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FIRST RESULTS ON BE STARS WITH COROT

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Abstract. In this paper we present an overview of the analysis of some of the Be stars observed with the CoRoT satellite up to this date. Be stars are very fast-rotating B-type stars which may pulsate as β Cephei or SPB stars. CoRoT has already observed 5 bright Be stars in the seismology fields and several tens of fainter ones in the exoplanet fields with an unprecedented quality and with a time duration from 20 to 150 days. Multiple frequencies are detected in the majority of the stars. Pulsations, outbursts, beating phenomenon, rotation, amplitude variability, etc. have been found in their light curves. In order to complement this study, ground-based spectroscopic data have also been analysed for the stars located in the seismology fields.

1 Introduction

Be stars are non-supergiant B stars that show or have shown at one or another moment emission in Balmer lines. It is generally agreed that the origin of this emission is the presence of an equatorial circumstellar disk, fed by discrete mass-loss events. For a complete review of the Be phenomenon and its properties, see Porter & Rivinius (2003).

Short-term variations are present in these stars due to non-radial pulsations or/and rotational modulation. The spectroscopic analysis led by Rivinius et al. (2001) of μ Cen suggested that non-radial pulsations combined to the near break-up rotational velocity are probably the mechanism responsible for the mass ejection. However, μ Cen is, up to now, the only known Be star for which this behaviour could be shown.

Recently, the Canadian mission MOST observed during several weeks 5 Be stars with spectral types ranging from 09.5V to B8V. Modes typical of β Cep and/or SPB stars have been identified, suggesting that pulsations are present in all rapidly rotating Be stars (see eg. Saio et al. 2007).

The observation of Be stars with the CoRoT satellite (Baglin et al. 2002) is providing photometric time series with an unprecedented quality that will allow us to perform a deep study of the role of non-radial pulsations and their relation with the Be star outbursts. The CoRoT mission is providing 5 months of continuous observations of 1 or 2 bright Be stars (seismo fields) per long run. In addition, CoRoT is observing simultaneously many faint Be stars (exo fields) per long run. Moreover, some bright and faint stars are being observed during shorter periods of observations (short runs).

Here we present the first results obtained from the analysis of the light curves of the Be stars observed with CoRoT in the exo fields during the initial run (IR1) in the Galactic anticenter direction as well as in the seismo fields in the first short run (SRC1) and long run (LRC1) in the Galactic center direction.

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2 Results

2.1 SEISMO fields

The analysis of two Be stars observed in the seismology fields of CoRoT, namely HD 181231 and HD 175869, are presented in this section.

HD 181231 is a B5IVe star that showed low-amplitude variability with a frequency at 0.67 c d^{-1} from ground-based observations (Gutiérrez-Soto et al. 2007). The CoRoT light curve of 156.6 days shows a beating due to the presence of multiple frequencies. About 30 significant frequencies have been detected. The three largest-amplitude frequencies are 1.24, 0.62 and 0.69 c d^{-1}, with semi-amplitudes of 1.6, 1.2 and 1.1 mmag respectively. The phase diagram with the frequency 0.62 c d^{-1} (upper panel of Fig. 1) shows a double wave with different maximum and minimum, while the frequency 0.69 c d^{-1} shows a single-wave diagram (lower panel of Fig. 1).

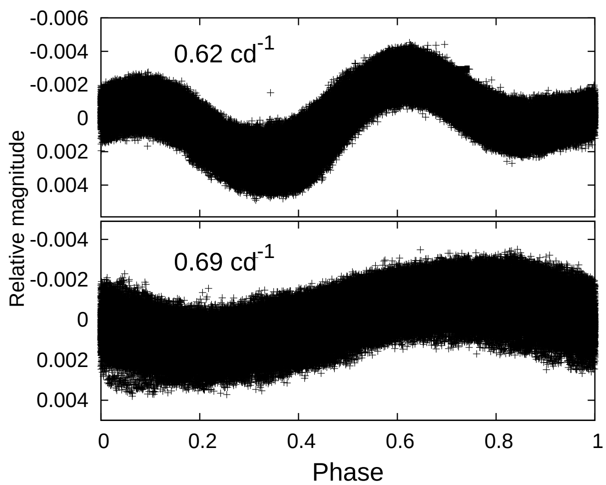

Fig. 1. Phase diagram of the star HD 181231 with the frequency 0.62 c d^{-1} (upper panel) and 0.69 c d^{-1} (lower panel).

Ground-based spectroscopic data of this star were also obtained with FEROS at the 2.2m telescope in La Silla as part of a large program (PI Ennio Poretti) and at the Pic du Midi with the NARVAL spectropolarimeter (PI Coralie Neiner). The line-profile of the Mg II 4481 shows variations with the frequency 0.69 c d^{-1}. Following Telting & Schrijvers (1997) we estimate a ℓ-value of $3 - 4$ from the phase distribution of these variations.

HD 175869 is a B8IIIVe star found to be non-variable from Hipparcos data. The CoRoT light curve of 27.2 days shows low-amplitude variations of the order of 0.2 mmag. A frequency compatible with the rotational frequency and its 5 harmonics are detected. Other significant low-amplitude frequencies with amplitudes of few ppm are also found.

2.2 EXO fields

To date, 7 confirmed Be stars were observed in the exo fields of CoRoT during the initial run. They show emission in the Hα line in the spectra taken with the CAFOS spectrograph at the 2.2m telescope in Calar Alto (PI Juan Fagregat). They have spectral types earlier than B5. All these stars are highly variable in the CoRoT light curves. Most of them present a beating of several close frequencies. As it is often observed in Be stars, the detected frequencies range from 0.4 to 4 c d^{-1}. The semi-amplitudes range from 40 to a few 0.01 mmag. Here we present a brief discussion of each individual star:

The CoRoT light curve of the star 102904910 shows beating of several frequencies. Many peaks around the frequencies 3.97, 3.84 and 1.92 c d^{-1} are clearly detected in the periodogram. We also find changes in the amplitude of the frequencies during the observations.

The light curve of the star 102791482 shows variability with large amplitude. The semi-amplitude of the largest-amplitude frequency is 40 mmag. The frequency analysis results on multiple frequencies (some tens) and many combinations.

The star 102766835 presents a long-term trend larger than the 58-day duration of the run and a beating of several frequencies. After removing this long-term trend, we find many frequencies around 0.93 and 0.88 c d^{-1} and their combinations. We noticed that even after prewhitening for a large number of frequencies (~ 50), some signal that appears to be non-sinusoidal is still present suggesting that the signal is not sinusoidal.

The analysis of the light curves of the stars 102761769, 102725623 and 102964342 yields several frequencies with low amplitudes. The largest semi-amplitudes in these stars range from 0.2 to 0.6 mmag.

The star 102719279 shows several fadings in its CoRoT light curve (see Fig. 2). A fading is due to an ejection of matter or outburst, but due to the inclination angle ($i \sim 90$), the material in the envelope is shadowing the star (see *Hubert & Floquet 1998* for some examples with Hipparcos data). From the light curve we see that a strong outburst occurs approximately at Julian day 2454151-2454152 (2606-2607 in the plot). Note that the outbursts produce a fading of $\sim$0.1 mag in the light curve. The amplitude of the oscillations increases until the strongest outbursts occurs, and then suddenly the amplitude decreases while the average magnitude increases slowly to approximately reach the same level as before the outbursts. It is important to highlight that the outburst occurs when the amplitude of the variations is the largest.

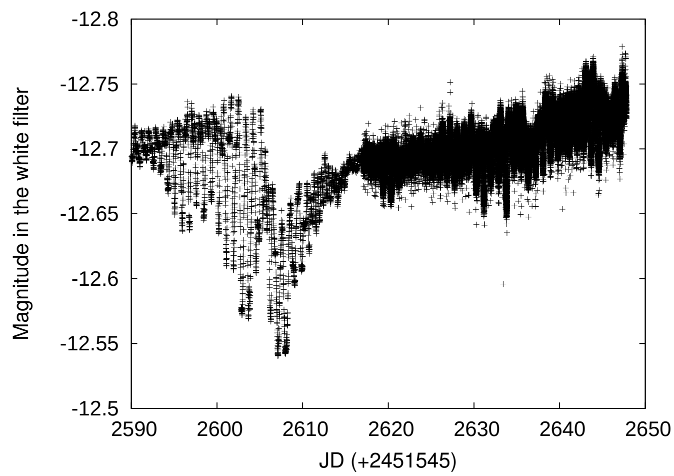

Fig. 2. Light curve of the star 102719279, observed in the exo fields.

From the Fourier analysis of the whole light curve, we detected several close frequencies around 1.16 c/d, the double 2.32 c d^{-1}, and around 0.98 c d^{-1}. As we noticed that the amplitudes of the variations change very much before and after the outbursts, we performed a Fourier analysis for both datasets. We clearly see in Fig. 3 that the amplitude of the peaks changes dramatically for the frequencies close to 1 (the peak disappears) and 1.16 c d^{-1} (the amplitude decreases from 20 to 5 mmag). Therefore, there is a link between the outbursts and the change in amplitude in this star.

3 Discussion and conclusions

The high precision, the high duty-cycle and the long-duration of the CoRoT observations have allowed us to detect many low-amplitude frequencies which would have never been detected from ground-based observations.

As a summary we can conclude that Be stars are highly variable, as all the Be stars studied here present short-term variations and most of them show a beating produced by multiple frequencies. For some stars, a change of amplitude of the oscillations the light curve has been observed. Finally, a link between amplitude variations and outbursts is found in one Be star.

These variations are probably due to the presence of non-radial pulsations, since multiple frequencies have been clearly detected. In addition, we have shown that an outburst occurred when the amplitude of the oscillations was the largest in a Be star. This results suggests that the oscillations may be linked to the ejection of matter in this star, as it was observed in the Be star μ Cen by Rivinius et al. (2001).

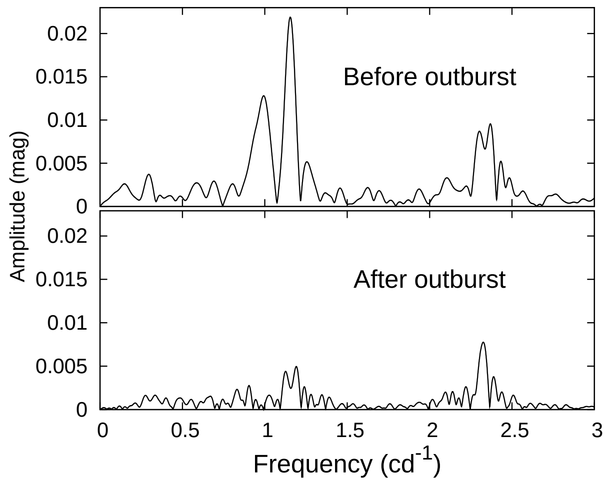

Fig. 3. Periodogram of the light curve of the star 102719279 before and after the outburst.

However, some questions are still opened after analyzing the CoRoT data. Some stars show double wave phase diagrams with 2 unequal minima for some frequencies, which would be in favor of the rotational modulation hypothesis (Balona 1990). For example inhomogeneities ejected from the central star attached with a magnetic field could produce these variations. Non-radial pulsations and rotational signatures were observed at the same time in few Be stars (eg. ω Ori, Neiner et al. 2003). However, no sign of magnetic field has been detected so far in the Corot Be stars studied here. Finally note that in addition to these frequencies, other frequencies clearly associated with pulsations are detected. Pulsating models taking into account the effects of fast rotation are then required in order to discriminate between rotation and pulsations and determine the internal structure of Be stars.

We wish to thank the CoRoT team for the acquisition and reduction of the CoRoT data. The FEROS data are being obtained as part of the ESO Large Programme LP178.D-0361 (PI: E. Poretti). This research is also based on data obtained at the Télescope Bernard Lyot (Pic du Midi).

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