HD49385: A cool solar-like target observed by CoRoT *

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Abstract

One of the goals of space mission CoRoT is to achieve a better knowledge of solar-like pulsating stars by a very high level characterization of their oscillations. Recently, the CoRoT data obtained on solar-like pulsators significantly hotter than the Sun have been discussed in [Michel et al.(2008)] and [Appourchaux et al.(2008)]. HD 49385 is a G type star presenting solar-like oscillations, and with a cooler temperature, closer to that of our Sun, though apparently in a more advanced stage of evolution. We present the results derived from a preliminary analysis of the CoRoT data obtained on this star. We performed a global fitting of the modes, based on a Maximum Likelihood Estimation of the power spectrum. A very high SNR combined with a long period of almost uninterrupted data (137 days) allowed us to obtain precise estimates of the frequencies, amplitudes and linewidths of the modes.

Stellar parameters

We adopted the following stellar parameters for HD 49385:

- $T_{\rm eff}$ = 6117 ± 62 K (IR SED, from the CorotSky database, [Charpinet et al.(2006)])
- $\log(L/L_\odot)$ = 0.63 ± 0.06 based on a Hipparcos parallax of π = 14.35 ± 1.02 mas and an absolute magnitude of m = 7.39 (*uvby* catalogue Hauck & Mermilliod 1998)
- [Fe/H] = 0.21 dex ([Nordström et al.(2004)])

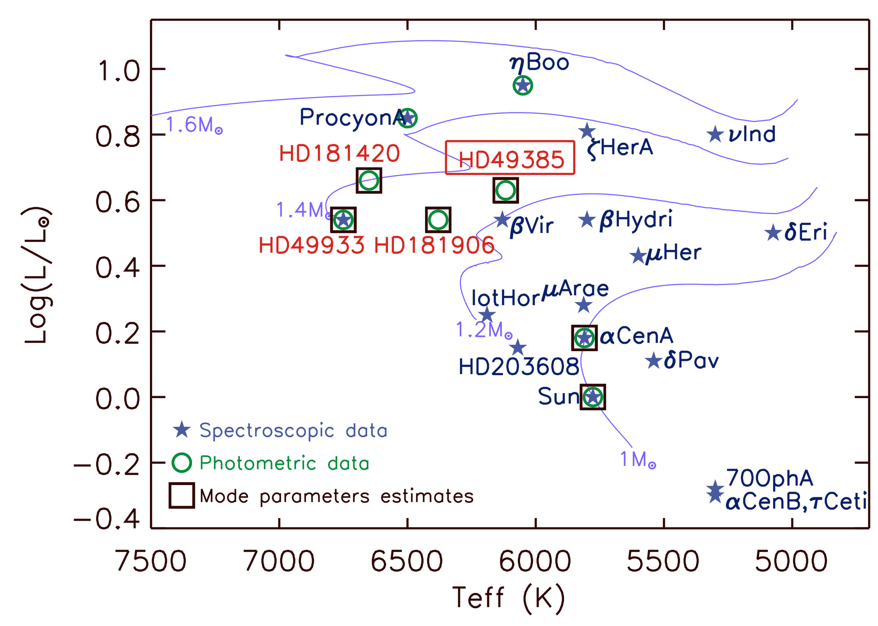

Figure 1: HR diagram featuring stars with detected solar-like oscillations. Blue stars: spectroscopic observations. Green circles: photometric observations. Black squares: stars with p-modes parameters estimates. Stellar evolutionary tracks are taken from Lebreton et al.(2008) for solar chemical composition. CoRoT targets that has been analysed so far are in red.

Time series

Fig. 2 shows the lightcurve obtained after a 137-day-run on HD 49385 (long run LRa01). It was detrended using instrumental information, and the multiples of the orbital frequency of CoRoT were removed. 3 days of data are missing from day 92 to day 95 of the run. In the present study, gaps were linearly interpolated.

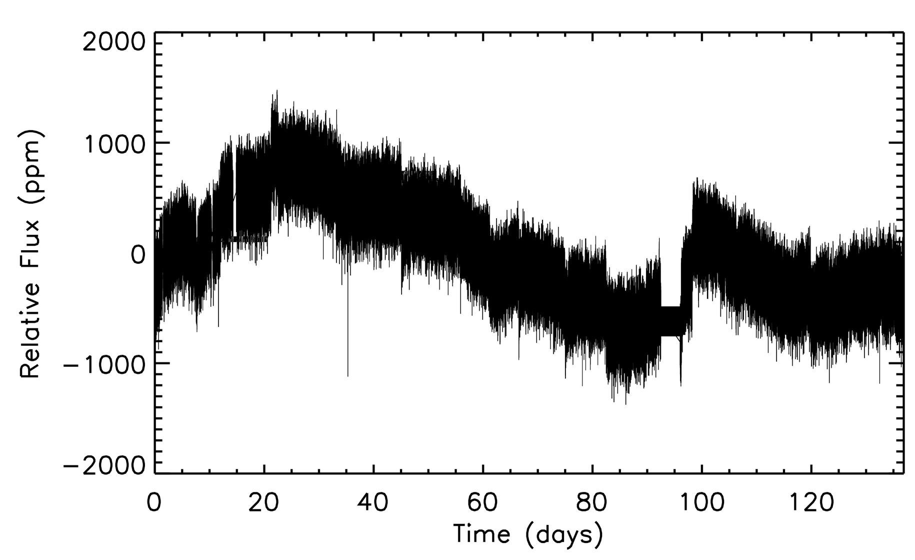

Figure 2: CoRoT lightcurve of HD 49385.

Power spectrum

The power spectrum of the time series was computed using the FFT algorithm. The signature of oscillations can clearly be seen on the power spectrum (see Fig. 3).

No clear signature of the rotation period of HD 49385 can be detected in the lightcurve or the power spectrum.

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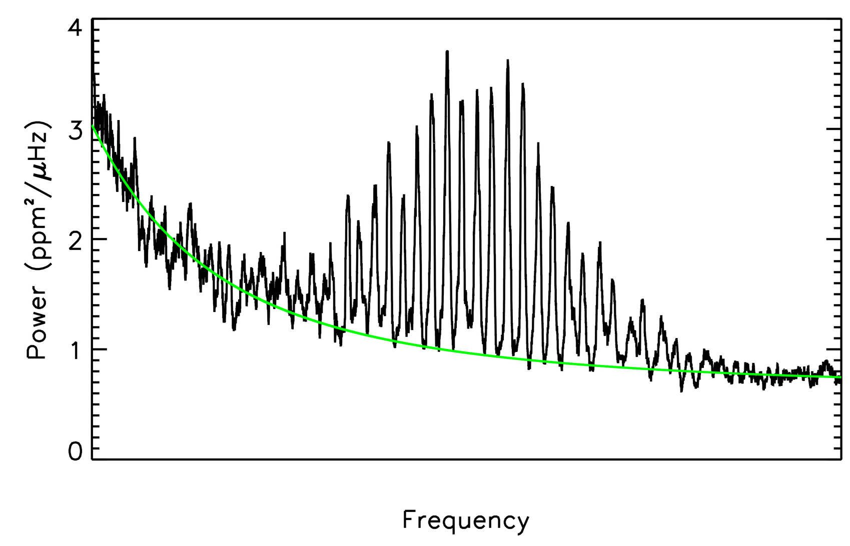

Figure 3: Smoothed power spectrum (with a 10-μHz boxcar) of HD 49385 in the frequency range of the solar-like oscillations. The green curve corresponds to the stellar noise.

An obvious identification of the modes !

The autocorrelation of the power spectrum over the frequency range of the p-modes gives a very precise estimate of the large spacing $\Delta\nu$. The power spectrum is piled up in sections of width $\Delta\nu$, providing the échelle diagram shown in Fig. 4. Two very clear ridges appear, as well as a fainter one. The identification of the modes is here obvious: we recognize the $\ell = 0$ and $\ell = 2$ ridges on the left of the diagram, and the $\ell = 1$ ridge on the right.

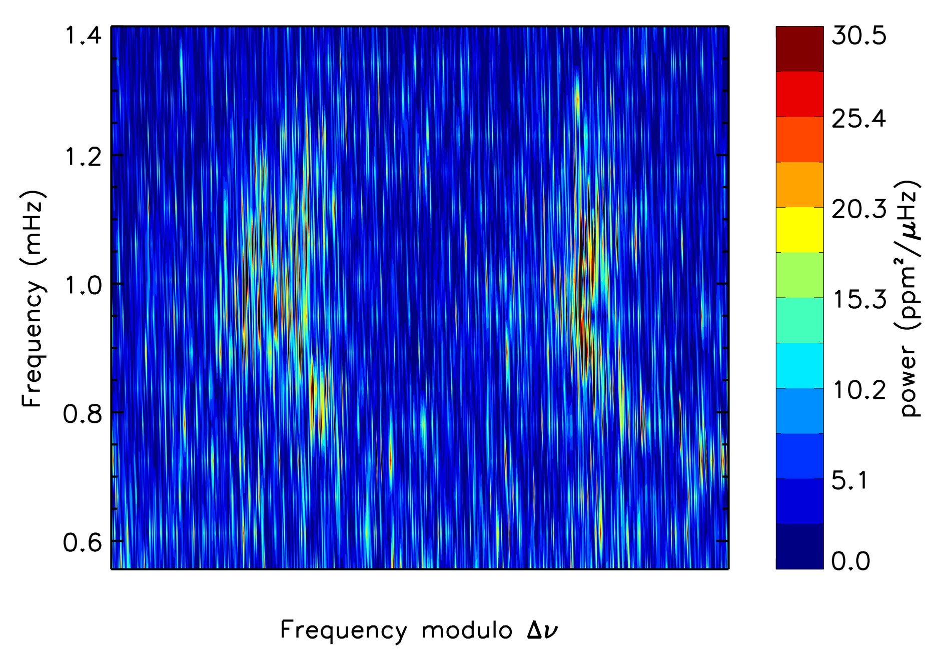

Figure 4: Échelle diagram of HD 49385

Extraction of mode parameters

We extracted mode parameters fitting Lorentzian profiles on the power spectrum (Maximum Likelihood Estimation, see [Duvall & Harvey(1986)]). Modes were first fitted on $\Delta\nu$-wide windows of the power spectrum (Fig. 5). The result of these fits gave us a first guess for a *global* fitting, for which 8 orders were fitted simultaneously.

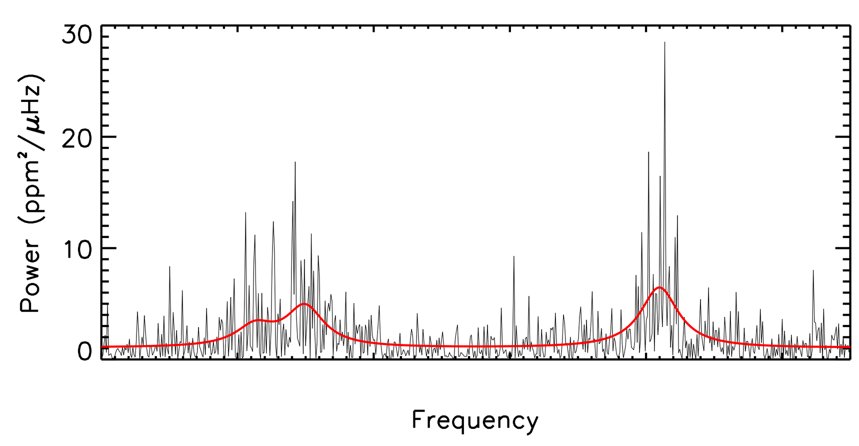

Figure 5: Power spectrum of HD 49385 on one overtone, with a superimposed Lorentzian fit (red curve).

Results of the fit

The fit we performed leads to the conclusion that we cannot resolve the different components of the multiplets. This can be explained by:

- either a **small inclination angle**, for which only the $m = 0$ component can be seen,
- or a value of the splitting which is small compared to the linewidth of the modes (possible only with a **large inclination angle**, see Table 1).

These two scenarios lead to almost identical mode frequencies, linewidths and amplitudes.

	i	v	T	ν_s
Case 1	$< 10°$	> 43 km s^{-1}	< 2.4 j	$> 5\mu$Hz
Case 2	$> 60°$	< 9 km s^{-1}	> 11.6 j	$< 1\mu$Hz

Table 1: Inclination angle, rotation velocity, period and rotational splitting for both hypothesis.

The obtained frequencies are presented in an échelle diagram in Fig. 6.

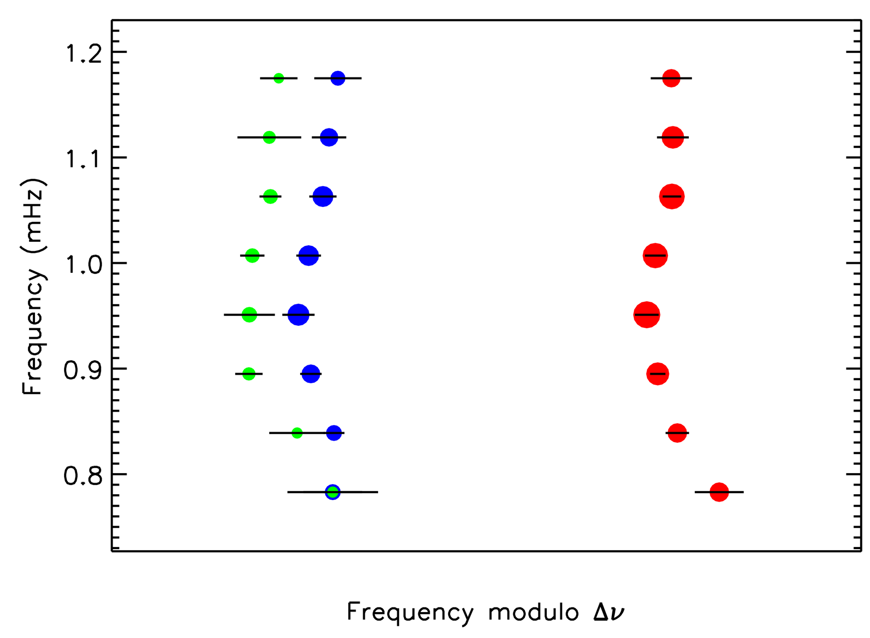

Figure 6: Échelle diagram of the best-fitting mode frequencies, with 3-σ error bars (blue circles: $\ell = 0$ modes, red circles: $\ell = 1$ modes, green circles: $\ell = 2$ modes). The surface of the circles is proportional to the amplitude of the modes.

Determination of the inclination angle

The analysis left us with two different hypothesis detailed in Table 1. HD 49385 was observed in high resolution spectropolarimetry during 2 hours, with the Narval spectropolarimeter on the Telescope Bernard Lyot, at Pic du Midi Observatory. Following [Reiners & Schmitt(2003)] and [Catala et al.(2007)], we have measured the first two zeroes of the Fourier transform of the Least Square Deconvolution mean photospheric profile, obtained at ultra-high SNR (about 1000). Their ratio provides an estimate of both $v\sin i$ and differential rotation, described with a single parameter $\alpha = (v_{\rm eq} - v_{\rm pole})/v_{\rm eq}$.

No solid rotation model as well as no model with a small inclination angle and reasonable values for α (< 0.8) can reproduce the position and ratio of the first 2 zeroes, which on the contrary are well fitted with a model having an inclination angle close to 90°, $v\sin i = 8.8$ km s^{-1} and $\alpha = 0.28$ (Fig. 7).

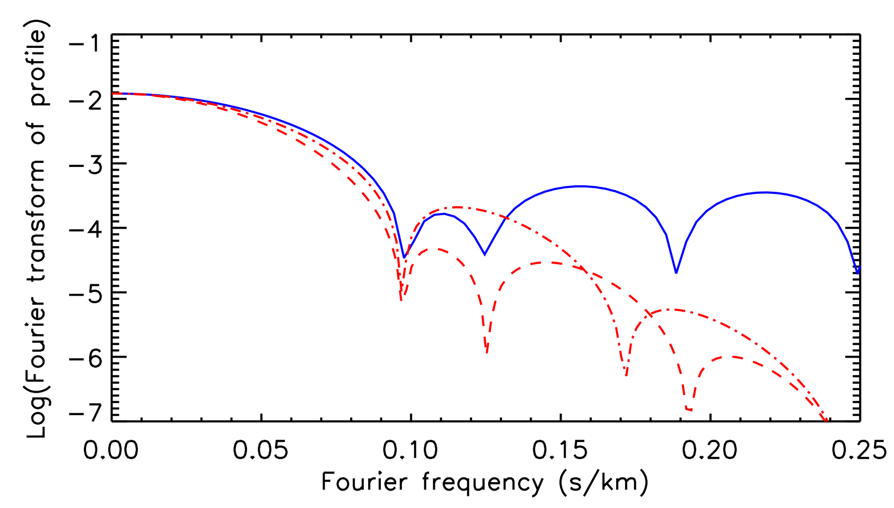

Figure 7: Fourier transform of the line profile. Blue full line: Fourier transform of the observed profile. Red dashed line: best fit with differential rotation ($\alpha = 28\%$), $v\sin i = 8.8$ km s^{-1} and $i = 90°$. Red dot-dashed line: best fit with rigid rotation ($v\sin i = 6.8$ km s^{-1})

This suggests a large inclination angle for HD 49385. Note however that this method is supposed to be efficient for $v\sin i > 10$ km s^{-1} ([Reiners & Schmitt(2003)]). Although our very high SNR allows us to measure the first 2 zeroes of the Fourier transform, these results are still very preliminary, and a critical analysis via simulations is currently under way.

Conclusion

Our preliminary analysis of HD 49385 lead to the extraction of p-mode parameters over a range of 8 overtones. A more thorough analysis will provide parameters on a wider frequency range, and investigate further in the determination of the inclination angle.

Due to the high amplitude of its oscillations, HD 49385 is the first solar-like CoRoT target for which the identification of the modes is clear and immediate. This makes HD 49385 a very promising object for modelling and seismic interpretation studies.

References

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