EIS/XRT study of hot jets in coronal holes - Does the plasma escape?

D. Baker[1], L. van Driel-Gesztelyi[1,2,3], L. Culhane[1], S. Kamio[4], L. Harra[1], J. Sun[1], P. Young[7], G. Doschek[5], D. Brooks[5], L. Lundquist[6], V. Hansteen[8]

1) Mullard Space Science Laboratory, UCL, Holmbury St. Mary, Dorking Surrey, RH5 6NT 2) Observatoire de Paris, LESIA 3) Konkoly Observatory, Hungary 4)NAOJ, Japan 5) NRL, USA 6) SAO, USA 7) STFC, RAL, UK 8) U. of Oslo, Norway

Abstract

It is generally accepted that X-ray jets in coronal holes (CHs) are caused by magnetic reconnection between emerging flux and ambient open magnetic field lines. In this work, we use data from Hinode EIS and XRT Instruments to present a multi-wavelength study of a number of such X-ray jets and their associated bright points observed in polar and equatorial CHs. Light curves in up to 22 different emission lines were compared to those of Hinode/XRT. The jets show post-jet increases in their EUV and X-ray light curves. These post-jet enhancements look systematically cooler than the jets. We suggest that this feature arises because the hot plasma of the jets, having failed to reach escape speeds, cools and falls back along the near vertical jet paths expected to be created by interchange reconnection with open field lines of CHs. Spectra obtained with EIS are analyzed to derive velocities of the jets in an equatorial CH in order to further test our hypothesis on the cause of the post-jet enhancements.

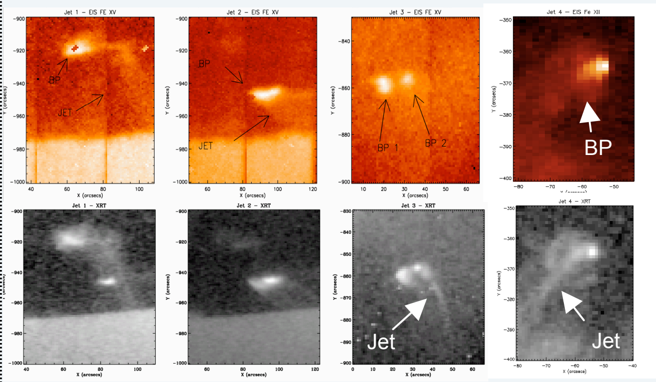

Figure 1 - EIS and XRT images of coronal bright points and associated jets. Jets 1, 2, and 3 were observed on 20 Jan 2007 in southern polar CH. Jet 4 was observed on 19 June 2007 in an equatorial CH. Arrows indicate bright points and jets in each image.

Observations

Coronal bright points and associated plasma jets were observed in both a southern polar coronal hole (CH) and an equatorial CH using Hinode's EUV imaging spectrometer. In the polar campaign, the 40 arc sec slot was used to provide spectral images (in 11 lines) for 3 jet events (see Jets 1 - 3 in Figure 1). EIS's 2 arc sec slit was used to provide spectral images from 22 lines and jet velocities found in the equatorial coronal hole (Jet 4). Corresponding XRT images were obtained for all jets. Light curves for each of the ions in the slot and slit images and XRT soft X-ray images were constructed by fitting a contour around each jet or bright point. Flux was summed and pre-event averaged background was subtracted within the contour region for each EIS line image and XRT image over the life time of the jet.

Discussion

Jet EIS light curves show a post-jet enhancement in a number of cooler coronal lines after a period of approximately 30 to 45 min. This increase in intensity is seen in lines of lower temperature ions such as Fe XI (1.3 MK), Fe XII (1.3 MK), and Fe XIII (1.6 MK) vs hotter lines of Fe XV (2 MK) and Fe XIV (2 MK) seen in jets 1 and 2. In the case of jet 4, O VI (0.3 MK) is seen in the post-jet enhancement vs Fe XI (1.3 MK) in the jet itself. In the equatorial CH, the jet plasma moves approximately along the line of sight and hence, is more likely to remain within the contour. Here, the cooling is expected to be continuous and relatively smooth from the time when the jet is at its hottest i.e. at maximum jet impulse. Figure 3 shows selected ion ratios for jet 4 illustrating this steady cooling of the jet plasma.

A plausible explanation for this distinctive feature of post-jet enhancement in cooler lines may be that the hot plasma originally propelled upward in the jet has velocity significantly below escape velocity. Having failed to reach solar escape velocity, the cooled plasma falls back and re-enters the contour which leads to a secondary increase in intensity. Jet velocities ranged from 26 km/s to 350 km/s, all of which are well below solar escape velocity of 618 km/s (see Table 1). The trajectory of the jets should affect the path of the falling back plasma. In the low plasma-ß regime of the CH, the plasma must follow the near-vertical open field lines, hence we would expect to find that post jet cool emission line enhancements occur preferentially in coronal hole jets.

EIS and XRT Light Curves

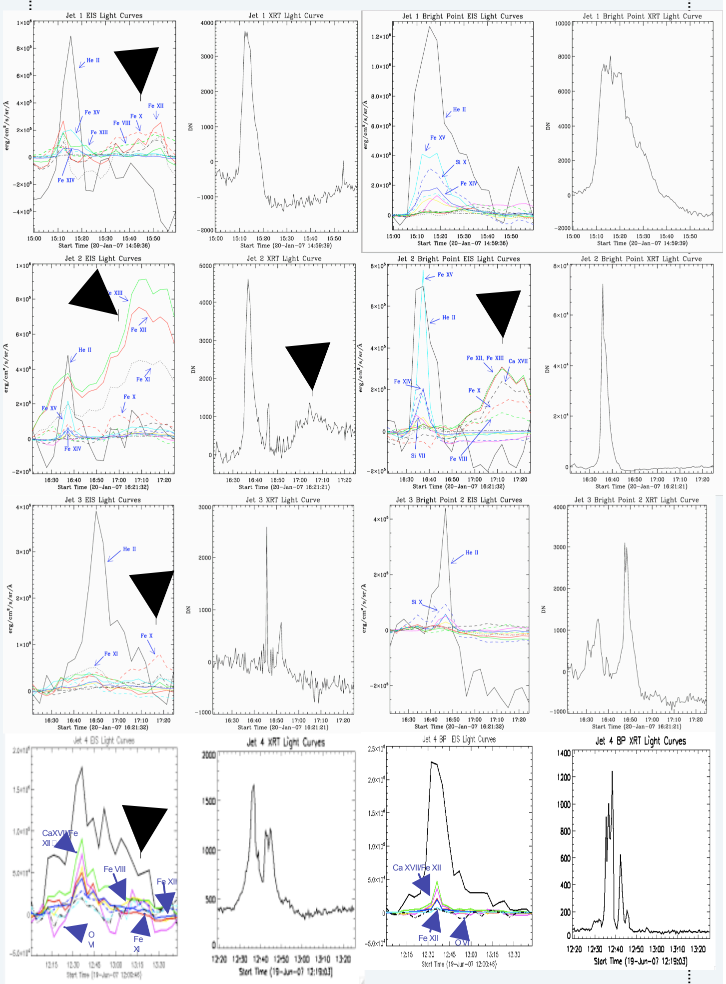

Figure 2 - Light curves of jets and bright points. EIS multi-line plots are shown on the left and the associated XRT soft X-ray plot to the right of each pairing. Key EIS lines are indicated. Post jet enhancements in cooler lines are shown by bold arrows.

	Speed (km/sec)
Jet 1	350
Jet 2	150
Jet 3	63
Jet 4	26
Escape	618

Table 1 - Jet velocities

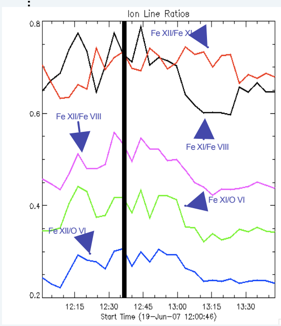

Figure 3 - Selected ion ratios for jet 4. See discussion section for temperatures of lines used. Time of maximum jet impulse is at 12:36 (black vertical line).

Summary

- All jets and bright points show impulsive behavior.
- Jets and bright points have coincident start and peak times in EIS and XRT light curves providing support for the interchange reconnection scenario (Yokoyama and Shibata, 1995).
- Bright points appear hotter than their associated jets and the post-jet enhancements, seen for the first time by Hinode, are cooler than the jets they follow.
- **Jet EIS light curves show post-jet enhancements in cooler lines interpreted to be due to the fall back of material to within the contour region as the jet plasma is well below escape velocity.**

References

Culhane, L., Harra, L., Baker, D., van Driel-Gesztelyi, L., Sun, J., Doschek, G. A., Brooks, D., Lundquist, L., Kamio, S., Young, P., and Hansteen, V.: 2007, *PASJ*, submitted

Yokoyama, T., & Shibata, K., 1995, *Nature*, **375**, 42-44.