Photospheric and chromospheric polarimetry of solar flares

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Goals

Flares occur because of changes in the magnetic field configuration. => **Determine magnetic field** in the photosphere and chromosphere.

Observational issues

Huge **intensity gradients**

Polarimetry: usually combination of at least 2 different images (for example I+Q and I-Q)

If images not perfectly aligned (or not simultaneous) → **spurious signals** in flare polarization

Ground-based obs.: limited observing time and timing problems
Example: Jan 29, 2007 C3.4 flare

IBIS at Dunn Solar Telescope

C3.4 flare from 16.41-17.22

time of IBIS observations (17.49-19.08)

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Spectropolarimetry of flares

AR 10940, Jan 29, 2007. FOV 40”x80”. (Kleint 2012).
Photospheric polarimetry

Material of opposite polarity into sunspot ➔ reconnection, shifting of field lines ➔ flare
Temporal evolution of a declining chromospheric flare (50 min sequence)
Stokes profiles

**Photosphere:** Strong upflow, maybe also downflow component (penumbra forming?)

**Chromosphere:** Up- and downflow? Need 2-component inversions.
C3.4 flare

Inflow into sunspot in the photosphere → triggering next flare? Otherwise photosphere mostly constant.

Strongest chromospheric Stokes V inside ribbon

Brightenings by rearranging loops, reconnection or enhanced beams?

That was a “simple“ C-flare, how about X-flares?
Dunn Solar Telescope (observing campaign):
- IBIS (6302, 8542 polarimetry, 6563 I)
- FIRS (He I 10830 polarimetry)
- Ca K context images
- G-band context images

IRIS:
- Slitjaw 1400, 2796, 2832
- 8-step raster (FUV+NUV)

Hinode:
- SP raster (just finished when flare began)
- Na IV shutterless
- Ca H intensity
- EIS, XRT

RHESSI:
- Caught full flare

SDO:
- AIA and HMI

STEREO:
- Recorded CME

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First step: Imaging
The X1 flare on 2014-03-29

Disruption to the North – probably stopped by sunspot in South

Courtesy of N. Nitta

University of Applied Sciences and Arts Northwestern Switzerland
The X1 flare – SDO/AIA

Filament eruption seems to start the flare
Second step: Spectroscopy
The X1 flare - IRIS

8 raster positions (every ~other shown in movie)

Filament eruption visible

FUV and NUV spectra recorded at each raster position.

First IRIS X-flare observation
The X1 flare - IRIS

Si IV line at each raster position.

=> Filament is accelerating

(Kleint et al. 2014, submitted)
Acceleration starts before HXR are visible. Eruption triggering the flare?

Acceleration high compared to previous observations (<1.5 km/s^2)
Third step: Polarimetry
The X1 flare - Hinode

Na I, Stokes IV shutterless

Disturbance in Stokes I => signature in Stokes V

Images reconstructed by Zoe Frank
The X1 flare – IBIS Ca II 8542 core

- Speckle-reconstructed Ca II 8542 images.
- Black filament vanishes
- Flux-rope/filament (?) untwists

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The X1 flare – IBIS 8542

Chromospheric polarimetry of a flare

Total linear polarization:
\[ \text{total}(\sqrt{Q^2 + U^2}) \]

Total circular polarization:
\[ \text{total}(\text{abs}(V)) \]
The X1 flare – Is the polarization real?

Q/I: noise, or small V crosstalk

U/I: looks real

V/I: looks real
Summary

Best observed X-flare: 3D picture of the flare

- **Photosphere:** Only small changes in $v_{\text{LOS}}$ and magnetogram (HMI). HXR follows white-light emission (RHESSI, HMI).

- **Upper photosphere:** V/I reverses its sign, only temporary. Disturbance of intensity (Hinode)

- **Chromosphere:** Interesting small-scale dynamics. Untwisting flux rope, filament eruption. First hi-res X-flare polarimetry. (IBIS, FIRS)

- **Transition Region:** Filament eruption at ~600 km/s upflow. (IRIS)

- **Corona:** Loop top hot ~25 MK. AIA 94 follows RHESSI HXR signal. (RHESSI, SDO).
The X1 flare - Conclusions

• Filament *eruption starts before HXR*. Flare triggered by filament?

• Twisted filament vanishes. How?

• Very *high acceleration* (3-5 km/s²) compared to previous observations (∼<1.5 km/s²)

• *Real chromospheric polarization*. Next: inversions (NICOLE).
X1 flare 20140329 – Timeline

start ofrant

End of rant
The X1 flare – Is the polarization real?

Data took a lot of effort to calibrate. Standard pipeline not enough.

Variation of continuum polarization over the FOV (in y direction) =>
good apart from 1 wavelength in the wing

Continuum images =>
I-> Q,U,V crosstalk below 1%
The X1 flare - Hinode

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