Coordinated flare observations with multiple instruments and limited field-of-view

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Introduction

• Previous high-resolution flare observations
• Overview of March 29, 2014 X1 flare
• Catching flares with limited FOV instruments
• Conclusions
Previous Observations

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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Previous Observations

C3.4 flare on Jan 29, 2007

FOV 1
photosphere chromosphere

FOV 2
photosphere chromosphere

Previous Observations

Scan through photosphere and chromosphere

Previous Observations

What might trigger a flare?

Outward motion

Note the apparent inward motion in the left penumbra

20 min sequence
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


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Previous Observations

C3.4 flare on Jan 29, 2007

Speculation! To be confirmed with more data.
Previous Observations

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?

X1 flare March 29, 2014

Need more observations, including spectroscopy and polarimetry, to investigate small-scale structures.

science questions:
- Why did this flare happen, what caused it?
- Are there differences to other 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

Kleint, January 26, 2015
X1 flare 20140329 – Timeline

GOES X-ray

IBIS, G-band, Ca K
FIRS raster
FIRS raster
FIRS raster
FIRS raster
FIRS raster
FIRS raster

Hinode Ca H and Na I
Hinode EIS
IRIS

RHESSI (daytime)

Ribbons visible in IRIS/IBIS/AIA
Filament liftoff in IRIS
Filament rising in IBIS

Start Time (29-Mar-14 16:00:00)

Loops rising, flux emergence?
Small flare, same AR

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Some background on planning...

For pointings and programs that run each day, which planner decides what when?

<table>
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<tr>
<th>Day of Observing</th>
<th>Sun</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
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<td>IRIS (Friday)</td>
<td>IRIS (Friday)</td>
<td>IRIS (Monday)</td>
<td>Hinode (Monday)</td>
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<td>IRIS (Thursday)</td>
<td>IRIS (Thursday)</td>
<td>Hinode (Sunday)</td>
<td>Hinode (Sunday)</td>
<td>IRIS (Tuesday)</td>
<td>IRIS (Tuesday)</td>
<td>IRIS (Thursday)</td>
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THESE DAYS ARE US TIME, NOT JST

Sunday: Hinode chooses programs to run on Tuesday & Wednesday
Monday: IRIS chooses pointings for Tuesday, Hinode chooses pointings for Wednesday
Tuesday: IRIS chooses programs for Thursday and Friday
Wednesday: IRIS chooses pointings for Thursday, Hinode chooses pointings for Friday
Thursday: IRIS chooses programs for Saturday, Sunday, Monday
Friday: IRIS chooses pointings for Saturday, Sunday & Monday

by T. Tarbell

Note: all pointings on the disk assume solar rotation tracking; all pointings at the limb are fixed. Since Hinode is limited to tracking at most 4 targets, this will limit the possible pointings on some days, especially weekends.
Some background: IRIS

IRIS: full weekend plan
The X1 flare on 2014-03-29

Disruption to the North – probably stopped by sunspot in South

 Courtesy of N. Nitta

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Overview – SDO/AIA

Filament eruption seems to start the flare

(movies not exactly simultaneous)

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Ground based observations

bad seeing

good seeing, speckled

good seeing, speckled, destretched
Overview – IBIS Ca II 8542 core

- Speckle-reconstructed Ca II 8542 images.
- Black filament vanishes
- Flux-rope (?) untwists
Overview – 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
Filament eruption - IRIS

Si IV line at each raster position.

=> Filament is accelerating

(Kleint et al. 2014, submitted)
Filament eruption – IRIS

Acceleration starts before HXR are visible. Eruption triggering the flare? Acceleration high compared to previous observations (<1.5 km/s²)

IRIS Si IV Doppler shifts

- RHESSI corrected count rates
- 5 km/s²
- 3 km/s²
- 1 km/s²

Start Time (29-Mar-14 17:44:00)

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Continuum emission – IRIS

The whole spectrum is enhanced at some locations.

Balmer continuum.
Continuum emission – X1 flare

Get data points from IRIS, HMI and FIRS

Blackbody: best fit $T=10200$ K, but not good fit in NUV $\Rightarrow$ Balmer contribution

Input energy calculated from RHESSI (cutoff 20 keV, prelim.): $7.5 \times 10^{10}$ erg s$^{-1}$ cm$^{-2}$

Energy losses in the continuum (integral of blackbody best fit): $5.2 \times 10^{10}$ erg s$^{-1}$ cm$^{-2}$
Na I, Stokes IV shutterless

Disturbance in Stokes I => signature in Stokes V

Images reconstructed by Zoe Frank

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Very low signals!

Total linear polarization:
total(sqrt(Q^2.+U^2.))

Total circular polarization:
total(abs(V))
Could one have predicted the flare?

Maybe...

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?
Conclusions

• Flare precursors:
  - Opposite flows in photosphere
  - Filament becoming unstable (increasing Doppler shifts)

• Must predict location within ~10” one day in advance for IRIS to catch the flare (~50” for Hinode)

• March 29 flare: Very high acceleration (3-5 km/s$^2$) compared to previous observations (~<1.5 km/s$^2$). Chromospheric polarization.

• Data available from NSO, IRIS, SDO, Hinode, RHESSI, STEREO – interesting science to be done!

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