Coronal Seismology

ASTR 598

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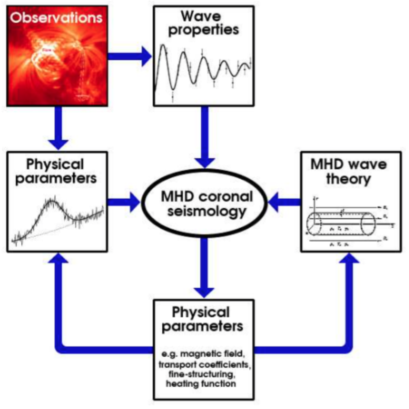
Spring 2016

Coronal seismology

Technique and motivation



Elusive coronal properties:

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

Solution: coronal seismology

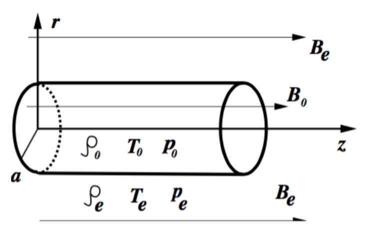
1. Observe disturbances
2. Measure properties
3. Identify the wave or mode
4. Extract coronal parameters

Motivation:

- Coronal heating
- Space weather prediction

Magnetohydrodynamics (MHD)

Theory



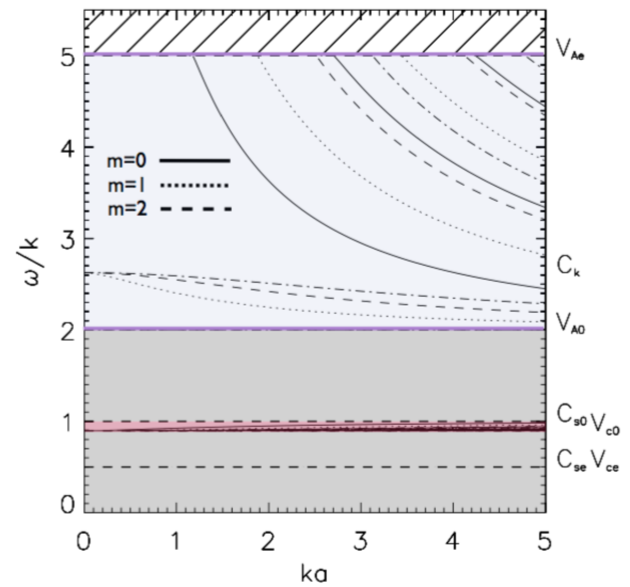
Model:

- Straight flux tube in uniform magnetic field.
- Frozen-in plasma is compressive and elastic.
- Characteristic wave speeds are determined by ρ, T, P, and $\vec{B}$

1. Magnetoacoustic $C_s = \sqrt{\frac{\gamma P}{\rho}}$
   (a) Fast $k_{A_0} < C_{fast} < C_{A_e}$
   (b) Slow $C_{T_0} < C_{slow} < C_{s_0}$
2. Alfvén $V_A = \frac{B}{\sqrt{\mu_0 \rho}}$

Dispersion diagram

Phase speed ($v_{ph} = \frac{\omega}{k}$) as function of ka

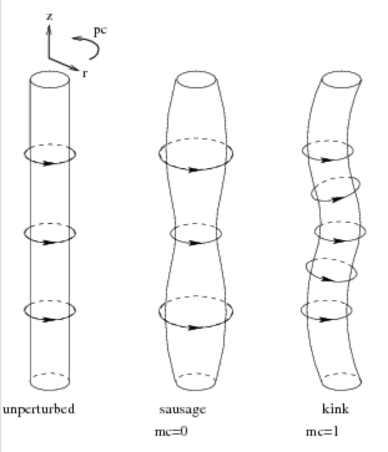


Research Topics

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

Fast standing oscillations

Kinks vs. Sausages



Kink

- loop spatial displacement
- Asymmetric
- No intensity change
- $k\sigma \ll 1$, or $\sigma \ll \lambda$
- Derive magnetic field!
- Period $P = \frac{2L}{V_A}\sqrt{\frac{1+\rho_e/\rho_o}{2}}$ where $\lambda = 2L$ (L is the loop length). Typically, $L \approx 60 - 600$ Mm in the corona.

Sausage

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

Standing oscillations vs. propagating waves

- In loops, propagating waves damp before reaching opposite footpoint.
- Velocity and intensity are 90° out of phase for standing oscillations, and are in phase for propagating acoustic waves.
- Frequencies less than the cutoff are standing oscillations, waves with frequency greater than the cutoff propagate into the chromosphere.

Torsional modes

aka. Alfvén wave

Properties:

- m=0 (Axisymmetric, or azimuthally symmetric)
- transverse (shear) perturbations
- Parallel to $\vec{B}$
- Driving force: magnetic tensioin
- incompressible
- velocity: $v_A = \frac{B}{\mu_o \rho}$; ~ 1000 km s^{-1} in the corona

How to observe:

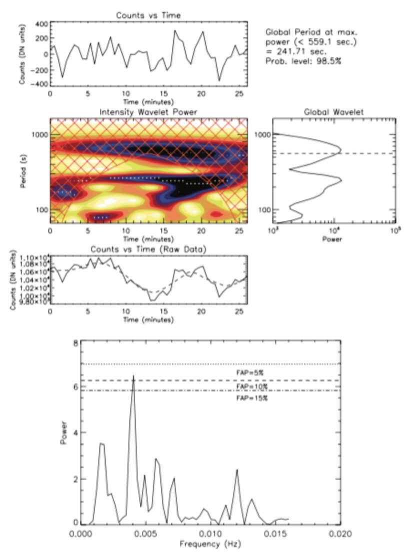
- Only get Doppler shifts from *long*-period waves ($>$ a few minutes).
- Measure additional (i.e. non-thermal) broadening of coronal emission lines; indirect way to observe short-period waves.
- Spatial variation in Doppler shift for long periods. Gyrosynchrotron emission in radio regime.

Effects of twisting:

- Coupling of various MHD modes

Examples from the literature

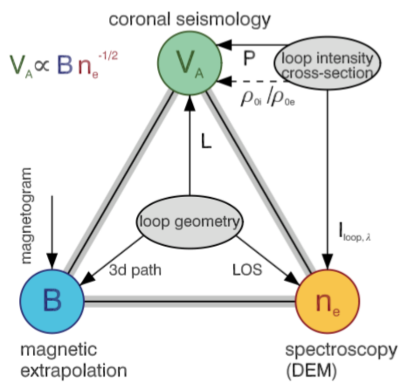
A. K. Srivastava and B. N. Dwivedi



- Observed bright point (BP) with EIS on *HINODE*
- HeII 256 Å (TR and low corona)
- FeXV 195 Å (Upper corona)
- Leakage of acoustic oscillations in the inner corona

Examples from the literature

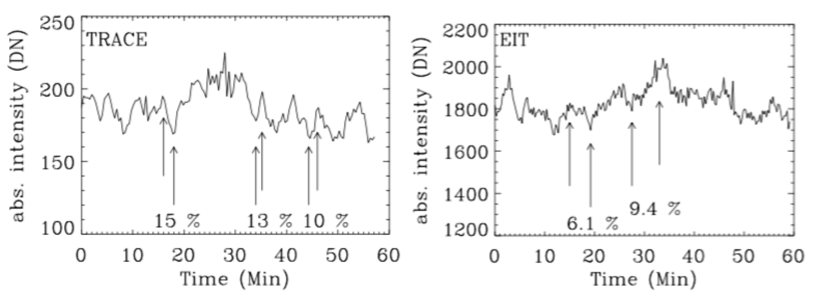
Verwichte et al.



- Comparison of coronal seismology and direct methods

Examples from the literature

Robbrecht, et al. (2001)



- Multi-wavelength observations

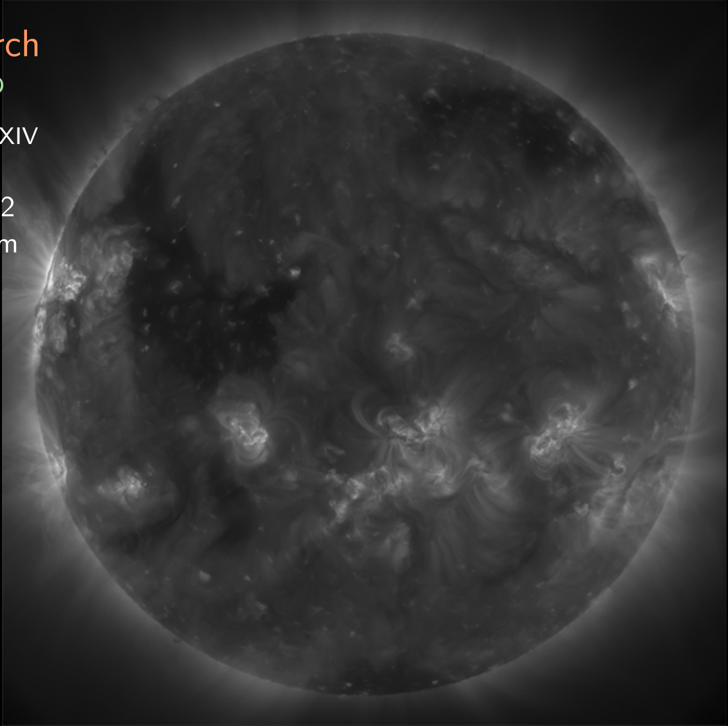
Important Properties

	period	decay time	velocity
kink osc	2–20 m	value	value
sausage osc	value	value	value
acoustic osc	20 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	value	1000 km s^{-1}

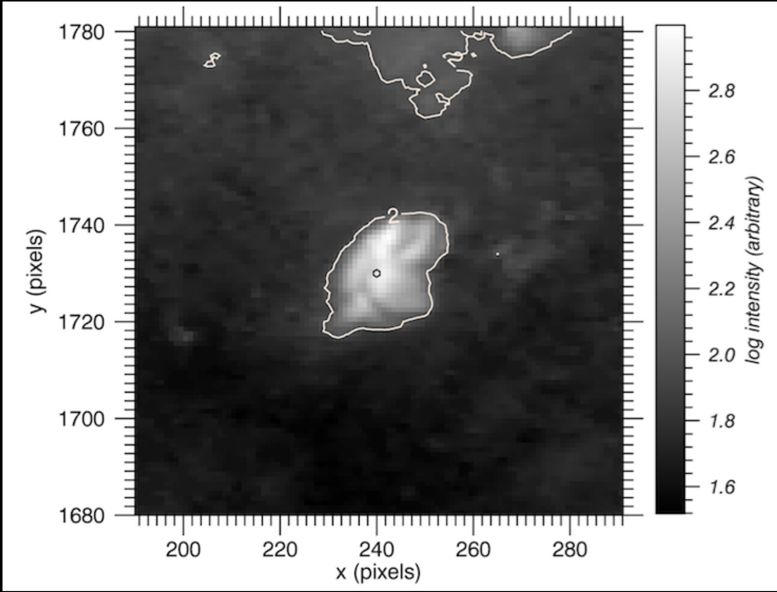
Research

AIA/SDO

Fe XII, XXIV
193 Å
July 2012
11–12 pm

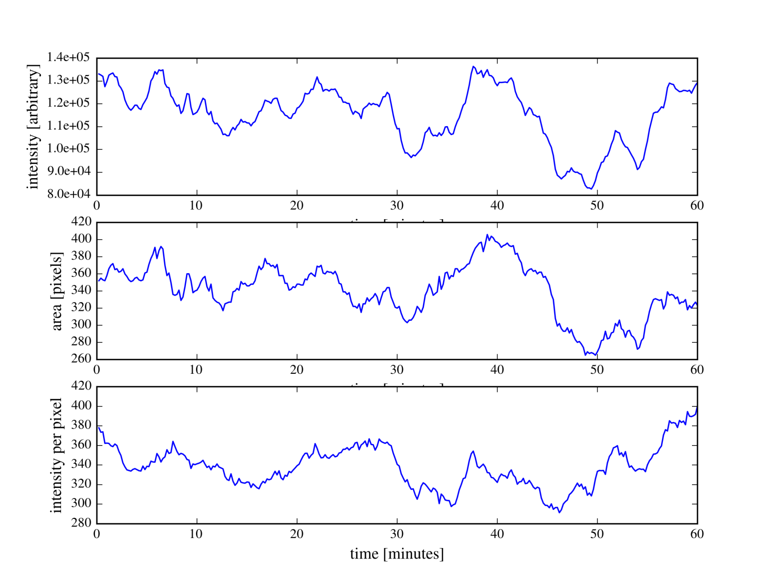


Research



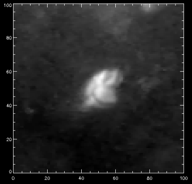
1780
1760
1740
1720
1700
1680
y (pixels)
200
220
240
260
280
x (pixels)
2
2.8
2.6
2.4
2.2
2.0
1.8
1.6
log intensity (arbitrary)

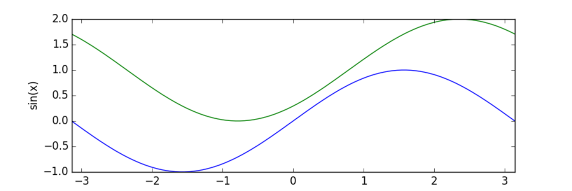
Research

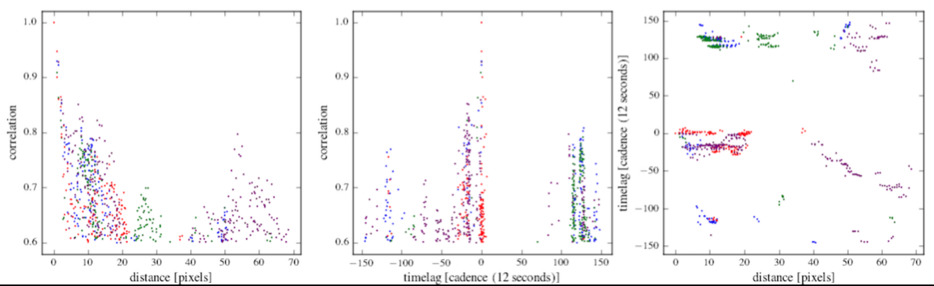

intensity [arbitrary]
1.4e+05
1.3e+05
1.2e+05
1.1e+05
1.0e+05
9.0e+04
8.0e+04
area [pixels]
intensity per pixel
420
400
380
360
340
320
300
280
260
0
10
20
30
40
50
60
time [minutes]

Research

Cross-correlations

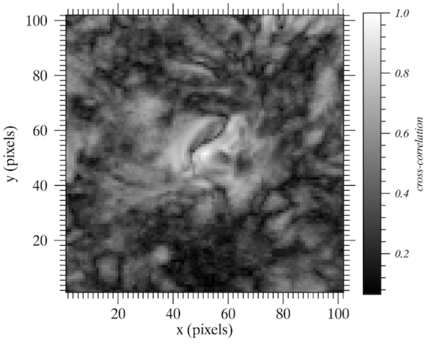




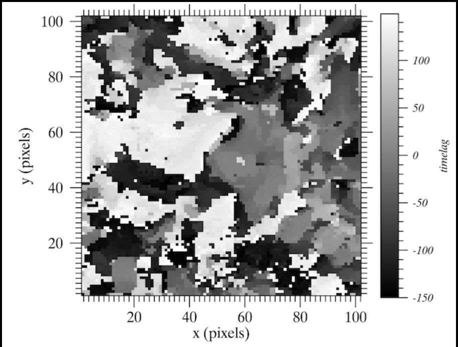


Research

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