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DISCOVERY OF THE VARIABILITY OF GSC 140.1831, GSC 959.1397 AND GSC 396.1710

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Introduction

The new variable stars reported here have been found as part of a programme to discover and classify new variables using CCD observations of selected fields on the edge of the northern Milky Way (eg. Bernhard et al. 1997, Bernhard 1999). In this paper the observations of three new variables resulting from this programme are reported. GSC 140.1831 is an EA binary with a period of 1.14962 days. GSC 959.1397 and GSC 396.1710 are both a-type RR Lyrae variables with periods of 0.64465 and 0.77892 days respectively. These stars have previously been referred to as BeV13, BeV14 and BeV15. The observations were made using a 20-cm Schmidt-Cassegrain telescope and an unfiltered Starlight Xpress SX CCD camera. The CCD camera uses a Sony ICX027B chip which has a very broad response, peaking near 5500 Å, giving approximate V-band magnitudes, depending on the colour of the star. Further details are given by Lloyd & Bernhard (1999). Additional unfiltered observations of GSC 140.1831 have also been obtained with an SBIG ST6 camera on a 32-cm Ritchey-Chrétien telescope (WM)

GSC 140.1831

GSC 140.1831 ($06^h18^m56\overset{s}{.}2$, $+04°09'20''$, J2000, 12.1 mag) has been observed nearly 300 times, mostly during the March 1999. The magnitudes are given relative to GSC 140.1277 (12.1 mag) and the second comparison star used was GSC 140.2015 (12.6 mag). The magnitude difference between the two comparisons stars, 0.542 ± 0.046, is remarkably consistent with the GSC magnitudes. The three sets of observations from the three instruments described above have been brought on to this magnitude scale by applying small shifts to the two less extensive sets. For the out of eclipse observations the shift is well determined, but for the other set, which lies wholly within the secondary eclipse, it

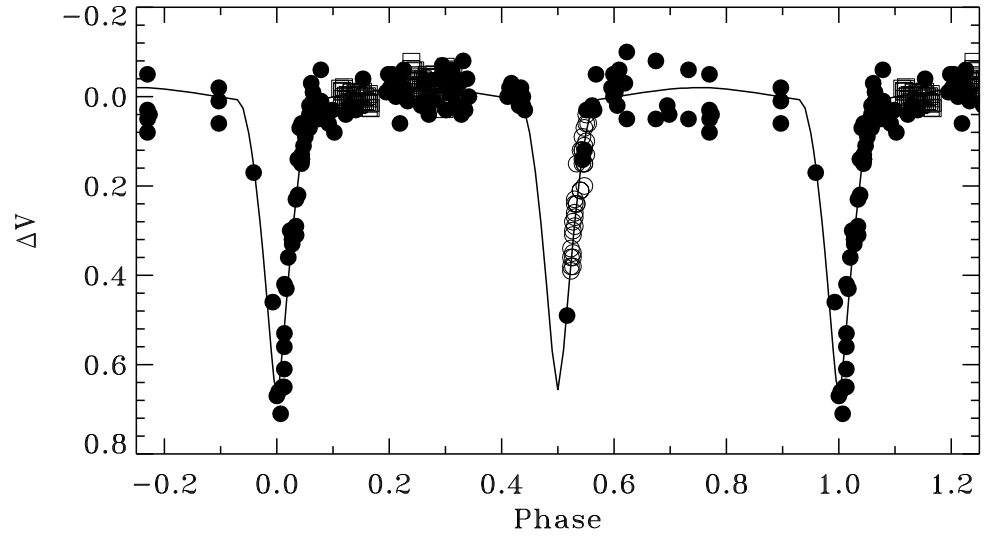

Figure 1. The observed light curve of GSC 140.1831 relative to GSC 140.1277 (12.1 mag) with the three sets of observations indicated thus, filled circles (KB), open circles (PF) and open squares (WM). The light curve solution assuming two similar A-type stars with $T_1 = T_2 = 8000\,\mathrm{K}$, $R_1/a = 0.21$, $R_2/a = 0.20$ and $i = 87.7$ deg.

is less certain. To some extent the shift depends on the period chosen but this has no material effect on the light curve.

From a period analysis of the observations and the times of minimum only one clear period emerges, 0.5748 days. However, for this type of light curve such a period is physically unrealistic so the true period is taken to be twice this value. The observations show GSC 140.1831 to be an eclipsing binary with primary and secondary eclipses of ~ 0.7 and 0.5 mag respectively, although it is clear that the secondary minimum has not been completely covered (see Figure 1). There is no spectroscopic information and the USNO A2.0 magnitudes of $b = 12.7$ and $r = 12.0$ do not provide any real constraint on the system. The ephemeris of primary minimum is

$$\mathrm{JD(I)} = 2451264.27\ (\pm\,0.02) + 1.14962\ (\pm\,0.00005) \times E.$$

An attempt has been made to model the system using the LIGHT2 code of Hill et al. (1989). A number of solutions have been made using a wide range of temperatures, and a range of mass ratios around unity. The derived parameters are very insensitive to both temperature and mass ratio, and not surprisingly suggest two stars of equal temperature and equal size. So, with $T_1 = 6000\,\mathrm{K}$ (fixed) and $q = 1.0$ (fixed), $T_2 = 5960 \pm 90\,\mathrm{K}$, $R_1/a = 0.21 \pm 0.04$, $R_2/a = 0.20 \pm 0.03$ and $i = 88 \pm 1$ deg. These values are representative of a range of temperatures. Given the uncertainty in the temperatures of the stars and the lack of observations around one of the minima it is possible that further observations will redefine which is the primary eclipse. From the relative radii it is possible to derive an internally consistent set of the parameters, P, M and R for a pair of late A-type main-sequence stars, giving $M \sim 1.9\,\mathrm{M}_\odot$, $R \sim 1.5\,\mathrm{R}_\odot$ and $T \sim 8000\,\mathrm{K}$. The solution with the stars it this temperature is shown in Figure 1.

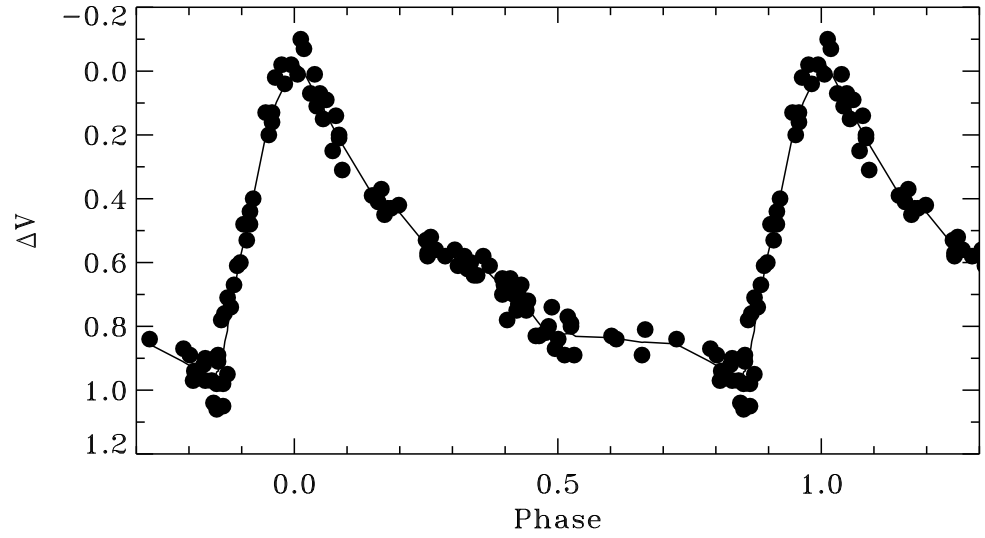

Figure 2. The light curve of GSC 959.1397 folded with a period of 0.64465 days with a high-order harmonic fit superimposed. The magnitudes are given relative to GSC 959.803 (12.6 mag)

GSC 959.1397

GSC 959.1397 ($16^{\rm h}24^{\rm m}49\overset{\rm s}{.}7$, $+08°04'15''$, J2000, 12.9 mag) has been observed 109 times mostly in June and July 1999. Initially the observation were quite sparse but when the short-period nature of the variation became clear several runs of approximately 20 observations were made. The magnitudes are given relative to GSC 959.803 (12.6 mag) which proved constant relative to the second comparison star, GSC 959.1049 (12.1 mag). The period analysis suffers from some aliasing problems but ultimately only one possible period emerges. The light curve, plotted in Figure 2, is clearly that of an a-type RR Lyrae and the ephemeris of maximum light is

$$\mathrm{JD(max)} = 2451355.457\ (\pm\ 0.005) + 0.64465\ (\pm\ 0.00012) \times E.$$

The co-ordinates of this star place it well above the galactic plane at $l = 23$ and $b = 36$. Adopting a mean magnitude, $V = 13.2$ and $M_{\rm V} = 0.5$, and assuming $A_{\rm V} = 0.3\ \mathrm{mag\,kpc^{-1}}$ yields a distance of 2.5 kpc and a height above the galactic plane of 1.4 kpc. Combined with the period this distance places this star firmly in the field halo population.

GSC 396.1710

GSC 396.1710 ($16^{\rm h}51^{\rm m}29\overset{\rm s}{.}9$, $+06°22'27''$, J2000, 13.1 mag, USNO A2.0 r: 12.6, b: 13.2) has been observed 159 times, mostly in August 1999. After the initial observations the vast majority were taken in eight long runs. The magnitudes are given relative to GSC 396.2221 (12.5) and GSC 396.1863 (12.5) was used as the second comparison star. The observed magnitude difference of 0.20 mag is consistent with the GSC magnitudes. The periodogram shows one clear period at 0.77892 days with relatively strong one-day aliases, although there is no real confusion. The light curve is unmistakably that of an a-type RR Lyrae variable, with an amplitude of ~ 0.7 mag. The light curve is plotted in Figure 3.

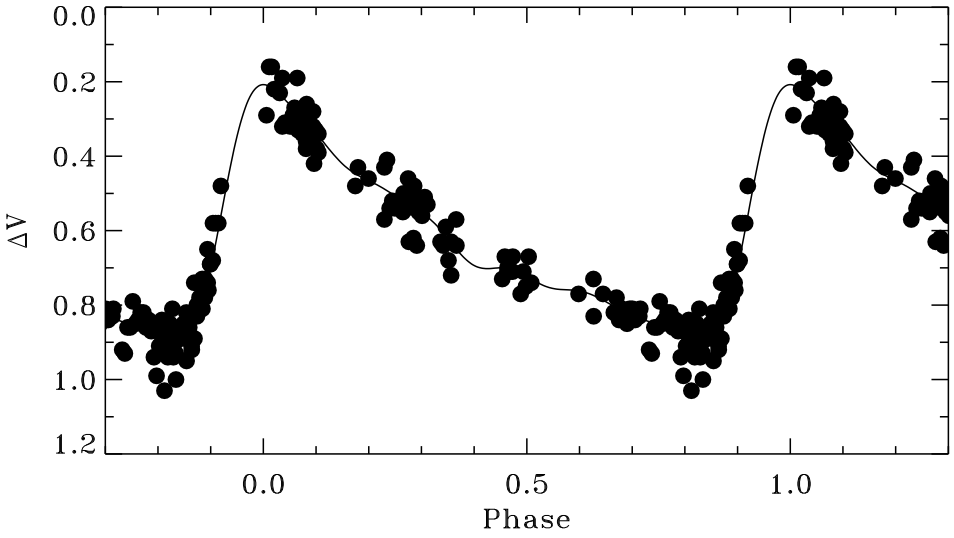

Figure 3. The light curve of GSC 396.1710 folded with a period of 0.77892 days with a high-order harmonic fit superimposed. The magnitudes are given relative to GSC 396.2221 (12.5 mag)

The ephemeris of maximum light is

$$\mathrm{JD(max)} = 2451410.835\ (\pm\ 0.004) + 0.77892\ (\pm\ 0.00009) \times E.$$

The galactic co-ordinates, $l = 24$ and $b = 29$, and mean magnitude, GSC $\sim$ 13.1, of GSC 396.1710 are similar to the other RR Lyrae star reported here, GSC 959.1397, and the same analysis also points to GSC 396.1710 belonging to the field halo population.

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