

*Forward Modelling of Propagating Slow Waves in Coronal Loops  
and Their Frequency-Dependent Damping.*

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Doorselaere , Dipankar Banerjee*

# Context:

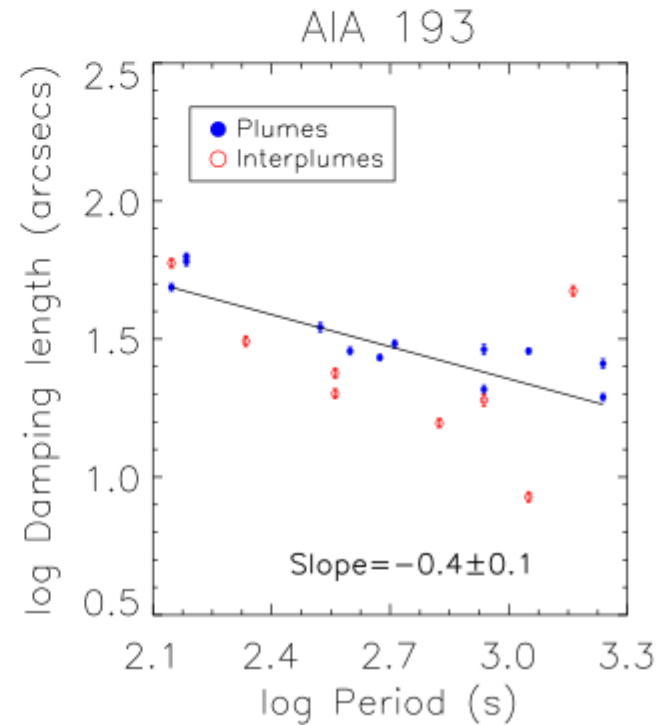
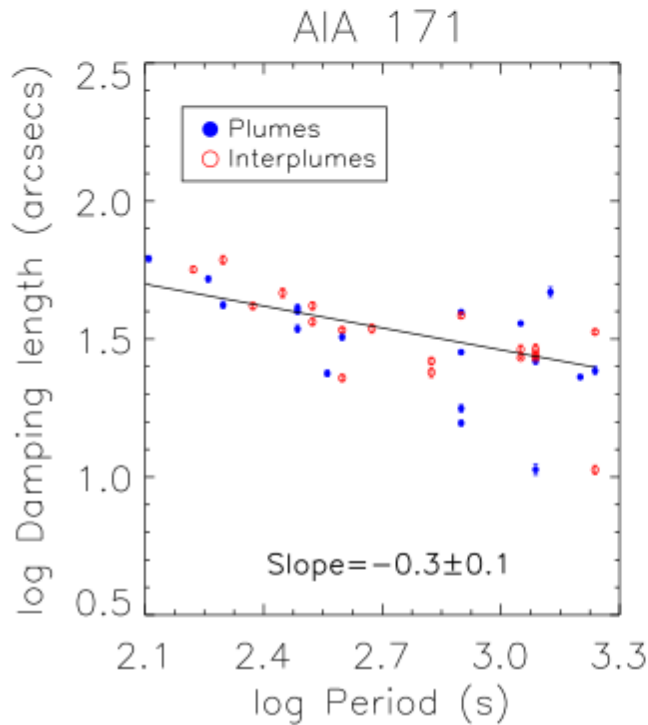
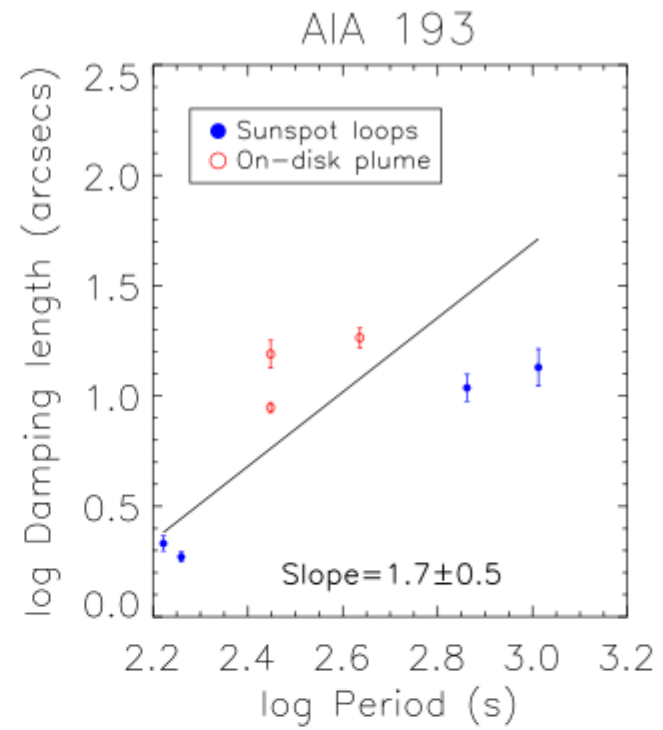
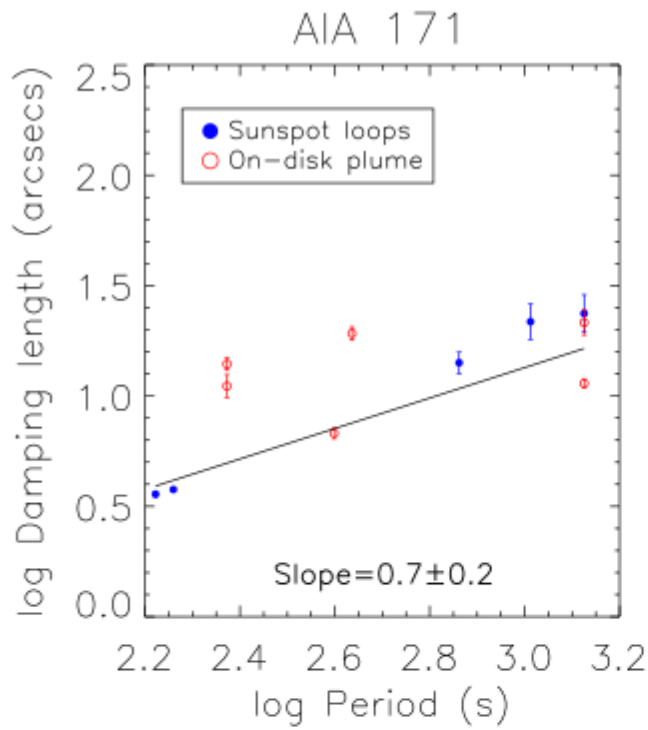
Propagating  
depends upon

This frequency  
where they have

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FREQUENCY

$2^2$  Center



Solar-x (arcsec)

which

2014

118

## Numerical Setup

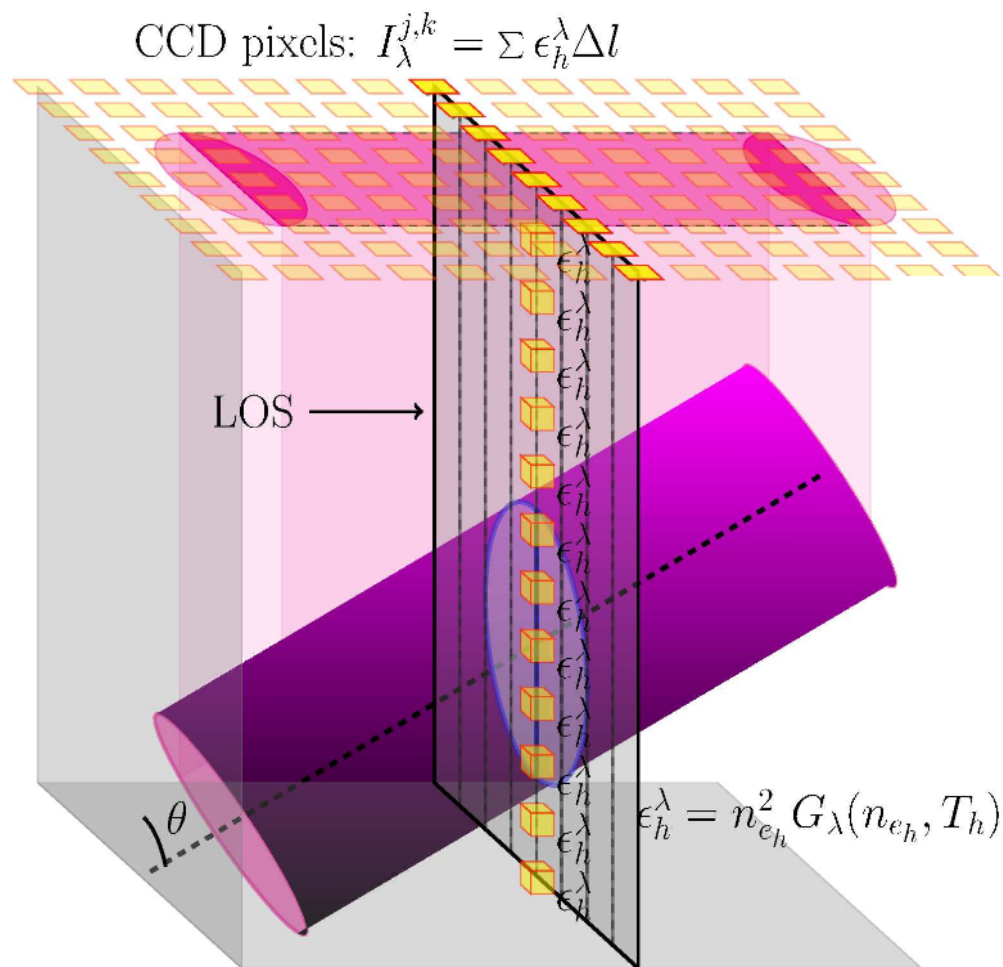
We have used MPI-AMRVAC code for our simulations.

- We have used a uniform grid with 96 x 96 x 600 cells.
- To generate the slow waves we perturb the pressure at the footpoints constantly with single (3 and 7 minutes) and multiple period (3,5,7 and 10 minutes) driver.
- We use different amplitude for different periods
- We also introduce thermal conductivity along the magnetic field with the Spitzer conductivity set to  $k = 10^{-12} T^{5/2}$  erg/cm/s/K
- We allow the waves to leave the system.

## Forward modelling:

Forward modelling has been done with the FoMo code developed by Tom Van Doorselaere et al.

FoMo code generates synthetic image/spectra of an instrument (SDO/AIA in our case) using the response function of that particular instrument.



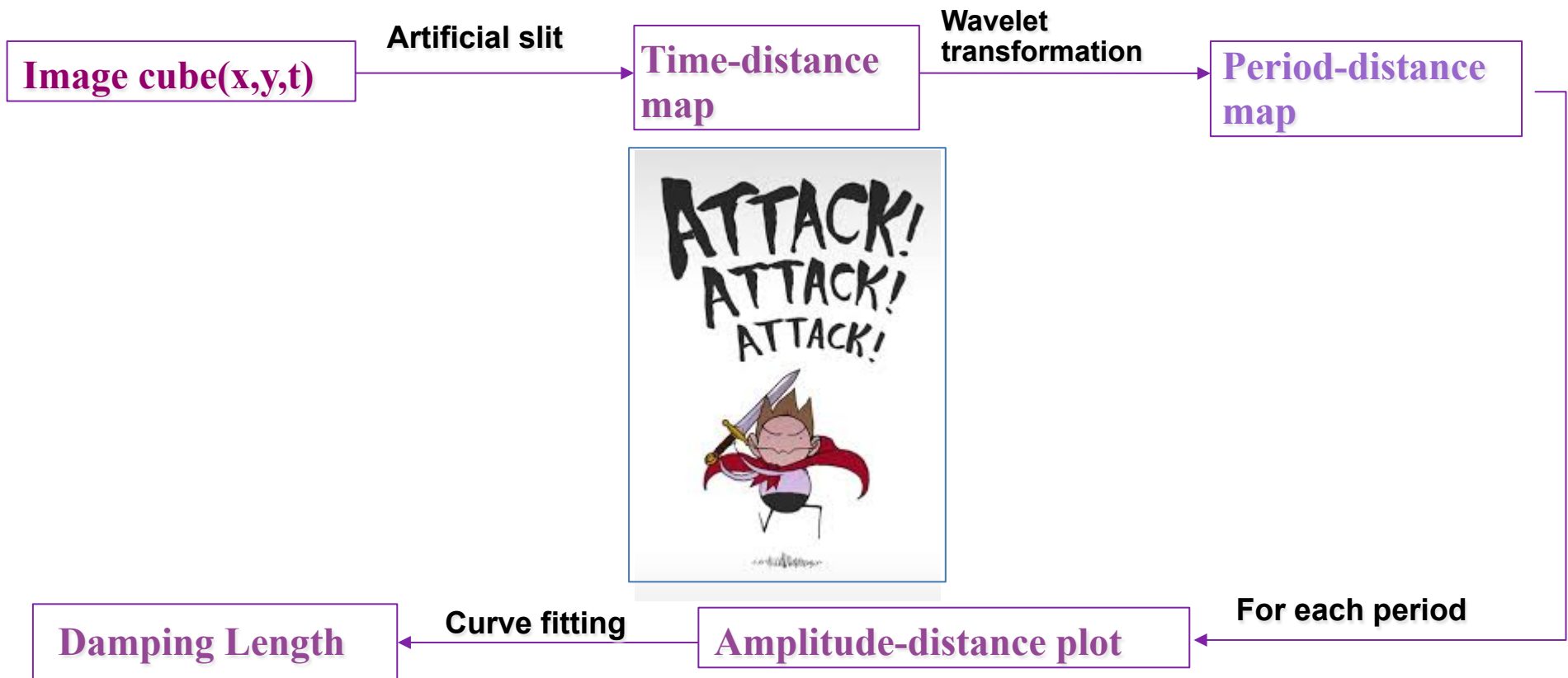
$$K_{\alpha}(n_e, T) = \int_0^{\infty} G(\lambda, n_e, T) R_{\alpha}(\lambda) d\lambda,$$

$$F_{\alpha}(\mathbf{x}) = \int_l K_{\alpha}(n_e, T) n_e^2 dl.$$

We have synthesized AIA 171 and 193 channel emission.

@yuan et al 2015,Apj

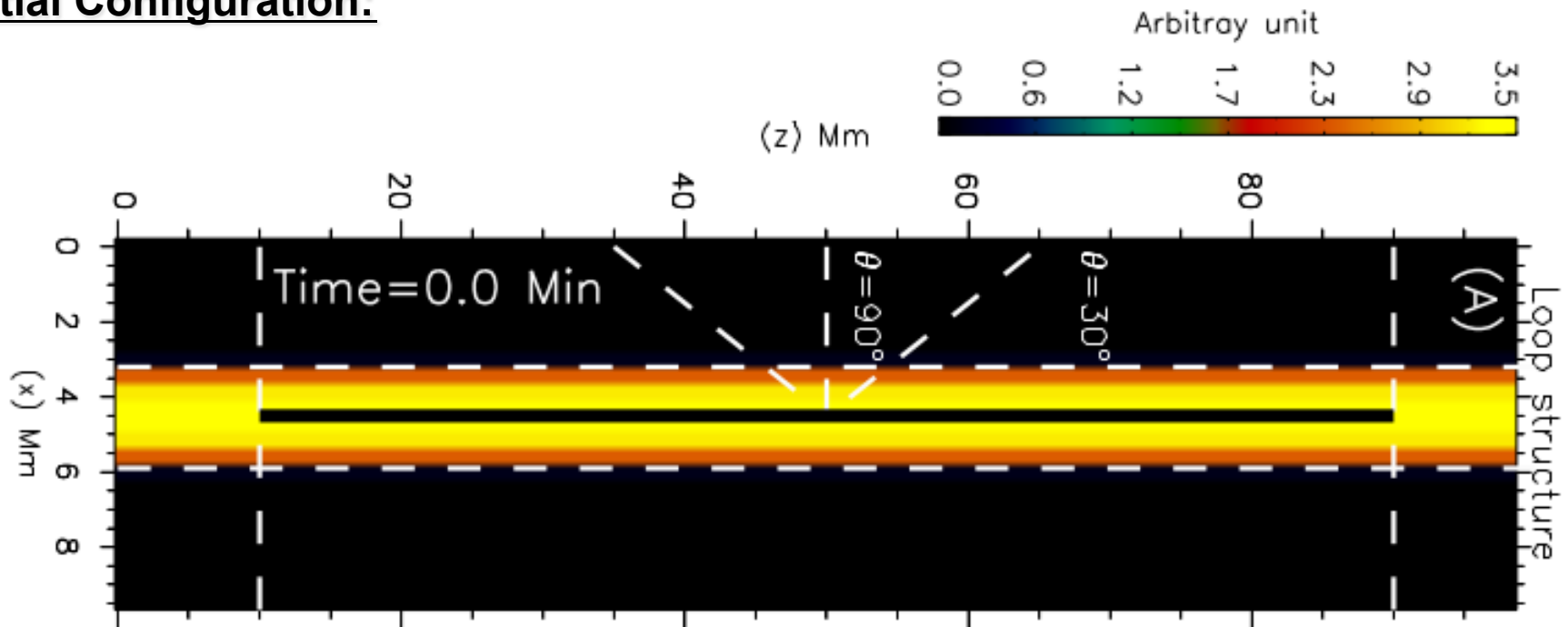
# Line of attack:



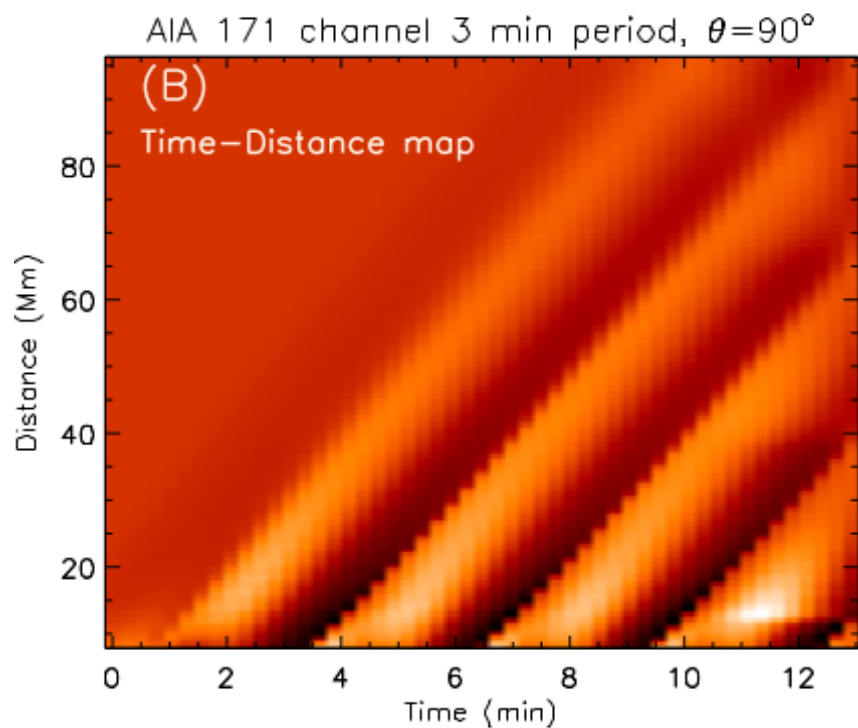
## Single Period Driver:



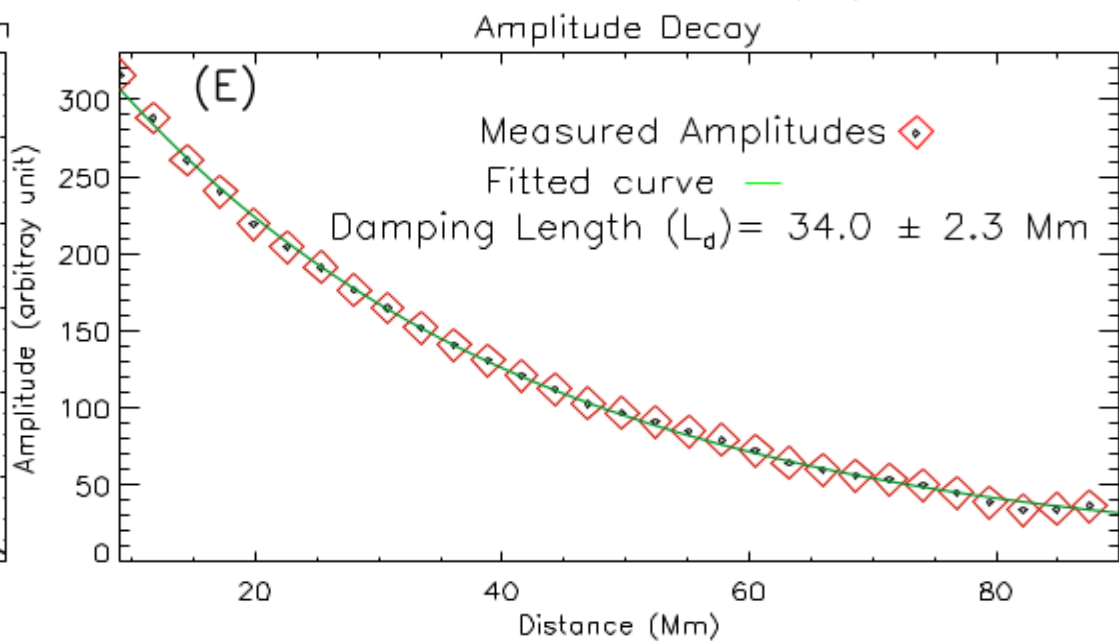
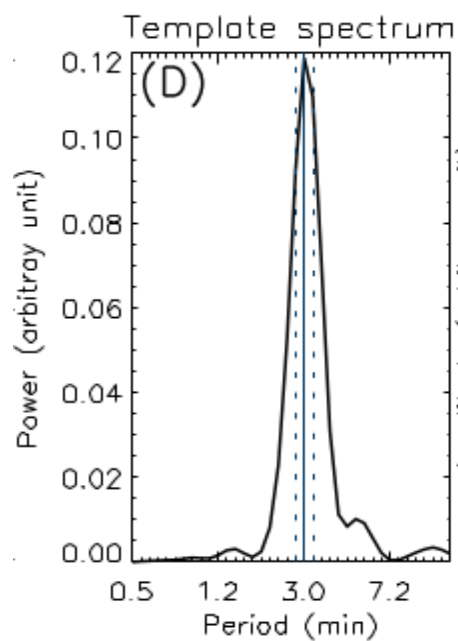
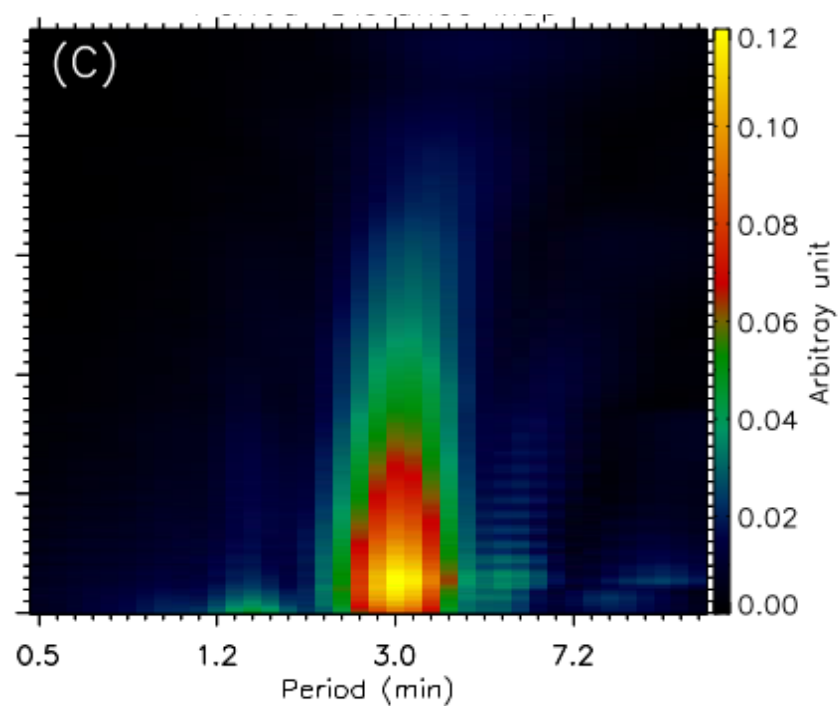
## Initial Configuration:



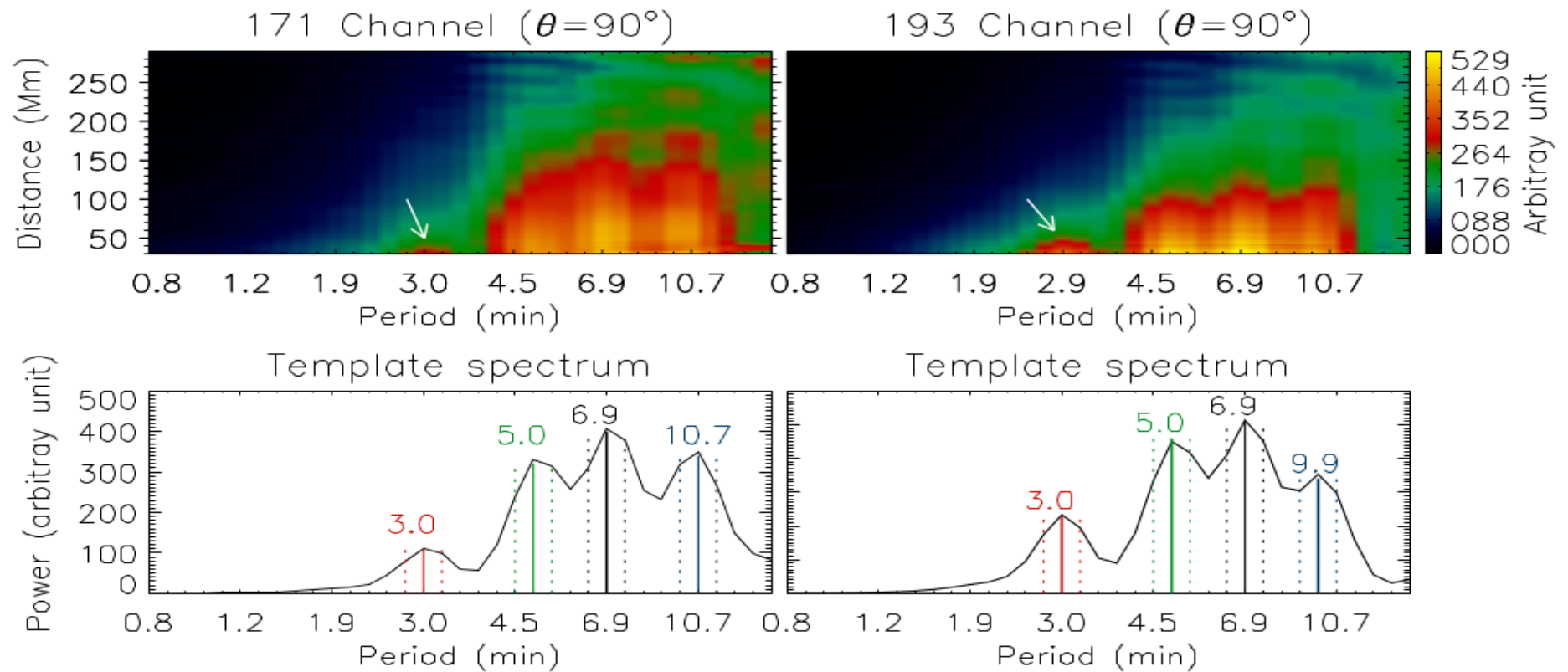
## Time-distance map:



## Period-distance map:



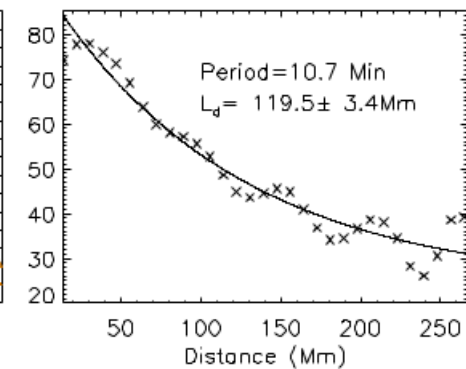
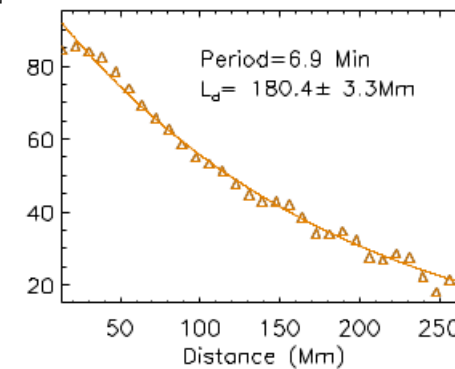
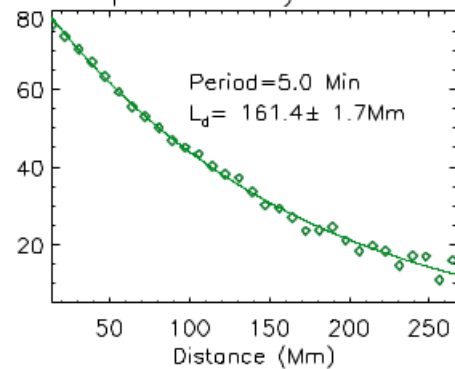
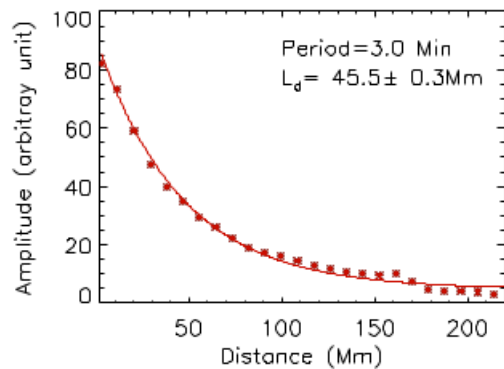
# Multi-Period Driver:



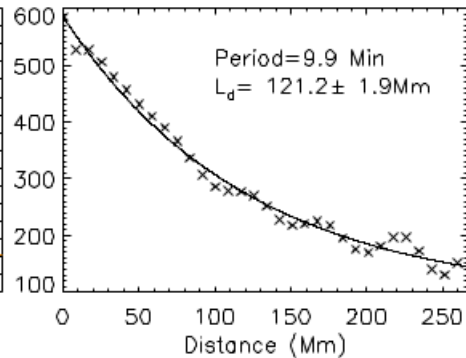
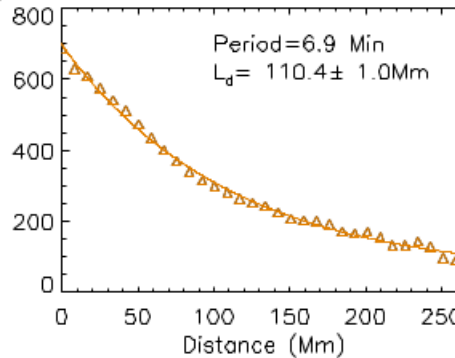
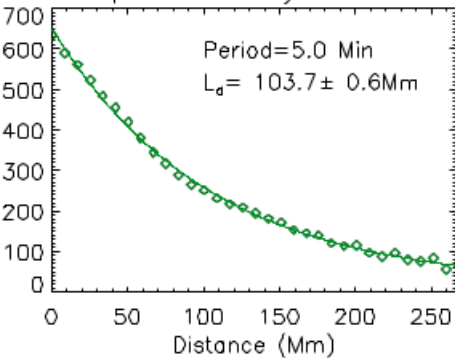
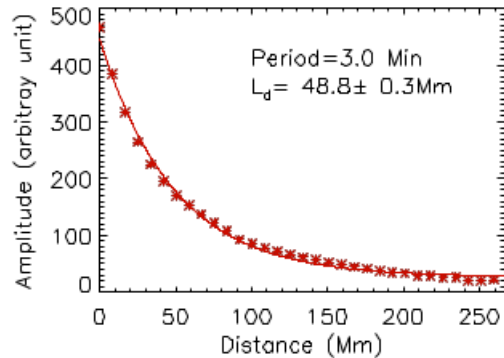


**Got it !!!**

Amplitude Decay for AIA 171,  $\theta=90^\circ$



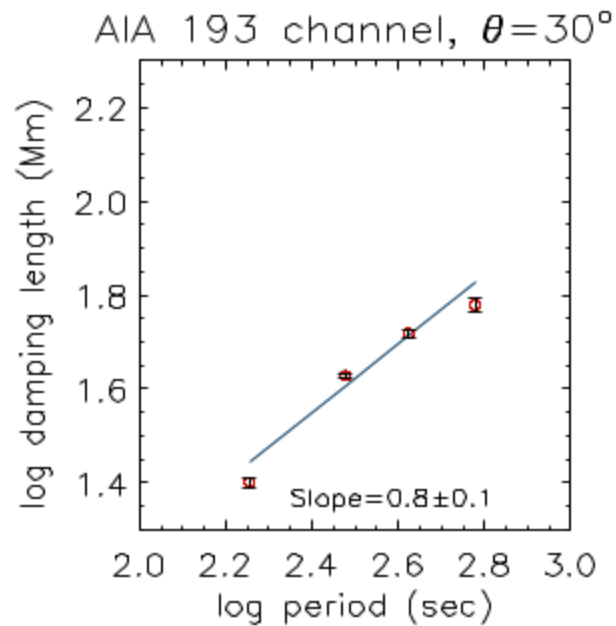
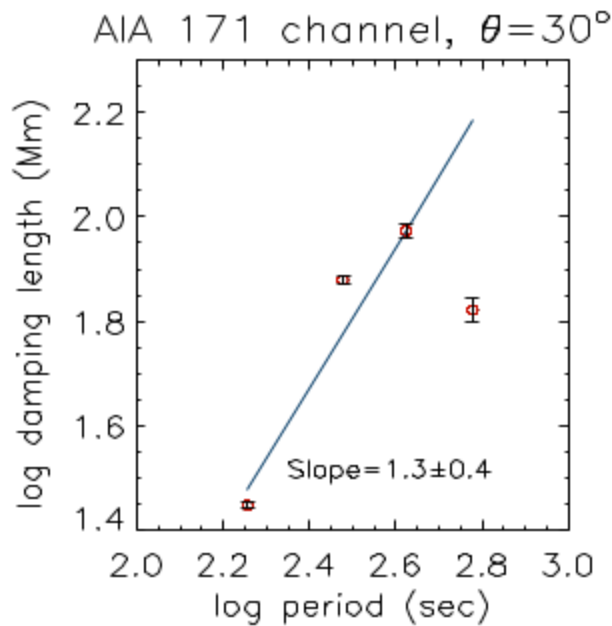
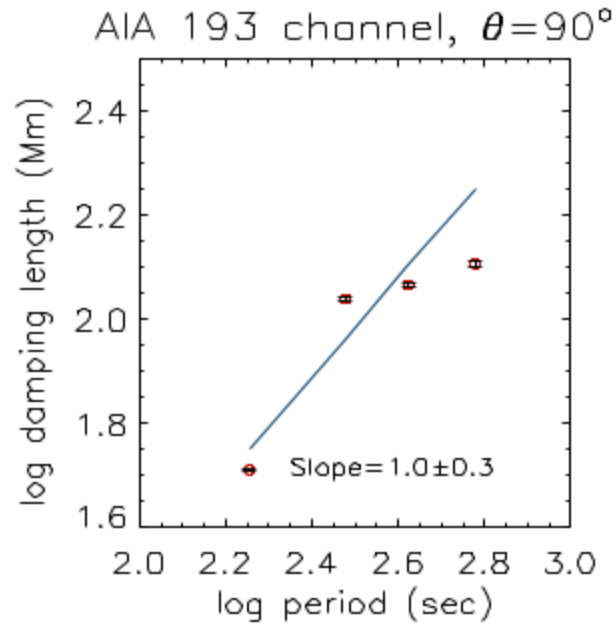
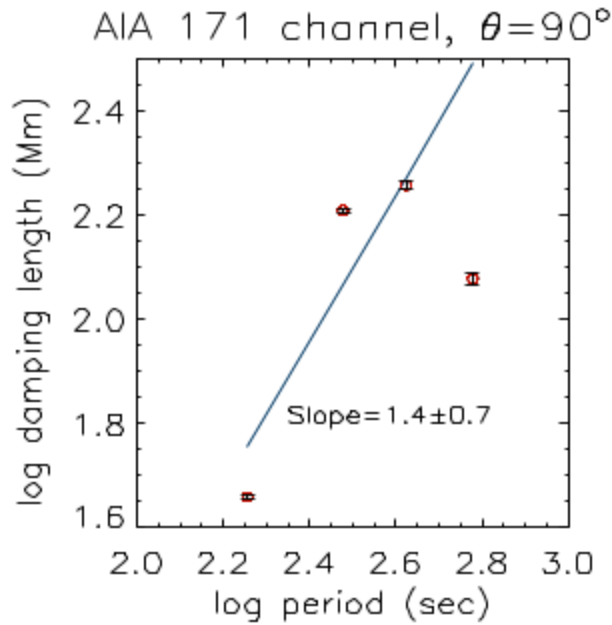
Amplitude Decay for AIA 193,  $\theta=90^\circ$



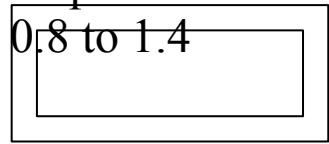
Damping Lengths obtained for  $\theta = 30^\circ$

| <i>AIA Channel</i> | <i>Period (Min)</i> | <i>Damping Length (Mm)</i> |
|--------------------|---------------------|----------------------------|
| 171 Å              | 3.0                 | $27.9 \pm 0.3$             |
|                    | 5.0                 | $75.6 \pm 0.7$             |
|                    | 6.9                 | $94.1 \pm 1.2$             |
|                    | 10.7                | $66.2 \pm 1.3$             |
| 193 Å              | 3.0                 | $25.1 \pm 0.3$             |
|                    | 5.0                 | $42.5 \pm 0.5$             |
|                    | 6.9                 | $52.3 \pm 0.5$             |
|                    | 9.8                 | $60.1 \pm 0.7$             |

That plot!!:



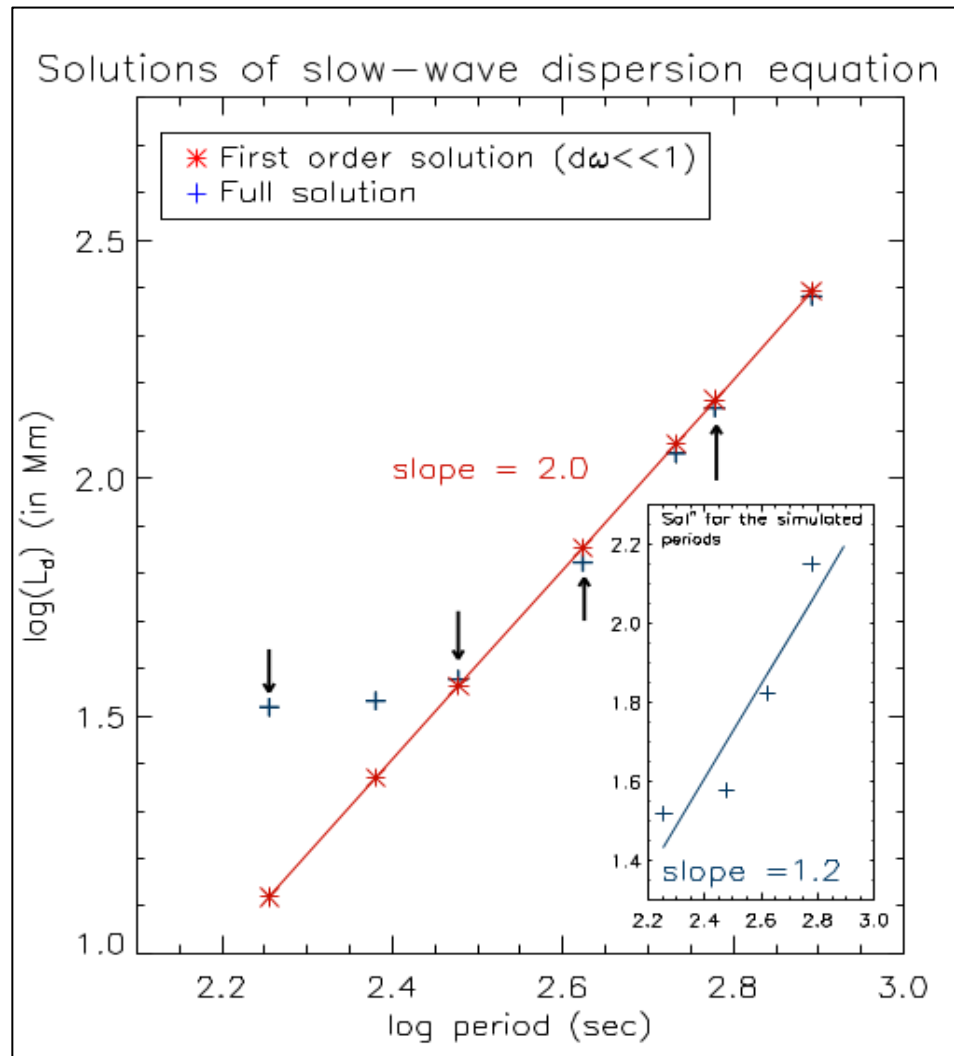
We observe that in all the cases the slope is positive and it ranges from 0.8 to 1.4



## Theory:

We have included thermal conduction as the damping agent. Krishna Prasad showed that in the low-thermal conduction limit the log-log plot gives a slope of 2.

Now we investigate the relationship by solving analytically solving the slow wave dispersion equation.



The equation has been solved for a period range of 3-13 minutes.

## Summary and conclusion:

In this study, we set out to explain the observed dependence of the damping of slow waves with their period. In the previous work, no theoretical prediction for damping dependence could explain the observed values. Here we aimed to simulate the damping, perform forward modelling and analyze the model output as in the observations in order to explain the unexpected damping length behaviour with the wave period.

- We obtained a slope of  $1.4 \pm 0.7$  (171A channel) and  $1.0 \pm 0.3$  (193A channel) for  $\theta = 90^\circ$  and  $1.3 \pm 0.4$  (171A channel) and  $0.8 \pm 0.1$  (193A channel) for  $\theta = 30^\circ$ .
- We have also studied in-depth the theoretical damping behaviour of the slow waves in the case when thermal conduction is not weak. We have found that in the general case (and not the weak conduction limit previously used) a similar positive slope, as in the observation, can be reproduced.
- On the other hand the negative slopes for polar plume and the interplume case obtained by Krishna Prasad et al. (2014) are still to be explained. They are possibly due to different nature of the plumes compared to the sunspot loops.