Propagating waves in coronal loops?

Dipankar Banerjee

&

Krishna Prasad S.

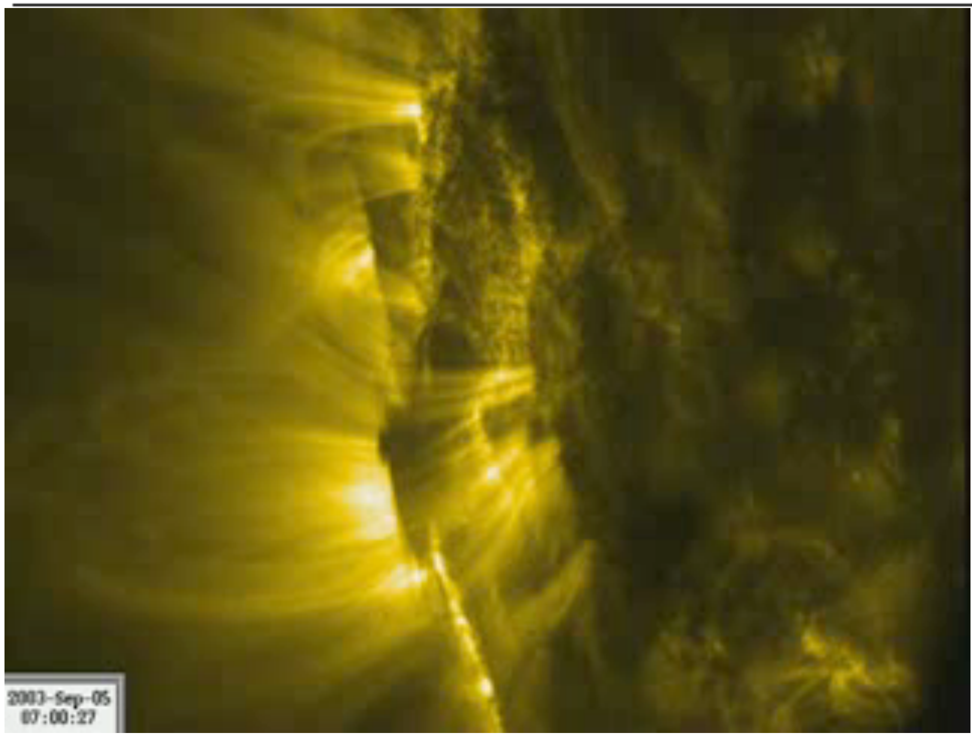
Indian Institute of Astrophysics

Introduction

- Ofman et al (1997) reported the first observation of propagating intensity disturbances in coronal plumes using SoHO/UVCS, followed by Deforest & Gurman (1998), Berghmans and clette (1999) using SoHO/EIT and more recently Banerjee et al (2009) using EIS and SUMER
- Ofman et al. (1999, 2000) interpreted them as MHD slow mode.
- Nightingale (1999) found these disturbances using TRACE near the coronal foot points followed by De Moortel et al (2000) and Robrecht et al (2001).
- Models interpreting these as damped magneto-acoustic oscillations in a stratified atmosphere were provided by Nakariakov et al (2000) and Tsiklauri & Nakariakov (2001).
- Later work revealed that the oscillations along foot points anchored in sunspot regions is dominated by 3 min and in the plage regions by 5 min. Periodicites.

Observed parameters

Parameter	Average	Range
Oscillation Period, P	284.0 ± 10.4 s	145–550 s
Propagation Speed, v	99.7 ± 3.9 km s^{-1}	$O(45)$–$O(205)$ km s^{-1}
Relative Amplitude, A	$3.7\% \pm 0.2\%$	0.7–14.6%
Detection Length, L_d	8.3 ± 0.6 Mm	2.9–23.2 Mm
Energy Flux, F	313 ± 26 erg cm^{-2} s^{-1}	68–1560 erg cm^{-2} s^{-1}



From McEwan and De Moortel (2006).

About the data

Details of the 11th September 2003 JOP165 data.

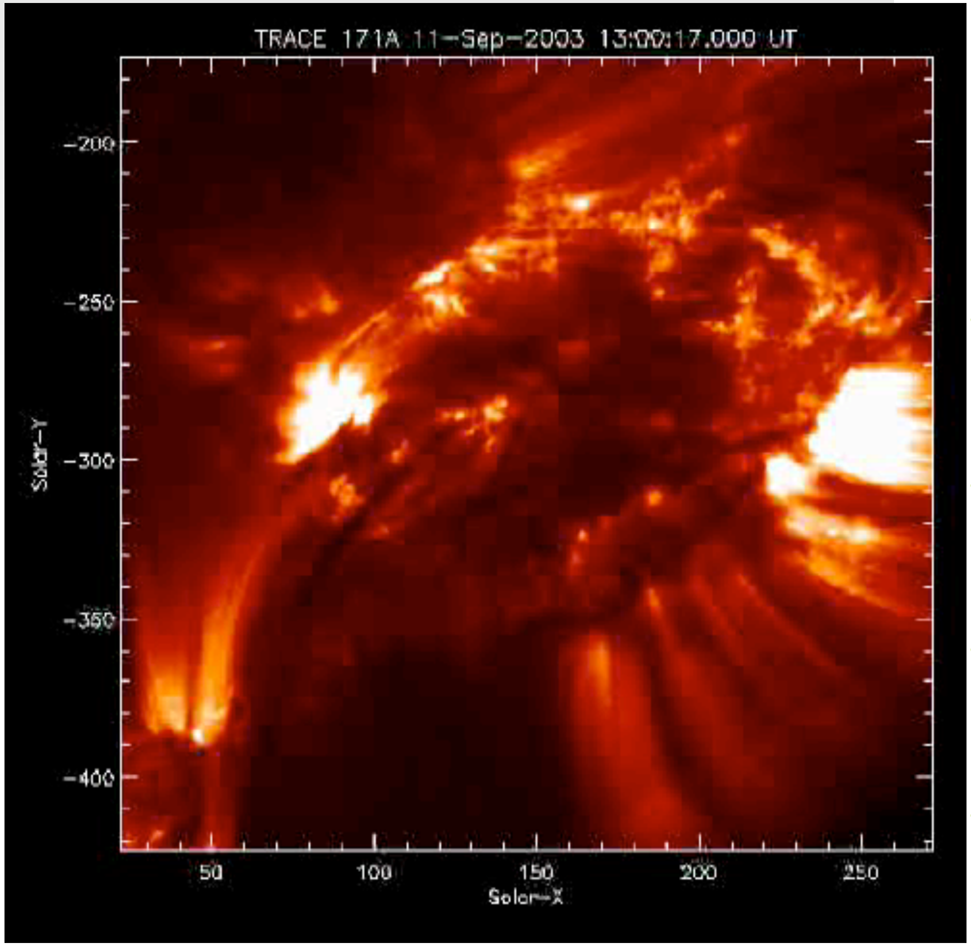
Data	Start & End time	Total duration (approx.)	Cadence	Exp. time	Spatial resolution
TRACE Images	13:00:17.000 - 20:59:32.000	8 Hours	1 min.	46.34 sec.	0.5" x 0.5"
CDS Raster	13:45:34.712 - 14:07:15.715	22 min.	21 sec	15 sec	4" x 3.3"
CDS Slits [Sit & Stare] (Total 11 slits 0-10, each of duration 30min.)	14:07:51.199 - 19:37:26.081	5 ½ Hours	21 sec.	15 sec.	4" x 3.3"
CDS Raster	19:38:10.087 - 19:59:49.583	22 min.	21 sec	15 sec	4" x 3.3"

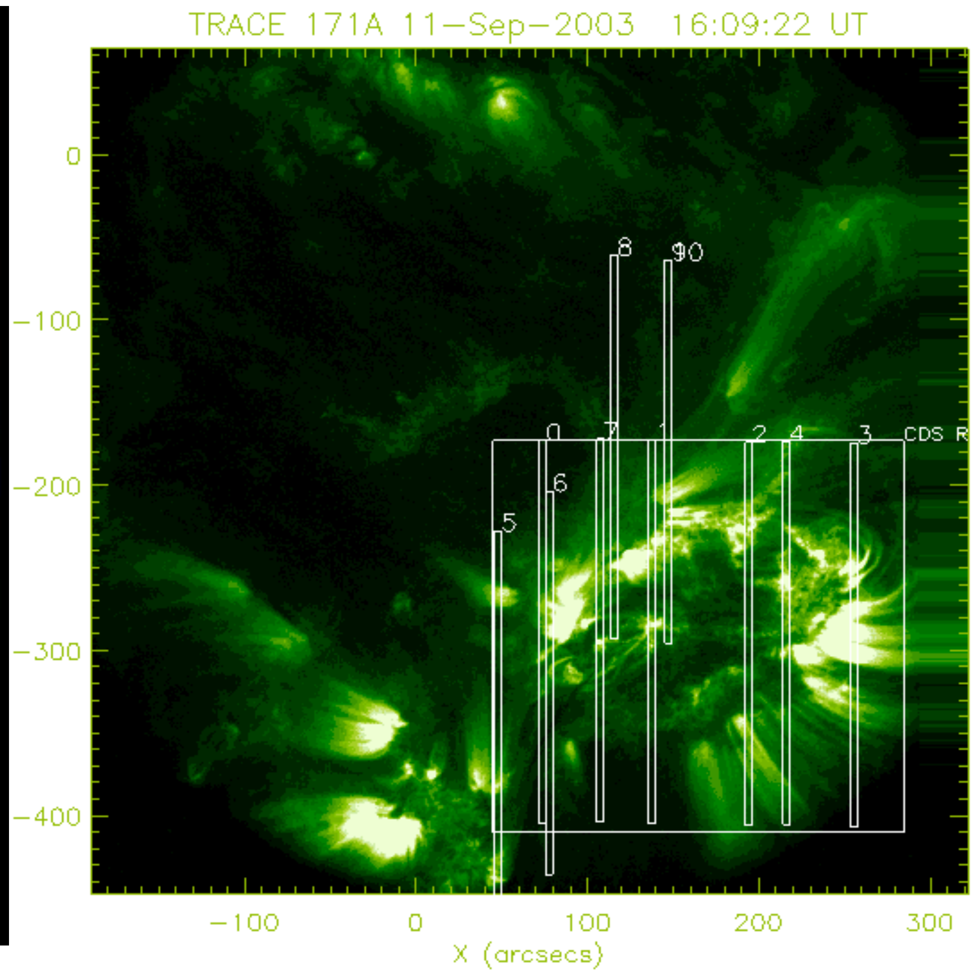
AR 10457

Field of view

TRACE FOV: 512” X 512”

CDS FOV: 240” X 231”

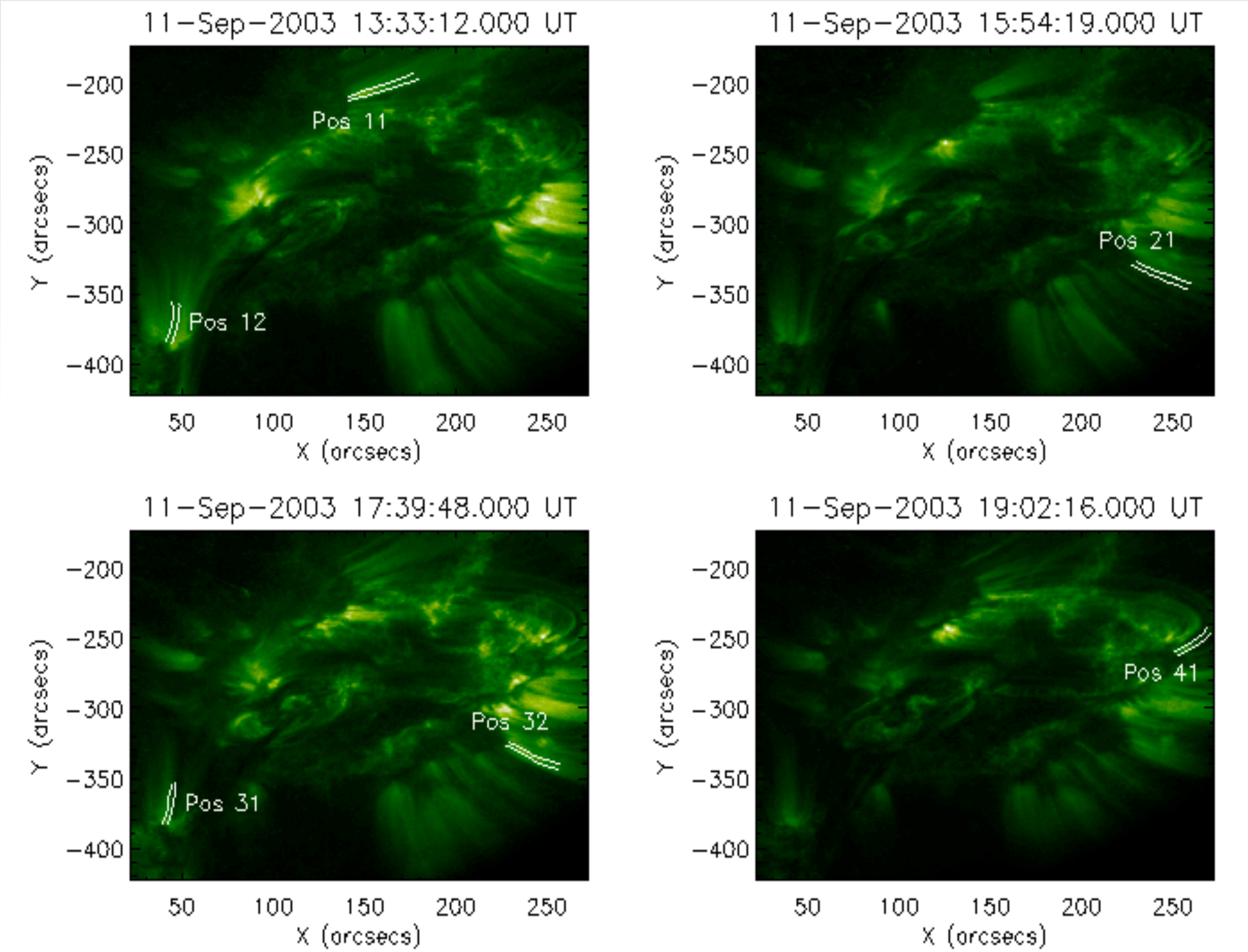




Analysis

- Our analysis with TRACE data is simlar to that discussed in De moortel et al. (2000, 2002a).
- We trace the boundaries of a desired loop, divide the region into cross-sections equal to the average length of the loop, normalize the counts in each cross-section and then construct space-time map from the data cube.
- We use running difference technique to search for the int. oscillation signatures and then perform wavelet analysis to obtain periodicities.
- In the running difference image we fit straight lines to obtain the projected propagation speeds.

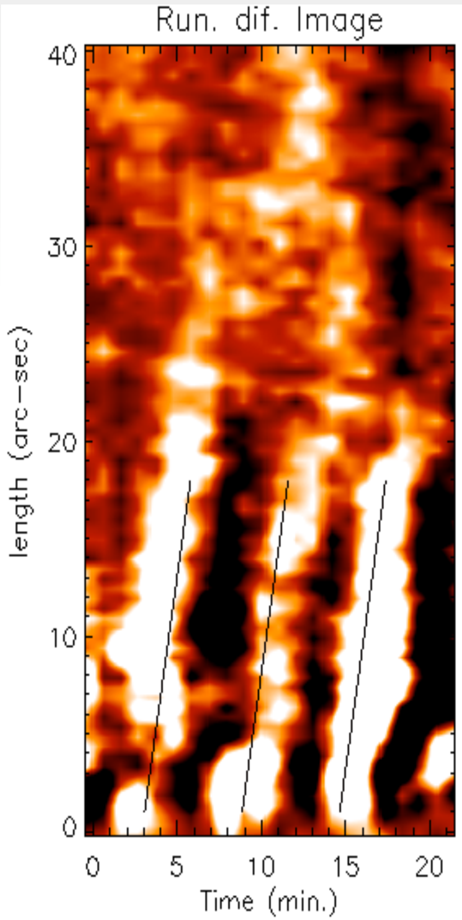
Image showing the locations where significant oscillation is found. Different images represent different time slots



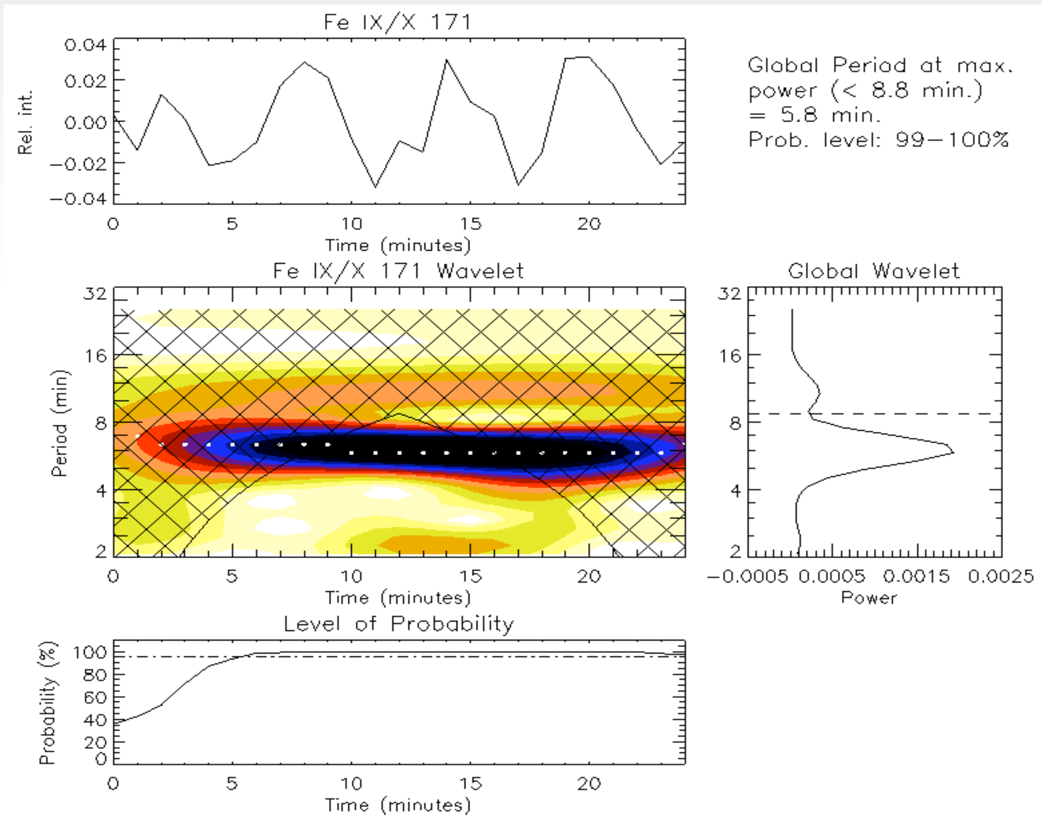
Results and discussion

At Pos 11 : Running difference image and wavelet diagram.

Projected propagation speed: 74.46 km/s
Periodicity: 5.8 min.



Wavelet at pixel 30 from the foot point

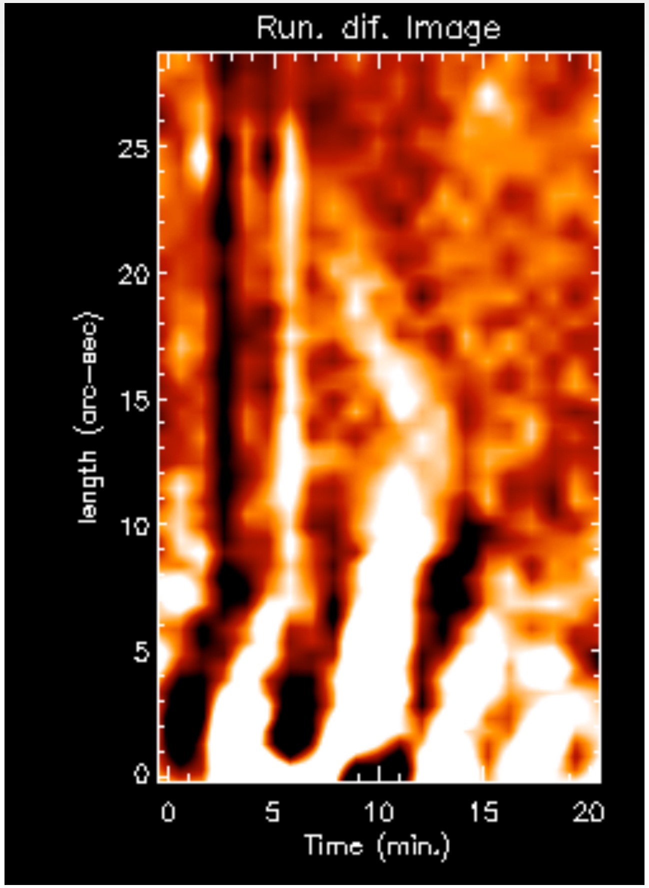


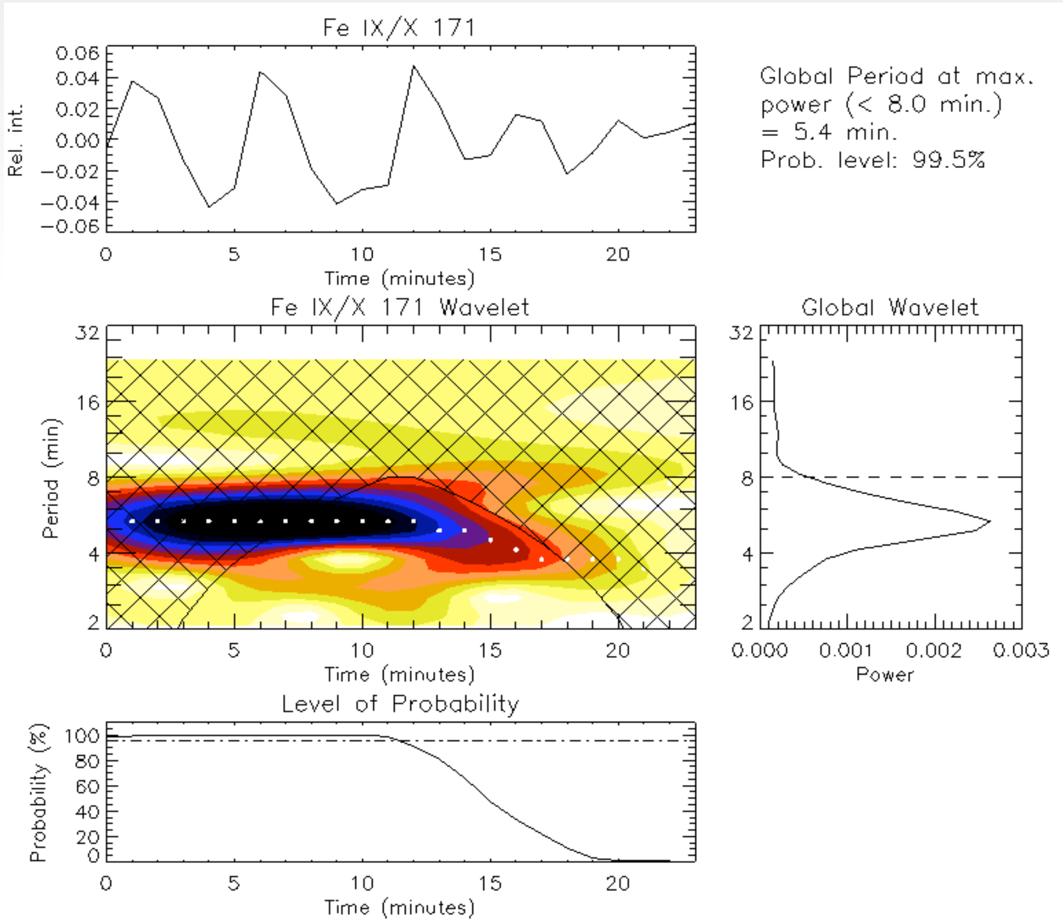
At Pos 31 : Running difference image and wavelet diagram.

Projected propagation
speed: 108.9 -25.1 km/s

Periodicity: 5.4 min.

Wavelet at pixel 6 from the foot point



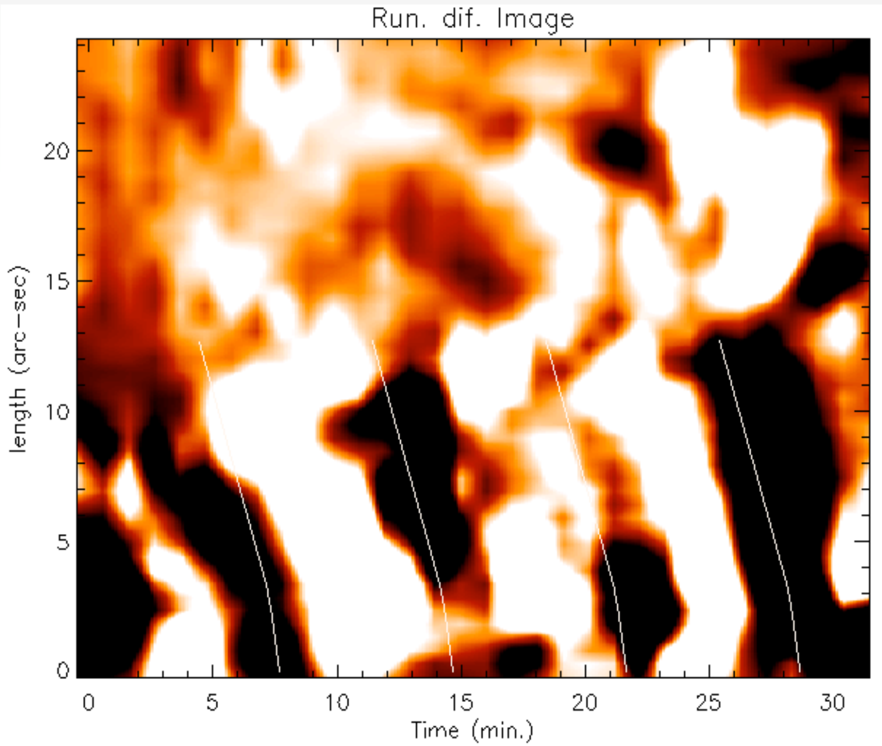


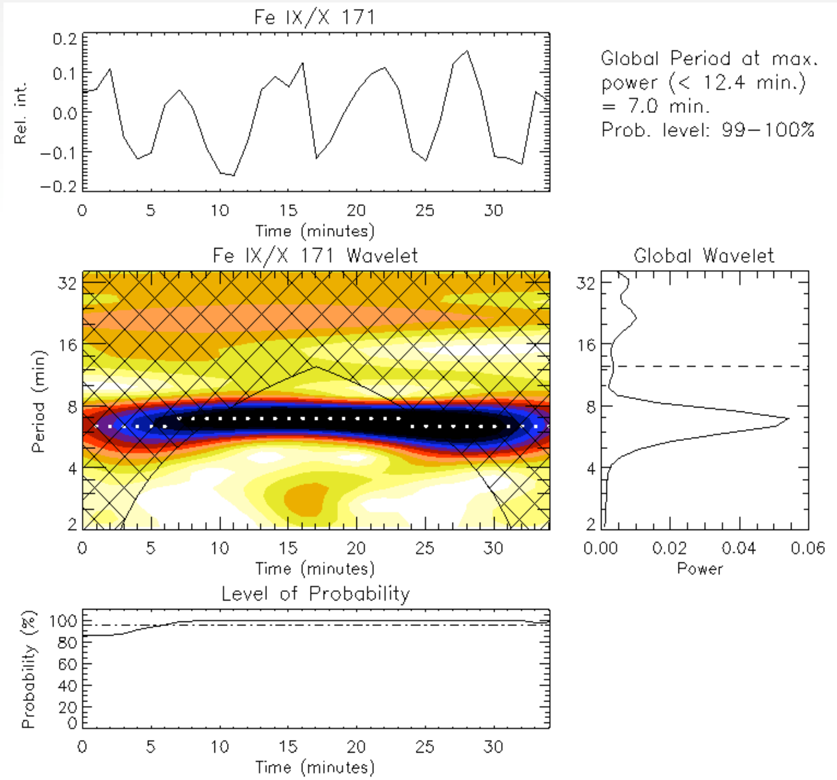
At Pos 41 : Running difference image and wavelet diagram.

Projected propagation speed:
84.6 – 41.3 km/s

Periodicity: 7.0 min.

Wavelet at pixel 7 from the foot point



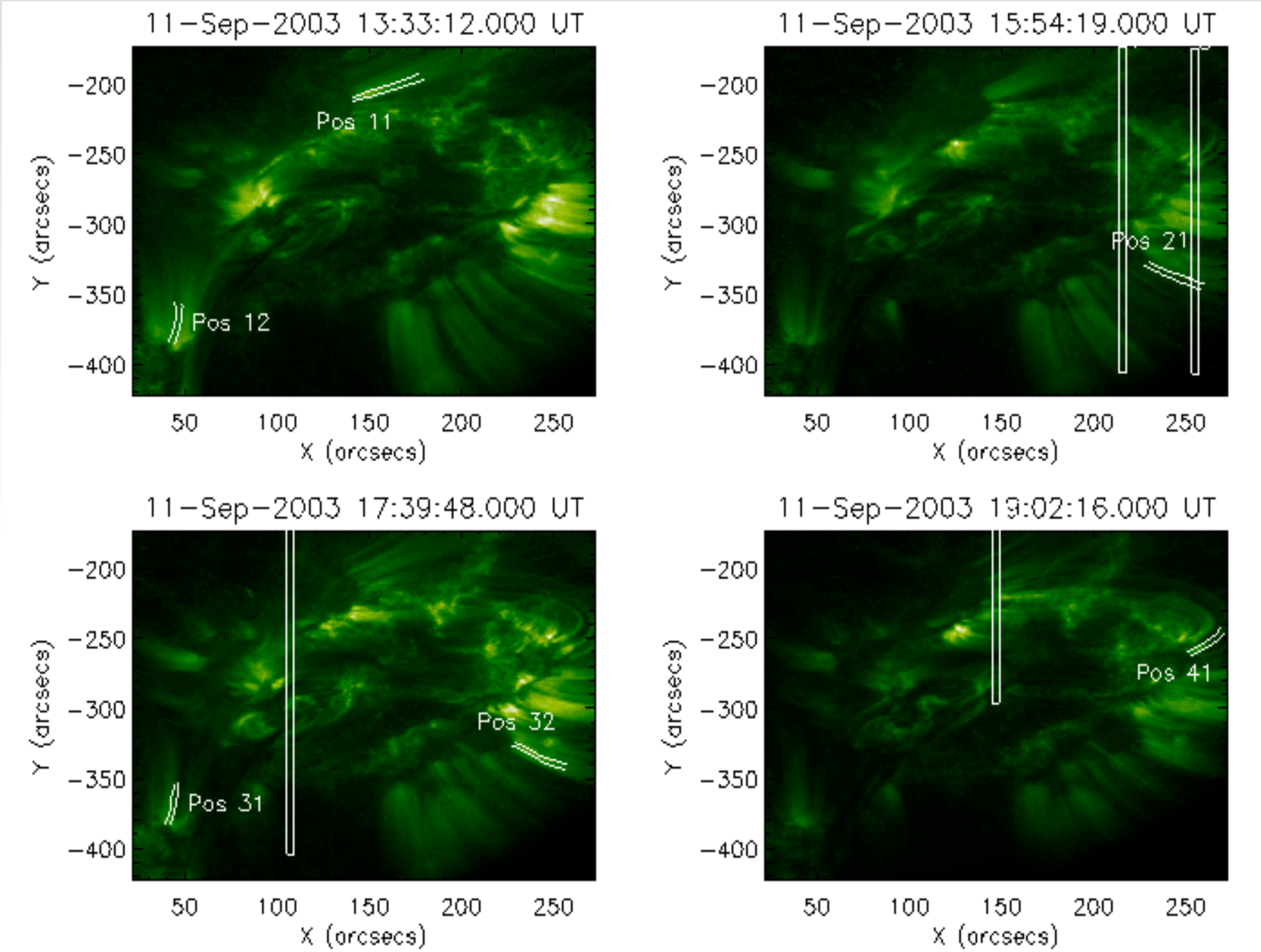


The following table lists the speeds and periodicities observed

Duration of study (UT)	Loop location	Periodicity (min.)	Projected speed of propagation (Km/s)
(13:33-13:57)	Pos 11	5.8	74.64
	Pos 12	6.4	68.88
(17:39-18:02)	Pos 31	5.4	108.9 – 25.14
(19:02-19:36)	Pos 41	7	84.67 - 41.36

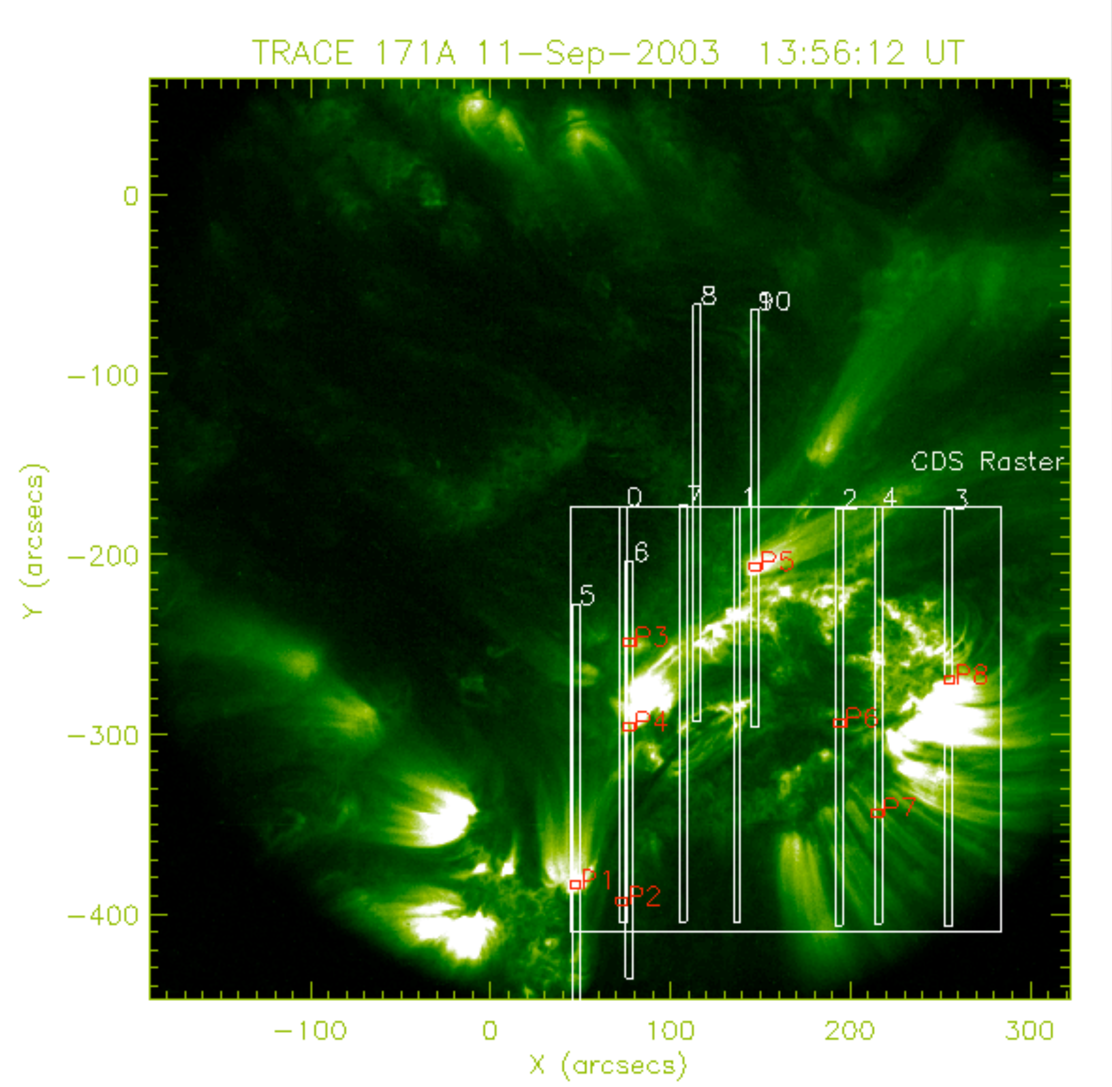
- So the observed properties such as the projected propagation speeds, fast damping, filamentary nature and mainly the periodicities suggests that these oscillations can be interpreted as slow magneto-acoustic waves.

Image showing CDS slit locations in the time slots chosen



No overlaps!!

We studied CDS independently. Following plot shows the locations on CDS where significant oscillations are identified.



No overlaps!!

Location (sol_x,sol_y)	Slit No.	Spectral line	Int. Oscill. period Primary (secondary) (in min.)	Prob. Level (%)	Vel. Oscill. period Primary (secondary) (in min.)	Prob. Level (%)
P1 (47,-384)	5	O_V	4.5 (6.9)	99-100	-	-
		He_I	6.3 (4.9)	99-100	4.9 (~10)	97.5
P2 (73,-393)	0	O_V	5.3(~10)	99-100	-	-
P3 (77,-249)	6	O_V	8.2(4.1)	99-100	8.2(2.9)	99-100
P4 (77,-296)	6	O_V	5.8(~10)	99-100	5.3 (~11)	99
P5 (147,-207)	10	O_V	9.0(4.9)	99-100	-	-
P6 (194,-294)	2	O_V	5.8(9.0)	99-100	-	-
P7 (215,-343)	4	O_V	6.3(9.8)	99-100	8.2(5.3)	99-100
		He_I	6.9(6.9)	99-100	5.3(~11)	99-100
P8 (255,-271)	3	O_V	9.8(4.9)	99-100	6.9(6.9)	99-100
		He_I	9.0(2.1)	99-100	9.0(9.0)	99-100

Summary

- We found propagating intensity disturbances from the TRACE images with projected speed ranges from 20-80 km/s and periodicities from 5-9 min. Also these are found to be fast damping and shows filamentary nature. Based on these properties we interpret them as slow magneto-acoustic waves.
- We've and example of decelerating disturbance which also damped with time. Further studies required to explain the behavior.
- The magnetic structures we studied are non-sunspot structures, so the dominance of 5 min. Oscillation is expected. The higher periodicities could be a lower harmonic since in some of the CDS locations (P3 & P8) we see the presence of multiples of periods.
- Why do you find these on selected loops only?