What IRIS is telling us about chromospheric evaporation

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IRIS - key features

- Launched June 2013
- Slit spectrograph with slitjaw camera
- Spatial resolution: 0.32 arcsec

- Far-UV (1330-1406 Å) and Near-UV (2790-2830 Å) spectral coverage
- Sees mainly chromospheric and transition region lines
- In flares: Fe XXI λ1354.1 (formed at 10 MK)

- Already 31 flare papers from IRIS
- Famous flares:
  - 29-Mar-2014 17:45 UT (8 papers)
  - 10-Sep-2014 17:47 UT (7 papers)

[Also: 12-Mar-2015 11:50 UT]
Heating-evaporation scenario

1. Coronal heating source
2. Non-thermal electrons descend loop legs
3. Electrons heat chromosphere
4. Heating drives hot evaporation flow up loop
5. Hot, dense post-flare loops form
Chromospheric evaporation

10-Sep-2014
X-flare

H. Tian et al.
Fe XXI 1354 at ribbon sites

29-Mar–2014 X-flare
29-Mar-2014 flare

- Fine structure of Fe XXI at ribbon sites
- Complex behavior:

Exposure number (E) corresponds to different locations along flare ribbons

North ribbon

South ribbon

Timing of Fe XXI

- Five papers have found a delay in appearance of Fe XXI at ribbon site

For a given spatial location there is a delay between Mg II and Fe XXI emission

Delay is about 60 seconds

Sadykov et al. (2016, arXiv)

10-Sep-2014 X-flare

Figure 3. Mg II intensity spacetime map (inverted B/W color table) with overlays of Mg II downflows at the 20% bisector level at 15 and 30 km s⁻¹ (red contours). The Fe XXI upflow velocities above 270, 200, and 100 km s⁻¹ are indicated with yellow, dark blue, and light blue crosses, respectively.
Change of blueshift with time

- At a given location, Fe XXI velocity decreases with time


10-Sep-2014 X-flare
Continuum emission

Battaglia et al. (2015) studied IRIS and RHESSI emission for 29-Mar-2014 flare
- Confirmed that continuum emission is co-temporal and co-spatial with HXRs
- Fe XXI blueshifts often delayed
- Fe XXI blueshifts can occur at locations with no HXRs
Continuum emission

- The NUV continuum represents heated *chromosphere* (not photosphere)

29-Mar-2014 X-flare
Continuum image at 2832 Å (NUV)

NUV continuum enhancement is mostly due to hydrogen (Balmer)

Model includes Balmer continuum contributions
Slipping reconnection

• The 10-Sep-2014 flare demonstrated clear “slipping motion” of loop footpoints

Slipping reconnection

- Knots of emission pass by the IRIS slit at speeds of 110 km/s, slowing to 20 km/s
- The knots show downflows of up to 50 km/s

Flare loops in Fe XXI

- IRIS is first instrument to see 10 MK plasma at sub-arcsecond resolution
- Flare loops are seen with a width of \( \approx 1 \) arcsec

Flare loop oscillation

- Tian et al. (2016, arXiv) have reported first oscillation seen with Fe XXI
- Identified as global sausage mode

12-Mar-2015 M2 flare
Summary

• IRIS has proven to be an excellent flare observatory
  - High spatial and spectral resolution
  - Combination of hot (Fe XXI) and cool emission lines

• Key results
  - Fe XXI evaporation results (velocities, timing)
  - Dynamics of ribbon evolution at high resolution
  - Flare loops (sizes, oscillations)

• Data provide stringent tests for 1D flare loop models
  - see session later today

• Many flares still not studied
  - see http://iris.lmsal.com/documents.html for a list