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Asteroseismology of solar-type stars with Coralie and Harps

I: Observations and modelling of single stars

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Abstract. We present here the detection and characterization of solar-like oscillations in several targets such as β Vir, η Boo, δ Eri, χ Eri and the Am star HD 209625 obtained with the Coralie and Harps spectrographs based at the ESO La Silla Observatory. The measurement of the frequencies of p-mode oscillations provides an insight into the internal structure and is nowadays the most powerful constraint on the theory of stellar evolution.

Key words. Stars: fundamental parameters – Stars: oscillations – Stars: evolution

1. Asteroseismology with Coralie

Campaigns on solar-like stars were conducted with the spectrograph Coralie mounted on the 1.2-m Swiss telescope at the ESO La Silla Observatory (Chile) in order to characterize solar-like oscillations (see Fig. 1). Between 800 and 2000 radial velocity measurements were commonly obtained for typical periods of about 12-14 nights (Carrier et al. 2001; Bouchy & Carrier 2002; Carrier & Bourban 2003; Eggenberger et al. 2004). The power spectra of four recent stars clearly present several identifiable peaks (see Fig. 2).

Oscillation modes are present between 400 and 1000 μHz in the power spectrum of η Boo, showing regularity with a large and small separation of $\Delta\nu = 39.9\,\mu$Hz and $\delta\nu_{02} = 3.95\,\mu$Hz respectively (Carrier et al. 2005a). Detailed models were computed using the Geneva evolution code including shellular rotation and atomic diffusion. We determine the following global parameters for η Boo: a mass of $1.57 \pm 0.07\,M_{\odot}$, an age $t = 2.67 \pm 0.10$ Gyr and an initial metallicity $(Z/X)_{\rm i} = 0.0391 \pm 0.0070$.

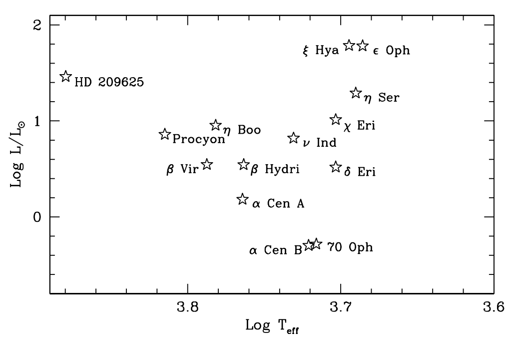

Fig. 1. Representation in the HR diagram of the solar-type seismic targets observed up to now by our team with the spectrographs Coralie and Harps (HD 209625 and 70 Oph).

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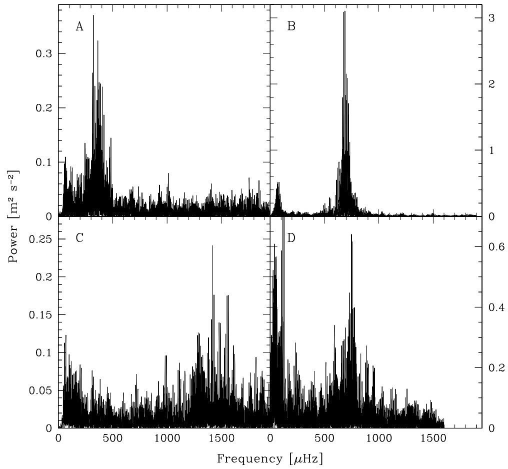

Fig. 2. Power spectra of the radial velocity measurements of χ Eri **(A)**, δ Eri **(B)**, β Vir **(C)** and η Boo **(D)**.

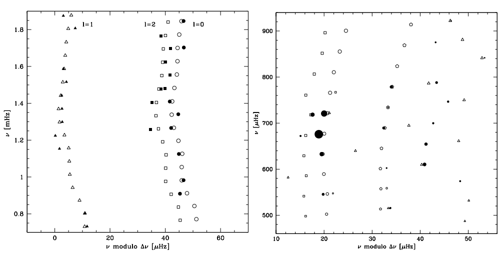

Fig. 3. Echelle diagram of extracted p-modes for β Vir (left) and δ Eri (right). Open symbols refer to theoretical frequencies, while filled circles correspond to the observed frequencies.

Twenty-seven oscillation frequencies have been identified for β Vir between 700 and 1900 μHz with mean large and small separations of 72.1 and 6.3 μHz respectively (Carrier et al. 2005b). Using the Geneva evolution code including rotation and atomic diffusion, we find that two distinct solutions well reproduce all existing observational constraints: a main-sequence model with a mass of $1.28 \pm 0.03\, M_{\odot}$ and an age $t = 3.24 \pm 0.20$ Gyr (see Fig. 3), or a model in the post-main sequence phase of evolution with a lower mass of $1.21 \pm 0.02\, M_{\odot}$ and an age $t = 4.01 \pm 0.30$ Gyr. For both models, the initial rotational velocity $V_{\rm i}$ and metallicity $(Z/X)_{\rm i}$ are $18\,{\rm km\,s^{-1}}$ and 0.0340 ± 0.0040 respectively.

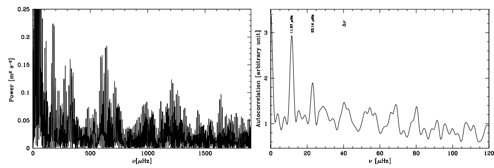

Fig. 4. Power spectrum of the radial velocity measurements of HD 209625 and its autocorrelation. The noise at low frequency in the power spectrum is mainly due to the binarity of the star (SB1).

The power spectrum of the velocity time series of δ Eri clearly shows several identifiable peaks between 500 and 900 μHz with an average large splitting of 43.8 μHz.

χ Eri shows oscillation modes between 200 and 600 μHz showing a regularity with a large separation of about 19.6 μHz.

2. The Am star HD 209625

In order to constrain the structure of hot metallic Am stars, four half-nights were allocated on Harps to search for solar-like oscillations in the Am star HD 209625. Indeed, stellar models including detailed treatement of radiative diffusion predict the existence of a convection zone close to the surface, coherent with the observed surface abundances anomalies of Am stars; this convection zone may be able to drive solar-like oscillations. In the power spectrum, we can see a power excess near 0.6 mHz, which could be due to solar-like oscillations revealing the presence of the convection zone. In this case, the large spacing would be about 40 μHz (see Fig 4), in agreement with our expectations.

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