High-resolution flare observations and their use for prediction

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Introduction

• Recap of high-resolution observations
• Attempt of flare observations at GREGOR
• Flare physics and prediction?
• Conclusions
Previous Observations

C3.4 flare on Jan 29, 2007

- Photosphere
- Chromosphere
- V/I blue wing
- V/I line core
- Dopplergram

Flare ribbon
Large Doppler shift
Opposite polarity
Reverse Evershed flow

Material of opposite polarity into sunspot ➔ reconnection? shifting of field lines? ➔ flare

Previous Observations

C3.4 flare on Jan 29, 2007

field lines may shift -> flare

reconnection

emerging flux (opposite)

sunspot magnetic field

Chromosphere

Photosphere

Speculation! To be confirmed with more data.

60 min after C4.5 flare, ribbon still visible and orientation apparently not related to photosphere.

Magnetogram again with opposite polarities close to each other.

October 10, 2011, 15:37 UT
M2.8 flare on Sep 24, 2011: small scale features, reverse Evershed flow again

What influence does the photospheric and chromospheric fine-structure have on flaring?

Recap hi-res obs – GREGOR – Flare physics – Conclusions

X1 flare March 29, 2014
- Speckle-reconstructed Ca II 8542 images.
- Black filament vanishes
- Flux-rope (?) untwists
Could one have predicted the flare?

Maybe... we sort of did.

Doppler shifts in Ca 8542 and Hα (chromosphere) increased ~15 min before flare.
Could one have predicted the flare?
Could one have predicted the flare?

Recap hi-res obs – GREGOR – Flare physics – Conclusions
Let’s test flare “predictions” at GREGOR


with C. Kuckein and M. Kuhar
• 1.5 m mirror (largest European solar telescope)
• FOV: ~150 arcsec (=large active region)
• foldable dome
• Three instruments
• Many, many mirrors (throughput...)

GREGOR Recap hi-res obs – GREGOR – Flare physics – Conclusions
Three GREGOR instruments

- **GRIS**: spectrograph
  => Infrared (656 nm and above)
  => H-α slitjaw, He 10830 spectra

- **GFPI**: Fabry Perot imager
  => visible (~500-650 nm)
  => e.g. Na I 5890

- **BBI / HIFI**: fast imaging
  => blue (<500 nm)
  => e.g. blue continuum, Ca K+H
Our observing run... no real flares

GOES X-ray (3 sec)
GREGOR observing run

Day 1

calima
(dust from the sahara)

Day 3++
Recap hi-res obs – GREGOR – Flare physics – Conclusions

GREGOR observing run

Our observing run... no real flares

GOES X-ray (3 sec)

Flux [W m⁻²]

Start Time (26–Jun–16 00:00:00)

Lucia Kleint, October 24, 2016
seeing variation (during 10 s of below average seeing)

ggregor observing run

edge of FOV (not of the Sun)
Our observing run... no real flares

GOES X-ray (3 sec)

- Dust
- Bad seeing

Start Time (26-Jun-16 00:00:00)

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Our observing run... no real flares

GOES X-ray (3 sec)

- 27–Jun: dust
- 29–Jun: bad seeing
- 01–Jul: planned power outage
- 03–Jul: unplanned power outage
- Start Time (26–Jun–16 00:00:00)

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Recap hi-res obs – GREGOR – Flare physics – Conclusions

GREGOR observing run

Our observing run… no real flares

Our skills in ping pong

Flux [W m$^{-2}$]


Start Time (26–Jun–16 00:00:00)

dust Bad seeing planned power outage unplanned power outage bad seeing
Our observing run... no real flares

GOES X-ray (3 sec)

27-Jun 29-Jun 01-Jul 03-Jul
Start Time (26-Jun-16 00:00:00)

- dust
- bad seeing
- planned power outage
- unplanned power outage
- observations!
- bad seeing

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Filament eruption (B1 GOES class)
Filament eruption (B1 GOES class)

Very unusual He spectra, high velocities

GREGOR He 10830 data

data analysis in progress
pores during good seeing – only flatfielded so far, no speckle reconstruction yet

data analysis in progress
In summary, we were not very lucky with the observing conditions, but we caught a filament eruption.

Data analysis in progress.
Ideas for flare prediction

- predict from spectra (IRIS)?
- predict from NLFFF modeling?
- predict from high-resolution features?
Flare predictions with IRIS?

Types of spectra during a flare, found with machine learning (k-means).

Are there typical spectra before a flare? Use machine-learning to classify (proposal pending).
Flare predictions from NLFFF modeling?

First check if NLFFF models reproduce the changes observed during flares, especially in higher atmospheric layers.

=> Magnetic field changes during flares
Magnetic field changes in the chromosphere

Photospheric $B$ has been found to change during strong flares and penumbra may disappear.


For chromospheric $B$, we have not had the measurements.
The change of $B_{\text{LOS}}$ in the photosphere and in the chromosphere seems independent, showing differences in timing (<3 min), sign, and size.
Magnetic field changes in the chromosphere: X1 2014-03-29

Recap hi-res obs – GREGOR – Flare physics – Conclusions

Top view

LOS view

before flare

Larger LOS component

after flare

Smaller LOS component


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Energy Storage and Dissipation: NLFFF modeling

Comparison of obs. and NLFFF modeling.
(by M. Wheatland and L. Kleint)

Photosphere

Difference of HMI images postflare-preflare

Difference of NLFFF extrapolations.

Comparisons do not yet agree, work in progress.
Statistical study of magnetic field changes

Master’s thesis of J.S. Castellanos Duran:

sample of 75 flares. Changes found for:

100% of X-class (18/18),
92% of M-class (35/38),
35% of C-class (6/17) flares.
Flare prediction from high-resolution features?

0.05" resolution observations
(H-alpha red wing)
Credit: BBSO, NJIT:
Jing Ju, Y.Xu, H. Wang

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Flare prediction from high-resolution features?

Trying to understand geometry. Cooling time after X-ray emission related to loop length and density. How to predict where flare will occur?
Conclusions

• Focus on opposite polarities, filaments, reverse flows

• GREGOR may get nice observation to understand flares

• Prediction: spectra and machine learning; NLFFF modeling; high-resolution features?