EUV Spectroscopy of solar flares observed by EIS/HINODE and IRIS

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Outline

- Background: Solar flares & EUV spectroscopy

- Two events observed by IRIS & Hinode/EIS:
  - 9\textsuperscript{th} March 2012
  - 3\textsuperscript{rd} February 2014

- Conclusions
EUV spectroscopy of solar flares

“Flare”: sudden brightening in the solar atmosphere

Spectral signatures of chromospheric evaporation are velocity blueshifts in high temperature emission lines (Doschek (1980), Antonucci (1982))

TO INVESTIGATE THE NATURE OF SOLAR FLARES:

- Determine local plasma dynamics (flows) and parameters (density, temperature, emission measure, abundances, etc.) as a function of space and time, which can then be compared with theoretical models.

→ NEED HIGH RESOLUTION EUV SPECTROSCOPY
Hinode/EIS (The EUV Imager Spectrometer)

- Two wavelength bands:
  - 170-210 Å (SW)
  - 250-290 Å (LW)
- Spectral resolution ~ 0.06 Å
- Spatial resolution ~ 3”

A JAXA/NASA/USA/UK project

- Transition region to coronal temperatures lines (0.05 MK < $T_{max}$ < 4 MK)
- Flare lines ($T_{max}$ > 4MK), especially Fe XXIII 263 Å (10 MK)
- Density diagnostic lines (such as FeXII $\lambda$196/$\lambda$195, FeXIV ratios, SiX $\lambda$258/$\lambda$261)
IRIS (Interface Region Imaging Spectrograph)

- FOV 175”X175”
- 1330 Å, 1400 Å, 2796 Å, 2832 Å
- Bandwidth 55 Å/4 Å

IRIS Slit Jaw Imager (SJI)
- Three wavelength passbands:
  - FUV1 (1331.56-1358.40 Å)
  - FUV2 (1390-1406.79 Å)
  - NUV (2782.56-2833.89 Å)
- Spectral resolution ~ 0.026/0.053 Å
- Spatial resolution ~ 0.33”/0.4”

IRIS Spectrograph (SG)
- Chromospheric (Mg h &k, OI 1355 Å) and transition region lines (SiIV, OIV doublets, CI 1356 Å)
- One coronal (Fe XII 1349 Å, 1.5MK) and one flare line (Fe XXI 1354 Å, 10MK)
- Density diagnostics (OIV doublets)

A NASA project

Chromospheric (Mg h &k, OI 1355 Å) and transition region lines (SiIV, OIV doublets, CI 1356 Å)

One coronal (Fe XII 1349 Å, 1.5MK) and one flare line (Fe XXI 1354 Å, 10MK)

Density diagnostics (OIV doublets)

Has been observed before (Skylab, SMM, SUMER) but at lower resolution
9th March 2012 observation

- 4 recurrent flares, from class C1 to M6.8 (from 00:37 UT to 03:24 UT).
- The last M6 flare was associated with a filament eruption (Doschek et al. 2012).
- The first three (C-class) flares were all confined.
Footpoints observation: FeXXIII 263 Å (10 MK), FeXVI 262 Å (3 MK), Fe XIV 264 & 274 Å (2 MK) - Flare C4.7

Blue asymmetry (~90 km/s) from one of the footpoints.

K1 & K2 – footpoints
LT - Loop Top

Fe XIV λ264/λ274
- Good density diagnostic ratio
  - The λ264 is not blended
  - The λ274 can be de-blended from Si VII λ274.18 using the ratio λ274/λ275
The density of the upflowing plasma increases more than an order of magnitude from the pre-flare average density value (~ 5\times10^9 cm^{-3})
**3rd February 2014 C6.5 flare**

- Difficult to find co-spatial and co-temporal spectroscopic observations of solar flares! (small fields of view, scanning in opposite directions!)

- IRIS SJI and SDO/AIA used as context images

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*Polito, Reeves, Del Zanna, Golub, Mason, 2014 in prep.*
The FeXXI (10MK) emission progressively moves from the northern ribbon towards the loop top.

EIS FeXXIII and FeXXIV (10MK) emissions are co-spatial with IRIS FeXXI.
Measuring hot (10MK) plasma upflows: Fe XXI blueshifts

- In the early phase we see a **broad and totally blueshifted** FeXXI emission. The velocity and non-thermal width of this emission decreases with time.

- Towards the peak of the flare, we see an **increase of the rest component** coming from the flare loops as they fill.
Conclusions

- High resolution spectrometers such as IRIS and EIS provide useful tools to study the nature of flares and flare-related events.

FURTHER WORK WILL INVOLVE...

- Looking for more joint observations (IRIS, EIS, SDO, RHESSI,..) to obtain a broad wavelength coverage.

- Comparison with 1D hydrodynamic models which simulate the plasma response to different heating mechanisms (HYDRAD, RADYN..).

- Magnetic field extrapolation also provides important information (heating source and conversion of energy).

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Thank you for your attention!