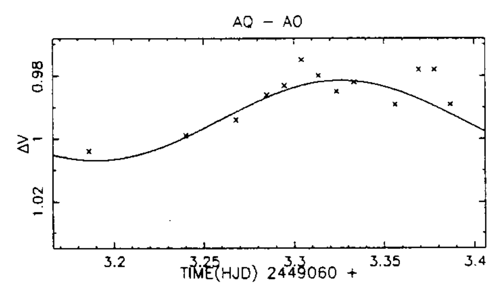

Figure 4

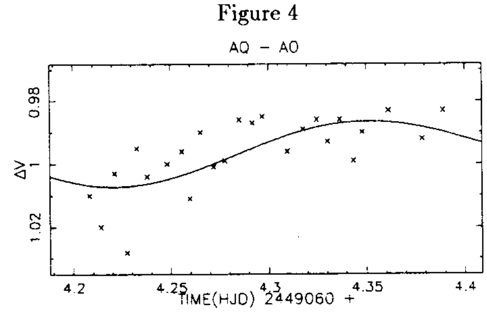

Figure 5

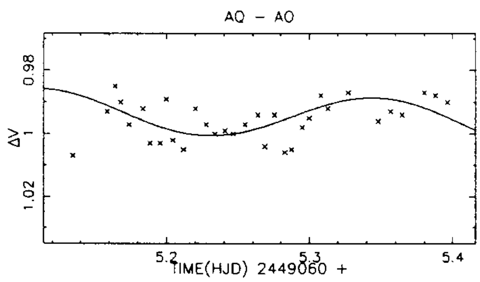

Figure 6

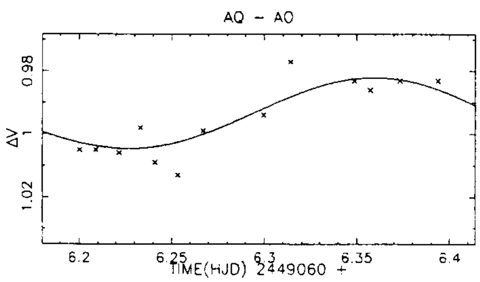

Figure 7

The CCD frames were reduced by DAOPHOT (Stetson, 1987) in IRAF which is mounted in the Sun 4/65 sparc workstation of Shanghai Observatory. Only the aperture photometry was used because it is not a crowded star field for these stars. Scargle's (1982) modified periodogram was used to analyse the unevenly sampled data.

A frequency of $\nu_1 \cong 3.961$ with a height of $z=19.54$ in the periodogram was first searched out. Though the number of the independent frequencies N_j is unknown, the false alarm probability $F=1-[1-e^{-z}]^{N_j}$ must be extremely low, no matter how to estimate N_j. For example, if N_j is calculated according to the formula 13 given by Horne and Baliunas (1986), then $N_j=100$ and $F\doteq 3.27\times10^{-7}$, so it is impossible that the period found here is an illusion!

After prewhitening with ν_1, the above procedure was repeated in order to search for other possible periods. Another frequency $\nu_2 \cong 2.64$ with a height of 6.24 was found ($F=0.17$, if we still let N_j equal the overestimated number 100). Assuming that the ν_2 is real then Breger's (1991) PERIOD program was used to run nonlinear least squares fitting to improve the values of the frequencies found above simultaneously. The results so obtained are:

$$m(t) = Zeropoint + \sum_{i=1}^{2} a_i sin(2\pi t/p_i + 2\pi\phi_i)$$

Here $P_1=0\overset{d}{.}25329$, $a_1=0.00943$, $\phi_1=0.6196$,

$P_2=0\overset{d}{.}37527$, $a_2=0.00416$, $\phi_2=0.8842$,

Zeropoint=0.995

The zeropoint 0.995 represents the mean magnitude difference between AQ and AO. The folded light curves are given in Figures 2 and 3. Each light curve is plotted with the data prewhitened with the other frequency. Here the squares refer to observations on 1993 March 16, the circles on March 17, the X's on March 18 and the triangle on March 19. The "real time" light curves are given in Figures 4, 5, 6 and 7 where the continuous curves represent the calculated ones using the formula given above. Time refers to the heliocentric Julian Date.

No we repeat what we have published before (Yao, 1987): M3 is a typical Oosterhoff I cluster. Early in the 1940's, Martin Schwarzschild found that the RR Lyrae stars in M3 are confined to a small compact region in the C−M diagram. It is very important to check how sharply the boundaries of this instability strip are defined; does pulsation stop entirely at a given point in the C−M diagram, or do variations of small amplitude persist on either side of the supposed limits of the strip? If this is the case, then an accurate determination of these boundaries would be very important for testing theoretical concepts as well as for practical purposes, e.g. for the estimate of interstellar reddening. The check was done 38 years ago by Roberts and Sandage (1955) with photographic photometry and by Walker (1955) with photoelectric photometry. "All stars lying within the region are variable and no variable stars are found outside the region with amplitudes $A_{pg} \geq 0.07$" was the conclusion of the photographic method and "the boundaries of the gap are extremely sharp, and that beyond the edges of the gap, no light variations occur with ranges greater than 0.02 magnitude" was Walker's conclusion.

Just because we have found a group of suspected low amplitude variables beyond the instability gap in the globular cluster M4 in 1975, and have confirmed some of them with CCD photometry in recent years, we always try to observe M3 to check this important classical conclusion too. Thanks to the use of the 2.16-m reflector plus the CCD detector, we have succeeded in doing so. Obviously, it is a challenge to the theory. We will continue to observe M3 and hope that our results will be checked by other observers.

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