

2012 US-Japan Workshop on Magnetic Reconnection
@ Princeton University, 23-25 May 2012

***Hinode observations of microflares
and plasma ejections in the solar
~~chromosphere and corona~~***

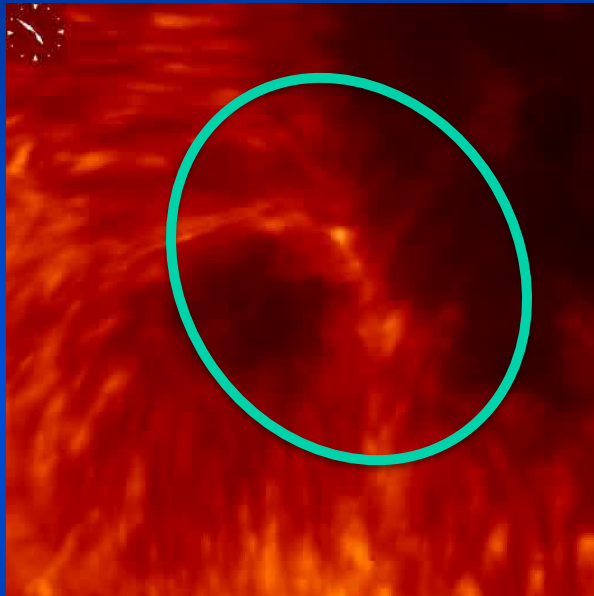
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(ISAS/JAXA)**

Topics of this talk

- In the solar atmosphere, magnetic reconnection takes place in two different plasma layers:
 - Corona – fully ionized, collisionless plasma
 - Chromosphere – weakly ionized, collisional plasma
- How does the magnetic reconnection release the magnetic energy, **heat up the plasma and generate hot (>1MK) coronal plasma?**
- From viewpoints of observations, a variety of heating signatures exist.
 - Observed only in chromospheric data.
 - Observed not only in chromosphere but also in coronal data.
 - A variety of heating events in coronal data.
 - **What makes a large variety of heating signatures?**

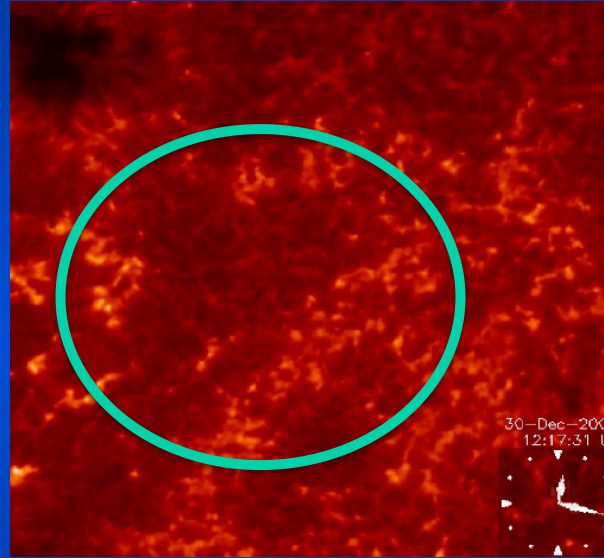
Two different heating & ejections with similar magnetic configuration

Intermittent & recurrent chromospheric ejections in sunspot light bridge

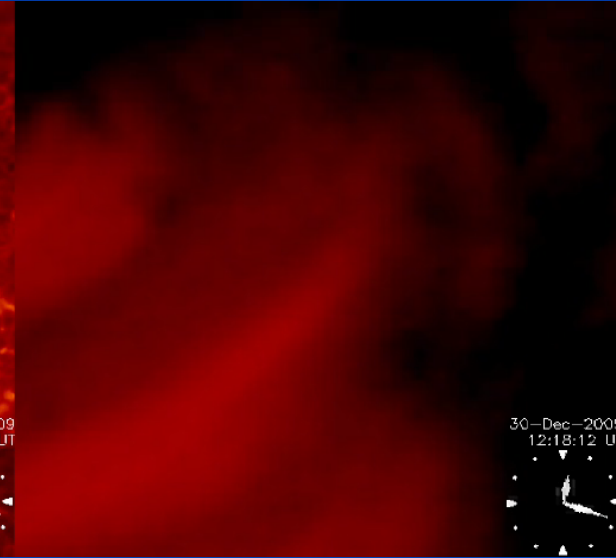


Hinode SOT Ca II H

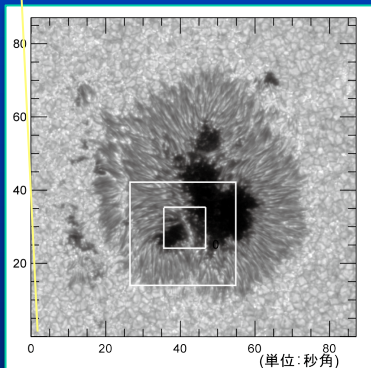
Chromospheric ejections and coronal microflaring in the elongated structure appeared during sunspot formation



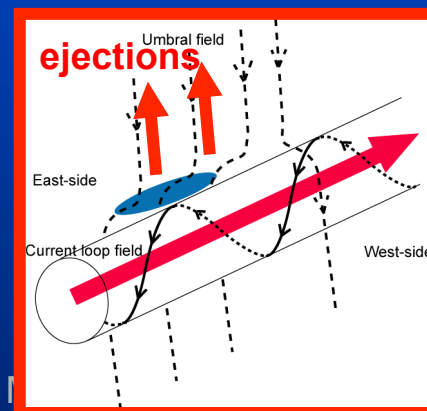
Chromosphere: Ca II H



Corona: soft X-ray
(Shimizu, Ichimoto & Suematsu 2012, ApJL 747, L18)



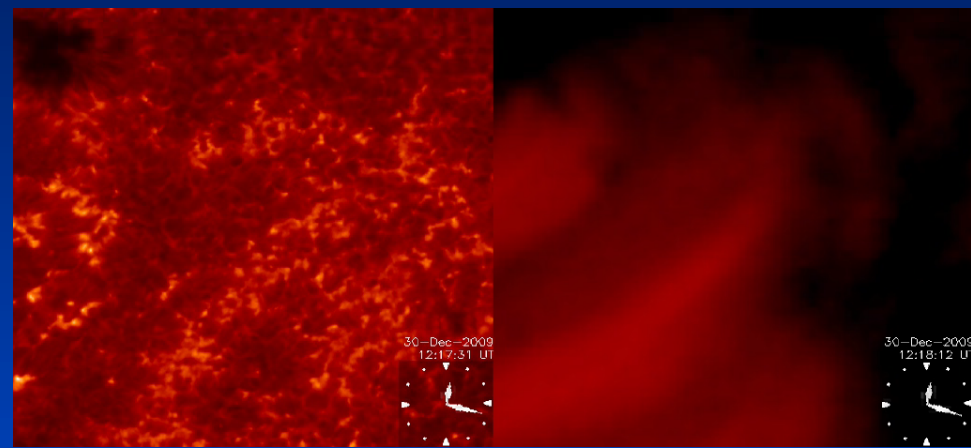
No coronal counterparts observed



Helical flux loops in umbral fields “component MR”

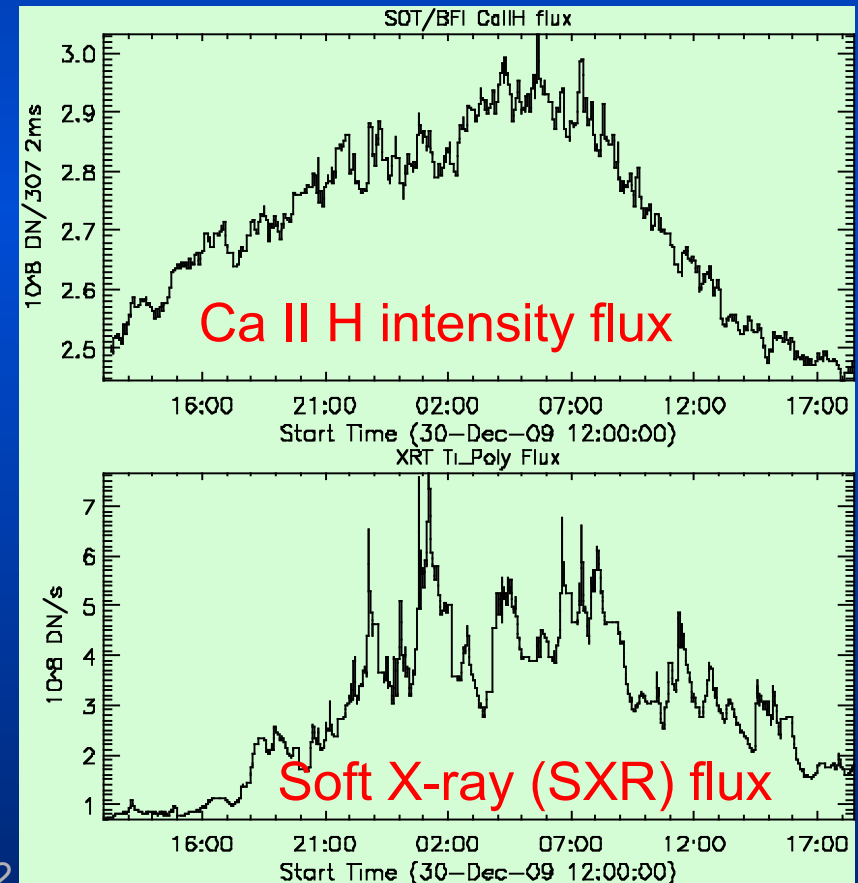
Temporal evolution of intensities

- More transient nature in soft X-ray coronal flux, compared to in Ca II H data.
- The both intensity is gradually increased after starting the emergence (~16UT on 30 Dec). Then the intensity is gradually decreased with relaxing the magnetic complex in the leading sunspot.
- Each of spikes in the SXR plot correspond to transient brightenings (microflares). They may produce >5 MK plasma (Shimizu 1995, Yokoh).



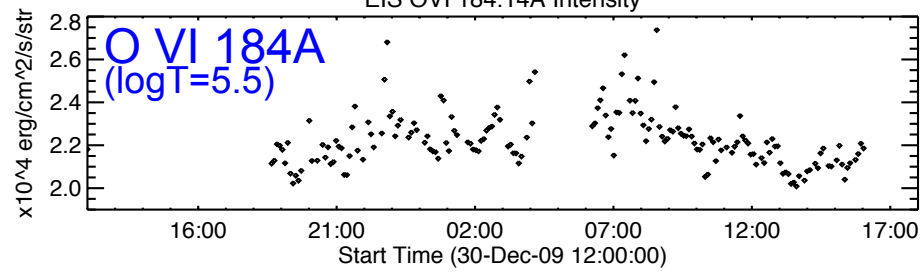
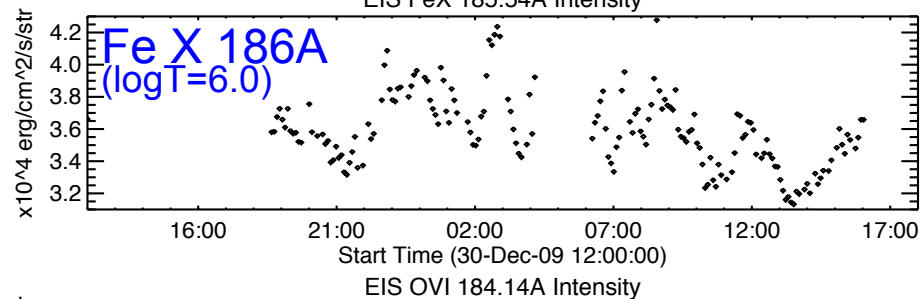
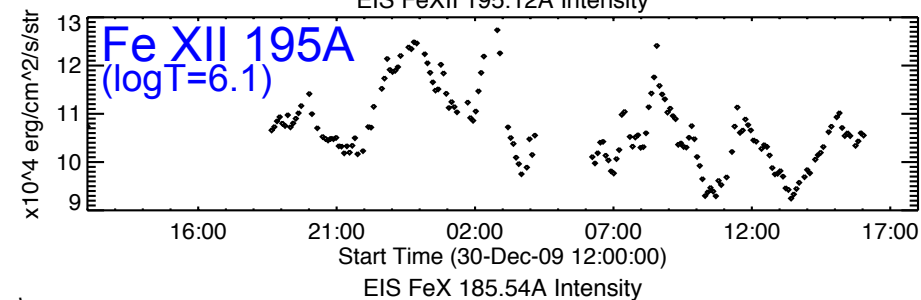
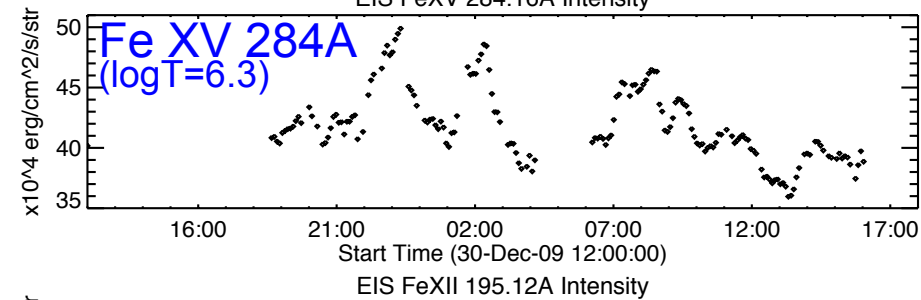
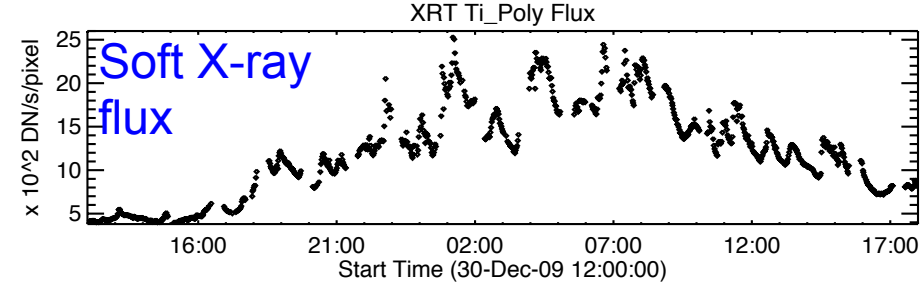
Chromosphere: Ca II H

Corona: soft X-ray

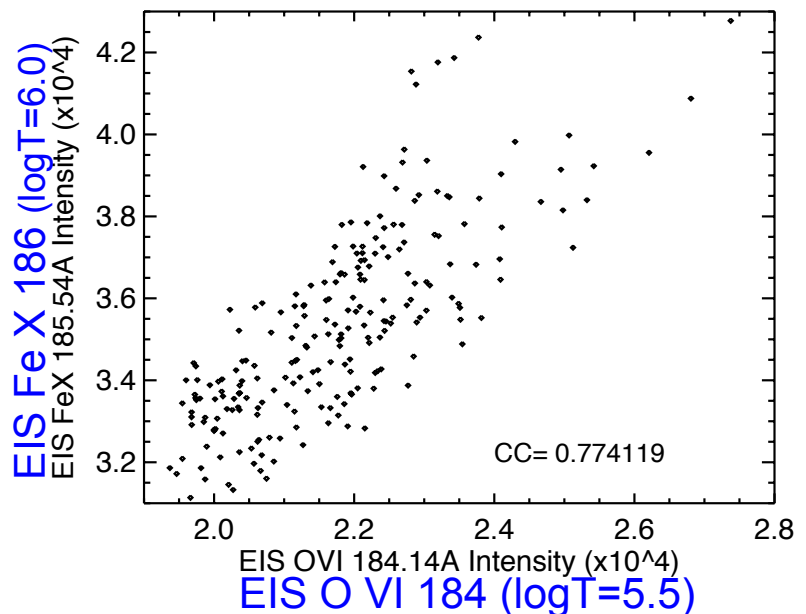
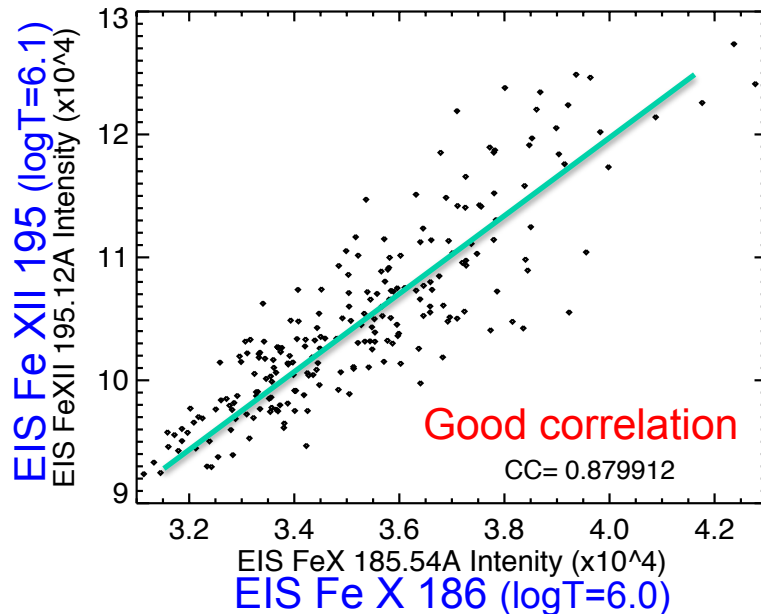
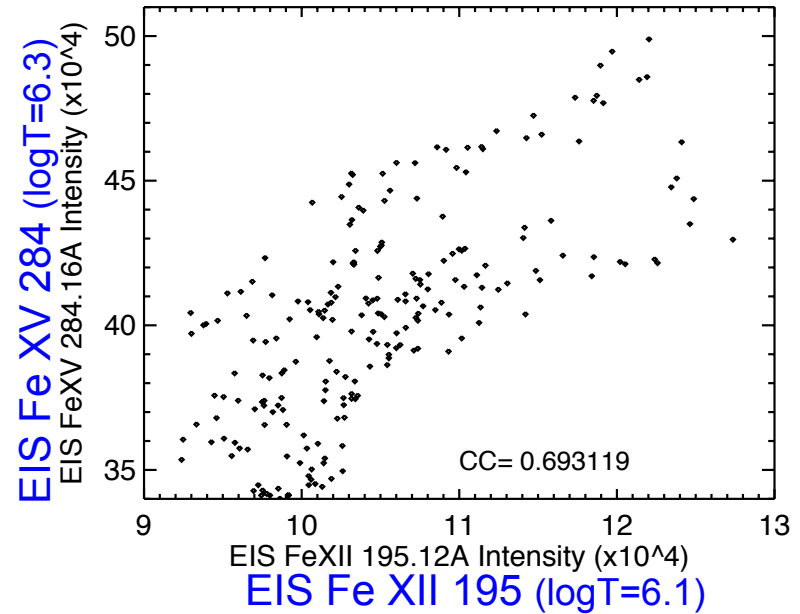
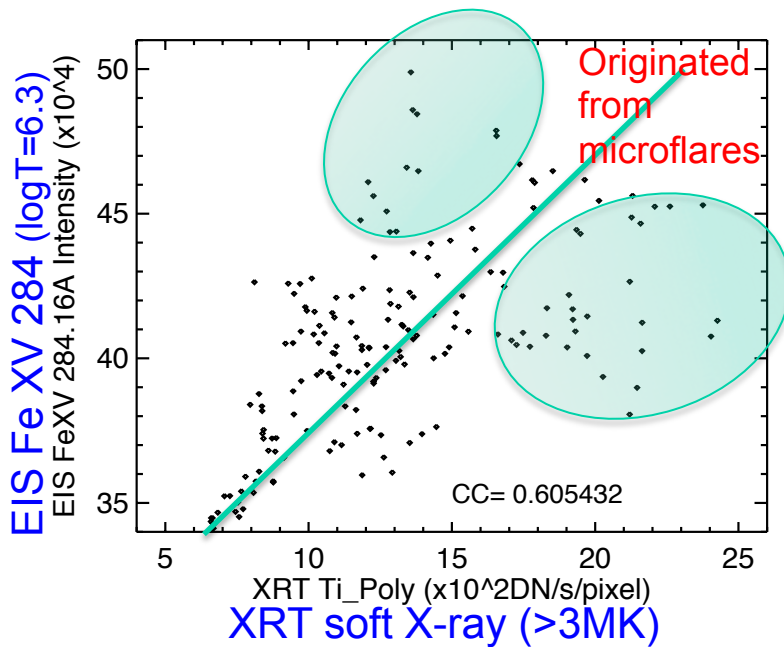


Investigate coronal plasma heated by microflares

- Intensity of EUV spectral lines from different temperature plasma (from Hinode EIS) are compared with soft X-ray flux (from Hinode XRT).
 - The intensity averaged over the emerging flux region (100" x 80") for simple analysis.
 - XRT's soft X-ray flux represents the temporal behaviors of >3 MK plasma.

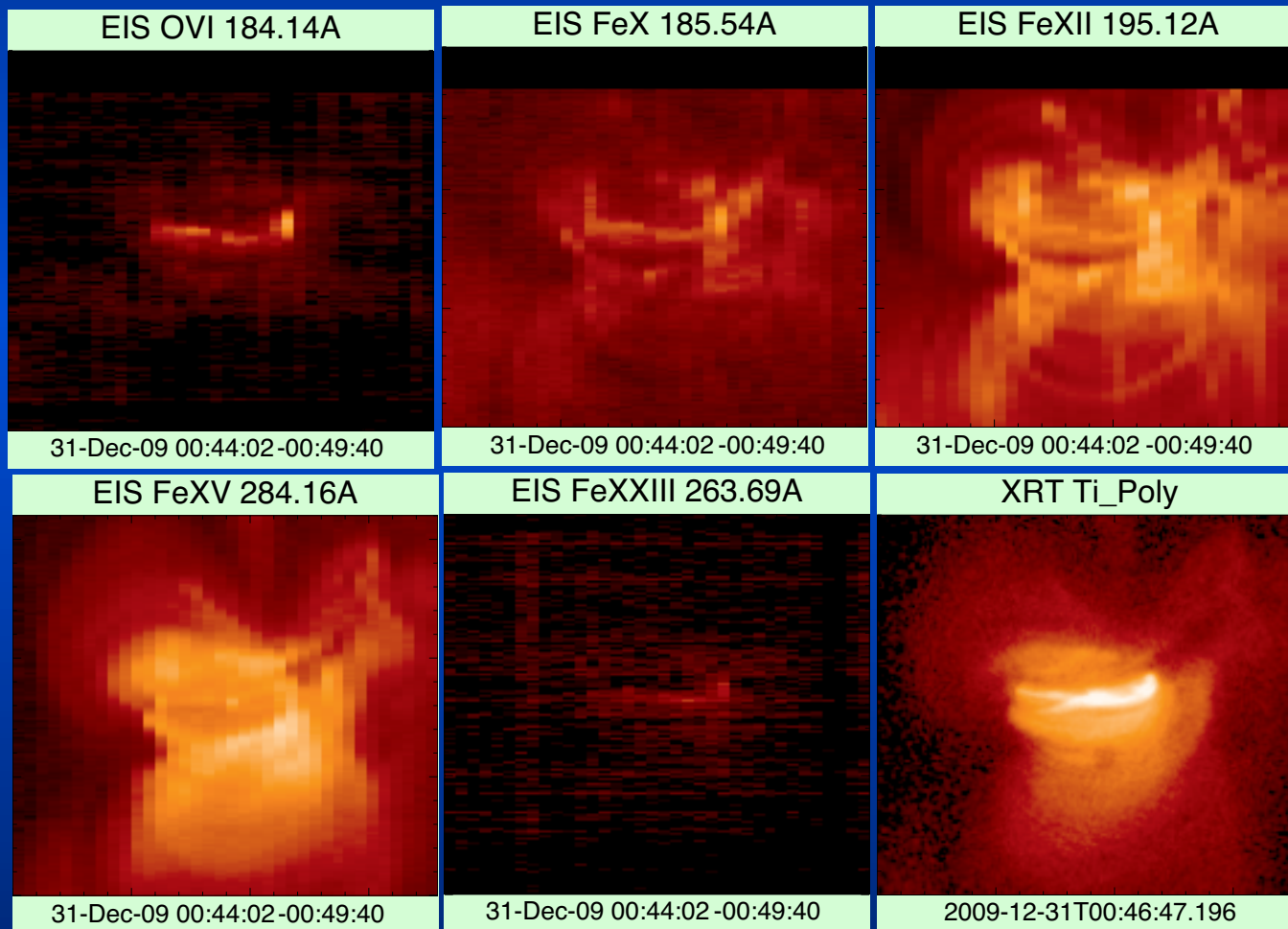


Intensity Correlation



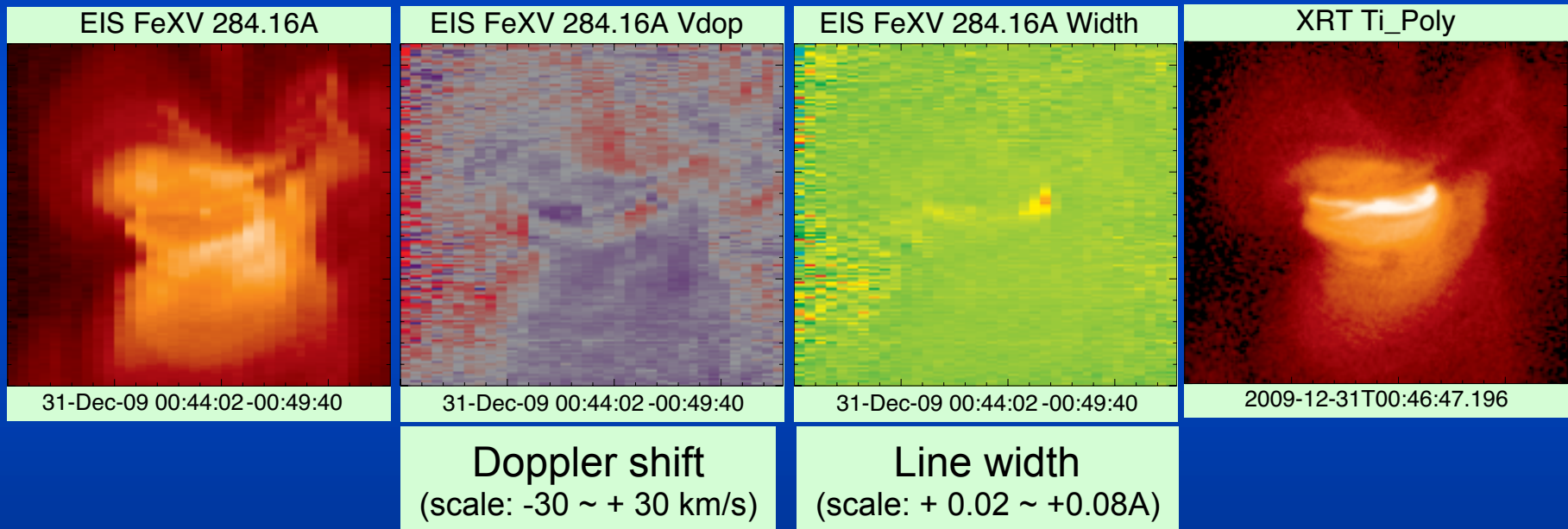
Microflare example: Intensity map comparisons (event A)

- Microflaring signals are quite different. In this case, brightening loops are bright in soft X-ray image, whereas brightening loops are **not well visible in Fe XV line**. “SXR rich & Fe XV poor” event



Dynamics near loop footpoints (Doppler shift and width)

- Brightening loops are **not well visible in Fe XV line**.
- Even in such case, Doppler shift and/or line width data show that **dynamical plasma flows are excited near the footpoints of brightening loops**, which is more related to energy release by magnetic reconnection.

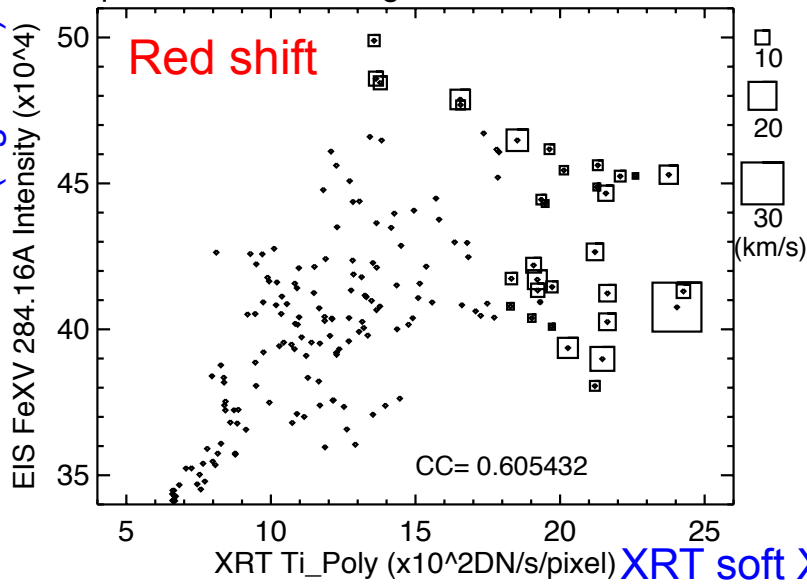


Line fitting results

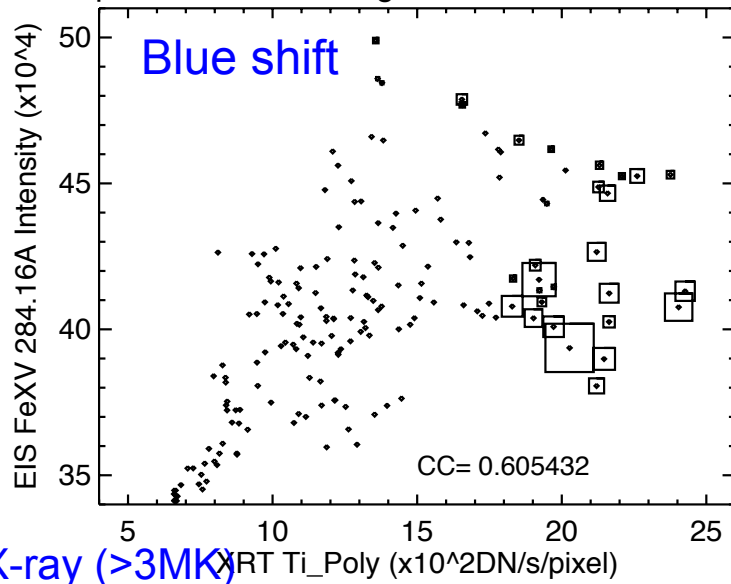
Magnitude of dynamics near loop footpoints in the FeXV-SXR correlation

EIS Fe XV 284 (logT=6.3)

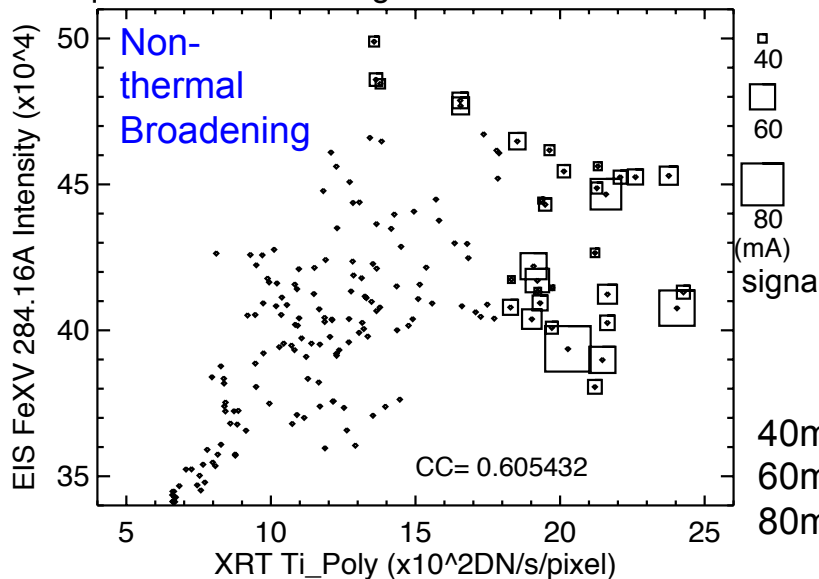
Squares - the most significant red-shift in FeXV



Squares - the most significant blue-shift in FeXV



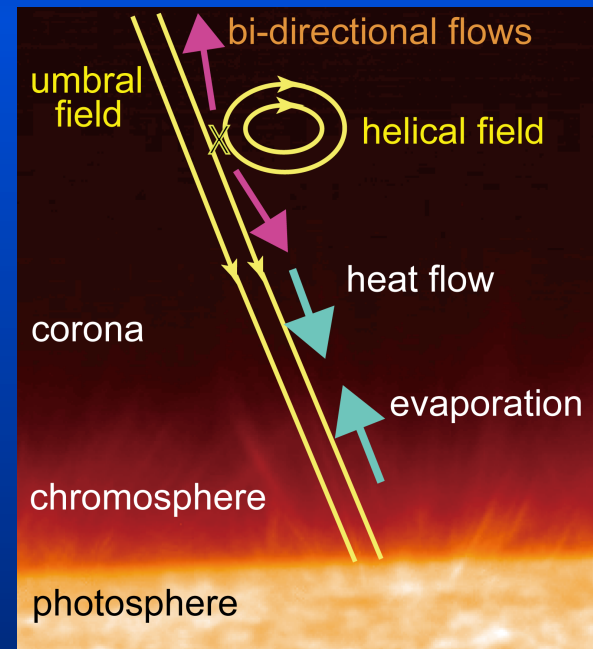
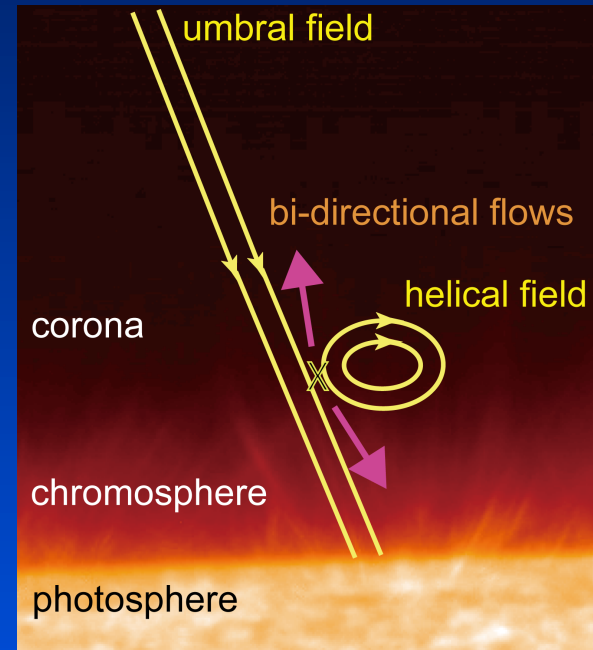
Squares - the most significant line width of FeXV



- When dynamical plasma flows (upflow, downflow, and/or non-thermal broadening) exist at the loop footpoint, hot plasma (>3MK) may be more efficiently created in the coronal loops, resulting in SXR-rich events.

Discussions

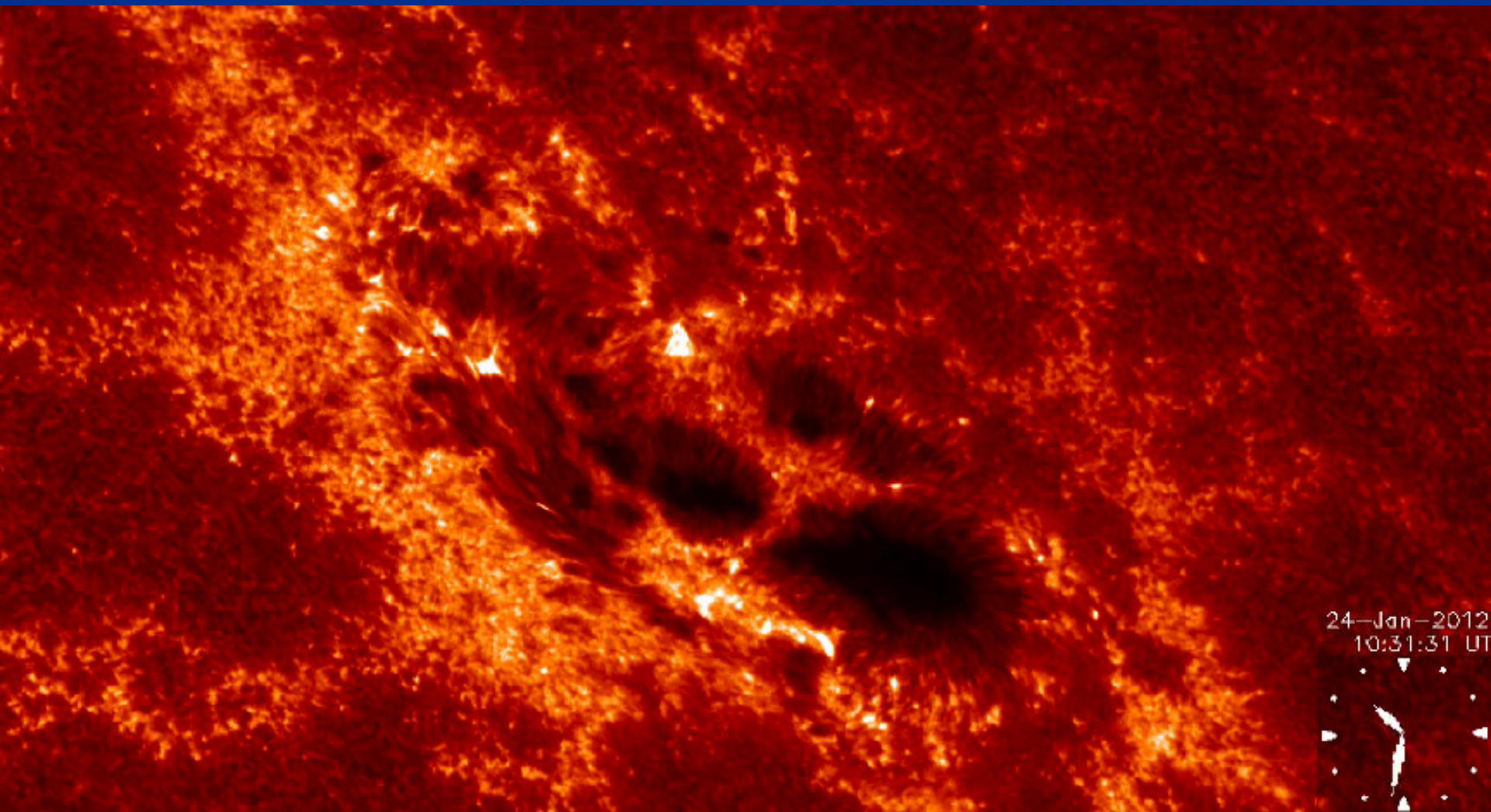
- Excitation of plasma flows (upflow, downflow, and/or non-thermal line broadening) at loop footpoint
 - Bi-directional plasma flows excited by reconnection?
 - Non-thermal line broadening may appear when both an upflow and an downflow exist simultaneously.
 - Hot plasma bulk flows are created by chromospheric evaporation. They may be observed as upflows.
 - When hot plasma is formed in the brightening loops, the strong heat conduction flows toward the chromosphere. They may be observed as downflows.
- Numerical simulations, including heat conduction and evaporation, for understanding dynamics excited at loop footpoints.



Summary

- A large variety of heating signatures by reconnection events has been observed in the solar atmosphere.
- Using coronal intensities as a function of time, we studied the behaviors of different temperatures' plasma generated by microflares (MR).
- Large deviation in the correlation between Fe XV (2MK plasma) and SXR (>3MK plasma); Two extremes exist in microflares,
 - “SXR rich & Fe XV poor” and “SXR poor & Fe XV rich”.
- Dynamics, i.e., Doppler shifts and non-thermal line broadening, are more observed in the SXR rich & Fe XV poor events.
- Whether or not dynamics is excited at loop footpoints create different nature of heated plasma.
- How does the excitation of dynamical plasma flows happen at loop footpoints with energy release by magnetic reconnection?

Recent observations: common dynamics



Hinode SOT Chromospheric Ca II H filter
AR11402, 24-25 Jan 2012, 1-day long movie