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Amplitude ratios as mode characterizors in δ Scuti stars

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Abstract. Seismology of δ Scuti stars holds great potential for testing theories of stellar structure and evolution. The ratio of mode amplitudes in light and in equivalent width of spectral lines can be used for mode identification. However, the amplitude ratios (AR) predicted from theory are usually inconsistent with observations. We here present the first results from a campaign aimed at calibrating observationally the absolute values of the AR.

Key words.

1. Introduction

The δ Scuti stars are A–F non-radial pulsators located near the base of the classical instability strip. Despite huge efforts it has turned out to be very difficult to match the observed mode frequencies with calculated ones, due to the large set of poissible excited modes and the small subset of possible modes actually excited.

Photometric observations of amplitude ratios and phase differences have been used to try to resolve this mode identification problem (e.g. Garrido 2000; Paparó & Sterken 2000), but the results obtained so far are not unambiguous. A possible better discriminator is the ratio of mode amplitudes in light and in equivalent width of spectral lines, denoted $R\alpha$ for the Hα line versus V band photometry. This ratio has been explored by several authors (e.g. Viskum et al. 1998; Frandsen 2000; Dall et al. 2002, 2003). However, the interpretation is not straightforward: The amplitude ratios predicted from theory are usually inconsistent with observations as shown by Dall & Frandsen (2002).

For these reasons we have undertaken a large campaign to establish an empirical calibration of the amplitude ratios, observing stars with well characterized pulsation modes to map the relationships and dependencies on stellar parameters like rotation, evolutionary stage, spectral type, etc. The campaign has been concluded, and we present here a progress report with initial results for two stars; AI Vel (HD 69213, HIP 40330) and X Cae (HD 32846, γ^2 Cae, HIP 23596).

2. Observations and Data Analysis

The project sample consists of 16 δ Scuti stars, chosen to cover a broad range of amplitudes

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Table 1. Amplitudes measured for X Cae and AI Vel. Uncertainties on amplitudes are 2-3mmag for photometry and 5-8*promille* for spectroscopy.

	mode frequency [cd^{-1}]	A(B) [mmag]	A(V) [mmag]	A($\Lambda_{H\alpha}$) [promille]	Rα
X Cae	f_1 = 7.394	48.4	37.9	93.9	2.5
	f_2 = 6.036	13.5	9.9	30.8	3.1
AI Vel	f_1 = 8.9627	212.9	163.9	219.4	1.34
	f_2 = 11.5998	193.2	149.2	222.7	1.49

and to include both HADS and low-amplitude pulsators.

Photometry was collected with the 24-inch telescope at Siding Spring Observatory, Australia, while the spectroscopy was obtained with the Danish 1.54m telescope and DFOSC at the European Southern Observatorys La Silla site in Chile.

X Cae is a well studied δ Scuti star (Mantegazza & Poretti 1992, 1996; Mantegazza et al. 2000) showing a wealth of excited modes. Mantegazza et al. (2000) found 17 frequencies, of which a few showed amplitude variations between observing seasons. AI Vel is a well known HADS, that has been studied since the works of Walraven (1952, 1955). Walraven et al. (1992) found that neither of the two main modes had changed amplitude in 40 years.

Our data are too sparsely sampled to allow anything but the strongest modes to be confirmed in either star (Table 1). Our X Cae amplitudes of f_1 and f_2 agree very well with the findings of Mantegazza et al., supporting their conclusion that these two modes do not change amplitude.

3. Interpreting the Amplitude Ratios

Balmer lines have sensitivity similar to radial velocity measurements because of the strong limb darkening in these lines, while photometry has very weak center-to-limb variation. Thus the equivalent width of Balmer lines and the photometry show different response to spatial variations across the stellar disk (i.e. to the ℓ value), reflected in the amplitude ratio. Intuitively, we expect radial modes to have the lowest values of $R\alpha$ with higher-order modes having progressively higher ratios. Large variations from star to star may be expected due to the wide range of rotational velocities encountered in δ Scuti stars.

For BN Cnc (Dall et al. 2002) and FG Vir Viskum et al. (1998) we found amplitude ratios for the radial modes around $R \sim 0.5$. Looking at the results for X Cae and AI Vel we find that the strongest modes in these stars may actually be non-radial modes, contrary to previous findings — however, the analysis has not yet been completed.

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