On the Coronal Reconnection Height and Hot Jet Formation in the North Polar Coronal Hole (NPCH) as Observed by Hinode/EIS

Pradeep Kayshap & Abhishek K. Srivastava
Aryabhatta Research Institute of observational SciencES (ARIES), Nainital, India

Abstract

We analyze a coronal jet from Hinode/EIS 2" observations, which was triggered on 22nd April 2009 in the North Polar Coronal Hole (NPCH). Many bright points and an elongated jet-like structures above distinct bright point were present in the observed NPCH. For this study we have chosen this jet and associated bright point in the NPCH. Spectroscopic analysis (i.e., Fe XII 195.120 Å, Log T ~ 6.1 K) revels the red-shifted base and blue-shifted jet plasma column above it, which suggest that jet is formed by magnetic reconnection. The straight elongation of the jet provides a great opportunity to measure the reconnection height in the polar atmosphere Reconnection occurs at a height of ~ 20 Mm from the footpoint of the jet laying at the limb as visible in Fe XII 195.120 Å, where the red0-shift is inverted into blue-shift in Doppler velocity component along the jet plasma column. Intensity analysis of Si VII 275.35 Å (Log T = 5.8 K) shows that Transition Region (TR) is located above above the limb. Therefore, the reconnection point is well above the TR and resides in the corona. From the reconnection point, plasma flows in upward as well as downward directions with a maximum speed of 9±3 km s^{-1} and ~ 15 km s^{-1} respectively. Cool TR line (Si VII 275.35 Å, Log Te~5.8K) emission does not shows the Jet that infer the absence of cool plasma component inside it. This clearly indicates that the reconnection at higher coronal heights above TR only forms the hot plasma jet component in the Polar jet, which is in agreement with standard numerical models of the reconnection driven coronal jets.

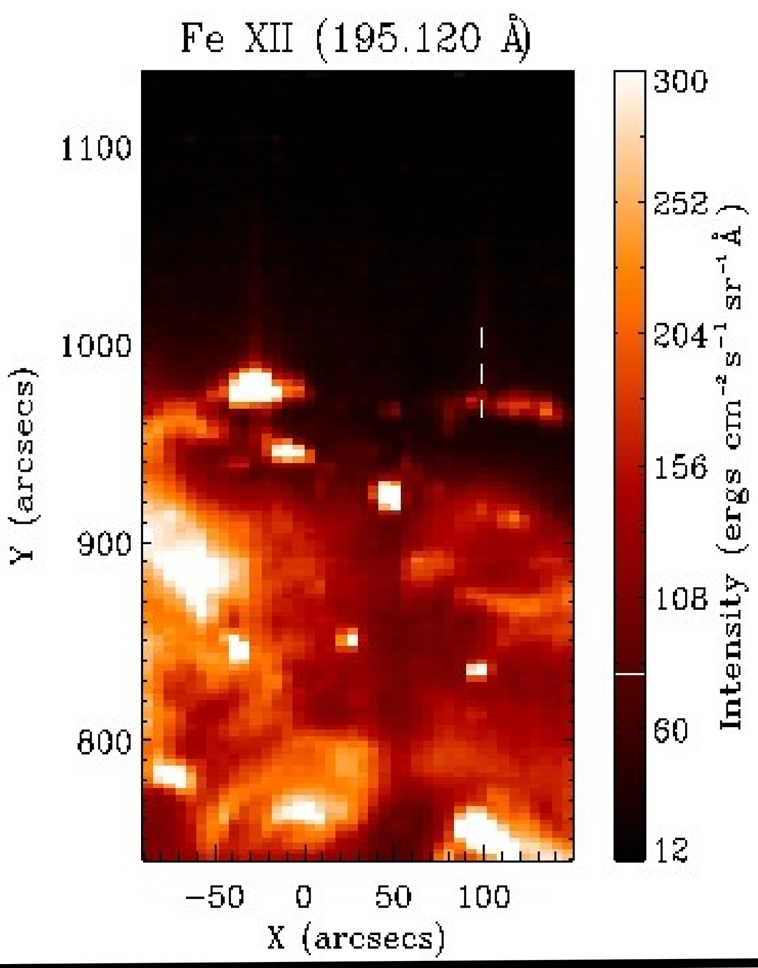
Introduction

The jets are basically the collimated plasma flows in the solar atmosphere. Various jet-like features, e.g., spicules, fibrils, surges, Ellerman bombs, EUV/X-ray jets, etc., are present in the solar atmosphere. Magnetic reconnection, which is energy conversion mechanism from magnetic energy into thermal and kinetic energies of the plasma, plays an important role in the formation of the jets in the solar atmosphere. On the basis of numerical simulation between the emerging magnetic flux and existing coronal magnetic fields, Yokoyama & Shibata (1995) have shown the presence of the cool and hot jets simultaneously. The presence of hot jets (e.g.,X-ray/EUV jets, etc.) and cool jets (e.g., Ca jet, Hα jet, dark EUV jet, etc.) simultaneously have been confirmed observationally (e.g., Yokoyama & Shibata 1995,1996). Recently Nishizuka et al. (2008) have taken more realistic coronal parameters in the numerical simulation of the jet rather than the one proposed by Yokoyama & Shibata jet model and successfully reproduced the jet, which is remarkably similar to the observed Ca jet. They have also shown the presence of hot and cool jets simultaneously. The height of the reconnection point is a crucial aspect of the reconnection driven jet model and it will determine that the both jets (i.e., hot and cool) will be present simultaneously or not. If the reconnection point lies in the Transition Region/upper chromosphere then the both hot and cool components of the plasma within the jets will be produced simultaneously. Determination of the reconnection height as well as examination of the presence of hot/cool jet plasma are the two motive of the present work.

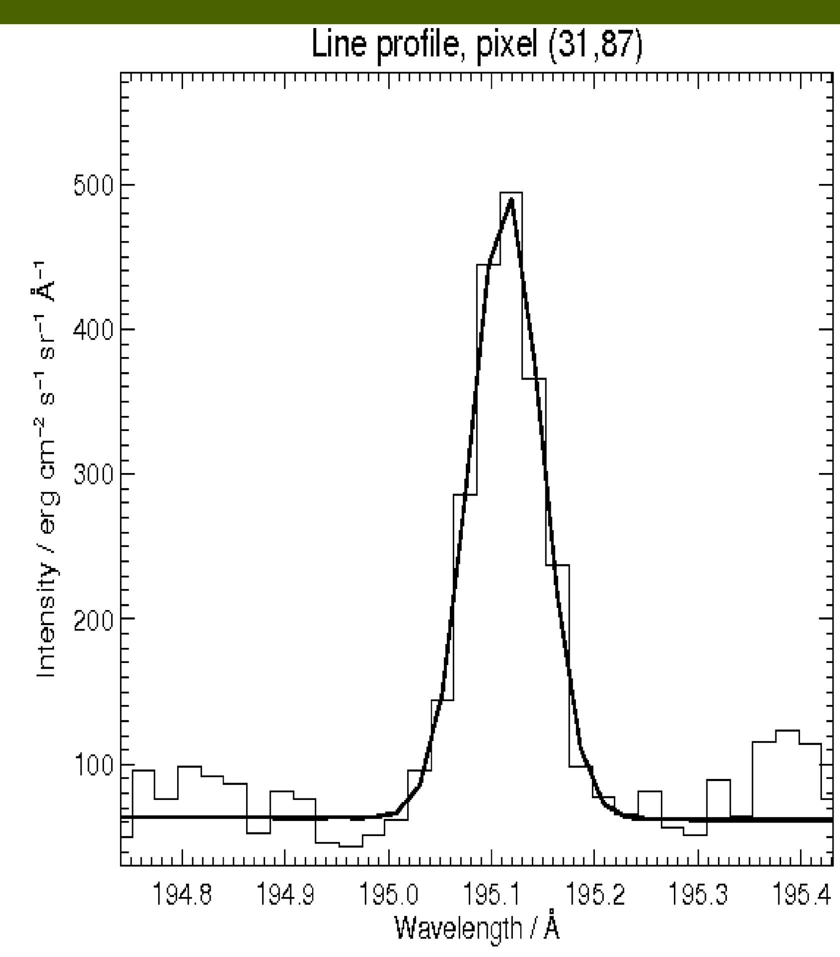
Observation and Data Reduction

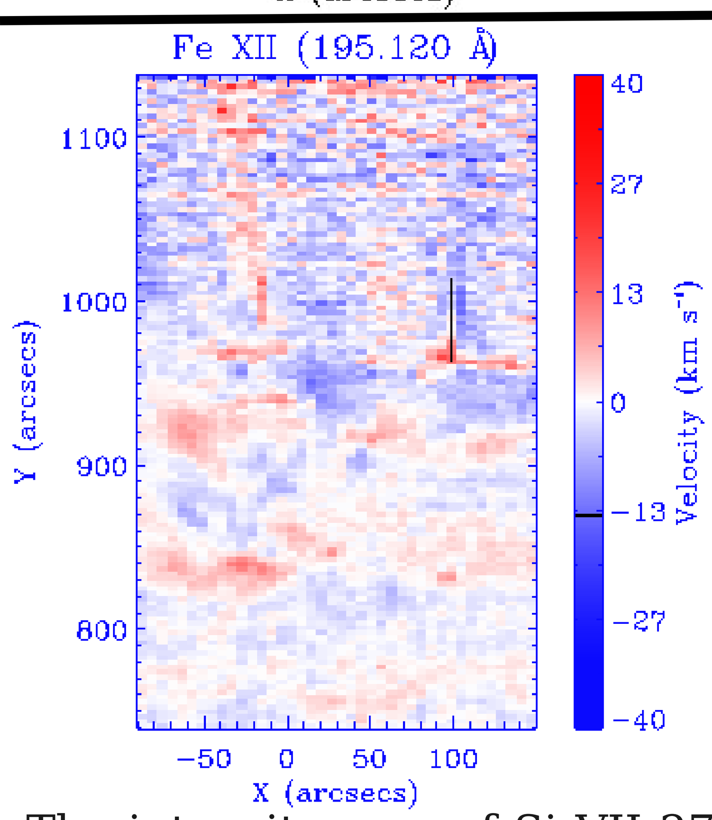
A North Polar Coronal Hole (NPCH) observation, which was recorded on 22nd April 2009, has been used in this present work. This NPCH was observed using 2" in the raster mode for more than one hour (i.e., from 03:24 UT to 04:27 UT). The average exposure time is not very high (i.e.,30 s), therefore the binning is required to increase the S/N ratio. Although, the data-set has spectra in 8 lines but we have used only Fe XII 195.120 Å and Si VII 275.35 Å lines in the present analysis. We have used standard Hinode/EIS routines, which are available in SolarSoft (SSW) package, to calibrate the data as well as to derive the physical parameters (e.g., Doppler Velocity, FWHM, Intensity) on each pixels of the observed region. We have used the eis_prep.pro routine to calibrate the raw data while eis_auto_fit.pro routine has been used for the fitting. Both used lines (i.e., Fe XII and Si VII) in this study are the clean lines (Young et al. 2007) while Young et al. (2009) have shown that Fe XII 195.120 Å is blended with Fe XII 195.180 Å only in the active regions. To improve the signal to noise ratio, a constant binning of 3 pixels in both directions has been performed in the whole observed region. After that, we have fitted the single Gaussian function on the spectra of both line profiles by using the eis_auto_fit.pro routine, which automatically corrects the combined effect of the slit tilt and orbit variations. After fitting of the Gaussian on these spectra, we have calculated the Doppler velocity, FWHM and Intensity from these fit structures on the each location of the observed region.

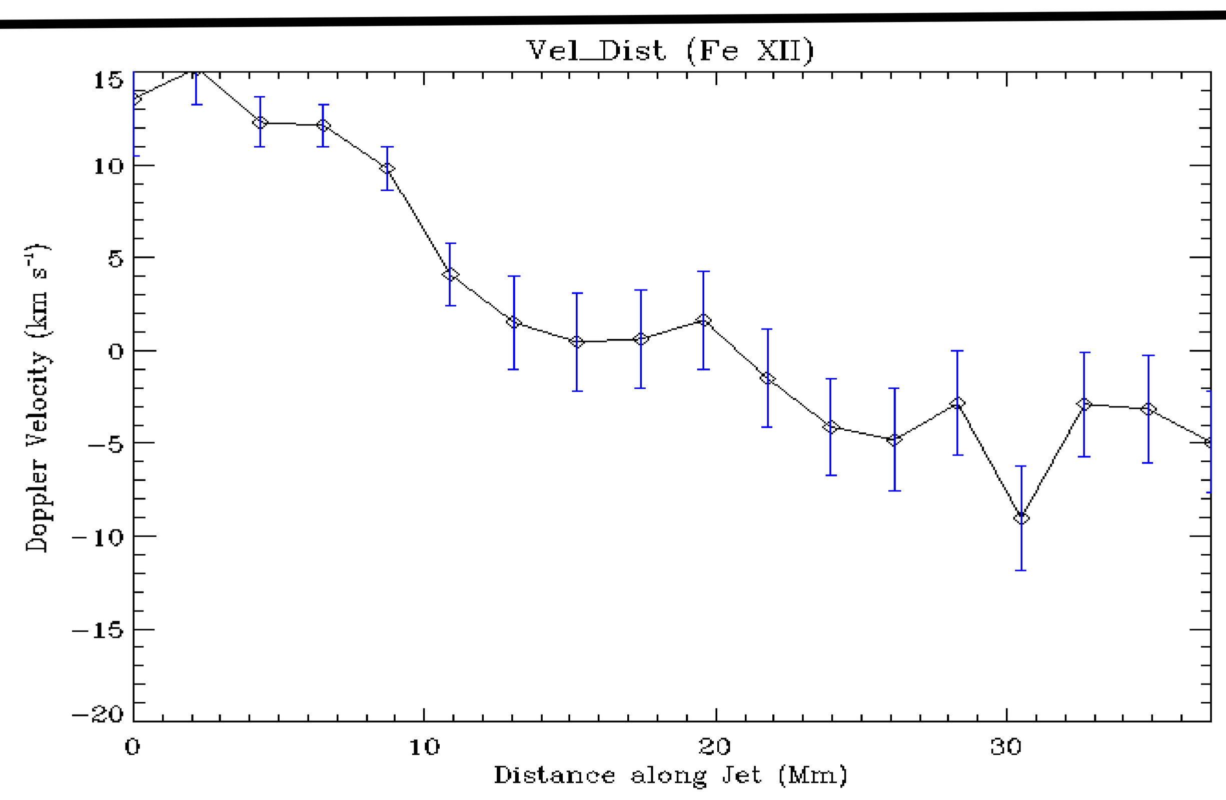
Results



We have analyzed a NPCH observation, which was observed by Hinode/EIS. The observed NPCH has two jet-like structures above the limb. For this present work, we have selected a small jet, which is located on the right of the comparatively big jet in the observed region. The intensity map, which is extracted from the fit structure of 195.120 Å line profile, the whole observed region has been shown in the left panel. Both jets are clearly visible in the intensity map of Fe XII 195.120 Å line. We have put a slit (i.e., white dashed line) along the selected jet from the base of the jet up to its visible point, which we have used in this present analysis. It seems that the base of the jet is bright point. A very fine collimated vertical plasma beam is visible above the bright point, which we have considered as a jet in this NPCH observation. Nishizuka et al. (2008) have shown that the vertical coronal jets which are the result of the magnetic reconnection between closed and existing open fields, can be triggered due to direct jxB forces. Presence of the bright point at the base of the jet and the vertical orientation of its plasma column may most likely associated with the magnetic reconnection between low-lying loops and existing open coronal fields. The right panel shows the sample fitting on the Fe XII 195.120 Å line spectra near the middle of the jet. We have checked the fittings all over the observed region, which are quite reasonable.

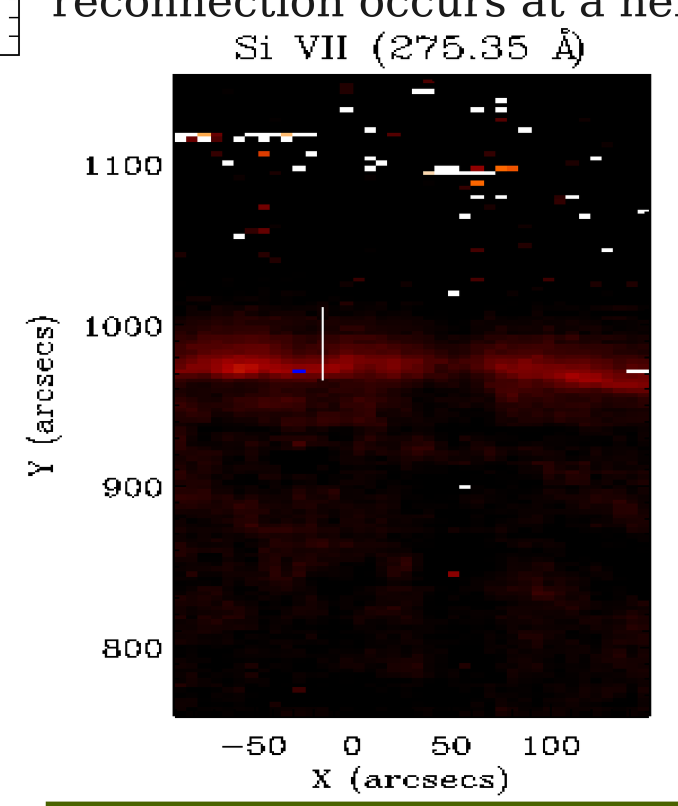


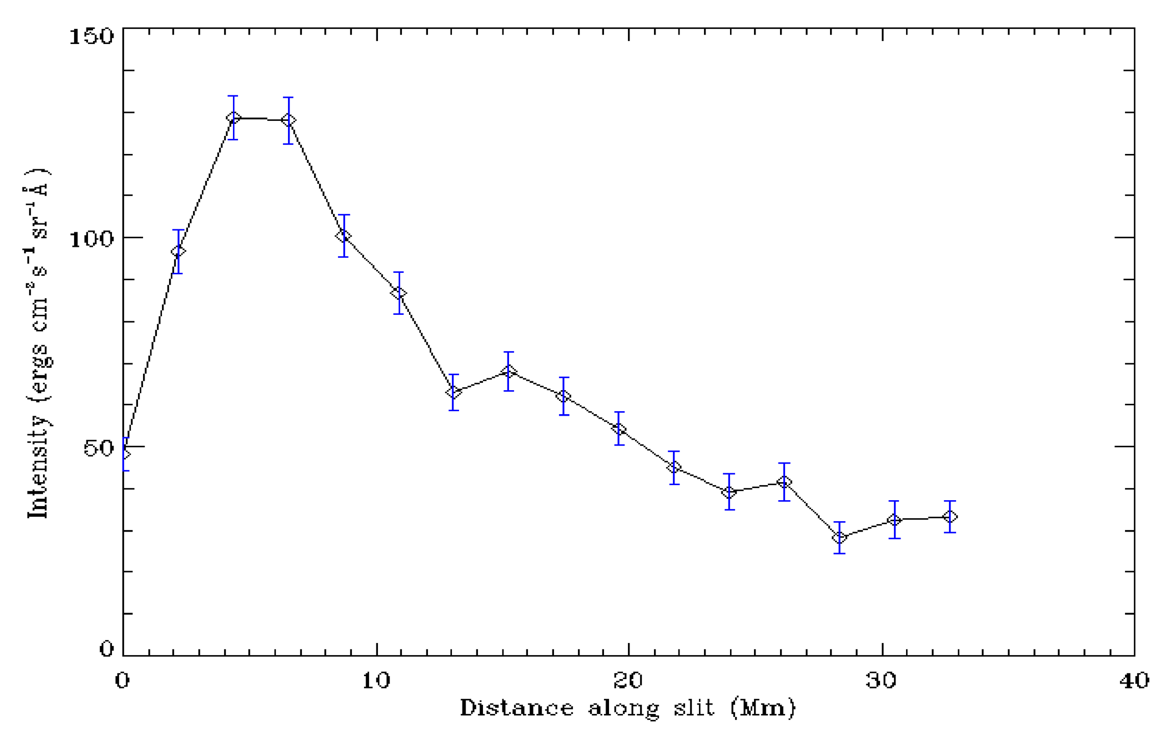




The Doppler velocity map of Fe XII 195.120 Å has been shown on the left. The base of the jet associated with bright-point loops is red-shifted while the plasma column above the base is blue-shifted, which is the typical signature of the magnetic reconnection at a certain height within the jet magnetic field topology in the coronal hole. Down flows dominate below the magnetic reconnection location while above the reconnection location up flows are evident. Therefore, this evidence supports that this vertical jet is triggered due to the magnetic reconnection in the corona. We have put a slit along the jet and tracked the Doppler velocity pattern along the jet. Initially the red-shift velocity is ~ 15 km s^{-1} which decreases along the jet and finally convert into blue-shift (i.e., up flows) with a maximum velocity of 6 km s^{-1}. The inversion height from red-shift to blue-shift is ~ 20 Mm from the bottom. Therefore, the reconnection occurs at a height of 20 ~Mm from the foot-point of the jet.

The intensity map of Si VII 275.35 Å line has been shown here. As we know that the temperature of Si VII line is ~log 5.8 K, which is correspond to the TR. We have used the Si VII intensity map to locate the TR height. We have put a vertical slit on the intensity map, which is shown on right-block to trace the intensity along the silt. Intensity along the silt has been shown, which estimates that TR is located ~ 5 Mm above the limb where the formation of this line is enhanced. Reconnection height is ~ 20 Mm from the foot-point of the jet within its body and TR is located at ~ 5 Mm above the limb, therefore, the reconnection site is well above the TR. Finally, we have found here that the reconnection site resides in the corona. Interestingly, the intensity image of cool Si VII line shows the absence of the jet. Therefore, the absence of the cool jet confirms that reconnection at higher coronal height only forms the hot component of the plasma within the jet.





Conclusions

On the basis of this Hinode/EIS observation, we have found that a vertical jet is triggered due to the reconnection between closed and open field lines under the magnetic field topology of a typical coronal jet within the coronal hole. The reconnection takes place at the coronal heights. Only hot jet is present in the coronal line (i.e., Fe XII 195.120 Å) and the jet signature is not present in the cool line (i.e., Si VII 275.35 Å). Therefore, these observational findings support the fact of the reconnection driven hot jets, if reconnection takes place at coronal heights within the existing magnetic field topology of the jet.

References

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Email: pradeep.kashyap@aries.res.in