

The 6th Solar-B Science meeting@Kyoto

Nov 9, 2005

**Flare-associated oscillations
in coronal multiple loops
observed with the Norikura
Green-line Imaging System**

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of Japan**

SUNRISE@NORIKURA

Observations of Loop Oscillations

(summary from Wang et al. Aschwanden et al.)

A. Standing waves

a) Slow mode (acoustic) oscillations :EUV lines

b) Fast mode (Alfvenic)

Kink mode oscillations :EUV

Sausage mode oscillations :Radio, HXR

B. Propagating waves :EUV, visible light...

▪ MHD waves \Rightarrow Possible source of coronal heating and/or acc. of solar wind ?

▪ Coronal Seismology : Physical parameters

e.g. loop length, period, duration \rightarrow Field strength, density, temperature...

(Uchida 1970, Roberts, Edwin & Benz 1984...)

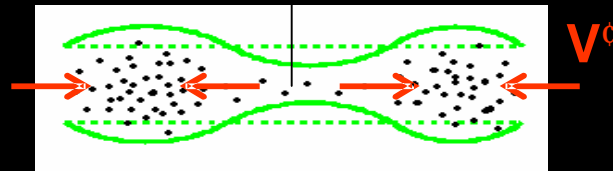
Interpretation of MHD waves (1)

(summary from Wang et al. Aschwanden et al.)

a) Slow mode

magneto-acoustic

$$B^c > 0, r^c < 0$$



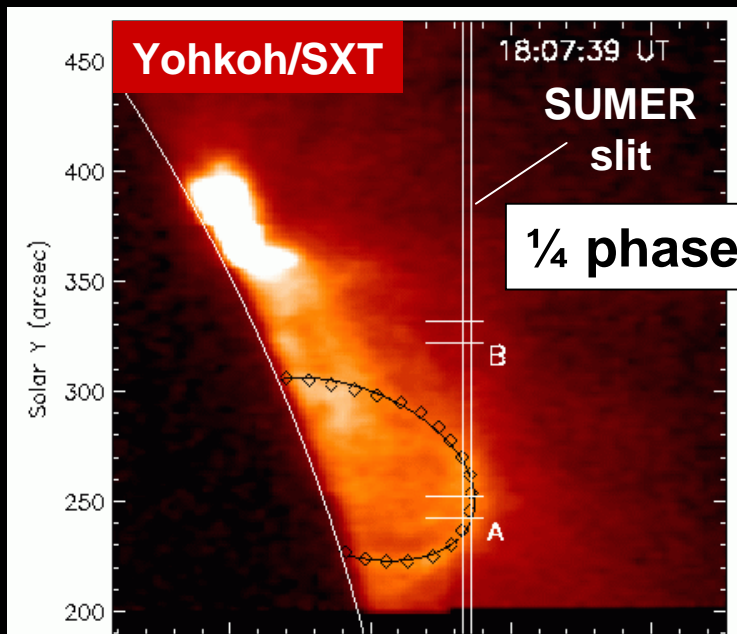
v^c

limited to 1D

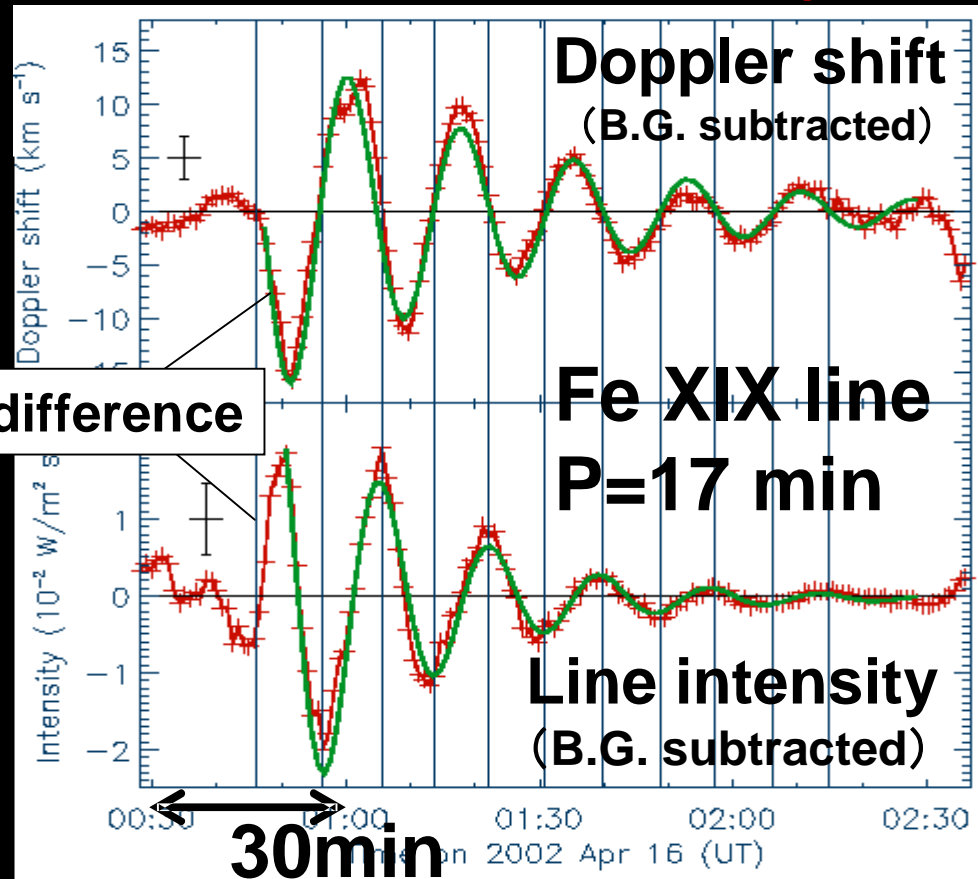
$P = 7 \sim 70 \text{ min}$

SOHO/SUMER (6-8MK)

Wang et al. (2002,2003)



2002 Apr 16, No Flare



Interpretation of MHD waves (2)

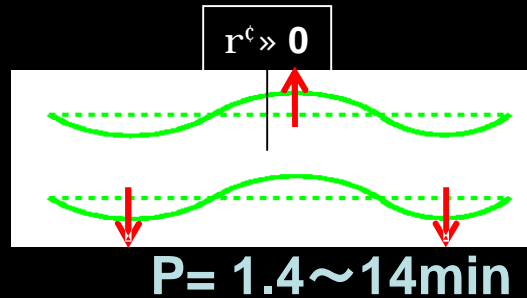
(summary from Wang et al. Aschwanden et al.)

b) Fast mode

KINK

-Asymmetric

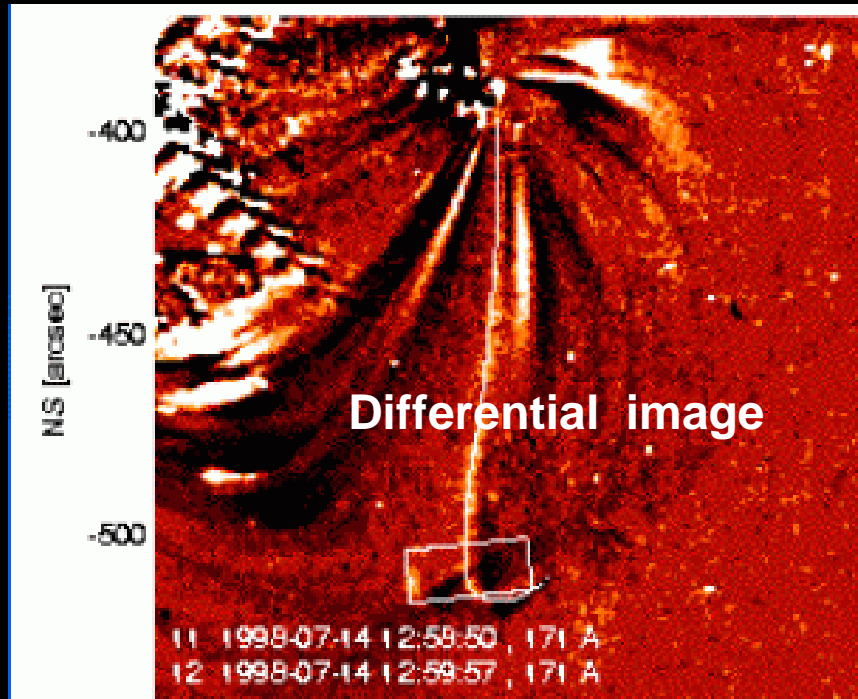
-No density variations



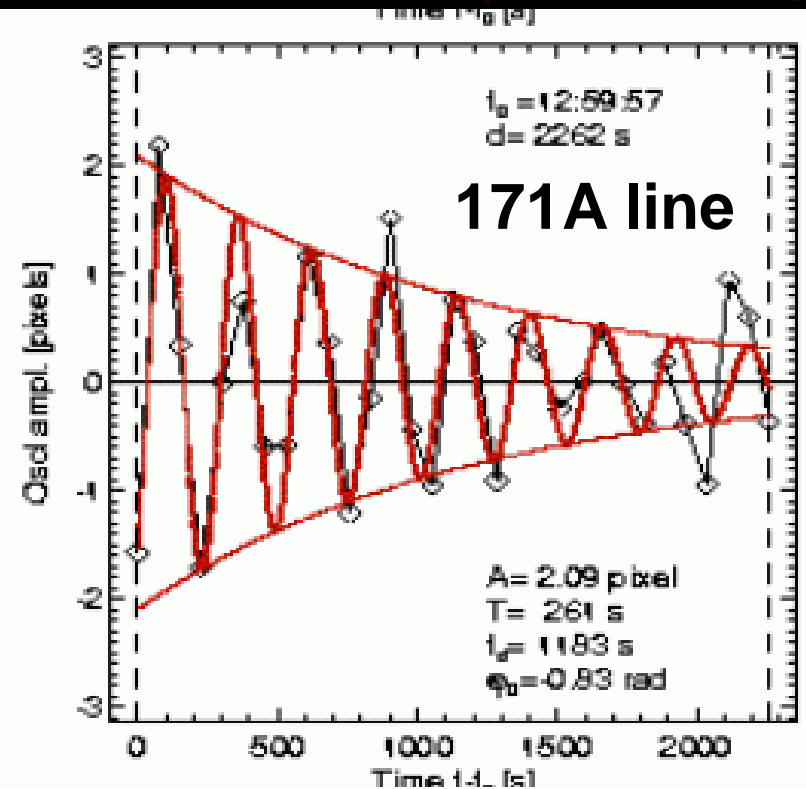
Aschwanden et al. 2002

2D but no Doppler Information

TRACE (1.0-2.0MK)



1998 July 14, **M4.6 Flare**



NOGIS

Norikura *Green-line* imaging System

Ichimoto et al. 1999



Coronal Green-line emission

Fe XIV 5303 Å ; **2MK**

Center, $\pm 0.45 \text{ \AA}$

⇒ **2D Doppler Images**

Time resolution $\sim 40 \text{ sec}$

Spatial resolution $1.84''/\text{pix}$ (PFI)

FOV(FFI) 2000×2000 pixels

$-25 \text{ km/s} \sim 25 \text{ km/s}$ ($\Delta v \sim 1 \text{ km/s}$)

⇒ **X Fast ejection**

○ waves & flows

Coronagraphs in the world

SOHO / LASCO C1
STEREO/SECCHI

SECIS
(eclipse)

2860m Pic du Midi
2634m Lomnický štít

Kislovodsk
2050m

2876m Norikura
NOGIS

3050m Haleakala
Mauna Loa
3400m

2840m Sacramento Peak

2400m MICA

2D diagnosis of coronal velocity fields from the ground

SUNSET@NORIKURA

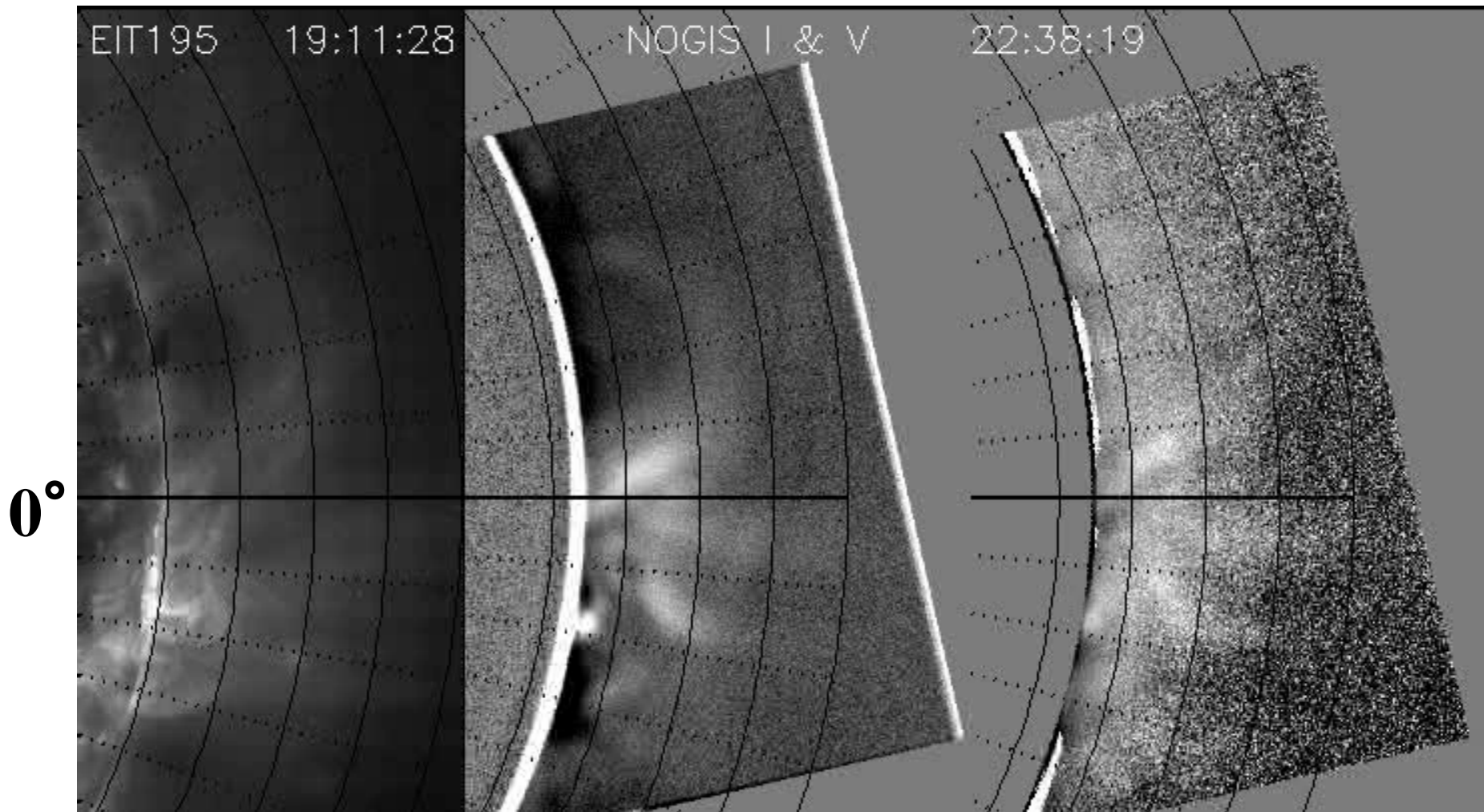
MOVIE

2003 Jun 01-02

EIT195

NOGIS (Intensity)

NOGIS (Doppler V)

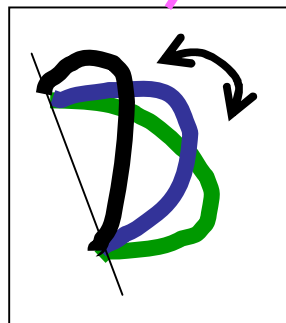
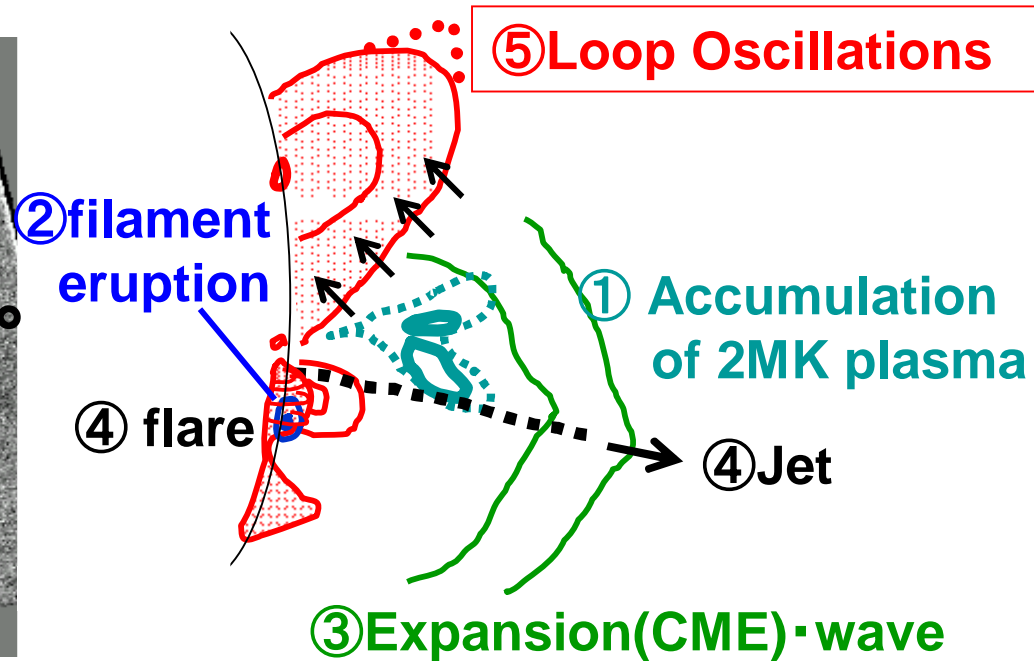
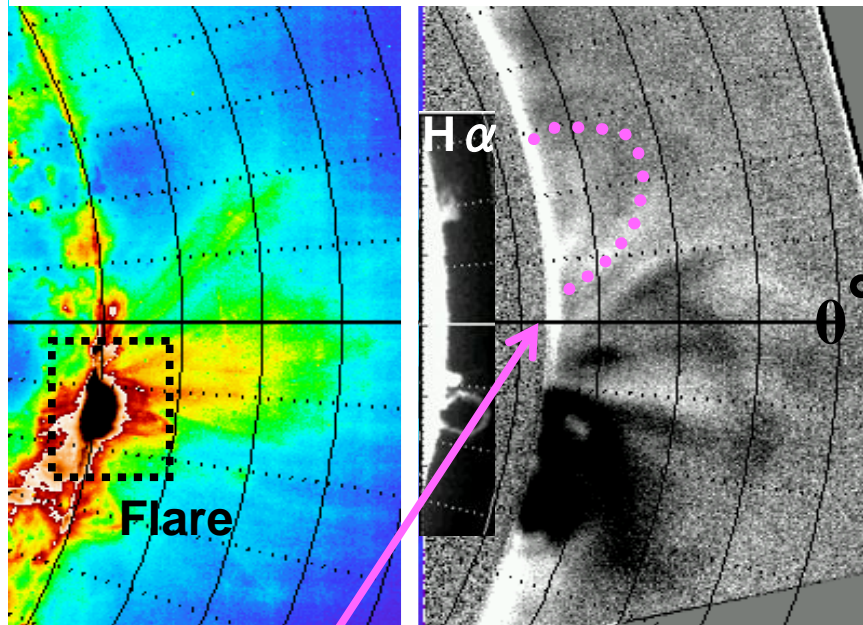


[Center+0.45 Å] – [Center-0.45 Å]

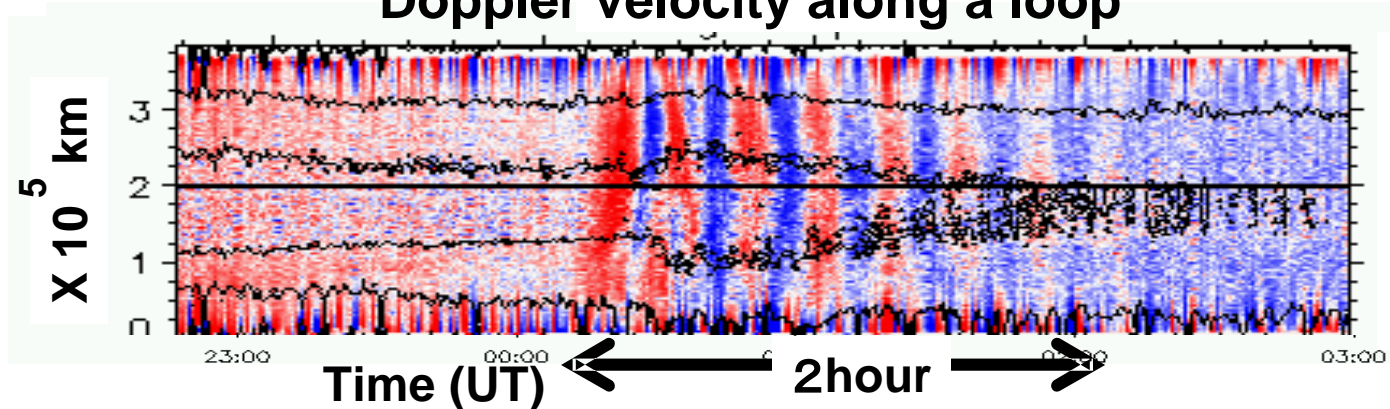
CME Onset and Loop Oscillations

2003 June 2
SOHO/EIT(195 Å) NOGIS (5303 Å)

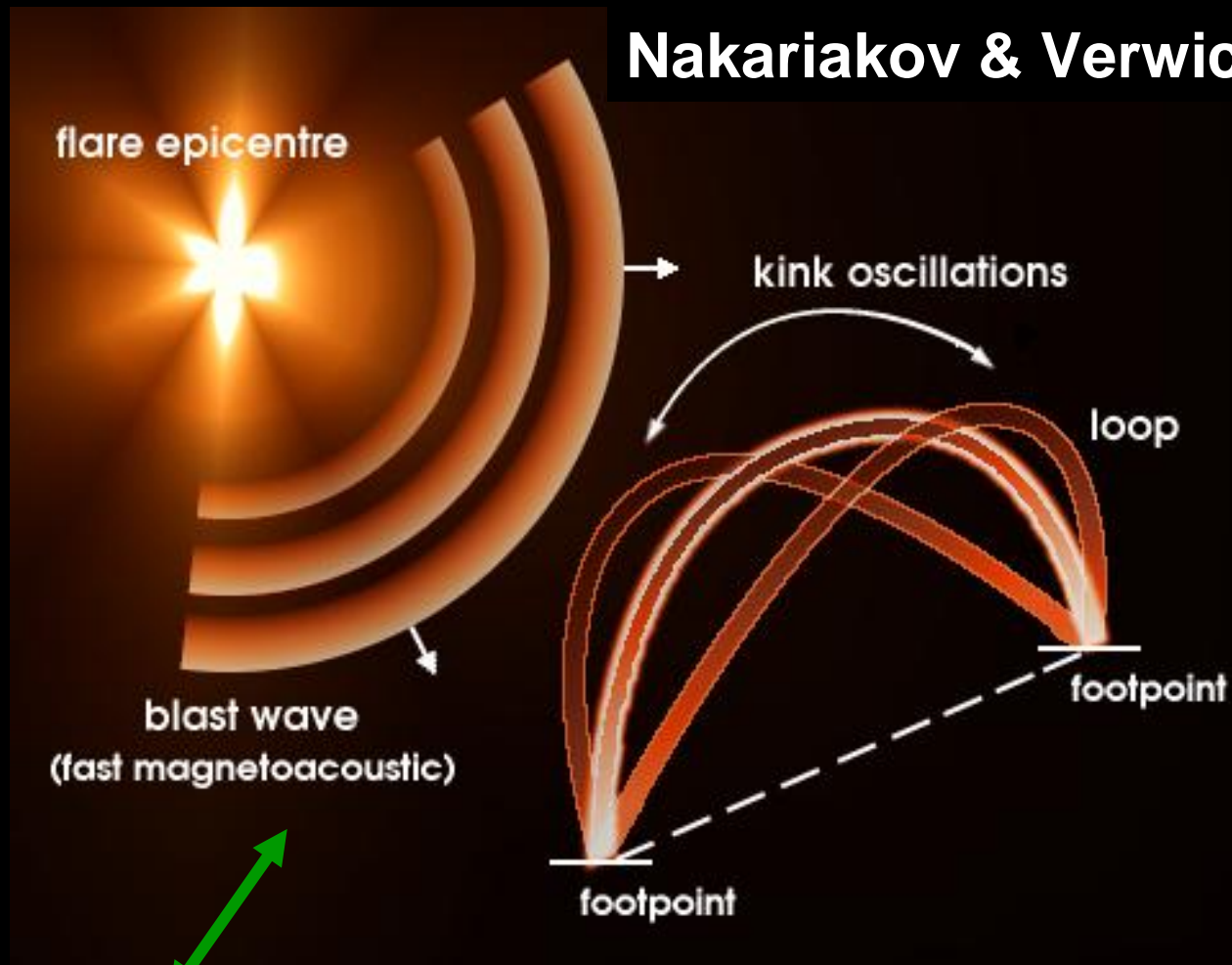
Hori et al. (2005)



Doppler velocity along a loop

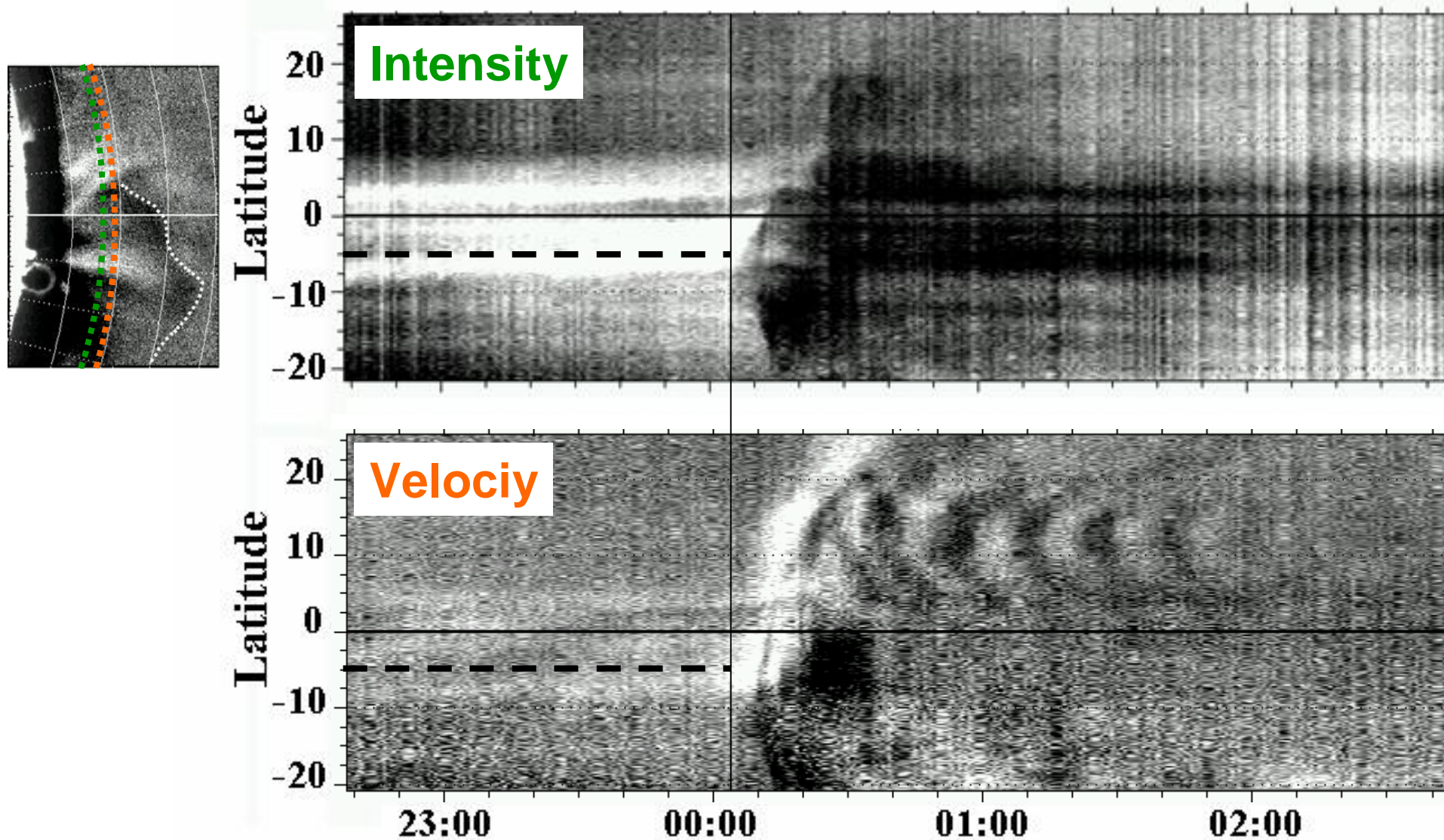


Nakariakov & Verwichte (2004)

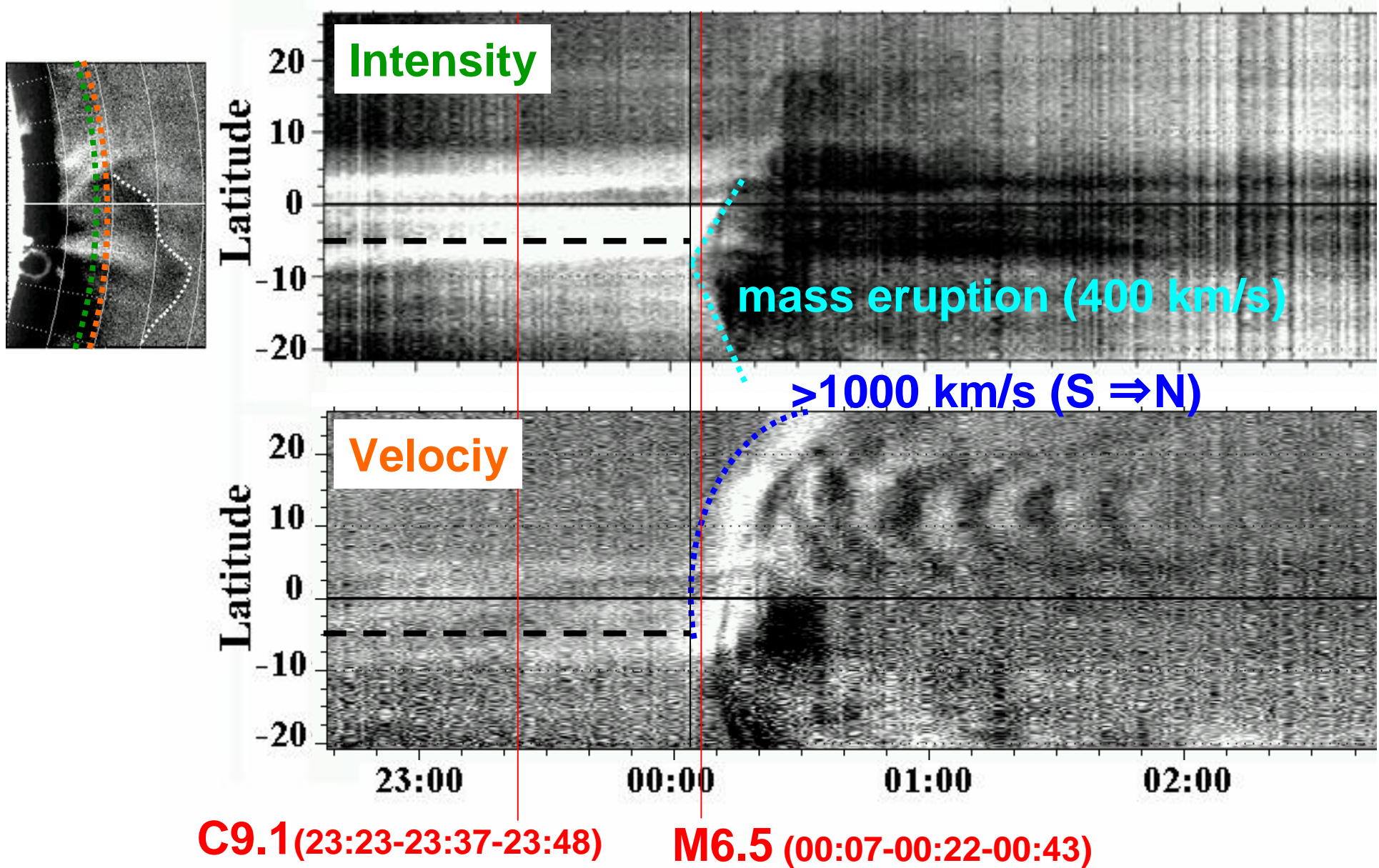


Type II burst
Hudson & Warmuth 2004

NOGIS time slice along the west limb (at 0.16/0.18Rs)



NOGIS time slice along the west limb (at 0.16/0.18Rs)



Multiple modes of waves / oscillations

1. **Separate the individual modes**

Wavelet analysis

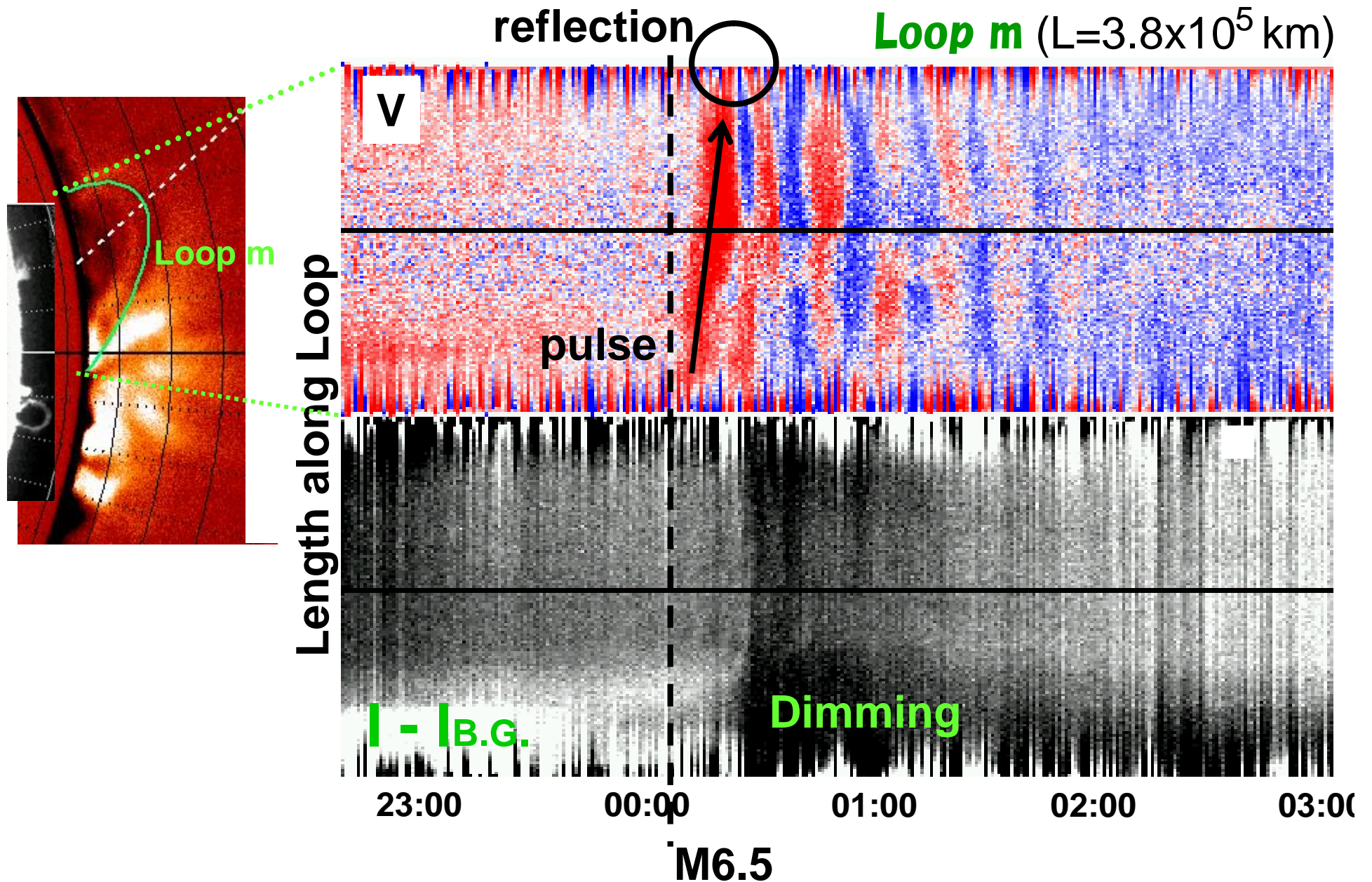
2. **Physical parameters for each mode**

⇒ **Identify the damping mechanism**

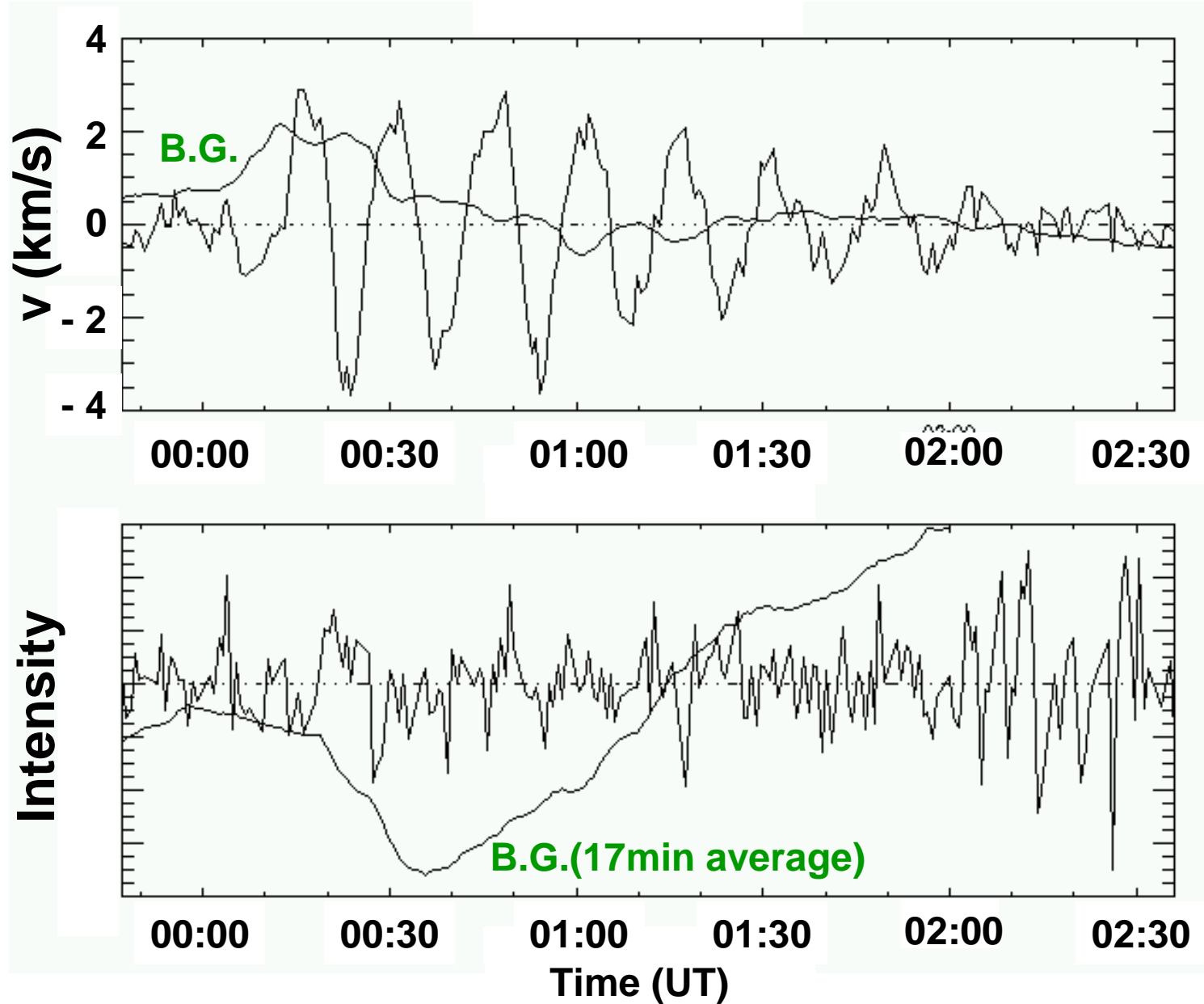
3. **Relation between different modes**

**e.g., energy exchange/transport
along/across the loops?**

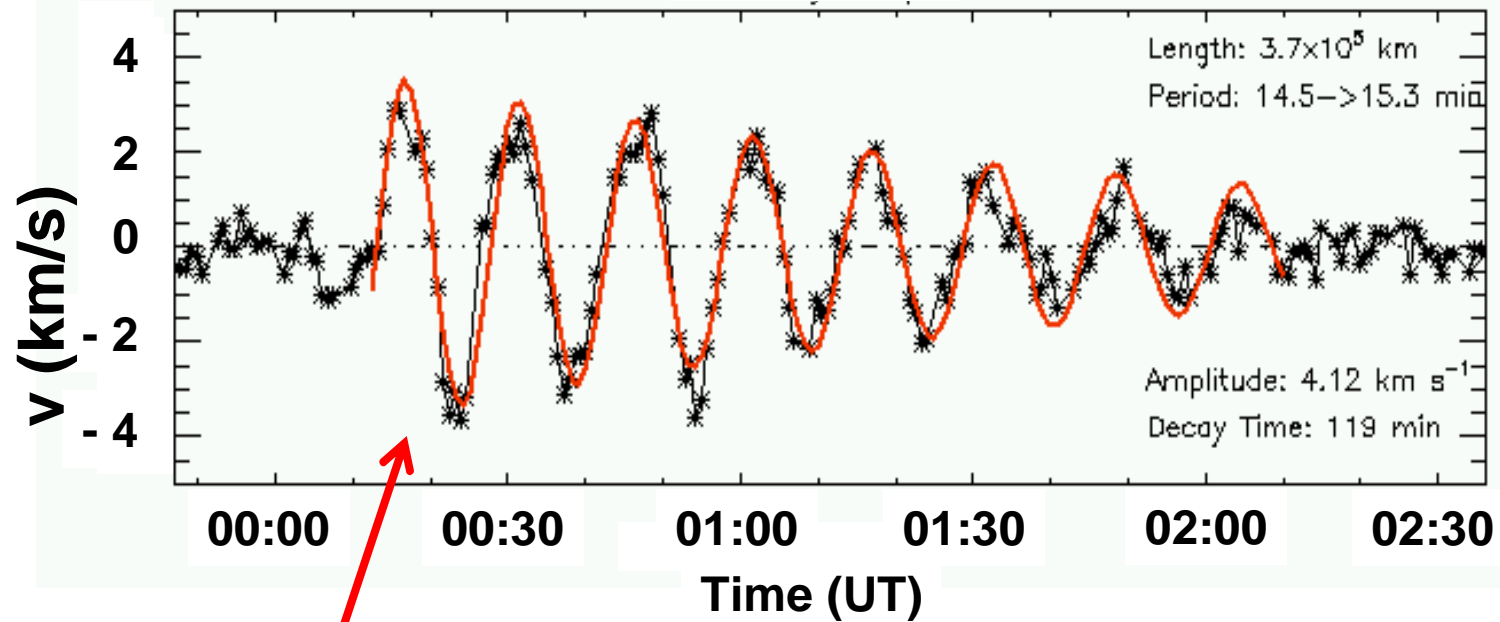
Time slice along a loop



Evolution around the apex



Evolution around the apex

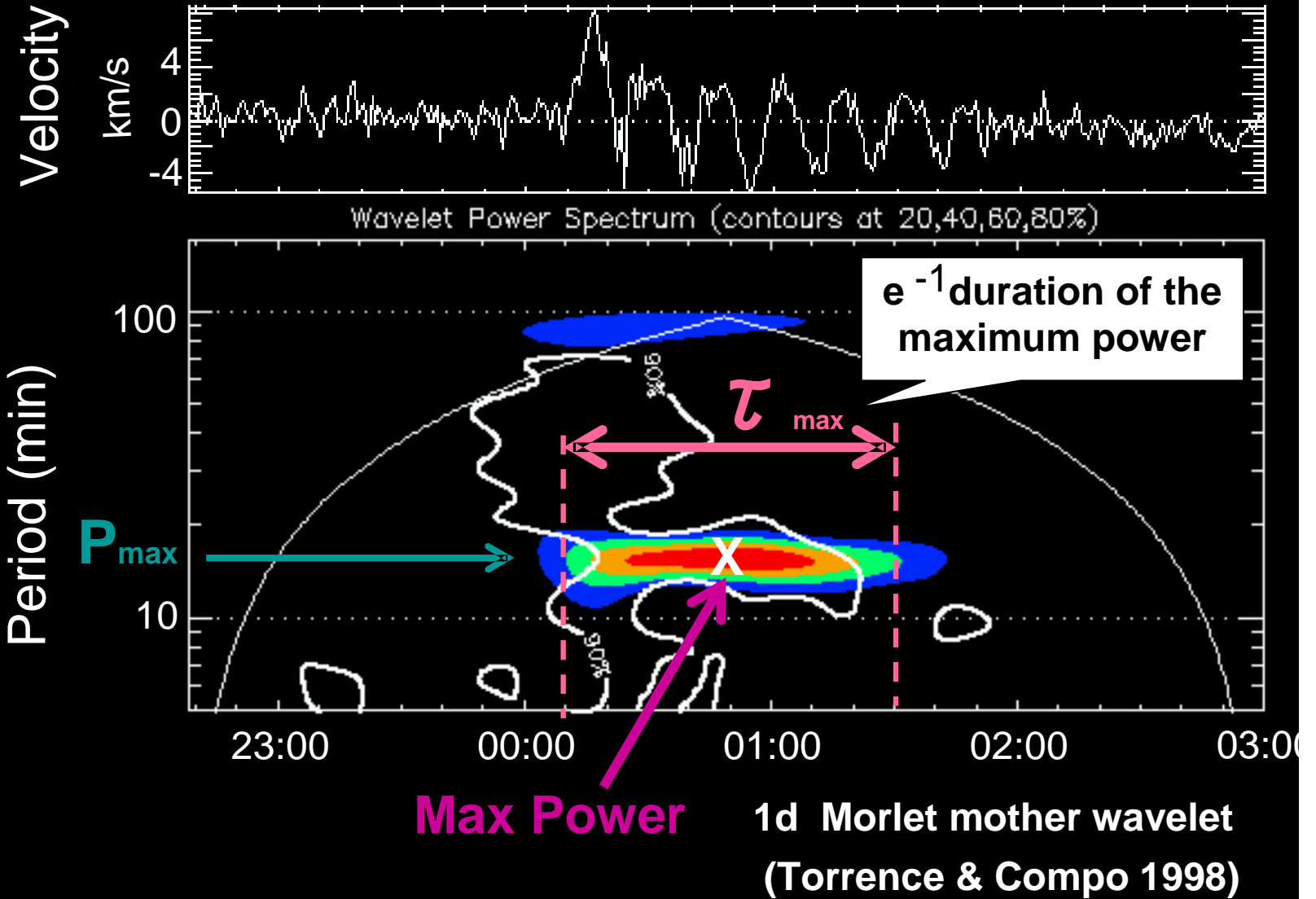
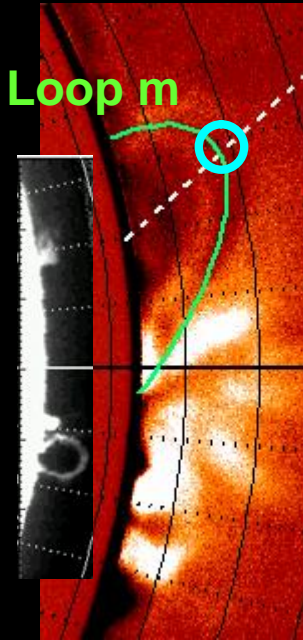


Fitting function

$$v(t) = v_0 \exp\left(-\frac{t}{\tau}\right) \sin\left(\frac{2\pi t}{P} + j_0\right)$$
$$P = P_0 (1 - A \times (t - t_0))$$

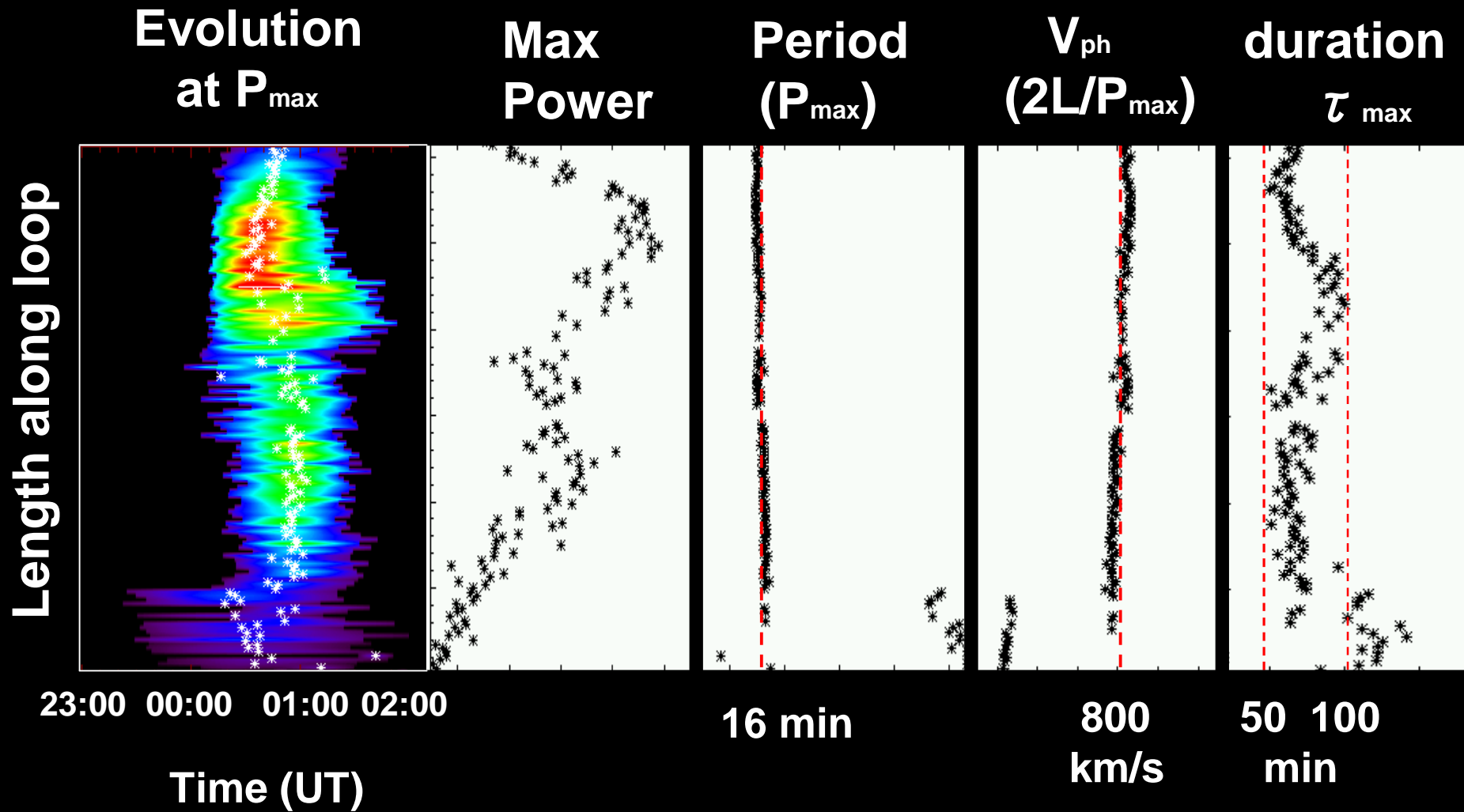
Wavelet analysis

Apex of Loop m ($L=3.8 \times 10^5$ km)

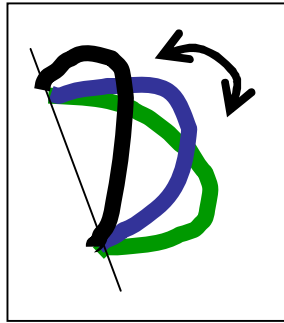


Wavelet analysis

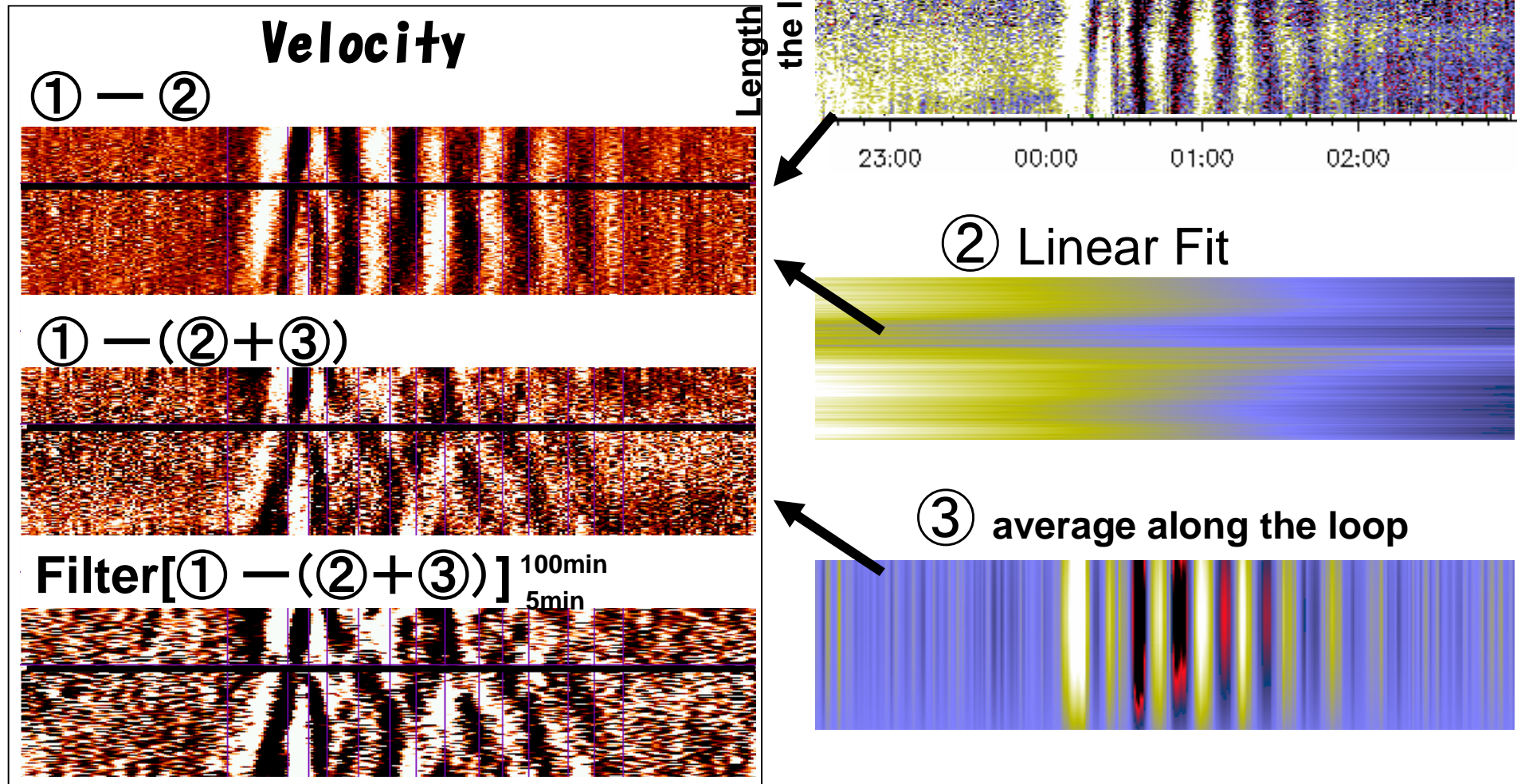
Apex of Loop m ($L=3.8 \times 10^5$ km)



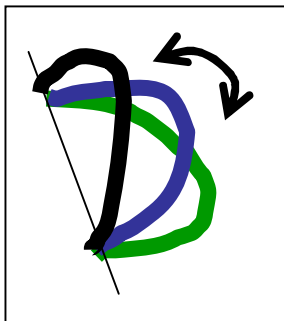
Kink



Loop m ($L=3.8 \times 10^5$ km)

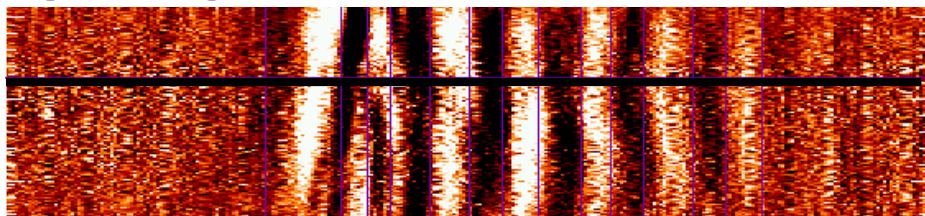


Kink

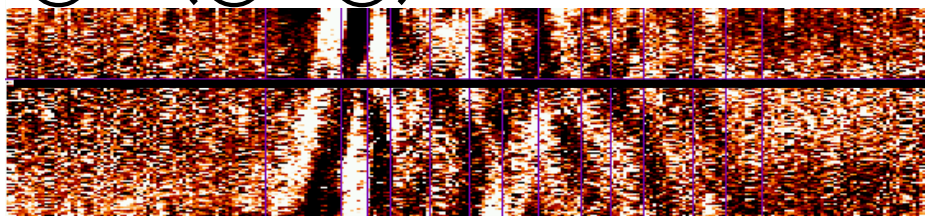


Velocity

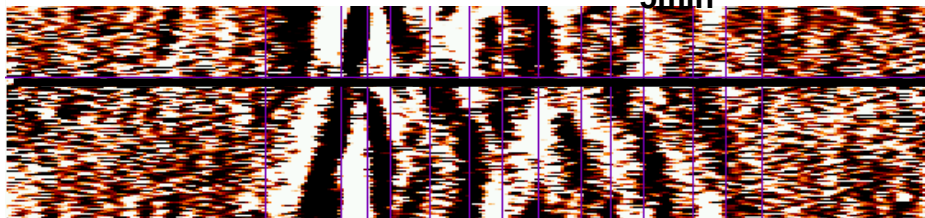
① - ②



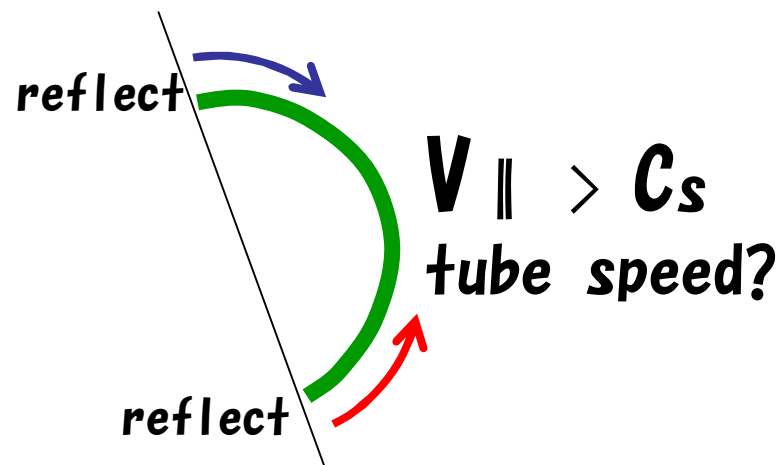
① - (② + ③)



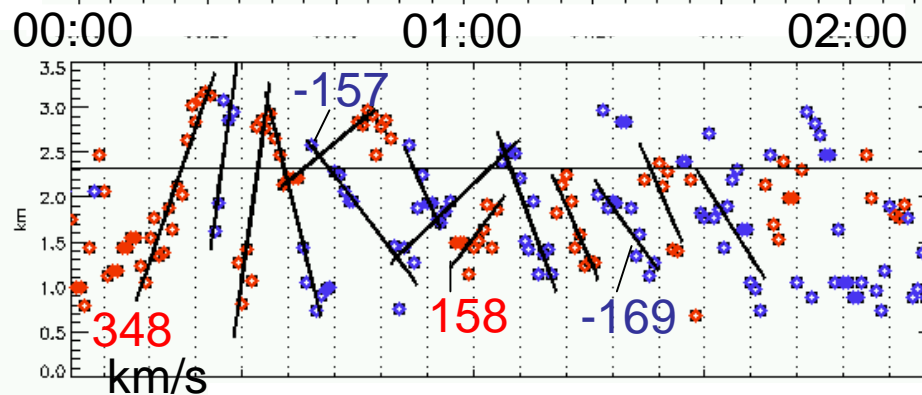
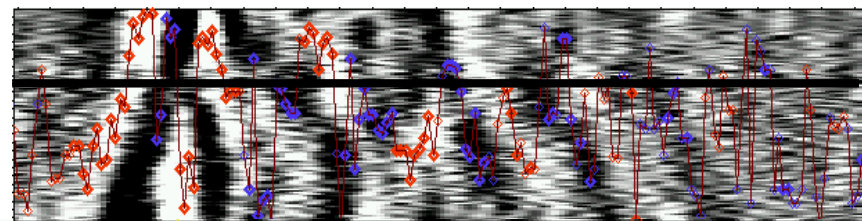
Filter[① - (② + ③)] 100min
5min



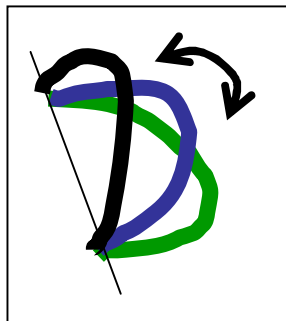
Plus....



Position of the max |V|

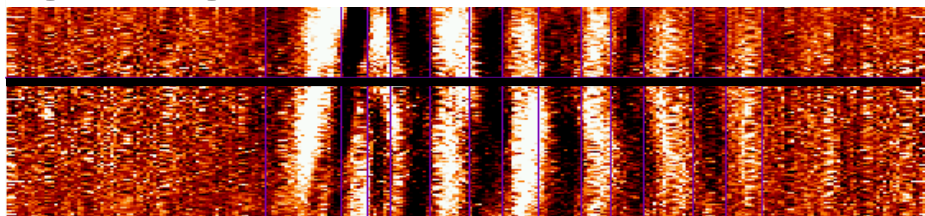


Kink

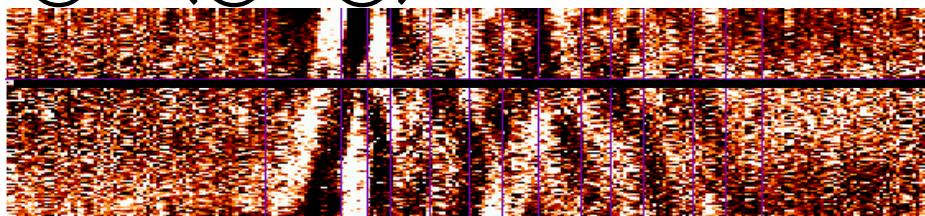


Velocity

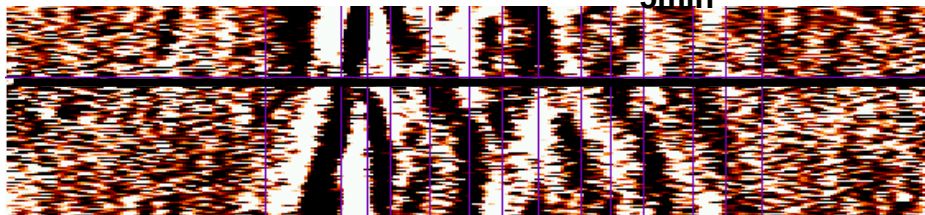
① — ②



① — (② + ③)

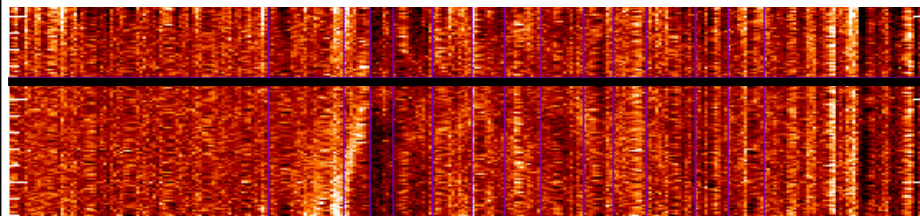


Filter[① — (② + ③)] 100min
5min

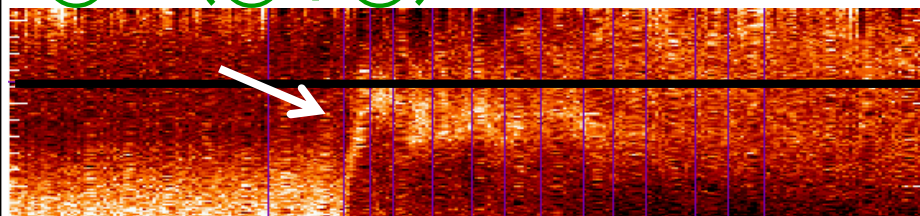


Intensity

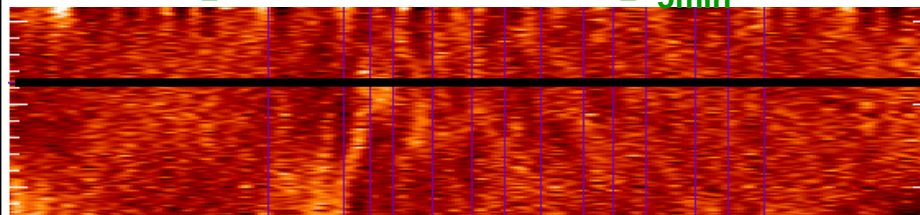
① — ②



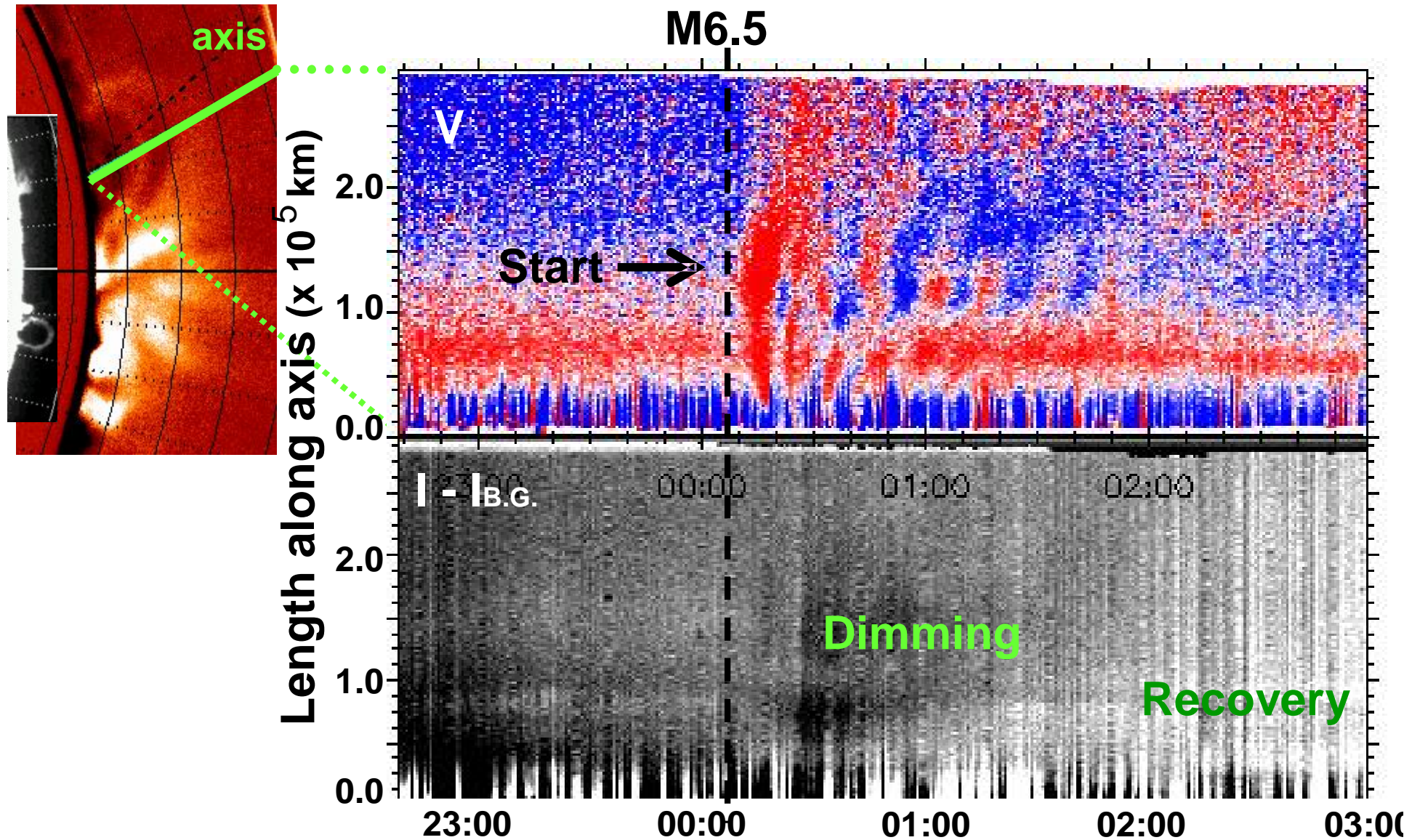
① — (② + ③)



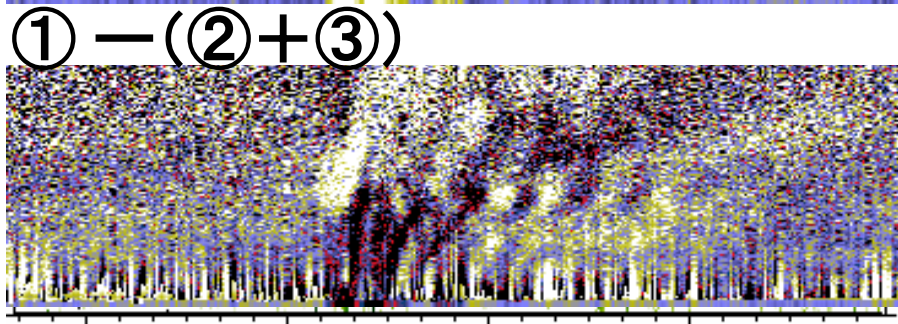
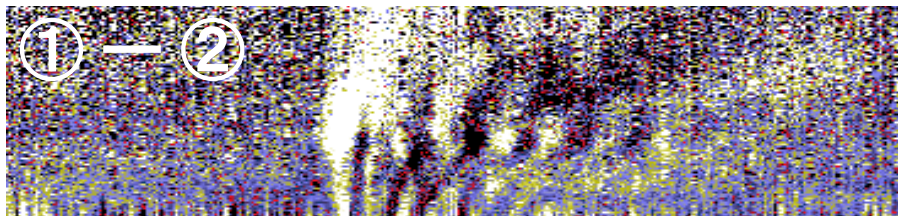
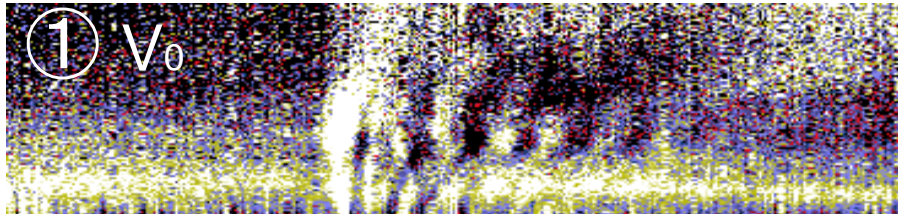
Filter[① — (② + ③)] 100min
5min



Time slice along the axis of the oscillations

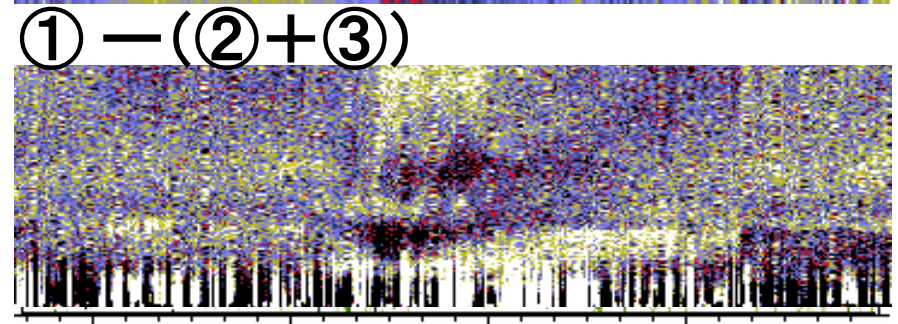
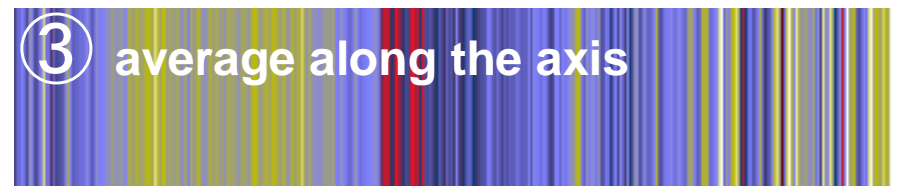
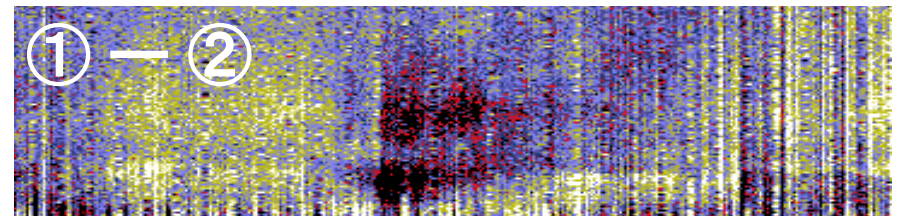
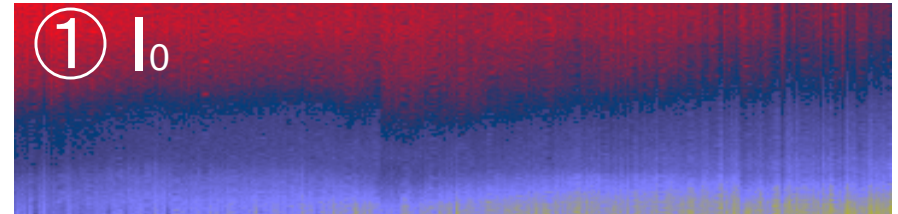


Velocity



23:00 00:00 01:00 02:00

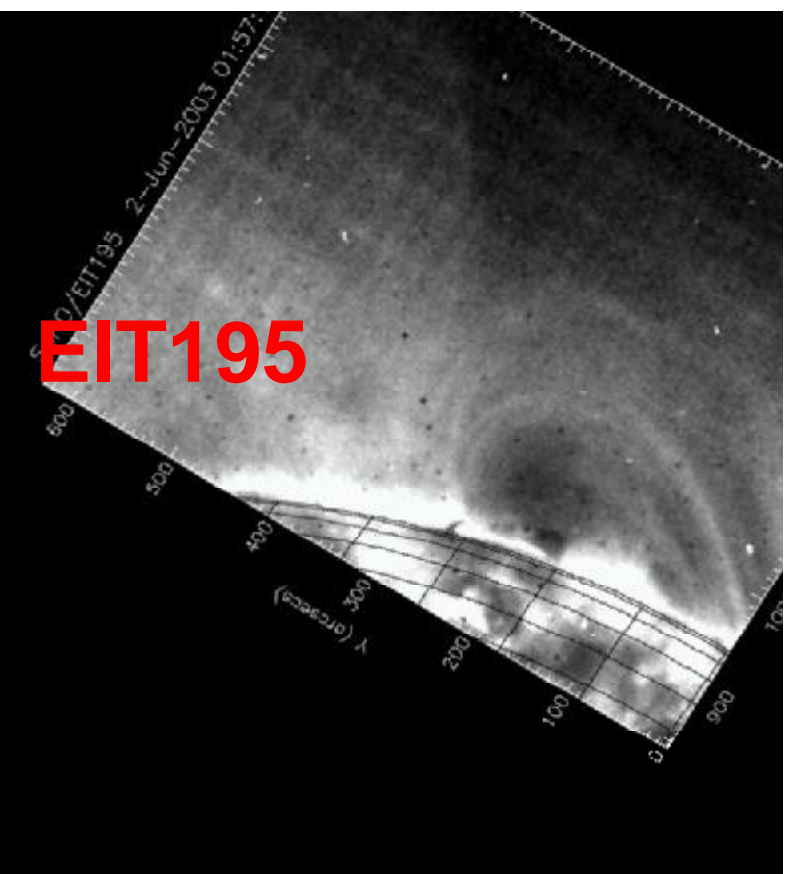
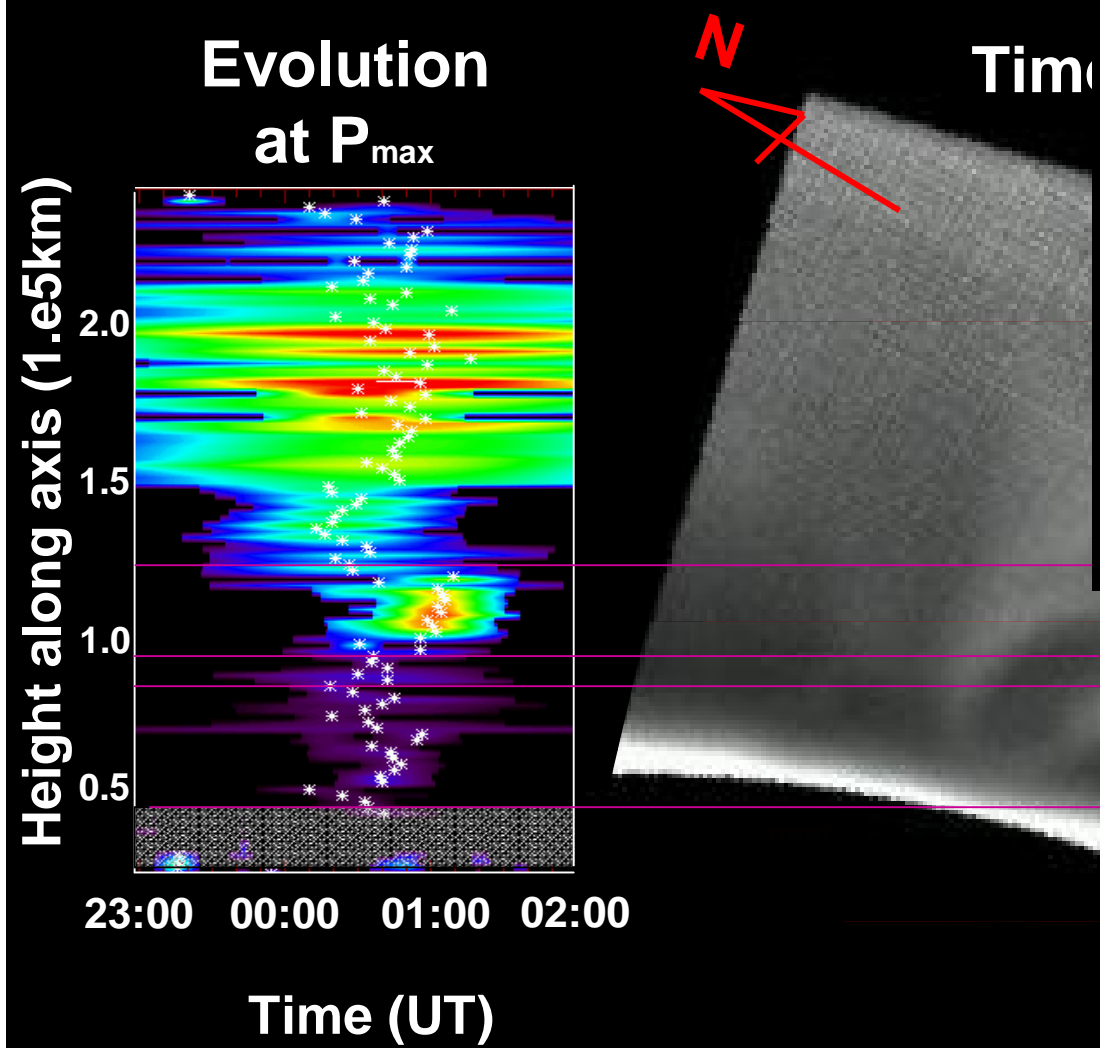
Intensity



23:00 00:00 01:00 02:00

Wavelet analysis

Alc

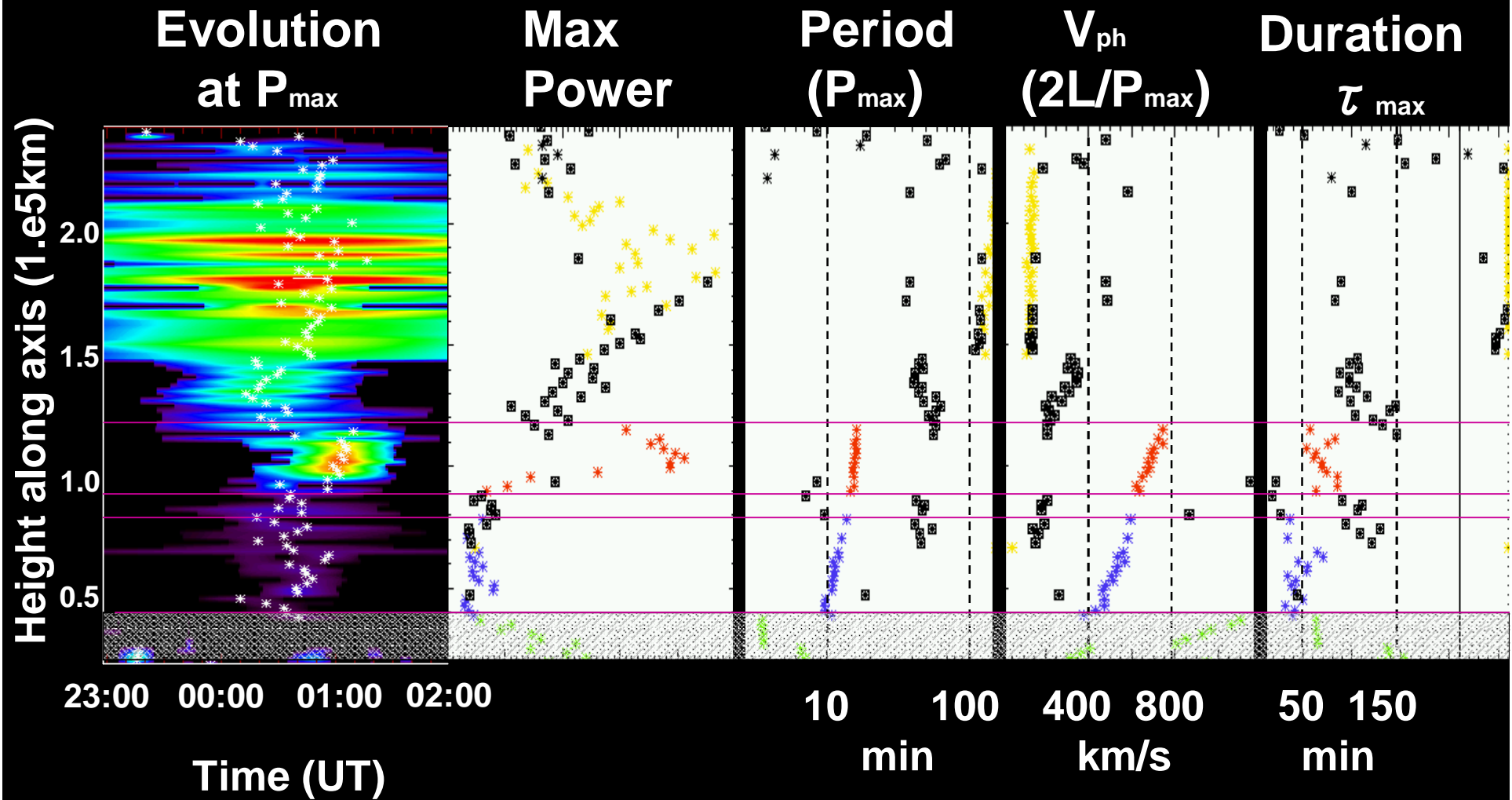


Outer loop(s)

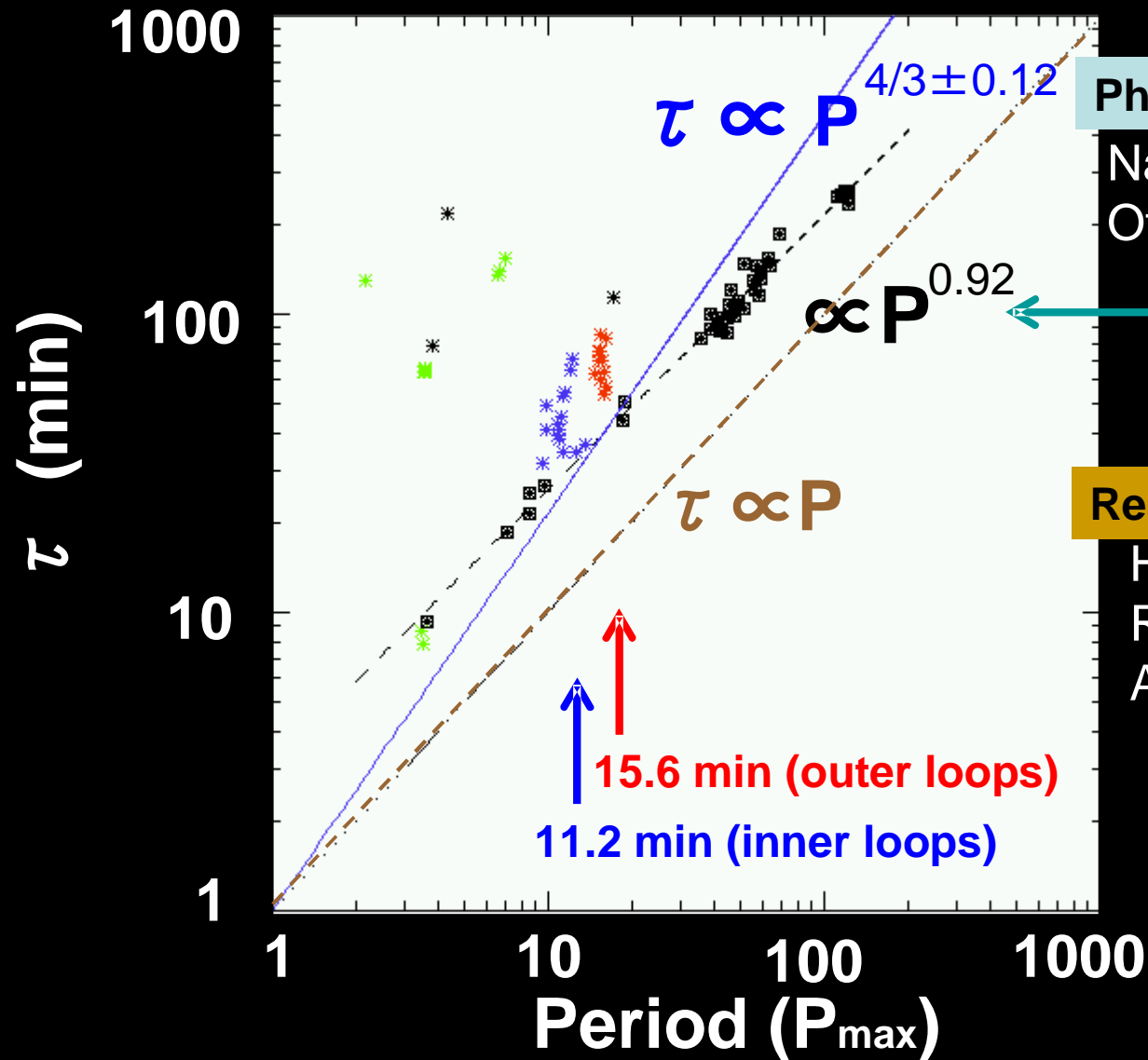
Inner loop(s)

Wavelet analysis

Along the axis ($h=2.9 \times 10^5$ km)



Wave dumping mechanisms



Phase mixing

Nakariakov et al. 1999
Ofman & Aschwanden 2002

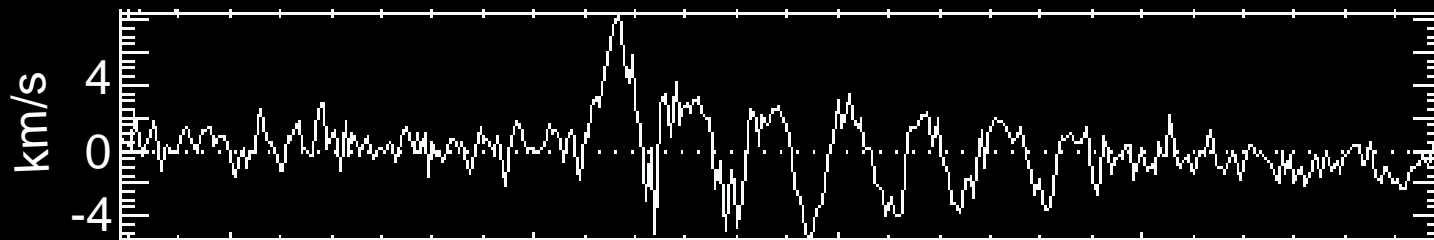
← Outside of the loops?

Resonant absorption

Hollweg 1990
Ruderman & Roberts 2002
Aschwanden et al. 2003

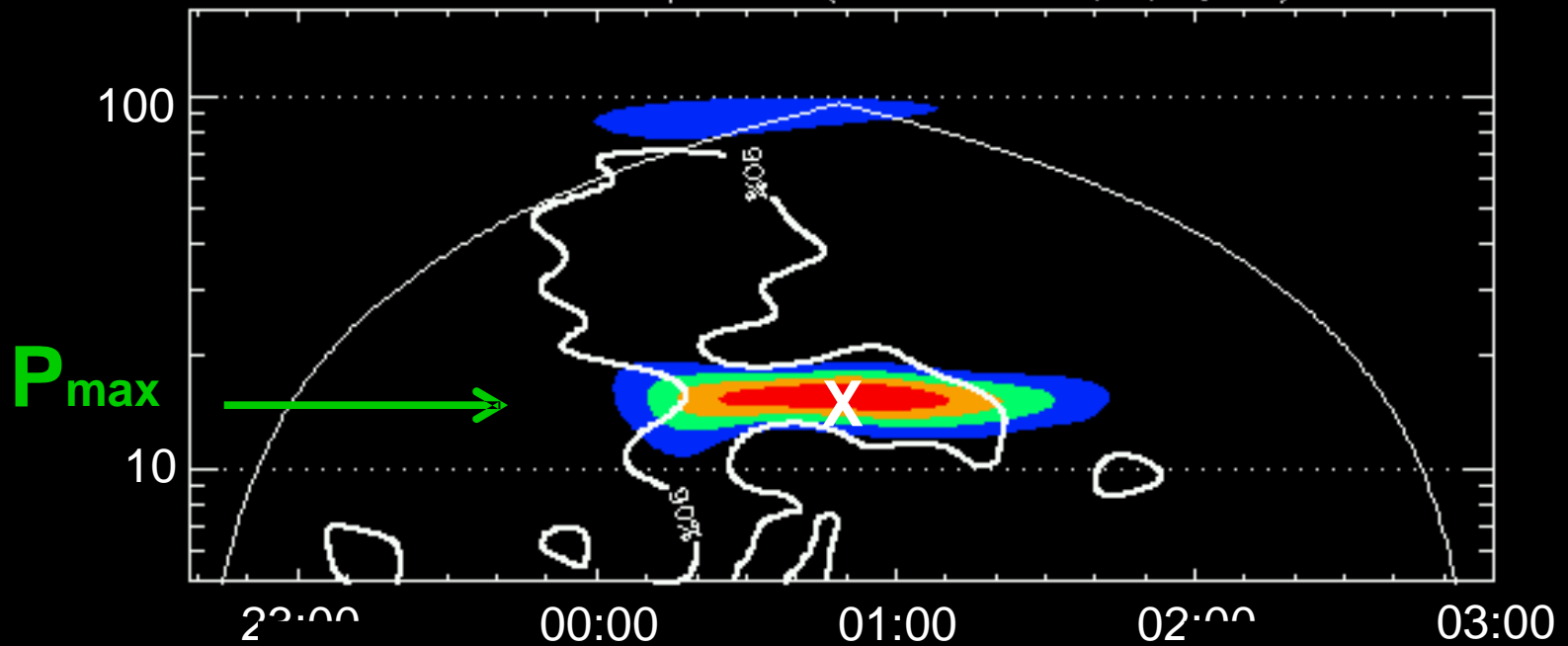
Wavelet analysis

Velocity



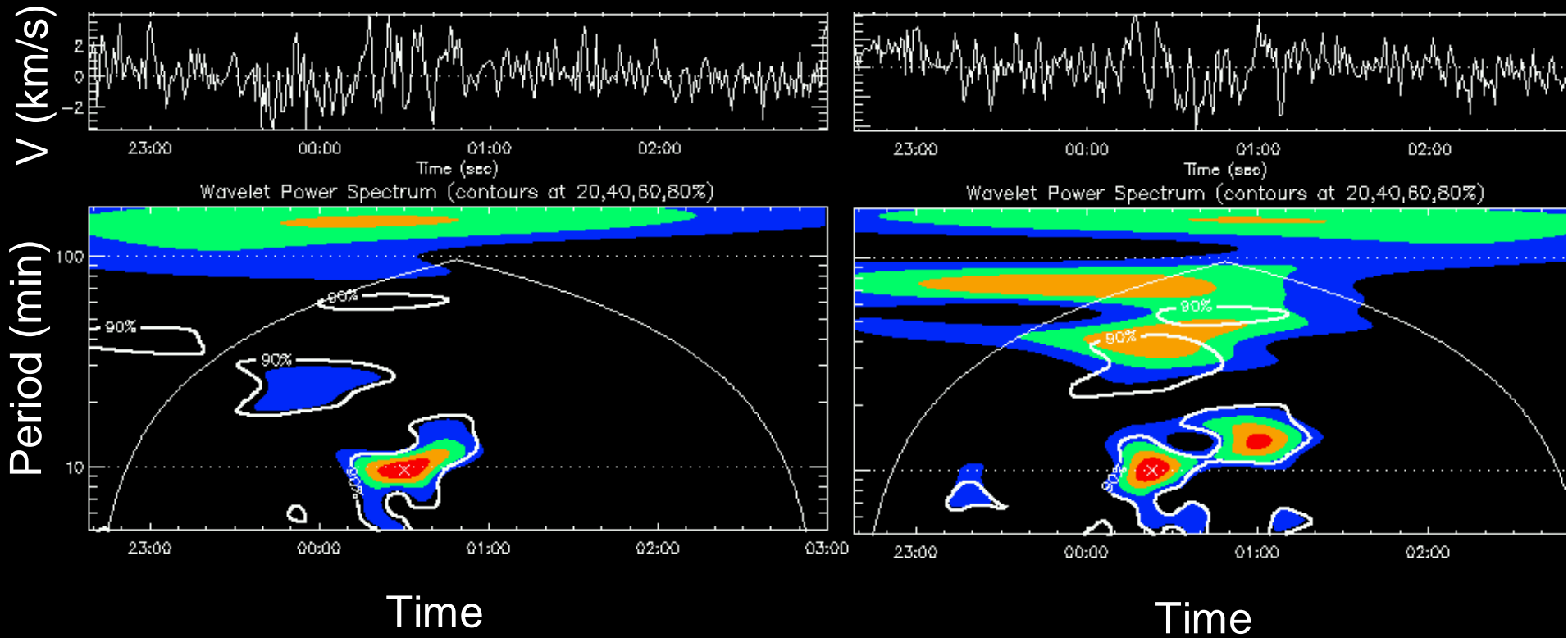
Wavelet Power Spectrum (contours at 20,40,60,80%)

Period (min)



Wavelet analysis

$$dP_{\max} / dt \neq 0$$



SUMMARY

We analyzed MHD oscillations in coronal multiple loops observed with NOGIS in the coronal green line (2MK).

- *Triggered by an impulsive pulse (traveling fast wave)*
- *Kink + slow mode?*
Doppler velocity was not maximum at the apex of each loop.
The turbulences propagated both transverse and parallel to the loops.
(Intensity oscillations were not seen...)*
- *Energy propagation toward outer (outside of the) loops?*
Longer period for outer (less dense) loops (10–16min)
Smooth variations: Fundamental mode for each loop

Collaborative observations with **solar-B/EIS** in a wide temperature range is crucial to understand the energy exchange (dissipation) process in oscillation/wave phenomena.



NOGIS image (our event)

030602:p1_0247/00:14:37



The image is split into two vertical panels. The left panel, labeled 'Intensity', shows a dark, curved, crescent-shaped feature against a dark background. The right panel, labeled 'Velocity', shows a similar curved feature but with a grainy, textured appearance, suggesting motion or velocity measurements. The two panels are separated by a thin vertical line.

Intensity

Velocity

June 2, 2003

NOGIS *best* image

050728:p1_0094/01:21:40

A grayscale image showing the intensity of a plasma jet. It features a bright, curved structure on the left side, with a dark, curved region on the right side. The overall appearance is somewhat blurry and noisy.

Intensity

A grayscale image showing the velocity of a plasma jet. It features a bright, curved structure on the left side, with a dark, curved region on the right side. The overall appearance is somewhat blurry and noisy.

Velocity

July 28, 2005 (P68 Suzuki, I. et al.)