Transverse Oscillations in coronal loop triggered by a jet

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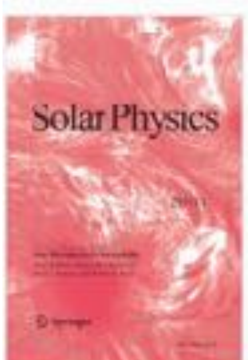

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Transverse Oscillations in a Coronal Loop Triggered by a Jet

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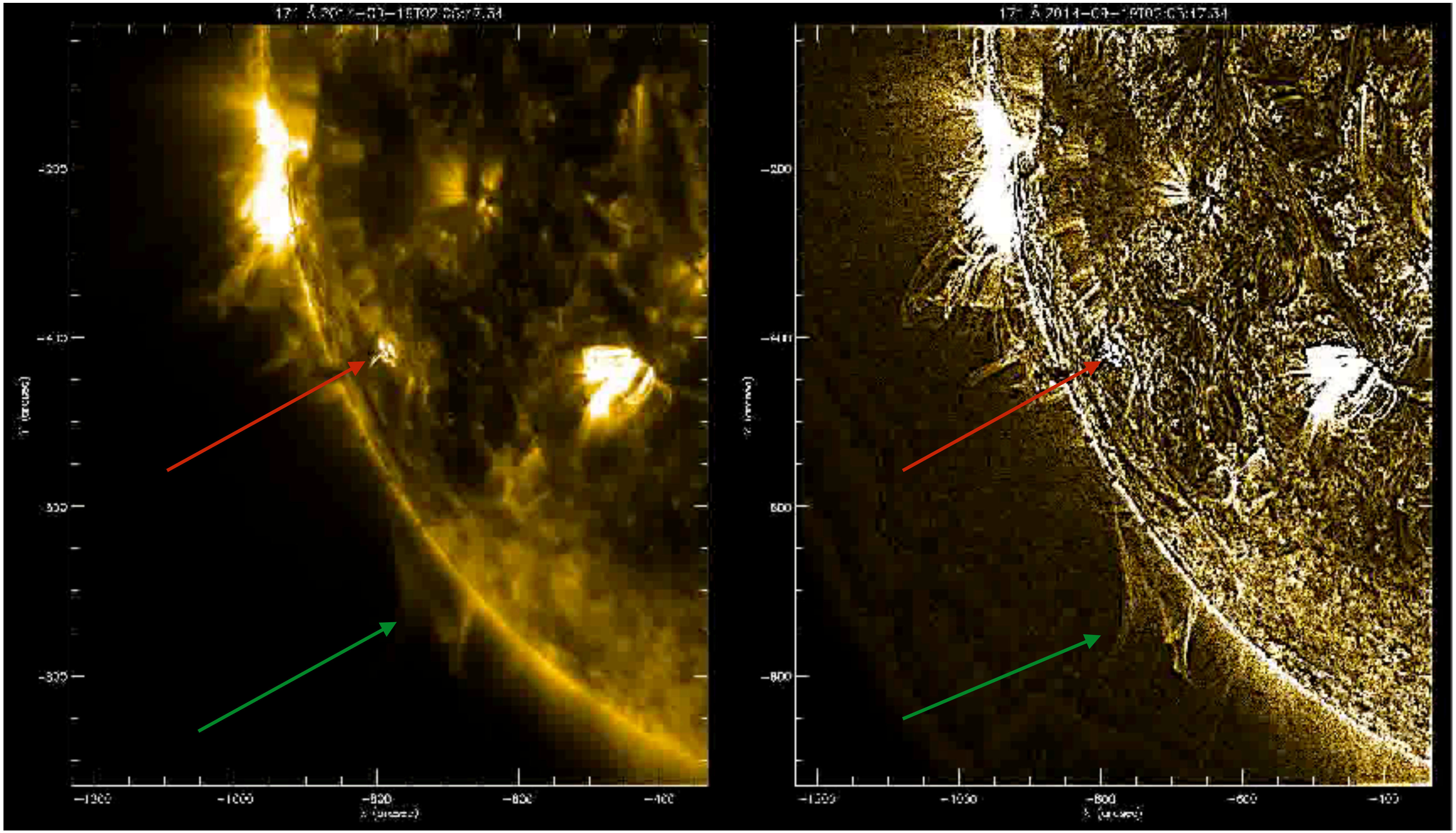
Introduction

- MHD waves are ubiquitous in solar corona
- Provide input for diagnosing the local plasma conditions using the principles of MHD seismology
- Around 95% of the transverse oscillations are associated with Low coronal eruptions (LCE) (Zimovets & Nakariakov, 2015)
- CMEs and associated shocks can trigger transverse oscillations in coronal loop
- Coronal jets have much less energy as compared to CMEs

Can coronal jets can trigger oscillations in coronal loop?

Observations

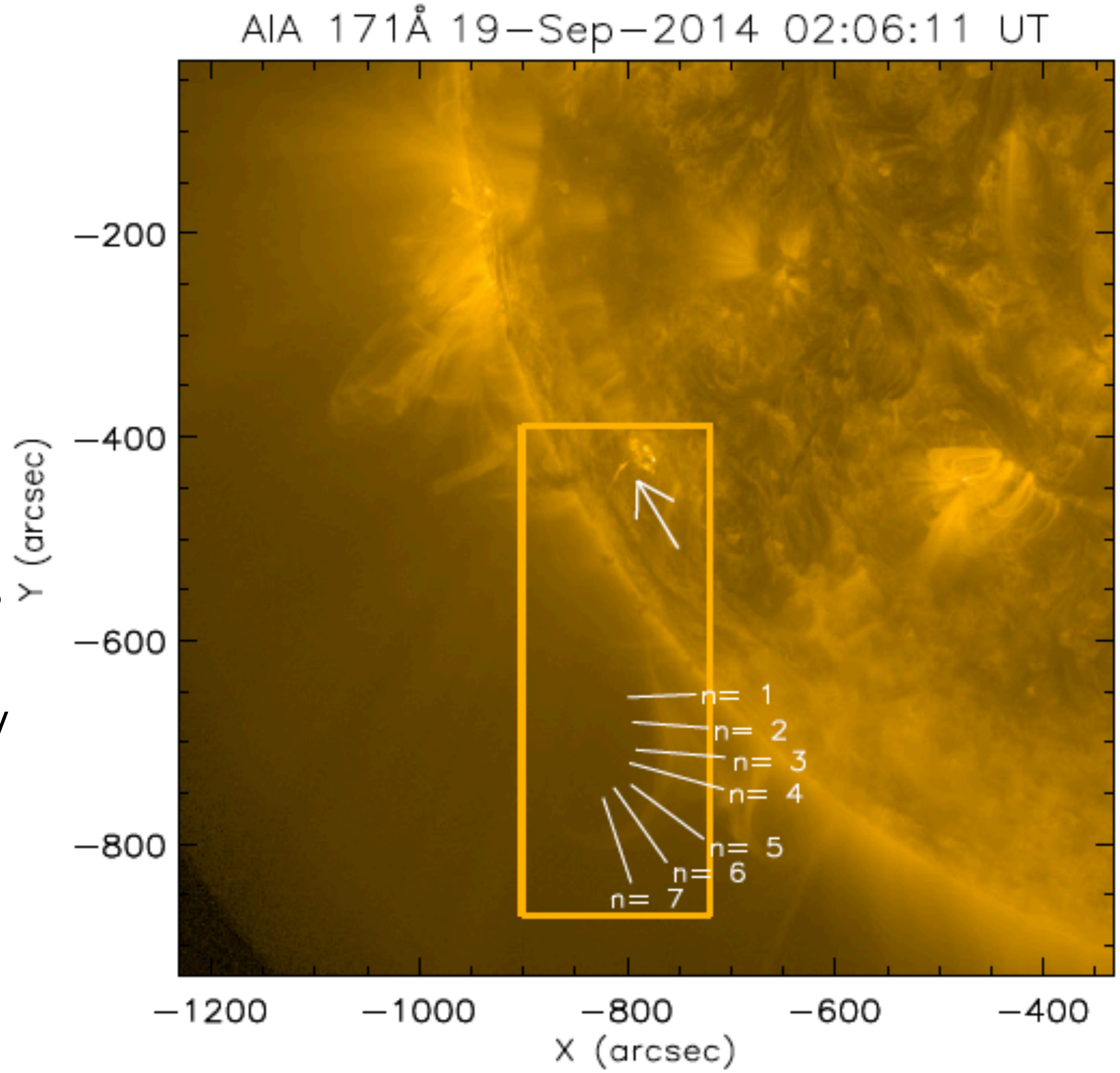


Normal intensity   Unsharp mask

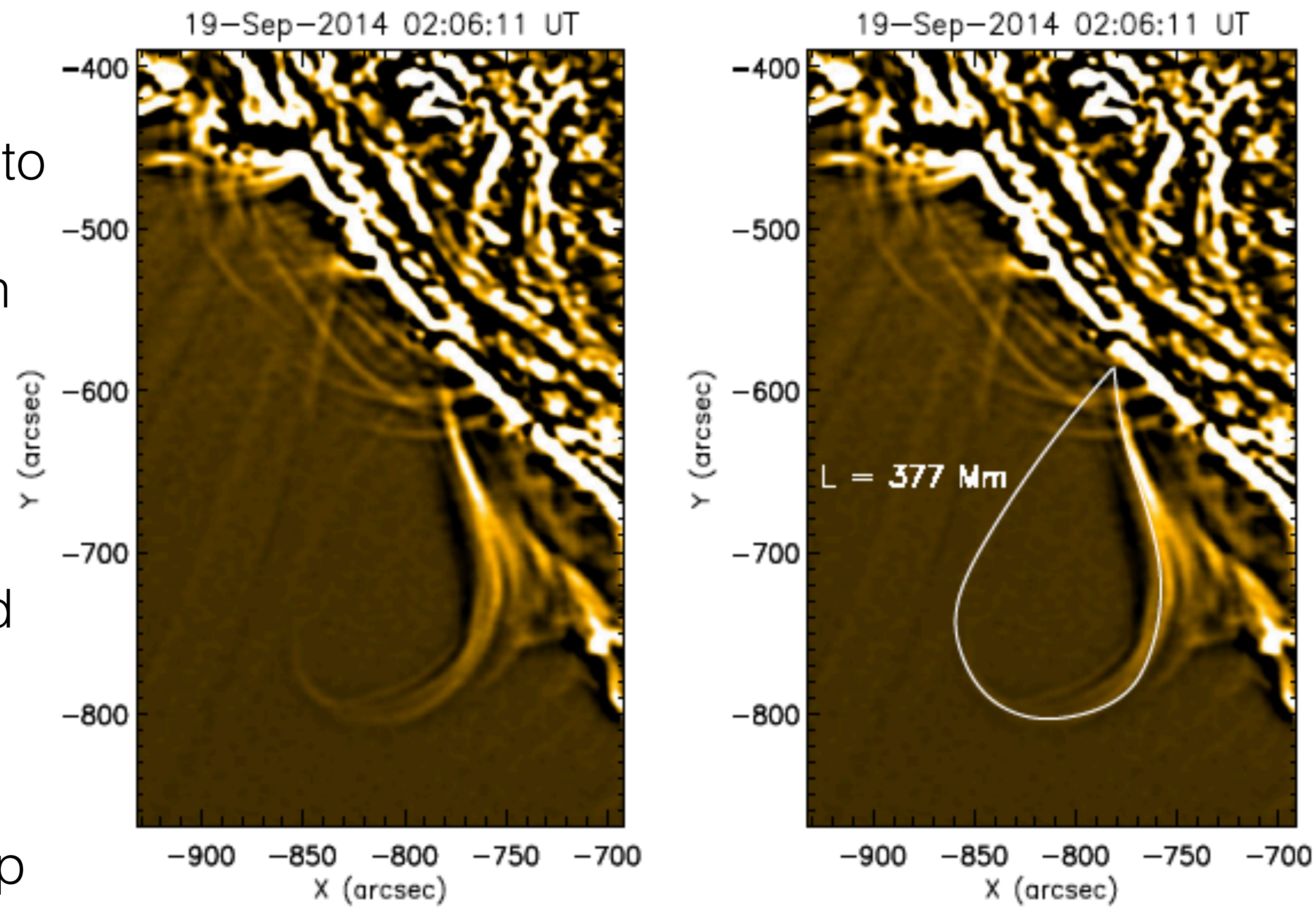
Red arrow -> jet footprint

Green arrow -> coronal loop under study

- A jet is marked with arrow
- Seven artificial slices are placed on coronal loop
- Only half of the loop is clearly visible
- Muti-wavelength study was done to find the association between jet and coronal loop

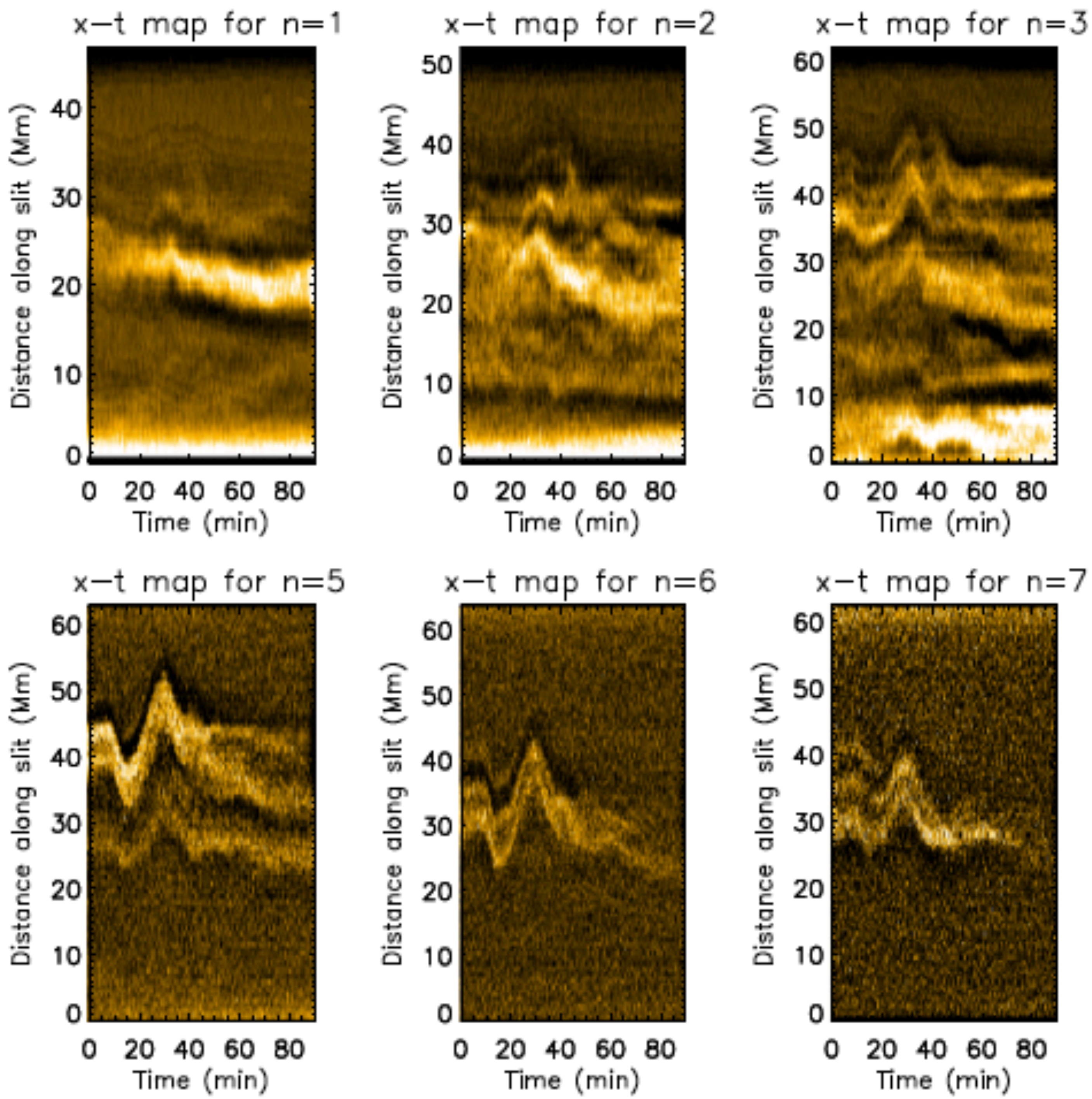


- We process the images to enhance the visibility of loop
- We smooth the images (to remove the noise) and convolved with laplacian operator to enhance the sharp edges
- Other end of loop is faintly visible
- Fitted a spline curve and estimated the projected length to be 377 Mm
- Semicircle model is also used to estimate the loop length
- Semi circle model estimate loop length to be 539 Mm



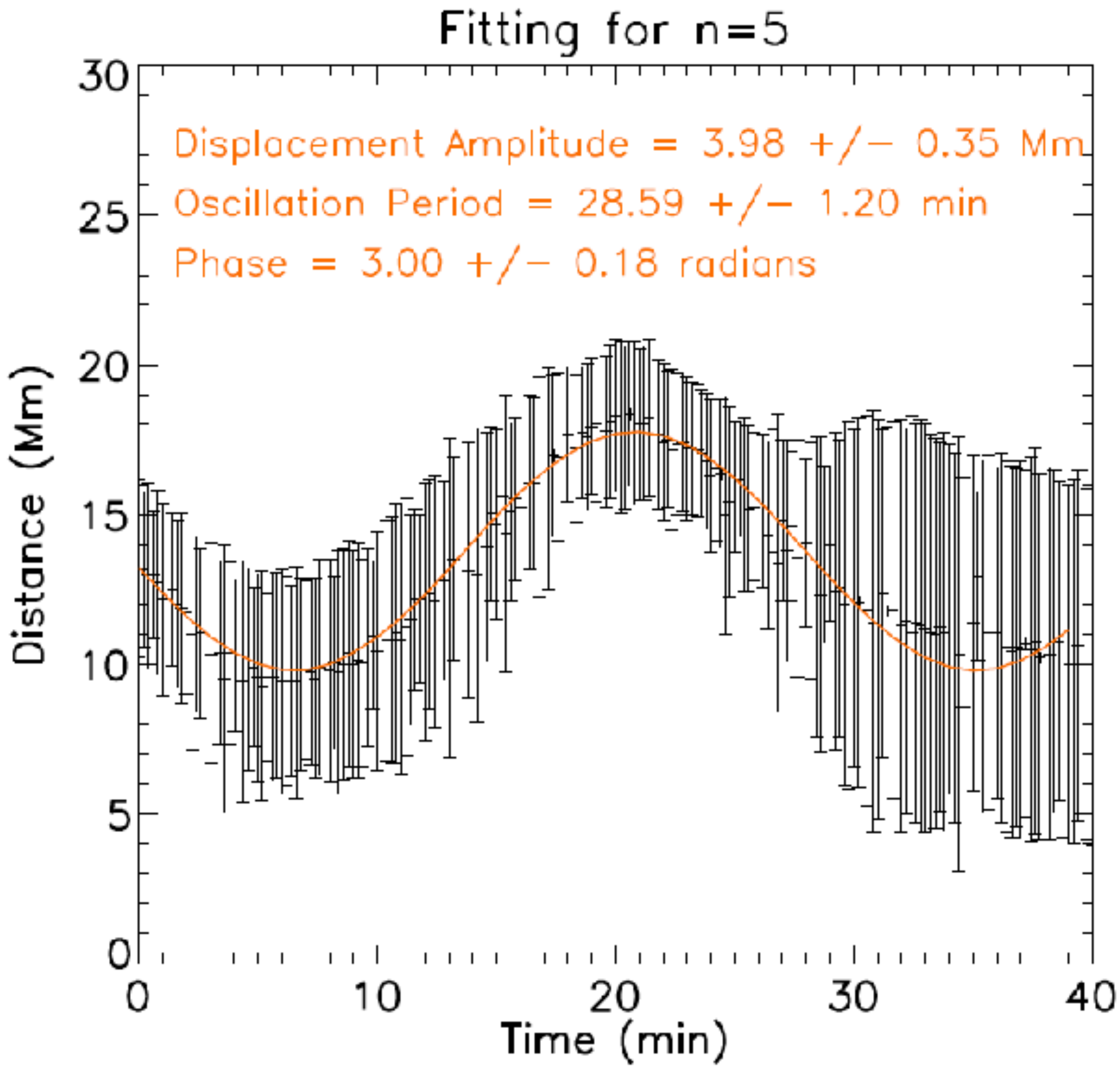
Lower limit -> 377 Mm
Upper limit -> 539 Mm

Time-distance maps

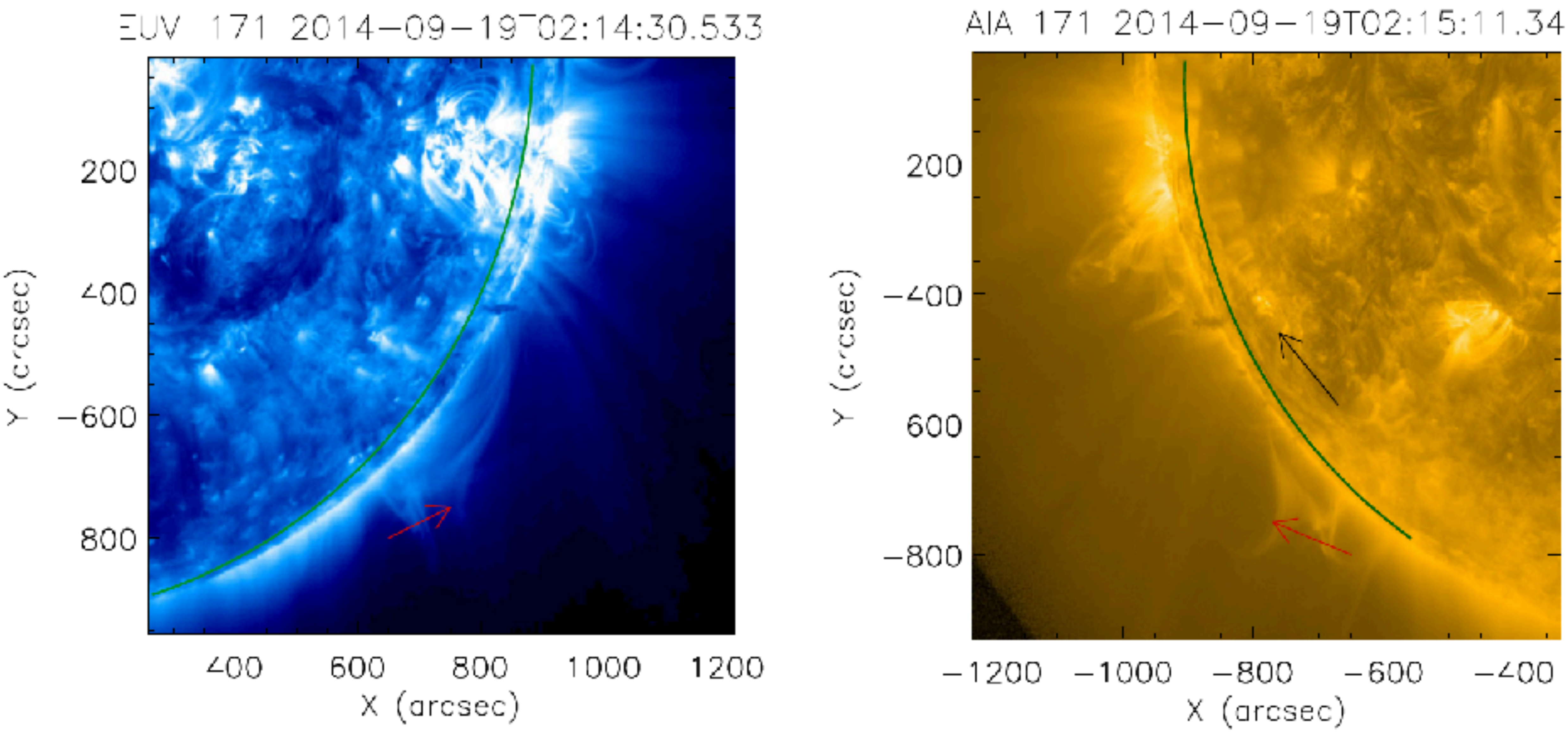


- Time-distance maps for seven artificial slices placed on coronal loop
- Loop is multi stranded
- Oscillations are coherent in different strands
- Oscillations are in phase in different slices

- Average oscillation period ~ 32 min
- Long period oscillations in coronal loops
- Not an active region loop

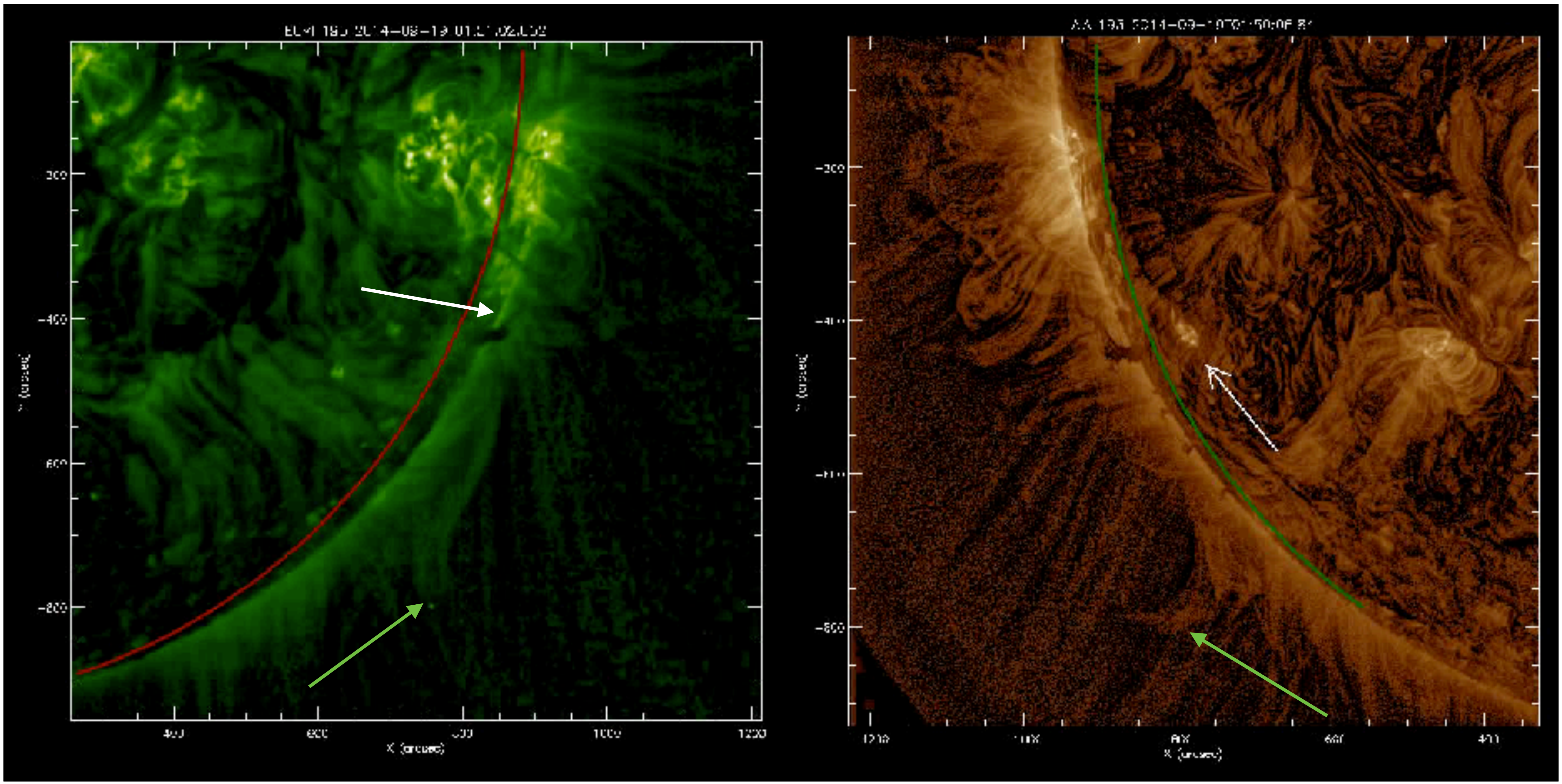


Observations from STEREO



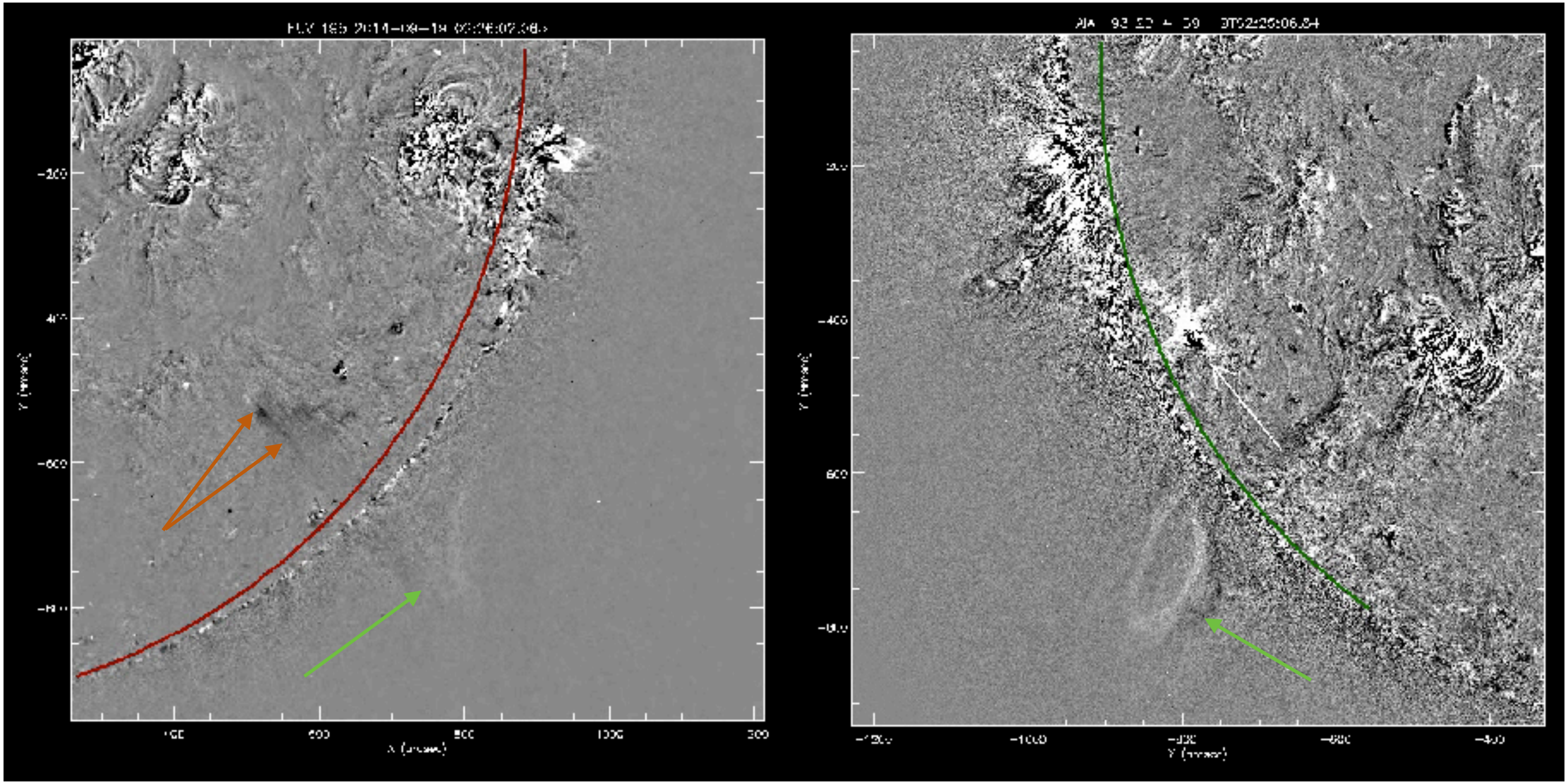
- Solar limb is plotted in green
- Jet footpoint is marked with black arrow and is beyond the limb in EUVI 171
- 3D reconstruction was not feasible
- Coronal loop is marked with arrow in red in AIA 171
- Coronal loop is not seen clearly in EUVI 171

Simultaneous view from STEREO and SDO



- Filtered images using Multi Gaussian Normalisation (MGN)
- jet footpoints -> white arrow
- coronal loop -> green arrow

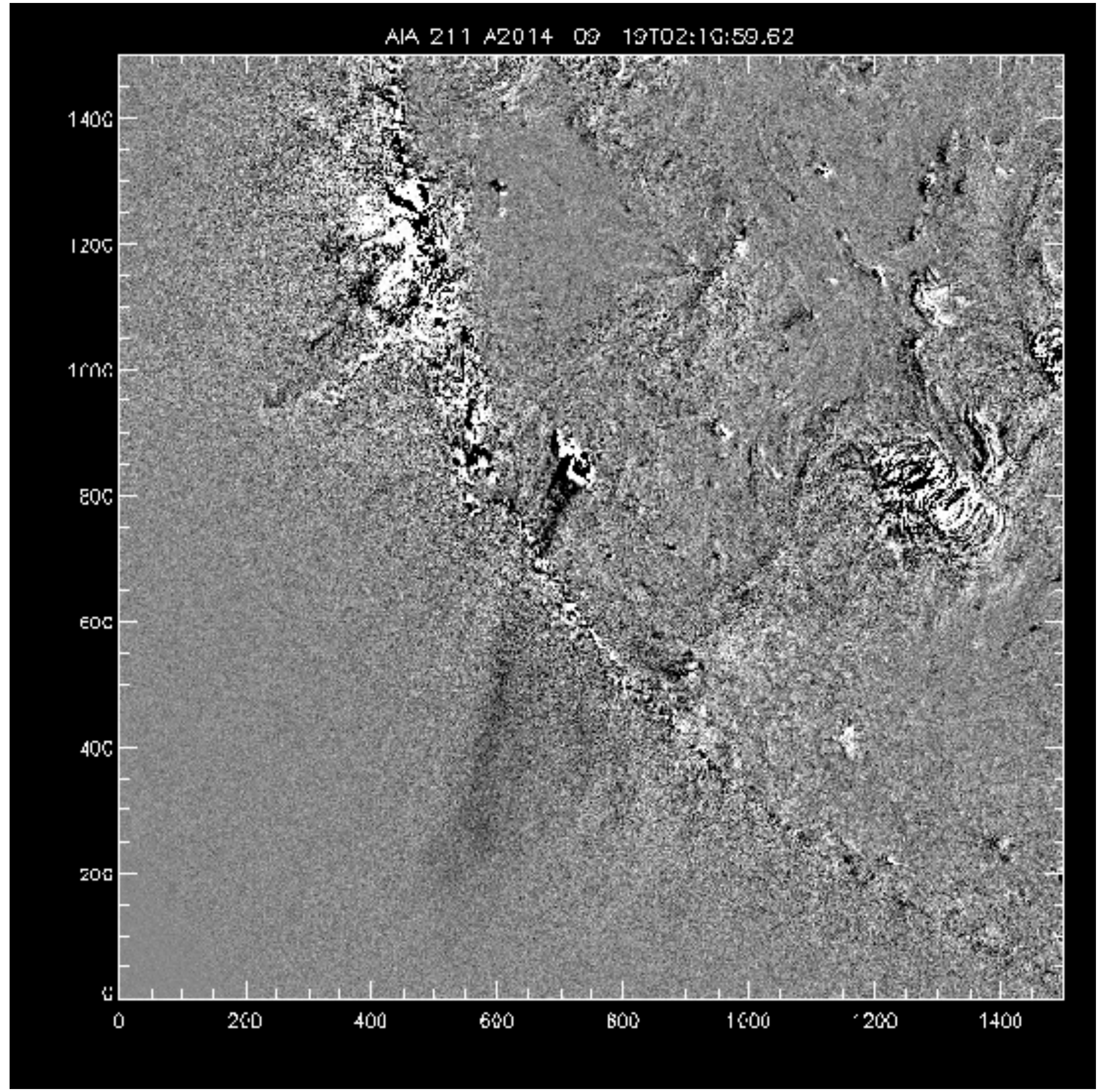
Difference images



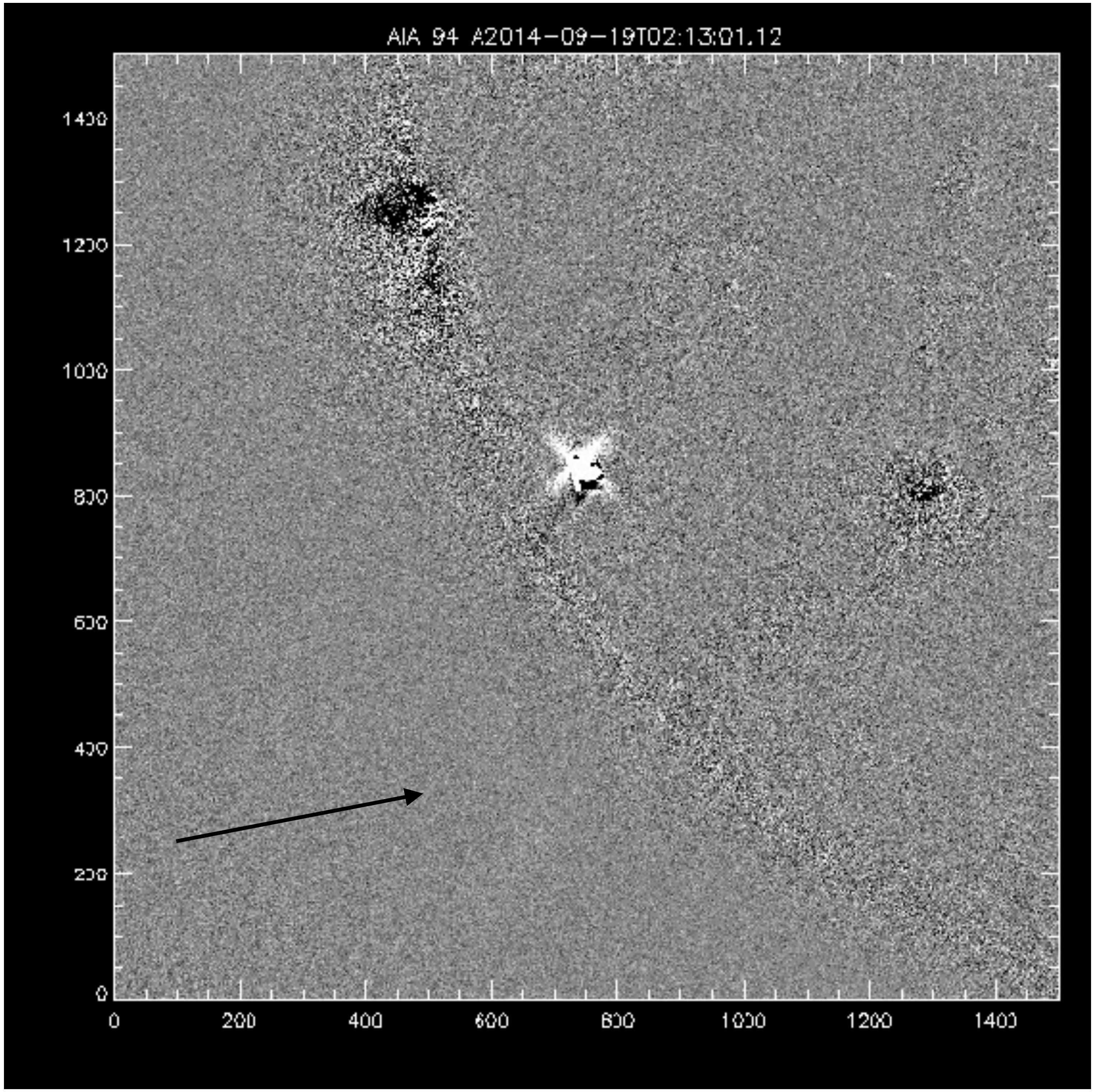
Dark features propagating inwards in EUVI 195 A
Unlikely to be an eruption otherwise it would be moving outward
Few scenarios are possible

- Plasma disappearance due to heating of plasma by nearby flare or jet associated with it
- Should get signatures in hotter temperature channels. EUVI do not have hot temperature channels
- Dark feature is also associated with the jet in AIA 193 A
- Dark feature in EUVI 195 could be the hot component of jet that subsequently appears in EUVI 195 A after displacing the coronal loop
- Should get signatures in hot temperatures channels of AIA

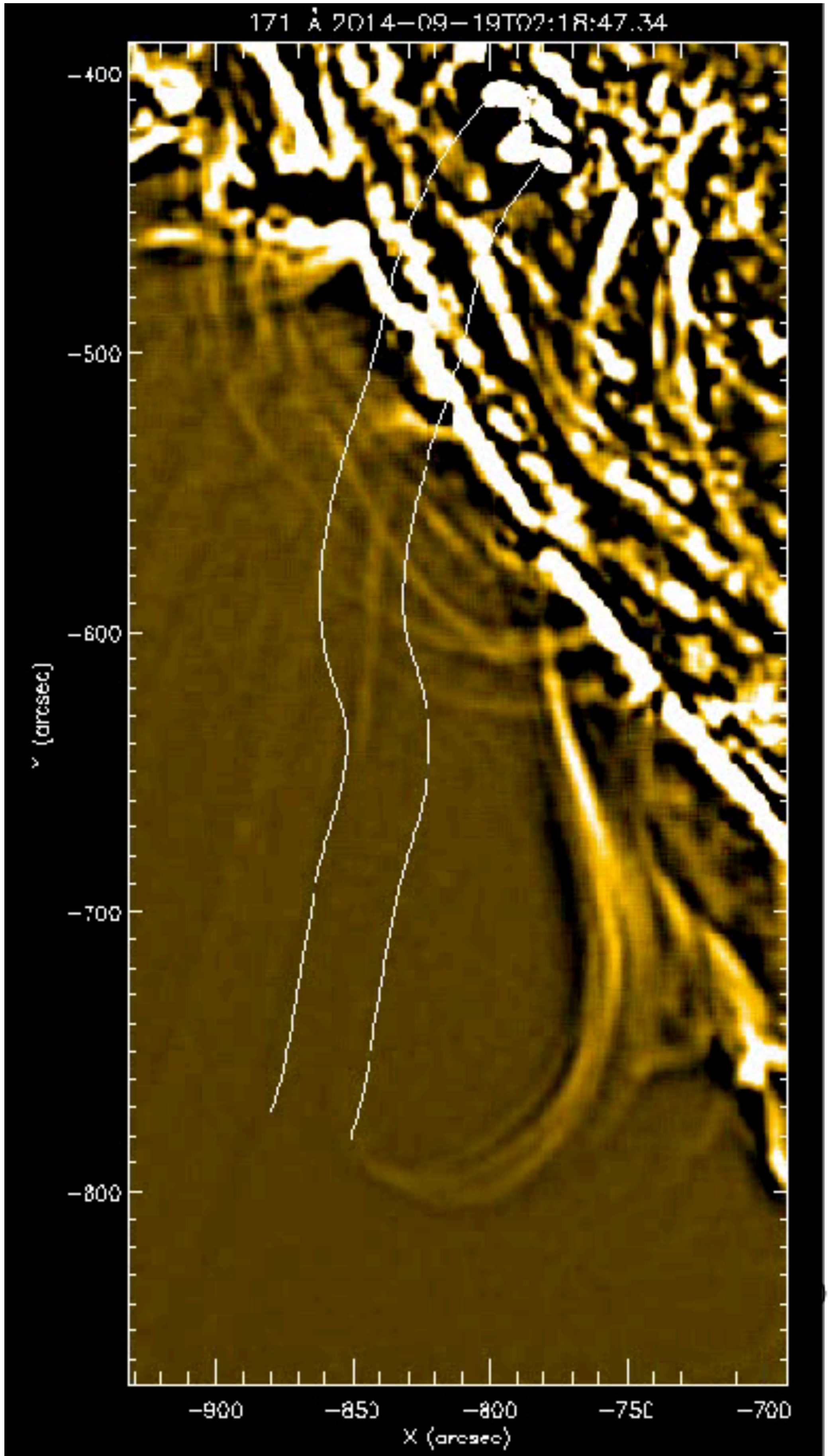
Note that a very dark feature is associated with the jet



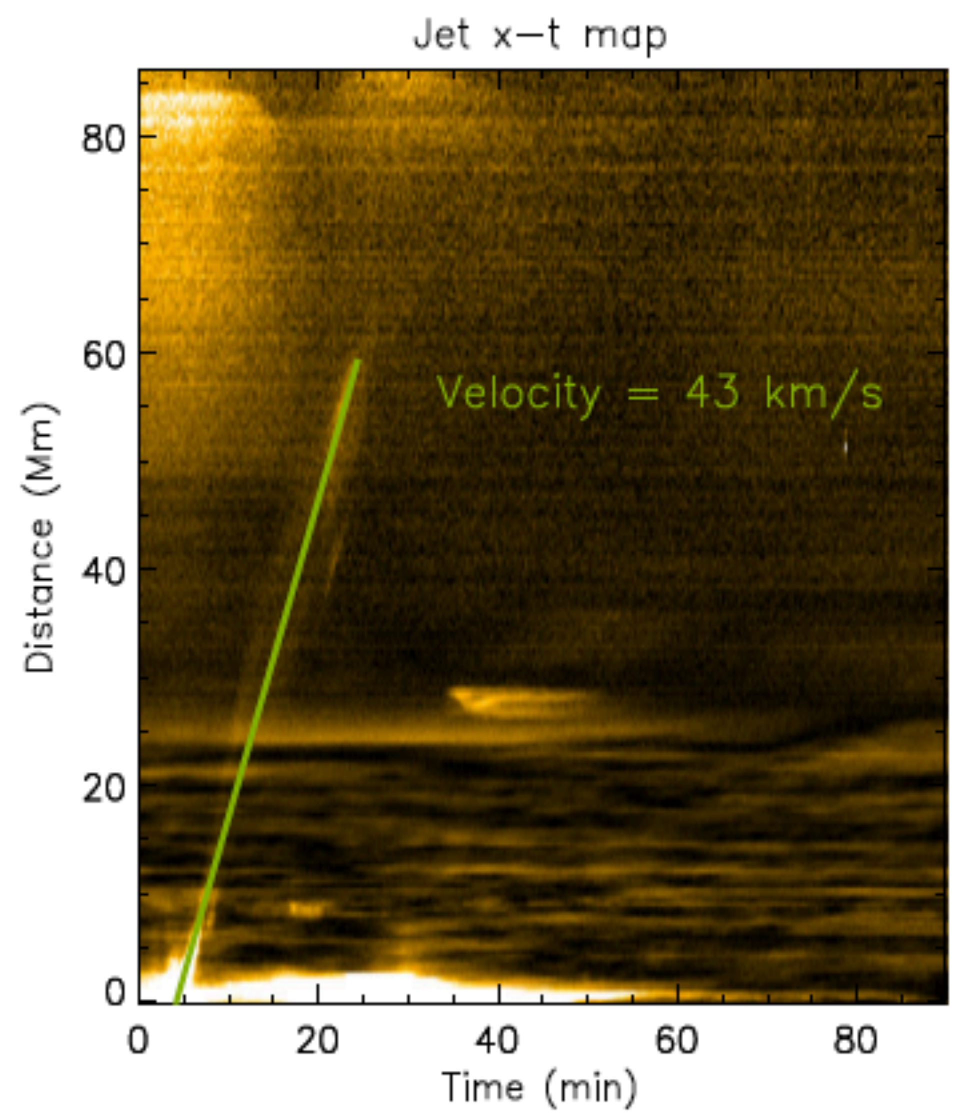
Dark feature is also seen in normal intensity images. It suggest that very hot plasma is associated with jet

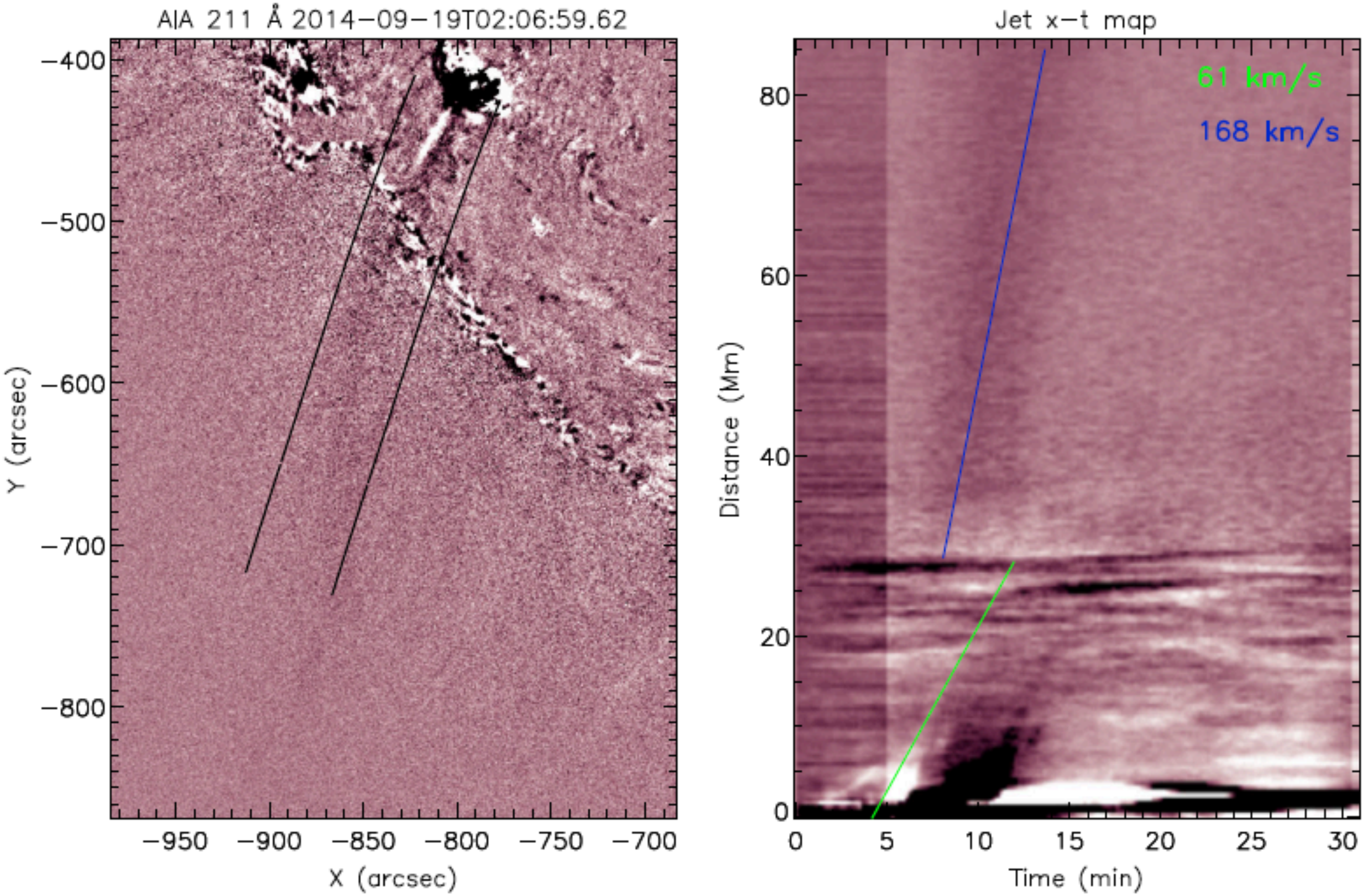


AIA 94 A shows a very faint emission at the location of dark feature



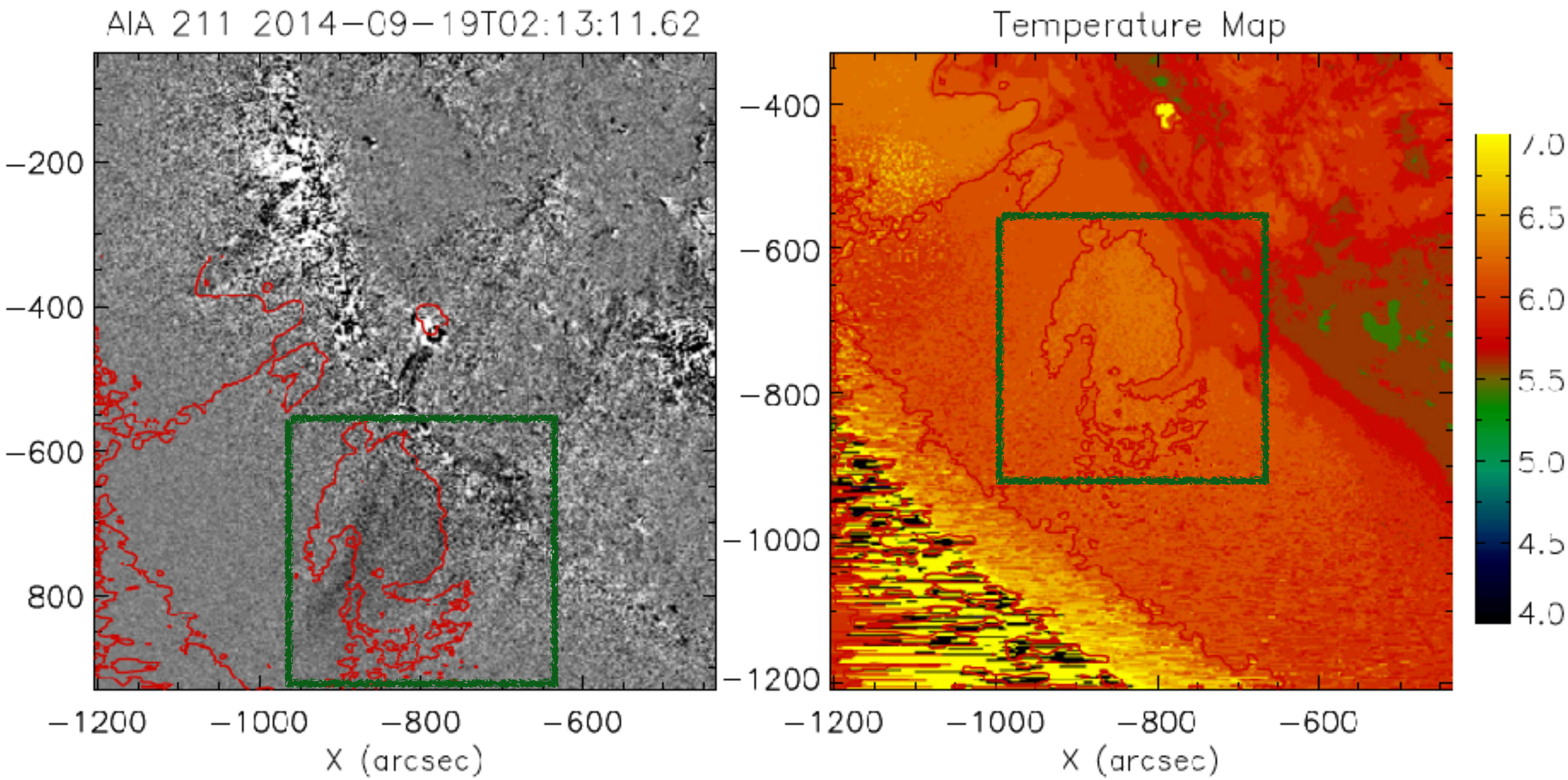
- Jet was oscillating while propagating
- To capture the trajectory of jet we choose the wavy artificial slice so that jet remain within the slit





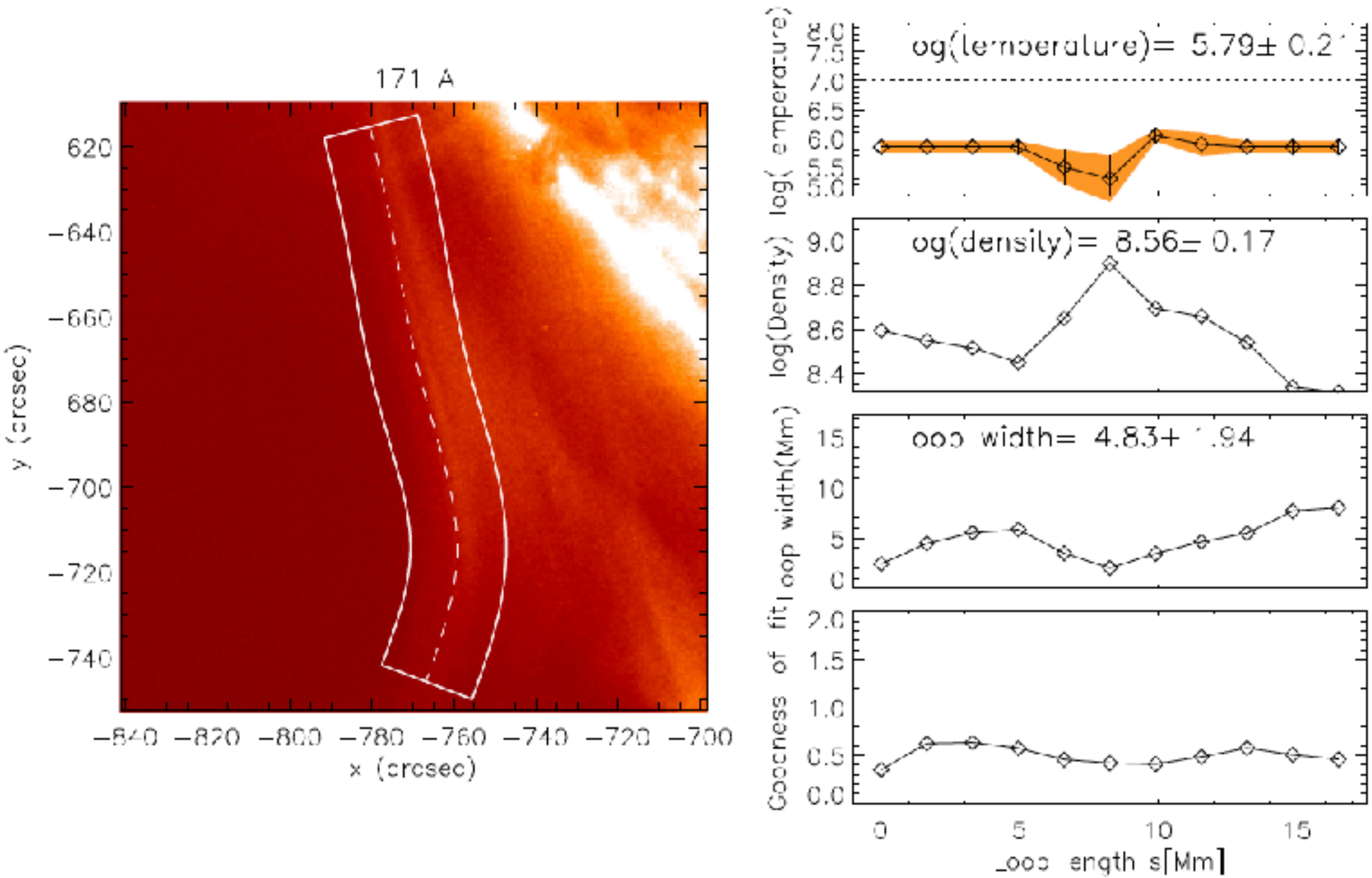
Time-distance map shows that jet has two components
Two components propagate with different velocities
Hot component has higher velocity

Temperature Map



Higher temperature at the location of dark feature

Density of coronal loop and estimation of magnetic field



Density of coronal loop and jet was estimated using Differential Emission measure

Loop density = $10^{8.56}$ / cm^3

Jet density = $10^{9.92}$ / cm^3

MHD seismology

We know, $V_{\text{ph}} = C_{\text{K}} = \frac{2L}{P}$

and $C_{A0} = \frac{C_{\text{K}}}{\sqrt{\frac{2}{1+\frac{\rho_e}{\rho_0}}}}$

where internal Alfven speed, $C_{A0} = B_0/\sqrt{\mu_0\rho_0}$,

Observables

- L -> length of coronal loop (**projected length and semicircular model**)
- P-> period of oscillations
- Density contrast estimated from intensity ratio

Density contrast depends on the EUV intensity ratio as $(\frac{\rho_e}{\rho_0})^2 = \frac{I_e}{I_o}$

- We estimated the EUV intensity ratio at several places along the loop at different times
- Intensity ratio varies from 0.18—0.5
- Density contrast varies from 0.4—0.7 (0.1 is kept as a standard practice)
- Once density constrast, L and P are calculated, Alfven speed inside the loop and magnetic field strength can be estimated

Table 1 Estimation of the Alfvén speed and the magnetic field strength inside the coronal loop.

$\frac{\rho_e}{\rho_0}$	Projected length			Semicircular model		
	0.1	0.4	0.7	0.1	0.4	0.7
C_{A0} (km s^{-1})	299 ± 27	328 ± 14	361 ± 16	415 ± 28	469 ± 32	516 ± 35
B (G)	2.68 ± 0.64	2.86 ± 0.12	3.20 ± 0.14	3.62 ± 0.24	4.1 ± 0.28	4.5 ± 0.31

Energy estimates

Energy of jet is defined by, $E_{\rm jet} = \frac{1}{2}\rho_{\rm jet} v^2 = (19.6 \pm 3.6) \times 10^{-3}\ {\rm J\,m^{-3}}$

Energy of oscillating monolithic loop is given by, $E_{\rm monolithic} = \frac{1}{4}\rho_0 \omega^2 {A_0}^2$

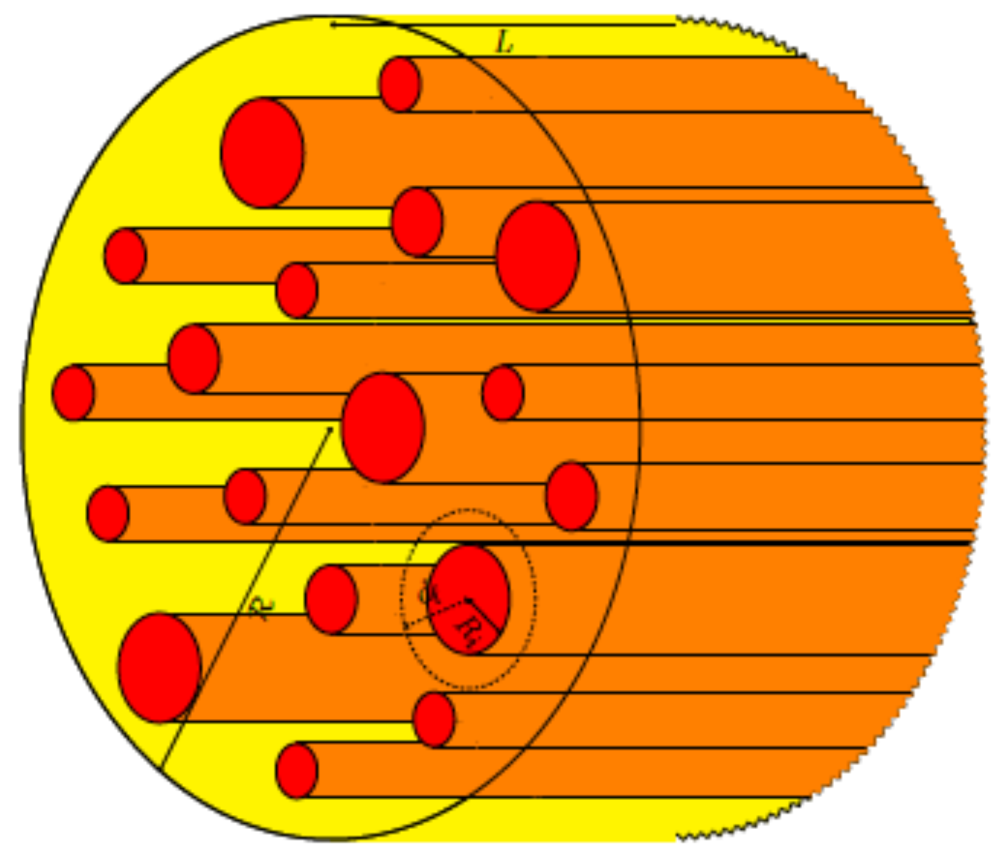
$= (1.22 - 3.28) \times 10^{-5}\ {\rm J\,m^{-3}}$

Energy of oscillating multi stranded loop is given by, $E_{\rm multistrand} = \frac{1}{2} f(\rho_0 + \rho_e)\omega^2 {A_0}^2$

where, f is the filling factor by

f= $\frac{\sum_{i=1}^{N} R_i^2}{\mathcal{R}^2}$ **(Van Doorsselaere et al, 2014)**

We estimated f by inspecting the cross-sectional intensity profiles at several instances along the length of the coronal loop. The sum of the widths of any intensity peak, which represents a single flux tube, is determined and divided by the overall width of the loop. f is found to be 0.17



Van Doorsselaere et al, 2014

We find that, $E_{multistrand}$=0.4—0.6 $E_{monolithic}$ Therefore, $E_{jet} >> E_{monolithic} > E_{multistrand}$

We find that jet has enough energy to displace coronal loop and induce transverse oscillations in it

Conclusions

- We find a coronal oscillations associated with nearby jet eruption
- Jet consists of hot and cool component
- Jet (probably the hot component) interacted with coronal loop and displaced it
- We find that magnetic field inside coronal loop is low as compared to the average values may be because this loop is not associated with active region
- We estimated the energy in jet and find that energy density of jet is larger than energy density of coronal loop
- Thus jet is inferred to be the cause of transverse oscillations in jet

Thank you for your attention