

# **Coronal Seismology**

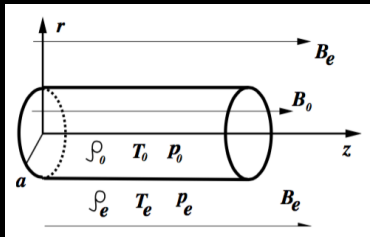
**ASTR 598**

**Laurel Farris**

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# Magnetohydrodynamics (MHD)

## Theory



## Model

- Straight cylindrical flux tube in uniform magnetic field.
- $\xi(x) = \xi(r)e^{i(kz+m\phi)}$
- Characteristic wave speeds are determined by  $\rho$ ,  $T$ ,  $P$ , and  $\vec{B}$

## Sound speed

- $C_s \propto \sqrt{\frac{P}{\rho}} \propto \sqrt{T}$

## Alfvén speed

- $V_A \propto \frac{B}{\sqrt{\rho}}$

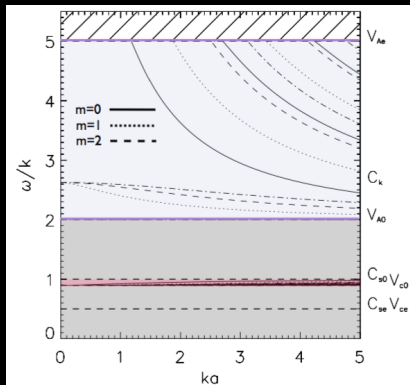


# MHD modes

## Research Topics

1. Kink oscillations
2. Sausage oscillations
3. Acoustic oscillations
4. Propagating acoustic waves
5. Propagating fast waves
6. Torsional (Alfvén) modes
  - Magnetoacoustic
    - Fast
    - Slow
  - Alfvén

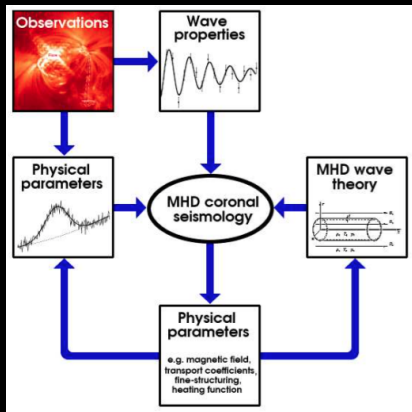
## Dispersion diagram



$$C_k = \sqrt{\frac{2}{1 + \rho_e/\rho_o}}$$

# Coronal seismology

## Technique and motivation



## Elusive coronal properties

- magnetic field strength,  $\vec{B}$
- density,  $\rho$
- Alfvén velocity,  $V_A$

## Motivation

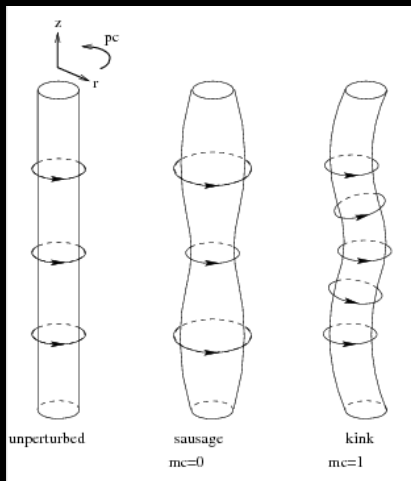
- Coronal heating
- Space weather prediction

## Coronal seismology

1. Observe disturbances
2. Measure properties
3. Identify the wave or mode
4. Extract coronal parameters

# Fast standing oscillations

## Kinks vs. Sausages



## Kink

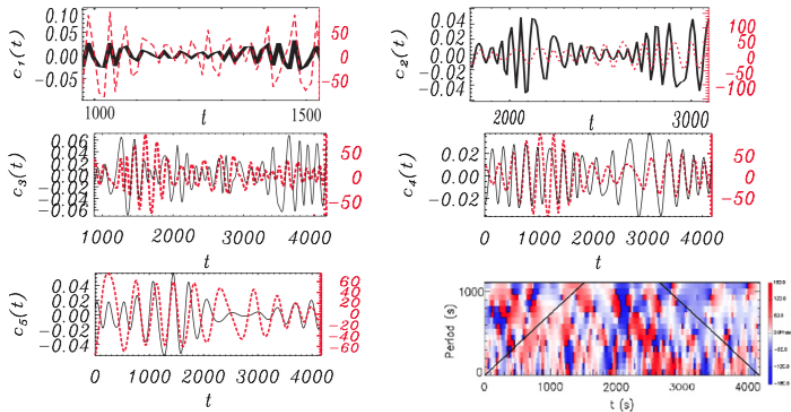
- loop spatial displacement
- Asymmetric
- No intensity change
- Period  $P = \frac{2\ell}{V_A} \sqrt{\frac{1+\rho_e/\rho_o}{2}}$   
where  $\lambda = 2\ell$

## Sausage

- No loop spatial displacement
- Symmetric
- Intensity change  
→ density change
- long-wavelength limit

# “Observations of sausage modes in magnetic pores”

Morton et al. 2011



- Periods  $\sim 30\text{--}45$  sec
- Possibly driven by 5-min acoustic oscillations.

# Acoustic waves

A. K. Srivastava and B. N. Dwivedi

## Observed

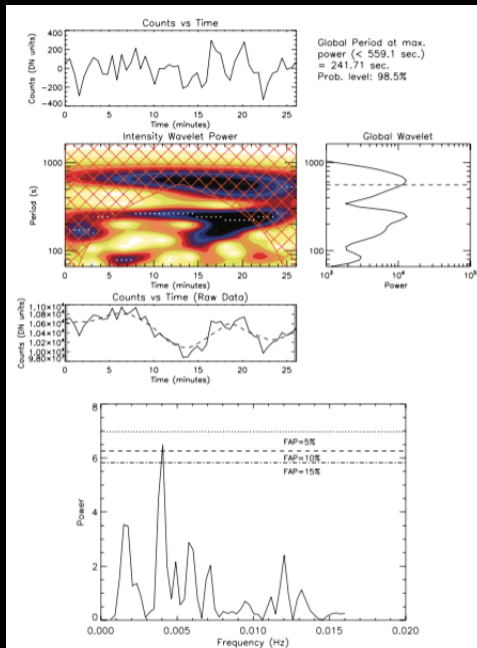
- Time series of a bright point (BP) in solar atmosphere

## Measured Periods

- He II 256 Å;  $P \sim 263$  s
- Fe XII 195 Å
- Fe XV 284 Å;  $P \sim 241$  s

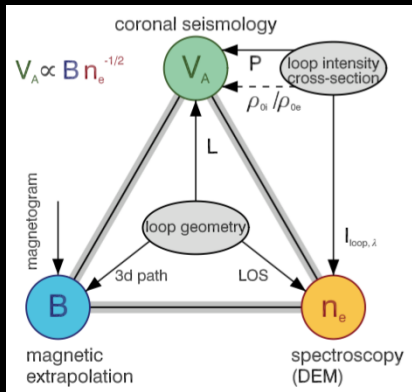
## Identified

- Acoustic oscillations leaking into the inner corona



# Alfvén waves

Verwichte et al.



- Determine Alfvén speed in two ways:

1. Coronal seismology
2. Magnetic extrapolation and spectral methods

## Observed

- Two transversely oscillating flares triggered by flare
- Observed with AIA



# Important Properties

	<b>period</b>	<b>decay time</b>	<b>velocity</b>
kink osc	2–20 m	quickly	value
sausage osc	value	value	value
acoustic osc	7–31 m	5–30 m (quickly)	$200 \text{ km s}^{-1}$
acoustic waves	value	value	$<150 \text{ km s}^{-1}$
fast waves	value	value	$>150 \text{ km s}^{-1}$
torsional modes	10 m	long	$1000 \text{ km s}^{-1}$

# Research

AIA/SDO

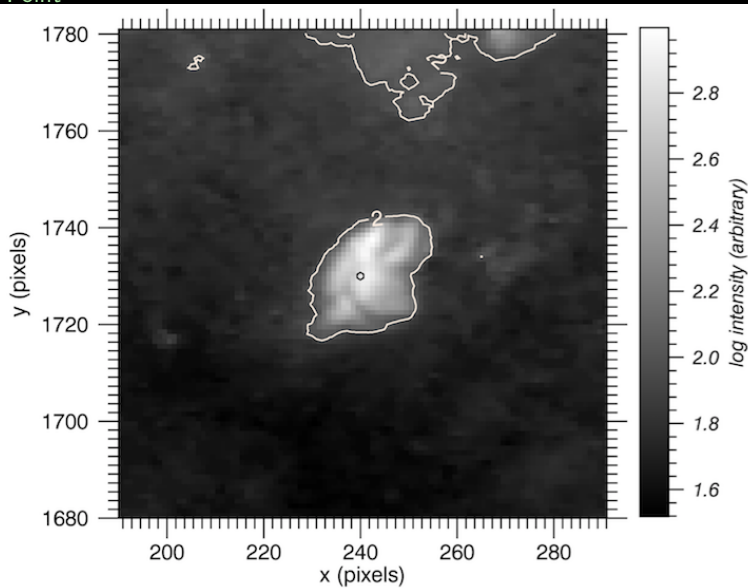
Fe XII, XXIV

193 Å



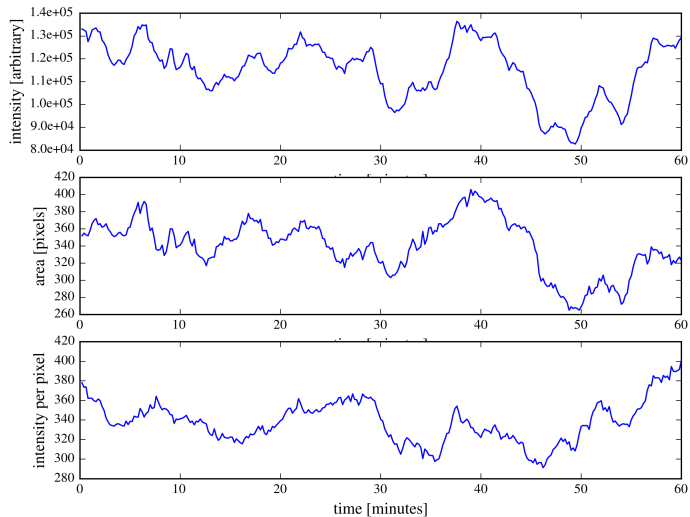
# Research

## Bright Point



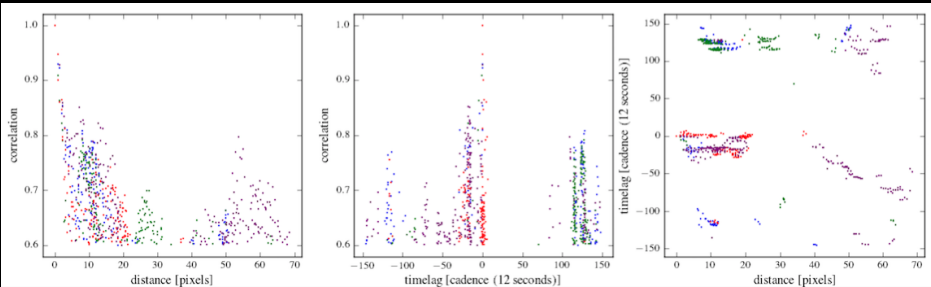
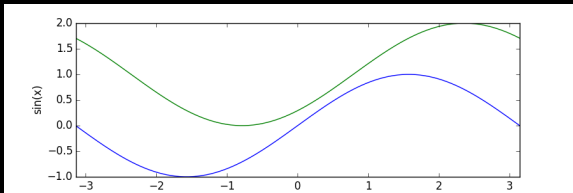
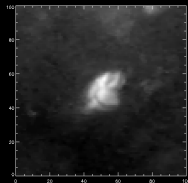
# Research

## Light curves



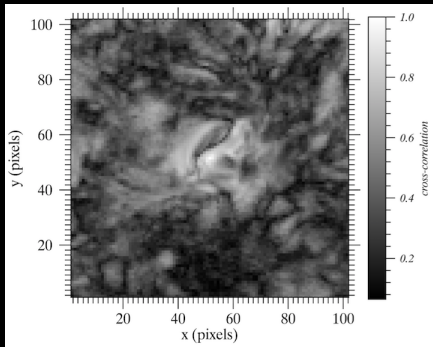
# Research

## Cross-correlations

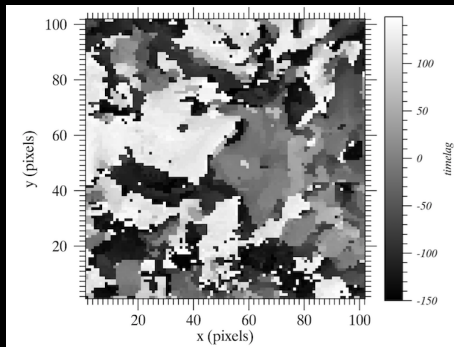


# Research

## Cross-correlation



## Timelag



# Future work

Other questions:

- What is the excitation mechanism for the observed disturbances?
- How are they damped, and what determines the timescales?

My future work:

- Download data in other wavelengths (i.e. coronal heights).
- Download data from other instruments, e.g. the Extreme Ultraviolet Variability Experiment (EVE) on SDO.
- Characterize other bright points in coronal hole, quiet sun, and active regions.

# Acknowledgements

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Extra slides here