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Amplitude Modulation in the δ Sct star KIC 7106205

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Abstract. The δ Sct star KIC 7106205 showed amplitude modulation in a single p mode, whilst all other p and g modes remained stable in amplitude and phase over 1470 d of the *Kepler* dataset. The data were divided into 30 time bins of equal length and a series of consecutive Fourier transforms was calculated. A fixed frequency, calculated from a least-squares fit of all data, allowed amplitude and phase for every mode in each time bin to be tracked. The missing p mode energy was not transferred to any other visible modes.

1 Introduction

The CoRoT and *Kepler* space missions have facilitated a dramatic improvement in our understanding of the mechanisms that drive pulsations in A and F variable stars, i.e. the δ Sct and γ Dor stars. Hybrid stars exhibit pulsation frequencies in both the δ Sct ($\nu > 5\,\mathrm{d}^{-1}$) and γ Dor ($\nu < 4\,\mathrm{d}^{-1}$) regimes [6] and are ideal test candidates to study pulsation energy conservation between p and g modes. If the visible pulsation energy is conserved, then an increase in amplitude of one mode would coincide with the decrease of another and vice versa. Therefore, mode energy that is not observed to be transferred to another mode, could have been lost to a damping region or due to nonlinear effects [1].

The parameters for KIC 7106205 in the *Kepler* Input Catalogue [4] are $T_{\mathrm{eff}} = 6960 \pm 150\,\mathrm{K}$ and $\log g = 4.05 \pm 0.15$, which characterises it as an early F-type star and places it inside both the δ Sct and γ Dor instability regions in the HR diagram – the ideal location for hybrid behaviour.

Theoretical models predict mode coupling in δ Sct stars, specifically, a parametric resonance condition, $\nu_1 \approx \nu_2 + \nu_3$, predicts that the instability of a linearly driven mode at ν_1 causes the growth of two modes at ν_2 and ν_3 [5]. The decay of a linearly driven p mode into two g modes is most likely, as they usually have low radial orders [5]. The δ Sct star 4 CVn showed pulsation modes that changed in amplitude and it was concluded that a mode coupling mechanism allowed energy to be transferred between different pulsation modes [2]. More recently, three families of coupled modes, consisting of two parent and one child modes, whose amplitude and frequency variations appeared correlated, were observed in the peculiar δ Sct star KIC 8054146 [3]. An analysis of all modes in KIC 7106205 showed a single modulated p mode whose energy was not transferred to any other visible modes [1].

2 Method and Results

To track amplitude and phase, a frequency was obtained by optimising the output from a Fourier transform using nonlinear least-squares for every mode. The data were divided into 30 bins and amplitude and phase were optimised using least-squares for a fixed frequency, respectively for each mode in each bin. The amplitude spectra using all data for KIC 7106205 for two pulsation modes (a stable pulsation mode at $\nu = 10.0324\,\mathrm{d}^{-1}$ and the only modulated mode at $\nu = 13.3942\,\mathrm{d}^{-1}$) are given in the top row of Fig. 1. Prewhitening with a single frequency was unable to remove the modulated mode due to the frequency and amplitude modulation exhibited over 1470 d. Plots of amplitude and phase values over 1470 d for the same two pulsation modes are given for comparison in the bottom row of Fig. 1.

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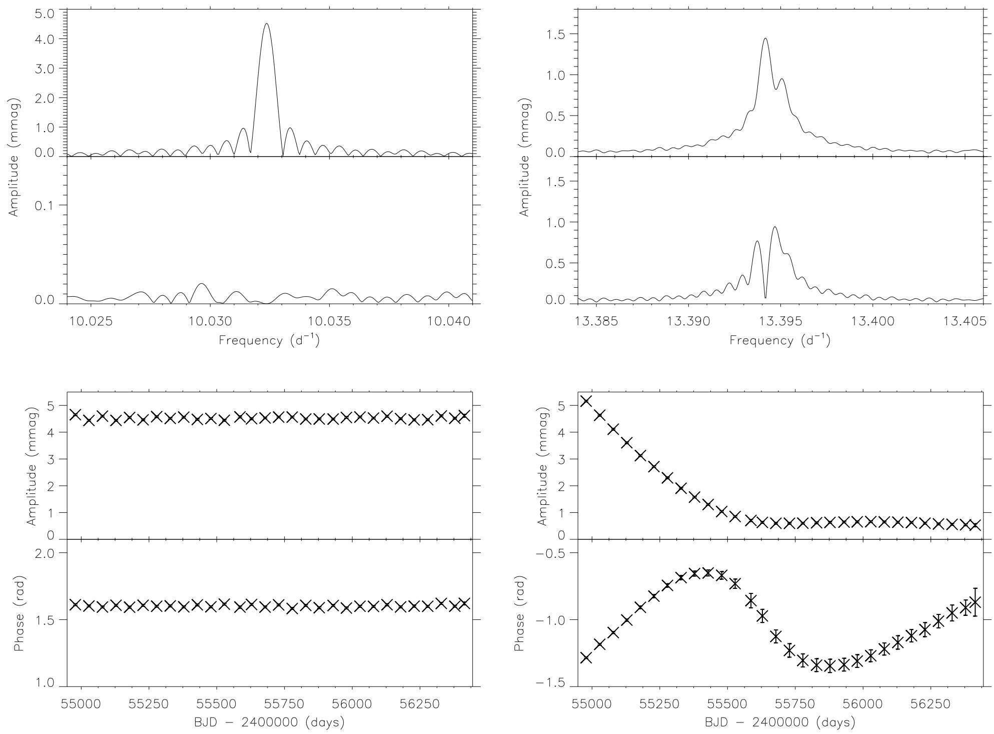

Fig. 1. The top left and top right panels show the amplitude spectrum for the strongest stable pulsation mode (ν = 10.0324 d^{-1}) and the only modulated pulsation mode (ν = 13.3942 d^{-1}) respectively, in which before and after prewhitening is shown. The bottom left and bottom right panels show the amplitude and phase tracked over 1470 d in 30 time bins (50 d in length) for the above pulsation modes respectively, in which the x-axis is the midpoint in time of each bin and 1σ uncertainties are plotted (generally smaller than the data points), which were calculated from the least-squares fit. Figures are from Bowman & Kurtz (2014, figures 2 and 4).

3 Conclusions

The visible pulsation energy was found not to be conserved within KIC 7106205, as all modes except ν = 13.3942 d^{-1}, were observed to be stable in frequency and amplitude [1]. A calculated pulsation constant of Q = 0.0168 d suggests that modulated mode is a third or fourth radial overtone mode, but since higher frequency p modes were observed to be stable, it is unlikely that the observed modulation affects only frequencies most sensitive to surface conditions. Mode coupling via the parametric resonance condition to high degree modes cannot be ruled out as these are invisible in broadband photometry. Therefore, it is concluded that both mode coupling to high degree modes and energy being lost to a damping region can explain the observed amplitude modulation [1]. Both possibilities are not mutually exclusive and so modelling studies are needed to address this problem.

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