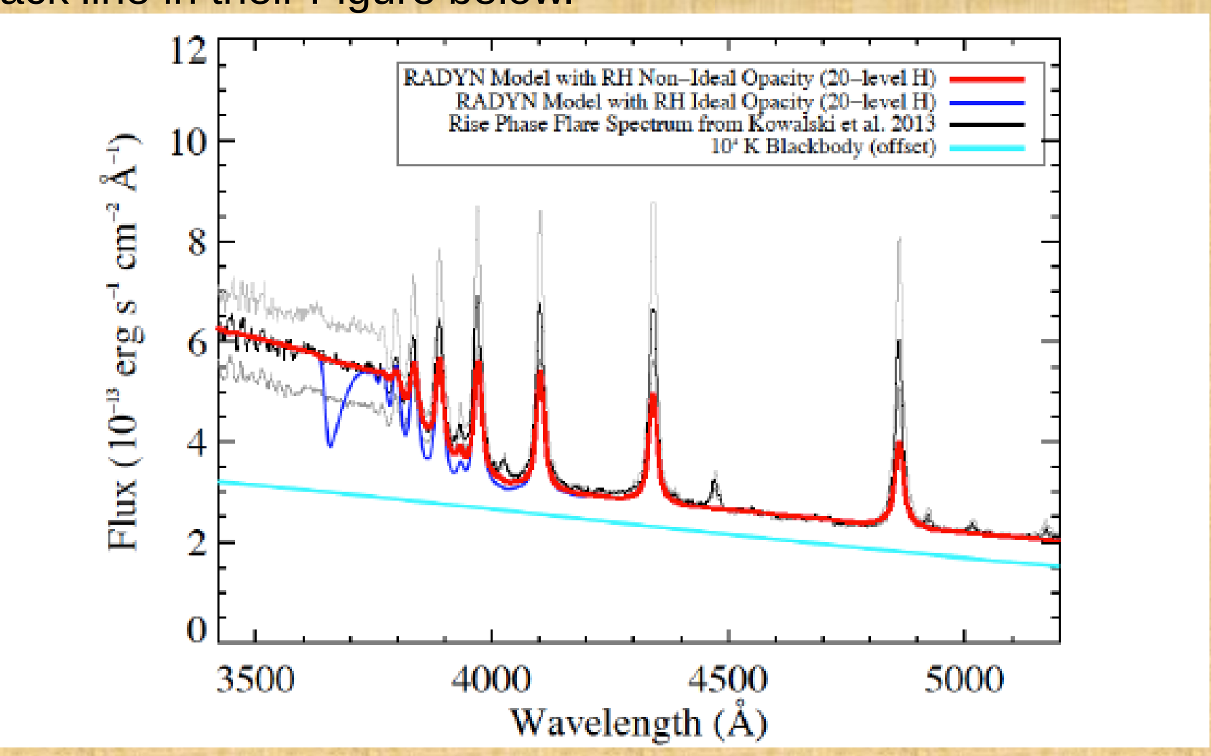
Fast measurements of optical spectral fluxes in solar flares

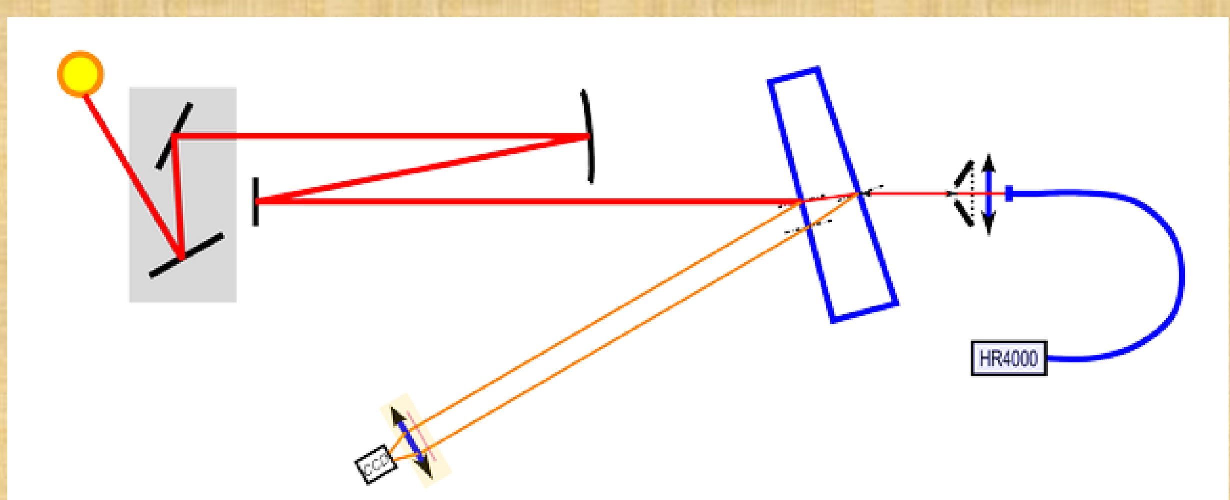
P. Kotrč [1], P. Heinzel [1] and O. Procházka [1,2]

[1] Astronomical Institute, v.v.i., Ondřejov, Czech Republic
[2] Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

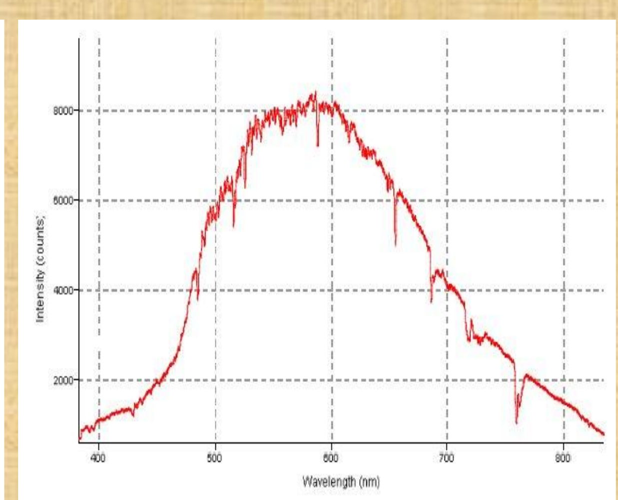
Study of continua in solar flares brings new information both to the topic of white-light flares and the physics of storage and release of the flare energy. Measurement of an increased Balmer continuum during a large stellar flare at M-type dwarf was reported by Kowalski et al. 2013, ApJS, 207, 15, see the black line in their Figure below.



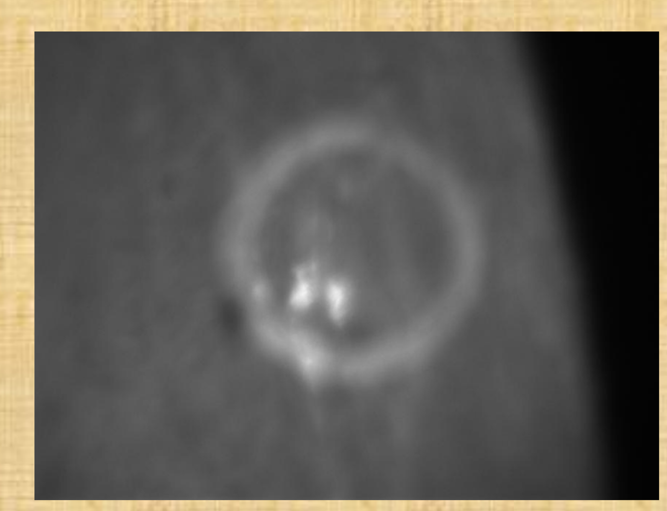
We measure spectra from a selected part of the solar flare region. As a measuring device we constructed a post-focal device consisting of an image selector and a fast spectrometer. A small H-α telescope takes snapshots from the reflecting optical surface in front of the diaphragm of the selector. See the schema below.

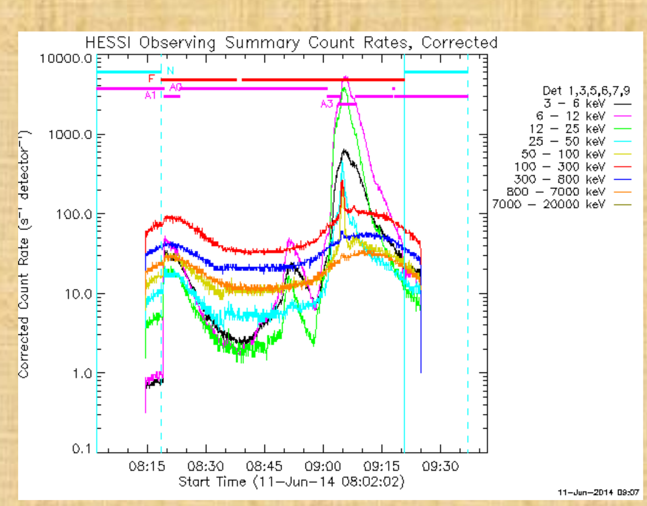


Horizontal solar telescope HSFA2 (red line) creates solar disk image Φ 32 cm at the optical surface (blue wedge). Light is partly reflected to the Hα telescope (light brown) and partly enters to the light collector through one of 7 diaphragms placed on a rotating wheel. Optical cable (blue arc) feeds the spectrometer HR4000 (right down).



The HR4000 high-resolution spectrometer with a 3648-element CCD-array enables optical resolution as precise as 0.02 nm (FWHM). The specific range and resolution depends on the grating and entrance slit choices.





Left: Hα image from the reflected light in front of the selector. Flare kernels are bright, the bright ring determines the entrance diaphragm collecting the light into the fast spectrometer. Right: RHESSI plot for the flare observed near the eastern limb.

Recently, we put the device into operation and succeeded to observe a few flares with it. We present preliminary results on the the flare on June 11, 2014 at 8:46 UT (according to GOES) of which the slit-jaw image is. See the Hα image and the RHESSI plot above.

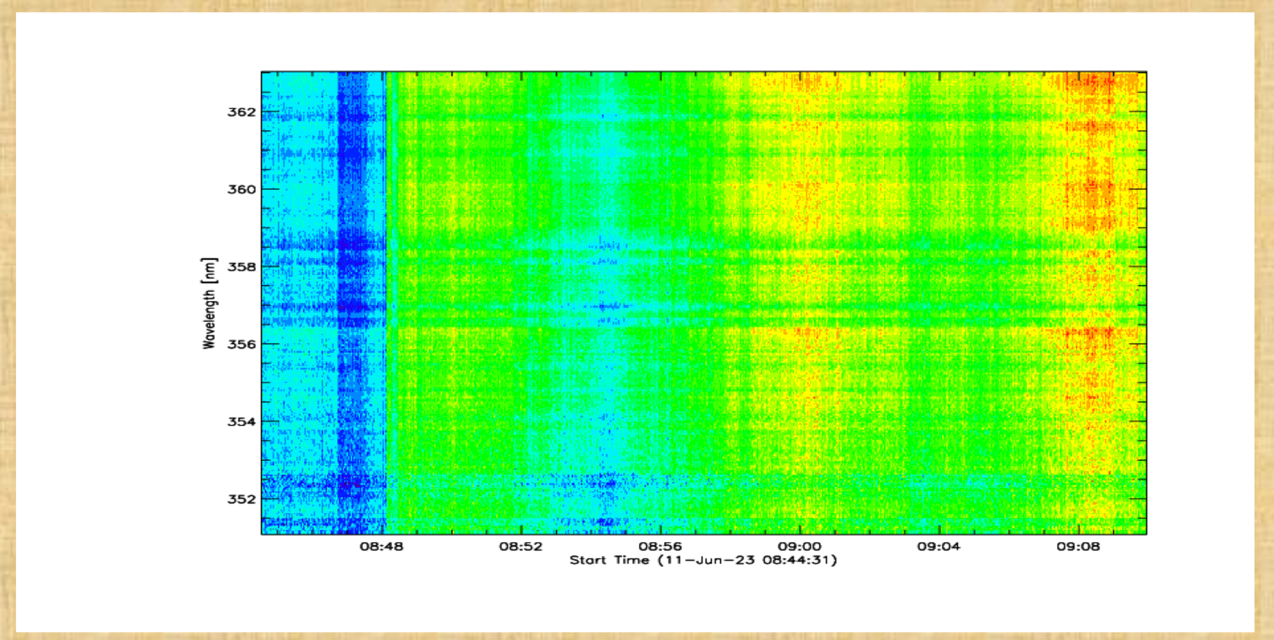
Motivation:

After the SDO launch, solar flares are routinely detected in EUV. There, the spectrometer EVE measures an integrated flux of the Sun-as-a-star, with a fast cadence in the spectral range from far EUV up to the Ly-alpha line. The flare spectra are well detected on the background of the solar disk. On the other hand, the detection of flare line emission from the Sun-as-a-star in optical is much more difficult due to a strong background radiation.

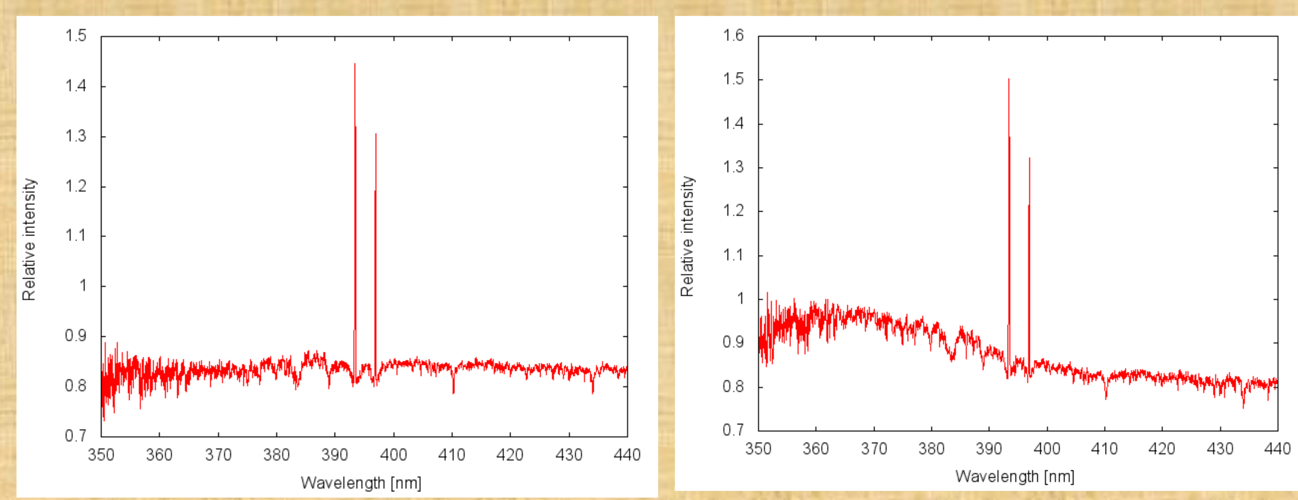
Here we present a novel technique to overcome such a difficulty. With a compact, low-dispersion spectrometer, we are able to detect flares and their fast time evolution simultaneously in the wavelength range 350 – 440 nm, covering many spectral lines and various continuum features. This data is complementary to the EUV spectra and can be used for a broad-band diagnostics of chromospheric flare plasmas. The spectral range can be easily extended up to the infrared one. We present a description of the device, the first measurements performed, and at lest qualitative results we obtained at Ondrejov observatory.

Conclusions:

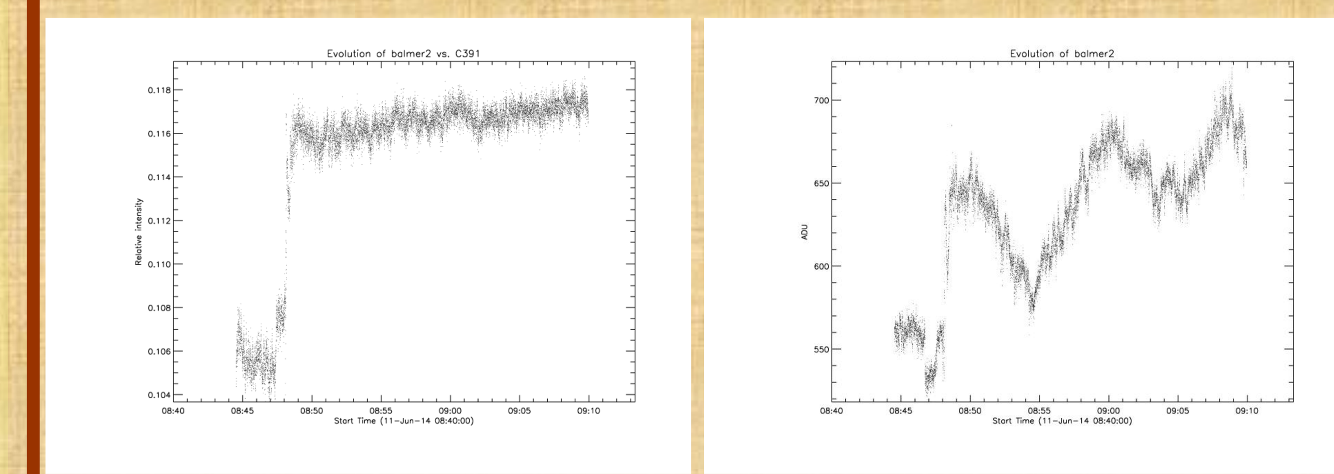
The preliminary results prove that the described device is sufficiently sensitive to measure possible changes of the Balmer continuum during a flare. Due to the high sensitivity we need a precise guiding of the telescope and a good pointing. We studied these problems and finally we have solved them in a satisfactory way. Analyzing data from several observed flares we found that the results are in a good agreement with the RHESSI observations. Using of statistical methods we are able to fully utilize possibilities of the fast spectrometer. This novel approach can reveal new possibilities in further study of solar flares.



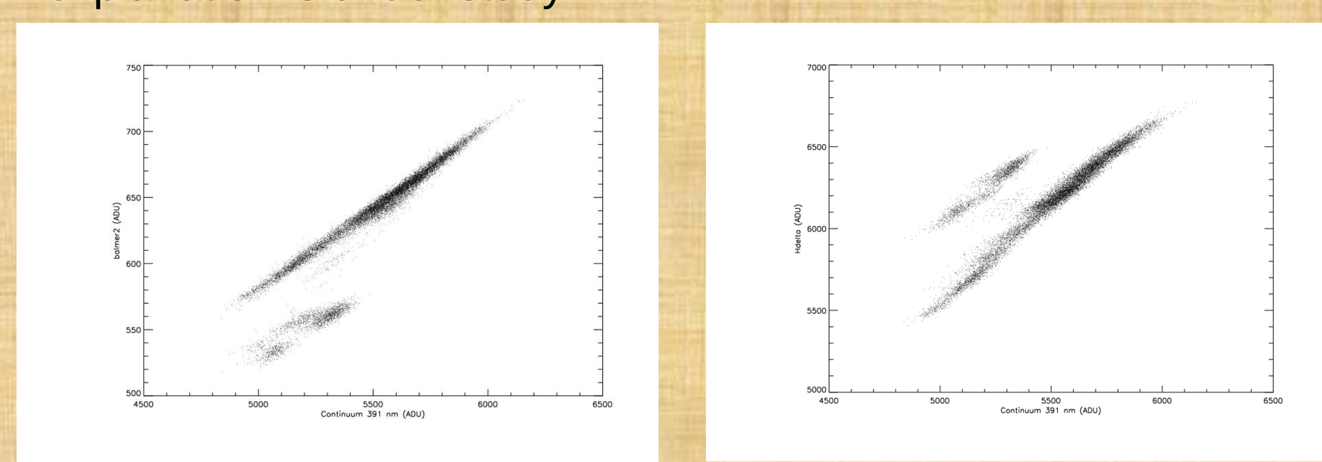
In the Figure above we see spectra in the range 351 to 363 nm (axis Y) and time from 8:45 – 9:10 UT (axis X). Blue colour means intensity maximum, red is for minimum.



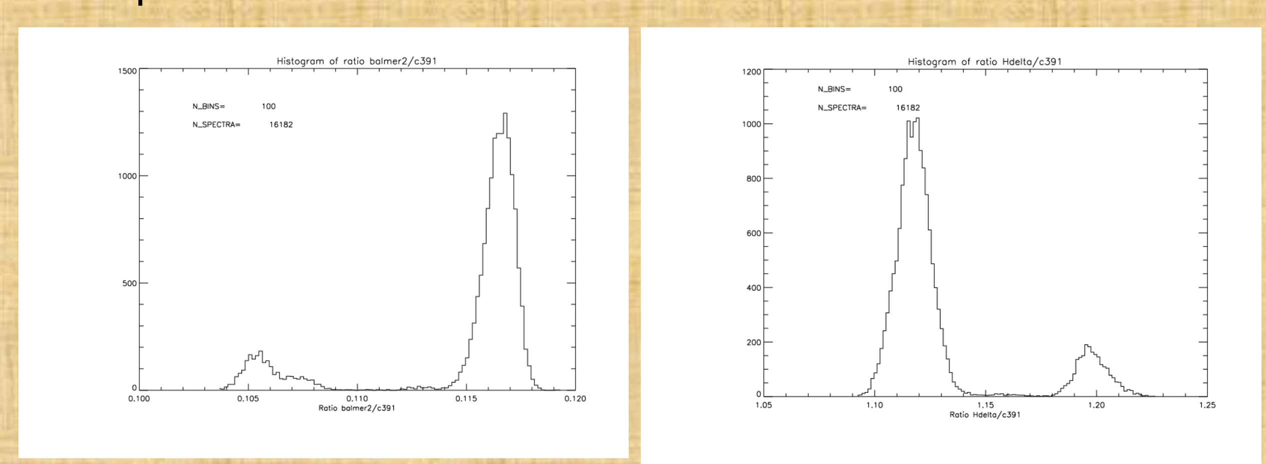
Two examples of the measured spectra before the flare (left) and during the flare (right). See the CaII H and K lines in emission and the increased continuum during the flare of which the "slit-jaw" image is left below.



We studied the spectral flux in several individual channels as the Balmer continuum, Balmer limit, Ca H or K lines, Fe lines, G-band etc. Eg. the Balmer2 stands for 351.10 - 363.03 nm, while c391 is for 391.06 - 391.53 nm We found that the individual channels had completely different behaviour before and during the flare. While some displayed an increase, others dropped. In the two Figures above we see that the relation of the Balmer continuum to c391 become stable (left), the Balmer continuum displays repeating changes. The explanation is under study.



In the Figure above we see a pair of two quite different populations of the Balme2r/c391 values in the various observed flare periods.



Histograms of Balmer2/c391 ratio (left) and that of Hδ/c391 (right) ratios. The physical explanation needs more observations and data analysis. We plan to observe more spectra and compare the quiet and flaring active region observations obtained at the same solar altitude above horizon due to changing differential absorption and refraction.
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Acknowledgements.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 606862 (F-CHROMA)".