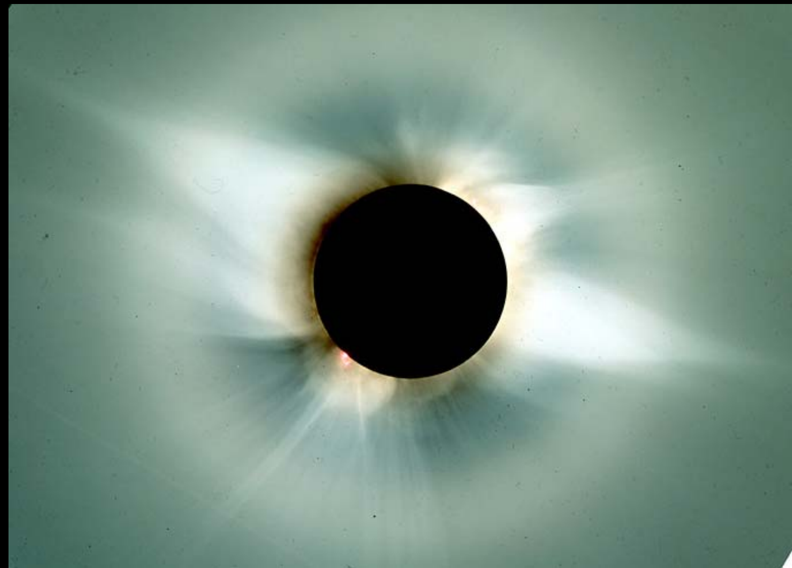
# Coronal oscillations observed by Hinode/EIS

FORGES, Nor Amberd 2008

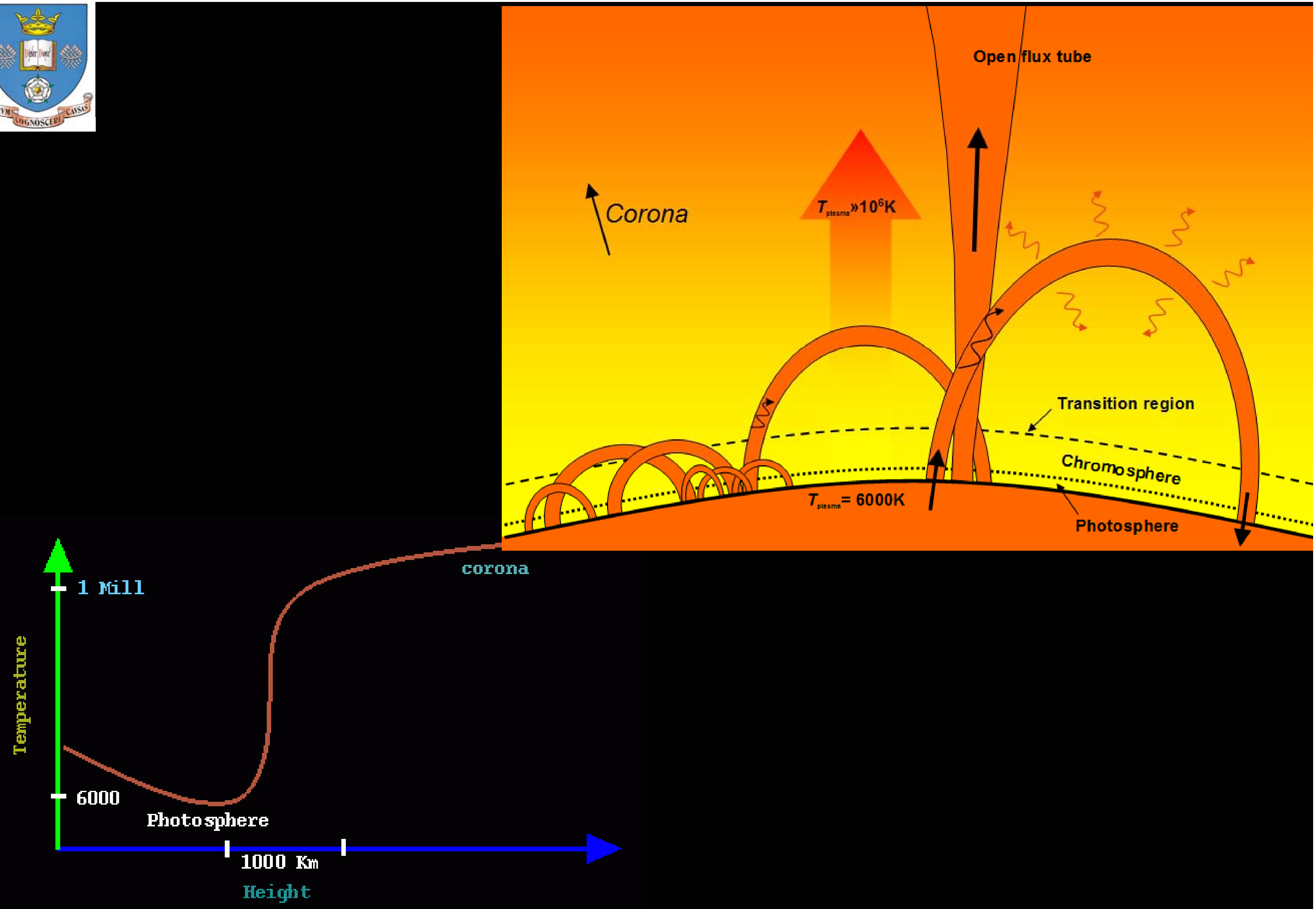
Youra Taroyan

Department of Applied Mathematics
University of Sheffield

# The Solar Corona



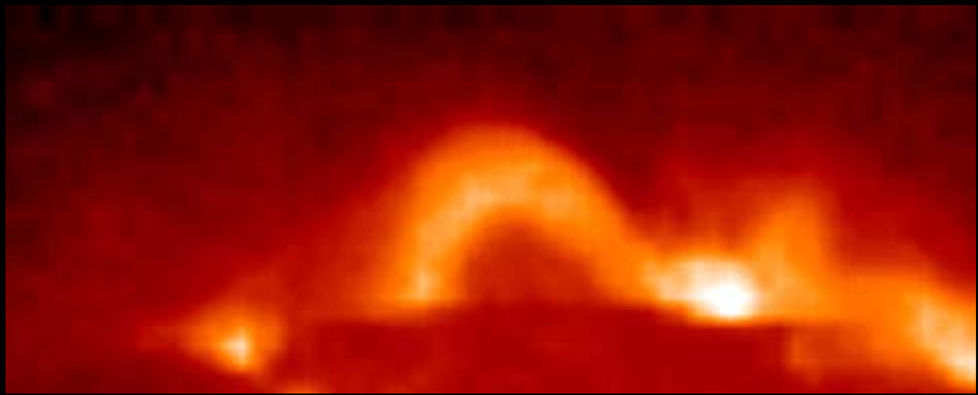
- 1860s – "coronium" discovered
- 1902 – "coronium" has lesser atomic weight than hydrogen (Mendeleev)
- 1930s – spectral lines due to known elements at very high stages of ionisation (Grotrian, Edlen)



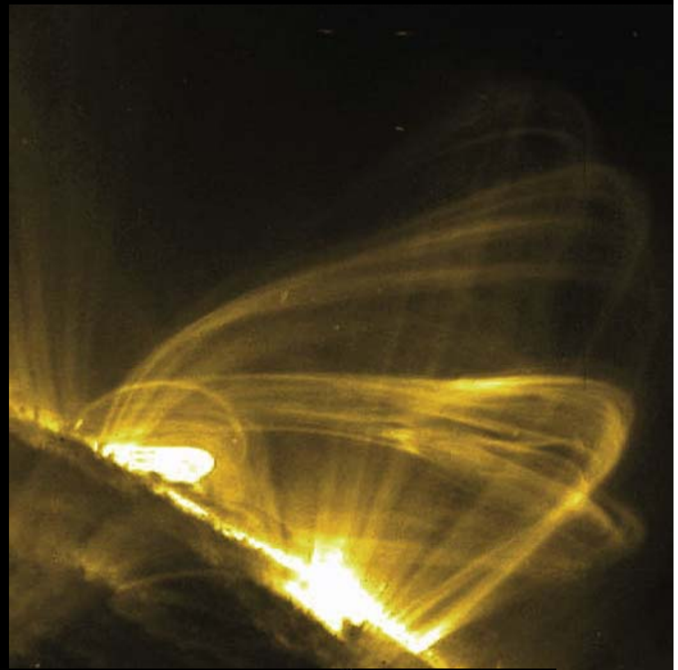
Open flux tube
Corona
$T_{plasma}$»10$^6$K
Transition region
Chromosphere
$T_{plasma}$= 6000K
Photosphere
corona
1 Mill
Temperature
6000
Photosphere
1000 Km
Height

# Loop structures are the "building blocks" of the corona

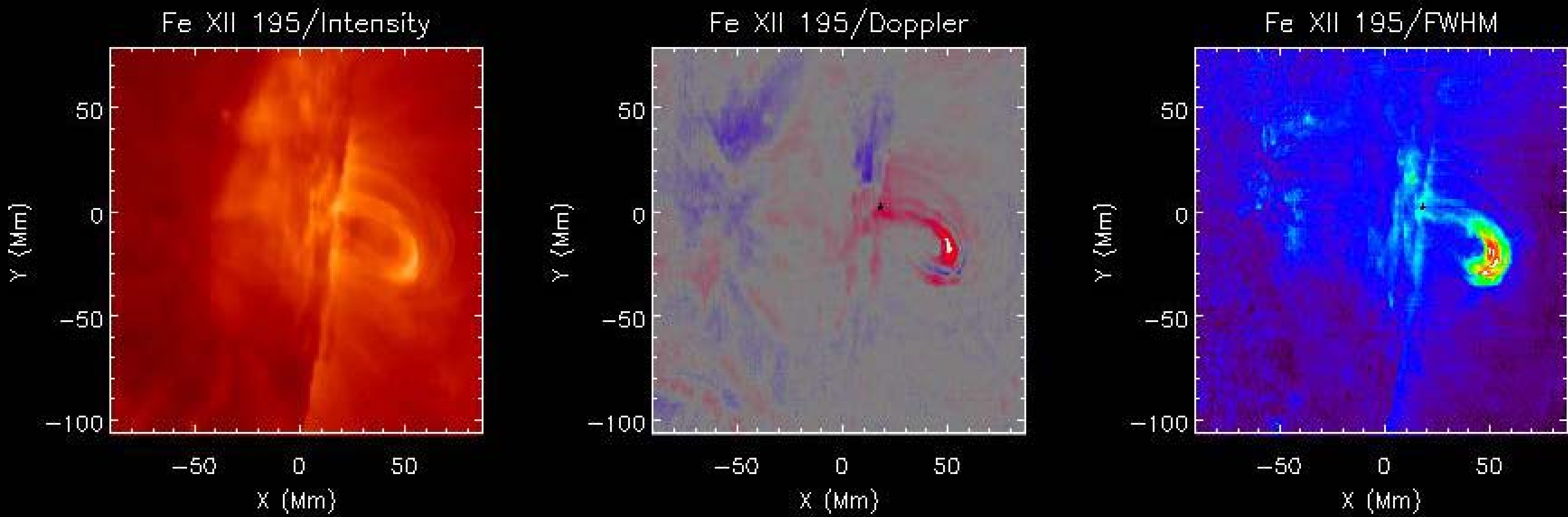
Yohkoh/SXT



TRACE

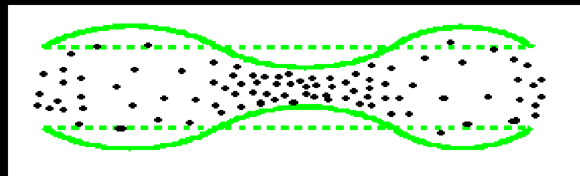


Hinode/EIS

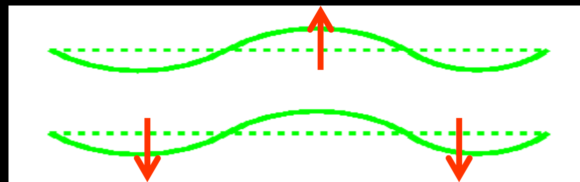


# Theoretically predicted MHD waves in coronal loops

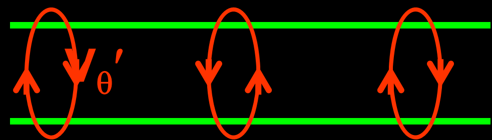
- Fast sausage



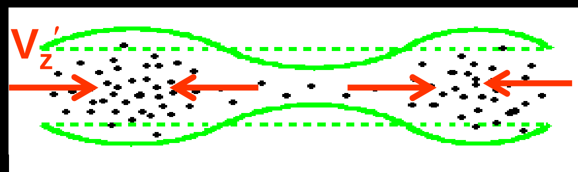
- Fast kink



- Alfvénic (torsional)




- Slow sausage (acoustic)

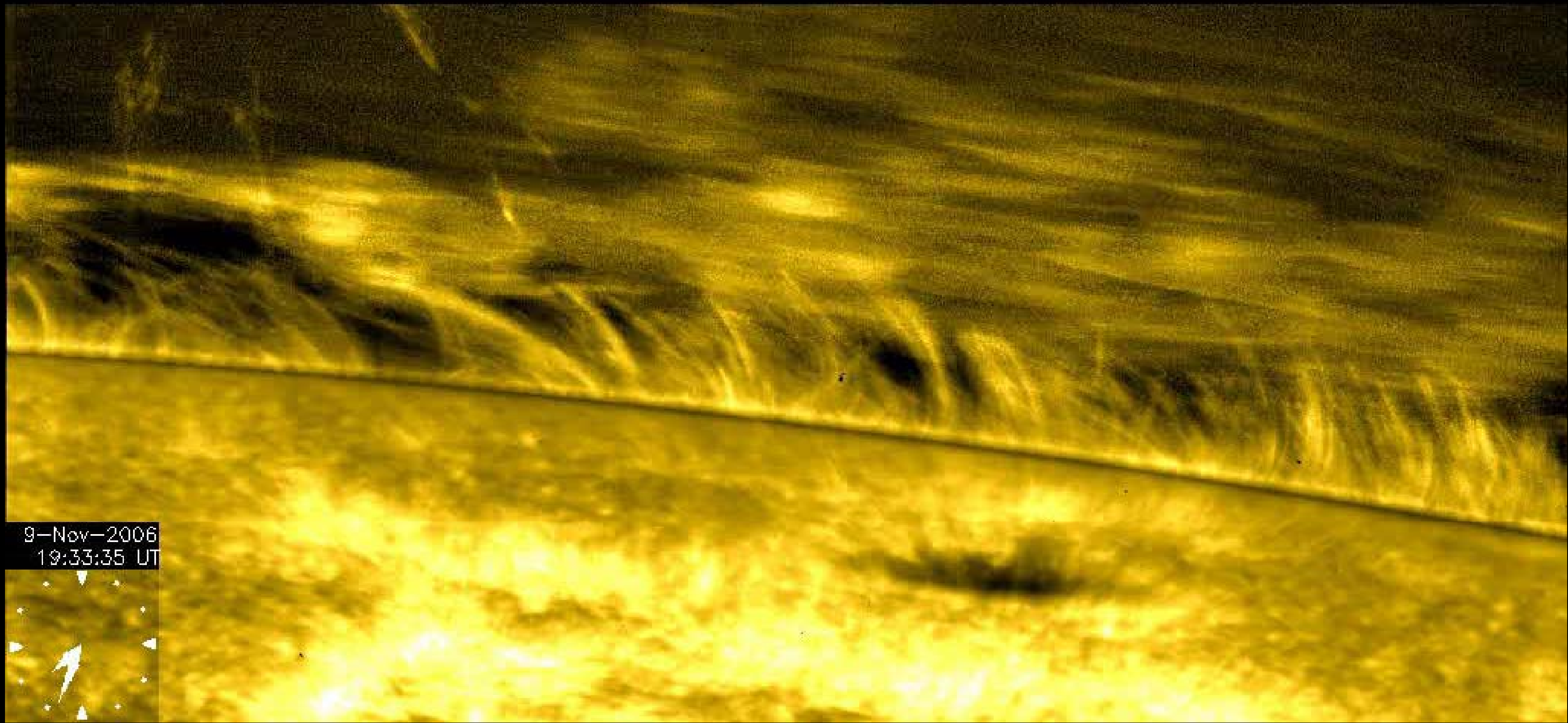


# Energetic and seismological implications of MHD waves

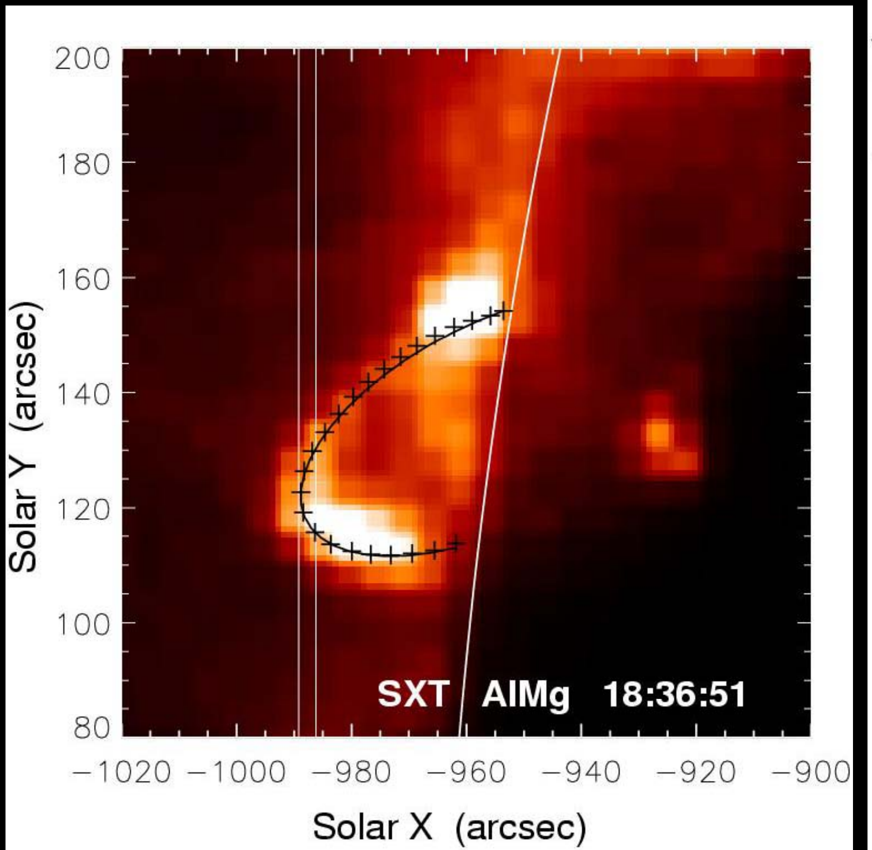
- Extraction and transfer of energy over long distances
- Energy deposition through various processes (nonlinear wave conversion and MHD shock formation, resonant absorption, phase mixing, etc.)
- Important dynamic (spicules, explosive events, etc.) and energetic consequences (plasma heating and acceleration)

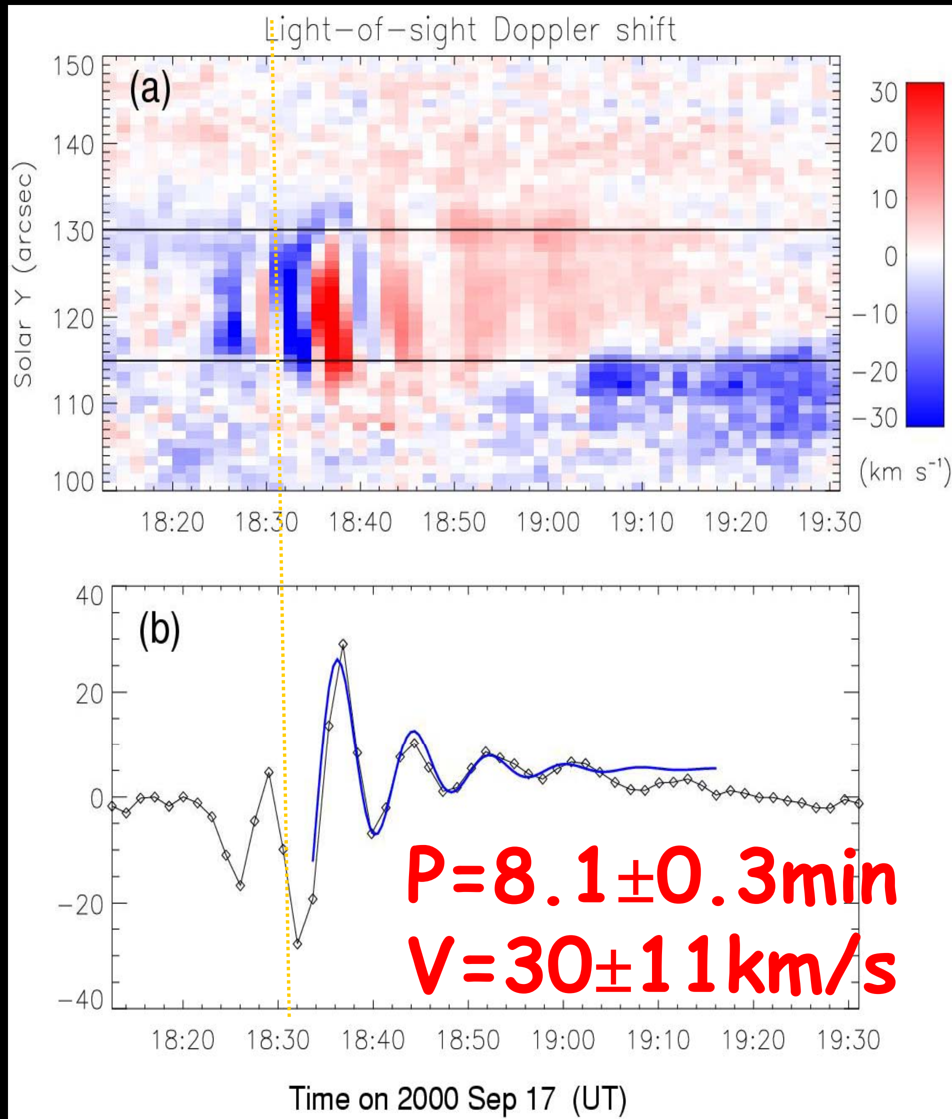
- Coronal waves provide information about the **magnetic field**, **transport coefficients**, **heating function**, etc.

# Examples of transverse oscillations 1 2



# SXT and SUMER observations of hot loop oscillations



# 1D loop modelling

Thermal conduction

Heating rate

Radiation

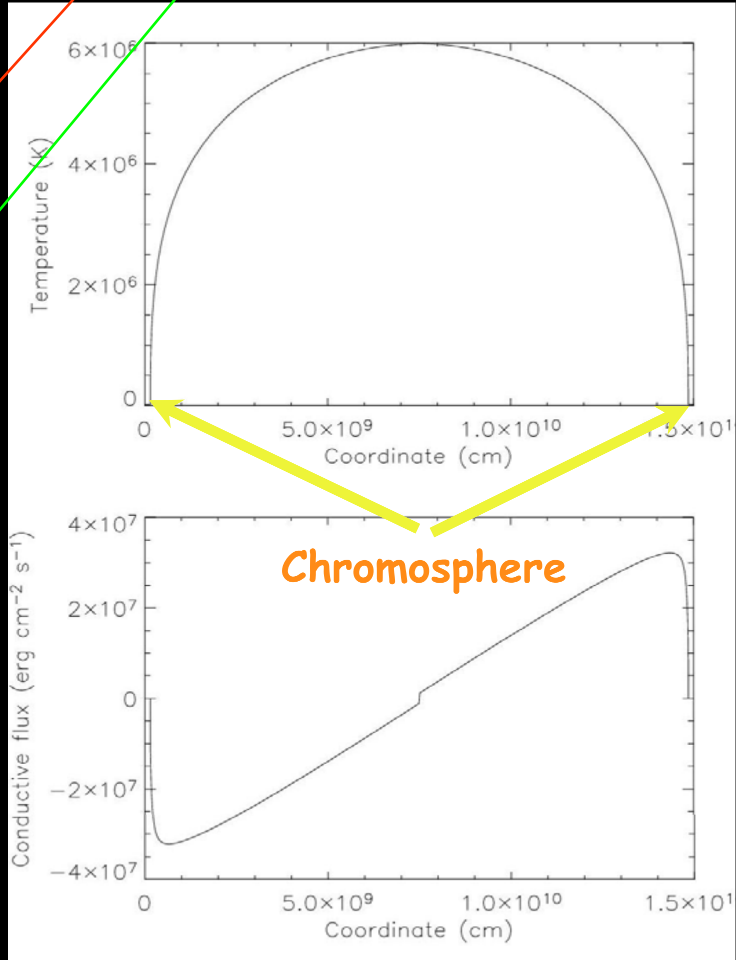
$$\frac{\partial}{\partial t}(\rho A) + \frac{\partial}{\partial s}(\rho v A) = 0,$$

$$\frac{\partial}{\partial t}(\rho v A) + \frac{\partial}{\partial s}(\rho v^2 A) = -A\left(\frac{\partial P}{\partial s} + \rho g_B\right),$$

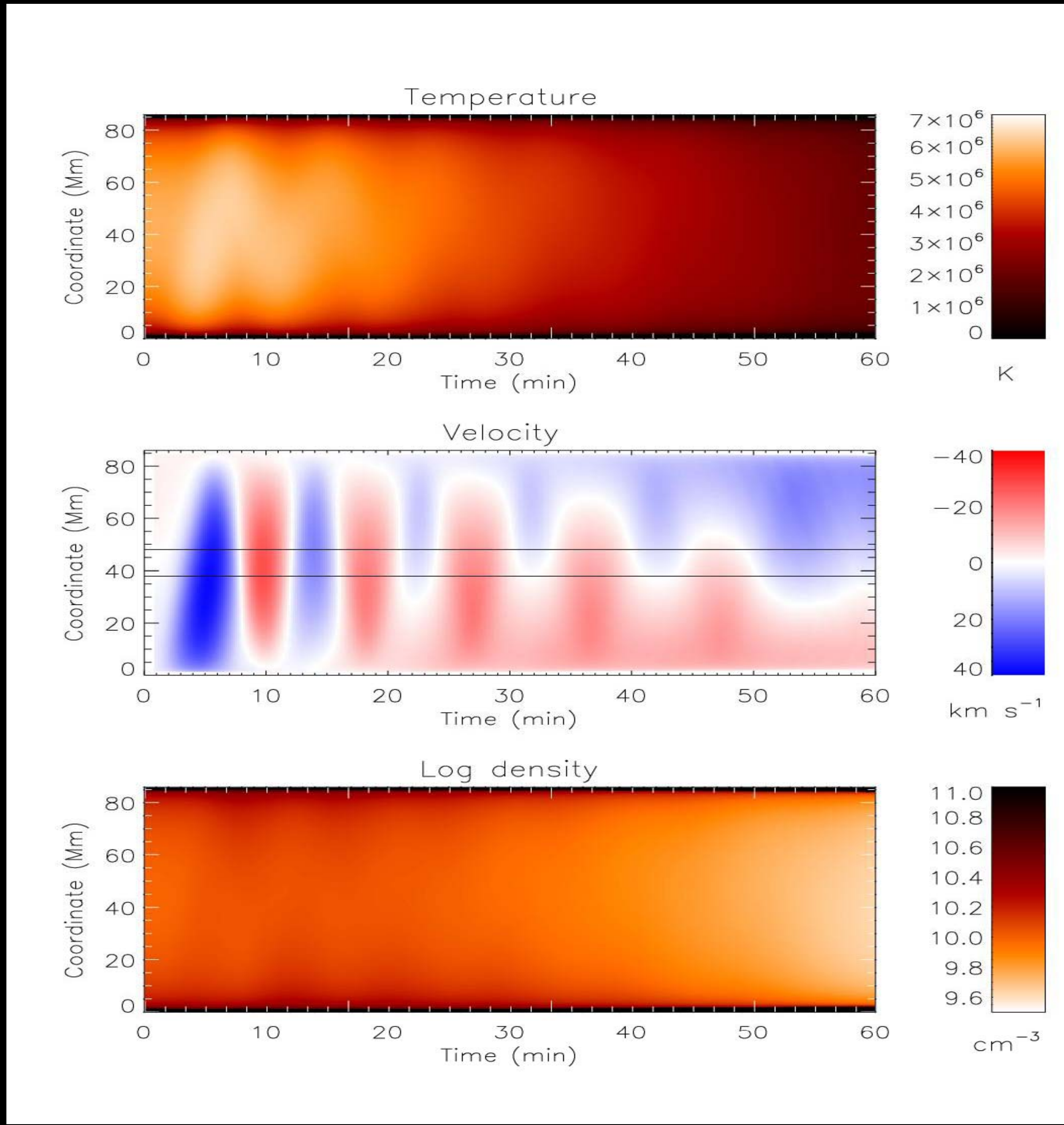
$$\frac{\partial}{\partial t}(EA) + \frac{\partial}{\partial s}(EvA) = -\frac{\partial}{\partial s}(PvA) + \rho v A g_B$$

$$-\frac{\partial}{\partial s}\left(-A\kappa T^{5/2}\frac{\partial T}{\partial s}\right) + A(H - L),$$

$$E = \frac{\rho v^2}{2} + \frac{P}{\gamma - 1}$$

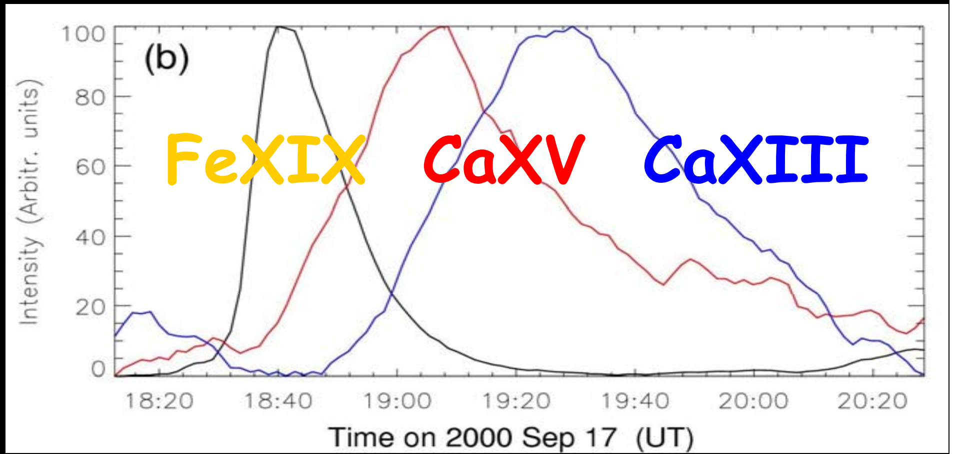


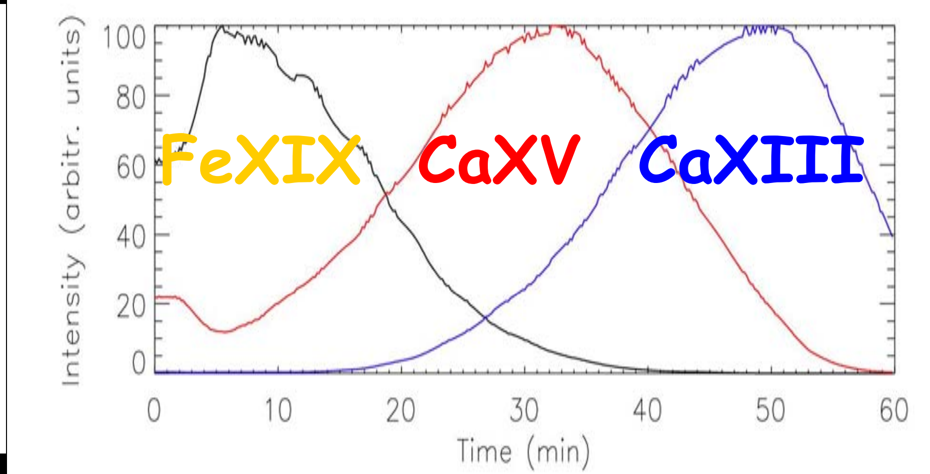
# Hydrodynamic evolution of the loop

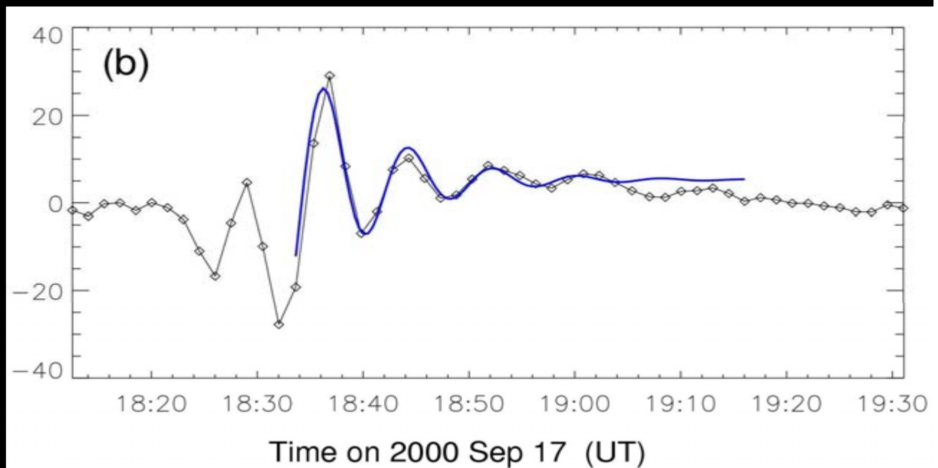


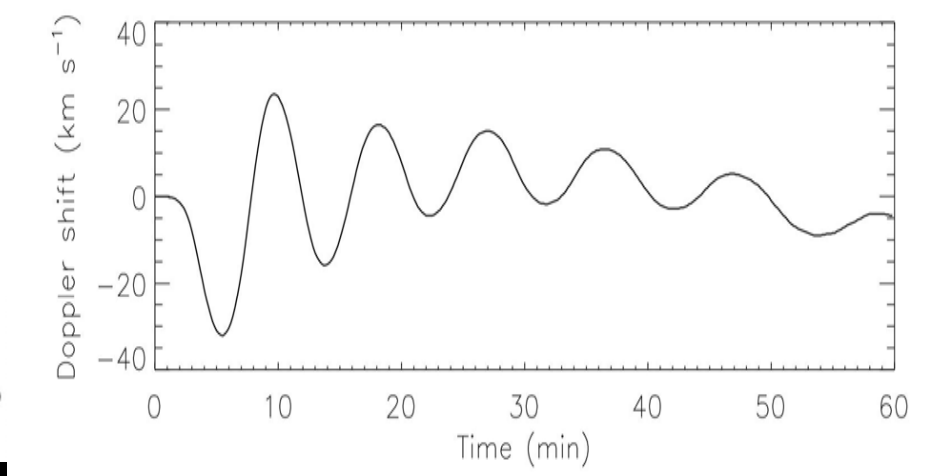
## SUMER measurements

## Results of line profile synthesis



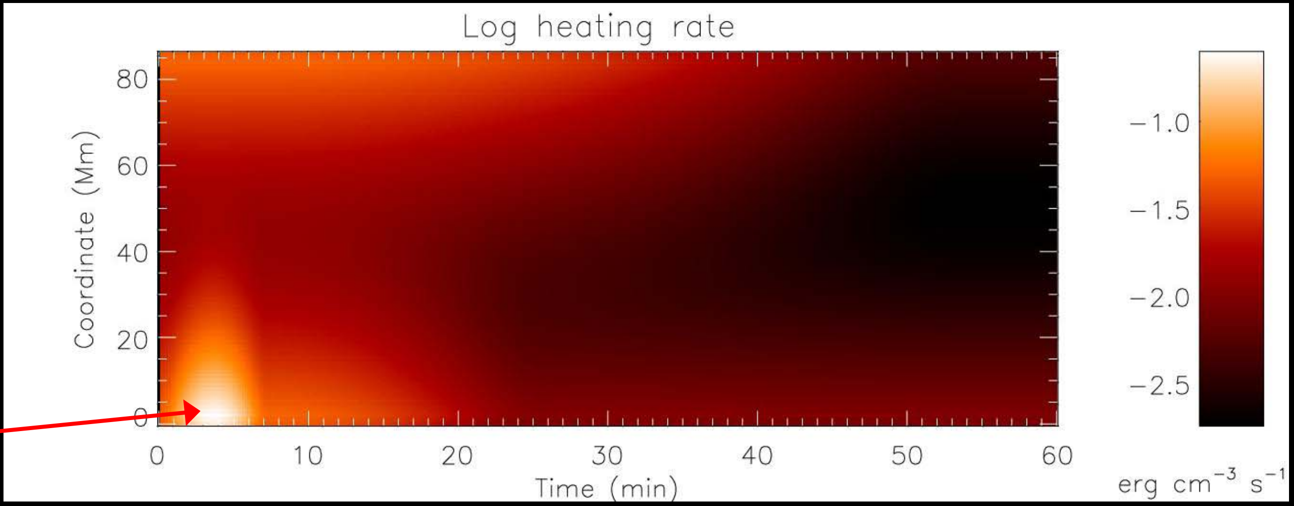



# Results of combined observations and modeling (from Taroyan et al. ApJ 2007)

- Establish the nature of the observed hot loop oscillations
- Standing acoustic waves set up by a footpoint microflare
- Reproduce the time-distance profile of the heating function (important for understanding the nature of the heating process)
- Why only hot loops?

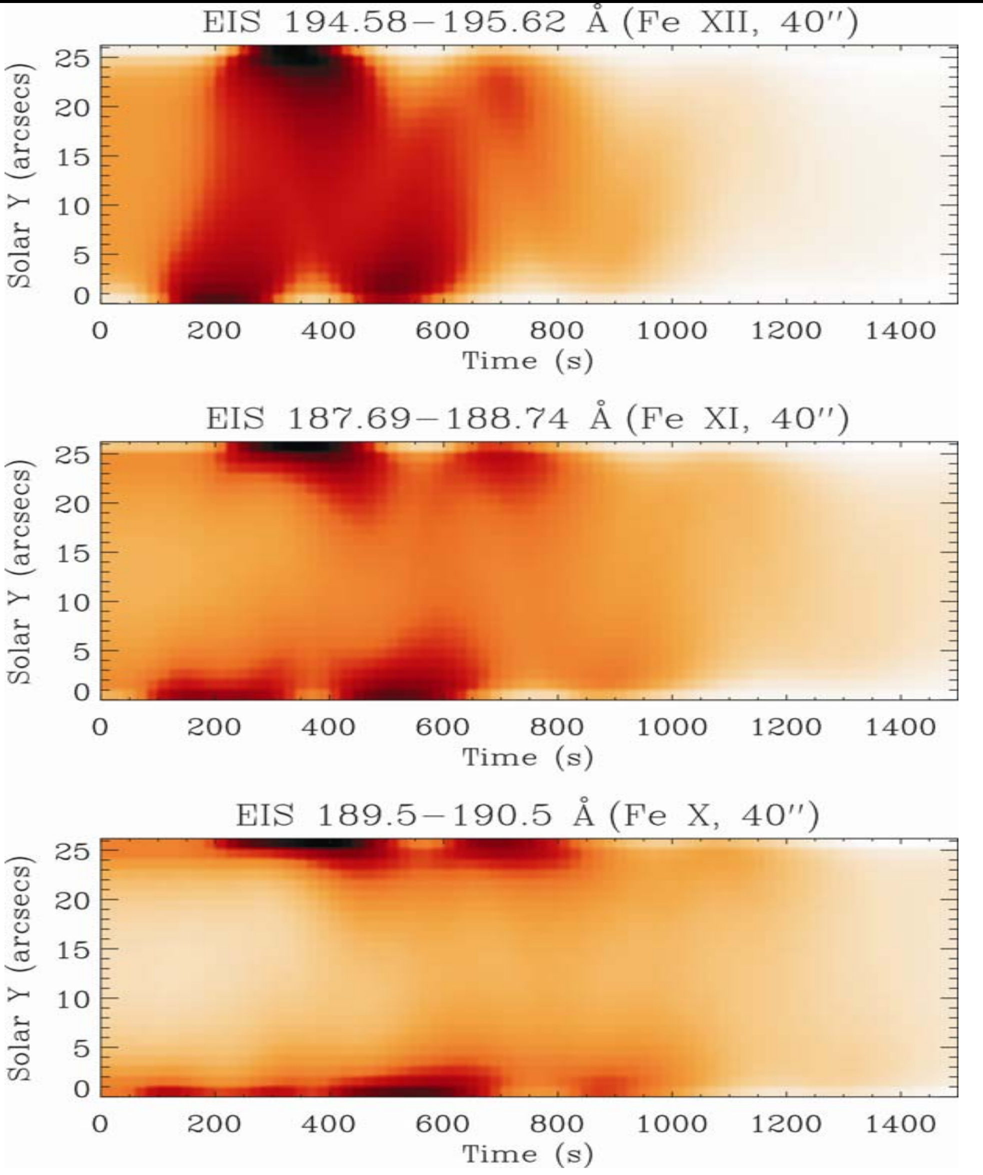
$1.5x10^{27}$ erg

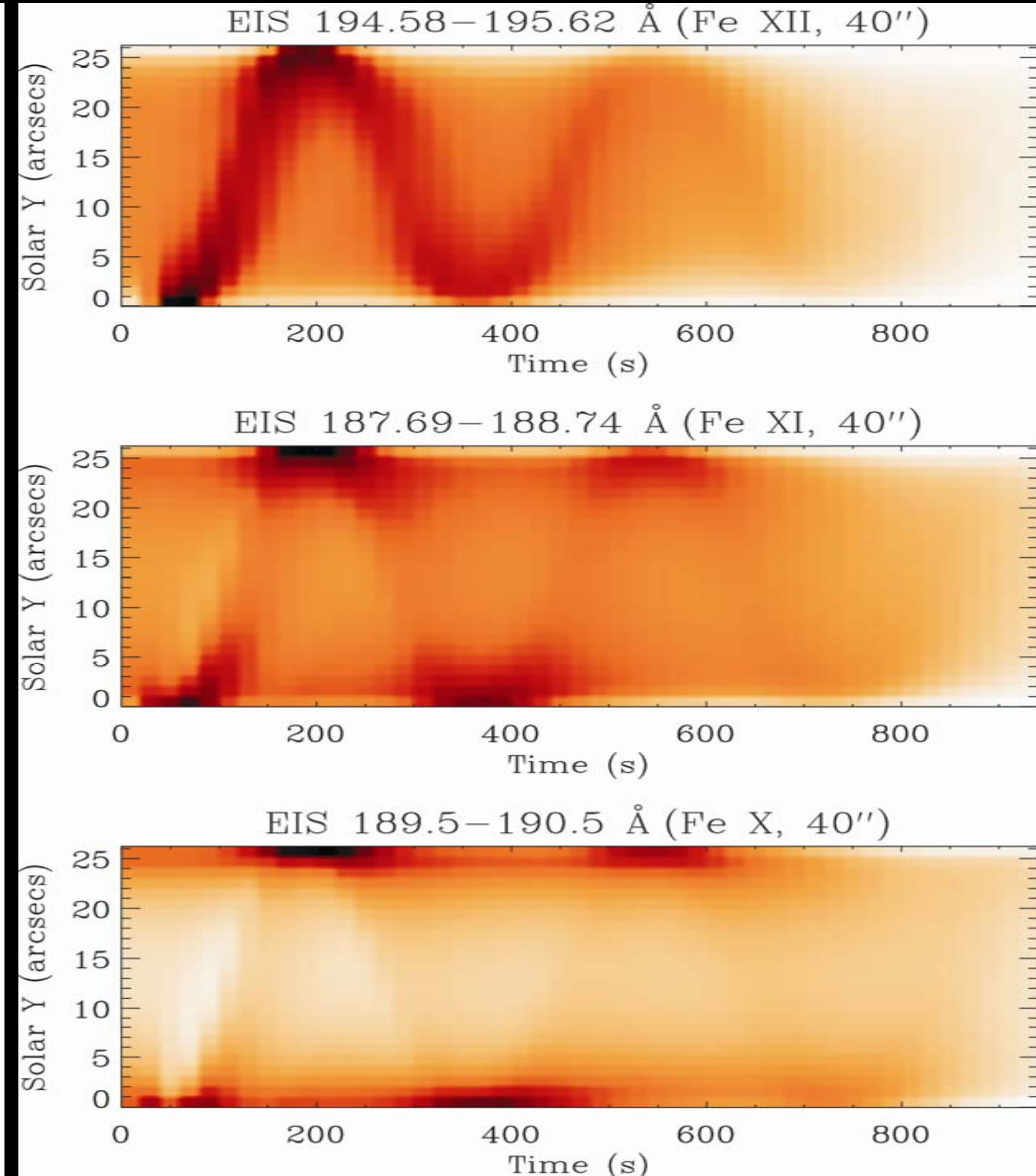


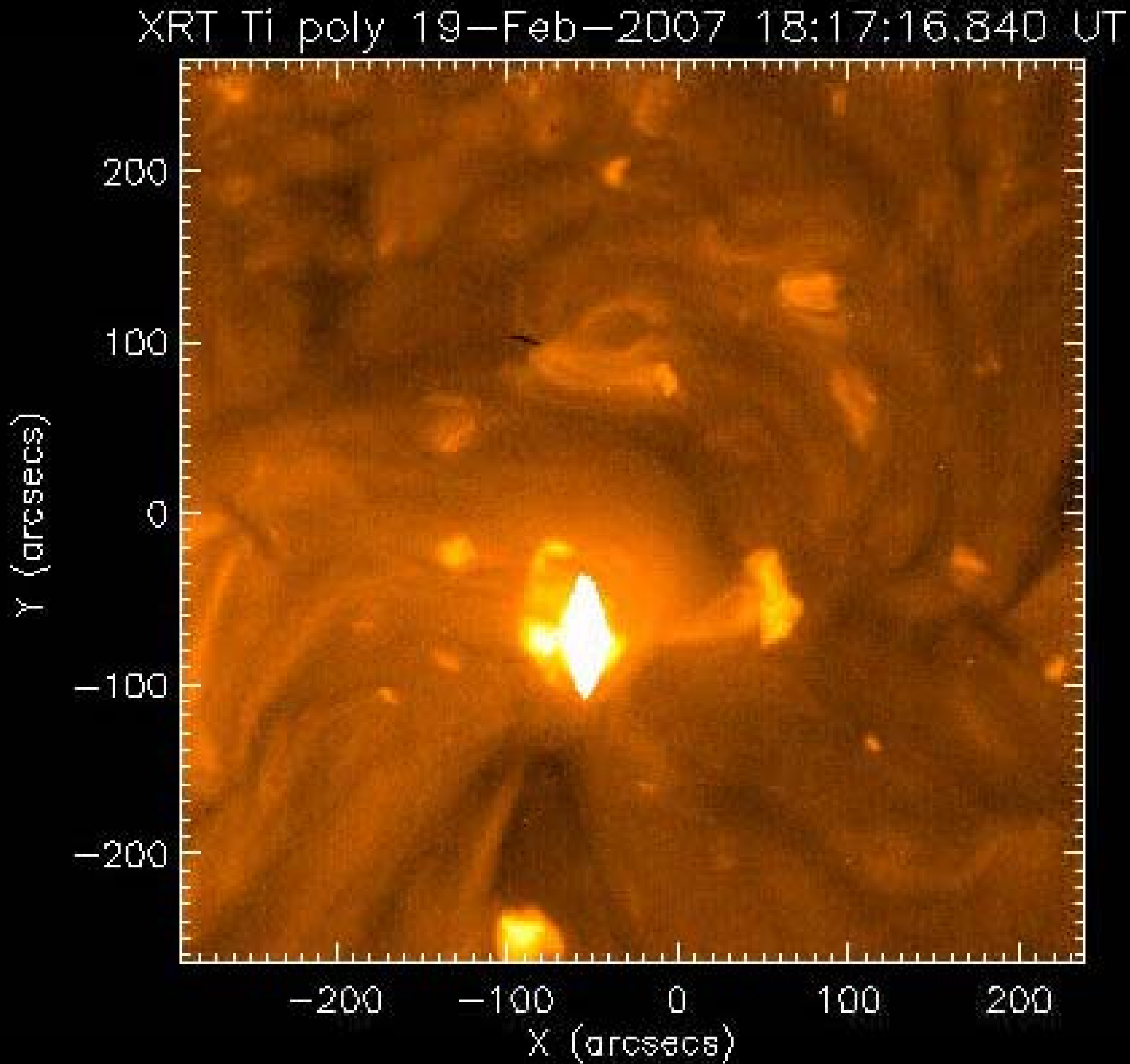
## Standing waves

(from Taroyan & Bradshaw A&A 2008)

## Propagating waves

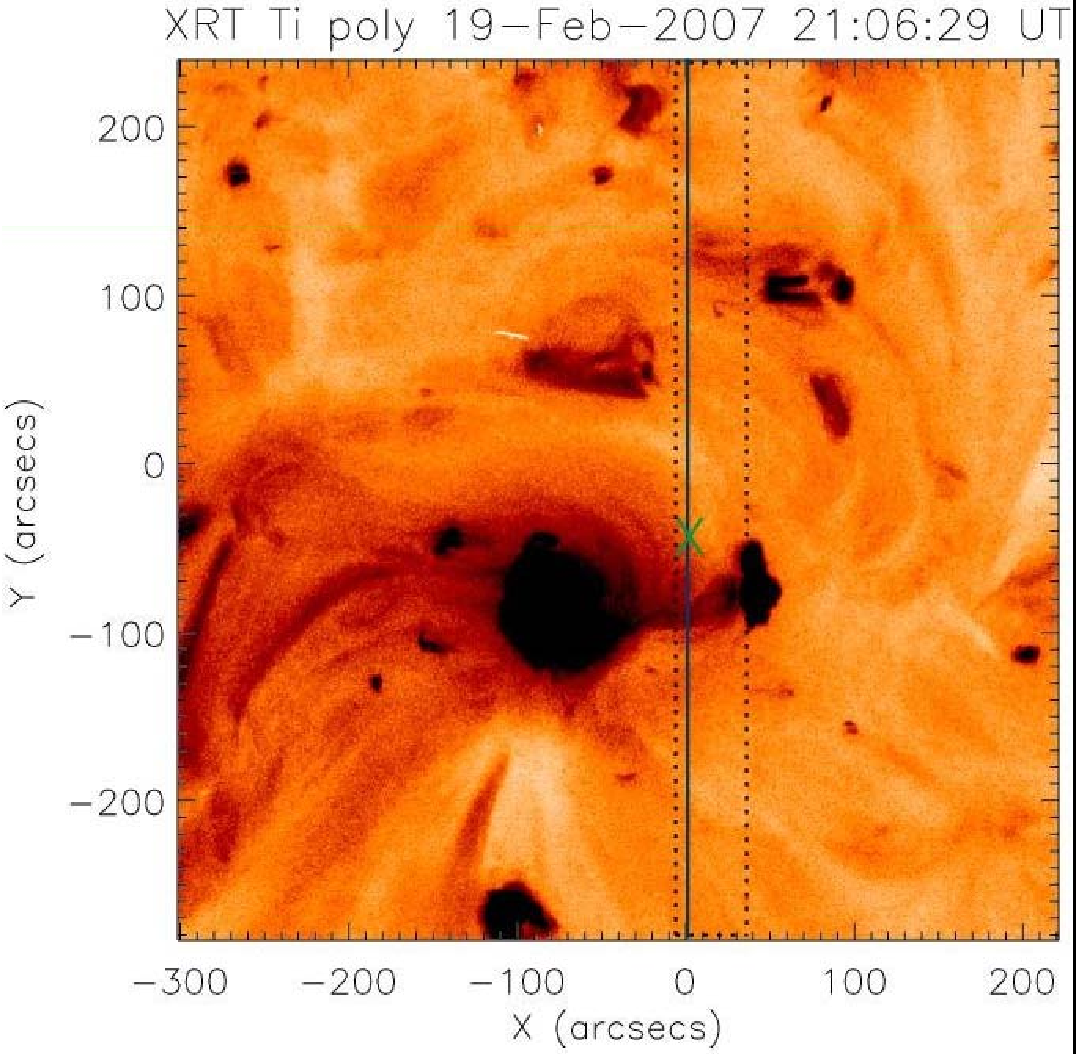


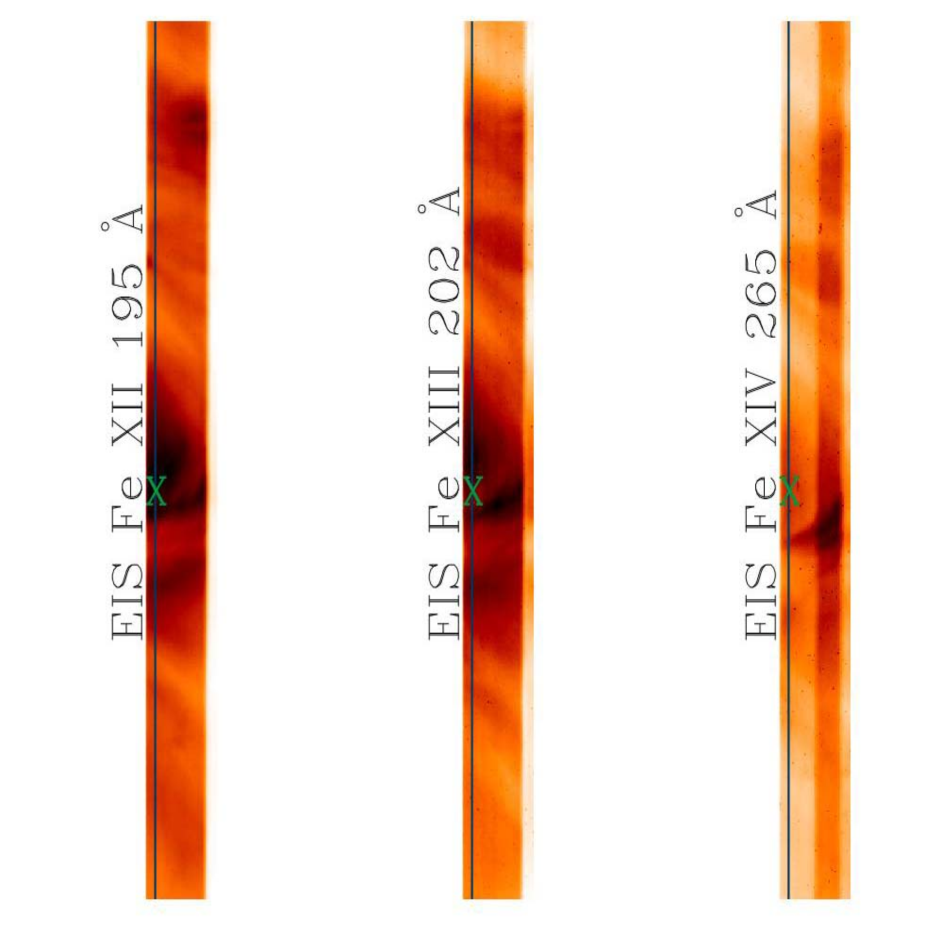





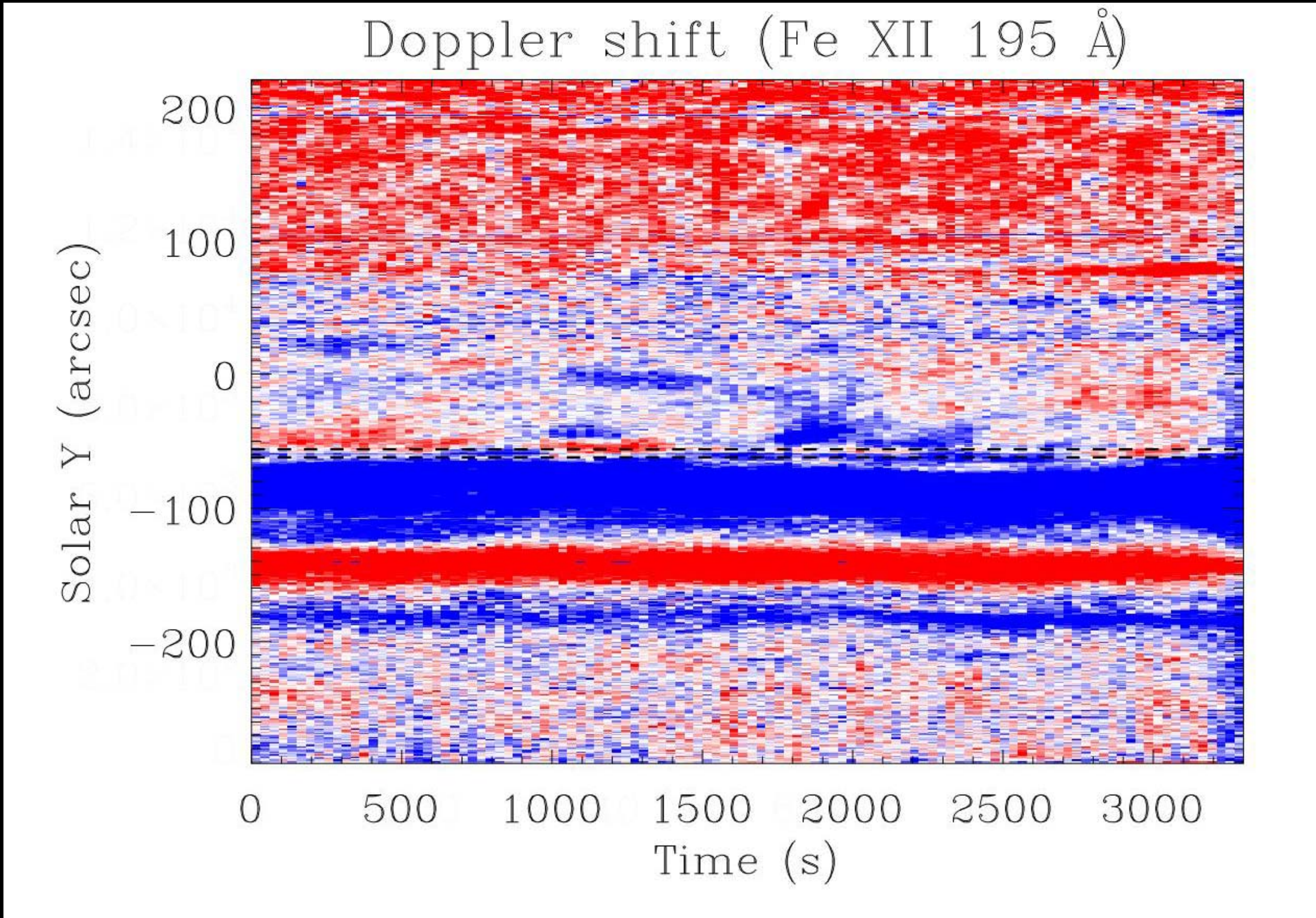
XRT Ti poly 19−Feb−2007 18:17:16.840 UT
200
100
0
−100
−200
Y (arcsecs)
−200
−100
0
100
200
X (arcsecs)

# XRT and EIS observations

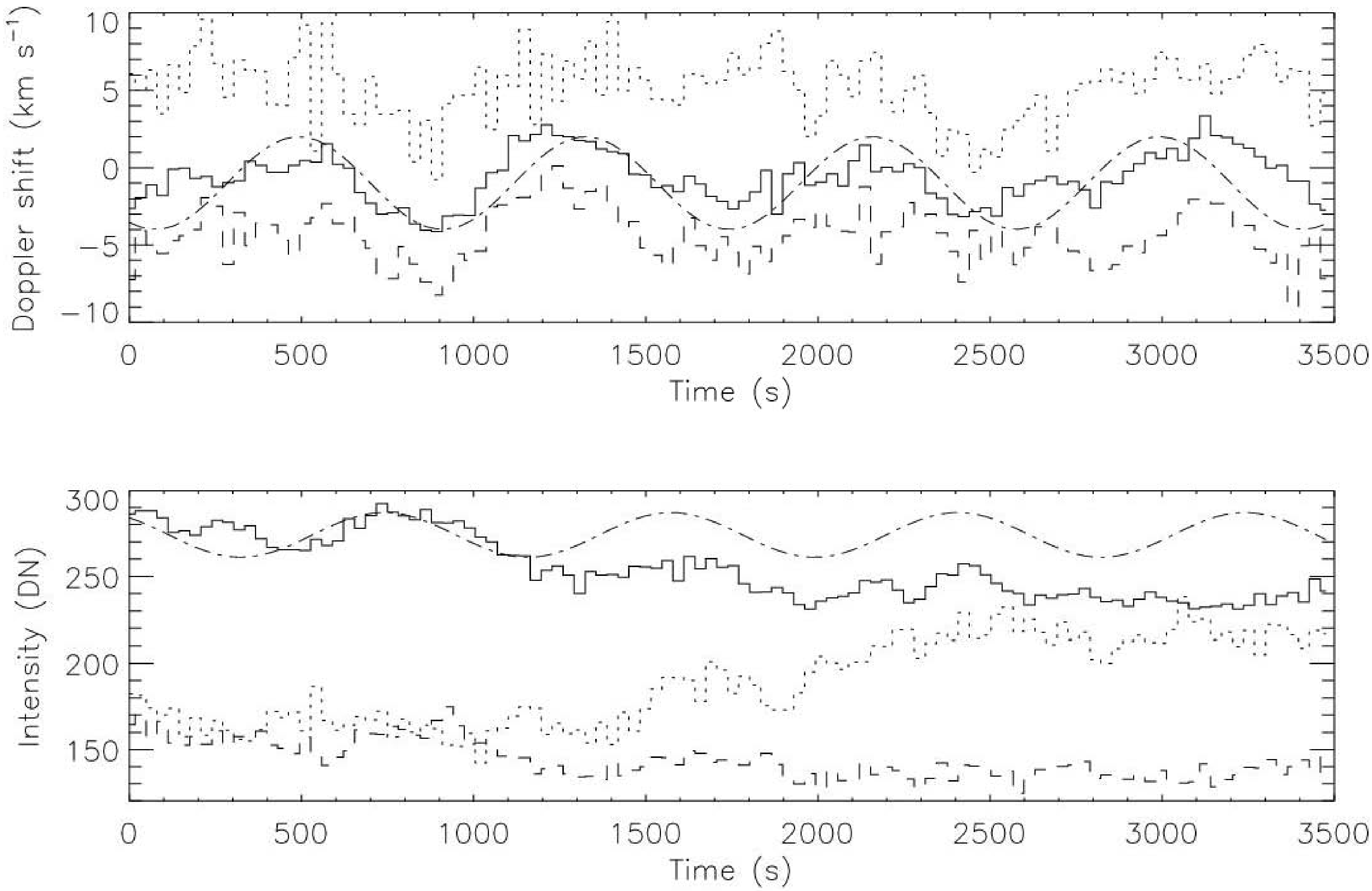


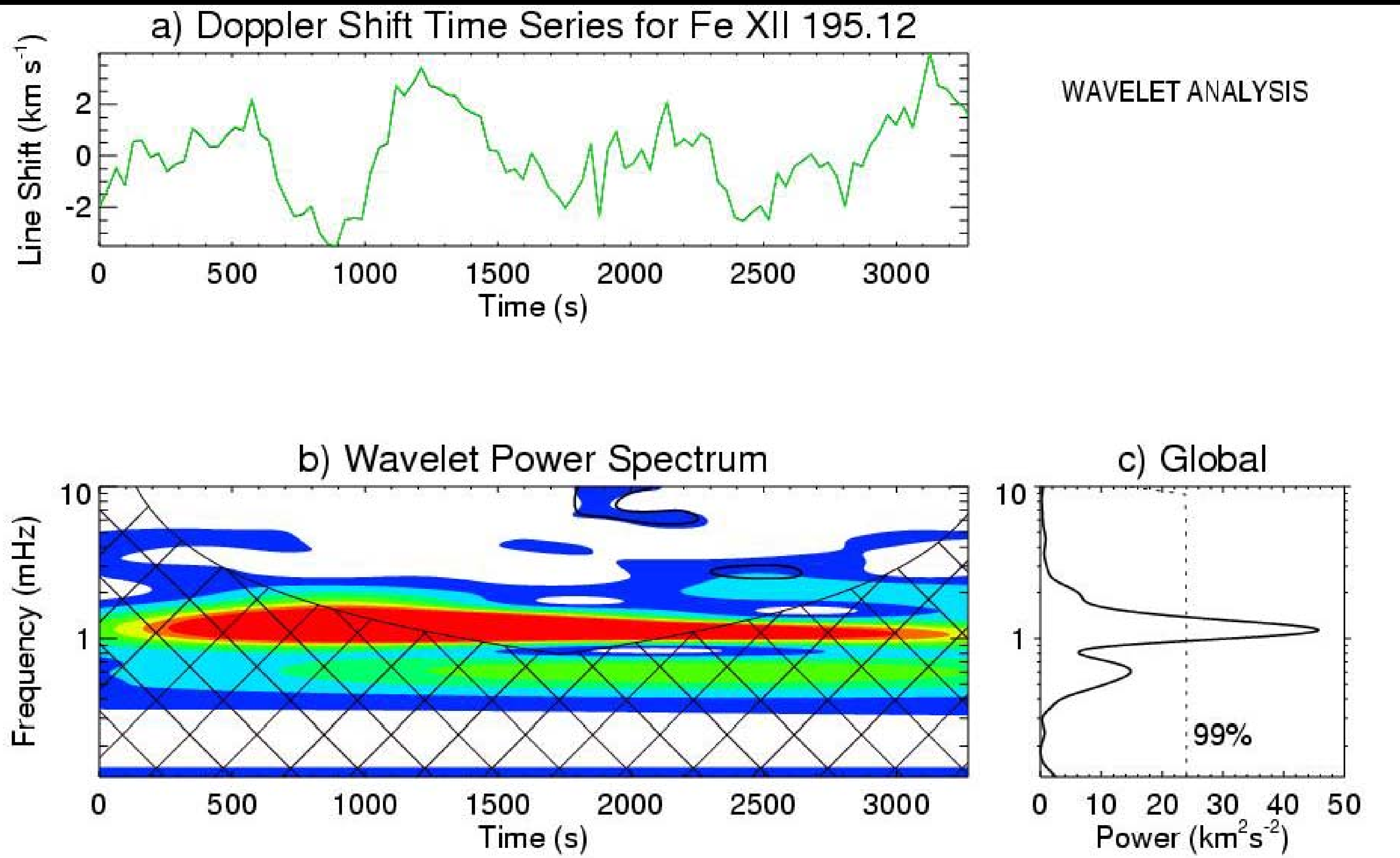
# Doppler shift along the slit



# Doppler shift and intensity time series averaged over 5 pixels



# Wavelet analysis



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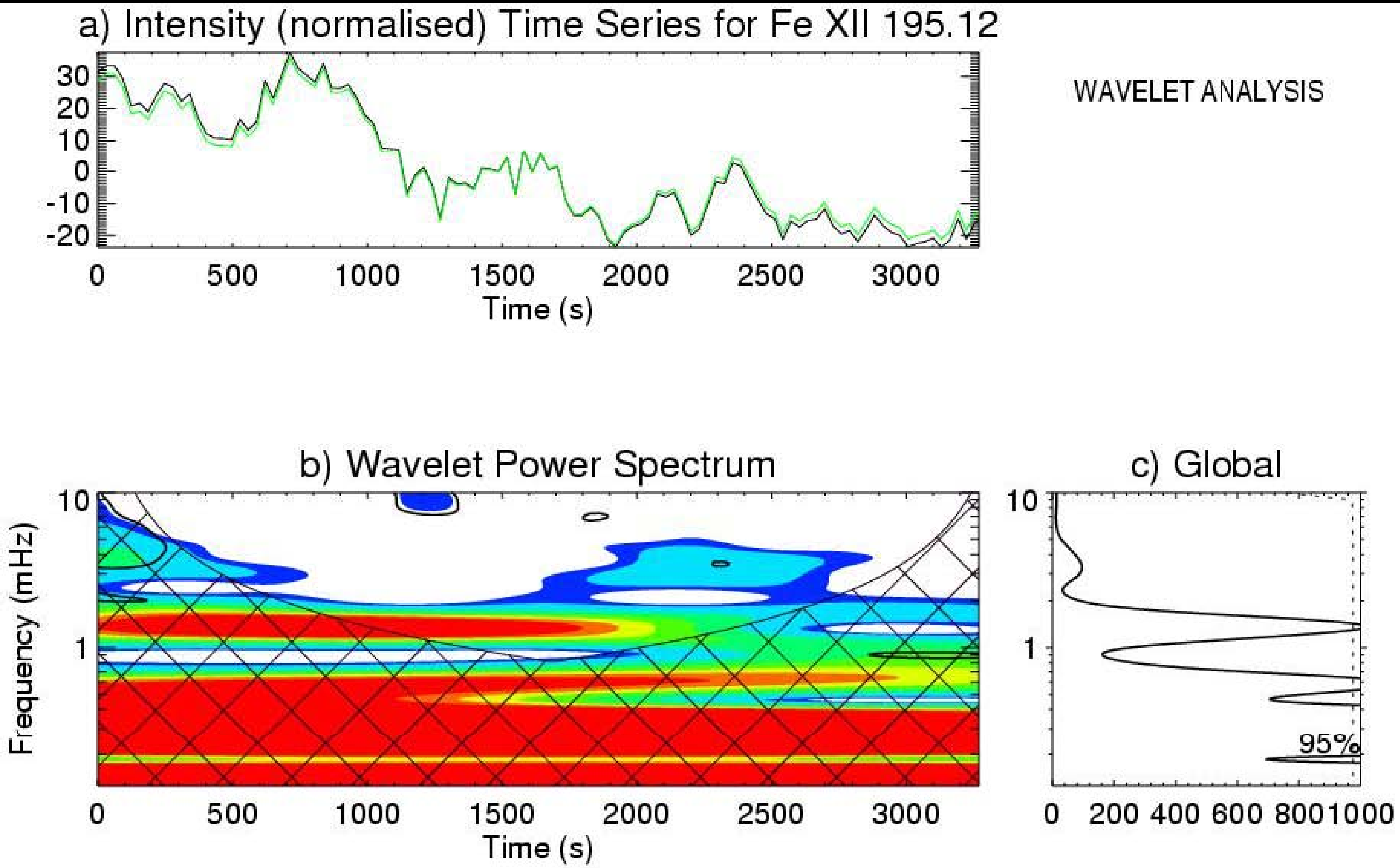
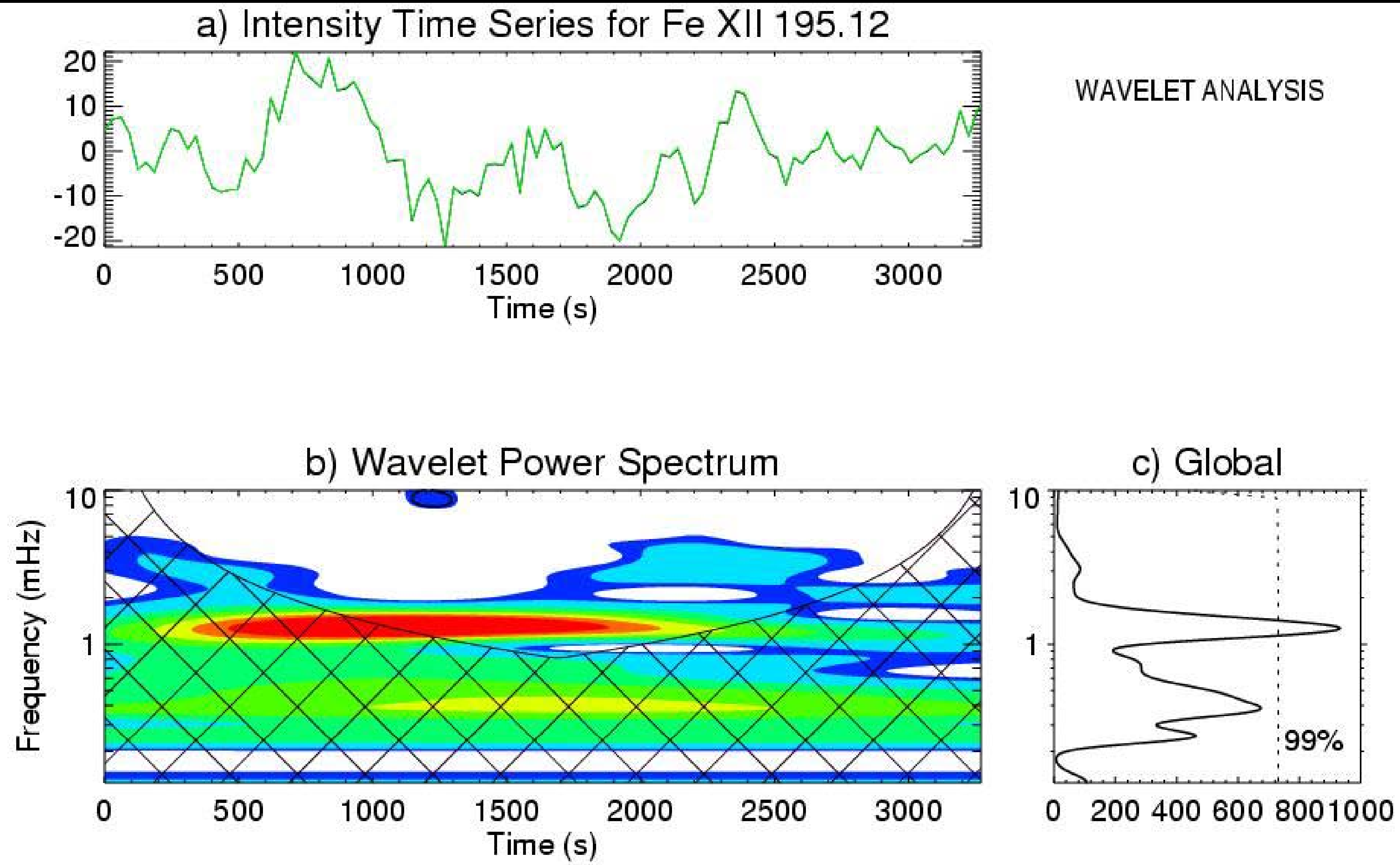


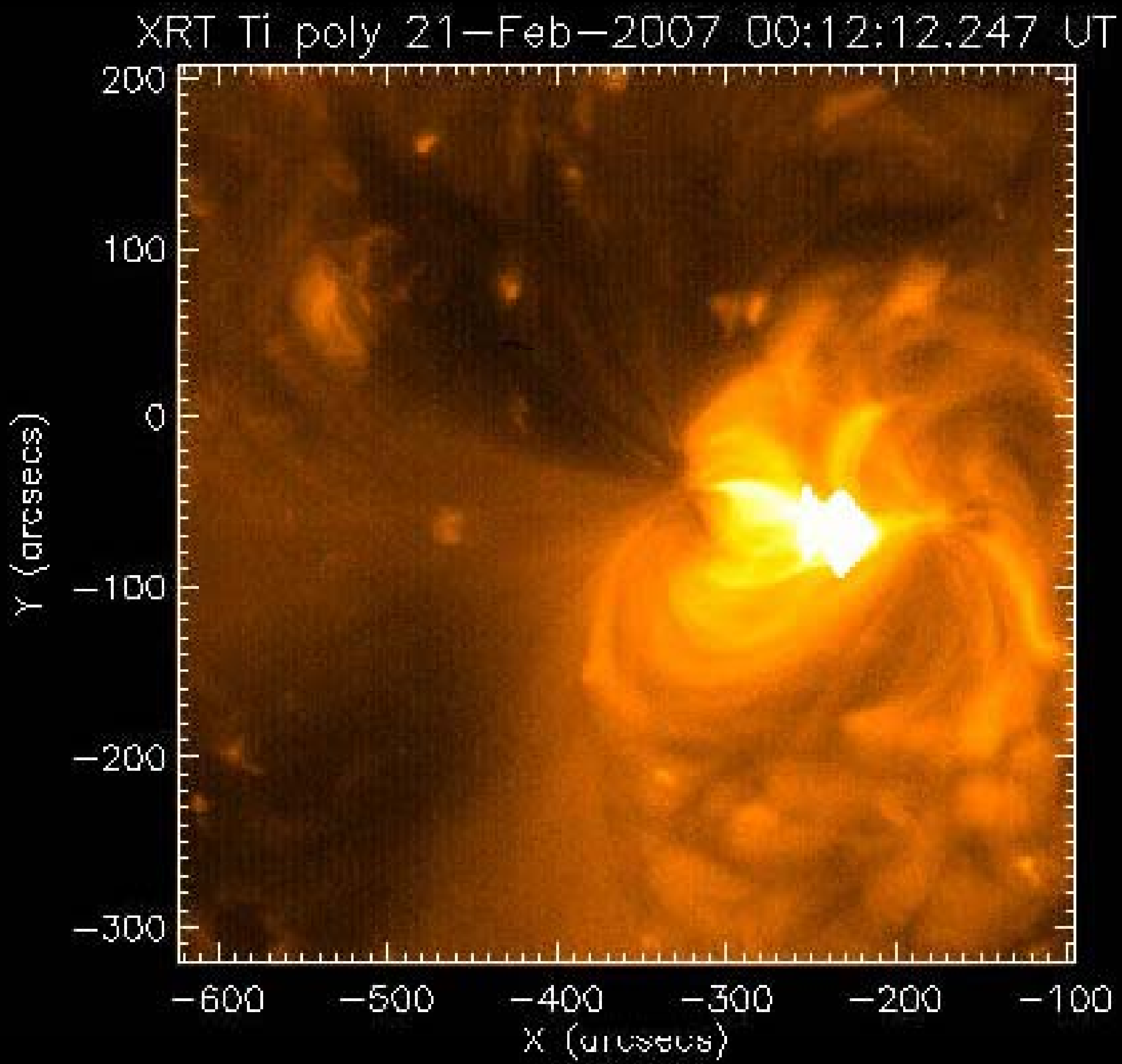
# Wavelet analysis



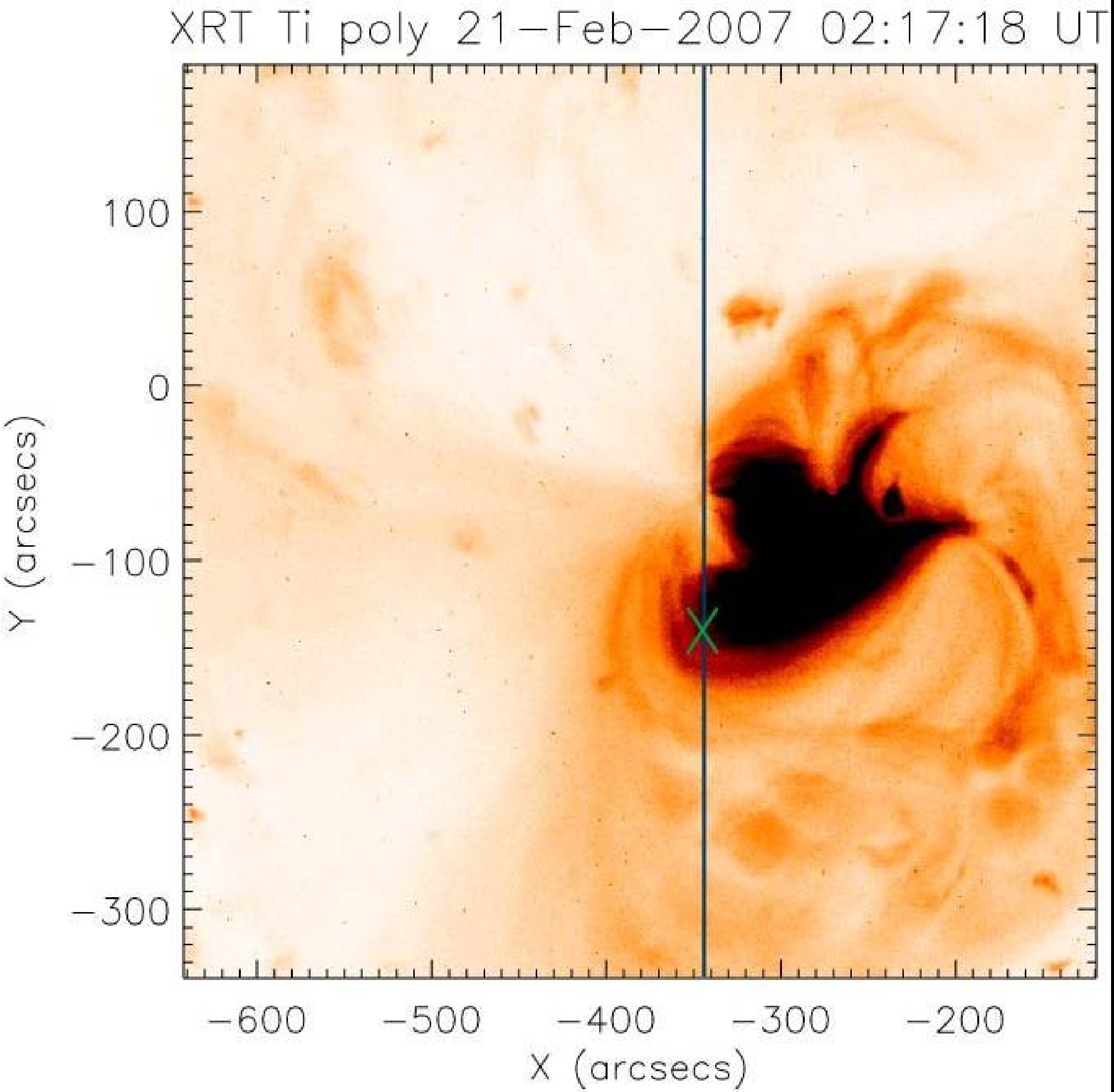
# Interpretation

The XRT and EIS snapshots suggest that

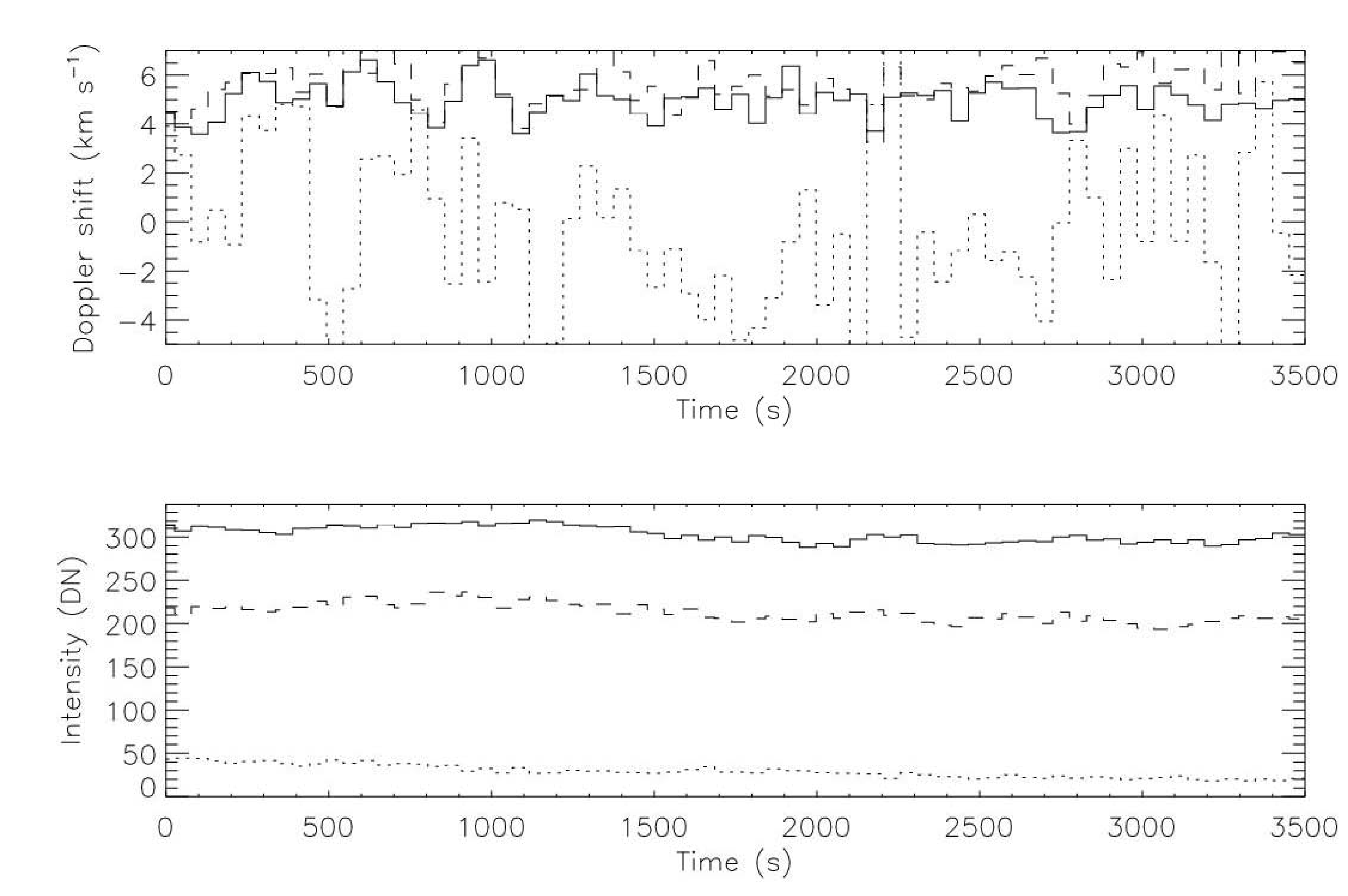
- The oscillations seen by EIS in spectroscopy mode correspond to a footpoint region of a loop;
- The oscillations are preceded by a microflare near the footpoint.
- Intensity increase in lower temperature lines (Fe VIII) and decrease in higher temperature lines (Fe XII, FeXIII, Ca XIII)
- Quarter period phase shifts between the intensity and Doppler shift oscillations.


XRT Ti poly 21-Feb-2007 00:12:12.247 UT
200
100
0
−100
−200
−300
Y (arcsecs)
−600
−500
−400
−300
−200
−100
X (arcsecs)

# XRT and EIS observations



# Doppler shift and intensity time series averaged over 5 pixels



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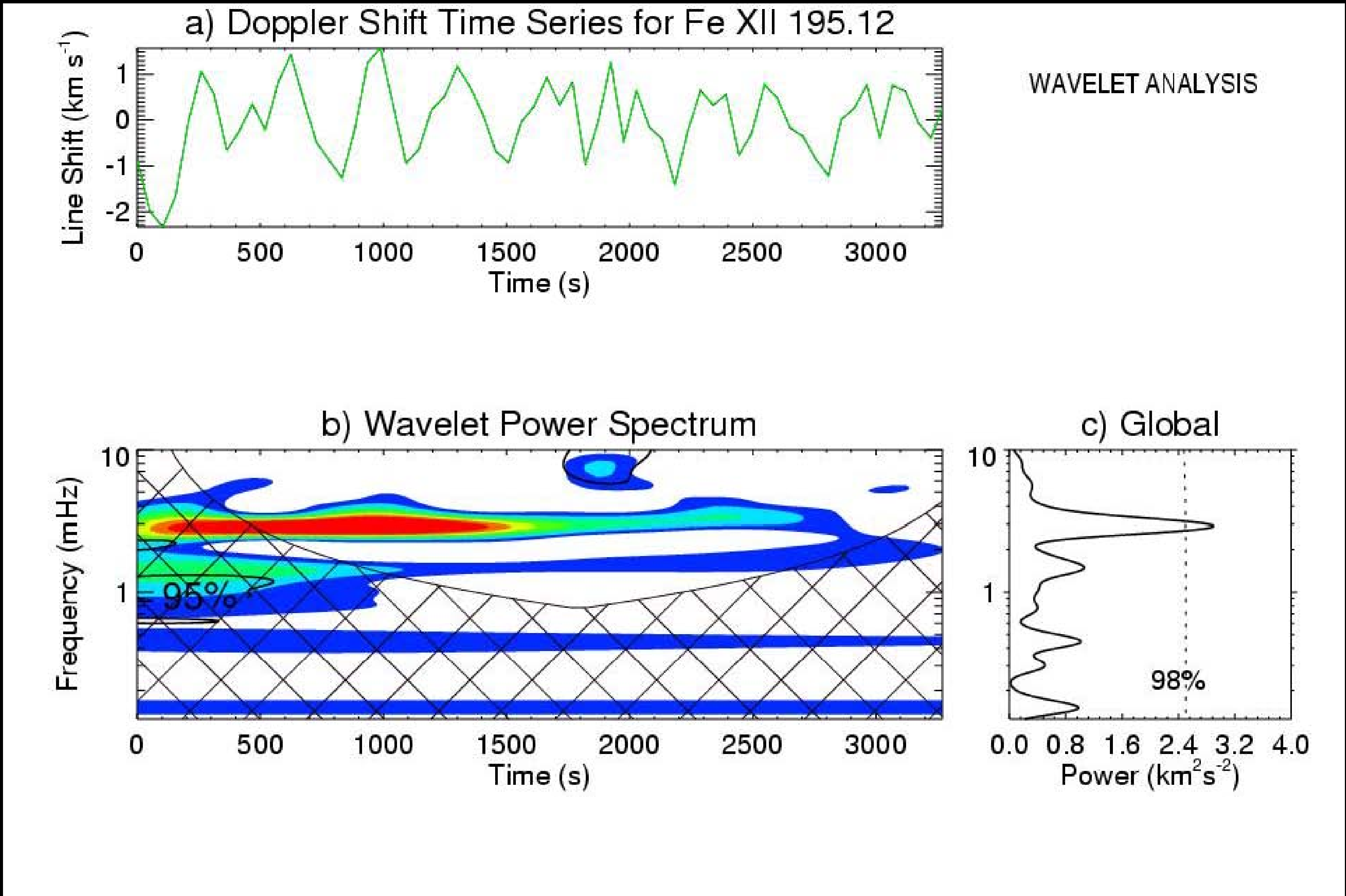

# Interpretation

- The XRT snapshots suggest that
  1. the oscillations seen by EIS correspond to an apex region of a loop crossed by the slit;
- Transverse motions should have a line-of-sight component
- Doppler and no intensity oscillations --> magnetoacoustic kink waves
- Magnetic field measurements using intensity ratios between different Fe lines: B~10 G

# Summary

•Hinode/XRT and Hinode/EIS observations in sit-and-stare mode are carried out to study oscillations in active region loops.

•Small amplitude oscillations are seen in different lines and pixels along the slit.

•Doppler shift and intensity oscillations (1 mHz) are detected near loop footpoints and are interpreted as standing longitudinal acoustic type waves.

•3 mHz oscillations in the Doppler shift are present at near apex regions and are most likely to be kink waves. These waves have small amplitudes and have different origins from previously studied examples of flare-triggered oscillations. The oscillations are used to measure the magnetic field.