The study of Be stars with the CoRoT satellite

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Abstract

In this contribution we present the results on Be stars studied with the space mission CoRoT in the seismology field. The analysis of Be stars with the high precision long-duration data carried by the CoRoT Be Team will provide new clues on the nature of the Be phenomenon. The frequency analysis performed on these stars conforms the basis of posterior seismic modelling.

Introduction

Be stars are main sequence or slightly evolved non-supergiant, late-O, B, or early-A stars which show or have shown at least once emission in their Balmer lines due to the presence of a decretion circumstellar disk. Emission can also appear in other lines of the spectrum, in particular in red HeI lines or FeII lines. Moreover, the disk produces an infrared excess in the spectral energy distribution. In addition to this disk, Be stars also exhibit polar winds. About *20%* of all B stars in our galaxy are Be stars, however this fraction depends on metallicity. Therefore, in other environments with lower metallicity, the fraction of Be stars over B stars can be much higher. In fact, only B stars with a sufficiently high rotational velocity at the ZAMS can become Be stars, and this velocity depends on the metallicity of the protostellar environment.

Be stars are known to be fast rotators (typically $V \sin i = 250$ km s^{-1}), nevertheless this velocity is not high enough to reach the critical limit at which the centrifugal force compensates grav ity. Indeed, Be stars rotate on average at *88%* of the critical angular velocity in our Galaxy. Thus, at least in most cases, rotation by itself cannot explain the ejection of matter from the star which lead to the formation of the decretion disk. Nowadays, non-radial pulsations combined to the near break-up rotational velocity have been proposed as mechanisms that could give rise to the additional amount of momentum needed to cause mass ejection. Up to now, this statement has been confirmed only for the Be star μ Cen, for which the beating produced by the non-radial pulsation modes determine the times of mass loss events. The question is: Is this fact valid for all Be stars?

CoRoT was launched on December 27, 2006. In the asteroseismology field, CoRoT obtains one measurement every second. Averaged measurements every *32* s are then calculated and constitute the light curve. To analyse the CoRoT light curves, we use three codes developed by the CoRoT Be team to search for the frequencies of variations in photometric time series: PASPER, TiSAFT, and CLEAN-NG. These codes are all based on Fourier analysis but have some differences, in particular, in the stopping criterion used for the frequency search. For a complete description of these methods, we refer to Gutiérrez-Soto et al. (2009). In this contribution we present a brief resume on the analysed Be stars observed in the seismology field.

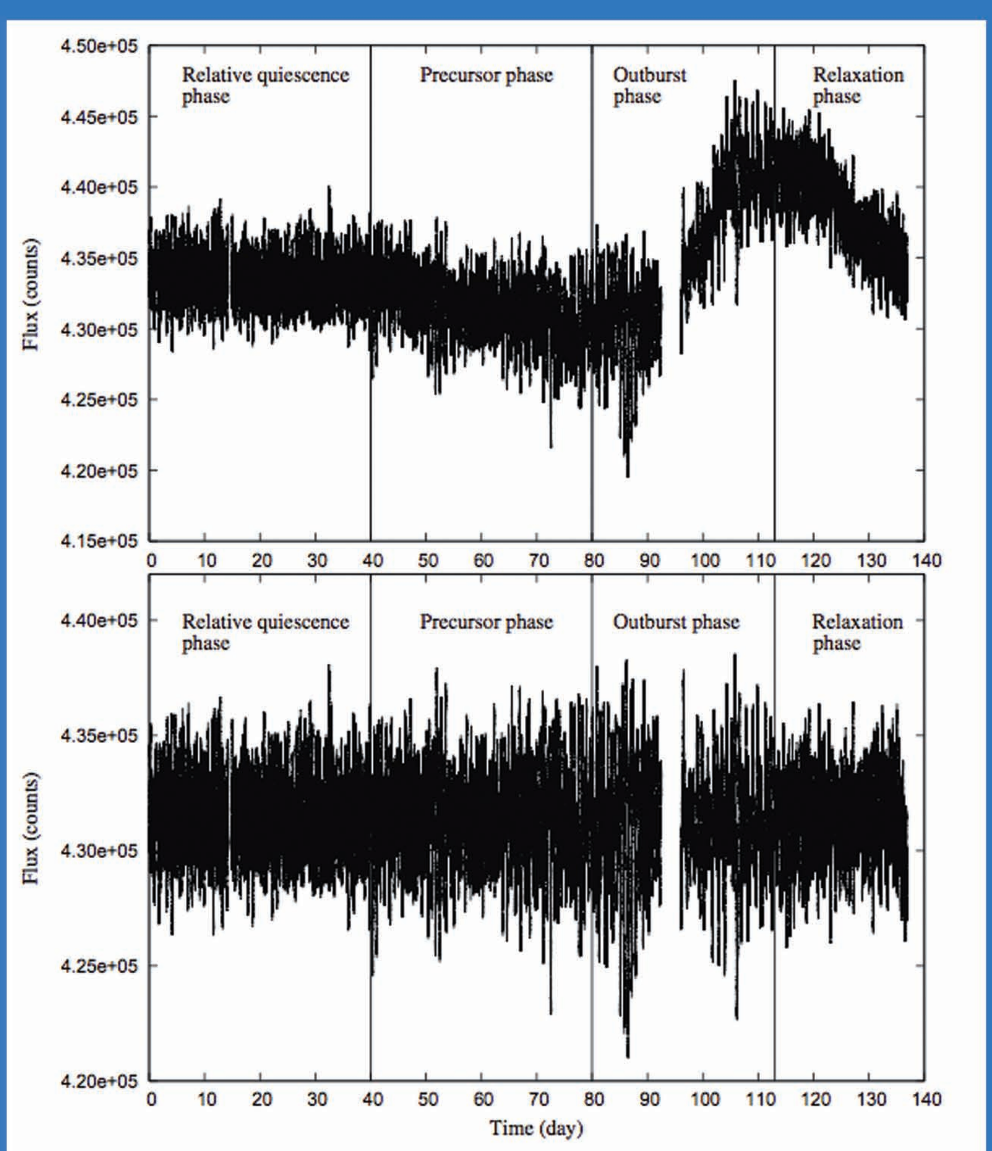
HD 49330

- HD 49330 is a rapidly rotating very early Be star (B0.5IVe).

- We detected over *300* frequencies in the CoRoT light curve.

- The light curve of this star present an outburst, typical of Be stars (see Fig. 1).

- We find pulsation modes typical of β Cep stars (*p* modes) and SPB stars (*g* modes) with amplitude variations along the run directly correlated with the outburst, as proposed by Rivinius et al. 1998 for μ Cen.



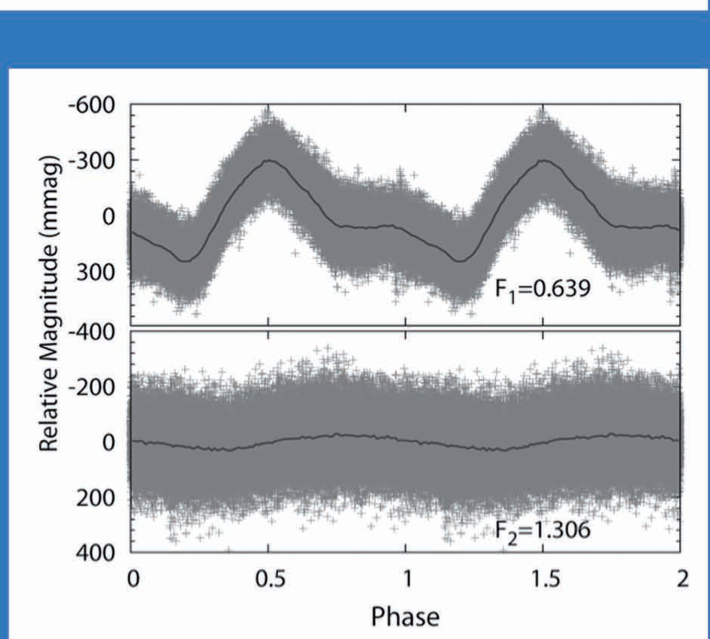
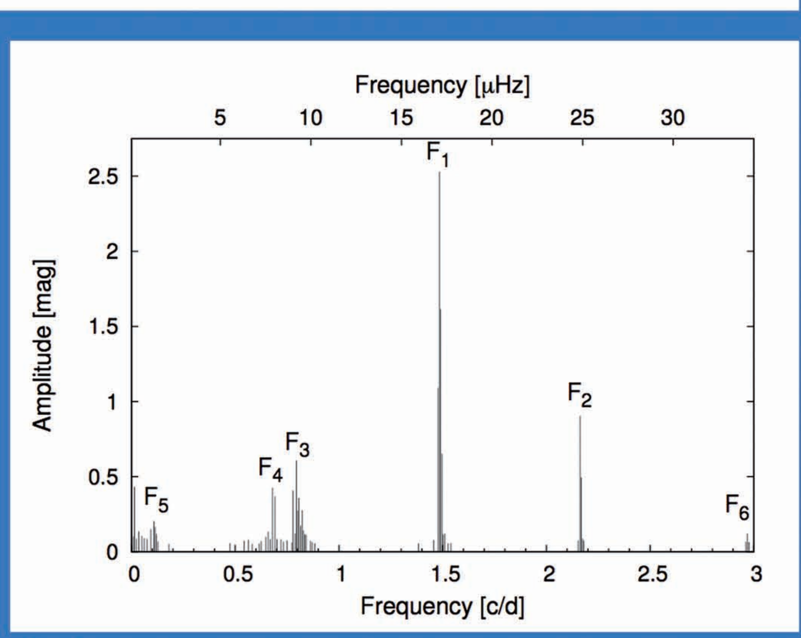


Fig. 1
Left: (Top panel) CoRoT light curve of HD 49330 in flux. The light curve was corrected for the loss in CCD gain. (Bottom panel) light curve of HD 49330 detrended from the shape of the outburst. The time origin is *JD=2454391.95*.
Top: (Top panel) phase diagram of the light curve of HD 175869 folded with the frequency f_1. Note the unequal maxima and minima. (Bottom panel) phase diagram of the residuals after prewhitening f_1 and its harmonics folded with the frequency $f_2 = 1.306$ c d^{-1}. The solid blue line represents the binned data.



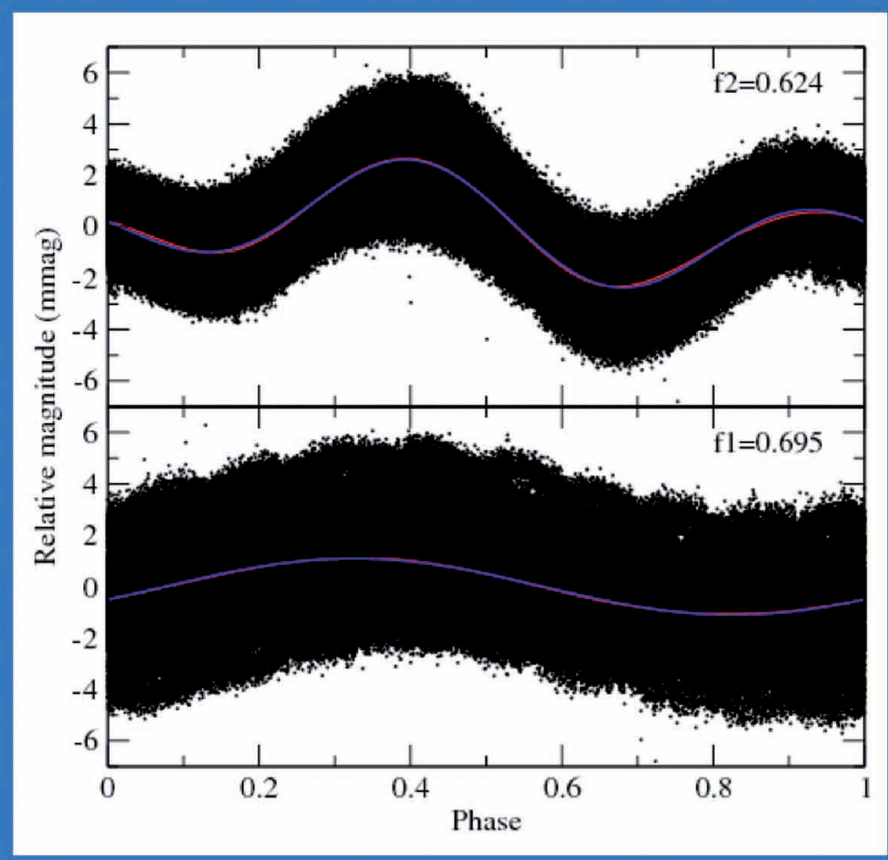


Fig. 2
Top: The *60* significant frequencies detected for the star HD 50209 grouped in six different frequency groups.
Right: CoRoT light curve for HD 181231 folded with the two main frequencies detected. A phase-binned curve (red) and a sinusoidal fit (blue) as a single (for f_1) or double wave (for f_2) are superimposed in each panel.

HD 50209

- HD 50209 is a late Be star of spectral type B8IVe and magnitude $V = 8.36$.

- We obtained *60* significant frequencies, grouped in six sets (see Fig. 2) that can be either single frequencies with variable amplitude or groups of close frequencies around a central value.

- We have found four frequencies which correspond to gravity modes with azimuthal order $m = 0, -1, -2, -3$ with the same pulsational frequency in the co-rotating frame. We also found a rotational period with a frequency of *0.679* c d^{-1}.

HD 181231

- We find that HD 181231 is a B5IVe star seen with an inclination of ~*45* degrees.

- No magnetic field is detected in its photosphere.

- We detect at least *10* independent significant frequencies of variations among the *54* detected frequencies, interpreted in terms of non-radial pulsation modes and rotation. Detail in Fig. 2.

- Two longer-term variations are also detected: one at ~*14* days resulting from a beating effect between the two main frequencies of short-term variations, the other at ~*116* days due either to a beating of frequencies or to a zonal pulsation mode.

HD 175869

- HD 175869 (*64 Ser*) is a bright B8IIIe star ($V = 5.56$).

- The light curve exhibits low-amplitude variations of the order of *300* μmag with a double wave shape.

- A frequency within the range determined for the rotational frequency and six of its harmonics are detected.

- The main frequency (see Fig. 1) and its first harmonic exhibit amplitude variations of a few days. Other significant frequencies of low-amplitude from *25* to a few μmag are also found.

- The analysis of line profiles from ground-based spectroscopic data does not detect any variation. In addition, no Zeeman signature was found.

- Inhomogeneities caused by stellar activity in or just above the photosphere are proposed to produce the photometric variability. The hypothesis that non-radial pulsations are the origin of these variations cannot be excluded.

Conclusions

The results coming from the space-based mission CoRoT are confirming *p*-mode and *g*-mode non-radial pulsations in Be stars, suggesting that the oscillations detected in Be star show different behaviour, which is in full accordance with those of β Cephei and SPB stars. These results provide new clues about the origin of the Be phenomenon as well as strong constraints on the seismic modelling of Be stars.

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* See http://corotbe.obspm.fr/ for details.

For more details:

Diago, P. D., et al. 2009, A&A, 506, 125
Gutiérrez-Soto, J., et al. 2009, A&A, 506, 133
Floquet, M., et al. 2009, A&A, 506, 103
Huat, A.-L., et al. 2009, A&A, 506, 95
Neiner, C., et al. 2009, A&A, 506, 143