Coronal Seismology

ASTR 598

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Motivation/Main Scientific Question

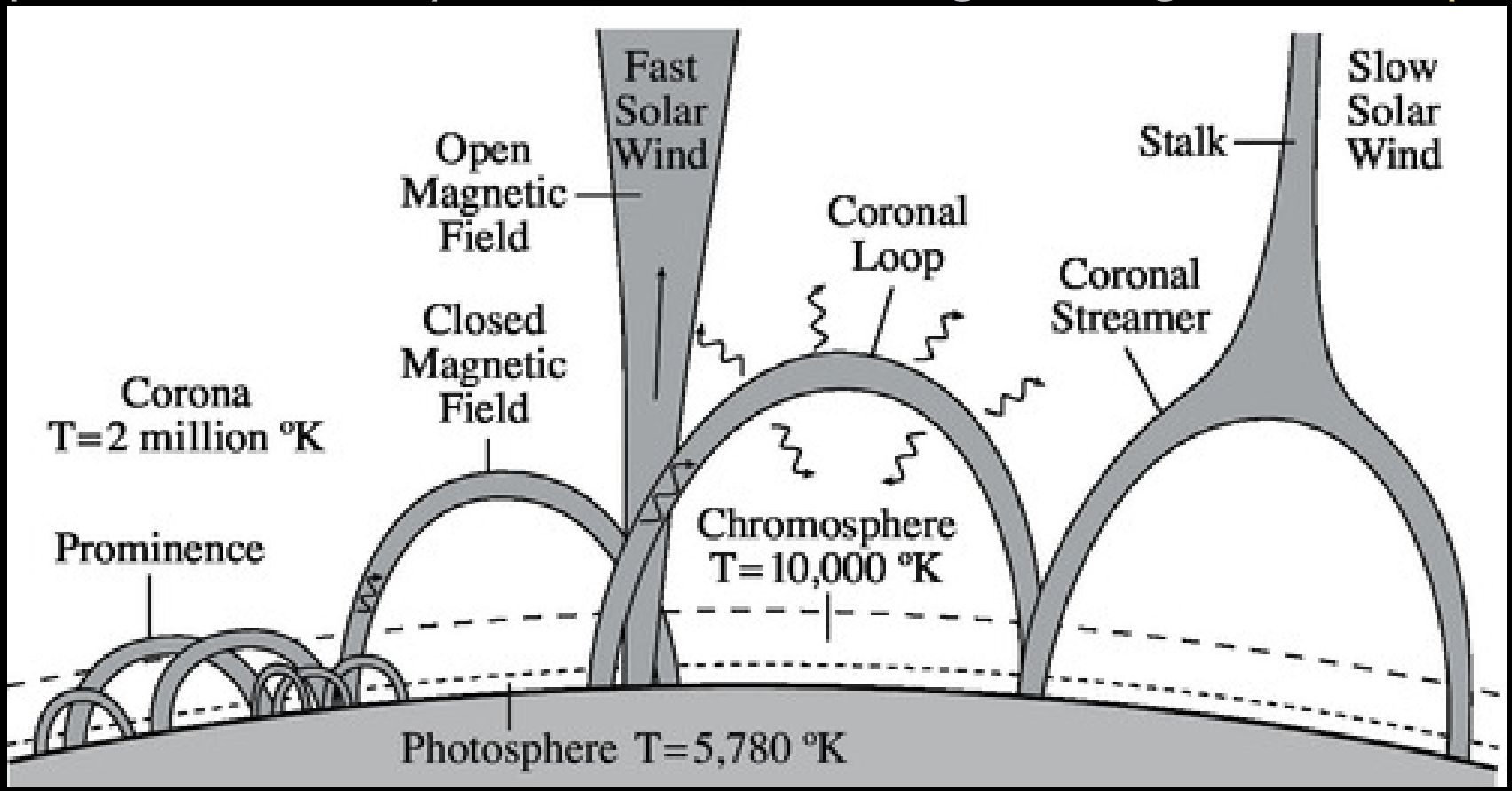
The coronal heating problem

- “Frozen-in” magnetic field creates structure in the solar atmosphere, such as loops and prominences.
- Can observe oscillations and waves in the corona to extract properties about the solar photosphere and atmosphere.

Coronal seismology

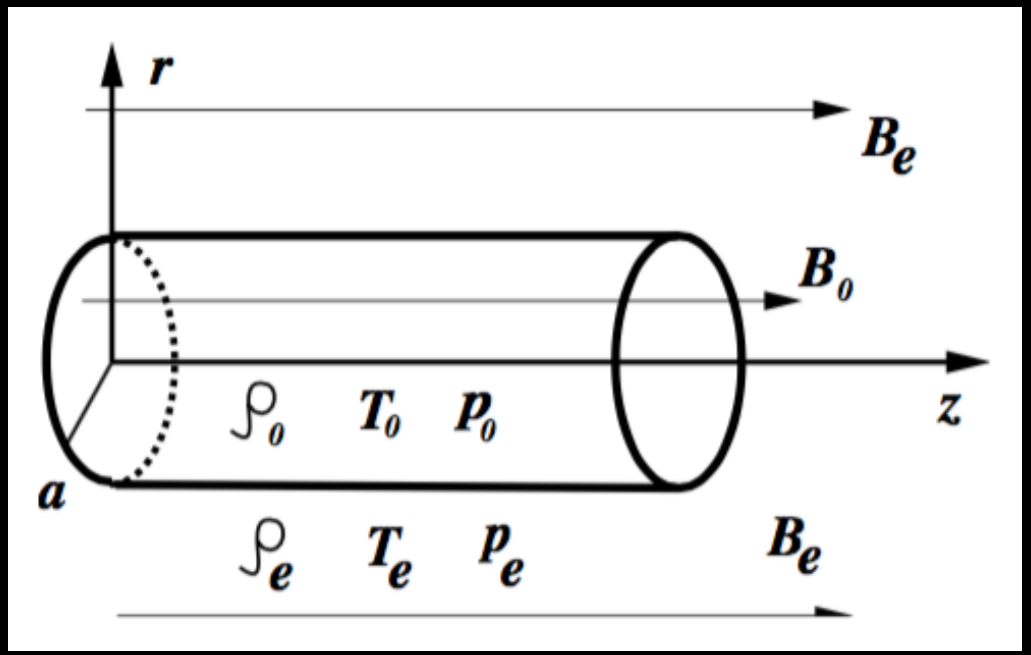
General idea

Based on how the phase speed is determined by local plasma parameters. Density structures act as waveguides, e.g. coronal loops.



Modeling

Theory before observations



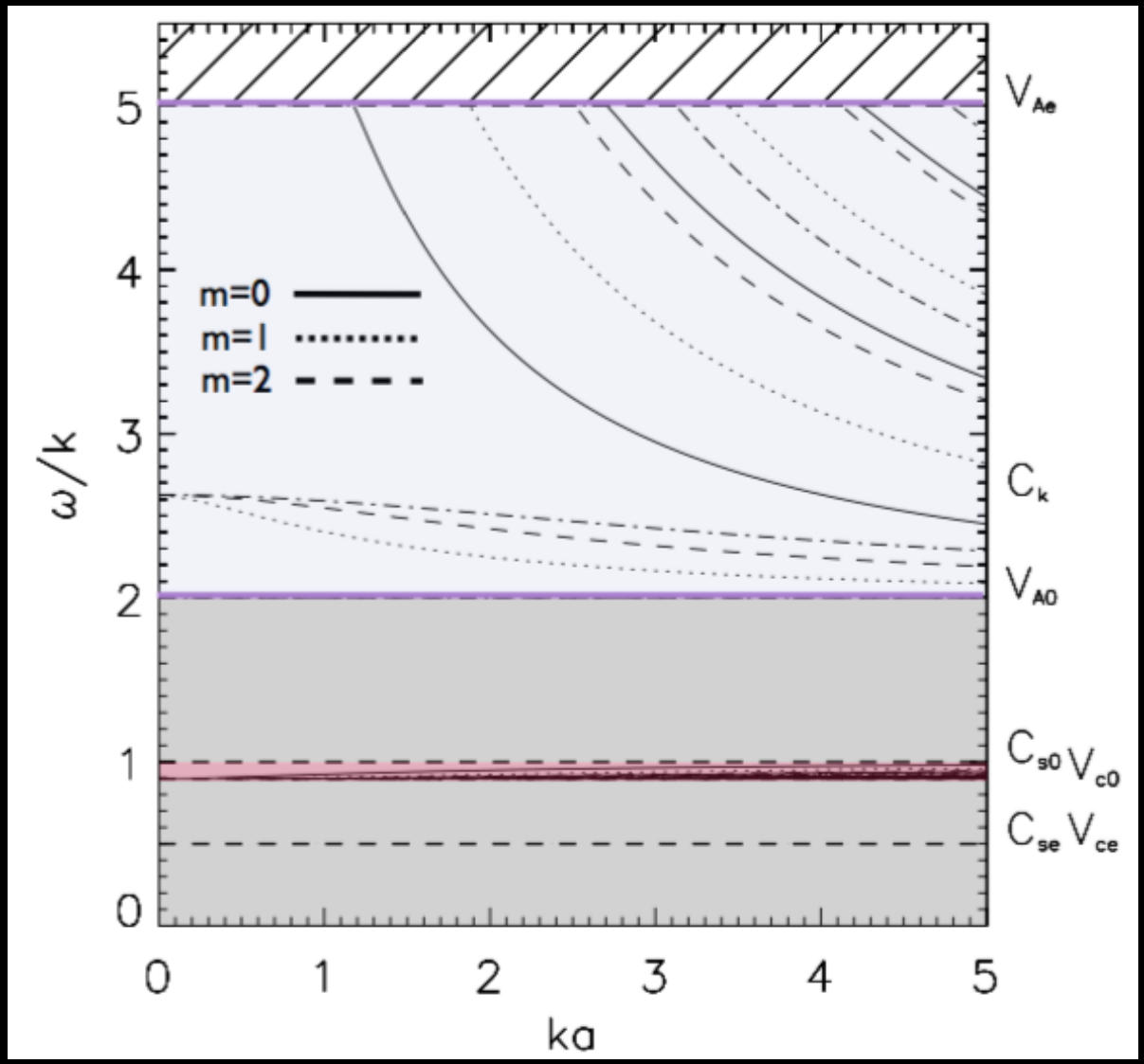
- Straight flux tube in uniform magnetic field.
- $\xi(x) = \xi(r)e^{i(kz+m\phi)}$

Basic MHD

Types of waves/oscillations:

- Alfvén: $V_A = \frac{B}{\mu_0 \rho}$
- Magnetoacoustic: $C_s = \sqrt{\frac{\gamma P}{\rho}}$
  - Fast $C_{A_0} < C_{fast} < C_{A_e}$
  - Slow $C_{T_0} < C_{slow} < C_{s_0}$

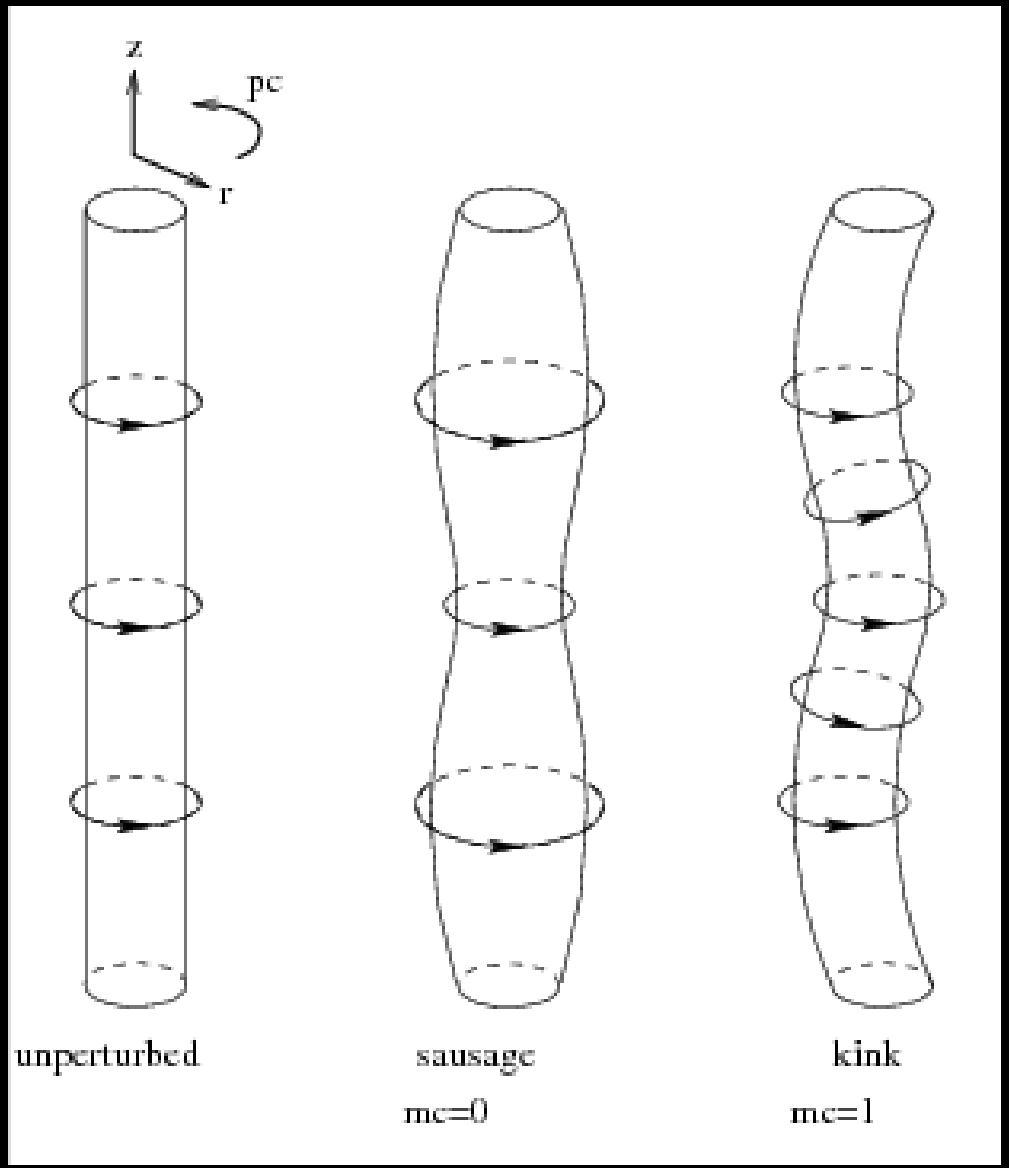
Dispersion diagram



MHD modes

- Kink
- Sausage
- Acoustic
- Propagating acoustic modes
- Propagating fast modes
- Torsional modes (aka. Alfvén waves)

Kinks vs. Sausages



Kink

- loop spatial displacement
- Asymmetric
- No intensity change
- $k\sigma \ll 1$, or $\sigma \ll \lambda$

Sausage

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

Kink modes

Coronal loop oscillations observed with the *Transition Region And Coronal Explorer (TRACE)*

- Gaussian vs. exponential
- Plasma motions around footpoints of coronal loops

Kink modes

Excitation and damping of broadband kink waves in the solar corona

Sausage modes

Observations of sausage modes in magnetic pores

Sausage modes

Sausage waves in transversely nonuniform monolithic coronal tubes

Acoustic oscillations

Propagating acoustic waves

Nodes are in motion; *traveling waves* (Oscillations have fixed nodes).

Propagating fast waves

- Moreton waves in the chromosphere
- Fast EUV waves in the corona

Torsional modes

aka. Alfvén wave

Mixed modes

Pulling individual modes out

Important Properties

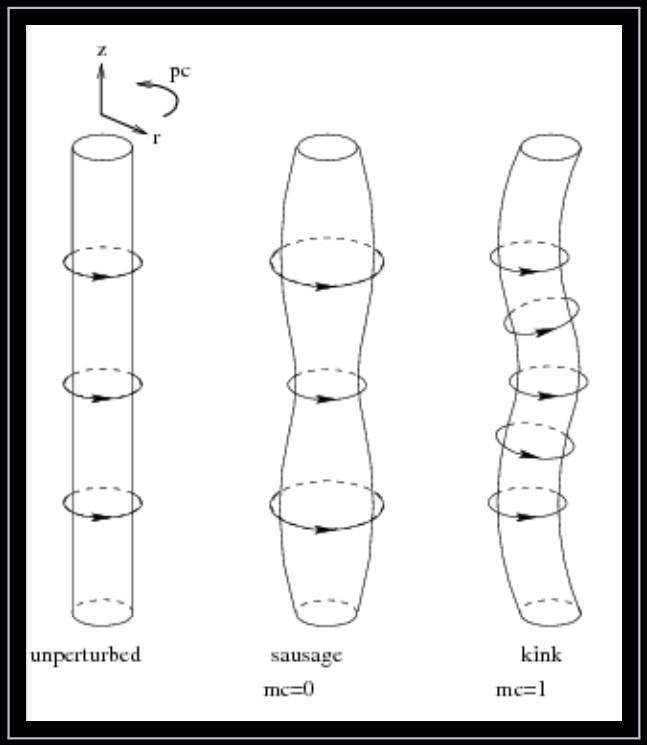
	timescale	**sizescale**	**obs. method**
kink osc	value	value	value
sausage osc	value	value	value
acoustic osc	value	value	value
acoustic waves	value	value	value
fast waves	value	value	value
torsional modes	value	value	value
mixed modes	value	value	value

Example Table

		Condition (Gold standard)	
		True	False
Test outcome	Positive	True Positive	False Positive
	Negative	False Negative	True Negative

Example of Two Column Output

Practical TEX 2005
Practical TEX 2005
Practical TEX 2005



My Research