New Astronomy 49 (2016) 17–21

Contents lists available at ScienceDirect

New Astronomy

journal homepage: www.elsevier.com/locate/newast

Light curve solutions of the eclipsing *Kepler* binaries KIC 5080652, KIC 5285607, KIC 9236858 and KIC 11975363

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HIGHLIGHTS

- Stellar parameters of four eclipsing *Kepler* binaries were determined.
- The out-of-eclipse light variability of KIC ∼ 5080652, KIC ∼ 9236858 and KIC ∼ 11975363 was attributed to spot activity.
- Several microflares of KIC 11975363 were detected.

ARTICLE INFO

Article history:
Received 4 May 2016
Accepted 11 May 2016
Available online 18 May 2016

Keywords:
Binaries: close
Binaries: eclipsing
Methods: data analysis
Stars: fundamental parameters: individual (KIC 5080652, KIC 5285607, KIC 9236858, KIC 11975363)

ABSTRACT

We carried out light curve solutions of four detached binaries with circular orbits, observed by *Kepler*. As a result their orbital inclinations, temperatures and relative stellar radii were determined. We estimated also their global parameters on the base of the obtained solutions and empirical relation "temperature, luminosity" for MS stars. The out-of-eclipse light curves of KIC 5080652, KIC 9236858 and KIC 11975363 reveal a trend the bigger amplitudes to correspond to single-waved shape while the two-waved shape to be inherent to the smaller amplitudes. This type of variability was attributed to gradually transition between state with two almost opposite cool spots and state with bigger in size polar spot. We detected also several microflares of KIC 11975363 with amplitudes of 0.002–0.003 mag.

1. Introduction

The study of the stellar structure and evolution requires rich statistics of binaries with precise global parameters. The space mission *Kepler* provided extended and nearly uninterrupted data set for a variety of variable stars. An automate fitting of these data was used for initial classification of the variability. Thus, above two thousands eclipsing binaries (EBs) were identified and included in the *Kepler* EB catalog (Prsa et al., 2011, further Paper I; Slawson et al., 2011). Most of the unprecedented precise *Kepler* data are available to astronomical community and some individual *Kepler* EBs became objects of detailed study (e.g., Southworth, 2011, Steffen et al., 2011, Welsh et al., 2011, Winn et al., 2011, Dimitrov et al., 2012, Kjurkchieva and Vasileva, 2015, etc.).

This paper presents light curve solutions of four eclipsing *Kepler* binaries with periods between 2 to 4 days and relatively wide eclipses (above 0.04 in phase units) allowing precise light curve solution.

2. The targets

The stars KIC 5080652 (2MASS J19000489+4017546), KIC 5285607 (2MASS J19390532+4027346), KIC 9236858 (2MASS J19522915+4539040) and KIC 11975363 (2MASS J19492020+5018400 ≡ HAT 199-30766) have been suspected as potential transit signal sources during the first quarters of the *Kepler* mission (Tenenbaum et al., 2012). Further they were flagged as "False Positive" and classified as eclipsing binary of Algol type (Paper I).

Table 1 presents available information for the targets in the EB catalog (Paper I): *Kepler* magnitude m_K; epoch T_0 of the primary minimum; orbital period P; mean temperature T_m; depths of the primary and secondary eclipses $d_{1,2}$ (in flux units); widths of the primary and secondary eclipses w_1 (in phase units); width of the secondary eclipse $w_{1,2}$ (in phase units).

The targets have long-cadence (LC) data from almost all quarters. One of the targets KIC 5285607 have also short cadence (SC) data covering parts of quarters Q3 and Q4.

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http://dx.doi.org/10.1016/j.newast.2016.05.004
1384-1076/

Table 1
Parameters of the targets from the EB catalog.

Star	m_K	P	T_m	d_1	d_2	w_1	w_2
KIC 5080652	15.0800	4.1443566	5344	0.3149	0.1708	0.0377	0.0409
KIC 5285607	11.4190	3.8994011	6235	0.0408	0.0403	0.0397	0.0350
KIC 9236858	13.0400	2.5370818	6510	0.2282	0.0611	0.0661	0.0738
KIC 11975363	15.4090	3.5184191	5482	0.3359	0.3079	0.0457	0.0454

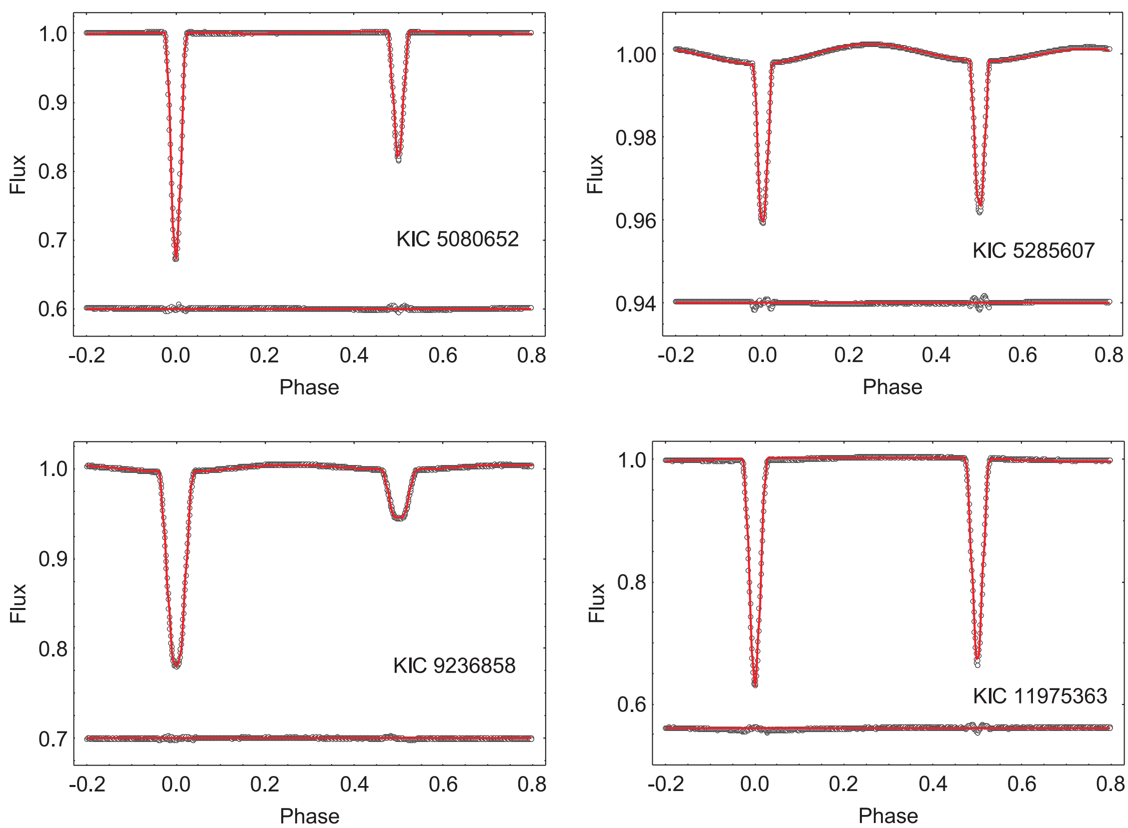

Fig. 1. Top of each panel: the folded light curve from the *Kepler* archive and its PHOEBE fit; bottom of panel: the corresponding residuals (shifted vertically by different number to save space).

Table 2
Parameters of the best light curve solutions.

Star	i	q	T_1	T_2	r_1	r_2	l_2/l_1
KIC 5080652	86.1(1)	0.683(1)	5447(21)	4867(25)	0.085(2)	0.083(1)	0.56
KIC 5285607	77.7(1)	0.515(1)	6210(19)	6058(28)	0.130(1)	0.129(1)	0.89
KIC 9236858	85.2(1)	0.577(1)	6676(15)	4993(19)	0.177(1)	0.081(1)	0.06
KIC 11975363	87.3(1)	0.436(1)	5517(12)	5420(23)	0.093(2)	0.089(1)	0.85

3. Light curve solutions

We carried out the modeling of our data by the package PHOEBE (Prsa and Zwitter, 2005) based on the Wilson–Devinney (WD) code (Wilson and Devinney, 1971). It is appropriate for our task because allows to model data in various filters including that of *Kepler* (Hambleton et al., 2013). The observational data (Fig. 1) show that our targets are detached systems that was expected for their orbital periods. That is why we modelled them using the mode “Detached binary”.

Besides eclipses the targets reveal variability with different time scales (see Section 5). To ignore this effect and to obtain adequate configuration parameters we modelled all available photometric data after appropriate binning. Moreover, we analyzed only the long cadence data of all targets to have comparability of the results.

The procedure of the light curve solutions is described in details in Kjurkchieva et al. (2016). Shortly, at the first stage we fixed primary temperature $T_1^0 = T_m$ and searched for fit varying the secondary temperature T_2, mass ratio q, orbital inclination i and potentials $\Omega_{1,2}$ (and simultaneously relative radii $r_{1,2}$). In order to reproduce the light curve distortion we added cool spots on the primary and varied their parameters (longitude λ, latitude β, angular size α and temperature factor κ). After reaching the best solution (corresponding to the minimum of χ^2) we adjusted the stellar temperatures T_1 and T_2 around the value T_m by the formulae