Stars and their variability observed from space
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STEREO OBSERVATIONS OF BE STARS

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Abstract. In this study, five-year STEREO data of five bright Be stars were investigated in order to clarify the physical processes in the photospheres of Be stars. All samples were selected from B spectral types in such a way as to cover the entire spectrum from B0 to B9. The analyses were performed with the Lomb-Scargle technique, and time-frequency diagrams were produced. The diagrams showed groups at a fundamental or a harmonic of the fundamental frequency. The phased light-curves that were constructed according to the main frequencies display sinusoidal variations, which can be attributed to rotation. The resulting suggestion, that a localized cloud was formed from ejected material, was discussed as the cause of the modulations.

Keywords: Stars: Be stars, rotation, mass loss, methods: STEREO data, data analysis

1 Introduction

The classical Be stars are dwarf and giant B stars whose Balmer lines (particularly H) show, or have at some time shown, emission in the core of the line (binary interactions are excluded) (Porter & Rivinius 2003). Observations of light and line profile variations indicate that many Be stars are periodic variables. The variability is interpreted in two ways: either pulsation or rotational modulation (Balona 2010). Since the observed period is close to the rotation period, it is difficult to distinguish between the two hypotheses. Pulsation is a rather attractive idea since it offers a plausible trigger for the mass loss. However, the photometric behaviour of these stars seems more simply understood as transient variations. They could easily be interpreted as non-radial pulsations if observed for only a few days, yet the overall shape of the light-curve is consistent with a rotating star where obscuration is present (Balona & Ozuyar 2019). Our aim was therefore to present observations of some Be stars provided by STEREO, in order to assist with clarifying which physical processes are active in the photospheres of these stars.

2 Data and Analyses

The data, which covered the period from 2007–2011, came from the HI-1A instrument of the STEREO-A satellite. Even though the main purpose of this satellite is to track solar mass ejections, it is also able to observing background stars brighter than 12 magnitude for a maximum of 20 days. The cadence of the light-curves is 40 minutes, which provides a maximum of 720 data points in a season. Since the satellite observes the region close to the solar disk, light curves are mostly affected by solar activity. The data are therefore first cleaned from those effects using an IDL code. Changes in the five years of data are represented by a time–frequency diagram. The amplitude of each frequency as a function of time was calculated by applying a sliding window whose length was chosen as five days. The window was shifted with a time-step of one day; in each step a Fourier analysis was performed with the Lomb-Scargle technique, and the results plotted against time.

3 Discussion

A localized cloud of ejected material would presumably cause a signal in the irregular light variations in Be stars, whether the cloud were ejected by pulsation or by some other mechanism. It was therefore quite possible that the periodic variations of the sample stars could arise analogously. The presence of transient frequencies presented in Fig. 1 provides evidence that the periodicities may be a result of rotation rather than pulsation.

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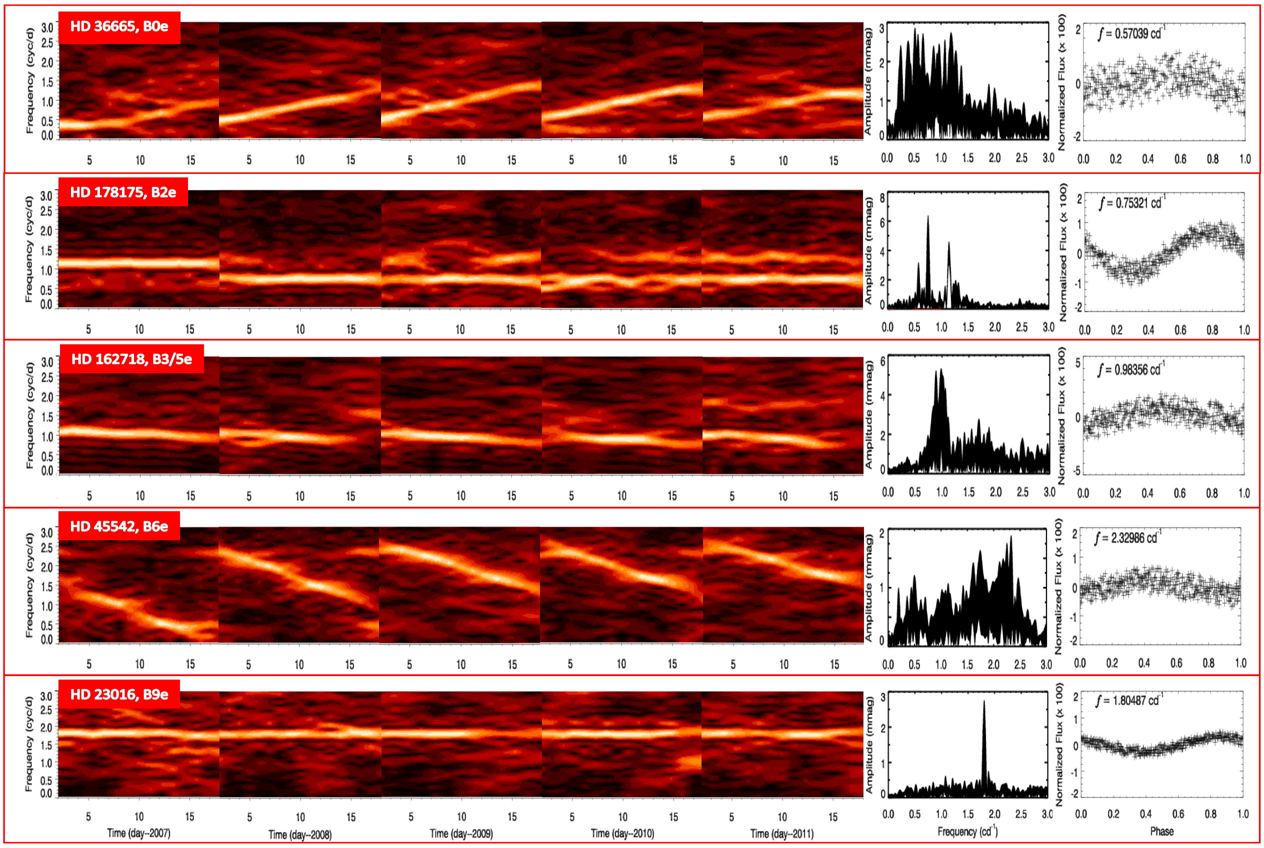

Fig. 1. Time–frequency diagrams, periodograms and phased light-curves of data combined over five years.

Furthermore, the amplitudes of the seasonal frequencies display variations which may be a signature of non-uniformly distributed regions. It is suggested that hose changes are related to a change in the size of the spot regions, or to a possible drift in latitude (Balona et al. 2011). Rotational modulation is supported by the phased light-curves of the five-year combined data (Fig. 1). Starspots on A and B stars, and also flares, have been observed in a large fraction of A and B stars (Balona 2013, 2016; Balona et al. 2019) using *Kepler* and *TESS* data. In a rapidly-rotating star, it is conceivable that such activity can lead to mass loss. Balona & Ozuyar (2019) have shown that mass loss caused by flaring is an impulsive event – which describes Be outbursts rather well. That study stimulated a discussion as to whether the highly-ionized gas released in the process could expand and become trapped in closed magnetic loops. The relative strength of the fundamental and first harmonic depends on the relative amount of gas trapped in the two regions. Gas escapes along open field lines and is dragged and accelerated by the rapid rotation of the star. The gas reaches circular orbital speeds at some distance from the star if it is still ionized, so that depends on the rotational velocity of the star. After some time the gas cools down, becomes neutral, and is then unaffected by the magnetic field; it slowly dissipates into the inner circumstellar disk, rotating at Keplerian velocity.

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