Comm. in Asteroseismology
Vol. 150, 2007

Detection of p-mode oscillations in β Hydri from photometric observations with WIRE

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Abstract

β Hydri was observed with the star tracker on the WIRE satellite for 34 days in August and September 2005. After correcting the data for stray light and satellite jitter, a clear excess is seen around 1 mHz in the power spectrum.

The photometric observations with WIRE were performed simultaneously with a ground-based campaign on β Hydri, where ultra-precise radial velocity data were obtained with HARPS at the ESO 3.6-m telescope and with UCLES at the 3.9-m AAT. Using the frequencies from the velocity data, we have obtained estimates of mode lifetime, rotation period and inclination by fitting a model to the power spectrum of the photometric data.

Observations and data reduction

The raw light curve of β Hydri from WIRE has a sampling rate (and integration time) of 0.5 s, an orbital duty cycle of 28%, and a rms noise of 28 mmag. As the main part of the noise in the raw light curve originates from stray light and satellite jitter, the light curve needs to be decorrelated to see oscillations with amplitudes of the order of ppm. By decorrelation, we mean that we remove any correlation between the measured flux and a set of decorrelation parameters. The decorrelation parameters we used were orbit phase, orbit number and the position of the star on the CCD chip. After correcting the light curve, we used Butler et al.'s (2004) technique for adjusting the measured error related to a given data point. Fig. 1 shows the final power spectrum. A large excess of power is seen at the orbital frequency (178.5 μHz) and its harmonics. We therefore excluded frequencies separated by less than 1.3 μHz from the orbital frequency or its harmonics in the simulation of the power spectrum.

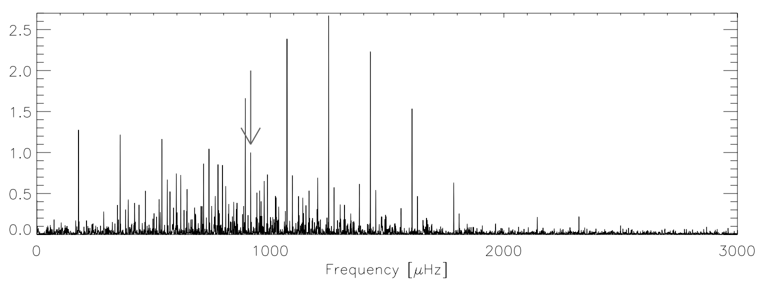

Figure 1: Normalized power spectrum of β Hydri. The spectrum has been normalized to the mode with the highest amplitude identified in the data (marked by an arrow at 916 μHz). The regularly separated peaks in the spectrum with amplitudes higher than 1 are the harmonics of the orbital frequency.

Simulation of the power spectrum

We employed the technique by Fletcher et al. (2006) for fitting the power spectrum. The model we fitted is a sum of standard Lorentzians centred on the frequencies of modes identified in a preliminary analysis of the ground-based velocity data (excluding ℓ=3 modes; Bedding et al. 2007), their first and second sidebands, their rotational splitting, and an offset with a $1/f$ background. The uncertainties were estimated assuming that the variance of the likelihood function was equal to $1/n$, where n is the number of frequencies fitted. The fit to the data is shown in Fig. 2. Vertical dashed lines mark the modes that have been identified in the ground-based velocity data and used in the simulation of the power spectrum. Each panel is shifted by 178.5 μHz, equal to the satellite's orbital frequency, and so sidebands from each mode are aligned vertically in adjacent panels. We note that some of the modes (peaks) have quite different amplitudes in the photometry and velocity data, although the observations were made simultaneously. A difference in amplitudes is expected (because of the finite mode lifetime) as the photometry campaign lasted four times longer than the spectroscopy campaign. This also explains why some modes are only present in the velocity data.

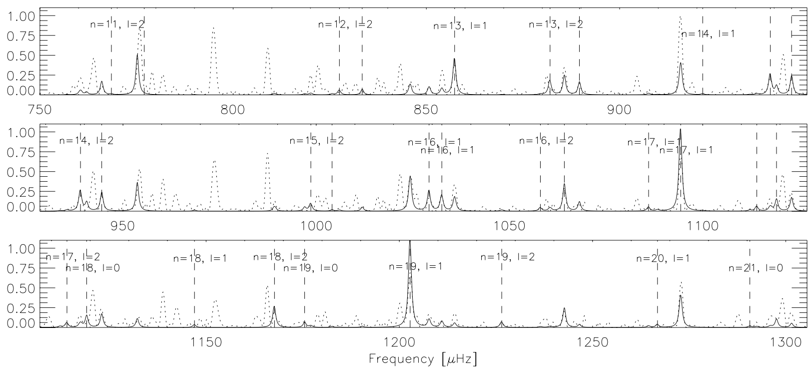

Figure 2: Normalized power spectrum of β Hydri (dotted line) and the simulation (solid line). Each panel is shifted by 178.5 μHz to make the sidebands align vertically. The vertical dashed lines mark the modes used in the simulation. The orbital frequency and its harmonics have been excluded from the plot. The normalization is the same as in Fig. 1.

Our results can be summarized as follows: we find a mode lifetime of $4.2^{+2.0}_{-1.4}$ days, a lower limit on the rotation period of 65 days and an inclination of $68^{\circ}{}^{+17^{\circ}}_{-52^{\circ}}$. The rotation period and inclination are compatible within the uncertainties with a $v \sin i$ of 2 ± 1 km s^{-1} and a radius of 1.6 ± 0.5 R$_{\odot}$ (Dravins et al. 1993).

The analysis of the β Hydri data is still not complete and the results presented here should only be considered as preliminary. The complete analysis will be presented in a later paper.

Acknowledgments. CK acknowledges support from the Instrument Centre for Danish Astrophysics. HB is supported by the Australian Research Council.

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