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Identifying modes in KIC 5807616, a Pulsating sdB Star from *Kepler* Field

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Abstract. KIC 5807616 is a pulsating B-type hot subdwarf, reported to harbor planets. Its *Kepler* spacecraft Q 2 and Q 5 - Q 8 light curves as well as spectroscopic data were already analyzed and parameters characterizing the star were derived. Since then, *Kepler* had collected 2 years of additional data (Q 9 - Q 16 and half of Q 17). One might think new data could improve previously derived parameters, but it doesn't seem to be that easy. It appears that the Fourier transform amplitude spectra of the KIC 5807616 data do not show "clear" multiplets. Therefore, in this work we performed the mode identification based mainly on the period spacing of g-modes, while the analysis of multiplet splitting relied on two p-modes with stable multiplet components. We also derived the rotational period of the star and analyzed the low frequency region of the FT, where signatures of two planets were found in the past, but we had difficulties confirming their existence.

1 Introduction

Pulsating B-type hot subdwarfs (sdB) are extreme horizontal branch stars and KIC 5807616 is one of them. Its preliminary Q 2.3 data from *Kepler* [2] exploratory phase was firstly analyzed by [5] and [6], while [4] had derived KIC 5807616's stellar parameters from spectroscopic observations. The star pulsates in both, gravity (g-) and pressure (p-) modes, therefore it is a hybrid sdBV star ([7], [1]). The star's 27 730 ± 270 K effective temperature, log $g = 5.52 \pm 0.03$ surface gravity and 0.496 ± 0.002 $M_\odot$ mass [4] are typical for that class of objects. The following Q 5 - Q 8 quarters of KIC 5807616 observing data have been analyzed by [3]. They found that the star has a rich pulsation spectrum, but only two p-modes and several g-modes were identified. The reason for the limited success of mode identification was the lack of clear multiplet structures in the Lomb-Scargle periodograms of the KIC 5807616 light curve. Since then *Kepler* spacecraft had collected eight quarters of KIC 5807616 observing data and in this work we present the results of the Fourier transform amplitude spectra (FT) analysis of the whole Q 5 - Q 17 light curve.

2 Mode identification

Since there are no clear FT multiplet structures we decided to visually choose multiplet central frequency positions from the FT, instead of relying on the fit frequencies. Then, we converted them to periods, for period spacing fit. The selection of periods for spacing fits started with an assumption that the largest amplitude periods are l_1 modes. The rest of the set of the periods were fit as l_2. The modes which deviated noticeably from one mode period spacing were fit with another set of periods and finally were assigned to the set in which the deviations from period spacing were smaller. Using period spacing one can identify modes between ~2000 and 12000 sec. For longer periods the spacing becomes comparable with the width of multiplets and period spacing fit does not work accurately. For

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shorter periods, the scatter of spacings between consecutive periods varies too much to rely on the period spacing fit. Therefore, without clear multiplets we could identify modes only in a narrow range of periods.

3 Multiplets and rotation

Because there are no clear g-mode multiplets in the FT, we used the only two clear structures of p-modes in the FT at 3431.712 and 3447.105 μHz to derive their splitting. These structures were stable for about 500 days and the calculated 0.29 μHz p-mode splitting is very reliable. From this value we calculated the expected g-mode splitting for l_1 and l_2 to be 0.242 and 0.144 μHz, respectively. Then we determined the real g-mode splitting from a histogram of the frequency separation between consecutive components of all multiplets. It appears, that in the histogram, two most common separations are close to 0.041 μHz and 0.10 μHz and their ratio is far from theoretical 0.6 l_1/l_2 ratio. However, there are also two weaker frequency separation maxima at 0.144 μHz and 0.224 μHz, very close to the values of expected g-mode splittings. These were taken for further calculation and the star rotation period was determined from both, the g-mode l_1 and l_2 multiplet splittings read from the histogram (P_{rot}=40.10 days and 43.00 days respectively), as well as from the p-mode splitting (P_{rot}=40.104 days). All values are in a good agreement confirming [3] calculations.

4 Planetary signatures in a low frequency region

In the low frequency range [3] found two frequencies at 33.839 and 48.182 μHz which, after careful analysis of Q 5 - Q 8 KIC 5807616 data, were interpreted as a result of the light reflected by planets orbiting the KIC 5807616 sdBV star. The observed frequency split of the 33.839 μHz structure was explained by the noise interferences. Here, using the new *Kepler* data set we were able to analyze these frequencies and amplitude change over a period of time three times longer then analysis done before and found some problems with previous interpretations of the signals. There is a complex structure visible in high resolution running FTs around 33.839 and 48.182 μHz, as well as, a clear amplitude variations of these two frequencies during Q 5 - Q 17. One can say, that these complex structures can be still interpreted as the noise frequency modulations, however, the amplitude of the 33.839 μHz signal is not constant as it was assumed in the previous work. It is twice larger at the end of the *Kepler* run then at the beginning and goes beyond the detection level between Q 9 - Q 11. The amplitude of the signal near 48.182 μHz also changes, but on a smaller scale. Since one would expect a constant amplitude of the FT signal during the whole observing period, if it is due to the light reflected by the orbiting planets, then change of this amplitude cannot be explained by this effect. Because both frequencies have small amplitudes (signal to noise ratio varies from 4 up to 7) we cannot exclude previous interpretations, but the observed amplitude variations give an argument against it.

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