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HD183648: a Kepler eclipsing binary with anomalous ellipsoidal variations and a pulsating component

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Abstract. KIC 8560861 (HD 183648) is a marginally eccentric ($e = 0.05$) eclipsing binary with an orbital period of $P_{\rm orb} = 31.973$ d, exhibiting mmag amplitude pulsations on time scales of a few days. We present the results of the complex analysis of high and medium-resolution spectroscopic data and *Kepler* Q0 – Q16 long cadence photometry.

1 Introduction

Eclipsing binary stars have long been recognized as key objects for calibrating astronomical observations in terms of fundamental stellar parameters. There is a special group of eclipsing binaries that take a very important place in astrophysics: those with pulsating components. Such systems are important laboratories for confronting theories with observations. The mass measured from an eclipsing binary can be compared with those coming from other determinations and models, such as evolutionary or pulsational models [1]. Here we present the analysis of KIC 8560861, an eclipsing binary with a pulsating component discovered in the *Kepler* dataset.

2 Observations

The photometric analysis is based on photometry from the *Kepler* space telescope. HD 183648 was observed both in long and short cadence mode between 2009 and 2013. We have downloaded the target pixel files for all quarters and performed several checks by using PyKE[1] tools. First, we verified that all signals come from one object; that is, no contamination is seen from a close-by blended object

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within Kepler's resolution. Due to the brightness of the star and saturation on the *Kepler* photometer, the target aperture mask was elongated. Along the elongation axis, we still detect signal from the star, and we assume the flux could be still detected in pixels outside the target aperture. However, we determined that the contribution of the peripheral pixels outside of the target aperture is negligible. We estimated that the lost flux from the star is less than 0.01 per cent.

We obtained high and medium resolution spectra at five observatories: 2 spectra at Kitt Peak National Observatory (KPNO), 34 spectra with the eShel spectrograph [2] mounted on a 0.5-m Ritchey-Chrétien telescope at the Gothard Astronomical Observatory (GAO), 36 spectra at Piszkéstető Observatory (PO), 5 spectra at Apache Point Observatory (APO) and 3 spectra at Lick Observatory. The radial velocities were determined by cross-correlating the spectra with a well-matched theoretical template spectrum from the extensive spectral library of [3].

3 Results

The iterative combination of spectral disentangling, atmospheric analysis, radial velocity and eclipse timing variation studies, separation of pulsational features of the light curve, and binary light curve analysis led to the accurate determination of the fundamental stellar parameters.

The spectral disentangling technique made possible to detect the spectral lines of the secondary star despite its small (less than 5%) contribution to the total light of the system which allowed us to calculate dynamical masses and hence, relatively accurate stellar parameters. We found that the binary is composed of two main sequence stars with an age of 0.9 ± 0.2 Gyr, having masses, radii and temperatures of $M_1 = 1.93 \pm 0.12\,\mathrm{M}_\odot$, $R_1 = 3.30 \pm 0.07\,\mathrm{R}_\odot$, $T_{\mathrm{eff}1} = 7650 \pm 100$ K for the primary, and $M_2 = 1.06 \pm 0.08\,\mathrm{M}_\odot$, $R_2 = 1.11 \pm 0.03\,\mathrm{R}_\odot$, $T_{\mathrm{eff}2} = 6450 \pm 100$ K for the secondary. Both stars were found to be rapid rotators with $(v_{\mathrm{rot}} \sin i_{\mathrm{rot}})_1 = 104\,\mathrm{km\,s^{-1}}$ and $(v_{\mathrm{rot}} \sin i_{\mathrm{rot}})_2 = 26\,\mathrm{km\,s^{-1}}$ which in the aligned case correspond to rotation periods $P_{\mathrm{rot}1} = 1.60 \pm 0.04\,\mathrm{d} \sim 19.98 f_{\mathrm{orb}}$ and $P_{\mathrm{rot}2} = 2.15 \pm 0.21\,\mathrm{d} \sim 14.87 f_{\mathrm{orb}}$, respectively.

After subtracting the binary model, we found three independent frequencies, two of which are separated by twice the orbital frequency. We also found an enigmatic half orbital period sinusoidal variation that we attribute to an anomalous ellipsoidal effect. Both of these observations indicate that tidal effects are strongly influencing the luminosity variations.

The analysis of the eclipse timing variations revealed both a parabolic trend, and apsidal motion with a period of $P_{\mathrm{apse}}^{\mathrm{obs}} = 10\,400 \pm 3\,000$ y, which is three times faster than what is theoretically expected. These findings might indicate the presence of a distant, unseen companion.

Our results are published in [4] where more details of the analysis can be found.

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