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Spectroscopic characterization of superflares on solar-type stars – a joint observing campaign

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Abstract. During the last decade numerous superflares have been detected on solar-type stars using broadband photometry from the Kepler and TESS satellites. Still the spectroscopic exploration of this high-energy phenomenon is lacking. This exploration would reveal what makes normal flares different from superflares. The spectroscopic detection of superflares requires dedicated observational efforts, as this phenomenon is sporadic. We present here one step of joint observational efforts to spectroscopically characterize superflares. We focus on the solar-type stars EK Dra, V833 Tau, and BY Dra, as those are relatively bright and active, and especially V833 Tau shows a high superflare rate in TESS data. The spectroscopic observations have been done at the Skalnaté Pleso observatory operated by the Slovak Academy of Sciences and the Ondřejov observatory operated by the Czech Academy of Sciences. Coordinated photometry in two filters has been done at Stará Lesná/Skalnaté Pleso

observatory run by the Slovak Academy of Sciences, ELTE Gothard Astrophysical Observatory, Szombathely, Hungary, and Lustbühel Observatory run by the University of Graz, Austria. In total around 24 hours were spent on EK Dra, 12 hours on BY Dra, and 20 hours on V833 Tau. However, no superflares have been detected. We discuss detection probabilities and the importance of studying superflares spectroscopically.

Key words: stars – solar-type – stellar activity – superflares

1. Introduction

Superflares are highly energetic ($>10^{33}$ erg) outbreaks of stellar radiation (see e.g. Maehara et al., 2012). Still, their origin and the origin of their emission is debated. Spectroscopic characterization is one tool to evaluate what makes superflares different from normal flares. Especially what spectral lines are affected and how the continuum enhancement in the blue spectral range is evolving, are still open questions.

2. Target stars, results and conclusions

We select three solar-type stars as targets which are relatively bright and show numerous flares in TESS data (see Table 1).

Table 1. Characteristics of the target stars of the campaign. XUV flare rates have been determined based on the flare power law from Audard et al. (2000), the Hα flare rates have been estimated based on Leitzinger et al. (2020), and the TESS flare rates have been determined by eye from the light curves. The logarithmic X-ray luminosities have been taken from Güdel (2007) and Hinkel et al. (2017).

	spectral type	Age [Gyr]	logLx [erg s^{-1}]	XUV/Hα/TESS flare rate [day^{-1}]	V [mag]
EK Dra	dG0	0.1	29.93	50/3/0.5	7.6
BY Dra	dK5e+dK7e	-	29.92	50/3/1.4	8.2
V833 Tau	dK2e	0.65	29.92	50/3/2.8	8.2

In total four observatories contributed to the joint observing campaign: Ondřejov Observatory, Czech Republic (spectroscopy/photometry) and Skalnaté Pleso Observatory, Slovakia (spectroscopy/photometry), ELTE Gothard Astrophysical Observatory, Hungary (photometry), and Lustbühel Observatory, Austria (photometry). In total three nights were spent on EK Dra, half a night on BY Dra, and nearly one night on V833 Tau. Comparing these observing times to Table 1, one can see that regarding the TESS flare rates we should have detected at least one flare on BY Dra and V833 Tau. But the observations were

not taken in a row, therefore the probability of observing the star in non-flaring state is higher.
Flares in optical spectra are identified via an increase in flux of e.g. Balmer lines (see e.g. Wollmann et al., 2023) and the sudden formation of temperature sensitive spectral lines. As the involved spectrographs are Echelle spectrographs (Kabáth et al., 2020) yielding resolving powers of 50000 (Ondřejov) and 38000 (Skalnaté Pleso), we binned the spectra in spectral direction, but even that did not reveal flaring signatures (for sample spectra see Fig. 1). Also the coordinated photometry (g-, and r-band) did not reveal any flares.
Certainly the total observing time was too short to see flares. However we probed with few hours on each target the potential of detecting flares on active solar analogues, and a follow-up campaign is already planned for 2023/2024 with an improved observing strategy involving consecutive nights. Due to the high flaring state and brightness of V833 Tau this target will be a promising candidate for detecting superflares spectroscopically.

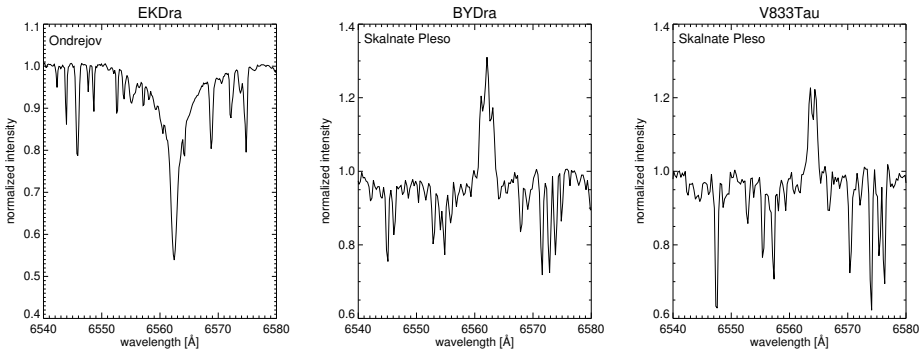

Figure 1. Hα spectra of EK Dra, BY Dra, and V833 Tau, obtained from Ondřejov and Skalnaté Pleso observatories. The spectra have been binned in spectral direction and are temporally averaged.

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