EURObservations of Bi-Directional Jets in the Solar Corona

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ABSTRACT

Jet-like signatures in low-temperature extreme ultraviolet (EUV) emission lines have been found in the solar corona above the active region NOAA 7974 using the SUMER spectrometer on SOHO. The structure observed implies that the jet is coming from a small stationary site high in the corona. An additional feature of this jet is a small region of intense, low velocity Ne vii emission on its sunward side. The jet looks very similar to the bi-directional jets seen in disk spectra. These observations support models of magnetic reconnection above active regions. Recent observations taken in the diffuse corona indicate that coronal high velocity events are more frequent and seem to be similar to explosive events.

Key words: EUV spectroscopy; transient flows; corona

1. INTRODUCTION

The spatial and temporal evolution of bright points on the disk in X-rays and ultraviolet emission lines and their association with the magnetic field configurations has been and will continue to be a topic of extensive research. Bright points provide clues for a better understanding of magnetic reconnection which has often been invoked to explain both, large-scale events (e.g., solar flares and coronal mass ejections) and small-scale phenomena (e.g., coronal and chromospheric microlites). In this paper, we report high Doppler shifts associated with a small site of bright EUV emission high in the corona.

Explosive events were first seen in EUV spectra obtained with the NRL High-Resolution Telescope and Spectrograph (HRTS) flown on several rocket flights and on Spacelab 2 (Brueckner and Bartoe, 1983). Dere et al. (1991) observed that explosive events were associated with flux cancellation and hence proposed that all explosive events result from magnetic reconnection. The structure of these flows has recently been resolved using the SUMER spectrometer, interpreting the evolution of the Si iv 1393 Å line profiles. Innes et al. (1997a) have shown that explosive events have the bi-directional nature of the jets predicted by Petschek (1964).

SUMER – Solar Ultraviolet Measurements of Emitted Radiation – is a stigmatic, high resolution normal-incidence spectrograph operating in the range from 465 to 1610 Å onboard the SOHO spacecraft. A detailed description of the instrument is given elsewhere (Wilhelm et al. 1995). With a spatial resolution close to 1 arcsec (715 km on the Sun), spectral pixels of 40 mÅ (with subpixel resolution) and a time resolution down to 250 milliseconds, it is well suited for the observation of small-scale high-velocity events. Here, we present off-limb EUV observations of dynamic events taken by SUMER on June 20, 1996 and on May 8, 1997. These may be similar to the high velocity coronal events seen by Kjeldseth-Moe and Cheng (1990). Our observations suggest that they have a bi-directional flow structure.

2. ACTIVE REGION CORONAL EVENT

These data were taken above the active region NOAA 7974 which was positioned right on the East equatorial limb at that time. The slit was stepped in increments of 4 arcsec starting at 40 arcsec off the limb and 36 spectra were taken altogether with an expo-

![Raster direction](image)

Figure 1. The SUMER raster superimposed on the He II 304 Å EIT image showing the active region NOAA 7974 on the limb and its neighbour NOAA 7973. (EIT image by courtesy of the EIT consortium)

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Figure 2. Images of the total line intensities in $\text{N} \text{ III} \ 992 \ \text{Å}$ and $\text{Ne VI} \ 999 \ \text{Å}, \ 1005 \ \text{Å}$ extracted from the $300 \times 140$-arcsec$^2$ section observed with SUMER.

Figure 3. $\text{N} \text{ III}$ lines observed at raster positions 16, 17, and 18 at 72.1, 74.8, and 77.5 Mm, respectively, above the limb showing the signature of a violent dynamic event with Doppler velocities from -170 km/s to 100 km/s. Note, that the emissions outside the event purely stem from scattered light of the $\text{N} \text{ III}$ lines from the solar disk indicating wavelengths at rest.
sure time increasing exponentially from 250 s to 867 s. The observation started on June 20, 1996 at 20:11 UT. A HeII 304 Å EIT image of June 20, 1996 at 19:39 UT illustrates the scenario (see Figure 1).

The telemetered spectral band extends from 980 to 1020 Å and includes the forbidden lines of Ne vi and some cold lines, mainly N iii with their respective temperatures of formation at 400 000 K and 80 000 K. The raw data have been decompressed, flat-field corrected and also corrected for the detector geometrical distortion. Finally, scattered light from the disk has been subtracted (except in Figure 3).

The total line intensities of three lines, namely Ne vi 999 Å, Ne vi 1005 Å, and N iii 992 Å across the area rastered are displayed in Figure 2. As expected, there are loop structures extending from the active region out into the corona. The feature of interest here is the small region of bright N iii emission that can be seen at 75 Mm above the limb and seems to be disconnected from the loop structure below. A closer look into the spectra reveals that this feature is seen in three consecutive exposures (Figure 3). The N iii profiles show a line-of-sight blue shift of up to ~170 km/s in spectrum 16, a strong brightening at zero-velocity at spectrum 17 and a red shift of up to 100 km/s in spectrum 18. This event was seen for 39 minutes.

The N iii intensity outside the event stems completely from scattered light. This has been subtracted and the red shifted spectrum has been superimposed onto the blue shifted spectrum to illustrate the evolution (see Figure 4).

The event extends 15 Mm along the slit, the northern part being red shifted and the southern part being blue shifted. We see also a brightening in Ne vi at and sunward of the event which is presumably related to the event.

We interpret the observation as a bi-directional high-velocity flow of cold, high emissivity plasma. The Ne vi brightening may be interpreted as the termination shock and stagnation point. By triangulation we determine an inclination angle (north-south) of 65-70° and a projection angle (out of plane) of 60-80°. The observational geometry is illustrated in Figure 5. A detailed analysis of this dynamic event will be published elsewhere (Innes et al. 1997b).

3. QUIET SUN CORONAL EVENT

More observations were taken in order to investigate the phenomenon and to collect statistical information about dynamic events in the corona. Only a first survey was possible, but several other events could be observed. One example is presented here. These data were taken on May 8, 1997 at 04:35 UT in the diffuse corona outside the North-West quadrant. Two spectra including the C ii doublet at 1335 Å were taken at the same position (45° latitude) with a temporal separation of 300 s.

Again, we see complex small-scale high-velocity features in Figure 6, with line-of-sight Doppler-shifts of approximately ±50 km/s. The cross-like feature may
be interpreted as two pairs of the plasma flow. We can see that in the 300 s between images there has been considerable evolution. The radial motion is approximately \( \pm 10 \) km/s. This observation demonstrates that coronal high velocity events are not necessarily linked to active regions.

4. SUMMARY

We see small regions of cold plasma high up in the corona. This kind of plasma cannot possibly be explained by any standard temperature gradient model. The EUV emission sites are of small scale indicating that the plasma is filamented, and possibly below the spatial resolution of the instrument.

Dynamical events are evidently more readily seen in cold rather than in hot plasma. This may suggest that magnetic fields confine the cold plasma.

This phenomenon is similar to explosive events observed on the disk and the observations presented here support models assuming jets being the source of dynamic events (e.g., Innes et al. 1997a). In this scenario, it is assumed that anti-parallel magnetic fields reconnect at the event site ejecting a bi-directional plasma jet.

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