High cadence observations of the solar flares in the Hα line

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Giardini-Naxos, 12 VI 2018

Outline:

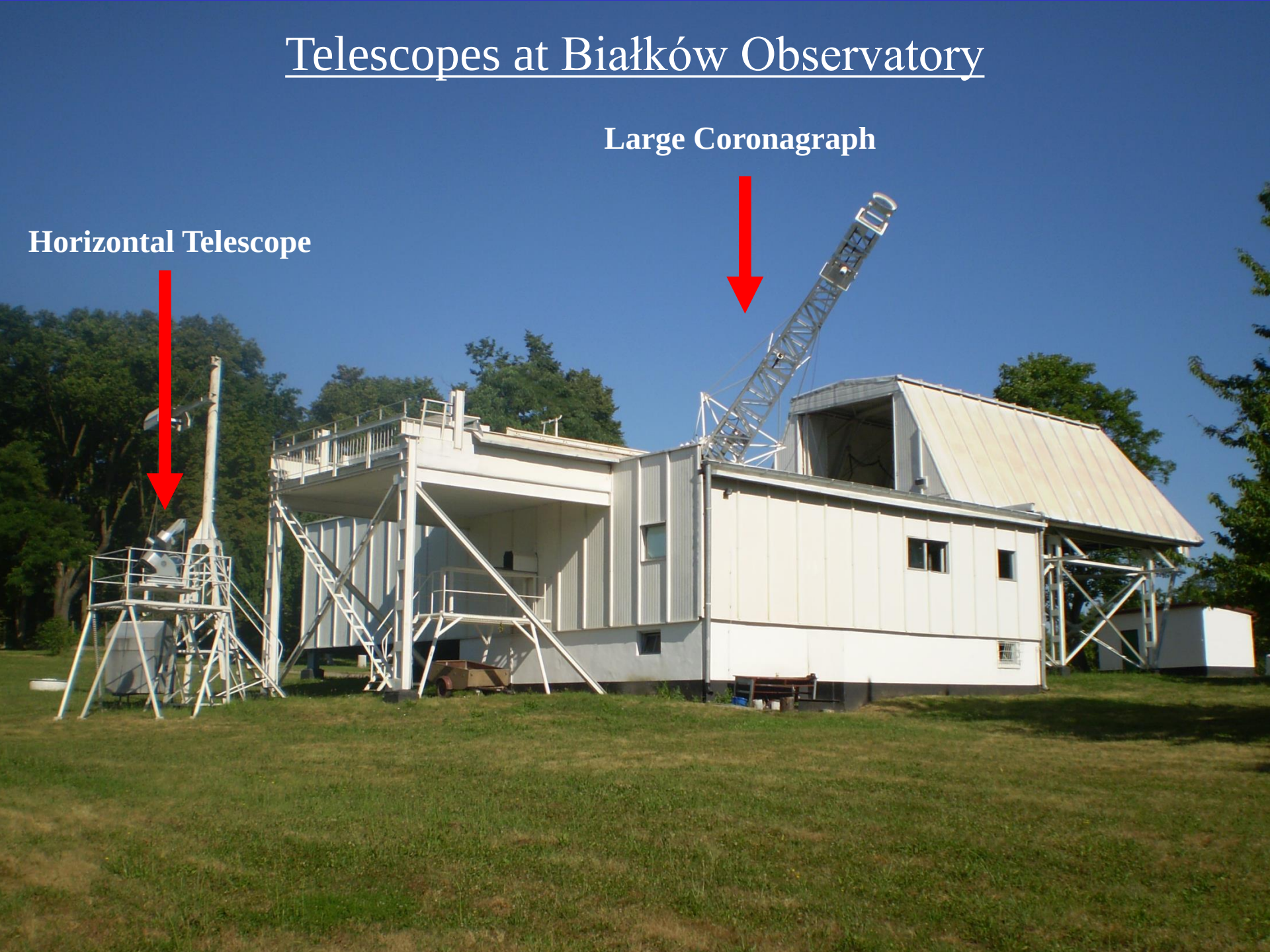
- Our telescopes (LC, HT) and spectrograph (MSDP)

- MSDP data processing and main goals of fast observations

- Future of spectral ground-based observations
  - fast observations with very high spatial resolution in the ferme of new EST Telescope operation

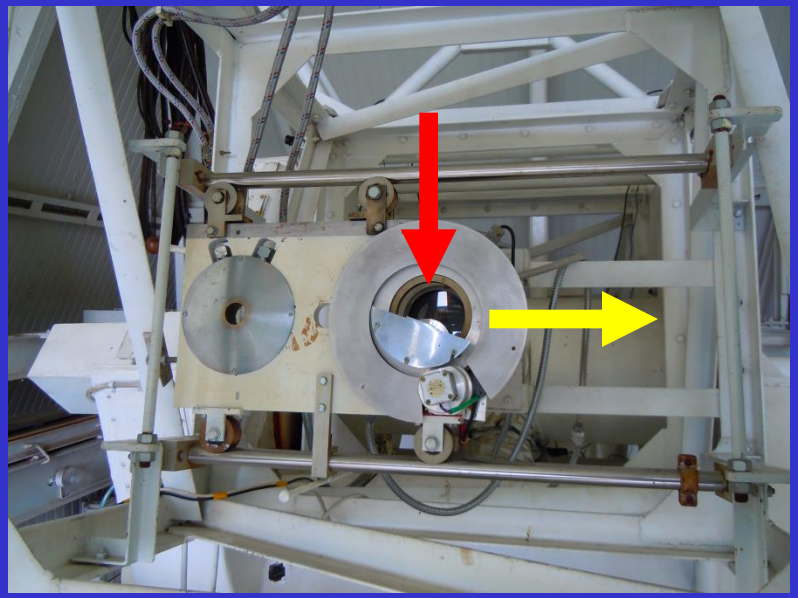
Our telescopes (LC, HT) and spectrograph (MSDP)

Telescopes at Białków Observatory

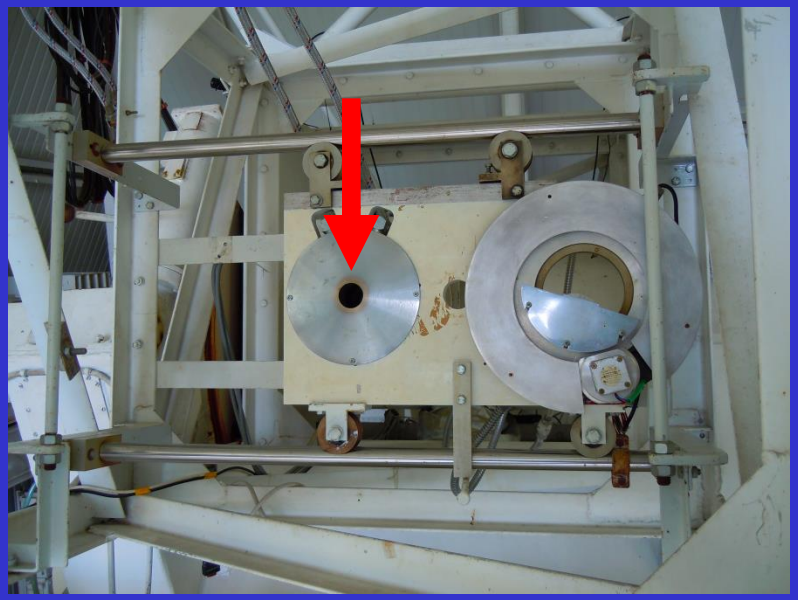



Large Coronagraph (LC)
∅ = 53 cm
f_{eff} = 1450 cm
TL-1

Artificial moon in LC



LC with artificial moon



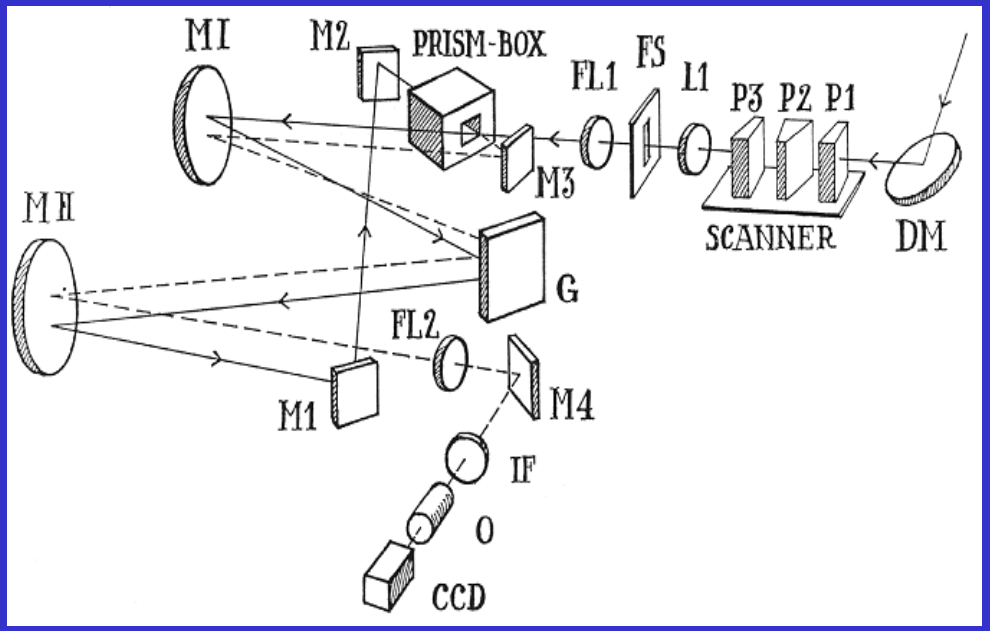
LC with full apperture

artificial moon shifted right (out of the light beam)

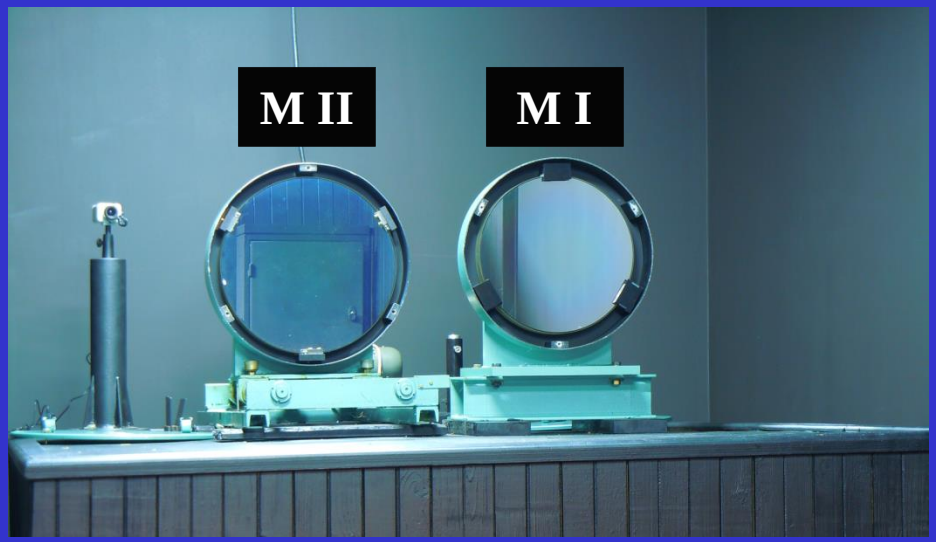

Horizontal Telescope (HT)
coelostat ∅ = 30 cm
∅ = 15 cm
f_{eff} = 500 cm

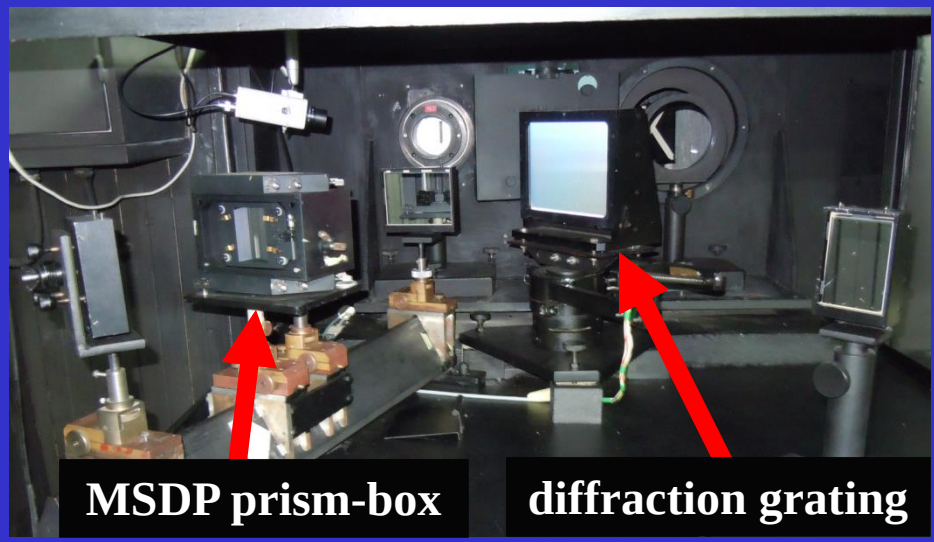
MSDP imaging spectrograph

[*Multichannel Subtractive Double Pass imaging spectrograph*]

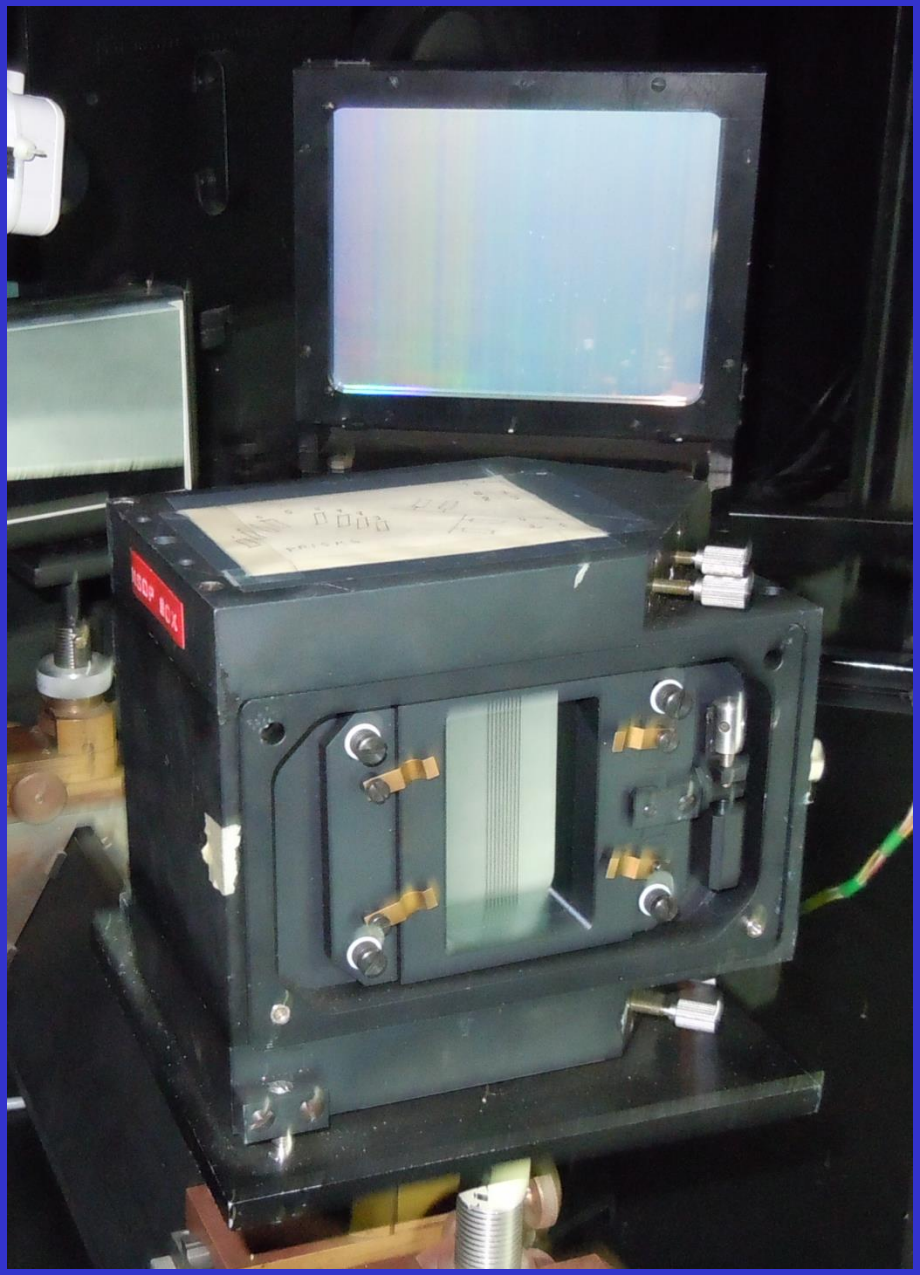


<= Total length of optical path from entrance window of MSDP to the CCD camera is almost 70 m.





MSDP imaging spectrograph

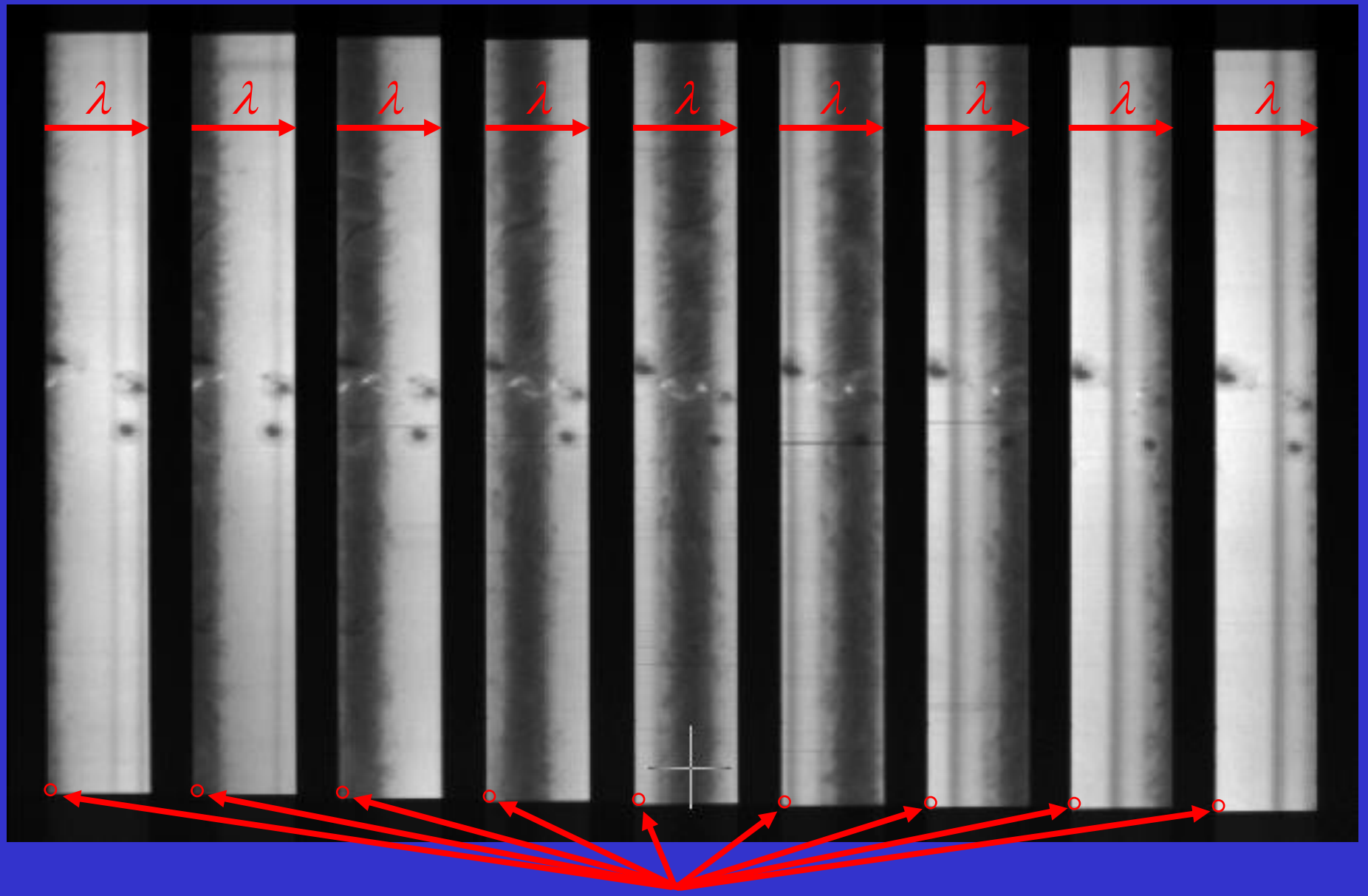


<= **diffraction grating** 600 ll/mm

- size: 206 × 254 mm^2
- 4th order of spectrum
  (angel of reflection = 48˚35')
- dλ = ±1.6Å for Hα line (6562.78 Å)
- effective λ for imaging: dλ = ±1.2 Å

<= **9 channel MSDP prism-box**

- width of channel = 0.4 mm
- separation of channels = 1.2 mm



9 pixels showing the same position on the Sun, but in different wavelengths

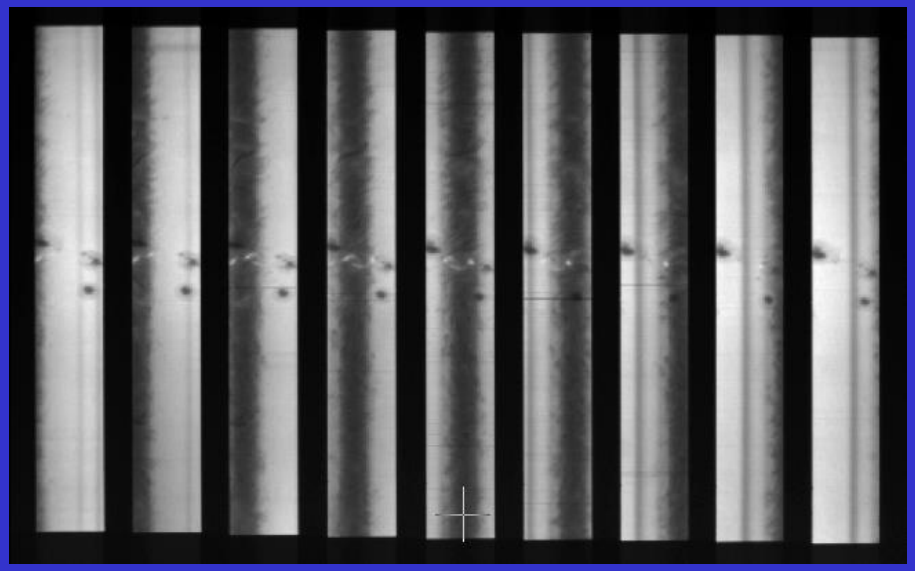
($\Delta\lambda$ = 0.4Å for consecutive channels; total range of measurement is ±1.6Å from Hα l.centre)

MSDP data processing

and

main goals of fast observations

MSDP data processing

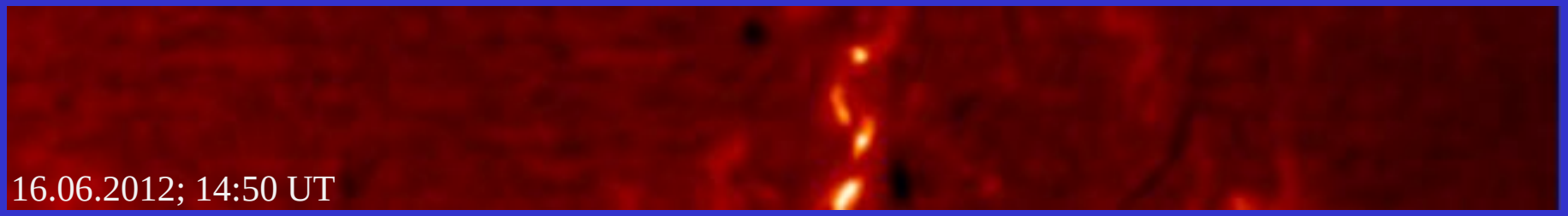


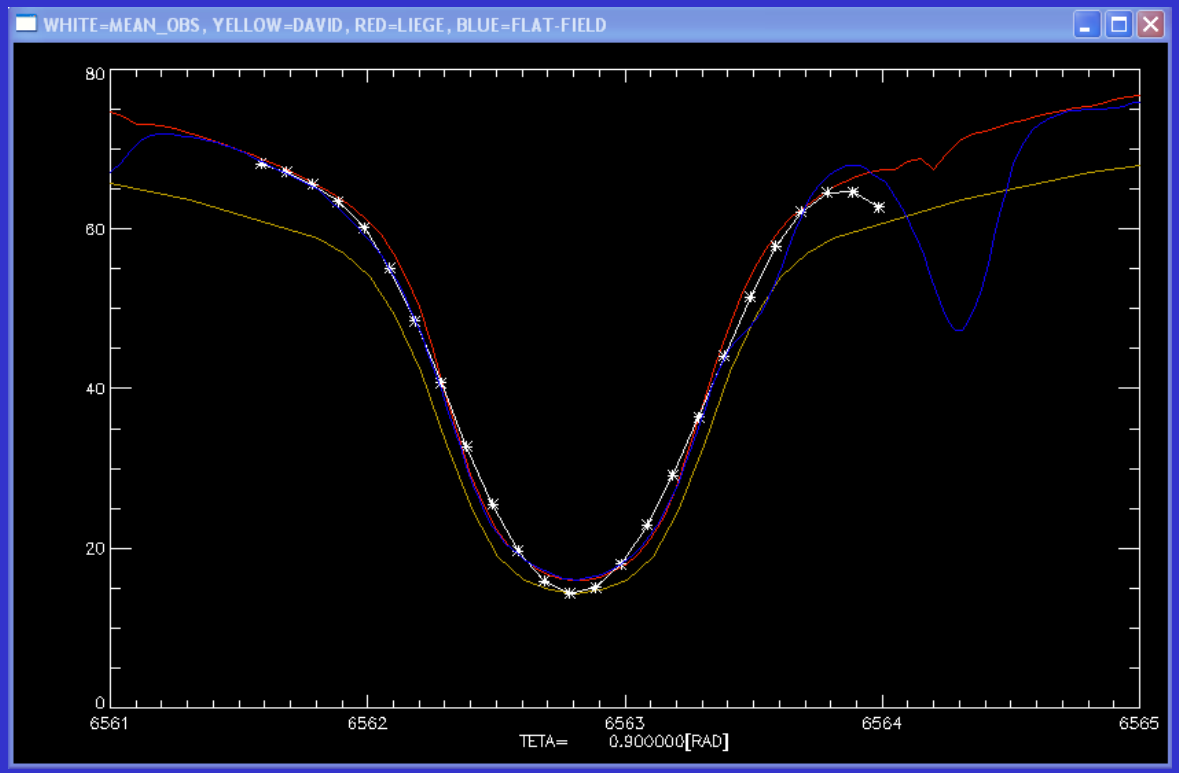
1. First step - determination of edges of the channels + standard data reduction (FF, DC)

2. Second step - the Hα line profile in each pixel of FOV (inside the channels) is calculated (in the range of ±1.6Å from the Hα line centre) on the basis of measurements in 9 wavelengths (from 9 channels) separated by 0.4Å.

3. Third step - the monochromatic (±0.025 Å) images in the range of ±1.6Å from the Hα line centre are restored.

Hα line centre monochromatic ($\pm 0.025 Å$) image:





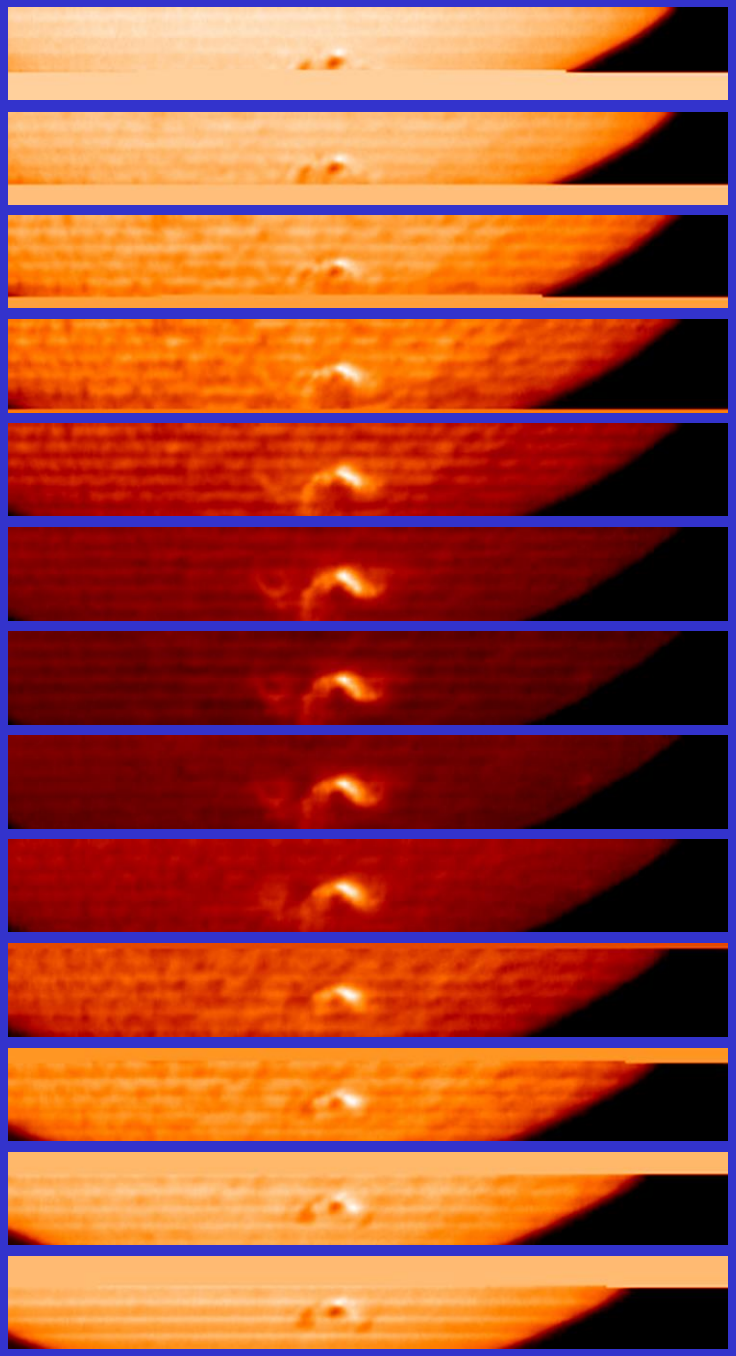
<= Hα line calibration:

WHITE – mean from obs.

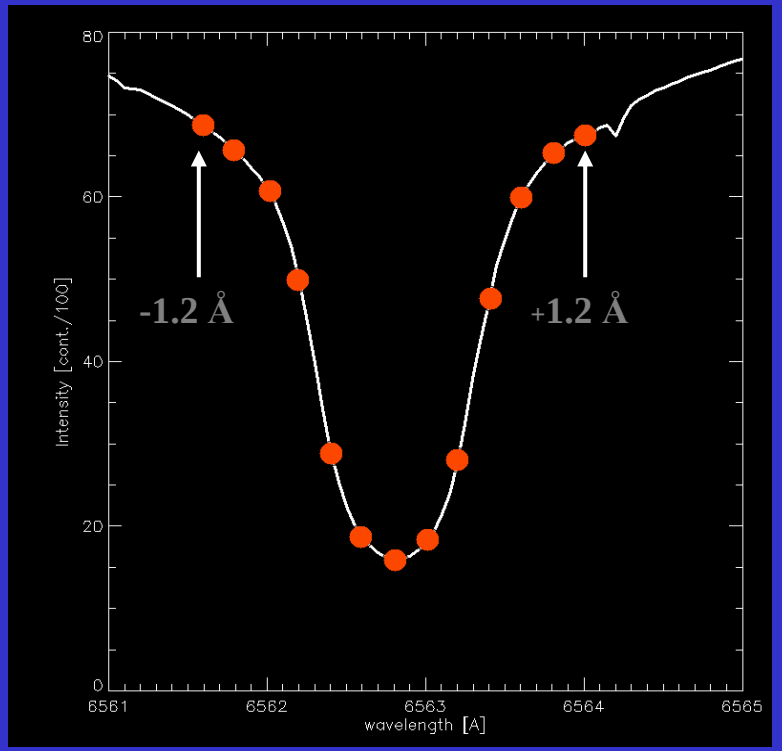
BLUE – Flat-Field

RED – Liege

YELLOW – David



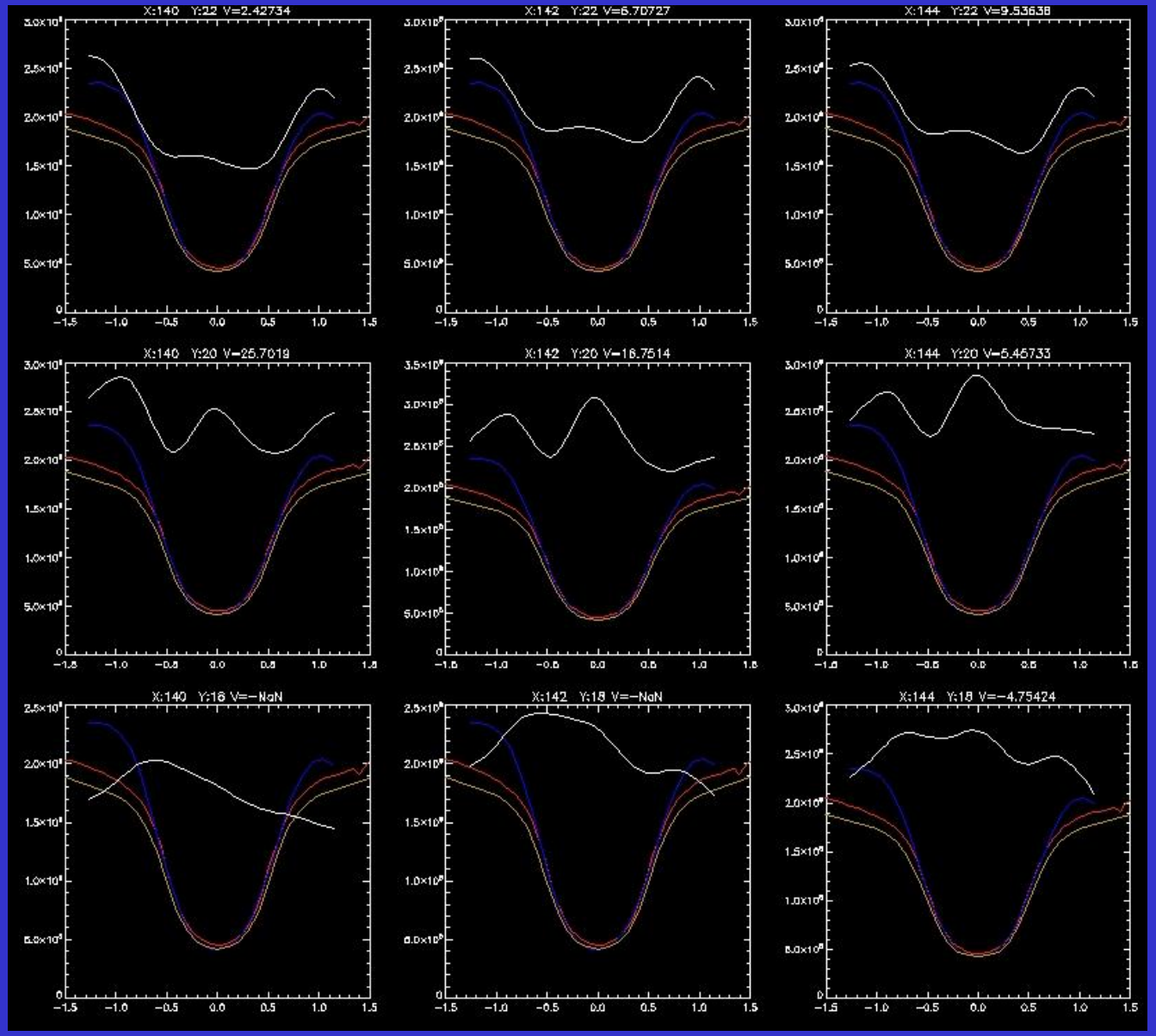
Monochromatic ($\pm 0.025 Å$) images restored in the range $\pm$ 1.2 Å from Hα line centre



For restored images:

- standard step in $\Delta\lambda$ = 0.2 Å
- range of $\lambda = \pm 1.2$ Å

Example of flaring Hα line profile (for 9 pixels)



WHITE - measured Hα line profiles

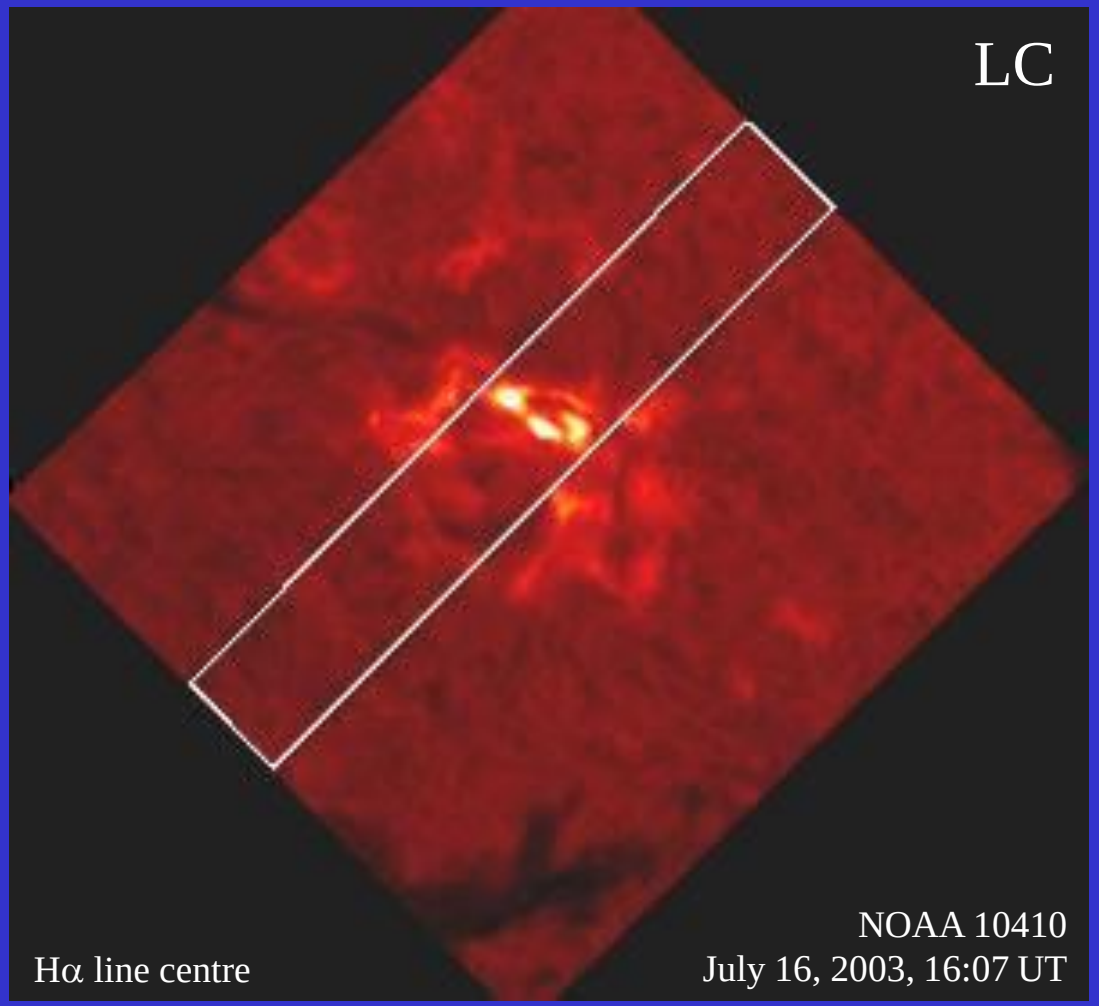
FOV during MSDP observations:

- Slow Mode (with scanner) – full image (14 steps in scan)
- Fast Mode (without scanner) – white rectangular box

- Entrance window of MSDP = 5 × 40 mm
- **FOV(LC) = 41 × 325 arcsec^2**
- **FOV(HT) = 119 × 943 arcsec^2**

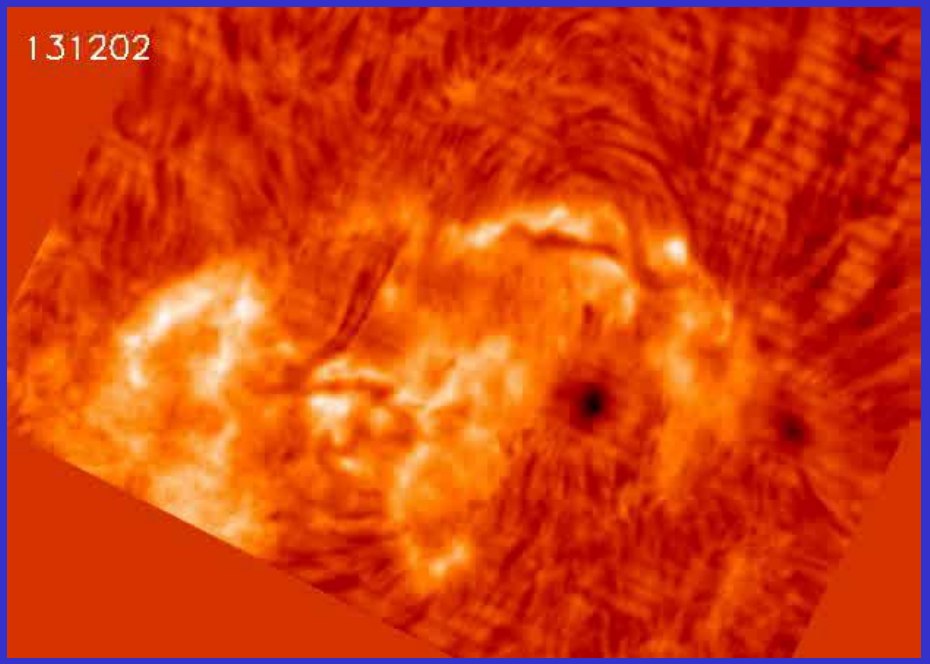
CCD:

- Andor iXon3 885 [1k×1k px^2]
- cadence of recording = 20 img/s
- **1 px ≈ 0.5 arcsec (for LC)**
- **1 px ≈ 1.5 arcsec (for HT)**



MSDP Hα line centre

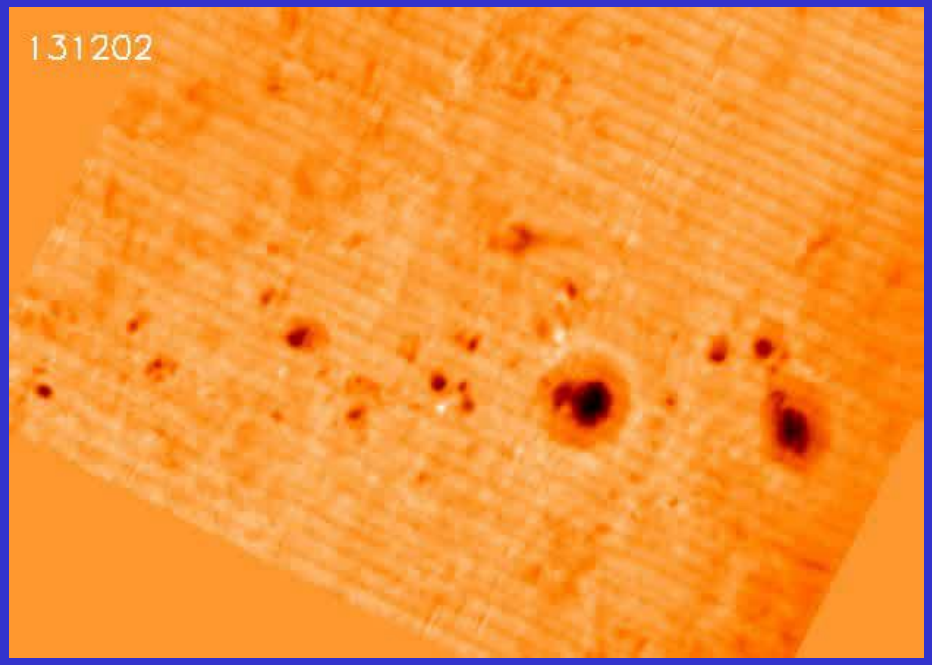
M 3.7
04.11.2015
13:12-13:58 UT



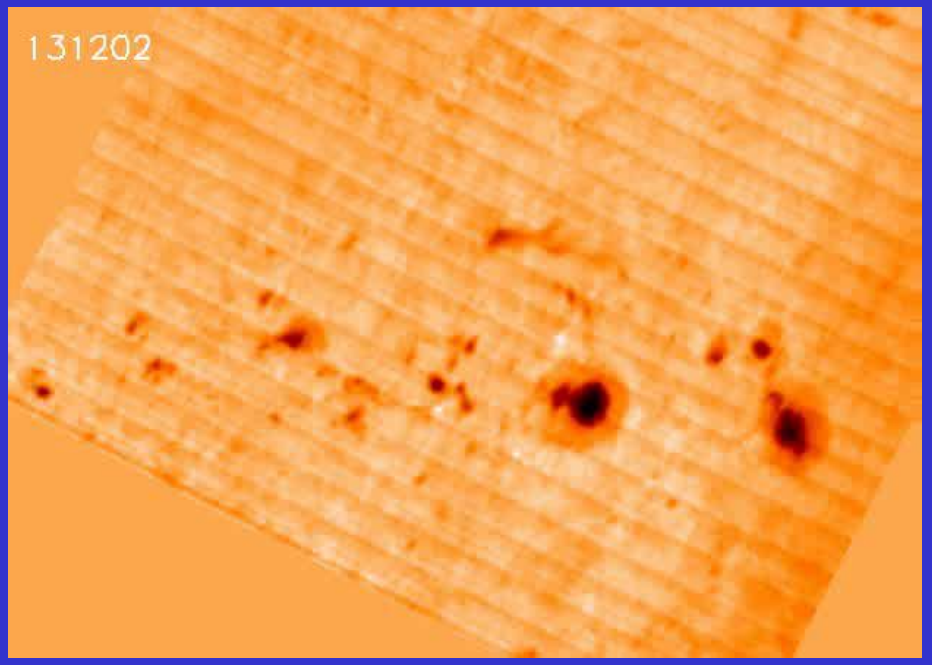
Slow Mode observations LC-MSDP

=> Movies:
- mpg1.mpg
- mpg2.mpg
- mpg3.mpg

MSDP Hα -1.0 Å

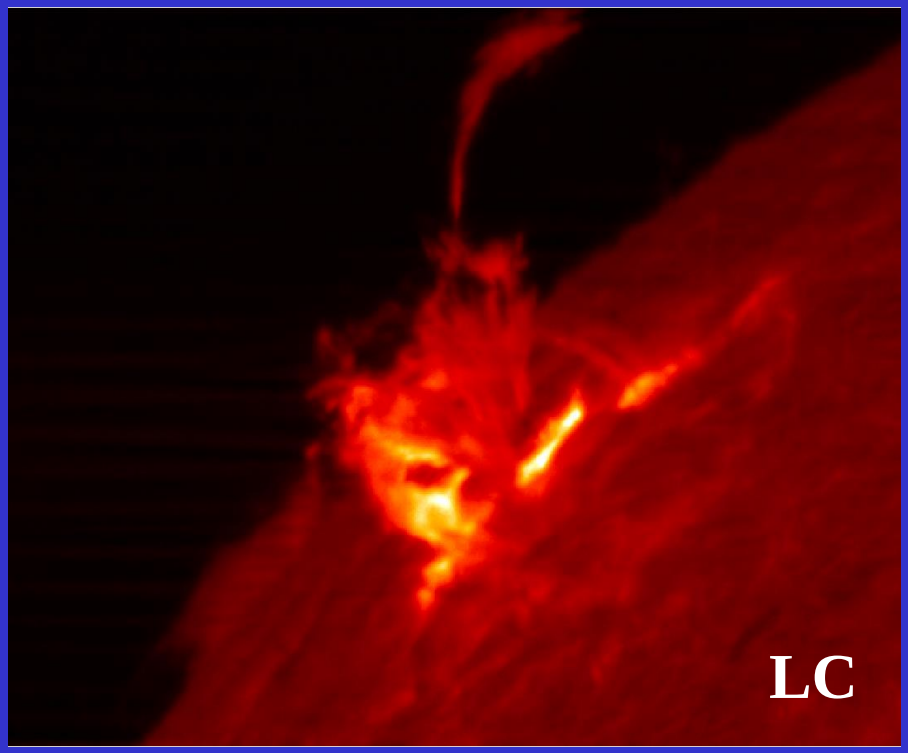


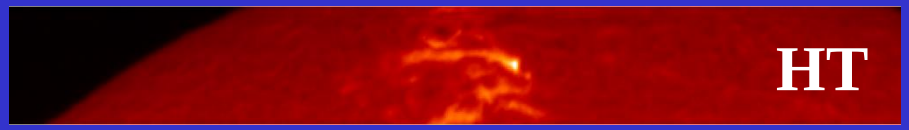
MSDP Hα +1.0 Å



LC vs. HT

Since **2003** (*15 years but with very deep solar minimum*) more than **100** flare evnts have been recorded at Bialkow Observatory using the **MSDP** imaging spectrograph with **high cadence 50 ms [20 img/sec]**.

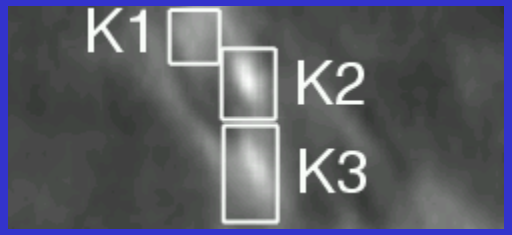




The **fast-mode** MSDP Hα line centre image of the B8.3 solar flare recorded on 22.07.2016 at 11:32:30 UT (observations made in the frame of F-HUNTERS 2 campaign).

The **slow-mode** MSDP Hα line centre image of the M5.5 solar flare recorded on 23.07.2016 at 05:32:55 UT (observations made in the frame of F-HUNTERS 2 campaign).

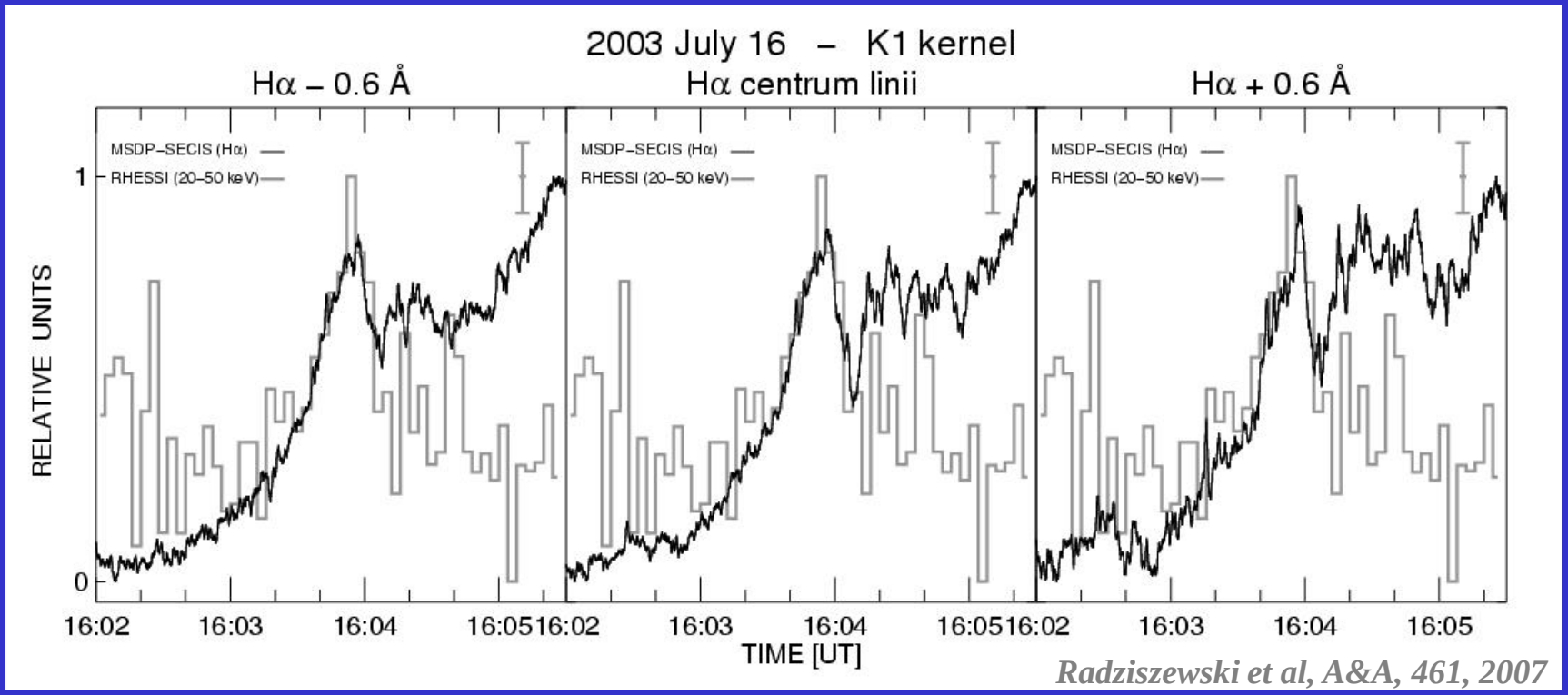
Fast variations of the Hα emission observed during impulsive phase of flares



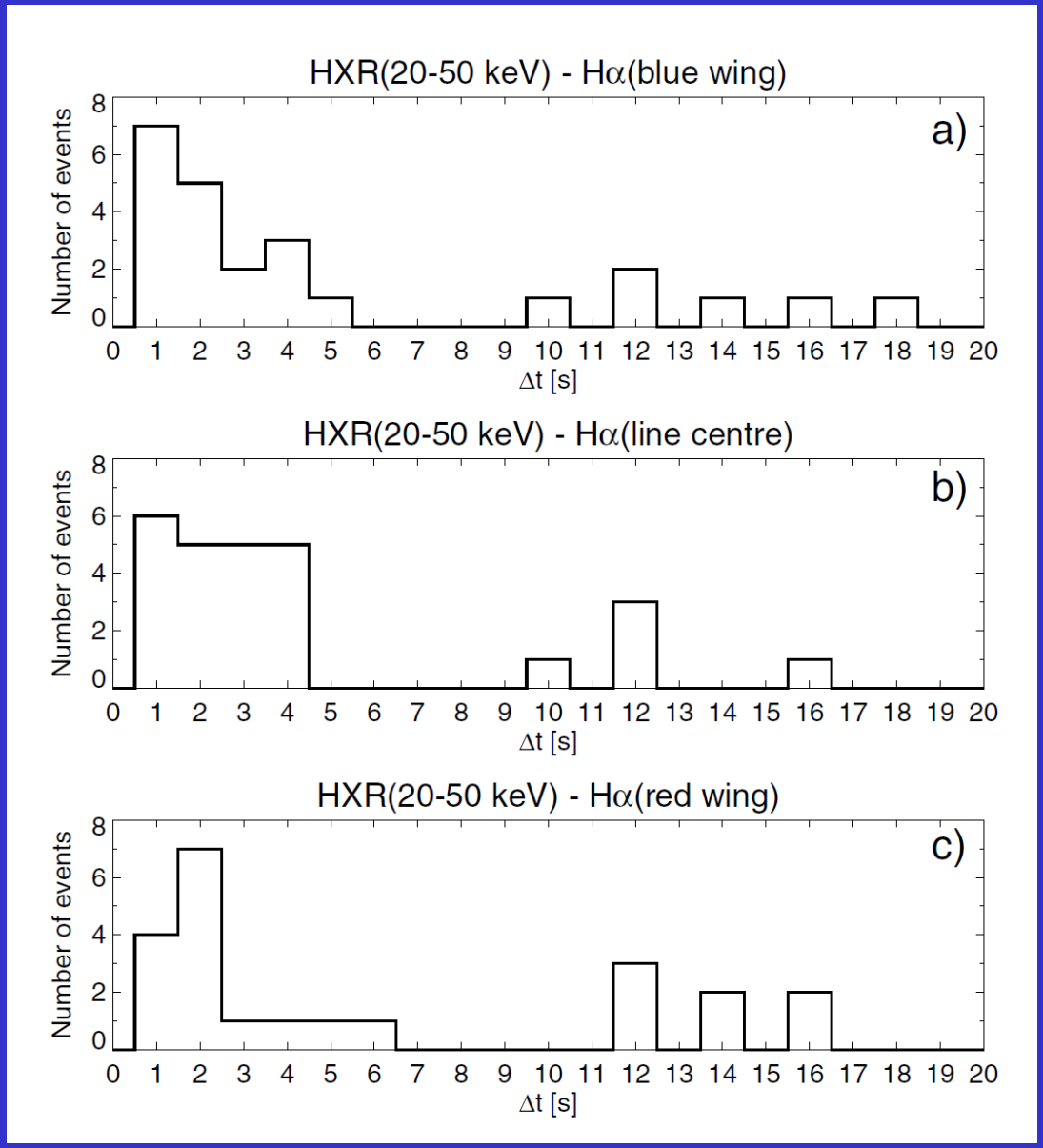
2003 July 16, NOAA 10410, Flare C1.2

MSDP-SECIS Hα line centre image

RHESSI 20-50 keV (Δt=4 sec) Hα light curves (Δt=50 ms, 20 img/sec)



Radziszewski et al, A&A, 461, 2007



Distribution of all 72 measurements of the time delays Δ*t* between RHESSI HXR (20–50 keV) and MSDP-SECIS Hα localised maxima measured at the line centre **a)**, blue wing **b)**, and red wing **c)**, respectively.

Radziszewski, et al., A&A, 535, A123, 2011

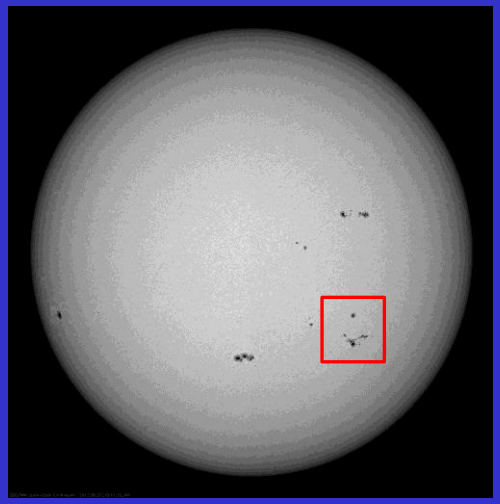
Flare analysis example

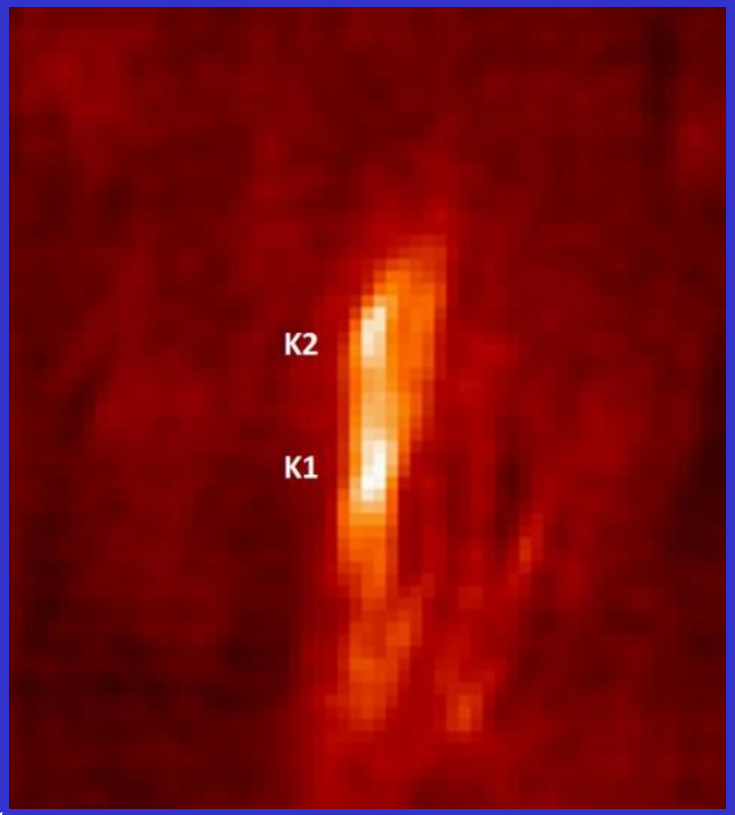
C1.1 *GOES*-class flare

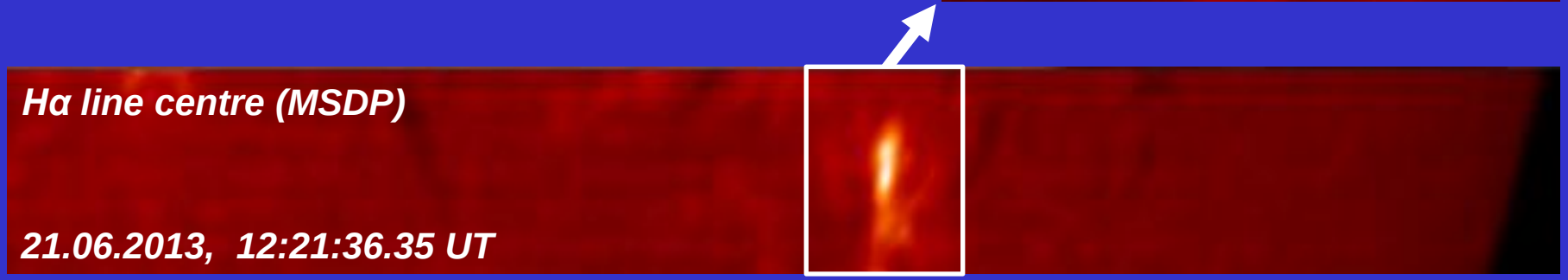
NOAA 11 772

21.06.2013, ~12:22 UT

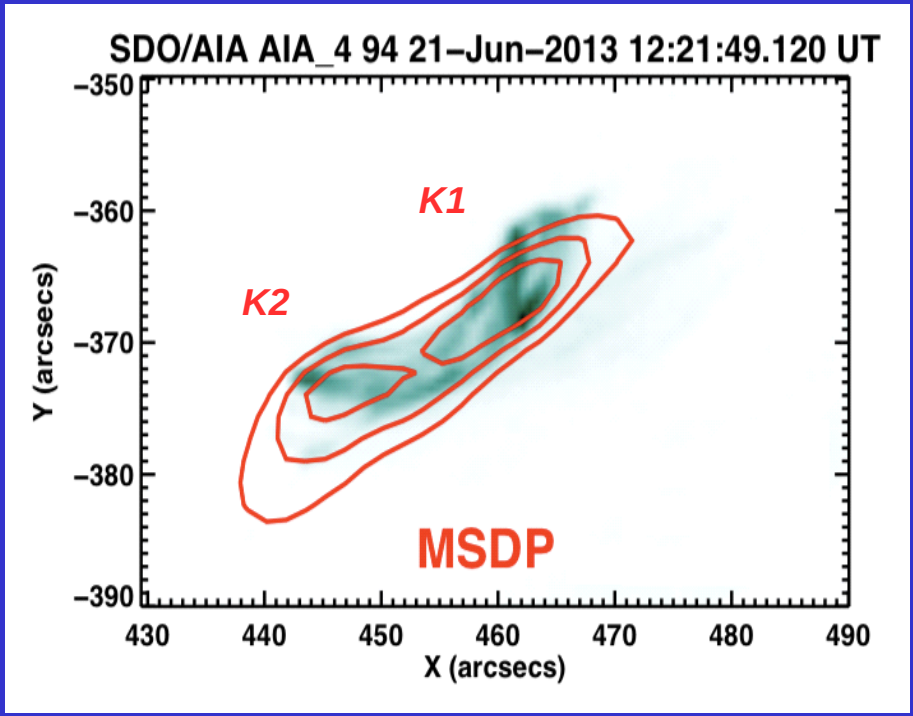
MSDP – Fast Mode observations (20 img/sec)



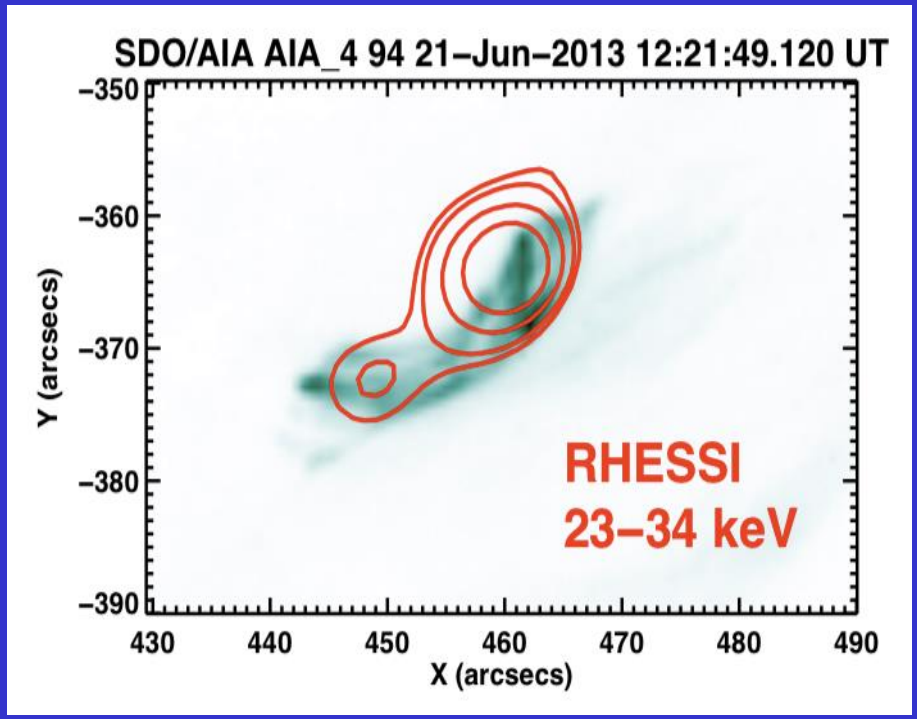




SDO/AIA 94 Å
&
Hα Line Centre (contour)

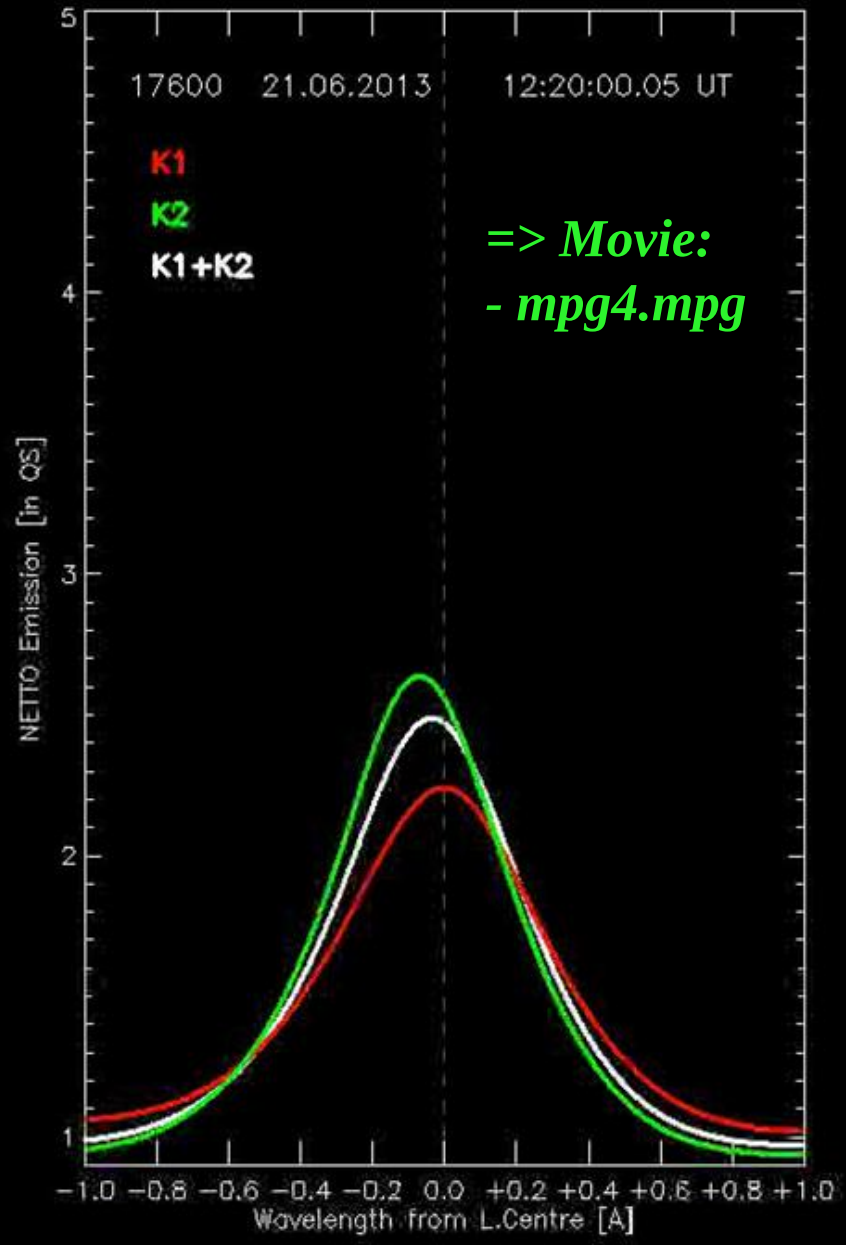


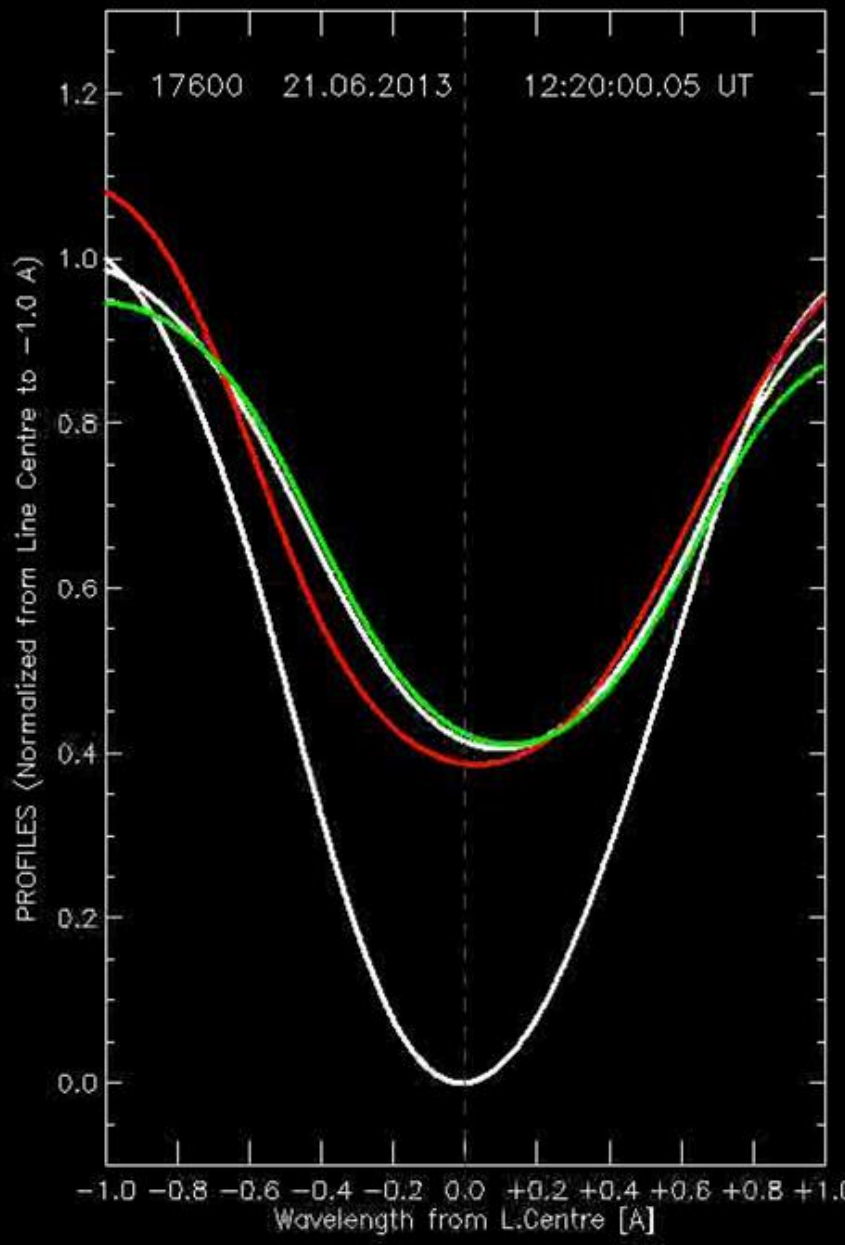
SDO/AIA 94 Å
&
RHESSI 23-34 keV (contour)



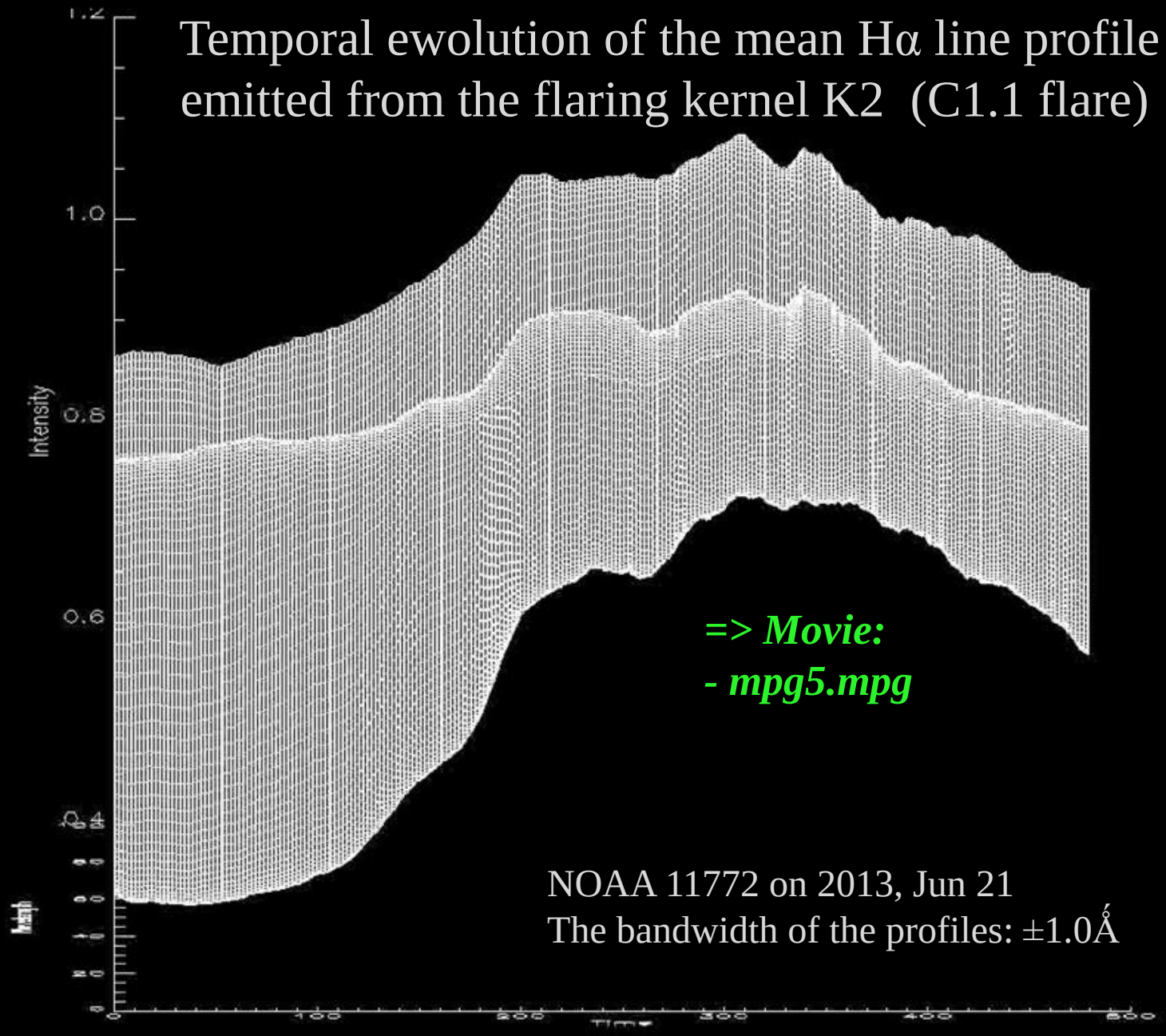
Falewicz, Radziszewski et al., ApJ, 847, 84F, 2017

Temporal variaions of the mean Hα line profiles emitted from the K1 and K2 flaring kernels (C1.1 flare)





Temporal ewolution of the mean Hα line profile emitted from the flaring kernel K2 (C1.1 flare)



=> Movie:
- mpg5.mpg

NOAA 11772 on 2013, Jun 21
The bandwidth of the profiles: ±1.0Å

Publications concerning Hα high cadence MSDP observations

- *Karlicky. M., Zemanova. A., Dudik. J., Radziszewski. K., ApJ Letters, 854, L29*
- *Falewicz, R., Radziszewski, K., Rudawy, P., Berlicki, A., ApJ, 847, 84F, 2017*
- *Radziszewski, K., Rudawy, P., Sol. Phys., 284, 397, 2013*
- *Radziszewski, K., Rudawy, P., Phillips, K. J. H., A&A, 535, A123, 2011*
- *Radziszewski, K., Rudawy, CoSka, 41, 183, 2011*
- *Ambróz, J.; Radziszewski, K.; Rudawy, P.; Rybák, J.; Phillips, K. J. H., CoSka, 40, 5, 2010*
- *Radziszewski, K., Rudawy, P., Annales Geophysicae, 26, 10, 2991, 2008*
- *Radziszewski, K.; Rudawy, P., CEAB, 31, 67, 2007*
- *Radziszewski, K.; Rudawy, P.; Phillips, K. J. H., A&A, 461, 303, 2007*
- *Radziszewski, K.; Rudawy, P.; Phillips, K. J. H.; Dennis, B. R., Adv. in Space Res., 37, 1317, 2006*
- *Radziszewski, K.; Rudawy, P.; Phillips, K. J. H., ESASP, 600, 37, 2005*
- *Radziszewski, K.; Rudawy, P.; Phillips, J. H., AIPC, 801, 412, 2005*

Summary and future

of spectral ground-based fast observations

in the ferme of new EST Telescope operation

Future and Summary

- EST Telescope will provide the best conditions for high spatial resolution and high cadence observations!

- Understunding of energy release during impulsive stage of solar flares from separate small sources located on the chromosperic level need very fast observations with very good spatial resolution.

- EST will be great opportunity for **sub-second** (spatial and time resolution) **spectral** observations of solar flares - and I hope it will be taken into account during operation of telescope.

Future and Summary

- For full analysis of energy deposit and chromospheric response we need additionally space-born observations (but it is separate topic concerning sattelite with X-ray spectometer).

- EST observations of implulsive stage of solar flares will be great chance for better confrontation of hydrodynamic and radiative numerical models of solar chromosphere.

- High cadence (on the level of **30-50 ms**) spectral observations in chromospheric lines (like Hα) **should be** included in scientific program of EST Telescope.

Thank you for attention

=> Movie:
- mpg6.mpg