The δ Scuti Pulsation Periods in KIC 5197256

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Abstract In this paper we present the pulsational spectrum for KIC 5197256. This object is an eclipsing binary system with a period of 6.96 days. We demonstrate that the light curve shows presence of δ Scuti pulsations with a dominant period of 0.1015 day. The object should therefore be included in the ever-growing class of eclipsing binary systems with at least one pulsating component.

1. Introduction

While the primary mission of the Kepler Space Telescope was the detection of exoplanets, several other branches of astronomy have benefited from the unprecedented photometry obtained by the instrument; perhaps none more so than that of asteroseismology. δ Scuti stars are an important component of this field, particularly if their pulsation modes can be identified. The light curves obtained from the instrument allow for detailed analysis of pulsation frequencies in a variety of regimes and thus, especially for targets which have been observed in both collection modes (LC for long cadence with integration times of ~30 minutes and SC for short cadence with integration times of ~1 minute; see Borucki (2008) for an overview of the mission and specifications), the complete pulsational behavior of certain intrinsic variables can be determined.

KIC 5197256 is a little-known system in Cygnus. It is also has the designation TYC 3139-1882-1 with coordinates R.A. $19^{h}\ 38^{m}\ 33.807^{s}$ and Dec. +40° 19' 25.999" (J2000, simbad.u-strasbg-fr) and a visual magnitude of 11.5 (Høg *et al.* 2000). It has been observed in 15 quarters over the course of the Kepler Space Telescope mission with observations in both the LC and SC modes. We present the δ Scuti periods in the SC data. According to the *Kepler Eclipsing Binary Catalog* (Kirk *et al.* 2015) it is an eclipsing binary with a period of 6.963389 days.

δ Scuti stars reside in the HR diagram where the instability strip crosses the main sequence. Thus δ Scuti stars tend to be either main sequence or only slightly evolved stars still in the hydrogen burning phase in their life-cycle. They have typical periods between 0.02 and 0.3 day, while their amplitudes are usually on the order of millimags (although HADS, high-amplitude δ Scuti's, can have amplitudes much higher). See Breger (2000) for an overview of the characteristics of δ Scuti stars. They can pulsate in radial or non-radial modes, and are important for asteroseismology as their short periods and detectable amplitudes allow for precise period determinations with less observing time required than for variables with longer periods. On the other hand, double-lined spectroscopic eclipsing binaries allow for the determination of various orbital and component characteristics such as velocities, the semi-major axis, and the sizes, masses, and temperatures of the individual components. To date, no spectroscopy has been performed on this object. These observations are planned for a future work and should yield a more detailed picture of the orbit.

2. Observations

The Kepler Space Telescope collected one set of SC data during Quarter 4 with a start time of 2010-02-18 19:13:13 (UT) and an end time of 2010-03-19 17:07:44 (UT) (or BJD 2455246.2981 and 2455275.2116, respectively). The data were obtained from the MAST archive (AURA 2015), in which publicly available data may be retrieved. A total of 42,300 data points were used in this analysis. The light curve generated from these data are shown in Figure 1. The light curve shows definite modulation, indicative of some variability or scatter. Figure 2 shows a portion of Figure 1 on an expanded time scale to show that, while there is some scatter in the data, the main source of the modulation is pulsation modes.

3. Analysis and results

After being obtained, the data were prepared for analysis through the following steps. First, the data set included both the SAP and PDCSAP fluxes. Only the PDCSAP fluxes were used. Second, all data points included in the set taken during periods of calibration or when the telescope was offline were neglected, yielding a total of 42,325 usable data points. Third, the data were normalized by taking the average flux of all the data points and then dividing the data set through by the average. Fourth, the data were divided up into five subsets with about 8,000 data points for each subset. These subsets were then fit with a series of second-order polynomials and the fluxes divided through by the fit to remove the binarity from the light curve. The results of the fitting are shown in Figure 3 (whole light curve) and Figure 4 (the same time-span as Figure 2).

The data, once the fitting was complete, were then period-searched using the PERANSO (Vanmunster 2007) software package between 0.01 and 0.3 day to encompass the δ Scuti regime using the Lomb-Scargle method (Lomb 1976; Scargle 1982). The resulting spectrum is shown in Figure 5. The dominant period (or the period with the highest theta, the Lomb-Scargle statistic) was determined to be 0.101549 ± 0.000024 d. Figure 6 shows the polynomial-fit data phased onto this period.

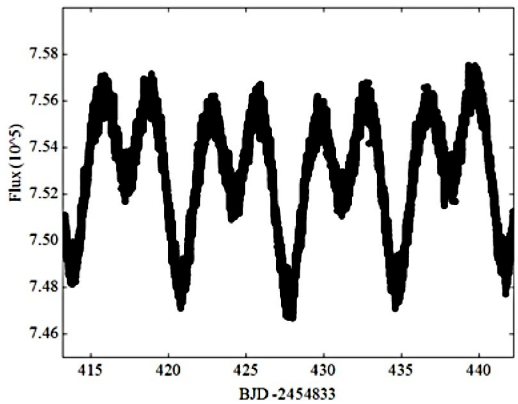

Figure 1. SC light curve from Q4 observations for KIC 5197256.

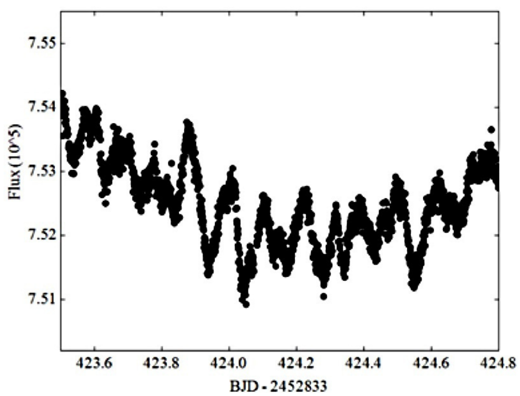

Figure 2. A portion of Figure 1 with expanded time scale to show the pulsations. Note the pulsations are visible during both eclipses.

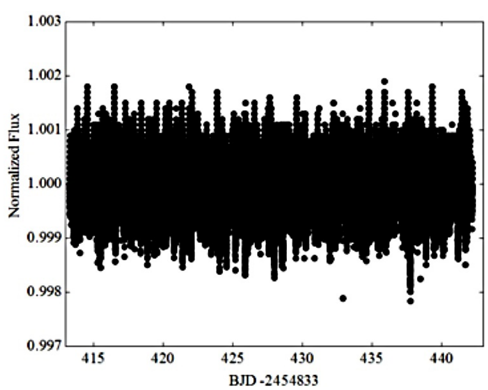

Figure 3. The entire SC light curve of KIC 5197256 after fitting with second order polynomials to eliminate orbital effects in the light curve.

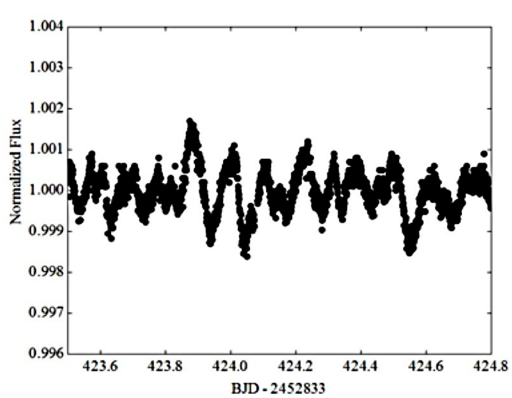

Figure 4. Shown are the data from Figure 2 after the polynomial fitting procedure was complete.

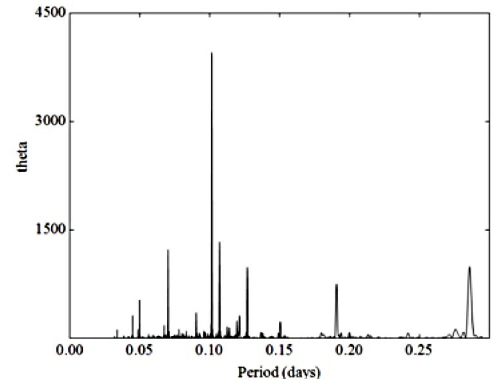

Figure 5. The power spectrum of KIC 5197256 after period searching the data between 0.01 and 0.03 day.

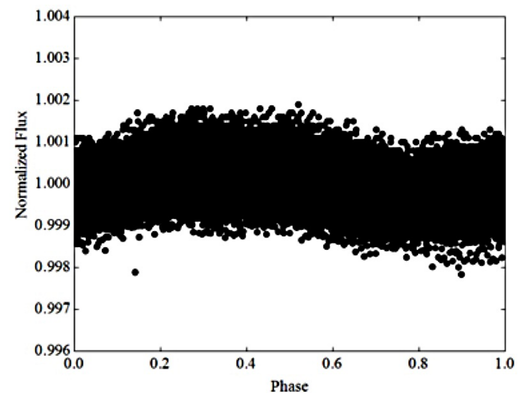

Figure 6. The normalized and fitted data of KIC 5197256 phased onto the dominant period of 0.101549 day.

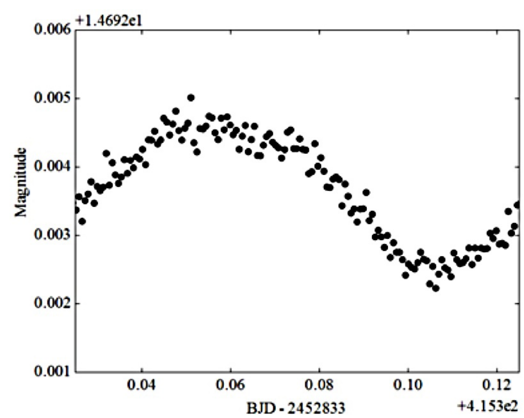

Figure 7. A small portion of data from Figure 1 set to a magnitude scale to estimate the amplitude of the dominant pulsation mode of KIC 5197256.

The ten most dominant periods found as a result of the period search are reported in Table 1 along with their associated uncertainties. It should be noted that, in an effort to ensure no true signals were lost or spurious signals gained during the polynomial fitting, the raw PDCSAP fluxes were also period-searched in the same range as the polynomial-fit data. The result is identical to Table 1.

As information about the amplitude is lost through both the normalization and the fitting, the original light curve was converted to a magnitude scale by taking the log (base 10) of the flux and then multiplying by 2.5 (the conventional minus

Table 1. Pulsational periods, uncertainties, and thetas for ten highest-theta periods found in KIC 5197256.

Period (d)	*σ (d)*	*theta*
0.101549	0.000024	3983.94
0.107027	0.000053	1343.2
0.070241	0.000023	1217.91
0.285877	0.000381	994.5
0.126898	0.000075	984.28
0.190713	0.000170	752.41
0.049836	0.000017	526.55
0.090390	0.000057	350.13
0.044873	0.000014	312.97
0.121364	0.000103	312.66

sign was omitted to retain the direction of brightening and dimming in the figures; this is allowable as to determine the amplitude only the difference in magnitude is important). A small representative portion of the resulting light curve (Figure 7) shows approximately one cycle of the dominant period. From this it is estimated that the amplitude is about 1.5 millimags (using the half-amplitude method). As all the other periods are much less significant, no estimation of their amplitudes is given.

Contamination from nearby stars is a common problem among Kepler objects. An inspection of the field using the image collected by Kepler with the coordinates bounding the target against the ALADIN LITE software (Bonnarel *et al.* 2000) reveals no other point sources included within the pixels Kepler used to collect the data. This strengthens the case that one of the components in the system is a δ Scuti-type variable with several modes of oscillation.

4. Discussion and conclusion

In this study we have presented evidence that KIC 5197256 is an eclipsing binary with at least one pulsating variable. The dominant pulsation period was found to be 0.101549 ± 0.000024 day with an amplitude of ~1.5 millimags. Until future observations indicate otherwise, this object should be included in the class of close binary systems with a δ Scuti component, as studied by Soydugan *et al.* (2006) and Liakos *et al.* (2012). If the object is a double-line spectroscopic binary, then the spectroscopic observations planned for a future study should help determine the nature of the system and characteristics of its components.

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