Superfast Variability of Line Profiles in the Spectra of Bright OBA Stars: New Results

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1 Searching the Superfast LPVs

Line profiles in spectra of OBA stars are varying on time scales from days to hours (e.g. Hubrig et al. 2017). To detect the short-period Line Profile Variations (LPVs) for OBA stars they have to be observed with a high temporal resolution (a minute or less) and with the large S/N ratio. Our **Large Observational Project** for studying such superfast line profile variations (sfLPV) started in 2015. In 2015-2017, the observations were carried out at the 6-meter telescope of the Special Astrophysical Observatory (Russia) using the low-resolution spectrograph SCORPIO (Afanasiev & Moiseev 2005). Observations made in 2015-2017 are reviewed by Tsiopa et al. (2020).

After a short break in 2018 observations were continued at the 6-meter telescope with the Main Stellar Spectrograph (MSS, Panchuk et al. 2014). In 2019-2020 spectroscopic observations were carried out with a 1.25-m telescope at the Crimean Astronomical Station of the Sternberg Astronomical Institute (SAI) of the Moscow State University (e.g., Kholtygin et al. 2020). Almost 5000 spectra of bright OBA stars were obtained in 2019-2020. Further we shortly review the observations of selected stars (see Table 1).

Table 1. Stars observed to detect the fast LPVs.

Star	Sp.Type	V	N_{sp}	Exp (s)	Date obs.
6-m telescope, SCORPIO					
HD 93521	O9 Vp	7.06	529	3	19-20.01.2015
ρ Leo	B1 Iab	3.87	1271	1	19-21.01.2015
α^2 CVn	A0spe	2.90	387	1	21-22.01.2015
HD 21839	A0Ia	4.54	330	11	19-20.01.2015
γ UMi	A2III	3.00	249	20	07.01.2017
6-m telescope, MSS					
ζ Ori	O92I	1.88	76	90	19.02.2019
ρ Leo	B1 Iab	3.87	80	90	19.02.2019
α^2 CVn	A0spe	2.90	71	90	5.1.2020
HD 34078	O9.5V	5.96	27	$320-420$	5-8.1.2020
HD 45314	O9:npe	6.64	20	600	5-8.1.2020
1.25-m telescope, Crimean Station SAI					
ρ Leo	B1 Iab	3.87	263	10	26-28.10+1-2.11.2019
α And	B8IV	2.06	2611	2	16-17.9.2020
γ Cas	B0.5IVpe	2.39	1575	2	17-18.9.2020
19 Cep	O9Ib	5.11	225	30	21-22.9.2020

2 Observations in 2019-2020

2.1 α^2 CVn

Totally 71 spectra of α^2 CVn were obtained. In Fig. 1 (left panel) one can see weak FeI, CrII and ThII lines near the strong CrII 4924 line. The corresponding difference spectra are given in the right panel. Regular components of LPVs with periods of $5-140$ minutes were discovered. The rotation period of α^2 CVn using the TESS satellite photometric data $P = 5^{\rm d}.43730$ is refined. The average of all the measured longitudinal magnetic field values is $\overline{B}_e = 600 \pm 56$ G.

2.2 ζ Ori A

The 76 spectra of the binary star ζ Ori A (O9.2Ib+B1IV) were obtained using the MSS spectrograph of the 6-meter BTA telescope based on observations made on February 19, 2019. The variability of the line profiles was analyzed. Short-period regular variations of the Balmer lines and He I lines with periods from ~ 89 to $\sim$295 minutes are found. The presence of short-period variations in the interval of periods of 10-20 minutes seems to be also possible. An analysis of the stellar brightness variations from the TESS satellite showed the presence of seven regular components, one of which is probably the second harmonic of the rotation period $P = 6.82 \pm 0.19$ days of the main component Aa.

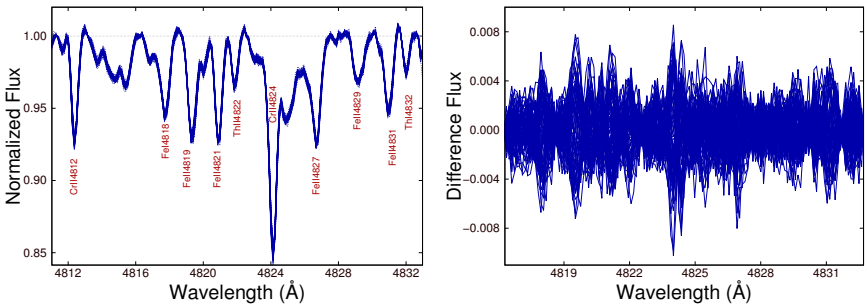

Fig. 1. Left panel: Cr II 4824 line profiles for all 71 spectra of α^2 CVn. **Right panel:** Difference spectra of Cr II 4824 line.

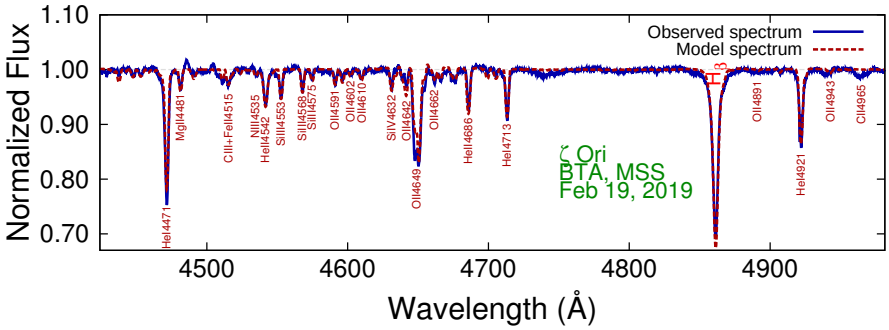

Fig. 2. A comparison of the observed (solid line) and model (dashed line) spectra of ζ Ori A.

The spectrum of the ζ Ori A was modeled with the non-LTE code CMFGEN by Hillier & Miller (1998). As it can be seen in Fig. 2 the mean observed spectrum is in a good agreement with the model one. The magnetic field of the star was measured for all observations. The *rms* value of the longitudinal component of the magnetic field measured by the regression method is $\sim$49 G.

2.3 α And

For a very bright B8IV star α And over 2600 spectra were obtained. Line profile variations of line H_α in spectra of α And is shown in Fig. 3 (left panel). Regular components of LPVs are found as it can be seen in the right panel. The regular LPVs with periods of 5, 19, 51, 58, and 67 minutes were detected.

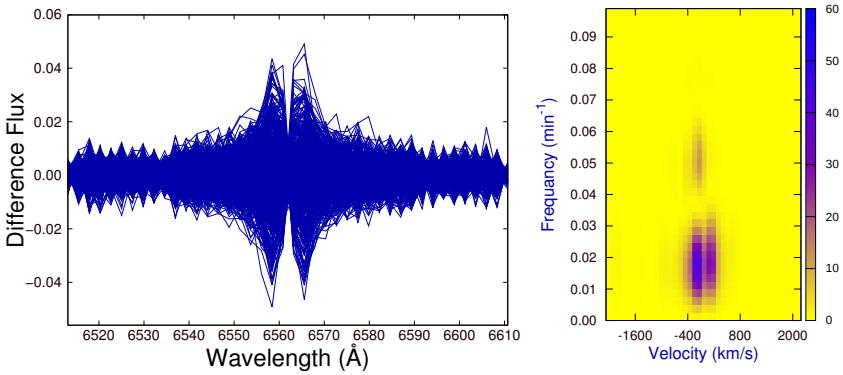

Fig. 3. Left panel: Difference spectra of line H_α in spectra of α And. **Right panel:** Fourier spectra for the H_α LPVs.

Resuming the results of our 6 year investigations we can conclude that fast variations in the line profiles were detected for all 14 of observed OBA stars. The detected LPVs are mainly regular with periods from 1 to 300 minutes and can be connected with the high modes of non-radial pulsations (NRP). LPVs in the frequency range $\nu < 0.1\,\mathrm{min}^{-1}$ have a transient nature with lifetimes from 30 to 120 minutes. The periods of these transients can be slightly varied by 10-20% during their lifetime. Such type of their behavior can be explained by the instability of high ($l > 100$) NRP modes.

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Bibliography

Afanasiev, V. L. & Moiseev, A. V. 2005, Astronomy Letters, 31, 194
Hillier, D. J. & Miller, D. L. 1998, ApJ, 496, 407
Hubrig, S., Mikulášek, Z., Kholtygin, A. F., et al. 2017, MNRAS, 472, 400
Kholtygin, A. F., Ikonnikova, N. P., Dodin, A. V., & Tsiopa, O. A. 2020, Astronomy Letters, 46, 168
Panchuk, V. E., Chuntonov, G. A., & Naidenov, I. D. 2014, Astrophysical Bulletin, 69, 339
Tsiopa, O., Batrakov, A., Kholtygin, A., et al. 2020, Astronomical Journal of Azerbaijan, 14, in press