Alfvén Waves in the Corona

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Collaborators

Instrumentation:
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Waves:
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Coronal Multi-channel Polarimeter (CoMP)

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 $R_{\text{sun}}$ Full Field-of-View
4.5 arcsec/pixel

Linear Polarization (Hanle) $\rightarrow$ POS Magnetic Field Direction (Not Strength)
Circular Polarization (Zeeman) $\rightarrow$ LOS Magnetic Field Strength
Doppler Shift $\rightarrow$ 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:

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, \( \Phi = \frac{1}{2} \tan^{-1}(U/Q) \)
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

Wave Propagation is Aligned with Magnetic Field Azimuth

Van Vleck Effect

Wave Propagation is Aligned with Magnetic Field Azimuth
Time-Distance Seismology

Wave Propagation Angle

FeXIII Intensity

Velocity

Steven Tomczyk
Hinode 2
30 September 2008
Coronal $k$-$\omega$ Diagram

- Low Spatial Frequency Noise
- Low Temporal Frequency Noise
Time-Distance Seismology

[Images of wave propagation angle and FeXIII intensity]

[Image of velocity over distance and time]
Coronal $k$-$\omega$ Diagram

$k$-$\omega$ Diagram

No Dispersion
Phase Speed = 650 km/s
Results of Travel Time Analysis
Wave Phase Speed
Upward/Downward Power

\[ \frac{P_{\text{up}} - P_{\text{down}}}{P_{\text{up}} + P_{\text{down}}} \]
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 \( \rho \) 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.