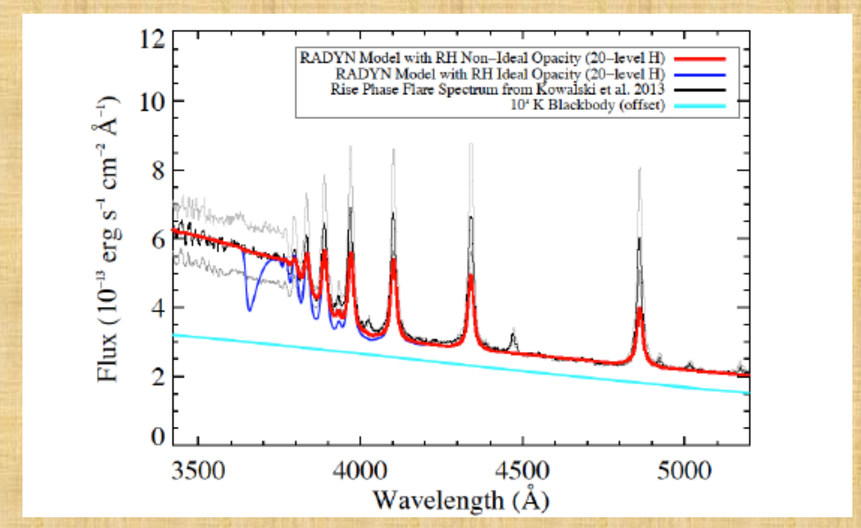
Fast measurements of 350 – 440 nm fluxes in solar flares

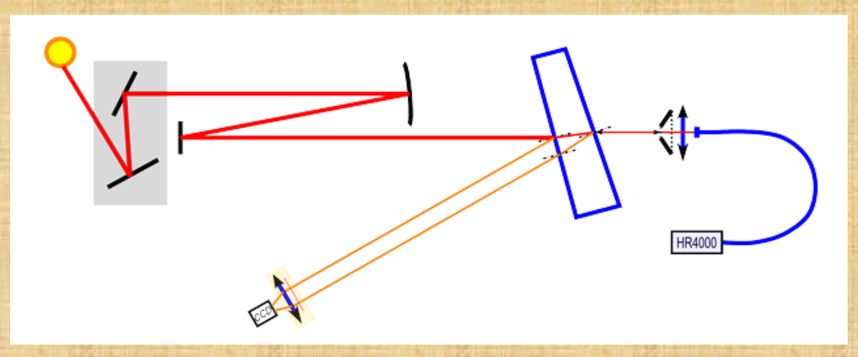
P. Kotrč [1], P. Heinzel [1] and O. Procházka [1,2]

[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.

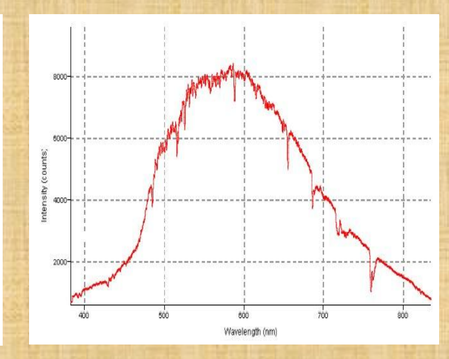


Zirin and Neidig, 1981, (ApJ 248, L45-L48) reported an increase of Balmer continuum in a solar flare up to 2.5 times the photosphere. Hiei, 1982 (SolPh 80, 113-127) measured an increase of Balmer continuum in the white-light flare from 7.5 up tu 14 percent. Both measurements were performed on the photographic detectors. We realized that that more precise and detail measurement of the Balmer continuum flux in solar flares can be provided by fast and sensitive CCD detectors. The expected flare/quiet region contrast is proportional to the size ratio of the flaring and the quiescent solar surface. Thus, we projected and realized a post-focal device consisting of an image selector and a fast spectrometer for measuring a flux from a part of a solar disk. 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.



Motivation:

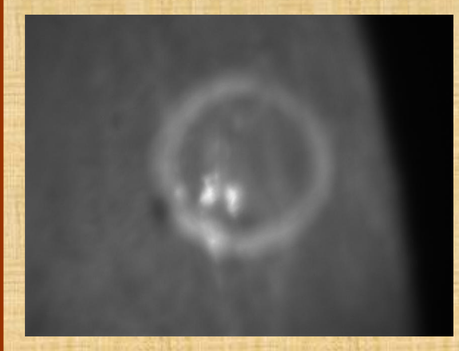
After the SDO launch, solar flares are routinely detected in EUV. There, the spectrometer EVE measures an integrated flux of the Sun-as-a-star, with a fast cadence in the spectral range from far EUV up to the Ly-alpha line. The flare spectra are well detected on the background of the solar disk. On the 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.

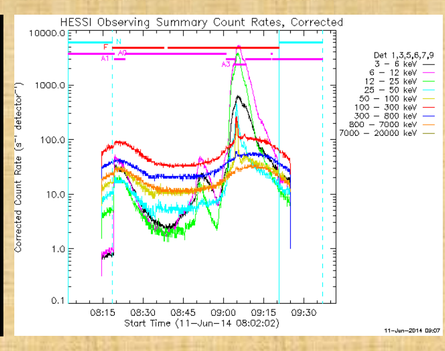
Here we present a novel technique to overcome such a difficulty. With a compact, low-dispersion spectrometer, we are able to detect flares and their fast time evolution simultaneously in the wavelength range 350 – 440 nm, covering many spectral lines and various continuum features. This data is complementary 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:

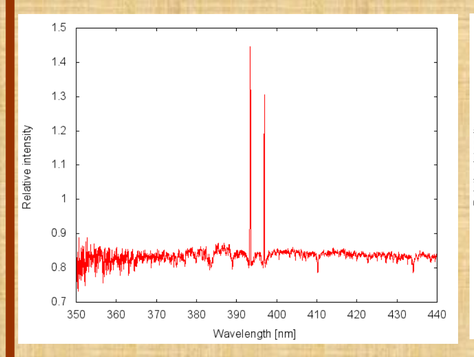
The preliminary results prove that the described device is sufficiently sensitive to measure possible changes of the Balmer continuum during a flare. Analyzing data from several observed flares we found that the flux observations are in a good agreement with the RHESSI data. For the flare analyzed we found a rough estimation of the Balmer continuum contrast up to value of 6. We analyze also interesting changes of the Balmer continuum flux starting even 12 minutes before the onset of the flare in Hα. We need more flare observations to analyze the general aspects of the Balmer continuum flux during flares.

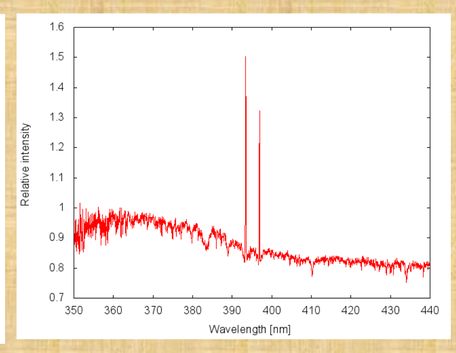
Recently, we put the device into operation and succeeded to observe a few flares with it. We present preliminary results on the X1 flare at S18E66 on June 11, 2014 at 8:59 – 9:10 UT, max. at 9:06 UT, (according to GOES).



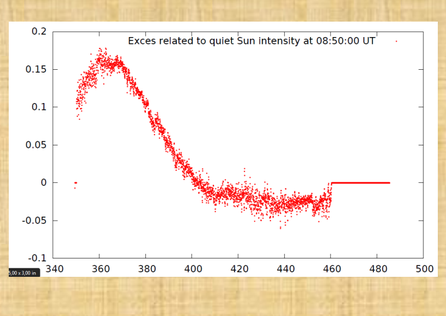


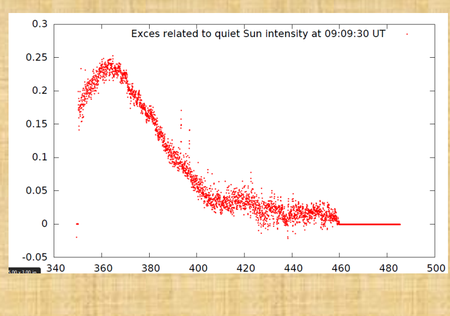
The Hα image of the flare inside the circular entrance diaphragm (left) and the RHESSI flare plot (right).



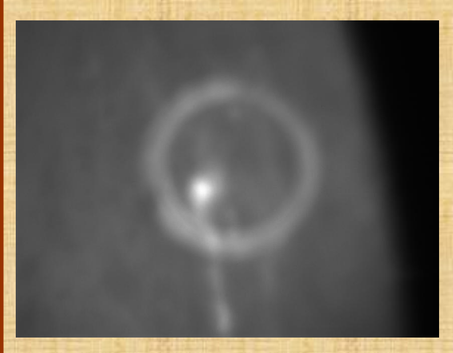


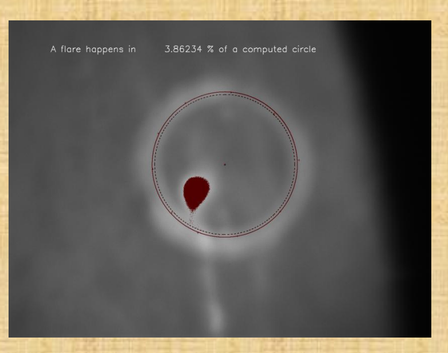
Two examples of the measured spectra before the flare (left) and during the flare (right). See the CaII H and K lines in emission and the increased continuum during the flare of which the “slit-jaw” image is left below.





Relative excess (contrast) of the flaring – quiescent solar flux at beginning of the flare at 08:50:00 UT (left), and maximum of the flare at 09:09:30 UT (right). The relative excess reaches maximum values 17, and 25 percent, respectively.





Original (left) and processed (right) Hα images from the image selector after the maximum of the flare at 09:09:30 UT. Only the flux from the red circle enters the spectrograph.

We suppose that the size of the flare kernels in Hα is the same as in Balmer continuum. As the flaring/quiescent size ratio reaches 4 percent of the entering circular diaphragm only, the Balmer continuum contribution from the flaring region itself has to be related to this small size kernel. A rough estimation of the flaring region at Balmer continuum radiation after maximum (09:09:30 UT) reaches 25 x 25, i.e 6.25 times the level of non flaring region. It is the highest ratio value that we obtained. The ratio value would be smaller when the size of the flare kernel in Balmer continuum would be larger than in Hα. As the flare occurs close to the solar limb, the geometrical projection and the limb darkening also explain to the high excess value.

Acknowledgements.

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