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Problems with exoplanets around sdBV and sdO stars from primary Kepler field

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Abstract. The existence of exoplanets around evolved objects is one of the most interesting subjects from the viewpoint of planetary system evolution and its fate. What happens to the exoplanets engulfed in the host star envelope during red giant branch (RGB) phase? Can planets survive this evolutionary stage of the host star? Here, we are showing that at least some of the exoplanetary candidates recently found around a couple of sdBV stars, KIC 5807616 and KIC 10001893, might not be exoplanets after all. One "exoplanetary signal" visible in the light curve FT of KIC 10001893 can be just a frequency combination of stellar pulsation modes, while others are likely artifacts. Similarly, low frequency signals found in KIC 5807616 light curve FT, are beating frequencies of stellar oscillations, rather than resulting from the exoplanetary radiation. We also analyzed frequency and amplitude changes of the signal around 0.256 c/d ($\sim$3.9 day) visible in the light curve FT of the KIC 10449976 sdO star. Our simulations show that it is difficult to reproduce the observed signal frequency variations by the weather changes in the exoplanet atmosphere.

Keywords. exoplanets, sdB, sdO

1. Introduction

Two pulsating blue subdwarfs (sdBVs) and a helium one (sdO) from the extreme horizontal branch (EHB) of the HR diagram were recently reported to harbor candidates for exoplanetary systems. The exoplanetary signals were found in the low frequency regions of sdBVs and sdO light curve Fourier Transforms (FTs). Some of the detections were done below or just above the standard 4σ detection threshold of their FT amplitude spectra, but supported by episodes of stronger signal occurrences during shorter sets of Kepler time series data. The signals were discovered below the cut-off frequency for gravity modes (Hansen *et al.* 1985) of the KIC 5807616 (Charpinet *et al.* 2011) and KIC 10001893 (Silvotti *et al.* 2014) stars. Based on data available at that time, in both stars the stellar nature of the signals was excluded and exoplanetary reflection/radiation effects were inferred to explain observed low FT frequency signals. A signal found in KIC 10449976 sdO star (Jeffery *et al.* 2013, Bear & Soker 2014) light curve was not firmly established as of the exoplanetary or stellar origin, but the pulsation nature or exoplaneatry reflection/radiation effects were suggested. Then, the weather in the exoplanet atmosphere was proposed as a cause of the observed signal amplitude and frequency variations (Bear & Soker 2014).

2. Data Analysis

Based on analysis of Q5-Q8 quarters of Kepler data, two planets in an extreme planetary system were suggested to orbit KIC 5807616 sdBV star (Charpinet *et al.* 2011).

The star itself is a typical sdB, but the exoplanets around it would be very hot Earth-sized remnants of former Jupiter mass planets. The "exoplanetary signals" were found in the star light curve FT at $F_2 = 33.755$ and $F_1 = 48.204\,\mu$Hz (Charpinet *et al.* 2011). Latter, using full Q5-Q17 data, Krzesinski (2015) determined slightly different values for $F_2 = 33.839$ and $F_1 = 48.182\,\mu$Hz signals in the low FT frequency region of KIC 5807616 light curve and prewhitened the full set of pulsation frequencies for this star. He also suggested that signals visible at the low FT frequency region might be actually of stellar, not the exoplanetary origin. Our analysis shows that F_2 signal fits the combination frequency of two 201.667 and 167.848 μHz gravity modes of moderate (836 and 125 ppm) amplitudes, while F_1 can be a beating frequency of 167.693 and 119.526 μHz pulsation frequencies (239 and 49 ppm respectively) of the star, with the accuracy better than 0.021 μHz.

Similar analysis was performed for the second candidate for extreme exoplanetary system around KIC 10001893 where three signals were found in the low FT frequency region at $k_1 = 52.683$, $k_2 = 35.578$ and $k_3 = 14.261\,\mu$Hz (Silvotti *et al.* 2014). Using the newest list of pulsation frequencies identified by Uzundag *et al.* (2017), as well as, frequencies prewhitened by us from pure SC (Q3.2, Q6-Q7) and LC (Q1-Q17) data, we performed analysis of pulsation frequency combinations. It appears, that allowing for n and m natural numbers > 1 in $n \cdot f_i - m \cdot f_k$ frequency combinations we can match all three low FT frequency signals with one or more combination frequencies. However, a simple beating frequency ($n = m = 1$) can be fit only to k_3 signal with an accuracy better than 0.0028 μHz (two gravity modes 238.983 and 224.719 μHz, 91 ppm and 54 ppm respectively). k_1 and k_2 seem to be just artifacts depending on data reduction methods.

There are no distinct features visible in the KIC 10449976 light curve FT, but some weak signal between 2.9−3.2 μHz. Jeffery *et al.* (2013) were not able to identify strictly the source of variations. Bear & Soker (2014) suggested, the weather changes in the exoplanet atmosphere could shift maximum amplitude of the flux within 1−3 days. Our simulations could not confirm that variation of the signal are caused by the weather changes in the atmosphere of an exoplanet orbiting the star. We found however, that observed FT pattern can be closely simulated by 435 day period phase modulation of the signal frequency. The source of the 435 day phase modulation is unknown. We also have shown that single night ground observations of the star did not reveal any short period (minutes) pulsations.

Summary: Low FT frequency signals observed in two sdBV stars are not necessarily signatures of exoplanetary systems. We suggest that the FT detection threshold should be increased up to 5σ level to avoid spurious or artifact signals to be taken for analysis.

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