Magnetic Reconnection Leading to a Mini-Flare and a Twisted Jet Observed with IRIS

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Overview : Mini-flare and the jet observed with IRIS

Motivation: to understand how jet forms and how twist is injected into the jet using the IRIS spectrographic observations and numerical simulations.

Observations: Interface Region Imaging Spectrograph (IRIS: spectra and slit jaw images) and Atmospheric Imaging Assembly (AIA), HMI vector magnetograms

Highlights: Why is there cool material over hot material in the flare site ? (Multi thermal flare model)

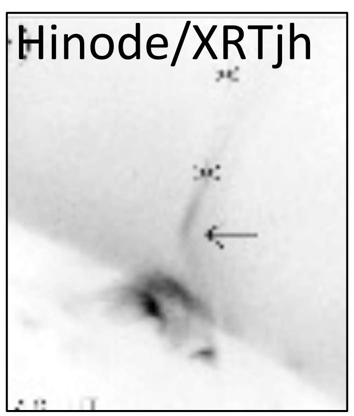
Where comes from the twist in the jet ? (Signature in the spectra : bidirectional flows (tilt), Dynamical model)

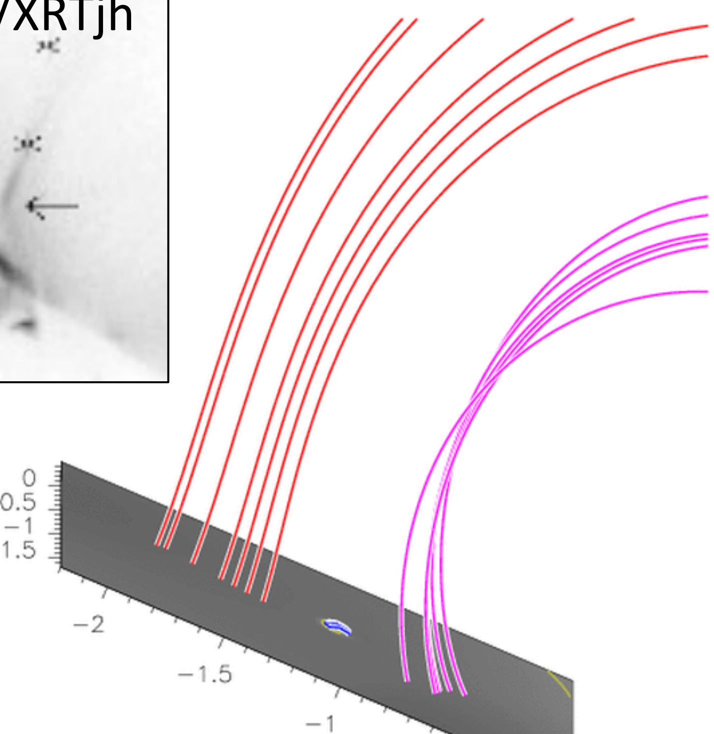
Numerical MHD simulations

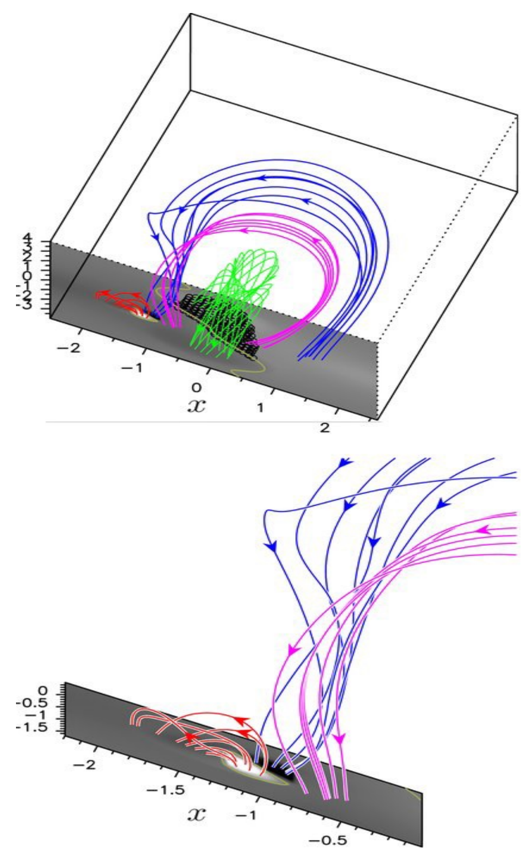
Two mechanisms are proposed for the initiation of jets:

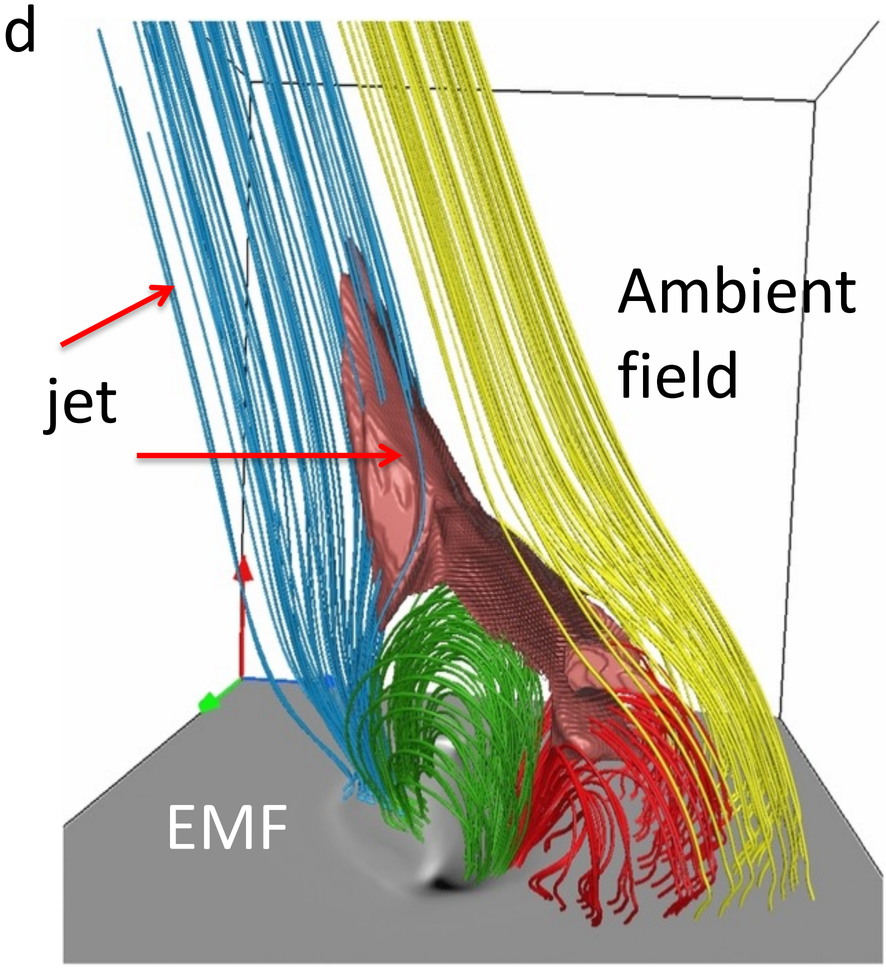
1. Emerging flux from below the surface, Yokoyama Shibata 1996 (2D), (3D) Moreno Insertis 2008, Torok et al 2009, Archontis 2010

The newly emerging field collides with the ambient coronal field









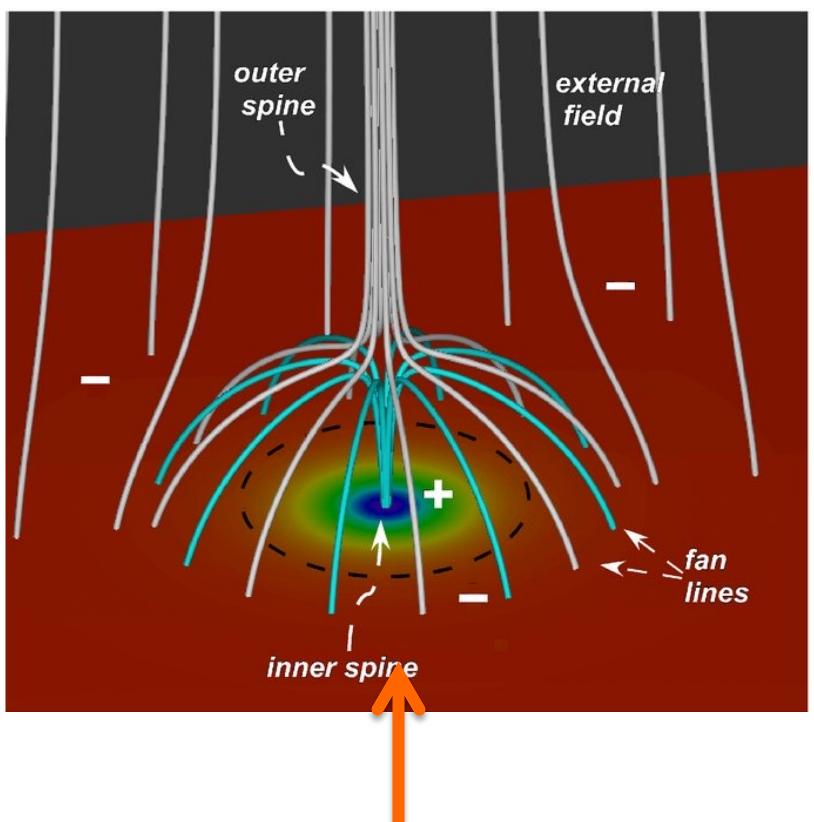
EMF at the feet of arcades

Torok, Aulanier,Schmieder 2009, Ruan, Schmieder, Aulanier, Masson 2019

Moreno Insertis 2008 ++

Numerical MHD simulations

2. The second mechanism is based on the *onset of instability or loss of equilibrium*, with stressed, non-potential, closed flux beneath a **null point,** and the reconnection with the ambient, quasi-potential flux exterior to the fan surface.



Null point

Magnetic Twist Jet

Release of the shear ➔ non linear Alvénic wave

Driver: Alfvén wave magnetic pressure

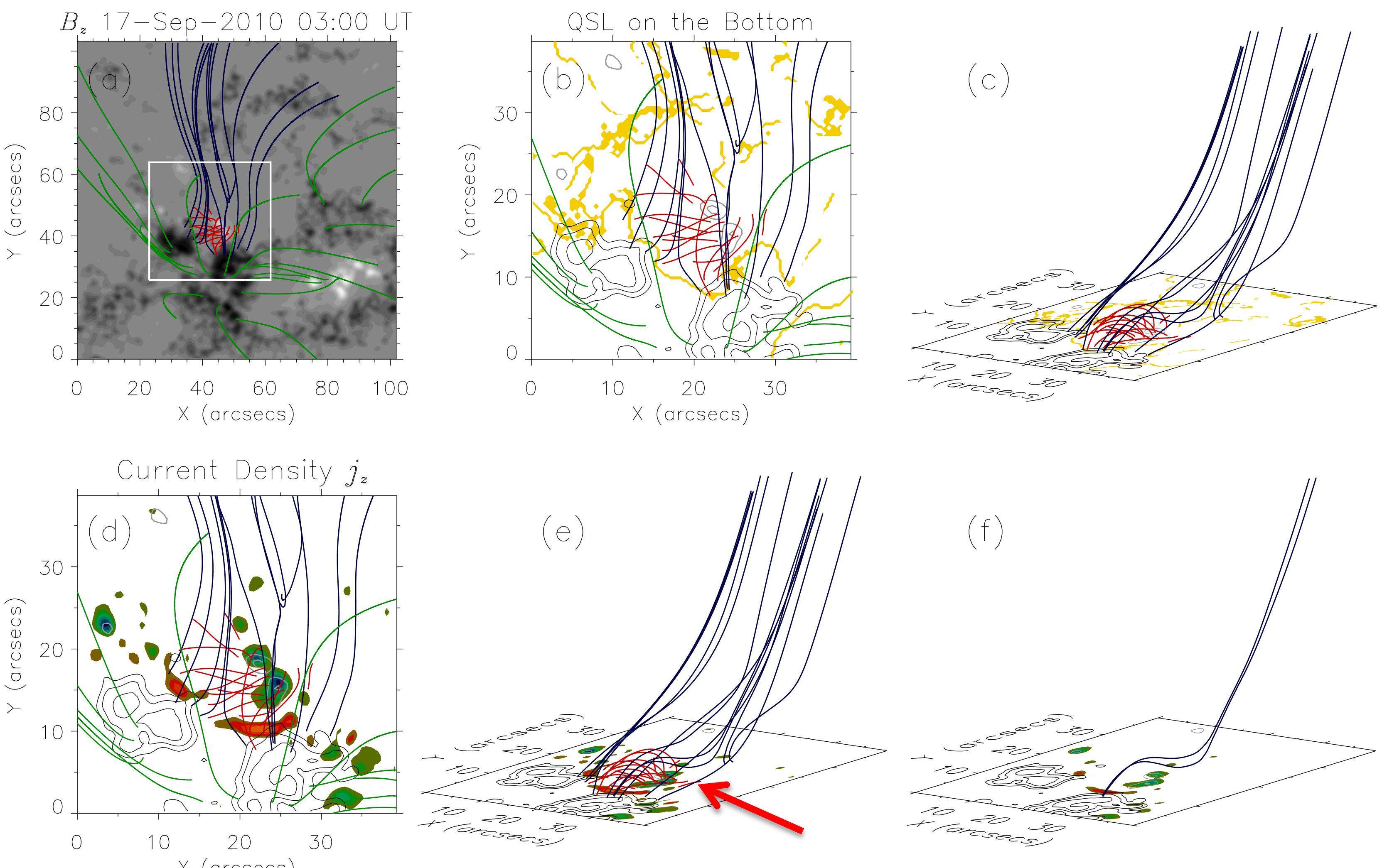
$\mathbf{V_{bulk\ flow} \neq V_{jet} \sim V_{alfvén}}$

(Pariat, Antiochos, DeVore 2009, 2010)

Recurrent jets: the Impulsive 3D null-point reconnection triggers rapid untwisting jets from previous helical field lines and escape in the open ambient magnetic field.

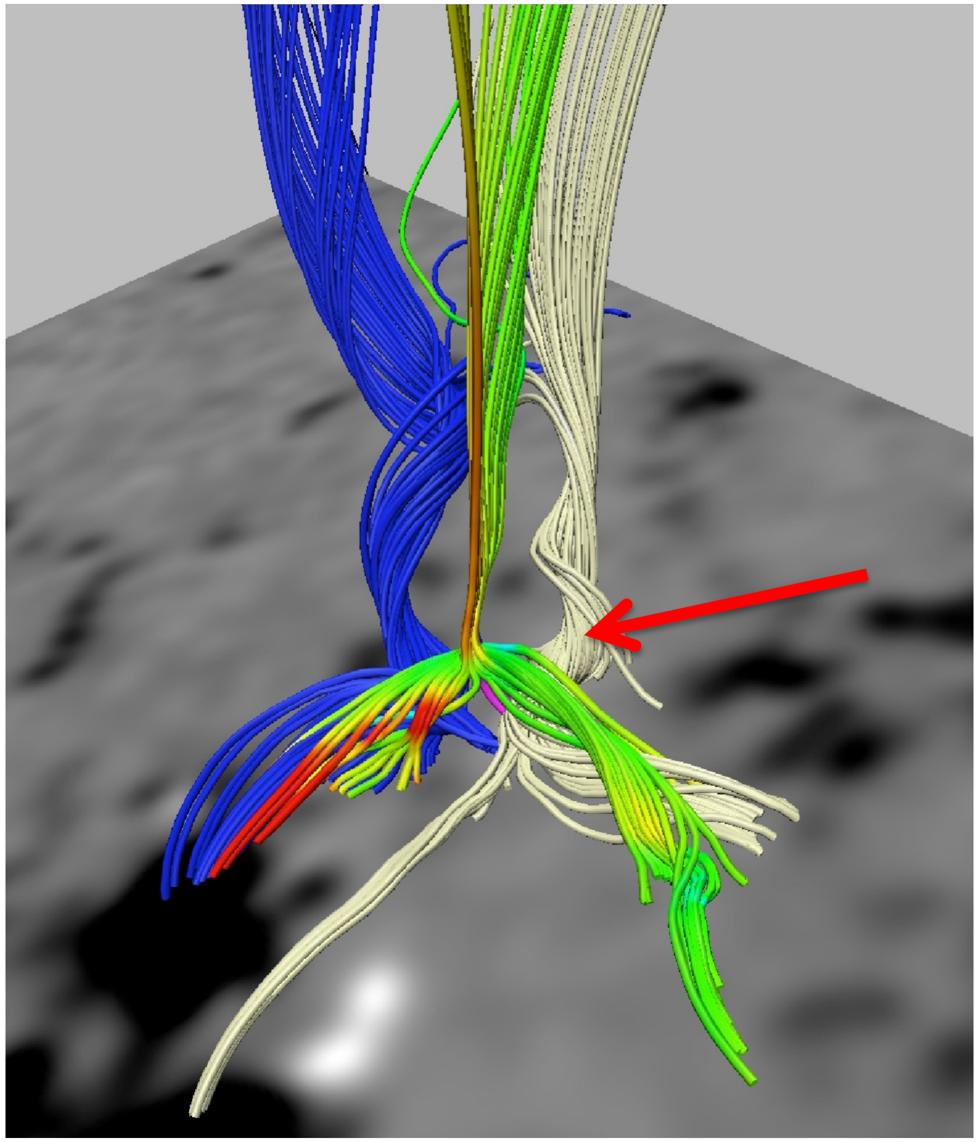
*A*daptively *R*efined *M*agnetohydrodynamic *S*olver (*ARMS*),

LFFF or NLFFF Magnetic Extrapolation Topology: null point or bald patch



bald Patch

Presence of bald patches (Guo, Schmieder et al 2013)



Null point (Schmieder, Guo, Moreno Insertis et al 2013)

Solar Jets

- act as a source for transporting mass and energy from lower solar atmosphere to upper coronal heights.
- can contribute for heating the solar corona and accelerating the solar wind.
- are the key tool to probe the broad dimensions of solar heliospheric problems.

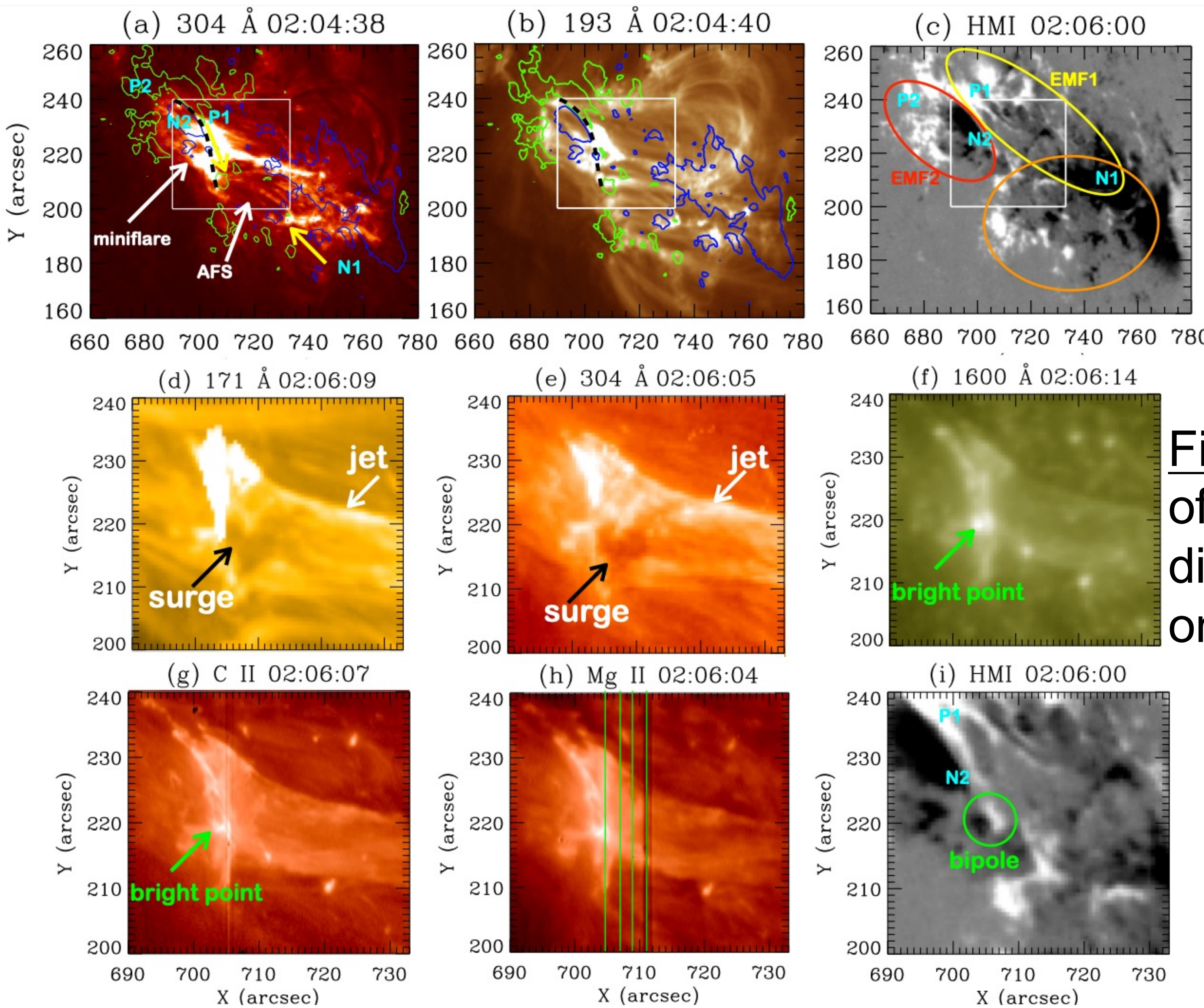


Fig1: Multiwavelength observations of a solar jet and mini-flare in different AIA and IRIS wavebands on March 22, 2019.

IRIS Spectra of the Jet Base

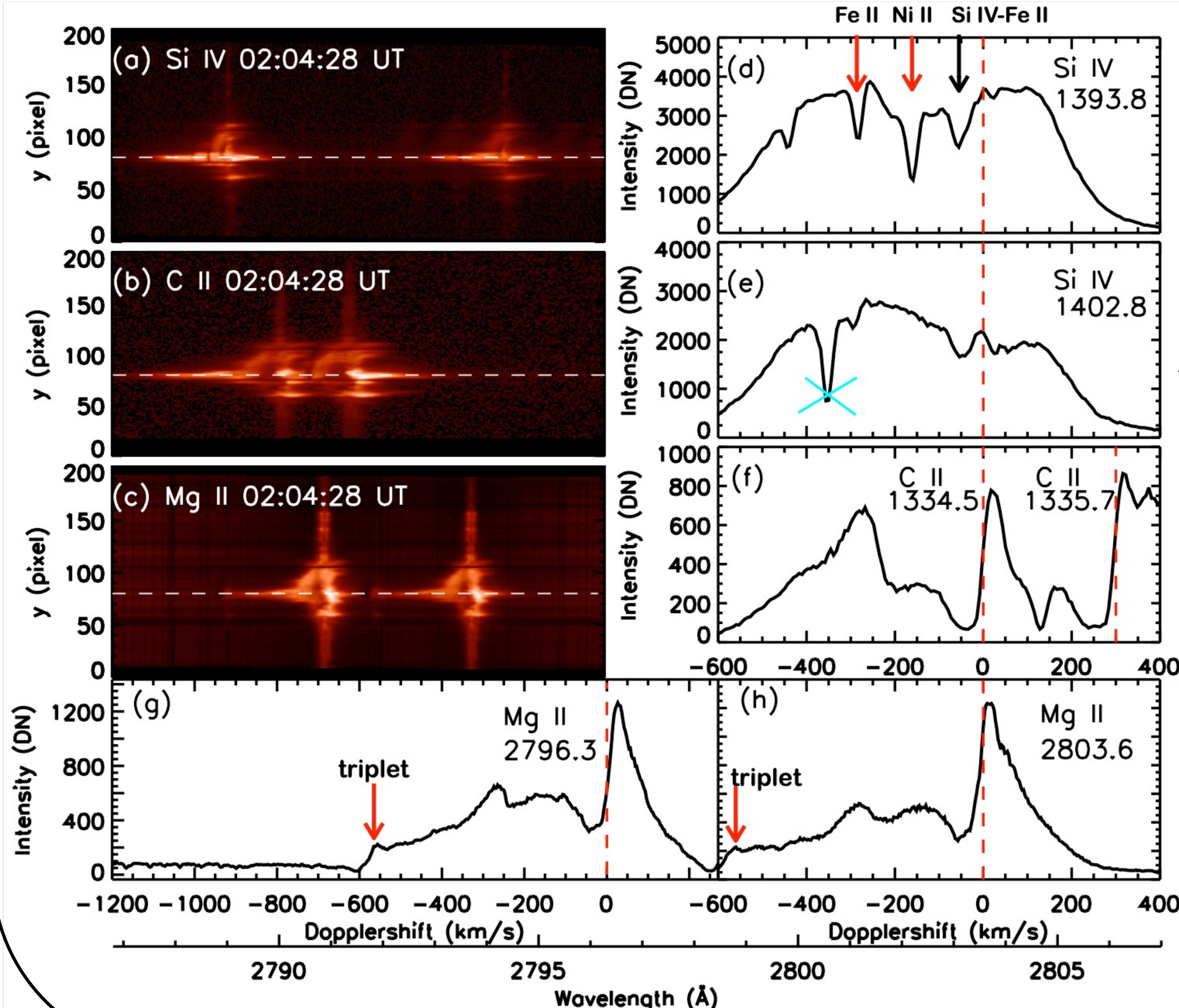
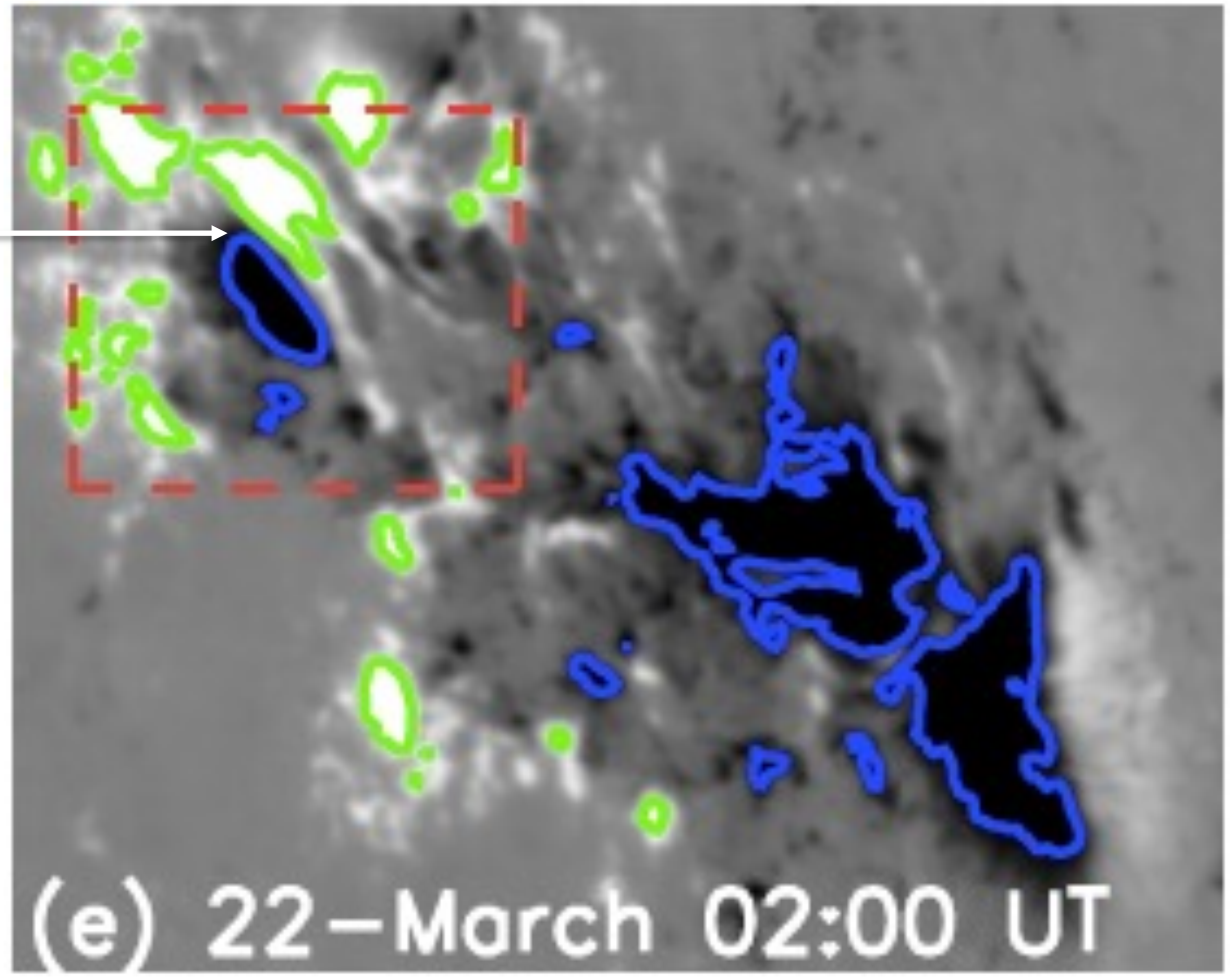


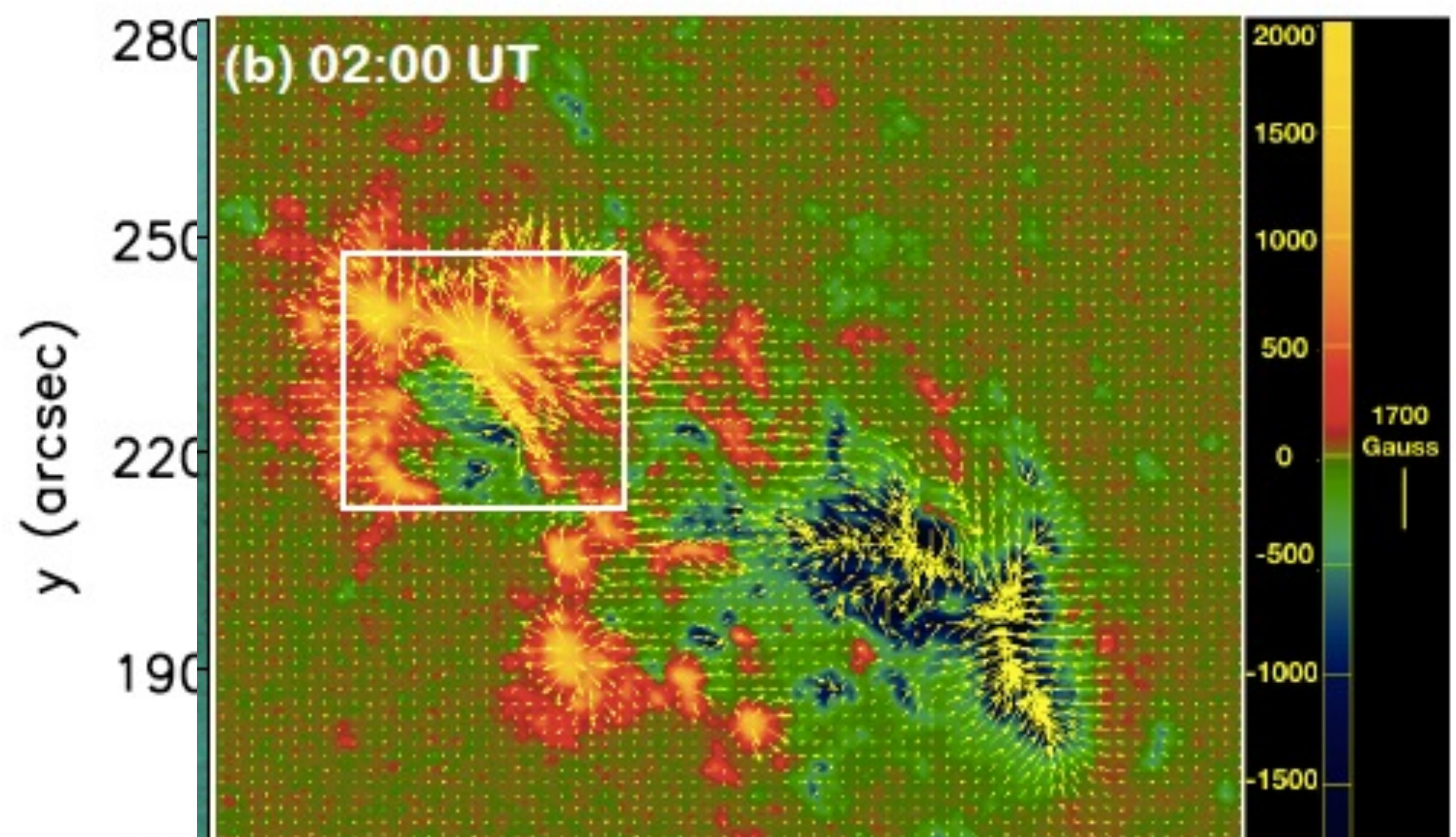
Fig2: Spectra and profiles of the jet base (UV burst) in Si IV, C II, and Mg II lines.

HMI Magnetogram

Shear



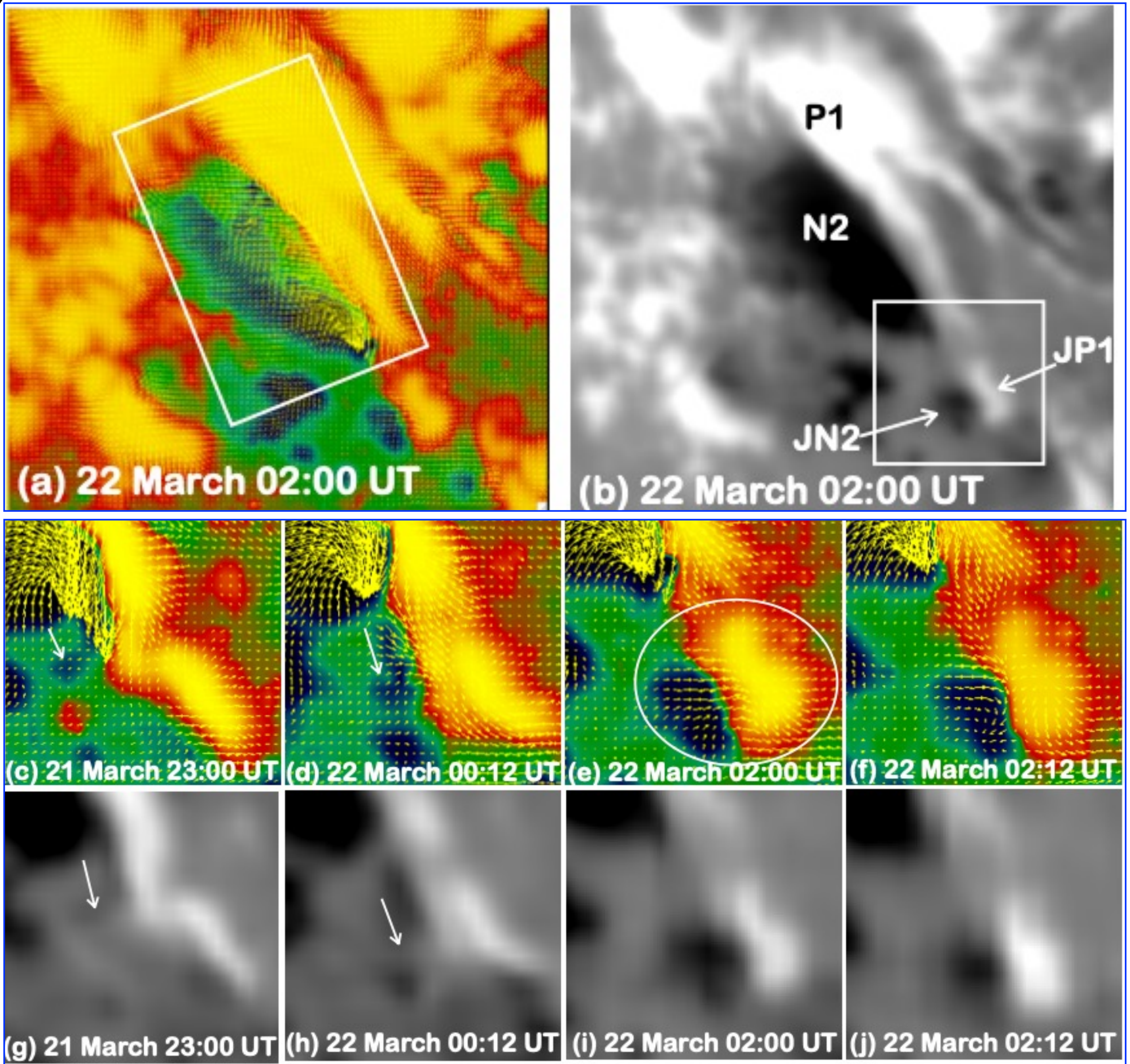
EMERGING Magnetic FLUX
Blue : negative polarity
Green : positive polarity



The arrows show the Horizontal magnetic flux

The box is the region of interest with the shear

Twisted Flux Rope



ZOOM

Fig3: Panel (a): Vector magnetic field configuration.

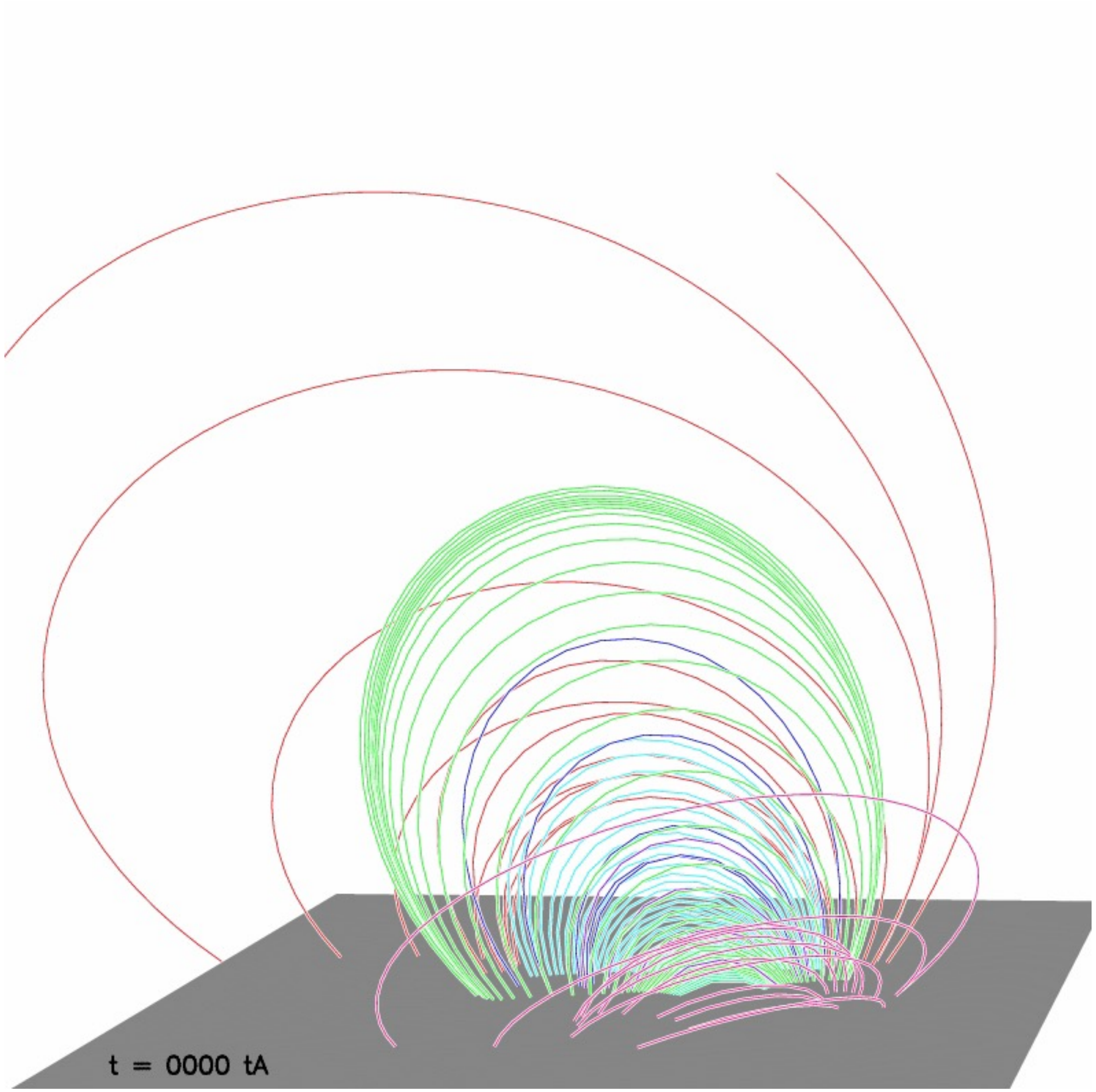
Panel (b): LOS magnetic configuration including the two bipoles P1-N2, JP1-JP2.

Panel (c–e): zoomed view of vector magnetic field configuration.

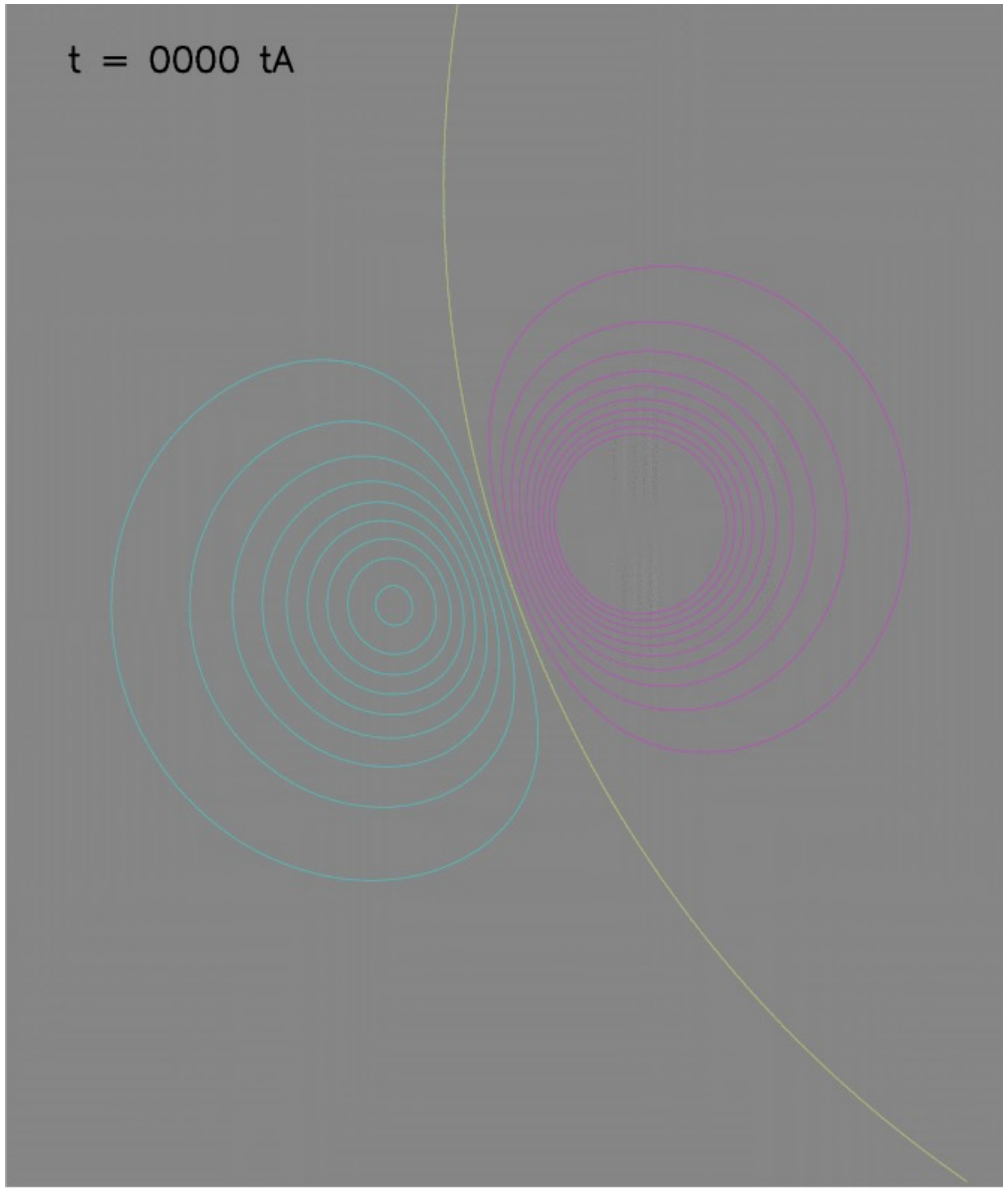
Panel (f–h): zoom view of LOS magnetic field configuration.

Simulation : sigmoid and currents

OHM code: 3D, non uniform mesh, $\beta = g = 0$, $\eta_{coronal} = cst$



Aulanier et al 2018



Current density Jz

Transfer of Twist: Comparison with Numerical Simulation

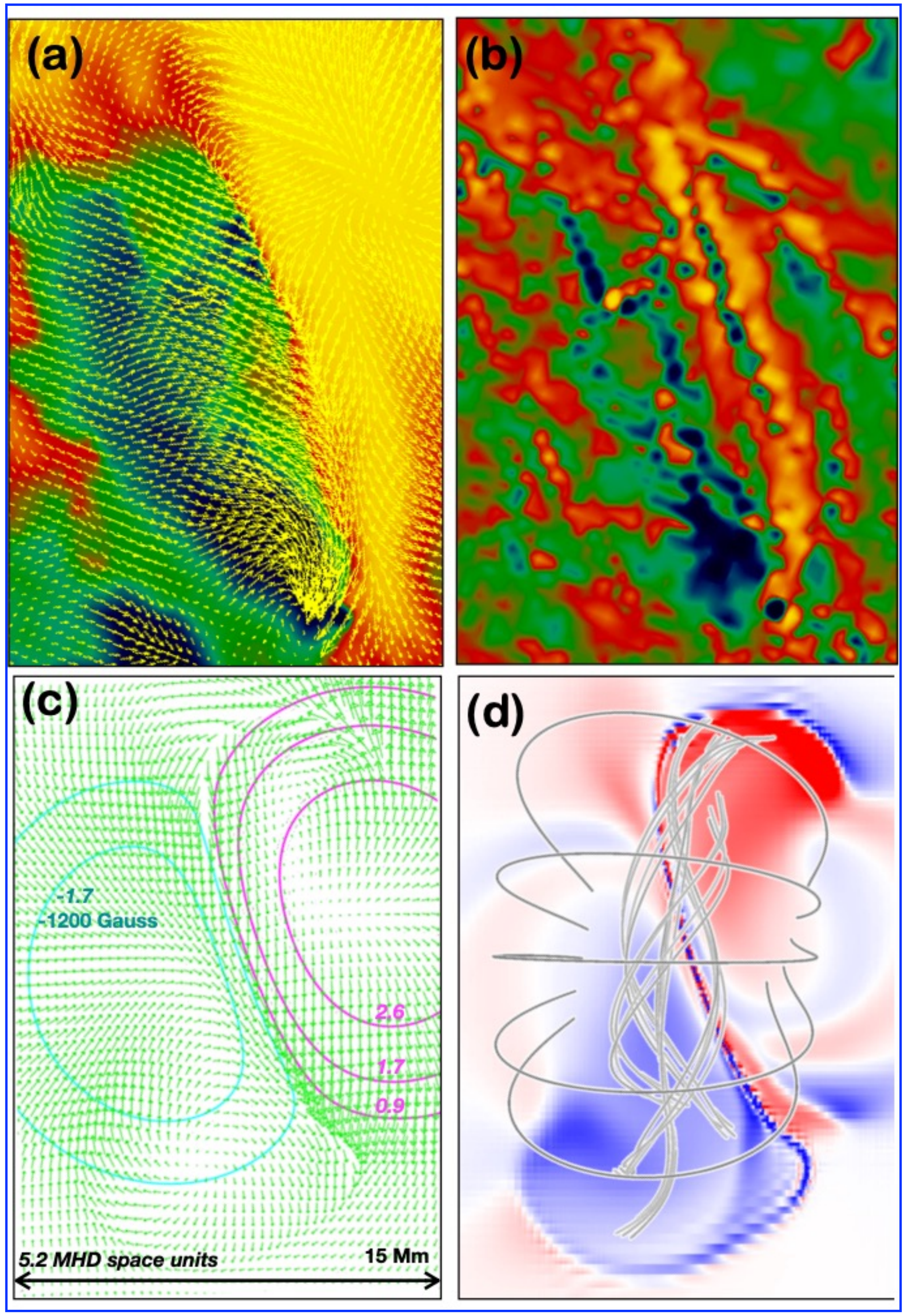


Fig4: Panel (a-b): Vector magnetic field and current density maps. Panel (c-d): MHD simulations which show that FR has very strong electric currents.

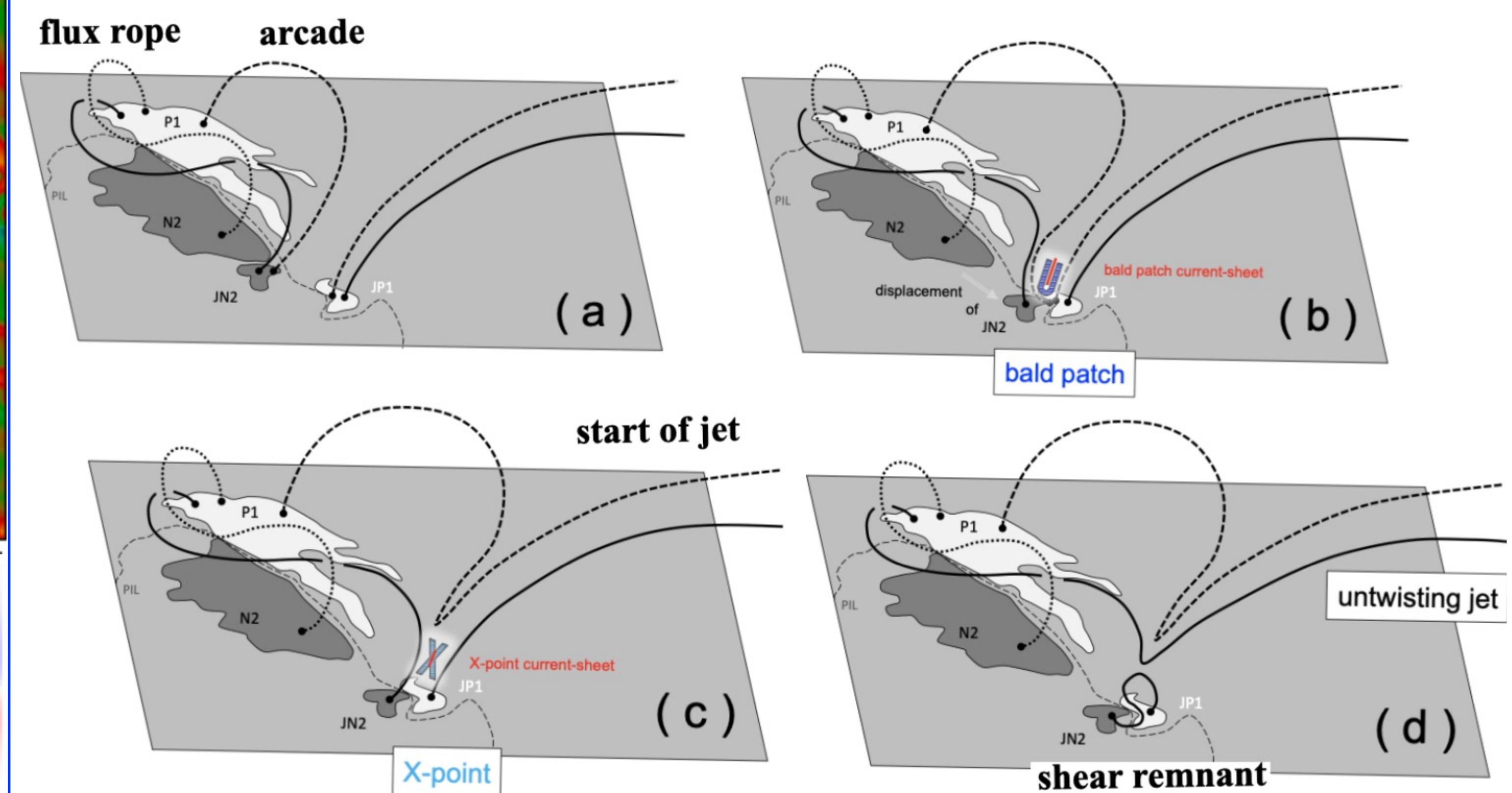


Fig5: Sketch of the formation of the jet and twist transfer

Panel (a): magnetic configuration before the reconnection

Panel (b): formation of the BP current sheet

Panel (c): X-point current sheet

Panel (d): the untwisting jet after the reconnection

Bombardment by energetic electrons

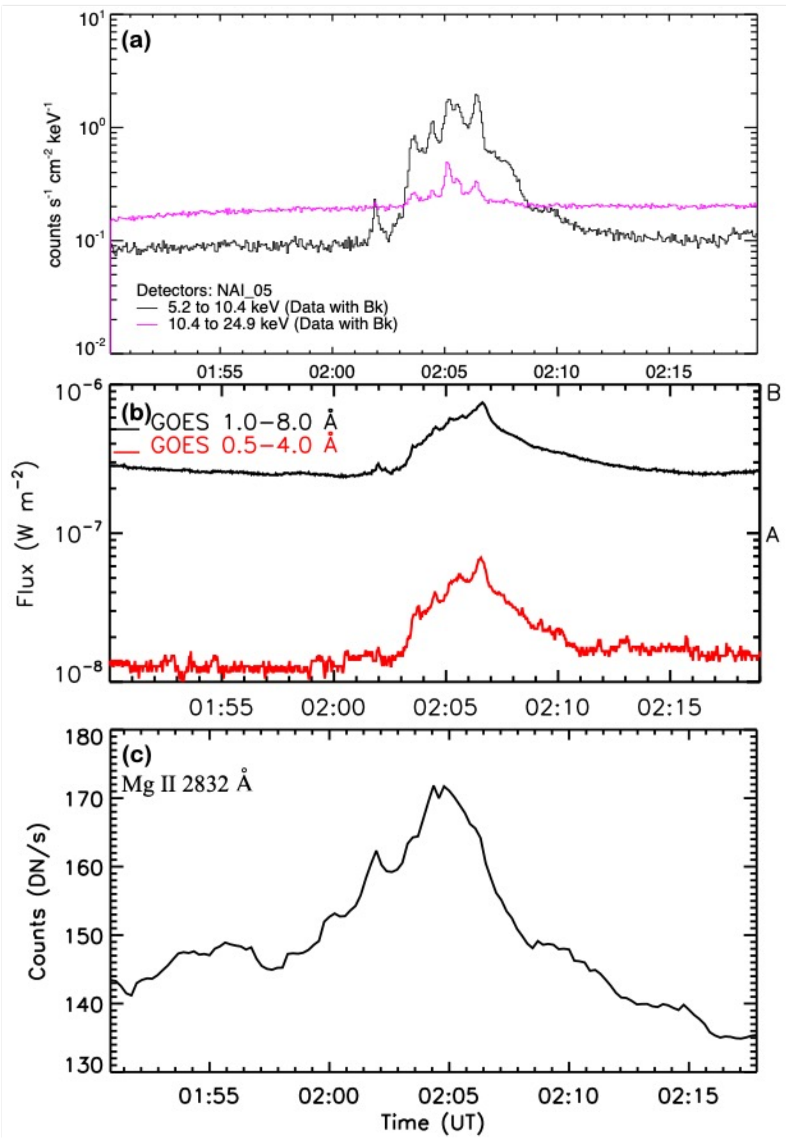


Fig6: Intensity variation at flare site observed in FERMI, GOES, and IRIS.
Panel(a): Soft X-ray (< 20 keV) correspondence in FERMI/GBM observations.
Panel (b): GOES light curve for the B6.7 class mini-flare
Panel (c): Light curve in Mg II SJIs.

Sandwich atmosphere model for mini flare

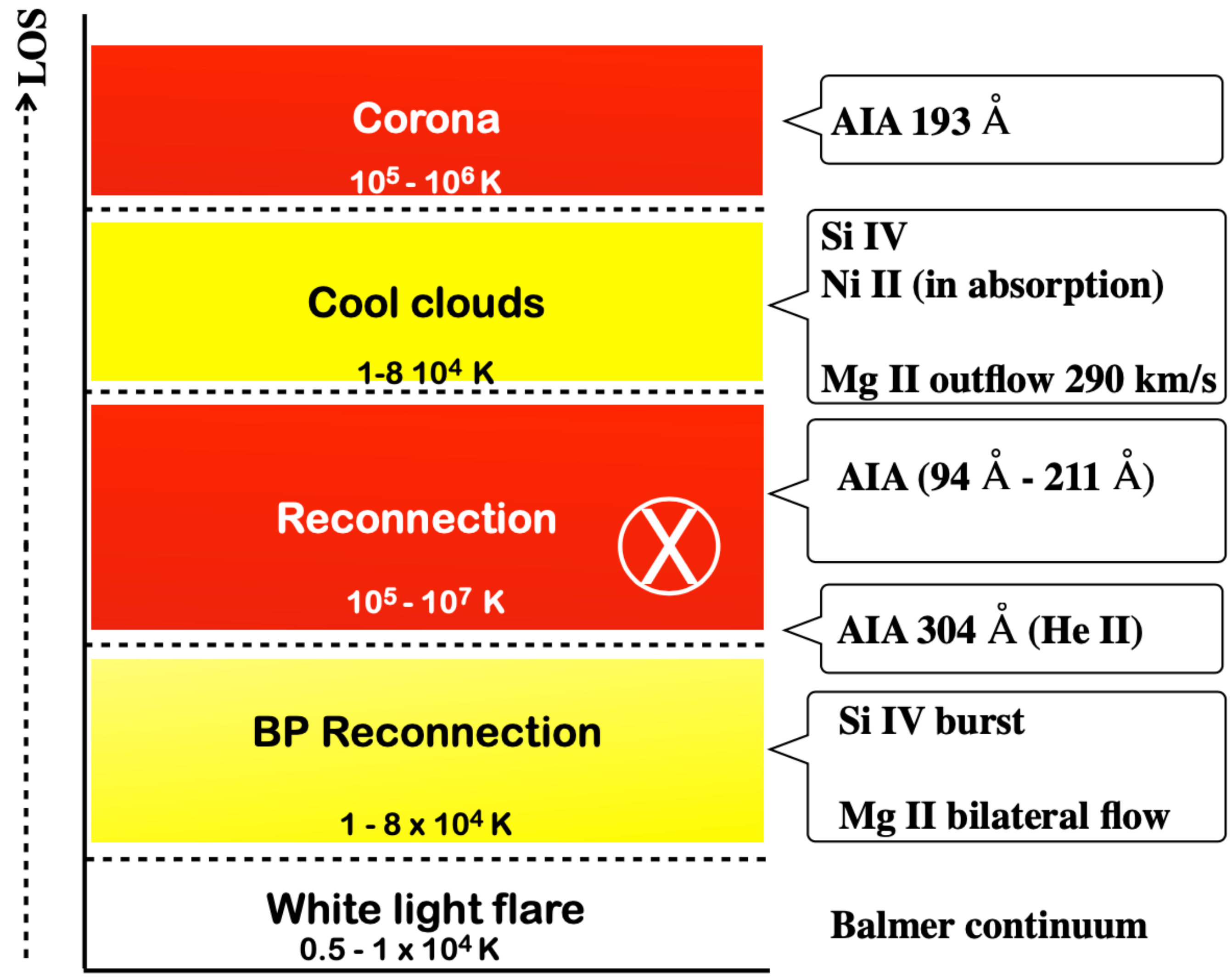


Fig7: Model of multi-layers of the mini flare atmosphere during the jet reconnection in a BP region.

Results

- A part of the flux rope formed a small bipole with a bald patch (BP) region, which dynamically became an X-current sheet during reconnection.
- A strong extension of the blue wing in Mg II decreased over a distance (from –300 km/s to a few km/s). This is the signature of the transfer of the twist to the jet.
- The reconnection would start in the low atmosphere in the BP reconnection region and extend at an X-point along the current sheet.
- The nonthermal HXR emission is related to the enhancement of the Balmer continuum emission, as a signature of a significant excess in heating. This supports the scenario of hydrogen recombination in flares after a sudden ionization at chromospheric layers.

Publications

These results are published as:

Joshi, Reetika, Schmieder, B., Aulanier, G., Chandra, R., Bommier, V., **2020, A&A 642, A169**,

Joshi, R., Schmieder, B., Tei, A., et al., **2021, A&A 645, A80,**

Joshi R., Schmieder, B., Heinzel, P., Tomin, J., Chandra, R., Vilmer, N., et al., **2021 A&A** , **654,A31**

And are presented in the **Ph.D. thesis** by Reetika Joshi (November 2021) .

Detection of high flows speed : 300 km/s by the cloud model method

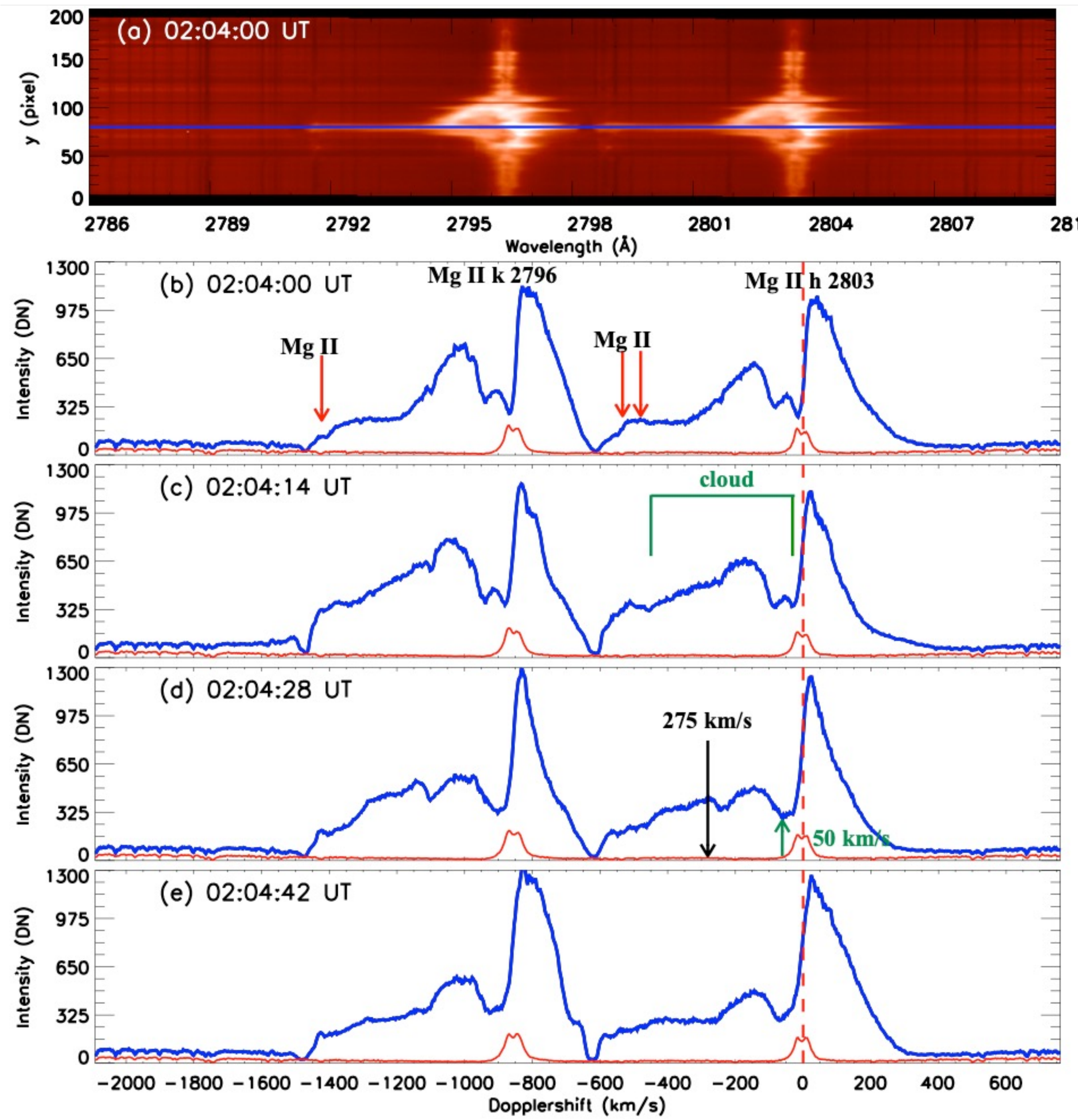
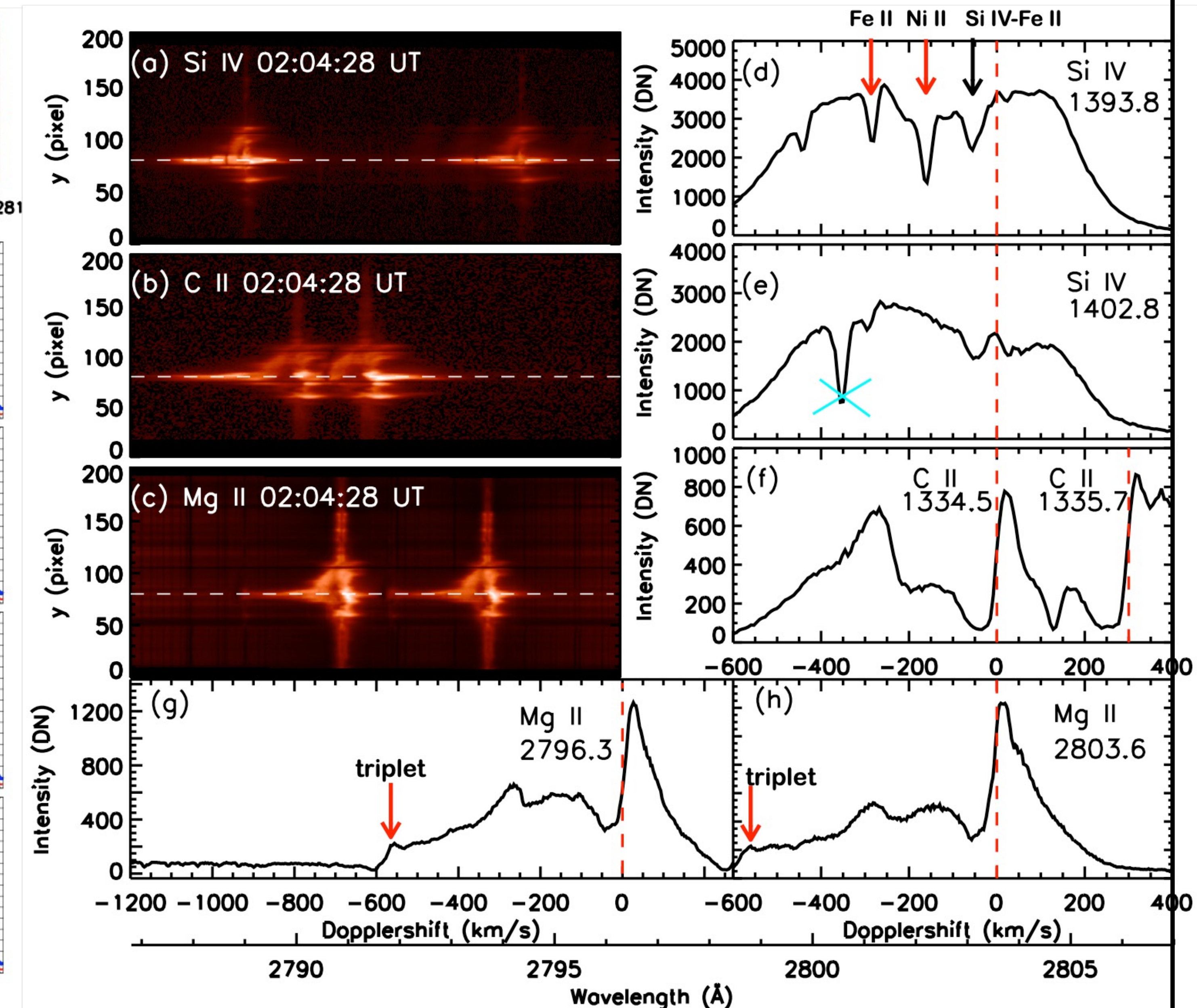


Fig2: Panel a: Mg II spectra before the UV burst. Panels b–e: evolution of the Mg II k and h line profiles.



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