A Misclassified ASAS-SN Short Period Eclipsing Binary:

Photometric Follow-up on ASASSN-V J204238.35+660600.7

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Abstract

This paper discusses a star on ASAS-SN's Photometry database that was classified as an EA-type by ASAS-SN's automatic classifier. Follow-up work was done in validating this classification using photometry on four nights' worth of observation. Photometric and time-series analysis indicates that this classification is wrong and that the target is but a single star, but it provides important information on the star's spectral class. This paper is the first of a longer series of projects involving the validation and follow-up photometry work on a set of ASAS-SN short-period binary stars.

1. Introduction

The All-Sky Automated Survey for Supernovae (ASAS-SN) mission is an enormous database of more than 1.3 million documented transients with astrometric and photometric data (Jayasinghe, et al. 2019b). More data is being collected at almost every hour of every day by several of the six observatories situated throughout the globe. ASAS-SN uses an automatic classifier to determine which type of transient an object could be that is based on the shape of the light curve. However, automatic classifiers may be incorrect, especially when a large dataset is not available for light curve analysis. Among these transients, eclipsing binary stars are a strong candidate for following up on ASAS-SN's automatic classification and validating light curves with their light curve's unique double-humped shape. The first public release of eclipsing binaries has an 81% accuracy in the correct classification of the target (Christy, et al. 2022). This 19% inaccuracy makes follow-up work in validating the classification of eclipsing binaries necessary because the automatic classifier is prone to mistakes, which creates disagreements between surveys.

Observations in this series of observations, of which this is the first, will focus on targets in ASAS-SN's Photometry Database that have very short periods (six or fewer hours). These targets both make follow-up observations relatively easy and quick, where a full period can be observed over a night of observation. In addition, there are present concerns regarding the classification of these stars as EA-type eclipsing binaries. There are no known cases of detached binaries having a period this rapid; there exists a sharp cutoff of orbital periods of detached binaries at about 0.24 days (Rucinski 2007). This raises an overarching question to be answered throughout the course of this project: can detached EA-type binary stars really have periods of less than six hours? They are more likely attached EW-type binaries; cases of this are known, such as an ASAS-detected contact binary with a period of 0.2178 days (Lohr, et al. 2013).

ASAS-SN's classification and light curve reports of ASASSN-V J204238.35+660600.7 states that the target is an EA-type eclipsing binary star with an orbital period of 3.41 hours, under the sharp cutoff seen in Rucinski's study (Rucinski 2007). This star was selected due to its classification's low confidence in addition to very little pre-existing data. Fig. 1a shows the only two reported light curves for this target (Shappee, et al. 2014). It was chosen from a target list of 85 ASAS-SN identified stars that have a magnitude between 8 and 14, an eclipse amplitude greater than 0.2, and a period less than six hours. Time-series photometry and period analysis are employed to validate ASAS-SN's classification.

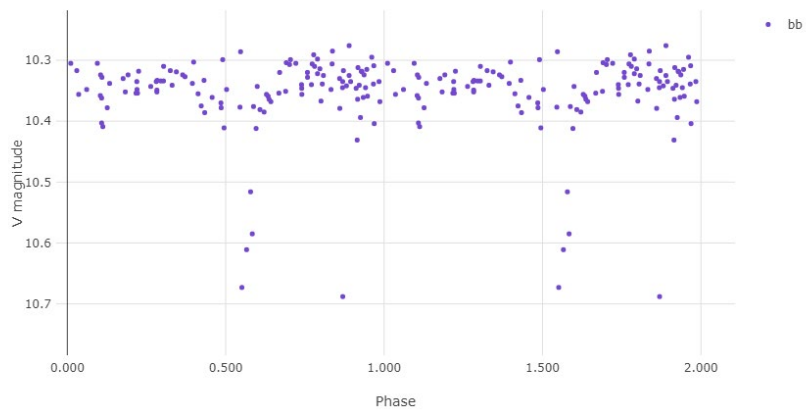

Figure 1. Phase light curve of ASASSN-V J204238.35+660600.7, taken from the ASAS-SN database

Table 1a. Basic parameters of ASASSN-V J204238.35+660600.7 from ASAS-SN database

Right Ascension	Declination	Amplitude	Period (hr)	Classification Confidence
310.65981	66.10019	0.23	3.407913	0.504

Table 1b. Basic parameters of ASASSN-V J204238.35+660600.7 from GAIA DR3

GAIA ID	Gmag	BPmag	RPmag	B-V	Parallax
DR3 2245910387028352768	9.986±0.003	10.648±0.003	9.201±0.004	0.973	1.503±0.104

2. Equipment and Methods

The initial search for potential targets utilized Tom Smith's EA-type ASAS-SN Excel spreadsheet, which identified and documented every target from the ASAS-SN Photometry Database that had a classification as an EA-type variable star. The spreadsheet identified the star's AP identification, Right Ascension, Declination, orbital period, transit amplitude, and ASAS-SN's confidence in the target's classification as an EA-type star. This last property is important in the validation work of this project: having a lower confidence value makes follow-up work much more valuable in confirming the star's classification. A basic Python script reduced the target list to 85 targets. The selected target had optimal RA and Declination for full-night observation, a large eclipse amplitude, a period of 3.41 hours, and a very low confidence level of 0.504.

The root of this low confidence level is the lack of pre-existing photometry data. ASAS-SN claimed this target as a new discovery, so prior data was not readily available. A search of the Variable Star Index, Zwicky Transit Factory, and SIMBAD databases did not indicate prior knowledge of this variable target, further substantiating their claim that this target is a new discovery. All photometric information that exists comes from the ASAS-SN database. In the case of ZTF, this is likely due to the target's high G magnitude of 9.981, which raises concerns for oversaturation during photometric analysis.

Boyce Astro's PlaneWave Instruments CDK-500 telescope is located at the Sierra Remote Observatories, and is equipped with a QHY600 MM 61.17-Megapixel CMOS camera. This telescope was remotely operated with ACP Observatory Control Software which iterated a sequence for 10 seconds in Johnson B, 10 seconds in Johnson V, and 20 seconds in Sloan i' in a repeated sequence for six hours each night from June 11 to June 14, 2024, inclusive. The i' filter has a longer exposure time to minimize oversaturation in the near-infrared range. 1,831 images were taken to process over the four nights. Peranso and Phoranso (Paunzen, Vanmunster 2016) were used for photometric analysis and period analysis, respectively. Peranso's EASolver was used to estimate the period and fold a phase graph.

3. Results

It appears that ASASSN-V J204238.35+660600.7 was wrongly classified as an EA-type eclipsing binary. Figure 3 shows the photometric data over the four nights, where the magnitude visibly has a higher level of variance in the i' band than the V or B bands. However, this variance has no signatures of being periodic, let alone at the predicted 3.41 hours. In Table 2, the magnitude in each bandpass deviates by about one magnitude, with i' being the brightest. i' also has a relatively large standard deviation compared to Johnsons V and Johnsons B.

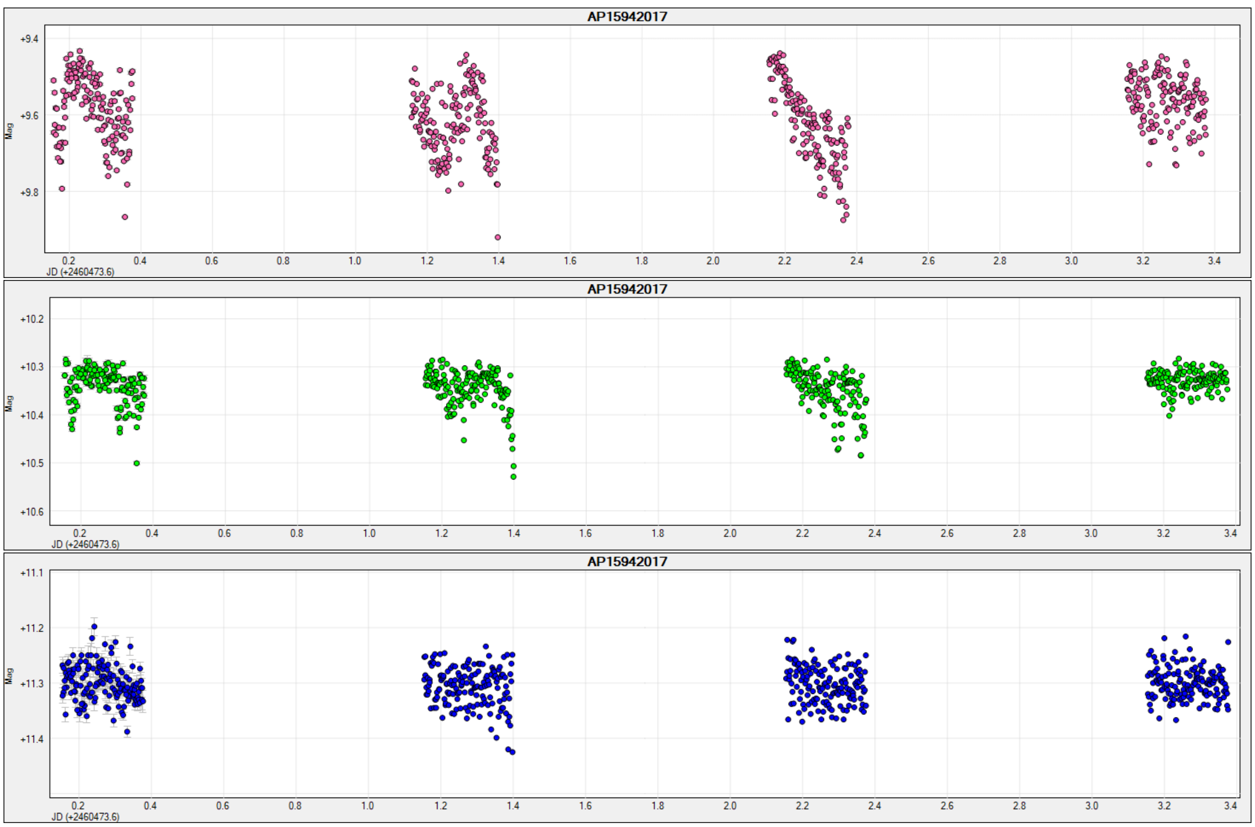

Figure 3. Raw time-series data of magnitude from each filter (from top to bottom: i', V, B)

Table 2. Average magnitude and standard deviation in each filter's bandpass.

Filter	Mean Magnitude	Standard Deviation
i'	9.597	0.0884
B	10.341	0.0367
V	11.302	0.0320

After using EASolver to solve the period and generate the phase graph, it was quickly discovered that the "period" matches very well with ASAS-SN's predicted period. EASolver's calculated period is 3.48 hours, which has a 2% error from ASAS-SN's 3.41-hour period. In the folded phase light curve, as seen in Figure 4, the mean magnitude across all three bandpasses does not deviate more than 0.03 magnitude from the normalized mean.

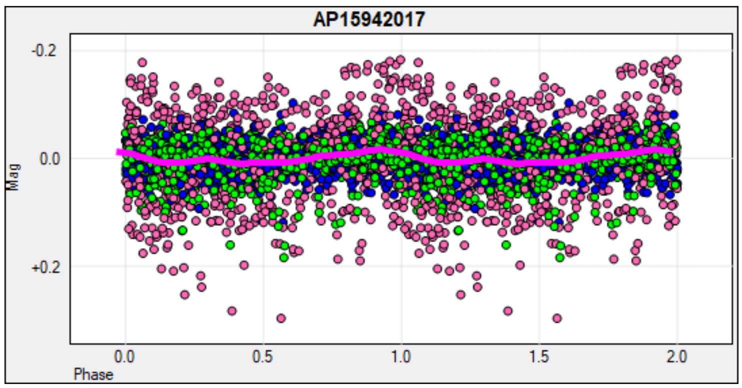

Figure 4. Folded phase light curve of normalized data from all three bandpasses.

4. Discussion

Between the raw data (Figure 1) and the normalized folded light curve (Figure 4), it is apparent that ASASSN-V J204238.35+660600.7 is not an eclipsing binary star. In fact, it does not fall into any subcategory of variable stars with periodically varying brightness. There are indeed some nonnegligible dips in brightness, especially at redder bandpasses, but these were not nearly big enough to match ASAS-SN's prediction of a 0.23-magnitude eclipse amplitude.

In addition, the light curve lacked the infamous double-dip of brightness. When looking at the original light curve (Figure 1), the automatic classifier presumably identifies two dips in light from one cluster of four observations and one solitary observation to create the second dip, indicating that they last only 3.4 minutes and 0.2 minutes, respectively. It is concluded that these observations are a result of imaging error or atmospheric interference, providing insight into potential pitfalls for future targets being observed that could cause such a classification. Such systematic errors that are beyond the survey's control and knowledge create "dips" in light that the automatic classifier picks up on. Nonetheless, it cannot be concluded in absolute terms that this star is an EA-type binary with a ~3.4-hour period.

The large variance in the raw data raises minor concerns about the effectiveness of the data. The significant standard deviations of all three filters slightly undermines the confident conclusions that can be made on periodic variance when there is significant nonperiodic variation. Nonetheless, the data lacks the aforementioned signs of an EA-type binary.

Another interesting discovery is that the calculated orbital period by Phoranso's period solver of 3.48 hours matches very well with the period presented in ASAS-SN's data. The calculated period has a 2% error from the given period length. However, under the conclusion that this star lacks periodicity in its brightness, this close relation between values lacks significant value. It remains an interesting coincidence, nonetheless.

With the bright magnitude of the ASASSN-V J204238.35+660600.7, other databases have information on the target, albeit under other nomenclature. It was previously stated that other databases had no knowledge of an object with periodically varying brightness; ZTF and VSX had no information at all due to its sole focus on variable stars. SIMBAD, however, identifies a basic star named "TYC 4258-2024-1" at the same coordinates whose GAIA identifier agrees with ASASSN-V J204238.35+660600.7. With this information, the conclusion that this target is misclassified as an EA-type binary is further supported.

5. Conclusion

After completing four nights of observation on ASASSN-V J204238.35+660600.7 and performing photometric and period analysis, the conclusion is that this star is misclassified as an EA-type eclipsing binary. This conclusion is upheld with the data on a non-variable star with the same GAIA DR3 identifier and coordinates. The created light curve lacks the double dip of an EA light curve that this classifier looks for. There is much variation that does not follow this structure of light curve, especially in the i' bandpass. The misclassification is probably due to the automatic classifier identifying two dips in light resulting from an imaging error or atmospheric interference.

The procedure outlined in this paper appears to create a significant dataset and is reproducible. It will be reused as the remainder of the 85 EA-classified targets in the current target list are observed and validated. More importantly, there are 15 targets that can be observed at the BARON telescope in which the this procedure can be repeated with the same telescope.

6. Acknowledgements

This research has made use of the ASAS-SN catalog, operated by The Ohio State University, https://www.astronomy.ohio-state.edu/asassn/. The catalog was utilized to create an easy-to-use target list by Tom Smith, a member of the Fairborn Institute. This research also has made use of the SIMBAD database, operated at CDS, Strasbourg, France. It could not have been completed without the assistance, primarily in granting access to time on the BARON telescope, of Boyce Astro, https://boyce-astro.org/. The BARON telescope employed the use of observatory control software ACP, available at https://acpx.dc3.com/. Peranso and Phoranso were used heavily in this project, thanks to Tonny Vanmunster, http://www.peranso.com/ & https://www.cbabelgium.com/Phoranso/.

7. References

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