TWO NEW SB2 BINARIES WITH MAIN SEQUENCE B-TYPE PULSATORS IN THE *KEPLER* FIELD

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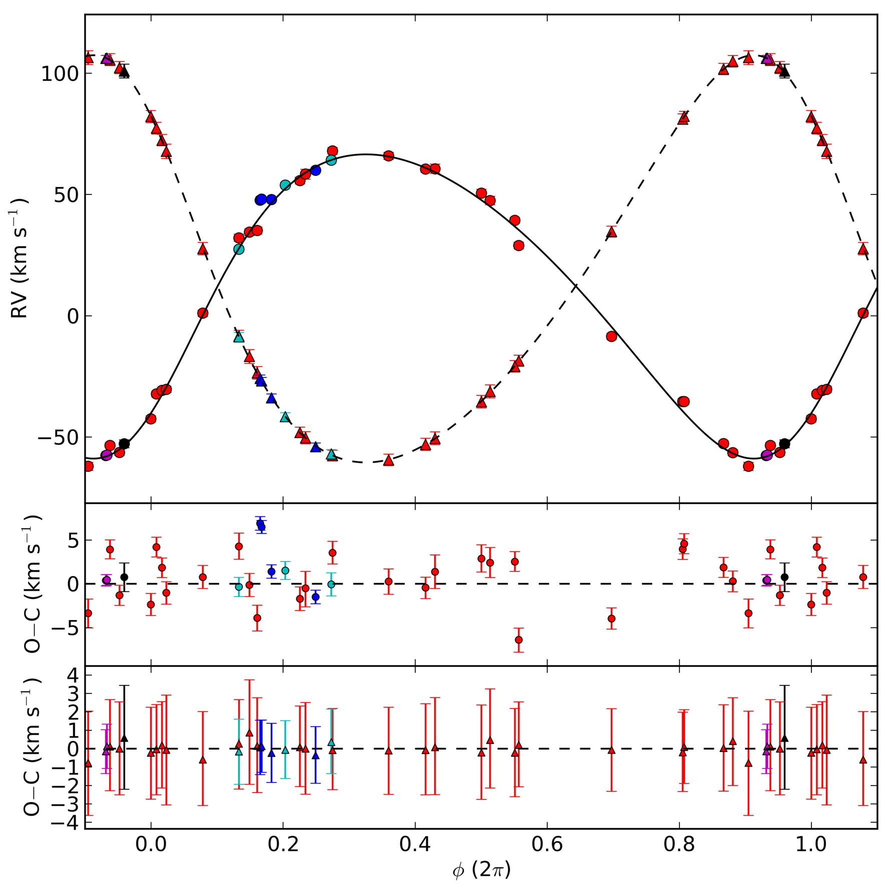
ABSTRACT

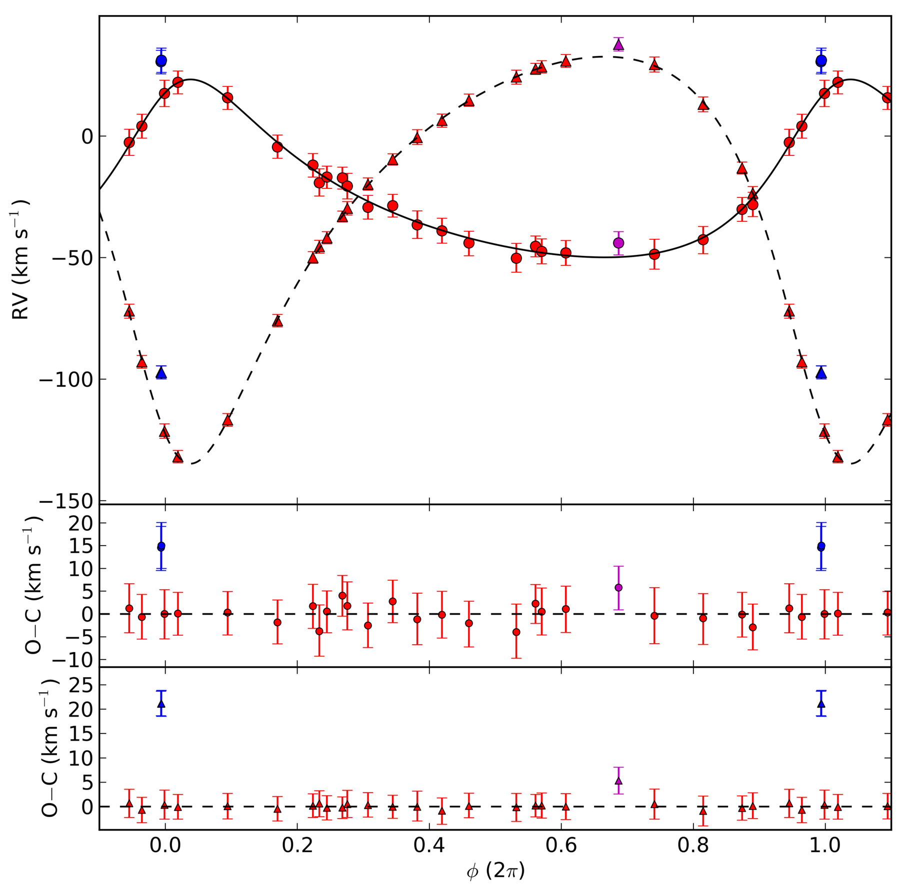
Models of stellar structure and evolution are cornerstones of many research fields in astrophysics, thus the calibration of these models is of high importance. ***Asteroseismology*** – the detection and interpretation of waves propagating through different layers of stars – provides the tools to study the interiors of stars with different masses and for most stages of stellar evolution. Comparing theoretical pulsation frequencies of stars computed using state-of-the-art pulsation codes and stellar evolution models with those of observed modes can not only deliver strict constraints on the fundamental parameters and on the structure of the studied objects, but discrepancies between models and observations can also point out shortcomings in the physics included in the model, or point towards a lack of knowledge concerning the target (e.g., presence of unknown magnetic field).

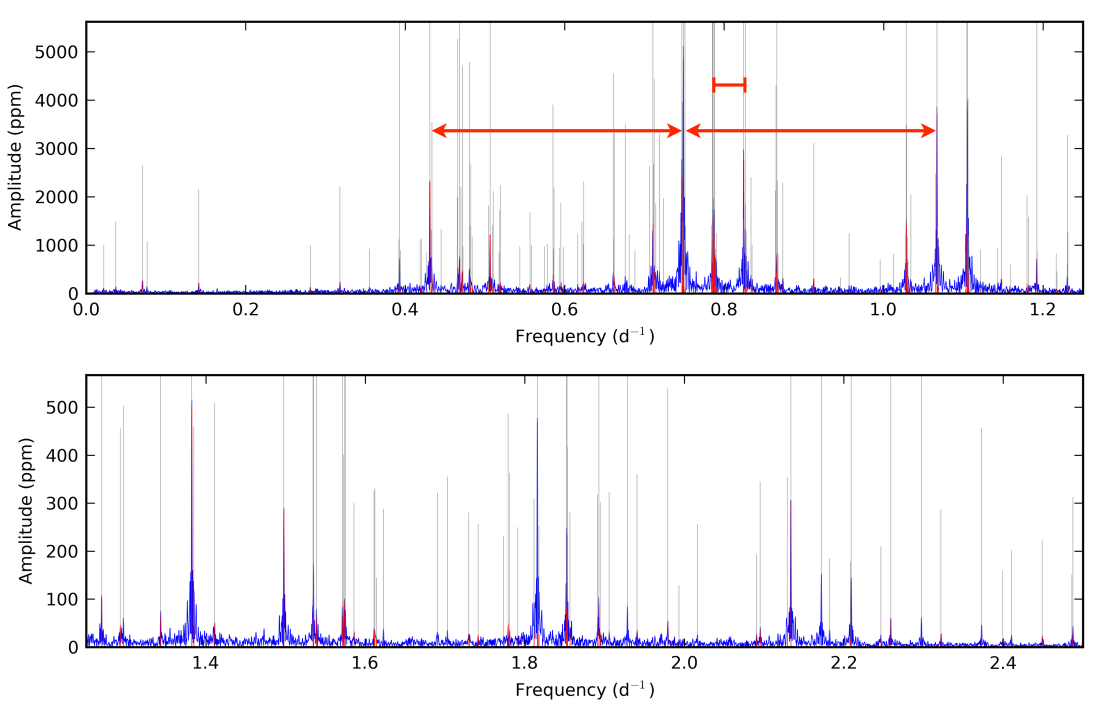
Main sequence B-type stars are massive and hot stars, playing an important role in the evolution of the Universe. They have a convective core and a radiative envelope, which means that for a full physical description of their structure and evolution, internal processes like core overshooting and rotation need to be included. These effects are poorly known, and a better precision can be reached through comprehensive seismic studies. However, up till now, the number of such studies detailed enough to provide feedback on current models is too limited.

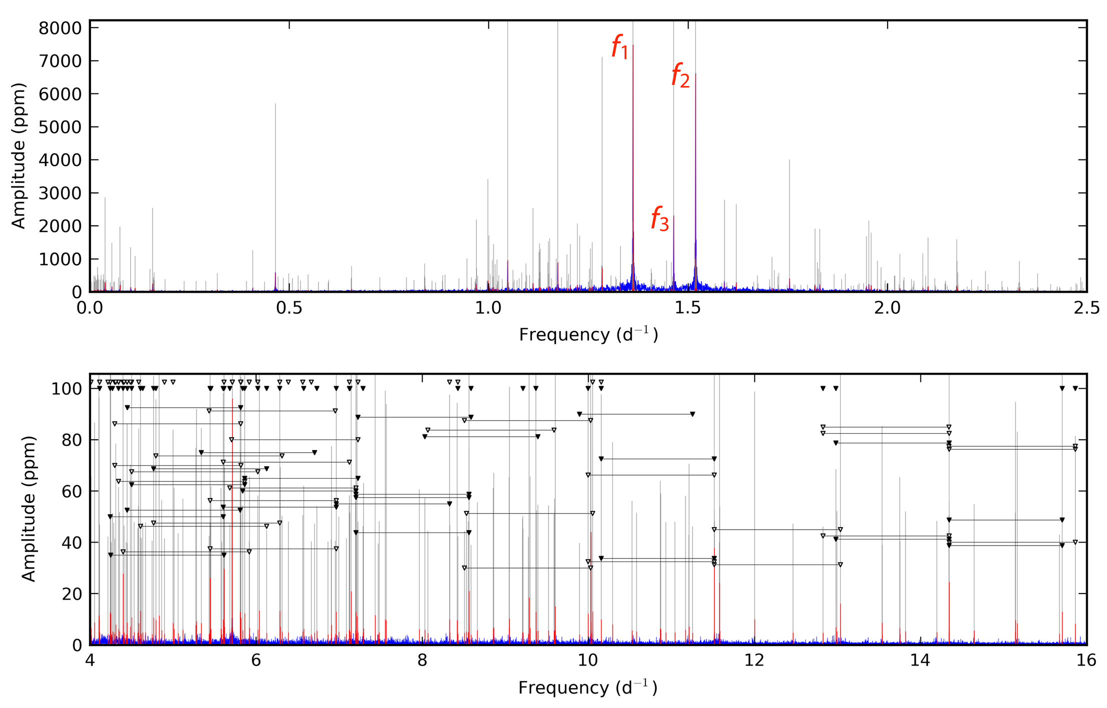
We have obtained *Kepler* Guest Observer (GO) time for 8 carefully selected main sequence B-type stars. We present here the results of the first detailed analysis of such stars based on more than three years of *Kepler* photometry and follow-up spectroscopy. We discovered two objects from our GO sample to be eccentric double-lined spectroscopic binary systems containing a total of three main sequence B-type stars (and one F-type component). We found pulsations excited by different mechanisms in the primary components.



Figures: *(Upper panel)* Spectroscopic orbital solution for KIC 4931738 *(left)* and KIC 6352430 *(right)* (solid line: primary, dashed line: secondary) and the measured radial velocities. Filled circles indicate measurements of the primary, filled triangles denote measurements of the secondary component using HERMES (red markers), FIES (blue markers), HAMILTON (cyan markers), ARCES (magenta markers), and ISIS (black markers). For KIC 6352430 *(right)*, HERMES measurements from 2011 and 2010 are plotted with magenta and blue markers, respectively. *(Middle panel)* Residuals of the primary component. *(Lower panel)* Residuals of the secondary component.







Figures: Sections of the Scargle periodogram of the full *Kepler* light curve (blue solid line) of KIC 4931738 *(left)* and KIC 6352430 *(right)* showing a selected subset of significant frequencies (red vertical lines). For better visibility, the red lines are repeated in grey in the background, after multiplying their amplitude with a factor ten, and the signal from outside the plotted ranges is prewhitened for each panel. The periodogram of KIC 4931738 *(left)* shows large amplitude peak regions and dense groups of peaks separated by two characteristic spacing values (shown with red markings). Peaks in the regions above 1.25 d^{-1} are low order combinations of peaks which can be found in the regions below 1.25 d^{-1}. The higher frequency region of the periodogram of KIC 6352430 *(right, lower panel)* shows spacing values connected to the three dominant *g* modes around 1.5 d^{-1}, in a way that many peaks are separated by frequency values equal to f_2-f_1, f_3-f_1, f_1, and f_2.

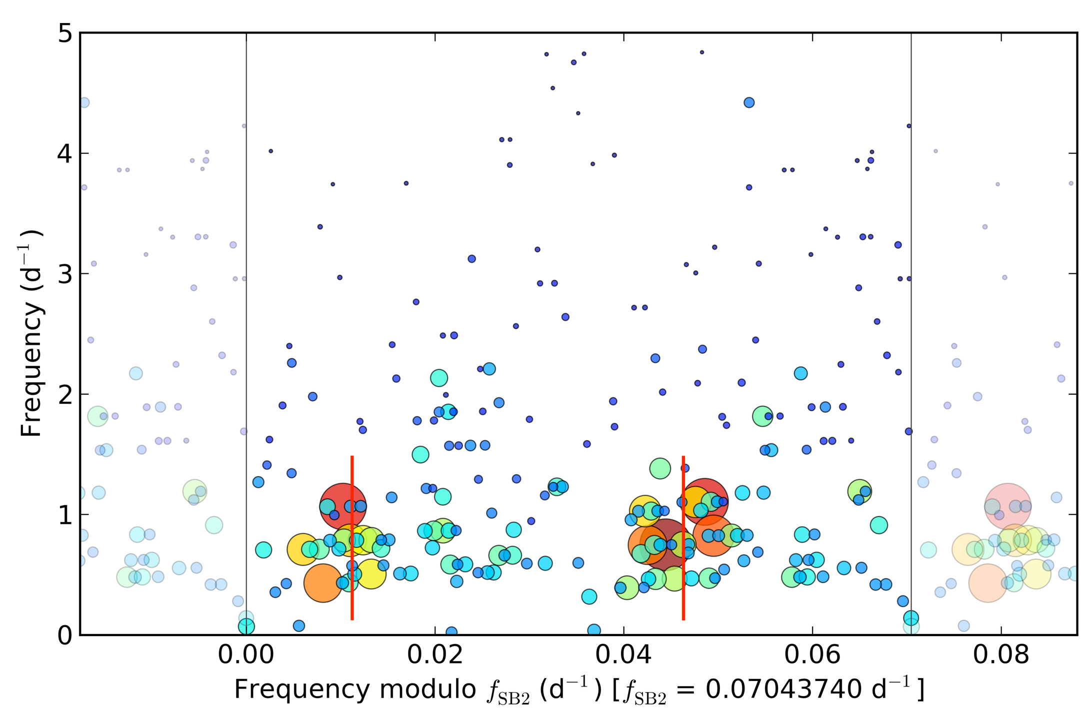


Figure: Échelle diagram of a selected subset of significant frequencies in the frequency analysis of KIC 4931738 shown between 0 and 5 d^{-1} calculated using the binary orbital frequency (f_{SB2}). Size and colour of the symbols are connected with the amplitude of the peaks (larger symbol and colour from blue to red is higher amplitude). The dominant independent modes below 1.25 d^{-1} lie along two ridges (red vertical lines), which are at 1/6 and 4/6 of the orbital frequency. Assuming a rotation frequency of $f_{\mathrm{rot}} = (7/6) f_{\mathrm{SB2}}$ all these peaks can be explained as tidally excited modes with *m* values of +1 and -2 (since the tidal forcing potential can be written as $f_{\mathrm{T}} = k f_{\mathrm{SB2}} + m f_{\mathrm{rot}}$).

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METHODS

We fit Keplerian orbits to radial velocities measured from selected absorption lines of high-resolution spectroscopy (from HERMES, FIES, HAMILTON, ARCES, and ISIS) using synthetic composite spectra to obtain orbital solutions. We applied spectral disentangling in the Fourier space and used spectral synthesis to derive fundamental parameters and abundances. We used revised masks to obtain optimal light curves from the original pixel-data from the *Kepler* satellite, which provided better long-term stability compared to the pipeline-processed light curves. We used various time-series analysis tools, to explore and describe the nature of variations present in the light curve.

KIC 4931738

The analysis of the disentangled spectra revealed that the binary consists of **two slowly rotating main sequence components**, a **B6 V primary** and a **B8.5 V secondary**. The radial velocity curves provided an orbital solution with a **period of 14.197 ± 0.002 d** and an **eccentricity of 0.191 ± 0.001**. The Fourier spectrum of the light curve is extremely structured, and the evaluation of different possible explanations led us to conclude that the observed brightness variations are related to **tidally excited *g* modes in the primary component**. Such an excitation mechanism is expected from theory but has only been observed in a few un-evolved main-sequence binaries before.

KIC 6352430

A similar analysis revealed two main sequence components (and probably a third body which is not visible in the spectra), **a moderate rotator B7 V primary** and a **slow rotator F2.5 V secondary** (with less than 10% contribution to the total light), with an orbital **period of 26.55 ± 0.02 d** and an **eccentricity of 0.370 ± 0.003**. We have detected ***g* mode pulsations typical for SPBs in the primary component, but also a rich spectrum of modes in the *p* mode region, which is atypical for stars at such low temperatures**. The high number of combination frequencies, and spacings connected to the frequency values of the dominant *g* modes suggest that the presence of these modes is **due to nonlinear resonant excitation by the dominant *g* modes**. Such excitation was never seen before in SPB stars and awaits theoretical verification and interpretation.

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