Asteroseismology of the Red-giant Hosts KOI-3886 and ι Draconis

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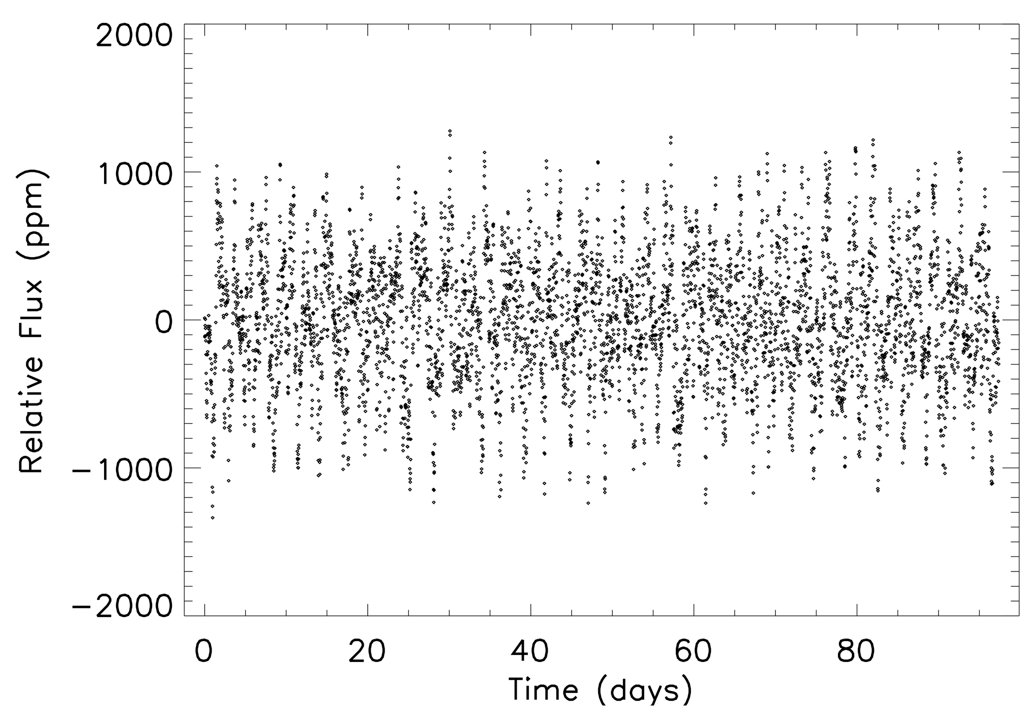
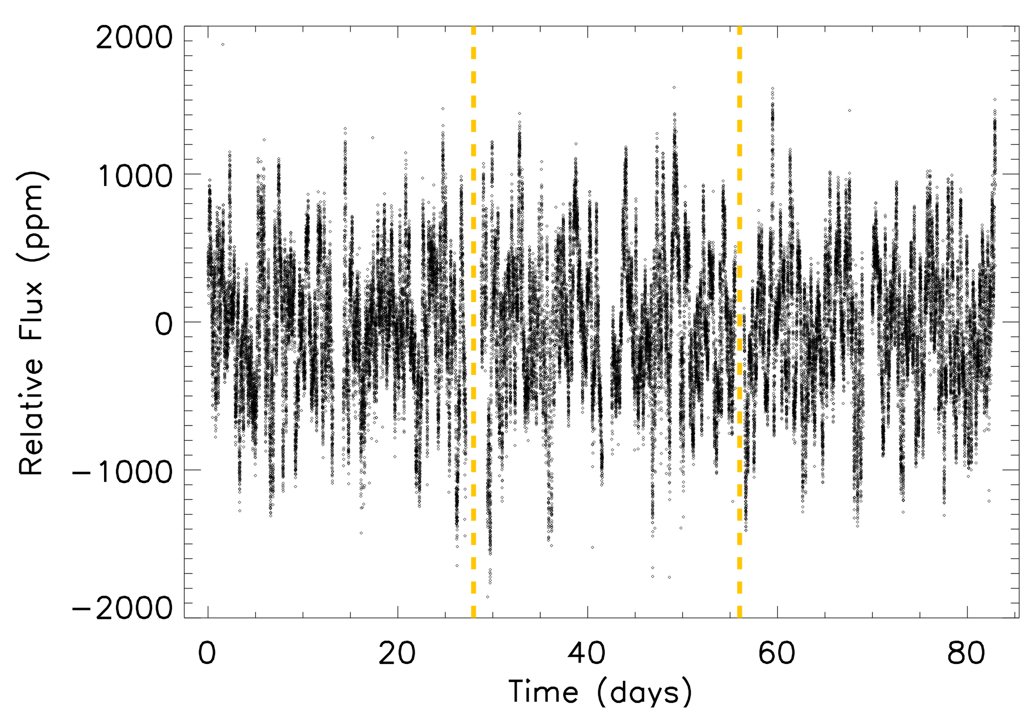
Abstract

Kepler asteroseismology has played an important role in the characterization of host stars and their planetary systems. Target selection biases, however, meant that this synergy would remain mostly confined to main-sequence stars. The advent of *TESS* has since lifted this restriction, enabling the systematic search for transiting planets around seismic giants, as well as revisiting previously known evolved hosts (mostly in radial-velocity systems) using asteroseismology.

Here, we present the detailed asteroseismology of two high-luminosity red-giant branch hosts, KOI-3886 and ι Draconis. KOI-3886, observed by *Kepler* over 4 years and later by *TESS* over 1 sector (27.4 days), has been a longtime candidate host [1]. ι Dra, observed by *TESS* over 5 sectors, hosts a planet (ι Dra b) in a highly eccentric ~511-day-period orbit [2].

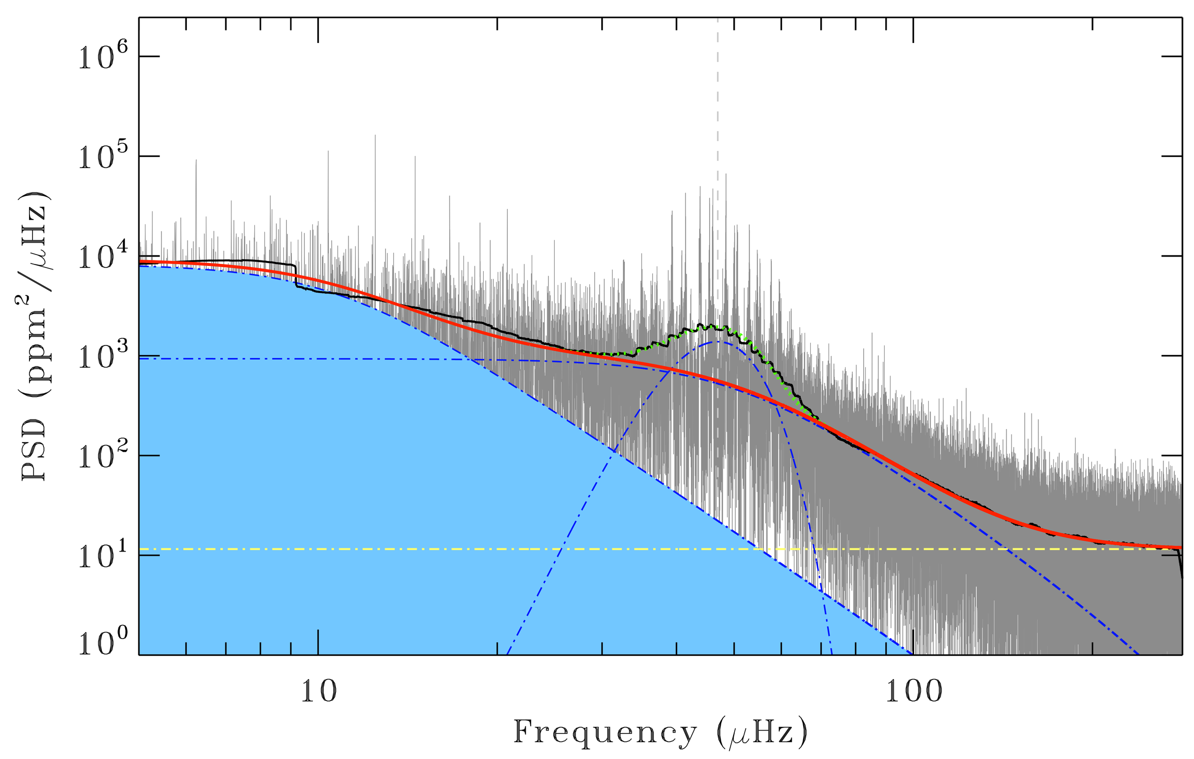
Photometry

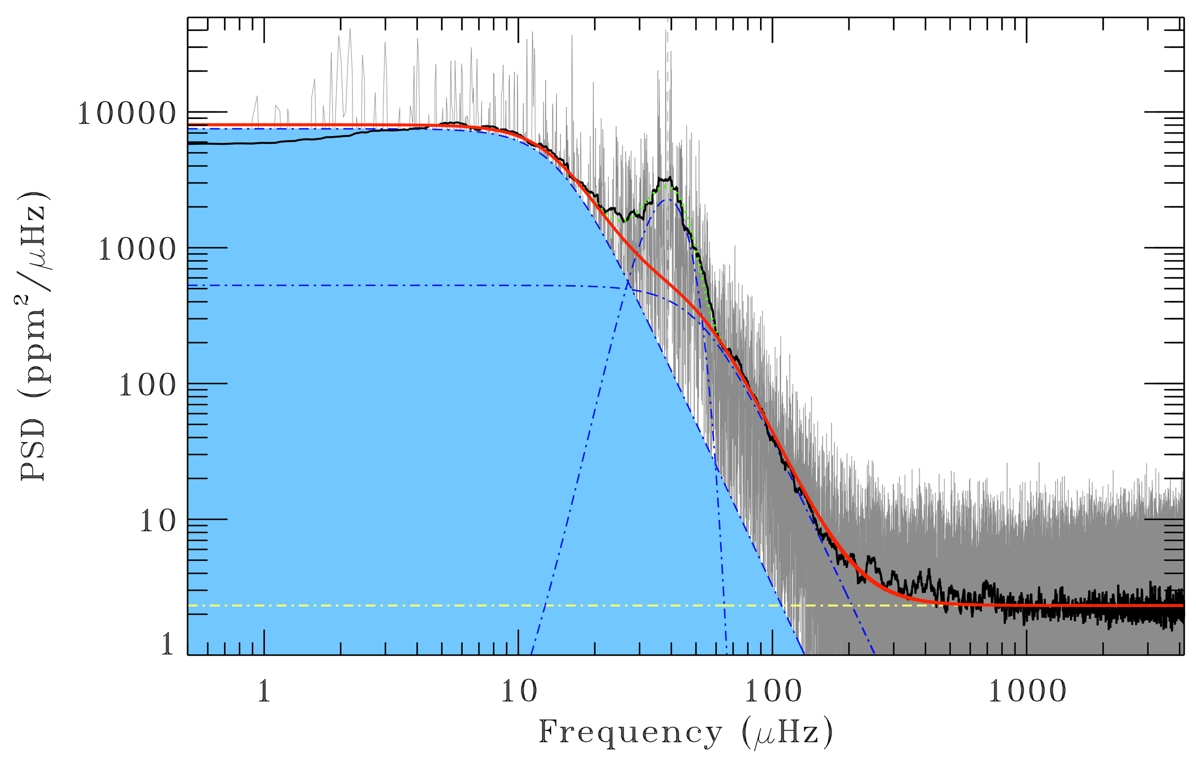




The top panel shows a segment (Quarter 9) of the long-cadence *Kepler* light curve of KOI-3886, optimized for asteroseismology [3]. The bottom panel shows a segment (Sectors 22–24) of the *TESS* light curve of ι Dra, acquired at a 2-minute cadence. To deal with the latter target's saturated nature, a large custom aperture had to be adopted [4].

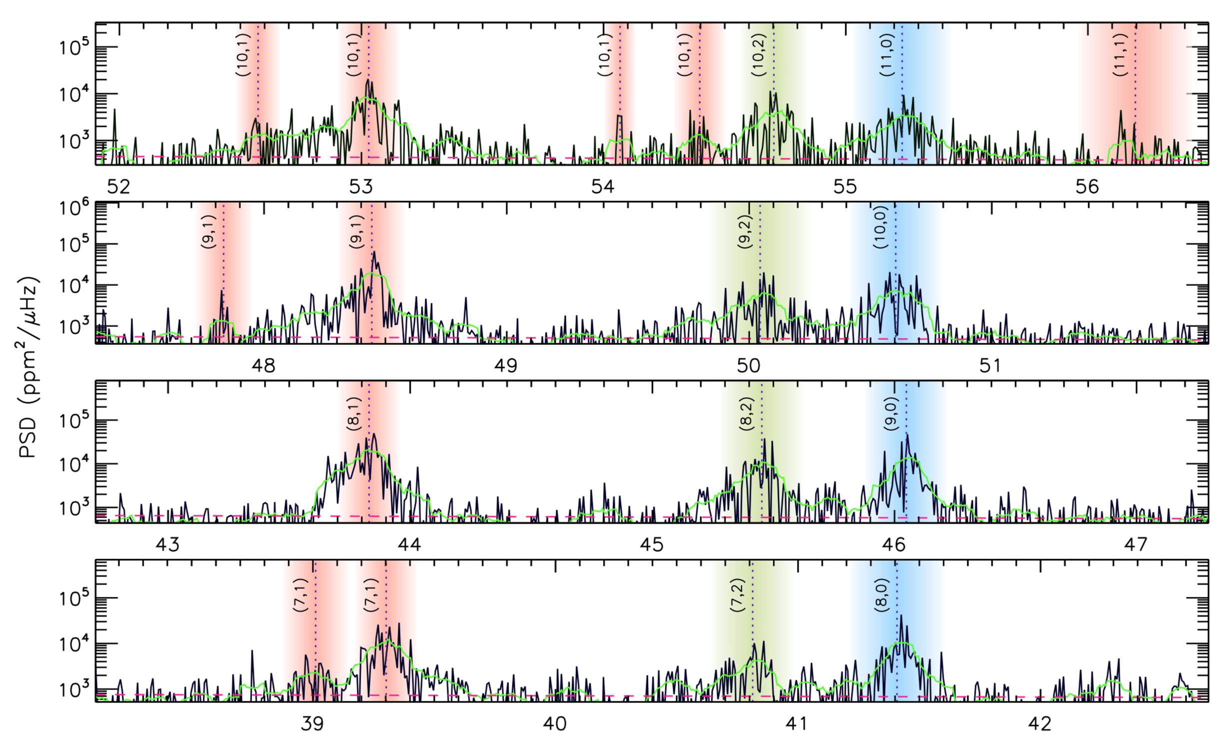
Global Oscillation Parameters





Power spectral density (PSD) of KOI-3886 (left) and ι Dra (right). Power spectra are shown in gray (smoothed version in black). Solid red curves are fits to the background [5], consisting of two Harvey-like profiles (blue dot-dashed curves) and a white noise offset (yellow dot-dashed line). Solar-like oscillations can be seen at $\sim 50\,\mu$Hz and $\sim 40\,\mu$Hz, respectively. We measured the large frequency separation, $\Delta\nu$, and the frequency of maximum oscillation amplitude, $\nu_{\rm max}$, using a range of automated methods [6]. Consolidated values for KOI-3886 (ι Dra) are $\Delta\nu = 4.60 \pm 0.20\,\mu$Hz and $\nu_{\rm max} = 46.9 \pm 0.3\,\mu$Hz ($\Delta\nu = 4.02 \pm 0.02\,\mu$Hz and $\nu_{\rm max} = 38.4 \pm 0.5\,\mu$Hz).

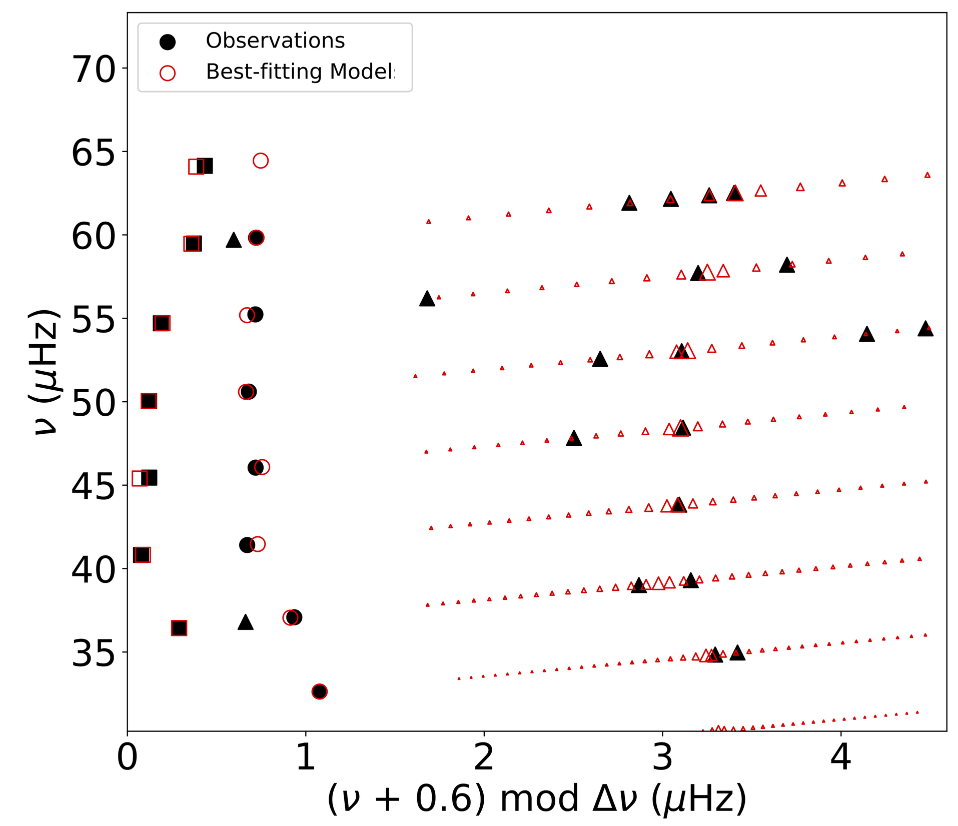
Individual Mode Frequencies



We extracted individual mode frequencies from the the power spectrum of each star using the FAMED pipeline [7]. A total of 34 (23) modes of angular degree $\ell = 0$, 1, 2, and 3 were extracted across 8 (7) radial orders for KOI-3886 (ι Dra).

The outcome of the *peak-bagging* process is shown above for the four central radial orders of KOI-3886. The green curve is a smoothing of the power density by an amount equivalent to the average radial-mode linewidth found by FAMED. The sloping dashed line represents the local background. Extracted individual mode frequencies are tagged according to their pressure radial order ($n_{\rm p}$) and angular degree (ℓ), with color bands indicating their 3σ uncertainties.

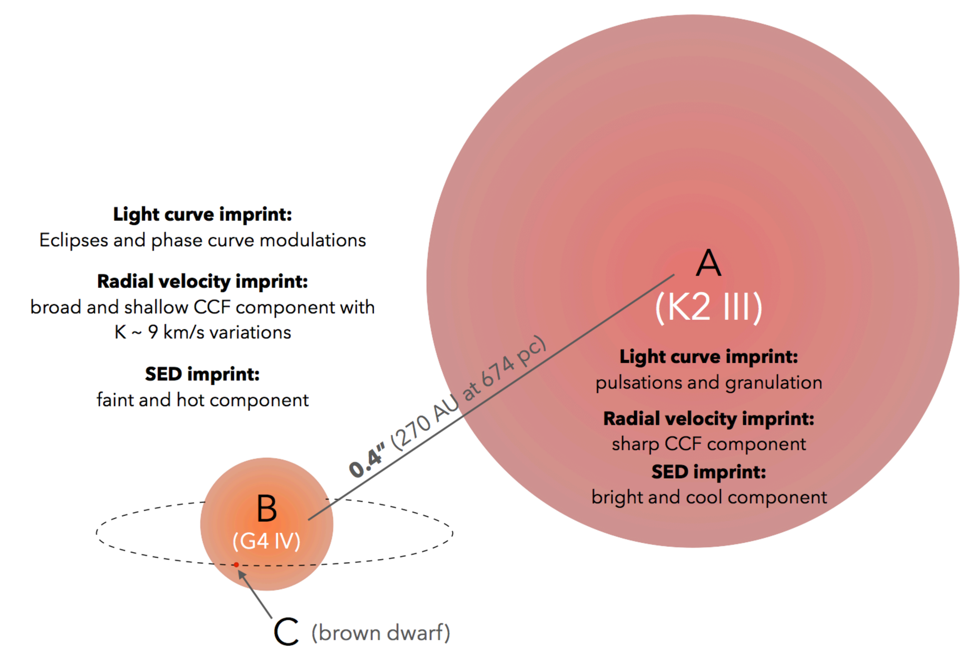
Detailed Modeling



A grid-based inference procedure was used to determine the fundamental stellar properties. It consisted in fitting the individual mode frequencies, along with a set of classical constraints, following the approach of [8], without considering interpolation.

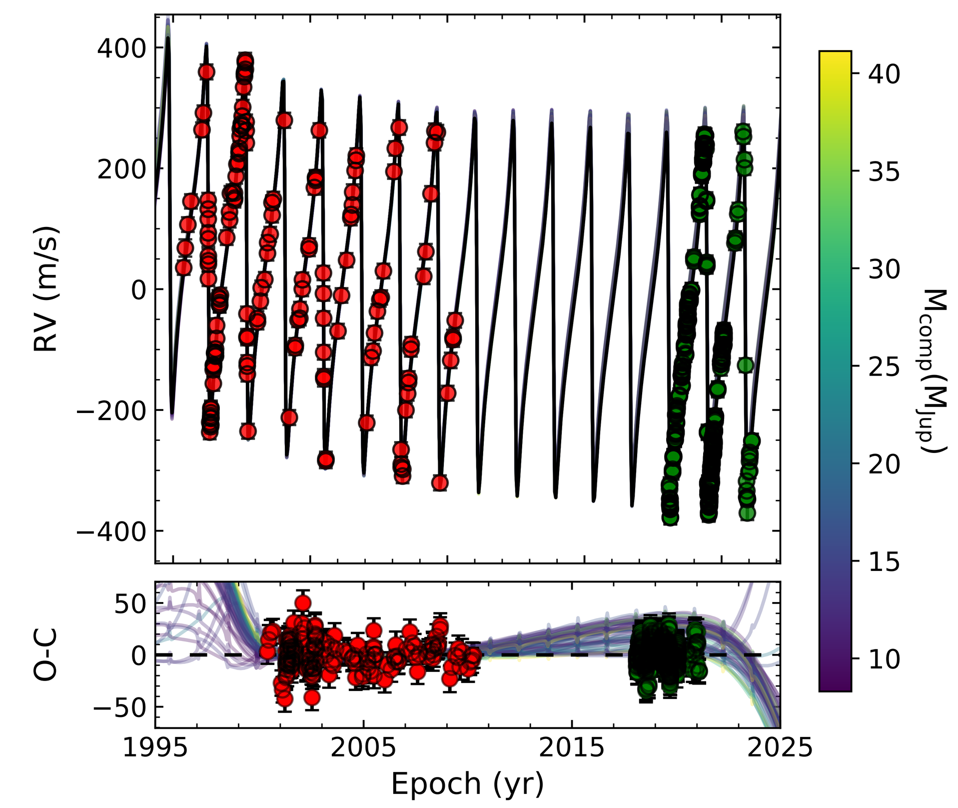
The échelle diagram displays the observed frequencies and the model frequencies corresponding to a representative best-fitting model of KOI-3886. Circles, triangles, and squares indicate modes of angular degree $\ell = 0$ (radial), $\ell = 1$ (dipole), and $\ell = 2$ (quadrupole), respectively. We plotted a range of g-dominated $\ell = 1$ model frequencies per order (with symbol size scaled as $I^{-0.5}$, I being the mode inertia).

A Planet Impostor



Asteroseismology, together with a set of follow-up observations and light curve analyses, helped reveal the planet candidate around KOI-3886 (A component) as a false positive and reinterpreting the system as an eclipsing brown dwarf in a hierarchical triple [9].

An Elusive Companion



The precise (~6%) seismic mass derived for ι Dra was used to enhance the precision of the known planet's parameters [4]. Moreover, the combination of continued radial-velocity (RV) monitoring with *Hipparcos* and *Gaia* astrometry led to the detection of an additional long-period companion, its mass estimate lying on the border of the planet and brown dwarf regimes.

References

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