OPEN EUROPEAN JOURNAL ON VARIABLE STARS
September 2009 http://var.astro.cz/oejv ISSN 1801–5964

IMPROVED PARAMETERS OF THE RR LYRAE VARIABLE USNO-A2.0 1200-07442272

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Abstract: A refined period of 0.3488463(18) and Fourier decomposition components are provided for the RR Lyrae variable USNO-A2.0 1200-07442272, which lies in the field of TY Boo. The star is found to an RRc variable with a hump on the rising branch, and also has very low metallicity, [Fe/H]_ZW = -1.5 and [Fe/H]_CG = -1.2, typical of the halo population. It is an extreme halo object and probably lies at nearly 6 kpc from the galactic plane.

The variable with the snappy name of USNO-A2.0 1200-07442272 lies at 15h 00m 47.56s +35d 09m 51.5s (2000 2MASS) in the field of the eclipsing binary TY Boo, and was doubtless discovered during observations of that star. It is also catalogued as USNO B1.0 1251-0223750 and 2MASS 15004755+3509514. Its variability, along with that of another nearby star (USNO-A2.0 ... 2402), was first reported by Agerer (2006) who published a light curve covering approximately one cycle and suggested that the star was an RR Lyrae variable with a period of 0.348836 days. Further times of light maxima, also by Agerer, have been published in compilations of *Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V.* (BAV) observations by Hubscher et al. (2006) and Hubscher (2007) and it seems likely that Agerer's (2006) ephemeris was actually based on all the data published in 2006 rather than what was given in the original paper.

New observations of the RR Lyrae star have been made by Öğmen on 31 May and 11 June 2009 at the Green Island Observatory (B34), Geçitkale, North Cyprus (for more information see www.greenislandobservatory.com) while obtaining times of minima of TY Boo. The equipment used was a Meade 35-cm LX200R SCT and Meade DSI Pro II CCD camera. Exposures were 10 × 10 seconds, unfiltered, and magnitudes were obtained by aperture photometry using the Maxim DL software package. The peak of the response of the CCD camera used is near 6000 Å so the magnitudes should be quite close to V for intermediate colours. Comparison stars used were (a) GSC 2568-0997 and (b) GSC 2568-0991 with (c) GSC 2568-1004 used as a check star. The details are given in Table 1 together with the mean differences in the instrumental system.

Table 1: Comparison star data for USNO-A2.0 1200-07442272

	Star	RA (2000)	Dec (2000)	Δm	V†	$B-V$†
a	GSC 2568-0997	15 00 53.67	+35 02 59.8		11.48	0.59
b	GSC 2568-0991	15 00 42.61	+35 05 16.9	0.508 ± 0.012	12.39	1.34
c	GSC 2568-1004	15 00 26.43	+35 04 33.9	2.422 ± 0.014		

† Calculated from SDSS magnitudes

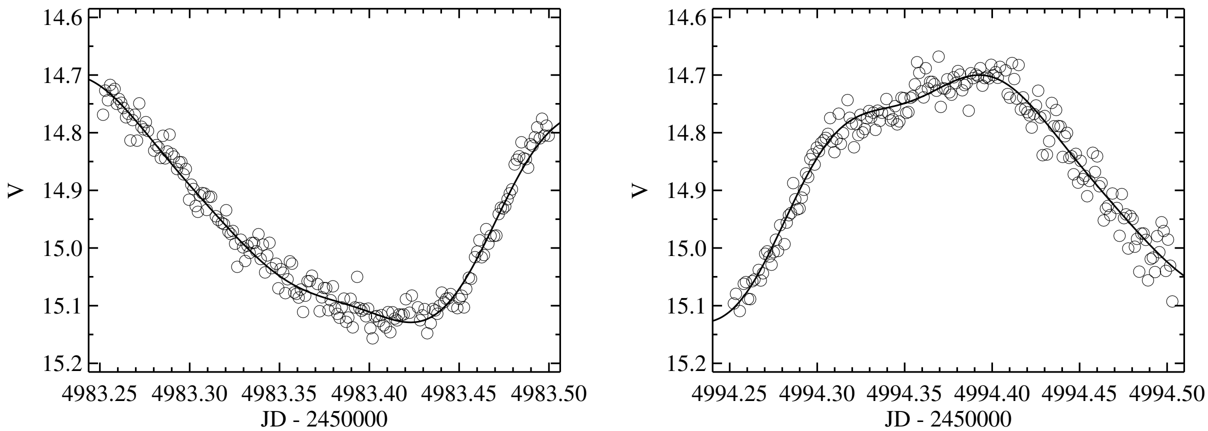

Figure 1: The light curves from 31 May and 11 June with the 4-order Fourier fit.

Magnitudes of the variable were calculated using both comparison stars, but are given with respect to the brightest comparison star, (a) GSC 2568-0997. From Tycho-2 (Høg et al., 2000) this star has a rather poorly defined $V = 11.586 \pm 0.10$ and $B - V = 0.376 \pm 0.13$. Photometry is also available from the SDSS (Adelman-McCarthy et al., 2007) so V and $B - V$ have been calculated for both comparison stars using the calibration of Jordi el al. (2006), and are given in Table 1. These are in good agreement with the values from TASS (Droege et al., 2006) but should have much higher precision. The difference between the instrumental magnitudes of the comparison stars is not the same as ΔV because the colours are rather different, but is consistent with a band pass between V and R, as expected.

The light curve for each of the two runs is shown in Figure 1 with a least-squares 4th order Fourier fit of the form

$$m(t) = m_0 + \sum_i a_i cos(2\pi ift + \phi_i)$$

over plotted. The standard deviation of the residuals is 0.023 magnitudes, which is consistent with the errors of the comparison and check stars. The light curve clearly has a hump on the rising branch which could lead to more uncertainty in determining the time of maximum, depending on the quality and time resolution of the observations. In this case the time of maximum lies at the later end of possible range. From these observations an independent period has been found, $P = 0.34874(3)$ and a single time of maximum light which is given in

Table 2: Times of maximum light

HJD	Error	$O-C$	Ref	HJD	Error	$O-C$	Ref
2452722.347	0.005	0.0057	1	2452793.507	0.010	0.0011	1
2452723.404	0.005	0.0162	1	2452858.395	0.001	0.0037	1
2452724.426	0.010	−0.0084	1	2453097.358	0.003	−0.0007	1
2452725.490	0.002	0.0091	1	2453145.4910	0.0005	−0.0007	1
2452726.532	0.005	0.0045	1	2453475.4760	0.0100	−0.0242	1
2452747.448	0.010	−0.0102	1	2454185.3860	0.0030	−0.0162	2
2452784.431	0.003	−0.0049	1	2454994.3940	0.0011	0.0174	3

References: 1. Hubscher et al., 2006, 2. Hubscher, 2007, 3. This paper

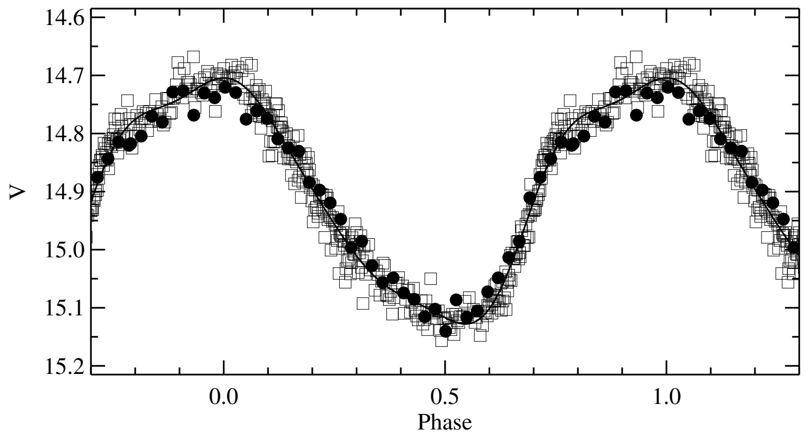

Figure 2: Phase diagram of the combined data using Equation 1, with data from this paper shown as □ and from Agerer as •.

Table 2, along with all the other published values. A similar fit to these data plus Agerer's (2006) observations is shown in Figure 2 and this leads to a much improved linear ephemeris for maximum light of

$$HJD_{Max} = 2452722.3462(11) + 0.3488462(19) \times E \text{ (Fourier)} \quad (1)$$

The O-C diagram of the times of maximum light is shown in Figure 3 and an unweighted linear fit gives an ephemeris of

$$HJD_{Max} = 2452722.3413(39) + 0.3488462(18) \times E \text{ (O} - \text{C)} \quad (2)$$

and the weighted fit is

$$HJD_{Max} = 2452722.3398(5) + 0.3488485(2) \times E \text{ (weighted)} \quad (3)$$

both of which are consistent with the Fourier ephemeris. Error bars are shown for illustration on the plot and it is clear that there is much more scatter than these would imply, and this leads to the underestimated errors in Equation 3. It is possible that the errors on the timings are grossly underestimated, or that there is some variation in the time of maximum light, but as was discussed earlier the shape of the maximum may make timings less reliable in lower quality data.

Based on fairly limited information Agerer suggested that USNO-A2.0 1200-07442272 is an RRab variable, but the period itself suggests that the star is more likely an RRc variable

Table 3: Fourier decomposition components

k	A	s.e.	ϕ	s.e.	R_{k1}	s.e.	ϕ_{k1}	s.e.
1	0.211	0.002	6.15	0.01				
2	0.017	0.002	1.04	0.10	0.08	0.01	4.97	0.10
3	0.024	0.002	0.07	0.07	0.11	0.01	4.11	0.07
4	0.010	0.002	3.28	0.16	0.05	0.01	2.47	0.16

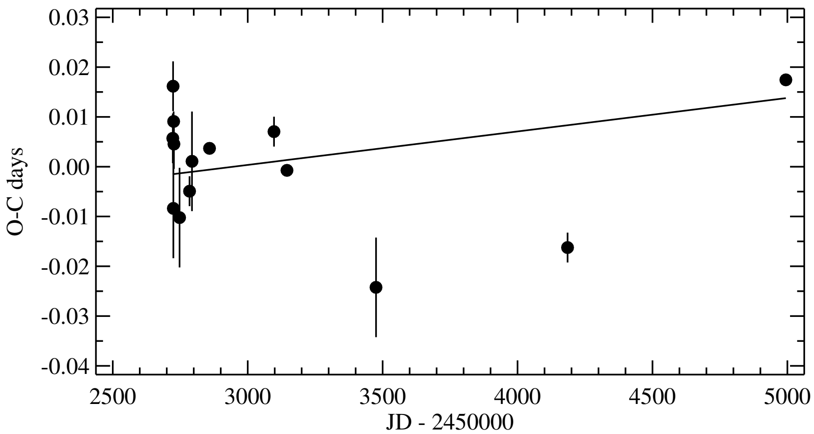

Figure 3: $O - C$ diagram of the times of maximum light from Table 2 using Equation 2, with the weighted fit from Equation 3 shown as the line.

and the low amplitude is consistent with this (cf. Figure 26 of Kinemuchi et al., 2006). The Fourier decomposition components of the light curve have been calculated and are given in Table 3. Although these are from unfiltered photometry the values should be quite close to those derived from V-band light curves. Almost all of the components are well within the range of seen for RRc stars, particularly the amplitude coefficients and ϕ_{31} and ϕ_{41}. Only ϕ_{21} could be considered as at all borderline (see Poretti 2001, Morgan 2003).

Using the metallicity relationships of Morgan et al. (2007) for RRc stars the period and ϕ_{31} combine to give $[\mathrm{Fe/H}]_{ZW} = -1.5$ and $[\mathrm{Fe/H}]_{CG} = -1.2$ on the Zinn & West (1984) and the Carretta & Gratton (1997) metallicity scales respectively. By this reckoning USNO-A2.0 1200-07442272 is very metal poor but consistent with it being an extreme Pop II, halo object as opposed to an intermediate, thick disc object.

It is possible to make a rough estimate of the distance to USNO-A2.0 1200-07442272 by assuming that with its high galactic latitude, the coordinates are $l = 57, b = +61$, the interstellar extinction will be small. With $< V > = 14.91$ from the Fourier fit and taking $M_V = +0.7$ and assuming $0 < A_V < 1.0$ the distance to the star is $4.4 - 7$ kpc, so it lies at least 4 kpc, and probably nearer 6 kpc from the galactic plane, making it an extreme halo object.

Acknowledgements

Öğmen would like to thank the AAVSO for providing the CCD camera on loan. This research has made use of the VizieR catalogue access tool and the SIMBAD database, operated at CDS, Strasbourg, France, and NASA's Astrophysics Data System.

References

Adelman-McCarthy J.K. et al., 2008, Astrophys. J. Suppl. Ser., 175, 297-313
2008ApJS..175..297A http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=II/282

Agerer F., 2006, Inform. Bull. Var. Stars, 5700, 20 (#90) 2006IBVS.5700....1

Carretta E., Gratton R.G., 1997, Astron. Astrophys. Suppl. Ser., 121, 95-112 1997A&AS..121...95C

Droege T.F., Richmond M.W., Sallman M., Creager R.P., 2006, Publ. Astron. Soc. Pac. 118, 1666-1678 2006PASP..118.1666D 2007PASP..119.1083R http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=II/271A

Høg E., et al., 2000, Astron. Astrophys., 355, L27-30 2000A&A...355L..27H

Hubscher J., Paschke A., Walter F., 2006, Inform. Bull. Var. Stars, 5731, 1-31 2006IBVS.5731....1H

Hubscher J., 2007, Inform. Bull. Var. Stars, 5802, 1 2007IBVS.5802....1H

Jordi K., Grebel E.K., Ammon K., 2006, Astron. Astrophys., 460, 339-347 2006A&A...460..339J

Kinemuchi K., et al., 2006, Astron. J, 132, 1202-1220 2006AJ....132.1202K

Morgan S.M., 2003, Publ. Astron. Soc. Pac., 115, 1250-1255 2003PASP..115.1250M

Morgan S.M., Wahl J.N., Wieckhorst R.M., 2007, Mon. Not. R Astron. Soc., 374, 1421-1426 2007MNRAS.374.1421M

Poretti E., 2001, Astron. Astrophys., 371, 986-996 2000A&A...371..986P

Zinn R., West M.J., 1984, Astrophys. J. Suppl. Ser., 55, 45-66 1984ApJS...55...45Z