Measuring coronal outflows in coronal loops

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This proposal requests *continuous* (24 hours/day) observations of the footpoint regions of an active region coronal loop system for *six consecutive day*s as the region rotates from the solar meridian to the limb. The initial observation will take place when the active region is close to the meridian, with the last taking place with the region close to the west limb.

Observations of active regions with EIS in the first year of Hinode operations have revealed that *virtually all* active regions show significant line broadening and *apparent* (see below) outflows in areas that are weak in intensity. An example of this effect is shown in Doschek et al. (2007). In addition, observations with XRT have demonstrated continuous apparent outflow in open or extended loop structures (Sakao et al. 2007). These outflows are an exciting new discovery from Hinode, and are a potential source of the slow solar wind.

The Sakao et al. observation demonstrated the value of continuous, uninterrupted observations of the footpoints region as they observed active region AR 10942 for three complete days. Unfortunately the EIS observations at this time were not homogeneous, consisting of several different studies pointed at different locations in the active region. By systematically using the same EIS sequence at the same location for 6 continuous days we will make a definitive statement about whether the EIS outflows are related to the XRT outflows, and we will investigate how the flows vary with longitude. In particular, by observing the region as it rotates towards the west limb, we hope to associate the outflows with in situ measurements from the ACE spacecraft which would make a clear association of the AR outflows with the slow solar wind.

The observation will have significant *heritage* value as they will also yield observations of coronal loop structures that will enable loop morphology and plasma properties to be determined over a long time-scale from a homogeneous XRT-EIS-SOT data-set.

A crucial aspect to the observation is that the Doppler shifts observed in the EIS emission lines can often not be definitively identified as blueshifts (outflows) because of the difficulty in obtaining an absolute EIS wavelength calibration. *It is critical for this observation that observations be taken that allow the EIS outflow velocities to be accurately calibrated, thus allowing the mass flux in the regions to be estimated*.

Figure 1 shows images from an active region observed on 2007 Feburary 20 in the Fe XII 195.12 emission line. The Doppler map (showing velocities between -30 and +30 km/s) clearly shows a region of strong blueshift (outflow) in a region that is dark in the intensity image. The line width map shows that the emission line is also broadened in this region. The problem with the EIS study used is that the field of view is only 240 arcsec in solar-Y and the active region extends over this full height. In order to accurately correct for the orbital variation of the EIS line centroids it is necessary to measure the variation of the line centroid of Fe XII over time (solar-X). The zero point of the velocity scale is derived by the average of the centroid variation over time. In the example above it is clear that there are large-scale velocity shifts associated with the active region that skew the determination of the velocity zero point, thus rendering inaccurate the measured velocities in the outflow region.

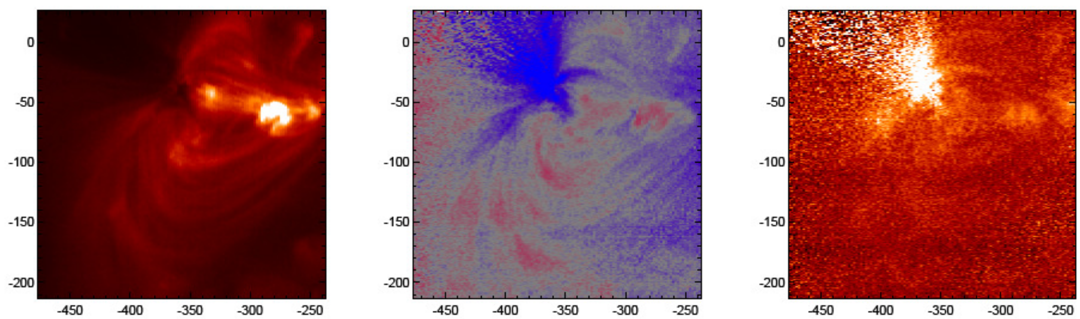

Figure 1. An active region observed with EIS on 2007 February 20 showing a dramatic example of an outflow region seen in the Fe XII 195.12 line. The left, middle and right panels show intensity, velocity and line width, respectively.

The solution to this problem is to extend the EIS field of view beyond the active region to an area of quiet Sun which typically shows smaller (both in magnitude and spatial scale) velocity shifts, which can then be used to correct the orbital variation and set the zero point.

Assuming a fixed data rate, an extension of solar-Y coverage to include quiet Sun regions means losing spectral information yet it is only with a wide range of emission lines that we can probe the temperature, density, and velocity structure of the outflow regions.

Our solution for this HOP is to allocate a greater share of the data recorder (DR) to EIS, thus allowing greater spatial coverage and retaining wide spectral coverage. The normal EIS DR allocation is 15%. For this specific study we request 32% (see below for justification). XRT will have the usual 15%, and SOT will be reduced to 53%.

In order to investigate the time variability of the outflows, it is *essential* to obtain a long, continuous set of observations. We thus make the following special observing requests:

- for each of the six days, a single, complete 24 hour observing run is made;
- to minimize disruption of the sequence, we request only 2 XRT synoptics each day;
- the observation begins at the start of a single upload plan on Day 1, and ends at the end of the Day 6 upload plan (so that the modified DR allocations only affect six Hinode planning days)
- if the instruments have particular engineering or calibration sequences that must be run during the 6 day period, then we request that the instrument teams schedule them for the same time slot to minimise any disruption to the coordinated data-set

Target/Pointing

A well-developed active region close to disk centre. The target will be the base of large loop structures found near the edge of the active region (see Figure 1 above). The SOT pointing should be at the footpoints of the loops. E.g., in Figure 1 the centre of the SOT field of view would be approximately (-360,-50).

Duration

The study should be run for six complete and consecutive 24 hour periods.

EIS study

EIS will run the study PRY_footpoints_HI which is identical to the well-used PRY_footpoints_v2 study except that the raster covers 512" in Y instead of the current 240". *This accounts for the increased share of the data recorder for EIS*. The increased field of view in Y allows EIS to access quiet Sun areas that can be used as a reference to fix the wavelength scale for velocity determinations.

Notes for EIS CO: the study should be scheduled in two 12 hour blocks each day. The block should begin with a context study **PRY_slot_context** (duration 3 minutes), and then **PRY_footpoints_HI** should be repeated to fill the block. For the following blocks, make sure to use the same mirror position (MIP) as the previous block to ensure that PRY_footpoints_HI is pointed in exactly the same place each time. Check with David Williams or David Brooks if you are not sure how to do this.

XRT study

A high cadence dynamics study using one filter and a 512x512 pixel field of view should be used. The filter should have some sensitivity to cool plasma, and we suggest Ti-poly. Every 10 minutes, single images in one or more different filters should be used to allow the temperature structure of the loops to be derived.

SOT study

SOT data are vital for identifying the photospheric and chromospheric roots of the loop footpoints, and measuring the vector magnetic field. Repeated Spectro-Polarimeter (SP) observations are requested over a spatial region of 180"x164" over the duration of the program, interspersed with BFI images in G-band, Ca II and H-alpha (focus optimised for Ca II).

References

Doschek, G.A., Mariska, J.T., Warren, H.P., et al., 2007, ApJ, 667, L109
Sakao, T. , Kano, R., Narukage, N., et al., 2007, Science, 318, 1585