Pulsations in the late-type Be star HD 50209 detected by CoRoT

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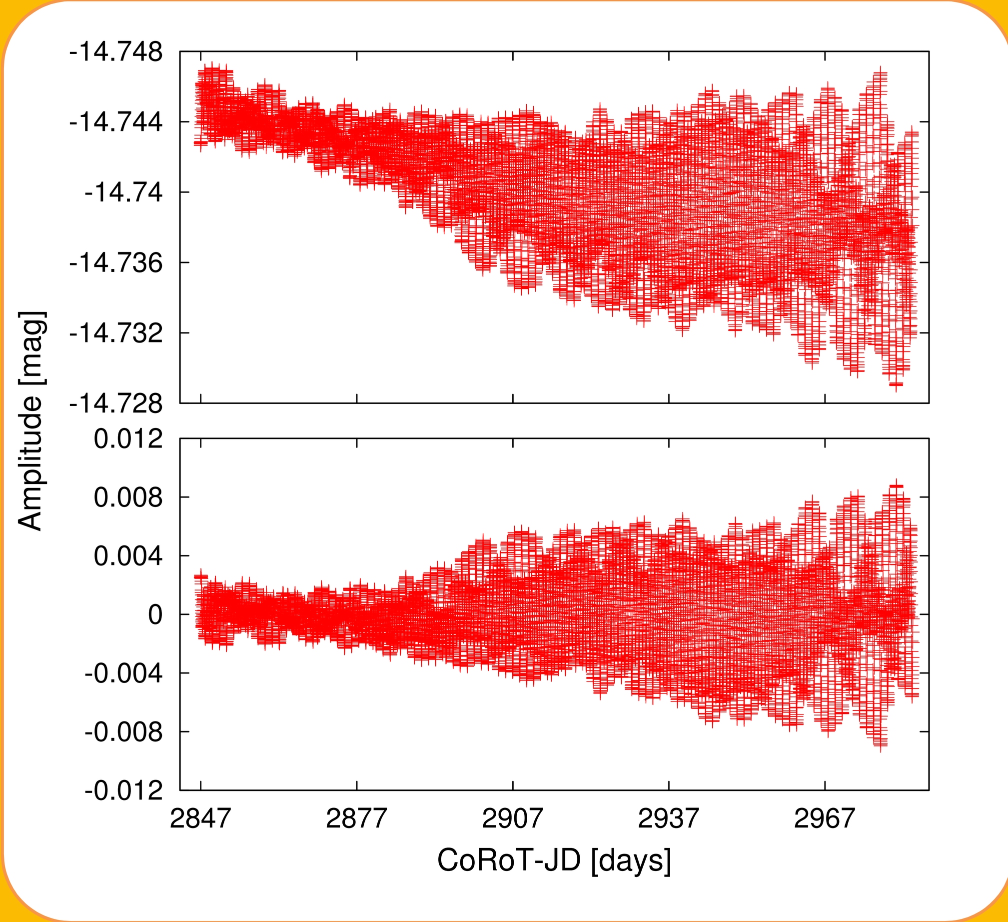
Be stars

Classical Be stars are defined as main sequence B-type stars whose spectrum has or had at some time one or more Balmer lines in emission. They are physically understood as rapidly rotating B-type stars with line emission arising from a circumstellar disk in the equatorial plane, made by matter ejected from the stellar photosphere by mechanisms not yet understood. A significant fraction of Be stars show short-term photometric and spectroscopic periodic variability which is commonly attributed to non-radial pulsations. As Be stars occupy the same region of the HR diagram that β Cephei and SPB stars, it is generally assumed that pulsations have the same origin, i.e., p- and/or g-mode pulsations driven by the κ-mechanism associated to the Fe bump. The occurrence of pulsations in late-type stars has been a matter of controversy in the recent literature.



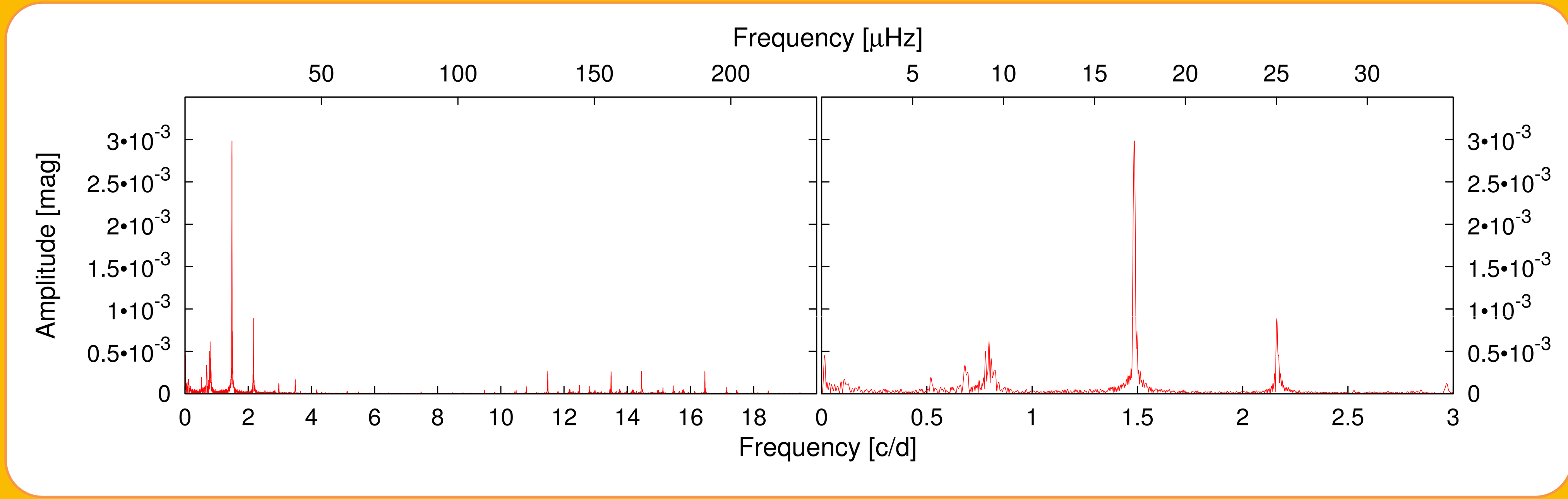
Observations

HD 50209 is a late Be star of spectral type B8IVe and magnitude V=8.36. The CoRoT satellite observed HD 50209 in the seismology field. Observations span 136 days in the Galactic anti-centre direction (LRA1), between the dates October 18th 2007 and March 3rd 2008, with a sampling of 32 seconds. The light-curve contains 328,279 data-points with a duty cycle of 89%.
The fundamental physical parameters have been accurately determined from high resolution spectroscopy by Frémat et al. (2006).

Ω/Ω_c	i [deg]	V sin i [km/s]	R_{eq} [$R_\odot$]	F_{rot} [c/d]
0.80	89 ± 20	192 ± 20	6.4 ± 1.5	0.60 ± 0.20
0.90	64 ± 14	205 ± 20	7.3 ± 1.7	0.62 ± 0.20
0.95	57 ± 15	211 ± 20	8.1 ± 2.0	0.62 ± 0.22
0.99	55 ± 12	221 ± 20	9.3 ± 2.3	0.58 ± 0.20

Set	Frequency [c/d]	Main freq.	Solution
F_1	1.48444 1.49028 1.47860 1.49613	f_1	$f_5 + 2 f_4$
F_2	2.16238 2.16822	f_2	$f_5 + 3 f_4$
F_3	0.79482 0.77874 0.80650	f_3	$f_5 + f_4$
F_4	0.67939 0.69108	f_4	f_{rot}
F_5	0.10911	f_5	
F_6	2.96889	f_6	$2 f_1$

Top Fig.: CoRoT data and light curve detrended with a 2 degree polynomial function.
Top Table (1): Fundamental parameters for HD 50209 corrected from veiling.
Left Table (2): Main frequencies of each set detected.
Right Fig.: The 60 frequencies detected for HD 50209 reveal 6 different and sepparated frequency groups.



Left: Complete Fourier scpectrum.

Right: Fourier spectrum at the range of the detected frequencies.

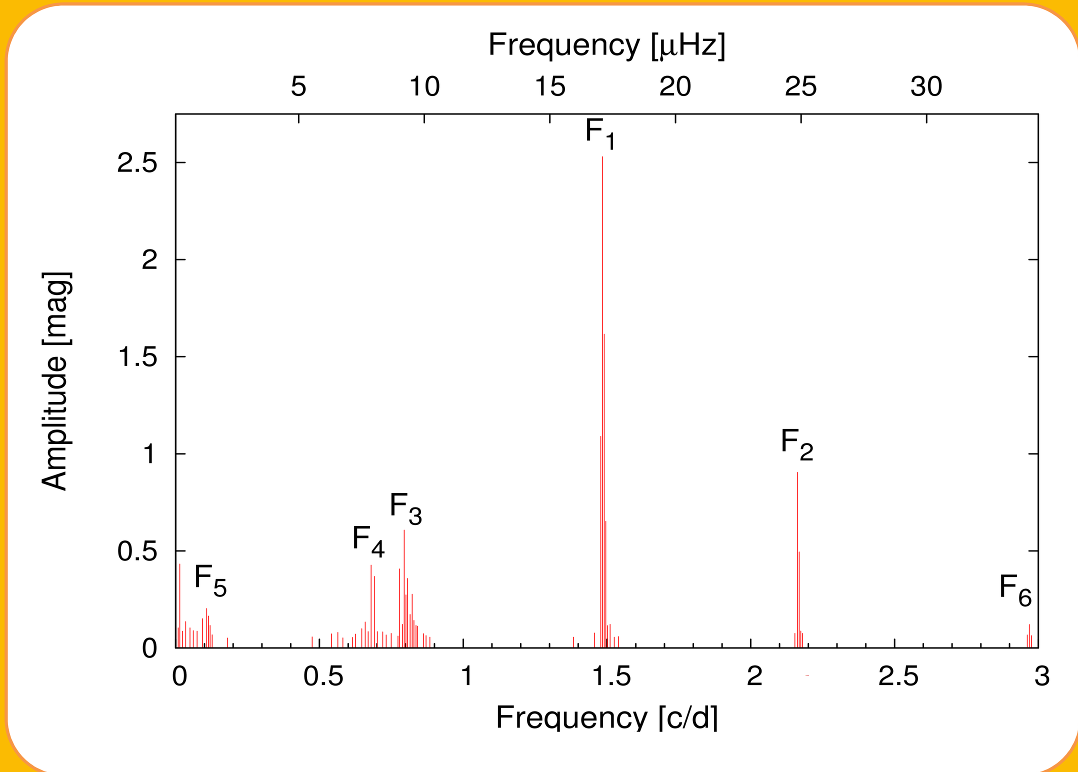
Frequency analysis

For the frequency analysis, we have employed standard Fourier techniques and linear least-squares fitting implemented in the code *pasper* (Diago et al. 2008). This code follows the S/N amplitude ratio requirement criterion described in Breger et al. (1993) in order to find out the statistical significant frequencies.

The frequencies found are distributed in 6 main groups (F_i with i=1,...,6). All groups are clearly separated, except F_3 and F_4. In each group we note the existence of equidistant multiplets separated by intervals marginally higher than our frequency resolution. In Table 2 we report the main detected frequencies.

Discussion

The first issue to be addressed is the presence of frequency multiplets and amplitude variations. Both phenomena are related, and can be due either to the presence of close frequencies or actual amplitude variation. In order to discriminate between the beating of several frequencies and amplitude change of a single frequency we have applied the method described in Breger & Pamyatnykh (2006) to the 6 frequency groups found in our analysis. However, the results obtained are inconclusive, due to two main reasons: i) the beating periods of the close frequencies are larger than the time coverage of CoRoT data, and hence, we can not evaluate the consistency of the phase variations; ii) the phase variation predicted by the models with four or more frequencies are very small, and the discrimination between the low amplitude variation of the model and no variation at all resulted very uncertain. Consequently, we can not firmly reject any of the two interpretations.



Regarding the frequency analysis, the highest frequency, f_6, is the first harmonic of f_1. Frequencies f_5, f_3, f_1 and f_2 are exactly equally spaced at our frequency resolution and the separation between them is exactly the frequency f_4. Moreover f_4 is consistent with the rotational period of the star given in Table 1. In consequence, we have only two independent main frequencies, f_4 and f_5, and all the others are of the form $f_4 = f_5 + n\, f_4$ with n=1,2,3.

Let us recall that the observed frequencies in a rotating star are related with the pulsational frequency in the co-rotating frame by the expression:

$$\nu = | \nu' - m\,\Omega |$$

were ν' is the frequency in the co-rotating frame and Ω is the rotational frequency of the star. From this expression, and considering f_4 as the rotational frequency as discussed above, the 4 frequencies f_5, f_3, f_1 and f_2 can be consistently interpreted as modes with the same pulsational frequency in the co-rotating frame and with m = 0, -1, -2, -3 respectively. We have not found any power in the frequency corresponding to m = -4 and we consider that this mode is not present in the data. In consequence, we propose that there are 4 active pulsating modes, with the same frequency in the co-rotating frame, with spherical harmonic degree ℓ=3 and azimuthal order m = 0, -1, -2, -3, respectively.

The fundamental parameters place HD 50209 marginally outside the SPB instability strip. Hence, we consider that the pulsations detected are gravity modes typical of SPB stars. HD 50209 is a SPBe star, the class defined by Walker et al. (2005) to design the Be stars pulsating in g-modes as rapidly rotating counterparts of the SPB stars.

Due to the fact that in late-type B stars the frequencies of the g-modes in the co-rotating frame are much smaller than the rotational frequency, they are in the observer`s frame close to | m Ω |. This leads to the difficulty that the observed frequencies close to the expected rotational frequency can be either interpreted as g-mode pulsations (Walker et al. 2005) or as rotational modulation (Balona 1995). For the first time we have been able to observe simultaneously the rotational frequency and the pulsational frequencies separately, implying that the frequencies we attribute to g-mode pulsations can not be interpreted as the effect of the rotational modulation. This constitute a proof of the presence of pulsations in HD 50209.

References:

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