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SPOTTED STARS AS CEPHEID IMPOSTORS OBSERVED WITH K2

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1 Introduction

Distinguishing Cepheids from rotational variables or eclipsing binary stars in ground-based photometric measurements is often a difficult task. Recent space missions revealed that a high percentage of stars labeled as Cepheid candidates based on sparse photometric survey data are misclassified (Szabó et al. 2011, Poretti et al. 2015). In this paper we present the analysis of three stars that were previously identified, erroneously, as potential Cepheid variables. The stars were observed by the *Kepler* space telescope in Campaigns 0 and 2 of the K2 mission (Howell et al. 2014).

The targets were selected based on existing classifications in ground-based surveys (Molnár et al. 2014, Plachy et al. 2016). All of three stars were observed by the All Sky Automated Survey[1] (ASAS; Pojmanski 1997). ASAS 064003+2825.6 was classified as a possible classical Cepheid, ASAS J162402-2910.8 as a Type II Cepheid, while ASAS J162308-2301.0 as either a Type II Cepheid or an eclipsing binary (Pojmanski 2002). However, the latter two stars were also identified as optical counterparts of the X-ray sources 1RXS J162402.5-291042 and 1RXS J162308.8-230046, respectively, by Berdnikov & Pastukhova (2008), and a new identification as RS CVn-type variables was suggested.

2 Data reduction

We applied the Extended Aperture Photometry (Klagyivik et al. 2016) on target pixel files provided by NASA Kepler Guest Observer Office to minimize the effects of spacecraft movements and collect all the available flux using the PyKE software (Still & Barclay 2012). We did not apply self-flat-fielding (SFF) correction to the data. The SFF algorithm in PyKE uses smoothing to separate the (slower) stellar variation from the instrumental variations, but we could not satisfactorily smooth out the flares and fit the periodic variations simultaneously. Light curves with EPIC (Ecliptic Plane Input Catalog) numbers and folded light curves are displayed in Fig. 1.

[1] http://www.astrouw.edu.pl/asas/

ASAS J064003+2825.6 (EPIC 202064452) was observed during Campaign 0 that was a full-length engineering test run for the K2 mission. During the first 16 days the telescope did not achieve fine pointing that led to gaps in the data and somewhat lower photometric accuracy. *Kepler* eventually went into safe mode that lasted for 24 days. After the observations restarted, data were collected for an additional 35 days, this time in fine pointing mode. As the star fell on one of the outer modules, its position varied in excess of 2 pixels due to the attitude changes of *Kepler*, causing small jumps and outlier points in the light curves coincident with the attitude control maneuvers. These jumps are also present in the detrended light curve produced by Armstrong et al. (2015).

ASAS J162402-2910.8 (EPIC 202571062) and ASAS J162308-2301.0 (EPIC 204264833) were observed during Campaign 2. *Kepler* collected data for 78 days, almost continuously. The first star was close to the edge of the field-of-view, therefore suffers from jumps and outliers, whereas the second was near to the center and is mostly unaffected by instrumental errors.

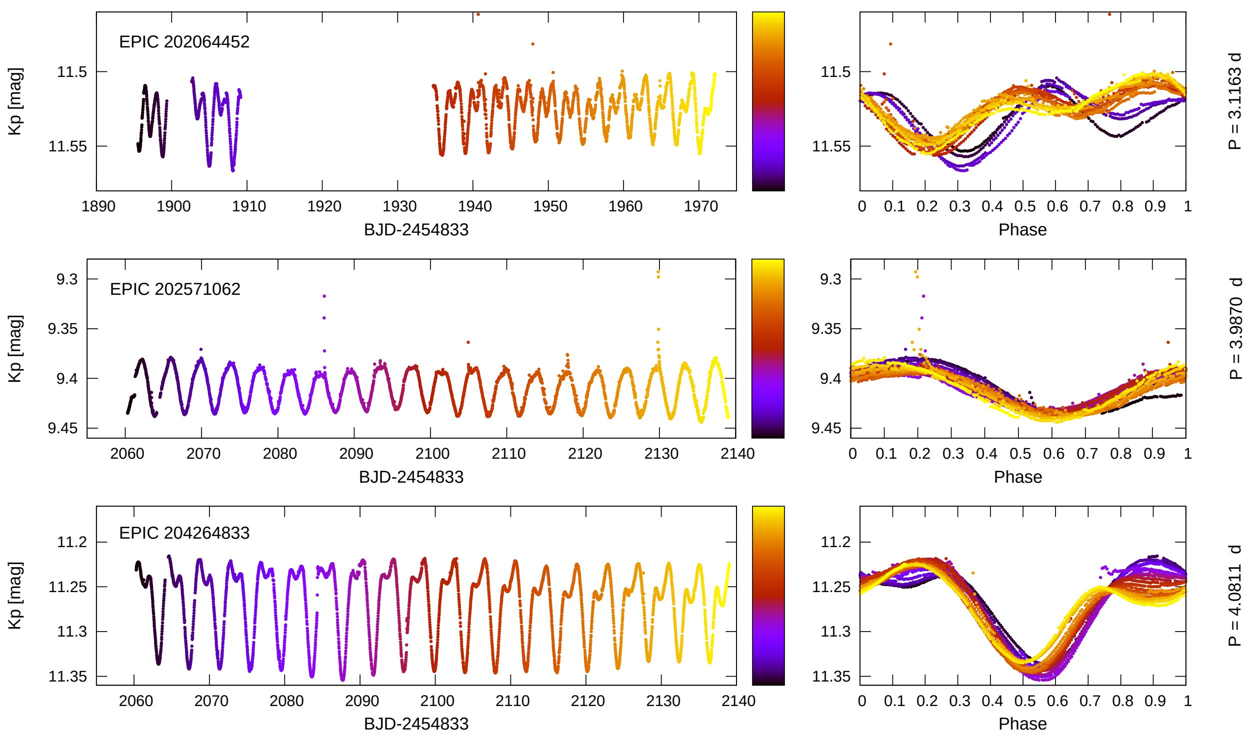

Figure 1. Light curves and folded light curves. Colors indicate the time evolution of the light curves. Periods were calculated with the Period04 software (Lenz & Breger 2005).

3 Analysis

The visual inspection of *Kepler* light curves suggests that these stars are not Cepheids: the cycle-to-cycle changes in the light curve shapes is typical of spotted stars (Kővári & Oláh 2014). In order to support the classification of the target stars we calculated the O–C values based on the times of minima in the light curves, that are presented in Fig. 2.

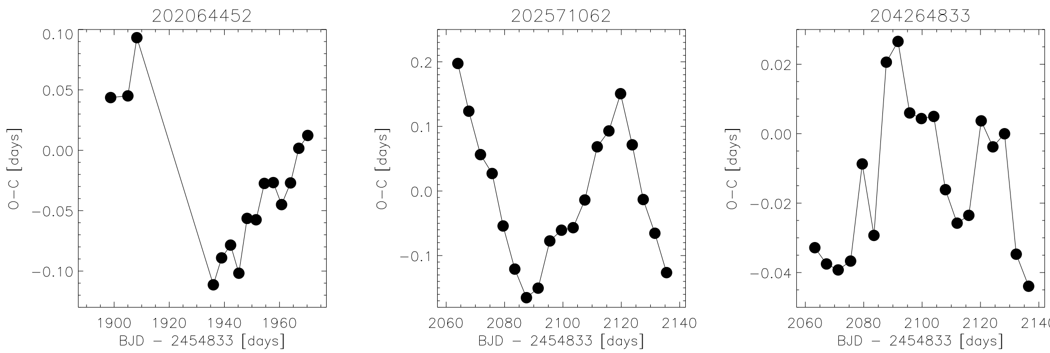

Figure 2. O–C diagrams of the three target stars.

EPIC 202064452 (ASAS J064003+2825.6, TYC 1892-1190-1) has a later-type nearby star according to SDSS images with a separation of 8.3″, but as this object is fainter by ≈ 6 magnitudes, it does not have much contribution to the observed light curve changes. In the catalogue of Schmidt et al. (2011) it was identified as a classical Cepheid with $P = 3.09580$ d, $T_{\rm eff} = 5050$ K, and $\log g = 4.41$. Our period analysis found an average period of $P_{\rm K2} = 3.1163$ d, but as a result of light curve evolution and the 25.6 day-long gap in the observation, the period of Schmidt et al. (2011), based on several years, describes our dataset better.

The light curve shows several flares, in total 5, during the ≈ 1146 hours of observation.

The observations also suggest two synchronously shifting active longitudes roughly on opposite hemispheres. At the beginning of the observations, the two nests were found around 0.2 and 0.7 phases, while around the end of the run, they shifted to 0.3 and 0.8. Also, the second active region became more prominent at the end of the observing run.

The O–C diagram (left panel of Fig. 2) shows a jump near the middle of the observations, which is in agreement with two active longitudes.

EPIC 202571062 (ASAS J162402-2910.8, HD 147611) is probably a wide binary (or multiple) system according to the 2MASS observations (Skrutskie et al. 2006). Torres et al. (2006) identified the object with spectral type of K7Ve and with $v \sin i = 9.7\ \rm km\,s^{-1}$.

This star also exhibits several (at least six) flaring events during the 78 days of observations, the major ones of which seem to concentrate around the same phase (≈ 0.2), which is a fairly common phenomenon on flaring cool dwarfs (cf. e.g., Vida et al. 2016). Note however, that due to the low number of detected flares, this cannot be stated quantitatively. The second major event could also be a sympathetic flare (i.e., a flare resulting from a transient phenomenon occurring elsewhere on the stellar surface, see Fig. 3).

Here, the longitudes of the active regions seem to be more stable, however, the O–C diagram of the times of minima (middle panel of Fig. 2) suggests large-amplitude, periodic variations.

EPIC 204264833 (ASAS J162308-2301.0) is a K5V type star in the solar neighbourhood (Riaz et al. 2006). Our period analysis yielded $P_{\rm rot} = 4.0811$ d. The light curve is

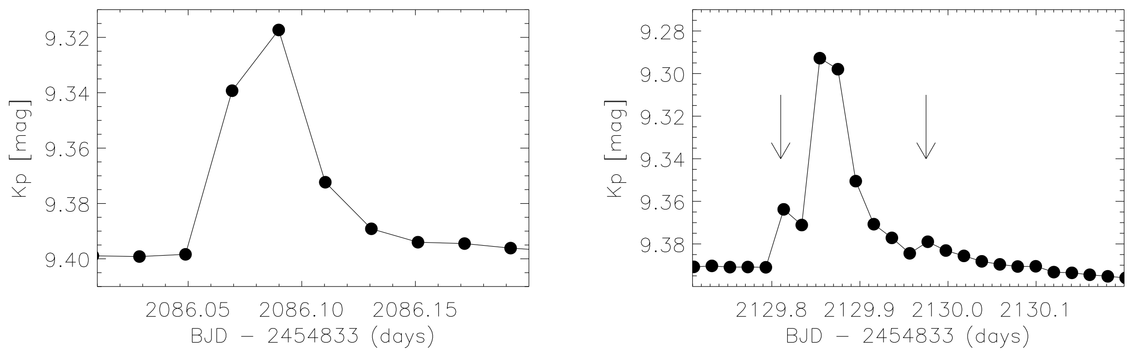

Figure 3. The two major flare events of EPIC 202571062. On the second panel, the arrows indicate possible sympathetic flares.

W-shaped, the changes are probably caused by two spotted regions (of which the more prominent being more stable in time), that is supported by the O–C diagram (right panel of Fig. 2), which shows relatively large variations in short timescale. Only weak flaring activity can be seen in the data.

4 Conclusions

According to K2 light curves, none of the analysed stars are Cepheid variables. The light curve shapes and the O–C diagrams suggest that their light variations are caused by stellar activity (i.e., spots on the surface) and probably not by stellar eclipses or ellipsoidal light variations in binary systems.

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