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Searching for pulsations in *Kepler* eclipsing binary stars

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Abstract. Eclipsing binaries can in principle provide additional constraints to facilitate asteroseismology of one or more pulsating components. We have identified 94 possible eclipsing binary systems in a sample of over 1800 stars observed in long cadence as part of the *Kepler* Guest Observer Program to search for γ Doradus and δ Scuti star candidates. We show the results of a procedure to fold the light curve to identify the potential binary period, subtract a fit to the binary light curve, and perform a Fourier analysis on the residuals to search for pulsation frequencies that may arise in one or both of the stellar components. From this sample, we have found a large variety of light curve types; about a dozen stars show frequencies consistent with δ Sct or γ Dor pulsations, or light curve features possibly produced by stellar activity (rotating spots). For several stars, the folded candidate 'binary' light curve resembles more closely that of an RR Lyr, Cepheid, or high-amplitude δ Sct star. We show highlights of our results and discuss the potential for asteroseismology of the most interesting objects.

Keywords. stars: binaries, stars: variables: δ Scuti, stars: variables: γ Doradus

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Out of 1800 stars observed in long cadence as part of the *Kepler* Guest Observer Program to search for γ Dor and δ Sct star candidates, 94 present binary-like features. This means that these light curves are periodically modulated by systematic signals that resemble photometric dimmings produced by mutual eclipses of tight pairs of stars. Since these binary-like signals are large enough to be detected without specific tools, the signatures of δ Sct or γ Dor pulsations are not easily detectable, and we must subtract the eclipse modulations from the light curves to find the pulsations.

This cleaning process first requires precise measurement of orbital periods, which were unknown for all 94 candidates. For contact or semi-detached systems (usually with $P < 2$ days), we estimated the orbital periods by fitting, for each, the highest peak of the oversampled Fourier power spectrum. Then we are able to refine the estimates for detached systems (usually with $P > 2$ days) by fitting each eclipse with a function used to adjust for exoplanetary transits: the timing of each transit allows for an accurate measurement of the orbital period. Once the orbital periods are determined, the light curves are cleaned in two different ways depending on orbital periods. When a time series is long enough to contain more than about 20 orbits, we can consider that the photometric fluctuations of the signal coming from either stellar or instrumental origin may be averaged out by folding and rebinning the signal. We thus subtract from the light curve the mean folded light curve repeated on the whole set of orbits in the dataset. This method is best in principle, because of its simplicity and the absence of any assumption about the origin of the photometric fluctuations. For longer periods, the signal during eclipse is replaced by a second-order bridging polynomial (see Gaulme *et al.* 2013 for details).

Table 1. Properties of eight pulsators belonging to eclipsing binary systems. $T_{\rm eff}$, $\log g$, and metallicity [M/H] are from the *Kepler* Input Catalog. ELV = contact ellipsoidal variable; D = detached system; SD = semi-detached system.

KIC number	Binary type	Period (days)	Frequency (μHz)	$T_{\rm eff}$ (KIC)	$\log g$ (KIC)	[M/H] (KIC)
4570326	ELV	1.1	100 – 230			
4739791	D	0.9	200 – 283	7538	3.873	−0.089
5783368	SD (?)	3.7	100 – 250	7910	3.835	−0.300
5872506	ELV (?)	2.1	100 – 283	7571	3.864	−0.386
6048106	D	1.6	5 – 38	6777	4.166	−0.399
6220497	SD	1.3	80 – 240	7254	3.933	−0.198
6541245	ELV	1.6	220 – 283	6315	4.166	−1.516
11401845	D	2.2	150 – 283	7590	3.902	−0.276

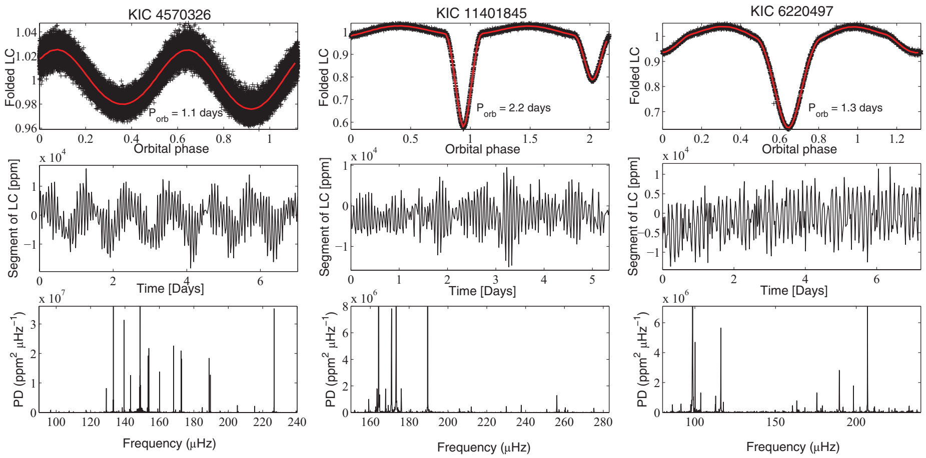

Figure 1. Folded light curve, light curve with binary signal subtracted, and power spectrum for KIC 4570326 (ellipsoidal variable), KIC 1140185 (detached system), and KIC 6220497 (semi-detached system). Each system shows frequencies in the δ Sct range.

Folding and cleaning the light curves allowed us to identify pulsations for eight binary systems (Table 1). Four candidates shown in our poster were eliminated here because they are likely δ Sct stars with a dominant large amplitude mode of period $0.1-0.2$ days. The remaining candidates are pulsating in the δ Sct frequency range, except for KIC 6048106 which is pulsating at γ Dor frequencies.

We have identified pulsators in about 10% of our eclipsing-binary candidates. The number of detections could certainly be increased by improving the filtering technique for eclipses. Indeed, for many contact or semi-detached systems, the eclipse depth actually fluctuates, preventing the folding approach from completely filtering out the eclipses. In addition, we must check that the pulsators truly belong to their associated eclipsing binaries. This can be done by checking the *Kepler* “target pixel files” and then obtaining radial velocity measurements to get masses and orbits of the eclipsing binary components. Modeling radial velocities coupled with light curves will lead to a complete characterization of these systems (masses, radii, orbital parameters).

Reference

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