Spectroscopic Observations of Propagating Disturbances in Polar Coronal hole

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Background about propagating disturbances in polar region: Slow magneto-acoustic waves or High speed up-flows

Observations: sit and stare

Analysis: Time-distance map
Average line profile
R-B asymmetry analysis

Discussion and Summary
Propagating Disturbances: First Observation

Propagation speed ~ 75-150 km/s with periods of 10-15 min

DeForest & Gurman, (1998)
Because of four key points, the observed features were identified as compressive waves rather than outflowing features by DeForest & Gurman (1998):

- They move at constant speed throughout the FOV.
- They were repeated in quasi-periodic trains.
- They were present in every plume which had been studied.
- Spectroscopic measurements of similar plumes do not show Doppler shifts corresponding to bulk motions at observed speeds (Hassler et al. 1998)

And followed by,

Ofman et al. 1999, 2000
Banerjee et al. 2000, 2009
Nakariakov 2006
These perturbations have very similar properties to those observed in active regions (McIntosh & De Pontieu 2009a), coronal holes (De Pontieu et al. 2009; McIntosh, Leamon & De Pontieu 2010), and quiet Sun (McIntosh & De Pontieu 2009b).

In each case, these perturbations have been connected spectroscopically to a strong upflowing, weak emission component at the magnetic footpoints. The spectroscopically determined upflows appear to be rooted in dynamic “Type-II” spicules in the upper chromosphere (De Pontieu et al. 2009; McIntosh & De Pontieu 2009a).

Followed by Tian et al. (2011).
Slow (acoustic) mode (fundamental, j=1)
Thus, for a propagating slow wave, the emission from the plasma is enhanced during the upward (blueshift) propagating phase of the wave and is decreased during the downward (redshift) propagating phase of the wave (Verwichte et al. 2010).
• Single Gaussian fits were applied to obtain the line peak, Doppler-shift and width of each spectrum.

• To convert the Doppler-shifts into absolute Doppler velocities, we have set the average Doppler velocity in the off-limb part (between Y~990″ and 1050″) to zero in each frame (LOS motions are expected to average out above the limb in an optically thin plasma, Doschek et al. (1976).

• The Doppler velocity calibrated in this way gives an average outflow speed of about 2.5 km s\(^{-1}\) in Ne VIII in the on-disk polar coronal hole.
Processed Y-T maps

Ne VIII 770 Å Intensity

Ne VIII 770 Å Velocity

Ne VIII 770 Å Line width

N IV 765 Å Line width

Solar-Y (arcsec)

Time (min)

200 250 300 350 400
Phase relationship between different line parameters at three different heights

NeVIII 770 Å

Solar-Y=−865°

km/s

Solar-Y=−890°

km/s

Solar-Y=−830°

km/s

Time (min)

Intensity

Velocity

Width

$C_{LV} = -0.64$

$C_{LV} = -0.30$

$C_{LV} = -0.48$

$C_{CW} = +0.31$

$C_{CW} = +0.24$

$C_{CW} = +0.63$

$C_{VW} = -0.10$

$C_{VW} = -0.20$

$C_{VW} = -0.51$
Average line profile analysis

N IV 765 Å

Ne VIII 770 Å
To further check for the presence of a second component, we calculated the R-B asymmetry at different velocities ($V_{RB}$) measured from the respective line centroid by using the formula (similar to De Pontieu et al. 2010),

$$R - B = \frac{I(V_{RB}) - I(-V_{RB})}{I(V_{RB}) + I(-V_{RB})}$$

The R-B asymmetry maps did not reveal propagating signatures in any of the velocity bins.
To test whether the obtained R-B asymmetry values are significant and of solar origin, we performed a similar analysis on simulated line profiles.

We generated a symmetric line profile (single Gaussian with constant background) but with spectral resolution ten times finer than the SUMER resolution.

Amplitude and FWHM are taken similar to those in our dataset. Finally, we added random noise to the signal in each data point.

From this high-resolution profile, we extracted several profiles with spectral sampling similar to SUMER by sampling every tenth data point with different starting points.

Finally, we performed a similar R-B analysis on these simulated line profiles.
The obtained R-B asymmetry profile shows Red-Blue wing asymmetries with amplitudes similar to those obtained from the observed profiles, although the modelled profile was completely symmetric, only sampled unsymmetrically.
Within the given signal-to-noise ratio and spectral sampling of our data, R-B asymmetry analysis can not detect any reliable secondary component.

This finding supports the result that the Ne VIII 770 Å line profiles associated with propagating disturbances are essentially symmetric in nature.

In our analysis we find the Doppler velocity amplitude of these disturbances to be relatively large at low latitudes, i.e., ±3 km s\(^{-1}\) (on top of the average plasma out-flow speed), which is much larger than that resulting from the simulations of De Pontieu et al. (2010) of about 1 km s\(^{-1}\).
Summary

• In summary, we found propagating disturbances in intensity, Doppler velocity and line width in the Ne VIII 770 Å spectral line in a polar coronal hole, with a projected propagation speed of 60 km s\(^{-1}\) and a period 14.5 min.

• We studied Ne VIII spectral line profiles averaged along the propagating ridges and found them to be symmetric, to be well fitted by a single Gaussian, and to have no noticeable Red-Blue asymmetry.

• We conclude that the most likely cause are slow magneto-acoustic waves. These waves may be caused by small-scale reconnections or explosive events occurring at lower heights in the solar atmosphere, as inferred from the N IV 765 Å spectral line profiles at the base of the propagating features.

Thank You for listening