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The Mons campaign on OB stars

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Abstract: In parallel with the monitoring of the periastron passage of the binary system WR 140, a number of B supergiants and Oe stars have been observed in the framework of a 4-month spectroscopic run using the Mons telescope at Teide observatory. We expose the motivations behind this campaign, present an overview of the Hα variations exhibited by the B supergiants and finally briefly discuss forthcoming developments in the data analysis.

1 The Mons project

The so-called Mons project is a collaboration between professional and amateur astronomers, which was primarily set up to monitor the periastron passage of the colliding-wind binary system WR 140 centred on January 12, 2009. A dedicated spectroscopic campaign was organised from December 2008 to March 2009 using the 50-cm Mons telescope at Teide Observatory, Canary Islands (see Eversberg 2011 and Fahed et al. 2011).[1] As WR 140 was observable for most of the run only close to sunset and sunrise, additional targets were required. We decided to focus on early B-type supergiants and Oe stars for which time-resolved observations of the Hα line can be used to investigate the properties of their large-scale wind structures and circumstellar material, respectively. The spectral coverage was 6360–6950 Å with a reciprocal dispersion of about 0.34 Å pixel^{-1}.

2 Motivations for this study

2.1 The B supergiants

Variability studies in the ultraviolet domain have shown that the winds of OB stars are likely made up of large-scale streams (the 'co-rotating interaction regions'; CIRs) whose formation may be triggered by the existence of non-uniform physical conditions at the stellar surface (as may be the case because of magnetic structures or pulsations; Cranmer & Owocki 1996). Establishing the incidence of anisotropic outflows is thus of relevance for issues related to pulsational and magnetic activity in early-type stars. In virtue of their density-squared dependence, optical recombination lines such as Hα are particularly good probes of the large density gradients expected to prevail in the CIRs. Revealing rotational modulation in these features would provide evidence that the CIRs extend relatively close to the star and are possibly directly emerging from the photosphere. Although previous campaigns have demonstrated that dramatic line-profile variability is widespread among OB supergiants, they generally suffered from a poor temporal sampling that hampered a detailed study of the line-profile variations on a rotational timescale (e.g., Ebbets 1982; Kaper et al. 1997).

Four bright B1–B3 supergiants were selected from Morel et al. (2004) based on previous indication of cyclical changes (HD 14134 and HD 42087 with a recurrence timescale of about 12.8 and 25 days, respectively) or unusually strong variations (HD 43384 and HD 52382). As discussed by Morel et al. (2004), three of these stars show evidence for a periodic behaviour in the *Hipparcos* photometric data: HD 14134 (12.823 days), HD 42087 (6.807 days) and HD 43384 (13.7 days). Further investigation is needed in the case of HD 42087 in view of the inconsistency between the spectroscopic and photometric periods, while the existence in HD 14134 of the same periodic signal both in the spectroscopic and in the photometric data makes it an especially attractive target.

[1] See also `http://www.stsci.de/wr140/index_e.htm`

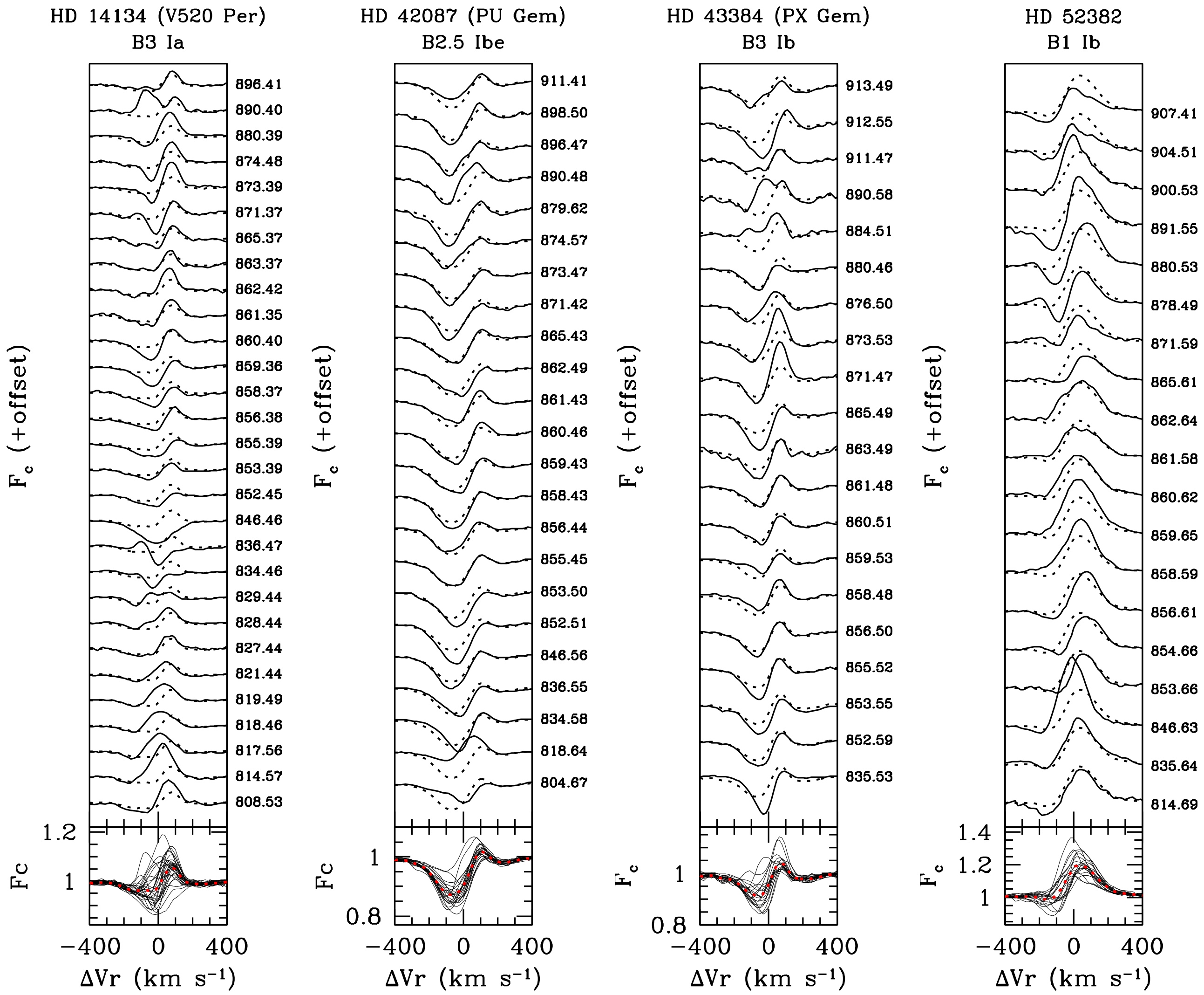

Figure 1: Hα time series for the B supergiants HD 14134, HD 42087, HD 43384 and HD 52382. Consecutive spectra are shifted by 0.15 continuum units, except in the case of HD 52382 (0.2 continuum units). The spectra are displayed in the stellar rest frame. The date of the observations at mid exposure (HJD–2,454,000) is indicated to the right of the panels. The bottom part of each panel shows a superposition of all the profiles. In all cases, the mean profile is overplotted as a dashed line for comparison.

2.2 The Oe stars

Another category of peculiar OB stars are the so-called Oe stars. In many respects, Oe stars are similar to Be stars. However, they are hotter and more massive than the latter and are very rare; only eight stars of this type are known in our Galaxy (Negueruela, Steele & Bernabeu 2004). These Oe stars have a spectrum that exhibits emission lines of the Balmer series of hydrogen as well as lower ionisation elements such as He I and Fe II, but do not display typical Of emission lines such as He II λ 4686 and N III λ 4634–40 (Conti & Leep 1974). As for Be-type stars, the emission lines of Oe stars frequently display a double-peaked morphology and the stars are often rapid rotators with equatorial rotational velocities that exceed 200 km s^{-1}. It is thus believed that the hydrogen emission lines arise in a disk-like outflow that surrounds the star, although this interpretation has been questioned because of the lack of a spectropolarimetric signature (Vink et al. 2009, but see Nazé, Rauw & ud-Doula 2011). Variability studies are crucial for a deeper understanding of these stars.

Indeed, their emission lines display strong variations that take the form of changing global intensities of the emission lines (by a factor of a few to about 10) and a change of the relative intensities of the violet and blue peak of the emissions (Rauw et al. 2007). The timescales of these variations are, however, poorly defined[2] and we thus selected two rather bright Oe stars, HD 45314 and HD 60848, for a spectroscopic monitoring in the framework of the Mons campaign.

3 Preliminary results

Here we present an overview of the Hα variations exhibited by the B supergiants (the data for the Oe stars are still being reduced). Strong line-profile variations operating on a daily timescale are observed in all the targets, as illustrated in the case of HD 14134 in Fig.1 by the great variety of profiles observed (strong emission/absorption, double peaked, classical or even inverse P-Cygni profile). This star is of particular interest because of the previous detection of a 12.8-d periodic signal both in photometry and in spectroscopy, with maximum light nearly coinciding with maximum wind emission (see Fig.2).[3] Although this clearly suggests a link between the development of extended wind structures and photospheric disturbances, unfortunately very little is known about the magnetic and pulsational properties of this star. A very similar correspondence between the photometric and spectroscopic behaviours (i.e., maximum Hα emission at maximum light) is observed in the O6.5f?pe–O8fp star HD 191612, whose wind is thought to be magnetically confined (Howarth et al. 2007, and references therein). Although a single circular polarization spectrum of HD 14134 obtained in 2003 with the MuSiCoS spectropolarimeter did not lead to the detection of a magnetic field (45$\pm$145 G; Morel et al. 2004), these data were unfortunately acquired at minimum Hα emission, i.e., when the longitudinal field is expected to be the lowest according to magnetically confined wind-shock models (e.g., Donati et al. 2002). Further observations with the much more sensitive instruments that are currently available may be warranted. On the other hand, to our knowledge no pulsation studies of this star have been conducted up to now. One of our objectives for the future is to fill this caveat (see below).

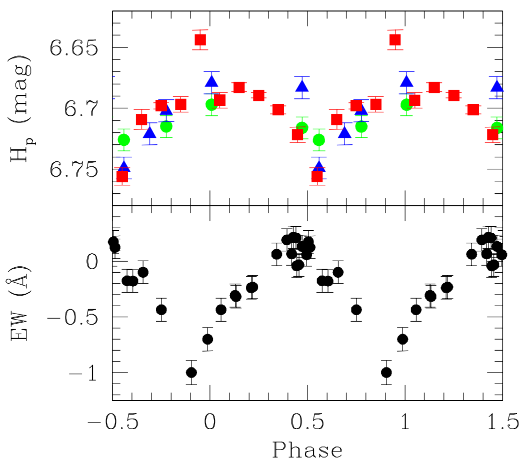

Figure 2: *Top panel: Hipparcos* light curve of HD 14134 binned to 0.1-phase resolution (squares). Our *B*- and *I*-band observations obtained in 2002 are overplotted as triangles and circles, respectively (the points are vertically shifted by a constant value to match the *Hipparcos* data). *Bottom panel:* EWs of the Hα line, as a function of phase. In all cases, the following ephemeris was used: $\mathcal{P}$=12.823 days and T_0=2,447,867.8 (zero phase arbitrarily set to maximum light). Adapted from Morel et al. (2004).

[2]Variations both on yearly (Rauw et al. 2007) and hourly timescales (Boyajian et al. 2007) have been reported, but there is a huge gap in our knowledge about timescales of weeks and months.

[3]A refined estimate of the period is needed to accurately phase together the *Hipparcos* and spectroscopic data, which were secured more than 10 years apart, and to assess the reality of the phase offset hinted at by Fig.2.

4 Conclusions and perspectives

Our efforts will now be directed towards the detection of a periodic behaviour that could allow us to identify the physical processes that drive the variations. For instance, a dipole magnetic field tilted with respect to the rotational axis in the Oe stars is expected to induce changes modulated by the rotational period, whereas the variations should take place on much longer timescales if they arise from some kind of disk instability. On the other hand, rotational modulation of the CIRs is expected to induce variations operating with a recurrence timescale of weeks in the B supergiants. The four B targets have already been intensively monitored over 36 nights in 2001–2002 (Morel et al. 2004). One of our main goals is to examine whether the pattern of variability remains coherent over such timescales and whether the 12.8- and 25-d periods detected in HD 14134 and HD 42087 are also present in this dataset.

We may expect a B3 supergiant such as HD 14134 to exhibit gravity-mode oscillations (Lefever, Puls & Aerts 2007). To obtain a more complete picture of the variability taking place in this star, high-resolution spectroscopic observations with SOPHIE are scheduled in November 2010 on the 193-cm telescope of the Observatoire de Haute Provence (OHP; France) to investigate the existence of pulsations and to eventually link the variations taking place in the photosphere to those in the wind. We wish in particular to examine whether the wind variability is the direct consequence of the interference of several pulsation modes with shorter periods, as might be the case in the B0.5 I star HD 64760 (Lobel & Blomme 2008).

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