

the solar EUV spectroscopy workshop

Flare Session

Overview of the IRIS Spectroscopic Studies on Flare Processes

by Ying Li (李瑛)

followed by another two Dr. Li's own works on

Quasi-periodic slipping reconnection

by Ting Li (李婷)

&

Explosive chromospheric evaporation

by Dong Li (李东)

Beijing, China | 2017-05-10

Overview of the IRIS Spectroscopic Studies on Flare Processes

the most popular model for typical eruptive flares —
the standard solar flare model (CSHKP)

flare loops
 & two ribbons

**magnetic
 reconnection**

plasmoid
 structure

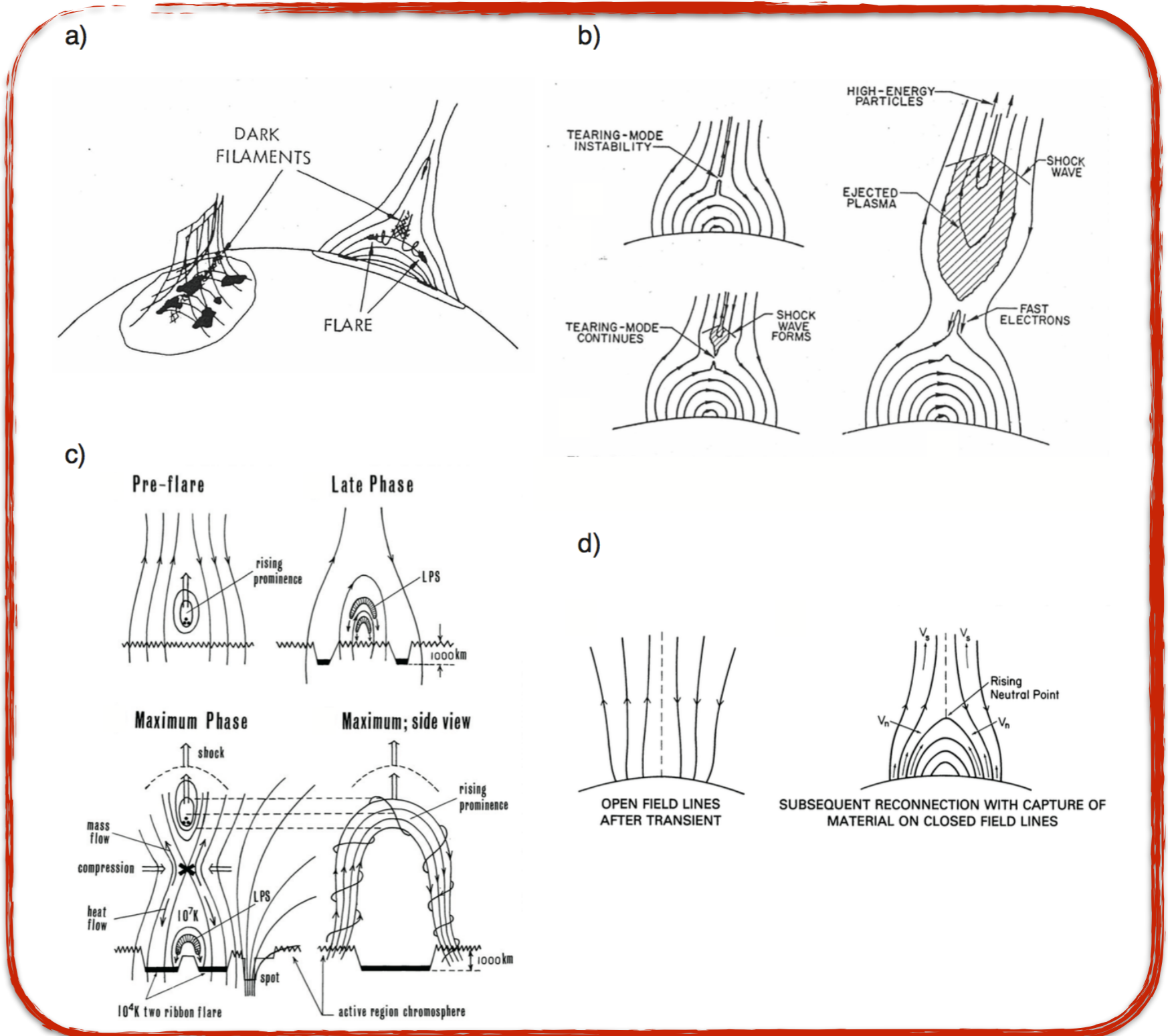
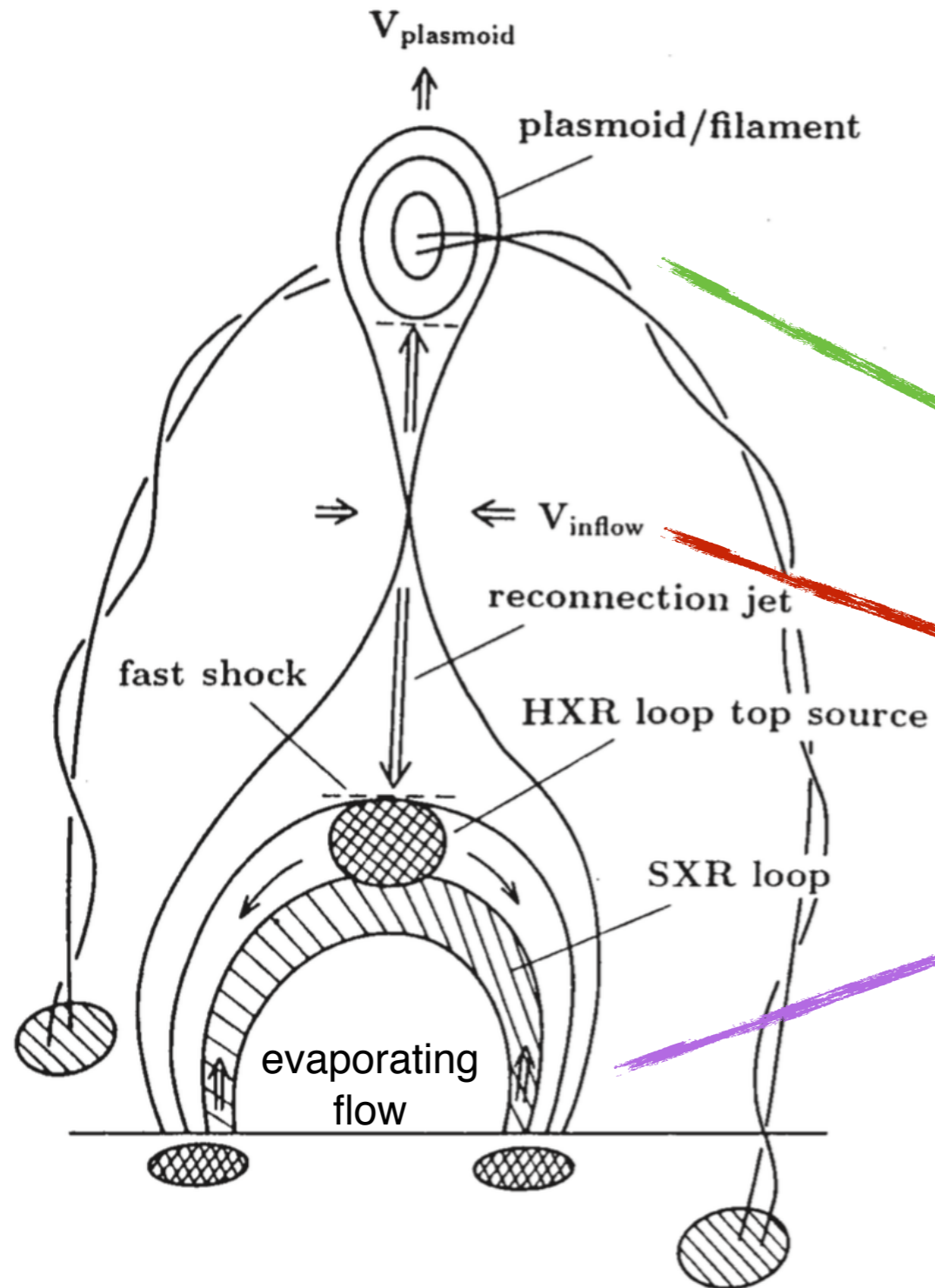


Figure 2: Phenomenological models for flares based on magnetic reconnection. Lines with arrows on them indicate magnetic field lines. (a) Carmichael (1964), (b) Sturrock (1966), (c) Hirayama (1974), (d) Kopp and Pneuman (1976).

a unified version (Shibata et al. 1995, 2011)



key dynamic processes

- filament (flux rope) eruption
- magnetic reconnection
- chromospheric evaporation

main results on flare dynamic processes from IRIS spectroscopic observations

Magnetic Reconnection

- **reconnection outflows or downflows** in the Fe XXI and Si IV lines above loop-top or in coronal loops
— Tian et al. 2014; Reeves et al. 2015; T. Li et al. 2015; Chen et al. 2016; ...

Chromospheric Evaporation

- **evaporating hot plasmas** at the flare ribbons via the Fe XXI line
- **compressed cool materials** at the ribbons via the Si IV and cooler lines
— Tian et al. 2014,2015; Graham & Cauzzi 2015; Young et al. 2015; Brosius & Daw 2015; Battaglia et al. 2015; Sadykov et al. 2015,2016; D. Li et al. 2015a,b; Brannon et al. 2015,2016; Zhang et al. 2016a,b; ...
Y. Li et al. 2015; Polito et al. 2015, 2016a; Brosius et al. 2016; ... (*EIS)

Filament Eruption & Flux Rope Related

- **filament eruption** clearly visible in the Si IV line
— Kleint et al. 2015; Chen et al. 2016; ...
- **flux rope and its formation** observed in the Fe XXI or some cooler lines in the preflare phase
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Chromospheric Evaporation

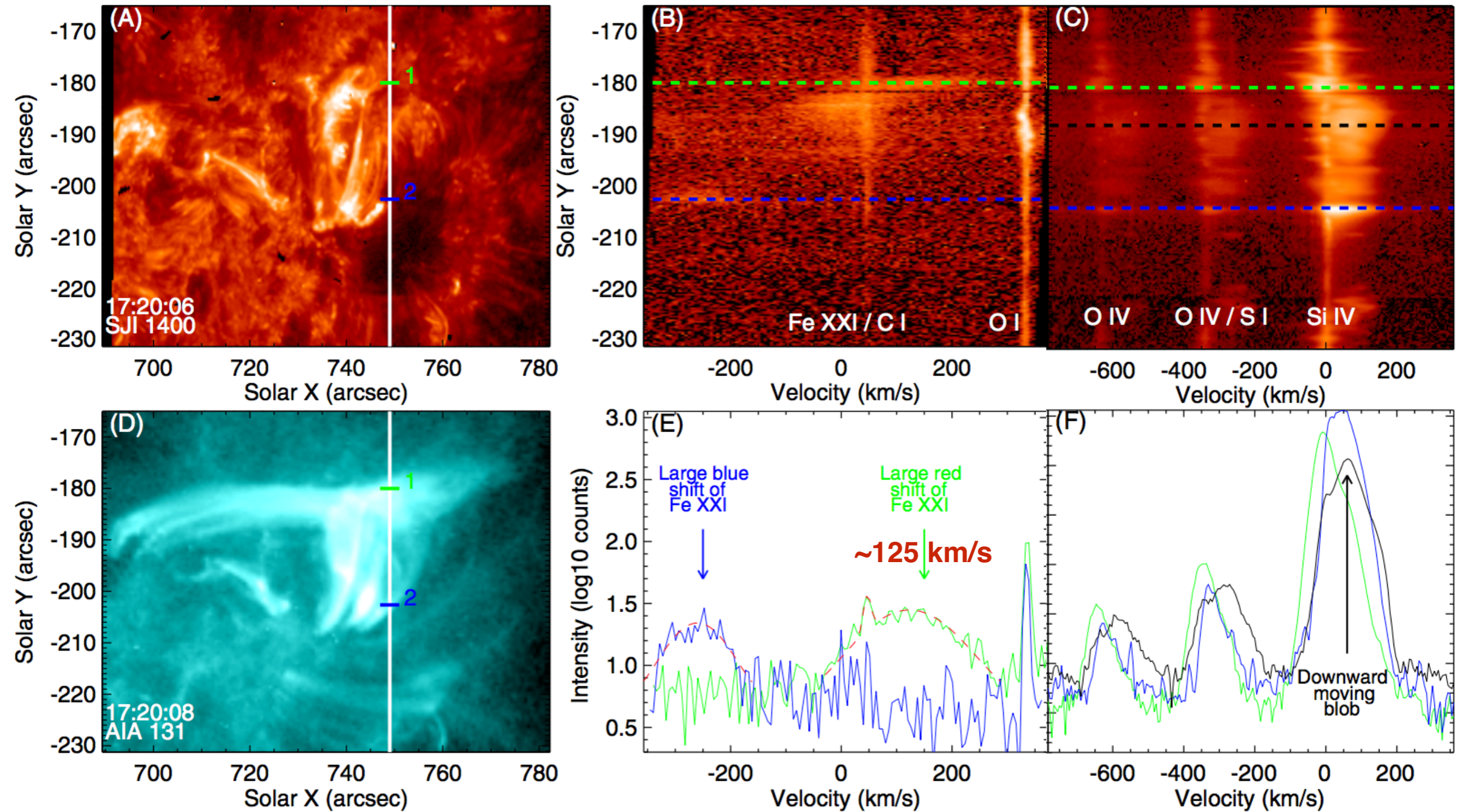
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large redshifts of hot Fe XXI in terms of downward-moving reconnection outflows

(Tian et al. 2014)

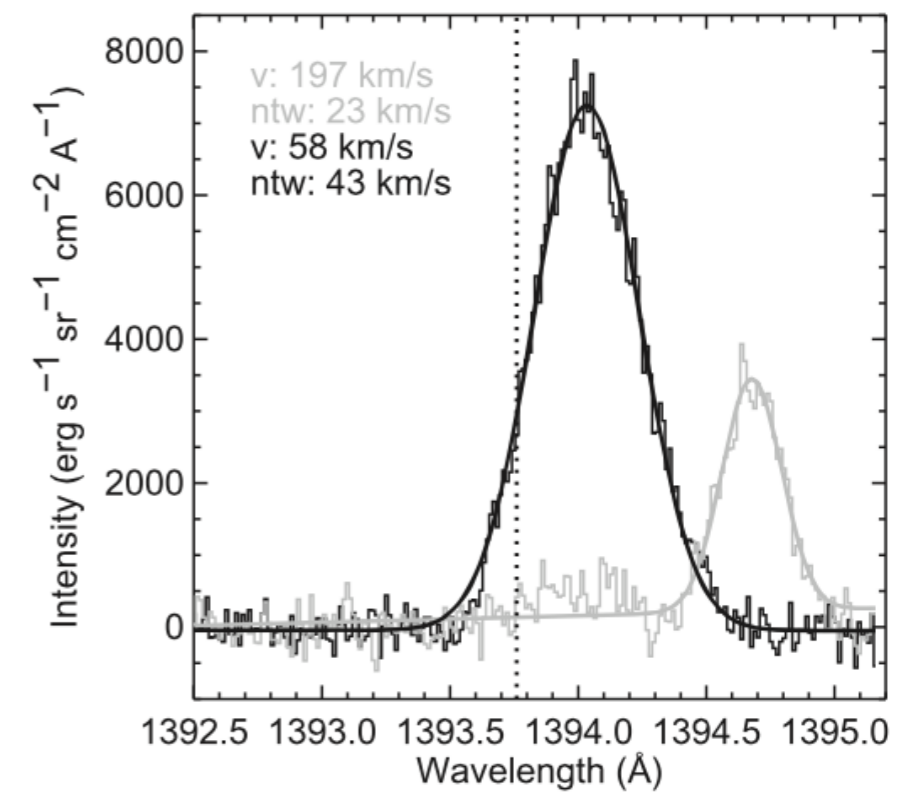
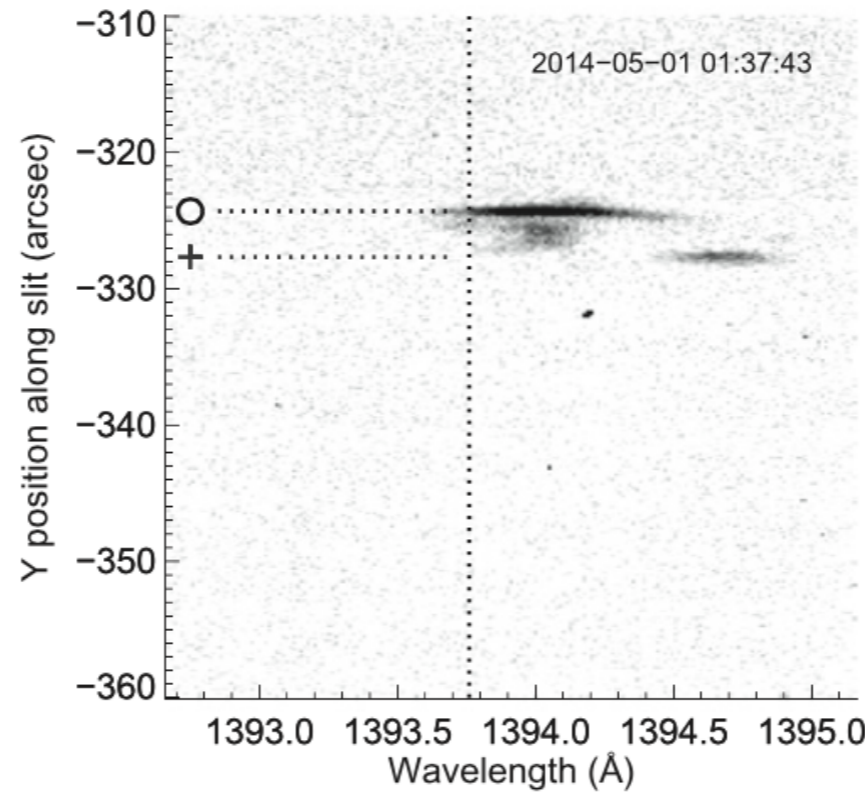
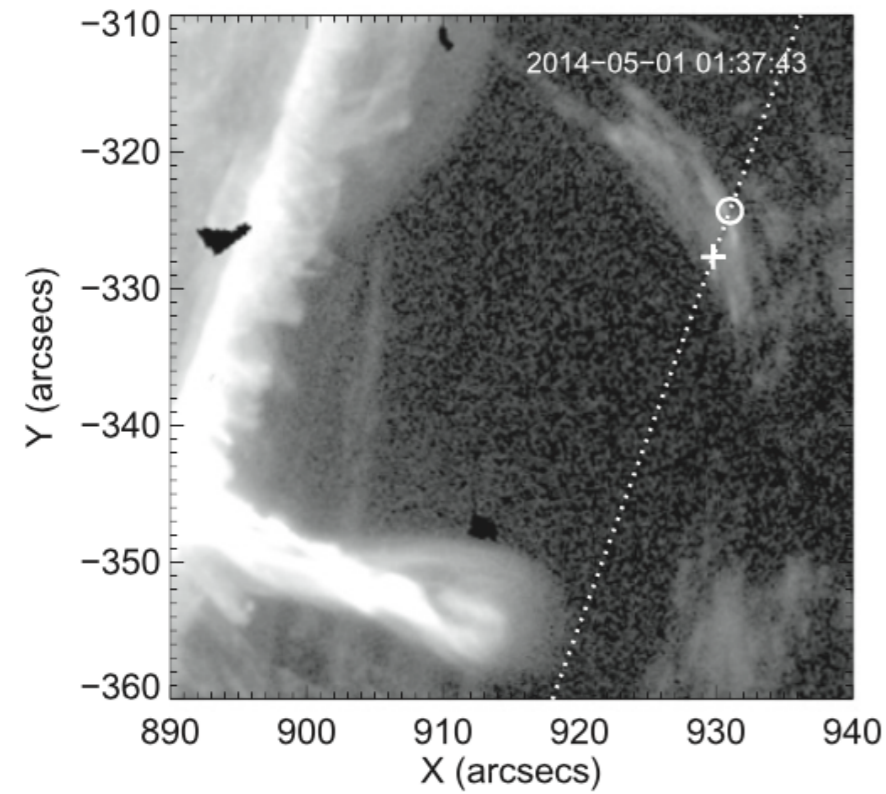


fast flows observed in IRIS Si IV & AIA

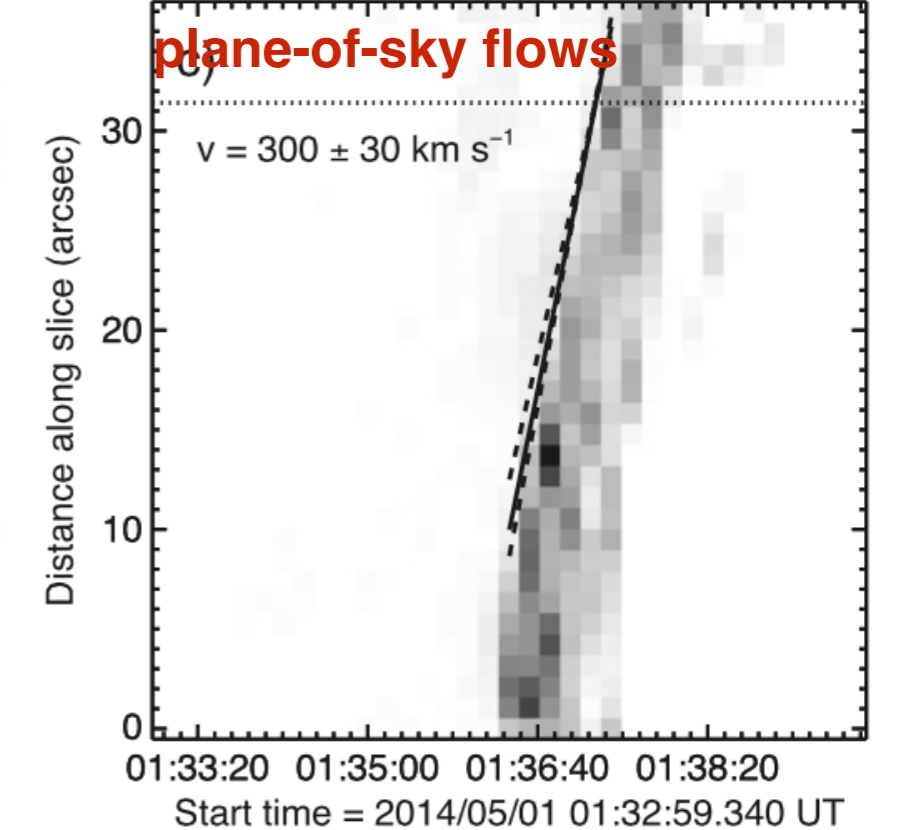
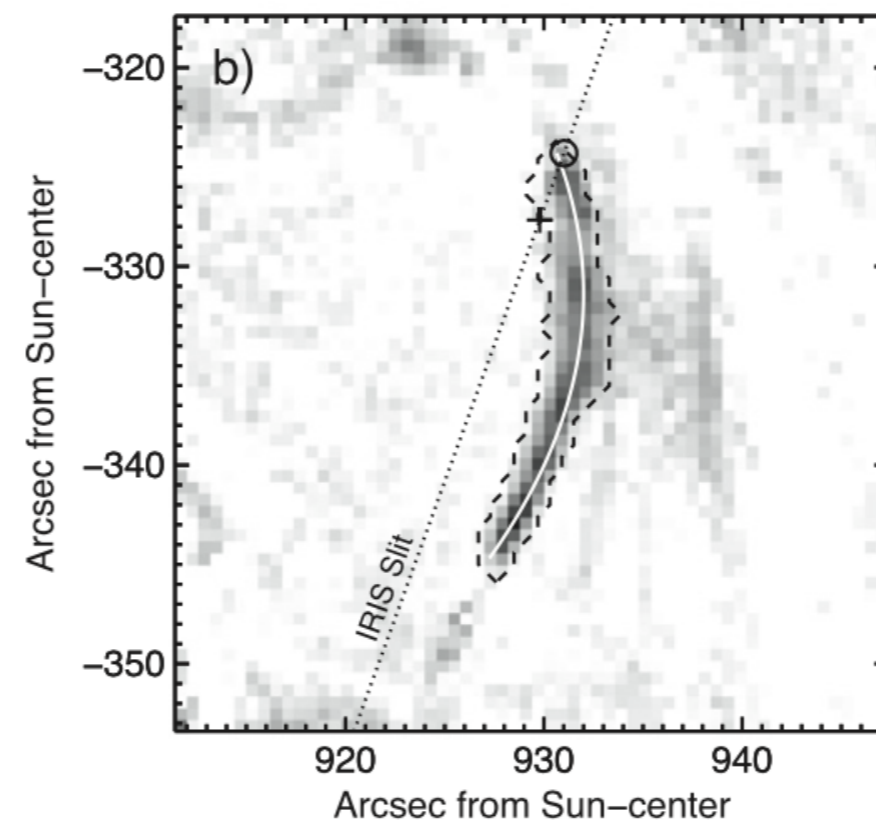
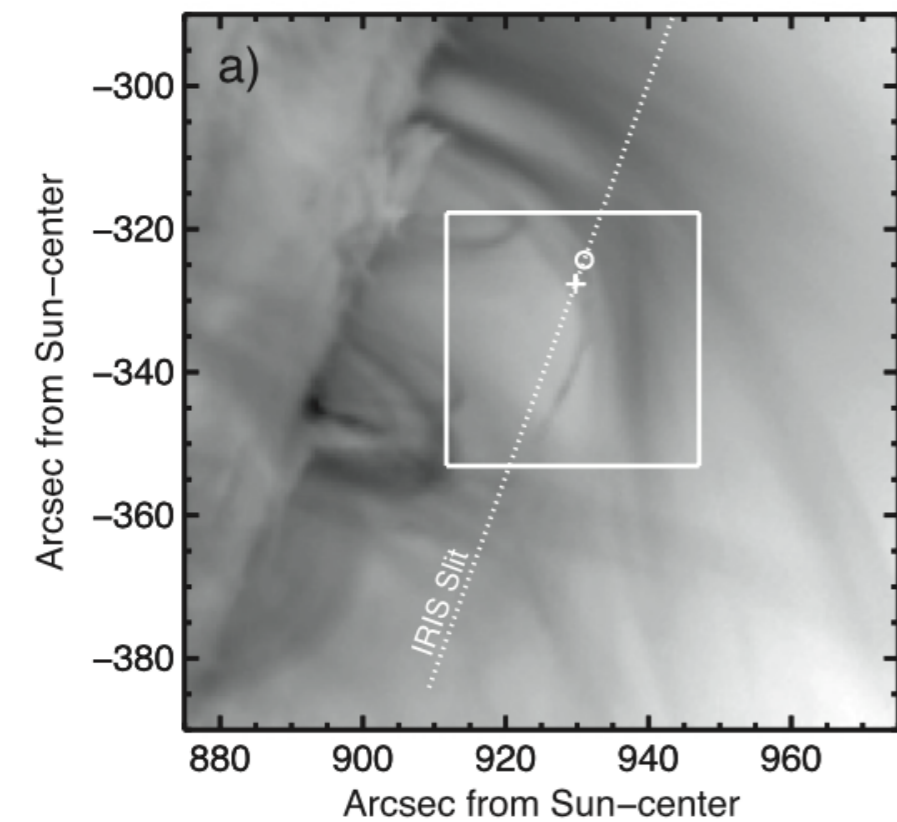
interpreted as reconnection outflows

(Reeves et al. 2015)

line-of-sight flows



plane-of-sky flows



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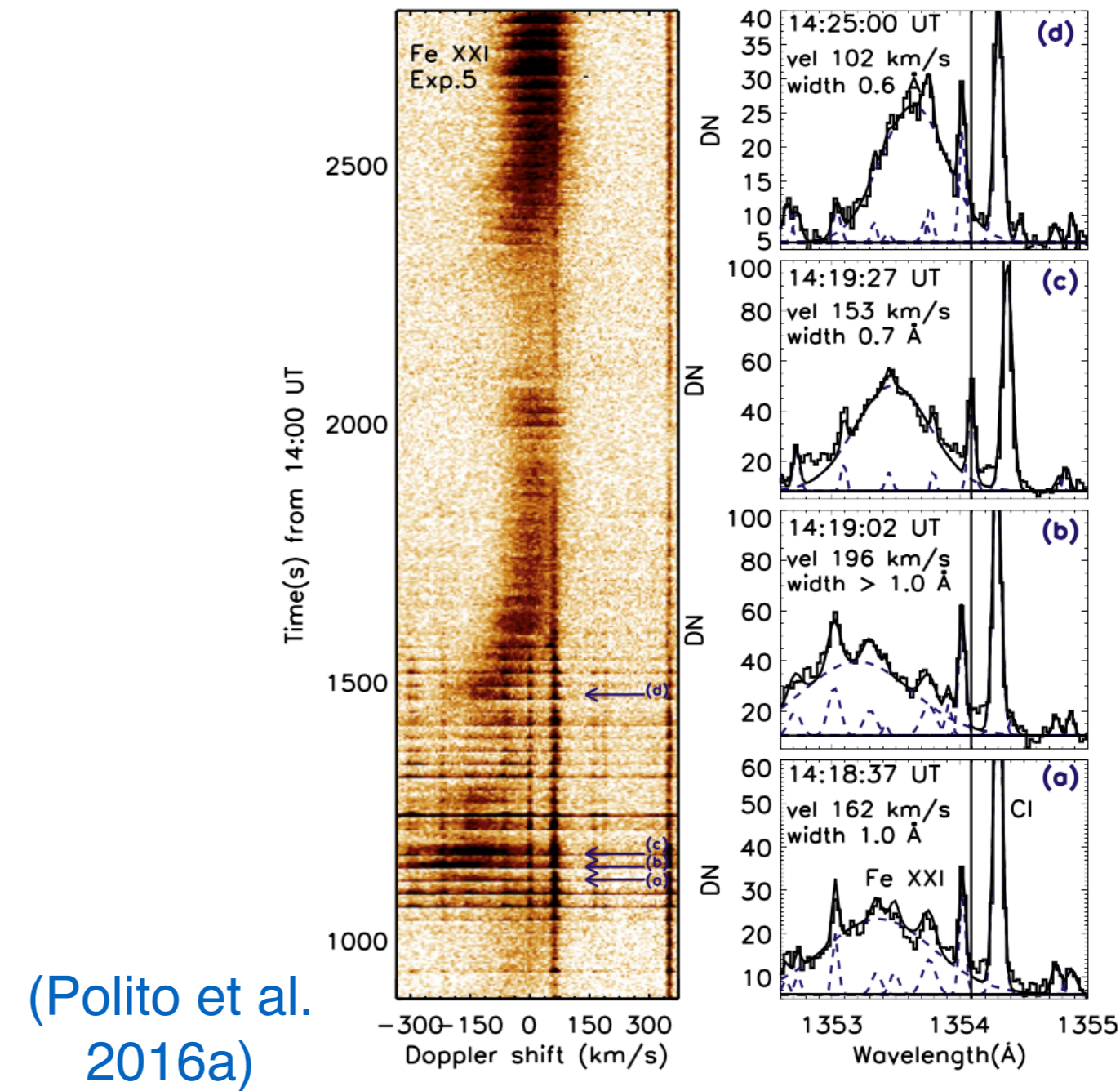
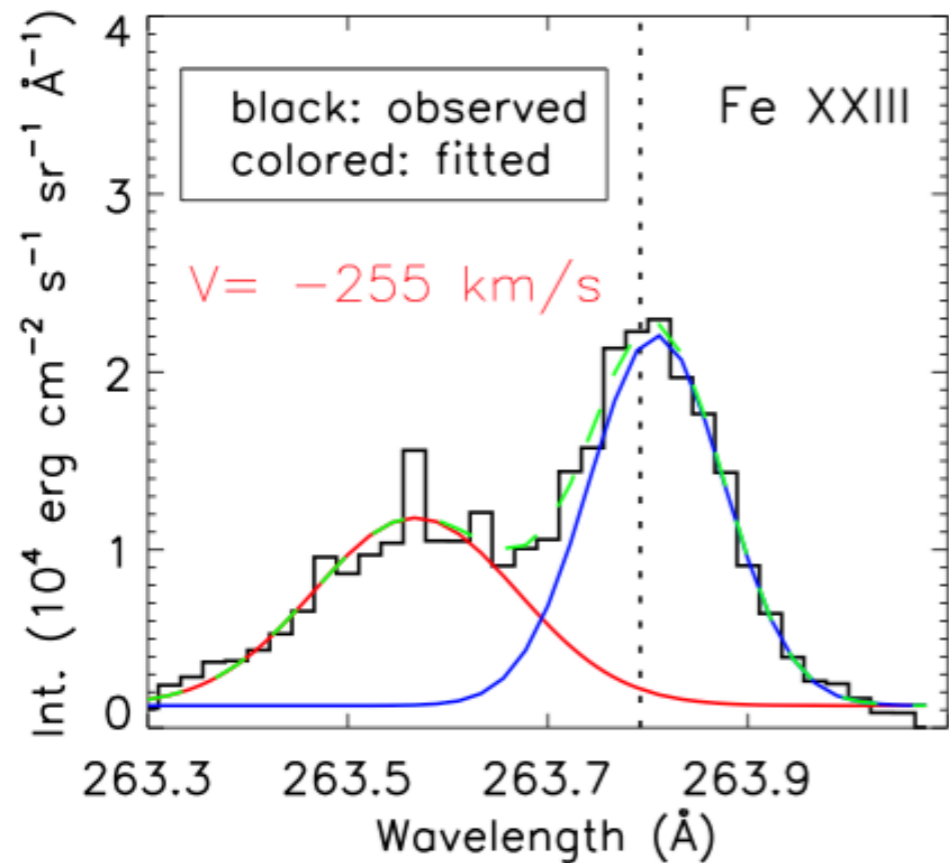
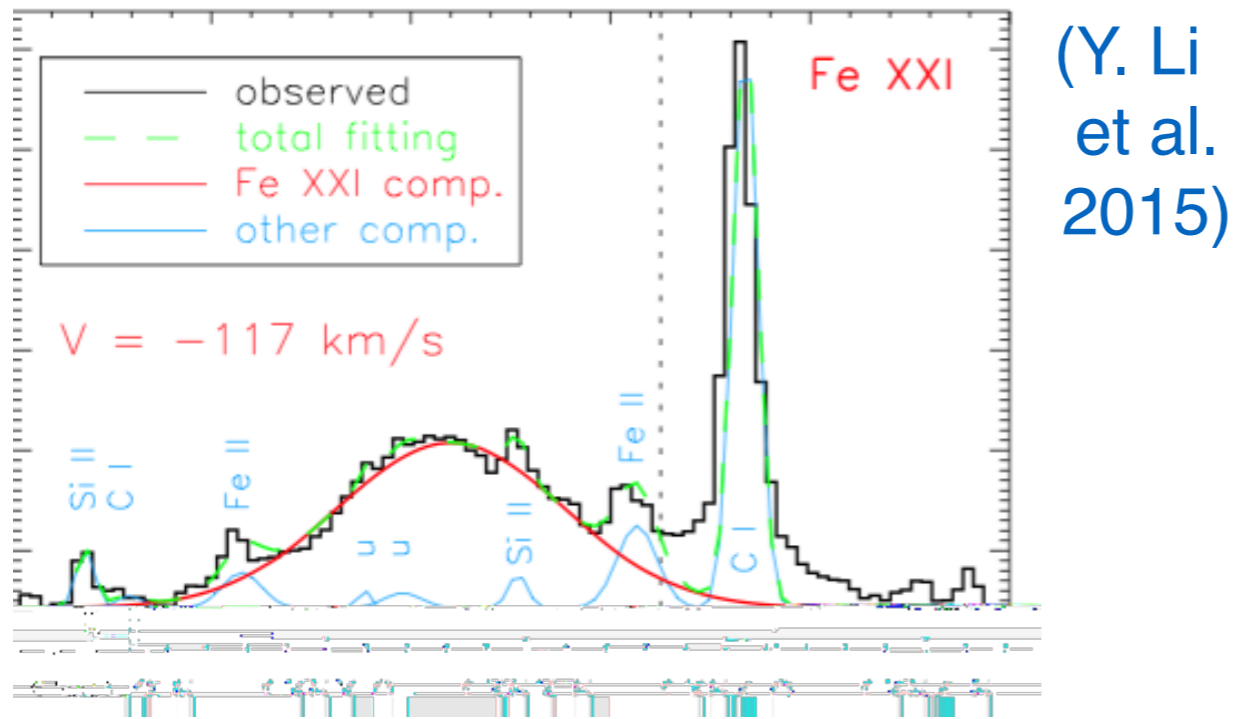
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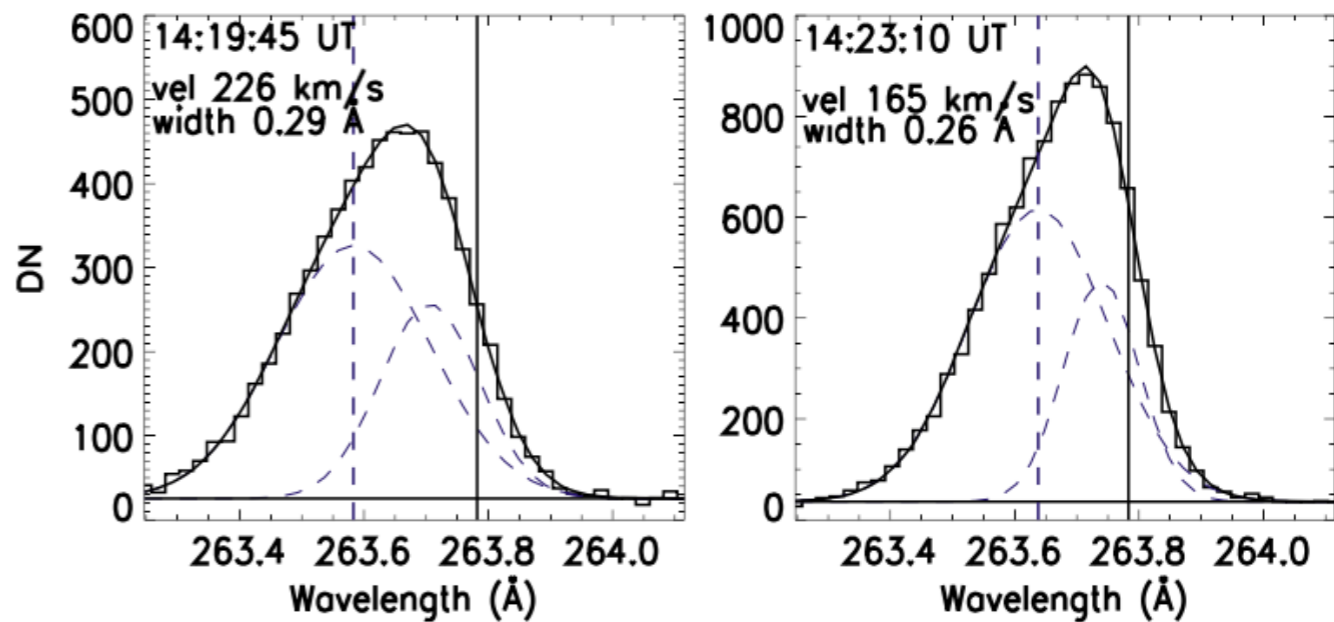
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entirely blueshifted Fe XXI line
consistent with evaporation model



(Polito et al. 2016a)

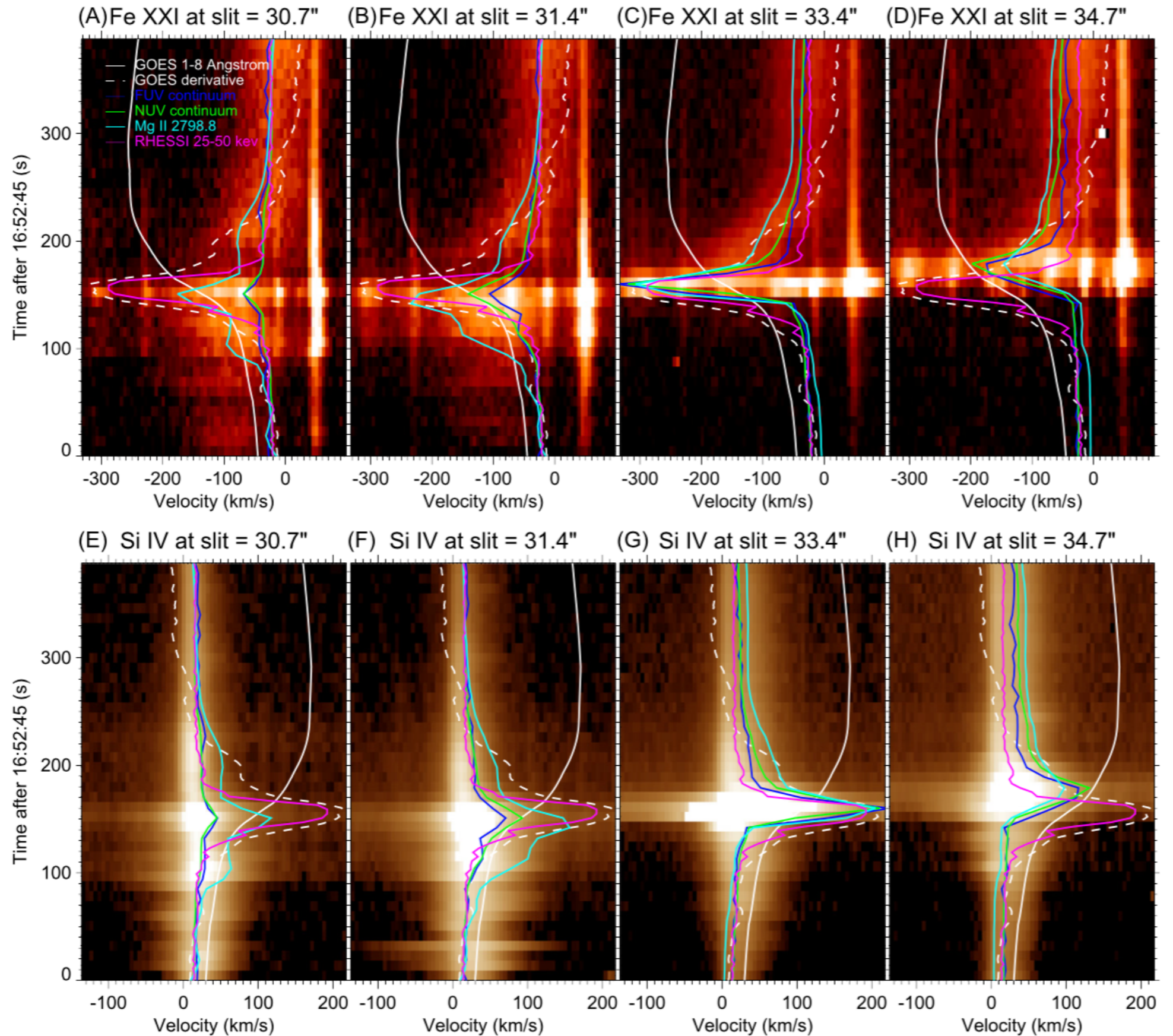


temporal evolution of evaporation

likely driven by non-thermal electrons

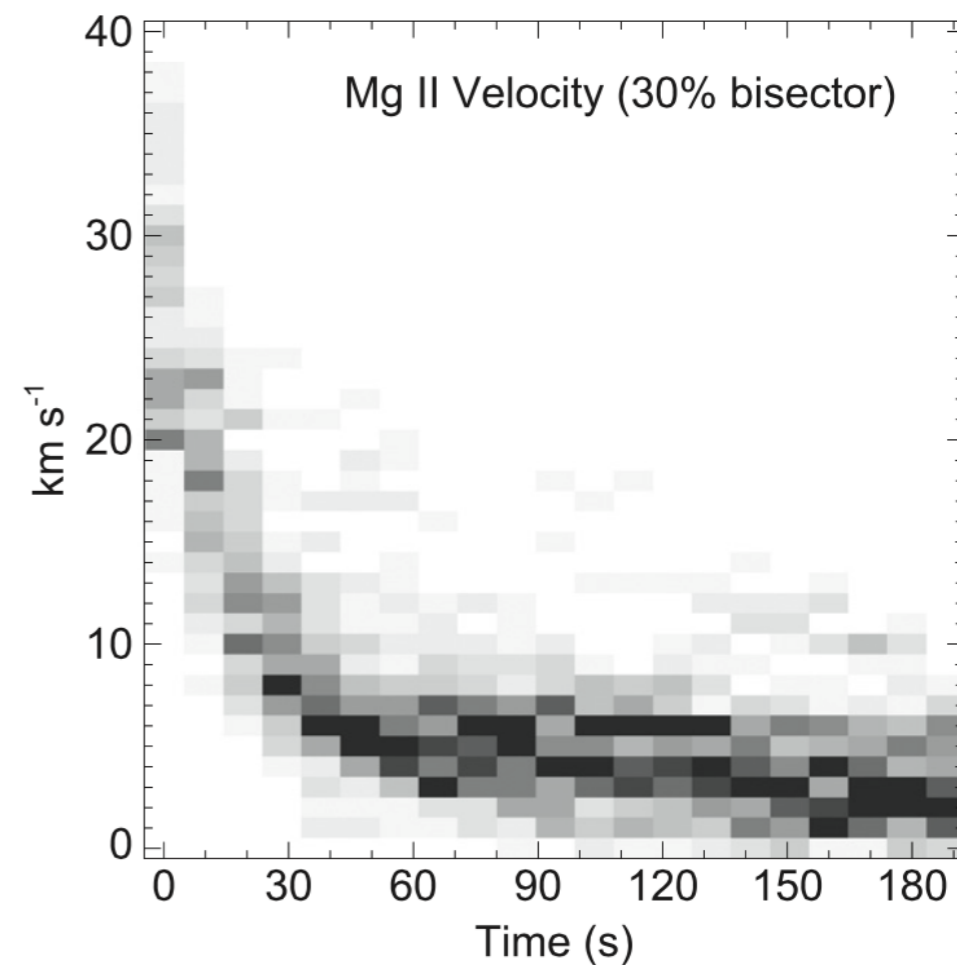
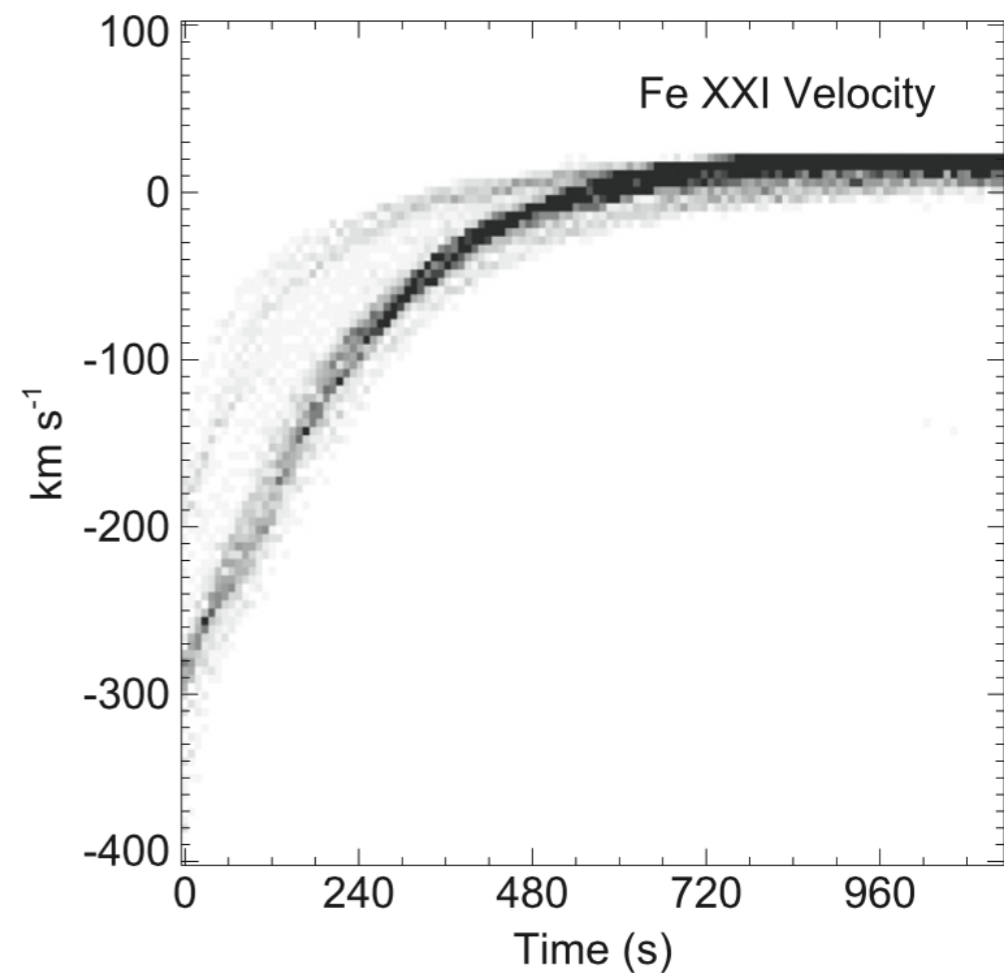
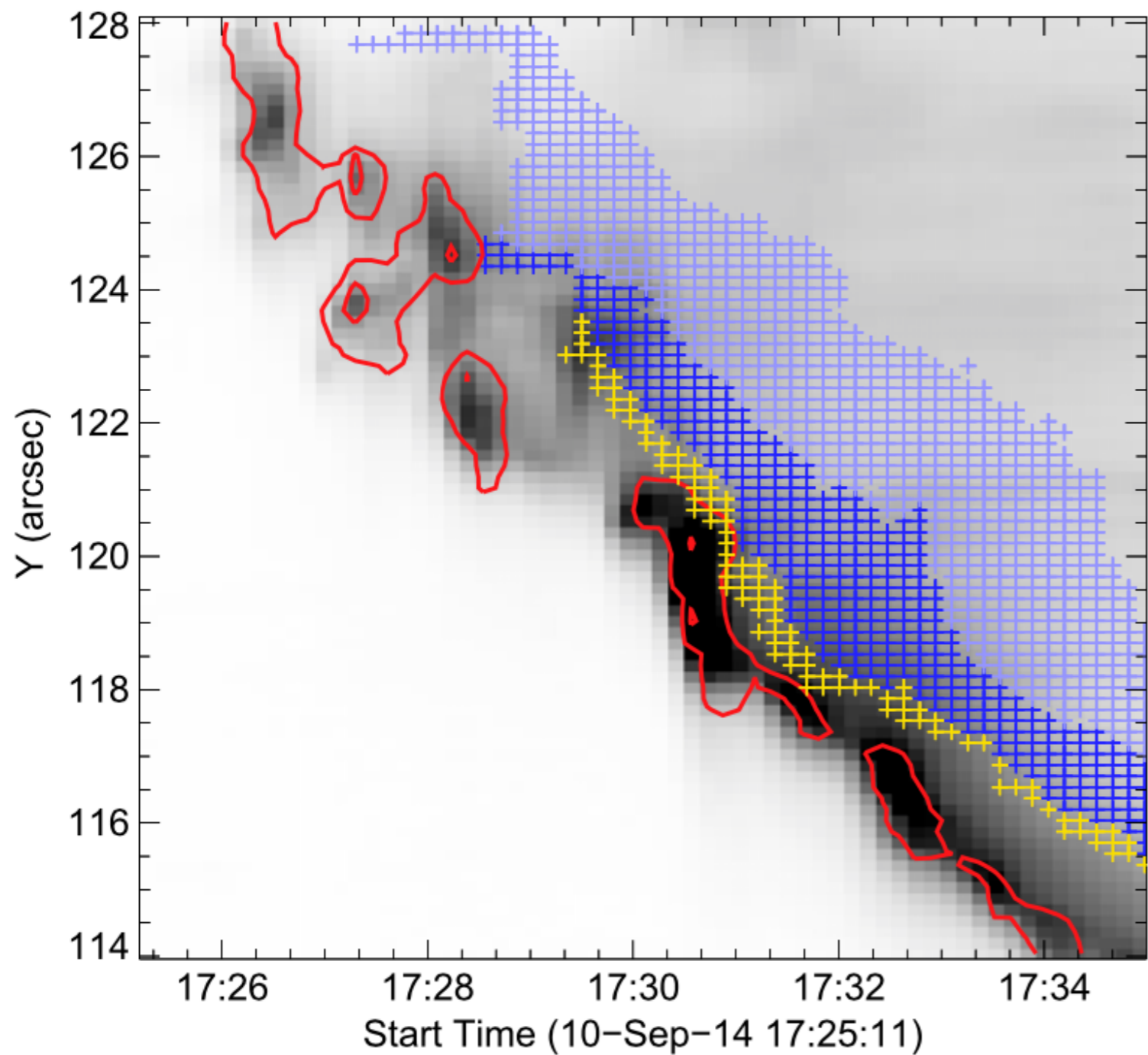
(Tian et al. 2015)

Fe XXI velocity correlates with HXR emission, SXR derivative, NUV continuum.



temporal evolution of evaporation prototypical elementary flare kernels

(Graham & Cauzzi 2015)



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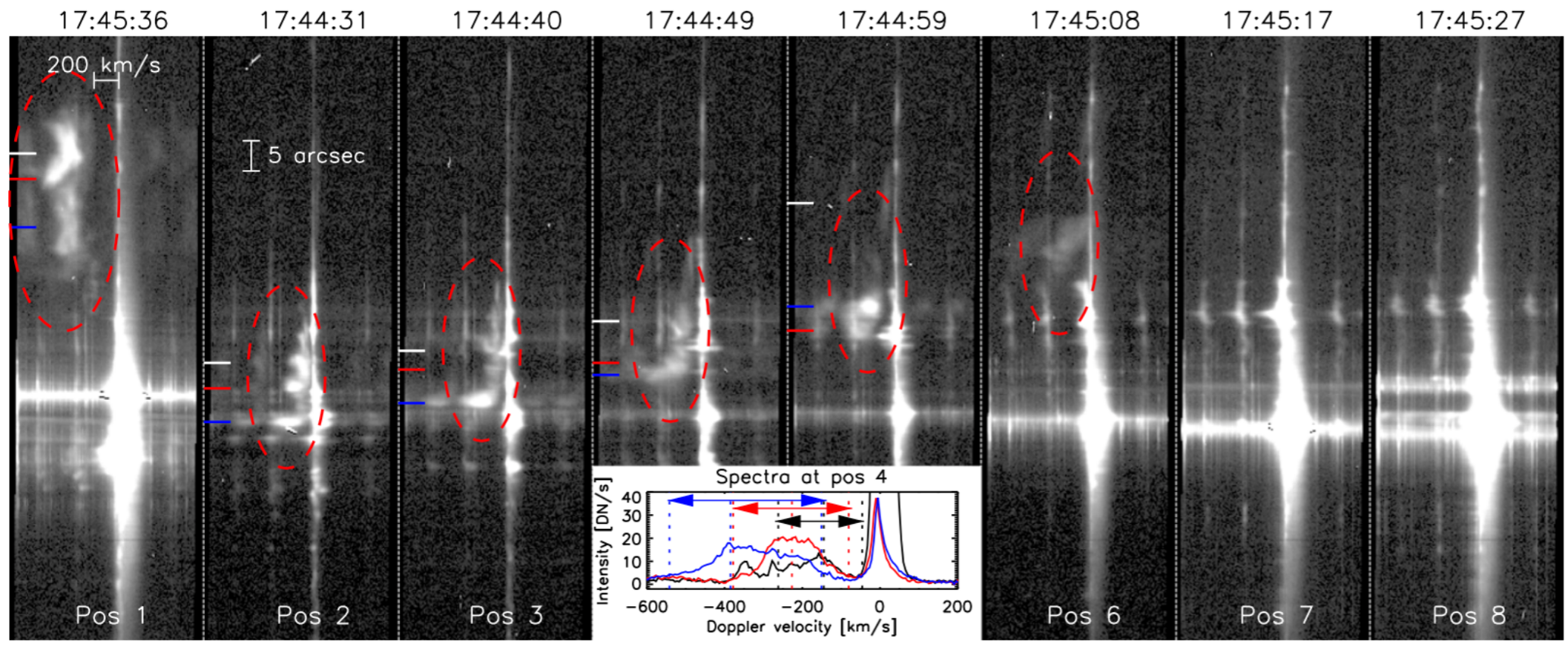
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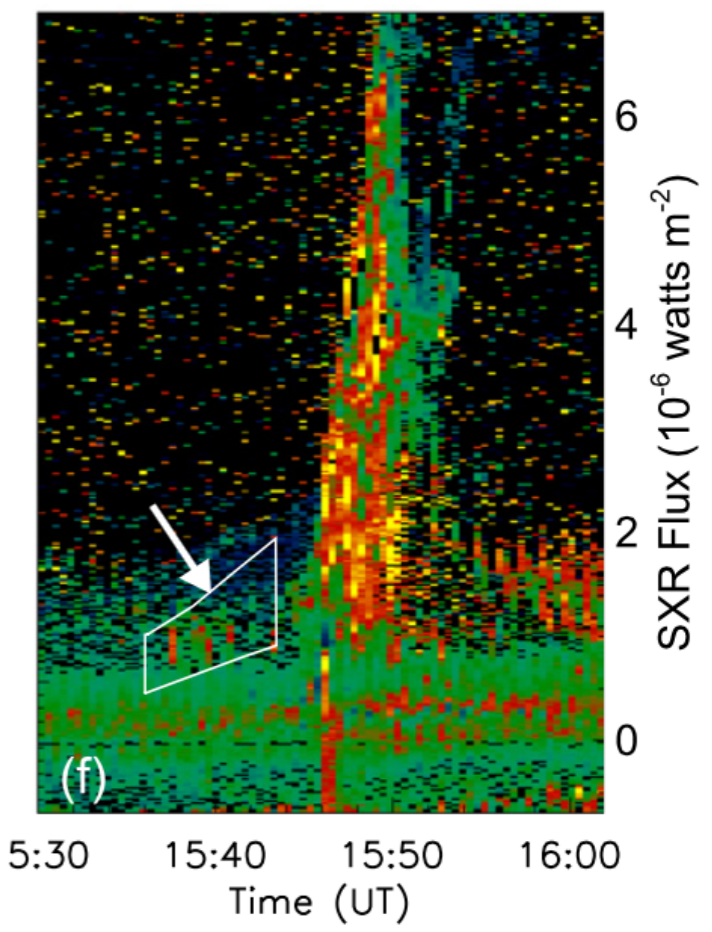
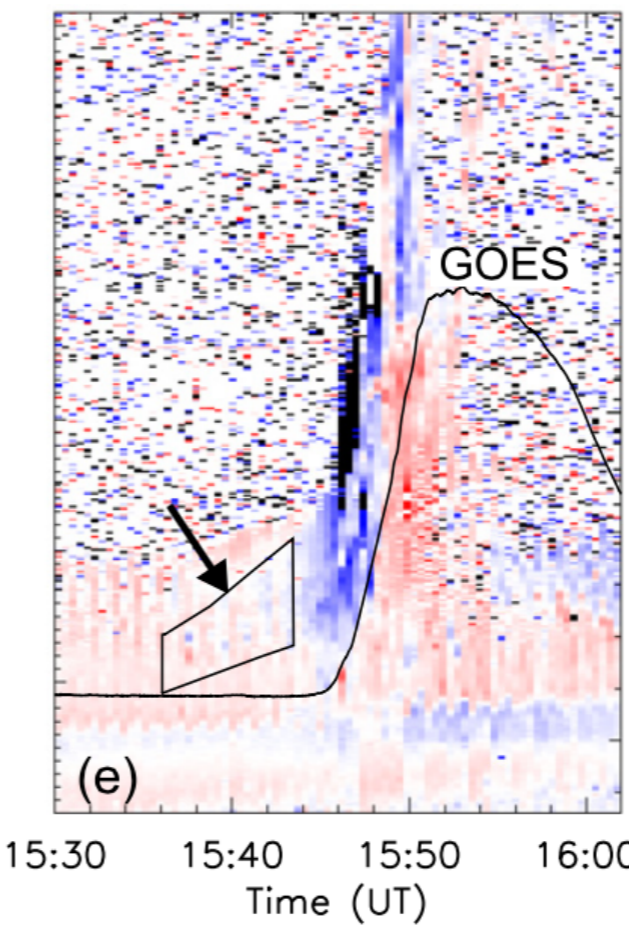
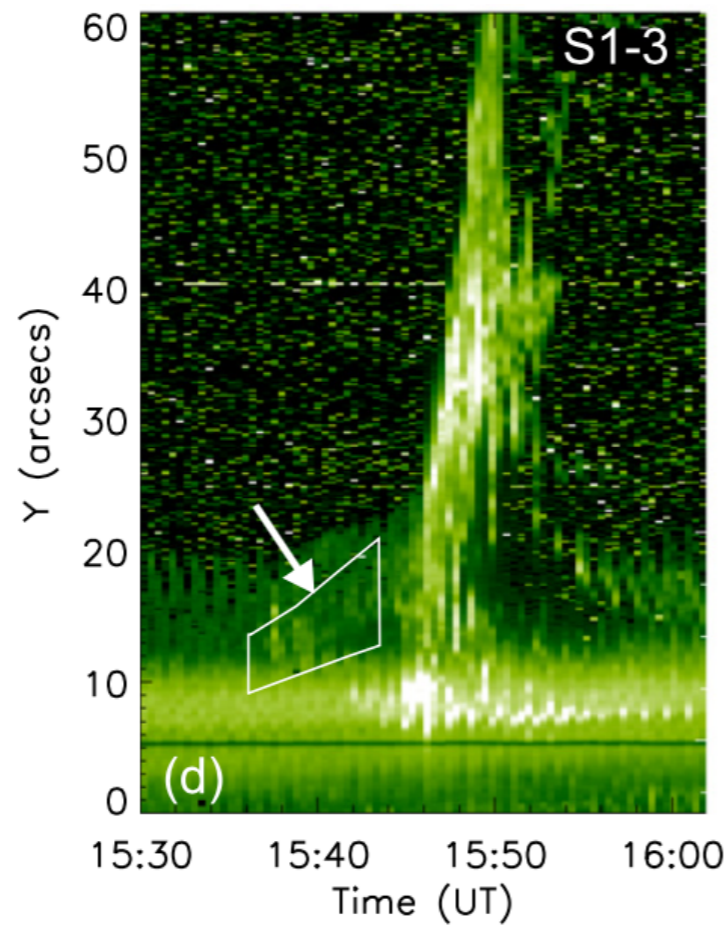
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large velocity in the Si IV line due to filament eruption



(Kleint et al. 2015)



(Chen et al. 2016)

main results on flare dynamic processes from IRIS spectroscopic observations

Oscillations in the above dynamic processes

- **quasi-periodic slipping magnetic reconnection** or *quasi-periodic pulsations caused by reconnection* exhibited in the Si IV line
 - **T. Li et al. 2015**; *D. Li et al. 2015a; Zhang et al. 2016b; ...*
- **magnetic flux rope oscillation** in the preflare phase detected in the Fe XXI line
 - **T. Li et al. 2016**; *Zhou et al. 2016; ...*
- **global sausage oscillation of flare loops** visible in the Fe XXI line
 - **Tian et al. 2016**

ISSI team of flare heating led by Hui Tian

<http://www.issibern.ch/teams/solflaspecobs/index.html>

Diagnosing Heating Mechanisms in Solar Flares through Spectroscopic Observations of Flare Ribbons

--- an ISSI team led by Hui Tian



[Homepage](#)

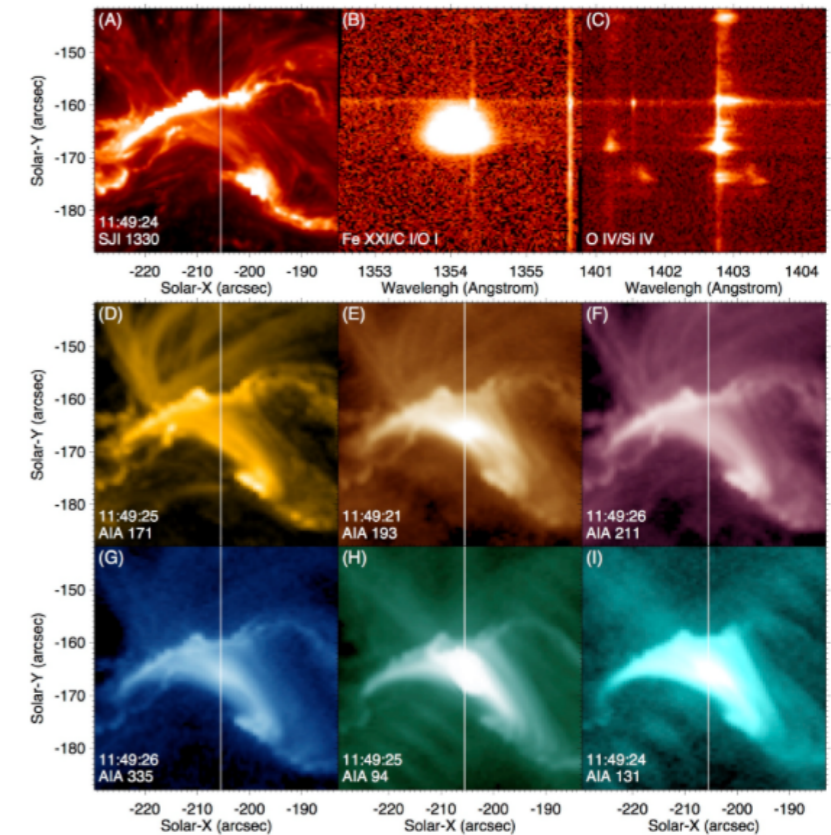
[Proposal](#)

[Members](#)

[Meetings](#)

[Publications](#)

Abstract: Solar flares are among the most energetic events in the solar system. Flare ribbons are one of their best observed features that can provide critical diagnostics for the fundamental flare physics not yet well understood. With a high cadence up to a few seconds and a resolution of ~ 0.33 arcsecond, NASA's Interface Region Imaging Spectrograph (IRIS) mission has revealed unprecedented details of ribbon dynamics in hundreds of flares since July 2013. Characteristics of emission line profiles observed at flare ribbons, e.g., Doppler shifts, line widths, asymmetries, central reversals and wing enhancements, are manifestations of various physical processes involved in solar flares. We propose a timely investigation to understand flare heating mechanisms through joint efforts of spectroscopic observations focusing on flare ribbons and advanced numerical modeling. Specifically, observers on the team will fully characterize the temporal evolution of several key emission lines, e.g., Mg II, Si IV, and Fe XXI, at ribbons in at least ten IRIS flares. Modeler team members will perform state-of-the-art radiative-hydrodynamic simulations by experimenting various heating mechanisms to reproduce observations. Supplementary space and ground-based observations will be used to provide additional constraints. We anticipate that the proposed team work will significantly advance our understanding of flare heating mechanisms and thus well prepare us for future opportunities offered by new space missions such as ESA's upcoming Solar Orbiter.



[Tian et al. \(2016\)](#)

for more figures from the team members, [click here](#)

Current News

- **21 January 2017:** The first team meeting was successfully held in Bern from 16-20 January 2017.
- **8 June 2016:** The proposal was approved by the Science Committee and the ISSI/ISSI-BJ Directorate.

Related Papers

- 39 references on flare heating [\[an ADS library\]](#)

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Diagnosing Heating Mechanisms in Solar Flares through Spectroscopic Observations of Flare Ribbons

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The 2nd team meeting will be held in Beijing in May 2018...

The 1st team meeting has been successfully held in Bern from 16-20 January 2017. [[agenda](#)] [[group photo](#)]

Presentations

Presenter	Title
H. Tian	Introduction
P. Heinzel	IRIS Observations of Solar Flares
P. Heinzel	Spectral Continua in Solar Flares: Blue, Red or White?
J. Kašparová	Modelling of Flare Processes: Comparison of Two RHD Codes Flarix and RADYN
G. Kerr	Observations and Simulations of Mg II h & k During Solar Flares
L. Kleint	What did We Learn about the March 29, 2014 Flare with IRIS
W. Liu	High-Energy Aspects of Solar Flares: Observations and Models
V. Polito	UV Spectroscopy of Solar Flares
J. Qiu	The UV Neupert Effect: Inferring Heating and Cooling of Flare Loops from Foot-point Signatures
K. Reeves	Signatures of Reconnection and Heating Observed in a Candle-Flame Solar Flare at the Limb
F. Rubio da Costa	Combining Hydrodynamics and Acceleration of Particles to Model the Emission of Solar Flares
P. Simões	Formation of the NUV, optical and IR continua in flares from RADYN simulations
H. Tian	Diagnosing Flare Dynamics through the Fe XXI 1354.08Å Line Observed with IRIS
P. Young	What Are the New Results from IRIS, and Can Models Explain Them?
H. Tian	Summary

Relevant Links: [IRIS flare list](#) (on IRIS page) | [IRIS flare list +](#) (more details, .xls file) | [IRIS flare papers](#) (maintained by Dr P.R.Young)

IRIS flare list (google docs)

IRIS Flare List (maintained by Kathy Reeves, Jakub Prchlik, and Hui Tian & supplemented by Ying Li)

20131011 14:54 C4.7, Fe XXI, ribbon

20131012 01:57 C5.2, full frame spectra, many unidentified lines, Fe XXI

20131015 05:42-05:50 Fe XXI line observed, raster of ribbons

20131024 19:55 no GOES class, SJI only, two-ribbon flare

20131024 21:14 C3.3, slit on ribbons and loops after peak

20131024 22:10 C5.7, slit missed, SJI only

20131102 15:20-15:30 strong Fe XXI line, but no SJI images because of flight software problem

20131114 18:29-20:44 C2.2, flare ribbon

20131225 05:18-15:00 C1.1, limb eruptions, flare and surge, no SADs in AIA - Fe XXI at 6:56 (raster 0) and 14:06 (raster 7)

20131225 21:53 flare at the edge of sunspot

20131229 23:45 no GOES class, slit on loops

20131230 02:43 no GOES class, loop brightening and plasma flows at bottom of SJI

20131230 08:04 no GOES class, SJI only

20131231 22:22 loops & footpoints from M flare visible in 1400 SJI images.

20140104 06:30 C5.6 flare. Nice 1400 SJI movie of footpoints, slit nowhere near them, though

20140105 02:24 C4.5 flare got footpoints

20140105 15:15 C6.6, ribbons, Fe XXI, good XRT data

20140105 18:13 C3.4, interesting loop brightening and flows at bottom of SJI

20140111 23:27:39-00:22:22 C6 raster 20 - interesting rotation in CII, very weak Fe XXI, nice eruption in 1400 SJI images

20140127 23:22-00:16 Small eruption on the limb, no GOES class, maybe some Fe XII in raster 8

20140128 07:30 M3.6 One edge of the raster landed on the footprints. All kinds of crazy unidentified lines, lots of Fe XXI, ~150 km/s redshifts in the C II lines. Good one for analysis.

IRIS flare paper list by Peter Young

http://www.pyoung.org/iris/iris_flare_papers.html

IRIS flare papers

This is work in progress but I intend to maintain a list of solar flare papers that make use of IRIS data. The IRIS team maintain a [list of all flares observed by IRIS](#).

Date	Peak	Class	Observation	Paper	Comment
2013-Oct-24	20:10,22:10	C3, C7	Raster (64-step)	D. Li et al. (2016, A&A, 587, A11)	
2014-Feb-3	13:34	C6.5	Raster (8-step)	Polito et al. (2015, ApJ, 803, 84)	
2014-Feb-13		M	Raster (8-step)	Kerr et al. (2015, A&A, 582, A50)	Study of Mg II.
2014-Mar-29	17:47	X1	Raster (8-step)	Heinzel & Kleint (2014, ApJ, 794, L23) Young et al. (2015, ApJ, 799, 218) Aschwanden (2015, ApJ, 804, 20) Kleint et al. (2015, ApJ, 806, 9) Y. Li et al. (2015, ApJ, 811, 7) C. Liu et al. (2015, ApJL, 812, 19) Matthews et al. (2015, ApJ, 812, 35) Battaglia et al. (2015, ApJ 813, 113) W. Liu et al. (2015, Sol. Phys., 290, 3525) Kleint et al. (2016, ApJ, 816, 88) Rubio da Costa et al. (2016, ApJ, 827, 38) Woods et al. (2017, arXiv:1701.06457) Kowalski et al. (2017, ApJ, 836, 12)	This is the "best-ever" flare observation, seen by many observatories (space and ground).
2014-Apr-18	13:03	M7	Sit-and-stare	X. Cheng et al. (2015, ApJ, 804, 82) Brosius & Daw (2015, ApJ, 804, 45) Brannon et al. (2015, ApJ, 810, 4) Brosius et al. (2016, ApJ, 830, 101)	