Draft version September 14, 2021
Typeset using LaTeX default style in AASTeX631

Updated Ephemeris and Evidence for a Period Change in the Eclipsing Novalike Variable 1RXS J064434.5+334451

A. W. Shafter[1] and Vladimir Bautista[1]

[1] Department of Astronomy, San Diego State University

Submitted to RNAAS

ABSTRACT

We report seven new eclipse timings for the novalike variable 1RXS J064434.5+334451. An analysis of our data, along with all previously available timings (36 published and 16 unpublished), yields a best-fitting linear ephemeris of $\mathrm{BJD_{ecl}} = 2,453,403.7611(2) + 0.269\ 374\ 43(2)$ E. We find a somewhat improved fit with a quadratic ephemeris given by: $\mathrm{BJD_{ecl}} = 2,453,403.7598 + 0.269\ 374\ 87\ \mathrm{E} - 2.0 \times 10^{-11}\ \mathrm{E}^2$, which suggests that the orbital period may be decreasing at a rate given by $\dot{P} \simeq -1.5\times10^{-10}$.

Keywords: Cataclysmic variable stars (203) — Nova-like variable stars (1126) — Eclipsing binary stars (444)

1. INTRODUCTION

The bright ($V \sim 13.5$) novalike variable 1RXS J064434.5+334451 (hereafter J0644) was discovered to be an eclipsing binary by Sing et al. (2007). Their photometric observations over 16 nights between 2005 Feb 02 UT and 2006 Oct 13 UT revealed deep ($1 - 1.2$ mag) eclipses that recurred with an orbital period, $P_{\mathrm{orb}} = 6.4649808 \pm 0.0000060$ hr. Five years later Boyd (2012) used 22 new eclipse timings, along with 20 unpublished eclipse timings from 2005 to 2008 (made available by D. Sing and B. Green from their original study) to refine the period and determine an eclipse ephemeris given by: $\mathrm{HJD_{ecl}} = 2453403.75955(12) + 0.26937447(4)$ E. Unfortunately, the 20 unpublished eclipse timings remained unavailable, as they were not reproduced in the Boyd (2012) paper.

The most recent determination of the eclipse ephemeris was made by Hernández Santisteban et al. (2017). These authors acquired the original data for four eclipses from the work of Sing et al. (2007) and remeasured the times of mid-eclipse. They then combined these timings with a total of 10 additional timings that were obtained from eclipses observed in 2008 January and 2010 November and December finding $\mathrm{HJD_{ecl}} = 2,453,403.759533 + 0.269\ 374\ 46$ E, which is nearly identical to the earlier ephemeris. The similarity is remarkable given that these authors were apparently unaware of the 22 timings that were reported in the work of Boyd (2012).

In this *Research Note*, we have compiled all previously published times of mid-eclipse (i.e., from Boyd (2012) and Hernández Santisteban et al. (2017)), including the 20 previously unpublished timings kindly provided by David Sing from his original work (Sing et al. 2007). We have used these timings, along with seven new eclipse timings that we have recently measured to update the ephemeris for J0644 and to check the stability of the orbital period. Of these seven timings, one is based on observations taken with the Transiting Exoplanet Survey Satellite (TESS).

2. OBSERVATIONS

We obtained time-resolved photometric observations of J0644 on six nights in early 2021: Feb 21, Mar 05, 26, 27, and Apr 08, 09 UT. The observations were arranged to span the eclipse times predicted by the ephemeris of Hernández Santisteban et al. (2017). The 2021 Feb 21 and Mar 05 UT data were obtained with the Boyce-Astro Research Initiatives and Education Foundation (BRIEF) BARO Telescope, which is a 17-in f/6.8 Corrected Dall-

Corresponding author: A. W. Shafter
ashafter@sdsu.edu

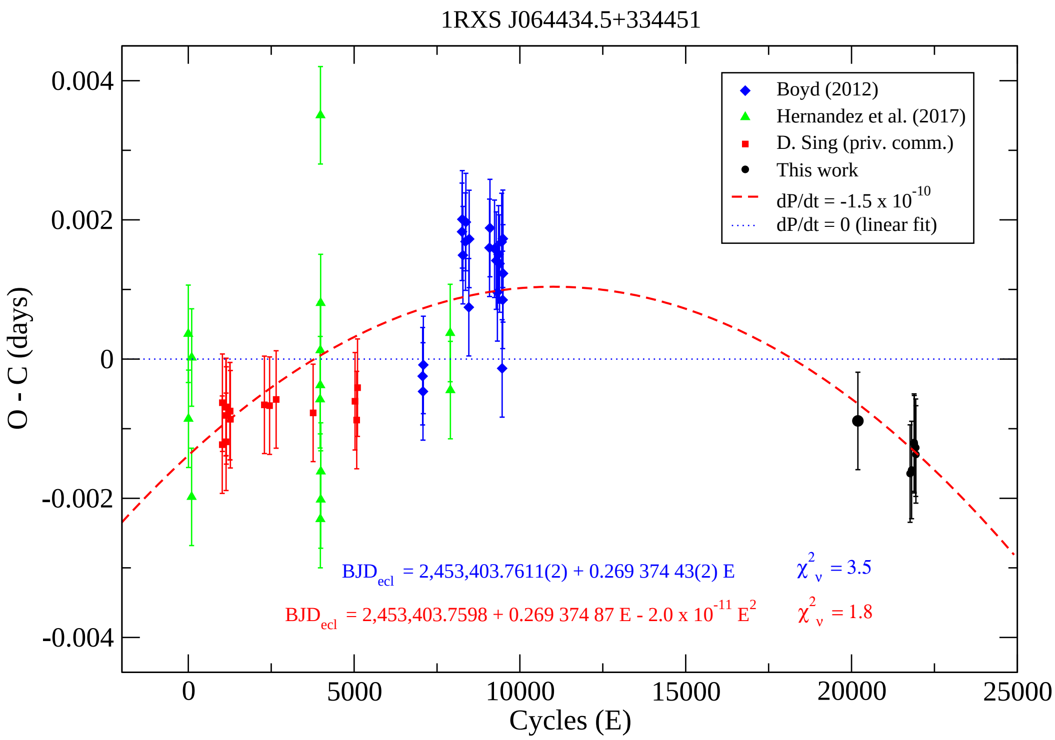

Figure 1. The $O-C$ diagram for J0644 showing the residuals from the best-fitting linear ephemeris given in the text. The residuals have been fit by a quadratic ephemeris that provides a slightly better match to the data, and suggests that the orbital period of J0644 may be decreasing at a rate given by $\dot{P} \simeq -1.5 \times 10^{-10}$. The sources of data are given in the legend. The larger black filled circle is based on the mean eclipse timing from the TESS data. The eclipse timings and $O-C$ values are available as the Data behind the Figure (see Table A1).

Kirkham Astrograph instrument located in Tierra Del Sol, California and operated remotely. Observations on the remaining nights were made with the facilities of the Las Cumbres Observatory (LCO). The 2021 Mar 27 UT data were obtained with the LCO telescope at McDonald Observatory, with the rest being obtained at the Haleakala facility. All observations consist of 30 s exposures through a Sloan r filter.

In addition to our ground-based eclipse observations, TESS observed a total of 86 (mostly sequential) eclipses over the interval between 2019 Dec 25 and 2020 Jan 19 UT. Given that the TESS eclipses were concentrated over a short time span, with relatively poor temporal resolution ($\sim$ 2 min) and signal-to-noise ratio during eclipse, we have determined a single fiducial eclipse timing for the TESS observations by fitting a linear function to the individual times of mid-eclipse and taking the intercept as the best measure of $T_{\mathrm{mid-ecl}}$ for this epoch. Times of mid-eclipse for both the ground-based and TESS observations were determined by fitting a parabola to the bottom half (as defined by the inflection points on ingress and egress) of each of the observed eclipses.

With the addition of our new eclipse measurements, we now have a total of 59 times of mid-eclipse for J0644: 14 from Hernández Santisteban et al. (2017), 22 from Boyd (2012), 16 previously unpublished timings provided by D. Sing, along with the 7 from the present study. A linear least squares fit of all 59 times of mid-eclipse yields the following ephemeris: $\mathrm{BJD_{ecl}} = 2,453,403.7611(2) + 0.269\ 374\ 43(2)$ E. The individual times of mid-eclipse and their residuals from this ephemeris are given in the machine-readable table associated with this *Research Note*. The residuals are also plotted in the $O-C$ diagram shown in Figure 1. The distribution of the residuals suggest that the orbital period of J0644 may be slowly decreasing. A quadratic fit to all 59 times of mid-eclipse yield the following ephemeris: $\mathrm{BJD_{ecl}} = 2,453,403.7598 + 0.269\ 374\ 87\ \mathrm{E} - 2.0 \times 10^{-11}\ \mathrm{E}^2$.

In order to estimate reduced χ^2 values of the fits, which are necessary to assess whether the improved quadratic fit is warranted, uncertainties must be specified for the individual eclipse timings. To avoid introducing unknown biases into the analysis, we have assumed that all eclipse timings are uncertain by 60 s (0.0007 d). A comparison of the reduced χ^2 values for the two fits ($\chi^2 = 3.5$ and $\chi^2 = 1.8$ for the linear and quadratic fits, respectively) suggests that neither fit provides a particularly good match to the eclipse timings, which is not necessarily surprising given that the uncertainties in the eclipse timings are poorly known and may be somewhat larger than we have assumed in our analysis. Nevertheless, if the eclipse timings and their associated errors are taken at face value, it appears that the quadratic fit offers a marginally significant improvement. In this case, we find that the orbital period of J0644 may be decreasing at a rate given by: $\dot{P} \simeq -1.5 \times 10^{-10}$. Future eclipse observations of J0644 will be required to better establish the stability of the orbital period.

We thank David Sing for providing unpublished eclipse timings from his previous work (Sing et al. 2007), Pat Boyce of BRIEF for access to the BARO Telescope, Michael Fitzgerald of the *Our Solar Siblings* project for assistance with image processing, and the Las Cumbres Observatory for a generous allocation of observing time.

Facilities: BARO Telescope, Las Cumbres Observatory

REFERENCES

Boyd, D. 2012, JAAVSO, 40, 295. https://arxiv.org/abs/1207.2432

Hernández Santisteban, J. V., Echevarría, J., Michel, R., & Costero, R. 2017, MNRAS, 464, 104, doi: 10.1093/mnras/stw2282

Sing, D. K., Green, E. M., Howell, S. B., et al. 2007, A&A, 474, 951, doi: 10.1051/0004-6361:20078026

Table A1. Eclipse Timings and $O-C$ Residuals

BJD[a] ($-2,450,000$)	Cycle Number (E)	$O-C$ (days)	Reference[b]
3403.7615	0	0.0004	(1)
3405.6459	7	−0.0009	(1)
3430.6966	100	−0.0020	(1)
3431.7761	104	0.0000	(1)
3679.8687	1025	−0.0012	(2)
3680.9468	1029	−0.0006	(2)
3709.7698	1136	−0.0007	(2)
3710.8468	1140	−0.0012	(2)
3711.9248	1144	−0.0007	(2)
3712.7328	1147	−0.0008	(2)
3741.8253	1255	−0.0007	(2)
3742.9028	1259	−0.0007	(2)
3745.8658	1270	−0.0009	(2)
4021.9748	2295	−0.0007	(2)
4063.9972	2451	−0.0007	(2)
4117.6028	2650	−0.0006	(2)
4417.9551	3765	−0.0008	(2)
4474.7933	3976	−0.0006	(1)
4475.8710	3980	−0.0004	(1)
4476.6772	3983	−0.0023	(1)
4476.9490	3984	0.0001	(1)
4477.7605	3987	0.0035	(1)
4478.8353	3991	0.0008	(1)
4479.6406	3994	−0.0020	(1)
4480.7185	3998	−0.0016	(1)
4757.9058	5027	−0.0006	(2)
4771.9130	5079	−0.0009	(2)
4778.9172	5105	−0.0004	(2)
5307.4300	7067	−0.0002	(3)
5310.3929	7078	−0.0005	(3)
5313.3564	7089	−0.0001	(3)
5531.0114	7897	0.0004	(1)
5532.8962	7904	−0.0004	(1)
5627.4489	8255	0.0018	(3)
5629.3347	8262	0.0020	(3)
5634.4523	8281	0.0015	(3)
5655.4637	8359	0.0017	(3)
5658.4271	8370	0.0020	(3)

Table A1 *continued on next page*

Table A1 *(continued)*

BJD[a] (−2,450,000)	Cycle Number (E)	$O-C$ (days)	Reference[b]
5682.4002	8459	0.0007	(3)
5685.3643	8470	0.0017	(3)
5850.4907	9083	0.0016	(3)
5854.5316	9098	0.0019	(3)
5891.4356	9235	0.0016	(3)
5905.4429	9287	0.0014	(3)
5914.3318	9320	0.0010	(3)
5924.2992	9357	0.0015	(3)
5932.3803	9387	0.0014	(3)
5949.3512	9450	0.0017	(3)
5953.3900	9465	−0.0001	(3)
5957.4316	9480	0.0008	(3)
5959.3181	9487	0.0017	(3)
5960.3951	9491	0.0012	(3)
8842.6994	20191	−0.0009	(4)
9266.6940	21765	−0.0016	(4)
9278.8159	21810	−0.0016	(4)
9299.8275	21888	−0.0012	(4)
9300.6356	21891	−0.0012	(4)
9312.7574	21936	−0.0013	(4)
9313.8348	21940	−0.0014	(4)

NOTE—This table is available in machine-readable format in the *AAS Research Notes.*

[a] BJD mid-eclipse times are computed with respect to the Barycentric Dynamical Time (TDB) standard.

[b] (1) Hernández Santisteban et al. (2017); (2) D. Sing (private communication); (3) Boyd (2012); (4) This work.