Spatial and temporal correspondence between enhanced blue wing observed with *Hinode*/EIS and propagating disturbances in fan loops seen in AIA images

Naomasa KITAGAWA and Takaaki YOKOYAMA

Department of Earth and Planetary Science, The University of Tokyo

Naomasa KITAGAWA

Abstract

We investigated a correspondence between enhanced blue wings (EBWs) in emission line profiles and propagating disturbances in fan loops seen in consecutive AIA images. The upflows from active region peripheries (also referred to as AR outflows) have been analyzed from the viewpoint of coronal heating. One idea is that these upflows are induced by impulsive heating. The property that AR outflows are seen at AR peripheries has been confirmed by many observations, however, their driving mechanism has not been revealed yet. One approach is to seek the counterpart of EBWs in imaging observations. Recently, McIntosh et al. (2012) interpreted these upflows in terms of propagating disturbances (PDs) in fan loops, based on the fact that EBWs were observed at their footpoints.

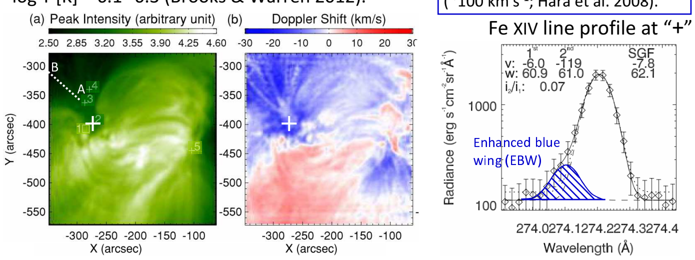
In this study, we analyzed emission line profiles in the wide temperature range from Si vii to Fe xiv (i.e., log T [K] = 5.8–6.3) observed with Hinode/EIS and investigate whether the PDs seen in AIA consecutive images coincide with the EBWs in those line profiles. Using the spectroscopic data of AR11106, we revealed that weak EBWs were indeed seen inside AIA fan loops, however, the strongest EBWs were located at a dark region outside those fan loops. It is also shown that the fluctuation caused by the PDs is up to 4% in AIA 193Å passband images which is consistent with the relative intensity of EBWs, while the EBWs in the dark region exceed 20% in Fe xii. Our results imply that the EBWs do not always coincide with the PDs. Tiny transient brightenings were detected at the dark region clearly in AIA images, which might be related to the source of the upflows.

Introduction

1. Strong upflows have been observed near the boundaries of active regions (AR outflows) by EIS spectroscopic scans. These AR outflows are known to have properties below.

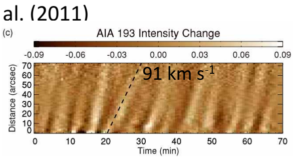
- $v_{Doppler}$=20-50 km s^{-1} (Harra et al. 2008; 1-Gaussian fit)
- Persistent for ~days (Bryans et al. 2010)
- log T [K] = 6.1--6.3 (Brooks & Warren 2012).

Major rest plasma + minor upflow (~100 km s^{-1}; Hara et al. 2008).



Figures from Tian et al. (2011)

2. There are often fan loops near the location of AR outflows. Tian et al. (2011) found a clear association of the minor upflow component in the EIS line profiles with the propagating disturbances in a fan loop. A similar result was reported by McIntosh et al. (2012).



x-t plot for A-B (*left upper* panel)

Aims

To reveal **spatial** and **temporal** correspondence between AR outflows observed with *Hinode*/EIS and the PDs seen AIA consecutive images.

Overview of AR11106

1. SDO images

NOAA AR11106

- Simple bipole
- Never exceed GOES B3 class during EIS scan
- Well developed fan loops

2. EIS maps

Data information

Date: 2010 Sep 16

Time: 10:38:14UT-

FOV: 300"×296"

Slit: 2"

Exposure: 30 s

There is an outflow region at the north east of the active region.

- Blueshift in Fe XII $v<-20$ km s^{-1}
- Enhanced widths

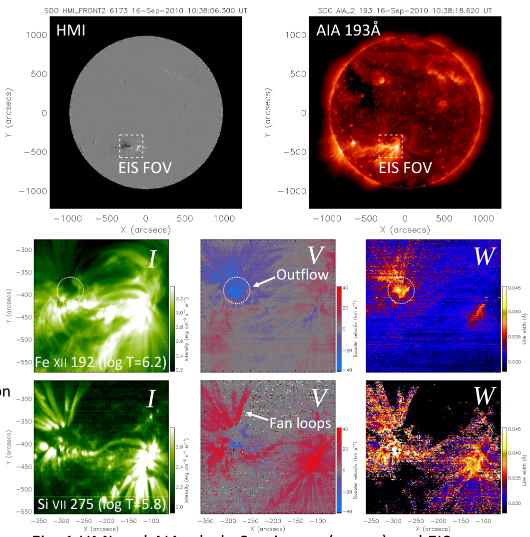


Fig. 1 HMI and AIA whole Sun image (upper) and EIS scan.

Spatial variation of Fe XII 193 line profiles

The line profiles of emission lines with the formation temperature log T [K]=6.1-6.3 have an enhanced blue wing. Fifteen locations (red-purple; indicated by diamonds in panel a) including the outflow region and fan loops are extracted from Fe XII 193 spectrum. *Upper* part of panel (b) shows 15 line profiles. The residuals from the single-Gaussian fitting are plotted in *lower* panel. The line profiles were fitted in the wavelength range $\lambda \geq 193.47$ (corresponding to v=-60 km s^{-1}) so that the residuals become a proxy of the EBW.

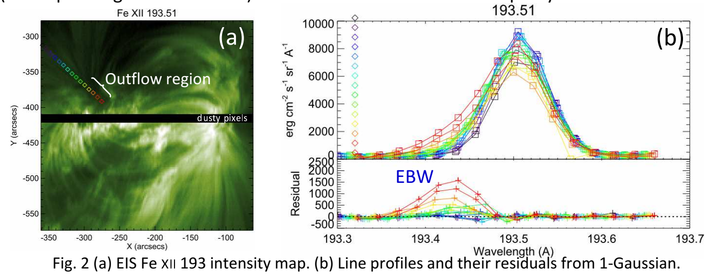


Fig. 2 (a) EIS Fe XII 193 intensity map. (b) Line profiles and their residuals from 1-Gaussian.

- The EBW clearly peaks at the outflow region (~20% of the major Gaussian in maximum).
- Outside the outflow region, the EBW rapidly becomes weak.

Temporal variation in AIA image

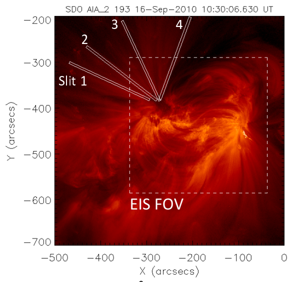


Fig. 3 AIA 193Å passband image.

Four slits along fan loops were located in order to investigate the temporal variation of intensity as indicated in the left image (Fig. 3). Those slits included not only fan loops but also the outflow region outside the fan loops. Fig. 4 show *x-t* diagrams (running difference), in which we can see clear signatures of upwardly propagating disturbances (PDs) with relative amplitude of 2-4%. These PDs have a speed around 140 km s^{-1} as indicated by *white dashed line* in the *upper left* panel. The outflow region (lower 15") also shows the fluctuation of several %. The relative amplitude of fluctuations at both region, but those in the outflow region do not exhibit a propagating signature. The frequent transient brightenings with small scale (≲5") were clearly seen in AIA consecutive images (though not shown here).

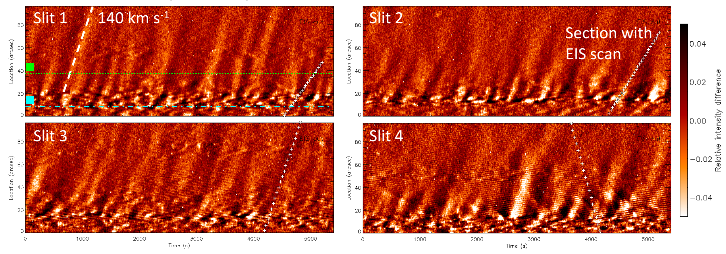


Fig. 4 *x-t* diagrams for four slits in Fig. 3.

The temporal variations in the slit 1 were plotted in Fig. 5. *Left* panel shows that at the leg of a fan loop (*light green square; dotted line*) and *right* panel shows that in the outflow region (*light blue square; dotted-dashed line*). Both locations exhibit the similar magnitude in the fluctuation (2-4%).

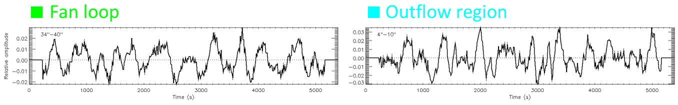


Fig. 5 Temporal variations of intensity in a fan loop (*left*) and at the outflow region (*right*) cut by slit 1.

Discussion

Summary of the results

- We found most significant EBW in the outflow region outside fan loops.
- The intensity fluctuations were seen both in fan loops and in the outflow region.

Spatial correspondence

EBW in EIS line profiles = propagating disturbances in fan loops?

EBWs were seen in a fan loop, and we indeed found the maximum EBW in the outflow region as indicated by Fig. 2. This implies that the EBWs do not necessarily exist only in fan loops. EBWs outside the fan loops exceeded ~10% which is much larger than the PDs in fan loops, therefore, it is clearly shown that there is another cause of the outflow. The transient brightenings were seen in the outflow region observed by AIA, but their amplitude (2-4%) was not enough to account for the magnitude of EBWs.

Temporal correspondence

This turns to be difficult by using only one scan of the outflow region. We think sit-and-stare mode observation would be preferable, which is our future work.

References

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