KARL-FRANZENS-UNIVERSITÄT GRAZ
UNIVERSITY OF GRAZ

Kanzelhöhe Observatory

Flare observations and real-time detections

Astrid Veronig & Werner Pötzi

Kanzelhöhe Observatory / Institute of Physics
University of Graz, Austria

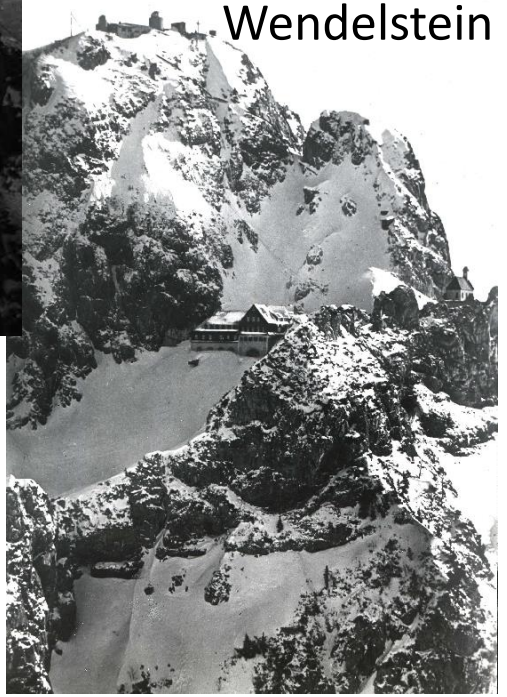
Institute of Physics

Kanzelhöhe Observatory

Historical

First network for space weather research („solar-terrestrial relations“) founded by Karl-Otto Kiepenheuer in frame of „Deutsche Luftwaffe“ during WW2.

Relevance: short wave radio communication and navigation



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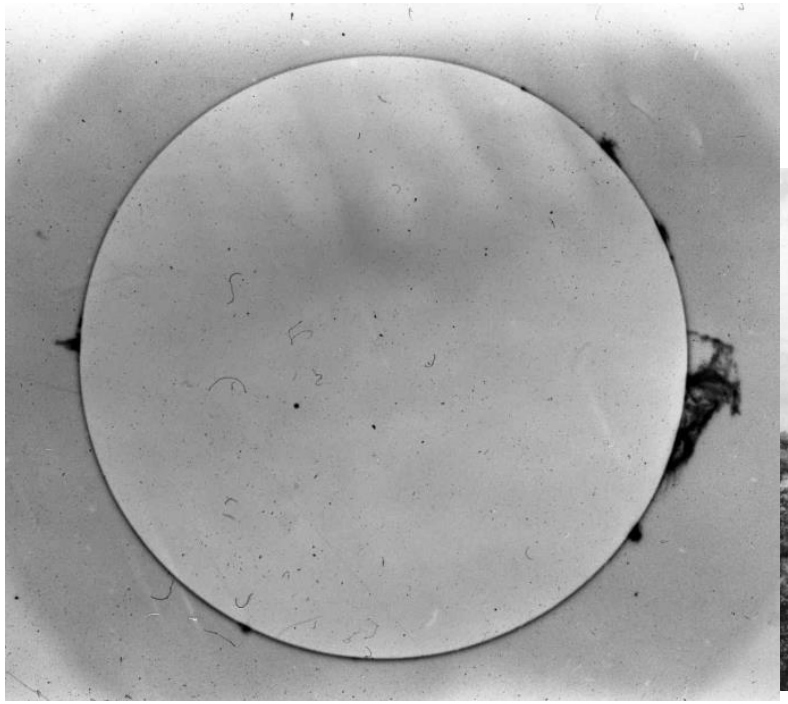
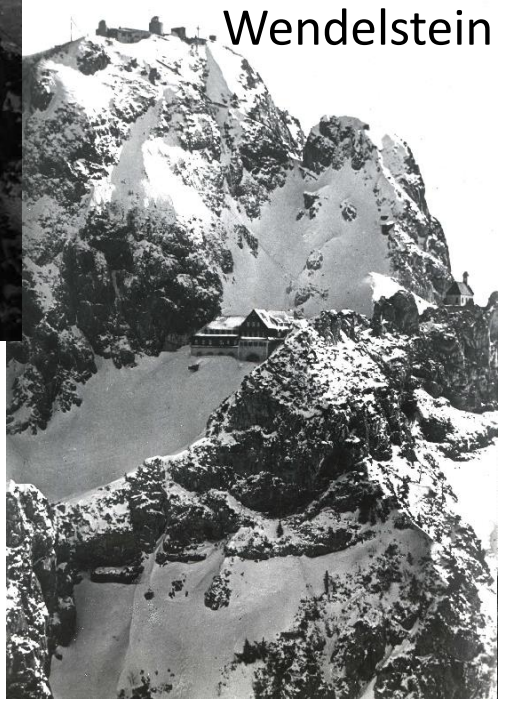
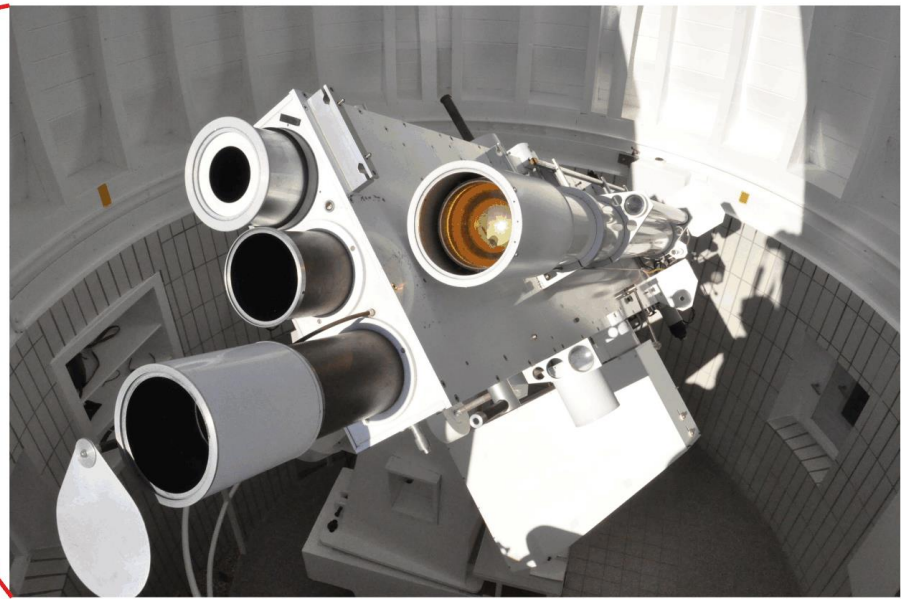
Kanzelhöhe Hα 12-Oct-1947





Observations



Kanzelhöhe Observatory (KSO):

High-cadence full-disk imaging of the Sun in Hα, Ca II K, and continuum.

Observations

Observations:

7 days/week: typically 300 days/year (~1500 hours)

Hα-Telescope:

d/f = 100/2000 mm

Lyot filter FWHM 0.7 Å

CCD : 2048x2048 pixel, 12bit

framerate: 7 images/sec → frame selection

Cadence: 6 s

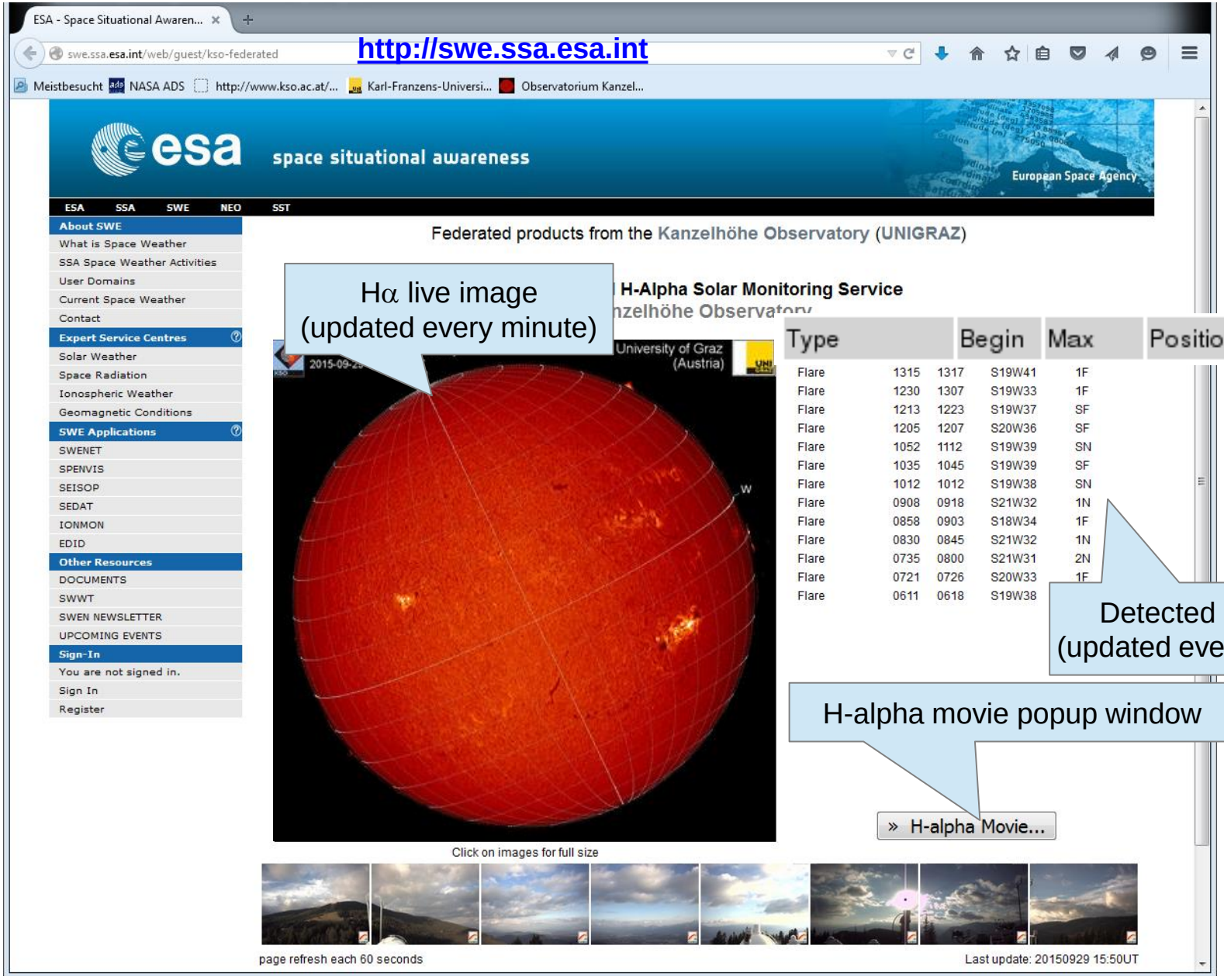
Automatic exposure control

Resolution ~ 2 arcsec

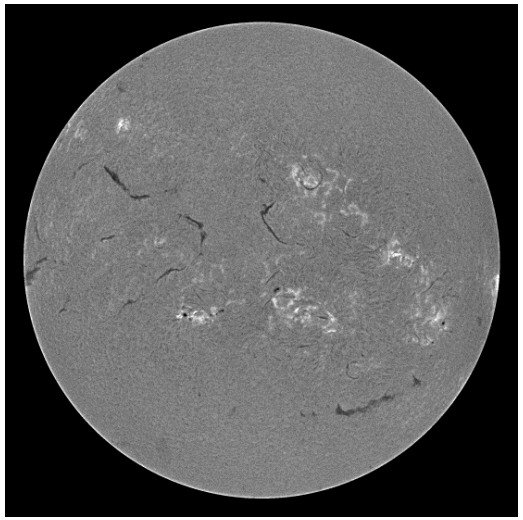
ESA Space Situational Awareness (SSA) Space Weather programme:

- Real-time provision of Hα images on ESA‘s SWE portal
- Real-time detection of flares and filaments

Real-time data provision for ESA's SSA SWE programme



Automatic real-time detection of flares and filaments at KSO

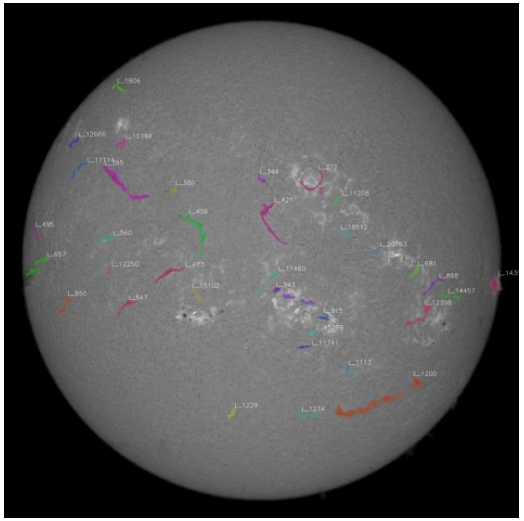


Preprocessing

Feature Selection

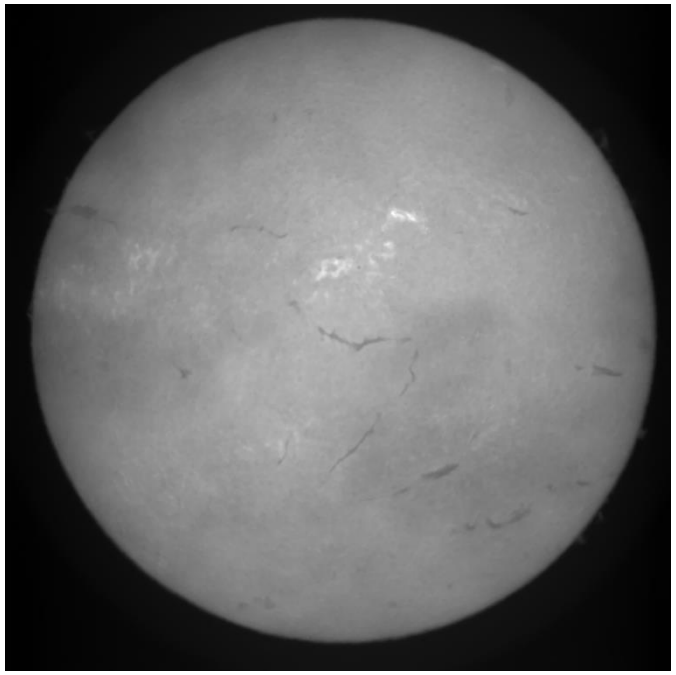
Multi-label Segmentation

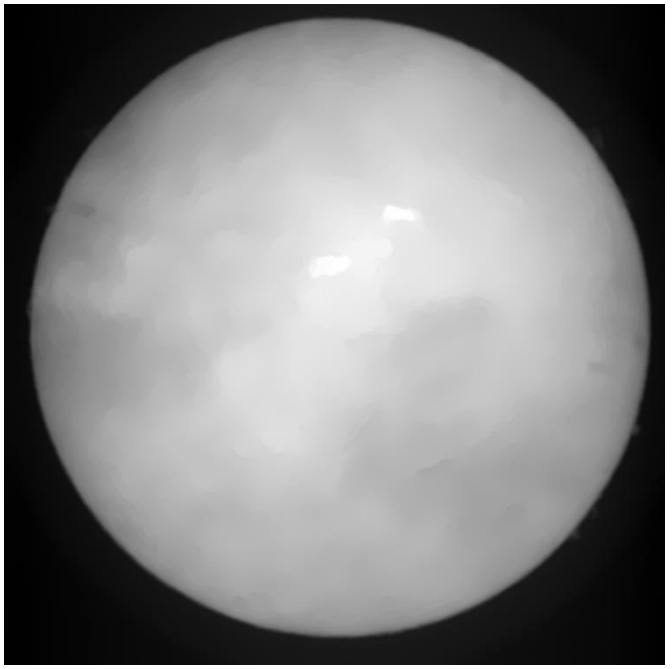
Postprocessing

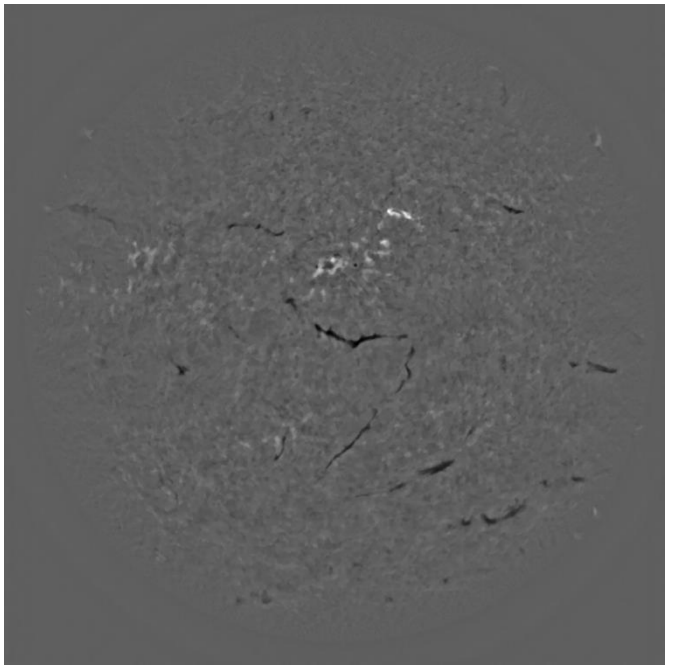


Automatic real-time detection of flares and filaments at KSO

1) **Preprocessing:** Image normalization. A structural bandpass suppresses noise in the images on small scales and filters large-scale intensity variations caused by clouds and the center-to-limb variation.



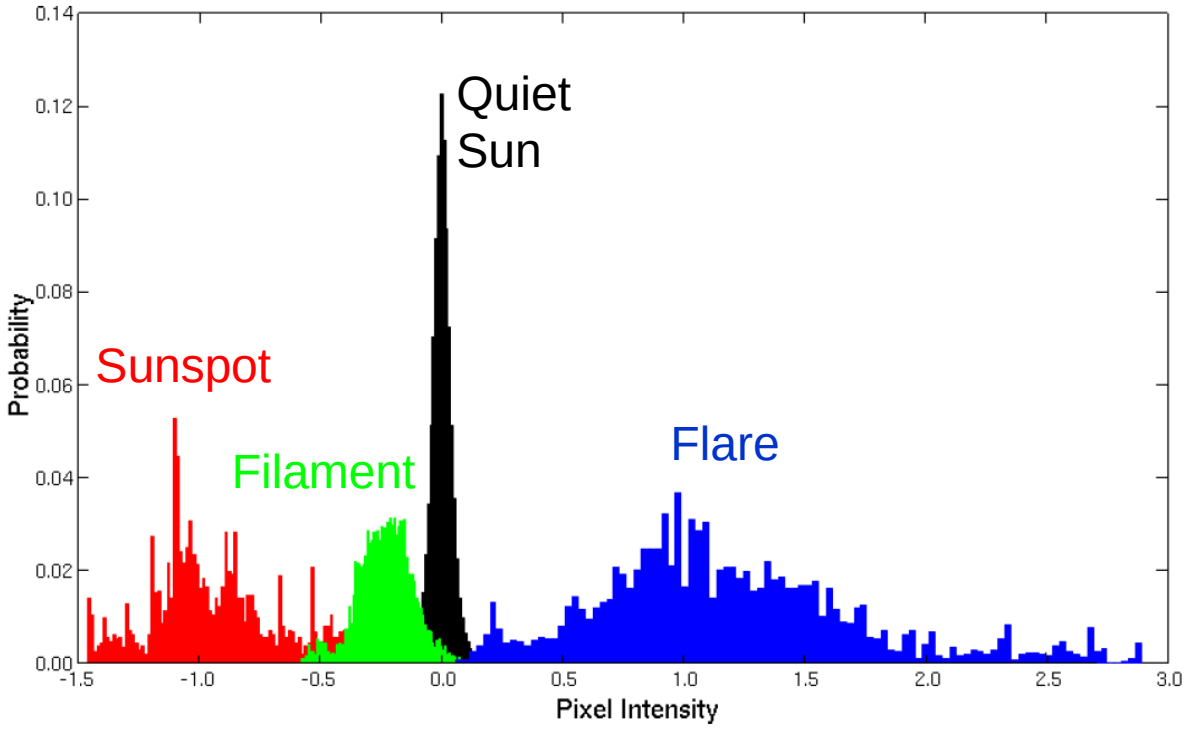




Automatic real-time detection of flares and filaments at KSO

1) **Preprocessing:** Image normalization. A structural bandpass suppresses noise in the images on small scales and filters large-scale intensity variations caused by clouds and the center-to-limb variation.

2) **Feature selection:** a) What are the characteristic attributes of filaments and of flares, i.e. what discriminates them from quiet solar regions ("background")? b) How can we efficiently model these attributes?



Distribution derived from training set. Hα images were annotated by an expert.

Automatic real-time detection of flares and filaments at KSO

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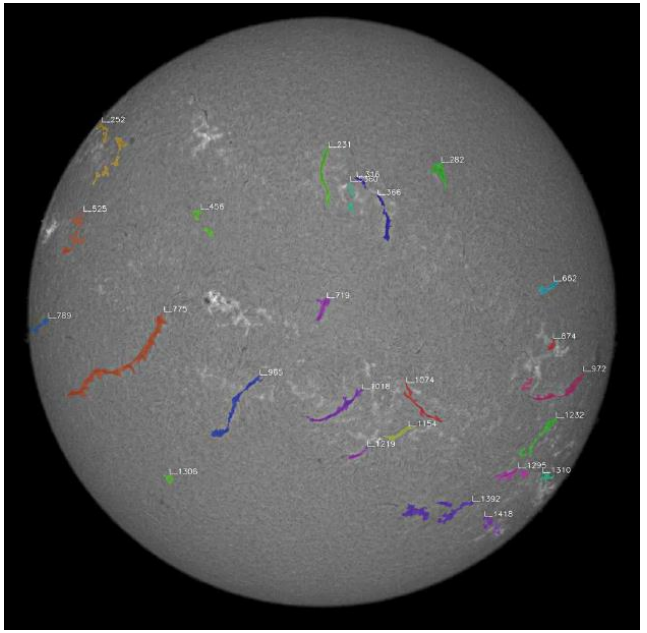
3) **Multi-label segmentation:** Assign a class probability to each pixel. Make the result smooth (regularize segmentation).

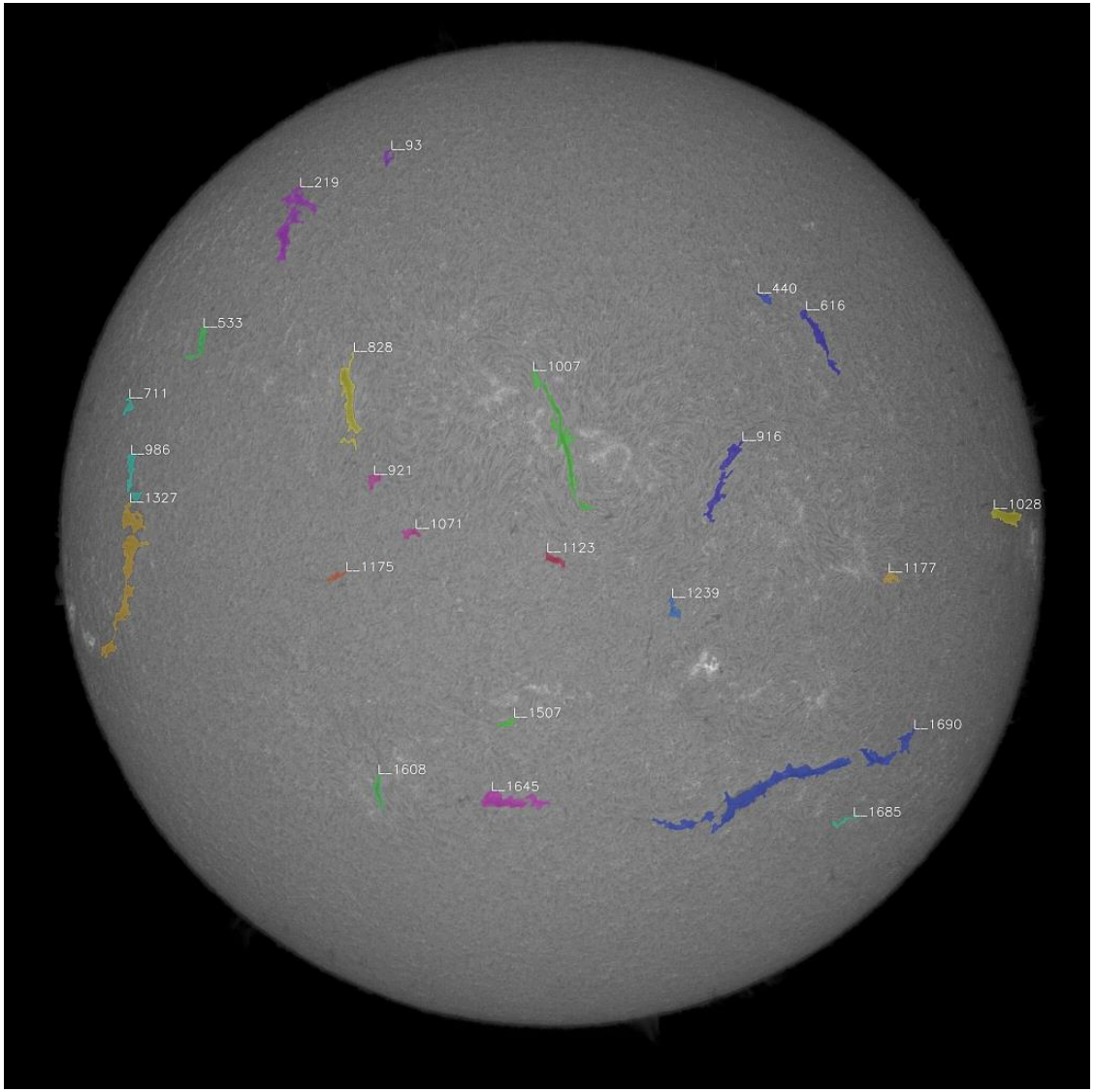
4) **Postprocessing:** Every object is identified with an ID and followed form image to image. Characteristic properties of the filaments and flares are derived to categorize them.



Automatic real-time detection of flares and filaments at KSO

Automatic detection of filaments:

Based on intensity and shape.
Connection of segments along main axis of direction
(Riegler et al. 2013, Pötzi et al. 2015)



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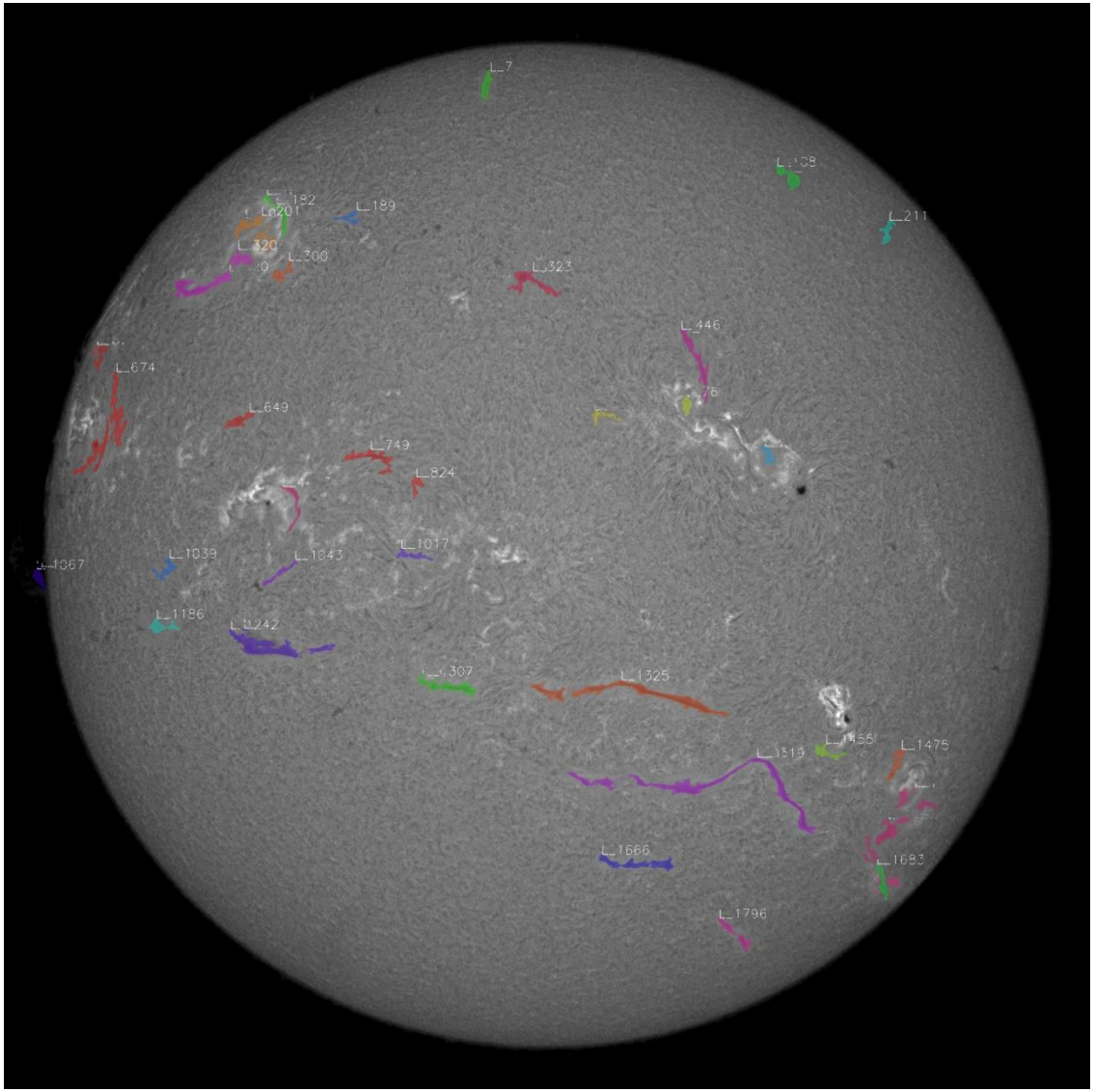


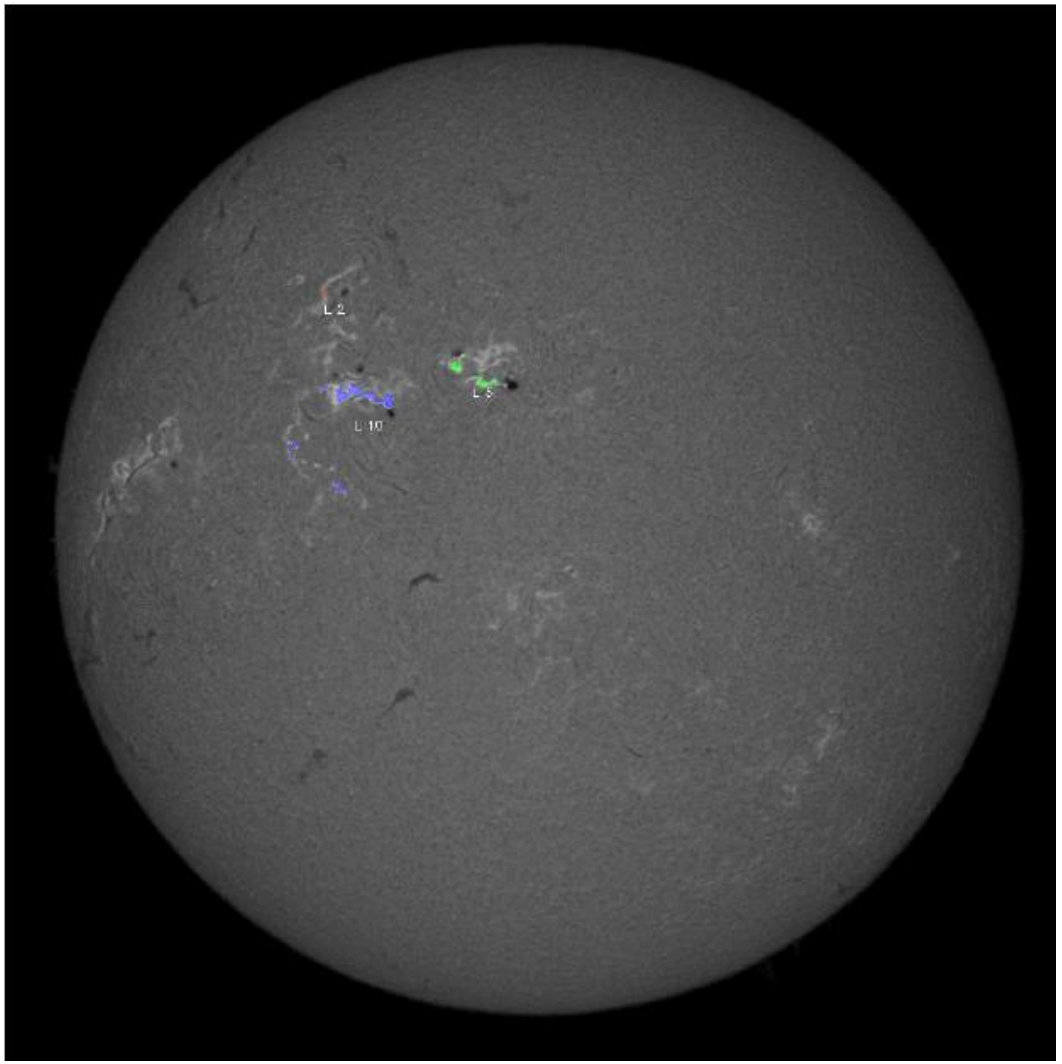
Automatic real-time detection of flares and filaments at KSO

Automatic detection of flares:

Based on increase of intensity in localized regions.

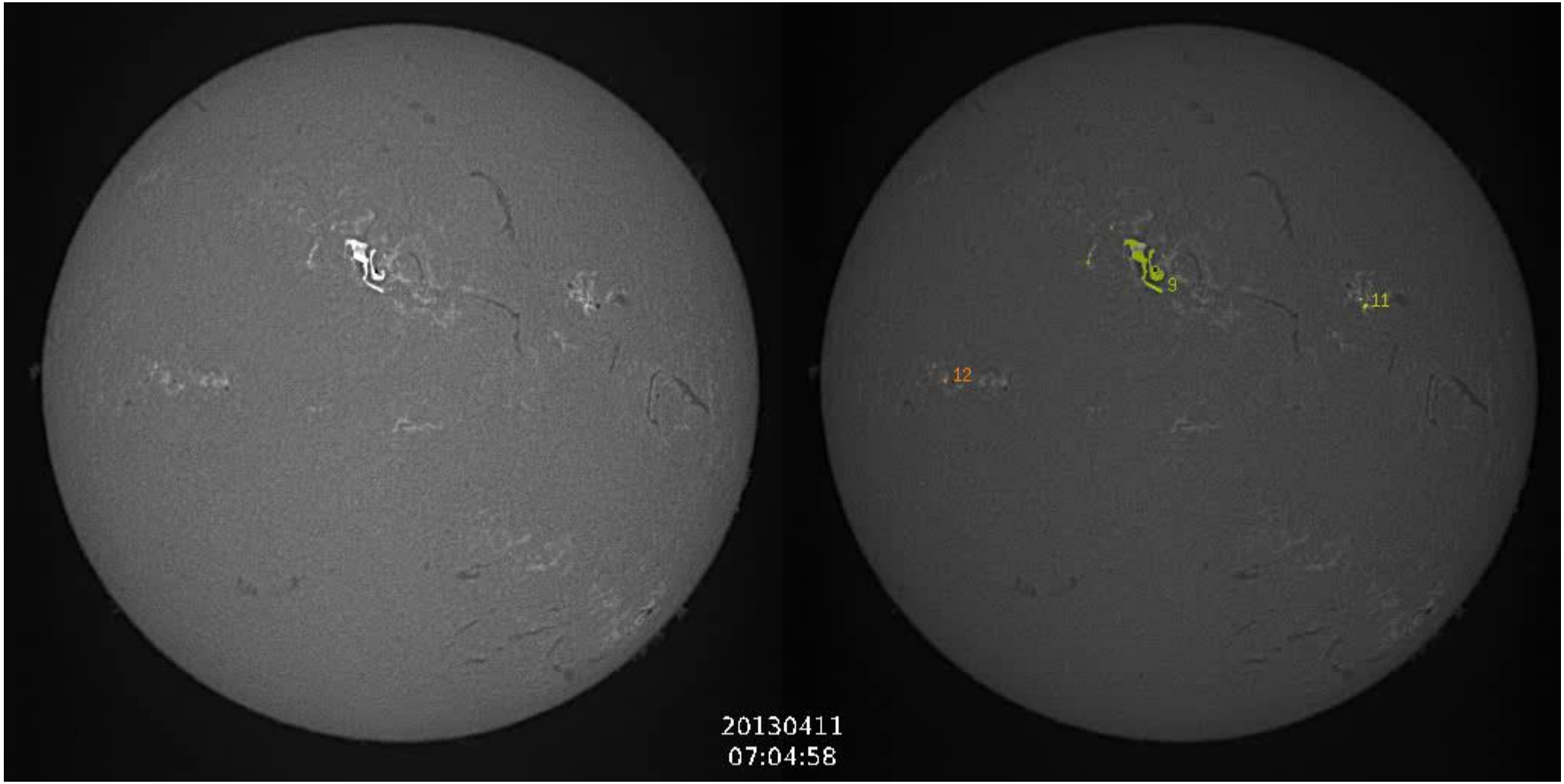
Real-time output:
- Start & peak time
- Heliographic location
- Importance class (size, brightness)

H-alpha flare importance	Flare area (in solar micro-hemispheres)
S[ubflares]	< 100
1	100 – 250
2	250 – 600
3	600 – 1200
4	> 1200



Automatic real-time detection of flares and filaments at KSO

Real-time output of flare-recognition program



Original raw Hα images.

Hα images with flare IDs identified.

Automatic real-time detection of flares and filaments at KSO

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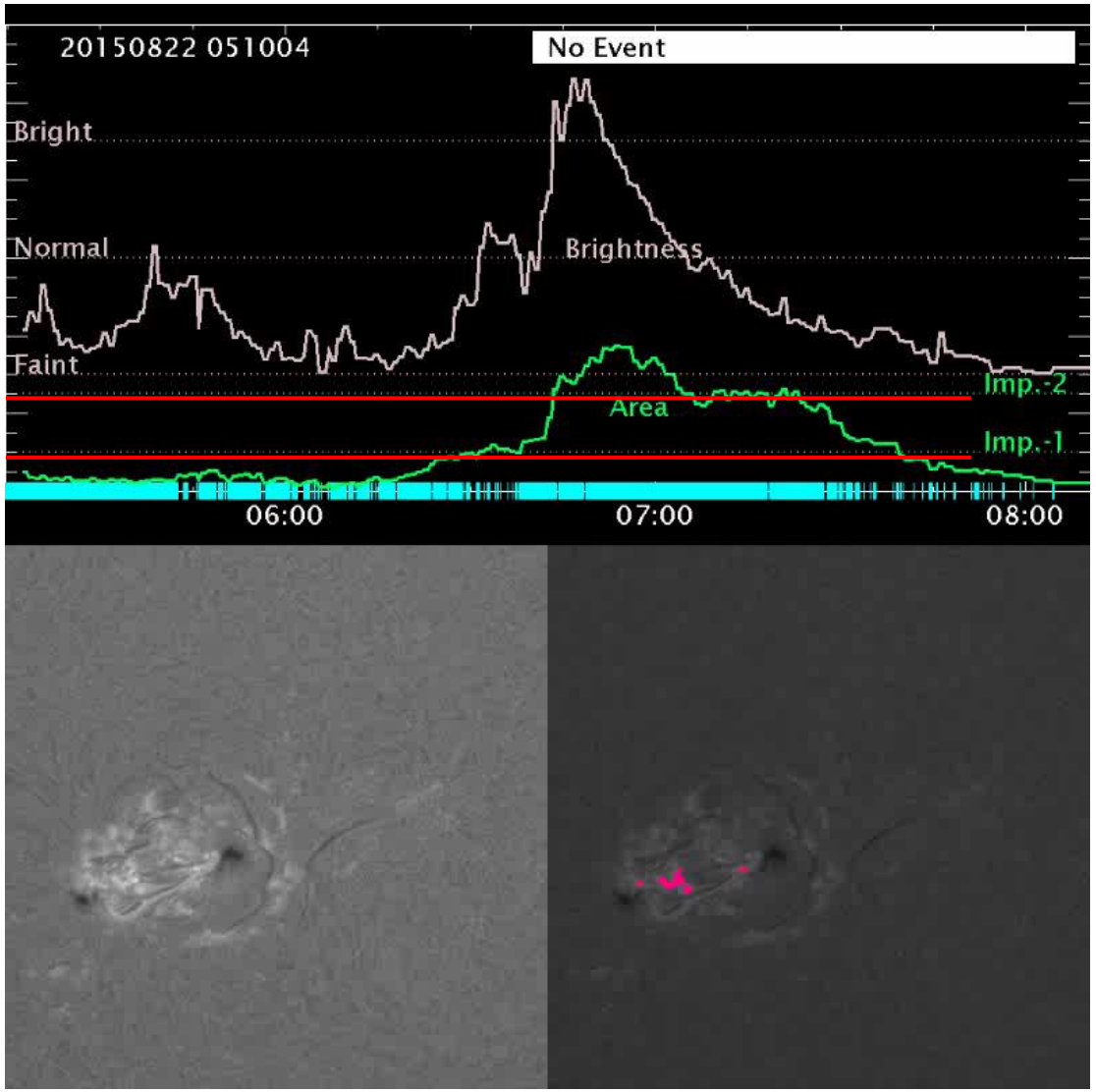
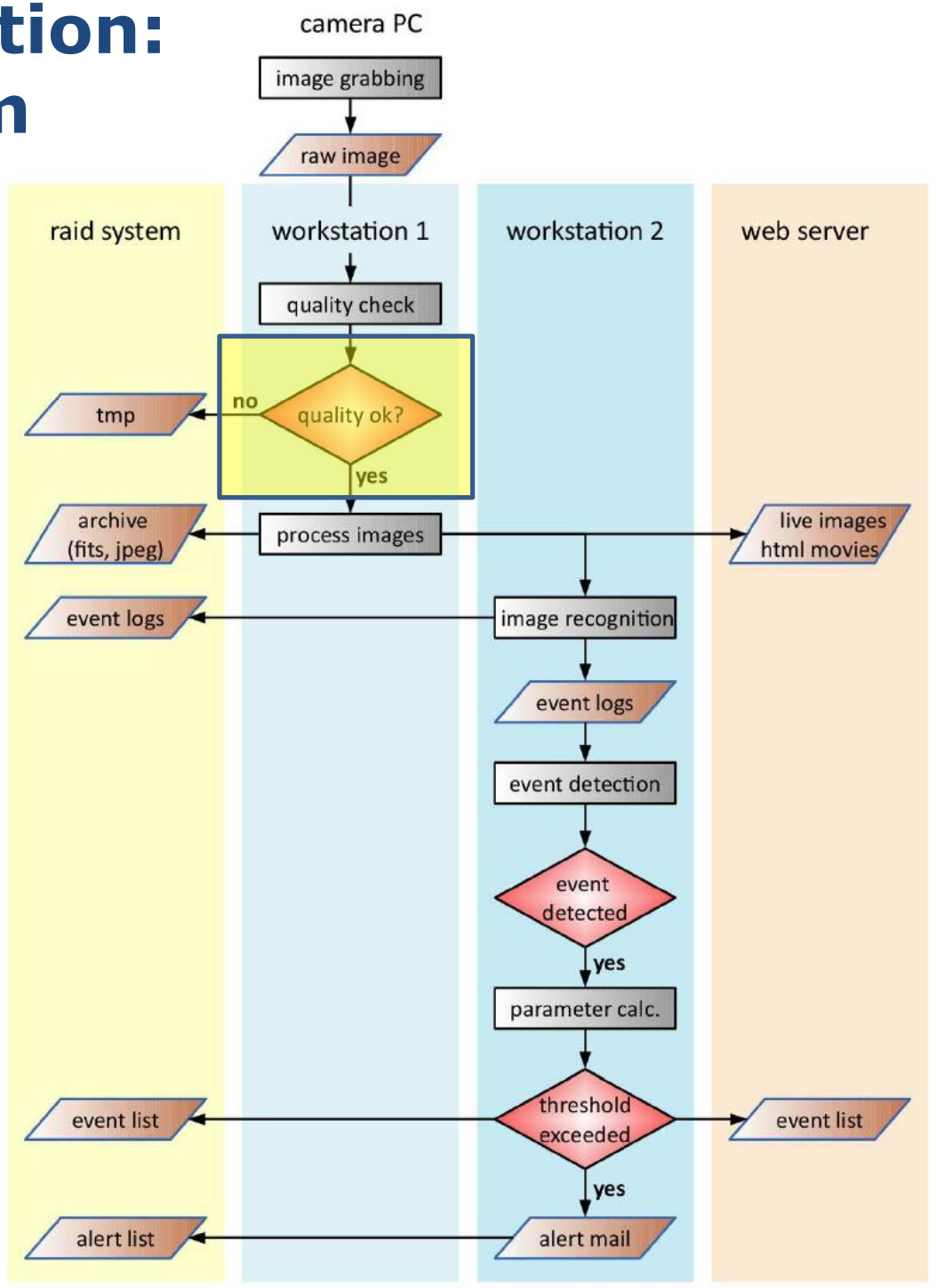


Flare area and brightness as function of time.

Implementation: flow diagram



Automatic real-time detection of flares and filaments at KSO

Image quality: defined by combination of three parameters

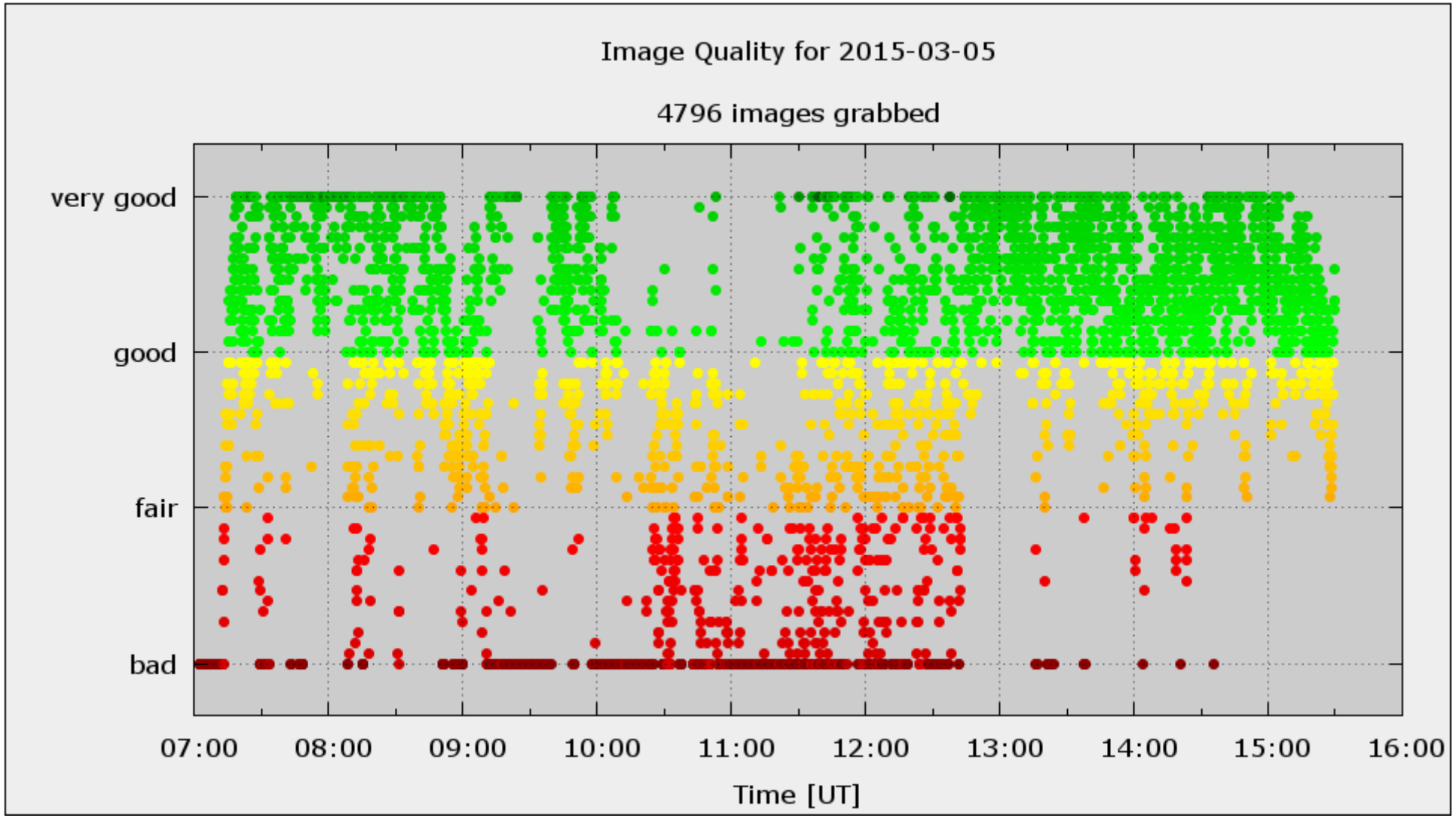
- accuracy of solar radius detection (limb fitting)
- large-scale intensity distribution over the solar disc
- sharpness of the image

Images are divided into 3 quality classes: good – fair – bad
Only images of quality “good” are used for further processing (flare detection).

Including images of low quality → automatic detection is susceptible to errors!

Automatic real-time detection of flares and filaments at KSO

Image quality: example



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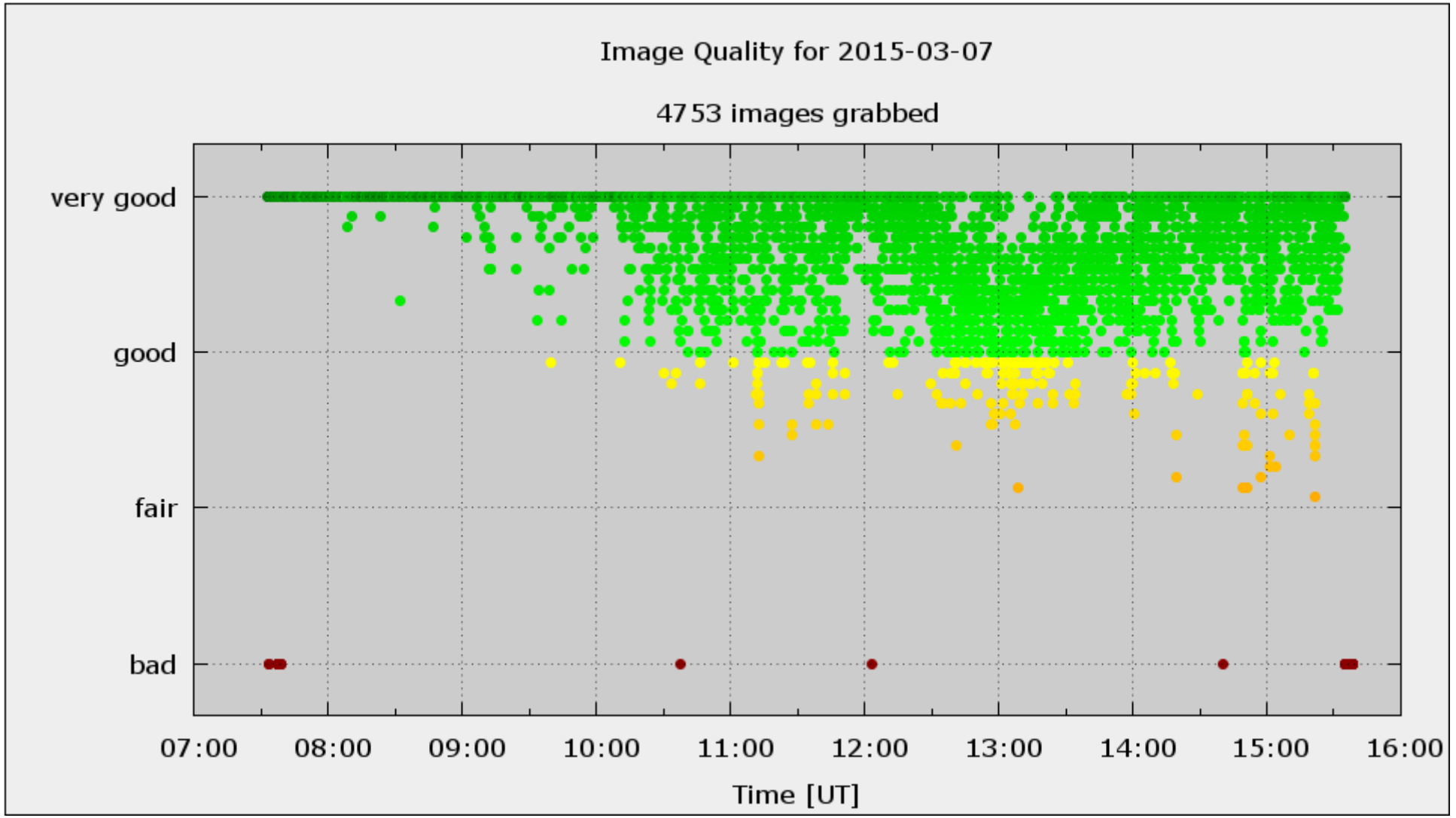


Automatic real-time detection of flares and filaments at KSO

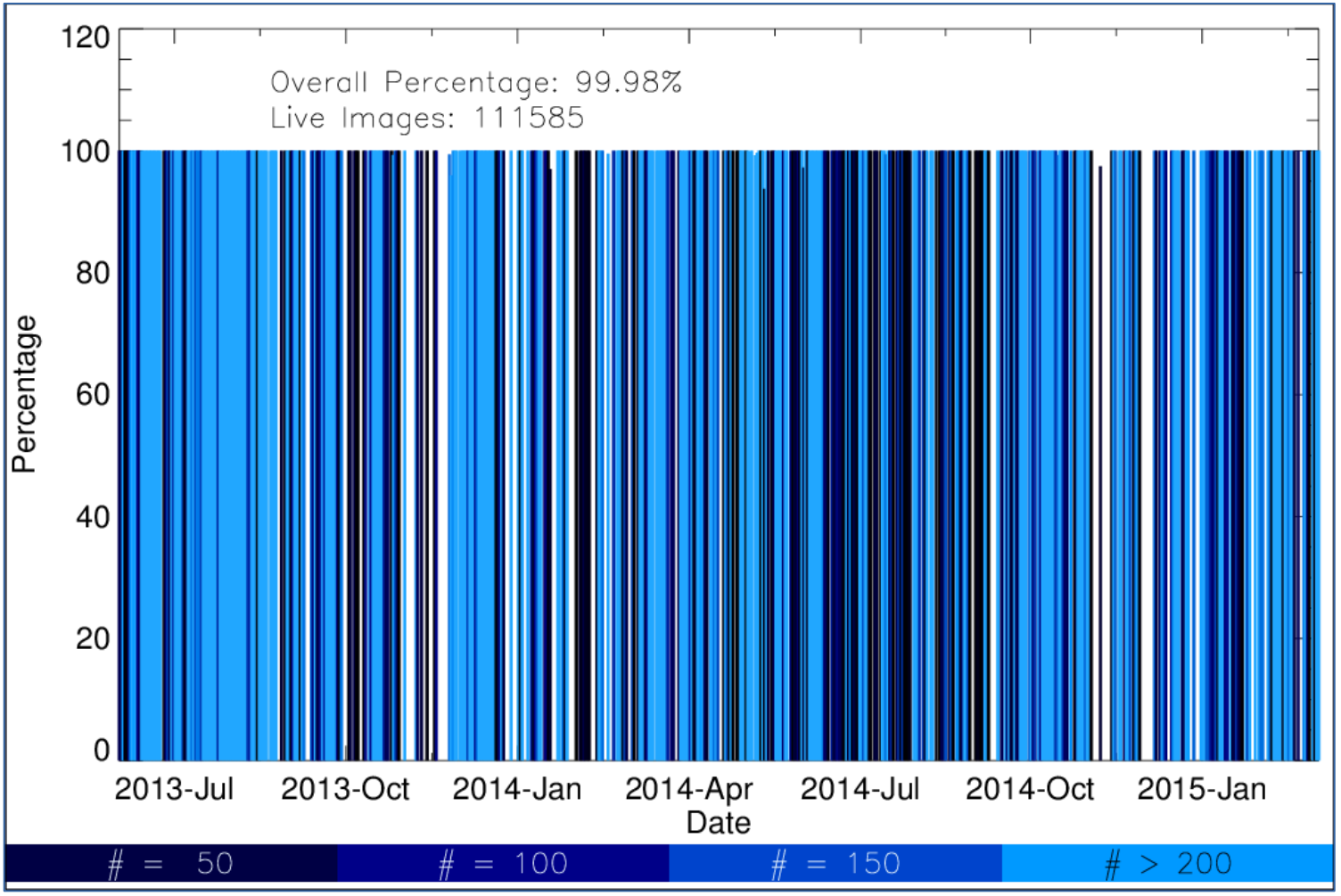
Evaluated for a period of 2.5 years (7/2013 – 11/2015):
data provision to ESA SWE portal & automatic flare detection

Results of the real-time automatic flare detection routine were compared to :

- **NOAA** - National Geophysical Data Center (NGDC) of the National Oceanic and Atmospheric Administration (NOAA) flare reports
  http://www.swpc.noaa.gov/ftpmenu/indices/events.html
- **KSOv** - visual KSO flare reports (which are regularly sent to NOAA)
  http://cesar.kso.ac.at/flare_data/kh_flares_query.php

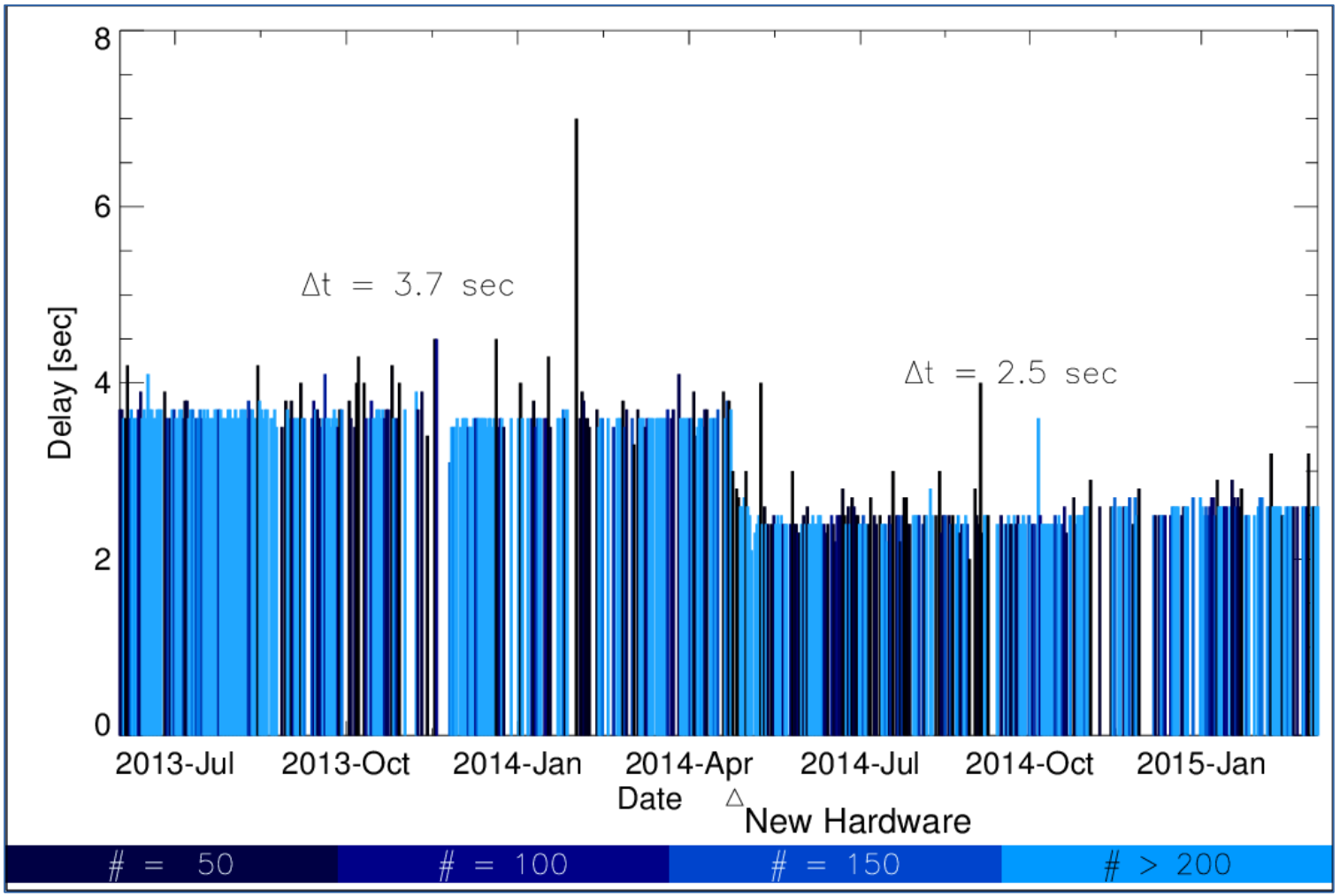
Automatic real-time detection of flares and filaments at KSO

Online data availability at ESA SWE portal: http://swe.ssa.esa.int



Automatic real-time detection of flares and filaments at KSO

Latency of online data provision:

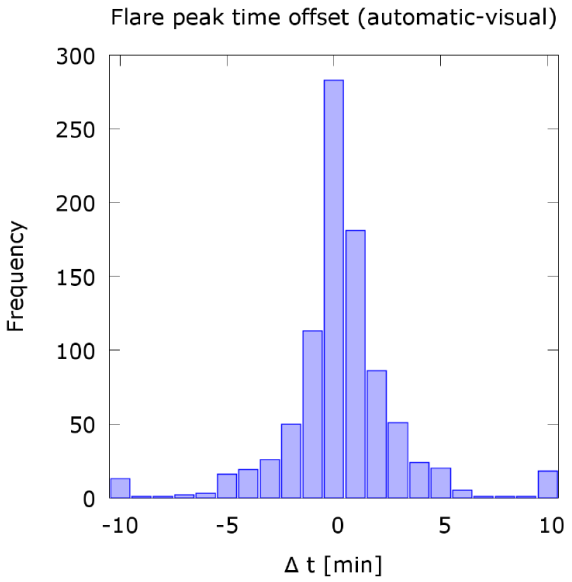


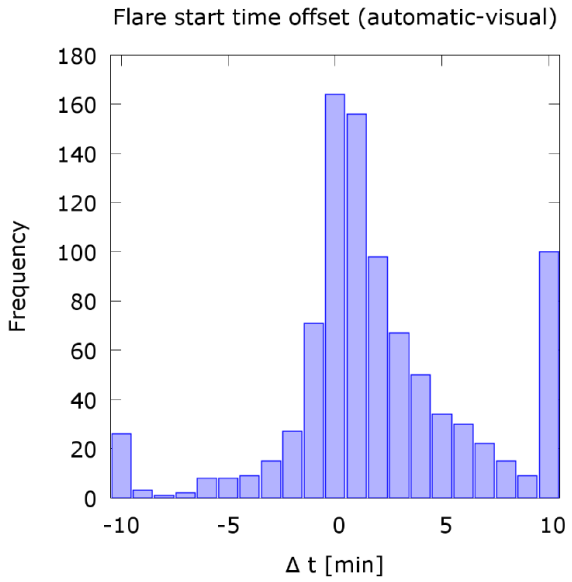
Automatic real-time detection of flares and filaments at KSO

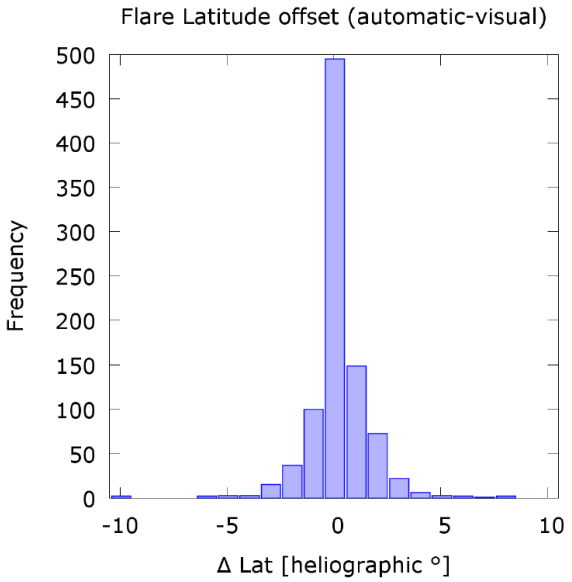
Validation period:

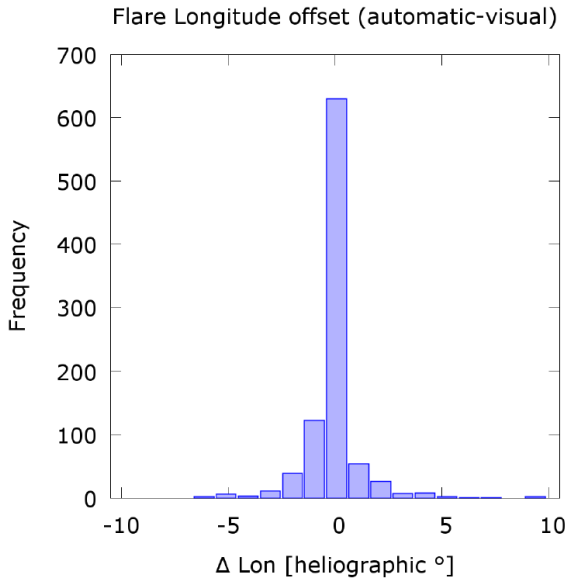
7/2013 – 11/2015
in total >800 flares

Subfl: 650 (79%)
Imp. 1: 155 (19%)
Imp. 2: 17 (2%)
Imp. 3: 2 (0.2%)









Veronig & Pötzi (2016)

Automatic real-time detection of flares and filaments at KSO

Verification measures applied to all flares ≥ importance 1:

174 events ≥1 identified

138: correctly detected *(h)*
8: detected but wrong class *(m)*
28: false alerts *(f)*
(mostly related to event splitting due to data gaps)

$$\mathrm{POD} = \frac{h}{h+m} = 94.8\%$$

$$\mathrm{FAR} = \frac{f}{h+f} = 16.1\%$$

- h number of hits: automatic = flare AND visual = flare,
- f number of false detections: automatic = flare AND visual ≠ flare,
- m number of missed detections: automatic ≠ flare AND visual = flare,

Thank you!

Data are available at http://cesar.kso.ac.at/main/ftp.php

The automatic detection study was developed within the framework of ESA Space Situational Awareness (SSA) Programme (SWE SN IV-2 activity).

The results are published in Pötzi et al. (2015, Solar Phys. 290, 951) and Veronig & Pötzi (2016, ASP Conf. Ser. 504, 247)