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LETTERS

G328: A Small-Amplitude Red Variable with a Period Near One Day

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Abstract G328 = A65 = L3314 ($V = 13.83$, $B - V = 1.91$) is a field star in the direction of the globular cluster M4. If we take $E(B - V) = 0.40$, then its $(B - V)_0 = 1.51$, corresponding to a spectral type of K5III if it is a giant star; or of dM2 if it is a dwarf. Observations at both the MSSSO and Yunnan Observatory have shown that G328 is a new variable with peak to peak amplitude $\simeq$ 0.05 mag in V. While it is not unusual for so red a star to be a variable, special attention must be paid to its short period of about one day. If the variability is due to pulsation, the spectral type and luminosity as well as effective temperature should be determined in order to compare it with Xiong's theory.

Key words: stars: variables – stars: individual (G328)

1 INTRODUCTION

G328 (Greenstein,1939) = A65 (Alcaino, 1975) = L3314 ($\alpha_{2000} = 16^{\rm h}23^{\rm m}49^{\rm s}$; $\delta_{2000} = -26^\circ23'31''$) is a field star in the direction of the globular cluster M4 (Lee 1977). A proper motion study shows that its membership probability $P = 0$ (Cudworth & Rees 1990). The magnitudes and colors of this star given by different authors are:

$m_{\rm pg}$ = 15.38	Cr = 2.27	(Greenstein 1939)
V = 13.71	$B - V$ = 2.02	(Alcaino 1975)
V = 13.81	$B - V$ = 1.86	(Lee 1977)
V = 13.83	$B - V$ = 1.91	(Cudworth & Rees 1990)

Taking $E(B - V) = 0.40$, $B - V = 1.91$, then G328's $(B - V)_0 = 1.51$, corresponding to spectral type K5III if it is a giant star, or dM2 if it is a dwarf.

It is well known that most (if not all) red stars are variables. Our observations at both the Mount Stromlo and Siding Spring Observatory (MSSSO) and Yunnan Observatory (YNO) have shown that G328 is a new variable with peak to peak amplitude $\simeq$ 0.05 mag in V and a period of about one day. In this letter, the photometric observations and data reduction are described in Section 2, and a discussion in Section 3.

2 OBSERVATIONS AND REDUCTION

Our time series observations of M4 were obtained at the Cassegrain focus of the 60-cm reflector at MSSSO in 1990–1991 using the coated GEC CCD detector (383×577 useful pixels, pixel size 22 μm at a scale of $0.42''$/pixel) with a field size of about $4' \times 2.5'$. A total of 233 useful V frames were obtained with exposure times of 300 s each and the seeing was between $2.1''$ and $3.5''$ (FWHM). The data we used are the same as that in the reduction of the field γ Dor star, G298, so the observation log is omitted here (see Yao et al. 2006). Twilight sky exposures were combined to get the flat field. After the bias was subtracted and the flat

field divided, the software DAOPHOT in IRAF was used to measure the stars. The magnitudes obtained by aperture photometry and psf analysis (routine *allstar*) are compared with each other. Generally they are similar but the aperture photometry gives better results when the frames were taken with bad guiding.

To our surprise, G328 shows a period of about one day. In order to confirm this, new time series observations of M4 were made at the Cassegrain focus of the 1-m Zeiss reflector at YNO in 2000–2004 using a coated Tek CCD detector (1024×1024 useful pixels, pixel size 24 μm at a scale of $0.38''$/pixel) with a field size of $6.5' \times 6.5'$. A total of 359 useful V frames were obtained with exposure times of 200–300 s each and the seeing was between $2.0''$ and $3.5''$ (FWHM). The observation log is given in Table 1.

Table 1 Observation Log with the YNO 1-m Telescope

Date	CCD Frames	Date	CCD Frames
2000 April 3	12	2002 April 7	50
2001 April 20	2	2002 April 8	40
2001 April 21	5	2002 April 9	13
2001 April 22	4	2003 April 7	67
2002 April 4	7	2003 May 26	59
2002 April 5	23	2003 May 29	9
2002 April 6	43	2004 May 28	25

The YNO instrumental magnitudes were transformed to the MSSSO system, then all the data were converted into Johnson's V by comparing with the stars measured by Lee (1977) and Alcaino (1975). Assuming the period of G328 to be constant in the past 15 years, the software Period98 (Sperl 1998) was used to analyze all the unevenly sampled data together. We obtain $P = 0.969082$ day. This period was also confirmed by using the Lafler-Kinman method (Lafler & Kinman 1964).

The folded light curve is given in Figure 1.

We note: (1) The observations at YNO were obtained at larger zenith distances and many of them, on non-photometric nights through thin cloud, so their precision was not so high. (2) The transformation from YNO to MSSSO is approximate: the different nights may have zero-point errors. (3) Roughly speaking, the data were obtained at a single site, so the drawback of one site observation was inevitable. Though the period is given to six places of decimals, we do not think the accuracy is that high. However, the period can never be longer than a few days. In the periodogram G328 has the highest peaks around $\nu = 0.03$. Using these values seemingly good but false light curves can be plotted, for example, the spurious folded light curve with $P = 35.5^{\rm d}$ shown in Figure 2. Of course this is a false period, because the star has a real period of about one day, observations in each night at a single site can only cover a small segment of the light curve, the average phase of the segment moves smoothly along the real light curve night by night, then a spurious folded light curve results, as shown in Figure 2.

Percy & Hosick (2002) pointed out that about 30 photometric variable red giant stars have periods less than 10 days as determined by compilers of the Hipparcos Catalogue. These periods may be spurious due to the particular aliasing properties of the Hipparcos photometry. Percy & Hosick (2002) showed that for the six stars having periods less than 3 d, one might expect to see significant hour-to-hour variability, but five of them show no significant variability greater than the photometric error over 0.3–0.6 d. Even for the remainging one, HIP 98815, with a period of 1.67 d and a total amplitude of 0.29 mag, only a variability of 0.07–0.09 mag was found over 0.8–0.9 d, and its $(B - V) = 1.225$ was also found to be unusually blue for its M4/5III spectral type.

We should emphasize that hour-to-hour variability really exists in G328's real time light curves, so there is no question of period aliasing with G328.

3 DISCUSSION

It is well known that most (if not all) red stars are variables. Therefore, we might expect G328 to be a variable; nevertheless, special attention must be paid to its short period of about one day if it is a giant. As far as we know, no red (AGB or RGB) giants with pulsation period as short as one day (either in the Galaxy or the Magellanic Clouds) have been reported in the literature. If the variability of G328 is due to pulsation,

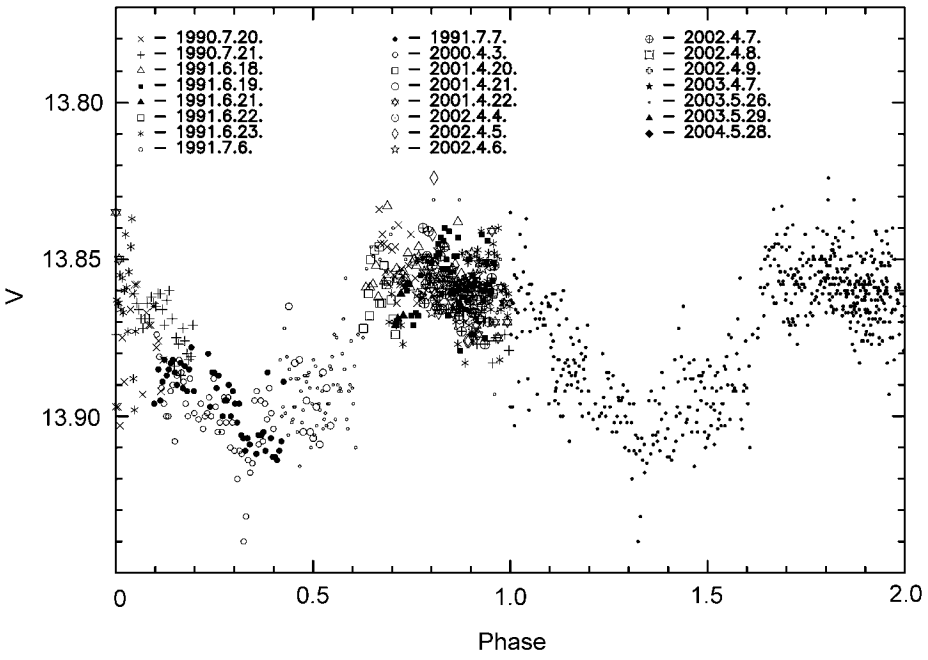

Fig. 1 Folded light curve of G328 with a period of 0.969082 day. For the different nights different symbols are used between phases 0.0–1.0. The same symbols are used between 1.0 and 2.0.

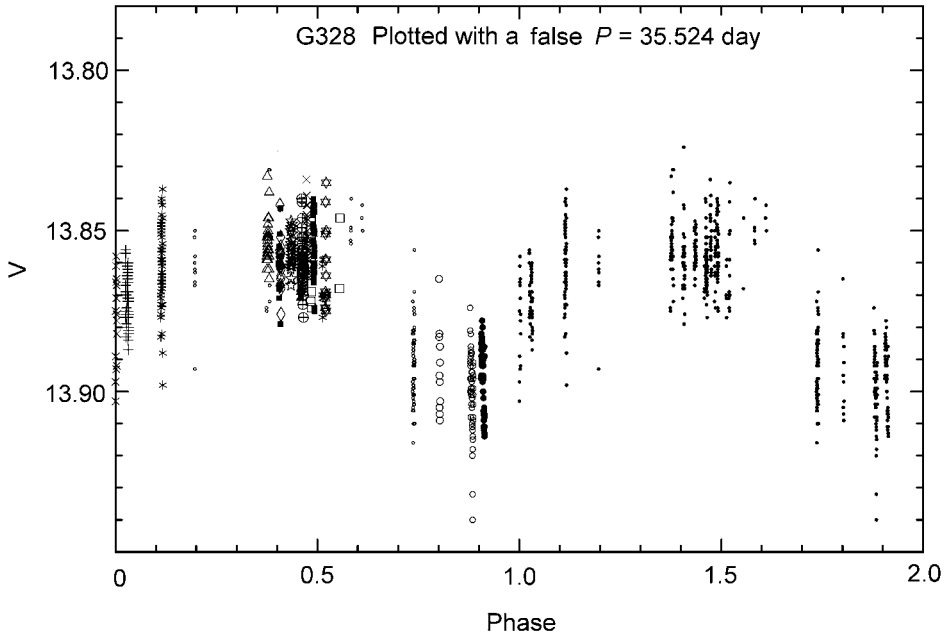

Fig. 2 Folded light curve of G328 with a false period of 35.5^{d}. The symbols are the same as Fig. 1.

then it is the first red variable with so short a period. Evidently, this would indicate that G328 is pulsating in very high overtone (Xiong & Deng 2006a, b, c). What we emphasize here is the shortness of the period, rather than the accuracy of the period value. In order to determine the period more accurately, cooperative round-earth network observations are required.

Obviously, the spectral type and luminosity as well as the effective temperature should be determined in order to compare G328 with Xiong's theory.

However, if G328 is a red dwarf, then it may be a BY Dra star. The classic characteristics of BY Dra stars are sinusoidal photometric variations with amplitudes between 0.05 and 0.5 mag, and the variability is due to the rotation of a spotted surface. Unfortunately, no monitoring in U filter has been made so far and no flares were detected by us in the V band. Moreover, the period of G328 also seems to be too short for a BY Dra star. Further spectroscopic observations would resolve these questions.

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