On measurements of optical continuum flux in solar flares.

P. Kotrč[(1)], P. Heinzel[(1)] , O. Procházka[(2)]
and M. Zapior[(1)]

(1) - Astronomical Institute, AS CR, v.v.i. Ondřejov, Czech Republic
(2) – Astrophysics Research Centre, Queen's University Belfast, Northern Ireland, UK

OUTLINE:

Introduction
White light flares, Balmer/blue continuum
Stellar and solar B.c.flare observations
A new device for B.c. flux measurements
First B.c. observation in flares in 2014
Preliminary results, timing, pulsations,… (?)

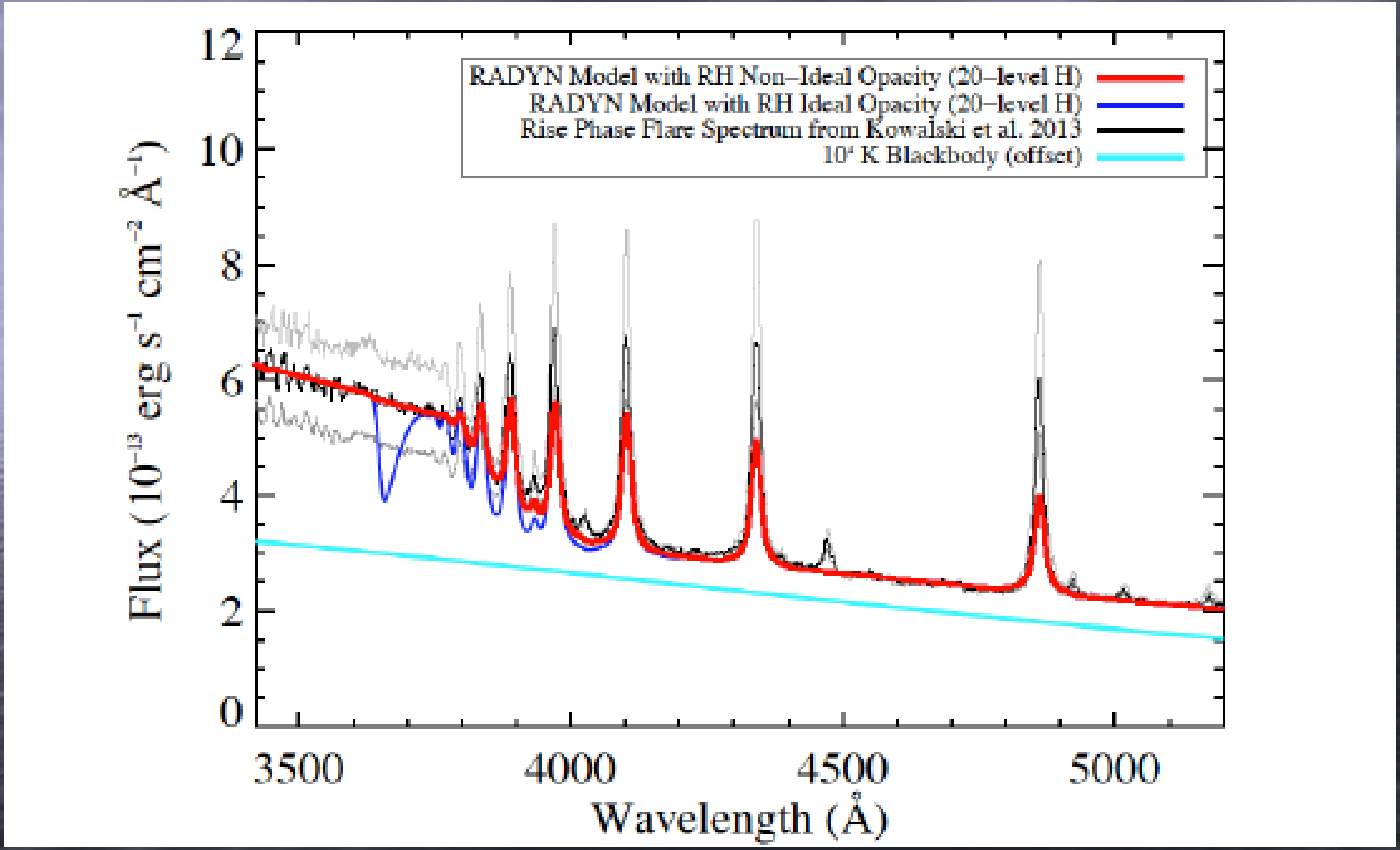
White-light flares (WLFs) / solar

- The Carrington flare on Sept. 1, 1859 = WLF
- WLF - the most energetic flaring events observable in the optical broad-band continuum of the solar spectrum (Wang, 2008)
- Very small white-light kernels <3” (Neidig, 1989)
- Role of atmospheric seeing in difficulties of detection of WLFs
- using ground-based telescope (Hiei, 1982)
- WLFs are associated with more energetic EUV and SXT flares (Neidig and Cliver, 1983)
- WLF mechanisms: (electron beams <20keV, Metcalf et al. 2003? or a back-warming effect in the energy transport from upper chromosphere – to photosphere? (Machado et al. 1989)
- Ding, 2007, 2 classes of WLF, I-photospheric H^- temp. increase,
  II - chromospheric H recombination

White-light flares (WLFs) / stellar

- White-light flares observed on late types of stars, namely dwarfs type M with emission lines, dMe
- The WL enhancement ends when the impulsive stage of the flare has ceased (Bopp & Moffett,1973), while
- a gradual decay in continuum emission, even after the end of the impulsive phase was found by Hawley & Pettersen (1991)
- A new measurement of Kowalski et al 2013 reported an increase of Balmer continuum in dMe stars.

WLF at dMe star by Kowalski et al.



Raised questions (and problems)

- How to measure blue/Balmer continua in solar flares?
- How to increase contrast in flare against the disk?
- Either to use filtergrams or spectral measurements?
- Which device is the best tool for observations of blue continuum?
- What method is more perspective/efficient?
- How to study changes in various parts of blue continuum ?
- How to observe flares at b.c. and in Hα simultaneously?
- Can we detect real changes of blue continuum flux in real time?
- What is time correlation of b. c. with Hα, SXT, EUV, … ?
- Are we able to suggest a simple non expensive device for that task?

An instrument for flux measurement

- Demands:

To follow active region for flares in H-alpha

Good guiding of the telescope

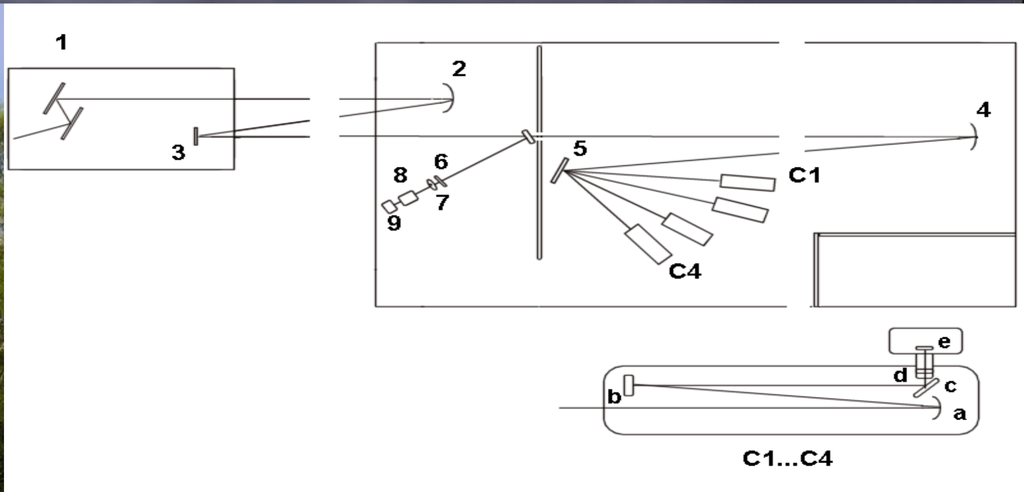
Increased sensitivity in blue continuum

To define the region of measurement

Enable to reduce the disk radiation

High cadence of at least 10 images/second

Ondřejov large horizontal telescope

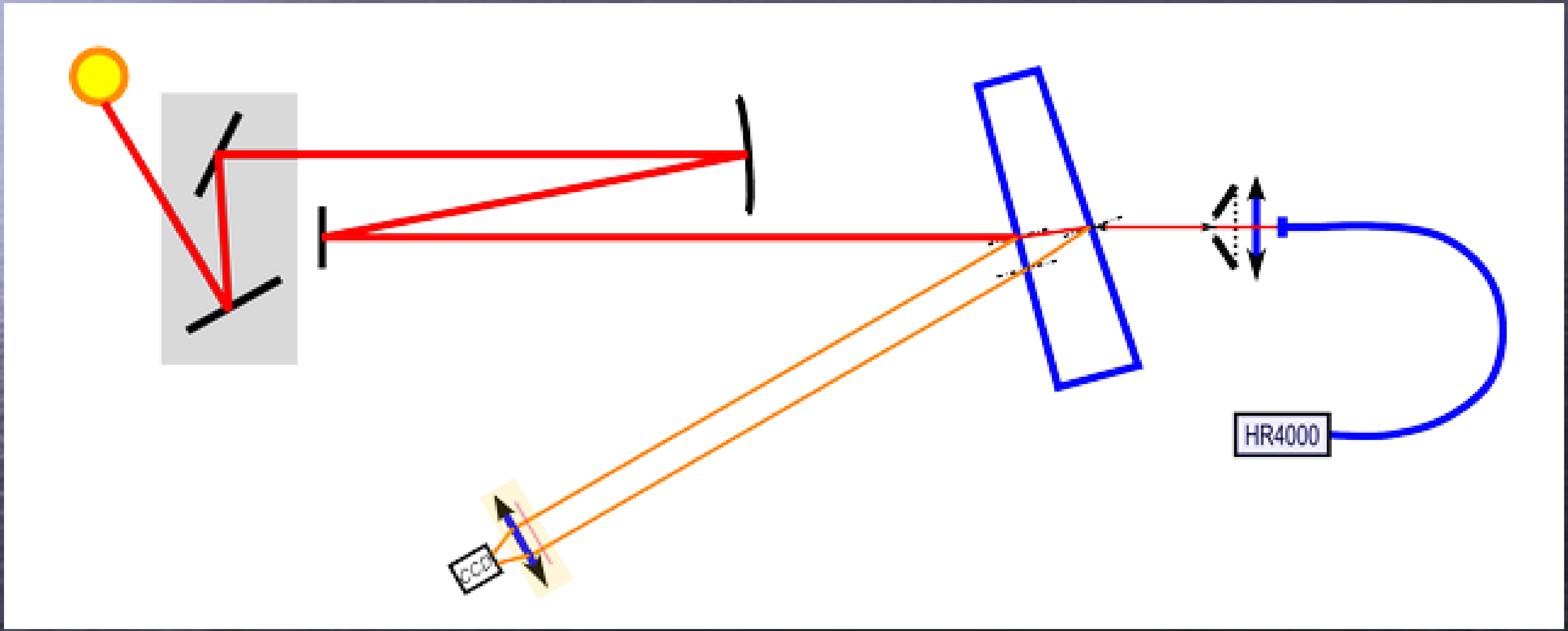


1 – Jensch coelostat, 2 – main objective, 3 – flat mirror, 4 – collimator, 5 – grating, 6 – thermal filter, 7 – slit-jaw objective, 8 – Hα filter, 9 – CCD camera

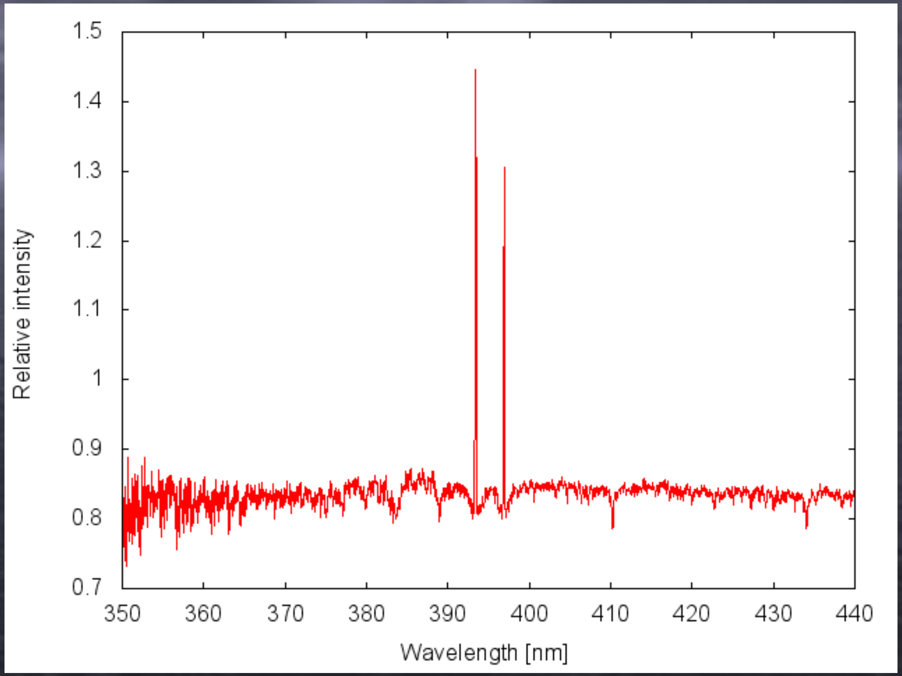
Jensch type coelostat 4 – 6 m above ground, sliding shelter, *Φ* of mirrors 60 cm, M1 *Φ* 50 cm, f 35 m.

Only the telescope was used, A new post-focus device installed

Optical schema of the device



Spectrometer

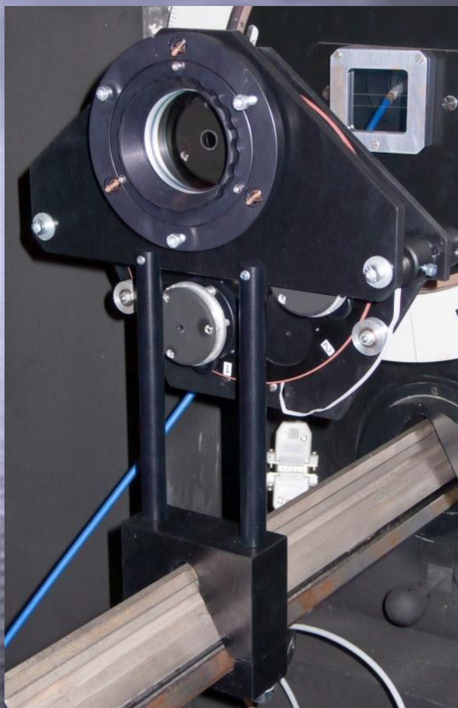


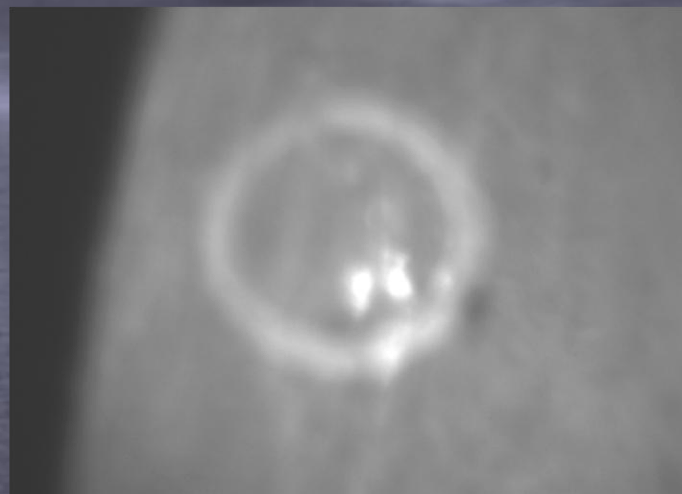
The HR4000 Spectrometer with a 3648-element CCD-array detector Toshiba enables optical resolution of 0.03 nm (FWHM).

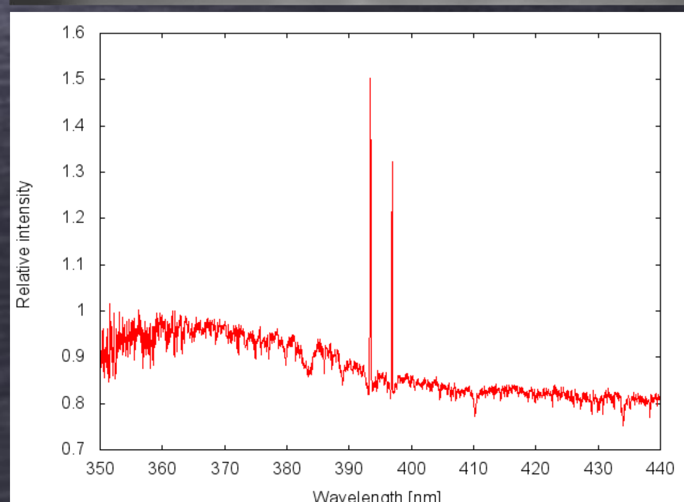
Generally it can be responsive from 200-1100 nm, but the specific range and resolution depends on the grating and entrance slit choices.

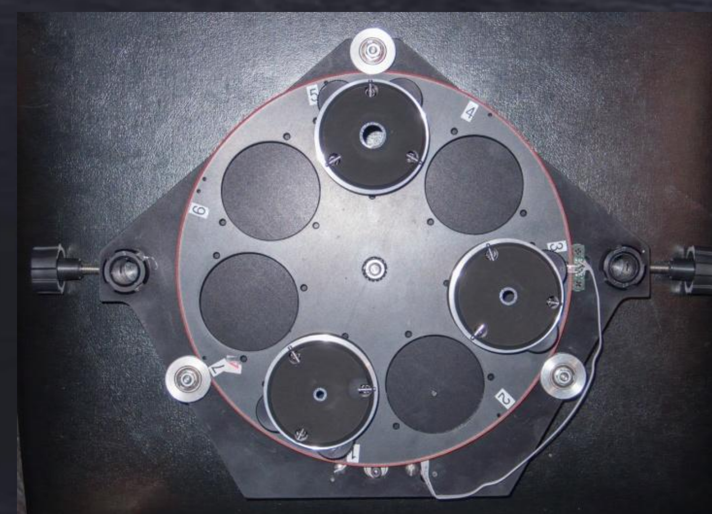
We selected 350 – 430 nm device (grating 1800 gr./mm) as a first step.

Image selector

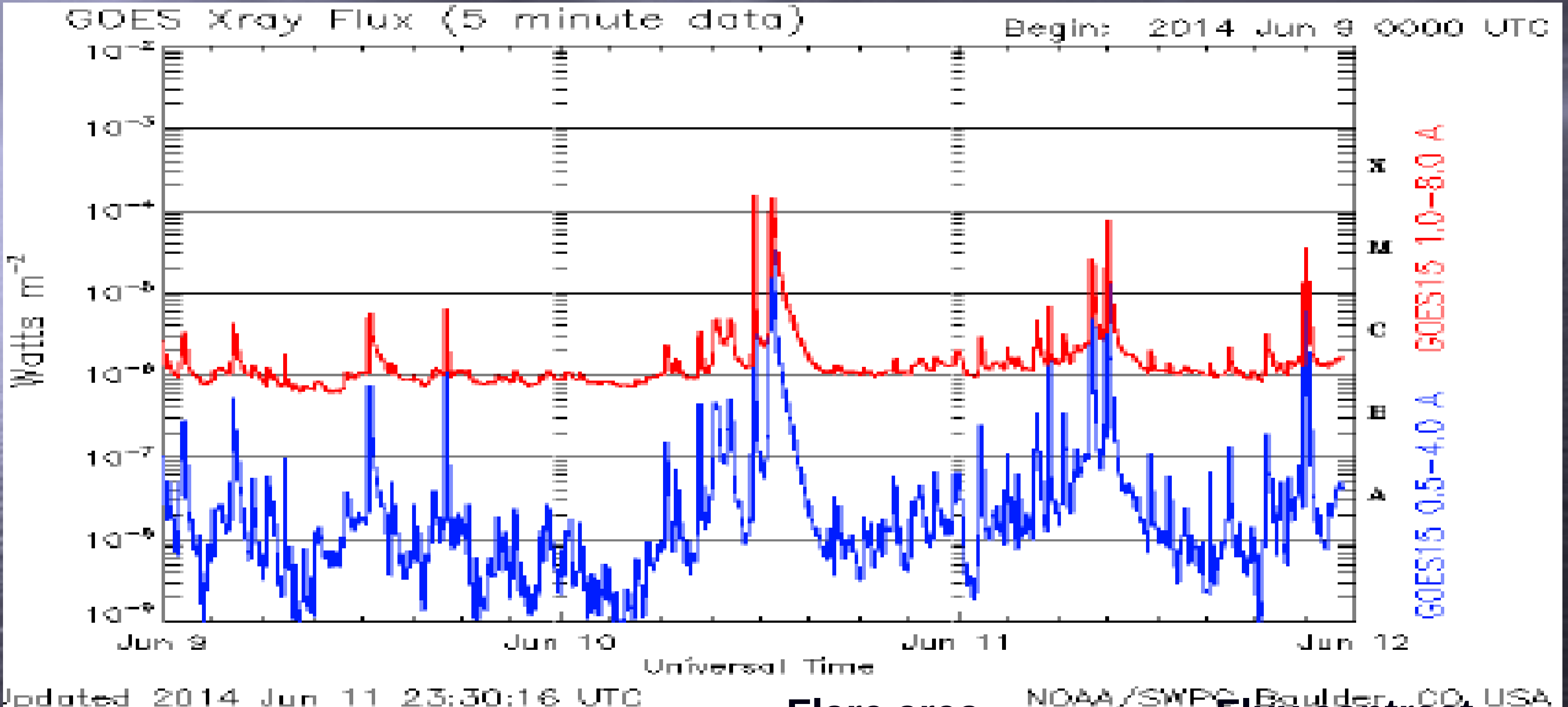






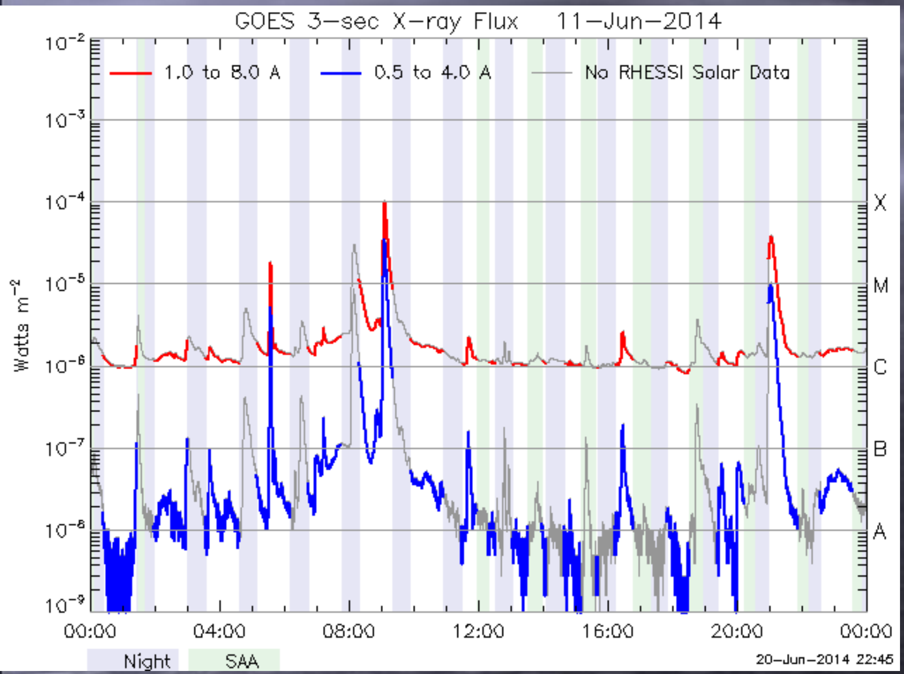


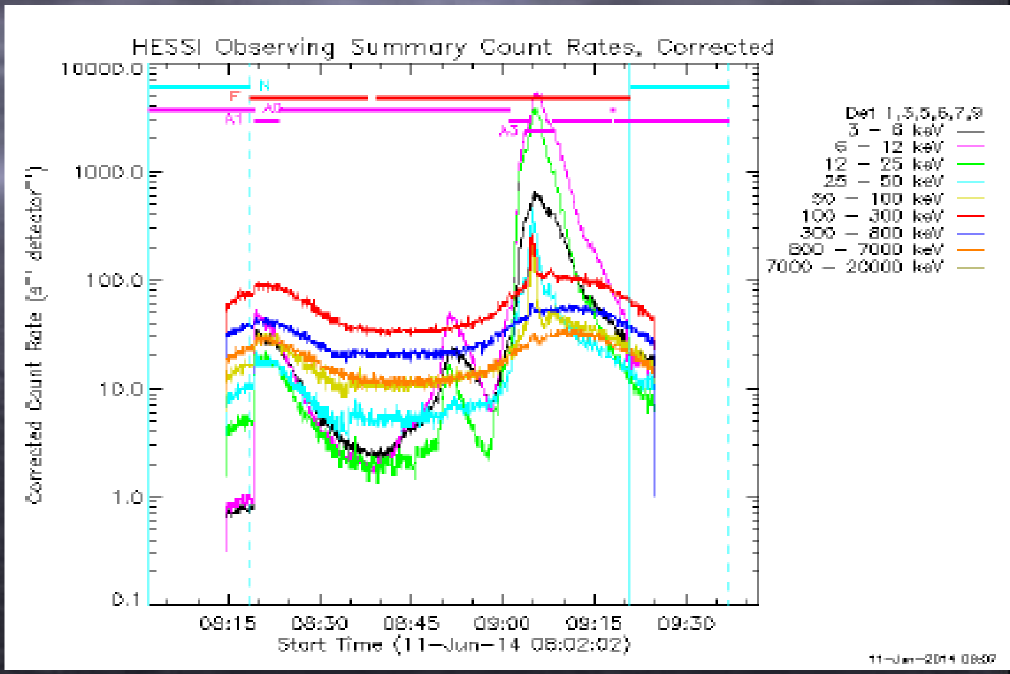
Measured flares in June 2014a

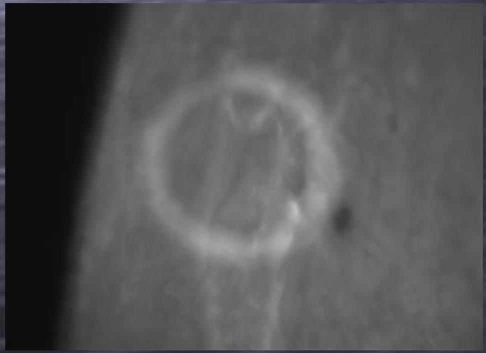


		Flare area	Flux contrast
X2.2	10.6. 11:42 UT	2.86 %	16 %
X1.5	10.6. 12:52 UT	8.46 %	13 %
X1.0	11.6. 9:04 UT	3.8 - 7.4 %	17 - 21 %

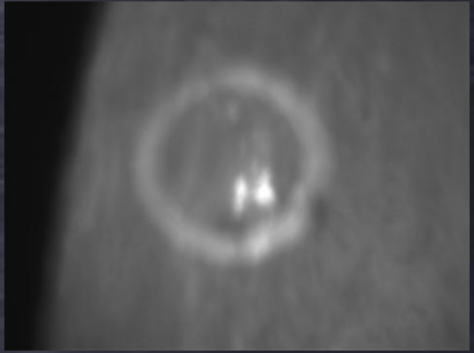
Flare X1.0 on June 11, 2014



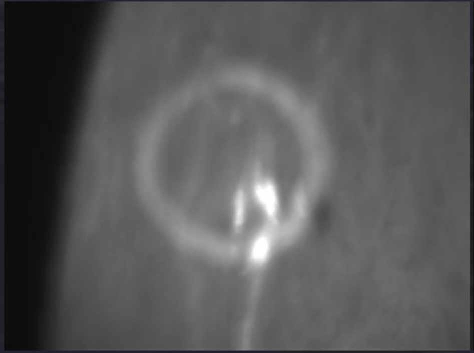




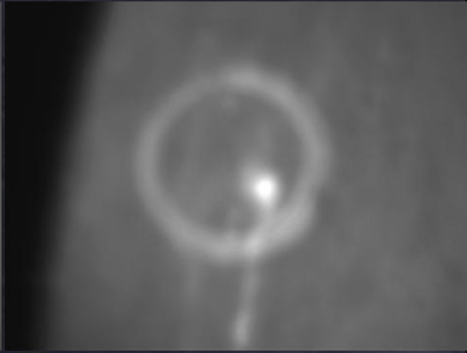
08:43:55 UT



09:02:14 UT

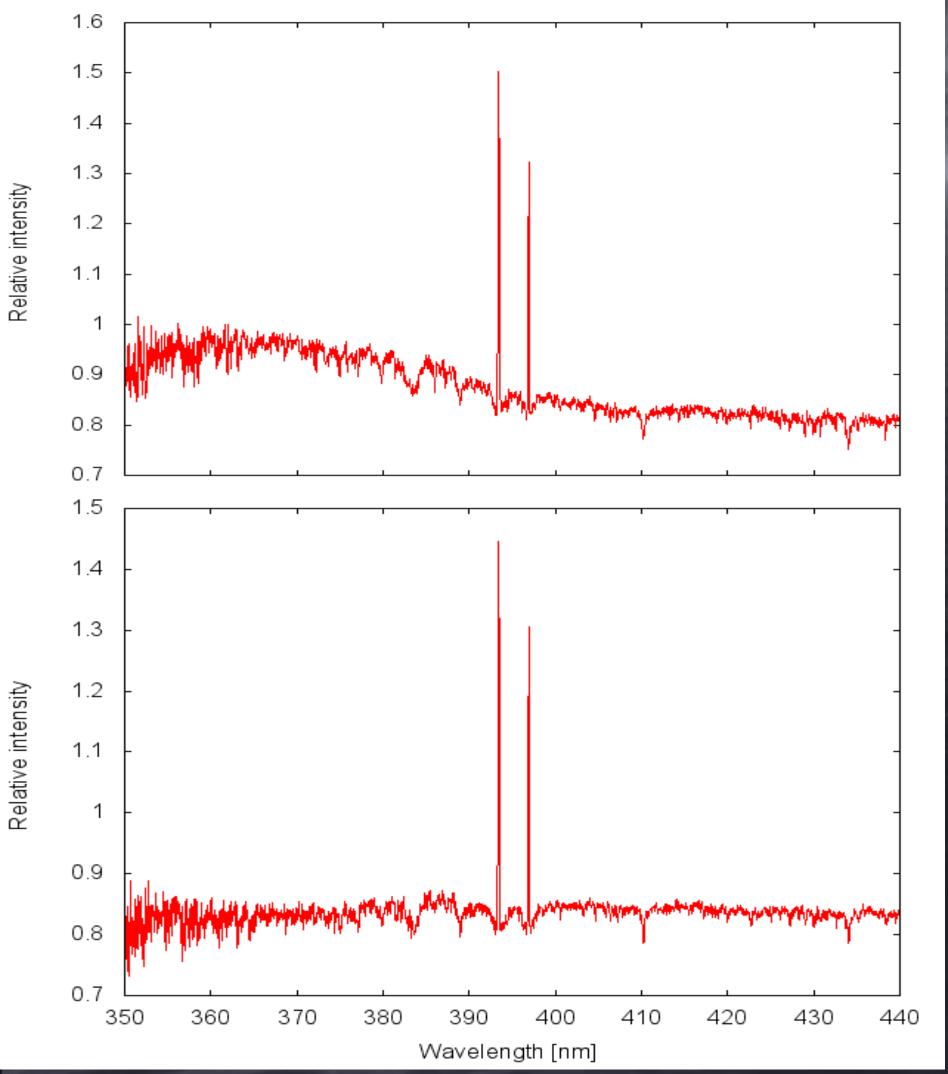


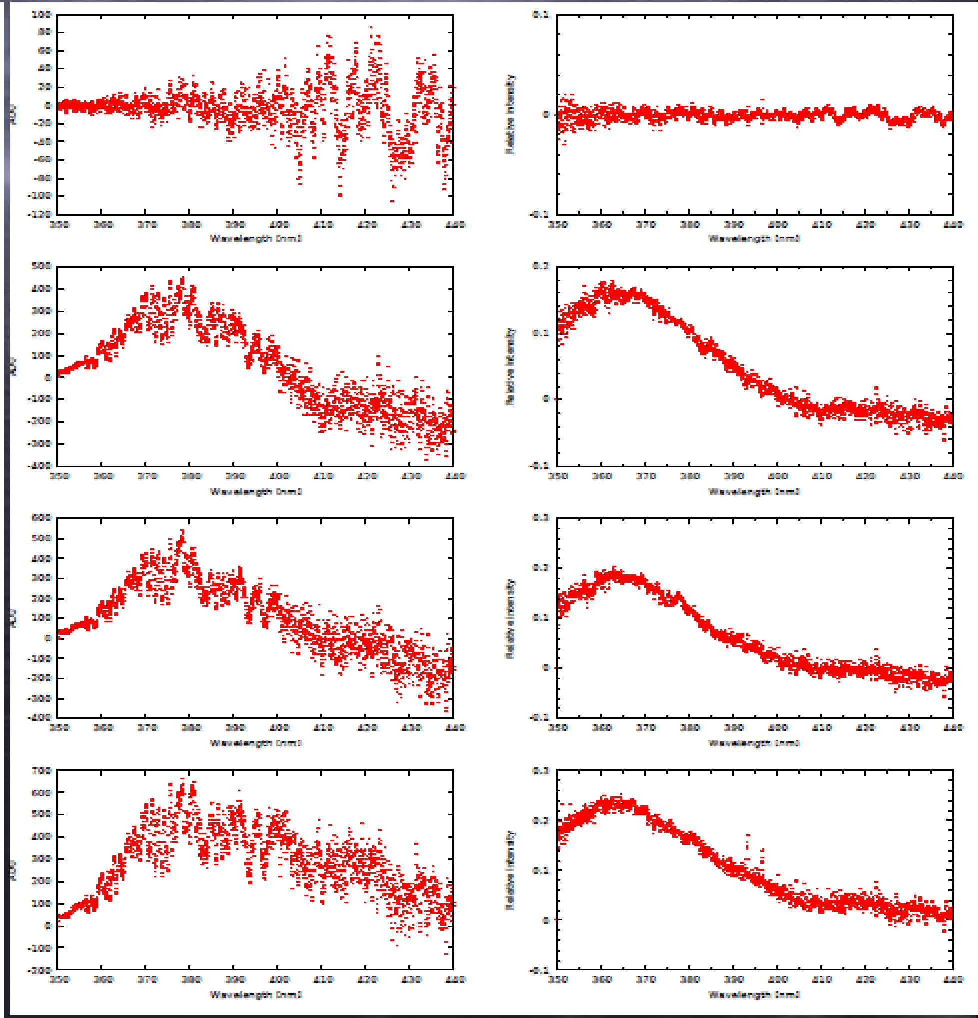
09:04:32 UT



09:09:32 UT

Measurements of blue continuum

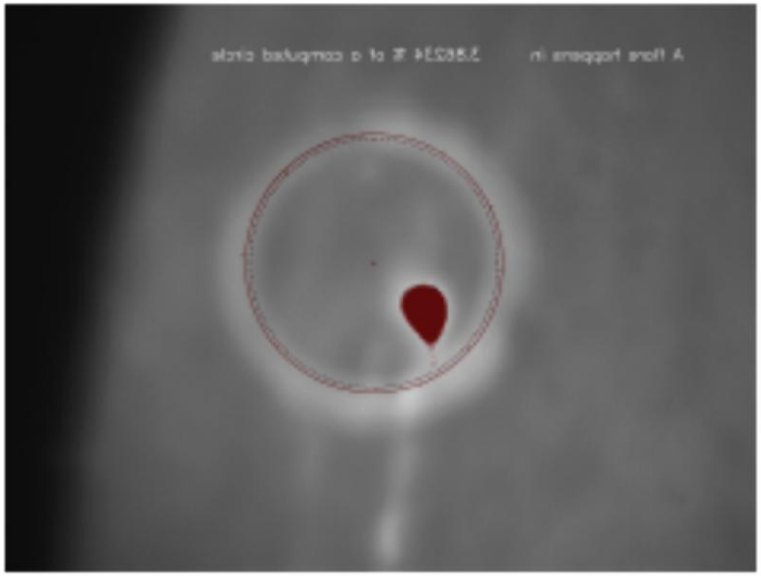


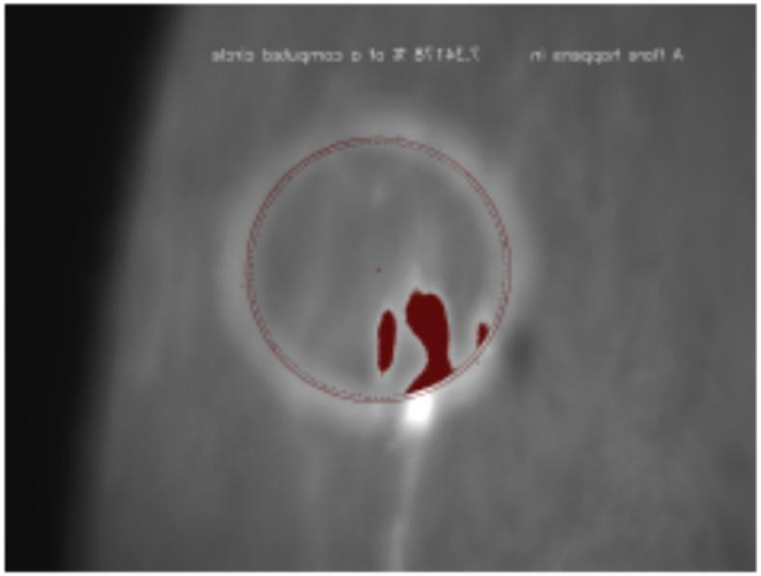


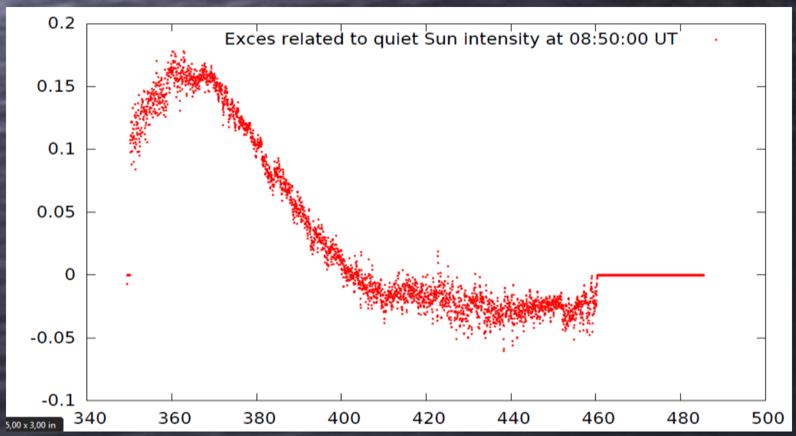
Difference F-QS **(F-QS)/QS**

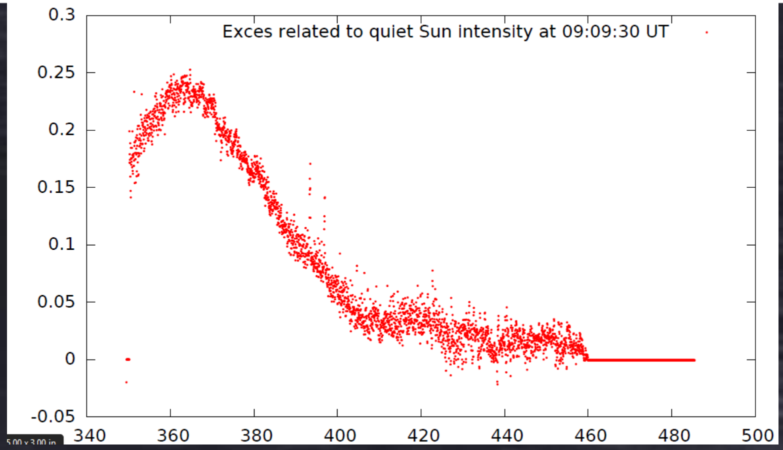
Balmer continuum contrast in flare

09:04:32 UT **09:09:30 UT**

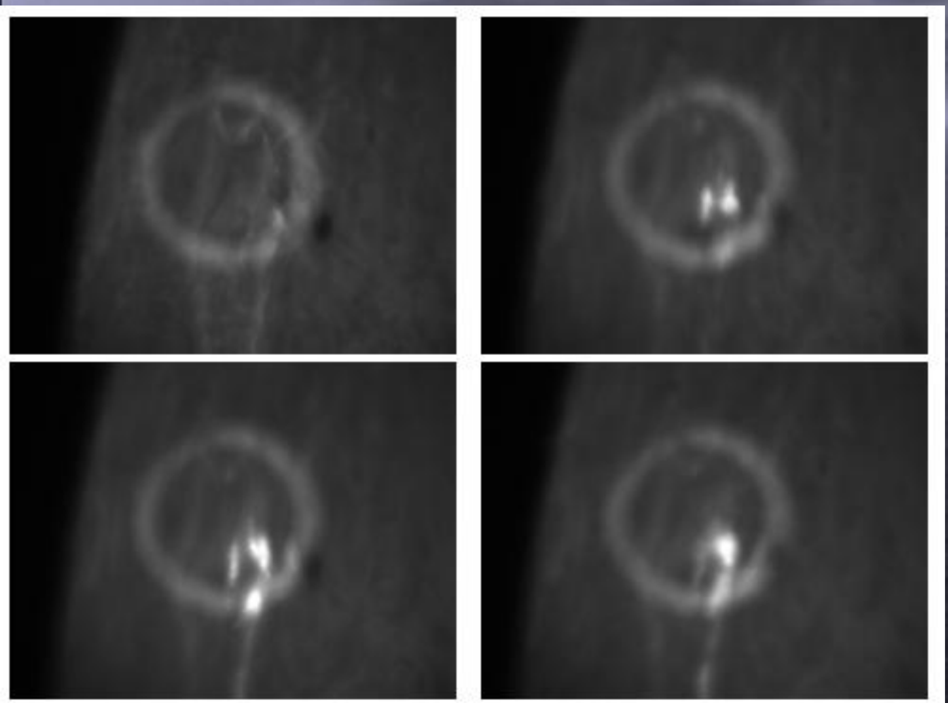




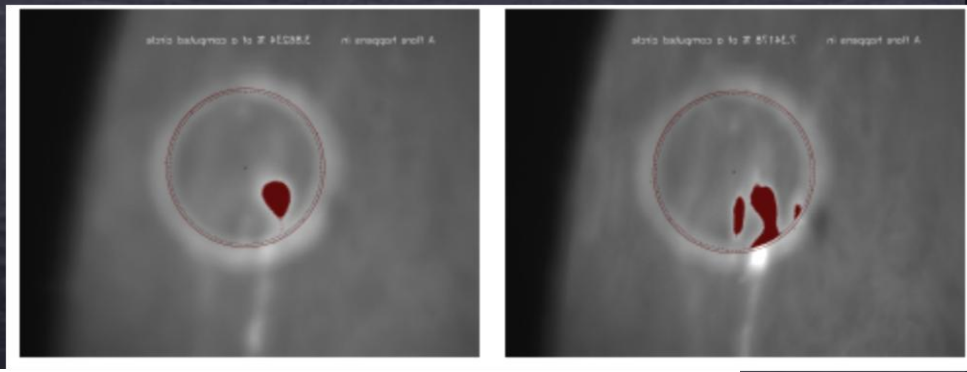




Balmer continuum flux - contrast

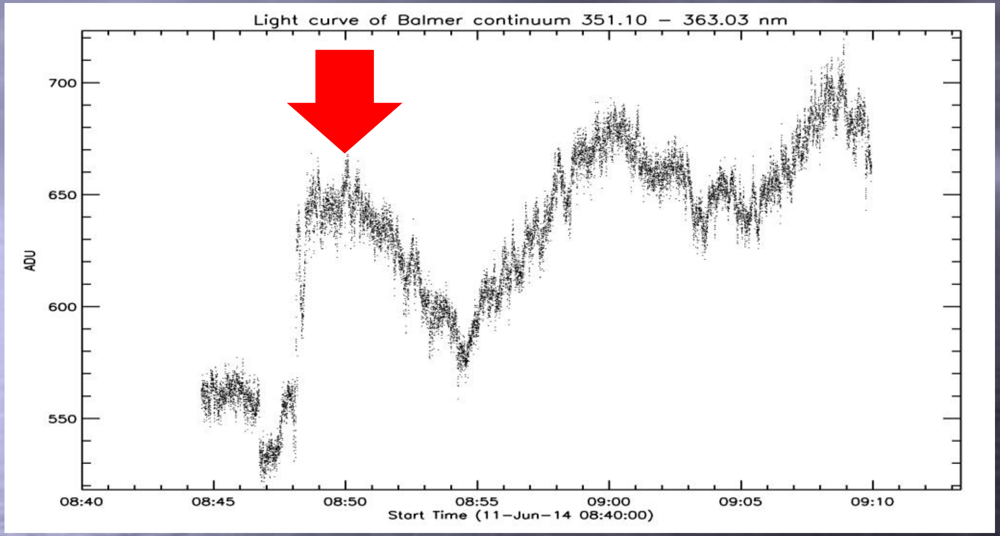


Supposing the plasma material flaring in H-alpha is the same as in Balmer cont., then the contrast in Balmer is about 500 percent.



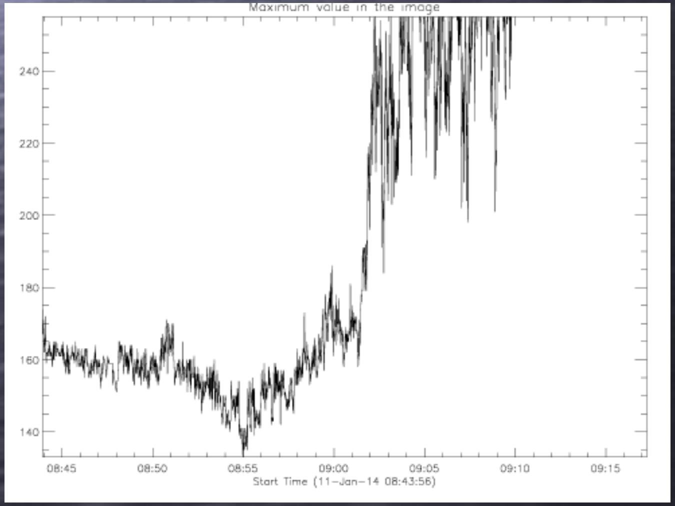
Třída erupce	Peak dle GOES	Plocha erupce na SJ	Nárůst ve spektru $\lambda = 364.6$ nm
X2.2	10.6. 11:42 UT	2.86 %	16 %
X1.5	10.6. 12:52 UT	8.46 %	13 %
X1.0	11.6. 9:04 UT	3.8 - 7.4 %	17 - 21 %

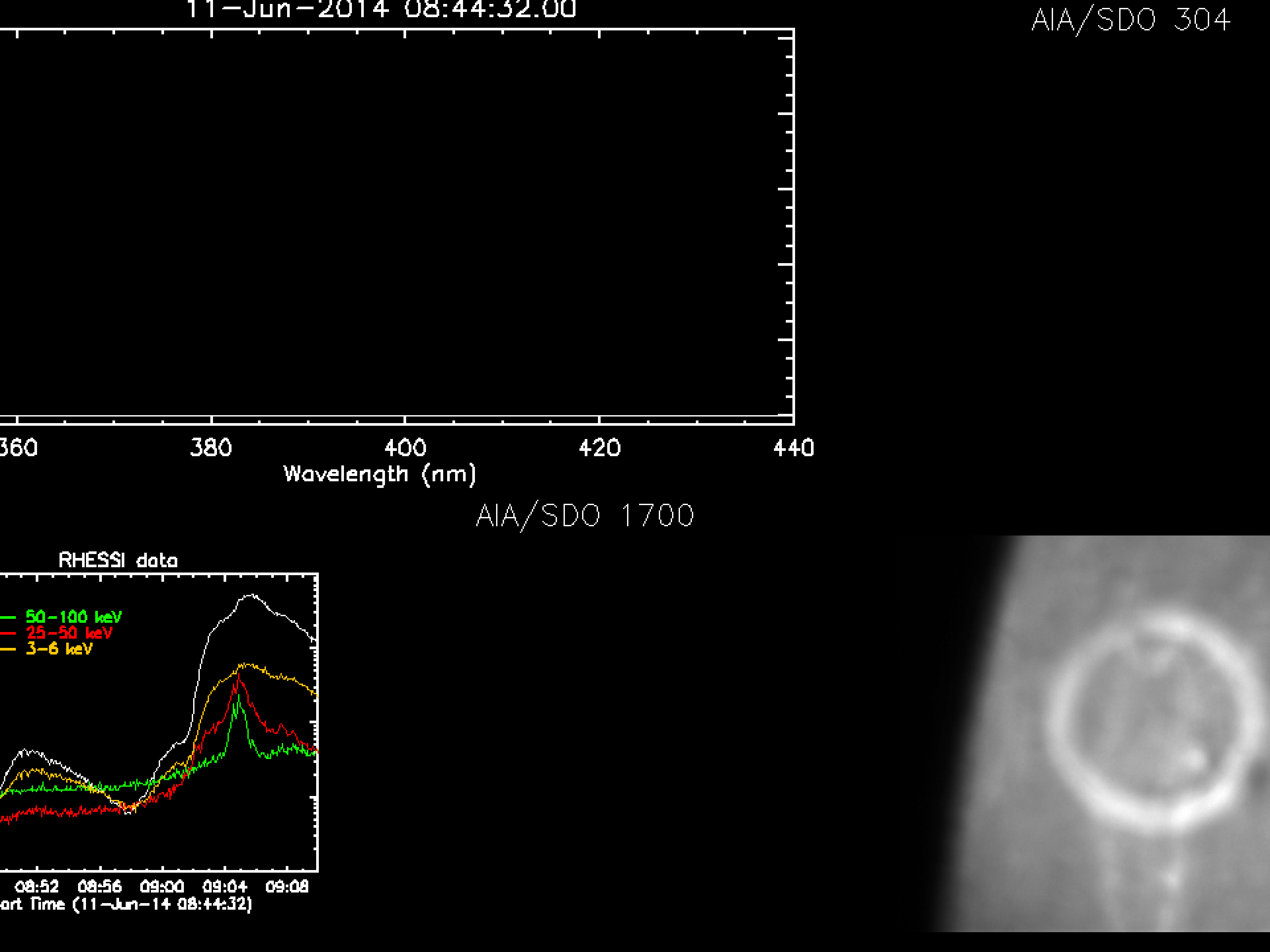
Balmer continuum – time changes



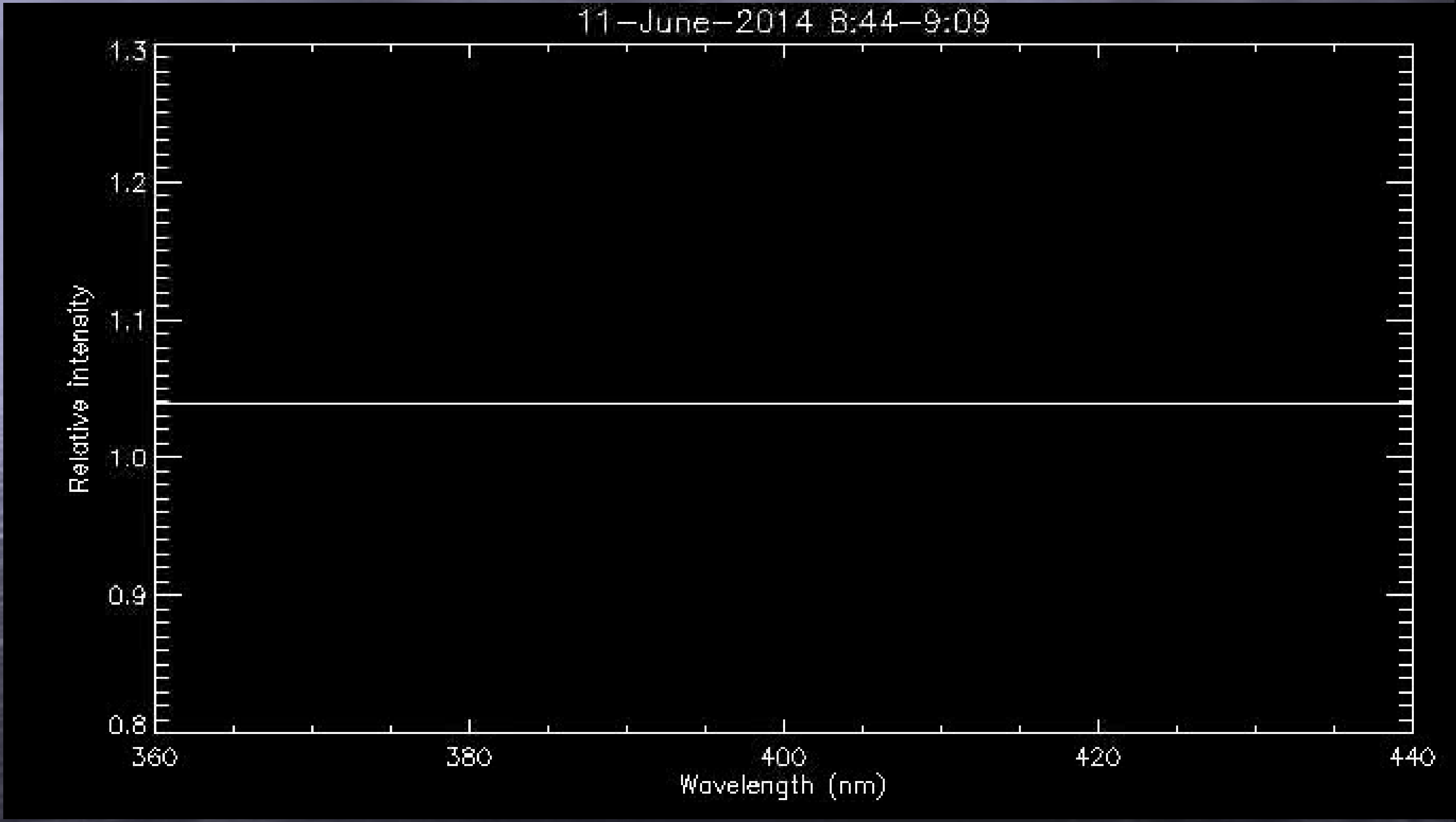
Balmer continuum channel specification:
351.10 – 363.03 nm

Time changes in B. c. preceeds H-alpha rising for 16 minutes

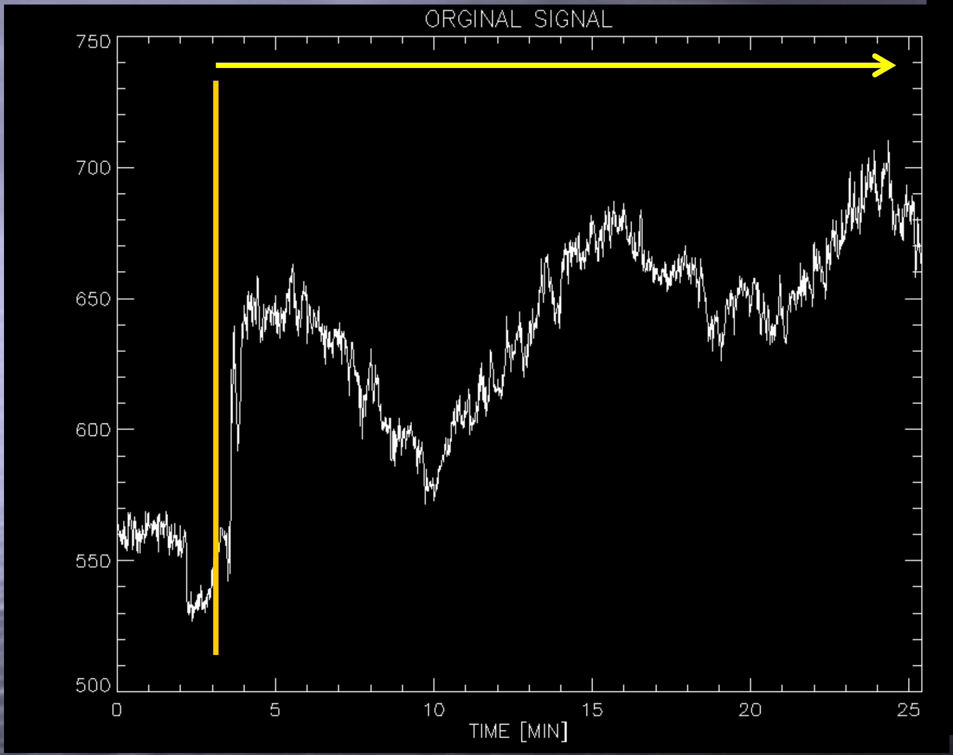


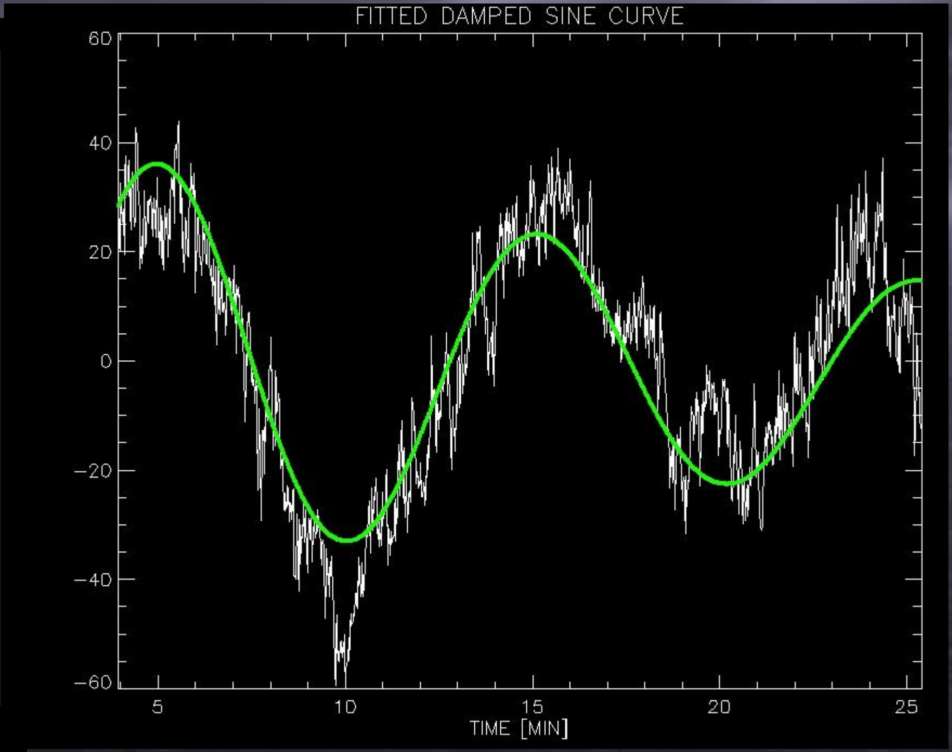

11-Jun-2014 08:44:32.00
AIA/SDO 304
360
380
400
420
440
Wavelength (nm)
AIA/SDO 1700
RHESSI data
50-100 keV
25-50 keV
3-6 keV
08:52
08:56
09:00
09:04
09:08
art Time (11-Jun-14 08:44:32)

Seeing effects removed



Balmer continuum flux oscillations?





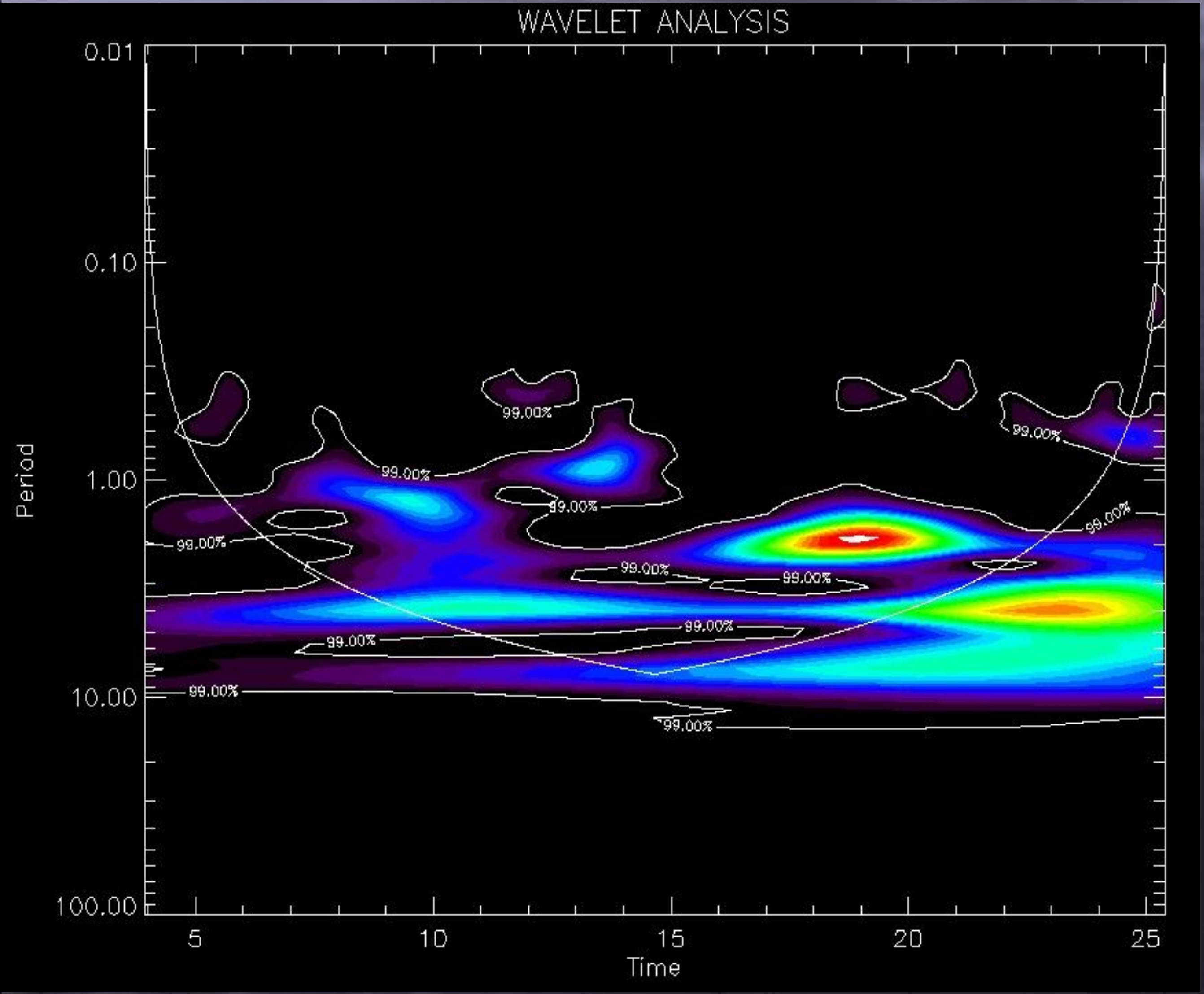
Balmer continuum channel specification:
351.10 – 363.03 nm

A*sin(2*π*t/P)*exp(-t/tau)

After de-trending the dataset
damped sine curve fitting performed

period P = 609 s
amplitude A = 39.77
damping time tau = 1479 s

Wavelet analysis of the residuum



Empirical Mode Decomposition (EMD) of the residuum into intrinsic mode functions (IMF) using code of J. Terradas.
Method created by Huang, N. E. and others

First IMF treated as a noise, summa of IMF2 to IMF12 taken for wavelet analysis.

Above 95 % level of confidence these periods found:

30s, 1min, 1.3 min, 2 min, 4 min.

Summary

- A new device for measuring blue continuum in solar flares was developed and put in operation in Ondrejov
- 3 X-class flares we observed, blue continuum was measured
- One flare observed and analyzed
- Contrast in Balmer continuum in flare maximum was evaluated to be 5 x higher than the background radiation
- An increase of flux in Balmer continuum started 16 minutes before the first H-alpha increase
- Further observations and analysis of the data are performed (correlation of channels, presence of QPP, etc.)

Conclusions

Blue continuum flux measurement in solar flares is a perspective tool for studing a mechanism of energy release in flares.

Now we are splitting the light beam for a second spectrometer measuring simultaneously in the range of 480 – 920 nm (Paschen continuum).

Thank for your attention