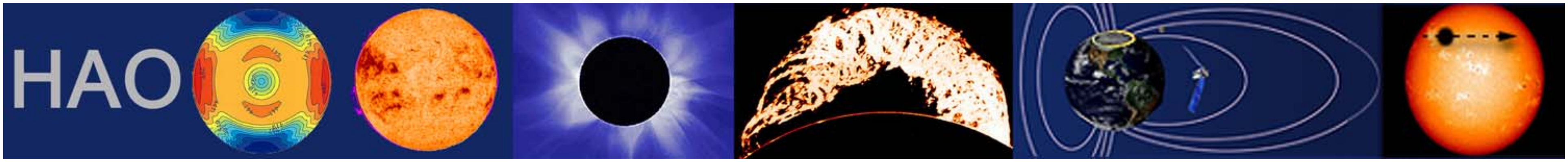


Alfvén Waves in the Corona

Steven Tomczyk (HAO/NCAR)

Collaborators

Instrumentation:

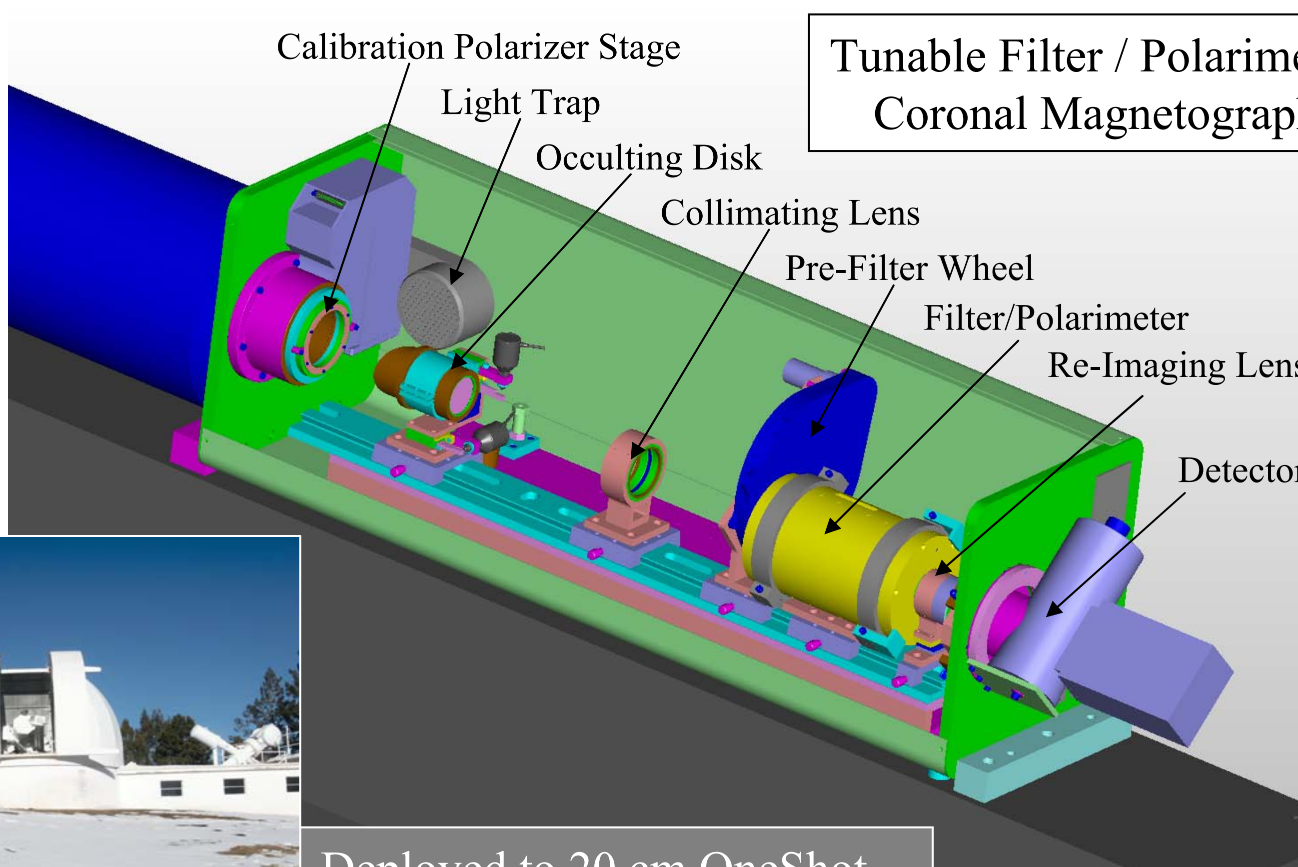
Greg Card, Tony Darnell, David Elmore, Ron Lull, Pete Nelson, Kim Streander (HAO), Jack Fox and EOL Shop

Waves:

Scott McIntosh (HAO), Steve Keil (NSO), Phil Judge (HAO), Tom Schad (U Arizona), Dan Seeley (Framingham High), Justin Edmondson (U Michigan), Leonard Sitongia (HAO)

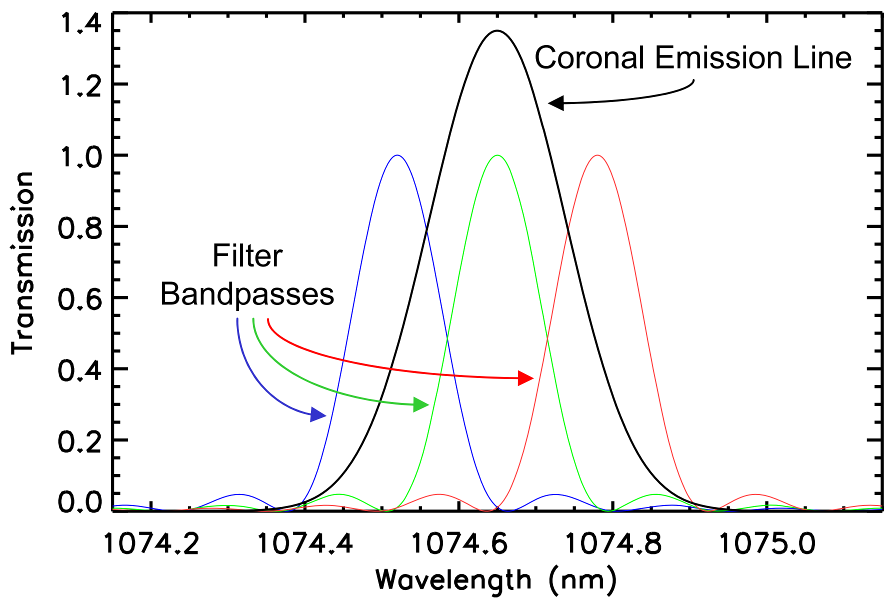
Coronal Multi-channel Polarimeter (CoMP)

Tunable Filter / Polarimeter
Coronal Magnetograph



Deployed to 20 cm OneShot
Coronagraph at NSO Sac Peak

CoMP Instrument



CoMP observes:

Stokes I, Q, U, V

FeXIII 1074.7 and 1079.8 nm, HeI 1083.0 nm

0.14 nm Tunable Bandpass

2.8 R_{sun} Full Field-of-View

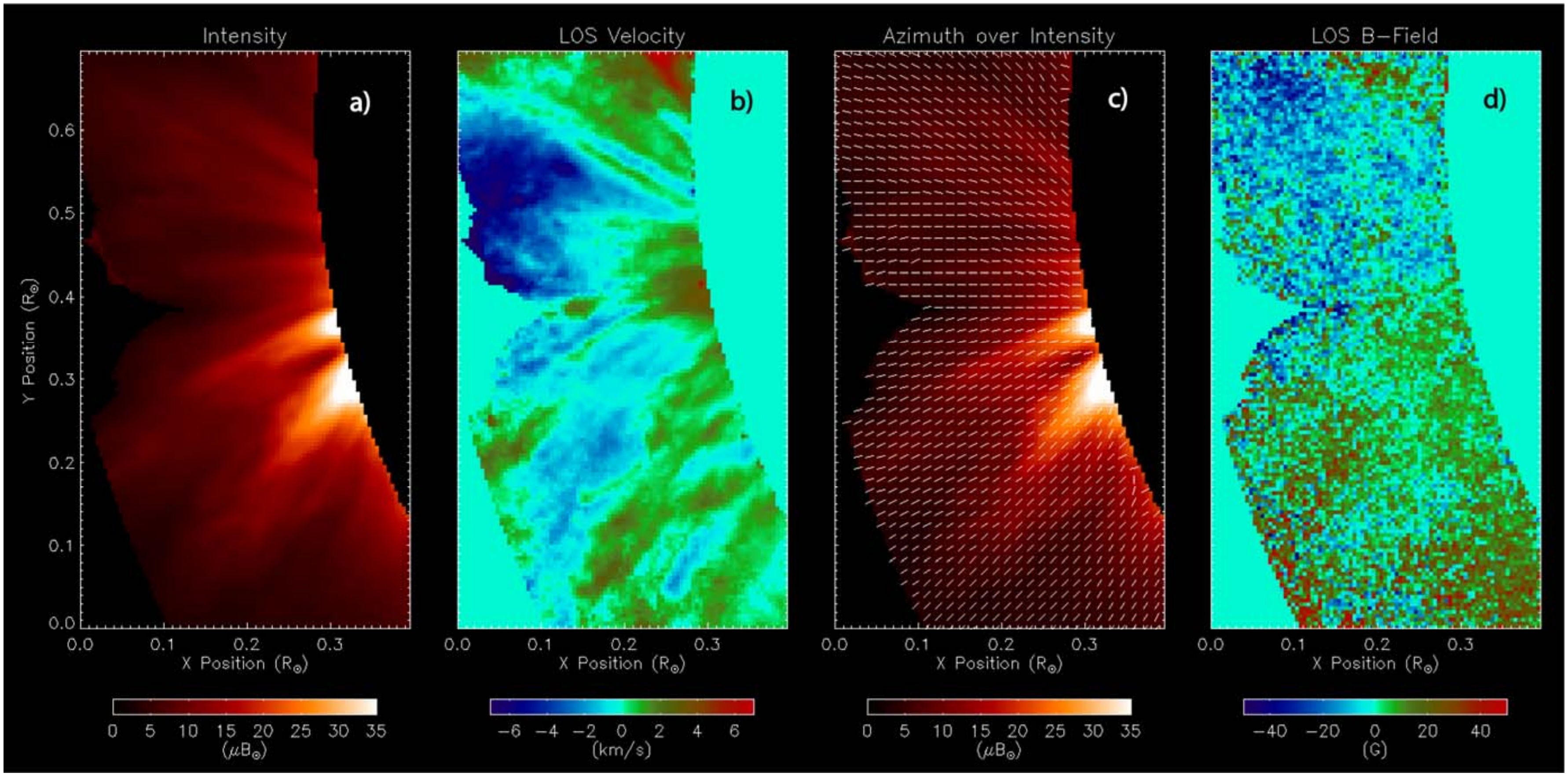
4.5 arcsec/pixel

Linear Polarization (Hanle) → POS Magnetic Field Direction (Not Strength)

Circular Polarization (Zeeman) → LOS Magnetic Field Strength

Doppler Shift → Velocity

CoMP Measurements



a) Intensity, b) LOS velocity, c) Field Azimuth, d) LOS Field Strength, obtained on Oct 31, 2005, 2.5 hour average

Coronal Seismology

Rapidly advancing field, refer to review papers:

Aschwanden, M.J., *NATO Sci. Series*, 2003.
Nakariakov, V.M. and Vervichte, E., *Liv. Rev. Solar Physics*, 2006.
Banerjee, D., et al., *Solar Physics*, 2007.

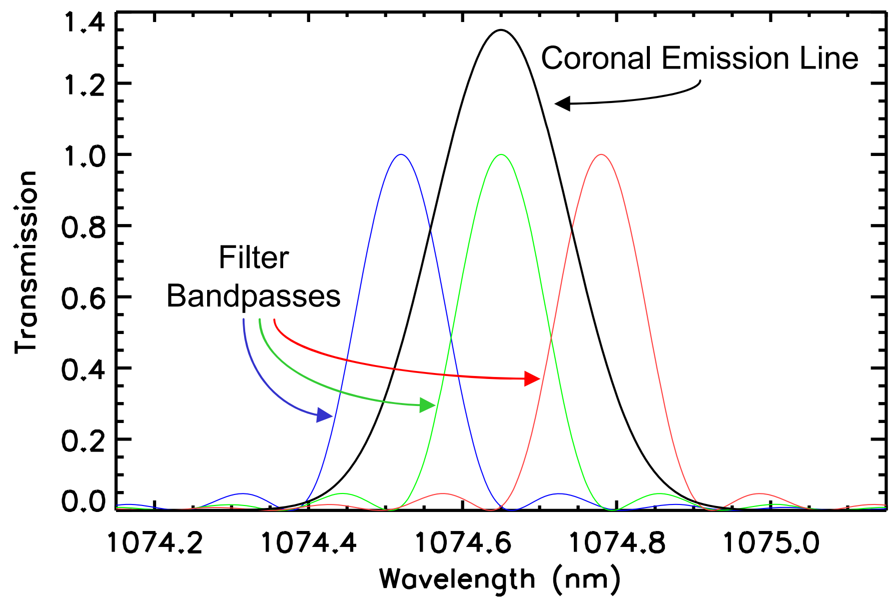
Observe MHD waves in the solar corona

Speed of wave propagation is a function of density and magnetic field

Observe waves traveling in the plane of the sky -
Can constrain transverse component of magnetic field

Wave Observations

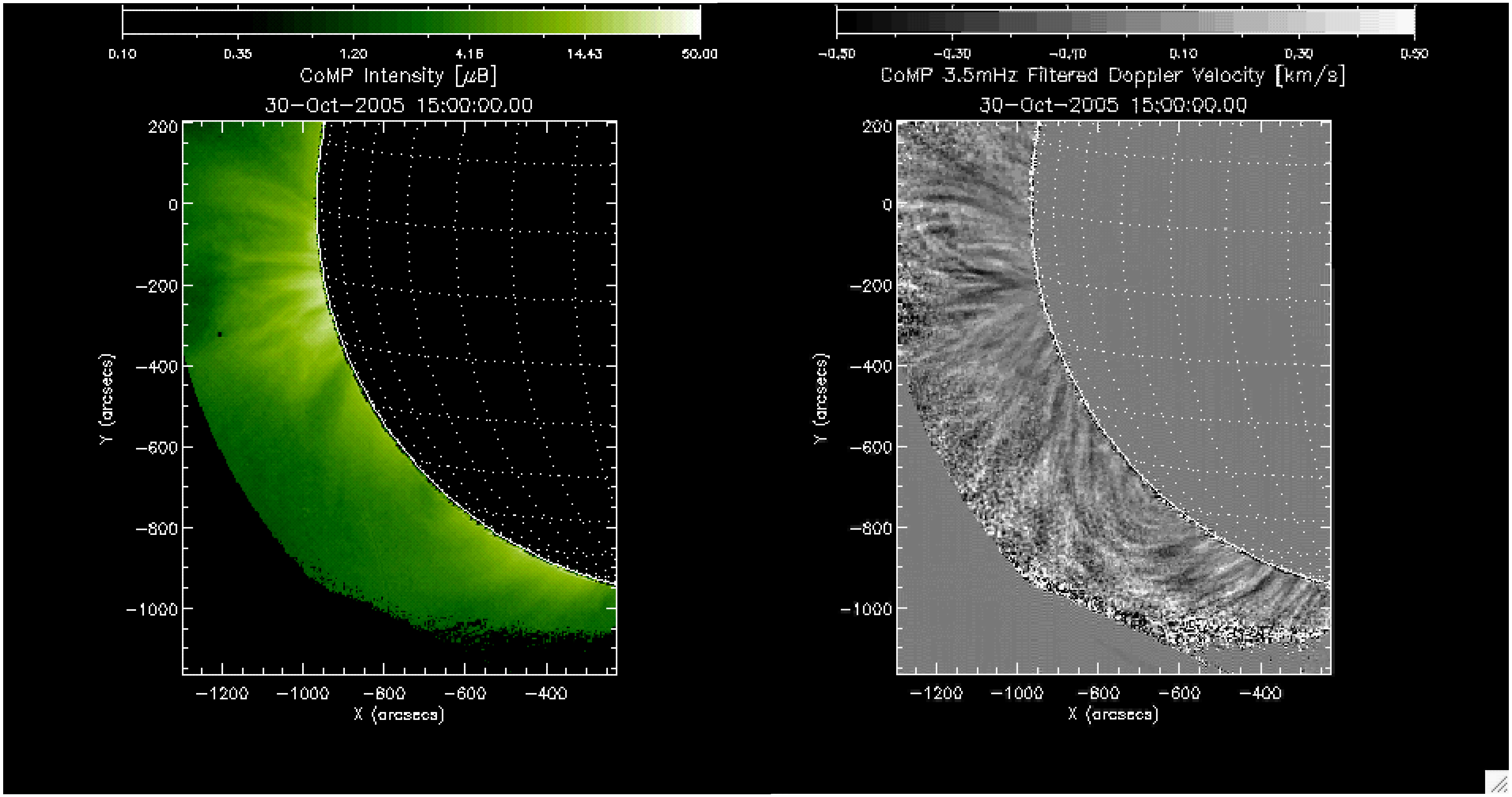
Stokes I, Q, U Measured in 3 Bandpasses around FeXIII 1074.7 nm
30 Oct 2005
28.7 s Cadence
3.22 Mm/pixel Sampling
8 hours Duration



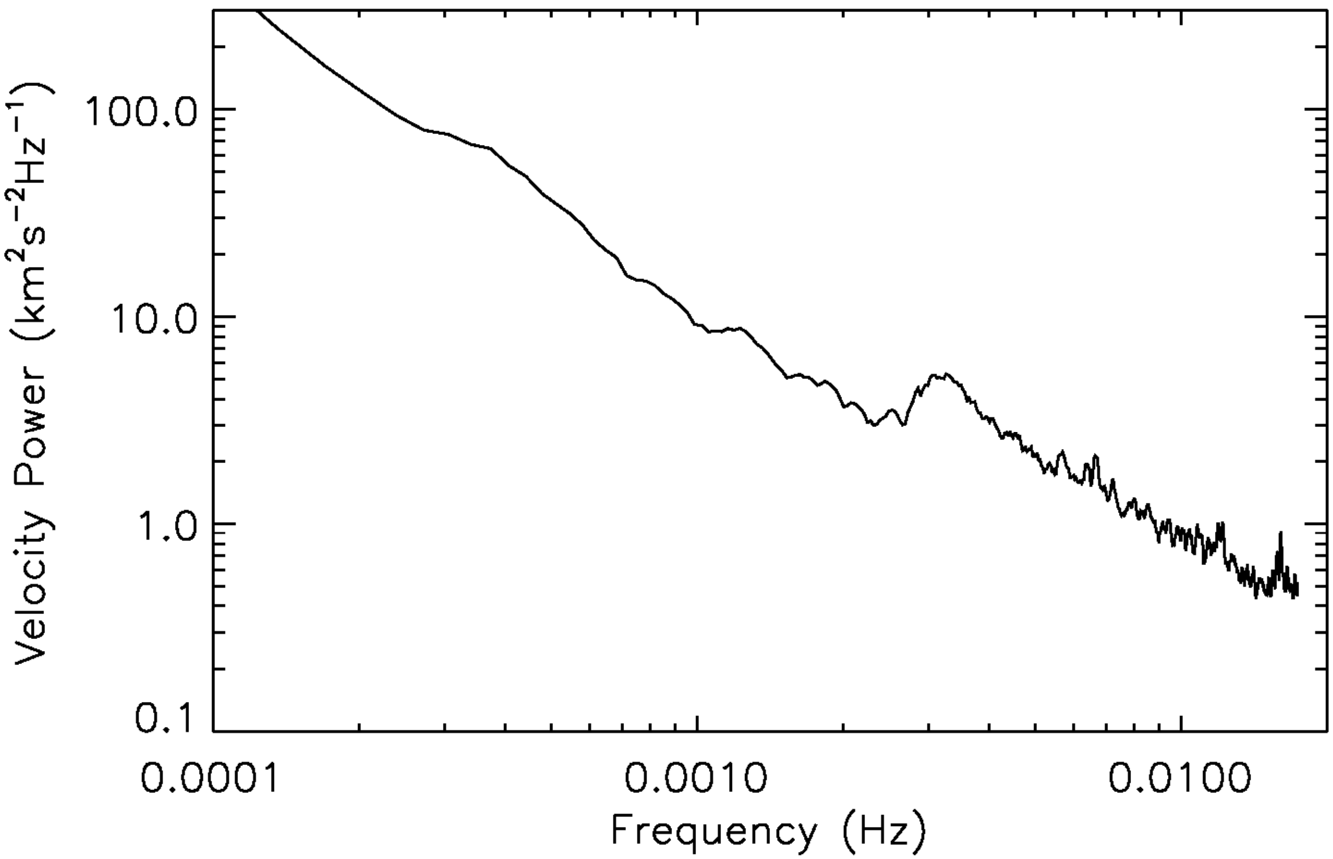
Can derive:

Central Intensity
Doppler Velocity
Line Width
Degree of Polarization, $p = \sqrt{(Q^2+U^2)}/I$
POS Azimuth of Magnetic Field, $\Phi = ½ \tan^{-1}(U/Q)$

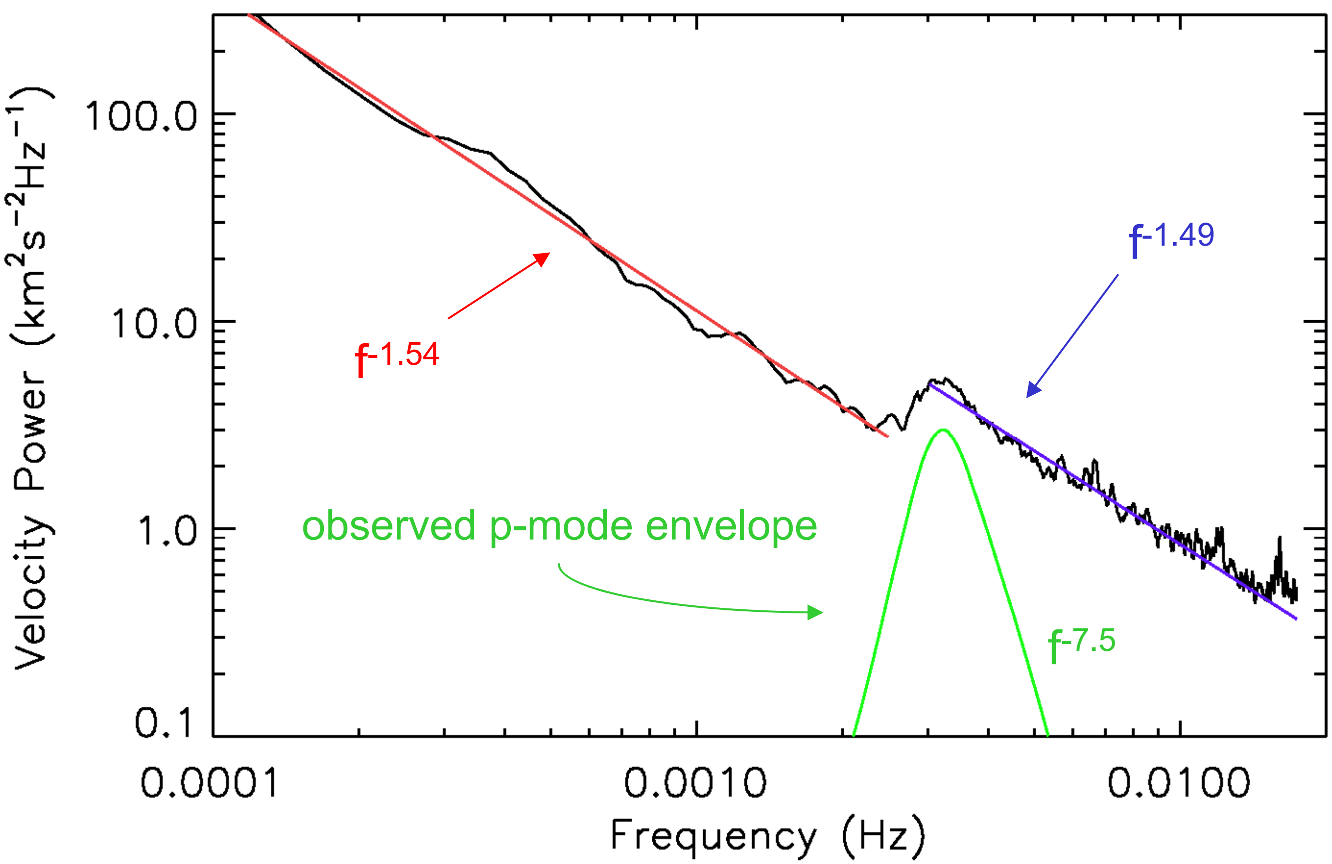
Intensity and Velocity Time Sequence



Velocity Power Spectrum



Velocity Power Spectrum

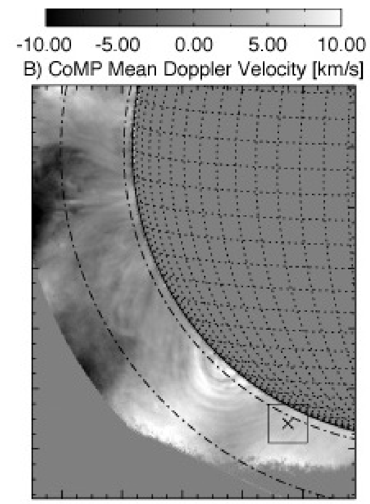


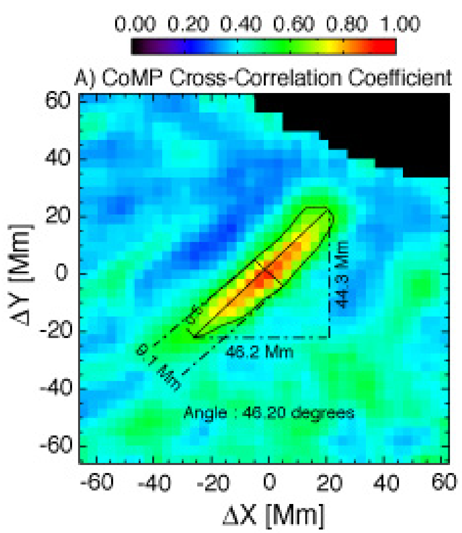
Wave Propagation Direction

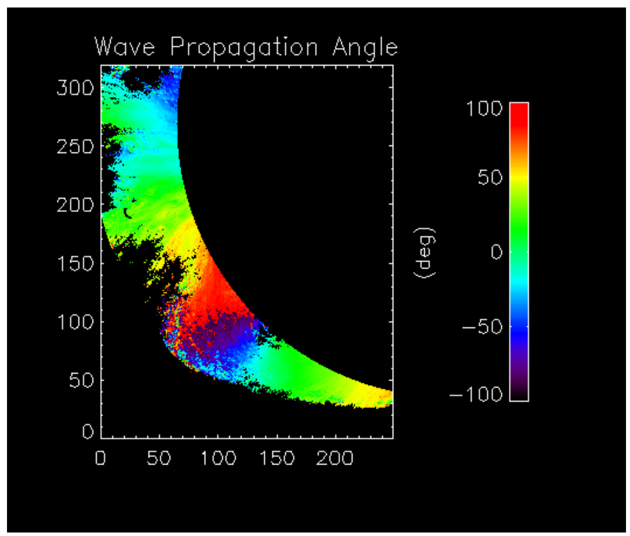
Adapted from photospheric/chromospheric travel time analysis (e.g. Jefferies, Finsterle, McIntosh)

Cross correlate reference pixel with surrounding pixels

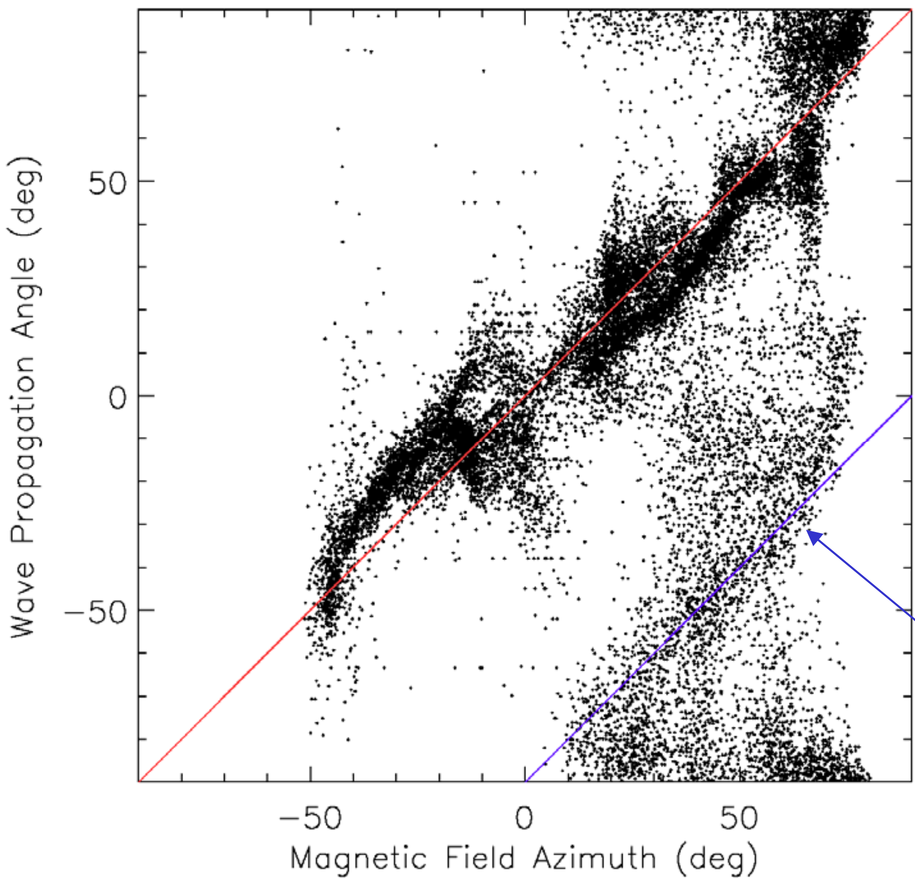
Measure direction of wave propagation

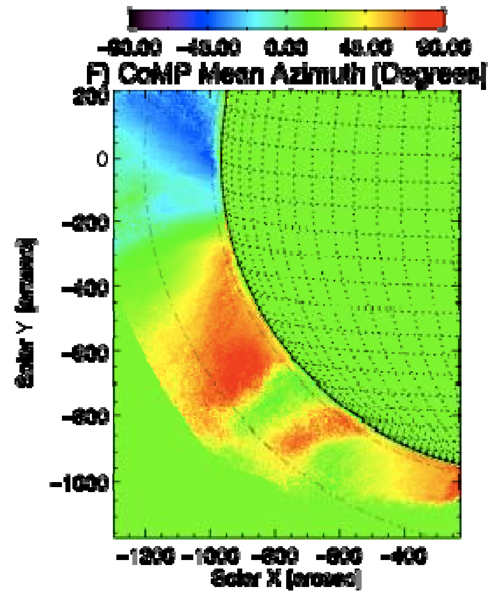






Wave Propagation Direction

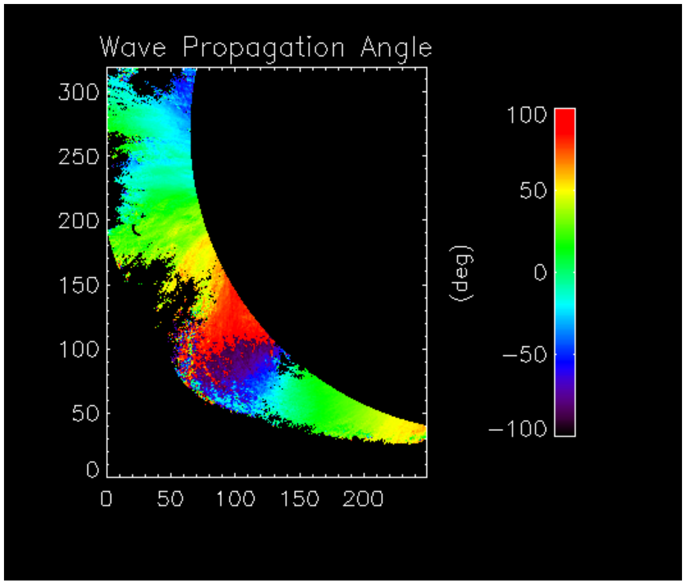


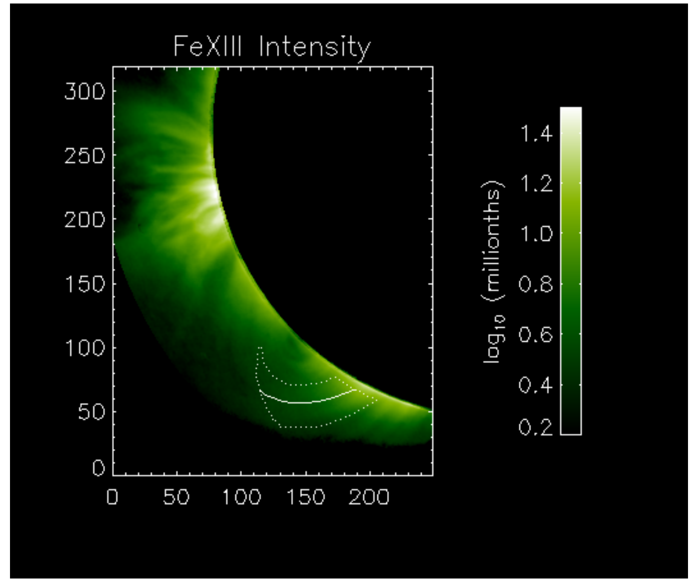


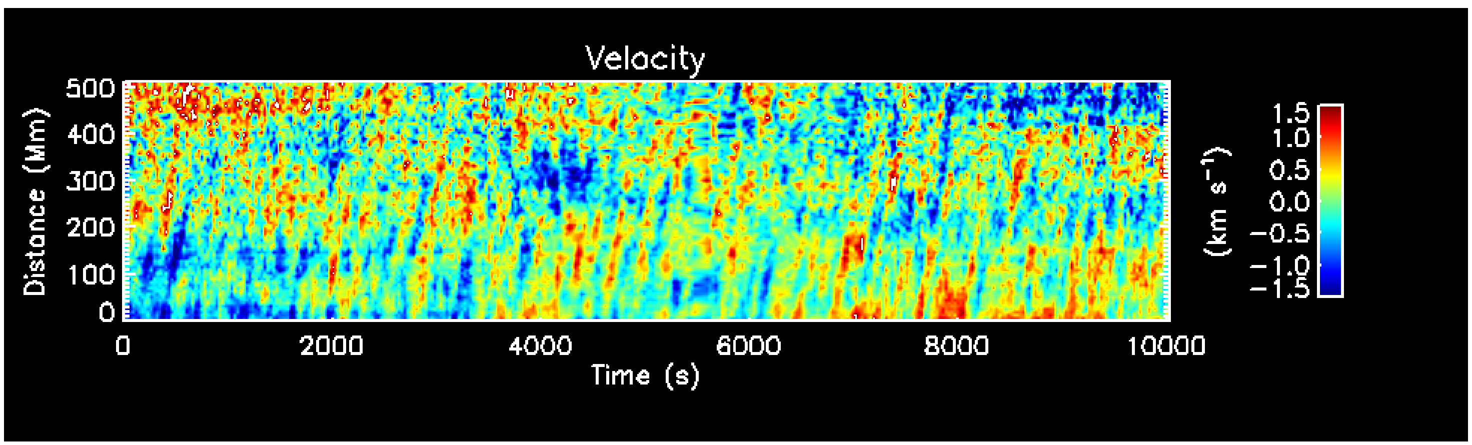
Van Vleck Effect

Wave Propagation is Aligned with Magnetic Field Azimuth

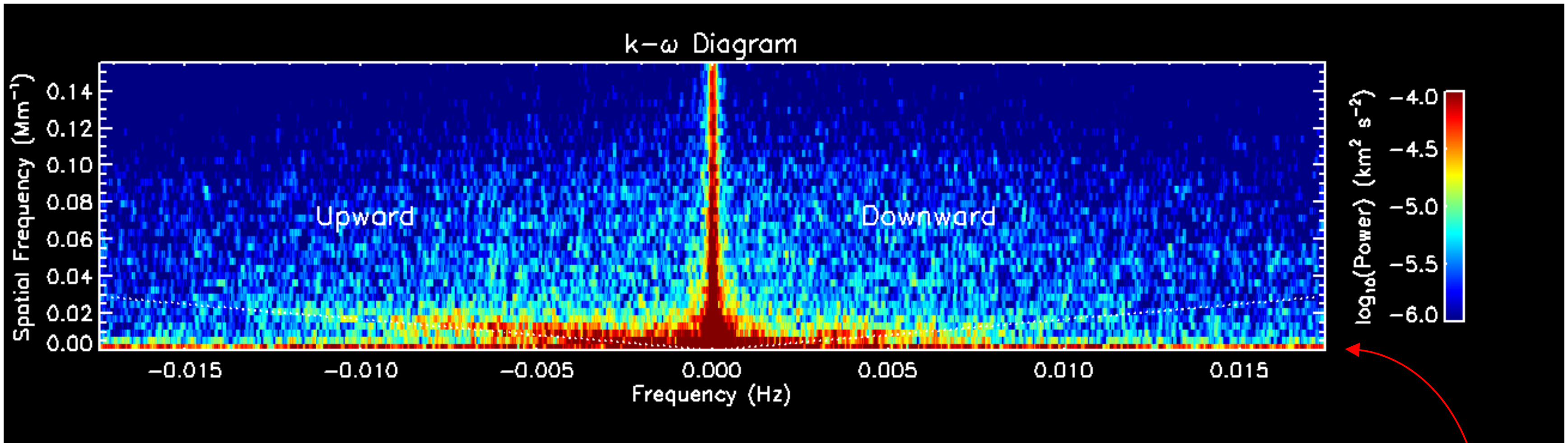
Time-Distance Seismology







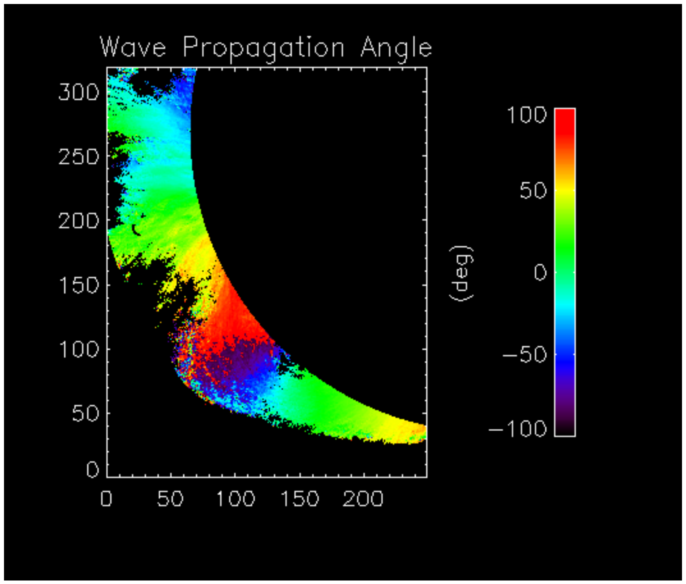
Coronal k-ω Diagram

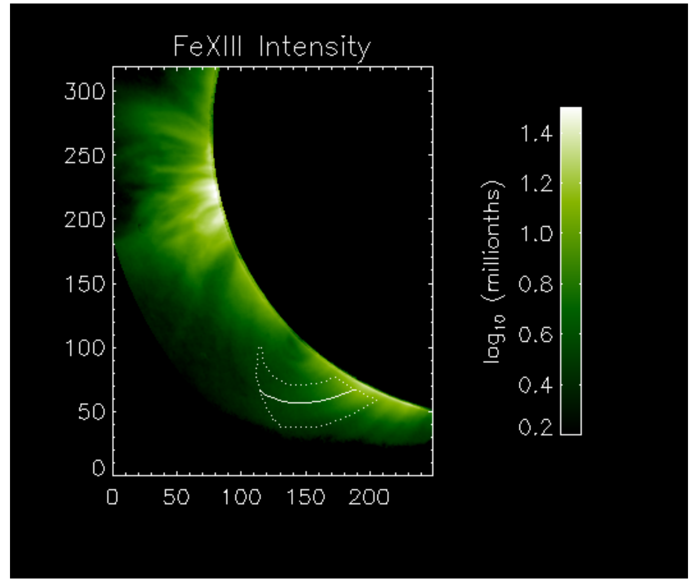


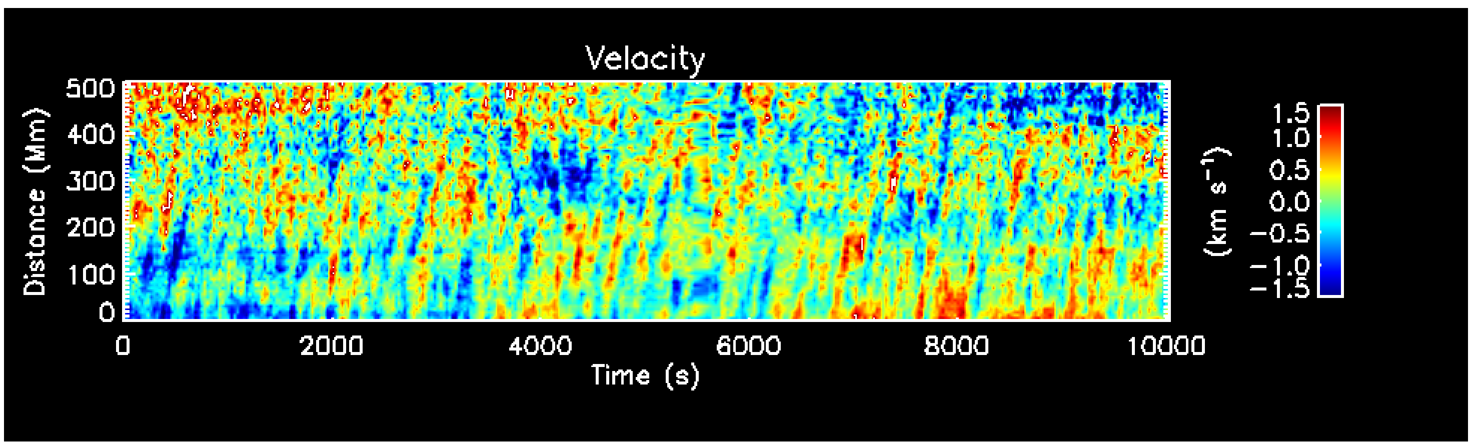
Low Spatial Frequency Noise

Low Temporal Frequency Noise

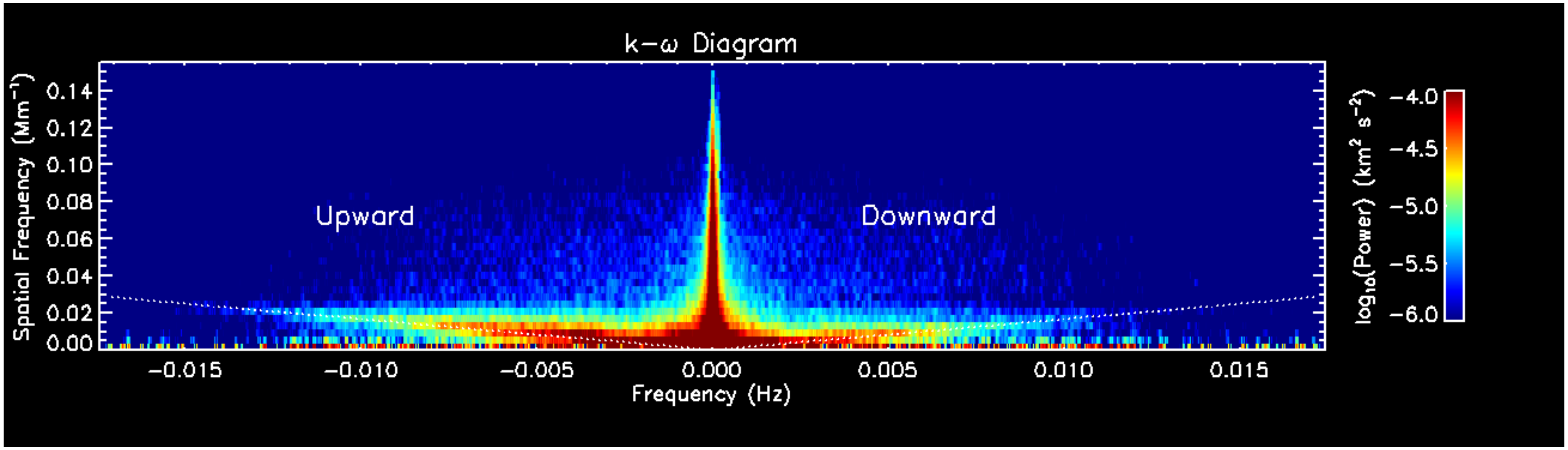
Time-Distance Seismology





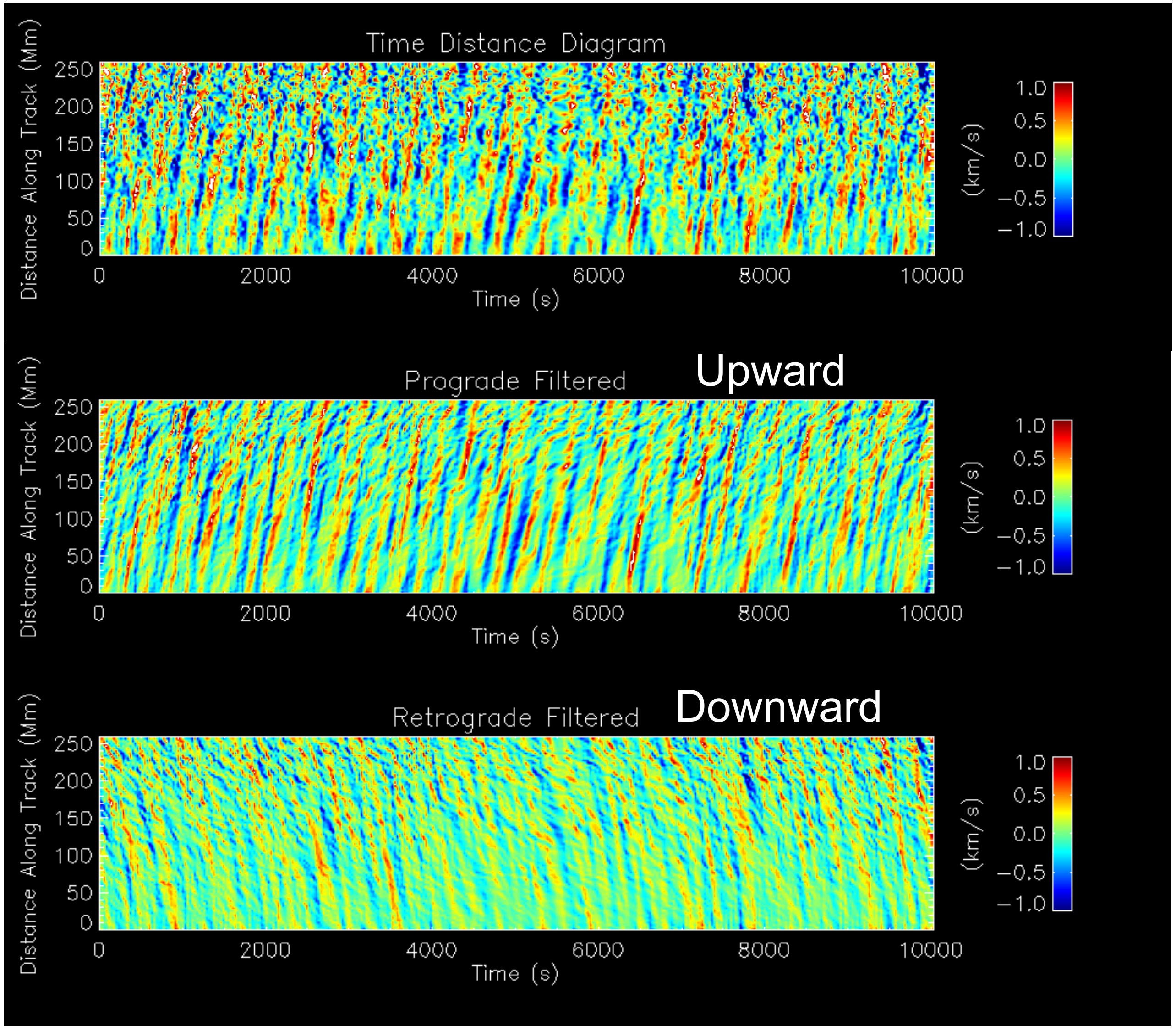


Coronal k-ω Diagram

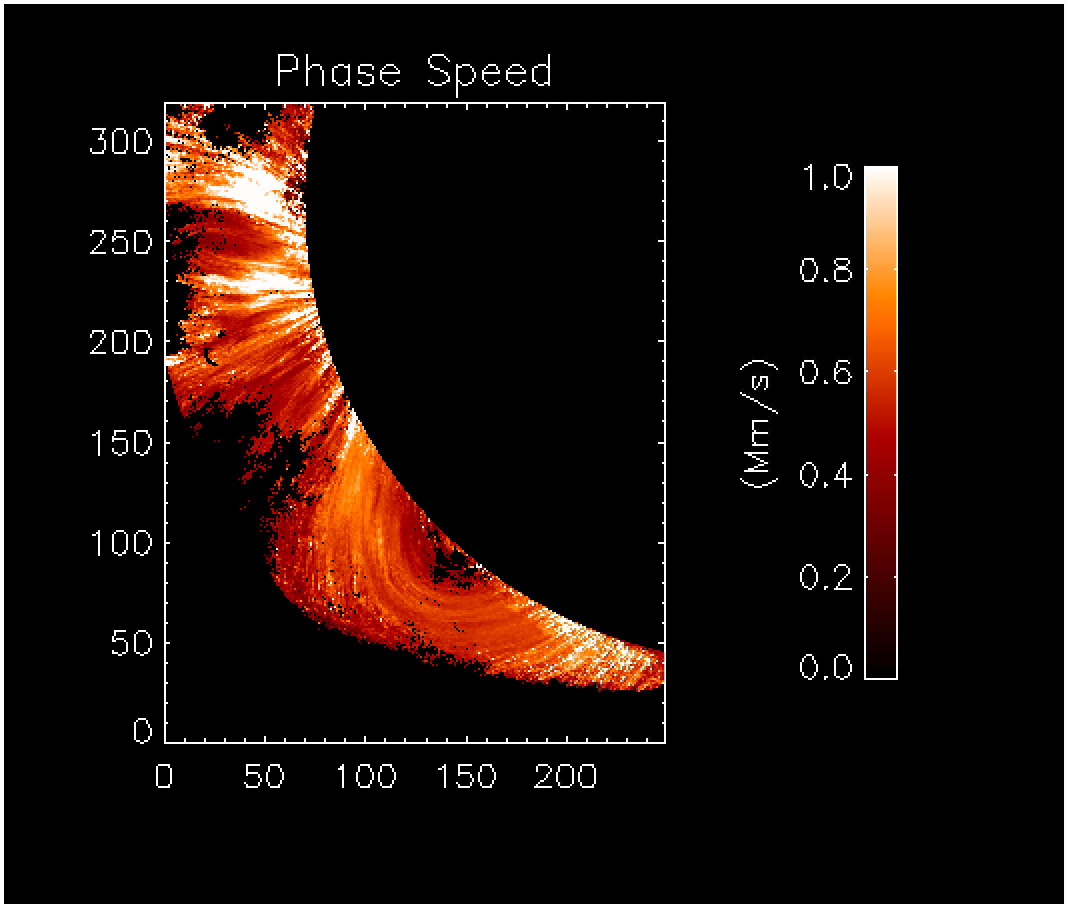


No Dispersion
Phase Speed = 650 km/s

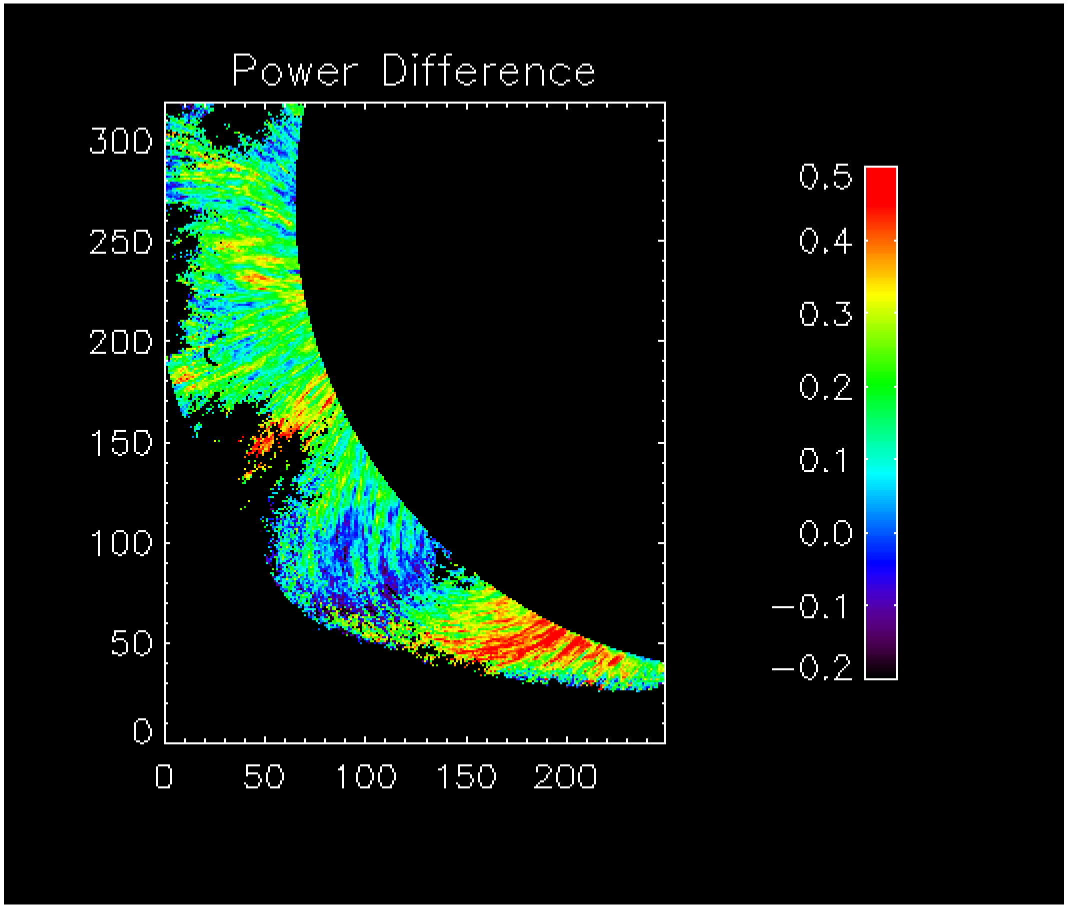
Results of Travel Time Analysis



Wave Phase Speed



Upward/Downward Power



$$\frac{P_{up} - P_{down}}{P_{up} + P_{down}}$$

Basic Wave Properties

Velocity

RMS Fluctuation	0.3 km/s
Peak Frequency	3.2 mHz
Trajectories	Follow field lines
Phase Speed	0.5-1 Mm/s
Wavelength	> 150Mm
Wavelength/Loop Radius	~1

Intensity

Fluctuation	< 0.003 (dI/I)

Wave Energy Content

The energy flux can be estimated by:

$$F_W = \rho \langle v^2 \rangle c_{ph}$$

where ρ is the density and c_{ph} is the wave phase speed. Assuming $\rho = 2 \times 10^{-16}$ g and using the measured values of v (~0.3 km/s) and c_{ph} gives a flux of the energy propagating in the observed waves of:

$$F_W \sim 0.01 \text{ Wm}^{-2}$$

Need ~100 Wm^{-2} to balance the radiative losses of the quiet solar corona

Conclusions

Doppler imaging with CoMP provides us with an unprecedented means to observe and characterize waves in the solar corona.

Need density measurement to perform coronal seismology. Ratio of FeXIII 1074.7 to 1079.8 nm, or other techniques?

The observed waves do not have enough energy to heat the corona.

Will deploy CoMP instrument to Haleakala early next year and obtain routine measurements.