Coronal Seismology

ASTR 598

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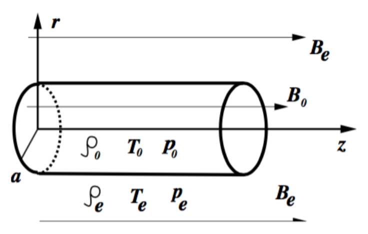
Spring 2016

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 ρ, T, P, and $\vec{B}$

Sound speed

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

Alfvén speed

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

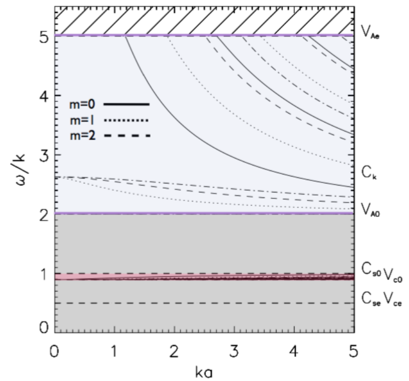
MHD modes

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

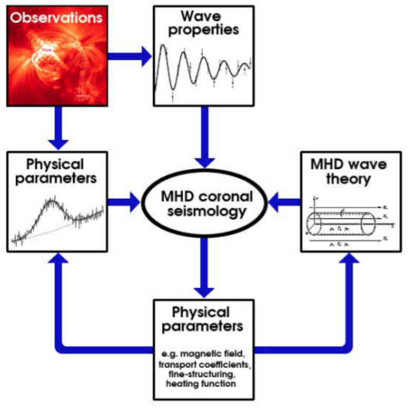
Dispersion diagram



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

Coronal seismology

Technique and motivation



Elusive coronal properties

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

Motivation

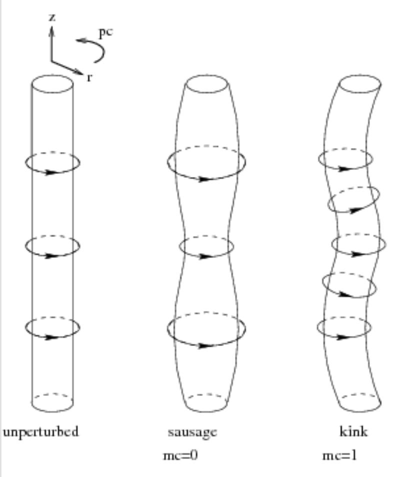
- Coronal heating
- Space weather prediction

Coronal seismology

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

Fast standing oscillations

Kinks vs. Sausages



Period

- $P = \frac{2\ell}{V_{ph}}$ $(\lambda = 2\ell)$

Kink

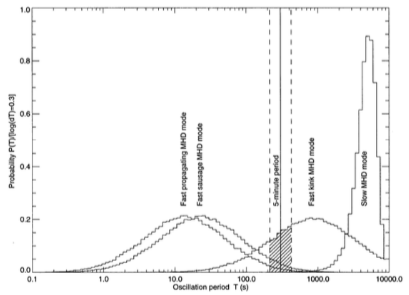
- loop spatial displacement
- Asymmetric
- No intensity change

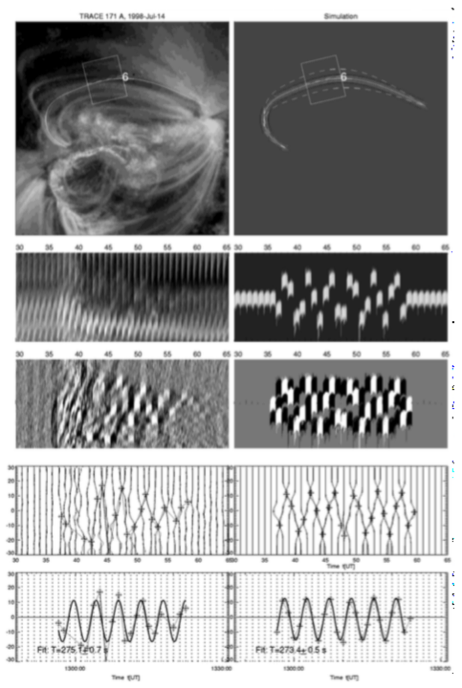
Sausage

- No loop spatial displacement
- Symmetric
- Intensity change
  $\rightarrow$ density change

Coronal loop oscillations observed with *TRACE*

Aschwanden et al. 1999



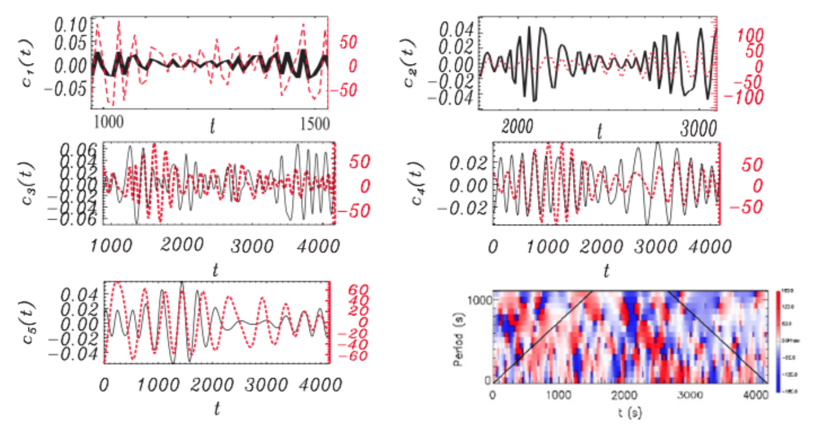


TRACE 171 A, 1998-Jul-14
Simulation
Fit: T=275.1±0.7 s
Fit: T=273.4±0.5 s
Time t[UT]

Excitation and damping of broadband kink waves in the solar corona

"Observations of sausage modes in magnetic pores"

Morton et al. 2011



- Periods $\sim$ 30–450 sec
- Possibly driven by 5-min acoustic oscillations.

Acoustic waves

A. K. Srivastava and B. N. Dwivedi

Observed

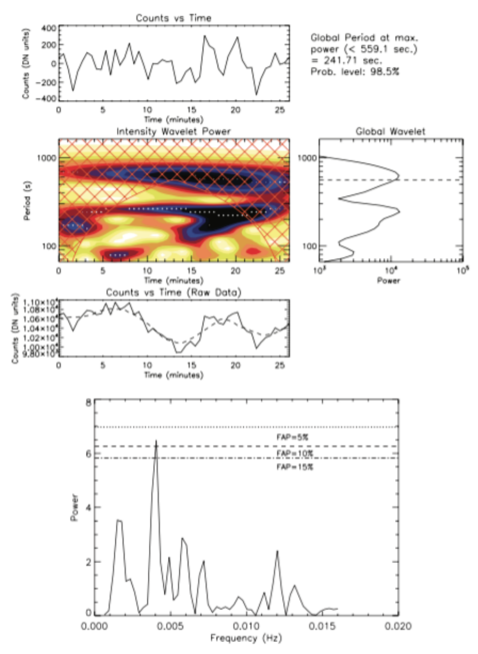
- Time series of a bright point (BP) in solar atmosphere

Measured Periods

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

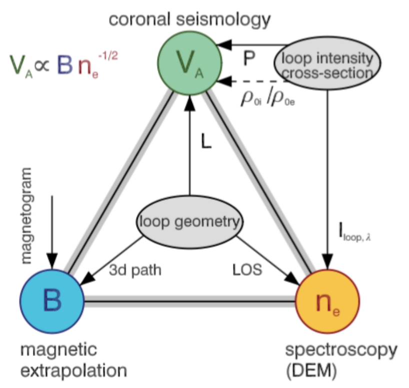
Identified

- Acoustic oscillations leaking into the inner corona



Alfvén waves

Verwichte et al.



Objective

- Determine Alfvén speed in two ways:
  1. Coronal seismology
  2. Magnetic extrapolation and spectral methods

Observed

- Two transversely oscillating flares triggered by flare
- AIA/SDO 171 Å

Important Properties

From papers, reviews, etc.

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

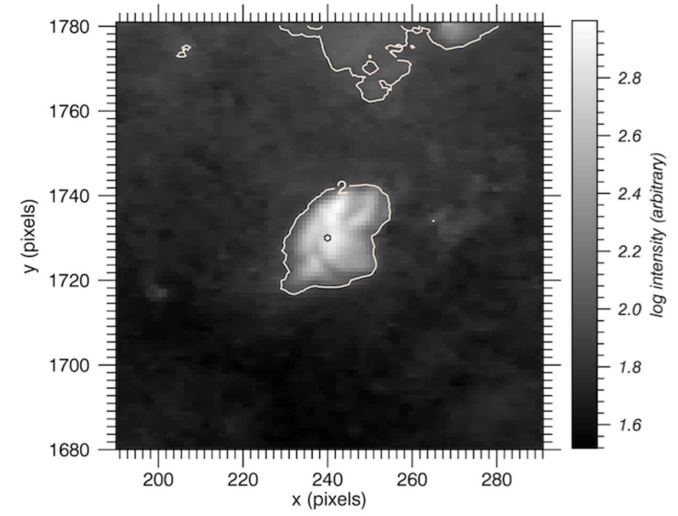
Research

AIA/SDO

Fe XII, XXIV
193 Å

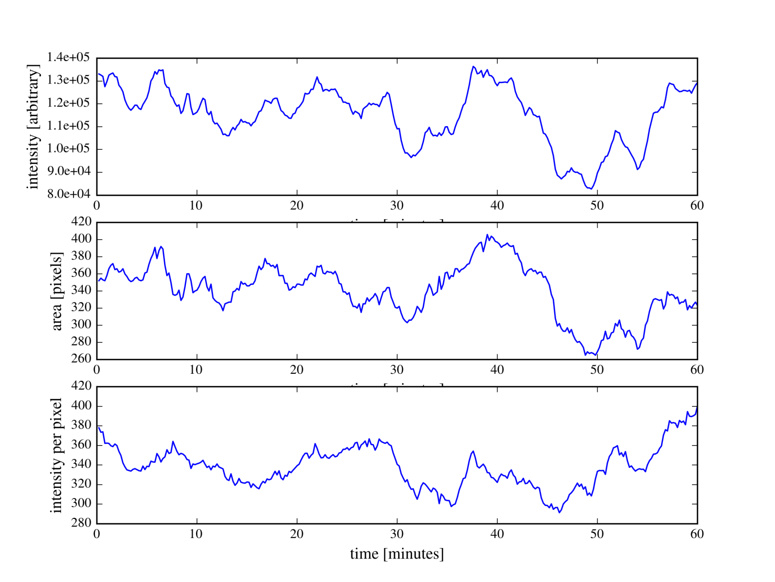
Research

Bright point (BP)



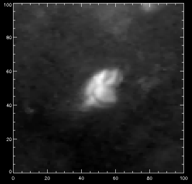
Research

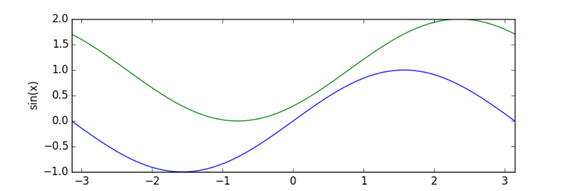
Light curves

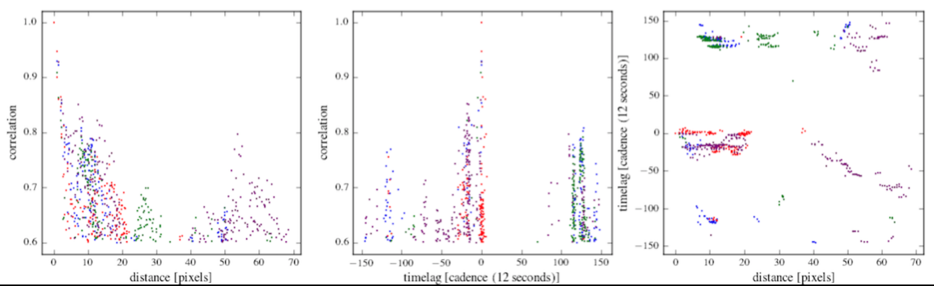


Research

Cross-correlations



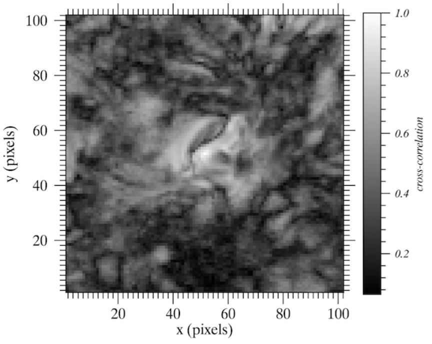




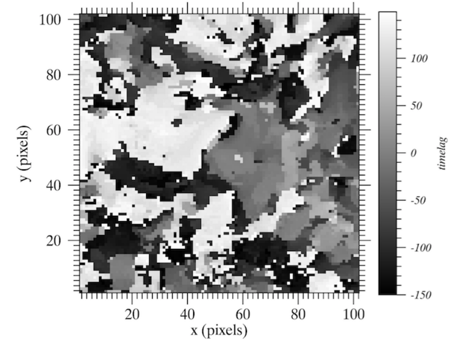
Research

Cross-correlation & timelag images

Cross-correlation



Timelag



2 pixels $\sim$ 1 arcsec $\sim$ 700 km

Other questions and 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