Spectroscopic Observations of Magnetic Reconnection and Chromospheric Evaporation in an X-shaped Solar Flare

Ying Li (李瑛)

M. Kelly, M.D. Ding, J. Qiu

Purple Mountain Observatory

Nanjing, China

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Contributed Talk

4. Eruptions in the solar atmosphere

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Y. Li[1], M. Kelly[2], M. D. Ding[3], J. Qiu[2]

[1]*Purple Mountain Observatory, Nanjing, China*
[2]*Montana State University, MT, USA*
[3]*Nanjing University, Nanjing, China*

We present observations of distinct UV spectral properties at different locations during an atypical X-shaped flare (SOL2014-11-09T15:32) observed by the Interface Region Imaging Spectrograph (IRIS). In this flare, four chromospheric ribbons appear and converge at an X-point where a separator is anchored. Above the X-point, two sets of non-coplanar coronal loops approach laterally and reconnect at the separator. The IRIS slit was located close to the X-point, cutting across some of the flare ribbons and loops. Near the location of the separator, the Si IV 1402.77 Å line exhibits significantly broadened line wings extending to 200 km s^{-1} with an unshifted line core. These spectral features suggest the presence of bidirectional flows possibly related to the separator reconnection. While at the flare ribbons, the hot Fe XXI 1354.08 Å line shows blueshifts and the cool Si IV 1402.77 Å, C II 1335.71 Å, and Mg II 2803.52Å lines show evident redshifts up to a velocity of 80 km s^{-1}, which are consistent with the scenario of chromospheric evaporation/condensation.

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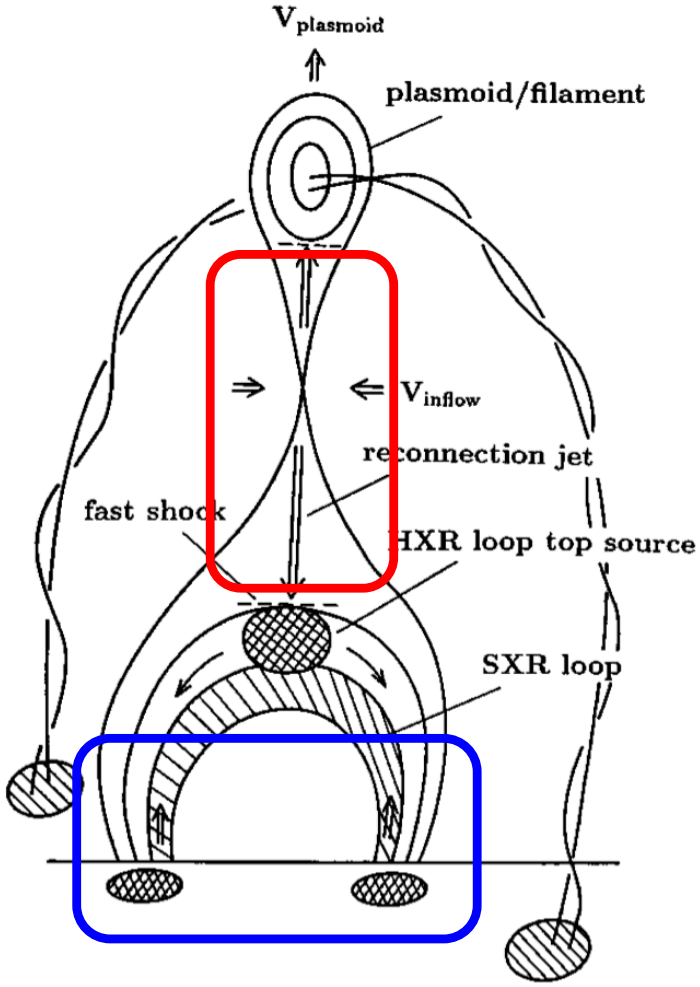
Introduction

- Solar flares are energetic events in the solar atmosphere.
- Energy release mechanism: magnetic reconnection
- Dynamic response: chromospheric evaporation
- Both can be diagnosed through spectroscopic observations.



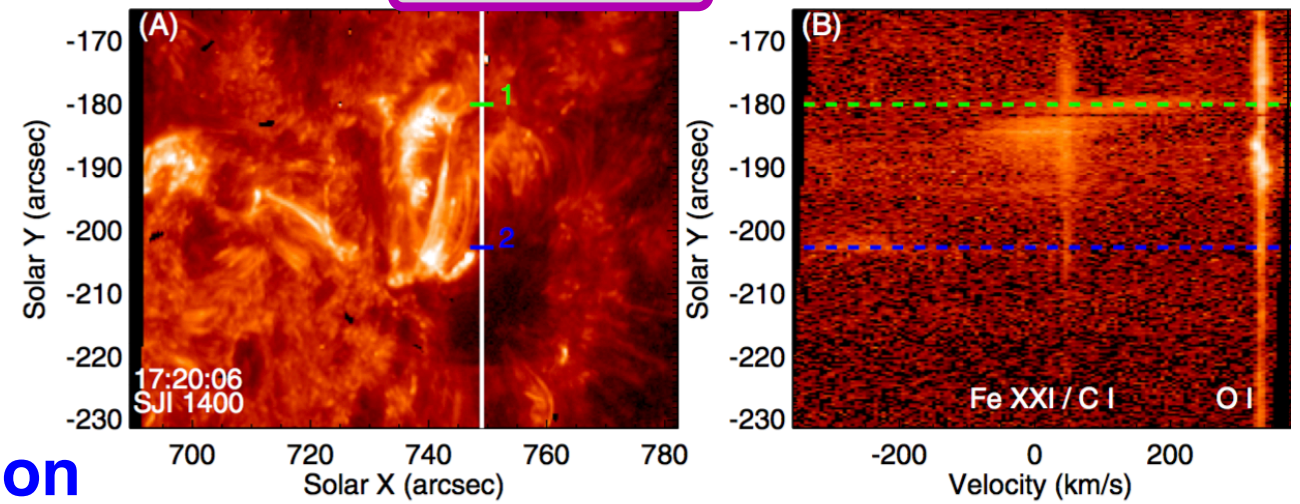
(Shibata et al. 1995, 2011)

Introduction

Spectroscopic signatures of magnetic reconnection:

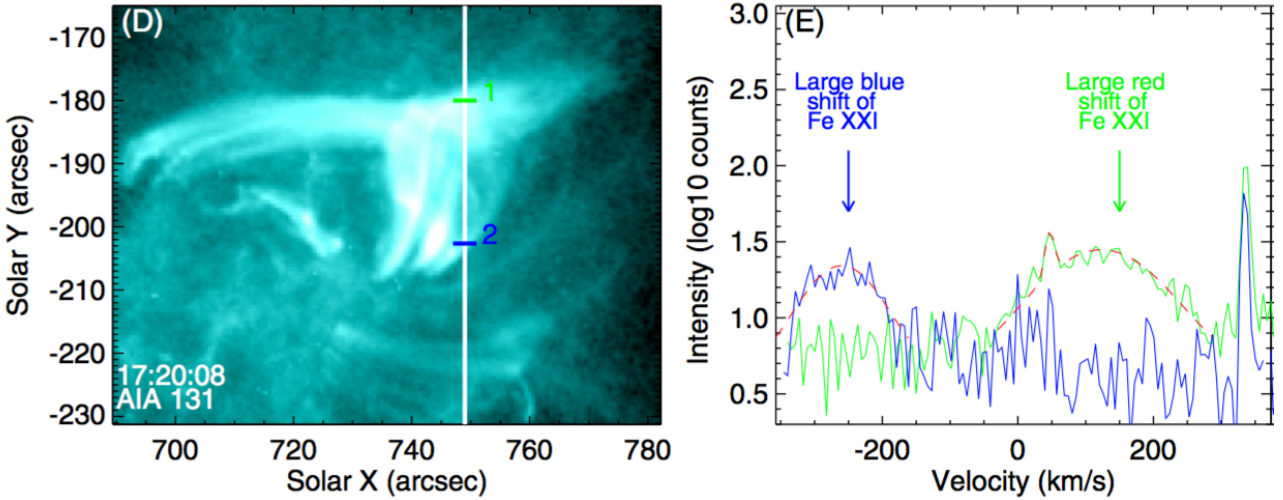
on the top of flare arcades, **blue-wing enhancements** in Fe XXI (Innes et al. 2003a,b), **blueshifted & redshifted jets** in Fe XIX (Wang et al. 2007), **high redshifts** in Fe XXIV (Hara et al. 2011, Simoes et al. 2015), **fast flows** in Si IV (Reeves et al. 2015), **bidirectional flows** in Ha (Hong et al. 2016).

an example (Tian et al. 2014)



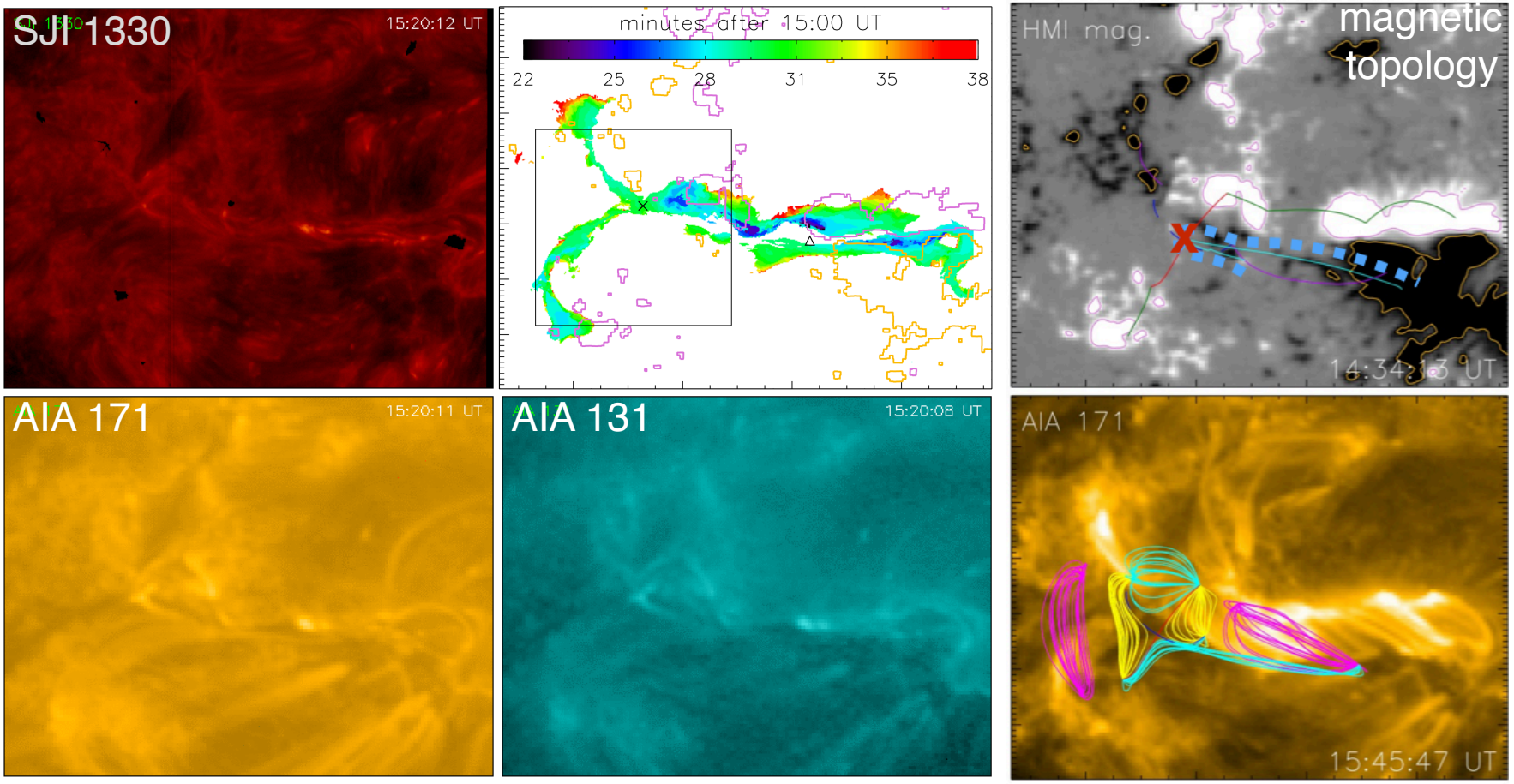
Chromospheric evaporation

at flare ribbons, **blueshifts** in coronal lines & **redshifts** in Transition region (TR) and chromospheric lines (a large number of studies..)



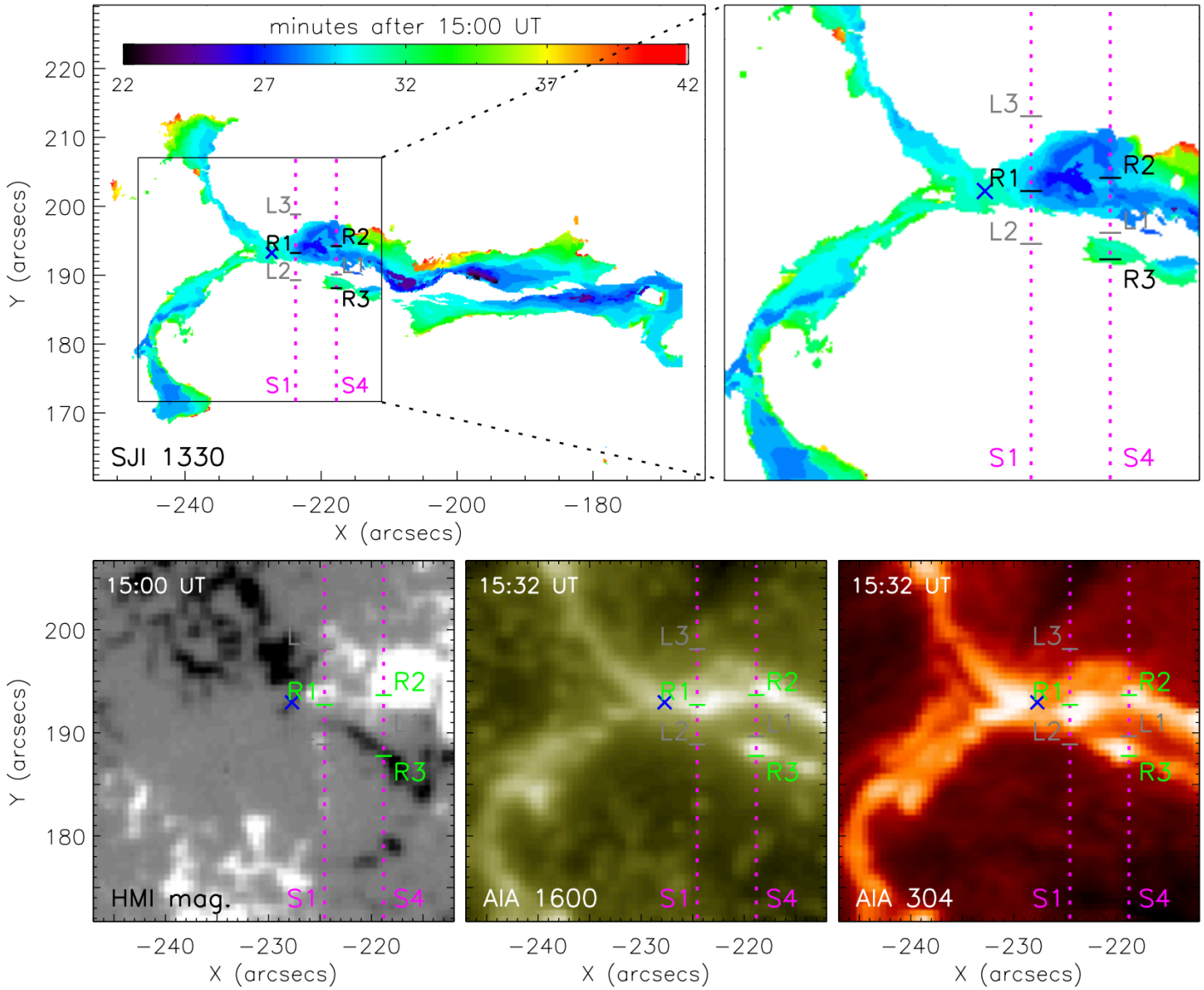
Observations

- an atypical X-shaped flare **(SOL2014-11-09T15:32 M2.3)**
- Magnetic reconnection occurs at a separator, creating an X-shaped ribbon (Li et al. 2016).



Spatial context

- **three locations (R1-R3)** at the X-shaped flare ribbons
- **three locations (L1-L3)** outside the ribbons (near the separator)



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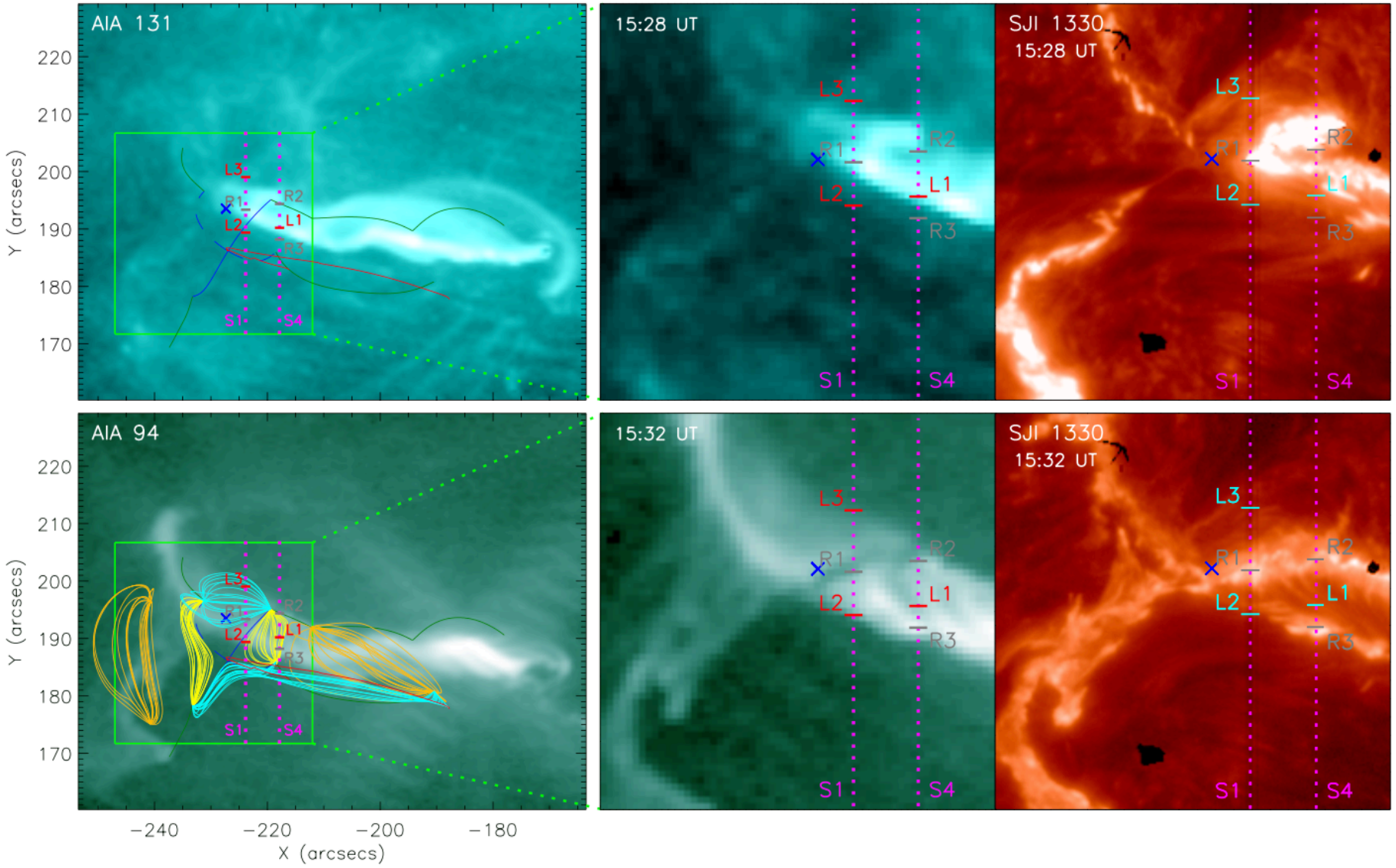
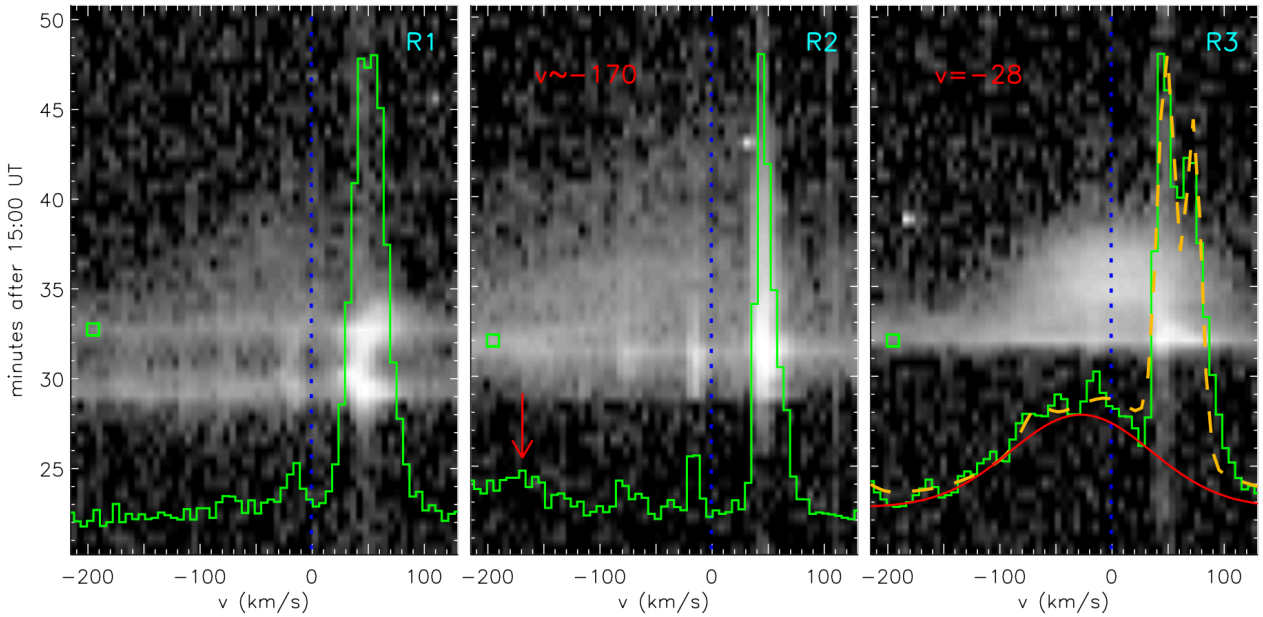


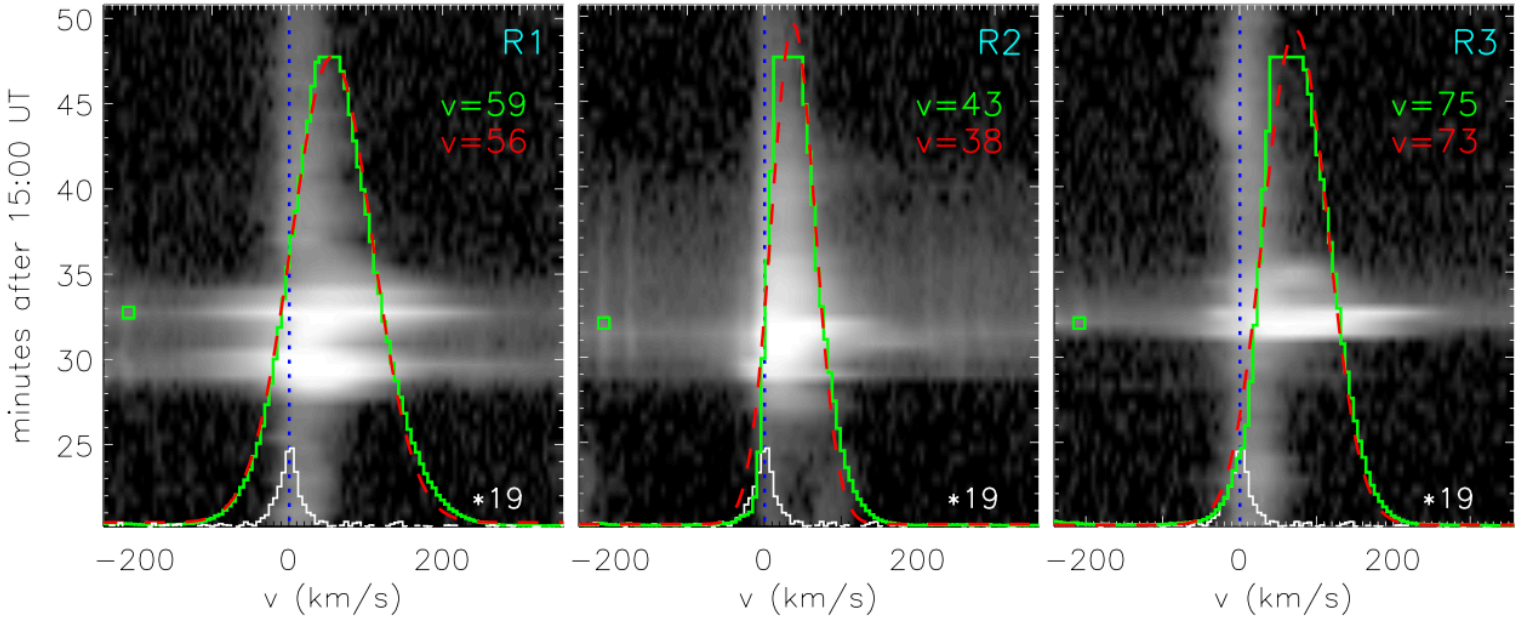
Spectral features at flare ribbons: R1-R3

Fe XXI

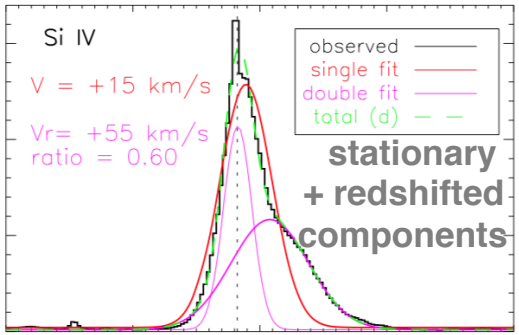
blueshifted



in particular, entirely redshifted **Si IV** profiles (single Gaussian fitting)



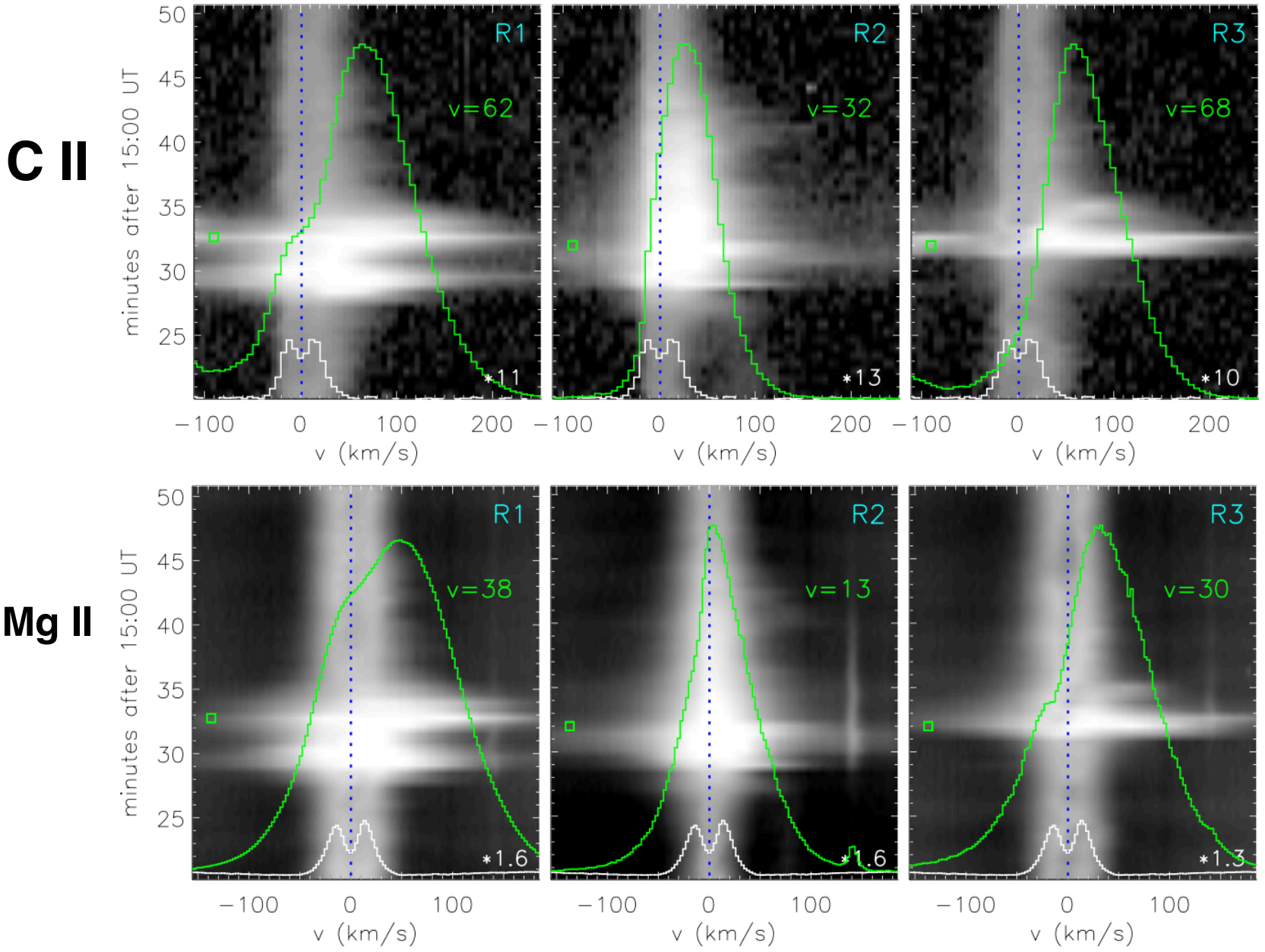
for comparison
(in an X1.0 flare)



(Li et al. 2015)

Spectral features at flare ribbons: R1-R3

Singly peaked, redshifted



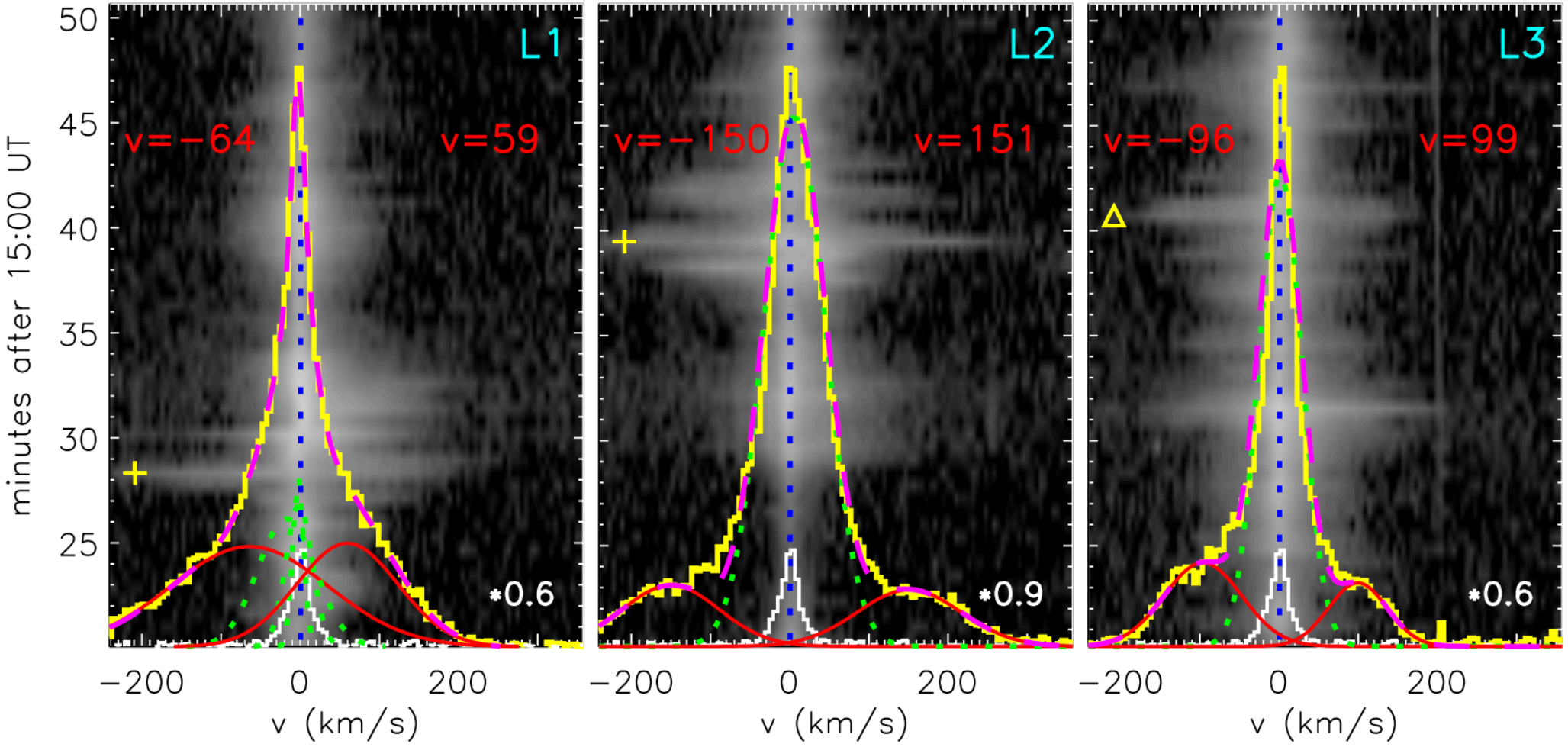
Spectral features at flare ribbons - **implications**

- blueshifts in Fe XXI & redshifts in Si IV, C II, and Mg II
  - consistent with **chromospheric evaporation** (explosive evaporation)

- wholly redshifted Si IV profiles vs.
  stationary + redshifted Si IV components
  - IRIS may resolve/unresolve the condensation region
  - energy deposition in a narrow/wide (multiple) layer by thermal/non-thermal heating?

Spectral features near the separator: L1-L3

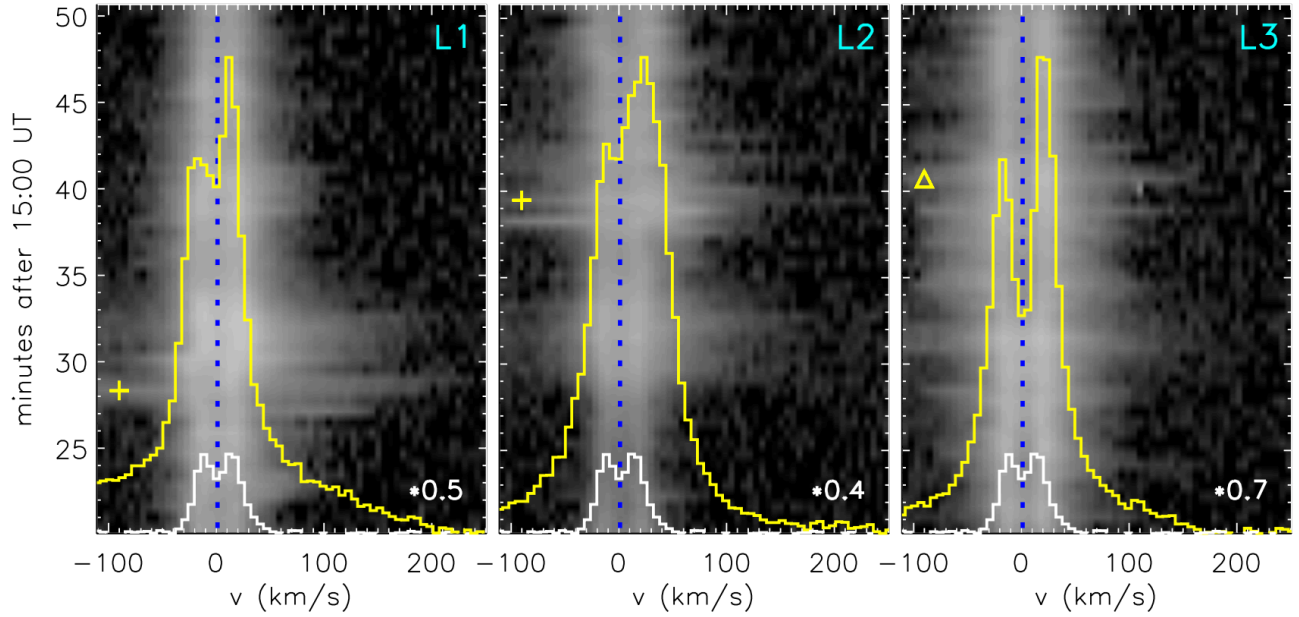
Si IV : broadened line wings extending to 200 km/s with an unshifted line core (multiple Gaussian fitting)



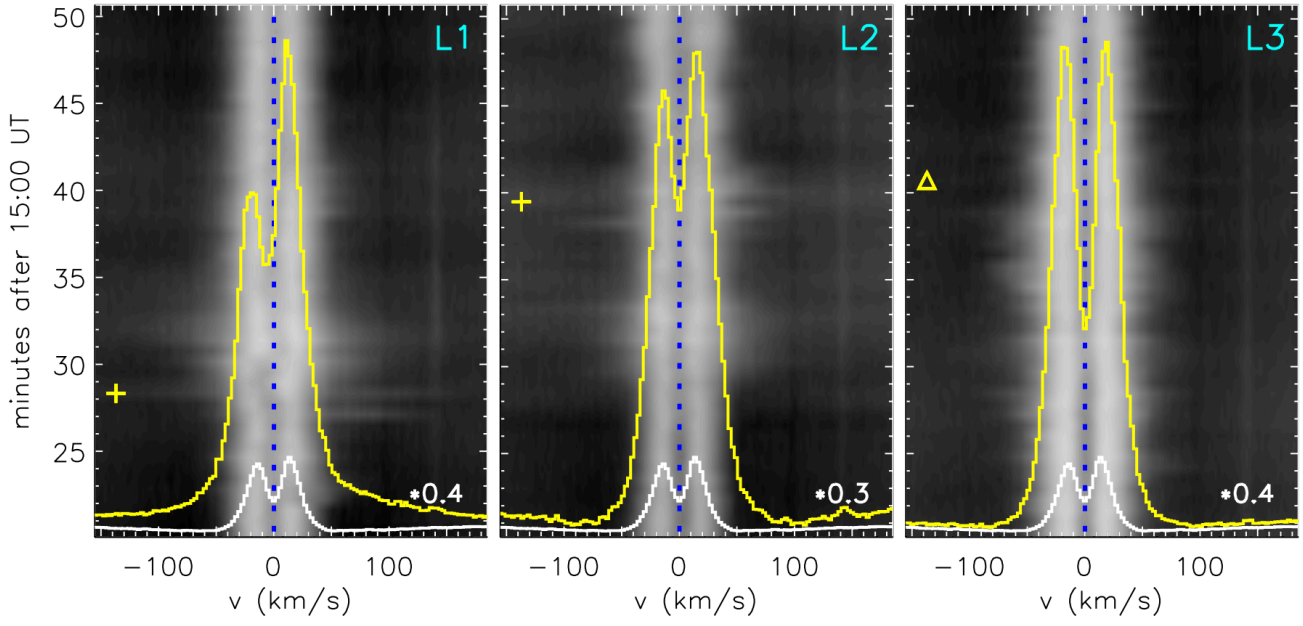
Spectral features near the separator: L1-L3

broadened line wings (double peaked) & red asymmetry

C II



Mg II



Spectral features near the separator - **implications**

- broadened line wings with bumps at ±(60-150) km/s in Si IV: **existence of bidirectional reconnection outflows**;
- broadened line wings with a red asymmetry in C II & Mg II: **downward reconnection outflows**;
- The energy is released via **separator reconnection** around the transition region, which is rarely reported in previous flare studies.

Summary

- Distinct spectral features are observed **at the flare ribbons** and **near the separator** in an X-shaped flare, as implications for energy release and dynamics in the flare atmosphere.
- Near the location of the separator, the Si IV line exhibits significantly broadened line wings extending to 200 km/s, suggesting the presence of bidirectional flows related to the separator reconnection in the transition region.
- At the flare ribbons, the hot Fe XXI line shows blueshifts and the cool Si IV, C II, and Mg II lines show evident redshifts up to 80 km/s, consistent with chromospheric evaporation/ condensation. In particular, the Si IV line is entirely redshifted with no rest component.

More details can be found in **Li et al. 2017, ApJ, 848, 118**

Thanks for your attention!