Observations of Recurrent Coronal Jets by IRIS, Hinode and SDO

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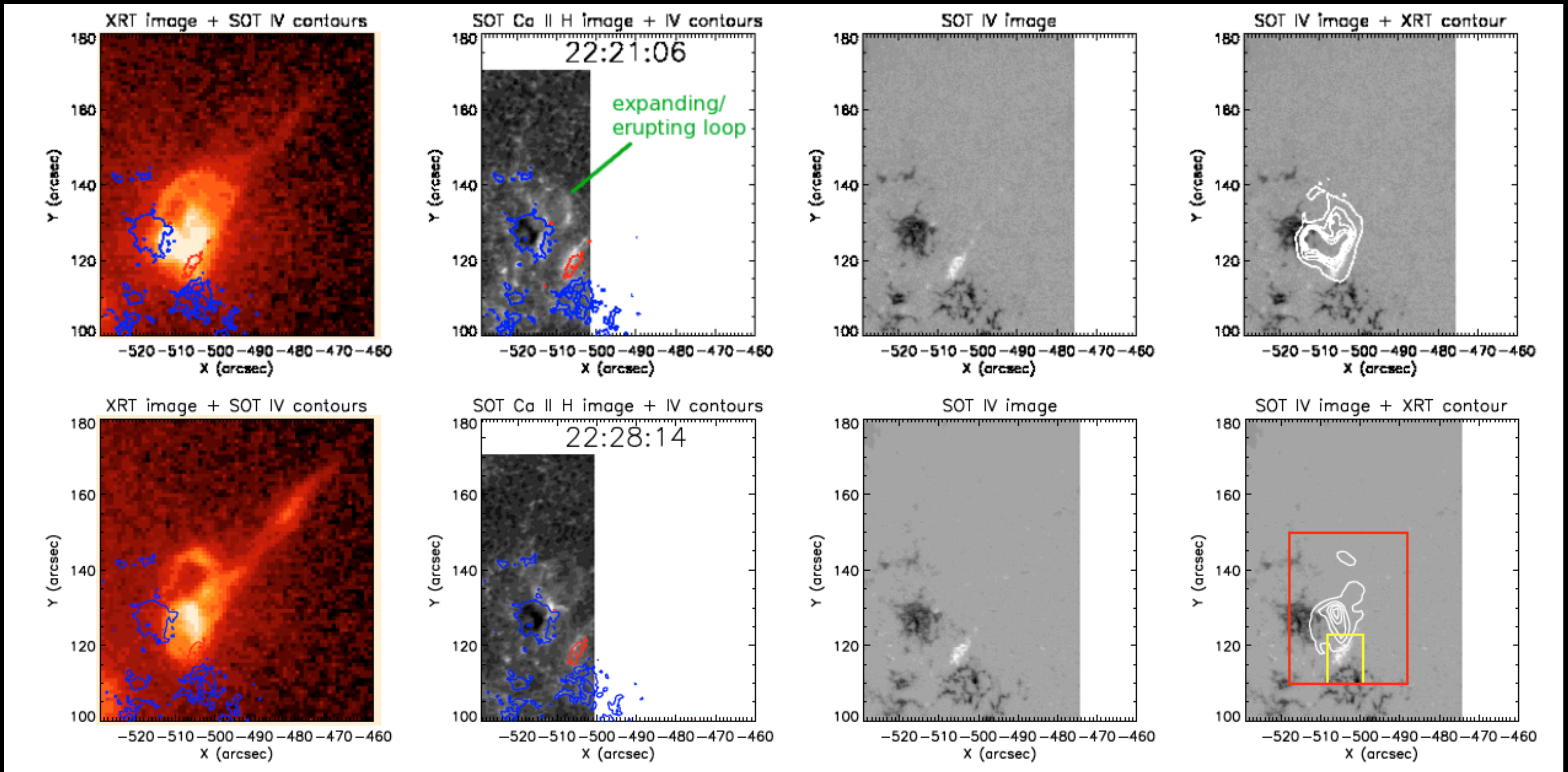
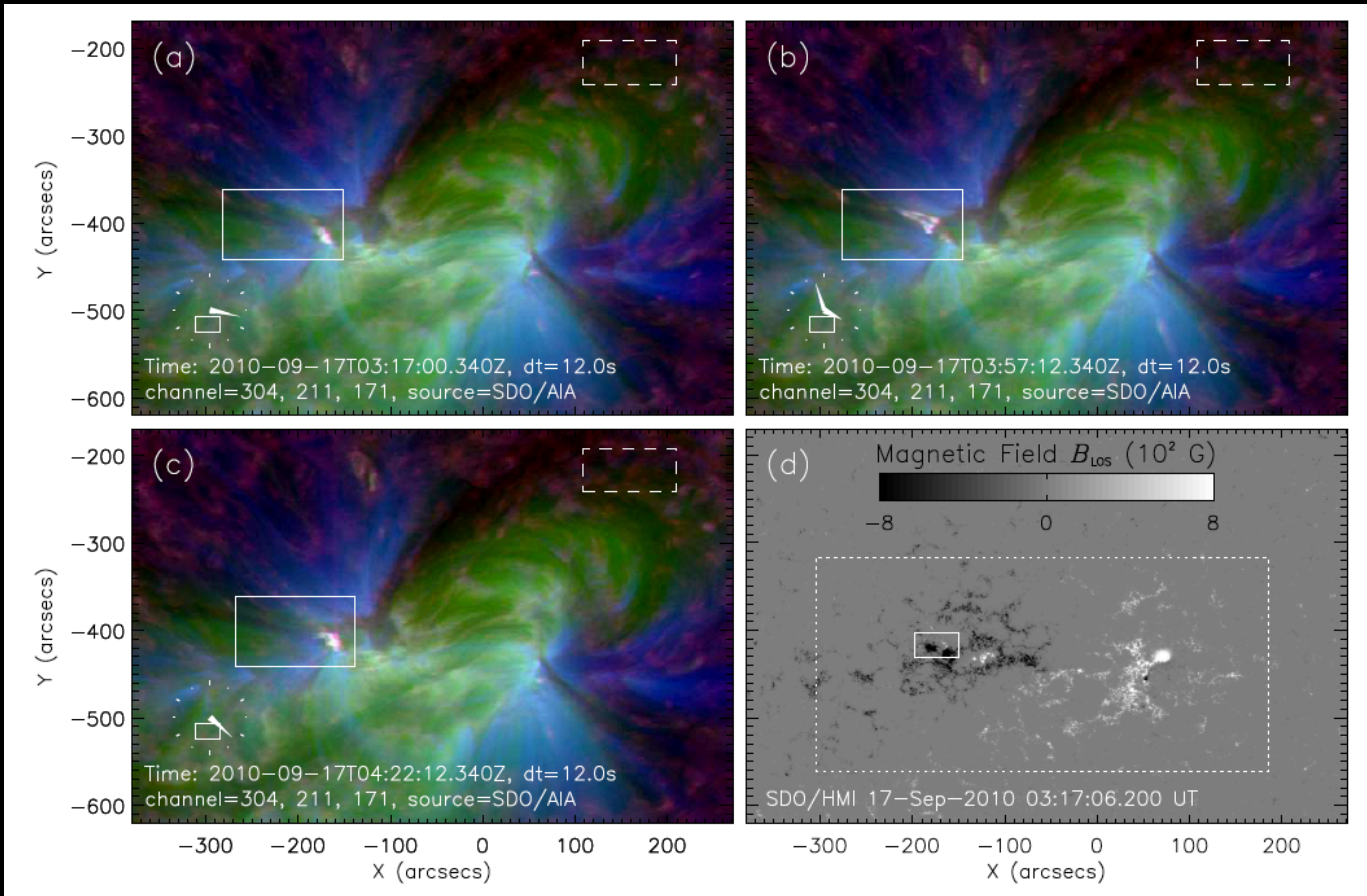
Hinode 7 Science Meeting, 12th - 15th November 2013, Takayama, Gifu

Outline

- Introduction: Some recent observational work on recurrent jets
- Observation of 4 jets by SDO, Hinode and IRIS
- Modeling of magnetic field structure and evolution
- Summary

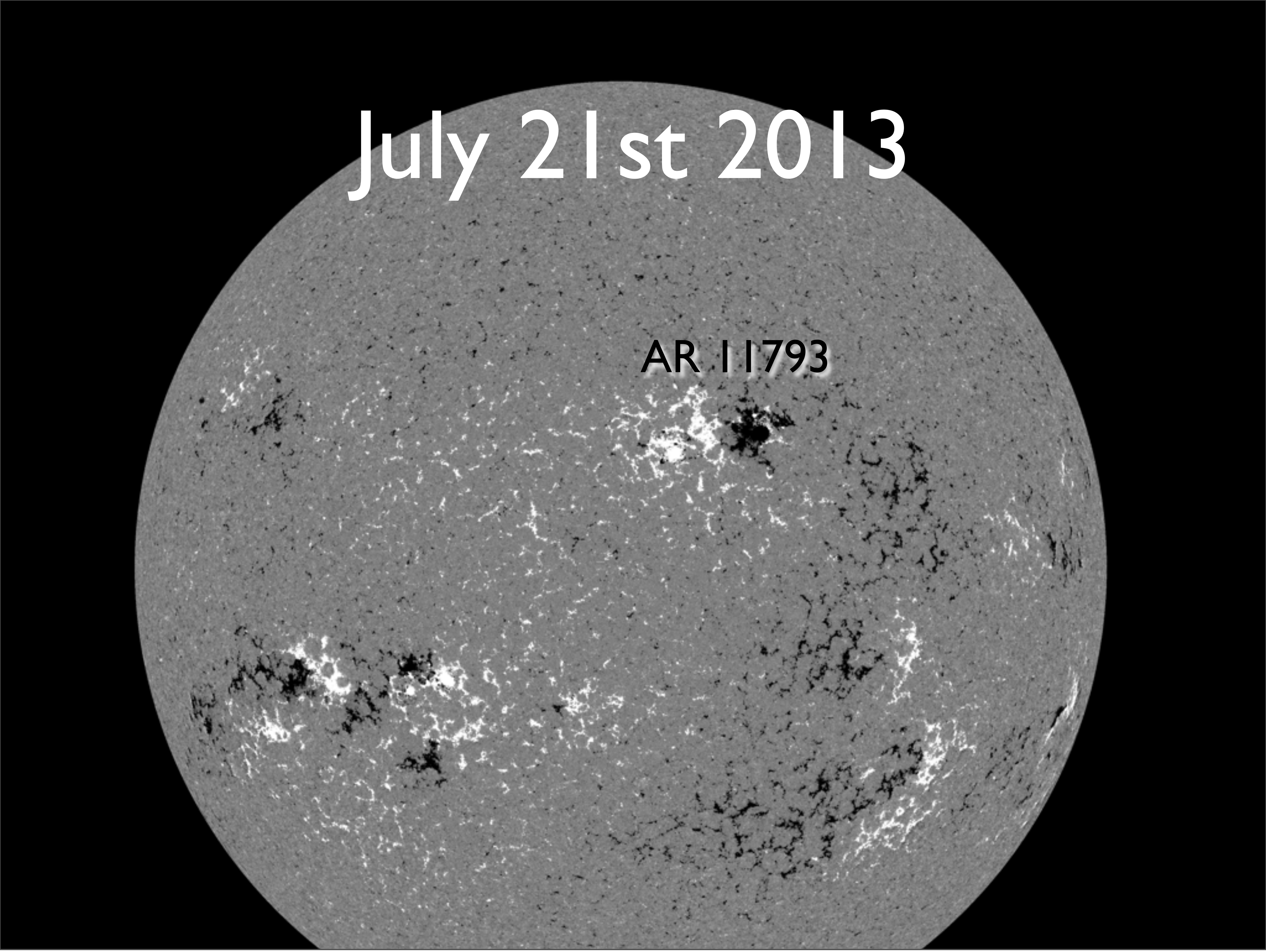


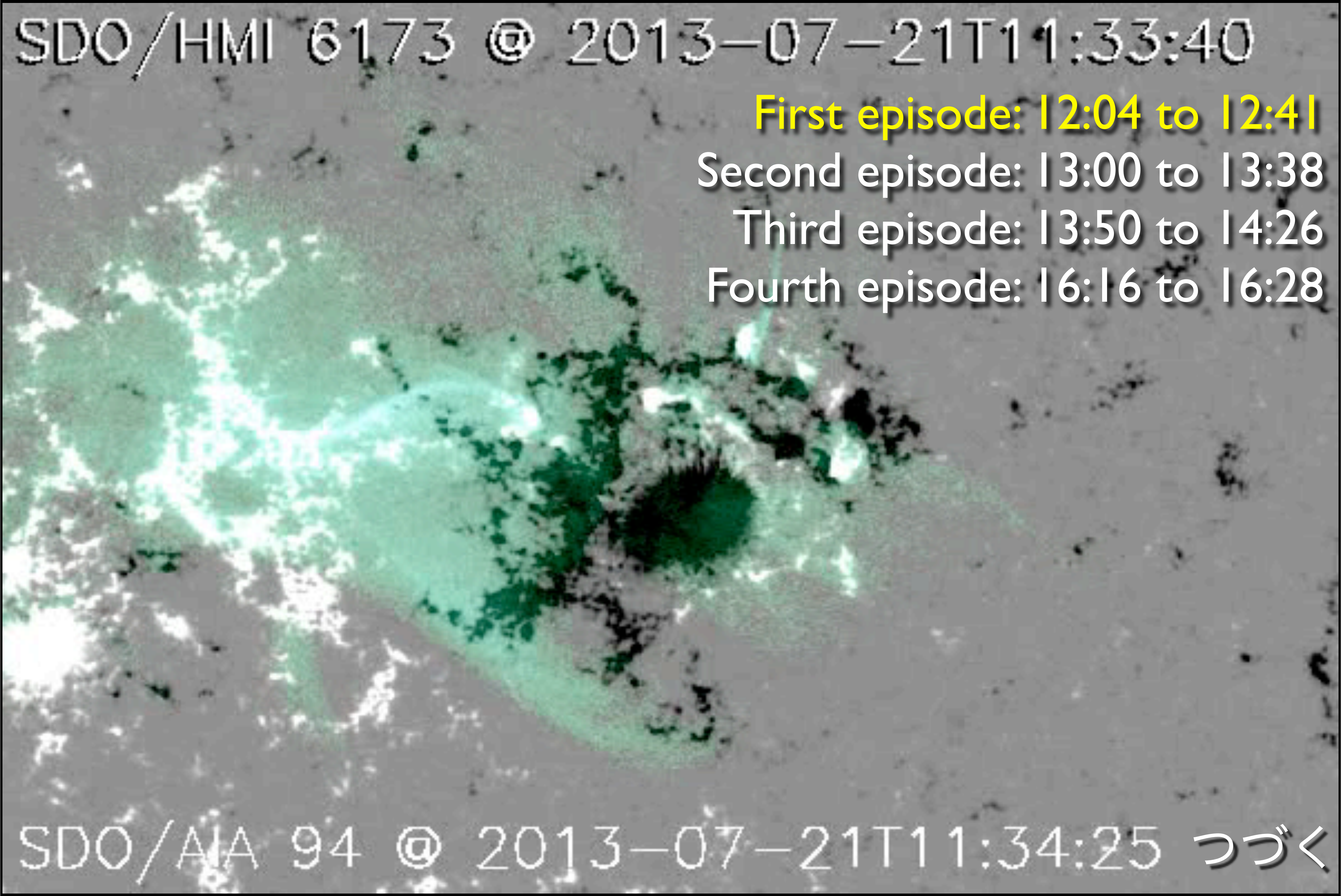
Chifor et al (2008): Recurrent photospheric flux cancellation events result in the appearance of X-ray and Ca II H jets (c.f. EUV jets observations by TRACE as studied by Chae et al 1999). No clear sign of rotational signature.

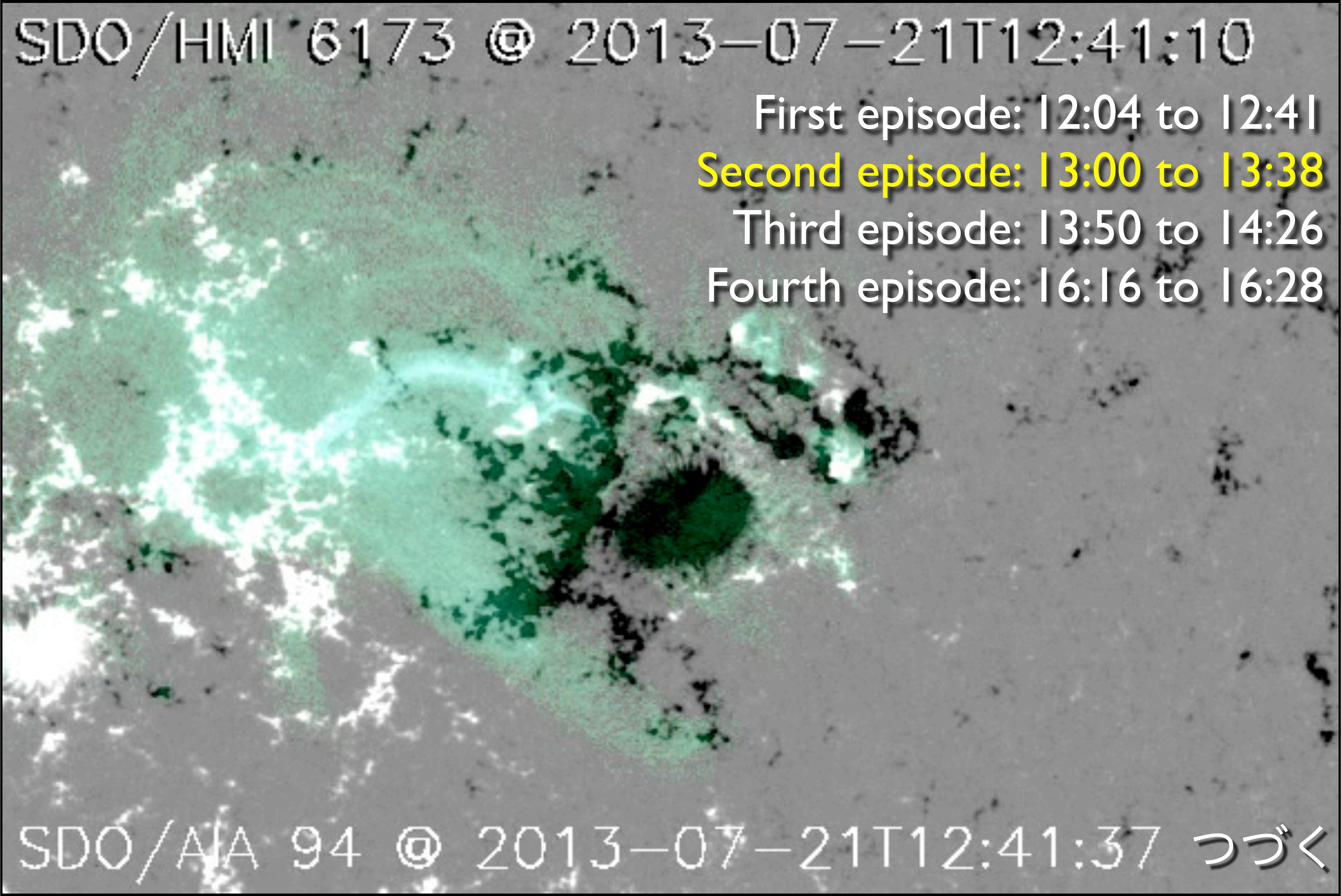


Guo et al (2013), Schmieder et al 2013: Recurrent EUV jets from a parasitic magnetic patch interacting with its \`host'. Diverging photospheric flows are thought to drive the jets. Integrated vertical current seems to peak at the same times (or just before) peaks in AIA 171 light curves.

July 21st 2013




SDO/HMI 6173 @ 2013-07-21T11:33:40
First episode: 12:04 to 12:41
Second episode: 13:00 to 13:38
Third episode: 13:50 to 14:26
Fourth episode: 16:16 to 16:28
SDO/AIA 94 @ 2013-07-21T11:34:25 つづく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SDO/AIA 94 @ 2013-07-21T12:41:37
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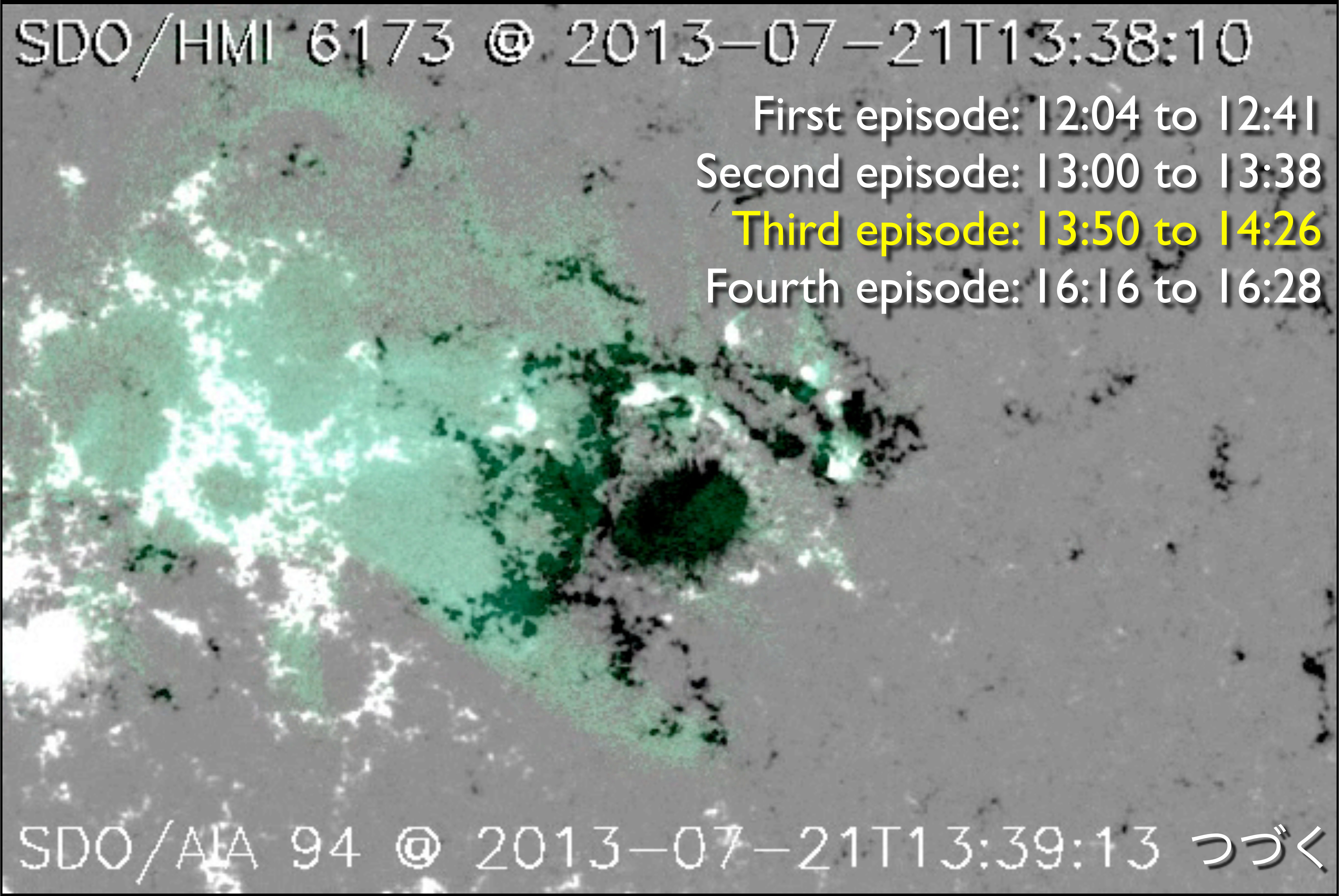
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Fourth episode: 16:16 to 16:28
SDO/AIA 94 @ 2013-07-21T13:39:13
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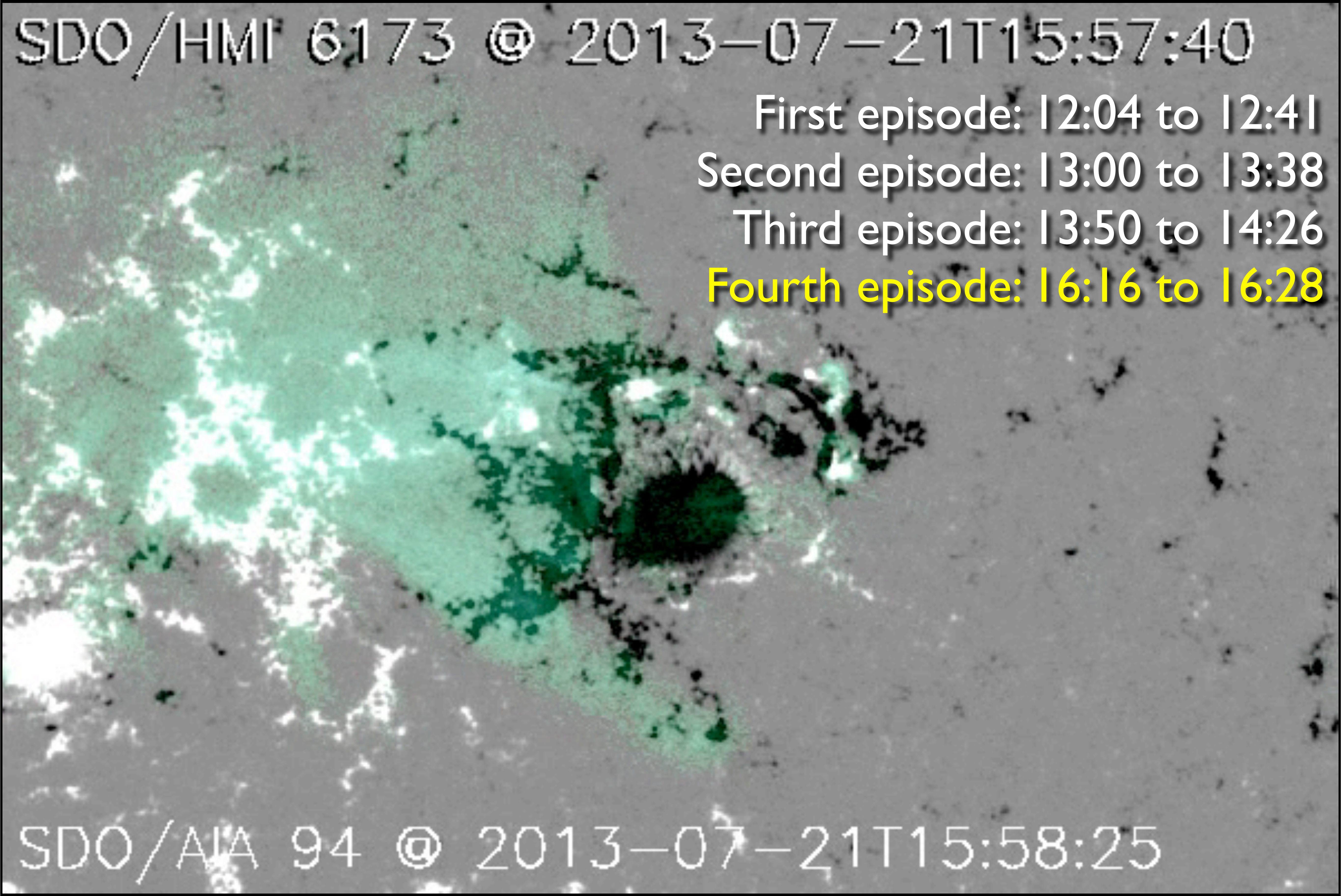
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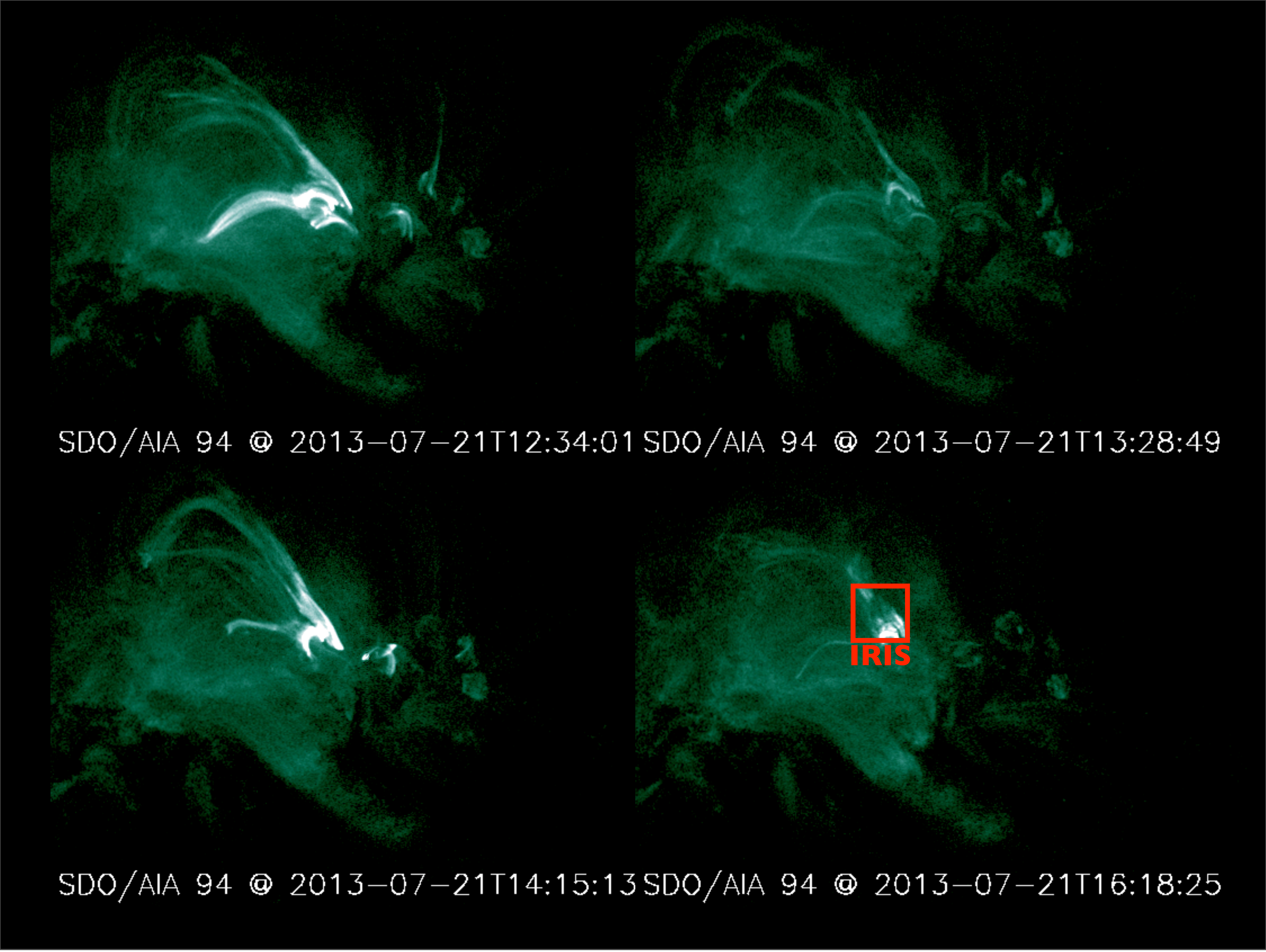
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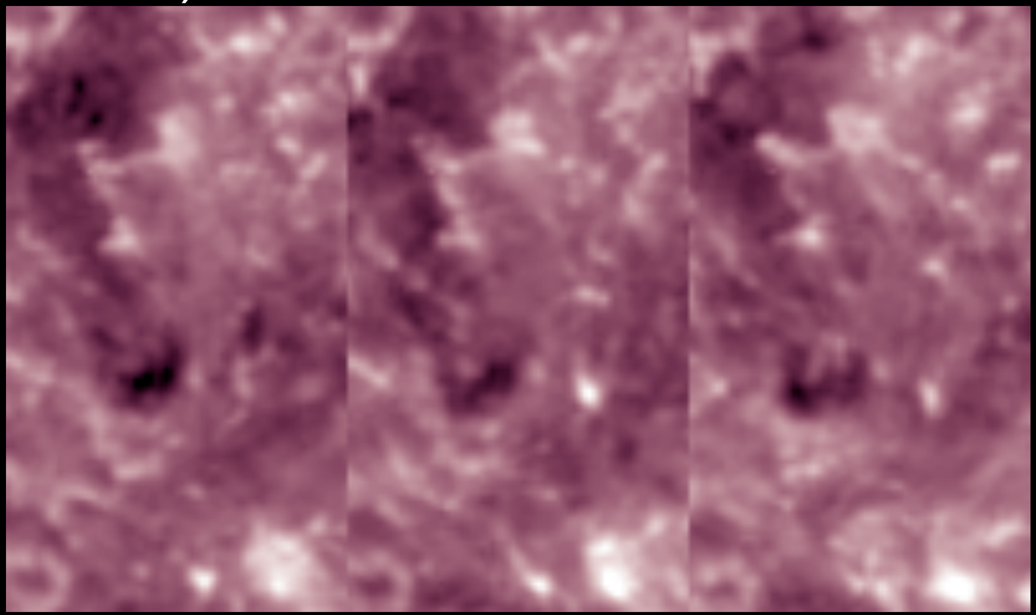
SDO/AIA 94 @ 2013-07-21T13:28:49
SDO/AIA 94 @ 2013-07-21T14:15:13
SDO/AIA 94 @ 2013-07-21T16:18:25
IRIS

- SOT Ca II H images show jet structure similar to the jet studied by Wei Liu et al (2009)
- Lower-atmospheric contribution to Ca II H shows hints of a rotating pore and (perhaps) flux emergence.
- Indirect evidence of flux emergence from appearance of elongated darkenings followed by appearance of bright grains (e.g. Strous & Zwaan 1999, Guglielmino et al 2010).



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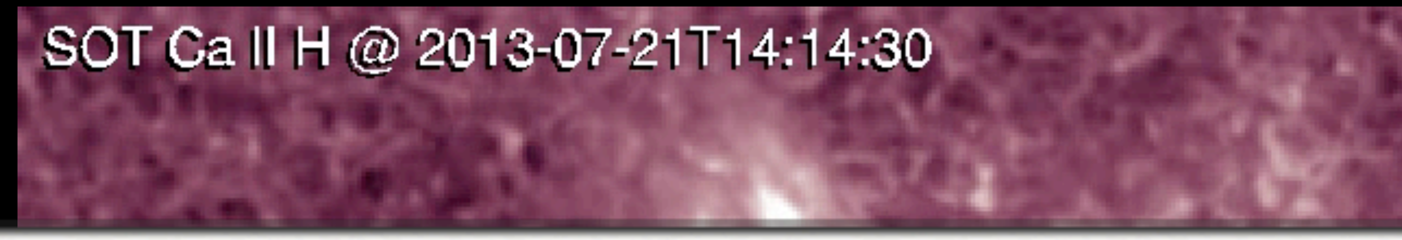

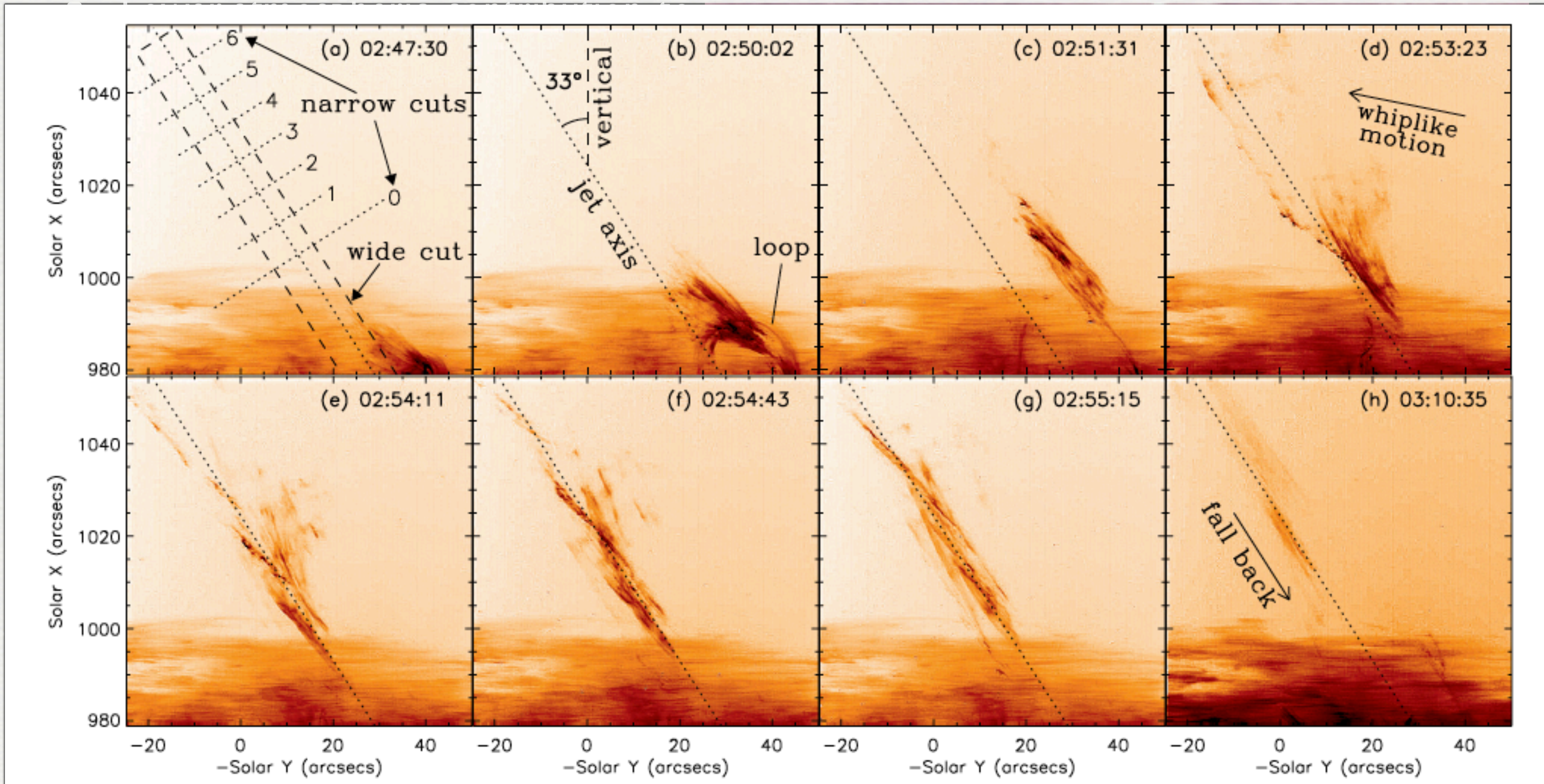

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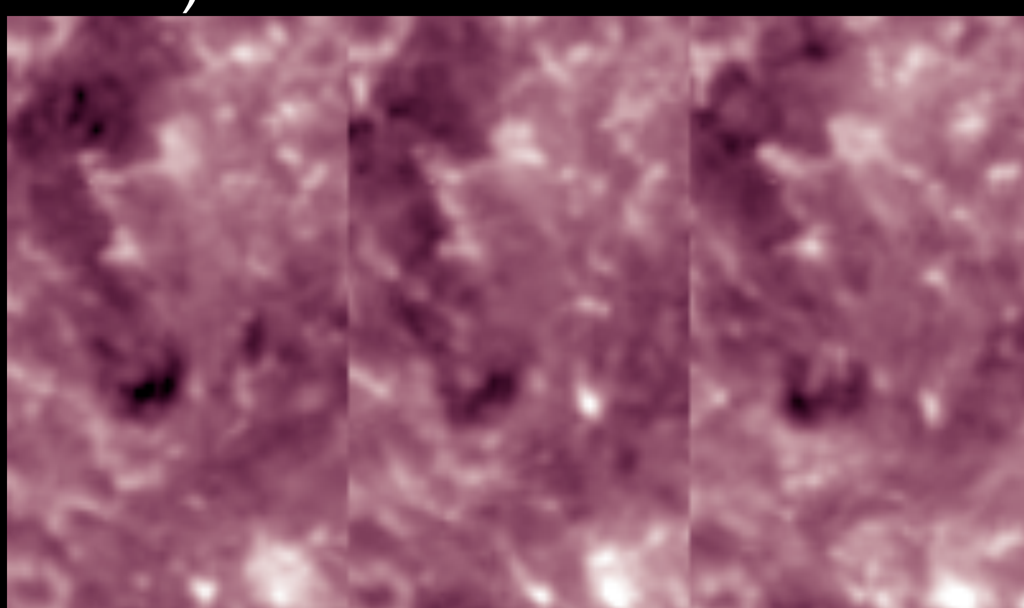

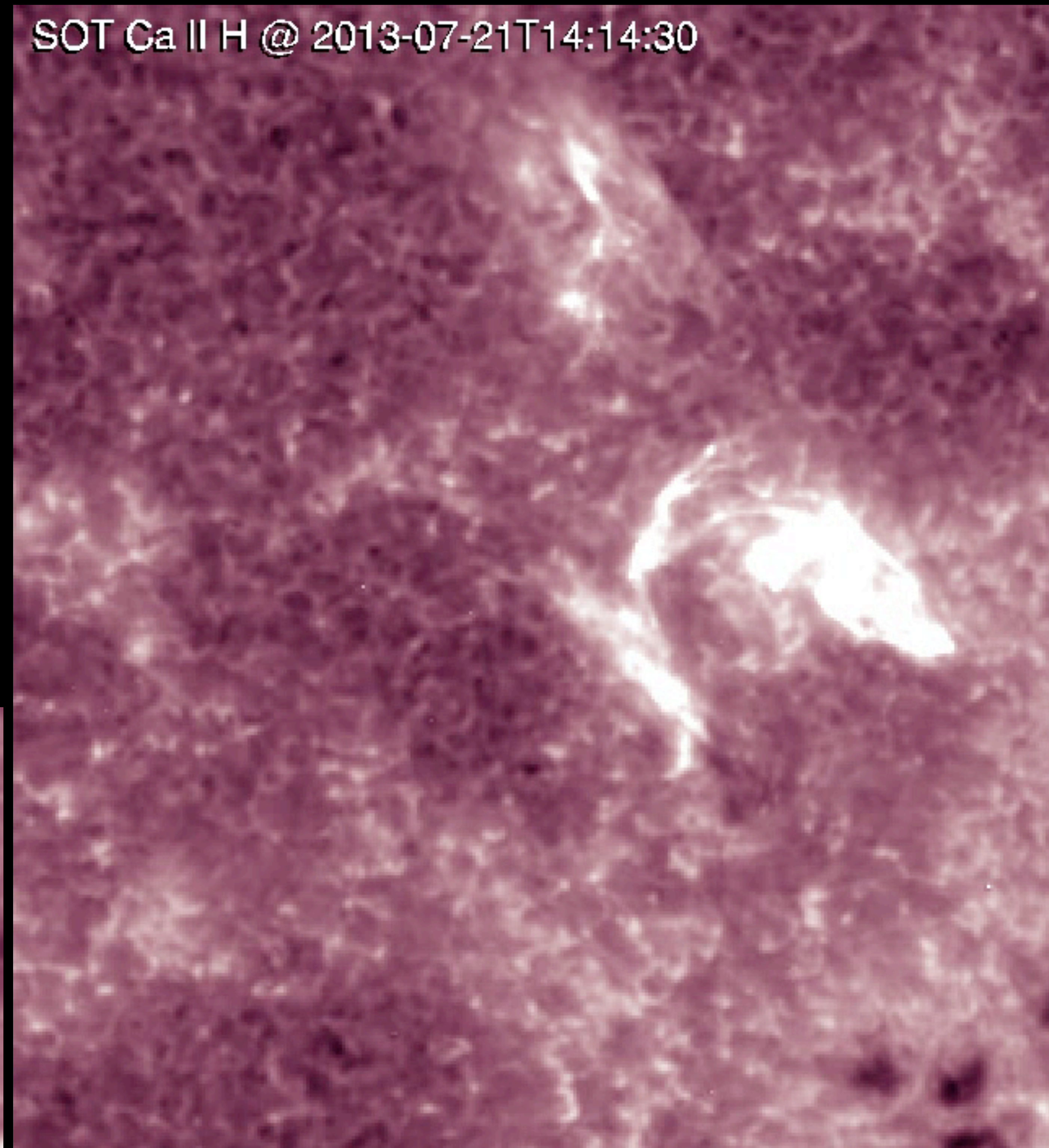

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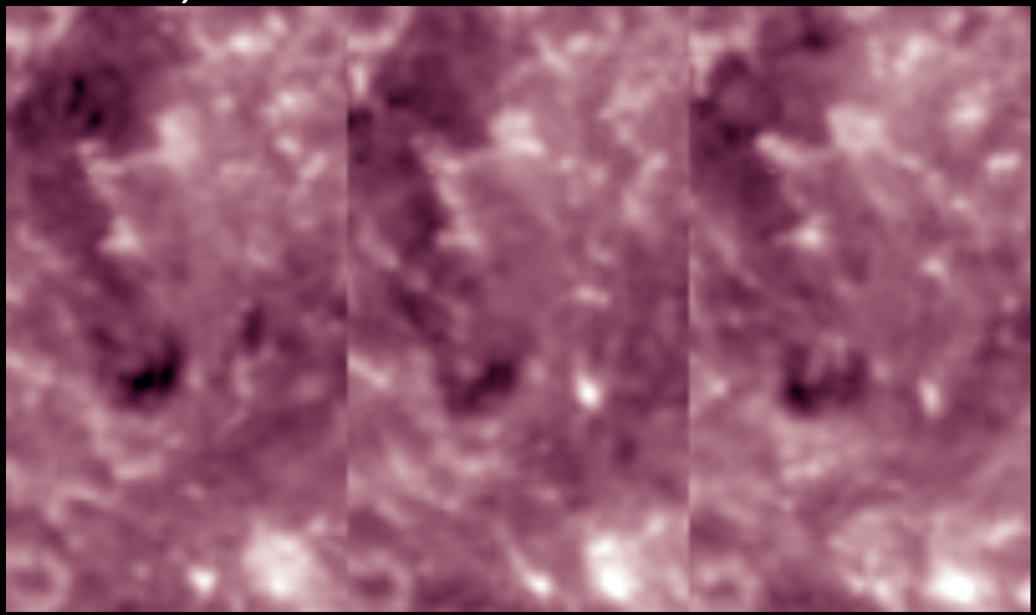

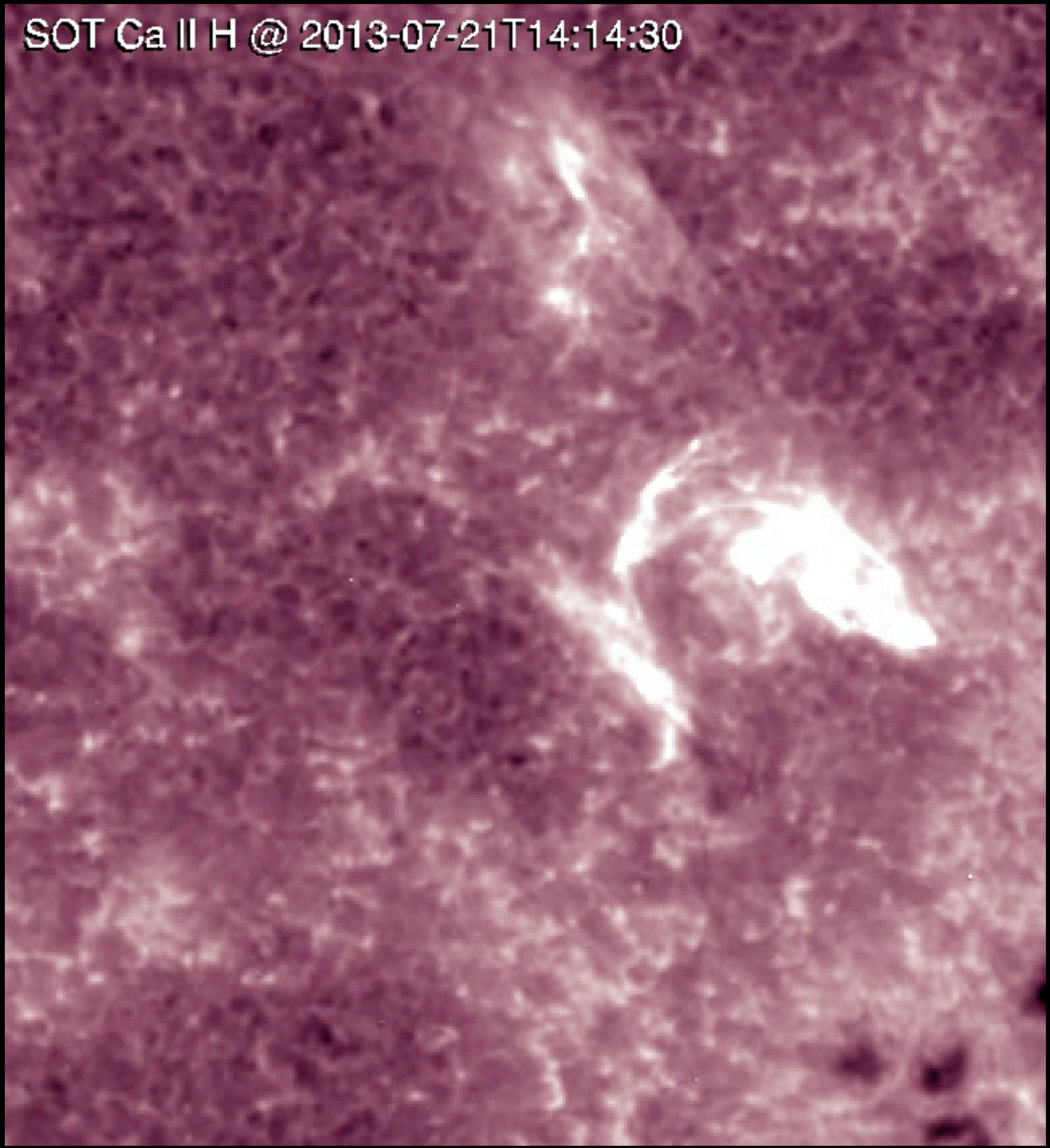

IRIS Observations

- SJI 1400, SJI 1330 and SJI 2796 @ 24s cadence, 60” x 60” FOV, 0.167” arcsec pixel size
- 20-step NUV and FUV spectral rasters with 2 arcsec steps, 2 min / raster, 38” x 60” FOV
- Focus on FUV spectra in this presentation.

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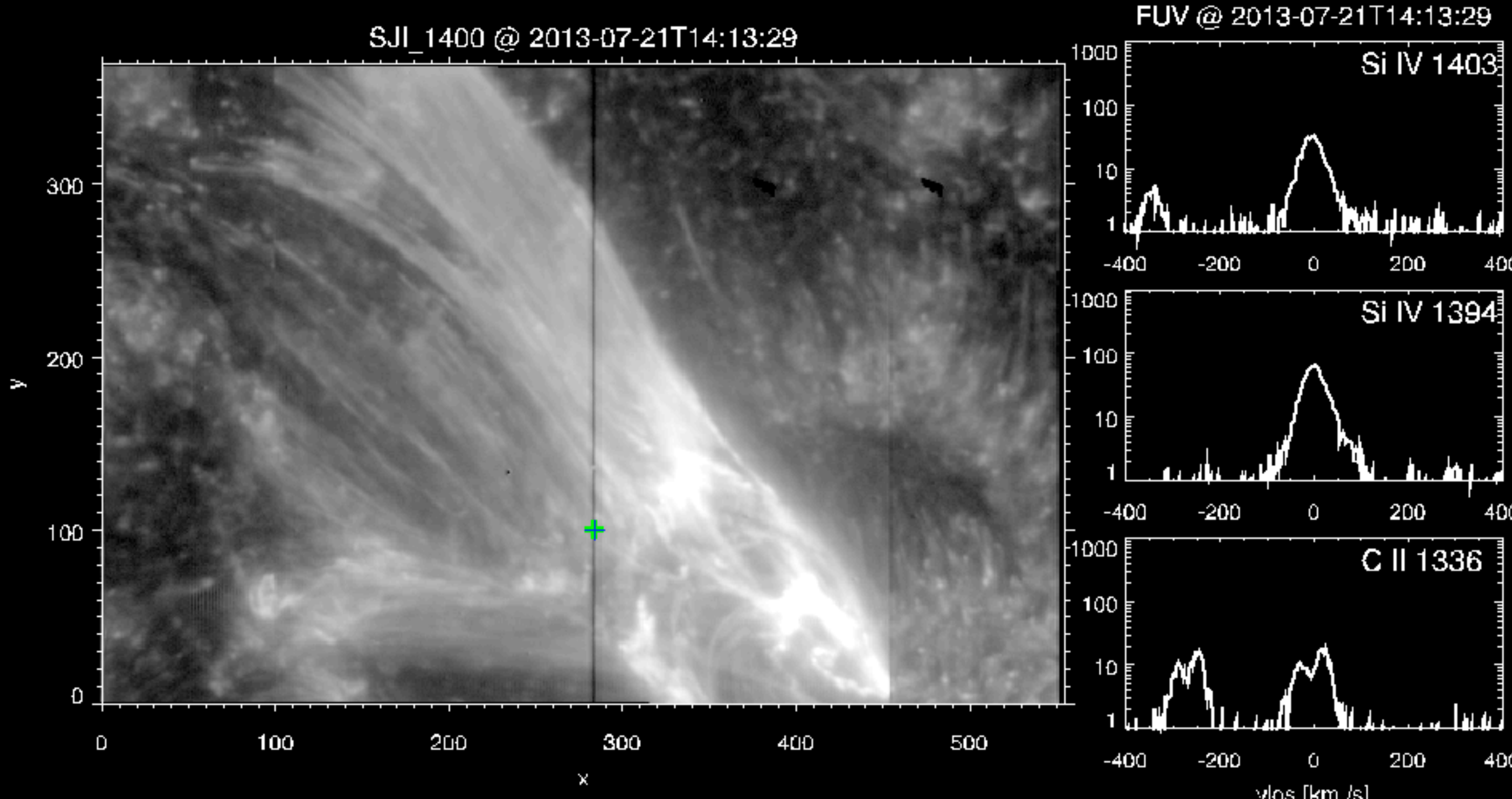

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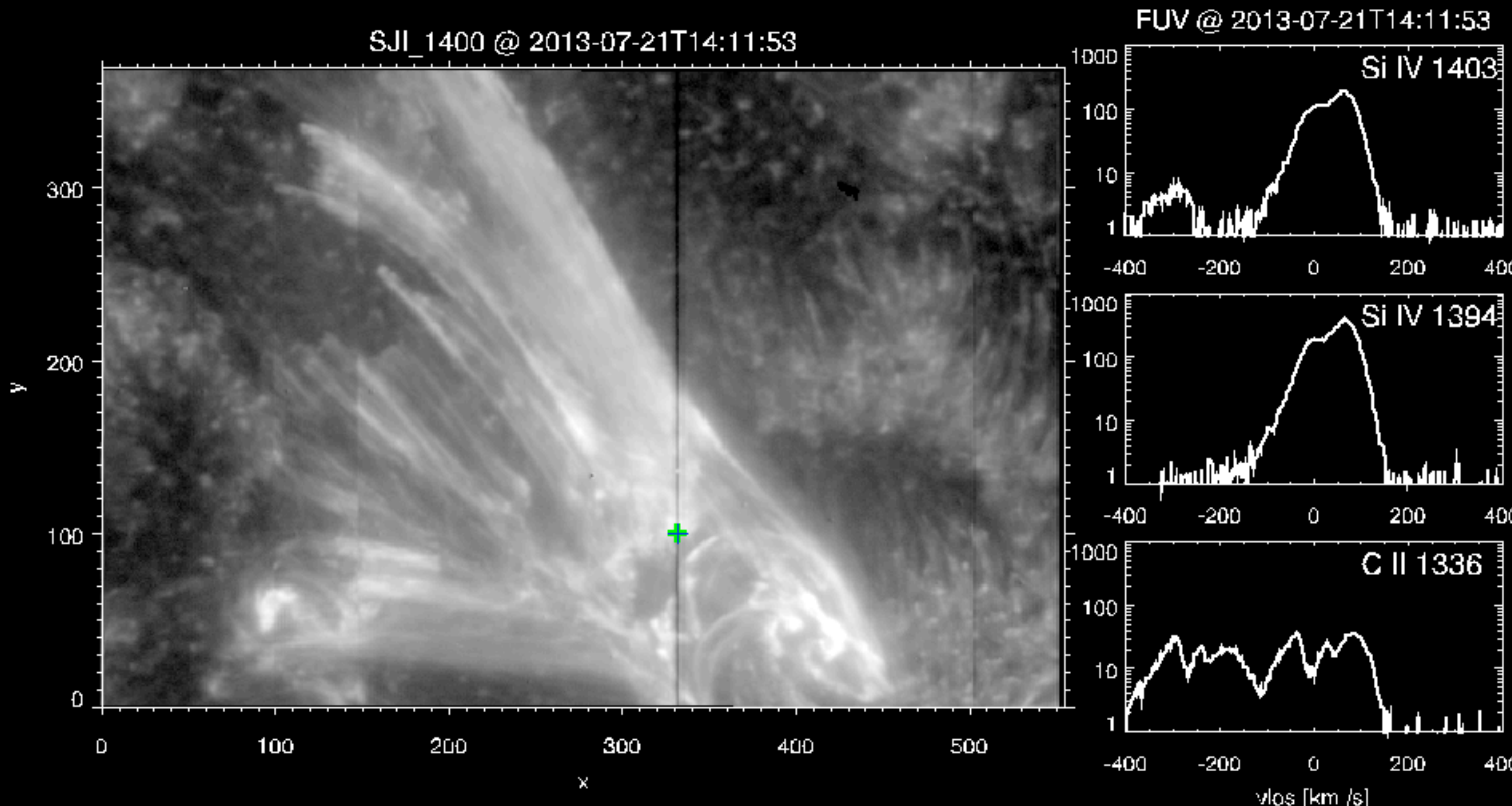
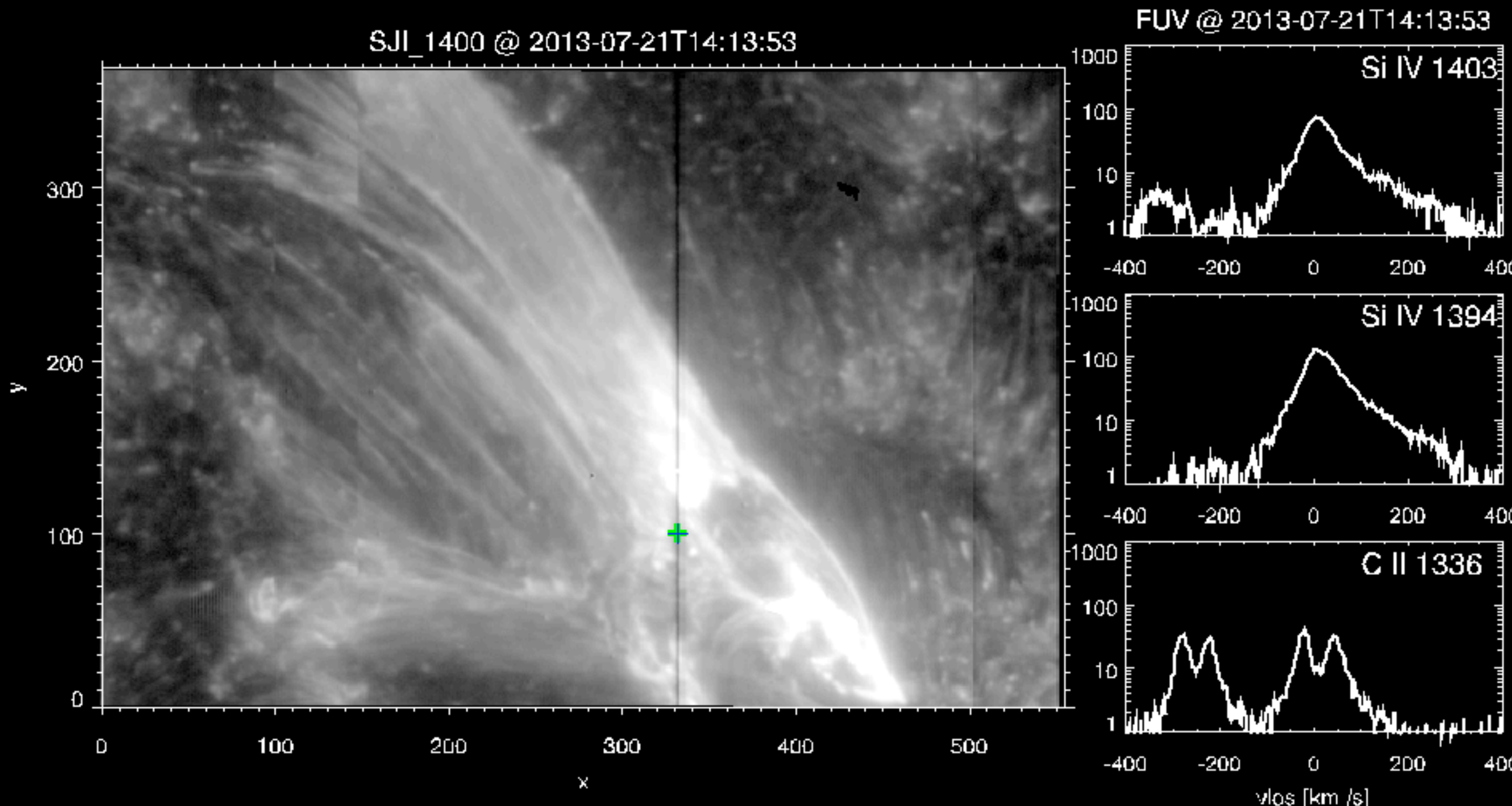


- Si IV 1403 and Si IV 1394 are TR lines with similar profiles.
- During the impulsive phase the Si IV profiles clearly have multiple components.
- The C II lines can be optically thick and care is required for interpretation (see poster by Rathore, S-2 P-02).



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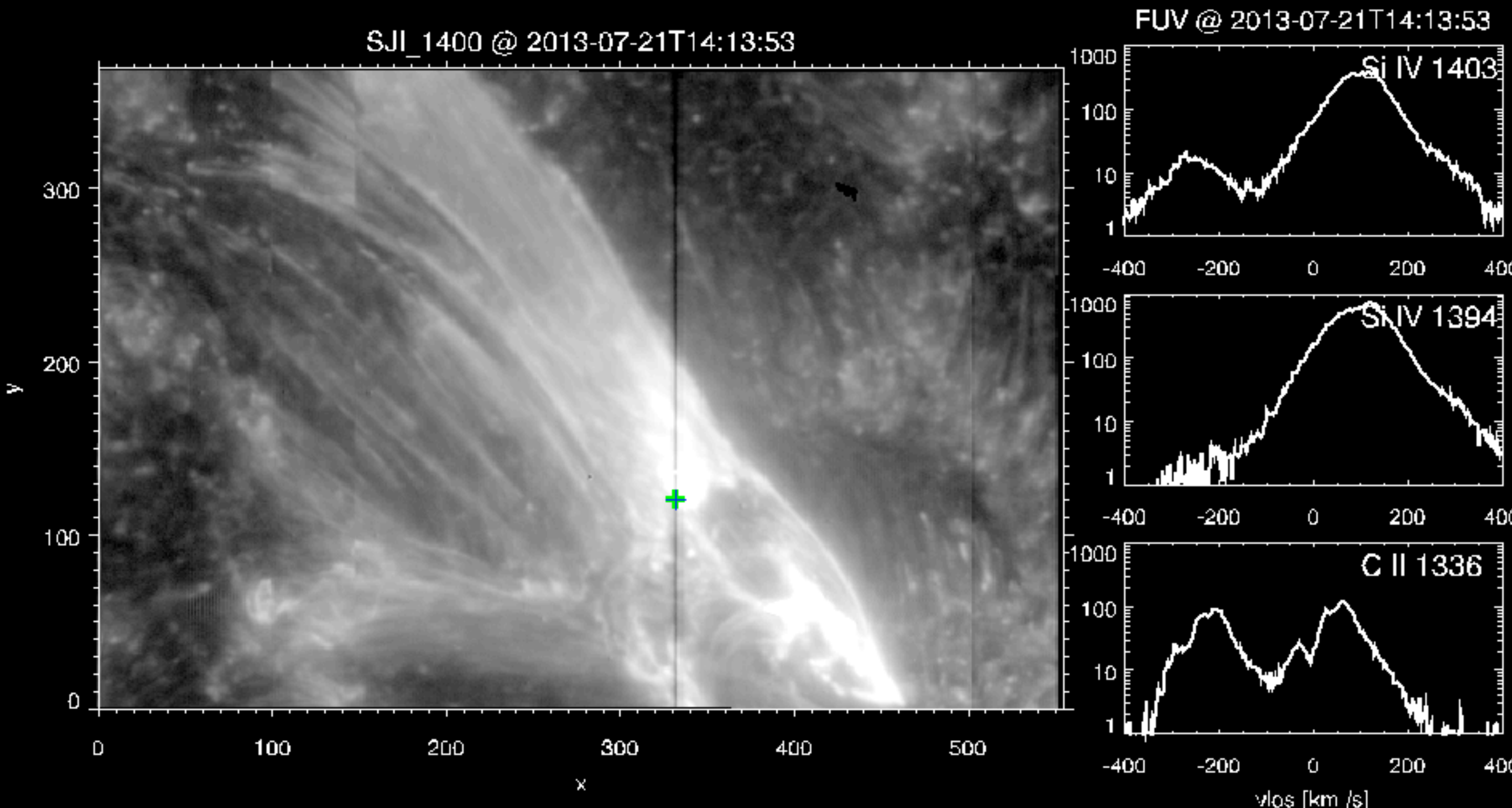

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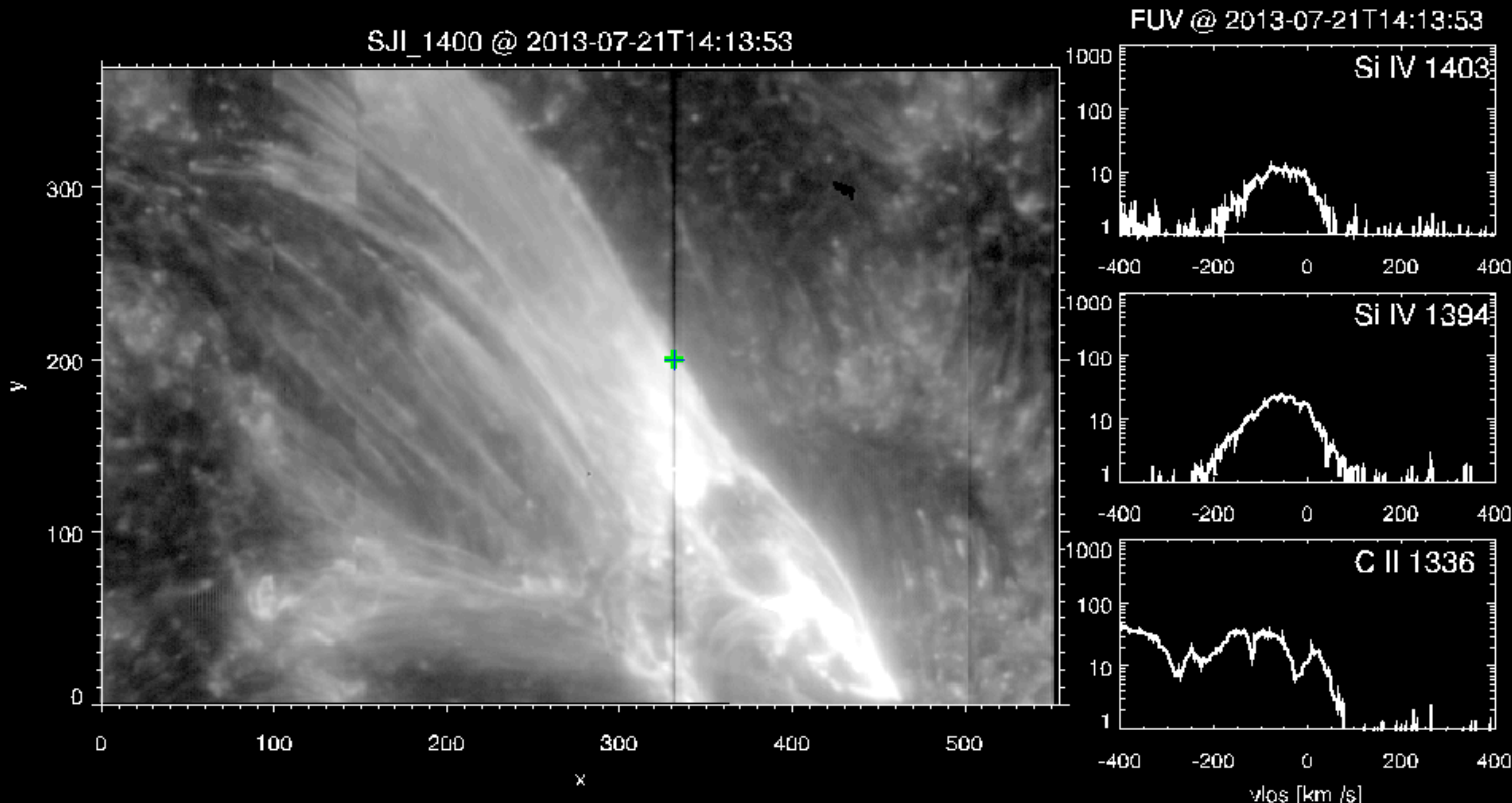

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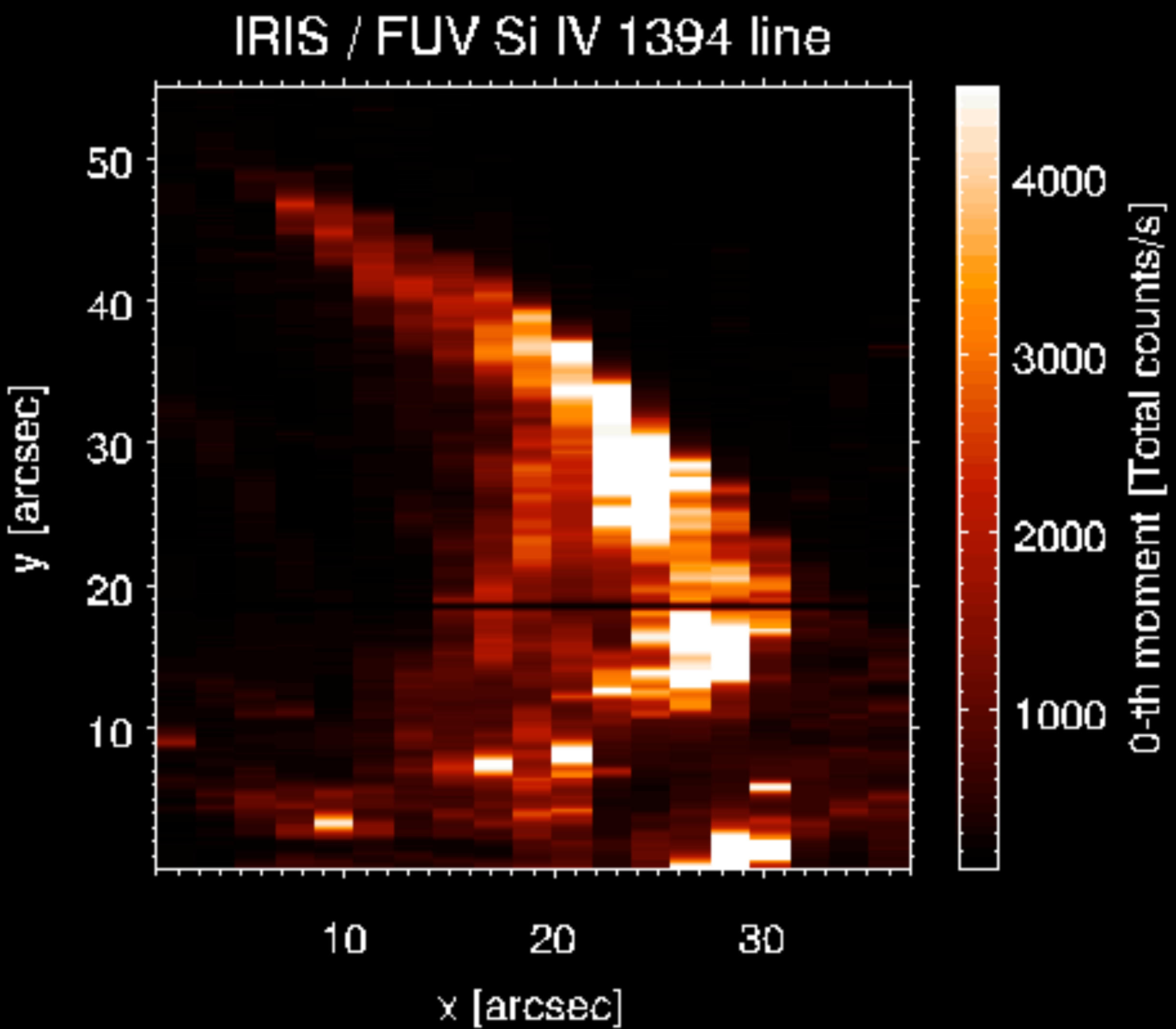
Helical Flow: 1st Jet

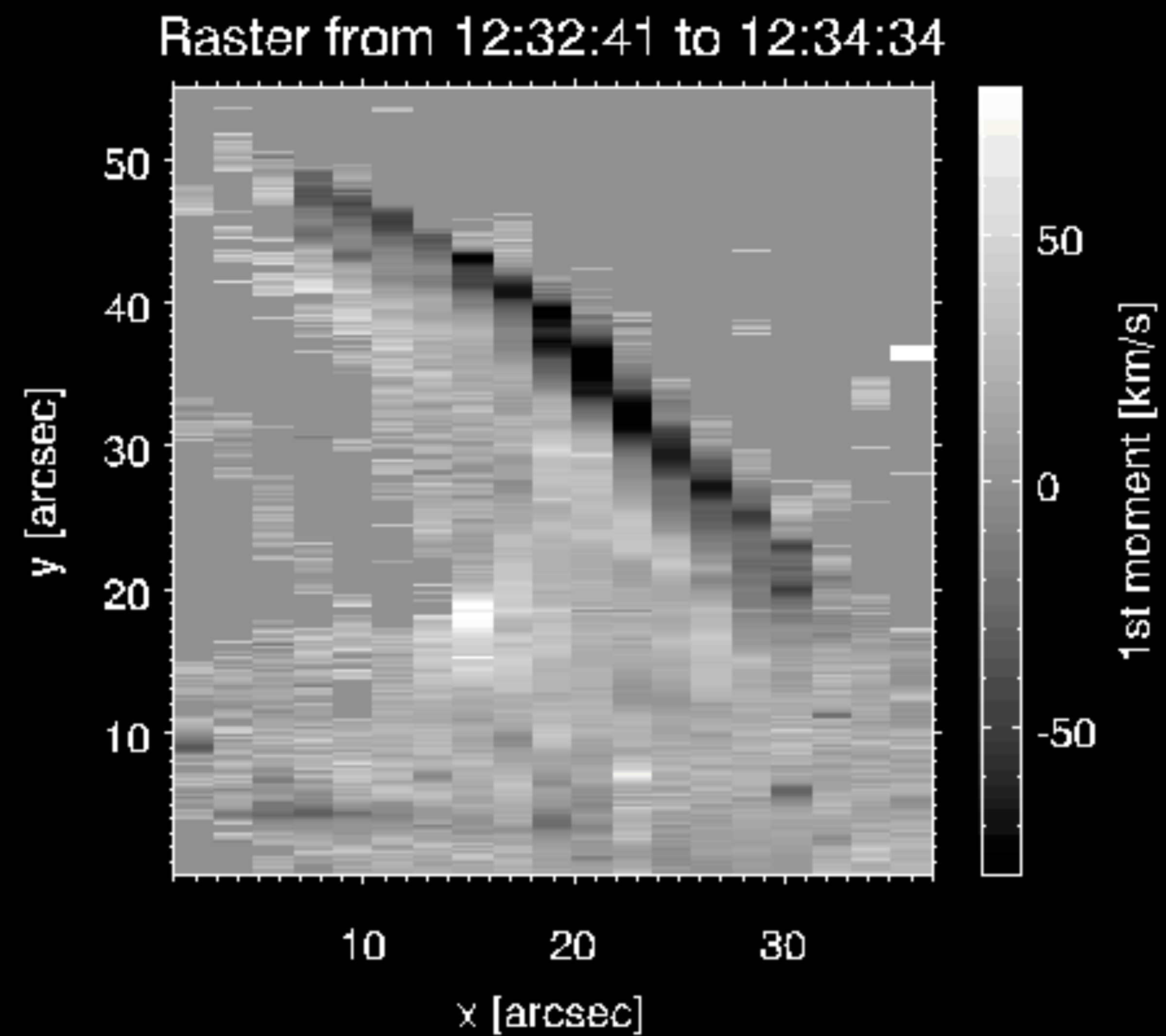
Integrated line intensity

First moment ~
weighted Doppler velocity

Helical Flow: 1st Jet



Integrated line intensity



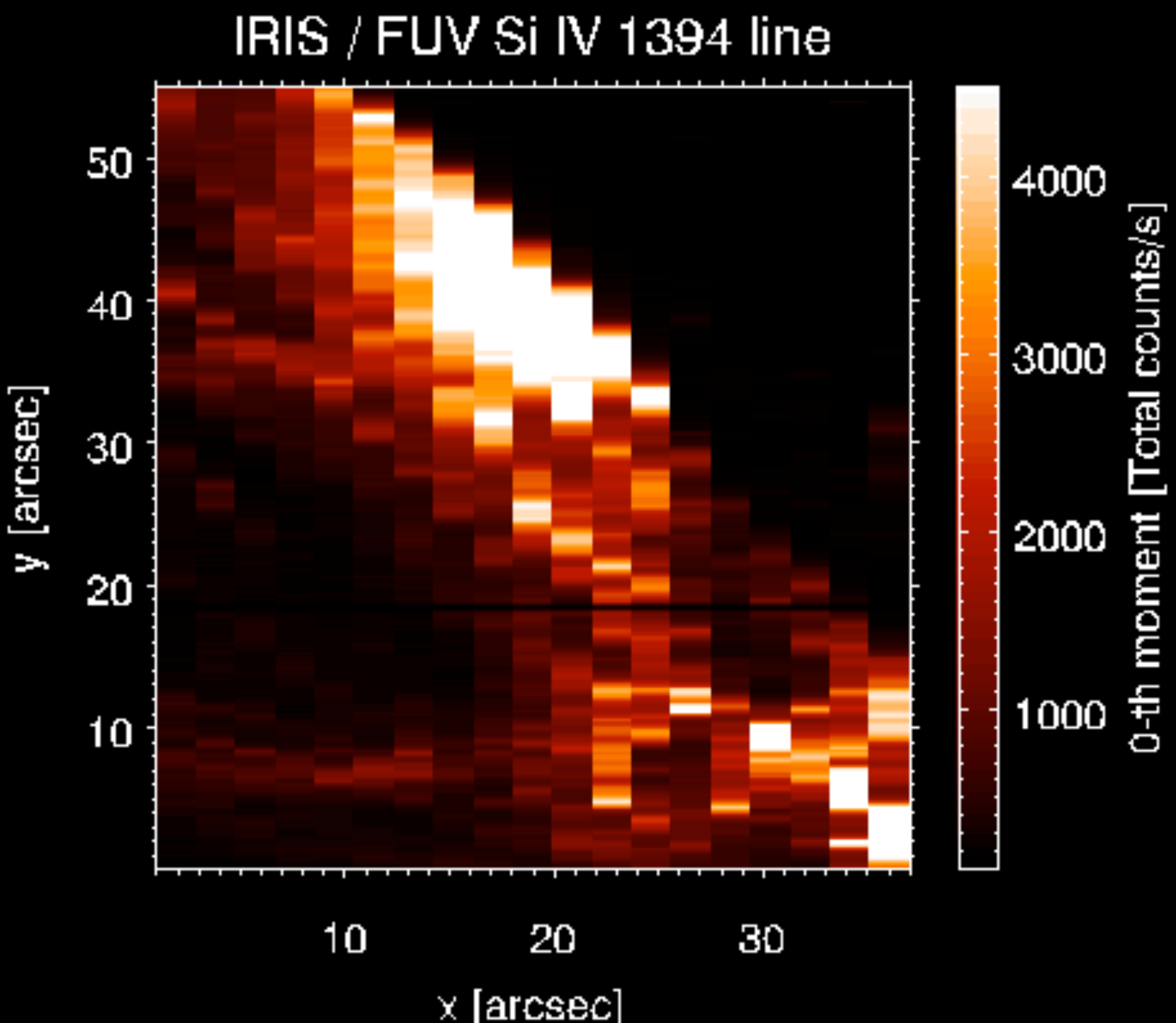
First moment ~
weighted Doppler velocity

Helical Flow: 3rd Jet

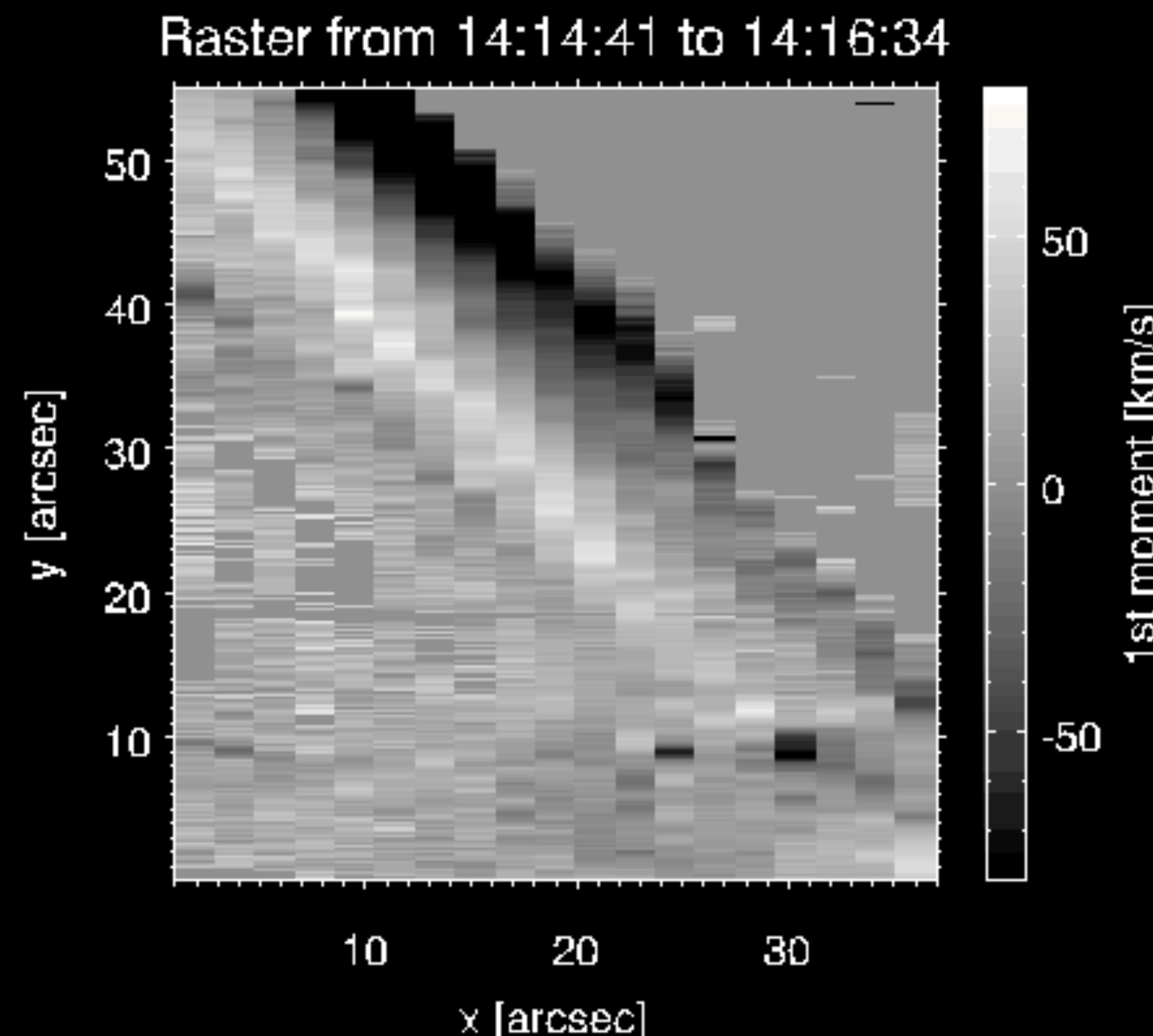
Integrated line intensity

First moment ~
weighted Doppler velocity

Helical Flow: 3rd Jet



Integrated line intensity



First moment ~
weighted Doppler velocity

Origin of Homologous Helical Jets

- Heyvaerts & Priest (1977): Reconnection between emerging flux and ambient field for solar flares.
- Shibata et al (1992, 1994): Reconnection model for jets -> interpret post-jet loop as small flare.
- Pariat, Antiochos & DeVore (2010) showed that persistent twisting of a parasitic polarity embedded in opposite field region can lead to recurrent, homologous jets.

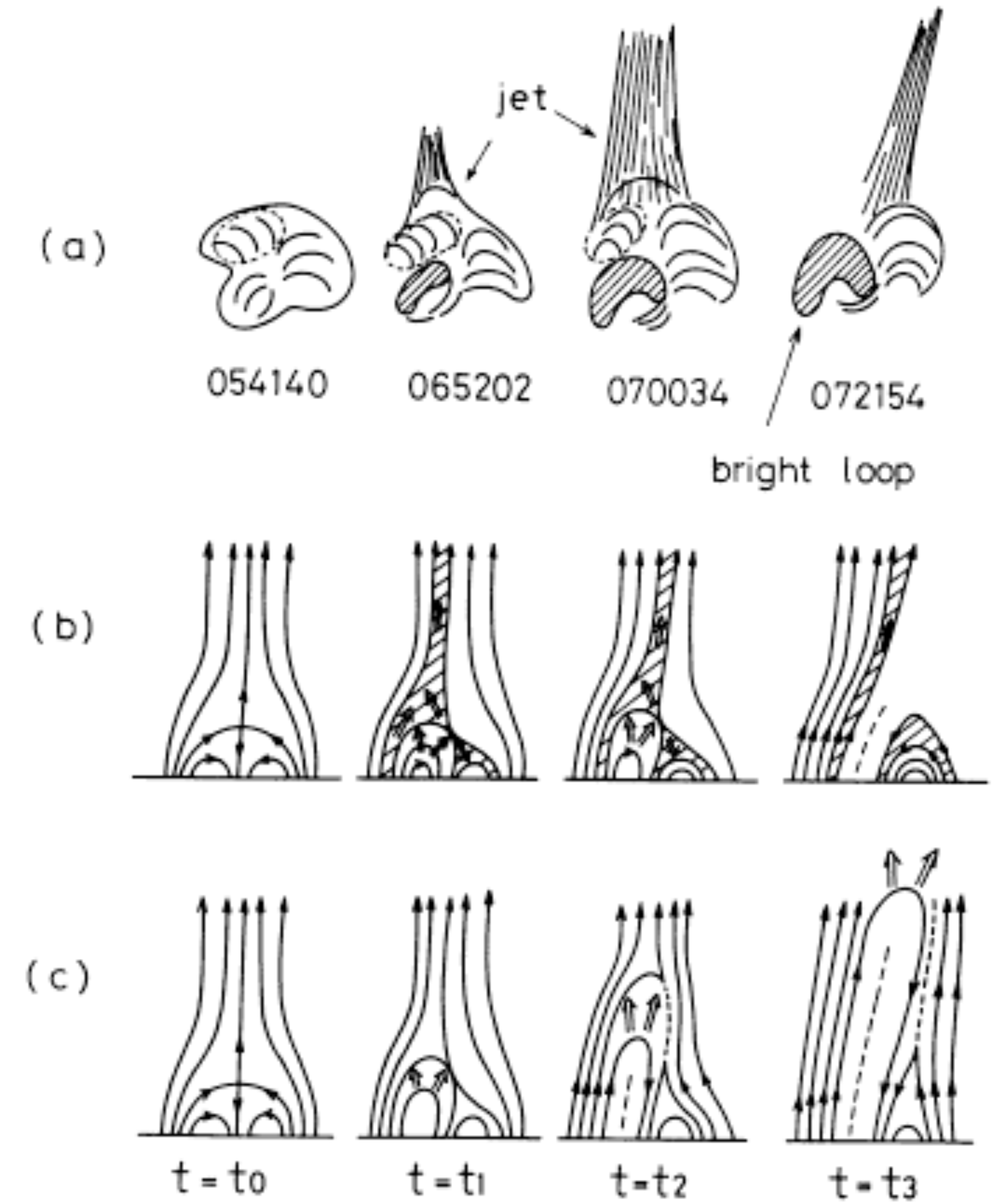


FIG. 2.—(*a*) Sketch of SXT images of the jet. Note that the loops just below the jet disappear after the jet ejection. (*b*) Hypothetical magnetic field configuration and a magnetic reconnection model explaining various observational aspects of the jet on 1992 January 11. (*c*) The expanding loop model for the gigantic jet on 1992 January 11. Note that this model eventually becomes similar to the reconnection model in (*b*) if reconnection occurs in the current sheet above the right-hand-side loop.

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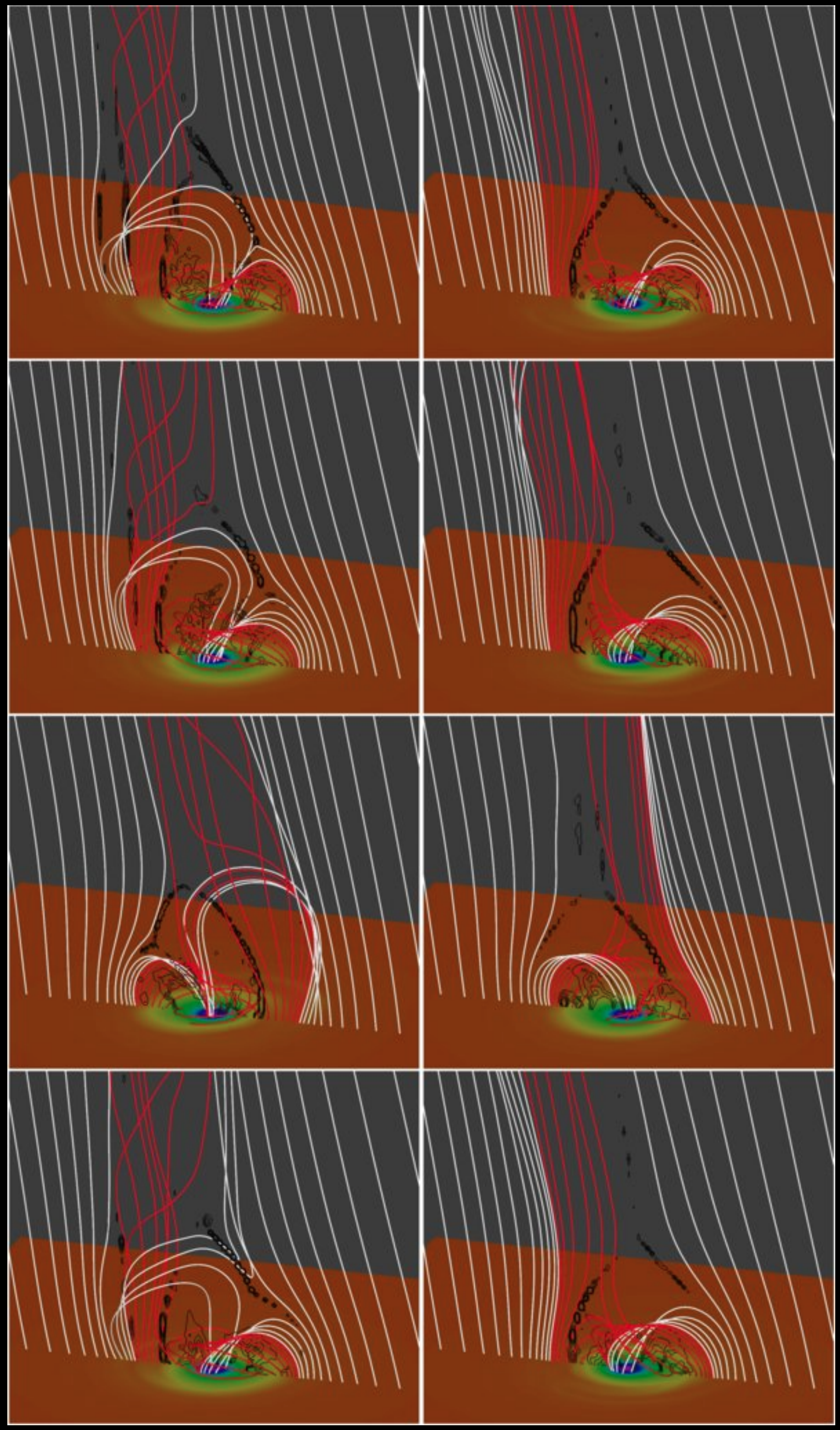
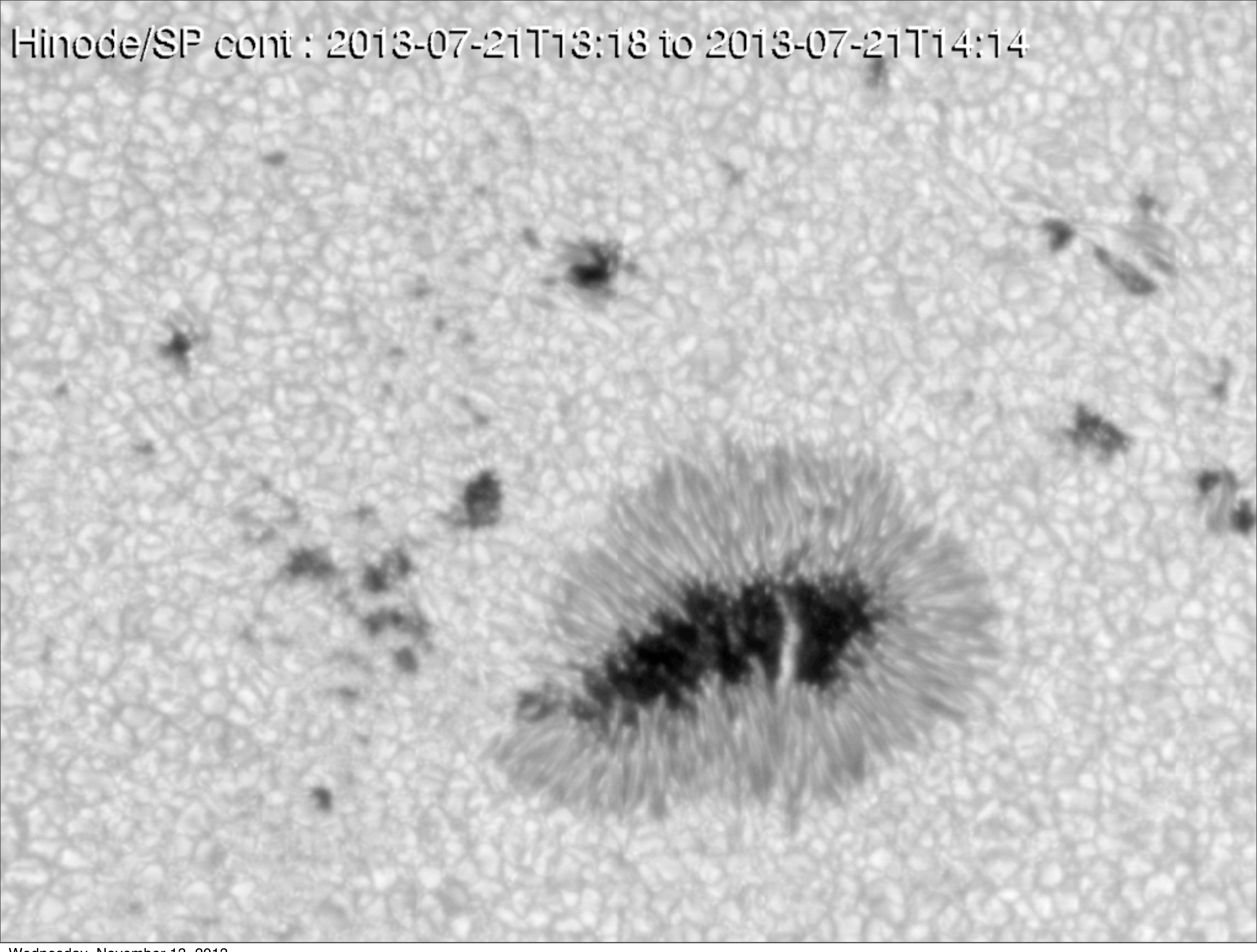
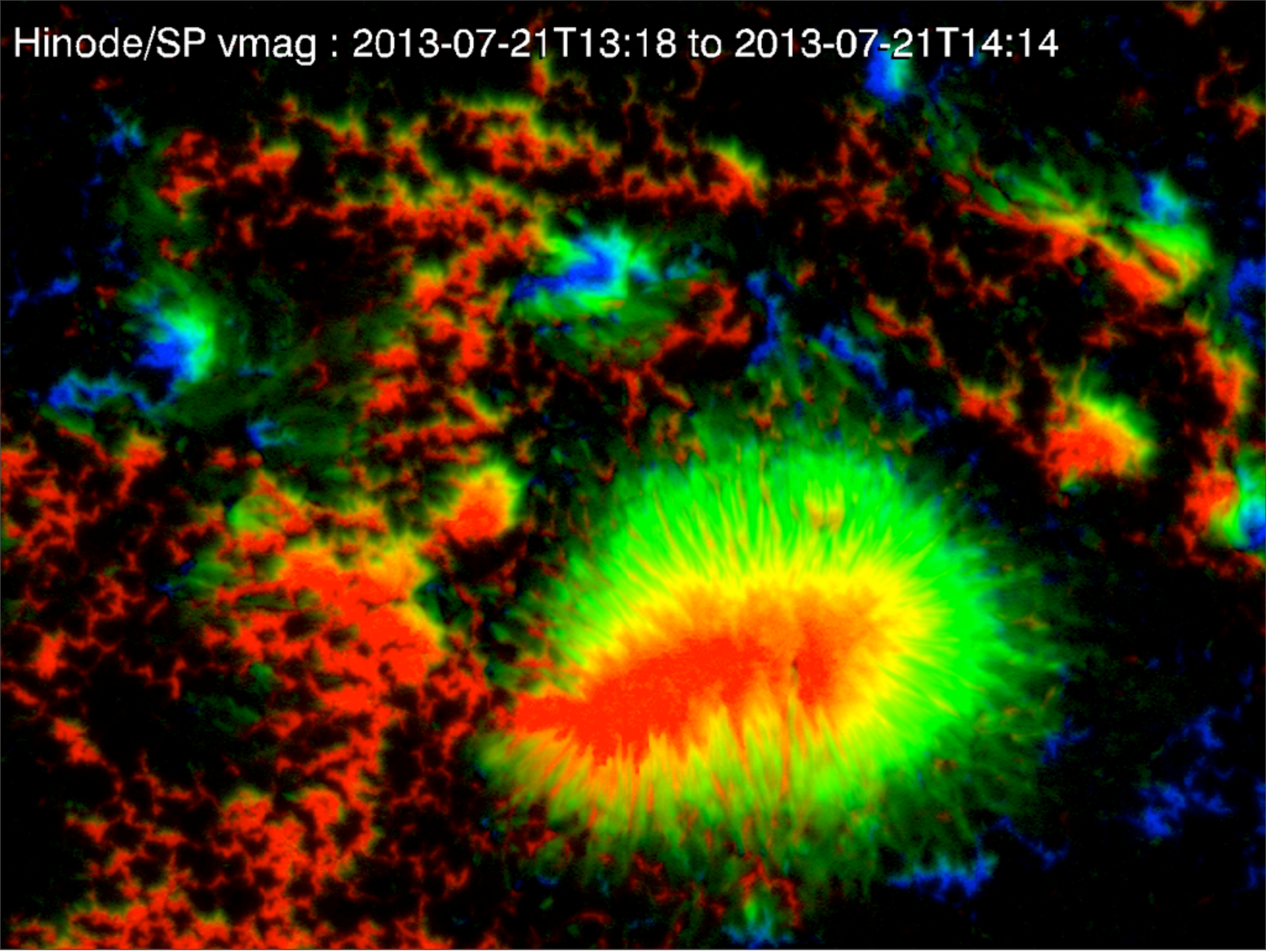
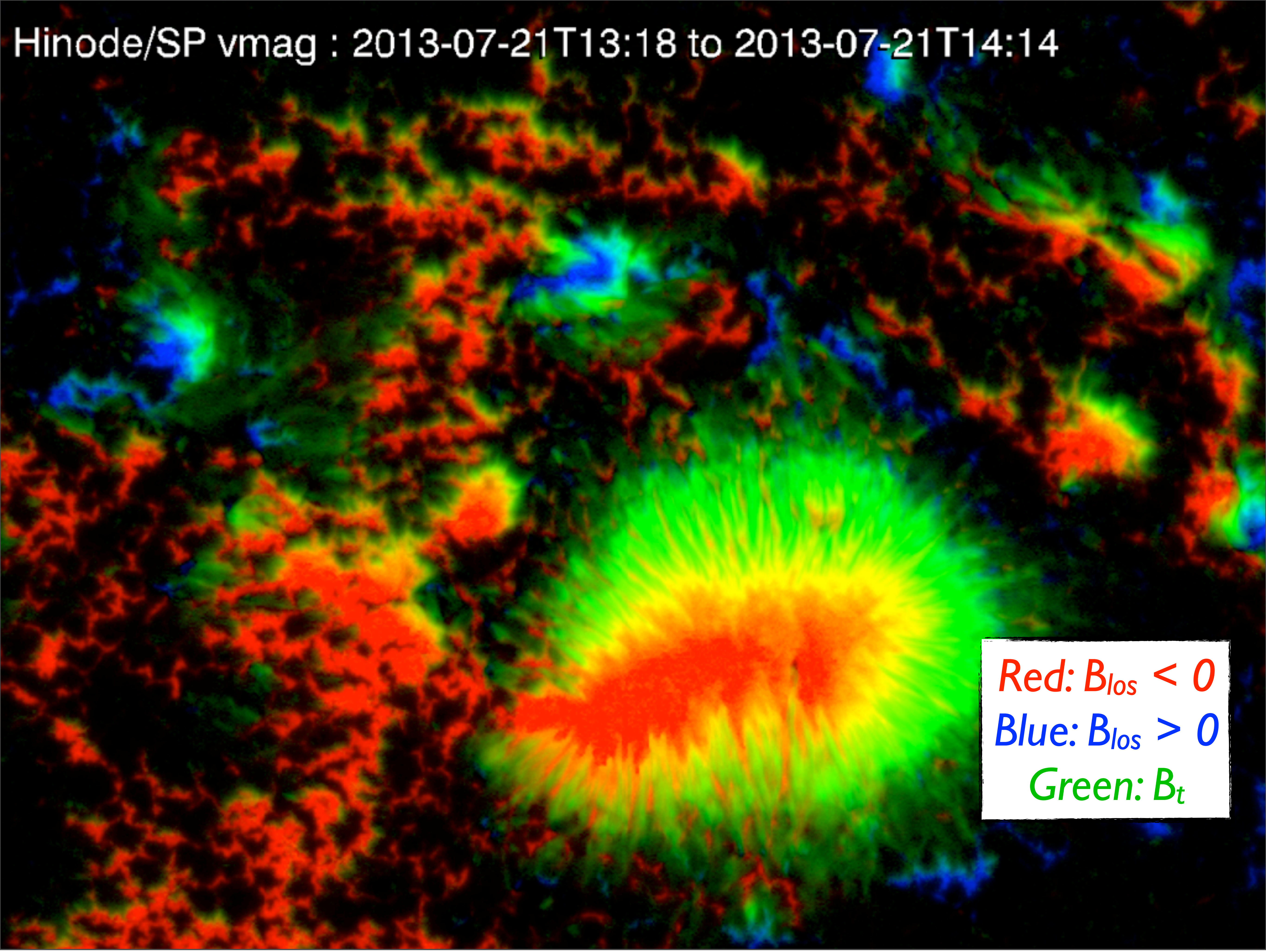
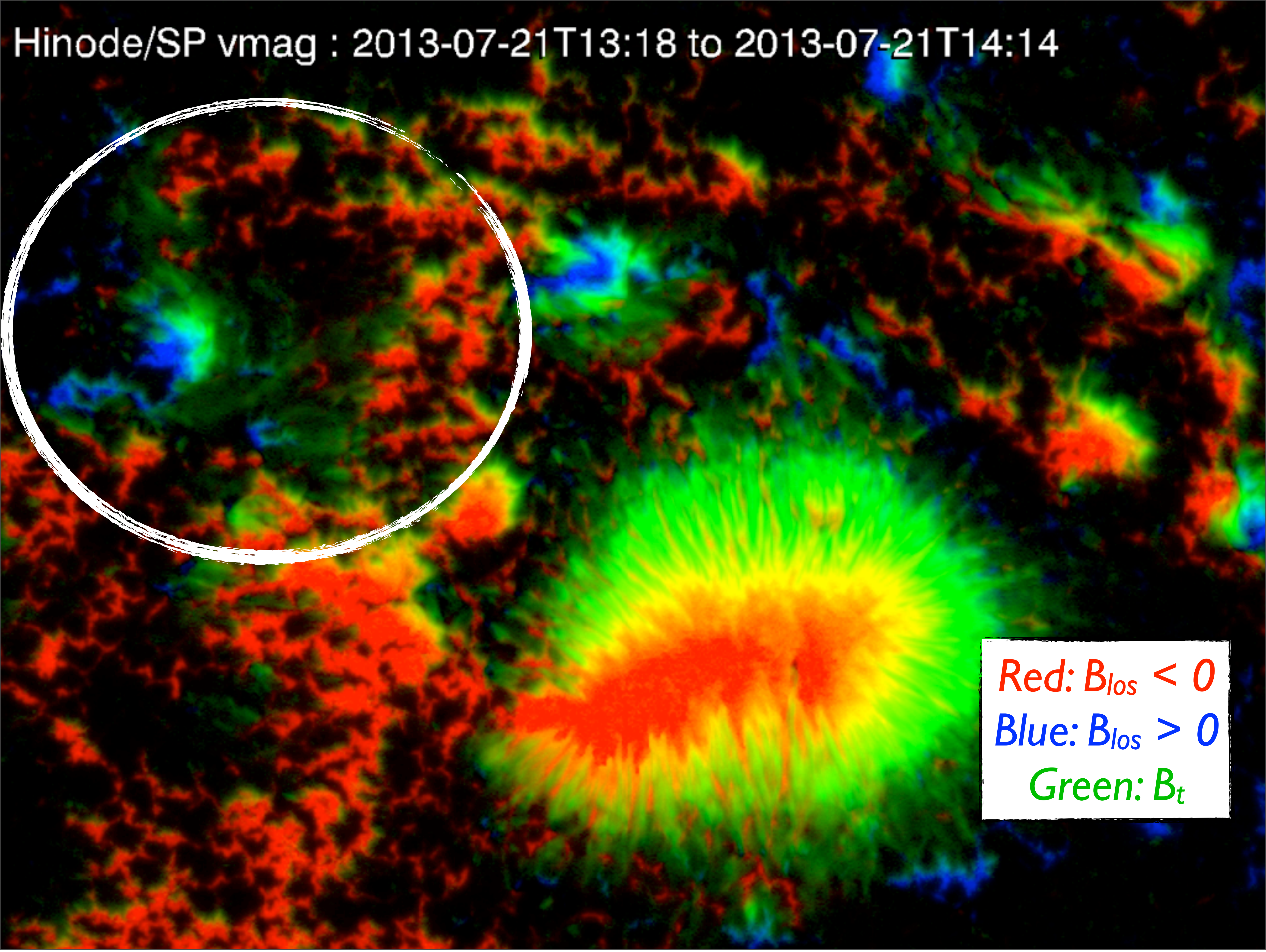



Hinode/SP cont : 2013-07-21T13:18 to 2013-07-21T14:14


Hinode/SP vmag : 2013-07-21T13:18 to 2013-07-21T14:14



Hinode/SP vmag : 2013-07-21T13:18 to 2013-07-21T14:14
Red: $B_{los} < 0$
Blue: $B_{los} > 0$
Green: B_t


Hinode/SP vmag : 2013-07-21T13:18 to 2013-07-21T14:14
Red: $B_{los} < 0$
Blue: $B_{los} > 0$
Green: B_t

Data-driven Simulation

- Data-driven evolution model of Cheung & DeRosa 2012 (magnetofriction; c.f. work by van Ballegooijen, Mackay, Yeates, Meyer et co-authors). Magnetic field is evolved according to:

$$\frac{\partial \boldsymbol{A}}{\partial t} = \boldsymbol{v} \times \boldsymbol{B} - \eta \boldsymbol{j}, \qquad \boldsymbol{v} = \frac{1}{\nu} \boldsymbol{j} \times \boldsymbol{B}.$$

- Looks like ambipolar diffusion (cf. Brandenburg & Zweibel 1994), sharpens current sheets.
- Driving data: Stanford's HMI_SHARP_CEA_720s series
- Ignore curvature in simulation: dx and dy = 360 km.
- Use B_z and J_z to constrain the time-dependent photospheric electric field E_x and E_y. ***Not entirely well-constrained and some assumptions are required, e.g. vertical gradient of Jz. -> Solar-C will help greatly here.
- J_z maps from SDO/HMI show persistent twist of persistent sign (and amplitude) in the parasitic pore.

Orange ~ $\int_{los} \langle j^2 \rangle dl$, *where* $\langle j^2 \rangle$ *is fieldline-averaged* j^2

Positive polarity B_r

Negative polarity B_r

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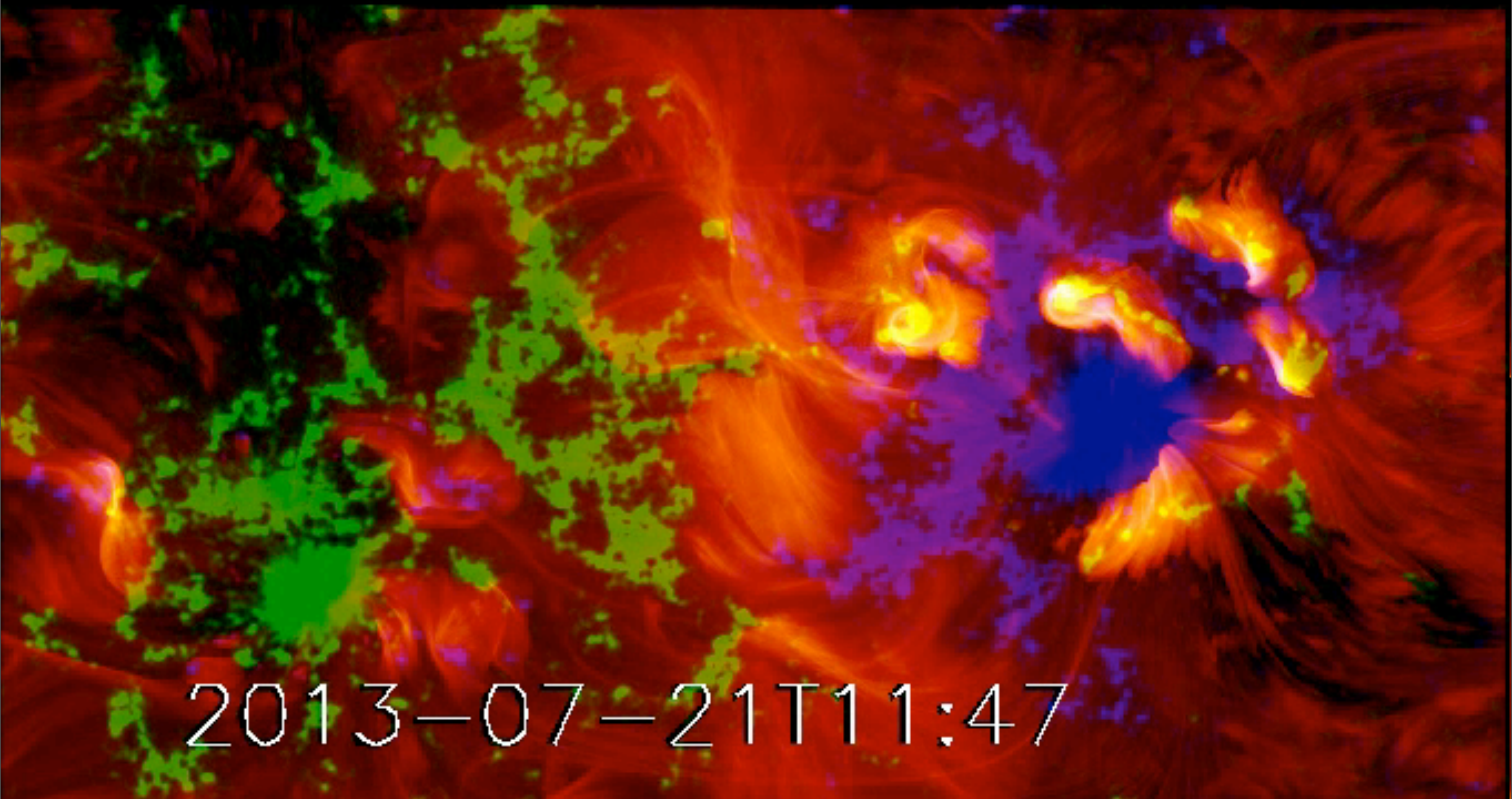
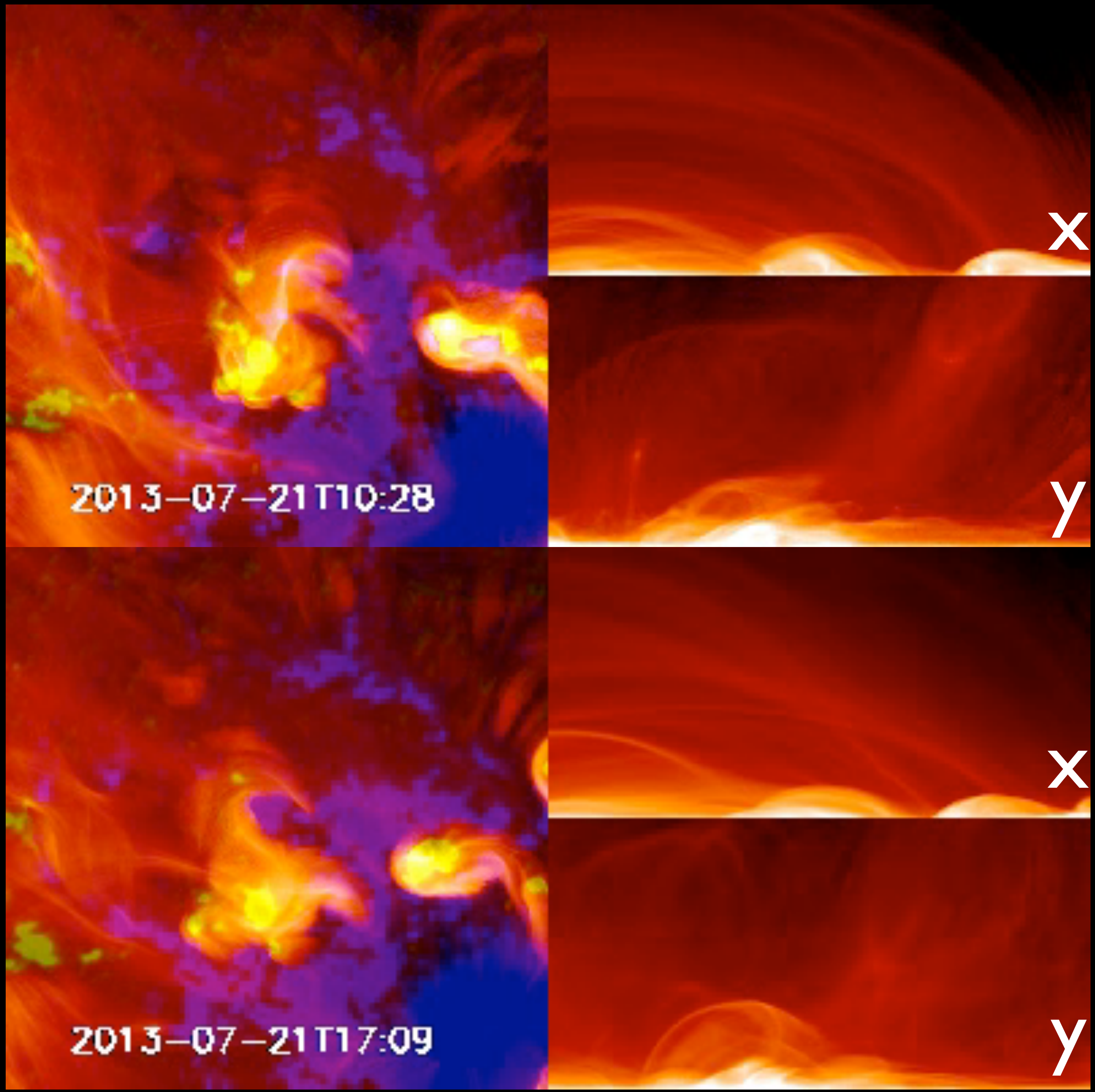


Close up look at data-driven model

Field lines twisted up by current/ rotation of parasitic pore. Two episodes of 'abrupt' changes in simulation with signs of untwisting field, slipping running reconnection.



View from top View from sides

Summary

Addressed in this presentation:

- A series of four homologous jets observed by IRIS, Hinode and SDO.
- Highly asymmetric TR line profiles in IRIS raster scans, with tails extending far beyond +/- 100 km/s.
- Direct detection of helical (out-of-plane) flow in all 4 jets.
- Vector magnetograms from Hinode/SP and SDO/HMI and a simple data-driven model point to an energy build-up mechanism similar to that used by Pariat, Antiochos & DeVore (2010) for homologous, helical jets.

Not addressed in this presentation (a.k.a. future work):

- Reconnection physics (e.g. is ambipolar diffusion important?)
- NUV spectra should be a treasure trove of physical information.
- Acceleration mechanism of jets: Is it due to direct reconnection out-flow? Or chromospheric evaporation? Or steepening slow-mode waves? c.f. talks by Pariat and Takasao.

Thank you for your attention.