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EVIDENCE FOR SHORT-TERM VARIATIONS IN TWO O-TYPE STARS.

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The study of spectral variability of O-type stars led, in a few cases, to the discovery of variations with periods of a fraction of a day (see e.g. ζ Pup, Baade et al. 1991, and ζ Oph, Kambe et al. 1997). These variations are often considered to be the signature of non-radial pulsations. More recently, Rauw et al. (2008) investigated in detail the case of HD 93521 and reported on variations on time scales of 1.75 and 2.89 h. As only a handful of O-type stars displaying short-term variations are known, any new detection constitutes as significant improvement of the catalog of short-term varying massive stars.

In this paper, we present the results of a spectroscopic monitoring of two O-type stars. HD 13268 is an ON8V star that belongs to the Per OB1 association. HD 15137 (O9.5V) is a runaway SB1 system (P $\sim$ 30 d) whose preliminary orbital parameters have been prublished by Boyajian et al. (2005) and McSwain et al. (2007). The former authors suggested that this star may have been ejected from the nearby cluster NGC 654 in the Perseus spiral arm. Both stars display broad absorption lines due to a rather high rotational velocity. Their projected rotational velocities are respectively estimated to be equal to 302 km s^{-1} (Penny 1996) and 178 km s^{-1} (Conti & Ebbets 1977).

Our analysis is based on data collected with the Aurélie spectrograph at the 1.52-m telescope of the Observatoire de Haute Provence (OHP, France). In the case of HD 13268, the time series is constituted of 62 spectra obtained between October 2004 and November 2007, but most of the data were obtained during 4 nights in Autumn 2007 (see Table 1). We observed HD 15137 44 times during the same epoch, with 12 spectra obtained on the same night with a timespan of about 6 hours (on 2006, October 26th, see Table 2). Our spectra covered wavelengths between 4460 and 4890 Å , with a resolving power of about 8000. Exposure times were of the order of 25–45 minutes depending on the sky conditions. The signal-to-noise of our spectra – estimated in regions devoid of spectral lines – was higher than 200. The data were reduced following the procedure described by Rauw & De Becker (2004).

We applied the Time Variance Spectrum (TVS) analysis technique as described by Fullerton et al. (1996) to our spectral time series. In the case of HD 13268, we detected a significant – although weak – variability in the profile of He I λ 4471, He I $\lambda\lambda$ 4542,4686, and H β. This variability was present both in the complete data set, and in data sets of individual nights during which several spectra were collected. We analyzed our time series using the generalized Fourier technique of Heck et al. (1985) and revised by Gosset et al. (2001). This technique is especially adapted to the case of unequally spaced data. The power spectra are shown in Fig. 1 for He II λ 4686 and H β. Our results point to potential variability time scales of 14.5 and 6.7 h respectively for the two lines, even though significant residuals are still present after prewhitening (see middle panels of Fig. 1). Several factors are likely to contribute to these residuals: (i) the reported time scales may be incorrect (aliasing, ...), (ii) the low amplitude of the variations makes our temporal analysis very sensitive to noise, and (iii) more than one unidentified time scale may contribute to the detected variations. The studies of the other few examples of short-term varying O-type stars suggest indeed that multiperiodic variations are occurring.

Table 1. Journal of the observations of HD 13268. The heliocentric Julian date at mid-exposure is given as HJD - 2 450 000, and the date (yyyy/mm/dd) is that of the beginning of the night.

#	HJD	Date	#	HJD	Date	#	HJD	Date
1	3286.512	2004/10/07	22	4396.484	2007/10/22	43	4421.454	2007/11/16
2	3289.595	2004/10/10	23	4396.505	2007/10/22	44	4421.475	2007/11/16
3	3290.490	2004/10/11	24	4396.551	2007/10/22	45	4421.499	2007/11/16
4	3294.634	2004/10/15	25	4396.574	2007/10/22	46	4421.549	2007/11/16
5	3295.482	2004/10/16	26	4396.595	2007/10/22	47	4421.573	2007/11/16
6	3295.672	2004/10/16	27	4407.364	2007/11/02	48	4421.598	2007/11/16
7	3296.597	2004/10/17	28	4407.381	2007/11/02	49	4422.356	2007/11/17
8	3648.620	2005/10/04	29	4407.399	2007/11/02	50	4422.373	2007/11/17
9	3652.586	2005/10/08	30	4407.418	2007/11/02	51	4422.388	2007/11/17
10	3654.456	2005/10/10	31	4407.436	2007/11/02	52	4422.402	2007/11/17
11	3982.621	2006/09/03	32	4407.454	2007/11/02	53	4422.439	2007/11/17
12	3984.575	2006/09/05	33	4407.473	2007/11/02	54	4422.454	2007/11/17
13	4034.408	2006/10/25	34	4407.490	2007/11/02	55	4422.469	2007/11/17
14	4034.466	2006/10/25	35	4407.553	2007/11/02	56	4422.484	2007/11/17
15	4034.524	2006/10/25	36	4407.570	2007/11/02	57	4422.516	2007/11/17
16	4034.585	2006/10/25	37	4407.691	2007/11/02	58	4422.533	2007/11/17
17	4035.386	2006/10/26	38	4421.613	2007/11/16	59	4422.557	2007/11/17
18	4396.369	2007/10/22	39	4421.350	2007/11/16	60	4422.570	2007/11/17
19	4396.392	2007/10/22	40	4421.370	2007/11/16	61	4422.594	2007/11/17
20	4396.414	2007/10/22	41	4421.393	2007/11/16	62	4422.608	2007/11/17
21	4396.462	2007/10/22	42	4421.433	2007/11/16			

Table 2. Journal of the observations of HD 15137.

#	HJD	Date	#	HJD	Date	#	HJD	Date
1	3652.642	2005/10/08	16	4035.545	2006/10/26	31	4409.528	2007/11/04
2	3654.538	2005/10/10	17	4035.568	2006/10/26	32	4410.475	2007/11/05
3	3980.585	2006/09/01	18	4035.588	2006/10/26	33	4411.551	2007/11/06
4	3982.552	2006/09/03	19	4035.611	2006/10/26	34	4412.504	2007/11/07
5	3984.545	2006/09/05	20	4035.632	2006/10/26	35	4413.584	2007/11/08
6	4033.406	2006/10/24	21	4035.655	2006/10/26	36	4414.530	2007/11/09
7	4033.495	2006/10/24	22	4396.438	2007/10/22	37	4415.546	2007/11/10
8	4033.602	2006/10/24	23	4397.516	2007/10/23	38	4416.453	2007/11/11
9	4034.670	2006/10/25	24	4400.646	2007/10/26	39	4417.467	2007/11/12
10	4035.413	2006/10/26	25	4401.598	2007/10/27	40	4418.383	2007/11/13
11	4035.437	2006/10/26	26	4402.588	2007/10/28	41	4419.412	2007/11/14
12	4035.458	2006/10/26	27	4405.599	2007/10/31	42	4421.525	2007/11/16
13	4035.480	2006/10/26	28	4406.590	2007/11/01	43	4422.421	2007/11/17
14	4035.502	2006/10/26	29	4407.532	2007/11/02	44	4423.322	2007/11/18
15	4035.524	2006/10/26	30	4408.591	2007/11/03			

In the case of HD 15137, our sampling of high frequencies is rather poor as this star was intensively observed during only one night. However, the TVS indicates a significant line profile variability of at least He I λ 4471 and Hβ, i.e. the strongest absorption lines in the blue spectrum, during that particular night. The comparison of the line profiles obtained during a same night reveals indeed variations from one spectrum to the other, with time intervals of the order of 30–40 minutes between two consecutive observations. These variations can be seen in the line profiles plotted in the left part of Fig. 2. We note that it is unlikely that these variations be due to the orbital motion of the SB1 as its period is of the order of 30 d, i.e. much longer than the time scales investigated during a single night. The right part of Fig. 2 shows the power spectrum of the complete time series for Hβ. The wavelength position of the line profile has been corrected for the orbital motion before computing the power spectrum. The corrections were calculated on the basis of a SB1 orbital solution computed from our data and the radial velocities published by Boyajian et al. (2005) and McSwain et al. (2005), using the same method as De Becker et al. (2006). We note the presence of a family of peaks close to 2 d^{-1}. Some power is also found at higher frequencies (see for instance a low amplitude family of peaks whose presence is suggested around 10 d^{-1}). A much better sampling of high frequencies is however needed in order to clarify the situation and propose valuable values for the short variability time scale(s). We note that Boyajian et al. (2005) already suggested the occurrence of short-term variations for this star.

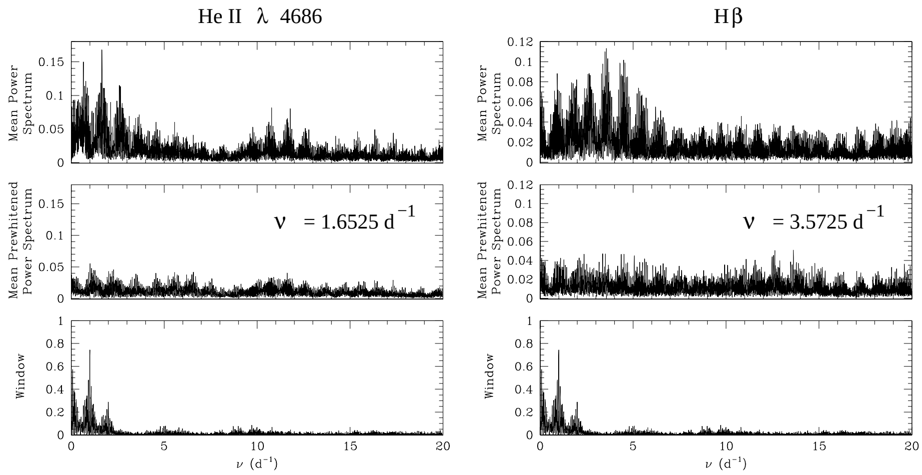

Figure 1. Fourier analysis of He II λ 4686 between 4682 and 4685 Å (*left part*) and Hβ between 4857 and 4860 Å (*right part*) in the case of HD 13268. *Upper panels:* mean power spectrum over the specified wavelength domain. *Middle panels:* prewhitened power spectrum using the specified frequency corresponding to the highest peak in the upper panel. Significant residual power is still present, but a much better sampling of higher frequencies is requested in order to determine accurately the variability time scales. *Lower panels:* spectral window related to the data sampling.

Considering (i) the low amplitude of the variations and (ii) their rather high frequency, intensive monitoring with large collecting area telescopes is really needed if one wants to investigate the short term behaviour of these stars. Typically, several complete nights on 4-m class telescopes, using rather high resolving power (at least 20000), should be devoted to these targets in order to characerize their short term variations in a way similar to that of HD 93521 (Rauw et al. 2008) or ζ Oph (Kambe et al. 1997).

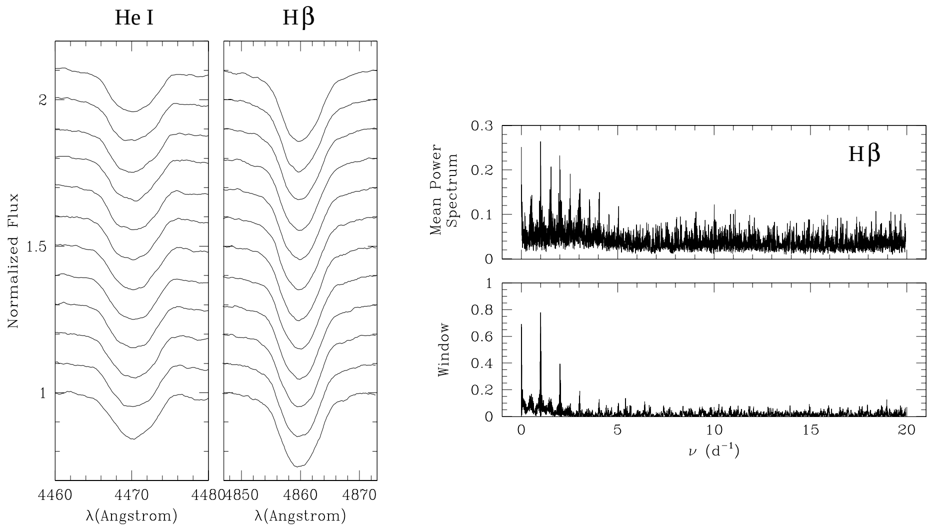

Figure 2. *Left part:* Line profiles of He I λ 4471 and Hβ in the case of HD 15137. The selected spectra are those obtained during a single night (number #10 to #21 in Table 2, from the top to the bottom). *Right part:* Fourier analysis of the complete time series (44 spectra) for Hβ after correction for the SB1 orbital motion. We note that some residual power due to the orbital motion may still be present at low frequencies. The power spectrum suggests however the presence of frequencies likely related to time scales of a fraction of a day.

In summary, we report on the detection of significant variations on time scales of a fraction of a day in the blue spectrum of two late-type main-sequence O stars: HD 13268 and HD 15137. The frequency sampling of our time series did not allow us to determine the variability time scale, but we claim that these stars should be considered as very valuable targets for future studies aiming at investigating rapid variations in O-type stars. Such variations may be the signature of non-radial pulsations, or of structures related to circumstellar rotating material. Intensive high spectral resolution spectroscopic campaigns are needed to investigate such a behaviour.

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